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Floppy disc units for data collection from neutron beam experiments

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FLOPPY DISC UNITS FOR DATA COLLECTION FROM NEUTRON BEAM EXPERIMENTS

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ABSTRACT

The replacement of paper tape output facilities on neutron beam equipment on DIDO and PLUTO reactors by floppy discs will improve reliability and provide a more manageable data storage medium. The cost of floppy disc drives is about the same as a tape punch and printer and less than other devices such as magnetic tape.

Suitable floppy disc controllers are not at present available and a unit was designed as a directly pluggable replacement for paper tape punches. This design was taken as the basis in the development of a prototype unit for use in neutron beam equipment. The circuit operation for this prototype unit is described.

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Introduction

The majority of neutron beam experiments on the DIDO and PLUTO reactors use paper tape as an output medium. The results are also printed out as they are collected.

In many experiments the results may be processed by the experimenters directly from the print out, while in other cases the paper tapes are dealt with by feeding them into the main computer.

The trend is for more and more data to be processed by the computer and more importance is being placed upon the paper tape. The reliability of the paper tape punching leaves something to be desired and the bulk of the tape produced can also be an embarrassment.

The users felt that there would be a considerable advantage if a more reliable data output medium such as DECtape was to be used.

We have, therefore, considered alternative output media and the floppy disc or "diskette" was chosen as the most suitable device for the following reasons:-

1. It provides a suitable storage capacity (equivalent to 2 rolls of paper tape).

2. It provides a reliable medium (manufacturers specifications of reliability are much better than those for paper tape and as good as magnetic tape).

3. The output medium is cheap at about £3.50 per disc. (A roll of paper tape is about £0.50).

4. Large amounts of data may be stored easily in a format that may be read directly by an IBM computer. The format will without doubt become an "industry standard" and thus it is reasonable to expect that, in time, university visitors will have facilities available on their own computers to read their data without further processing.

5. The cost of a disc drive and control should be equivalent to that of paper tapes, punches and teletypes at c. £1,200. (This is about the same as the cost of a DECtape drive without any control electronics.)

The Neutron Beam Experiments

The present data collection characteristics of the neutron beam experiments that are the subject of this study are given in Table 1.

The experiments listed in Table 1 all use teleprinter and paper tape output and have very simple control requirements usually served by a simple program set up on a series of thumb switches. The paper tape is 5 hole tape punched on a CREED perforator for all except the GLOPPER which punches on a TELETYPE 8 hole "BRPE" punch. The 5 hole tape presents a problem since it can no longer be processed on the main computer and in these cases the data is hand punched from listings to cards when computer processing is needed. It is proposed to replace the 5 hole punches by 8 hole punches for this reason, possibly using the less reliable model ASR-33 teletype.

Alternative Output Media

1. 5 hole paper tape has been in use as an output medium but has now been largely replaced in general use by the 8 hole paper tape. Paper tape punches are usually quite slow and not very reliable but paper tape remains one of the cheapest transfer media.

2. Punched cards are not well suited to automatic output, are expensive, and mechanical punches are not very reliable, unattended output capacity is somewhat limited.

3. Magnetic tape is now a fairly reliable output medium and 9 track half inch tape is an "industry standard" compatible with most computers. Tape may be recorded at 550, 800 or 1600 8 bit bytes per inch length: the trend is toward the higher figure which means that 20 to 40 million characters could be recorded on a 10" spool of tape. The transport, control and other associated electronics are expensive and it is unlikely that a stand alone unit could cost less than £4000. However, this cost could be spread by "pooling" a number of experiments in the same way that the commercial "key to tape" systems operate to eliminate punched cards.

   An alternative to the 9 hole tape at a much lower cost has been exploited in the past few years. This is the cassette tape. This provides about 10^5 characters storage and a stand alone unit would cost about £1,000 - £1,500 including transport and electronics. The main disadvantage of the cassette tape is a lack of an industry standard for digital work. (The DEC cassette is not the same as the 3M cassette and neither is the same as the Phillips audio cassette, which is used with varying "standards" on many computer terminals.)

4. Magnetic Disc or drums are frequently used as data storage devices and reducing costs together with increasing capacity has enabled discs to replace magnetic tapes in many applications in recent years: notably in the key-punch area. Discs fall into two categories: fixed head-per-track and moving head, the former being more reliable but of limited capacity and discs are not usually interchangeable. The moving head discs are now as reliable as magnetic tape and offer storage capacities of the same order as tape spools. The cost of the mechanisms are probably higher than tape but the disc offers millisecond access to individual items of data whereas tape requires seconds and much greater movement and consequent mechanical wear. A development over the past few years that has been fostered by IBM is the "Diskette" or "floppy disc": this is comparable to the tape cassette offering the same order of data storage capacity with fast access.

What is a Floppy Disc?

The floppy disc or "diskette" as IBM call it is a small flexible disc of magnetically coated film - a similar material to magnetic tape - about the size of an E.P. record. The disc is contained in a semi-rigid plastic jacket within which it rotates at 360 rpm when an IBM compatible drive is used. The "diskette" can be easily removed from its drive unit and stored for later replay, probably on a different machine.

The floppy disc is essentially an IBM development, being used originally as a device to write the control store program on the /360 computers.

Pressure represented by key to tape and key to disc data preparation units which vied for the same market as IBM's card punches, caused IBM to consider these developments and to produce the 3740 data entry system. The 3740 system uses the "diskette" as its data storage medium and offers two ways in which the data can be entered into the computer:

1. 3747 Data converter which transfers the data onto 9 track tape.

2. 3540 I/O unit which "plays" a stack of cassettes directly into the computer.

While IBM were developing their "diskette" a number of manufacturers marketed floppy disc drives. Century Data Systems and Potter provided disc units 2 years ago capable of storing 1.4 million and 0.6 million bits respectively. These units were premature as was that of a third contender Memorex, since IBM, perhaps obtusely with an eye to confusing rivals, continued developing the disc until it finally had an unformatted capacity of more than 3 million bits and spun at 360 rpm (compared with 90 rpm of the early Potter unit). It is significant that Shugart who was responsible for development of the "diskette" at IBM, joined Memorex before going on to form his own firm.

The final version of the "diskette" provides an unformatted data capacity of 3.1 million bits in 77 tracks. Data is recorded with inter-leaved clock pulses on each track spaced 4 μs apart (double frequency recording). The IBM track format is shown in Figure 1. This format reduces the data storage capacity to 1 943 552 bits (242 944 bytes) in 73 tracks, allocating the outside track (00) to a directory and leaving two tracks as alternatives in case bad tracks are found.

To ensure format compatibility with the IBM 3740 the disc contains address marks which are recognised by being associated with missing clock pulses. This makes initialisation somewhat more difficult but the IBM literature implies that initialisation is a very infrequent requirement. Indeed, the only need for initialisation is after some catastrophic hardware fault or possibly damage to the disc.

Choice of Medium for the Neutron Beam Experiments

Any recording medium suitable for use for the neutron beam equipment should be able to hold the data from at least one experiment and, if possible, from 2 or 3 days running without needing attention. It is seen from Table 1 that this requires a capacity of at least 2.5×10^5 characters to cope with the most demanding situation. Of the media listed in Table 2 cards do not meet this requirement, 9 track magnetic tape and discs easily meet it while the other media are marginal for single drives but could cope if dual drives were supplied. Single drives are adequate for 4 out of the 6 applications.

One further consideration is that many users of the neutron beam facilities come from universities for short visits to carry out a single set of experiments. While at Harwell they use computers at A.E.R.E. or Rutherford Laboratories, as do all users. Once finished they return to their universities and will process their results on their own computers.

The output medium chosen must be suitable for these users, this aspect is considered in Table 2. All the media could be processed both at A.E.R.E. and Rutherford Laboratories, but the facilities at a University are likely to be more restricted. To satisfy the university users cards, 9 track magnetic tape or "diskette" output could be provided for them to take away - the amount of processing is minimised if one of these was the output medium from the experiment. A 110 baud link via G.P.O. lines would require an excessive time to complete a transfer while the higher speed lines would require special installation.

A number of possible configurations, using the various media, for these experiments were considered. Only paper tape and "diskette" permitted each equipment to remain independent and in addition gave the lowest cost solutions: the "diskette" scheme costing only 60% that of the next cheapest (that used DECtape). Since the object was to find an alternative to the unreliable and inconvenient paper tape output, the use of the "diskette" was proposed. At the time there was no suitable floppy disc unit to provide a plug in replacement for paper tape punches although floppy disc drive units were on the market, a design for an output recorder using a floppy disc was made.

Choice of Disc Drive

When the decision to build floppy disc units for the neutron beam experiments was made there were only 4 suitable drive mechanisms on the market in the U.K. Characteristics of these mechanisms are presented in Tables 3 and 4. There is very little difference in the costs of the drives and it may be seen from the tables that there is also little to choose between the specifications.

The Calcomp-CDS Model 140 was chosen for this application. On all drives the head may be taken out of contact with the disc to increase the disc life time. The fast head load time allows the head to be brought back into contact with the disc while moving to a new track. The CDS 140 does not need additional electronics to drive the head positioning motor, it offers a phase locked oscillator to separate clock and data, requires only two power supplies, has an integral blower and incorporates the "Low Current" facility required to provide more reliable writing on the inner, higher density tracks. The specification of this unit is most detailed in respect to environmental conditions and is more precise concerning reliability.

A disadvantage of the CDS 140 is the absence of a file interlock on faulty Read drive conditions but with a MTBF of 5 000 hours the probability of these error conditions must be infinitessimal.

Interface and Data Formats

The control for the disc drive in addition to processing the signals to the disc mechanism will provide an interface to accept and convert incoming data.

For the paper tape application, data will be presented as:

1. 5 level parallel data in "Ferranti" code.

2. 8 level parallel data in USASCII code.

3. 10 or 11 bit serial code with USASCII code.

and data will be recorded to disc using 8 bit EBCDIC coding.

The most straightforward application would keep a format completely compatible with the IBM 3740 using the full 128 byte sector, however this will not be readable in the same way as cards, i.e. using the "SYSIN" command (page 30 of the IBM Manual GA21-9153-0). This means that for the time being the sector will be packed only 80 bytes per sector. The 128 byte sector may be read in by other OS or DOS/VS commands which may be adopted as a standard for future data processing programmes.

Initial Limitations of the Controller

The IBM 3741 and 3742 have display capabilities as well as verification, programming (e.g. fields, duplication, skip) and other functions. The majority of users of card punches do not need facilities other than display and duplication. It would thus be possible to make a simple data preparation terminal using say a video terminal and keyboard in conjunction with the floppy disc. However, this is not the immediate aim but flexibility will be left in the system for later adaptation.

The floppy disc unit will not have any disc initialisation facility and the discs used will be those provided by IBM which are preformatted. In the paper tape application the cost of a disc is very small compared with the cost of the neutrons and is regarded as consumable: thus the disc will probably be used only once, collecting data from experiments lasting between 1 day to 2 weeks.

It is estimated that a maximum writing rate equivalent to between 100 and 300 cards per minute (130 to 500 characters per second) will be achieved with read after write check. The control will be able to read out data from the disc at about twice the rate of writing. These values correspond to those achieved for the single sector transfers on the IBM 3540 as shown in Table 5 (which is from the IBM Manual GC21-5072-1). Table 6 shows the timing of certain operations on the 3741 data station and is included here to provide an idea of rates on the IBM equipment.

Controller Electronics

A microcomputer using PROM stores for programs is used as part of the floppy disc unit control electronics. This offers considerable flexibility for future applications: sector length may be altered, display facilities increased or I/O formats and codes adapted to meet special requirements. There were only three or four microcomputer chip sets available on the U.K. market when the design of the controller was started and of these the INTEL 4004 was considered quite adequate. The 4004 was available as part of a complete processor on an 8" x 6.3" card capable of accepting 1024 words of PROM stores for about £200 (an equivalent INTEL 8008 or N.S. IMP system costed about twice as much).

The microcomputer could not process sector data directly to and from disc. Suitable capacity static (MOS) shift register (SR) integrated circuits had just been introduced, that were ideal to buffer the sector data as it was written (or read) from disc at 4µs/bit or processed by the microcomputer at 100 µs/bit.

A more detailed description of the operation and installation will be published later (Ref. 1): however, a simplified description is given here. Figures 2-5 are schematic diagrams of the disc control circuits showing the four basic functions:-

(1) input data, routing and code translation;

(2) head positioning;

(3) writing data on disc;

(4) reading data from disc.

The microcomputer supplies signals to special interface circuits on a separate board. The main tasks carried out by the microcomputer are:

(1) Accept input data as ASCII Coded characters.

(2) Convert characters from ASCII to EBCDIC coding.

(3) Output the EBCDIC characters into a disc WRITE BUFFER.

(4) When one disc WRITE BUFFER SR is full, initiate the recording and route output to the other buffer.

(5) Remember current disc sector and track addresses and set them up when recording is initiated.

(6) Monitor flags to determine that a track has been found.

(7) Check for error conditions: e.g. disc full, track not found etc.

(8) Provides disc read and teletype print out for test and maintenance.

Originally it had been intended to generate the two "Cyclic Redundancy Check" (CRC) characters using a processor program (the CRC greatly reduces the probability of undetectable record and read errors, it must be recorded correctly to allow data to be compatible with IBM systems and is generated using the cyclic binary polynomial (no carry between digits):-

$$G(X) = x^{16} + x^{12} + x^{5} + 1$$

acting on each bit of data). It was, however, decided to use a commercial polynomial generator L.S.I. circuit since a 16 bit shift register would be needed anyway, there would be no increase in component count and the microcomputer program would be simplified.

Data Routing

Incoming, ASCII coded data is presented to the microcomputer via a second (communications) processor as in Figure 6, via a UART or direct from the experiment into 8 input wires. The ASCII code is translated into EBCDIC code which is then output, bit by bit into the appropriate WRITE BUFFER SR which are selected alternately by the SR1/2 signal from the processor (Figure 2). This data routing continues as head positioning, writing or reading is carried out.

Head Positioning

Figure 3 shows the head positioning function. The same circuit is used to compare track number or sector number. It is seen from Figure 1 that both track and sector address appear in the "Sector ID" block as byte 2 and byte 4 respectively. The SECTOR ID pulse (see Table 7 for ID mark codes) occurs when the hexadecimal values of the 8 bits in the CLOCK SR and DATA SR are C7 and FE respectively (for all except ID bytes the CLOCK SR has the value FF). If the CHECK TRACK command from the processor is set, the next byte is compared with the 7, TRACK/SECTOR lines from the processor and if they correspond the AT TRACK signal is sent to the processor. If the CHECK TRACK signal is not set, the 4th byte is compared with the TRACK/SECTOR lines and, if these correspond, a SECTOR FOUND pulse occurs. There are 5 LED octal indicators on the unit, 2 digits continually set from the 6 least significant TRACK/SECTOR lines indicate the current sector and other three digits are set from all 7 lines by the CHECK TRACK signal to show the current track. These indicators give a visual display to the user and for test purposes.

The head track is changed when the processor asserts TRACK STEP PULSE with the appropriate value set on TRACK STEP DIRN. The >T43 signal causes the disc drive unit to decrease the writing currents on the inner tracks. To assist in positioning the head at initialisation and when there is an error, pulses from the processor can be issued to step the head out until AT TRACK ØØ is asserted.

Writing to Disc

The operation of writing to disc is shown in Figure 4. Before incoming characters are loaded into the WRITE BUFFER SR a 16 bit pseudo value is issued by the processor to compensate for the initialisation of the CRC register to zeros instead of '1's. When the 80th character enters, the processor issues a further 48 zero bytes to fill the sector, then gives an SR1/2 pulse to change over to the other WRITE BUFFER SR. The correct track having been selected and found, the sector value is placed in the TRACK/SECTOR latches of the processor. When the GO and WRITE signals are issued by the processor the next SECTOR FOUND pulse primes the write circuits. After a 14 byte delay the WRITE ENABLE signal to the disc is asserted and alternate clock and data pulses are applied to the WRITE DATA line. At first,6 clock (with a value FF) and data (value ØØ) bytes are written in the gap between the SECTOR ID block and Data. This allows any transients due to phasing errors between old and new recorded pulses to occur in a region where they will not affect the recording. The 21st byte after the sector address is the Data ID mark and has the value C7 (clock) and FB (data): these values were loaded into the shift registers when the write circuits were primed. By this time the first 16 pseudo data bits that were entered to compensate for the CRC initialisation have passed through the CRC register but have not been recorded. These bits have left the register in the state that a correctly initialised CRC would have after processing the Data ID byte. Once all 128 data bytes have been recorded the MP pulse causes the 2 bytes of the CRC to be recorded, another 2 zero bytes are then sent to avoid "splicing" problems when the record current switches off at the end of the WRITE cycle.

After the data is recorded it should be read back on the next disc revolution through the CRC circuit and if this gives a zero result recording may proceed. At present, this circuit has not been developed.

Reading From Disc

Reading data from disc (Figure 5) is achieved by setting the head at the required track, setting the required sector address and issuing the GO command. When the correct sector address is read the data ID (clock = C7, data = FB) causes the data to clock into the READ BUFFER SR. Once the data is read from disc the signal ITWENT is asserted. This data may be transferred, one bit at a time, to the processor by the CLOCK DATA OUT signal.

Mechanical Implementation

The hardware for the floppy disc unit is constructed in Modular form: the disc drive, a card frame and the power unit. A horizontal format with a single card frame will fit in a rack height of 7.8" and requires a depth behind the panel of 17.5", a free-standing version will fit in a standard equipment case. The units can be mounted in vertical format in 10.5" of rack panel with the same depth requirement: in the vertical format a second disc drive or card frame (e.g. for 6000 modules) can be fitted within the 10.5" height).

The unit will incorporate its own power supplies and weighs about 22 Kg.

Design Considerations

The development of the floppy disc unit has involved the design of an interface card of similar complexity to the processor. The component count has been reduced compared to other disc control units from about 200 I.C. chips to a total of about 80, mainly due to the use of the microcomputer. Development of the unit was held up on a number of counts. Firstly, difficulty in obtaining the PLO option board for the disc (it no longer appears to be a standard option since the O.E.M. market did not really produce a demand for it). Secondly, the initialisation of the CRC register was changed by IBM after the commercial chips were produced: the register had only a clear input - logically it should have been set to '1's to avoid indeterminacy when the data stream started with 'Ø' bits. The third difficulty was that there were no local facilities for testing until mid 1975, this meant that the implications of the PLO and CRC were not realised during the early design stages.

The floppy disc unit is intended primarily as a replacement for paper tape devices on neutron beam spectrometers where the data is printed and punched as it is collected. Although the "hardcopy" is considered essential at present it is possible that as the users' confidence in the reliability of the disc increases a V.D.U. could be used in place of the printer to reduce maintenance costs. It is also probable that the experiments may later be connected via the floppy disc buffer to a central computer. To permit these facilities to be included at a later stage, possibly in different ways on different experiments, space is included for a second processor board. This arrangement is shown in Figure 6.

The concept of a second processor has permitted the programs for the control microcomputer to be limited to about 500 instructions which reduces programming time on two counts:-

(i) programming time $\propto$ (program size)^2

(ii) the microcomputer card includes only 1000 bytes of ROM memory for program and programming time increases greatly as the program size approaches the store capacity.

Another advantage of the second microcomputer is that facilities for maintenance can be incorporated in a program on a special maintenance microcomputer card that plugs into the second processor slot in place of the special facilities card. The maintenance card will drive a printer and run exerciser programs for the disc controller.

Conclusions

The floppy disc appears to offer a cheap and reliable data storage medium for neutron beam experiments. It has been traditional in the past to print out data as they were punched onto paper tape. This has resulted in the printed character code being punched, since this is not the most efficient way of storing data it may be an advantage, later, to convert to binary storage on disc. This would more than double the capacity of a single floppy disc to meet the most stringent demands of the PANDA equipment over periods in excess of 1 day. The maximum data rates given in Table 2 are unlikely to be maintained for extended periods and average rates would probably be only half of those values.

The floppy disc has many advantages over paper tape and magnetic tape, it has displaced these media in many applications (e.g. Video display terminals and minicomputer peripherals). As yet very few of these units have IBM data compatibility. As the number of IBM computers using 3740 data stations increases it is to be expected that units of the type that we have produced will come onto the market, possibly during the next 2 or 3 years.

Acknowledgements

Thanks are due to neutron beam users on the DIDO and PLUTO reactors in their help with the analysis of the requirements of the experiments.

The specific "floppy disc" unit described in this report is the prototype designed by Mr. R.W. Sims and Mr. S. Evans based on my original circuit scheme, since it was considered more valuable to describe an actual implementation. Their collaboration is gratefully acknowledged.

Tables 5 and 6 are copied from IBM documentation of the 3540 and 3740 systems.

Reference

Evans, S.E. and Sims, R.W. (1976). Floppy Disc Unit. AERE Report (in preparation).

TABLE 1

Neutron Beam Experiments

Equipment	Reactor	Locn.	No. of Detectors	No. of Prints Per Hr.	Angles		Total Steps Per Expt.	Max.Char. Per Day
					Step(°)	Range(°)		
PANDA	PLUTO	7H4R	9	120	.02	120	6000	2.5×10^5
HRPD	PLUTO	7H4R	5	120	.05	150	3000	1.5×10^5
GUIDE TUBE	PLUTO	7H2R	1	240	0.2	100	500	2×10^4
LIQUIDS DIFFR.	DIDO	10H	3	60	.1	50	500	5×10^4
CURRAN	DIDO	4H	5	60	.02	70	1000	10^5
GLOPPER	PLUTO	7H3R	25	6	-	-	-	3.6×10^4

TABLE 2

Suitability of Output Media

Medium	Facility at:-		
	A.E.R.E.	Rutherford	University
5 hole paper tape	x[1]	x[2]	??
8 hole paper tape	✓	✓	??[3]
DECtape	✓	✓	x[3]
Cards	✓	✓	✓
9 track Magtape	✓	✓	✓
Cassette Magtape	*	*	x[3]
Diskette	*[4]	*[4]	*[3,4]
Discs	?	?	?
Link (110 baud)[5]	✓	✓	✓
Link (1200 baud)[6]	*	*	?
Link (9600 baud)[7]	*	*	x

Key
✓ = Available
x = Not available
? = Possibly available
?? = Probably unavailable
* = Can be made available

Notes

1. Facility has been withdrawn.
2. Facility was available at ATLAS Laboratory.
3. Facility at Rutherford Laboratories could be used to convert to cards or 9 track magtape.
4. At present the "diskette" is not available but it will probably be a standard item within the next few years.
5. Most computers will have "modems" for remote teletype terminals using the public telephone system.
6. 1200/2400 baud is the highest speed that is available at present using the normal telephone connection.
7. 9600 baud uses private connection and is thus only suitable for short distances.

TABLE 3

Manufacturers Specifications

		DRI Mode/74	SHUGART SA 900	CALCOMP 140	MEMOREX 652
CAPACITY:	Bits/track	40 833	41 300	41 664	41K
HEAD MOVEMENT:	Track-track	6 ms	10 ms	6 ms	10 ms
	Settling	24 ms	10 ms	10 ms	10 ms
	Load	30 ms	50 ms	16 ms	40 ms
POWER:	Voltage Supplies	+5/-12/+24	+5/-5/+24	+5/+24	+5/-15/+24
	Currents	0.75/0.1/1.5	1/0.12/2	1.8/1.5	1/0.1/1.5
	Dissipation (AC/DC)	50W/45W	75W/50W		
			275 B.T.U.	160W	280 B.T.U.
LOGIC LEVELS:	Input Impedance to:				
	+5 V	220	100		
	0 V	330			48 ma
	Output impedance to:				
	+5 V	4.7K			
	Current to 0 V	47 ma	100 ma		48 ma
DIMENSIONS:	Height	9"	9½"	8.4"	9"
	Width	4½"	4 5/8"	4.9"	4½"
	Depth	14"	14 1/4"	15" (+3')	14"
	Weight (lbs)	15	15	16	17
RELIABILITY (DRIVE):	MTBF			5 000 hrs	
	Repair time			0.5 hrs	
	Lifetime			35 000 hrs	
	Recoverable Position errors	1 in 10^6			
RELIABILITY (DISC):	Recoverable	> 1 x 10^6 bits read/error			
	Irrecoverable	> 1 x 10^{12} bits/read/error			
	Lifetime (head loaded)	> 2 x 10^6 Passes			
ENVIRONMENTAL:	Specification	Temperature and humidity as per disc			
	Shock (Unit only)			5Gs	
	Vibration (Operating)			± 2Gs	

TABLE 4

Interface Signals v. Manufacturer

Signal Line	DRI Model 74	SHUGART SA 900	CALCOMP 140	MEMOREX 652
Read Data	Y		Y	Y
Separated Data		Y	O	
Separated Clock		Y	O	
Write Data	Y	Y	Y	Y
Write Gate	Y	Y	Y	Y
Erase Gate	Y	Y		Y
Step Track	Y	Y	Y	
Step Direction	Y	Y	Y	
ØA to stepping motor				Y
ØB to stepping motor				Y
Load Head (put head in contact)	Y	Y	Y	Y
Index (disc index hole)	Y	Y	Y	Y
Track ØØ (Head at track ØØ)	Y	Y	Y	Y
Ready (Disc in and going)	Y	O	Y	
Write Protect/Write Enabled	O	O	Y	Y
File Inoperable, Unsafe (Error condition)	Y	Y		
File Inoperable Reset	Y	Y		
PLO Sync. (Synchronise to track clocking)			O	
Sector (for non-IBM application)	O	O	Y	
Select (for multi-unit operations)			Y	

<u>Notes</u>

Y : Signal Line is standard

O : Optional extra

Options on SHUGART and MEMOREX supplied with different model number.

Options given for CALCOMP are supplied with PLO at a cost of C. £40.

TABLE 5

Reading/Writing Rates for IBM 3540

Sectors per Revolution (Number of sectors in Command-chain)	Reading Rate (Sectors/Minute, Full Disk)	Writing Rate (Sectors/Minute, Full Disk)
Single Sector	624	174
Two Sectors	624	324
13 Sectors (1/2 track)	3120	1872
26 Sectors (full track)	4680	3120

Notes:

1. Rates do not include time required to Feed and Open nor do they include user processing time.

2. Effective speed depends upon the way that sectors are command-chained. The number of sectors which are command-chained is dependent upon buffer size allocated in real storage.

3. After each write, a verify operation is performed. This requires another disk revolution. (This factor applies only to Write operations.)

4. The speeds in this figure reflect the optimum throughput under the conditions specified. The following factors, which will affect the throughput performance, should be considered: to perform a Read/Write operation, the head must be in contact with the medium. If the head is not loaded (in contact with the medium) at the time a Read/Write command is issued, an interval of 80 milliseconds is needed for loading. Head loading, however, is frequently overlapped with the Seek operation, so that this performance loss can be avoided; in addition, this procedure is designed to balance long media life with high performance.

TABLE 6

"Diskette" Operations

The following chart provides approximate timing information for search, copy, and initialisation operations on the 3741. Timings are shown for the normal sector sequence (1,2,3, ... 25,26) and for the alternate sector sequence (1,3,5, ... 25,2,4, ... 24,26). The timings provided in the chart should serve as a useful guide when relative job timing must be considered.

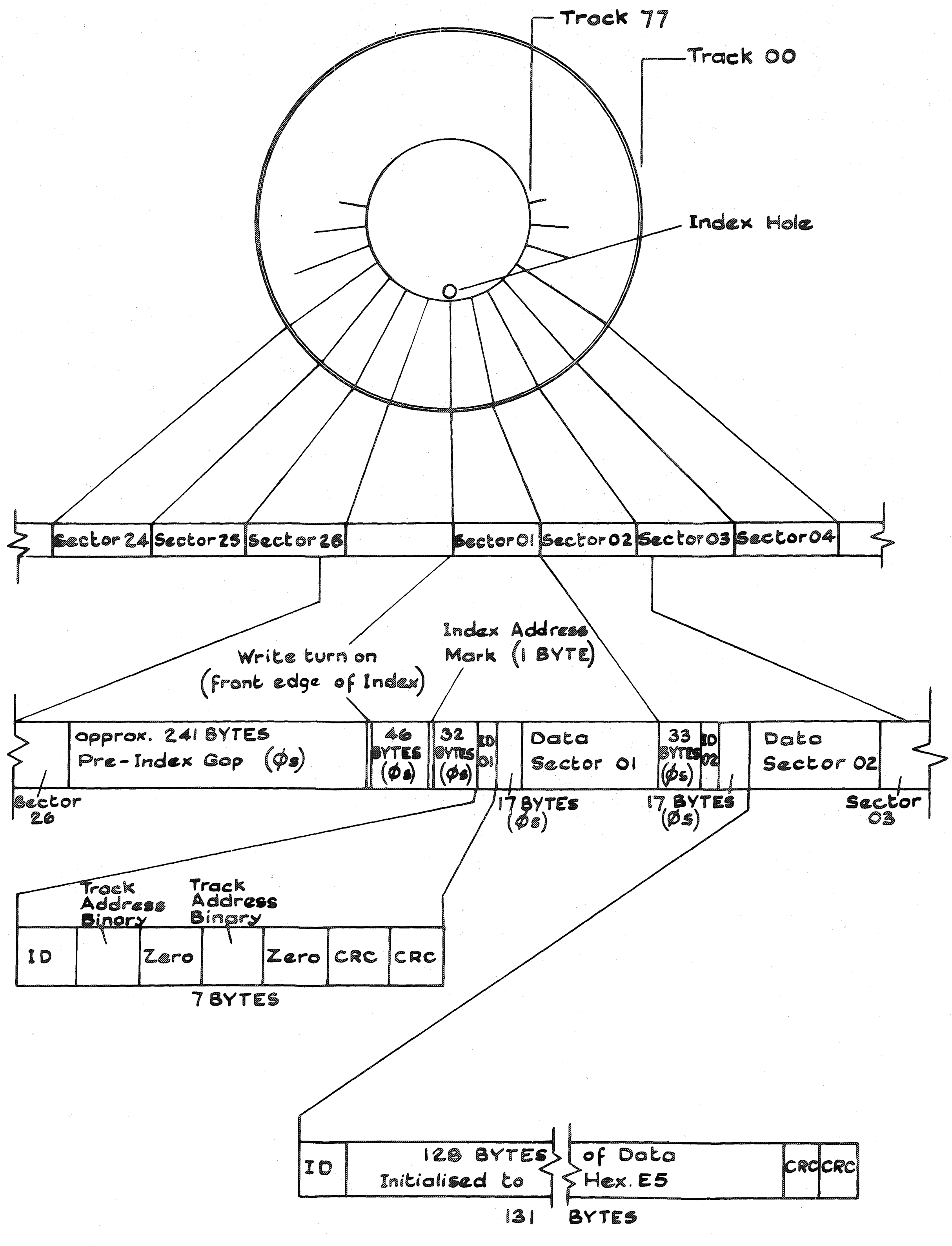
The timings are based on 80 character records. Timing can be affected by such things as disk speed, length and location of search masks, and the location of data sets on the disk.

Operation	Number of Records	Normal Sector Sequence		Alternate Sector Sequence	
		Disk 1	Disk 2	Disk 1	Disk 2
Search end of data	1898 (Assume EOD is 74001)	5 sec	5 sec	5 sec	5 sec
	949 (assume EOD is 37014)	3 sec	3 sec	3 sec	3 sec
	400 (assume EOD is 16001)	2 sec	2 sec	2 sec	2 sec
Search on sequential content	1898	30 sec	8 sec	30 sec	8 sec
	949	15 sec	8 sec	15 sec	8 sec
	400	8 sec	8 sec	7 sec	7 sec
Search on content	1898	5 min 30 sec	5 min 30 sec	2 min 50 sec	8 min
	949	2 min 45 sec	2 min 45 sec	1 min 30 sec	4 min
	400	1 min 10 sec	1 min 10 sec	40 sec	1 min 45 sec
Disk initialisation	-	1 min 50 sec	-	1 min 50 sec	-
Image copy	1898 plus index track	3 min 30 sec	-	10 min	-
Data set copy	949	10 min	-	9 min	-
Data set copy	400	4 min 30 sec	-	3 min 50 sec	-

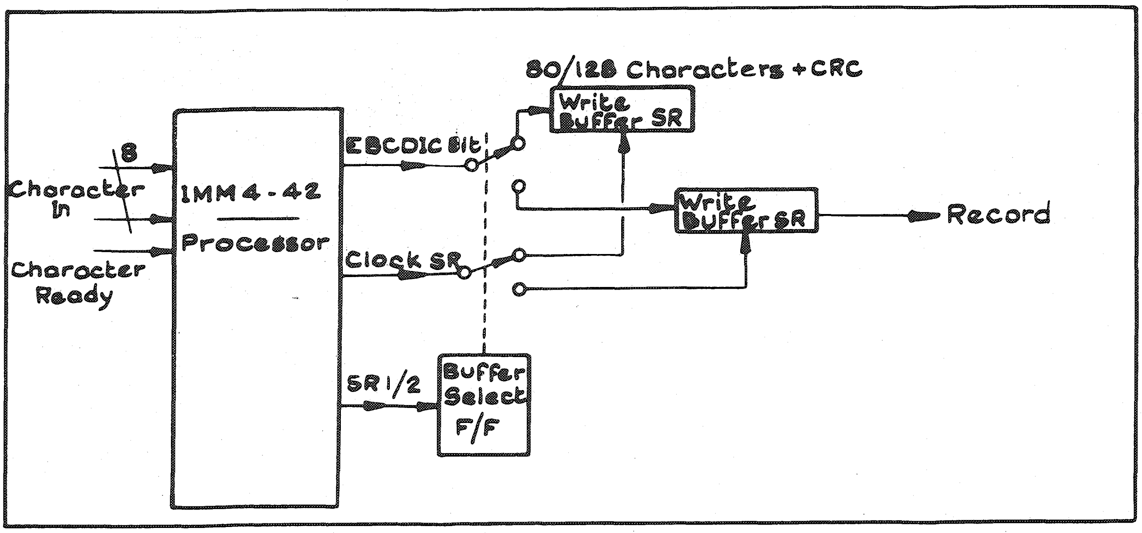
TABLE 7

Hexadecimal Values of ID Mark Bytes in IBM Data Format

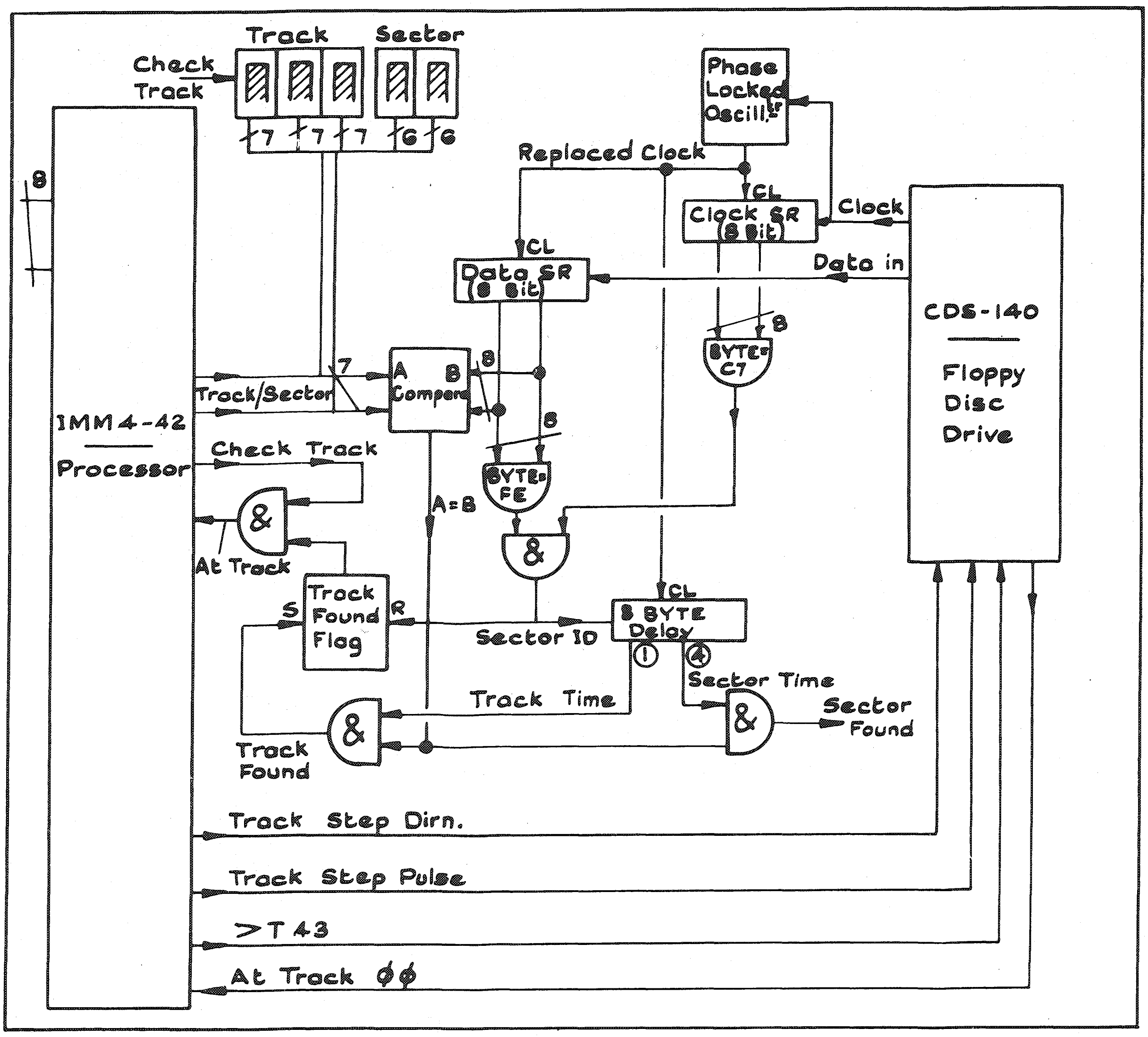
Type of ID Mark	Data Byte	Clock Byte
Index	FC	D7
Sector	FE	C7
Data	FB	C7
Deleted Data		C7



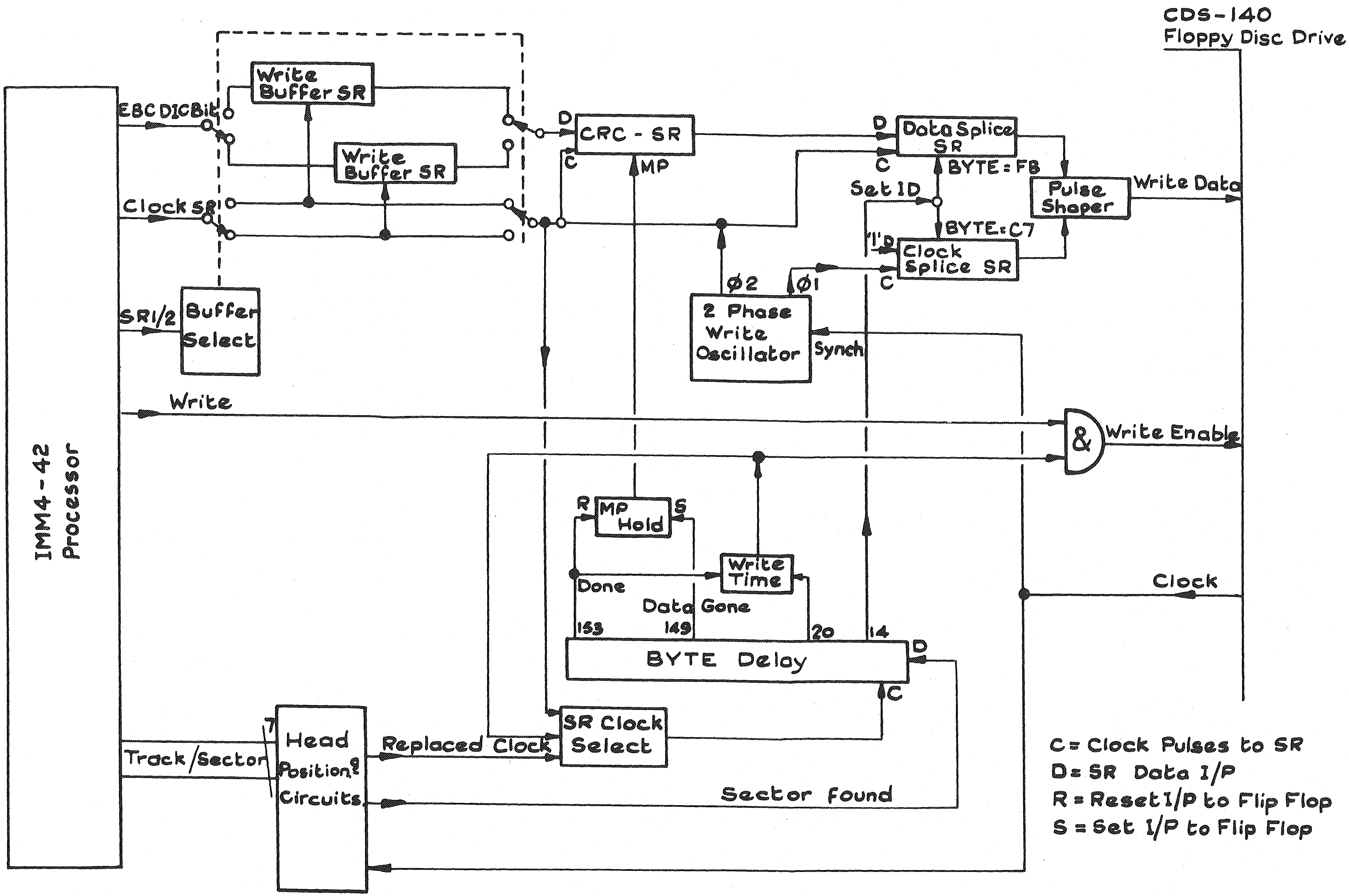
A.E.R.E. REPORT 2778. FIGURE 1. TRACK/SECTOR FORMAT OF IBM COMPATIBLE DISC.



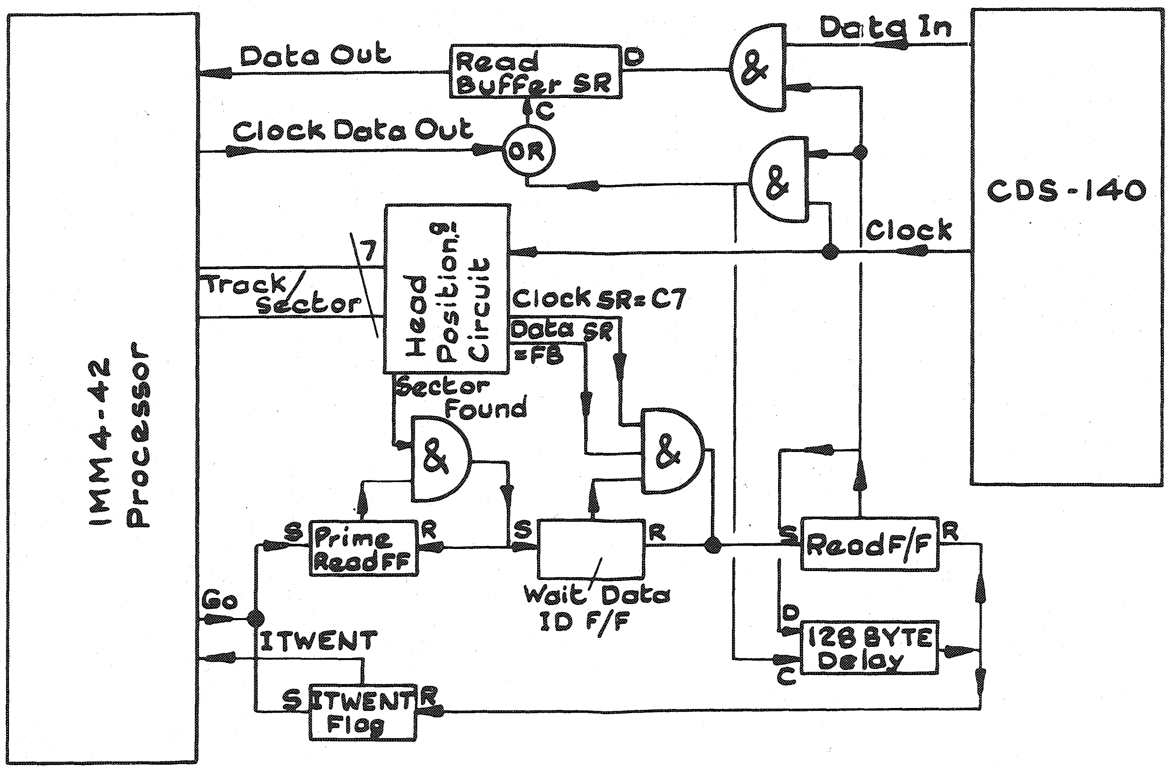
A.E.R.E. REPORT M2778. FIGURE 2. INPUT, DATA, ROUTING, CODE CONVERSION & BUFFER LOAD.



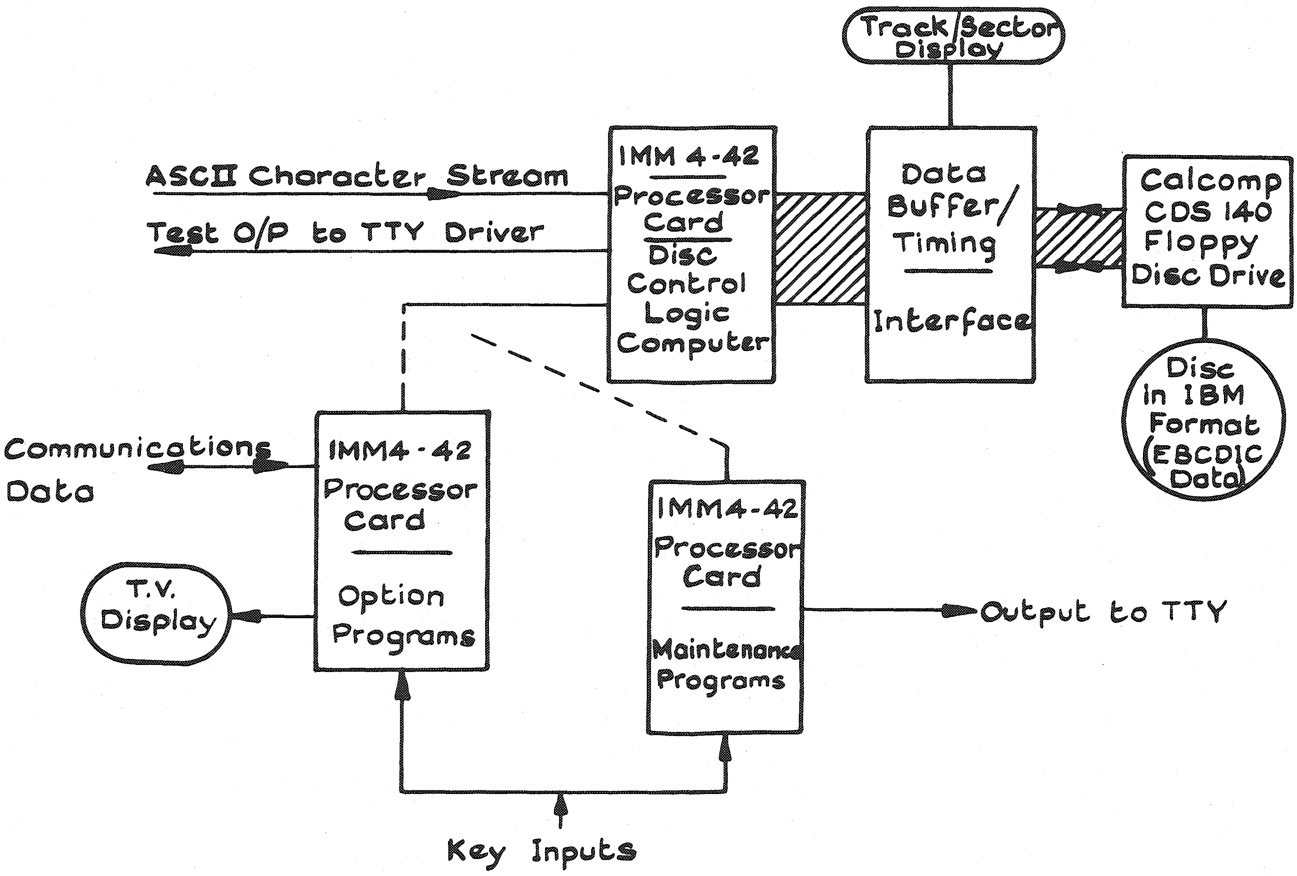
A.E.R.E. REPORT M2778. FIGURE 3. HEAD POSITIOING CIRCUITS.



A.E.R.E. REPORT M2778. FIGURE 4. WRITE DATA TO DISC.



A.E.R.E. REPORT 2778. FIGURE 5. DISC READ CIRCUITS.



A.E.R.E. REPORT 2778. FIGURE 6. FLOPPY DISC IMPLEMENTATION - SCHEMATIC DIAGRAM.