T H E   U N I V E R S I T Y   O F   M I C H I G A N

Memorandum 22

THE ELECTROWRITER AS A COMPUTER I/O DEVICE

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ABSTRACT

This report describes the hardware used in the tests of the Victor Comptometer Corporation's Electrowriter as a computer input/output device. Tests were performed on a DEC PDP-9 computer equipped with an A-to-D converter and a D-to-A converter.

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1. INTRODUCTION

This report describes the hardware used in the tests of the Victor Comptometer Corporation's Electrowriter as a computer input-output (I/O) device.

Equipment that will duplicate motion of a pen or stylus at remote locations has been available for quite some time. Primitive versions were available before 1900. As a message is written at the transmitter, the motions of the pen are transmitted as electrical signals to a receiver where the message is duplicated.

Two sources of such equipment were considered for the planned tests. Equipment from Victor Comptometer Corporation was selected. Frequently in the report there are specific references to the Victor Electrowriter®*, but similar tests could have been conducted with other similar devices.

The plans for the tests specified that there should be no changes in the Electrowriter equipment. The plans also specified that the tests should be performed on a Digital Equipment Corporation Model PDP-9 computer equipped with an analog-to-digital converter (A to D) and a digital-to-analog converter (D to A). It was necessary to provide auxiliary electronics for communicating between the Electrowriter hardware and the computer analog terminations.

*Electrowriter® is the registered trademark of the Victor Comptometer Corporation, Chicago, Illinois; hereinafter referred to simply as Electrowriter.

The University of Michigan Radio Astronomy Observatory designed and built a prototype version of the required auxiliary electronics. This work was performed under the supervision of the University of Michigan Systems Engineering Laboratory who are funded for the investigation by the Advanced Research Projects of the Department of Defense under contract number DA-49-083. Testing of the Electrowriter with the computer, including the programming, was performed by the Systems Engineering Laboratory. A discussion of the programming and the results of the tests are given in another memorandum.*

2. BACKGROUND INFORMATION

2.1 THE CONVENTIONAL ELECTROWRITER SYSTEM

The Electrowriter and similar devices have found rather wide usage for transmission of a brief written messages. For certain types of communications it is important to have a written record of the messages, and these devices meet this need very well.

The wiring required for electrical connections between Electrowriters in a communication network may be provided by the customer. This is generally the case for terminals all located in the same building or in buildings at a common site. If the terminals are farther apart, they are usually

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*Powers, V.M., Portaterm Software, Memorandum 21, Concomp Project, University of Michigan, Ann Arbor, in preparation, March 1969.

connected by leased telephone lines or the regular dial networks of the telephone company. Figure 1 shows a block diagram of a telephone network.

The telephone company generally requires that any equipment using the telephone company lines must be connected to the lines via suitable telephone-company-provided junction boxes. A variety of such junction boxes are available. The junction box used with the Electrowriter equipment is the 601-A data set (Figure 2). It can function as a standard telephone, but, in addition, when the user depresses the Write button, the Electrowriter will be connected to the line.

Typical operation of an Electrowriter system such as shown in Figure 1 would be somewhat as follows:

1. The operators initiating the communication would telephone the other operator in the usual manner. ("Talk" button is depressed.)
2. The operator at the receiving station would answer and then converse in the usual manner. So long as the Talk buttons are depressed the system is a standard telephone system.
3. When the operators agree that they are ready to transmit the written message, they both depress the Write button. The Electrowriters at both terminals are now connected to the line.

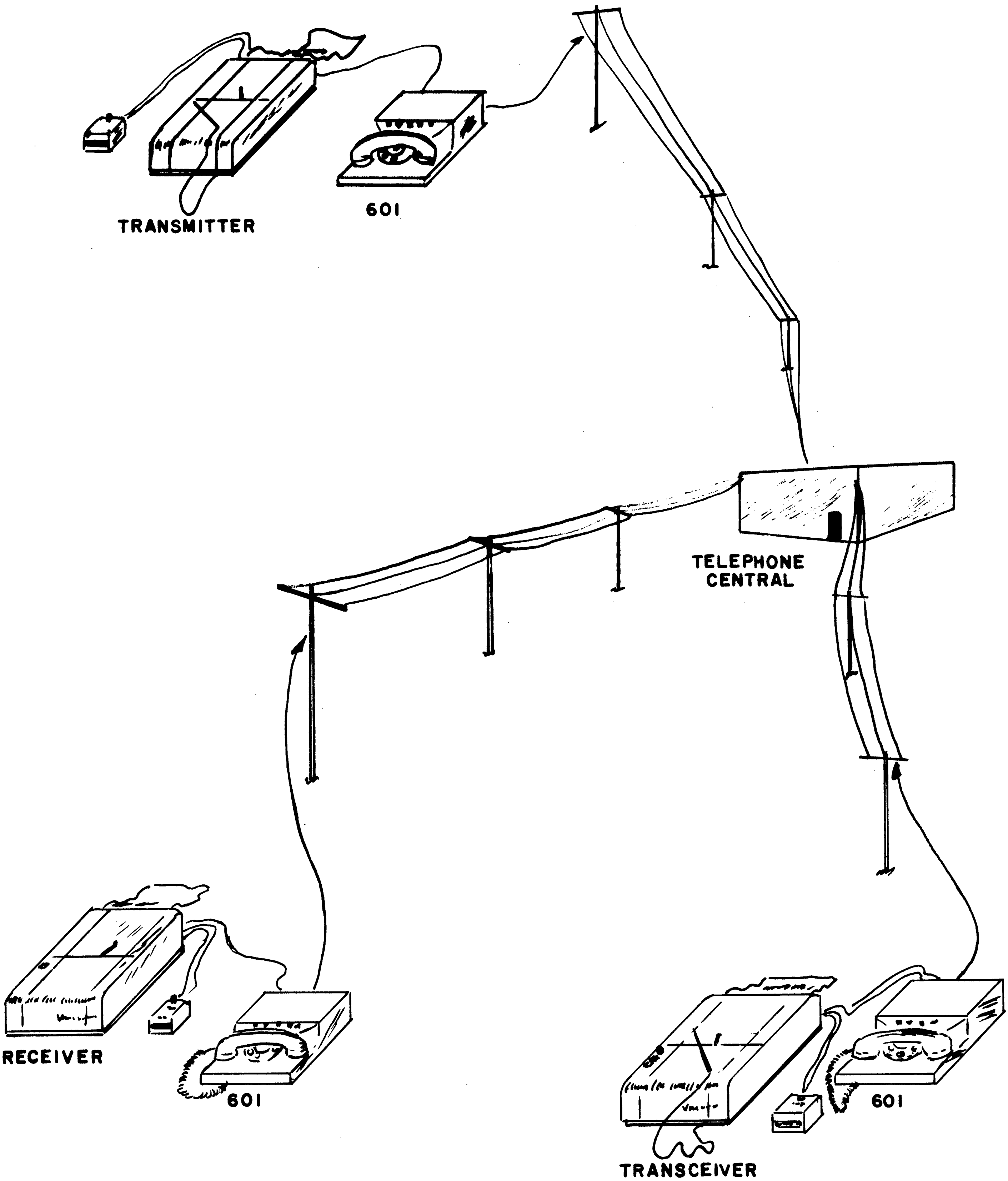


Figure 1. Block Diagram of a Telephone Network

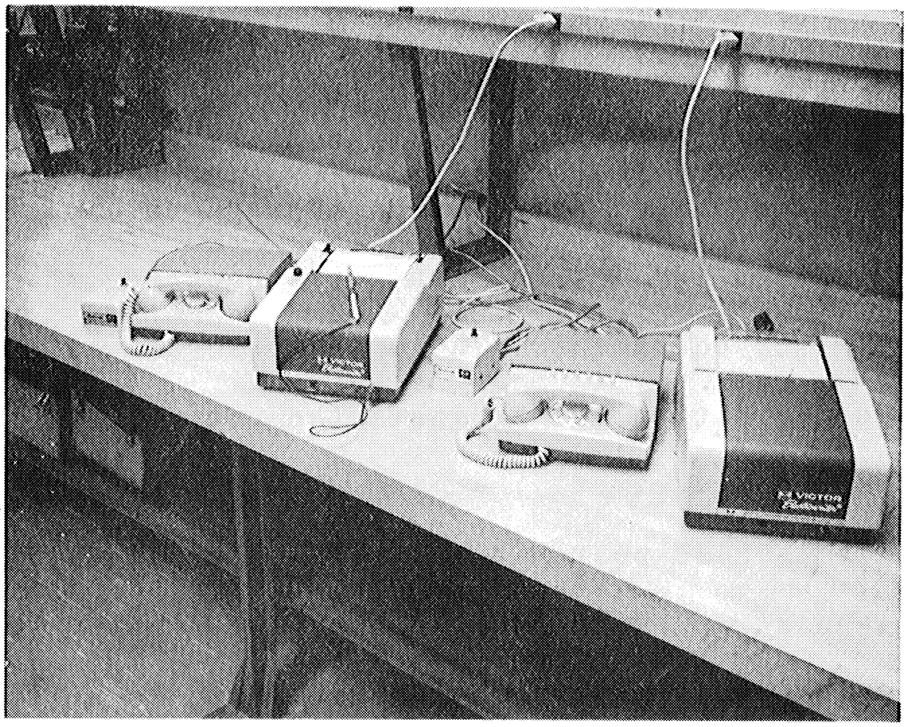


Figure 2. The 601-A Data Set

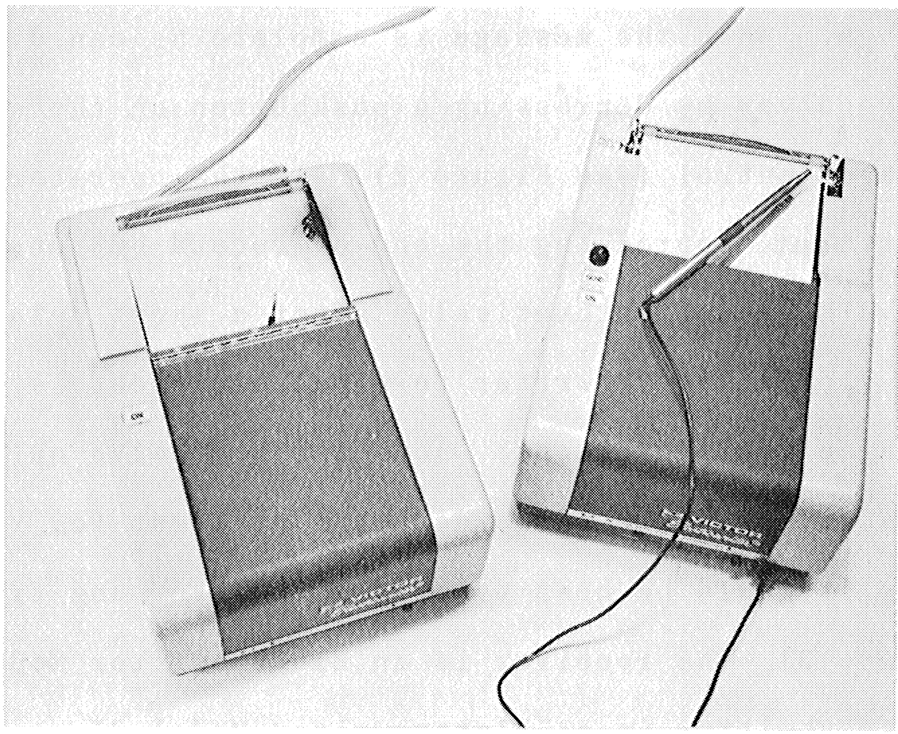


Figure 3. Electrowriter Model 25 Receiver and Electrowriter Model 21 Transmitter

4. The written message is transmitted.
5. At the end of the written message both operators again depress the Talk button, disconnecting the Electrowriter equipment. The operators can now continue their conversation or terminate the communication by hanging up the receiver.

It is also possible to transmit messages that will be received at an unattended terminal. In such a situation the data set at the receiving end is in an automatic mode (by depressing the "auto" pushbutton) and it will respond to a call with a tone. When the operator at the transmitter hears the tone he knows the receiver is ready to write. He depresses the write button and writes the message. When the message is complete he can disconnect the receiver by depressing a pushbutton on the end of message control (see Figure 2). If the operator just hangs-up without depressing the end-of-record button, the receiver will disconnect automatically after a short delay.

Victor Electrowriter terminal equipment is available in three configurations: send only, receive only, or a transceiver. It was decided that at least for the initial tests it would be best to have a receiver and transmitter (Figure 3). The receiver is an Electrowriter Model 25 and the transmitter is an Electrowriter Model 21.

2.2 THE INTEREST IN NEW I/O DEVICES

The number of digital computers continues to increase at an amazing rate. The size and variety now permit applications that were not possible or even considered a few years ago. Technological advances have resulted in computers with storage and logic elements that are smaller and faster, yet more reliable and less expensive than previous models.

The effects of these advances are apparent in the current generation of computing devices in at least two major ways. First, for many small to moderate size computing systems, the so-called main frame is often most reliable and one of the less expensive parts of the system. Second, these advances plus development of intermediate speed, bulk storage devices such as disk files, have resulted in design of timeshare systems. The timeshare systems are very large computer systems designed to service many users simultaneously.

Both of these effects have emphasized the need for new input-output (I/O) devices, although the problem is not new. Practically ever since the first electronic computer, there has been a great deal of attention devoted to improving the peripherals. There have been some rather impressive developments but the improvements in the main frame have been so great that it seems that peripherals are more of a "bottleneck" than ever.

The timeshare systems generally use teletype equipment at the remote terminals. The data rate possible with standard telephone lines is quite low so great speed is not possible regardless of changes in the terminal devices. There is great interest, however, in any device that can add flexibility and capability at the remote location.

3. DESIGN OBJECTIVES

The hardware discussed in this report was required to investigate the feasibility of using a Victor Electrowriter or similar equipment as a digital computer input-output device. A secondary objective was to investigate the possibility of using such a device at a remote computer terminal. The Radio Astronomy Observatory was required to provide the hardware for the Systems Engineering Laboratory, who would then make the evaluation. Design objectives for the hardware activity were as follows:

1. A source for lease or purchase of terminal equipment shall be selected based upon hardware requirements of the investigation. The probable source is Telautograph Corp. of Los Angeles, California, or Victor Comptometer Corporation of Chicago, Illinois.
2. The equipment to be leased or purchased from the selected source shall be sufficient to test communications in and out of the computer.
3. The equipment shall not be modified in any way. Auxiliary electronics will be used to interface with the computer.
4. The digital computer to be used in the evaluation is the Systems Engineering Laboratory's Digital Equipment Corporation Model PDP-9 located in the East Engineering Building.

5. The Systems Engineering Laboratory's PDP-9 computer system includes a digital-to-analog (D to A) converter and an analog-to-digital (A to D) converter which shall be the source and termination of the communications with the equipment being evaluated.

6. The selected equipment will be tested in a conventional system configuration. The equipment will be connected to the telephone system with appropriate 601 data sets and use two additional lines to be installed in the RAO Laboratory facilities at North Campus.

7. The performance of the equipment and the quality of the output when operating as a computer I/O device will be similar to that expected in the conventional system.

8. Tests of the equipment and any system evaluations using telephone company lines will not violate legal restrictions or telephone company engineering practice.

9. A secondary objective that will receive consideration during evaluations and design activities is the possible use of the selected device for two-way communication with the digital computer from a remote location. It is desirable that the terminal device be very mobile and, if possible, designed so that it can be used with any telephone hand set.

10. The final report will include some discussion of the possibility of providing a device similar to the equipment being tested, except that its communications would be digital signals and not require the A to D and D to A at the computer.

4. DESIGN PROCEDURE

4.1 SELECTION OF EQUIPMENT

Two sources of equipment were considered for the investigation: the Telautograph Corporation of Los Angeles, California, and the Victor Comptometer Corporation of Chicago, Illinois, both sell and lease equipment that would be suitable for the tests. The products of the two companies seem very competitive, and systems using the equipments function in a similar manner.

Equipment leased from the Victor Comptometer Corporation was leased for the test for two reasons.

1. The Victor Electrowriter transceiver is a single unit the same size as the receiver and transmitter (see Figure 3). The Telautograph transceiver station is two somewhat larger units. The difference in size, etc. was judged important in view of the secondary objective of the investigation, the consideration of the selected device as a remote computer terminal. The size and weight of the device would be particularly important if the terminal is portable and usable with any telephone.
2. The leasing arrangements with the Victor Comptometer Corporation seemed better suited to the needs of the investigation. It was decided that an Electrowriter receiver and transmitter would be rented for the initial tests and possibly these would be replaced with two transceivers later.

4.2 TESTS OF THE EQUIPMENT IN THE USUAL SYSTEM CONFIGURATION

An Electrowriter receiver and transmitter were each leased for the investigation and two additional telephone lines with 601-A data sets were installed in the RAO Laboratory at North Campus. The data sets were installed side by side on the same workbench.

Tests were made with the Electrowriter transmitter and receiver connected by a short cable. Other tests were made with the Electrowriter units connected to the 601 data sets and then connected to each other through the dial system network and the U of M Centrex switching center. A third series of tests was made with the telephone network routed through the Ann Arbor switching central. The results in all three cases seemed to be the same. There was no evidence of problems or indications of potential difficulty. It seems probable that line noise and/or cross talk could be a problem under some circumstances, but there was no indication of such problems during any of our tests.

The initial tests of the Electrowriter equipment confirmed a characteristic of these devices which is undesirable for the planned application. The so-called horizontal and vertical components of pen motion are not rectilinear coordinates. This does not present a problem for communication between Electrowriter equipment, because the receiver duplicates transmitter stylus motion using a similar mechanical linkage. However, it will be necessary to use some sort of transform equation to generate or modify Electrowriter instructions in a digital computer.

4.3 INTERFACE REQUIREMENTS

Auxiliary electronics are required to interface the Electrowriter equipment with a digital computer. It is convenient to think of the auxiliary electronics as made in two major sections (see Figure 4). One section is required for input to the computer, the other section is required for output to the Electrowriter. The interface for each section is as follows:

4.3.1 Electrowriter to Computer

The auxiliary electronics are designed to use separate vertical and horizontal signals. They are available from both the receiver and the transmitter, although the transmissions between devices in an Electrowriter system consist of a composite signal. The vertical signal is frequency modulated and has a range of 1310 to 1490 cps. The horizontal signal is also frequency modulated and has a range of 2060 to 2340 cps. The horizontal signal also provides the pen control signal (up or down).

The output of the Electrowriter system is input to the digital computer through an analog-to-digital converter. The auxiliary electronics are required to provide three signals: one each for the vertical and horizontal components

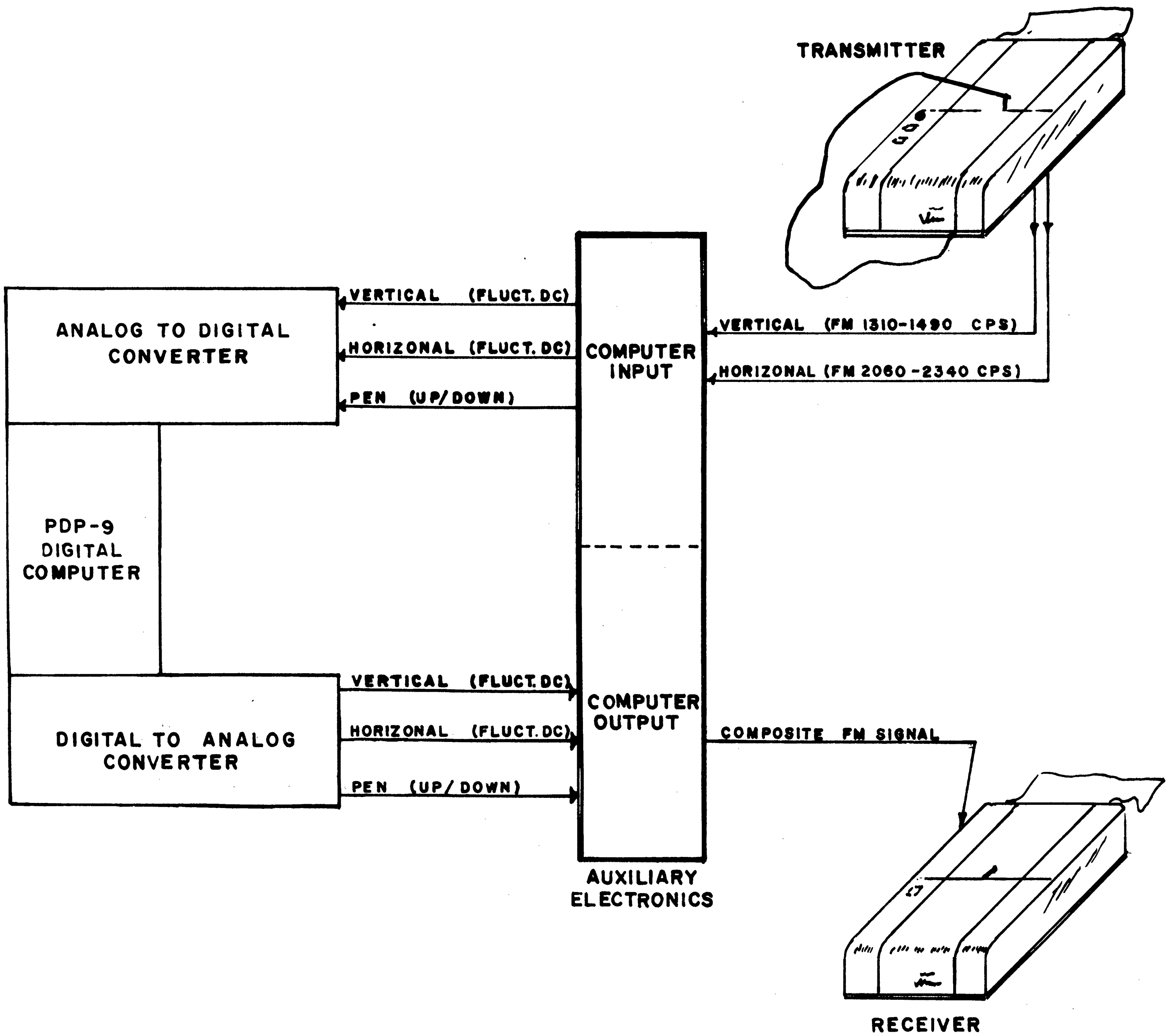


Figure 4. Auxiliary Electronics Interfacing the Electrowriter with the Digital Computer

of pen motion, and a third for pen up/down control. The amplitude and voltage range of these signals must match the A to D converter. The analog-to-digital converter used in the test has a range of 0 to -10 volts.

4.3.2 Computer to Electrowriter

The signals from the computer are output through a digital-to-analog converter. A separate signal is received for the vertical and horizontal component of pen motion, and a third signal indicates if the pen is up or down. These signals have an amplitude similar to the corresponding input signals and a maximum range of 0 to -10 volts.

The signal from the auxiliary electronics to the Electrowriter system is a single composite signal such as transmitted between Electrowriter devices in such a system. The composite signal has vertical information as a frequency modulated component with a range of 1310 to 1490 cps, horizontal information as a frequency modulated component with a range of 2060 to 2340 cps. The pen control signal (up/down) is part of the horizontal component.

4.4 ELECTROWRITER-TO-COMPUTER BREADBOARD TESTS

A preliminary step in the construction of the auxiliary electronics was the breadboard tests of the proposed design. Some tests were made with the setup shown in Figure 5. The Electrowriter transmitter was connected to a breadboard of auxiliary electronics which were connected to an oscilloscope. The output of the auxiliary electronics was then displayed on the oscilloscope CRT.

Figure 6 shows a message that was written at the transmitter (top) duplicated at a receiver (center) and also displayed on the CRT (bottom). The non-linearity of the coordinates as mentioned in Section 4.2 is quite apparent in the photograph of the CRT display.

The output signal levels from the breadboard circuitry were not as great as desired for the computer input, but the CRT display shows that the frequency modulated components are being changed to fluctuating DC voltage, as desired.

4.5 COMPUTER-TO-ELECTROWRITER BREADBOARD TESTS

The setup used for breadboard tests of the computer-to-Electrowriter auxiliary electronics is shown in Figure 7. The computer was simulated with a device shown in Figure 8. Motion of the pen of this device causes the X and Y pulleys to turn which are each connected to a potentiometer. The change in position of the potentiometer results in a change in output voltage. The pen up/down signal is controlled by the microswitch on the left side of the plotting board shown in Figure 8. Closing the microswitch puts a 120-cycle signal on the horizontal fluctuating DC voltage that is the horizontal component of motion.

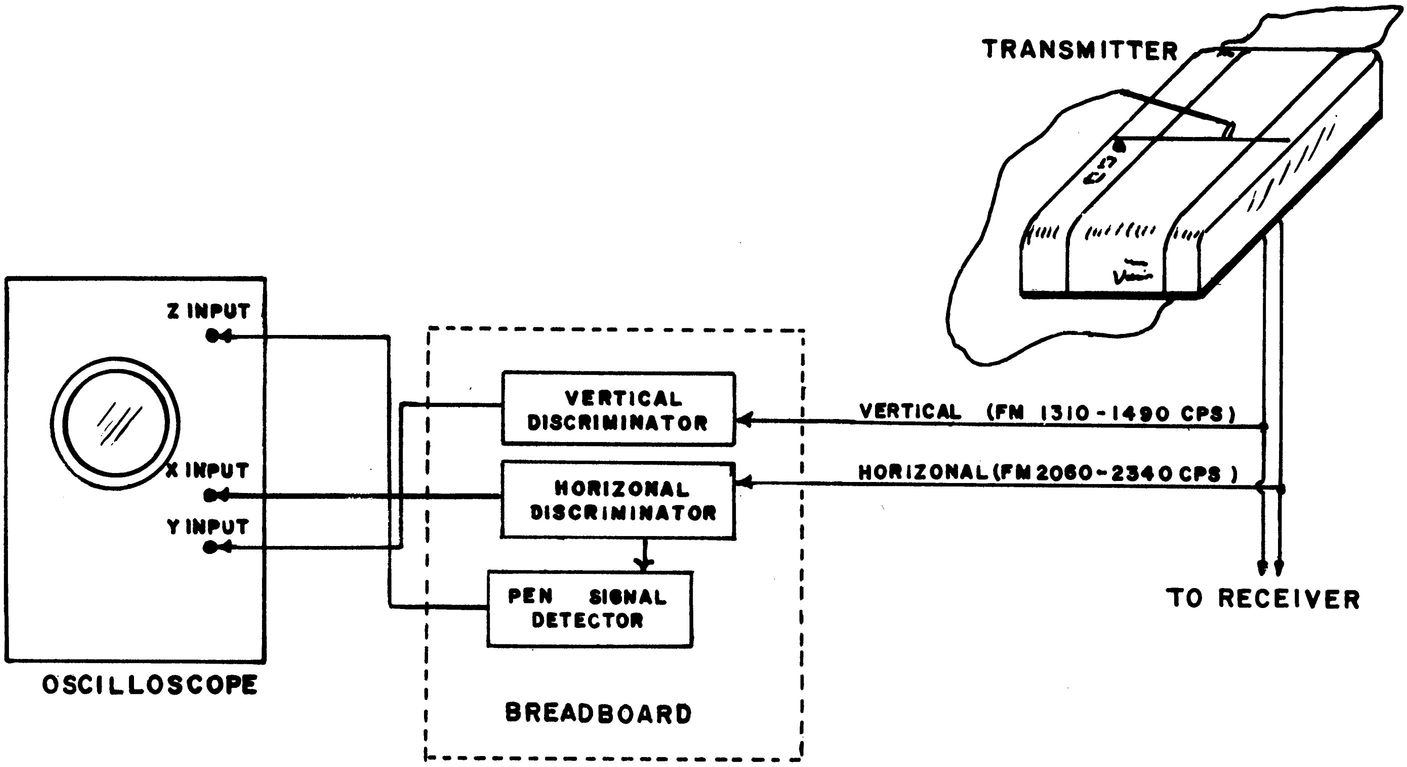
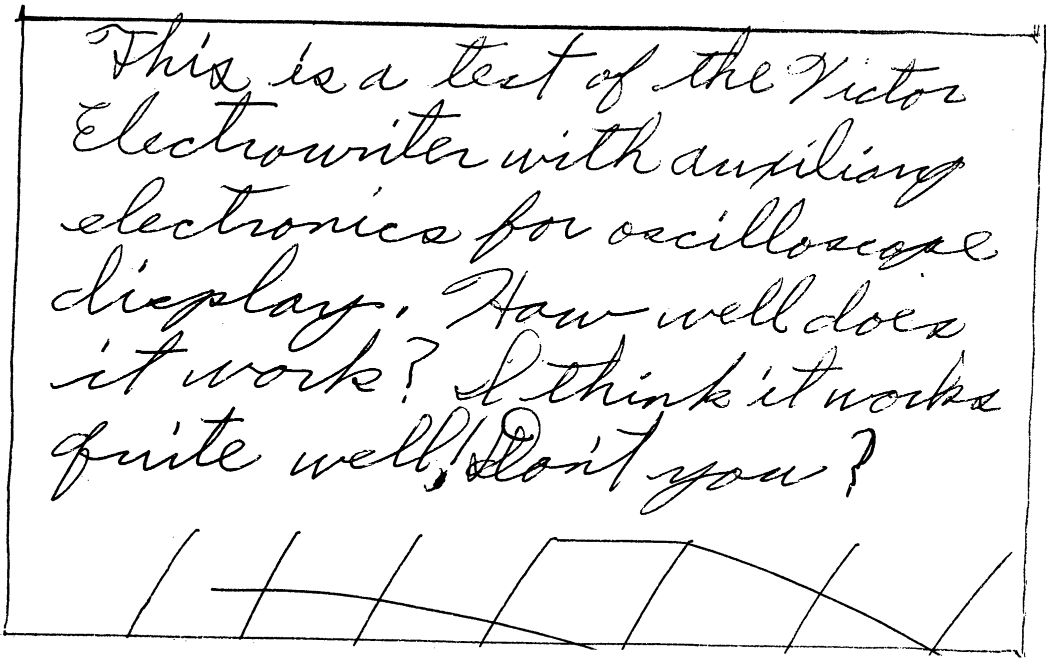
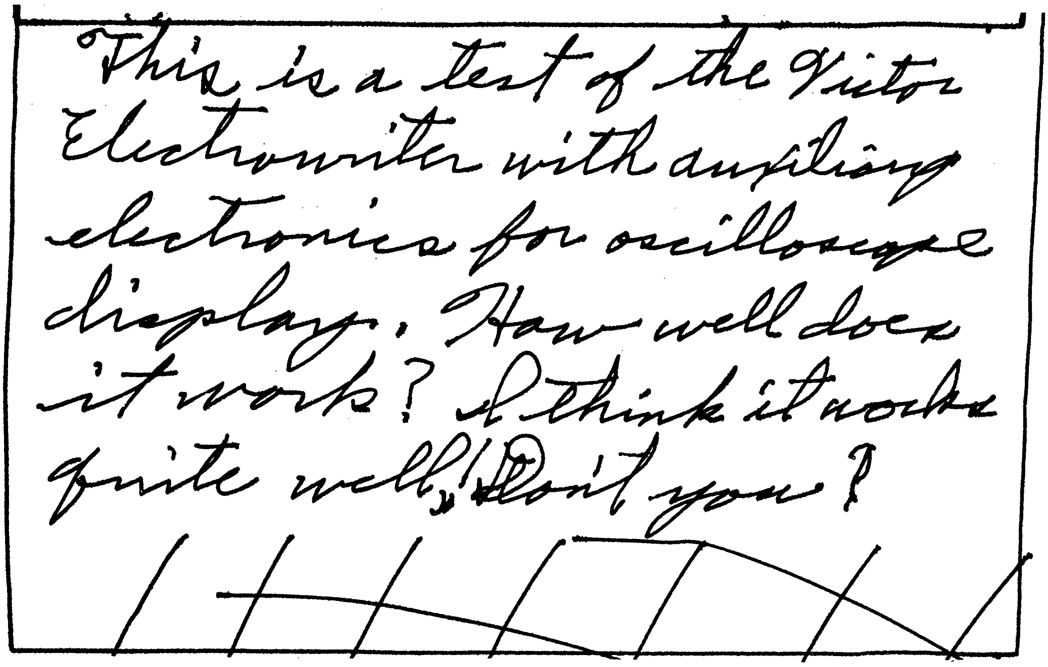


Figure 5. Diagram of Breadboard Tests of the Proposed Design





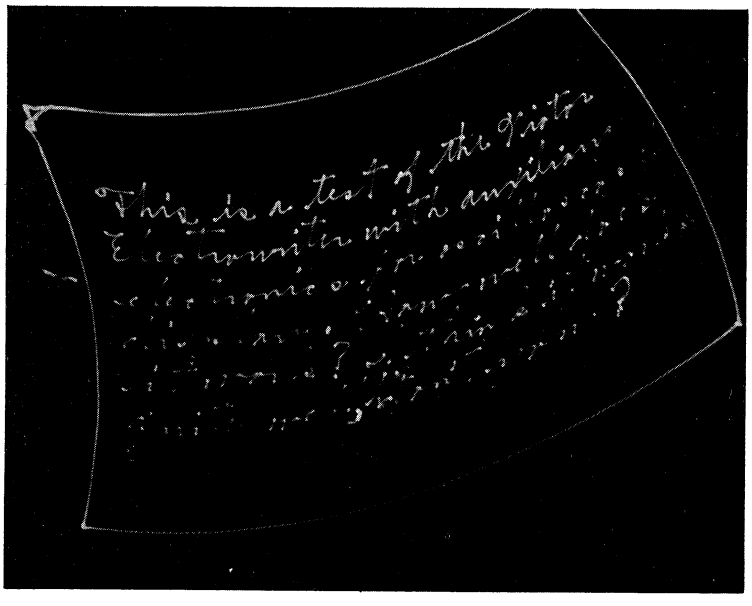


Figure 6. Message Written at the Transmitter (top), Duplicated at Receiver (center), and Displayed on CRT (bottom).

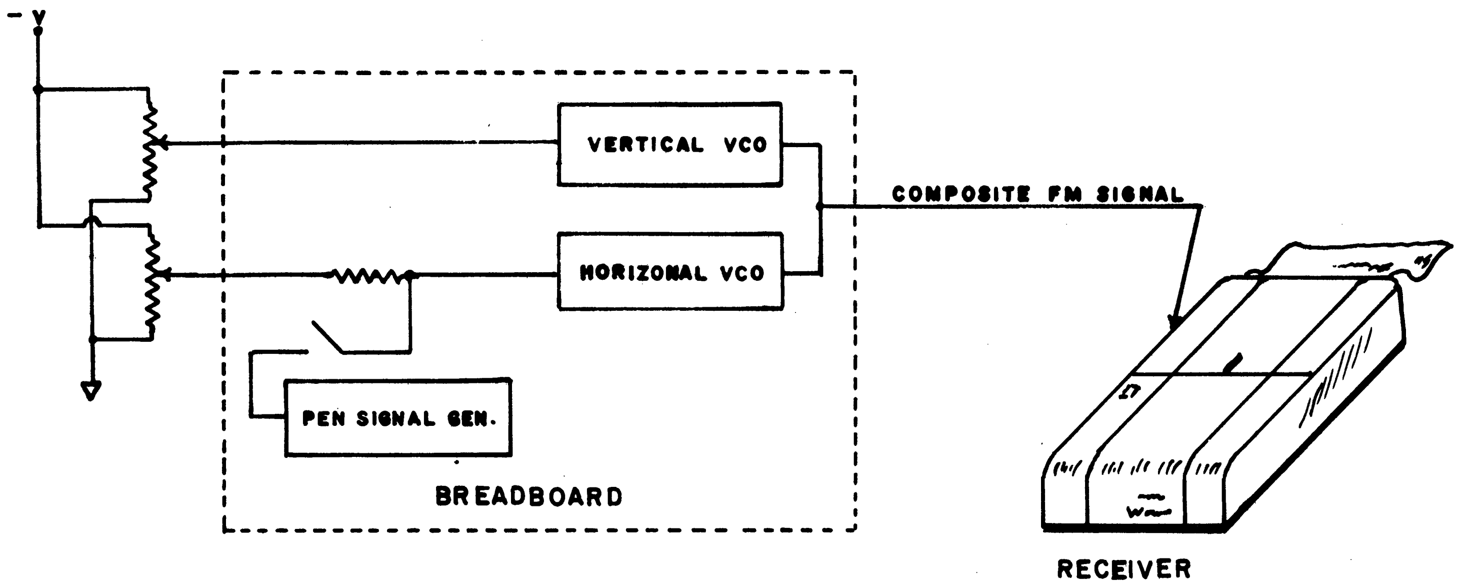


Figure 7. Configuration of Breadboard Tests of Computer-to-Electrowriter Auxiliary Electronics

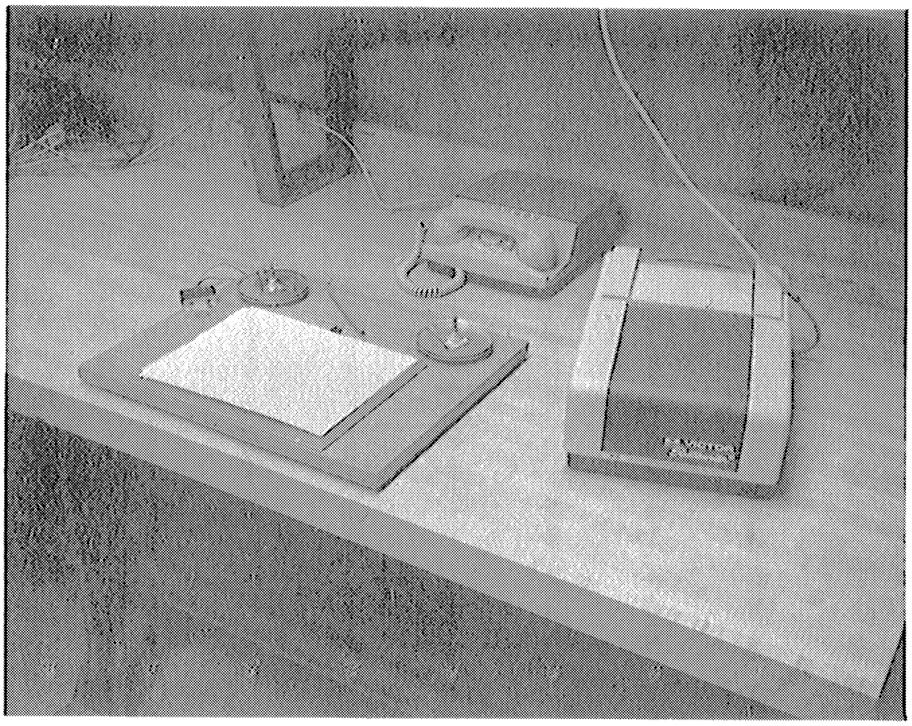


Figure 8. Device for Simulating the Computer

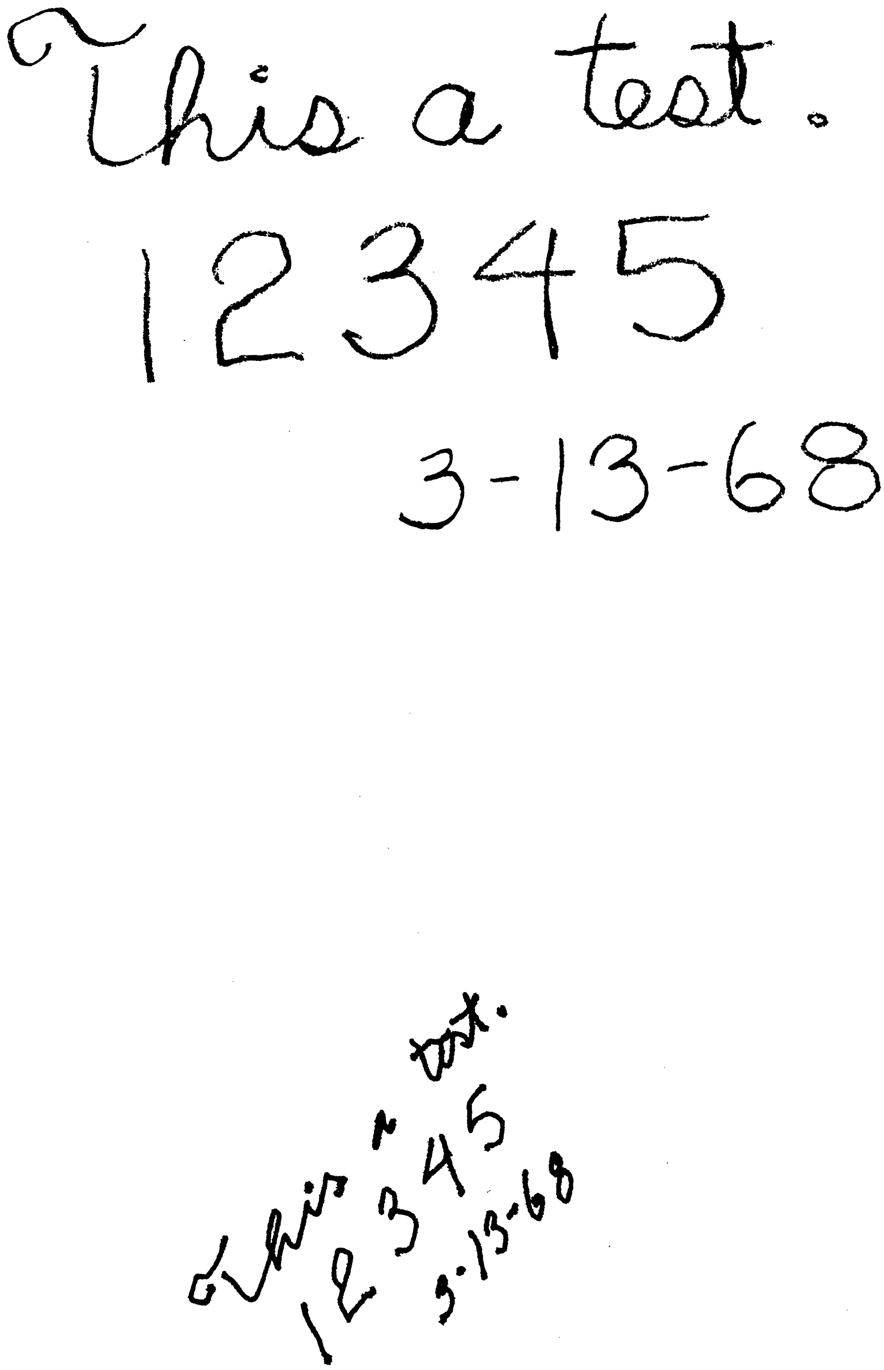


Figure 9. Results of Breadboard Tests

Figure 9 shows the results of the tests of the breadboard. At the top, as a message written on the plotter simulating the computer output it produces a message such as shown at the bottom on an Electrowriter receiver.

5. PROTOTYPE OF AUXILIARY ELECTRONICS

The success of the tests of the breadboard versions of the auxiliary electronics led to construction of the prototype.

5.1 CONSTRUCTION

The PDP-9 computer used in this investigation is assembled from small plug-in printed circuit card modules. Blocks of such modules are mounted in racks with appropriate power supplies. It was decided that the auxiliary electronics should be built on similar cards and installed in a card block reserved for this circuitry.

Figure 10 shows two views of the construction. The circuitry was divided into eight parts. Transformers etc. were mounted on one end of the chassis and the other seven parts each built on a plug-in module. Photographs of the modules are shown in Appendix A.

5.2 CIRCUITRY

Figure 11 is a circuit diagram of the auxiliary electronics. The function and location of each part of the circuitry is indicated on the drawing. Each part is briefly

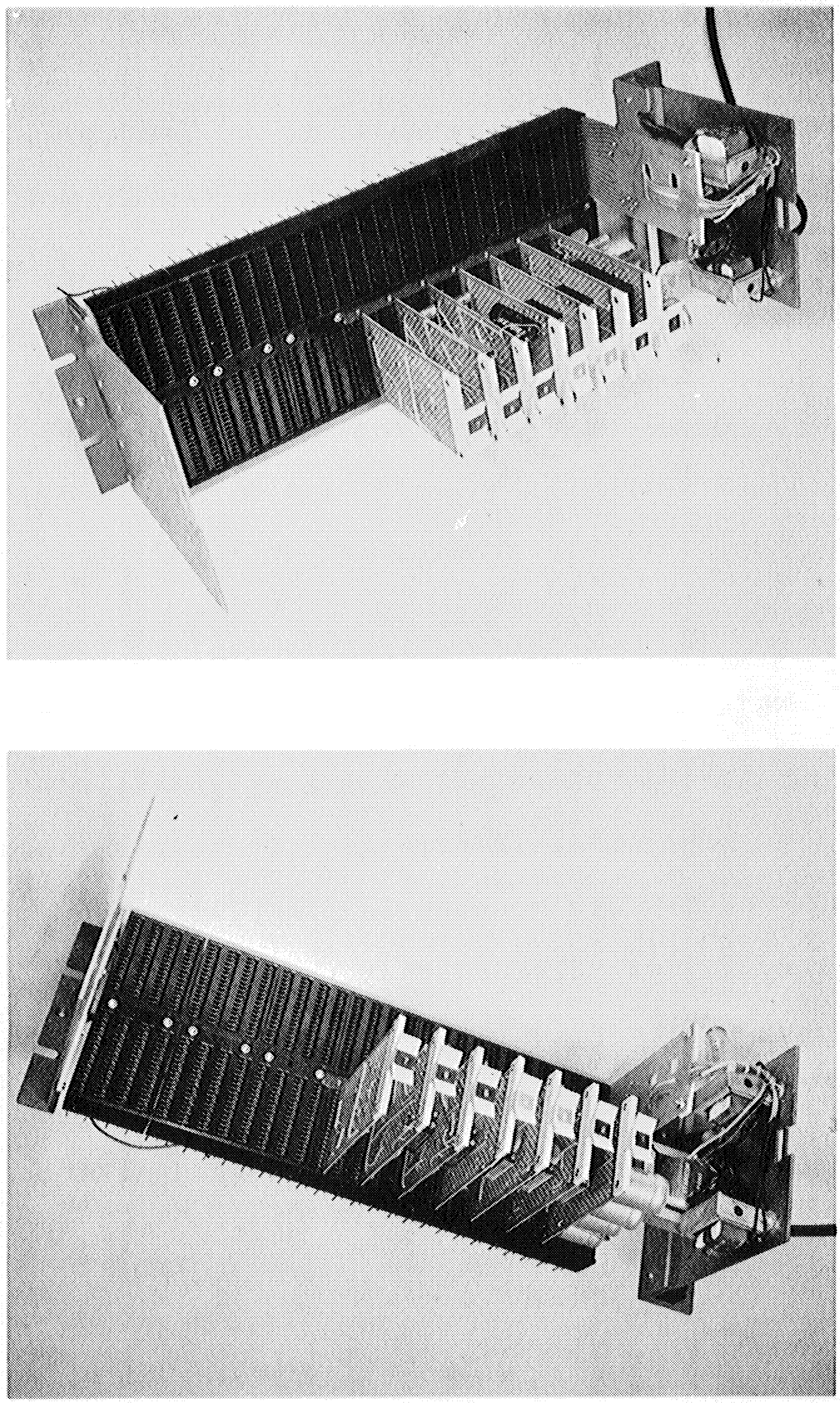


Figure 10. Two Views of the

Construction of Auxiliary Electronics

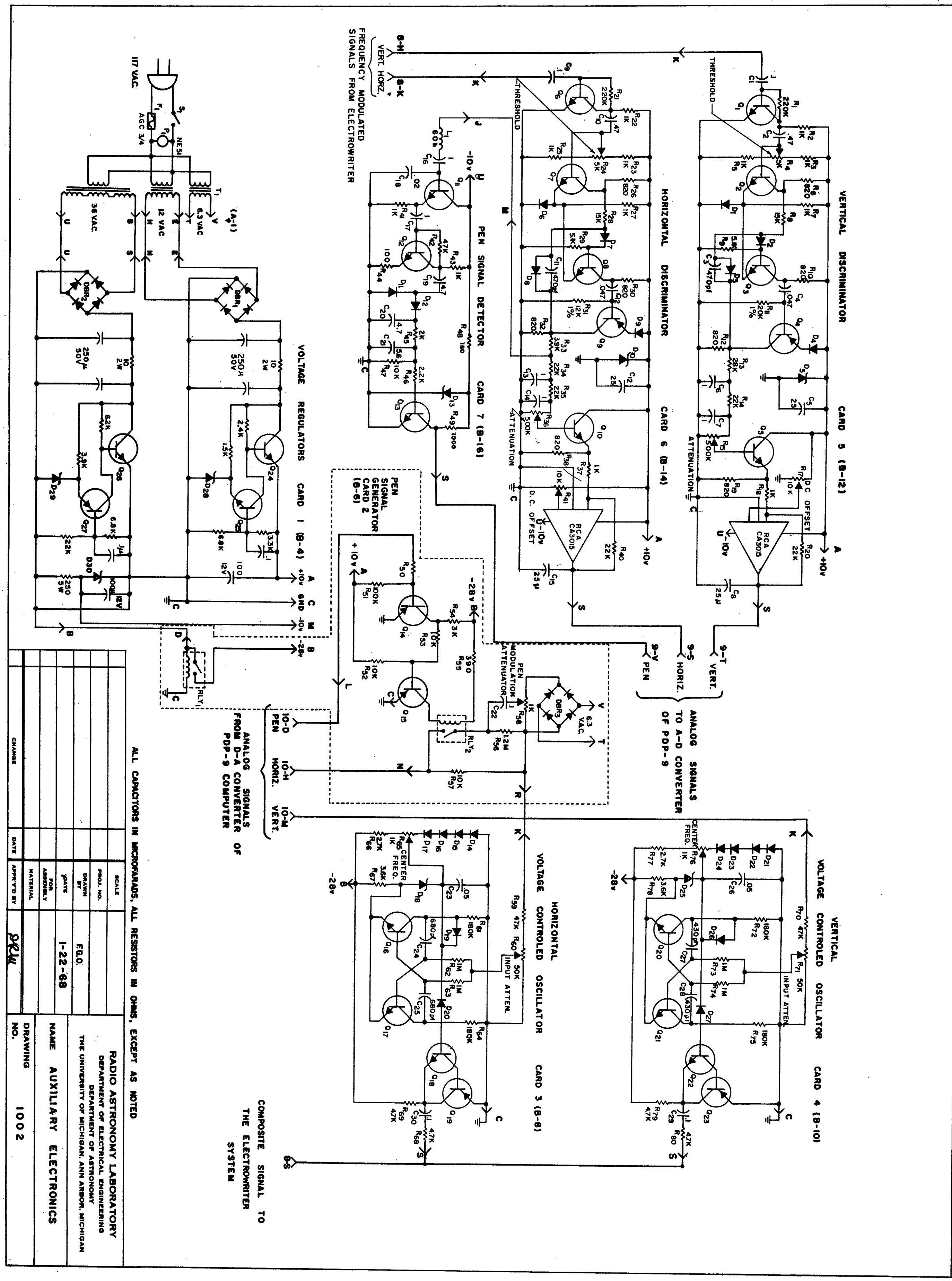


Figure 11. Circuit Diagram of Auxiliary Electronics

Table 1

Active Components of the Auxiliary Electronics

TRANSISTORS

Q-1,2,3,6,7,8,18,22,25,27	2N2923
Q-4,9,12,19,23	T1561
Q-5,10,16,17,20,21	2N2925
Q-11,13,14,15	2N1301
Q-24,26	2N3054

DIODES

D-1,2,3,4,6,7,8,9,14,15,16,17,19,20,21,22,23,24,26,27	1N914
D-5,10	1N756A
D-18,25,28,29	1N753
D-13	1N821
D-11,12	1N100
D-30	1N1771

RECTIFIERS

DBR-1,3	I.R.C.	3058A
DBR-2	I.R.C.	3058A

RELAYS

RLY-1,2	-MAGNACRAFT W102PCX-3

discussed in the following. The active components are listed in Table 1.

5.2.1 Transformers and Power Supply

The auxiliary electronics have a self-contained power supply. The transformers for the supplies are in the lower left corner of the drawing. Transformers T_1 provide 6.3 volts to card 2. Transformers T_2 and T_3 provide 12 volts and 36 volts to card 1. The primary of the transformers are connected to an AC plug through a switch and a fuse. A neon indicator, NE51, indicates when the auxiliary electronics in ON.

5.2.2 Voltage Regulators, Card 1

Card 1 contains two bridge rectifiers, DBR_1 and DBR_2, and series regulators which supply +10 volts, -10 volts, and -28 volts to other parts of the circuitry.

5.2.3 Pen Signal Generator, Card 2

The pen control signal from the computer D-to-A converter is -6 volts if the pen is to be up, and gnd if the pen is to be down. Transistors Q_{14} and Q_{15} are part of a relay driver for the reed relay RLY_2. When the input is gnd, the relay will be energized and a 120-cycle signal from the bridge rectifier DBR_3 will be added to the horizontal component signal.

R_{57} is located on Card 2. The relay is necessary so

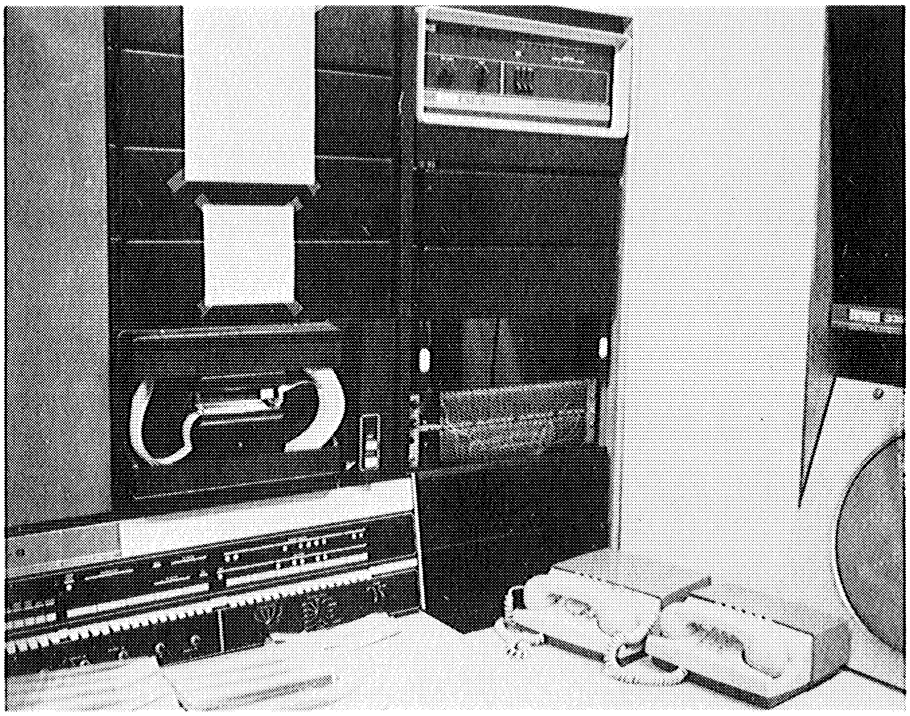


Figure 12. Auxiliary Electronics Installed in PDP-9 Computer

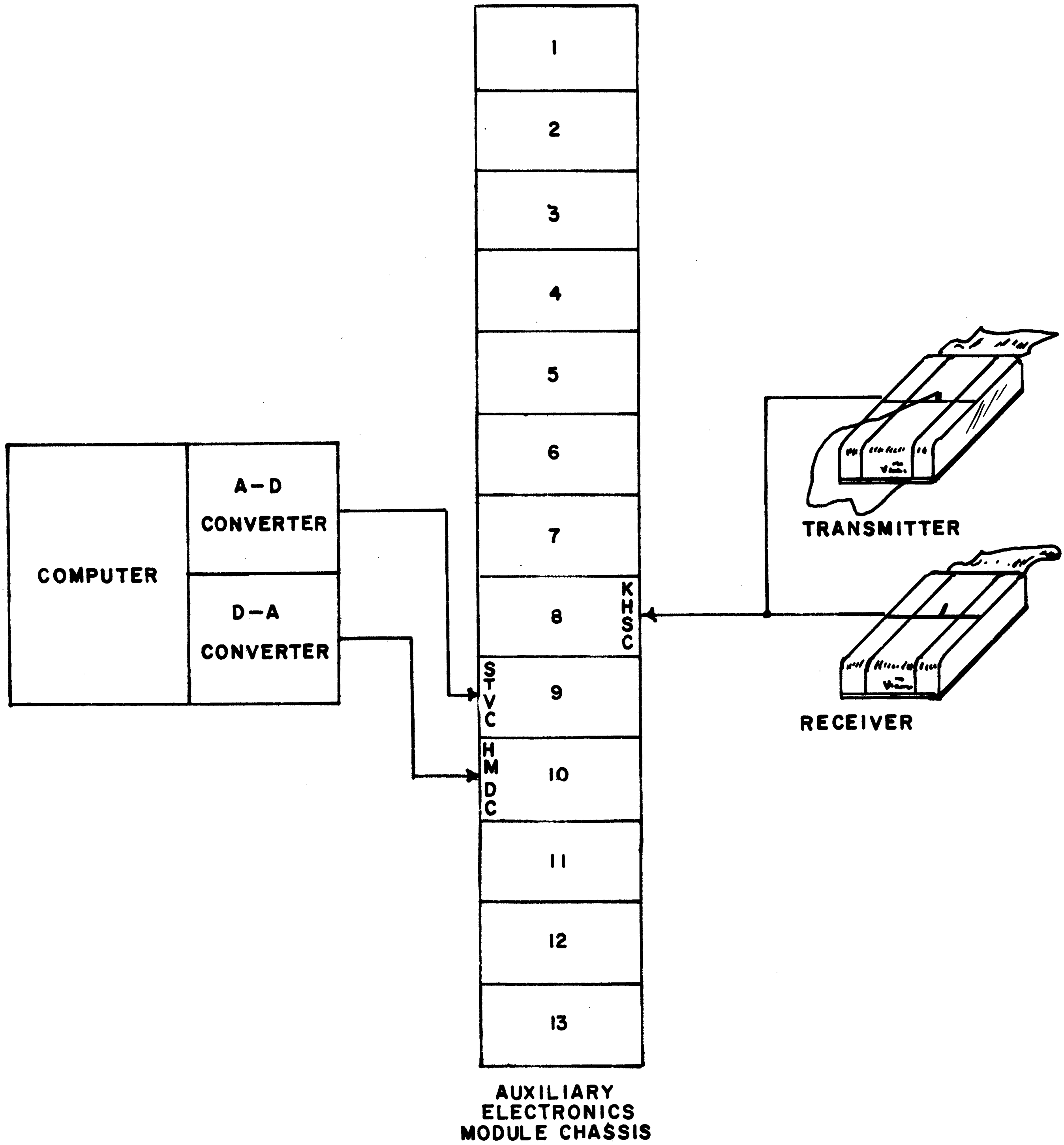


Figure 13. Cable Connections of Auxiliary Electronics to Other Equipment

that the -28 volt supply required for the VCO circuitry on cards 3 and 4 will have a sharp rise time.

5.2.4 Voltage Controlled Oscillators, Cards 3 and 4

The circuitry on cards 3 and 4 is very similar. Both are voltage controlled oscillators (VCOs) which change the fluctuating DC voltage, corresponding to horizontal and vertical components of pen motion, into frequency modulated signals in the appropriate frequency range.

5.2.5 Discriminators, Cards 5 and 6

The circuitry on cards 5 and 6 is very similar. Both are discriminators followed by an operational amplifier. The frequency modulated signal from the Electrowriter system is changed into a fluctuating DC voltage for input to the computer A-to-D converter.

5.2.6 Pen Signal Detector, Card 7

If the pen is down, the horizontal FM signal will include a 120-cycle component. The presence of the signal is detected by circuitry on card 7. If the 120-cps signal is present, the output from Q_{13} will be gnd. If the signal is absent the output will be -6 volts.

5.3 INSTALLATION

The auxiliary electronics required for the test were installed in the PDP-9 equipment cabinet which also contains the A-to-D converter and the D-to-A converter. The wire-wrap terminals, etc. on the area of the card block can be seen in Figure 12. The A-to-D converter can be seen at the top of this cabinet. The D-to-A can not be seen, but it is located below the auxiliary electronics.

The cable connections of the auxiliary electronics to other equipment are shown in Figure 13. Except for power, all connections are made with cables that plug into the card block in the same way as the circuitry.

6. CONCLUSIONS

It has been demonstrated that it is possible to use the Victor Electrowriter as a computer input-output device. Information has been successfully read from a transmitter into a computer and then from the computer out to a receiver. The tests have not been as complete or comprehensive as desired, but feasibility has been proven. There is some interest in continuing the investigation but no firm plans at this time.

A number of things delayed the tests: the PDP-9 was delivered late; there was considerable confusion about the connection and use of the analog terminations; there were personnel changes; and programming efforts were slowed because of inexperience with the new system.

The auxiliary electronics used to interface the Electrowriter units with the computer analog terminations have operated reasonably well, but there are changes which would be considered if the hardware was to be updated.

1. The capacity of the power supplies could be greater.
2. The stability of the hardware is strongly affected by the regulation of the power supplies, so better regulation would improve stability.
3. The operational amplifiers used in the discriminator circuitry are being "pushed" to produce the maximum gain. The electronics would probably function better if it was not necessary to require maximum gain.
4. Despite the adjustment for maximum gain of the operational amplifiers, the output voltage range of the discriminators is not as great as desired. The output was roughly 0 to -5 volts. The range of the A-to-D and D-to-A converters is 0 to -10 volts.

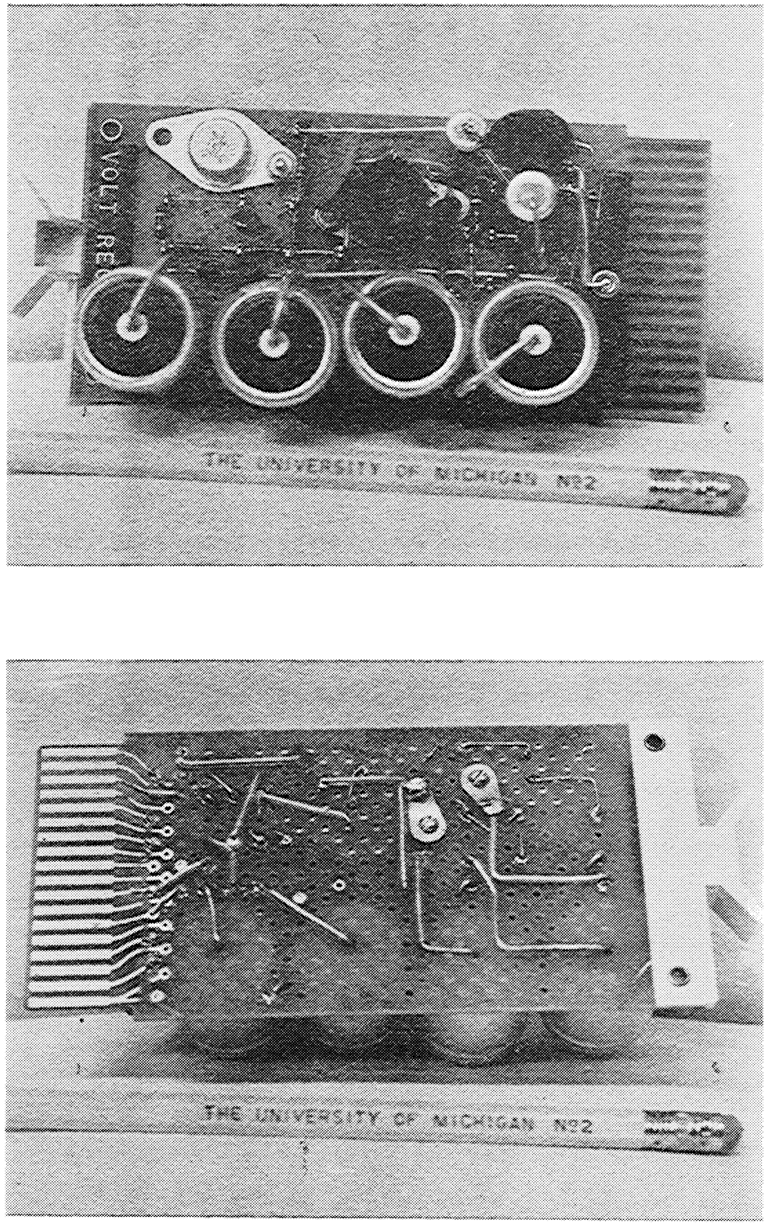
There were no tests of the Electrowriter as an I/O device at a remote location. However, there are good reasons to believe that such tests would have been successful. The most significant change of the system for such tests would be transmission of the Electrowriter signals over telephone lines. This certainly should not be a problem for the Electrowriter equipment. The reason no such tests were made was the absence of a 601-A data set at the PDP-9 site. A more sophisticated version of such tests would eliminate the data set at the remote location and replace it with an audio pick-up and a standard telephone hand set.

There was some consideration given to the possibility of designing an Electrowriter type device that would communicate in a similar way except use a digital data format. Such a device would not require the analog terminations for communication with a digital computer. It would not be easy to modify standard Electrowriter components to operate efficiently in this manner. A new design for a similar device is possible, but it is difficult to find a component that will convert a digital code into a change in position of a stylus. The reverse operation, the generation of the digital code, is not quite so difficult, but shaft encoders and components of this kind are quite costly, delicate, and require special logic to insure no ambiguity in the read-out. It seems a better solution would use the present Electrowriter equipment and for communication with a digital computer expand the auxiliary electronics to perform the required A-to-D and D-to-A conversions.

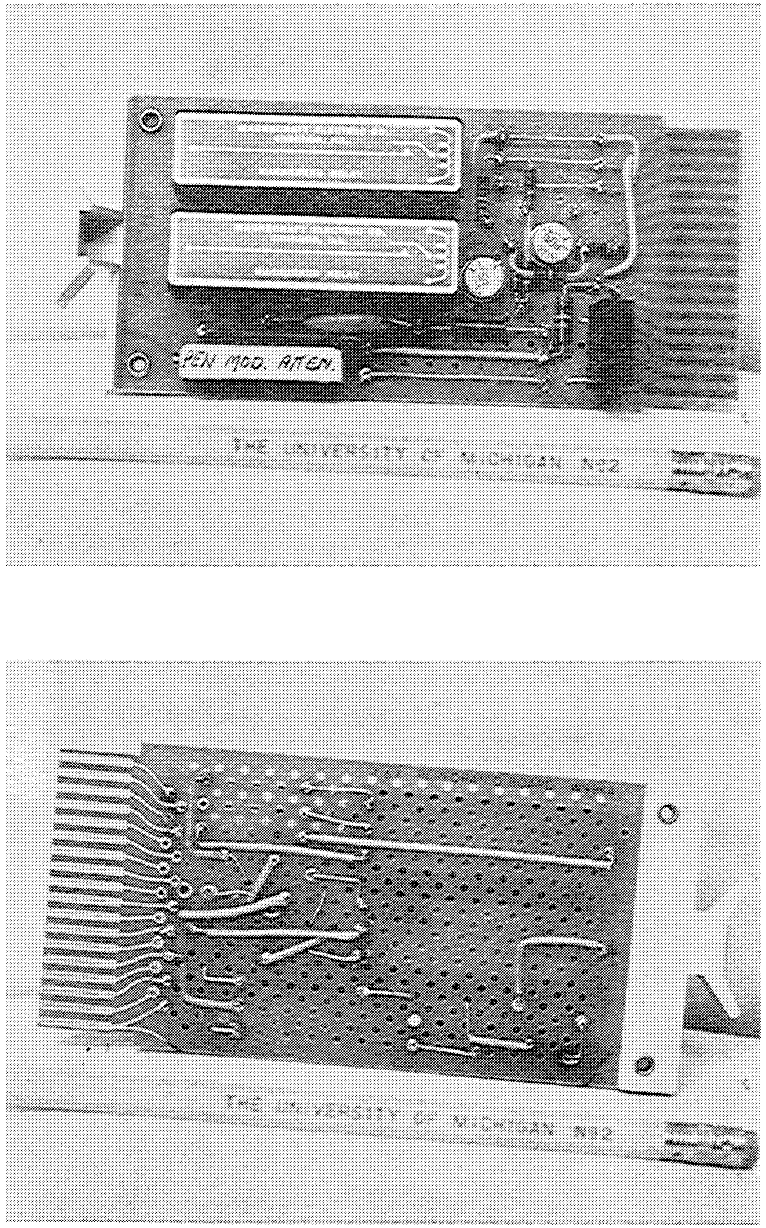
APPENDIX A.

PHOTOGRAPHS OF MODULES

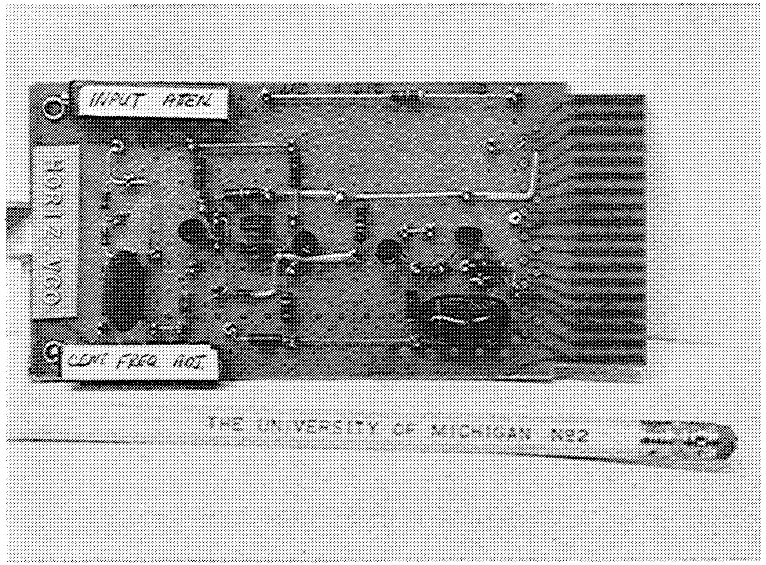
Circuitry for the prototype unit of the auxiliary electronics was constructed on plug-in modules. In the following are photographs of the modules. The circuit diagram is shown as Figure 11. The chassis for the modules is shown in Figure 10.

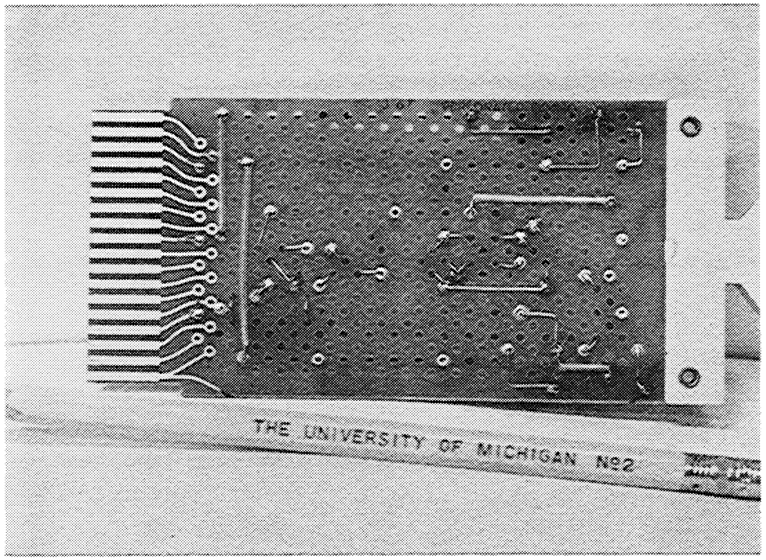


Card #1. Voltage Regulators

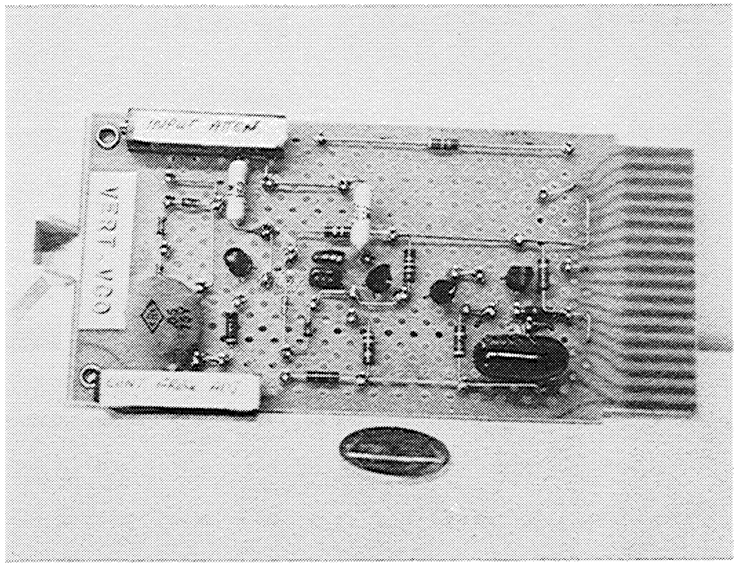


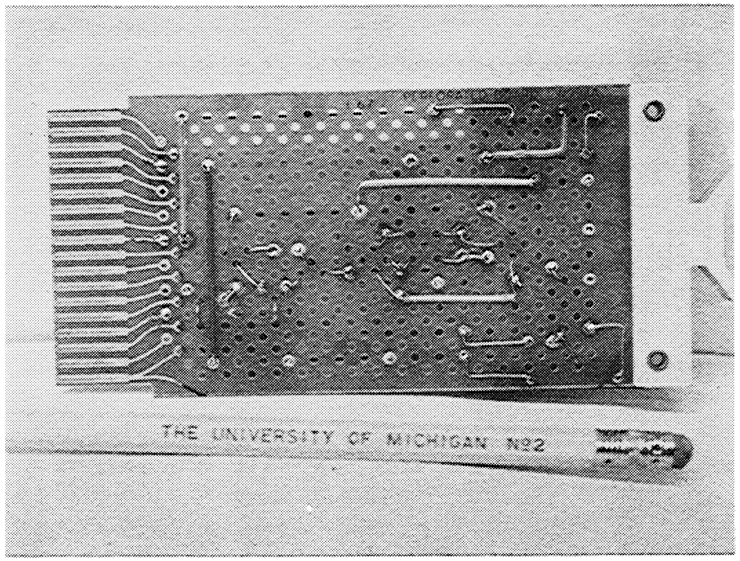
Card #2. Pen Signal Generator



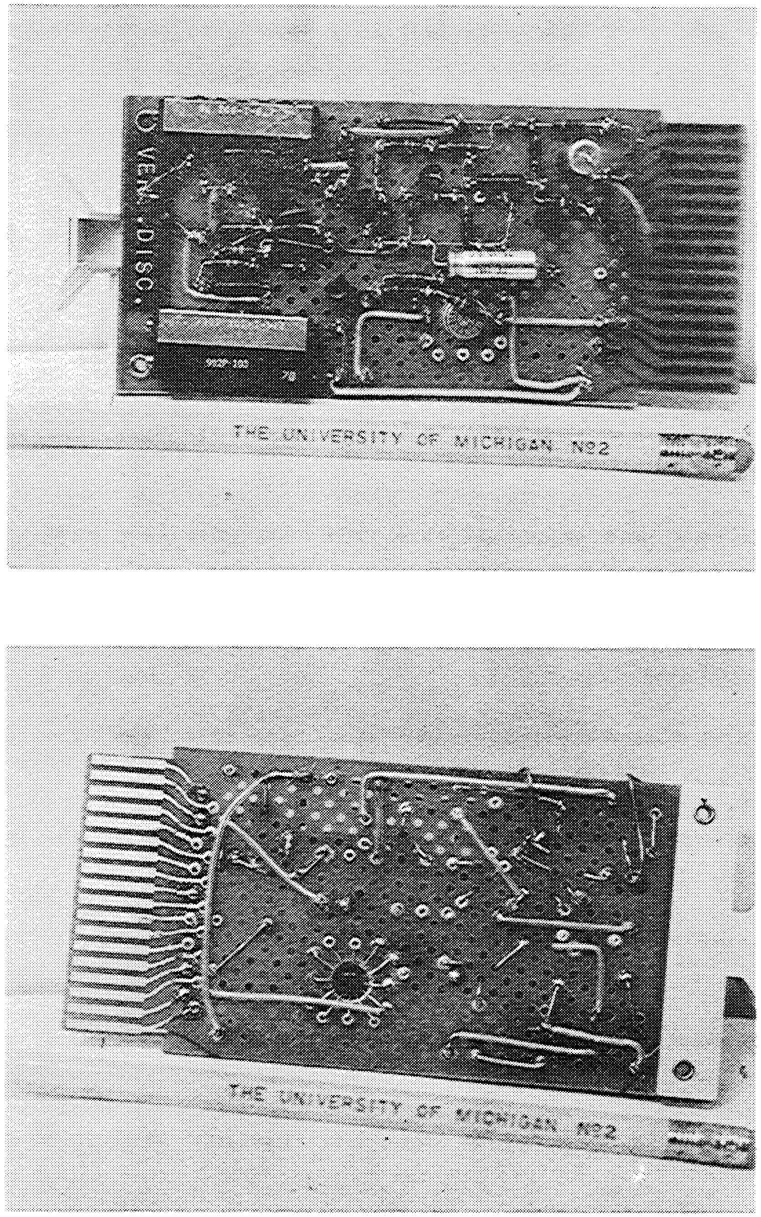


Card #3. Horizontal VCO

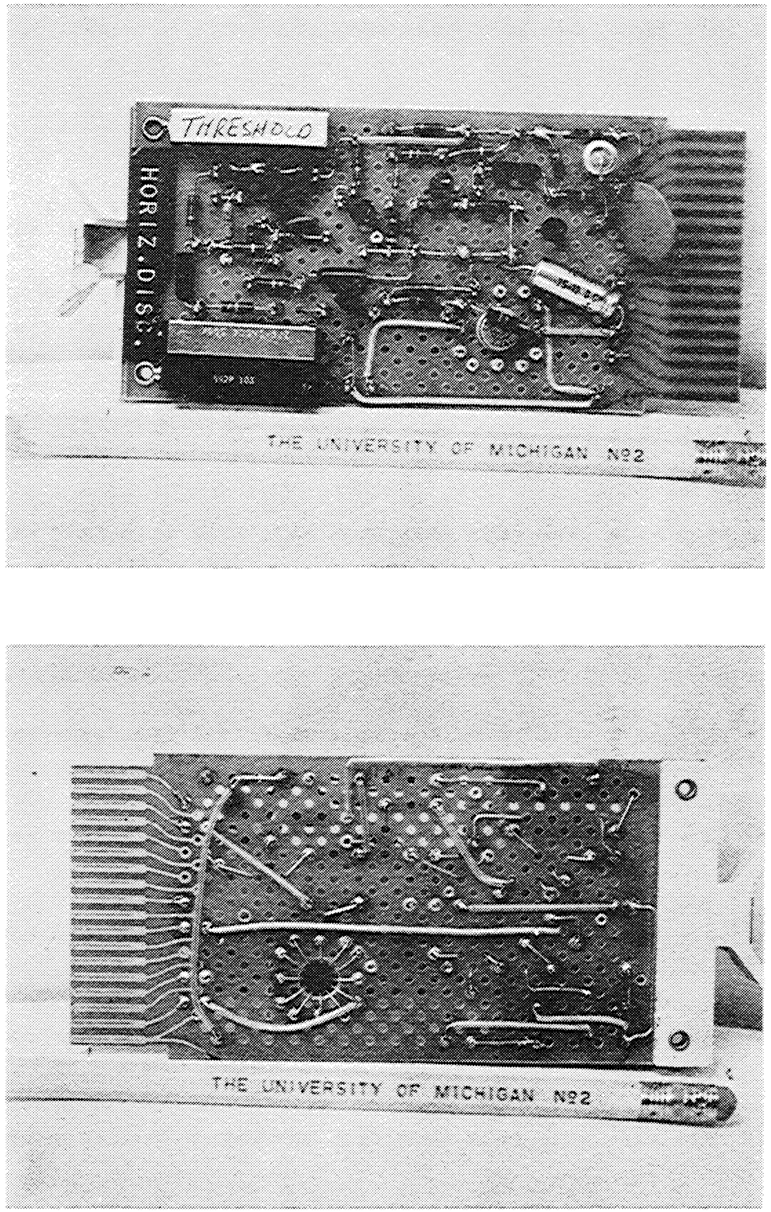




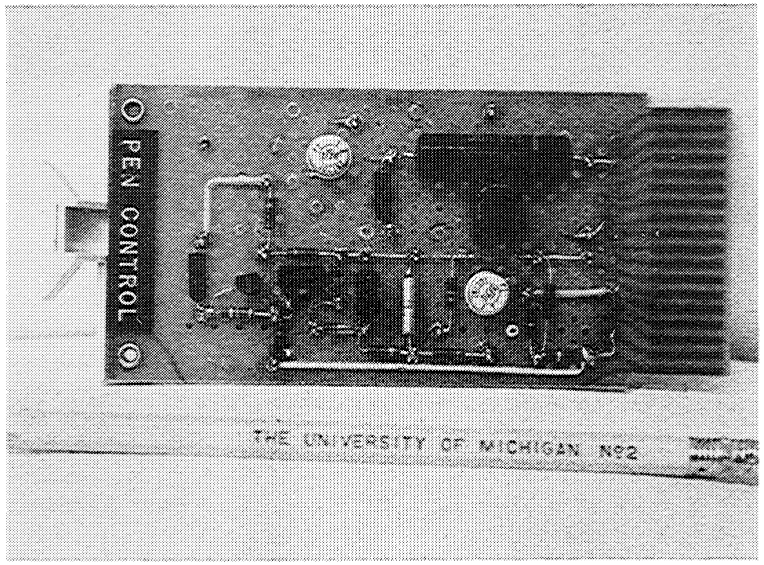
Card #4. Vertical VCO

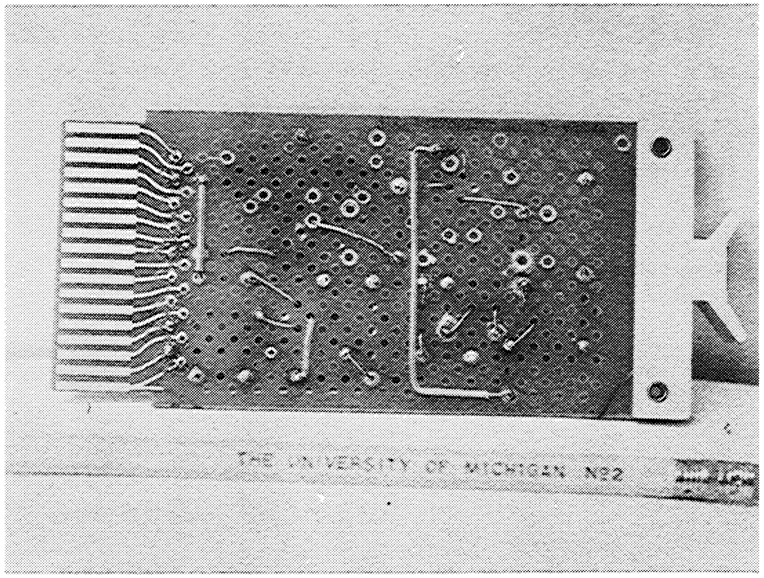


Card #5. Vertical Discriminator



Card #6. Horizontal Discriminator





Card #7. Pen Signal Detector

APPENDIX B.

VICTOR ELECTROWRITER DOCUMENTATION

The Victor Comptometer Corporation has given permission to include copies of the specifications and circuit diagrams of the Electrowriter equipment in this report.

ELECTROWRITER SPECIFICATION, TRANSMITTER, RECEIVER, TRANSCEIVER

DIMENSIONS:	Transmitter and Receiver	Transceiver
Width	9-½"	9-½"
Length	14-5/16"	14-5/16"
Height, Front	5"	5-½"
Height, Rear	6"	6-½"

WEIGHT:	Transmitter	Receiver	Transceiver
Net	20 lbs.	27 lbs.	28 lbs.
Packed (Domestic)	25 lbs.	32 lbs.	33 lbs.

AVAILABLE WRITING SURFACE: 5" horizontal x 3-½" vertical

OPERATION TEMPERATURE RANGE (AMBIENT) 10° to 140° F

POWER SOURCE: 105-125 volts 50/60 Hz
190-260 volts 50/60 Hz

POWER CONSUMPTION: .2 amp standby
1 amp peak load on paper feed function

FREQUENCIES: Vertical - 1310 to 1490 Hz (sine wave)
Horizontal - 2060 to 2340 Hz (sine wave)

FREQUENCY SHIFT: One Hz frequency shift causes
0.021 pen movement horizontally, and
0.025" pen movement vertically

IMPEDANCE CHARACTERISTICS

Transmitter alone - approximately 500 ohms resistive from 300 to 3000 Hz

Lockout Amplifier alone - appears as 0.22 mf capacitance 0.02 henry inductance in parallel. This approximates 900 ohms at 2200 Hz and 200 ohms at 1400 Hz.

The Transmitter and lockout amplifier are both connected to the signal line through isolated windings. Only one of these impedances, Transmitter or lockout amplifier, is presented to the signal line at any one time.

Receiver - approximately 600 ohms from 1310 to 1490 Hz and also from 2060 to 2340 Hz; high impedance at other frequencies. A 1200 ohms resistor, ½ watt, ± 10% may be shunted across the input circuit to limit maximum impedance.

The above impedance values exist across signal line input terminals whether or not the unit is active, and whether the ac power switch is on or off.

The Receiver is also connected to the signal line through an isolated winding.

TRANSMITTED SIGNAL LEVEL (TRANSMITTER OR TRANSCEIVER)

760 to 1020 millivolts (production tolerance) into an open circuit. This provides 380 to 750 mv into a 600 ohm load. (-3.3 dbm plus or minus 3 db.)

LOCKOUT AMPLIFIER SENSITIVITY (USED IN TRANSMITTER ONLY)

35 mv composite signal (25 mv 2200 Hz component)

RANGE OR RECEIVER INPUT SIGNAL:

10 mv to 2.5 volt composite signals (measured through an audio filter to reject non-Electrowriter® signal components such as noise and 60 Hz modulation) or -38 to +10 dbm.

REGISTRATION ON RULED PAPER: ± 3/32"

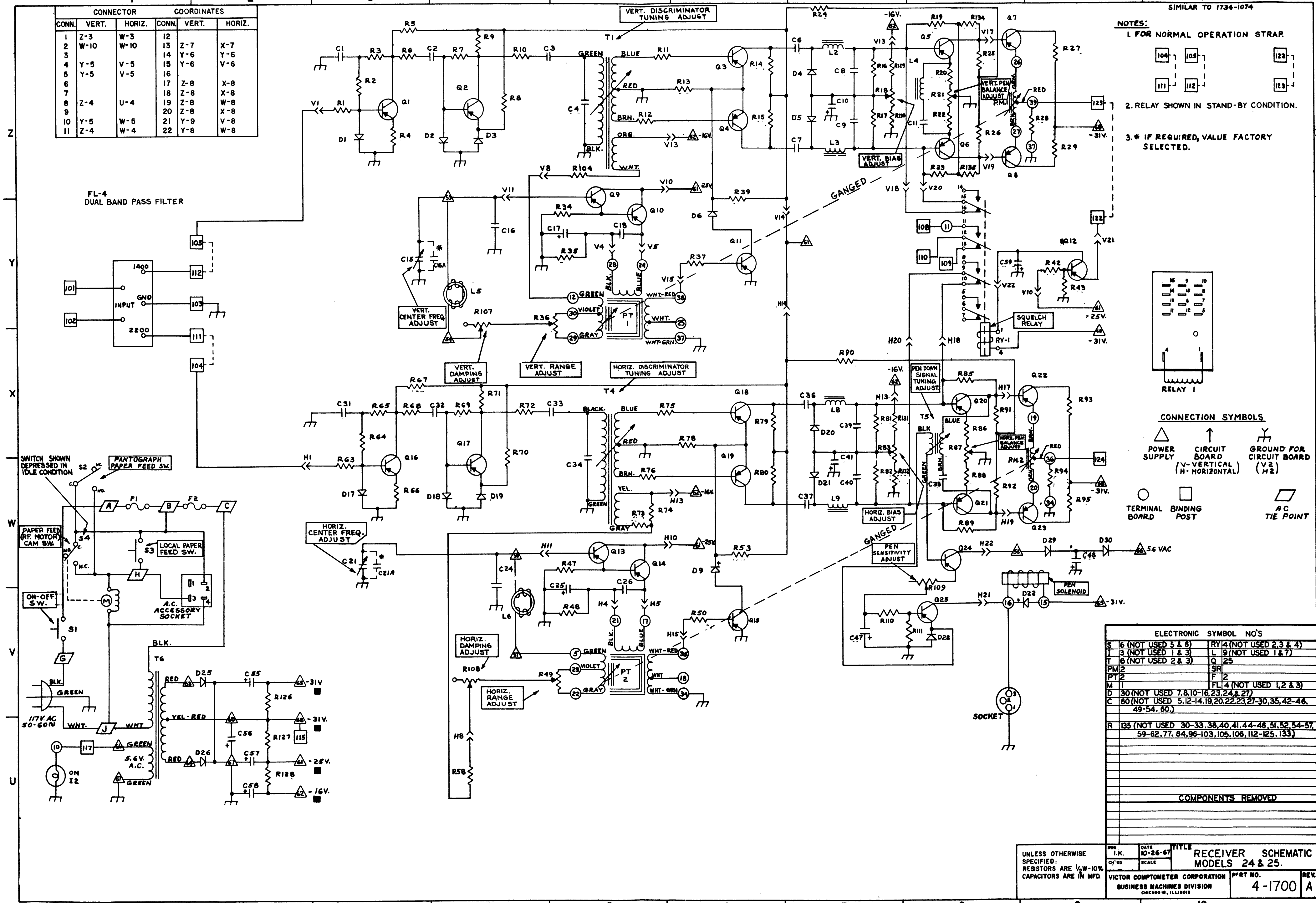
STABILITY (PEN DISPLACEMENT)

Temperature 10° to 140° F. ± 1/16"
Time (Aging) ± 1/16"
Input Signal at Receiver 5 mv to 600 mv ± 1/32"
Power line variation 105-125 volts, ± 1/32"
190-250 volts, ± 1/32"

The center frequency may be readjusted to meet any fixed set of conditions within the foregoing limits.

SIGNAL LINE CHARACTERISTICS

Maximum line frequency response deviation in either band (1310-1490 Hz or 2060-2340 Hz) 3 db.
Maximum line frequency response deviation between the two bands 25 db.



CONNECTOR			COORDINATES		
CONN.	VERT.	HORIZ.	CONN.	VERT.	HORIZ.
1	Z-3	W-3	12		
2	W-10	W-10	13	Z-7	X-7
3			14	Y-6	Y-6
4	Y-5	V-5	15	Y-6	V-6
5	Y-5	V-5	16		
6			17	Z-8	X-8
7			18	Z-8	X-8
8	Z-4	U-4	19	Z-8	W-8
9			20	Z-8	X-8
10	Y-5	W-5	21	Y-9	V-8
11	Z-4	W-4	22	Y-8	W-8

NOTES:
1. FOR NORMAL OPERATION STRAP.
2. RELAY SHOWN IN STAND-BY CONDITION.
3. * IF REQUIRED, VALUE FACTORY SELECTED.

CONNECTION SYMBOLS
- POWER SUPPLY
- CIRCUIT BOARD (V- VERTICAL, H- HORIZONTAL)
- GROUND FOR CIRCUIT BOARD (V2) (H2)
- TERMINAL BOARD
- BINDING POST
- AC TIE POINT

ELECTRONIC SYMBOL NO'S			
S	6 (NOT USED 5 & 6)	RY	4 (NOT USED 2,3 & 4)
I	3 (NOT USED 1 & 3)	L	9 (NOT USED 1 & 7)
T	6 (NOT USED 2 & 3)	Q	25
PM	2	SR	
PT	2	F	2
M	1	FL	4 (NOT USED 1,2 & 3)
D	30 (NOT USED 7,8,10-16,23,24,& 27)		
C	60 (NOT USED 5,12-14,19,20,22,23,27-30,35,42-46, 49-54, 60.)		
R	135 (NOT USED 30-33,38,40,41,44-46,51,52,54-57, 59-62,77, 84,96-103,105,106,112-125,133)		

COMPONENTS REMOVED

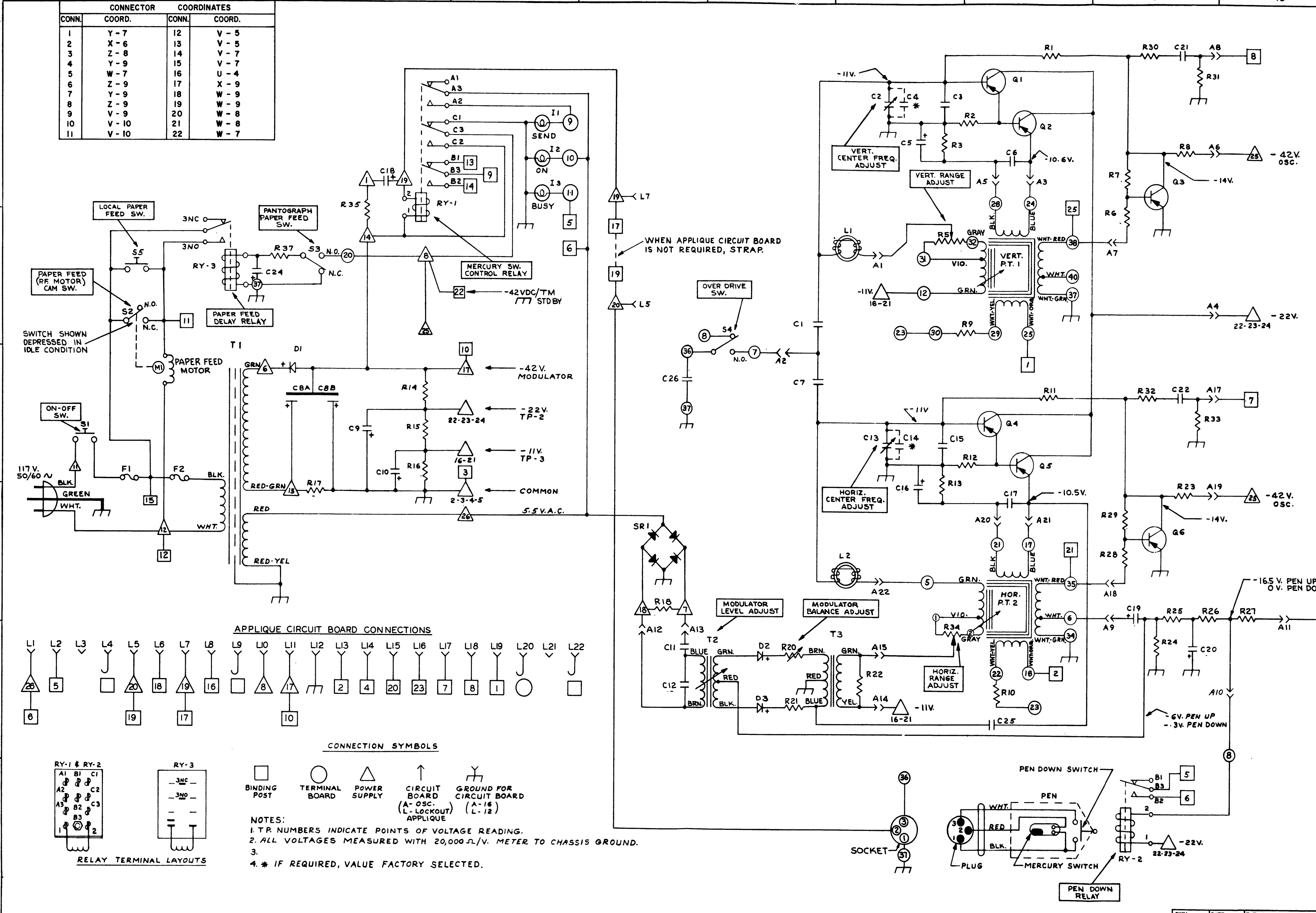
UNLESS OTHERWISE SPECIFIED:
RESISTORS ARE 1/2W-10%
CAPACITORS ARE IN MFD.

DWN	DATE	TITLE
I.K.	10-26-67	RECEIVER SCHEMATIC MODELS 24 & 25.
CH'KD	SCALE	

VICTOR COMPTOMETER CORPORATION
BUSINESS MACHINES DIVISION
CHICAGO 18, ILLINOIS

PART NO. 4-1700 REV. A

CONNECTOR	COORDINATES		
CONN.	COORD.	CONN.	COORD.
1	Y - 7	12	V - 5
2	X - 6	13	V - 5
3	Z - 8	14	V - 7
4	Y - 9	15	V - 7
5	W - 7	16	U - 4
6	Z - 9	17	X - 9
7	Y - 9	18	W - 9
8	Z - 9	19	W - 9
9	V - 9	20	W - 8
10	V - 10	21	W - 8
11	V - 10	22	W - 7



NOTES:
1. T.P. NUMBERS INDICATE POINTS OF VOLTAGE READING.
2. ALL VOLTAGES MEASURED WITH 20,000 Ω/V. METER TO CHASSIS GROUND.
3.
4. * IF REQUIRED, VALUE FACTORY SELECTED.

ELECTRONIC SYMBOL NOS USED	
S	5
RY	3
T	3
R	37
SR	1
Q	6
I	3
L	2
D	3
C	26
PT	2
F	2
M	1
COMPONENTS REMOVED	
R	4, 19, 36
C	23

UNLESS OTHERWISE SPECIFIED:
RESISTORS ARE ½W 10%
CAPACITORS ARE IN MFD

DWN. P.S.	DATE 4-22-65	TITLE TRANSMITTER SCHEMATIC MODELS 20 & 21
CHKD	SCALE	
VICTOR COMPTOMETER CORPORATION BUSINESS MACHINES DIVISION CHICAGO 18 ILLINOIS	PART NO. 4 - 717	REV. T

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5. AUTHOR(S) *(First name, middle initial, last name)*

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H.W. Estry
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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
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13. ABSTRACT

This report describes the hardware used in the tests of the Victor Comptometer Corporation's Electrowriter as a computer input/output device. Tests were performed on a DEC PDP-9 computer equipped with an A-to-D converter and a D-to-A converter.

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Electrowriter, computer I/O devices						

Unclassified
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