Project Whirlwind
Servomechanisms Laboratory
Massachusetts Institute of Technology
Cambridge, Massachusetts

SUBJECT: BI-WEEKLY REPORT, PART I, JANUARY 23, 1948

To: 6345 Engineers

From: Jay W. Forrester

Date: January 27, 1948

1.0 WHIRLWIND I COMPUTER ELEMENTS

(N. H. Taylor)

Re-assignment of Personnel

J. J. O'Brien will expand the work he has already started on detailed study of reliability of the 5-Digit Multiplier. This work will include a study of all the tube and crystal failures which occur in the continuous running of the multiplier. It will also include the solution of the problems which arise as a result of these component failures.

R. L. Best will carry on the basic flip-flop research which O'Brien is now carrying.

C. A. Rowland will expand his activity on bus drivers to include the problems of gate drivers which Best is at present working on.

1.1 Listed by Block Diagram Number

101 Master Clock

(H. Kenosian) The sketch for the Master Clock is being drawn in the drafting room. This unit will provide the high (2 megacycles) and low (1 megacycle) frequency time pulses for WWI.

102 Program Counter

(D. R. Brown) The circuit schematic of the program counter, D-31516 has been completed. Electrical parts list is ready for typing.

103 Program Register

(D. R. Brown) The circuit schematic of the program register, D-31514, has been completed. Preliminary electrical parts list will be ready January 30.

106 Time Pulse Distributor (control circuits)

(H. Kenosian) The schematics of restorer and push-button pulse generator for time pulse distributor control has been sketched. The remainder of the circuit is now in the process of being sketched, then will be submitted to the drafting room.

A modified method of generating the restorer pulses will be tested as soon as the breadboard test circuit is completed.

202 Toggle Switch Storage

(J. A. O'Brien) The type of switch to be used in "Toggle Switch Storage" has been tentatively selected and it will be a row of 16 push button switches with a release button so linked as to release all of the 16 other buttons when it is depressed.

(R. E. Hunt) Made investigation to determine best panel for toggle switch storage. Located a gang switch (push-button release type) manufactured by General Control Company of Boston. This switch seems to be ideal for the application and seems to be acceptable to everyone concerned.

General Control is now in the process of working up sketches for us on a 16-button single-release switch. We should have the initial data within a week.

203 Flip-flop Storage

(D. R. Brown) The circuit schematics of the flip-flop-storage register, D-31531, and the flip-flop-storage output, D-31450, have been completed. Preliminary electrical parts list ready January 30.

300 Arithmetic Control

(G. C. Sumner) Schematic diagrams of four panels of arithmetic control are in the drafting room. Prints of information grade are expected by January 31 for two of the panels. The design of arithmetic control is otherwise progressing according to schedule. It is felt that a report from the group investigating the driving problem should be forthcoming on the near future; so that design of the control line drivers can be accomplished.

(N. Daggett) A block schematic and a circuit schematic for the divide control are in the drafting room. In designing mixer circuits for the divide control, a need was apparent for a circuit offering somewhat higher input impedance than the usual types. A circuit which may offer an improvement in this respect will be described in an engineering note.

(N. H. Taylor) A new circuit requested by the Block Diagram and Mathematics Group will be incorporated in the arithmetical control which will necessitate adding two flip-flops and their associated gate tubes to the present block schematics for arithmetic control. This change will cause small delay and will not affect A, B, or Accumulator registers except in the cabling plans for these units. More information from the Block Diagram Group is forthcoming.

301 A-Register

(N. H. Taylor) A decision has been reached concerning the panel for the 0-digit position of the A-register in WWI construction which will cause this panel to contain 3 more tubes than the other 15 A-register panels.

(C. W. Watt) Schematic of A-register, digits 1-15, finished and delivered to Sylvania. Grade I. A parts list for this schematic is almost finished.

Schematic of digit 0, A-register, will now be drawn. This will have 11 tubes, while digits 1-15 have 8 tubes each.

All 16 digits will be laid out on the same size panels.

302 Accumulator

(N. H. Taylor) The left-hand 0-digit position of the accumulator section of the arithmetic element in WWI will be a different design than Section 1 through 15.

(C. W. Watt) The accumulator schematic is not yet completed. It should be done by Friday, January 30. Delays have been due to higher priority for A-register and B-register schematics, and press of other work.

The layout of the accumulator is progressing.

303 B-Register

(N. H. Taylor) All 16 sections of the B-register will be of identical design. This decision will necessitate some redrawing of the B-register schematic. The schematic should be ready for delivery to Sylvania by February 9th as scheduled.

(C. W. Watt) The B-register schematic has been finished, but due to a recent decision to include gate tube 302.08, the round-off gate, in all chassis instead of in BR-C only, the schematic must be revised.

500 Input and Output Registers

(D. R. Brown) A block diagram of the number register of the input-output register is shown in A-37116. A block diagram of the complement register of the input-output register is shown in A-37117. These diagrams and M-179 were discussed with the group at Eastman Kodak on January 20 and 21.

601 Check Register

(D. R. Brown) The circuit schematic of the check register, D-31515, has been completed. Electrical parts list ready for typing.

(J. A. O'Brien) The bus-to-check register input gate tubes have been changed so that they are normally cut off. (see sections 4.1 and 2.16)

Operators Console

(R. E. Hunt) Made investigation into the physical aspects of the operators console. Gave all data to Wainwright of Sylvania so that he could start work on laying on the console panels.

Contacted Underwood Sundstrand Corporation asking for physical data on their keyboard. (10 key). Will start work on the decimal input mechanism upon receiving this data.

(C. W. Watt) Some investigation of components for the console has been made, and is covered in R. Hunt's report. Preliminary prints of what drawings we have for the console were given to Wainwright of Sylvania, who will have some exploratory design sketches made.

1.2 System Engineering

1.21 Power Control and Distribution

(C. W. Watt)
Harry Lee has been investigating filament loads, and his report covers his findings. We should be able to approve filament transformers for ordering by Feb. 1. Lee and Anderson of Sylvania are cooperating to obtain a power breakdown so that rotary machinery may soon be ordered for all the power supplies. A conference of all interested parties must soon be held to crystallize thinking about power distribution.

1.22 Power Cabling

(N. H. Taylor) Present plans for decoupling circuits assume that marginal testing procedures will be based on a digit-by-digit test sequence. Most discussions indicate that some of the procedures may be on a register-by-register basis. At this stage of the development it is becoming apparent that we cannot make a definite decision on this point, and so power distribution panels must be constructed in such a manner that connection can be made using either of the above methods.

1.3 Auxiliary Equipment

1.31 Power Supplies

(N. H. Taylor) Two Sorensen Model 500 Voltage Regulators have been ordered to relieve the line fluctuation problem in the laboratory. These will serve as a stop gap measure until more basic measures can be taken for the whole laboratory.

(H. S. Lee) A good estimate of the filament power requirements has been obtained. The calculated requirement to date is 23 KW. This figure does not include the requirements for the Console, Test Panel and Film Equipment. It is believed that 30 KW will be required for filament power to cover losses, unknown requirements and power factor compensation.

Specifications for the filament power source (a-c alternator) and filament transformers are being prepared and will be presented for approval within a week.

It is anticipated that by February 6 the analysis of d-c power requirements will have been completed.

1.32 Air Conditioning

(J.C. Proctor) Specifications are being drawn up with a view to obtaining bids from one or two more firms for the necessary equipment.

A study is being made of possible locations for the equipment, and sketches will be prepared so a definite decision can be made. As soon as this is done we plan to have another discussion with Carrier to see if any modifications of their original bid would be required.

1.32 Air Conditioning

(R. E. Hunt) Made further investigation into the air conditioning system. Worked up an outline of specifications more or less based on Carrier Corp. proposal but incorporating recent changes. These specifications will be put in final form when the final decision on machinery space is made.

Work is now being done on specification prints which should also expedite the selection of machinery space.

Am now in the process of making complete calculations on heating and cooling loads involved to facilitate checking of the final proposals.

1.33 Cabinets

(C. W. Watt) A meeting was held Monday, January 19, at which Wainwright of Sylvania presented the latest cabinet proposals. They featured:

1. Racks 27¼" wide.
2. Uniform drilling of racks on 2" centers for panel mounting.
3. Panels whose widths are multiples of 2" plus 3½", to permit universal mounting on the racks.
4. Distributed mounting of filament transformers on brackets attached to the racks.
5. Mounting of power terminal strips vertically on a channel on the back of the racks.
6. Built-in overhead cable ducts.
7. Aluminum channels at base of racks, that will be used for air-ducts also.

These features were accepted as parts of the final design. Detail improvements and door design will soon be forthcoming, and after M. I. T. approval, prototype racks will be built.

1.4 Unclassified

Building Alterations for WWI

(J. C. Proctor) Most of the partitions have been removed from the WWI area. As soon as an electrician is available, work will

be started on the lighting.

A sketch showing the necessary alternations has been drawn up, and will be submitted to the State Fire Inspector for approval.

Standard Circuits

(J. A. O'Brien) The circuit schematics of the standard circuits are being revised in accordance with the latest development and are to be drawn in line with the newly established drafting specifications. The circuit for the gate generator GG-1 is to be completely changed. See 2.16. These drawings will be distributed as soon as they are completed.

2.0 WHIRLWIND I RESEARCH

2.1 Circuits

2.11 Flip-flop Design and Stability

(A. B. Horton, Jr.) The Master's thesis report on the a-c flip-flop has been submitted to M. I. T. and copies for the laboratory files are being assembled.

A preliminary conference between R. R. Everett, N. H. Taylor, W. P. Horton and myself has been held in regard to the possibility of formulating a testing program for the a-c flip-flop. This program, the details of which must yet be worked out, would be the subject of a Bachelor's thesis by W. P. Horton.

Five Digit Multiplier

Plans are being made to install a-c flip-flops in the experimental multiplier digit panel and test their operation in conjunction with other circuits.

(H. Kenosian) The breadboard model of the a-c flip-flop is undergoing tests. The main problem is that of designing a satisfactory triggering method. The application of negative pulses to the plates seems to show promise.

Connection of the output to the suppressor grid of a gate tube indicates that the flip-flop can easily handle the load. 1 megacycle pulses were gated successfully. Thus far all tests have been made at a PRF of 1 megacycle and with 100kilocycles restorer pulses.

The IN34s in the grid circuit have been replaced by IN38s. The higher back resistance of the IN38s considerably increases the free-running period.

Further tests are being made in cooperation with A. B. Horton.

(J. J. O'Brien) "Sticking" is being investigated with a test circuit using poor tubes from the multiplier. During his visit, Mr. Kiser of Sylvania supplied much valuable information on tube characteristics which explained certain phenomena already observed in the "sticking" problem.

Multiplier life data is showing a considerable decline in plate current after 1000 hours which accounts for some of the sticking.

Without too strong evidence, parasitic oscillations are causing sticking.

In the present circuit the screen voltage is lower than the plate voltage. Since this will contribute to such oscillations, the circuit will probably be modified somewhat.

Parasitic suppressors will be added to the circuit.

A principal difficulty has been the marginal nature of the sticking in many cases. If a parameter was varied and caused the circuit to become unstuck, then when that parameter was returned to its original state, the circuit would still remain unstuck for long periods of time.

2.16 Gate Generator

(J. A. O'Brien) Since the writing of the last report a new gate generator has been developed. The output is a flat top gate with 0.1 μsecs rise time and whose length is determined by a delay line. The resolution time of the circuit is twice the length of the gate. The details of this circuit will be published in an Engineering Note now in preparation.

2.2 Components

2.22 Pulse Transformers

(C. A. Rowland) Pulse transformers suitable for $\frac{1}{2}$ μsec gate pulses are being developed to work into 94Ω and 47Ω impedance levels from a gate amplifier.

2.23 7AK7 Tests and Specifications

(D. R. Brown) Dr. B. Kievit and Mr. N. L. Kiser visited this laboratory on January 15 to discuss our vacuum-tube problems. We agreed to furnish pulse equipment so that Emporium can run life tests on the 7AK7 under expected operating conditions. Characteristics of the 7AK7 will be obtained on the oscilloscope curve tracer at Emporium. Fallows and I may go to Emporium at that time. Mr. Kiser feels that the "sticky" flip-flop is caused by parasitic oscillations and suggests that we watch for gas, grid poisoning, and especially changes in leakage or interelectrode capacitance.

2.25 Tube Testing

(R. L. Ellis) Tube investigation has been very active. Somewhat more than 2000 readings have been taken and recorded. Data for complete families of curves for five 7AK7 tubes have been obtained and curves plotted. Other tests became more urgent. Retests were made on the tubes in each multiplier digit while the units were inactive in the last few days.

37 - 6AG7's and 9 - 6AS6's retired from the multiplier were retested. Data for families of curves, plate current - plate voltage, and screen current - plate voltage were obtained for a 7AD7 and curves plotted.

Firing and cut-off voltages for 3 - 2050's and 2D21's gas tubes were determined.

6 - 12L8's are now being run for plate and screen current.

Plans for the future call for:

Tests on five or six more 7AK7's
Tests on twenty 6AS7-G's
A reserve of 50 to 75 replacement tubes for the multiplier digits, when a suitable preliminary test has been determined.
Families of curves on 6L6's, 6Y6's and 6V6's.
A capable technician is needed to help out in this work.

2.3 Systems-

2.31 5-Digit Multiplier

(N. H. Taylor) The multiplier has been out of operation for the past week to enable the switchover from electronic power supplies to rotary d-c equipment. A delay has arisen due to the failure of one of the generators to perform to specifications. A new generator has been procured and is being installed. During this period, considerable work on tube measurements, and revising present temporary wiring in the system has taken place. Operation will be resumed within the next week. It has been decided to replace the 4-position matrix switch in each of the multiplier panels with a Whiffle Tree circuit which will be used in the WWI design. As this work cannot be allowed to interfere seriously with continued multiplier operation, the panels will be modified one at a time.

Flip-flop sticking is still a prevalent problem in multiplier operation. A certain amount of success in curing this sticking has been attained, using suppressor chokes in the grid leads of the flip-flop. Comments and suggestions on flip-flop sticking are invited.

(H. L. Ziegler) The multiplier is temporarily out of operation while the switch is being made to the motor-generator power supplies. When completed, all voltages supplied to the multiplier and to auxiliary equipment will be separately metered and controlled. Completion of the change-over is being held up by replacement of the + 150 volt generator which was found to be unsatisfactory. The new + 150 volt generator is now ready to be installed and the complete change-over should be completed early next week.

Separate screen voltages for the flip-flop tubes are being provided at each digit panel. Selector switches provide a choice of screen voltage for each tube of the flip-flop and are to be used as a check on flip-flop sticking. This alteration has been completed on Digit #1 and work is continuing on the other digits.

Multiplier Life Data

(J.J.O'Brien) All the tubes of the multiplier having 1500 hours of life have been tested. This data is being assembled in suitable form.

Crystal controlled clock for 5-digit multiplier

(H. Kenosian) The first phase of testing the bread-board model has been completed by E. Nickerson. Because of its low priority, full time work is not being devoted to this project.

Adding Circuits

(H. Kenosian) Step-by-step addition has been made successfully using a temporary step-up similar to the proposed setup. Trouble was encountered on automatic addition, due to the insufficient delay of the single pulse synchronizers. It is expected that this difficulty will be remedied as soon as one of the variable delay pulse and gate generators is completed and installed.

Test Equipment

(H. Kenosian) The test equipment used in the 5-digit multiplier has been re-designed to accommodate the voltage obtained from the rotary equipment being installed.

2.4 Unclassified

Gate-Tube Driver Panel
(R. L. Feet)
This panel, which simulates the horizontal driving problem, has been completed. Data has been taken on a successful circuit for driving the control grids of 16 gate tubes, 3 feet apart, from the middle, using a 6Y6 driver.

Other horizontal driving problems will be solved on this rack as time permits.

3.0 SPECIAL CIRCUITS

3.2 Test Equipment

3.21 Standard Test Equipment

(J. O. Ely) Preliminary design of electronic circuits for a delayed-pulse generator and a gate-and-register panel are continuing. An attempt is being made to reduce the number of tubes and amount of power required. For this reason, circuit designs incorporating type 12L8GT dual pentodes are under investigation. An attempt will be made to incorporate miniature types in the interest of power conservation and space conservation if practicable.

An apparent conflict exists between the requirement of high stability (low percentage jitter) and wide delay range with fast recovery time in simple multivibrator-type delay circuits. For this reason some more complex delay schemes have been considered. The result is, apparently, too many tubes. A design for phantastron-type delay circuit has been made incorporating a type 7AK7 tube. It is hoped that an improved balance between the conflicting factors can be achieved with fewer tubes than in the case of a multivibrator type delay.

Requests for construction of the following breadboards have been submitted to R. H. Murch:

1. Cathode-coupled flip-flop and sawtooth generator for delay element use. (12L8GT tube).

2. Flip-flop and gate tubes for gate-and-register panel. (12L8GT, 7AK7). The flip-flop is designed for operation of its cathode at d-c ground. Negative grid return (to 250 volts) is employed and triggering on the cathode is by means of a choke between cathode and ground.

3. Phantastron delay circuit. (7AK7, 6SN7GT).

3.22 Special Test Equipment

(R. L. Best) Frequency Divider A frequency divider, which has an output near 4KC regardless of input pulse repetition frequency, has been completed, and is undergoing test.

(H. Kenosian) Variable Delay Pulse and Gate Generator The first of two of these units is being tested. Modifications have been made as a result of the tests made with the 3-channel unit delivered to Sylvania.

2:1 4:1 Binary Frequency Divider Four additional units are now under construction. Delays have been experienced getting materials necessary for construction.

Variable Frequency Clock-Restorer Pulse Distributor
The frequency divider circuit is under construction. A special chassis has been ordered for this unit, since the prefabricated chassis do not meet the need.

The distributor section has been drawn up and is now in the process of being laid out for construction.

(R. L. Massard) The amplifier is push - pull throughout - 3 stages, the first stage being in the form of a cathode - coupled phase inverter. The compensating circuits are being lined up. Delays result because stages must be compensated separately, and if one compensating circuit is changed, the amplifier must be set up to test for phase-shift through each of the push - pull sides to see that there is no difference before the point-by-point gain versus frequency characteristic can be plotted. Changing a-c line voltage makes the plotting of the frequency characteristic particularly tedious. (Ref. M-125)

4.0 BLOCK DIAGRAMS

(R. R. Everett) Investigations of the following problems are being made with the cooperation of the mathematics group.

a) Inclusion of a special order to determine automatically the first non-zero digit of a number.

b) The most desirable location of the 11 digits describing the register number in a standard order.

c) Review of rounding off procedures.

d) Possible modifications to arithmetic check.

A primary requirement in these investigations is that no changes shall be suggested which will affect repetitive units.

(E. Blumenthal) Work has continued on block diagram revisions. All computer elements have been revised in accordance with latest design information: The drafting room has already begun the task of redrawing these elements. At present, additional orders are being incorporated into the system to provide for automatic subprogramming, the manipulation of the absolute magnitudes of numbers, and to enable the determination of the first non-zero digit of a number (as a coding aid).

4.1 Timing Studies

(J. A. O'Brien) The timing studies were reviewed by myself and E. Blumenthal in regards to the faster rise time of the new gate generator, see section 2.16, and it was found that with the new gate generator the system could be returned to the original method of operating the Check Register with the Bus-to-Check Register gate tubes normally off. This result was pointed out to R. R. Everett and D. Brown and it was decided to return to the original system.