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IBM System/360 Component Descriptions-
2820 Storage Control And
2301 Drum Storage

This publication contains reference information for the operation and programming of the IBM 2820 Storage Control and IBM 2301 Drum Storage. It also contains a brief description of the special features that are available for use with the devices.

PREFACE

This publication is intended as a reference for operators and programmers of an IBM System/360 that has an IBM 2820 Storage Control and an IBM 2301 attached.

The operator or programmer should be familiar with the following publication:

IBM System/360 Principles of Operation, Form A22-6821.

Third Edition (September 1968)

This publication (Form A22-6895-2) is a major revision of the previous manual (Form A22-6895-1). This publication replaces and makes obsolete all previous editions and Technical Newsletters.

Significant changes or additions to the specifications contained in this publication are continually being made. When using this publication in connection with the operation of IBM equipment, check the latest SRL Newsletter for revisions or contact the local IBM branch office.

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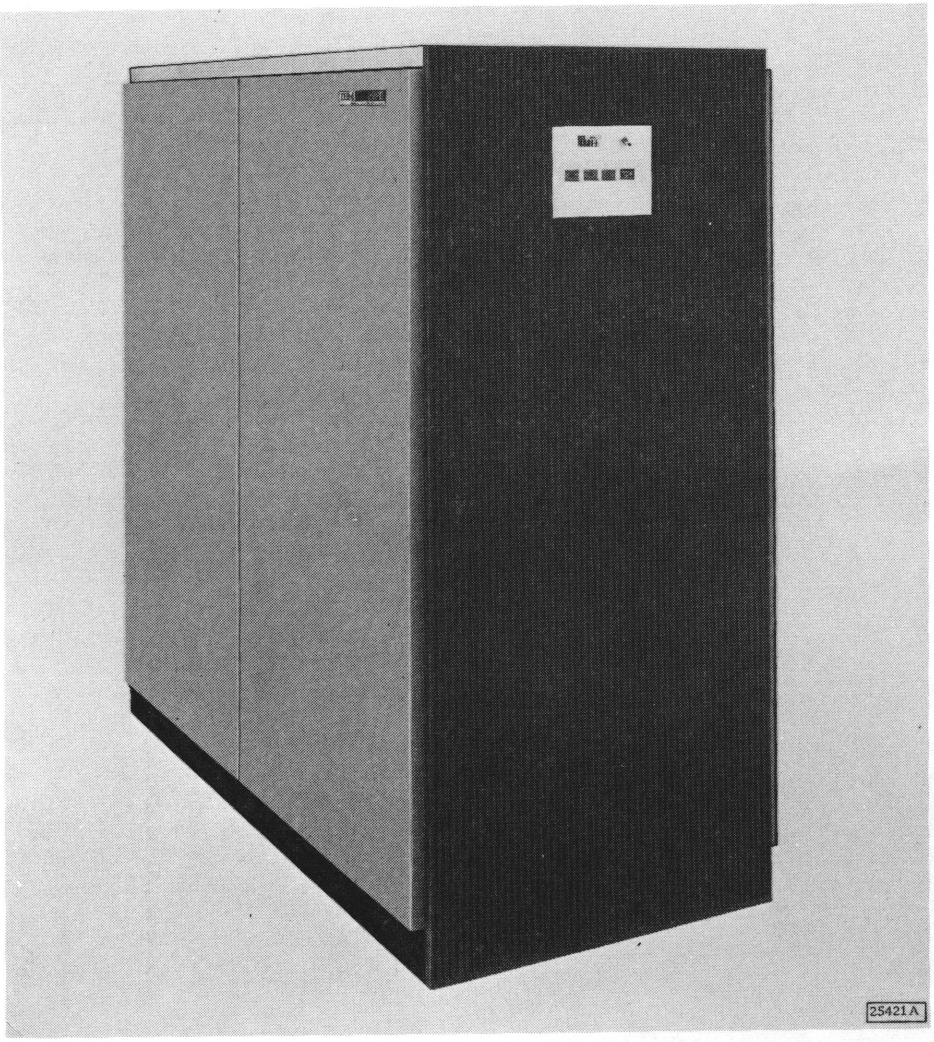


- IBM 2820 Storage Control Unit

INTRODUCTION

The IBM 2820 Storage Control Unit (SCU) provides the logical capabilities necessary to operate and control IBM 2301 Drum Storage devices. The 2820 adapts the characteristics of the 2301 to the standard form of control provided by a channel of an IBM System/360. To minimize programming efforts and requirements, System/360 channel commands for the 2820 are functionally compatible with other IBM Storage Controls (IBM 2841 Storage Control and IBM 2314 Direct Access Storage Facility).

The 2820 is designed for attachment to System/360 Model 65, 67, 75, or 85. The communication link between the system and control unit is an IBM 2860 Selector Channel, Model 1, 2, or 3. The number of 2820 SCU's that can be connected to a system is determined by the model of selector channel attached to the central processing unit (CPU). A 2860 model 1 allows either one or two storage control units to be attached to the System/360. 2860 Selector Channel, Models 2 and 3, allow for the attachment of as many as four 2820's (maximum of two per channel).

Simultaneous operation of two 2820's is possible provided the 2820's are connected to channels 1 and 2. Data is transferred between the control unit and the channel at a maximum rate of 1.25 million bytes per second. Sense and control information is transferred at a rate of 1.2 million bytes per second. Data transmission between the 2820 and the channel is in burst mode only.

Each 2820 may have either one, two, three, or four 2301 Drum Storage units attached to it. Each 2301 provides a storage capacity of more than four million bytes.

Operation of the 2820 is dependent upon the ability of the channel to perform channel command word (CCW) chaining. Chaining of CCW's is necessary to perform file searches, implement file protection, and find and write single records on the drum.

File protection is provided for data stored on the drum. This protection is primarily intended to prevent loss of data resulting from accidental writing on the drum, and is implemented by the 2820 in conjunction with the system supervisor program.

An optional feature, two-channel switch, provides for inclusion of a second interface in the 2820. When the two-channel switch feature is installed, either of two channels and its associated CPU control the 2820 and its attached 2301 Drum Storage units.

The large capacity, high data rate, direct access storage characterized by the 2820/2301 is particularly suitable for: processor storage extension, table and index storage, programming system residence, and other frequently referenced data.

As in other System/360 equipment, the 2820 Storage Control circuitry is packaged using solid logic technology (SLT).

IBM 2820 Functions

The IBM 2820 performs the following functions:

1. Interprets and executes commands from the channel attached to the CPU.
2. Provides a path for data between the standard interface and the IBM 2301 Drum Storage (Figure 1).
3. Translates data as it is transferred between the 2301 and the standard interface.
4. Furnishes operation status information to the channel.
5. Checks for accuracy of data transfer.

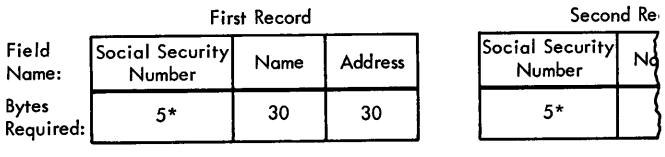
DATA CHARACTER FORMAT AND TRANSFER

Data Characters

The basic unit of data within all components of the IBM System/360 is called a byte. Each byte contains eight binary bit positions, which can be set on or off to indicate a logical 1 or 0, respectively. Within a byte there is a maximum of 256 valid binary bit combinations (Figure 2).

A single byte can represent one alphameric character, one 8-bit binary number, two decimal digits, or one decimal digit and sign.

A group of related bytes is called a "field." A series of related fields is called a "record." A series of similar records is called a "logical file." Both record length and organization are variable; their selection is based on the requirements of the data processing application.



*Two Digits per Byte (Packed Format).

Records and Fields within a File 11251A

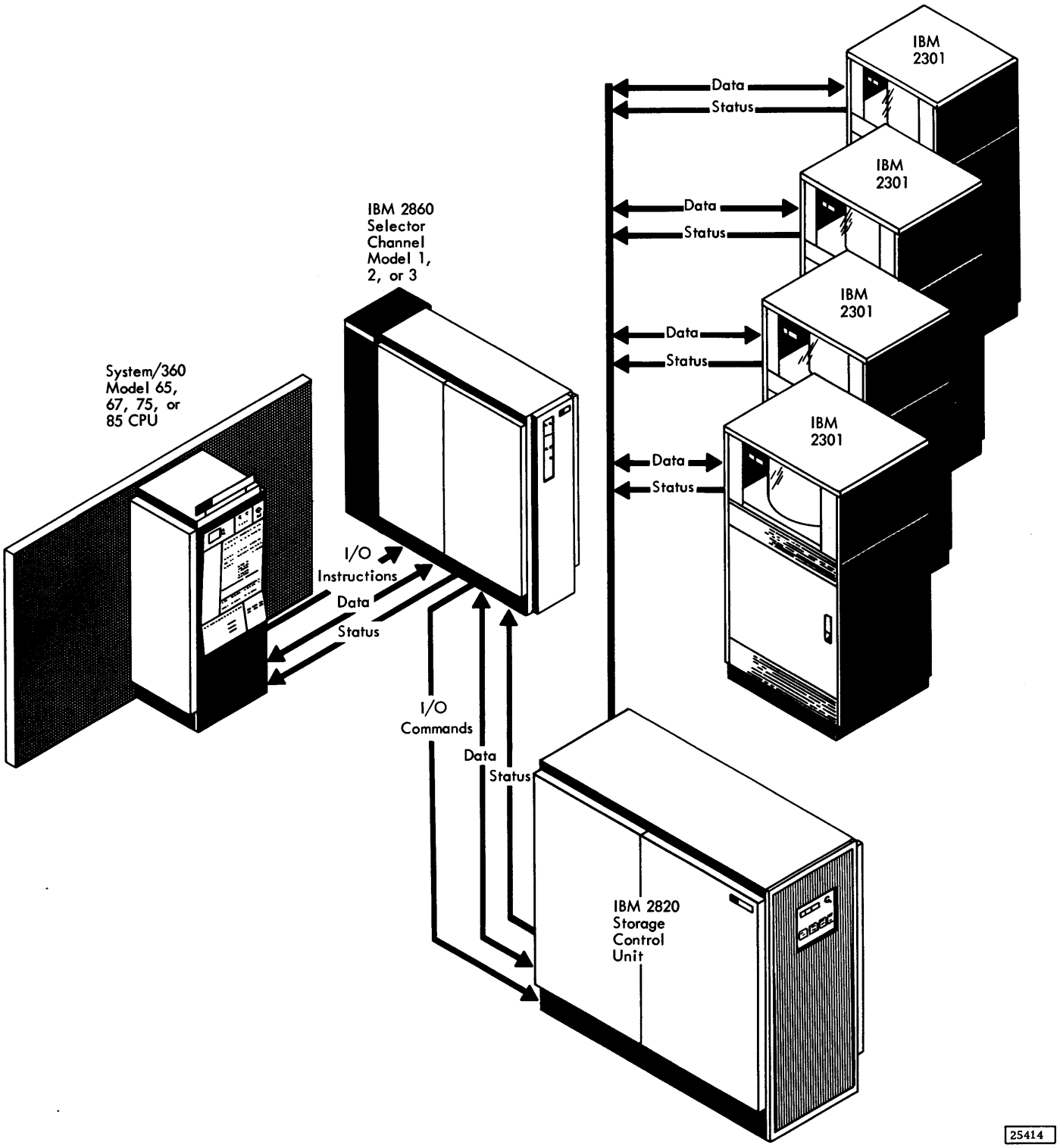


Figure 1. IBM 2820 Data Flow

Decimal Values of Byte Positions

128	64	32	16	8	4	2	1
0	1	2	3	4	5	6	7

Binary Representation of Decimal Number 19

0	0	0	1	0	0	1	1
0	1	2	3	4	5	6	7

11250B

Figure 2. Byte Format

Data Transfer

Information is transferred to and from the 2820 and the CPU parallel by byte and with a parity bit. The parity bit is removed by the 2820 prior to recording the data on the drum. (See Figure 3.)

Data is transferred between the 2820 and the 2301 over two sets of data lines. Each set, one for writing data and one for reading data, consists of four data lines in parallel. When writing information, the 2820 divides each byte received from the channel into two equal parts (four bits each) and writes it serially by half byte on the drum. When reading information from the drum, the control reassembles

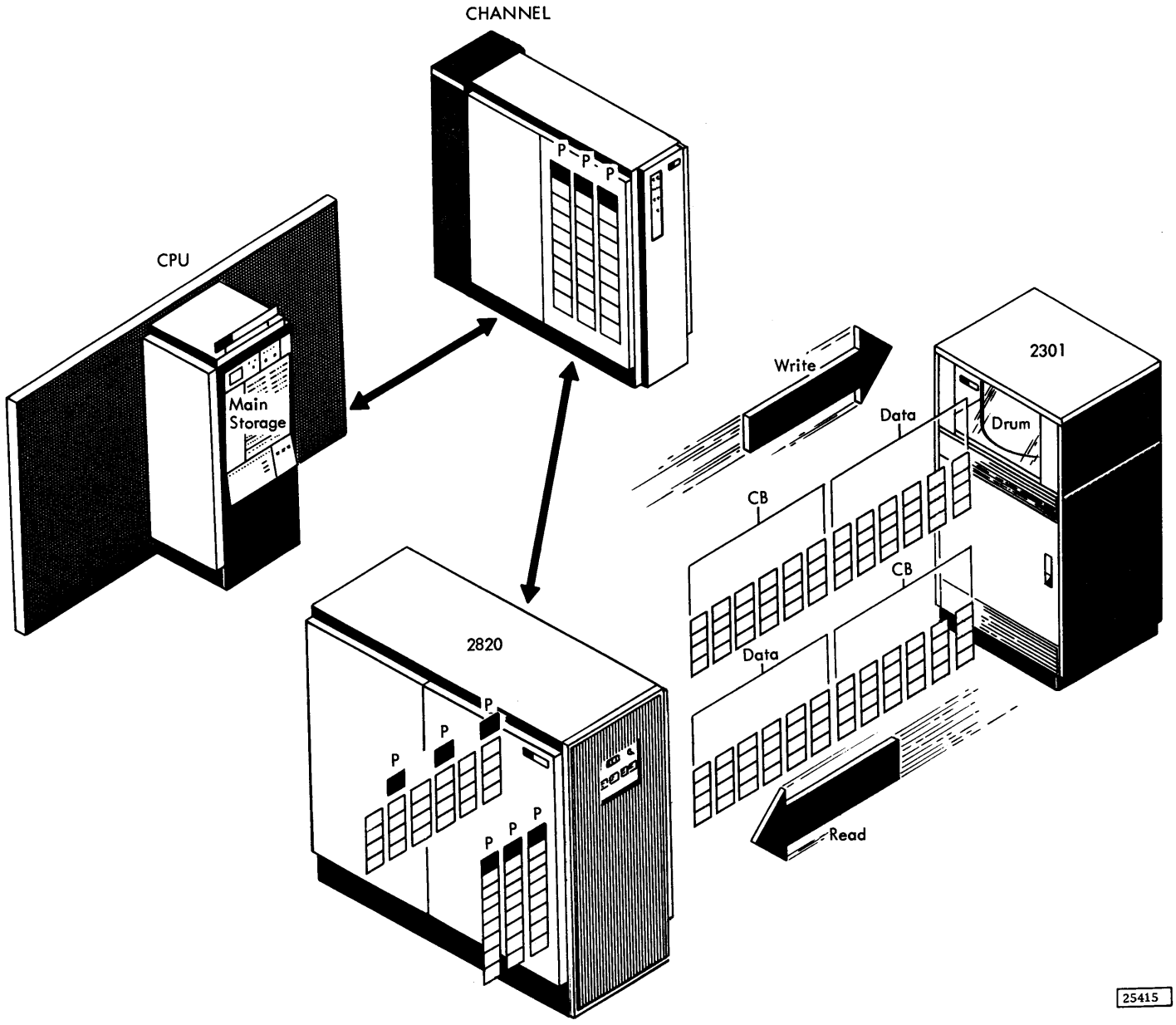


Figure 3. IBM 2820 Data Transfer

the two halves into one byte and adds parity bits as needed prior to sending it to the channel. These functions are automatic and are not controlled by the program.

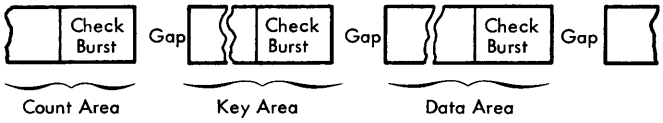
Data Checking

CPU Parity

To check data accuracy, a parity bit is associated with each byte within the CPU. When a byte is formed, the parity bit is set to either 1 or 0 to maintain an odd number of 1 bits within the byte (odd parity). Each byte of data to be written is checked for correct parity as it is received by the 2820.

Check Burst

Data is stored on and retrieved from areas (home address, count, key, and data areas) on the 2301 Drum Storage. Storage capacity is increased by associating check bits with each area rather than each byte.



Areas Within Records 25397

As data is transferred from the CPU to the 2301, the 2820 removes the parity bit from each byte. Three bytes of cyclic check information containing 19 significant bits are generated by the 2820 and recorded after each area.

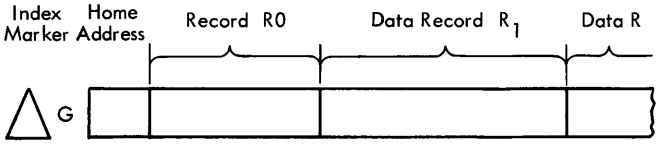
During transfer of data from the 2301 to the CPU, the 2820 inspects the check bytes to check data accuracy and then removes the check bytes and adds parity bits as needed to maintain odd parity.

Compatibility with IBM 2841 Storage Control

Whenever possible, the design of the 2820 has been made program compatible with the IBM 2841. This minimizes the effort necessary to support the two storage controls on System/360. Major areas of compatibility are the data format, the channel commands, the instruction set, and the permissible instruction sequences.

TRACK FORMAT

The track format of the 2301 Drum Storage is compatible with the track format of other IBM Storage Devices. Each track consists of a home address (HA), a record 0 (R0), and one or more variable length data records.



Track Format 11255

The 2301 drum is divided into 200 addressable fields or tracks numbered sequentially from 0 to 199. Each track may be further divided into records. The number of records on a track is under program control and is limited by the length of the individual records on the track.

Index Marker

The index marker indicates the physical beginning of each track. The index signal is generated by a magnetic slug which is mechanically attached to the rotating drum in the 2301. All tracks on the 2301 are synchronized by the same index marker.

Gap

A gap separates each recorded track area. The gap does not contain any data. (See Figure 6.)

Home Address

Each track contains one home address record, which is used to identify the binary address of that track. The home address is the first record on the track after index. The length of the record is eight bytes, which include a flag byte (F), a cylinder number (CC), a head number (HH), and three check bytes (Figure 4). The first four bytes (FCCH) are always zero. (They are retained for compatibility with devices that attach to the 2841.) The fifth byte, (H), contains the binary address of the track, 0000 0000 to 1100 0111 (decimal 0-199).

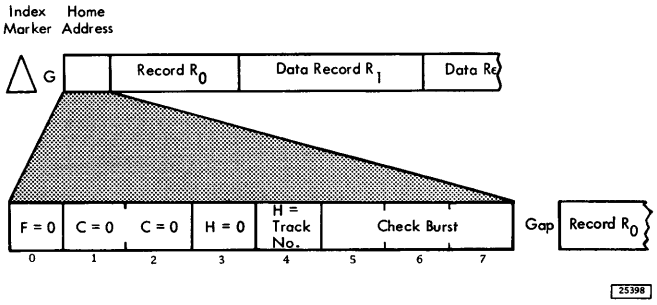


Figure 4. Write Home Address

Record 0 (R0)

The first record following the home address on each data track is record 0 (R0). R0 does not serve any significant function in 2820 operations and is provided primarily for 2841 compatibility. R0 differs from data records in that it does not contain an address marker. It may be used as a data record with the limitations resulting from the fact that it is record 0 and does not contain an address marker.

Data Records

One or more data records may follow R0 on a track. Each data record consists of an address marker, a count area, a key area (optional), and a data area (Figure 5).

Address Marker (AM)

The address marker denotes the beginning of a data record. The 2820 recognizes the address marker as the start of any data record other than record 0. Address markers are supplied by the 2820 as data records are written, and they are used by the SCU to locate the start of a record for search, write, and read operations. Address markers are not under program control and are not read out to the channel.

Count

The count area (Figure 6) contains the location of a data record on a specific track, and the size of the key and data areas of that record. Included in the count area are: a record identifier (ID), a count key (CK) field, and a count data (CD) field.

ID (Record Identifier)

The ID is a six-byte field that indicates the location of a data record on a specific track. The ID field (FCCHHR) contains a flag byte and five address bytes.

Flag Byte (F)

The flag byte (F) is written and used by the 2820 SCU and is not transferred to or from main storage. The functions of the flag byte are erasing defective records and identifying overflow records. Bit 1 of the flag byte is associated with overflow records, and bit 2 controls skipping of erased records. Bits 0 and 3-7 are always zero.

Bytes 2, 3, and 4 (CCH) of the ID are always zero. Byte 5 (H) contains the track number and byte 6 (R) contains the record number.

Count Key (CK)

The count key (CK) is a one-byte count field that defines the length of the key field. The key area length is expressed in any value from 0 to 255. When CK is zero, the key area is omitted from the data record.

Count Data (CD)

The CD is a two-byte count field that defines the length of the data field. The data area length is expressed in any value from 1 to 20,483. A CD of zero indicates end of file, and one byte of data is recorded in the data area by the 2820. This byte is not referenced to the channel and is not transferred on any subsequent read operation.

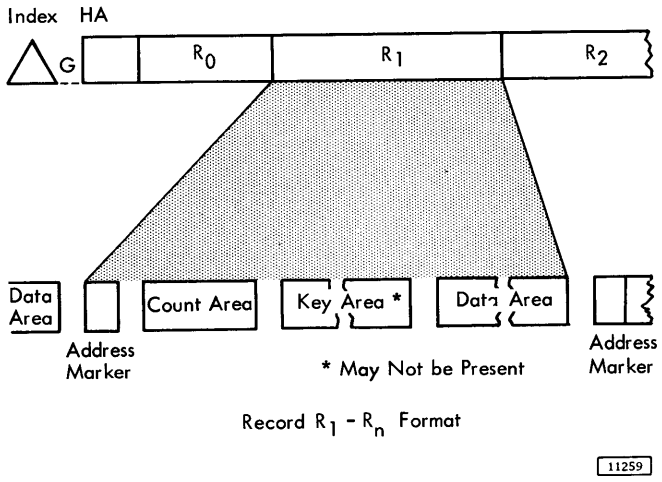


Figure 5. Data Record Format

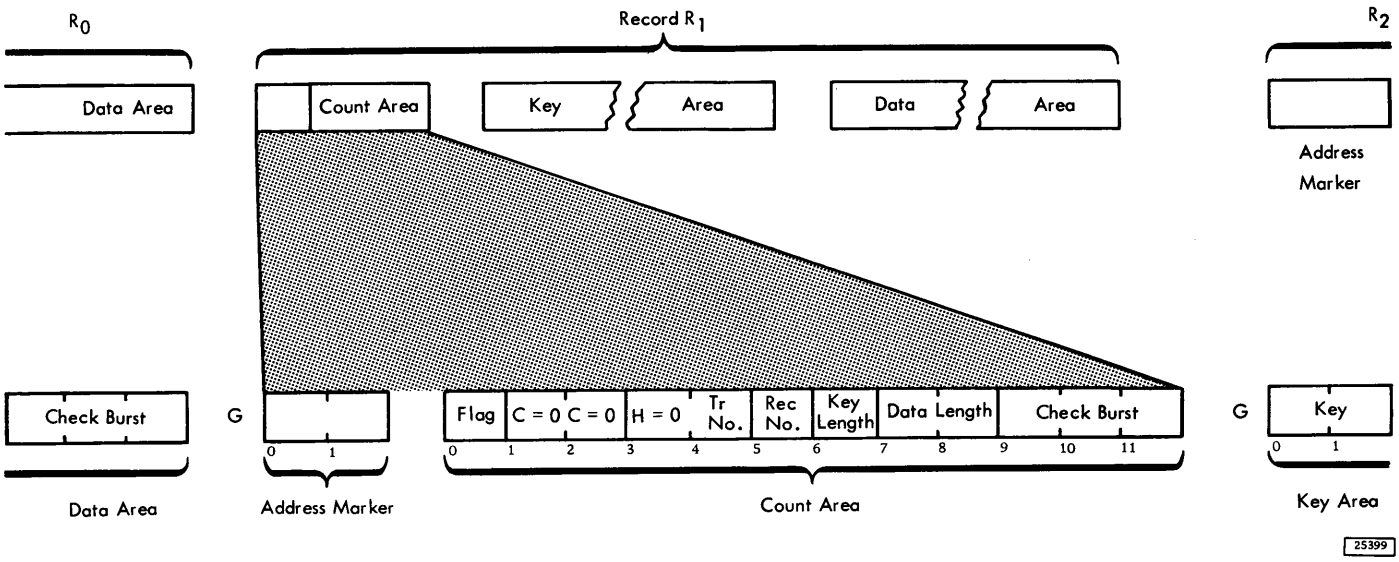


Figure 6. Count Area

Check Burst (CB)

Three check bytes (CB) are written at the end of the count area and are used to ensure data accuracy.

Key

Use of the key field is at the discretion of the programmer. When used, the key field of the record contains the primary identification of the data portion of the record; i.e., Social Security number, man number, part number, or any other identifying information. The CK byte in the count field specifies the length of the key field. Three check bytes (CB) are written at the end of the key area and are used to check data accuracy.

Data

The data area contains the information identified by the count and key areas of the record. Data information is organized and arranged by the programmer. Three check bytes (CB) are also written after the data area to check data accuracy.

ADDRESSING

Each drum storage has a unique I/O address that is designated by an 11-bit binary number in an I/O instruction. The I/O address consists of two parts: a channel address in the three high-order bit positions, and a device address in the eight low-order bit positions. The channel address specifies the channel to which the I/O instruction applies, and the device address specifies a particular 2820 and a 2301 controlled by that unit. See "I/O Instructions."

The 2820 address is contained in bits 0 through 4 of the address byte of each I/O instruction. The 2820 address is established by means of internal wiring within the 2820 when it is initially installed. The two low-order bits of the address byte select a particular 2301 attached to the addressed 2820.

INPUT/OUTPUT OPERATIONS

Input/Output (I/O) operations pertaining to the 2820 involve transfer of information between the central processing unit and the 2301 Drum Storage. The 2301 reads, writes, and searches for information under control of the 2820, which is attached to the CPU by means of a channel.

All IBM 2820 SCU operations are initiated by a Start I/O instruction issued by the CPU. The status of the channel, control unit, and drum storage are examined to determine whether the operation can be performed. This information is contained in the channel status word (CSW). If the CSW indicates the channel, SCU, and drum storage are available, the command is accepted and the CPU continues with its program. The status of the system in relation to the program currently being executed is contained in the PSW. (See "Program Status Word.")

The channel selects the SCU and the drum storage and reads out a channel address word (CAW). The CAW contains the address of the first channel command word (CCW). The designated CCW specifies the operation to be performed, the main storage area to be used, and the action to be taken when the operation is completed.

The end of an I/O device operation normally is indicated to the program by an I/O interrupt. When the interrupt occurs, the CSW is stored with status bits indicating channel end and device end. The channel end condition indicates the 2820/2301 has received or provided all information associated with the operation and no longer needs channel facilities. The device end condition indicates that the 2301 Drum Storage has finished the operation. The device end can occur concurrently with the channel end or later.

It is typical for the 2820/2301 to execute a series of commands as a result of a single Start I/O instruction. This method of operation is called command chaining and is initiated by turning on the CC bit (bit 33) in the CCW. The channel fetches a new CCW, specifying a new I/O operation, on completion of the current CCW. The new I/O operation is automatically executed when the 2301 has completed the current operation and signaled device end to the channel. The completion of the current CCW does not cause an I/O interrupt, and the count indicating the amount of data transferred during the current operation is not available to the program. Unusual conditions and errors will terminate the chain and cause an I/O interrupt. The CSW containing the status of the device that caused the interrupt is then stored in main storage.

Command chaining is normally used with all 2820/2301 channel programs. Time is made available to execute command chaining functions in the gap area between record areas. Certain restrictions exist regarding sequences of commands within chains and will be discussed with individual commands.

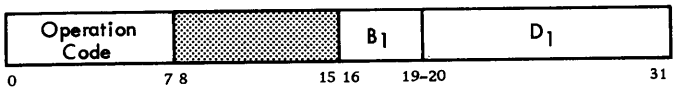
The count, key, and data areas of a record transferred between the 2301 and the CPU may be chained. This method of operation is called data chaining and is initiated by turning on the CD bit (bit 32) in the CCW. When data chaining is specified, the channel fetches a new CCW on completion of the current CCW. The new CCW designates a new storage area into which data can be placed or taken from. (Each area within the record must correspond with a continuous area in main storage.) The type of operation to be performed (read or write) is determined by the CCW specified by the Start I/O instruction.

Time is made available to execute data chaining functions in the gap area between record areas. Since the 2820/2301 is a high speed device, data chaining cannot be initiated in the middle of a data area. The next CCW will not be available soon enough and errors will result.

When both command and data chaining are used, the first CCW associated with the operation specifies the operation to be executed, and the last CCW indicates whether another operation follows.

I/O INSTRUCTIONS

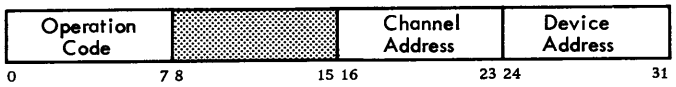
The System/360 uses only four I/O instructions: Start I/O, Halt I/O, Test I/O, and Test Channel. The format and bit designations concerning 2820/2301 operation are as follows:



I/O Instruction Format

Fields in the instruction are allocated as follows:

Bit Position	Field Designation	Function
0-7	Operation (OP) Code	Designates the operation to be performed.
8-15	Not Used	
16-19	Base Address Register Location (B_1)	Designates the address of a general register in the CPU. The register is 32 bits in length, but only the low order 24 bits are used.
20-31	Displacement (D_1)	The sum obtained by the addition of the contents of the register at B_1 and the contents of the D_1 field identifies the channel and device addressed by the instruction. The result has the following format:



Bit Position	Field Designation	Function
0-7	Operation (OP) Code	Designates the operation to be performed.
8-15	Not Used	
16-20	Must be Zero	
21-23		Specifies channel to which the I/O instruction applies.
24-28		2820 address, internal wiring specified by the customer and installed by CE.
29		Not used by 2820; must be zero.
30-31		Specifies 2301 Drum Storage to which the I/O instruction applies.

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Start I/O

All I/O operations are initiated by a Start I/O instruction. If the channel facilities are free, the Start I/O is accepted and the CPU continues its program. The channel independently selects the I/O device specified by the instruction.

The CAW in main storage location 72 contains the storage protection key and the address of the first CCW. The protection key establishes the right of access (whether data can be stored or fetched) to the particular main storage area. The CCW specifies the operation to be performed and the main storage area to be used.

If the I/O device is busy, has an error, or is not operational, or if the control unit is busy or has pending status, the Start I/O instruction sets the condition code in the PSW and causes the status portion of the CSW to be replaced with a new set of status bits. These status bits pertain to the device addressed by the instruction. The remaining fields of the CSW are not changed and the I/O operation is not started.

Halt I/O

The Halt I/O instruction terminates a channel operation, and the 2820 is disconnected from the channel. If the operation in progress was a write operation, the 2820 completes the write operation by inserting 0's to the end of the field or track.

Halt I/O may be used to break a command chain which would otherwise continue.

Test I/O

The Test I/O instruction sets the condition code in the PSW to indicate the state of the addressed channel, subchannel, and I/O device. When the status byte from the 2820 is not an all-zero byte, the condition code in the PSW is set to 1, and the status byte is stored in the CSW at main storage location 64.

Test I/O clears any pending status but does not reset previous error conditions.

Test Channel

Execution of the Test Channel instruction sets the condition code in the PSW to indicate the state of the channel addressed by the instruction. It does not affect the 2820 Storage Control unit.

CHANNEL OPERATION

After the successful execution of a System/360 I/O instruction, the channel independently governs the I/O device specified by the instruction. Reserved main storage locations contain information and instructions that enable the channel to perform the functions necessary to complete the operation. The channel issues commands to the 2820 Storage Control unit, which translates the commands into specific orders for the 2301 Drum Storage.

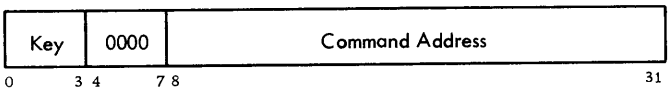
Channel Address Word (CAW)

Issuing a Start I/O instruction causes the channel to fetch a CAW from main storage location 72. Bits 0-3 of the CAW form the protection key for all commands associated with the Start I/O instruction. This key is compared with a key in storage whenever reference is made to main storage. The keys are said to match when the key bits of the CAW are the same as the key bits in storage.

When a protection mismatch is detected, the contents of the protected main storage location remains unaltered. The violation of the key causes the I/O operation to be terminated, with the protection mismatch indicated in the CSW stored at the end of the I/O operation.

The command address (bits 8-31) designates the location of the first CCW in main storage. The three low-order bits of the command address must be 0's to specify the CCW on integral boundaries for double words.

The format of the channel address word is:



Channel Address Word

CAW fields are allocated for the following purposes:

CAW Bit Position	Field Designation	Function
0-3	Protection Key	Forms the Storage Protection key for all commands associated with Start I/O. This key must match the storage key.
4-7		Always zero.
8-31	Command Address	Designates the location of the first CCW in main storage.

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Channel Command Word (CCW)

The address specified by the CAW is the first of eight bytes of information that the channel fetches from main storage. These 64 bits of information are called the channel command word. The address of the leftmost position of the CCW must be divisible by 8. (In binary notation the three low-order bits of the address are 0's.) One or more CCW's make up the channel program that directs channel operations.

The CCW specifies the command to be executed. For commands initiating I/O operations, it designates the storage area associated with the operation.

CCW's can be located anywhere in main storage except the first 384 positions. More than one CCW may be associated with a Start I/O. The channel refers to a CCW in main storage only once per Start I/O instruction. Once obtained, the pertinent information is retained in the channel.

The first CCW is fetched during the execution of Start I/O. If this CCW has the chain command flag bit set on, the next CCW in the sequence is obtained by the channel when the operation has progressed to a point where the additional CCW is needed. Fetching of CCW's by the channel does not affect the contents of main storage.

The channel command word format is shown in Figure 7.

Multiple Track Mode (MTM)

The MTM bit (bit 0 of the 2820 command code) may accompany any read or search command. When this bit is present and index is passed, the track address is updated so that operation can continue on the next track. The MTM address update operation is subject to the following restrictions:

1. If an address update is to take place, it occurs immediately after index prior to any transfer of data to that track.
2. Only read and search operations may use the MTM bit. (Read Initial Program Load is not permitted to use the MTM bit.)
3. If an attempt is made to increment the track address past 199, the end of cylinder bit is set in the sense register.
4. If an attempt is made to use MTM while the file mask has restricted the program to a particular track or tracks, the file protect bit is set in the sense register.

Channel Status Word (CSW)

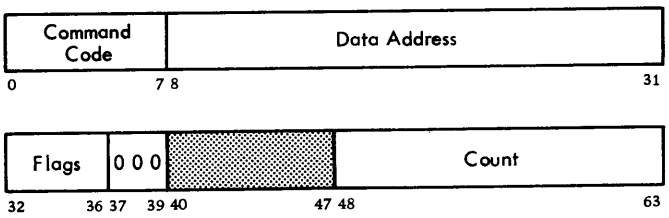
The channel status word (Figure 8) provides information concerning the termination of an operation. It can be formed or changed by Start I/O, Halt I/O, or Test I/O, or by an I/O interrupt. The CSW is stored in main storage location 64.

During the initial selection phase of an I/O operation, the 2820 control sends a byte to the channel indicating the status of the control unit and drum. If the operation is an immediate operation (not requiring a data transfer other than the command over the I/O interface), the 2820 normally responds with a status byte in which the channel end and device end bits are set on, thus indicating the command will be executed and that the channel is freed. If the operation requires data transfer, the 2820 control responds either with a status byte of all 0's, indicating the channel is free to proceed with the command or with a status byte of other than all 0's, indicating the command has not been accepted.

When a command has not been accepted, the status byte is stored in bits 32-39 of the CSW. (Non-acceptance of a command also sets the condition code in the PSW.) Status stored in the CSW remains unchanged until a subsequent I/O interrupt occurs or an I/O instruction is processed.

Program Status Word (PSW)

Two program status words are associated with System/360 and therefore with 2820/2301 interrupt conditions: an "old" PSW which contains the necessary status information of the system existing at the time of the interrupt, and a current or "new" PSW which is used to control instruction sequencing and to hold and indicate the status of the system in relation to the program being executed. By storing the current PSW during an interruption, the status of the CPU is



Fields in the CCW are allocated for the following purposes:

CCW Bit Position	Field Designation	Function
0-7	Command Code	Specify the operation to be performed. The two low-order bits, or when these bits are 00, the four low-order bits of the command code identify the operation of the channel. The channel distinguishes the operations: Write, Control, Read, Sense, or Transfer in Channel. Commands that initiate I/O operations cause all eight bits to be transferred to the I/O device.
8-31	Data Address	Specify the location of an 8-bit byte in main storage. This is the address of the area designated by the CCW.
32	Chain Data (CD) Flag	When set to one, specifies chaining of data. Make sure the data rate of the I/O device permits chaining by the particular System/360 model before using.
33	Chain Command (CC) Flag	When set to one, and when the CD flag is zero, specifies chaining of commands. It causes the operation specified by the command code in the next CCW to be initiated on normal completion of the current operation.
34	Suppress Length Indicator (SLI)	When set to one, an incorrect length condition is suppressed (except when the CCW count is not exhausted, channel end is present and data chaining is indicated). Should be set to one for No-op, and for any command with a count of zero.
35	Skip Flag	When set to one, specifies suppression of a transfer of information to storage during a Read or Sense operation. Cyclic checking takes place as though the information had been placed in storage. When bit 35 is zero, normal transfer of data takes place.
36	Program-Control-Interruption (PCI) Flag	When set to one, causes the channel to generate an interruption condition upon fetching the CCW. When bit 36 is zero, normal operation takes place.
37-39		Bit positions 37-39 of every CCW other than one specifying transfer in channel must contain zeros. Violation of this restriction generates the program-check condition. For additional information, see Control Command-Transfer-in-Channel.
40-47		Not used.
48-63	Count	Specify the number of 8-bit byte locations in the storage area designated by the CCW.

25401

Figure 7. Channel Command Word

preserved for subsequent inspection. By loading a new PSW the state of the CPU can be initialized or changed to branch to a new instruction sequence. If, at the conclusion of an interrupt routine, there is an instruction to make the old PSW the current PSW, the system is restored to the state prior to the interruption and the interrupted routine continues.

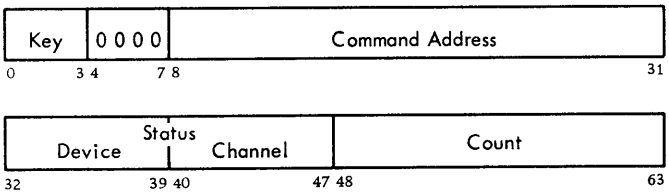
The format and bit designation of the PSW are shown in Figure 9.

BRANCHING IN 2820/2301 CHANNEL PROGRAMS

Normally, the next CCW in a chain is taken from CPU main storage starting at an address eight positions higher than the current CCW. This sequence can be modified in either of two ways:

1. If command chaining is specified in the current CCW and execution of this CCW results in a status modifier indication (without detection of other unusual conditions), the channel fetches the next CCW from a main storage location 16 positions higher than the current CCW.

   Since all search commands cause a status modifier condition (when the search is satisfied), branching from the chain is accomplished when the search is satisfied.
2. The programmer can modify the CCW chain sequence by using the Transfer in channel (TIC) command. This command directs the channel to fetch the next CCW from an address specified in the data address field of the TIC. It is normally used to cause a search command to be repeated



Channel Status Word

Fields in the CSW are allocated for the following purposes:

CSW Bit Position	Field Designation	Function
0-3	Protection Key	Form the storage protection key used in the chain of operations.
4-7	Not Used	Always zero.
8-31	Command Address	Form an address eight positions higher than the address of the last CCW used.
32	Attention	Not Used for the 2820.
33	Status Modifier	Set whenever a Search High, Search Equal, or a Search High or Equal command has been executed and the condition satisfied. The Status Modifier is also set whenever the 2820 is Busy. This bit, in conjunction with the Busy Bit, signifies Control Unit Busy.
34	Control Unit End	Set if a Control Unit Busy status has been generated previously and the busy condition has been terminated. Also set with Unit Check when Unit Check occurs after Device End.
35	Busy	Indicates that the selected device is busy. In conjunction with the Status Modifier bit, indicates the control unit is busy. It is also set when a start I/O is issued while the 2820 is causing a track to be erased following a Format Write command or Erase command.
36	Channel End	Set at the end of each channel command.
37	Device End	Indicates that a 2301 is available for use.
38	Unit Check	Set whenever an unusual or error condition is detected in the 2820 or the selected device. A Sense I/O Command may then be used to identify the condition.
39	Unit Exception	Indicates an End-of-File has been detected during a Read R0, Read IPL, Read CKD, Read KD, Read D, Write KD, Search KD, or a Write D operation. It results from a Data Length of zero being detected in the Count Area of a record. When this condition is detected, no data is transferred from the data area. If Key Length is not zero, the Key Area is transferred.
40-47	Channel Status	Indicate channel conditions as follows: Bit — Designation 40 — Program-controlled interruption 41 — Incorrect length 42 — Program check 43 — Protection check 44 — Channel data check 45 — Channel control check 46 — Interface control check 47 — Chaining check
48-63	Count	The residual count from the last CCW used.

25402

Figure 8. Channel Status Word

when the search did not locate the desired record (no status modifier returned).

These methods of modifying the sequence of a chain of CCW's provide branching capabilities in the channel program.

CHANNEL COMMANDS

Channel commands initiate and control 2820 Storage Control operations. The basic operations performed by the 2820 are: write, search, read, control, and sense. The command generated by the channel is sent to the 2820 as an eight-bit command byte. The command byte is divided into two parts: bits 6 and 7 specify the type of operation (read, write, etc.), and bits 0-5 are the modifier bits and specify how and on which area the operation is to be executed. The bit structure of the 2820 Storage Control commands is shown in Figure 10.

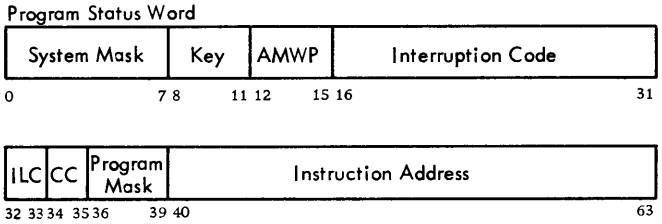
Control Commands

No Operation (No-Op)

The No-Op command is executed on receipt of any one of three command codes (Figure 11):

1. The normal No-Op, used for all System/360 I/O devices (command code 0000 0011).

Program Status Word

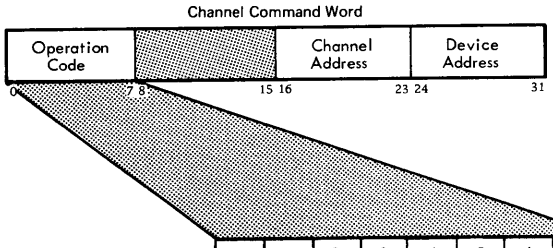


PSW Bit Position	Field Designation	
0	Channel 0 mask	System Mask
1	Channel 1 mask	
2	Channel 2 mask	
3	Channel 3 mask	
4	Channel 4 mask	
5	Channel 5 mask	
6	Channel 6 mask	
7	External mask	
8-11	Protection key	
12	ASCII-8 mode (A)	
13	Machine check mask (M)	
14	Wait state (W)	
15	Problem state (P)	
16-31	Interruption code	
32-33	Instruction Length code (ILC)	
34-35	Condition code (CC)	
36	Fixed-point overflow mask	Program Mask
37	Decimal overflow mask	
38	Exponent underflow mask	
39	Significance mask	
40-63	Instruction address	

30068

Figure 9. Program Status Word

Channel Command Word



	0 M/T	1 HI	2 =	3 C	4 K	5 D	6	7
Write Data	0	0	0	0	0	1	0	1
Write Key, Data	0	0	0	0	1	1	0	1
Write Count, Key, Data	0	0	0	1	1	1	0	1
Write Home Address	0	0	0	1	1	0	0	1
Write Record Zero	0	0	0	1	0	1	0	1
Write Overflow	0	0	0	0	0	0	0	1
Erase	0	0	0	1	0	0	0	1
Search Equal ID	X	0	1	1	0	0	0	1
Search Equal Key	X	0	1	0	1	0	0	1
Search Equal Home Address	X	0	1	1	1	0	0	1
Search Hi ID	X	1	0	1	0	0	0	1
Search Hi Key	X	1	0	0	1	0	0	1
Search Hi Equal ID	X	1	1	1	0	0	0	1
Search Hi Equal Key	X	1	1	0	1	0	0	1
Read Data	X	0	0	0	0	1	1	0
Read Key, Data	X	0	0	0	1	1	1	0
Read Count, Key, Data	X	0	0	1	1	1	1	0
Read Home Address	X	0	0	1	1	0	1	0
Read Record Zero	X	0	0	1	0	1	1	0
Read Count	X	0	0	1	0	0	1	0
Read Initial Program Load (IPL)	0	0	0	0	0	0	1	0
Control Seek (BBCCHH) ‡	0	0	0	0	0	1	1	1
Control Recalibrate * *	0	0	0	1	0	0	1	1
Control Restore * *	0	0	0	1	0	1	1	1
Control No Op	0	0	0	0	0	0	1	1
Control Cyl. Seek (CCHH) ‡	0	0	0	0	1	0	1	1
Control Head Seek (HH)*	0	0	0	1	1	0	1	1
Control Set File Mask	0	0	0	1	1	1	1	1
Test I/O (Not written by programmer)	0	0	0	0	0	0	0	0
Sense I/O	0	0	0	0	0	1	0	0

X: On Search and Read commands B0 can be either "0" or "1". If "0", head switching will not take place when Index Point is detected. If "1", head switching will take place when Index Point is detected (Multiple Track Mode).

* Head Seek command has the Domain Seek function in 2820.

* * Executed as a No Op in 2820.

‡ Perform same seek operation.

25403A

● Figure 10. 2820 Command Codes

2. The Restore command, used with IBM 2841 Storage Control (command code 0001 0111).
3. The Recalibrate command, used with IBM 2841 Storage Control (command code 0001 0011).

The No-Op is a command immediate, which means that no data other than the command itself is transferred to the 2820 from main storage. Either one or two status bytes are sent from the 2820 as a result of receiving a No-Op command. Usually, only the initial status byte indicating channel end and device end is transferred to the channel. However, if the No-Op follows a formatting write command, an ending status byte is also sent to the channel when index is detected. The ending status byte contains channel end and device end.

Since no data is transferred, the suppress length indicator (SLI) bit in the No-Op CCW must be on. (See bit 34, Figure 7.)

Note: Indiscriminate use of the No-Op command between track format oriented commands could cause an overrun condition (late command error). If the two commands preceding a No-Op are a search and a Transfer in Channel respectively, a data field must be read or written before a new search command is issued. If a data field is not read or written, a no record found error condition may be encountered.

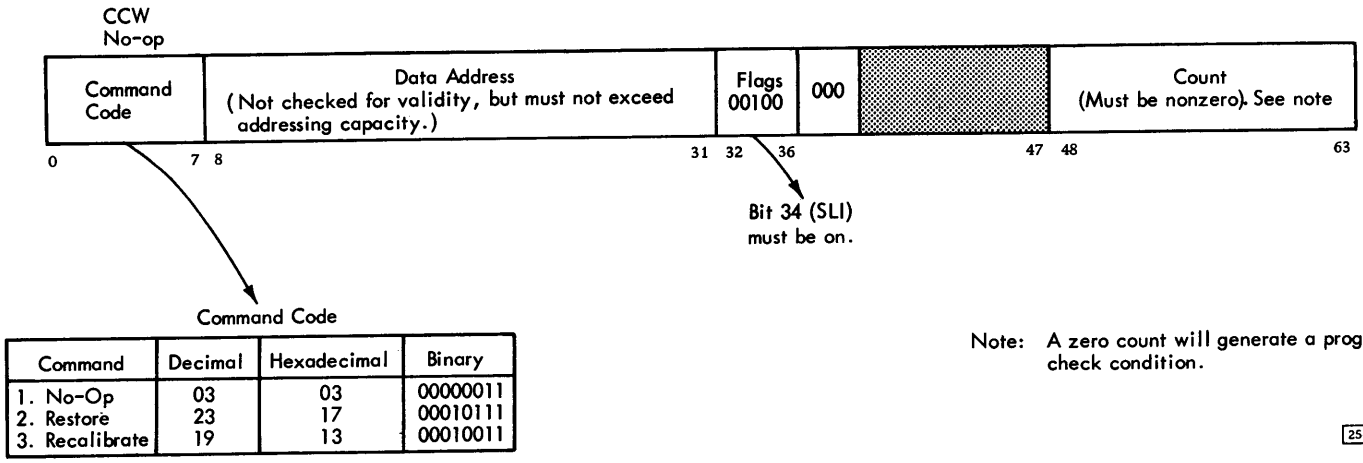


Figure 11. No-Op CCW

Set File Mask

The Set File Mask command sets the write and seek masks which provide protection for 2301 data. It causes one byte of data, the file mask, to be sent from main storage to the 2820. At the completion of the transfer, channel end and device end signals are sent to the channel. The file mask describes the write and seek commands that can be performed in the CCW chain. Only four of the eight bits in the file mask byte are significant (Figure 12). Bits 0 and 1 pertain to write operations, and bits 3 and 4 pertain to seek operations. The remaining bits -- 2, 5, 6, and 7 -- must be set to zero. If they are not zero, the mask is considered to be invalid and a CSW unit check signal is generated. A subsequent Sense I/O command will indicate command reject.

If a command is issued which violates the file mask, the command is not executed and errors are indicated by the file protect sense and unit check status bits. Multiple track mode of operation cannot cause exit from a protection domain. (Protection domains are described under "Seek Commands.") A file protect indication will occur when the domain boundary is reached.

A Set File Mask command may be issued anywhere within a CCW chain. However, it can only be processed once; other Set File Mask commands issued in the same CCW chain will be rejected. A subsequent Sense I/O command will indicate command reject and invalid sequence.

The file mask in the 2820 is reset to all 0's at the completion of the CCW chain, by a system reset, or by a malfunction reset.

Seek Commands

Seek commands are the means of sending the hardware address of the desired track from the CPU to the 2820. A seek can be initiated by any of three commands (Figure 13):

1. Seek (command code 0000 0111).
2. Cylinder Seek (command code 0000 1011).
3. Head Seek (command code 0001 1011).

The execution of any of the seek commands causes a six-byte transfer of the seek address from main storage to the 2820. Of the six bytes transferred, the five high-order bytes are always set to zero. The low order byte contains the binary value of the track address (decimal 0-199).

When a Seek or Cylinder Seek command is executed, any of the 200 tracks of the drum can be addressed. The address contained in the low-order byte replaces any previous seek address stored by the 2820. When a Head Seek command is executed, only the three low-order bits of the seek address stored in the 2820 are changed by the new address information. Therefore, Head Seeks are restricted to the protection domain specified by the last Seek or Cylinder Seek command issued to the SCU.

Which seek commands are accepted is determined by the seek mask portion of the file mask. Completion of the seek operation is indicated by channel end and device end in the status byte after the transfer of the initial six bytes of information. If an invalid seek address (greater than decimal 199) is received by the 2820, the seek command is rejected and a CSW unit

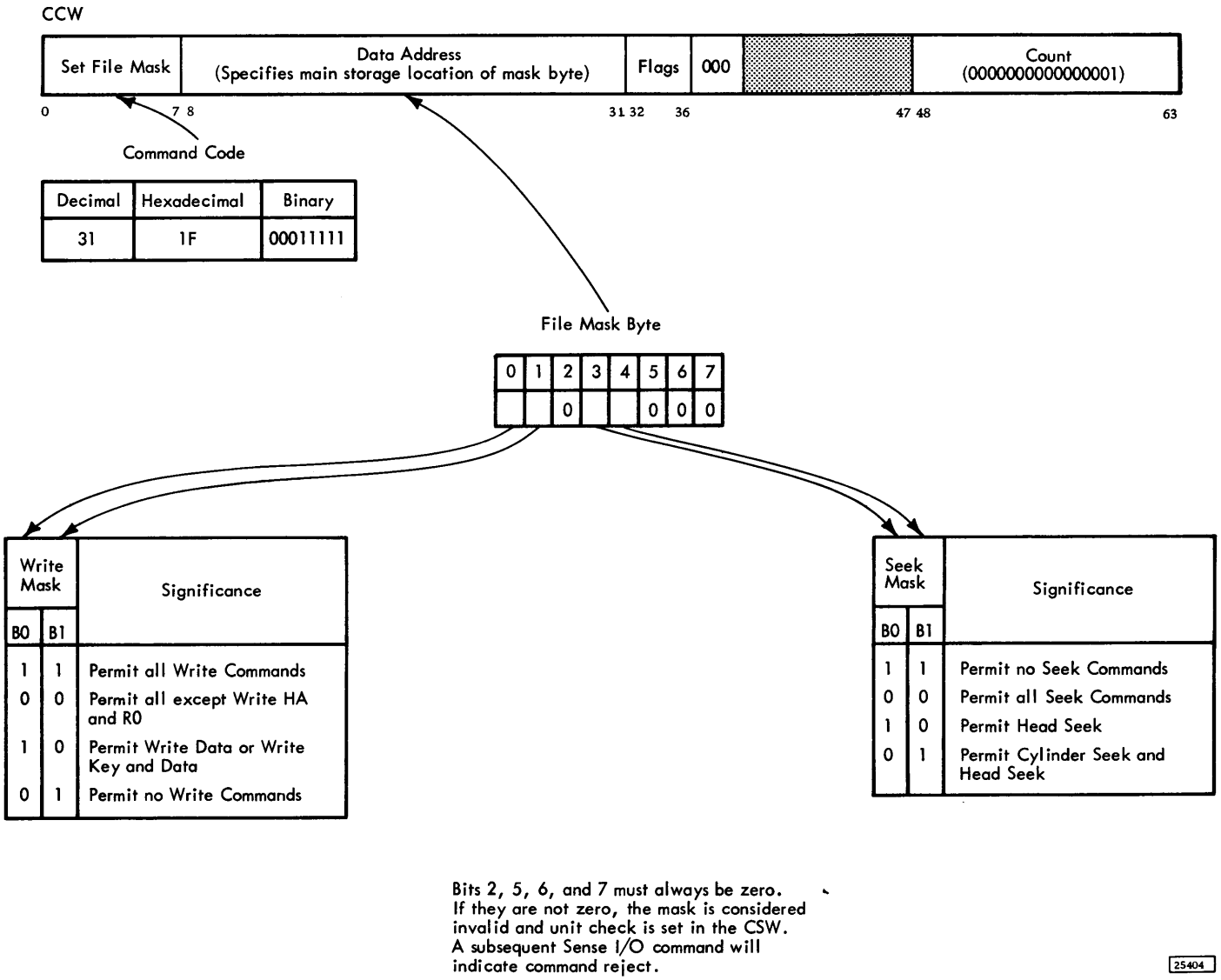


Figure 12. Set File Mask

check signal is generated. A subsequent Sense I/O command will indicate command reject and invalid address.

Protection Domain: The 200 addressable tracks of the drum are divided into 25 groups of 8 tracks each. Each group is a protection domain as follows;

Domain 1:	Tracks 0-7
Domain 2:	Tracks 8-15
Domain 3:	Tracks 16-23
etc.	etc.
Domain 25:	Tracks 192-199

Read Commands

A read command is used to transfer information from the 2301 Drum Storage to the central processing unit. Read commands can operate in either single track or multiple track mode.

For all read commands the 2820 checks the validity of each area of each record as it is transferred to the 2820 from the 2301. After the check bytes have been examined and the validity of the data is established, the 2820 sends an ending status byte containing channel end and device end bits to the channel.

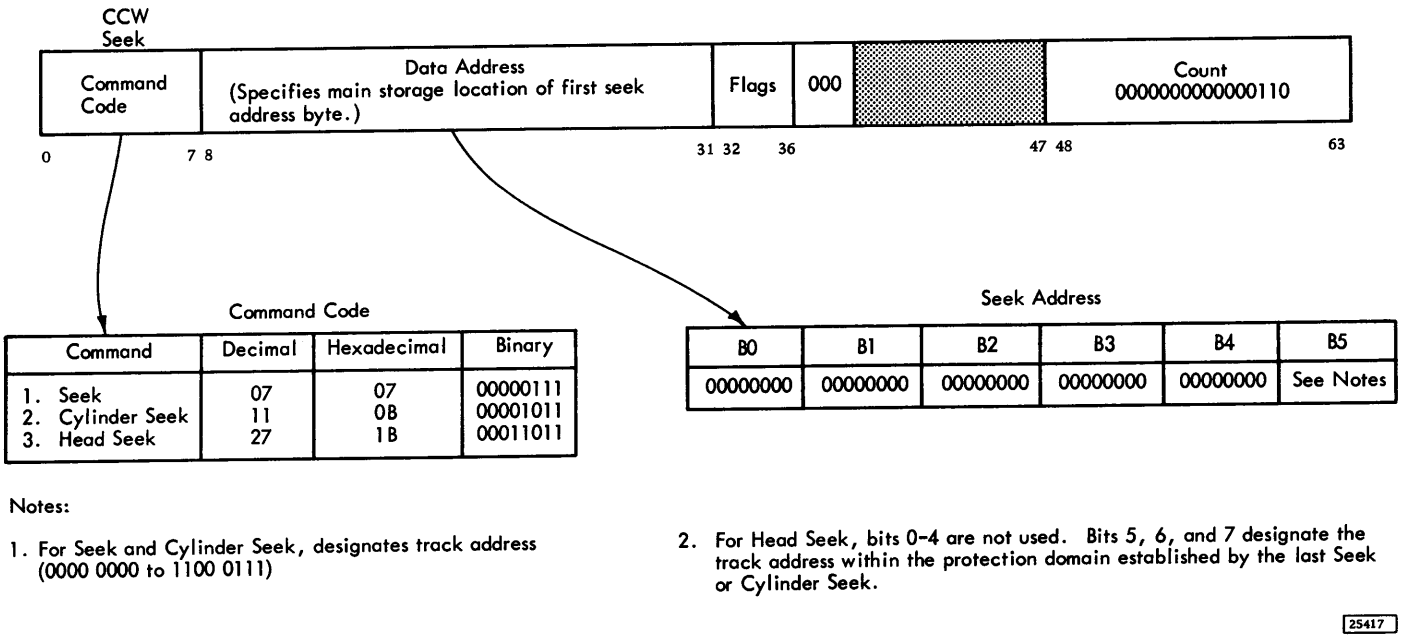


Figure 13. Seek CCW

Multiple Track Mode (Read): The multiple track mode (MTM) bit can accompany all read commands except Read Initial Program Load. When MTM is specified and index point is passed, the track address is automatically updated so that operation can continue on the next track. The command containing the MTM bit must be chained from a previous seek command. An attempt to continue MTM operation in violation of the file mask will result in a file protect indication in the sense information and a unit check in the status byte.

Read Home Address

The Read Home Address command causes the contents of the home address area of the selected track to be transferred to main storage.

Read HA Command Code		
Decimal	Hexadecimal	Binary
26	1A	00011010

Read HA Command Code Multiple Track		
Decimal	Hexadecimal	Binary
154	9A	10011010

11286

The five bytes of home address information (FCCHH) are placed in main storage beginning at the address specified in the channel command word.

Read Record 0

The Read Record 0 command causes the contents of the record 0 area of the selected track to be transferred to main storage.

Read R0 Command Code		
Decimal	Hexadecimal	Binary
22	16	00010110

Read R0 Command Code, Multiple-Track		
Decimal	Hexadecimal	Binary
150	96	10010110

11288A

The contents of record 0, excluding the flag byte, are placed in main storage beginning at the address specified in the channel command word.

Read Count

The contents of the count field (ID, CK, and CD) of a record in an addressed track are read and transferred to main storage.

Read Count Command Code		
Decimal	Hexadecimal	Binary
18	12	00010010

Read Count Command Code, Multiple-Track		
Decimal	Hexadecimal	Binary
146	92	10010010

11287

The data, excluding the flag byte, is placed in main storage beginning at the main storage location specified in the channel command word.

Read Data

This command causes the data area of a record to be transferred to main storage. The data to be transferred is one of the following:

1. The data area of the same record read by a Search ID or Search Key command from which the Read Data command is chained.
2. The data area of the record read by a Read Count command from which the Read Data command is chained.
3. The data area of the record following the next address marker encountered on the track.

Read Data Command Code		
Decimal	Hexadecimal	Binary
06	06	00000110

Read Data Command Code Multiple-Track		
Decimal	Hexadecimal	Binary
134	86	1000110

30172

Read Key and Data

This command causes the key and data areas of a record to be transferred from the 2301 to main storage (Figure 14).

Read Key and Data Command Code		
Decimal	Hexadecimal	Binary
14	0E	00001110

Read Key and Data Command Code, Multiple-Track		
Decimal	Hexadecimal	Binary
142	8E	10001110

30173

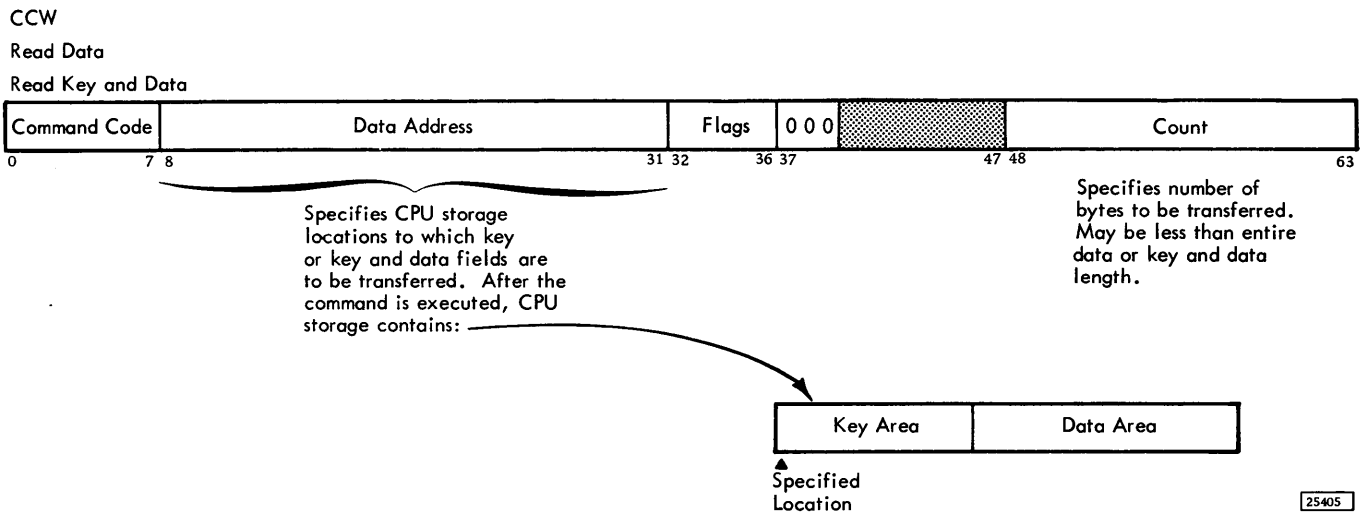


Figure 14. Read Data and Read Key and Data

If the key length is zero, this command operates like a Read Data command. The key and data areas to be transferred are from one of the following:

1. The key and data areas of the same record read by a Search ID command from which the Read Key and Data command is chained.
2. The key and data areas of the same record read by the Read Count command from which the Read Key and Data command is chained.
3. The key and data areas of the record following the next address marker on the track.

Read Count, Key, and Data (Read CKD)

Read Count, Key, and Data Command Code		
Decimal	Hexadecimal	Binary
30	1E	00011110

Read Count, Key and Data Command Code, Multiple-Track		
Decimal	Hexadecimal	Binary
158	9E	10011110

30168

Execution of this command causes the transfer of one complete record (count, key, and data areas) from the 2301 to main storage (Figure 15).

Read Initial Program Load (Read IPL)

This command is initiated by hardware when the IPL key on the console is pressed with the address of the direct access device in the load unit switches.

Read IPL Command Code		
Decimal	Hexadecimal	Binary
02	02	0000 0010

11507

This command causes the 2820 to force the specified 2301 to seek to track 0, and then search for the index marker. After index is detected, the Read IPL command reads the data field of record R1 and transfers the contents of R1 to main storage.

It is the responsibility of the programmer to set up the data area of record 1 of track 0 as the IPL record.

If a read command without modifier bits (a Read IPL) is sent to the 2820, record 1 cf the track currently addressed is sent to the channel.

Write Commands

A write command is used to transfer data from an area of main storage to a specified 2301 Drum Storage.

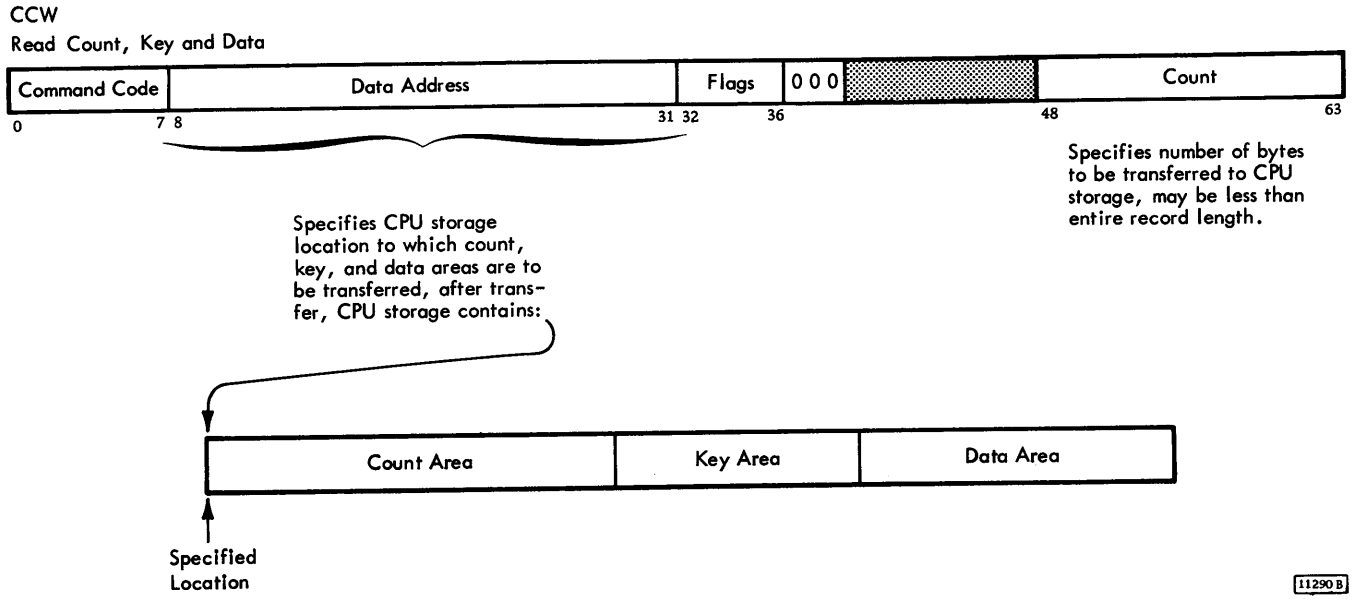


Figure 15. Read Count, Key, and Data

Write operations in general require a verification of physical location on the drum before they can be executed. The prerequisites for each write operation are included in the particular operation. If the prerequisites are not met, the command is not executed and the invalid sequence bit is set in the status byte.

During a write operation, the 2820:

1. Requests bytes from the channel.
2. Checks the parity of each byte.
3. Sends the data four bits at a time to the 2301 Drum Storage.
4. Generates check bytes, which are written after each area.

The length of each key and data area is specified by the key and data length bytes in the count area. If the channel stops sending data before the number of bytes equals the specified count, the remainder of the record is written with 0's.

Formatting Write Commands

Formatting write commands are used to initialize tracks and records, and establish the length of the areas within each record. After the last format write command in a chain has been executed, the 2820 causes the remaining portion of the track to be written with a burst of 1's and then 0's to index. Formatting write commands are:

Write Home Address.
Write Record Zero.
Write Count, Key, and Data.
Write Count, Key, and Data Overflow.
Write Count, Key, and Data Erase.

Each of the formatting write commands has a particular logical ending time which occurs after writing the specified data and check burst. At the logical ending time, channel end and device end bits are set in the status byte in order to free the channel. However, the 2820 and the 2301 are committed to writing or erasing the remainder of track. If there are no further commands to be chained, the 2301 and the 2820 remain busy until the following index time. Commands issued during this time are rejected with a control unit busy indication. If command chaining is being performed, the 2820 accepts the next command. This command is executed if it is a formatting write command, or held until the rest of the track is written with 0's, if it is a legal command other than a formatting write.

Nonformatting Write Commands

Nonformatting Write commands must operate on previously formatted tracks. Nonformatting write commands are:

Write Data.
Write Key and Data.

There is no requirement for the remainder of the track to be written with 0's after these commands; therefore the operation is completed by a status byte containing channel end and device end bits immediately after the data check bytes are written. No control unit busy condition is held over after the ending status byte is issued. Nonformatting write operations can operate on previously formatted overflow records.

Overflow: Overflow is used when it is necessary or desirable to write a data record whose length exceeds normal track capacity (20,483 bytes). Bit 1 (on) of the flag byte initiates an overflow operation. When the 2820 detects a bit in flag byte position 1, the track address is automatically updated at index time. When overflow is specified, the maximum length of the data record is restricted by the maximum binary value that can be expressed in the DL bytes of the count field (65,535 bytes). See "Write Count, Key, and Data Overflow."

Write Checking: To achieve optimum performance from the 2820/2301, the program should provide specified error recovery procedures (Appendix A) to ensure data integrity when a unit check has occurred. Errors so indicated are often due to temporary conditions that can be corrected and the data recovered by using the suggested procedures.

A write command that does not place accurate data on the drum because of temporary or intermittent conditions can be detected immediately by verifying the data just written. In this way, any "soft" write errors can be corrected while the data is still available in main storage. If the write check procedure is not followed, the "soft" error becomes a "hard" error, which can only be corrected by reconstruction or adjustment. In almost all cases, permanent data files should be verified as soon as written. Verification of transient or work files may not be required. The programmer should weigh the possible reconstruction time versus the time consumed verifying the write data before deciding not to write check.

Write Home Address

A Write Home Address command (Figure 16) is used to establish track identity within the 2301. Each track must be initialized with a home address before a data operation involving that track can take place. The Write Home Address command is for initial drum setup only and is not contained in user application programs.

When executed, the Write Home Address command causes the transfer of the five bytes in the home address from the CPU to the 2820. The 2820 adds three check bytes to the data prior to transferring it to the 2301 Drum Storage. At this point, channel end and device end are signaled to the channel.

Chaining requirements: Execution of this command is dependent upon a correct Set File Mask command preceding it in the same command chain.

Write Record 0

The Write Record 0 command causes the first record on the addressed track to be filled with data from main storage. The CD bytes in the count field should not be zero. This record differs from other records in that it does not contain an address marker.

Write Record Zero Command Code		
Decimal	Hexadecimal	Binary
21	15	00010101

25406

Chaining requirements: This command must be chained from a successful Search HA or from a Write HA.

Write Count, Key, and Data

Execution of this command causes the specified data to be transferred from main storage to the 2301 (Figure 17).

The first eight bytes of data transferred from main storage make up the count area. The flag byte is generated by the 2820. The remaining data is written in the key and data areas as specified by the key and data lengths stated in the count area. Channel end and device end are signaled to the channel

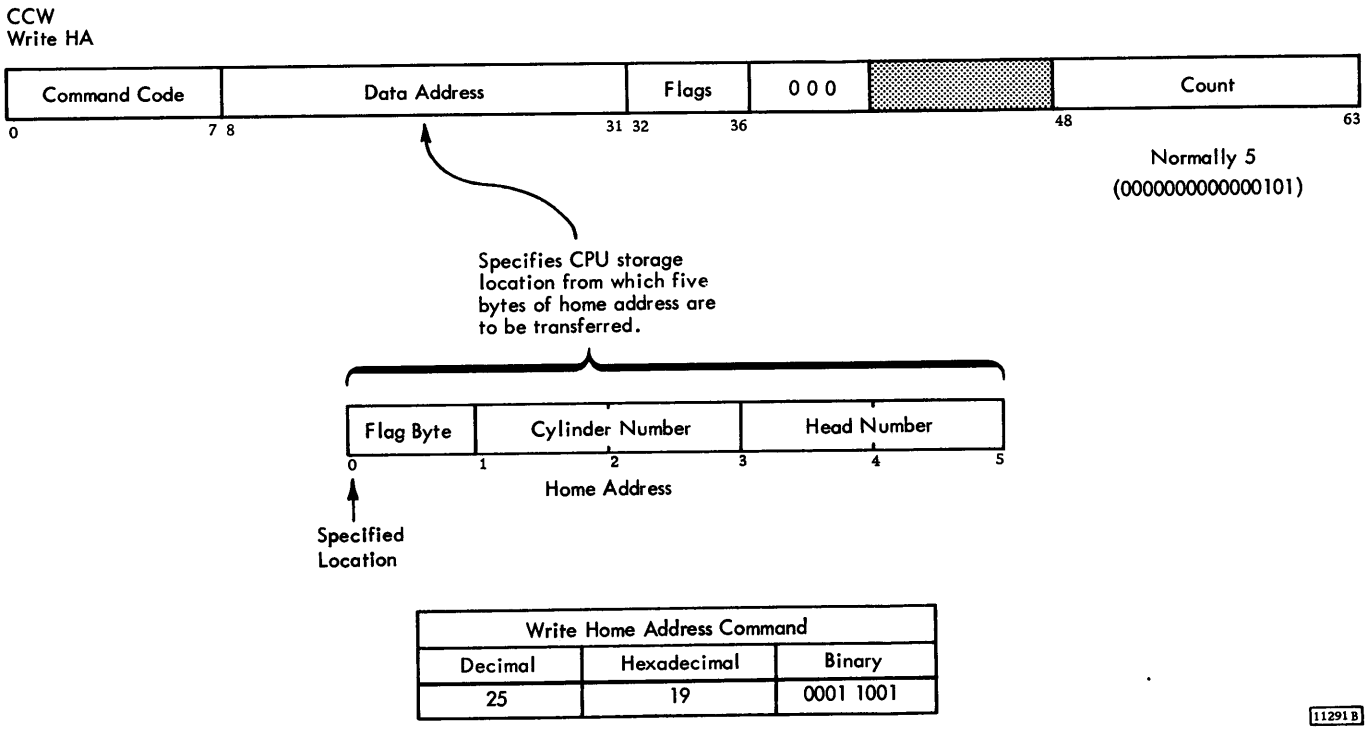


Figure 16. Write Home Address

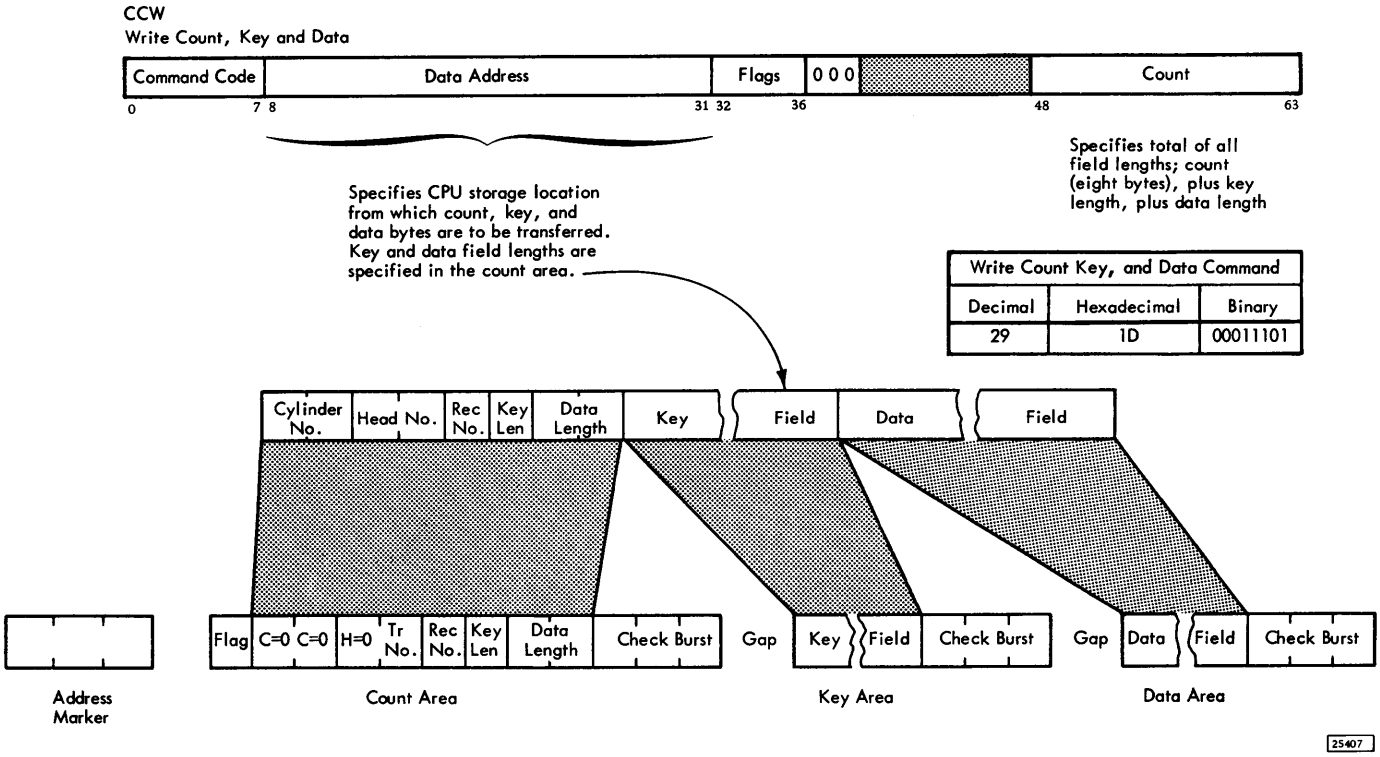


Figure 17. Write Count, Key, and Data

after the 2820 has written the check burst following the data area.

End-of-file can be indicated by specifying a Write Count, Key, and Data operation in which the CD bytes in the count field are set to zero. If the CD bytes in the count field of the record are set to zero, a data area of one byte is automatically written by the 2820 so that format monitoring can be maintained.

Chaining requirements: This command must be chained from a successful Search Equal ID, Search Equal Key, or from a Write R0, or another Write Count, Key, and Data command or a Write Count, Key, and Data Erase command.

Write Count, Key, and Data Overflow

This format operation has the same prerequisites as a Write Count, Key, and Data command. All references elsewhere to Write Count, Key, and Data apply to this command.

Write CKD Overflow Command Code		
Decimal	Hexadecimal	Binary
01	01	00000001

25418

Execution of the Write CKD Overflow command differs from Write CKD only in that the 2820 places bit 1 (overflow indicator) in the flag byte on for use during subsequent read or nonformatting write operations.

No further operation on a track may take place after this command. Channel end and device end are signaled, and the next command byte of a chain is accepted by the 2820, but the remainder of the track is padded before the later command is executed.

If the logical record spans more than two tracks, the record on each of the intermediate tracks should be written with this command as well as the beginning portion of the first track.

This command should not be used with a data length of zero.

Write Count, Key, and Data Erase

The Write CKD Erase command has the same prerequisites as a Write Count, Key, and Data operation.

Write CKD Erase Command Code		
Decimal	Hexadecimal	Binary
17	11	00010001

25419

Execution of Write Count, Key, and Data Erase differs from Write CKD only in that the 2820 places bit 2 in the flag byte on for use later when reading. Bytes for the full format are requested and written.

When the 2820 is reading and recognizes the erase bit, the 2820 ignores the remainder of the record following the count check burst. This overrides the data-length-equals-zero condition for setting unit exception (end of file). If the count check burst is in error, the operation is terminated and data check is set. If no error occurs, the operation is attempted again in the next record.

Write Key and Data

Execution of this nonformatting command causes the addressed main storage data to be written in the key and data fields of the addressed record. The number of bytes to be written is specified by the Write Key and Data CCW. The length of the key and data areas may be less than the lengths specified in the count area when the record was formatted; if so, the 2820 fills in the remainder with 0's.

Write Key and Data Command Code		
Decimal	Hexadecimal	Binary
13	0D	0000 1101

11509A

If a CCW count exceeds the previously formatted count field, the control unit will transfer data to the device only until the data length specified by the data length bytes in the count area has been reached. The control unit will then signal the channel with device end. The CCW residual count will not be zero; therefore, the channel will set bit 41 (incorrect length) in the CSW on unless the SLI (bit 34) bit is present in the CCW.

When the number of bytes specified in the CCW has been written on the 2301, the 2820 adds the check burst and signals channel end and device end to the channel.

Chaining requirements: A Write Key and Data command must be chained from a successful Search ID Equal command.

Write Data

Execution of the Write Data command causes the addressed main storage data to be written in the data field of the addressed record. The number of bytes to be written is specified by the Write Data CCW and may be less than the data length specified by the count area when the record was formatted. If the CCW specifies a shorter data length than specified in the format, the 2820 fills in the remainder with 0's. After the specified number of bytes has been written on the drum, the 2820 adds the cyclic check bytes to the data area and signals channel end and device end to the channel.

Write Data Command Code		
Decimal	Hexadecimal	Binary
05	05	0000 0101

11508A

If a CCW count exceeds the previously formatted count field, the control unit will transfer data to the device only until the data length specified by the data length bytes in the count area has been reached. The control unit will then signal the channel with device end. The CCW residual count will not be zero; therefore, the channel will set bit 41 (incorrect length) in the CSW on unless the SLI (bit 34) bit is present in the CSW.

Chaining requirements: A Write Data command must be chained from a successful Search Equal ID command or a Search Equal Key command.

Search Commands

The purpose of a search command is to locate and identify information or areas previously written on the 2301 Drum Storage. A read or write command is usually preceded by a search command which establishes the area to be written or read. The search

operation is performed in the 2820 by comparing data from the 2301 with data from the CPU. Both the channel and the 2820 are busy during the execution of a search command.

The lengths of the track area and the channel area which are compared during the search operation do not have to be equal. If an area on the drum is shorter than that which the channel sends, the 2820 compares only as long as the track area exists. The same procedure is followed if the channel area is shorter than the track area; comparing stops when the shorter area is completed. The channel automatically handles wrong length record checking and suppression of checking when necessary.

Comparison begins at the most significant, or leftmost, bit of the data and progresses to the right. High-order 0's must be provided by the channel to match high-order 0's from the drum. If the search condition is satisfied (comparison equal), a status modifier bit is sent to the channel. The channel fetches the next CCW in the command chain from a position 16 positions higher than the current (search) CCW. That is, one CCW, usually a TIC, is skipped. This allows modification of the command chain as a result of finding the desired record on the track.

Multiple Track Mode (Search): On all search commands, command code bit 0 determines whether multiple track mode is selected. If bit 0 is set to 1, the next track is used if the search command is repeated. The command containing the MTM bit must be chained from a previous seek command. An attempt to continue multiple track mode in violation of the file mask results in a file protect indication in the sense information and a unit check in the status byte.

Search Home Address

Execution of this command causes the 2820 to search for the index point of the addressed track. When the index point is recognized, the 2820 compares CCHH of the home address read from the drum against the CCHH bytes received from the channel.

Search HA Command Code		
Decimal	Hexadecimal	Binary
57	39	0011 1001

30083

If the logical comparison is equal, channel end, device end, and status modifier are signaled to the channel. If the comparison is unequal, channel end and device end are signaled to the channel. An unequal compare sets the no record found bit in the sense byte and the unit check bit in the status byte. The flag byte is not part of the comparison.

Search Identifier (Search ID)

Search ID commands cause a comparison to be made between five bytes of data from the CPU and the record identifier (cylinder number, head number, and record number) portion of a count area from the 2301.

Command	Search ID Command Code		
	Decimal	Hexadecimal	Binary
Search ID Equal	49	31	00110001
Search ID High	81	51	01010001
Search ID Equal or High	113	71	01110001

Command	Search ID Multiple Track Command Code		
	Decimal	Hexadecimal	Binary
Search ID Equal	177	B1	10110001
Search ID High	209	D1	11010001
Search ID Equal or High	241	F1	11110001

11283

If the CCW count is greater than five bytes, the search operation is completed when the 2820 count equals zero. The 2820 terminates the command with a channel end and device end. The status modifier is generated if the logical comparison was satisfied.

If the CCW count is less than five bytes, the logical comparison between the data coming from main storage and the data coming from the 2301 continues until the CCW count reaches zero. A status modifier is generated if the search condition was satisfied on the short field, but unless the usual five bytes are compared, the operation does not fulfill the prerequisite for a write operation.

Search ID Equal, ID High, and ID Equal or High: These three commands are used to compare the ID

from the 2301 Drum Storage device to the ID data from main storage. When these commands are satisfied, they indicate that the ID from the 2301 is equal to (Search ID Equal), higher than (Search ID High), or either equal to or higher than (Search ID Equal or High) the ID from main storage.

Multiple track mode operation is optional in all search ID commands.

Search Key

Execution of a search key command causes the 2820 to compare a key area from main storage with a key area read from the 2301 Drum Storage. The key to be searched is either the key of the record following the next address marker or, if the command is chained from a Read Count or Search ID command, the key is in the same record in which the ID is read or searched. A search key command passes over record 0 unless chained from a search ID command that has searched the ID of record zero.

Command	Search Key Command Codes		
	Decimal	Hexadecimal	Binary
Search Key Equal	41	29	00101001
Search Key High	73	49	01001001
Search Key Equal or High	105	69	01101001

Command	Search Key Command Codes, Multiple Track		
	Decimal	Hexadecimal	Binary
Search Key Equal	169	A9	10101001
Search Key High	201	C9	11001001
Search Key Equal or High	233	E9	11101001

11284

If the CCW count is greater than the key length written when the track was formatted, the search operation is terminated when the number of bytes specified by the key length in the count area has been transferred to the 2820. If the search has not been successful, the 2820 terminates the operation and signals channel end and device end to the channel. A status modifier signal is sent to the channel with channel end and device end when the search is successful.

If the CCW count is less than the key length specified when the track was formatted, the search operation is terminated when the number of bytes specified by the CCW has been transferred to the 2820. If the search has not been successful, the 2820 terminates the operation and signals channel end and device end to the channel. A status modifier bit accompanies channel end and device end in the ending status when the search has been successful.

The search key command should not be used if the key length of the record to be searched is zero. A key length of zero will never return a status modifier.

Search Key Equal, Key High, and Key High or Equal: These commands are used to compare the key area from main storage with the key area read from the 2301. When the specified condition is satisfied, the key area from the 2301 is equal to (Search Key Equal), higher than (Search Key High), or either equal to or higher than (Search Key Equal or High) the key area from the CPU. If the specified condition is not satisfied or if the record has no key area, channel end and device end are signaled to the channel.

Multiple track mode operation is optional in all search key commands.

Transfer In Channel (TIC)

The Transfer In Channel command provides for chaining between CCW's not located in adjacent CPU main storage locations. The next CCW is fetched from the location specified by the data address field in the TIC command. TIC does not initiate any channel I/O operation, and the I/O device is not signaled that the command is being executed.

TIC Command Code		
Decimal	Hexadecimal	Binary
X8	X8	XXXX1000
Positions Marked "X" Are Ignored		

11280

TIC cannot be the first CCW designated by a channel address word. One TIC command cannot transfer directly to another TIC command. When either of these programming errors is detected or when an invalid address (TIC CCW data address field does not specify a double word boundary) is specified, a program check signal is generated. Detection of these errors during data chaining causes the operation of the 2301 to be terminated. During command chaining, detection of these errors causes an I/O interrupt.

Bit positions 0-3 and 32-63 of the TIC CCW are ignored. Bits 29-31 must be zero to meet the boundary requirement for double words. Note that a TIC is

the only CCW that may have a count field of zero. Also, an incorrect length indication cannot occur during execution of a TIC; the SLI flag is ignored in a TIC.

Sense I/O

The 2820 sense operation, initiated by the execution of a Sense I/O command, involves the transfer of six bytes of information from the 2820 to the CPU. The contents of the six bytes provide information regarding the cause of a unit check condition in the CSW.

Sense I/O Command Code		
Decimal	Hexadecimal	Binary
04	04	0000 0100

11277

The data address portion of the Sense I/O CCW directs the six bytes of information to a specific CPU storage location.

Figure 18 describes the six bytes and the significance of each bit in the bytes. Appendix B contains a detailed explanation of the conditions that cause each bit to be turned on.

Test I/O Operation

A Test I/O "command" is generated in either of two ways. It is generated automatically by the channel when the channel requires status information, or it is the result of processing a Test I/O instruction. In either case it requests the 2820 to send outstanding status information to the channel. If no status information is present in the status register at the time a Test I/O is accepted, an all-0 byte is sent to the channel.

Control Unit (CU) busy is signaled if the 2820 is padding an unused portion of a track after a formatting operation, or completing a record area after a Halt I/O sequence.

CU end is signaled if CU busy had been previously indicated and the busy condition no longer exists. CU end is signaled in answer to Test I/O only if it is outstanding (that is, if it was previously sent to the channel, or if it was stacked).

BYTE 0		COMMENTS
Bit 0	Command Reject	
1	Intervention Required	
2	Bus Out Check	
3	Equipment Check	
4	Data Check	
5	Overrun	Set by Late Command or Service Overrun
6		Not Used
7	Invalid Address	Command Reject is also set

BYTE 1		
Bit 0	Data Check in Count Field	Data Check is also set
1	Track Overrun	
2	End of Cylinder	
3	Invalid Sequence	Command Reject is also set
4	No Record Found	
5	File Protect	Command Reject may also be set
6	Service Overrun	Overrun is also set
7	Overflow Incomplete	File Protect or End of Cylinder is also set.

BYTE 2		
Bit 0	Unsafe	Equipment Check is also set
1	Shift Register Check	Equipment Check is also set
2	Skew Failure	Equipment Check and LRC bit(s) also set
3	Counter Check	Equipment Check is also set
4	Compare Check	Equipment Check is also set
5		Not Used
6		Not Used
7		Not Used

BYTE 3		
Bit 0	Longitudinal	Drum Bit 0 Parity Error
1	Redundancy	Drum Bit 1 Parity Error
2	Checks	Drum Bit 2 Parity Error
3		Drum Bit 3 Parity Error (Data Check or skew failure is also set with drum bit parity error.)
4-7		Not Used

BYTE 4		
Bit 0	Sequence Indicator 0	
1	Sequence Indicator 1	
2	Sequence Indicator 2	If any sequence Indicator is on
3	Sequence Indicator 3	when sampled, Equipment Check
4	Sequence Indicator 4	is set.
5	Sequence Indicator 5	
6	Sequence Indicator 6	
7	Sequence Indicator 7	

BYTE 5	
Bit 0-4	Not Used-all zeros
5	Data Modifier 1
6	Read Operation
7	Write Operation
	Overflow Incomplete is also set

Byte 5 contains a command byte which informs the channel whether an Overflow Incomplete occurred on a Read Data or a Write Data Operation.

All sense bits in bytes 0, 1, 2 and 3 cause Unit Check to appear in the Status Byte.

13084B

Figure 18. Definition of Sense Bytes

The ending status byte of an operation interrupted by a Halt I/O signal sequence may answer a Test I/O.

Note: A Test I/O command (command code 00000000) is not written by the programmer. A command code of all 0's is considered to be invalid and a unit check signal is generated. A subsequent Sense I/O command will indicate command reject.

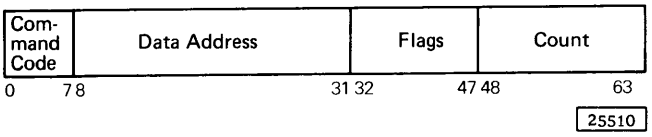
Write End of File

The Write End of File command is a Write CKD command in which the data length specified is zero. (See "Write Count, Key, and Data.")

CHANNEL PROGRAMS

The following channel programs are typical examples of how CCW's are arranged to format, read, and write records on the 2301. The examples given do not include the CPU program which would be used to initiate the channel program.

The format for each of the CCW's is as follows:

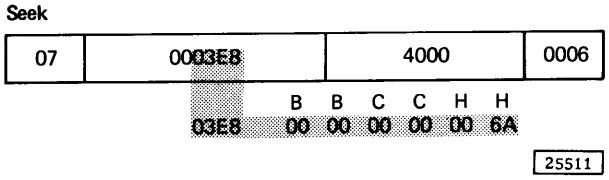


All numbers used are hexadecimal numbers.

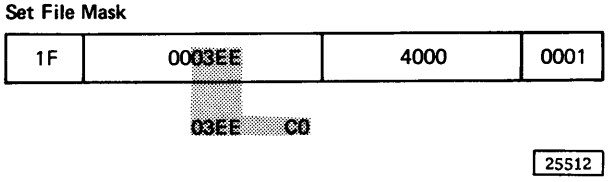
Example 1: Format track 6A with home address, record 0, and records R1, R2, and R3 for customer records. Assume the following: 1) R0 has a key length of 0 and a data length of eight bytes, 2) R1, R2, and R3 have a key length of six bytes and a data length of 03E8 (1,000) bytes. In that case, the channel program used is:

Seek
Set File Mask
Write Home Address
Write Record Zero
Write CKD
Write CKD
Write CKD

Summary of Example 1: The first CCW in the channel program is a Seek command. All seek commands transfer six bytes of data from main storage to the 2820. (Thus the byte count of 6.) Since the first five bytes of the seek address are always 0's, the track address (6A) is specified in the sixth byte (03ED).

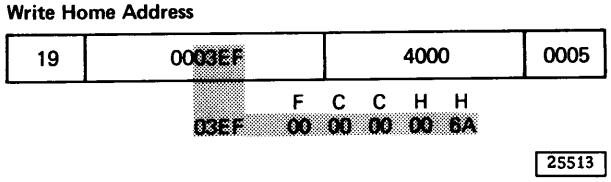


The next command in the channel program is a Set File Mask command. The mask byte in this case (1100 0000 at address 03EE) permits all write and seek commands. The mask is reset to all 0's at the end of each chain of commands.



The Write Home Address command creates the home address area on the track. The home address area is five bytes long (FCCHH). For 2301 programming, the flag byte normally is 0, the CC and first H byte must be 0's, and the second H byte normally contains the physical address of the track (6A at address 03F3).

Note: Write Home Address is the only write command in which the flag byte is transferred from main storage. The flag byte is generated automatically by the 2820 for all other write commands.

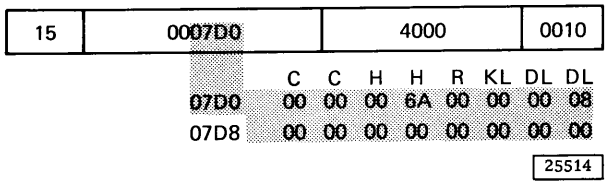


Following the home address area is record 0. The Write R0 command writes a count area, a key area (if the key length specified is not 0), and a data area whose length is dependent upon the value specified in the DL bytes of the count field.

Since the key length specified is 0, address 07D5 is coded 00, and no key area is written. The data length specified is eight bytes so addresses 07D6 and 07D7 are coded 0008 and the data in following eight main storage locations is written in the data area.

Note that the byte count in the Write R0 command is sixteen and the 2820 requested 16 bytes (eight for the count area and eight for data). Therefore no incorrect length error is generated.

Write Record 0



The next command in the channel program is a Write CKD command. Execution of this command causes an address marker, count area, key area (if the key length specified is not 0), and a data area whose length is dependent upon the value specified in the DL bytes of the count field, to be written on the drum.

As in the Write R0 command, the first byte written is the first cylinder byte. Main storage locations 0BB8 to 0BBF are coded with the track number, record number, key length, and data length of record R1. Since the key length specified is 6, a key area six bytes long will be created. The data length specified is 03E8 (1,000) bytes. Although a byte count of 8 is specified in the CCW, and the channel byte count will go to 0 after eight bytes have been written, the 2820 is committed to writing a key area six bytes long and a data area 1,000 bytes long. Therefore, the 2820 inserts 0's into the applicable byte positions on the track until the 2820 byte count equals 0. The difference in the channel byte count and the 2820 byte count causes an incorrect length indication. Therefore, the SLI bit (bit 34) is on in the CCW.

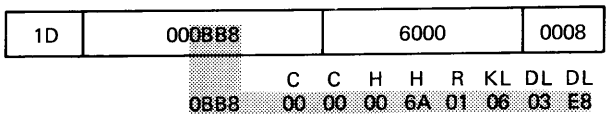
In this example, six bytes of 0's will be recorded in the key area followed by three check bytes, a gap, 1,000 bytes of 0's, and three more check bytes. At a later time, valid data could be recorded in the key and data areas with the following CCW sequence:

Search ID Equal (R1)
TIC*-8
Write Key and Data
Search ID Equal (R2)
TIC*-8
Write Key and Data
Search ID Equal (R3)
etc.

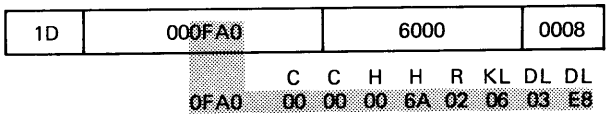
The next two commands in the channel program perform the same function as the Write CKD (R1). The only differences are that the record numbers are 2 and 3, and the chain flag is not on in the last CCW.

Valid data records could have been written in records R1, R2, and R3 with this channel program by increasing the byte count in the Write CKD CCW's. Then instead of 0's, the specified data would have been recorded in the key and data areas.

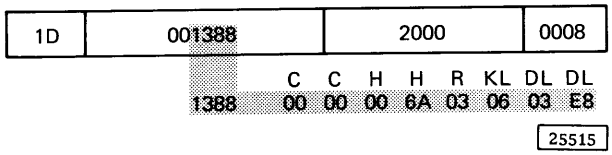
Write CKD (R1)



Write CKD (R2)



Write CKD (R3)



Example 2: Update Frank Smith's payroll record. Assumed:

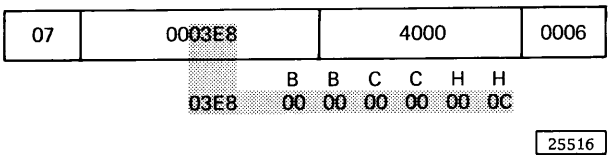
1. The drum is organized by key areas.
2. Each key area contains a man number.
3. Frank Smith's man number is 656151.
4. His man number is located on track 0C.
5. Key areas are six bytes long and data areas 64 (100_{10}) bytes long.

The channel program used is:

Seek
Search Key Equal
TIC*-8
Write Data

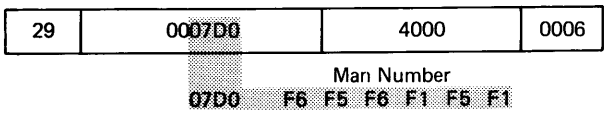
Summary of Example 2: The first command in the channel program is a Seek command. The sixth byte of the seek address (main storage location (03ED) specifies track 0C. This is the track on which Frank Smith's payroll record is located.

Seek

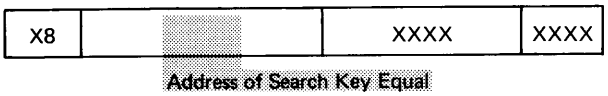


After locating the proper track, it is necessary to find which record on the track is Frank Smith's. Since the drum is organized by key areas, a Search Key Equal command is executed. Execution of Search Key Equal command causes the 2820 to search the key field after the first address marker it finds on track 0C. If the key is not equal to Frank Smith's man number (main storage locations 07D0 to 07D5) the 2820 signals channel end and device end to the channel and the TIC command (back to Search Key Equal) is executed. Subsequent key areas are searched until Frank Smith's record is found. The 2820 then signals channel end, device end, and status modifier to the channel. The status modifier condition in the ending status byte causes the channel to skip the next command (TIC) and chain to the Write Data command.

Search Key Equal



TIC

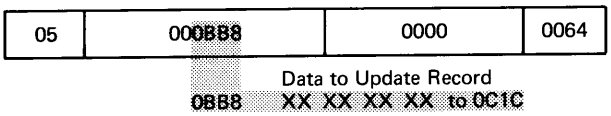


X = Positions Ignored

25517

The Write Data command then writes 64 (100_{10}) bytes of data into Frank Smith's payroll record from main storage locations 0BB8 to 0C1C.

Write Data



25518

If Frank Smith's payroll record had not been on track 0C, or some other programming error had been made which resulted in not satisfying the Search Key Equal, the program would loop between the Search Key Equal and the TIC until every key on the track had been searched (index passed twice). The 2820 would then signal unit check to the channel. A subsequent Sense command would indicate no record found.

Example 3: Find and read Joe Brown's insurance policy number. Assumed:

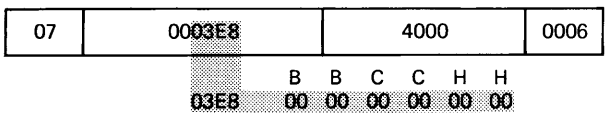
1. The physical address of the record containing the policy number is unknown.
2. The drum is organized by ID -- no key areas.
3. Joe Brown's ID is 12345.
4. The data length of his record is 64 (100_{10}) bytes.
5. His policy number is in the data area.

The channel program used is:

Seek
Read Home Address
Search ID Equal
TIC*-8
Read Data

Summary of Example 3: Since the physical address of Joe Brown's record is not known, each record of each track must be searched until the record is located. The first command in this channel program is a Seek to begin the search on the first track on the drum.

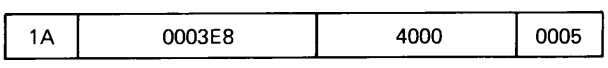
Seek



25519

To ensure that every record on track 00 is searched, a Read Home Address command is executed to orient the program to the index. The data in the home address area is not significant to the program; so the skip flag (bit 35) is turned on in the Read HA CCW. This allows the data in the home address area to be read by the channel, but not transferred to main storage.

Read Home Address



25522

Since the drum is organized by ID areas, a Search ID Equal command (using Joe Brown's ID in the search argument) is executed. Also, Joe Brown's record may not be on track 00 so the MTM bit is placed on in the Search ID Equal command. This causes the track address to be incremented by one each time index is passed. Each track is searched until the Search ID Equal is satisfied or until the track address is incremented from 199 to 200.

All unequal comparisons of ID's cause the 2820 to signal channel end and device end to the channel, and the TIC command (back to Search ID Equal) is executed. When an equal comparison is encountered, the 2820 signals channel end, device end, and status modifier to the channel. The status modifier causes the next command (TIC) to be skipped, and the Read Data command is executed.

Search ID Equal

31	0005DC	4000	0005

ID number
05DC F1 F2 F3 F4 F5

TIC

X8		XXXX	XXXX

Address of Search ID Equal

X = Positions Ignored

25520

Execution of the Read Data command causes the data area containing Joe Brown's insurance policy number, to be read into main storage locations 0BB8 to 0C1C.

If the Search ID Equal is not satisfied, and the track address has incremented to 200, unit check is set in the status byte. A subsequent Sense command would indicate end of cylinder.

Read Data

06	000BB8	0000	015E

Insurance Policy Number
0BB8 XX XX XX XX to 0D1C

25521

RESETS

System Reset

A System/360 reset occurs when:

1. The system reset key is pressed.
2. Initial program loading is performed.
3. Power is brought up on the system.

A system reset stops all channel operations, resets all channel status and interrupt conditions, and sends the system reset signal to all control units attached to the channels. Any control currently communicating over the I/O interface is immediately disconnected from the channel. Data transfer and other operations using the control are terminated.

All status information in the control unit is reset.

Malfunction Reset

A malfunction reset is performed when the channel detects malfunctioning equipment and sends the malfunction reset signal to the selected control.

When the channel signals malfunction reset over the I/O interface to a control, the control immediately disconnects from the channel. All status information and the file mask in the control are reset, and all other effects are the same as a system reset.

After an equipment malfunction has been corrected, all controls and drums are available for new operations as directed by the channel.

OPERATOR CONTROLS AND INDICATORS

The operator's panel contains the usage meter, an on/off toggle switch, and four indicators (Figure 19).

Usage Meter: Records actual process time of the 2820.

On/Off Switch: Enables (on) or disables (off) communication between the 2820 and the CPU. This switch also enables or disables the usage meter.

DC On Indicator: Indicates that dc power is on.

AC On Indicator: Indicates that ac power is on.

Power On File Indicator: Indicates that power is available to the attached drum storages and that 2301 power on sequencing has been completed.

Circuit Breaker/Thermal Indicator (CB/TH): When lit, indicates that a circuit breaker has tripped or been turned off, or that the logic gate temperature has exceeded 134° F.

During normal operation, AC ON, DC ON, and POWER ON FILE indicators will be lit, and the CB/TH indicator will be dark (off). If these conditions are not observed on the panel, notify a customer engineer.

A customer engineer should also be notified if:

1. Five minutes after a power on sequence has been initiated, AC ON and DC ON are lit and POWER ON FILE is still off.
2. Thirty seconds after a power off sequence is started, DC ON and POWER ON FILE are lit and AC ON is off.

Power Transitions

If power on or power off sequences are performed on the SCU when other devices are attached to the channel used by the SCU, the other devices should be in the stopped state. If the devices are in the run mode, they can cause errors in the channel.

Usage Meter

When a power on sequence occurs, the present setting of the enable switch determines whether meter time is to be recorded (enable switch on) and operations are to be allowed with the 2820.

The usage meter and the 2820 are disabled from the channel if the following conditions exist simultaneously:

- The enable switch is in the off position.
- The CPU is in the stop or wait state.
- The 2820 is not performing an operation.
- Command chaining is not in effect.
- The channel selection switch in the 2820 must not be selected to that channel (two-channel switch).
- There must not be any status pending (unit check or interrupt causing status).

The usage meter can then be enabled if:

- The CPU is in the stop or wait state.
- The enable switch is in the on position.

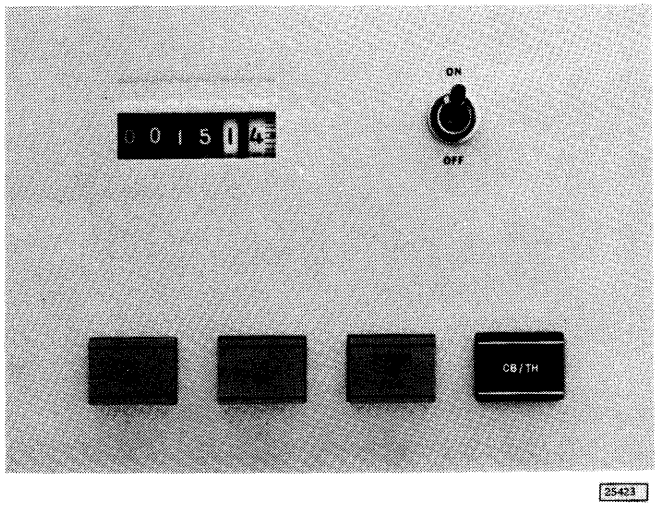


Figure 19. IBM 2820 Operator Panel

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SPECIAL FEATURES

TWO-CHANNEL SWITCH

The two-channel switch special feature permits operation of the 2820 and attached 2301's to be controlled from either one of two selector channels. The two channels can be on the same or separate processing units. The switching of the 2820/2301's to either channel and the reservation of a 2301 to either channel are under program control. Connection to a channel is also under manual control, through use of the usage meter enable/disable switch.

Channel Selection Switch

The program-controlled channel selection switch has three positions:

- Neutral.
- Channel A.
- Channel B.

When the switch is in the neutral position, selection of the 2820 is determined by the channel which first requests it. In the event of a tie, channel A obtains service first.

When the switch is in channel A position, it remains in that position until ending status is presented. At that time, the switch returns to neutral unless:

1. The channel indicates command chaining.
2. The last command received by the 2820 is a formatting write. In this case, return to neutral is delayed until index point is sensed.
3. The last status byte contained unit check, and no command other than Test I/O or No-Op has been initiated.

If Channel A attempts an initial selection sequence to the 2820 while the switch is in the channel B position, control unit busy (busy bit plus status modifier bit) is sent to channel A. The control unit busy indication can occur for any initial selection sequence (IPL, Test I/O, and all initial commands of a chain).

If control unit busy is issued, a control unit end interruption is sent to the channel that received the control unit busy status when the switch returns to the neutral position.

Note that when control unit end is issued, the address byte associated with it is the base address of the 2820 on the channel to which this status is directed. This status does not cause the 2820 to appear busy to the other channel.

Considerations applied to channel A also apply to Channel B.

Two-Channel Switch Commands

Two switching commands are used with the 2820: Device Reserve and Device Release. Both commands are used only with the two-channel switch special feature. Without the two-channel switch special feature, Device Reserve and Release commands are rejected by the 2820, and the unit check bit in the CSW status byte is set. The command reject bit in sense byte 0 is set to indicate what caused the unit check condition.

The Device Reserve and Device Release commands address a particular 2301 attached to a 2820. There is no provision for reserving the entire 2820 and all attached 2301's by a single command.

Device Reserve

The Device Reserve command causes the addressed 2301 to be reserved to the channel that issues the command. If the Device Reserve command is preceded by a Set File Mask command in the same chain, the Reserve command is rejected. Unit check status and invalid sequence sense indicate the rejection.

Device Reserve Command Code		
Decimal	Hexadecimal	Binary
180	B4	1011 0100

11320

After a device is reserved to a channel, it remains reserved until:

1. The reserving channel issues a Device Release command to the reserved device.
2. A system or malfunction reset occurs on the reserving channel.

In addition to reserving a particular device, the Device Reserve command performs the functions of a normal sense command (causes the six sense bytes to be presented to the channel). See Sense I/O command for additional information.

Device Release

The Device Release command causes the reservation of the addressed device to be terminated. If the Device Release command is preceded by a Set File Mask command in the same chain, the Release command is rejected. Unit check status and invalid sequence sense indicate the rejection.

Device Release Command Code		
Decimal	Hexadecimal	Binary
148	94	1001 0100

11321

In addition to releasing a particular device, the Device Release command performs the functions of a normal sense command. However, if a Sense I/O command is issued after a unit check is detected:

1. The sense bytes are not reset.
2. The channel selection switch is placed in the neutral position.

This allows the other channel to operate with any nonreserved 2301. If the 2820 is busy, the sense command is rejected.

Response to Channels

Control unit busy is returned to a channel during an initial selection sequence if any one of the following conditions exist.

1. The 2820 is erasing to index point after a formatting write operation.
2. The 2820 was disconnected from the channel by a Halt I/O instruction, but the logical end of the operation has not been reached.
3. The 2820 is connected to the other channel, or the other channel is resetting the 2820.

If a device is reserved to channel A, and a command is issued to the reserved device by channel B, busy status is sent to channel B. When the reservation is terminated, a device end interruption is sent to channel B.

If a channel stacks device end or control unit end that was the result of a 2820 initiated interruption, the channel selection switch returns to neutral.

A stacked control unit end does not inhibit operation with the other channel. However, the channel to which the control unit end interruption is presented must accept that interruption before it can issue any command (other than Sense or Test I/O) to the 2820.

Considerations applied to channel A also apply to channel B.

Resets with Two-Channel Switch

A system reset can be initiated by either channel at any time. A system reset causes all reservations and status of the 2820 related to the resetting channel to be reset. Reservations, operations, and status conditions concerning the other channel are not affected.

Both channels can initiate resets at the same time. If a channel initiates a reset when the channel selection switch is not in the other channel position, the 2820 is also reset. A malfunction reset ("see Malfunction Reset") has the same effect as a system reset.

If channel A is disabled from the 2820, the 2820 is automatically reset by channel A whenever channel B completes a command chain. Therefore, any seek address used for a chain is reset to all 0's at the completion of the chain. However, the track address is not reset in the 2301. Therefore, the track addressed in a subsequent chain will be the track used in the previous chain unless another seek command is issued in the new chain.

Enable Switches

A separate usage meter enable switch is provided for each channel connection to the 2820. The operation and function of the switches is the same as described for single channel operation. The prerequisites for disabling and enabling channel connections are listed in the "Usage Meter" section of this manual.

Power Control with Two Channel Switch

A power indication from either channel causes power to be turned on at the 2820. Power can be turned off:

1. If power off indications occur on both channels.
2. If the emergency pull switch associated with either CPU is pulled and a multisystem emergency power off (EPO) control is installed.

REMOTE SWITCH ATTACHMENT

This feature is used to place the enable switches of a 2820 in an IBM 2167 Configuration Unit, or in an IBM System/360 Model 65 multiprocessor configuration control panel.

When the configuration unit or panel is used, the enable switches are removed from the 2820 and are replaced, in function, by those on the configuration unit or panel.

The two-channel switch special feature is a prerequisite to the remote switch attachment feature.

STORAGE PRIORITY

The storage priority feature is required when the high speed direct access storage priority (HSDASP) feature is used on an IBM 2860 Selector Channel attached to an IBM System/360 Model 67. Only one set of these features (HSDASP and storage priority) can be installed on a 2860 Selector Channel. An IBM 2846 Channel Controller must be installed concurrently with these features.

When the storage priority feature is installed, the system ignores storage requests from other I/O devices during 2301 read or write operations. Other requests are ignored until the data (or key) area of the addressed record has been transferred to or from the channel. Use of this feature therefore eliminates service overrun in 2820/2301 operations.

INTRODUCTION

The IBM 2301 Drum Storage (Figure 20) is used in conjunction with the IBM 2820 Storage Control Unit to provide large capacity, direct access storage for IBM System/360 Models 65, 67, 75, or 85. Each 2301 is capable of storing 4,096,600 eight-bit bytes of data on 200 addressable tracks of the drum. One, two, three, or four 2301 Drum Storage devices can be attached to each 2820 on the system.

The nominal data transfer rate between the 2820 and the 2301 is 1.2 million bytes per second. Records on the drum can be accessed in an average time of 8.6 milliseconds.

The IBM 2820 Storage Control Unit controls the 2301 Drum Storage and provides the required functional link between the drum and the system it services. Instructions and channel commands governing the operation of the two units, as well as the data and track formats of the 2301, are compatible with other IBM Storage Controls and storage devices (IBM 2841 Storage Control Unit, IBM 2314 Direct Access Storage Facility, IBM 2311 Disk Storage, IBM 2303 Drum Storage, etc.). In normal operation, power on and power off sequencing for the 2301 are initiated by the 2820.

GENERAL DESCRIPTION

The 2301 drum is a vertically mounted metal cylinder that rotates at approximately 3,500 revolutions per minute. Data is stored in the form of magnetic spots on the surface of the drum. Reading or writing of data is accomplished through the use of fixed magnetic heads which float aerodynamically on a thin film of air close to the drum surface.

The drum surface under each read/write head is called a track. There are a total of 200 addressable tracks (0-199) around the drum cylinder. Each addressable track is comprised of four physical tracks for a total of 800 data tracks. Four data tracks are written or read simultaneously on or from the drum. Each data track has its own read/write head; therefore no access motion is required by the heads to locate a specific track on the drum. The drum read or write operation must wait until the addressed area of the track passes under the read/write heads before data transfer can occur. This waiting time is known as "rotational delay time" and can vary from 0 to 17.5 milliseconds.

The beginning of each track (index point) is indicated by a magnetic slug that is mechanically attached to the drum. All tracks are referenced by the same index point.

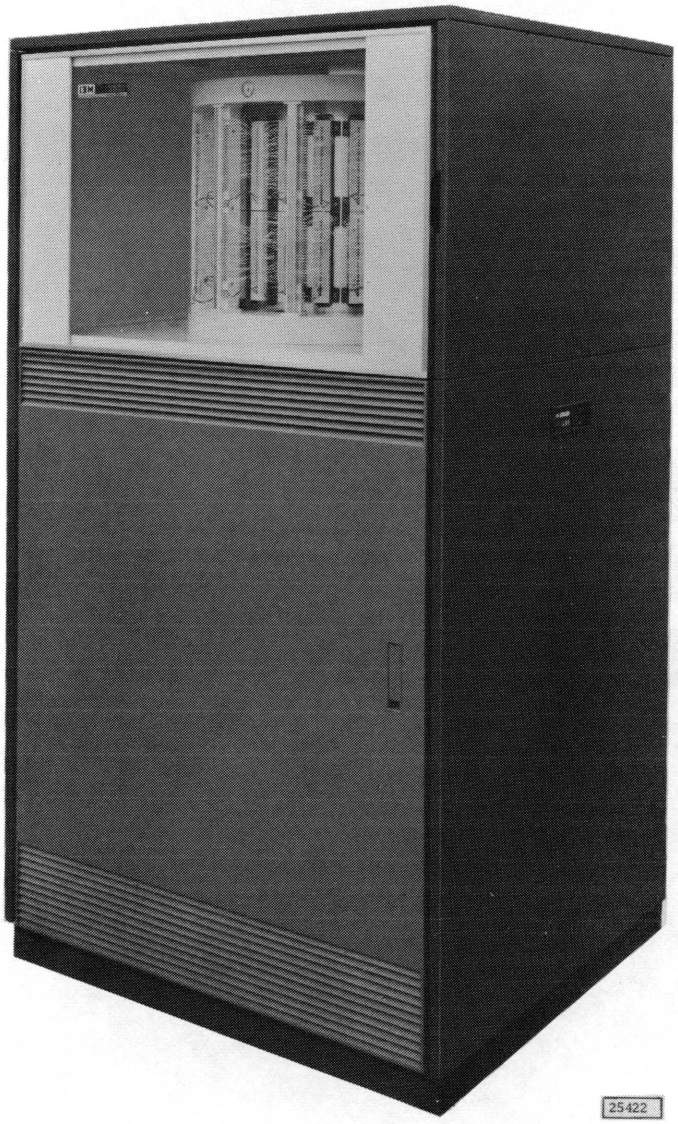

Figure 20. IBM 2301 Drum Storage

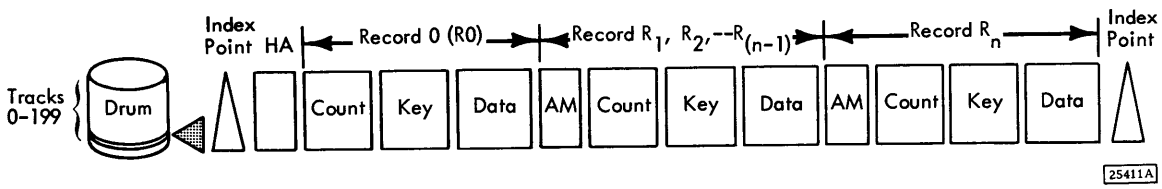

Figure 21. IBM 2301 Track Format

Data Record Addressing

Each of the 200 addressable tracks on the drum is assigned a binary address within 0000 0000 to 1100 0111 (decimal 0-199). Individual records on a track are assigned an address which is contained in the count field of the particular record. The length of the individual records on a track is variable and is defined in the key and data length fields of the count area of the record.

During the writing of data, an overflow capability can be used. This facility allows writing to continue onto the next sequential track if a record is not completed when the track ends (index point is reached). When overflow is used, the maximum length of a data record is restricted by the maximum binary value that can be expressed in the data length bytes of the count field (65,535 bytes).

Track Format

Data is stored on the 2301 Drum Storage in the format defined by the 2820 Storage Control (Figure 21). The data format, instruction set, and permissible instruction sequences are as compatible as possible with devices that attach to the 2841 Storage Control.

Capacity

IBM Programming Systems reserve the use of the first record on the track (record 0) to store various information about the track. This information is used by the programming system, and no application data is included. Use of this format allows each track to contain 20,483 data bytes. If a key field is used, the maximum number of data bytes is reduced to 20,430 data bytes per track.

The maximum data capacity of a 2301 is 4,096,600 bytes or 8,193,200 packed decimal digits and signs. Methods for determining track capacity under selected conditions are explained in Appendix C.

Alternate Tracks

With the high-density recording techniques used in the 2301, minute contamination particles can affect data reading and writing. Therefore, spare tracks are provided to ensure that the stated capacity, based on 200 addressable tracks, is maintained. If a defect is encountered on a track, the entire track is disabled by the customer engineer and a spare track is substituted. This spare track is assigned the address of the original disabled track.

Enable/Disable Switch

When the CPU is in the stopped or wait state, this switch enables or disables communication of the 2301 with the 2820. It also enables or disables the usage meter on the 2301.

If the CPU is running when the switch setting is changed, the operating status of the 2301 is not changed.

APPENDIX A. SUGGESTED ERROR RECOVERY PROCEDURES

Priority	Condition	CSW Bit	Sense		Action requirement
			Byte	Bit	
1	Channel control check	45			3A
2	Interface control check	46			3A
3	Channel data check	44			3B
4	Should not occur	32			2
5	Unit check	38			8
6	Should not occur		0	6	2
7	Equipment check		0	3	6
8	No record found		1	4	11
9	Invalid address		0	7	10
10	Intervention required		0	1	9
11	Bus out check		0	2	6
12	Data check		0	4	5
13	Overrun		0	5	7
14	Command reject		0	0	4
15	Track overrun		1	1	4
16	End of cylinder		1	2	12
17	File protect		1	5	13
18	Overflow incomplete		1	7	14
19	Chaining check	47			7
20	Program check	42			4
21	Protection check	43			4
22	Unit exception	39			15
23	Incorrect length	41			4
**	Status modifier	33			
**	Control unit end	34			
**	Busy	35			
**	Channel end	36			
**	Device end	37			
**	Program controlled interruption	40			

Note: ** indicates normal conditions and no priority is assigned to them.

Note: Indications listed in this table must be checked in sequence until the cause of the error condition is found. If bit 38 is not present in the CSW, it is not necessary to issue a Sense command or to check the sense information.

Action Procedure

1. If an additional recovery procedure is available, exit to it. If an additional recovery procedure is not available or fails, consider the drum to be inoperative, provide an operator message and exit.
2. If an additional recovery procedure is available, exit to it. If an additional recovery procedure is not available or fails, consider the control to be inoperative, provide an operator message and exit.
3. If an additional recovery procedure is available, exit to it. If an additional recovery procedure is not available or fails, consider the channel to be inoperative, provide an operator message and exit.

3A Channel Control Check of Interface control check in system with Automatic System Recovery (ASR) use action procedure 10. If system does not have ASR then take action 3.

3B Channel Data Check with ASR use action procedure 5.

4. If an additional recovery procedure is available, exit to it. If an additional recovery procedure is not available or fails, consider the program to be unreliable, provide an operator message and exit.
5. Retry the chain of commands from the last restart point 255 times. On the 256th occurrence of the error condition, provide an operator message and perform action 1.
6. Retry the chain of commands from the last restart point once. On the second occurrence, of the error condition, provide an operator message to indicate that there has been an uncorrectable error. Then if the condition indicated was equipment check, perform action 1; if the condition indicated was bus out check, perform action 2.
7. Retry the chain of commands from the last restart point 5 times. On the sixth occurrence of the error condition, provide an operator message and perform action 4.
8. Issue a Sense command and continue with the checks indicated in the table.
9. Provide an operator message and perform action 1.
10. Issue a Recalibrate command and retry chain of commands from last restart point five times. If error condition persists at the 6th retry, issue message and perform action 1.
11. Read Home Address of track in question and verify that the Seek was correct. If Seek correct take action 10; if not take action 1. (This procedure is aimed primarily at disks with mechanically driven arms).
12. Update seek address to next cylinder and head 0, restart channel program.
13. If write file protect violated or (07) seek, perform action 4. If multi-track command or Head/Cylinder seek being performed, update seek address and restart users channel program.
14. Appropriately restart user on next "logical" segment of overflow record. (e.g. alternate track if overflow incomplete concurrent with track condition check).
15. Treat as end of data set or end of extent of current segment of data set.

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PRINTOUT MESSAGE

The following messages should be included in the operating program structure of all 2820 user programs.

Message 1

This message should be printed out for all errors considered to be hard or uncorrectable:

1. Message code.
2. Type of error: read, write, or control.
3. Channel designation.
4. Device addressed and the actual seek address.
5. Status and sense bytes sent to CPU.

Message 2

This message should be printed after the completion of a job or on request of the operator:

1. Device used.
2. Number of entries into error routines.
3. Number of uncorrectable errors.

APPENDIX B. SENSE BYTES AND STATUS BYTE

Sense Byte Table		
Sense Byte and Condition	Cause	Additional Indications
Byte 0, Bit 0 Command Reject	1. Invalid command code.	None
	2. Invalid seek address.	Byte 0, Bit 7
	3. A second Set File Mask command was issued in the same chain.	Byte 1, Bit 3
	4. The write portion of the file mask has been violated.	Byte 1, Bit 5
	5. A Write command has not been preceded by the necessary Write or Search command.	Byte 1. Bit 3
	6. The seek address is less than six bytes long.	Byte 0, Bit 7
	7. Bytes 0 through 4 of the seek address are not zero.	Byte 0, Bit 7
Byte 0, Bit 1 Intervention Required	1. The 2301 specified by the command is not attached to the system.	None
	2. The 2301 specified by the command is not ready.	None
Byte 0, Bit 2 Bus Out Parity	1. The 2820 has detected bad parity in data transferred from the CPU.	None
Byte 0, Bit 3 Equipment Check	1. The 2820 has detected a malfunction in a drum storage unit.	Byte 2, Bit 0
	2. The 2820 has detected bad parity in the check burst generation.	Byte 2, Bit 1
	3. The 2820 has detected excessive skew in the four physical tracks of the addressed track.	Byte 2, Bit 2
	4. The 2820 has detected bad parity in the 2820 counter circuits.	Byte 2, Bit 3
	5. The 2820 has detected a discrepancy in the search compare circuits.	Byte 2, Bit 4
	6. The 2820 has detected the failure to execute a step in the execution of a command.	Byte 4
Byte 0, Bit 4 Data Check	1. A data check has been detected by the 2820 in the data area, key area, or home address area received from the selected 2301.	None
	2. A data error has been detected in the count area received from the selected 2301.	Byte 1, Bit 0
Byte 0, Bit 5 Overrun	1. The command was received too late to act upon the drum area specified by the command.	None
	2. The 2820 received a byte from the drum before the last byte read has been accepted by the channel.	Byte 1, Bit 6
	3. A data byte was received too late from the channel during a write operation.	Byte 1, Bit 6
Byte 0, Bit 6	1. Not used.	
Byte 0, Bit 7 Invalid Address	1. Track address specified by a Seek command was greater than 199 (decimal).	Byte 0, Bit 0
	2. Track address specified by a Seek command does not contain zeros in the five high order bytes of the address.	Byte 0, Bit 0
	3. Track address specified by a Seek command is less than six bytes long.	Byte 0, Bit 0
Byte 1, Bit 0 Data Check in Count Field	1. The 2820 has detected an error in the count field of the addressed record.	Byte 0, Bit 4
Byte 1, Bit 1 Track Overrun	1. During a read or write operation an attempt was made to exceed the track capacity.	None
Byte 1, Bit 2 End of Cylinder	1. The end of drum was detected during a read or search in multiple track mode.	None
	2. The end of drum was detected during a read or non-formatting write operation for an overflow record on the last track.	Byte 1, Bit 7
Byte 1, Bit 3 Invalid Sequence	1. A Write command was not preceded by the necessary Write or Search command.	Byte 0, Bit 0
	2. A second Set File Mask was issued in the same chain.	Byte 0, Bit 0

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Sense Byte Table		
Sense Byte and Condition	Cause	Additional Indications
(continued) Byte 1, Bit 3 Invalid Sequence	3. An attempt was made to update the track address by use of the MTM bit, or an overflow record and the command attempted was not preceded by a Seek or Cylinder Seek in the chain.	Byte 1, Bit 7 Byte 0, Bit 0
Byte 1, Bit 4 No Record Found	1. The record called for in a search operation was not found and the following conditions were satisfied during the operation. Continuous command chaining was being performed. A search was made of every record on the track. No change in track address occurred. The index point was sensed twice. No data fields of any record on the track were read or written between the two index points.	None
	2. A Search Home Address Equal resulted in an unequal comparison.	None
	3. The 2820 was unable to begin execution of the command within two drum revolutions.	None
Byte 1, Bit 5 File Protect	1. A Read or Search command with the MTM bit on violated the seek mask in the current file mask.	Byte 1, Bit 7
	2. A Seek operation violated the seek mask in the current file mask.	None
	3. A Write operation violated the file mask.	Byte 0, Bit 0
	4. A read or non-formatting write operation on an overflow record violated the seek mask in the current file mask.	Byte 1, Bit 5 (See sense byte five)
Byte 1, Bit 6 Service Overrun	1. The 2820 did not receive channel service in time to handle a data byte.	Byte 0, Bit 5
Byte 1, Bit 7 Overflow Incomplete	1. A Read or non-formatting Write command violated the seek mask in the current file mask while attempting to operate on an overflow record.	Byte 1, Bit 5 (See sense byte five)
	2. An attempt has been made to perform a Read or non-formatting Write command on an overflow record on the last track.	Byte 1, Bit 2 (See sense byte five)
	3. An attempt has been made to update the track address due to an overflow record, and a Seek or Cylinder Seek has not been issued in the chain.	Byte 0, Bit 0 Byte 1, Bit 3 (See sense byte five)
Byte 2, Byte 3, Byte 4	1. Information is sense bytes 2, 3, and 4 is used in diagnostic routines run by the Customer Engineer. Setting any significant bit in these bytes also causes a data check (byte 0, bit 4) or an equipment check (byte 0, bit 3).	Byte 0, Bit 3 Byte 0, Bit 4
Byte 5, Bit 0	1. Not used.	
Byte 5, Bit 1	1. Not used.	
Byte 5, Bit 2	1. Not used.	
Byte 5, Bit 3	1. Not used.	
Byte 5, Bit 4	1. Not used.	
Byte 5, Bits 5 through 7	1. These bits will contain the command code of the operation in progress when an overflow incomplete occurred.	
Note: All sense bits in bytes 0, 1, 2, and 3 cause a unit check to appear in the status byte.		

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Status Byte		
Status Bit and Indication	CSW Bit	Cause
Bit 0, Attention	32	1. Not used.
Bit 1, Status Modifier	33	1. Successful termination of a search operation.
		2. Control unit busy during an initial status cycle.
Bit 2, Control Unit End	34	1. The 2820 is available for use and the program caused the 2820 to be interrogated while executing an operation.
		2. The 2820 is available for use and has detected an unusual condition during part of the operation after channel end and device end have been signaled to the channel.
Bit 3, Busy	35	1. The selected 2301 is busy.
		2. The 2820 is busy.
Bit 4, Channel End	36	1. Transfer of data or control information between the 2820 and channel has been completed.
Bit 5, Device End	37	1. The 2301 has completed the designated function and is available for the next operation.
Bit 6, Unit Check	38	1. The conditions causing unit check are detailed by information available to the Sense command. (See Sense Byte Table)
Bit 7, Unit Exception	39	1. A zero data length has been detected on a Read IPL, Read R0, Read CKD, Read KD, Read Data, Write KD, Write Data, or a Search KD operation. (A zero data length record is used to indicate end-of-file).

25420.2A

The following formula is used to calculate the number of records without a key field that may be placed on a track:

$$N = \frac{20,624 - LO}{L + 133}$$

To calculate the number of records with a key field that may be placed on a track, use the formula

$$N = \frac{20,624 - LO}{L + 186} ,$$

where:

N = Number of records that can be placed on a track.

LO = Length of data field in R0 if there is no key field in it, or length of data and key fields + 53 if there is a key field in it.

L = Length of record (sum of key and data fields in the record).

The figure 20,624 is arrived at by subtracting the number of bytes to be allowed for index, home address area, and record zero (total of 232 bytes), from the capacity of the track before formatting (20,856 bytes).

The figure 133 is the factor allowed for one record without a key field.

The figure 186 is the factor allowed for one record with a key field.

When record 0 is used as specified by IBM programming systems, the maximum number of data bytes that can be placed on a track by using one record without a key field is 20,483; the maximum number by using one record with a key field is 20,430. The maximum data capacity of a 2301 is 4,096,600 data bytes.

There is no restriction that all records on a track must be the same length.

Use of programming systems developed and supported by IBM must be assumed when the following formulas are used to determine capacity and transmission times. The formulas are:

1. Bytes per record, except last record on a track: 186 - C + (KL + DL).
2. Bytes per record, last record on track only: 53 - C + (KL + DL).
3. Capacity (in bytes) per track: 20,483.
4. Records per track:

$$\left[\frac{20,483 - [53 - C + (KL + DL)]}{186 - C + (KL + DL)}\right]^{*} + 1 .$$

*Drop any decimals.

5. Data rate (in ms per byte): 0.0008333.
6. Transmission time (in ms per record): [data bytes (KL + DL) per record] x (data rate).

In the preceding formulas:

DL = data length
KL = key length
C = 0 when KL $\neq$ 0.
C = 53 when KL = 0.

Capacity and transmission time for records with keys are shown in Table 1; without keys in Table 2. In the following examples, a record is considered to be information recorded between two gaps.

Example 1: Determine the effect of the record length on the number of records that can be stored on a drum.

Assuming a record length of 272 to 279 bytes (without keys) is required, 50 records can be placed on each track (Table 2). Reducing the record length below 272 bytes permits 51 records per track, an increase of 200 records per drum. Increasing the record length over 279 bytes permits only 49 records per track, a decrease of 200 records per drum.

Example 2: Determine read/write time.

Assume that the key length is equal to zero and the data length is 80 bytes. Table 2 indicates that 96 records can be stored on each track if a blocking factor of 1 (a gap after each 80-byte record) is used. Table 2 also shows a transmission time of 0.07 ms per record. Average read/write time is the sum of the average rotational delay time (8.6 ms) and the

Table 1. Capacity and Transmission Time for Records with Keys

Bytes per Record		Records per		Transmission Time in ms per Record		Bytes per Record		Records per		Transmission Time in ms per Record		Bytes per Record		Records per		Transmission Time in ms per Record	
Min	Max	Track	Module	Min	Max	Min	Max	Track	Module	Min	Max	Min	Max	Track	Module	Min	Max
10123	20430	1	200	8.44	17.02	372	386	36	7200	0.31	0.32	101	104	71	14200	0.08	0.09
6687	10122	2	400	5.57	8.43	357	371	37	7400	0.30	0.31	97	100	72	14400	0.08	0.08
4969	6686	3	600	4.14	5.57	343	356	38	7600	0.29	0.30	93	96	73	14600	0.08	0.08
3938	4968	4	800	3.28	4.14	330	342	39	7800	0.27	0.28	89	92	74	14800	0.07	0.08
3251	3937	5	1000	2.71	3.28	317	329	40	8000	0.26	0.27	86	88	75	15000	0.07	0.07
2760	3250	6	1200	2.30	2.71	305	316	41	8200	0.25	0.26	82	85	76	15200	0.07	0.07
2392	2759	7	1400	1.99	2.30	294	304	42	8400	0.24	0.25	79	81	77	15400	0.07	0.07
2105	2391	8	1600	1.75	1.99	283	293	43	8600	0.24	0.24	75	78	78	15600	0.06	0.06
1876	2104	9	1800	1.56	1.75	273	282	44	8800	0.23	0.23	72	74	79	15800	0.06	0.06
1689	1875	10	2000	1.41	1.56	263	272	45	9000	0.22	0.23	69	71	80	16000	0.06	0.06
1533	1688	11	2200	1.28	1.41	253	262	46	9200	0.21	0.22	66	68	81	16200	0.05	0.06
1400	1532	12	2400	1.17	1.28	244	252	47	9400	0.20	0.21	63	65	82	16400	0.05	0.05
1287	1399	13	2600	1.07	1.17	235	243	48	9600	0.20	0.20	60	62	83	16600	0.05	0.05
1189	1286	14	2800	0.99	1.07	227	234	49	9800	0.19	0.19	57	59	84	16800	0.05	0.05
1103	1188	15	3000	0.92	0.99	219	226	50	10000	0.18	0.19	54	56	85	17000	0.04	0.05
1027	1102	16	3200	0.86	0.92	211	218	51	10200	0.18	0.18	51	53	86	17200	0.04	0.04
960	1026	17	3400	0.80	0.85	203	210	52	10400	0.17	0.17	49	50	87	17400	0.04	0.04
900	959	18	3600	0.75	0.80	196	202	53	10600	0.16	0.17	46	48	88	17600	0.04	0.04
845	899	19	3800	0.70	0.75	189	195	54	10800	0.16	0.16	44	45	89	17800	0.04	0.04
796	844	20	4000	0.66	0.70	183	188	55	11000	0.15	0.16	41	43	90	18000	0.03	0.04
752	795	21	4200	0.63	0.66	176	182	56	11200	0.15	0.15	39	40	91	18200	0.03	0.03
711	751	22	4400	0.59	0.63	170	175	57	11400	0.14	0.15	36	38	92	18400	0.03	0.03
674	710	23	4600	0.56	0.59	164	169	58	11600	0.14	0.14	34	35	93	18600	0.03	0.03
639	673	24	4800	0.53	0.56	158	163	59	11800	0.13	0.14	32	33	94	18800	0.03	0.03
607	638	25	5000	0.51	0.53	152	157	60	12000	0.13	0.13	29	31	95	19000	0.02	0.03
578	606	26	5200	0.48	0.50	147	151	61	12200	0.12	0.13	27	28	96	19200	0.02	0.02
551	577	27	5400	0.46	0.48	142	146	62	12400	0.12	0.12	25	26	97	19400	0.02	0.02
525	550	28	5600	0.44	0.46	137	141	63	12600	0.11	0.12	23	24	98	19600	0.02	0.02
502	524	29	5800	0.42	0.44	132	136	64	12800	0.11	0.11	21	22	99	19800	0.02	0.02
480	501	30	6000	0.40	0.42	127	131	65	13000	0.11	0.11	19	20	100	20000	0.02	0.02
459	479	31	6200	0.38	0.40	122	126	66	13200	0.10	0.10	17	18	101	20200	0.01	0.01
439	458	32	6400	0.37	0.38	118	121	67	13400	0.10	0.10	15	16	102	20400	0.01	0.01
421	438	33	6600	0.35	0.36	113	117	68	13600	0.09	0.10	13	14	103	20600	0.01	0.01
404	420	34	6800	0.34	0.35	109	112	69	13800	0.09	0.09	11	12	104	20800	0.01	0.01
387	403	35	7000	0.32	0.34	105	108	70	14000	0.09	0.09	9	10	105	21000	0.01	0.01
												7	8	106	21200	0.01	0.01
												5	6	107	21400	0.00	0.00

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record transmission time (0.07 ms) or for this example: 8.6 ms + 0.07 ms = 8.67 ms.

Example 3: effect of blocked records.

Assuming 960 storage locations available for a common input/output area, and a data length of 80 bytes, a maximum blocking factor of 12 can be established using 960-byte records. Table 2 indicates that 18 records of this length can be written on each track for a total of 216 80-byte logical records. The transmission time for each record (composed of 12 logical records) is 0.84 ms (without keys).

Table 2. Capacity and Transmission Time for Records without Keys

Bytes per Record		Records per		Transmission Time in ms per Record		Bytes per Record		Records per		Transmission Time in ms per Record		Bytes per Record		Records per		Transmission Time in ms per Record	
Min	Max	Track	Module	Min	Max	Min	Max	Track	Module	Min	Max	Min	Max	Track	Module	Min	Max
10176	20483	1	200	8.48	17.07	264	271	51	10200	0.22	0.23	70	71	101	20200	0.06	0.06
6740	10175	2	400	5.62	8.48	256	263	52	10400	0.21	0.22	68	69	102	20400	0.06	0.06
5022	6739	3	600	4.18	5.62	249	255	53	10600	0.21	0.21	66	67	103	20600	0.05	0.06
3991	5021	4	800	3.33	4.18	242	248	54	10800	0.20	0.21	64	65	104	20800	0.05	0.05
3304	3990	5	1000	2.75	3.32	236	241	55	11000	0.20	0.20	62	63	105	21000	0.05	0.05
2813	3303	6	1200	2.34	2.75	229	235	56	11200	0.19	0.20	60	61	106	21200	0.05	0.05
2445	2812	7	1400	2.04	2.34	223	228	57	11400	0.19	0.19	58	59	107	21400	0.05	0.05
2158	2444	8	1600	1.80	2.04	217	222	58	11600	0.18	0.18	57	57	108	21600	0.05	0.05
1929	2157	9	1800	1.61	1.80	211	216	59	11800	0.18	0.18	55	56	109	21800	0.05	0.05
1742	1928	10	2000	1.45	1.61	205	210	60	12000	0.17	0.17	53	54	110	22000	0.04	0.04
1586	1741	11	2200	1.32	1.45	200	204	61	12200	0.17	0.17	52	52	111	22200	0.04	0.04
1453	1585	12	2400	1.21	1.32	195	199	62	12400	0.16	0.17	50	51	112	22400	0.04	0.04
1340	1452	13	2600	1.12	1.21	190	194	63	12600	0.16	0.16	48	49	113	22600	0.04	0.04
1242	1339	14	2800	1.03	1.12	185	189	64	12800	0.15	0.16	47	47	114	22800	0.04	0.04
1156	1241	15	3000	0.96	1.03	180	184	65	13000	0.15	0.15	45	46	115	23000	0.04	0.04
1080	1155	16	3200	0.90	0.96	175	179	66	13200	0.15	0.15	44	44	116	23200	0.04	0.04
1013	1079	17	3400	0.84	0.90	171	174	67	13400	0.14	0.14	42	43	117	23400	0.03	0.04
953	1012	18	3600	0.79	0.84	166	170	68	13600	0.14	0.14	41	41	118	23600	0.03	0.03
898	952	19	3800	0.75	0.79	162	165	69	13800	0.13	0.14	39	40	119	23800	0.03	0.03
849	897	20	4000	0.71	0.75	158	161	70	14000	0.13	0.13	38	38	120	24000	0.03	0.03
805	848	21	4200	0.67	0.71	154	157	71	14200	0.13	0.13	36	37	121	24200	0.03	0.03
764	804	22	4400	0.64	0.67	150	153	72	14400	0.12	0.13	35	35	122	24400	0.03	0.03
727	763	23	4600	0.61	0.64	146	149	73	14600	0.12	0.12	34	34	123	24600	0.03	0.03
692	726	24	4800	0.58	0.60	142	145	74	14800	0.12	0.12	32	33	124	24800	0.03	0.03
660	691	25	5000	0.55	0.58	139	141	75	15000	0.12	0.12	31	31	125	25000	0.03	0.03
631	659	26	5200	0.53	0.55	135	138	76	15200	0.11	0.11	30	30	126	25200	0.02	0.02
604	630	27	5400	0.50	0.52	132	134	77	15400	0.11	0.11	29	29	127	25400	0.02	0.02
578	603	28	5600	0.48	0.50	128	131	78	15600	0.11	0.11	27	28	128	25600	0.02	0.02
555	577	29	5800	0.46	0.48	125	127	79	15800	0.10	0.11	26	26	129	25800	0.02	0.02
533	554	30	6000	0.44	0.46	122	124	80	16000	0.10	0.10	25	25	130	26000	0.02	0.02
512	532	31	6200	0.43	0.44	119	121	81	16200	0.10	0.10	24	24	131	26200	0.02	0.02
492	511	32	6400	0.41	0.43	116	118	82	16400	0.10	0.10	23	23	132	26400	0.02	0.02
474	491	33	6600	0.39	0.41	113	115	83	16600	0.09	0.10	21	22	133	26600	0.02	0.02
457	473	34	6800	0.38	0.39	110	112	84	16800	0.09	0.09	20	20	134	26800	0.02	0.02
440	456	35	7000	0.37	0.38	107	109	85	17000	0.09	0.09	19	19	135	27000	0.02	0.02
425	439	36	7200	0.35	0.37	104	106	86	17200	0.09	0.09	18	18	136	27200	0.01	0.01
410	424	37	7400	0.34	0.35	102	103	87	17400	0.08	0.09	17	17	137	27400	0.01	0.01
396	409	38	7600	0.33	0.34	99	101	88	17600	0.08	0.08	16	16	138	27600	0.01	0.01
383	395	39	7800	0.32	0.33	97	98	89	17800	0.08	0.08	15	15	139	27800	0.01	0.01
370	382	40	8000	0.31	0.32	94	96	90	18000	0.08	0.08	14	14	140	28000	0.01	0.01
358	369	41	8200	0.30	0.31	92	93	91	18200	0.08	0.08	13	13	141	28200	0.01	0.01
347	357	42	8400	0.29	0.30	89	91	92	18400	0.07	0.08	12	12	142	28400	0.01	0.01
336	346	43	8600	0.28	0.29	87	88	93	18600	0.07	0.07	11	11	143	28600	0.01	0.01
326	335	44	8800	0.27	0.28	85	86	94	18800	0.07	0.07	10	10	144	28800	0.01	0.01
316	325	45	9000	0.26	0.27	82	84	95	19000	0.07	0.07	9	9	145	29000	0.01	0.01
306	315	46	9200	0.25	0.26	80	81	96	19200	0.07	0.07	8	8	146	29200	0.01	0.01
297	305	47	9400	0.25	0.25	78	79	97	19400	0.06	0.07	7	7	147	29400	0.01	0.01
288	296	48	9600	0.24	0.25	76	77	98	19600	0.06	0.06	6	6	148	29600	0.00	0.00
280	287	49	9800	0.23	0.24	74	75	99	19800	0.06	0.06	5	5	149	29800	0.00	0.00
272	279	50	10000	0.23	0.23	72	73	100	20000	0.06	0.06						

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International Business Machines Corporation
Data Processing Division
112 East Post Road, White Plains, N.Y. 10601
[USA Only]

IBM World Trade Corporation
821 United Nations Plaza, New York, New York 10017
[International]