Project Whirlwind
Servomechanisms Laboratory
Massachusetts Institute of Technology
Cambridge, Massachusetts

SUBJECT: BI-WEEKLY REPORT, PART I, JANUARY 21, 1949

To: 6345 Engineers

From: Jay W. Forrester

1.0 WHIRLWIND I COMPUTER ELEMENTS

1.01 Production Report

(H. F. Mercer)

The following WWI panels (production units) have been received from Sylvania to date:

Arithmetic Element (complete)
Bus Driver, Arithmetic Element (complete)
Program Register (complete)
Fixed Voltage Switching Panels (complete)
Fuse Indication Panels (complete)
Restorer Pulse Generator (complete)
Time Pulse Distributor Output
Bus Driver, Flip-Flop Storage (complete)
32 Control Pulse Output Units
2 Digit Interlock Panels
3 Register Driver, Type I

1.02 WWI System Tests

(N. H. Taylor)

Testing on arithmetic control with the console test equipment has reached the stage where further work would be uneconomical. It is planned therefore to begin the merger of this equipment with the arithmetic element proper during the next two-week period.

Channel by channel testing on the arithmetic element proper is proceeding satisfactorily. Use of the arithmetic control to supply test pulses to this equipment will speed these measurements.

1.02 WWI System Tests (continued)

During this initial period, several changes in component parts have been necessary. The WWI modification system, which was set up to handle these changes, seems to be working satisfactorily. Some delay has occurred in the testing program due to the actual work of making modifications.

It has been suggested that a second shift of technicians be used to make these modifications day by day as they become necessary. This suggestion has considerable merit and may well apply to the problem of completing the installation wiring which is being held up during the time the testing is going on.

(G. C. Sumner)

The past two-week period has seen significant progress in system testing. As was expected, a number of system problems have been encountered. But, to date, all such problems have been solved satisfactorily. The present stage of testing consists of thoroughly examining certain channels individually, using a rack of test equipment to furnish the required pulses. For these channels measurements of allowable amplitude variations, pulse shape, and timing are being made. Data is being recorded on graphs so that comparison of the performance of different digits is facilitated. Such detailed testing of all channels will not be done at this time. Only the high-speed channels used in multiplication are receiving such attention. This provides a foundation to begin work on the multiply operation, which will be the first operation to be tested using the temporary console. A summary of the results obtained appears below.

1. It was found that under the worst conditions signals of 4 to 5 volts were fed onto the common restorer lines of those registers not having trigger tubes. This was enough to trigger flip-flops which are above average sensitive to cathode signals. When the B-register was shifted containing alternate 1's and 0's faulty results were obtained. The fault has been corrected by feeding restorer pulses to each digit through a 220 ohm resistor. The maximum spurious signal now obtained is less than $1\frac{1}{2}$ volts. Discovery and rectification of this condition alone has justified the approach used to systems testing. Had multiplication been attempted earlier, the discovery of this fault would have been exceedingly difficult.

1.02 WWI System Tests (continued)

2. Negative feedback to reduce amplitude and provide stabilization has been provided in the add channel. Also the termination of the add line from AR to AC has been made pure resistive to eliminate distortion. It was found that the upper limit of amplitude for the AR to AC channel is slightly too low. This reduces to the problem of making the flip-flops less sensitive to grid signals. This problem has been referred to R. Best.

3. The time for high speed carry to pass through 16 gate circuits and two buffer amplifiers was measured to be 0.81 microseconds. Unsatisfactory pulse shapes and excessive amplitudes were observed. Considerable further work will be required.

4. Changes of circuit constants of the shift register-drivers were made in collaboration with C. Rowland to improve P.R.F. sensitivity.

Within a few days the temporary console can be used efficiently for systems testing. A shut-down of 1 to 2 days will be required in the next week for the adjustment of filament transformers and video cable installation.

(G. G. Hoberg)

All arithmetic-control panels are installed in their racks. Although complete power wiring is available for all panels, only the step counter, multiply-shift control, and divide control panels have so far been operated.

To expedite the overall arithmetic-element program, the arithmetic-control panels are being set up independent of the repetitive registers as far as practicable. While Summer is testing the repetitive registers from an auxiliary rack of test equipment, arithmetic control is being tied in with the temporary console to form an integrated control system. Merger of these two parallel test programs should take place within two weeks.

Necessary timing and control pulses have been supplied to the three above-mentioned panels from the temporary console with the following results:

1. With coder toggle switches on the console set up for a multiply operation, satisfactory pulses at the proper times were made to appear at the "to BR15 digit sense" and "shift right to RD" jacks. Multiplication was

successfully simulated both cyclically at WWI prf's and at push-button rates. In high-speed operation, indicator lights could be examined after any arbitrary time pulse or high-frequency clock pulse. Performance appeared satisfactory in all respects.

2. With the control-coder toggle switches set for "shift right" and "shift left" correct pulses were obtained at the proper jacks. Performance appeared satisfactory in all respects.

3. With the control-coder toggle switches set for "divide", correct pulses were obtained at the proper jacks a) with the divide counter set for two-position counting and b) with the counter set for three positions. Sumner's experiments with the high-speed carry indicate that two positions may suffice. If this is so, division will require 34 microseconds in addition to the time for a normal operation cycle. With a 3-position divide counter this time would be increased by 17 microseconds. Performance of divide control appeared satisfactory in all respects.

Experiments with point-off control were begun on January 21. Initial tests were satisfactory. However, there is a possibility that vacuum-tube and cable delays will be great enough to prohibit use of 2 mc pulses for this operation as originally planned. Replacement of 2 mc by 1 mc would, however, increase the time required for this operation by 32 microseconds, and would not be very desirable. This question will be investigated carefully. The block diagrams group has already devised a means for correcting the difficulty if it actually does cause trouble.

Relatively little can be done with the AC-O-carry & special add memory panel and the divide-error and sign control panel until after the merger of the control system with the repetitive registers.

All observations to date have been only qualitative, since it is felt that the recording of quantitative measurements is much less important than integration and stabilization of the system as a whole.

Because utilization of the "test reset" function of the step counter during multiplication and division requires the breaking of connections to built-in preset lines, toggle switches have been installed on the step counter to facilitate the change-over required for testing. Pilot lights at the console indicate when the connections are broken. This new arrangement seems desirable as a permanent feature, so drawings will be modified accordingly. If it becomes necessary later to have the toggle switches on the console, a biased-crystal gate to permit remote switching can probably be installed at the step counter.

1.1 Listed by Block Diagram Number

109 Clock Pulse Control

(J. A. O'Brien)

The Sylvania drawings of this unit have been received. The necessary changes have been itemized and turned over to the drafting room for completion.

111 Synchronizer

(A. K. Susskind)

The design of that part of the alarm-indicator circuit which affects the restart-pulse channel having been established, the design of the MVI synchronizer could be completed. The panel will contain ten separate push-button pulse outputs, including four spares. Of these, seven are synchronized with 62.5 kc clock pulses and three with the RPG End Carry.

The block schematic is currently being drawn up and the circuit schematic has been given to the drafting room.

201 Storage Switch

(M. Hayes)

Because of the unreliability of the 5687 tubes, the storage switch output amplifiers have had to be redesigned. The new circuit, employing a 2C51 tube, operates satisfactorily although not as well as the previous circuit. The difficulty in obtaining fast rise and fall times was solved by using a peaking coil and grid current clipping. The changes have not altered the layout to any extent.

202 Toggle Switch Storage

(J. A. O'Brien)

The drawings of this unit have been received from Sylvania and due to the fact that a decision has been made to replace the 5687's with 2C51's changes are necessary in the drawings. These changes and additions have been itemized and preparations are being made to schedule the work on the unit.

302 Accumulator

(W. Papian)

Digit 0 - Testing and minor modifications were completed, and the panel installed.

700 Operator's Console

(G. G. Hoberg) Temporary Console

Operation of arithmetic control panels with the temporary console has so far indicated that the console is logically sound. All functions called for by the design have been successfully performed. As yet no major unexplained or persistent trouble has been encountered.

A number of minor improvements have been made in the original layout:

1. The experimental model of a matrix-type time-pulse distributor has been replaced by a test-equipment whiffletree which performs much better.

2. Compensating delays in the form of pulse standardizer channels (0.1 μsec per channel) were introduced to insure that 1 mc clock pulses occur simultaneously with 2 mc clock pulses both at clock-pulse control and at the arithmetic-control panels. Until this was done, differential time delays due to differences in pulse routing resulted in occasional difficulties. The design of the WWI master clock already includes this delay compensation, so no trouble is expected when the change to the permanent central-control system is made.

3. A number of coders were added for convenience in distributing clock and restorer pulses throughout the system.

4. To save test equipment, the 3 delay-line panels were omitted which were intended to delay read-out pulses until after the rise of read-in gates. If the time differential of .08 μsec due to pulse routing proves inadequate, correction will be made by interconnecting coders with 0.1 μsec delay lines, or by introducing additional pulse standardizer channels.

5. To save test equipment, frequency division from the 2 mc clock is performed by available non-standard 4:1 binary counters instead of scarce standard register panels.

6. The experimental model of clock-pulse control has been modified so as to agree functionally with current WWI

700 Operator's Console (continued)

design. This modification permits changing to push-button operation between clock pulses during multiply, divide, etc.

7. Application of a scope probe to a circuit terminal has frequently been found to cause interruption of cyclic operation by blocking a single step-counter end-carry pulse in a feedback loop which cannot operate without this pulse. To avoid this undesirable feature, a scheme for providing an artificial end-carry pulse will be tried out. It is perhaps important to note that when WWI is performing non-repetitive operations, as in actual computation, any slight disturbance of circuits by application of scope and meter probes is apt to cause completely incorrect results.

In interconnecting the 50-odd pieces of test equipment with about 250 separate video cables, the following equipment failures were encountered:

1. One short-circuited T-connector for coax.
2. Two intermittent connections within RG62/U coaxial cables fitted with standard connectors.
3. One case of lack of operation believed due to a defective female Jones connector in a d-c power strip.
4. Three failures within standard test-equipment units.

(A. K. Susskind)

Development of the alarm indicator circuit is continuing. A satisfactory method of clearing the alarm indicators and subsequently originating a restart pulse has been worked out. There still remains the problem of reliably firing the alarm-indicator gas tubes from single pulses of .1 microsecond duration. To achieve reliability of operation the output pulse of the blocking oscillators which drive the gas tubes will have to be lengthened. Suitable design changes are being considered.

(W. Papian)

Trouble is being experienced with flickering of Console indicator lights which are supposed to be in the extinguished state. It was found that placing a resistor of the order of 5 or 10 megohms across the light (or from B+ to the low side of the light) will stop the flickering without significantly affecting indication of the "duty factor" of the associated flip-flop.

700 Operator's Console (continued)

(R. H. Gould)

The experimental breadboard model of clock pulse control was modified so that it conformed in its essential operations to the revised block schematic C-32642-3.

(H. Kenosian)

Temporary Console - Work is under way to check the reliability of the console and eliminate closed loops which may stop operation when a mistake occurs in arithmetic control.

1.2 System Engineering

(C. W. Watt)

Installation - During the period from January 10 to 21st, the power has been on most of the time.

Two men have been proceeding with installation of marginal checking panel selection equipment in rack P-9, and with the installation of a little of the power control wiring.

Some time was spent in preparing schedules of future installation work. Installation drawings and wiring schedules will shortly be started on some of the racks in central control.

(R. E. Hunt)

Installation - The master installation drawing R-32129 now is in complete enough form to be issued for general reference. This drawing now replaces D-37559-2. This drawing references the complete installation of WWI to date.

Installation drawings are now in process for the flip-flop storage bay P0 thru F15.

Installation drawings for arithmetic control racks C-8 thru C-12 will be started in the next few days.

Marginal Checking Installation - Installation of the marginal checking apparatus in rack P-9 and control in the temporary console has been started. Wiring and cabling on this installation will constitute a fill-in job for installation technicians over the next month and a half.

Manual marginal checking should be available about the first of March.

1.21 Power Control & Distribution

(R. E. Hunt)

Power Supply Control Panel - This panel is mechanically complete. It will be wired up as soon as some minor changes in the circuit schematic have been made.

Filament Voltage Control - This panel was formerly called "Filament Sequencing Panel". Drafting is now almost complete; this panel will go to the shop for manufacturing next week.

Power Supply Control Drawings - The drawings for power supply control are now being given a final revision. These should be ready and checked next week.

Marginal Checking Control - The schematic for this system is almost in its final form (sketch). This will go to the drafting room in a week or two for final drawings.

Manual Control Pot for Marginal Checking - This potentiometer has been worked out and the final mechanical design started. This should be ready for manufacture within one week.

1.22 Power Cabling

(H. S. Lee)

The installation of power cables in the arithmetic control racks has been completed.

Gavitt Mfg. Co. is now engaged in fabricating power cables for flip-flop storage. A partial order was given that concern on January 12. An order for the remainder will be forwarded within the next week.

At present consideration is being given to the design of distribution circuits, for the interphone system and the oscilloscope synchronizing pulses.

Design and detailing of the external power cables for the voltage variation panels is underway.

Within the near future a new drawing will be published delineating the approved pin connections for the standard power connector. This drawing will obsolete all such present drawings.

The initial layout of the interrack wiring for the power bay is practically completed. However, extensive checking will be required prior to commencing the actual installation.

1.23 Video Cabling WWI

(R. H. Mureh)

The vertical video cables for the arithmetic element have been received from Sylvania and will be installed during the next installation period.

All AR, BR, and AC horizontal video cables are installed.

Installation of arithmetic control video cabling is complete except for about 15 cables.

1.25 Time Schedules

(R. A. Osborne)

New time schedules covering the various phases of WWI design, construction, installation and test for the year 1949 are being drawn up. These will be ready for inclusion in the Summary Report for January.

1.3 Auxiliary Equipment

1.31 Power Supplies

(J. J. Cano)

Whirlwind I Filament Power - Tests are being conducted to determine the temperature rise of the motor from which the fan blades were removed in order to reduce noise. The air stream delivered by the four widely spaced blades had a frequency of 120 cycles per second and pulsated with the four arms of the end bell. Not only was the sound objectionable, but the sound waves also caused the floor above to vibrate perceptibly. The removal of the blades reduced the noise and vibrations to unobjectionable levels. A large quantity of air is still being delivered since the rotor poles still act as blades of a centrufugal fan. The blades that were removed directed the air into the channels between the stator laminations and the housing. Inasmuch as the motor will not be run at full load, the temperature rise of the motor is not expected to be excessive.

(C. R. Wieser)

Test Power for Computer - R.F. chokes (90 microhenries) are being wound for reduction of transients in the+90, +120, and -150 volt supplies.

1.51 Power Supplies (continued)

The Power Equipment Co. -15 and -30 volt supplies should be delivered by January 27. They will be installed at once.

WWI Filament Power - The 100 H.P. drive motor has been aligned with the bed. Wiring of the motor (except for exciter) is complete and the motor has been operated. Operation was satisfactory except for excessive noise. Noise reduction is being studied.

WWI Drawing List	Block Diagram	Block Schematic	Circuit Schematic
System	B-37071-5		
Control	B-37098-4		
Master Clock	B-37159-1		
101 Pulse Generator	B-37155-2	B-32385	E-32333-3
102 Program Counter	B-37062-4	B-32213-1	D-31516-4
103 Program Register	B-37067-2	B-39289-1	D-31276-8
104 Control Switch	B-37066-3	T60CS00-4-C	Z60CS00-A W60CS00-1-A Z60CS00-2-A
105 Operation Matrix		S600M00	Z600M00-1-C
Control-Pulse Output		R60CP00	S60CP00-1-B
106 Time-Pulse Distributor	B-37068-3	T60PD00-8-B	
106 Time-Pulse Distributor Counter		T60PD00-3-A	Y60PD00-C
106 Time-Pulse Distributor Output		T60PD00-4-B	Z60PD00-1-B
109 Clock-Pulse Control	B-39817-2	C-32642-3	R-31916-4
110 Frequency Divider	B-37154-2	B-32264-1	R-31729-1
111 Synchronizer	---	---	---
112 Restorer-Pulse Generator	B-37160-1	B-32209-4	D-31909-7
200 Storage	C-37156-1		
201 Storage Switch	B-37121-1	B-32855 T60CS00-4-C	Z60CS00-A Z60CS00-2-A E-32830-1 R-32722-1
202 Toggle-Switch Storage	B-37122-3		E-32711
202 Toggle-Switch Storage Output		C-32080	E-32721-2
203 Flip-Flop Storage Output	B-37060-5	B-32269-1	E-31635-4
203 Flip-Flop Storage Register	B-37057-4	B-32268-1	E-31621-4
203 Flip-Flop Storage Control	B-37061-7	D-32106-2	

WWI Drawing List	Block Diagram	Block Schematic	Circuit Schematic
301 A-Register, Digits 1-15	B-37056-3	B-31211-3	D-31276-8
301 A-Register, Digit 0	B-37056-3 B-37072-7	B-31574-1	D-31573-4
302 Accumulator, Digits 1-14	B-37063-5	D-31213-3	R-31275-6
302 Accumulator, Digit 0	B-37096-5	D-32851	R-32850
302 Accumulator, Digit 0, Aux. Panel	B-37096-5	B-32492-2	D-32602-1
303 B-Register	B-37097-3	B-31212-4	D-31277-5
304 Sign Control & 308 Divide-Error Control	B-37072-7	C-31576-3	E-31619-2
305 Step Counter	B-37074-5	D-31828-1	D-39764-2
305 Step Counter Output		A-32723-1	D-32735-2
306 Multiply & 307 Shift Control	B-37072-7	C-31532-3	E-31588-5
308 Divide Control	B-37072-7	C-31552-3	R-31718-5
309 Special Add Memory & ACO Carry	B-37072-7	C-31575-4	E-31632-3
310 Point-Off Control	B-37072-7	C-31600-6	E-31717-6
403 In-Out Register	B-37119-2	B-32434-1	D-31277-5
404 Comparison Register	B-37120-2	B-32578-1	E-32576-3
601 Check Register	B-39816-2	B-32577-1	E-32576-3
601 Check Register Check		B-32018	E-32023-2
Bus Connections	B-37124-3	C-37123-3	
Bus Driver, Arithmetic Element		A-32297-1	D-31727-6
Bus Driver, Flip-Flop Storage		A-32296-1	D-31726-6
Register Driver, Type I		B-32207-1	E-32261-4
Register Driver, Type II		B-32691-2	D-32690-2
Fuse Indication Panel			W60PP00-7-D
Voltage Variation Panel			W60PP00-6-B
WWI Power-Connector Pin Connections			B-31955-5

2.0 WHIRLWIND I RESEARCH

2.1 Circuits

2.11 Flip-Flop Design and Stability

(J. M. Hunt)

An analogue of the WWI basic flip-flop circuit has been constructed; provision has been made on this analogue panel for convenient instrument connections to permit measurements at appropriate points in the circuit. All capacitances are connected to the circuit through plugs and jacks to facilitate observation of the effects of the various capacitances on flip-flop operation. The analogue operates on P-1 regulated d-c supplies to avoid the effects of slight irregularities in the voltages of the laboratory d-c supply system.

Interconnecting cables are now being constructed; tests of the complete analogue system will begin within a few days.

(K. E. McVicar)

Initial tests on a d-c coupled flip-flop utilizing cathode-follower coupling indicate that such a circuit is satisfactory for certain applications in input-output control and other places where restorer pulses are especially inconvenient.

The cathode-follower coupling, in addition to allowing the plate of the "off" tube to be operated at ground potential, results in good rise time of the plate waveform even with comparatively high-capacity loads.

A d-c flip-flop panel has been constructed to replace the flip-flops in the temporary clock pulse control, and will be installed as soon as possible without interrupting the tests on WWI. This should provide additional information regarding the adaptability of the d-c flip-flop.

2.2 Components

2.23 Vacuum Tube Studies

(H. B. Frost)

A lot of 7AD7 tubes built to L7P specifications has been placed on life test with filament voltage only to check

2.23 Vacuum Tube Studies (Continued)

formation of interface. All electrodes are grounded; one side of the filament is also grounded, so that there is no possibility for a voltage greater than 6.3 a-c to develop within the tubes.

The pulse tube tester mentioned in the last report has been completed and de-bugged. Operation is equal to expectations.

(R. L. Ellis)

Four more samples of 7AD7 tubes and three more 7AK7 samples for quality study have been prepared. The data is being plotted for a graphic report supplementary to E-179.

In the preparation of 7AD7 tubes for flip-flop use in WWI, Sylvania found about 20 percent with sufficient plate current in the last four hundred tubes.

Renumbering of tubes to meet WWI specifications was completed on the DEC, SAM, and POC panels.

Tested tubes were delivered for the following test equipment: crystal tester, voltage calibrator and gate inverter amplifier.

About 300 more tube cards were received from Sylvania. These are complete except for circuit numbers.

Sylvania memorandum 60-119 reports on testing and pre-burning 7AD7 and 7AK7 tubes for WWI.

2.3 Systems

2.31 Five-Digit Multiplier

(E. S. Rich)

Modifications on the test equipment used with the Multiplier have been completed so satisfactory operating margins for this equipment have been obtained. It is believed that the checking procedures have been worked out sufficiently well so that a life test can be started the

2.31 Five-Digit Multiplier (Continued)

first of next week.

It is planned to run an initial life test for about a month to see if these procedures are adequate. At the end of that time all the tubes will be tested and then an extensive life test will be begun.

3.0 SPECIAL CIRCUITS

3.2 Test Equipment

3.21 Standard Test Equipment

(R. L. Massard)

Video Amplifier: The third of the latest and final series of amplifiers has been "lined-up". The fourth and fifth are built and the sixth and seventh are being built. Work is being done to make the power supplies for the amplifiers inter-changeable. The problem of building amplifiers with all the same size peaking elements is being tackled. If all amplifiers can be built with the same peaking, a great amount of time and trouble will be saved in future construction and maintenance.

4.0 BLOCK DIAGRAMS

(J. M. Salzer and R. P. Mayer)

A change of cabling was necessary in the Arithmetic Element to prevent errors after a sl order, as described in Engineering Note, E-177.

The actual form of the Test Storage Switch is described in M-737. It discusses the use of the toggle-switch bank provided for added flexibility in Test Storage.

(J. M. Salzer)

The block diagram of the accumulator has been revised and brought up to date. The two existing block diagrams B-37063 and B-37096 were consolidated into one drawing (no number yet) for the sake of clarity.

Representation of delays in block diagrams has been clarified and standardized by Memorandum, M-750.

A revision of R-127 is being undertaken. The new report will probably have a new number. It will include an up-to-date description of WWI, including Electrostatic Storage and Input-Output Equipment. Depending on the progress made in the construction and testing of the computer, the report is likely to be completed some time during the summer of 1949.

(R. P. Mayer)

Work on block diagrams for ES Control has been resumed due to the need for such diagrams in the near future. The diagrams that were designed some time ago have been, and are being, brought up to date and will be issued shortly. In addition, some simpler methods of control are being investigated, and will be written up and issued if they seem practical.