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SUBJECT: PROGRAMMING FOR IN-OUT UNITS

To: Group 61 and Applications Group

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Abstract: This memo contains some of the details of programming for the various modes of operation of each in-out unit. The necessary instructions and selection addresses are given, together with the timing and possible alarms involved. This memo supersedes M-1514, M-1551, M-1623, M-1623 Supplement #1, and M-1623-1.

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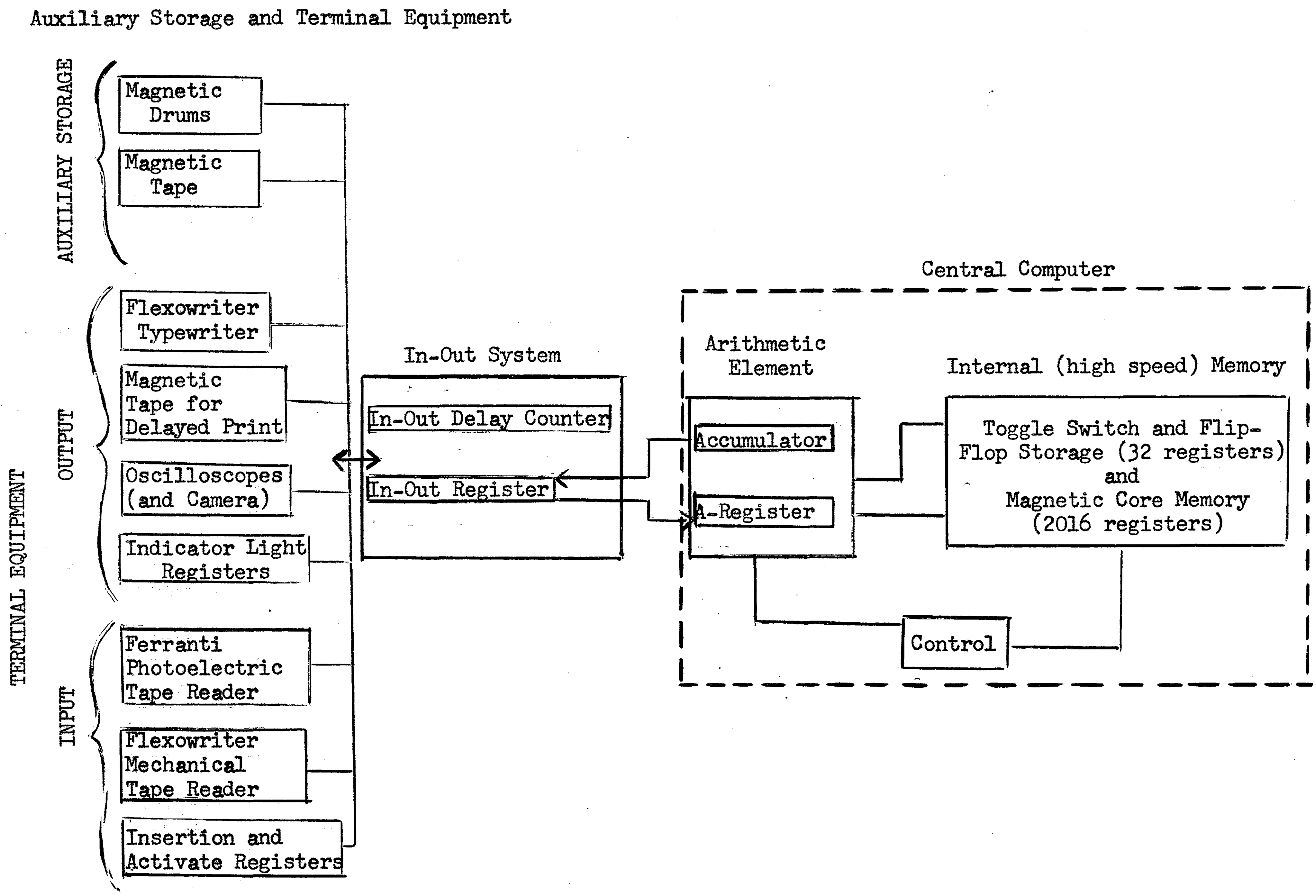
IN-OUT NOTES

In-Out Operations. The group of computer operations termed "in-out" operations is composed of the operations involved with the transmission of Whirlwind words (instructions or numbers) into and out of the central computer (arithmetic element, magnetic core memory, control). These operations are si (select in-out equipment), bi (block input), rd (read), bo (block output), and rc (record). They are used both for the auxiliary storage of information by the magnetic drums and tape units and for the input of information to, or the output of information from, the computer by the various pieces of terminal equipment. (See Figure 1).

si Instructions. The action of the instruction sipqrs is to select a particular in-out unit and prepare it to start operating in a specified mode designated by the octal address digits pqrs. In general, q designates the class of equipment (for example, q=1 selects the magnetic tape equipment), and r and s together designate the number of the unit and mode of operation. (At present, p is used only with the vector and character generators for oscilloscope displays.) An si normally precedes one or more of the other in-out instructions bi, rd, bo, and rc, except in certain special cases, involving the camera, clock, computer stop orders, etc., where only one si instruction is used.

Any instructions other than in-out instructions may intervene between the si and its associated bi, rd, bo, or rc, without affecting the in-out process (physical motion of the selected equipment may continue, which could result in a program alarm, etc.). Following an si instruction which specifies a read mode, the computer must not execute another si until the process initiated by the earlier si has ended. Since this is not insured by the computer hardware, it is necessary to program at least one rd or bi instruction after every si which selects a read mode.

Assigned si Addresses. All the si addresses which have been assigned functions are listed under the equipment to which they apply. A complete list of assigned si addresses in numerical order is given at the end of this memorandum. Unassigned si addresses may not be used indiscriminately. Certain unassigned addresses are "illegal": that is, they may cause an in-out unit to operate in an unpredictable fashion. Other unassigned


Auxiliary Storage and Terminal Equipment
AUXILIARY STORAGE
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In-Out Register
Central Computer
Arithmetic Element
Accumulator
A-Register
Internal (high speed) Memory
Toggle Switch and Flip-Flop Storage (32 registers) and Magnetic Core Memory (2016 registers)
Control

Figure 1

addresses are reserved for possible use at a later date.

Stop Instructions. The si operation is also used to provide a "stop," either to stop the computer or to stop any in-out unit which does not stop automatically (that is, a magnetic tape unit or the photoelectric reader). si 0 will stop the computer. si 1 will stop the computer only if the "STOP ON si 1" switch is ON. si (any assigned address) will stop any other free running in-out unit which may be running, without stopping the computer; however, if no in-out unit need be selected by this si stop instruction, the unique designation si 630 (octal) or si 408 (decimal) should be used, both for program clarity and for safety of operation.

rd and rc Instructions. After an si instruction has been given which selects a unit to operate in the read mode, the next available word from this piece of in-out equipment is transferred from this equipment into the IOR (In-Out Register) before the action of the si instruction is regarded as complete. The following rd (or bi) instruction completes the transfer of information by bringing the word from the IOR into the Accumulator by way of the A Register (see Figure 1). When an si for recording on a certain piece of in-out equipment is given, the word is not transferred from the central computer until the following rc instruction is given. When this rc is given, the word is transferred from the central computer to the selected in-out equipment, by way of the IOR (see Figure 1). The address section of the rd instruction is not used at present, and the address section of the rc instruction is used only with the vector and character generators.

Block Transfer Instructions. Blocks of words can be transferred from the high-speed memory of the central computer to certain pieces of in-out equipment, and vice-versa, by means of the block transfer orders bi and bo. The bi order is used to transfer a block of words from certain pieces of in-out equipment into a selected position of the high-speed memory, while the bo order is used to transfer a group of words from a selected position in the high-speed memory to a certain position in the in-out equipment or to record a block of characters on certain output units.

Delay Counts. If a number of in-out instructions are given in a program, since the in-out equipment operates at a much slower speed than the central computer in processing these instructions, some means of halting the computer until a previous in-out instruction has been performed before doing another is required. The Whirlwind computer checks a special flip-flop in the In-Out system, called the interlock, whenever an in-out instruction is to be performed. If the interlock is set to a 1 at this time, the computer halts: at the end of the first in-out instruction the interlock will be cleared and the later in-out instruction can then be performed. There exist two ways at present of deciding that an in-out instruction is finished. One is to have a pulse (called a completion pulse) return from the selected equipment to indicate this fact. The other is to count a delay in the computer sufficiently long so that this operation must be completed. The interlock is then cleared at the end of this delay. Such delay counting is done in the IODC (In-Out Delay Counter). For operations which actually require a sequence of events, such as recording a word on magnetic tape, the IODC may be used to time these various events, and the total delay will be the sum of the individual delays.

Alarms which can Occur when Using In-Out Equipment.

1. Program alarms. While an in-out unit is operating in the read mode, and an rd instruction is given before the next word from the selected unit has arrived in the IOR, the computer must wait until this word arrives before completing the rd instruction. Until this word has been read from the IOR, the computer is not ready to receive another word from the selected in-out unit, and should another word arrive before the first word has been read from the IOR, a program alarm will occur. This situation can arise only with the free-running units (the magnetic tape and photoelectric tape reader). In general, this alarm indicates information arriving in the IOR when the computer is not ready for it, and since it is not known whether this is an error or not, the program alarm is given.
2. Inactivity alarm. If the computer is in "stop clock" for more than about 1/2 second, an inactivity alarm is generally given. However, this alarm will be suppressed when we are performing in-out

instructions connected with the magnetic tape equipment, the paper tape equipment, or the camera, since the computer can legitimately be in stop clock for periods of this length when these units are being used.

3. Parity alarm. A parity check system is used with auxiliary storage on the magnetic drums. An additional parity digit is recorded with each register on the drum, and whenever a word is read from the drum a parity check is performed, and a parity alarm given if parity does not check.

AUXILIARY MAGNETIC DRUM

Function of the Auxiliary Drum. The auxiliary magnetic drum provides 24,576 registers of "intermediate speed storage," where each register can store a 16-digit binary word. The computer can transfer a word to or read a word from any drum register.

Register Numbering. The registers on the drum bear consecutive addresses from 0 to 24,575. The registers are in 12 groups along the drum, each group consisting of 2048 registers around the circumference. A drum address is specified by a 16-digit binary word -- digit 0 is immaterial, digits 1-4 specify the group number, and digits 5-15 specify the storage address. Within any register group, the storage addresses are treated modulo 2048. For example, a block transfer starting at address 2047 will deal in turn with registers 2047, 0, 1, 2, etc., in the same register group.

Access Time. To gain access to a specific register on the drum takes, on the average, 8.3 milliseconds, equal to the time for one-half revolution of the drum. An additional 64 microseconds delay occurs on si instructions for reading from the drum. (A drum group change delay was formerly counted on all si instructions which selected a new drum group. This delay has been 12 milliseconds, then 32 milliseconds, and was recently removed altogether when electronic switching of the recording circuits replaced relay switching. This delay may be changed to about 100 microseconds in the near future.)

Register Selection. The next drum address to be selected is determined by the si instruction and by any necessary portions of the contents of AC at the time the si is executed. The si instruction may call for a new group number or a new initial storage address, or neither, or both. When a new group number is needed, it is taken from digits 1-4 of AC. When a new initial storage address is needed, it is taken from digits 5-15 of AC. The group selected on the drum remains selected until an si instruction specifically calls for a change of group. The next storage address selected will be one greater than the storage address most recently referred to unless an si instruction specifically calls for a new initial storage address. To provide for all the cases above, there are four possible ways for an si instruction to specify a register:

1) Select no new group or initial address
2) Select new initial storage address only
3) Select new group only
4) Select both new group and new initial storage address

In addition, the si instruction selects reading or recording.

Recording Single Words on the Auxiliary Drum. Programming for recording on the auxiliary drum is as follows:

si a — Selects the auxiliary drum and the record mode. If the si instruction calls for a new group number, it is selected in accordance with the contents of digits 1-4 of AC and the group change delay, if any, is counted. If the si calls for a new initial storage address, it is selected in accordance with the contents of digits 5-15 of AC.

rc-- — Records the contents of AC at the next address called for by the si instruction, or at the next consecutive address following the last address at which a word was recorded. The computer cannot perform another in-out operation until the in-out equipment completes the recording process, which takes an average of 8.3 milliseconds and a maximum of 16.7 milliseconds. An rc instruction is required for each word to be recorded. As many rc instructions as necessary may be used before the next si instruction. Any number of instructions other than in-out instructions may precede each rc.

Recording by Block-Transfer Instruction. A bo instruction may be substituted for a series of rc instructions. The address of the bo must be the initial address of the block to be taken from MCM (magnetic core memory), and ± n, the number of words to be recorded, must be stored (times 2^{-15}) in AC. The block transfer will require an average of 8.3 milliseconds and a maximum of 16.7 milliseconds for the first word to be recorded, and 32 microseconds for each additional word. If the block transfer involves both registers 2047 and 0, in that sequence, an additional 16.7 milliseconds is required to complete the transfer. Any sequence of rc and bo instructions may follow a single si for the record mode.

Reading from the Auxiliary Drum. Programming for reading from the auxiliary drum is as follows:

si b Selects the auxiliary drum and the read mode. If the si instruction calls for a new group number, it is selected in accordance with the contents of digits 1-4 of AC. If the si calls for a new initial storage address, it is selected in accordance with digits 5-15 of AC. Reads into IOR the word from the chosen drum address. The time required to obtain the word is an average of 8.3 milliseconds and a maximum of 16.7 milliseconds (plus any drum group change delay if a group change is necessary). One, and only one, rd instruction should intervene between this and the next si instruction.

rd-- Transfers the word in IOR to AC, then clears IOR.

Reading by Block-Transfer Instruction. A bi instruction may be substituted for a series of rd instructions. The address of the bi must be the initial address of the block of registers in MCM to which the words will be transferred, and ± n, the number of words to be read, must be stored (times 2^{-15}) in AC. The block transfer will require an average of 8.3 milliseconds and a maximum of 16.7 milliseconds for the first word to be read, and 32 microseconds for each additional word. If the block transfer involves both registers 2047 and 0, in that sequence, an additional 16.7 milliseconds is required to complete the transfer. Only one bi instruction should follow an si instruction.

Zero-Length Block Transfers on bi and bo. The use of a bi instruction calling for a block transfer zero words in length will result in the indicated word being read but not transferred into AC. The reading of the word actually is initiated by the preceding si instruction, hence one word is already read by the time the bi is ready to be performed. If the bi calls for the transfer of no words, the word already read is simply discarded. Zero-length block transfers on bo will always be performed correctly, i.e., no recording will take place.

si Addresses for Auxiliary Drum. The si addresses referring to the auxiliary drum are as follows:

READ (from drum) MODE:

1) no address specified	si 700 (o) or si 448 (d)
2) select new initial address (angular position)	si 701 (o) or si 449 (d)
3) select new group	si 702 (o) or si 450 (d)
4) select new group and address	si 703 (o) or si 451 (d)

RECORD (onto drum) MODE:

1) no address specified	si 704 (o) or si 452 (d)
2) select new initial address (angular position)	si 705 (o) or si 453 (d)
3) select new group	si 706 (o) or si 454 (d)
4) select new group and address	si 707 (o) or si 455 (d)

where (o) indicates an octal number, (d) a decimal number.

Reference:

E-520: The WWI Auxiliary Magnetic Drum System.

BUFFER MAGNETIC DRUM

The buffer magnetic drum is used both for auxiliary storage and as buffer storage for special input data. The buffer drum is similar to the auxiliary drum in physical structure; however, at present the programmer is permitted to use only groups 4, 5, 6, and 7 for auxiliary storage (groups 2 and 3 will be available shortly for use as auxiliary storage). Programming for auxiliary storage on the buffer drum is the same as for the auxiliary drum, except that different si addresses must be used (see below) and not all the groups are available (see above).

<u>si Addresses for the Buffer Drum</u>:

READ MODE:

1) no address specified	si 710 (o) or si 456 (d)
2) select new initial address (angular position)	si 711 (o) or si 457 (d)
3) select new group	si 712 (o) or si 458 (d)
4) select new group and address	si 713 (o) or si 459 (d)

RECORD MODE:

1) no address specified	si 714 (o) or si 460 (d)
2) select new initial address (angular position)	si 715 (o) or si 461 (d)
3) select new group	si 716 (o) or si 462 (d)
4) select new group and address	si 717 (o) or si 463 (d)

<u>Use of the Drums by the Applications Group</u>. Group 11 of the auxiliary drum has a particular program (the "Drum Input Program") permanently stored on it (the recording circuits for this group are normally disabled). Thus programmers cannot use this group for auxiliary storage under ordinary circumstances. Also, group 0 of the auxiliary drum is used by the input program to hold a copy of MCM, and therefore the programmer must be careful if he wishes to use this group. All the available groups of the buffer drum are also used by the applications group to hold some of the frequently used utility programs, such as the Comprehensive System conversion program, post mortem programs, etc. These programs will be destroyed by the programmer recording on the buffer drum which, while permitted, requires that these programs be rewritten on the buffer drum when they are needed again. Thus the programmer ordinarily cannot use Group 11 of the auxiliary drum, should use Group 0 of the auxiliary drum only if its use by the input program will not invalidate his use of it, and should use the buffer drum auxiliary storage groups only if he cannot use the auxiliary drum or its capacity is not sufficient for his needs.

MAGNETIC TAPE UNITS

Action of Magnetic Tape Units. The five* magnetic tape units used with WWI will record and read 16 binary digit words. Normally these words are recorded in blocks of arbitrary lengths (set by programmer). The start of a block is identified by a block mark automatically recorded when si instructions for recording on the tape are given. Normal running speed of the tape is 30 inches per second. When an order affecting the state of motion of the tape is given, approximately 5.5 milliseconds are required before the tape motion is affected. Thus a tape unit which is running and is deselected by some other si instruction will continue to run at normal speed for about 5.5 milliseconds, and then will decelerate to a stop in about 0.5 milliseconds (but recorded data passing under the heads during this period will not be affected). A tape unit running in a given direction and instructed to change direction will continue to move in the original direction for about 5.5 milliseconds, then decelerate until it is moving in the opposite direction at full speed, which requires about 1 millisecond. The tape units are free-running units: once started by an si instruction they run free until stopped by another si instruction.

Modes of Operation of the Tape Units (determined by si instructions).

1. Record. Words are recorded on the tape by proper combinations of si instructions for recording and successive rc orders. It is not possible to record on the magnetic tape by the block transfer instruction bo.

2. Read. Words are read from the magnetic tape by use of the proper si instructions followed by one or more rd or bi orders. Any sequence of rd and bi instructions may follow a single si instruction for reading from the magnetic tape.

3. Re-Record. In the re-record mode, the tape unit starts in the read mode and continues to read until a block mark is detected; it then switches to the record mode.

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*Of the five tape units (called 0, 1, 2, 3A, and 3B) a maximum of four may be actually connected to the computer at any time. One of the Units 3A or 3B is connected to delayed output reading equipment, the other to the computer. These connections may be exchanged by throwing a toggle switch. Unit 2 is connected either to the computer or to delayed output reading equipment (which condition is controlled by the position of another toggle switch).

4. Stop. Two methods of stopping the magnetic tape units can be used. The first method is to deselect the unit by giving any si instruction not requiring that unit to move. However, if the program does not require a specific si instruction, the unique designation si 630 (octal) or si 408 (decimal) should be used. When the unit is deselected in this fashion, it is switched to the read mode and ignores but does not disturb the data over which it passes while it is stopping. However, if it is desired to stop the tape in a region of cleared tape (to clear old information from the tape between blocks, for example), si instructions for stopping in cleared area should be used. In this case, the selected unit switches to the record mode in the indicated direction for 14.3 milliseconds, then is instructed to reverse direction, still in the record mode, and 14.3 milliseconds later, the unit is deselected. Since the unit erases tape passing under the head while in the record mode, when no rc orders are given, this combination erases about 0.6 inches of tape beyond the point at which it was given, then reverses direction, and finally is deselected so that, if permitted, the tape stops in this cleared area just in front of the point at which the order was given. No other instructions (internal or in-out) can be performed until the deselection of the unit occurs.

Automatic Assembly and Disassembly of Words. A 16-digit word is in actuality recorded as eight pairs of digits on magnetic tape, the word being automatically disassembled by digit pairs in IOR. On reading, the word is automatically assembled (by successive shifts left) by digit pairs in IOR. The word will be assembled properly only if the tape is running in the same direction as it was when recorded. If the tape is read in the direction opposite to that in which it was recorded, the resulting words must be unscrambled by a special subroutine.

Recording. Programming for recording a block of words is as follows:

si m Selects the tape unit and starts the unit in forward or reverse, depending on the address m. An interblock space 14.3 milliseconds long (less any time required to accelerate the tape to normal speed) is generated on the tape, then a block mark is automatically recorded (which requires 160 microseconds). The computer cannot perform another in-out instruction until this 14.5-millisecond period has elapsed.

rc-- Records on tape the contents of AC. 2.6 milliseconds must elapse before the computer can perform another in-out instruction. An rc is required for each word to be recorded. As many rc instructions as necessary may be used before the next si instruction. Any number of instructions other than in-out instructions may precede each rc (however, the tape continues to move).

si n Stops the tape unit in cleared area. About 0.6 inches of tape are erased beyond the point at which this order was given; the tape stops, if permitted, about 0.2 inches beyond the point this order was given. This order requires about 28.6 milliseconds.

Reading. Programming for reading of words is as follows:

si m Selects the tape unit and starts the unit in forward or reverse, depending upon the address of m. After a delay count of 5.1 milliseconds, the computer reads into IOR the first word after the next block mark. The amount of time required for this process will depend on the distance of the next block mark from the reading heads. This si instruction must not be followed by another si without at least one intervening rd or bi instruction.

rd-- Transfers the contents of IOR to AC, then clears IOR in preparation for receiving the next word from tape. As many successive rd instructions will be needed as there are words to be read from tape. Assuming that the words were recorded at maximum density (one word every 2.6 milliseconds) a pair of digits will be read to IOR at intervals of approximately 326 microseconds. The computer must execute an rd instruction often enough to extract a word from IOR and clear IOR before the first pair of digits of the next recorded word arrives from the tape unit; otherwise a program alarm will result. To stop reading before the end of a recorded block has been reached, give an instruction to deselect the tape unit within about 2.8 milliseconds after the last desired word has been read; otherwise a program alarm may result. Any instructions other than in-out instructions may precede each rd.

si-- Deselect the tape unit. Any si instruction which has been assigned a function will stop the tape unit, but if the program does not require a specific si instruction, use si 630 (octal) or si 408 (decimal).

Reading by Block-Transfer Instruction. A bi instruction may be substituted for a series of rd instructions. The address of the bi must be the initial address of the block of registers in MCM to which the words will be transferred, and $\pm$ n, the number of words to be read, must be stored (times 2^{-15}) in AC at the time the computer executes the bi. Any sequence of rd and bi instructions may follow the si instruction. A program alarm will occur if the unit is not deselected before the first two digits of the second word after the last one read into MCM are transferred into IOR.

Zero-Length Block Transfer on bi. No word will be transferred from IOR to AC when a bi instruction calling for the transfer of a block zero words in length is given. The previous si, rd, or bi (for non-zero block transfer) results in a word being transferred from the tape to IOR. If the bi calls for the transfer of no words, this word already read is left in IOR, and a program alarm will occur unless another si (which clears IOR), rd, or bi (for non-zero length block transfer) occurs before the first two digits of the next word on the magnetic tape are transferred to IOR (a minimum of 320 microseconds between the si, rd, or bi which precedes the zero block length bi and the si, rd, or non-zero block length bi which follows it).

Re-Recording. Re-recording is similar to recording except that the tape unit starts in the read mode (which means that a 5.1 millisecond delay is counted in IODC before the unit starts searching for a block mark); after a block mark is detected, the unit switches to the record mode. No new block mark is recorded; the original block mark is not erased.

Skipping Blocks. The re-record instruction can perform an auxiliary function: that of making possible the skipping of any number of blocks, in either forward or reverse. Each si instruction to re-record causes the tape unit to search for the next block mark and to switch to the record mode as soon as the block mark is found. Since the record mode erases previously recorded data, however, another si instruction must switch the unit out of the record mode in time to avoid erroneously erasing. The maximum permissible interval between the si to re-record and the si to switch out of the record mode is dependent on the distribution of data on the tape, but in no case will it be less than 5.1 milliseconds.

si Addresses for Magnetic Tape Units. The si addresses for the magnetic tape units are as follows:

si Instruction	Unit 0	Unit 1	Unit 2	Unit 3A or 3B*
Re-record forward	100(o) 64(d)	110(o) 72(d)	120(o) 80(d)	130(o) 88(d)
Re-record reverse	101(o) 65(d)	111(o) 73(d)	121(o) 81(d)	131(o) 89(d)
Read forward	102(o) 66(d)	112(o) 74(d)	122(o) 82(d)	132(o) 90(d)
Read reverse	103(o) 67(d)	113(o) 75(d)	123(o) 83(d)	133(o) 91(d)
Stop in cleared area forward	104(o) 68(d)	114(o) 76(d)	124(o) 84(d)	134(o) 92(d)
Stop in cleared area reverse	105(o) 69(d)	115(o) 77(d)	125(o) 85(d)	135(o) 93(d)
Record forward	106(o) 70(d)	116(o) 78(d)	126(o) 86(d)	136(o) 94(d)
Record reverse	107(o) 71(d)	117(o) 79(d)	127(o) 87(d)	137(o) 95(d)

*These si addresses refer to whichever unit is connected to the computer through the transfer switch.

References:

E-482: Operation of Magnetic Tape Units.

M-2269-1: Use of the Magnetic Tape and Delayed Output Equipment.

DELAYED OUTPUT VIA MAGNETIC TAPE

Delayed-Output Units. Where printed page or punched paper tape output is desired, computer time can be conserved by the use of the delayed output units. The binary characters which control the printer or the punch are recorded on certain magnetic tape units by the computer, and these tapes are later run through the delayed-output units; these units read the characters, select the printer or the punch automatically, and then print or punch these characters. Flexowriter characters for delayed output can be recorded at the rate of 133 per second. A 1000-foot reel of magnetic tape can store over 50,000 characters, which can be recorded in a minimum of 6.7 minutes, and which can be printed in about 90 minutes or punched in about 63 minutes.

Tape Unit Connections. There are three magnetic tape units, 2, 3A, and 3B, associated with the delayed-output equipment. Either one of the units 3A or 3B may be connected to the computer while the other is connected to the delayed-output equipment; these connections may be interchanged by a manual transfer switch mounted on the panel on the Flexowriter enclosure. Unit 2 may be connected either to the computer for normal use as auxiliary storage, or for recording Flexowriter characters for delayed printing; when such characters have been recorded. Unit 2 may be connected to its delayed-output equipment by throwing another switch. (While connected to the delayed-print equipment, Unit 2 cannot be used by the computer.)

Programming for Delayed Output. In order to record on magnetic tape a series of Flexowriter characters for later automatic printing or punching, the following conventions must be observed:

1. A full 16-digit word is recorded on magnetic tape to store each 6 binary-digit Flexowriter character and two control digits. The six binary digits corresponding to the character to be printed or punched occupy digit positions 0 through 5 of AC when the word is recorded. Digit position 7 is used to determine whether the output is to be printed or punched; a 1 in digit 7 selects the punch, a 0 selects the printer. When the punch is selected, digit position 6 determines whether or not the 7th hole is to be punched on that line of paper tape; if digit 6 is a 1, the 7th hole is punched, if a 0, it is not

punched. This control information must accompany each character recorded for delayed output; neither the printer nor the punch remains selected after a character is printed or punched.

2. The separation between characters recorded on the magnetic tape for delayed output should be not less than 7.5 milliseconds (between the same points of two successive words) when the tape is running at normal speed. The programmer may count the necessary delay (4.9 milliseconds) between words, using the same si orders and programming given previously. However, this minimum delay can be obtained automatically by using the special si orders for recording given at the end of this section. When these si orders are given, the same interblock delay (14.3 milliseconds) is counted, and a block mark recorded at the end of this period, but on each succeeding rc instruction, a 5.1 millisecond delay is counted before the word is recorded. Since the recording of the word requires 2.6 milliseconds, approximately the minimum spacing between words is obtained on the tape. Thus the programmer can use the program outlined on Pages 12 and 13, substituting only the following si instructions, to record for delayed printing. Only if the non in-out orders intervening between successive rc orders require more than 7.5 milliseconds will any unnecessary magnetic tape be used.

3. It is advisable, but not necessary, to provide a Flexowriter stop character as the last character recorded, so that the Flexowriter, and therefore the tape unit, will stop after this character is read from the tape. Then the delayed output equipment may operate unattended.

si Addresses for Delayed Printing Via Magnetic Tape. The si addresses used to obtain the correct spacing between characters recorded on the magnetic tape are as follows:

si Instruction	Unit 2	Unit 3A or 3B*
Record for delayed print, forward	166(o) 118(d)	176(o) 126(d)
Record for delayed print, reverse	167(o) 119(d)	177(o) 127(d)

*These si addresses refer to whichever unit is connected to the computer through the transfer switch.

Reference:

M-2269-1: Use of the Magnetic Tape and Delayed Output Equipment.

PHOTOELECTRIC TAPE READER

Punched Paper Tape. The conventional form of a 16-digit word on punched paper tape is known as the "5-5-6" form. The binary digits (numbered 0 through 15) are physically distributed on the tape as shown in Figure 2, where a hole in a digit position indicates that digit is a 1, no hole indicates a 0.

hole no.	(1)	(2)	(3)		(4)	(5)	(6)	(7)
one word	0	1	2	.	3	4	X	
	5	6	7	.	8	9	Y	
	10	11	12	.	13	14	15	
				feed holes				

Figure 2

Positions X and Y are normally unpunched to aid in visually reading the tape. However, they may contain the same information as positions 5 and 10 respectively. The word-by-word reading modes of the in-out system are devised to correctly assemble into a 16-digit word a word punched in 5-5-6 form. Each line of tape which contains information must have the 7th hole position punched. If this were not done, the tape reader could not distinguish a line of significant zeros (which it must read) from a line of blank tape (which it must ignore). The omission of the 7th hole then allows the feature of punched visual identification numbers which will be ignored by the reader.

Action of the Photoelectric Reader. The Ferranti photoelectric tape reader, abbreviated hereafter "PETR," "reads" the 6-digit binary combination punched in a line of paper tape and transmits it to the right-hand six digit places of IOR. In the line-by-line mode, each reading operation reads one line of tape and forms a word of which the left-hand ten digits are zeros and the right-hand six digits correspond to the binary combination punched in the tape. In the word-by-word mode, each reading operation reads three lines of tape and assembles (by successive shifts left in IOR) a 16-digit word from the digits punched in the tape in 5-5-6 form. PETR is a free-running unit; that is, it runs free until stopped by an si instruction.

Programming for Line-By-Line Mode. Programming for reading in the line-by-line mode is as follows:

si r Starts PETR. Reads the first 6-digit character from tape into the right-hand six digits of IOR. This si instruction must not be followed by another si without at least one intervening rd or bi instruction.

rd-- Transfers contents of IOR to AC, then clears IOR in preparation for receiving the next character. The contents of digits 0-9 of AC will be zeros, and the contents of digits 10-15 of AC will correspond to the binary combination read from tape. As many successive rd instructions are necessary as there are lines of tape to be read. If there are no intervening lines of blank tape, a 6-digit character will arrive at IOR every 4.5 to 5.0 milliseconds. The computer must execute an rd instruction often enough to extract a word from IOR and clear IOR before the next character arrives from the reader; otherwise a program alarm will result. Any instructions other than in-out instructions may precede each rd.

si-- Stops the reader. If PETR is deselected soon enough after a particular line is read, it can decelerate to a stop and still pick up the next line on the paper tape when the programmer again gives an si for reading from PETR. The maximum safe time between the rd instruction which reads the last desired line before the stop and the si instruction which deselects PETR is about 2 milliseconds, which insures that the next line on the tape will not be skipped when PETR is used again. Any si instruction which has been assigned a function will deselect and stop the reader, but if the program does not require a specific si instruction, use the unique designation si 630 (octal) or si 408 (decimal).

Reading Line-By-Line By Block-Transfer Instruction. A bi instruction may take the place of a series of rd instructions. The address of the bi must be the initial address of the block of registers in MCM to which the words will be transferred, and $\pm$ n, the number of words to be read, must be stored (times 2^{-15}) in AC. The time required for the block transfer is the same as the total time required to perform the rd instructions it replaces. Any sequence of rd and bi instructions may follow a single si.

Programming for Word-By-Word Mode. Programming for reading in the word-by-word mode is as follows:

si r — Starts PETR. Reads the next three lines of tape (which must be punched in the 5-5-6 form) and assembles them into a 16-digit word in IOR. This si instruction must not be followed by another si without at least one intervening rd or bi instruction.

rd-- — Transfers contents of IOR to AC, then clears IOR in preparation for receiving the next character. The contents of AC will correspond to the 16-digit word originally punched on tape. As many successive rd instructions are necessary as there are words to be read from tape. If there are no intervening lines of blank tape, a 6-digit character will arrive in IOR every 4.5 to 5.0 milliseconds (13.5 to 15 milliseconds per word). The computer must execute an rd instruction often enough to extract a word from IOR and clear IOR before the next character arrives from the reader; otherwise program alarm will result. Any instructions other than in-out instructions may precede each rd.

si-- — Stops the reader. Any si instruction which has been assigned a function will deselect and stop the reader, but if the program does not require a specific si instruction, use the unique designation si 630 (octal) or si 408 (decimal). As noted above, if

PETR is not deselected in blank tape, the si for deselecting PETR should follow the last rd instruction within 2 milliseconds in order not to skip a line on the tape.

Reading Word-By-Word By Block-Transfer Instruction. A bi instruction may take the place of a series of rd instructions. The address of the bi must be the initial address of the block of registers in MCM to which the words will be transferred, and ± n, the number of words to be read, must be stored (times 2^{-15}) in AC. The time required for the block transfer is the same as the total time required to perform the rd instructions it replaces. Any sequence of rd and bi instructions may follow a single si.

Zero-Length Block Transfer on bi. The use of a bi instruction calling for the transfer of a block zero words in length will result in one word being read but not transferred. The reading of the word actually is initiated by the preceding si (or bi or rd) instruction, hence one word is already read by the time the bi is ready to be performed. If the bi calls for the transfer of no words, the word already read is simply discarded.

si Addresses for the Photoelectric Reader. The si addresses for the Ferranti photoelectric reader are as follows:

read line-by-line:	si 211 (octal) or si 137 (decimal)
read word-by-word:	si 213 (octal) or si 139 (decimal)

Reference:

M-2715: Programming for the Ferranti Photoelectric Tape Reader.

MECHANICAL TAPE READER

Action of the Mechanical Tape Reader. The mechanical tape reader "reads" the 6-digit binary combination punched in a line of paper tape and transmits it to the right-hand six digit places of IOR. In the line-by-line mode, each reading operation reads one line of tape and forms a word of which the left-hand ten digits are zero and the right-hand six digits correspond to the binary combination punched in the tape. In the word-by-word mode, each reading operation reads three lines of tape, and assembles (by successive shifts left in IOR) a 16-digit word from the digits punched in the tape in 5-5-6 form. The mechanical tape reader does not need to be stopped by an si instruction.

Programming for Line-By-Line Mode. Programming for reading in the line-by-line mode is as follows:

si r Selects the mechanical reader.

rd-- Reads the next 6-digit character from paper tape into the right-hand six digit positions of AC via IOR, and clears IOR in preparation for receiving the next character. The contents of digits 0-9 of AC will be zeros; and the contents of digits 10-15 of AC will correspond to the binary combination read from tape. In this mode with the mechanical reader, the computer requires about 105 milliseconds to execute each rd instruction. As many successive rd instructions are necessary as there are lines of tape to be read. Any number of instructions other than in-out instructions may precede each rd.

Reading Line-By-Line By the Block-Transfer Instruction. A bi instruction may take the place of a series of rd instructions. The address of the bi must be the initial address of the block of registers in MCM to which the words will be transferred, and $\pm$ n, the number of lines to be read, must be stored (times 2^{-15}) in AC. The time required to execute the block transfer is the same as the total time required to perform the rd instructions it replaces. Any sequence of rd and bi instructions may follow a single si.

Programming for Word-By-Word Mode. Programming for reading in the word-by-word mode is as follows:

si r Selects the mechanical reader.

rd-- Reads the next three lines of tape (which must be punched in 5-5-6 form) and assembles them via IOR into a 16-digit word in AC, and clears IOR in preparation for receiving the next word. In this mode with the mechanical reader, the computer requires about 315 milliseconds to execute each rd instruction. As many successive rd instructions are necessary as there are words to be read from tape. Any number of instructions other than in-out instructions may precede each rd.

Reading Word-By-Word By the Block-Transfer Instruction. A bi instruction may take the place of a series of rd instructions. The address of the bi must be the initial address of the block of registers in MCM to which the words will be transferred, and $\pm$ n, the number of words to be read, must be stored (times 2^{-15}) in AC. The time required to execute the block transfer is the same as the total time required to perform the rd instructions it replaces. Any sequence of rd and bi instructions may follow a single si.

Zero-Length Block Transfer on bi. Zero-length block transfers should not be used with the mechanical tape reader in either mode of operation. Such an order (bi with $\pm$ 0 in AC) actually reads a line or word from the paper tape, which will be lost. Program alarms may also occur if zero-length block transfers are attempted with the mechanical reader.

si Addresses for the Mechanical Reader. The si addresses for the mechanical tape reader (mounted on the Flexowriter unit by the console) are as follows:

read, line-by-line:	si 200 (octal) or si 128 (decimal)
read, word-by-word:	si 202 (octal) or si 130 (decimal)

PRINTERS

Action of the Printer. Each character to be printed or machine function to be performed (for example, carriage return) requires that the computer send to the printer a 6-digit binary character from the left-hand six digit places of AC. Each key on the printer is actuated by a unique code character. The printer utilizes only 51 of the 64 possible code combinations, and it will ignore without consequence the remaining combinations. The computer-controlled printers will also ignore the "stop" code.

The Flexowriter Code. The 6-digit code, known as the "FL" Flexowriter Code, is assigned arbitrarily by the manufacturer. The code is given in the accompanying tables. Table 1 is in alphanumerical sequence and Table 2 is in numerical sequence of binary code characters.

Programming for Printer Operation. The printing of alphanumerical characters and the performance of machine functions is accomplished by the following sequence of instructions:

si t — Selects the printer designated by the address t. The printer will remain selected until the next si instruction is executed.

rc-- — Actuates the printer key corresponding to the 6-digit code character contained in digits 0-5 of AC. A time (listed below) equal to that required for the printer to respond to the most recent character must elapse before the computer can perform the next in-out instruction. An rc instruction is required for each character to be printed or machine function to be performed. As many rc instructions as necessary may be used before the next si instruction. Any number of instructions other than in-out instructions may precede each rc.

Printing Via the Block-Transfer Instruction. If the Flexowriter codes for a group of characters to be printed are stored in sequence and in the left-hand 6-digit places in a block of consecutive registers, a bo instruction may be substituted for a series of rc instructions. The address of the bo must be the initial address of the block of registers, and ± n, the number of registers in the block, must be stored (times 2^{-15}) in AC at the time the bo instruction is executed. The time required for the block transfer to the printer will be the same as the total time required to execute the rc instructions it replaces. Any sequence of rc and bo instructions may follow a single si.

Printer Response Times. The approximate times required for the printer to carry out various processes are listed below:

print any alphanumerical character or symbol, space, color change, upper and lower case shifts........................ 125 milliseconds

back space.................................. 180 milliseconds

tabulation and carriage return........200 to 900 milliseconds

si Address for Printer. The si address for the printer is as follows:

record, Flexowriter Output Unit (by console): si 225 (o) or si 149 (d)

PUNCH

Action of the Punch. Each line of digits to be punched on tape is transmitted to the punch from the left-hand 6 digit-places of IOR. In the line-by-line mode, each recording operation punches one line of tape corresponding to the contents of digits 0-5 of IOR. In the word-by-word mode, each recording operation punches three lines of tape in 5-5-6 form (by successive shifts left in IOR) corresponding to the word in IOR.

Programming for Line-By-Line Mode. Programming for punching in the line-by-line mode is as follows:

si p — Selects the punch, and prepares to punch or suppress the 7th hole, according to the address p. The punch will remain selected until the next si instruction is executed.

rc-- — Punches in one line on paper tape the 6-digit binary combination corresponding to the contents of digits 0-5 of AC. The 7th hole position is automatically punched, or not, according to the mode determined by the most recent si instruction. About 80 milliseconds must elapse before the computer can perform the next in-out instruction. An rc is required for each line of tape to be punched. As many rc instructions as necessary may be used before the next si instruction. Any number of instructions other than in-out instructions may precede each rc.

Punching Line-By-Line By Block-Transfer Instruction. If the characters to be punched are stored in sequence and in the left-hand 6-digit places in a block of consecutive storage registers, a bo instruction may be substituted for a series of rc instructions. The address of the bo must be the initial address of the block of registers, and $\pm$ n, the number of registers in the block, must be stored (times 2^{-15}) in AC at the time the bo instruction is executed. The time required for the block transfer to the punch will be the same as the total time required to execute the rc instructions it replaces. Any sequence of rc and bo instructions may follow a single si.

Programming for Word-By-Word Mode. Programming for punching in the word-by-word mode is as follows:

si p — Selects the punch, and prepares to punch or suppress the 7th hole, according to the address p. The punch will remain selected until the next si instruction is executed.

rc-- — Punches in 5-5-6 form (in three lines) the 16-digit binary combination corresponding to the contents of AC. The 7th hole position is automatically punched, or not, according to the mode determined by the most recent si instruction. About 240 milliseconds must elapse before the computer can perform the next in-out instruction. An rc is required for each word to be punched in three lines on tape. As many rc instructions as necessary may be used before the next si instruction. Any number of instructions other than in-out instructions may precede each rc.

Punching Word-By-Word By Block-Transfer Instruction. If the words to be punched are stored in sequence in a block of consecutive storage registers, a bo instruction may be substituted for a series of rc instructions. The address of the bo must be the initial address of the block of registers, and $\pm$ n, the number of registers in the block, must be stored (times 2^{-15}) in AC at the time the bo instruction is executed. The time required for the block transfer to the punch will be the same as the total time required to execute the rc instructions it replaces. Any sequence of rc and bo instructions may follow a single si.

si Addresses for Punch. The si addresses for the punch are as follows:

line-by-line normal:	si 205 (o) or si 133 (d)
line-by-line, 7th hole suppressed:	si 204 (o) or si 132 (d)
word-by-word, normal:	si 207 (o) or si 135 (d)
word-by-word, 7th hole suppressed:	si 206 (o) or si 134 (d)

References:

M-1985: Operation of Indicator Lights and Intervention Registers.

M-2729: Paper Tape Units and Printers in WWI Input-Output System.

OSCILLOSCOPES

Selection of Scope Displays. The addresses of the si instructions for displays on the oscilloscopes specify a particular "scope intensification line" and mode of operation (point, character, or vector display). Any scope connected to the selected line will display a point or character or vector on each succeeding display instruction until a different si instruction is given. A bank of toggle switches at each scope permits the connection of that scope to any one or more of the 256 scope lines. (A special toggle switch on the manual intervention panel on the console table connects all three of the scopes in Test Control to all of the scope lines when it is on (up) and disconnects them from all lines when it is off.)

Scope Deflection. The left-hand 11 digits of AC (including the sign digit) at the time a display instruction is given determine the direction and amount of deflection. The positive direction of horizontal deflection is to the right and positive vertical deflection is upward. The value $1 - 2^{-10}$ or its negative will produce the maximum deflection.

Display of a Single Point. The display of a single point is programmed by the following sequence of instructions:

si s Selects the scope intensification line designated by the address s. Sets the vertical deflection of all scopes to a value corresponding to the contents of digits 0-10 of AC.

rc-- Sets the horizontal deflection of all scopes to a value corresponding to the contents of digits 0-10 of AC. Intensifies a point on all scopes which are connected to the intensification line selected by the above si instruction. About 160 microseconds will elapse before the computer can perform the next in-out instruction. Any number of instructions other than in-out instructions may precede each rc. Each point to be displayed is programmed in a similar manner.

Display of Horizontal Lines (Point-By-Point). The vertical deflection is set up by any si instruction (including those which do not refer to scopes) and remains unchanged until a new si instruction is executed. Similarly, the horizontal deflection is set up by any rc instruction (while a scope line is selected) and remains unchanged until a new rc instruction is executed. Hence a horizontal line may be displayed simply by a single si to set the vertical deflection followed by a succession of rc instructions to set up the horizontal deflections and display the individual points on the horizontal line. After each rc, about 170 microseconds must elapse before the computer can perform the next in-out instruction.

The Character Generator. To display alphanumerical information on the oscilloscopes, programs have been used which display such characters by plotting a number of points in their outlines. In order to save both programming and computer time and registers, an automatic method of displaying certain types of characters on the oscilloscopes can be used. These characters are formed by intensifying the desired lines in a rectangular figure eight, as shown in Figure 3.

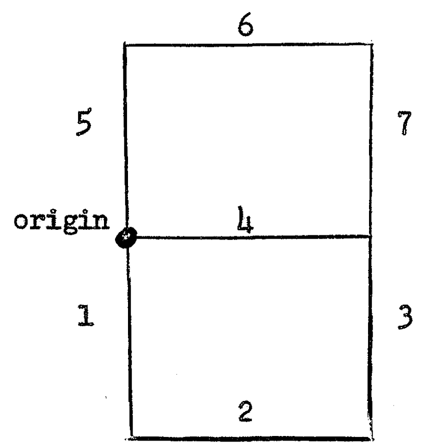

Figure 3: Character Generator Basic Figure

The "origin" of the character is at the left center of the figure eight, and the position of the origin on the face of the oscilloscope is determined by the contents of AC when the si (for vertical deflection) and rc for horizontal deflection) for displaying the character are given, exactly as is done for plotting individual points (see above). The lines in the figure eight which will be intensified when the rcx order is given are specified by digits 1 to 7 of register x. Each of these seven digits corresponds to one of the seven lines shown in Figure 3; a one in one of these digit positions indicates that the corresponding line should be intensified. The size of the character outline is about 7 units wide and 8 1/2 units high, where a unit is the minimum distance between two points displayed on a scope (which corresponds to a difference of 2^{-10} in the contents of AC when an si or rc order for point display is given).

Display of a Character. The display of a character is programmed by the following sequence of instructions:

six Selects a scope intensification line for character display. Sets the vertical deflection of all scopes to a value corresponding to the contents of digits 0-10 of AC.

rcy Sets the horizontal deflection of all scopes to a value corresponding to the contents of digits 0-10 of AC. Intensifies the lines of the character according to the contents of digits 1-7 of register y. About 326 microseconds will elapse before the computer can perform another in-out instruction. Any number of instructions other than in-out instructions may precede each rc. Each character to be displayed is programmed in a similar manner.

The Vector Generator. To aid in displaying alphanumerical data, drawing curves, plotting axes, etc. on the scopes, an automatic method of displaying vectors on the scopes is available. The coordinates of one end of the vector are determined by the contents of AC when the si and rcv instructions for displaying a vector are given, just as occurs when displaying an individual point. The horizontal and vertical components of the vector are determined by a pair of numbers stored in register v. Digits 0 to 5 of this register give the horizontal deflection of the vector from its origin, with maxima of $\pm$ 31 units, where a unit is equivalent to 2^{-8} spacing when displaying points; digits 8 to 13 provide a similar range for the vertical component of the vector. The largest horizontal or vertical vector is thus about 1/16th the distance across the usable portion of the scope face (for 16-inch diameter scopes, only the inscribed square is used, and thus for these scopes the maximum horizontal or vertical line which can be made with a single vector is about 0.7 inches long).

Display of a Vector. A vector is displayed by the following sequence of instructions:

si u Selects a scope intensification line for vector display. Sets the vertical deflection for all scopes to a value corresponding to the contents of digits 0-10 of AC.

rc v Sets the horizontal deflection of all scopes to a value corresponding to the contents of digits 0-10 of AC. Intensifies a vector starting at the point whose coordinates have just been established, where the sign and length of the horizontal component are given by the first six digits of v, and the sign and length of the vertical component are given by digits 8 to 13 of this register. About 166 microseconds will elapse before the computer can perform another in-out instruction. Any number of instructions other than in-out instructions may precede each rc. Each vector to be displayed is programmed in a similar manner.

Oscilloscope Amplification Settings. Since the characters are of such small size that, with the usual gain settings for the Test Control scopes for point display, they are too small to be photographed clearly, a rotary switch has been mounted below the camera in Test Control so that, in one position, the usual gain and intensity settings for point display occur on the scope with the camera, and in the other position, the gain and intensity settings have been increased so that the characters will be legible when photographed. However, with the switch in this last position, the maximum deflections for the origins of the characters cannot be used. The limits of the scope face will be reached with deflections of the character origins 1/2 to 2/3 the maximum permissible with point displays.

si Addresses for Scope Lines. The si addresses referring to oscilloscope displays are as follows:

point display		si 600(o) or si 384(d)	to	si 677(o) or si 447(d)
vector display		si 1600(o) or si 896(d)	to	si 1677(o) or si 959(d)
character display		si 2600(o) or si 1408(d)	to	si 2677(o) or si 1471(d)
	and	si 3600(o) or si 1920(d)	to	si 3677(o) or si 1983(d)

As indicated above, the connections of the oscilloscopes to the above lines are determined by the particular switches associated with each scope and the wiring of these switches.

Reference:

M-2188: Programming for and Operation of Oscilloscope and Camera.

CAMERA

Action of the Camera. The selection of the camera by the si 4 instruction results in the following cycle of operations, termed an index cycle:

1) Bulb lights, recording the frame number, time, and card data for the previous frame.
2) Close shutter
3) Advance film one frame
4) Open shutter

The shutter of the camera is always open when camera power is on.

Programming for the Index Cycle. The index cycle is affected by the single instructions si 4. About 500 milliseconds will elapse after this si instruction before the computer can perform another in-out instruction.

Manual Control. A push-button, labeled "INDEX", on the camera control panel in Test Storage provides for manually indexing the camera. Each time this button is depressed, an index cycle is given.

Film Alarm. When the film supply in the film magazine on the camera gets low, an alarm buzzer sounds and a red light on the camera control panel goes on (labeled "FILM ALARM"). The magazine should then be replaced with one containing fresh film. When the alarm activates, however, there are still at least 10 frames of film left in the camera magazine. The buzzer will be turned off when the operator presses the "ALARM ACKNOWLEDGE" button on the panel, but the light remains lit until the magazine is replaced by one with sufficient film.

LIGHT GUNS*

Action of a Light Gun. A light gun signal generated by the display of a point on a scope (see SCOPES) is transmitted immediately to IOR (which has been reset to zero by the display instruction). The signal causes ones to appear in two digit positions of IOR: namely, in the sign digit position, indicating that a signal has been received, and in the digit position to which the light gun is connected. Several light guns may send signals to IOR simultaneously.

*At present, about 12 light guns are available.

Programming for Light Gun Inputs. To determine if a light gun signal has occurred, it is necessary to program an rd after the point has been displayed and before another in-out instruction. The rd will bring the contents of IOR into AC, a cp instruction will examine the sign digit to see if any signal has been received, and successive cl or sf instructions will determine which light guns generated the signals.

CLOCK (TIMING REGISTER)

Description. The real-time clock associated with the WWI computer is a 21 binary digit counter (counting modulo 2^{21}), whose normal* input to the rightmost digit is a 60-pulses-per-second source synchronized with the AC power lines. It is possible to read out (to IOR) only the first 19 digits of this counter; the last two digits provide frequency division, so that the counter output can advance one count each 1/15th second. Thus the output of the clock can indicate the time as a number of 1/15th-second intervals, counting from 0 to a maximum of 2^{19} -1, which corresponds to about 9.7 hours. Provisions have been made for clearing all the flip-flops of the clock, complementing the first 19, and reading out the first 19 digits in two parts. (See Figure 4.)

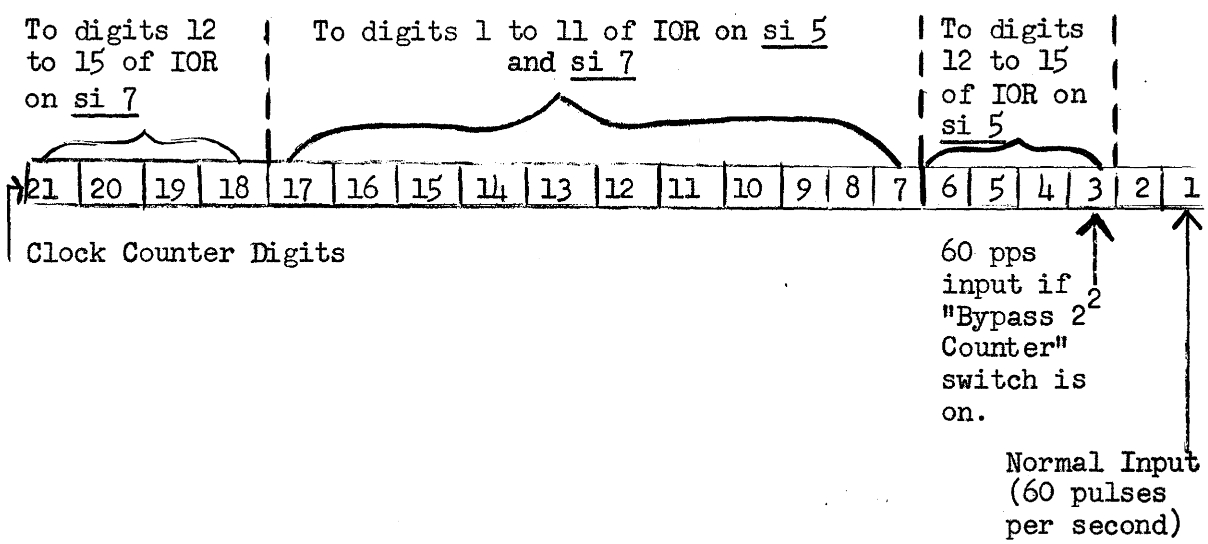

Figure 4: Clock (Timing Register)

*Other pulse sources can be fed into this counter. This source must be cabled into a special input of the counter, and a switch (in Rack E7) thrown up. When this switch is up, a light on the control panel labeled "TIMING REGISTER, EXTRAORDINARY INPUT" is lit.

Programming to Use the Clock.

si 5 Transfers the contents of digits 17 through 3 inclusive of the clock to corresponding positions from digit 1 to 15 inclusive of IOR. Digit 0 of IOR is 0.

rd-- Transfers the contents of IOR to AC.

si 7 Transfers digits 17 through 7 inclusive of the clock into corresponding positions from digit 1 through 11 inclusive of IOR, just as is done on si 5 above. Digits 21 through 18 inclusive of the clock are transferred to digits 12 through 15 inclusive of IOR. Digit 0 of IOR is 0.

rd-- Transfers the contents of IOR to AC. This number must be unscrambled to provide the proper time count in increments of 1 and 1/15th seconds.

si 11(o) or si 9(d) Clears all 21 digits of clock (sets all flip-flops to 0).

si 12(o) or si 10(d) Complements the first 19 digits of the clock (digits 21 through 3 inclusive).

In order to provide more accurate timing for certain programs, a switch has been provided in Rack E7 which bypasses the source of pulses around the last two flip-flops of the counter (thus it can count 1/60th second intervals). Otherwise, the clock operation is unchanged. When this switch is thrown, a light on the control panel, labeled "TIMING REGISTER, BYPASS 2^2 COUNTER", remains lit.

Note: The clock is used by the Applications Group in connection with the automatic logging of the computer time used by various problems. In order not to disturb this timing during the periods when this group is using the machine, a switch (labeled "STOP ON si 11 or si 12") has been added to the console. When this switch is on, a light on the control panel (similarly labeled) is lit and the computer will stop if an si 11 or si 12 is given.

Reference:

M-2675: Operation of New Timing Register

MANUAL INSERTION REGISTERS

Intervention Registers

Description. A group of special registers have been provided so that asynchronous information can be given to the computer by the operator or other personnel as a program is being performed. Each such register is provided with a number of binary, octal, or decimal switches which are connected such that certain binary digits of the register may be set to 0 or 1 manually as desired.

Programming to Use the Insertion Registers. To read the contents of any insertion register, the following sequence of instruction is used:

si x   Reads the contents of the insertion register indicated by the address x into IOR. Since the switches which govern this information are of the latching type, the information in the register remains there, until some of the switches are changed.

rd--   Transfers the contents of IOR to AC and clears IOR.

si Addresses for the Insertion Registers. The si addresses for the insertion registers (numbered 2 to 31) are as follows:

Insertion registers   si 302(o) to si 337(o)
or si 194(d) to si 223(d)

Manual insertion registers referred to by addresses 336(o) and 337(o) are mounted on a panel on the console in Test Control, and are used by the computer operators to select special utility programs, etc.

Activate Registers

Description. Another form of manual insertion of information into the computer is provided by the activate registers. These are two registers of gas-tubes (32), any one of which is fired by pressing the push-button associated with that tube. When the information is read from such a gas tube, it is automatically extinguished, so that it may be fired again when its button is pushed. Also associated with each tube is a light which remains lit as long as that tube is fired.

Programming to Use the Activate Registers. The contents of an activate register may be read as follows:

si y Reads a word into IOR, indicating the states of the 16 gas tubes which form the activate register indicated by the address y. Ones will be in the digit positions corresponding to gas tubes fired since this same si y instruction was given previously. These gas tubes are then extinguished.

rd-- Read the contents of IOR into AC and clear IOR.

si Addresses for the Activate Registers. The si addresses referring to the activate registers are as follows:

Activate register 0	si 300(o) or si 192(d)
Activate register 1	si 301(o) or si 193(d)

The push-buttons which fire and the lights indicating the states of the gas tubes corresponding to digits 0 and 1 of the word obtained by using si 300(o) to read activate register 0 are positioned on the panel on the console in Test Control, and are used by the computer operators with the insertion registers located on this panel.

INDICATOR LIGHT REGISTERS

Description. A group of eight special registers have been provided so that the computer program can give desired information to the operators, programmers, or other personnel. Each such register represents a group of 16 gas tubes which can be fired under control of the computer. An si instruction referring to one of these registers extinguishes all the tubes in that register, and the succeeding rc instruction fires the tubes corresponding to the digit positions in AC which contain 1's. Lights associated with each gas tube of each register remain lit as long as that gas tube is fired. The complement of the contents of the register may also be given in a parallel set of lights.

Programming to Use the Indicator Light Registers. To record a word in an indicator light register, the sequence of instructions used is:

si z Extinguish all the gas tubes of the indicator light register selected by address z.

rc-- Read the contents of AC to IOR, and wherever a 1 occurs in this word, fire the gas tube corresponding to that digit in the selected indicator light register. The lights associated with this register then show the contents of AC. Two seconds must intervene between two si instructions for the same light register, in order to insure that its gas tubes are completely extinguished.

si Addresses for the Indicator Light Registers. The following si instructions refer to the indicator light registers:

indicator light registers 0 to 7 or si 510(o) to si 517(d)
si 328(o) to si 335(d)

The lights for indicator light register 0, whose address is si 510(o) are located on the panel on the console in Test Control for use by the computer operators and programmers.

PROGRAMMED MARGINAL CHECKING

In order to program the use of the marginal checking system associated with Whirlwind, the proper switches must first be thrown on Test Control Rack TC1 MARGINAL CHECKING CONTROL panel. The rotary switch must be set to PMC, and any other controls as needed. The instruction si 3, with the marginal checking line number in binary-coded decimal in AC, and followed by two rc orders, starts the cycle:

1) The computer goes into Stop Clock.
2) The proper marginal checking line is selected and the voltage excursion starts.
3) A Start Over pulse is sent to computer control, and the checking program may start.
4) At the end of the voltage excursion cycle, the computer is again put into Stop Clock.
5) The line is then deselected.
6) Another Start Over pulse occurs.

In order for the program to distinguish the above two Start Over pulses, since both start the program at the register indicated in the PC RESET switches, another si instruction (si 2) is provided. If a line is selected when this instruction is given, a 1 is put in IOR digit 0; if no line is selected, this digit remains a 0. A following rd instruction brings the contents of IOR into AC, so that a cp instruction can then distinguish the two cases.

si Addresses Used With Programmed-Marginal Checking. The two si addresses used with programmed marginal checking are si2 and si3, and their actions are described above.

TABLE 1. THE "FL" FLEXOWRITER CODE

Alphanumerical Sequence

Lower Case	Upper Case	Character 123456	Decimal Value	Octal Value
a	A	000110	6	6
b	B	110010	50	62
c	C	011100	28	34
d	D	010010	18	22
e	E	000010	2	2
f	F	011010	26	32
g	G	110100	52	64
h	H	101000	40	50
i	I	001100	12	14
j	J	010110	22	26
k	K	011110	30	36
l	L	100100	36	44
m	M	111000	56	70
n	N	011000	24	30
o	O	110000	48	60
p	P	101100	44	54
q	Q	101110	46	56
r	R	010100	20	24
s	S	001010	10	12
t	T	100000	32	40
u	U	001110	14	16
v	V	111100	60	74
w	W	100110	38	46
x	X	111010	58	72
y	Y	101010	42	52
z	Z	100010	34	42

Lower Case	Upper Case	Character 123456	Decimal Value	Octal Value
0	^{0}	111110	62	76
1	^{1}	010101	21	25
2	^{2}	001111	15	17
3	^{3}	000111	7	7
4	^{4}	001011	11	13
5	^{5}	010011	19	23
6	^{6}	011011	27	33
7	^{7}	010111	23	27
8	^{8}	000011	3	3
9	^{9}	110110	54	66
|	_	000101	5	5
space bar		001000	8	10
=	°	001001	9	11
+	/	001101	13	15
color change		010000	16	20
.	)	010001	17	21
,	(	011001	25	31
-	‾	011101	29	35
back space		100011	35	43
tabulation		100101	37	45
carr. return		101001	41	51
stop		110001	49	61
upper case		111001	57	71
lower case		111101	61	75
nullify		111111	63	77

TABLE 2. THE "FL" FLEXOWRITER CODE

Binary Numerical Sequence

Decimal Value	Octal Value	Character 123456	Lower Case	Upper Case	Decimal Value	Octal Value	Character 123456	Lower Case	Upper Case
0	0	000000	not used		32	40	100000	t	T
1	1	000001	not used		33	41	100001	not used	
2	2	000010	e	E	34	42	100010	z	Z
3	3	000011	8	^{8}	35	43	100011	back space	
4	4	000100	not used		36	44	100100	l	L
5	5	000101		_	37	45	100101	tabulation	
6	6	000110	a	A	38	46	100110	w	W
7	7	000111	3	^{3}	39	47	100111	not used	
8	10	001000	space bar		40	50	101000	h	H
9	11	001001	=		41	51	101001	carr. return	
10	12	001010	s	S	42	52	101010	y	Y
11	13	001011	4	^{4}	43	53	101011	not used	
12	14	001100	i	I	44	54	101100	p	P
13	15	001101	+	/	45	55	101101	not used	
14	16	001110	u	U	46	56	101110	q	Q
15	17	001111	2	^{2}	47	57	101111	not used	
16	20	010000	color change		48	60	110000	o	O
17	21	010001	.	)	49	61	110001	stop	
18	22	010010	d	D	50	62	110010	b	B
19	23	010011	5	^{5}	51	63	110011	not used	
20	24	010100	r	R	52	64	110100	g	G
21	25	010101	1	^{1}	53	65	110101	not used	
22	26	010110	j	J	54	66	110110	9	^{9}
23	27	010111	7	^{7}	55	67	110111	not used	
24	30	011000	n	N	56	70	111000	m	M
25	31	011001	,	(	57	71	111001	upper case	
26	32	011010	f	F	58	72	111010	x	X
27	33	011011	6	^{6}	59	73	111011	not used	
28	34	011100	c	C	60	74	111100	v	V
29	35	011101	-	$^{-}$	61	75	111101	lower case	
30	36	011110	k	K	62	76	111110	0	^{0}
31	37	011111	not used		63	77	111111	nullify	