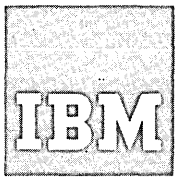
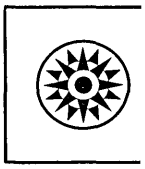
File No. S360-19
Form A26-1586-1



Systems Reference Library

IBM 2312/2313 Disk Storage
Original Equipment Manufacturers' Information

This manual provides the definitions and functional descriptions of the interface lines between the IBM 2312/2313 Disk Storage and the Control Unit. In addition, it contains electrical and cabling considerations, and specifications of this interface. It is assumed that the reader of this manual is engineering oriented and understands computer engineering techniques and terminology.



PREFACE

This document provides information of interest to designers and manufacturers of equipment to be attached to the IBM 2312/2313 Disk Storage. IBM's responsibilities resulting from such an attachment are defined in the Multiple Supplier System Bulletin, Form 120-6648.

Original equipment manufacturers are cautioned that specifications are subject to change by IBM. The data contained in this manual is current as of May 1969. Complete logic diagrams and maintenance manuals, at the latest engineering change level, are included with each machine shipment.

Reference Publications

The following manual is recommended as a reference:

IBM System/360 Component Description -- 2314 Direct Access Storage Facility and 2844 Auxiliary Storage Control, Form A26-3599

The manual pertains to the 2314 storage control, but contains a detailed description of programming commands, operating procedures, sense and status indicators, which may aid the non-IBM engineer.

Second Edition (July 1969)

This edition, A26-1586-1, is a major revision of A26-1586-0, which is now obsolete. An index has been added, metric equivalents and timing specifications have been corrected, and various editorial alterations have been made. Technical changes are indicated by a vertical line to the left of the change.

Significant changes or additions to the specifications contained in this publication are continually being made. Before 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.

The illustrations in this manual have a code number in the lower corner. This is a publishing control number and is not related to the subject matter.

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A form for reader's comments is provided at the back of this publication. If the form has been removed, send your comments to the address below.

This manual was prepared by the IBM Systems Development Division, Product Publications, Department G24, San Jose, California 95114.

This manual is intended to provide sufficient data to satisfy the special needs of equipment designers who wish to attach the IBM 2312/2313 Disk Storage to their equipment. It provides definitions and functional descriptions of the interface lines for the Disk Storage. It also contains specifications, timings, and cable information.

Note: Where a statement refers to "Disk Storage," it applies to both the 2312 and 2313.

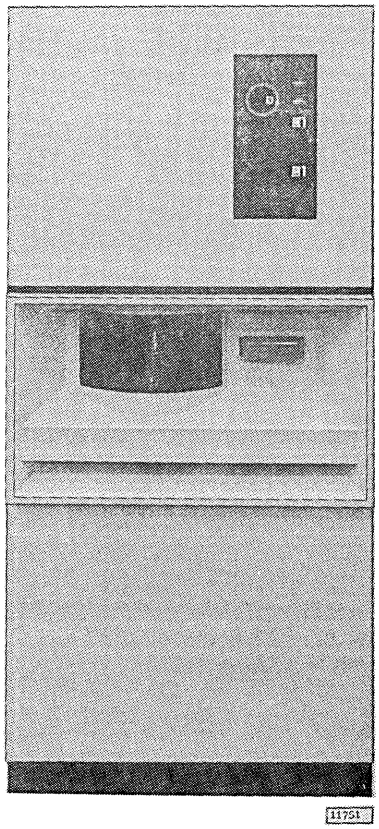
GENERAL DESCRIPTION

The IBM Disk Storage (Figure 1) is a random access storage device designed as a key component of a data processing system. It uses a removable and interchangeable IBM 2316 Disk Pack, which provides virtually unlimited off-line storage capacity. The Disk Storage is not a separate operational entity, but operates as a slave to a storage control unit (SCU), which in turn serves a central processing unit. This manual describes the standard production 2312 and 2313 units, which do not have metering facilities. Two models of disk storage are available: the 2312 and the 2313. The differences in the two models are:

- The 2312 contains a single disk module.
- The 2313 contains four disk modules.
- The 2312 contains one electronic gate.
- The 2313 contains two electronic gates. Each gate serves two modules.

Dimensions

The external dimensions and heat dissipation of the disk storage are given in Figure 2.



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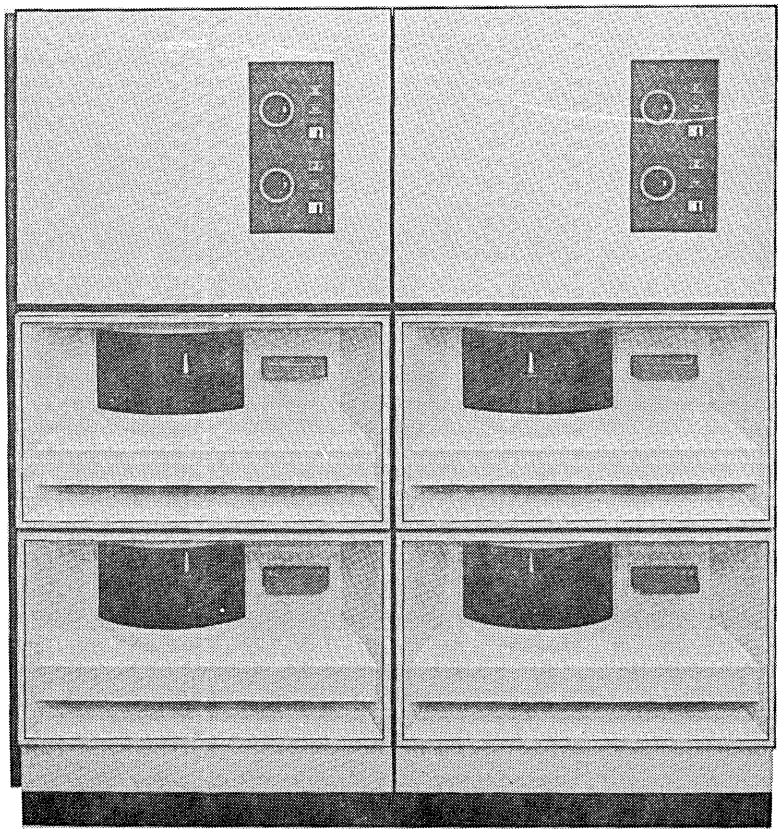

2313

Figure 1. IBM 2312/2313 Disk Storage

Unit	Length	Width	Height	Weight	BTU
2312	32"	28"	60"	500 lbs	2150
2313	32"	56"	60"	1375 lbs	8480

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Figure 2. Physical Dimensions

Safety

The 2312 and the 2313 Disk Storage units do not have Underwriters Laboratories (UL) approval except when part of a 2314 Direct Access Storage Facility.

The 2312 and 2313 Disk Storage are not stand-alone units.

DANGER
The 2312 and 2313 Disk Storage units must be bolted down. Either unit will tip over when the drawers are pulled out unless the units are secured. Until secured, do not pull out the disk storage drawers.

The disk storage consists of two main components: the IBM 2312 (or 2313) Disk Storage and the IBM 2316 Disk Pack.

DISK STORAGE MODULE

Access Mechanism

The access mechanism consists of a rack mounted movable carriage which supports 20 read/write heads. These heads are mounted on a common block and are placed in pairs, each pair lying between two disk surfaces of the disk pack. A hydraulic actuator moves the carriage and positions the read/write heads to any of 203 cylinders. When the disk pack is mounted in the disk storage module, information can be written or read from twenty disk surfaces. Once put in motion, the hydraulic actuator moves the recording mechanism horizontally to any one of the cylinder positions. After motion ceases, the drive sends a 'seek complete' signal to the control unit. At this time, the system selects the desired read/write head by electronic switching. In this manner, all records within a module can be located.

The module utilizes direct accessing between cylinder locations, which allows the access mechanism to proceed from any cylinder position to another without returning to home (reference) position.

The use of a comb-type access on a multi-disk module provides a cylinder of storage area at each of the physical settings of the access mechanism. The cylinder concept (Figure 3) may be visualized as cylinders or drums, one inside the other. Once the proper access location is made, any area in the cylinder is available in one revolution of the disk pack. One revolution requires 25 milliseconds.

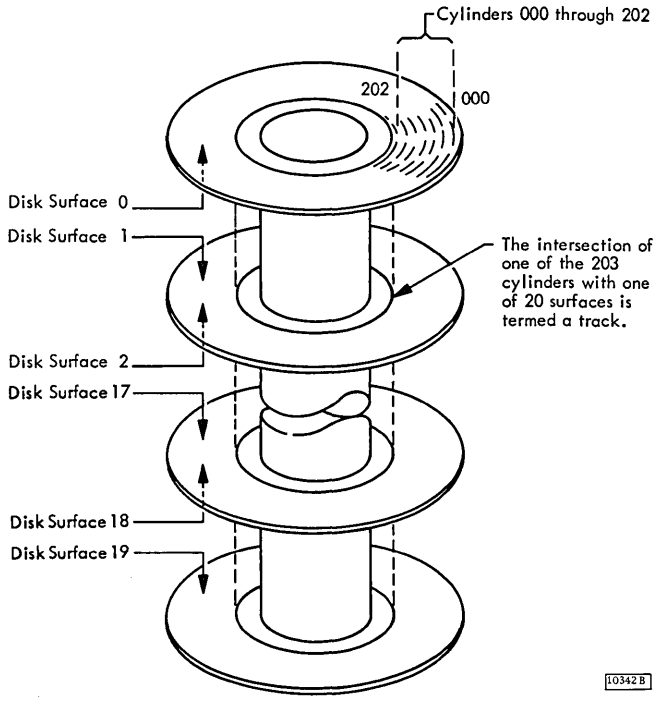

Figure 3. Cylinder Concept

Access Times

Cylinder-to-cylinder (horizontal) access time varies according to the number of cylinders traveled. Access time from one cylinder to the adjacent cylinder is 25 milliseconds. Other access times are given in Figure 4. After the access mechanism has reached a cylinder position, additional time may be required for the disk to rotate to the desired storage area. At 2,400 revolutions per minute, one complete revolution takes 25 milliseconds, where the average rotational time is 12.5 milliseconds (one-half revolution).

Access Time*	Milliseconds
Maximum	130
Average Random	60
Minimum (Cylinder-to-Cylinder)	25

*These access times include a provision for settling-down time, but do not include rotational delay. Average rotational delay is 12.5 milliseconds.

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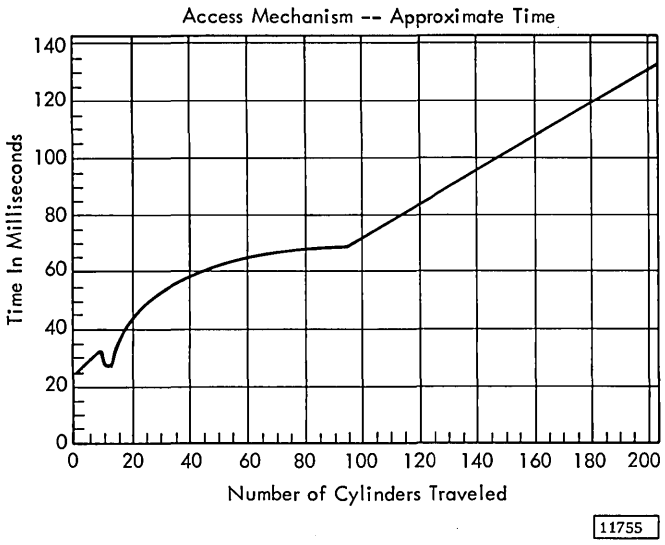
Figure 4. Access Times

The following curve is a plot of the cylinders traveled against time for the access mechanism and can be used as an aid in programming for the most efficient use of the disk storage.



In addition, an Access Timing Chart in Appendix C (Figure 26) illustrates a typical access operation.

Operational and Timing Specifications

A summary of the specifications for operation and timing of the disk storage is given in Figure 5.

Disk Storage Addressing

Each disk pack has 20 usable surfaces with 203 tracks on each surface. The vertical alignment of tracks can be thought of as a cylinder of tracks (Figure 3). In order to provide maximum accessibility of a storage area, the tracks are numbered vertically within the cylinder. Therefore, a track-to-track operation only requires microseconds of switching time rather than milliseconds of access time. To place the recording mechanism at a specific cylinder of tracks, a seek command must be given to the module. The command must provide the identification of the module and the cylinder to which the access mechanism should move. In addition, in order to select individual tracks within the cylinder, the command must designate the recording head.

DISK PACK

The IBM 2316 Disk Pack, as shown in Figure 6, is composed of eleven disks, 14 inches in diameter and spaced 0.35 inches apart on a vertical shaft. Circular protective plates are mounted above the top disk and under the bottom disk to protect the assembly. The upper surface of the top disk and the lower surface of the bottom disk are not available for data storage because of the protective plates. The entire assembly of disks, vertical shaft and protective plates rotates at a speed of 2,400 revolutions per minute, 25 ms per revolution.

Item	Nominal	Maximum	Minimum
Disk Rotational Speed	2400 rpm	2448 rpm	2352 rpm
*Oscillator Frequency	5.00 MHz	5.0025 MHz	4.9975 MHz
*Write Clock Pulse Period	400.0 nanoseconds	400.2 nanoseconds	399.8 nanoseconds
*Write Clock Pulse Rate	5.00 Megabits	5.0025 Megabits	4.9975 Megabits
*Write Data Bit Rate	2.50 Megabits	2.50125 Megabits	2.49875 Megabits
*Write Data Bit Width	70 nanoseconds	80 nanoseconds	60 nanoseconds
Read Data Bit Rate	2.50 Megabits	2.6025 Megabits	2.3975 Megabits
Read Data Bit Width	80 nanoseconds	100 nanoseconds	60 nanoseconds
Read Back Data Rate	312 k Bytes	328 k Bytes	296 k Bytes
*These items developed by Control Unit			

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Figure 5. Operational and Timing Specifications

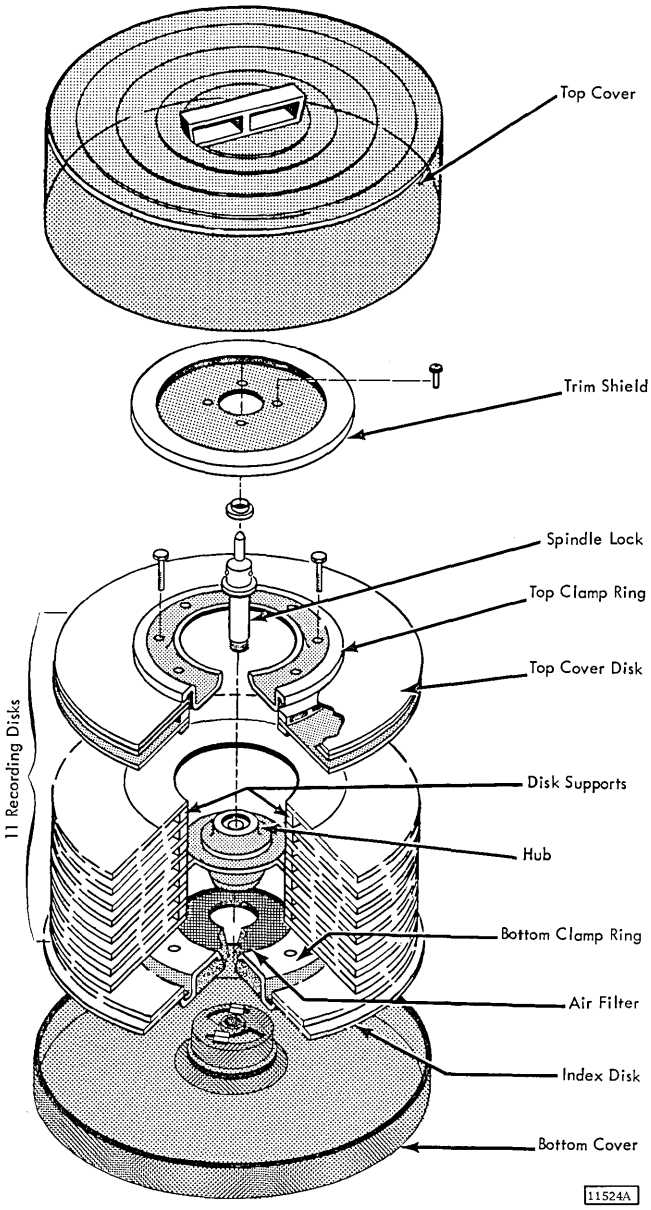

Figure 6. 2316 Disk Pack

A two-piece plastic cover for the entire pack assembly, is designed to protect disks against damage. A built in handle on the top cover makes carrying easy. A self-locking device in the handle permits removal of the top cover only when the pack is mounted on the disk storage.

Disk Pack Capacity

The maximum capacity of the 2316 Disk Pack is 29,176,000 eight-bit bytes. In packed decimal mode the maximum capacity is 58,352,000 digits (numeric only). See Figure 5 for the read/write electronic specifications. Using the worst case figures (2.49875 MHz write data bit rate and 2,448 rpm) indicates a total track capacity of 7,652 eight-bit bytes. However, the data should be checked for recording accuracy by the control unit, and this checking requires time. The IBM control units require data gaps following each record field, which reduces the track capacity. The track capacity of the 2316 Disk Pack, when used in a disk storage system attached to the 2314 Storage Control is 7,294 eight-bit bytes if one data record is written per track. The total capacity is reduced as the number of records per track increases

> Note: IBM guarantees that the 2316 has 4000 error-free tracks. Therefore, the total capacity quoted is based on 4,000 tracks. Up to 60 alternate tracks are provided. The IBM control units have the facility to assign alternate tracks to replace defective tracks.

Data is transferred between the control unit and the disk storage module serially, one bit at a time.

DATA RECORDS AND FORMAT

The organization of data and the capacity of the disk storage module are dependent on the format used to store information. The read/write format should be designed to satisfy the needs of the attaching system.

Component tolerances and specific requirements of data flow electronics in the disk storage, which may affect the design of the control unit, are as follows:

- Disk Speed: 2,400 rpm ±2%.
- Write oscillator frequency: 5.0 MHz ±0.05%.
- Radial dimension of magnetic tracks:
  Track 202 4.64 inches (approximately)
  Track 000 6.506 inches (approximately).
- Read back data bit cell time:
  Nominal 400 nanoseconds
  Maximum 416.4 nanoseconds
  Minimum 383.6 nanoseconds.
- Minimum time from head deselect to head advance: 11.2 microseconds.
- Minimum time from head advance to head select: 1.6 microseconds.

- Relative position of one index pulse to all other index pulses: ±18 microseconds.
- Relative position of all read/write heads to a given pulse: Position tolerance ±0.0125 inches.
- Read gate: This must occur a minimum of 60 microseconds after head select or the fall of 'write gate'.
- Unavailable disk area: A section of each disk surface is not available for data storage. The centerline of this section is located under the head at the leading edge of the index pulse. This area is contained within ±0.088 inches of the centerline. Refer to Figure 5 for additional information.

Data Checking

The engineer designing a control unit for the disk storage should provide some means of data checking.

DATA TRANSFER ELECTRONICS

The data transfer electronics include circuits for head selection, writing, and reading. Safety circuits are also included to provide protection for recorded data.

A full complement of data transfer electronic circuits is installed in each drive. This includes the head selection circuitry, the write data line receiver, the write trigger, the write driver, the erase driver, safety circuits, read preamplifier and the main read amplifier.

When data transfer to or from a particular disk surface is desired, the appropriate head address and module lines are conditioned by the control unit.

Write gate and erase gate signals must be provided by the control unit for writing data on the disk storage pack. The write data to the disk storage module must be in serial pulse form and driven by a special line driver. (See "Signal Specifications" section of this manual.)

During read operations, the recorded signals from the disk surface are sensed by the read/write head and directed to the input of the read amplifier. The read amplifier produces raw data at its output in the form of one discrete pulse for each transition on the recording disk. The output stage of the read amplifier is a coaxial line driver which provides 80 nanosecond wide pulses through an impedance of 95 ohms.

Usually only a particular portion of the signal at the read amplifier output is usable. The control unit must provide a read gate signal to gate the read amplifier output. When the read gate signal is present, the read amplifier output is allowed to be sent to the control unit. At the recording frequency of 5.0 megahertz it is absolutely necessary to minimize the time shift of recording and read-back bits along the data flow path. To achieve this, it is best to think of the whole data path as an integral unit. The data flow path consists of a read and write clock, located in the control unit, and recording and detection circuitry which is located in the disk storage module.

Write Circuitry

The write circuitry contains the necessary components for changing the write data pulses from the control unit into a current drive for the write coil of the magnetic head. Current in the write coil of the magnetic head produces a flux which magnetizes the oxide material on the disk.

The input write data to the disk module is under control of the control unit. The write data signal must be driven by a special coaxial line driver. The line receiver terminates the coaxial write data line in addition to supplying an output to the write trigger. The write trigger converts the discrete pulse data into binary levels, with each pulse defining a change of state. The control unit conditions the write gate and erase gate lines to signal the write circuitry for a write operation. When the write gate is on, the write driver follows the output of the write trigger. The write driver provides the current drive through the address matrix to the write coil. The write driver has two outputs, one for each write element in the write coil. Current passes through only one element at a time depending on which of the two outputs from the write driver is active. Following recording the erase driver provides current for a tunnel erase to constrain the width of the recorded track.

The frequency of the write data signal is 5.0 megabits per second. Thus a minimum of 200 nanoseconds occurs between the leading edges of any two successive bits. The duty cycle of writing with a particular write driver shall not exceed 50% -- averaged over 1 second. This limitation provides adequate protection for the write driver as well as the magnetic heads.

Read Circuitry

The read circuitry includes the necessary components for converting signals sensed by the read heads into

discrete pulses that can be interpreted as being data or clock bits. The output stage of the read amplifier is a coaxial line driver which provides pulses, 80 nanoseconds wide, for the control unit read clock.

The same diode and transistor head select matrix employed in the write head selection is used when read information is desired. One of 20 heads is electronically selected, and the output sensed by the head is fed into the read amplifier. The read amplifier is used to increase the amplitude of the head signals originating from the selected read head.

The head signal is amplified and differentiated by the read amplifier and the resulting pulses are fed through a shaper and line driver, which provides a standard level pulse. The nominal pulse width of the read amplifier output is 80 nanoseconds. One bit, 80 nanoseconds wide, is put on the data line for each change of magnetic state sensed by the read head from the disk surface.

The nominal output frequency of the read data is that frequency at which the data was written. The instantaneous output data frequency is dependent upon: the relative clocking oscillation frequency and relative disk rotational speed during writing and reading; the bit pattern written; and the bit shift caused by the head, disk, and electronic circuitry.

SAFETY CIRCUITRY

Write safety circuits are provided to protect recorded information in the disk module. The outputs of all safety circuits are joined together and form a single unsafe line that is available to the control unit.

The following conditions in a disk module cause an unsafe signal to be sent to the control unit:

1. Multiple head select.
2. DC write current and not write gate.
3. Erase current and not erase gate.
4. Write gate and not erase current.
5. Write gate and no ac write current.
6. Read gate or not seek ready and either write gate or erase gate.
7. Overvoltage or undervoltage on +6, +3, -3, and -36 Vdc.
8. Loss of line voltage.

For any of the above unsafe conditions, the disk module deselects the heads, turns off selected write and erase gates, and holds them off until the unsafe condition is corrected.

The following conditions should be checked by the control unit and an unsafe status generated if:

1. More than one module selected line is up.
2. Write gate is up but no selected write current is sensed.

SELECTION CIRCUITRY

It is necessary to select out of 20 heads for transferring data into and from the disk pack. This is done by setting a head number into the head address register which has 20 outputs. Each output of this register is connected to the center-tap lead of each read/write head. The head is selected when 'head select' comes up. Selecting a head brings the voltage level at its center tap from -36 Vdc to +3.0 Vdc. Once a head is selected, conditioning the write and erase gates causes the write and erase drivers to supply current to the selected head.

After selecting a head in a read operation, a selected read gate is used to gate the output of the read amplifier, thus allowing raw read data to be detected by the control unit read clock.

SIGNAL INTERFACE

INPUT COMMUNICATION LINES

The input communication interface is composed of an eight line time-shared bus (address bus), four tag lines that select the information from the bus, a module select line, and a write data line.

Only one of the four tag lines is up at a time to describe the information on the bus. (See Figure 7.)

Control Tag: This line conditions the drive for a control cycle. Simultaneously activating one of the signals on the bus determines which operation is performed (such as write, read, seek, etc.).

Set Cylinder Tag: This line is used for carriage operations so that the signals on the bus function to identify the cylinder to be addressed. The 'set cylinder' pulse must be completely contained within the time that the cylinder address is on the eight-line bus.

Set Head Tag: This line and one of the bus signals perform a head select function. In addition, two other operations can be designated: select lock reset and turning on the 'forward' latch. A reset is given to the head register before a head selection.

> Note: The pulse width of the tag lines is 1.5 microseconds minimum. The bus line information must be present for the full duration of the tag line pulse.

Set Difference Tag: This line, when it is on, identifies the signals on the bus as the calculated difference between the present cylinder position and the newly addressed cylinder.

Bus Line	Conversion In Storage Module	Function During: Control Cycle	Set Cylinder	Set Head	Set Difference	Set Half Counter
File Bus 0	A128	Write Gate	Cyl 128	Forward Latch	Not 128	64
" " 1	A64	Read Gate	Cyl 64	Select Lock Reset	Not 64	32
" " 2	A32	Seek Start	Cyl 32		Not 32	16
" " 3	A16	Reset Head Reg	Cyl 16	Hd Add 16	Not 16	8
" " 4	A8	Erase Gate	Cyl 8	Hd Add 8	Not 8	4
" " 5	A4	Select Head	Cyl 4	Hd Add 4	Not 4	2
" " 6	A2	Return to 000	Cyl 2	Hd Add 2	Not 2	1
" " 7	A1	Head Advance	Cyl 1	Hd Add 1	Not 1	Not Used

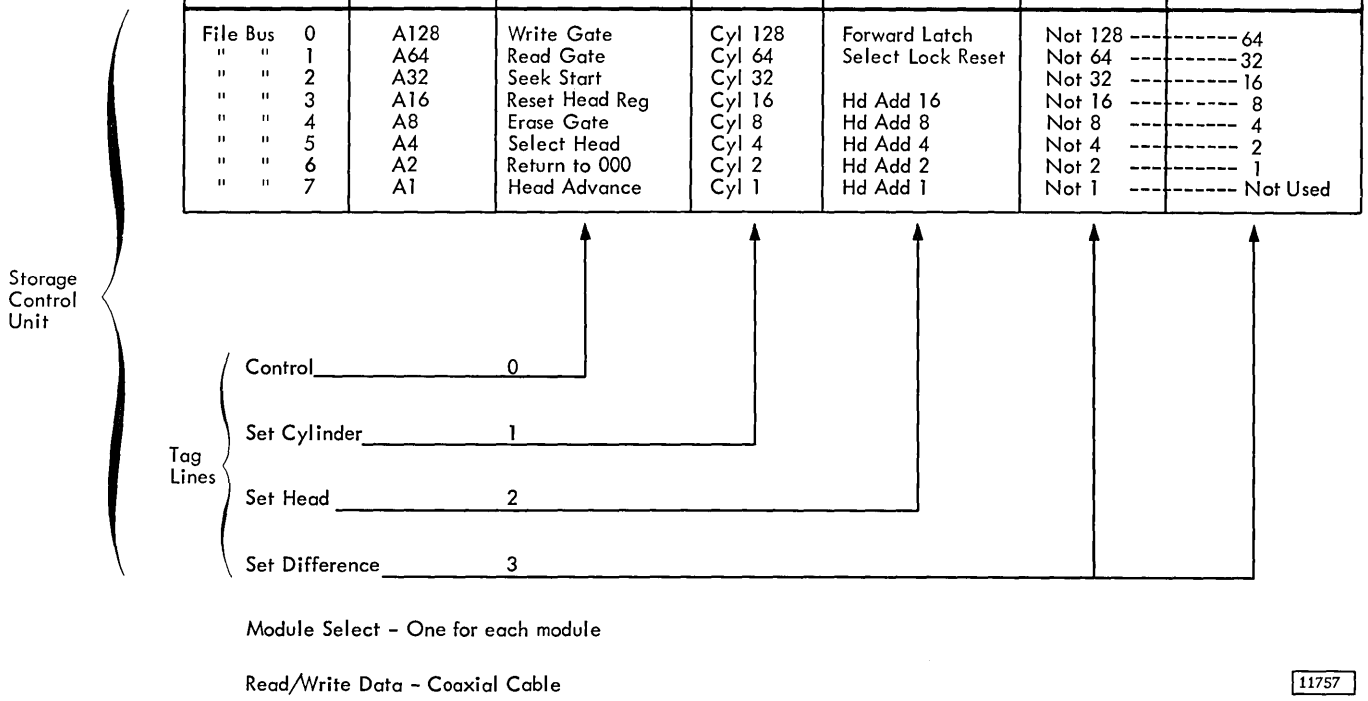

Figure 7. Input Signal Lines

Module Select: This signal is a line, in the multiplex cable, used to gate signal lines to the proper disk storage modules. This signal is gated to the proper module through the use of the module identification plug inserted in the operator panel. (See Figure 16.)

Write Data: This signal is a simplex line, one per module.

OUTPUT COMMUNICATION LINES

The disk storage supplies 19 lines that can be used by the control unit to determine the status of the disk module. The following lines are available to the control unit.

Cylinder Address Register

Eight output lines from the cylinder address register (CAR) may be used to indicate the present disk module cylinder address. These lines are active when the module is selected and changed to a new address at 'set cylinder' time. The line names are:

CAR 1
CAR 2
CAR 4
CAR 8
CAR 16
CAR 32
CAR 64
CAR 128

Gated Attention

This line indicates that a seek has been completed or that 600 milliseconds has passed since the seek command was given without a detent-in being detected. It is reset by the read gate. 'Gated attention' is a line in the multiplex cable from the control unit, controlled by the module identification plug inserted in the operator panel. This line is not module selected.

Selected Module

This line indicates that a module has been selected. It is used in the 2314 Storage Control for the multi-module select safety logic. It is a simplex line and is module selected.

Selected File Busy

This line, when it is up, indicates that the access mechanism is in the seeking process. When the line is down, it indicates that the disk storage is ready to perform. This line is module selected.

Selected Index

This is an index pulse generated by the disk module once per disk revolution. This line is module selected.

Write Current Sense

This line indicates that the selected module is writing on the disk pack.

Unsafe

This line indicates that the disk module is unsafe and will not perform any operation. This line is module selected.

Seek Incomplete

This line indicates that the seek complete operation did not occur within 600 milliseconds after a seek command was given. This line is module selected.

End of Cylinder

The 'end of cylinder' signal occurs if, during a cylinder operation, the head select register in the disk drive goes from 19 to 20. This line is module selected.

Read Data

The 'read data' line is driven with a special line driver through a coaxial line. It is active during all read operations and is module selected.

Heads Extended

This line indicates that the heads are extended. It is used in the control unit for sequencing power-off logic. In a control unit power down sequence, the dc voltages to the disk storage modules cannot be removed until the last heads extended switch has opened, indicating that the heads are unloaded.

Selected On Line

This line indicates that the heads are extended and ready to read or write. This line is module selected.

Sequence Pick

The signal on this line starts each module drive motor in sequence when the control unit is powered up. 'Sequence pick' remains energized as long as power is on. The 'controlled ground' line is opened

to power down the disk storage drive motors when the control unit power is turned off.

Pack Change

This line indicates that a pack change has occurred.

SIGNAL CONNECTOR AND CABLE

The signal connector for connection at the disk storage is shown in Figure 9. The pin connections and signal names are listed in Figure 10. Figure 8 lists the logic voltage levels.

Cable Lengths

The disk storage is designed to operate with a maximum cable length of 16 feet.

POWER INTERFACE

AC Power Requirements

Three phase ac power is connected to each disk storage. However, an individual module draws power from only one phase. Therefore, in multiphase systems, phases should be rotated for disk storage units in sequence. The ac voltage requirements for the disk storage are listed in Figure 11. Machines wired for 50 hertz can be operated in delta or wye systems.

The disk storage takes 3.2 amperes steady and 25 amperes starting load, for each module. The power requirement for the 2312 is 0.63 kilowatt. The 2313 requires 2.37 kilowatts.

Up Level	Maximum	Minimum
+L	+ 6.28	+ 2.0
+V	+38.9	+28.4
+W	+38.9	+28.4
+Q	+ 3.5	+ 0.65
Down Level	**Maximum**	**Minimum**
-L	+ 0.3	0.0
-V	+ 0.4	0.0
-W	+ 1.3	0.0
-Q	- 0.5	-3.5

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Figure 8. Logic Voltage Levels

AC Power Distribution

The ac power connections are made directly to TS1 (terminal strip) in the disk storage. Figure 12 illustrates the wiring for 50 and 60 hertz systems. Refer to Figure 25 (Appendix B) for the location of TS1.

DC Power Requirements

The control unit must supply all dc voltages for the disk storage units. The dc power requirements for each module are as follows:

- +3.0 Vdc at 0.90 amperes.
- -3.0 Vdc at 0.60 amperes.
- +6.0 Vdc at 1.10 amperes.
- +36.0 Vdc at 1.45 amperes.
- -36.0 Vdc at 0.39 amperes.

The currents specified are at nominal voltage and duty cycle. Voltage tolerances, except for +36V, are ±4%, measured at the voltage bus on the SLT gates. The tolerance of the +36V is ±8%. The voltage tolerances include any variable combinations of steady state or short duration transients.

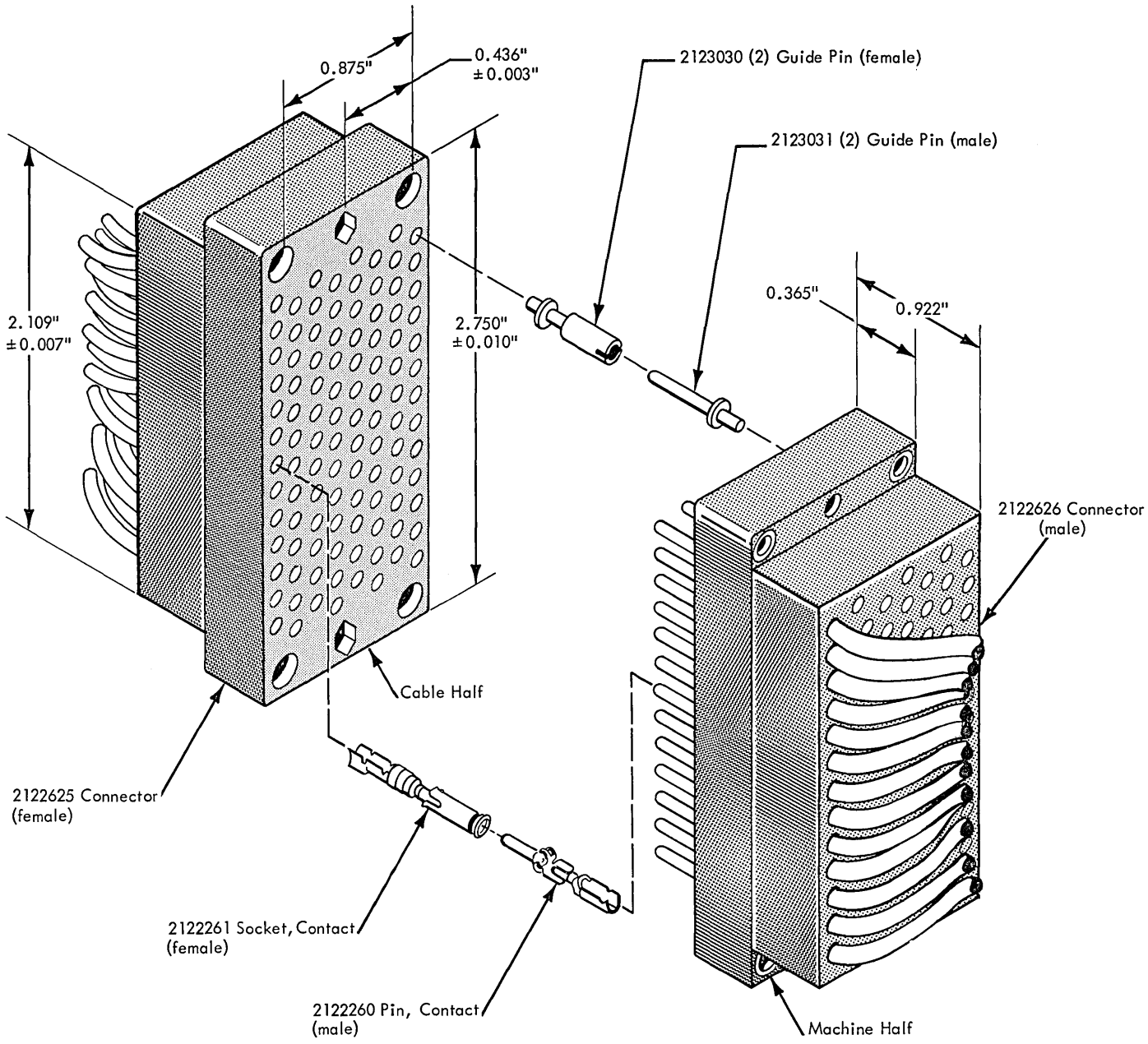
DC Connector and Cable

The dc power connector along with the pin assignments and signal lines is illustrated in Figure 13. In addition, Figure 27 in Appendix D shows the dc connector assembly and the mating plug in the disk module and lists the IBM part numbers for all parts of the connectors. Equivalent part numbers are also listed. Pins 3 and 4 are ground returns for +3, +6 and +12 volt power supplies. Pins 10 and 11 are grounds for +36V.

Note: Maximum cable length is 16 feet.

POWER SEQUENCING

Power sequencing of the disk storage is the joint responsibility of the disk storage and the control unit. Each module provides the logic and interlocks for its operation and supplies the control unit with a 'heads extended' line (i.e., an access on-line signal). One set of contacts of relay K4 are provided for the purpose of multi-module turn-on power sequencing. Relay K4 energizes when the disk has reached 70% of the rated rpm.



Cross Reference	
IBM P/N	AMP* P/N
2122260	66098-1
2122261	66100-1
2122625	201037-1
2122626	201345-1
2123030	201389-2
2123031	201388-2
*AMP Incorporated, Harrisburg, Pennsylvania 17105	

Inches = Centimeters	
0.003	0,008
0.007	0,018
0.010	0,025
0.365	0,927
0.436	1,107
0.875	2,222
0.922	2,342
2.109	5,357
2.750	6,985

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Figure 9. Signal Connector

Control Unit to Disk Storage

From WF011 Line Title	*Signal Level	Sig Connector Pin	Sig Connector Twisted Wire	File Logic Pages	File FD's	File Line Title
File Bus 0	Q	Sig - A	Sig - B	FL/FU020	FD101	-2.5V +1.5V File Bus 0
File Bus 1	Q	Sig - C	Sig - D	FL/FU020	FD101	-2.5V +1.5V File Bus 1
File Bus 2	Q	Sig - E	Sig - F	FL/FU020	FD101	-2.5V +1.5V File Bus 2
File Bus 3	Q	Sig - H	Sig - J	FL/FU020	FD101	-2.5V +1.5V File Bus 3
File Bus 4	Q	Sig - K	Sig - L	FL/FU020	FD101	-2.5V +1.5V File Bus 4
File Bus 5	Q	Sig - M	Sig - N	FL/FU021	FD101	-2.5V +1.5V File Bus 5
File Bus 6	Q	Sig - P	Sig - R	FL/FU021	FD101	-2.5V +1.5V File Bus 6
File Bus 7	Q	Sig - S	Sig - T	FL/FU021	FD101	-2.5V +1.5V File Bus 7
Set Difference	Q	Sig - U	Sig - V	FU/FL021	FD101	-2.5V +1.5V Set Difference
Set Cylinder	Q	Sig - W	Sig - X	FU/FL021	FD101	-2.5V +1.5V Set Cylinder
Set Head	Q	Sig - Y	Sig - Z	FU/FL021	FD101	-2.5V +1.5V Set Hd + Direction
Control	Q	Sig - a	Sig - b	FU/FL021	FD101	-2.5V +1.5V Control
Mod 0 Select	Q	Sig - c	Sig - d	YB001		-2.5V +1.5V Mod 0 Select
Mod 1 Select	Q	Sig - f	Sig - g	YB001		-2.5V +1 5V Mod 1 Select
Mod 2 Select	Q	Sig - h	Sig - i	YB001		-2.5V +1.5V Mod 2 Select
Mod 3 Select	Q	Sig - j	Sig - k	YB001		-2.5V +1.5V Mod 3 Select
Mod 4 Select	Q	Sig - m	Sig - n	YB001		-2.5V +1.5V Mod 4 Select
Mod 5 Select	Q	Sig - p	Sig - q	YB001		-2.5V +1.5V Mod 5 Select
Mod 6 Select	Q	Sig - r	Sig - s	YB001		-2.5V +1.5V Mod 6 Select
Mod 7 Select	Q	Sig - t	Sig - u	YB001		-2.5V +1.5V Mod 7 Select
Spare Mod Select	Q	Sig - v	Sig - w	YB001		-2.5V +1.5V Spare Mod Select
Controlled Gnd from FCU		Sig - CK	- -	YB001		Controlled Gnd from FCU
Sequence Pick In	W	Sig - CL	- -	YB001		Seq. Pick (Incoming)
+3V File Terminator		Int - AT	- -	WE001		+3 Vdc
		Int - AU	- -			+3 Vdc
AC Power		TS K	- -	YA001		208 Vac - 3 Phase
+36 V		TS 4/5	- -	YB001		+36 V
-36 V		TS 4/5	- -	YB001		-36 V
+6 V		TS 4/5	- -	YB001		+6 V
+3V		TS 4/5	- -	YB001		+3 V
-3V		TS 4/5	- -	YB001		-3 V
GND		TS 4/5	- -	YB001		GND
-3V Pwr on Reset		Sig - BP		FU/FL090	FD103	-3V Pwr on Reset + C.E. Reset Select Lock
Read/Write Coax	Q	R/W Board		YB001	FD102	-2.5V +1.5V Read/Write Coax
Selected Module	Q	Edge Conn		YB001	FD101	-2.5V +1.5V Selected Module
Disk Storage to Control Unit						
Gated Attention 0	Q	Sig - x	Sig - y	YB001		-2.5V +1.5V Gated Attention 0
Gated Attention 1	Q	Sig - z	Sig - AA	YB001		-2.5V +1.5V Gated Attention 1
Gated Attention 2	Q	Sig - AB	Sig - AC	YB001		-2.5V +1.5V Gated Attention 2
Gated Attention 3	Q	Sig - AD	Sig - AE	YB001		-2.5V +1.5V Gated Attention 3
Gated Attention 4	Q	Sig - AF	Sig - AH	YB001		-2.5V +1.5V Gated Attention 4
Gated Attention 5	Q	Sig - AJ	Sig - AK	YB001		-2.5V +1.5V Gated Attention 5
Gated Attention 6	Q	Sig - AL	Sig - AM	YB001		-2.5V +1.5V Gated Attention 6
Gated Attention 7	Q	Sig - AN	Sig - AP	YB001		-2.5V +1.5V Gated Attention 7
Gated Attention Spare Mod	Q	Sig - AR	Sig - AS	YB001		-2.5V +1.5V Gated Attention Spare Mod
Cylinder Addr Reg 1	Q	Sig - AX	Sig - AY	FU/FL026	FD101	-2.5V +1.5V Cyl Addr Reg 1
Cylinder Addr Reg 2	Q	Sig - AZ	Sig - BA	FU/FL026	FD101	-2.5V +1.5V Cyl Addr Reg 2
Cylinder Addr Reg 4	Q	Sig - BB	Sig - BC	FU/FL026	FD101	-2.5V +1.5V Cyl Addr Reg 4
Cylinder Addr Reg 8	Q	Sig - BD	Sig - BE	FU/FL026	FD101	-2.5V +1.5V Cyl Addr Reg 8
Cylinder Addr Reg 16	Q	Sig - BF	Sig - BH	FU/FL026	FD101	-2.5V +1.5V Cyl Addr Reg 16
Cylinder Addr Reg 32	Q	Sig - BJ	Sig - BK	FU/FL026	FD101	-2.5V +1.5V Cyl Addr Reg 32
Cylinder Addr Reg 64	Q	Sig - BL	Sig - BM	FU/FL026	FD101	-2.5V +1.5V Cyl Addr Reg 64
Cylinder Addr Reg 128	Q	Sig - BN		FU/FL026	FD101	-2.5V +1.5V Cyl Addr Reg 128
Selected File Busy	Q	Sig - BR	Sig - BS	FU/FL025	FD104	-2.5V +1.5V Sel File Busy
Selected On Line	Q	Sig - BT	Sig - BU	FU/FL025	FD104	-2.5V +1.5V Sel On Line
Selected Index	Q	Sig - BV	Sig - BW	FU/FL025	FD104	-2.5V +1.5V Sel Index
File Unsafe	Q	Sig - BX	Sig - BY	FU/FL025	FD104	-2.5V +1.5V File Unsafe
Selected Seek Incomp	Q	Sig - BZ	Sig - CA	FU/FL025	FD104	-2.5V +1.5V Sel Sk Incomp
Selected End of Cyl	Q	Sig - CB	Sig - CC	FU/FL025	FD104	-2.5V +1.5V Sel End of Cyl
Selected Pack Change	Q	Sig - CD	Sig - CE	FU/FL025	FD104	-2.5V +1.5V Sel Pack Change
Write Current Sense	Q	Sig - CF	Sig - CH	FU/FL025		-2.5V +1.5V WR Current Sense
Heads Extended	W	Sig - CJ	- -	YB001		0V +36V Heads Extended
	W	Sig - CM	- -	YB001		0V +36V Sequence Pick (Outgoing)
						(To Next File Frame)
-3V				YB003		-3V
+6V				YB003		+6V
-3V				YB003		-3V
-Enable A				YB003		-3V +6V -Enable A
-Disable A				YB003		-3V +6V -Disable A
-Enable B				YB003		-3V +6V -Enable B
-Disable B				YB003		-3V +6V -Disable B
+6 to -3 Multi-Tag SW				YB003		+6 to -3 Multi-Tag SW

*See Figure 8 for minimum and maximum limits

11759

Figure 10. Signal Connector Pin Connections

AC Power	Single Phase 60 Hz VAC	Single Phase 50 Hz VAC Δ or Y Connected
Power Input	208,230	195,220,235: Δ 220,238: Y
Convenience Outlet	115	195,220,235: Δ 220,238: Y
Tolerance: Voltage ±10% Frequency ±1/2 Hz		

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Figure 11. AC Voltage Requirement

Turn-on Sequencing

In order to make a module 'ready', a disk pack must be installed and the front cover interlock must be closed. Assuming that the control unit is not powered-up then, if the start-stop switch for the module (see Figure 16) is placed in start position, the module will power-up when the control unit is powered-up.

The timing diagram, Figure 14, illustrates the sequential events which occur when the module is turned on. A brief explanation of the events follows.

1. The 'sequence pick' signal, which is energized, and remains energized as long as the control unit has power up, activates the sequence relay in the disk module. The sequence relay then energizes the motor relay. The disk cleaning cycle starts and the heads are extended into the disk pack. Presence of ac voltage to the drive motor, energizes the ac safety relay.
2. When the disk pack reaches 70% of the rated rpm, the speed relay is energized which then signals the next module (in a multimodule system) to start.
3. After a disk cleaning cycle is completed, the access mechanism drives forward to positive stop at high speed. The heads load while the access mechanism moves toward positive stop.
4. At positive stop the access mechanism changes direction and then moves at fast reverse speed toward hydraulic home position.
5. At hydraulic home position, the access mechanism changes direction again and moves forward at slow speed. A detent is made at cylinder 000.
6. The control unit is then sent a signal indicating that the access is ready.
7. The disk module generates the gated attention signal.

Turn-Off Sequencing

The disk module can be turned off locally by switching the module start-stop switch to the stop position or remotely by the control unit opening the 'controlled ground' line. Either action unloads and retracts the heads from the disk pack. At the same time the drive motor shuts off.

When the heads retract, the selected on-line signal will drop and the 'heads extended' line opens. The control unit must never drop all the voltages to the logic and special circuits of the module until the 'heads extended' signal is dropped.

For a multimodule system, the turn-off sequence remains unchanged for a particular module. However, the power to those circuits in the control unit that are common to all the modules in the system must not be dropped until the head extended signals from all modules are dropped.

Thermal Shutdown: The turn-off sequence must be executed during thermal shutdown.

Emergency Power Off (EPO): All voltages may be dropped immediately for an emergency off situation.

A turn-off sequence timing chart is shown in Figure 15.

CAUTION
All dc voltages must be at the proper level before ac power is applied to the drive motor. To prevent damage to the internal circuits of the disk storage, these dc voltages must be applied and removed at the same time.

Other than normal power-off, serious damage to internal circuits will result if the dc cable is disconnected during a power-on condition. Disconnecting the signal cable, during a power-on condition, causes the drive motor to stop.

The signal out connector on the last disk storage in the system must be terminated. Erroneous results will occur if this terminator is disconnected during a power-on condition.

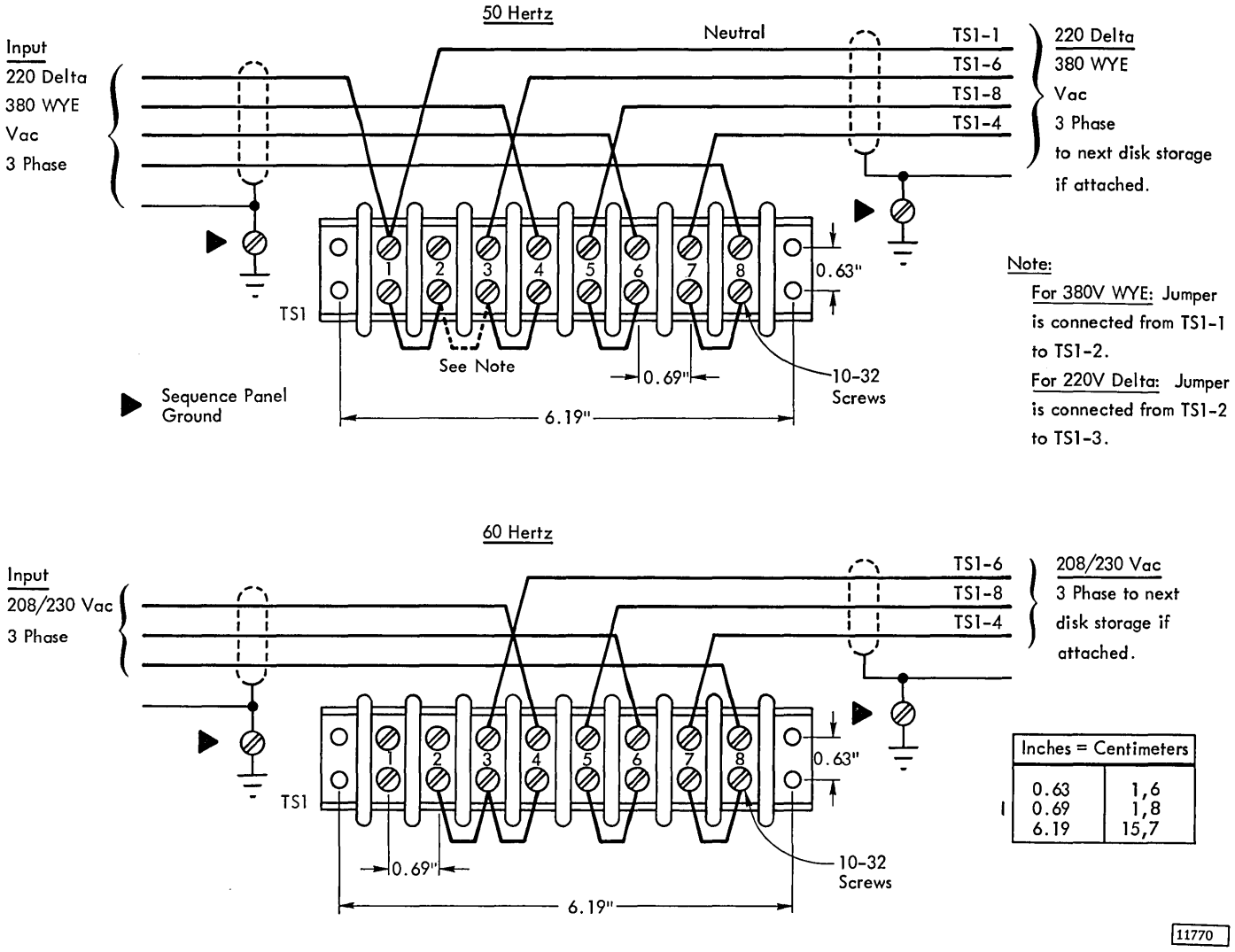
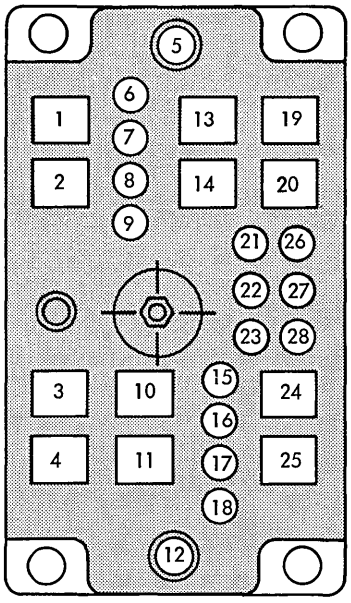


Figure 12. AC Power Distribution



Wiring Side

File DC Power

Pin	Signal
1	+6 Vdc
2	-3 Vdc
3	DC Gnd
4	DC Gnd
5	
6	
7	
8	
9	
10	DC Gnd
11	DC Gnd
12	Read/Write Data
13	+3 Vdc
14	+3 Vdc
15	-36 Vdc
16	
17	
18	
19	+36 Vdc
20	+36 Vdc
21	
22	Selected Mod
23	
24	
25	
26	
27	DC Gnd
28	

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Figure 13. DC Power Connector and Pin Assignment

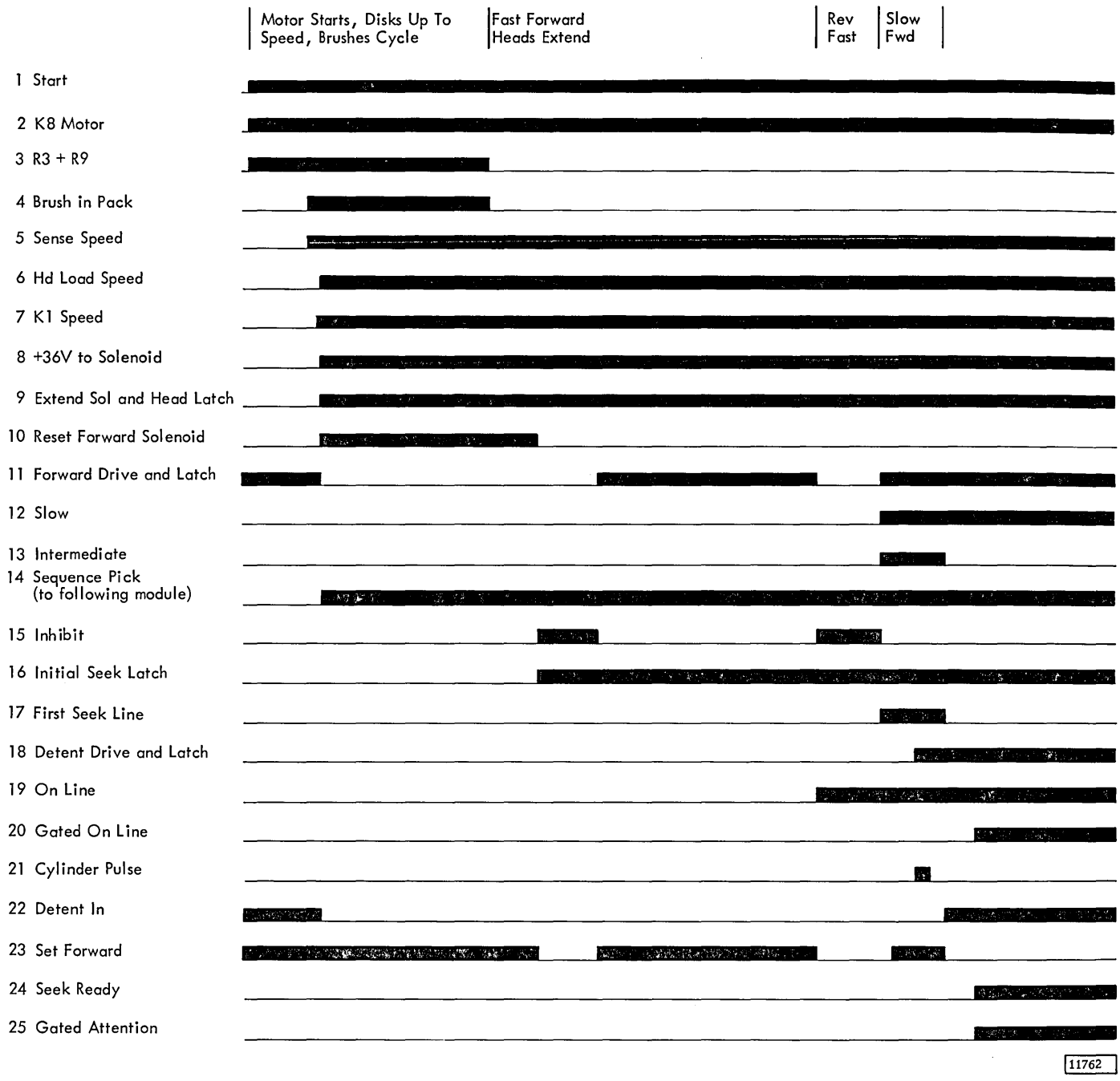
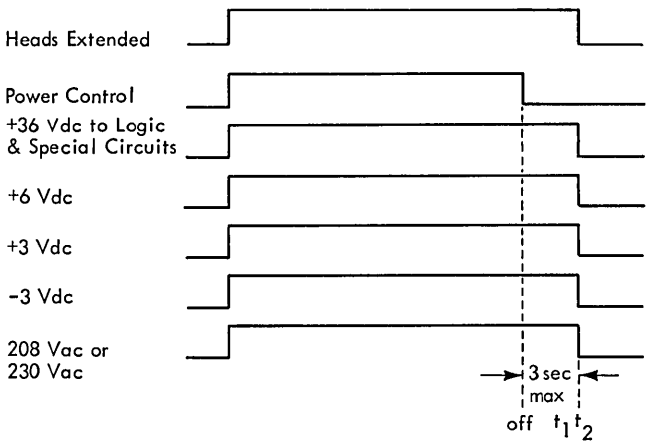


Figure 14. Power On Sequence



t_1 off occurs at the time + 36V to solenoids is dropped.

t_2 off occurs after heads have unloaded from disk pack.

16054A

Figure 15. Turn-Off Sequence

OPERATOR CONTROLS AND INDICATORS

The operator panel for the disk storage is shown in Figure 16. Each module of the disk storage has a start-stop switch and two indicators: access ready and select lock.

Start-Stop Switch

The start-stop switch is inoperable unless all ac and dc power are applied. Also, the disk pack must be in place and the cover must be closed so that the index block switch is closed. Placing the switch in the start position energizes the disk drive motor, loads the heads, and moves the carriage to cylinder position 000.

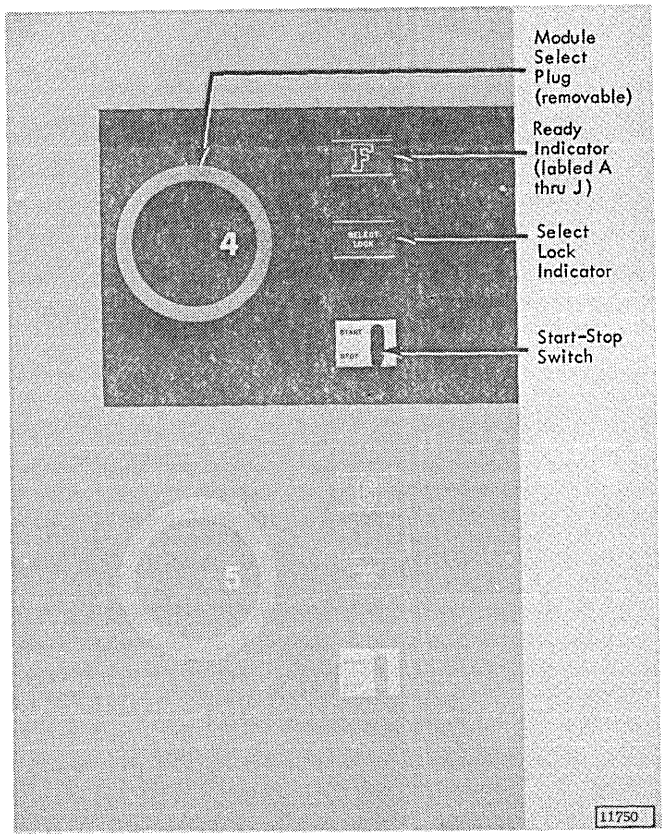


Figure 16. Operator Panel

Assuming the module is on-line, placing the switch in the stop position deenergizes the disk drive motor, unloads the heads, and retracts the carriage.

Access Ready Indicator (Labeled A-J)

This is a green lens with the physical device location (A-J) imprinted on it, this indicator will turn on following completion of the head loading sequence, this indicator turns off during the following times:

1. When a seek operation is being performed - this is a normal condition.
2. When the access mechanism has not detented properly - this is an abnormal condition.

Select Lock Indicator (Red)

The select lock indicator lights if any of the conditions monitored by the drive safety circuits is detected.

Resetting the safety circuit and turning off the select lock lamp is accomplished by moving the start-stop switch to STOP.

SERVICING CONTROLS

AC Disconnect Switch (Sequence Panel)

With the AC Line switch off, ac power cannot be applied to the drive motor, the brush motor, or the card gate fan.

Front Cover Switch

The front cover switch prevents making the module ready if the switch is open. If the module is on-line and the access drawer is slid out (for changing the disk pack, etc.), the heads unload, the drive motor turns off, and the carriage retracts.

CAUTION
See "Safety" section of this manual.

General

Signal lines to the disk storage can be driven by single or multiple drivers and can feed single or multiple receivers. All signal lines must terminate with an impedance of 95 ohms.

Single Driver and Receiver

When a transmission line is supplied by a single driver and feeds a single receiver, the driver and receiver must be located at the ends of the line but not beyond the line terminator.

Multiple Drivers and Receivers

Transmission lines can be driven by a maximum of eight drivers and can supply a maximum of eight receivers. Any combination of drivers or receivers, up to a maximum of eight drivers and eight receivers, can be logically ORed to the transmission line.

Multiple receivers on a line should not be less than 3 feet apart. However, no minimum spacing requirements have been set for:

- The distance between drivers.
- The distance between an end-of-line terminator and a driver.
- The distance between an end-of-line terminator and a receiver.

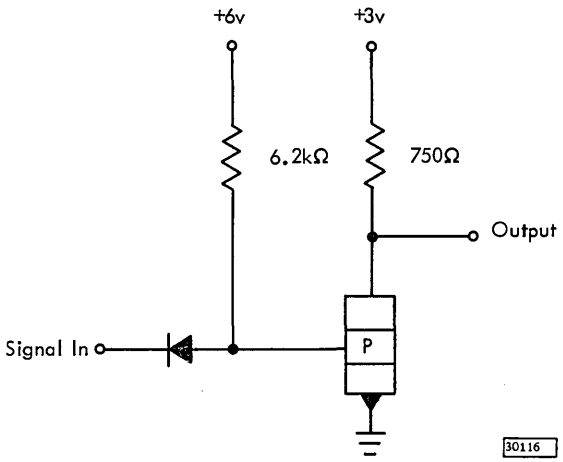


Figure 17. Line Receiver

Figure 17 is a diagram of the typical line receiver. Figure 18 shows a line driver.

GENERAL ELECTRICAL CONSIDERATIONS

Current Flow

The direction of current flow (conventional) is minus (-) if it flows into a component or positive (+) if it flows out of a component.

Voltage Levels

Refer to Figure 8 for the logic voltage levels used in the disk storage. A signal line is considered active when it has a value specified in the table.

Impedance

Line terminators must have a characteristic impedance of 95 ohms ± 10 ohms. Figure 19 shows the line terminator.

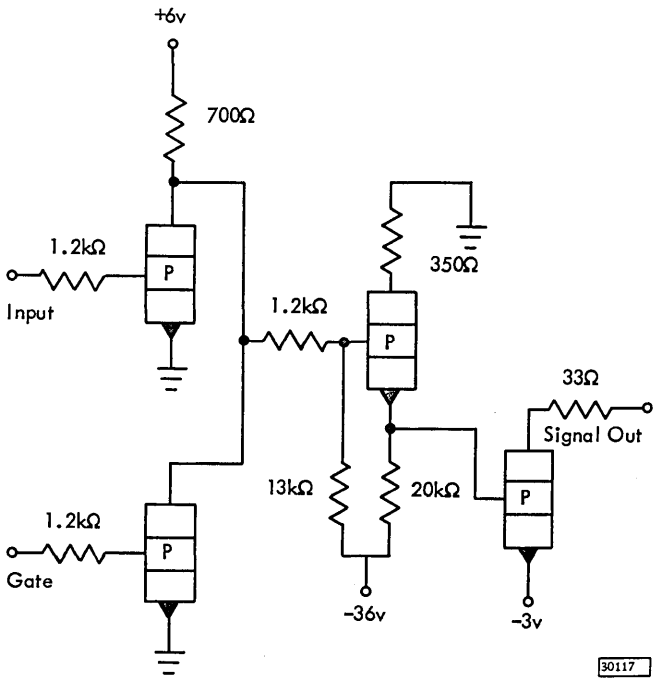


Figure 18. Line Driver

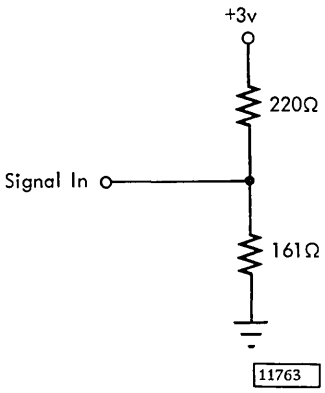


Figure 19. Line Terminator

Noise

The maximum noise coupled onto any signal line within a cable and due to any combination of changes external to that line must not exceed 300 millivolts.

Fault Conditions

The signal line may be grounded with no damage to drivers, receivers, or terminators.

Loss of power at either end does not cause any damage. Loss of power at the terminator may cause random errors in information transmission. The line operation is unaffected if power is off in any driver or receiver unit.

SPECIFIC ELECTRICAL REQUIREMENTS

The receiver circuits in the disk storage are designed to interpret input signals as follows:

1. The more negative line signal is a logical 1.
2. The more positive line signal is a logical 0.
3. An open input is treated as positive (logical 0).
4. The switching level from logical 1 to logical 0 is 2.0 volts.
5. The switching level from logical 0 to logical 1 is -1.0 volts. The receiver must not be subjected to a voltage level more positive than +3.5 volts or more negative than -3.5 volts. Refer to Figure 17 for the line receiver input circuit.

Input Requirements

Up Level: The dc voltage must be less than +3.50 volts and greater than +0.65 volts.

Down Level: The dc voltage must be greater than -0.50 volts and less than -3.50 volts.

Direct Current: The direct current requirements are 1.03 milliamps at -0.50 volts and 0.00 milliamps at +0.65 volts.

Terminator

The terminator is considered a two-terminal network, consisting of resistors and power supplies, and must meet the following requirements:

- The terminal connected to the signal line must present an open-circuit voltage between +1.0 and +2.0 volts.
- Impedance between the terminals must not be less than 90 ohms or greater than 105 ohms.

Driver

To transmit a logical 1, the voltage source driver draws approximately 25 milliamps from the line. To transmit a logical 0, the driver is off. (See Figure 18 for the driver circuit.)

Cables

The cables may consist of any combination of twisted pair, coaxial cable, and printed circuit wire within the following limitation: the maximum allowable internal cable resistance offered is 1.5 ohms. The measurement of this value is made between the external connector pins.

The nominal characteristic impedance of coaxial cable is 92 ohms. The characteristic impedance of twisted pair ranges from about 90 to 105 ohms.

Connectors

The maximum allowed coupled noise due to all connectors in each control unit, and including external cable connectors, is 250 millivolts.

The IBM System/360 Channel Interface used by the 2314 Storage Control is described in the following manual:

- IBM System/360 I/O Interface Channel to Control Unit Original Equipment Manufacturers' Information -- A26-6843.

There are unique timings used by the 2314 Storage Control when controlling the 2312/2313 Disk Storage. The following supplemental timings are required and apply to the IBM 2314 Storage Control.

OVERRUN LIMITS

The 2314 Storage Control will post 'overrun' if all the indicated requisites are not met for the chaining cases listed in Figure 20. Unless stated otherwise, all times are given with reference to the rise of 'status in', measured at the control unit, for the previous ending status.

Requisites for Case A

- 'Command out' must rise within 70 μs.
- Initial status acceptance within 98 μs.
- First byte of data available within 134 μs.

Requisites for Case B*

- 'Command Out' must rise within 79 μs.
- Initial status acceptance within 88 μs.
- First byte of data available within 134 μs.

Requisites for Case C*

- Initial status acceptance within 116 μs.
- First byte of data available within 129 μs.

Requisites for Case D*

- Initial status acceptance within 116 μs.

Requisites for Case E

- 'Command Out' must be received within 183 μs.
- Requisites for Case D apply if 'Command Out' rises before 75 μs.

*Detection of 'Command Out' between 77 through 85 μs will be delayed until 86 μs. 'Status In' will not rise until 8 μs after detection of 'Command Out'.

First Command (s)	Second Command (s)	Case
Search Key, Read ID, Search ID	Search ID, Read ID, Read Count/Key/Data	E
Read ID, Search ID	Read Key/Data, Read Data	D
Search ID	Write Key/Data, Write Data (K_L is 0)	A
Search ID	Write Data (K_L is not 0)	D
Read Count/Key/Data	Read Count/Key/Data	D
Write Count/Key/Data	Write Count/Key/Data	B
Search Key	Read Data	D
Search Equal Home Address	Read Record Zero	D
Search Equal Home Address	Write Record Zero	A
Read Count	Search Key	C

11771

Figure 20. Chaining Cases

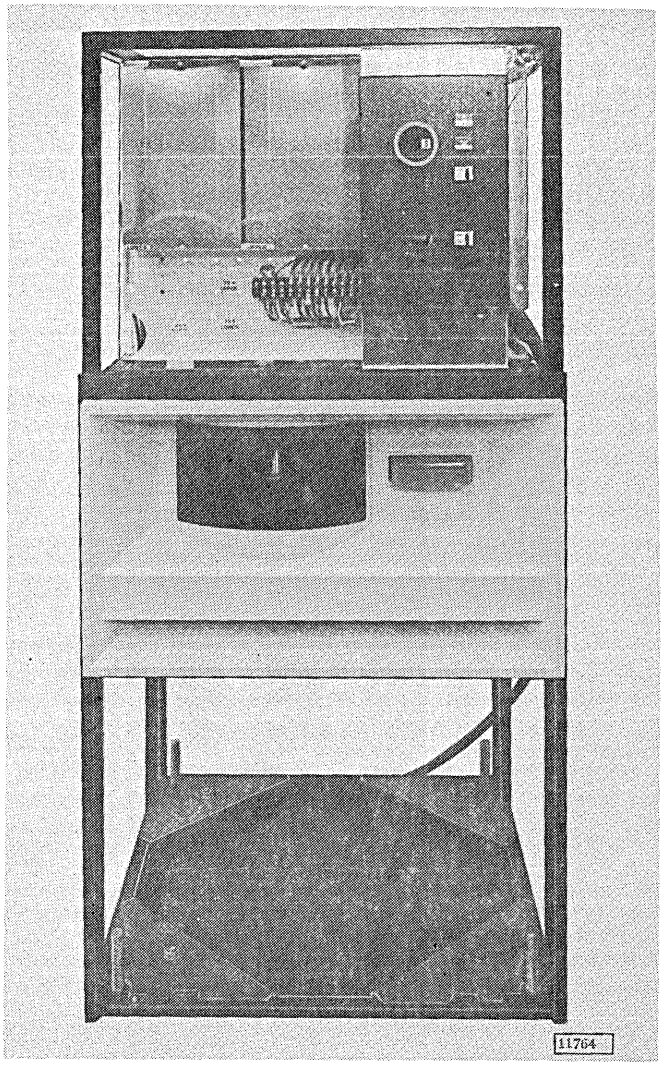


Figure 21. 2312 Disk Storage – Front View

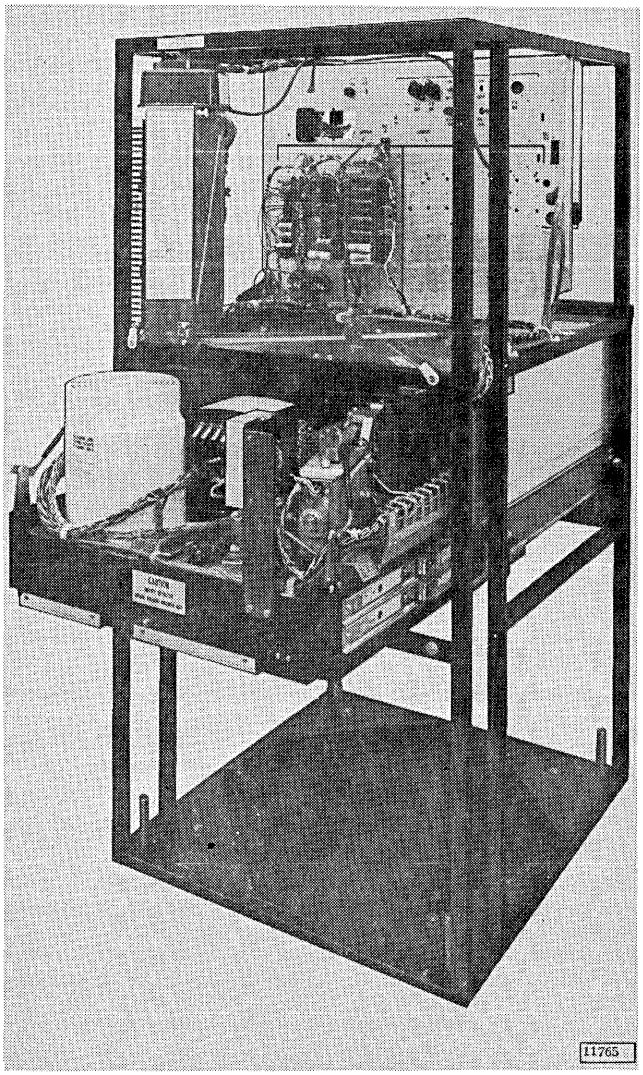


Figure 22. 2312 Disk Storage – Rear View

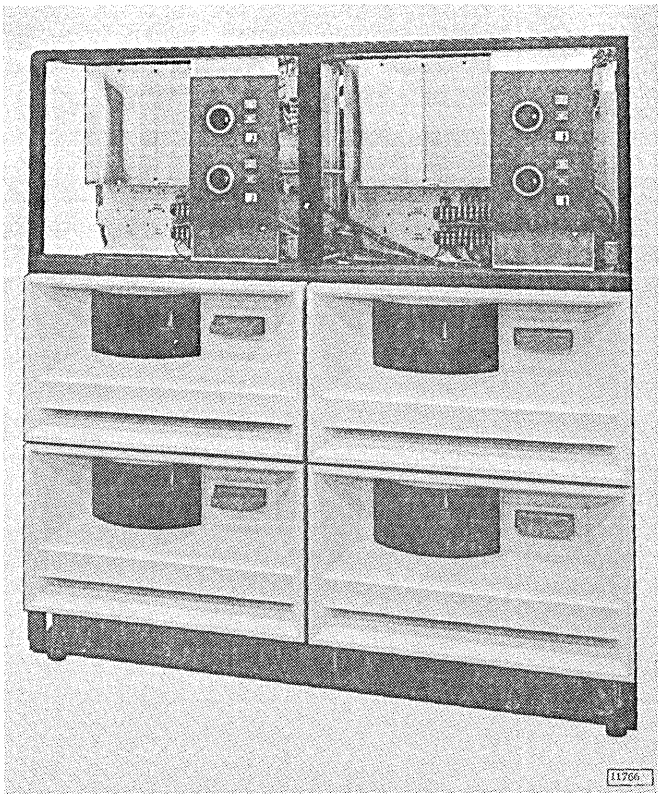


Figure 23. 2313 Disk Storage – Front View

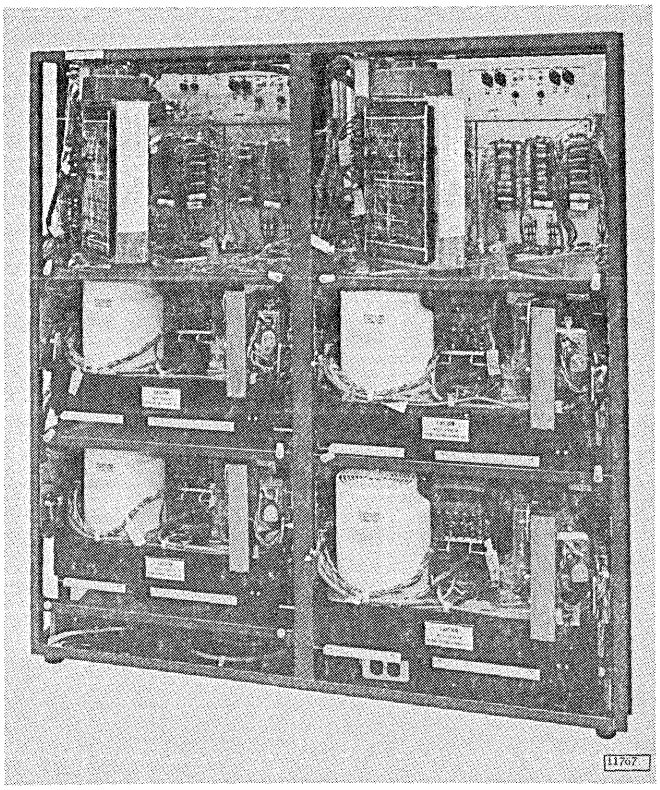


Figure 24. 2313 Disk Storage – Rear View

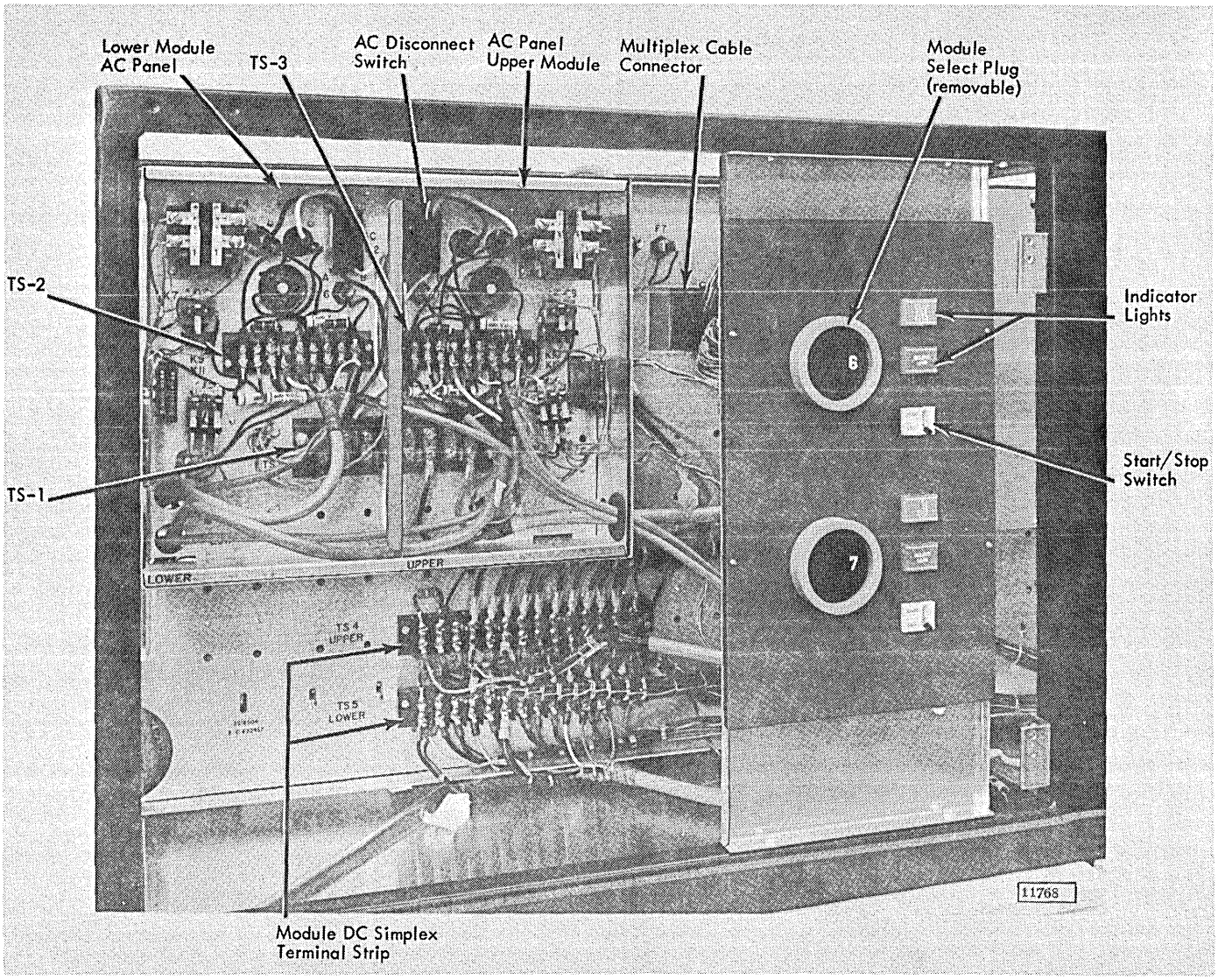


Figure 25. Disk Storage – Power Panel

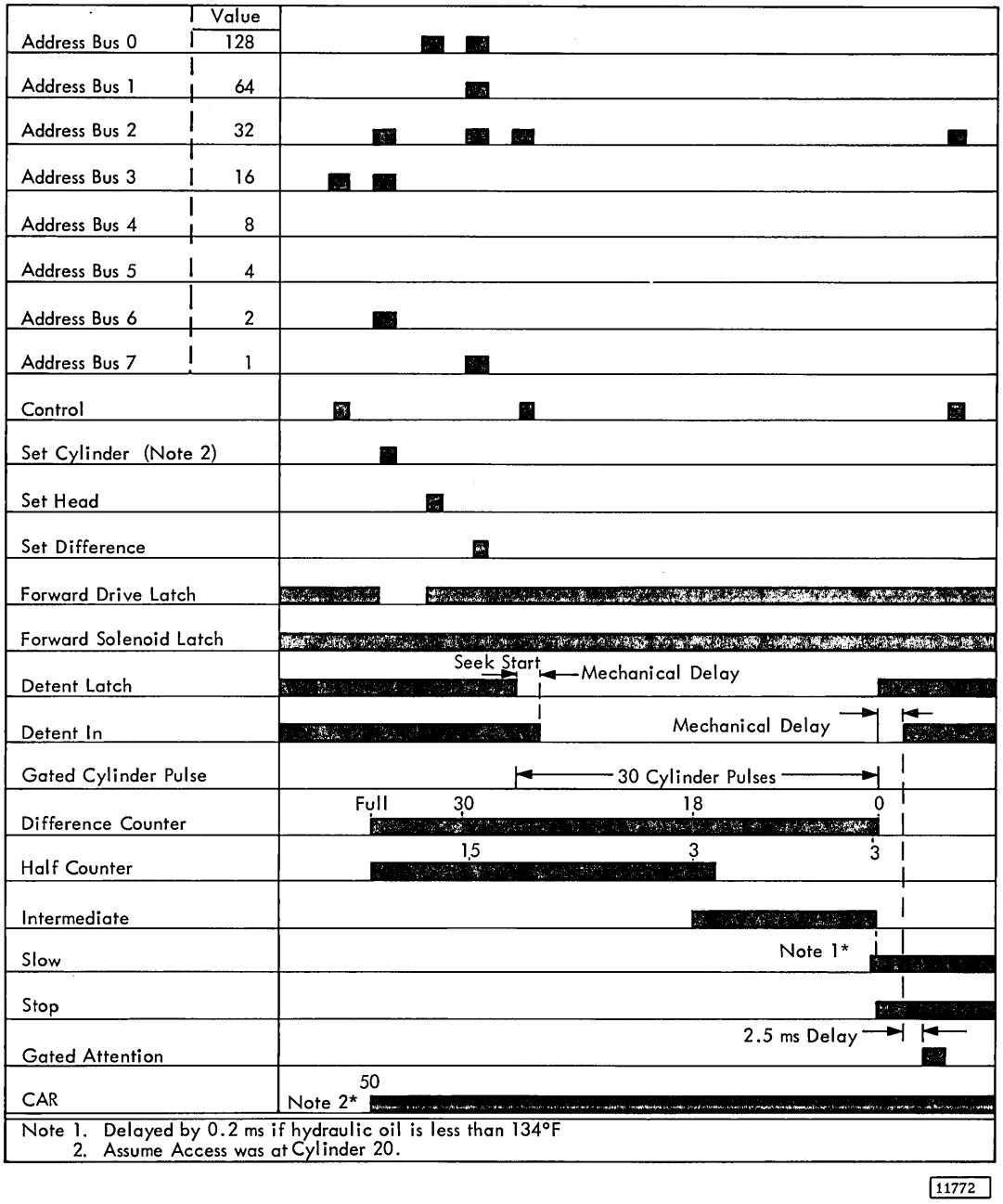
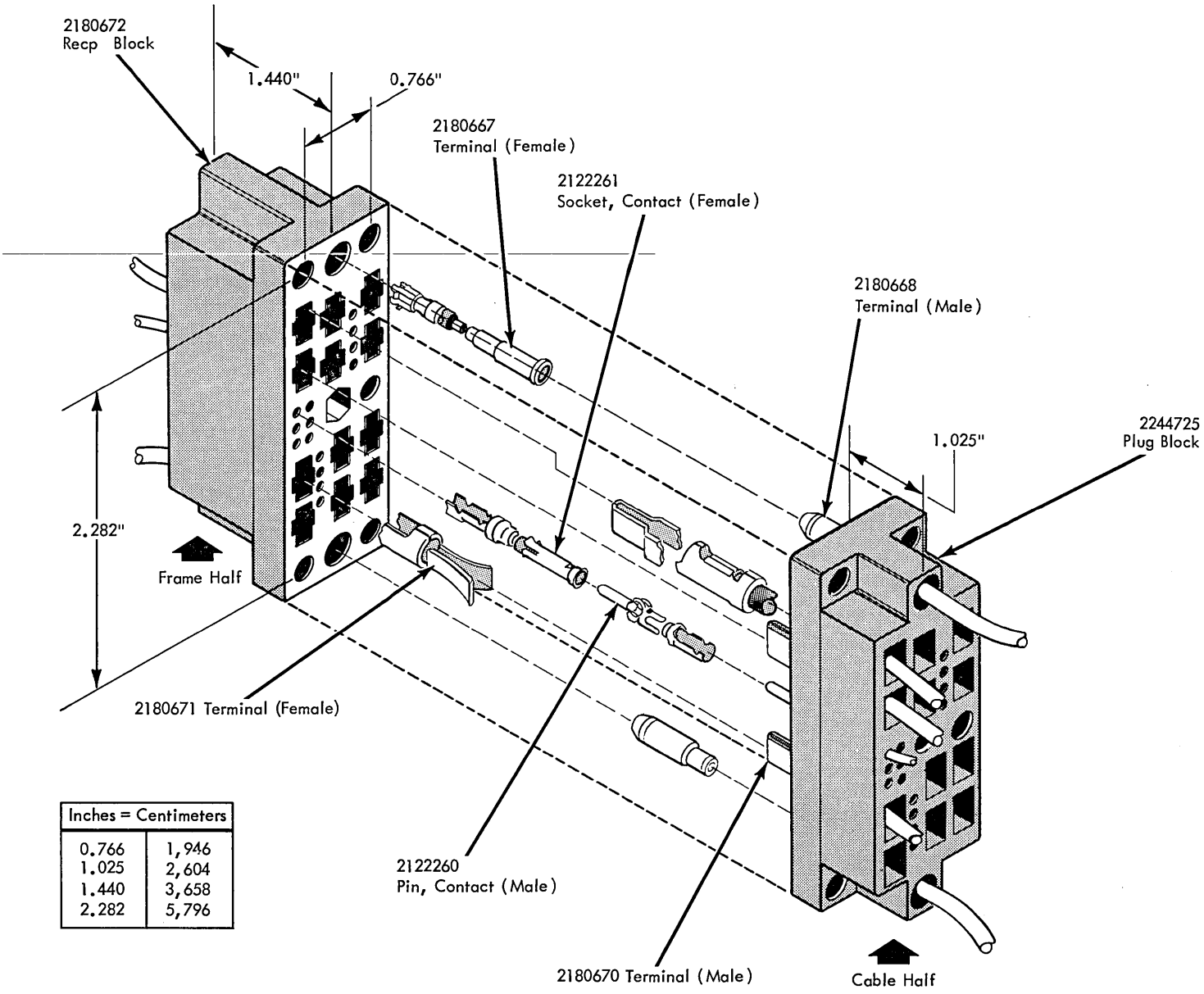


Figure 26. Access Timing for Cylinder 020 to 050

APPENDIX D. DC POWER CONNECTOR



Inches = Centimeters	
0.766	1,946
1.025	2,604
1.440	3,658
2.282	5,796

Cross Reference			
IBM Part Number	Equivalent Part Number	IBM Part Number	Equivalent Part Number
2122260	AMP* 66098-1	2180670	AMP 66253-2
2122261	AMP 66100-1	2180671	AMP 66251-2
2180667	AMP 329013	2180672	AMP C-202477-4
2180668	AMP 329014	2244725	AMP C-202476-6
*AMP Incorporated, Harrisburg, Pennsylvania 17105			

11572

Figure 27. DC Power Connector

The following parts will be provided with all 2312/2313 Disk Storage orders:

Installation instructions and diagrams -- Theory of Operation manuals, MDM's.

Maintenance Manual and Parts Catalogs.

Logic diagrams.

Terminator plug.

Cleaning paddle and tissue.

Head adjusting tool.

Head cleaning brush.

Head clearance gage.

Isopropyl alcohol.

Hexadecimal label.

Covers and kickstrips: front, rear and left end.

The following is a continuation of the parts listing for parts that are unique for each model:

2312

One module select (relocatable address) plug -- selective.

One dc cable.

One signal cable.

One ac cable.

2313

Four module select plugs.

Four dc cables -- selective first or second quad.

One signal cable.

One ac cable.

The signal cable and plug (AMP #201345-1) extend beyond the right end of the frame so that it can be connected to a mating plug (AMP #201037-1) in the adjacent module or control unit to the right.

The ac cable also extends beyond the frame to the right and connects to the adjacent unit with ring terminals.

INSTALLATION

When the disk storage unit(s) are installed, a solid member to which to attach the disk storage frames must be provided by the customer. This is absolutely necessary in order to prevent the disk storage unit(s) from tipping over when drawers are pulled out. The locations of the holes in the disk storage frame are shown in Figure 28. Slots should be provided in the solid member for ease of installation. The solid member should be located to the right of the disk storage frame.

When the disk storage is serviced by IBM, a facility to turn power on/off must be provided adjacent to the unit.

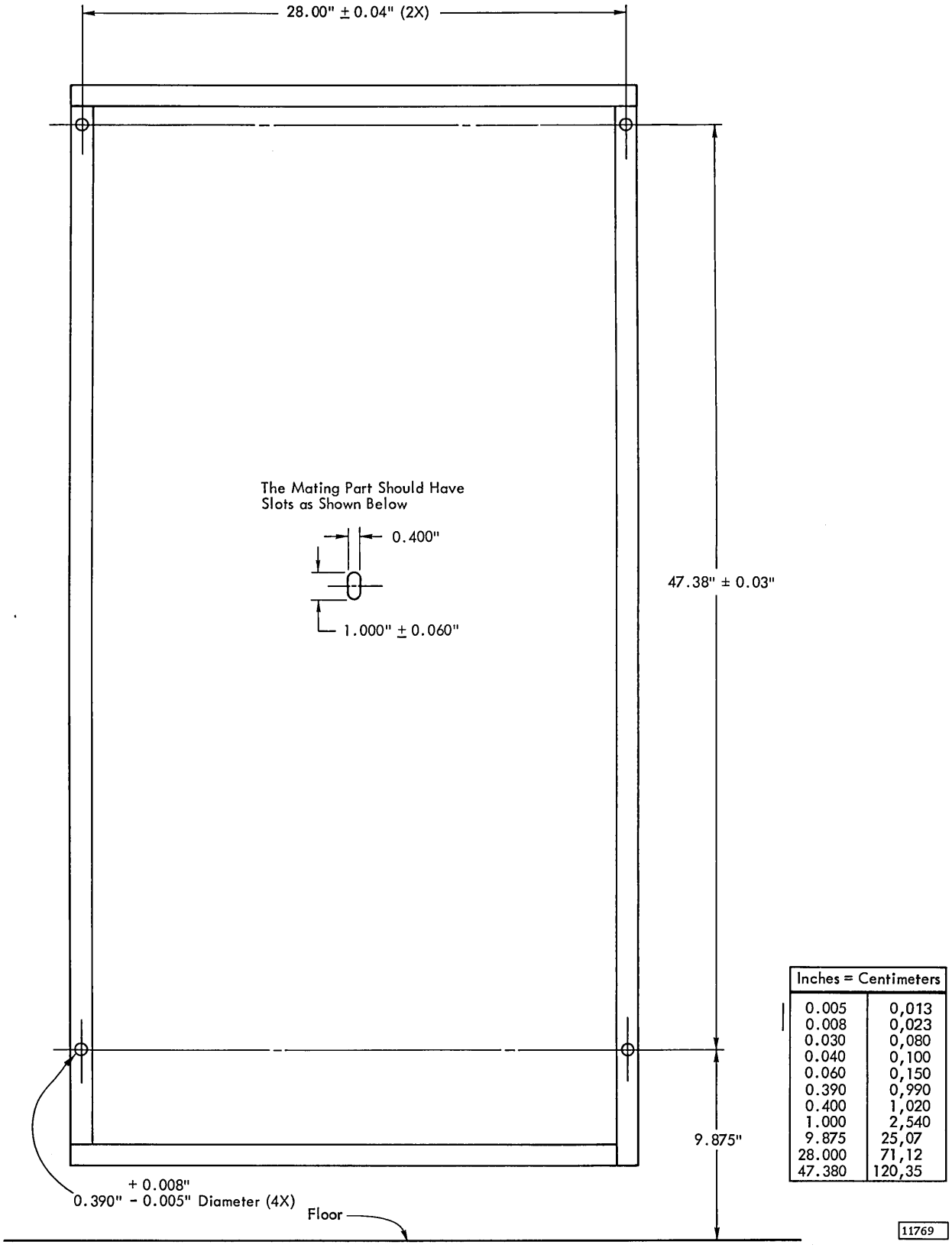


Figure 28. Location of Holes in Disk Storage Frame

IBM 2612/2313 Disk Storage OEMI Printed in U.S.A. A26-1586-1

IBM

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]

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IBM 2/2313 Disk Storage OEMI Printed in U.S.A. A26-1586-1

IBM Technical Newsletter

File Number S360-19

Re: Form No. GA26-1586-1

This Newsletter No. GN26-0259

Date June 12, 1970

Previous Newsletter Nos. GN26-0252

IBM 2312/2313/2318 Disk Storage — Original Equipment Manufacturers' Information

This Technical Newsletter provides replacement pages for the subject manual. Pages to be inserted and/or removed are:

3 through 6
6.1, 6.2 added
7 through 10
13, 14
19, 20

A change to the text or a small change to an illustration is indicated by a vertical line to the left of the change; a changed or added illustration is denoted by the symbol • to the left of the caption.

Summary of Amendments

1. Provide correction for read data bit rate.
2. Clarify bit cell times.
3. Provide additional information for read data detection.
4. Provide additional information for line termination.

Note: Please file this cover letter at the back of the manual to provide a record of changes.

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The disk storage consists of two main components: the IBM 2312/2313/2318 Disk Storage and the IBM 2316 Disk Pack.

DISK STORAGE MODULE

Access Mechanism

The access mechanism consists of a rack mounted movable carriage which supports 20 read/write heads. These heads are mounted on a common block and are placed in pairs, each pair lying between two disk surfaces of the disk pack. A hydraulic actuator moves the carriage and positions the read/write heads to any of 203 cylinders. When the disk pack is mounted in the disk storage module, information can be written or read from twenty disk surfaces. Once put in motion, the hydraulic actuator moves the recording mechanism horizontally to any one of the cylinder positions. After motion ceases, the drive sends a 'seek complete' signal to the control unit. At this time, the system selects the desired read/write head by electronic switching. In this manner, all records within a module can be located.

The module utilizes direct accessing between cylinder locations, which allows the access mechanism to proceed from any cylinder position to another without returning to home (reference) position.

The use of a comb-type access on a multi-disk module provides a cylinder of storage area at each of the physical settings of the access mechanism. The cylinder concept (Figure 3) may be visualized as cylinders or drums, one inside the other. Once the proper access location is made, any area in the cylinder is available in one revolution of the disk pack. One revolution requires 25 milliseconds.

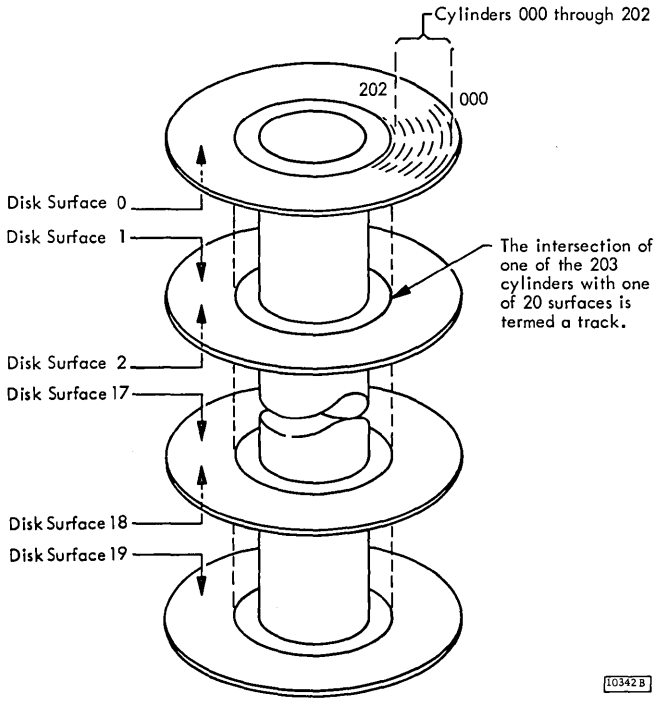

Figure 3. Cylinder Concept

Access Times

Cylinder-to-cylinder (horizontal) access time varies according to the number of cylinders traveled. Access time from one cylinder to the adjacent cylinder is 25 milliseconds. Other access times are given in Figure 4. After the access mechanism has reached a cylinder position, additional time may be required for the disk to rotate to the desired storage area. At 2,400 revolutions per minute, one complete revolution takes 25 milliseconds, where the average rotational time is 12.5 milliseconds (one-half revolution).

Access Time*	Milliseconds
Maximum	130
Average Random	60
Minimum (Cylinder-to-Cylinder)	25

*These access times include a provision for settling-down time, but do not include rotational delay. Average rotational delay is 12.5 milliseconds.

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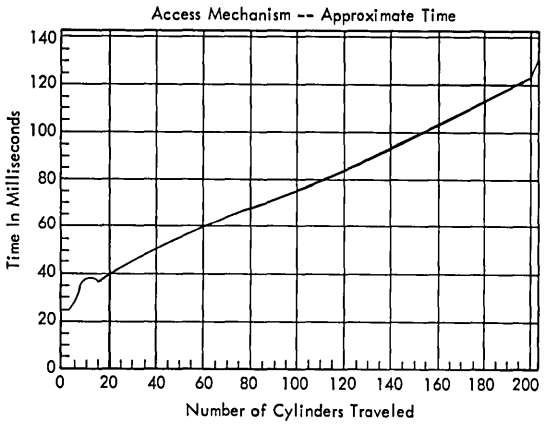
Figure 4. Access Times

The following curve is a plot of the cylinders traveled against time for the access mechanism and can be used as an aid in programming for the most efficient use of the disk storage.



In addition, an Access Timing Chart in Appendix C (Figure 26) illustrates a typical access operation.

Operational and Timing Specifications

A summary of the specifications for operation and timing of the disk storage is given in Figure 5.

Disk Storage Addressing

Each disk pack has 20 usable surfaces with 203 tracks on each surface. The vertical alignment of tracks can be thought of as a cylinder of tracks (Figure 3). In order to provide maximum accessibility of a storage area, the tracks are numbered vertically within the cylinder. Therefore, a track-to-track operation only requires microseconds of switching time rather than milliseconds of access time. To place the recording mechanism at a specific cylinder of tracks, a seek command must be given to the module. The command must provide the identification of the module and the cylinder to which the access mechanism should move. In addition, in order to select individual tracks within the cylinder, the command must designate the recording head.

DISK PACK

The IBM 2316 Disk Pack, as shown in Figure 6, is composed of eleven disks, 14 inches in diameter and spaced 0.35 inches apart on a vertical shaft. Circular protective plates are mounted above the top disk and under the bottom disk to protect the assembly. The upper surface of the top disk and the lower surface of the bottom disk are not available for data storage because of the protective plates. The entire assembly of disks, vertical shaft and protective plates rotates at a speed of 2,400 revolutions per minute, 25 ms per revolution.

Item	Nominal	Maximum	Minimum
Disk Rotational Speed	2400 rpm	2448 rpm	2352 rpm
*Oscillator Frequency	5.00 MHz	5.0025 MHz	4.9975 MHz
*Write Clock Pulse Period	400.0 nanoseconds	400.2 nanoseconds	399.8 nanoseconds
*Write Clock Pulse Rate	5.00 Megabits	5.0025 Megabits	4.9975 Megabits
*Write Data Bit Rate	2.50 Megabits	2.50125 Megabits	2.49875 Megabits
*Write Data Bit Width	70 nanoseconds	80 nanoseconds	60 nanoseconds
Read Data Bit Rate	2.50 Megabits	2.625 Megabits	2.375 Megabits
Read Data Bit Width	80 nanoseconds	100 nanoseconds	60 nanoseconds
Read Back Data Rate	312 k Bytes	328 k Bytes	296 k Bytes
*These items developed by Control Unit			

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● Figure 5. Operational and Timing Specifications

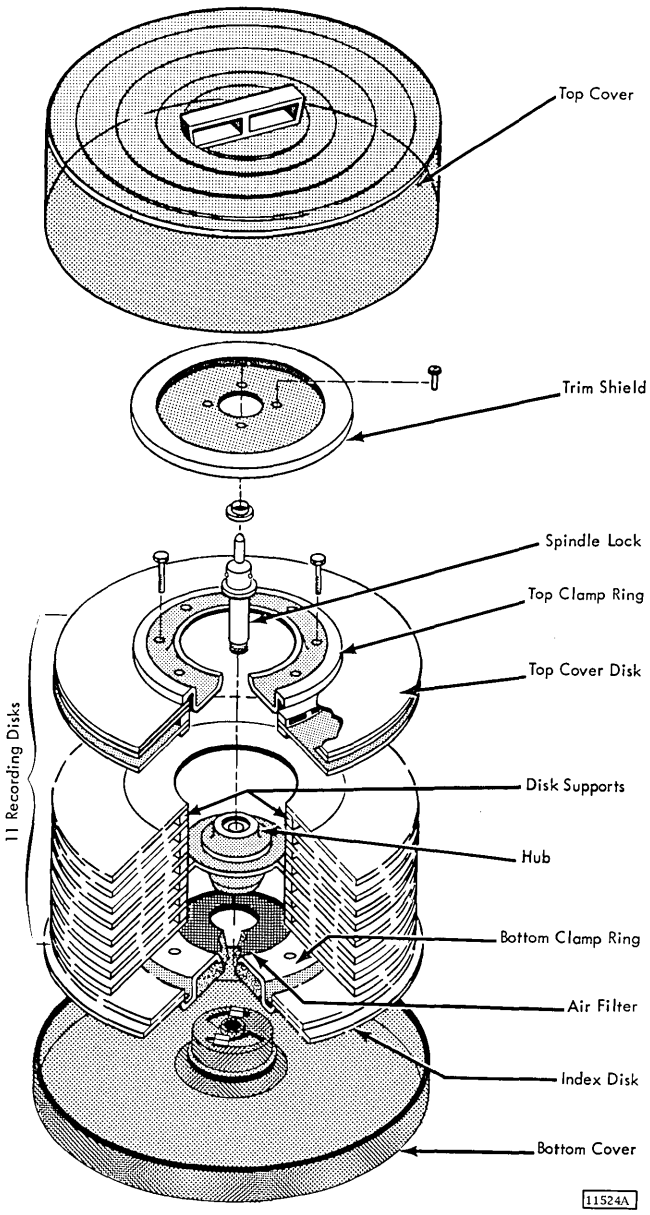

Figure 6. 2316 Disk Pack

A two-piece plastic cover for the entire pack assembly, is designed to protect disks against damage. A built in handle on the top cover makes carrying easy. A self-locking device in the handle permits removal of the top cover only when the pack is mounted on the disk storage.

Disk Pack Capacity

The maximum capacity of the 2316 Disk Pack is 29,176,000 eight-bit bytes. In packed decimal mode the maximum capacity is 58,352,000 digits (numeric only). See Figure 5 for the read/write electronic specifications. Using the worst case figures (2.49875 MHz write data bit rate and 2,448 rpm) indicates a total track capacity of 7,652 eight-bit bytes. However, the data should be checked for recording accuracy by the control unit, and this checking requires time. The IBM control units require data gaps following each record field, which reduces the track capacity. The track capacity of the 2316 Disk Pack, when used in a disk storage system attached to the 2314 Storage Control is 7,294 eight-bit bytes if one data record is written per track. The total capacity is reduced as the number of records per track increases.

> Note: IBM guarantees that the 2316 has 4000 error-free tracks. Therefore, the total capacity quoted is based on 4,000 tracks. Up to 60 alternate tracks are provided. The IBM control units can assign alternate tracks to replace defective tracks, when so directed by the stored program.

Data is transferred between the control unit and the disk storage module serially, one bit at a time.

DATA RECORDS AND FORMAT

The organization of data and the capacity of the disk storage module are dependent on the format used to store information. The read/write format should be designed to satisfy the needs of the attaching system.

Component tolerances and specific requirements of data flow electronics in the disk storage, which may affect the design of the control unit, are as follows:

- Disk Speed: 2,400 rpm ±2%.
- Write oscillator frequency: 5.0 MHz ±0.05%.
- Radial dimension of magnetic tracks:
  Track 202 4.5 inches (approximately)
  Track 000 6.6 inches (approximately).
- Minimum time from head deselect to head advance: 11.2 microseconds.
- Minimum time from head advance to head select: 1.6 microseconds.
- Relative position of one index pulse to all other index pulses: ±4 microseconds.
- Relative position of all read/write heads to a given pulse: Position tolerance ±0.0125 inches.

- Read gate: Minimum time of 60 microseconds after head select or the fall of 'write gate'.

- Write and erase gate: Minimum time of 60 microseconds after head select.

Read Data Detection

During a read operation the signal received from each disk drive module (via the coaxial cable) consists of interleaved clock and data pulses. Normally, controllers contain circuitry to remove the clock pulses, and to use their time relationship to sense the presence or absence of data pulses. Design parameters (based on the use of a 5.0 MHz ±0.05% write oscillator when the data was written) to accomplish this are as follows:

- Nominal bit cell time is 400 nanoseconds

  Note: Bit cell is the time between the rise of any two adjacent clock bits.

- Nominal data bit to clock bit time is 200 nanoseconds.

  Note: Data bit to clock bit is the time from the rise of a data bit to the rise of the following clock bit.

- Maximum continuous variation of clock bits is ±5% of nominal bit cell time.

  Note: Continuous variations are slow changes due to write oscillator drift and disk speed changes during writing, and disk speed changes during reading.

- Maximum continuous variation of data bits is ±5% of nominal data bit to clock bit time.

- Maximum instantaneous variations of clock bits is ±30% of nominal bit cell time. This includes ±5% for continuous variations.

  Note: Instantaneous variations are fast changes due to magnetic characteristics, and to voltage fluctuations within the specified parameters. Instantaneous variations compensate for each other in several bit cell times.

- Maximum instantaneous variations of data bits is ±30% of nominal data bit to clock bit time. This includes ±5% for continuous variations.

- Recommended synchronization time is 12.8 microseconds.

  Note: Synchronization time is the time to completely resynchronize to the read data signal. This is only a recommendation since the final parameter is determined by the synchronization area in the pre-record format.

Transient conditions can cause temporary read signal changes in excess of these parameters. To compensate for this, error checking and retry procedures are normally designed into the system using the disk drive.

DATA TRANSFER ELECTRONICS

The data transfer electronics include circuits for head selection, writing, and reading. Safety circuits are also included to provide protection for recorded data.

A full complement of data transfer electronic circuits is installed in each drive. This includes the head selection circuitry, the write data line receiver, the write trigger, the write driver, the erase driver, safety circuits, read preamplifier and the main read amplifier.

When data transfer to or from a particular disk surface is desired, the appropriate head address and module lines are conditioned by the control unit.

Write gate and erase gate signals must be provided by the control unit for writing data on the disk storage pack. The write data to the disk storage module must be in serial pulse form and driven by a special line driver. (See "Signal Specifications" section of this manual.)

During read operations, the recorded signals from the disk surface are sensed by the read/write head and directed to the input of the read amplifier. The read amplifier produces raw data at its output in the form of one discrete pulse for each transition on the recording disk. The output stage of the read amplifier is a coaxial-line driver which provides 80 nanosecond wide pulses through an impedance of 95 ohms.

Usually only a particular portion of the signal at the read amplifier output is usable. The control unit must provide a read gate signal to gate the read amplifier output. When the read gate signal is present, the read amplifier output is allowed to be sent to the control unit. At the recording frequency of 5.0 megahertz it is absolutely necessary to minimize the time shift of recording and read-back bits along the data flow path. To achieve this, it is best to think of the whole data path as an integral unit. The data flow path consists of a read and write clock,

located in the control unit, and recording and detection circuitry which is located in the disk storage module.

Write Circuitry

The write circuitry contains the necessary components for changing the write data pulses from the control unit into a current drive for the write coil of the magnetic head. Current in the write coil of the magnetic head produces a flux which magnetizes the oxide material on the disk.

The input write data to the disk module is under control of the control unit. The write data signal must be driven by a special coaxial line driver. The line receiver terminates the coaxial write data line in addition to supplying an output to the write trigger. The write trigger converts the discrete pulse data into binary levels, with each pulse defining a change of state. The control unit conditions the write gate and erase gate lines to signal the write circuitry for a write operation. When the write gate is on, the write driver follows the output of the write trigger. The write driver provides the current drive through the address matrix to the write coil. The write driver has two outputs, one for each write element in the write coil. Current passes through only one element at a time depending on which of the two outputs from the write driver is active. Following recording the erase driver provides current for a tunnel erase to constrain the width of the recorded track.

The frequency of the write data signal is 5.0 megabits per second. Thus a minimum of 200 nanoseconds occurs between the leading edges of any two successive bits. The duty cycle of writing with a particular write driver shall not exceed 50% -- averaged over 1 second. This limitation provides adequate protection for the write driver as well as the magnetic heads.

Read Circuitry

The read circuitry includes the necessary components for converting signals sensed by the read heads into

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discrete pulses that can be interpreted as being data or clock bits. The output stage of the read amplifier is a coaxial line driver which provides pulses, 80 nanoseconds wide, for the control unit read clock.

The same diode and transistor head select matrix employed in the write head selection is used when read information is desired. One of 20 heads is electronically selected, and the output sensed by the head is fed into the read amplifier. The read amplifier is used to increase the amplitude of the head signals originating from the selected read head.

The head signal is amplified and differentiated by the read amplifier and the resulting pulses are fed through a shaper and line driver, which provides a standard level pulse. The nominal pulse width of the read amplifier output is 80 nanoseconds. One bit, 80 nanoseconds wide, is put on the data line for each change of magnetic state sensed by the read head from the disk surface.

The nominal output frequency of the read data is that frequency at which the data was written. The instantaneous output data frequency is dependent upon: the relative clocking oscillation frequency and relative disk rotational speed during writing and reading; the bit pattern written; and the bit shift caused by the head, disk, and electronic circuitry.

SAFETY CIRCUITRY

Write safety circuits are provided to protect recorded information in the disk module. The outputs of all safety circuits are joined together and form a single unsafe line that is available to the control unit.

The following conditions in a disk module cause an unsafe signal to be sent to the control unit:

1. Multiple head select.
2. DC write current and not write gate.
3. Erase current and not erase gate.
4. Write gate and not erase current.
5. Write gate and no ac write current.
6. Read gate or not seek ready and either write gate or erase gate.
7. Overvoltage or undervoltage on +6, +3, -3, and -36 Vdc.
8. Loss of line voltage.

For any of the above unsafe conditions, the disk module deselects the heads, turns off selected write and erase gates, and holds them off until the unsafe condition is corrected.

The following conditions should be checked by the control unit and an unsafe status generated if:

1. More than one module selected line is up.
2. Write gate is up but no selected write current is sensed.

SELECTION CIRCUITRY

It is necessary to select one of 20 heads for transferring data into and from the disk pack. This is done by setting a head number into the head address register which has 20 outputs. Each output of this register is connected to the center-tap lead of each read/write head. The head is selected when 'head select' comes up. Selecting a head brings the voltage level at its center tap from -36 Vdc to +3.0 Vdc. Once a head is selected, conditioning the write and erase gates causes the write and erase drivers to supply current to the selected head.

After selecting a head in a read operation, a selected read gate is used to gate the output of the read amplifier, thus allowing raw read data to be detected by the control unit read clock.

SIGNAL INTERFACE

INPUT COMMUNICATION LINES

The input communication interface is composed of an eight line time-shared bus (address bus), four tag lines that select the information from the bus, a module select line, and a write data line.

Only one of the four tag lines is up at a time to describe the information on the bus. (See Figure 7.)

Control Tag: This line conditions the drive for a control cycle. Simultaneously activating one of the signals on the bus determines which operation is performed (such as write, read, seek, etc.).

Set Cylinder Tag: This line is used for carriage operations so that the signals on the bus function to identify the cylinder to be addressed. The 'set cylinder' pulse must be completely contained within the time that the cylinder address is on the eight-line bus.

Set Head Tag: This line and one of the bus signals perform a head select function. In addition, two other operations can be designated: select lock reset and turning on the 'forward' latch. A reset is given to the head register before a head selection.

> Note: The pulse width of the tag lines is 1.5 microseconds minimum. The bus line information must be present for the full duration of the tag line pulse.

Set Difference Tag: This line, when it is on, identifies the signals on the bus as the calculated difference between the present cylinder position and the newly addressed cylinder.

Bus Line	Conversion In Storage Module	Function During: Control Cycle	Set Cylinder	Set Head	Set Difference	Set Half Counter
File Bus 0	A128	Write Gate	Cyl 128	Forward Latch	Not 128	64
" " 1	A64	Read Gate	Cyl 64	Select Lock Reset	Not 64	32
" " 2	A32	Seek Start	Cyl 32		Not 32	16
" " 3	A16	Reset Head Reg	Cyl 16	Hd Add 16	Not 16	8
" " 4	A8	Erase Gate	Cyl 8	Hd Add 8	Not 8	4
" " 5	A4	Select Head	Cyl 4	Hd Add 4	Not 4	2
" " 6	A2	Return to 000	Cyl 2	Hd Add 2	Not 2	1
" " 7	A1	Head Advance	Cyl 1	Hd Add 1	Not 1	Not Used

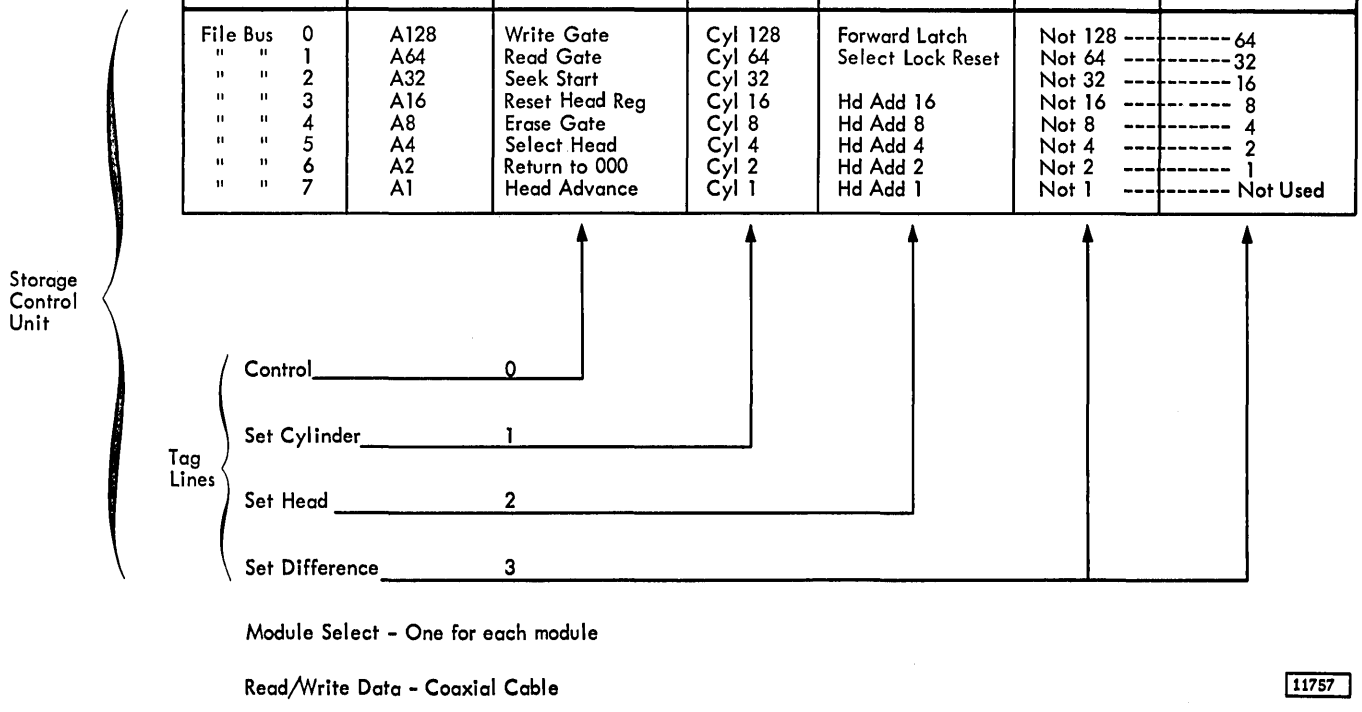

Figure 7. Input Signal Lines

Module Select: This signal is a line, in the multiplex cable, used to gate signal lines to the proper disk storage modules. This signal is gated to the proper module through the use of the module identification plug inserted in the operator panel. (See Figure 16.)

Write Data: This signal is a simplex line, one per module.

OUTPUT COMMUNICATION LINES

The disk storage supplies the following signal lines that can be used by the control unit to determine the status of the disk module.

Cylinder Address Register

Eight output lines from the cylinder address register (CAR) may be used to indicate the present disk module cylinder address. These lines are active when the module is selected and changed to a new address at 'set cylinder' time. The line names are:

CAR 1
CAR 2
CAR 4
CAR 8
CAR 16
CAR 32
CAR 64
CAR 128

Gated Attention

This line indicates that a seek has been completed or that 600 milliseconds has passed since the seek command was given without a detent-in being detected. It is reset by the read gate. 'Gated attention' is a line in the multiplex cable from the control unit, controlled by the module identification plug inserted in the operator panel. This line is not module selected.

Selected Module

This line indicates that a module has been selected. It is used in the 2314 Storage Control for the multi-module select safety logic. It is a simplex line and is module selected.

Selected File Busy

This line, when it is up, indicates that the access mechanism is in the seeking process. When the line is down, it indicates that the disk storage is ready to perform. This line is module selected.

Selected Index

This is an index pulse generated by the disk module once per disk revolution. This line is module selected.

Write Current Sense

This line indicates that the selected module is writing on the disk pack.

Unsafe

This line indicates that the disk module is unsafe and will not perform any operation. This line is module selected.

Seek Incomplete

This line indicates that the seek complete operation did not occur within 600 milliseconds after a seek command was given. This line is module selected.

End of Cylinder

The 'end of cylinder' signal occurs if, during a cylinder operation, the head select register in the disk drive goes from 19 to 20. This line is module selected.

Read Data

The 'read data' line is driven with a special line driver through a coaxial line. It is active during all read operations and is module selected.

Heads Extended

This line indicates that the heads are extended. It is used in the control unit for sequencing power-off logic. In a control unit power down sequence, the dc voltages to the disk storage modules cannot be removed until the last heads extended switch has opened, indicating that the heads are unloaded.

Selected On Line

This line indicates that the heads are extended and ready to read or write. This line is module selected.

Sequence Pick

The signal on this line starts each module drive motor in sequence when the control unit is powered up. 'Sequence pick' remains energized as long as power is on. The 'controlled ground' line is opened

to power down the disk storage drive motors when the control unit power is turned off.

Pack Change

This line indicates that a pack change has occurred.

SIGNAL CONNECTOR AND CABLE

The signal connector for connection at the disk storage is shown in Figure 9. The pin connections and signal names are listed in Figure 10. Figure 8 lists the logic voltage levels.

Cable Lengths

The disk storage operates with a maximum DC cable length of 16 feet, and a maximum signal cable length of 19 feet 4 inches from the control unit to the furthest disk drive. The signal cable extends approximately 40 inches past the machine frame for attachment to the control unit or another disk storage unit. Refer to Figure 11 for a cable view.

POWER INTERFACE

AC Power Requirements

Three phase ac power is connected to each disk storage. However, an individual module draws power from only one phase. Therefore, in multiphase systems, phases should be rotated for disk storage units in sequence. The ac voltage requirements for the disk storage are listed in Figure 12. Machines wired for 50 hertz can be operated in delta or wye systems.

The disk storage takes 3.2 amperes steady and 25 amperes starting load, for each module. The power requirement for the 2312 is 0.7 kVA; the 2313 requires 2.8 kVA; and the 2318 requires 1.4 kVA.

Up Level	Maximum	Minimum
+L	+ 6.28	+ 2.0
+V	+38.9	+28.4
+W	+38.9	+28.4
+Q	+ 3.5	+ 0.65
Down Level	**Maximum**	**Minimum**
-L	+ 0.3	0.0
-V	+ 0.4	0.0
-W	+ 1.3	0.0
-Q	- 0.5	-3.5

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Figure 8. Logic Voltage Levels

AC Power Distribution

The ac power cable has four wires: three phase leads and one ground lead. The cable extends 5 inches past the machine frame (measured from the cable breakout). See Figure 11 for a cable view.

DC Power Requirements

The control unit must supply all dc voltages for the disk storage units. The dc power requirements for each module are as follows:

- +3.0 Vdc at 0.90 amperes.
- -3.0 Vdc at 0.60 amperes.
- +6.0 Vdc at 1.10 amperes.
- +36.0 Vdc at 1.45 amperes.
- -36.0 Vdc at 0.39 amperes.

The currents specified are at nominal voltage and duty cycle. Voltage tolerances, except for +36V, are ±4%, measured at the voltage bus on the SLT gates. The tolerance of the +36V is ±8%. The voltage tolerances include any variable combinations of steady state or short duration transients.

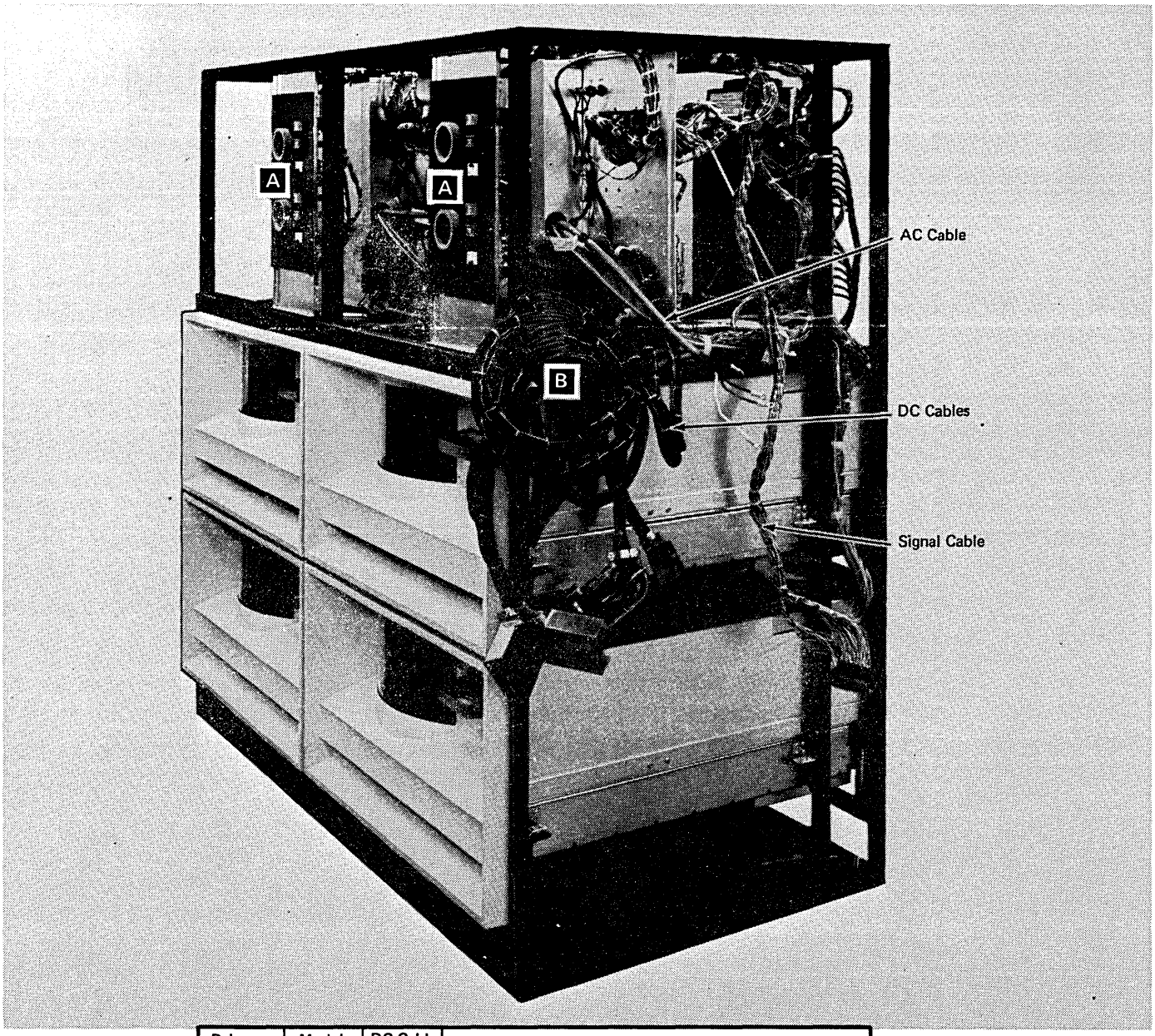
DC Connector and Cable

The dc power connector along with the pin assignments and signal lines is illustrated in Figure 13. In addition, Figure 27 in Appendix D shows the dc connector assembly and the mating plug in the disk module and lists the IBM part numbers for all parts of the connectors. Equivalent part numbers are also listed. Pins 3 and 4 are ground returns for +3, +6 and +12 volt power supplies. Pins 10 and 11 are grounds for +36V.

> Note: Maximum cable length is 16 feet. Figure 11 lists other available cable lengths.

POWER SEQUENCING

Power sequencing of the disk storage is the joint responsibility of the disk storage and the control unit. Each module provides the logic and interlocks for its operation and supplies the control unit with a 'heads extended' line (i.e., an access on-line signal). One set of contacts of relay K4 are provided for the purpose of multi-module turn-on power sequencing. Relay K4 energizes when the disk has reached 70% of the rated rpm.



Drive Ready Indicator	Module Select Plug	DC Cable Length in.	DC Cable Length cm
A	0	90	229
B	1	90	229
C	2	90	229
D	3	90	229
E	4	90	229
F	5	154	391
G	6	154	391
H	7	154	391
J	Spare	154	391

Notes

A Module select plugs can be interchanged between drives.

B Cable lengths supplied are based on the assumption that the A-drive is closest to the control unit and additional units are further away.

The module select plug address and dc cable lengths listed are standard for a 2314 facility.

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● Figure 11. AC/DC Cable Views and Standard DC Cable Lengths

AC Power	Volts ac Single Phase 60 Hz	Volts ac Single Phase 50 Hz Δ or Y Connected
Power Input	208,230	200,220,235: Δ 220,238: Y
Convenience Outlet	115	200,220,235: Δ 220,238: Y
Tolerance: Voltage ±10% Frequency ±1/2 Hz		

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● Figure 12. AC Voltage Requirement

Turn-on Sequencing

In order to make a module 'ready', a disk pack must be installed and the front cover interlock must be closed. Assuming that the control unit is not powered-up then, if the start-stop switch for the module (see Figure 16) is placed in start position, the module will power-up when the control unit is powered-up.

The timing diagram, Figure 14, illustrates the sequential events which occur when the module is turned on. A brief explanation of the events follows.

1. The 'sequence pick' signal, which is energized, and remains energized as long as the control unit has power up, activates the sequence relay in the disk module. The sequence relay then energizes the motor relay. The disk cleaning cycle starts and the heads are extended into the disk pack. Presence of ac voltage to the drive motor, energizes the ac safety circuits.
2. When the disk pack reaches 70% of the rated rpm, the speed relay is energized which then signals the next module (in a multimodule system) to start.
3. After a disk cleaning cycle is completed, the access mechanism drives forward to positive stop at high speed. The heads load while the access mechanism moves toward positive stop.
4. At positive stop the access mechanism changes direction and then moves at fast reverse speed toward hydraulic home position.
5. At hydraulic home position, the access mechanism changes direction again and moves forward at slow speed. A detent is made at cylinder 000.
6. The control unit is then sent a signal indicating that the access is ready.
7. The disk module generates the gated attention signal.

Turn-Off Sequencing

The disk module can be turned off locally by switching the module start-stop switch to the stop position or remotely by the control unit opening the controlled ground' line. Either action unloads and retracts the heads from the disk pack. At the same time the drive motor shuts off.

When the heads retract, the selected on-line signal will drop and the 'heads extended' line opens. The control unit must never drop all the voltages to the logic and special circuits of the module until the 'heads extended' signal is dropped.

For a multimodule system, the turn-off sequence remains unchanged for a particular module. However, the power to those circuits in the control unit that are common to all the modules in the system must not be dropped until the head extended signals from all modules are dropped.

Thermal Shutdown: The turn-off sequence must be executed during thermal shutdown.

Emergency Power Off (EPO): All voltages may be dropped immediately for an emergency off situation.

A turn-off sequence timing chart is shown in Figure 15.

CAUTION
All dc voltages must be at the proper level before ac power is applied to the drive motor. To prevent damage to the internal circuits of the disk storage, these dc voltages must be applied and removed at the same time.

Other than normal power-off, serious damage to internal circuits will result if the dc cable is disconnected during a power-on condition. Disconnecting the signal cable, during a power-on condition, causes the drive motor to stop.

The signal out connector on the last disk storage in the system must be terminated. Erroneous results will occur if this terminator is disconnected during a power-on condition.

General

Signal lines to the disk storage can be driven by single or multiple drivers and can feed single or multiple receivers. All signal lines must terminate with an impedance of 95 ohms.

Single Driver and Receiver

When a transmission line is supplied by a single driver and feeds a single receiver, the driver and receiver must be located at the ends of the line but not beyond the line terminator.

Multiple Drivers and Receivers

Transmission lines can be driven by a maximum of eight drivers and can supply a maximum of eight receivers. Any combination of drivers or receivers, up to a maximum of eight drivers and eight receivers, can be logically ORed to the transmission line.

Multiple receivers on a line should not be less than 3 feet apart. However, no minimum spacing requirements have been set for:

- The distance between drivers.
- The distance between an end-of-line terminator and a driver.
- The distance between an end-of-line terminator and a receiver.

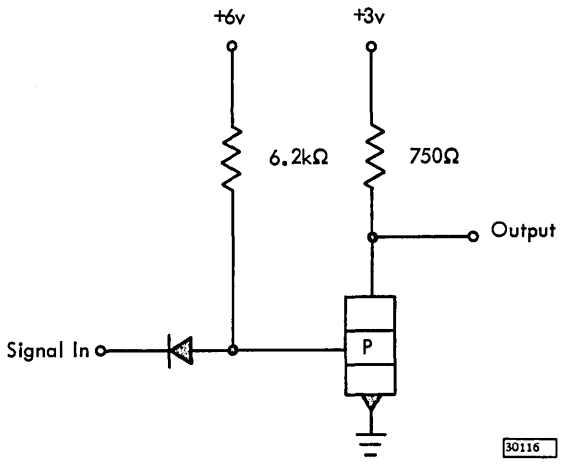

Figure 17. Line Receiver

Figure 17 is a diagram of the typical line receiver. Figure 18 shows a line driver.

ELECTRICAL CONSIDERATIONS

Current Flow

The direction of current flow (conventional) is minus (-) if it flows into a component or positive (+) if it flows out of a component.

Voltage Levels

Refer to Figure 8 for the logic voltage levels used in the disk storage. A signal line is considered active when it has a value specified in the table.

Impedance

Line terminators must have a characteristic impedance of 95 ohms ±10 ohms. The terminator network shown in Figure 19 is provided for each signal line by the terminator plug. The terminator plug (included in the ship group) is installed in the last female multiplexer connector position in the 2312/2313/2318.

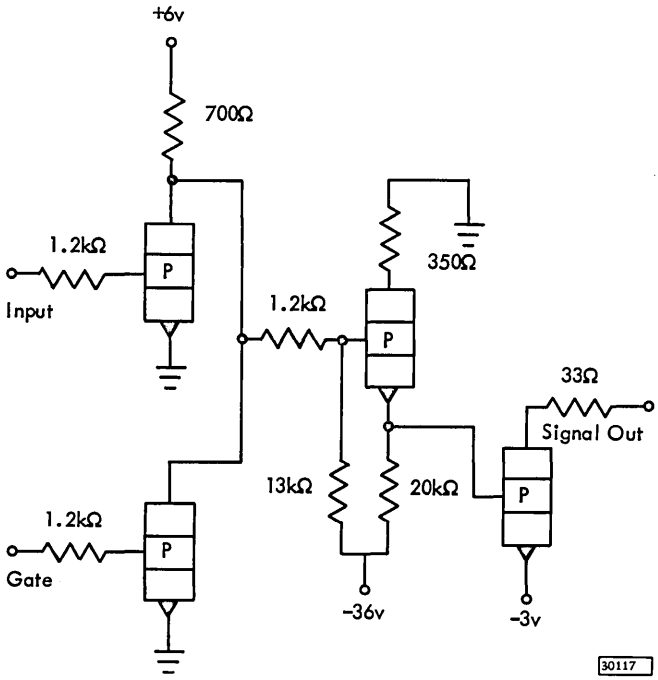

Figure 18. Line Driver

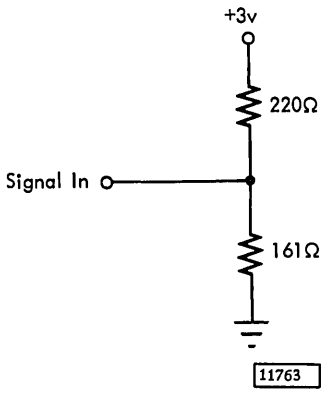

Figure 19. Line Terminator

Noise

The maximum noise coupled onto any signal line within a cable and due to any combination of changes external to that line must not exceed 300 millivolts.

Fault Conditions

The signal line may be grounded with no damage to drivers, receivers, or terminators.

Loss of power at either end does not cause any damage. Loss of power at the terminator may cause random errors in information transmission. The line operation is unaffected if power is off in any driver or receiver unit.

SPECIFIC ELECTRICAL REQUIREMENTS

The receiver circuits in the disk storage are designed to interpret input signals as follows:

1. The more negative line signal is a logical 1.
2. The more positive line signal is a logical 0.
3. An open input is treated as positive (logical 0).
4. The switching level from logical 1 to logical 0 is 2.0 volts.
5. The switching level from logical 0 to logical 1 is -1.0 volts. The receiver must not be subjected to a voltage level more positive than +3.5 volts or more negative than -3.5 volts. Refer to Figure 17 for the line receiver input circuit.

Input Requirements

Up Level: The dc voltage must be less than +3.50 volts and greater than +0.65 volts.

Down Level: The dc voltage must be greater than -0.50 volts and less than -3.50 volts.

Direct Current: The direct current requirements are 1.03 milliamps at -0.50 volts and 0.00 milliamps at +0.65 volts.

Terminator

The terminator is considered a two-terminal network, consisting of resistors and power supplies, and must meet the following requirements:

- The terminal connected to the signal line must present an open-circuit voltage between +1.0 and +2.0 volts.
- Impedance between the terminals must not be less than 90 ohms or greater than 105 ohms.

Driver

To transmit a logical 1, the voltage source driver draws approximately 25 milliamps from the line. To transmit a logical 0, the driver is off. (See Figure 18 for the driver circuit.)

Cables

The cables may consist of any combination of twisted pair, coaxial cable, and printed circuit wire within the following limitation: the maximum allowable internal cable resistance offered is 1.5 ohms. The measurement of this value is made between the external connector pins.

The nominal characteristic impedance of coaxial cable is 92 ohms. The characteristic impedance of twisted pair ranges from about 90 to 105 ohms.

Connectors

The maximum allowed coupled noise due to all connectors in each control unit, and including external cable connectors, is 250 millivolts.