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PROJECT WHIRLWIND
(Device 24-x-3)

SUMMARY REPORT NO. 7

APRIL 1948

Submitted to the
SPECIAL DEVICES CENTER, OFFICE OF NAVAL RESEARCH
under Contract N5ori60
Project NR-720-003

SERVOMECHANISMS LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Cambridge 39, Massachusetts
Project DIC 6345

TABLE OF CONTENTS

FOREWORD

Project Whirlwind

Project Whirlwind at the Massachusetts Institute of Technology Servomechanisms Laboratory is sponsored by the Special Devices Center of the Office of Naval Research under contract N5ori60. The original objective of the Project was the development of a device that would simulate airplanes in flight. An integral part of such a simulator is a digital computer of large storage capacity and very high speed, to provide continuous solutions to the equations of motion of an airplane.

As Project Whirlwind has evolved, applications to other types of simulation and to control have become important. Because the digital computer is basic to all these as well as to important applications in mathematics, science, engineering, and military problems including logistics and guided missiles, nearly all project resources are at present devoted to design of a suitable computer.

The Whirlwind Computers

The Whirlwind computers will be of the high-speed electronic digital type, in which quantities are represented as discrete numbers, and complex problems are solved by the repeated use of fundamental arithmetic and logical (i.e., control or selection) operations. Computations are executed by fractional-microsecond pulses in electronic circuits, of which the principal ones are (1) the flip-flop, a circuit containing two vacuum tubes so connected that one tube or the other is conducting, but not both; (2) the gate or coincidence circuit; (3) the electrostatic storage tube, which uses an electron beam for storing digits as positive or negative charges on a storage surface.

Whirlwind I (WWI), now being developed, may be regarded as a prototype from which other computers will be evolved. It will be useful both for a study of circuit techniques and for the study of digital computer applications and problems.

Whirlwind I will use numbers of 16 binary digits (equivalent to about 5 decimal digits). This length was selected to limit the machine to a practical size, but it will permit the computation of many simulation problems. Calculations requiring greater number length will be handled by the use of multiple-length numbers. Five special orders expedite the subprogramming of multiple-length operations, so that coding is no more complicated than for single-length numbers, but computing time is substantially increased. Rapid-access electrostatic storage will have a capacity of 32,000 binary digits, sufficient for large classes of actual problems and for preliminary investigations in most fields of interest. The goal of 20,000 multiplications per second is higher than general scientific computation demands at the present state of the art, but is needed for control and simulation studies.

Reports

Summary Report No. 2, issued in November, 1947, was a collection of all information on the Whirlwind program up to that time. The present series of monthly reports is a continuation of the Summary Report series, designed to maintain a supply of up-to-date information on the status of the Project.

Detailed information on technical aspects of the Whirlwind program may be found in the R-, E-, and M-series reports and memorandums that are issued to cover the work as it progresses. Of these, the R series are the most formal, the M-series the least. A list of publications issued during the period covered by this Summary appears at the end as an appendix. Authorized personnel may obtain copies of any of them by addressing a request to The Special Devices Center, Office of Naval Research, Port Washington, Long Island, New York; or where approval has previously been arranged, to Jay W. Forrester, Project Whirlwind, Servomechanisms Laboratory, Massachusetts Institute of Technology, Cambridge, Mass.

GENERAL STATUS

During the months of March and April, detailed design progressed on many elements of the computer. The computer elements whose status is listed below include a large portion of the whole machine. The only elements which are not reported on in this section are electrostatic storage tubes with their associated circuits and the registers and control circuits associated with the film input-output devices. None of these are needed for the assembly and initial testing of the arithmetic element, which, as previously described, will be the first part of the computer to be delivered by Sylvania. Register, drivers which will be needed initially are in the preliminary design stage, but progress is satisfactory. Parts of the master clock are also in a preliminary stage but most of it can be specified from combinations of existing equipment.

Elements of the computer on which Sylvania will do the final design and construction are listed under four headings below, grouped according to the progress of the design.

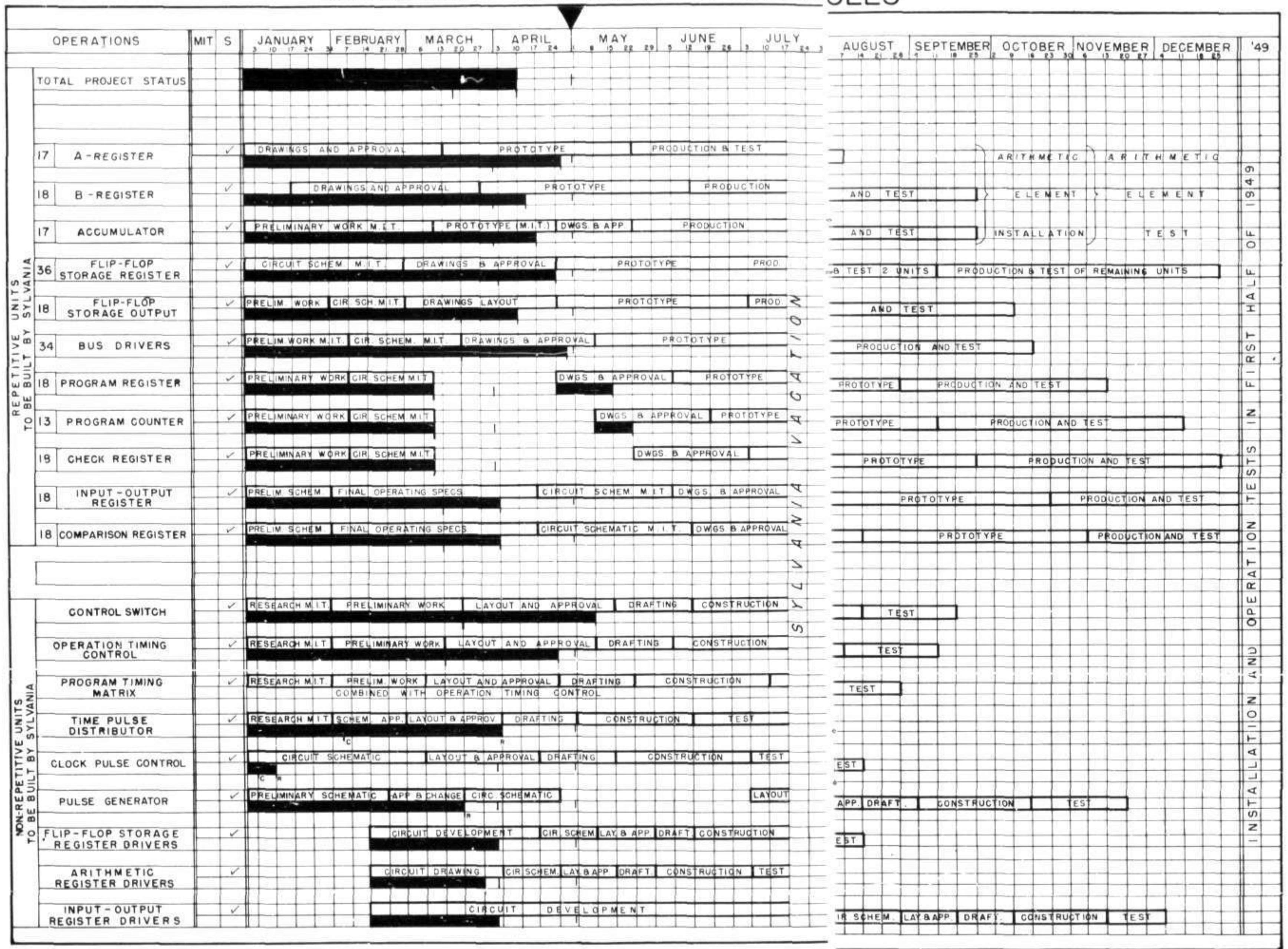
1. Circuit schematics have been approved for layout of the program counter, which includes eleven identical panels of nine tubes each, and the check register, which includes sixteen 8-tube panels. Circuit schematics have also been approved for the time-pulse distributor counter panel and the time-pulse distributor output panel. There will be one panel of each, including respectively twenty-two and twenty-eight tubes.
2. Layouts have been approved for the general arrangement of the control switch, operation matrix drivers, operation matrix, and time-pulse distributor. These units will occupy six standard 26" x 100" racks. Detailed video layouts have been approved for the time-pulse distributor counter panel mentioned above, for the flip-flop storage output, of which sixteen 10-tube panels are required, and for the program register, which consists of sixteen 5-tube panels.
3. Final drawings have been approved for construction of prototypes of the sixteen 8-tube A-register panels, the sixteen 11-tube B-register panels, the thirty-two 10-tube flip-flop storage register panels, and the thirty-two 5-tube bus driver panels.
4. Construction of a prototype of the control pulse output unit has been authorized from a preliminary sample. There will be approximately 100 of these 2-tube plug-in units associated with the operation matrix.

Construction has been completed at M.I.T. on the prototype of the 28-tube accumulator panel from which Sylvania will make production drawings and construct the required sixteen panels. Video layout at M.I.T. is about 30 percent complete on the 150 tubes in arithmetic control. There will be one each of six different panels all of which will be built at M.I.T.

As shown on the chart which follows, Whirlwind I planning and construction is running about three weeks behind the schedule set up at the beginning of 1948. The general arrangement of the computer apparatus is described and illustrated on Page 10 of this Report, and photographs of typical panels are shown. Power requirements have been further analyzed, and plans for power supply equipment are taking shape.

A computer with the flexibility and speed of the Whirlwind machines will have numerous uses of widely divergent kinds. Studies of computer applications continue; an article in this Report describes investigations into conversion of computer output into two possible forms.

SUMMARY - WHIRLWIND I SCHEDULES



LEGEND

JANUARY

Period of one month, comprising the total number of days in the month.

PROTOTYPE

Operation to be performed, and estimated time allotted for its completion. Estimates made in January 1948.

Work done. The ratio of the length of the solid bar to the length of the open bar above it shows percentage of completion at the end of the month.

Date of latest posting.

Summary line. Shows overall status of the project.

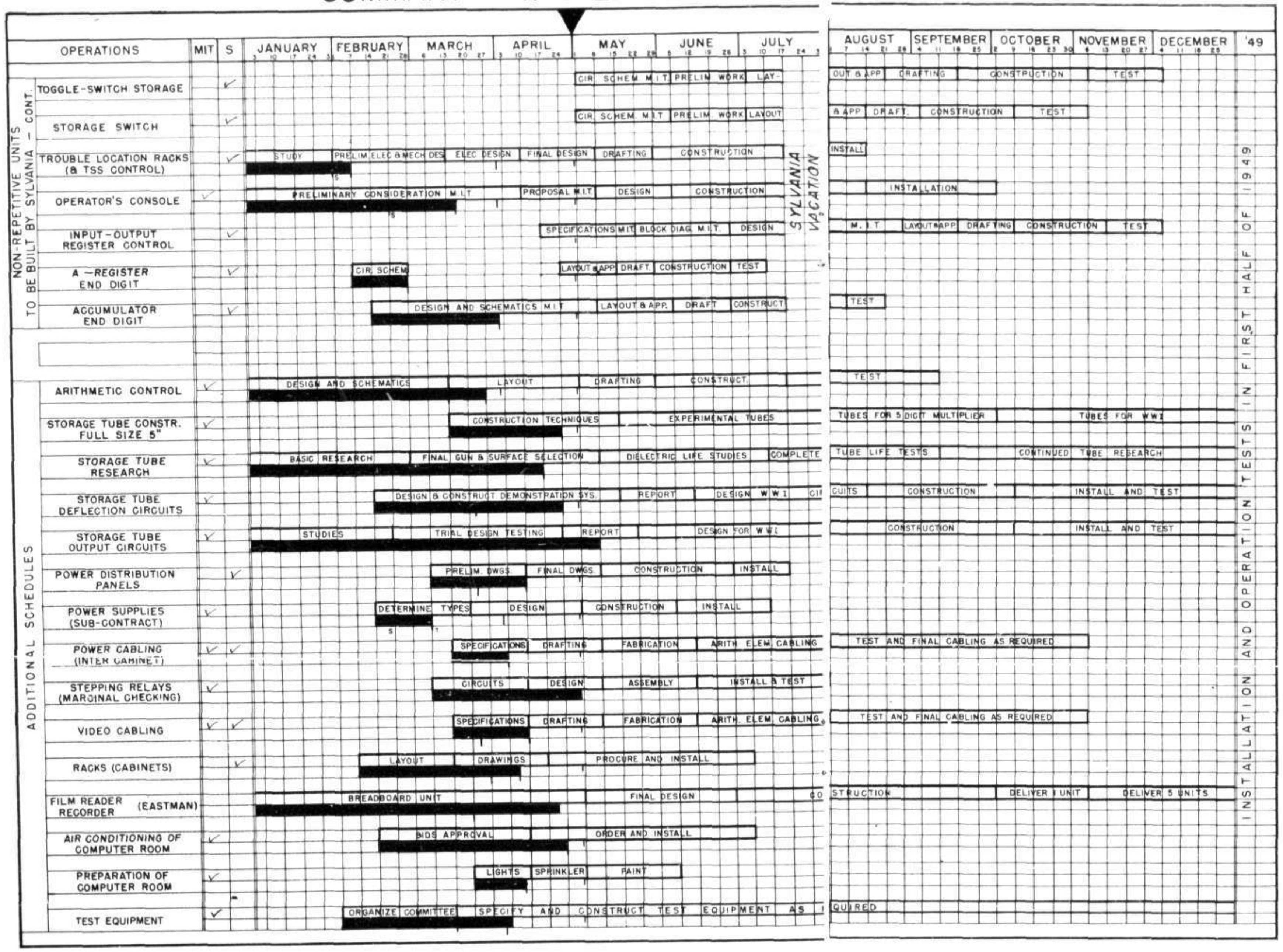
MIT	S
	✓

Column showing whether M.I.T. or Sylvania will do major portion of the job.

NOTES

- C Changes in specifications have delayed this item.
- S Studies and specifications still incomplete, due principally to lack of staff time.
- R Revised schedule does not call for same completion date as originally planned.
- T Temporary arrangements can be made to meet required schedule.

SUMMARY - WHIRLWIND I SCHEDULES CONT.



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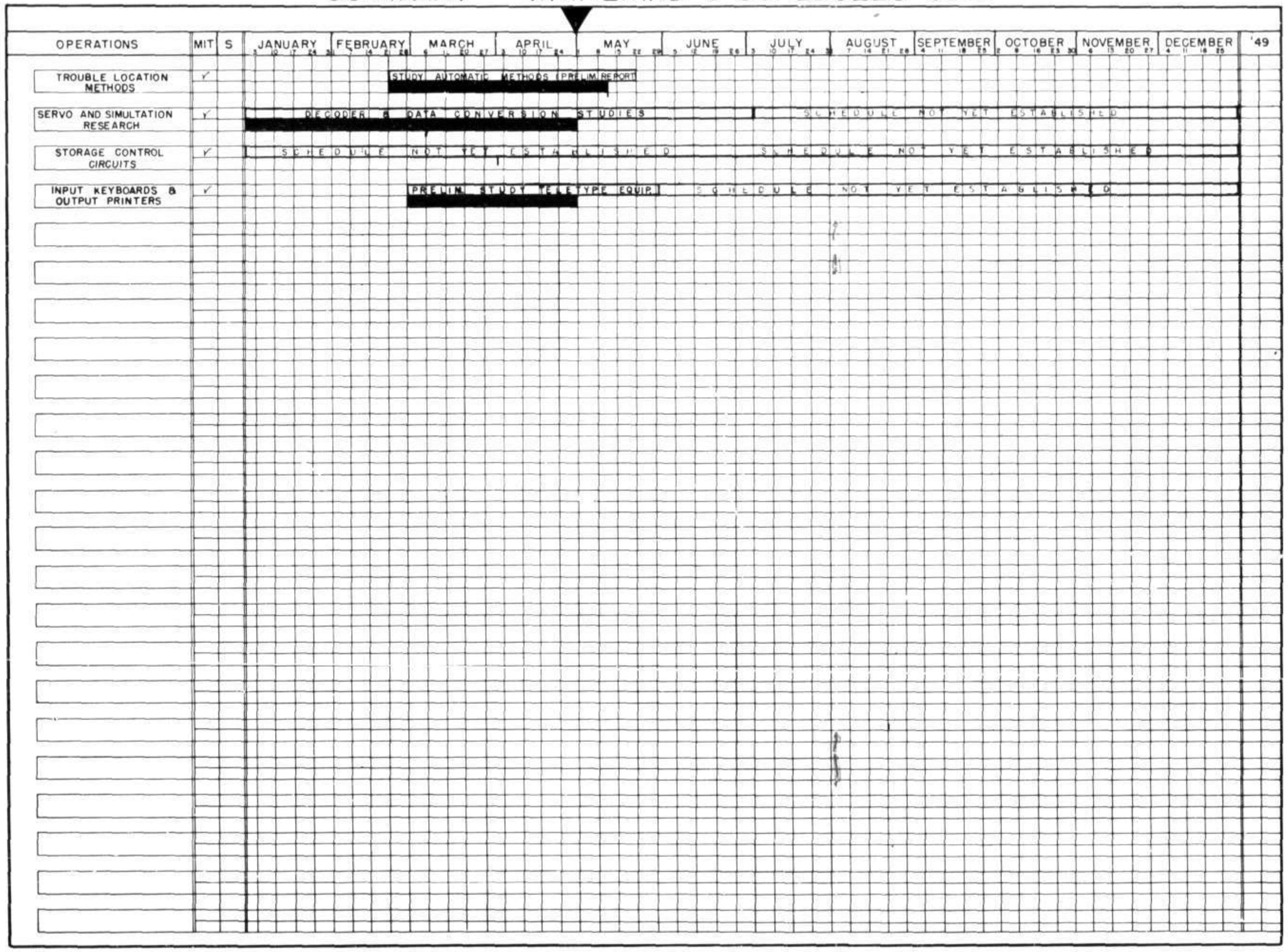

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ARRANGEMENT OF WHIRLWIND I APPARATUS

The digital calculating machine of the future will ideally be a compact device which can be installed in one corner of a room, or mounted on a truck, or carried on a ship or an airplane. Before such accomplishments are possible, however, the basic techniques of building and using digital computers must be fully explored.

WWI belongs to the first phase of a long-range program of digital-computer development. Of itself it will be highly useful for a number of applications, but its primary functions are to demonstrate that high-speed electronic digital computation is practicable and to ascertain the merits of the particular methods chosen for performing the various required functions. The designers of WWI have therefore made no attempt to minimize the volume which the machine will occupy.

Fig. 1 shows the proposed overall physical arrangement of the computer apparatus. All the main computer elements will be placed in one large room, whose dimensions are indicated, on the 2nd floor of the Barta Building at 211 Massachusetts Avenue, Cambridge.

Adjacent to the Computer Room is the Control Room in which will be located such auxiliary apparatus as the operator's console, film and teletype equipment for input and output, meters indicating power-supply voltages, and pairs of neon lights which show the positions of all the flip-flops in the computer. Although the arrangement of the Computer Room is definitely planned as in the drawing, the Control Room layout shown is merely an artist's conception intended to give some idea of what will be required.

The electronic circuits of the computer will be built onto panels as shown in Fig. 2 and the prototype photographs which appeared on page 2 of Summary Report 5 (February). A number of panels, each containing a different functional unit, will be mounted on a rack, or frame, similar to that of Fig. 2. The racks will be placed side by side and housed in cabinets as indicated in Fig. 1.

This arrangement of the computer will permit easy access to all portions of the apparatus. The essentially two-dimensional layout of components on the panels is especially conducive to the easy replacement of defective elements and all circuit terminals will be readily available to maintenance technicians who wish to observe waveforms or determine d-c voltages. Moreover, most panels will be readily removable from the racks, so that an entire panel known to contain a fault can be replaced by a spare and then repaired at relative leisure.

Power will be distributed to the computer from the power panels against the west wall by means of a network of wire ducts (not shown) which will run both longitudinally along the tops of the cabinet rows and transversely between corresponding cabinets of adjacent rows at cabinet-top height. The power supplies for the computer do not appear on the drawing since they will be on the basement floor of the building. Video cabling for transferring digits between computer elements will also be contained in the transverse ducts, but video control lines for the various registers will run longitudinally in wireways mounted on the racks inside the cabinets, except at the north-south aisle, where the crossover will be effected via the ducts along the cabinet tops.

An air-conditioning system will provide cooling air to each row of cabinets to carry away the heat arising from the dissipation of about 50 kilowatts in the computer components. Design of racks and cabinets is such as to permit free flow of air across all tubes and circuit components. The maximum cabinet temperature is to be limited to about 75 F.

STORAGE

Deflection Circuits

As described under the same heading in the February Summary Report, No. 5, each of the electrostatic storage tubes used as a memory element in the Whirlwind computers is to have 1024 available storage positions. The position to be used for any storage operation will be specified in the program order which calls for that operation, the information being supplied to the storage-control circuits as a binary number in pulse-coded form. A group of "deflection circuits" in the storage-control system will convert the pulse-coded number into two potential differences whose magnitudes correspond to the magnitude of the input number. These potential differences will then be applied to the deflection plates of the electron guns of all storage tubes in the system, and will thus control the position on the storage surface at which the storage operation is performed.

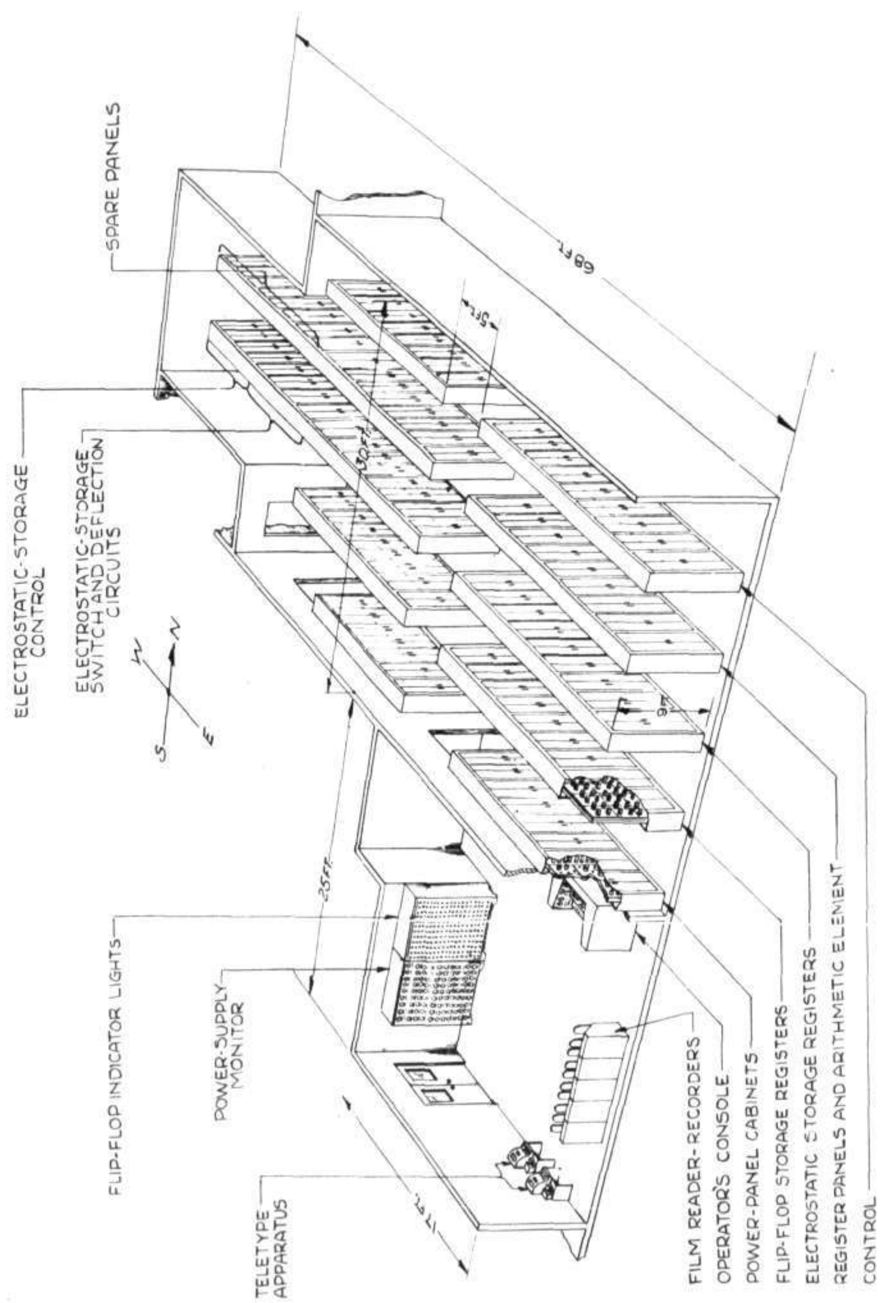
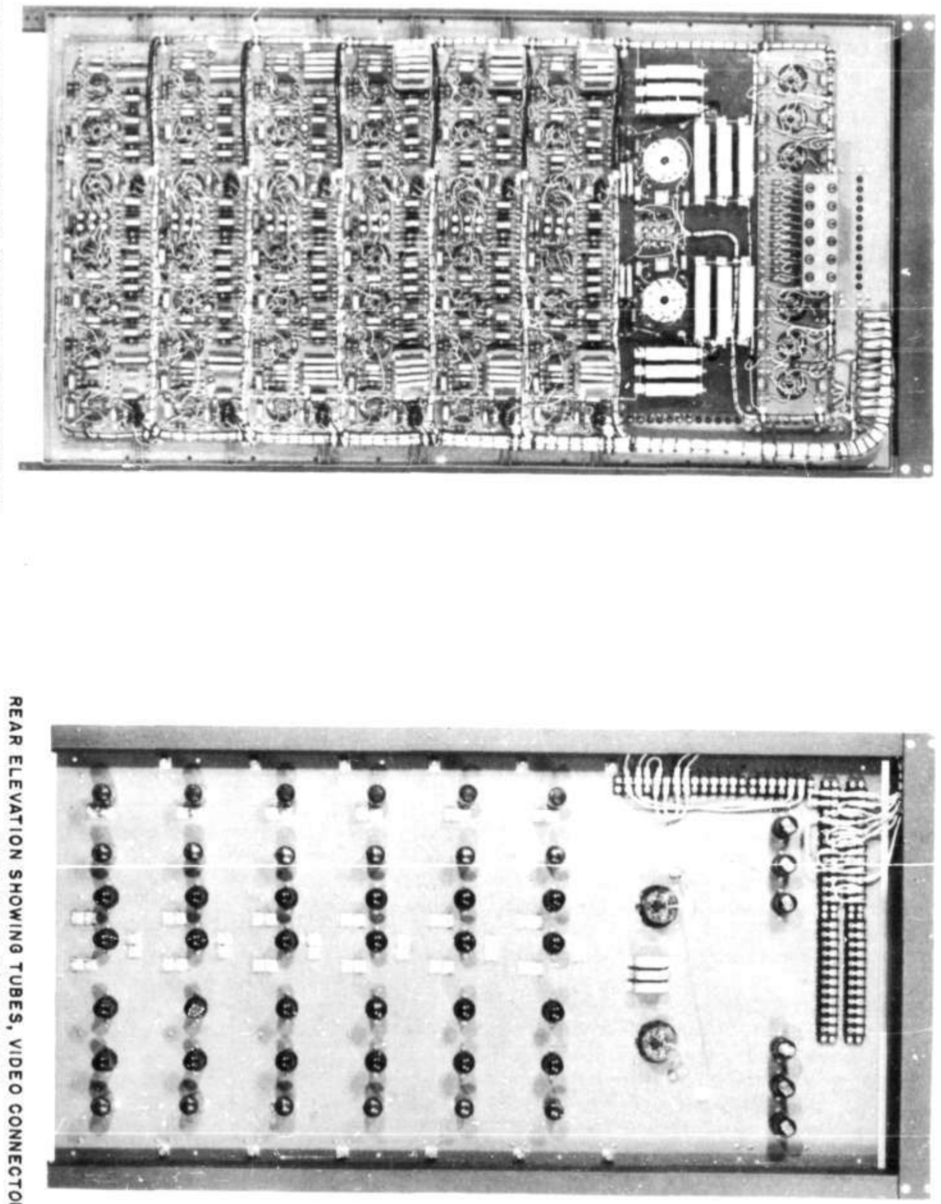


Fig. 1 PROPOSED ARRANGEMENT OF WHIRLWIND I APPARATUS



FRONT ELEVATION, SHOWING COMPONENTS AND WIRING

REAR ELEVATION SHOWING TUBES, VIDEO CONNECTORS, AND POWER CONNECTORS

FIG. 2 EXPERIMENTAL DEFLECTION-VOLTAGE GENERATOR

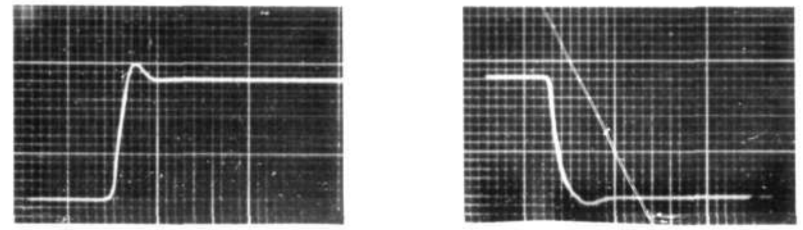


FIG. 3. TYPICAL OUTPUT VOLTAGE WAVEFORMS.

These oscillograms show the voltage transients which result when the decoder is switched from the cleared (or 0) position to the position corresponding to an input number 15 and when the decoder is cleared to the 0 position from the 15 position. At the time the photographs were taken the deflection-voltage generator was connected to a load equivalent to three electrostatic storage tubes. The vertical scale is 65.5 volts per major division, the horizontal scale 0.91 microsecond per major division. Rise time from initiation of switching to steady-state output is 1 microsecond.

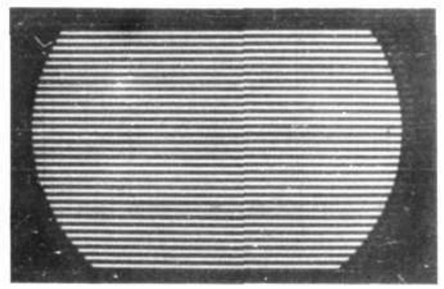


FIG. 4. OUTPUT VOLTAGE LEVELS.

For this oscillogram the flip-flops and read-out gate tubes of the decoding elements were connected to operate as a scale-of-32 counter driven by the pulse which was used to start the oscilloscope sweep. The output of the decoder was thus caused to assume a different level at each sweep, stepping in succession from the 0 position to the 1 position, from the 1 position to the 2 position, etc., until the 31 position was reached, and then repeating the cycle. The oscillogram demonstrates the uniformity of steps as resistor combinations are switched.

An experimental set of circuits for generating storage-tube deflection voltages is currently under construction. The completed deflection-voltage generator will be capable of converting any two 5-digit binary numbers into corresponding potential differences at the vertical and horizontal deflection plates of the connected electrostatic storage tubes, giving 32 deflection levels in each coordinate, or a total of 1024 combinations. After tests have been completed, these circuits will be used for demonstration purposes and may also be used in conjunction with 5-inch electrostatic storage tubes to make storage reliability tests.

One panel of the preliminary model deflection circuit was completed during April and tests were begun. This single panel furnishes deflection voltages to one pair of deflection plates in each tube to which it is connected, giving 32 separate values of deflection in either the vertical or the horizontal coordinate. The accompanying photographs show the type of construction used in this unit and representative oscillograms of the output voltages secured.

Construction of the second deflection-voltage generator panel is currently in progress and will be completed about May 19. Assembly of test equipment and power supplies required for testing and demonstrating the performance of the completed circuits is also under way. Detailed tests of the first panel have been begun and will continue throughout May and the first two weeks of June.

Tests of 5-inch Storage Tube

Tests of the first large size (5-inch) electrostatic storage tube (described in the March report) show that its operation is the same in most respects as that of smaller research tubes with the same storage surface materials. The tube has a high-velocity well-focused electron beam for storing digits as spots of positive or negative charges on a storage surface and a low-velocity diffuse beam spraying the surface to maintain the stored charges. A wire mesh screen held closely in front of the storage surface acts as the collector of secondary electrons and a metal backing plate picks up the signal current by capacitive coupling to the storage surface.

The constructional details of the 5-inch tube are quite different from those of the smaller tubes, resulting in an increase in the signal output capacitance by a factor of about 8. This gives slower rise times on the output pulse. Efforts will be made on new tubes to reduce the output capacitance. The calcium tungstate storage surface requires a slightly lower holding-beam electron velocity than the same surface in the smaller research tubes, but gives a writing time of 30 microseconds and read time of 2 microseconds, the same as for the small tubes with the same storage surface.

The tube in general is very satisfactory, since it shows that the construction problems are not insurmountable and that operation is substantially unchanged as tube size is increased. Only part of the storage surface was studied because the holding gun did not illuminate the entire surface properly. Other 5-inch tubes will be made to find better processing and construction procedures. Small research tubes, however, will also be made to try new ideas, since these tubes are simpler and more economical to make. As the results from the small research tubes indicate surfaces or electrode configurations with better storage characteristics, these ideas will be built into 5-inch tubes to make certain that unexpected troubles do not develop to prevent the construction of the final tubes with the latest design features.

DYNAMIC ANALYSIS OF D-C LOAD

For any electronic device the size of the Whirlwind I computer, the provision of a suitable d-c power supply is by no means a minor problem. Not only must maximum total power requirements be estimated, but, since violent load changes necessitate equipment with exceptionally good voltage regulation and other characteristics, the minimum limit also must be established.

The maximum instantaneous power consumed by any large machine depends not only on the power consumed by the individual units but also on the maximum number of units that can consume power simultaneously. The WWI computer is so arranged that some units (as: flip-flops) always consume power, while other units consume power or not -- depending on certain conditions. Still other units (as: gates) consume power only when they are "pulsed". Generally speaking, the pulses occur at a one-megacycle rate. The result of this arrangement is that the total power consumption of WWI can have any value, within limits, and that this value can change at any random frequency up to one megacycle.

The limits were estimated for each d-c voltage supply-line by an analysis of the number of units in the computer which consume power simultaneously. It is assumed that the electronic decoupling circuits will allow only the average pulse-power to appear on the supply lines; therefore, the average rather than the peak value of pulse-power was evaluated.

The result of the estimate shows that for most of the WWI circuits except the electrostatic storage tubes the total consumption can vary between about 5.6 and 7.0 kw. (Storage tube power is of the order of 3 kw.) The upper limit is only about 1.3 times the lower limit for total power, and about 1.8 times for the "worst" d-c supply-line. The lower limit can occur only when the computer is not operating, but is energized; the upper limit can occur only during full automatic computation.

On the basis of this estimate, three-phase grid-controlled thyratron rectifying equipment for each d-c voltage supply-line seems to be an adequate design for WWI. Isolating alternators are planned to prevent power line surges from affecting d-c output voltages.

CONVERSION OF COMPUTER OUTPUT

Conversion from Binary to Binary-decimal Form

The Whirlwind Computer is designed to operate on numbers expressed in binary form. In this system the digits of a number are the coefficients of powers of the base 2, just as in the ordinary decimal system the digits are coefficients of powers of the base 10. Each digit is either one or zero, indicating the presence or absence of the power of two corresponding to the position of that digit. Thus, in binary form the number 10011 represents (reading from the right) $1 \times 2^0 + 1 \times 2^1 + 0 \times 2^2 + 0 \times 2^3 + 1 \times 2^4 = 1 + 2 + 16 = 19$.

Usually it will be desirable to supply information to the machine and to receive results from it in conventional decimal form. Conversion from one form to the other is a fairly simple arithmetic operation which can be carried out by the computer itself. To accomplish this, it is useful to introduce a third representation of a number, a hybrid binary-decimal form, in which each decimal digit of the number is represented by a group of four binary digits, a binary tetrad. Thus the decimal number 138 could be represented in binary-decimal form by 0001 0011 1000, each tetrad representing one decimal digit in binary form. The true binary form of 138 would be 10001010.

By use of this binary-decimal form, decimal numbers can be put directly into the computer. A program can then be written for the computer by which the binary-decimal number can be converted to true binary form suitable for further use by the computer. Similarly, another program can be used to convert from binary to binary-decimal form suitable for output of results. Both types of conversions together will require less than 5% of the limited storage capacity of WWI.

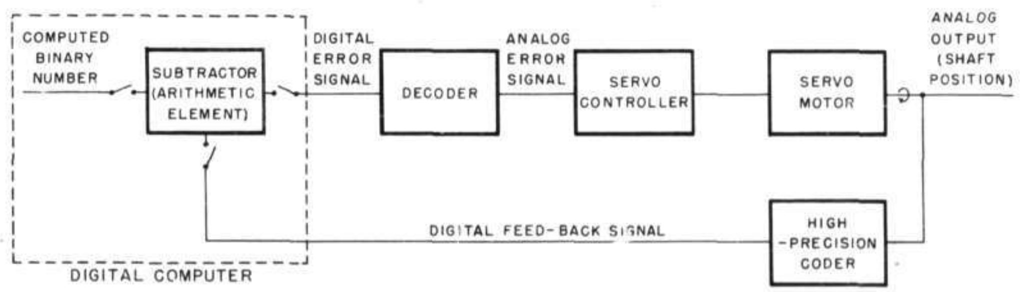
Standard teletype equipment may be used for input and output purposes. Teletype equipment makes use of groups of five binary digits to represent 32 different symbols, so that input and output from WWI may be wanted not in binary-decimal tetrads but in teletype pentads. Because the teletype code represents decimal digits by arbitrary combinations of five binary digits, this conversion cannot be accomplished directly. Instead, the binary-decimal form may be used as an intermediate step, with the conversion between teletype and binary-decimal being accomplished by a selection process. Such a further conversion increases time and storage requirements somewhat, but not unreasonably.

Small difficulties arise from the fact that the Whirlwind I register will hold 16 binary digits, corresponding to a sign digit and about 4.5 decimal digits. These 16 digits can accommodate only 4 tetrads or 3 pentads (and a single digit which might be used for a sign), so that if single registers are used for input and output, some accuracy will be lost, but the loss is not great. Where accuracy is important 2 registers can be used. An order for WWI is designated by two letters and four decimal digits; therefore two registers will be required to store an order in either binary-decimal or teletype form. Double length numbers (i.e. two registers in pure binary form, corresponding to 30 binary digits or 9 decimal digits) also are more complicated. Details of coding the numerous conversions from one form to another are being considered at present, but no serious trouble is anticipated in any of these problems.

Sampling Servo

The application of a digital computer to a physical system such as the Aircraft Stability and Control Analyzer requires conversion of computed digital quantities to analog quantities, some of which will be shaft positions. For example, the indicated readings of simulated aircraft instruments are produced by a needle which is rotated by a shaft.

To date, no sufficiently sensitive device for direct conversion of a binary number to an analog quantity (decoder) is available. It is felt that greater sensitivity can be obtained in converting a shaft position to a binary number (coding). Hence a closed-cycle servomechanism is under study for conversion to shaft position. As shown in the accompanying block diagram, such a system would utilize a coding device to measure the analog output (shaft position). The coded output is subtracted



SERVO FOR DIGITAL-TO-ANALOG CONVERSION

from the computed quantity by the arithmetic element of the computer to give a binary error signal. This error signal is then decoded to an analog voltage by a device of moderate sensitivity and used to control the shaft position of a servo motor. The arithmetic element is part of the closed-cycle system.

Since the computer has only one arithmetic element for all computations, the servo error signal is necessarily computed at discrete intervals, probably 0.05 to 0.10 second apart. This means that the servo feed-back path is not continuously operative, but is closed periodically to "sample" the error. This type of system is called a sampling servomechanism.

Sampling servos present unique design problems which require extension of the usual techniques applied to design of continuous servomechanisms. Methods of establishing stability criteria for sampling servos have been described in published literature, but their use as a basis of design is limited by the complexity of the mathematics involved.

Studies are under way to broaden the understanding of sampling servo theory. The principal objective is to derive a form of mathematical representation which may be used for analysis and will in addition serve as a guide for sampling servo synthesis.

VISITORS

Dr. R. D. O'Neal and T. D. Cochran of the Eastman Kodak Company attended conferences on checking procedures to be used with input and output equipment. H. M. Trent of the Naval Research Laboratory was interested in the use and availability of digital computers for research studies, and Mr. M. Katzin discussed electronics techniques and possible application to other fields of research at N. R. L. C. V. L. Smith of ONR and Harley Iams of North American Aviation visited the Project.

Project staff discussed the problem of analog-to-digital data conversion and use of computers in storage and analysis of radar data with representatives of the Coles Signal Laboratory.

F. E. Bothwell, D. H. Schiller, and N. H. Painter of Project Chore, University of Chicago, were shown the results of preliminary studies on simulation of aircraft based on wind tunnel data.

Training programs in the field of digital computers were discussed with Capt. T. K. Oliver of Wright Field, who is responsible for training of men in digital computers for the armament research laboratory.

Test equipment information as developed by Project Whirlwind and the Bureau of Standards for research and evaluation of computer components was interchanged with S. N. Alexander and H. R. Senf.

Storage tubes and vacuum tube laboratory techniques were of special interest to John E. Gorham of the Evans Signal Corps Laboratory and Professor A. R. Samuel and Professor R. S. Julian of the University of Illinois

APPENDIX

REPORTS AND PUBLICATIONS

The following reports and memorandums on Project Whirlwind work were issued during April.

No.	Title	No. of Pages	No. of Drwgs.	Date	Author
SR-4	Summary Report No. 4	9	-	1-48	
R-135	History of Secondary Emission (Abstract in E-111)	76	11	3-30-48	H. L. Heydt
E-108	Sylvania Test Equipment	1	-	3-26-48	N. H. Taylor
E-109	6AS6 Vacuum Tube Life Data	2	2	4-5-48	J. J. O'Brien
E-110	Life Data - 6AG7 Tubes of D. C. Flip-Flop Rack	2	2	4-14-48	J. J. O'Brien
E-112	Tube Failures	2	2	4-23-48	J. J. O'Brien
E-113	Block Diagram of Master Clock for Whirlwind I	2	1	4-27-48	D. R. Brown
M-328	Double-Length Operations in WWI	11	-	3-31-48	C. W. Adams
M-329	Modification of Basic Circuit Ind-1	4	3	4-2-48	J. M. Hunt
M-331	Bi-Weekly Report, Part I, April 2	18	-	4-2-48	
M-332	Bi-Weekly Report, Part II, April 2	21	-	4-2-48	
M-334	Wedge Sleeve Clamp for BNC Connectors	1	2	4-5-48	H. Fahnestock
M-335	Progress Report: A Trouble Location Scheme for a Digital Electronic Computer	2	1	4-5-48	E. Blumenthal
M-336	Progress Report: A Trouble Location Scheme for a Digital Electronic Computer	2	-	4-5-48	G. Hoberg
M-337	Progress Report: A Storage Tube Output System	2	-	4-3-48	C. Campling
M-339	WWI Rack Door Material	1	-	4-5-48	J. W. Forrester
M-341	Trip to Power Equipment Co., Detroit, Mich., on March 29th	3	-	4-6-48	H. R. Boyd
M-342	Standards Committee Approval of Mechanical Parts Designed by Sylvania	1	-	4-7-48	C. W. Watt, Jr.
M-343	17S Dural Channel	1	-	4-7-48	C. W. Watt, Jr.
M-344	Machining of Nickel	2	-	4-7-48	R. Shaw, Jr.
M-345	Binary to Binary-Decimal Conversion	4	2	4-8-48	C. W. Adams
M-346	Power Supply Proposal No. 2	4	1	4-8-48	H. R. Boyd
M-348	Master's Thesis Research Proposal: Conversion of Binary Pulse Code to Voltage Amplitude	9	6	4-6-48	E. W. Sard
M-351	Meetings of the Electronics Group, March 26 and April 2, 1948	1	-	4-8-48	J. J. O'Brien
M-352	WWI Control Desk Proposal No. 1	7	4	4-13-48	J. W. Forrester
M-353	Signal Plate Assembly for ST25	2	-	4-13-48	R. Shaw, Jr.

No.	Title	No. of Pages	No. of Drwgs.	Date	Author
M-358	Time Pulse Distributor - Counter Panel: Circuit Schematic Corrections	1	-	4-14-48	H. Fahnestock
M-361	Vacuum-Tube Life-Tests Proposal	3	11	4-15-48	J. J. O'Brien
M-363	Bi-Weekly Report, Part I, April 16	19	-	4-16-48	
M-364	Bi-Weekly Report, Part II, April 16	18	-	4-16-48	
M-366	Layout of Panels to Permit Proper Cooling of Tubes and Components	1	1	4-20-48	C. W. Watt
M-367	Progress Report: A Storage Tube Output System	3	-	4-17-48	C. Campling
M-373	Meeting of the Electronics Group, April 9 and April 16, 1948	1	-	4-23-48	E. S. Rich
M-374	Test Procedures for WWI Tubes	2	4	4-23-48	N. H. Taylor
M-375	Construction of a Second Tube Tester	1	-	4-26-48	D. R. Brown
M-376	Rack Ground Bus	1	-	4-27-48	H. S. Lee
M-377	Project Whirlwind Seminar Schedule April 26 - May 26	1	-	4-27-48	R. R. Everett
M-379	Voltage Regulation Proposal	4	2	4-27-48	C. R. Wieser
M-380	WWI Dynamic Analysis of D. C. Load	3	1	4-26-48	R. P. Mayer
M-383	Video Layouts and Mechanical Drawings for Accumulator	2	-	4-28-48	C. W. Watt
M-387	WWI Video Cabling	1	-	4-29-48	H. Fahnestock
M-389	Bi-Weekly Report, Part I, April 30	18	-	4-30-48	
M-390	Bi-Weekly Report, Part II, April 30	19	-	4-30-48	
C-27	Project Whirlwind Seminar No. 1, Introduction	4	-	1-12-48	J. W. Forrester

Translation

No.	Title	No. of Pages	No. of Drwgs.	Date	Author
M-370	Electronic Devices with High Emission of Secondary Electrons - (BULLETIN OF THE ACADEMY OF SCIENCES OF U.S.S.R., Physics Series, Vol. 8 (1946) by R. M. Aranovich)	8	5	4-21-48	M. Daniloff