

TECHNICAL DATA ON THE DISCFILE\* BY data products corporation

Model dp/f-5020

The data products corporation DISCFILE is a versatile, reliable, field-proved mass random-access memory system. This equipment provides the solution to the problems created by the growing need for fast random-access data storage.

The DISCFILE Model dp/f-5020 is an integrated memory system using mechanical, magnetic and solid state elements to provide rapid access to a large amount of information at a low cost and a small physical size per bit. Due to the fast access time to random data, it adds versatility to systems for program storage, compiler routines, real time inquiries and non-batched processing.

The use of these DISCFILES in digital data systems provides a large-capacity external store which supplements an internal store. When addressed in a binary manner the capacity is in excess of 25 million alphanumeric characters. When addressed in the decimal mode, it will store 100,000 records each of which contains 200 parity-checked alphanumeric characters or more than 300 parity-checked decimal characters.

FEATURES

- . proved reliability of operation
- . ease of maintenance
- . minimum maintenance time
- . wide range of capacity
- . serial or parallel data transmission
- . high density non-contact recording
- . phase modulated recording
- . linear positioning
- . precision magnetic head positioners
- . separate head positioner for each disc
- . position hold
- . programming flexibility
- . interface choice
- . multiple heads electronically switched
- . successive records accessed without interrupt
- . binary or decimal addressing
- . fixed heads available for 26 millisecond data access

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- suitable for operating flicker-free displays
- wide range of system functions
- read-after-write without seek delay
- multiple file operation by a single controller
- simultaneous seek on two or more files
- computer interrupt when record located
- address validation before accessing
- wide range of record length
- automatic head retraction on power loss
- no loss of data on power failure
- parity checked address transmission
- entire recording surface of disc subjected to rigid inspection
- operates over wide temperature and humidity range
- precision assembly shock mounted

## GENERAL

The basic storage element of the system is a magnesium disc 31 inches in diameter coated on both sides with a magnetic oxide material. The system employs from four to sixteen discs mounted on a vertical shaft. The entire stack is rotated at 1200 rpm nominal.

The data is stored on concentric tracks using magnetic recording techniques. There are 512 such tracks on each disc. The tracks are accessed by means of read/write heads which are positioned to the selected track using a Linear-Head-Positioner.

Each disc has its own positioner. The positioner is a linear d.c. actuator providing extremely precise positioning accuracy. Attached to the armature of the positioner is a forked arm. Each side of the fork carries four flying read/write heads. These flying heads -- four on the top surface and four on the bottom surface of the disc -- move in and out on a radius of the disc as the armature changes position. As a result eight data tracks are available at each position, and all eight tracks may be read or written sequentially, or at random, without any delay due to the motion of the positioner.

The data on each track is usually divided into records of equal length, and data products corporation supplies the equipment with the desired record length. The records are identified on the disc by pre-recorded headers which contain the record address. This consists of the selected disc number, the position of the positioner, and the selected record from the possible set of records associated with that position.

Two additional discs are supplied with the DISCFILE. One of these is a baffle disc and the other is a control disc which is used to store format and clock data required to locate records and to generate the proper frequency for recording. These tracks are accessed with fixed heads. The format tracks are written by data products corporation prior to delivery to correspond to the selected record length. The control disc may also be provided with as many as 28 fixed heads which may be used to store more than 700,000 bits with an average data access time of 26 milliseconds. This data may be used for table storage, program storage, or storage to refresh a display device. This combination of flying, fixed and moving heads provides the advantages of a drum and the random-access feature of a disc in one storage mechanism.

The maximum data capacity of a data products corporation DISCFILE is  $155 \times 10^6$  bits or more than  $25 \times 10^6$  alphanumeric characters. Each disc stores nearly ten million bits, and from four to sixteen discs may be used to suit the application at hand.

In addition to supplying random access to any record of the file, the DISCFILE is capable of sequentially reading or writing all the records from the eight heads at a

given positioner location. This makes 151,858 bits available sequentially without additional access time. In the random mode any individual record accessed at the same position as the last one accessed requires an average access time of 26 milliseconds which is due to rotational delay.

Important features of the DISCFILE are "confirmation" and "validation". When a new address is received it is stored and data is read from the selected head while the positioner is moving. When the track portion of the record address read from the DISCFILE agrees with the stored address, the head is "on track". Reading or writing is not allowed, since the head may not be accurately located on the track. The DISCFILE then must read a sufficient number of record addresses to assure that the head is settled. This process is called Track "Confirmation". Even after confirmation, data is not read or written until the selected record address is read from the DISCFILE. This is called "Validation". After the positioner is on track and "confirmation" and "validation" are complete data may be read or written.

The average operating rates of the data products corporation DISCFILE have been measured using on-line user programming. The rate obviously varies with the computer employed and the nature of the program. Under typical non-batched or random conditions the system can operate at a rate exceeding 15,000 transactions per hour. Rates far exceeding this are often experienced even under apparently random conditions, This is because individual positioners are employed which remain on a track even when other positioners have been selected. The normal average times that are experienced are as follows:

Motion Time	130 milliseconds
Time to Confirmation	180 milliseconds
Access Time	205 milliseconds

The average access time never exceeds 225 milliseconds.

The system design of the DISCFILE makes it possible to utilize fully the interrupt features of a computer. After the address of the desired record is transferred to the file, the file is logically disconnected from the computer. After the file has located the desired record, it signals the computer to re-connect the file and information is transferred. In an installation where multiple DISCFILES are used, it is possible to have all the files on line simultaneously seeking. The file which is ready for information transmission is connected to a single transmission bus while the other files continue to seek the records assigned to them.

The DISCFILE will be employed to store very valuable data for relatively long periods of time and has been designed to ensure that the loss or destruction of data is minimized. Intended for applications in business and industry where continuous availability is of prime importance, the DISCFILE reduces maintenance to the absolute minimum.

This high reliability is achieved through conservative design and through the use of non-contact recording techniques. Non-contact magnetic recording utilizes the flying heads in conjunction with precision discs, which are completely tested both optically and electrically on a laboratory basis before being installed in a DISCFILE.

## DATA ORGANIZATION

Each record in the DISCFILE is uniquely identified by its record address. In the address ten bits always define the disc and position address. The number of remaining bits are a function of the number of records per track, which in turn, is dependent on the record length.

The circular tracks of each disc are located in inner and outer zones. Each zone contains 128 tracks. An outer zone track contains twice as many bits as an inner one. If all records are the same size, the number of records on an outer zone track are twice as many as on an inner zone track.

The usual practice in arranging records is to put a binary number of records in the outer zone tracks. Thus the usual formatting arrangements are:

Outer Zone Records/Track	2	4	8	16	32
Inner Zone Records/Track	1	2	4	8	16
No. of Bits Required	1	2	3	4	5

The table also gives the number of bits required to select a record. There are eight heads attached to each positioner arm, and three additional bits are required to select a head. The total number of bits is 13 plus the number to select a record. If there are 16 records on the outer zone, 17 bits are used as the record address. It should be noted that although 17 bits are used to define the address, there may not be  $2^{17}$  records in the DISCFILE. The reason is that four bits are used to describe the outer zone records as well as the inner zone records, but there are only eight inner zone records. If there are  $n = 2^k$  records in the outer zone, then the file contains  $16 \times 64 \times 4 \times (2^k + 2^{k-1})$  records, for  $n = 16$ ,  $k = 4$ , the number of records in the DISCFILE is 98,304. The record length in this case could be 207, 7-bit characters. If desired other format arrangements may be provided. For example, seventeen 200 character records may be recorded in the outer tracks while keeping eight on the inner tracks. This, together with a modification of the addressing logic, permits the file to store 100,000 decimally addressed records.

The DISCFILE can be supplied with built-in hardware to check that the address is valid. If a programmer inadvertently uses an invalid address, an error indication occurs.

## SEQUENTIAL ACCESSING

In some DISCFILE applications there is a requirement to read or write a number of records in sequential address locations. The DISCFILE can be provided with the feature of continuing to read or write records sequentially at a given position without wasting access time.

When the record format (binary addressing) is such that there are 16 records on an outer zone track, then 96 sequential records may be accessed without additional access time. In the decimal mode 100 records may be sequentially accessed. Of course, the first record of the sequence requires an average access time of 225 milliseconds, but after the first record is read, the other records are accessed in sequence. This is called the Continue mode.

Even when the DISCFILE is in the Continue mode each record read or written has its address validated. As each record is accessed, the stored address in the DISCFILE is automatically augmented by one. Before reading or writing the next record, the stored augmented address is compared with the record address read from the file. If the equipment is malfunctioning, an alarm prevents records from being read or written unless validation occurs.

## POSITION HOLD

The DISCFILE may be provided with the ability to rapidly access a record using the Position Hold feature. After a positioner has been used to select a record at a given position, the positioner remains on that position. If a new record is selected at that same position, the average access time to the new record is just the average rotational latency.

The DISCFILE logic contains circuits which check the new address to see if the disc field and the position field are the same as that for the last record accessed. If they are the same, then the new record is on one of the eight tracks associated with that position and at most a different head will have to be used for the new record. The DISCFILE selects the new head, if required, and automatically starts the validation procedure.

## FIXED HEADS

It is possible to add as many as 28 fixed heads to the control disc for rapid access. The average access time to data on these tracks is the average rotational latency. Data stored on these tracks could be used for tables or indexes where rapid access is required. Records are selected on the fixed head tracks by switching heads. The amount of data which may be stored in this way is 708,400 bits.

The data from the fixed heads may also be used to refresh display devices. In order to have flicker-free displays, it may be necessary to record the data twice around a track. This would refresh a display 40 times a second.

## COMPUTER INTERFACE

The DISCFILE normally interfaces a computer by means of a Controller. The function of the Controller is to interpret computer commands, control the DISCFILE, and assemble or dis-assemble data.

The DISCFILE requires that the Controller transmit the address of the record to be accessed. Since up to five DISCFILES may be connected to one Controller, the Controller must be capable of selecting a given file. The Select pulse selects a given file on a unique line to that DISCFILE. After the DISCFILE is selected, the Controller transmits the address and terminates the transmission with an Address Terminate pulse, or Seek pulse.

Normally the address is transmitted serially on a line common to all DISCFILES. It is possible to modify the equipment in order to send the address in parallel.

After the Seek pulse is given, the Controller is logically disconnected from the selected DISCFILE. The file seeks the desired record without any further requests from the Controller. In a multiple DISCFILE system, the Controller then is free to select another DISCFILE.

The process of seeking a record consists of selecting a positioner, a position and a read/write head. The selected positioner moves to the selected position while the read/write head is searching for records on the selected track to perform track confirmation. This is followed by a validation of the selected record. After validation, the DISCFILE transmits a Ready pulse to the Controller which is used to inform the Controller that the DISCFILE has found the selected record.

There are two basic schemes in the timing relationship between the Ready pulse and the time at which information is to be transferred to or from the DISCFILE. In the first, data transfer occurs immediately following the Ready pulse, provided that the

DISCFILE is so signalled. In the second there is a delay which corresponds to the time to read one data record before data may be transferred. The second scheme allows time for the computer to be interrupted after a Ready pulse and for the computer to decide whether or not it is ready to operate on the data.

In either case after the Ready pulse is received by the Controller it may initiate data transfers by signaling the DISCFILE with a Data Alert pulse, which logically reconnects the DISCFILE to the Controller. A Read or Write pulse follows the Data Alert pulse to inform the DISCFILE which operation is to proceed. If the second scheme is used, the stored address in the file is automatically augmented by one so that the record actually accessed is the record selected plus one.

If the operation is Read, the DISCFILE starts transmitting the serial by bit data when the record data passes under the read/write head. It stops transmitting data when all the data for a record has been read.

If the operation is Write, then the DISCFILE transmits Clock pulses to the Controller. The Controller, in turn, transmits to the DISCFILE a ONE or a ZERO upon the receipt of each Clock pulse. The Clock pulses are transmitted when the read/write head passes over the region of the track to be used for recording data. When all the clock pulses for a record have been transmitted, transmission ends.

At the end of record transmission the Controller may decide to end the operation or continue with the process to accomplish sequential record accessing. If it is desired to terminate the process, the Controller transmits an End pulse. If it is desired to continue reading sequential records, then a Read pulse is transmitted to the DISCFILE. If it is desired to continue writing in sequential records, then a Write pulse is transmitted. All of the records associated with a given position of the positioner may be accessed sequentially.

While data transmission occurs, the Controller and DISCFILE are logically connected. After the transmission is terminated by an End pulse the DISCFILE disconnects and may be reselected by the Controller issuing a new Select pulse.

The DISCFILE also contains the ability to perform an automatic read-after-write function. If a Read pulse is issued following the writing of a record, then that same record is read automatically on the next revolution of the disc. Thus the record may be checked using the minimum time which is rotational latency to re-access the record.

#### AUTOMATIC ERROR CHECK FEATURES

The DISCFILE may be supplied with the capability to perform automatic error checks assuring the user that data is properly stored.

The first error checks are related to the address of the record to be accessed. The transmission of the address to the DISCFILE is checked by using a parity bit with the address. The file automatically checks the address for validity. It also checks address length and control signal timing. Following these address checks there is another check to see that the address is transferred correctly from the DISCFILE receiving address register to the DISCFILE storage address register. If any of these conditions are incorrect, an Error alarm pulse is sent to the Controller indicating that the Seek operation will not proceed.

The next error checks are related to the positioner accessing the proper record. If the positioner does not get track confirmation after a fixed time delay, then a Positioner Alarm is activated.

If validation does not occur after track confirmation a Sector Alarm exists. Sector Alarms assure the user that only the correct record will be accessed.

The DISCFILE also checks the data read to see that the zero crossings of the information read from the disc occurs at the proper frequency. If the frequency is wrong, then there are holes in the data which indicate a physically damaged disc. The frequency of data from the Clock track, and the data transmitted for recording is also checked. Any discrepancies in proper data frequency is reported to the Controller as an error condition.

Data parity checks are usually performed in the Controller, however the DISCFILE can be supplied with parity checking circuits as an optional feature. The most usual forms of parity checking are to record a parity bit for each six bits of information or each two decimal digits stored. This circuit generates a parity bit when writing, and checks for parity when reading.

## DATA TRANSMISSION RATES

Data transmission rates from the DISCFILE are determined by the bit density of the data stored and the rotational speed of the discs. The innermost track of the inner zone and the innermost track of the outer zone have a nominal bit density of 400/bits/inch. The other tracks in each zone have the same number of bits per track, and hence a lower density.

The data transmission rate from the inner zone is 250,000 bits/second, and from the outer zone the rate is 500,000 bits/second. The DISCFILE may be modified to read data from the inner zone at the same rate as the outer zone. This is accomplished by reading and writing two simultaneous tracks on the inner zone.

Data is normally transferred serially between the Controller and the DISCFILE, but it can be modified to various forms of parallel transmission. If bits are transferred in parallel, then the average transfer rate is the same as the serial by bit system.

Phase modulation is used to record on the discs. This method is used because it is highly reliable and is impervious to noise and to signal amplitude variations. The data is written using a clock generated from the clock track on the control disc. The data is self-clocking when read.

It is sometimes desired to transfer at rates which are different from the ones normally associated with the DISCFILE. In those cases the data products corporation can supply core memory buffers to take care of these special speed requirements.

## DESIGN FEATURES OF THE HEAD POSITIONERS

An individual head positioner is assigned to each disc. The eight heads on each positioner are mounted on the bifurcated arm in pairs. Two pairs are on one arm and two pairs on the other. The two pairs on one side are mounted so that one pair covers the inner zone and the other pair covers the outer zone of the disc. Each pair of heads is arranged so that one head reads or writes a track in between the tracks read or written by the other.

Precise positioning of the heads is inherent to the positioner stators which are fixed to the disc shroud. The stator has an array of precisely ground magnetic teeth on the top and on the bottom. Currents are switched into the stator to select the correct top and bottom teeth. The armature then moves to the selected tooth position. It should be noted that the shape of the armature pole-pieces and of the teeth are so chosen that very precise alignment is achieved. This results in an accuracy which is a function only of the stator mechanical dimensions and not of the magnetic field or the current or the voltage which produces it.

Because the stators determine the position, the armature and heads may be removed and replaced for cleaning without disturbing the information on the disc and without using precision re-alignment equipment.

## DESIGN OF THE "FLYING" HEADS

The DISCFILE employs a read/write and an erase head to record on the disc surfaces. The erase head is much wider than the read/write head to reduce cross talk between tracks. Heads are pressed against a lamina air layer on the disc surface by means of air pressure. The heads are so shaped that they "fly" on the lamina as close as

200 micro-inches from the disc surface, but without danger of brushing against the surface. The air pressure system has a "fail safe" feature so that if the air supply fails the heads are instantly retracted from the disc.

## RELIABILITY

Routine scheduled preventative maintenance procedures should not exceed a monthly average of three man-hours per week per DISCFILE, plus a nominal scheduled cleaning time for heads each week. Unscheduled maintenance should not exceed an average of one hour per month.

The reliability of the DISCFILE is determined by its ability to maintain error-free operation. Errors may be classified into three types:

1. Program Recoverable Errors (Type I). An error is detected, and a repeated operation initiated either automatically or under program control is error-free.
2. Maintenance Recoverable Errors (Type II). An error condition can be corrected only as the result of unscheduled maintenance, but no data is lost.
3. Unrecoverable Errors (Type III). The error is such that data is lost and cannot be recovered by any of the above means.

Typical examples of Type I errors are: (a) a redundancy check error is detected in the Controller and then is re-read successfully, (b) an error is detected in the clock frequency on writing and the record is re-written successfully without error, (c) an error is detected during a read-after-write check and the record is re-written with a valid read-after-write check, and (d) a positioner error occurs where a head does not settle on a track properly and track confirmation does not occur. The positioner is moved to another position and then to the selected position. This time track confirmation does occur.

A Type II or Type III error occurs if the data loss cannot be recovered by means of program intervention. When it is determined that it is not a Type I error, and if data is sufficiently valuable, the programmer should introduce a computer halt for maintenance.

If the error occurs on reading and cannot be cleared by maintenance, it is a Type III error. If it occurs on writing it is always a Type II error, because data cannot be permanently lost during writing provided that the normal write-check procedure is employed. It should be recognized that in most storage applications writing occurs less frequently than reading and the time taken by write-check does not add

materially to the average operation time, but does improve reliability of operation very materially. Consequently, if the data written has not been verified after the write, an error cannot be classified as a Type III error.

The experience of data products corporation with DISCFILES in service is that the error rates do not exceed:

1. Program Recoverable Errors. One error for every  $10^8$  bits of data transferred in and out of the file.
2. Maintenance Recoverable Errors. Not more than one error every 80 hours of cumulative file operation.
3. Unrecoverable Errors. One single bit non-recoverable error per 24 hours of cumulative file operation. One multiple bit non-recoverable error in any single DISCFILE per 720 hours of cumulative file operation.

#### PRE-DELIVERY TESTS

Before shipment, a series of tests are performed on the equipment to ensure that the equipment is operating properly and reliably. The tests are performed in two phases. The preliminary phase consists of tests of the sub-assemblies and a final phase which consists of a functional test of the completed assembly followed by a reliability test.

In the preliminary tests, all sub-assemblies are tested against acceptance criteria before the final test. The important sub-assemblies are the discs, the read/write/erase heads, and the positioners.

Each disc is inspected by means of optical and mechanical aids to ensure that they meet rigid manufacturing tolerances. An electrical test is then performed which consists of measuring the recording and playback ability using special heads and amplifiers which scan the entire recording surface.

The read/write heads are tested and then attached to the armature arm which will be used as part of the final assembly. Air pressure is applied to make the heads fly on a standard calibrated disc. Measurements are taken of the ability to write and read. Proper spacing of the heads is also checked by reading standard tracks precisely spaced.

The positioner stators are first checked for static accuracy. A tester is used to switch current to a calibrated armature so that all positions are checked. A plotter plots a curve of the deviations from calibrated positions. The final armature is then used and the whole assembly is re-checked. Motion times and positioning accuracy

are then tested under dynamic conditions. During these tests the heads are also checked for writing and reading. The maximum position time, the minimum positioning time, and the average positioning time are measured. The average positioning time is measured by moving through all 4096 possible motions and measuring the total time. Positioning accuracy is also checked under all possible combinations of motion and head selection.

The final test starts out by checking that all the functions and features of the DISCFILE are operating properly. The pulse waveforms and noise conditions are checked as well as a marginal check of the read amplifiers. All of the alarm conditions are checked by simulating error conditions.

### RELIABILITY TEST

The final reliability test is performed to demonstrate satisfactory performance of the DISCFILE for a period of 48 hours while operating with a computer simulator in modes similar to those encountered in operational computer system use. The majority of the time is spent operating the equipment on a program which consists of randomly addressing the DISCFILE and randomly reading or writing a record at that address. All data written is checked by a read-after-write verify operation. All data read is completely checked against the data written in that record.

The test begins by writing into all records of the DISCFILE. The information written into a record differs from that in any other record. The complete DISCFILE is then read continuously at maximum speed, in ascending and descending address sequences. This test occupies eight hours.

The remaining 40 hours are devoted to a program in which addresses are selected randomly and in which reading or writing is also chosen at random. When data is written for the first time during this test the original information is complemented and, in addition, a control bit is changed. This bit is used by the simulator to control subsequent reading and writing operations. At the end of the test the complete DISCFILE is re-tested to verify that its properties and performance have not changed during the 48 hour test period.

The DISCFILE must exhibit reliability and performance characteristics during the 48 hour reliability test consistent with the specification.

SPECIFICATIONS  
dp/f-5020 DISCFILE

	<u>16 Disc Model</u>	<u>8 Disc Model</u>	<u>4 Disc Model</u>
Disc Diameter	31 inches	31 inches	31 inches
Rotational Speed (Nominal)	1200 rpm	1200 rpm	1200 rpm
Recording Surfaces	32	16	8
Number of Heads (movable)	128	64	32
Number of Head Positioners	16	8	4
Tracks per Recording Surface	256	256	256
Bit Density (Nominal)	400 bits/in.	400 bits/in.	400 bits/in.
Track Density	26.7/inch	26.7/inch	26.7/inch
Storage Capacity (Maximum)			
Per File	155,508,736	77,754,368	38,877,184
Per Disc	9,719,296	9,719,296	9,719,296
Per Track - Inner Zone	12,666	12,666	12,666
Outer Zone	25,300	25,300	25,300
Transfer Rate (Nominal)			
Inner Zone	250,000 bits/sec.	250,000	250,000
Outer Zone	500,000 bits/sec.	500,000	500,000
Average Access Time (includes latency of 26 milliseconds)	225 ms.	225 ms.	225 ms.
Physical Dimensions:			
Length	84 inches	84 inches	84 inches
Height	60 inches	60 inches	60 inches
Width	36 inches	36 inches	36 inches
Weight	2500 lbs.	2250 lbs.	2125 lbs.

Power (208 volts  $\pm 10\%$ , 3 phase, 60 cps  $\pm 1$

5 kw (all models)

Environment: Operating

60°F to 85°F, 20% to 80% R.H.

Storage and Shipping

-20°F to 150°F, 98% R.H.

### Optional Features

Fixed Heads

1 to 28

Decimal Address

Parallel Transfer

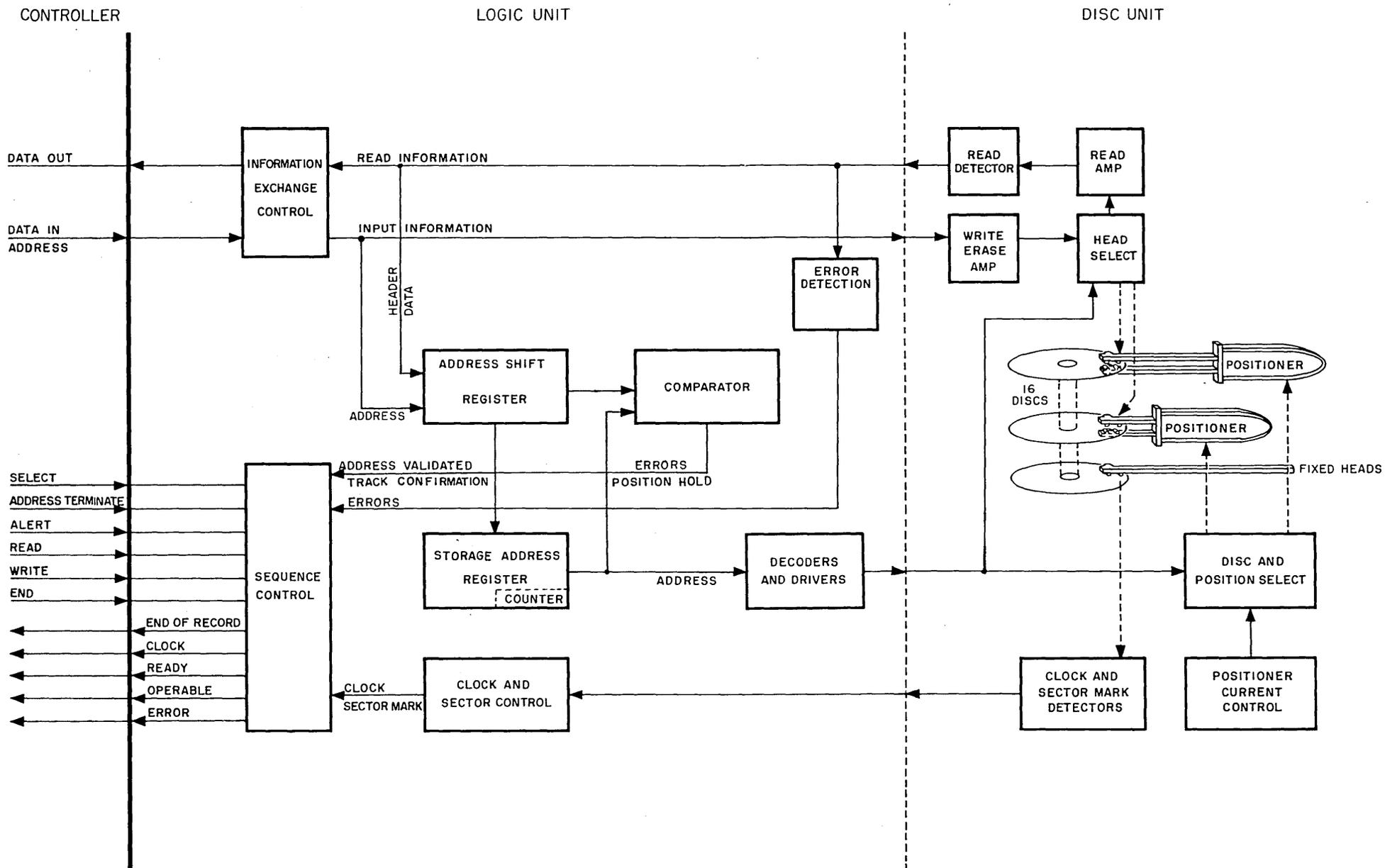
Error Checking

Parity Checking

Continue

Positioner Hold

Address Validation



DP/F-5020 DISCFILE

