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SUBJECT: PROGRAMMING FOR IN-OUT UNITS

To: Group 61 and Applications Group

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Abstract: This memo contains 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, and M-1623 Supplement #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 words into and out of the computer: namely, si, bi, rd, bo, and rc. The block-transfer operations bi and bo will not be available until January, 1953.

si instructions. The action of the si instruction is to select a particular in-out unit and prepare it to start operating in a specified mode designated by the octal address digits p q r. p designates the class of equipment (such as magnetic tape units) and q and r together designate the number of the unit and the mode of operation. An si normally precedes one or more of the other in-out instructions involving bi, rd, bo, and rc, except in the case of the camera, which is operated by a single si alone, or in the case in which si is used to stop the computer or an in-out unit. Any instructions other than in-out instructions may intervene between si and its associated bi, rd, bo, or rc, without affecting the in-out process. 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 electronic means, it must be insured by programming at least one rd 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 section. Unassigned si addresses may not be used indiscriminately. At present, the use of addresses containing 1's in the binary digit positions 5, 6, or 10 of an instruction will cause the computer to stop in a transfer check alarm. Certain other unassigned addresses are "illegal": that is, they may cause an in-out unit to operate in an unpredictable fashion. Other unassigned 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 "Conditional Stop" switch is ON. si (any assigned address) will stop any 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.

Possible changes in rc and rd operations. It is possible that at some future date the address sections of the rc and rd instructions may specify the address to which control should be transferred if the in-out unit is not ready to carry out the required recording or reading process. It is therefore advisable to set the address section of each rc and rd instruction equal to the address of the register containing the instruction. For example, register x would contain rc x or rd x.

Punched paper tape. The conventional form of a 16-digit word on punched paper tape is known as "556" form (distinct from a previous form termed "5-5-6"). The binary digits (numbered 0 through 15) are physically distributed on the tape in the following manner:

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				

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 556 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.

Delays and alarms associated with the read mode. While an in-out unit is operating in the read mode, if the computer attempts to perform any in-out instruction (normally an rd) before a word or character has arrived in IOR, it must wait until the word or character arrives. If the computer has not cleared IOR (by an rd instruction) before the succeeding word arrives in IOR from an in-out unit, an in-out alarm results. In connection with programming for in-out units, the only type of alarm which occurs is an in-out alarm. All cases in which in-out alarms can occur are specifically noted in the discussion of each unit.

AUXILIARY MAGNETIC DRUM (NOT YET AVAILABLE)

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, in a manner similar to the way it does in electrostatic storage.

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. A drum address is specified by a 16-digit binary word, of which 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 milliseconds, equal to the time for one-half revolution of the drum. An additional 12 milliseconds seconds delay occurs if the register lies in a group different than the group last used.

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 group only
3) Select new initial storage address 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. If the si calls for a new initial storage address, it is selected in accordance with the contents of digits 5-15 of AC. The computer cannot perform another in-out instruction until the group change, if any, requiring 12 milliseconds, is completed.

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 milliseconds and a maximum of 16 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 ES, and $\pm$ 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 milliseconds and a maximum of 16 milliseconds for the first word to be recorded, and 64 microseconds for each additional word. If the block transfer involves both registers 2047 and 0, in that sequence, an additional 16 milliseconds is required to complete the transfer. Any sequence of rc and bo instructions may follow a single si.

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

si a 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 milliseconds and a maximum of 16 milliseconds, plus an additional 12 milliseconds if a group change is necessary. One, and only one, rd or bi instruction must 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 an rd instruction. The address of the bi must be the initial address of the block of registers in ES to which the words will be transferred, and ± n, the number of words to be read, must be stored times 2^{-15} in AC. Each bi must be preceded by an si. The block transfer will require an average of 8 milliseconds and a maximum of 16 milliseconds for the first word to be read, and 64 microseconds for each additional word. If the block transfer involves both registers 2047 and 0, in that sequence, an additional 16 milliseconds is required to complete the transfer.

Zero-length block transfers on bi and bo. 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 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. When the auxiliary drum becomes available, the si addresses will be as follows:

READ MODE:

1)	no address specified	si 700 octal or si 448 decimal
2)	select new group	si 701 octal or si 449 decimal
3)	select new initial address	si 702 octal or si 450 decimal
4)	select new group and address	si 703 octal or si 451 decimal

RECORD MODE:

1)	no address specified	si 704 octal or si 452 decimal
2)	select new group	si 705 octal or si 453 decimal
3)	select initial address	si 706 octal or si 454 decimal
4)	select new group and address	si 707 octal or si 455 decimal

CAMERA

Action of the camera. The selection of the camera by an si instruction results in the following cycle of operation, termed an "index cycle":

1) Close shutter
2) Advance film one frame
3) Open shutter

If shutter is initially closed, the first step is omitted.

Programming the index cycle. The index cycle is effected by the single instruction si 500 (octal) or si 320 (decimal). 220 milliseconds will elapse after the si instruction before the computer performs the next in-out instruction.

Manual controls. Three push-buttons, labeled CLOSE, OPEN, and INDEX, on the camera control panel provide for manual control of the camera. Depressing the INDEX button advances the film one frame; if the shutter is initially open, it is automatically closed during the period required to advance the film. A remote push-button unit is also available, which may be plugged into any one of several jacks. Depending upon whether the shutter is initially open or closed, one of the following sequences of operation will result.

> If the shutter is initially closed, depressing the button opens the shutter; releasing the button closes the shutter and advances the film.
>
> If the shutter is initially open, depressing the button has no effect; releasing the button closes the shutter, advances the film, and reopens the shutter.

CLOCK

Use of the "clock," or "time register." The "clock" is provided to indicate increments of time, counting in one-quarter second units from 0 to 32767 (136.53) minutes) and then starting over. It is a 16-digit flip-flop register of which the sign is always positive, and it is located (arbitrarily) at address 31 (decimal) in Test Storage. The contents of the clock may be read out by an instruction (ex, ca, cs, ad, su, cm, sa, ad, ao, mr, mh, dv, dm) in ES (but not in TS); information cannot be transferred to the clock by the computer. The clock is reset to zero by a pushbutton.

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 unit. The 6-digit binary characters to control the printer or the punch are recorded on magnetic tape by the computer and the tape is later run through the delayed-output unit. The tape for delayed output can be recorded at the rate of 100 characters per second. An 800-foot reel of magnetic tape will store about 32,000 characters, which can be recorded in a minimum of 5.2 minutes and can be printed or punched out in about 75 minutes.

Tape unit connections. There are two magnetic tape units, designated 1A and 1B, associated with the delayed-output equipment. Either one of the units may be connected to the computer while the other is connected to the delayed-output equipment. The connections may be interchanged by a manual switch.

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

1) A full 16-digit word must be recorded on magnetic tape to store each 6-digit binary character; each character occupies digit positions 2 through 7 of the recorded word, the contents of the other digit positions being immaterial. The necessary binary characters for the "delayed printer" are identical to those used for the printer (see the Flexowriter Code).

2) The temporal separation of the words on magnetic tape must be no less than 7 milliseconds. A 12-millisecond separation will automatically be achieved if the individual words are recorded as blocks each 1 word long. If recording time is to be a minimum, the program must "count" a 7-millisecond delay between individual recorded words.

3) It is advisable (but not necessary) to provide a Flexo-unit stop character as the last recorded character so that the automatic printing or punching equipment may operate unattended.

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.

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 sf or cl instructions will determine which light guns generated the signal.

Present light gun equipment. At present, the one available light gun is permanently connected to the sign digit of IOR, and can be connected by a four-position switch to any one of digit positions 1, 2, 3, and 4 of IOR. At some future date there will be more light guns, which may or may not be tied to specific digits of IOR.

MAGNETIC TAPE

Action of magnetic-tape units. The magnetic-tape units will record and read 16-digit binary words. An individual block is of arbitrary length, the start of the block being identified by a block marker automatically recorded. In addition to provisions for recording and reading, a mode termed "re-record" searches for a block marker and then switches to the record mode. Previously recorded information is automatically erased from a tape which is running in the record mode. A tape unit which is instructed to stop will continue to coast for approximately 6 milliseconds, but will not affect the recorded data which passes under the heads during this coasting period. A tape unit running at full speed and instructed to reverse direction will continue moving in the original direction for approximately 6 milliseconds, but will immediately being erasing and counting the delay for a block space if recording, or counting a delay and then searching for a block marker if reading or re-recording. The tape unit is a free-running unit: once started by an si instruction, it runs free until stopped by another si instruction.

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 12 milliseconds long is generated on the tape, then a block marker is automatically recorded. The computer cannot perform another in-out instruction until this 12-millisecond period has elapsed.

rc-- — Records on tape the 16-digit word contained in AC. 2.5 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.

si m — Identical to the si m above, for the purpose of erasing any previously recorded data at the end of the block. If the tape has been previously erased so that there is no possibility of old data occurring at the end of a newly-recorded block, this instruction and the succeeding si n may be omitted.

si n — Selects the same unit for recording, but in the opposite direction. The tape will coast in the original direction for approximately 6 milliseconds; it will then reverse, erase the block marker recorded by the preceding si m and move the newly-erased space under the heads. After 12 milliseconds a block marker will be recorded. This si instruction must follow within 16 milliseconds of the previous si.

si-- Stops 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 the unique designation si 630 (octal) or si 408 (decimal). The maximum safe interval between this si and the preceding si n, if any, is 12 milliseconds.

Recording by block-transfer instruction. The system is not designed to permit recording on magnetic tape by the block-transfer instruction.

Re-recording. Re-recording is similar to recording except that the unit runs for approximately 5 milliseconds and then begins the recording process after passing the next block marker instead of beginning to record immediately irrespective of the tape position. Only one block marker precedes the newly-recorded block.

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 waiting for 5 milliseconds, the computer reads into IOR the first word after the next block marker. The amount of time required for this process will depend on the distance of the next block marker 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 2.5 milliseconds) a pair of digits will be read to IOR at intervals of approximately 300 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 an in-out alarm will result. To stop reading before the end of a recorded block has been reached, give an instruction to stop the tape unit within 2 milliseconds after the last desired word has been read; otherwise an in-out alarm may result. Any instructions other than in-out instructions may precede each rd.

si-- Stops 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 the unique designation 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 ES 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 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 in 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.

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 marker and to switch to the record mode as soon as the block marker 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 milliseconds.

si addresses for magnetic tape units. The si addresses for the magnetic tape units are as follows:

UNITS 2 AND 3 NOT YET AVAILABLE

Unit	0	1A, 1B*	2	3
Re-record, forward	100 octal 64 decimal	110 octal 72 decimal	120 octal 80 decimal	130 octal 88 decimal
Re-record, reverse	101 octal 65 decimal	111 octal 73 decimal	121 octal 81 decimal	131 octal 89 decimal
Read, forward	102 octal 66 decimal	112 octal 74 decimal	122 octal 82 decimal	132 octal 90 decimal
Read, reverse	103 octal 67 decimal	113 octal 75 decimal	123 octal 83 decimal	133 octal 91 decimal
Record, forward	106 octal 70 decimal	116 octal 78 decimal	126 octal 86 decimal	136 octal 94 decimal
Record, reverse	107 octal 71 decimal	117 octal 79 decimal	127 octal 87 decimal	137 octal 95 decimal

* associated with delayed-output equipment

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 556 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 zero, 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 106 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 ES to which the words will be transferred, and +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 556 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 318 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 ES 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 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. 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 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 mechanical reader. The si addresses for the mechanical tape reader (Flexowriter Input Unit #0) connected in "normal" fashion are as follows:

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

PHOTOELECTRIC TAPE READER

Action of the photoelectric reader. The 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 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 556 form. PETR is a free-running unit; that is, it runs free until stopped by an si instruction.

Substitution of mechanical reader for PETR. A switch will soon be available to connect the mechanical reader in place of the PETR whenever it is necessary to go instruction-by-instruction in a program which calls for the PETR. At other times the mechanical reader will be connected in its normal place, with its own selection addresses.

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 zero, 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 7 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 an in-out alarm will result. Any instructions other than in-out instructions may precede each rd.

si-- Stops the reader. Since the reader passes about three-quarters of an inch of tape after it has been ordered to stop, it should not be stopped except where at least one and one-half inches of blank tape have been provided, otherwise information which coasts by the reading head will be lost. Any si instruction which has been assigned a function will 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 ES 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 556 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 7 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 an in-out alarm will result. Any instructions other than in-out instructions may precede each rd.

si-- Stops the reader. Since the reader passes about three-quarters of an inch of tape after it has been ordered to stop, it should not be stopped except where at least one and one-half inches of blank tape have been provided, otherwise information which coasts by the reading head will be lost. Any si instruction which has been assigned a function will 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 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 ES 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 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 photoelectric reader (Flexowriter Input Unit #1) are as follows:

line-by-line: si 211 (octal) or si 137 (decimal)

word-by-word: si 213 (octal) or si 139 (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 or of a storage register. 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 $\pm$ 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 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	.135 milliseconds
back space.	.180 milliseconds
tabulation and carriage return. . .	.200 to 900 milliseconds

si addresses for printers. The si addresses for the printers are as follows: UNIT NO. 3 NOT YET AVAILABLE

Flexo Output Unit #1 (Room 222):	si 215 (octal) or si 141 (decimal)
Flexo Output Unit #2:	si 225 (octal) or si 149 (decimal)
Flexo Output Unit #3:	si 235 (octal) or si 157 (decimal)

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 556 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. 93 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 556 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. 280 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 (octal) or si 133 (decimal)
line-by-line, 7th hole suppressed:	si 204 (octal) or si 132 (decimal)
word-by-word, normal:	si 207 (octal) or si 135 (decimal)
word-by-word, 7th hole suppressed:	si 206 (octal) or si 134 (decimal)

SCOPES

Selection of scope displays. The computer program will specify by the address of the si instruction a particular "scope intensification line." Any scope connected to the selected line will display a point on each of the succeeding display instructions. A bank of toggle switches at each scope unit permits the connection of the scope to any one or more of the 16 intensification lines.

Scope deflection. The left-hand 11 digits of AC 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 horizontal deflection of all scopes to a value corresponding to the contents of digits 0-10 of AC.

rc-- — Sets the vertical 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. 100 microseconds will elapse before the computer performs 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 vertical lines. The horizontal 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 vertical 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 vertical line may be displayed simply by a single si to set the horizontal deflection followed by a succession of rc instructions to set up the vertical deflections and display the individual points on the vertical line. After each rc, 100 microseconds must elapse before the computer can perform the next in-out instruction.

si addresses for scope lines. The si addresses designating scope intensification lines are as follows:

scope line	octal address	decimal address	scope line	octal address	decimal address
0	si 600	si 384	8	si 610	si 392
1	si 601	si 385	9	si 611	si 393
2	si 602	si 386	10	si 612	si 394
3	si 603	si 387	11	si 613	si 395
4	si 604	si 388	12	si 614	si 396
5	si 605	si 389	13	si 615	si 397
6	si 606	si 390	14	si 616	si 398
7	si 607	si 391	15	si 617	si 399

TABLE 1. THE "FL" FLEXOWRITER CODE

Alphanumerical Sequence

Lower Case	Upper Case	Character 123456	Decimal Value	Octal Value	Lower Case	Upper Case	Character 123456	Decimal Value	Octal Value
a	A	000110	6	6	0	°	111110	62	76
b	B	110010	50	62	1	1	010101	21	25
c	C	011100	28	34	2	2	001111	15	17
d	D	010010	18	22	3	3	000111	7	7
e	E	000010	2	2	4	4	001011	11	13
f	F	011010	26	32	5	5	010011	19	23
g	G	110100	52	64	6	6	011011	27	33
h	H	101000	40	50	7	7	010111	23	27
i	I	001100	12	14	8	8	000011	3	3
j	J	010110	22	26	9	9	110110	54	66
k	K	011110	30	36	|	_	000101	5	5
l	L	100100	36	44	space bar		001000	8	10
m	M	111000	56	70	=	:	001001	9	11
n	N	011000	24	30	+	/	001101	13	15
o	O	110000	48	60	color change		010000	16	20
p	P	101100	44	54	.	)	010001	17	21
q	Q	101110	46	56	,	(	011001	25	31
r	R	010100	20	24	-	"	011101	29	35
s	S	001010	10	12	back space		100011	35	43
t	T	100000	32	40	tabulation		100101	37	45
u	U	001110	14	16	carr. return		101001	41	51
v	V	111100	60	74	stop		110001	49	61
w	W	100110	38	46	upper case		111001	57	71
x	X	111010	58	72	lower case		111101	61	75
y	Y	101010	42	52	nullify		111111	63	77
z	Z	100010	34	42					

TABLE 2. THE "FL" FLEXOWRITER CODE

Binary Numerical Sequence

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

REFERENCE LIST OF si ADDRESSES

All of the presently assigned si addresses are listed below in numerical sequence, together with very brief notations of their functions.

AD = Auxiliary magnetic drum
BD = Buffer magnetic drum
CA = Camera
FI = Flexowriter input unit
FO = Flexowriter output unit
MT = Magnetic tape
SC = Scope intensification line
ST = Stop

Address Oct.(Dec.)	Unit Class	Ser.	Mode	Address Oct.(Dec.)	Unit Class	Ser.	Mode
0 (0)	ST	-	stop comp.	137 (95)	MT	3	rcd rev
1 (1)	ST	-	cond. stop	200 (128)	FI	0	l-by-l
100 (64)	MT	0	rer fwd	202 (130)	FI	0	w-by-w
101 (65)	MT	0	rer rev	204 (132)	FO	0	l-by-l;supp 7
102 (66)	MT	0	read fwd	205 (133)	FO	0	l-by-l;no sup
103 (67)	MT	0	read rev	206 (134)	FO	0	w-by-w;supp 7
106 (70)	MT	0	rcd fwd	207 (135)	FO	0	w-by-w;no sup
107 (71)	MT	0	rcd rev	211 (137)	FI	1	l-by-l
110 (72)	MT	1	rer fwd	213 (139)	FI	1	w-by-w
111 (73)	MT	1	rer rev	215 (141)	FO	1	-
112 (74)	MT	1	read fwd	220 (144)	FI	2	l-by-l
113 (75)	MT	1	read rev	221 (145)	FI	2	b-by-l
116 (78)	MT	1	rec fwd	222 (146)	FI	2	w-by-w
117 (79)	MT	1	rec rev	223 (147)	FI	2	b-by-w
120 (80)	MT	2	rer fwd	225 (149)	FO	2	-
121 (81)	MT	2	rer rev	230 (152)	FI	3	l-by-l
122 (82)	MT	2	read fwd	231 (153)	FI	3	b-by-l
123 (83)	MT	2	read rev	232 (154)	FI	3	w-by-w
126 (86)	MT	2	rcd fwd	233 (155)	FI	3	b-by-w
127 (87)	MT	2	rcd rev	235 (157)	FO	3	-
130 (88)	MT	3	rer fwd	500 (320)	CA	-	-
131 (89)	MT	3	rer rev	600 (384)	SC	0	-
132 (90)	MT	3	read fwd	601 (385)	SC	1	-
133 (91)	MT	3	read rev	602 (386)	SC	2	-
136 (94)	MT	3	rcd fwd	603 (387)	SC	3	-

Address Oct.(Dec.)	Unit Class	Ser.	Mode	Address Oct.(Dec.)	Unit Class	Ser.	Mode
604 (388)	SC	4	-	617 (399)	SC	15	-
605 (389)	SC	5	-	630 (408)	ST	-	unit stop
606 (390)	SC	6	-	700 (448)	AD	-	rd: -
607 (391)	SC	7	-	701 (449)	AD	-	rd: new gp
610 (392)	SC	8	-	702 (450)	AD	-	rd: new addr
611 (393)	SC	9	-	703 (451)	AD	-	rd: gp& addr
612 (394)	SC	10	-	704 (452)	AD	-	rc: -
613 (395)	SC	11	-	705 (453)	AD	-	rc: new gp
614 (396)	SC	12	-	706 (454)	AD	-	rc: new addr
615 (397)	SC	13	-	707 (455)	AD	-	rc: gp& addr
616 (398)	SC	14	-				

REFERENCES

Further details concerning the WWI system may be found in the following documents:

E-466 Operation of the In-Out Element
E-469 Display Facilities in the Final In-Out System
E-473 Input Program, September, 1952
E-479 Basic Conversion Program, September, 1952
E-482 Operation of Magnetic Tape Units
E-499 Operation of Block Transfer Orders

M-1516 Use of the Interim Magnetic Tape Print-Out Equipment
M-1591 Special Input Program, T-2000
M-1624-1 Short Guide to Coding and Whirlwind I Operation Code

R-127-1 Whirlwind I Block Diagrams
R-180 Functional Description of the Whirlwind I Computer

being written { Paper Tape Facilities; Auxiliary Magnetic Drum; Buffer Magnetic Drum }

Signed: P. R. Bagley

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