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CRAY X-MP™ AND CRAY-1® COMPUTER SYSTEMS

DISK SYSTEMS HARDWARE REFERENCE MANUAL

HR-0077

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PREFACE

This publication describes the operation of the Cray Research, Inc., DCU-4 and DCU-5 Disk Controller Units and the DD-29, DD-49, and DD-39 Disk Storage Units. It is written to assist programmers and engineers, and it assumes the reader has a familiarity with digital computers and has experience programming a Cray I/O Subsystem.

Section 1 provides an overview of the system. Section 2 explains the operation of the DD-29s under control of the DCU-4; section 3 explains the operation of the DD-49s under control of the DCU-5; and section 4 explains the operation of the DD-39s under control of the DCU-5. Appendixes contain detailed reference information.

The disk system is accessed by the Cray Computer System through either the Buffer I/O Processor or the Disk I/O Processor of the Cray I/O Subsystem. Refer to the hardware reference manual for your I/O Subsystem for detailed information.

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WARNING

This equipment generates, uses, and can radiate radio frequency energy and if not installed and used in accordance with the instructions manual, may cause interference to radio communications. It has been tested and found to comply with limits for a Class A computing device pursuant to Subpart J of Part 15 of FCC Rules, which are designed to provide reasonable protection against such interference when operated in a commercial environment. Operation of this equipment in a residential area is likely to cause interference in which case the user at his own expense will be required to take whatever measures may be required to correct the interference.

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INTRODUCTION 1

The disk system provides long-term data storage for the Cray Computer System. Components of the disk system include: I/O Processors (either Buffer I/O Processors or Disk I/O Processors), disk controller units, and disk storage units. The operation of the I/O Processors (IOPs) is described in a separate publication (see preface).

This publication deals only with disk controller units (DCUs) and the disk storage units (DSUs) that they control. Figure 1-1 illustrates a disk system for a Cray Computer System.

Each Buffer I/O Processor (BIOP) and Disk I/O Processor (DIOP) can have up to four DCUs and each DCU can control data flow for up to four DSUs. The DCU modules are contained in the I/O Subsystem (IOS) chassis and are connected to IOP channels.

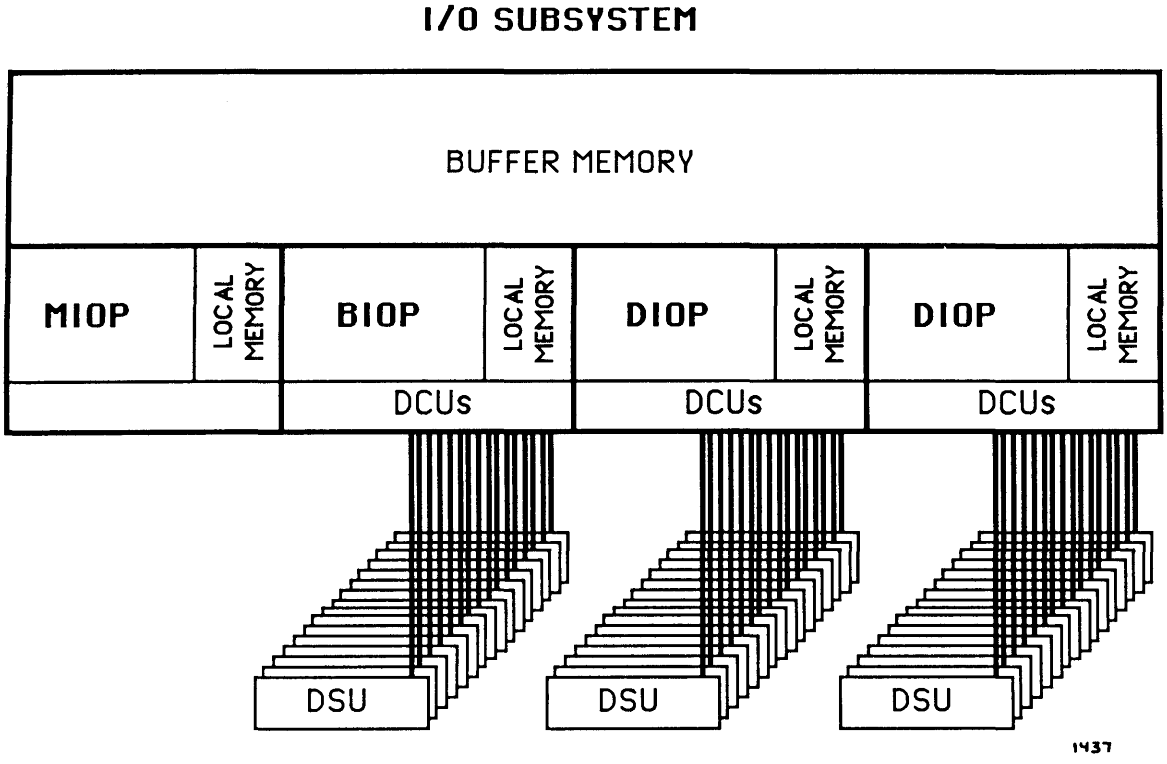


Figure 1-1. Disk System for a Cray Computer System
(Maximum Configuration)

Each DCU requires one DMA port and one to four accumulator channels from the IOP it is connected to. The DCU-4 controls DD-29 Disk Storage Units, the DCU-5 controls DD-39 and DD-49 Disk Storage Units. Both types of controllers can be present on the same I/O Subsystem, although normally only one type will be present.

Each DSU can operate independently through the DCUs and all DSUs can transfer data at the same time.

The disk storage units are controlled by channel functions from the I/O Processor to a disk controller unit. The disk controller unit interprets the functions and generates the proper control signals for the DSU. Status is returned by the DSUs to registers in the DCU where it can be returned to the IOP's accumulator through the proper channel function.

The minimum configuration for the disk system has a single DCU and two DSUs connected to the BIOP. The maximum number of disk storage units on an IOS is 48, which requires an IOS with two DIOPs.

DISK CONTROLLER UNITS

Disk controller units are housed in the IOS and are the interface between the IOP and the disk drives. The DCUs consist of logic modules for data transfer, buffer storage, and control. Information about DCU buffers and registers and the channel control functions are contained in sections appropriate to the disk storage unit that they control (see sections 2, 3, and 4).

The DCU-5 communicates with the IOP and DSUs over 16-bit synchronous channels; the DCU-4 communicates over 4-bit synchronous channels. The DCUs position and monitor each disk storage unit simultaneously through independent control circuits. Data transfer rates are shown in table 1-1.

The DCU-4 interfaces with DD-29 Disk Storage Units. A 32-bit interface between the DCU and the DSU transfers data to and from the drive. Head deskew and data assembly and disassembly are handled by the DCU.

The DCU-5 interfaces with DD-49 and DD-39 Disk Storage Units. A 48-bit interface between the DCU and the DSU transfers parcel size parameters, statuses, and data. Head deskew and data assembly and disassembly are handled in the drive interface logic. Data and some statuses are transferred in 16-parcel packets.

Odd parity is provided by the controller for all transfers between the DCU and the DSU (refer to the IOS manual for information about data protection for data transfers to and from Local Memory).

DISK STORAGE UNITS

The DSUs (figure 1-2) store data on magnetic disks. The DD-29 has a data capacity of approximately 75 million words, the DD-39 has a capacity of approximately 155 million words, and the DD-49 has a capacity of approximately 152 million words. Refer to table 1-1 for a comparison of the disk storage units specifications.

The DD-29s and DD-49s house a single disk drive within the cabinet. The DD-39 cabinet contains three disk drives that are logically connected to operate as a single unit.

Sector slipping mechanisms are provided on both the DD-39 and DD-49 so that the operating system has fewer flaws to keep track of. All disk storage units are dual ported and may be shared by two DCUs. Specific characteristics of the disk storage units are provided in sections 2 through 4.

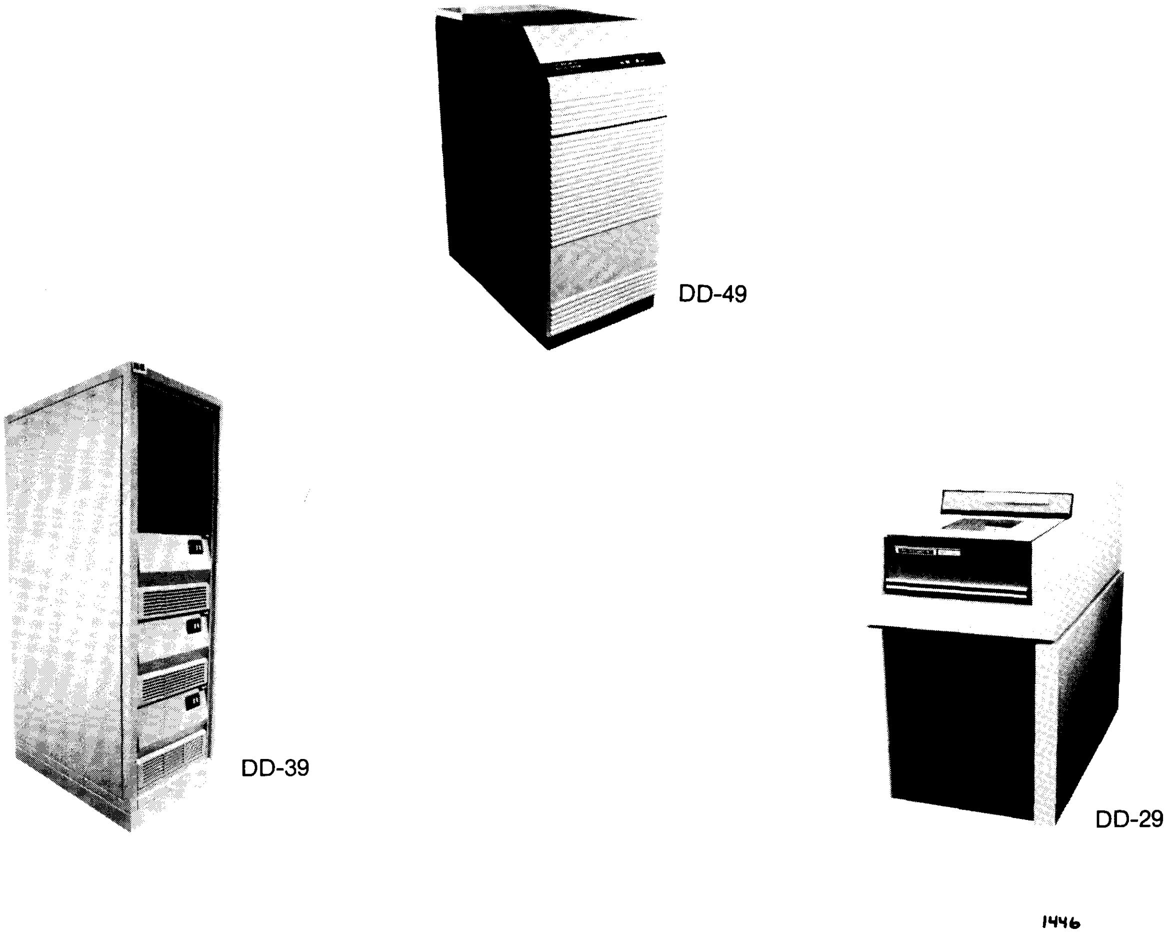


Figure 1-2. Disk Storage Units

Table 1-1. Disk Storage Unit Specifications

Specification	Disk Storage Unit		
	DD-29	DD-49	DD-39
Bits/byte	8	8	8
Bytes/word	8	8	8
Words/sector	512	512	512
Sectors/track	18	42	24
Tracks/cylinder	10	8	5
Cylinders/drive	823	886	841
Drives/DSU cabinet	1	1	3
Total data bits per cabinet	4,854,251,520	9,754,902,528	9,920,839,680
Latency time (ms)	0 - 16.6	0 - 16.6	0 - 15.2
Typical seek times (ms)			
Minimum (1 track)	15	2.5	5.5
Average	50	16	18
Maximum (full stroke)	80	30	35
Access time (ms)	0 - 96.6	0 - 46.6	0 - 50.0
Max. transfer rate (bits/sec/track)	32.2E6	82.6E6	52.4E6
Revolutions per minute	3600	3600	3961

DD-29/DCU-4 OPERATION

2

This section contains information concerning the DD-29 Disk Storage Units (DSUs) and the DCU-4 Disk Controller Unit (DCU). Included in this section is a general description of DD-29 DSU characteristics, descriptions of data formats, DCU registers and buffers, disk channel functions, and error processing. The section also includes a DD-29 programming example.

DISK STORAGE UNIT CHARACTERISTICS

The DD-29 DSU consists of 40 rotating disk surfaces with a read/record head on each surface. The period of disk rotation is 16.6 ms. The heads are moved simultaneously to one of 823 disk cylinders by a servomechanism. Positioning time from one cylinder to another varies from 15 ms to 80 ms, depending on the distance the head assembly must travel.

Within each disk cylinder, the 40 read/record heads are divided into ten groups. Each head group reads or records 4 bits of data in parallel. The selection of a new head group requires 6 microseconds.

The recording surface available to each head group is called a disk track, and it is the basic storage unit reserved by the operating system. A flaw on the disk surface requires that a track be removed from the available resources in the track reservation table for the system.

Within each disk track are 18 sectors in which data can be recorded and read back. The data in one sector is called a data block and consists of 2048 16-bit parcels of I/O Processor (IOP) data (512 64-bit words) plus verification and error correction data. Data can be transferred between the IOP's Local Memory and the disk surface only in blocks of this fixed size.

DATA SEQUENCE PATTERN

Data recorded in a sector of a disk track consists of a number of parts, as shown in figure 2-1. The numbers below each segment in the figure are the total bits of all four heads for the segment.

INDEX	GAP	PREAMBLE	SYNC	ID	DELAY	PREAMBLE	SYNC	512 WORDS	CRC	POSTAMBLE	
	720	912	8	24	304	912	8	32,768	128	24	BITS

1025

Figure 2-1. DD-29 DSU Data Sequence Pattern

The total number of bits in the above figure is 35,808. This is the portion of a disk track assigned to a sector. An additional gap after the last sector on the track has 576 bits. The total number of data and control bits in a disk track is 645,120.

The bit positions assigned to the angular locations on the disk surface are determined by an index mark and a servo clock. The index mark is a unique mark on the rotating mechanism that provides a pulse once per disk revolution. This pulse clears a counter which then counts servo pulses to define the remainder of the disk timing. Servo clock pulses are also derived from the rotating mechanism and occur every 12 bit positions. The clock used for recording data on the disk surface is obtained by a frequency multiplier.

The index mark begins the data sequence pattern for sector 0 as shown in figure 2-1 sector 0. The beginning location for the other sectors is determined by the servo counter. These begin every 746 servo pulses (8952 bit positions).

The data sequence pattern for a sector, as shown in figure 2-1, is recorded in two separate processes. The sector identification (ID) word, which appears as 6 bits under each recording head, is recorded on each new set of disk surfaces and is not modified in normal use of the DSU. The data block (512 words) and the CRC checkwords are recorded with each disk write function in normal operation. A preamble and sync for ID, and a preamble, sync, and postamble are associated with each of these recordings. They are necessary parts of the recording and reading process.

The write heads are turned on for a normal disk block write function during the inter-sector gap. Writing begins with the second group of preamble and sync bits, which are sequenced by the disk control circuits. Data from Local Memory is then recorded in a block of 32,768 bits. This is followed by four 32-bit cyclic redundancy checkwords which are generated from the data by a Fire code generator. The write heads are turned off after the 24-bit postamble.

Cylinder verification word

A special mode of operation with the DKA : 3 function is used to prerecord a cylinder verification word on the disk surface. Refer to the description of the DKA : 3 function (format mode).

Sector identification word

The sector identification (ID) word for each sector is 24 bits. It is composed of a cylinder number, a head-group number, a sector number, and four parity bits. The ID format is shown in figure 2-2.

2^{23}	2^{22} … 2^{13}	2^{12} … 2^{9}	2^{8} … 2^{4}	2^{3} … 2^{0}
0	Cylinder	Head	Sector	Parity

Figure 2-2. Sector ID Format

Each parity bit in the sector identification word protects a cross-section of the other 20 bits of the ID. The assignment of parity bits to groups of ID bits is shown in table 2-1.

Table 2-1. Sector ID Parity Bit Assignments

Parity Bits	2^0	2^1	2^2	2^3
Data Bits	2^{20} 2^{16} 2^{12} 2^{8} 2^{4}	2^{21} 2^{17} 2^{13} 2^{9} 2^{5}	2^{22} 2^{18} 2^{14} 2^{10} 2^{6}	2^{23} 2^{19} 2^{15} 2^{11} 2^{7}

DCU-4/DD-29 REGISTERS AND BUFFERS

The DCU-4 and DD-29 contain buffers and registers for data transfer and control. Buffers in the DCU-4 allow data to be streamed between the DSU and Local Memory; deskew buffers in the DCU-4 assure data written to disk is accurately recorded at the correct position under the read/write heads. Registers hold memory addresses, status responses and other information. Registers used by the DCU-4 and DD-29 include:

- Fault registers
- Offset register
- Interlock register
- Difference register
- Local Memory Address register
- Status Response register

The Local Memory Address register and the Status Response register are directly accessible to the IOP accumulator. Information from the other registers is available to the IOP through the DKA : 1 function.

LOCAL MEMORY ADDRESS REGISTER

The Local Memory Address register of the DCU-4 is both an interface input register and an interface output register for the channel. The beginning address for a block of disk data is entered in the register by the IOP (using the DKA : 14 function) before issuing a read or write function. This address is restricted to values that are a multiple of four because of the burst mode used in moving data into and out of Local Memory. The low-order 2 bits of the address are forced to 0 in the register. If the processor enters bit values other than 0 in these positions, these values are discarded.

The address in the Local Memory Address register is increased by a count of four as each burst of four words is transferred to or from Local Memory. This address can be monitored by the IOP using the DKA : 10 function. The address must be updated at the beginning of each sector transferred.

STATUS RESPONSE REGISTER

The Status Response register of the DCU-4 is used for the specific response requested by a DKA : 1 function and also for the implied response of a DKA : 5 function. Details of these functions are listed under the appropriate headings. The DKA : 11 function moves the contents of the Status Response register to the IOP accumulator.

DD-29 CHANNEL FUNCTIONS

APML mnemonics DKA through DKP indicate channel function for the DD-29. The functions for the first channel are explained in detail in the following paragraphs, and summarized in appendix D. For functions 0 through 3, 6, and 7, allow 1 clock period (CP) before checking the interrupt channel number (IOR : 10).

DKA : 0 - CLEAR CHANNEL

The DKA : 0 function clears the Channel Busy and Channel Done flags. No parameters are required for this function, which is not interlocked with any disk sequence in process.

DKA : 1 - SELECT MODE

The DKA : 1 function allows an IOP to select a mode of operation for the DSU or to request status information from the interface. The contents of the accumulator when the function is issued is used as a selecting parameter. The parameter values are summarized in table 2-2 and described in the following paragraphs.

Table 2-2. DKA : 1 Accumulator Parameters

Value	Meaning
000xxx	Release unit
001xxx	Reserve unit
002xxx	Clear fault flags
003xxx	Return to zero cylinder
004xxx	Select cylinder margin
005xxx	Read sector number
006xxx	Read error flags
007000	Read Cylinder register
007001	Read Head register
007002	Read Margin/Difference Register
007003	Read Interlock register

Parameter 000xxx - Release unit

Parameter 000xxx sets the Channel Busy flag and clears the Channel Done flag. No other flag request can be made on a particular DSU until a DKA : 1 function is issued for that unit. After a few microseconds, the interface clears the Channel Busy flag and sets the Channel Done flag. The DSU is released from the reservation on the current port and is free for reservation on the other port.

Parameter 001xxx - Reserve unit

Parameter 001xxx sets the Channel Busy flag and clears the Channel Done flag. After a few microseconds, the interface clears the Channel Busy flag and sets the Channel Done flag.

The DSU is reserved for the requesting IOP if it is not currently reserved by another IOP using the DSU access port. Parameter 001xxx does not automatically return a status response. The IOP must issue a separate DKA : 1 status request (parameter 007xxx) to determine whether the reservation was accepted.

Parameter 001xxx automatically selects head group 0. The unit must be reserved before it can recognize a read function (DKA : 2), a write function (DKA : 3), or a select cylinder function (DKA : 5). All other functions can be issued to an unreserved unit, unless the DSU is reserved on another access port.

Parameter 002xxx - Clear fault flags

Parameter 002xxx sets the Channel Busy flag and clears the Channel Done flag. After a few microseconds, the interface clears the Channel Busy flag and sets the Channel Done flag. Fault conditions, stored in fault registers in the interface and in the DSU, are all cleared.

NOTE

Parameter 002xxx may have to be issued twice before all fault conditions are cleared.

Parameter 003xxx - Return to zero cylinder

Parameter 003xxx sets the Channel Busy flag and clears the Channel Done flag. The read/write heads of the DSU are positioned to cylinder 0 as if the DSU were just powered up. The time for positioning the heads depends on the distance to be traveled (up to 625 ms for an 822-cylinder move). When the positioning is completed, the interface clears the Channel Busy flag and sets the Channel Done flag.

Parameter 004xxx - Select cylinder margin

Parameter 004xxx sets the Channel Busy flag and clears the Channel Done flag. After a few microseconds, the interface clears the Channel Busy flag and sets the Channel Done flag.

Through parameter 004xxx, the DSU's read/write heads are moved slightly away from the normal cylinder center in an attempt to read data that cannot be recovered by normal head positioning. The amount of offset is determined by the low-order 5 bits in parameter 004xxx. Each unit of the 5-bit value offsets the heads 25 microinches (0.64 micrometers). Bit 2^5 of the parameter defines the direction of the offset: a 1 indicates an offset toward the center of the disk, and a 0 specifies a move away from the center of the disk.

The nominal cylinder width for the DD-29 is 2200 microinches (56 micrometers), and the nominal center-to-center cylinder spacing is 2600 microinches (66 micrometers). The offset position is maintained until the next positioning function is received, either another margin select or a new cylinder select. Another cylinder select automatically cancels the margin select and centers the heads over the new cylinder.

The direction and amount of offset is contained in the DSU Offset register and can be inspected by a DKA : 1 function with parameter 007002 in the accumulator.

Parameter 005xxx - Read sector number

Parameter 005xxx sets the Channel Busy flag and clears the Channel Done flag. After approximately 10 CPs, the interface clears the Channel Busy flag and sets the Channel Done flag. When parameter 005xxx is completed, the sector number of the sector currently under the read/write heads is loaded into the Status Response register in the interface. A DKA : 11 function to the interface then reads the Status Response register to the IOP's accumulator.

The sector number is not read from the disk. Instead, an interface counter operates from the DSU servo clock, tracking the sector number. The counter is updated at the start of the inter-sector gap, and cleared by the index mark.

Parameter 006xxx - Read error flags

Parameter 006xxx sets the Channel Busy flag and clears the Channel Done flag. After a few microseconds, the interface clears the Channel Busy flag and sets the Channel Done flag. At this time the Status Response register of the interface receives data from the fault registers in the DSU and in the interface. This data remains in the Status Response register until it is replaced by data from another function. Table 2-3 shows the bit assignments in the Status Response register for the error flags and explains each error condition. Parameter 006xxx should be followed by a DKA : 11 function to move the flags to the accumulator.

Table 2-3. Bit Assignments for Error Flags in the Status Response Register

Bit	Name	Meaning
2^0	Read/write off cylinder	An attempt was made to read or write data when the read/write heads were still in motion on a change of cylinder.
2^1	Read and write conflict	An attempt was made to strobe data simultaneously early and late, or an attempt was made to write data with the cylinder margin offset, or the unit attempted to read and write at the same time.
2^2	Multiple head select	More than four heads were selected simultaneously.
2^3	Write fault channel 0	A failure occurred associated with the recording head for channel 0.
2^4	Write fault channel 1	A failure occurred associated with the recording head for channel 1.
2^5	Write fault channel 2	A failure occurred associated with the recording head for channel 2.
2^6	Write fault channel 3	A failure occurred associated with the recording head for channel 3.
2^7	Seek error	A failure occurred in moving the read/write heads to a new cylinder number.
2^8	Address error	The DSU received a head group select for a group number greater than 11_8, or a cylinder select for a cylinder number greater than 1466_8, or a margin selection when the disk was not on cylinder, or a cylinder select when the disk was not on cylinder.
2^9	Data error channel 0	An error occurred in the channel 0 data during the last read operation.
2^{10}	Data error channel 1	An error occurred in the channel 1 data during the last read operation.
2^{11}	Data error channel 2	An error occurred in the channel 2 data during the last read operation.

Table 2-3. Bit Assignments for Error Flags in the Status Response Register (continued)

Bit	Name	Meaning
2^{12}	Data error channel 3	An error occurred in the channel 3 data during the last read operation.
2^{13}	Lost data	The data transfer between Local Memory and the deskewing buffers did not keep up with the disk read/write transfer in a read or write operation.
2^{14}	Lost function	A function was received before a previous function completed.
2^{15}	Angular position counter error	The index mark from the DSU was received in the middle of a sector.

Parameter 007000 - Read Cylinder register

Parameter 007000 sets the Channel Busy flag and clears the Channel Done flag. After a few microseconds, the interface clears the Channel Busy flag and sets the Channel Done flag. At this time the interface's Status Response register receives the currently selected cylinder number from the DSU. The cylinder number occupies the 10 low-order bits of the Status Response register. This data remains in the Status Response register until replaced by data from another function.

Parameter 007001 - Read Head register

Parameter 007001 sets the Channel Busy flag and clears the Channel Done flag. After a few microseconds, the interface clears the Channel Busy flag and sets the Channel Done flag. At this time the interface's Status Response register receives the currently selected head group number from the DSU, if the DSU is reserved to the IOP.

The head number goes in the 4 low-order register bits, and bit 2^5 is a 1 to show reservation to the requesting IOP. Bit 2^6 indicates the DSU capacity is 600 Mbytes. The register value has a range of 140_8-151_8 (DD-29) for the 10 head groups. A zero word returned indicates the DSU is not reserved to the requesting IOP. Status data remains in the register until replaced by data from another function.

Parameter 007002 - Read margin/difference register

Parameter 007002 sets the Channel Busy flag and clears the Channel Done flag. After a few microseconds, the interface clears the Channel Busy flag and sets the Channel Done flag. At this time, the interface's Status Response register receives either the currently selected offset margin from the Offset register or the difference between the present position of the heads and the final cylinder position during a seek from the DSU.

If the last operation was an offset margin selection (parameter 004*xxx*), the status returned is the ones complement of the offset number selected by that operation. The 5 low-order bits of the Status Response register hold the offset number; bit 2^5 shows the offset direction. Bit 2^5 is set to 0 if the offset is toward the center of the disk. See figure 2-3.

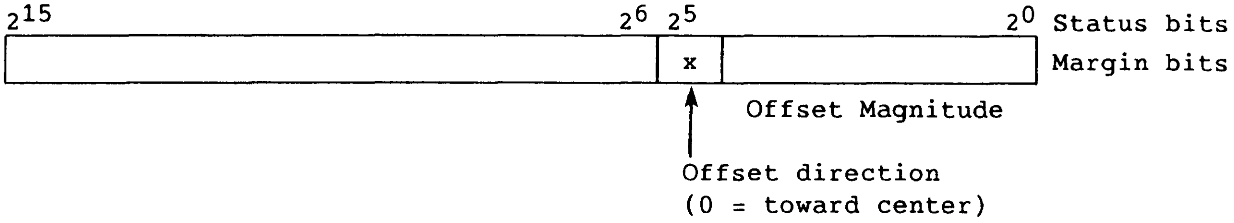


Figure 2-3. Offset Margin in Status Response Register

If the previous function was a select cylinder function (DKA : 5), the interface's Status Response register receives the ones complement of the number of cylinder positions to be crossed before reaching the desired cylinder. The register contains 1777_8 (all 1's) when the heads are positioned at the desired cylinder. The difference number goes into the least significant 10 bits of the Status Response register. For example, if 294 (0100100110_2) track positions remain to be crossed, the Status Response register contains the ones complement value illustrated in figure 2-4.

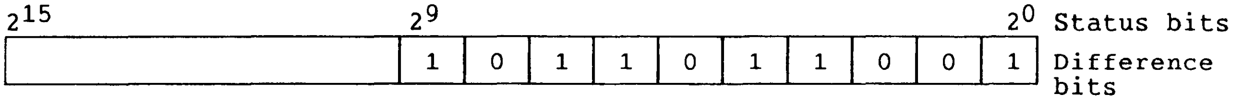


Figure 2-4. Cylinder Positioning in Status Response Register

Parameter 007003 - Read Interlock register

Parameter 007003 sets the Channel Busy flag and clears the Channel Done flag. After a few microseconds, the interface clears the Channel Busy flag and sets the Channel Done flag. At this time the interface's Status Response register receives the contents of the Interlock register from the DSU. Eight interlock flags are placed in the low-order bit positions of the Status Response register. A fault condition exists if a bit is set to 1. Table 2-4 shows the bit assignments in the Status Response register for the interlock flags and explains the purpose of each one.

NOTE

A status function (DKA :1) can be issued after a select cylinder (DKA : 5) function and before the select cylinder function has finished. But the status function should be issued immediately after the select cylinder function to allow sufficient time between the Done flag of the status request and the Done flag of the cylinder select. If the two Done flags occur close together, the program cannot distinguish between them and handles the conditions incorrectly. Avoid status functions near the end of a head positioning sequence.

DKA : 2 - READ DISK DATA

A DKA : 2 function reads a block of data from the disk into Local Memory at the beginning address specified by the interface Local Memory Address register. The disk sector number is specified by the accumulator contents at the time of the DKA : 2 function. The head group number and cylinder number are the values last selected by the functions for those purposes.

The DKA : 2 function clears the Channel Done flag and sets the Channel Busy flag. The reading process begins with a hardware test for proper angular position of the disk surface. The sector number requested by the IOP is compared with the sector number currently under the reading heads. If the disk is not in the proper position, the execution of the DKA : 2 function is delayed until the disk surface is properly positioned.

Table 2-4. Bit Assignments for Interlock Flags in the Status Response Register

Bit	Name	Meaning
2^0	High temperature	The disk drive cabinet is over the normal temperature range.
2^1	Disk not up to speed	The disk surfaces are not up to speed.
2^2	Heads not loaded	The disk heads are not loaded on the disk surface.
2^3	First seek error	This bit is set for approximately one minute after the drive power is turned on.
2^4	Start switch turned off	The disk drive start switch is turned off.
2^5	Off cylinder	The heads are not over the selected cylinder.
2^6	Low negative supply voltage	The negative voltage supply for the disk drive is below normal voltage.
2^7	Low positive supply voltage	The positive voltage supply for the disk drive is below normal voltage.

When other functions have been satisfied, the interface anticipates the IOP's request to read data. It begins to read sectors with the expectation that the read request for that data is coming.

Once read from the disk, data is routed to Local Memory through two buffers, A and B. Each buffer holds 256 parcels of IOP data. Buffer A receives the first 256 parcels of disk data. Buffer B receives the second 256 parcels. The use of the two buffers alternates until the entire 2048-parcel block of data (one sector) is processed.

The currently anticipated reading process is accepted if buffer A has not filled with the first 256 parcels of data from the disk surface. If the read process has proceeded beyond this point, or if the sector number is wrong, the current read process is aborted and the function waits up to one disk revolution for sector coincidence.

The data in buffer A begins moving to the IOP's Local Memory as the disk read circuits begin filling buffer B. The data moves to Local Memory in bursts of four 16-bit parcels and normally empties buffer A before the disk read circuits have filled buffer B. The roles of the two buffers then reverse and data continues moving from the disk surface to Local Memory until the entire block is processed.

Eight parcels of error correction data follow the data block and are read into the buffer as the last section of the data block is moving from the other buffer to Local Memory. Reading stops at this point for a check of the Fire code generators, which have been summing the data as it is read from the disk surface. If all four generators are clear, the data read from the disk is correct (see the subsection on DD-29 Disk Error Correction). The Channel Done flag is set and the Channel Busy flag is cleared as the last word of disk data is entered in Local Memory.

DKA : 2 - Abnormal conditions

An abnormal condition in the DSU or in the reading or processing of data is indicated to the IOP by a terminating sequence that sets the Channel Done flag and leaves the Channel Busy flag. The IOP program can then analyze the error by appropriate DKA : 1 functions for status information.

The following types of error conditions cause this termination:

- Recorded data error
- Lost data error
- Lost function error
- Time-out (Done flage does not set for a time-out.)

Recorded data error - While the recorded data is transferring from the DSU to the interface, the Fire code generators operate on the data as explained in the DD-29 Disk Error Correction subsection. The 32-bit error correction code from each read head also passes through the Fire code generator for that head. The four new error correction codes generated should each be 32 zeros, if the data was stored and read correctly.

If any error correction code is nonzero, the Recorded Data Error flag for that head is set in the Fault register. The four read channels each have such a flag. The IOP can use a special read mode to obtain the error correction code necessary to proceed with the software algorithm for correction. (The special read mode is described under DKA : 2 - Special modes.)

Lost data error - The Lost Data flag is set in the Fault register if the transfer of data from the buffers did not keep up with the reading of data from the disk surface. The IOP must reread the sector.

Lost function error - The Lost Function flag in the error status response (DKA : 1 parameter 006*xxx*) is set if a function is received at the interface before a previous function finishes. The new function is lost and should be requested again.

Time-out - When a time-out occurs on the channel, a clear fault command (DKA : 1 parameter 002*xxx*) should be issued on the channel before any other command. This will clear the read command and allow successful recovery of the channel. Issuing a read status command before a clear fault command can result in the channel locking up with the read command hanging the channel. If that happens, the channel can be cleared only by a system Master Clear.

DKA : 2 - Special modes

Special modes for reading disk data are requested by the IOP by using sector numbers larger than 40_8. The low-order 5 bits of the requested sector number are translated for sector coincidence. The high-order bits are interpreted for the special mode.

The following special modes may be indicated:

- Format mode
- Read correction code
- Read early
- Read late
- Mixed modes
- Buffer echo mode

Format mode - Sectors 40_8 through 61_8 request that the reading process begin with the verification word and continue for a total of 4000_8 parcels. The next 8 words are then interpreted as the error correction code. This read mode is used only for maintenance. The error correction code is not generated by the Fire code generators because the data length during the write sequence is much longer than the requested length for this mode. This combination of long write and short read allows the maintenance routine to test for various failure modes in the Fire code generators.

Read correction code - Sectors 100_8 through 121_8 request that the reading process begin with the error correction code and continue for the 8 words of that code. This mode is used when the data in the associated sector is read incorrectly and the IOP program wishes to perform error correction.

Read early - Sectors 200_8 through 221_8 cause the reading heads to sample the data from the disk surface somewhat earlier than normal. This mode is used to recover data that cannot be read in a normal mode.

Read late - Sectors 400_8 through 421_8 cause the reading heads to sample the data from the disk surface somewhat later than normal. This mode is used to recover data that cannot be read in a normal mode.

Mixed modes - The read early and read late selections described above can be used together with the other special modes by combining the high-order bit values in a logical sum.

Buffer echo mode - A special diagnostic feature allows writing a test data block into the A and B buffers, and then reading out the test data. This test can only be done after a Master Clear and before a DKA : 1 function. The Master Clear is generated during a deadstart sequence. A DKA : 14 function, to enter the starting address for the read to Local Memory, must precede the DKA : 2 read function. Refer to the buffer echo mode explanation in the DKA : 3 subsection which follows.

DKA : 3 - WRITE DISK DATA

A DKA : 3 function writes a block of data from Local Memory to the disk surface. The Local Memory address for beginning the block of data is specified by the contents of the interface's Local Memory Address register. The disk sector number is specified by the accumulator contents at the time of the function. The head group number and cylinder number are the values last selected by the appropriate functions for those purposes. A DKA : 3 function sets the Channel Busy flag and clears the Channel Done flag.

The writing process begins by filling buffer A with data from Local Memory. When this buffer is full, the interface monitors the angular position of the disk surface for the proper position to begin writing data. This position is slightly past the prerecorded address verification word for the requested sector. The write circuits are turned on when the disk is in the proper position, and data in buffer A is then transmitted to the disk surface.

At this time, the interface begins filling buffer B with data from Local Memory. Buffer B should be filled before the disk writing circuits have emptied buffer A. The Lost Data flag in the interface's Fault register is set if this is not the case. The disk writing circuits begin transmitting data from buffer B to the disk surface as soon as buffer A is emptied. This process continues with the roles of buffers A and B alternating until the last of the data in the block has been loaded into buffer B.

No other data is read from Local Memory and the interface waits for completion of the data transfer from buffer A to the disk surface. The interface then sets the Channel Done flag and clears the Channel Busy flag, if no error has occurred in the writing process. The IOP is free at this point to issue another write function and begin loading buffer A with data for another sector on this track. In the meantime, the interface continues with the final data from buffer B until the buffer is empty and the sector is complete.

The disk write circuits follow the last data from buffer B with 8 parcels of error correction code. This data comes directly from the Fire code generators. The writing circuits are turned off at this time and the interface prepares to write data in the next sector if the IOP has requested this function.

DKA : 3 - Abnormal conditions

If a lost data error or a lost function error occurs during the writing process, the Channel Busy flag remains set along with the Channel Done flag. If a time-out occurs the Channel Busy flag remains set, but the Channel Done flag does not set.

Lost data error - The Lost Data flag is set if the data transfer from Local Memory has not kept up with the data transfer to the disk surface.

Lost function error - The Lost Function flag is set if a function is received at the interface before the previous function is finished. The new function is lost and must be issued again to continue.

Time-out - When a time-out occurs on the channel, a clear fault command (DKA : 1 parameter 002*xxx*) should be issued on the channel before any other command. This will clear the write command and allow successful recovery of the channel. Issuing a read status command before a clear fault command can result in the channel locking up with the write command hanging the channel. If that happens, the channel can be cleared only by a system Master Clear.

DKA : 3 - Special modes

A DKA : 3 function request has the following special modes:

- Format mode
- Buffer echo mode
- Write all zeros error correction code

Format mode - A special mode of operation is provided in the disk channel interface to prerecord the cylinder verification data on the disk surface. This mode is selected by a DKA : 3 function with a sector number value of 40_8 through 61_8. The disk control circuits translate the low-order 5 bits of the sector number to select the sector for recording. The high-order bit causes the writing process to begin earlier than normal.

This selection records a 4000_8-parcel block of data on the disk surface so that the first word of this data block is properly positioned for the cylinder verification word. The remainder of the recording in this format mode is used for maintenance functions and is then erased by the recording of the normal sector data. Figure 2-5 shows the pattern written in each sector under format mode.

INDEX	GAP	PREAMBLE	SYNC	ID	ALL ZEROS	CRC	POSTAMBLE	GAP	
	720	912	8	24	32,744	128	24	1,248	Bits

Figure 2-5. Format Mode Sector Pattern (used when writing addresses on disk)

Buffer echo mode - A special diagnostic feature allows writing a test data block into buffers A and B and then reading out the test data. This can only be done after a Master Clear from a deadstart sequence and before a DKA : 1 function. The sequence is as follows:

1. Master Clear
2. DKA : 14, enter Local Memory starting address
3. DKA : 3, write data to buffers A and B
4. DKA : 14, enter Local Memory starting address
5. DKA : 2, read data from buffers
6. Verify data
7. DKA : 1, place controller in normal operation mode

Write all zeros error correction code - This mode is for maintenance purposes only, and enables writing a sector with an all zeros error correction code. This is accomplished by setting bit 2^6 in the accumulator and issuing a DKA : 3 write function to the interface.

DKA : 4 - SELECT HEAD GROUP

A DKA : 4 function reserves the DSU and causes the head group selection circuits to select a head group. The new head group number is specified by the low-order 4 bits of the accumulator at the time of the function.

A DKA : 4 can be requested at any time with respect to the execution of other disk channel functions. The 4-bit code for selection of the head group is captured in a special register in the DCU. The action of switching the head group circuits requires about 6 microseconds and is delayed until the completion of any other function currently in progress. Therefore, it is possible to select a new head group during a read or write sequence and continue the reading or writing from the last sector of one track to the first sector of a different track in the same disk cylinder without missing a disk revolution.

A DKA : 4 function does not alter the condition of the Channel Busy or Done flags.

NOTE

A DKA : 4 function can be followed immediately by another function to be done as soon as the new head group is active. For example, a read disk data function can be stacked behind the select head group function.

The disk drive requires 7.5 microseconds between head selects. Successive head selects could cause a multiple head select fault and should be avoided.

DKA : 5 - SELECT CYLINDER

A DKA : 5 function causes the disk read/write head assembly to move to a cylinder position. The cylinder number is specified by the 10 low-order bits of the accumulator at the time the function issues.

The Channel Busy flag is set and the Channel Done flag is cleared by the function. When the function issues, the servomechanism for positioning the head assembly then begins moving to the new cylinder position. This process takes from 15 ms, for adjacent cylinders, to 80 ms, for maximum travel. A cylinder selection for the current cylinder requires a few microseconds for the process.

The DCU monitors cylinder positioning. When the read/record heads are on the newly requested cylinder, the data recorded on the selected track is read for verification of the cylinder. The data in the first verification word to pass under the read heads is captured and entered in the Status Response register. The Channel Busy flag is cleared to indicate completion of the requested function and the Channel Done flag is set. If the function cannot be completed because of an abnormal condition in the disk storage unit, the Channel Done flag is set and the Channel Busy flag remains set.

The DCU can be programmed to monitor the progress of the cylinder positioning. The normal sequence described above can be aborted with a DKA : 1 status function. This action resets the Channel Busy flag, clears the Channel Done flag, and begins the status response sequence. The cylinder positioning continues, but the verification process does not occur. The progress of the cylinder positioning can then be monitored by reading the Difference register content from the disk storage unit. A verification can be programmed by repeating the cylinder selection.

If the ID read is aborted with a DKA : 1 function after the cylinder select is issued, another select cylinder function cannot be issued to the DCU until the previous select completes at the drive level.

NOTE

A status function (DKA :1) can be issued after a select cylinder (DKA : 5) function and before the select cylinder function has finished. But the status function should be issued immediately after the select cylinder function to allow sufficient time between the Done flag of the status request and the Done flag of the cylinder select. If the two Done flags occur close together, the program cannot distinguish between them and handles the conditions incorrectly. Avoid status functions near the end of a head positioning sequence.

DKA : 6 - CLEAR INTERRUPT ENABLE FLAG

A DKA : 6 function clears the Channel Interrupt Enable flag. This function prevents interruption of the IOP program and requires program monitoring of the Channel Done flag for proper sequencing of disk control functions.

DKA : 7 - SET INTERRUPT ENABLE FLAG

A DKA : 7 function sets the Channel Interrupt Enable flag. This function allows an I/O interrupt request for this channel whenever the Channel Done flag is set.

DKA : 10 - READ LOCAL MEMORY ADDRESS

A DKA : 10 function reads the current value in the channel interface's Local Memory Address register and enters the value in the IOP's accumulator. A DKA : 10 function can be performed at any time with respect to a disk sequence.

DKA : 11 - READ STATUS RESPONSE

A DKA : 11 function reads the current contents of the Status Response register and enters the value in the IOP's accumulator. A DKA : 11 request can be performed at any time with respect to the disk sequence. The value read is the response from the last function that entered the Status Response register.

DKA : 14 - ENTER LOCAL MEMORY ADDRESS

A DKA : 14 function enters the current IOP accumulator contents into the channel interface's Local Memory Address register. The Channel Busy and Done flags are not altered in this process.

DKA : 15 - STATUS RESPONSE REGISTER DIAGNOSTIC

A DKA : 15 function can verify the operation of the Status Response register. The function transfers a test value from the IOP's accumulator to the Status Response register, overwriting the current status.

A DKA : 11 read status response function immediately following this diagnostic function returns the test value to the accumulator for verification. The Channel Busy and Done flags are not affected by the DKA : 15 function.

DD-29 DISK ERROR CORRECTION

IOP software should take the following steps when a disk error condition is recognized:

1. Read the data in which the error was detected and the Fire code that was generated when the data was written.

2. Simulate the hardware process of determining the correction vector.

3. Applying the correction vector, correct the error.

FIRE CODE GENERATION ON A WRITE TO DISK

As data is transferred from the IOP to the interface buffers, the interface generates the Fire code, or cyclic redundancy checkword (CRC). The Fire code generator uses the polynomial $x^{32} + x^{23} + x^{21} + x^{11} + x^{2} + 1$ to create one 32-bit checkword for each of the four DSU write heads. This polynomial allows for correcting data in a single error burst of 11 bits or less and for detecting errors if there are two bursts, or bursts of more than 11 bits in error for that head.

The checkword is generated by a 32-bit shifting register. The register is cleared before a data transfer is begun. The data bit going to the buffer is compared to bit 2^{31} of the shifting register. If the two bits are alike, bit 2^{0} of the register is cleared and the register is shifted left one position. If the bits are not alike, register bits 2^{1}, 2^{10}, 2^{20}, and 2^{22} are complemented, the register contents are then shifted left one position, and bit 2^{0} of the register is set to 1. The next data bit is compared with register bit 2^{31} and the register contents are altered as before.

Data bit 2^{63} is the first data bit to be used in generating the checkword for DSU head 3, 2^{62} is the first data bit used for DSU head 2, 2^{61} for head 1, 2^{60} for head 0 and so on for the first 16-bit channel word. Bits 2^{47}, 2^{31}, and 2^{15} are the other bits used first for DSU head 3 from the second, third, and fourth 16-bit channel words, respectively.

The checkword is generated continuously while the interface transfers data to the DSU. The four 32-bit error correction codes are appended to the data block (one quarter of the bits in one block and one error correcting code to each head).

ERROR CORRECTION ON A READ FROM DISK

The error correction routine attempts to correct read data errors using the Fire codes. Since the correction vector built by the hardware cannot be read directly, the routine simulates the hardware procedure to obtain a correction vector. The correction vector is used in correcting errors spanning 11 bits for each head. Appendix A contains the APML algorithm that builds the correction vector and corrects the error.

PROGRAMMING EXAMPLE

The following example illustrates a programming sequence in APML for the DD-29. A single target sector is read from the drive.

```
        DKA : 0                         .clear channel controller
        PASS
SEL     A = 1000                        .select parameter
        DKA : 1                         .Select Unit

                  Wait for interrupt

        P = ERROR, DKA = BZ             .sense error (both DN and BZ)
        P = ERROR, DKA # DN             .sense done error

CYL     A = CC                          .desired cylinder CC  (0-1466)
        DKA : 5                         .Select Cylinder

                  Wait for interrupt

        P = ERROR, DKA = BZ             .sense error
        P = ERROR, DKA # DN             .sense done error
        DKA : 11                        .read status response register
        A = A > 5                       .cylinder from verification word
        P = ERROR, A # CC               .sense mismatch

HEAD    A = HH                          .desired head group HH  (0-11)
        DKA : 4                         .Select Head

READ    A = AD                          .desired buffer address AD
        DKA : 14                        .enter local memory address
        PASS
        DKA : 10                        .echo back
        P = ERROR, A # AD               .sense register error
        A = SS                          .desired sector (0-21)
        DKA : 2                         .Read Data

                  Wait for interrupt

        P = ERROR, DKA = BZ             .sense error
        P = ERROR, DKA # DN             .sense done error

RELS    A = 0                           .release parameter
        DKA : 1                         .Release Unit

                  Wait for interrupt

        P = ERROR, DKA = BZ             .sense error
        P = ERROR, DKA # DN             .sense done error

        EXIT                            .end of illustration
```

The above illustration's read can be expanded from one sector to three sectors, if all sectors are on the same cylinder, as follows:

```
READ    A = AD                          .desired buffer address AD
        DKA : 14
        PASS
        DKA : 10                        .echo back
        P = ERROR, A # AD               .sense register error
        A = SS1                         .1st desired sector SS1
        DKA : 2                         .Read data
        PASS
        A = HH2                         .2nd desired sector's head HH2
        DKA : 4                         .select head when read complete

                  Wait for interrupt

        P = ERROR, DKA = BZ             .sense error
        P = ERROR, DKA # DN             .sense done error
        AD = AD + 4000                  .next desired buffer
        DKA : 14
        PASS
        DKA : 10                        .echo back
        P = ERROR, A # AD               .sense register error
        A = SS2                         .2nd desired sector SS2
        DKA : 2                         .Read data
        PASS
        A = HH3                         .3rd desired sector's head HH3
        DKA : 4                         .select head when read complete

                  Wait for interrupt

        P = ERROR, DKA = BZ             .sense error
        P = ERROR, DKA # DN             .sense done error
        AD = AD + 4000                  .next desired buffer
        DKA : 14
        PASS
        DKA : 10                        .echo back
        P = ERROR, A # AD               .sense register error
        A = SS3                         .3rd desired sector SS3
        DKA : 2                         .Read data

                  Wait for interrupt

        P = ERROR, DKA = BZ             .sense error
        P = ERROR, DKA # DN             .sense done error
        P = RELS                        .release unit
```

DD-49/DCU-5 OPERATION 3

This section contains information concerning the DD-49 Disk Storage Units (DSUs) and the DCU-5 Disk Controller Unit (DCU). Included in this section is a general description of DD-49 DSU characteristics, a description of the data sequence pattern, data and CE cylinders, flaw tables, the sector slipping mechanism, DCU registers and buffers, disk channel functions, and error processing. The section also includes a DD-49 programming example.

DD-49 DISK STORAGE UNIT CHARACTERISTICS

The DD-49 DSU consists of 9 rotating platters. Data is accessed by 32 read/write heads organized into eight groups, four read/write heads per group. The period of disk rotation is 16.6 ms; heads are controlled and positioned by two identical head actuator (servo) mechanisms to one of 886 disk cylinders. The servo mechanisms are identified as Servo-A and Servo-B. Positioning time from one cylinder to another varies from 2.5 ms to 30 ms, depending on the distance the head assembly must travel.

The recording surface available to each head group is a disk track, which is the basic storage unit reserved by the operating system. Within each disk track there are 42 sectors (and two spare sectors) in which data can be recorded and read back. The data in one sector is called a data block and consists of 2048 16-bit parcels of IOP data (512 64-bit words) plus verification and error correction data. Data can be transferred between the IOP's Local Memory and the disk surface only in blocks of this fixed size.

Sectors may be chained for both read and write operations by issuing an initial read or write request followed by a sequence of DIA : 16 functions.

The DD-49 DSU responds to commands from the IOP through a microprocessor unit card (MPU card) that contains a 68000 type 16-bit microprocessor and a second processor called the Supervisor.

DD-49 DATA SEQUENCE PATTERN

Data recorded in a sector of a disk track consists of a number of parts, as shown in figure 3-1. The numbers below each segment in the figure are the total bits of all four heads used.

ID PREAMBLE	ID SYNC	ID FIELD	ID PAD	DATA PREAMBLE	DATA SYNC	DATA FIELD (2048 parcels)	ECC	DATA PAD
1792	32	128	288	640	32	32768	192	288

Bits

1914

Figure 3-1. DD-49 DSU Data Sequence Pattern

The total number of bits in the above figure is 36,160. This is the portion of a disk track assigned to a sector. An additional gap after the last sector on the track has 6400 bits. The total number of bits in a disk track is 1,597,440.

DATA CYLINDERS AND CE CYLINDERS

The DD-49 disk contains 888 cylinders: 886 user data cylinders and two hardware-protected cylinders (known as CE cylinders). Cylinders 0 through 885 are data cylinders. Cylinder 887 (CE 1) contains the Factory Flaw table. Cylinder 889 (CE2) is the diagnostic scratch cylinder. Cylinder numbers 886 and 888 are not used, and cannot be accessed.

By default, the data cylinders are write enabled while CE1 and CE2 are write protected. A diagnostic function is required to write protect the data cylinders and write enable the CE cylinders. CE cylinders can be individually write protected or enabled.

FLAW TABLES

Each DD-49 contains three flaw tables that list the defective sectors on the disk. CE1 contains the Factory Flaw Table and the User Flaw Table. An Operating System Flaw Table is found on data cylinder 0.

The Factory Flaw Table is a list of the defective sectors originally on the device; it must not be modified. The User Flaw Table is a list of defective sectors currently on the device. The User Flaw Table is initially the same as the Factory Flaw Table, but can be modified to include additional flaw information. The Operating System Flaw Table is a list of defective logical sectors currently on the drive. This table is created by a diagnostic program according to operating system specifications and should be updated by the diagnostic program any time the User Flaw Table is modified.

The Factory Flaw Table and User Flaw Table entries are 2 parcels long. Parameters must be entered, right justified, into the following fields.

1st Parcel	Chan	Cylinder
	4 bits	12 bits

2nd Parcel	Head	†	Sector
	7 bits	1 bit	8 bits

The drive channel bits (Chan, above) are set to indicate one or more channels, as follows.

Bit	Channel
2^{15}	B2
2^{14}	B1
2^{13}	A2
2^{12}	A1

Each flaw table is two sectors long. Table entries must be in ascending orders with entries arranged with cylinder number first, head number second, and sector number last. No duplicate entries are allowed.

The table must be terminated with an entry of -1's (2 parcels of 177777_8) and and subsequent (unused) entries must also be filled with -1's.

DD-49 SECTOR SLIPPING MECHANISM

The DD-49 provides a sector slipping mechanism that allows a full track to remain available to the system even after one or two sectors of the track become flawed.

---

† Set to indicate an entry added by Cray Research, Inc.

As shown in figure 3-2, a DD-49 has 44 sectors per track; although only 42 sectors are used for data. Under normal circumstances, the two spare sectors are ignored. If one of the data sectors becomes flawed, however, a spare sector is used as a data sector, figure 3-3.

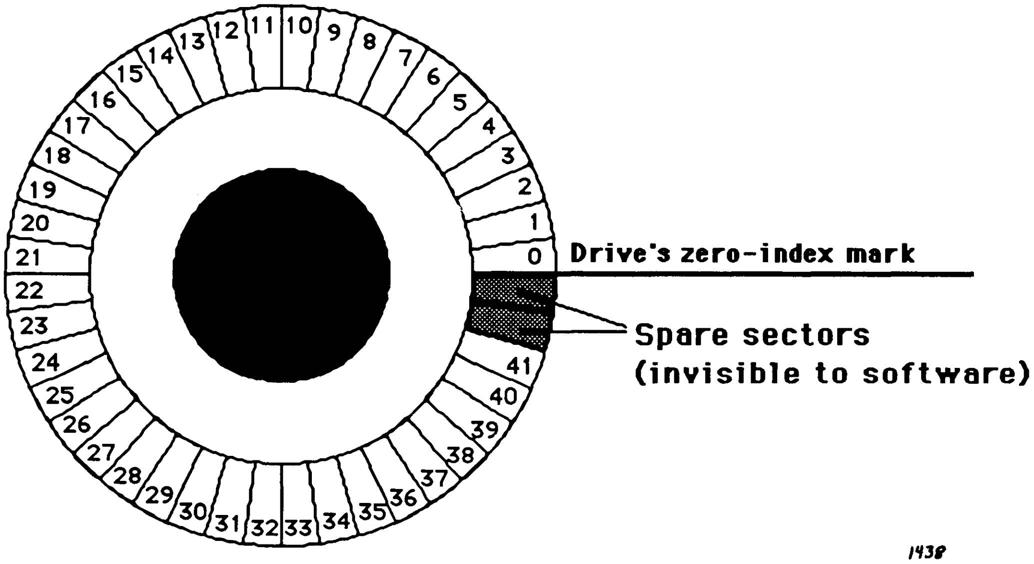


Figure 3-2. DD-49 Track

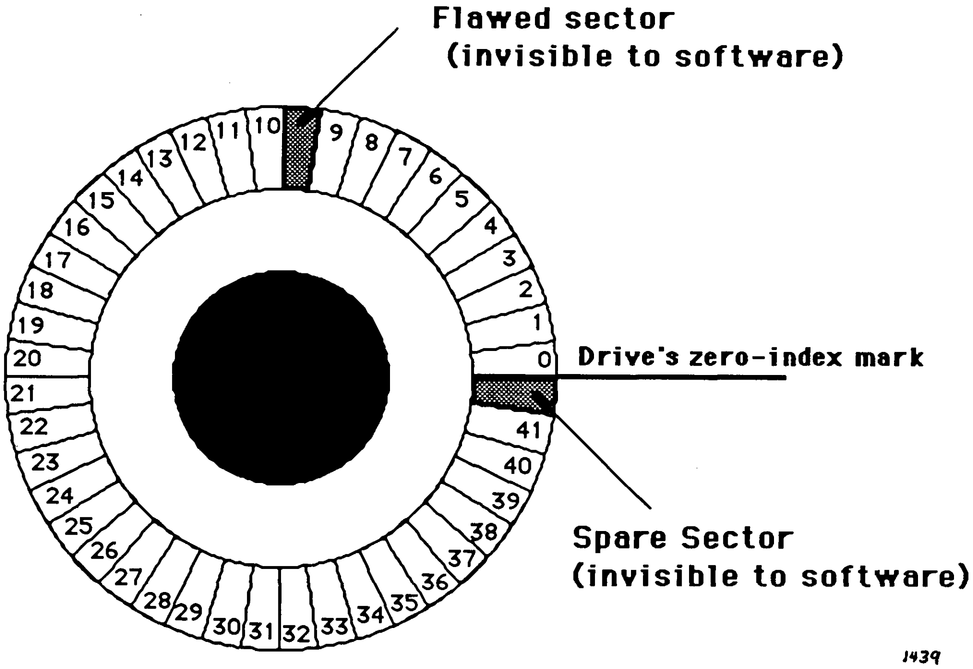


Figure 3-3. DD-49 Track With One Slipped Sector

Sectors are slipped from the flawed sector to the end of the track. As shown in figure 3-3, data sector 10 becomes physical sector 11, data sector 11 becomes physical sector 12, and so on. Because of data sector slipping, data must be recreated for sectors 10 through 41.

In general, if sector *n* becomes flawed, sectors *n* through 41 of the track are slipped and the data contained in sectors *n* through 41 must be recreated. If a second sector becomes flawed, the process is repeated.

If a third sector in a track becomes flawed, the operating system must mark the sector as unavailable.

Sector slipping takes place off-line. A hardware diagnostic reformats the track with slipped sectors.

DCU-5/DD-49 REGISTERS AND BUFFERS

The DCU-5 and DD-49 contain buffers and registers for data transfer and control. Buffers in the DCU-5 allow data to be streamed between the DSU and Local Memory; deskew buffers in the DD-49 assure data written to disk is accurately recorded at the correct position under the read/write heads. Registers hold memory addresses, status responses, and other information. Registers used by the DCU-5 and DD-49 include:

- Status registers (0 and 1)
- Local Memory Address registers (0 and 1)

STATUS REGISTERS

The DCU-5 contains two status registers: Status Register 0 and Status Register 1. The status registers return information about the current state of the drive, echo the last function issued, and provide other information needed by the IOP program.

LOCAL MEMORY ADDRESS REGISTERS

The DCU-5 contains two Local Memory Address registers: Local Address Register 0 and Local Address Register 1. The two registers are used during read and write operations to permit sector chaining. The addresses contained in the registers indicate the starting address for the next sector of information to be read to or from Local Memory.

DD-49 CHANNEL FUNCTIONS

APML mnemonics DIA through DIP indicate channel functions for the DD-49. The functions for the first channel are explained in detail in the following paragraphs and summarized in appendix D. For functions 0 through 7 and 17, allow 1 clock period (CP) before checking the interrupt channel (IOR : 10). For all functions, allow 6 CPs before issuing another function through the same DCU.

DIA : 0 - CLEAR CHANNEL CONTROLLER

A DIA : 0 function clears the Channel Busy, Channel Done, and internal status error flags of the DCU. It also clears the Special Diagnostic Control Mode flag.

DIA : 1 - DRIVE CONTROL OPERATIONS

A DIA : 1 function selects an IOP drive control operation. Drive operations may be commands to the drive or requests for status from the drive. When this function issues, the contents of the IOP accumulator specifies the drive operation.

This function sets the Channel Busy flag and clears the Channel Done flag. When the function completes, the Channel Done flag sets and, if no error occurs, the Channel Busy flag clears. If an error occurs, the Channel Busy flag remains set and the DCU Status Register 0 contains the cause of the error; the Status Register 1 value is determined by the particular drive operation.

The drive control operations are summarized in table 3-1 and described in the following paragraphs.

Parameter 012524 - Unit select

Parameter 012524 attempts to logically connect the IOP channel to a DD-49 and reserve the DSU for the channel, locking out the other port to the DSU. This parameter must be issued successfully before most other drive functions are allowed. An alternating bit pattern is included in parameter 012524 to help prevent unintended (open cable) drive commands.

Upon successful completion of this command, Status Register 0 contains 052003_8, indicating drive status available and drive ready, and Status Register 1 contains the drive general status.

Issuing parameter 012524 on a port that has already been selected will not cause an error.

Table 3-1. DD-49 DIA : 1 Drive Control Operations

Parameter	Operation
012524	Unit select
04xx00	Head select
0700xx	Select status
100000	General status
11xxxx	Diagnostic select
130000	Reset
140000	Clear faults
150000	Return to zero
162524	Release opposite channel and select
172524	Release

Parameter 04xx00 - Head select

Parameter 04xx00 specifies the logical head group for the next read or write operation. Bits 2^8 through 2^{10} of the accumulator are encoded to specify head group 0 through 7.

Upon successful completion of this command, Status Register 0 indicates drive ready, and Status Register 1 contains an echo of the next head group in bits 2^8 through 2^{10}.

Parameter 0700xx - Select status

Parameter 0700xx requests a status from the drive. The desired status is encoded in bits 2^0 through 2^4 of the accumulator. Upon successful completion of this command, Status Register 0 indicates drive status available and drive ready; Status Register 1 contains the requested drive status.

The statuses that may be returned are:

Status Selected	Information Returned
0	Version/revision level
1	Echo status word
2	Cylinder offset status word
3	Head number status word
4	Physical sector number status word
5	Last non-status command status word
6	Last non-status command option status word

Status Selected	Information Returned
7	Drive sense 1 status word
8	Extended status word 1
9	Extended status word 2
10	68000's fault code status word
11	Fault code parameter status word
12	Supervisor processor fault code status word
13	Maintenance mode status word
14	Thermal warm-up timer countdown counter
15	Velocity scale factor status word
16	Extended status word 3
17	Extended status word 4
18	Servo sense 1 status word
19	Servo sense 2 status word
20	ID sync, ID comparison, and data sync for sector *n*
21	ID sync, ID comparison, and data sync for sector *n*+1
22	ID sync, ID comparison, and data sync for sector *n*+2
23	Diagnostic status word

Status 0 - A parameter of 070000 selects the drive's microprocessor microcode revision level. Status Register 1 contains a 4-digit BCD value with the 2 most significant digits indicating the version and the 2 least significant digits indicating the revision level.

Status 1 - A parameter of 070001 selects the echo status word. Status Register 1 contains the value output by the last diagnostic echo function (DIA : 4). If the diagnostic echo function has not been issued, the drive returns a zero value.

Status 2 - A parameter of 070002 selects the cylinder offset status word. Status Register 1 contains the current cylinder offset. The cylinder number is provided in bits 2^0 through 2^9. Bit 2^{15} is set to indicate that Servo-B is offset. Bit 2^{14} is set to indicate that Servo-B is offset toward the spindle. Bit 2^{13} is set to indicate that Servo-A is offset. Bit 2^{12} is set to indicate that Servo-A is offset toward the spindle. All bits are set if the current cylinder is not known, as is the case when a seek error is asserted in the general status word or while the spindle is either stopped or sequencing up or down.

Status 3 - A parameter of 070003 selects the head number status word. Status Register 1 contains the current head number in bits 2^8 through 2^{10}. The drive gets this status from the Head Address register. Since this register is only updated at the beginning of each sector, a lag of up to one sector can occur between the time a head select operation (parameter 04xx00) is issued and the time this status corresponds.

Status 4 - A parameter of 070004 selects the physical sector number status word. The low-order 8 bits of Status Register 1 contain the physical sector number currently under the data heads.

Status 5 - A parameter of 070005 selects the last nonstatus command status word. Status Register 1 contains the function code for the last nonstatus command (a command other than general status or status select) in the 4 low-order bits. When bit 2^4 is set along with the function code, it indicates that the command should have returned an error indication.

Status 6 - A parameter of 070006 selects the last nonstatus command option status word. Status Register 1 contains the contents of bus-out for the command indicated by status 5.

Status 7 - A parameter of 070007 selects the drive sense 1 status word. Status Register 1 contains bits set to indicate the status of the drive. Table 3-2 explains the meaning of each bit set in Status Register 1 when this parameter is issued.

Table 3-2. Status Register 1 Bits Set for DIA : 1 Status 7

Bits	Meaning
2^{15}	Spindle motor is enabled
2^{14}	Read/write logic power enabled
2^{13}	Servo calibration fault
2^{12} - 2^8	Not used
2^7	Over temperature
2^6	Run switch on
2^5	Port B enable switch on
2^4	Port A enable switch on
2^3	Write protect switch off
2^2	Current cylinder position is write enabled
2^1	0=Port A selected, 1=Port B selected
2^0	Blower air is present

Status 8 - A parameter of 070010 selects extended status word 1. Status Register 1 contains bits set to indicate error conditions that inhibit the unit from sequencing up. Error conditions are reset by the reset command (parameter 130000). Table 3-3 explains the meaning of each bit set in Status Register 1 for status 8.

Table 3-3. Status Register 1 Bits Set for DIA : 1 Status 8

Bits	Meaning
2^{15}	Spindle motor not up to speed
2^{14}	Spindle did not stop within allotted time
2^{13} - 2^{8}	Not used
2^{7}	Over temperature
2^{6} - 2^{4}	Not used
2^{3}	Power supply voltage out of range
2^{2}	Power interruption
2^{1}	Bus error occurred
2^{0}	Blower air not present

<u>Status 9</u> - A parameter of 070011 selects extended status word 2. Status Register 1 contains bits set to indicate error conditions that inhibit the unit from sequencing up. Error conditions are reset by the reset command (parameter 130000). Table 3-4 explains the meaning of each bit set in Status Register 1 for status 9.

<u>Status 10</u> - A parameter of 070012 selects the 68000's fault code status word. The low-order 7 bits of Status Register 1 contain the 68000 LED fault code. The high-order bit of the fault code status word (bit 2^{6}) indicates which servo was selected at the time of the error (0=Servo A, 1=Servo B). The 68000 fault code (see the DD-49 Pocket Reference Guide, CRI Part No. 0124400) gives detailed information relating to drive fault conditions detected by the 68000.

<u>Status 11</u> - A parameter of 070013 selects the fault code parameter status word related to the 68000 fault code (see the DD-49 Pocket Reference Guide, CRI Part No. 0124400). Status Register 1 contains a value that is dependent on the particular 68000 error code.

<u>Status 12</u> - A parameter of 070014 selects the supervisor processor fault code status word. Status Register 1 contains bits set to indicate faults detected by the supervisor. Table 3-5 explains the meaning of each bit set in Status Register 1 for status 12.

<u>Status 13</u> - A parameter of 0070015 selects the maintenance mode status word. Bits 2^{4} through 2^{2} of Status Register 1 indicate which cylinders are write protected. Bit 2^{4} is set to indicate user data cylinders are write protected. Bit 2^{3} is set to indicate CE cylinder 2 is write protected. Bit 2^{2} is set to indicate CE cylinder 1 is write protected.

Table 3-4. Status Register 1 Bits Set for DIA : 1 Status 9

Bits	Meaning
2^{15}	Data head unsafe condition occurred during a write
2^{14}	Hardware problem between supervisor processor and 68000
2^{13}	Failure of phase lock oscillator (PLO) unlock test
2^{12}	Failure of PLO to acquire phase lock in time
2^{11} - 2^{5}	Not used
2^{4}	Supervisor processor memory parity error
2^{3}	Parity error on the CPU data bus
2^{2}	68000 multiple bit memory error
2^{1}	68000 check bit memory error
2^{0}	68000 single bit memory error

Table 3-5. Status Register 1 Bits Set for DIA : 1 Status 12

Bits	Meaning
2^{15}	Sync time-out on last read
2^{14}	ID field no compare on last read/write
2^{13} - 2^{11}	Not used
2^{10}	Function parity error on previous command
2^{9}	Argument error detected by supervisor
2^{8}	Supervisor contributed to drive fault status
2^{7}	Not used
2^{6}	Function/data ready not expected
2^{5}	Not used
2^{4} - 2^{0}	Supervisor processor fault code

Status 14 - A parameter of 070016 selects the thermal warm-up timer countdown counter. Status Register 1 contains a value that indicates the number of 34-microsecond intervals remaining until the counter reaches a value of -1 (all bits set), which ends the countdown.

Status 15 - A parameter of 070017 selects the velocity scale factor status word. The low-order 10 bits of Status Register 1 contain bits set to indicate the following conditions. Bit 2^9 sets to indicate that Servo-B has been successfully calibrated. Bit 2^8 sets to indicate that Servo-A has been successfully calibrated. (Calibration is performed automatically when the drive is powered up.) The value indicated by bits 2^7 through 2^4 is the 4-bit velocity scale factor for Servo-B. The value indicated by bits 2^3 through 2^0 is the 4-bit velocity scale factor for Servo-A.

Status 16 - A parameter of 070018 selects extended status word 3. The content of this status word is meaningful only following a read or write function that returns an error. The word is reset by the clear fault, reset, read, and write commands. Bits 2^7 through 2^4 in Status Register 1 contain bits set to indicate the following conditions.

Bit 2^7 sets to indicate that a bus-out parity error is still waiting to be reset.

Bit 2^6 sets to indicate that a servo unsafe or off track condition occurred on an actuator during the read or write operation.

Bit 2^5 sets to indicate that the read operation data transfer has completed. The bit is meaningful only when examined to determine the source of read command errors. A 0 in bit position 2^5 indicates that a read data transfer operation did not complete.

Bit 2^4 sets to indicate that the write operation data transfer has completed. The bit is meaningful only when examined to determine the source of write command errors. A 0 in bit position 2^4 indicates that a write data transfer operation did not complete.

Status 17 - A parameter of 070021 selects extended status word 4. Status Register 1 contains bits set to indicate the status of the drive as shown in table 3-6.

Status 18 - A parameter of 070022 selects the servo sense 1 status word. Status Register 1 contains bits set to indicate the status of the servos. Table 3-7 explains the meaning of each bit set in Status Register 1 for status 18.

Status 19 - A parameter of 070023 selects the servo sense 2 status word. Status Register 1 contains bits set to indicate the status of the servos. Bit 2^{14} sets to indicate a seek fault occurred due to extraneous track crossing on Servo-B. Bit 2^6 sets to indicate a seek fault occurred due to extraneous track crossing on Servo-A. Bit 2^{11} sets to indicate trajectory attenuation due to an over-temperature condition in the linear motor for Servo-B. Bit 2^3 sets to indicate trajectory attenuation due to an over-temperature condition in the linear motor for Servo-A.

Table 3-6. Status Register 1 Bits Set for DIA : 1 Status 17

Bits	Meaning
2^{15} - 2^{14}	Not used
2^{13}	Channel B2 write-path parity error
2^{12}	Channel B1 write-path parity error
2^{11}	Channel B2 read overrun condition
2^{10}	Channel B1 read overrun condition
2^{9}	Channel B2 write underrun condition
2^{8}	Channel B1 write underrun condition
2^{7} - 2^{6}	Not used
2^{5}	Channel A2 write-path parity error
2^{4}	Channel A1 write-path parity error
2^{3}	Channel A2 read overrun condition
2^{2}	Channel A1 read overrun condition
2^{1}	Channel A2 write underrun condition
2^{0}	Channel A1 write underrun condition

Table 3-7. Status Register 1 Bits Set for DIA : 1 Status 18

Bits	Meaning
2^{15}	Servo-B not ready
2^{14}	Servo-B phase locked
2^{13}	Servo-B on track
2^{12}	Servo-B is on even track
2^{11}	Servo-B is on CE cylinder 2
2^{10}	Servo-B is on CE cylinder 1
2^{9}	Servo-B is in outer guard band
2^{8}	Servo-B is in inner guard band
2^{7}	Servo-A not ready
2^{6}	Servo-A phase locked
2^{5}	Servo-A on track
2^{4}	Servo-A is on even track
2^{3}	Servo-A is on CE cylinder 2
2^{2}	Servo-A is on CE cylinder 1
2^{1}	Servo-A is in outer guard band
2^{0}	Servo-A is in inner guard band

Status 20 - A parameter of 070024 selects the ID sync, ID comparison, and data sync status for the physical sector corresponding to the current target sector *n*. The status word is valid only following a read or write command that ends with error set. The meaning of each bit set in Status Register 1 as a result of status select 20 is shown in table 3-8.

Table 3-8. Status Register 1 Bits Set for DIA : 1
Status 20, 21, or 22

Bits	Meaning
2^{15}	Channel B2 ID field sync byte found
2^{14}	Channel B1 ID field sync byte found
2^{13}	Channel A2 ID field sync byte found
2^{12}	Channel A1 ID field sync byte found
2^{11}	Channel B2 ID field contents did not match target sector's ID field
2^{10}	Channel B1 ID field contents did not match target sector's ID field
2^{9}	Channel A2 ID field contents did not match target sector's ID field
2^{8}	Channel A1 ID field contents did not match target sector's ID field
2^{7}	Channel B2 data field sync byte found
2^{6}	Channel B1 data field sync byte found
2^{5}	Channel A2 data field sync byte found
2^{4}	Channel A1 data field sync byte found
2^{3} - 2^{1}	Not used
2^{0}	This word updated on previous read or write command. Read or write commands may terminate under circumstances in which all three possible sector locations are attempted.

Status 21 - A parameter of 070025 selects the ID sync, ID comparison, and data sync status for the physical sector corresponding to the current target sector plus 1 (*n*+1). The status word is valid only following a read or write command that ends with error set. This status word has the same format as status 20 in table 3-8.

Status 22 - A parameter of 070026 selects the ID sync, ID comparison, and data sync status for the physical sector corresponding to the current target sector plus 2 (*n*+2). The status word is valid only following a read or write command that ends with error set. This status word has the same format as status 20 in table 3-8.

Status 23 - A parameter of 070027 selects the diagnostic status word. Status Register 1 returns the results from specific diagnostic commands. The value returned is specified in the descriptions of the appropriate diagnostic commands.

Parameter 100000 - General status

Parameter 100000 returns the drive general status. Upon successful completion, Status Register 0 indicates drive status available and drive ready. Status Register 1 contains the drive general status. Table 3-9 is a summary of the bit position assignments for general status.

Table 3-9. Status Register 1 Bit Assignments for General Status

Bit	Name	Meaning
2^0	Function parity error	An error was detected while receiving function codes from the IOP.
2^1	Bus-out parity error	An error was detected while handling data.
2^2	Data underrun/ overrun	Error occurs if IOP does not pass data to the drive fast enough on a write (underrun), or if the IOP does not take data from the drive fast enough on a read (overrun).
2^3	Seek error	A drive fault was encountered during a seek operation.
2^4	Invalid option or argument	An invalid option or argument was detected by the drive.
2^5	ECC error channel A1	An error was detected on drive channel A1 during the last read operation.
2^6	ECC error channel A2	An error was detected on drive channel A2 during the last read operation.
2^7	ECC error channel B1	An error was detected on drive channel B1 during the last read operation.
2^8	ECC error channel B2	An error was detected on drive channel B2 during the last read operation.

Table 3-9. Status Register 1 Bit Assignments for General Status (continued)

Bit	Name	Meaning
2^9	ID not found	The ID was not found on the specified physical sector or, if that sector was formatted as defective, on the following two physical sectors (slipped sectors).
2^{10}	Sync time-out	The sync bytes for each channel were not found within the allowed window for the field.
2^{11}	Function lost	The drive detected an unexpected ready function.
2^{12}	Invalid command	The drive detected a data function (6) outside the context of read/write or detected an unused function (12_8).
2^{13}	Sequencing operation in progress	The drive spindle sequence up/down operation is in progress due to a change on the drive's front panel run switch. Only unit select, release, release opposite channel and select, and general status functions will execute successfully.
2^{14}	Drive fault	An unrecoverable error in the drive logic was detected.
2^{15}	In maintenance mode	The drive is currently in the maintenance mode of operation and at least one of the write enable/write protect control bits specified by the select diagnostic function is nonzero. The user may request seeks only to the maintenance cylinders CE1 and CE2.

Parameter 11xxxx - Diagnostic select

Parameter 11xxxx requests the drive to perform in some type of diagnostic mode. These diagnostic modes are selected by issuing parameter 11xxxx with the appropriate bit set, as shown in table 3-10.

Table 3-10. Diagnostic Modes

Bit	Name	Meaning
2^0	Force bus-in parity error	Forces a parity error on bus-in for this command. The bus-in parity bit of Status Register 0 should be set upon completion.
2^1	Force status parity error	Forces a parity error on status for this command. The status parity bit of Status Register 0 should be set upon completion.
2^2	Write-enable CE cylinder 1	Allows CE cylinder 1 to be written. CE cylinder 1 is cylinder 887 and contains the flaw tables.
2^3	Write-enable CE cylinder 2 (scratch)	Allows CE cylinder 2 to be written. CE cylinder 2 is cylinder 889 and is the diagnostic scratch cylinder.
2^4	Write-protect data cylinders	Allows the data cylinders to be write protected. The data cylinders are cylinders 0 through 885.

The write enable/write protect diagnostic modes remain in effect until one of the following occurs:

- Diagnostic select command is reissued with enable off
- Select command is issued
- Release command is issued
- Reset command is issued
- The drive is power cycled

The following diagnostic functions are also available by issuing parameter 11*xxxx* with the value of *xxxx* as shown below:

Parameter	Function
4001	Request spindle sequence up
2002	Confirm spindle sequence up
4002	Request spindle sequence down
2004	Confirm spindle sequence down
4003	Perform servo calibration
4004	Test single-bit error detection and correction (EDC) for the 68000's memory
4005	Test multiple-bit EDC detection for the 68000's memory

Parameter	Function
4006	Force single data bit error (0 failed to 1)
4007	Force single data bit error (1 failed to 0)
4010	Force single check bit error (0 failed to 1)
4011	Force single check bit error (1 failed to 0)
4012	Force multiple data bit error (00 failed to 11)
4013	Force multiple data bit error (11 failed to 00)
4014	Force multiple check bit error (00 failed to 11)
4015	Force multiple check bit error (11 failed to 00)

Upon successful completion of this command, Status Register 0 indicates drive ready. If a parity error was requested, it shows both the error and the corresponding parity bits. Status Register 1 echos the diagnostic bits selected.

Parameter 130000 - Reset

Parameter 130000 causes the drive to go through a reset sequence, if the opposite port is not selected. Port selection is retained by the issuing port if the issuing port was selected at the time of the reset command. The reset sequence is as follows:

1. Hardware reset the supervisor processor and the 68000 processor.
2. Reset all fault conditions and status.
3. Reset all software implemented status.
4. Execute a subset of the power-on diagnostics.
5. Perform a return to zero command function (DIA : 1 parameter 150000).
6. Zero the 16 write-buffer data words.
7. Reestablish default drive conditions (data cylinders are write enabled and CE cylinders are write protected) and clear maintenance mode bit.

Upon successful completion of parameter 130000, both Busy and Done flags are set, and Status Register 0 indicates both drive error and drive ready. The drive is now ready although the Drive Ready signal went inactive during the reset sequence. Status Register 1 contains the drive general status.

Parameter 140000 - Clear faults

Parameter 140000 resets all fault status flags in the drive. Hardware faults are not cleared. The drive will remain ready throughout the clear faults. The clear faults does not perform a return to zero and therefore does not reset seek error conditions. Upon successful completion of this command, Status Register 0 indicates drive status available and drive ready. Status Register 1 contains the drive general status.

Parameter 150000 - Return to zero

Parameter 150000 clears all seek-related faults and repositions the read/write heads to cylinder 0. Offsets are cleared by this command; head selection is unaffected. Upon successful completion of this command, Status Register 0 indicates drive status available and drive ready. Status Register 1 contains the drive general status.

Parameter 162524 - Release opposite channel and select

Parameter 162524 breaks the current drive reservation, regardless of port, and the port issuing the command is selected. The command is recognized only between command executions by the port to be released. This type of recognition allows a more orderly release, but this command should be used with extreme caution.

An alternating bit pattern is included in the parameter field to help prevent unintended (open cable) drive commands. Upon successful completion of this command, Status Register 0 contains 052003_8 indicating drive status available and drive ready. Status register 1 contains the drive general status.

Issuing parameter 162524 on the selected port will not cause an error.

Parameter 172524 - Release

Parameter 172524 breaks the drive reservation established in the unit select or release opposite channel and select commands. This command makes the drive available for reservation by either drive port.

The release command reestablishes the default drive conditions. An alternating bit pattern is included in the parameter field to help prevent unintended (open cable) drive commands.

Upon successful completion of this command, Status Register 0 contains 052003_8, indicating drive status available and drive ready. Status Register 1 contains the drive general status.

DIA : 2 - REQUEST READ

A DIA : 2 function transfers information from the disk to Local Memory. The read function can request any of the following:

- Data record (2048 parcels)
- Sector ID (16 parcels)
- Absolute data record (2048 parcels)
- Deskew buffer (16 parcels)
- Syndrome block (16 parcels)
- Error correction vectors (16 parcels)

The contents of the IOP's accumulator at the time of the read function specifies the type of read desired, the sector number, and the next head number. The significance of each accumulator bit is shown below:

Accumulator Bit	Significance	
2^0	Sector 2^0	0 through 43 (Decimal)
2^1	Sector 2^1	
2^2	Sector 2^2	
2^3	Sector 2^3	
2^4	Sector 2^4	
2^5	Sector 2^5	
2^6	Unused (Must be 0)	
2^7	Unused (Must be 0)	
2^8	Next head 2^0	0 through 7
2^9	Next head 2^1	
2^{10}	Next head 2^2	
2^{11}	Unused (Must be 0)	
2^{12}	Read option 2^0	
2^{13}	Read option 2^1	
2^{14}	Read option 2^2	
2^{15}	Unused (Must be 0)	

Local Memory Address Register 0 in the DCU specifies the Local Memory address to receive the data.

This function sets the Channel Busy flag and clears the Channel Done flag. When the function completes, the Channel Done flag sets and, if no error occurs, the Channel Busy flag clears. If an error occurs, the Channel Busy flag remains set, and Status Register 0 contains the cause of the error.

Upon successful completion of a single sector read or the last sector of a chained read, Status Register 0 indicates drive ready, and Status Register 1 echos the accumulator parameter of the last read function.

If an error occurs (Busy flag remained set) or chaining is broken, a DIA : 17 function with an accumulator parameter of 0 should be issued to obtain statuses.

The Read options (bits 2^{12} through 2^{14}) are encoded as shown in table 3-11.

Table 3-11. DIA : 2 Read Options for the DD-49

Value	Meaning
00*xxxx*	Read data
01*xxxx*	Read ID
02*xxxx*	Read absolute
03*xxxx*	Read buffer
04*xxxx*	Read ECC parameter block
05*xxxx*	Compute and transfer correction vectors

Parameter 00*xxxx* - Read data

Parameter 00*xxxx* specifies the logical sector to be read in the low-order 6 bits (bits 2^0 through 2^5). The next head number (bits 2^8 through 2^{10}) specifies the head group to be used on subsequent functions. The next (that is, new) head group is not used during the current read request. The head group used for the current read request is the one specified by the most recent head select, read, or write function.

The correct sector to read is selected as follows. For logical sector *n*, physical sector *n*'s ID is checked for a matching cylinder, head, and sector. If the physical sector is formatted as defective, the track is assumed to include one or two slipped sectors, and the following two physical sectors are checked for correct cylinder, head, and sector information. If none of the three sectors matches the desired disk address, an ID not found error occurs.

Once the correct sector is located, the drive begins sending data. The drive transfers 2048 parcels of data to the channel, 16 parcels at a time, using the status data ready/function data ready channel protocol.

Parameter 01*xxxx* - Read ID

Parameter 01*xxxx* causes the drive to transfer 16 parcels of data to the channel. These 16 parcels contain the ID field of the physical sector specified in the accumulator. The ID is encoded into the first 8 parcels of data transferred as follows:

Parcel	Accumulator Bit Position															
#	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Channel B2				Channel B1				Channel A2				Channel A1			
0	0	h2	h1	h0	0	h2	h1	h0	0	h2	h1	h0	0	h2	h1	h0
1	0	0	c9	c8	0	0	c9	c8	0	0	c9	c8	0	0	c9	c8
2	c7	c6	c5	c4	c7	c6	c5	c4	c7	c6	c5	c4	c7	c6	c5	c4
3	c3	c2	c1	c0	c3	c2	c1	c0	c3	c2	c1	c0	c3	c2	c1	c0
4	0	0	s5	s4	0	0	s5	s4	0	0	s5	s4	0	0	s5	s4
5	s3	s2	s1	s0	s3	s2	s1	s0	s3	s2	s1	s0	s3	s2	s1	s0
6	p7	p6	p5	p4	p7	p6	p5	p4	p7	p6	p5	p4	p7	p6	p5	p4
7	p3	p2	p1	p0	p3	p2	p1	p0	p3	p2	p1	p0	p3	p2	p1	p0
8-15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

where: h2 through h0 = head group number
c9 through c0 = cylinder number
s5 through s0 = logical sector number
and: p7 = -c7
p6 = -(h2 XOR c6)
p5 = -(h1 XOR c5 XOR s5)
p4 = -(h0 XOR c4 XOR s4)
p3 = -(c3 XOR s3)
p2 = -(c2 XOR s2)
p1 = -(c9 XOR c1 XOR s1)
p0 = -(c8 XOR c0 XOR s0)

Parameter 02*xxxx* - Read absolute

Parameter 02*xxxx* causes the drive to transfer the 2048-parcel data record for the physical sector specified by the accumulator parameter. This function is intended as a data recovery technique should an ID field become unreadable. The function does not compare ID fields. The data is referenced by its absolute position reference from index.

Parameter 03*xxxx* - Read buffer

Parameter 03*xxxx* transfers 16 parcels of data from the drive data buffer to the channel. The function is intended simply as a diagnostic.

Parameter 04*xxxx* - Read ECC parameter block

Parameter 04*xxxx* transfers 16 parcels of data to the channel that contains the syndrome of the last sector read. The function is only valid following a read operation (either normal read data or read absolute function). The channel syndromes are encoded as follows:

Parcel #	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1			Channel B2 syndrome bits 47 through 32													
2			Channel B2 syndrome bits 31 through 16													
3			Channel B2 syndrome bits 15 through 0													
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5			Channel B1 syndrome bits 47 through 32													
6			Channel B1 syndrome bits 31 through 16													
7			Channel B1 syndrome bits 15 through 0													
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9			Channel A2 syndrome bits 47 through 32													
10			Channel A2 syndrome bits 31 through 16													
11			Channel A2 syndrome bits 15 through 0													
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13			Channel A1 syndrome bits 47 through 32													
14			Channel A1 syndrome bits 31 through 16													
15			Channel A1 syndrome bits 15 through 0													

Parameter 05xxxx - Compute and transfer correction vectors

Parameter 05xxxx commands the drive to compute correction vectors for the last sector read (normal read data or read absolute function). Sixteen parcels of data containing the correction vectors are then transferred to the channel. This command is only valid following a read sector function. The channel correction vectors are encoded as follows:

Parcel #	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	Channel B2 correction mask											
1		Channel B2 correction parcel offset														
2	0	0	0	0	Channel B1 correction mask											
3		Channel B1 correction parcel offset														
4	0	0	0	0	Channel A2 correction mask											
5		Channel A2 correction parcel offset														
6	0	0	0	0	Channel A1 correction mask											
7		Channel A1 correction parcel offset														
8-15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Channel correction masks are 12-bit fields that hold 7-bit correction masks. The channel correction parcel offset is the relative displacement within the sector just read that the 4 most significant bits (bits 2^{11} through 2^8) of the 12-bit correction mask should be applied to. The next 4 bits (bits 2^7 through 2^4) should be applied to the parcel at offset + 1 and the last 4 bits (bits 2^3 through 2^0) should be applied to the parcel at offset + 2.

The user must determine if (and how much of) the correction mask lies within the data field of the sector that was just read and apply the correction accordingly. The sector may be uncorrectable (indicated by a correction parcel offset of 177777_8) or the correction may apply (solely or partially) to the syndrome for which the correction has already been applied.

DIA : 3 - REQUEST WRITE

A DIA : 3 function transfers information from Local Memory to the disk. The write function can transmit either:

- Data record (2048 parcels)
- Sector ID (16 parcels)
- Defective ID (16 parcels)
- Deskew buffer (16 parcels)
- Data record with zero ECC (2048 parcels)

The contents of the accumulator at the time of the write function specifies the type of write desired, the sector number, and the next head number. The significance of each accumulator bit is shown below:

Accumulator Bit	Significance	
2^0	Sector 2^0	0 through 43 (Decimal)
2^1	Sector 2^1	
2^2	Sector 2^2	
2^3	Sector 2^3	
2^4	Sector 2^4	
2^5	Sector 2^5	
2^6	Unused (Must be 0)	
2^7	Unused (Must be 0)	
2^8	Next head 2^0	0 through 7
2^9	Next head 2^1	
2^{10}	Next head 2^2	
2^{11}	Unused (Must be 0)	
2^{12}	Write option 2^0	
2^{13}	Write option 2^1	
2^{14}	Write option 2^2	
2^{15}	Unused (Must be 0)	

Local Memory Address Register 0 specifies the Local Memory address the data was taken from. The function sets the Channel Busy flag and clears the Channel Done flag. When the function completes, the Channel Done flag sets and, if no error occurs, the Channel Busy flag clears. If an error occurs, the Channel Busy flag remains set, and Status Register 0 contains the cause of the error.

Upon successful completion of a single-sector write or the last sector of a chained write, Status Register 0 indicates drive ready, and Status Register 1 echos the accumulator parameter of the last write function.

If an error occurs (Busy flag remains set), or chaining is broken, a DIA : 17 function with an accumulator parameter of 0 should be issued to obtain statuses. The write options (bits 2^{12} through 2^{14}) are encoded as shown in table 3-12.

Table 3-12. DIA : 3 Write Options for DD-49

Value	Meaning
00*xxxx*	Write data
01*xxxx*	Write ID
02*xxxx*	Write defective ID
03*xxxx*	Write buffer
04*xxxx*	Write zero ECC field

Parameter 00*xxxx* - Write data

Parameter 00*xxxx* specifies the logical sector to be written in bits 2^0 through 2^5. The next head number (bits 2^8 through 2^{10}) specifies the head group to be used on subsequent functions. The next (that is, new) head group is not used during the current write request. The head group used for the current write request is the one specified by the most recent head select, read, or write function.

The correct sector to be written is selected as follows. For logical sector *n*, physical sector *n*'s ID is checked for a matching cylinder, head, and sector. If the physical sector is formatted as defective, the track is assumed to include one or two slipped sectors, and the following two physical sectors are checked for correct cylinder, head, and sector information. If none of the three sectors matches the desired disk address, an ID-not-found error occurs.

Once the correct sector is located, the channel begins sending data. 2048 parcels of data are transferred to the drive, 16 parcels at a time, using the function-data-ready/status-data-ready protocol.

Parameter 01*xxxx* - Write ID

Parameter 01*xxxx* causes the drive to expect 16 parcels of data from the channel. These 16 parcels contain the ID field of the physical sector specified in the accumulator contents. The ID is encoded into the first 8 parcels of the data transferred as follows:

Parcel	Accumulator Bit Position															
#	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Channel B2				Channel B1				Channel A2				Channel A1			
0	0	h2	h1	h0	0	h2	h1	h0	0	h2	h1	h0	0	h2	h1	h0
1	0	0	c9	c8	0	0	c9	c8	0	0	c9	c8	0	0	c9	c8
2	c7	c6	c5	c4	c7	c6	c5	c4	c7	c6	c5	c4	c7	c6	c5	c4
3	c3	c2	c1	c0	c3	c2	c1	c0	c3	c2	c1	c0	c3	c2	c1	c0
4	0	0	s5	s4	0	0	s5	s4	0	0	s5	s4	0	0	s5	s4
5	s3	s2	s1	s0	s3	s2	s1	s0	s3	s2	s1	s0	s3	s2	s1	s0
6	p7	p6	p5	p4	p7	p6	p5	p4	p7	p6	p5	p4	p7	p6	p5	p4
7	p3	p2	p1	p0	p3	p2	p1	p0	p3	p2	p1	p0	p3	p2	p1	p0
8-15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

where: h2 through h0 = head group number
c9 through c0 = cylinder number
s5 through s0 = logical sector number

and: p7 = -c7
p6 = -(h2 XOR c6)
p5 = -(h1 XOR c5 XOR s5)
p4 = -(h0 XOR c4 XOR s4)
p3 = -(c3 XOR s3)
p2 = -(c2 XOR s2)
p1 = -(c9 XOR c1 XOR s1)
p0 = -(c8 XOR c0 XOR s0)

Parameter 02xxxx - Write defective ID

Parameter 02xxxx transfers 16 parcels of data from the channel to the drive. It causes the drive to write a zero ID field (including the sync byte) in the physical sector specified in the accumulator parameter. The 16 parcels to be transferred must be zero-filled. This function is intended for formatting defective sectors so they cannot be accidentally accessed by a read or write data function.

Parameter 03xxxx - Write buffer

Parameter 03xxxx is intended as a diagnostic, and transfers 16 parcels of data from the channel to the drive data buffer. The contents of the data buffer can then be read using the read buffer command.

Parameter 04xxxx - Write zero ECC field

This function is intended solely as a diagnostic for the ECC logic. Parameter 04xxxx transfers 2048 parcels of data from the channel to the drive. The data is written to the sector specified in the accumulator parameter, and the ECC (error correction code) block is written with zeros.

DIA : 4 - DIAGNOSTIC ECHO

A DIA : 4 function transmits the contents of the accumulator to the drive. The drive stores this parcel in its echo status word. The function sets the Channel Busy flag and clears the Channel Done flag. When the function completes, the Channel Done flag sets and, if no error occurs, the Channel Busy flag clears. If an error occurs, the Channel Busy flag remains set and Status Register 0 contains the cause of the error.

Upon successful completion of this function, Status Register 0 indicates drive ready, and Status Register 1 contains an echo of the accumulator contents.

This function is intended as a diagnostic as it tests much of the status and parameter paths as well as the cables and control logic. The function accumulator contents can be read back from the drive at any time through the select status (echo) function.

DIA : 5 - SELECT CYLINDER

A DIA : 5 function initiates either seek or offset operations as specified by the accumulator contents. The parameter is specified in the accumulator as follows:

Accumulator Bit	Significance
2^0	Cylinder 2^0
2^1	Cylinder 2^1
2^2	Cylinder 2^2
2^3	Cylinder 2^3
2^4	Cylinder 2^4
2^5	Cylinder 2^5
2^6	Cylinder 2^6
2^7	Cylinder 2^7
2^8	Cylinder 2^8
2^9	Cylinder 2^9
2^{10}	Unused (Must be 0)
2^{11}	Unused (Must be 0)
2^{12}	Offset direction - A
2^{13}	Offset enable - A
2^{14}	Offset direction - B
2^{15}	Offset enable - B

Bits 2^0 through 2^9 specify the cylinder to be selected on seek operations. A seek to a different cylinder operation cannot be initiated with the offsets enabled.

Bits 2^{12} through 2^{15} specify the offset parameters used for offset operations. Heads must already be on the desired cylinder to initiate an offset operation. Either or both actuators may be offset by setting the appropriate actuator offset enable. The offset direction is specified per actuator. Only a single degree of offset is available and it applies to both forward and reverse directions.

If an offset direction bit is set with offset enable, it causes the actuator to offset toward the spindle; conversely, if the offset direction bit is not set with offset enable, the actuator will offset away from the spindle. Write operations to the disk are disabled with either offset enabled.

This function sets the Channel Busy flag and clears the Channel Done flag. When the function completes, the Channel Done flag sets and, if no error occurs, the Channel Busy flag clears. If an error occurs, the Channel Busy flag remains set and Status Register 0 contains the cause of the error.

Upon successful completion of this function, Status Register 0 indicates drive ready, and Status Register 1 echos the accumulator contents.

DIA : 6 - CLEAR CHANNEL INTERRUPT ENABLE FLAG

A DIA : 6 function clears the Channel Interrupt Enable flag. This prevents interruption of the IOP program by this channel and requires that the program monitor the Channel Done flag for proper sequencing of the DD-49 control functions. A DIA : 6 function is also used to clear a pending interrupt during sector chaining.

DIA : 7 - SET CHANNEL INTERRUPT ENABLE FLAG

A DIA : 7 function sets the Channel Interrupt Enable flag. This allows the IOP's program to be interrupted by this channel whenever the Channel Done flag is set or when the channel needs servicing during sector-chained read or write functions.

DIA : 10 - READ LOCAL MEMORY ADDRESS REGISTER 0

A DIA : 10 function reads the current contents of Local Memory Address Register 0 into the IOP's accumulator. This function may be executed at any time with respect to a DD-49 program sequence. The Channel Busy and

Done flags are not altered by this function. The value read will be an echo of the address entered or the current Local Memory address if data has been transferred to or from Local Memory. The significance of each accumulator bit is shown below:

Accumulator Bit	Significance
2^0	Entered value or 0 if address has incremented
2^1	Entered value or 0 if address has incremented
2^2	Current Local Memory address bit 2
2^3	Current Local Memory address bit 3
2^4	Current Local Memory address bit 4
2^5	Current Local Memory address bit 5
2^6	Current Local Memory address bit 6
2^7	Current Local Memory address bit 7
2^8	Current Local Memory address bit 8
2^9	Current Local Memory address bit 9
2^{10}	Current Local Memory address bit 10
2^{11}	Current Local Memory address bit 11
2^{12}	Current Local Memory address bit 12
2^{13}	Current Local Memory address bit 13
2^{14}	Current Local Memory address bit 14
2^{15}	Current Local Memory address bit 15

DIA : 11 - READ LOCAL MEMORY ADDRESS REGISTER 1

A DIA : 11 function reads the current contents of Local Memory Address Register 1 into the IOP's accumulator. (Refer to the description of the DIA : 10 function.)

DIA : 12 - READ STATUS REGISTER 0

A DIA : 12 reads the current contents of Status Register 0 into the IOP's accumulator. Status Register 0 contains the DCU internal status that is loaded after functions 1, 2, 3, 4, 5, and 17. Channel Busy and Done flags are not altered by this function. The contents of the accumulator after this function issues is bit mapped as shown in table 3-13.

Table 3-13. Bit Position Assignments for Status Register 0

Bit	Name	Meaning
2^0	Drive ready	The state of the channel's Ready signal when the register was loaded. It tells the controller the drive is ready to accept channel commands.
2^1	Drive status available	The channel's Status/Data Ready signal was asserted at the same time as Drive Done. It indicates that a drive status is available in Status Register 1.
2^2	Drive busy/ invalid drive command	The channel's Status/Data Ready signal and Error signal were both asserted at the same time as Drive Done. It indicates the drive is busy (connected to the other port), it received an invalid command, or a drive function failed. General status is in Status Register 1.
2^3	Drive error	The channel's Error signal was asserted at the same time as Drive Done.
2^4	Status parity error	A parity error was detected on the channel's Status lines.
2^5	Bus-in parity error	A parity error was detected on the channel's Bus-in lines.
2^6	Read data parity error	Indicates a parity error was detected at the controller's buffer outputs on a read operation
2^7	Error flag	A global error flag that indicates one or more controller status bits (2^0 or bits 2^2 through 2^6) are in error. It also indicates the drive went not ready during some part of the previous interval, as in the case of a reset command.
2^8 - 2^{15}	Parameter register bits 0 through 7	This is the lower byte of bus-out for the last drive function issued by the controller.

DIA : 13 - READ STATUS REGISTER 1

A DIA : 13 function reads Status Register 1 into the IOP's accumulator. This function may be issued at any time with respect to the DD-49 program sequence. The Channel Busy and Done flags are not altered by this function. The value read will be the drive's response to the last function that the drive executed. Depending on the function and whether or not it executed successfully, the drive's response will:

- An echo of the function's bus-out
- The drive's general status
- The particular drive status requested
- Undetermined (if a Status Register 0 error was indicated)

DIA : 14 - ENTER LOCAL MEMORY ADDRESS REGISTER 0

A DIA : 14 function enters the accumulator contents into Local Memory Address Register 0. The Channel Busy and Done flags are not altered by this function. The significance of each accumulator bit is shown below:

Accumulator Bit	Significance
2^0	Unused
2^1	Unused
2^2	Local Memory address bit 2^2
2^3	Local Memory address bit 2^3
2^4	Local Memory address bit 2^4
2^5	Local Memory address bit 2^5
2^6	Local Memory address bit 2^6
2^7	Local Memory address bit 2^7
2^8	Local Memory address bit 2^8
2^9	Local Memory address bit 2^9
2^{10}	Local Memory address bit 2^{10}
2^{11}	Local Memory address bit 2^{11}
2^{12}	Local Memory address bit 2^{12}
2^{13}	Local Memory address bit 2^{13}
2^{14}	Local Memory address bit 2^{14}
2^{15}	Local Memory address bit 2^{15}

DIA : 15 - ENTER LOCAL MEMORY ADDRESS REGISTER 1

A DIA : 15 function enters the accumulator contents into Local Memory Address Register 1. Refer to the description of the DIA : 14 function.

DIA : 16 - ENTER NEXT READ/WRITE PARAMETER

A DIA : 16 function is used during sector-chaining operations to queue the next read or write operation. The accumulator contents become the read or write parameter transmitted to the drive with the next read or write function. The Busy and Done flags are not directly altered by this function. The significance of each accumulator bit is shown below:

Accumulator Bit	Significance	
2^0	Sector 2^0	0 through 43 (Decimal)
2^1	Sector 2^1	
2^2	Sector 2^2	
2^3	Sector 2^3	
2^4	Sector 2^4	
2^5	Sector 2^5	
2^6	Unused (Must be 0)	
2^7	Unused (Must be 0)	
2^8	Next head 2^0	0 through 7
2^9	Next head 2^1	
2^{10}	Next head 2^2	
2^{11}	Unused (Must be 0)	
2^{12}	Mode option 2^0	
2^{13}	Mode option 2^1	
2^{14}	Mode option 2^2	
2^{15}	Unused (Must be 0)	

For a read operation, the mode options should be set as shown in table 3-11. For a write operation, the mode options should be set as shown in table 3-12.

The associated Local Memory address on each issue of a DIA : 16 function alternates between Local Memory Address Register 0 and Local Memory Address Register 1.

To perform sector-chaining, an initial request read function (DIA : 2) or request write function (DIA : 3) is followed by a sequence of DIA : 16 functions. Each DIA : 16 function must be issued prior to the completion of the current read or write sector in order to continue the chaining operation. An interrupt is generated to signal the completion of each sector, and is cleared by the DIA : 6 function. The Channel Busy flag remains set, however, and the Channel Done flag remains clear throughout the chaining sequence. When the sequence completes, the Channel Done flag sets and the Channel Busy flag clears.

DIA : 17 - SELECT SPECIAL CONTROLLER MODE/STATUS

A DIA : 17 function is used to place the controller in one of several special diagnostic modes of operation. The controller remains in this mode until one of the following occurs:

- Clear channel controller function (DIA : 0) is issued
- Function is reissued with mode bit disabled
- Power is cycled

This function transfers a copy of the channel's status to Status Register 0 and updates Status Register 1, thus allowing the drive Ready signal to be tested without evoking a drive function.

The function sets the Channel Busy flag and clears the Channel Done flag. Upon successful completion, the Channel Done flag sets and the Channel Busy flag clears. The amount of time this function takes is dependent on controller activity, but will be 10 to 20 CPs. Table 3-14 shows how diagnostic modes are bit-mapped in the accumulator.

Table 3-14. Bit Position Assignments for DD-49 DIA : 17 Diagnostic Modes

Bit	Name	Meaning
2^0	Sync testpoint	Sync point available for scope loops or logic analyzer sync triggers
2^1	Buffer echo	This forces the subsequent read or write operations to be internal to the controller. It is intended as a diagnostic for the controller's data buffers and control logic. A write function request writes 2048 parcels of data to the controller's two quarter-sector buffers. Parcels 0-511 are written to buffer A and parcels 512-1023 are written to buffer B. Then parcels 1024-1535 are written to buffer A (overwriting parcels 0-512) and parcels 1536-2047 are written to buffer B (overwriting parcels 512-1023). The data can then be read back by a read function request. Buffer A is read into parcels 0-511 and buffer B is read into parcels 512-1023. Then buffer A is reread into parcels 1024-1535 and buffer B is reread into parcels 1536-2047.
2^2	Force control parity error	This forces parity (code) to be asserted on subsequent drive functions.
2^3	Force bus-out parity error	This forces parity (bus-out) to be asserted on all subsequent bus-outs.
2^4	Force data parity error	This forces the data parity to be asserted on all subsequent data being written from the buffer on write operations.
2^5 - 2^{15}		Unused

DD-49 DISK ERROR CORRECTION

The DCU-5 and the DD-49 allow the controller hardware and drive microcode to check data integrity with the following features:

- Parity on functions to the drive
- Parity on parameters to the drive
- Special parameter patterns, when parameters are not required
- Parity on control signals from the drive
- Parity on status words from the drive
- Automatic echo of seek, read, write, head select, and maintenance function parameters from the drive back to the controller and IOP
- Parity on all data transfers, including the controller data buffers
- Echo capability of Local Memory Address registers in the controller for testing before and after a transfer is executed
- ID fields are read and verified prior to each sector transfer, but if an ID field is destroyed, the sector can still be read and the ID field rewritten without altering the data field
- Parity with the ID field to verify errors while reading. Error correction codes written with data fields to verify and correct single burst errors while reading
- Buffer echo checks are available both to the controller and/or the drive if on-line or in-line testing is desired
- Diagnostic ability to create sectors with either correctable or noncorrectable data field errors
- Ability to offset the heads marginally in order to recover data
- Temperature, blower air pressure, power supply voltages, internal drive logic and memory errors, and servo faults, and so on, are monitored by the drive
- Special cylinders are write protected to prevent flawing information
- A sector slipping algorithm is implemented within the drive to minimize the system's flaw management effort

Some of the above features are self-supporting and some require support through the software driver. Appendix B provides an example of an error recovery procedure for use with the DD-49 DSU.

PROGRAMMING EXAMPLE

The following example illustrates a programming sequence in APML for the DD-49. The drive is tested to see if it is ready to accept commands. Once ready, a single target sector is read from the drive.

```
         DIA : 0                          .clear channel controller

TRDY     ZZ = ZZ + 2                      .delay  (6 clock periods)
         A = 0                            .get status
         DIA : 17                         .get current status
         WAIT, DIA # DN
         P = ERROR, DIA = BZ              .sense error (both DN and BZ)
         DIA : 12
         A = A & 1
         P = TRDY, A = 0                  .sense drive ready

SEL      A = 012524                       .select parameter
         DIA : 1                          .Select Unit

         Wait for interrupt

         P= ERROR, DIA = BZ               .sense error
         P = ERROR, DIA # DN              .sense done error
         DIA : 12
         P = ERROR, A # 052003            .sense controller status
         DIA : 13
         P = ERROR, A # 0                 .sense general status

CYL      ES = CC                          .desired cylinder CC  (0-1565_8)
         DIA : 5                          .Select Cylinder

                   Wait for interrupt

         P = ERROR, DIA = BZ              .sense error
         P = ERROR, DIA # DN              .sense done error
         ES = CC < 10 + 1                 .form expected status
         DIA : 12
         P = ERROR, A # ES                .sense controller status
         DIA : 13
         P = ERROR, A # CC                .sense drive echo error

HEAD     A = HH                           .desired head HH  (0-7)
         FE = A < 10                      . (save for function echo)
         A = A + 040000
         DIA : 1                          .Select Head

                   Wait for interrupt
```

```
          P=ERROR, DIA = BZ                .sense error
          P = ERROR, DIA # DN              .sense done error
          DIA : 12
          P = ERROR, A # 1                 .sense controller status
          DIA : 13
          P = ERROR, A # FE                .sense drive echo error

READ      A = AD                           .desired buffer address AD
          DIA : 14
          ZZ = ZZ + 2                      .delay  (6 clock periods)
          DIA : 10
          P = ERROR, A # AD                .sense register error
          A = SS                           .desired sector SS  (0-51$_8$)
          DIA : 2                          .Read Data

                    Wait for interrupt

          P = R/WERR, DIA = BZ             .sense error
          P = R/WERR, DIA # DN             .sense done error
          ES = SS < 10 + 1                 .form expected status
          DIA : 12
          P = R/WERR, A # ES               .sense controller status
          DIA : 13
          P = R/WERR, A # SS               .sense drive echo error

RELS      A = 172524                       .get release parameter
          DIA : 1                          .Release Unit

                    Wait for interrupt

          P = ERROR, DIA = BZ              .sense error
          P = ERROR, DIA # DN              .sense done error
          DIA : 12
          P = ERROR, A # 52003             .sense controller status
          DIA : 13
          P = ERROR, A # 0                 .sense general status

          EXIT                             .end of illustration
```

The above illustration's read can be expanded from one sector to three sectors, if all on the same cylinder, as follows:

```
READ      A = AD                           .desired buffer address AD
          DIA : 14
          ZZ = ZZ + 2                      .delay  (6 clock periods)
          DIA : 10
          P = ERROR, A # AD                .sense error
          ER = 0                           .clear error flag
          IR = 0                           .clear interrupt counter
```

```
         A = HH2                        .2nd desired sector's head HH2
         A = A < 10
         A = A + SS1                    .1st desired sector SS1  (0-51$_8$)
         DIA : 2                        .Read DATA
         AD = AD + 4000                 .next desired buffer
         DIA : 15
         ZZ = ZZ + 2                    .delay  (6 clock periods)
         DIA : 11
         P = ERROR, A # AD              .sense LMA 1 register error
         A = HH3                        .3rd desired sector's head HH3
         A = A < 10
         A = A + SS2                    .2nd desired sector SS2  (0-51$_8$)
         DIA : 16

LOOP     P = TEST, DIA = DN             .sense controller Done
         P = R/WERR, ER # 0             .sense interrupt error
         P = LOOP

TEST     P = R/WERR, DIA = BZ           .sense error
         P = R/WERR, IR # 3             .all sectors read?
         P = R/WERR, DIA # DN           .sense done error
         ES = SS3 < 10 + 1              .get expected status
         DIA : 12
         P = R/WERR, A # ES1            .sense controller status
         ES = HH3 < 10 + SS3            .get expected status
         DIA : 13
         P = R/WERR, A # ES             .sense drive echo error
         P = RELS

R/WERR   A = 0                          .get status
         DIA : 17                       .get current status
         WAIT, DIA # DN
         P = ERROR                      .go report error
```

The interrupt service routine for this channel might perform the following:

```
ISR      DIA : 6                        .Clear Interrupt Enable
         IR = IR + 1                    .count interrupts
         P = FINI, IR = 3               .sense 3rd interrupt
         P = FINI, DIA = DN             .sense controller done
         P = MORE, IR = 2               .sense 2nd interrupt
         AD = AD + 4000                 .next desired buffer
         DIA : 14
         ZZ = ZZ + 2                    .delay  (6 clock periods)
         DIA : 10
         P = NEXT, A = AD               .sense LMA reg. 0 error
         ER = 1                         .set error flag
         P = FINI
```

```
NEXT     A = SS3                              .3rd desired sector SS3 (0-51₈)
         DIA : 16
         ZZ = ZZ + 2                          .delay   (6 clock periods)
MORE     DIA : 7                              .Set Interrupt Enable
FINI     EXIT                                 .return
```

DD-39/DCU-5 OPERATION 4

This section contains information concerning the DD-39 Disk Storage Units (DSUs) and the DCU-5 Disk Controller Unit (DCU). Included in this section is a general description of DD-39 characteristics, a description of the data sequence pattern, data and CE cylinders, flaw tables, the sector slipping mechanism, DCU registers and buffers, disk channel functions, and error processing. The section also includes a DD-39 programming example.

DISK STORAGE UNIT CHARACTERISTICS

The DD-39 Disk Storage Unit contains three disk drives and required interface logic to operate as a single disk drive unit. Each disk drive within the cabinet consists of 6 rotating platters. Data is accessed by 20 read/write heads organized into five groups. The period of disk rotation is 15 ms; heads are controlled and positioned by a servo mechanisms to one of 842 disk cylinders. Positioning time from one cylinder to another varies from 5.5 ms to 35 ms depending on the distance the head assembly must travel.

The 20 read/write heads are divided into five groups, four read/write heads per group. The recording surface available to each head group is a disk track, and it is the basic storage unit reserved by the operating system.

Within each disk track there are 24 sectors (and one spare sector) in which data can be recorded and read back. The data in one sector is called a data block and consists of 2048 16-bit parcels of IOP data (512 64-bit words) plus verification and error correction data. Data can be transferred between the IOP's Local Memory and the disk surface only in blocks of this fixed size. Sectors may be chained for both read and write operations by issuing an initial read or write request followed by a sequence of DIA : 16 functions.

Interface logic in the DD-39 cabinet adapts the DCU-5 signals and protocol to the individual drive units, handles routing among the drives, and buffers the drive data. The interface logic performs the following functions:

- Handles unit selection among the three drives
- Passes control functions to the selected drive

- Buffers read and write data for transfers
- Generates error correction codes for write data
- Checks read data correction codes and corrects read data if necessary

DD-39 DATA SEQUENCE PATTERN

Data recorded in a sector of a disk track consists of a number of parts, as shown in figure 4-1. The numbers below each segment in the figure are the total bits of all four heads used.

GAP 1	SYNC	ID FIELD	GAP 2	SYNC	DATA FIELD (2048 parcels)	ECC	GAP 3
544	32	128	896	32	32768	128	1312

Bits

1415

Figure 4-1. DD-39 DSU Data Sequence Pattern

The total number of bits in the above figure is 35,840. This is the portion of a disk track assigned to a sector. An additional gap after the last sector on the track has 160 bits (20 bytes); the track header is 140 bytes. The total number of bits in a disk track is 901,120.

DATA CYLINDERS AND CE CYLINDERS

Each DD-39 disk contains 842 cylinders per spindle: 840 user data cylinders and two reserved cylinders (known as CE1 and CE2). DD-39 DSU cylinders are numbered as follows: cylinders 0 through 839 are data cylinders, cylinder 840 (CE1) contains the Factory Flaw Table and Current Flaw Table, and cylinder 841 (CE2) is the diagnostic scratch cylinder.

FLAW TABLES

Each DD-39 disk contains three flaw tables that list the defective sectors on each disk. CE1 contains the Factory Flaw Table and the User Flaw Table. An Operating System Flaw Table is found on data cylinder 0.

The Factory Flaw Table is a list of the defective sectors that is assembled from defect data written on the track header at point and time of manufacture; it must not be modified. The User Flaw Table is a list of the defective sectors currently on the device, and is initially identical to the Factory Flaw Table. This table can be modified to include additional flaw information.

The Operating System Flaw Table, residing on data cylinder 0, is a list of the defective logical sectors currently on the drive. The table is created by a diagnostic program according to operating system specifications. It should be updated by the diagnostic program anytime the User Flaw Table is modified.

The Factory Flaw Table and the User Flaw Table entries are 2 parcels long. Parameters must be entered, right justified, into the following fields:

1st Parcel	Chan	Cylinder
	4 bits	12 bits

2nd Parcel	Head	†	Sector
	7 bits	1 bit	8 bits

The drive channel bits (Chan in the previous illustration) are set to 1 to indicate one or more drive channels, as follows.

Bit	Channel
2^{15}	3
2^{14}	2
2^{13}	1
2^{12}	0

Each flaw table is one sector long. At 2 parcels (words) per flaw entry, there is room for 1023 flaws plus a table terminator.

Table entries must be in ascending order of cylinder number, head number, and sector number. For example, all flaws on Cylinder 1 precede flaws on Cylinder 2; a flaw in Cylinder 2, Head 1, Sector 3 precedes a flaw in Cylinder 2, Head 2, Sector 2. No duplicate entries are allowed.

---

† Set to indicate an entry added by Cray Research, Inc.

The table must be terminated with an entry of -1's (2 parcels of 177777$_8$) and any subsequent (unused) entries must also be filled with -1's.

Figure 4-2 illustrates the layout of the physical flaw tables (for both the Factory Flaw Table and the User Flaw Table).

Bit

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Parcel 0	Drive Channel				← Cylinder # (0th flaw)											
Parcel 1	← Head # (0th flaw)							CRI	← Sector # (0th flaw)							
Parcel 2	Drive Channel				← Cylinder # (1st flaw)											
Parcel 3	← Head # (1st flaw)							CRI	← Sector # (1st flaw)							
								⋮								
Parcel 2044	Drive Channel				← Cylinder # (1022nd flaw)											
Parcel 2045	← Head # (1022nd flaw)							CRI	← Sector # (1022nd flaw)							
Parcel 2046	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Parcel 2047	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Figure 4-2. Physical Flaw Table Layout

DD-39 SECTOR SLIPPING MECHANISM

Sector slipping allows a full DD-39 track to remain available for user data even after one sector on the track becomes flawed. As shown in figure 4-3, a DD-39 disk has 25 sectors per track, although only 24 are used for data. When not in use, the spare sector is ignored by the software. If one of the data sectors becomes flawed, however, the spare sector is available as a data sector, as shown in figure 4-4.

Sectors are *slipped* from the flawed sector to the end of the track. In figure 4-4, data sector 10 becomes physical sector 11, data sector 11 becomes physical sector 12, and so on. Because of data sector slipping, data must be recreated for sectors 10 through 23 in this example.

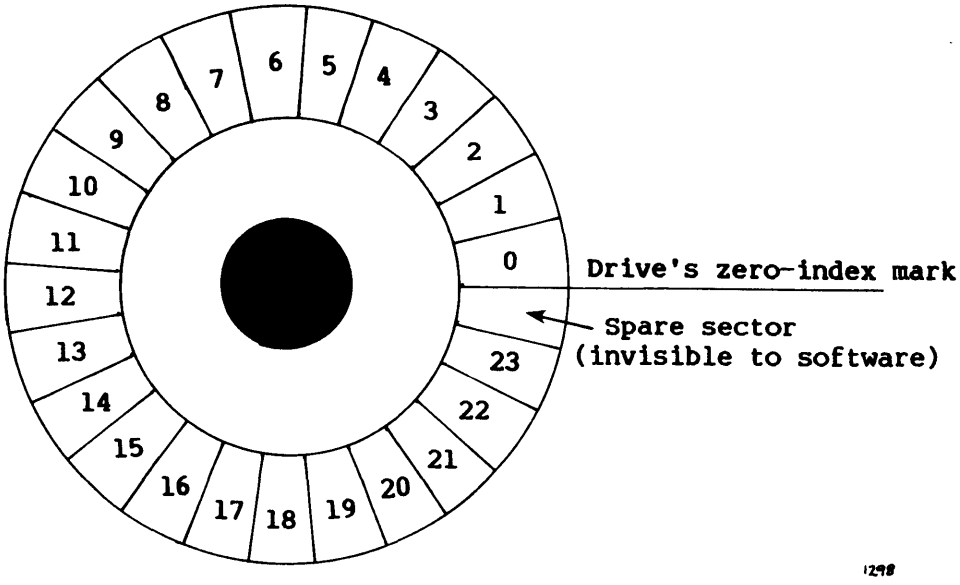


Figure 4-3. DD-39 Track Without Slipped Sector

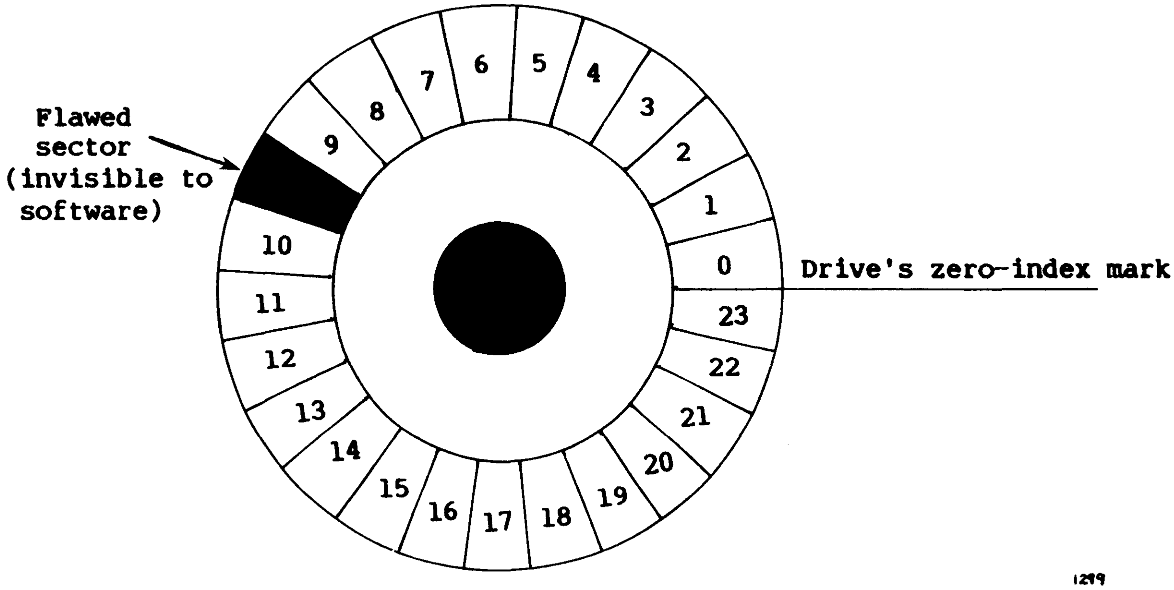


Figure 4-4. DD-39 Track With a Slipped Sector

In general, if sector *n* becomes flawed, sectors *n* through 23 of the track are slipped, and the data contained in sectors *n* through 23 must be recreated.

If a second sector in a track becomes flawed, the operating system must mark the sector as unavailable. Sector slipping takes place off-line. A hardware diagnostic reformats the track with slipped sectors.

DCU-5/DD-39 REGISTERS AND BUFFERS

The DCU-5 and DD-39 contain buffers and registers for data transfer and control. Buffers in the DCU-5 allow data to be streamed between the DSU and Local Memory; deskew buffers in the DD-39 assure data written to disk is accurately recorded at the correct position under the read/write heads. Registers hold memory addresses, status responses and other information. Registers used by the DCU-5 and DD-39 include:

- Status registers (0 and 1)
- Local Memory Address registers (0 and 1)

STATUS REGISTERS

The DCU-5 contains two status registers: Status Register 0 and Status Register 1. The status registers return information about the current state of the drive, echo the last function issued, and provide other information needed by the IOP program.

LOCAL MEMORY ADDRESS REGISTERS

The DCU-5 contains two Local Memory Address registers: Local Address Register 0 and Local Address Register 1. The two registers are used during read and write operations to permit sector chaining. Addresses contained in the registers indicate the starting address for the next sector of information to be written to or read from Local Memory.

DD-39 CHANNEL FUNCTIONS

APML mnemonics DIA through DIP represent the 16 channels available on an I/O Processor (BIOP or DIOP) for DD-39 functions. The functions for the first channel are explained in detail in the following paragraphs, and summarized in appendix D.

For functions 0 through 7 and 17, allow 1 clock period (CP) before checking the interrupt channel (IOR : 10). For all functions, allow 6 CPs before issuing another function through the same DCU.

DIA : 0 - CLEAR CHANNEL CONTROLLER

A DIA : 0 function clears the Channel Busy, Channel Done, and internal status error flags of the DCU. It also clears the special diagnostic control mode bits and the control sequence logic.

DIA : 1 - DRIVE CONTROL OPERATIONS

A DIA : 1 function selects an IOP drive operation. The drive operation may be a command to the drive or a request for a status from the drive. When this function issues, the contents of the IOP accumulator specifies the drive operation.

This function sets the Channel Busy flag and clears the Channel Done flag. When the function completes, the Channel Done flag sets and, if no error occurs, the Channel Busy flag clears. If an error occurs, the Channel Busy flag remains set, Status Register 0 contains the cause of the error, and the Status Register 1 value is determined by the particular drive operation.

The drive control operations are summarized in table 4-1. Each drive control operation is described in the following paragraphs.

Table 4-1. DD-39 DIA: 1 Drive Control Operations

Parameter	Meaning
01000x	Unit select
04xx00	Head select
07000x	Select status
100000	General status
11000x	Diagnostic select
130000	Reset
140000	Clear faults
150000	Return to zero
16000x	Release opposite channel and select
170000	Release

Parameter 01000x - Unit select

Parameter 01000x attempts to logically connect the IOP channel to a DD-39 and reserve the drive for the channel, locking out the other port to the drive. This parameter must be issued successfully before most[†] other drive functions are allowed. The specific drive's number in the DSU is specified in bits 2^0 through 2^2 of the accumulator.

Upon successful completion, Status Register 0 contains $00xx03_8$, indicating drive status available and drive ready. Status Register 1 contains the drive general status.

Issuing parameter 01000x to an already selected port will not cause an error.

Parameter 04xx00 - Head select

Parameter 04xx00 specifies the logical head group for the next read or write operation. Bits 2^8 through 2^{10} of the accumulator are encoded to specify head group zero through five.

Upon successful completion, Status Register 0 indicates drive ready, and Status Register 1 contains an echo of the next head group in bits 2^8 through 2^{10}.

Parameter 07000x - Select status

Parameter 07000x requests a status from the drive. The desired status is encoded in bits 2^0 through 2^2 of the accumulator. Upon successful completion, Status Register 0 indicates drive status available and drive ready; Status Register 1 contains the requested drive status.

The statuses that may be returned are:

Status Selected	Information Returned
0	Unit status
1	Sector status
2	Read/write status
3	Access status
4	ID status

[†] All other functions except release opposite channel and select.

All status select commands return the same information in bits 2^0 through 2^7 of Status Register 1, see table 4-2. They return different status bits 2^8 through 2^{15}. The common status bits are described under general status later in this section. The status bits unique to each status select command (bits 2^8 through 2^{15}) are described in the following paragraphs.

Table 4-2. Common Status Bits in Status Register 1
for Select Status (Parameter 07000x)

Bit	Status
2^0	Function parity error
2^1	Bus-out parity error
2^2	Command error
2^3	ECC error, channel 0
2^4	ECC error, channel 1
2^5	ECC error, channel 2
2^6	ECC error, channel 3
2^7	Interface logic fault

Status 0 - A parameter of 070000 returns the unit status encoded in Status Register 1. The status is indicated as shown in table 4-3 for bits 2^8 through 2^{15} of the register.

Status 1 - A parameter of 070001 returns the sector number that is currently under the heads. Sector numbers range from 0 to 200. Each disk has 25 addressable sectors, and each addressable sector contains 8 physical sectors on the disk. The sector counter in the drive returns the 0-200 sector number to the drive's interface logic, which passes it to the DCU-5. To determine the current addressable sector number, divide the sector number in this status by eight.

Bits 2^8 through 2^{15} of Status Register 1 contain the sector number in binary format, with bit 2^8 the low-order bit position and 2^{15} the high-order bit position.

Status 2 - A parameter of 070002 indicates the faults that were found during a read or write operation. When one or more of these faults occurs in the drive, the fault status bit sets in the unit status (status 0). The read/write status flags can be cleared by issuing a DIA : 1 function with parameter 140000 in the accumulator (clear faults).

The status is indicated as shown in table 4-4 for bits 2^8 through 2^{15} of Status Register 1.

Table 4-3. Status Register 1 Bits for Status 0

Bit	Name	Meaning
2^8	Unit ready	Sets when the drive's spindle reaches its rated speed. Although other faults may prevent the use of the disk, the unit ready status bit will set regardless. When there is a deviation from rated speed, this bit will be cleared.
2^9	On cylinder	Sets when the heads are positioned over the desired cylinder. During an offset operation, the on cylinder bit drops for about 3 ms at the beginning and end of the operation. If a new cylinder is selected, the on cylinder bit drops until the heads are over the new track. For a zero track seek (that is, the new cylinder specified is the same cylinder) the on cylinder bit drops for a maximum of 10 microseconds.
2^{10}	Seek error	Sets if any of the following conditions occur: • A seek or return-to-zero operation is not completed within the specified time • The heads travel to a position outside the recording area • An illegal cylinder address is received by the drive • The heads overshoot to a wrong cylinder address • A seek command is received by the drive while the drive is in the not-on-cylinder state, while the heads are in motion, or during a read or write operation If the seek error status bit sets, the on-cylinder status bit will not set. The seek error is cleared by a return-to-zero operation, by pressing the fault switch located on the operator's control panel, or by pressing the drive maintenance panel's MRTZ (manual return-to-zero) switch.

Table 4-3. Status Register 1 Bits for Status 0 (continued)

Bit	Name	Meaning
2^{11}	Drive fault	Sets when a fault condition occurs that prevents the drive from reading or writing. Refer to Status 2, read/write status, later in this section for fault information. When a fault condition occurs, writing is immediately stopped and the fault information is passed to the DCU-5 status registers. To clear the fault flags in the interface logic and in the drive: • Issue a DIA : 1 drive control function to clear faults (parameter 140000). • Turn off the main power circuit breaker at the rear of the DD-39 cabinet. To clear the fault flags in the drive only: • Press the fault switch on the operator's panel. • Press the MRTZ switch on the drive's maintenance panel. • Press the start switch on the operator's panel to the off position. This stops spindle rotation.
2^{12}	Write protected	Sets if the protect switch on the DSU's operator panel is on when the drive is selected. The setting of the protect switch is sensed at the time the drive is selected. To change the write protect condition, the drive must be deselected, the switch changed, and the drive selected again.
2^{13}		Unused
2^{14}	Index	Sets for approximately one microsecond (2 data bytes), once each revolution, to indicate the drive has found the index mark.
2^{15}	Sector	Sets for approximate one microsecond (2 data bytes), 140 times per revolution, to indicate the drive has found a sector mark. Refer to the Status 1 explanation.

Table 4-4. Status Register 1 Bits for Status 2

Bit	Name	Meaning
2^8	Index check/ sector non-compare	Sets when the index mark is not detected as it should have been. Either it was not found when it should have been, or it was found at the wrong time. Applies only to read or write operations.
2^9	Control check/deskew error protected	Sets under the following conditions: • Write and read gates active at the same time • Write operation while in offset mode • Write gate is active while in write mode • Test deskew circuit error - sync bytes on the four channels have a skew of 16 bytes or more
2^{10}	Not synchronized check	Sets to show a loss of synchronization between the variable frequency oscillator and the Servo Clock or Read Data signal. The loss of synchronization is caused by an abnormal condition in the Servo Clock or the Read Data signal.
2^{11}	Head short check	Sets if an abnormal current was detected in the drive Write Select line during write operation. The fault could be in any one of the channels.
2^{12}	Write current on read check	Sets when one of the heads senses write current during a read operation
2^{13}	Write transition check	Sets if the write current has not been switched during the time that varying data should be written. The transition should occur when the data stream changes between 0 and 1. If all zeros or all ones were written during this time, the drive logic assumes a hardware fault.
2^{14}	Delta i write check	Sets if an abnormal write current was sensed in the inner or outer head on one disk surface. This signal is an OR of the heads in each channel, and of all channels.
2^{15}	Servo off track	Sets to indicate the head is ± 100 microinches off the desired track during the write operation, or to indicate the write gate or read gate is active while the heads are not on cylinder, while the heads are in motion, or when there is a seek error.

Status 3 - A parameter of 070003 shows the conditions of the head during seek and return to zero operations, and the start and stop sequence of the spindle motor.

Table 4-5 shows bits 2^8 through 2^{15} returned in Status Register 1 to indicate those conditions.

Table 4-5. Status Register 1 Bits for Status 3

Bit	Name	Meaning
2^8	DE sequence check	Sets if an abnormality occurred in the drive enclosure (DE) start/stop sequence. Contact your Cray site analyst for information. This fault can only be cleared by stopping and restarting the spindle motor.
2^9	Access time-out check	Sets if the on-cylinder command did not set within 250 ms (±30%) after access start during a return to zero or seek operation. This fault can be cleared by a return to zero (RTZ) operation.
2^{10}	Overshoot check	Sets to indicate the following faults: • The heads went past the desired track during a seek or RTZ operation. • The heads went into the guard band or into the ID position during a seek operation. Both faults indicate the heads were moving too fast during an RTZ action. This status can be cleared by executing an RTZ.
2^{11}- 2^{15}		These status bits show the states of latches associated with the sequences of seek and RTZ operations. Contact your Cray site analyst for information. The status bits can be cleared by issuing an RTZ command.

Status 4 - A parameter of 070004 shows which channel or channels have an ID error. An ID error occurs when an ID is not found at physical sector *n* or *n*+1. These status bits can be cleared with a clear faults operation (parameter 140000).

Status Register 1 bits 2^8 through 2^{15} identify the mismatched sector and channel as follows:

Accumulator Bit	Significance
2^8	ID mismatch, sector *n*, channel 0
2^9	ID mismatch, sector *n*, channel 1
2^{10}	ID mismatch, sector *n*, channel 2
2^{11}	ID mismatch, sector *n*, channel 3
2^{12}	ID mismatch, sector *n*+1, channel 0
2^{13}	ID mismatch, sector *n*+1, channel 1
2^{14}	ID mismatch, sector *n*+1, channel 2
2^{15}	ID mismatch, sector *n*+1, channel 3

Parameter 100000 - General status

Parameter 100000 returns the drive general status. Upon successful completion, Status Register 0 indicates drive status available and drive ready. Status Register 1 contains the drive general status. Table 4-6 is a summary of the bit position assignments for general status.

Table 4-6. Status Register 1 Bit Assignments for General Status

Bit	Name	Meaning
2^0	Function parity error	An error was detected during the reception of the function codes from the IOP.
2^1	Bus-out parity error	An error was detected during the handling of data.
2^2	Command error	A function was lost or a new function issued before the previous command completed.
2^3	ECC error channel 0	An error was detected on drive channel 0 during the last read operation.
2^4	ECC error channel 1	An error was detected on drive channel 1 during the last read operation.
2^5	ECC error channel 2	An error was detected on drive channel 2 during the last read operation.
2^6	ECC error channel 3	An error was detected on drive channel 3 during the last read operation.

Table 4-6. Status Register 1 Bit Assignments for General Status (continued)

Bit	Name	Meaning
2^7	Interface logic fault	Sets when fault is found in the interface logic. It may be a recoverable error or diagnostics may be required to isolate the failing module.
2^8	Unit ready	Sets when the drive's spindle reaches rated speed; will set regardless of other faults (such as seek error and read/write error) preventing disk use. When there is a deviation from rated speed, this bit is cleared.
2^9	On cylinder	Sets when heads are positioned over the desired cylinder. During an offset operation, the on-cylinder bit drops for about 3 ms at the beginning and end of the operation. If a new cylinder is selected, the on-cylinder bit drops until the heads are over the new track. For a zero track seek (that is, the new cylinder specified is the same cylinder) the on-cylinder bit drops for a maximum of 10 microseconds.
2^{10}	Seek error	Sets if any of the following conditions occur: • A seek or return-to-zero operation is not completed within the specified time • Heads travel to a position outside the recording area • An illegal cylinder address is received by the drive • Heads overshoot to a wrong cylinder address • A seek command is received by the drive while the drive is in the not-on-cylinder state, while the heads are in motion, or during a read or write operation If the seek error status bit sets, the on-cylinder status will not set. The seek error bit is cleared by a return-to-zero operation, by pressing the fault switch located on the operator's control panel, or by pressing the drive maintenance panel's MRTZ (manual return-to-zero) switch.

Table 4-6. Status Register 1 Bit Assignments for General Status (continued)

Bit	Name	Meaning
2^{11}	Drive fault	Sets when a fault condition occurs that prevents the drive from reading or writing. (Refer to Status 2, read/write status, earlier in this section for fault information.) When a fault condition occurs, writing is immediately stopped and the fault information is passed to the DCU-5 status registers. Clear the fault flags in the drive unit with one of the following: • Issue a DIA : 1 drive control function to clear faults (parameter 140000). • Press the fault switch on the DD-39's operator panel. • Press the MRTZ switch on the disk drive's maintenance panel. • Turn the drive off using the start switch on the DD-39's operator panel. This stops spindle rotation. • Turn off the main power circuit breaker at the rear of the DD-39 cabinet. Clear the fault flags in the interface logic with one of the following: • Issue a DIA : 1 drive control function to clear faults (parameter 140000). • Issue a DIA : 1 drive control function to reset the logic (parameter 130000). • Turn off the main power circuit breaker at the rear of the DD-39 cabinet.

Table 4-6. Status Register 1 Bit Assignments for General Status (continued)

Bit	Name	Meaning
2^{12}	Data underrun/ overrun	Sets if the IOP does not pass data to the drive fast enough on a write (underrun) or if the IOP does not take data from the drive fast enough on a read (overrun).
2^{13}	ID not found	Sets if the ID was not found on the specified physical sector or (if that sector was formatted as defective) on the following physical sector (slipped sector).
2^{14}	Sync time-out	Sets if the sync bytes for each channel were not found within the allowed window for the field.
2^{15}	Sequencer parity error	Sets if the microcode sequencer in the interface logic found a parity error at one microcode address. Use diagnostics to isolate the fault. The microcode is stored in PROMs (programmable read-only memory chips); if the PROM is faulty it, must be replaced.

Parameter 11000x - Diagnostic select

Parameter 11000x requests the drive to perform in one of two diagnostic modes. If bit 2^0 is set, it forces a parity error on bus-in. The bus-in parity bit of Status Register 0 will be set upon completion. If bit 2^1 is set, it forces a parity error on status. The status parity bit of Status Register 0 will be set upon completion.

When this operation completes, Status Register 0 indicates drive ready. If a parity error was requested, it will show both the error and corresponding parity bits. Status Register 1 echos the diagnostic bits selected.

Parameter 130000 - Reset

Parameter 130000 causes the drive to go through the following reset sequence:

1. Reset all fault conditions and status (port must be selected to do a reset).

2. Perform a return to zero command function.

Upon successful completion of this command, Status Register 0 indicates drive status available and drive ready; Status Register 1 contains the drive general status.

Parameter 140000 - Clear faults

Parameter 140000 resets all fault status flags in the drive. Hardware faults are not cleared. The drive will remain ready throughout the clear faults operation. Clear faults does not perform a return to zero, and therefore does not reset seek error conditions.

Upon successful completion of this command, Status Register 0 indicates drive status available and drive ready. Status Register 1 contains the drive general status.

Parameter 150000 - Return to zero

Parameter 150000 clears all seek-related faults and repositions the read/write heads to cylinder 0. Offsets are cleared by the return to zero command; head selection is unaffected. Upon successful completion of this command, Status Register 0 indicates drive status available and drive ready. Status Register 1 contains the drive general status.

Parameter 16000*x* - Release opposite channel and select

Parameter 16000*x* breaks the current drive reservation, regardless of port, and the port issuing the command is selected. The disk unit number of the DSU is specified in bits 2^0 through 2^2.

The command is recognized only between command executions by the port to be released. This type of recognition allows a more orderly release, but this command should be used with extreme caution. Upon successful completion of this command, Status Register 0 contains $0xx003_8$, indicating drive status available and drive ready; Status Register 1 contains the drive general status.

Issuing this command on the selected port will not cause an error.

Parameter 170000 - Release

Parameter 170000 breaks the drive reservation established in the unit select (00000*x*) or release opposite channel and select (16000*x*) commands. This command makes the drive available for reservation by either drive port. Upon successful completion of this command, Status Register 0 contains $00xx03_8$ indicating drive status available and drive ready; Status register 1 contains the drive general status.

DIA : 2 - REQUEST READ

A DIA : 2 function transfers information from the disk to Local Memory. The read function can request any of the following:

- Data record (4096 bytes)
- Sector ID (16 parcels)
- Absolute data record (2048 parcels)
- Deskew buffer (16 parcels)
- Syndrome block (16 parcels)
- Error correction vectors (16 parcels)

The contents of the IOP's accumulator at the time of the read function specifies the type of read desired, the sector number, and the next head number. The significance of each accumulator bit is shown below:

Accumulator Bit	Significance	
2^0	Sector 2^0	0 through 24 (Decimal)
2^1	Sector 2^1	
2^2	Sector 2^2	
2^3	Sector 2^3	
2^4	Sector 2^4	
2^5	Sector 2^5	
2^6	Unused (Must be 0)	
2^7	Unused (Must be 0)	
2^8	Next head 2^0	0 through 4
2^9	Next head 2^1	
2^{10}	Next head 2^2	
2^{11}	Unused (Must be 0)	
2^{12}	Read option 2^0	
2^{13}	Read option 2^1	
2^{14}	Read option 2^2	
2^{15}	Read option 2^3	

The contents of Local Memory Address Register 0 specifies the Local Memory address to receive the data.

This function sets the Channel Busy flag and clears the Channel Done flag. When the function completes, the Channel Done flag sets and, if no error occurs, the Channel Busy flag clears. If an error occurs, the Channel Busy flag remains set and Status Register 0 contains the cause of the error.

Upon successful completion of a single sector read or the last sector of a chained read, Status Register 0 indicates drive ready. Status register 1 echos the accumulator parameter of the last read function.

If an error occurs (Busy flag remained set) or chaining is broken, a DIA : 17 function with an accumulator parameter of 0 should be issued to obtain statuses.

The read options (bits 2^{12} through 2^{15}) are encoded as shown in table 4-7.

Table 4-7. DIA : 2 Read Options for DD-39

Parameter	Meaning
00xxxx	Read data
01xxxx	Read ID
02xxxx	Read absolute
03xxxx	Read buffer
04xxxx	Read ECC parameter block
05xxxx	Compute and transfer correction vectors
10xxxx	Read track header

Parameter 00xxxx - Read data

Parameter 00xxxx specifies the logical sector to be read in the low-order 5 bits of this parameter (bits 2^0 through 2^4). The next head number (bits 2^8 through 2^{10}) is not used on this issue of the read function, but will specify the head group on subsequent functions. The head used for this read is specified either by the next head number field of the previous read or write function, or by the head select function, whichever occurred most recently.

The sector to be read will be searched for at the physical sector equal to the logical sector specified in the accumulator parameter. The ID field for this sector should match the current cylinder, current head, and logical sector specified. If this sector is formatted as defective, then the next physical sector is compared. This slipped sector's ID must produce a match or an ID-not-found error will occur.

Successful location of the sector begins the data field reading process. The drive will attempt to synchronize to the data on all four physical heads of the current head group. Through the ready/resume channel protocol, 2048 parcels of data will be transferred to the channel, 16 parcels at a time.

Parameter 01xxxx - Read ID

Parameter 01xxxx causes the drive to transfer 16 parcels of data to the channel. These 16 parcels contain the ID field of the physical sector specified in the accumulator parameter. The ID is encoded into the first 8 parcels of the data transferred as follows:

Parcel	Accumulator Bit Position															
#	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Channel 3				Channel 2				Channel 1				Channel 0			
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	h2	h1	h0	0	h2	h1	h0	0	h2	h1	h0	0	h2	h1	h0
3	0	0	c9	c8	0	0	c9	c8	0	0	c9	c8	0	0	c9	c8
4	c7	c6	c5	c4	c7	c6	c5	c4	c7	c6	c5	c4	c7	c6	c5	c4
5	c3	c2	c1	c0	c3	c2	c1	c0	c3	c2	c1	c0	c3	c2	c1	c0
6	0	0	s5	s4	0	0	s5	s4	0	0	s5	s4	0	0	s5	s4
7	s3	s2	s1	s0	s3	s2	s1	s0	s3	s2	s1	s0	s3	s2	s1	s0
8-15	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

where: h2 through h0 = head group number
c9 through c0 = cylinder number
s5 through s0 = logical sector number

Parameter 02xxxx - Read absolute

Parameter 02xxxx causes the drive to transfer the 2048-parcel data record for the physical sector specified in the accumulator parameter. (xxxx is the same sector number as used for read data or read ID, and is the physical sector only.) This command is intended as a data recovery technique should an ID field become unreadable. The command does not compare ID fields; data is referenced by its absolute position reference from index.

Parameter 03xxxx - Read buffer

Parameter 03xxxx transfers 16 parcels of data from the drive data buffer to the channel. The command is intended simply as a diagnostic.

Parameter 04xxxx - Read ECC parameter block

Parameter 04xxxx transfers 16 parcels of data containing the last-read sector's syndromes to the channel. The command is only valid following a read operation (either normal read data or read absolute function). The channel syndrome bits (s) are encoded as follows:

Parcel	Accumulator Bit Position			
#	15 14 13 12	11 10 9 8	7 6 5 4	3 2 1 0
	Channel 3	Channel 2	Channel 1	Channel 0
0	s31s30s29s28	s31s30s29s28	s31s30s29s28	s31s30s29s28
1	s27s26s25s24	s27s26s25s24	s27s26s25s24	s27s26s25s24
2	s23s22s21s20	s23s22s21s20	s23s22s21s20	s23s22s21s20
3	s19s18s17s16	s19s18s17s16	s19s18s17s16	s19s18s17s16
4	s15s14s13s12	s15s14s13s12	s15s14s13s12	s15s14s13s12
5	s11s10 s9 s8	s11s19 s9 s8	s11s10 s9 s8	s11s10 s9 s8
6	s7 s6 s5 s4	s7 s6 s5 s4	s7 s6 s5 s4	s7 s6 s5 s4
7	s3 s2 s1 s0	s3 s2 s1 s0	s3 s2 s1 s0	s3 s2 s1 s0
8-15	x x x x	x x x x	x x x x	x x x x

Parameter 05xxxx - Compute and transfer correction vectors

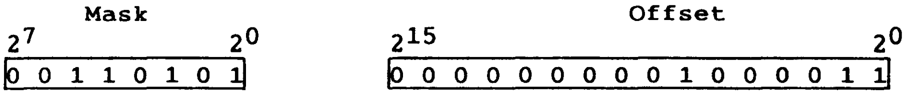
Parameter 05xxxx commands the drive to compute correction vectors for the last sector read (normal read data or read absolute function). Sixteen parcels of data containing the correction vectors are then transferred to the channel. The command is valid only following a read sector function. Channel correction vectors are encoded as follows:

Parcel	Accumulator Bit Position			
#	15 14 13 12	11 10 9 8	7 6 5 4	3 2 1 0
	Channel 3	Channel 2	Channel 1	Channel 0
0	m7 m6 m5 m4	m7 m6 m5 m4	m7 m6 m5 m4	m7 m6 m5 m4
1	m3 m2 m1 m0	m3 m2 m1 m0	m3 m2 m1 m0	m3 m2 m1 m0
2	f15f14f13f12	f15f14f13f12	f15f14f13f12	f15f14f13f12
3	f11f10 f9 f8	f11f10 f9 f8	f11f10 f9 f8	f11f10 f9 f8
4	f7 f6 f5 f4	f7 f6 f5 f4	f7 f6 f5 f4	f7 f6 f5 f4
5	f3 f2 f1 f0	f3 f2 f1 f0	f3 f2 f1 f0	f3 f2 f1 f0
6-15	x x x x	x x x x	x x x x	x x x x

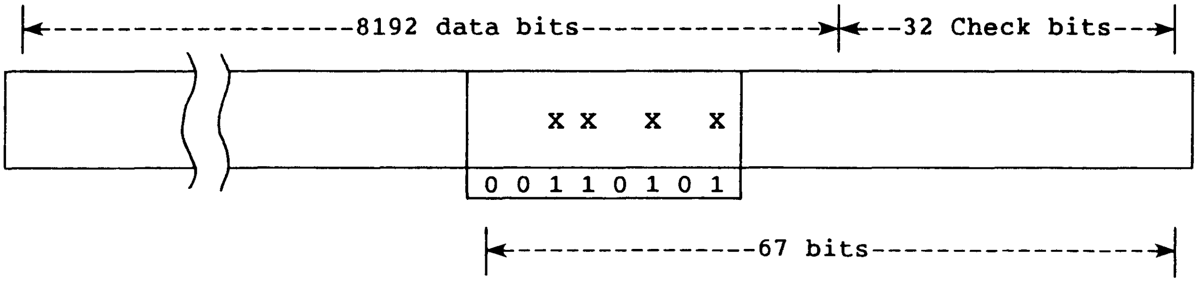
where: m = mask bits
f = offset bits

The offset is counted from the end of the check bits. The most significant bit of the mask is applied to the bit at the offset, and the less significant mask bits become the next 7 data bits toward the end of the data field.

Example:



This mask is applied to the data field as follows:



The bits marked with X are the incorrect bits and must be toggled to correct the data field.

The user must determine if, and how much of, the correction mask lies within the data field of the sector just read and apply the correction accordingly. The sector may be uncorrectable (indicated by a correction offset of 177777_8) or the correction may apply solely or partially to the syndrome for which the correction has already been applied.

Parameter 10xxxx - Read track header

Parameter 10xxxx reads factory flaws and generates a Factory Flaw Table. The table is written by a diagnostic and does not concern the operating sytem.

DIA : 3 - REQUEST WRITE

A DIA : 3 function transfers information from Local Memory to the disk. The request write function can transmit:

- Data record (2048 parcels)
- Sector ID (16 parcels)
- Defective ID (16 parcels)
- Deskew buffer (16 parcels)
- Data record with zero ECC (2048 parcels)
- Write track header (2048 parcels)

The contents of the accumulator at the time of the write function specifies the type of write desired, the sector number, and the next head number. The significance of each accumulator bit is as follows:

Accumulator Bit	Significance	
2^0	Sector 2^0	0 through 24 (Decimal)
2^1	Sector 2^1	
2^2	Sector 2^2	
2^3	Sector 2^3	
2^4	Sector 2^4	
2^5	Sector 2^5	
2^6	Unused (Must be 0)	
2^7	Unused (Must be 0)	
2^8	Next head 2^0	0 through 4
2^9	Next head 2^1	
2^{10}	Next head 2^2	
2^{11}	Unused (Must be 0)	
2^{12}	Write option 2^0	
2^{13}	Write option 2^1	
2^{14}	Write option 2^2	
2^{15}	Write option 2^3	

The contents of Local Memory Address Register 0 specifies the Local Memory address from which the data is obtained. The function sets the Channel Busy flag and clears the Channel Done flag. When the function completes, the Channel Done flag sets and, if no error occurs, the Channel Busy flag clears. If an error occurs, the Channel Busy flag remains set and Status Register 0 contains the cause of the error.

Upon successful completion of a single-sector write or the last sector of a chained write, Status Register 0 indicates drive ready, and Status Register 1 echos the accumulator parameter of the last write function.

If an error occurs (Busy flag remains set) or chaining is broken, a DIA : 17 function with an accumulator parameter of 0 should be issued to obtain statuses. The write options (bits 2^{12} through 2^{14}) are encoded as shown in table 4-8.

Table 4-8. DIA : 3 Write Options for DD-39

Parameter	Meaning
00xxxx	Write data
01xxxx	Write ID
02xxxx	Write defective ID
03xxxx	Write buffer
04xxxx	Write zero ECC field
10xxxx	Write track header

Parameter 00xxxx - Write data

Parameter 00xxxx specifies the logical sector to be written in bits 2^0 through 2^5. The next head number (bits 2^8 through 2^{10}) is not used on this issue of the write function request, but specifies the head group to be used on subsequent functions. The head group used for the current write function is the one specified by the most recent head select, read, or write function.

The sector to be written will be searched for at the physical sector equal to the logical sector specified in the accumulator parameter. The ID field for this sector should match the current cylinder, current head, and logical sector specified. If this sector is the first sector on this track to be formatted as defective, then the next physical sector is compared. This slipped sector's ID must produce a match or an ID-not-found error will occur.

The writing process begins after the sector is successfully located. The drive will write data to all four physical heads of the current head group. Through the ready/resume channel protocol, 2048 parcels of data will be transferred to the drive, 16 parcels at a time.

Parameter 01xxxx - Write ID

Parameter 01xxxx causes the drive to expect 16 parcels of data from the channel. These 16 parcels contain the ID field of the physical sector specified in the accumulator parameter. The ID is encoded into the first 8 parcels of the data transferred as follows:

Parcel	Accumulator Bit Position															
#	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Channel 3				Channel 2				Channel 1				Channel 0			
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	h2	h1	h0	0	h2	h1	h0	0	h2	h1	h0	0	h2	h1	h0
3	0	0	c9	c8	0	0	c9	c8	0	0	c9	c8	0	0	c9	c8
4	c7	c6	c5	c4	c7	c6	c5	c4	c7	c6	c5	c4	c7	c6	c5	c4
5	c3	c2	c1	c0	c3	c2	c1	c0	c3	c2	c1	c0	c3	c2	c1	c0
6	0	0	s5	s4	0	0	s5	s4	0	0	s5	s4	0	0	s5	s4
7	s3	s2	s1	s0	s3	s2	s1	s0	s3	s2	s1	s0	s3	s2	s1	s0
8-15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

where:
h2 through h0 = head group number
c9 through c0 = cylinder number
s5 through s0 = logical sector number

Parameter 02xxxx - Write defective ID

Parameter 02xxxx transfers 16 parcels of data from the channel to the drive. It causes the drive to write a zero ID field (including the sync byte) in the physical sector specified in the accumulator parameter. The 16 parcels to be transferred must be zero-filled. The function is intended for formatting defective sectors so they cannot be accessed accidentally by a read or write data function.

Parameter 03xxxx - Write buffer

Parameter 03xxxx transfers 16 parcels of data from the channel to the drive deskew buffer. The contents of the deskew buffer can then be read using the read buffer command. The write buffer command is intended as a diagnostic.

Parameter 04xxxx - Write zero ECC field

Parameter 04xxxx transfers 2048 parcels of data from the channel to the drive. The data is written to the sector specified in the accumulator parameter and the ECC block is written with zeros. This command is intended solely as a diagnostic for the ECC logic.

Parameter 10xxxx - Write track header

Parameter 10xxxx writes track header information to construct flaw tables. For more information, contact your Cray field engineer.

DIA : 4 - DIAGNOSTIC ECHO

A DIA : 4 function transmits the contents of the accumulator to the drive. It sets the Channel Busy flag and clears the Channel Done flag. When the function completes, the Channel Done flag sets and, if no error occurs, the Channel Busy flag clears. If an error occurs, the Channel Busy flag remains set and Status Register 0 contains the cause of the error.

Upon successful completion of this function, Status Register 0 indicates drive ready, and Status Register 1 contains an echo of the accumulator contents.

This function is intended as a diagnostic, as it tests much of the status and parameter paths as well as the cables and control logic.

DIA : 5 - SELECT CYLINDER

A DIA : 5 function initiates seek or offset operations as specified by the accumulator parameter. The parameter is specified in the accumulator as follows:

Accumulator Bit	Significance
2^0	Cylinder 2^0
2^1	Cylinder 2^1
2^2	Cylinder 2^2
2^3	Cylinder 2^3
2^4	Cylinder 2^4
2^5	Cylinder 2^5
2^6	Cylinder 2^6
2^7	Cylinder 2^7
2^8	Cylinder 2^8
2^9	Cylinder 2^9
2^{10}	Unused (Must be 0)
2^{11}	Unused (Must be 0)
2^{12}	Offset direction in
2^{13}	Offset direction out
2^{14}	Overlapped seeks
2^{15}	Unused

Bits 2^0 through 2^9 specify the cylinder to be selected on seek operations. A seek to a different cylinder operation cannot be initiated with the offsets enabled.

Bits 2^{12} and 2^{13} specify the offset direction for offset operations. Heads must already be on the desired cylinder to initiate an offset operation. Only a single degree of offset (100 microinches) is used, and it applies to both the inward and outward directions.

An offset direction-in bit that is set causes the actuator to offset toward the spindle; conversely, if the offset direction-out bit is set, the actuator will offset away from the spindle. Write operations to the disk are disabled with either offset enabled.

Bit 2^{14} is set to allow the controller to initiate a seek operation without waiting for its completion. While the heads are traveling, the IOP is free to issue other functions. At the end of the seek, the controller must go out and read statuses.

The select cylinder function sets the Channel Busy flag and clears the Channel Done flag. When the function completes, the Channel Done flag sets and, if no error occurs, the Channel Busy flag clears. If an error occurs, the Channel Busy flag remains set and Status Register 0 contains the cause of the error.

Upon successful completion of this function, Status Register 0 indicates drive ready, and Status Register 1 echos the accumulator parameter.

DIA : 6 - CLEAR CHANNEL INTERRUPT ENABLE FLAG

A DIA : 6 function clears the Channel Interrupt Enable flag. This prevents interruption of the I/O Processor program by this channel and requires program monitoring of the Channel Done flag for proper sequencing of the DD-39 control functions.

DIA : 7 - SET CHANNEL INTERRUPT ENABLE FLAG

A DIA : 7 function sets the Channel Interrupt Enable flag. This allows the IOP's program to be interrupted by this channel whenever the Channel Done flag is set or when the channel needs servicing during sector-chained read or write functions.

DIA : 10 - READ LOCAL MEMORY ADDRESS REGISTER 0

A DIA : 10 function reads the current contents of Local Memory Address Register 0 into the IOP's accumulator. This function may be executed at any time with respect to a DD-39 program sequence. The Channel Busy and Done flags are not altered by this function. The value read will be an echo of the address entered or the current Local Memory address if data has been transferred to or from Local Memory. The significance of each accumulator bit is shown below:

Accumulator Bit	Significance
2^0	Entered value or 0 if address has incremented
2^1	Entered value or 0 if address has incremented
2^2	Current Local Memory address bit 2^2
2^3	Current Local Memory address bit 2^3
2^4	Current Local Memory address bit 2^4
2^5	Current Local Memory address bit 2^5
2^6	Current Local Memory address bit 2^6
2^7	Current Local Memory address bit 2^7
2^8	Current Local Memory address bit 2^8
2^9	Current Local Memory address bit 2^9
2^{10}	Current Local Memory address bit 2^{10}
2^{11}	Current Local Memory address bit 2^{11}
2^{12}	Current Local Memory address bit 2^{12}
2^{13}	Current Local Memory address bit 2^{13}
2^{14}	Current Local Memory address bit 2^{14}
2^{15}	Current Local Memory address bit 2^{15}

DIA : 11 - READ LOCAL MEMORY ADDRESS REGISTER 1

A DIA : 11 function reads the current contents of Local Memory Address Register 1 into the IOP's accumulator. (Refer to the description of the DIA : 10 function.)

DIA : 12 - READ STATUS REGISTER 0

A DIA : 12 function reads the current contents of Status Register 0 into the IOP's accumulator. Status Register 0 contains the DCU internal status that is loaded at the completion of functions 1 through 5 and 17. The Channel Busy and Done flags are not altered by this function. The contents of the accumulator, after this function issues, is bit-mapped as shown in table 4-9.

DIA : 13 - READ STATUS REGISTER 1

A DIA : 13 function reads Status Register 1 into the IOP's accumulator. This function may be issued at any time with respect to the DD-39 program sequence. The Channel Busy and Done flags are not altered by this function. The value read will be the drive's response to the last function that the drive executed. Depending on the function, and whether or not it executed successfully, the drive's response will be one of the following:

- An echo of the function's bus-out
- The drive's general status
- The particular drive status requested
- Undetermined (if a Status Register 0 error was indicated)

DIA : 14 - ENTER LOCAL MEMORY ADDRESS REGISTER 0

A DIA : 14 function enters the accumulator contents into Local Memory Address Register 0. The Channel Busy and Done flags are not altered by this function. The significance of each accumulator bit is shown below:

Accumulator Bit	Significance
2^0	Unused
2^1	Unused
2^2	Local Memory address bit 2^2
2^3	Local Memory address bit 2^3
2^4	Local Memory address bit 2^4
2^5	Local Memory address bit 2^5

Accumulator Bit	Significance
2^6	Local Memory address bit 2^6
2^7	Local Memory address bit 2^7
2^8	Local Memory address bit 2^8
2^9	Local Memory address bit 2^9
2^{10}	Local Memory address bit 2^{10}
2^{11}	Local Memory address bit 2^{11}
2^{12}	Local Memory address bit 2^{12}
2^{13}	Local Memory address bit 2^{13}
2^{14}	Local Memory address bit 2^{14}
2^{15}	Local Memory address bit 2^{15}

DIA : 15 - ENTER LOCAL MEMORY ADDRESS REGISTER 1

A DIA : 15 function enters the accumulator contents into Local Memory Address register 1. (Refer to the description of the DIA : 14 function.)

DIA : 16 - ENTER NEXT READ/WRITE PARAMETER

A DIA : 16 function is used during sector-chaining operations to queue the next read or write operation. Its associated accumulator parameter becomes the read or write parameter transmitted to the drive with the next read or write function. The Channel Busy and Done flags are not directly altered by this function. The significance of each accumulator bit is shown below:

Accumulator Bit	Significance	
2^0	Sector 2^0	0 through 24 (Decimal)
2^1	Sector 2^1	
2^2	Sector 2^2	
2^3	Sector 2^3	
2^4	Sector 2^4	
2^5	Sector 2^5	
2^6	Unused (Must be 0)	
2^7	Unused (Must be 0)	
2^8	Next head 2^0	0 through 4
2^9	Next head 2^1	
2^{10}	Next head 2^2	
2^{11}	Unused (Must be 0)	
2^{12}	Read or write option 2^0	
2^{13}	Read or write option 2^1	
2^{14}	Read or write option 2^2	
2^{15}	Read or write option 2^3	

Table 4-9. Bit Position Assignments for DD-39 DIA : 12 Read Status Register 0

Bit	Name	Meaning
2^0	Drive ready	This is the state of the channel's Ready signal when the register was loaded. It tells the controller that the drive is ready to accept channel commands.
2^1	Drive status available	The channel's Status/Data Ready signal was asserted at the same time as drive done. It indicates that a drive status is available in Status Register 1.
2^2	Drive busy/ invalid drive command	The channel's Status/Data Ready signal and Error signal were both asserted at the same time as drive done. It indicates that the drive is busy (connected to the other port), the drive received an invalid command, or a drive function failed and general status is available in Status Register 1.
2^3	Drive error	The channel's Error signal was asserted at the same time as Drive Done.
2^4	Status parity error	This indicates that a parity error was detected on the channel's Status lines.
2^5	Bus-in parity error	This indicates that a parity error was detected on the channel's bus-in lines.
2^6	Read data parity error	This indicates that a parity error was detected at the controller's buffer outputs on a read operation.
2^7	Error flag	This is a global error flag which indicates that one or more of the controller status bits, bit 2^0 or bits 2^2 through 2^6, are in error. It can also indicate that the drive went not ready during the previous interval (a latch of the inverse of channel ready) as in the case of a reset command.
2^8 - 2^{15}		Parameter register bits 0 through 7. This is the lower byte of bus-out for the last drive function issued by the controller.

On each issue of a DIA : 16, the associated Local Memory address alternates between Local Memory Address Register 0 and Local Memory Address Register 1.

To perform sector-chaining, an initial read function (DIA : 2) or write function (DIA : 3) is followed by a sequence of DIA : 16 functions. Each DIA : 16 function must be issued prior to the completion of the current read or write sector in order to continue the chaining operation.

An interrupt is generated to signal the completion of each sector, however, the Channel Busy flag remains set and the Channel Done flag remains clear throughout the chaining sequence. When the sequence completes, the Channel Done flag sets and the Channel Busy flag clears.

DIA : 17 - SELECT SPECIAL CONTROLLER MODE/STATUS

A DIA : 17 function is used to place the controller in one of several special diagnostic modes of operation. The controller remains in this mode until one of the following occurs:

- Clear channel controller function (DIA : 0) is issued
- Function is reissued with mode bit disabled
- Power is cycled

This function transfers a copy of the channel's status to Status Register 0, which allows the drive Ready signal to be tested without evoking a drive function.

The function sets the Channel Busy flag and clears the Channel Done flag. Upon successful completion, the Channel Done flag sets and the Channel Busy flag clears. The amount of time this function takes depends on controller activity, but it will be 10 to 20 clock periods.

The diagnostic modes are bit mapped in the accumulator as shown in table 4-10.

DD-39 DISK ERROR CORRECTION

When data is stored on the disk, a 32-bit checkword is written along with it. This checkword is generated by sending the data through a linear feedback shift register. When the data is read back from the disk, the data goes through the same shift register. If the data and check bits are without error, the shift register will contain all zeros at the completion of the transfer. If a data or check bit error has occurred, the shifter will not contain all zeros and an error will be flagged. The error is reported back to the controller.

Table 4-10. Bit Position Assignments for DD-39 DIA : 17 Diagnostic Modes

Bit	Name	Meaning
2^0	Sync testpoint	Sync point available for scope loops or logic analyzer sync triggers
2^1	Buffer echo	Forces the subsequent read or write operations to be internal to the controller. It is intended as a diagnostic for the controller's data buffers and control logic. A write function writes 2048 parcels of data to the controller's two quarter-sector buffers. Parcels 0-511 are written to buffer A and parcels 512-1023 are written to buffer B. Then parcels 1024-1535 are written to buffer A (overwriting parcels 0-512) and parcels 1536-2047 are written to buffer B (overwriting parcels 512-1023). The data can then be read back by a read function. Buffer A is read into parcels 0-511 and buffer B is read into parcels 512-1023. Then buffer A is reread into parcels 1024-1535 and buffer B is reread into parcels 1536-2047.
2^2	Force control parity error	Forces parity (code) to be asserted on subsequent drive functions
2^3	Force bus-out parity error	Forces parity (bus-out) to be asserted on all subsequent bus-outs
2^4	Force data parity error	Forces the data parity to be asserted on all subsequent data being written from the buffer on write operations
2^5 - 2^{15}		Unused

After an error has been flagged, the contents of the shifter can be used to correct the error if the error is no longer than a burst of 8 bits. The hardware algorithm for computing the correction vector is as follows.

1. The shifter is preshifted by 65,536 - (8192 + 32) = 57,312 times.

   Where: 65,536=natural length of the polynomial used
   8,192=number of data bits from one channel in a sector
   32=number of check bits

2. The shifter is then shifted until the low-order 24 bits all equal zeros. At this time, the high-order 8 bits of the shift register contain the mask portion of the correction vector. A counter keeps track of the number of positions shifted. A zero shift number means the mask is applied at the first data bit.

3. When the low-order bits of the shifter are all zeros, the ones complement (inverse) of the number of position shifts is loaded into bits 8 through 23 of the shifter. This inverse number is equal to 65,536 minus the number of position shifts, which equals the offset from the end of the data field.

4. The offset and mask now in the high-order 24 bits of the shifter are sent to the controller as the correction vector.

5 If the shifter shifts 65,536 times and no correction vector is found, the inverse of the counter now equals all ones. The 24 ones are loaded into the shifter positions 8 through 23 and are sent to the controller. The all-ones offset indicates an uncorrectable error.

Additional information about the correction vector is included under the description of the DIA : 2 function, parameter 04xxxx.

The DCU-5 controller and the DD-39 drive were designed so that controller hardware and drive microcode would perform a considerable amount of data integrity checking. Some of the features included are:

- Parity on functions to the drive
- Parity on parameters to the drive
- Parity on control signals from the drive
- Parity on status words from the drive
- Automatic echo of seek, read, write, head select, and maintenance function parameters from the drive back to the controller and I/O processor
- Parity on all data transfers, which includes the controller data buffers
- Echo capability of Local Memory Address registers in the controller for testing before and after a transfer is executed
- ID fields read and verified prior to each sector transfer. If an ID field is destroyed, the sector can still be read and the ID field rewritten without altering the data field.

- Error correction codes are written with the data fields in order to verify and/or correct single burst errors while reading
- Buffer echo checks are available both to the controller and/or the drive if on-line or in-line testing is desired
- Diagnostic ability to create sectors with either correctable or noncorrectable data field errors
- Ability to offset the heads marginally in order to recover data
- Monitoring of temperature, blower air pressure, internal drive logic and memory errors, servo faults, and so on, by the drive
- Implementation of a sector slipping algorithm within the drive to minimize the system's flaw management effort

Some of the above features are self-supporting and some require support through the software driver. Appendix C provides an example of an error recovery procedure for use with the DD-39.

PROGRAMMING EXAMPLE

The following example illustrates a programming sequence in APML for the DD-39. The drive is tested to see if is ready to accept commands. Once ready, a single target sector is read from the drive.

```
         DIA : 0                        .clear channel controller

TRDY     ZZ = ZZ + 2                    .delay  (6 clock periods)
         A = 0     .get status
         DIA : 17                       .get current status
         WAIT, DIA # DN
         P = ERROR, DIA = BZ            .sense error (both DN and BZ)
         DIA : 12
         A = A & 1
         P = TRDY, A = 0                .sense drive ready

SEL      A = UN +10000                  .select parameter
         DIA : 1                        .Select Unit
         ES = A < 10 + 3
```

```
         Wait for interrupt

         WAIT, DIA = BZ                  .sense error
         P = ERROR, DIA # DN             .sense done error
         DIA : 12
         P = ERROR, A # ES               .sense controller status
         DIA : 13
         P = ERROR, A # 1400             .sense general status

CYL      A = CC                          .desired cylinder CC  (0-1510_8)
         DIA : 5                         .Select Cylinder

                   Wait for interrupt

         WAIT, DIA = BZ                  .sense error
         P = ERROR, DIA # DN             .sense done error
         ES = CC < 10 + 1                .form expected status
         DIA : 12
         P = ERROR, A # ES               .sense controller status
         DIA : 13
         P = ERROR, A # CC               .sense drive echo error

HEAD     A = HH                          .desired head HH  (0-4)
         FE = A < 10                     . (save for function echo)
         A = A + 040000
         DIA : 1                         .Select Head

                   Wait for interrupt

         WAIT, DIA = BZ                  .sense error
         P = ERROR, DIA # DN             .sense done error
         DIA : 12
         P = ERROR, A # 1                .sense controller status
         DIA : 13
         P = ERROR, A # FE               .sense drive echo error

READ     A = AD                          .desired buffer address AD
         DIA : 14
         ZZ = ZZ + 2                     .delay  (6 clock periods)
         DIA : 10
         P = ERROR, A # AD               .sense register error
         A = SS                          .desired sector SS  (0-27_8)
         DIA : 2                         .Read Data
```

```
                 Wait for interrupt

          WAIT, DIA = BZ                 .sense error
          P = RWERR, DIA # DN            .sense done error
          ES = SS < 10 + 1               .form expected status
          DIA : 12
          P = RWERR, A # ES              .sense controller status
          DIA : 13
          P = RWERR, A # SS              .sense drive echo error

RELS      A = UN + 170000                .get release parameter
          DIA : 1                        .Release Unit
          ES = A < 10 + 3

                 Wait for interrupt

          WAIT, DIA = BZ                 .sense error
          P = ERROR, DIA # DN            .sense done error
          DIA : 12
          P = ERROR, A # ES              .sense controller status
          DIA : 13
          P = ERROR, A # 1400            .sense general status

          EXIT                           .end of illustration
```

The above illustration's read can be expanded from one sector to three sectors, if all on the same cylinder, as follows:

```
READ      A = AD                         .desired buffer address AD
          DIA : 14
          ZZ = ZZ + 2                    .delay  (6 clock periods)
          DIA : 10
          P = ERROR, A # AD              .sense error
          ER = 0                         .clear error flag
          IR = 0                         .clear interrupt counter
          A = HH2                        .2nd desired sector's head HH2
          A = A < 10
          A = A + SS1                    .1st desired sector SS1  (0-27$_8$)
          DIA : 2                        .Read DATA
          AD = AD + 4000                 .next desired buffer
          DIA : 15
          ZZ = ZZ + 2                    .delay  (6 clock periods)
          DIA : 11
          P = ERROR, A # AD              .sense LMA 1 register error
          A = HH3                        .3rd desired sector's head HH3
          A = A < 10
          A = A + SS2                    .2nd desired sector SS2  (0-27$_8$)
          DIA : 16
```

```
LOOP      P = TEST, DIA = DN               .sense controller Done
          P = RWERR, ER # 0                .sense interrupt error
          P = LOOP

TEST      P = RWERR, DIA = BZ              .sense error
          P = RWERR, IR # 3                .all sectors read?
          P = RWERR, DIA # DN              .sense done error
          ES = SS3 < 10 + 1                .get expected status
          DIA : 12
          P = RWERR, A # ES1               .sense controller status
          ES = HH3 < 10 + SS3              .get expected status
          DIA : 13
          P = RWERR, A # ES                .sense drive echo error
          P = RELS

RWERR     A = 0                            .get status
          DIA : 17                         .get current status
          WAIT, DIA # DN
          P = ERROR                        .go report error
```

The interrupt service routine for this channel might perform the following:

```
ISR       DIA : 6                          .Clear Interrupt Enable
          IR = IR + 1                      .count interrupts
          P = FINI, IR = 3                 .sense 3rd interrupt
          P = FINI, DIA = DN               .sense controller done
          P = MORE, IR = 2                 .sense 2nd interrupt
          AD = AD + 4000                   .next desired buffer
          DIA : 14
          ZZ = ZZ + 2                      .delay  (6 clock periods)
          DIA : 10
          P = NEXT, A = AD                 .sense LMA reg. 0 error
          ER = 1                           .set error flag
          P = FINI

NEXT      A = SS3                          .3rd desired sector SS3 (0-27₈)
          DIA : 16
          ZZ = ZZ + 2                      .delay   (6 clock periods)
MORE      DIA : 7                          .Set Interrupt Enable
FINI      EXIT                             .return
```

APPENDIX SECTION

DD-29 DISK ERROR CORRECTION ROUTINE

A

The following APML routine attempts to correct errors on data read from IOS disk using Fire codes. It simulates the correction vector built by the hardware and uses that vector to correct the error. (The macros used in the following code are defined by Cray Research, Inc. They are described in the IOS Software Internal Reference Manual, CRI publication SM-0046.)

```
*************************************************************************
*                                                                       *
*        FIRECODE  Disk read data error correction routine              *
*                                                                       *
*        Attempts to correct read data errors using the Fire codes      *
*        generated when the data was written to disk.  This routine     *
*        simulates the hardware Fire code generation procedure to ob-   *
*        tain a correction vector.  The correction vector is used to    *
*        correct the data.  The algorithm corrects errors spanning      *
*        11 bits for each head.                                         *
*                                                                       *
*        Parameter registers:                                           *
*                                                                       *
*        DATA      Disk data buffer address                             *
*        CHECKWD   Fire codes as read from disk (8 parcels)             *
*        INFO      Buffer in which syndrome information is stored       *
*                  (8 parcels)                                          *
*                                                                       *
*        Return:   A = 0 if data has been corrected.                    *
*                                                                       *
*************************************************************************
         SPACE     2
         REGDEFS   ,(DATA,CHECKWD,INFO),(RC,PB,PC,ZA,ZB,ZC,ZD,ZE,ZG,ZH,
                   ZI,F0,F1,F2,F3,F4,F5,F6,F7)
         EJECT
         R!F0 = 0                      .Clear CRC accumulators
         R!F1 = A
         R!F2 = A
         R!F3 = A
         R!F4 = A
         R!F5 = A
         R!F6 = A
         R!F7 = A
         R!PB = R!DATA                 .Disk data buffer
         R!ZI = R!PB + D'2048
         R = GENERATE                  .Generate CRC for data
```

```
         R!PB = R!CHECKWD              .Checkwords from disk
         R!ZI = R!PB + D'8
         R = GENERATE                  .Use checkwords to get syndrome
         R!%W1 = D'8
         B = F7
         R!%W2 = R!INFO

         $UNTIL    (R!%W1 = 0)         .Save syndrome in memory
           (R!%W2) = (B)
           B = B - 1
           R!%W2 = R!%W2 + 1
           R!%W1 = R!%W1 - 1
         $ENDTIL

         R!PB = R!DATA
         R!PC = R!INFO
         R!RC = 0
         R = CORRECT                   .Correct data if possible
         RETREG    R!RC,A              .Return response code
         RETURN
         EJECT
*        Simulate the hardware CRC generation.

GENERATE *

NXWRD    ZD = (PB)

         ZC = 4

NXBIT    ZA = F0
         ZB = F1
         R = CRI
         F0 = ZA
         F1 = ZB

         ZA = F2
         ZB = F3
         R = CRI
         F2 = ZA
         F3 = ZB

         ZA = F4
         ZB = F5
         R = CRI
         F4 = ZA
         F5 = ZB

         ZA = F6
         ZB = F7
         R = CRI
         F6 = ZA
```

```
         F7 = ZB
         ZC = ZC - 1
         P = NXBIT, ZC # 0
         PB = PB + 1
         P = NXWRD, PB < ZI        ..LAST WORD?

         EXIT
         EJECT
CRI      ZA = ZA < 1
         B = A > D'16
         ZB = ZB < 1 + B
         P = TEST1, C = 1
         ZD = ZD < 1
         P = NOCO, C = 1
         EXIT
TEST1    ZD = ZD < 1
         P = NOCO, C = 0
         EXIT

NOCO     ZG = 177777 - ZA & 4005   ..TOGGLE LOWER
         ZA = ZA & 173772 + ZG     ..  POLYNOMIAL BITS

         ZG = 177777 - ZB & 240    ..TOGGLE UPPER
         ZB = ZB & 177537 + ZG     ..  POLYNOMIAL BITS
         EXIT
         EJECT
*
*  CORRECT DATA
*
*
*   ON ENTRY:
*
*   PB   CONTAINS DATA BUFFER ADDRESS
*   PC   CONTAINS SYNDROME ADDRESS
*

CORRECT  *
         ZH = 4                    .SET HEAD COUNTER TO LAST HEAD + 1
         R!ZE = R!PC                    .Pointer to syndrome

CRC0     ZH = ZH - 1               .DECREMENT HEAD COUNTER
         EXIT, C # 1               .IF DONE, RETURN
         ZC = D'8224               .NUMBER OF BITS + 32 BIT FIRE
         F1 = (ZE)                 .GET FIRECODE UPPER BITS
         ZE = ZE + 1               .INC ADDRESS
         F0 = (ZE)                 .GET LOWER BITS
         ZE = ZE + 1               .INC ADDRESS
         P = CRC1, F0 # 0          .ERROR THIS HEAD?
         P = CRC1, F1 # 0          .
         P = CRC0                  .NEXT HEAD
```

```
CRC1      P = CRC2, F0 # 0          .CORRECTION VECTOR FOUND?
          A = F1 & 37
          P = CRC2, A # 0           .NO
          P = CRC6                  .YES, CORRECT DATA

CRC2      ZC = ZC - 1               . DECREMENT COUNTER
          P = CRC9, C = 0           .NOT CORRECTABLE?
          ZA = F0                   .SAVE F0
          F0 = F0 > 1               .SHIFT
          F1 = F1 >> 1              .  RIGHT 1
          F0 = F0 + 100000, C=1     .MERGE 2^17th DOWN
          A = ZA < D'16             .CHECK 2^0
          P = CRC1, C = 0           .2 TO THE 0 = 0?

          F2 = 177777 - F0 & 2002   .TOGGLE LOWER
          F0 = F0 & 175775 + F2     .  POLYNOMIAL BITS

          F3 = 177777 - F1 & 100120.TOGGLE UPPER
          F1 = F1 & 077657 + F3     .  POLYNOMIAL BITS
          P = CRC1                  .NEXT ITERATION

CRC6      F1 = F1 & 177740          .MASK CORRECTION VECTOR

CRC7      A = ZC - D'8192           .ARE BAD BITS IN FIRECODE WORD?
          P = CRC0, C = 1           .YES, DON'T CORRECT, NEXT HEAD
          F2 = F1 & 100000          .GET A BIT TO BE CORRECTED
          ZA = ZC > 2               .DIVIDE BIT CNT. BY 4 TO GET ADDRESS
          B = ZC & 3 < 2            .REMAINDER TO B
          B = B + ZH                .ADD IN HEAD COUNTER FOR SHIFT CNT
          ZA = ZA + PB              .ADD BIAS FOR START OF BUFFER
          F2 = F2 > B               .SHIFT TO CORRECT BIT POSITION
          F3 = (ZA)                 .GET PARCEL TO BE CORRECTED
          F4 = 177777 - F3 & F2     .TOGGLE THE BIT
          A = 177777 - F2 & F3 + F4.

          (ZA) = A                  .STORE CORRECTED DATA
          ZC = ZC + 1               .NEXT BIT POSITION
          F1 = F1 < 1               .ALIGN NEXT BIT
          P = CRC7, A # 0           .DONE?
          P = CRC0                  .NEXT HEAD

*  DATA UNCORRECTABLE

CRC9      *
          R!RC = 1
          EXIT
```

DD-49 DISK ERROR CORRECTION ROUTINE

B

To implement an effective error recovery algorithm for the DD-49, it is necessary to partition the driver error recovery into five major areas. By doing this, the recovery algorith allows a limited number of retries (that tolerate changing conditions as a result of a system request) and also handles errors on the recovery functions themselves. The major areas of the algorithm are:

- Unit select process
- Cylinder select process
- Head select-LMA select-read process
- Head select-LMA select-write process
- Release process

Each area is assumed to be a single process whereby it is rarely required to go from one process to another during error recovery. For example, when one process is complete, most retry counters can be reset prior to beginning the next process.

Since it is not known what combination of errors will occur, an overall maximum retry count, per I/O sector and individual process, is chosen as a starting point. Within each process, a limit is assigned to the various subprocess errors; that is, tolerance to errors on reset, various status commands, and so on. See table B-1.

With this scheme, it is possible to see multiple occurrences of every possible error (per sector, seek, and so on), to process those errors through retries or resets, and to keep the software manageable. Tables are kept for each device in the error recovery process. Error counts are incremented until either the error is recovered or a counter reaches the limits defined in table B-1. This exhausts the hardware error recovery process for that request; it should not limit any software recovery mechanisms such as reallocation or alternate pathing.

Figures B-1 through B-6 describe the suggested error recovery procedures to be implemented by either an IOP or mainframe error recovery program.

The following algorithms are used in the course of read/write error recovery described in figure B-3.

Table B-1. Retry and Reset Counters for DD-49

Select	Seek	Read Sector[†]	Write Sector[††]	Release	Description
63	63	63	63	63	Total available retries and/or resets
15	15	15	15	15	Time-out resets per 30 seconds
15	15	15	15	15	Not Ready retries per 30 seconds
15	-	-	-	15	Busy response retries per 30 seconds
15	15	15	15	15	Input parity error retries per 30 seconds
30	30	30	30	30	Sequence operation in progress retries per 60 seconds
15	15	15	15	15	Invalid operation, invalid command, function parity error, or bus-out parity error retries per 30 seconds
15	15	15	15	15	Functions lost retries per 30 seconds
-	15	15	15	-	Catastrophic seek status retries per 60 seconds
-	15	15	15	-	Seek error/fault resets and reseek attempts per 30 seconds
-	-	30	30	-	Overrun/underrun retries per 30 seconds
-	-	45	3	-	ECC, ID Not Found, or Sync Time-out retries per offset position per sector
-	-	1	1	-	LMA initial echo error retries per 30 seconds
-	-	15[†††]	15	-	LMA final echo error retries per 30 seconds
-	-	15	0	-	Sector number echo error retries

[†] Head select, LMA select, read, and so on

[††] Head select, LMA select, write, and so on

[†††] If within sector buffer

ALGORITHM A:

1. Clear faults and retry read/write at least 15 times.
2. If ID-not-found error, perform seek error recovery.
3. Determine actuators in error (read).
4. Offset actuators in error toward spindle.
5. Retry read at least 15 times.
6. Offset actuators still in error away from spindle.
7. Retry read at least 15 times.

ALGORITHM B:

Superimposed on algorithm A is the following algorithm used to determine correctable data.

On each retry that yields a correctable ECC error status, save the correction vectors in a buffer and compare with the previous correctable ECC correction vectors. If the calculated error locations are consistent (within a parcel) on all channels in error, then apply the vectors to correct the last read data.

If the above algorithm proves to be ineffective, then it may be necessary to do error recovery on each of the four serial channels of a logical head group independently. This should not be coded without first seeing a demonstrable requirement over several disk units.

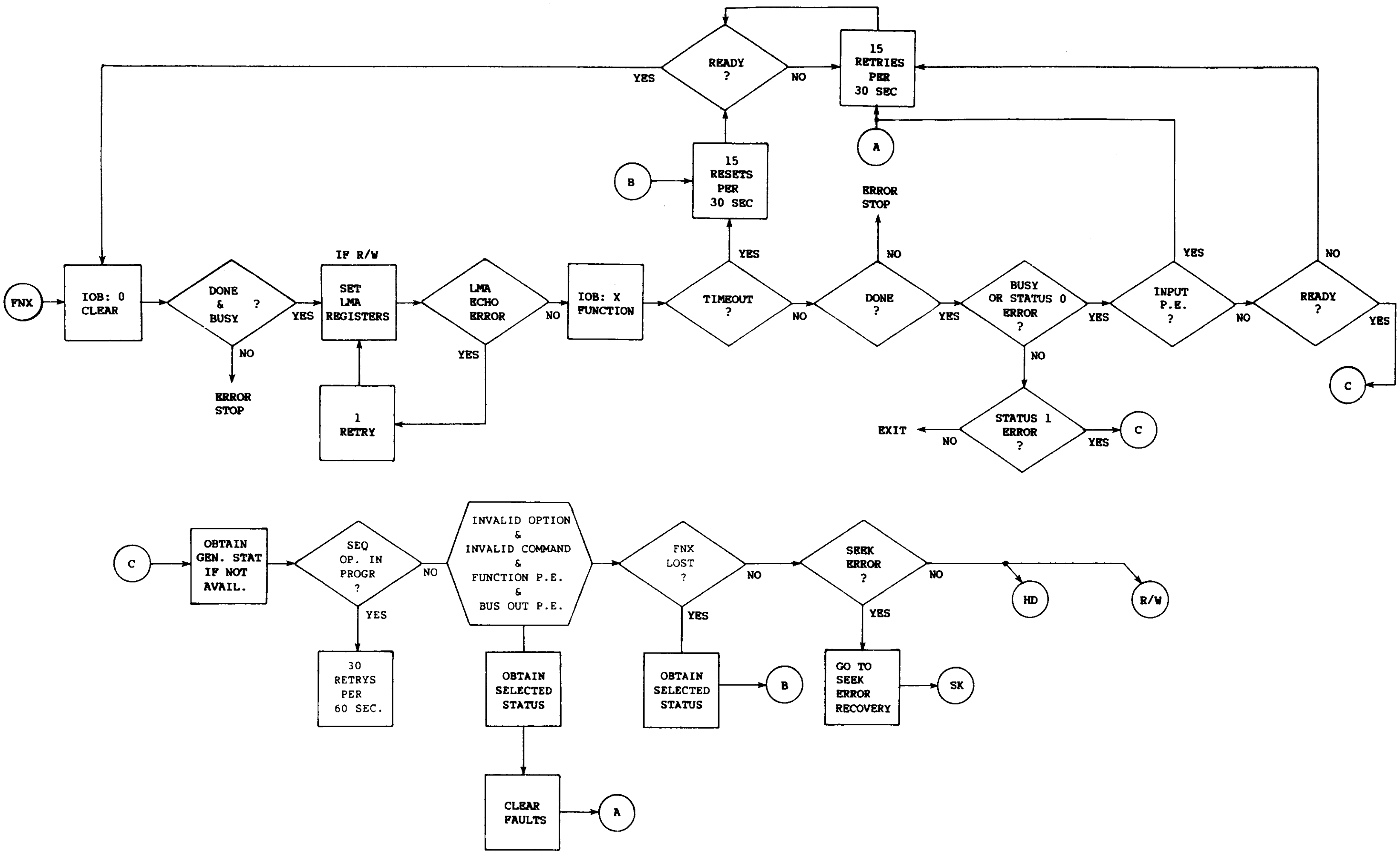


Figure B-1. General Function Processing

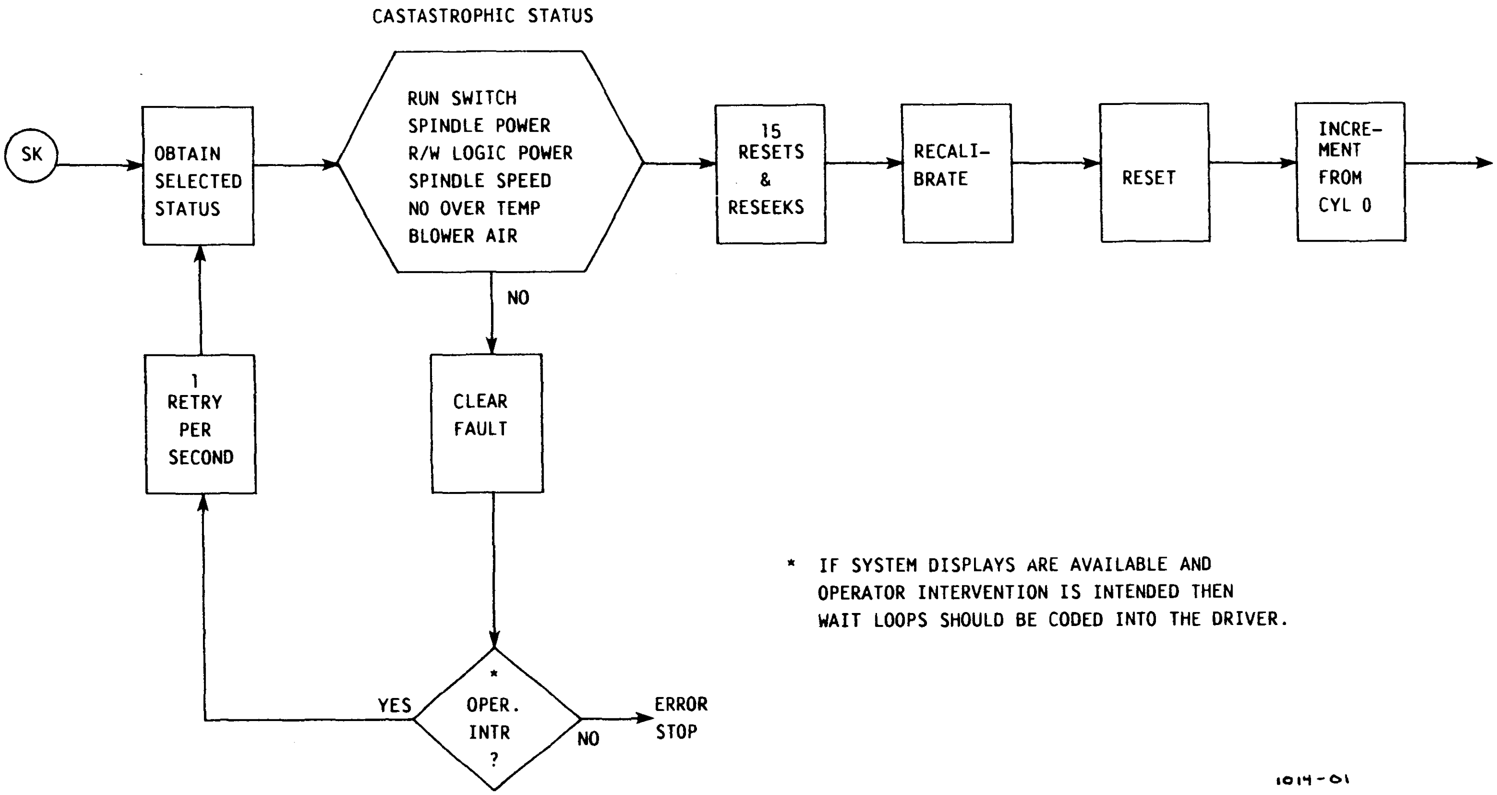


Figure B-2. Seek Error Recovery

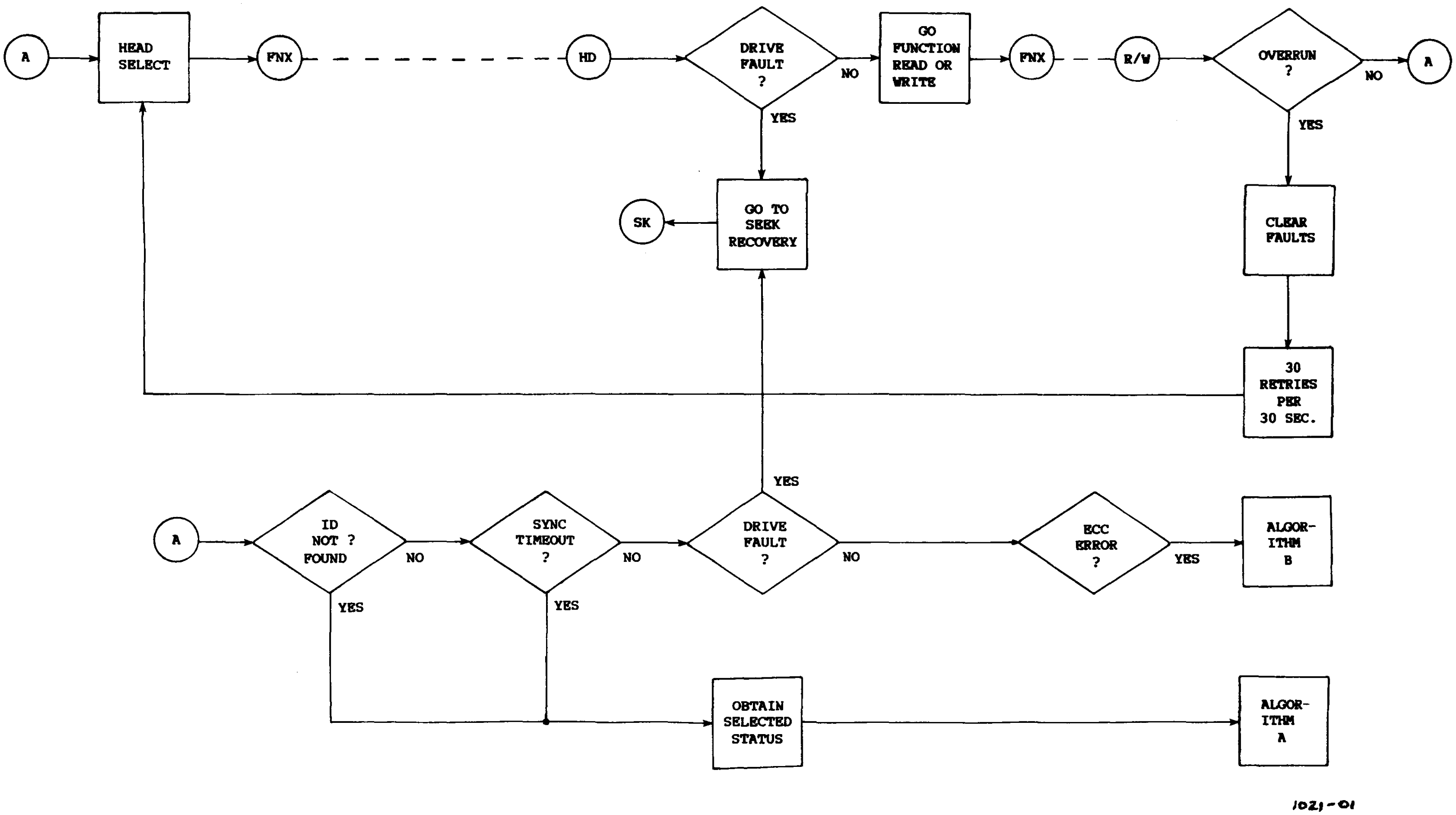


Figure B-3. Read/write Error Recovery

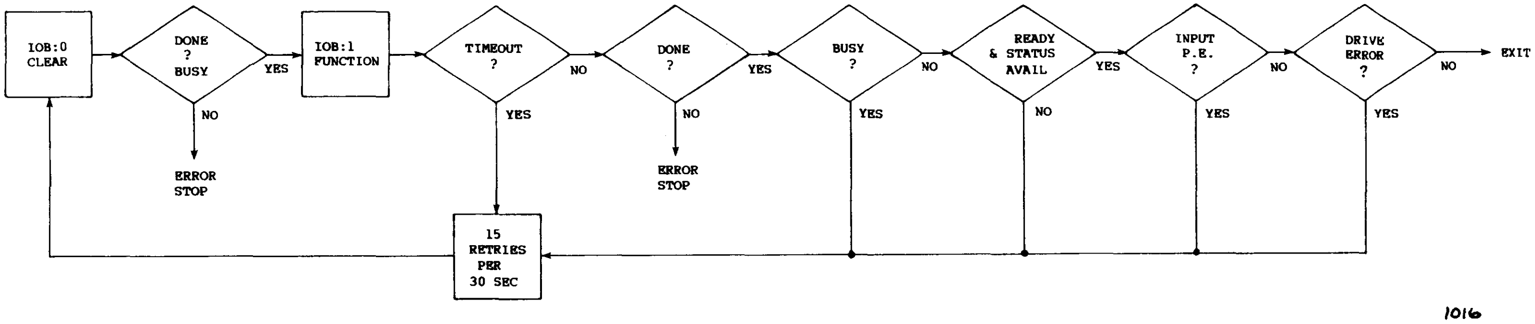
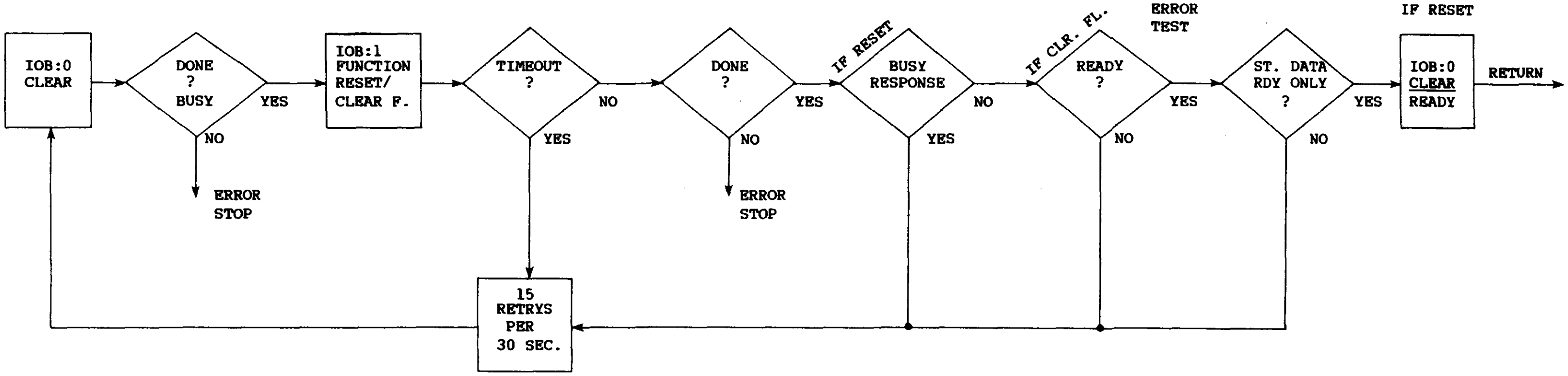


Figure B-4. Status Determination



DRIVE ERROR TEST INCLUDES CHECK FOR BAD COMMAND, FUNCTION LOST, DATA PATH ERROR AND FUNCTION PARITY ERROR.

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Figure B-5. Reset/clear Faults

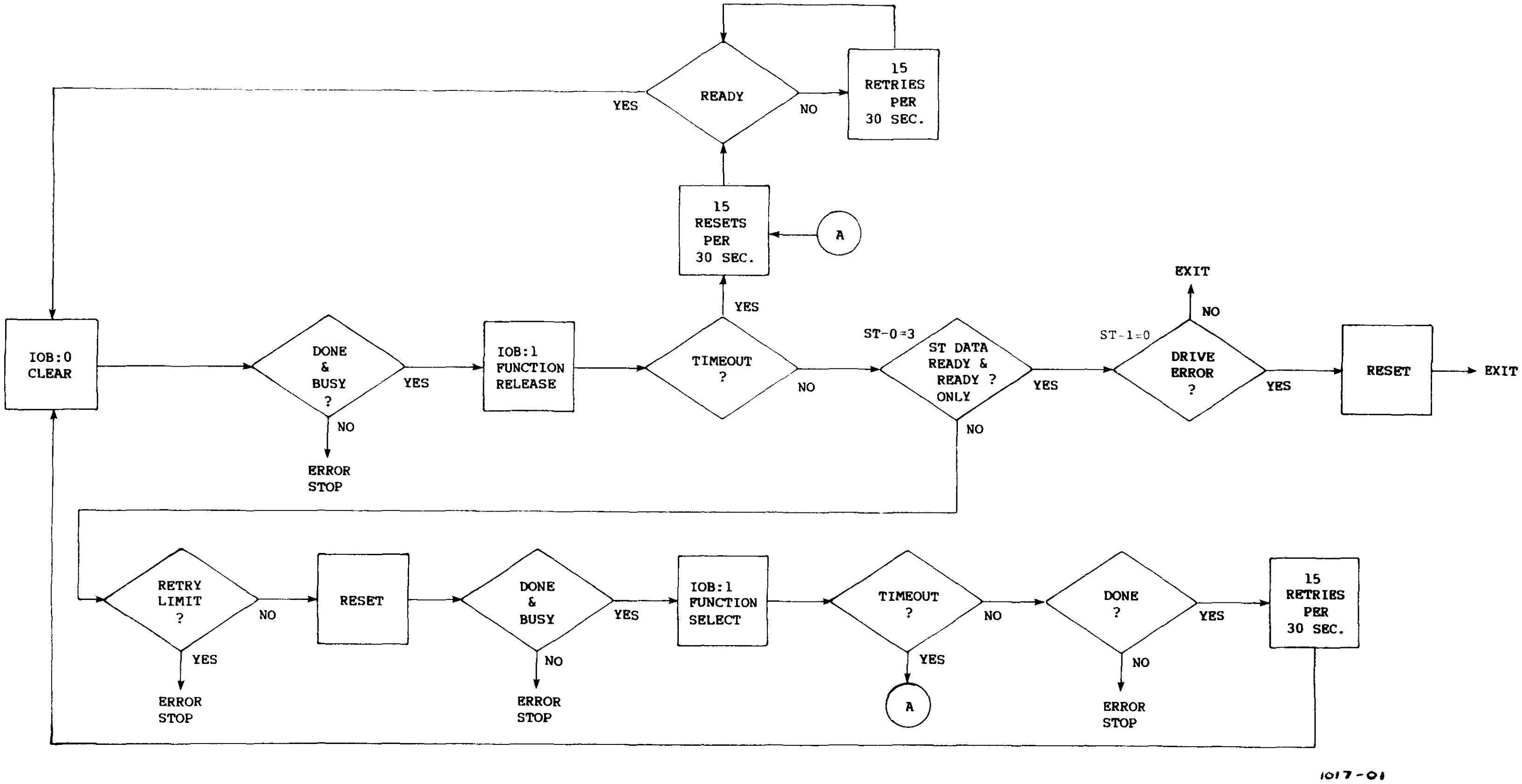

Figure B-6. Release Error Recovery

DD-39 DISK ERROR CORRECTION ROUTINE

C

To implement an effective error recovery algorithm for the DD-39, it is necessary to partition the driver error recovery into five major areas. By doing this, the recovery algorith allows a limited number of retries (that tolerate changing conditions as a result of a system request) and also handles errors on the recovery functions themselves. The major areas of the algorithm are:

- Unit select process
- Cylinder select process
- Head select-LMA select-read process
- Head select-LMA select-write process
- Release process

Each area is assumed to be a single process whereby it is rarely required to go from one process to another during error recovery. For example, when one process is complete, most retry counters can be reset prior to beginning the next process.

Since it is not known what combination of errors will occur, an overall maximum retry count, per I/O sector and individual process, is chosen as a starting point. Within each process, a limit is assigned to the various subprocess errors; that is, tolerance to errors on reset, various status commands, and so on. See table C-1.

With this scheme it is possible to see multiple occurrences of every possible error (per sector, seek, and so on), to process those errors through retries or resets, and to keep the software manageable. Tables are kept for each device in the error recovery process. Error counts are incremented until either the error is recovered or a counter reaches the limits defined in table C-1. This exhausts the hardware error recovery process for that request; it should not limit any software recovery mechanisms such as reallocation or alternate pathing.

Figures C-1 through C-6 describe suggested error recovery procedures.

The following algorithms are used in the course of read/write error recovery described in figure C-3.

Table C-1. Retry and Reset Counters for DD-39

Select	Seek	Read Sector†	Write Sector††	Release	Description
63	63	63	63	63	Total available retries and/or resets
15	15	15	15	15	Time-out resets per 30 seconds
15	15	15	15	15	Not Ready retries per 30 seconds
15	-	-	-	15	Busy response retries per 30 seconds
15	15	15	15	15	Input parity error retries per 30 seconds
15	15	15	15	15	Command error, sequencer parity error, function parity error, or bus-out parity error retries per 30 seconds
-	15	15	15	-	Catastrophic seek status retries per 60 seconds
-	15	15	15	-	Seek error/fault resets and reseek attempts per 30 seconds
-	-	30	30	-	Overrun/underrun retries per 30 seconds
-	-	45	3	-	ECC, ID-Not-Found, or Sync Time-out retries per offset position per sector
-	-	1	1	-	LMA initial echo error retries per 30 seconds
-	-	15†††	15	-	LMA final echo error retries per 30 seconds
-	-	15	0	-	Sector number echo error retries

† Head select, LMA select, read, and so on

†† Head select, LMA select, write, and so on

††† If within sector buffer

ALGORITHM A:

1. Clear faults and retry read/write at least 15 times.
2. If ID-Not-Found error, perform seek error recovery.
3. Offset actuator toward spindle.

4. Retry read at least 15 times.
5. Offset actuator away from spindle.
6. Retry read at least 15 times.

ALGORITHM B:

Superimposed on algorithm A is the following algorithm used to determine correctable data.

On each retry that yields a correctable ECC error status, save the correction vectors in a buffer and compare with the previous correctable ECC correction vectors. If the calculated error locations are consistent (within a parcel) on all channels in error, apply the vectors to correct the last read data.

If the above algorithm proves to be ineffective, it may be necessary to do error recovery on each of the four serial channels of a logical head group independently. This should not be coded without first seeing a demonstrable requirement over several disk units.

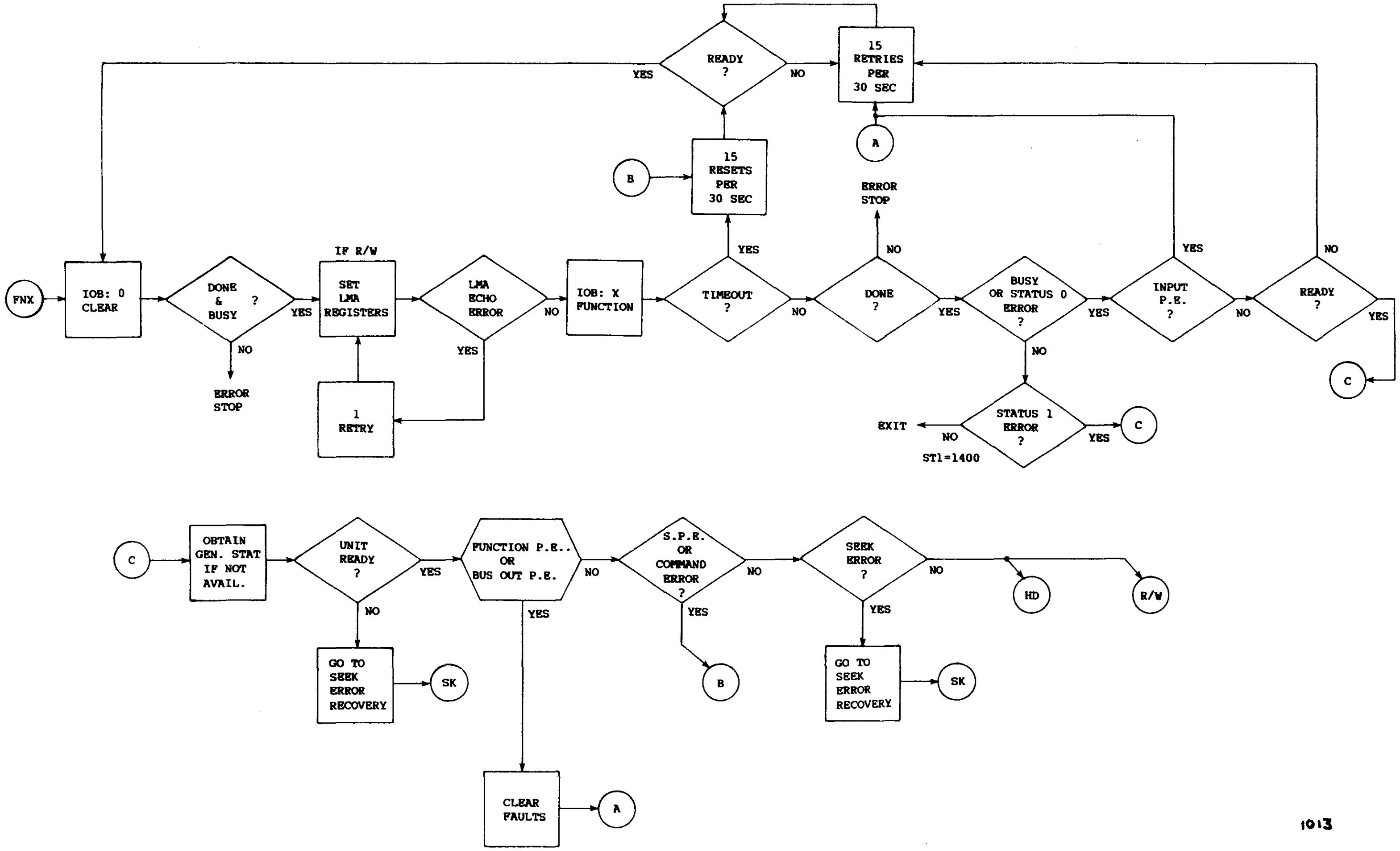

Figure C-1. General Function Processing

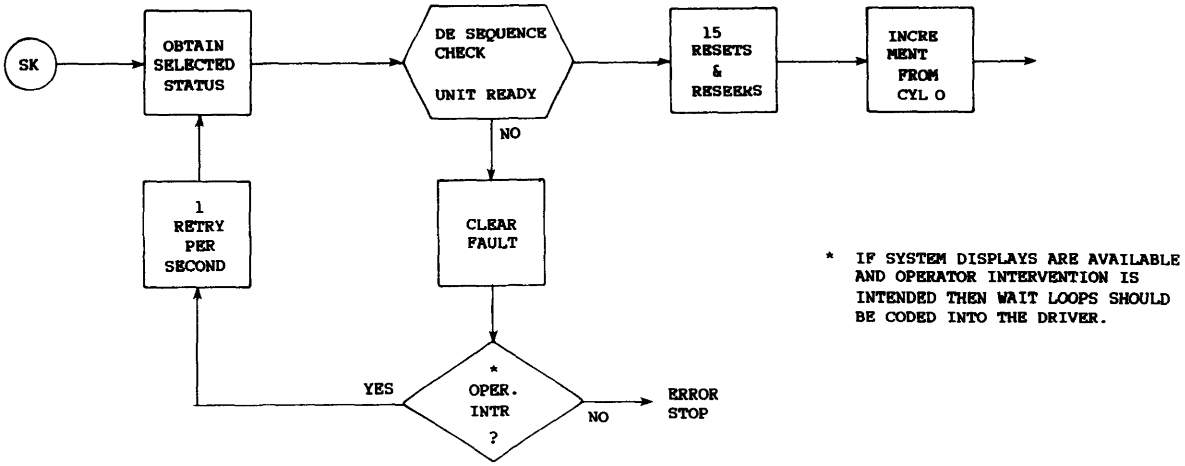

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Figure C-2. Seek Error Recovery

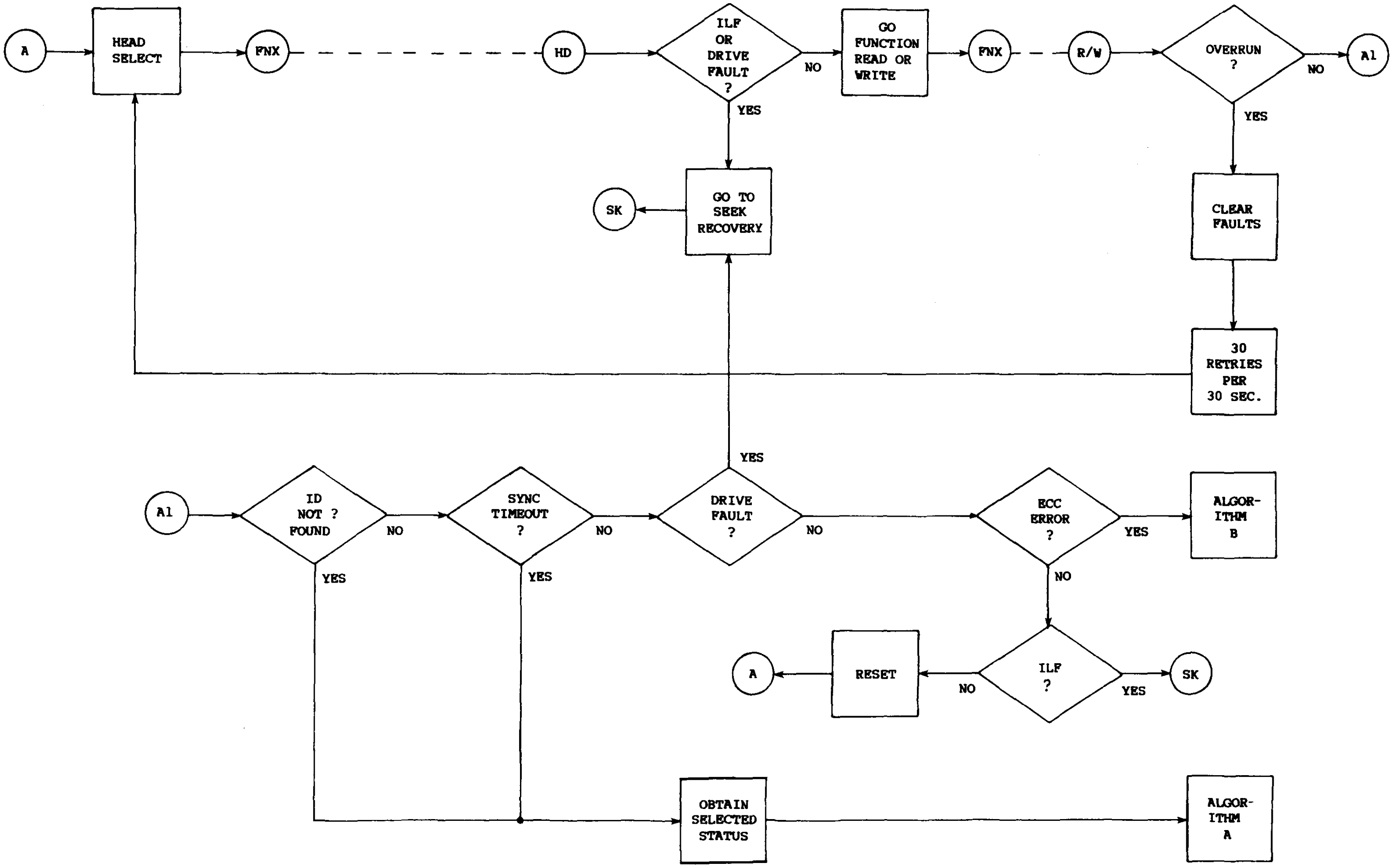

Figure C-3. Read/write Error Recovery

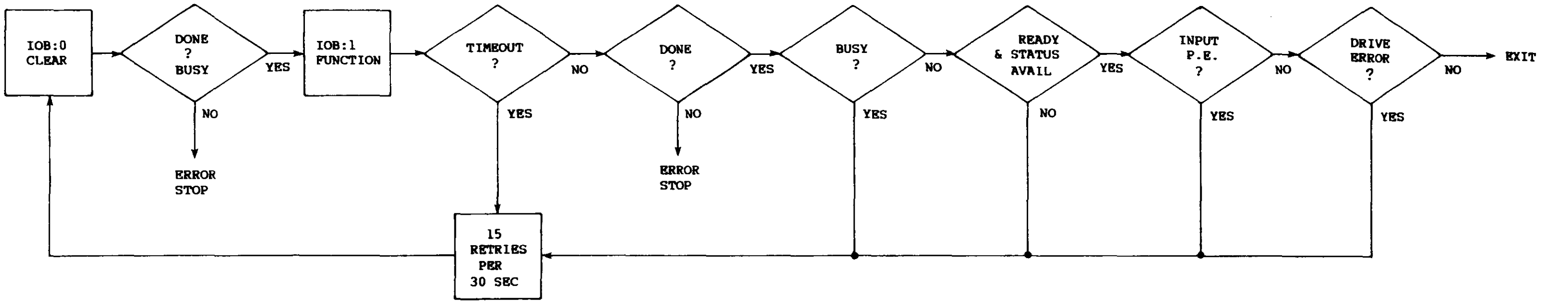

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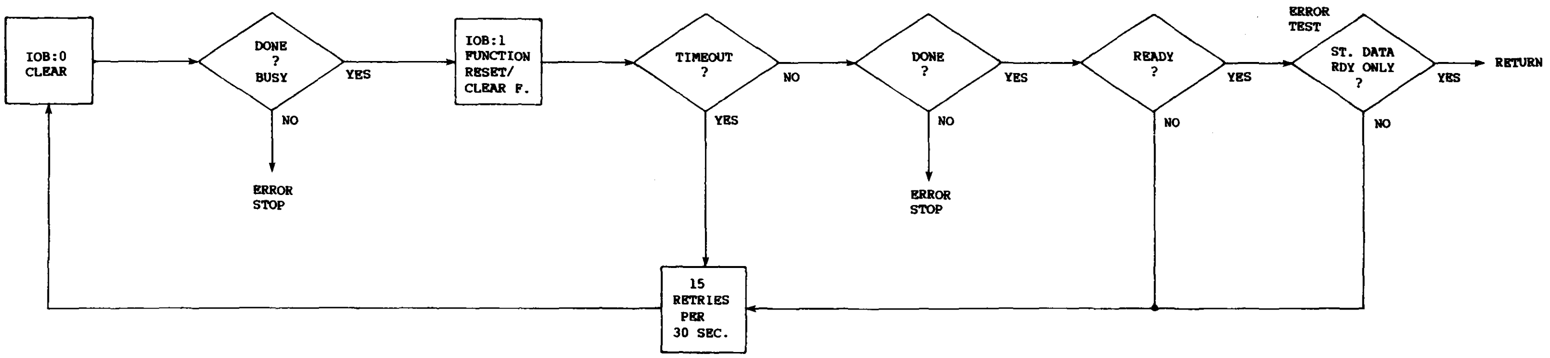
Figure C-4. Status Determination



DRIVE ERROR TEST INCLUDES CHECK FOR
BAD COMMAND AND FUNCTION PARITY ERROR.

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Figure C-5. Reset/clear Faults

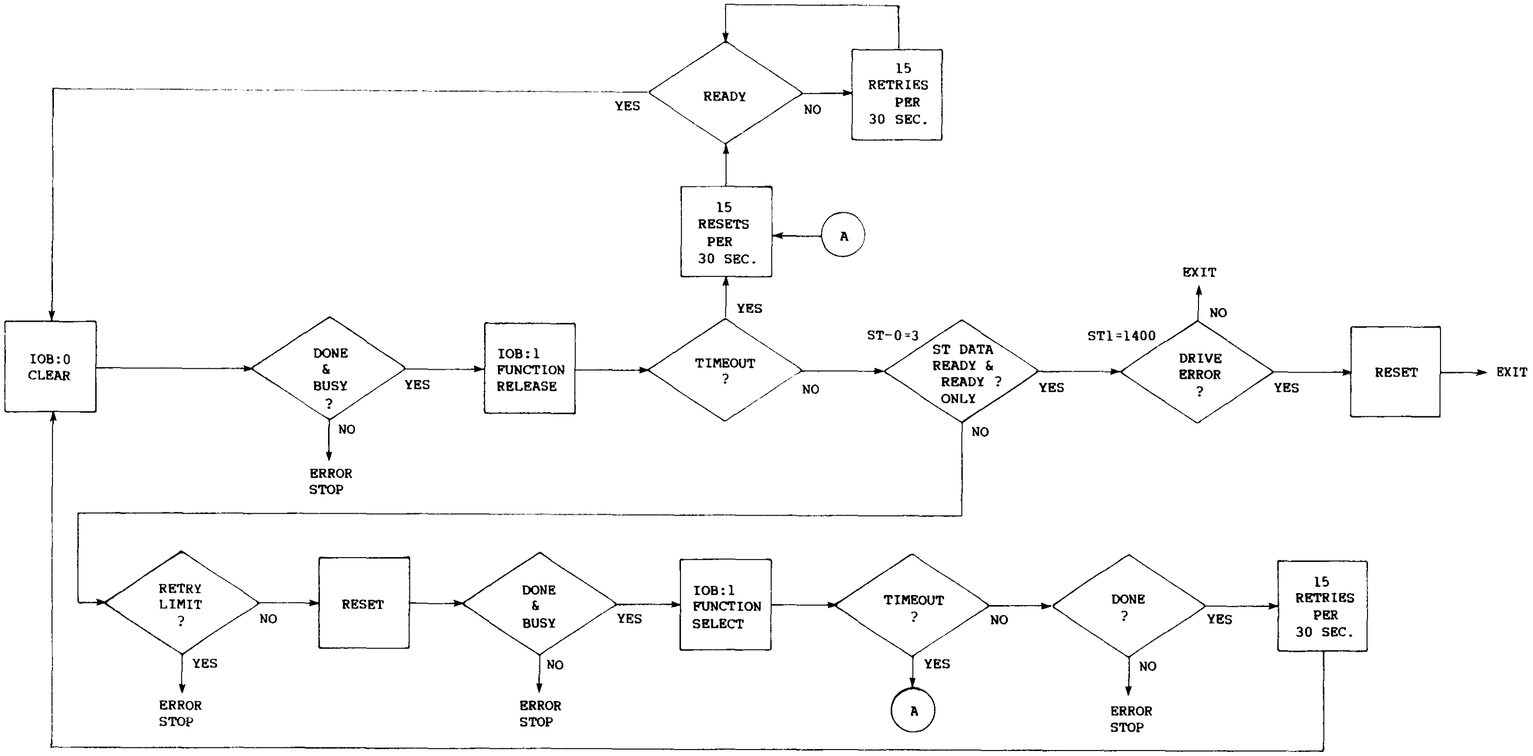

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Figure C-6. Release Error Recovery

SUMMARY OF DISK CHANNEL FUNCTIONS

APML mnemonics indicate channel functions for the disk storage units. The functions are explained in detail in the appropriate sections of this manual, and summarized below. Only the mnemonics for the first channel are given.

Table D-1. Summary of Disk Channel Functions

Device	Function	Description
DD-29 Disk Storage Units	DKA : 0	Clear channel controller.
	DKA : 1	Select mode or request status.
	DKA : 2	Read data into Local Memory.
	DKA : 3	Write data from Local Memory.
	DKA : 4	Select a new head group.
	DKA : 5	Select a new cylinder.
	DKA : 6	Clear the Channel Interrupt Enable flag.
	DKA : 7	Set the Channel Interrupt Enable flag.
	DKA : 10	Read Local Memory current address.
	DKA : 11	Read status response.
	DKA : 14	Enter Local Memory beginning address.
	DKA : 15	Enter Status Response register for diagnostics.
DD-49 Disk Storage Unit and DD-39 Disk Storage Unit	DIA : 0	Clear channel controller.
	DIA : 1	Drive control operations.
	DIA : 2	Request read.
	DIA : 3	Request write.
	DIA : 4	Diagnostic echo.
	DIA : 5	Select cylinder.
	DIA : 6	Clear Channel Interrupt Enable flag.
	DIA : 7	Set Channel Interrupt Enable flag.
	DIA : 10	Read Local Memory Address Register 0.
	DIA : 11	Read Local Memory Address Register 1.
	DIA : 12	Read Status Register 0.
	DIA : 13	Read Status Register 1.

Table D-1. Summary of Disk Channel Functions (continued)

Device	Function	Description
DD-49 Disk Storage Unit and DD-39 Disk Storage Unit (continued)	DIA : 14	Enter Local Memory Address Register 0.
	DIA : 15	Enter Local Memory Address Register 1.
	DIA : 16	Enter next read/write parameter.
	DIA : 17	Select special controller mode/status.

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