A MAGNETIC TAPE SYSTEM FOR THE
CERN MERCURY COMPUTER

by

H.J. Slettenhaar and G. Affaticati
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ABSTRACT

An Ampex TM-400 M magnetic tape unit has been connected to the CERN Mercury computer in such a way that reading and writing is in strict accordance with IBM magnetic tape specifications. A second magnetic tape unit is being added. This report describes the computer facilities used, the compatibility requirements and the logical design of the control system.

*) Mr. G. Affaticati has left CERN and did not contribute to the writing of this report.
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1. **Introduction**

1.1 **History**

A Ferranti Mercury computer was brought into operation at CERN in October, 1958. This was the first electronic computer to be installed at CERN, and it is still in use.

The Mercury computer as installed had one input channel (connected to a paper tape reader) and one output channel (connected to a paper tape punch). In March, 1960 the computer was modified so as to allow the selection under programme control of any one of a number of input and output channels.

The load on the Mercury computer, particularly the processing of data from bubble chamber photographs, increased steadily, and in November, 1960 an IBM 709 computer was brought into use at CERN. The 709 computer as installed had eight magnetic tape units (later increased to ten), a card reader and a card punch. There was no facility for reading paper tape, but two off-line IBM '046' converters were available for transferring data from paper tape to punched cards. Since the paper tapes resulting from the measurement of bubble chamber photographs were not in a format acceptable to these converters, it was necessary for these tapes to undergo a preliminary processing on the Mercury computer to produce paper tapes which could be converted to punched cards for use as input data to the main bubble chamber processing programmes. These Mercury programmes also performed certain preliminary calculations on the data.

Communication between the Mercury and the 709 by converting paper tape to punched cards was troublesome and slow. It was therefore decided to connect one or more magnetic tape units to the Mercury computer. These tape units were to be able to write and read in accordance with the IBM magnetic tape specifications applicable to the 709 computer. This would provide the following facilities on the Mercury computer:

(a) To write magnetic tapes which could be used as input to the 709.

(b) To read magnetic tapes which had been written on the 709.
(c) To provide a magnetic tape backing store for the Mercury computer.

(d) To output Mercury results onto magnetic tape for printing on a fast off-line printer.

(e) To allow Mercury compilers and library programmes to be stored on magnetic tape.

In order to reduce cost and construction time it was decided to connect the magnetic tape units directly to the Mercury computer without using a buffer store. The system is thus synchronous, in that basic character timing is determined by Mercury programme, and that all control operations (start, stop, reset and test various triggers; etc.) are initiated by Mercury instructions. The magnetic tape control circuits provide the necessary interlocks and delays to ensure that the programme cannot get out of step with the tape unit. Writing and reading is in strict accordance with IBM specifications.

The first magnetic tape unit was ordered in July, 1961 and was delivered in February, 1962. During this waiting period work on the design and construction of the control circuits was begun. The tape unit and its control circuits were successfully tested in April, 1962 and the transfer of bubble chamber data to magnetic tape via the Mercury computer began in June, 1962. A second magnetic tape unit has been delivered since then and will be connected during 1963.

1.2 Brief description of the magnetic tape system

Tape units : Ampex TM-400 M
Character density : 200 characters/inch
Tape speed : \(16\frac{2}{5}\) inches/sec.
\((333\frac{1}{3}\) characters/sec.)
\((300\) microsec/character)
The system allows for a maximum of four magnetic tape units, each of which may be connected to any of the Mercury input/output channels 4, 5, 6 or 7. The first two magnetic tape units (Unit "A" and Unit "B") have been allocated to channels 4 and 5. There is a channel selection switch on the control desk of the computer which selects either "channel 4 = A, channel 5 = B" or vice versa.

Information is recorded simultaneously on seven tracks across the tape. Each transverse row of seven bits constitutes a character containing six information bits and one parity bit. Characters are written onto the tape in blocks called records, each record being followed by a longitudinal check character, which is separated from the record by a short gap. Between records is a longer inter-record gap of length 0.75 inch, (see Fig. 1).

The moment at which each character is written is determined by programme. It is possible to construct a loop of instructions which will write characters at intervals of 240 microseconds, and a loop which will read at the same rate. However, in order to allow for fluctuations in tape speed, it is necessary that the reading programme should be able to read a character in less time than was taken to write the character (the tape control circuits cause the computer to wait until the arrival of the next character before continuing). This means that the writing loop must be slower than the reading loop by at least one machine cycle (60 microseconds), and therefore fixes the writing time at 300 microseconds per character. The nominal tape speed is determined by the requirement that this inter-character time shall correspond to the IBM standard low density spacing of 200 characters per inch.

1.3 Brief description of the Mercury multi-channel input/output facilities

The Mercury computer has seven input channels which are numbered from 1 to 7, and seven output channels which are independently numbered from 1 to 7. Each channel allows the parallel transmission on ten wires

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of signals representing ten binary digits. These signals are transmitted between an external device and the short accumulator, "Sac", which is also index register E7. The two instructions which initiate a multi-channel input and output operation respectively are as follows:

<table>
<thead>
<tr>
<th>Operation</th>
<th>Programmers code</th>
<th>Internal binary representation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input to Sac</td>
<td>90b, n</td>
<td>1 0 1 1 0 0 1</td>
</tr>
<tr>
<td>Output from Sac</td>
<td>91b, n</td>
<td>1 0 1 1 1 1 1</td>
</tr>
</tbody>
</table>

(b is an integer between 1 and 7)

The 3-bit integer b, which is the third digit of the programmer's code specifies the channel number of the input or output channel which is to be selected. The significance of the 10-bit integer n which occupies the address part of the instruction depends on whether the channel number lies in the range 1 to 3 or in the range 4 to 7:

- channels 1, 2 or 3: n is added arithmetically to the 10-bit number which is being transmitted.
- channels 4, 5, 6 or 7: n has no effect on the number transmitted, and the value of n may be used to determine which of up to $2^{10}$ "subcodes" shall be selected.

The magnetic tape system makes use of this sub-code facility available on channels 4 to 7. The four least significant bits of the address part of the "90" or "91" instruction are connected to a decoder which has one output wire for each of the possible magnetic tape input or output operations. Thus, in the case of "90" and "91" instruction referring to magnetic tape units, it is the address part of the instruction which determines the operation which is to be performed.

Associated with each input and output channel there is a "busy" wire. The time required to execute a "90" or a "91" instruction is normally two machine cycles (120 microseconds), but if there is a signal
on the appropriate busy wire the computer will stop at the end of the first
60 microseconds cycle and will not transmit information until the busy
wire returns to its normal potential. The presence of a signal on one
of the busy wires does not prevent the computer from executing any
instructions except a "90" or "91" instruction which refers to that par-
ticular input or output channel.

Each magnetic tape unit is connected to one input channel and
to one output channel having the same channel number. The "input busy"
and the "output busy" lines associated with this channel number are
connected together to form a single busy line associated with this magnetic
tape unit.

1.4 Parity checking facilities

Associated with each 10-wire input channel is an eleventh "parity"
wire. If this wire is used, the standard Mercury circuits test whether
the number of binary ones arriving in parallel on these eleven wires is
even or odd. If the parity is odd, the stop flip-flop of the computer
is normally turned on. On the CERN Mercury these circuits have been
modified so that, instead of the stop flip-flop, it is the parity flip-
flop of the magnetic tape unit which is turned on in the case of odd parity.

Two different transverse parity conventions are used on IBM
magnetic tapes. In the BCD (Binary Coded Decimal) convention each 7-bit
character has even parity. To deal with this situation, two reading
modes have been provided in the Mercury magnetic tape system. In both
modes the 7-bit character which is read from magnetic tape is transferred
directly to the seven least significant positions of $S_a$ and the three most
significant positions are set to zero. The potential of the parity wire
is set to correspond to a "0" in the BCD mode and to a "1" in the binary
mode. The mode is selected by the instruction which starts the tape
moving forwards for reading; there are two versions of this instruction,
one version for reading BCD, and one version for reading binary. The
seventh bit (track C) of the character which has been read from tape is not normally required and is later removed by programme. Thus, if \( P \) denotes the parity wire, the input connections while reading a character from magnetic tape can be shown schematically as follows:

\[
\begin{array}{c}
0 \text{ (BCD)} \\
1 \text{ (binary)} \\
\downarrow \\
\text{zeros} \\
\downarrow \\
\text{Tape tracks} \\
\downarrow \\
C \quad B \quad A \quad 8 \quad 4 \quad 2 \quad 1 \\
\end{array}
\]

\[
\begin{array}{c}
\text{Sac} \\
\uparrow \\
\text{parity bit to be removed by programme.}
\end{array}
\]

Associated with each 10-wire output channel is an eleventh output wire which is fed from a parity-bit generating circuit. The output from this circuit is such that the parity of the 11-bit group is even. Therefore, if at the moment when a "91" instruction is executed, the number of ones in \( \text{Sac} \) is even an "0" will be transmitted on the eleventh wire; if the number of ones is odd a "1" will be transmitted.

When executing a "91" instruction which writes a character onto magnetic tape the contents of the six least significant positions of \( \text{Sac} \) are transferred to the six information tracks at the same time as the output from the parity-bit circuit is transferred to the seventh track (track C). Although the four most significant bits of \( \text{Sac} \) are not written onto magnetic tape, these bits are taken into account when generating the parity bit. Therefore the magnetic tape programmes set these bits to zero when writing BCD records (even parity), but set one of these bits of \( \text{Sac} \) to "1" when writing binary records (odd parity). Thus, if \( P \) denotes the output from the parity-bit circuit, the output connections while writing a character onto magnetic tape can be shown schematically as follows:

\[
\begin{array}{c}
\text{Sac} \\
\downarrow \\
\text{Tape tracks} \\
\downarrow \\
C \quad B \quad A \quad 8 \quad 4 \quad 2 \quad 1 \\
\end{array}
\]

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1.5 Short table of magnetic tape sub-codes

This table lists the tape operations corresponding to different values of the integer \( n \) appearing in the address part of the input or output instruction.

**Input ("90" instruction)**
1. Read character from magnetic tape to Sac.
2. Read check flip-flop to most significant bit of Sac.
3. Read beginning-of-tape flip-flop to most significant bit of Sac.
4. Read end-of-tape flip-flop to most significant bit of Sac.

**Output ("91" instruction)**
0. Clear (reset various flip-flops to their initial state).
1. Write a character from Sac to magnetic tape.
2. Reset write flip-flops (write longitudinal check character).
3. Start tape forwards for writing.
4. Start tape forwards for reading BCD characters (even parity).
5. Start tape forwards for reading binary characters (odd parity).
6. Stop tape forwards.
7. Start tape backwards.
8. Stop tape backwards.
14. Turn off the "write permit" (do not allow writing).
15. Rewind.

1.6 Basic programme loops for writing, reading and back-spacing

(a) **Writing loop**

It is assumed that the record consists of \( n \) characters which are stored in successive \( H \)-registers starting at medium address \( a \) and is to be written onto magnetic tape on channel 4. The dummy "570" instruction has no effect other than to waste 60 microseconds, thus ensuring an inter-character time of 300 microseconds. It is assumed that the tape is moving forwards at its standard speed.
Microseconds | 106 \ -n + 1 | Set character count in B6
60 | 206 \ a + n - 1 | Pick up character to Sαc
60 | 570 0 | Dummy instruction
120 | 914 1 | Write character from Sαc to tape
60 | 186 \ -3^* | if Bt ≠ 0, add 1 to B6 and repeat

(b) Reading loop

In order to make possible a reading loop of 240 microseconds (allowing 60 microseconds in which to await the arrival of the next character), a special instruction with programmer's code "19" has been provided on the CERN Mercury computer. The effect of the instruction "19b n" (where \(b\) is the B-digit specifying index register B and \(n\) is the contents of the address part of the instruction) is as follows:

\[
\begin{align*}
&\text{if } S t \neq 0 \text{ and } B t \neq 0, \text{ B}' = B + 1, \text{ and jump to location n.} \\
&\text{if } S t = 0 \text{ or } B t = 0, \text{ B}' = B + 1
\end{align*}
\]

The characters are read from magnetic tape on channel 4 and are stored in successive H-registers starting at medium address a. Exit from the reading loop occurs when either: a) The end of the record is reached (indicated by zero in Sαc) or b) when \(n_{\text{max}}\) characters have been read (indicated by zero in B6). It is assumed that the tape is moving forwards at its standard speed.

Microseconds | 106 \ -n_{\text{max}} | Set character count.
120 | 904 1 | Read character to Sαc.
60 | 216 \ a + n_{\text{max}} | store character
60 | 196 \ -2^* | if St ≠ 0 and Bt ≠ 0, add 1 to B6 and repeat.
(c) Back-spacing loop

One record is to be back-spaced on the magnetic tape on channel 4. It is assumed that the tape is moving backwards at its standard speed.

| 904 1 | Read check sum (or last character) |
| 904 1 | Read check sum gap (or last but one character) |
| → 904 1 | Read characters until a gap (zero) |
| 280 -l* | } is found |

The first two "904 1" instructions ensure that the subsequent "search for zero" loop does not exit in the short gap between the check sum and the record. One use of back-spacing is to return to the gap between the record just read and the previous record in the case of a check failure.
2. **Technical description**

2.1 **Abbreviations**

The following abbreviations are used in the descriptions of the control circuits:

- F.F. = Flip-flop
- E.F. = Emitter-follower
- O.S. = One-shot multivibrator

2.2 **IBM Compatibility requirements**

Figure 1 shows the magnetic tape format used for reading and writing on the IBM 7291 tape unit. The Mercury magnetic tape system is designed to be strictly compatible with this format. Certain compatibility features are already provided by the Ampex TM-400 M digital tape transport which is used. These are:

(a) Type of magnetic recording
(b) Detection of the reflecting beginning-of-tape and end-of-tape markers
(c) Output levels
(d) Number of tracks, track width, track spacing
(e) Type of tape reels accepted

The following requirement for compatibility had to be achieved by the development of suitable electronics and programmes.

(f) Information density
(g) Transverse and longitudinal parity checking
(h) Record to check-character gap
(i) Inter-record gap
2.3 The control electronics

The control electronics consists basically of two assemblies: additional circuits in the Mercury computer and two card-rack assemblies in the tape unit itself (which are fully transistorized). Circuit blocks have been chosen for some basic electronic circuits: e.g. flip-flops and one-shot multivibrators.

The logical symbols used in the diagrams of the control electronics are shown in Figure 2. The inputs and outputs are generally voltage waveforms. An input is said to be present when the waveform goes positive. This is the opposite of the usual Mercury convention according to which an input is said to be present when the waveform goes negative.

2.4 The sub-channel decoder

Each Mercury input and output channel consists of ten input or output lines and one input or output parity line.

Only six output lines have been used, since there are 6 information channels on the tape. Four of these lines (OID₀ - OID₃) are also used in the sub-channel decoder which is part of the control electronics.

For the duration of the input or output selection signal from the Mercury (see Figure 3) the output lines contain the address part of the input or output instruction, which specifies the sub-channel required.

The timing is shown in Figure 3 and the logic in Figure 4. The four output digits are emitter-followed, and each of them is fed into the inhibit input (inverter) of a set of inhibit 'and' gates. The other input of the inhibit 'and' gates is the strobing waveform GSS (General Selection Signal). This waveform is the output of a negative 'or' gate whose inputs are the write selection and read selection signals from the Mercury. The output of the inhibit 'and' gates is emitter-followed and fed into the A,C. input of a set of flip-flops called D flip-flops (D₀ - D₃).
Thus if there is an output on the output-lines during the selection signal (10 \mu sec waveform) this output will set the appropriate D flip-flop.

Both outputs of the D flip-flop are used to select the subcode by means of a selection matrix.

Combinations of $D_0$ and $D_1$ strobed with the start input or start output signal (20 \mu sec) from the Mercury select the vertical lines, and combinations of $D_2$ and $D_3$ select the horizontal lines. The output of that inhibit 'and' gate which has one horizontal and one vertical input is the selected subcode, represented by a positive-going waveform of 20 \mu sec length. (See also Figure 11).
3. Technical description of the sub-code instructions

This description is divided into four parts:

3.1 Instructions used when writing a record.
3.2 Instructions used when reading a record.
3.3 Instructions used when back-spacing a record.
3.4 Other instructions.

3.1 Instructions used when writing a record (see also 1.6 (a)).

The timing of these instructions in a simple application is shown in Figure 7.

(a) \( \text{OP} 3 \) = Start tape forwards for writing

**Action**
Set BUSY
Set Forward actuator (energizes write heads.)
Sets Magnetic Tape Moving F.F., accelerates tape to full speed)
6 msec delay
Reset BUSY

Figure 5 shows the logic. \( \text{OP} 3 \) is fed through 'or' gate 1.
The output of this gate is the input to the Forward F.F. and is also one of the inputs to 'or' gate 2. Thus \( \text{OP} 3 \) sets both the Forward and the BUSY F.F. The output of 'or' gate 1 is also fed to 'or' gate 7. The output of this gate sets the magnetic tape moving F.F. (MTM) which output is fed to the Mercury Basic Unit in order to prevent the computer from stopping whilst the tape is moving. As soon as a stop tape instruction is decoded the MTM F.F. is re-set directly by the output of the Decoder F.F.'s.

The output of the Forward F.F. is fed through an inhibit 'and' gate with Reverse on the inhibit input.

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Only if the Reverse F.F. is in the zero position (negative output) will the gate be open, causing the Forward actuator in the transport electronics to be set. This interlock system is to prevent the execution of Forward commands while the tape is moving backwards.

$0/p 3$ also sets the READ/WRITE FF into the 'WRITE' state in the case when this FF was in the 'READ' state (see Figure 6).

The output of the Forward also sets a one-shot whose output resets the BUSY FF after 6 msec. The output of this Start Time Delay (STD) circuit is fed through an inhibit 'and' gate 3, with READ on the inhibit input. The output of gate 3 is the input of the 'or' gate 4, whose output is connected to the reset side of the BUSY FF. Thus the Start Time Delay will reset the BUSY FF only when the tape is moving forward for writing after an $0/p 3$ instruction.

(b) $0/p 1$ = write a character from Sac to tape.

**Action**

When BUSY is off write a character from Sac to tape.

Figure 6 shows the logic. A character from Sac will arrive as $0/p D_0$ to $0/p D_5$ in the control electronics, $0/p D_0$ representing the least significant ($2^0$) bit and $0/p D_5$ the most significant ($2^5$) bit. An output parity digit called $0/p P$ arrives at the same time. The parity convention is even when writing BCD characters and odd when writing binary characters. The Mercury parity-bit generating circuit works on an even parity convention, which is correct for BCD characters. When writing binary records one of the four most significant bits in Sac is set equal to 1. This bit does not go on the tape but deceives the parity-bit generating circuit into generating an odd parity.

The output digits 0 to 5 ($0/p D_0 - 0/p D_5$) are gated with the $0/p 1$ code and the 10 μs waveform HS, amplified and fed into the write amplifiers. The write amplifier consists of two circuits: a flip-flop
and a driver. Each input pulse causes the flip-flop to switch from one state to the other. The direction of current flowing through the write head is dependent upon the state of the flip-flop. The output of the flip-flop is fed through an 'and' gate with Write Permit on the other input. The Write Permit input signal is available as soon as the READ/WRITE flip-flop is in the WRITE State. Information passed by the 'and' gate causes the driver circuit to feed an alternately positive and negative current to the write head. The resultant head flux records the signals on the tape in the form of a series of saturation reversals.

(c) \( 0/p 2 = \) Reset WRITE flip-flops.

**Action**

When BUSY is off reset the WRITE flip-flops.

If the WRITE flip-flops are not all zero, this instruction will reset them and thus write onto the tape a character which is the longitudinal check character of the record just written. The logic is shown in Figure 6. \( 0/p 2 \) is passed through an 'or' gate with CLEAR on the other input, inverted, and fed into the reset input of all seven WRITE flip-flops.

(d) \( 0/p 6 = \) Stop tape forwards

**Action**

Set BUSY

14.5 msec delay

Reset Forward Actuator (stops tape)

5 msec delay

Reset BUSY

This instruction is normally executed 25.5 msec after the \( 0/p 2 \) instruction. The 25.5 msec delay has to be a programming delay and is necessary to allow the read head to pass the longitudinal check character. The \( 0/p 6 \) instruction sets a fixed delay a further 14.5 msec to ensure the correct inter-record gap.

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The total inter-record gap has to be \( \frac{1}{4} \) inch. This is equivalent to 45 msec at full speed. The time lost in stopping and subsequently starting the tape is about 1 msec and therefore a total delay of 44 msec is required. This delay should be the sum of a programmed delay of 25.5 msec a Stop Delay Forwards of 14.5 msec and a Start Time Delay of 6 msec, provided by the \( 0/p 3 \) instruction.

Figure 5 shows the logic. \( 0/p 6 \) sets the BUSY FF and 14.5 msec one-shot. The output of this one-shot is fed through an 'or' gate to the reset input of the FORWARD FF, which will be reset 14.5 msec after the \( 0/p 6 \) code. The zero side of the FORWARD FF sets another delay of 5 msec to allow the tape to stop and to inhibit any other tape commands during this period. The output of the Delay Stop Time resets the BUSY FF through an 'or' gate.

3.2 Instructions used when reading a record (see also 1.6 (b))

The timing of these instructions in a simple application is shown in Figure 8.

(a) \( 0/p 4 \) = Start tape forwards for reading

BCD characters

Action
Set BUSY
Set Bin/BCD flip-flop to BCD
Set Magnetic Tape Moving FF
De-energize the write heads
Accelerate tape
Reset BUSY upon the arrival of a character under the read head.

Figure 5 shows the logic. \( 0/p 4 \) sets the BUSY, Magnetic Tape Moving FF and the Forward FF in the same way as the \( 0/p 3 \) instruction (see section 3.1 (a)). Only the output of the Start Time Delay (STD) cannot
reset the BUSY FF because this output cannot pass the inhibit 'and' gate 3, the READ/WRITE FF having been set in the READ state by the 0/p 4 instruction (see Figures 5, 6). The first digit of a character arriving under the read sets a one-shot of 100 µsec. The output of this sync delay resets the BUSY FF. The output of the sync delay is fed through 'and' gate 4, to allow the BUSY FF to be reset only during the reading of a record and not when writing, during the rewind operation, or when waiting for the longitudinal check character to pass under the read head. 0/p 4 is fed through 'and' gate 3 to the BCD side of the Bin/BCD F.F. (Figure 6).

(b) 0/p 5 = Start tape forwards for reading
Binary characters.

Action
Set BUSY
Set Bin/BCD flip-flop to Binary
Set Magnetic Tape Moving F.F.
De-energize the write-heads
Accelerate tape
Reset BUSY upon the arrival of a character under the read head.

The only difference between 0/p 4 and 0/p 5 is the setting of the Input parity (1/p P) (see section 1.4). Figure 6 shows the Bin/BCD F.F. 0/p 5 sets the F.F. into the Binary state. The output of the F.F. is fed through an inhibit 'and' gate with Shuffle (SH) on the inhibit input. Shuffle is negative when reading a record and becomes positive as soon as the gap at the end of a record is reached. The output of the gate is emitter-followed and fed into the Mercury input parity circuits (1/p P). Thus during the reading of Binary characters 1/p P represents a one (earth level) and during the reading of BCD character a zero (negative level).
(c) \( \frac{i}{p} \) 1 = Read character from magnetic tape to Sac.

**Action**

When BUSY is off transfer the information from the tape translators to Sac

Set BUSY

Set 800 \( \mu \) sec Shuffle.

BUSY will be reset 100 \( \mu \) sec after the arrival of the first digit of a character (see Figure 5). The 100 \( \mu \) sec delay is called the Sync delay (SD). This sync delay is used as a synchronizing strobe to ensure that all bits in a given character on the magnetic tape will be read from the tape as belonging to the same character. The sync delay is actuated by the arrival of the first pulse from the translator i.e. the first bit of a character to reach the read head. This pulse triggers the 100 \( \mu \)sec one-shot. The output of the sync delay is fed through 'and' gate 4 to the reset side of the BUSY F.F. (see Figure 5). As soon as the BUSY F.F. is reset the next magnetic tape instruction will be executed within the next 60 \( \mu \)sec. In a normal read loop this is an \( \frac{i}{p} \) 1 instruction.

The output of the seven translators (T01-T07) is fed to the inhibit input of a set of inhibit 'and' gates (see Figure 6) with \( \frac{i}{p} \) 1 at the other inputs. The output of these gates is emitter-followed and fed to the input circuits of the Mercury \( \frac{i}{p} \) D0 - \( \frac{i}{p} \) D5 which carry the information to Sac. \( \frac{i}{p} \) 1 sets the BUSY F.F. through 'or' gate 2 (see Figure 5). It also sets the Shuffle (SH), a 800 \( \mu \) sec delay circuit. This Shuffle will be set for another 800 \( \mu \) sec by each \( \frac{i}{p} \) 1 instruction. In a normal read loop the interval between two \( \frac{i}{p} \) 1 instructions will be 300 \( \pm \) 60 \( \mu \)sec. Thus the Shuffle will be negative until 800 \( \mu \) sec after the reading of the last character. The Shuffle then goes positive and resets the BUSY F.F.: it also sets a 1.5 msec delay, called Delay Longitudinal Check (DLC). The next \( \frac{i}{p} \) 1 instruction will now read a
zero to Sac, which indicates the end of a record in a read programme. The last \( \frac{1}{p} \) 2 instruction cannot set the Shuffle anymore since the Delay Longitudinal check inhibits the \( \frac{1}{p} \) 1 (gate 5) which sets the Shuffle, it also allows the longitudinal check character (which can be zero) to pass under the read head without reading it to Sac. After 1.5 msec the output of the one-shot resets the BUSY F.F. and the next magnetic tape instruction is allowed to be executed, this is normally an \( \frac{1}{p} \) 2 instruction (see paragraph (a)).

(d) \( \frac{1}{p} \) 2 = Read check flip-flop to most significant bit of Sac.

**Action**

When BUSY is off read the contents of the parity check flip-flop to the \( 2^9 \) bit of Sac.

Reset Longitudinal Check flip-flops.

During a normal read programme, BUSY will be reset by the Delay Longitudinal Check before the execution of the \( \frac{1}{p} \) 2 instruction (see paragraph (c)).

Each character in a record contains a transverse parity check bit (see section 1.4). This check bit is read into the Mercury parity check circuits together with the 6 information bits. If the parity of any character is wrong Mercury sends a parity set trigger pulse (PST) back to the Parity flip-flop (FFF) in the control electronics, (see Figure 4). The output of the Parity flip-flop is fed through inhibit 'and' gate 1 with \( \frac{1}{p} \) 2 on the other input to 'or' gate 2. The output of this 'or' gate is the input digit 9 (\( \frac{1}{p} \) D) fed to the input circuits of Mercury, which carry it to the most significant bit of Sac.

Each record is followed by a longitudinal check sum. A set of seven flip-flops called the Longitudinal check flip-flops indicate at any moment whether the number of binary "1" s which have passed the read head on each of the seven channels is even or odd. After the longitudinal check sum has passed the read head these flip-flops should all be in the
"even" state. The output of the Longitudinal Check flip-flops (LCD₀ - LCD₀) is fed to 'or' gate 3. The inverted output of this gate is one input of the inhibit 'and' gate 4, with \( \frac{1}{p} 2 \) on the other input. The output of this gate is another input of 'or' gate 2. Thus, if any parity set trigger pulse (PST) has set the Parity flip-flop (PFF), or if any Longitudinal Check flip-flop is not zero (i.e. not even) during \( \frac{1}{p} 2, \frac{1}{p} D₀ \) will be a "1", and consequently the most significant bit of Sae will be a "1".

(e) \( \frac{0}{p} 6 = \) Stop tape forwards

**Action**
- Set BUSY
- 14.5 msec delay
- Reset Forward actuator (stop tape)
- 5 msec delay
- Reset BUSY

This instruction is the same as described in paragraph (d) of section 3.1.

3.3 **Instructions used when back-spacing a record** (see also 1.6 (c))

(a) \( \frac{0}{p} 7 = \) Start tape backwards.

**Action**
- Set BUSY
- Set Bin/BCD flip-flop to BCD
- Set Magnetic Tape Moving F.F.
- De-energize the write heads.
- Accelerate tape backwards
- Reset BUSY upon the arrival of a character under the read head.

7319/p
The only difference between the $0/p 7$ and the $0/p 4$ instruction is that the tape is moving backwards instead of forwards. The logic is shown in Figure 5. $0/p 7$ sets the BUSY, the Magnetic Tape Moving FF and the Reverse flip-flop. Sync delay resets BUSY (see also 3.2 (a)).

(b) $i/p 1 = \text{Read character from magnetic tape to Sac.}$

**Action**

When BUSY is off transfer the information from the tape translators to Sac
Set BUSY
Set $800\mu\text{sec}$ Shuffle.

The only difference between an $i/p 1$ instruction when back-spacing and an $i/p 1$ when reading is the setting of the Delay Longitudinal Check (DLC), which should not be set when back-spacing. The Longitudinal check character is read as a character and the gap between the longitudinal check character and the last character is read as a zero character but does not cause an exit from the read loop (see 1.6 (c)). The logic is shown in Figure 5. The output of the Shuffle is fed through 'or' gate 6 to the input of the Delay Longitudinal check O.S. If Reverse is set a positive going pulse from the Shuffle circuit cannot set the Delay Longitudinal check O.S.

(c) $0/p 8 = \text{Stop tape backwards}$

**Action**

Set BUSY
20 msec delay
Reset Reverse actuator (stop tape)
5 msec delay
Reset BUSY
Apart from the direction in which the tape is moving, there is only one difference between an \( \frac{1}{0} p_8 \) and an \( \frac{1}{0} p_6 \) instruction. This is the 20 msec delay instead of the 14.5 msec delay of the \( \frac{1}{0} p_6 \) instruction (section 3.1 (d)). The 20 msec delay is necessary to bring the tape into the correct position after the read head has found the gap between two records. The logic is shown in Figure 5. \( \frac{1}{0} p_8 \) sets the 20 msec Stop Delay Reverse O.S. (SDR). This O.S. resets the Reverse F.F. The zero side of this F.F. sets the 5 m sec Delay Stop Time (DST) (see also 3.1 (d)). The tape should now be in such a position that the record just back-spaced can be re-read or re-written.

3.4 Other instructions

(a) \( \frac{1}{2} p_3 = \) Read beginning-of-tape flip-flop to most significant bit of Sac.

Action

When BUSY is off transfer the contents of the Beginning of tape FF to the 2\(^n\) bit of Sac.

Reset Beginning of tape FF

As soon as the Beginning-of-tape reflecting marker has passed under the Beginning-of-tape photo cell, the photosense Unit gives a trigger pulse (BOT M) to the Beginning-of-tape flip-flop (BOT). The logic is shown in Figure 4. \( \frac{1}{2} p_3 \) is fed to inhibit 'and' gate 5 with BOT (zero side of the BOT F.F.) on the inhibit input. The output of gate 5 is an input of 'or' gate 2, whose output is the Input Digit 9 \( \left( \frac{1}{2} p D_9 \right) \) fed to the input circuits of Mercury, which carry it to the most significant bit of Sac. \( \frac{1}{2} p_3 \) inverted is fed to the reset side of the BOT F.F. Thus at the end of the 20 \( \mu \)sec the BOT F.F. is reset.

(b) \( \frac{1}{2} p_4 = \) Read end-of-tape flip-flop to most significant bit of Sac.

7319/p
Action

When BUSY is off, transfer the contents of the end-of-tape FF to the $2^9$ bit of SAC.
Reset end-of-tape FF.

As soon as the end-of-tape reflecting marker has passed under the end-of-tape Photo cell, the Photosense Unit gives a trigger pulse (EOTN) to the end-of-tape flip-flop (EOT). Logically the $i/p$ 4 instruction is the same as the $i/p$ 3 instruction (see Figure 4 and paragraph (b)).

(c) $0/p 14 = \text{Turn off the "Write Permit".}$

Action

When BUSY is off set the READ/WRITE F.F. into the READ state.

Figure 6 shows the READ/WRITE FF. $0/p 14$ is fed to the READ side of the F.F. The output of this side of the F.F. (READ) is fed to an inverter level changer whose output is "Write Permit". Write Permit is fed to the seven write amplifiers. The levels of Write Permit are +12V when on and earth when off, while the levels of READ are earth level when on and -12V when off. Thus if READ is set (earth level) Write Permit is at earth level and if WRITE is set (READ is -12V) WRITE Permit is at +12V.

When the Write Permit is at earth level no output information can reach the write head. A character of all "1"'s is written onto tape when ever the write permit is turned off.

(d) $0/p 15 = \text{Rewind}$

Action

Set BUSY

If the Beginning-of-tape F.F. is not set, rewind the tape until the Beginning-of-tape F.F. is set

50 msec delay

Reset BUSY

7319/p
The logic is shown in Figure 5. $^0/p\,15$ sets the BUSY F.F. through 'or' gate 2 and $^0/p\,15$ sets the Rewind F.F. If the Beginning-of-tape F.F. is set, this F.F. resets the Rewind F.F. immediately. The output of the Rewind F.F., is connected to the Rewind Relay which actuates the fast Rewind servo in the transport electronics. Thus if the Beginning-of-tape FF was not set (tape not at the load point) the tape is rewound until the Beginning-of-tape marker sets the Beginning-of-tape F.F. This F.F. resets the Rewind FF and the tape stops. The stopping takes time and therefore the zero side of the Rewind FF sets a 50 usec delay called Rewind Stop Time (RST). The output of this O.S. resets the BUSY F.F.

$^0/p\,0 = \text{Clear (reset various flip-flops to their initial state)}$

Action:

Reset: BUSY F.F.
Write F.F.'s
Translator F.F.'s
Forward F.F.
Reverse F.F.
Rewind F.F.
Beginning-of-tape F.F.
End of tape F.F.
Parity F.F.
Magnetic Tape Moving F.F.

$^0/p\,0$ is 'or' gated with Clear Button (CB) (see gate 6 of Figure 6). The output of the 'or' gate is called CLEAR and fed to the various flip-flops (see Figure 4, 5 and 6). Pressing a 'clear' button on the Mercury or Ampex has the same effect as the $^0/p\,0$ instruction, except that in addition the 'clear' button turns off 'Write permit', which the $^0/p\,0$ instruction does not affect.
4. **Further information**

The basic logical electronic circuits are shown in Figures 9 and 10. The circuits in the control electronics are constructed on special cards with some printed circuit wiring which were developed to facilitate the mounting of circuit blocks (see Figure 12).

An 'automatic control panel' is connected to the tape unit. Indicator tubes display the contents of all flip-flops in the control-electronics.

A picture of the tape-unit with all the control-electronics is shown in Figure 13.
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The circuitry was wired and mounted by P. Egger and C. Mazzari. We gratefully acknowledge their contributions.
References

1) "The Mercury Computer Multiple Input/output Facility". Ferranti Ltd.,

2) "Requirements for Compatibility with IBM tape format" by D. W. Halfhill. Ampex Computer Products Division.

3) "Circuit Blocks". Philips Industrial Components and Materials Division.

Notes:
Oxide side up on diagram, recording head on same side as oxide.

Fig. 1
Fig. 2
Fig. 7
Fig. 8
See 'Philips circuit blocks description' FF1 set and reset generally on the AC input (differentiated input A1, A2)

One-shot

See 'Philips circuit blocks description' OS1

Emitter-follower

And gate with inverter

And gate with inhibit

And gate

Fig. 9