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SUBJECT: OPERATION OF IN-OUT CONTROL

To: Mathematics and Applications Group, Block Diagram Group, Input-Output Group, and Analysis Group of Project 6889

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Date: August 30, 1951

Abstract: In the past few months a plan for the tie-in of external equipment to the computer has been developed which appears to be acceptable from the point of view of both the amount of equipment involved and the desires of a programmer. The purpose of this memorandum is to describe the in-out control which will be constructed and to explain its operation as a unit of the in-out element. To accomplish this it is necessary to present a brief description of the in-out orders, in-out element, and the external units. The basic principles of this system were presented in M-1167. The main variations which have been incorporated are: The use of a counter to count delays required by IOS and external units. The transfer of a sixteen (16) digit word with each rc and rd when using magnetic tape units. And the incorporation of another mode of operation with magnetic tape units which allows the recording of a new block of information to begin at exactly the same place on tape that an old block began.

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1. INTRODUCTION

Few of the terminal devices considered for integration with the WWI computer were designed specifically for such an application, so many of these devices would require complicated controls to perform data transfers with just a single initiation signal from the computer. While these controls could be built, considerable simplification is obtained by using computer subprograms to perform some of these control functions. Therefore to speed the completion of the in-out system and to reduce the equipment contained in it, the computer is burdened with many of the control functions necessary to accomplish an in-out operation. Thus, in the system to be described in this memorandum, the control of a complete in-out operation involves three factors: computer subprograms, the in-out element, and external unit controls.

A distinction should be made for the purposes of this memorandum between an in-out process and an in-out operation. The in-out process is the actual reading or recording done by the external unit and involves the transfer of one character of information between a buffer storage unit (the in-out register) and the external unit. The in-out operation includes one or more in-out processes and those actions that are commanded by the computer in preparing for and in finishing up after the in-out process itself. Thus in-out control (IOC) and the external unit controls are in command of in-out processes once they have been initiated, but the computer subprogram has control of those actions necessary for the preparation and completion of the in-out operation.

The whole input-output system may be divided into two groups: The in-out element (IOE, 400) and the external units (EU, 500). IOE coordinates the operations of the computer and the external units by:

(a) Selecting external units and their modes of operation.

(b) Providing buffer storage for data being transferred between the computer and external units.

(c) Stopping the computer if it attempts to get ahead of a remote unit.

(d) Giving an alarm if a remote unit gets ahead of the computer program.

(e) Synchronizing internal and external pulse signals.

(f) Allowing certain external units to operate through several steps or in-out processes in response to a single computer order.

(g) Counting delays needed between steps in the in-out operation.

External units may be grouped in two ways: readers or recorders, and line-by-line or block-by-block units. A line-by-line unit reads or records one character or line of data each time it is started, stopping after each in-out process. Block-by-block units start and continue running when selected, and if they provide their own initiation pulses, they will read or record information at approximately regular intervals until stopped. The computer must keep up by performing its preparatory and completion actions before and after each in-out process.

The in-out process (including the location of the proper space to read or record) is time consuming and slow when compared to the speed of the computer, therefore it is desirable to have the in-out operation performed in a manner which allows the computer to perform other operations while the in-out process is taking place. With this objective in mind a brief general picture of the transfer of information between the computer and external unit follows. An order from the computer selects the external unit and its mode of operation. If the unit selected is a reader, the order also starts the reader and initiates the in-out process. The reader will transfer data to the in-out register (IOR, 403) as soon as possible. While this in-out process is taking place, the computer may perform any operations which are desired and do not require the participation of other external units. If the reader is a line-by-line unit the computer program can remove the information in IOR with a second order anytime after the in-out process has been completed, except if the reader is a block-by-block unit the computer program must remove the information before the reader is ready to read a second piece of information into IOR. If a line-by-line recorder was selected, the record process is not initiated because another order is necessary to place the information to be recorded in IOR. The order which places the information in IOR also initiates the record process, and the computer program may contain as many operations as desired before and after this order. With block-by-block recorders (magnetic tape) the order which selects the unit also starts it to allow it to reach operating speed, to form the space between blocks, and to record a block mark. This may require 15 milliseconds and while it is taking place the computer may be performing other orders. If the block-by-block recorders initiate their recording, sometime after the block mark is recorded and before the recorder is ready to record again the order which places the information to be recorded in IOR must take place. This placing of information in IOR must continue as long as the recorder is running, but while the actual recording process is taking place the computer may be performing other orders.

It is seen that the computer program must place the proper information in and remove it from IOR during recording and reading, and with block-by-block units it must perform this within certain time limits. It must also arrange information read from external units in the desired manner, place it in the proper place in storage, keep track of the amount of information being transferred, and perform all checks on the transfer which are desired. The programmer must consider both the speed of the computer and of the external units in the preparation of programs to obtain the maximum use of the time available during in-out processes.

2. IN-OUT ORDERS

The transfer of information between the computer and external units is accomplished by three orders:

si - select in-out operation

rc - record

rd - read

Those who are familiar with the in-out instructions originally assumed and described briefly in the Short Guide to Coding and in some detail in R-180 will note that rc and rd are essentially unchanged, but si replaces three previous orders: rs, rf, and rb. The sequence of events, probable timing, and tentative assignment of CPO units for the in-out orders are shown on the attached traffic diagrams SA-50261, SA-50262, and SA-50263 and drawing SB-50139-1. These orders are discussed in more detail in the following sections.

Although other computer orders may be interspersed, the in-out orders must occur in the proper sequence. These sequences are:

(a) For line-by-line readers:

Sequence	Effect
si (read)	si (read) - selects and starts desired
rd x	line-by-line reader which then places
si (read)	information in IOR and stops.
rd x	rd x - places information that is in IOR in
.	storage register x.
.	
.	
si (read)	
rd x	

(b) For block-by-block readers:

Sequence	Effect
si (read)	si (read) - selects and starts desired
rd x	reader which then places information in
rd x	IOR at approximately regular intervals.
.	rd x - places information that is in IOR in
.	storage register x, and prepares IOR
.	and IOC for next transfer of information
rd x	from EU to IOR which follows automatically
si (stop)	unless EU is stopped.
	si (stop) - Because any si order stops all external units which may be operating, this order is required only if another external unit is not to be selected immediately.

It may be any si order which does not start an EU, i.e., any si order which selects a line-by-line recorder. It stops any unit which is running.

(c) For all recorders:

Sequence	Effect
si (record)	si (record) - selects recorder, and if
rc x	block-by-block unit is selected, starts
rc x	unit and sets IOC to form block space and
rc x	record block marker.
.	rc x - places information that is in storage register x
.	in IOR to be recorded, and starts line-to-line
.	
rc x	units which stop after each recording process.
si (stop)	si (stop) - Identical to si (stop) order
	used with readers. It stops any unit
	running and therefore is needed only after
	recording with a block-by-block unit.

2.1 si - Select In-Out Operation

The detail of events and traffic diagram for the si order are shown on drawings SB-50139-1 and SA-50261. The purpose of the si order is manifold. It switches the computer from one external unit to another and performs other functions depending on whether the new unit is a reader or a recorder. If the new unit is a reader the si order prepares for reading and starts those readers which do not run all of the time selected (line-by-line units) so that a read process may take place. If a recorder is selected, the record process must not take place until after the rc order places the information to be recorded in IOR, but, if selected, magnetic tape recorders are allowed to start and after a delay are allowed to record block marks.

The si order must first make sure that the last recording process is complete (a reading process is always complete after the last rd order). A special sensing pulse checks the interlock in IOC for this reason. After this sensing the old EU is dismissed by clearing the in-out switch and sending a stop pulse to any unit requiring one.

The new EU is selected by transferring the address (right 8 digits) of the si order to the in-out switch (IOS). The si order itself must make use of the new setting of IOS, and for this reason the si operation is interrupted for a specific length of time to permit completion of the selection by IOS. The actions that depend on the new selection are the setting of IOC and the starting of the new EU. For example, for all input units IOC is set to allow a reading process to take place and "start" commands are sent to line-by-line readers since the information should be transmitted into IOR before an rd order is allowed. If the rd order were to initiate the read process the computer would have to wait during the read order for the completion of the reading process. Detailed settings of IOC are discussed in section 4.3.

Certain output units require two pieces of data for each output process, e.g., both the horizontal and the vertical deflections of scope must be set for the display of each spot. The si order provides this second piece of information in the case of the display scopes by transferring the content of AC to the horizontal decoder on every si order. No harm results if the new EU is not a scope.

2.2 rd - Read

The detail of events and traffic diagram for the rd instruction which serves the purpose of transferring to storage the information placed in IOR by the external unit are shown on drawings SB-50139-1 and SA-50262. The rd order first senses to see if the external unit has completed its transfer of information to IOR, and if the transfer has not been completed the computer is stopped until completion. After sensing and possibly waiting, the rd order transfers the information in IOR to the storage register specified by the rd address. The usual transfer check procedure may accompany this transfer. If a line-by-line reader is being used, this transfer would complete the necessary duties of rd, but if a block-by-block reader is being used, IOR and IOC must be prepared in anticipation of another rd order to follow. Because of this, IOR will always be cleared and IOC will be set after the transfer to storage takes place. This will also prevent the next rd (but not si) from occurring before EU reads the next information into IOR.

When operating with a magnetic tape unit a 16-digit word is formed in IOR by IOC before the rd order is allowed to remove the information from IOR. Thus from the computer's point of view, magnetic tape units always handle 16-digit words, but the paper tape units deliver only one six (6) digit character at a time and the computer program must arrange these characters in the desired manner.

If rd orders appear too close together, the computer must stop and wait for the EU to catch up, but if the rd orders are spaced too far apart so that an EU operating in block-reading supplies an initiation pulse for its second word before an rd order occurs to remove the first word from IOR, an in-out alarm occurs. In line-by-line reading the external unit does not care if the time between rd orders is large.

2.3 rc - Record

The actions which take place on the rc order and their timing are shown on drawings SB-50139-1 and SA-50263. The rc order will sense the IOC interlock to insure that EU has completed any previous recording. It then prepares to record the next word by clearing IOR and the vertical decoder, transferring the contents of the storage register specified by the address section of the rc order to IOR and the vertical decoder, checking the transfer to IOR, and setting IOC for the particular record operation selected.

If rc orders are spaced too close together, the computer will be forced to stand idle. If they are spaced too far apart, the operation with various units are affected in different ways. For block-by-block recorders supplying their own initiation pulses (magnetic tape and film recorders) an in-out alarm is given, while line-by-line recorders are not affected by a slow rate of rc orders.

A program should never be written with an rc order preceding or following an rd order without an si order occurring between them, because each si order selects either a reader or recorder, never both, and therefore must be followed by either rc or rd orders, but never both.

3. EXTERNAL UNITS (EU)

The in-out units whose incorporation into the WWI system has been accomplished on a temporary basis or is being actively undertaken, are the following:

(1) Magnetic tape units. Each can be a reader recorder.

(2) Paper tape units, including

(a) Punches
(b) Printers
(c) Mechanical Readers
(d) Photoelectric Readers

(3) Oscilloscopes

(4) Scope Cameras

The following in-out units have been considered in the design of the in-out element, but their incorporation into the WWI system is not being actively undertaken:

(1) Eastman Kodak film units.

(2) Punched card equipment.

(3) Manual intervention registers.

(4) Analog units.

(5) Asynchronous inputs and outputs requiring buffer storage.

(6) Teletype line.

(7) Marginal checking control.

(8) Bells and lights for special indications.

Magnetic drums were also considered in the design of IOE, but current thinking indicates that possibly it will be desirable to operate them in a manner sufficiently different from other external units to warrant separate controls. This, of course, does not preclude the possibility of making use of some of the equipment found in IOE.

The following paragraphs give brief descriptions of those external units which will be included in the initial installation of the in-out system. The connections between external units and IOS, IOC, and the control matrix (CM) are shown on the attached drawing (SB-50138-1), In-Out System-External Units (500).

3.1 Magnetic Tape Units

The tapes used in the magnetic tape units can accommodate 6 channels of information. The tape will be erased (cleared) by biasing it to saturation in one direction: a 0 will be recorded by leaving leaving a spot in this state, a 1 by saturating a spot in the other direction. This agrees with the binary philosophy of WWI and will mean the reading of only 1's from tape. A character of four binary digits will be read in parallel from four of the six channels, the other two channels being used for index and block marks. The channel used for index marks, say #6, will have properly spaced 1's recorded wherever the tape is free of blemishes. In subsequent use of the tape, a character will be recorded only in line with these index pulses. The channel used for block markers, say #5, has a 1 recorded at the beginning of each block. This is done automatically by the si order which selects a magnetic tape unit for recording a new block.

Magnetic tape units have several modes of operation. These modes, which are selected by the setting of IOS with the address section of the si order are:

(a) record - Always followed by one or more rc orders which takes from storage a 16-digit number and places it in IOR to be recorded in 4 characters on magnetic tape. The si order which selects this mode of operation also forms an inter-block space and records a block mark in channel #5 before the first rc order is allowed to occur. This mode would be used for recording on tape which had been erased and the exact point at which recording begins is not important as long as a sufficient inter-block space has been formed.

(b) re-record - Identical to the record mode except the si order does not form an inter-block space or record a block mark, and recording takes place immediately after passing an old block mark. With this mode the rc order may take place any time after the si order and before the first index mark following the block mark is reached. This mode would be used to replace a block of old information with a new block of equal or shorter length.

(c) read forward - Always followed by one or more rd orders to take the 16-digit word formed in IOR and place it in storage. Reading of information into IOR starts as soon as a block mark has been passed. The use of the block marks makes possible rapid and simple location of the position of the tape because no matter where the tape is when started, the first word transferred to IOR in a reading process will be the first word of a block.

(d) read reverse - Identical to read forward except the 4 characters which form the 16 digit word will not be arranged in the proper sequence. Therefore, this mode will probably be used mainly for counting blocks on tape to locate desired information which would then be read with the tape moving forward.

(e) rewind - The exact operation of this mode has not been established, but an order which will rewind the tape to the beginning is intended.

Further details on the operation of magnetic tape units are given in section 5.0.

Magnetic tape units are the only units for which present plans call for the handling of 16-digit words with each rc and rd order although this could be done for other units. Also because magnetic tape units are block-by-block units and initiate their own read or record pulses, the computer must supply information to or remove it from IOR within definite time limits. These limits have not been definitely determined, but approximately 1.3 milliseconds will be required per 16-digit word with about 300 us between the reading or recording of the last group of 4 digits in a word and the first group of the next word.

3.2 Paper Tape Units

Paper tape units are used at present with the computer by means of temporary operations (qr, qp). Their operation and coding have been described extensively (E-380, M-1067, and M-1084), but for the present purpose, only a few salient features are important.

With the exception of the photoelectric tape reader, which will be discussed last, these units are all line-by-line units. The paper tape has seven information channels (i.e., seven hole positions across the tape in addition to an indexing channel, called the feed-out hole. A character is recorded (punched) or read only in line with a feed-out hole, which is thus seen to correspond to the index channel on the magnetic tape. Of the seven channels, one (the reference channel) is used to indicate the line in which a character has been recorded, and the remaining six are used for data. At present, a word is recorded in three characters of 5,5 and 6 digits respectively.

Each si order which selects a mechanical paper tape reader starts the reader. The reader proceeds to the first line on the tape which contains a hole in the reference channel and reads the six-digit character punched in that line into IOR. After the reader has placed the character in IOR it stops, and an rd order may remove this character at any time.

Recording with paper tape equipment (i.e., punching and/or printing) is also done line-by-line. The si order selects the unit while the rc order places the information in IOR and initiates the recording process. When the process has been completed, the recorder sends a pulse to IOC which clears the interlock and allows another in-out operation to take place.

The photoelectric reader operates block-by-block. When an si order selects the reader, it starts and runs until dismissed by another si order. Each feed-out hole which is reached generates a pulse which senses the reference channel. If this channel contains a "1", indicating that a character has been recorded in the other six channels, the character is read into IOR and the interlock in IOC is cleared to signify that the read-in has been completed. An rd order may now remove the character from IOR. The time between successive feedout holes is approximately 7 milliseconds.

3.3 Display Oscilloscopes

For scope displays information must be supplied for both the horizontal and the vertical deflections of the cathode ray beams. On si, the contents of AC are placed in the horizontal decoder, and on rc, which may follow at any time, the contents of the storage register corresponding to the address section of the rc order are placed in the vertical decoder. The rc order also initiates the delay required for the deflection-amplifier transients to die out, and at the end of this delay the electron beam of the selected scope is turned on. After the intensification delay has been counted, the electron beam is turned off and the interlock in IOC is cleared.

If scopes having electrostatic deflection are used separately or in parallel with a magnetic-deflection scope, no delay is required for the deflection-amplifiers, but the intensification should last for a longer time. This is accomplished by immediately intensifying these scopes after reading into the vertical decoders, and leaving the beam on while the delays for the magnetic-deflection amplifiers and for the intensification of the magnetic-deflection scopes are taking place.

3.4 Scope Camera

The automatic camera used for taking pictures of scope displays is described in M-1166. Since the only action performed is that of framing, only a single order (si) is required to control this unit. The si order will advance the film one frame and then send a pulse to IOC indicating that the operation has been completed and that other in-out operations may begin.

4. IN-OUT ELEMENT (IOE, 400)

The purpose of the in-out element is to handle the data traffic between external units and the computer proper.

The functions of IOE, which were listed on page 3 may be divided into three groups. One is to select the external unit with which data is to be communicated. The second role of IOE is the temporary (or buffer) storage of information being transmitted. Finally, IOE provides the necessary controls for harmonizing the actions of the computer and the external unit selected. According to these groupings IOE can be divided into three parts, which are dealt with below.

4.1 In-Out Switch (IOS, 420)

The in-out switch is an 8-digit register with connections to and from the computer bus. This register operates a crystal matrix which decodes the words read into the register into a large number of outputs (256 maximum possible). Selection of an external unit in a particular mode of operation is accomplished by the transfer to IOS of an 8-digit character (or address), which is the code of the desired selection.

A given setting of IOS may energize several output lines, and certain output lines are energized by more than just one particular IOS content. For example, if one wants to record on magnetic tape unit #2, the corresponding setting of IOS would raise the potential of the following, and only the following output lines.

1. MAGNETIC TAPE UNIT #2
2. ALL MAGNETIC TAPE RECORDERS
3. ALL OUTPUT UNITS
4. ALL READERS, CAMERA, REWIND AND MAGNETIC TAPE RECORDERS NOT RE-RECORDING
5. ALL MAGNETIC TAPE RECORDERS NOT RE-RECORDING
6. ALL MAGNETIC TAPE UNITS.

The description of a given line is a listing of all selections for which that line would be energized.

The flip-flops of IOS have output gate tubes to permit the checking of the transfer from storage to IOS. Note, however, that the checking loop includes only the flip-flops of IOS, not the switching matrix also. Complete checking of the selection would incur considerable complication of equipment, and since matrix operation has proved very reliable in WWI experience, such checking is being omitted in the interest of simplicity.

4.2 In-Out Register (IOR, 403)

The purpose of the in-out register is to store the word the program has supplied for recording until the selected recorder calls for it and to store the word read from the selected reader until the program removes it. IOR also has facilities for shifting. The IOC controls shifting in the IOR to form 16-digit words from 4-digit characters when reading from magnetic tape and for dividing 16-digit words into 4-digit characters when recording on magnetic tape. The shifting facilities will also be used to accommodate serial external units. Additional gate tubes an provided for reading to the check bus to check transfers between IOR and other parts of the computer.

4.3 In-Out Control (IOC, 410)

The in-out control finds the common denominator in the timing of the computer, of external units, and of the in-out switch. The last five of the seven functions of IOE listed on page 3 and listed again below are performed by IOC.

(a) Synchronization of internal and external pulse signals.
(b) Stopping the computer if it attempts to get ahead of an external unit.
(c) Giving an alarm of an external unit gets ahead of the computer program.
(d) Counting delays needed between steps in an in-out operation.
(e) Allowing certain external units to operate through several cycles or in-out processes in response to a single computer order.

Each of these five functions can be generally assigned to one of the following five components found in IOC:

Synchronizer (415)
Interlock (413)
Alarm Control (414)
IOC Counter (411)
IO Delay Counter (404)

The sixth component, which completes IOC, is reset control (412). This unit receives information from the setting of IOS and controls the setting of the other components of IOC so that they will operate in the manner desired for the particular external unit selected by IOS. A more detailed discussion of the purpose and operation of these components is given below. The block diagram of IOC is shown on drawing D-50053-1.

4.31 <u>Synchronizer (415)</u>

The synchronizer serves the purpose of taking certain pulses which originate in external units and synchronizing them with computer pulses. These pulses may indicate that the external unit is ready for or that it has completed an in-out process, or that an alarm has been produced. For example, all readers and magnetic-tape recorders send a pulse when they are ready to read or record. Paper tape printers and punches and the scope camera send a pulse when they are through recording or changing film. The scopes send no pulses to the synchronizer because they receive their initiation and completion from IOC and the only pulse which they send to IOC (intensification delay) originated in IOC as a synchronous initiation pulse. The pulses which indicate that the external unit is ready for or has completed an in-out process enter the synchronizer as asynchronous initiation pulses. The pulses which are to generate an alarm enter as asynchronous alarm pulses and also go to alarm control so that the synchronized pulse will be certain to find alarm control set to give an alarm.

The synchronizer consists of two flip-flops, FF01 and FF02, and two gate tubes, GT01 and GT02. Each asynchronous pulse from external units sets FF01 to the 1 position turning on GT01. The next RPG end-carry will pass through GT01 and set FF02 to the 1 position turning on GT02. The first LFSP after the RPG-EC will pass through GT02 becoming scope sync #2; after a short delay it is used as a synchronized external-unit pulse and to reset FF02 and FF01 to the 0 position preventing other LFSP and RPG-EC pulses from passing.

The delay of the LFSP after it passes through GT02 serves two purposes. It provides a short time between scope sync #2 and the synchronized EU pulse so that the latter may be viewed on scopes, and prevents the pulse from trying to reset FF02 before the pulse has had time to pass completely through GT02. (This latter delay is probably inherent in the equipment). The short delay shown between GT01 and FF02 serves no purpose in the mode just described, but was inserted to allow the substitution of LFSP pulses for RPG-EC pulses. The use of RPG-EC's synchronizes the pulses from the external units with computer restorer pulses. This feature is useful in observing computer action following an in-out process, but it introduces a delay of from one to 30 microseconds between the asynchronous initiation from the external unit and the synchronous pulse. This variation in timing or jitter may not be harmful with presently considered external units, but units with more critical timing may not be able to tolerate it.

4.32 Interlock (413)

The interlock is the unit which prevents the computer program from getting ahead of the external unit which is operating. This is accomplished by having each in-out order sense the interlock and if the program is trying to get ahead of the external unit, the sense pulse will stop the computer. When the external unit has caught up, the completion pulse restarts the computer.

The interlock FF01 is set by every rc and rd order and by those si orders which must be followed by an in-out process or delay before another in-out order. It is cleared by each completion pulse from the IOC counter. The only time an in-out order should not be stopped when the interlock is set, is when an si order follows an rd order. This is due to the fact that each rd order completes an in-out operation, and prepares for another rd order in case a block-by-block reader is being used. The rd which may follow must be held up until an in-out process takes place, but the si order which would stop the unit, must not be held up. The proper sensing of the interlock is accomplished by sending a pulse from the control matrix to GT02 at the beginning of each rc and rd order. If the interlock is set (in the 1 position) the pulse will pass through the GT and become a stop-clock pulse. If an si order is given, a pulse is sent to GT01 which is controlled by IOS. If IOS has selected a recorder, the pulse passes through and senses GT02 as for an rc or an rd order. If IOS has selected a reader, GT02 is closed and the sense pulse is blocked.

If the computer has been stopped by a pulse from the interlock, the completion pulse which usually clears the interlock must start the computer. Therefore, each stop-clock pulse which originates from the interlock also clears the interlock so that the completion pulse will then pass through GT03 to start the clock.

The interlock permits the computer to continue its program during the recording or reading processes. So for the most efficient use of the time between the recording or reading of two consecutive characters the length of the computer program between in-out orders should equal that required for the respective in-out process.

If this program is shorter the computer will be idle during the rest of the time interval, but if this program is longer, the in-out unit will wait if it can, or sound an in-out alarm if it cannot wait, as discussed in the next article.

4.33 Alarm Control (414)

Units which begin an in-out process only upon or after a specific command to this effect from the computer, can never get ahead of the computer program. In this group are:

(a) Mechanical paper tape readers
(b) Paper tape punches and printer
(c) Scopes

The block-by-block units which initiate their own reading or recording processes must read or record when the proper position has been reached on the tape regardless of computer action; among such units are:

(a) Magnetic tape units
(b) Photoelectric paper tape readers

If these units start a reading or recording process before the computer program has prepared for this process, an alarm must be given. This is accomplished by alarm control.

Each of the external units which can get ahead of the computer sends an asynchronous initiation pulse to IOC when it is ready to read or record. This pulse is synchronized and sent to the gate tubes* GT01 and GT02 in the alarm control. If FF01 is in the 1 (set) position, GT02 is open and an in-out alarm is given, if in the 0 (cleared) position GT01 is open and the synchronized EU pulse gives a synchronous initiation which performs the actual reading or recording in the external unit. The alarm control is cleared by an in-out order each time the interlock is set, and it is set by a completion pulse from the IOC counter at the same time that the interlock is cleared or that the clock is started (if it has been previously stopped by IOC). Therefore a pulse from the external unit indicating that it is ready to read or record again will give an alarm if an in-out order has not occurred since the previous completion pulse was produced.

4.34 IO Delay Counter (404)

The delay counter was incorporated in IOC to provide the facility of accurately and reliably counting the delays required by different external units and IOC. At present these delays include:

(a) The delay required by IOS to complete its selection.
(b) The delay to form an inter-block space with block recorders.
(c) The time the recording gate generators should be on when recording on magnetic tape.
(d) The delay for the magnetic-deflection scope amplifiers.
(e) The time the scope intensification gate generators are on.

These delays may be divided into two groups; those which are initiated directly by an in-out order, and those initiated by external units. Therefore, the counter may be started in two ways, by the in-out order sending a pulse through reset control, or by a pulse from the external unit. If the external unit cannot send a pulse already synchronized with computer pulses, it first goes to the synchronizer. Because of this, all pulses from the synchronizer which do not give an alarm, start the counter. If no specific delay is desired, the counter will contain all one's and a short (2-5 usec) delay will result before an end-carry is sent to the control counter and back to reset control.

The delay counter consists of 16 flip-flops. Fourteen of these flip-flops, FF's01, are connected to form a conventional counter. One flip-flop, FF02, controls the supply of pulses to the 14-digit counter. When FF02 is in the 0 position no pulses can go to the counter flip-flops, but when it is in the 1 position GT02 will be open and 1-mc pulses will pass to the counter. The end-carry from the 14-digit counter sets FF02 back to the 0 position cutting off the supply of 1 mc pulses, and sets FF03 to the 1 position allowing the next LFSP to pass through GT03. The LFSP through GT03 is used to reset FF's01 to the one position, to reset FF03 to the zero position shutting of other LFSP's, and as scope sync #3. After a short delay, this pulse is used as the delay-counter end-carry and is sent to the control counter and to reset control. The reason for having FF03 and not using the end-carry from the 14-digit counter as the delay-counter end-carry is that the end-carry from the 14-digit counter will have to pass through 14 gate tubes and will be delayed more than half a microsecond. FF03 permits the delay-counter end-carry to be coincident with computer clock pulses. Also without FF03, LFSP's would have to be counted instead of 1 mc pulses so it would not be possible to count delays as accurately.

The delay counter is normally in the all one's condition because it resets itself after each end-carry. When a delay is required, the delay counter may be set in several ways; by a pulse during an in-out order, by the end-carry from the delay counter itself, or by a pulse sent from an external unit. The delay-counter-reset timing will be discussed in section 4.36.

4.35 IOC Counter (411)

The control counter allows certain external units to operate through several cycles or in-out processes in response to a single computer order. It performs its task by counting and properly distributing the end-carries from the delay counter which signify that one step or in-out process has been completed. The end-carries from the delay counter must be distributed in two ways. Until the proper number of processes have been performed, they must give a cycle pulse to indicate that the delay is over and the next step or process may begin. After the proper number of processes have been performed, they must produce a completion pulse so that the next in-out order may proceed. The completion pulse (end-carry from IOC counter) clears the interlock, starts the computer if the computer stopped for the in-out process, sets the alarm control, and goes to those EU requiring a completion pulse.

The control counter consist of two flip-flops, FF01 and FF02, and four gate tubes. GT01 and GT02 are connected to the 1 side of FF01 and FF02 respectively and form a conventional counter giving an end-carry when both flip-flops contain one and an add pulse is supplied. This end-carry serves as a completion pulse. GT03 and GT04 are connected to the zero sides of FF01 and FF02 respectively. Each add pulse to the counter also goes to GT03 and each pulse through GT01 which compliments FF02 goes to GT04. The outputs of these two gate tubes are mixed and if either flip-flop of the counter contains zero (counter contains 0, 1, or 2) a pulse appears on the output. This output serves as a cycle pulse and by passing through two delays produces four pulses to shift IOR. While it is not always necessary to shift the contents of IOR each time a cycle pulse is produced, the shifting pulses sent to IOR are not harmful and could be gated off by IOS if desired.

With the exception of magnetic tape units and scopes only one delay is desired per in-out order so in such cases the control counter is preset to all ones (3) and no cycle pulses are produced. The settings of the control counter required by magnetic tape units and scopes and the functions performed by the cycle pulses are listed below.

(a) Setting of zero - for si orders selecting a magnetic tape reader and for rc and rd orders following the selection of a magnetic tape unit. Following each of the above orders there must be four in-out processes before a completion pulse is produced which will permit the next in-out order to proceed. The setting of zero therefore allows three cycle pulses to occur, the IOR being shifted four places on each cycle. After the fourth cycle the completion pulse is produced.

(b) Setting of two - for si orders selecting a magnetic tape recorder to record, and for rc orders when referring to the scopes. For magnetic tape recorders on an si order a relatively long delay must be counted to form the inter-block space and then a second delay must be counted while recording a block mark. For scopes on an rc order a delay is required for the amplifiers to stabilize after a word is read into the vertical decoder if magnetic-deflection scopes are used, and after this delay a second delay is counted while the scope intensification is taking place.

For si orders selecting a magnetic tape recorder for re-recording no delays are counted so the control counter setting is immaterial. The order performs a selection only and is complete within itself. Therefore the interlock is not set and the rc order which is to follow may come immediately setting the control counter to zero (see (a) above). Actually for re-recording on magnetic tape the counter is set to zero by the si order, but as shown this causes no trouble.

The control counter is preset to contain all ones (3) by each si order when the IOS delay count is started. It is also preset by each end-carry (completion pulse). Thus the counter will be in the all one's position for those units which do not require some other setting and the counter is reset only by those in-out orders which require settings different from the all one's position. Settings are controlled by reset control through the preset, the "0"-reset, and the "2"-reset lines. These allow the counter to be set to 3,0, and 2 respectively.

4.36 IOC Reset Control (412)

Reset control receives pulses from the following sources; the control matrix during in-out orders, the end-carries from the control counter and delay counter, and from external units. The destination of these pulses is controlled by the setting of IOS.

Each si order supplies an IOS-delay start pulse after transferring the address section of the si order to ICS. This pulse stops the computer, clears the interlock if it was set, presets the delay counter and control counter to contain all ones, resets the delay counter for a short (5-20 usec) delay and starts the delay counter. The end-carry from the delay counter will pass through the control counter starting the computer and again preseting the delay and control counters. The next control pulse to IOC is IOC reset (si). This pulse will pass through GT02 setting the interlock and clearing alarm control if a delay or an in-out process is to follow the si order. If ICS has selected a magnetic tape unit, the delay and control counters must be reset. The reset pulse therefore, goes through GT01 and resets the control counter to zero for all magnetic tape units. It also goes to GT03, and if a recorder has been selected to record a new block, it sets the control counter to two, sets the delay counter for the delay while an inter-block space is formed, goes to magnetic tape control to indicate that a block mark should be recorded after the inter-block space is formed, and starts the delay counter. The end-carry after the delay goes back to reset control and passes through GT04 resetting the delay counter for the delay when the block mark is being recorded.

After the completion pulse from the control counter, the next in-out order may proceed. It will be an rd or rc order and will send an IOC reset (rc and rd) pulse to reset control. This pulse will always set the interlock and clear alarm control because an in-out process must follow. It will also proceed to GT01, GT04, and GT05 to properly set the two counters. If a magnetic tape unit has been selected, GT01 will be open and the reset pulse will set the control counter to zero. If a magnetic tape recorder has been selected, GT04 will be open and the delay counter will be set for the time the recording gate generators should be on. It will also be reset to this value by every end-carry from the delay counter when GT04 is open. When a scope has been selected, GT05 will be the only gate tube open, the control counter will be set to two, the delay counter will be set for the delay required by the magnetic-deflection amplifiers, and the delay count will be started. The delay-counter end-carry will now indicate that the scopes may be intensified. The cycle pulse from the control counter therefore will turn on the selected scope, and will return to reset control to set the delay for the time the scopes are to be intensified and to start the counter. The completion pulse will then turn the scopes off. For all units other than scopes and magnetic tape the counters will be left in the all one's position.

5. OPERATION OF MAGNETIC TAPE UNITS

The operation of external units shown in the drawing, In-Out System - External Units (500), was briefly discussed in Section 3 - External Units (EU). The operation of magnetic tape units and their control is sufficiently complex to warrant further discussion of how the different modes of operation are achieved.

When an si order selects a magnetic tape unit, the unit will be started automatically by magnetic-tape selection control. This will be accomplished by having the energized lines from IOS go directly to the clutch circuits of the different units, or to gate tubes which will allow the start pulse from CM to pass to the proper unit. The lines from IOS will also switch the head of the selected unit so that it will be the only head connected to the gate tubes which communicate with IOR and the proper gate tubes (reading or recording) will be opened depending on the mode selected by IOS. The channel containing index marks, say #6, will always be connected to the pulse generator and will read.

If a recorder has been selected to record a block in a space which does not contain previously recorded information and if the delay counter has been started for the delay necessary to form the inter-block space, FF02 will be in the 1 position to record a block mark, channels 1 to 4 will be connected to GT's 09, and channel 5 will be connected to GT08. The index marker pulses will be sent to GT03 and GT01 but will always find GT03 closed because the line from IOS, Magnetic Tape Readers and Recorders not Re-Recording, will not be energized. GT01 will also be closed until FF01 is set to the 1 position by the cycle pulse from IOC which indicates that the delay has been completed. After this, index-marker pulses will pass through GT01 and become asynchronous initiation pulses. The first asynchronous initiation pulse which goes to IOC starts the delay counter, which has been reset for the recording delay, and it returns to the magnetic tape control as a synchronous initiation pulse. This pulse goes to GT05 and GT06 and will pass through GT05 to turn the recording gate generator GG01 on because IOS has selected a magnetic tape recorder. This will record a 1 in the block-marker channel because FF02 is set to 1 and it will record zeroes in channels 1 to 4, because IOR has just been cleared. After the recording delay has been counted, a completion pulse is produced since the control counter was initially set to 2. This completion pulse will turn the recording gate generator off, set FF02 to 0 to prevent recording additional block marks, clear the interlock so that the next in-out order (rc) may proceed, and set alarm control so an alarm will be given if another asynchronous initiation pulse is given before the rc order. The rc order will place the word to be recorded in IOR, set the interlock, clear alarm control, set the control counter to zero (allowing four in-out processes before the completion pulse), and set the delay counter for the recording delay. The next four index-marker pulses will pass through GT01 in magnetic-tape control and after being synchronized will start the delay counter and return as synchronous initiation pulses to turn the recording gate generator on. Each of the first three end-carries from the delay counter will add one to the control counter, turn the recording gate generator off and shift the contents of IOR four places to put new information in the left four digits of IOR. The fourth end-carry from the delay counter will give a completion pulse from the control counter, which turns the gate generator off and prepares for the next in-out order.

If the unit has been selected to record a block of information in place of another block (re-record), channels 1 to 4 will be connected to GT's 09 as before but channel 5 will be connected to GT04 and will always read. The IOC interlock will not be set so the rc order may follow immediately. Each index marker pulse will go to GT03 and GT01 but will now find GT03 open because the re-record mode has been selected. The index marker pulses passing through GT03 will sense the block-marker channel until a block mark is located. This block-marker pulse will then set FF01 to the 1 position and allow the following index pulses to pass through GT01 and record the information placed in IOR by the rc order. Operation now proceeds in a manner identical to the previously described recording except channel 5 containing block marks is being continuously read and if a second block mark is passed the pulse will pass through GT02 giving an alarm. This prevents recording over a second block. It is the programmers responsibility to make sure that the new block is equal or shorter than the old block. If the new block is slightly longer (approx. 10 words) no alarm will be given but recording will have overflowed into the inter-block space so that errors may occur during subsequent reading.

If the unit is selected to operate as a reader, channels 1 to 4 will be connected to GT's 07 and channel 5 to GT04. The IOC interlock will be set and the control counter set to zero. The index pulses will scan channel 5 until a block mark is found. The block marker pulse will set FF01 to 1 allowing the following index pulses to pass as asynchronous initiation pulses. These pulses will be synchronized by IOC and then will start the delay counter and return through GT06 to read the contents of channels 1 to 4 into the right end of IOR. Because the delay counter was left in the preset or all-ones position the delay is very short (2-5 us). The end-carry to the control counter will shift the contents of IOR four times gradually building up a 16-digit word from 4-digit characters. The fourth delay counter end-carry will not shift IOR, but will clear the interlock to allow the rd order to proceed, transferring the contents of IOR to storage and preparing for another rd order which may follow.

6. PRINTING FROM MAGNETIC TAPE

Operating a Flexowriter printer directly from the computer is inherently a slow process. One possibility for speeding up the computer's task in transferring data from the computer to printed form is to transfer data to magnetic tape and then to print from the magnetic tape.

Flexowriter printers require a 6-digit character while the magnetic tape units handle 4-digit characters. Therefore, at least part of two four digit characters must be used in each printing process.

One of the possibilities for printing from tape would be to record single-word blocks from the computer and then read the tape using the system of drawing SA-50137-1. To print, the tape unit is started, and the tape moves until the first block mark is located. Six digits out of the next two characters are read into the relays associated with the printer, the tape unit is stopped, and the printer is started. When the printer has completed its process, a completion pulse restarts the tape unit, the next block is located, and six digits again placed in the relay storage. The process may be stopped by suppressing the completion pulse from the relays by a Flexowriter character such as "stop for insert" or by a special character utilizing one of the extra digits read from magnetic tape. The recording of single-word blocks may be done at a rate of approximately one every 11 to 16 ms (depending on the delay necessary for the inter-block space) corresponding to from 60 to 90 Flexowriter characters per second. It should be noted that the preponderance of recording time is taken up by the forming of the block space necessary to stop the tape. If additional storage were available with the printer to allow the printer to use more than one 6-digit character from each block recorded on tape, the recording time of each Flexowriter character would be reduced by approximately one half for each doubling of storage.

An alternative to stopping the tape after recording each word would be to have the index marks spaced about 1/4 inch apart on the tape and to record opposite every mark. This spacing would permit stopping between marks when printing but the magnetic tape recorder would not have to stop and start to form this space. Therefore the average speed of the tape during recording would be approximately doubled, but with the index marks spaced uniformly on the tape about 1/4 of an inch apart, twice as much tape would be required per Flexowriter character and the recording speed would be approximately the same as when single word blocks were used. To speed this up the index marks could be arranged as follows: two marks 0.01 inches apart followed by 1/4 inch of blank tape then two more marks 0.01 inches apart followed by 1/4 inch of blank tape, etc. This could give a recording speed of 120 Flexowriter characters per second, but the recording of block marks in this manner and having to have special tapes appear to be serious problems.

Signed by B.E. Morriss
B. E. Morriss

Approved by E S Rich
E. S. Rich

BEM:kst

Drawings Attached:

D-50053-1
SB-50138-1
SB-50139-1
SA-50137-1
SA-50261
SA-50262
SA-50263