IBM RT PC Advanced Interactive Executive Operating System

AIX Operating System Programming Tools and Interfaces

Programming Family

Personal
Computer
Software

59X9111

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Portions of the code and documentation described in this book were developed at the Electrical Engineering and Computer Sciences Department at the Berkeley Campus of the University of California under the auspices of the Regents of the University of California.

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About This Book

This book introduces you to the programming tools and services for writing an application program using an IBM RT PC. It provides an overview of the programming process, and describes how to use the RT PC programming tools and interfaces within that programming process. It includes information about:

- What the system structure is
- Designing output for the display
- C language programming tools
- Program maintenance and source code control
- Using System Calls
- Using Library Functions
- Installing a program on the system
- Using the trace and error logging facilities
- Writing messages.

What You Should Know

The book uses the C programming language in the examples, and many of the tools work only with C language source files. Therefore, you should be familiar with the C programming language to get the most out of this book. However, programmers working with other high level languages can also benefit from the information in this book. In addition to knowing the C language, you should:

- Have experience in writing application programs.
- Be able to use the RT PC system to:
  - Enter commands
  - Create and delete files
  - Edit files
  - Move around in the file system.

Related Information

To get familiar with the operating procedures of the RT PC system, refer to the following book(s):

- *IBM RT PC Using and Managing the AIX Operating System*
- *IBM RT PC Using AIX Operating System DOS Services*

To help understand the information in this book, and to provide more detail about the commands, calls and library functions introduced in this book, refer to the following books:

- *IBM RT PC AIX Operating System Commands Reference*
- *IBM RT PC AIX Operating System Technical Reference*
- *IBM RT PC C Language Guide and Reference*

To write device drivers for use on the RT PC system, refer to the following books:

- *IBM RT PC Virtual Resource Manager Technical Reference*
- *IBM RT PC AIX Operating System Technical Reference*

The programs described in this book generate messages when errors occur. Refer to the following book for explanation of messages that the system programs generate:

- *IBM RT PC Messages Reference*

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Chapter 1. Programming with RT PC

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About This Chapter

This chapter describes the IBM RT PC tools and services for developing application programs. In addition, it indicates where to get more information about these facilities, both in this book and in other RT PC books.

Programming Tools

The RT PC system has many tools to help develop a C language program. To access any of these tools, enter a system command on the command line. These tools provide help in the following programming areas:

- Entering a program into the system
- Checking a program
- Compiling and linking a program
- Correcting errors in a program
- Filing and maintaining a program.

Entering a Program

The system has a line editor to help enter a program into a file to be compiled. The editor is called **ed**. Refer to *Using and Managing the AIX Operating System* for instructions about how to use this editor.

In addition, the system has two full screen editors, INed[1] and **vi**. These editors display a full screen of data and allow interactive editing of the file.

Checking a Program

The following programs help check the format of a program for consistency and accuracy:

lint Checks for syntax, data type and other programming and usage errors. Refer to "Checking C Programs" on page 2-5 for information about using this program.

cflow Generates a flow diagram of a C language program. Refer to "Other C Programming Tools" on page 2-19 for information about this program.

cxref Generates a cross reference listing for a C language program. Refer to "Other C Programming Tools" on page 2-19 for information about this program.

cb Reformats a C language source program into a consistent, indented format. Refer to "Other C Programming Tools" on page 2-19 for information about this program.

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1 INed is a trademark of Interactive Systems Corporation

Compiling and Linking a Program

The **cc** command compiles and links a C language program with one command line entry. Refer to Chapter 2, "Compiling and Linking Programs" on page 2-1 for information about using this program.

Correcting Errors in a Program

The symbolic debug program, **sdb** helps find logic errors in a C language program. Refer to Chapter 8, "Debugging Programs" on page 8-1 for information about using this program.

In addition, string searching programs such as **grep**, **sed** and **awk** help locate and change character strings (such as parameter names and syntax problems) in program files. Refer to Chapter 11, "Finding and Changing Strings" on page 11-1 for information about using these programs.

Building and Maintaining a Program

Two programs help control changes to a program and build the final program module. These programs are:

make A program that builds programs from several source modules and that compiles only those modules that have changed. Refer to "Building Programs with make" on page 2-22 for information about using this program.

sccs A program that maintains separate versions of a program without storing separate copies of each version. Refer to Chapter 10, "Maintaining Different Versions of a Program" on page 10-1 for information about using this program.

Programming Interfaces

When writing an application program for RT PC, use the following system services:

- Shell commands
- Library routines
- System calls.

These services are available from a C language program.

Shell Commands

To include the functions of any of the shell commands in a program, use the **fork** and **exec** system calls to allow the command to run in a part of the system (called a ***process***) that is separate from the program. The **system** library routine also runs a shell command in a program, and the **popen** library routine uses shell filters. When using shell commands in a program, ensure that these commands are also available on all systems that will use the program. Refer to *AIX Operating System Commands Reference* for details about shell commands.

Library Routines

Routines from the system libraries handle many complex or repetitive programming situations so that you can concentrate programming effort on the unique programming situations. Details of each library subroutine are in *AIX Operating System Technical Reference.* Some of the libraries on the system are:

C library
A collection of input/output formatting routines, system call interface routines and other functions. This library includes the library **stdio**, which is the standard buffered input/output system.

Run Time Services library
A collection of routines that help a program use the following system services:

- Configuration
- Messages
- Trace
- Error log.

Math library
A collection of mathematics functions.

Extended curses library
A collection of routines for writing programs that help control display screen input and output without regard to the type of terminal that the system uses.

See Chapter 3, "Using the Subroutine Libraries" on page 3-1 for a summary of the functions available in some of the libraries. See Chapter 5, "Controlling the Terminal Screen" on page 5-1 for a description of using the **Extended curses** library.

System Calls

System calls offer some additional control of the system, allow more detailed control of input and output operations, and provide functions not available through the library routines. However, system calls do not format the data, or take care of system housekeeping like the library routines do. Therefore, when using system calls, be sure to provide data stream control and housekeeping functions. Each system call is explained in *AIX Operating System Technical Reference.* See Chapter 4, "Using System Calls" on page 4-1 for examples of how to use many of the system calls.

Using the Programming Examples

Note: The Programming Examples in this book have been tested using Release 1.0 of the operating system software. Changes that may be made to subsequent releases of the operating system may change how these programs operate. Be sure that the level of the Programming Examples is compatible with the level of the operating system at your site.

This book uses sample programs to demonstrate the tools and interfaces in the system. These programs are working models that perform a task to demonstrate the function that the text explains. The source code (in C language) for these programs is on the diskette located in the back of this book. To install the Programming Examples, refer to Appendix A, " Installing Programming Examples" on page A-1.

Although the programs may not perform useful functions, use the syntax and declarations in the sample programs as templates for program development. Look at or change the programs in these files as needed. However, if you change the program, change only a copy of it. Please keep the original sample program files so that another person using this book can also use them.

The sample program files contain detailed comments that explain how the program operates. This book includes many of the program listings, but because of space restrictions, the comments are not printed. To print the listings of the program files, use the command:

```
print filename
```

Where *filename* is the path name of the file to print. For example, to print the file that contains the source program for the signal system call (used in Chapter 4, "Using System Calls" on page 4-1), use the following command:

```
print /usr/lib/samples/sigtst.c
```

You should also compile and run these programs. Compiling the programs helps you become familiar with the compiler command **cc**. Seeing the program run (most of the sample programs display output to the screen) helps you understand the idea that the sample program demonstrates. To compile the programs, copy the programs from the directory **/usr/lib/samples** to your current directory:

```
cp /usr/lib/samples/* .
```

To compile a program from that directory into a file that can be run, use the command:

```
cc filename.c -o filename
```

where *filename* is the name of the file to compile. For example:

```
cc sigtst.c -o sigtst
```

compiles the signal sample program and puts the output in a file named **sigtst**. Run this file by entering the command:

```
sigtst
```

If problems occur with the program, compare it with the listing in this book. Except for the comments, the program should be identical to the listing in this book.

Chapter 2. Compiling and Linking Programs

CONTENTS

About This Chapter

To make source code into a program that the system can run, process the source file with a compiler program and a linker program. The compiler changes the source statements into object code that the computer can run; the linker connects program modules together and determines how to put the finished program into memory. This chapter discusses the following programming processes:

- Compiling the program
- Checking C programs
- Other C programming tools
- Processing assembler language routines
- Linking the program
- Building the program using the **make** utility program.

This chapter does not contain complete information about any of the programs. For complete information refer to the reference book for the language compiler or to *AIX Operating System Commands Reference* (for the C language compiler).

Compiling A Program

A ***compiler*** is a program that reads program text from a file and changes the programming language statements in that file to a form that the system can understand. The following steps show how the system creates this final form of the program:

1. Includes additional files specified with the `#include` directive, and expands macros into programming language statements.
2. Changes the programming language statements into assembler language code using the language compiler.
3. Changes the assembler language into object code (a form that the system can understand) using the assembler (**as** command). The object code is stored in a file with a **.o** suffix. This form of the program cannot be executed.
4. Links the object code (using the **ld** command) into a program that the system can execute. If you do not specify differently, the executable program is in the file **a.out** in the current directory.

If the program is written in the C language, use the **cc** program to perform these steps. See "Using the cc Program" on page 2-4 and *AIX Operating System Commands Reference* for information about this program. If the program is written in assembler language, see "Processing Assembler Language Routines" on page 2-20.

Choosing a Compiler

The following list includes some of the programming languages that are available for use with the AIX Operating System:

- BASIC
- FORTRAN
- Pascal
- C
- IBM RT PC Assembler Language.

The books that come with the compiler programs contain information for using those languages. The examples in this chapter use the C language.

You can also write parts of the program in different languages and have one main routine call the separate routines to execute. To do this, however, follow the rules explained in *Assembler Language Reference* under the topic of ***calling conventions***.

Using the cc Program

The **cc** program calls the C language compiler, but it can do much more. The **cc** program can:

- Process the input with a macro preprocessor
- Compile a high-level language program
- Assemble an assembler language program
- Link program modules.

You can select any or all of these functions. In addition, you can replace the supplied programs for any of these steps with a program suited to special needs. *AIX Operating System Commands Reference* contains detailed reference information about the **cc** program.

Examples of Commands

The following examples show some operations with the **cc** program using command line flags.

Compile source file `testfile.c` using the C library (**libc.a**) and the run time library (**librts.a**), link the resulting module and place the output in **a.out**:

```
cc testfile.c
```

Process source file `testfile.c` to produce assembler language output, and place the output in `testfile.s`:

```
cc testfile.c -S
```

Compile source file `testfile.c` using the C library (**libc.a**) and the run time library (**librts.a**), and place the unlinked output in `testfile.o`:

```
cc testfile.c -c
```

Process source file `testfile.c` using the macro preprocessor only, and place the output in `testfile.i`:

```
cc testfile.c -P
```

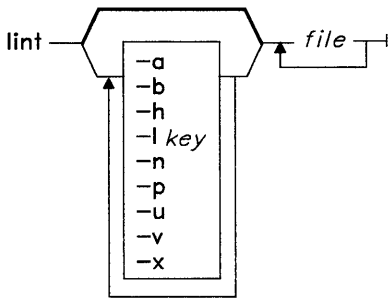
Compile source file `testfile.c` using the C library (**libc.a**) and the run time library (**librts.a**), but using the `newcpp` and `newcomp` compiler programs in the directory `/u/jim`. Place the unlinked output in `testfile.o`:

```
cc testfile.c -c -B/u/jim/new -tp0
```

Checking C Programs

Use the **lint** program to ensure that C programs do not contain syntax errors, as well as to verify that the programs do not contain data type errors. The **lint** program checks these areas of a program more carefully than the C compiler does, and displays many messages that point out possible problems. These messages may not require you to change the program if you decide to ignore the possible problems.

To start **lint**, enter the command according to the following diagram as shown in *AIX Operating System Commands Reference*:



The parameters for the **lint** command are in the following categories:

flags Optional flags to control **lint** messages. This section contains examples of some useful flags. See *AIX Operating System Commands Reference* for a complete list of the flags for the system.

filename The name of the C language source file for **lint** to check. The file name must end with **.c**.

library-name The name of a library that **lint** uses when checking the program. The following libraries are included with the system:

-ldos	Checks DOS file library call syntax
-lcurses	Checks Extended curses library call syntax
-m	Checks math library call syntax
-port	Checks for portability with other systems.

You can also create your own lint library. See "Creating A lint Library" on page 2-15 for more information.

With no flags specified on the command line, the **lint** program checks the C source files and writes messages about the following coding errors and programming style differences that it finds:

- Data types that are not used correctly
- Variables and functions that are not used
- Functions that are not used correctly
- Syntax errors
- Techniques that could cause problems in moving the program to other systems.

Operation

The **lint** program checks a group of files using the following procedure:

1. Checks each file and writes messages for problems found in that file
2. Collects errors in included files and writes those messages
3. Checks for consistency of labels and data types among the group of files
4. Writes the source file name followed by a ? (question mark) if any errors remain that are not assigned to either a source file or an included file.

If **lint** does not report any errors, the program has correct syntax and will compile without errors. Passing that test, however, does not mean that the program will operate correctly, or that the logic design of the program is accurate. The **lint** program does not check for design problems. It only checks language semantics and syntax.

Program Flow

The **lint** program detects parts of the program that cannot be reached. It writes messages about statements that do not have a label, but immediately follow statements that change the program flow, such as:

- goto
- break
- continue
- return.

The **lint** program also detects and writes messages for the following conditions:

- A loop that cannot be exited at the bottom
- A loop that cannot be entered at the top
- Infinite loops such as:
  - while(1)
  - for(;;)

Some programs that work may have such loops. However, the loops can cause problems.

The **lint** program does not detect functions that are called, but never return to the calling program. For example, a call to **exit** may result in code that cannot be reached, but **lint** does not detect it.

Programs generated by **yacc** and **lex** may have hundreds of **break** statements that cannot be reached. The **lint** program normally writes an error message for each of these **break** statements. Use the **-O** flag for the **cc** command when compiling the program to eliminate the resulting object code inefficiency, so that these extra statements are not important. Use the **-b** flag with the **lint** program to prevent writing of these messages when checking **yacc** and **lex** output code.

Data Type Checking

The **lint** program enforces the type checking rules of C language more strictly than the compiler does. In addition to the checks that the compiler makes, **lint** checks for the data type errors in the following areas:

- Binary operators and implied assignments
- Structures and unions
- Function definition and uses
- Enumerators
- Type checking control
- Type casts.

Binary Operators and Implied Assignments

The C language allows mixing of the following data types in statements, and the compiler does not indicate an error when they are mixed:

- char
- short
- int
- long
- unsigned
- float
- double.

The language converts data types within this group automatically to allow the programmer more flexibility in programming. This flexibility, however, means that the programmer, *not* the language, must ensure that the data type mixing produces the desired result.

You can mix these data types when using them in the following ways (in the examples, `alpha` is type **char**, and `num` is type **int**):

- Operands on both sides of an assignment operator, for example:

```
alpha = num;
```

- Operands in a conditional expression, for example:

```
value = ( alpha < num ) ? alpha : num;
```

- Operands on both sides of a relational operator, for example:

```
if( alpha != num )
```

- The type of an argument in a **return** statement is converted to the type of the value that the function returns. For example:

```
funct(x)        /* returns an integer */
{
  return( alpha );
}
```

The data types of pointers must agree exactly, except that you can mix arrays of `x`'s with pointers to `x`'s.

Structures and Unions

The **lint** program checks structure operations for the following requirements:

- The left operand of the -> operator must be a pointer to a structure.
- The left operand of the . operator must be a structure.
- The right operand of these operators must be a member of the same structure.

The **lint** program makes similar checks for references to unions.

Function Definition and Uses

The **lint** program applies strict rules to function argument and return value matching. Arguments and return values must agree in type with the following exceptions:

- You can match arguments of type **float** with arguments of type **double**.
- You can match arguments within the following types:
  - char
  - short
  - int
  - unsigned.
- You can match pointers with the associated arrays.

Enumerators

The **lint** program checks enumerated data type variables to ensure that:

- Enumerator variables or members are not mixed with other types or other enumerators
- The enumerated data type variables are only used in the following areas:
  - Assignment (=)
  - Initialization
  - Equivalence (==)
  - Not equivalence (!=)
  - Function arguments
  - Return values.

Type Checking Control

To turn off strict type checking for one expression in the program, add the directive:

```
/*NOSTRICT*/
```

to the program immediately before the expression. This directive prevents strict type checking for only the next line in the program.

Type Casts

Type casts in the C language allows the program to treat data of one type as if it were data of another type. The **lint** program can check for type casts and write a message if it finds one.

The **-c** flag for the **lint** program controls the writing of comments about casts. Without the **-c** flag, **lint** treats casts as though they were assignments subject to messages. The resulting messages indicate the casts that are in the program. With the **-c** flag, **lint** ignores all legal casts.

Variable and Function Checking

The **lint** program detects variables and functions declared in the program, but not used. When it finds one of these cases, it writes a message. Variable and function errors that **lint** finds include the following:

- Functions that return values inconsistently
- Variables and functions that are defined, but not used
- Arguments to a function call that are not used
- Functions that can return either with or without values
- Functions that return values that are never used
- Programs that use the value of a function when the function does not return a value.

Inconsistent Function Return

If a function returns a value under one set of conditions, but does not return a value under another set of conditions, you cannot predict the results of the program. The **lint** program detects this type of error. For example, if both of the following statements are in a function definition:

```
return( expr );
```

and

```
return;
```

The **lint** program writes the message:

```
function name contains return(e) and return
```

When using this function, the program may or may not receive a return value. The error message points out that problem.

The **lint** program also detects function returns caused by reaching the end of the function code (an implied return). For example, in the following part of a function:

```
checkout (a)
{
        if (a) return (3);
        fix_it ();
}
```

If a tests false, `checkout` calls `fix_it` and then returns with no defined return value. In this case, **lint** writes the message:

```
function checkout contains return(e) and return
```

If `fix_it`, like `exit`, never returns, **lint** still writes the message even though nothing is wrong.

Function Values That Are Not Used

The **lint** program detects cases where a function returns a value and the calling program may not use the value. If the value is never used, the function definition may be inefficient and should be checked. If the value is sometimes used, the function may be returning an error code that the calling program does not check.

Disabling Function Related Error Messages

To prevent **lint** from reporting these types of errors, specify one or more of the following flags to the **lint** command:

-x Do not write messages about variables that are declared in an **extern** statement, but are never used.

-v Do not write messages about arguments to functions that are not used (except those that are also declared as register arguments).

-u Do not write messages about functions and external variables that are either used and not defined, or defined and not used. Use this flag to run **lint** on a subset of files of a larger program.

To prevent **lint** from reporting errors for one function add the directive:

```
/*ARGSUSED*/
```

to the program before the function.

Add the following directive before the function definition to prevent the program from writing messages about variable numbers of arguments in calls to a function:

```
/*VARARGSn*/
```

To check the first several arguments and leave the later arguments unchecked, add a digit to the end of the VARARGS directive to give the number of arguments that should be checked, such as:

```
/*VARARGS2*/
```

When **lint** reads this directive, it checks only the first two arguments.

When using **lint** with some (but not all) files that operate together, many of the functions and variables defined in those files may not be used. Also, many functions and variables defined elsewhere may be used. Use the **-u** flag to prevent **lint** from writing these messages.

Using Variables Before They Are Initialized

The **lint** program detects if a program uses a local variable (automatic and register storage classes) before assigning a value to it. In this case, *using a variable* also includes taking the address of the variable. This is because the program can use the variable (through its address) any time after it knows the address of the variable. Therefore, if the program does not assign a value to the variable before it finds the address of the variable, **lint** reports an error. Because **lint** only checks the physical order of the variables and their usage in the file, it may write messages about a program that actually does not contain errors.

The **lint** program recognizes and writes messages about:

- Initialized automatic variables
- Variables that are used in the expression that first sets them
- Local variables that are set and never used.

Note: The operating system initializes static and external variables to zero. Therefore, **lint** assumes that these variables are set (to zero) at the start of the program, and does not check to see if they have been assigned a value when they are used. When developing a program for a system that does not do this initialization, ensure that the program sets static and external variables to an initial value.

Portability Checking

Use **lint** to help ensure that you can compile and run the program on other systems that have a C language compiler that conforms to the UNIX System V[1] requirements for a C compiler. The following paragraphs indicate areas to check before compiling the program on another system. Checking only these areas, however, does not guarantee that the program will run on any system.

---

1 Trademark of AT&T Bell Laboratories.

Character Uses

Some systems define characters in a C language program as signed quantities with a range from -128 to 127; other systems define characters as positive values. The **lint** program writes messages when it finds character comparisons or assignments. The messages indicate that the use of characters may not be portable to other systems. For example, the fragment:

```
char c;
.
.
.
if( ( c = getchar() ) <0 ) . . .
```

may work on one system but fail on systems where characters always take on positive values. The **lint** program writes the message:

```
nonportable character comparison
```

when it checks the program.

To make the program work on systems that use positive values for characters, declare `c` as an integer because **getchar** returns integer values.

Bit Field Uses

Bit fields may also produce problems when transferring a program to another system. When assigning constant values to bit fields, the field may be too small to hold the value, because bit fields may be signed quantities on the new system. To make this assignment work on all systems, declare the bit field to be of type **unsigned** before assigning values to it.

External Name Size

When changing from one type of system to another, be aware of differences in the information retained about external names during the loading process. The number of characters allowed for external names can vary. The AIX Operating System C language compiler considers at least the first 64 characters in internal and external identifiers as significant. Some programs that the compiler command calls and some of the functions that your programs call may further limit the number of significant characters in identifiers. In addition, the compiler adds a leading underscore to all names, and keeps uppercase and lowercase characters separate. On other systems, uppercase or lowercase may not be important or allowed. To avoid problems with loading the program when transferring from one system to another:

1. Find out the requirements of each system
2. Run **lint** with the **-p** flag.

The **-p** flag tells **lint** to change all external symbols to one case and limit them to six characters while checking the input files. The messages produced indicate the terms that may need to be changed.

Multiple Uses and Side Effects

Be careful when using complicated expressions. Many C compilers evaluate complex expressions in different orders. Function calls that are arguments of other functions may or may not be treated the same as ordinary arguments. Also, operators such as assignment, increment, and decrement may cause problems when used on another system. For example, if any variable is changed by a side effect of one of the operators and is also used elsewhere in the same expression, the result is undefined. For example, the evaluation of the variable `years` in the following example is confusing because on some machines `years` is incremented before the function call, while on other machines `years` is incremented after the function call:

```
printf( "%d %d\n", ++years, amort( interest, years ) );
```

The **lint** program checks for simple scalar variables that may be affected by evaluation order problems. For example, the statement:

```
a[i]=b[i++];
```

causes **lint** to write the message:

```
warning: i evaluation order undefined
```

Coding Errors and Style Differences

Use **lint** to detect some coding errors and differences in coding style from the style that **lint** expects. Although coding style is mainly a matter of individual taste, examine each difference to ensure that the difference is both needed and accurate. The following paragraphs indicate the types of coding and style problems that **lint** can find.

Assignments of Long Variables to Integer Variables

If you assign variables of type **long** to variables of type **int**, the program may not work properly. The long variable is truncated to fit in the integer space and data may be lost. An error of this type occurs frequently when converting a program that uses **typedef**s to run on a different system. When changing a **typedef** variable from **int** to **long**, the program can stop working because an intermediate result may be assigned to an integer variable, and the intermediate result is truncated.

To assign a long variable to an integer variable and prevent **lint** from writing messages for these assignments, use the **-a** flag with the **lint** program.

Operator Precedence

The **lint** program detects errors in operator precedence. Without parentheses to show order in complex sequences, these errors are hard to find by looking at the code. For example, the following statements are not clear:

```
if(x&077==0) . . .          /* actually: if(x & (077 == 0) ) */
                           /* should be: if( (x & 077) == 0) */
```

or

```
x<<2+40                    /* shift x left 42 positions */
                           /* should be: (x<<2) + 40 */
```

Use parentheses to make the operation more clearly understood. If you do not, **lint** writes a message.

Conflicting Declarations

The **lint** program writes messages about variables that are declared in inner blocks in a way that conflicts with their use in outer blocks. This practice is allowed but may cause problems in the program. Use the **-h** flag with the **lint** program to prevent writing of messages about conflicting declarations.

Creating A lint Library

For programming projects that define additional library routines, create an additional lint library to check the syntax of the programs. Using this library, the **lint** program can check the new functions in addition to the standard C language functions. Perform the following steps to create a new lint library (see the following paragraphs for more information about these steps).

1. Create an input file that defines the new functions
2. Process the input file to create the lint library file
3. Run **lint** using the new library.

Creating the Input File

Figure 2-1 on page 2-17 shows an input file that defines three additional functions for **lint** to check. This file is a text file that you create with an editor. It consists of:

1. A directive to tell the **cpp** program that the following information is to be made into a library of **lint** definitions:

   ```
   /*LINTLIBRARY*/
   ```

2. A series of function definitions that define:

   - The type of the function (**int** in the example)
   - The name of the function
   - The parameters that the function expects
   - The types of the parameters
   - The value that the function returns.

Name this file in the following format:

`llib-l`*pgm*

In this format, the letters *pgm* represent a unique name that indicates the functions contained in the input file. For example, in the example input file the name of this input file could be **llib-ldms**. When choosing the name of the file, ensure that it is not the same as any of the existing files in the **/usr/lib** directory.

```
/*LINTLIBRARY*/

#include <dms.h>


int  dmsadd( rmsdes, recbuf, reclen )
               int rmsdes;
               char *recbuf;
               unsigned reclen;
             { return 0; }
int  dmsclos( rmsdes)
               int rmsdes;
             { return 0; }
int  dmscrea( path, mode, recfm, reclen )
               char *path;
               int mode;
               int recfm;
               unsigned reclen;
             { return 0; }
```

Figure 2-1. Example lint Library Input File

Creating the lint Library File

To create a lint library file, process the input file using the following command:

```
$ /lib/cpp -C -Dlint llib-lpgm | /usr/lib/lint1 -Htmpfile > \
  /usr/lib/llib-lpgm.ln
```

This command tells the preprocessor program **cpp** and an intermediate program **lint1** to create a lint library file, `/usr/lib/llib-lpgm.ln` using the input file `llib-lpgm`. In each of these cases, the *pgm* in the file name represents the identifier for the input file. The file name `tmpfile` can be any temporary file name. The **lint1** program creates this file and uses it for intermediate storage. When the program completes, delete this file:

```
rm tmpfile
```

Checking a Program with the New Library

To check a program using the new library, use the command:

`lint -l`*pgm filename.c*

In this command, the letters *pgm* represent the identifier for the library, and *filename.c* represents the name of the file containing the C language source code to check. With no other flags, the **lint** program checks the C language source code against the standard lint library in addition to checking the indicated special lint library.

Other C Programming Tools

The AIX Operating System provides tools to help format and check the structure of the C language program. These tools include:

cb ***c beautifier***: This program formats the C language source program into a form that uses indention levels to show the structure of the program.

cflow ***c flow diagram generator***: This program produces an output diagram that shows the logic flow of the C language source program.

cxref ***c cross reference list***: This program produces a list of all external references for each module of the C language program, including where the reference is resolved (if it is).

AIX Operating System Commands Reference explains the syntax and options for these programs. The sample programs contain a C language source program that shows the effects of the **cb** command. This file, `cbtest`, contains the program from one of the other sample programs used in this book. However, the program in this file is without format. Use the **pg** command to look at this file:

```
pg cbtest
```

Press **Enter** at the end of each screen. Then use the **cb** command to format the file and put the formatted output in a file, `test.pretty.c`:

```
cb cbtest > test.pretty.c
```

Look at the output file `test.pretty.c` using the **l** command to see the effect of the **cb** command.

Processing Assembler Language Routines

To use program modules written in RT PC assembler language in a program, assemble the source code and link the resulting output with any other modules in the program. To perform these steps, either:

1. Use the **as** program to assemble the source code into an object module
2. Use the **ld** program to link the object modules with the other object modules that form the program.

or

1. Use the **cc** program to both assemble and link the program.

Using the as Program

The following command sequences show some uses of the **as** program to assemble an assembler language module into an object module:

- Assemble source file `asmtest.s` and place the output in the default file, **a.out**.

```
as asmtest.s
```

- Assemble source file `asmtest.s` and place the output in the file `myfile.o`.

```
as -o myfile.o asmtest.s
```

Using the ld Program

After assembling the source program with the **as** program, use the **ld** program to link that object module with other object modules, or to prepare it to run on the system.

Using the cc Program

To use the **cc** program to process an assembler language file, the file name must end in **.s** to indicate that it is an assembler language source file. The following command sequences show some uses of the **cc** program to assemble an assembler language module into an object module, and link it with other object modules to form the program:

- Assemble and link the file `asmtest.s` and place the resulting program in file **a.out**.

  ```
  cc asmtest.s
  ```

- Assemble the file `asmtest.s` and place the resulting unlinked object code in file `asmtest.o`.

  ```
  cc asmtest.s  -c
  ```

- Assemble the file `asmtest.s`, link it with object files `oldfile.o` and `otherfile.o`, and place the resulting program in file **a.out**.

  ```
  cc asmtest.s oldfile.o otherfile.o
  ```

Building Programs with make

The **make** program builds up-to-date versions of programs. It keeps track of the commands that are needed to create the files, and uses a list of files that must be current before the operations can be done. After changing any part of a program, enter the **make** command on the command line. The **make** program then creates only the files that are affected by the change, according to the rules in its rules file.

Using the **make** program to maintain programs, you can:

- Combine the instructions for creating a large program in a single file
- Define macros to use within the **make** description file
- Define new flags to use with the **make** program
- Create any file to use with the operating system, including SCCS files
- Use shell commands to define the method of file creation, or use the **make** program to create many of the basic types of files
- Create libraries
- Include files from other programs when creating a file.

The **make** program is most useful for medium-sized programming projects. It does not solve the problems of maintaining more than one source version and describing huge programs (see Chapter 10, "Maintaining Different Versions of a Program" on page 10-1).

Operation

The **make** program uses the following sources of information:

- A description file that you create
- File names
- Time stamps of the files from the file system
- Rules in the **make** program that tell how to build many of the standard types of files.

The file containing the completed program is called a **target file**. The **make** program creates a target file using a step-by-step procedure:

1. Finds the name of the target file in the description file, or in the **make** command
2. Ensures that the files on which the target file depends exist and are up-to-date
3. Determines if the target file is up-to-date with the files it depends on

4. If the target file or one of the parent files is out of date, creates the target file using one of the following:
   a. Commands from the description file
   b. Internal rules to create the file (if they apply)
   c. Default rules from the description file.

If all files in the procedure are up-to-date when running the **make** program, **make** displays a message to indicate that the file is up-to-date, and then stops. If some files have changed, **make** creates only those files that are out of date, and does not create files that are already current.

When the **make** program runs commands to create a target file, it replaces macros with their values, writes each command line, and then passes the command to a new copy of the shell.

Using the make Program

Start the **make** program from the directory that contains the description file for the file to create. The variable name *desc-file* represents the name of that description file. Then, enter the command:

`make -f` *desc-file*

on the command line. Enter macro definitions, flags, description file names, and target file names along with the **make** command on the command line as follows:

```
make [flags] [macro definitions] [targets]
```

The **make** program then examines the command line entries to determine what to do. First, it looks at all macro definitions on the command line (entries that are enclosed in quotes and have equal signs in them) and assigns values to them. If it finds a definition for a macro on the command line different from the definition for that macro in the description file, it chooses the command line definition for the macro.

Next, the **make** program looks at the flags. See *IBM RT PC AIX Operating System Commands Reference* for a list of the flags that **make** recognizes.

The **make** program expects the remaining command line entries to be the names of target files to be created. The **make** program creates the target files in left to right order. Without a target file name, the **make** program creates the first target file named in the description file that does not begin with a period. With more than one description file specified, **make** searches the first description file for the name of the target file.

Description Files

The description file tells **make** how to build the target file, what files are involved, and what their relationships are to the other files in the procedure. The description file contains the following information:

- Target file name
- Parent file names that make up the target file
- Commands that create the target file from the parent files
- Definitions of macros in the description file.

The **make** program determines what files to create to get an up-to-date copy of the target file by checking the dates of the parent files. If any parent file was changed more recently than the target file, **make** creates the files that are affected by the change, including the target file.

If you name the description file **makefile** or **Makefile**, and are working in the directory containing that description file, enter the command:

```
make
```

to bring the first target file and its parent files up-to-date, regardless of the number of files that were changed since the last time **make** created the target file. In most cases, the description file is easy to write and does not change often.

To keep many different description files in the same directory, name them differently. Then, enter the command:

```
make -f desc-file
```

substituting the name of the description file to use in place of the variable name *desc-file*.

Format of a Description File Entry

The general form of an entry is:

```
target1 [target2..]:[:] [parent1..][; commands] [#..]
[(tab) commands] [# . . . ]
 . . .
```

The items that are inside brackets are optional. Targets and parents are file names (strings of letters, numbers, periods, and slashes). **make** recognizes wildcard characters such as * (asterisk) and ? (question mark). Each line in the description file that contains a target file name is called a dependency line. Lines that contain commands must begin with a tab character.

Put comments in the description file by using a # (number sign) to begin the comment phrase. The **make** program ignores the # and all characters on the same line after the #. The **make** program also ignores blank lines.

If the line is not a comment line, you can enter lines that are longer than the line width of the input device. To continue a line on the next line, put a \ (backslash) at the end of the line that is to be continued.

Using Commands in a Description File

A command is any string of characters not including a # or a new line. A command can use a # if it is in quotes. Commands can appear either after a semicolon on a dependency line, or on lines beginning with a tab immediately following a dependency line.

When defining the command sequence for a particular target, specify either one command sequence for each target in the description file, or specify separate command sequences for special sets of dependencies. Do not do both.

To use one command sequence for every use of the target, use a single : (colon) following the target name on the dependency line. For example:

```
test:        dependency list1...;
        command list...
            .
            .
            .
test:        dependency list2...;
```

defines a target name, `test`, with a set of parent files, and a set of commands to create the file. The target name, `test`, can appear in other places in the description file with another dependency list, but that name cannot have another command list in the description file. When one of the files that `test` depends on changes, **make** runs the commands in that one command list to create the file, `test`.

To specify more than one set of commands to create a particular target file, enter more than one dependency definition. Each dependency line must have the target name, followed by :: (two colons), a dependency list, and a command list that **make** uses if any of the files in the dependency list changes. For example:

```
test::      dependency list1...;
        command list1...

test::      dependency list2...;
        command list2...
```

defines two separate processes to create the target file, `test`. If any of the files in dependency list1 changes, **make** runs command list1; if any of the files in dependency list2 changes, **make** runs command list2. To avoid conflicts, a parent file cannot appear in both dependency list1 and dependency list2.

Note: Because **make** passes the commands from each command line to a new shell, be careful when using certain commands (for example, **cd** and shell control commands) that have meaning only within a single shell process. The **make** program forgets these results before running the commands on the next line.

To group commands together, use the \ (backslash) at the end of a command line. The **make** program continues that command line into the next line in the description file. The shell sends both of these lines to a single new shell.

Calling the Make Program from a Description File

Nest calls to the **make** program within a **make** description file by including the **$(MAKE)** macro in one of the command lines in the file. If this macro is present, **make** calls another copy of **make** even if the **-n** flag (*do not execute*) is set. The **make** program passes the flags to the new copy of **make** through the **MAKEFLAGS** variable.

If the **-n** flag is set when the **$(MAKE)** macro is found, the new copy of **make** does not do any of its commands, except another **$(MAKE)** macro. Use this characteristic to test a set of description files that describe a program. Enter the command:

```
make -n
```

The **make** program does not do any of the operations, but it writes all of the steps needed to build the program, including output from lower level calls to **make**.

Preventing the make Program from Writing Commands

To prevent **make** from writing the commands while it runs, do any of the following:

- Use the **-s** flag on the command line when using the **make** command.
- Put the fake target name **.SILENT** on a dependency line by itself in the description file. Because **.SILENT** is not a real target file, it is called a ***fake target***.
- Put an @ in the first character position of each line in the description file that **make** should not write.

Prevent Stopping on Errors

The **make** program normally stops if any program returns an error code that is not zero. Some programs return status that has no meaning.

To prevent **make** from stopping on errors, do any of the following:

- Use the **-i** flag on the command line when using the **make** command.
- Put the fake target name **.IGNORE** on a dependency line by itself in the description file. Because **.IGNORE** is not a real target file, it is called a ***fake target***.
- Put a - (hyphen) in the first character position of each line in the description file where **make** should not stop on errors.

Example of a Description File

For example, a program named **prog** is made by compiling and loading three C language files `x.c`, `y.c`, and `z.c` with the C library (**libc.a**) and the run time library (**librts.a**). The files `x.c` and `y.c` share some declarations in a file named `defs`. The file `z.c` does not share those declarations. A description file to create **prog** looks like:

```
# Make prog from 3 object files
prog:  x.o y.o z.o
# Use the cc program to make prog
    cc  x.o y.o z.o -o prog

# Make x.o from 2 other files
x.o:   x.c defs
# Use the cc program to make x.o
    cc  -c x.c

# Make y.o from 2 other files
y.o:   y.c defs
# Use the cc program to make y.o
    cc  -c y.c

# Make z.o from z.c
z.o:   z.c
# Use the cc program to make z.o
    cc  -c z.c
```

If this file is called **makefile**, just enter the command:

```
make
```

to make **prog** up-to-date after making changes to any of the four source files `x.c`, `y.c`, `z.c` or `defs`.

Making the Description File Simpler

To make this file simpler, use the internal rules of the **make** program. Using file system naming conventions, **make** knows that there are three **.c** files corresponding to the needed **.o** files. It also knows how to generate an object from a source file (that is, issue a **cc -c** command).

By taking advantage of these internal rules, the description file becomes:

```
# Make prog from 3 object files
prog:  x.o y.o z.o
# Use the cc program to make prog
    cc  x.o y.o z.o -o prog

# Use the file defs and the .c file
# when making x.o and y.o
x.o y.o:   defs
```

Internal Rules

The internal rules for the **make** program are in a file that looks like a description file. With the **-r** flag the **make** program does not use the internal rules file; you must supply the rules to create the files. The internal rules file contains a list of file name suffixes (such as, **.o**, or **.a**) that **make** understands, plus the rules that tell **make** how to create a file with one suffix from a file with another suffix. If you do not change the list, **make** understands the following suffixes:

.o Object file

.c C source file

.e Efl source file

.r Ratfor source file

.f FORTRAN source file

.s Assembler source file

.y Yacc-c source grammar

.yr Yacc-Ratfor source grammar

.ye Yacc-Efl source grammar

.l Lex source grammar

The list of suffixes is like a dependency list in a description file, and follows the fake target **.SUFFIXES**. Because **make** looks at the suffixes list in left to right order, the order of the entries is important. The **make** program uses the first entry in the list that satisfies two requirements:

- The entry matches input and output suffix requirements.
- The entry has a rule assigned to it.

The **make** program creates the name of the rule from the two suffixes of the files that the rule defines. For example, the name of the rule to transform a **.r** file to a **.o** file is **.r.o**.

To add more suffixes to the list, add an entry for **.SUFFIXES** in the description file. For a **.SUFFIXES** line without any suffixes following the target name in the description file, **make** erases the current list. To change the order of the names in the list, erase the current list and then assign a new set of values to **SUFFIXES**.

Figure 2-2 shows the paths that **make** uses to create a file. If two paths connect a pair of suffixes, **make** uses the longer one only if the intermediate file exists or is named in the description file.

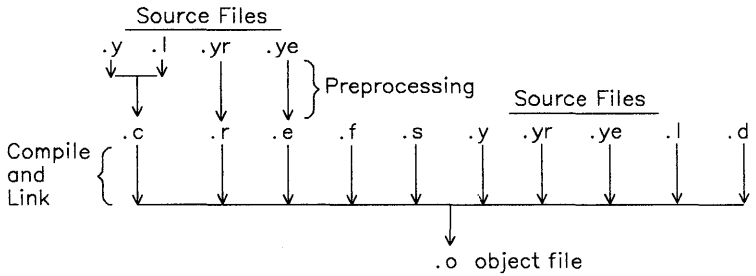


Figure 2-2. Rules for Creating Files

Example of Default Rules File

Figure 2-3 on page 2-31 shows a portion of the default rules file.

```
# Define suffixes that make knows
.SUFFIXES:  .o .c .e .r .f .y .yr .ye .l .s

# Begin macro definitions for
# internal macros
YACC = yacc
YACCR = yacc -r
YACCE = yacc -r
YFLAGS =
LEX = lex
LFLAGS =
CC =cc
AS = as
CFLAGS =
RC = ec
RFLAGS =
EC = ec
EFLAGS =
FFLAGS =
# End macro definitions for
# internal macros

# Create a .o file from a .c
# file with the cc program
.c.o:
        $(CC) $(CFLAGS) -c $<

# Create a .o file from either a
# .e , a .r , or a .f
# file with the efl compiler
.e.o .r.o .f.o:
        $(EC) $(RFLAGS) $(EFLAGS) $(FFLAGS) -c $<
```

Figure 2-3 (Part 1 of 2). Example Default Rules File

```
# Create a .o file from
# a .s file with the assembler
.s.o:
        $(AS) -o $@ $<

.y.o:
# Use yacc to create an intermediate file
        $(YACC) $(YFLAGS) $<
# Use cc compiler
        $(CC) $(CFLAGS) -c y.tab.c
# Erase the intermediate file
        rm y.tab.c
# Move to target file
        mv y.tab.o $@

.y.c:
# Use yacc to create an intermediate file
        $(YACC) $(YFLAGS) $<
# Move to target file
        mv y.tab.c $@
```

Figure 2-3 (Part 2 of 2). Example Default Rules File

Single Suffix Rules

The **make** program also has a set of single suffix rules to create files directly to a file name that does not have a suffix (command files for example). The **make** program has rules to change the following source files with a suffix to object files without a suffix:

.c: From a c language source file

.c~: From an SCCS C language source file

.sh: From a shell file

.sh~: From an SCCS shell file

Therefore, to maintain a program like **cat**, enter:

```
make cat
```

if all of the needed files are in the current directory.

Using Make with Archive Libraries

Use **make** to build libraries and library files. The **make** program recognizes the suffix **.a** as a library file. The internal rules for changing source files to library files are:

.c.a c source to archive

.c~.a SCCS C source to archive

.s~.a SCCS assembler source to archive

Changing Macros in the Rules File

The **make** program uses macro definitions in the rules file. To change these macro definitions, enter new definitions for those macros on the command line or in the description file. The **make** program uses the following macro names to represent language processors that it uses:

- AS for the assembler
- CC for the c compiler
- RC for the ratfor compiler
- EC for the efl compiler
- YACC for yacc
- YACCR for yacc -r
- YACCE for yacc -e
- LEX for lex.

The **make** program uses the following macro names to represent flags that it uses:

- CFLAGS for c compiler flags
- RFLAGS for ratfor compiler flags
- EFLAGS for efl compiler flags
- YFLAGS for yacc flags
- LFLAGS for lex flags.

Therefore, the command:

```
make "CC=newcc"
```

tells **make** to use the **newcc** program in place of the usual C language compiler. Similarly, the command:

```
make "CFLAGS=-O"
```

tells **make** to optimize the final object code produced by the C language compiler.

To look at the internal rules (in **rules.c**) that **make** uses, enter the following command:

```
make -f -p /dev/null 2>/dev/null
```

The output appears on the standard output.

Defining Default Conditions

When **make** creates a target file and cannot find commands in the description file and internal rules to create a file, it looks at the description file for default conditions. To define the commands that **make** performs in this case, use the .DEFAULT target name in the description file:

```
.DEFAULT:
        command
        command
          .
          .
          .
```

Because .DEFAULT is not a real target file, it is called a ***fake target***. Use the .DEFAULT fake target for an error recovery routine, or for a general procedure to create all files in the program that are not defined by an internal rule of the **make** program.

Including Other Files

Include files other than the current description file by using the word **include** as the first word on any line in the description file. Follow the word with a blank or a tab, and then the set of file names for **make** to include in the operation. For example:

```
include     /u/tom/temp /u/tom/sample
```

tells **make** to read the files temp, sample and the current description file to build the target file.

Do not use more than 16 levels of nesting with the include files feature.

Defining Macros

A macro is a name (or label) to use in place of several other names. It is a shorthand way of using the longer string of characters. To define a macro:

1. Start a new line with the name of the macro.
2. Follow the name with an = (equal sign).
3. To the right of the =, enter the string of characters that the macro name represents.

The macro definition can contain blanks before and after the = without affecting the result. The macro definition cannot contain a : (colon) or a tab before the =.

The following are examples of macro definitions:

```
# Macro "2" has a value of "xyz"
2 = xyz

# Macro "abc" has a value of "-ll -ly"
abc = -ll -ly

# Macro "LIBES" has a null value
LIBES =
```

A macro that is named but is not defined has a value of the null string.

Using Macros in a Description File

After defining a macro in a description file, use the macro in the description file commands by putting a $ (dollar sign) before the name of the macro. If the macro name is longer than one character, put ( ) (parentheses) or { } (braces) around it. The following are examples of using macros:

```
$(CFLAGS)
$2
$(xy)
$Z
$(Z)
```

The last two examples have the same effect.

The following fragment shows how to define and use some macros:

```
# OBJECTS is the 3 files x.o, y.o and
# z.o (previously compiled)
OBJECTS = x.o y.o z.o

# LIBES is the standard library
LIBES = -lc

# prog depends on x.o y.o and z.o
prog:  $(OBJECTS)
# Link and load the 3 files with
# the standard library to make prog
      cc $(OBJECTS) $(LIBES) -o prog
```

The **make** program that uses that description file loads the three object files with the **libc.a** library.

A macro definition entered on the command line replaces any macro definitions in the description file that define the same macro label. Therefore, the command:

```
make "LIBES= -ll"
```

loads the files with the Lex (`-ll`) library.

Note: When entering macros with blanks in them on the command line, put " (double quotes) around the macro. Without the double quotes, the shell interprets the blanks as parameter separators and not a part of the macro.

Internal Macros

The **make** program has built-in macro definitions for use in the description file. These macros help specify variables in the description file. The **make** program replaces the macros with one of the following values:

$@	The name of the current target file
$$@	The label name on the dependency line
$?	The names of the files that have changed more recently than the target
$<	The name of the out-of-date file that caused a target file to be created
$*	The name of the current parent file without the suffix
$%	The name of an archive library member.

Target File Name

If the $@ macro is in the command sequence in the description file, **make** replaces the symbol with the full name of the current target file before passing the command to the shell to be run. The **make** program replaces the symbol only when it runs commands from the description file to create the target file.

Label Name

If the $$@ macro is on the dependency line in a description file, **make** replaces this symbol with the label name that is on the left side of the colon in the dependency line. This name could be a target file name, the name of a new flag, or the name of another macro. For example, if the following is included in a dependency line:

```
cat:      $$@.c
```

The **make** program translates it to:

```
cat:      cat.c
```

when **make** evaluates the expression. Use this macro to build a group of files, each of which has only one source file. For example, to maintain a directory of system commands, use a description file like:

```
# Define macro CMDS as a series
# of command names
CMDS = cat dd echo date cc cmp comm ar ld chown

# Each command depends on a .c file
$(CMDS):      $$@.c

# Create the new command set by compiling the out of
# date files ($?) to the target file name ($@)
        $(CC) -O $? -o $@
```

The **make** program changes the $$(@F) macro to the file part of $@ when it runs. For example, use this symbol when maintaining the **usr/include** directory while using a description file in another directory. That description file would look like:

```
# Define directory name macro INCDIR
INCDIR = /usr/include

# Define a group of files in the directory
# with the macro name INCLUDES
INCLUDES = \
        $(INCDIR)/stdio.h \
        $(INCDIR)/pwd.h \
        $(INCDIR)/dir.h \
        $(INCDIR)/a.out.h \

# Each file in the list depends on a file
# of the same name in the current directory
$(INCLUDES):       $$(@F)

# Copy the younger files from the current
# directory to /usr/include
        cp $? $@

# Set the target files to read only status
        chmod 0444 $@
```

This description file creates a file in the **/usr/include** directory when the corresponding file in the current directory has been changed.

Younger Files

If the $? macro is in the command sequence in the description file, **make** replaces the symbol with a list of parent files that have been changed since the target file was last changed. The **make** program replaces the symbol only when it runs commands from the description file to create the target file.

First Out-of-date File

If the $< macro is in the command sequence in the description file, **make** replaces the symbol with the name of the file that started the file creation. The file name is the name of the parent file that was out of date with the target file, and therefore caused **make** to create the target file again.

In addition, use a letter (D or F) after the < (less-than sign) to get either the directory name (D) or the file name (F) of the first out-of-date file. For example, if the first out-of-date file were:

```
/u/tom/sample.c
```

then **make** gives the following values:

```
$(<D)    =    /u/tom
$(<F)    =    sample
$<       =    /u/tom/sample
```

The **make** program replaces this symbol only when it runs commands from its internal rules or from the .DEFAULT list.

Current File Name Prefix

If the $* macro is in the command sequence in the description file, **make** replaces the symbol with the file name part (without the suffix) of the parent file that **make** is currently using to generate the target file. For example, if **make** is using the file:

```
test.c
```

then the $* represents the file name, `test`.

In addition, use a letter (D or F) after the * (asterisk) to get either the directory name (D) or the file name (F) of the current file.

For example, **make** uses many files (specified either in the description file or the internal rules) to create a target file. Only one of those files (the ***current file***) is used at any moment. If that current file were:

```
/u/tom/sample.c
```

then **make** gives the following values for the macros:

```
$(*D)   =  /u/tom
$(*F)   =  sample
$*      =  /u/tom/sample
```

The **make** program replaces this symbol only when it runs commands from its internal rules (or from the .DEFAULT list), and not when running commands from a description file.

Archive Library Member

If the $% macro is in a description file, and the target file is an archive library member, **make** replaces the macro symbol with the name of the library member. For example, if the target file is:

```
lib(file.o)
```

then **make** replaces the $% with the member name, `file.o`.

Changing Macro Definitions in a Command

When macros in the shell commands are in the description file, you can change the values that **make** assigns to the macro. To change the assignment of the macro, put a : (colon) after the macro name, followed by a replacement string. The form is as follows:

```
$(macro:string1=string2)
```

When **make** reads the macro and begins to assign the values to the macro from the macro definition, it replaces each `string1` in the macro definition with a value of `string2`. For example, if the description file contains the macro definition:

```
FILES=test.o sample.o form.o defs
```

you can replace the file `form.o` with a new file, `input.o`, by using the macro in the description file commands:

```
cc -o $(FILES:form.o=input.o)
```

Changing the value of a macro in this manner is useful when maintaining archive libraries (see the **ar** program in *AIX Operating System Commands Reference*).

Using Make with SCCS Files

The **make** program does not allow references to prefixes of file names. Because SCCS file names begin with an **s.**, do not refer to them directly within a **make** description file. The **make** program uses a different suffix, the ~ (tilde), to represent SCCS files. Therefore, `.c~.o` refers to the rule that transforms an SCCS C language source file into an object. The internal rule is:

```
.c~.o:
        $(GET) $(GFLAGS) -p  $<  >$*.c
        $(CC) $(CFLAGS) -c $*.c
        -rm -f $*.c
```

The ~ added to any suffix changes the file search into an SCCS file name search with the actual suffix named by the . (period) and all characters up to (but not including) the ~. The `GFLAGS` macro passes flags to SCCS to determine the version of the SCCS files to be used.

The **make** program recognizes the following SCCS suffixes:

.c~	c source
.y~	yacc source grammar
.s~	assembler source
.sh~	shell
.h~	header

The **make** program has internal rules for changing the following SCCS files:

```
.c~:
.sh~:
.c~.o:
.s~.o:
.y~.o:
.l~.o:
.y~.c:
.c~.a:
.s~.a:
.h~.h:
```

Description Files Stored in SCCS

If you specify a description file, or a file named **makefile** is in the current directory, **make** does not look for a description file within SCCS. If a description file is not in the current directory and you enter the command, `make`, the **make** program looks for an SCCS file named either **s.makefile** or **s.Makefile**. If either of these files are present, **make** uses a **get** command to tell SCCS to build the description file from that source file. The value of the internal macro, **GETFLAGS**, determines the level of the file that SCCS creates. When SCCS creates the description file, **make** uses the file as a normal description file. When **make** finishes, it removes the created description file from the current directory.

How make Uses the Environment Variables

Each time **make** runs, it reads the current environment variables and adds them to its defined macros. In addition, it creates a new macro called **MAKEFLAGS**. This macro is a collection of all input flags to the **make** program (without the minus signs). Command line flags and assignments in the description file can also change the **MAKEFLAGS** macro. When **make** starts another process, it passes **MAKEFLAGS** to that process by using the **export** command.

When **make** runs, it assigns macro definitions in the following order:

1. Reads the **MAKEFLAGS** environment variable to set debug on, if it is needed.

   If **MAKEFLAGS** is not present or null, **make** sets its internal **MAKEFLAGS** variable to the null string. Otherwise, **make** assumes that each letter in **MAKEFLAGS** is an input flag. The **make** program uses these flags (except for the **-f, -p,** and **-r** flags) to determine its operating conditions.

2. Reads and sets the input flags from the command line. The command line adds to the previous settings from the **MAKEFLAGS** environment variable.

3. Reads macro definitions from the command line. **Make** ignores any further assignments to these names.

4. Reads the internal macro definitions.

5. Reads the environment, including the **MAKEFLAGS** macro. The **make** program treats the environment variables as macro definitions and passes them to other shell programs.

Example of a Description File

Figure 2-4 shows the description file that maintains the **make** program. The source code for **make** is spread over a number of C language source files and a Yacc grammar.

```
# Description file for the Make program

# Macro def: send to be printed
P = und -3 | opr -r2

# Macro def: source filenames used
FILES = Makefile version.c defs main.c
        doname.c misc.c files.c
        dosy.c gram.y lex.c gcos.c

# Macro def: object filenames used
OBJECTS = version.o main.o doname.o
          misc.o files.o dosys.o
          gram.o

# Macro def: lint program and flags
LINT = lint -p

# Macro def: c compiler flags
CFLAGS = -O

# make depends on the files specified
# in the OBJECTS macro definition
make:    $(OBJECTS)
# Build make with the cc program
         cc $(CFLAGS) $(OBJECTS) -o make
# Show the file sizes
         size make
```

Figure 2-4 (Part 1 of 3). Example Description File

```
# The object files depend on a file
# named defs
$(OBJECTS):  defs

# The file gram.o depends on lex.c
# uses internal rules to build gram.o
gram.o:  lex.c

# Clean up the intermediate files
clean:
        -rm *.o gram.c
        -du

# Copy the newly created program
# to /usr/bin and deletes the program
# from the current directory
install:
        @size make /usr/bin/make
        cp make /usr/bin/make ; rm make

# Empty file "print" depends on the
# files included in the macro FILES
print:   $(FILES)
# Print the recently changed files
        pr $? | $P
# Change the date on the empty file,
# print, to show the date of the last
# printing
        touch print
```

Figure 2-4 (Part 2 of 3). Example Description File

```
# Check the date of the old
# file against the date
# of the newly created file
test:
        make -dp |grep -v TIME >1zap
        /usr/bin/make -dp | grep -v TIME >2zap
        diff 1zap 2zap
        rm 1zap 2zap

# The program, lint, depends on the
# files that are listed
lint:   dosys.c doname.c files.c main.c misc.c
        version.c gram.c
# Run lint on the files listed
# LINT is an internal macro
        $(LINT) dosys. doname.c files.c main.c
        misc.c version.c gram.c
        rm gram.c

# Archive the files that build make
arch:
        ar uv /sys/source/s2/make.a $(FILES)
```

Figure 2-4 (Part 3 of 3). Example Description File

The **make** program usually writes out each command before issuing it.

The following output results from typing the simple command **make** in a directory containing only the source and description file:

```
cc -O -c version.c
cc -O -c main.c
cc -O -c doname.c
cc -O -c misc.c
cc -O -c files.c
cc -O -c dosys.c
yacc  gram.y
mv y.tab.c gram.c
cc -O -c gram.c
cc version.o main.o doname.o misc.o files.o dosys.o
   gram.o -o make
13188+3348+3044 = 19580b = 046174b
```

Although none of the source files or grammars are specified in the description file, **make** uses its suffix rules to find them and issues the needed commands. The string of digits is the result of the **size make** command. The @ (at sign) on the **size** command in the description file prevented writing of the command, so only the sizes are written.

The output can be sent to a different printer or to a file by changing the definition of the **P** macro on the command line as follows:

```
make print "P = print -sp"
         or
make print "P = cat >zap"
```

Chapter 3. Using the Subroutine Libraries

CONTENTS

About This Chapter

This chapter describes the subroutine libraries that are included with the AIX Operating System. Refer to *AIX Operating System Technical Reference* for complete technical information about each library function. That book is organized alphabetically by the name of the function. This section groups the functions by library, and by function within the library. It describes the following commonly used libraries:

- C library (with or without hardware floating-point)
- Run time services library
- Math library (with or without hardware floating-point).

System Libraries

Figure 3-1 on page 3-4 lists the system libraries. The libraries are collections of commonly used functions and declarations. Use them in a program to avoid creating the functions for each new program.

To use the library functions:

- Include any declarations for the variables that the library routines use in the program
- Link the library routines with the program files after the program is compiled, or in the same process using the **cc** command.

Name	Path name	cc flag	Function
General C Libraries:			
C library	/lib/libc.a	Not required	Common C language subroutines for file access, string operations, character operations, memory allocation and other functions.
C library (floating-point)	/lib/libfc.a	-lfc	The same routines as the C library, except that some were compiled to use the hardware Floating-Point Accelerator to perform floating-point arithmetic.
Math library	/lib/libm.a	-lm	Mathematical functions using software routines to perform floating-point arithmetic.
Floating-Point Math library	/lib/libfm.a	-lfm	The same routines as the math library, except that they were compiled to use the hardware Floating-Point Accelerator to perform floating-point arithmetic.
Run Time Services library	/lib/librts.a	Not required	Support system services such as system configuration, messages, trace and error log support.
Programmer Workbench library	/lib/libPW.a	-lPW	Miscellaneous operating system functions.
Standalone Subroutine Library	/usr/lib/lib2.a	-l2	Miscellaneous operating system functions.

Figure 3-1 (Part 1 of 3). Summary of System Libraries

Name	Path name	cc flag	Function
Terminal I/O Libraries:			
curses	/usr/lib/libcurses.a	-llibcurses	Control functions for writing data to and getting data from the terminal screen.
Extended curses	/usr/lib/libcur.a	-lcur -lcurses	Control functions for writing data to and getting data from the terminal screen that support color, multiple windows, and an enhanced character set. See Chapter 5, "Controlling the Terminal Screen" on page 5-1.
DOS Libraries:			
DOS library	/usr/lib/libdos.a	-llibdos	DOS (Disk Operating System) functions from a program running on RT PC.
DOS I/O library	/usr/lib/libdossio.a	-llibdossio	Access to DOS (Disk Operating System) file systems and I/O functions from a program running on RT PC.
Graphics Libraries:			
DASI 300 Graphics Interface library	/usr/lib/lib300.a	-l300	Graphics functions to a DASI 300 terminal.
DASI 300s Graphics Interface library	/usr/lib/lib300s.a, or /usr/lib/lib300S.a	-l300s, or -l300S	Graphics functions to a DASI 300s terminal.
DASI 450 Graphics Interface library	/usr/lib/lib450.a	-l450	Graphics functions to a DASI 450 terminal.
Tektronix 4014 Graphics Interface library	/usr/lib/lib4014.a	-l4014	Graphics functions to a Tektronix 4014 terminal.

Figure 3-1 (Part 2 of 3). Summary of System Libraries

Name	Path name	cc flag	Function
tplot Filters Graphics Interface library	/usr/lib/libplot.a	-lplot	Graphics functions for tplot filters.
IBM PC Graphics Printer Interface library	/usr/lib/libprint.a	-lprint	Graphics functions to an IBM 5250 Graphics Printer.
Other Libraries:			
Data Base Subroutine library	/usr/lib/libdbm.a	-ldbm	Data base subroutines.
Queue Backend Subroutine library	/usr/lib/libqb.a	-lqb	Subroutines for queue backends.
sdb library	/usr/lib/libg.a	-lg	Subroutines that create object code with extra space for debugging with the **sdb** program.
lex library	/usr/lib/libl.a	-ll	Subroutines for programs created by the **lex** program generator.
yacc library	/usr/lib/liby.a	-ly	Subroutines for programs created by the **yacc** program generator.

Figure 3-1 (Part 3 of 3). Summary of System Libraries

Including Declarations

Some functions require a set of ***declarations*** to operate properly. You must specifically request that these declarations be included in a program. The system stores some declaration files, called ***header files***, in the **/usr/include** directory. To include a header file, use the following directive within a C language program:

```
#include <file.h>
```

where *file* is the name of one of the header files. Put all header file directives at the beginning of all files being compiled that use the header file.

Linking the Library Routines

When you compile a program, the **cc** program uses the **ld** program to search the C language library and the run time services library to locate and include functions that are used in the program. To locate and include functions from other libraries, specify these libraries on the command line when starting the **cc** command. For example, when using functions of the math library, request that the math library be searched by including the argument:

```
-lm
```

on the command line, such as:

```
cc file.c -lm
```

Use this method for all functions that are not part of the C language or run time services libraries. Using this method, the compiler searches the C library and the run time services library after searching the specified libraries. Refer to the description of the **ld** command in *AIX Operating System Commands Reference* for information about linking other libraries to a program.

Library Descriptions

The rest of this chapter describes the functions and header files of the libraries. Each library description begins with how to include the functions and/or header files in a program. Then, each function is listed and briefly described. Following the listing are descriptions of the header files associated with these functions (if any).

The C Library

The C library routines perform the following types of services:

- Input/output control
- String manipulation
- Character manipulation
- Time functions
- Miscellaneous functions.

The compiler loads the functions of the C library automatically. However, you must include any required declarations in the program.

Input/Output Control

The input and output (I/O) functions provide buffered I/O for a program that is easier to use than using the **read** and **write** system calls (see Chapter 4, "Using System Calls" on page 4-1). Do not specify any special flag to the compiler to use the I/O control functions.

Include the header file for these functions in the program. To include a header file, use the following statement:

```
#include <stdio.h>
```

All include statements should be near the beginning of the first file being compiled, usually in the declarations section before `main( )`, and must occur before using any library functions.

Using I/O Routines

The system treats devices as if they were files for input and output. Any of the I/O system calls or library routines can send data to or from either a device or a file. You must also open and close a device the same as a file.

Some of the I/O library routines are actually macros defined in a header file, and some are object modules of functions. In many cases the library contains a function and a macro that do the same type of operation. Consider the following points when deciding which to use:

- You cannot set a breakpoint for a macro using the debug program.
- Functions may have side effects to avoid.
- Macros usually are faster than the functions because the preprocessor replaces the macros with actual lines of code in the program.
- Macros result in larger object code after being compiled.

Some of the I/O routines use **stdin** and **stdout** as their input and output channel. Most of the routines, however, allow you to specify a file for the source or destination of the data transfer. Some specify the file using a file pointer (which points to a structure containing the file name); others accept a file descriptor (a positive integer assigned to the file when it is opened).

Figure 3-2 on page 3-10 summarizes some important characteristics of the input and output routines. The column headings mean:

Operation The name of the I/O routine or system call

Macro/Function If the operation is a library routine, this column shows if it is a macro or a function. If it is a system call, this column shows that it is a system call.

Input/Output The source and/or destination of the operation is either a file that you can **Specify** or it uses **stdio** (standard input and output).

Formatted The resulting data stream is formatted (**Yes**) or not formatted (**No**).

Operation Type The data type of the information being transferred: byte, character, word (4-bytes) or string.

Operation	Macro/Function	Input/Output	Formatted	Operation Type
read	System Call	Specify	No	Byte
write	System Call	Specify	No	Byte
fread	Function	Specify	No	Byte
fwrite	Function	Specify	No	Byte
printf	Function	stdio	Yes	Byte
fprintf	Function	Specify	Yes	Byte
sprintf	Function	Specify	Yes	Byte
scanf	Function	stdio	Yes	Byte
fscanf	Function	Specify	Yes	Byte
ungetc	Function	Specify	No	Character
getc	Macro	Specify	No	Character
getchar	Macro	stdio	No	Character
fgetc	Function	Specify	No	Character
putc	Macro	Specify	No	Character
putchar	Macro	stdio	No	Character
fputc	Function	Specify	No	Character
getw	Function	Specify	No	Word
putw	Function	Specify	No	Word
gets	Function	stdio	No	String
fgets	Function	Specify	No	String
puts	Function	stdio	No	String
fputs	Function	Specify	No	String
sscanf	Function	Specify	Yes	String

Figure 3-2. Comparison of I/O Operations

I/O Routines Descriptions

The I/O routine descriptions are grouped into the following categories:

- File access
- File status
- Input
- Output
- Miscellaneous.

In the following descriptions, ***stream*** input and output refers to sequential input and output using open file descriptors. The terms ***stdin*** and ***stdout*** refer to the device or file that is currently assigned as standard input or standard output.

File Access

fclose Closes an open stream.

fdopen Associates stream with an opened file.

fileno Returns a file descriptor associated with an open stream.

fopen Opens a stream with specified permissions. A stream is what **fopen** returns.

freopen Substitutes named file in place of open stream.

fseek Repositions stream pointer.

pclose Closes a stream opened by **popen**.

popen Creates a pipe as a stream between two processes.

rewind Repositions stream pointer at beginning of file.

setbuf Turns buffering to stream on and off.

File Status

clearerr Resets error condition on stream.

feof Tests for end of file on stream.

ferror Tests for error condition on stream.

ftell Returns current stream pointer.

Input

fgetc	Reads next character from stream (function for the macro **getc**).
fgets	Reads string from stream.
fread	Reads from stream, buffered.
fscanf	Reads using format from stream.
getc	Returns next character from stream.
getchar	Returns next character from **stdin**.
gets	Reads string from **stdin**.
getw	Reads word from stream.
scanf	Reads using format from **stdin**.
sscanf	Reads using format from string.
ungetc	Puts back one character on stream.

Output

fflush	Writes all currently buffered characters from stream.
fprintf	Writes using format to stream.
fputc	Writes next character to stream (function for **putc**).
fputs	Writes string to stream.
fwrite	Writes to stream, buffered.
printf	Writes using format to **stdout**.
putc	Writes next character to stream.
putchar	Writes next character to **stdout**.
puts	Writes string to **stdout**.
putw	Writes word to stream.
sprintf	Writes using format to string.

Miscellaneous

ctermid	Returns file name for controlling terminal.
cuserid	Returns login name for owner of current process.
system	Executes system command.
tempnam	Creates temporary file name using directory and prefix.
tmpnam	Creates temporary file name.
tmpfile	Creates temporary file.

I/O Header File

The I/O header file is **stdio.h** in the **/usr/include** directory. This file contains macro definitions and parameters that the I/O library routines use. The shell automatically opens the following files:

stdin	Standard input file
stdout	Standard output file
stderr	Standard error file.

String Manipulation

The string manipulation functions include:

- Locate a character position within a string
- Copy a string
- Concatenate strings
- Compare strings.

You do not need to specify any special flag to the compiler or include any header file for these functions in the program to use the string functions.

The string routines perform the following functions:

regcmp Compiles a regular expression (consider using the **regcmp** command instead.

regex Executes a compiled regular expression against a string.

strcat Concatenates two strings.

strchr Searches string for character.

strcmp Compares two strings.

strcpy Copies string over string.

strcpsn Returns the length of initial string not containing set of characters.

strlen Returns the length of string.

strncat Concatenates up to a specified number of characters from one string to another string.

strncmp Compares up to a specified number of characters from one string with another string.

strncpy Copies up to a specified number of characters from one string to another string.

strpbrk Searches string for any set of characters.

strrchr Searches string backwards for character.

strspn Returns the length of initial string containing set of characters.

strtok Searches string for token separated by any of a set of characters.

Memory Manipulation

The memory functions operate on arrays of characters in memory called ***memory areas***. The memory manipulation functions include:

- Locating a character within a memory area
- Copying characters between memory areas
- Comparing contents of memory areas
- Setting a memory area to a value.

You do not need to specify any special flag to the compiler to use the memory functions.

Include the header file for these functions in the program. To include a header file, use the following statement:

```
#include <memory.h>
```

All include statements should be near the beginning of the first file being compiled, usually in the declarations section before `main( )`, and must occur before using any library functions.

The memory routines perform the following functions:

memccpy Copies characters from one memory area to another, stopping at the first occurrence of a specified character or after a specified number of characters are copied.

memcpy Copies a specified number of characters from one memory area to another.

memchr Finds the first occurrence of a specified character in a memory area, and returns a pointer to that character.

memcmp Compares the contents of two memory areas up to a specified maximum number of characters.

memset Sets the contents of a memory area to a specified value.

Character Manipulation

The character manipulation functions test and translate ASCII characters. You do not need to specify any special flag to the compiler to use the character manipulation functions.

Include the header file for these functions in the program. To include a header file, use the following statement:

```
#include <ctype.h>
```

All include statements should be near the beginning of the first file being compiled, usually in the declarations section before `main( )`, and must occur before using any library functions.

The character manipulation functions are grouped into the following categories:

- Character testing
- Character translation.

Character Testing

Use these functions to find out the type of a character:

isalnum Is character alphanumeric?

isalpha Is character alphabetic?

isascii Is integer ASCII character?

iscntrl Is character a control character?

isdigit Is character a digit?

isgraph Is character a printing character (not including space)?

islower Is character a lowercase letter?

isprint Is character a printing character (including space)?

ispunct Is character a punctuation character?

isspace Is character a white space character?

isupper Is character an uppercase letter?

isxdigit Is character a hex digit?

Character Translation

Use these functions to translate characters from one form to another:

toascii Converts integer to ASCII character.

tolower Converts character to lowercase.

toupper Converts character to uppercase.

Character Header File

The character header file is **ctype.h** in the **/usr/include** directory. It contains macro definitions and data declarations that the string functions use.

Time

The time functions access and reformat the current system date and time. You do not need to specify any special flag to the compiler to use the time functions.

Include the header file for these functions in the program. To include a header file, use the following statement:

```
#include <time.h>
```

All include statements should be near the beginning of the first file being compiled, usually in the declarations section before `main( )`, and must occur before using any library functions.

These functions (except **tzset**) convert a time such as the time returned by the **time** system call:

asctime Returns string representation of date and time.

ctime Returns string representation of date and time, given integer form.

gmtime Returns Greenwich Mean Time.

localtime Returns local time.

tzset Sets time zone field from environment variable.

Time Header File

The header file for the time functions is **time.h** in the **/usr/include** directory. It includes declarations for variables that the time functions use, such as:

tm A structure that the **gmtime** and **localtime** functions return.

daylight An integer that is nonzero to use Daylight Savings Time conversions.

tzname A character that defines the name of time zones. (The system overides this variable if the **TZ** variable is defined in the system environment. Setting the **TZ** variable changes the values defined in the header file for **daylight**, **timezone** and **tzname**.)

Numerical Conversion

These functions perform numerical conversion. You do not need to specify any special flag to the compiler or include a header file to use these functions.

a64l Converts string to base 64 ASCII.

atof Converts string to floating.

atoi Converts string to integer.

atol Converts string to long.

frexp Splits floating into mantissa and exponent.

l3tol Converts 3-byte integer to long.

ltol3 Converts long to 3-byte integer.

ldexp Combines mantissa and exponent.

l64a Converts base 64 ASCII to string.

modf Splits mantissa into integer and fraction.

Group File Access

These functions access the group file. You do not need to specify any special flag to the compiler to use these functions.

Include the header file for these functions in the program. To include a header file, use the following statement:

```
#include <grp.h>
```

All include statements should be near the beginning of the first file being compiled, usually in the declarations section before `main( )`, and must occur before using any library functions.

endgrent	Closes group file being processed.
getgrent	Gets next group file entry.
getgrgid	Returns next group with matching gid.
getgrnam	Returns next group with matching name.
setgrent	Rewinds group file being processed.

Password File Access

These functions search and access information stored in the password file **/etc/passwd**.

Include the header file for these functions in the program. To include a header file, use the following statement:

```
#include <pwd.h>
```

All include statements should be near the beginning of the first file being compiled, usually in the declarations section before `main( )`, and must occur before using any library functions.

endpwent	Closes password file being processed.
getpw	Searches password file for uid.
getpwent	Gets next password file entry.
getpwnam	Returns next entry with matching name.
getpwuid	Returns next entry with matching uid.
putpwent	Writes entry on stream.
setpwent	Rewinds password file being accessed.

Parameter Access

These functions get several different types of parameters from the system. You do not need to specify any special flag to the compiler or include any header file to use these functions.

getopt Gets next option from option list in command.

getcwd Returns string representation of current directory.

getenv Returns string value associated with environment variable.

getpass Reads string from terminal without echoing.

Hash Table Management

These functions manage hash search tables. You do not need to specify any special flag to the compiler or include any header file to use these functions.

hcreate Creates hash table.

hdestroy Destroys hash table.

hsearch Searches hash table for entry.

Binary Tree Management

These functions manage a binary tree. You do not need to specify any special flag to the compiler or include any header file to use these functions.

tdelete Deletes nodes from binary tree.

tsearch Searches binary tree.

twalk Walks through a binary tree to a specified level, and performs a specified action at each node of the tree.

Table Management

These functions manage a table. The table is a two-dimensional character array. The first subscript defines the maximum number of entries in the table. The second subscript defines the width (or length) of a single entry. These functions do not allocate storage. Be sure to allocate sufficient memory before using these functions.

You do not need to specify any special flag to the compiler or include any header file to use these functions.

bsearch Searches table using binary search.

lsearch Searches table using linear search.

qsort Sorts table using quicker-sort algorithm.

Memory Allocation

These functions allocate or free memory from the program.

You do not need to specify any special flag to the compiler or include any header file to use these functions.

calloc Allocates zeroed storage.

free Frees previously allocated storage.

malloc Allocates storage.

realloc Changes size of allocated storage.

Pseudo-random Number Generation

These functions generate pseudo-random numbers. The functions that end with **48** use a pseudo-random number generator based upon the linear congruential algorithm and 48-bit integer arithmetic. The **rand** and **srand** functions use a multiplicative congruential random number generator with period of 2^{32}.

You do not need to specify any special flag to the compiler or include any header file to use these functions.

drand48 Returns a random double , n, in the interval:

$0 \leq n < 1.$

lcong48 Sets parameters for **drand48**, **lrand48**, and **mrand48**.

lrand48 Returns a random long, n, in the interval:

$0 \leq n < 2^{31}$

mrand48 Returns a random long, n, in the interval:

$-2^{31} \leq n < 2^{31}$

rand Returns a random integer, n, in the interval:

$0 \leq n < 2^{15}$

seed48 Seeds the generator for **drand48**, **lrand48**, and **mrand48**.

srand Seeds the generator for rand.

srand48 Seeds the generator for **drand48**, **lrand48**, and **mrand48**.

Signal Handling

These functions simulate the functions available from the signal handling functions provided by the system calls for signals described in "Signal Calls" on page 4-26. These functions indicate error handling to other processes, and communicate with other cooperating processes.

You do not need to specify any special flag to the compiler to use these functions.

Include the header file for these functions in the program. To include a header file, use the following statement:

```
#include <signal.h>
```

All include statements should be near the beginning of the first file being compiled, usually in the declarations section before `main( )`, and must occur before using any library functions.

These declarations define ASCII names for each of the software signals.

gsignal Sends a software signal.

ssignal Arranges for handling of software signals.

Miscellaneous

These functions perform services that do not appear in any of the previous categories.

You do not need to specify any special flag to the compiler or include any header file to use these functions.

abort Sends an IOT (I/O terminate) signal to the process.

abs Returns the absolute integer value.

ecvt Converts double to string.

fcvt Converts double to string using Fortran format.

gcvt Converts double to string using Fortran F or E format.

isatty Tests whether integer file descriptor is associated with a terminal.

mktemp Creates file using template.

monitor Causes process to record a histogram of program counter location.

swab Swaps and copies bytes.

ttyname Returns the path name of terminal associated with integer file descriptor.

Run Time Services Library

The run time services library routines allow you to access the following system functions from your program:

- Configuration services
- Message services
- Trace
- Error logging.

The functions are in the file **librts.a** in the **/usr/lib** directory. The **cc** command automatically locates and loads the requested functions when it compiles a C language program.

Include header files, as needed, when using these routines. See *AIX Operating System Technical Reference* for the header files needed with each routine, as well as detailed information about their use.

cfgadev	Adds a device.
cfgamni	Adds a minidisk.
cfgaply	Applies configuration information.
cfgddev	Deletes a device.
cfgdmni	Deletes a minidisk.
errunix	Logs errors that occur when running a program.
msghelp	Retrieves and displays a predefined help message.
msgimed	Retrieves and outputs a predefined immediate message.
msgqued	Retrieves and outputs a predefined queued message.
msgrtrv	Retrieves text for a message, insert or help.
trcunix	Records trace log entries for a program.
vrcppr	Installs a protocol procedure.

The library also contains other routines that these routines use to perform their functions.

Math Library

The math library consists of functions and a header file. Use the following command line entry to tell the **cc** command to locate and load the needed functions when it links a C language program:

```
cc file.c -lm
```

Include the header file for these functions in the program. To include a header file, use the following statement:

```
#include <math.h>
```

All include statements should be near the beginning of the first file being compiled, usually in the declarations section before `main( )`, and must occur before using any library functions.

The math header file is **math.h** in the **/usr/include** directory. This file contains definitions for functions and macros that the math library routines use. All functions in the math library return double precision values.

The functions are grouped into the following categories:

- Trigonometric functions
- Bessel functions
- Hyperbolic functions
- Miscellaneous functions.

Trigonometry

These functions compute angles (in decimal radian measure), sines, cosines, and tangents. All of these values are expressed in double precision. The file **math.h** declares the values as **double**.

acos Returns arc cosine.

asin Returns arc sine.

atan Returns arc tangent.

atan2 Returns arc tangent of a ratio.

cos Returns cosine.

hypot Returns the square root of the sum of the squares of two numbers.

sin Returns sine.

tan Returns tangent.

Bessel

These functions calculate bessel functions of the first and second kinds of several orders for real values. The bessel functions are:

j0, j1, jn, y0, y1, and yn

For descriptions of the functions see **bessel** in *AIX Operating System Technical Reference.*

Hyperbolic

These functions compute the hyperbolic sine, cosine, and tangent for real values.

cosh Returns hyperbolic cosine.

sinh Returns hyperbolic tangent.

tanh Returns hyperbolic tangent.

Miscellaneous

These functions do not fall into any of the previously defined categories.

ceil Returns the smallest integer not less than a given value.

exp Returns the exponential function of a given value.

fabs Returns the absolute value of a given value.

floor Returns the largest integer not greater than a given value.

fmod Returns the remainder produced by the division of two given values.

gamma Returns the natural log of gamma as a function of the absolute value of a given value.

log Returns the natural logarithm of a given value.

pow Returns the result of a given value raised to another given value.

sqrt Returns the square root of a given value.

Chapter 4. Using System Calls

CONTENTS

About This Chapter

This chapter discusses how to access the services of the operating system from a program through ***system calls***. See *AIX Operating System Technical Reference* for reference information about a system call described in this chapter.

Header Files Needed for Calls

Some system calls depend on special macro definitions and declarations for the values that they return. The system provides this information in files called ***header files*** that are in the directory **/usr/include**. Therefore, when using system calls, ensure to also include any header files that the system call needs. To include a file in a program, use the following statement in the program:

```
#include <file.h>
```

where the parameter, *file.h*, represents the name of the header file to use.

The header files needed for each system call are:

Header File	Calls That Use The Header File
fcntl.h	open, fcntl
stdio.h	getpass
lockf.h	lockf
sys/types.h	msgxrcv, msgrget, msgop, msgctl, msgget, semctl, semget, semop, shmctl, shmget, shmop, stat, fstat, times, ustat, utime
sys/ipc.h	msgxrcv, msgrget, msgop, msgctl, msgget, semctl, semget, semop, shmctl, shmget, shmop
sys/msg.h	msgxrcv, msgrget, msgop, msgctl, msgget,
sys/shm.h	shmctl, shmget, shmop
sys/sem.h	semctl, semget, semop
sys/lock.h	plock
sys/signal.h	signal
sys/stat.h	stat, fstat, open, creat
sys/times.h	times
sys/utsname.h	uname
ustat.h	ustat

Process Calls

When a program runs in the system, that program, together with the environment that it runs in, is a process. Many processes are running in the system: some running system programs (like **init**) and some running application programs. When each process begins, the system assigns it an identification number (***process ID***) that is a positive integer between 0 and 32,767. As long as the process remains active, the system uses this number to identify that process. When the process ends, the system can assign the number to a new process.

Process Handling Calls

Use the following calls to control creating, operating and stopping processes (see *AIX Operating System Technical Reference* for more information about these calls):

Call	Description
exec	Runs a new program in the currently running process.
exit	Stops a process.
fork	Creates a new process.
nice	Changes priority of a process.
pipe	Creates an inter-process channel.
plock	Locks process, text, or data in memory.

Starting a Process

All processes that run in the system, except **init**, are started through the **fork** system call. The **fork** call creates a second independent process from the one running process through the following sequence of events:

1. Gets a new process ID from the system.
2. Creates a new process that has access to the code running in the existing process and the environment of the existing process. By using virtual memory mapping, the system does not actually copy the information into the new process until the new process actually uses it. If, for example, the first instruction executed in the new process is an **exec** system call, the system does not waste time copying the first program only to throw it out when the **exec** call occurs.
3. Starts the new process running from the place in the program that immediately follows the fork call.

The original process is called the ***parent***; the new process is called the ***child***. The value returned to a process from the **fork** call tells that process whether it is a child or a parent process. The parent process receives the process ID of the child process; the child process

receives a value of zero. Therefore, in most programs that use a **fork** system call, it appears within a conditional statement.

```
if( x = fork() )
{
        [code executed by the parent process]
}
else
{
        [executed by the child process]
        execv( newprog );
}
```

The parent process may continue running and create more new processes with other **fork** calls. However, to ensure that the child process completes successfully, the parent process usually stops running until the child process completes its assigned task. The parent process uses the **wait** system call to stop until the child process ends. When used in this manner, **fork** and **wait** are similar to calling a subroutine -- the calling program waits for the subroutine to complete and return a value before continuing.

If the fork operation is successful, the first instruction that the child process executes is usually an **exec** system call. The **exec** call replaces the program currently running in the child process with a new program and starts executing the new program.

When the child process completes, the parent process receives a completion code to indicate the conditions of the child process at the end. A value of zero indicates a normal end; a value that is not zero indicates an error (defined by the value of **errno**, the system variable that reports error codes).

Note: If the parent process does not wait for a completion code from the child process, and the child ends with an error condition, no other process gets the completion code to recover from the error. If the parent does not wait for a completion code when it creates the child process, it can continue to perform operations as a separate process. After taking care of some other tasks, the parent can then issue a **wait** call. If the child process has not ended before the **wait** occurs, the parent still gets the completion code when the child process ends.

Example of Process Life Cycle

When the shell executes a command, it performs the fork and wait process just described. See Figure 4-1 on page 4-7 for an illustration of the following process. For example, the command:

```
pr
```

tells the shell to execute a program called **pr**. To do this:

1. The shell issues a **fork** system call to get a new process.
2. The system marks the shell data and stack space as ***copy on reference*** for the new process space.
3. The system schedules the new process to be run.
4. The first shell issues a **wait** to wait for the new process (child) to complete.

The new process (also a shell) then:

1. Issues an **exec** system call to load and run the **pr** program in the new process
2. Issues an **exit** system call with a completion code when it is done.

When the parent shell process receives the completion code from the **exit** system call in the child, it starts running again. You can then enter another command on the command line.

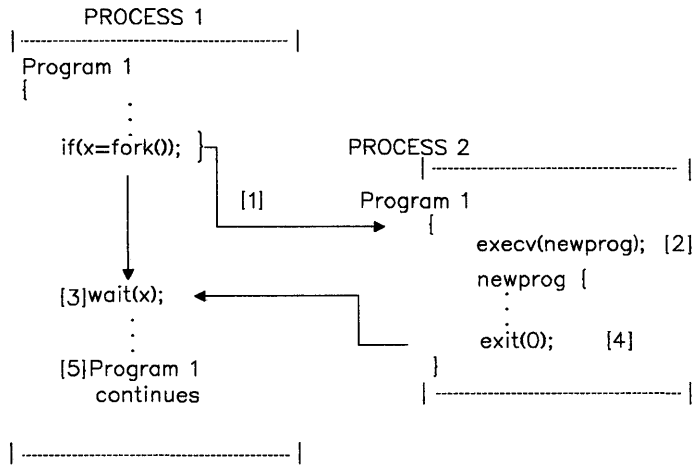


Figure 4-1. Using the Fork System Call

Special Processes

All processes in the system begin from a fork. One special process, process ID 1, is the initialization process (**init**). This process is the ancestor process to all other processes in the system. It uses the **exec** system call to start the remaining system programs.

Example of Fork System Call

The program in Figure 4-2 on page 4-8 uses the **fork** system call in a simple, but operating program. If you are using the Programming Examples, the program is stored as `forktst1.c`. Compile the program using the **cc** command:

```
cc forktst1.c -o forktst1
```

To run the program, enter the command:

```
forktst1
```

When the program runs, it writes output to the screen. The two processes that the program creates (parent and child) both write to the screen without regard to the other process. Therefore, the result that appears on the screen depends upon system activity and random luck. Sometimes it is a perfect output like in Figure 4-3 on page 4-9; other times the output from the two processes mix together on the screen. Run the program several times to experiment with the operation of two concurrent processes.

```
#include <stdio.h>
#define PR(value)  fprintf(stdout,"%s\n",(value) )

main()
{
  int c_count;
  int p_count;

  PR("starting main process");
  if (fork() == 0)
  {
     PR("starting child process");
     for(c_count = 0; c_count <= 4; c_count++)
        PR("child");
     PR("ending child process");
     exit(0);
  }
  PR("starting parent process");
  for(p_count = 0; p_count <= 4; p_count++)
     PR("parent");

  PR("ending parent process");
}
```

Figure 4-2. Example of Fork System Call

Well Behaved Output	Possible Output
starting main process	starting main process
starting parent process	starting parent process
parent	parent
parent	parent
parent	parstarting child process
parent	child
parent	child
ending parent process	child
starting child process	child
child	child
child	ending child process
child	ent
child	parent
child	parent
ending child process	ending parent process
$	$

Figure 4-3. Output from forktst1 Program

An Interesting Side Effect

Run the sample program, `forktst1`, again. This time redirect the output of the program to a file with the command:

```
forktst1 > testout
```

Then look at the output from the program in the file:

```
pg testout
```

The output will be like the *Well Behaved Output* from before except for one major difference: the message written in the program before the **fork** call (`starting main program`) appears twice -- once before the start of each process. This repetition shows one characteristic of the **fork** call. When the main process does the **fork**, each process (parent and child) receives a copy of the buffers and open file descriptors of the parent process.

In this example, the buffer at the time of the fork contained the message, `starting main program`, and each process got a copy of that message. When the processes ended, the

system wrote each of the buffers into the same file space because both buffers contained the same file pointers. Therefore, it produces one file that contains first the complete output from one process and then the complete output from the second process. The order that the outputs occur may vary, but they are not mixed as in the previous example when the program wrote to the terminal.

Another Experiment

Copy the source file `forktst1.c` into another file called `test.c` using the command:

```
cp forktst1.c test.c
```

and then edit the new file, `test.c`. Delete the line in the child process code that contains the **exit** system call:

```
exit(0);
```

Store the file. Then compile the file, rename **a.out**, and run the new program file. This time the parent process code executes twice: once as part of the child process and once as part of the parent process. This operation produces some confusing messages because the child process is writing out *parent* messages. The **exit** call is in the original program to end the child process and prevent the child process from falling into the parent code.

Note: This experiment also shows that the child process gets a complete copy of the original parent program code, because the child does run code that it should not.

The **exit** system call also returns a completion code to the parent process if the parent uses a **wait** system call (see "Example of Fork and Wait System Calls").

Example of Fork and Wait System Calls

The program in Figure 4-4 on page 4-11 uses the **fork** and **wait** system calls in a simple program that runs. If you are using the Programming Examples, the program is stored as `forktst2.c`. Compile the program using the **cc** command and copy it to its own file, `forktst2`, as in the previous **fork** example.

To run the program, enter the command:

```
forktst2
```

When the program runs, it writes output to the screen. The two processes that the program creates both write to the screen, but this time the parent waits for the child to complete before it writes to the screen. Therefore, the result that appears on the screen is much more predictable than the previous example. The output looks like Figure 4-5 on page 4-12.

```
#include <stdio.h>
#define PR(value)  fprintf(stdout,"%s\n",(value) )
#define PD(value)  fprintf(stdout,"%d\n",(value) )

main()
{
  int c_count;
  int p_count;
  int status;
  int frkpid;
  int chldpd;

  PR("starting main process");
  PD(frkpid);
  if( (frkpid = fork() ) == 0)
  {
     PR("starting child process");
     for(c_count = 0; c_count <= 4; c_count++)
        PR("child");
     PR("ending child process");
     PD(frkpid);
     exit(0);
  }
  chldpd = wait(&status);
  PR("starting parent process");
  for(p_count = 0; p_count <= 4; p_count++)
     PR("parent");
  PR("ending parent process");
  PD(chldpd);
  PD(status);
}
```

Figure 4-4. Fork and Wait System Calls - Sample Program

```
starting main process
0
starting child process
child
child
child
child
child
ending child process
0
starting parent process
parent
parent
parent
parent
parent
ending parent process
96
0
$
```

Figure 4-5. Output from forktst2 Sample Program

Example of Exec System Call

The program in Figure 4-6 on page 4-13 uses **exec** system call together with the **fork** and **wait** system calls in a simple program that runs. If you are using the Programming Examples, the program is stored as `forktst3.c`. Compile the program using the **cc** command and copy it to its own file, `forktst3`, as in the previous **fork** example.

To run the program, enter the command:

```
forktst3
```

When the program runs, it writes output to the screen. The two processes that the program creates both write to the screen; the parent waits for the child to complete before it writes to the screen. The output looks like Figure 4-7 on page 4-14.

```
#include <stdio.h>
#define PR(value)  fprintf(stdout,"%s\n",(value) )

main()
{
  int p_count;
  int status;
  int frkpid;
  int chldpd;

  PR("starting main process");
  if( (frkpid = fork() ) == 0)
  {
     PR("starting child process");
     execl( "/bin/sh", "sh", "-c", "date",NULL);
  }
  chldpd = wait(&status);
  PR("starting parent process");
  for(p_count = 0; p_count <= 4; p_count++)
     PR("parent");
  PR("ending parent process");
}
```

Figure 4-6. Exec System Call - Sample Program

The child portion of this program does not contain an **exit** call because when it performs the **execl** call, the new program, **date** loads on top of the program in the child process (destroying any program code that is there). When the new program ends, it stops the child process and returns a completion code to the waiting parent process.

Example Pipe System Call

The program in Figure 4-8 on page 4-15 uses the **pipe** system call in a simple, but operating program. If you are using the Programming Examples, the program is stored as `pipetst.c`. Compile the program using the **cc** command and copy it to its own file, `pipetst`, as in the previous **fork** example.

```
starting main process
starting child process
Wed May 15 15:26:25 CDT 1985
starting parent process
parent
parent
parent
parent
parent
ending parent process
$
```

Figure 4-7. Output from forktst3 Sample Program

```
#include <stdio.h>
#include <signal.h>
#define PR(value)  fprintf(stdout, "%s\n", (value) )
#define WRITE                1
#define READ                 0
#define chkmd(a, b)          (mode == READ ? (b) : (a) )

int   p_pid;

main()
{
  int w_fdesc;
  int lnmsg = 22;

  w_fdesc = openp("pr", WRITE);
  if (write(w_fdesc, "Writing piped message.", lnmsg) != lnmsg)
     PR("error writing to pipe");
  closep(w_fdesc);

}

openp(cmd,  mode)
char *cmd;
int  mode;
{
  int p_fdesc[2];

  if (pipe(p_fdesc) < 0 )
     return(NULL);
```

Figure 4-8 (Part 1 of 2). Using the pipe System Call

```
  if ( (p_pid = fork() ) == 0)
  {
     close(chkmd(p_fdesc[WRITE], p_fdesc[READ]) );
     close(chkmd(0, 1) );
     dup(chkmd(p_fdesc[READ], p_fdesc[WRITE]) );
     close(chkmd(p_fdesc[READ], p_fdesc[WRITE]) );
     execl("/bin/sh", "sh", "-c", cmd, 0);
     _exit(1);
  }
  if (p_pid == -1)
     return(NULL);
  close(chkmd(p_fdesc[READ], p_fdesc[WRITE]) );
  return(chkmd(p_fdesc[WRITE], p_fdesc[READ]) );
}

closep(fd)
int fd;
{
   register r;
   int status;

   close(fd);
   while ( (r = wait(&status) ) != p_pid && r != -1);
   if (r == -1)
      status = -1;
   return(status);
}
```

Figure 4-8 (Part 2 of 2). Using the pipe System Call

To run the program, enter the command:

```
pipetst
```

This program shows how to handle pipe file descriptors to use pipe for interprocess communication. It creates a pipe, forks another process, and writes a simple message to the pipe. The child process writes the message to the screen after receiving the message through the pipe.

When the program runs, it calls **popen** to open a pipe and fork to create a new process. The **pipe** call returns two file descriptors to the calling program: one describes the end of the pipe to use for writing; the other describes the end of the pipe to use for reading. Both processes must cooperate to use the pipe. If one process writes to the pipe, the other process should not write to the same pipe at the same time. Similarly, if one process reads from the pipe, the other process should write something into the pipe to be read. Therefore, after the fork in this program, the child process closes the write file descriptor for the pipe and the parent process closes the read file descriptor for the pipe. The parent can then write into the pipe and the child can read from the pipe, using the remaining open file descriptors.

Note: To have two-way data transfer between processes, open two different pipes: one for reading and one for writing. Do not use one pipe for two-way data transfer.

After the child process closes the read end of the pipe, it also closes the file descriptors for standard input and standard output that belong to that process (file descriptors 0 and 1). Then it uses a **dup** system call to copy the read file descriptor for the pipe. Because the system assigns file descriptors starting at the lowest number available and file descriptors 0 and 1 are now available, the copy of the read end of the pipe becomes standard input for the child process. The child then closes the original read file descriptor for the pipe, leaving only the file descriptor for standard input assigned to the pipe in the child process.

Note: You can also use the **dup2** system call in the previous description. The **dup2** system call does much of the work for you.

Having set up the pipe as standard input, the child process loads and executes (**execl**) the shell and the command that is passed to it from the parent process (**pr**). The new program in the child process then waits for input from its standard input, the read end of the pipe.

The parent process closes the read file descriptor for the pipe and returns the write file descriptor to the calling process (**pipetst**). **Pipetst** writes a message into the pipe, which is written out by the **pr** command running in the child process.

Because the **pr** command writes a formatted page output to the screen (standard output), the output may flash on the screen too fast to see it happen. If this occurs, use the command:

```
stty page length 24
```

to set the terminal to paging mode. The output fills the screen and then waits for you to press **Enter** before it displays another screen of data.

Process Identification Calls

Each process in the system has a unique number (***process ID***) that the system uses to control the activities in the system. In addition to the process ID, the system also assigns the following identifiers to a process (see Figure 4-9 on page 4-20):

Parent Process ID
The process ID of the parent process that issued a fork call to create the process.

Process Group ID
The process ID of the process that issued a fork call to create a group of processes.

TTY Group ID
A process ID that identifies all processes that started from a particular terminal.

Real User ID
The user ID of the process that started the process.

Real Group ID
The group ID of the process that started the process.

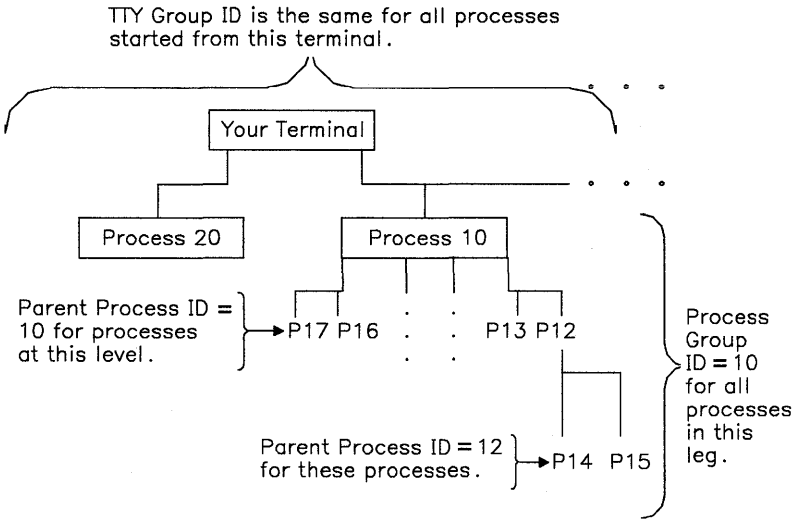
Effective User ID
The user ID that determines what files the program can access. In most cases this is the same as the real user ID; however, you can create a process that has access permission that is different from your own, and the effective user ID would be different. Refer to the **exec** system call in *AIX Operating System Technical Reference* for information about setting the set user ID bit.

Effective Group ID
The group ID that determines what files the program can access. In most cases this is the same as the real group ID; however, you can create a process that has access permission that is different from your own, and the effective group ID would be different. Refer to the **exec** system call in *AIX Operating System Technical Reference* for information about setting the set group ID bit.

A program can determine any of the above identification codes with the following system calls:

Call	Description
getegid	Gets effective group ID of the calling process.
geteuid	Gets effective user ID of the calling process.
getgid	Gets real group ID of the calling process.
getpass	Reads a password.
getpgrp	Gets process group ID.
getpid	Gets process ID.
getppid	Gets parent process ID.
getuid	Gets real and effective, user and group IDs.
setgid	Sets group ID.
setpgrp	Sets process group ID.
setuid	Sets user ID.
ulimit	Gets and sets user limits.
uname	Gets name of current system.

See *AIX Operating System Technical Reference* for complete information about any of these system calls.



Real User ID = Your ID number for all processes.
Effective User ID = Your ID number, or an ID number that gives special access permissions to the process.
Real Group ID = Your group ID number for all processes.
Effective Group ID = Your group ID number, or an ID number that gives special access permissions to the process.

Figure 4-9. Relationship of IDs in the System

Concurrent Groups

The operating system allows you to belong to many different groups. Being a member of a group, you can access the files whose permission bits allow access to members of that group. If you belong to more than one group, you can access the files that are available to all of those groups at any time. The ability to access files from many groups at the same time is called ***concurrent groups***.

When you log in to the system, the **login** program checks **/etc/passwd** and **/etc/group** to determine group membership. The **login** program then sets up access to the files of those groups, and assigns a group ID to indicate which of the groups is the ***primary group***. When you create files, those files become available to other members of the primary group. To change the primary group, use the **newgrp** command to change the group ID to that of another group to which you belong.

You can run a program only if you own it, if it is available to one of your groups, or if the *others* permission of the program allows you to execute it. When the program runs, it behaves much like a user with respect to groups. It normally takes on the group memberships of the person running the program. For example, if you run a program, that program can access all files that you can access; if another user runs the same program, the program no longer can access your files, but can access the files that the new user can access. You can change this behavior by using the **chmod** command to set the program to always run under its own set of user and group IDs. See *AIX Operating System Commands Reference* for information about the **chmod** command.

Example of Process ID

The program in Figure 4-10 on page 4-22 uses the process ID system calls in a simple, but operational program. If you are using the Programming Examples, the program is stored as `ppidtst.c`. Compile the program using the **cc** command and copy it to its own file, `ppidtst`, as in the previous **fork** example.

To run the program, enter the command:

```
ppidtst
```

When the program runs, it writes output to the screen. The program creates three processes: a parent, a child and a grandchild. Each process writes messages to the screen to indicate its:

- Process ID
- Process group ID
- Parent process ID
- Child process ID (except for the grandchild process).

The processes cooperate so that the output to the screen is orderly. The output looks like Figure 4-11 on page 4-23. Notice that:

- All process group IDs are the same, and are equal to the parent process ID of the parent process (the shell is the parent of the parent process in this case).
- All process IDs are different.
- The parent process ID of each of the child processes is the same as the process ID of its parent process.
- The child process ID returned to each parent is the same as the process ID of its child.

The **ps** (process status) command reports the process ID of active processes. Use the **ps** command to verify that the shell is the parent process of the parent process when you run this example.

```
#include <stdio.h>
#define PR(value)  fprintf(stdout, "%s\n", (value) )
#define PRT(s1, v1) fprintf(stdout, "%s%d.\n", (s1), (v1) )

main()
{
  int status1;
  int status2;
  int frkpid1;
  int frkpid2;
  int chldpd;
  int g_chldpd;

  PR("starting main process");
  if( (frkpid1 = fork() ) == 0)
  {
     if( (frkpid2 = fork() ) == 0)
     {
        PRT("grandchild: my process id is ", getpid() );
        PRT("grandchild: my parent process id is ", getppid() );
        PRT("grandchild: my process group id is ", getpgrp() );
        PR("ending grandchild process");
        exit(0);
     }
     g_chldpd = wait(&status2);
     PRT("child: my child's process id is ", g_chldpd);
     PRT("child: my process id is ", getpid() );
     PRT("child: my parent process id is ", getppid() );
     PRT("child: my process group id is ", getpgrp() );
     PR("ending child process");
     exit(0);
  }
```

Figure 4-10 (Part 1 of 2). Example of Process ID System Calls

```
  chldpd = wait(&status1);
  PRT("parent: my child's process id is ", chldpd);
  PRT("parent: my process id is ", getpid() );
  PRT("parent: my parent process id is ", getppid() );
  PRT("parent: my process group id is ", getpgrp() );
  PR("ending parent process");
}
```

Figure 4-10 (Part 2 of 2). Example of Process ID System Calls

```
starting main process
grandchild: my process id is 266.
grandchild: my parent process id is 265.
grandchild: my process group id is 221.
ending grandchild process
child: my child's process id is 266.
child: my process id is 265.
child: my parent process id is 264.
child: my process group id is 221.
ending child process
parent: my child's process id is 265.
parent: my process id is 264.
parent: my process group id is 221.
parent: my parent process id is 221.
ending parent process
$
```

Figure 4-11. Output for Process ID System Call Program

Process Tracking Calls

The system provides the following calls to monitor the operation of a process or group of processes in the system. These calls are the means by which the system commands of similar names are created. Use these calls within a program to gain information about how the program runs in each section of the program. They are primarily tools for use during development which would not be included in the final version of the program. See *AIX Operating System Technical Reference* for information about the syntax and flags of these calls.

Call	Description
acct	Enables/disables process accounting.
profil	Provides an execution time profile.
ptrace	Provides a process trace.
times	Gets process and child process times.

Interprocess Communications

The system provides many methods for two or more processes to communicate with each other. It provides system calls for:

- Sending and receiving signals.
- Setting and reading semaphores
- Sending and receiving messages.

Each of these sets of calls provides one method of sending small pieces of information between processes. For larger blocks of data, use the shared memory facility described in "Shared Memory Calls" on page 4-63.

Signal Calls

Signals provide a simple method of communication between two processes. Using signals, one process can inform another process of status conditions that occur during the process, or can tell the other process when an event occurs. Use signals to activate a process for error recovery, or to help control access to shared resources (see "Semaphore Calls" on page 4-38 and "Shared Memory Calls" on page 4-63 for more advanced control of shared resources). The signals that a program can use are defined in the system file, **/include/sys/signal.h** (see **signal** in *AIX Operating System Technical Reference*). The system calls that allow a program to use signals are:

Call	Description
alarm	Sets a process alarm clock.
kill	Sends signal to process(es).
pause	Suspends process until signal.
signal	Specifies what to do when the process receives a signal.
wait	Waits for child process to end.

The signal is an integer value. The meanings of these values are defined in the header file **/include/sys/signal.h**. The system generates most of these signals to tell a program of error or status conditions in the system. A program should be able to respond to these conditions. The program can, however, use a few of the signals for its own purposes. Figure 4-12 lists the user signals.

Signal	Value	Definition
SIGALRM	14	Use the **alarm** system call to set a time value. The system sends SIGALRM to the program when that time is up.
SIGUSR1	16	A signal defined by cooperating processes to mean the same thing to those processes. One process can generate this signal using the **kill** system call. The other cooperating processes that receive the signal can then react to the condition indicated by that signal.
SIGUSR2	17	Another signal defined by cooperating processes.

Figure 4-12. User Controlled Signals

How to React to a Signal

If a program does not have code to handle signals that it could receive, it will end when it receives a signal. Therefore, include enough code to recognize all signals that the program might receive (including system error signals). Use the **signal** system call to define the actions to be performed when the program receives a particular signal. The format of the **signal** call is:

```
signal(sig,func);
```

where:

sig Is the integer for the signal, or the system macro name that represents that value (defined in **sys/signal.h**)

func Is a function code to indicate what action to take when the program receives the signal. This code can indicate to:

- End a program when the indicated signal occurs (a function code of **0**).
- Ignore the indicated signal (a function code of **1**).
- Go to a predefined routine to handle the condition (a function code that is the address of the routine).

For example:

```
signal(SIGPIPE,SIG_IGN);
```

tells the program to ignore a signal that indicates a pipe error.

Example of Trapping a Signal

The program in Figure 4-13 on page 4-29 uses the signal system call in a simple program that runs. If you are using the Programming Examples, the program is stored as `sigtst.c`. Compile the program using the **cc** command with the output going to the file, `sigtst`, as in the previous **fork** example.

To run the program, enter the command:

```
sigtst
```

When the program runs, it asks you to press any letter key (the `e` letter key to exit the program). Whatever letter you enter, the program echoes to the screen. That is the main part of the program, but it does not use signal processing.

You can generate an interrupt signal to the program (SIGINT) by pressing the key that the driver program for the terminal defines as sending that signal. This key is often the **Ctrl-Bksp** key sequence. When the program receives this signal, it branches to a routine that writes a message to the screen. The program then returns to its main program operation.

Although this function is not very useful, it shows how to build interrupt handling routines into a program. The program first tests whether interrupts (SIGINT) are ignored, and creates the jump to the interrupt trap routine only if interrupts are not ignored.

```
 /* assign the previous value of */
 /* SIGINT to istat.   */
istat = signal(SIGINT, SIG_IGN);
 .
 .
 .
/* check previous condition of SIGINT */
if(istat != SIG_IGN)
        signal(SIGINT,onintr);
        /* jump to onintr when an  */
        /* interrupt signal occurs */
```

The program makes this check because, if the program is run in background, the shell sets SIGINT to be ignored. Therefore, the system only passes the interrupt signal to foreground processes. Testing this signal condition allows the program to get the interrupt signal when running in background as well as in foreground.

The program also uses the **setjmp** and **longjmp** library functions to handle the return to the main program. Before the program begins running the main loop, it stores the machine status in a structure `sjbuf`. The structure type, `jmp_buf` is defined in the system file **setjmp.h**. When the interrupt occurs, the system transfers control to the `onintr` routine. This routine is a dummy interrupt handling routine. When it finishes, it uses the **longjmp**

function to set the machine status to the conditions stored in the `sjbuf` structure. The main routine begins running again as if an interrupt had not occurred.

Each time the program returns from the `onintr` routine, it sets up the interrupt signal condition again. If it did not do this, it would not receive any more interrupt signals. The system sends only one interrupt signal for each request it receives. Once it sends that signal, the program must request another. If another interrupt signal occurs before the program sets up to catch the interrupt signal, the program stops. The enhanced signal facility (see "Enhanced Signal Facility" on page 4-30) provides a way to avoid this problem.

```
#include <signal.h>
#include <setjmp.h>
#include <stdio.h>
jmp_buf sjbuf;

main()
{
   int (*istat)(), onintr();
   int i;
   char c;
   istat = signal(SIGINT, SIG_IGN);
   setjmp(sjbuf);
   if (istat != SIG_IGN)
      signal(SIGINT, onintr);
   printf("%s\n", "Please enter a letter (e to exit).");
   while (c != 'e')
   {
      c = fgetc(stdin);
      if (c != '\n' && c != 'e')
      {
         printf("%s%c\n", "You typed the following letter: ", c);
         i++;
         printf("%d\n", i);
         printf("%s\n", "Please enter a letter (e to exit).");
      }
   }
}

onintr()
{
   printf("%s\n", "You pressed an interrupt key!");
   longjmp(sjbuf);
}
```

Figure 4-13. Example of Signal Trapping

Enhanced Signal Facility

In addition to the standard signal facilities described in "Signal Calls" on page 4-25, the system provides an enhanced signal facility. The enhanced facility treats signals received from the system in a way similar to the handling of hardware interrupts, allowing a program to mask each type of signal while it is processing. The facility allows for up to 32 different signals, but only those defined in the file **/include/sys/signal.h** can be used. These are the same signals that the standard signal facility uses. You can choose to use either facility in a program, but for programs used only on RT PC, use the enhanced signal facility.

The system calls that comprise the enhanced signal facility are listed in Figure 4-14. *AIX Operating System Technical Reference* provides complete information for each of these calls.

Call	Function
sigblock	Sets specified bits in the signal mask to block the signals associated with those bits.
sigsetmask	Sets the signal mask to a new value.
sigpause	Sets the signal mask to a new value, waits for a signal allowed by the new mask and restores the old mask value when a signal is received.
sigstack	Defines a separate stack to contain signal processing.
sigvec	Establishes conditions to handle a specified signal.
execve	Starts a new program in the current process, resets all signals that are being caught by the old program to terminate the new program, resets signal stack state, and retains the current signal mask value.

Figure 4-14. Enhanced Signal Calls

Responding to Signals

A program can receive signals from the sources shown in Figure 4-15.

Source	Description
Program faults	A programming error such as an illegal instruction or memory reference produces this type of message.
Terminal keys	Special key sequences generate signals to running processes in the system that belong to the terminal group of the terminal. These signals include **interrupt**, **quit**, **hangup** or **kill** (the **kill** signal cannot be masked).
Hardware exceptions	Hardware faults, such as a power failure, generate signals to running processes.
System	The system can generate signals, such as the death of a child process, to aid in process control.
Other processes	Other processes can send signals to a process to coordinate system activities.

Figure 4-15. Sources of Signals

Figure 4-16 on page 4-32 shows the defined responses for responding to a signal once a program receives it. Each of these responses is defined in the header file **signal.h** as a pointer to a routine that returns the constant value assigned to that response. For example, that file defines SIG_DFL as follows:

```
#define  SIG_DFL      (int (*) ( ) ) 0
```

This definition provides a function that always returns the value 0. Defining the responses as pointers to functions allows you to use them in the **sigvec** structure (see "Using Enhanced Signals" on page 4-32) as the pointer to the handler routine. See "Example Programs" on page 4-36 for a sample of using the responses in the structure.

Response	Meaning
SIG_DFL	Specifies that the system should perform the default action for a specific signal when it receives that signal. For most signals, the default action is to terminate the process. For some signals the default action ignores the signal, or creates a core file before terminating.
SIG_IGN	Specifes that the system should ignore the specified signal when it occurs.
SIG_CATCH	Specifies that the system should call a procedure in the current process when the specified signal occurs. The system also blocks any other occurrences of the same signal while the process is handling the signal.
SIG_HOLD	Specifies that the system should block a specified signal when it occurs. When blocked, the signal remains pending until the block is released. The signal is not lost.

Figure 4-16. Signal Responses

Using Enhanced Signals

When a process receives a signal, the system automatically:

1. Blocks another signal of that type from being sent to the process.
2. Saves the environment of the process.
3. Builds a new environment for the process to respond to the signal.
4. Transfers control to the signal ***handler*** routine in the process.

The signal ***handler*** is a routine that you provide to respond to the receipt of a signal. It may be a complex error recovery routine, or it may be SIG_DFL. You choose how the program responds to each of the signals. Once you have created the handler routines for all of the signals that you expect to receive, tell the system how to handle each of the signals. First, include the header file **signal.h** with the following statement:

```
#include <signal.h>
```

This file contains definitions for all the constant names used by the signal handling facility. In addition, this file contains the following structure definition:

```
struct  sigvec
{
        int     (*sv_handler) ( );
        int     sv_mask;
        int     sv_onstack;
};
```

This is the structure type that passes information to the system when using the **sigvec** system call. It contains three integer members as shown in Figure 4-17 on page 4-33.

Name	Description
(*sv_handler) ( );	A pointer to the routine that you have created to handle the signal processing for a particular signal, or one of the responses defined in **signal.h** as pointers to routines that return constant values.
sv_mask;	A 32-bit mask containing one bit for each of the 32 possible signals (not all are used). If a bit in this mask is set, then the system adds the corresponding signal to the current set of signals that are blocked from interrupting the handler routine while the handler is running. In addition, the signal that caused the handler to be run is also blocked.
sv_onstack;	Only bits 0 and 1 of this integer are valid; the rest of the bits should be zero. Valid values for this integer are: **0** Use enhanced signals and process signals on the process stack. **1** Use enhanced signals and process signals on a separate stack that you specify using the **sigstack** system call. **2** Use standard signal processing **3** Not a valid value.

Figure 4-17. sigvec Structure Members

For example, to set up a routine to receive the SIGALRM signal, use the following system call:

```
sigvec( SIGALRM , new_vec , old_vec );
```

The parameters for this call have the following meaning:

Parameter Meaning

SIGALRM The name of the signal, SIGALRM, which is signal 14, the alarm clock.

new_vec A pointer to the structure of type `sigvec` that defines the information for the signal handler.

old_vec A pointer to a structure of type `sigvec` where the system returns the values it is using for the specified signal. If this pointer is `NULL`, the system ignores it.

Using a Separate Signal Stack

You can choose to handle signal conditions using a stack that is separate from the process stack. Using a separate stack is not often useful or needed. Use it when catching the signal SIGSEGV to detect a stack overflow. You can then use the small signal stack to operate from while trying to recover from the overflow condition. However, when using a separate stack, you must control all stack operations and detect overflow. The system does not provide control for the separate stack. To use a separate stack for a particular handler, or set of handlers, perform the following steps:

1. Use the **sigstack** call to create a signal stack for handlers in the process to use.
2. Set the value of the **sv_onstack** variable to 1 in the structure of type `sigvec` for each of the handlers that use the separate stack.

Waiting for a Signal

The **sigpause** system call stops processing in a program to wait for the occurrence of any or all of the signals, and then resume processing without altering the signal mask (`sv_mask`) with which the program normally operates. The following sequence illustrates how to stop program operation, wait for any signal to occur, and then resume program operation:

1. Program begins.
2. Program issues **sigpause** call with a mask value of zero to enable catching all signals:

   ```
   sigpause( 0 );
   ```

3. A signal occurs for the process.
4. The **sigpause** call returns with a `-1` return code, and **errno** set to EINTR.
5. The system restores the previous signal mask value.
6. The program continues.

Protecting Important Program Events

During some parts of a program, you may want to continue processing in spite of any signals that the program may receive. Some activities, such as processing a linked list, could be difficult or impossible to recover from if the program were interrupted at that point. To protect sections of the program from interruption from all but the most serious signals (SIGKILL cannot be masked), use the **sigblock** and **sigsetmask** system calls together, as shown in the following sequence:

1. At the beginning of the important section of the program, use the **sigblock** system call with a mask value that, when ORed with the current mask, blocks all expected signals. Provide an integer variable to hold the returned value (the old mask value) for later use:

   ```
   old_mask = sigblock( block_mask );
   ```

2. Process the important section of the program.

3. Restore the program to normal operation with the **sigsetmask** system call, using the saved mask value from the **sigblock** call:

   ```
   block_mask = sigsetmask( old_mask );
   ```

4. Continue normal program operation.

Finding Out the Current Signal Mask

Each process running in the system has its own signal mask, regardless of whether or not the process uses signals. If the program does not use the signal calls to change this mask, the system assigns a value of zero to the signal mask (no signals blocked).

Two system calls provide information about the signal conditions that a program is using for a specified signal. The first call, **sigvec**, requires a defined structure of type **sigvec** where the system can write the current information. The following call tells the system to store the current information for the signal SIGINT in the structure `old_vec`. Because the second parameter that normally points to the new signal structure is NULL, the current signal structure for SIGINT does not change, but it is copied to the structure `old_vec`.

```
sigvec( SIGINT , NULL , old_vec );
```

You can use the **sigblock** system call to get only the value of the current mask:

```
old_mask = sigblock( 0 );
```

This call ORs the supplied value of zero with the current mask and returns the value of the current mask to `old_mask`. The supplied value of zero does not change the current mask.

Example Programs

Figure 4-18 shows an example program using enhanced signals. This program performs the same function as the example program used for signals in "Example of Trapping a Signal" on page 4-27. Refer to the program description in that section. This program is stored as **newsig.c** in the example program directory.

```
#include <stdio.h>
#include <signal.h>
#include <setjmp.h>
char c;
int i;
jmp_buf sjbuf;

main()
{
   int onintr();
   char fgetc();
   struct sigvec oldvec, newvec;
   newvec.sv_handler = SIG_IGN;
   newvec.sv_mask = 0;
   newvec.sv_onstack = 0;
   sigvec( SIGINT, &newvec, &oldvec );
   if( oldvec.sv_handler != SIG_IGN )
   {
      newvec.sv_handler = onintr;
      sigvec( SIGINT, &newvec, NULL );
   }
```

Figure 4-18 (Part 1 of 2). Enhanced Signals Example Program

```
   setjmp( sjbuf );
   printf( "%s\n", "Please enter a letter (e to exit)." );
   while ( c != 'e' )
   {
      c = fgetc( stdin );
      if( c != '\n' && c != 'e' )
      {
        printf( "%s%c\n", "You typed the following letter: ", c );
        i++;
        printf( "%d\n", i );
        printf( "%s\n", "Please enter a letter (e to exit)." );
      }
   }
}          /* End Main */


onintr()
{
   printf( "%s\n", "Performing processing upon interrupt." );
   printf( "%s\n", "Finished interrupt processing; returning to main." );
   longjmp( sjbuf, 1 );
}                /* End onintr */
```

Figure 4-18 (Part 2 of 2). Enhanced Signals Example Program

Semaphore Calls

Semaphores provide a general method of communication between two processes that is an extension of the features of signals. Use semaphores in much the same way as signals, except that semaphores are:

More flexible: Processes can define a semaphore to mean what they want it to mean.

More controllable: Programs have direct control over semaphores and do not need to depend on the system to generate them.

Broader in scope: A semaphore can be any integer value, not just 1 or 0. Use them for counting as well as process coordination (see program example).

The system calls that allow a program to use semaphores are:

Call	Description
semctl	Semaphore control operations
semget	Get set of semaphores
semop	Semaphore operations

Structure of a Semaphore Set

When using the **semget** system call to create a set of semaphores, the system returns an integer that is the ***semid***, or semaphore ID, for the set of semaphores that were created. Each semid points to a set of semaphores and a data structure that contains information about the semaphores. The data structure for semid is shown in Figure 4-19 on page 4-39. See Figure 4-20 on page 4-39 for the data structure of a semaphore.

Name	Function
sem_perm cuid cgid uid gid mode	Operation Permission Struct creator user ID creator group ID user ID group ID read and alter permission
sem_nsems	Number of Semaphores in the Set
sem_otime	Time of the Last Operation (seconds since 1/1/1970)
sem_ctime	Time of the Last Change (seconds since 1/1/1970)

Figure 4-19. Semid Data Structure

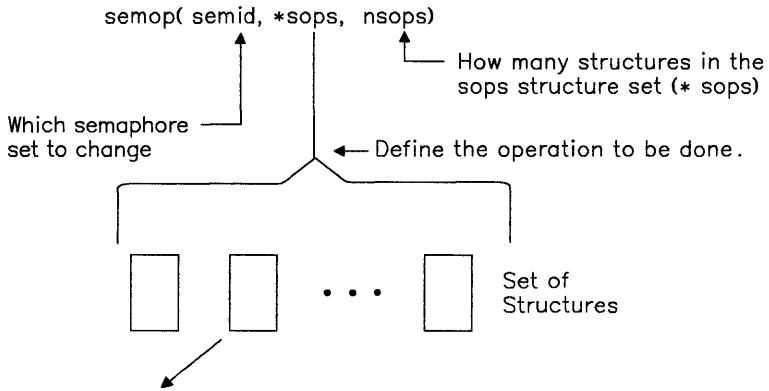
Name	Function
semval	Value of the semaphore (0 or positive)
sempid	Process ID of the Last Operation
semncnt	The number of processes that are waiting for semval to be > current value of its last semop( ) call
semzcnt	The number of processes that are waiting for semval to be = 0.

Figure 4-20. Semaphore Structure

How to Use Semaphores

Semaphores are counters that a program can test and change with a single system call (**semop**). Specify the amount of the change in the **semop** call using the **sem_op** variable within the **sops** structure as shown in Figure 4-21. When using this call, the system tests the value of **sem_op** against the value of the semaphore indicated by **sem_num**. If (sem_flg & IPC_NOWAIT) is true, the call returns without further action. If it is false, the table in Figure 4-22 on page 4-41 summarizes the actions that occur.

Use semaphores for passing data between processes and for other one time data transfers. You can also use them to control access to a limited resource, such as a shared buffer.



Name	Function
sem_num	Number of the semaphore to be changed
sem_op	The semaphore operation
sem_flg	Operation flags

Figure 4-21. Semop System Call Parameters

Value of sem_op	Relationship to semval	Actions
< 0	|sem_op| <= semval	1. semval = semval - | sem_op |
	|sem_op| > semval	1. semncnt = semncnt + 1 2. wait for semval >= | sem_op |; then semval = semval - | sem_op | semncnt = semncnt - 1
> 0		1. semval = semval + sem_op
0	semval = = 0	1. return
	semval !=0	1. semzcnt = semzcnt + 1 2. wait for semval = 0; then semzcnt = semzcnt - 1 return

Figure 4-22. How sem_op Specifies a Semaphore Operation

Example of Semaphores

For example, two processes `proca` and `procb` share a buffer `bufr`. `proca` produces data packages and places each package in the buffer as it produces that package. `procb` uses the data packages from the buffer in its operation, but does not use them at the same rate that `proca` puts them in the buffer. The buffer can hold only three data packages. The processes use two semaphores to ensure that:

- `proca` does not try to put a package in a full buffer.
- `procb` does not try to take a package from an empty buffer.

The processes agree that the semaphores have the following meanings:

sem1 The number of empty slots in the buffer. If sem1 is greater than zero, then `proca` can put a package in the buffer.

sem2 The number of data packages in the buffer. If sem2 is greater than zero, then `procb` can take a package from the buffer.

Figure 4-23 shows the relation of the processes to the buffer and semphores. When the processes start, `sem1` has a value of 3 (empty slots) and `sem2` has a value of 0 (packages in `bufr`).

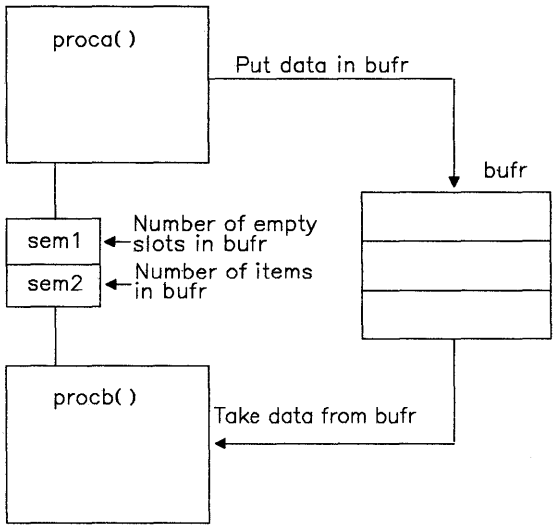


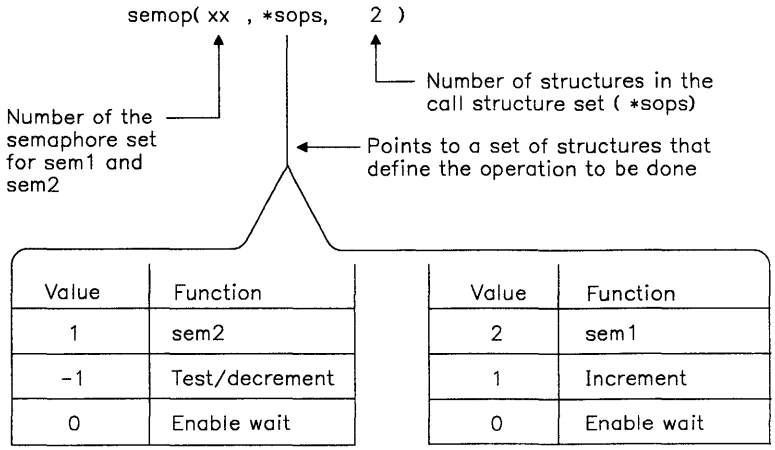
Figure 4-23. Using Semaphores Concept Example

proca

proca puts items into the buffer. Before it can put an item in the buffer, it tests seml to find out if there is room in the buffer for the item. If seml is greater than, or equal to 1 (the number of items to be put into bufr), then it:

1. Decrements seml by 1
2. Puts an item in the buffer
3. Increments sem2 by 1.

If seml is less than 1, proca waits until there is room in the buffer (seml > = 1), and then performs the preceding steps. If proca has to wait, it increments the semncnt flag for seml to indicate that it is waiting. It decrements this flag when it continues. Figure 4-24 shows the **semop** call and structure that handles all of the semaphore operations for proca.



Value	Function
1	sem2
-1	Test/decrement
0	Enable wait

Value	Function
2	sem1
1	Increment
0	Enable wait

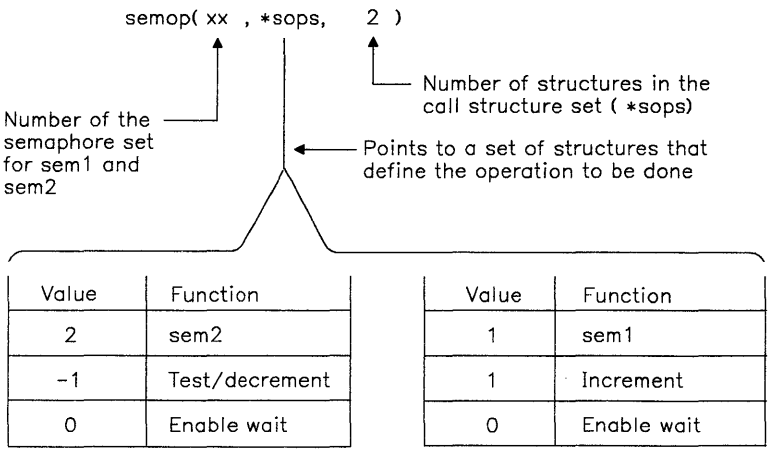
Figure 4-24. Semop Call for Proca

procb

procb takes items from the buffer. Before it can take an item, it tests sem2 to find out if there is anything in the buffer. If sem2 is greater than, or equal to 1 (the number of items to be taken), then it:

1. Decrements sem2 by 1
2. Takes an item from the buffer
3. Increments sem1 by 1.

If sem2 is less than 1, procb waits until there is something in the buffer (sem2 > = 1), and then performs the preceding steps. If procb has to wait, it increments the semncnt flag for sem2 to indicate that it is waiting. It decrements this flag when it continues. Figure 4-25 shows the **semop** call and structure that handles all of the semaphore operations for procb.



Value	Function
2	sem2
-1	Test/decrement
0	Enable wait

Value	Function
1	sem1
1	Increment
0	Enable wait

Figure 4-25. Semop Call for procb

Operation

The chart in Figure 4-26 on page 4-45 shows the operation of the semaphores to control access to the buffer.

Event	sem1		sem2	
	Value	semncnt	Value	semncnt
1. Start: The initial state of the parameters	3	0	0	0
2. Procb tries to get item:	3	0	0	1
3. Proca puts item in bufr.	2	0	1	1
4. Procb can now get item.	3	0	0	0
5. Proca puts item in bufr.	2	0	1	0
6. Proca puts item in bufr.	1	0	2	0
7. Proca puts item in bufr.	0	0	3	0
8. Proca tries to put item in bufr.	0	1	3	0
9. Procb gets item from bufr.	1	1	2	0
10. Proca can now put item in bufr.	0	0	3	0

Figure 4-26. Semaphore Usage

Example of Semaphore Programming

The program in Figure 4-27 on page 4-46 shows the use of semaphores in a situation similar to the example concept described previously. This program also uses some shared memory calls as described in "Shared Memory Calls" on page 4-63. If you are using the Programming Examples, this program is stored under the name **semtst.c**. You can compile and run this program to see the effects of the system calls.

```
#define STKSZ                   2
#define SNSLTS                  0
#define SNITMS                  1
static int sp = 0;
static char *itmstk[STKSZ];

#include <stdio.h>
#include <sys/types.h>
#include <sys/ipc.h>
#include <sys/sem.h>
#include <sys/shm.h>
#include <errno.h>
#define MADDR                   0

int semid;
int shmid;
extern int errno;
struct ITM
  {
     char *itmstk[2];
     int sp;
  } *stkptr;
```

Figure 4-27 (Part 1 of 5). Using Semaphore Calls

```
main()
{
  char *popitm();
  int nsems, semflg;
  int pid_1, pid_2;
  int stts_1, stts_2;
  register rt_1, rt_2;
  key_t key, ftok();
  char *shmat();
  int shmdt();
  struct sembuf soa1[1], soa2[1];
  struct sembuf *sops1 = soa1,
                *sops2 =  soa2;

  key = ftok( "semtst.c", 's' );
  nsems = 2;
  semid = semget( key, nsems, IPC_CREAT | SEM_A | SEM_R );
  semctl( semid, 0, SETVAL, 2 );
  semctl( semid, 1, SETVAL, 0 );
  shmid = shmget( key, STKSZ, IPC_CREAT | SHM_W | SHM_R );
  stkptr = (( struct ITM * ) shmat( shmid, MADDR,
                                    IPC_CREAT | SHM_W | SHM_R ));
  if(( pid_1 = fork() ) == 0 )
  {
     int i;

     stkptr->sp = 0;
     for( i = 0;i <= 5;i++ )
     {
        printf( "\nProducer: Sending item number %d   ", i );
        p( SNSLTS, sops1 );
        pushitm( "Test Item", stkptr );
        v( SNITMS, sops2 );
     }
     exit(0);
  }
```

Figure 4-27 (Part 2 of 5). Using Semaphore Calls

```
  if(( pid_2 = fork() ) == 0 )
  {
     int i;
     char *itmptr;

     for( i = 0;i <= 5;i++ )
     {
        p( SNITMS, sops1 );
        semctl( semid, 1, GETVAL );
        itmptr = popitm( stkptr );
        v( SNSLTS, sops2 );
        printf( "\nConsumer: Got item number %d; item is '%s'", i, itmptr );
     }
     exit(0);
  }
  while((( rt_1 = wait( &stts_1 ) != pid_1 ) &&
         ( rt_1 != -1 )) &&
        (( rt_2 = wait( &stts_2 ) != pid_2 ) &&
         ( rt_2 != -1 )))
  ;
  if( rt_1 == -1 )
  {
     stts_1 = -1;
  }
  if( rt_2 == -1 )
  {
     stts_2 = -1;
  }
  printf( "Producer process ended with status = %d\n", stts_1 );
  printf( "Consumer process ended with status = %d\n", stts_2 );
}
```

Figure 4-27 (Part 3 of 5). Using Semaphore Calls

```
int stpop, stvop;

p( s, sops )
int s;
struct sembuf *sops;
{
  int nsops;

  nsops = 1;
  sops->sem_num = s;
  sops->sem_flg = ~IPC_NOWAIT;
  sops->sem_op = -1;
  stpop = semop( semid, sops, nsops );
  return;
}

v( s, sops )
int s;
struct sembuf *sops;
{
  int nsops;

  nsops = 1;
  sops->sem_num = s;
  sops->sem_flg = ~IPC_NOWAIT;
  sops->sem_op = 1;
  stvop = semop( semid, sops, nsops );
  return;
}
```

Figure 4-27 (Part 4 of 5). Using Semaphore Calls

```
char *popitm( ip )
struct ITM *ip;
{
  if( ip->sp > 0 )
  {
     printf( "\npop: stack pointer = %d   ", --ip->sp );
     return( ip->itmstk[ip->sp] );
  }
 else
     return( NULL );
}

int s;
pushitm( item, ip )
char *item;
struct ITM *ip;
{
  ip->itmstk[ip->sp++] = item;
  printf( "\npush: stack pointer = %d   \n", ip->sp );
}
```

Figure 4-27 (Part 5 of 5). Using Semaphore Calls

Message Calls

Messages provide a general method of communication between two processes. Using messages one process can pass information of any kind to another process. The information may be data that is produced by one process and used in another, or it could be flags that indicate when events occur. To use the message process, perform the following steps:

1. Use the **ftok** subroutine to get a ***key*** assigned to a message queue.
2. Use the **msgget** call to get a message queue assigned to the processes.
3. Use the **msgsnd** call to send a message to a queue that is assigned to another process.
4. Use the **msgrcv** or **msgxrcv** call to receive a message from the message queue.

Use the following system calls to create and use message queues:

Call	Description
msgctl	Gets status, changes permissions, or removes a queue.
msgget	Gets message queue.
msgrcv	Receives a message.
msgrget	Gets remote message queue.
msgsig	Sends signal on arrival of a local message.
msgsnd	Sends a message.
msgxrcv	Receives a message with additional information.

In addition, the **ftok** subroutine provides the ***key*** that the **msgget** call uses to create the message queue. Include the following header files when using message queue calls:

```
#include <sys/types.h>
#include <sys/ipc.h>
#include <sys/msg.h>
```

Terms

The use of message queue elements is similar in structure to the way the system creates and uses files. Defining the terms used for message queues with respect to the more familiar file terms provides a framework to build an understanding of message queues. Figure 4-28 shows the new terms and how they relate to terms used with files.

Term	Definition
key	The ***key*** is a unique identifier (of type **key_t**) that names the particular message queue. It is always associated with the message queue as long as the message queue exists. In this respect, it is similar to the *filename* of a file.
msqid	The ***msqid*** is an identifier assigned to the message queue for use within a particular process. It is similar in use to a *file descriptor* of a file.
Permissions	The message queue structure also contains information that describes the access permissions for the message queue. These permissions are similar in function to the access permission bits for a file (owner, group and others).

Figure 4-28. Message Queue Terms

In effect, message queues are a more general form of the **pipe** system call. Either method passes information between two processes. For message queues, however, you do not need to perform the steps of opening a pipe, forking, and then closing two of the ends of the pipe as described in "Example Pipe System Call" on page 4-13 In fact, the two processes using message queues to communicate do not need to be created from the same ancestor process;

they only need to cooperate by using the same name for the queue, and agreeing about what the messages mean.

General Operation

When a process gets a message queue, it uses an internal name (***key***) to apply to the queue. Any other programs that use that key can access that queue, subject to the read/write access permissions set up for the queue. The process can either send messages to the queue or receive messages from the queue (or both if it wants to send messages to itself). Normally, the process that receives a message does not receive any indication that there are messages in the queue unless it tries to get a message from the queue. In that case, if a message is not in the queue, the process is blocked until a message of the requested type is received. To allow the process to continue processing while waiting for a message, it can use the **msgsig** call. Using the **msgsig** call, the process can request that the system send a signal each time the queue receives a message. The process must allow for catching the signal in the program code (see "Enhanced Signal Facility" on page 4-30 for information about catching signals).

After opening the queue, the process continues operating until it reaches the point that it needs input from the other cooperating process. The first process checks its message queue using the **msgrcv** call. Using the parameter, ***msgtype***, in the **msgrcv** call, the process can specify which type of message it wants to receive. If a message that satisfies the request is not in the queue, the first process halts until something is put into the queue that does satisfy the request. If there is a message of the requested type in the queue, the system gives the process the first message of that type that was put into the queue (first-in-first-out).

Similarly, after opening the queue, the other process can send messages to the queue of the first process. If the queue is full, the system returns an error indication and the process must wait until the first process empties the queue enough to add the new message.

Because either of these wait conditions could halt the process indefinitely, the program should include a timeout loop to end the stalled condition.

Sending messages to a queue is completely independent from receiving messages from that queue. The amount of data that one process can put into the message queue of the other process depends on the queue size and the speed that the other process takes the data from the queue. More than one process can put messages into a queue. The receiving process must take them out of the queue in the order that they were put into the queue, modified only by selecting a message type.

The receiving process can also use the **msgxrcv** call instead of the **msgrcv** call to get messages. This call provides more information to the receiving process about the nature of the message.

Using Message Queues

The following sequence shows how to create and use a message queue:

1. Create a key to uniquely identify the message queue. Use the **ftok** subroutine to create the key. For example, to create a key `mykey` using a project ID of `X` contained in the **char** variable `proj` and a file name of `null_file`, use a statement like:

   ```
   mykey = ftok( null_file, proj );
   ```

2. Either:

   - Create a new message queue with the **msgget** system call. For example, to create a message queue and assign the **msqid** to an integer variable `msg_qid`, use a statement like:

     ```
     msg_qid = msgget( mykey, IPC_CREAT );
     ```

     or

   - Get a previously created message queue with the **msgget** system call. For example, to get a message queue that is already associated with the key `mykey` and assign the **msqid** to an integer variable `msg_qid`, use a statement like:

     ```
     msg_qid = msgget( mykey, IPC_ACCESS );
     ```

3. Use the queue to send or receive messages with other processes.

4. If the queue is no longer needed, eliminate it from the system using the **msgctl** system call:

   ```
   msgctl( msg_qid, IPC_RMID );
   ```

See *AIX Operating System Technical Reference* for specific information about parameters for the calls and subroutines.

Using Distributed Message Queues

The message calls can send messages to another system at a remote location and manipulate the queue for those messages without regard to the actual physical location of the queue. Each system on the network of systems maintains the local queues for the users on its system. Each local queue contains a queue header that stores the information to send messages to the other system associated with the queue and to identify the queue used on the remote system. In addition, each entry in the queue stores the information required to satisfy the **msgxrcv** system call requirements. The **msgxrcv** system call returns the following information:

- The message
- The time the message was sent
- The user ID, group ID, node ID and process ID of the sender
- The size of the message in bytes.

A message queue structure contains this information in the following form:

```
struct msg
{
   struct msg  *msg_next;        /* pointer to next message */
   long        msg_type;         /* message type */
   caddr_t     msg_spot;         /* message text address */
   time_t      msg_time;         /* time message was sent */
   short       msg_uid;          /* user ID of sender */
   short       msg_gid;          /* group ID of sender */
   short       msg_nid;          /* node ID of sender */
   short       msg_pid;          /* process ID of sender */
   short       msg_ts;           /* message text size in bytes */
}
```

The ***msg_type*** is an integer value that the cooperating processes use to classify the messages that they send. The values do not have any system-defined meaning. However, the message queue handler interprets the values in the following manner:

zero Returns the first message of any type.

positive Returns the first message of only the indicated type.

negative Returns the first message that has a type that is less than or equal to the absolute value of the indicated type.

Use the time stamp information from this call to determine if the message contains current information, or whether to remove it from the system. The sending process must provide the information for this structure along with the message text.

Example of Message Queue Calls

The program in Figure 4-29 on page 4-55 shows the use of message queues in a simple producer-consumer relationship. One process produces an item for the other process and passes it to the other process on a message queue.

If you are using the Programming Examples, this program is stored under the name **msgqtst.c**. You can compile and run this program to see the effects of the system calls.

```
#include <stdio.h>
#include <sys/types.h>
#include <sys/ipc.h>
#include <sys/msg.h>
#include <errno.h>
#define MSGSIZ          15
#define MSGRTYP          0
#define MTYPE            1

static char *msg[11] = {
                          "this is item 0", "this is item 1",
                          "this is item 2", "this is item 3",
                          "this is item 4", "this is item 5",
                          "this is item 6", "this is item 7",
                          "this is item 8", "this is item 9",
                          "this is item 10"
                        };
int  msgqid;
extern int errno;

main()
{
  int pid_1, pid_2;
  key_t key, ftok();
  char *receive();
  int send();
  register rt_1, rt_2;
  int stts_1, stts_2;
```

Figure 4-29 (Part 1 of 3). Example of Using Message Queues

```
key = ftok( "msgqtst.c", 'm' );
msgqid = msgget( key, IPC_CREAT | MSG_R | MSG_W );
printf("msgqid = %d\n", msgqid);
if(( pid_1 = fork() ) == 0 )
{
   int i ;

   for( i = 0;i <= 10;i++ )
   {
      printf( "Producer process: sending message number %d\n", i );
      send(msg[i]);
   }
   exit(0);
}
if(( pid_2 = fork() ) == 0 )
{
   int i;

   for( i = 0;i <= 10;i++ )
   {
       printf( "Consumer process: message number %d is: %s\n",
                 i, receive() );
   }
   exit(0);
}
while((( rt_1 = wait( &stts_1 ) != pid_1 ) &&
       ( rt_1 != -1 )) &&
      (( rt_2 = wait( &stts_2 ) != pid_2 ) &&
       ( rt_2 != -1 )))
;
```

Figure 4-29 (Part 2 of 3). Example of Using Message Queues

```
  if( rt_1 == -1 )
  {
     stts_1 = -1;
  }
  if( rt_2 == -1 )
  {
     stts_2 = -1;
  }
  printf( "Producer process ended with status = %d\n", stts_1 );
  printf( "Consumer process ended with status = %d\n", stts_2 );
}

struct msgbuf msgb, *msgp = &msgb;
char *strcpy();

send( item )
char *item;
{
  msgp->mtype = MTYPE;
  strcpy(( msgp->mtext ), item );
  msgsnd( msgqid, msgp, MSGSIZ, ~IPC_NOWAIT );
  return;
}

char *receive()
{
  msgrcv( msgqid, msgp, MSGSIZ, MSGRTYP, ~IPC_NOWAIT );
  return(( msgp->mtext ));
}
```

Figure 4-29 (Part 3 of 3). Example of Using Message Queues

System Memory Management

The system provides a continuous range of memory addresses for accessing data from 0x0000000000 to 0xFFFFFFFFFF, for a total addressable space of more than 10^{12} bytes. The system reserves some ranges of addresses for use by the VRM and the input/output bus, but it treats most of the addresses as memory that the operating system can use. The actual physical memory on any system is much smaller than the address space. Because the address space does not correspond, one-to-one, with ***real memory***, the address space and the way the system makes it correspond to real memory is called ***virtual memory***. Some other terms that are needed to define memory management are:

page A unit of virtual memory space that holds 2 K-bytes of data.

segment A unit of virtual memory space that holds up to 256 M-bytes, or 128K pages of data.

K-byte A unit of data capacity equal to 1024 bytes.

M-byte A unit of data capacity equal to 1,048,576 bytes.

To accommodate the large virtual memory space with a limited real memory space, the system uses real memory as a work space and keeps the inactive data and programs that are not mapped in an area on disk called the ***paging space***. When it needs data or a program that is in the paging space, the system:

1. Finds an area of memory that is not currently active.
2. Ensures that an up-to-date copy of the data or program from that area of memory is in the paging space on disk.
3. Reads the new program or data from the paging space on disk into the newly freed area of memory.

The process of moving data between memory and disk as the data is needed is called ***paging***. The system also has methods for tracking the most frequently used data in the paging space to shorten the time that it takes to find that data. In addition, many important pieces of code, including much of the operating system kernel, are fixed in memory and cannot be paged to disk.

The 10^{12} byte address space available implies that a program can use 40-bit (or 10 hexadecimal digits) addresses. However, programs can only use 32-bit (or 8 hexadecimal digits) addresses. To bridge the gap between the two addresses, the system uses a set of 12-bit (or 3 hexadecimal digits) ***segment registers***. The system loads these registers with values that become the high-order 12 bits of the **40-bit** address needed to select all available addresses. The high-order 4 bits of the **32-bit** address select which of the segment registers to use. This process, in effect, exchanges the top 4 bits for 12 bits, creating the 40-bit address as shown in Figure 4-30 on page 4-59.

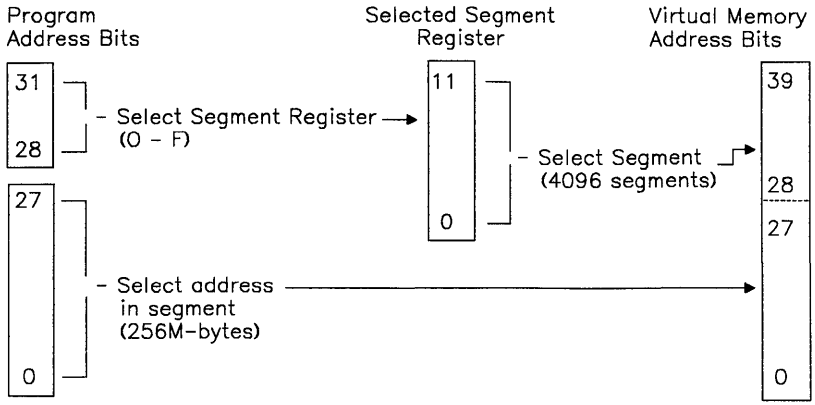


Figure 4-30. Segment Register Addressing

Segment Registers

The system uses a set of 16 segment registers for each process to select the areas of virtual memory that the process can use. Figure 4-31 shows how the system uses the segment registers. The VRM uses one of these registers (number 14) for its program space and another (register number 15) contains the addresses assigned to the input and output data bus hardware. Therefore, the operating system can use only registers 0 through 13. Of these registers, a process cannot address the kernel segment (register 0). Therefore, each process can access up to 13 different segments for a total available address space of approximately 3.5 billion bytes. The amount of actual memory and the paging space available on disk limit the addresses that can be used to a much smaller number that depends on system configuration.

Register	Addresses (Hex)	Used for
0	00000000 to 0FFFFFFF	Kernel code, data and stack Floating point code
1	10000000 to 1FFFFFFF	Current program code
2	20000000 to 2FFFFFFF	Current program static data and heap
3	30000000 to 3FFFFFFF	Current program stack
4 through 13	40000000 to DFFFFFFF	Shared segments accessed through shared memory system calls (**shm***xxx*) - 10 different shared segments per process
14	E0000000 to EFFFFFFF	VRM
15	F0000000 to FFFFFFFF	Hardware input/output addresses

Figure 4-31. Segment Register Usage

Using a Mapped Data File

The system provides a feature called ***mapped files*** to eliminate much of the overhead involved in writing and reading the contents of the files. This feature assigns the contents of the mapped file to an area of user memory. Once the program establishes this relationship, it can manipulate the file as if it were data in memory, using pointers to that data instead of input/output calls. However, the system does not detect end of file. If a program reads past the end of a file, it reads zeroes. The copy of the file on disk serves as the paging area for that file, saving paging space.

A program can use any regular file as a mapped data file. To create the mapped data file, perform the following actions:

1. Open (or create) the file and save the file descriptor:

```
if( ( fildes = open( filename , 2 ) ) < 0 )
{
        printf( "cannot open file\n" );
        exit(1);
}
```

2. Map the file to a segment using the **shmat** system call:

```
file_ptr = shmat( fildes, 0, SHM_MAP );
```

The parameter, **SHM_MAP**, is a constant defined in the header file, **/usr/include/sys/shm.h**. It indicates that the file is a mapped file. Include this header file and the other shared memory header files in a program with the directives:

```
#include <sys/shm.h>
#include <sys/types.h>
#include <sys/ipc.h>
```

Note: The following steps show a method for detecting the end of a mapped file. The program must detect end of file in some manner.

3. Use the **lseek** system call to go to the end of file:

```
eof = file_ptr + lseek( fildes, 0, 2 );
```

This example sets the value of `eof` to an address that is 1 byte beyond the end of file. Use this value as the end of file marker in the program.

4. Now use `file_ptr` as a pointer to the start of the data file, and access the data as if it were in memory. The system calls for input and output, **read** and **write**, also work on the file, and produce the same data as when using pointers to access the data.

```
while( file_ptr < eof )
{
    .
    .
    .
    (references to file using file_ptr)
}
```

5. Close the file when the program is finished working with it:

```
close( fildes );
```

Using a Mapped Executable File

You can also extend the features of mapped data files to files containing compiled and executable object code. Because mapped files can be accessed more quickly than regular files, the system can load a program more quickly if its executable object file is a mapped file.

To create a program as a mapped executable file, compile and link the program using the **-K** flag with the **cc** or **ld** command. This flag tells the linker to create an object file with a page aligned format. That is, each part of the object file starts on a page boundary (an address that can be divided by 2K with no remainder). This option results in some empty space in the object file, but it allows the executable file to be mapped into memory. When the system maps an object file into memory, the text and data portions are handled differently:

Text This part of the program is mapped as a ***read only*** file, unless the program is running under the **sdb** program while debugging.

Data This part of the program is mapped as a ***copy on write*** file. Any changes made to the data are stored in the system paging area and are not written back to the original file (see "Copy on Write Mapped Files").

Copy on Write Mapped Files

To prevent the changes made to mapped files from appearing immediately in the file on disk, map the file as a ***copy on write*** mapped file. This option creates a mapped file with changes that are saved in the system paging space, instead of saving the changes to the copy of the file on disk. You must choose to write those changes to the copy on disk to save the changes. Otherwise, you lose the changes when closing the file.

Because the changes are not immediately reflected in the copy of the file that other users may access, use **copy on write** mapped files only among processes that cooperate with each other. See "Interprocess Communications" on page 4-25 for information about coordinating process activity.

If a program writes beyond the current end-of-file in a **copy-on-write** mapped file by storing into the corresponding memory segment (where the file is mapped), the actual file (on disk) is extended with blocks of zeroes in preparation for the new data. If the program does not perform an **fsync** system call before closing the file, the data written beyond the previous end-of-file is not written to disk. The file appears larger, but contains only the added zeroes. Therefore, always use an **fsync** system call before closing a **copy on write** mapped file to preserve any added or changed data.

To create a **copy on write** mapped data file, perform the following actions:

1. Open (or create) the file and save the file descriptor:

```
if( ( fildes = open( filename , 2 ) ) < 0 )
{
        printf( "cannot open file\n" ,
        exit(1);
}
```

2. Map the file to a segment as ***copy on write***, using the **shmat** system call:

```
file_ptr = shmat( fildes, 0, SHM_CPY );
```

   The parameter, **SHM_CPY**, is a constant defined in the header file, **/usr/include/sys/shm.h**. It indicates that the file is a **copy on write** mapped file. Include this header file and the other shared memory header files in a program with the directives:

```
#include <sys/shm.h>
#include <sys/types.h>
#include <sys/ipc.h>
```

3. Now use `file_ptr` as a pointer to the start of the data file, and access the data as if it were in memory.

4. Use the **fsync** system call to write changes to the copy of the file on disk to save the changes:

```
fsync( fildes );
```

5. Close the file when the program is finished working with it:

```
close( fildes );
```

Shared Memory Calls

The ***shared memory*** calls set aside an area of memory that cooperating processes can access. This area can serve as a large pool for exchanging data among the processes. The shared memory calls do not provide locks or access control among the processes. Therefore, processes using the shared memory area must set up a signal or semaphore control method to prevent access conflicts and to keep one process from changing data that another process is using. Use shared memory when the amount of data to be exchanged between processes is too large to transfer with messages, or when many processes maintain a common large data base.

Use the following calls to create and use shared memory segments from a program:

Call	Description
shmctl	Controls shared memory operations.
shmget	Gets or creates a shared memory segment.
shmat	Attaches a shared memory segment to a process.
shmdt	Detaches a shared memory segment from a process.

In addition, the **ftok** subroutine provides the ***key*** that the **shmget** call uses to create the shared segment. Include the following header files when using shared memory calls:

```
#include <sys/types.h>
#include <sys/ipc.h>
#include <sys/shm.h>
```

Terms

The use of shared memory segments is similar in structure to the way the system creates and uses files. Defining the terms used for shared memory with respect to the more familiar file terms provides a framework to build an understanding of shared memory. Figure 4-32 shows the new terms and how they relate to terms used with files.

Term	Definition
key	The ***key*** is a unique identifier that names the particular shared segment. It is always associated with the shared segment as long as the shared segment exists. In this respect it is similar to the *filename* of a file.
shmid	The ***shmid*** is an identifier assigned to the shared segment for use within a particular process. It is similar in use to a *file descriptor* of a file.
attach	A process must ***attach*** a shared segment to use the shared segment. Attaching a shared segment is similar to opening a file.
detach	A process must ***detach*** a shared segment once it is finished with the shared segment. Detaching a shared segment is similar to closing a file.

Figure 4-32. Shared Memory Terms

Using Shared Segments

The following sequence describes the life cycle of a shared segment from initial creation to final removal from the system:

1. Create a key to uniquely identify the shared segment. Use the **ftok** subroutine to create the key. For example, to create a key `mykey` using a project ID of `R` contained in the variable `proj` (type **char**) and a file name of `null_file`, use a statement like:

   ```
   mykey = ftok( null_file, proj );
   ```

2. Either:

   - Create the shared memory segment with the **shmget** system call. For example, to create a shared segment that contains 4096 bytes and assign the **shmid** to an integer variable `mem_id`, use a statement like:

     ```
     mem_id = shmget( mykey, 4096, IPC_CREAT | 0666 );
     ```

     or

   - Get a previously created shared segment with the **shmget** system call. For example, to get a shared segment that is already associated with the key `mykey` and assign the **shmid** to an integer variable `mem_id`, use a statement like:

     ```
     mem_id = shmget( mykey, 4096, IPC_ACCESS );
     ```

3. Attach the shared segment to the process with the **shmat** system call. For example, to attach the previously created segment, use a statement like:

   ```
   ptr = shmat( mem_id );
   ```

   In this example, the variable `ptr` is a pointer to a structure that defines the fields in the shared segment. Use this template structure to store and retrieve data in the shared segment. This template should be the same for all processes using the segment.

4. Work with the data in the segment using the template structure.

5. Detach from the segment using the **shmdt** system call:

   ```
   shmdt( mem_id );
   ```

6. If the shared segment is no longer needed, remove it from the system using the **shmctl** system call:

```
shmctl( mem_id, IPC_RMID, ptr ) ;
```

See *AIX Operating System Technical Reference* for specific information about parameters for the calls and subroutines. You can also use the commands **ipcs** to get information about a segment and **ipcrm** to remove a segment. See *AIX Operating System Commands Reference* for information about these commands.

Memory Management Calls

Use the following calls to control a program's use of memory during execution:

Call	Description
brk	Change data segment space allocation
sbrk	Change data segment space allocation (see brk)

File System Calls

The system provides calls to create files, move data into and out of files, close files, and describe the restrictions and structure of the file system. Because the system treats input and output to all devices the same as input and output to files, you can use many of the ***file system*** calls for control of devices in the system also. The system calls do not provide the data formatting and housekeeping services that the C library subroutines for input and output do. See Chapter 3, "Using the Subroutine Libraries" on page 3-1 for information about the library calls.

Data Handling Calls

Use the following system calls to control data handling in the system. These calls create files, open and close files, and move data into and out of them.

Call	Description
close	Closes a file descriptor.
creat	Creates a new file or rewrite an existing one.
dup	Duplicates an open file descriptor.
ioctl	Controls device.
lseek	Moves read/write file pointer.
mknod	Makes a special file that provides an interface to a device for input and output.
open	Opens a file or device for reading or writing.
read	Reads from a file or device.
readx	Reads from a file or device and uses an extra parameter for communication with the device driver.
write	Writes on a file or device.
writex	Writes on a file or device and uses an extra parameter for communication with the device driver.

Using Files

When transferring data on the system, ensure that the files are created, opened and closed at the proper times so that data is not lost. The following sequence of events describes the actions to perform when using files for data storage:

1. Use the **creat** system call to create the file

   or

   Use the **open** system call to open the file if it already exists (the **creat** call leaves the file open).

2. Use the **write** and **read** system calls to transfer data into and out of the file.
3. Use the **close** system call to close the file.

In most cases, closing the file is enough. The system writes the file to disk from its buffers in memory at its own convenience. However, to write the data to disk immediately, use the **fsync** system call to force the system to write its buffers to disk before closing the file.

File Descriptors

The system performs all input and output by reading or writing files. It uses ***special files*** to form the interface between a device and the operating system. When you **open** a file, the system checks to see if you can access it. If you have access to the file, the system returns a small positive integer called a ***file descriptor***. The system uses this file descriptor instead of the name to identify the file. Therefore, programs must use the file descriptor when doing input and output with system calls.

The system assigns the file descriptor number on an *as available* basis, but it reserves three numbers for special functions:

0 ***standard input***: This file normally handles input from the keyboard of the terminal.

1 ***standard output***: This file normally handles output to the terminal screen.

2 ***standard error***: This file normally handles error messages to the terminal screen.

These file descriptors are normally always open, so that a program can get input from the standard input and send output to standard output or error without opening a file.

Opening and Closing Files

To use input and output other than **stdin**, **stdout**, or **stderr**, either **open** or **creat** a file. The **open** system call sets up an existing file for access, and returns a file descriptor to the calling program:

```
int fildes;
fildes = open (filename,oflag,[mode]);
```

In this call, the parameters have the following meaning:

filename The character string that corresponds to the external file name of the file to be opened.

oflag A flag that indicates the conditions of the access for the file.

mode An optional access mode for the operation to be performed:

0	Read only access
1	Write only access
2	Read and write access

If an error occurs, **open** returns `-1` as the file descriptor. Trying to open a file that does not exist is an error.

To create a new file, use the **creat** system call:

```
fildes = creat(filename,mode);
```

In this call, the parameters have the following meaning:

filename The character string that corresponds to the external file name of the file to be opened.

mode The access permission bits for the file to be created as described for the **chmod** command in *AIX Operating System Commands Reference.*

The **creat** call returns `-1` as the file descriptor if it cannot create the file. If the file exists, this call truncates that file to zero length and returns the file descriptor for that file.

To free up a file descriptor for use with another file, use the **close** system call when access to the file is complete:

```
close(fildes);
```

When the program stops using an **exit** call, or a **return** from **main**, the system closes all file descriptors associated with the program.

Random Access to Files

Normal access to files is sequential. Each **read** or **write** occurs in the file position directly following the previous operation. To perform random access I/O, use the **lseek** system call to move around in the file. This system call does not read or write to the file, it only changes the position where the next **read** or **write** will occur. The format of this call is:

```
lseek(fildes, offset, whence);
```

In this call, the parameters have the following meaning:

fildes The file descriptor for the file.

offset The number of bytes to move, or an absolute address as specified by the *whence* parameter.

whence Determines how to use *offset* to move in the file:

- **0** Moves to the address contained in *offset*
- **1** Moves to the address that is the current location plus the value contained in *offset.*
- **2** Moves to the address that is the number of bytes contained in *offset* plus the address of the end of the file.

For example, to append to a file when it is not positioned at the end, seek to the end before writing:

```
lseek(fildes, 0, 2);
```

To get back to the beginning of the file:

```
lseek(fildes, 0, 0);
```

To create ***sparse files***, or files with ***holes*** in them to allow for relative record access within the file, create a new file and then use the **lseek** call to move to selected places in the file before writing. The spaces between the data (***holes***) become part of the file, but do not take up disk space until they are actually filled with data.

Reading and Writing to a File

The **read** and the **write** system calls perform input and output for the system. These calls require three arguments:

1. **File descriptor**: The integer assigned to the file involved in the read or write.
2. **Buffer**: An area in the program that supplies or receives the data.
3. **Byte count**: The number of bytes to be transferred.

Each call returns the number of bytes actually transferred. For a **read**, this number may be less than the number requested in the byte count parameter. For a **write**, if this number is not the number requested, an error occurred. A returned value of 0 indicates the end of file; a returned value of -1 indicates an error occurred during the operation.

The number of bytes to transfer is the programmer's choice. Some useful values are:

1 One character at a time, or *unbuffered* transfer.

512 The block size for many peripheral devices.

1024 The internal block size for the operating system. This size, or a multiple of this size, is efficient for normal operations.

Using the Extended Calls

The system provides extended versions of the following system calls:

readx

writex

These calls perform the same functions as their original versions, but they also provide an extra parameter to pass information to the device driver. How the parameter is used depends on the device driver with which the calls are used. The parameter can be used either as a value or a pointer to a buffer area containing additional information. Use them only with device drivers that understand the additional information.

File Maintenance Calls

Use the file maintenance calls for programs that change protection of files in the file system, access many different files, or provide control of files for the user of the program. Many of these calls are the base for the system commands that have similar names. You can, however, use these calls to write new commands or utilities to help in the program development process, or to include in an application program. The file maintenance calls on the system include:

Call	Description
access	Determines accessibility of a file.
chdir	Changes working directory.
chmod	Changes mode of a file.
chown	Changes owner and group of a file.
chroot	Changes root directory.
fclear	Clears space in a file.
fcntl	Controls file operations.
fstat	Gets data returned by **stat** system call.
fsync	Forces changes in a file to disk.
ftruncate	Makes a file shorter.
link	Links to a file.
lockf	Locks a region of a file, or provides exclusive regions in a file.
mount	Mounts a file system.
stat	Gets file status.
sync	Updates superblock.
umask	Sets and gets file creation mask.
umount	Unmounts a file system.
unlink	Removes a directory entry.
ustat	Gets File system statistics.
utime	Sets file access and modification times.

Time System Calls

The system provides the following calls to set the system time and to find out what the system time is. See the description for the **ctime** library routine in *AIX Operating System Commands Reference* to get formatted time data from the system.

Call	Description
stime	Sets time.
time	Gets time.

Both calls use a value of time that is the number of seconds since 00:00:00 Greenwich Mean Time (GMT) on January 1, 1970. Therefore, the program must be able to calculate the date using that starting date and the elapsed time value used by the time calls, total seconds. For convenience, some of the common time units converted to seconds are:

Unit	Value in Seconds
minute	60
hour	3600
day	86,400
week	604,800
month	2,419,200 (28 days)
	2,592,000 (30 days)
	2,678,400 (31 days)
year	31,536,000 (365 days)
	31,622,400 (366 days)

Chapter 5. Controlling the Terminal Screen

CONTENTS

About This Chapter

The system contains two libraries of routines to support input and output to the terminal screen. These libraries are:

curses A set of screen control routines. This library is included for compatibility with existing application programs.

Extended curses An enhancement to the **curses** set of routines for IBM RT PC that provides extended function for:

- Expanded character set
- Color
- Multiple character attributes
- Error detection and handling
- Efficient handling of a window-oriented screen presentation, including:
  - Window stacking and layers
  - Linked scrolling of windows
  - Scrolling data in windows that are partially covered
  - Automatic tracking of active panes.

Use these routines for new program development or to increase the function of existing programs.

This chapter discusses only the **Extended curses** library. Information about both libraries is in *AIX Operating System Technical Reference.*

Introduction

The **Extended curses** library contains a set of C language routines that:

- Updates a screen.
- Gets input from the terminal in a screen-oriented fashion.
- Moves the cursor from one point to another independent of other screen activities.
- Creates and manages a screen containing windows, panels and panes.

The routines do the most common type of terminal-dependent functions. The routines use the file **/usr/lib/terminfo** to describe what the terminal can do.

The routines are in the following categories:

- Screen updating
- Screen updating with user input
- Cursor motion optimization.

You can use motion optimization by itself. You can use screen updating and input without knowing about either motion optimization or the data.

New Terms

The **Extended curses** routines use the concepts and terms listed in Figure 5-1 on page 5-4.

Term	Definition
terminal	Sometimes called ***terminal screen***, the ***terminal*** is a memory image of what the terminal screen currently looks like. This is a special *screen*.
screen	A ***screen*** is a special type of window that is as large as the terminal screen. You can define screens for a program. The **Extended curses** routines define two screens for their use: **stdscr** The ***standard screen*** is a memory image of the screen that the routines make changes to. **curscr** The ***current screen*** is the actual image that is currently on the terminal.
window	A memory image of what a section of the terminal screen looks like at some point in time. A window can be either the entire terminal screen, or any smaller portion down to a single character.
Presentation Space	The data and attribute array associated with a window.
Pane	An area of the display that shows all or a part of the data contained in a presentation space associated with that pane. A pane is a subdivision of a panel.
Panel	A rectangular area on the display consisting of one or more panes that a program can treat as a unit. That is, the panes in a panel are displayed together, erased together and represent a unit to the operator. The routines stack or overlap panels on the screen, and remember the order of the stack and the contents of each panel.
Field	An area in a presentation space where the program can accept operator input.

Figure 5-1. Terms

What You Need

To use the library, define the types and variables that the routines use. The file **cur01.h** contains all of the definitions that are needed for the library routines for most common uses. Include this file in the program by putting the statement:

```
#include <cur01.h>
```

at the top of the program source. When using the library routines for panel and pane management (those routines begin with the letters **ec**), use the statement:

```
#include <cur05.h>
```

in the program source to include a larger set of definitions.

Use an additional header file **cur00.h** in the program if the program uses the global variables defined to represent the information taken from the terminal file. This header file also contains include statements for the following header files:

- stdio.h
- sgtty.h
- cur01.h

You do not need to include those files separately in the program.

To compile a program with the **cc** command, specify the two additional libraries shown in the following example on the command line. This example compiles the program, `myprog.c`, with the linked output going to **a.out**, by using the following command:

```
cc myprog.c -lcur -lcurses
```

See Chapter 3, "Using the Subroutine Libraries" on page 3-1 for information about using libraries in a program.

Using the Screen Update Routines

To update the screen, the routines must know what the screen currently looks like and what it should be changed to. The routines define a data type, ***WINDOW***, to hold this information. This data type is a structure that describes a window image to the routines, including the starting position on the screen (the (line, col) coordinates of the upper left corner) and size. See Appendix B, "Extended curses Structures" on page B-1 for a definition of the WINDOW structure.

A window is like an array of characters on which to make changes. Using the window, a program builds and stores an image of a portion of the terminal that it later transfers to the actual screen. When the window is complete, use one of the following routines to transfer the window to the terminal:

refresh Transfers the contents of **stdscr** to the terminal

wrefresh Transfers the contents of a named window (not **stdscr**) to the terminal

ecrfpl Transfers the contents of a named panel to the terminal

ecrfpn Transfers the contents of a named pane to the terminal.

This two-step process maintains several different copies of a window in memory and selects the proper one to display at any time. In addition, the program can change the contents of the screen in any order. When it has made all of the changes, the library routines update the terminal in an efficient manner.

What the Screen Looks Like

The screen is a matrix of character positions that can contain any character from the character set (see Appendix D, "ASCII Characters" on page D-1) that can be displayed. Do not use control characters except when the descriptions of the library indicate that you can. The actual dimensions of the matrix are different for each type of terminal. These dimensions are defined in the file **/usr/lib/terminfo** that the **initscr** routine uses. However, the routines enforce the following limits on the terminal:

Coordinate	Description
lines	The number of lines on the terminal screen are in the range of 5 to 48. If the terminal specification defines less than 5 lines, the routines use a value of 24 lines. If the terminal specification defines more than 48 lines, the routines use a value of 48 lines.
columns	The number of columns on the terminal screen are in the range of 5 to 1000. If the terminal specification defines less than 5 columns, the routines use a value of 80 columns. If the terminal specification defines more than 1000 columns, the routines use a value of 1000 columns.

Line 0 is at the top of the screen. Line values in the routine syntax are represented by `line`. Column 0 is at the left side of the screen. Column values in the routine syntax are represented by `col`. When used in calls to the library routines, the *line* value comes first.

```
move(line, col);
```

Figure 5-2 on page 5-8 shows the coordinate boundaries of the largest screen that the routines allow.

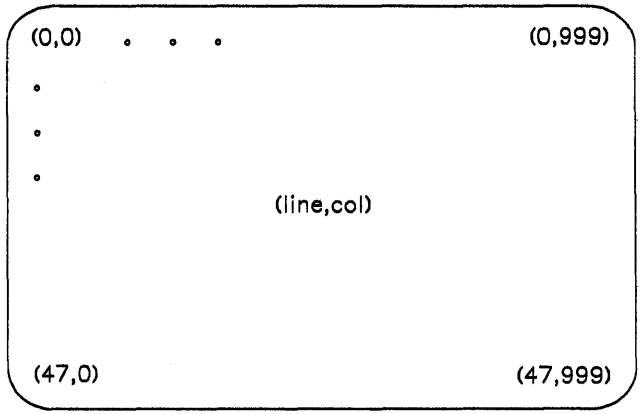


Figure 5-2. Screen Coordinate Boundaries

Function Names

Functions that change the contents of a specified window other than **stdscr** usually begin with the letter `w`, indicating an operation for a specific window. Deleting the leading `w` provides the name of the same function that uses **stdscr**. For example, the function `addch` adds a character to **stdscr**, but the function `waddch` adds a character to a specified window. If a function does not have a form that operates only on **stdscr**, the function does not have a form that begins with the letter `w`. Always indicate a window name when using these functions.

Use the routines **move** and **wmove** to change the current (line, col) coordinates from one point to another. To move and then write to or read from the new position, use the following shorthand method for most routines:

1. Add the letters **mv** to the front of the routine name.
2. The first two arguments of the routine must be the (line, col) coordinates of the destination of the move.

For example, the following call sequence:

```
move(line, col);
addch(ch);
   .
   .
   .
wmove(win, line, col);
waddch(win, ch);
```

is the same as the following call sequence:

```
mvaddch(line, col, ch);
   .
   .
   .
mvwaddch(win, line, col, ch);
```

Note that the window description pointer `win` comes before the added (line, col) coordinates.

Variables

The following system variables defined in the header files describe the terminal environment. Use these variables in a program.

Name	Type	Description
My_term	bool	If this value is TRUE, the routines use the terminal type specified by Def_term as the terminal type being used. If this value is FALSE, the routines first check the terminal type specified in the $TERM for the system environment. If $TERM is not specified, the routines use the value in Def_term.
Def_term	char*	Default terminal type if $TERM is not specified in the system environment.
ttytype	char*	Full name of the current terminal.
COLS	int	Number of columns on the terminal.
ERR	int	Flag that the routines return when a failure occurs.
LINES	int	Number of lines on the terminal.
OK	int	Flag that the routines return when the function completes successfully.
curscr	WINDOW*	Current version of the terminal screen.
stdscr	WINDOW*	Standard screen.

The routines also define the following **#define** constants and types:

bool A type of *boolean* used as:

```
bool doneit;     /* defines variable doneit */
```

reg A type with storage class *register* used as:

```
reg int i;       /* defines i */
```

FALSE The value of boolean false (0).

TRUE The value of boolean true (1).

Using the Library Routines

The following paragraphs outline the steps to follow when building a program to use these routines. The description uses routines that change **stdscr**, but the same concepts work with any window when using the W form of the routine as described in "Function Names" on page 5-9. See *AIX Operating System Technical Reference* for complete descriptions of these library routines, and their W forms.

Setting Up the Environment

To use these routines, the program must set up the operating conditions for the program. Perform the following actions in the program, if they apply, in the order that they appear in the following procedure:

1. Perform all necessary actions to load the program and make sure that it is operating successfully.
2. To change the defined size of the terminal, set the variables **LINES** and **COLS** to new values.
3. Use the routine **initscr** to get information about terminal characteristics, and to allocate memory for **stdscr** and **curscr**. Call **initscr** before calling any routines that affect windows. If the program uses a window routine before **initscr**, the program will not run.
4. Check the value that **initscr** returns to see if the screen setup was successful. If this value is 0 (FALSE or ERR), then **initscr** could not get enough memory for the needed windows.
5. Use any needed terminal status changing routines, such as, **nl** or **crmode**.
6. Create any new windows with the **newwin** or **subwin** routines.
7. Create panels using **ecbpls**, **ecbpns**, **ecdvpl** or **ecdfpl**.
8. Define or change the characteristics of the windows as needed. For example, the routine **scrollok** allows the window to scroll, or the routine **leaveok** leaves the cursor at the position of the last change.

The program can now work with the windows that it has defined. When the program is done, use the routine **endwin** to clean up before exiting the program. This routine restores terminal modes to what they were when the program first started.

Writing to a Window

Use the following functions to change the contents of a window. Refer to *AIX Operating System Technical Reference* for complete information about each routine.

Routine Description

addch(c)
Adds the character `c` on the window at the current (line, col) coordinates.

addstr(str)
Adds the string pointed to by `str` on the window at the current (line, col) coordinates.

box(win, vert, hor)
Draws a box around the window using `vert` as the character for drawing the vertical sides, and `hor` for drawing the horizontal lines. See also **fullbox** and **cbox**.

cbox(win)
Draws a box around the window using the box characters defined in **/usr/lib/terminfo** (BX[ ]). If no box characters are defined, it uses | for vertical lines, - for horizontal lines, and + for corners. See also **box** and **fullbox**.

chgat(num_chars, mode)
Changes the attributes of the next `num_chars` characters, starting at the current (line, col) coordinates to the attribute(s) specified by `mode` (one or more of the attributes defined in "Display Attributes" on page 5-26). See also **pchgat**.

clear
Resets the entire window to blanks.

clearok(scr, boolf)
Sets the clear flag for the screen `scr` to the value of `boolf`.

clrtobot
Clears the window from the current (line, col) coordinates to the bottom.

clrtoeol
Clears the window from the current (line, col) coordinates to the end of the line.

colorend
Returns the terminal to *normal* attributes following a **colorout** call.

Routine	Description
colorout(mode)	Sets the current standout bit pattern (_csbp in the **window** structure) to the value of `mode` (one or more of the attributes defined in "Display Attributes" on page 5-26) and turns on **_STANDOUT**. All characters following this call are displayed with `mode` as the attribute.
delch	Deletes the character at the current (line, col) coordinates.
deleteln	Deletes the current line.
ecactp	Specifies the active pane.
ecshpl	Shows a specified panel by bringing it to the top of the stack of panels.
ecrfpl	Refreshes the panel on the display.
ecrfpn	Refreshes the pane on the display.
ecrmpl	Removes a panel from the display.
ecscpn	Scrolls a specified pane.
erase	Erases the window to blanks without setting the clear flag. See also **perase**.
fullbox(win, vert, hor, topl, topr, botl, botr)	Draws a box around the window using `vert` as the character for vertical sides, `hor` for horizontal, and `topl`, `topr`, `botl` and `botr` as the corner characters. See also **box** and **cbox**.

Routine	Description
insch(c)	Inserts character `c` at the current (line, col) coordinates.
insertln	Inserts a line above the current line.
move(line, col)	Changes the current (line, col) coordinates of the window to (line, col).
overlay(win1, win2)	Overlays `win1` on `win2`. Windows need not be the same size.
overwrite(win1, win2)	Overwrites `win1` on `win2`. Windows need not be the same size.
printw(fmt, arg1, arg2, ...)	Performs a **printf** on the window starting at the current (line, col) coordinates.
refresh	Writes the contents of the specified window to the terminal.
standend	Stops putting characters onto `win` in standout mode.
standout	Starts putting characters onto `win` in standout mode.

Use the **refresh** routine to transfer the contents of the current window to the screen after all changes to the window are complete. The **refresh** routine does not rewrite any part of the window that has not changed since the last refresh call. To force the whole window to be rewritten, use the **touchwin** routine before the **refresh** routine. Also use **ecrfpn** to refresh a pane, and **ecrfpl** to refresh a panel.

Getting Input from the Terminal

Input is the complementary function to output. The screen package needs to know what is on the terminal at all times. Therefore, if a program echoes input characters, the terminal must be in a mode that passes characters immediately to the program, rather than waiting for a carriage return to send input to the program. The **getch** routine sets the terminal to the character input mode and then reads in the character.

Use the following routines for input from the terminal:

Routine **Description**

crmode
Sets the terminal to allow character by character input and not wait for a carrier return to send input to the process.

nocrmode
Sets the terminal to wait for a carrier return to send input to the process.

echo
Sets the terminal to echo characters.

noecho
Sets the terminal to not echo characters.

ecflin
Gets input from the screen as long as the cursor is in a specified area (***field***) of the screen.

ecpnin
Gets input from the screen in a specified pane, and scrolls the pane as needed to keep the cursor in the field.

getch
Gets a character from the terminal and (if necessary) echoes it on the window.

getstr(str)
Gets a string through the window and puts it in the location pointed to by `str`. The location must be large enough to hold the string. The string is terminated by `\n` (new-line).

Routine	Description
keypad	Gets input from the keyboard. See "Getting Input with the keypad Routine" on page 5-32 for more information.
raw	Sets the terminal to raw mode.
noraw	Resets the terminal from raw mode.
scanw(fmt, arg1, arg2, ...)	Performs a **scanf** through the window using `fmt`.

Controlling the Screen

Use the following library routines to control and manipulate the windows, panes, and panels on the screen.

Routine	Description
delwin(win)	Deletes the window and frees the resources assigned to the window.
ecadpn	Adds the specified window to the list of windows that can be displayed in a pane, but does not display it.
ecaspn	Specifies a window to be displayed in the specified pane, but requires a **refresh** call to display it.
ecbpls	Builds a panel structure.
ecbpns	Builds a pane structure.
ecdfpl	Creates **WINDOW** structures to define a panel.
ecdppn	Removes the specified window from the list of windows that can be displayed in the pane.

Routine	Description
ecdspl	Returns all structures associated with a panel to the storage pool, including structures for panes linked to the panel.
ecdvpl	Divides a panel into panes. All panes must be defined, and be linked to the panel.
ecrlpl	Returns structures associated with a panel to the storage pool, but not those that define the panel or the panes linked to the panel.
endwin	Restores the terminal to the state it was before **initscr** was called. Always use **endwin** before exiting.
gettmode	Gets the information about the terminal. This routine is called by **initscr**.
getyx(win, line, col)	Puts the current (line, col) coordinates of `win` in the variables `line` and `col`.
inch	Returns the character at the current (line, col) coordinates on the specified window.
initscr	Initializes the screen routines. Call this routine before using any of the screen routines. Use the **endwin** before exiting the screen routines.
leaveok(win, boolf)	Sets the boolean flag **_leave** to the value specified by `boolf`. This flag indicates that the cursor should be positioned after the last change.
longname(termbuf, name)	Fills in `name` with the long (full) name of the terminal described by the terminfo entry in `termbuf`.

Routine Description

mvcur(lastline, lastcol, newline, newcol)
Moves the terminal cursor from (`lastline, lastcol`) to (`newline, newcol`).

Note: Each window and the terminal have a cursor. The terminal cursor becomes the cursor on the active window or pane.

mvwin(win, line, col)
Moves the home position of the window `win` from its current starting coordinates to (line, col).

newview(orig_win, num_lines, num_cols)
Creates a new window that is `num_lines` lines and `num_cols` columns. The window is a viewport of the `orig_win` starting at the current (line, col) coordinates of `orig_win`.

newwin(lines, cols, begin_line, begin_col)
Creates a new window with `lines` lines and `cols` columns starting at position (`begin_line, begin_col`).

nl
Sets new-line mode so that the system starts changing return characters to linefeed characters.

nonl
Resets new-line mode so that the system does not change return characters. This setting helps the **refresh** routine perform optimization.

resetty
Restores the tty characteristic flags to what **savetty** stored.

savetty
Saves the current tty characteristic flags.

scroll(win)
Scrolls the window upward one line.

scrollok(win, boolf)
Sets the scroll flag for the given window to the value specified by `boolf`. A value of FALSE (disable scrolling) is the default setting.

Routine Description

setterm(name)
Sets the terminal characteristics to be those of the terminal name `name`.

subwin(win, lines, cols, begin_line, begin_col)
Creates a new window with `lines` lines and `cols` columns starting at position (`begin_line`, `begin_col`) in the window `win`.

touchwin(win)
Forces the **refresh** routine to write all of the specified window, instead of just the parts that have changed.

tstp
When using the tty driver, this function saves the current tty state and then puts the process to sleep. When the process is started again, the process restores the tty state and then calls **wrefresh(curscr)** to redraw the screen. The **initscr** routine sets the signal SIGTSTP to trap to this routine.

unctrl(ch)
Returns a string which is a representation of `ch`. To use **unctrl**, put the statement:

```
#include <cur04.h>
```

in the program file.

vscroll(view_win, deltaline, deltacol)
Scrolls the viewport window (see **newview**) down `deltaline` lines and right `deltacol` columns. If the numbers are negative, the directions are up and left, respectively.

Routines for Panels and Panes

The **Extended curses** library contains routines to help create a screen appearance similar to that used for Usability Services. The following paragraphs describe the concept of the panel and pane interface, and list the routines for creating a panel and pane interface. Refer to *AIX Operating System Technical Reference* for detailed information about each routine.

Defining Panels and Panes

To define a panel, provide the following information about the panel:

- The size of the panel as it appears on the display
- The location on the display of the upper left corner of the panel
- Whether the panel is to have a border or not
- How the panel is to be divided into panes.

In addition, provide the following information for each pane within the panel:

- The size of the presentation space associated with the pane
- The relative size of the pane within the panel
- Whether the pane is to have a border
- If and how the pane is to be further divided into smaller panes.

To divide panels and panes into smaller panes, follow a few simple rules. These rules ensure that a program can access all areas on the panel or pane that it creates:

- You can divide a panel or pane either horizontally (using a horizontal dividing line) or vertically (using a vertical dividing line).
- Panes created by a horizontal division must be linked together from top to bottom.
- Panes created by a vertical division must be linked together from left to right.
- Panes that are divided again must be linked to the first pane of its sub-panes. The original pane in this case is not a part of the presented panel, but it is needed to define the structure of the panel.
- Panes created by a horizontal division have a fixed horizontal dimension that is the same as its parent pane.
- Panes created by a vertical division have a fixed vertical dimension that is the same as its parent pane.
- Specify the variable dimension for a pane as being in one of three categories:

  Fixed For a ***fixed*** pane, specify the number of rows or columns, including any border, to assign to the pane.

  Fractional For a ***fractional*** pane, specify the percentage of the available space to assign to the pane.

  Floating For a ***floating*** pane, do not specify a size. The floating pane shares the available space equally with any other floating panes that the program creates.

The linkage of the panes forms a tree structure. The root of the tree is a panel description. All other elements in the tree are pane descriptions.

Creating Panels and Panes

To create a panel that looks like the outline shown in Figure 5-3 on page 5-24, perform the following steps (following the rules for dividing panels and panes) as shown in Figure 5-4 on page 5-24.

1. Define panel **P** using the **ecbpls** routine with a link to pane **A**.
2. Divide the panel (**P**) with two horizontal splits into three panes. Use the **ecbpns** routine to define the three panes with the following links:

A	No links
B	Linked to **A** and **D**
C	Linked to **B** and **F**

3. Divide pane **B** with a single vertical split into two panes. Use the **ecbpns** routine to define the two panes with the following links:

D	No links
E	Linked to **D**

4. Divide pane **C** with two vertical splits into three panes. Use the **ecbpns** routine to define the three panes with the following links:

F	No links
G	Linked to **F**
H	Linked to **G**

Although the program must create panes **B** and **C** to get the smaller panes, those two panes do not appear as panes in the final display.

Figure 5-5 on page 5-25 shows how the panel and pane descriptions for the final structure are linked. Horizontal lines show the links within a pane; vertical lines show links to the parent panel or pane.

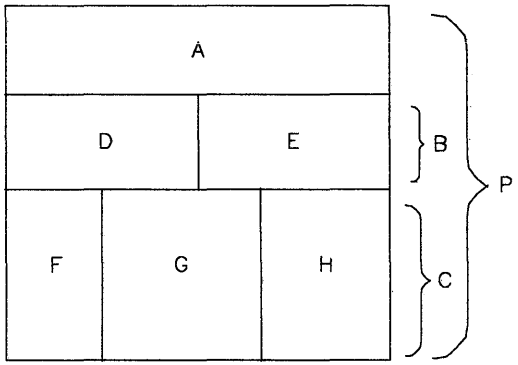


Figure 5-3. Example Panel Final Appearance

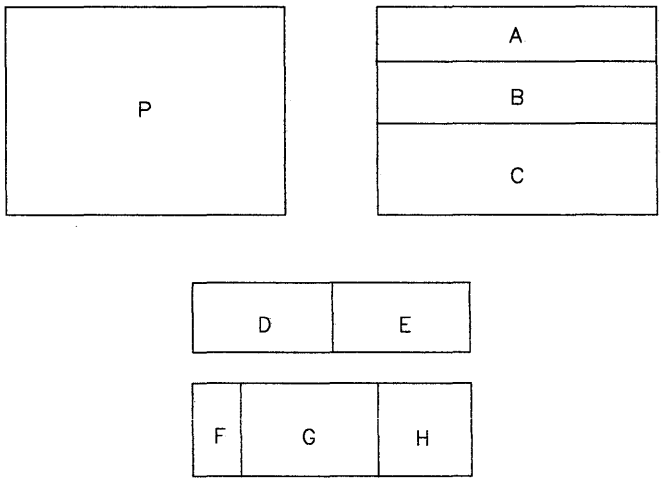


Figure 5-4. Creating Panes in the Panel

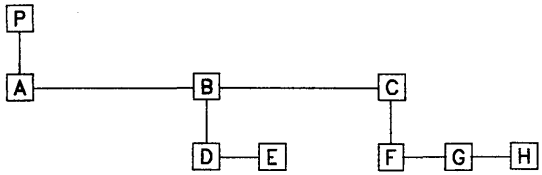


Figure 5-5. Links in the Panel and Pane Structure

Display Attributes

Use the color and display characteristics defined in Figure 5-6 on page 5-27. These names are external variables that define the attributes that a program can use on the current terminal. The values of these variables depend on the capabilities of the current terminal and the priorities that you assign to the attributes. Change the values of these variables with the **sel_attr** routine as explained in "Changing the Defined Attributes" on page 5-28.

The characteristics that a program selects for the terminal are loaded into the attribute byte associated with the data being displayed. Select as many of the attributes as needed, but those selected are packed into the attribute byte in the following order:

1. BOLD,
2. REVERSE,
3. F_WHITE,
4. F_RED,
5. F_BLUE,
6. F_GREEN,
7. F_BROWN,
8. F_MAGENTA,
9. F_CYAN,
10. F_BLACK,
11. B_BLACK,
12. B_RED,
13. B_BLUE,
14. B_GREEN,
15. B_BROWN,
16. B_MAGENTA,
17. B_CYAN,
18. B_WHITE,
19. UNDERSCORE,
20. BLINK,
21. INVISIBLE,
22. DIM,
23. STANDOUT,
24. PROTECTED,
25. FONT0,
26. FONT1,
27. FONT2,
28. FONT3,
29. FONT4,
30. FONT5,
31. FONT6,
32. FONT7,
33. NULL

To change the order, see "Changing the Defined Attributes" on page 5-28. Once the attribute byte is full, the routines ignore the remaining lower priority attributes. If an attribute does not work with the current display, the routines ignore that attribute. Therefore, you can specify color attributes and still be able to use the program with a monochrome display. Figure 5-6 defines the external variable names that the routines use to set the display attributes.

Name	Attribute
UNDERSCORE	Display characters with underline.
REVERSE	Display characters in reverse video.
NORMAL	Display characters without highlighting (return to normal).
INVISIBLE	Do not display characters.
STANDOUT	Display characters in high intensity (can be used with other attribute colors). On many terminals, this is the same as **BOLD**.
BOLD	Display characters in bold font (or high intensity on some terminals).
BLINK	Display blinking characters (can be used with other attribute colors).
DIM	Display characters in reduced intensity.
PROTECTED	Protected display field.
F_BLACK	Set foreground color to black.
F_BLUE	Set foreground color to blue.
F_GREEN	Set foreground color to green.
F_CYAN	Set foreground color to cyan.
F_RED	Set foreground color to red.
F_MAGENTA	Set foreground color to magenta.
F_BROWN	Set foreground color to brown.
F_WHITE	Set foreground color to white.
B_BLACK	Set background color to black.
B_BLUE	Set background color to blue.
B_GREEN	Set background color to green.
B_CYAN	Set background color to cyan.
B_RED	Set background color to red.
B_MAGENTA	Set background color to magenta.
B_BROWN	Set background color to brown.
B_WHITE	Set background color to white.
FONT0	Select defined character font 0.
FONT1	Select defined character font 1.
FONT2	Select defined character font 2.
FONT3	Select defined character font 3.
FONT4	Select defined character font 4.

Figure 5-6 (Part 1 of 2). Display Attributes

Name	Attribute
FONT5	Select defined character font 5.
FONT6	Select defined character font 6.
FONT7	Select defined character font 7.

Figure 5-6 (Part 2 of 2). Display Attributes

Changing the Defined Attributes

To change the characteristics assigned to the external variables listed in Figure 5-6 on page 5-27, use the **sel_attr** routine. This routine uses a set of defined constants contained in the header file **cur04.h**. To use this routine, put the following statement at the beginning of the program file:

```
#include <cur04.h>
```

The file **cur04.h** defines the following constants:

_dNORMAL
_dREVERSE
_dBOLD
_dBLINK
_dUNDERSCORE
_dDIM
_dINVISIBLE
_dPROTECTED
_dSTANDOUT
_dF_BLACK
_dF_RED
_dF_GREEN
_dF_BROWN
_dF_BLUE
_dF_MAGENTA
_dF_CYAN
_dF_WHITE
_dB_BLACK
_dB_RED
_dB_GREEN
_dB_BROWN
_dB_BLUE
_dB_MAGENTA
_dB_CYAN
_dB_WHITE
_dFONT0
_dFONT1
_dFONT2
_dFONT3
_dFONT4
_dFONT5
_dFONT6
_dFONT7

These constants are only valid when using the **sel_attr** routine. They cannot be used with any other routine.

Changing Screen Attributes

The code fragment in Figure 5-7 shows how to use these constants to change the default set of attributes.

```
#include <cur00.h>
#include <cur04.h>

int     attrs[] =
{
        _dBOLD, _dBLINK,
        _dF_WHITE, _dF_RED, _dF_BLUE, _dF_GREEN,
        _dF_BROWN, _dF_MAGENTA, _dF_CYAN, _dF_BLACK,
        _dB_BLACK, _dB_RED, _dB_BLUE, _dB_GREEN,
        _dB_BROWN, _dB_MAGENTA, _dB_CYAN, _dB_WHITE,
        _dREVERSE, _dINVISIBLE, _dDIM, _dUNDERSCORE,
        NULL
};

main( )
{

sel_attr(attrs);
initscr( );
if( REVERSE == NORMAL ) REVERSE = F_BLACK | B_WHITE;
if( INVISIBLE == NORMAL ) INVISIBLE = F_BLACK | B_BLACK;
if( DIM == NORMAL ) DIM = F_BLACK | BOLD;
if( UNDERSCORE == NORMAL ) UNDERSCORE = F_WHITE | B_RED;
STANDOUT = REVERSE;

        <rest of program>

endwin( );
}  /* end main */
```

Figure 5-7. Example Panel Final Appearance

The routines only define 8 bits of unique attribute information. Selecting foreground color, background color or font requires either 1, 2 or 3 bits depending upon the number of colors or fonts in the list: 1 bit for 2 or fewer, 2 bits for 3 or 4, and 3 bits for 5 to 8. Each character attribute takes 1 bit. However, the attribute names passed to **wcolorout** are variables, so that you can make combinations from the other attributes as shown in the last part of the previous example. If a requested attribute (that is not the terminal default) is equal to NORMAL, then it is either not supported by the terminal, or there is not enough space in the window structure for its mask.

Using Other Features

Getting Input with the keypad Routine

The **keypad** routine allows a program to recognize control sequences in the input without searching the input or introducing device dependencies. If **keypad** is active, it scans all input data for control sequences. If it finds a control sequence, it returns the associated code to the program instead of the actual control sequence. The control codes are shown in Figure 5-8. These codes are defined in the file **cur02.h** with values greater than 0x100.

Name	Description
KEY_NOKEY	No keyboard data and no delay on
KEY_BREAK	Break
KEY_DOWN	Cursor down
KEY_UP	Cursor up
KEY_LEFT	Cursor left
KEY_RIGHT	Cursor right
KEY_HOME	Home - top left
KEY_BACKSPACE	Backspace
KEY_DL	Delete line
KEY_IL	Insert line
KEY_DC	Delete character
KEY_IC	Insert character mode start
KEY_EIC	Exit insert character mode
KEY_CLEAR	Clear screen
KEY_EOS	Clear to end of screen
KEY_EOL	Clear to end of line
KEY_SF	Scroll forward
KEY_SR	Scroll backward (reverse)
KEY_NPAGE	Next page
KEY_PPAGE	Previous page
KEY_STAB	Set tab stop
KEY_CTAB	Clear tab stop
KEY_CATAB	Clear all tab stops
KEY_ENTER	Enter key

Figure 5-8 (Part 1 of 2). Control Codes

Name	Description
KEY_SRESET	Soft reset key
KEY_RESET	Hard reset key
KEY_PRINT	Print or copy
KEY_LL	Lower left (last line)
KEY_A1	Pad upper left
KEY_A3	Pad upper right
KEY_B2	Pad center
KEY_C1	Pad lower left
KEY_C3	Pad lower right
KEY_DO	DO key
KEY_QUIT	QUIT key
KEY_CMD	Command key
KEY_PCMD	Previous command key
KEY_NPN	Next pane key
KEY_PPN	Previous pane key
KEY_CPN	Command pane key
KEY_END	End key
KEY_HLP	Help key
KEY_SEL	Select key
KEY_SCR	Scroll right key
KEY_SCL	Scroll left key
KEY_TAB	Tab key
KEY_BTAB	Back tab key
KEY_NEWL	New-line key
KEY_F0	Function key - 128 values
KEY_F(n)	Not used
KEY_ESC1	Added to the ending character code for ESC sequences in the form ESC c with c in the range 0x30 - 0x7f. The value sent is in the range 0x200 to 0x24f.
KEY_ESC2	Added to the ending character code for ESC sequences in the form ESC [s c with c in the range 0x40 - 0x7f. The value sent is in the range 0x250 to 0x28f.

Figure 5-8 (Part 2 of 2). Control Codes

To use the control sequences in a program, first use a call to the **keypad** routine:

```
keypad(TRUE);
```

Scrolling Windows

If a window includes the lower right corner of the terminal screen, the flag byte bit, **_SCROLLWIN**, in the WINDOW structure for that window is set. This bit indicates that if a character is placed in the lower right corner of the window, the terminal inserts a blank line at the bottom of the screen (scrolls) to make room for more information. If a program defines the window with **scrollok** to allow it to scroll and place a character in the lower right corner of the window, the routines automatically call the **scroll** routine.

If a program does not define the window with **scrollok**, scrolling is not allowed. When a character is placed in the lower right corner of the window, the routines reset the current `col` coordinate to zero (beginning of line) and does not scroll.

To move a window to the lower right corner, use the **mvwin** routine. The **_SCROLLWIN** flag bit for that window is not automatically set. However, the **wrefresh** routine handles that window as if the **_SCROLLWIN** flag bit were set.

Improving Performance

To speed up output, create an output buffer using statements similar to the following program fragment:

```
#include  <stdio.h>

char      obuf[BUFSIZ];

main( )
{
   setbuf (stdout, obuf);
      .
      .
      .
   /* rest of program */
}
```

Example Program

Figure 5-9 shows the use of some of the routines to create a series of displays on the screen. If you are using the Programming Examples, the program is stored as **twinkle.c**. Compile and run the program to see the effects of the Extended curses functions.

```
#include        "curOO.h"
#include <signal.h>

#define NCOLS 80
#define NLINES 24
#define MAXPATTERNS 11

struct locs
{
   char  y, x;
};

typedef struct locs  LOCS;

LOCS  layout[ NCOLS * NLINES ];  /* current board layout */

int   pattern,                   /* current pattern number */
      numstars;                  /* numbers of stars in ptern */
```

Figure 5-9 (Part 1 of 6). Example of Extended curses Program

```
main()
{
   char *getenv();
   int die();

   srand( getpid() );            /* initialize random sequence */
   initscr();
   signal( SIGINT, die );
   noecho();
   leaveok( stdscr, TRUE );
   scrollok( stdscr, FALSE );

   for( ;; )
   {
      makeboard();               /* make the board setup */
      puton( '*' );              /* put on '*'s */
      system( "sleep 2" );
      erase();
      refresh();
   }
}

die()
{
   signal( SIGINT, SIG_IGN );
   mvcur( LINES/2, COLS/2, 0, 0 );
   wclear( curscr );
   wrefresh( curscr );
   endwin();
   exit(0);
}
```

Figure 5-9 (Part 2 of 6). Example of Extended curses Program

```
makeboard()
{
   reg int  y, x;
   reg LOCS  *lp;

   pattern = rand() % MAXPATTERNS;
   lp = layout;
   for( y = 0; y < NLINES; y++ )
   {
      for( x = 0; x < NCOLS; x++ )
      {
         if( ison( y, x ))
         {
            lp -> y = y;
            lp++ -> x = x;
         }
      }
   }
   numstars = lp - layout;
}

ison( y, x )

reg int y, x;

{
   switch( pattern )
   {
      /*
      ** Alternating lines:
      */
      case 0:
         return !( y & 01 );
```

Figure 5-9 (Part 3 of 6). Example of Extended curses Program

```
/*
** Box:
*/
case 1:
   if( y < 3 || y >= NLINES - 3 )
      return TRUE;
   return( x < 4 || x >= NCOLS - 4 );
/*
** Cross:
*/
case 2:
   return( ( x + y ) & 01 );
/*
** Bar across center:
*/
case 3:
   return( y >= 9 && y <= 15 );
/*
** Alternating columns:
*/
case 4:
   return !( x & 02 );
/*
** Bar down center:
*/
case 5:
   return( x >= 36 && x <= 44 );
/*
** Bar across and down center:
*/
case 6:
   return( ( y >= 9 && y <= 15 ) || ( x >= 37 && x <= 43 ));
```

Figure 5-9 (Part 4 of 6). Example of Extended curses Program

```
/*
** Bar across and down center, in a box:
*/
case 7:
   if( y < 3 || y >= NLINES - 3 )
      return TRUE;
   if( x < 4 || x >= NCOLS - 4 )
      return TRUE;
   return( ( y >= 10 && y <= 14 ) || ( x >= 36 && x <= 44 ));
/*
** Asterisk:
*/
case 8:
   if( abs( x - y ) <= 2 || abs( NLINES - ( x + y )) <= 2 )
      return TRUE;
   if( abs( ( NLINES/2 ) - x ) <= 2 )
      return TRUE;
   return( abs( ( NLINES/2 ) - y ) <= 1 && x <= NLINES );
/*
**  Ellipse:
*/
case 9:
   return
   (
      (
         (( float ) (( x-40 ) * ( x-40 )) ) / 1521 +
         (( float ) (( y-12 ) * ( y-12 )) ) / 121
      ) <= 1
   );
```

Figure 5-9 (Part 5 of 6). Example of Extended curses Program

```
      /* Circle: */
      case 10:
         return
         (
            (
               (( float ) (( x-28 ) * ( x-28 )) ) / 729 +
               (( float ) (( y-12 ) * ( y-12 )) ) / 121
            ) <= 1
         );
   }    /* end of switch( pattern ) */
}       /* not reached */

puton(ch)
reg char ch;
{
   reg LOCS  *lp;
   reg LOCS  *end;
   LOCS      temp;
   reg  int     r;

   end = &layout[ numstars ];
   for( lp = layout; lp < end; lp++ )
   {
      r = rand() % numstars;
      temp = *lp;
      *lp = layout[ r ];
      layout[ r ] = temp;
   }
   for( lp = layout; lp < end; lp++ )
   {
      mvaddch( lp -> y, lp -> x, ch );
      refresh();
   }
}  /* end of twinkle */
```

Figure 5-9 (Part 6 of 6). Example of Extended curses Program

Chapter 6. Writing Messages and Help

CONTENTS

About This Chapter

The programs that run on RT PC should provide feedback information to the person using the program. If an error occurs while the program is running, no matter if the error is produced by the program or the operator, provide an indication to the operator that the error occurred. Error indications, or any brief information that a program writes to standard error or a queue, are called ***messages***.

In addition, a program may provide information that explains in detail how the program operates. This information can include command summaries, operating procedures, explanation of ideas or information to make using the program easier to understand. Explanatory information that a program provides is called ***help***.

This chapter explains how to use the operating system services to provide both messages and help from a program. It describes the message and help text files, how to make them, and how to incorporate them into a program. The chapter also describes the format of messages.

Messages

A ***message*** is information that the program generates to inform the person using the program, or **/dev/console** of conditions in the program. If the conditions require steps to recover, the message provides those steps. A program can generate two types of messages:

Immediate message
: The message appears on the screen associated with the program. The message is usually in response to something that the person using the program did.

Queued message
: The message appears in the message queue file **/qmsg** and can only be seen by listing or editing the message queue file. When a message enters the queue file, a beep tone notifies **/dev/console**. Programs that operate directly with the user usually do **not** produce queued messages. Background processes, such as daemons, produce queued messages. Queued messages **cannot be longer than 79 characters**, including spaces but not including the message number.

The operating system provides a set of routines, called ***message services*** to help create, update and display messages from a program. The routines are in the library file **/lib/librts.a**. The services for generating messages include:

- A standard message format that matches the format of the operating system messages
- A file containing a template to use to create messages
- Two routines that help to generate either immediate or queued messages from a program
- Header files to simplify declarations needed to use message services
- Variable field symbols in the messages. When message services displays the message, it replaces these symbols with values that you specify.

Message Format

Each of the two types of messages has a different format. When displayed, queued messages are in the following format:

```
MM/DD  HH:mm  y       z  pgm-nnn
This is a sample queued message ( 79 characters or less).
```

Immediate messages have the following format.

```
pgm-nnn This is a sample immediate message:
        a. Short line.
        b. This is a long line.  Note that
           the message is presented
           as you format it. It is not
           reformatted before being displayed.
    Time = HH:mm.  Severity = y.  Error Number = z.
```

The symbols have the following meaning. See "Using Routines to Display Messages" on page 6-14 for a description of the library routines for generating messages.

Field	Description
pgm	A 3-character program identifier that is unique to the program. To ensure that these characters do not conflict with numbers already assigned to system programs, choose a number that is larger than **500**. You can also use alphabetic characters for the program identifier. Figure 6-2 on page 6-6 shows some of the identifiers that the system programs use. To match the style of the system messages, choose three digits for the program identifier. Message services displays this identifier to help the operator know what program generated the message. Message services does not use the identifier as an index into the messages.
nnn	A 3-digit sequence number for the message within the set of messages for the program identifier specified by *pgm*. This number allows looking up a description of the message in a book. Message services does not use the number.

Figure 6-1 (Part 1 of 2). Message Fields

Field	Description
text	The words that explain the condition associated with the message. If this is a queued message, the message cannot be longer than 79 characters.
MM/DD	The month and day that the message was generated.
HH:mm	Time (24 hour format) that the message was issued. When a program generates an immediate message with the **msgimed** function and uses the **msgfltim** flag, message services supplies the time. Message services automatically provides the time for queued messages.
y	Severity code is the severity code specified when using the message services routines to write the message. If you do not specify a severity code, this field does not appear.
z	Error number is the error code specified when using the message services routines to write the message. If you do not specify an error code, this field does not appear.

Figure 6-1 (Part 2 of 2). Message Fields

For example, if the operator makes a mistake when entering the date, the program could generate the following message:

```
345-007 The system cannot recognize the date that you
        entered.  Please enter the date again.
```

The optional information (time, severity or error code) does not appear in this message because the program did not specify that they be displayed when it called for the message. The book for this program should include an entry for error number 345-007 that contains information about the correct date format, or other information to help correct this problem.

ID	System Program
000	Common
001	BASIC Compiler
002	BASIC Interpreter
003	VRM ATOC
005	Coprocessor Configuration
006 - 007	Not Available
008	Multiple Work Station Install
009 - 012	Not Available
013	Operating System Install and Maintenance
014 - 016	Not Available
017	Device Driver - APA8 Display
018 - 020	Not Available
021	Operating System Trace Points
022	Coprocessor Trace Points
023	Coprocessor Control
024 - 026	Not Available
027	VRM Dump
028 - 031	Not Available
032	VRM Debugger
033	Coprocessor Software
040 - 041	Operating System Configuration
042	Data Management Services
043	Data Management Utilities
044	Not Available
046	VRM Install
047	VRM Device Driver - Diskette
048	Install and Update Services
049 - 051	Not Available
052	VRM Device Driver - Streaming Tape
053 - 060	Not Available
061	Dialog Manager
062	Interactive Work Station
063	Not Available
064	Virtual Terminal Resource/Screen Control
065 - 067	Not Available
068	Device Driver - Keyboard
069	Activity Manager
070 - 074	Not Available

Figure 6-2 (Part 1 of 2). System Identifiers

ID	System Program
075	Hardware Access Support
076	Base LAN Install
077	Pascal Compiler
078	Not Available
079	Device Drivers - ports
080 - 081	Not Available
082	Print I/O Services
083 - 089	Not Available
090	Message Services
091	Tools Application
092 - 094	Not Available
095	Operating System
096	Dialog Definition Statements
097	Files Application
098	Not Available
099	Device Driver - Sound
100	Device Driver - Locator (mouse)
101 - 102	Not Available
103	Operating System
104 - 105	Not Available
106	Data Base Command Line
107	Data Base Program Interface
108	**dumpfmt** Command
109	Error Log
110	Trace
111 - 499	Not Available
500 +	Available for new programs

Figure 6-2 (Part 2 of 2). System Identifiers

Building a Message Table

The services of the operating system can help to build a table of messages that is separate from the source code of the program. To build the table of messages, first get a file containing the standard message format from the file system. Then add messages to that file, compile the table of messages (using **cc**), and link the messages with the compiled program (object modules) and the messages library **/lib/librts.a**. This method keeps the messages in memory when the program is in memory. Do not use this method for long text, such as help (see "Help" on page 6-22).

Having a separate table of messages makes it easier to change messages, add messages, and translate the messages to another language.

Perform the following steps to build a message table and incorporate it in the program. Refer to the following paragraphs for additional explanation for some of the steps:

1. Copy the example message table file **msg07.h** into the current directory:

   ```
   cp /usr/include/msg07.h .
   ```

2. Rename the example file to the name of the message source file. Use a **.c** file extension.

   ```
   mv msg07.h mymsgs.c
   ```

3. Replace the name of the table, *tablename* in the example file, with the external name of the table.
4. Use an editor to add the message definitions and text to the message table source file.
5. Compile the message table and program source files using the **cc** command.

   ```
   cc program-files.c mymsgs.c -o myname
   ```

   In this command, *program-files.c* can be any number of C language source files each with a *.c* extension. The resulting executable program is in the file *myname*.

Copying the Standard Format File

In the directory **/usr/include** is a file called **msg07.h**. This file is an ASCII file that contains the framework for building a message table. Figure 6-3 on page 6-9 shows the major parts of this file.

```
            /*******************/
 #define TABLE_NAME /***/ tablename /***/
            /*******************/

 #include <msg08.h>
             /* structure declarations */

/*
**      ** MESSAGE DEFINITIONS **
*/

 static msg__msg msg_defs[] = {

 0, "345", "007",
 "The system cannot recognize the date that you \n\
  entered.  Please enter the date again.",
                 /* message 001 */
 } ;

/*
**      ** TEXT INSERT DEFINITIONS **
*/

 static msg__ins ins_defs[] = {

 "month",              /* insert 001 */
 "day",                /* insert 002 */
 "year",               /* insert 003 */
 } ;

 #include <msg09.h>  /* pointers table */
```

Figure 6-3. Content of Message Standard Format File

Naming the Message Table

The name of the table is the name assigned to it in the first line of the table file. The following line defines a table name of 345tab1.

```
#define TABLE_NAME 345tab1
```

For consistency with system table conventions, use the following guidelines when naming the table:

1. The first three characters should be the program identifier (345 in the example).
2. The next three characters should be the letters tab to indicate a table.
3. The last character should be an identifier to set this table apart from other tables in the program (1 in the example).

Adding Message Definitions

The ***message definition*** is the entry in the message table that describes the message. For example, in the previous standard format file, the entry:

```
0,"345","007",
"The system cannot recognize the date that you \n\
entered.  Please enter the date again.",
```

is a message definition. The message definition has the following parts.

0

The first number should be the index number for the help for the message. In the example, the number **0** indicates that help is not available for the message. A positive number in this position is the index number for help. A negative number in this position is the index number for help contained in the common help file. This number can only be used by the dialog manager.

program identifier

The second field (345 in the example) is a 3-character field that identifies the program. It must not conflict with identifiers already used by the system programs. Figure 6-2 on page 6-6 shows the identifiers that the system programs use. The identifier is enclosed in quotes.

message number

The third field (007 in the example) is a 3-digit field that indicates the number of the message within all messages for the program identifier. This number helps to find the message in the documentation. Message services does not use it.

message text

Queued messages cannot be longer than 79 characters. Immediate messages can be any length, but must include \n (new-line) characters as appropriate to keep the final output line length, including expanded variable fields (see "Using Variable Fields in Message Text" on page 6-15), to no longer than 71 characters. Message text is enclosed in quotes.

,

A comma that is not enclosed in a set of quotes marks the parts and the end of a message definition.

};

A right brace followed by a semicolon that is not enclosed in a set of quotes indicates the end of all message definitions.

Message Index

The message index is the position of the message definition within all message definitions in the table. The first definition is number 1; the second definition is number 2. The index does not depend on any number in the table file, only on the order of the message definitions in the file. Therefore, to delete a message definition, replace it with a null definition. If you remove a definition without providing a place-holding null definition (or a new definition in that position), the index to all message definitions that occur later in the file will change.

Adding Text Insert Definitions

The text insert definition is the entry in the message table that describes the fixed text strings to insert into messages in place of the symbols **@T1**, **@T2** or **@T3**. If one or more of these symbols is in the message definition, the program can select any text insert string from the message table to replace that symbol. The method for doing that is described in "Using Variable Fields in Message Text" on page 6-15.

The requirements of the text insert definition section of the message table are that it:

- Follows the message definitions section
- Begins with the statement:

```
static msg__ins ins_defs[] = {
```

- Contains a series of text strings that are:
  - Enclosed in quotes
  - Separated by commas
- Ends with a }; (right brace and semicolon).

The example message table in Figure 6-3 on page 6-9 shows an example of the text insert definition section. That example contains the following text strings:

```
"month",
"day",
"year",
};
```

Using Messages in A Program

To use the operating system message services to display messages from a message table, the program should:

1. Include the correct header files in the program
2. Pass needed values to message services by setting system external variables (see "Using Variable Fields in Message Text" on page 6-15)
3. Use the message services routines to generate the messages.

Including Header Files

Message services uses the header files shown in Figure 6-4. Include these files in the program when using message services. These header files are in the directory **/usr/include**. Display these files (using the **pg** command) to see the exact content.

File Name	Function
msg00.h	Contains **#include** statements for the following main header files to make including those files easier: • msg01.h • msg02.h • msg03.h • msg04.h • msg05.h • msg06.h • msg08.h
msg01.h	Defines the bits of the **flags** argument to message routines.
msg02.h	Defines severity codes displayed in messages.
msg03.h	Defines origin codes that indicate where the error was detected.
msg04.h	Defines error return codes.

Figure 6-4 (Part 1 of 2). Header Files

File Name	Function
msg05.h	Defines a structure for the **msgrtrv** function when a zero value is specified for the nbyte argument.
msg06.h	Defines the external variables that pass values to message services.
msg08.h	Defines structures to be used when compiling a message table.

Figure 6-4 (Part 2 of 2). Header Files

Using Routines to Display Messages

After including the needed header files and setting any needed values in the message services external variables, use one of the following routines to display the message. The message can be either immediate or queued.

Generating an Immediate Message

The **msgimed** routine performs the following functions:

1. Gets message text from the message table
2. Expands standard symbols in the message text
3. Outputs the message to either **stderr** or to a specified file.

Refer to *AIX Operating System Technical Reference* for information about the format and syntax of this routine.

Generating a Queued Message

The **msgqued** routine performs the following functions:

1. Gets message text from the message table
2. Expands standard symbols in the message text
3. Outputs the message to the queued message file **/qmsg**.

Note: Queued messages:

1. Are sent to **/qmsg** and generate a beep tone at the system console. They are not directed at the person using the program
2. Cannot be longer than 79 characters after the standard symbols are expanded.

Refer to *AIX Operating System Technical Reference* for information about the format and syntax of this routine.

Using Variable Fields in Message Text

A variable field is a standard symbol in the text of the message that is replaced with a value when message services displays the message. The value can be either a static (unchanging) text string or a new value each time, depending on the type of variable field used. The program passes values to message services by setting external variables. Use the following standard symbols in message definitions:

Symbol	Definition
@I1	Message services replaces this symbol with the character form of the integer value in the external variable **msgvi1**.
@I2	Message services replaces this symbol with the character form of the integer value in the external variable **msgvi2**.
@L1	Message services replaces this symbol with the character form of the long integer value in the external variable **msgvl1**.
@L2	Message services replaces this symbol with the character form of the long integer value in the external variable **msgvl2**.
@C1	Message services replaces this symbol with the null-terminated character string pointed to by the external variable ***msgvc1**.
@C2	Message services replaces this symbol with the null-terminated character string pointed to by the external variable ***msgvc2**.
@C3	Message services replaces this symbol with the null-terminated character string pointed to by the external variable ***msgvc3**.
@T1	Message services replaces this symbol with the text insert (from the text insert definitions section of the message table) selected by using the external variable **msgvt1** as an index value.
@T2	Message services replaces this symbol with the text insert (from the text insert definitions section of the message table) selected by using the external variable **msgvt2** as an index value.

Figure 6-5 (Part 1 of 2). Standard Symbols

Symbol	Definition
@T3	Message services replaces this symbol with the text insert (from the text insert definitions section of the message table) selected by using the external variable **msgvt3** as an index value.

Figure 6-5 (Part 2 of 2). Standard Symbols

Example of the Integer Symbol

If a message definition contains the message:

```
"Your value of @I1 is out of range."
```

To display the value that the operator entered, assign that value to the external variable **msgvi1** in the program before calling for the message to be displayed.

Figure 6-6 on page 6-17 shows an outline of a program to display that message. In this program, if index 3 of `345tab1` contains the message definition of the previous example, and the value of `val` is 14, message services displays the following message:

```
Your value of 14 is out of range.
```

```
/* Define integer to hold operator input */
integer val;
/* Define integer for return code */
integer i;
/* Include required files to use message services */
#include <msg00.h>

{
   extern msg__table 345tab1;

/*
** Code that handles input and determines
** that the value is out of range.
*/

/*
** Assign bad value to external variable, and
** call the routine to display an immediate message
** to standard error, using message index 3
** and message table, 345tab1.
*/
msgvi1 = val;
i = msgimed(MSGFLTAB,&345tab1,3);
/*
** Rest of program
*/
}
```

Figure 6-6. Example of Integer Symbol Programming

Example of the Long Integer Symbol

Inserting a long integer value into a message is the same as inserting an integer value, except it uses the external variable **msgvll** to assign a value to the symbol **@L1**, and the variable assigned to the **msgvll** must be of type **long**. With those exceptions, use the example for integer values as a framework to use a long integer value.

Example of the Character String Symbol

If the message definition contains the message:

```
"The day that you entered, @C1, is not\n
 a correct day of the week.  Please try again."
```

To display the string that the operator entered, assign a pointer to that string to the external variable **msgvcl** in the program. Then call for the message to be displayed. The string must end with a \0 (null character).

Figure 6-7 on page 6-19 shows the outline of a program to display that message. In this program if index 4 of `345tabl` contains the message definition of the previous example and the string entered is `munday`, message services displays the following message:

```
The day that you entered, munday, is not
a correct day of the week.  Please try again.
```

```
/* Define pointer to operator input. */
char *inp;
/* define integer for return code. */
integer i;
/* Include required files to use message services. */
#include <msg00.h>

{
   extern msg__table 345tab1;

/*
** Code that handles input and determines
** that the string entered is not correct.
** Code sets inp to point to the null
** terminated string received from the user.
*/

/*
** Assign pointer inp to external variable, and
** call the routine to display an immediate message
** to standard error, using message index 4
** and message table, 345tab1.
*/
 msgvc1 = inp;
 i = msgimed(MSGFLTAB,&345tab1,4);

/*
 rest of program
*/
}
```

Figure 6-7. Example of Character String Symbol Programming

Example of Text Insert Symbol

If the message definition contains the message:

```
"The @T1 that you entered is not\n
 a correct @T1.  Please try again."
```

Use this message to indicate errors in many areas of the program. First create a ***text insert definition*** section in the message table. See "Adding Text Insert Definitions" on page 6-11 for the format of a text insert definition section. If the text insert definition section contains the following few entries at the beginning of the table:

```
"day"           /* index 1 */
"week"          /* index 2 */
"month"         /* index 3 */
"year"          /* index 4 */
```

you can insert any of the strings `day`, `week`, `month` or `year` in place of the symbol **@T1** in the message by setting the external variable **msgvt1** to the index value (1, 2, 3 or 4) that selects the string to insert. When displaying the message, message services looks up the text string in the message table and inserts it in place of the symbol **@T1**.

Figure 6-8 on page 6-21 shows the outline of a program that displays this message. In this example, if index 3 of `345tabl` contains the message definition of the previous example and the value of `i_text` is 3, message services displays the following message:

```
The month that you entered is not
a correct month.  Please try again.
```

```
/* Define integer for return code. */
integer i;
/* Define integer to select insert text. */
integer i_text;
/* Include required files to use message services. */
#include <msg00.h>

{
   extern msg__table 345tab1;

/*
** Code that handles input and determines
** that a field entered is not correct.
** Code sets i_text to the index value to
** select the name of the field in error.
*/

/*
** Assign i_text to external variable, and
** call the routine to display an immediate message
** to standard error, using message index 3
** and message table, 345tab1.
*/
 msgvt1 = i_text;
 i = msgimed(MSGFLTAB,&345tab1,3);

/*
 rest of program
*/
}
```

Figure 6-8. Example of Text Insert Symbol Programming

Help

Help is text that explains difficult concepts, quick procedure steps, or other information to make it easier to use the program. You determine when to display the help from the program, and what information to include in the help. Message services provides a way to incorporate help into the program while lowering memory usage.

You can use help in the program with all of the variable symbols used with messages, including text inserts. Define text inserts in the same file that defines the help text.

Because help usually contains a lot of text, help is not compiled into the program like messages are. Instead, help is in a specially formatted help file that is not kept in memory unless it is being used. Overlaying the help file in this manner helps lower memory requirements for the program.

Note: The method for storing and displaying help described in this part of the book can also be used for messages that are not kept in memory with the program. You can put both help definitions and message definitions in the same file.

Message services provides a routine to help display help from the program. The routine is in the library file **/lib/librts.a**. When using message services, link this library file with the program. In addition, two programs **gettext** and **puttext** help to change or create information in the help files. The services include:

- A routine that displays help from the program
- Header files to simplify declarations needed to use message services
- Variable field symbols in the help that message services replaces with values that you specify when it displays the help.

Help Format

Choose any format for the help text that fits the program. You can use the format described for messages (see "Message Format" on page 6-4), you can change that format, or you can define a different format. However, follow the format defined for the help file.

File Path Name

If you do not change the default path, the file that contains the help text must have the path name of:

`/usr/lib/msg/`*`program`*`_EN.m`

where the file name parts are:

program
: A program identifier that is unique.

`_EN.m`
: The ending sequence that message services requires of all help (and message) files that are not linked with the program.

Changing the File Path Name

You can specify an alternative directory to contain the help and message file for the program. Use the rules for naming the help file as described in "File Path Name." To specify the alternative directory, assign a pointer to the new path name prefix to the external variable **msgpath** in your program. For example:

```
msgpath = "/u/myprog/";
```

This statement tells message services to look in directory **/u/myprog** for the new help file. Message services looks in the default directory only if it cannot find the file in the directory you specify with the **msgpath** variable. If **msgpath** contains a null value, message services looks only in the default directory. To specify the current directory as the directory that contains the help file, set the **msgpath** variable to a pointer to a null string.

The **msgpath** variable is declared in **msg06.h**.

Changing the File Path Name for Debugging

You can also specify an alternative path name to use for the help file when testing help definitions. An alternative path name allows you to test new or changed help definitions without affecting the existing help file that is installed on the system. You can also use the alternative path name to test a new help file before installing it on the system. Use the rules for naming the help file as described in "File Path Name" on page 6-23.

To specify the alternative directory, assign the new path name prefix to the environment variable **MSGPATH** from the command line. For example:

```
MSGPATH=/u/mytest/
```

assigns the path name prefix `/u/mytest/` to the **MSGPATH** variable. Then, export the variable with the **export** command on the command line:

```
export MSGPATH
```

This operaton tells message services to look in directory **/u/mytest** for the help file. Message services looks in the default directory only if it cannot find the file in the directory specified with the **MSGPATH** variable.

Building a Help File

Message services can help to build a file of help text that is separate from the source code of the program. To build the help file, first get a file containing the standard help format from the file system. Then add help definitions to that file, and, using a program from message services, format that file for use as a help file. This method puts the help text in a file that message services can read.

Having a separate help file makes it easier to change the help text, add help text, and translate the text to another language.

Perform the following steps to build a help file and format it for use by message services. Descriptions of the commands **gettext** and **puttext** are in *AIX Operating System Commands Reference*. Refer to the following paragraphs for additional explanation for some of the steps.

1. Use the **gettext** command to create a file containing the input format for a help file. This file contains formats to fill in for including messages and text inserts, as well as help text, in the help file. For example:

   ```
   gettext myhelps
   ```

   creates a file `myhelps` that contains the framework for a help file.

2. Add help text to the proper places in the file.

3. Use the **puttext** command to format the help file. For example:

   ```
   puttext myhelps myprog_EN.m
   ```

   uses the help text in the file `myhelps` to create the help file `myprog_EN.m`. See "File Path Name" on page 6-23 for information about naming the help file.

Content of the Help Text File

When the **gettext** command gets a help file format to fill in, the file that the command creates contains entries like those in Figure 6-9 on page 6-26.

```
COMPONENT ID = prgxxx

**(((Start message)))************************************
INDEX#:
COMPSRC:
MSGSRC:
DCOMPID:
DMSGID:
STATUS:
HELP#:
TEXT:

**(((Start insert)))*************************************
INDEX#:
COMPSRC:
MSGSRC:
DCOMPID:
DMSGID:
STATUS:
TEXT:

**(((Start help)))**************************************
INDEX#:
COMPSRC:
MSGSRC:
DCOMPID:
DMSGID:
STATUS:
TITLE:
TEXT:
```

Figure 6-9. Content of Help Text Format File

The fields shown in the figure have the following meaning:

COMPONENT ID = prgxxx

Replace `prgxxx` with a 6-character identifier to indicate which program uses this help file. Do not use the characters: *** ? [ ]** and blank.

****(((Start** *typename***)))*********************

This line is a delimiter that starts each new message and must be in the format indicated. Replace *typename* with either `message`, `insert` or `help`, as appropriate.

INDEX#:

A 3-digit field that indicates the number of the message within each type (message, insert or help). Numbers start with 001 at the beginning of the definitions for each type. Message services uses this index number to locate the text to be displayed.

COMPSRC:

Component source - Defines where the text definition for this message is located. Enter `======` for *in this file.*

MSGSRC:

Message source - A 3-digit field that defines the index number to use to display text for this message. Enter either `===` to indicate the current **INDEX#**, or a number to get text from a different message in this file.

DCOMPID:

Component ID - A 3-character field that identifies the program. It must not conflict with identifiers already used by the system programs.

DMSGID:

Message ID - A 3-digit field that indicates the number of the message within all messages for the program identifier. This number helps to find the message in the documentation. Message services does not use it.

STATUS:

Status of the message - Enter `null` to indicate the message is not used. Enter `current` to indicate the message is an active message.

HELP#:

A 3-digit index number to locate the help text for a message. This field is not required. Access this field using the **msgrtrv** call.

TITLE:

A character field of up to 79 characters that can provide a title for help text displayed on the screen. You can access this field only with the **msgrtrv** call, not with the **msghelp** call.

TEXT:

Enter the text for the message, insert or help, formatted as it appears on the screen.

Help text, like immediate messages, can be as long as needed to cover the information. Do not include any message ID for help text unless it refers to the book supplied with the program. You can also use variable fields in the help text. Refer to "Using Variable Fields in Message Text" on page 6-15 for information about using variable fields.

Using Help in a Program

To use the operating system message services to display help from the help file, the program must:

1. Include the correct header files in the program
2. Pass needed values to the message services by setting system external variables (see "Using Variable Fields in Message Text" on page 6-15)
3. Use the message services routines to display the help text.

Including Header Files

The operating system message services uses header files. Include these files in the program when using message services. These header files are described in "Including Header Files" on page 6-13.

Using Routines to Display Help

After including the needed header files and setting any needed values in the message services external variables, use the following routines to generate the help.

Displaying a Help

The **msghelp** routine performs the following functions:

1. Gets help text from the help file
2. Expands standard symbols in the help text
3. Outputs the help to either **stderr** or to a specified file.

Refer to *AIX Operating System Technical Reference* for information about the format and syntax of this routine.

Putting Help in a Buffer

The **msgrtrv** routine performs the following functions:

1. Gets help text from the help file
2. Expands standard symbols in the help text
3. Outputs the help to a specified buffer.

Refer to *AIX Operating System Technical Reference* for information about the format and syntax of this routine.

Chapter 7. Monitoring Program Activities

CONTENTS

About This Chapter

This chapter contains a short overview of the three categories of monitoring software plus one longer section for each group.

The first section describes the trace facilities. The trace facilities allow you to log and format trace data. This includes a functional definition of the trace components and information on using the trace commands and subroutines.

The second section describes the error log facilities. These are similar to the trace facilities except that you log error data rather than trace data.

The third section describes the dump facilities. These are used to analyze data stored that was stored in memory at the time of a system failure.

This chapter does not contain complete usage information for the commands and subroutines used with these facilities. For more detailed information, see:

- *EIX Operating System Technical Reference*:

  errsave
  errunix
  trace_on
  trcunix
  trsave

- *EIX Operating System Commands Reference*:

  dumpfmt
  errdead
  errdemon
  errpt
  errstop
  errupdate
  trace
  trcrpt
  trcstop
  trcupdate.

- *Virtual Resource Manager Technical Reference*:

  _dmptbl
  _errvrm
  _trcvrm.

Overview

The system provides several software components that enable you to monitor program activities. These components can be grouped into three basic categories:

- Trace

  You use the trace facilities to monitor system performance or to aid in debugging programs. The system programs have several event classes, each of which can be turned on or off depending on your needs. For each event class, several trace points have been defined in various system software components. When a component containing a trace point is processed, the trace point generates a trace entry. You can also generate trace entries from your own programs using the three subroutines provided with the system. These subroutines allow you to generate trace entries from applications, AIX Operating System kernel components, or VRM components.

  All trace entries are stored in a trace log file. The trace log can be formatted into a readable trace report and sent to the display screen, a printer, or another file.

- Error Logging

  Error logging is automatically enabled when you initialize the system. It can be disabled if necessary, but it usually runs as a background process, collecting error entries generated by software components. The error entries are stored in an error log that can be formatted into a readable error report. As with the trace facilities, you can use special subroutines to generate error entries from your own programs.

- Dump

  The system supports a VRM dump function and an AIX Operating System command called **dump**. This chapter is concerned with the VRM dump function only.

  You use VRM dump to collect data stored in memory at the time of a system failure. The dump data is written to a blank, formatted diskette. The dump program collects a pre-defined set of VRM data plus any additional data structures that you identify through the use of a VRM subroutine. The amount of dump data is limited to the capacity of a formatted high-capacity diskette.

  Once the dump data is placed on a diskette, it can be formatted and analyzed. Because the data is obtained from VRM components, you will probably not be able to interpret the output. This data is mainly used by IBM to determine the cause of a system failure.

Using the Trace Facilities

The trace facilities are used to monitor changes to variable data within software components. Tracing can be used as a debugging aid and to check the performance of various sections of code. Some of the basic trace terms are defined below:

trace entry A data structure containing a header of identifying information plus up to 20 bytes of defined data. Trace entries are generated by trace points and written to a trace log file that can be formatted by the trace formatter.

trace point A group of code statements that generates a trace entry from within a software component. Trace points are assigned to an event class which can be active or inactive. Trace points with active event classes are able to generate trace entries.

event class A number assigned to a group of trace points that relate to a specific subject or system component. The defined event classes are listed in the trace profile, **/etc/trcprofile**.

hook ID A unique number assigned to a specific trace point. All trace entries include the hook ID of the originating trace point in the trace entry header. Pre-defined trace points use assigned hook IDs ranging from 0 to 299. User-defined trace points can choose hook IDs ranging from 300 to 399.

How you use the trace facilities depends on what you want to accomplish:

- To choose the event classes that you want to trace, you should learn how to alter the default trace profile, **/etc/trcprofile**, and how to create your own trace profile.
- To start a trace session, you should use the **trace** command.
- To end a trace session, you should use the **trcstop** command.
- To format a trace log file, you should learn how to use the **trcrpt** command.
- To change the name or size of the default trace log file, you should learn how to alter the **/etc/rasconf** file.
- To create trace points that generate trace entries, you should learn how to use the trace subroutines: **trcunix**, **trsave**, and **_trcvrm**.
- If you create your own trace entries, you should learn how to create a trace template for each type of trace entry. You also need to learn how to use the **trcupdate** command to add trace templates to the template file, **/etc/trcfmt**.

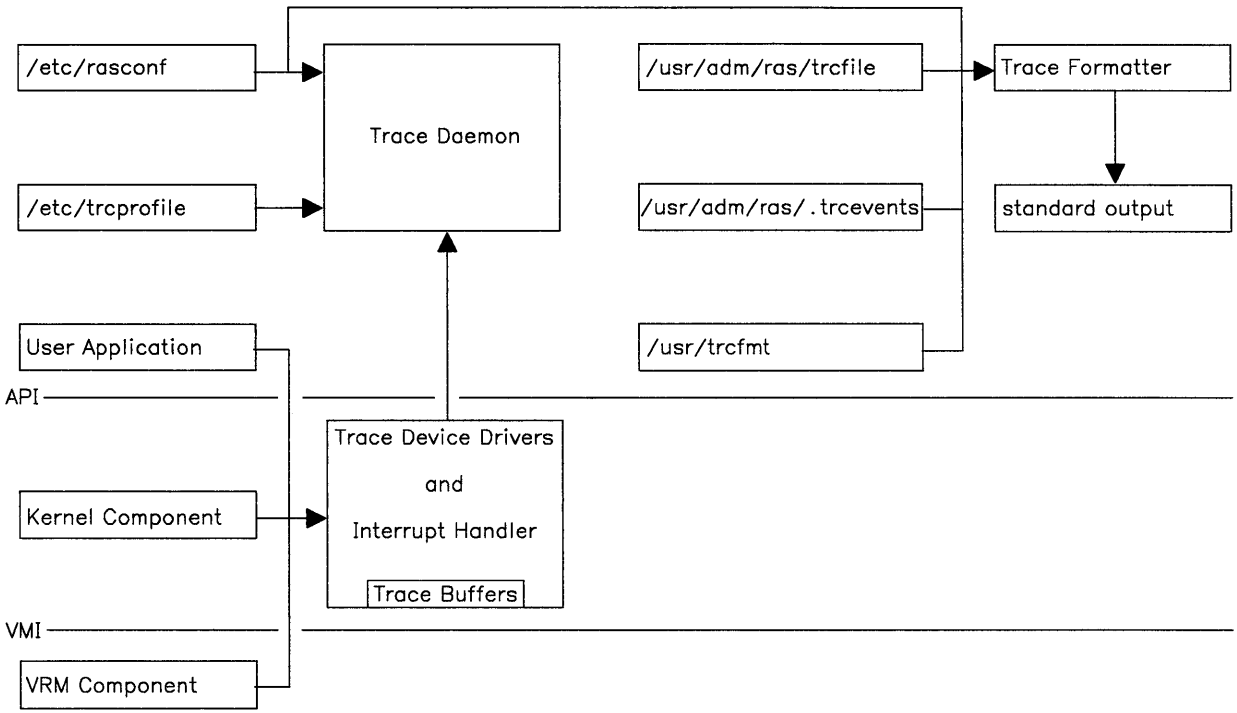


Figure 7-1. Trace Components

Figure 7-1 shows how data is passed between the various files and components that constitute the trace facilities. The lines labeled API, which stands for Application Program Interface, and VMI, which stands for Virtual Machine Interface, show the logical distinction between application programs, kernel components, and the VRM. The lines connecting the files and components show where data comes from and where it goes.

The components and files in Figure 7-1 are described on the next page. They are explained in more detail elsewhere in this chapter in the appropriate sections.

The following descriptions start at the point where the trace entries are first generated and end where the trace entries are formatted and sent to standard output.

- Applications, kernel components, and VRM components generate trace entries using trace points placed at strategic places in the execution path. The system programs contain several pre-defined trace points relating to various event classes.
- The trace device drivers collect the trace entries in trace buffers. There is one trace buffer for each of the three trace subroutines.
- The **/etc/rasconf** file contains configuration data. For the trace daemon, it defines the name and size of the trace log file to be opened to receive trace entries. For the trace formatter, it defines the default trace log file if none is specified when it is invoked.
- The default trace profile is **/etc/trcprofile**. This file contains a list of the defined event classes. An event class is either active or inactive. If an event class is active, the trace points related to that event class will generate trace entries. You can use the default trace profile, or create your own trace profile.
- The trace daemon is an important part of the trace facilities. When it is initialized, it performs three major tasks:
  - It reads the trace profile to determine which event classes should be active.
  - It opens the file specified in the trace stanza in **/etc/rasconf** as the trace log file.
  - It begins reading the trace buffers as they become full and writes them out to the trace log file.
- The default trace log file is **/usr/adm/ras/trcfile**. This file stores all of the trace entries generated by software programs. If the trace log file becomes full, the newest trace entry overwrites the oldest trace entry.
- The **/usr/adm/ras/.trcevents** file contains lists of event classes and the hook IDs associated with those event classes. The ***hook ID*** is a specific number associated with a particular trace point. The trace formatter uses information in this file to count the trace entries that occur for each event class. You do not edit this file directly. It is automatically updated when you use the **trcupdate** command.
- The trace format file, **/etc/trcfmt**, contains trace templates that determine how each trace entry appears when it is formatted. The pre-defined trace entries also have pre-defined templates. If you generate trace entries from your own programs, you need to define trace templates for those entries.
- The trace formatter formats the trace entries in a trace log file into a readable format. If a trace log file is not specified when the trace formatter is invoked, it uses the file specified in **/etc/rasconf**. The formatted trace entries are sent to standard output and can therefore be sent to the display screen, a file, or a printer.

Altering the Trace Configuration Files

There are two basic files that you can alter to change the operation of the trace facilities. The first is the ***trace profile***, which is used by the trace daemon to set up three bit masks that show which event classes are active. The trace daemon reads the trace profile when it is initialized. A trace profile contains a single line entry for each defined event class. Each line entry begins with a * (asterisk). Only those event classes that have had the * removed will be able to generate trace entries during a trace session.

You edit a trace profile using a standard text editor. You can create several trace profiles, each designed for different tracing needs. When you run **trace**, you can specify which trace profile it should use. If you do not specify a trace profile, it uses the default trace profile, **/etc/trcprofile**. To create your own trace profile, copy the default trace profile into your current directory and edit the new copy.

If you have defined trace points in your own programs, you need to have the trace daemon activate the **User-defined Events** event class. It appears in the trace profile as:

```
*       150 User-defined Events
```

To have the trace daemon activate this event class, remove the * from the beginning of that line in the trace profile. It should now appear as:

```
        150 User-defined Events
```

If you do not enable this event class, your trace points will not be able to generate trace entries in the trace log file.

The other file that you can alter is the **/etc/rasconf** file. This is a configuration file that is read by the trace daemon and the trace formatter. It contains various types of information, but the information you are interested in is the stanza that defines the name and maximum block size of the default trace log file. It appears in **/etc/rasconf** as:

```
/dev/trace:
    file = /usr/adm/ras/trcfile
    size = 80
```

Other users may change the contents of this file. You may want to change the trace log file name if the current trace log is full, or if you want to keep different logs for different trace sessions.

Each time **trace** is invoked, the trace daemon checks **/etc/rasconf** to see which file it should open to receive trace entries. All trace entries generated during the trace session are directed to that file. When you use the trace formatter, it uses the file name in **/etc/rasconf** as the default trace log file if a trace log file is not specified. If you have several trace log files, you can format up to 10 at a time by invoking the trace formatter with a list of file names.

Using the Trace Commands

There are four commands associated with the trace facilities. They each perform one basic task:

trace Starts a trace session. This command accepts a trace profile as an input file name parameter. Once a trace session is initiated, all trace points with active event classes will generate trace entries if their particular component is run.

If you do not specify a trace profile, the default trace profile, **/etc/trcprofile**, is used. The following example invokes **trace** with a user-defined trace profile. Note that an & (ampersand) is required at the end of the command line. This causes **trace** to run as a background process:

```
trace /u/myfile/myprof &
```

trcstop Stops a trace session. Any trace entries remaining in the trace buffers are written out to the trace log file. Any open files are closed and the trace daemon is terminated. This command does not require any input parameters.

trcrpt Formats trace entries contained in trace log files. This command accepts 1 to 10 trace log file names as input parameters. If you do not specify a trace log file, it uses the default trace log file specified in **/etc/rasconf**. The formatted trace entries are sent to standard output.

The following example formats two trace log files named **trace1** and **trace2** and sends the output to the printer:

```
trcrpt trace1 trace2 | print
```

Because all trace entries are time-stamped, the trace formatter can also format a subset of a trace log file consisting of trace entries that fall within a certain time interval. You specify a starting time and end time using the **-s** and **-e** flags. The time is specified as *MMddhhmmyy* (month, day, hour, minute, year).

The following example formats the default trace log entries ranging from January 3, 1985 at 11 a.m. to 11:06 a.m. of the same day:

```
trcrpt -s0103110085 -e0103110685
```

trcupdate Adds, updates, or deletes trace templates in the **/etc/trcfmt** file. Also updates the **/etc/.trcevents** file. Before using this command to add or update trace templates, you need to create an input file with the extension `.trc`. This file will contain two types of entries:

- Template definitions. These contain a + (plus sign) in the first column to specify that the template is to be merged into the master template file. A single template definition may require several lines. The + is only required on the first line of each template.
- Template deletions. These contain a - (minus sign) in the first column, one blank, and the hook ID of the template you want to delete.

  Note: Do not delete the pre-defined trace templates (hook IDs 0 to 299). These are required to format the pre-defined trace points imbedded in the system programs.

The following example shows a file that will add trace template 330 to the master template file and delete templates 320 and 321. Note that the first line in the file must be entered as shown. It is used by the **trcupdate** command to verify that this file contains template information.

```
* /etc/trcfmt
+ 330 1.0 InitPtr Printer PtrNode A8: \n: \t: \
          PtrType D4: PtrActv B0.1, 1 Yes, 0 No:
- 320
- 321
```

To update a trace template, you need to create a new template with the same hook ID but with a version and release number (*VV.RR* field) greater than the version and release number of the trace template that you want to update. When **trcupdate** merges the `.trc` file into the master template file, it will replace the old template with the updated one.

The trace formatter writes the total number of trace entries attributed to each event class at the end of a trace report. If you want trace entries generated by new trace points to be counted under the **User-defined Events** event class, you must also create a file with an extension of `.evt`.

The `.evt` file contains entries that specify an event class number and any new hook IDs that you want to associate with that event class. It is merged into the **/etc/.trcevents** file when you use the **trcupdate** command. For user-defined trace entries, the event number is always 150. Thus, to add hook ID 330 to the **User-defined Events** event class, you would create a file as shown below. Note that the first line in the file must be entered as shown:

```
* /ras/.trcevents
150 330
```

Once you create a file containing new or updated template definitions and/or template deletions, you can use **trcupdate** to process it. In the following example, the template definitions and deletions are contained in

a file called **newtemps.trc**. The event class and hook ID lists are contained in a file called **newtemps.evt**:

```
trcupdate  newtemps
```

Using the Trace Subroutines

Before using the trace subroutines, you need to understand how the trace daemon uses the trace profile and how event classes are represented as active or inactive in the system.

After the trace daemon reads the trace profile, it sets up three tables in memory. Each table consists of a one-word array of flag bits. Each bit is called a ***channel*** and is named after the bit position it occupies. The most significant bit is called **channel 0** and the least significant bit is called **channel 31**. Each event class is represented by one or more of these channels. When the trace daemon reads the trace profile and sees that an event class should be active, it sets the appropriate channels in each channel table.

When the trace daemon has read the entire trace profile, it sends one channel table to each of the three trace device drivers. When one of these drivers is called by a trace subroutine, the device driver compares the channel number, which is a required part of the trace entry, against its own channel table. If the channel is active, it puts the trace entry in a trace buffer. If not, it does nothing; however, in each case it returns a successful return code unless there is a problem in the calling procedure.

With 32 bits available for each channel table, it is possible to have 96 different event classes. However, an event class may use the same channel in more than one table. Thus, the actual number of event classes is less than 96. The **User-Defined Events** event class uses channel 31 in each of the three channel tables. This allows you to create user-defined trace entries using any of the three trace subroutines. User applications can use the **trace_on** subroutine to see if a specific channel is enabled.

Note: If you look at the trace profile, you will see a number placed before each event class. This number identifies a specific event class; however, it is not a channel number. Channel numbers can only be in the range from 0 to 31.

When you use a trace subroutine, one of the input parameters contains a channel number and hook ID to identify which event class that trace entry belongs to and which trace point generated the call. This is called the ***trace ID***. Bits 0 through 4 of the trace ID contain the binary representation of the channel number. Bits 5 through 15 contain the binary representation of the hook ID. Thus, for user trace entries, bits 0 through 4 should always be set to 1 (channel 31) and the hook ID should be a number ranging from 300 to 399.

The parameters used by the three trace subroutines are briefly explained below:

trcunix Generates a trace entry from an AIX Operating System application and requires two input parameters. The first is the address of a buffer containing the 2-byte trace ID and up to 20 bytes of trace data. The second is the length of the buffer.

trsave Generates a trace entry from an AIX Operating System kernel component and requires 3 input parameters. The first is a 2-byte trace ID. The second is the length of the data buffer. The third is the address of the data buffer.

_trcvrm Generates a trace entry from a VRM component and requires 3 input parameters. The first is a 2-byte trace ID. The second is a buffer of trace data and the third is the length of the data buffer.

When you create your own trace points, remember that each trace point should use a unique hook ID in the range from 300 to 399. You must also create trace templates for your trace points. Here are some general guidelines:

- Put a trace point at the beginning or end of an important function. The trace data should show the values of any important data structures or I/O parameters.
- If a function takes a significant amount of processing time, you may want to put a trace point at its entry and exit points. This will allow you to trace how long it takes to process different types of input parameters.
- Put a trace point at a critical junction in the logic flow of a component.
- Do not put a trace point inside a loop that is repeated many times if you can catch the important data before the loop begins.
- Try to limit the trace entry data to four variables or less.

The trace device drivers have access to the channel tables, so they know whether or not to put a trace entry in the trace buffers. However, you may want to explicitly check to see if your channel is active before you call a trace subroutine so you can design the trace point to skip around data collection code if the channel is not on. For kernel components, the usual procedure is to perform the subroutine call without checking for an active channel because kernel trace points do not contain much data.

A sample trace point for application level components is shown in Figure 7-2 on page 7-12. Notice how it uses the **trace_on** subroutine to see if the **User-Defined Events** channel (31) is on before calling the **trcunix** subroutine. Also, notice how the trace ID is created. First, you shift the variable containing the channel number left 11 bits so that it is in bits 0 through 4. Then you perform an OR operation on that variable with the variable containing the hook ID. The result is a trace ID containing the channel number in bits 1 through 4 and the hook ID in bits 5 through 15.

```
#include <sys/trace.h>
#include <trcdefs.h>
#include <stdio.h>

main(argc, argv)
   int argc;
   char **argv;
{
   extern int trace_on();
   extern int trcunix();
   int chan_no = 31;
   long channel = 0x1;    /* Set bit 31 (user-defined channel) to 1 */
   long hookid = 300;     /* Define the hook ID for this trace point */
   int tracing;
   int rc = 0;
   struct
   { unsigned short traceid;
      char data[20];
   } trcstruct;

   /* See if channel 31 is active.  */

   if ( (tracing = trace_on(channel) ) < 0)
   {
      fprintf(stderr,"trace_on failed\n");
      return(-1);
   }
```

Figure 7-2 (Part 1 of 2). Example Program Fragment Showing Use of trcunix Subroutine.

```
   /* Imbed this trace point anywhere in your program code. */

   if (tracing)
   {
      trcstruct.traceid = ((chan_no<<11) | hookid);
      sprintf(trcstruct.data, "This is trace data.");
      if (trcunix(&trcstruct, sizeof(trcstruct)) < 0)
      {
         fprintf(stderr,"trcunix failed\n");
         rc = -1;
      }
   }
   exit(rc);
}   /* end main */
```

Figure 7-2 (Part 2 of 2). Example Program Fragment Showing Use of trcunix Subroutine.

Figure 7-3 on page 7-14 creates a trace entry from within an AIX Operating System kernel component. Notice how it uses a defined constant (TR_USER) to set the channel number in the trace ID parameter. TR_USER contains channel number 31 in bits 0 through 4. This is only available for kernel components using the **trsave** routine.

```
#include <sys/trace.h>
#define TRACEDATA 1

function()
{
   long hookid = 310;
   int t_data;

   /* The following trace point can appear anywhere in your function. */

   t_data = TRACEDATA;
   trsave((TR_USER | hookid), sizeof(int), &t_data);
}   /* end function */
```

Figure 7-3. Example Program Fragment Showing Use of trsave Subroutine.

Creating Trace Templates

The trace formatter uses ***trace templates*** to determine how the data contained in trace entries should be formatted. All trace templates are stored in the master template file, **/etc/trcfmt**. After you create some new or updated trace templates, place them in a file that can then be merged into the master template file using the **trcupdate** command. The **trcupdate** command requires that trace templates identify themselves by placing a + and a blank in the first two columns of the first line of the trace template.

Trace templates contain four required fields and zero or more data description fields. The required fields identify the template hook ID, the version and release number, the hook ID label, and the event class label. The data description fields contain formatting information for the trace entry data and can be repeated as many times as is necessary to format all of the trace data in the trace entry.

Trace entries are formatted and written to standard output one entry at a time. For each entry, the trace formatter performs the following operations:

1. Locates the trace template corresponding to the hook ID in the trace entry.
2. Writes the time the entry was generated. It also writes a sequence number that shows when the entry was generated as an interval within a second. This sequence number allows the formatter to sort trace entries that are generated during the same second. They can then be formatted and written in the order in which they occurred. These fields are placed in the trace entry header by the trace subroutine.
3. Writes the PID, IODN, and IOCN contained in the trace entry header. These fields are placed in the trace entry header by the trace subroutine.
4. Writes the hook ID and event class. You can use the actual numbers that equate to the hook ID and event class, or you can create a name up to eight characters for each field. The trace formatter will write whatever is placed in the field.
5. Writes up to 20 bytes of data according to the *data_descriptors* in the trace template, if any are present. Any data that occurs after the last *data_descriptor* in the template is ignored. A *data_descriptor* does the following:
    a. Writes the data label (*d_label*), if it is specified.
    b. Writes the actual data according to the *format* field and the optional match fields. You can define match fields that will replace data values with descriptive labels or change to a different *data_descriptor* depending on the current data value.

Figure 7-4 on page 7-16 shows the syntax used to define a trace template. Figure 7-5 on page 7-17 defines each of the fields in a trace template.

Trace template lines can be as long as you need. You can continue a trace template on another line by adding the \ (backslash) character to the end of the line where the split occurs. Note that \ is not a substitute for a required blank. A blank is also required after a colon or comma.

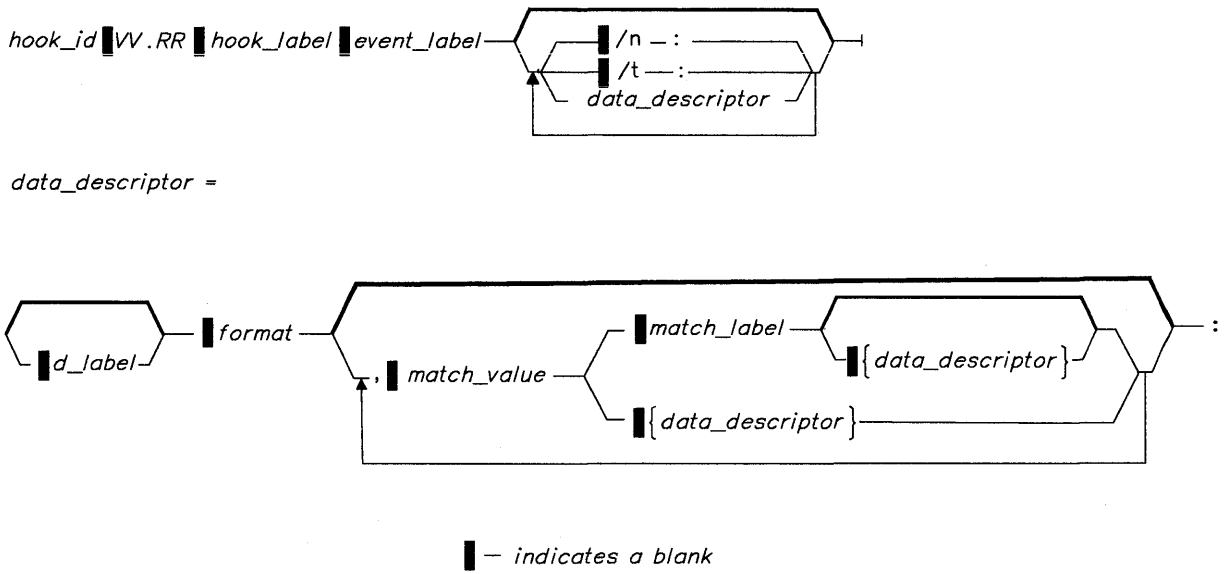


Figure 7-4. Trace Template Syntax

Field	Description
hook_id	The 3-digit hook ID of the trace entries that use this template.
VV.RR	A number representing the version and release level of this template.
hook_label	A label field of up to 8 characters that describes the hook ID.
event_label	A label field of up to 8 characters that describes the event class.
\n	A special string used to start output data on a new line.
\t	A special string used to start output data after one tab unit.
d_label	A label field of up to 8 characters that describes the trace entry data.
format	An alphanumeric code that defines the format of the trace data.

Code	Format of Data
A*m*	ASCII string of *m* characters.
B*m*	Binary string of *m* bytes.
B*m.n*	Binary string of *m* bytes and *n* bits. If this format leaves some unformatted bits in the current byte, they are not written unless this format is followed by another format that specifies bits.
D2	Decimal short integer.
D4	Decimal long integer.
F4	Floating-point number of type *float*, rounded to four places.
F8	Floating-point number of type *double*, rounded to four places.
O*m*	Omit (do not write) the next *m* bytes.
O*m.n*	Omit (do not write) the next *m* bytes and *n* bits. If this format leaves some unformatted bits in the current byte, they are not written unless this format is followed by another format that specifies bits.
U2	Unsigned decimal short integer.
U4	Unsigned decimal long integer.
X*m*	Hexadecimal number of *m* bytes.

match_value	A value with a data type the same as the *format* field. If you specify a *match_value*, you must also specify a *match_label* or *data_descriptor*.
match_label	A character field up to 120 characters that replaces output data that matches a *match_value* field.
data_descriptor	A field containing formatting information for a portion of the output data.

Figure 7-5. Fields in a Trace Template

Replacing Values in the Output Data

The *match_value* field provides a function that is similar to a switch statement in programming. You can use this function to do either or both of the following:

- Replace an output data value with a character string that describes the data. For example, you can replace a numeric error code with a description of that error. The replacement character string is called a *match_label.*
- Change the data descriptor used to format the output data. For example, you can design trace points that will record different data at different times, depending on the state of your machine or program. You can then define a set of *match_values* with a different *data_descriptor* for each type of data.

You can specify any number of *match_value* fields for a particular output data value as long as each field is accompanied by a *match_label* and/or a *data_descriptor* field. If the output data value matches *match_value*, the trace formatter uses the *match_label* and/or *data_descriptor* associated with the *match_value.*

You can use the special string * as a *match_value.* This will match any output data value in the current data field. When the trace formatter finds this string, it does not check any *match_values* that occur after this string. Therefore, you should use this string as the last *match_value* in a list to provide a default action if none of the other *match_values* are matched. If no match is found, the data value is written.

If a new *data_descriptor* follows the *match_value*, the trace formatter uses the formats from the new *data_descriptor* until one of the following occurs:

- It has formatted all of the trace entry data.
- It has used all of the defined *data_descriptors* for the current output data.

The trace formatter then looks for a new *data_descriptor* field to define the format for the rest of the data in the trace entry. If a new *data_descriptor* is not found, it writes the data literally according to the format given in the *format* field of the last *data_descriptor.*

Note: The trace formatter compares a *match_value* field and the current output data as two character strings. For real numbers (*F* format), it uses the **printf** subroutine to round the data to four decimal places. If you plan to use a *match_value* field with output data formatted as a real number, the *match_value* field should use the same precision, four decimal places.

Appearance of the Formatted Output Data

The following examples show you how to format data using a single *data_descriptor*. The data is defined as 8 bytes consisting of IBM4341A. The *data_descriptor* fields have the following values:

d_label	PtrNode
format	A8
match_value	IBM4341A
match_label	Model4X

Each of the following examples shows a *data_descriptor* using a combination of *data_descriptor* fields and how the output data would look if it used that *data_descriptor*:

- If you just specify a *format* field, the *data_descriptor* would be:

  ```
  A8:
  ```

  The formatted trace report would show the data as:

  ```
  IBM4341A
  ```

- If you specify *d_label* and *format* fields, but do not specify a *match_value* field, the *data_descriptor* would be:

  ```
  PtrNode A8:
  ```

  The formatted trace report would show the data as:

  ```
  PtrNode=IBM4341A
  ```

- If you specify *format*, *match_value*, and *match_label* fields, but do not specify a *d_label* field, the *data_descriptor* would be:

  ```
  A8, IBM4341A Model4X:
  ```

  The formatted trace report would show the data as:

  ```
  Model4X
  ```

- If you specify *d_label*, *format*, *match_value*, and *match_label* fields, the *data_descriptor* would be:

  ```
  PtrNode A8, IBM4341A Model4X:
  ```

  The formatted trace report would show the data as:

  ```
  Ptrnode=Model4X
  ```

Trace Template Example

This section shows you how a trace entry using a sample trace template would appear after being formatted. In the example, a trace point belonging to the **Printer** event class generated a trace entry during printer initialization. The header data for the trace entry includes the hook ID, which in this example is 330. The trace entry data is listed below:

`PtrNode` The printer node ID (8 ASCII characters). The *format* for this data would be A8.

`PtrType` The printer type (a decimal long integer). The *format* for this data would be D4.

`PtrActv` A 1-bit flag that indicates if the printer is active (1) or inactive (0). The *format* for this data would be B0.1.

Figure 7-6 shows a sample trace template for trace entries with a hook ID of 330. Notice the newline and tab descriptors before the `PtrType` field. This will cause the `PtrType` field to appear on the next line and indented one standard tab unit. Also, notice that two pairs of *match_value* and *match_label* fields are defined for the 1-bit `PtrActv` flag. This tells the trace formatter to write `Yes` if the flag equals `1` and `No` if the flag equals `0`:

```
330 1.0 InitPtr Printer PtrNode A8: \n: \t: \
        PtrType D4: PtrActv B0.1, 1 Yes, 0 No:
```

Figure 7-6. Example of a Trace Template for hook ID 330

Figure 7-7 on page 7-21 shows how a trace entry with a hook ID of 330 might appear in a formatted trace report. In the report, the sample trace entry is the seventh formatted entry. Notice that the last part of the report shows a list of event classes and how many trace entries belong to each event class.

```
                                TRACE LOG REPORT

File: /usr/adm/ras/trcfile

Fri Jan  3 13:19:35 1985
System: ****            Node: ****

Version: 0                      Machine: ****

TIME         SEQ   PID  IODN  IOCN TYPE     HOOK     DATA

23:23:34.01 0001 00195            I/O_Sys  ioctl[x] fildes=5 request=23
        arg=536872136
23:23:34.01 0002 00195            I/O_Sys  ioctl[x] fildes=1 nbyte=28
23:23:34.01 0003 00195            I/O_Sys  write[x] fildes=1 nbyte=40
23:23:34.01 0004 00195            I/O_Sys  write[x] fildes=1 nbyte=31
23:23:34.01 0005 00142            I/O_Sys  write[x] fildes=2 nbyte=1
23:23:34.01 0006 00142            I/O_Sys  write[x] fildes=2 nbyte=2
23:23:34.01 0007 00140           Printer  Initptr  PtrNode=IBM4341
        Ptrtype=3 PtrActv= No
23:23:34.01 0008 00196            I/O_Sys  read[x]  fildes=3 nbyte=128
23:23:34.01 0009 00196            I/O_Sys  access   errno=2 filemode=1
23:23:34.01 0010 00196            I/O_Sys  access   errno=2 filemode=1
23:23:34.01 0011 00196            I/O_Sys  ioctl[x] fildes=0 request=17
        arg=1073737112

Summary of event counts.
Event 0: 2              Event 66: 8
Event 150: 1

Total number of events: 3
```

Figure 7-7. Example of Output from the Trace Formatter

Using the Error Log Facilities

The error log facilities are used to record errors that may occur in the system. These errors can be in hardware or software, and can be of several different types. Some of the basic error terms are defined below:

error entry A data structure containing a header of identifying information plus several bytes of defined data. Error entries are generated by error points and written to an error log file that can be formatted by the error formatter.

error point A group of code statements that generates an error entry from within a software program. Error entries are generated when a software or hardware component encounters an error.

error ID This is part of the data required by an error entry. It is a unique combination of three hexadecimal digits that identifies the component that generated the error entry.

error identifier A three-character code used to identify error templates and to specify which error entries the error formatter should process. This code is based on the error ID; however, it use alphanumeric characters instead of hexadecimal digits.

How you use the error facilities depends on what you want to accomplish:

- To start the error log facilities, you should use the **errdemon** command. You usually will not have to use this command because the default initialization process is set to turn error logging on.
- To stop error logging, you should use the **errstop** command. You must have superuser authority to use this command.
- To format the error log files, you should learn how to use the **errpt** command.
- To change the name or size of the default error log files, you should learn how to alter the **/etc/rasconf** file.
- To create error points that generate error entries, you should learn how to use the error subroutines: **errunix**, **errsave**, and **_errvrm**.
- If you create your own error entries, you should learn how to create an error template for each type of error entry. You also need to learn how to use the **errupdate** command to add error templates to the template file, **/etc/errfmt**.

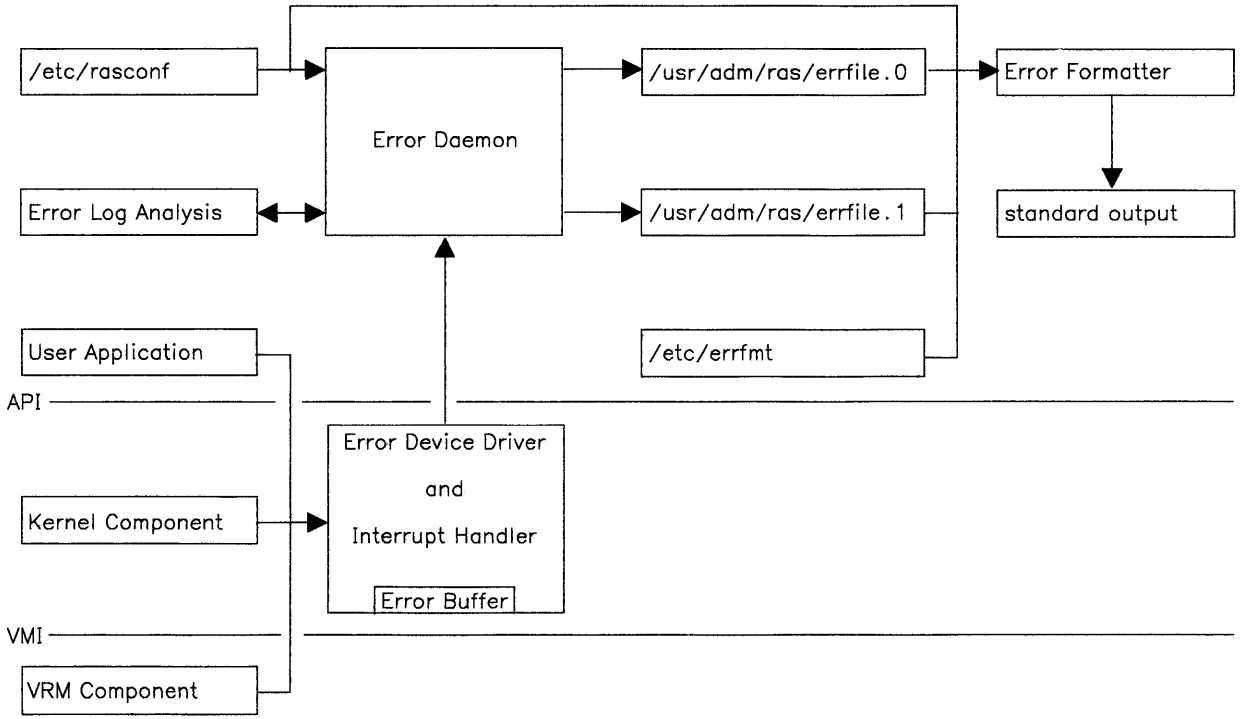


Figure 7-8. Error Components

Figure 7-8 shows how data is passed between the various files and components that constitute the error facilities. The lines labeled API, which stands for Application Program Interface, and VMI, which stands for Virtual Machine Interface, show the logical distinction between application programs, kernel components, and the VRM. The lines connecting the files and components show where data comes from and where it goes.

The components and files in Figure 7-8 are described on the next page. They are explained in more detail elsewhere in this chapter in the appropriate sections.

The descriptions below start at the point where the error entries are first generated and end where the error entries are formatted and sent to standard output.

- Applications, kernel components, and VRM components generate error entries using error points. The system programs contain several pre-defined error points that generate error entries when necessary.
- The error device driver collects the error entries in the error buffer. There is one error buffer that collects error entries from all three error subroutines.
- The **/etc/rasconf** file contains configuration data. For the error daemon, it defines the name and size of the file that the error daemon uses to open two error log files. For the error formatter, it defines the default error log file name if a file name is not specified when it is invoked.
- The error daemon is an important part of the error facilities. When it is initialized, it performs the following major tasks:
  - It opens two error log files by appending the extensions **.0** and **.1** to the file name specified in the error stanza in **/etc/rasconf**.
  - It checks the non-volatile RAM and if there is data, generates an error entry.
- The default error log files are **/usr/adm/ras/errfile.0** and **/usr/adm/ras/errfile.1**. These files are organized as a circular buffer and store all of the error entries generated by the software programs. If one of the error log files becomes full, the next error entry is written into the other file, discarding any entries that may have been in the file.
- The error format file, **/etc/errfmt**, contains error templates that determine how each error entry appears when it is formatted. The pre-defined error entries also have pre-defined templates. If you generate error entries from your own programs, you need to define error templates for those entries.
- The error formatter formats the error entries in the error log files into a readable format. If an error log file is not specified when the error formatter is invoked, it uses the file specified in **/etc/rasconf**. It reads the error files and sends error entries to the error log problem determination program, **errpd**. The **errpd** program analyzes the error entries and returns probable cause information to the error formatter. When **errpd** is finished, the error formatter appends the **errpd** analysis information, if any, onto the error entry and formats the entry. The formatted error entries are sent to standard output and can therefore be sent to the display screen, a file, or a printer.

Altering the Error Log Configuration File

There is one file that you can modify before starting the error daemon. This is the **/etc/rasconf/** file, which is a configuration file that is read by the error daemon and the error formatter. It contains various types of information, but the information you are interested in is the stanza that defines the name and maximum block size of the default error log file. It appears in **/etc/rasconf** in the following form:

```
/dev/error:
    file = /usr/adm/ras/errfile
    size = 50
```

Some other use may change the contents of this file. You may want to change the error log file name if the current error log files are full, or if you want to keep different logs for different types of error entries.

Each time **errdemon** is invoked, the error daemon checks **/etc/rasconf** to see which files it should open to receive error entries. The error daemon does not open the actual file name specified in **/etc/rasconf**. It merely uses the file name as the basis for two other file names with extensions of **.0** and **.1**. The file names with the extensions are the ones that are actually opened. For example, if the error stanza in **/etc/rasconf** is:

```
/dev/error:
    file = /usr/adm/ras/errfile
    size = 50
```

the error daemon will open two files using the names:

```
/usr/adm/ras/errfile.0
/usr/adm/ras/errfile.1
```

All error entries generated while the error daemon is active are directed to these two files. When you use the error formatter, it uses the file name in **/etc/rasconf** as the default error log file if an error log file is not specified. The error formatter adds the **.0** and **.1** extensions to the error log file name to determine the actual names of the two error log files.

Using the Error Log Commands

There are five commands associated with the error log facilities. They each perform one basic task:

errdemon Starts an error session. Once the error daemon is initiated, all error points will generate error entries whenever their error conditions are met. This command is usually placed in the command file **/etc/rc**, which is run when the system is initialized. This command does not require any input parameters.

errstop Stops the error daemon. Any error entries remaining in the error buffer are written out to the error log file. Any open files are closed and the error daemon is terminated. This command does not require any input parameters. Note that it is not necessary to stop the error daemon in order to format the error log files.

errpt Formats error entries contained in error log files. This command accepts one or more error log file names as input parameters. If you do not specify an error log file, it uses the default error log file specified in **/etc/rasconf**. The formatted error entries are sent to standard output.

The following example formats two error log files named **myerr.0** and **myerr.1** and sends the output to the printer. Notice that you use the file name **myerr** as input. The error formatter automatically appends the extensions and looks for those files, not the file named in the command:

```
errpt myerr | print
```

There are several options available to format subsets of the entire error log. See the description of the **errpt** command in *AIX Operating System Commands Reference.*

errupdate Adds, updates, or deletes error templates in the **/etc/errfmt** file. Before using this command to add or update error templates, you need to create an input file with the extension `.err`. This file will contain two types of entries:

- Template definitions. These contain a + in the first column to specify that the template is to be merged into the master template file. A single template definition may require several lines. The + is only required on the first line of each template.
- Template deletions. These contain a - (minus sign) in the first column, one blank, and the error identifier of the template you want to delete.

  Note: Do not delete the pre-defined error templates. The only templates that you should consider deleting are those that are user-defined. User-defined error templates have an error identifier beginning with **U** or **HF**.

The following example shows a file that will add error template U13 to the master template file and delete templates U11 and U12. Note that the first line in the file must be entered as shown. It is used by the **errupdate** command to verify that this file contains template information.

```
* /etc/errfmt
+ U13 Serial/Parallel Adapter: \n: \
      ErrorType A1: -n: LastI/O X1: \
      LineStatus D4: PrinterStatus B0.1:
- U11
- U12
```

To update an error template, you need to create a new template with the same error identifier but with a version and release number (*VV.RR* field) greater than the version and release number of the error template that you want to update. When **errupdate** merges the `.err` file into the master template file, it will replace the old template with the updated one.

Once you have created a file containing new or updated template definitions and/or template deletions, you can use **errupdate** to process it. In the following example, the template definitions and deletions are contained in a file called **newtemps.err**:

```
errupdate  newtemps
```

errdead

Extracts hardware error information from memory or from a dump file. This is used if the error daemon was not running or did not have a chance to log the error before a system failure. To use this command, invoke **errdead** with the name of a file containing dump information:

```
errdead mydump
```

Using the Error Log Subroutines

To use the error log subroutines, you need to understand the relationship between error IDs and error identifiers. You also need to know how to identify the type of an error.

Error IDs are 3 bytes long, and are created using hexadecimal digits. When you use the error log subroutines, you must specify the error ID of the program that generates the error entry. The pre-defined error IDs can range from 0x010000 to 0x050F0F. User-defined error IDs can range from 0x060000 to 0x060F0F. There is a special set of user-defined error IDs for hardware error entries. These error IDs can range from 0x010F00 to 0x010F0F. Note that the second and third bytes cannot use values greater than 0x0F for any error ID.

The error ID is used to categorize the error entries into appropriate groupings. The first digit is the ***class***; the second is the ***subclass***, and the third is the ***mask***. The digits are hierarchical in that a class consists of zero or more subclasses and a subclass consists of zero or more masks.

The class digits range from 0x01 to 0x06. Each value represents a general category of errors. The categories are assigned as follows:

- 0x01 — Hardware
- 0x02 — Software
- 0x03 — IPL/Shutdown
- 0x04 — General System Condition
- 0x05 — Not Available
- 0x06 — User-Defined.

The subclass and mask digits range from 0x00 to 0x0F. They are used to further subdivide the category represented by the class digit. Classes 0x01 through 0x05 may have pre-defined subclasses and masks. Class 0x06 has no pre-defined subclasses or masks because it is user-defined.

When you format a file containing error entries, you have the option of specifying which class of errors should be formatted. You can also specify the subclass within the class and the mask within the subclass. Note that when you format error entries, you do not use the error ID. Instead, you use an ***error identifier***. Error identifiers are similar to error IDs, except they consist of characters instead of hexadecimal digits and an alphabetic letter is used to specify the class instead of a digit. The letter is the first letter of the first word describing the class.

For example, if the error ID of an error entry is 0x010102, the error entry is in the **Hardware** class. The error identifier for this type of error entry would be H12. An error entry in the **Software** class might have an error ID of 0x020303. The error identifier would be S33. Thus, An error entry in the **User-defined** class would have an error identifier that began with the letter U.

Note: You should avoid defining error IDs that have a subclass or mask value of 0x00. This is because the error formatter uses the character 0 as a pattern-matching character. For example, to format all hardware error entries, regardless of subclass or mask, you

would specify H00 when you invoke the **errpt** command. The use of 0 within an error ID limits your selection options when you format the error entries.

When you design a program, you must decide what constitutes an error condition and what actions should take place if an error does occur. You decide in advance what the error ID will be for any error entries generated by a specific component. You must also specify the ***type*** of error entry that is being generated. There are several pre-defined types of error entries. Your component must contain an algorithm for deciding which type of error has occurred. Once the type is identified, it is used as input data to the error log subroutines.

The types of error entries are defined as follows:

1 — Permanent
These are errors that are severe enough to prevent successful completion of an operation.

2 — Temporary
These are errors that require an operation to be retried a defined number of times before being successfully completed.

3 — Information
These are not necessarily errors. A component may generate an error entry of this type if an unusual condition occurs.

4 — Counters
These error entries are generated by device driver components. Certain device drivers are able to generate retries if an operation is not successful on the first attempt. They use counters to monitor the number and cause of retries and contain algorithms that decide when these counters should be sent to the error log.

5 — Abbreviated Error Entries
If the system fails before storing an error entry in the error log, it writes an abbreviated entry into non-volatile storage. When the system is started following such a failure, it writes this abbreviated entry into the error log.

6 — Expert Analysis Appended.
These error entries contain information from the Error Log Analysis routine.

The data in an error entry is entirely dependent on the component generating the error entry. There is no defined limit on the size of an error entry. How you organize the information required to generate an error entry depends on which error log subroutine you use. Both **errunix** and **errsave** use an integer length field. This field specifies the length plus one (in words) of the error entry data. They are briefly defined below:

errunix Generates an error entry from an AIX Operating System application and requires two input parameters. The first is the address of a buffer containing the 3-byte error ID, the 1-byte type number, an integer length field, and the error data for the error entry. The second is the length of the buffer.

errsave Generates an error entry from an AIX Operating System kernel component and requires two input parameters. The first is the address of a buffer containing the 3-byte error ID, the 1-byte type number, an integer length field, and the error data for the error entry. The second is the length of the buffer.

_errvrm Generates an error entry from a VRM component and requires one input parameter. See the definition of the **_errvrm** subroutine for information on creating error entries within VRM components.

A sample error point for application level components is shown in Figure 7-9. Notice how the input data structure used by the error log subroutine is organized and how the required data is placed in it. Also, the error ID for the trace entry is 0x060104. Thus, the error template used to format the error entry would use an error identifier of U14.

```
#include <sys/erec.h>

main(argc, argv)
   int argc;
   char **argv;
{
   extern int errunix();
   int error=0;
   struct error_struct   /* this is an input parameter for errunix */
   { union
      { struct
         {
            char e_class;
            char e_subclass;
            char e_mask;
            char e_type;
         } e_csmt;
         int csmt;
      } e_id;
      int e_len;        /* length + 1 of error entry data in words */
      char e_data[40];
   } error_data;

   #define CLASS     error_data.e_id.e_class
   #define SUBCLASS  error_data.e_id.e_subclass
   #define MASK      error_data.e_id.e_mask
   #define TYPE      error_data.e_id.e_type
```

Figure 7-9 (Part 1 of 2). Example of a Program Fragment Showing Use of errunix Subroutine.

```
   /* Check for errors and increment error flag if an error is found. */

   if (error_check() < 0)           /*  User-defined function */ /
     error++;

   /* if the error flag is positive, generate an error entry. */

   if (error)
   {
      CLASS    = E_USER;   /* E_USER is predefined as 0x06. */
      SUBCLASS = 0x01;
      MASK     = 0x04;
      TYPE     = E_TMP;    /* E_TMP is pre-defined as 0x40 */

      /* Collect the error data and put it in error_data.e_data */

      fill_in(error_data.e_data);   /*  User-defined function */ /

      /* Perform the subroutine call */

      if (errunix(&error_data, sizeof(struct error_struct) ) < 0)
      {
         fprintf(%s: Cannot log error. errunix failed.-n", argv[0]);
         exit(-1);
      }
   }
   .
   .
   .
}   /* end main */
```

Figure 7-9 (Part 2 of 2). Example of a Program Fragment Showing Use of errunix Subroutine.

Figure 7-10 creates an error entry from within an AIX Operating System kernel component. Note that the user-defined subroutine **fill_in** must define the error ID and error data. The method is similar to that used in Figure 7-9 on page 7-31; therefore, it is not repeated for this example:

```
#include <sys/erec.h>

main(argc,argv)
    int argc;
    char **argv;
{
   struct errinfo *errptr;

   if (error)

   /* collect error data and call errsave */
   {
      fill_in(errptr);   /* User-defined subroutine)
      errsave(errptr, sizeof(struct errinfo));
   }
}   /* end main */
```

Figure 7-10. Example of a Program Fragment Showing Use of errsave Subroutine.

Creating Error Templates

The error formatter uses ***error templates*** to determine how the data contained in error entries should be formatted. All error templates are stored in the master template file, **/etc/errfmt**. After you create some new or updated error templates, place them in a file that can then be merged into the master template file using the **errupdate** command.

Error templates contain three required fields and zero or more data description fields. The required fields consist of the error identifier, the version and release number, and the error label. The data description fields contain formatting information for the error entry data and can be repeated as many times as is necessary to format all of the error data in the error entry.

Error entries are formatted and written to standard output one entry at a time. For each entry, the error formatter performs the following operations:

1. Locates the error template whose error identifier corresponds to the error ID in the error entry. If the error entry has an error ID of 0x010201, the corresponding error template would have an error identifier of H21.
2. Writes the time the entry was generated. This field is placed in the error entry header by the error subroutine.
3. Writes the PID, IODN, and IOCN contained in the error entry header. These fields are placed in the error entry header by the error subroutine.
4. Writes the error label contained in the format template. You can use the actual error identifier, or you can create a name up to 8 characters. The error formatter will write whatever is placed in the field.
5. Writes the error data according to the *data_descriptors* in the error template, if any are present. Any data that occurs after the last *data_descriptor* in the template is ignored. A *data_descriptor* does the following:
   a. Writes the data label (*d_label*), if it is specified.
   b. Writes the actual data according to the *format* field and the optional match fields. You can define match fields that will replace data values with descriptive labels or change to a different *data_descriptor* depending on the current data value.

Figure 7-11 on page 7-35 shows the syntax used to define an error template. Figure 7-12 on page 7-36 defines each of the fields in an error template.

Error template lines can be as long as you need. You can continue an error template on another line by adding the \ (backslash) character to the end of the line where the split occurs. Note that \ is not a substitute for a required blank. A blank is also required after a colon or comma.

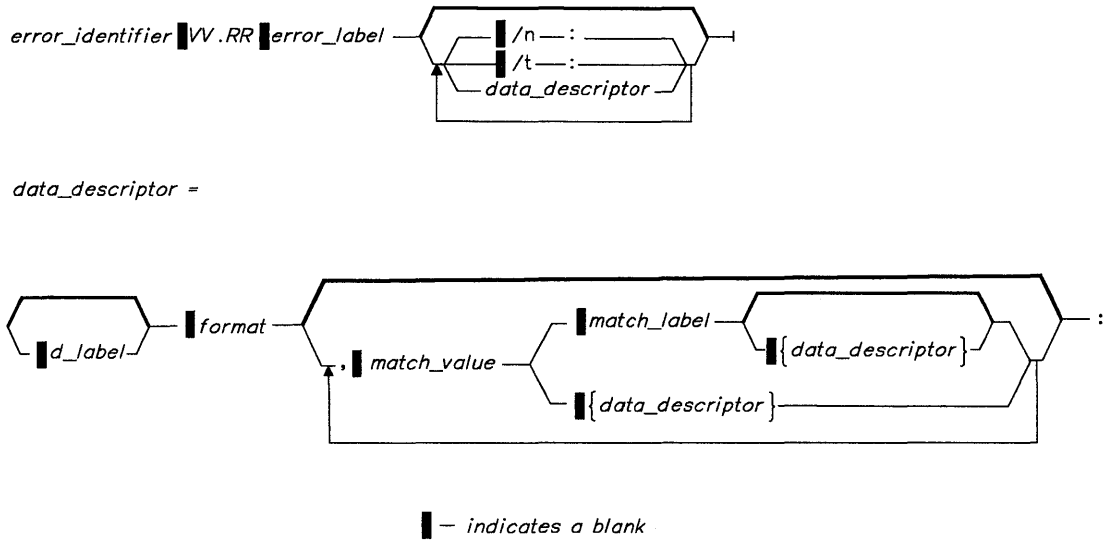


Figure 7-11. Error Template Syntax

Field	Description
error_identifier	The 3-character error identifier of this template.
VV.RR	A number representing the version and release level of this template.
error_label	A field of up to 14 characters that describes the error entries that use this template. This appears in the summary header list under the `Subclass` heading.
\n	A special string used to start output data a new line.
\t	A special string used to start output data after one tab unit.
d_label	A field of characters that describes the error entry data.
format	An alphanumeric code that defines the format of the error data.

Code	Format of Data
A*m*	ASCII string of *m* characters.
B*m*	Binary string of *m* bytes.
B*m.n*	Binary string of *m* bytes and *n* bits. If this format leaves some unformatted bits in the current byte, they are not written unless this format is followed by another format that specifies bits.
D2	Decimal short integer.
D4	Decimal long integer.
F4	Floating-point number of type *float*, rounded to four places.
F8	Floating-point number of type *double*, rounded to four places.
O*m*	Omit (do not write) the next *m* bytes.
O*m.n*	Omit (do not write) the next *m* bytes and *n* bits. If this format leaves some unformatted bits in the current byte, they are not written unless this format is followed by another format that specifies bits.
U2	Unsigned decimal short integer.
U4	Unsigned decimal long integer.
X*m*	Hexadecimal number of *m* bytes.

match_value	A value with a data type the same as the *format* field. If you specify a *match_value*, you must also specify a *match_label* or *data_descriptor*.
match_label	A character field up to 120 characters that replaces output data that matches a *match_value* field.
data_descriptor	A field containing formatting information for a portion of the output data.

Figure 7-12. Fields in an Error Template

Replacing Values in the Output Data

The *match_value* field provides a function that is similar to a switch statement in programming. You can use this function to do either or both of the following:

- Replace an output data value with a character string that describes the data. For example, you can replace a numeric error code with a description of that error. The replacement character string is called a *match_label.*
- Change the data descriptor used to format the output data. For example, you can design error points that will record different data at different times, depending on the state of your machine or program. You can then define a set of *match_values* with a different *data_descriptor* for each type of data.

You can specify any number of *match_value* fields for a particular output data value as long as each field is accompanied by a *match_label* and/or a *data_descriptor* field. If the output data value matches *match_value*, the error formatter uses the *match_label* and/or *data_descriptor* associated with the *match_value.*

You can use the special string * as a *match_value.* This will match any output data value in the current data field. When the error formatter finds this string, it does not check any *match_values* that occur after this string. Therefore, you should use this string as the last *match_value* in a list to provide a default action if none of the other *match_values* are matched.

If a new *data_descriptor* follows the *match_value*, the error formatter uses the formats from the new *data_descriptor* until one of the following occurs:

- It has formatted all of the error entry data.
- It has used all of the defined *data_descriptors* for the current output data.

The error formatter then looks for a new *data_descriptor* field to define the format for the rest of the data in the error entry. If a new *data_descriptor* is not found, it writes the data literally according to the format given in the *format* field of the last *data_descriptor.*

Note: The error formatter compares a *match_value* field and the current output data as two character strings. For real numbers (*F* format), it uses the **printf** subroutine to round the data to four decimal places. If you plan to use a *match_value* field with output data formatted as a real number, the *match_value* field should use the same precision, four decimal places.

Appearance of the Formatted Output Data

The following examples show you how to format data using a single *data_descriptor*. The data is defined as 8 bytes consisting of IBM4341A. The *data_descriptor* fields have the following values:

d_label	PtrNode
format	A8
match_value	IBM4341A
match_label	Model4X

Each of the following examples shows a *data_descriptor* using a combination of *data_descriptor* fields and how the output data would look if it used that *data_descriptor*:

- If you just specify a *format* field, the *data_descriptor* would be:

  ```
  A8:
  ```

  The formatted error report would show the data as:

  ```
  IBM4341A
  ```

- If you specify *d_label* and *format* fields, but do not specify a *match_value* field, the *data_descriptor* would be:

  ```
  PtrNode A8:
  ```

  The formatted error report would show the data as:

  ```
  PtrNode=IBM4341A
  ```

- If you specify *format*, *match_value*, and *match_label* fields, but do not specify a *d_label* field, the *data_descriptor* would be:

  ```
  A8, IBM4341A Model4X:
  ```

  The formatted error report would show the data as:

  ```
  Model4X
  ```

- If you specify *d_label*, *format*, *match_value*, and *match_label* fields, the *data_descriptor* would be:

  ```
  PtrNode A8, IBM4341A Model4X:
  ```

  The formatted error report would show the data as:

  ```
  Ptrnode=Model4X
  ```

Error Template Example

This section shows you how an error entry using a sample error template would appear after being formatted. In the example, a hardware error entry was generated for the Serial/Parallel Adapter. The header data for the error entry includes the error ID, which in this example is 0x060103. Thus, the error identifier in the template is U13. The error entry data is listed below:

`ErrorType` The type of error encountered (1 ASCII character). The *format* for this data would be A1.

`LastI/O` The last character transmitted (1 hexadecimal digit). The *format* for this data would be X1.

`LineStatus` The status of the printer (1 decimal word). The *format* for this data would be D4.

`PrinterStatus`
A 1-bit flag that indicates if the printer is active (1) or inactive (0). The *format* for this data would be B0.1.

Figure 7-13 shows a sample error template for error entries with an error ID of 0x060103. Notice the newline descriptor on the first line of the template. This will cause the data to start on a new line.

```
U13 Ser/Par: \n: \
    ErrorType A1: \n: Last_I/O X1: LineStatus D4: PrinterStatus \
    B0.1:
```

Figure 7-13. Example of an Error Template for Error Entries with Error ID 613

Figure 7-14 on page 7-40 shows how an error entry using the template U13 would appear in a formatted error report. The first entry is from a different error. The second entry is the one that uses template U13.

```
                                ERROR LOG REPORT

Error log: /usr/adm/ras/errfile

---------------------------------------------------------------------------
Date/Time            Class          Subclass        Type      Device  Cause
Thu May  9 16:54:42  Hardware       Diskette Adptr  Counters  DSKT    Hardware
        IODN=4  IOCN=576
        Base Port Addr=1010
        Dev Name=DSKT
        Internal Dev Type=D1015200
Counter_Type=00000000000000000000000000010000
Bad_Count=512
Good_Count=3506438155
Bad_Threshold=61624
Ratio=5

---------------------------------------------------------------------------
Date/Time            Class          Subclass        Type      Device  Cause
Thu May  9 16:54:45  Hardware       Ser/Par         Perm      Ser/Par Hardware
        IODN=7  IOCN=600
        Base Port Addr=0278
        Dev Name=Ser/Par
        Internal Dev Type=91002300
ErrorType=3
Last_I/O=44 LineStatus=0 PrinterStatus=0


===========================================================================
```

Figure 7-14. Example Output from the Error Formatter

Using the Dump Facilities

The dump facilities allow you to dump VRM data onto a dump diskette in the event of a system failure at the VRM level. Some of the basic terms are defined below:

dump data The data collected by the dump program. It is obtained from memory locations used by VRM components.

dump diskette
The diskette used to store the dump data. This must be a formatted, high-capacity diskette and it must be placed in diskette drive A before the dump is started. A dump operation is limited to the storage capacity of a single dump diskette.

component dump table
A structure used by VRM components to identify data structures that should be collected by the dump program. Each record in a component dump table identifies the name, length and location of a specific data structure.

dump table entry
A record in the master dump table that identifies the location of a component dump table. All VRM components that need to have special data collected by the dump program need to generate a dump table entry. Each entry contains the component ID, length, and location of a component dump table.

master dump table
A structure containing dump table entries generated by VRM components. The dump program uses this table to locate data structures that should be included in a dump.

How you use the dump facilities depends on what you want to accomplish:

- To start a dump operation, you should learn how to use the dump key sequence.
- To format the contents of a dump diskette or dump file, you should learn how to use the **dumpfmt** command.
- To create dump table entries in the master dump table, you should learn how to use the **_dmptbl** subroutine. All of the guide information for this subroutine is contained in *Virtual Resource Manager Technical Reference.*

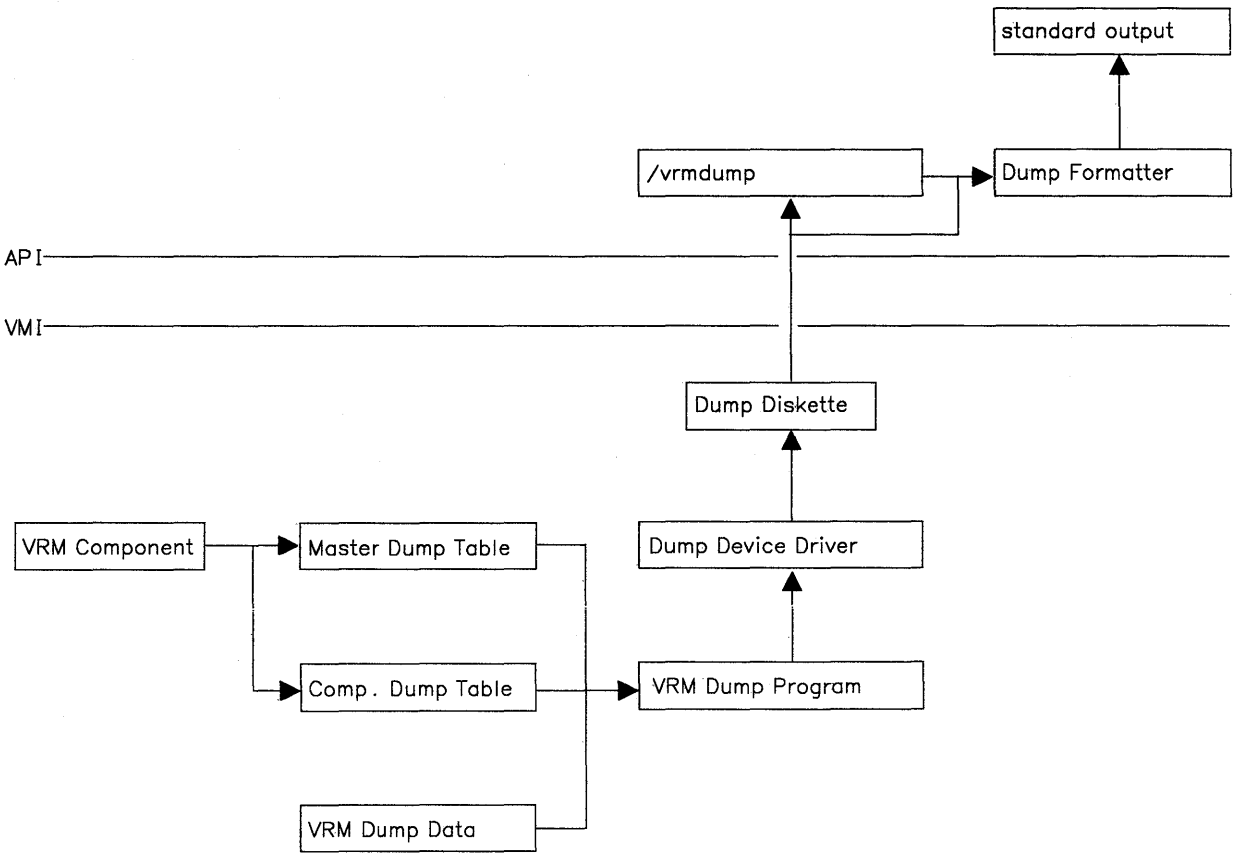


Figure 7-15. Dump Components

Figure 7-15 shows how data is passed between the various files and components that constitute the dump facilities. The lines labeled API, which stands for Application Program Interface, and VMI, which stands for Virtual Machine Interface, show the logical distinction between application programs, kernel components, and the VRM. The lines connecting the files and components show where data comes from and where it goes to.

The components and files in Figure 7-15 are described on the next page. They are explained in more detail elsewhere in this chapter in the appropriate sections.

The descriptions below start with the input to the dump program and end where the dump diskette or file is formatted and sent to standard output.

- VRM components generate master dump table entries using the **_dmptbl** subroutine. Only VRM programs are supported by this subroutine.
- The master dump table contains dump table entries that identify the component ID, length, and location of component dump tables. Your only interaction with the master dump table is through the **_dmptbl** subroutine.
- Component dump tables are created and maintained by individual VRM components. Each component dump table contains a list of entries that specify the name, length, and location of data structures that should be included in the dump. There is a 4-byte length field at the beginning of each component dump table. This field contains the overall length of the component dump table. Each entry in the table is 20 bytes long. Thus, a component dump table with two entries would be 44 bytes long.
- The VRM dump data is pre-defined and consists of various types of VRM data. This includes tables, control blocks, queue areas, error and trace buffers, virtual machine information, registers, and other data structures. You may not be able to understand all of this data. It is used by IBM to determine the cause of a system failure.
- The VRM dump program collects the VRM dump data plus any data specified in component dump tables and writes it onto a dump diskette. This program is always resident in memory and is invoked through the dump key sequence or by a routine below the VMI executing a signal error.

  When VRM dump is initiated, it sets the two-digit display on the system unit to **c6** to indicate that it wants to perform a dump. You can cancel the dump, or insert a dump diskette and press the dump key sequence that begins the dump operation.
- The dump device driver is used only by the dump program to write to the dump diskette. This device driver allows the dump program to operate without the use of any VRM device drivers. The VRM dump program is independent of any VRM resources.

  Because the dump data is written in dump/restore format, you can use the **restore** command to write the diskette data onto a file in the current directory. The file name of a restored dump data file is always *vrmdump.*, but you can rename it if you wish.
- The dump formatter formats the data from the dump diskette or from a specified file into a readable format. If a file is not specified, it looks for the information in **/dev/fd0**, which is where the dump diskette should be. The formatted dump data is sent to standard output and can therefore be sent to the display screen, a file, or a printer.

Using the Dump Commands

There are only two dump commands. The first command is the key sequence that is used to start the dump program. You use this sequence when your system fails and c6 is displayed on the two-digit display on the system unit. The dump procedure is fully discussed in the *Problem Determination Guide*. The following steps outline the dump procedure:

1. Insert a formatted diskette into diskette drive A:. The diskette can have AIX Operating System or DOS format.
2. Press **Ctrl-Alt-Num8**. c9 is displayed on the two-digit display to indicate that the dump program has started.

The dump program runs until it completes the dump or encounters an error condition. The two-digit display shows the result of the dump upon termination. The possible two-digit display values are:

0 — Dump Successfully Completed
2 — Dump Diskette Full
3 — Dump Suspended Due to Recursive Call
4 — Dump Abended.

Before you can use the second command, **dumpfmt**, you have to get the system back in working order. Once you get the system restarted, you can use **dumpfmt** to format the dump data and send it to standard output.

The **dumpfmt** command invokes the dump formatter, which can be used in batch mode or interactive mode. In batch mode, all of the dump data appears in the report. In interactive mode, you select the data you want to format from a menu of options. If you do not specify batch mode using the **-a** flag, the formatter automatically comes up in interactive mode.

Example of the Dump Formatter Output

Figure 7-16 on page 7-45 shows how part of a dump diskette or dump file might appear after being formatted. It displays data in hexadecimal format with ASCII interpretation at the right. Non-printing hexadecimal values are shown as a period. Notice how each set of dump data structures has a different title. A name title (GP Register) indicates that the data is part of the standard VRM dump data. A number title (126) indicates that the data is obtained from a component dump table.

Note: The dump report shown in Figure 7-16 does not show all of the pre-defined VRM dump data. The dump program collects all of the pre-defined VRM dump data before it begins collecting the component dump table data. If you use the dump formatter in interactive mode, you can select which types of dump data you wish to format.

```
Tue Jan 03 12:00:00 1985

Failing Component: ""

Module Start Address: "00000000"

Module Offset Address: "00000000"

                    GP Register  Starting Address : "C0028C40"

 reg#_13
C0028C40   DD2E0040 69F0CC6B 04001920 00000BA0     | ...@ i..k .... ....|
C0028C50   0002CED8 F0000000 00028C20 0000B3E0     | .... .... .... ....|
C0028C60   701B0203 65100008 659ABE50 630D3013     | p... e... e..P c...|
C0028C70   71BBE2BA 31B3D402 000292A8 00008B54     | q... .... .... ...T|
C0028C80   BE526DD2 300DDD9E 0040001C 6400E549     | .Rm. .... .@.. d..I|
C0028C90   64349141 6840E289 6910E298 B49A091B     | d..A h@.. i... ....|
C0028CA0   E29A0204 E21A311B 000B63A9 E213311B     | .... .... ..c. ....|
C0028CB0   62A4BE52 703B6DD2 303D319D 302BDD4E     | b..R p;m. .=.. ...N|
C0028CC0   004031F7 8DFFB87A 62656500 302BDD4E     | .@.. ...z bee. ....|
    .
    .
    .
                    126  Starting Address : "0"

 Header
00000000   54686973 64617461 63616D65 66726F6D     | This data came from|
00000010   636F6D70 6F6E656E 74206475 6D702074     | comp onen t.du mp.t|
00000020   61626C65 77697468 20494420 20313236     | able with .ID. .126|
00000030   701B0203 65100008 659ABE50 630D3013     | p... e... e..P c...|
00000040   BE526DD2 300DDD9E 0040001C 6400E549     | .Rm. .... .@.. d..I|
00000050   71BBE2BA 31B3D402 000292A8 00008B54     | q... .... .... ...T|
```

Figure 7-16. Example of Output from the Dump Formatter

Chapter 8. Debugging Programs

CONTENTS

About This Chapter

This chapter explains how to use the **sdb** program to help locate and fix program logic problems (***bugs***). It shows how to use the **sdb** commands and discusses the idea of a controlled program testing environment. At the end of the chapter is an example of an **sdb** session.

Overview

The **sdb** program performs three functions:

- Examines core images of programs that did not end properly.
- Displays and manipulates sections of source text.
- Controls and monitors the execution of programs.

The **sdb** commands that perform these functions are usually a single letter or character.

Refer to *AIX Operating System Commands Reference* for complete reference information about the **sdb** program.

Features

Using **sdb**, you can:

- Debug programs at either the source language or assembler language level.
- Issue commands from either standard input or a named file.
- Access variables, including arrays and structure elements, symbolically and display them in the correct format.
- Display or modify the contents of machine registers.
- Examine the source text using simple search and scrolling functions.
- Set breakpoints at selected statements.
- Run a program one line at a time.
- Call program or diagnostic procedures directly from the debugger.

sdb Command Summary

Start/Stop sdb

sdb <*filename*>
: Starts **sdb** using file <*filename*>

e <*name*>
: Uses the file or procedure indicated by <*name*>

e
: Displays the name of the current file and current procedure

q
: Quits sdb

Setting Breakpoints

[*procedure*][*line number*]**b**
: Sets a breakpoint at *line number* in *procedure*.

B
: Displays a list of all breakpoints that are set.

[*procedure*][*line number*]**d**
: Removes a breakpoint at *line number* in *procedure*.

D
: Removes all breakpoints.

[*variable*]**$m**[*count*]
: Runs current procedure one line at a time until *variable* changes or *count* number of lines are run.

[*address*]**:m**[*count*]
: Runs current procedure one line at a time until *address* changes or *count* number of lines are run.

Setting Trace Options

[*procedure*]**a**
: Displays procedure name and its arguments each time it is called.

[*procedure*][*line number*]**a**
: Displays source line *line number* each time it is executed.

t
: Traces procedure calls.

Running the Program from sdb

r *args*
: Runs the current procedure using *args* as the starting parameters.

r
: Runs the current procedure using the same starting parameters as the last time the procedure ran.

R
: Runs the current procedure with no starting parameters.

[*procedure***][***line number***]c**
: Continues running a stopped program.

[*procedure***][***line number***]C**
: Continues running a stopped program - passes signal that stopped program back to program (test signal handler).

[*line number***]g**
: Starts running the program at *line number* in the current procedure.

k
: Stops the program being debugged.

Single Stepping

[*level***]v**
: Sets level of information displayed during single step mode.

s
: Runs a single line of source code.

S
: Runs a single line of source code, but does not stop during execution of called procedures.

i
: Runs a single assembler instruction rather than source line - ignores signals that stop the program.

I
: Runs a single assembler instruction rather than source line - passes signals that stop the program to the program.

Displaying Information

variable/
: Displays value of *variable.*

[*procedure*]:[*line number*]?
: Displays assembler language statements associated with *line number.*

[*address*]:?
: Displays assembler language statement associated with *address* in text space.

x
: Displays the values of all registers and the process status word.

X
: Displays the value of IAR and the assembler language instruction at that location.

variable=
: Displays address of *variable.*

p
: Displays current line.

w
: Displays 10 lines around the current line.

z
: Displays 10 lines starting at the current line. Changes current line to current line + 10.

ctrl-d
: Displays the next 10 lines of instructions, source code or data.

Changing Values of Program Variables

variable!*value*
: Assigns new *value* to *variable.*

Changing Position in the File

n
: Sets current line to *n*.

Enter key
: Moves current line forward 1 line.

+[*n***]**
: Moves current line forward *n* lines (1 line if no *n*).

-[*n***]**
: Moves current line backward *n* lines (1 line if no *n*).

/string
: Searches forward for *string*.

?*string*
: Searches backward for *string*.

Reference Metacharacters

*****
: Matches any sequence of characters.

?
: Matches any single character.

.
: Refers to the last referenced variable.

Using the Program

To use **sdb** with a program, compile the source program with the **-g** flag. The compiler generates additional information about the variables and statements of the compiled program.

The following rules apply to the use of the **-g** flag:

- The **sdb** program displays an error message if used on a main program compiled without the **-g** flag.
- Use **sdb** for any procedures compiled with the **-g** flag, even if the main program was compiled without the **-g** flag.
- If an error occurs in a procedure compiled without the **-g** flag, **sdb** displays only the procedure name and the address at which the error occurred.

The following example shows the generation of an executable program called `samp`. When the program runs, it produces a ***bus error*** and stops. The commands that follow the error message show how to start and end the **sdb** program:

```
$ cc -g samp.c -o samp
$ samp
Bus error - core dumped
$ sdb samp
main:25:    x[i] = 0;
*q
$
```

In the example, the program `samp` has an error which causes a core dump. When **sdb** starts, it reports that the bus error occurred in procedure `main` at line 25 (line numbers are always relative to the beginning of the file) and then displays line 25. The * indicates that **sdb** is waiting for an **sdb** command. The **q** command then exits the **sdb** program.

In the above example, **sdb** is called with one argument, `samp`. The **sdb** program can have up to three arguments on the command line:

- The name of the executable file to be debugged. Without a file name, **sdb** uses **a.out**.
- The name of the core file. Without a file name, **sdb** uses **core**.
- The name of the directory containing the program source. The **sdb** program requires all source to reside in a single directory. Without a file name, **sdb** uses the current directory.

In the example, the second and third arguments used the correct values, so only the first was specified.

You can redirect standard input or output while in **sdb**. Therefore, **sdb** command input can come from a file and output can be sent to another file or even the printer. Redirect input and output with the < and > commands. When redirecting standard input, all **sdb** commands come from a named file until the end of the file is reached. The input then reverts back to the keyboard. This command cannot be nested. The following example redirects input to come from a file of **sdb** commands called `sdbbatch`:

```
*< sdbbatch      # input now comes from sdbbatch
```

Displaying a Stack Trace

To get a listing of the procedure calls that led to an error, use the `t` command. In the following example, the executable file `samp.c` contains the standard procedure `main` and two additional procedures called `last` and `middle`:

```
*t
last(x=2,y=3)       [samp.c:25]
middle(i=16012)       [samp.c:96]
main(argc=1,argv=0x7fffff54,envp=0x7fffff5c)      [samp.c:15]
```

The stack trace shows the calls in reverse order. Starting at the bottom, the following events occurred:

1. **shell** called `main` with three arguments referred to as `argc`, `argv` and `envp`. Note that `argv` and `envp` are pointers, so their values are written in hexadecimal.
2. `main` called `middle` at line 15 with the value `i=16012`.
3. `middle` called `last` at line 96 with the values `x=2, y=3`.
4. `last` contained an error at line 25.

Refer to *Assembler Language Reference* for a description of how the system calling conventions operate.

Examining Variables

To display the value of a variable, type the variable name followed by a slash:

```
*countvar/      # display the value of countvar
```

Unless otherwise specified, variables are assumed to be either local to or useable by the current procedure. To specify a different procedure, use the form:

```
procedure:variable/
```

The **sdb** program supports a limited form of pattern matching for variable and procedure names. The symbol * is used to match any sequence of characters of a variable name and ? to match any single character. Consider the following commands:

```
*x*/
*procwild:y?/
**/
```

The first writes the values of all variables beginning with x, the second writes the values of all two letter variables in procedure procwild beginning with y, and the third writes all variables. In the first and third examples, only variables useable by the current procedure are written.

The following command displays the variables for each procedure on the call stack:

```
**:*/
```

To reference a particular instance of a variable on the stack, use the form:

```
procedure:variable,number
```

For example, the following command displays the value of the variable y in the call to procwild closest to the top of the stack:

```
*procwild:y,1/
```

To match only global variables, use the form:

```
:variable
```

The **sdb** program usually displays variables in a format determined by their type as declared in the source program. To request a different format, use the form:

```
variable/[count][length][format]
```

Without a *format* parameter, **sdb** uses decimal notation.

This command is explained in detail in the reference information for **sdb** (see *AIX Operating System Commands Reference*).

For example, the variable `i` can be displayed in hexadecimal with:

```
*i/x
```

To specify `i` in short form in hexadecimal, use the *length* specifier `h`, along with the *format* specifier `x`:

```
*i/hx
```

Memory locations can also be displayed by specifying their absolute addresses. The following command displays location 1024 in decimal:

```
*1024/
```

Because numbers can be specified in octal or hexadecimal, the following two commands also display location 1024 in decimal:

```
*02000/
*0x400/
```

You can also mix numbers and variables. The next example refers to an element of a structure starting at address 1000:

```
*1000.x/
```

The following example refers to a structure element whose address is at location 1000:

```
*1000->x/
```

For commands of the type `*1000.x/` and `*1000->x/`, **sdb** uses the format of the last structure referenced.

The address of a variable is displayed with the = command:

```
*i=
```

The dot command redisplays the last referenced variable:

```
*./
```

Referencing Arrays, Pointers, and Structures

The **sdb** program also works with arrays, pointers, and structures, such as:

```
*array[2][3]/
*sym.id/
*psym->usage/
*xsym[20].p->usage/
```

The only restriction is that array subscripts must be numbers. Note that as a special case:

```
*psym->/d
```

displays the location pointed to by `psym` in decimal.

Elements of a multi-dimensional array may be referenced as variable[number][number]..., or as variable[number,number...]. *Number* can be one of the following:

number;*number* Indicates a range of values.

***** Indicates all legal values for that subscript.

omitted Does not use a *number* parameter to display the full range of values if the number is the last subscript.

As with structures, **sdb** normally displays all the values of an array or of the section of an array if trailing subscripts are omitted. When the = command is applied to an array, **sdb** displays only the address of the array itself or of the section specified by the user if subscripts are omitted. The following are all valid references to the two-dimensional array a[5][6]:

```
*a/
*a[2;5][4]/
*a[3]/
*a[3,4]/
*a[*][3]/
```

Displaying and Manipulating the Source File

The **sdb** program allows you to search through and display portions of the source files for a program. You do not need a current source listing. The **sdb** program keeps track of the current file, current procedure and current line. If the core file exists, the current line and current file are initially set to the line and file containing the source statement where the process ended. Otherwise, they are initially set to the first line in `main`. While manipulating the source file, the values for current line and current procedure may change.

Displaying the Current File

Four commands exist for displaying lines in the current file:

p	*Print* displays the current line.
w	*Window* displays a window of 10 lines around the current line.
z	Displays 10 lines starting at the current line. Advances the current line by 10.
ctrl-d	*Scroll* displays the next 10 lines and advances the current line by 10.

The **sdb** program displays the line number corresponding to the displayed line. The line number not only gives an indication of the relative position of the line in the file, but some **sdb** commands also use it as input.

Changing the Current File or Procedure

Use the **e** command to change the current file or procedure. In both cases, the current line becomes the first line in that procedure or file. Use one of the following two forms:

```
*e file.c
*e procedure
```

An **e** command without an argument displays the name of the current file and current procedure.

Changing the Current Line

The **z** and **ctrl-d** commands change the current line in the source file. The following commands also change the current line:

/string/	Searches forward for *string*. You can omit the second /.
?*string***?**	Searches backward for *string*. You can omit the second ?.
+[*n***]**	Moves the current line forward n lines.
-[*n***]**	Moves the current line backward n lines.
enter key	Moves the current line forward one line.
n	Sets the current line to n.

You can combine these commands with the display commands. The following example advances the current line by 15, displays 10 lines, and advances the current line by 10:

```
*+15z
```

Controlling Program Execution

The **sdb** program allows you to set ***breakpoints***, stopping places in the program. After entering **sdb**, specify what lines in the source program are to be ***breakpoints***. Then run the program from within **sdb**. When the program reaches a breakpoint, it stops running. The **sdb** program reports that it has reached a breakpoint. Then use **sdb** commands to examine the procedure calls and variables. If the program is working correctly to this point, you can add or remove other breakpoints and continue running the program.

An alternative to setting breakpoints is single stepping, which causes the program to run a single line of code and then stop. If the procedure was not compiled with the **-g** flag, the program runs until **sdb** finds a procedure that was compiled with the **-g** flag. You can also execute one assembler instruction at a time.

Setting and Deleting Breakpoints

Breakpoints can be set at any line in a procedure that contains executable code. Enter the command as follows:

```
[procedure][line number]b
```

The following examples show how to set a breakpoint:

```
*12b            # at line 12 in current procedure
*samp:12b       # at line 12 in procedure samp
*samp:b         # at the first line of samp
*b              # at the current line
```

The line numbers are relative to the beginning of the file as written by the source file display commands.

Remove breakpoints using the letter **d** instead of **b**. The only difference is when using **d** by itself, **sdb** displays each breakpoint and asks whether to remove it or not. If you respond with **y** or **d**, **sdb** removes the breakpoint.

To display a list of the current breakpoints, use the **B** command. To remove all of the breakpoints, use the **D** command. Remember that **sdb** commands are case sensitive. There is a big difference between the **d** command and the **D** command.

The **b** command can also automatically perform a sequence of commands at a breakpoint and then continue running the program. For example, the command:

```
*12b t;x/
```

displays both a trace back and the value of `x` each time the program runs line 12.

The **a** command is a variation of the above command. There are two ways of using the **a** command:

```
*samp: a
*samp:12 a
```

The first displays the procedure name, in this case `samp`, and its arguments each time it is called. The second displays the source line, 12, each time it is about to be executed. For both forms of the **a** command, execution continues after the procedure name or source line is displayed.

To change the value of a variable when the program is stopped at a breakpoint, use the following command format:

```
variable!value
```

The value may be a number, character constant, register, or the name of another variable. If the data type of the variable is float or double, the value can also be a floating-point constant.

Running the Program

The **r** command starts running the program. The command format is:

*`r` *args*

The program runs using the arguments as if they were typed on the **shell** command line. If arguments are not specified, then the arguments from the last execution of the program are used. To run a program without arguments, use the **R** command.

After the program starts, it runs until one of the following occurs:

- It reaches a breakpoint
- A signal, such as INTERRUPT or QUIT, occurs
- The program ends.

In each case when the program stops, **sdb** receives control and displays a message to tell why the program stopped.

Use the **c** command to continue running a stopped program. To specify a line number in the **c** command:

```
*procwild:12 c
```

places a temporary breakpoint at the named line. The breakpoint is removed when the **c** command finishes. There is also a **C** command which continues execution but passes the signal that stopped the program back to the program. Use the **C** command for testing user-written signal handlers.

To tell **sdb** where to start running the program, specify a line number with the **g** command. For example:

```
*17 g
```

starts the program at line 17 of the current procedure. Use this command to avoid running a section of code that does not work. Do not start running in a different procedure than the one containing the breakpoint.

The **s** command runs a single line of source code. Use it to slowly run the program to examine its behavior in detail. The **S** command is like the **s** command but does not stop within called procedures. Use the **S** command to test the calling procedure when the called procedure works correctly.

Use the **m** command to monitor a specified memory location. The **sdb** program runs the program one line at a time until:

- The contents of the memory location change
- A specified number of steps are executed.

The **m** command is:

```
[variable]$m [count]
[address]:m [count]
```

The following examples show some uses of the **m** command:

```
*i$m
*i$m 10
*0x100bc:m
*0x100bc:m 5
```

If the count is omitted, **sdb** uses a value of infinity. The current procedure must be able to get to the variable. The **m** command is implemented in software and can be very slow.

To control how much information is displayed when single-stepping, set the level with the **v** command. The following examples show the range of information available:

```
*v        # show current file and procedure name
            this is the standard value used
*1 v      # also display each source line before execution
*2 v      # also display each assembler statement
```

Calling Procedures

Call any of the procedures of the program from **sdb** for testing individual procedures with different arguments, or for calling diagnostic procedures that format data to aid in debugging. There are two ways to call a procedure:

```
*proc(arg1, arg2,  . . . )
*proc(arg1, arg2,  . . . )/
```

The first way runs the procedure. The second way runs the procedure and writes the value that it returns. Use the second way for calling procedures. The value is written in decimal unless some other format is specified. Arguments to procedures may be integer, character or string constants, or values of variables that are accessible from the current procedure.

Note: If a procedure is called when the program is *not* stopped at a breakpoint (such as when a core image is being debugged) all variables are initialized before the procedure is started. This makes it impossible to use a procedure which relies on data from a core dump.

Debugging Assembler Language

The **sdb** program can also examine programs at the assembler language level. It can display the assembler language statements associated with a line in the source and place breakpoints at arbitrary addresses. The **sdb** program can also display or modify the contents of the machine registers.

Displaying Assembler Language Statements

To display the assembler language statements associated with line 25 in procedure `main`, use the command:

```
*main:25?
```

The **?** command is identical to the / command except that it displays from the memory space for the program code (text space) instead of the data space. The standard format for displaying text space is the **i** format, which interprets the assembler language instruction.

Absolute addresses may be specified instead of line numbers by adding a : to them. For example:

```
*0x1024:?
```

displays the contents of address 0x1024 in text space. Note that the command:

```
*0x1024?
```

displays the instruction corresponding to line 0x1024 in the current procedure. You can also set or remove a breakpoint by specifying its absolute address. The following example sets a breakpoint at address 0x1024:

```
*0x1024:b
```

To single-step by assembler instruction rather than source line, use the **i** command. The **i** command ignores the signal that stopped the program. There is also the **I** command, which causes the program to execute one assembler instruction at a time, but also passes the signal that stopped the program back to the program.

Manipulating Registers

The **x** command writes the values of all the registers and the process status word (**psw**).

To specify individual registers, append a % to their name. The next example changes the value of register r3 to 22:

```
*r3%!22
```

Use the following names when referring to the registers and pointers:

- *Floating point registers*: f0, f2, f4, and f6
- *Frame pointer*: r4 or fp
- *Argument pointer*: r5 or ap

The **X** command displays the value of the Instruction Address Register (IAR) and the assembler language instruction at that location.

An Example of a Debug Session

Figure 8-1 shows the use of some **sdb** commands.

```
$ cat testdiv2.c
main(argc, argv, envp)
char **argv, **envp;
{
   int i;
   i = div2( -1 );
   printf( "-1/2 = %d\n" , i );
}
div2(i)
{
   int j;
   j = i>>1;
   return(j);
}
$ cc-g testdiv2.c
$ a.out
-1/2 = -1
$ sdb
No core image #Warning message from sdb
*/ div2         #Search for procedure "div2"
8:div2(i){     #It starts on line 8
*z             #Print the next few lines
8:div2(i)
9:{
10:     int j;
11:     j = i>>1;
12:      return(j);
13:}
*div2:b #Place a breakpoint at the beginning of "div2"
div2:11b       #sdb echoes proc name and line number
```

Figure 8-1 (Part 1 of 2). Example of Debug Session

```
*r              #Run the procedure
a.out           #sdb echoes command line executed
Breakpoint at #Executions stops just before line 11
div2:11:j = i>>1;
*t              #Print trace of subroutine calls
div2(i=-1)[testdiv2.c:11]
main(argc=1,argv=0x7fffff50,envp=0x7fffff58)[testdiv2.c:4]
*i/             #Print i
-1
*s              #Single step
div2:11:return(j)#Execution stops just before line 11
*j/             #Print j
-1
*10d             #Delete the breakpoint
*div2(1)/       #Try running "div2" with different arguments
0
*div2(-2)/
-1
*div2(-3)/
-2
*q
$
```

Figure 8-1 (Part 2 of 2). Example of Debug Session

Chapter 9. Installing and Updating a Program

CONTENTS

About This Chapter

After finishing the development and testing of a program, prepare it to be installed on other systems. This chapter describes the operating system services that help simplify installation procedures for people using the program. It describes:

- What the installation services can do
- What an installation program must do
- What files to include on the distribution diskette
- The format of each of the needed files.

At a later time you may need to change the program to provide additional features, or to correct problems encountered in actual usage of the program. This chapter also describes the operating system services that help change an installed program. It describes:

- What the update services can do
- What an update program must do
- What files to include on the update diskette.

Note: If your program includes support for a new device or added features for a currently supported device, you must also provide information to be added to the system configuration files. This information tells the system how to interface with the new driver support. Refer to Appendix E, "Customizing System Files for New Devices" on page E-1 for information about the type of configuration information you must supply.

Understanding System Guidelines

When preparing your program to install on the RT PC system, be aware of how the system files are organized so that the program can work as an integral part of the whole system. The following paragraphs describe some of the system conventions that any new program should follow.

Protecting System Directories

Each of the directories supplied with the system has a defined purpose. The permissions, owner and group id for these directories are set so that the directories work properly with the system programs that use them.

CAUTION
Do not change the permission, owner or group id of any system file or directory. Changing these permissions prevents the programs supplied with the system from operating properly.

Many of the administrative system functions can be performed by a member of the **system** group without having to log in as root or know the root password. Refer to the description of each command in *AIX Operating System Commands Reference* to determine which functions the **system** group can perform. Some sensitive commands are still reserved for the person with superuser authority.

In addition, reserve the following directories for their intended purpose only:

/ — Do not add files or mount file systems to subdirectories in the root file system without an urgent need to do so. The root file system contains fixed system directories and should not be used for application programs or user files.

/usr — Do not add files or directories to the **/usr** directory without an urgent need to do so. The **/usr** directory contains files and directories that the system uses.

/usr/bin — This directory contains common user executable files and is part of the default search path for all users. Put a short binary program or shell script in this directory that calls your large executable files. Put the large executable files in the directory **/usr/lpp/***pgm-name* (*pgm-name* is the identifier you choose for your program, as described in "What You Need to Install a Program" on page 9-8).

/usr/lpp	Create a directory in this directory to store your programs as described in "What You Need to Install a Program" on page 9-8.
/usr/lib	Use this directory to store those library files that have general use to all users. Store other library files in your directory, **/usr/lpp/***pgm-name*.
/usr/include	Use this directory to store those include files that have general use to all users. Store other include files in your directory, **/usr/lpp/***pgm-name*.

Providing User Documentation

You should provide documentation along with your program to enable the user to easily find any needed information, and to install and run your program properly. Pattern installation procedures after the format and steps shown in *Installing and Customizing the AIX Operating System* so that the user can use familiar procedures when installing any program on the system. Refer to information in *AIX Operating System Technical Reference* about creating device drivers and about the **vrcppr** routine when designing the installation. In addition to the normal installation and use information, provide information about your program's use of disk space in each of the following directories:

- **/usr**
- **/usr/bin**
- **/usr/lib**
- **/usr/lpp**
- **/usr/include**

Give usage information in terms of the number of 512-byte blocks that the program uses in each of the directories. The information for the operating system and VRM is in *Installing and Customizing the AIX Operating System.* The usage information helps the person installing your program determine if there is enough space on the file system to load the program. If there is not enough space, refer the user to *Using and Managing the AIX Operating System* for information about expanding an existing file system. *Installing and Customizing the AIX Operating System* contains information about expanding the VRM and page space minidisks.

Using Installation and Update Services

The installation and update services require only a few simple steps to install the program on the system. Typically, the person that installs the program only needs to put the first installation diskette in the diskette drive and enter the command:

```
installp
```

From that point on, messages to the screen tell the person when to change diskettes and what the status of the installation is.

In addition to providing an easy interface for the person installing the program or update, installation and update services also help ensure that the installation is correct. They:

- Maintain an accurate record of the revision state of the program on the system
- Check the revision level of other needed programs to ensure that they will work with the program
- Provide instructions to install the program
- Provide online copies of changes to documentation.

Commands

Installation and update services provides the following commands to enter from the command line to install or update a program. Complete information about the syntax and usage of these commands is in *AIX Operating System Commands Reference.*

Command	Description
installp	Installs the program or programs on the diskette in the specified drive, according to an installation program on the installation diskette.
updatep	Installs one or more changes to an installed program. Changes must be in **backup** format, and can be in a file on disk, on tape, or on a diskette in the specified drive. Changes can be installed on a conditional basis to try them out. At a later time, you can either accept the changes for permanent installation or reject them. Rejecting the changes returns the changed program to its condition before the changes were installed.

Figure 9-1. Install and Update Commands

Internal Commands

Once either of the commands is running, the installation or update program can use the internal commands to access the installation and update services. Use these commands like shell commands. If the installation program is a shell procedure, use the commands like any other command. If the installation program is a C language program, use the **fork** and **exec** system calls, or the **system** subroutine to run the commands. Detailed information about the internal commands is in *AIX Operating System Commands Reference*. The internal commands do the functions outlined in Figure 9-2 on page 9-7.

Command	Description
/etc/ckprereq	Checks the revision level of programs.
/etc/cvid	Backs up the VRM minidisk. Use this command to make an install diskette before making any changes to the VRM minidisk. You can then recover the previous version from this diskette if the changes cause an error.
/etc/errupdate	Adds, replaces, or deletes the error report format templates in the file **/etc/errfmt**.
/etc/inudocm	Gets copies of update instructions or book changes to look at or print.
/etc/inurecv	Recovers all files and archived member files that a previous execution of **inusave** saved. This command also recovers any other saved files recorded in the configuration list file, or active list file.
/etc/inurest	Does simple restores and archives.
/etc/inusave	Saves some, or all, of the files and archived member files that will be replaced or modified when the program is installed or updated.
/etc/inuupdt	Applies a maintenance update for a single program.
/etc/mvmd	Does one of the following actions to a file on a VRM minidisk. • Adds a file • Deletes a file • Replaces an existing file • Changes file permissions • Moves the position of a file entry in a VRM directory listing.
/etc/trcupdate	Adds, replaces, or deletes trace report format templates in the file **/etc/trcfmt**.

Figure 9-2. Internal Commands

What You Need to Install a Program

To install a program on the RT PC system using the **installp** command, provide a set of control and program files in **backup** format on the installation media (either diskette or magnetic tape). The control files (see "Control Files" on page 9-9) must appear before the program files (see "Program Files" on page 9-10).

Put the control and program files on the installation media using the **backup -i** command (backed up ***by name***). See the description of this command in *AIX Operating System Commands Reference*. In addition, when backing up the files, use a relative path name with respect to the / directory on the installed system. For example, to create an installation diskette for a single program file (**ftrn**) to be stored in the **/bin** directory on the target system, provide an ordered list of files to the **backup -i** command:

```
./lpp_name
./usr/lpp/fortran/liblpp.a
./bin/ftrn
```

The first two files are control files; the last file is the program file (or a group of files). This is the minimum required list of files.

Control Files

Provide the following control files at the beginning of the installation media:

- A file named **lpp_name** that contains the title of the program or programs on the installation media (see "Creating the Program Name File" on page 9-30).
- A library file named **./usr/lpp/*pgm-name*/liblpp.a** (***pgm-name*** is a name for the program with a maximum of 8 lowercase, alphabetic characters). Create this library using the **ar** command. The library contains the following files:

  lpp.hist A file for logging changes to the program (see "Creating the Program History File" on page 9-25).

  instal The installation program that installs special features and files that the program uses. This program must be either a shell procedure or an executable program in **a.out** format.

  al An apply list file that contains the relative path names with respect to the / directory of all files to be restored.

  copyright An optional file that contains appropriate copyright information for this program.

  prereq An optional file that lists the programs that the program uses and that, therefore, must be installed on the system (see "Creating the Program Requirements File" on page 9-28).

  lpp.acf An optional file that defines archiving procedures for the program (see "Creating an Archive Control File" on page 9-32).

  config An optional executable file that contains a procedure to update the system configuration. This is **not** the customization helper program specified in **/etc/master**. If the program does not do any customization, the **config** file is not needed. The procedure may be either a shell procedure, or a compiled procedure in **a.out** format.

  lpp.doc An optional file containing changes to the book for the program.

  Other files Other optional files can be added to the end of the archive file as needed by special installation programs that you decide to use.

The **installp** program restores the library file, **./usr/lpp/*pgm-name*/liblpp.a** and extracts the files in it. Then **installp** executes your **instal** program and passes it a single parameter that specifies the device containing the restore files. Access this parameter with `$1` if using a shell procedure or with `argv[1]` if using a C language program:

```
main(argc,argv)
int argc;
char *argv[];
```

When the **instal** program returns to **installp**, **installp** removes all files that do not begin with `lpp` from the directory, **/usr/lpp/*pgm-name***. Directories in that directory are not deleted, however.

Program Files

The program files are the files needed to run the program. Include these files after the needed control files in **backup -i** format.

Creating the Installation Procedure

In the archive file **./usr/lpp/*pgm-name*/liblpp.a**, provide an executable file, named **instal** to install the program and its files. The **installp** program executes this program during the installation procedure after it completes its preliminary tasks.

The installation program can then do some of the following tasks to complete the installation of the program.

1. Ensure that the needed level of other programs are installed on the system using **ckprereq**.
2. Perform active file processing if any of the files to be restored are being used. See "Installing and Updating Active Files" on page 9-20.

   CAUTION

   Do not use inusave when installing large programs that will fill the disk with the backup files.
3. Use **inusave** to back up any files that will be replaced.
4. Use **inurest** to restore files listed in the apply list file, and to archive constituent files.
5. Customize the system for the program. See *AIX Operating System Technical Reference* and Appendix E, "Customizing System Files for New Devices" on page E-1 for information to help you customize the system.
6. If an error occurs and **inusave** was previously used, then use **inurecv** to recover the previous state of the system.
7. If **inusave** was used, delete the directory, **/usr/lpp/*pgm-name*/inst_updt.save**.
8. Return a completion code to the **installp** program.

Restoring the Program Diskette

After the installation program determines that the needed programs are on the system, it can use the **inurest** command to restore the program diskette. For example, to restore the files listed in the apply list file **al** for the program named **myprog**, use a shell command in the following format:

```
/etc/inurest -d device /usr/lpp/myprog/al myprog
```

This command restores all files from the specified device. The installation program uses the device passed to it by the **installp** program. The parameter `/usr/lpp/myprog/al` is the full path name of the apply list file, and `myprog` is the name of the program being installed.

Also use the **inurest** command to archive and then delete any restored archive member files. To enable the archive process, include a file **lpp.acf** in the library **./usr/lpp/*pgm-name*/liblpp.a** on the product diskette. See "Creating an Archive Control File" on page 9-32 for the format of this file. If this file is present, **inurest** archives and then deletes all restored files that are listed in both **lpp.acf** and the apply list file (**al** in the example).

Quiescing the System

When installing the program, the **installp** and **updatep** programs instruct the user that he must be working with a quiet system (one that has just been started and has no other users or user programs running). The **instal** or **update** procedure expects that the system is in a quiet state.

Allowing for Individual Needs

The installation program may need to do some special tasks to ensure that the program operates properly. Special tasks to take care of include the following:

- Use the **inurest** command together with an apply list file and archive control file to store files in a library.
- Display progress messages during the different stages of the installation procedure.
- Recover from errors, or back out of the installation if errors occur.

Customizing the System for a Program

If a program requires changes to the system configuration, such as adding a new device driver, include a procedure to do this customization task. This procedure must be called **config** and must be in the archive file **./usr/lpp/*pgm-name*/liblpp.a** when the program is installed. Create an input file containing the stanzas to be added to the customization files. The stanzas may include a device stanza for the device and device driver stanzas associated with the device for both the VRM and the operating system. Refer to Appendix E, "Customizing System Files for New Devices" on page E-1 for more

information about providing configuration information to the system. Steps you may need to include in the customization procedure are:

- Archive any new device driver code into the kernel libraries.
- Back up system files that may be changed, such as:
  - **/etc/master**
  - **/etc/system**
  - **/etc/predefined**
- Restore any **/etc/ddi** files which may be associated with the new device.
- Use the **cfgcopsf** routine to open the input file.
- Use the **cfgcrdsz** routine to read each stanza from the input file.
- Use the **cfgddev** routine to delete device stanzas from **/etc/system**, if appropriate. If the the program is reinstalled, remove previous device stanzas before adding the same device stanzas.
- Use the **cfgadev** routine to add device stanzas to **/etc/system** and to add operating system and VRM device driver stanzas to **/etc/master**. The **cfgadev** routine receives a pointer to a device stanza to add to **/etc/system**, and pointers to an operating system and a VRM device driver stanza. It adds each of these device driver stanzas to **/etc/master**.
- Use the **cfgcadsz** routine to add any device stanzas to **/etc/predefined**. If the new device associated with the program can be deleted from the system, adding the device stanza to **/etc/predefined** allows users to add the device again by using the **devices** command.
- Use the **cfgcclsf** routine to close the input file.
- Return a completion code to **instal**.

Refer to *AIX Operating System Technical Reference* for detailed information about the subroutines and file formats for customizing the system files.

Sending a Return Code to installp

When the installation program completes, it must send a return code to the **installp** program. This return code signals the end of the install program, and determines what actions the **installp** program will do next. Use one of the following values for a return code:

Code	Description
0	Successful completion. No additional action is needed.
2	Successful completion. The **installp** program updates superblocks, the i-node list, and flushes the buffers (**sync**). Then it performs an IPL on the operating system.
3	Successful completion. The **installp** program uses the **cfgaply** routine to build a new kernel. Then it updates superblocks, the i-node list, and flushes the buffers. Then it instructs the user to IPL the system and shuts down the VRM system.
4	Successful completion. The **installp** program uses the **cfgaply** routine to build a new kernel. Then it updates superblocks, the i-node list, and flushes the buffers before it performs an IPL on the operating system.
5	Installation cancelled by the **install** procedure without errors.
6	Successful completion. The **installp** program updates superblocks and the i-node list, and flushes the buffers (**sync**). Then it instructs the user to IPL the system and shuts down the VRM system.
other	Error. The **installp** program sets the `Version`, `Release` and `Level` fields of the last information record in **lpp.hist** to all zeros, and writes the return code value in **lpp.hist** as an error code.

Figure 9-3. Return Codes to installp

What You Need to Update a Program

Note: When providing an update for a program that has had previous updates, ***all*** previous updates since the last release of the program must also be supplied on the update media to ensure that the current update can be installed successfully.

To update a program on the RT PC system using the **updatep** command, supply the following files on the first diskette of the product update. All files are in the format used by the **backup** command, and must be backed up by **name**, using a relative path name with respect to the / directory on the target system. The files must be in the following order:

1. An optional file named **./copyright** that contains a copy of the copyright information of each program on the diskette. If this file is present, it must be the first file on the diskette. It is referenced by the external diskette copyright label if there is not enough space on the label to include all of the appropriate copyright notices.
2. A file named **./lpp_name** that contains the title of each program (see "Creating the Program Name File" on page 9-30)
3. A library named **./usr/sys/inst_updt/control** and created with the **ar** command that contains the following files:

   ***pgm-name*_vri**

   A file for each program to be updated that contains the version, release and level numbers of the program after the update has been applied. The format of the one-record file is:

   ```
   VV RR LLLL
   ```

   which is similar to all version numbers used in this section, except that there are spaces between the version, release and level numbers instead of periods. The record ends with a new-line character.

lppsize

An optional file that contains an entry for each program that is being updated. Each entry contains:

pgm-name size

The *size* parameter specifies the size of the update for the indicated program in 512-byte blocks. The two parameters must be separated by a blank. Each entry ends with a single new-line character.

The **updatep** program uses the size information to determine if there is enough space in the **/usr** file system to save the old versions of the program during the update procedure. If the size of the programs being added is larger than the available free space in the **/usr** file system, **updatep** gives the user the following options:

- Stop the update
- Continue with the update

If the user continues, **updatep** does not save the current versions of the files and automatically commits the update. The previous version of the program cannot be recovered.

Although this file is optional, you should include an **lppsize** file in all program updates. If **updatep** does not find this information, it does not check to see if there is enough space to save the previous version of the program.

***pgm-name*_instr**

An optional library, one for each program being updated, that contains a set of files that contain instructions. If you do not provide instruction files, do not include this library. These files are standard text files. They are named according to the update level to which they apply, according to the format:

```
ui.VV.RR.LLLL
```

In this format the symbols VV, RR and LLLL represent the version, release and level numbers. You can have instruction files for one or more of the program levels that are being updated.

***pgm-name*_erata**

An optional library, one for each program being updated, that contains a set of files that contain changes to the book(s) for the program. If you do not provide changes to the books, do not include this library. These files are standard text files. They are named according to the update level to which they apply, according to the format:

```
me.VV.RR.LLLL
```

In this format the symbols VV, RR and LLLL represent the version, release and level numbers. You can have book change files for one or more of the program levels being updated.

4. One file named **./usr/sys/inst_updt/special** that identifies special update requirements for each program being updated. See "Creating a Special Requirement File" on page 9-33 for information about this file.

5. Program data for each program being updated, consisting of the following:

   - A library, created with the **ar** command and named **./usr/lpp/*pgm-name*/inst_updt/arp**, that contains the following files:

     update
     An executable file that contains a procedure to update the program. The procedure may be either a shell procedure, or a compiled procedure in **a.out** format.

     config
     An executable file that contains a procedure to update the system configuration. If the program does not do any customization, this file is not needed. The procedure may be either a shell procedure, or a compiled procedure in **a.out** format.

     al_*VV.RR.LLLL*
     An apply list file that contains the relative path names with respect to the / directory of all files to be updated. See "Creating an Apply List File" on page 9-31 for information about the file format. Include one apply list file for each update to the program. The symbols **V** , **R** and **L** represent version, release and level numbers as described in "Creating the Program History File" on page 9-25.

     lpp.acf
     An optional file that defines archiving procedures for the program as described in "Creating an Archive Control File" on page 9-32.

     copyright
     An optional file that contains appropriate copyright information for this program. If this file is present, **updatep** displays the contents of this file when it applies the update to this program.

   - The new and replacement program files.

In addition, be sure to provide instructions for the update in the **instr** file (optional), instead of providing a manual that tells the operator how to do procedures required to update the program. This information should supply information needed for special configurations.

Using the updatep Program

In the library **./usr/lpp/*pgm-name*/inst_updt/arp**, provide a program, named **update** to do the update procedures that the program needs. The **updatep** program executes this program during the update procedure after it does the following preliminary tasks:

1. Restores the library that contains the update control files.
2. Determines which files need to be updated.
3. Extracts the update procedure **update** from the library file.
4. Starts the update procedure.

When the update procedure completes, the **updatep** program does the following cleanup tasks:

1. Updates the **lpp.hist** file to the indicated revision level
2. Performs any IPLs, kernel rebuild or shutdown based on the code returned by the update procedure.

Sending a Return Code to updatep

When the update program completes, it must send a return code to the **updatep** program. This return code signals the end of the update program, and determines what actions the **updatep** program will do next. Use one of the following values for a return code:

Code	Description
0	Successful completion. No additional action is needed.
2	Successful completion. The **updatep** program updates superblocks and the i-node list and flushes the buffers (**sync**). Then it performs an IPL on the operating system.
3	Successful completion. The **updatep** program uses the **cfgaply** routine to build a new kernel. Then it updates superblocks and the i-node list and flushes the buffers. Then it instructs the user to IPL the system and shuts down the VRM system.
4	Successful completion. The **updatep** program uses the **cfgaply** routine to build a new kernel. Then it updates superblocks and the i-node list and flushes the buffers before it performs an IPL on the operating system.

Figure 9-4 (Part 1 of 2). Return Codes to updatep

Code	Description
5	Update cancelled by the **update** procedure without errors.
6	Successful completion. The **updatep** program updates superblocks and the i-node list and flushes the buffers (**sync**). Then it instructs the user to IPL the system and shuts down the VRM system.
7	The update was cancelled by the **update** procedure with errors. The **updatep** program recovers the previous state of the system.

Figure 9-4 (Part 2 of 2). Return Codes to updatep

Example Update Procedure

Figure 9-5 on page 9-19 shows a simple example shell procedure to update an example program. The example procedure is simple. It would be more complicated if the update included a kernel update and required an IPL following the update. In this program the parameters have the following meaning:

$1	A variable that passes the full path name of the apply list file to the update procedure.
$2	A variable that passes the device path, usually **/dev/rfd0**.
programname	The name of the program (up to 8 characters)

```
programname = pgm-name
/etc/inusave  $1  "$programname"
rc=$?
if test $rc -ne 0
then
    exit  $rc          # return an error code
fi

/etc/inurest -d"$2" $1 "$programname"
rc=$?
if test $rc -ne 0
then
   exit $rc
fi

# The following section exits with a return
# code of 4 (kernel rebuild) if file myfile.o
# was included in the apply list.

fgrep myfile.o $1
rc=$?
if test $rc -eq 0
then
   exit 4
fi

exit 0
```

Figure 9-5. Example of update Procedure Code

Installing and Updating Active Files

When using **installp** and **updatep** with files on the system that are active at the start of the installation, the **instal** or **update** procedure provided with the program should ensure that the files are not active during the installation. The following suggestions can help to ensure that active files are installed correctly:

1. Identify all files in your installation or update that could be active at the start of the procedure, or that may become active during the procedure. The following files are among those that are active even in a quiesced state:

   - **/bin/sh**
   - **/etc/cron**
   - **/etc/qdaemon**
   - **/etc/init**
   - **/usr/lib/errdemon**
   - **/usr/lib/errpd**

   If you do not have any potentially active files, ignore the rest of these guidelines. Do not perform any of this processing on active files that are not included in the apply list.

2. In the **instal** or **update** procedure, provide code that performs the following functions in the indicated order:

   a. Call **inusave** as part of the normal procedure.

   b. First delete and then create a temporary directory named **inst_updt.actv** for each file system that is being updated. Each directory must be at the top level of the file system. For example, for active files in the **/usr** file system, the temporary directory must be **/usr/inst_updt.actv**. From a shell procedure, use the **rm -rf** command to delete the directory to prevent messages from being displayed. If an error occurs, return from the procedure with an error code of 40.

c. ***Move*** all potentially active files in each file system to the temporary directory for that file system and rename the files in the format of `active.`*n*, where *n* is an integer or other unique identifier for each file. If an error occurs, return from the procedure with an error code of 50.

d. After moving each file, make an entry in the file **/usr/lpp/*pgm-name*/inst_updt.save/active.list**. (***pgm-name*** represents the name of the program being installed.) The format of an entry in this file is:

`active.`*n* *pathname* *dirname*

Where:

n is an integer or other identifier to identify the file in the directory.
pathname is the full path name of the active file before being moved.
dirname is the full path name of the temporary directory.

For example, if the first active file is **/etc/init**, the entry in **active.list** is:

```
active.1  /etc/init  /inst_updt.actv
```

e. ***Copy*** the moved files from the active directory back to their original positions.

f. Call **inurest** to restore the updated versions of the files.

g. When the procedure completes successfully, return with one of the following codes:

2	If an operating system IPL is required
3	If the kernel must be rebuilt and a shutdown is required
4	If the kernel must be rebuilt and an operating system IPL is required.
5	If **updatep** cancels the update without an error occurring
6	If a shutdown is required
7	If **updatep** cancels the update with errors.

For updates, ensure that the **special** file indicates that an IPL is required. If active files have been changed, return a code that causes **updatep** to IPL the system.

For installations, tell the user in the written instructions that the installation performs an IPL when it completes.

h. If **inurest** does not complete successfully, your procedure should:

- If installing, call **inurecv** to recover the previous version (including any active files), log the error condition in the history file, and return the **inurest** return code to **installp**.
- If updating, return the **inurest** return code to **updatep**. **updatep** then calls **inurecv** to recover the previous version (including any active files).

Installing and Updating /bin/sh or /etc/restore

The two files **/bin/sh** and **/etc/restore** are special case active files. Use the following guidelines to install or update these files:

1. The user moves the file to a different name.
2. The user restores the file by name from the restore diskette.

   Note: If the file **/etc/restore** is being changed, the user must use the name of the file where he moved this file.
3. If **/bin/sh** was restored, IPL the operating system.
4. The user executes the **updatep** or **installp** program.

Use an update instruction to tell the user how to perform the update, and how to recover from any errors. If the update fails or is rejected, the user must move the saved copies of these files back to their original positions. If **/bin/sh** is moved, IPL the operating system.

Allowing for Recovery

The **update** program requires that you save enough information to allow it to recover the previous level of the program being updated. For simple updates you can save this information from your update procedure by calling **inusave** before trying to change anything. The **inusave** program saves the current version of any normal files, and can also save any constituent file in the directory **/usr/lpp/***pgm-name***/inst_updt.save** if you request that they be saved.

The **update** program either restores or deletes the saved files, depending upon how the update turns out. It deletes the saved files if:

- The user commits (accepts) the update
- An error occurs during the update process, but before any files have been changed by the update process.

It recovers the saved files if:

- The user rejects the update
- An error occurs during the update process after files have been changed by the update process.

Recovering from Kernel or Configuration Changes

When your program makes changes to either the kernel or configuration files, you must provide additional information and take extra steps. Supply an update instruction to inform the user that the kernel or a particular configuration file is being changed. Include in the instruction a warning that the files involved in the changes must not be further changed until the user either commits or rejects the update.

In addition, your update procedure must include instructions to perform the following steps controlled by the information contained in the apply list file, **al**:

1. Copy the current level of the file(s) being changed (either the kernel or the configuration file) into a file named,

   `/usr/lpp/`*`pgm-name`*`/inst_updt.save/config.`*`n`*

   In this name, the letter *n* is a unique number assigned by the procedure.

2. Add an entry in the file,

   `/usr/lpp/`*`pgm-name`*`/inst_updt.save/config.list`

   to document the saved file. Your procedure may need to create **config.list** if it does not already exist.

3. Run **inusave**.
4. Run **inurest**.
5. Perform any configuration dependent operations.
6. Return one of the following exit codes to **inuupdt**:

   2 Sync and reboot
   4 Use **cfgaply** to build the kernel. Then sync and reboot.

By following the preceding procedure, your program creates a copy of the current level of the updated file and provides information about whether a reboot is required to recover the current level. The **update** program can then recover from a rejected update.

Sequencing Configuration File Updates

When a program changes a particular configuration file more than once over a period of several updates, the changes must always be applied in the same order until the next release of the program. Your program's update procedure must adopt a file naming convention to allow it to do the updates in the required order.

For example, if a program contains changes for a configuration file called `/etc/config.1` in its updates numbered `01.00.0010` and `01.00.0030`, the updates could be contained in files named:

`/usr/lpp/`*`pgm-name`*`/config.1/f.1`
`/usr/lpp/`*`pgm-name`*`/config.1/f.2`

If the program being updated is at level 0000, the two changes could be applied in order. Similarly, if the program being updated is at level 0020, only the level 0030 change file would be included in the update apply list.

Creating the Program History File

The program history file **/usr/lpp/*pgm-name*/lpp.hist** contains information to identify the installed release and version of a program on the system. This file is an ASCII file. List these files to see samples of history files that exist on the system. See also *AIX Operating System Technical Reference* for more information about the history file.

Figure 9-6 shows the record format of the history file. Figure 9-7 defines the fields in the history record.

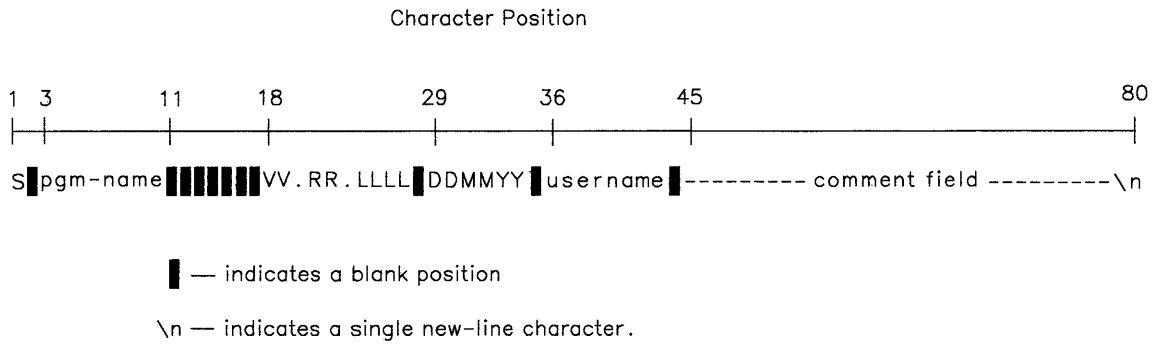


Figure 9-6. Record Format for the History File

Field	Description
S	Indicates the condition that the program is in, using the following characters: **a** An update was applied. **c** An update was committed (accepted). **r** An update was rejected. **t** This record is a title record. Positions 3 through 32 contain a title for the program. **v** The VRM minidisk has been changed. This entry occurs only in the VRM history file (refer to *Virtual Resource Manager Technical Reference* for more information). ***** This record is a comment field (put an * in position 79 to ensure a full length record).
pgm-name	The name assigned to the program (lowercase alphabetic characters only). If the name is less than 8 characters, the field must be filled out with blanks.
VV.	A 2-digit numeric field followed by a period indicating the version level of the program. The version number indicates which level of the hardware and operating system the program works with.
RR.	A 2-digit numeric field followed by a period indicating the release number of the program. The release number tracks changes to external programming interfaces since the last version change. This number increments each time the external interface to the program changes.
LLLL	A 4-digit numeric field indicating the update state of the program. This field increments when the program changes and the change does not affect external programs that may use the documented external interface for the program. The level, together with the S field, ensures that all changes up to and including the current change are installed on the system. Change only the high-order 3 digits; the low-order digit is used for local changes.
DDMMYY	These three numeric fields indicate the date of the change to the program: DD Day of the month (01 to 31) MM Month of the year (01 to 12) YY Year (00 to 99)

Figure 9-7 (Part 1 of 2). Fields in a History Record

Field	Description
username	An alphanumeric field that contains the user ID of the person that installed the program. If the user ID is less than 8 characters, this field must be filled out with blanks. This field is filled in at installation time, and can be blank when the update is distributed.
comment field	A 35-character field for adding comments.
\n	A required new-line character.

Figure 9-7 (Part 2 of 2). Fields in a History Record

Creating the Program Requirements File

You can use the **ckprereq** routine to determine if required programs are already installed on the system. The **ckprereq** routine uses the program requirements file **prereq** to make that determination. This file is an ASCII file. Figure 9-8 shows the record format of an entry in the requirements file. Figure 9-9 defines the fields in the requirements record.

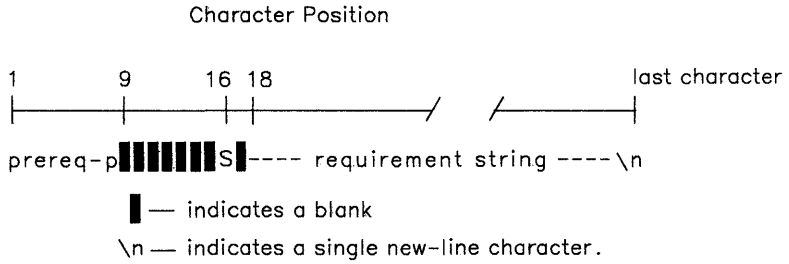


Figure 9-8. Record Format for Requirements File

Field	Description
prereq-p	An 8-character alphabetic field that contains the pgm-name of the program that is required.
S	**ckprereq** result code: Leave this field blank. The **ckprereq** command fills in this 1-character field with one of the following letters: **l** The requested level is not installed on the system. **n** A history file for that program is not installed on the system. **r** The requested release is not installed on the system. **s** The **prereq** file entry has a syntax error. **v** The requested version is not installed on the system. **blank** The prerequisite program is installed on the system in the proper configuration.

Figure 9-9 (Part 1 of 2). Fields in Requirements Record

Field	Description
`requirement string`	A set of logical expressions that define the version, release and level parameters that the prerequisite program must have. Use the following symbols to build expressions as shown in "Requirements File Example Entry." **v** Version **r** Release **l** Level **<** Less than **>** Greater than **=** Equal **o** Logical OR **integers** Parameter values
`\n`	Required new-line character

Figure 9-9 (Part 2 of 2). Fields in Requirements Record

Requirements File Example Entry

For example, the following entry:

```
myprog              v=2 r>30 o =10 o =15
```

in a requirements file indicates that:

- The program `myprog` is a required program
- It must be version 2
- Any level is valid (*l* is not specified)
- The release may be either 10, 15 or greater than 30.

Creating the Program Name File

The program name file contains the names of the programs on the set of installation or update diskettes. Name this file **./lpp_name**. It contains one or more entries.

Figure 9-10 shows the format of an entry in the program name file. Figure 9-11 defines the fields in the entry.

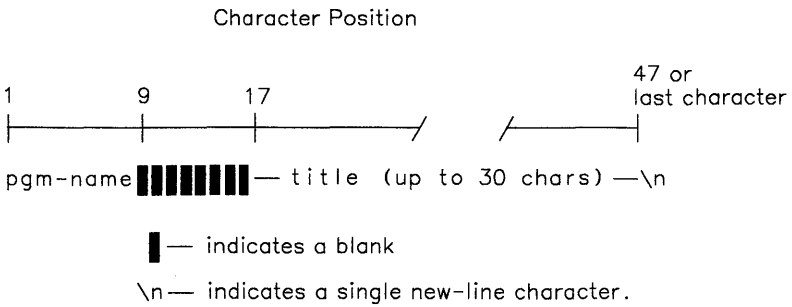


Figure 9-10. Entry Format for Program Name File

Field	Description
pgm-name	The name assigned to the program (lowercase alphabetic characters only). If the name is less than 8 characters, this field must be filled out with blanks.
title	A descriptive title of up to 30 characters.
\n	A required new-line character.

Figure 9-11. Fields in Program Name Entry

Creating an Apply List File

The apply list file contains an entry for each file to restore during an installation or an update procedure. The apply list file for an install, or the merged apply list for an update cannot be larger than 14K bytes. If the list is larger, then the change should not be an update. Use the install procedure to replace the program. Your **instal** program should then use the **restore** command, rather than **inurest** to restore the files.

Each entry in the file is a relative path name. The **installp** and **updatep** programs set the current directory to / before doing the restore operations. Therefore, the path names in this file specify the full installed path name of the file relative to /. For example, if the apply list file contains the following entry:

```
./usr/bin/newcmd
```

the program will be installed as **/usr/bin/newcmd** in the system.

Creating an Archive Control File

The **install** and **update** programs use the archive control file to replace individual member files into libraries that other programs own, such as adding a new file to the kernel. The **update** program also uses the archive control file to replace individual member files in libraries that it owns.

Supply an ***archive control file*** in the library **liblpp.a** for an install or in the **arp** file for an update (if the archive control file is not already present, or if the archive control file needs to be changed for the update procedure). The archive control file allows you to:

- Save a library member file
- Archive restored files into a library

during an installation or update procedure. The archive control file lists the library member files to save along with the name of the library file where the file can be found. Name the archive control file **lpp.acf**. This file consists of one or more lines. Each line has the following format:

filename *archive_file*

The parameters on each line are separated by one or more blanks, and have the following meaning:

`filename` The relative full path name (with respect to /) where the library member file should be restored.

`archive_file` The full path name of the library file that contains the member file **filename**.

When **lpp.acf** is present, the installation program can use the **inusave** command to save the listed files before it installs an update to the files. The **inusave** command compares the **filename** parameters in this file with the files to be updated (listed in the apply list file). If the same filename appears in both places, the **inusave** program saves the old version of the file before copying the new version of the file into the system. The **inusave** program does not produce an error message if a file listed in the apply list file does not exist. The **inurest** command also uses **lpp.acf** to archive the listed files.

Creating a Special Requirement File

The **updatep** command uses the special requirement file to determine the grouping of descriptive titles to be displayed to the user during the update procedure. You must provide this file, even if it is zero length (empty). Name this file **./usr/sys/inst_updt/special**. Depending on the program and the update being applied, this file can contain many types of entries, as described in the following paragraphs.

Figure 9-12 defines the variable parameters used in the following paragraphs.

Entry	Definition
pgm-name	The name of the program.
other-pgm	The name of another program that this program depends on.
LLLL	The level of the program that causes the change.
\n	Required new-line character.

Figure 9-12. Requirements File Parameters

Dependent Program Entry

The dependent program entry indicates that this update includes changes for another program that must also be applied. The format of this entry in the special requirement file is:

coreq *pgm-name LLLL other-pgm*\n

If the special requirements file contains another entry for either of the programs listed in the dependent program entry, then both programs must be updated by themselves. They cannot be updated together as dependent programs. Include information in your update instructions to tell the user to update both programs independently.

Changes to Report Templates Entry

This entry indicates that the update includes changes to the report templates for error tracking or trace reports. These templates are in the files **/etc/errfmt** and **/etc/trcfmt**. When this entry is present, the update for the program must be installed and accepted independent from updates for other programs. When using this entry, use an update instruction in the **instr** file to tell the user to recover the template files that were saved during the update procedure. The format of this entry in the special requirement file is:

`ras` *pgm-name* *LLLL*`\n`

IPL Required Entry

This entry indicates that the operating system must be loaded and started again following installation of this update. When this entry is present, the update for the program must be installed and accepted independent from updates for other programs. The format of this entry in the special requirement file is:

`ipl` *pgm-name* *LLLL*`\n`

Changes to Configuration Entry

This entry indicates that the update includes a change to the system configuration. When this entry is present, the update for the program must be installed and accepted independent from updates for other programs. The format of this entry in the special requirement file is:

`config` *pgm-name* *LLLL*`\n`

Changes to VRM Entry

This entry indicates that the update includes a change to the VRM. When this entry is present, the update for the program must be installed and accepted independently from updates for other programs. The format of this entry in the special requirement file is:

`vrm` *pgm-name* *LLLL*`\n`

Creating a Save and Recover Directory

The save and recover directory (**/usr/lpp/*pgm-name*/inst_updt.save**) contains copied files and extracted archived files that were saved during a reinstallation, or during application of an update. If a reinstallation procedure created the directory, the installation procedure must run **inurecv** if an error occurs, or delete the directory when installation is complete. If an update procedure created the directory, the directory exists until the update is either committed or rejected, or until **updatep** recovers the directory because of an error during the update procedure. At that time the **updatep** program deletes this directory, after recovering the saved files if the update was rejected. However, if the update is rejected without automatic recovery, the directory is not deleted to allow for manual recovery of the saved files. The directory must then be manually deleted after the files are recovered.

The directory contains the files listed in Figure 9-13. The order is not important. The directory can contain only the file names in the list.

File	Contents
update.list	An optional file that lists any regular files that were saved in this directory as described by **update.*n*** below. This file consists of one record for each file saved. This record has the following format: `update.`*n* *pathname*`\n` Where *pathname* is the full path name of the file when it is restored on the system, and `\n` represents a single new-line character.
update.*n*	A file named in this form for each record in the **update.list** file. In this form for naming the file: **update** Identifies the file as a backed up file. **n** Is an integer. Each backed up file has a unique *n* associated with it, starting with 1 for the first file backed up. For example, three backed up files have the names `update.1`, `update.2` and `update.3`.

Figure 9-13 (Part 1 of 4). Save/Restore Directory Content

File	Contents
archive.list	An optional file that lists any archived files that were extracted and saved in this directory as described in **archive.n** below. This file consists of one record for each archive file saved. This record has the following format: `archive.`*n* *member-name archive-name*`\n` Where *member-name* is the full path name of the file when it is restored on the system, *archive-name* is the full path name of the target archive file where this file belongs, and `\n` represents a single new-line character.
archive.*n*	A file named in this form for each record in the **archive.list** file. The file contains the file that was saved as listed in the **archive.list** file. In this form for naming the file: **archive** Identifies the file as a backed up archive file. **n** Is an integer. Each backed up file has a unique *n* associated with it, starting with 1 for the first file backed up. For example, three backed up files have the names `archive.1`, `archive.2` and `archive.3`.
config.list	An optional file that lists any configuration files that were saved in this directory as described in **config.n** below. This file consists of one record for each configuration file saved. This record has the following format: `config.`*n* *pathname*`\n` Where *pathname* is the full path name of the configuration file when it is restored on the system, and `\n` represents a single new-line character.

Figure 9-13 (Part 2 of 4). Save/Restore Directory Content

File	Contents
config.*n*	A file named in this form for every record in the **config.list** file. The file contains the file that was saved as listed in the **config.list** file. In this form for naming the file: **config** Identifies the file as a backed up configuration file. **n** Is an integer. Each backed up file has a unique *n* associated with it, starting with 1 for the first file backed up. For example, three backed up files have the names `config.1`, `config.2` and `config.3`.
active.list	An optional file that lists any active files that were saved by the program procedure. This file consists of one record for each active file saved. Each record has the format: `active.`*n filename directory*`\n` In this form the entries mean: *n* An integer that identifies the active file. *filename* The full path name of the active file before it was saved in the indicated directory *directory* The full path name of the directory where the active file is saved `\n` A single new-line character
active.*n*	A file named in this form for every record in the **active.list** file. The file contains the file that was saved as listed in the **active.list** file. In this form for naming the file: **active** Identifies the file as a backed up active file. **n** Is an integer. Each backed up file has a unique *n* associated with it, starting with 1 for the first file backed up. For example, three backed up files have the names `active.1`, `active.2` and `active.3`.

Figure 9-13 (Part 3 of 4). Save/Restore Directory Content

File	Contents
uniq_dir.list	An optional file that lists any install or update directories that were created during the process of archiving library members during an update. It permits **updatep** to delete any **inst_updt/***libname* directories when committing or rejecting an update (except for the directories **/usr/sys/inst_updt** and **/usr/lpp/***pgm-name***/inst_updt** which are used by the update process). The file consists of one record for each member file in the directory that is created. The record consists of the full path name of the member file: */path*/inst_updt/*libname/member* In this form the parts have the following meanings: *path* The full path name to the **inst_updt** directory *libname* The name of the library that was created *member* The name of the member file

Figure 9-13 (Part 4 of 4). Save/Restore Directory Content

Chapter 1. Programming with RT PC

CONTENTS

About This Chapter

This chapter describes the IBM RT PC tools and services for developing application programs. In addition, it indicates where to get more information about these facilities, both in this book and in other RT PC books.

Shared Libraries

With traditional libraries, each program has a private copy of the program text for each library module it uses. The AIX shared library facility lets multiple processes share the same copy of program text. The text is the executable portion of a program. The programs are linked as before, but the text has been removed from each object module and combined into one text image that is loaded at runtime and shared by many programs.

Shared libraries offer the following benefits:

- Programs that use shared libraries may use less disk space because the text sections for shared routines are not linked into each executable program.
- Processes that use shared libraries may require less main memory because the shared text sections are only mapped into main memory once.
- The system may require less time to load programs that use shared libraries because the shared text image may already be in main memory.
- Fewer page faults may be generated when shared libraries are used because the shared text image may already be in main memory. This can result in reduced disk activity which in turn can sometimes result in better response time.

Creating a Shared Library

Use the **shlib** command to create a shared library. **shlib** accepts the names of object modules or archive libraries (created by the **ar** command) as input and creates a shared library as output. See *AIX Operating System Commands Reference* for specific information about using the **shlib** command.

You can use object modules produced by the **C** and Fortran compilers without modification as input to **shlib**. You can also use assembler language routines as input if there are no external references in the text section other than **call** or **callr** instructions. You cannot use an object file that is already shared as input.

The **shlib** command copies the text section of each input module into one shared library text image. A shared library ***key*** is added to the header of each input module and the key identifies the name of the shared library text image so each module can be linked correctly by the **ld** command.

It is important that you keep the original object files so you can rebuild the libraries if they change.

Shared Library Keys

You can use the **-k** option of the **shlib** command to assign a specific shared library key. The default key is the name of the first archive or object file on the **shlib** command line. If you do not supply a suffix for the key, the Julian date is appended in the form **yyddd** where **yy** is the year and **ddd** is the sequential day within the year. **shlib** puts the key in each modified output file and **ld** (the link program) includes the key in every program that uses the shared library text image.

You can use the **-r** option of **shlib** to include an arbitrary character string in the shared library text image in addition to the key name.

You can use the **what** command to display all shared library keys a program uses and the key embedded in a shared library text image. Use the **-b** option of the **dump** command to display the key for the shared library an object module belongs to.

Normally, the system appends the key name to each **LIBPATH** directory to form the path name of a possible shared library, in the same way the shell searches for programs using **PATH**. However, if a shared library key begins with a / (slash), it is treated as an absolute name; the system does not append any directories to the key name, and the system attempts to open a file with that name.

Installing Shared Libraries

After you build a shared library, you need to install the text image in an appropriate library directory. If the shared library is not installed in **/lib** or **/usr/lib**, users of programs that are linked to the shared library need to define the **LIBPATH** environment variable to include the directory containing the shared library text image. The **LIBPATH** variable defines the search path for a shared library text image in the same manner the **PATH** variable defines the search path for a file. The system searches for the shared library as follows:

- If the **LIBPATH** variable is defined, the system combines the path names found in the **LIBPATH** variable and the library key found in the **a.out** header and searches for a shared library with that combined name. If the search does not produce a match, an error message is printed and the program is not started.
- If the **LIBPATH** variable is not defined, then the directories **/lib** and **/usr/lib** are searched for the shared library name.
- If the program has the **setuid** or **setgid** flags set, only **/lib** and **/usr/lib** are searched. This prevents someone from replacing a library call with another, assuming write permission is restricted for the **/lib** and **/usr/lib** directories.

Linking Shared Libraries

To link (**ld**) shared modules, specify object file names or an archive library name just as you would if you were linking modules that are not shared. When the **ld** command processes shared modules, it gets the key (generated by **shlib**) from the object file or archive library header and places it in the **a.out** file so **exec** can determine what shared library text images are needed at run time. There is an option for the **ld** command to control which segment the text image is mapped into.

It is best to keep the number of text images that must be mapped by a program to a minimum. This could reduce program startup overhead, assuming all the text images are not already mapped by some other process.

If the shared library text image key is different from the file name of the text image, you must use the **-k** option of **ld** and specify the correct file name. See *AIX Operating System Commands Reference* for more information about the **ld** command.

Changing Shared Libraries

Very limited changes are allowed to programs that are a part of a shared library without requiring programs that use the library to relink it:

- You can change integer constant values.
- You cannot change:
  - Floating-point constants
  - String constants.
- You cannot add, remove or rearrange:
  - Static variable definitions
  - External variable definitions
  - References to functions
  - References to external variables.

You can use the **-a** or **-v** option on the **shlib** command to determine whether or not you have to relink your programs after changing a shared library. Both options create a new shared library text image, but instead of building new output files, **shlib** verifies whether or not the new files would be identical to the files created previously. If the output files would be identical, the key of the new shared library text image is identical to the previous key. Verifying that the new output files would be identical is sufficient proof that the existing programs do not have to be relinked. **shlib** reports any discrepancy between the previous key and the new key.

If you make changes to a shared library that cause a change in the output files, you can handle the changes in either of two ways:

- You can build a new version of the shared library and relink the programs that use it.
- You can modify individual archive members locally and continue to use the old shared library.

If you build a new shared library because of program changes and you specify the same key as an existing shared library, programs that use the new shared library may not run correctly until they are relinked because they may still be using the old text image.

To make local changes to an archive that refers to a shared library text image, replace any member of the archive with an individual object file that has not been processed by **shlib**. You should also change the unshared version of the archive so you can generate a new shared library at some later date. When a program is linked with the modified archive, the new member is not shared and the text associated with the member is copied into the program.

You can also replace a member of an archive with a member that refers to a different shared library if the new member has been processed by **shlib**.

Chapter 10. Maintaining Different Versions of a Program

CONTENTS

About This Chapter

This chapter shows how to use the Source Code Control System (SCCS) to control revisions to source code or documentation files using the major SCCS commands.

First it gives background information about SCCS. This includes new terms, the format of SCCS files, and how to use the SCCS commands.

Next it shows a sample SCCS session and describes the three major SCCS commands in detail. These commands are **admin**, **get**, and **delta**. The other commands are described in *AIX Operating System Commands Reference.*

Introducing SCCS

The ***Source Code Control System*** (SCCS) allows one person or a group to control and account for changes made to source code or documentation files. It stores the changes made to a file instead of storing the changed file. This allows several versions of the same file to exist in the system. To edit the file, specify the version. SCCS builds that version based on its stored information about previous changes made. Using SCCS reduces storage requirements and helps track the development of a project that requires keeping many versions of large programs.

Features

The SCCS commands form a complete system. Once you create an SCCS file, use an SCCS command to change it. Do not edit or compile the SCCS file itself. Use another file that is derived from the original SCCS file for these operations.

SCCS commands can do the following:

- Create an SCCS file
- Get a version of an SCCS file
- Save changes made to that file version
- Define who can change an SCCS file
- Record who made changes to the SCCS file
- Record when and why the changes were made.

New Terms

The following descriptions of SCCS terms are used in this chapter.

SCCS file Any file containing text (source code or documentation) that is controlled with SCCS commands. All SCCS files begin with `s.`. This file contains the original file contents and sets of changes to the original file or later versions of that file. It also contains information about who can change the file, who made changes and when they were made. Do not edit this file directly. It contains information to build the stored files.

delta A set of changes made to an SCCS file. After changing a file, use the **delta** command to save those changes in the SCCS file, thereby creating a new delta. Create a new delta only to save the changes made. When editing a specific version of an SCCS file, that version may consist of several different deltas.

SID ***SCCS Identification***: The name assigned to a delta. An SID has up to four parts as shown in Figure 10-1 on page 10-5.

Every SCCS file starts out with an SID of 1.1. which means release 1, level 1. After editing version 1.1 and saving the changes, SCCS gives the new delta an SID of 1.2, which means release 1, level 2.

A typical SCCS file only uses release and level numbers and grows in a straight line. In these cases, the latest file version uses every previous delta to that file. However, a file may branch to a path where a file version consists of a subset of all of the deltas. For example, a common file can be used by two different groups. Both groups need the same code up to a certain point, and then each group goes its own way. In this case, create a branch delta that allows each group to add deltas onto a common base.

The file then has a trunk, with deltas identified by release and level, and one or more branches, which have deltas containing all four parts of an SID. On a branch, the release and level numbers are fixed and new deltas are identified by changing sequence numbers. Note that a file version built from a branch does not use any deltas placed on the trunk after the point of separation. See Figure 10-2 on page 10-5.

SCCS can combine different deltas. However, when combining many deltas into one, SCCS loses track of the changes that created each of the smaller (old) deltas and only tracks the change to create the larger (new) delta.

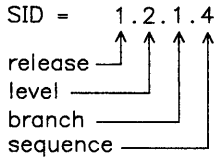


Figure 10-1. Parts of an SID

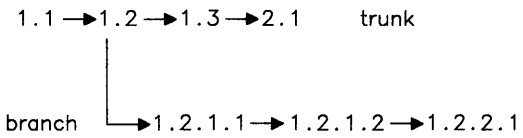


Figure 10-2. Growth of an SCCS File with Branching

SCCS File Format

SCCS files have two major sections called the header and the body. The header has five subsections, which identify who created the file, who can change it and other administrative details. The body has one or more subsections consisting of the text portions of the file. There is one text portion for each delta in the SCCS file.

The **get** command uses the header and body to create the specified file version. Other SCCS commands make use of the header and body to perform their functions.

Never edit the SCCS file itself except to modify incorrect information in the header as described in "Locating Damaged SCCS Files" on page 10-10. Editing the SCCS file can damage the structure of the file. The SCCS commands can do any necessary modifications of the header or body. To see how an SCCS file is organized, examine an SCCS file using simple commands such as **cat** or an editor. However, do not edit the SCCS file.

The SCCS File Header

The sections of an SCCS file header are described in the following.

Checksum A number containing the logical sum of all of the characters in the file. The **admin** command uses the checksum to ensure that all changes to the file were made by using the SCCS system.

Delta Table Information about each delta including type, SID, date and time of creation, and comments.

User Names List of login names or group IDs of users who are allowed to modify the SCCS file by adding or removing deltas. If this parameter does not exist, anyone can modify the SCCS file.

Options List of indicators that control specific actions of various SCCS commands.

Comments Descriptive text provided by the user to describe the contents or purpose of the file.

The SCCS File Body

The SCCS File body includes the actual text of the deltas in the file. The body also contains SCCS control text intermixed with the delta text. Notice that the deltas are in reverse order. That is, the most recently created delta is the first one in the list.

Warning: Using non-SCCS commands with SCCS files can damage the SCCS files. Changing an SCCS file with a non-SCCS command makes the checksum incorrect. See "Locating Damaged SCCS Files" on page 10-10 for information about working with the checksum.

Command Conventions

In most cases, SCCS commands accept the following two types of parameters:

flags Flags begin with the - (minus sign), followed by a lowercase character, and sometimes followed by a value. They control how the command operates.

arguments Arguments may be file or directory names. They specify the file or files with which the command operates. Using a directory name as an argument specifies all SCCS files in the directory.

Arguments cannot begin with a - (minus sign). If you specify the - (minus sign) by itself, the command reads standard input until it reaches an end of file character (Ctrl-D). This can be useful when using pipes. When using the keyboard for input, it reads until it finds **Ctrl-D**.

Any flags specified for a command apply to all files specified for that command and are processed before arguments to that command. Their placement in the command line is not important. Arguments are processed left to right. Some SCCS files contain flags that determine how the command operates on the file. See "Using the admin Command" on page 10-9 for more information.

SCCS Commands produce error messages with the following format:

```
ERROR [file]: message text (code)
```

The code in parentheses can be used as an argument to the **help** command. The **help** command can sometimes provide more information about a particular error code.

An SCCS command stops processing a file that contains a fatal error. Any other files in the command are still processed.

Command Summary

The following summary presents the commands in the order of their use. They are further defined in *AIX Operating System Commands Reference.*

admin	Creates an SCCS file or changes some characteristic of an existing SCCS file.
get	Gets a specified version of an SCCS file. Use this command to get a copy of a file to edit or compile.
unget	Undoes the effect of a previous use of the **get -e** command.
delta	Adds a set of changes (delta) to the text of an SCCS file.
rmdel	Removes a delta from an SCCS file. The delta must be the most recent delta on its branch.
cdc	Changes the comments associated with a delta.
what	Searches a system file for a pattern and displays what follows it. Use this command to find identifying information.
sccsdiff	Shows the differences between any two versions of an SCCS file.
comb	Combines two or more consecutive deltas of an SCCS file into a single delta. Combining deltas may reduce storage requirements.
val	Checks an SCCS file to see if its computed checksum matches the figure listed in the header.
prs	Prints portions of an SCCS file in a specified format.
help	Provides an explanation of a diagnostic message.

Using SCCS Commands

Figure 10-3 shows how to create, change and update the contents of an SCCS file. The SCCS commands have much more function than what is shown in the figure. System responses to the SCCS commands are not shown.

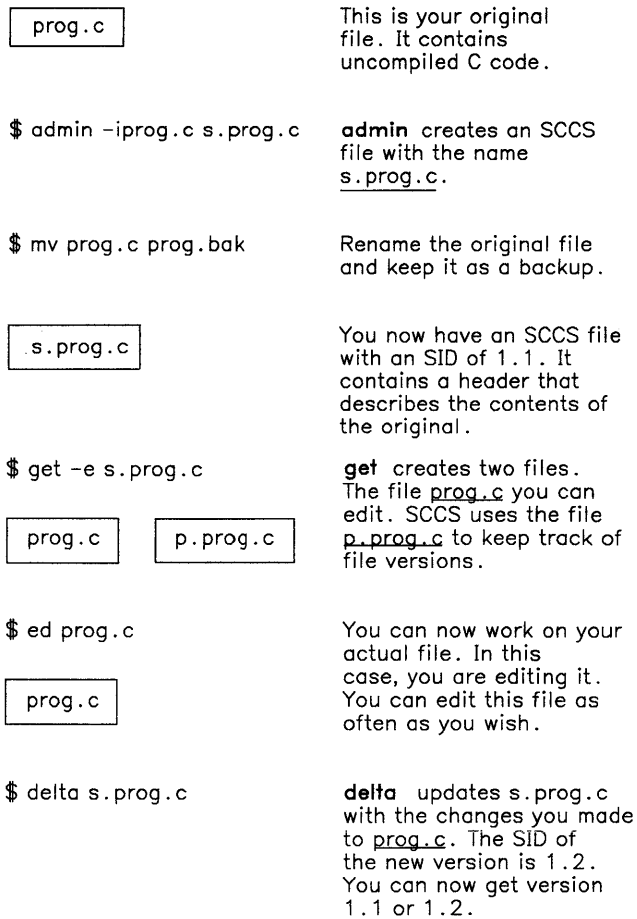


Figure 10-3. Example of Using SCCS to Create and Update a File

Using the admin Command

These examples use an imaginary text file called `test.c`, and an editor such as **ed** to edit files.

First, create an ordinary SCCS file. If you use the **-i** flag, **admin** creates delta 1.1 from the specified file. Without the **-i flag**, **admin** creates an empty SCCS file. Once delta 1.1 is created, rename the original text file so it does not interfere with SCCS commands. For example, to create an SCCS file from a file `test.c`:

```
$ admin -i test.c s.test.c
No id keywords (cm7)
$ li
s.test.c test.c
```

Then rename the original text file:

```
$ mv test.c  back.c
```

The message, `No id keywords (cm7)` does not indicate an error. SCCS writes this message when there are no identification keywords in the file. Identification keywords are variables that can be placed in an SCCS file. The values of these variables provide information, such as date, time, SID, or file name. See "Getting Read-Only File Versions" on page 10-11 for an explanation of identification keywords. If there are no identification keywords, SCCS writes the message.

Name the SCCS file anything as long as it begins with `s.`. In the above example, the original file and the SCCS file have the same name, but that is not necessary.

Because you did not specify a release number, **admin** gave the SCCS file an SID of 1.1. SCCS does not use the number 0 to identify deltas. Therefore, a file cannot have an SID of 1.0 or 2.1.1.0. All new releases start with level 1. To start the `test.c` file with a release number of 3, use the **-r** flag with the **admin** command, as shown below:

```
/* create SCCS file, version 3.1 */
$ admin -i test.c -r3 s.test.c
```

To restrict permission to change SCCS files to a specific set of user IDs, list their user IDs or group ID numbers in the user list of the SCCS file by using the **-a** flag of the **admin** command. These IDs then appear in the SCCS file header. Without the **-a** flag to restrict access, all user IDs can change the SCCS files.

```
/* dan is a user ID  */
$ admin -adan s.test.c
```

Locating Damaged SCCS Files

Although SCCS provides some error protection, you may need to recover a file that was accidentally damaged. This damage may result from a system malfunction, operator error, or changing an SCCS file without using SCCS commands.

SCCS commands use the checksum to determine whether a file was changed since it was last used. The only SCCS command that processes a damaged file is the **admin** command when used with the **-h** or **-z** flags. The **-h** flag tells **admin** to compare the checksum stored in the SCCS file header against the computed checksum. The **-z** flag tells **admin** to recompute the checksum and store it in the file header.

Check SCCS files on a regular basis for possible damage. The easiest way to do this is to run the **admin** command with the **-h** flag on all SCCS files or SCCS directories as shown below:

```
$ admin -h s.file1  s.file2 ...

$ admin -h directory1  directory2  ...
```

If **admin** finds a file where the computed checksum is not equal to the checksum listed in the SCCS file header, it displays this message:

```
corrupted file (co6)
```

If a file was damaged, try to edit the file again, or read a backup copy. After fixing the file, run the **admin** command with the **-z** flag and the repaired file name:

```
$ admin -z s.file1
```

This operation replaces the old checksum in the SCCS file header with a new checksum based on the repaired file contents. Other SCCS commands can now process the file.

Using the get Command

The **get** command gets files in either ***read-only*** or ***editable*** form. You can only use the ***editable*** form to create a delta to the SCCS file. Use the ***read-only*** form to print or compile the file. The results of using **get** on a file depend on whether you specify the file as read-only or editable. The examples are divided into read-only examples and editable examples. The examples are not related unless the comments specify that they are related.

Note: You must use the **-e** flag with the **get** command, to create a delta.

Getting Read-Only File Versions

To compile a program or print a document from an SCCS file, get the file as read-only. The **get** command performs different tasks when it gets a read-only document.

The difference between the two types of **get** operations is important when using identification keywords in a file. Identification keywords can appear anywhere in a file. They are symbols that are replaced with some text value when **get** retrieves the file as read-only. For example, to print the current date and SID in a file, put the following symbols in the file:

```
%H%  %I%
```

%H% is the symbol for the current date and %I% is the symbol for the SID. When **get** retrieves a file as editable, it leaves the symbols in the file and does not do text value substitution. See *AIX Operating System Commands Reference* for the identification keywords to use in a file.

Several examples of the **get** command are shown below:

```
$ li                /* check file directory */
s.test.c
$ get s.test.c      /* get file test.c */
3.5
59 lines
$ li                /* check file directory */
s.test.c test.c
```

Because you did not specify a version of the file, **get** built the version with the highest SID. In the next two examples, the **-r** flag specifies which version to get:

```
$ get -r1.3 s.test.c
1.3
40 lines
$ get -r1.3.1.4 s.test.c
1.3.1.4
50 lines
```

If you specify just the release number of the SID, **get** finds the file with the highest level within that release number.

```
$ get -r2 s.test.c
2.7
21 lines
```

If the SID specified is greater than the highest existing SID, **get** gets the highest existing SID. If the SID specified is lower than the lowest existing SID, SCCS writes an error message. In the following example, release 7 is the highest existing release:

```
$ get -r9 s.test.c
7.6
400 lines
```

The **-t** flag gets the top version in a given release or level. The top version is the most recently created delta, independent of its location. In the next example, the highest existing delta in release 3 is 3.5, while the most recently created delta is 3.2.1.5.

```
$ get -t -r3 s.test.c
3.2.1.5
46 lines
```

Getting Editable File Versions

All of the previous examples use the **get** command to get a read-only file. To edit the file and create a new delta, use the **-e** flag. The **get** command works differently when using the **-e** flag, so the previous examples may not apply. Restrictions for files built with the **-e** flag are explained in the *AIX Operating System Commands Reference* under the **get** and **admin** commands. If you build the wrong version of the file, use **unget** to undo the effect of the **get -e** command.

Several examples of the **get** command are shown below:

```
$ li                  /* check file directory */
s.test.c
$ get -e s.test.c     /* get editable version of test.c */
1.3
new delta 1.4
67 lines
$ li                  /* check file directory */
p.test.c  s.test.c  test.c
```

The working file is `test.c`.. If you edit `test.c` and save the changes with the **delta** command, SCCS creates a new delta with an SID of 1.4. The file `p.test.c` is a temporary file used by SCCS to keep track of file versions.

In the previous example, you could use the **-r** flag to get a specific version. Assuming delta 1.3 already exists, the following three uses of the **get** command are the same:

```
$ get -e s.test.c
$ get -e -r1 s.test.c
$ get -e -r1.3 s.test.c
```

To start using a new (higher in value) release number, get the file with the **-r** flag and specify a release number greater than the highest existing release number. In the next example, release 2 does not yet exist:

```
$ get -e -r2 s.test.c
1.3
new delta 2.1
67 lines
```

Notice that **get** indicates the version of the new delta that will be created if the **delta** command stores changes to the SCCS file. If the example did not include the **-e** flag, **get** would build the highest existing SID (1.3) and would not indicate a new delta, even though the **-r2** flag requests a version 2.1.

To develop a version of the SCCS file that does not depend on the most recently created delta, create a branch delta as shown in Figure 10-4.

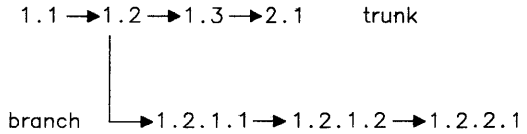


Figure 10-4. Growth of an SCCS File with Branching

In the figure, a branch exists at version 1.2. Adding new deltas at two different places in the SCCS file creates programs for two environments that have some similar code (1.1 and 1.2) and some code that is not the same.

Creating another branch from delta 1.2 builds a second series of program files. The new branch begins with delta **1.2.2.1**.

To create a branch delta, use the **-r** flag and specify the release and level where the branch occurs. In the next example, deltas 1.3 and 1.4 already exist.

```
$ get -e -r1.3 s.test.c
1.3
new delta 1.3.1.1
67 lines
```

Create deltas on branches using the same methods.

Getting Duplicate File Versions

To edit a file, get the file version using the **get** command (with the **-e** flag) and save the changes with the **delta** command. Several different editable versions of an SCCS file can exist as long as each one is in a different directory. If you try to get the same editable file version more than once without using the **delta** command, SCCS writes an error message.

To get the same editable file version more than once, set the **j** option in the SCCS file with the **admin** command. Set the **j** option using the **-f** flag. You can then get the same SID several times from different directories, creating a separate file for each **get** command. Although the files originate from a single SID, SCCS gives each of them a unique new SID.

```
$ pwd
   /u/dan/sccs        /* starting directory   */
$ admin -fj s.test.c     /* set the j option     */
$ get -e s.test.c        /* get latest version   */
1.1
new delta 1.2
5 lines
$ cd /u/new           /* change to directory new  */
$ get -e /u/dan/sccs/s.test.c  /* get 1.1 again  */
1.1
new delta 1.1.1.1
5 lines
```

Notice that SCCS creates two deltas, 1.2 and 1.1.1.1, from the single original file version of 1.1. Look at the `p.test.c` file. It shows a separate entry for each version currently in use. The `p.test.c` file remains in the directory until you take care of both file versions with either the **delta** command or the **unget** command.

Using the delta Command

The **delta** command saves the changes made to a particular version of an SCCS file. To use the **delta** command:

1. Use **get -e** to get an editable version of the file
2. Edit that file
3. Use **delta** to create a new version of the SCCS file.

When using the **delta** command, it prompts for comments. The comments are for that particular delta and appear in the SCCS file header. The comments are not retrieved when you **get** the delta and do not appear in the text of a retrieved file. Use comments to keep track of why a delta was created.

To see the comments, use an editor to look at the SCCS file, write the SCCS file to the display screen with the **cat** command, or print selected parts of the file to standard output using the **prs** command. Refer to *AIX Operating System Commands Reference* for descriptions of these commands. Remember not to change the contents of the SCCS file directly. To change the delta comments, use the **cdc** command.

A common use of the **delta** command is shown below:

```
$ delta s.test.c
Enter comments, terminated with EOF or blank line:
```

Then enter comments, as follows:

```
This delta contains the payroll function
```

delta then finishes processing and displays:

```
1.4
24 inserted
3 deleted
45 unchanged
```

The above example stores the comment in the SCCS file header and creates delta 1.4. It then lists how many lines of text are inserted, deleted, or unchanged. SCCS may give unexpected numbers for these categories because of its definition for an edited line of text. However, the number of lines inserted plus the number of lines left unchanged should equal the total number of lines in the file.

SCCS does not allow using the **delta** command if an editable file does not exist. However, once an editable file exists (created with **get -e**), SCCS creates the delta without checking the data being stored in the file.

Note: When using identification keywords in SCCS files, do not use the **delta** command with a file built as read-only if an editable version of the file also exists. When you get a file as read-only, SCCS replaces identification keywords with their values. Using the **delta** command on the file saves the values and the identification keywords are lost. To recover, remove the delta, or re-edit the file and replace the identification keywords.

Using the help Command

SCCS provides a limited form of help for certain error codes and all of the SCCS commands. To get help on a specific command or error code, use the following format:

`help [`*command*`] .. [`*code*`] ..`

The **help** program prompts for a `command` or an `error code` if those parameters are not included in the command. If it does not have information about a specific error code, **help** writes an error message and continues processing. For example, to get help on **rmdel** and two error codes, enter the following:

```
$ help rmdel gee ge5
```

The **help** command replies:

```
rmdel:
        rmdel -r<SID> <file> ...

ERROR: gee not found (hel)

ge5:
"nonexistent sid"
The specified sid does not exist in the given file.  Check for typos.
```

The response indicates that either the **help** command does not have information for the error code `gee` or the code does not exist.

Chapter 11. Finding and Changing Strings

CONTENTS

About This Chapter

This chapter contains introductory information to some of the system programs that are useful when developing a program on RT PC. These programs are not required to create programs, but they do provide added services that make checking and maintaining programs easier. Use these programs in **shell** programs that you develop. The commands described in this chapter:

- Find a specified series of characters in a text file.
- Find and change information in a text file.
- Make fast editing changes on a large text file.

Complete reference information about all commands is in *AIX Operating System Commands Reference.*

Finding Strings

The system provides three similar programs to help locate a series of characters (***string***) in a file. These programs are:

grep A general function program that finds literal strings in a file, and also finds strings that you specify using wildcard characters. (These are not the same as the shell wildcard characters).

fgrep A faster version of **grep** that only finds literal strings in a file (wildcards are not allowed).

egrep An extended version of **grep** to look for more complex expressions.

Use these programs to search one or more files at a time to answer the following questions:

- In which file(s) does the string occur (**-l** flag)?
- On how many lines in each file does the string occur (**-c** flag)?
- What is the line number of each place that the string occurs (**-n** flag)?
- What lines in which file(s) contain the string (no flag)?
- What lines in which file(s) exactly match the string (**-x** flag)?
- What lines in which file(s) do not contain the string (**-v** flag)?
- What is the disk block number of each place that the string occurs (**-b** flag)?

Strings

A ***string*** is any group of characters to find. Enclose the string in ' ' (single quotes) to ensure that the shell does not interpret blanks or special shell characters in the string as part of its syntax.

For example, because blanks separate the parameters on the command line, the shell interprets the command:

```
fgrep find me myfile
```

as a request to find the string, `find`, in the files `me` and `myfile`. To find the string, `find me`, in `myfile` specify the command like:

```
fgrep 'find me' myfile
```

Literal Strings

A literal string is a string that does not contain wildcard characters, and can, therefore, be interpreted just as it is. The previous example contains a literal string, `find me`. Use literal strings to specify exactly what to find.

For example, to find the file that contains the module, `eprog()`, in five source files that contain several modules each, use the command:

```
fgrep 'eprog()' file1 file2 file3 file4 file5
```

This command finds not only the actual module but any references to it. Look at the output lines to determine which reference actually contains the module definition. To find only the module definition, use the **-x** flag:

```
fgrep -x 'eprog()' file1 file2 file3 file4 file5
```

For coding formats that put each module definition left-justified on a line by itself, this command writes out only that line, together with the name of the file in which it occurs.

Regular Expressions

A regular expression is a string that contains wildcard characters and operators that define a set of one or more possible strings. The find string programs use a set of wildcard characters that is different from the shell wildcards, but the same as the line editor, **ed**. These wildcard characters and operators are:

.(period)
Specifies any character except new-line.

^ (caret)
Specifies the beginning of the line when it is the first character in a regular expression

$ (dollar sign)
Specifies the end of the line when it is the last character in a regular expression

[ ] (square brackets)
Encloses a set of characters (not empty) that represents any **one** of the characters in the set.

[abc] Represents either a or b or c

[a-c] Is the same as [abc] (**grep** only). The hyphen defines a range of ASCII values that starts with the value of the first letter and ends with the value of the second letter.

[A-z] Defines more than just the letters of the alphabet (**grep** only). It defines the range of ASCII values from A (065) to z (122).

|

OR - indicates a search for either one string or another:

```
egrep 'prog()|progl()' file1
```

finds lines containing either `prog()` or `progl()`.

Refer to the **ed** program in *AIX Operating System Commands Reference* for details for building regular expressions.

Example of Commands

To check a C program for proper nesting of braces, use the following two commands:

```
grep -c '{' file1
```

and

```
grep -c '}' file1
```

Each command responds with a number that represents the number of lines in the file containing either { or }, respectively. If the numbers are not the same, you may have a problem. Check the file again using a different form of the command:

```
egrep '{|}' file1
```

This command displays each line in the file that contains either a { or a }. It displays the lines in the order that they occur in the file, so that you can quickly check for matching pairs of open and closed braces.

Scanning Files

The **awk** program is an extension of the features of **grep**. It performs the following operations:

- Scans a file or list of files to find matches to a ***regular expression***.
- Performs an operation on the lines that are found, defined by an ***action***.

It uses all of the regular expression building features that **egrep** uses, plus it allows you to:

- Write selected fields of the line
- Calculate running totals
- Change syntax in a program source file
- Change system calls when porting from one system to another.

The **awk** program finds and changes strings in text files. In addition, it provides numeric processing, variables, more general pattern selection for finding strings, and flow control statements. This program treats both string and numeric data. In general, this program is useful for:

- Processing input to find numeric counts, sums or subtotals
- Verifying that the contents of a field contains only numeric information
- Checking to see that delimiters are balanced in a programming file
- Processing data contained in fields within lines
- Changing data from one program into a form that can be used by a different program.

Program File

When using **awk**, you can either enter the search pattern directly on the command line as with **grep**, or you can build a file that contains both the search pattern and the actions to perform. Using a program file puts many patterns in one file, and saves typing the command again to correct an error in the search pattern. When using a program file, run **awk** with the **-f** flag, such as:

```
awk -f pfile file1 file2 file3
```

In this command, `pfile` is the name of the program file, `file1`, `file2`, and `file3` are the files to be searched, and **-f** tells **awk** to look in `pfile` for the search program.

The program file is a series of statements that look like:

```
pattern         { action }
pattern         { action }
pattern         { action }
    .
    .
    .
```

Where:

pattern Is a regular expression, or series of regular expressions, that defines the search pattern, including:

- Boolean combinations of regular expressions using the operators **!** **||** **&&** and **()**.
- Boolean combinations of relational operators on strings, numbers, fields, variables, and array elements.

action Is a set of steps to perform on the line, designated with **awk** commands and operators, including:

- Any expressions that are used in a ***pattern***
- Arithmetic and string expressions
- Assignment statements
- If-else statements
- While-for statements
- More than one output stream.

{ } Are delimiters that set off the action from the search pattern.

In any line, you can omit either the pattern or the action. If you omit the pattern, **awk** performs the action on all lines in the file(s); if you omit the action, **awk** copies the line to standard output.

When **awk** runs, it reads the first line of the input data file and matches it against each of the ***patterns*** in the program file in the order that they appear in the program file. When **awk** finds a pattern that matches the line, it performs the associated ***action*** on that line. Then it continues to search for more matches in the program file. When it has compared the first input line against all patterns in the program file, **awk** reads the next input line and starts at the beginning of the program file with that line.

Variables

Awk recognizes the following built-in variables:

FILENAME	The name of the current input file.
NR	The number of the current record.
NF	The number of fields in the current record.
FS	The character used for a field separator.
RS	The character used for a record separator.
$0	The contents of the input record.
$n	The contents of field *n* of the input record.
OFS	The character used for output field separator (the character between fields when the data is written; a blank if you do not change it).
ORS	The character used for output record separator (the character between records when the data is written; a new-line if you do not change it).

BEGIN and END

The **awk** program recognizes two special keywords that define the beginning (**BEGIN**) and the end (**END**) of the input file. The pattern **BEGIN** matches the beginning of the input before reading the first record. Therefore, **awk** performs any actions associated with this pattern once, before processing any of the input file. **BEGIN** must be the first pattern in the program file. For example, to change the field separator to a colon for all records in the file, include the following line as the first line of the program file:

```
BEGIN   {FS=":"}
```

Similarly, the pattern, **END**, matches the end of the input file after processing the last record. Therefore, **awk** performs any actions associated with this pattern once, after processing all of the input file. **END** must be the last pattern in the program file. For example, to print the total number of lines in the input file, include the following line as the last line in the program file:

```
END     {print NR}
```

Using Regular Expressions as Patterns

The simplest regular expression is a literal string of characters, enclosed in slashes. For example, if the program file contains only the entry:

```
/the/
```

the file is a complete program that displays all lines containing the string `the`. Because the string does not specify any blanks or other qualifiers, the program also displays lines containing words such as:

```
theater
northern
```

that have the string as part of them. The program is sensitive to uppercase and lowercase, and only displays lines containing the lowercase form of the string.

Character Class

To find lines that contain `The` (the string as the first word in a sentence) in addition to the lowercase version, use a character class to represent either uppercase or lowercase. A ***character class*** is a set of characters, enclosed in `[ ]` (square brackets). Each character in the character class satisfies the search conditions for **one** character position. For example, to find lines containing both forms of the word `the` (and words containing it), use the string:

```
/[Tt]he/
```

The following string:

```
/[cCdDhH]ome/
```

finds lines that contain the words:

```
come
Come
dome
Dome
home
Home
```

Use ranges within a character class to indicate a group of consecutive ASCII characters. To define a range, enter the following:

1. [
2. The first character of the range
3. - (minus)
4. The last character of the range
5.]

Note: Ranges specify a continuous sequence of ASCII character codes, not alphabetic order. For example, the range [Z-a] specifies only eight characters from ASCII code 90 (Z) to 97 (a).

Special Characters

The **awk** program defines the symbols shown in Figure 11-1 to use in building patterns:

Symbol	Meaning
/	String delimiter: Indicates the start and end of a string or regular expression.
\	Escape: Tells **awk** to treat the next character as a regular ASCII character instead of a symbol that **awk** treats as a special character.
$0	Matches the entire line with the pattern.
$n	Matches field *n* (*n* is an integer) in each input line.
~	Match field operator: Tells **awk** to match the regular expression with a specified field in each line, not the line.
!~	Not match field operator: Tells **awk** to compare the regular expression with a specified field in each line and perform the action only if the expression does not match the field.
^	Beginning of the line or field: When placed at the start of a string, tells **awk** to match the string only when it occurs at the start of a line or specified field.

Figure 11-1 (Part 1 of 2). awk Special Characters

Symbol	Meaning
$	End of the line or field: When placed at the end of a string, tells **awk** to match the string only when it occurs at the end of a line or specified field.

Figure 11-1 (Part 2 of 2). awk Special Characters

Using Relational Expressions as Patterns

Use a relational expression as a pattern in the program file. The **awk** program defines the following relational operators for use in building patterns:

<	Less than
>	Greater than
<=	Less than or equal
>=	Greater than or equal
==	Equivalent
!=	Not equivalent

Examples of Relational Expressions in a Pattern

To find all lines where the second field ($2) is at least 100 greater than the first field:

```
$2 > $1 + 100
```

To find lines that contain an even number of fields:

```
NF % 2 == 0
```

To find lines that begin with `s, t, u,...`:

```
$1 >= "s"
```

To perform a string comparison between the first two fields:

```
$1 > $2
```

Using Combinations of Patterns

Combine two or more patterns using Boolean operators:

||	Or
&&	And
!	Not

For example, the pattern:

```
$1 >= "T" && $1 < "U" && $1 != "The"
```

finds lines that begin with T, and are not the word *The*.

Using Pattern Ranges

A pattern range allows the use of one pattern to begin an action on the lines of text, and another pattern to end the action on lines of text. Specify a pattern range by using two patterns separated by commas. The first pattern specifies the starting pattern; the second pattern specifies the ending pattern. Therefore, the line:

```
/The/,/End/  {action}
```

finds the first line that contains the pattern `The` and begins performing the `action` on all lines following it in the file until **awk** finds a line containing the pattern `End`. **Awk** does not change either the line containing `The` or the line containing `End`.

Similarly, the line:

```
NR==100,NR==200        {action}
```

performs the action starting at line 100 and ending at line 200 of the input file.

Using Functions in an Action

The **awk** program provides the following functions to use within an action:

length Returns the length of the current record.

length(arg) Returns the length of the string specified by **arg**.

sqrt(arg) Returns the square root of **arg**

log(arg) Returns the base e logarithm (natural logarithm) of **arg**.

exp(arg) Returns the exponential part of **arg**.

int(arg) Returns the integer part of **arg**.

substr(s,m,n) Returns a string that is part of string **s**, beginning at character **m** and continuing for **n** characters (or the end of string **s**). If **m** is 1, the string starts at the beginning of string **s**. If you do not supply a value for **n**, the string continues to the end of string **s**.

index(s1,s2) Returns the character position in string **s1** where string **s2** occurs. If **s2** is not in **s1**, this function returns a zero.

sprintf(f,e1,e2,...) Returns a formatted string. The parameters are:

f A formatting specification string defined using the formatting specifications of the **printf** library routine.

e1,e2,... A series of strings that the **f** format specification acts upon.

The function formats the argument strings (**e1, e2, ...**) using the format specification **f**, and returns the formatted string.

Using Variables in an Action

The **awk** program sets all variables in actions to zero when it begins executing the action. The variables do not have a strict type; they take on numeric (floating point) values or string values depending on their use in the action expression. For example, the expression:

```
x = 1
```

indicates that x is a numeric variable. Similarly, the expression:

```
x = "smith"
```

indicates that x is a string variable. However, **awk** converts between strings and numbers when needed. Therefore, the expression:

```
x = "3" + "4"
```

assigns a value of 7 (numeric) to x, even though the arguments are literal strings. If **awk** cannot change a string variable to numeric when you are using it as a numeric variable, **awk** assigns it a numeric value of zero. To force a variable to be treated as a single type:

string Add the null string (" ") to the value assigned to the variable

numeric Add zero (0) to the value assigned to the variable.

Using Operators in an Action

Use the following operators to build expressions within the action statement:

+	Addition
-	Subtraction
*	Multiplication
/	Division
%	Modulo (remaindering)
+	Increment
--	Decrement
+ =	Increment by value
- =	Decrement by value
* =	Multiply by value
/ =	Divide by value
% =	Modulo by value
~	Match string
!~	Not match string

For example, to find the sum of all the first fields and the sum of all the second fields in a file with the program file:

```
                {s1 +=$1; s2 += $2}
END             {print s1,s2}
```

Using Field Variables in an Action

Fields in **awk** share the same properties as variables. They can be used in arithmetic or string operations and may be assigned to a numeric or string value. For example, to replace the first field with a sequence number:

```
{$1 = NR;print}
```

To accumulate two fields into a third field:

```
{$1 = $2 + $3;print $0}
```

Use numeric expressions for field references, such as:

```
{print $i,$(i+1),$(i+n)}
```

How you use a field determines whether **awk** treats a field as numeric or string. If it cannot tell how the field is used, **awk** treats fields as strings.

awk splits input lines into fields as needed. You can also split any variable or string into fields. For example:

```
n = split(s,array,sep)
```

splits the string `s` into `array[1]...array[n]` and returns the number of elements. If you provide the `sep` argument, it is the field separator. If you do not provide `sep`, the field separator is the character defined by the variable **FS**.

Concatenating Strings

Concatenate strings by placing their variable names together in an expression. For example, the expression:

```
length($1 $2 $3)
```

Returns the length of the first three fields. The expression:

```
print $1 " is " $2
```

Prints the first two fields separated by " is ". You can use variables and numeric expressions when concatenating strings.

Using Arrays

You do not need to declare array elements. **awk** sets them to zero when first used. Use any value that is not null, including a string value, for a subscript. An example of the numeric subscript is:

```
x[NR] = $0
```

This expression assigns the current input record to the NRth element of the array x. For an example of using a string subscript, suppose that the input contains fields with values like apple or orange. Then the program:

```
/apple/         {x["apple"]++}
/orange/        {x["orange"]++}
END             {print x["apple"], x["orange"]}
```

increments counts for the named array elements and prints them at the end of the input.

Using Control Statements

The **awk** language also provides the following control structures as in the C language:

- If-else
- While
- For
- Break
- Continue
- Next
- Exit
- Braces for statement grouping
- Comments.

If-Else Statement

The **if-else** statement is exactly like that of the C language. The condition in parentheses of an **if-else** statement is evaluated; if it is true, the statement following the **if** is performed. The **else** part is optional.

While Statement

The **while** statement is exactly like that of the C language. For example, to print all input fields, one on each line, use the following program:

```
i = 1
while(i<=NF)
{
        print $i
        ++i
}
```

For Statement

The **for** statement is also like that of the C language. For example, the previous **while** example could also be written:

```
for(i=1;i<=NF;++i)
        print $i
```

Break Statement

The **break** statement causes an immediate exit from an enclosing **while** or **for** loop.

Continue Statement

The **continue** statement causes the next iteration of an enclosing loop to begin.

Next Statement

The **next** statement causes **awk** to skip to the next input record and begin scanning the patterns from the top of the program file.

Exit Statement

The **exit** statement causes the program to stop as if the end of the input occurred.

Comments

Include comments in the **awk** program file to explain program logic. Comments begin with the # character and end with the end of the line. For example:

```
print x,y        #this is a comment
```

Editing Files with sed

The **sed** program is a text editor that has similar functions to those of **ed**, the line editor. Unlike **ed**, however, the **sed** program performs its editing without interacting with the person requesting the editing. This method of operation allows **sed** to:

- Edit very large files
- Perform complex editing operations many times without requiring extensive retyping and cursor positioning (as interactive editors do)
- Perform global changes in one pass through the input.

The editor keeps only a few lines of the file being edited in memory at one time, and does not use temporary files. Therefore, the file to be edited can be any size as long as there is room for both the input file and the output file in the file system.

Starting the Editor

To use the editor, create a command file containing the editing commands to perform on the input file. The editing commands perform complex operations and require a small amount of typing in the command file. Each command in the command file must be on a separate line. Once the command file is created, enter the following command on the command line:

`sed -f`*cmdfile* `>`*output* `<`*input*

In this command the parameters mean:

cmdfile The name of the file containing editing commands.

output The name of the file to contain the edited output.

input The name of the file, or files, to be edited.

The **sed** program then makes the changes and writes the changed information to the output file. The contents of the input file are not changed.

How sed Works

The **sed** program is a stream editor that receives its input from standard input, changes that input as directed by commands in a command file, and writes the resulting stream to standard output. If you do not provide a command file and do not use any flags with the **sed** command, the **sed** program copies standard input to standard output without change. Input to the program comes from two sources:

Input stream A stream of ASCII characters either from one or more files or entered directly from the keyboard. This stream is the data to be edited.

Commands A set of addresses and associated commands to be performed, in the general form of:

```
[line1 [,line2] ] command [argument]
```

The parameters `line1` and `line2` are called ***addresses***. Addresses can be either patterns to match in the input stream, or line numbers in the input stream as explained in "Selecting Lines for Editing" on page 11-23.

You can also enter editing commands along with the **sed** command by using the **-e** flag.

When **sed** edits, it reads the input stream one line at a time into an area in memory called the ***pattern space*** as shown in Figure 11-3 on page 11-22. When a line of data is in the pattern space, **sed** reads the command file and tries to match the addresses in the command file with characters in the pattern space. If it finds an address that matches something in the pattern space, **sed** then performs the command associated with that address on the part of the pattern space that matched the address. The result of that command changes the contents of the pattern space, and thus becomes the input for all following commands.

When **sed** has tried to match all addresses in the command file with the contents of the pattern space, it writes the final contents of the pattern space to standard output. Then it reads a new input line from standard input, and starts the process over at the start of the command file.

Some editing commands change the way the process operates. See the **Control** commands in Figure 11-6 on page 11-26.

Flags used with the **sed** command can also change the operation of the command as shown in Figure 11-2 on page 11-22.

Flag	Function
-n	**sed** does not copy all input lines to standard output. Instead, it copies only those lines that editing commands specifically write to standard output. See the **print lines** and **substitution** commands in Figure 11-6 on page 11-26.
-e	**sed** uses the argument that directly follows this flag as an editing command.
-f	**sed** uses the argument that directly follows this flag as the name of the file containing the editing commands. This file must contain editing commands with each command on a separate line.

Figure 11-2. sed Command Flags

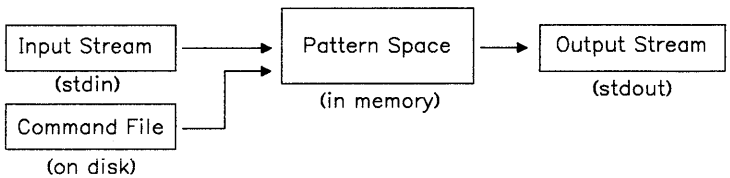


Figure 11-3. sed Block Diagram

Selecting Lines for Editing

Use one of the following forms of addressing to select lines in the input stream for editing:

Line numbers As the editor reads each input line, it increments its line counter starting with line 1 as the first line of the first file in the input stream. The line counter runs cumulatively through all files in the input stream. The editor does not reset the counter when it opens a new file in the same input stream. The value of the line counter for each line is the ***line number*** for that line.

Specifying a decimal integer as either `line1` or `line2` in the editing commands indicates the line number of the line to be edited. The character **$** matches the last line of the last file in the input stream.

Context addresses A context address is a ***regular expression*** enclosed in / (slashes). See "Regular Expressions" for a description of the regular expressions that **sed** recognizes. The whole regular expression must match some part of the pattern space for a successful context address match.

Editing commands can have zero, one, or two addresses, depending on the command and how you use it. The number of addresses determines how the address is used:

Addresses	Use of Command
No address	The command is applied to every line in the input stream.
One address	The command is applied to each line that matches the address.
Two addresses	The command is applied to the range of addresses starting with the line that matches the first address up to and including the first line that matches the second address. The editor then tries to match the first address again to find another range. Separate two addresses with a comma as shown in the syntax diagrams in Figure 11-6 on page 11-26.

Regular Expressions

A regular expression is a string that contains literal characters, wildcard characters and/or operators that define a set of one or more possible strings. The stream editor uses a set of wildcard characters that is different from the shell wildcards, but the same as the line editor, **ed**. These wildcard characters and operators are shown in Figure 11-4 on page 11-24.

Symbol	Function
.	A period specifies any character except new-line.
^	A caret specifies the beginning of the line when it is the first character in a regular expression.
$	A dollar sign specifies the end of the line when it is the last character in a regular expression.
[ ]	Square brackets enclose a set of characters (not empty) that represents any **one** of the characters in the set. If the first character inside the brackets is a ^ (caret), the regular expression matches any character *except* the characters in the set and the new-line at the end of the pattern space. **[abc]** Represents either a or b or c :dt[a-c] Is the same as [abc]. The hyphen defines a range of ASCII values that starts with the value of the first letter and ends with the value of the second letter. **[A-z]** Defines more than just the letters of the alphabet. It defines the range of ASCII values from A (065) to z (122).
\n	A new-line character matches a new-line character that is not the new-line character at the end of the pattern space.
*	A regular expression followed by an asterisk matches any number (including 0) of adjacent occurrences of that regular expression.
\(and \)	A set of backslash-parentheses enclose a regular expression that can be repeated using the \d expression.
\d	**d** is a single digit. This symbol in *string* is replaced by the set of characters in the input lines that matches the dth substring in *pattern*. Substrings begin with the characters \(and end with the characters \). See "String Replacement" on page 11-31 for more information about using this expression.
//	The null string is the same as the last regular expression in the edit stream.
\	A backslash tells **sed** to treat the next character as a regular ASCII character instead of a symbol that **sed** treats as a special character.

Figure 11-4. sed Wildcard Characters

Refer to the **ed** program in *AIX Operating System Commands Reference* for details for building regular expressions.

sed Command Summary

All **sed** commands are single letters plus some parameters, such as line numbers or text strings. Figure 11-6 on page 11-26 summarizes the commands that make changes to the lines in the pattern space. The table uses the symbols shown in Figure 11-5 in the syntax diagrams:

Symbol	Meaning
[ ]	Square brackets enclose optional parts of the commands
italics	Parameters in italics represent general names for a name that you enter. For example, *filename* represents a parameter that you replace with the name of an actual file.
line1	This symbol is a line number or regular expression to match that defines the starting point for applying the editing command.
line2	This symbol is a line number or regular expression to match that defines the ending point to stop applying the editing command.

Figure 11-5. Syntax Symbols

Category	Function	Syntax/Description
Line Manipulation:	Append lines	[*line1*]a\\n*text* Writes the lines contained in *text* to the output stream after *line1*. The *a* command must appear at the end of a line. See "Text in Commands" on page 11-30 for the format of the *text*.
	Change lines	[*line1* [,*line2*]]c\\n*text* Deletes the lines specified by *line1* and *line2* as the **delete lines** command does. Then it writes *text* to the output stream in place of the deleted lines.
	Delete lines	[*line1* [,*line2*]]d Removes lines from the input stream and does not copy them to the output stream. The lines not copied begin at line number *line1*. The next line copied to the output stream is line number *line2* + *1*. If you specify only one line number, then only that line is not copied. If you do not specify a line number, the next line is not copied. You cannot perform any other functions on lines that are not copied to the output.
	Insert lines	[*line1*]i\\n*text* Writes the lines contained in *text* to the output stream before *line1*. The i command must appear at the end of a line. See "Text in Commands" on page 11-30 for the format of the *text*.
	Next line	[*line1* [,*line2*]]n Reads the next line, or group of lines from *line1* to *line2* into the pattern space. The current contents of the pattern space are written to the output if it has not been deleted.

Figure 11-6 (Part 1 of 5). sed Command Summary

Category	Function	Syntax/Description
Substitution:	Substitute for Pattern	[*line1* [,*line2*]]s/*pattern*/*string*/*flags* Searches the indicated line(s) for a set of characters that matches the regular expression defined in *pattern*. When it finds a match, the command replaces that set of characters with the set of characters specified by *string*. See "String Replacement" on page 11-31 for specifications for this command.
Input and Output:	Print lines	[*line1* [,*line2*]]p Writes the indicated lines to **stdout** at the point in the editing process that the **p** command occurs.
	Write lines	[*line1* [,*line2*]]w *filename* Writes the indicated lines to *filename* at the point in the editing process that the **w** command occurs. If *filename* exists, it is overwritten; otherwise, it is created. A maximum of 10 different files can be mentioned as input or output files in the entire editing process. Include exactly one space between **w** and *filename*.
	Read file	[*line1*]r *filename* Reads *filename* and appends the contents after the line indicated by *line1*. Inclued exactly one space between **r** and *filename*. If *filename* cannot be opened, the command reads it as a null file without giving any indication of an error.
Matching Across Lines:	Join next line	[*line1* [,*line2*]]N Joins the indicated input lines together, separating them by an imbedded new-line character. Pattern matches can extend across the imbedded new-line(s).

Figure 11-6 (Part 2 of 5). sed Command Summary

Category	Function	Syntax/Description
	Delete first line of pattern space	[*line1* [,*line2*]]D Deletes all text in the pattern space up to and including the first new-line character. If only one line is in the pattern space, reads another line. Starts the list of editing commands again from the beginning.
	Print first line of pattern space	[*line1* [,*line2*]]P Prints all text in the pattern space up to and including the first new-line character to **stdout**.
Pick up and Put down:	Pick up copy	[*line1* [,*line2*]]h Copies the contents of the pattern space indicated by *line1* and *line2* if present, to the holding area. The previous contents of the holding area are destroyed.
	Pick up copy, appended	[*line1* [,*line2*]]H Copies the contents of the pattern space indicated by *line1* and *line2* if present, to the holding area, and appends it to the end of the previous contents of the holding area.
	Put down copy	[*line1* [,*line2*]]g Copies the contents of the holding area to the pattern space indicated by *line1* and *line2* if present. The previous contents of the pattern space are destroyed.
	Put down copy, appended	[*line1* [,*line2*]]G Copies the contents of the holding area to the end of the pattern space indicated by *line1* and *line2* if present. The previous contents of the pattern space are not changed. A new-line character separates the previous contents from the appended text.

Figure 11-6 (Part 3 of 5). sed Command Summary

Category	Function	Syntax/Description
	Exchange copies	[*line1* [,*line2*]]x Exchanges the contents of the holding area with the contents of the pattern space indicated by *line1* and *line2* if present.
Control:	Negation	[*line1* [,*line2*]]! The ! (exclamation point) applies the command that follows it on the same line to the parts of the input file that are *not* selected by *line1* and *line2*.

	Command groups	[*line1* [,*line2*]]{
		grouped commands
		}
		
		The { (left brace) and the } (right brace) enclose a set of commands to be applied as a set to the input lines selected by *line1* and *line2*. The first command in the set can be on the same line or on the line following the left brace. The right brace must be on a line by itself. You can nest groups within groups.

	Labels	:*label* Marks a place in the stream of editing commands to be used as a destination of a branch (see the **b** and **t** commands). The symbol *label* is a string of up to 8 characters. Each *label* in the editing stream must be different from any other *label*.
	Branch to label, unconditional	[*line1* [,*line2*]]b*label* Branches to the point in the editing stream indicated by *label* (see **:label** above) and continues processing the current input line with the commands following *label*. If *label* is null, branches to the end of the editing stream, which results in reading a new input line and starting the editing stream over. The string *label* must appear as a label in the editing stream.

Figure 11-6 (Part 4 of 5). sed Command Summary

Category	Function	Syntax/Description
	Test and Branch	[*line1* [,*line2*]]t*label* If any successful substitutions were made on the current input line, branches to *label*. If no substitutions were made, does nothing. Clears the flag that indicates a substitution was made. This flag is cleared at the start of each new input line.
	Quit	[*line1*]q Stops editing in an orderly fashion by: • Writing the current line to the output • Writing any appended or read text to the output • Stopping the editor.
	Find line number	[*line1*]= Writes to standard output the line number of the line that matches *line1*.

Figure 11-6 (Part 5 of 5). sed Command Summary

Text in Commands

The **append**, **insert** and **change** lines commands all use a supplied text string to add to the output stream. This text string conforms to the following rules:

- Can be one or more lines long,
- Each \n (new-line character) inside *text* must have an additional \ character before it (\\n).
- The *text* string ends with a new-line that does not have an additional \ character before it (\n).
- Once the command inserts the *text* string, the string:
  - Is always written to the output stream, regardless of what other commands do to the line that caused it to be inserted.
  - Is not scanned for address matches.
  - Is not affected by other editing commands.
  - Does not affect the line number counter.

String Replacement

The **s** command performs string replacement in the indicated lines in the input file. If the command finds a set of characters in the input file that satisfies the regular expression *pattern*, it replaces the set of characters with the set of characters specified in *string*.

The *string* parameter is a literal set of characters (digits, letters and symbols). Two special symbols can be used in *string*:

& This symbol in *string* is replaced by the set of characters in the input lines that matched *pattern*. For example, the command:

```
s/boy/&s/
```

tells **sed** to find a pattern `boy` in the input line, and copy that pattern to the output with an appended `s`. Therefore, it changes the input line:

```
From: The boy look at the game.
To:   The boys look at the game.
```

\d **d** is a single digit. This symbol in *string* is replaced by the set of characters in the input lines that matches the `d`th substring in *pattern*. Substrings begin with the characters `\(` and end with the characters `\)`. For example, the command:

```
s/\(stu\)\(dy\)/\1r\2/
```

tells **sed** to find a pattern `study` in the input line, and copy that pattern to the output with an `r` inserted in the middle. Therefore, it changes the input line:

```
From: The study chair
To:   The sturdy chair
```

The letters that appear as flags change the replacement as follows,

g Substitute *string* for all instances of *pattern* in the indicated line(s). Characters in *string* are not scanned for a match of *pattern* after they are inserted. For example, the command:

```
s/r/R/
```

changes:

From: the round rock
To: the Round rock

But, the command:

```
s/r/R/g
```

changes:

From: the round rock
To: the Round Rock

p Print (to **stdout**) the line that contains a successfully matched *pattern.*

w *filename* Write to *filename* the line that contains a successfully matched *pattern.* If *filename* exists, it is overwritten; otherwise, it is created. A maximum of 10 different files can be mentioned as input or output files in the entire editing process. Include exactly one space between **w** and *filename.*

Chapter 12. Using the Macro Processor (m4)

CONTENTS

About This Chapter

The **m4** macro processor is a front-end processor for a compiled (or assembled) programming language. The **#define** statement in C language is an example of the facility provided by the macro processor.

At the beginning of a program, you can define a symbolic name or symbolic constant as a particular string of characters. The **m4** macro processor then replaces later unquoted occurrences of the symbolic name with the corresponding string. Besides replacing one string of text with another, the **m4** macro processor provides the following features:

- Arithmetic capabilities
- File manipulation
- Conditional macro expansion
- String and substring functions.

A ***token*** is a string of letters and digits. The **m4** program reads each alphanumeric token and determines if the token is the name of a macro. It then replaces the name of the macro with its defining text, and pushes the resulting string back onto the input to be rescanned. You can call macros with arguments, in which case the arguments are collected and substituted into the right places in the defining text before the defining text is rescanned.

The **m4** program provides built-in macros; you can also define new macros. Built-in and user-defined macros work the same way except that some of the built-in macros change the state of the process. Refer to "Using Other m4 Macros" on page 12-8 for a list of the macros.

Using the Macro Preprocessor

To use the **m4** macro processor, enter the following command:

```
m4 [file]
```

The **m4** program processes each argument in order. If there are no arguments or if an argument is −, **m4** reads standard input as its input file. The **m4** program writes its results to standard output. Therefore, to redirect the output to a file for later use, use a command like:

```
m4 [file] >outputfile
```

Defining Macros

The **define** macro is a built-in function that defines macros. For example, if the following statement is in a program:

```
define(name, stuff)
```

the **m4** program defines the string `name` as `stuff`. When the string `name` occurs in a program file, **m4** replaces it with the string `stuff`. The string `name` must be alphanumeric and must begin with a letter or underscore. The string `stuff` is any text, but if the text contains parentheses the number of open, or left, parentheses must equal the number of close, or right, parentheses. Use the / slash character to spread the text for `stuff` over multiple lines. The open parenthesis must immediately follow the word **define**. For example:

```
define(N, 100)
  . . .
if (i > N)
```

defines `N` to be 100 and uses the symbolic constant `N` in a later **if** statement. Macro calls in a program have the following form:

```
name(arg1,arg2, . . . argn)
```

A macro name is only recognized if it is surrounded by nonalphanumerics. Using the following example:

```
define(N, 100)
  . . .
if (NNN > 100)
```

the variable `NNN` is not related to the defined macro `N`.

You can define macros in terms of other names. For example:

```
define(N, 100)
define(M, N)
```

defines both `M` and `N` to be 100. If you later change the definition of `N` and assign it a new value, `M` retains the value of 100, not `N`.

The **m4** macro processor expands macro names into their defining text as soon as possible. The string N is replaced by 100. Then the string M is also replaced by 100. The overall result is the same as using the following input in the first place:

```
define(M, 100)
```

The order of the definitions can be interchanged as follows:

```
define(M, N)
define(N, 100)
```

Now M is defined to be the string N, so when the value of M is requested later, the result is the value of N at that time (because the M is replaced by N, which is replaced by 100).

Using the Quote Characters

To delay the expansion of the arguments of **define**, enclose them in the ***quote*** characters. If you do not change them, the ***quote*** characters are left and right single quotes (‘ ’). See "Changing the Quote Characters" on page 12-10 to change these characters. Any text surrounded by the quote characters is not expanded immediately, but the quote characters are removed. The value of a quoted string is the string with the quote characters removed. If the input is:

```
define(N, 100)
define(M, 'N')
```

The quote characters around the N are removed as the argument is being collected. The result of using quote characters is to define M as the string N, not 100. The general rule is that **m4** always strips off one level of quote characters whenever it evaluates something. This is true even outside of macros. To make the word `define` appear in the output, enter the word in quote characters, as follows:

```
'define' = 1;
```

Another example of using quote characters is redefining N. To redefine N, delay the evaluation by putting N in quote characters. For example:

```
define(N, 100)
  . . .
define('N', 200)
```

To prevent problems from occurring, quote the first argument of a macro. For example, the following fragment does not redefine N:

```
define(N, 100)
  . . .
define(N, 200)
```

The N in the second definition is replaced by 100. The result is the same as the following statement:

```
define(100, 200)
```

The **m4** program ignores this statement because it can only define names, not numbers.

Arguments

The simplest form of macro processing is replacing one string by another (fixed) string. However, macros can also have arguments, so that you can use the macro in different places with different results. To indicate where an argument is to be used within the replacement text for a macro (the second argument of its definition), use the symbol **$***n* to indicate the nth argument. When the macro is used, **m4** replaces the symbol with the value of the indicated argument. For example, the symbol:

```
$2
```

refers to the second argument of a macro. Therefore, if you define a macro called bump as:

```
define(bump, $1 = $1 + 1)
```

m4 generates code to increment the first argument by 1. The `bump(x)` statement is equivalent to `x = x + 1`.

A macro can have as many arguments as needed. However, you can access only nine arguments using the **$***n* symbol ($1 through $9). To access arguments past the ninth argument, use the **shift** macro which drops the first argument and reassigns the remaining arguments to the **$***n* symbols (second argument to $1, third argument to $2 ... tenth argument to $9). Using the **shift** macro more than once allows access to all arguments used with the macro.

The macro name **$0** returns the name of the macro. Arguments that are not supplied are replaced by null strings, so that you can define a macro that concatenates its arguments like this:

```
define(cat, $1$2$3$4$5$6$7$8$9)
```

Thus:

```
cat(x, y, z)
```

is the same as:

```
xyz
```

Arguments $4 through $9 in this example are null since corresponding arguments were not provided.

The **m4** program discards leading unquoted blanks, tabs, or new lines in arguments, but keeps all other white space. Thus:

```
define(a, b c)
```

defines `a` to be `b c`.

Arguments are separated by commas. Use parentheses to enclose arguments containing commas, so that the comma does not end the argument. For example:

```
define(a, (b,c))
```

has only two arguments. The first argument is `a`. The second is `(b,c)`. To use a comma or single parenthesis, enclose it in quote characters.

Using Other m4 Macros

The **m4** program provides a set of macros that are already defined. The **define** macro already mentioned is one of them. Figure 12-1 lists each of these macros and provides a brief explanation of its function. The following paragraphs further explain many of the macros and how to use them.

Macro	Function
changecom(*l* , *r*)	Changes the left and right comment characters to the characters represented by *l* and *r*.
changequote(*l* , *r*)	Changes the left and right quote characters to the characters represented by *l* and *r*.
decr(*number*)	Returns the value of *number* - 1.
define(*macroname* , *replacement*)	Defines new macro *macroname* with a value of *replacement*.
defn(*macroname*)	Returns the quoted definition of *macroname*.
divert(*number*)	Changes output stream to *number*.
divnum	Returns the value of the current output stream.
dnl	Delete characters up to and including new-line.
dumpdef('*macroname*'...)	Prints the *macroname* and current definition of named macros.
errprint(*string*)	Prints *string* to the diagnostic output file.
eval(*expression*)	Evaluates *expression* as a 32-bit arithmetic expression.
ifdef('*macroname*' , *arg1* , *arg2*)	If macro *macroname* is defined, returns *arg1*; otherwise, it returns *arg2*.

Figure 12-1 (Part 1 of 3). m4 Built-in Macros

Macro	Function
ifelse(*string1* , *string2* , *arg1* , *arg2*)	If *string1* matches *string2*, returns the value of *arg1*; otherwise, returns the value of *arg2*.
include(*file*)	Returns the contents of the file *file*.
incr(*number*)	Returns the value of *number* + 1.
index(*string1* , *string2*)	Returns the character position in *string1* where *string2* starts (starting with character number 0), or -1 if *string1* does not contain *string2*.
len(*string*)	Returns the number of characters in *string*.
m4exit(*code*)	Exits **m4** with a return code of *code*.
m4wrap(*macroname*)	Runs macro *macroname* at the end of **m4**.
maketemp(*string...XXXXX...string*)	Creates a unique file name by replacing the characters *XXXXX* in the argument string with the current process ID.
popdef(*macroname*)	Removes the definition of *macroname* and then defines *macroname* to be its previous value that was saved with the **pushdef** macro.
pushdef(*macroname* , *replacement*)	Saves the current definition of *macroname* and then defines *macroname* to be *replacement*.
shift(*parameter list*)	Returns all but the first element of *parameter list* to perform a destructive left shift of the list.
sinclude(*file*)	Returns the contents of the file *file*, but does not report an error if it cannot access *file*.
substr(*string* , *position* , *length*)	Returns a substring of *string* that begins at character number *position* and is *length* characters long.

Figure 12-1 (Part 2 of 3). m4 Built-in Macros

Macro	Function
syscmd(*command*)	Executes the system command *command* with no return value.
sysval	Gets the return code from the last use of the **syscmd** macro.
traceoff(*macro list*)	Turns off trace for any macro in *macro list.* If *macro list* is null, turns off all tracing.
traceon(*macroname*)	Turns on trace for macro *macroname.* If *macroname* is null, turns trace on for all macros.
translit(*string* , *set1* , *set2*)	Searches *string* for characters that are in *set1.* If it finds any, changes those characters to corresponding characters in *set2.*
undefine('*macroname*')	Removes the definition of *macroname.*
undivert(*number* , *number...*)	Appends the contents of the indicated diversion numbers to the current diversion.

Figure 12-1 (Part 3 of 3). m4 Built-in Macros

Changing the Quote Characters

Quote characters are normally left and right single quotes (‘ ’). If those characters are not convenient, change the quote characters with the following built-in macro:

```
changequote([,])
```

The built-in **changequote** makes the left and right brackets the new quote characters. To restore the original quote characters, use **changequote** without arguments as follows:

```
changequote
```

Removing a Macro Definition

The **undefine** macro removes the definition of some macro or built-in. For example:

```
undefine('N')
```

The macro removes the definition of N. **undefine** can also remove built-ins, as follows:

```
undefine('define')
```

Once you remove a built-in macro, you cannot use the definition of the built-in again.

Checking for A Defined Macro

The built-in **ifdef** determines if a macro is currently defined. The **ifdef** macro permits three arguments. If the first argument is defined, the value of **ifdef** is the second argument. If the first argument is not defined, the value of **ifdef** is the third argument. If there is no third argument, the value of **ifdef** is null. If the first argument is undefined, the value of **ifdef** is the third argument.

Using Integer Arithmetic

The **m4** program provides the following built-in functions for doing arithmetic on integers only:

incr Increments its numeric argument by 1

decr Decrements its numeric argument by 1

eval Evaluates an arithmetic expression

Thus, to define a variable as one more than N, use the following:

```
define(N, 100)
define(N1, 'incr(N)')
```

which defines N1 as one more than the current value of N.

The **eval** function can evaluate expressions containing the following operators (listed in decreasing order of precedence):

unary + and −

** or ^ (exponentiation)

* / % (modulus)

+ −

= = != < <= > >=

!(not)

& or && (logical and)

| or || (logical or).

Use parentheses to group operations where needed. All operands of an expression must be numeric. The numeric value of a true relation (like 1 > 0) is 1, and false is 0. The precision in eval is 32 bits.

For example, define M to be 2==N+1 using eval as follows:

```
define(N, 3)
define(M, 'eval(2==N+1)')
```

Use quote characters around the text that defines a macro unless the text is very simple.

Manipulating Files

To merge a new file in the input, use the built-in function: **include**. For example:

`include(`*filename*`)`

This function inserts the contents of *filename* in place of the include command.

A fatal error occurs if the file named in **include** cannot be accessed. To avoid a fatal error, use the alternate form **sinclude**. The built-in **sinclude** (silent include) does not write a message, but continues if the file named cannot be accessed.

Redirecting Output

The output of **m4** can be redirected to temporary files during processing, and the collected material can be output upon command. The **m4** program maintains nine possible temporary files, numbered 1 through 9. If you use the built-in macro:

`divert(n)`

The **m4** program writes all output from the program after the **divert** function at the end of temporary file, `n`. To return the output to the display screen, use either the **divert** or **divert(0)** command, which resumes the normal output process.

The **m4** program writes all redirected output to the temporary files in numerical order at the end of processing. The **m4** program discards the output if you redirect the output to a temporary file other than 0 through 9.

To bring back the data from all temporary files in numerical order, use the built-in **undivert**. To bring back selected temporary files in a specified order, use the built-in **undivert** with arguments. When using **undivert**, **m4** discards the temporary files that are recovered and does not search the recovered data for macros.

The value of undivert is *not* the diverted text.

The built-in **divnum** returns the number of the currently active temporary files. If you do not change the output file with the **divert** macro, **m4** puts all output in temporary file 0.

Using System Programs in A Program

You can run any program in the operating system from a program by using the **syscmd** built-in. For example, the following statement runs the **date** program:

```
syscmd(date)
```

Using Unique File Names

Use the built-in **maketemp** to make a unique file name from a program. If this macro receives an argument that contains the string XXXXX, it changes the XXXXX to the process ID of the current process. For example, for the statement:

```
maketemp(myfileXXXXX)
```

the **m4** program returns a string that is `myfile` concatenated with the process ID. Use this string to name a temporary file.

Using Conditional Expressions

The built-in **ifelse** performs conditional testing. In the simplest form:

```
ifelse(a, b, c, d)
```

compares the two strings a and b. If a and b are identical, **ifelse** returns the string c. If they are not identical, it returns string d. For example, you can define a macro called **compare** to compare two strings and return yes if they are the same, or no if they are different, as follows:

```
define(compare, 'ifelse($1, $2, yes, no)')
```

The quote characters prevent the evaluation of ifelse from occurring too early. If the fourth argument is missing, it is treated as empty.

The built-in **ifelse** can have any number of arguments, and therefore, provides a limited form of multiple path decision capability. For example:

```
ifelse(a, b, c, d, e, f, g)
```

This statement is logically the same as the following fragment:

```
if(a == b) x = c;
else if(d == e) x = f;
else  x = g;
return(x);
```

If the final argument is omitted, the result is null, so:

```
ifelse(a, b, c)
```

is c if a matches b, and null otherwise.

Manipulating Strings

The built-in **len** returns the length of the string (number of characters) that makes up its argument. Thus:

```
len(abcdef)
```

is 6, and:

```
len((a,b))
```

is 5.

The built-in **substr** provides substrings of strings. Using input, **substr(*s*, *i*, *n*)** returns the substring of *s* that starts at the *i*th position (origin zero) and is *n* characters long. If *n* is omitted, the rest of the string is returned. For example, the function:

```
substr('now is the time',1)
```

returns the following string:

```
ow is the time
```

The built-in **index(s1, s2)** returns the index (position) in **s1** where the string **s2** occurs, or -1 if it does not occur. As with **substr**, the origin for strings is 0.

The built-in **translit** performs character transliteration. It has the general form:

```
translit(s, f, t)
```

which modifies `s` by replacing any character found in `f` by the corresponding character of `t`. For example, the function:

```
translit(s, aeiou, 12345)
```

replaces the vowels by the corresponding digits. If `t` is shorter than `f`, characters that do not have an entry in `t` are deleted. If `t` is not present at all, characters from `f` are deleted from `s`. So:

```
translit(s, aeiou)
```

deletes vowels from string `s`.

The built-in **dnl** deletes all characters that follow it up to and including the next new line. Use this macro to get rid of empty lines. For example, the function:

```
define(N, 100)
define(M, 200)
define(L, 300)
```

results in a new-line at the end of each line that is not part of the definition. These new-line characters are passed to the output. To get rid of the new-lines, add the built-in **dnl** to each of the lines.

```
define(N, 100) dnl
define(M, 200) dnl
define(L, 300) dnl
```

Printing

The built-in **errprint** writes its arguments on the standard error file. For example:

```
errprint ('error')
```

The built-in **dumpdef** dumps the current names and definitions of items named as arguments. If you do not supply arguments, **dumpdef** prints all current names and definitions. Do not forget to quote the names.

Chapter 13. Creating an Input Language

CONTENTS

About This Chapter

If a program needs to receive input, either interactively or in a batch environment, you must provide a program or routine to receive the input. If the input is complicated, it may require additional code to break the input into pieces that mean something to the program. This section describes two programs that help develop these input programs.

First this chapter describes **lex**, a program that generates a program from a set of rules. The **lex** program generates a program, called a ***lexical analyzer***, that analyzes input and breaks it into categories, such as: numbers, letters or operators. Define the categories in the input to **lex**.

Next the chapter describes the **yacc** program. This program also generates a program from a set of rules. However, the program that **yacc** generates is a ***parser*** program. A parser is a program that analyzes input, using the categories that the lexical analyzer identified, and determines what to do with the input.

Finally, this chapter includes an example of a **lex** and a **yacc** program that together generate a third program, a simple desk calculator.

Writing a Lexical Analyzer Program with lex

The **lex** program helps write a C language program that can receive a character stream input and translate that input into program actions. To use the **lex** program, write a specification file that contains the following parts:

Regular expressions
: Character patterns that the generated lexical analyzer recognizes

Action statements
: C language program fragments that define how the generated lexical analyzer reacts to regular expressions that it recognizes.

The actual format and logic allowed in this file is discussed in "The lex Specification File" on page 13-6.

What lex Does

Using the information in the specification file, the **lex** program generates a C language program to analyze an input stream according to the specifications. The **lex** program puts the output program in a file called **yy.lex.c**. If the output program recognizes a simple one-word input structure, compile the **yy.lex.c** output file using the command:

```
cc -ll yy.lex.c
```

to get an executable lexical analyzer. However, if the lexical analyzer recognizes more than one-word syntax, create a parser to ensure proper handling of the input (see "Creating a Parser with yacc" on page 13-25).

The **yy.lex.c** output file can be moved to other systems that have a C compiler that supports the **lex** library functions.

The compiled lexical analyzer performs the following functions:

- Reads an input stream of characters
- Copies the input stream to an output stream
- Breaks the input stream into smaller strings that match the regular expressions in the **lex** specification file
- Executes an action for each regular expression that it recognizes. The action(s) are C language program fragments in the **lex** specification file. The action fragments can call actions or subroutines outside of the action fragment.

How the Lexical Analyzer Works

The lexical analyzer that **lex** generates uses an analysis method called a ***deterministic finite-state automaton***. This method provides for a limited number of conditions that the lexical analyzer can exist in, along with the rules that determine what state the lexical analyzer is in.

For a simple example, Figure 13-1 shows a chart of a program that has three states: start, good and bad. The program gets a stream of characters for input. It begins in the `start` condition. When it receives the first character, the program compares the character with the rule. If the character is alphabetic (according to the rule), the program changes to the `good` state; if it is not alphabetic, the program changes to the `bad` state. The program stays in `good` until it finds a character that does not match its conditions, and then it moves to `bad` (which terminates the program).

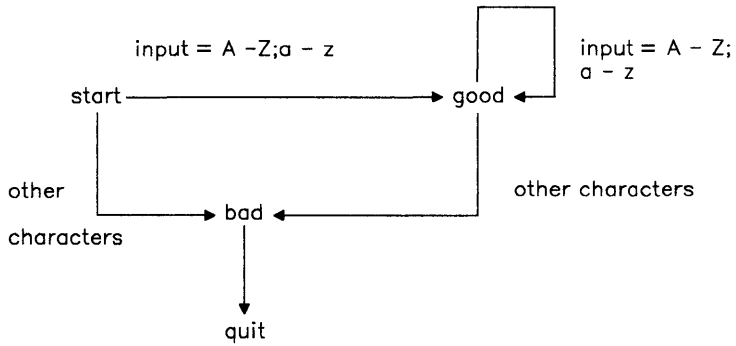


Figure 13-1. Simple Finite State Model

The automaton allows the generated lexical analyzer to look ahead in an input stream more than one or two characters. For example, define two rules in the **lex** specification file, one that looks for the string `ab` and the other that looks for the string `abcdefg`. If the lexical analyzer gets an input string of `abcdefh`, it reads characters to the end of string `abcdefg` before finding that the input string does not match the string `abcdefg`. The lexical analyzer then returns to the rule that looks for the string `ab`, decides that it matches part of the input, and begins trying to find another match using the remaining input `cdefh`.

The lex Specification File

The format of the **lex** specification file is:

```
{definitions}
% %
{rules}
% %
{user subroutines}
```

You can omit the definitions and the user subroutines. The second % % is optional, but the first % % is required to mark the beginning of the rules. The minimum **lex** specification file contains no definitions and no rules:

```
% %
```

Without a specified action for a pattern match, the lexical analyzer copies the input pattern to the output without changing it. Therefore, the previous specification file results in a lexical analyzer that copies all input to the output unchanged.

Rules

The rules section of the specification file contains control decisions that define the lexical analyzer that **lex** generates. The rules are in the form of a table. The left column of the table contains regular expressions; the right column of the table contains ***actions***. Actions are C language program fragments. When the lexical analyzer finds a match for the regular expression that appears in the left column of the table, the lexical analyzer executes the action.

For example, to create a lexical analyzer to look for the string `integer` and print a message when the lexical analyzer finds the string, define a rule:

```
integer      printf("found keyword int");
```

This example uses the C language library function **printf** to print the string. The first blank or tab character in the action indicates the end of the expression. When using only one expression in an action, put it on the same line and to the right of the regular expression (`integer`). When using more than one statement, or if the statement takes more than one line, enclose the action in braces, the same as in a C language program.

For another example, a lexical analyzer to change some words in a file from British spelling to the American spelling has a specification file that contains rules such as:

```
colour                          printf("color");
mechanise                       printf("mechanize");
petrol                          printf("gas");
```

This specification file is not complete because it changes the word `petroleum` to `gaseum`.

Regular Expressions

Specifying ***regular expressions*** in a **lex** specification file is similar to methods used in **sed** or **ed**. A regular expression specifies a set of strings to be matched. It contains text characters and operator characters. Text characters match the corresponding characters in the strings being compared. Operator characters specify repetitions, choices, and other features.

The letters of the alphabet and the digits are always text characters. For example, the regular expression `integer` matches the string `integer`, and the expression `a57D` looks for the string `a57D`.

Operators

The operator characters for specifying a regular expression are:

Symbol	Use
"	Encloses literal strings to interpret as text characters
\	(Escape character). Indicates that the operator symbol represents the character rather than the operator when used before one of the character class operators. For example, `[\^abc]` represents the class of characters that includes the characters `^abc`.
[ ]	Encloses character classes.
^	In a character class, indicates the complement of the set of characters when the `^` is the first character in a set of characters. For example, `[^abc]` matches all characters except `a`, `b` or `c`, including all special or control characters. Similarly, `[^a-zA-Z]` is any character that is not a letter. In an expression, indicates a match only when the expression is at the beginning of the line when the `^` is the first character in an expression.

Figure 13-2 (Part 1 of 3). Regular Expression Operators

Symbol	Use
−	In a character class, indicates a range of characters from the ASCII value of the character that comes before the − to the ASCII value of the character that follows the −. For example, `[a-z0-9]` indicates the character class containing all the lowercase letters and the digits. A range can be either in ascending or descending order, but the order is that of the ASCII values of the characters for RT PC. If the program is moved to a system that uses a different set of character codes (like EBCDIC), the range may be a different set of characters. **lex** displays a warning message if moving to another system is likely to cause a problem.
?	(Optional element). Indicates that the character that precedes the ? is not required to match the string, but may be present in that position. For example, `ab?c` matches either `ac` or `abc`
	Matches any single character except new-line.
*	Matches any number of consecutive occurrences, including zero, of the character that comes before the *. For example, `a*` is any number of consecutive `a` characters, including zero. The usefulness of matching zero occurrences is more obvious in complicated expressions. For example, the expression, `[A-Za-z][A-Za-z0-9]*` indicates all alphanumeric strings with a leading alphabetic character, including strings that are only one alphabetic character. Use this expression for recognizing identifiers in computer languages.
+	Matches any number of consecutive occurrences, but not zero, of the character that comes before the +. For example, `a+` is one or more instances of `a`. Also, `[a-z]+` is all strings of lowercase letters.
|	Indicates a match for either the expression that precedes the | or the expression that follows the |. For example, `ab|cd` matches either `ab` or `cd`.
( )	Groups more complex expressions. For example, `(ab|cd+)?(ef)*` matches such strings as `abefef`, `efefef`, `cdef`, or `cddd`; but not `abc`, `abcd`, or `abcdef`.
a/b	/ indicates a match of expression `a` only if expression `b` immediately follows expression `a`. For example, `ab/cd` matches the string `ab` but only if followed by `cd`.

Figure 13-2 (Part 2 of 3). Regular Expression Operators

Symbol	Use
$	Indicates a match only when the expression is at the end of the line when used as the last character in an expression. For example, `ab$` is the same as `ab/\n` where \n is a new-line character. See the description of the `a/b` operator.
{ }	When enclosing numbers, the numbers indicate a number of consecutive occurrences of the expression that comes before it. For example, `a{1,5}` indicates a match for from 1 to 5 occurrences of the letter `a`. When enclosing a name, the name represents a string defined earlier in the specification file. Define the named string in the first part of the **lex** specification, before the rules. For example, `{digit}` looks for a defined string named `digit` and inserts it at that point in the expression.
<x>	Encloses a start condition (see "Start Conditions" on page 13-21). The lexical analyzer executes the associated action only if the lexical analyzer is in the indicated start condition (`x`). If the condition of *being at the beginning of a line* is start condition `ONE`, then the ^ operator would be the same as the expression, `<ONE>`.

Figure 13-2 (Part 3 of 3). Regular Expression Operators

To use the operator characters as text characters, indicate that they are text characters by using one of the escape sequences: " " (quotes) or \ (backslash). The operator ″ (quotation mark) indicates that what is between a pair of quotes is text. Thus:

```
xyz"++"
```

matches the string `xyz++`. Note that a part of a string may be quoted. Quoting an ordinary text character has no effect. For example, the expression:

```
"xyz++"
```

is the same as the previous one. Quoting all characters that are not letters or numbers, ensures that text is interpreted as text.

Another way to turn an operator character into a text character is to put a backslash character before it. For example:

```
xyz\+\+
```

is another form of the above expressions.

Putting Blanks in an Expression

Normally, blanks or tabs end a rule and therefore, the expression that defines a rule. However, you can enclose the blanks or tab characters in quotation marks to include them in the expression. Use quotes around all blanks in expressions that are not already within sets of brackets ([ ]).

Other Special Characters

The **lex** program recognizes many of the normal C language special characters. These character sequences are:

Sequence	Meaning
\n	New-line - Do not use the actual new-line character in an expression.
\t	Tab
\b	Backspace
\\	Backslash

Figure 13-3. Special Characters

When using these special characters in an expression, you do not need to enclose them in quotes. Every character, except these special characters and the previously described operator symbols, is always a text character.

Character Classes

Character classes are ranges of characters that **lex** uses to match a single character in the input stream. For example, a character class may contain the letters `a, b, c`. If this character class is a match pattern, **lex** accepts any one of the characters `a, b` or `c` from the input stream.

Define character classes using the [ ] operator pair. Therefore, to define the above character class use the following expression:

```
[abc]
```

The operator symbols, `-`, `^` and `\` can also help define the patterns represented in a character class. See "Operators" on page 13-8 for the definitions of these symbols. All other operators within square brackets do not have any meaning other than as an ordinary character.

Matching Rules

When more than one expression can match the current input, **lex** chooses in the following order:

1. The longest match
2. Among rules that match the same number of characters, the rule that occurs first.

For example, if the rules

```
integer       keyword action...;
[a-z]+        identifier action...;
```

are given in that order, and `integers` is the input word, **lex** matches the input as an identifier, because `[a-z]` matches eight characters while `integer` matches only seven. However, if the input is `integer`, both rules match seven characters. **lex** selects the keyword rule because it occurs first. A shorter input, such as `int`, does not match the expression `integer` and so **lex** selects the identifier rule.

Matching a String Using Wildcard Characters

Because **lex** chooses the longest match first, do not use rules containing expressions like `.*`. For example:

```
'.*'
```

might seem like a good way to recognize a string in single quotes. However, the lexical analyzer reads far ahead, looking for a distant single quote to complete the long match. If a lexical analyzer with such a rule gets the following input:

```
'first' quoted string here, 'second' here
```

it matches:

```
'first' quoted string here, 'second'
```

To find the smaller strings, `first` and `second`, use the following rule:

```
'[^'\n]*'
```

This rule stops after `'first'`.

Errors of this type are not far reaching, because the . (period) operator does not match a new-line character. Therefore, expressions like `.*` stop on the current line. Do not try to defeat this with expressions like [.\n] +. The lexical analyzer tries to read the entire input file and an internal buffer overflow occurs.

Finding Strings within Strings

The **lex** program partitions the input stream, and does not search for all possible matches of each expression. Each character is accounted for once and only once. For example, to count occurrences of both she and he in an input text, try the following rules:

```
she                     s++
he                      h++
\n                      |
.                       ;
```

where the last two rules ignore everything besides he and she. However, because she includes he, **lex** does *not* recognize the instances of he that are included in she.

To override this choice, use the action REJECT. This directive tells **lex** to go to the next rule. **lex** then adjusts the position of the input pointer to where it was before the first rule was executed, and executes the second choice rule. For example, to count the included instances of he, use the following rules:

```
she                     {s++; REJECT;}
he                      {h++; REJECT;}
\n                      |
.                       ;
```

After counting the occurrences of she, **lex** rejects the input stream and then counts the occurrences of he. Because in this case "she" includes "he" but not vice versa, and you can omit the REJECT action on "he". In other cases, it may be difficult to determine which input characters are in both classes.

In general, REJECT is useful whenever the purpose of **lex** is not to partition the input stream but to detect all examples of some items in the input, and the instances of these items may overlap or include each other.

Actions

When the lexical analyzer matches one of the regular expressions in the rules section of the specification file, it executes the ***action*** that corresponds to the regular expression. Without rules to match all strings in the input stream, the lexical analyzer copies the input to standard output. Therefore, do not create a rule that only copies the input to the output. Use this default output to find gaps in the rules.

When using **lex** to process input for a parser that **yacc** produces, provide rules to match all input strings. Those rules must generate output that **yacc** can interpret.

Null Action

To ignore the input associated with a regular expression, use a ; (C language null statement) as an action. For example:

```
[ \t\n]   ;
```

ignores the three spacing characters (blank, tab, and new-line).

Same as Next Action

To avoid repeatedly writing the same action, use the | (vertical bar) character . This character indicates that the action for this rule is the same as the action for the next rule. For example, the example to ignore blank, tab and new-line characters (shown above), can be written as:

```
"    "                    |
" \t"                     |
" \n"                      ;
```

The quotes around \n and \t are not required.

Printing a Matched String

To find out what text matched an expression in the rules section of the specification file, include a C language **printf** function as one of the actions for that expression. When the lexical analyzer finds a match in the input stream, the program puts that matched string in an external character array, called **yytext**. To print the matched string, use a rule like:

```
[a-z]+          printf("%s",yytext);
```

The C language function **printf** accepts a format argument and data to be printed. In this example the arguments to **printf** have the following meanings:

%s A symbol that converts the data to type **string** before printing.
yytext The name of the array containing the data to be printed

Printing the output like this is common. You may want to define it as a macro in the definitions section of the specification file. If this action is defined as ECHO, then the rules section entry looks like:

```
[a-z]+          ECHO;
```

Finding the Length of a Matched String

To find the number of characters that the lexical analyzer matched for a particular regular expression, use the external variable **yyleng**. For example, to count both the number of words and the number of characters in words in the input, use the following action:

```
[a-zA-Z]+       {words++;chars += yyleng;}
```

This action totals the number of characters in the words matched and puts that number in chars.

The following expression finds the last character in the string matched:

```
yytext[yyleng-1]
```

Getting More Input

The lexical analyzer may run out of input before it completely matches an expression in a rules file. In this case, include a call to the **lex** function **yymore** in the action for that rule. Normally, the next string from the input stream overwrites the current entry in **yytext**. If you use **yymore**, the next string from the input stream is added to the end of the current entry in **yytext**.

For example, to define a language that includes the following syntax:

- A string is any set of characters between " (quotes)
- A \ (backslash) must come before all strings.

use the rules:

```
\"[^"]*  {
                if (yytext[yyleng-1] =='\\')
                yymore();
        else
                ... normal user processing
                }
```

When this lexical analyzer receives a string such as `"abc\"def"`, it first matches the five characters `"abc\`. Then the call to **yymore** adds the next part of the string `"def` to the end. The part of the action code labeled `normal processing` must process the final quote that ends the string.

Putting Characters Back

The lexical analyzer may not need all of the characters that are matched by the currently successful expression, or it may need to return matched characters to the input stream to be checked again for another match. To return characters to the input stream, use the call:

```
yyless(n)
```

where `n` is the number of characters of the current string to keep. Characters that are beyond the `nth` character in the stream are returned to the input stream. This function provides the same type of look ahead that the / operator uses, but it allows more control over its usage.

Use the **yyless** function to process text more than once. For example, when parsing a C language program an expression such as `x=-a` is difficult to understand. Does it mean *x is equal to minus a*, or is it an older representation of *x -= a* which means *decrement x by the value of a*? To treat this expression as *x is equal to minus a*, but print a warning message, use a rule such as:

```
=-[a-zA-Z]  {
            printf("Operator (=-) ambiguous\n");
            yyless(yyleng-1);
            ... action for =-...
            }
```

Input/Output Routines

The **lex** program allows a program to use the input/output (I/O) routines it uses. These routines are:

input Returns the next input character

output(c) Writes the character `c` on the output

unput(c) Pushes the character `c` back onto the input stream to be read later by **input**.

lex provides these routines as macro definitions. You can override them and provide other versions.

These routines define the relationship between external files and internal characters. If you change them, change them all in the same way and they should follow these rules:

- All routines must use the same character set.
- The **input** routine must return a value of zero to indicate end of file.
- Do not change the relationship of **unput** to **input** or the look ahead functions will not work.

The standard **lex** library allows the lexical analyzer to back up a maximum of 100 characters.

Create a different version of **input** to be able to read a file containing nulls. Using the normal version of **input**, the returned value of 0 (from the null characters) indicates the end of file and ends the input.

Character Set

The lexical analyzers that **lex** generates process character I/O through the routines **input, output,** and **unput**. Therefore, to return values in **yytext**, **lex** uses the character representation that these routines use. Internally however, **lex** represents each character with a small integer. When using the standard library, this integer is the value of the bit pattern that the computer uses to represent the character. Normally, the letter **a** is represented in the same form as the character constant **'a'**. If you change this interpretation with different I/O routines, put a translation table in the definitions section of the specification file. The translation table begins and ends with lines that contain only the entries:

```
%T
```

The translation table contains lines of the form:

```
%T
{integer}    {character string}
{integer}    {character string}
{integer}    {character string}
%T
```

that indicate the value associated with each character.

End of File Processing

When the lexical analyzer reaches the end of a file, it calls a library routine called **yywrap**. This routine returns a value of 1 to indicate to the lexical analyzer that it should continue with normal wrap-up at the end of input. However, if the lexical analyzer receives input from more than one source, change the **yywrap** function. The new function must get the new input and return a value of 0 to the lexical analyzer. A return value of 0 indicates that the program should continue processing.

You can also include code to print summary reports and tables when the lexical analyzer ends in a new version of **yywrap**. The **yywrap** function is the only way to force **yylex** to recognize the end of input.

Passing Code to the Generated Program

You can define variables in either the definitions section or the rules section of the specification file. **lex** changes statements in the specification file into a lexical analyzer. Any line in the specification file that **lex** cannot interpret is passed, unchanged, to the lexical analyzer. Three types of entries can be passed to the lexical analyzer in this manner:

- *Lines beginning with a blank or tab* that are not a part of a **lex** rule are copied into the lexical analyzer. If this entry occurs before the first %% in the specification file, the entry is external to any function in the code. If the entry occurs after the first %%, it must be a C language program fragment that defines a variable. Define these statements before the first **lex** rule in the specification file.
- *Lines beginning with a blank or tab* that are program comments are included as comments in the generated lexical analyzer. The comments must be in the C language format for comments.
- *Any lines that lie between lines containing only %{ and %}* is copied to the lexical analyzer. The symbols %{ and %} are not copied. Use this format to enter preprocessor statements that must begin in column 1, or to copy lines that do not look like program statements.
- *Any lines occurring after the third %% delimiter* are copied to the lexical analyzer without format restrictions.

Defining Substitution Strings

You can define string macros that **lex** expands when it generates the lexical analyzer. Define them before the first %% delimiter in the **lex** specification file. Any line in this section that begins in column 1 and that does not lie between %{ and %} defines a **lex** substitution string. Substitution string definitions have the general format:

```
name                    translation
```

where `name` and `translation` are separated by a least one blank or tab, and `name` begins with a letter. When **lex** finds the string `name` enclosed in { } (braces) in the rules part of the specification file, it changes `name` to the string defined in `translation` and deletes the braces.

For example, to define the names `D` and `E`, put the following definitions before the first %% delimiter in the specification file:

```
D           [0-9]
E           [DEde][-+]{D}+
```

Then, use these names in the rules section of the specification file to make the rules shorter:

```
{D}+                    printf("integer");
{D}+ "." {D}*({E})?     |
{D}*"."{D}+({E})?       |
{D}+{E}                 printf("real");
```

You can also include the following items in the definitions section:

- Character set table
- List of start conditions
- Changes to size of arrays to accommodate larger source programs.

Start Conditions

Any rule may be associated with a start condition. **lex** recognizes that rule only when **lex** is in that start condition. You can change the current start condition at any time.

Define start conditions in the definitions section of the specification file by using a line in the following form:

```
% Start  name1 name2
```

The symbols, `name1` and `name2`, are names that represent conditions. There is no limit to the number of conditions and they can appear in any order. You can also shorten the word `Start` to `s` or `S`.

When using a start condition in the rules section of the specification file, enclose the name of the start condition in <> (angle brackets) at the beginning of the rule:

`<name1>` *expression*

defines a rule, *expression* that **lex** recognizes only when **lex** is in start condition `name1`. To put **lex** in a particular start condition, execute the action statement (in the action part of a rule):

```
BEGIN name1;
```

This statement changes the start condition to `name1`. To resume the normal state:

```
BEGIN 0;
```

resets **lex** to its initial condition. A rule can be active in several start conditions. For example:

```
<name1,name2,name3>
```

is a legal prefix. Any rule that does not begin with a start condition is always active.

Compiling the Lexical Analyzer

Compiling a **lex** program is a two-step process:

1. Use **lex** to change the specification file into a C language program. The resulting program is in the **lex.yy.c** file.
2. Use the **cc -ll** command to compile and link the program with a library of **lex** subroutines. The resulting executable program is in the **a.out** file.

For example, if the **lex** specification file is called **lextest**, enter the following commands:

```
lex lextest
cc lex.yy.c -ll
```

Although the default **lex** I/O routines use the C language standard library, the lexical analyzers that **lex** generates do not. You can include different copies of the **input, output,** and **unput** routines to avoid using the library (see "Input/Output Routines" on page 13-17).

Using lex with yacc

When used alone, the **lex** program generator makes a lexical analyzer that recognizes simple one-word input or receives statistical input. You can also use **lex** with a parser generator, such as **yacc**. The **yacc** program generates a program, called a parser, that analyzes the construction of more than one word input. This parser program operates well with lexical analyzers that **lex** generates. The **lex** program recognizes only regular expressions and formats them into character packages called ***tokens***.

token The smallest independent unit of meaning as defined by either the parser or the lexical analyzer. A token can contain data, a language keyword, an identifier, or other parts of a language syntax.

yacc produces parsers that recognize many types of grammar with no regard to context. These parsers need a preprocessor to recognize input tokens such as the preprocessor that **lex** produces.

When using **lex** to make a lexical analyzer for a parser, the lexical analyzer (from **lex**) partitions the input stream. The parser (from **yacc**) assigns structure to the resulting pieces. Figure 13-4 on page 13-24 shows how the two generated programs work together. You can also use other programs along with the programs generated by either **lex** or **yacc**.

The **yacc** program must have a lexical analyzer named **yylex**, which is what the lexical analyzer from **lex** is named. Normally, the default main program in the **lex** library calls this routine, but if **yacc** is loaded and its main program is used, **yacc** calls **yylex**. In this case, each **lex** rule should end with:

```
return(token);
```

where the appropriate token value is returned.

To find out the names for tokens that **yacc** uses, compile the **lex** output file as part of the **yacc** output file by placing the line:

```
#include "lex.yy.c"
```

in the last section of the **yacc** grammar file. For example, if the grammar file is **good** and the specification file is **better**, the final program is created with the following command sequence:

```
yacc good
lex better
cc y.tab.c -ly -ll
```

The **yacc** library (`-ly` in the preceding example) should be loaded before the **lex** library to get a main program that invokes the **yacc** parser. You can generate **lex** and **yacc** programs in either order.

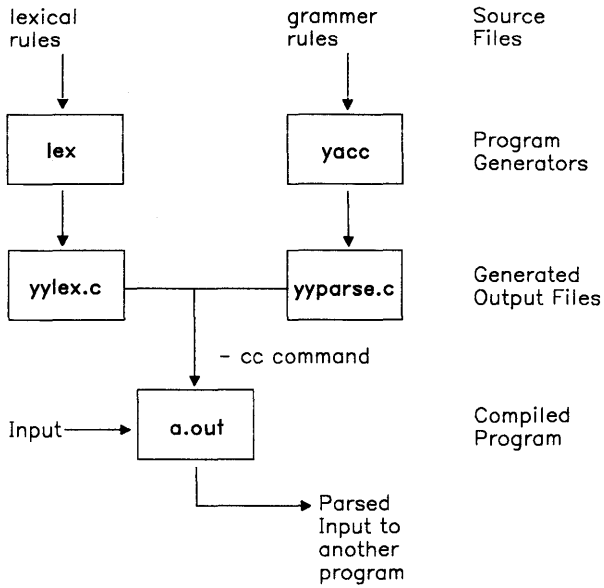


Figure 13-4. Lex With Yacc

Creating a Parser with yacc

The **yacc** program creates parsers that define and enforce structure for character input to a computer program. To use this program, supply the following inputs:

Grammar file
: A source file that contains the specifications for the language to recognize. This file also contains the programs **main**, **yyerror** and **yylex**. You must supply these programs.

main
: A C language program that as a minimum contains a call to the function **yyparse** that **yacc** generates. A limited form of this program is in the **yacc** library.

yyerror
: A C language program to handle errors that can occur during parser operation. A limited form of this program is in the **yacc** library.

yylex
: A C language program to perform lexical analysis on the input stream and pass tokens to the parser. You can generate this lexical analyzer using the **lex** program.

When **yacc** gets a specification, it generates a file of C language programs, called **y.tab.c**. When compiled using the **cc** command, these programs form a function called **yyparse** that returns an integer. When it is called, **yyparse** calls **yylex**, the lexical analyzer to get input tokens. **yylex** continues providing input until either the parser detects an error, or **yylex** returns an end-marker token to indicate the end of operation. If an error occurs and **yyparse** cannot recover, it returns a value of 1 to **main**. If it finds the end-marker token, **yyparse** returns a value of 0 to **main**.

Grammar File

To use **yacc** to generate a parser, give it a grammar file that describes the input data stream and what the parser is to do with the data. The grammar file includes rules describing the input structure, code to be invoked when these rules are recognized, and a routine to do the basic input.

The **yacc** program uses the information in the grammar file to generate a program that controls the input process. This program, called a ***parser***, calls an input routine (the ***lexical analyzer***) to pick up the basic items (called ***tokens***) from the input stream. The parser organizes these tokens according to the structure rules in the grammar file. The structure rules are called ***grammar rules***. When the parser recognizes one of these rules, it executes the user code supplied for that rule. The user code is called an ***action***. Actions return values and use the values returned by other actions.

Use the C programming language to write the action code and other subroutines. **yacc** uses many of the C language syntax conventions for the grammar file.

main and yyerror

You must provide these two routines for the parser. To ease the initial effort of using **yacc**, the **yacc** library contains simple versions of **main** and **yyerror**. Include these routines using the **−ly** argument to the loader (or to the **cc** command). The source code for the **main** library program is:

```
main()
{
     return ( yyparse() );
}
```

The source code for the **yyerror** library program is:

```
#include <stdio.h>

yyerror(s)
        char *s;
{
        fprintf( stderr, " %s\n" ,s);
}
```

The argument to **yyerror** is a string containing an error message, usually the string `syntax error`.

These are very limited programs. You should provide more function in these routines. For example, keep track of the input line number and print it along with the message when a syntax error is detected. You may also want to use the value in the external integer variable **yychar**. This variable contains the look-ahead token number at the time the error was detected.

yylex

The input routine that you supply must be able to:

- Read the input stream
- Recognize basic patterns in the input stream
- Pass the patterns to the parser along with ***tokens*** that define the pattern to the parser.

A ***token*** is a symbol or name that tells the parser which pattern is being sent to it by the input routine. A ***nonterminal symbol*** is the structure that the parser recognizes.

For example, if the input routine separates an input stream into the tokens of WORD, NUMBER and PUNCTUATION, and it receives the input:

```
I have 9 turkeys.
```

the program could choose to pass the following strings and tokens to the parser:

String	Token
I	WORD
have	WORD
9	NUMBER
turkeys	WORD
.	PUNCTUATION

The parser must contain definitions for the tokens that the input routine passes to it. If you use the **-d** option for **yacc**, it generates a list of tokens in a file called **y.tab.h**. This list is a set of **#define** statements that allow the lexical analyzer (**yylex**) to use the same tokens as the parser.

To avoid conflict with the parser, do not use names that begin with the letters yy.

You can use **lex** to generate the input routine, or you can write it in the C language. See "The lex Specification File" on page 13-6 for information about using **lex**.

Using the Grammar File

A **yacc** grammar file consists of three sections:

- Declarations
- Rules
- Programs.

Two %% (percent signs) that appear together separate the sections of the grammar file. To make the file easier to read, put the %% on a line by themselves. A complete grammar file looks like:

```
declarations
% %
rules
% %
programs
```

The declarations section may be empty. If you omit the programs section, omit the second set of %%. Therefore, the smallest **yacc** grammar file is:

```
% %
rules
```

yacc ignores blanks, tabs and new-line characters in the grammar file. Therefore, use these characters to make the grammar file easier to read. Do not, however, use blanks, tabs or new-lines in names or reserved symbols.

Using Comments

Put comments in the grammar file to explain what the program is doing. You can put comments anywhere in the grammar file that you can put a name. However, to make the file easier to read, put the comments on lines by themselves at the beginning of functional blocks of rules. A comment in a **yacc** grammar file looks the same as a comment in a C language program; it is enclosed in /* */. For example:

```
/* This is a comment on a line by itself. */
```

Using Literal Strings

A literal string is one or more characters enclosed in ' ' (single quotes). As in the C language, the \ (backslash) is an escape character within literals, and all the C language escape codes are recognized. Thus, **yacc** accepts the symbols in the following table:

Symbol	Definition
'\n'	New-line
'\r'	Return
'\''	Single quote (')
'\\'	Backslash (\)
'\t'	Tab
'\b'	Backspace
'\f'	Form feed
'\xxx'	The value xxx in octal

Figure 13-5. yacc Literal Strings

Never use \0 or 0 (the NUL character) in grammar rules.

How to Format the Grammar File

Use the following guidelines to help make the **yacc** grammar file more readable:

1. Use uppercase letters for token names and lowercase letters for nonterminal symbol names.
2. Put grammar rules and actions on separate lines to allow changing either one without changing the other.
3. Put all rules with the same left side together. Enter the left side once and use the vertical bar to begin the rest of the rules for that left side.
4. For each set of rules with the same left side, enter the semicolon once on a line by itself following the last rule for that left side. You can then add new rules easily.
5. Indent rule bodies by two tab stops and action bodies by three tab stops.

Using Recursion in a Grammar File

Recursion is the process of using a function to define itself. In language definitions, these rules normally take the form:

```
rule    :   <end case>
        |   rule,<end case>
```

which means that the simplest case of the `rule` is the `end case`, but `rule` can also be made up of more than one occurrence of `end case`. The entry in the second line that uses `rule` in the definition of `rule` is the `recursion`. The parser cycles through the input until the stream is reduced to the final `end case`.

When using recursion in a rule, always put the call to the name of the rule as the leftmost entry in the rule (as it is in the above example). If the call to the name of the rule occurs later in the line, such as:

```
rule    :   <end case>
        |   <end case>,rule
```

the parser may run out of internal stack space, stopping the parser.

Errors in the Grammar File

The **yacc** program cannot produce a parser for all sets of grammar specifications. If the grammar rules contradict themselves or require different matching techniques than **yacc** has, **yacc** will not produce a parser. In most cases, **yacc** provides messages to indicate the errors. To correct these errors, redesign the rules in the grammar file, or provide a lexical analyzer (input program to the parser) to recognize the patterns that **yacc** cannot.

Declarations

The declarations section of the **yacc** grammar file contains:

1. Declarations for any variables or constants used in other parts of the grammar file
2. #include statements to use other files as part of this file (used for library header files)
3. Statements that define processing conditions for the generated parser.

A declaration for a variable or constant follows the syntax of the C programming language:

type specifier declarator ;

where, *type specifier* is a data type keyword, and *declarator* is the name of the variable or constant. Names can be any length and consist of letters, dots, underscores, and digits. A name cannot begin with a digit. Uppercase and lowercase letters are distinct. The names used in the body of a grammar rule may represent tokens or nonterminal symbols.

Without declaring a name in the declarations section, you can use that name only as a nonterminal symbol. Define each nonterminal symbol by using it as the left side of at least one rule in the rules section. The **#include** statements are identical to C language syntax, and perform the same function.

The **yacc** program has a set of keywords that define processing conditions for the generated parser. Each of the keywords begin with a % and is followed by a list of tokens. These keywords are:

%left Identifies tokens that are left associative with other tokens

%nonassoc Identifies tokens that are not associative with other tokens

%right Identifies tokens that are right associative with other tokens

%start Identifes a name for the start symbol

%token Identifies the token names that **yacc** accepts. Declare all token names in the declarations section.

All of the tokens on the same line have the same precedence level and associativity; the lines appear in the file in order of increasing precedence or binding strength. Thus:

```
%left '+' '-'
%left '*' '/'
```

describes the precedence and associativity of the four arithmetic operators. The + (plus) and - (minus) are left associative and have lower precedence than * (asterisk) and / (slash), which are also left associative.

Defining Global Variables

To define variables to be used by some or all actions, as well as the lexical analyzer, enclose the declarations for those variables in the %{ %} symbols. Declarations enclosed in these symbols are called ***global*** variables. For example, to make the `var` variable available to all parts of the complete program, use the following entry in the declarations section of the grammar file:

```
%{ int var = 0; %}
```

Start Conditions

The parser recognizes a special symbol called the ***start*** symbol. The start symbol is the name of the rule in the rules section of the grammar file that describes the most general structure of the language to be parsed. Because it is the most general structure, it is the structure where the parser starts in its *top down* analysis of the input stream. Declare the start symbol in the declarations section using the keyword, `%start`. If you do not declare the name of the start symbol, the parser uses the name of the first grammar rule in the grammar file.

For example, when parsing a C language procedure, the most general structure for the parser to recognize is:

```
main()
{
   code_segment
}
```

The start symbol should point to the rule that describes this structure. All remaining rules in the file describe ways to identify lower-level structures within the procedure.

Token Numbers

Token numbers are nonnegative integers that represent the names of tokens. If the lexical analyzer passes the token number to the parser instead of the actual token name, both programs must agree on the numbers assigned to the tokens.

You can assign numbers to the tokens used in the **yacc** grammar file. If you do not assign numbers to the tokens, **yacc** assigns numbers using the following rules:

1. A literal character is the numerical value of the character in the ASCII character set.
2. Other names are assigned token numbers starting at 257.

Note: Do not assign a token number of 0. This number is assigned to the ***endmarker*** token. You cannot redefine it.

To assign a number to a token (including literals) in the declarations section of the grammar file, put a positive integer (not zero) immediately following the token name in the `%token` line. This integer is the token number of the name or literal. Each number must be different from the rest of the token numbers. All lexical analyzers used with **yacc** must return a 0, or a negative value for a token when they reach the end of their input.

Rules

The ***rules*** section contains one or more grammar rules. Each rule describes a structure and gives it a name. A grammar rule has the form:

```
A : BODY;
```

where A is a nonterminal name, and BODY is a sequence of zero or more names and literals. The colon and the semicolon are required **yacc** punctuation.

Repeating Nonterminal Names

If there are several grammar rules with the same nonterminal name, use the | (vertical bar) to avoid rewriting the left side. In addition, use the ; (semicolon) only at the end of all rules joined by vertical bars. Thus the grammar rules:

```
A  :  B  C  D  ;
A  :  E  F  ;
A  :  G  ;
```

can be given to **yacc** as:

```
A  :  B  C  D
   |  E  F
   |  G
   ;
```

by using the vertical bar.

Empty String

To indicate a nonterminal symbol that matches the empty string, use a ; (semicolon) by itself in the body of the rule. Therefore, to define a symbol `empty` that matches the empty string, use a rule like the following rule:

```
empty  :  ;
```

End of Input Marker

When the lexical analyzer reaches the end of the input stream, it sends an end of input marker to the parser. This marker is a special token called ***endmarker***, and has a token value of 0. When the parser receives an end of input marker, it checks to see that it has assigned all of the input to defined grammar rules, and that the processed input forms a complete unit (as defined in the **yacc** grammar file). If the input is a complete unit, the parser stops. If the input is not a complete unit, the parser signals an error and stops.

The lexical analyzer must send the end of input marker at the correct time, such as the end of a file, or the end of a record.

Actions

With each grammar rule, you can specify ***actions*** to be performed each time the parser recognizes the rule in the input stream. Actions return values and obtain the values returned by previous actions. The lexical analyzer can also return values for tokens.

An action is a C language statement that does input and output, calls subprograms, and alters external vectors and variables. Specify an action in the grammar file with one or more statements enclosed in braces { and }. For example:

```
A  :  '('B')'
   {
     hello(1, "abc" );
   }
```

and

```
XXX  :  YYY  ZZZ
     {
     printf("a message\n");
     flag = 25;
     }
```

are grammar rules with actions.

Passing Values Between Actions

An action can get values generated by other actions by using the **yacc** parameter keywords that begin with a dollar sign ($1, $2 ...). The keywords that begin with a dollar sign refer to the values returned by the components of the right side of a rule, reading from left to right. For example, if the rule is:

```
A  :  B  C  D  ;
```

then $2 has the value returned by the rule that recognized C, and $3 the value returned by the rule that recognized D.

To return a value, the action sets the pseudo-variable $$ to some value. For example, the action:

```
{ $$ = 1;}
```

returns a value of one.

By default, the value of a rule is the value of the first element in it ($1). Therefore, you do not need to provide an action for rules that have the following form:

```
A : B ;
```

Putting Actions in the Middle of Rules

To get control of the parsing process before a rule is completed, write an action in the middle of a rule. If this rule returns a value through the $ parameters, actions that come after it can use that value. It can use values returned by actions that come before it. Therefore, the rule:

```
A  :  B
         {
            $$ =1;
         }
         C
   {
         x = $2;
         y = $3;
   }
   ;
```

sets x to 1 and y to the value returned by C.

Internally, **yacc** creates a new nonterminal symbol name for the action that occurs in the middle, and it creates a new rule matching this name to the empty string. Therefore, **yacc** treats the above program as if it were written in the following form:

```
$ACT   :   /* empty */
       {
          $$ = 1;
       }
       ;
A      :   B  $ACT  C
       {
          x = $2;
          y = $3;
       }
       ;
```

where $ACT is an empty action.

Programs

The programs section contains C language programs to perform functions used by the actions in rules section. In addition, if you write a lexical analyzer (input routine to the parser), include it in the programs section.

Error Handling

When the parser reads an input stream, that input stream might not match the rules in the grammar file. The parser detects the problem as early as possible. If there is an error handling routine in the grammar file, the parser can allow for entering the data again, skipping over the bad data, or a cleanup and recovery action. When the parser finds an error, for example, it may need to reclaim parse tree storage, delete or alter symbol table entries, and set switches to avoid generating any further output.

When an error occurs, the parser stops unless you provide error handling routines. To keep processing the input to find more errors, restart the parser at a point in the input stream where the parser can try to recognize more input. One way to restart the parser when an error occurs is to discard some of the tokens following the error, and try to restart the parser at that point in the input stream.

The **yacc** program has a special token name, **error**, to use for error handling. Put this token in the rules file at places that an input error might occur so that you can provide a recovery routine. If an input error occurs in this position, the parser executes the action for the **error** token, rather than the normal action.

To prevent a single error from producing many error messages, the parser remains in error state until it processes three tokens following an error. If another error occurs while the parser is in the error state, the parser discards the input token and does not produce a message.

As an example, a rule of the form:

```
stat  :  error ';'
```

tells the parser that, when there is an error, it should skip over the token and all following tokens until it finds the next semicolon. All tokens after the error and before the next semicolon are discarded. When the parser finds the semicolon, it reduces this rule and performs any cleanup action associated with it.

Providing for Error Correcting

You can also allow the person entering the input stream in an interactive environment to correct any input errors by entering a line in the data stream again. For example:

```
input : error  '\n'
        {
          printf(" Reenter last line: " );
        }
        input
      {
        $$ = $4;
      }
      ;
```

is one way to do this. However, in this example the parser stays in the error state for three input tokens following the error. If the corrected line contains an error in the first three tokens, the parser deletes the tokens and does not give a message. To allow for this condition, use the **yacc** statement:

```
yyerrok;
```

When the parser finds this statement, it leaves the error state and begins processing normally. The error recovery example then becomes:

```
input : error '\n'
        {
          yyerrok;
          printf( "Reenter last line: " );
        }
        input
      {
        $$ = $4
      }
      ;
```

Clearing the Look Ahead Token

The ***look ahead token*** is the next token that the parser examines. When an error occurs, the look ahead token becomes the token at which the error was detected. However, if the error recovery action includes code to find the correct place to start processing again, that code must also change the look ahead token. To clear the look ahead token, include the statement:

```
yyclearin ;
```

in the error recovery action.

Lexical Analysis

You must provide a lexical analyzer to read the input stream and send tokens (with values, if required) to the parser that **yacc** generates. The lexical analyzer is a function called **yylex**. The function must return an integer that represents the kind of token that was read. The integer is called the ***token number***. In addition, if a value is associated with the token, the lexical analyzer must assign that value to the external variable **yylval**.

To build a lexical analyzer that works well with the parser that **yacc** generates, use the **lex** program (see "The lex Specification File" on page 13-6).

Parser Operation

The **yacc** program turns the grammar file into a C language program. That program, when compiled and executed, parses the input according to the grammar specification given.

The parser is a finite state machine with a stack. The parser can read and remember the next input token (called the ***look ahead*** token). The ***current state*** is always the state that is on the top of the stack. The states of the finite state machine are represented by small integers. Initially, the machine is in state 0, the stack contains only 0, and no look ahead token has been read.

The machine can perform one of four actions:

shift n The parser pushes the current state onto the stack, makes `n` the current state, and clears the look ahead token.

reduce r The letter `r` is a rule number. When the parser finds a string defined by rule number `r` in the input stream, the parser replaces that string with the rule number in the output stream.

accept The parser looked at all input, matched it to the grammar specification, and recognized the input as satisfying the highest level structure (defined by the start symbol). This action appears only when the look ahead token is the endmarker and indicates that the parser has successfully done its job.

error The parser cannot continue processing the input stream and still successfully match it with any rule defined in the grammar specification. The input tokens it looked at, together with the look ahead token, cannot be followed by anything that would result in a legal input. The parser reports an error and attempts to recover the situation and resume parsing.

The parser performs the following actions during one process step:

1. Based on its current state, the parser decides whether it needs a look ahead token to decide the action to be taken. If it needs one and does not have one, it calls **yylex** to obtain the next token.
2. Using the current state and the look ahead token if needed, the parser decides on its next action and carries it out. This may result in states being pushed onto the stack or popped off of the stack and in the look ahead token being processed or left alone.

Shift

The **shift** action is the most common action the parser takes. Whenever the parser does a shift, there is always a look ahead token. For example, for the following grammar specification rule:

```
IF shift 34
```

if the parser is in the state that contains this rule and the look ahead token is IF, the parser:

1. Pushes the current state down on the stack
2. Makes state 34 the current state (puts it on the top of the stack)
3. Clears the look ahead token.

Reduce

The ***reduce*** action keeps the stack from growing too large. The parser uses reduce actions after it has matched the right side of a rule with the input stream and is ready to replace the characters in the input stream with the left side of the rule. The parser may have to use the look ahead token to decide if the pattern is a complete match.

Reduce actions are associated with individual grammar rules. Because grammar rules also have small integer numbers, you can easily confuse the meanings of the numbers in the two actions, shift and reduce. For example, the action:

```
. reduce 18
```

refers to grammar rule 18, while the action:

```
IF shift 34
```

refers to state 34.

For example, to reduce the rule:

```
A  :  x y z ;
```

The parser pops off the top three states from the stack. The number of states popped equals the number of symbols on the right side of the rule. These states are the ones put on the stack while recognizing x, y, and z. After popping these states, a state is uncovered which is the state the parser was in before beginning to process the rule (the state that needed to recognize rule A to satisfy its rule). Using this uncovered state and the symbol on the left side of the rule, the parser performs an action called **goto**, which is similar to a shift of A. A new state is obtained, pushed onto the stack, and parsing continues.

The **goto** action is different from an ordinary shift of a token. The look ahead token is cleared by a shift but is not affected by a goto. When the three states are popped, the uncovered state contains an entry such as:

```
A  goto 20
```

causing state 20 to be pushed onto the stack and become the current state.

The reduce action is also important in the treatment of user-supplied actions and values. When a rule is reduced, the parser executes the code that you included in the rule before adjusting the stack. In addition to the stack holding the states, another stack running in parallel with it holds the values returned from the lexical analyzer and the actions. When a shift takes place, the external variable **yylval** is copied onto the value stack. After executing the code that you provide, the parser performs the reduction. When the parser performs the **goto** action, it copies the external variable **yyval** onto the value stack. The **yacc** variables that begin with $ refer to the value stack.

Using Ambiguous Rules

A set of grammar rules is ***ambiguous*** if any possible input string can be structured in two or more different ways. For example, the grammar rule:

```
expr : expr '-' expr
```

states a rule that forms an arithmetic expression by putting two other expressions together with a minus sign between them. Unfortunately, this grammar rule does not specify how to structure all complex inputs. For example, if the input is:

```
expr - expr - expr
```

using that rule, a program could structure this input as either ***left associative***:

```
(  expr - expr ) - expr
```

or as ***right associative***:

```
expr - ( expr - expr )
```

and produce different results.

Understanding Parser Conflicts

When the parser tries to handle an ambiguous rule, it can become confused over which of its four actions to perform when processing the input. Two major types of conflicts develop:

shift/reduce conflict
: A rule can be evaluated correctly using either a shift action or a reduce action but the result is different.

reduce/reduce conflict
: A rule can be evaluated correctly using one of two different reduce actions, producing two different actions.

A **shift/shift** conflict is not possible. These conflicts result from a rule that is not as complete as it could be. For example, using the previous ambiguous rule, if the parser receives the input:

```
expr - expr - expr
```

after reading the first three parts the parser has:

```
expr - expr
```

which matches the right side of the grammar rule above. The parser can reduce the input by applying this rule. After applying the rule, the input becomes:

```
expr
```

which is the left side of the rule. The parser then reads the final part of the input:

```
- expr
```

and reduces it. This produces a left associative interpretation.

However, the parser can also look ahead in the input stream. If when it receives the first three parts:

```
expr - expr
```

it reads the input stream until it has the next two parts, it then has the following input:

```
expr - expr - expr
```

Applying the rule to the rightmost three parts reduces them to `expr`. The parser then has the expression:

```
expr - expr
```

Reducing the expression once more produces a right associative interpretation.

Therefore, at the point that the parser has read only the first three parts, it can take two legal actions: a shift or a reduction. If the parser has no rule to decide between them, this situation is called a **shift/reduce** conflict.

A similar situation occurs if the parser can choose between two legal reduce actions. That situation is called a **reduce/reduce** conflict.

How the Parser Responds to Conflicts

When shift/reduce or reduce/reduce conflicts occur, **yacc** produces a parser by selecting one of the valid steps wherever it has a choice. If you do not provide a rule that makes the choice, **yacc** uses two rules:

1. In a shift/reduce conflict, do the shift.
2. In a reduce/reduce conflict, reduce by the grammar rule that it can apply at the earliest point in the input stream.

Using actions within rules can cause conflicts if the action must be done before the parser can be sure which rule is being recognized. In these cases, using the above rules leads to an incorrect parser. For this reason, **yacc** reports the number of shift/reduce and reduce/reduce conflicts that it resolved using its rules.

Turning On Debug Mode

For normal operation, the external integer variable **yydebug** is set to 0. However, if you set it to a value that is not zero, the parser generates a description of:

- The input tokens that it receives
- The actions that it takes for each token

while it is parsing an input stream.

Set this variable in one of two ways:

- Put the C language statement:

  ```
  yydebug = 1;
  ```

  in the declarations section of the **yacc** grammar file.

- Use **sdb** to execute the final parser, and set the variable on or off using **sdb** commands. See Chapter 8, "Debugging Programs" on page 8-1 for information about using **sdb**.

Creating a Simple Calculator Program - Example

This section describes the example programs for **lex** and **yacc** that are in the set of example programs. The **lex** and **yacc** programs together create a simple desk calculator program that performs addition, subtraction, multiplication and division operations. The calculator program also allows you to assign values to variables (each designated by a single lower case letter) and then use the variables in calculations. The files that contain the program are:

File	Content
calc.lex	The **lex** specification file that defines the lexical analysis rules.
calc.yacc	The **yacc** grammar file that defines the parsing rules, and calls the **yylex** function created by **lex** to provide input.

To use these files, they must be in your current directory. Copy them from the directory **/usr/lib/samples** if you have installed the Programming Examples. The remaining text expects that the current directory is the directory that contains the **lex** and **yacc** example program files.

Compiling the Example Program

Perform the following steps, in order, to create the example program using **lex** and **yacc**:

1. Process the **yacc** grammar file using the **-d** option. The **-d** option tells **yacc** to create a file that defines the tokens it uses in addition to the C language source code:

   ```
   yacc -d calc.yacc
   ```

2. Use the **li** command to verify that the following files were created:

   y.tab.c The C language source file that **yacc** created for the parser.

   y.tab.h A header file containing define statements for the tokens used by the parser.

3. Process the **lex** specification file:

   ```
   lex calc.lex
   ```

4. Use the **li** command to verify that the following file was created:

   lex.yy.c The C language source file that **lex** created for the lexical analyzer.

5. Compile and link the two C language source files:

```
cc y.tab.c lex.yy.c
```

6. Use the **li** command to verify that the following files were created:

   y.tab.o The object file for **y.tab.c**.

   lex.yy.o The object file for **lex.yy.c**.

   a.out The executable program file.

You can then run the program directly from **a.out** by entering the command:

```
$ a.out
```

or, you can move the program to a file with a more descriptive name, like in the following example, and then run it:

```
$ mv a.out calculate
$ calculate
```

In either case after you start the program, the cursor moves to the line below the $ (command prompt); Then enter numbers and operators in calculator fashion. After you press the **Enter** key, the program displays the result of the operation. If you assign a value to a variable:

```
m=4 <enter>
_
```

the cursor moves to the next line. You can then use the variable in calculations and it will have the value assigned to it:

```
m+5 <enter>
9
_
```

The Parser Source Code

Figure 13-6 on page 13-53 shows the contents of the file **calc.yacc**. This file has entries in all three of the sections of a **yacc** grammar file: declarations, rules and programs.

```
%{
#include <stdio.h>

int regs[26];
int base;

%}

%start list

%token DIGIT LETTER

%left '|'
%left '&'
%left '+' '-'
%left '*' '/' '%'
%left UMINUS  /*supplies precedence for unary minus */


%%                    /* beginning of rules section */

list:                          /*empty */
         |
         list stat'\n'
         |
         list error'\n'
         {
           yyerrok;
         }
         ;
```

Figure 13-6 (Part 1 of 4). yacc Grammar File for Calculator Program - calc.yacc

```
stat:    expr
         {
           printf("%d\n",$1);
         }
         |
         LETTER '=' expr
         {
           regs[$1] = $3;
         }
         ;
expr:    '(' expr ')'
         {
           $$ = $2;
         }
         |
         expr '*' expr
         {
           $$ = $1 * $3;
         }
         |
         expr '/' expr
         {
           $$ = $1 / $3;
         }
         |
         expr '%' expr
         {
           $$ = $1 % $3;
         }
         |
         expr '+' expr
         {
           $$ = $1 + $3;
         }
```

Figure 13-6 (Part 2 of 4). yacc Grammar File for Calculator Program - calc.yacc

```
        |
        expr '-' expr
        {
          $$ = $1 - $3;
        }
        |
        expr '&' expr
        {
          $$ = $1 & $3;
        }
        |
        expr '|' expr
        {
          $$ = $1 | $3;
        }
        |
        '-' expr %prec UMINUS
        {
          $$ = -$2;
        }
        |
        LETTER
        {
          $$ = regs[$1];
        }
        |
        number
        ;
number: DIGIT
        {
          $$ = $1;
          base = ($1==0) ? 8:10;
        }
```

Figure 13-6 (Part 3 of 4). yacc Grammar File for Calculator Program - calc.yacc

```
        |
        number DIGIT
        {
          $$ = base * $1 + $2;
        }
        ;
%%
main()
{
 return(yyparse());
}

yyerror(s)
char *s;
{
  fprintf(stderr," %s\n",s);
}

yywrap()
{
  return(1);
}
```

Figure 13-6 (Part 4 of 4). yacc Grammar File for Calculator Program - calc.yacc

Declarations Section

This section contains entries that perform the following functions:

- Includes standard I/O header file
- Defines global variables
- Defines the rule `list` as the place to start processing
- Defines the tokens used by the parser
- Defines the operators and their precedence.

Rules Section

The rules section defines the rules that parse the input stream.

Programs Section

The programs section contains the following routines. Because these routines are included in this file, you do not need to use the **yacc** library when processing this file.

main( ) The required main program that calls **yyparse( )** to start the program.

yyerror(s) This error handling routine only prints a syntax error message.

yywrap( ) The wrap-up routine that returns a value of 1 when the end of input occurs.

The Lexical Analyzer Source Code

Figure 13-7 on page 13-58 shows the contents of the file **calc.lex**. This file contains include statements for standard input and output, as well as for the file **y.tab.h**. The **yacc** program generates that file from the **yacc** grammar file information if you use the **-d** flag with the **yacc** command. The file **y.tab.h** contains definitions for the tokens that the parser program uses. In addition, **calc.lex** contains the rules to generate the tokens from the input stream.

```
%{

#include <stdio.h>
#include "y.tab.h"
int c;
extern int yylval;
%}
%%
" "       ;
[a-z]     {
            c = yytext[0];
            yylval = c - 'a';
            return(LETTER);
          }
[0-9]     {
            c = yytext[0];
            yylval = c - '0';
            return(DIGIT);
          }
[^a-z0-9\b]    {
                 c = yytext[0];
                 return(c);
               }
```

Figure 13-7. lex Specification File for Calculator Program - calc.lex

System Libraries

Figure 3-1 on page 3-4 lists the system libraries. The libraries are collections of commonly used functions and declarations. Use them in a program to avoid creating the functions for each new program.

To use the library functions:

- Include any declarations for the variables that the library routines use in the program
- Link the library routines with the program files after the program is compiled, or in the same process using the **cc** command.

Note: You should not store your files in the following system libraries because you could lose the files if you reinstall or update the AIX Operating System. You should instead keep your files in your own seperate library.

Name	Path name	cc flag	Function
General C Libraries:			
C library	/lib/libc.a	Not required	Common C language subroutines for file access, string operations, character operations, memory allocation and other functions.
C library (floating-point)	/lib/libfc.a	-lfc	The same routines as the C library, except that some were compiled to use the hardware Floating-Point Accelerator to perform floating-point arithmetic.
Math library	/lib/libm.a	-lm	Mathematical functions using software routines to perform floating-point arithmetic.
Floating-Point Math library	/lib/libfm.a	-lfm	The same routines as the math library, except that they were compiled to use the hardware Floating-Point Accelerator to perform floating-point arithmetic.
Run Time Services library	/lib/librts.a	Not required	Support system services such as system configuration, messages, trace and error log support.
Programmer Workbench library	/lib/libPW.a	-lPW	Miscellaneous operating system functions.
Standalone Subroutine Library	/usr/lib/lib2.a	-l2	Miscellaneous operating system functions.

Figure 3-1 (Part 1 of 3). Summary of System Libraries

Header Files Needed for Calls

Some system calls depend on special macro definitions and declarations for the values that they return. The system provides this information in files called ***header files*** that are in the directory **/usr/include**. Therefore, when using system calls, ensure to also include any header files that the system call needs. To include a file in a program, use the following statement in the program:

```
#include <file.h>
```

where the parameter, *file.h*, represents the name of the header file to use.

The header files needed for each system call are:

Header File	Calls That Use The Header File
fcntl.h	open, fcntl
stdio.h	getpass
lockf.h	lockf
sys/types.h	msgxrcv, msgop, msgctl, msgget, semctl, semget, semop, shmctl, shmget, shmop, stat, fstat, times, ustat, utime
sys/ipc.h	msgxrcv, msgop, msgctl, msgget, semctl, semget, semop, shmctl, shmget, shmop
sys/msg.h	msgxrcv, msgop, msgctl, msgget,
sys/shm.h	shmctl, shmget, shmop
sys/sem.h	semctl, semget, semop
sys/lock.h	plock
sys/signal.h	signal
sys/stat.h	stat, fstat, open, creat
sys/times.h	times
sys/utsname.h	uname
ustat.h	ustat

Process Calls

When a program runs in the system, that program, together with the environment that it runs in, is a process. Many processes are running in the system: some running system programs (like **init**) and some running application programs. When each process begins, the system assigns it an identification number (***process ID***) that is a positive integer between 0 and 32,767. As long as the process remains active, the system uses this number to identify that process. When the process ends, the system can assign the number to a new process.

Process Handling Calls

Use the following calls to control creating, operating and stopping processes (see *AIX Operating System Technical Reference* for more information about these calls):

Call	Description
exec	Runs a new program in the currently running process.
exit	Stops a process.
fork	Creates a new process.
nice	Changes priority of a process.
pipe	Creates an inter-process channel.
plock	Locks process, text, or data in memory.

Starting a Process

All processes that run in the system, except **init**, are started through the **fork** system call. The **fork** call creates a second independent process from the one running process through the following sequence of events:

1. Gets a new process ID from the system.
2. Creates a new process that has access to the code running in the existing process and the environment of the existing process. By using virtual memory mapping, the system does not actually copy the information into the new process until the new process actually uses it. If, for example, the first instruction executed in the new process is an **exec** system call, the system does not waste time copying the first program only to throw it out when the **exec** call occurs.
3. Starts the new process running from the place in the program that immediately follows the fork call.

The original process is called the ***parent***; the new process is called the ***child***. The value returned to a process from the **fork** call tells that process whether it is a child or a parent process. The parent process receives the process ID of the child process; the child process

```
  chldpd = wait(&status1);
  PRT("parent: my child's process id is ", chldpd);
  PRT("parent: my process id is ", getpid() );
  PRT("parent: my parent process id is ", getppid() );
  PRT("parent: my process group id is ", getpgrp() );
  PR("ending parent process");
}
```

Figure 4-10 (Part 2 of 2). Example of Process ID System Calls

```
starting main process
grandchild: my process id is 266.
grandchild: my parent process id is 265.
grandchild: my process group id is 221.
ending grandchild process
child: my child's process id is 266.
child: my process id is 265.
child: my parent process id is 264.
child: my process group id is 221.
ending child process
parent: my child's process id is 265.
parent: my process id is 264.
parent: my process group id is 221.
parent: my parent process id is 221.
ending parent process
$
```

Figure 4-11. Output for Process ID System Call Program

Changing the Controlling Terminal

Typically, each process is associated with a process group and has a controlling terminal. Each process group has a group leader process. For example, when you log in, the shell process is the process group leader and any process descendants are in that process group. The terminal you are typing on is the controlling terminal.

However, it is sometimes necessary for a program to establish the controlling terminal on its own or to disassociate itself from the process group and not have a controlling terminal. You use the **setpgrp** system call in both cases, and in both cases it is important that you perform a series of steps completely and in the correct order. If you do not follow the correct procedures, problems can occur that are sometimes intermittent and always very difficult to diagnose.

Establishing a Controlling Terminal

To establish a controlling terminal, perform the following steps in the following order:

1. Close all the file descriptors of the controlling terminal for the current process, if there are any.
2. Issue the **setpgrp** system call. This makes the current process the group leader.
3. Open the desired terminal. If this terminal is not already a controlling terminal for some other process group, it becomes the controlling terminal for this process group. The rule is as follows: The first group leader process to open a terminal that is not already a controlling terminal, acquires that terminal as a controlling terminal for that process group.
4. Issue the **dup** system call so that additional file descriptors also refer to that terminal. File descriptors 0, 1, and 2 refer to the terminal as the default.

The following program fragment illustrates these steps:

```
close(0);
close(1);
close(2);

setpgrp();

if ( open("/dev/console",O_RDWR) == -1)
  return(errno);
else
{
  dup(0);
  dup(0);
}
```

If you fail to establish the process group correctly, some functions behave improperly. For example, the **SIGINT** signal is sent to all processes in the process group and if the process group is incorrect for a particular terminal, the signal is not sent or is sent to the wrong group of processes. The **SIGHUP** signal is sent to all processes in the process group when the group leader exits and if the process group is incorrect, the signal behaves incorrectly.

Eliminating the Controlling Terminal

It is sometimes necessary that a program not have a process group and a controlling terminal. For example, a program that runs in the background might want to write error or information messages to a terminal (such as the system console) but not accept information from the terminal.

To eliminate the controlling terminal, perform the following steps in the following order:

1. Close all the file descriptors for the controlling terminal for the current process if there are any. Do this even if the inherited files are for the same terminal as the desired output terminal.
2. Open the desired output terminal.
3. Issue the **setpgrp** system call. This makes the current process the group leader. This also means that the terminal opened in the previous step is not the controlling terminal. In fact, this process group has no controlling terminal.

The following program fragment illustrates these steps:

```
close(0);
close(1);
close(2);

if ( open("/dev/console",O_RDWR) == -1)
  return(errno);

setpgrp();
```

In this situation, the program can write to the terminal (system console) but should not read from it. The interrupt key from the terminal does not affect the program because the terminal is not the controlling terminal for that process group. It is valid for another process to obtain the terminal (system console) as a controlling terminal.

A typical scenario would be where you invoke a background program from the /etc/rc shell and the background program, traditionally called a ***daemon***, uses **/dev/console** as an output device for messages. **/dev/console** is enabled to allow another user to log into it.

Failure to observe the above rules could cause the following undesirable behavior for the user who managed to log into terminal **/dev/console**:

- The interrupt key might not work as expected because the terminal is not the controlling terminal for the proper group.
- Many commands would fail because **/dev/tty** could not be opened. **/dev/tty** is a pseudo device that is the controlling terminal for some command processes. If the process has no controlling terminal, the open for **/dev/tty** fails.

Process Tracking Calls

The system provides the following calls to monitor the operation of a process or group of processes in the system. These calls are the means by which the system commands of similar names are created. Use these calls within a program to gain information about how the program runs in each section of the program. They are primarily tools for use during development which would not be included in the final version of the program. See *AIX Operating System Technical Reference* for information about the syntax and flags of these calls.

Call	Description
acct	Enables/disables process accounting.
profil	Provides an execution time profile.
ptrace	Provides a process trace.
times	Gets process and child process times.

Use the following system calls to create and use message queues:

Call	Description
msgctl	Gets status, changes permissions, or removes a queue.
msgget	Gets message queue.
msgrcv	Receives a message.
msgsnd	Sends a message.
msgxrcv	Receives a message with additional information.

In addition, the **ftok** subroutine provides the ***key*** that the **msgget** call uses to create the message queue. Include the following header files when using message queue calls:

```
#include <sys/types.h>
#include <sys/ipc.h>
#include <sys/msg.h>
```

Terms

The use of message queue elements is similar in structure to the way the system creates and uses files. Defining the terms used for message queues with respect to the more familiar file terms provides a framework to build an understanding of message queues. Figure 4-28 shows the new terms and how they relate to terms used with files.

Term	Definition
key	The ***key*** is a unique identifier (of type **key_t**) that names the particular message queue. It is always associated with the message queue as long as the message queue exists. In this respect, it is similar to the *filename* of a file.
msqid	The ***msqid*** is an identifier assigned to the message queue for use within a particular process. It is similar in use to a *file descriptor* of a file.
Permissions	The message queue structure also contains information that describes the access permissions for the message queue. These permissions are similar in function to the access permission bits for a file (owner, group and others).

Figure 4-28. Message Queue Terms

In effect, message queues are a more general form of the **pipe** system call. Either method passes information between two processes. For message queues, however, you do not need to perform the steps of opening a pipe, forking, and then closing two of the ends of the pipe as described in "Example Pipe System Call" on page 4-13 In fact, the two processes using message queues to communicate do not need to be created from the same ancestor process; they only need to cooperate by using the same name for the queue, and agreeing about what the messages mean.

General Operation

When a process gets a message queue, it uses an internal name (***key***) to apply to the queue. Any other programs that use that key can access that queue, subject to the read/write access permissions set up for the queue. The process can either send messages to the queue or receive messages from the queue (or both if it wants to send messages to itself).

After opening the queue, the process continues operating until it reaches the point that it needs input from the other cooperating process. The first process checks its message queue using the **msgrcv** call. Using the parameter, ***msgtype***, in the **msgrcv** call, the process can specify which type of message it wants to receive. If a message that satisfies the request is not in the queue, the first process halts until something is put into the queue that does satisfy the request. If there is a message of the requested type in the queue, the system gives the process the first message of that type that was put into the queue (first-in-first-out).

Similarly, after opening the queue, the other process can send messages to the queue of the first process. If the queue is full, the system returns an error indication and the process must wait until the first process empties the queue enough to add the new message.

Because either of these wait conditions could halt the process indefinitely, the program should include a timeout loop to end the stalled condition.

Sending messages to a queue is completely independent from receiving messages from that queue. The amount of data that one process can put into the message queue of the other process depends on the queue size and the speed that the other process takes the data from the queue. More than one process can put messages into a queue. The receiving process must take them out of the queue in the order that they were put into the queue, modified only by selecting a message type.

The receiving process can also use the **msgxrcv** call instead of the **msgrcv** call to get messages. This call provides more information to the receiving process about the nature of the message.

Creating Panels and Panes

To create a panel that looks like the outline shown in Figure 5-3 on page 5-24, perform the following steps (following the rules for dividing panels and panes) as shown in Figure 5-4 on page 5-24.

1. Define panel **P** using the **ecbpls** routine with a link to pane **A**.
2. Divide the panel (**P**) with two horizontal splits into three panes. Use the **ecbpns** routine to define the three panes with the following links:

A	No links
B	Linked to **A** and **D**
C	Linked to **B** and **F**

3. Divide pane **B** with a single vertical split into two panes. Use the **ecbpns** routine to define the two panes with the following links:

D	No links
E	Linked to **D**

4. Divide pane **C** with two vertical splits into three panes. Use the **ecbpns** routine to define the three panes with the following links:

F	No links
G	Linked to **F**
H	Linked to **G**

Although the program must create panes **B** and **C** to get the smaller panes, those two panes do not appear as panes in the final display.

Figure 5-5 on page 5-25 shows how the panel and pane descriptions for the final structure are linked. Horizontal lines show the links within a pane; vertical lines show links to the parent panel or pane.

The program in Figure 5-5.0 on page 5-26 creates the panel shown in Figure 5-3 on page 5-24.

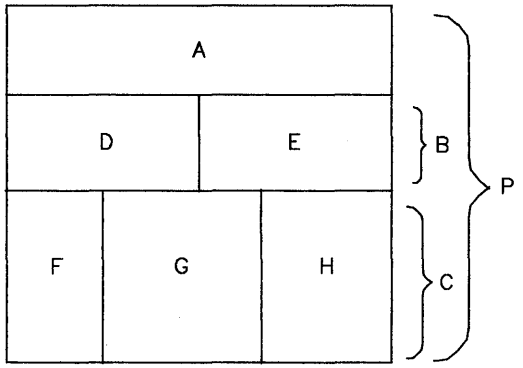


Figure 5-3. Example Panel Final Appearance

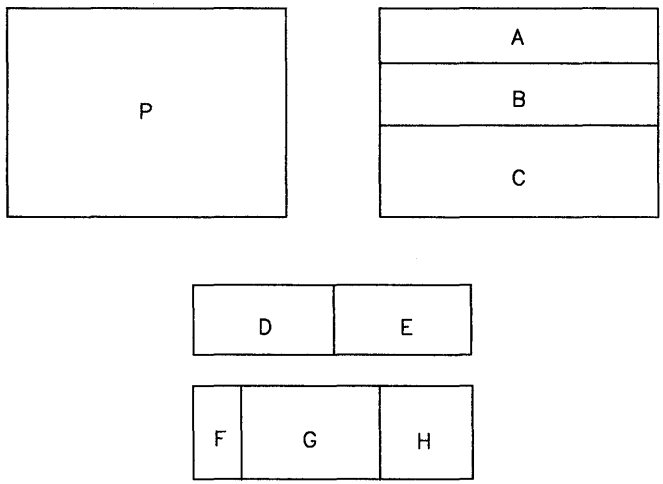


Figure 5-4. Creating Panes in the Panel

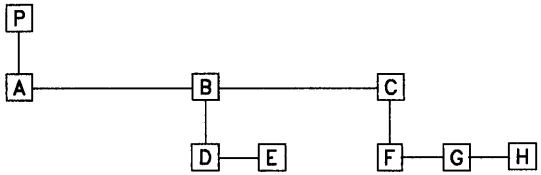


Figure 5-5. Links in the Panel and Pane Structure

```
#include <cur01.h>
#include <cur05.h>

main()

{

      pane    *A, *B, *C, *D, *E, *F, *G, *H ;
      panel   *P ;

initscr () ;

A = ecbpns (24, 80, NULL, NULL, 0, 2500, Pdivszp, Pbordry, NULL, NULL);

D = ecbpns (24, 80, NULL, NULL, 0, 0, Pdivszf, Pbordry, NULL, NULL);
E = ecbpns (24, 80, D,    NULL, 0, 0, Pdivszf, Pbordry, NULL, NULL);

B = ecbpns (24, 80, A, D, Pdivtyh, 3000, Pdivszp, Pbordry, NULL, NULL);

F = ecbpns (24, 80, NULL, NULL, 0, 0,    Pdivszf, Pbordry, NULL, NULL);
G = ecbpns (24, 80, F,    NULL, 0, 5000, Pdivszp, Pbordry, NULL, NULL);
H = ecbpns (24, 80, G,    NULL, 0, 3000, Pdivszp, Pbordry, NULL, NULL);

C = ecbpns (24, 80, B, F, Pdivtyh, 0, Pdivszf, Pbordry, NULL, NULL );

P = ecbpls (24, 80, 0, 0, NULL, Pdivtyv, Pbordry, A );

ecdvpl ( P );
ecdfpl ( P, FALSE );
ecshpl ( P );
ecrfpl ( P );

endwin();
}       /* end main program */
```

Figure 5-5.1. Program to Create Example Panel

Display Attributes

Use the color and display characteristics defined in Figure 5-6 on page 5-27. These names are external variables that define the attributes that a program can use on the current terminal. The values of these variables depend on the capabilities of the current terminal and the priorities that you assign to the attributes. Change the values of these variables with the **sel_attr** routine as explained in "Changing the Defined Attributes" on page 5-28.

The characteristics that a program selects for the terminal are loaded into the attribute byte associated with the data being displayed. Select as many of the attributes as needed, but those selected are packed into the attribute byte in the following order:

1. BOLD,
2. REVERSE,
3. F_WHITE,
4. F_RED,
5. F_BLUE,
6. F_GREEN,
7. F_BROWN,
8. F_MAGENTA,
9. F_CYAN,
10. F_BLACK,
11. B_BLACK,
12. B_RED,
13. B_BLUE,
14. B_GREEN,
15. B_BROWN,
16. B_MAGENTA,
17. B_CYAN,
18. B_WHITE,
19. UNDERSCORE,
20. BLINK,
21. INVISIBLE,
22. DIM,
23. STANDOUT,
24. PROTECTED,
25. FONT0,
26. FONT1,
27. FONT2,
28. FONT3,
29. FONT4,
30. FONT5,
31. FONT6,
32. FONT7,
33. NULL

To change the order, see "Changing the Defined Attributes" on page 5-28. Once the attribute byte is full, the routines ignore the remaining lower priority attributes. If an attribute does not work with the current display, the routines ignore that attribute. Therefore, you can specify color attributes and still be able to use the program with a monochrome display. Figure 5-6 defines the external variable names that the routines use to set the display attributes.

Name	Attribute
UNDERSCORE	Display characters with underline.
REVERSE	Display characters in reverse video.
NORMAL	Display characters without highlighting (return to normal).
INVISIBLE	Do not display characters.
STANDOUT	Display characters in high intensity (can be used with other attribute colors). On many terminals, this is the same as **BOLD**.
BOLD	Display characters in bold font (or high intensity on some terminals).
BLINK	Display blinking characters (can be used with other attribute colors).
DIM	Display characters in reduced intensity.
PROTECTED	Protected display field.
F_BLACK	Set foreground color to black.
F_BLUE	Set foreground color to blue.
F_GREEN	Set foreground color to green.
F_CYAN	Set foreground color to cyan.
F_RED	Set foreground color to red.
F_MAGENTA	Set foreground color to magenta.
F_BROWN	Set foreground color to brown.
F_WHITE	Set foreground color to white.
B_BLACK	Set background color to black.
B_BLUE	Set background color to blue.
B_GREEN	Set background color to green.
B_CYAN	Set background color to cyan.
B_RED	Set background color to red.
B_MAGENTA	Set background color to magenta.
B_BROWN	Set background color to brown.
B_WHITE	Set background color to white.
FONT0	Select defined character font 0.
FONT1	Select defined character font 1.
FONT2	Select defined character font 2.
FONT3	Select defined character font 3.
FONT4	Select defined character font 4.

Figure 5-6 (Part 1 of 2). Display Attributes

Name	Attribute
FONT5	Select defined character font 5.
FONT6	Select defined character font 6.
FONT7	Select defined character font 7.

Figure 5-6 (Part 2 of 2). Display Attributes

Changing the Defined Attributes

To change the characteristics assigned to the external variables listed in Figure 5-6 on page 5-27, use the **sel_attr** routine. This routine uses a set of defined constants contained in the header file **cur03.** To use this routine, put the following statement at the beginning of the program file:

```
#include <cur03.h>
```

The file **cur03.h** defines the following constants:

_dNORMAL
_dREVERSE
_dBOLD
_dBLINK
_dUNDERSCORE
_dDIM
_dINVISIBLE
_dPROTECTED
_dSTANDOUT
_dF_BLACK
_dF_RED
_dF_GREEN
_dF_BROWN
_dF_BLUE
_dF_MAGENTA
_dF_CYAN
_dF_WHITE
_dB_BLACK
_dB_RED
_dB_GREEN
_dB_BROWN
_dB_BLUE
_dB_MAGENTA
_dB_CYAN
_dB_WHITE
_dFONT0
_dFONT1
_dFONT2
_dFONT3
_dFONT4
_dFONT5
_dFONT6
_dFONT7

These constants are only valid when using the **sel_attr** routine. They cannot be used with any other routine.

Changing Screen Attributes

The code fragment in Figure 5-7 shows how to use these constants to change the default set of attributes.

```
#include <curOO.h>
#include <curO3.h>

int     attrs[] =
{
        _dBOLD, _dBLINK,
        _dF_WHITE, _dF_RED, _dF_BLUE, _dF_GREEN,
        _dF_BROWN, _dF_MAGENTA, _dF_CYAN, _dF_BLACK,
        _dB_BLACK, _dB_RED, _dB_BLUE, _dB_GREEN,
        _dB_BROWN, _dB_MAGENTA, _dB_CYAN, _dB_WHITE,
        _dREVERSE, _dINVISIBLE, _dDIM, _dUNDERSCORE,
        NULL
};

main( )
{

sel_attr(attrs);
initscr( );
if( REVERSE == NORMAL ) REVERSE = F_BLACK | B_WHITE;
if( INVISIBLE == NORMAL ) INVISIBLE = F_BLACK | B_BLACK;
if( DIM == NORMAL ) DIM = F_BLACK | BOLD;
if( UNDERSCORE == NORMAL ) UNDERSCORE = F_WHITE | B_RED;
STANDOUT = REVERSE;

        <rest of program>

endwin( );
}  /* end main */
```

Figure 5-7. Example Panel Final Appearance

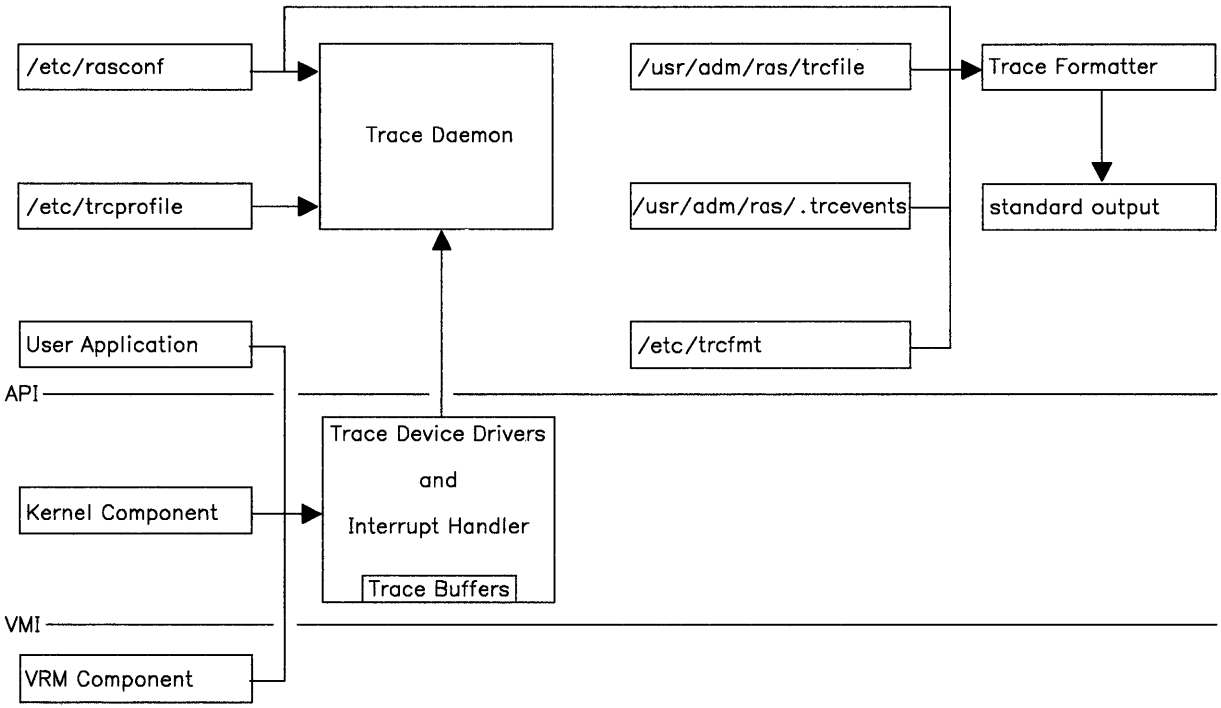


Figure 7-1. Trace Components

Figure 7-1 shows how data is passed between the various files and components that constitute the trace facilities. The lines labeled API, which stands for Application Program Interface, and VMI, which stands for Virtual Machine Interface, show the logical distinction between application programs, kernel components, and the VRM. The lines connecting the files and components show where data comes from and where it goes.

The components and files in Figure 7-1 are described on the next page. They are explained in more detail elsewhere in this chapter in the appropriate sections.

The following descriptions start at the point where the trace entries are first generated and end where the trace entries are formatted and sent to standard output.

- Applications, kernel components, and VRM components generate trace entries using trace points placed at strategic places in the execution path. The system programs contain several pre-defined trace points relating to various event classes.
- The trace device drivers collect the trace entries in trace buffers. There is one trace buffer for each of the three trace subroutines.
- The **/etc/rasconf** file contains configuration data. For the trace daemon, it defines the name and size of the trace log file to be opened to receive trace entries. For the trace formatter, it defines the default trace log file if none is specified when it is invoked.
- The default trace profile is **/etc/trcprofile**. This file contains a list of the defined event classes. An event class is either active or inactive. If an event class is active, the trace points related to that event class will generate trace entries. You can use the default trace profile, or create your own trace profile.
- The trace daemon is an important part of the trace facilities. When it is initialized, it performs three major tasks:
  - It reads the trace profile to determine which event classes should be active.
  - It opens the file specified in the trace stanza in **/etc/rasconf** as the trace log file.
  - It begins reading the trace buffers as they become full and writes them out to the trace log file.
- The default trace log file is **/usr/adm/ras/trcfile**. This file stores all of the trace entries generated by software programs. If the trace log file becomes full, the newest trace entry overwrites the oldest trace entry.
- The **/usr/adm/ras/.trcevents** file contains lists of event classes and the hook IDs associated with those event classes. The ***hook ID*** is a specific number associated with a particular trace point. The trace formatter uses information in this file to count the trace entries that occur for each event class. You do not edit this file directly. It is automatically updated when you use the **trcupdate** command.
- The trace format file, **/etc/trcfmt**, contains trace templates that determine how each trace entry appears when it is formatted. The pre-defined trace entries also have pre-defined templates. If you generate trace entries from your own programs, you need to define trace templates for those entries.
- The trace formatter formats the trace entries in a trace log file into a readable format. If a trace log file is not specified when the trace formatter is invoked, it uses the file specified in **/etc/rasconf**. The formatted trace entries are sent to standard output and can therefore be sent to the display screen, a file, or a printer.

Error Template Example

This section shows you how an error entry using a sample error template would appear after being formatted. In the example, a hardware error entry was generated for the Serial/Parallel Adapter. The header data for the error entry includes the error ID, which in this example is 0x060103. Thus, the error identifier in the template is U13. The error entry data is listed below:

`ErrorType` The type of error encountered (1 ASCII character). The *format* for this data would be A1.

`LastI/O` The last character transmitted (1 hexadecimal digit). The *format* for this data would be X1.

`LineStatus` The status of the printer (1 decimal word). The *format* for this data would be D4.

`PrinterStatus`
A 1-bit flag that indicates if the printer is active (1) or inactive (0). The *format* for this data would be B0.1.

Figure 7-13 shows a sample error template for error entries with an error ID of 0x060103. Notice the newline descriptor on the first line of the template. This will cause the data to start on a new line.

```
U13 Ser/Par: \n: \
    ErrorType A1: \n: Last_I/O X1: LineStatus D4: PrinterStatus \
    B0.1:
```

Figure 7-13. Example of an Error Template for Error Entries with Error ID 613

Figure 7-14 on page 7-40 shows how an error entry using the template U13 would appear in a formatted error report. The first entry is from a different error. The second entry is the one that uses template U13.

```
                                ERROR LOG REPORT

Error log: /usr/adm/ras/errfile
-------------------------------------------------------------------------------
Date/Time            Class          Subclass       Type      Device  Cause
|Thu May  9 16:54:42  Hardware       Diskette       Counters  DSKT    Hardware
|IODN=0004       IOCN=0240
|Base_Port_Address=000003F2
|Dev_Name=DSKT
|Internal_Dev_Type=D1015200
|        Switchable_to_Coprocessor
|        8_bit_device
|        No._Interrupts=1
|        Slot_Number=1
|        Adapter_Type=52
|        Port_Number=00
|Bad_IO_Address_Mark

|Bad_Count=4
|Good_Count=74
|Bad_Threshold=3
|Ratio=0

-------------------------------------------------------------------------------
Date/Time            Class          Subclass       Type      Device  Cause
Thu May  9 16:54:45  Hardware       Ser/Par        Perm      Ser/Par Hardware
        IODN=7  IOCN=600
        Base Port Addr=0278
        Dev Name=Ser/Par
        Internal Dev Type=91002300
ErrorType=3
Last_I/O=44 LineStatus=0 PrinterStatus=0

===============================================================================
```

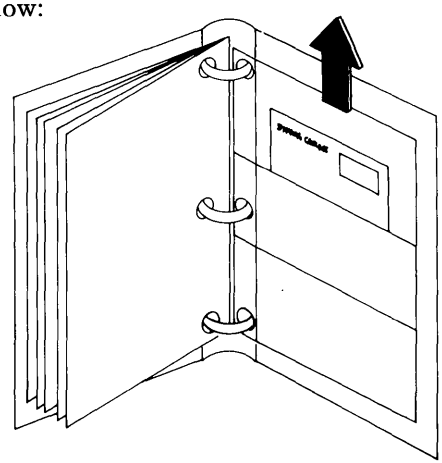
Figure 7-14. Example Output from the Error Formatter

Appendix A. Installing Programming Examples

This appendix explains how to install the Programming Examples. Before installing Programming Examples on the system, install the *IBM RT PC Virtual Resource Manager Licensed Program Product* and the *IBM RT PC AIX Operating System Licensed Program Product.*

Locating The Programming Examples Diskette

Remove the Programming Examples diskette from the plastic envelope in the back of the binder, as shown below:



Installing Programming Examples from the Command Line

To install Programming Examples from the command line, use the steps that follow. If an error occurs during the procedure, see *IBM RT PC Messages Reference* for details.

How to Install Programming Examples

1. Log in as su.
2. After the # prompt, type `installp`. Then press **Enter**.
3. Follow the prompts to insert the Programming Examples diskette and install the sample programs.
4. When installation is complete, remove the diskette and return it to the plastic envelope in the binder.
5. Log off the system.

More Detailed Information

1. Log in to the system as su. See *Using and Managing the AIX Operating System* for information about logging in as **su**.
2. Type `installp` command at the # prompt, then press **Enter**. The following prompt appears:

```
Insert the licensed program product volume 1 diskette
into diskette drive 0 and then press Enter.
```

3. Insert the Programming Examples diskette into the diskette drive, and press **Enter**. The following prompt appears:

```
Beginning installation of the licensed program product
      "Programming Examples"

Type "y" to continue or "n" to cancel, then press Enter.

--> y
```

4. Type y to continue the installation, and press **Enter**. The following message appears:

```
Installation of the licensed program product
      "Programming Examples"
is in progress.
```

   When installation is complete, the following message appears:

```
Installation of the licensed program product
      "Programming Examples"
was successfully completed.
```

5. Remove the Programming Examples diskette from the diskette drive. Return it to the plastic envelope in the binder or other safe place.
6. Log off the system.

Use the Programming Examples as directed in this book.

Appendix B. Extended curses Structures

WINDOW Structure

The ***Extended curses*** library routines use a structure, ***WINDOW***, to hold information about each window that it is working with. Figure B-1 on page B-2 shows the contents of that structure.

```
struct _win_st
{
   short    _cury, _curx;
   short    _maxy, _maxx;
   short    _begy, _begx;
   short    _winy, _winx;
   short    _flags;
   short    *_firstch;
   short    *_lastch;
   bool     _clear;
   bool     _leave;
   bool     _scroll;
   char     _csbp;
   char     **_y;
   char     **_a;
   struct   _win_st *_view;
} ;

#define     WINDOW struct  _win_st
#define     _SUBWIN        001
#define     _ENDLINE       002
#define     _FULLWIN       004
#define     _SCROLLWIN     010
#define     _ISVIEW        040
#define     _HASVIEW       100
#define     _STANDOUT      200
#define     _NOCHANGE       -1
```

Figure B-1. Structure Definition for WINDOW

The variables in this structure perform the following functions:

_cury and _curx
The current (y, x) coordinates for the window. New characters added to the screen are added at this point.

_maxy and _maxx
One more than the maximum values allowed for _cury and _curx.

_begy and _begx
The starting (y, x) coordinates on the terminal for the window (the home position for the window). The variables _cury, _curx, _maxy, and _maxx are measured relative to _begy and _begx, not the home position for the terminal.

_winy, _winx
The starting (y, x) coordinates of a viewport within the original window.

_flags
A flag byte that can have one or more of the following values ORed into it:

_SUBWIN
Indicates that the window is a subwindow. The **delwin( )** call checks this flag. If this flag is set, the space for the lines is not freed when the window is deleted.

_END-LINE
Indicates that the end of the line for this window is also the end of a screen.

_FULLWIN
Indicates that this window is a full screen window.

_SCROLLWIN
Indicates that the last character of this screen is at the lower right corner of the terminal. If a character is put there, the terminal scrolls.

_ISVIEW
Indicates that the window is a viewport window.

_HASVIEW
Indicates that the window has a viewport window in it.

_STANDOUT
Indicates that all characters added to the screen are in standout mode.

***_firstch**
Pointer to the first position (row by row) in the optimization array that was changed. If this pointer contains the value _NOCHANGE, then a change was not made to a line since the last time that **refresh( )** changed **curscr**.

***_lastch**

Pointer to the last position (row by row) in the optimization array that has been changed.

_clear

Tells if a clear-screen sequence is to be generated on the next **refresh( )** call. This is only meaningful for screens. The initial clear-screen for the first **refresh( )** call is generated by initially setting `clear` to be TRUE for **curscr**. When this variable is set for the current screen (**curscr**), each **refresh( )** generates a clear screen.

_leave

TRUE if the current (y, x) coordinates and the cursor are to be set to the character position following the last character changed on the terminal, or not moved if there is not a change.

_scroll

TRUE if scrolling is allowed.

_csbp

Current Standout Bit Pattern: The attribute pattern for characters that are written to the window in **standout** mode. See the _STANDOUT flag. See Figure 5-6 on page 5-27 for the patterns that can be combined into this variable.

****_y**

A pointer to an array of lines which describe the terminal. The expression:

```
_y[i]
```

is a pointer to the `i`th line, and:

```
_y [i][j]
```

is the `j`th character on the `i`th line.

****_a**

A pointer to the attribute array space. The expression:

```
_a [i][j]
```

is a pointer to the attribute byte that corresponds to the `j`th character on the `i`th line, represented as `_y [i][j]` in the array specified by the ****_y** field.

struct _win_st *_view

A pointer to the original window from a viewport window.

PANEL Structure

The **Extended curses** library routines use a structure, ***PANEL***, to hold information about each panel that it is working with. Figure B-2 shows the contents of that structure.

```
#define PANEL   struct Panel

struct  Panel
  {
  short int     p_depth ;
  short int     p_width ;
  short int     orow    ;
  short int     ocol    ;
  char          *title  ;
  char          divty   ;
  char          bordr   ;
  PANEL         *p_under;
  PANEL         *p_over ;
  PANE          *fpane  ;
  PANE          *dpane  ;
  PANE          *apane  ;
  WINDOW        *p_win  ;
  int           dfid    ;
  char          plobsc  ;
  char          plmodf  ;
  char          PLfill[6] ;
  }             ;
```

Figure B-2. Structure Definition for PANEL

The variables in this structure perform the following functions:

p_depth Number of rows in panel

p_width Number of columns in panel

orow Origin row (top left)

ocol Origin column

***title** Title string pointer

divty Divide type code

bordr Border flag byte

The following fields are used to relate multiple panels on the display:

***p_under** Next panel in chain under this panel

***p_over** Previous panel in chain over this panel

The following fields are used by the library routines. Do not change these fields directly:

***fpane** First pane after divisions

***dpane** First root pane for div

***apane** Current active pane

***p_win** Window struct for panel

dfid External panel ident

plobsc Panel obscured flag

plmodf Panel modified flag

PLfill[6] Not used

PANE Structure

The **Extended curses** library routines use a structure, ***PANE***, to hold information about each pane that it is working with. Figure B-3 on page B-7 shows the contents of that structure.

```
#define PANE    struct Pane

struct  Pane
  {
  short int     w_depth ;
  short int     w_width ;
  short int     v_depth;
  short int     v_width ;
  short int     orow    ;
  short int     ocol    ;
  PANE          *vscr   ;
  PANE          *hscr   ;
  PANE          *nxtpn  ;
  PANE          *prvpn  ;
  PANE          *divs   ;
  PANE          *divd   ;
  char          divty   ;
  short int     divsz   ;
  char          divszu  ;
  char          bordr   ;
  WINDOW        *w_win  ;
  WINDOW        *v_win  ;
  int           pnvsid  ;
  PANEL         *hpanl  ;
  PANEPS        *exps   ;
  char          alloc   ;
  char          pnobsc ;
  char          pnmodf ;
  char          PNfill[6]
  }             ;
```

Figure B-3. Structure Definition for PANE

The variables in this structure perform the following functions:

w_depth Rows of data in presentation space for this pane.

w_width Columns of data in presentation space for this pane.

v_depth Rows being shown on the display of this pane including space for borders.

v_width Columns being shown on the display of this pane including space for borders.

orow Top row on panel of view for this pane (including the border).

ocol First column on panel of view for this pane (including the border).

***vscr** Pane to scroll vertically with this pane.

***hscr** Pane to scroll horizontally with this pane.

***nxtpn** Next pane in chain.

***prvpn** Previous pane in chain.

***divs** Next pane that is part of current division specification.

***divd** Start of division of this pane into smaller parts.

divty Division type code that applies to divisions of this pane. May have the following values:

Pdivtyv '0' Divide vertical dimension of this pane. Divisions appear above each other.

Pdivtyh '1' Divide horizontal dimension of this pane. Divisions appear beside each other.

divsz Division size specification:

divszu Division size unit specification that indicates the form for divsz value using one of the following values:

Pdivszc '1' Size is a fixed constant. Fixed constants must be in the range from 1 to the dimension being divided.

Pdivszp '2' Size is a proportional value. Proportional values must be in the range of 1 to 10,000. They represent the number of 10,000ths of the available screen space to assign to the pane.

Pdivszf '0' Size is float. A **float** pane shares an equal amount of the available screen space with all other panes that have the float attribute.

bordr	Border flag for this pane.
***w_win**	Pointer to pspace window.
***v_win**	Pointer to view window.
pnvsid	External identifier for this p-pspace and view window.
***hpanl**	Pointer to panel that contains this pane.
***exps**	Pointer to chain of extra p-spaces for this pane.
alloc	An allocation flag that indicates whether ecdfpl allocated the window so that ecrlpl should free it.
pnobsc	A flag that indicates that the pane is obscured by an overlayed panel.
pnmodf	A flag that indicates the pane was modified.
PNfill[6]	Not used.

Appendix C. RT PC Printer Support Data Stream

Using Printers from A Program

The printer support of the RT PC system allows a program to produce output on any installed printer, as long as the program produces an output data stream that conforms to the control and data characters defined in this appendix. Printer support changes that data stream into the specific data stream that the installed printer needs.

Figure C-1 on page C-3 lists the printer control codes to use when printing using the RT PC printer support. If the printer can perform the function by itself, printer support passes the codes directly to the printer. If the codes do not work on the printer that is installed on your system, printer support performs one of the following actions:

- Tries to emulate the control with functions that the installed printer does have.
- Removes the control from the output stream. The function is not performed.

The three code columns in the table show different representations of the same code, depending on how you enter the code into the data stream:

Control Name This column shows the name of the control character. In many cases this name is the same as the keyboard keys that produce the required ASCII code for the control code.

Hex Code This column shows the hexadecimal representation of the control code.

ASCII Code This column shows the decimal representation of the control code.

Category	Function Performed	Control Name	Hex Code	ASCII Code
Control:	Null value. Used as a list terminator.	NUL	00	0
	Sound the buzzer. [1]	BEL	07	7
	Print the next character as a printable character. The next character is a control with an ASCII value of less than 32.	ESC ^	1B5E	27 94
	Print more than one character with an ASCII value that is below 32.	ESC \ *m n c*	1B5C *m n c*	27 92 *m n c*
Positioning the Printhead:	Back space.	BS	08	8
	Horizontal tab.	HT	09	9
	Set horizontal tabs. (*n* is a list of one or more tab positions.)	ESC D *n* NUL	1B44*n*00	27 68 *n* 0
	Set tab stops to power-on settings.	ESC R	1B52	27 82
	Line feed.	LF	0A	10
	Reverse line feed.	ESC]	1B5D	27 93
	Start automatic line feed.	ESC 5 1	1B35 1	27 53 1
	Stop automatic line feed.	ESC 5 0	1B35 0	27 53 0
	Carriage return (no line feed).	CR	0D	13
	Vertical tab.	VT	0B	11
	Set vertical tabs (*n* is a list of one or more tab positions).	ESC B *n* NUL	1B42*n*	27 66 *n* 0

Figure C-1 (Part 1 of 5). Printer Control Codes

Category	Function Performed	Control Name	Hex Code	ASCII Code
Paper Control:	Form feed.	FF	0C	12
	Set top of forms. [1]	ESC 4	1B34	27 52
	Ignore End of Forms. [1]	ESC 8	1B38	27 56
	Respect End of Forms. [1]	ESC 9	1B39	27 57
	Set skip perforation [1] (*n* is lines to skip).	ESC N *n*	1B4E *n*	27 78 *n*
	Stop skip perforation [1]	ESC O	1B4F	27 79
Formatting the Page Image:	Use 12 characters-per-inch printing.	ESC :	1B3A	27 58
	Set 1/8″ Line spacing.	ESC 0	1B30	27 48
	Start *n*/72″ Line spacing.	ESC 2	1B32	27 50
	Set *n*/72″ Line spacing.	ESC A *n*	1B41 *n*	27 59 *n*
	Set Page Length. [1] (*n* is lines per page).	ESC C *n*	1B43 *n*	27 67 *n*
	Set Page Length. [1] *n* is inches per page.	ESC C 0 *n*	1B43 0 *n*	27 67 0 *n*
	Set left and right margins (*m* and *n* are column numbers).	ESC X *m n*	1B58 *m n*	27 88 *m n*
	Set top and bottom margins (*m* and *n* are length of control; *t1 t0* are high/low order bytes of top margin; *b1 b0* are high/low order bytes of bottom margin).	ESC [S *m n t1 t0 b1 b0*	1B5B53 *m n t1 t0 b1 b0*	27 91 83 *m n t1 t0 b1 b0*

Figure C-1 (Part 2 of 5). Printer Control Codes

Category	Function Performed	Control Name	Hex Code	ASCII Code
	Start automatic line justification.	ESC M 1	1B4D 1	27 77 1
	Stop automatic line justification.	ESC M 0	1B4D 0	27 77 0
	Start proportional spacing.	ESC P 1	1B50 1	27 80 1
	Stop proportional spacing.	ESC P 0	1B50 0	27 80 0
Controlling the Ribbon:	Set color band 1 (yellow).	ESC y	1B79	27 121
	Set color band 2 (magenta).	ESC m	1B6D	27 109
	Set color band 3 (cyan).	ESC c	1B63	27 99
	Set color band 4 (black).	ESC b	1B62	27 98
	Set automatic ribbon band shift.	ESC a	1B61	27 97
Selecting Print Mode:	Start double wide.	SO	0E	14
	Stop double wide.	DC4	14	20
	Start double wide continuous.	ESC W 1	1B57 1	27 87 1
	Stop double wide continuous.	ESC W 0	1B57 0	27 87 0
	Start compressed.	SI	0F	15
	Stop compressed.	DC2	12	18
	Start underline.	ESC -1	1B2D 1	27 45 1
	Stop underline.	ESC -0	1B2D 0	27 45 0
	Start emphasized.	ESC E	1B45	27 69
	Stop emphasized.	ESC F	1B46	27 70

Figure C-1 (Part 3 of 5). Printer Control Codes

Category	Function Performed	Control Name	Hex Code	ASCII Code
	Start double strike.	ESC G	1B47	27 71
	Stop double strike.	ESC H	1B48	27 72
	Start superscript.	ESC S 0	1B53 0	27 83 0
	Start subscript.	ESC S 1	1B53 1	27 83 1
	Stop superscript or subscript.	ESC T	1B54	27 84
Selecting the Character Set:	Use PC character set 2	ESC 6	1B36	27 54
	Use PC character set 1	ESC 7	1B37	27 55
	Select font (*n* specifies the font; varies with printer type.).	ESC I *n*	1B49 *n*	27 73 *n*
	Set graphic set ID (*c* selects graphic set 0, 1 or 2)	ESC [T 1 0 *c*	1B5B54 1 0 *c*	27 91 84 1 0 *c*
Using Bit Image Graphics: [2]	Bit graphics normal (*n* is a string of control bytes.).	ESC K *n*	1B4B *n*	27 75 *n*
	Graphics dual-half speed (*n* is a string of control bytes.).	ESC L *n*	1B4C *n*	27 76 *n*
	Bit graphics dual-normal speed (*n* is a string of control bytes.).	ESC Y *n*	1B59 *n*	27 89 *n*
	Bit graphics high-half speed (*n* is a string of control bytes.).	ESC Z *n*	1B5A *n*	27 90 *n*
	Set aspect ratio to 1:1.	ESC n 1	1B6E 1	27 110 1
	Set aspect ratio to 5:6.	ESC n 0	1B6E 0	27 110 0

Figure C-1 (Part 4 of 5). Printer Control Codes

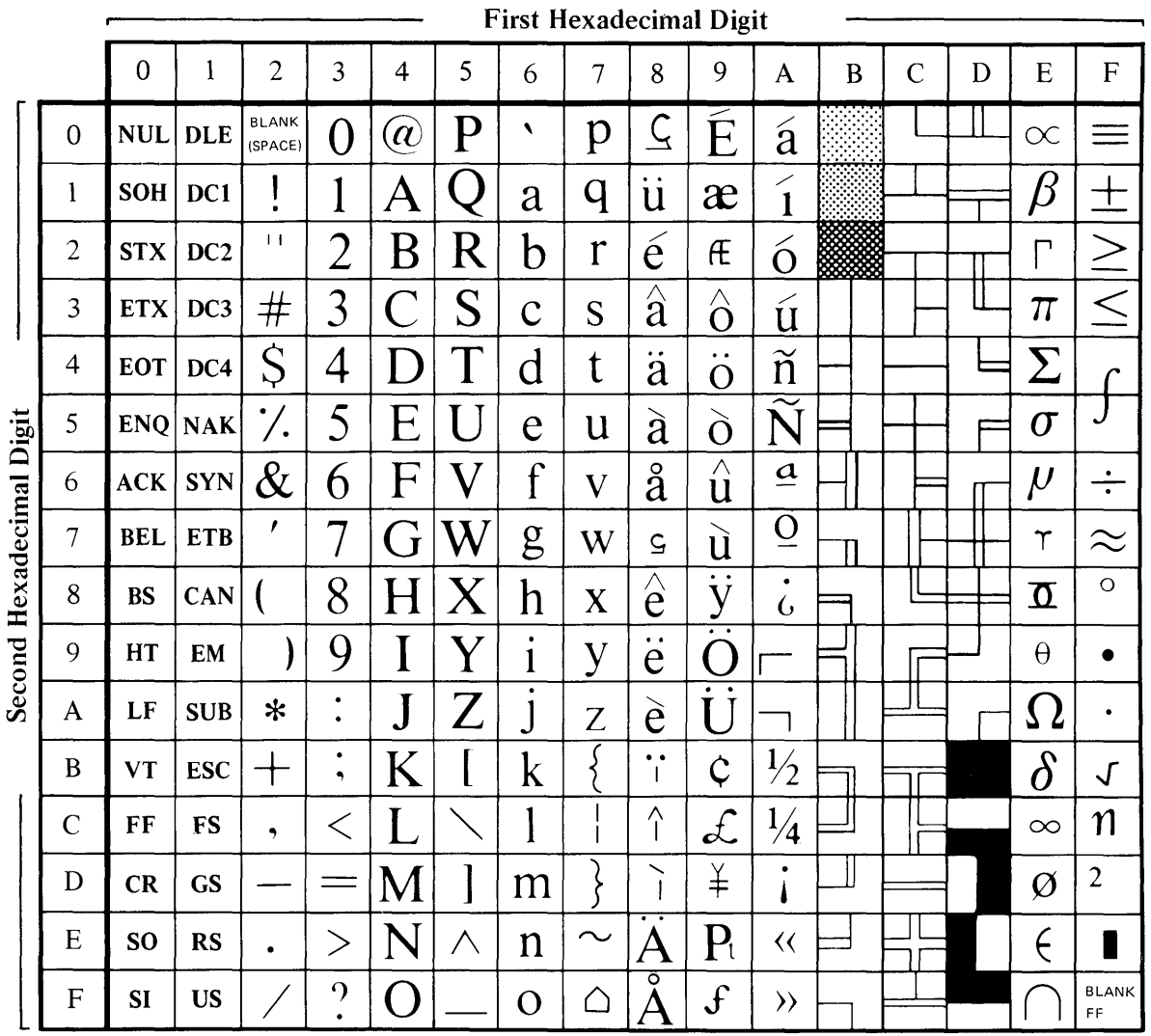
Category	Function Performed	Control Name	Hex Code	ASCII Code
	Move carriage to home position.	ESC <	1B3C	27 60
	Move right *n*/120.	ESC d *n*	1B64 *n*	27 100 *n*
	Move left *n*/120.	ESC e *n*	1B65 *n*	27 101 *n*
	Start unidirectional printing.	ESC U 1	1B551	27 85 1
	Stop unidirectional printing.	ESC U 0	1B550	27 85 0
	Set 7 dot line spacing.	ESC 1	1B31	27 49
	Set graphics line spacing (*n* is the number of 1/216-inch steps).	ESC 3 *n*	1B33 *n*	27 51 n
	Variable space line feed (*n* is the number of 1/216-inch steps).	ESC J *n*	1B4A *n*	27 74 *n*
Selecting a Printer:	Select. [1]	DC1	11	17
	Deselect. [1]	DC3	13	19
	Specific deselect. [1]	ESC Q 2	1B51 2	27 81 2
	Set initialize function on. [1]	ESC ? 1	1B3F 1	27 63 1
	Set initialize function off. [1]	ESC ? 0	1B3F 0	27 63 0

Figure C-1 (Part 5 of 5). Printer Control Codes

1 Do not use these controls when using the print queue.

2 These controls may not work on the installed printer. Use *passthrough* mode to send these codes to the printer.

Appendix D. ASCII Characters



Appendix E. Customizing System Files for New Devices

CONTENTS

About This Appendix

The operating system provides tools and programming interfaces to help customize the system for adding new devices. If your program supports a new device, or adds capability to the system support of a device, this chapter outlines the programs and interfaces that help you install that support into the system. For detailed information about any of the described programs, refer to *AIX Operating System Commands Reference.* For information about the described files and routines, refer to *AIX Operating System Technical Reference.*

Configuration Files

The configuration files provide the information that the customizing routines use to install the device drivers for the system. The information in these files must conform to the format for an ***attribute file*** as described in the file formats section of *AIX Operating System Technical Reference*. Figure E-1 on page E-4 shows the relationship of the configuration files using a printer as an example device.

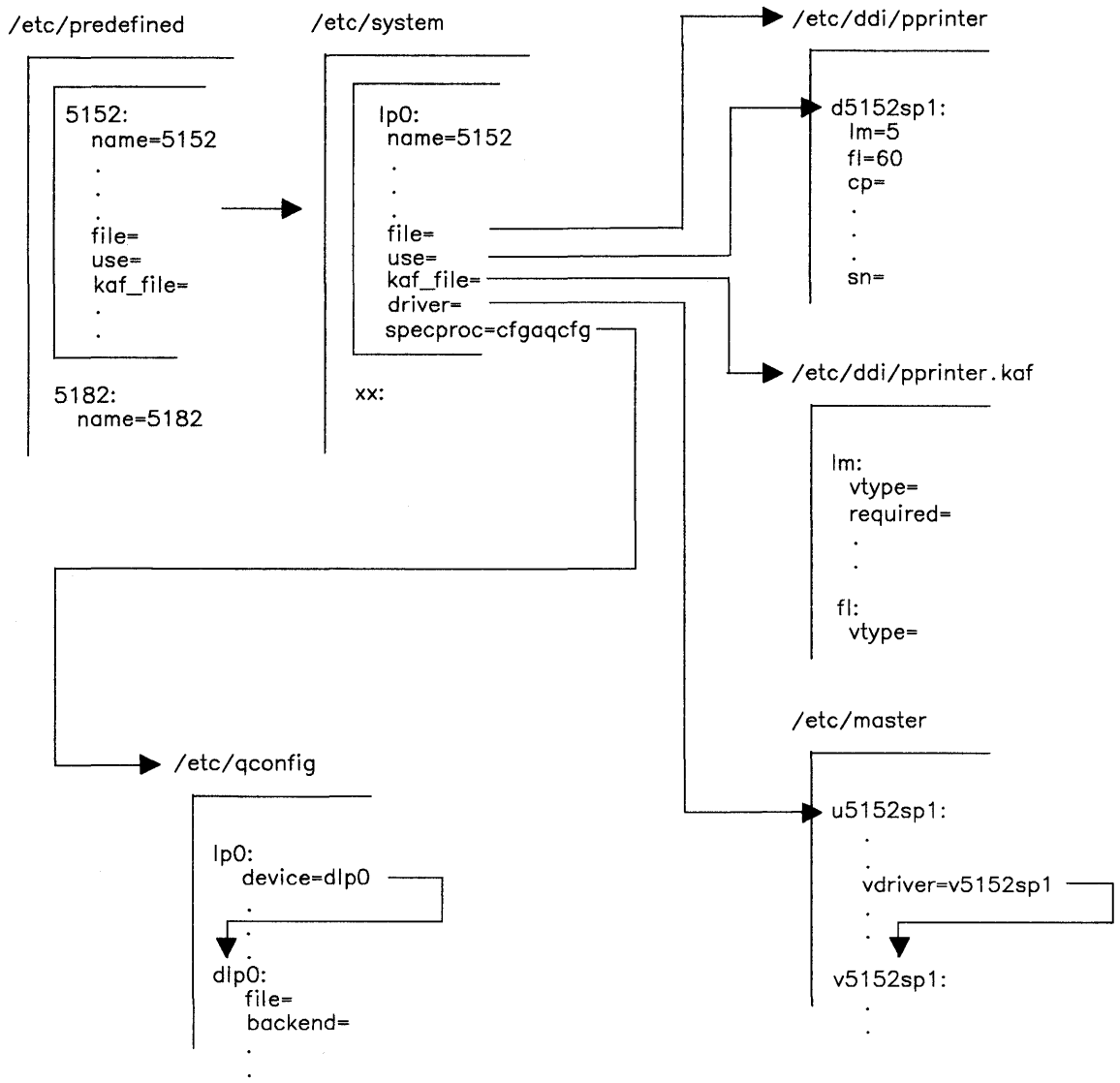


Figure E-1. Relationship of the Configuration Files and Keywords

Customizing Tools

Use the following programs and routines to help configure the system to work with the new device:

- **devices** command
- **vrmconfig** command
- Customizing helper programs

The devices Command

Use the **devices** command to add, delete, change and display devices on the system. It processes information in the following configuration files:

- **/etc/master**
- **/etc/system**
- **/etc/predefined**
- Files in the **/etc/ddi** directory
  - Device-dependent information files (**ddi**)
  - Keyword attribute files (**kaf**)

Refer to *Installing and Customizing the AIX Operating System* for more information about the **devices** command.

The Device-Dependent Information (ddi) Files

The **/etc/ddi** directory contains a file for each type of device that:

- Can be installed on the system
- Requires special device information.

This file contains ***device-dependent information*** (ddi) in the form of keywords that define device characteristics. Each keyword in a **ddi** file has an associated stanza in the **kaf** file. The keyword in the **ddi** file is the name of the corresponding stanza in the **kaf** file. For example, in Figure E-1 on page E-4, the **ddi** file is named **/etc/ddi/pprinter**. That file is for a printer. It includes information for left margin (`lm`) and forms length (`fl`) and could include other similar characteristics. If you want to change device characteristics, use the **devices** command to display some or all of the keywords.

ddi Parameters

Some important ddi parameters are:

sysadd This parameter indicates the action that **devices** takes after adding the device. Valid entries are:

```
sysadd=a      IPL the system
sysadd=v      Call vrmconfig
sysadd=none   Take no special action.
```

sysdel This parameter indicates the action that **devices** takes after deleting the device. Valid entries are:

```
sysdel=a      IPL the system
sysdel=v      Call vrmconfig
sysdel=none   Take no special action.
```

The Keyword Attribute (KAF) Files

The **/etc/ddi** directory also contains **kaf** files. These files contain stanzas that:

- Contain instructions for processing device information
- Control whether the **devices** command displays the associated information
- Control whether the information can be changed
- Determine what input validation the **devices** command should perform.

kaf File Parameters

Some important parameters in the **kaf** file stanzas are:

syschg The value of this parameter determines what action the **devices** command should take when the user changes a device characteristic. Meaningful values are:

```
syschg=a      IPL the system.
```

```
syschg=s      Call the special processing routine specified by the specproc
              keyword in /etc/system.
```

```
syschg=none   Take no special action.
```

display This parameter determines whether the **devices** command displays the keyword in the **ddi** file. If,

```
display=true
```

is in a stanza, **devices** displays the device characteristic keyword so you can change its value.

dsrc This parameter determines whether the **devices** command displays the adapter characteristic keyword in the **ddi** file. If,

`dsrc=`*XX,XX,...,XX*

is in a stanza and the number *XX* matches that of the adapter associated with the device, the **devices** command displays the adapter characteristic keyword so you can change its value.

required This parameter determines whether the **devices** command requires you to change the value of the associated keyword to match system customizing. If the entry,

`required=true`

occurs in a stanza, **devices** displays the keyword and advises you to be sure this keyword value matches the system configuration. The **devices** command does not verify that the entered value matches the system configuration.

rsrc This parameter determines whether the **devices** command displays the associated adapter characteristic keyword in the **ddi** file and requires you to enter a value. If,

`rsrc=`*XX,XX,...,XX*

is in a stanza and the number *XX* matches that of the adapter associated with the device, the **devices** command displays the associated keyword and does not continue until you enter a valid value for the keyword. The **devices** command does not verify that the entered value matches the system configuration.

range This parameter defines the valid range of values for a keyword, so that the **devices** command can validate input for that keyword. It is required if the **vtype** parameter is **3**. If the entry,

`range=`*f,l,i*

occurs in a stanza, then **devices** validates input for that keyword using *f* as the first number of the range, *l* as the last number of the range, and *i* as the allowable increment value.

type This parameter defines the data type of the value for this field. If the entry,

`type=`*T*

occurs in a stanza, **devices** ensures that the values entered are the correct data type, according to the following values of *T*:

F	Float
H	Hex

I	Integer
L	Long
S	Short
U	Unsigned

vtype This parameter defines the type of input validation the **devices** command performs. If the entry,

```
vtype=V
```

occurs in a stanza, **devices** validates input according to the following values of *V*:

0	No validation
1	*Mapping Validation*: The input must match one of the keywords found in the stanza named by the map keyword. Each keyword in the map stanza should be prefixed with an m.
2	*List Validation*: The input must match the list of possible choices. The choices that come with the system are shown in the comment following the keyword in the **ddi** file.
3	*Range Validation*: The input must fall within the range specified by the `range` keyword, it must also be the correct data type as specified by the **type** parameter.

The /etc/predefined File

The **/etc/predefined** file contains information about all configurable adapters and devices. The **devices** command uses this file to build the list of devices that can be added to the system. When you select a device to add, the **devices** command copies the device stanza from **/etc/predefined**, makes any needed changes to the stanza, and adds the stanza to **/etc/system**.

The /etc/system File

The **/etc/system** file contains information about currently configured hardware adapters and devices. The stanzas in the file are set up so specific operating system and VRM device drivers are associated with each device. Stanzas in **/etc/system** also point to device characteristics associated with that particular device. The **devices** command deletes the device stanza from **/etc/system** when you select a device to be deleted from the system. The following keywords in **/etc/system** provide information to help the system install a device:

adp The list of adapters that can be added with the device. If the **aflag** keyword is true, then **devices** looks at the **adp** keyword when adding devices. It reads each value of this keyword, finds the adapter description for that value under the **adpts** keyword in **/etc/predefined**, and displays the adapter as a member of the list of adapters from which you can choose.

aflag This is a required parameter that indicates whether or not an adapter is associated with the device. If the entry,

```
aflag=true
```

appears in a stanza, **devices** displays the values of the **adp** keyword as adapters from which you can choose.

crname This is a required parameter that indicates whether a new driver name must be created. If the entry,

```
crname=true
```

appears in a stanza, the devices command takes one of the following actions:

- If *aflag* is true, the devices command appends the adapter you chose for *aflag* to the current driver keyword value.
- If *aflag* is false, the devices command appends a number from 0 to *n* to the current driver keyword value. *n* is the maximum number of devices that can be configured for this device type (*maxminor*).

dname This parameter indicates the prefix name that is used to create the name of the special file in the **/dev** directory. For example, stanzas for printers supplied with the system contain the following entry,

```
dname=lp
```

dtype This parameter supplies the descriptive type name for a device. After you choose add, **devices** displays a list of all **dtype** parameters defined in **/etc/predefined** as device classes from which you can choose. For example, the entry for an IBM 5152 printer has the following keyword:

```
dtype=printer
```

nname This is a required parameter that identifies the type and adapter of the device. If *aflag* is true, the devices command appends the adapter you chose for *aflag* to *nname*. If *aflag* is false, the devices command appends the next available integer between 0 and *n* - 1, where *n* is *maxminor* for this device.

noduplicate This entry prevents **devices** from installing more than one device of the indicated **dtype** on the system. If the entry,

```
noduplicate=true
```

appears in a stanza, **devices** determines whether a device of this **dtype** is already installed. If a duplicate type is not found, the name of the device class is displayed, allowing you to select a device of that class for addition.

noshow This parameter controls the displaying of device information. If the entry,

```
noshow=true
```

appears in a stanza, **devices** does not display the device on the **showall** summary screen, and does not display any of the device characteristics. If the entry,

```
noshow=false
```

appears in a stanza, **devices** displays all device characteristics in response to a device information request. However, you cannot change those characteristics from the device information display.

nodl This parameter indicates that **devices** cannot delete the device from the system. If the entry,

```
nodl=true
```

appears in a stanza, **devices** does not display this device for you to delete.

noddi This parameter indicates if there is a device-dependent information file for this device. If the entry,

```
noddi=true
```

appears in a stanza, there is no **ddi** file and no additional device characteristic information.

specproc This is the name of the special processing routine that runs when a device is added, changed or deleted. This name must be a full path name unless the routine is a system-supplied routine. For example, **devices** calls a special processing routine to add device and queue stanzas to **/etc/qconfig** when you add a printer.

switchable This parameter indicates whether the device can be shared with the Personal Computer AT Coprocessor Services. If the entry,

```
switchable=true
```

appears in a stanza, **devices** displays the associated device as one that you can add to the Personal Computer AT Coprocessor Services.

The /etc/master File

The **/etc/master** file contains information about all device drivers in the system. Some operating system device driver stanzas contain a keyword that points to its associated VRM device driver stanza. Another keyword in **/etc/master** is:

maxminor This parameter specifies the maximum number of minor devices that this driver supports. An error code is returned if this limit is exceeded when you try to add a stanza to the configuration files.

Refer to *Installing and Customizing the AIX Operating System* for more information about the **devices** command.

Adding Descriptions for devices Command Screens

Most screens displayed by the **devices** command contain a column for descriptions. You must provide the descriptions in the configuration files in order for them to be displayed.

Descriptions fall into two categories:

- Descriptions for keywords in the **/etc/master**, **/etc/system**, and **/etc/predefined** files
- Descriptions for keywords in the ddi files.

Descriptions in /etc/master, /etc/system and /etc/predefined

To add a descriptive phrase for a keyword in one of these files, put the description in a comment line following the keyword it describes. Figure E-2 on page E-12 shows how the comment for the 5152 printer might appear in the **/etc/predefined** file.

```
5152:
* IBM PC Graphics Printer (5152)
.
.
.
noddi = false
dtype = printer
* Printer
```

Figure E-2. Example Descriptive Information in /etc/predefined

Descriptions in /etc/ddi

There are two methods for providing descriptions in the **/etc/ddi** files. They both produce the same results but the second method can save some file space.

Method one — This method is the same as descriptions for the master, system and predefined files. Put the description in a comment line following the keyword it describes. Figure E-3 shows descriptive information added to the ddi file for the printer.

```
default:
.
.
.
     lpi = 6
* Lines Per Inch          * 6,8
     ep = no
* Emphasized Print        * yes,no
```

Figure E-3. Example Descriptive Information in a ddi File

Method Two — For this method, you combine all the descriptions into file **/etc/ddi/descriptions**. This file is in a specific format that is described in *AIX Operating System Technical Reference* in the File Formats chapter under the ddi topic. You must follow the format described. If a description line following the keyword (as described in

method one) is not found, **devices** uses the keyword as the key to search the **/etc/ddi/descriptions** file for a description to display.

Adding POSSIBLE CHOICES For Devices Command Screens

Some screens provided by the **devices** command contain a **Possible Choices** column heading that shows the valid choices for the associated ddi keyword. **Possible Choices** is also used by the **devices** command to perform list validation (vtype = 2). You must provide the possible choices in the configuration files in order for them to be displayed. There are two methods for providing the possible choices.

Method One — Incorporate the possible choices with the keyword descriptions as explained in "Descriptions in /etc/ddi" on page E-12. In the same line as the keyword description, insert an * (asterisk) followed by the possible choices. For example, in Figure E-3 on page E-12 the second set of comments (6,8 and yes,no) are the valid choices for the **possible choices** column and also for list validation if the **vtype** parameter is set to 2.

Method Two — Combine all valid options into one file called **/etc/ddi/options**. This file is in a specific format that is described in *AIX Operating System Technical Reference* in the File Formats chapter under the ddi topic. You must follow the format described. If the **devices** command does not find a description line following the keyword as explained in method one under "Descriptions in /etc/ddi" on page E-12, **devices** looks for the **opts** keyword in the **kaf** file stanza for the keyword. **devices** then uses the **opts** keyword to generate a key to search on in the **/etc/ddi/options** file. The **devices** command then displays the choices column. The format of the **/etc/ddi/options** file is important.

The vrmconfig Command

The **vrmconfig** command installs VRM device drivers and initializes the corresponding operating system device drivers to allow them to attach to and use the VRM device driver. This command reads the contents of **/etc/system** and **/etc/master** to determine what to do. When the system starts, **vrmconfig** installs the devices defined in these files, such as terminals and printers. Other options for this command allows the addition or deletion of individual devices. Refer to *AIX Operating System Commands Reference* for more information about this command. One step that **vrmconfig** may take is to run the customizing helper program defined by the keyword **config**.

Some keywords that **vrmconfig** uses are in the **/etc/predefined** and **/etc/system** files:

noipl This parameter determines whether this stanza is processed when the system is started. If the entry,

```
noipl=true
```

occurs in a stanza, then that stanza is not processed when the system is started.

nospecial This parameter determines whether a new file is created in the **/dev** directory when the system is started. If the entry,

```
nospecial=true
```

occurs in a stanza, then a special file is not created and a **/dev** file is not created.

modes This parameter specifies the read, write and execute permissions assigned to the **/dev** file for this device. **vrmconfig** passes this information to the **mknod** program to create the special file in the **/dev** directory.

Customizing Helper Programs

You must provide a customizing helper program to build Define_Device Structures (DDS) for the VRM device drivers. The helper program must also issue the **Define_Device** system call for the VRM device drivers. Programs provided with RT PC use the customizing helper program **/etc/vrcmain**.

Another cusomizing helper program available is **/etc/biohelp**. You can use this program for devices that use the **BIOCA** area. **/etc/biohelp** builds the DDS for the device, including the BIOCA device characteristics. See *Virtual Resource Manager Technical Reference* for more information about devices that use block I/O.

A tool is available to create a customizing helper that builds a Define_Device Structure as documented in the Define_Device SVC section of the *Virtual Resource Manager Technical Reference*. The tool is subroutine **cfgabdds** and it allows you to build the DDS for devices (devices only and not for device managers). The tool also builds the AIX device driver structure and calls the init routine for that driver.

The following sections describe how you should set up customizing files and how you should interface to existing code to create a customizing helper for a device. When you are testing the customizing helper, **vrmconfig** and library routines used by the customizing helper, expect certain keywords in the appropriate files. Refer to the file formats section of *AIX Operating System Technical Reference* for more detailed information about files and keywords.

```
/etc/ddi/<ddi_file_name>
         <ddi_file_stanza_name>:
                                    - nr
                                      if nr = false
                                            - rsa
                                            - rea
                                  - biopa
                                  - iopar
                                  - brsa
                                  - brea
                                  - dmas
                                    if dmas = true
                                            - fp
                                            - ioccb
                                            - sdmac
                                            - dmao
                                            - dnec
                                            - sg
                                            - now
                                            - cn
                                  - if noi > 0
                                            - ei<n> where n = 1 through 4
                                            - si<n>
                                            - ic<n>
                                            - il<n>
                                  - rl
                                  - ddbw
                                  - noi
                                  - sn
                                  - at
                                  - pn
```

Figure E-4 (Part 1 of 3). Example Of Descriptive Information in /etc/ddi

```
/etc/ddi/<kaf_file_name>
         <kaf_use_stanza_name>:
                        - add
                        - delete
                        - startup
                        - shutdown
/etc/system and /etc/predefined device stanza:
                        - iodn
                        - name
                        - switchable
                        - vint
                        - minor
                        - kaf_file = <kaf_file_name>
                        - kaf_use  = <kaf_use_stanza_name>
                        - file         = <ddi_file_name>
                        - use          = <ddi_file_stanza_name>
                        - noipl
                        - nospecial
                        - if nospecial = false
                            - modes
                        - driver
```

Figure E-4 (Part 2 of 3). Example Of Descriptive Information in /etc/ddi

```
/etc/master
      AIX device driver stanza
                        - major
                        - prefix
                        - routines
                        - mpx
                        - vdriver
                        - config

      VRM device driver stanza
                        - iocn
                        - code
                        - ctype
```

Figure E-4 (Part 3 of 3). Example Of Descriptive Information in /etc/ddi

Programming Interfaces

After you have determined the values for these keywords, create the device stanza for the **/etc/predefined** and **/etc/system** files and the AIX and VRM device driver stanzas for the **/etc/master** file. Append the stanzas to the appropriate files.

The Define_Device SVC section in *AIX Operating System Technical Reference* refers to device dependent information (ddi). Some examples of ddi are in the chapter on predefined device drivers in *Virtual Resource Manager Technical Reference*. If the device you are adding requires ddi, you must write the code that creates and initializes the structure containing the ddi.

Write a main() routine that builds the ddi and that includes a call to **cfgabdds**. This subroutine in the **librts** library builds the common sections (header and hardware characteristics) of the dds. It then copies the structure you have created to the end of the common sections and calls the Define_Device SVC.

The value for the **config** keyword in the AIX device driver stanza in **/etc/master** is the name of your executable module. When you invoke **vrmconfig** to configure the device, it looks at the **config** keyword to see what to execute. **vrmconfig** expects the executable customizing helper to be in the **/etc** directory. **vrmconfig** passes all keyword-value pairs associated with your device to the executable module. These parameters must be passed along to the library routine, along with the pointer and length of your ddi structure.

The following is an example of the customizing helper interface:

```
main(argc, argv)

int argc;              /* argument count passed from vrmconfig */
char *argvfff";          /* argument list passed from vrmconfig  */

{
  char *ptr;           /* pointer to structure to be created   */
  int len;            /* length (bytes) of structure          */
  int rc;             /* return code from library routine     */


/*
*     code to create and initialize ddi goes here
*/

  rc = cfgabdds(argc, argv, ptr, len);
  if (rc != 0)
    printf("Define_Device Structure not created\n");
  return (rc);
}
```

Figure E-5. Example of Customizing Helper Interface

Figures

Glossary

access. To obtain data from or put data in storage.

access permission. A group of designations that determine who can access a particular AIX file and how the user may access the file.

action. In **awk**, **lex** and **yacc**, a C language program fragment that defines what the program does when it finds input that it recognizes.

All Points Addressable (APA) display. A display that allows each pel to be individually addressed. An APA display allows for images to be displayed that are not made up of images predefined in character boxes. Contrast with *character display*.

allocate. To assign a resource, such as a disk file or a diskette file, to perform a specific task.

alphabetic. Pertaining to a set of letters a through z.

alphanumeric character. Consisting of letters, numbers and often other symbols, such as punctuation marks and mathematical symbols.

American National Standard Code for Information Interchange (ASCII). The code developed by ANSI for information interchange among data processing systems, data communications systems, and associated equipment. The ASCII character set consists of 7-bit control characters and symbolic characters.

American National Standards Institute. An organization sponsored by the Computer and Business Equipment Manufacturers Association for establishing voluntary industry standards.

application. A program or group of programs that apply to a particular business area, such as the Inventory Control or the Accounts Receivable application.

application program. A program used to perform an application or part of an application.

ASCII. See *American National Standard Code for Information Interchange*.

attribute. A characteristic. For example, the attribute for a displayed field could be blinking.

auto carrier return. The system function that places carrier returns automatically within the text and on the display. This is accomplished by moving whole words that exceed the line end zone to the next line.

background process. (1) An activity that does not require operator intervention that can be run by the computer while the work station is used to do other work. (2) A mode of program execution in which the shell does not wait for program completion before prompting the user for another command.

backup copy. A copy, usually of a file or group of files, that is kept in case the original file or files are unintentionally changed or destroyed.

backup diskette. A diskette containing information copied from a fixed disk or from another diskette. It is used in case the original information becomes unusable.

bad block. A portion of a disk that can never be used reliably.

base address. The beginning address for resolving symbolic references to locations in storage.

basename. The last element to the right of a full path name. A file name specified without its parent directories.

batch printing. Queueing one or more documents to print as a separate job. The operator can type or revise additional documents at the same time. This is a background process.

batch processing. A processing method in which a program or programs process records with little or no operator action. This is a background process. Contrast with *interactive processing.*

binary. (1) Pertaining to a system of numbers to the base two; the binary digits are 0 and 1. (2) Involving a choice of two conditions, such as on-off or yes-no.

bit. Either of the binary digits 0 or 1 used in computers to store information. See also *byte.*

block. (1) A group of records that is recorded or processed as a unit. Same as *physical record.* (2) In data communications, a group of records that is recorded, processed, or sent as a unit. (3) A block is 512 bytes long.

block file. A file listing the usage of blocks on a disk.

block special file. A special file that provides access to a device which is capable of supporting a file system.

branch. In a computer program an instruction that selects one of two or more alternative sets of instructions. A conditional branch occurs only when a specified condition is met.

breakpoint. A place in a computer program, usually specified by an instruction, where execution may be interrupted by external intervention or by a monitor program.

buffer. (1) A temporary storage unit, especially one that accepts information at one rate and delivers it at another rate. (2) An area of storage, temporarily reserved for performing input or output, into which data is read, or from which data is written.

bug. A problem in the logic of a program that causes the program to perform differently than expected.

byte. The amount of storage required to represent one character; a byte is 8 bits.

C language. A general-purpose programming language that is the primary language of the AIX Operating System.

call. To activate a program or procedure at its entry point. Compare with *load.*

cancel. To end a task before it is completed.

carrier return. (1) In text data, the action causing line ending formatting to be performed at the current cursor location followed by a line advance of the cursor. Equivalent to the carriage return of a typewriter. (2) A keystroke generally indicating the end of a command line.

channel. One of 32 bits in a table used to represent which event classes are active or inactive. The most significant bit is called **channel 0** and the least significant bit is called **channel 31.**

character. A letter, digit, or other symbol.

character class. Ranges of characters that match a single character.

character display. A display that uses a character generator to display predefined character boxes of images (characters) on the screen. This kind of display can not address the screen any less than one character box at a time. Contrast with *All Points Addressable display.*

character key. A keyboard key that allows the user to enter the character shown on the key. Compare with *function keys.*

character position. On a display, each location that a character or symbol can occupy.

character set. A group of characters used for a specific reason; for example, the set of characters a printer can print or a keyboard can support.

character special file. A special file that provides access to an input or output device. The character interface is used for devices that cannot or do not want to use a file system.

character string. A sequence of consecutive characters.

character variable. The name of a character data item whose value may be assigned or changed while the program is running.

child. (1) Pertaining to a secured resource, either a file or library, that uses the user list of a parent resource. A child resource can have only one parent resource. (2) In the AIX Operating System, child is a *process* spawned by a parent process that shares resources of parent process, for example, the definition is one characteristic of the parent/child relationship. Contrast with *parent.*

close. To end an activity and remove that window from the display.

code. (1) Instructions for the computer. (2) To write instructions for the computer; to *program.* (3) A representation of a condition, such as an error code.

code segment. See *segment.*

collating sequence. The sequence in which characters are ordered within the computer for sorting, combining, or comparing.

color display. A display device capable of displaying more than two colors and the shades produced via the two colors, as opposed to a monochrome display.

column. A vertical arrangement of text or numbers.

column headings. Text appearing near the top of columns of data for the purpose of identifying or titling.

command. A request to perform an operation or execute a program. When parameters, arguments, flags, or other operands are associated with a command, the resulting character string is a single command.

command line editing keys. Keys for editing the command line.

compile. (1) To translate a program written in a high-level programming language into a machine language program. (2) The computer actions required to transform a source file into an executable object file.

compiler. A program that reads program text from a file and changes the programming language statements in that file to a form that the system can understand.

component dump table. A structure used by VRM components to identify data structures that should be collected by the VRM dump program.

compress. (1) To move files and libraries together on disk to create one continuous area of unused space. (2) In data communications, to delete a series of duplicate characters in a character string.

compression. A technique for removing strings of duplicate characters and for removing trailing blanks before transmitting data.

concatenate. (1) To link together. (2) To join two character strings.

concurrent groups. The ability to access files from many groups at the same time.

condition. An expression in a program or procedure that can be evaluated to a value of either true or false when the program or procedure is running.

configuration. The group of machines, devices, and programs that make up a computer system. See also *system customization.*

constant. A data item with a value that does not change. Contrast with *variable*

control block. A storage area used by a program to hold control information.

control program. Part of the AIX Operating System that determines the order in which basic functions should be performed.

controlled cancel. The system action that ends the job step being run, and saves any new data already created. The job that is running can continue with the next job step.

copy. The action by which the user makes a whole or partial duplicate of already existing data.

crash. An unexpected interruption of computer service, usually due to a serious hardware or software malfunction.

creation date. The program date at the time a file is created.

current directory. The currently active directory, displayed with the **pwd** command.

current file. In **make**, the file that the **make** command is working with at a given moment. **make** replaces the macro $* with the name of the current file.

current line. The line on which the cursor is located.

current screen. In **Extended curses**, the actual image that is currently on the terminal.

current working directory. See *current directory.*

cursor. (1) A movable symbol (such as an underline) on a display, used to indicate to the operator where the next typed character will be placed or where the next action will be directed. (2) A marker that indicates the current data access location within a file.

cursor movement keys. The directional keys used to move the cursor.

customize. To describe (to the system) the devices, programs, users, and user defaults for a particular data processing system.

cylinder. All fixed disk or diskette tracks that can be read or written without moving the disk drive or diskette drive read/write mechanism.

daemon. See *daemon process.*

daemon process. A process begun by the root or the root shell that can be stopped only by the root. Daemon processes generally provide services that must be available at all times such as sending data to a printer.

data communications. The transmission of data between computers, or remote devices or both (usually over long distance).

data stream. All information (data and control information) transmitted over a data link.

declaration. A statement in a program that defines how a label is used.

default. A value, attribute, or option that is used when no alternative is specified by the operator.

default directory. The directory name supplied by the operating system if none is specified.

default drive. The drive name supplied by the operating system if none is specified.

default value. A value stored in the system that is used when no other value is specified.

delete. To remove. For example, to delete a file.

dependent work station. A work station having little or no standalone capability, that must be connected to a host or server in order to provide any meaningful capability to the user.

device. An electrical or electronic machine that is designed for a specific purpose and that attaches to your computer, for example, a printer, plotter, disk drive, and so forth.

device driver. A program that operates a specific device, such as a printer, disk drive, or display.

device name. A name reserved by the system that refers to a specific device.

diagnostic. Pertaining to the detection and isolation of an error.

diagnostic aid. A tool (procedure, program, reference manual) used to detect and isolate a device or program malfunction or error.

diagnostic routine. A computer program that recognizes, locates, and explains either a fault in equipment or a mistake in a computer program.

digit. Any of the numerals from 0 through 9.

directory. A type of file containing the names and controlling information for other files or other directories.

diskette. A thin, flexible magnetic plate that is permanently sealed in a protective cover. It can be used to store information copies from the disk or another diskette.

diskette drive. The mechanism used to read and write information on diskettes.

display device. An output unit that gives a visual representation of data.

display screen. The part of the display device that displays information visually.

display station. A device that includes a keyboard from which an operator can send information to the system and a display screen on which an operator can see the information sent to or received from the computer.

dump. (1) To copy the contents of all or part of storage, usually to an output device.
(2) Data that has been dumped.

dump data. The data collected by the VRM dump program. It is obtained from memory locations used by VRM components.

dump table entry. A record in the master dump table that identifies the location of a component dump table. All VRM components that need to have special data collected by the VRM dump program need to generate a dump table entry.

EBCDIC. See *extended binary-coded decimal interchange code.*

EBCDIC character. Any one of the symbols included in the 8-bit EBCDIC set.

edit. To modify the form or format of data.

editor. A program used to enter and modify programs, text, and other types of documents.

emulation. Imitation; for example, when one computer imitates the characteristics of another computer.

enable. To make functional.

enter. To send information to the computer by pressing the Enter key.

entry. A single input operation on a work station.

environment. The settings for shell variables and paths set when the user logs in. These variables can be modified later by the user.

error-correct backspace. An editing key that performs editing based on a cursor position; the cursor is moved one position toward the beginning of the line, the character at the new

cursor location is deleted, and all characters following the cursor are moved one position toward the beginning of the line (to fill the vacancy left by the deleted element).

error entry. A data structure containing a header of identifying information plus several bytes of defined data. Error entries are generated by error points and written to an error log file.

error ID. This is part of the data required by an error entry. It is a unique combination of three hexadecimal digits that identifies the component that generated the error entry.

error identifier. A three-character code used to identify error templates and to specify which error entries the error formatter should process. This code is based on the error ID; however, it uses alphanumeric characters instead of hexadecimal digits.

error point. A group of code statements that generates an error entry from within a software program. Error entries are generated when a software or hardware component encounters an error.

error type. One of six categories of errors. The type of an error is determined by the software program that generates the error. When you format an error log, you can specify which types of errors you want to format.

escape character. The backslash character, used to indicate to the shell that the next character is not intended to have the special meaning normally assigned to it by the shell.

event class. A number assigned to a group of trace points that relate to a specific subject or system component. The defined event classes are listed in the trace profile.

exit value. (1) A code sent to either standard output or standard error on completion of the command. (2) A numeric value that a command returns to indicate whether it completed successfully. Some commands return exit values that give other information, such as whether a file exists. Shell programs can test exit values to control branching and looping.

expression. A representation of a value. For example, variables and constants appearing alone or in combination with operators.

extended binary-coded decimal interchange code (EBCDIC). A set of 256 eight-bit characters.

fake target name. A control name used in a **makefile** that looks like a target name, but actually tells **make** to perform some operation differently.

feature. A programming or hardware option, usually available at an extra cost.

field. (1) An area in a record or panel used to contain a particular category of data. The smallest component of a record that can be referred to by a name. (2) In **Extended curses**, an area in a presentation space where the program can accept operator input.

FIFO. See *first-in-first-out.*

file. A collection of related data that is stored and retrieved by an assigned name.

file descriptor. A small positive integer that the system uses instead of the file name to identify the file.

file name. The name used by a program to identify a file. See also *label.*

file specification (filespec). The name and location of a file. A file specification consists of a drive specifier, a path name, and a file name.

file system. The collection of files and file management structures on a physical or logical mass storage device, such as a diskette or minidisk.

filename. In DOS, that portion of the file name that precedes the extension.

filter. A command that reads standard input data, modifies the data, and sends it to standard output.

first-in-first-out (FIFO). A named permanent pipe. A FIFO allows two unrelated processes to exchange information using a pipe connection.

fixed disk. A flat, circular, nonremoveable plate with a magnetizable surface layer on which data can be stored by magnetic recording.

fixed-disk drive. The mechanism used to read and write information on fixed disk.

flag. A modifier that appears on a command line with the command name that defines the action of the command. Flags in the AIX Operating System almost always are preceded by a dash.

font. A family or assortment of characters of a given size and style.

foreground. A mode of program execution in which the shell waits for the program specified on the command line to complete before returning your prompt.

format. (1) A defined arrangement of such things as characters, fields, and lines, usually used for displays, printouts, or files. (2) The pattern which determines how data is recorded.

formatted diskette. A diskette on which control information for a particular computer system has been written but which may or may not contain any data.

free list. A list of available space on each file system. This is sometimes called the free-block list.

full path name. The name of any directory or file expressed as a string of directories and files beginning with the root directory.

function. A synonym for procedure. The C language treats a function as a data type that contains executable code and returns a single value to the calling function.

function keys. Keys that request actions but do not display or print characters. Included are the keys that normally produce a printed character, but when used with the code key produce a function instead. Compare with *character key.*

generation. For some remote systems, the translation of configuration information into machine language.

Gid. See *group number.*

global. Pertains to information available to more than one program or subroutine.

global action. An action having general applicability, independent of the context established by any task.

global character. The special characters * and ? that can be used in a file specification to match one or more characters. For example, placing a ? in a file specification means any character can be in that position.

global search. The process of having the system look through a document for specific characters, words, or groups of characters.

global symbol. A symbol defined in one program module, but used in other independently assembled program modules.

graphic character. A character that can be displayed or printed.

group name. A name that uniquely identifies a group to the system.

group number (Gid). A unique number assigned to a group of related users. The group number can often be substituted in commands that take a group name as an argument.

handler. A software routine that controls a program's reaction to specific external events, such as an interrupt *handler.*

hardware. The equipment, as opposed to the programming, of a computer system.

header. Constant text that is formatted to be in the top margin of one or more pages.

header file. A text file that contains declarations used by a group of functions or users.

header label. A special set of records on a diskette describing the contents of the diskette.

help. Explanatory information that a program provides.

highlight. To emphasize an area on the display by any of several methods, such as brightening the area or reversing the color of characters within the area.

history file. A file containing a log of system actions and operator responses.

hole in a file. See *sparse file.*

home directory. (1) A directory associated with an individual user. (2) The user's current directory on login or after issuing the **cd** command with no argument.

hook ID. A unique number assigned to a specific trace point. All trace entries include the hook ID of the originating trace point in the trace entry header. Pre-defined trace points use assigned hook IDs ranging from 0 to 299. User-defined trace points can choose hook IDs ranging from 300 to 399.

I/O. See *input/output.*

ID. Identification.

IF expressions. Expressions within a procedure, used to test for a condition.

informational message. A message providing information to the operator, that does not require a response.

initial program load (IPL). The process of loading the system programs and preparing the system to run jobs. See *initialize.*

initialize. To set counters, switches, addresses, or contents of storage to zero or other starting values at the beginning of, or at prescribed points in, the operation of a computer routine.

i-node. The internal structure for managing files in the system. I-nodes contain all of the information pertaining to the node, type, owner, and location of a file. A table of i-nodes is stored near the beginning of a file system.

i-number. A number specifying a particular i-node on a file system.

input. Data to be processed.

input device. Physical devices used to provide data to a computer.

input file. A file opened in the input mode.

input list. A list of variables to which values are assigned from input data.

input-output file. A file opened for input and output use.

input-output device number. A value assigned to a device driver by the guest operating system or to the virtual device by the virtual resource manager. This number uniquely identifies the device regardless of whether it is real or virtual.

input/output (I/O). Pertaining to either input, output, or both between a computer and a device.

interactive processing. A processing method in which each system user action causes response from the program or the system. Contrast with *batch processing.*

interface. A shared boundary between two or more entities. An interface might be a hardware component to link two devices together or it might be a portion of storage or

registers accessed by two or more computer programs.

interrupt. (1) To temporarily stop a process. (2) In data communications, to take an action at a receiving station that causes the sending station to end a transmission. (3) A signal sent by an I/O device to the processor when an error has occurred or when assistance is needed to complete I/O. An interrupt usually suspends execution of the currently executing program.

IPL. See *initial program load.*

job. (1) A unit of work to be done by a system. (2) One or more related procedures or programs grouped into a procedure.

job queue. A list, on disk, of jobs waiting to be processed by the system.

justify. To print a document with even right and left margins.

K-byte. See *kilobyte.*

kernel. The memory-resident part of the AIX Operating System containing functions needed immediately and frequently. The kernel supervises the input and output, manages and controls the hardware, and schedules the user processes for execution.

key. A unique identifier (of type **key_t**) that names the particular interprocess communications member.

key pad. A physical grouping of keys on a keyboard (for example, numeric key pad, and cursor key pad).

keyboard. An input device consisting of various keys allowing the user to input data, control cursor and pointer locations, and to control the user-to-work station dialogue.

keylock feature. A security feature in which a lock and key can be used to restrict the use of the display station.

keyword. One of the predefined words of a programming language; a reserved word.

kill. An AIX Operating System command that stops a process.

kill character. The character that is used to delete a line of characters entered after the user's prompt.

kilobyte. 1024 bytes.

label. (1) The name in the disk or diskette volume table of contents that identifies a file. See also *file name.* (2) The field of an instruction that assigns a symbolic name to the location at which the instruction begins, or such a symbolic name.

left margin. The area on a page between the left paper edge and the leftmost character position on the page.

left-adjust. The process of aligning lines of text at the left margin or at a tab setting such that the leftmost character in the line or filed is in the leftmost position. of the field is in the leftmost position. Contrast with *right-adjust.*

lexical analyzer. A program that analyzes input and breaks it into categories, such as: numbers, letters or operators.

library. A collection of functions, calls, subroutines, or other data.

licensed program product (LPP). Software programs that remain the property of the manufacturer, for which customers pay a license fee.

linefeed. An ASCII character that causes an output device to move forward one line.

literal. A symbol or a quantity in a source program that is itself data, rather than a reference to data.

load. (1) To move data or programs into storage. (2) To place a diskette into a diskette drive, or a magazine into a diskette magazine drive. (3) To insert paper into a printer.

loader. A program that reads run files into main storage, thus preparing them for execution.

local. Pertaining to a device directly connected to your system without the use of a communications line. Contrast with *remote.*

log. To record; for example, to log all messages on the system printer.

log in (v). To sign on at a work station.

log off (v). To sign off at a work station.

logical device. A file for conducting input or output with a physical device.

loop. A sequence of instructions performed repeatedly until an ending condition is reached.

main storage. The part of the processing unit where programs are run.

mapped file. A file that can be accessed using direct memory operations, rather than having to read it from disk each time it is accessed.

mask. A pattern of characters that controls the keeping, deleting, or testing of portions of another pattern of characters.

master dump table. A structure containing dump table entries generated by VRM components. The dump program uses this table to locate data structures that should be included in a dump.

matrix. An array arranged in rows and columns.

memory. Storage on electronic chips. Examples of memory are random access memory, read only memory, or registers. See *storage.*

memory areas. Arrays of characters in memory.

menu. A displayed list of items from which an operator can make a selection.

message. (1) A response from the system to inform the operator of a condition which may affect further processing of a current program. (2) An error indication, or any brief information that a program writes to standard error or a queue. (3) Information sent from one user in a multi-user operating system to another. (4) A general method of communication between two processes.

message queue ID. An identifier assigned to a message queue for use within a particular process. It is similar in use to a *file descriptor* of a file.

message services. A set of routines to help create, update and display messages from a program.

minidisk. A logical division of a fixed disk that may be further subdivided into one or more partitions. See *partitions.*

modem. See *modulator-demodulator.*

modulation. Changing the frequency or size of one signal by using the frequency or size of another signal.

modulator-demodulator (modem). A device that converts data from the computer to a signal that can be transmitted on a communications line, and converts the signal received to data for the computer.

module. A discrete programming unit that usually performs a specific task or set of tasks. Modules are subroutines and calling programs that are assembled separately, then linked to make a complete program.

msqid. See *message queue ID.*

multiprogramming. The processing of two or more programs at the same time.

multivolume file. A diskette file occupying more than one diskette.

nest. To incorporate a structure or structures of some kind into a structure of the same kind.

For example, to nest one loop (the nested loop) within another loop (the nesting loop); to nest one subroutine (the nested subroutine) within another subroutine (the nesting subroutine).

network. A collection of products connected by communication lines for information exchange between locations.

new-line character. A control character that causes the print or display position to move to the first position on the next line.

null. Having no value, containing nothing.

null character (NUL). The character hex 00, used to represent the absence of a printed or displayed character.

numeric. Pertaining to any of the digits 0 through 9.

object code. Machine-executable instruction, usually generated by a compiler from source code written in a higher level language. Consists of directly executable machine code. For programs that must be linked, object code consists of relocatable machine code.

octal. A base eight numbering system.

open. To make a file available to a program for processing.

operating system. Software that controls the running of programs; in addition, an operating system may provide services such as resource allocation, scheduling, input/output control, and data management.

operation. A specific action (such as move, add, multiply, load) that the computer performs when requested.

operator. A symbol representing an operation to be done.

output. The result of processing data.

output devices. Physical devices used by a computer to present data to a user.

output file. A file that is opened in either the output mode or the extend mode.

override. (1) A parameter or value that replaces a previous parameter or value. (2) To replace a parameter or value.

overwrite. To write output into a storage or file space that is already occupied by data.

owner. The user who has the highest level of access authority to a data object or action, as defined by the object or action.

pad. To fill unused positions in a field with dummy data, usually zeros or blanks.

page. A block of instructions, data, or both.

pagination. The process of adjusting text to fit within margins and/or page boundaries.

paging. The action of transferring instructions, data, or both between real storage and external page storage.

paging space. An area on disk that the system uses to store information that is resident in virtual memory, but is not currently being accessed.

pane. In **Extended curses**, an area of the display that shows all or a part of the data contained in a presentation space associated with that pane. A pane is a subdivision of a panel.

panel. In **Extended curses**, a rectangular area on the display consisting of one or more panes that a program can treat as a unit.

parallel processing. The condition in which multiple tasks are being performed simultaneously within the same activity.

parameter. Information that the user supplies to a panel, command, or function.

parent. (1) Pertaining to a secured resource, either a file or library, whose user list is shared with one or more other files or libraries. Contrast with *child*. (2) Also pertains to a

process that has **fork**ed to create one or more child processes.

parent directory. The directory one level above the current directory.

parser. A program that analyzes input and determines what to do with the input.

partition. A logical division of a fixed disk.

password. A string of characters that, when entered along with a user identification, allows an operator to sign on to the system.

password security. A program product option that helps prevent the unauthorized use of a display station, by checking the password entered by each operator at sign-on.

path name. A complete file name specifying all directories leading to that file.

pattern-matching character. Special characters such as * or ? that can be used in a search pattern. Some are used in a file specification to match one or more characters. For example, placing a ? in a file specification means any character can be in that position. Pattern-matching characters are also called *wildcards.*

permission code. A three-digit octal code indicating the access permissions. The acces permissions are read, write, and execute.

permission field. One of the three-character fields within the permissions column of a directory listing indicating the read, write, and run permissions for the file or directory owner, group, and all others.

physical device. See *device.*

physical file. An indexed file containing data for which one or more alternative indexes have been created.

physical record. (1) A group of records recorded or processed as a unit. Same as *block.* (2) A unit of data moved into or out of the computer.

PID. See *process ID.*

pipe. To direct the data from one process to another process.

pipeline. A direct, one-way connection between two or more processes.

pitch. A unit of width of typewriter type, based on the number of times a letter can be set in a linear inch. For example, 10-pitch type has 10 characters per inch.

platen. The support mechanism for paper on a printer, commonly cylindrical, against which printing mechanisms strike to produce an impression.

position. The location of a character in a series, as in a record, a displayed message, or a computer printout.

presentation space. In **Extended curses**, the data and attribute array associated with a window.

primary group. In concurrent groups, the group that is assigned to the files that you create.

print queue. A file containing a list of the names of files waiting to be printed.

printing device. Any printer or device that prints, such as a typewriter-like device or a plotter.

printout. Information from the computer produced by a printer.

priority. The relative ranking of items. For example, a job with high priority in the job queue will be run before one with medium or low priority.

problem determination. The process of identifying why the system is not working. Often this process identifies programs, equipment, data communications facilities, or user errors as the source of the problem.

problem determination procedure. A prescribed sequence of steps aimed at recovery from, or circumvention of, problem conditions.

procedure. See *shell procedure.*

process. (1) A sequence of actions required to produce a desired result. (2) An entity receiving a portion of the processor's time for executing a program. (3) An activity within the system begun by entering a command, running a shell program, or being started by another process.

process ID (PID). A unique number assigned to a process that is running.

profile. (1) A file containing customized settings for a system or user (2) Data describing the significant features of a user, program, or device.

program. A file containing a set of instructions conforming to a particular programming language syntax.

prompt. A displayed request for information or operator action.

propagation time. The time necessary for a signal to travel from one point on a communications line to another.

queue. A line or list formed by items waiting to be processed.

queued message. A message from the system that is added to a list of messages stored in a file for viewing by the user at a later time. This is in contrast to a message that is sent directly to the screen for the user to see immediately.

quit. A key, command, or action that tells the system to return to a previous state or stop a process.

random access. An access mode in which records can be read from, written to, or removed from a file in any order.

real memory. Memory that is physically present in the system. Contrast with *virtual memory.*

recovery procedure. (1) An action performed by the operator when an error message appears on the display screen. Usually, this action permits the program to continue or permits the operator to run the next job. (2) The method of returning the system to the point where a major system error occurred and running the recent critical jobs again.

recursion. The process of using a function to define itself.

redirect. To divert data from a process to a file or device to which it would not normally go.

regular expression. A set of characters, metacharacters and operators that define a string or group of strings in a search pattern.

relational expression. A logical statement describing the relationship (such as greater than or equal) of two arithmetic expressions or data items.

relational operator. The reserved words or symbols used to express a relational condition or a relational expression.

relative address. An address specified relative to the address of a symbol. When a program is relocated, the addresses themselves will change, but the specification of relative addresses remains the same.

relative addressing. A means of addressing instructions and data areas by designating their locations relative to some symbol.

relative path name. The name of a directory or file expressed as a sequence of directories followed by a file name, beginning from the current directory.

remote. Pertaining to a system or device that is connected to your system through a communications line. Contrast with *local.*

reserved word. A word that is defined in a programming language for a special purpose, and that must not appear as a user-declared identifier.

reset. To return a device or circuit to a clear state.

restore. Return to an original value or image. For example, to restore a library from diskette.

right adjust. The process of aligning lines of text at the right margin or tab setting such that the right-most character in the line or file is in the right-most position.

right-adjust. To place or move an entry in a field so that the rightmost character of the field is in the rightmost position. Contrast with *left-adjust.*

right margin. The area on a page between the last text character and the right upper edge.

root. Another name sometimes used for superuser.

root directory. The top level of a tree-structured directory system.

root file system. The basic AIX Operating System file system, which contains operating system files and onto which other file systems can be mounted. The root file system is the file system that contains the files that are run to start the system running.

routine. A set of statements in a program causing the system to perform an operation or a series of related operations.

run. To cause a program, utility, or other machine function to be performed.

run-time environment. A collection of subroutines and shell variables that provide commonly used functions and information for system components.

SCCS. See *Source Code Control System.*

SCCS identification. In SCCS, a number assigned to a version of a program to keep track of each version of the program.

scratch file. A file, usually used as a work file, that exists until the program that uses it ends.

screen. (1) See *display screen.* (2) In **Extended curses**, a special type of window that is as large as the terminal screen.

scroll. To move information vertically or horizontally to bring into view information that is outside the display or pane boundaries. to bring into view information that is outside the display's boundaries.

sector. (1) An area on a disk track or a diskette track reserved to record information. (2) The smallest amount of information that can be written to or read from a disk or diskette during a single read or write operation.

security. The protection of data, system operations, and devices from accidental or intentional ruin, damage, or exposure.

segment. A contiguous area of virtual storage allocated to a job or system task. A program segment can be run by itself, even if the whole program is not in main storage.

segment registers. Registers in the system that hold the actual addresses of the memory segments currently in use.

semaphore. A general method of communication between two processes that is an extension of the features of signals.

semaphore ID. An integer that points to a set of semaphores and a data structure that contains information about the semaphores.

semid. See semaphore ID

separator. A character used to separate parts of a command. See *delimiter.*

sequential access. An access method in which records are read from, written to, or

removed from a file based on the logical order of the records in the file.

shared memory. A area of memory that more than one cooperating process can access simultaneously.

shared memory ID. An identifier assigned to the shared segment for use within a particular process. It is similar in use to a *file descriptor* of a file.

shared printer. A printer that is used by more than one work station.

shell. See *shell program.*

shell procedure. A series of commands combined in a file that carry out a particular function when the file is run or when the file is specified as an argument to the **sh** command. Shell procedures are frequently called shell scripts.

shell program. A program that accepts and interprets commands for the operating system (there is an AIX shell program and a DOS shell program).

shmid. See shared memory ID.

sign off. To end a session at a display station.

sign on. To begin a session at a display station.

sign-off. The action an operator uses at a display station to end working at the display station.

sign-on. The action an operator uses at a display station to begin working at the display station.

signal. A simple method of communication between two processes.

software. Programs.

sort. To select a particular group of records from a file based upon some criterion. Also, to rearrange some or all of a group of records based upon items in a particular field of those records.

Source Code Control System (SCCS). A program for maintaining version control for the source files of a developing program.

source diskette. The diskette containing data to be copied, compared, restored, or backed up.

source program. A set of instructions written in a programming language, that must be translated to machine language compiled before the program can be run.

sparse file. A file that is created with a length greater than the data it contains, leaving empty spaces for future addition of data.

special character. A character other than an alphabetic or numeric character. For example; *, +, and % are special characters.

special file. Special files are used in the AIX system to provide an interface to input/output devices. There is at least one special file for each device connected to the computer. Contrast with directory and ordinary AIX files.

standalone work station. A work station that can be used to preform tasks independent of (without being connected to) other resources such as servers or host systems.

standard error. The place where many programs place error messages.

standard input. The primary source of data going into a command. Standard input comes from the keyboard unless redirection or piping is used, in which case standard input can be from a file or the output from another command.

standard output. The primary destination of data coming from a command. Standard output goes to the display unless redirection or piping is used, in which case standard output can be to a file or another command.

standard screen. In **Extended curses**, a memory image of the screen that the routines make changes to.

stanza. A group of lines in a file that together have a common function. Stanzas are usually separated by blank lines, and each stanza has a name.

statement. An instruction in a program or procedure.

status. (1) The current condition or state of a program or device. For example, the status of a printer. (2) The condition of the hardware or software, usually represented in a status code.

stderr. See *standard error.*

stdin. See *standard input.*

stdout. See *standard output.*

storage. (1) The location of saved information. (2) In contrast to memory, the saving of information on physical devices such as disk or tape. See *memory.*

storage device. A device for storing and/or retrieving data.

stream. Sequential input or output from an open file descriptor.

string. A linear sequence of entities such as characters or physical elements. Examples of strings are alphabetic string, binary element string, bit string, character string, search string, and symbol string.

subdirectory. A directory contained within another directory in the file system hierarchy.

subprogram. A program invoked by another program. Contrast with *main program.*

subroutine. (1) A sequenced set of statements that may be used in one or more computer programs and at one or more points in a computer program. (2) A routine that can be part of another routine.

subscript. An integer or variable whose value refers to a particular element in a table or an array.

substring. A part of a character string.

subsystem. A secondary or subordinate system, usually capable of operating independently of, or synchronously with, a controlling system.

superblock. The most critical part of the file system containing information about every allocation or deallocation of a block in the file system.

superuser. The system user with superuser privileges.

superuser priviledges. The unrestricted ability to access and modify any part of the operating system associated with the user who manages the system.

system. The computer and its associated devices and programs.

system call. A request by an active process for a service by the system kernel.

system customization. A process of specifying the devices, programs, and users for a particular data processing system.

system date. The date assigned by the system user during setup and maintained by the system.

system dump. A printout of storage from all active programs (and their associated data) whenever an error stops the system. Contrast with *task dump.*

system profile. A file containing the default values used in system operations.

system unit. The part of the system that contains the processing unit, the disk drives, and the diskette drives.

system user. A person who uses a computer system.

target diskette. The diskette to be used to receive data from a source diskette.

task. A basic unit of work to be performed. Examples are a user task, a server task, and a processor task.

task dump. A printout of storage from a program that failed (and its associated data). Contrast with *system dump.*

terminal. (1) An input/output device containing a keyboard and either a display device or a printer. Terminals usually are connected to a computer and allow a person to interact with a computer. See *work station.* (2) In **Extended curses**, a memory image of what the terminal screen currently looks like.

text. A type of data consisting of a set of linguistic characters (for example, alphabet, numbers, and symbols) and formatting controls.

text application. A program defined for the purpose of processing text data (for example, memos, reports, and letters).

token. (1) The smallest independent unit of meaning as defined by either the parser or the lexical analyzer. A token can contain data, a language keyword, an identifier, or other parts of a language syntax. (2) In M4, any string of letters and digits that **m4** recognizes.

token numbers. Nonnegative integers that represent the names of tokens.

trace. To record data that provides a history of events occurring in the system.

trace entry. A data structure containing a header of identifying information plus up to 20 bytes of defined data. Trace entries are generated by trace points and written to a trace log file.

trace point. A group of code statements that generates a trace entry from within a software program. Trace points are assigned to an event class which can be active or inactive. Trace points with active event classes can generate trace entries.

trace profile. An ASCII file that can be modified to activate or deactivate the various event classes. The trace profile is used by the trace daemon to set up three channel tables that show which event classes are active.

trace template. Used by the trace formatter to determine how the data contained in a trace entry should be formatted. All trace templates are stored in the master template file.

track. A circular path on the surface of a fixed disk or diskette on which information is magnetically recorded and from which recorded information is read.

trap. An unprogrammed, hardware-initiated jump to a specific address. Occurs as a result of an error or certain other conditions.

tree-structured directories. A method for connecting directories such that each directory is listed in another directory except for the root directory, which is at the top of the tree.

truncate. To shorten a field or statement to a specified length.

typematic key. A key that repeats its function multiple times when held down.

type style. Characters of a given size, style, and design.

Uid. See *user number.*

user ID. See *user number.*

user name. A name that uniquely identifies a user to the system.

user number (Uid). A unique number identifying an operator to the system. This string of characters limits the functions and information the operator is allowed to use. The Uid can often be substituted in commands that take a user's name as an an argument.

user profile. A file containing a description of user characteristics and defaults (for example, printer assignment, formats, group ID) to be conveyed to the system while the user is signed on.

utility. A service; in programming, a program that performs a common service function.

valid. (1) Allowed. (2) True, in conforming to an appropriate standard or authority.

value. (1) In Usability Services, information selected or typed into a pop-up. (2) A set of characters or a quantity associated with a parameter or name. (3) In programming, the contents of a storage location.

variable. A name used to represent a data item whose value can change while the program is running. Contrast with *constant.*

verify. To confirm the correctness of something.

version. Information in addition to an object's name that identifies different modification levels of the same logical object.

virtual device. A device that appears to the user as a separate entity but is actually a shared portion of a real device. For example, several virtual terminals may exist simultaneously, but only one is active at any given time.

virtual machine. A functional simulation of a computer and its related devices.

virtual machine interface (VMI). A software interface between work stations and the operating system. The VMI shields operating system software from hardware changes and low-level interfaces and provides for concurrent execution of multiple virtual machines.

virtual memory. Addressable space that appears to be real memory. From virtual memory, instructions and data are mapped into real memory locations. Contrast with *real memory.*

virtual resource manager (VRM). A set of programs that manage the hardware resources (main storage, disk storage, display stations, and printers) of the system so that these resources can be used independently of each other.

virtual storage. See virtual memory

Volume ID (Vol ID). A series of characters recorded on the diskette used to identify the diskette to the user and to the system.

VRM. See *virtual resource manager.*

wildcard. See *pattern matching characters.*

window. In **Extended curses**, a memory image of what a section of the terminal screen looks like at some point in time. A window can be either the entire terminal screen, or any smaller portion down to a single character.

word. A contiguous series of 32 bits (four bytes) in storage, addressable as a unit. The address of the first byte of a word is evenly divisible by four.

work file. A file used for temporary storage of data being processed.

work station. A device at which an individual may transmit information to, or receive information from, a computer for the purpose of performing a task, for example, a display station or printer.

working directory. See *current directory.*

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The IBM RT PC
Family

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Summary of Changes

This technical newsletter contains various changes and additions to the explanations provided in *AIX Operating System Programming Tools and Interfaces.* The TNL updates the publication to Version 1.01 which is functionally equivalent to Version 1.1.

Perform the following:

Remove Pages	Insert Update Pages
vii through x	vii through x
1-1 and 1-2	1-1 and 1-2
none	1-4.1 through 1-4.4
3-3 and 3-4	3-3 and 3-4
4-3 and 4-4	4-3 and 4-4
4-23 and 4-24	4-23 through 4-24.4
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5-23 through 5-30	5-23 through 5-30
7-5 and 7-6	7-5 and 7-6
7-39 and 7-40	7-39 and 7-40
E-1 through E-18	E-1 through E-18
X-23 through X-34	X-23 through X-34

Notes:

1. Keep the original diskette that came with Version 1.0.
2. A change to the text or to an illustration is indicated by a vertical line to the left of the change.
3. Please file this cover letter at the back of the manual to provide a record of changes.