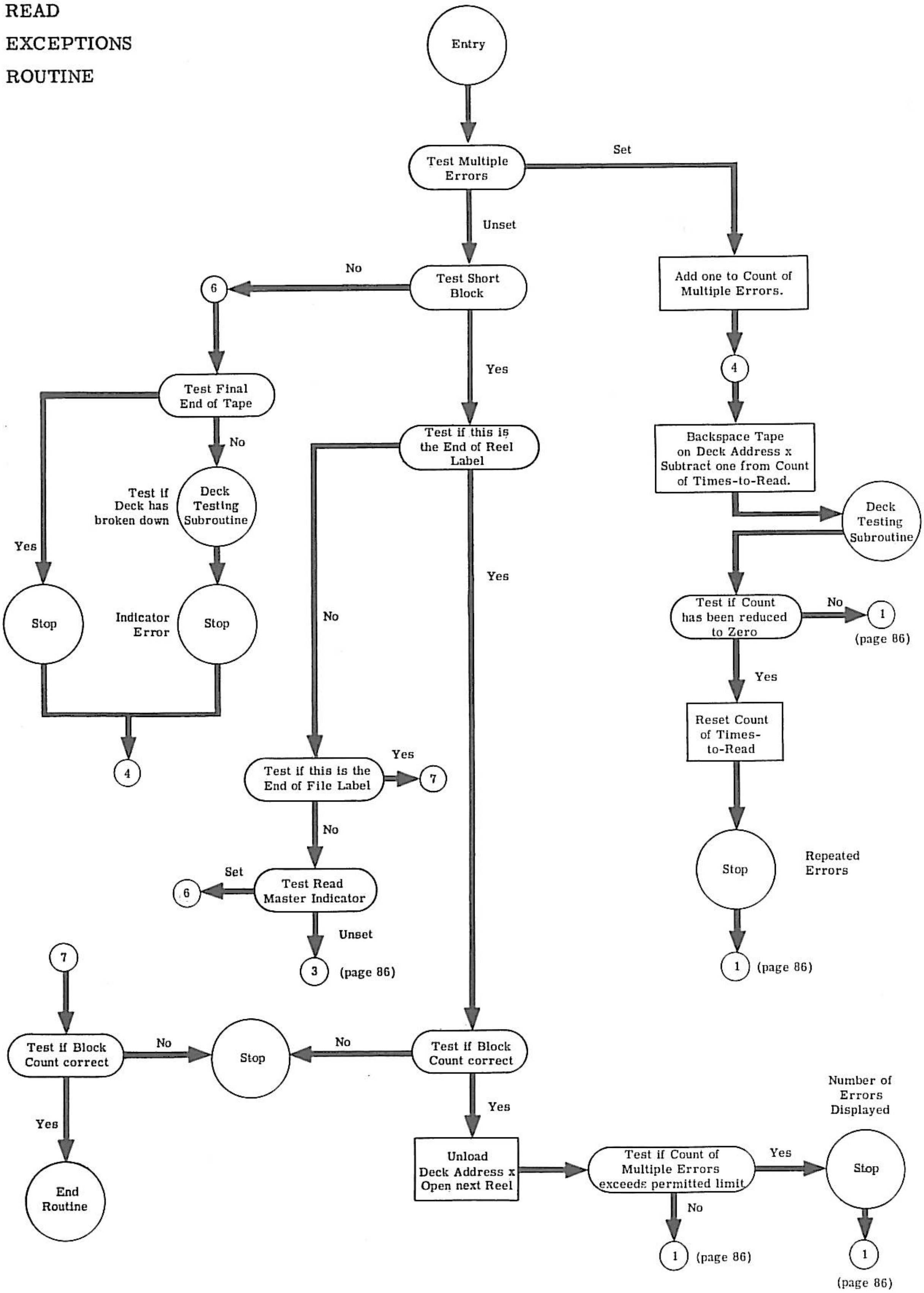
READ

EXCEPTIONS

ROUTINE



Read Exceptions Routine

The Read Exceptions routine discovers which exceptions condition has arisen and deals with it appropriately. A count is kept of any multiple errors which occur.

If a multiple error occurs the tape is backspaced and another attempt made to read the block. If necessary, several attempts are made until the times-to-read count is reduced to zero. The computer is then stopped as an indication that the tape deck may be faulty. Restart causes further attempts to be made.

If a short block is detected, it is examined to see if it is the end of reel or end of file label. The end of file label is written after the last data block. It acts as an end of reel label and in addition indicates that there is no further reel to follow. When the end of reel or end of file label is detected a check is made to ensure that the number of blocks read corresponds to the block count stored in the label. If a short block is not an end of reel or end of file label, then it is treated as an ordinary data block.

If the final end of tape label is detected the computer is stopped. This condition should never arise since the end of reel label should always be read before the final end of tape label.

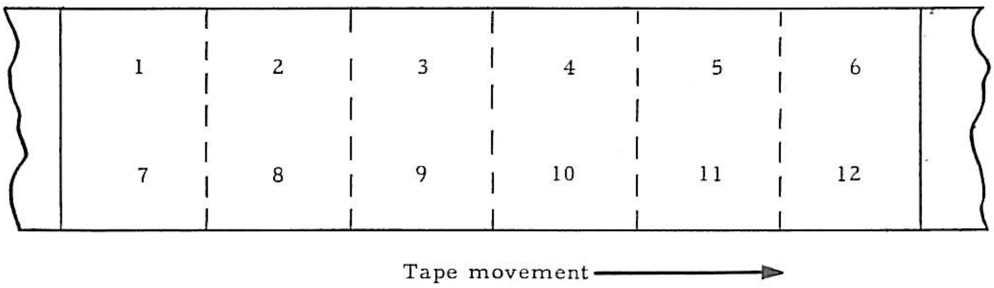
THE ONE-INCH (90 kc/s) MAGNETIC-TAPE SYSTEM 3.9

The magnetic tape is one inch wide and is divided into 16 longitudinal tracks. Data is recorded on the tape in the form of bits. Thus a cross-section of the tape consists of 16 bit positions and is called a frame. The tape moves at a speed of 150 inches a second. The packing density is 600 digits (50 words) to the inch and the tape digit transfer speed is therefore 90,000 digits a second (90 kc/s). The time for one word to pass the read/write heads is 133 microseconds.

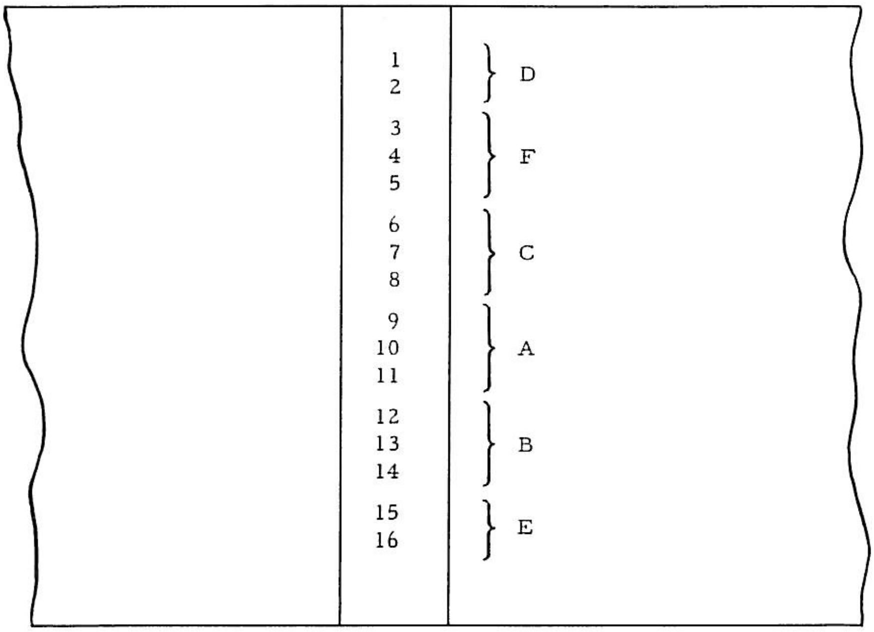
The maximum length of tape on a spool is 3,600 feet. The length of tape between the end of tape marker and the end of the tape is a minimum of 15 inches. The length of tape between the early end of tape marker and the end of tape marker is a minimum of 15 feet.

Representation of Data on Tape 3.9.1

One tape frame contains eight data bits and eight check bits. The eight data bits comprise two four-bit digits and it follows that one word of data occupies six tape frames. The digits of a word are written on the tape as follows:



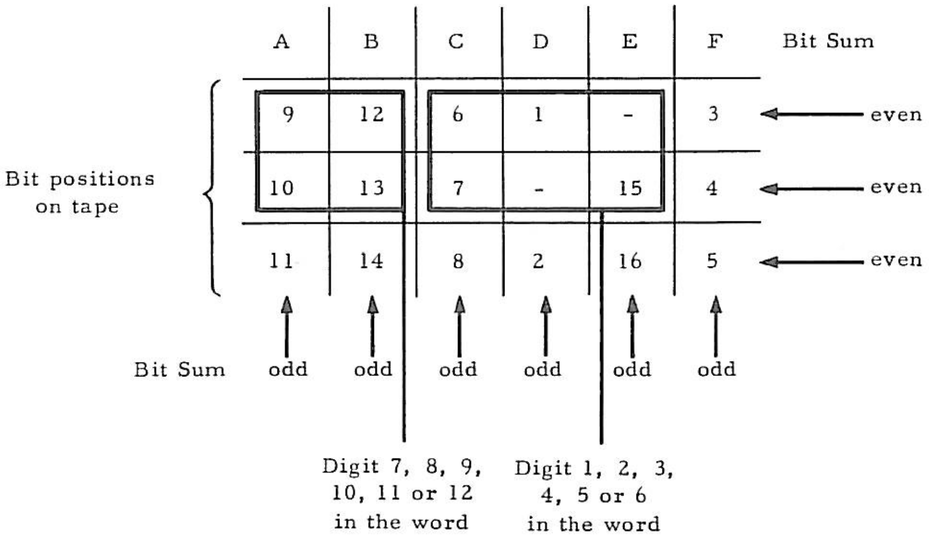
The bit positions in one tape frame are grouped as follows:



The groups are lettered for explanation purposes only.

The 1, 2, 4 and 8 bits of digit 1, 2, 3, 4, 5 or 6 in the word are recorded in bit positions 1, 6, 7 and 15 respectively. The 1, 2, 4 and 8 bits of digit 7, 8, 9, 10, 11 or 12 in the word are recorded in bit positions 9, 10, 12 and 13 respectively. Bit positions 2, 3, 4, 5, 8, 11, 14 and 16 are reserved for check bits.

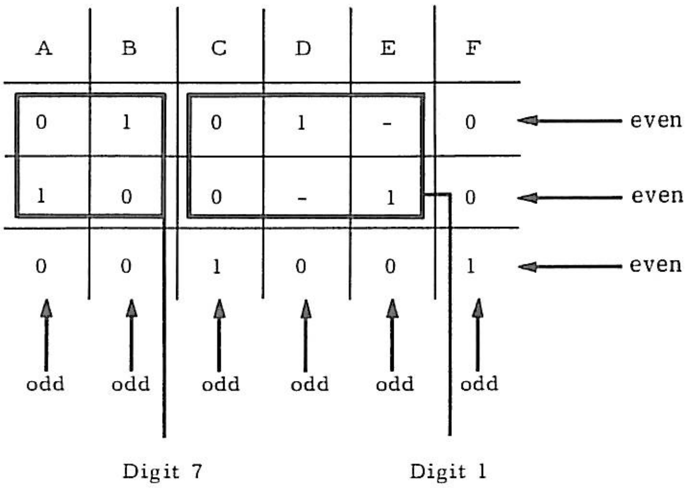
The check bits are generated so as to make unique combinations of odd and even parities for the digits represented. The way in which the parity bits are generated can be illustrated by the following diagram:



	A	B	C	D	E	F	Bit Sum
	9	12	6	1	-	3	even
	10	13	7	-	15	4	even
	11	14	8	2	16	5	even
Bit Sum	odd	odd	odd	odd	odd	odd	

The check bits are generated so that the sum of the bits held in the bit positions in each column is odd and that the sum in each row is even.

The data and parity bits for a 9 in digit position 1 and a 6 in digit position 7 of a word are as follows:



A	B	C	D	E	F	
0	1	0	1	-	0	even
1	0	0	-	1	0	even
0	0	1	0	0	1	even
odd	odd	odd	odd	odd	odd	

This is recorded on a tape frame as:

1	D
0	
0	F
0	
1	
0	C
0	
1	
0	A
1	
0	
1	B
0	
0	
1	E
0	

Example

Consider a word in I.A.S. with the value 000042972481.

When transferred to tape this is recorded in six frames thus:

0	0	0	0	4	2
9	7	2	4	8	1

Tape movement

The data and check bits are recorded on tape as follows:

Tape movement

0	0	0	0	0	0
1	1	1	1	1	1
1	0	0	1	0	0
1	1	1	0	0	0
1	0	0	0	1	1
0	0	0	0	0	1
0	0	0	0	1	0
1	1	1	1	0	0
1	1	0	0	0	1
0	1	1	0	0	0
0	1	0	1	1	0
0	1	0	1	0	0
1	0	0	0	1	0
0	0	1	0	0	1
0	0	0	0	0	0
1	1	1	1	1	1

The check bits are generated when information is written to tape. When a word is read from tape the odd and even parity configuration is checked for each pair of digits. The system is such that a single-bit gain or loss can be detected precisely.

Time for a queued tape unit to come under computer control.	800 milliseconds after the unload instruction has been accepted
Fixed Delay Period on reading or writing	0.48 ms
Delay before writing first block	2 seconds
Rewinding or unloading speed	Two speeds available, choice depending on engineers adjustment. (a) 150 inches a second. (b) 300 inches a second, subject to last 600 feet (approx.) of tape being rewound at 150 inches a second; previous 2,400 feet (approx.), or remainder of tape if less than 3,000 feet, is rewound at the full speed of 300 inches a second; remainder, up to 600 feet, is rewound at 150 inches a second.
Time to rewind a 3,600 foot reel.	At 150 inches a second, 4 minutes 48 seconds At 300 inches a second, 3 minutes 12 seconds
Length of long gap.	1.35 inches
Length of short gap.	1.12 inches
Time to create long gap on writing	11.2 ms
Time to create short gap on writing	7.5 ms
Time to traverse long gap on reading - with stop/start	11.2 ms
Time to traverse long gap on reading - without stop/start	9.0 ms
Time to traverse short gap on reading - with stop/start	9.7 ms
Time to traverse short gap on reading - without stop/start	7.5 ms
Time for a word to be transferred from Register G to I.A.S. during reading	15 µs
Time for a word to be transferred from I.A.S. to Register F during writing	15 µs
Minimum distance between final end of tape marker and actual end of tape	15 inches
Minimum distance between early end of tape marker and final end of tape marker	15 feet

Timing 3.9.3

When the tape is being read or written, one word passes the read/write heads every 133 microseconds. Of these 133 microseconds, only 15 microseconds are used for transferring information between tape and I.A.S. and the remaining 118 microseconds can be used for other processing.

It follows that if tape reading or writing is being time-shared with the main program, then for every 118 microseconds of program there is a delay of 15 microseconds to allow the tape transfer to take place. This corresponds to an increase in program time of approximately 12.7 per cent.

If both reading and writing are taking place then of every 133 microseconds, 30 microseconds are used for transfers between tape and I.A.S., leaving 103 microseconds available for other processing.

It follows that if reading and writing are being simultaneously time-shared with the main program, then for every 103 microseconds of program there is a delay of 30 microseconds to allow the actual transfers to take place. This corresponds to an increase in program time of approximately 29.1 per cent.

The actual time for a block to be read or written on tape can be calculated by allowing 133 microseconds for each word in the block.

In calculating the total time for reading or writing tape, allowance should be made for the time to traverse the inter-block gaps. It is advisable to allow for long gaps when estimating times.

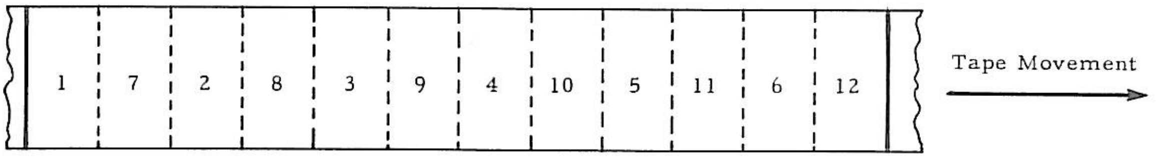
THE HALF - INCH ($22\frac{1}{2}$kc/s) MAGNETIC - TAPE SYSTEM 3.10

The tape is half an inch wide and is divided into ten longitudinal tracks. Data is recorded on the tape in the form of bits. Thus a cross-section of the tape consists of ten bit positions and is called a frame. The tape moves at a speed of 75 inches a second. The packing density is 300 digits (25 words) to the inch and the tape digit transfer speed is therefore 22,500 digits a second ($22\frac{1}{2}$ kc/s). The time for one word to pass the read/write heads is 533 microseconds.

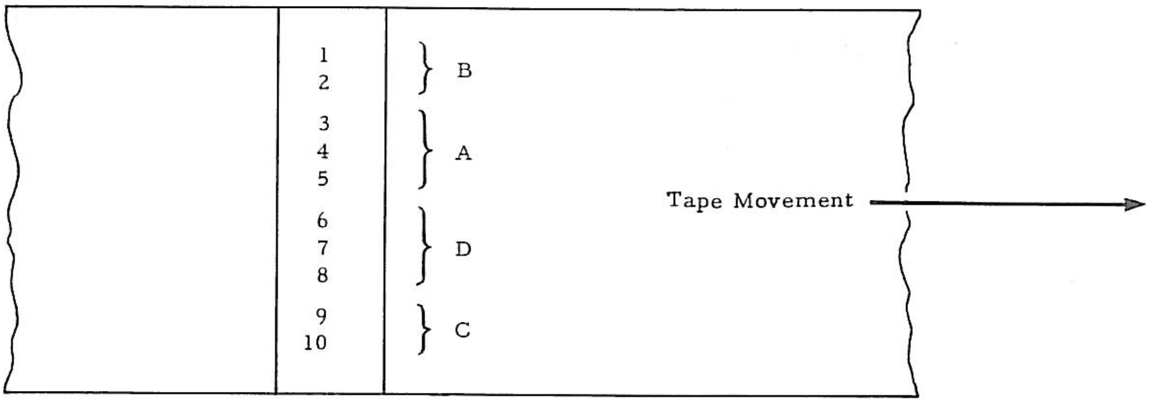
The maximum length of tape on a spool is 3,600 feet. The length of tape between the end of tape marker and the end of tape is a minimum of 15 inches. The length of tape between the early end of tape marker and the end of tape marker is a minimum of 20 feet.

Representation of Data on Tape 3.10.1

One tape frame contains four data bits and six check bits. The four data bits represent one digit, and it follows that one word of data occupies twelve tape frames. The digits of a word are written on tape as follows:



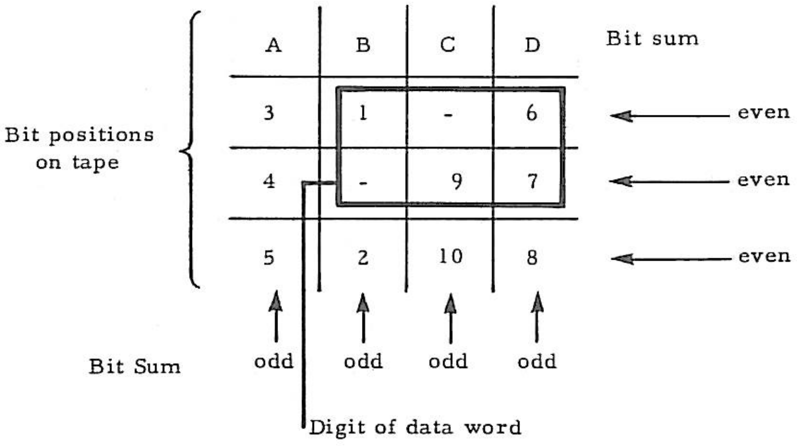
The bit positions in one tape frame are grouped as follows:



The groups are lettered for explanation purposes only.

The 1, 2, 4 and 8 bits of a digit are recorded in bit positions 1, 6, 7 and 9 respectively. Bit positions 2, 3, 4, 5, 8 and 10 are reserved for check bits.

The check bits are generated so as to make unique combinations of odd and even parities for the digit represented. The way in which the parity bits are generated can be illustrated by the following diagram:



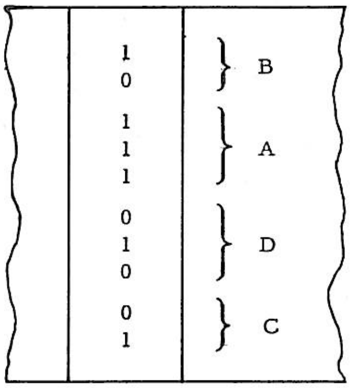
	A	B	C	D	Bit sum
Bit positions on tape	3	1	-	6	even
	4	-	9	7	even
	5	2	10	8	even
Bit Sum	odd	odd	odd	odd	

The check bits are generated so that the sum of the bits held in the bit positions in each column is odd, and that the sum in each row is even.

The data and parity bits for a digit with value 5 are as follows:

A	B	C	D	
1	1	-	0	even
1	-	0	1	even
1	0	1	0	even
odd	odd	odd	odd	

This is recorded in a tape frame as:



The check bits are generated when information is written to tape. When a word is read from tape the odd and even parity configuration is checked. The system is such that a single bit which has been gained or lost can be detected precisely.

Timings and Statistics 3.10.2

Time for a queued tape unit to come under computer control	800 ms after the unload instruction has been accepted.
Fixed delay period on reading or writing	2.04 ms
Delay before writing first block	2 seconds
Rewinding or unloading speed	The rewinding speed is not constant but decreases as the length of tape on the loading spool increases. The time to rewind half a reel is therefore more than half the complete rewind time.
Time to rewind a 3, 600 foot reel	Under 4 minutes
Length of long gap	1.24 inches
Length of short gap	1 inch
Time to create long gap on writing	18.8 ms
Time to create a short gap on writing	13.4 ms
Time to traverse long gap on reading - with stop/start	18.8 ms
Time to traverse long gap on reading - without stop/start	16.6 ms
Time to traverse short gap on reading - with stop/start	15.6 ms
Time to traverse short gap on reading - without stop/start	13.4 ms
Time for a word to be transferred from Register G to I.A.S. during reading	15 µs
Time for a word to be transferred from I.A.S. to Register F during writing	15 µs
Minimum distance between final end of tape marker and actual end of tape	15 inches
Minimum distance between early end of tape marker and final end of tape marker	15 feet

Timings 3.10.3

When the tape is being read or written, one word passes the read/write heads every 533 microseconds; only 15 microseconds are used for transferring information between tape and I.A.S., and the remaining 518 microseconds can be used for other processing.

It follows that if tape reading or writing is being time-shared with the main program, then for every 518 microseconds of program there is a delay of 15 microseconds to allow the tape transfer to take place. This corresponds to an increase in program time of approximately 2.9 per cent.

If both reading and writing are taking place then of every 533 microseconds, 30 microseconds are used for transfers between tape and I.A.S. leaving 503 microseconds available for other processing.

It follows that if reading and writing are being simultaneously time-shared with the main program, then for every 503 microseconds of program there is a delay of 30 microseconds to allow the actual transfers to take place. This corresponds to an increase in program time of about 6 per cent.

The actual time for a block to be read or written to tape can be calculated by allowing 533 microseconds for each word in the block. In calculating the total times for reading and writing to tape, allowance should be made for the time to traverse the inter-block gaps. It is advisable to allow for long gaps when estimating times.

THE QUARTER-INCH (16 kc/s) MAGNETIC-TAPE SYSTEM 3.11

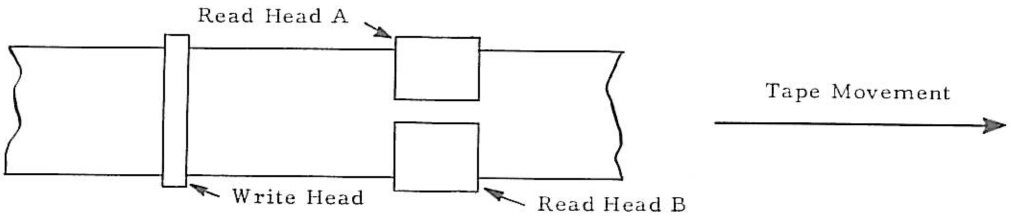
Four, six or eight tape decks can be linked to the computer and used as extra storage for program and/or data words. Each tape deck is capable of handling one reel of tape at a time. When the tape is in motion it passes from one tape spool, past the read/write heads, where information is read or recorded on the tape, and onto another spool. Information cannot be written to tape unless the spool has a writing ring fitted to it by the operator. This prevents the accidental overwriting of master information. It is possible to read from one deck and write to another deck simultaneously.

There is a tape control unit which acts as a link between the central processor and the individual tape decks. The tape control unit consists of a read unit and a write unit each containing a buffer store for use when reading or writing tape. Program instructions are available for controlling the tapes. Words may be transferred from magnetic tape to I.A.S. and vice versa, the transfer taking place via the appropriate buffer and Register A.

Single instructions initiate the transfer of consecutive words between tape and I.A.S., the unit of transfer being called a block. There is no restriction on the number of words in a block other than the size of I.A.S. and the remaining length of the tape.

Information is recorded on tape by varying the length of the signals on the tape to represent different digital values. This means that information is recorded across the full width of the tape.

The tape is divided into two tracks which run longitudinally along the tape. There is one write head which writes information across the full width of the tape, and two read heads (designated A and B), one for each track. Program instructions are available for reading from either track.



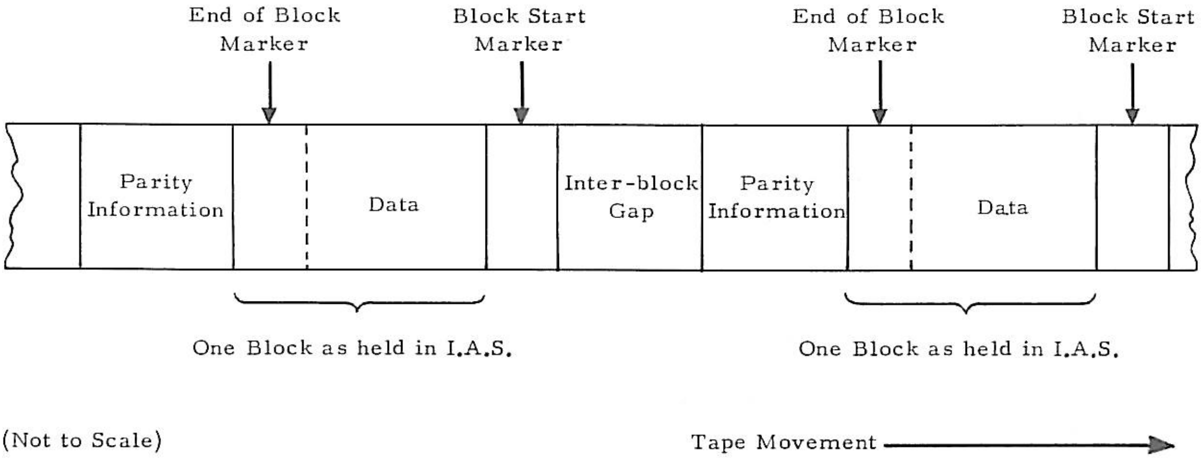
Tape Layout 3.11.1

The last word of each block is the end of block marker which consists of a word with 15 in every digit position. When writing to tape the programmer must position the end of block marker in the I.A.S. word immediately following the last data word of the block. A write instruction causes writing to commence at a specified word of I.A.S. Consecutive words are written to tape up to and including the end of block marker. A read instruction causes a block to be read into I.A.S. starting at a word specified in the instruction. The end of block marker is read and stored in I.A.S. as the last word of the block.

While a block is being written to tape, parity information is accumulated and stored on the tape at the end of the block, immediately following the end of block marker.

After the parity information has been recorded on tape there is a delay while it is check-read after which the tape is brought to rest. A subsequent write instruction causes the tape to start moving again, and writing to take place when the tape has reached the necessary speed. These delays during writing give rise to gaps between consecutive blocks of data. They are called inter-block gaps. They are erased by the write head and therefore contain no information.

Immediately before writing commences a block start marker is written to tape consisting of six words of zeros. On subsequent reading this indicates that the data block is about to reach the reading heads. The tape layout is summarized below.



When reading, the tape is brought to rest between consecutive read instructions. The stopping and starting takes place in the inter-block gap.

Soon after the beginning of the tape there is a beginning of tape marker. This is read photo -electrically and prevents the first block being written on the leading end of the tape which may easily be damaged.

Just before the end of tape there is an end of tape marker. An indicator is set if this is detected on writing to tape.

Tape Organization

3.11.2

It is recommended that certain blocks should be written on the tape for organizational purposes only. It is important that the correct tape reels should be loaded for the job to be run and for this reason the first block on tape is made a label block; and should be recorded on the tape when the tape is written, and checked whenever it is read. There is a recommended layout for this block and also for the last block on a particular tape and for the final block of a tape file. General routines are available for reading and writing tape and for creating and checking label blocks. These 'housekeeping' routines are described in Part 5 and full details are given in the tape manual (Magnetic Tape Housekeeping Routines and Conventions).

Checking Facilities

Data values are recorded on tape by recording in one direction for a given time interval. When a new value is to be recorded, the direction of recording is changed. A change in recording direction is known as a flux reversal. On reading back, the value of data is assessed by time intervals elapsing between successive flux reversals. There are four basic time intervals and each data digit is recorded uniquely on the tape as a combination of two of these intervals. With this method of recording the following transfer errors may occur:

(a) A reversal may be missed or an extra reversal generated.

(b) The time interval may have deviated from its correct value sufficiently for it to be interpreted as an adjacent time interval.

Checks are made to detect both these types of error. Error indicators are set when errors are detected.

Writing Tape

As a block is being written to tape, parity bits are accumulated for the data contained in the block. These bits are recorded on the tape at the end of the block as a series of time intervals and are used for checking purposes. When information has been written to tape it is passed to the read heads where it is automatically checked on read head A. During check-reading a check is made that the time interval between any two consecutive flux reversals does not exceed a certain fixed limit. A check is also made that the total reversals read in a block represent an integral number of words. These two checks detect errors due to reversals being missed or extra reversals being generated. During check-reading the parity bits are re-accumulated as the data is read. When the complete block has been check-read these bits are compared with the parity bits recorded on the tape. Any discrepancy indicates that a write transfer error has occurred and an appropriate error indicator is set. The parity checking system detects errors which occur due to the time interval extending into an adjacent range. When an error occurs during writing tape, the tape should be backspaced, a section of tape should be cancelled and the block re-written on the next section. If necessary this procedure should be repeated several times before stopping the computer and indicating that there is a persistent error. Cancelled tape is ignored when subsequently read.

Data are transferred from I.A.S. to the tape control unit from whence they are written to tape. When the end of the block marker is detected in the control unit, the transfer from I.A.S. ceases and the end of block marker is written to tape. As each complete word is check-read, it is tested to see if it is the end of block marker. If reversals are gained or lost during writing the check-reading becomes out of phase and parts of two separate words are interpreted as one word. The data may be such that two part words form a word of fifteens and are interpreted as the end of block marker. This condition is detected and an error indicator set, when the following characters are read. This is because the first part of the parity information, which immediately follows the end of block marker, should contain zeros. If reversals are gained or missed, or if the reversals extend to an adjacent range, the end of block marker may not be detected at all. In this case check -reading continues until the inter-block gap is detected when the tape is automatically stopped.

Reading Tape

When tape is read, a check is made that the time interval between consecutive reversals does not exceed a fixed limit, and also that the reversals in a block represent an integral number of words. The parity bits are regenerated and compared with those recorded on the tape. Indicators are set if any transfer errors are detected by these means. If errors occur during reading tape, the tape should be backspaced and the block re-read.

Data are read from tape to tape control unit from whence they are transferred to I.A.S. When the end of block marker is detected in the tape control unit, reading ceases and the end of block marker is stored in I.A.S. If reversals are gained or missed, the reading becomes out of phase, and parts of two separate words are interpreted as one word. The data may be such that two part words form a word of fifteens and are interpreted as the end of block marker. This condition is detected, and an error indicator set, when the following characters are read. This is because the first part of the parity information, which immediately follows the end of block marker, should contain zeros. If reversals are gained or missed, or if the data is misread due to the time interval extending to an adjacent range, the end of block marker may not be detected at all. In this case reading continues until the inter-block gap is detected when the tape is automatically stopped.

Tape Deck Addresses 3.11.4

Each tape deck has a fixed address in the range 1 - 8, which is specified in magnetic-tape instructions.

The pressing of the Allocate button on the tape deck causes the deck to come under computer control. It is then operated by any instructions referring to its address.

The housekeeping routines provide facilities for overcoming the difficulties of fixed addresses. This is done by allowing the programmer to specify a programmed address which can be made, by operator action, to correspond to an actual deck address. This means that the operator can allocate the decks as he wishes and prevents program running being held up because a particular deck is not available.

The housekeeping routines also provide facilities for queueing. When an unload instruction has been given to a tape deck, it is possible for its programmed address to be allocated to another deck. Details of these facilities are given in the Tape Housekeeping Manual.

Tape Write Instruction

Effect This instruction causes one block to be written from I.A.S. to magnetic tape.

Operation Starting at a specified word of I.A.S., successive words are written on both tracks of the tape, up to and including the end of block marker.

Notes The instruction is double-length and is made up as follows:

First half	Function digits	- 39
	First two address digits	- 00
	Third address digit	- 1
	Fourth address digit	- Tape deck address i.e., a number in the range 1 to 8
Second half	Function digits	- 00
	Address digits	- Address of first I.A.S. word to be written to tape

Thus the instruction

D	F	A	R
	39	0012	
	00	0035	10

causes a block to be written to deck address 2 starting at word 35 block 10.

During the execution of this instruction the write unit is occupied. Further instructions to the specified tape deck or write or cancel instructions to any tape deck cause the Tape Order.Error indicator to be set.

Tape Read Instructions

Effect These instructions cause a block to be read into I.A.S. from magnetic tape. Reading may take place either on track A or on track B.

Operation Information from tape is stored in successive words of I.A.S. up to and including the end of block marker. Two instructions are available, one using the read head on track A and the other using that on track B.

Notes The instructions are double-length and are made up as follows:

First Half
Function digits - 39
First two address digits - 00
Third address digit - 2 if reading on track A
7 if reading on track B
Fourth address digit - Tape deck address

Second half
Function digits - 00
Address digits - Address of first I.A.S. word in which information is to be stored

For example the instruction

D	F	A	R
--	39	0073	---
	00	0009	16

causes a block to be read, using track B, from deck address 3 and to be stored in I.A.S. starting at word 9 block 16.

During the execution of these instructions the read unit is occupied. Further instructions to the specified tape deck or read or backspace instructions to any other tape deck will cause the Tape Order Error indicator to be set.

Backspace Instruction

Effect This instruction causes the tape to be backspaced one block.

Operation The tape on a specified unit is rewound one block. When it has stopped the tape is positioned so that the block can be read, written or cancelled. The previous block is unaltered.

Notes The instruction is a single-length instruction as follows:

Function digits - 39
First two address digits - 00
Third address digit - 3
Fourth address digit - Tape deck address

Thus the instruction

D	F	A	R
--	39	0034	---

causes the tape on tape deck address 4 to be rewound one block.

During the execution of this instruction the read unit is occupied. Further instructions to the specified tape deck or read or backspace instructions to any tape deck cause the Tape Order Error indicators to be set.

Cancel Instruction

Effect This instruction causes a section of tape to be cancelled so that it is ignored when subsequently read.

Operation The tape is erased while it moves forward for a fixed length of time. A cancelled section of tape contains no information and is therefore ignored by subsequent read or backspace instructions and no error indicators are set.

Notes The instruction is a single-length instruction as follows:

Function digits - 39
First two address digits - 00
Third address digit - 4
Four address digit - Tape deck address

Thus the instruction:

D	F	A	R
	39	0041	

causes a section of tape to be cancelled on tape deck address 1.

During the execution of the cancel instruction the write unit is occupied. Further instructions to the specified tape deck or write or cancel instructions to any tape deck cause the Tape Order Error indicator to be set.

Rewind Instruction

Effect This instruction causes the tape on a specified deck to be rewound to the beginning of the tape.

Operation The tape on the specified deck is rewound to the beginning of the tape. A subsequent read or write instruction causes the first block on tape to be read or a new block to be written.

Notes The instruction is a single-length instruction as follows:

Function digits - 39
First two address digits - 00
Third address digit - 5
Fourth address digit - Tape deck address

Thus the instruction

D	F	A	R
	39	0056	

causes the tape on tape deck address 6 to be rewound to the start of the tape. While the tape is being rewound, any further instructions to the same tape deck cause the Tape Order Error indicator to be set. Any tape instructions can be carried out on other decks. When the tape has been rewound there is a delay before the first block is read or written.

Unload Instruction

Effect This instruction causes the tape on a specified tape deck to be rewound ready for removal from the deck.

Operation The tape on the specified deck is rewound on the loading spool and the spool made ready for removal. When an unload instruction has been accepted the tape deck is no longer under computer control.

Notes The instruction is a single-length instruction made up as follows:

Function digits - 39
First two address digits - 00
Third address digit - 6
Fourth address digit - Tape deck address

Thus the instruction

D	F	A	R
	39	0062	

causes the tape on deck address 2 to be rewound on the loading spool ready for removal.

Any instruction to a deck for which the unload instruction has been accepted causes the Tape Order Error indicator to be set. Any tape instructions can be carried out on other decks.

Digit Position	1 2	3	4	5	6	7	8	9 10 11 12	
	Function	0	0	Command	Deck Address	0	0	I.A.S.	Effect
Double-length Instructions	39	0	0	1	1-8	0	0	I.A.S. Address	Write
	39	0	0	2	1-8	0	0	I.A.S. Address	Read Track A
	39	0	0	7	1-8	0	0	I.A.S. Address	Read Track B
Single-length Instructions (may begin either half of word)	39	0	0	3	1-8				Backspace
	39	0	0	4	1-8				Cancel
	39	0	0	5	1-8				Rewind (Back to Start of Spool)
	39	0	0	6	1-8				Unload (Tape Rewound on Spool)

SUMMARY OF MAGNETIC-TAPE INSTRUCTIONS, AS HELD IN THE COMPUTER.

Indicators 81 to 88 Deck Address Ready

Purpose There are eight of these indicators, one for each possible deck address. They are used to test whether a tape deck is ready for use before giving instructions to use it.

Operation The indicators are numbered 81 to 88, and are associated with deck addresses 1 to 8 respectively. The Deck Address Ready indicator is automatically set if:

(a) The appropriate tape deck is not busy, i.e. no tape instruction is currently being executed on that deck, and

(b) the tape deck is mechanically ready.

The indicator is unset if either of the above conditions are not satisfied, indicating that the deck is not ready to receive an instruction.

Notes For example the instruction

D	F	A	R
4	85	0009	B

tests whether deck address 5 is ready for use, if it is ready a jump is made to word 9 of the current block.

The appropriate Deck Address Ready indicator should be tested before giving a tape instruction. This prevents a tape order error due to an instruction being given to a deck which is not ready.

Indicator 89 Transport Mechanically Ready

Purpose This indicator is associated with the Deck Address Ready indicators. If one of the indicators 81 to 88 is unset, this indicator can be used to discover which condition caused it to be unset.

Operation Indicator 89 is automatically set if:

(a) The last Deck Address Ready indicator to be tested was found to be set, or

(b) the last Deck Address Ready indicator was unset because the tape deck was busy.

The indicator is automatically unset if the last Deck Address Ready indicator was unset because the tape deck was mechanically unready. If a tape deck becomes mechanically unready, indicator 89 will become unset after a delay of up to 500 milliseconds.

Notes Indicator 89 should be tested when one of the indicators 81 to 88 is found to be unset.

If indicator 89 is set the tape deck is busy, the program must wait until the deck is not busy before giving it an instruction.

If indicator 89 is unset operator action is required because the deck is mechanically unready.

For example

I	D	F	A	R
5	4	81	0007	B
	4	89	0005	B
6		11	2002	

will cause the following:

If deck address 1 is ready for use a jump is made to word 7 of the block which continues with the tape program.

If deck address 1 is not ready for use, indicator 89 is tested. If indicator 89 is set the tape deck is busy and a jump is made to re-test indicator 81 to see if the deck is no longer busy. If indicator 89 is unset the computer is stopped with 2003 displayed in CR3. This indicates to the operator that action must be taken.

Indicator 80 Tape Order Error

Purpose This indicator is set whenever a tape instruction is given which cannot be accepted.

Operation Indicator 80 is automatically set if:

(a) A tape instruction is given to a tape deck which has not been allocated.
(b) An instruction is given to a tape deck which is busy.
(c) A write or cancel instruction is given to any tape deck while either type of instruction is being executed.
(d) A read or backspace instruction is given to any tape deck while either type of instruction is being executed.
(e) A write or cancel instruction is given to a deck which has not had a writing ring fitted to below the tape spool.
(f) A tape instruction is given without specifying a deck address.

Notes When indicator 80 is set the Tape Order Error light on the console is lit. If the Optional Stop switch is on, the computer stops automatically when there is a tape order error, CR3 containing the faulty instruction with 1 added to it. In this case, restarting the computer causes the light to go out, but the indicator remains set until tested by program.

Indicator 70 Write Unit Ready

Purpose This indicator is used to test whether the write unit is busy.

Operation Indicator 70 is set automatically when a write or cancel instruction has been completed, indicating that the write unit is ready to accept another instruction.

It is unset automatically when a write or cancel instruction is accepted.

Notes Indicator 70 should be tested before a write or cancel instruction to ensure that the write unit is ready and to prevent a possible tape order error. For example instruction:

I	D	F	A	R
10	4	70	11	B
	4	00	10	B
11		39	0013	
		00	0005	15

will cause the following:

Indicator 70 is repeatedly tested until the write unit is ready. When the write unit is ready the instruction to write to deck address 3 is obeyed.

Indicator 72 Read Unit Ready

Purpose This indicator is used to test whether the read unit is busy.

Operation Indicator 72 is set automatically when a read or backspace instruction has been completed, indicating that the read unit is ready to accept another instruction.

It is unset automatically when a read or backspace instruction is accepted.

Notes Indicator 72 should be tested before a read or backspace instruction to ensure that the read unit is ready and to prevent a possible tape order error.

Indicator 74 Write Errors

Purpose This indicator is used to detect any transfer errors which occur during writing tape.

Operation Indicator 74 is automatically set if any errors are detected during the check-reading which follows writing.

Indicator 74 is unset when a write or cancel instruction is accepted.

Indicator 75 Read Errors

Purpose This indicator is used to detect any transfer errors which occur during reading tape.

Operation Indicator 75 is automatically set if any errors are detected during reading.

Indicator 75 is unset when a read instruction is accepted.

Notes Indicator 75 is unaffected when a section of tape is read which has been previously cancelled.

Indicator 76 End of Tape, Writing

Purpose This indicator is used to detect the end of tape marker when writing tape.

Operation Indicator 76 is automatically set if the end of tape marker is detected when writing or cancelling tape.

Indicator 76 is unset by program test.

Notes The end of tape marker is read photo-electrically at a station situated before the write head. It is not possible to write over the endof tape marker and therefore writing is automatically inhibited when the end of tape marker is detected. When the next instruction is given, writing is automatically suspended until the end of tape marker has passed the write head.

When writing is inhibited, a block may have been only partly written. This condition is detected at the check-reading station and the Write Errors indicator is set. The normal error procedure of backspacing, cancelling and re-writing the block ensures correct recording.

Indicator 77 Short Block, Reading

Purpose This indicator is used to detect a short block of four words.

Operation Indicator 77 is set automatically when a short block, consisting of exactly four words (including the end of block marker) is detected on reading. Short blocks may be used for identification purposes and are used as label blocks by the housekeeping routines.

Indicator 77 is unset by program test.

Indicator 71 Write Master

Purpose This indicator is used to test whether writing has been successfully completed.

Operation Indicator 71 is set if indicator 74 or indicator 76 is set, i.e. if:

(a) Any errors have been detected on writing, or

(b) if the end of tape marker has been detected on writing.

Indicator 71 is unset if both indicator 74 and indicator 76 are unset.

Notes If indicator 71 is unset it follows that writing has been successful. Only if indicator 71 is set is it necessary to test indicators 74 and 76 to discover which exceptions condition has arisen.

Indicator 73 Read Master

Purpose This indicator is used to test whether reading has been successfully completed.

Operation Indicator 73 is set if either indicator 75 or indicator 77 is set, i.e. if:

(a) Any errors have been detected while reading, or

(b) if a short block has been read.

Indicator 73 is unset when indicators 75 and 77 are both unset.

Notes If indicator 73 is unset it follows that reading has been successful. Only if indicator 73 is set is it necessary to test indicators 75 and 77 to discover which exceptions condition has arisen.

Indicator 79 Writing Ring Present

Purpose This indicator is used to ensure that a writing ring has been fitted before a write instruction is given.

Operation This indicator is associated with the last Deck Address Ready indicator to be tested.

Indicator 79 is set if a writing ring is present on the tape deck for which the last Deck Address Ready indicator was tested and if indicator 89 (Transport Mechanically Ready) is set.

It is unset if the writing ring is absent, or if indicator 89 (Transport Mechanically Ready) is unset. If a tape deck becomes mechanically unready, indicator 79 will become unset after a delay of up to 500 milliseconds.

Notes Indicator 79 should be tested before writing to tape. This ensures that a writing ring has been fitted and prevents a possible tape order error.

The Secure lamp on the tape deck is lit when no writing ring is present on the load reel.

INDICATOR	TITLE	SET BY	UNSET BY
70	Write Unit Ready	Write Unit not busy	Write or Cancel Instruction
71	Write Master	Indicator 74 or 76 becoming set	Unsetting of both Indicators 74 and 76
72	Read Unit Ready	Read Unit not busy	Read or Backspace Instruction
73	Read Master	Indicators 75 or 77 becoming set	Unsetting of both Indicators 75 and 77
74	Write Errors	Any Errors during Writing	Write or Cancel Instruction
75	Read Errors	Any Errors during Reading	Read or Backspace Instruction
76	End of Tape	End of Tape Marker during Writing	Program Test
77	Short Block	Short Block Read	Program Test
79	Writing Ring Present	Writing Ring Present on Spool and transport mechanically ready and address seized on deck last tested	Writing Ring not Present on Spool or Transport Mechanically unready or address not seized on deck last tested.
80	Tape Order Error	Unacceptable Instruction	Program Test
81 to 88	Deck Address (1 to 8) Ready	Tape Deck not busy and Mechanically Ready	Tape Deck busy or not Mechanically Ready
89	Transport Mechanically Ready	Transport Mechanically Ready and address seized on deck last tested	Transport not Mechanically ready or address not seized on deck last tested

Figure 39: SUMMARY OF MAGNETIC-TAPE INDICATORS

Program Interrupt Facility

Once a tape instruction has been initiated it is carried out automatically and does not require constant program control. This means that other programs can be obeyed while the tape is in motion. An automatic interrupt facility is incorporated to cater for the transfer of words between I.A.S. and the tape control unit. Thus the need for any program control during reading or writing tape is eliminated. This enables the programmer to make maximum use of the time available while the tape is in motion.

When a rewind or unload instruction is being obeyed, there is no transfer between I.A.S. and magnetic tape and thus any instruction may be obeyed other than a tape instruction to the same deck.

During a cancel or backspace instruction there is no transfer between I.A.S. and magnetic tape and any instructions can be obeyed other than tape instructions to the same deck.

Reading Tape

Information from tape is read into a special register, Register G. Register G is a register used as a buffer store when tape reading is taking place. Register G can be considered as being in two halves, each consisting of a 6-digit register and a small buffer. The layout of the registers is shown diagrammatically in Figure 40.

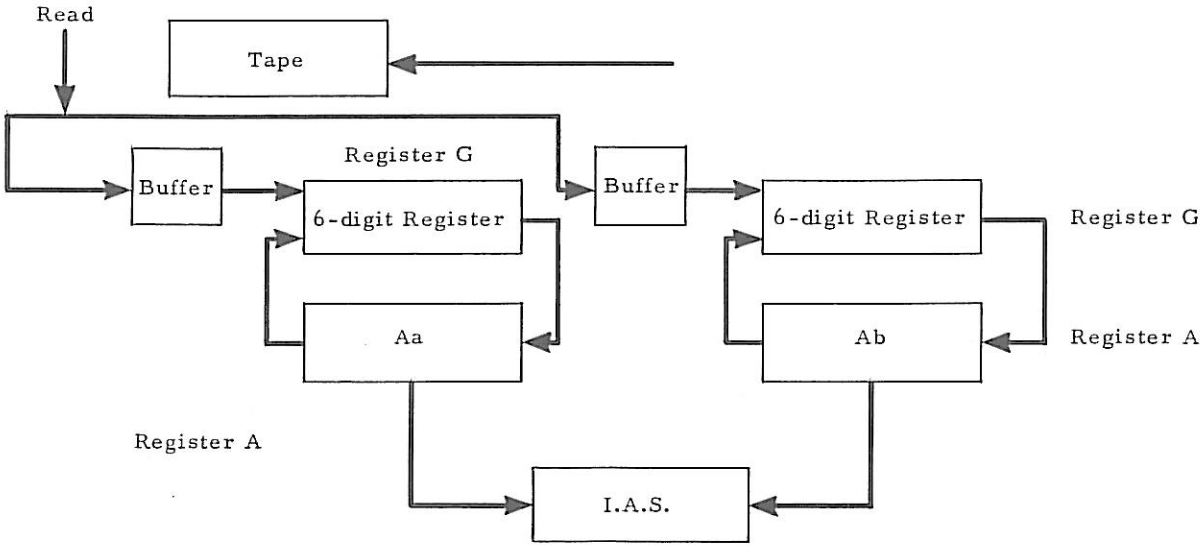


Figure 40: TAPE READ

Information is read from tape into the small buffers and thence transferred into the two 6-digit registers.

When a complete word is contained in the 6-digit registers, the tape control unit indicates to the central processor that it is ready to interrupt the main program in order to transfer the word to I.A.S.

When the current program instruction has been completed the tape control unit breaks in. The contents of the registers are circulated so that they are interchanged with the contents of Register A. The data read from tape is now contained in Register A and is transferred to I.A.S. When the transfer has been completed, the contents of the registers are again interchanged with those of Register A. The original contents of Register A have thus been restored and the main program continues until the next word has been read into the registers, when it is again interrupted.

When the tape control unit is ready to break in, the program is interrupted at the end of the instruction it is obeying. If it is obeying a multibeat instruction, e.g. multiplication, the break-in takes place at the end of the micro instruction currently taking place. Drum transfers cannot be obeyed while reading is taking place since they take longer than the frequency at which the break-in occurs, and cannot be interrupted in the middle of execution. Great care should be taken if other peripheral units are used while the tape is moving since the interruptions from the tape unit upset the timings. In particular the full P.P.F. cannot be used during tape reading. **Processing** should not take place on the current block while it is still being read since, if any transfer error occurs, the whole block is re-read.

Writing Tape

Information to be written to tape passes through a special register, Register F, which is used as a buffer store. Register F can be considered as being in two halves, each consisting of a 6-digit register and a small buffer. The layout of the registers is shown diagrammatically in Figure 41.

When a word is to be written to tape the contents of the 6-digit registers are interchanged with those of Register A. A word is then written from I.A.S. to Register A and the contents of the registers again interchanged. The original contents of Register A have thus been restored and the word to be written to tape is held in the two 6-digit registers. The word is written to tape via

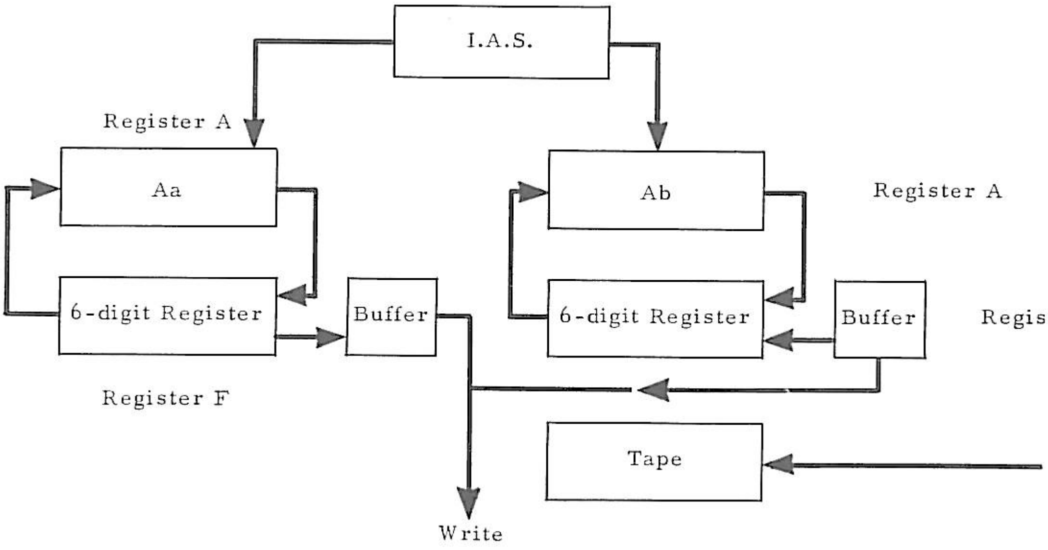


Figure 41: **TAPE WRITE**

the small buffers. When the 6-digit registers have become empty the tape control unit is ready to receive another word from I.A.S. and a request to break in is made to the central processor.

The program is interrupted at the end of the instruction it is obeying, or at the end of the micro instruction if it is obeying a multi-beat instruction. Drum transfers cannot be obeyed while writing is taking place as they take longer than the frequency at which the break-in occurs, and cannot be interrupted in the middle of execution. Great care should be taken if other peripheral units are used while the tape is moving since the interruptions from the tape control unit upset the timings. In particular the full P.P.F. cannot be used during tape writing. Processing should not take place on the block which is being written to tape since, if any transfer error occurs, the whole block is re-written.

It is possible to read from one tape deck and write to another tape deck simultaneously. In this case the main program is interrupted by both the read unit and the write unit, the read unit taking preference if they should both require to break in at the same time.

The time-sharing with a tape read or write program is effected as follows:

When the read or write instruction has been given, a jump is made from the tape program to the section of program which is to be time-shared with the reading or writing. This program is then executed with occasional automatic interruptions from the tape control unit when it requires to communicate with I.A.S. When the program has been completed a return is made to the tape program which when the transfer has been completed, tests the necessary indicators to ensure that the block has been correctly read or written. If the section of main program takes longer than the reading or writing of the block, causing the tape to have stopped before control is returned to the tape program, this does not matter. If drum transfers occur within the time-sharing program they should be preceded by tests of Read and Write Unit Ready indicators (72 and 70) to ensure that the tape transfer has been completed. Facilities for time-sharing when reading or writing tape are provided with the tape housekeeping routines.

Method of Recording on Tape 3.11.8

Information is recorded by lengths of tape which correspond to time intervals between successive flux reversals. There are four basic time intervals referred to as intervals t_0, t_1, t_2, and t_3 respectively. The table below shows the actual value given to each interval when writing tape, together with the range of timings associated with each interval when reading.

Time Interval	Duration of Recording during Writing (microseconds)	Permitted Range on Reading (microseconds)
t_0	16	10 to 21
t_1	28	22 to 34
t_2	43	35 to 51
t_3	62	52 to 72

If time intervals are read which are less than 10 microseconds or greater than 72 microseconds, the error indicators are set.

When a block of words is written to tape, each digit is recorded uniquely as a combination of two of the basic time intervals. In order to achieve this, the 4-bit digit is first converted into two digits. These digits are known as quaternary digits since they may assume the values 0, 1, 2 or 3, each one corresponding to a basic time interval. The conversion is achieved as follows:

(a) The 4-bit and the 1-bit of the data digit are combined to give the first quaternary digit. A quaternary digit of value 0, 1, 2 or 3 is achieved by giving a value of 2 to the original 4-bit and a value of 1 to the original 1-bit.

(b) The 8-bit and the 2-bit of the data digit are combined to give the second quaternary digit. A quaternary digit of value 0, 1, 2 or 3 is achieved by giving a value of 2 to the original 8-bit and a value of 1 to the original 2-bit.

Example

The digit 14 is recorded in the computer as an 8-bit, a 4-bit and a 2-bit.

The first quaternary digit is formed by assigning a value 2 to the original 4-bit. This gives a quaternary digit of 2, which is recorded on tape by time interval t_2 elapsing between successive flux reversals.

Digit Value	Binary Coding in Computer				Quaternary Equivalent		Time Intervals between Flux Reversals		
	Bit Value				First Digit	Second Digit	First Digit (microseconds)	Second Digit (microseconds)	Digit Total (microseconds)
	8	4	2	1	4 and 1 Bits	8 and 2 Bits			
0	0	0	0	0	00 or 0	00 or 0	16	16	32
1	0	0	0	1	01 or 1	00 or 0	28	16	44
2	0	0	1	0	00 or 0	01 or 1	16	28	44
3	0	0	1	1	01 or 1	01 or 1	28	28	56
4	0	1	0	0	10 or 2	00 or 0	43	16	59
5	0	1	0	1	11 or 3	00 or 0	62	16	78
6	0	1	1	0	10 or 2	01 or 1	43	28	71
7	0	1	1	1	11 or 3	01 or 1	62	28	90
8	1	0	0	0	00 or 0	10 or 2	16	43	59
9	1	0	0	1	01 or 1	10 or 2	28	43	71
10	1	0	1	0	00 or 0	11 or 3	16	62	78
11	1	0	1	1	01 or 1	11 or 3	28	62	90
12	1	1	0	0	10 or 2	10 or 2	43	43	86
13	1	1	0	1	11 or 3	10 or 2	62	43	105
14	1	1	1	0	10 or 2	11 or 3	43	62	105
15	1	1	1	1	11 or 3	11 or 3	62	62	124

Figure 42: QUATERNARY EQUIVALENTS OF DIGITS 0 TO 15 SHOWING TIME INTERVALS BETWEEN FLUX REVERSALS

The second quaternary digit is formed by assigning a value 2 to the original 8-bit and a value 1 to the original 2-bit. This gives a quaternary digit of 3, which is recorded on tape by time interval t_3 elapsing between successive flux reversals.

The table in Figure 42 shows the quaternary digits for each digit value 0 to 15 together with the time intervals associated with them.

Parity Checking System 3.11.9

While information is being written to tape, parity bits (dependent on the data value) are accumulated in two special parity registers. After the end of block marker has been written, these parity bits are converted into eight quaternary digits. Eight reversals, with time interval t_0, are written immediately after the end of block marker and these are followed by eight reversals representing the parity information. When reading or check-reading takes place, the parity bits are regenerated in the parity registers in the reading or check-reading unit. At the end of the block the parity bits are converted to quaternary digits and are automatically compared with the parity digits recorded on tape.

The generation of the parity bits in the parity registers is achieved as follows:

For each quaternary digit written to tape there is a corresponding parity digit. The parity digit has the value 0, 1, 2 or 3 and is expressed as 2 bits, a 2-bit and a 1-bit. The quaternary digits and the corresponding parity digits are shown below:

Quaternary Digit	0	1	2	3
Parity Digit	0	3	2	1
Parity Digit Bit 2	0	1	1	0
Parity Digit Bit 1	0	1	0	1

There are six possible transitions for which a time interval may be interpreted as an adjacent interval, i.e. the transitions t_0 to t_1, t_1 to t_0, t_1 to t_2, t_2 to t_1, t_2 to t_3 and t_3 to t_2. It can be seen that four of these transitions change both the 2-bit and the 1-bit of the parity digit, and the other two change the 1-bit of the parity digit only.

Two groups of parity bits are accumulated as follows:

One group is formed by accumulating the 2-bits of the parity digits in a 5-bit shifting register.

A second group is formed by accumulating the 1-bits of the parity digits in a 7-bit shifting register.

The arrangement is shown diagrammatically in Figure 43.

The accumulation consists of summing the bit which has been shifted out of the register with the appropriate bit of the parity digit in a modulo 2 adder. The result is then shifted into the

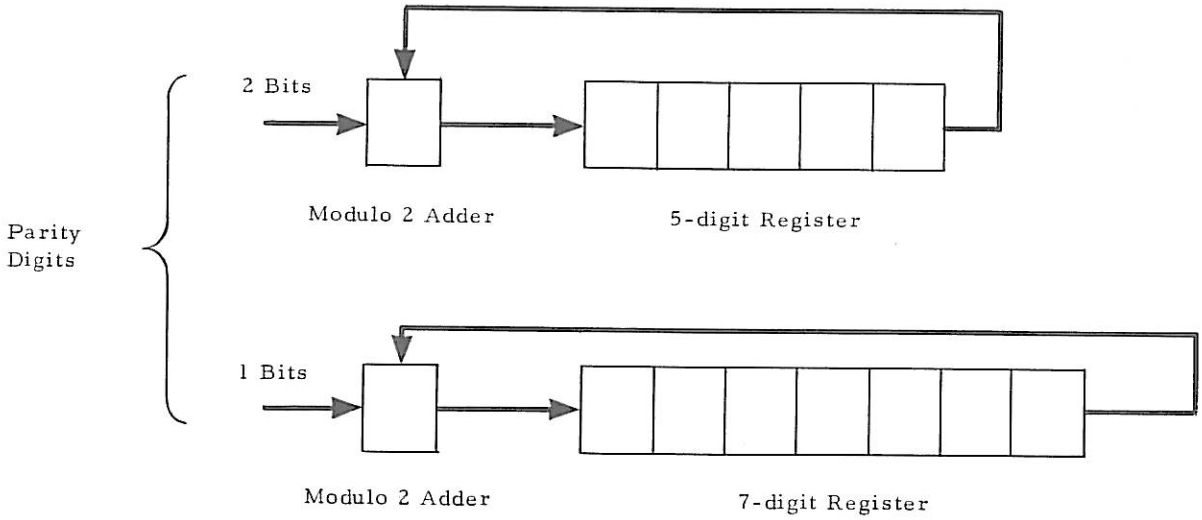
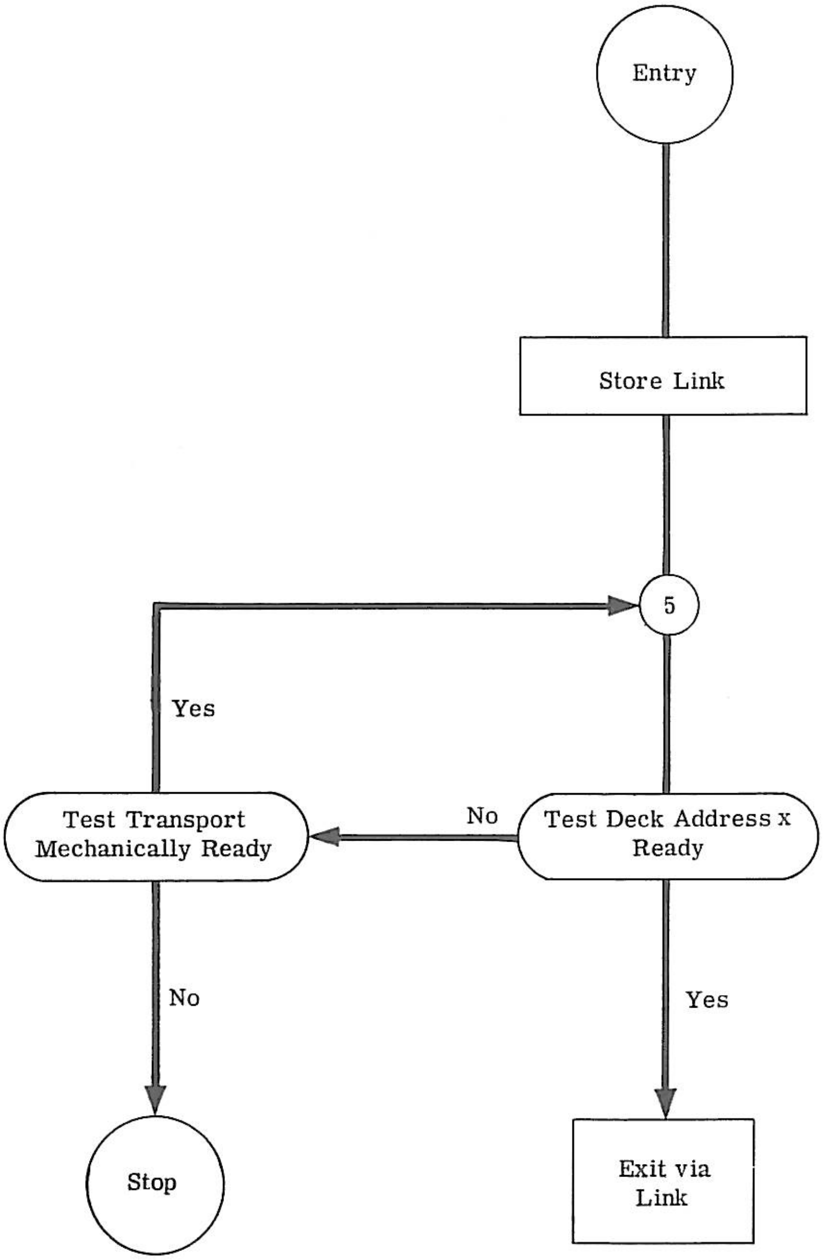


Figure 43: PARITY CHECKING

register. The summation modulo 2 in effect means that if the output from the register and the parity bit are the same, then a zero is entered into the register; if they are different, then a one is entered into the register.

DECK
TESTING
SUBROUTINE



Deck not correctly allocated or there is a Mechanical Failure. Correct Fault and restart from beginning.

Flowcharts for Reading and Writing Tape

Flowcharts for reading and writing magnetic tape are included as an illustration of the use of the various indicators and instructions. These flowcharts do not cover all the housekeeping procedures in the standard routines and are intended as an example only. It is assumed that beginning of tape labels have already been written or checked. Reading and writing takes place on tape deck address x. The value of x would be entered as a parameter at the start of the routine.

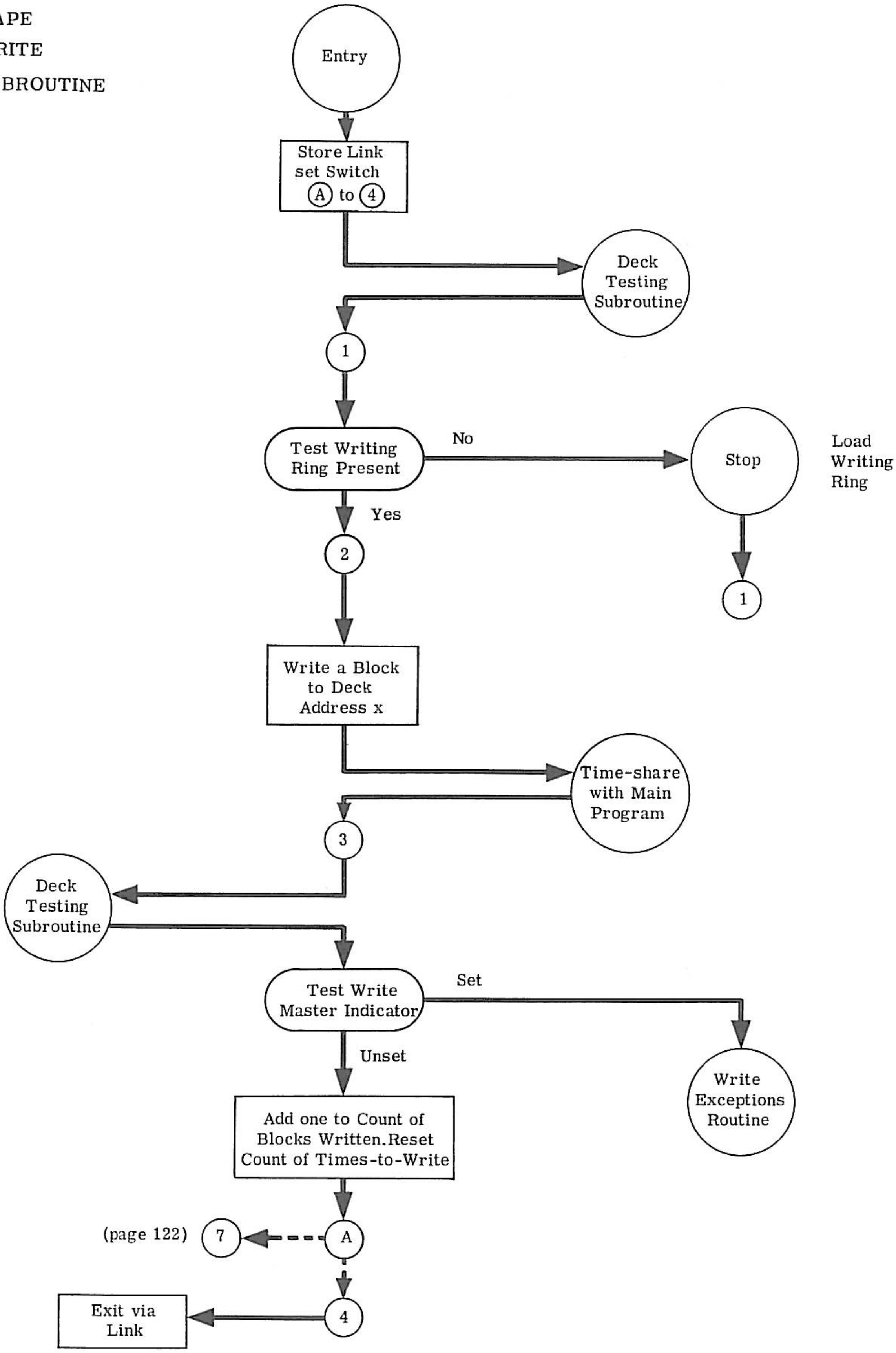
Deck Testing Subroutine

This routine determines if deck address x is busy. It may be used to ensure that a tape deck has finished obeying the current instruction and is ready to receive a further instruction. The use of this routine prevents any tape order errors arising due to instructions being given to decks which are busy.

To ensure that tape deck address x is mechanically ready the appropriate Deck Address Ready indicator and indicator 89 Transport Mechanically Ready are repeatedly tested until the deck ceases to be busy and is ready to receive another instruction. If the tape deck is not mechanically ready, then the deck has not been correctly allocated or there is a mechanical failure. The fault should be corrected and the job restarted from the beginning.

The Deck Testing routine has been made into a subroutine since it is used in several places by the other routines.

TAPE
WRITE
SUBROUTINE



Tape Write Subroutine

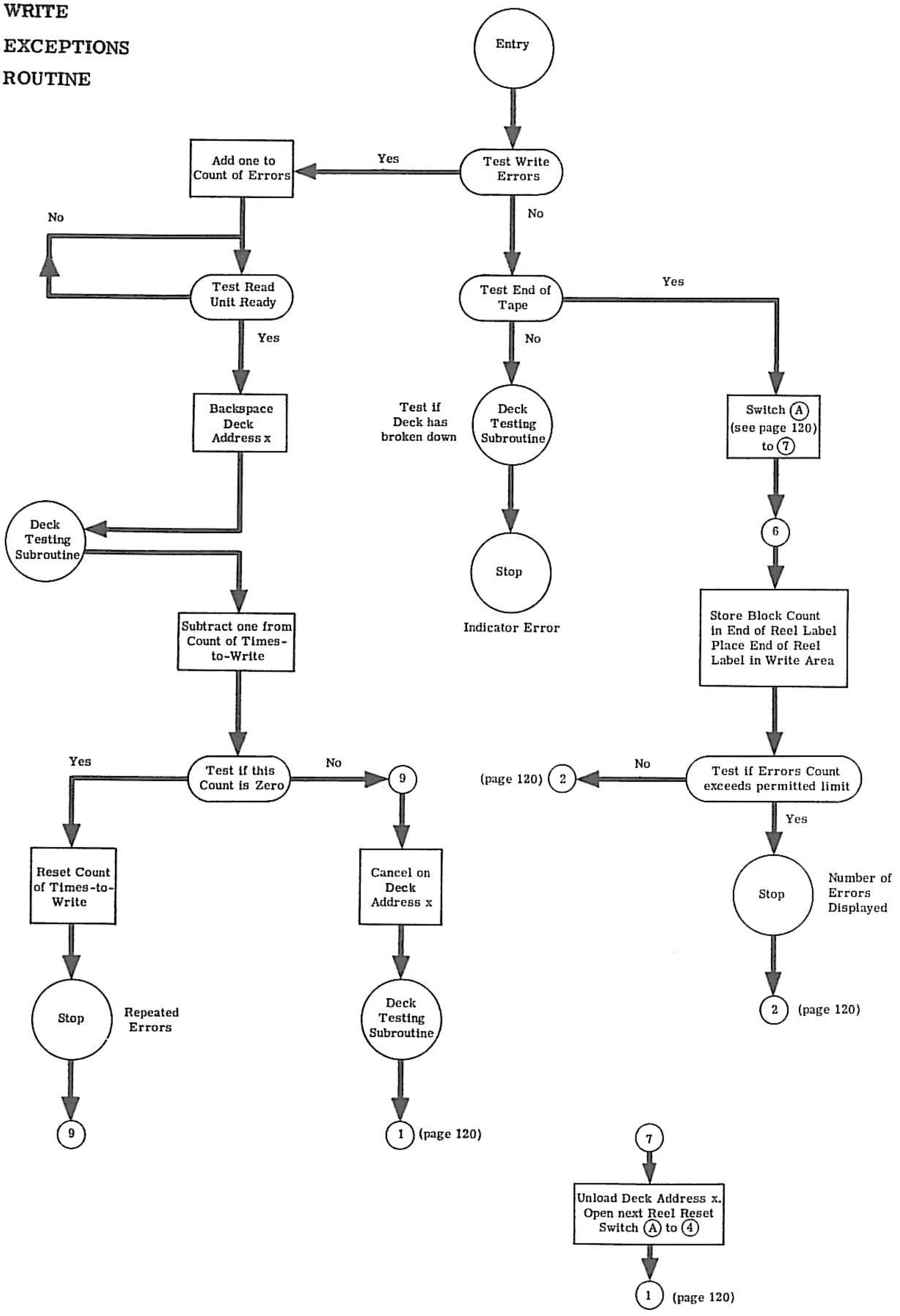
This routine writes a block from I.A.S. to magnetic tape on deck address x. A test is made to ensure that writing has been successfully completed and a count (initially zero) of the number of blocks which have been written is updated.

A test is made to ensure that a writing ring has been fitted before an attempt is made to write. The Deck Testing routine is entered before this test since it tests the Deck Address Ready indicator and thus associates the Writing Ring Present indicator with the correct deck address.

When the write instruction has been given, an exit is made so that the writing routine can be time-shared with the main program. On return to the write routine the Deck Testing routine is entered to test whether writing has been completed. When the block has been written indicator 71 (Write Master) is tested. If it is unset then there have been no writing errors and no special conditions have arisen, and the block count is updated. The times-to-write count is used when transfer errors occur.

The times-to-write count corresponds to the number of attempts to be made to write a block on successive sections of tape before giving an indication that there are persistent errors. If indicator 71 (Write Master) is set, then an error (or exceptional case) has arisen and the Write Exceptions routine is entered.

WRITE EXCEPTIONS ROUTINE



Write Exceptions Routine

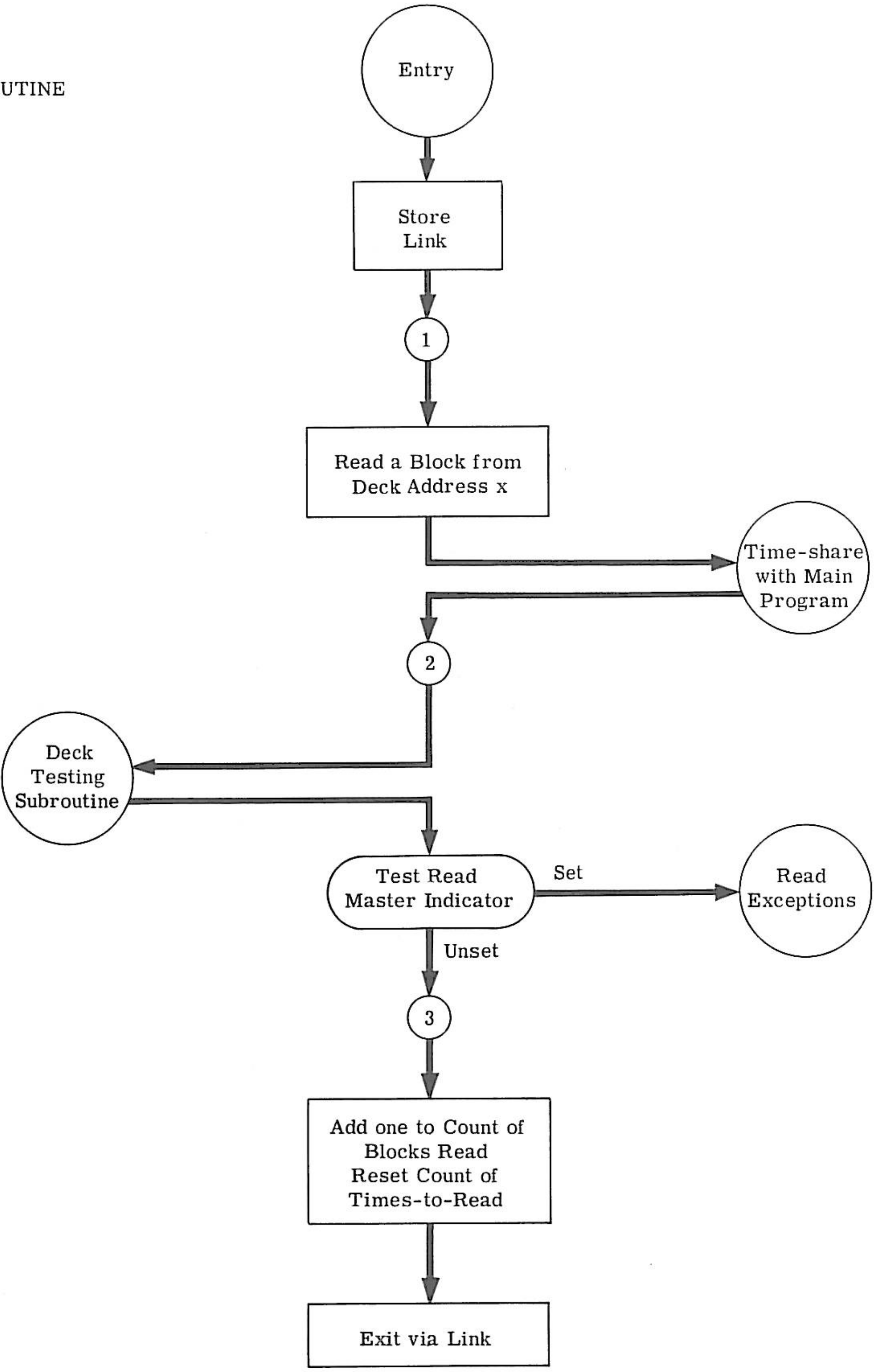
The Write Exceptions routine discovers which exceptions condition has arisen and deals with it appropriately.

A count is kept (initially zero) of any transfer errors which occur.

If an error occurs, the tape is backspaced, a section of tape is cancelled and an attempt is made to write the block on the next section. If necessary this is repeated several times until the times-to-write count is reduced to zero. If this happens the computer stops with an indication that there are repeated errors. Restart causes further attempts to be made on following sections of tape.

If the end of tape marker is detected then a short block is written to tape as the last block on the reel. This is called the end of reel label and has a special format to distinguish it from other short blocks. The block count is stored in the end of reel label. A test is made to discover whether the transfer errors have exceeded the permitted number. If this happens the computer stops with the number of errors displayed. When the end of reel label has been correctly written, deck address x is unloaded and a new reel is opened.

TAPE
READ
SUBROUTINE

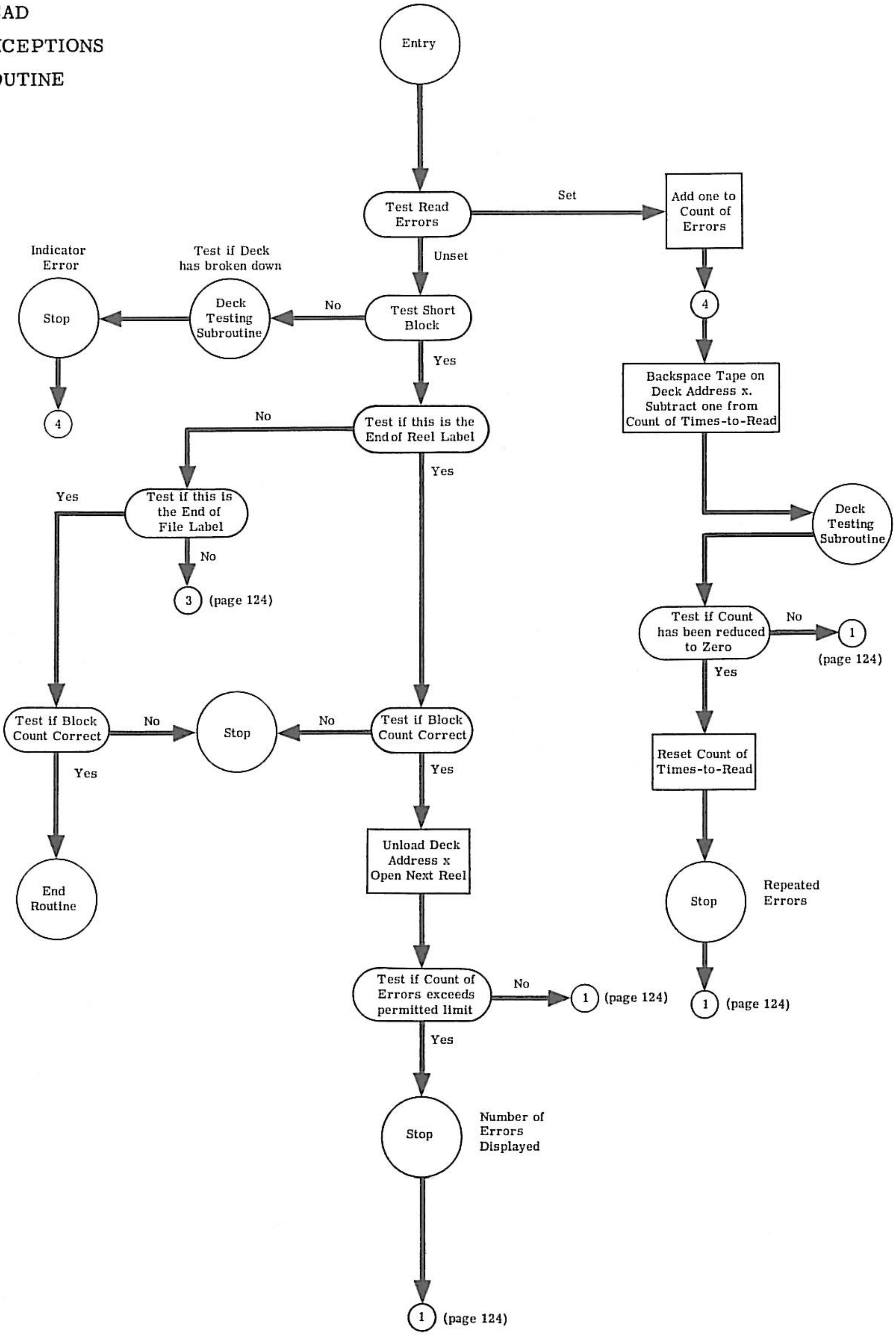


Tape Read Subroutine

This routine reads a block from deck address x and stores it in I.A.S. It tests that reading has been successfully completed and updates a count (initially zero) of the number of blocks which have been read.

When the read instruction has been given, an exit is made so that the read routine can be time-shared with the main program. When the block has been completely read indicator 73 (Read Master) is tested. If it is unset no special conditions have arisen and the block count is updated. The times-to-read count is used when errors occur and corresponds to the number of attempts to be made to read a block before stopping the computer. If the Read Master indicator is set, then a transfer error or exceptional condition has arisen and the Read Exceptions routine is entered.

READ
EXCEPTIONS
ROUTINE



Read Exceptions Routine

The Read Exceptions routine discovers which exceptions condition has arisen and deals with it appropriately. A count is kept of any errors which occur.

If an error occurs, the tape is backspaced and another attempt made to read the block. If necessary several attempts are made until the times-to-read count is reduced to zero. The computer is then stopped as an indication that the tape deck may be faulty. Restart causes further attempts to be made.

If a short block is detected, it is examined to see if it is the end of reel or end of file label. The end of file label is written after the last data block. It acts as an end of reel label and in addition indicates that there is no further reel to follow. When the end of reel or end of file label is detected a check is made to ensure that the number of blocks read corresponds to the block count stored in the label. If a short block is not an end of reel or end of file label, then it is treated as an ordinary data block.

Maximum length of tape on spool	1,800 feet
Minimum distance between end of tape marker and actual end of tape	25 feet
Distance between beginning of tape and beginning of tape marker	7 to 10 feet
Tape Speed	$37\frac{1}{2}$ inches a second
Delay before writing first block	5 seconds
Rewind time for a complete reel	Under 3 minutes
Packing density - assuming random distribution of digits	440 digits an inch
Packing density - assuming 25% of digits are zero - otherwise random distribution	480 digits an inch
Digit rate - assuming random distribution	16,500 digits a second
Digit rate - assuming 25% of digits zero otherwise random distribution	18,000 digits a second
Digit rate for all zeros	32,000 digits a second
Digit rate for all fifteens	8,000 digits a second
Average time for one word to pass the read/write heads - assuming random distribution	727 µs
Length of inter-block gap	Approx. 0.8 inches
Time to traverse inter-block gap on writing and write block start marker - excluding time when tape is awaiting an instruction	20 to 25 ms
Time to traverse inter-block gap and block start marker on reading - excluding time when tape is awaiting an instruction	20 to 25 ms
Break-in time when transferring a word to or from I.A.S.	16 µs
Time tape is erased during Cancel Instruction	50 ms (equivalent to a block of about 60 words)

Timing

Assuming random distribution, one word takes 727 microseconds to pass the read/write heads. When reading or writing is taking place, the break-in time for transferring a word to or from I.A.S. takes 16 microseconds, thus leaving 711 microseconds available for other programs. It follows that when a program is being time-shared with tape reading or writing, the program time is effectively increased by 16 microseconds for every 711 microseconds. This corresponds to an effective increase of 2.2 per cent. When reading and writing are simultaneously being time-shared with the main program, the break-in time amounts to 32 microseconds leaving 695 microseconds available for program. This corresponds to an effective increase in program time of 4.6 per cent.

The actual time to write or read a block can be calculated by allowing 727 microseconds for each word in the block. In calculating the total time for reading or writing tape, allowance should be made for the time to traverse the inter-block gaps.