Project Whirlwind
Servomechanisms Laboratory
Massachusetts Institute of Technology
Cambridge, Massachusetts

SUBJECT: BLOCK DIAGRAM WORK

To: H. Fahnestock

From: R. R. Everett

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This memorandum is in response to your request made at a conference with Sylvania on Friday, September 12. It is an attempt to list the present objectives of block diagram work and to define the expected results of that work in sufficient detail to allow estimating its effect on Whirlwind I computer design.

I hope in the near future to produce concrete diagrams and timing studies, accurately defining these matters. This work will be greatly expedited by the return of J. E. Swain who is expected early this month. I would appreciate comments of any sort on the work, particularly on the order in which the different problems should be studied in order to best meet project needs.

SUMMARY: The block diagrams distributed to date and described in R-127 (expected publication date October 15) describe the elements of a working computer. The control and arithmetic element are essentially complete as they stand. The storage described is the test storage proposed for Whirlwind I. The input and output devices described are only those needed for this test storage. Before the block diagrams can be considered complete for Whirlwind I, the following work must be done.

1) The effects of adding electrostatic storage must be examined.

2) The input and output devices needed in order to use Whirlwind I with electrostatic storage at all efficiently must be described in fair detail.

3) Further work must be done on checking. This work should include specifying not only additional equipment required for continuously checking computer elements but also more or less complete analyses of all the checking methods to be used for determining and isolating failures. This latter information can

be used for determining trouble-shooting procedures and necessary equipment as well as for discovering the information which must be brought from the computer to the control desk.

4) The additional orders required in the code must be fully investigated.

5) More exact methods and timing must be determined for generating restorer pulses for a c coupling.

These problems are discussed in the latter part of this memorandum.

The expected effects on Whirlwind I design are:

1) The requirement of a fair number of gate tubes and matrix space in the control beyond that now defined. This provision is, I believe, being made but should be adequate for additions beyond those conceived at present.

2) The possible addition of a special register for storing program counter numbers during automatic subprograms. It may be possible to avoid the use of this register. A study of this problem could probably be made in a few days if worthwhile at this time.

3) Modifications to the program counter to allow up to three special pre-set numbers. The problem is the same as that presented by pre-setting the step counter.

4) The design of a control for electrostatic storage. Although the necessary information for a final design is not available, an approximate design could now be made.

5) Design of shifting registers for input and output devices. These must be designed eventually and provision must be made for connecting them to the bus. Control cables to the registers and to the film devices themselves are needed.

6) Design of counter controls for storage buffers between computer and input and output devices as well as counters for film position. The same comments hold as for 5.

7) Modification of the step counter to provide restorer pulses during lengthy operations.

8) No discussion of checking or control desk problems is given in this memorandum.

ELECTROSTATIC STORAGE CONTROL: The possibility of considerable change and the uncertainty of time requirements have so far prevented any exact description of the electrostatic storage control but a possible sequence of events in using electrostatic storage has been given some consideration. An outline of this sequence and the necessary control equipment is as follows:

There will be 2 banks of 16 electrostatic storage tubes each. Two 32-way switches will be provided, one to set the vertical deflection voltage and the other to set the horizontal deflection voltage. These voltages will be applied simultaneously to all tubes. A 2-way switch will be provided for selecting which of the 2 storage banks is to be used.

On the output of each tube will be a 3-position flip-flop. When this flip-flop is set to its neutral position it will be switched to one position by a positive pulse and to the other by a negative pulse. This flip-flop is connected to the bus by read-in and read-out gates and is also connected to the screen of the storage tube.

The sequence for getting information from the storage is then:

1) Clear all storage flip-flops (i.e., return them to neutral).

2) Transmit the control order to the storage switches.

3) A period of time will be required for the deflection voltages to reach their final values.

4) The screens of the storage tubes will be set to neutral by the storage flip-flops. The beams of the tubes are now turned on. The selected spot will charge up or down depending on whether a 1 or a 0 was stored. The signal coming from the signal plate will thus be positive or negative and when applied to the 3-way flip-flop will change it to one or the other of the non-neutral positions.

The connections from screen to flip-flop are arranged to move the screen to the original potential of the spot charge. It is necessary to keep the screen potential at neutral during the entire reading step. Some sort of corrective delay must therefore be introduced between the signal plate and the screen setting.

The 2-way switch for selecting the bank may be used either to select which beams are to be gated or else to select which flip-flops are to be read onto the bus.

5) The flip-flops are then examined to make sure that none are in the neutral position. A flip-flop in neutral position would

represent the failure of that particular tube to read out.

6) The row of flip-flops will then be read out onto the main bus and the check bus.

7) The flip-flops remain set to the position corresponding to the orig nal contents of the tubes. The stored signal in the tube has been erased in the reading process. The screens are then set according to the flip-flop settings and the beams again pulsed. The signal will thus be replaced in the tubes.

The outputs from the signal plates during the rewriting procedure will be sent to the flip-flop inputs resetting them to their neutral positions. Examination of the positions of all flip-flops following the restoring will discover if any tube has failed to operate.

At the close of the operation, the original contents of the storage tubes remain. The number has been read out to main bus and check bus and all parts of the operation have been checked.

The use of a holding beam complicates the above sequence. It may be necessary to cut off the holding beam during writing and reading. It will be necessary to keep the screen at some potential other than neutral during the normal holding beam operation. It may even be desirable to provide 2, 3-way flip-flops, one for screen potential and one for the number, connecting them by gate tubes in order to have better control over screen potential.

Storing a number is done in similar manner. Depending on the timing, the old number may be read out, the flip-flops cleared and reset, and the new number stored instead of the old, or the new number may be stored without reading out the old.

Because of the complexity of the sequence and the lack of knowledge of the timing, the control for the electrostatic storage will be a separate entity from the main control of the computer. The control sequence will be inserted in the main timing sequence in the same manner as several of the other operations. In effect this special control sequence will be inserted in place of the delay counter delay. It is doubtful if the overlapping which will be resorted to in the case of Whirlwind II for the purpose of increasing operation speeds will be worthwhile for Whirlwind I.

INPUT AND OUTPUT DEVICES: The input and output devices, which are under development at Eastman Kodak Co., require some special equipment for connecting them to the computer.

A single mechanical housing and film drive design is planned, the device being suited to its particular purpose by differences in the optical and electronic systems. There will also be a separate design for a multiple-element graphical recorder.

DIGITAL INPUTS: The input readers consist of a film drive, a cathode-ray tube and optical system for sweeping a spot of light across the film, and a photocell. The film has stored on it both the number and its complement. The reader reads both number and complement and sends these out serially on a single cable. There is a clutch film drive which can be started or stopped on receipt of an order from the computer.

The computer equipment is as follows:

1) Two registers capable of shifting. The information coming serially from the reader is shifted into the end of the proper register, the number into the number register and the complement into the complement register. Following this shift the number is added to its complement in the complement register. Any reading errors will appear as discrepancies in the sum.

The number may then be read from the number register onto the bus.

2) It is desirable to allow the computer to continue calculations while the film is being read. A possible method of accomplishing this end and at the same time simplifying the ordering process is as follows.

Allocate a section of storage, perhaps 64 registers, to serve as a sort of flexible connecting link between the computer and the tape. Consider this section as a ring. Each new number coming from the tape is put in the first vacant space. Each number taken by the computer is taken from the first full space. Two counters keep track of the positions of these spaces. If the reader has gotten ahead to the extent that the ring is nearly full, a signal will be sent to the film drive to stop. If the ring is empty, the computer will be stopped to allow the reader to catch up.

3) Another counter will be provided for each reader to keep track of film position for use in scanning rather than extracting large blocks of information. Each transfer from the reader registers to storage should be checked. The computer must be stopped while the bus and storage are in use for this purpose.

4) An input typewriter and decimal-to-binary converter

will be attached directly to the bus. A number can be typed in along with the desired storage location. The computer will then stop its standard procedure long enough to store the new information.

DIGITAL OUTPUTS: The output writers are similar to the readers except that the spot of light from the cathode-ray tube is used to expose the raw film in the writer.

The computer equipment is as follows:

1) Two registers of the same type as used with the readers. The number from the bus is sent to these registers, the number being placed in one and its complement in the other. The number is shifted out serially onto a single cable to the writer. The writer records both number and complement, recording 1's in the number lines if the digits shifted in are 1's and 1's in the complement lines if the digits shifted in are 0's.

2) Photocells are provided to determine if the writer has recorded and whether it has recorded in the number or complement line. The recorded digits are shifted into the vacated end of the number register. If all digits have been recorded and all recorded properly, the exact number will have been replaced in the number register. This fact is checked by adding the contents of the number register into the complement register. The result should be all 1's.

3) A buffer section in the storage can be provided for each reader. Note that setting up these buffer sections does not prevent their use for internal computer needs. The size of the buffer section can be adjusted at will by setting the counter, or the section can be omitted entirely and the film controlled by direct stop and start orders.

ANALOGUE INPUTS: In general these will be measures of shaft positions or other mechanical or electrical amplitudes. One or more converters to binary code will be provided. The computer will obtain the desired information by transmitting to the converter first, an order to convert a certain quantity and, second, an order to transmit to the bus with the number of the register which is to receive the information. These orders will be separated by enough time (used for other operations) to allow the converter to select the desired quantity and perform the conversion. The time involved is unknown at present. The converter will be a self-contained unit with its own control.

ANALOGUE OUTPUTS: Such outputs will be used for positioning open-cycle or closed-cycle instruments or mechanical servos. In general the conversion will be from binary code to an electrical magnitude which can then be transformed into any desired analogue quantity. Several converters will be provided depending on the number, sensitivity, and accuracy of the quantities converted.

The number to be converted will be sent to the converter unit along with an order designating the ultimate destination of the quantity converted. The converter will perform the necessary conversion and switch the result to the desired place. No further orders are required but care must be taken not to order another conversion by the same unit until the previous one is complete. If another conversion is ordered before the converter is ready or if the input converter is asked for information before it is available, the computer will be stopped until the orders can be carried out.

An alternative possibility is to retain the new order until it can be performed, the computer proceeding meanwhile, If the order storage is full, the computer can then be stopped. This method would reduce stoppage time for a given care in programming but does not seem whorthwhile for Whirlwind I.

Graphical recorders are but one form of analogue output and will be handled with the others except for the addition of start-stop orders and possible speed selection and scale factor recording. Scale factor recording might be carried out less efficiently by the use of another recording channel. Another possibility is to note scale factor changes by some definite trace in the recorded channel.

CHECKING AND CONTROL DESK: This category is probably the least understood and yet most important of all at this time. However, since this problem is to be discussed in detail by concerned parties in the near future, it seems preferable to defer its discussion.

ADDITIONAL ORDERS: These orders fall into three categories:

1) Extension of ca, ad, cs, su, to handle absolute magnitude of numbers. Absolute magnitude may be obtained using existing orders but the greater speed and simplicity of special orders seems warranted here. It is estimated that further equipment includes control connections and possibly two extra gate tubes in the operation timing matrix.

Into this category also go possible modifications in existing orders. The only modifications now under consideration are in rounding procedures. It is not expected that additional equipment except for control matrix connections will be needed for these orders even if they entail the actual construction of new orders for different rounding procedures (as mr and mh).

2) Orders required for the control of the input and

output devices.

For film readers -

a. Start film x - go to position marked by next order.

b. Desired film position.

c. Read in x words.

For film writers -

a. Start film x.

If buffer storage sections are used, no further orders are necessary. In fact, if buffer sections are permanently allocated to a film, no orders at all are needed. Such a system would be wasteful of storage, and would prevent scanning.

The above orders require control lines, control matrix connections and control gate tubes.

For analogue inputs -

a. Convert quantity x.

b. Store last converted quantity in storage register x.

For analogue outputs -

a. Convert quantity supplied and send to x.

b. Start film x, at speed x_2.

Scale factors can probably be recorded in the same channel by special marks or in a separate channel.

c. Orders for automatic subprograms.

The coding of Whirlwind I with its short register length would be simplified in many problems if multiple length number operations could be ordered as simply as single length. In Whirlwind II such a facility might also be desirable, for instance in ordering interpolations or multiple length number operations. The system proposed is basically a way of allowing the operator a small number of special operations to be selected at random by himself and handled as if they were built into the computer. The following method has been proposed.

Three orders are needed. One gives the number of the register holding the first half of the first number to be operated on. The second gives the number of the register holding the first half of the second number to be operated on. The third gives the number of the register which is to hold the first half of the result. The second halves of all numbers are assumed to be in registers immediately following the first halves. One of the three orders must designate the operation to be performed.

The 3-order register numbers are made available to the subprogram as follows:

A new order is derived which does the following -

1) Transmits the contents of AC to BR.

2) Transmits the contents of AR to AC.

3) Transmits the order itself to AR.

Two applications of this order will store the first two orders in AR and AC. Another new order is needed which -

1) Does the same as the above order.

2) In addition, transmits the contents of PC to some special register provided for its storage. This register will probably be a flip-flop register to be provided in addition to present registers. A little recent study has shown that it may be possible to store the contents of PC in electrostatic storage. If this is possible, and some timing studies should discover if this is so, the extra register as well as any extra order can be avoided.

3) Sets PC to one of several possible permanently (at least semi-permanently) selected register numbers. There must be as many of these orders as there are special operations to be provided. In Whirlwind I there might be 3 for addition, subtraction, and multiplication of multiple-length numbers. Note, however, that the kinds of operations that may be performed have not been specified, only their number. The operations themselves are as general as the subprograms stored in the register sequence beginning with the number set in PC. The subprograms may have subprograms of their own. The subprograms may be changed at will even at the behest of the machine itself.

The result of 2 applications of the first order above followed by 1 application of an order of the second kind is:

1) The desired register numbers are stacked in AE, 1 in AR, 1 in AC, 1 in BR.

2) The starting register number of the subprogram to be used is in PC.

3) The order number to which the machine should return is in a known place.

The subprogram now starts. The first step is to remove the order in AC by a ts or td order. The order in BR is then transferred to AC and removed. The order, in AR is transferred to AC using the same type of order as put in AR in the first place. The subprogram then proceeds.

When the subprogram is complete the last order is a subprogram order returning the control to the main program. If a special register is used for storing the return number, a special order is needed. If the return number is stored in electrostatic storage, the standard subprogram order will suffice, the number being transferred to it by a td order.

RESTORER PULSES: At present the restorer pulses are to be generated by the delay counter during storage setup. The high speed 32-position switch removes the necessity for the delay counter which remains, however, as a restorer pulse source. When electrostatic storage is added the restorer pulses can be generated by the storage control. Certain operations, particularly division, require sufficient time between storage operations so that restoring must be done while they are being carried out. The step counter may be used for this purpose, stopping the flow of clock pulses part way through the operation and generating a pair of restorer pulses in the off interval.

An alternative is a restorer pulse generator which counts clock pulses and generates restorer pulses at regular intervals. This possibility has been discarded in the past as wasteful since restoring can usually be done at times when the computer is normally idle. If more accurate information as to electrostatic storage control timing were available, a final decision as to restorer pulse sources and timing could be made.

Robert R. Everett

Robert R. Everett

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