

MODEL 3040 DISK CONTROLLER SYSTEM

REFERENCE MANUAL

FOR THE PDP-8

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1. INTRODUCTION

The System Industries Model 4400/4500 Disk Systems are designed to provide a wide range of bulk storage capabilities to users of various minicomputers. All of these systems incorporate the System Industries Model 3040 Disk Controller combined with either the Diablo Systems Inc. Model 40 series moving-head disk drives, or the Applied Magnetics Corporation (AMC) fixed head disk drives, or combinations of both. The moving-head drives provide a large on-line capacity plus the convenience and flexibility of a removeable storage medium, while the fixed-head drives provide very fast access. Thus, these storage systems can be configured to meet in an efficient fashion the needs of a variety of minicomputer system requirements and applications.

This manual describes the Model 4400/4500 Disk System when the Model 3040 Disk Controller is interfaced to a PDP-8 Series Computer.

The manual includes the functional descriptions and capabilities of the system, procedures on its operational aspects, and includes checkout and diagnostic data. The appendixes contain information regarding installation procedures along with all the necessary diagrams and schematics for a complete understanding of the system.

2. FUNCTIONAL CAPABILITIES

System Configurations

The Model 4400 Disk Storage Systems employ fixed-head disks only and are used in those applications requiring very fast access to limited amounts of data.

Model 4500 Systems employ moving-head disk drives and are best suited for those applications requiring large capacity, or the flexibility and convenience of a removable medium for off-line storage. With either system, the user has the option of adding one or more of the other type of disk. Such combinational systems can provide rapid access to those parts of the data or program files that require it, and at the same time offer large-capacity on-line data storage.

The Model 4400/4500 Systems utilize both the Program I/O and the Direct Memory Access (DMA) facility of the minicomputer. All commands from the minicomputer to the disk system and status information from the disk system to the computer are transferred via Program I/O. All data transfers between the computer memory and the disk use the DMA facility.

The Model 3040 Controller, which is the heart of each disk storage system, has four independent, parallel peripheral parts. Each port can accommodate one of the following:

- ° One Diablo Model 43 Disk Drive
- ° One Diablo Model 44 Disk Drive
- ° One AMC Model 200-D Disk Drive

Any combination of the 3 disk drives may be attached to the 3040 Controller to form a storage system. Since the same set of instructions is used for both the moving-head and the fixed-head disks, the programming is independent of the particular storage system configuration.

Changes to the Model 4400 or 4500 Disk System's configuration can be made conveniently in the field by plugging the cable interfaces for the additional disk drives into the unused ports of the 3040 Controller.

Table 2-1 summarizes the capacities, access times, and transfer rates for the Model 4400 Systems and Table 2-2 provides that information for the Model 4500 Systems.

Data Transfer Operation

The main functions of a disk controller are to provide the user with a method of addressing the blocks of data on the disk and to control the parallel to serial or serial to parallel conversions of the data when writing onto or reading from the disk respectively. This subsection describes the methods employed by the Model 3040 Disk Controller when used in the Model 4400/4500 Systems.

* Disk Addressing

The smallest, addressable, block of data in a Model 4400/4500 Disk System is called a sector. For PDP-8 series computers, the sector contains 256 12-bit words of data and there are 16 sectors per track. The number of tracks in any one disk drive is a function of the type of disk drive and can be obtained from either Table 2-1 or 2-2. Thus, to specify a disk address, the user must specify two numbers: a track address and a sector address.

* Data Transfer Specification

Besides the starting disk address, only two other parameters are needed to be specified to initiate a data buffer of any size - from one word up to 4096 words. These two other parameters are the word count and the starting core address.

These parameters are initialized prior to a data transfer initiation by a single I/O instruction and are automatically maintained and updated by the 3040 Controller throughout the ensuing transfer.

TABLE 2-1

Moving-Head Disk Specifications for PDP-8 Series Computers

	<u>Model 43</u>	<u>Model 44</u>
Number of Tracks per Drive	816	1632
Number of Sectors per Track	16	16
Number of Words per Sector	256	256
Total Drive Capacity (Words)	3,342,336	6,684,672
Maximum System Capacity (Words)	13,369,344	26,738,688
Bit Transfer Rate	2500 Khz	2500 Khz
Word Transfer Rate	208 Khz	208 Khz
Average Rotational Latency	12.5 ms	12.5 ms
Head Movement Times, Max.		
Cylinder to Cylinder	12 ms	12 ms
Average	38 ms	38 ms
All Cylinder?	?	?

TABLE 2-2

Specifications for a Maximum Capacity Fixed-Head Disk System for the PDP-8 Series Computers.

Maximum Number of Tracks*	128
Number of Sectors/Track	16
Number of Words/Sector	256
Total Disk Capacity (words)	524,288
Maximum System Capacity (words)	2,097,152
Bit Transfer Rate	3.4 MHz
Word Transfer Rate	255 KHz
Average Access Time	8.3 ms

* AMC drives are available with 1-16 heads. Each head records on 8 tracks. Formatting is performed prior to shipment.

Once these three parameters have been initialized and the data transfer is started, the 3040 Controller will transfer the exact number of words as specified by the word count and will automatically cross any sector, track, or cylinder boundary to access these words.

This word count/current address approach to data transfer operations enables the user to transfer large blocks of data with just a single sequence of I/O instructions, without regard to disk boundaries. Sectors of data are transferred consecutively, even when going across track boundaries. A revolution of time is lost only on moving-heads disks when going across cylinder boundaries to allow time for the heads to move to the next cylinder.

° Read and Write Operations

The I/O instructions which initiate the read or write operation actually initiate a combined seek-read or a seek-write operation. This concept thus helps simplify the programming steps to start a data transfer since the user doesn't have to separately preposition the head before a read or write instruction is executed. The longer time it takes to do a seek-read or seek-write over just a read or write after the head has been positioned does not affect the total system, since the disk ports are parallel in construction and overlap seeks on any other port may be initiated at any time. In addition, the combined seek-read (or write) operation make the moving-head disk appear to the user to be no different than the fixed-head disk except for the response time, allowing programming to be done independently of the type of disk.

° Address Verification

For the moving-head drives, the Model 3040 Controller automatically verifies that the correct track has been located before a read or write operation can take place on any sector located in that track. This is done for each and every sector to be read or written, and is especially important for the write operation where an inaccurate head movement would cause a loss of data without this verification. This address verification is accomplished by comparing the address of the desired track and the actual address written at the beginning of each sector on the disk. These track addresses are written on each disk cartridge prior to its use by means of a disk formatting program. Should an addressing error be sensed, an automatic restore is done on that disk port by the Model 3040 Controller to alleviate the programmer from having to accomplish this by additional instructions.

° Double Buffering

In order to allow the computer some timing leeway while still keeping up with the high transfer rates of the disk drives, a double buffering data transfer scheme is employed.

Data coming off the disk during a read operation, comes in in a bit serial fashion and shifts into the Data Shift Register in the 3040 Controller. When this shift register is full, a parallel transfer must take place from the shift register into a buffer interface register which holds the data for a computer DMA cycle while the shift register is busy shifting in the next word. If only one buffer interface register were employed, this would require that the computer answer the DMA request within the time it takes to shift in one word to the disk controller. This would

place limitations on both system architectures and the types of instructions one could use while the data transfer was taking place.

To alleviate this problem, a double buffering scheme using a second buffer interface register was employed. This gives the computer twice the amount of time it takes the disk to transmit one word to the controller for it to answer a DMA request. This scheme is also utilized when writing onto the disk. This thus gives the system designer and programmer the flexibility needed without worrying about the speed of the disk transfers.

◦ Error Checking

The Model 4400/4500 Disk Systems are constantly sensing for the occurrence of nine different errors. Four of these, which are sensed by the disk drives themselves, are the File Ready, Write Check, Logical Address Interlock and Seek Incomplete errors. The other five, which are sensed by the Model 3040 Controller, are the Address Verification, Cyclic Redundancy Check, Computer Timing, Write-Lockout and Format errors. When any of these errors are sensed, the operation is terminated with the cause of the termination displayed in the Status Register of the Model 3040 Controller.

◦ Post Transfer Status Information

At the completion of a data transfer, as well as during it, the contents of the Track Address and Sector Address Registers, and the Control and Status Registers in the Model 3040 Controller are available via program I/O instructions. The combined information

in the Track and Sector Address register will contain either the address of the sector on the disk following the last one involved in the transfer operation if the transfer was successfully completed, or the address of the sector on the disk when one of the nine errors was sensed. The contents of the Status Register indicates which errors, if any, occurred during the transfer operation.

ADDITIONAL FEATURES

The following features, in addition to those directly involved in the data transfer operation, enhance the capabilities and ease of use of the Model 4400/4500 Disk Systems.

° Bad Sector Indication

Bad sectors on a disk cartridge used in moving-head drives can be identified and then flagged by means of a format program. This is done by incorrectly formatting the bad sector, thus forcing an address verification error. Software look-up tables may then be used to identify the replacement sector.

° Write Protection

For moving-head disks, any sector on a cartridge can be write-protected by setting the write-protect bit in the Track Address Word. The setting of this bit is done when the sector is formatted prior to its use. When it is set and during the course of normal operation (when the format switch is in the "NORMAL" position), an attempt to write that sector will result in the generation of a write-protect error and a termination of the write operation. The initial writing of write-protected sectors or the updating of information in write-protected sectors can be

accomplished through manual intervention by switching the format switch to the "FORMAT" position before attempting to write on those sectors. In this case, the format switch serves as a write-protect override switch.

Write-protection in the fixed-head disks may only be accomplished if the disk is equipped with the write-protect option. With this option, groups of eight tracks may be protected against write operations by setting the write-protect switch (located on the front panel of the disk) associated with that set of tracks. As with the cartridge disk, if a write operation is attempted on any sector in a set of tracks whose write-protect switch has been set, the write operation will be terminated and the occurrence of the write-protect error will be indicated in the Status Register of the Controller.

° Overlap Seeking

With four parallel ports and separate Seek Address and Track Address Registers, the design of the Model 3040 Disk Controller allows the user to initiate overlap seeks (head-positioning actions without data transfers automatically following) on a disk port at any time, even if a data transfer is in progress on another disk port. This capability can greatly enhance system response times by overlapping the longer head movement times with other system actions and reducing the access times of data transfers down to the lower limit of the average rotational delay of the drive.

° Interrupt Generation

The Model 4400/4500 Disk Systems are designed to fully utilize both the skip-on-condition (either "done" or "error") instructions and the interrupt capabilities of the PDP-8 series computers to which it is interfaced. The programmer may test both the done and error flags at any time, and can control interrupts locally in the Model 3040 Disk Controller via the interrupt enable bit of the Control Register. If the interrupt enable bit is set when the done flag gets set, an interrupt request will be generated to the computer.

The done flag will be set when a data transfer completes, either successfully or having sensed an error, or when a head movement terminates from an overlap seek while there is no data transfer in progress.

The information needed to interpret the cause of the interrupt is contained in the Status Register of the Controller for data-transfer-related interrupts and in the Seek Status Register for interrupts generated at the completion of a seek operation. Both of these registers may be interrogated by an I/O instruction in an interrupt subroutine.

° Instruction Timing

The Model 4400/4500 Systems have been designed to eliminate timing problems that could result under certain sequences of disk system commands. For example:

- ° The Controller will automatically queue a data transfer instruction for a cartridge disk drive that is presently seeking and will execute that data transfer instruction upon the completion of the seek operation.

- The Controller will automatically queue a data transfer instruction until the completion of the sequence that sets up the Word Count Register and Current Address Register. This relieves the CPU of any waiting when initiating the data transfer operation.
- Overlap seeks may be initiated on any port at any time. However, the execution of an overlap seek on a port is ignored when that port is presently seeking or performing a data transfer.
- The registers in the Controller that receive commands from the computer are always available; the programmer does not have to observe any minimum waiting time restrictions.