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RANGEMETER FOR XM23 RANGEFINDER

Ira R. Marcus

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ABSTRACT

The rangemeter is a digital time-interval counter that displays range when coupled to the XM23 Laser Rangefinder. It receives start and stop pulses from the rangefinder and displays range readings from 200 to 9995 m. The total volume of the rangemeter is less than 18 in.^{3}. The readout is made of electroluminescent material, and optical coupling is used between the computing circuits and the photoconductive readout matrix.

1. INTRODUCTION

In early 1962, Frankford Arsenal began development plans for a lightweight laser rangefinder. The design considered required a small-sized lightweight interval timer, capable of operating at 30 Mc with a minimum of power consumption. Since there was no counter commercially available satisfying these requirements, HDL submitted a proposed design that was developed following authorization in Sept 1962. The design approach included the use of miniature discrete components to reduce size and weight, and to develop a single power-saving circuit to reduce the power consumption of the entire counter. This counter has been designated "rangefinder" throughout this report.

The rangemeter is a digital time-interval counter that computes and displays range when coupled to the XM23 Laser Rangefinder. It receives start and stop pulses from the rangefinder and displays range from 200 to 9995 m, to the nearest 5±5 m. It is a completely solid-state device and is designed to operate from -55^{o} to $+75^{o}$C. It requires 6 v ±20 percent at 40 ma when it is not computing and 240 ma for about 20 ms when it is computing. Readout requires an additional 200 ma. The rangemeter also supplies a 6-v ready-to-lase signal to the rangefinder and cuts off the motor in the rangefinder after each lase. The time base is a 29.971-Mc crystal oscillator, and the computing circuits are high frequency flip-flops. A solid-state electroluminescent readout displays the range readings. The readout assembly is optically coupled to the computing circuits: the computing flip-flops have microminiature incandescent lamps as loads, and the readout assembly has photoconductive sensors.

2. RANGEMETER SYSTEM

Figure 1 is a basic block diagram of the rangemeter system. The 29.971-Mc crystal oscillator is gated by the start-stop gates to a flip-flop. This flip-flop changes state for each five meters of range. The output of the first flip-flop drives three cascaded binary decades. The first decade cycles every 100 m; the second, every 1000 m; and the third, every 10,000 m of range. The last decade can cycle only once. Each decade is composed of four flip-flops and one NOR circuit (fig. 2). Figure 3 shows the states of the flip-flops for all ten states of the decade. The decade uses a 1-2-4-8 counting system. Each lip-flop has a microminiature lamp in both collector circuits so that only one lamp is on at any one time. The lamp that is on indicates the state of the flip-flop (fig. 4). On the surface of the lamp is a photo-conductive material that switches 600 v to a decoding matrix. The matrix converts the 1-2-4-8 binary code to a nine-segment numeric readout.

The stop gate requires two inputs to stop the counting process. The inputs are from the backscatter control flip-flop and the target return. The backscatter control flip-flop insures that premature echoes caused by atmospheric effects do not stop the counter.

Figure 5 is a more extensive block diagram of the system.

Figure 6 is a sequence-of-events diagram.

The power control block in figure 5 represents a circuit whose function it is to conserve the batteries. It allows the device to be on and for all the flip-flops to retain their state at a low voltage level. When the device is called upon to operate, the power control is activated, and the voltage across the circuits is smoothly raised from one volt to battery voltage. This is called the controlled B+. When battery voltage is reached, the sequencer circuit senses this and puts out an external ready signal to the rangefinder indicating that lasing action may proceed and that the start gate can now accept a start signal. Lasing will take place within 3 ms. After a delay of about 15 ms, the controlled B+ voltage is returned to the memory level. During this delay, a target echo has been received. Before a stop signal can activate the stop gate, the backscatter control must be activated. The backscatter control is operated by signals from the counter. Two minimum range selections are available, 200 and 1000 m. The operator selects the backscatter range. The backscatter setting does not allow ranging on targets closer than the setting. The inputs to the backscatter control come from the counter flip-flops and, in terms of time, do not allow stopping before 1.33 μs for the 200-m setting or 6.66 μs for the 1000-m setting.

The BOM indicator circuit on the readout assembly indicates if the target echo returned before the backscatter setting or if the target echo returned after 66.6 μs, which indicates either that it is beyond the counting capability of the system (an over-range) or that there is no target echo (a miss).

The counter test circuit allows the operator to quickly check the operation of the rangemeter without ranging. It checks the oscillator-amplifier, the entire counting section, the gates, the power control, the sequencer, and the backscatter control. Proper operation is indicated on the readout by the number 8010 to 8025 appearing on the readout.

The dc-to-ac inverter supplies the 600 v required by the electroluminescent readout assembly.

Table I lists the switches in the rangemeter and describes their function.

TABLE I. SWITCH FUNCTIONS

Sw1	On-off switch	Connects the battery to the rangemeter
Sw2	Read switch	Raises controlled B+ to B+ and turns on the high voltage to the readout
Sw3	Range switch	Starts the automatic ranging sequence
Sw4	Counter test switch	Tests the operating condition of the counter
Sw5	Reset switch	Manual reset to all flip-flops and the SCR in the BOM circuit
Sw6	Test switch	Allows the rangemeter to be tested by a pulse generator
Sw7	Motor reset switch	Reset for mirror motor in rangefinder when Sw1 is not used.

3. OPERATING INSTRUCTIONS

Testing Procedure

1. Turn power on (Swl)
2. Push Counter Test (Sw4).
3. Push Read (SW2). If 8010, 8015, 8020, or 8025 is displayed, the counters are working properly, and the sequence may be continued.

Operating Procedure

4. When it is desired to start the ranging operation, turn on Sw7. This turns on the mirror motor.
5. Set the backscatter to 200 or 1000 m depending upon the estimated distance to the target.
6. Five seconds or more after step 4, range by pushing the range button Sw3.
7. Turn off the mirror motor (Sw7).
8. Read the range by pushing Sw2.
9. To range again, repeat steps 4 through 8.
10. Turn off the power (Swl).

4. CIRCUIT DESCRIPTION

4.1 Oscillator-Amplifier

The oscillator (fig. 7) is a crystal oscillator developed at the Harry Diamond Laboratories (ref 1). The crystal is a third overtone 29.971-Mc quartz resonator. The laser beam travels 10 m in 33.3×10^{-9} sec, which is the period of the oscillator. Since it must travel to the target and back to the rangefinder, each pulse of the oscillator represents 5 m of range. The crystal oscillator is followed by a four-stage amplifier and an emitter follower. Six oscillator-amplifiers were fabricated and successfully tested during the design study period. Three of these units were temperature cycled from -55°to +75°C, and no difficulty was encountered. Power is applied to the oscillator section whenever the rangefinder is turned on. Controlled B+ powers the amplifier. This arrangement allows the oscillator to be warmed up, the amplifier to be ready, and the power supply to be conserved. Gating is accomplished at the base of Q6. The base of Q6 is grounded through a control transistor to inhibit the oscillator pulses from reaching the first flip-flop. The collector of Q6 is decoupled from the controlled B+ line by the 56-ohm resistor and the 1000-pf capacitor. This is because Q6 supplies power drive-pulses to the first flip-flop, and, if it is not decoupled, it tends to cause ripple in the power supply line. All the transistors in the oscillator-amplifier circuit are Fairchild FSP 293-1 transistors.

4.2 Flip-Flops and Flip-Flop Decades

Figure 4 shows the basic computing flip-flop used throughout the rangemeter. It is designed for high-speed operation and can compute up to 50 Mc. Its speed in the rangemeter is 30 Mc. The diodes across the 5600-ohm resistors in the hybrid steering circuits are speedup diodes. The collector circuit has, in addition to the collector resistor a miniature lamp as part of its load. The miniature lamp is used for readout purposes and is part of a lamp switch assembly. The operating collector current was determined by the lamp. All flip-flips in the counting circuits are powered from the controlled B+ line to conserve power. The direct current gain of the transistors has to satisfy both a 7-v and a 1-v B+. The gain was measured at both an I_C of 10 ma and of 1 ma for all transistors used in the flip-flops. The minimum gain required at both of these levels is about 10. The minimum room temperature gain of transistors used in all circuits was 35. Figure 2 shows the interconnection of four flip-flops and a NOR circuit to form a decade counter. The flip-flops are connected so as to have a 1-2-4-8 weight. Figure 3 illustrates the ten states of the decade and their logical order.

The counter section is made up of one flip-flop operating at 30 Mc and three decades. The first decade operates at 15 Mc; the second, at 1.5 Mc; and the third, at 150 kc. Between the flip-flop and the first decade and between the first decade and the second decade is a one-stage amplifier. This is to provide isolation between counting units and to provide low-impedance drive sources for the first two high-speed decades.

4.3 Power Control Circuit

The purpose of the power control circuit is to conserve power when the rangemeter is not ranging. This is accomplished by controlling the voltage across the counting circuits and other selected circuits. The voltage before and after ranging is about 1 v. During ranging, the voltage is automatically raised to B+, which is 6 v ± 20 percent. Figure 8 shows the power control circuit. Controlled B+ goes to all circuits powered from the power control circuit. Switch Sw1 (on-off switch) applies B+ to the power control circuit. The 120-ohm resistor across Q18 is in series with the load across the power control circuit. Thus, when Q18 is not conducting and shorting out the 120-ohm resistor, the controlled B+ voltage is about 1 v. When Q18 does conduct, it shorts out the 120-ohm resistor, and the controlled B+ goes to B+.

When switch Sw3 (range switch) is closed, the sequence controlling the lasing operation is begun. Silicon-controlled rectifier (SCR) Q19 is turned on, and base current flows through Q18. Collector current flows through Q18 shorting the 120-ohm resistor. The rate of rise of the controlled B+ is regulated by controlling the rate of rise of the base current with the 39-μf capacitor between the base and emitter of Q18. The 120-ohm resistor and the 39-μf capacitor across the controlled B+ line also influence the rate of rise of the controlled B+. The controlled B+ is returned to the memory voltage by turning off the SCR Q19 and interrupting the base current to Q18. This is done by the sequencer circuit pulsing Q20, which momentarily reduces the current through Q19 below its holding value and thus turns off Q19. The turn-off voltage is smoothly returned to the memory voltage by the shunt capacitor across the controlled B+ line. The power control circuit may also be controlled manually by the read switch Sw2A and the test switch Sw6A. Ranging is accomplished during the time interval that the controlled B+ is at B+. Figure 9(a) shows the waveform of the controlled B+ going from memory voltage to B+ back to memory voltage.

4.4 Sequencer

The purpose of the sequencer (fig. 10) is to program the succession of events that take place between the time switch Sw3 is closed (this starts the lasing sequence) and the time the lasing operation is over and the controlled B+ is returned to the memory level. The sequencer performs the following functions:

(a) Senses when controlled B+ is close to B+.
(b) Resets all circuits when controlled B+ is close to B+.
(c) Indicates to the start gate that controlled B+ is up to full B+ and allows the start gate to receive start pulses. This is the internal ready signal.
(d) Indicates by a B+ pulse to the rangefinder that the counter is ready and that lasing may commence. This is the external ready signal.
(e) Pulses the power control circuit after 15 ms of sensing that the controlled B+ is at B+, so that the controlled B+ is returned back to the memory level.
(f) Turns off the laser mirror motor after lasing has occurred.

The basic circuits in the sequencer are a Schmitt trigger, a 2-ms one-shot and a 15-ms one-shot. The Schmitt trigger senses the controlled B+ and changes state at about 80 percent of B+. The output of the Schmitt trigger pulses the 2-ms one-shot. The 2-ms one-shot pulse is differentiated. The leading edge is used to pulse the reset circuit while the trailing edge triggers the 15-ms one-shot. By this time the controlled B+ is up to B+. This 15-ms pulse has two outputs, the internal ready and the external ready. The internal ready allows the start gate to accept the start pulse. The external ready indicates to the rangefinder that it may commence a lasing sequence. The lase will begin within 3 ms of the start of the pulse, and the reflected signal will be received during the 15-ms pulse. At the end of the 15-ms pulse, the power control circuit is pulsed to bring the controlled B+ to the memory level. This is accomplished by differentiating the 15-ms pulse and using the trailing edge to pulse the power control circuit. The differentiating circuit is between Q14 and Q15. In addition, the differentiated trailing edge of the 15-ms one-shot pulse is used to turn off the mirror motor in the rangefinder.

The mirror motor, located at the collector terminal of Q17, is turned on by the operator before he starts the lasing action. The mirror motor is turned on by closing Sw7. SCR-Q16 is not conducting, and base current flows to Q17. The trailing edge of the 15-ms one-shot pulse turns on Q16. Q17 and the mirror motor are turned off. When it is desired to range again, Sw7 (in the rangefinder) is opened, Q16 stops conducting, and Sw7 is closed again, turning on the motor.

Figure 9 shows the waveforms at various points in the sequencer.

4.5 Gates

The function of the gate circuit (fig. 11) is to control the flow of oscillator pulses to the first flip-flop of the counter. The collector of Q26 is connected to the base of Q6 (Q6 is in the oscillator-amplifier circuit). If base current flows into Q26, the collector of Q26 goes to ground, shorting the oscillator pulses that appear at the base of Q6 to ground. Thus, if there is an input to Q26, the counter does not receive pulses. The inputs to Q26 are two flip-flop outputs. The flip-flop containing Q24 and Q25 is the start control flip-flop, and Q35 and Q34 make up the stop control flip-flop. Upon being reset, the on control flip-flop causes Q26 to saturate blocking oscillator pulses to the counter. The off control flip-flop input to Q26 is at ground. When the proper conditions for starting the count exists, the on control fip-flop changes state. Both inputs to Q26 are at ground, and oscillator pulses pass to the counter. When the proper conditions exist for stopping the counter, the off control flip-flop changes state and stops the counter from receiving oscillator pulses.

For the start flip-flop to be pulsed, two conditions must exist simultaneously. The sequencer must supply an internal ready-signal to Q22, and a start pulse must be received from the rangefinder and turn on Q23. These two signals are ANDED to pulse the on control flip-flop. The start pulse from the rangefinder is a negative pulse.

For the stop flip-flop to be pulsed, two conditions must exist simultaneously. The backscatter control flip-flop must have been activated so that its output can be ANDED with the stop pulse from the rangefinder. The AND circuit is composed of Q32 and Q33. The stop pulse from the rangefinder is a negative pulse.

4.6 Backscatter Control

The purpose of the backscatter control circuit (fig. 12) is to prevent false stop inputs from turning off the rangemeter. When light leaves the rangefinder, reflections from the atmosphere occur during the first 1000 m and are received by the stop-circuit optics. This is called backscatter. To prevent these backscatter pulses from stopping the counter, the stop circuit is inhibited during this period. This is accomplished by using the counter circuits to generate the desired hold-off times. The operator selects either a 200-m or a 1000-m backscatter inhibit by a switch. The counter supplies a time pulse equivalent to 200-m range and a time pulse equivalent to 1000-m range to two amplifiers. The switch powers only the amplifier of the chosen backscatter distance. The output of both amplifiers controls the backscatter flip-flop. Only the powered amplifier can pulse the backscatter flip-flop. The backscatter flip-flop must be pulsed before a stop pulse will stop the counter.

Switching the power to the amplifiers is preferred to switching the inputs to the amplifier because it minimizes cross-talk. The backscatter flip-flop output is an input to the stop-gate-AND circuit.

4.7 BOM Indicator Circuit

The purpose of the Backscatter, Over-range, and Miss (BOM) indicator is to indicate that no stop signal was received during the stop interval. The stop interval is between the setting of the backscatter range and the capacity of the counter. The BOM indicator circuit (fig. 13) is pulsed at the base of Q71 when the counter goes from 9995 to 0000 m. This will occur (a) if the stop signal is received before the backscatter flip-flop changes state, (b) if the stop signal is received after 10,000 m, an over-range, or (c) if there is no stop signal, a target miss. The input to the BOM turns on SCR Q72. When the read switch Sw2B is pressed, SCR Q72 allows the lamp in the lamp switch to be on. The readout section will explain how the indicator operates. The indicator may be reset by the sequencer through Q74 or by the manual reset button (Sw5, fig. 15). It is not reset by the reset circuit. This is because the reset circuit is activated when the BOM indicator is activated.

4.8 Counter Test Circuit

The purpose of the counter test circuit is to test a major portion of the rangemeter circuitry without lasing. This is accomplished by closing switch Sw4 (fig. 14). This applies power to the counter test circuit and also triggers the power control circuit to go to the operating voltage. The sequencer starts its program. The internal ready signal to the start-AND circuit also is an input to the counter test circuit. Since the counter test circuit is now powered, it amplifies the internal ready signal from the sequencer, and the amplified pulse is used to simulate a start signal, and the counter starts. Stopping the counter is accomplished by feeding the output of the last flip-flop in the counter to the stop amplifier of the counter test circuit. This amplified pulse is fed to the stop circuit and stops the counter. The readout switch is then pushed, and the number 8000 m should appear. Due to the propagation time of the binaries, the readout will read between 8010 and 8025 m. The counter test circuit checks the operation of the oscillator-amplifier, the gates, the power control, the sequencer, the counter, the reset circuit, and the readout.

4.9 Reset Circuit

The purpose of the reset circuit is to reset the various binaries in the rangemeter to the desired state (fig. 15). The resetting method used is to ground the collector of the desired transistor in the flip-flop. The inputs to the reset circuit come from the sequencer and from the BOM indicator. The counter flip-flops, the gate flip-flops, and the backscatter flip-flop are reset. A manual reset Sw5 is included, and, in addition, it resets the SCR in the BOM indicator circuit.

4.10 Test Switch (Sw6)

The purpose of the test switch (Sw6)(fig. 8, 11) is to facilitate troubleshooting and testing of the rangemeter. It turns on the power control circuit, so that B+ is on all the circuits all the time. It also bypasses the internal ready for the start gate, so that a start pulse will operate the start gate at any time. Thus the circuits can be tested with a delay generator. The start pulse into the start circuit can be delayed by the delay generator and used as a stop pulse. By adjusting the delay, the counters and the backscatter circuit can be tested. The test switch will be included in the first prototype. It is not expected to be included in future models except possibly inside the chassis.

4.11 Readout

The readout display is made of electroluminescent material. Numbers from zero through nine may be displayed by applying voltage to the proper segments of the numeric pattern (fig. 16). The pattern is composed of nine segments. The segments that are illuminated are determined by the states of the flip-flops in the decades. The readout display is composed of four such numeric patterns. These patterns, from right to left, are controlled by the 30-Mc flip-flop, the tens-meter decade, the hundreds-meter decade, and the thousands-meter decade.

The segments, which determine the readout display, are controlled by lamp switches. Each flip-flop has a lamp switch in its collector load. The lamp switch is a four-terminal device. It is composed of a microminiature incandescent lamp with photoconductive material on its surface. Two leads are wound on the surface of the lamp with the photoconductive material between the two leads. The entire assembly is potted in opaque potting material. Thus, when the lamp does not have current through it, it does not glow, and the photoconductor switch has a high impedance (about 10 meg). When the lamp does have current through it, it glows, and the photoconductor switch has a lower impedance (about 50 kohms). Since the lamp part of the lamp switch is in the flip-flop, the state of conductance of the photoconductors reflect the state of the flip-flop. In series with each photoconductor is an electroluminescent (EL) bar lamp and a 600-v peak-to-peak, 1600-cps supply. The bar lamps are rectangular strips of electroluminescent material and will be illuminated if the photoconductor in series with it is conducting. Now the state of each flip-flop is represented by which one of two bar lamps is illuminated (fig. 17). Each decade, therefore, controls eight bar lamps of which only four are on at any time. It is now necessary to convert the information contained in the illuminated bar lamps to numbers on the display (fig. 18). This is accomplished by having, across the bar lamps, photoconductors which control the segments. These photoconductors are in series with the segments making up the numeric and the high-voltage power supply. Thus each combination of illuminated bar lamps activate photoconductors that control the segments. The illuminated EL segments form the number.

The bar lamps, the photoconductor matrix across the bar lamps, and the readout panel form the readout assembly (fig. 19,20, and 21). This concept and logic were originated at the Harry Diamond Laboratories. The lamp switches and readout assembly were fabricated by a contractor. The entire readout assembly is a solid-state device and has a volume of 4 in.^{3}. The numerals are 1-in. high.

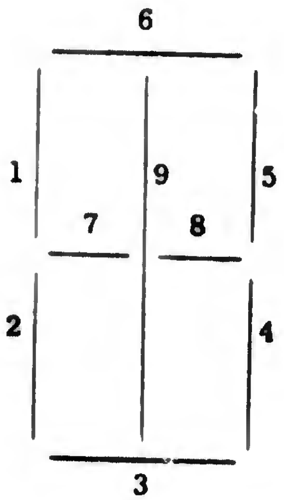
The main advantage of this readout is its potential low cost, low power requirement, and extreme ruggedness. The power consumption for this first model is 1.8 w. It is expected that the power will be further reduced to 0.6 w in the second model. In addition, the readout in no way interferes with the functioning of the flip-flips since coupling is done by optical means.

The number of photoconductors comprising the matrix was substantially reduced by application of Boolean Algebra (ref 2). Table II describes the photoconductor matrix that coupled the bar lamps to the readout segments.

The binary code column lists the counting order of the binary decade as described in figure 3. The segment column lists the

TABLE II. READOUT MATRIX

8-4-2-1 Binary Conversion to 9-Segment Numeric Readout



Readout Display	Binary Code D	C	B	A	Segment 1	2	3	4	5	6	7	8	9
0	0	0	0	0	1	1	1	1	1	1	0	0	0
1	0	0	0	1	0	0	0	0	0	0	0	0	1
2	0	0	1	0	0	1	1	0	1	1	1	1	0
3	0	0	1	1	0	0	1	1	1	1	0	1	0
4	0	1	0	0	1	0	0	1	1	0	1	1	0
5	0	1	0	1	1	0	1	1	0	1	1	1	0
6	0	1	1	0	1	1	1	1	0	1	1	1	0
7	0	1	1	1	0	0	0	1	1	1	0	0	0
8	1	0	0	0	1	1	1	1	1	1	1	1	0
9	1	0	0	1	1	0	1	1	1	1	1	1	0

Decade Matrix After Minimizing

Segment 1 = $\bar{A}(\bar{B}+C) + C\bar{B}+D$

Segment 2 = $\bar{A}(B+\bar{C})$

Segment 3 = $\bar{A}(B+\bar{C}) + \bar{C}B+C\bar{B}A+D$

Segment 4 = $BA+\bar{A}\bar{B}+C+D$

Segment 5 = $\bar{A}(\bar{B}+\bar{C})+BA+D$

Segment 6 = $B + \bar{C}\bar{A}+D+CA$

Segment 7 = $B\bar{A}+C\bar{B}+D$

Segment 8 = $B\bar{A}+\bar{C}B+C\bar{B}+D$

Segment 9 = $A\bar{B}\bar{C}\bar{D}$

30-Mc Flip-Flop, 0- or 5-M Readout, Using the Decade Matrix

Digit 0 = $\bar{C}\bar{A}\bar{B}$ — "0" side of 30-Mc FF controls $\bar{C}$ and $\bar{A}$ bar lamps

Digit 5 = $CA\bar{B}$ — "1" side of 30-Mc FF controls C and A bar lamps

Read voltage controls $\bar{B}$ bar lamp segments that must be on so that the nine-segment readout will display the decimal digit that corresponds to the state of the binary decade. A "1" indicates that the segment is on, and a "0", that it is off. The equations describe all the input combinations that turn on each segment. These equations describe the photoconductor matrix that controls the readout. The 30-Mc flip-flop is read out by the same binary decade matrix. This flip-flop must read out the digit 0 when the flip-flop is in the "0" state and must read out the digit 5 when the flip-flop is in the "1" state. This is accomplished by the "0" side of the flip-flop controlling the $\bar{C}$ and $\bar{A}$ bar lamps and the "1" side controlling the C and A bar lamps. The $\bar{B}$ bar lamp is on at all times during readout.

4.12 High-Voltage Power Supply

The EL readout assembly requires a high-voltage supply. Figure 22 shows the circuit used to generate the 600-v peak, 1600-cps square wave. It is a conventional saturable core inverter. Since the EL readout assembly is a highly capacitive load, the inverter is designed to supply high peak currents. It uses low-saturation-voltage germanium transistors. It is expected that silicon transistors will be used in the inverter for the second-generation EL readouts, because the newer readouts will require less current, and the constraint of low saturation voltage at high current will no longer dictate the use of germanium transistors.

4.13 Prototype Packaging

Figures 23 and 24 are schematics of the entire rangemeter. Table I is a list of the switches and their functions.

The prototype models were built using miniature components, high density packaging, and printed circuitry. All the electronic circuitry required a volume of about 5 $in.^3$. There are two printed circuit cards (fig. 25, 26). They are approximately 2 by 4 in. The first contains the counter, which is composed of the thirteen flip-flops. The second card contains the reminder of the circuitry. Figures 27 through 31 shows the prototype packaging.

5. BREADBOARD TEST

During February 1963, the rangemeter breadboard was successfully tested at Frankford Arsenal with the XM23 rangemeter. Table III shows the results of the tests on various targets. All ranges were indicated within the ±5-m resolution of the counters, the absolute accuracy was verified with Frankford Arsenal Laboratory counters.

TABLE III. RANGEMETER TEST RESULTS

HDL Rangemeter			FA Lab Counter	HDL Rangemeter		
Voltage (v)	Range reading* (m)	Range time** (µs)	Range time*** (µs)	Backscatter setting (m)	BOM indicator	Remarks
			Target No. 1			
6.0	0915	6.11	6.10	0200	Not recorded	Low power laser
	0920	6.14	6.10	0200	Not recorded	
	0910	6.07		0200	Not recorded	
	0910	6.07		0200	Not recorded	
	0910	6.07		0200	Not recorded	
6.0	0000	N/A		1000	ON	Low power laser
	0000	N/A		1000	ON	
	0000	N/A		1000	ON	
	0000	N/A		1000	ON	
	0000	N/A		1000	ON	
			Target No. 2			
6.0	0805	5.37	5.38 estimated	0200	Not recorded	Low power laser
	0800	5.34	5.38 estimated	0200	Not recorded	
	0800	5.34		0200		
	0805	5.37		0200		
	0800	5.34		0200		
			Target No. 3			
6.0	2825	18.85	18.87	1000	Not recorded	High power laser
	2825	18.86	18.84	1000	Not recorded	
	2825	18.85	18.85	1000	Not recorded	
	2825	18.85	18.85	1000	Not recorded	
	2825	18.85		1000	Not recorded	
	2820	18.82		1000	ON	
	2825	18.85		1000	ON	
	2825	18.85		200	OFF	
	2820	18.82		200	Not recorded	Low power laser
	2825	18.85		200	Not recorded	
	2825	18.85		200	OFF	
	2820	18.82		200	OFF	
	2820	18.82		200	OFF	
	2820	18.82		1000	OFF	
	2820	18.82		1000	OFF	
	2825	18.85		1000	ON	
	2825	18.85		1000	ON	
	2825	18.85		1000	OFF	
	2825	18.85		200	OFF	
			Target No. 4			
6.0	4090	27.29	Not recorded	1000	ON	Low power laser
	4090	27.29	estimated correct	1000	OFF	
	4090	27.29	by FA personnel	1000	OFF	
	4090	27.29		1000	OFF	
	4090	27.29		1000	OFF	

* The rangemeter resolution is 5 meters.
** Range time is converted from range reading, resolution is 0.03 µs, accuracy better than 0.01 percent.
***Resolution is 0.01 µs, estimated accuracy, ±0.02 µs.

TABLE III. RANGEMETER TEST RESULTS (Cont'd)

HDL Rangemeter			FA Lab counter	HDL Rangemeter		
Voltage (v)	Range reading* (m)	Range time** (μs)	Range time*** (μs)	Backscatter setting (m)	BOM indicator	Remarks
			Target No. 5			
6.0	2520	16.82	16.86	1000	ON	
	2520	16.82	16.86	1000	OFF	
	2525	16.85	16.86	1000	OFF	
	2525	16.85	16.86	1000	ON	
			16.84			
			16.84			
4.8	2525	16.85		1000	ON	
	2520	16.82		1000	ON	
	2525	16.85		1000	ON	
	2520	16.82		1000	ON	
	2525	16.85		1000	ON	
7.2	2520	16.82		1000	OFF	
	2525	16.85		1000	OFF	
	2525	16.85		1000	OFF	
	2525	16.85		1000	OFF	
			Target No. 6			
7.2	0410	2.74	2.75	200	OFF	Low power laser
	0405	2.70	2.75	200	OFF	
	0410	2.74		200	OFF	
	0410	2.74		200	OFF	
	0410	2.74		200	OFF	
7.2	0000			1000	ON	
	0000			1000	ON	

* The rangemeter resolution is 5 meters.

** Range time is converted from range reading, resolution is 0.03 μs, accuracy better than 0.01 percent.

*** Resolution is 0.01 μs, estimated accuracy, ±0.02 μs.

6. FUTURE MODELS

Field testing of the XM23 Rangefinder by Frankford Arsenal indicates that additional circuitry should be incorporated into the rangemeter. This circuitry will be incorporated into the second-generation rangemeter prototypes. The most important change is the addition of a target counter in the stop gate. The purpose of the target counter is to allow the operator to select the desired echo to stop the counter. This is required since multiple echos are sometimes received. In addition, the total number of echoes are to be displayed. The second-generation prototype will also include updating of all the existing circuitry and a lower-power readout assembly.

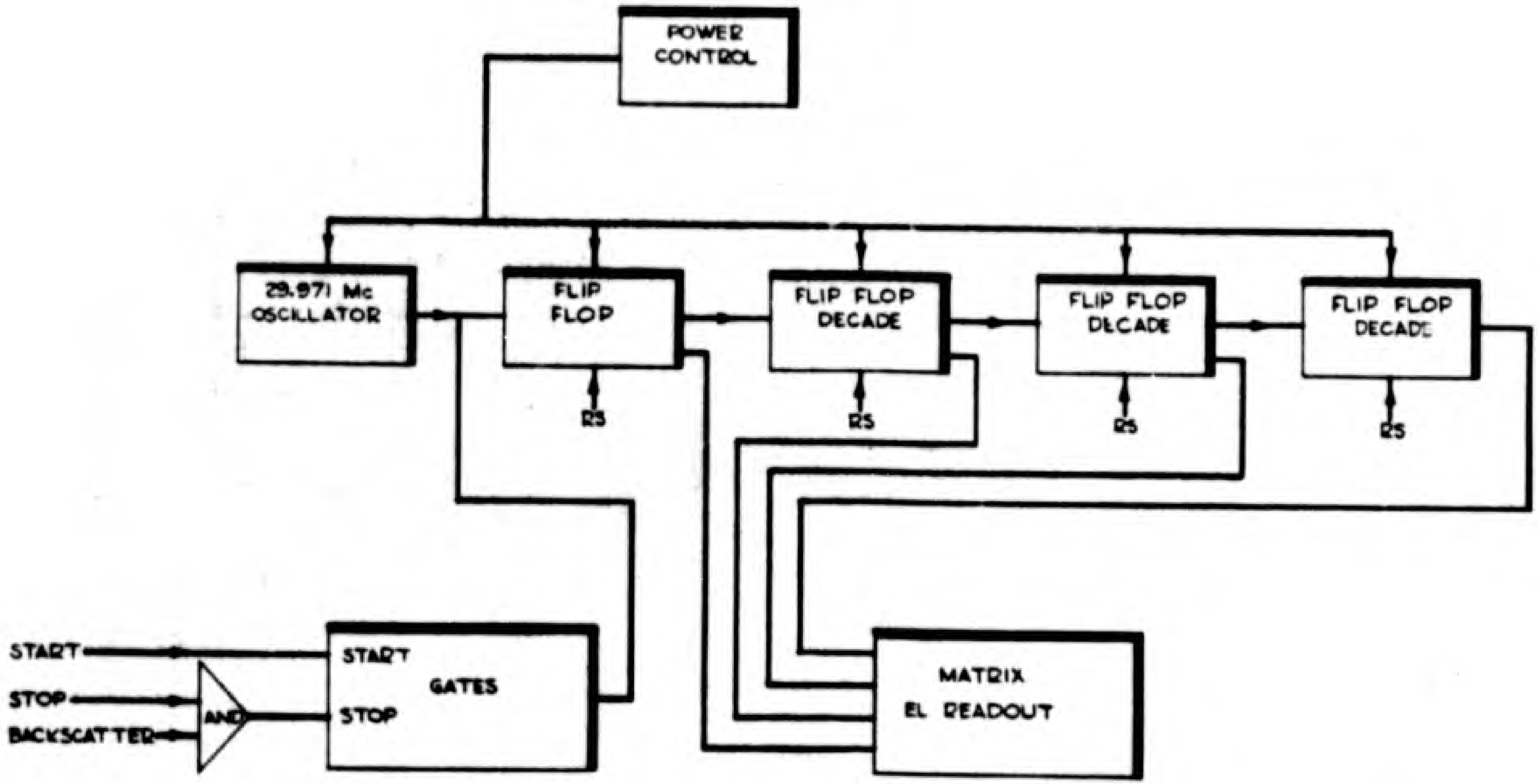
7. REFERENCES

(1) K. H. Sann, "Miniaturized High Precision Crystal Oscillator," DOFL Report TR-878, 10 November 1960.

(2) Samuel H. Calwell, "Switching Circuits and Logical Design," John Wiley & Sons, 1960.

ACKNOWLEDGMENT

Acknowledgment is gratefully given to Charles Dabney who fabricated and tested the breadboard models, to Ray Farrar who drafted all the drawings and printed circuit layouts, to Tom Protz who designed the chassis and made numerous suggestions and to Beulah Buddington who skillfully assembled the prototype models.



RS = RESET

Figure 1. Rangemeter basic block diagram.

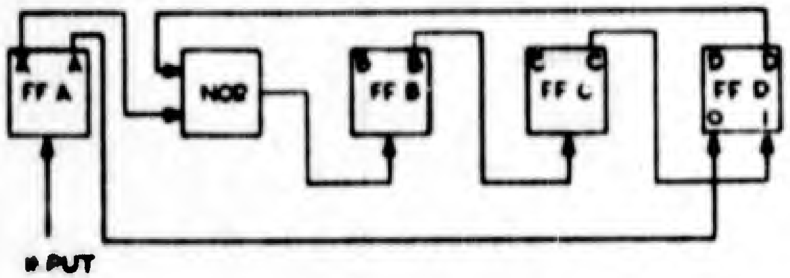


Figure 2. Binary decade

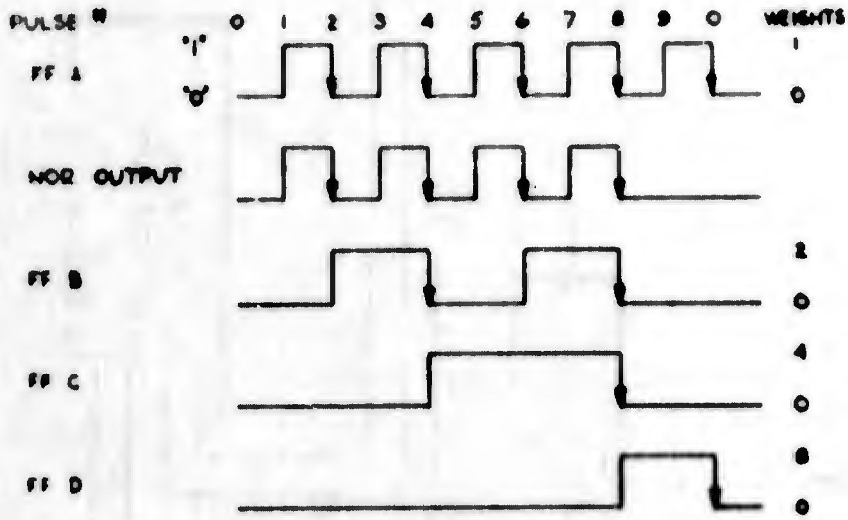


Figure 3. Decade logic.

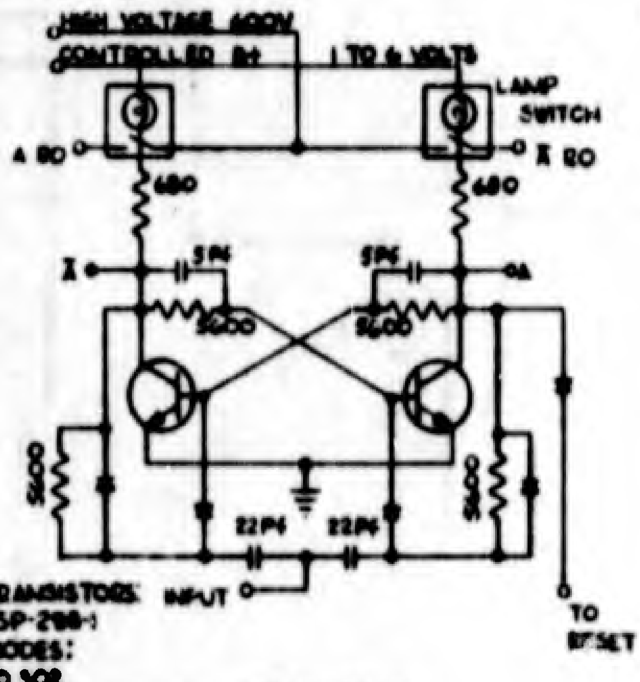


Figure 4. Flip-flop.

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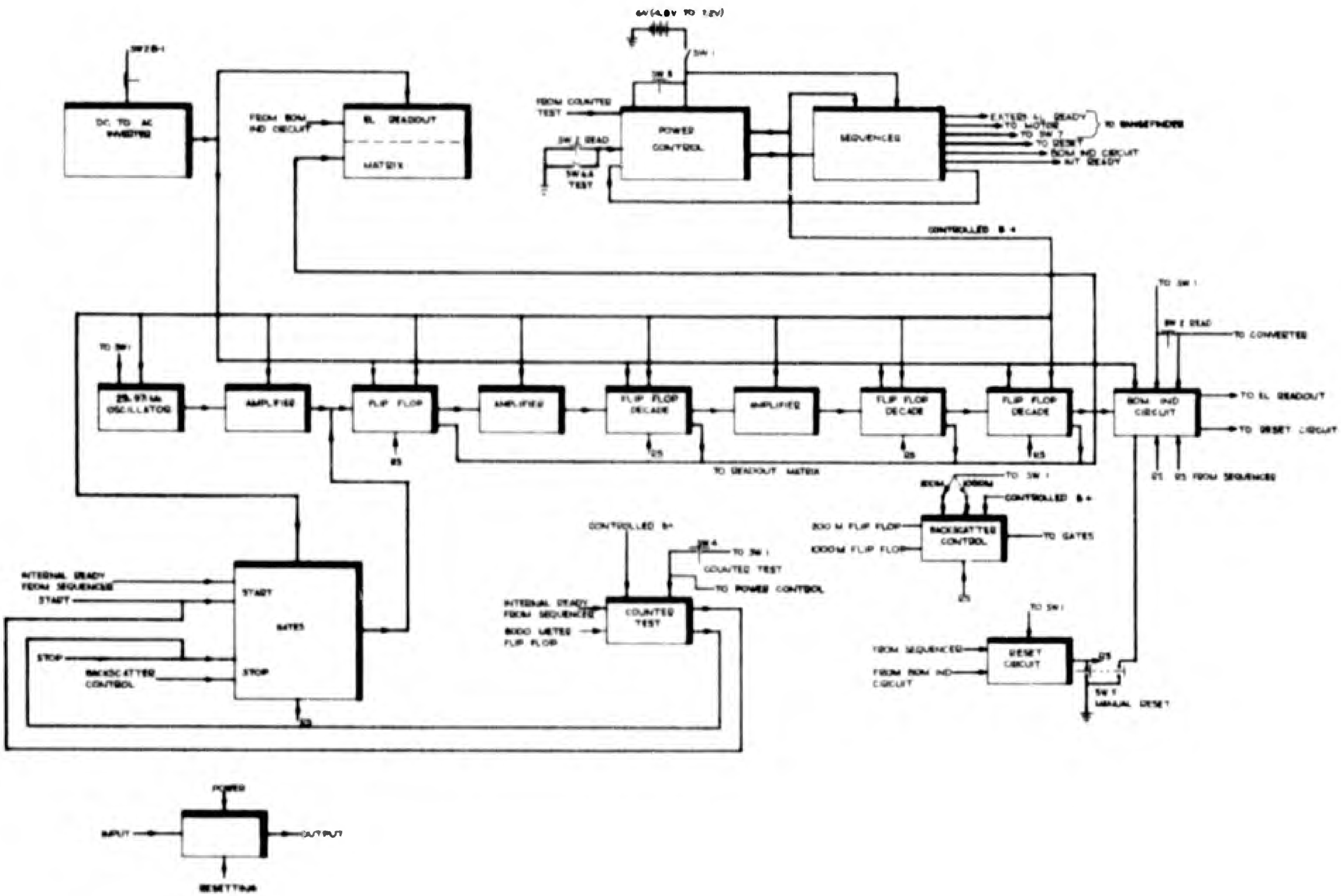

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Figure 5. Complete block diagram of rangemeter.

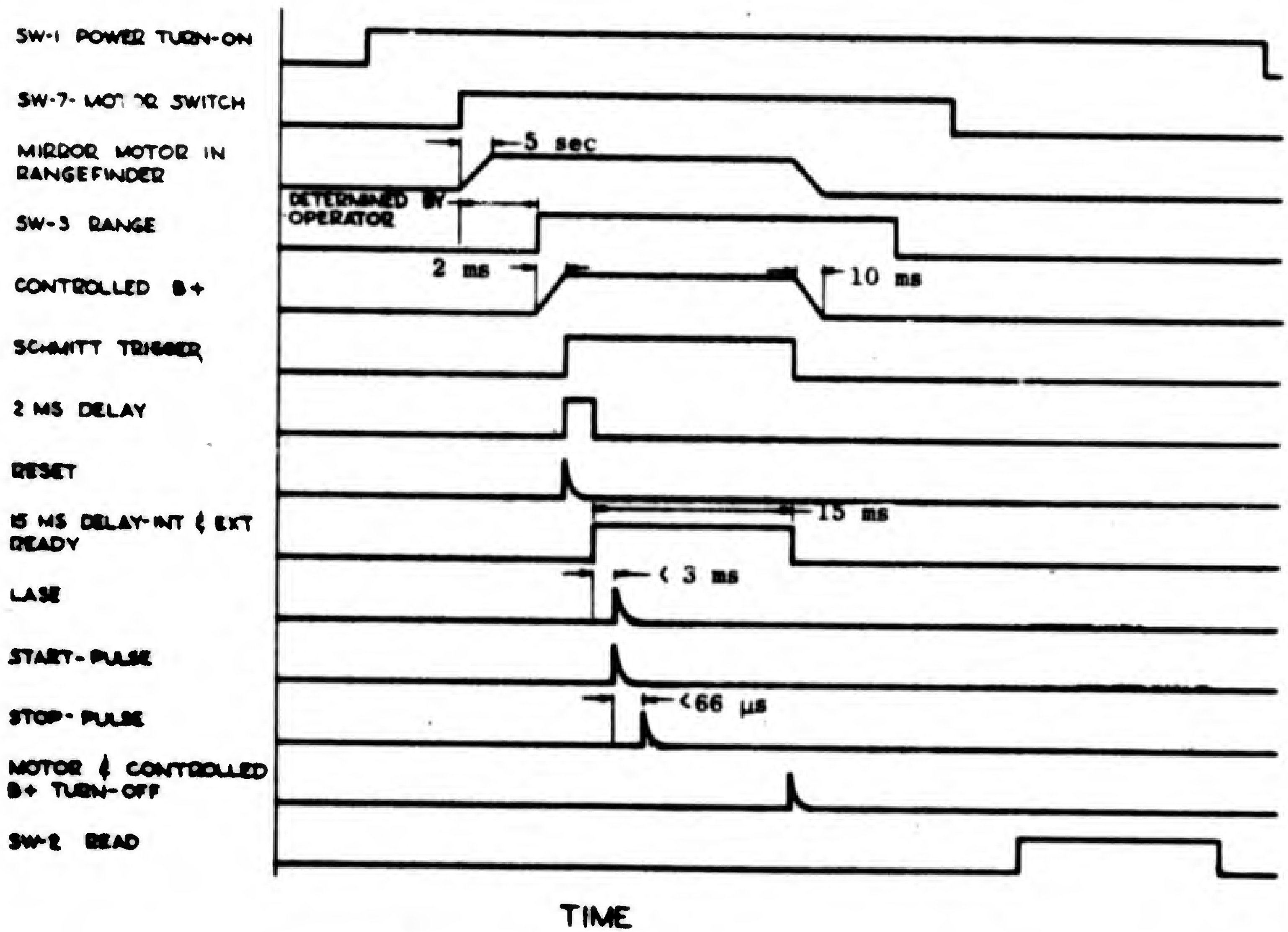

Figure 6. Sequence of events during operation.

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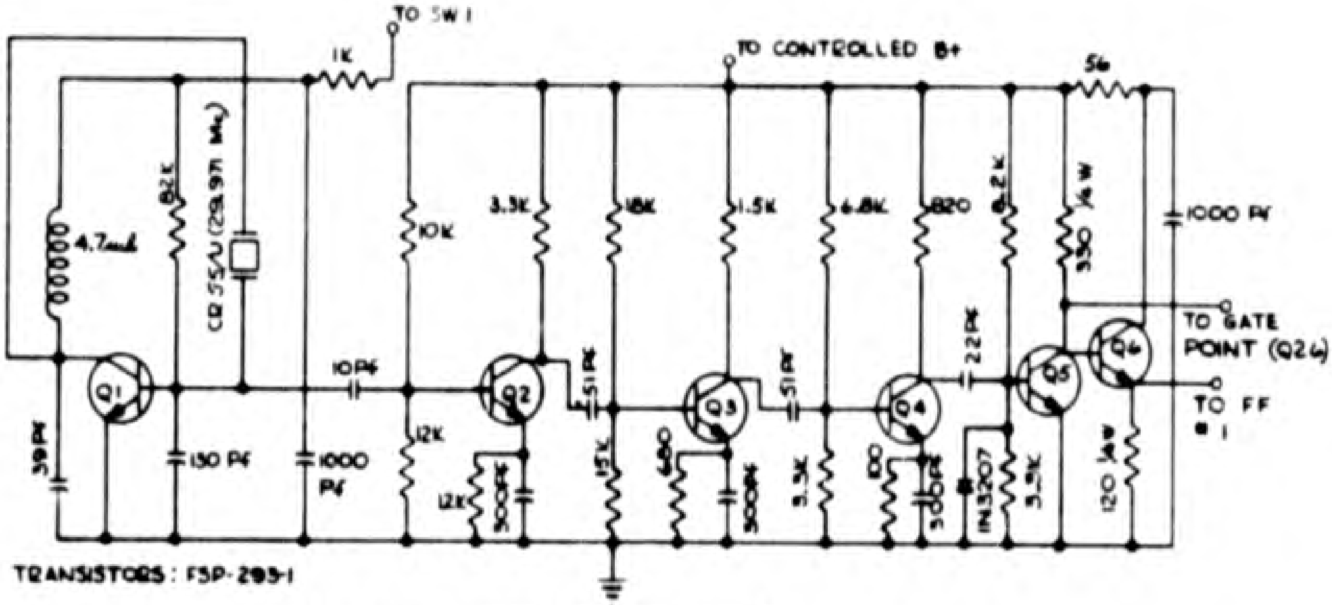


Figure 7. Oscillator-amplifier

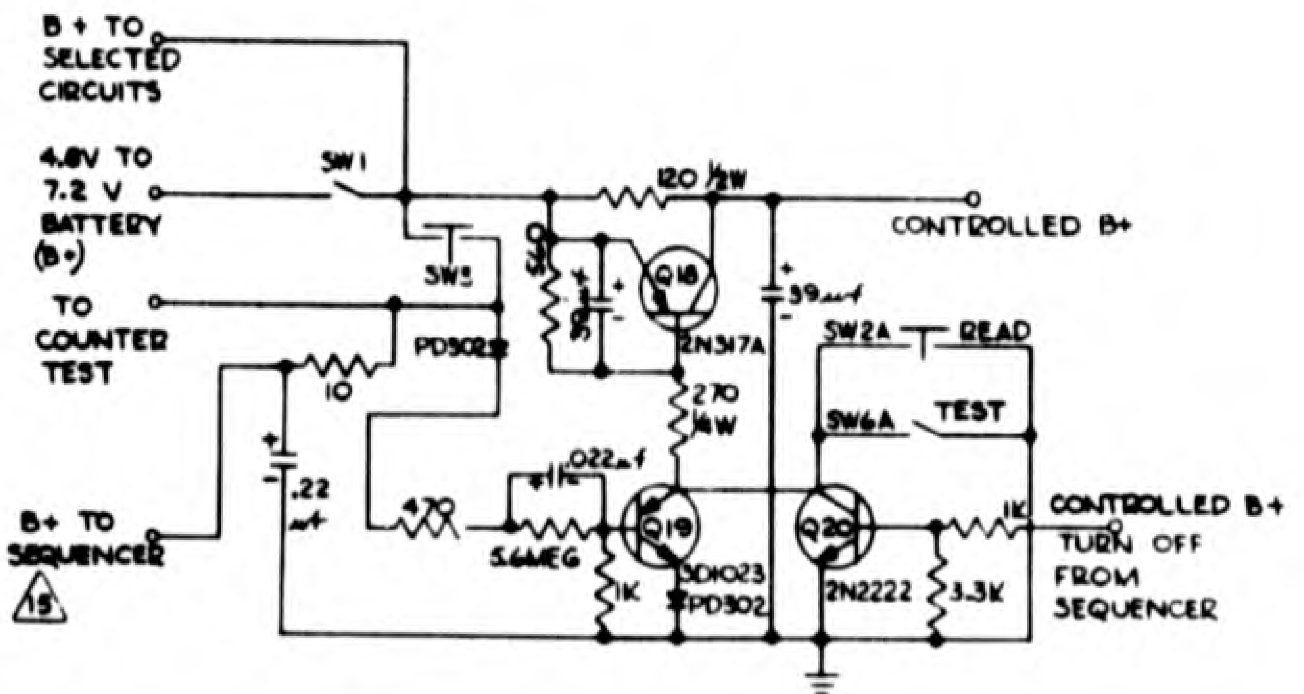
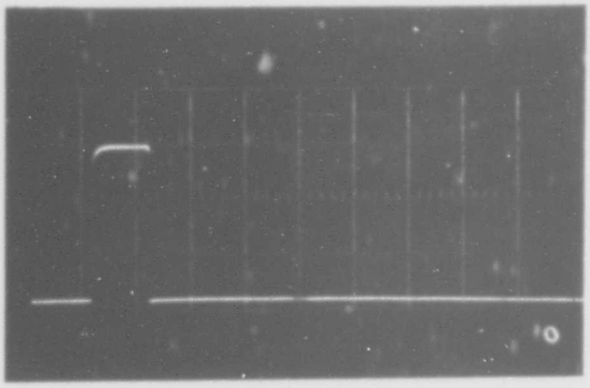
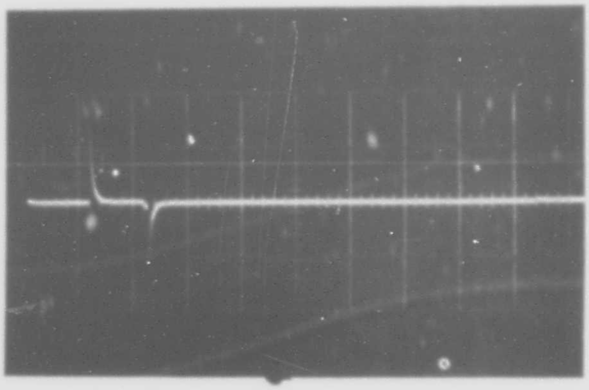


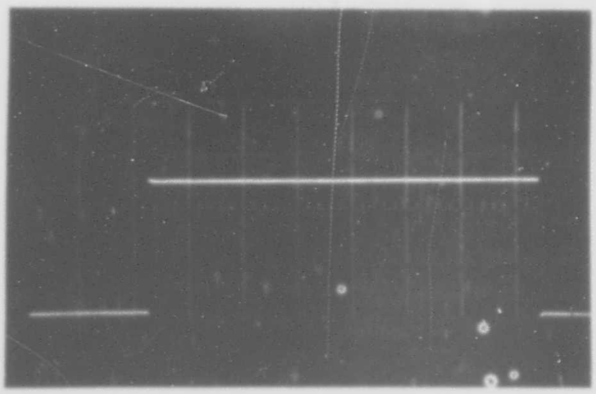
Figure 8. Power supply



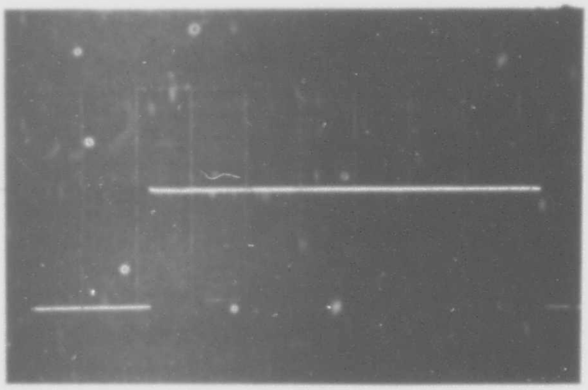
(d) 2 ms monostable MV
(collector of Q10)



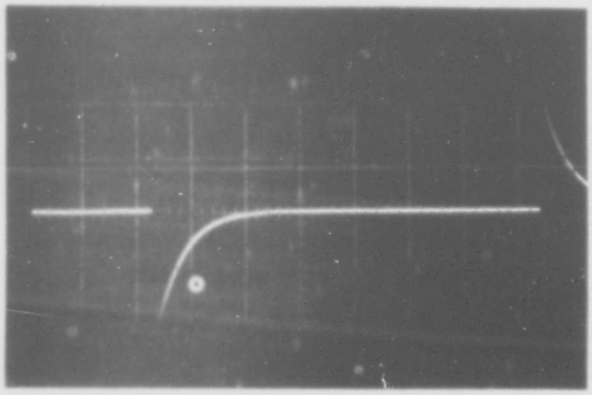
(e) 2 ms monostable
differentiated



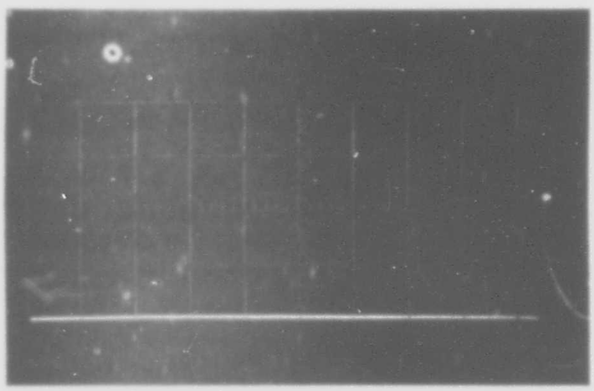
(f) 15 ms monostable MV
(collector of Q12)



(g) Internal ready



(h) 15 ms monostable
differentiated
(anode of diode at Q15)



(i) Controlled B+ turn off

Horizontal - 2 ms/cm
Vertical - 2 v/cm

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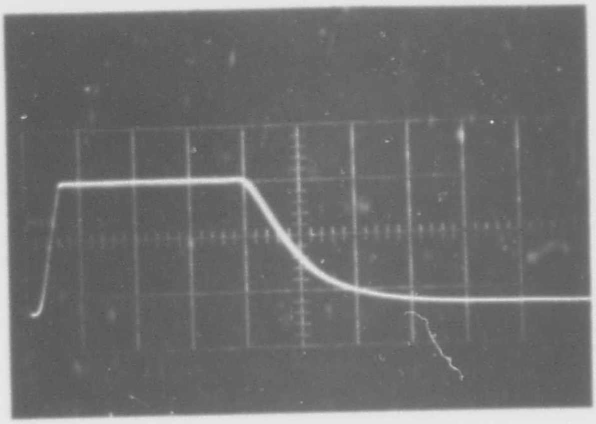
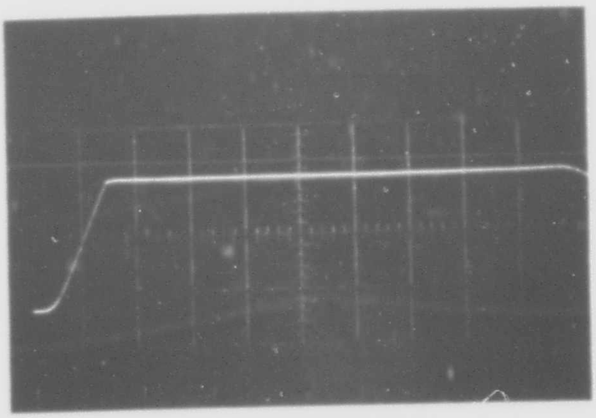
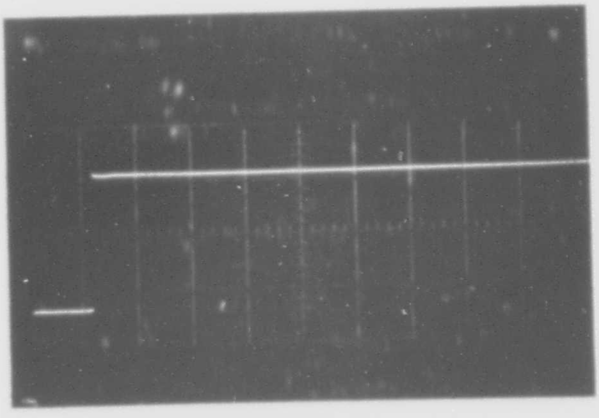
Figure 9. Waveforms of sequencer.



(a) Controlled B+



(b) Controlled B+



(c) Schmitt trigger
(collector of Q8)

a = Horizontal - 5 ms/cm: Vertical - 2 v/cm
b&c = Horizontal - 2 ms/cm: Vertical - 2 v/cm

168363

Figure 9 (Continued). Waveforms of sequencer.

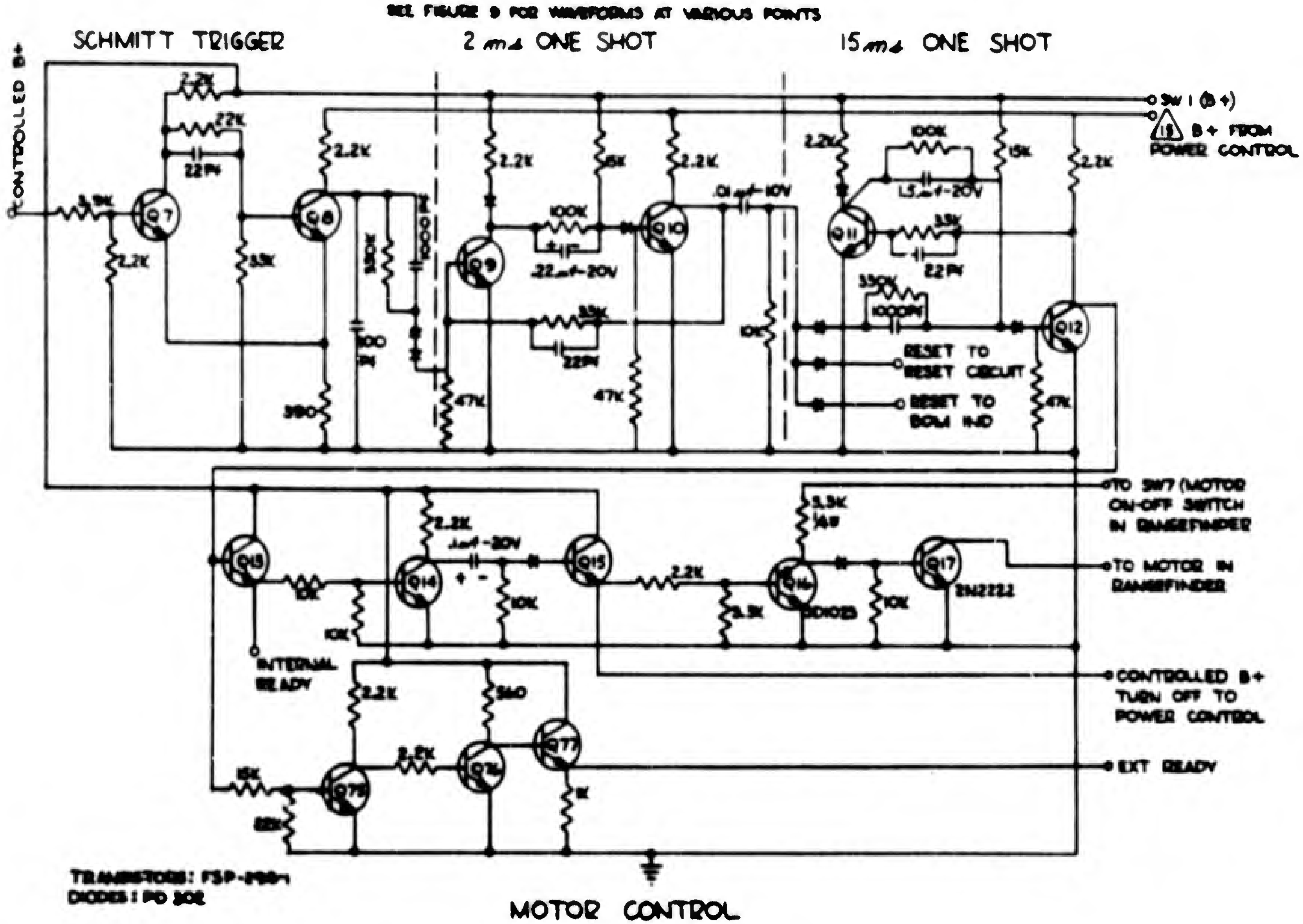


Figure 10. Sequencer

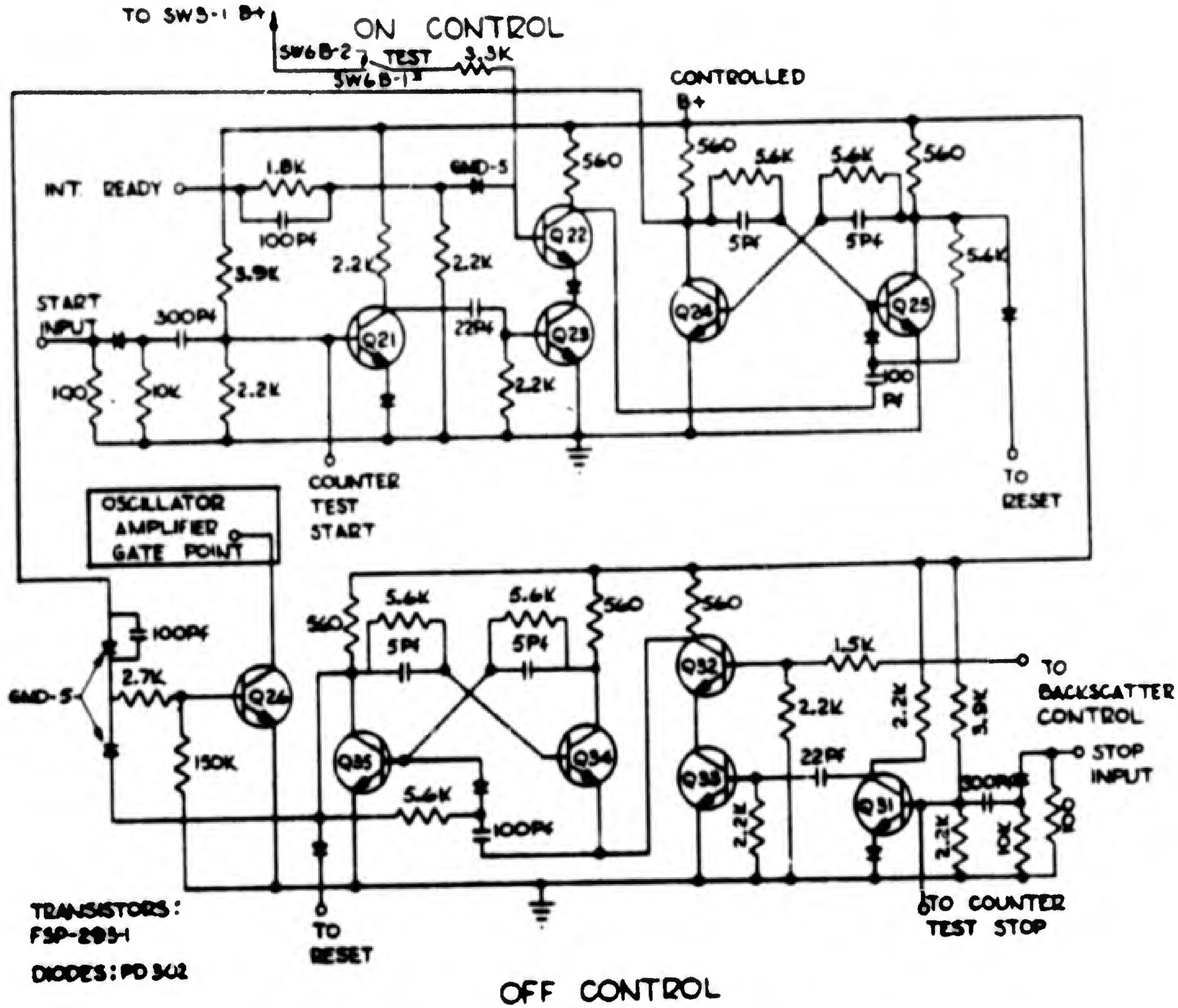


Figure 11. Gates

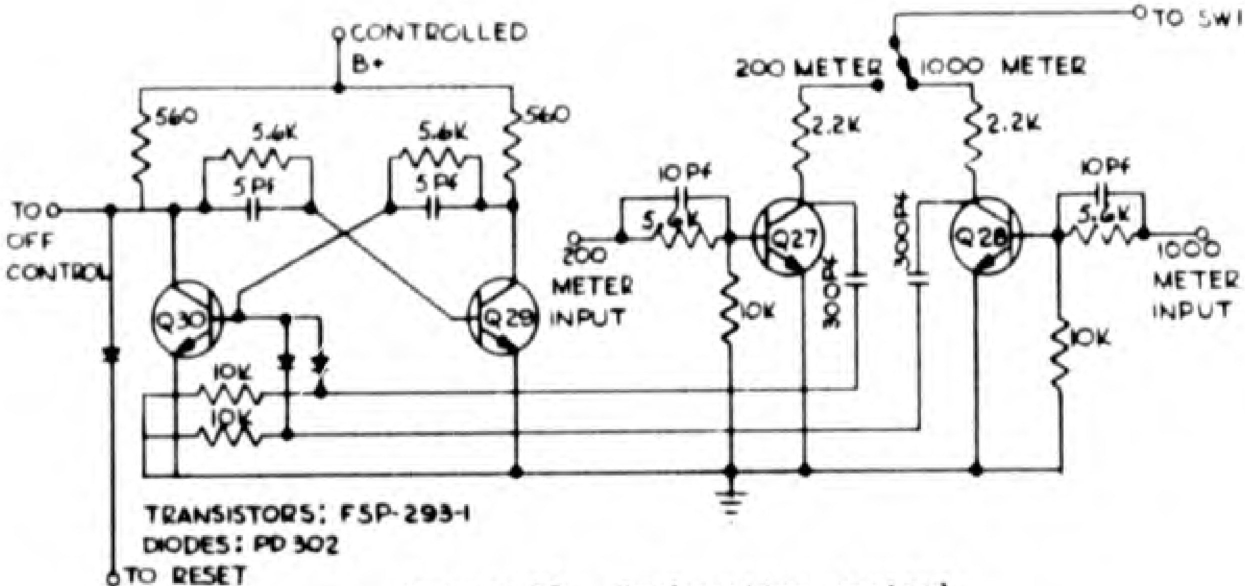


Figure 12. Backscatter control

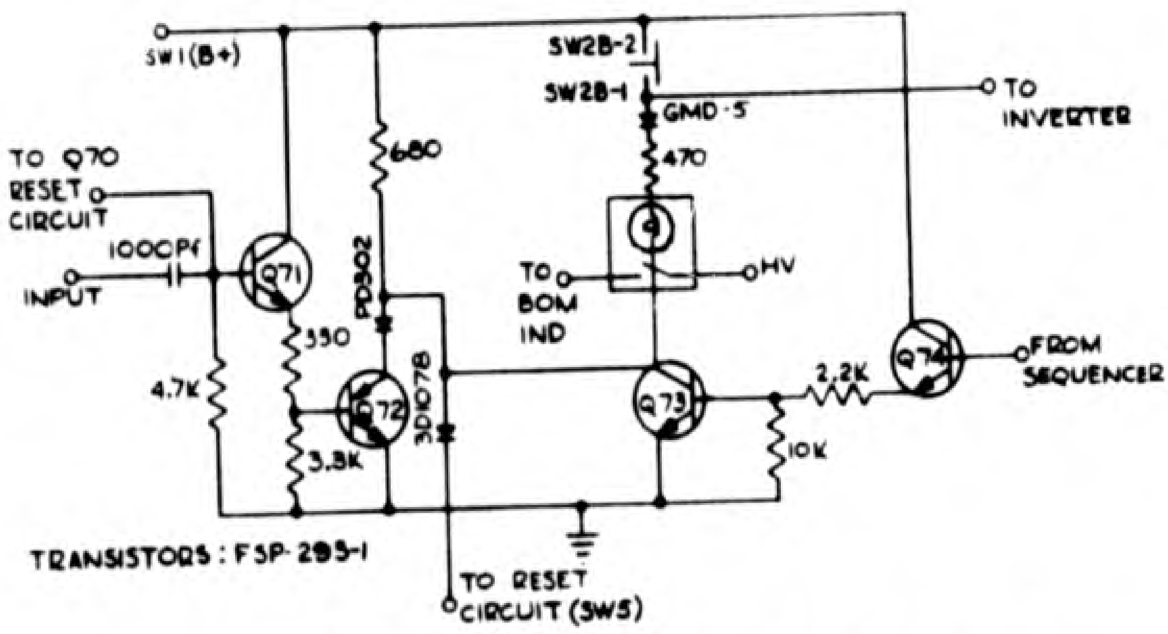


Figure 13. Backscatter, over-range, and miss indicator.

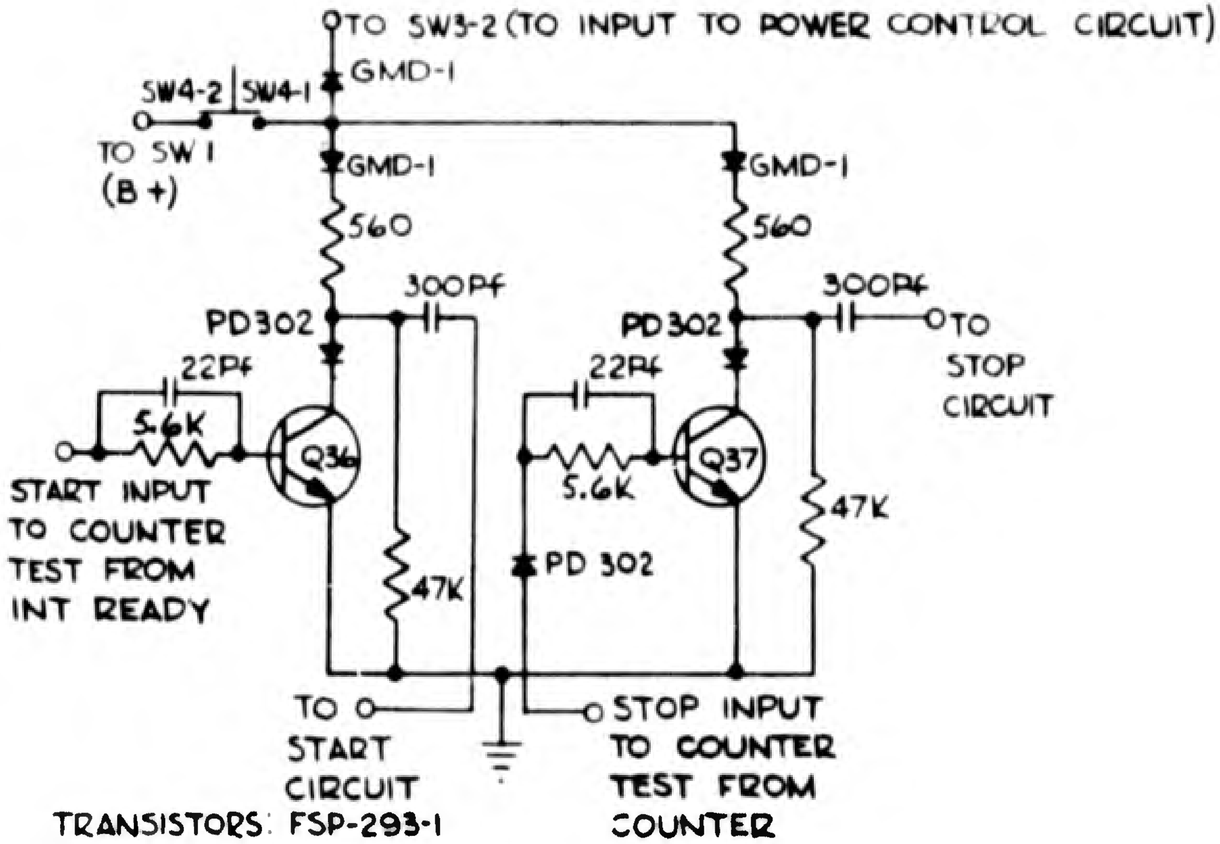


Figure 14. Counter test

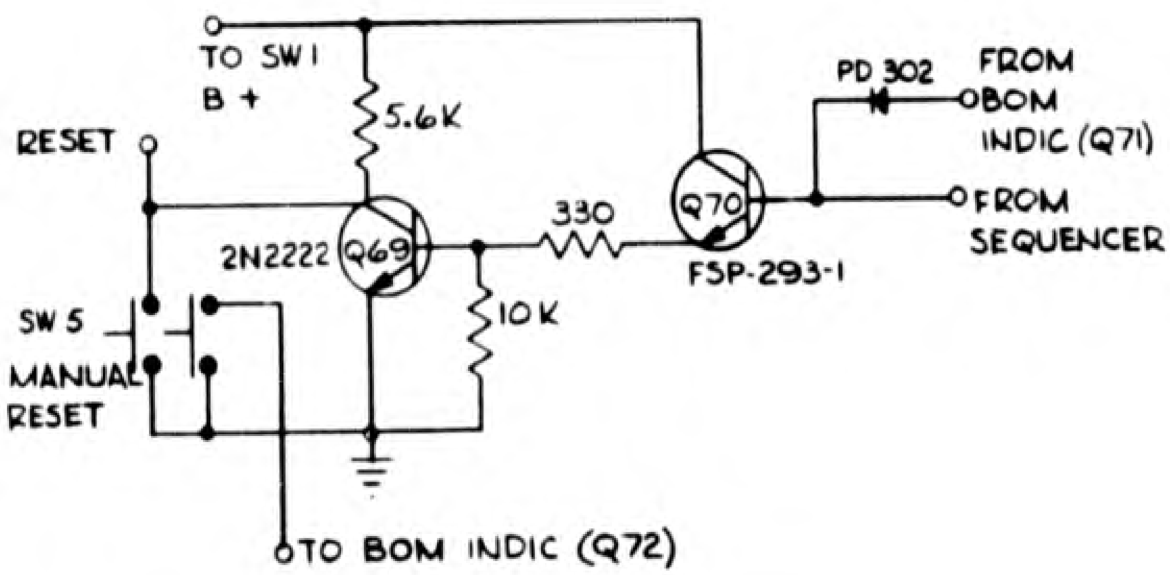


Figure 15. Reset circuit

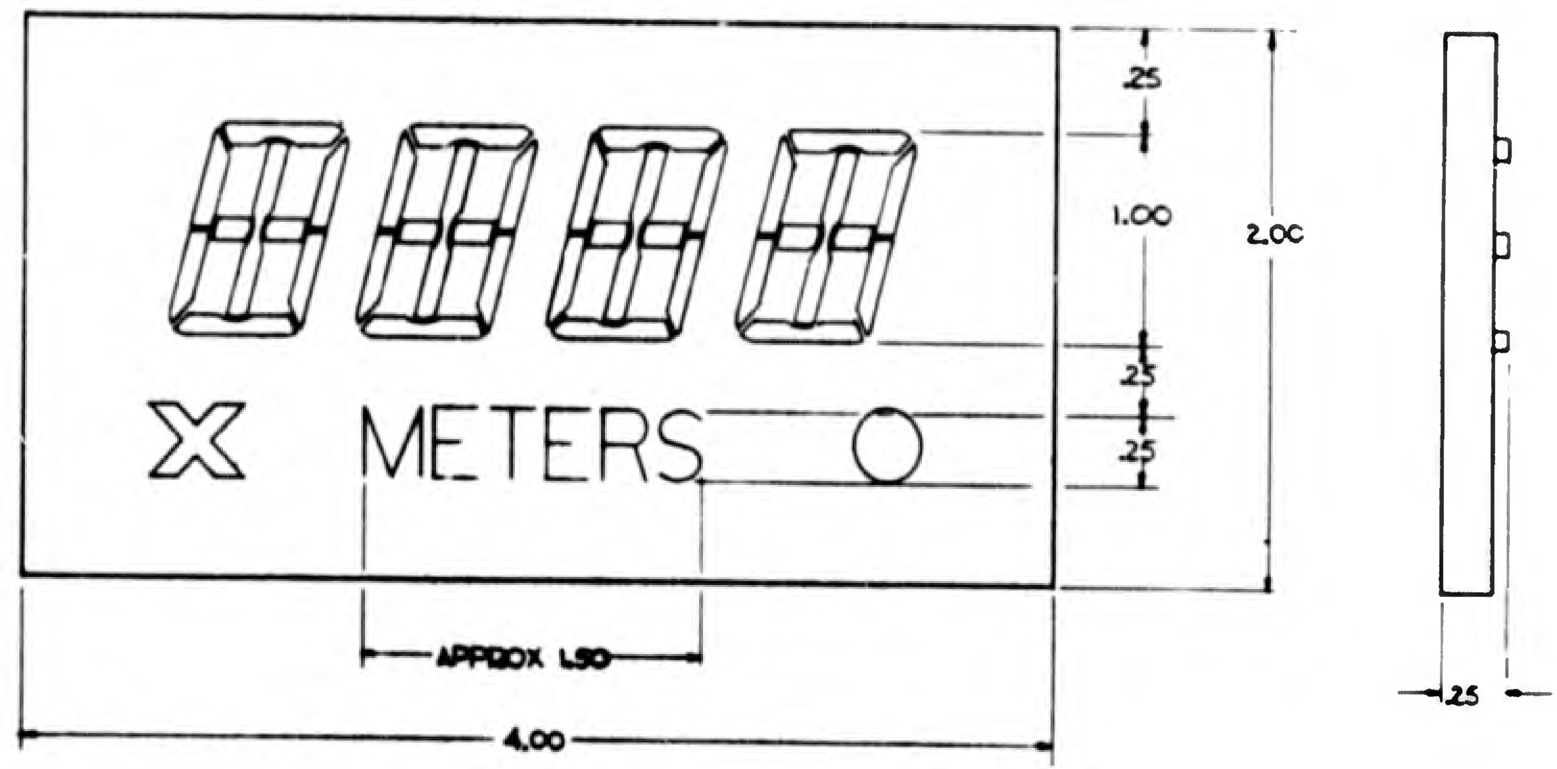
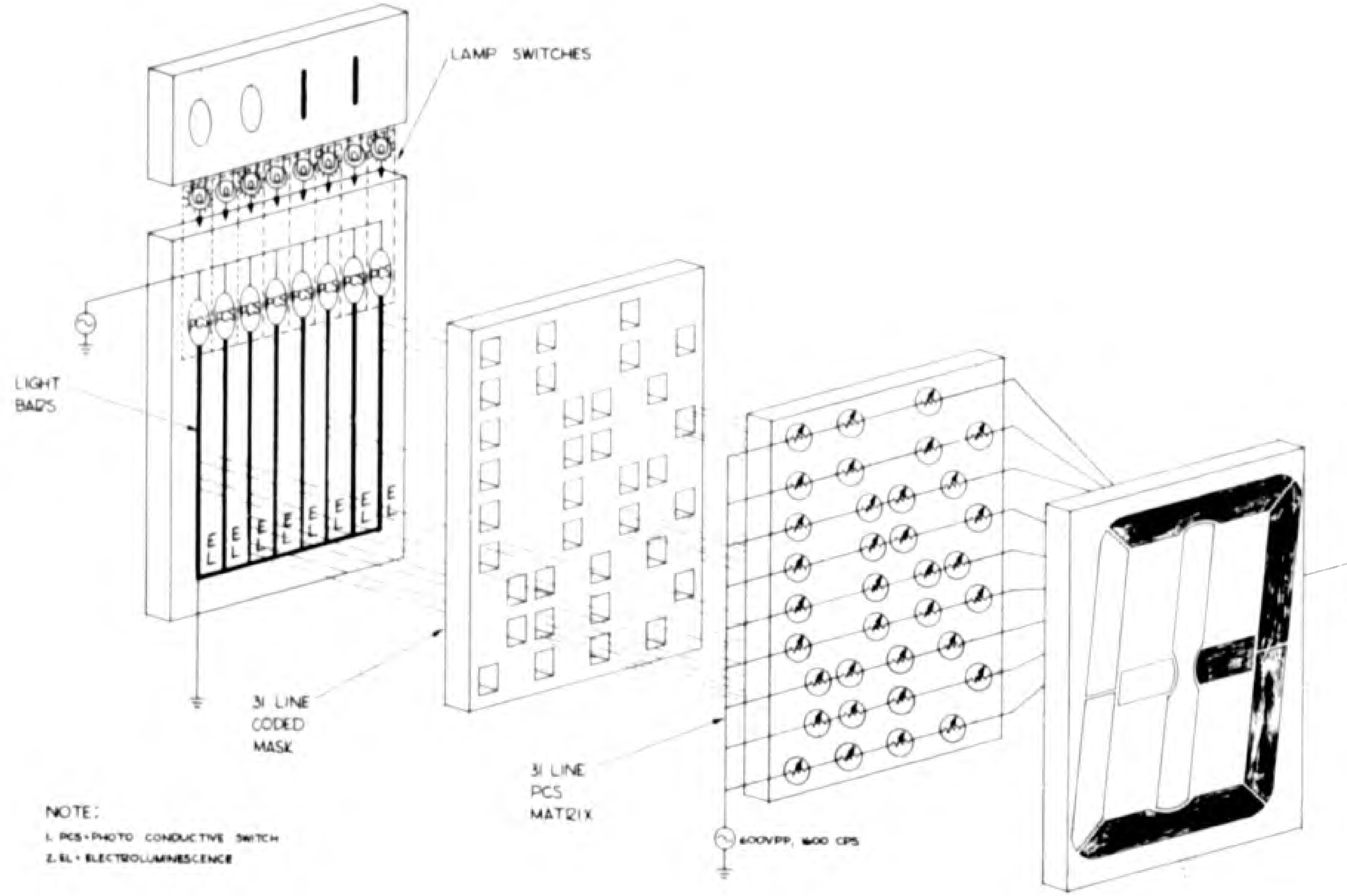
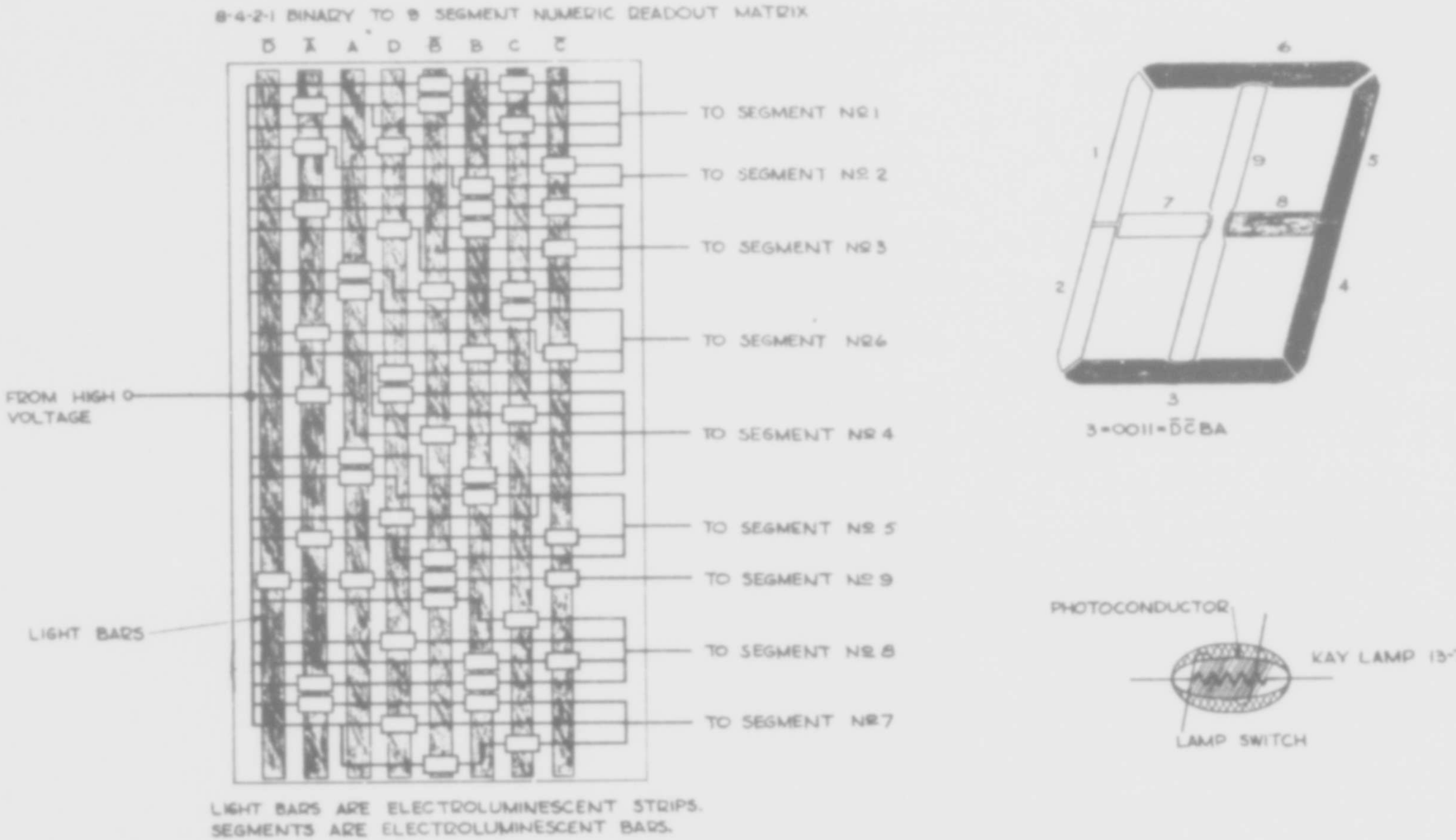


Figure 16. Readout display.



2030-63

Figure 17. Symbolic exploded view of one digit of readout assembly.

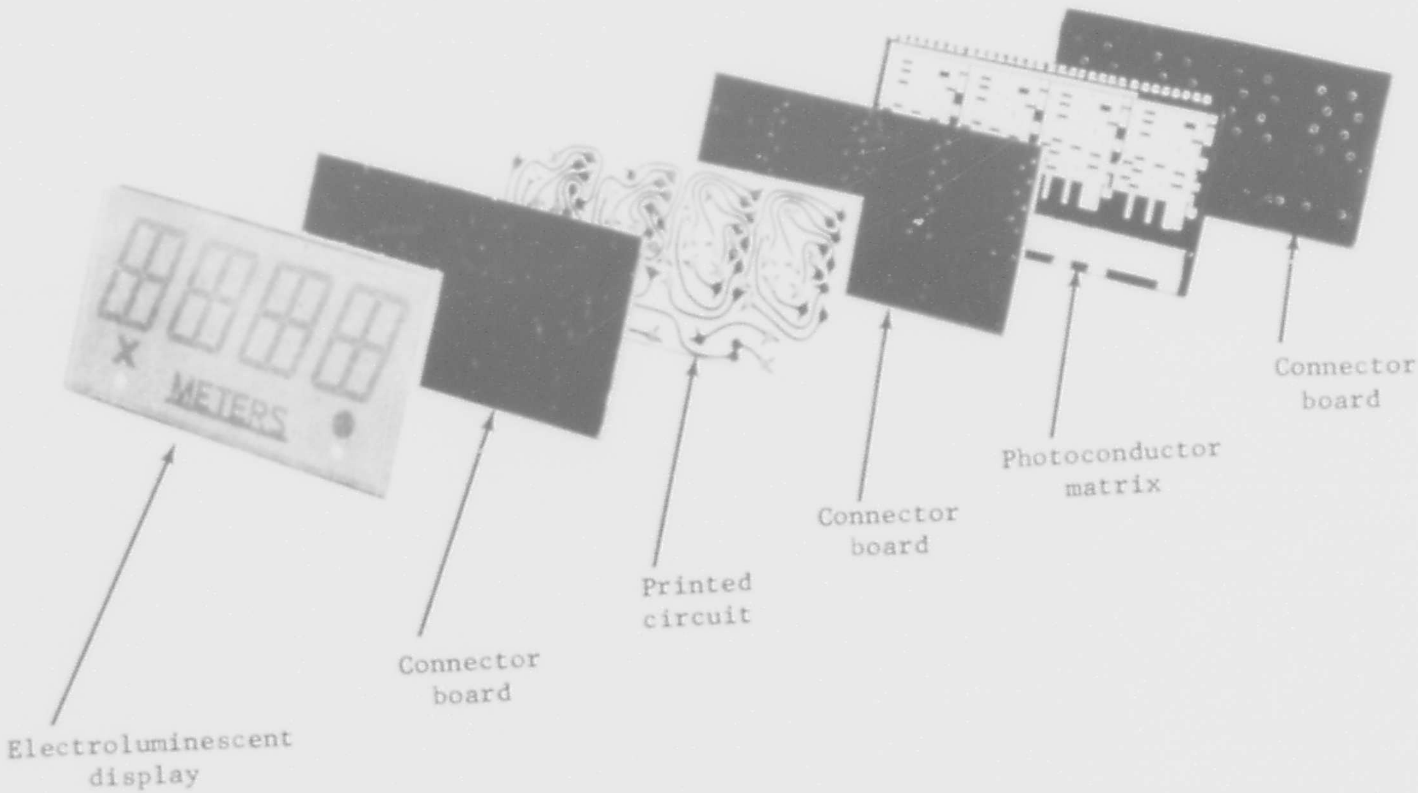


NOTE:

1. WHEN ALL PHOTOCONDUCTORS IN SERIES WITH HV & SEGMENTS ARE ILLUMINATED BY LIGHT BAR SEGMENT IS ON.

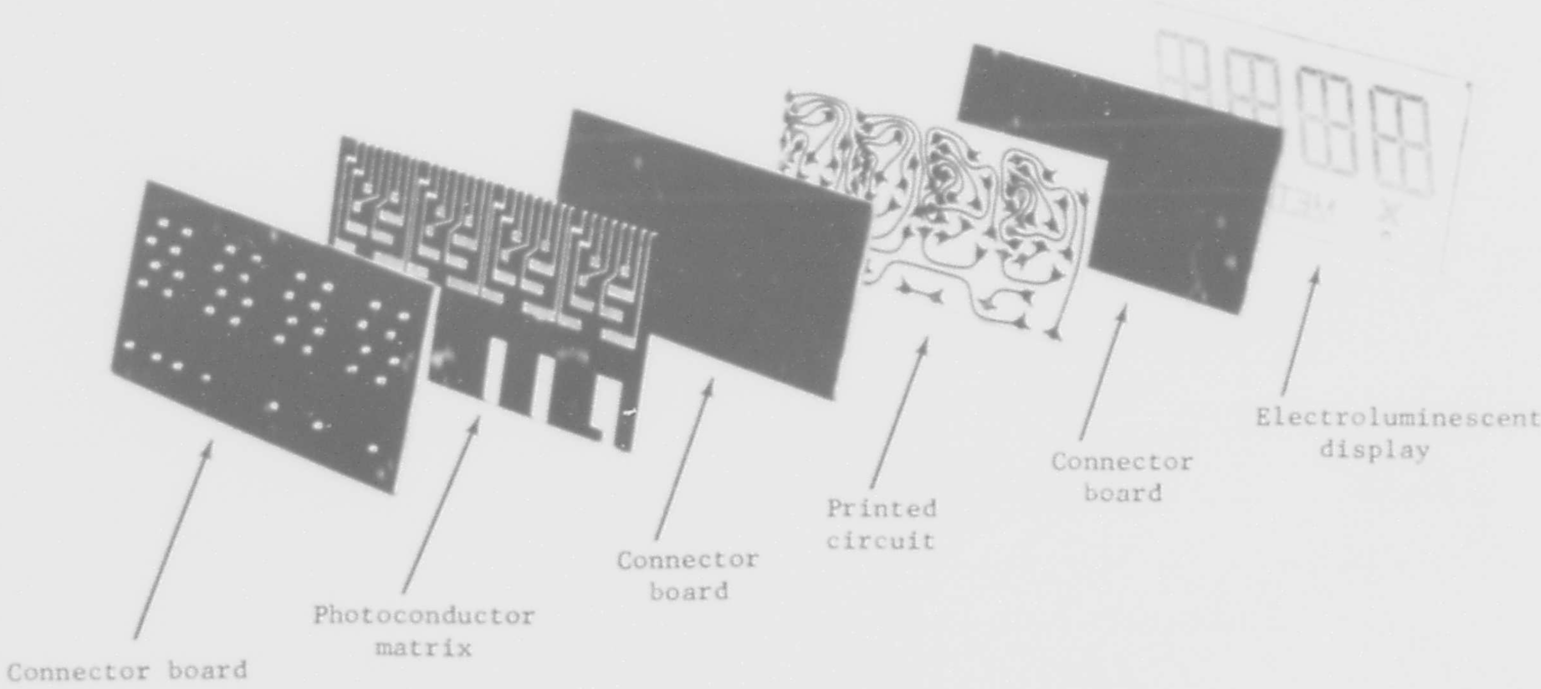
2033-63

Figure 18. Photoconductor readout matrix.



1132-63

Figure 19. Electroluminescent readout and photoconductor matrix assembly - front to rear.



1133-63

Figure 20. Electroluminescent readout and photoconductive matrix assembly - rear to front.

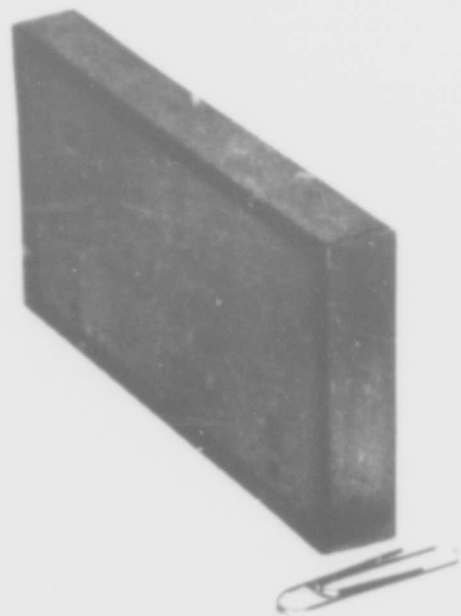

1131-63

Figure 21. Electroluminescent readout assembly.

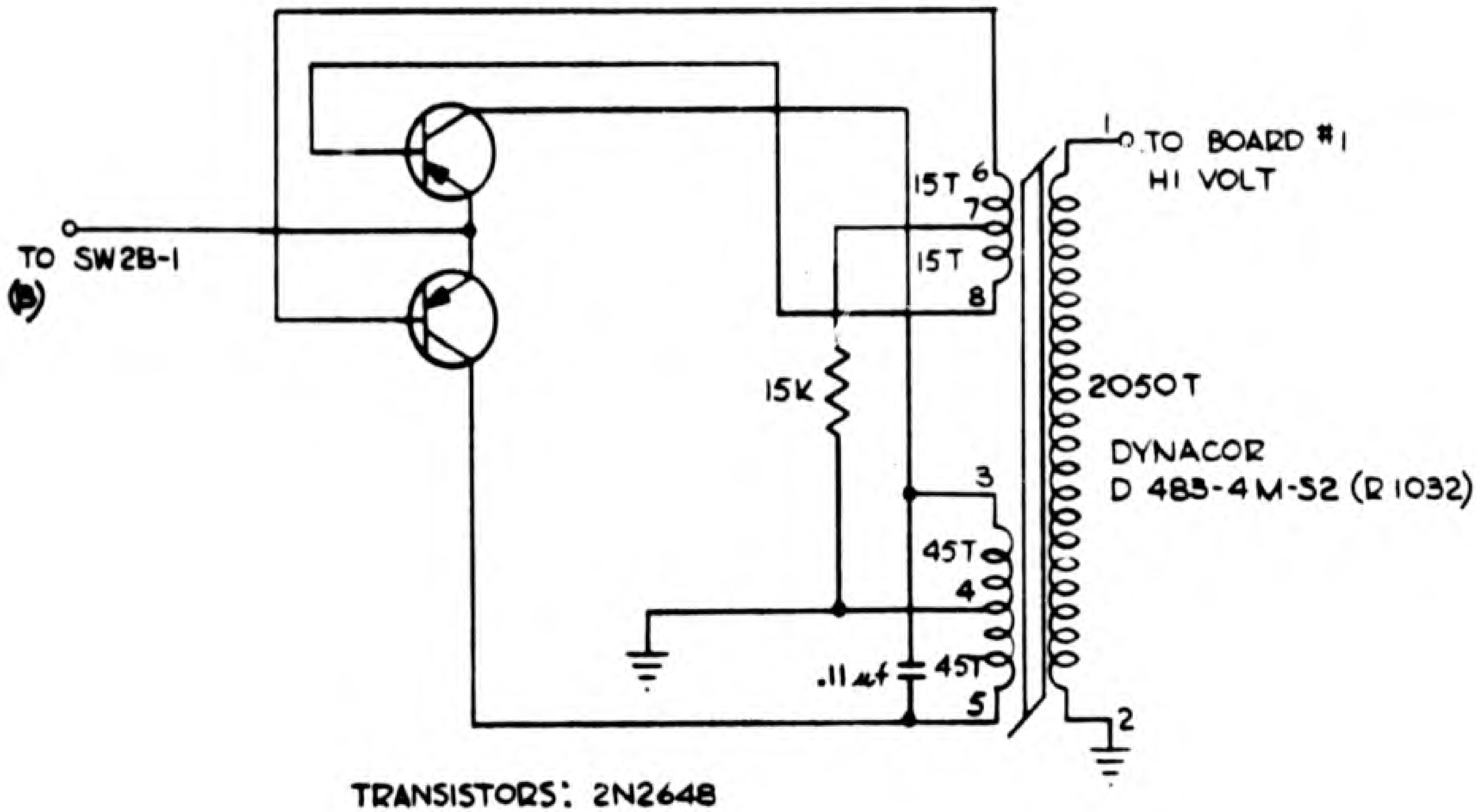
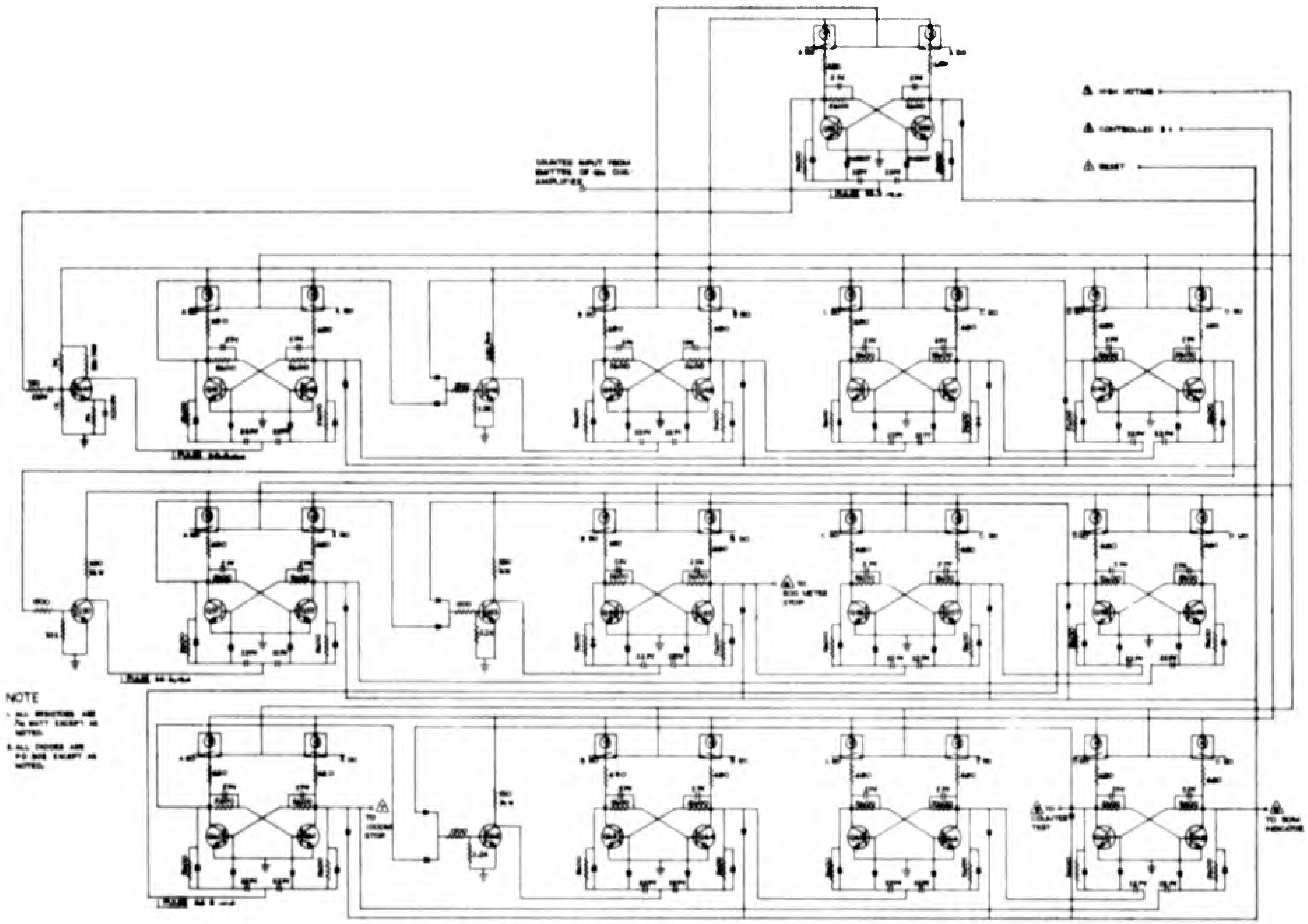
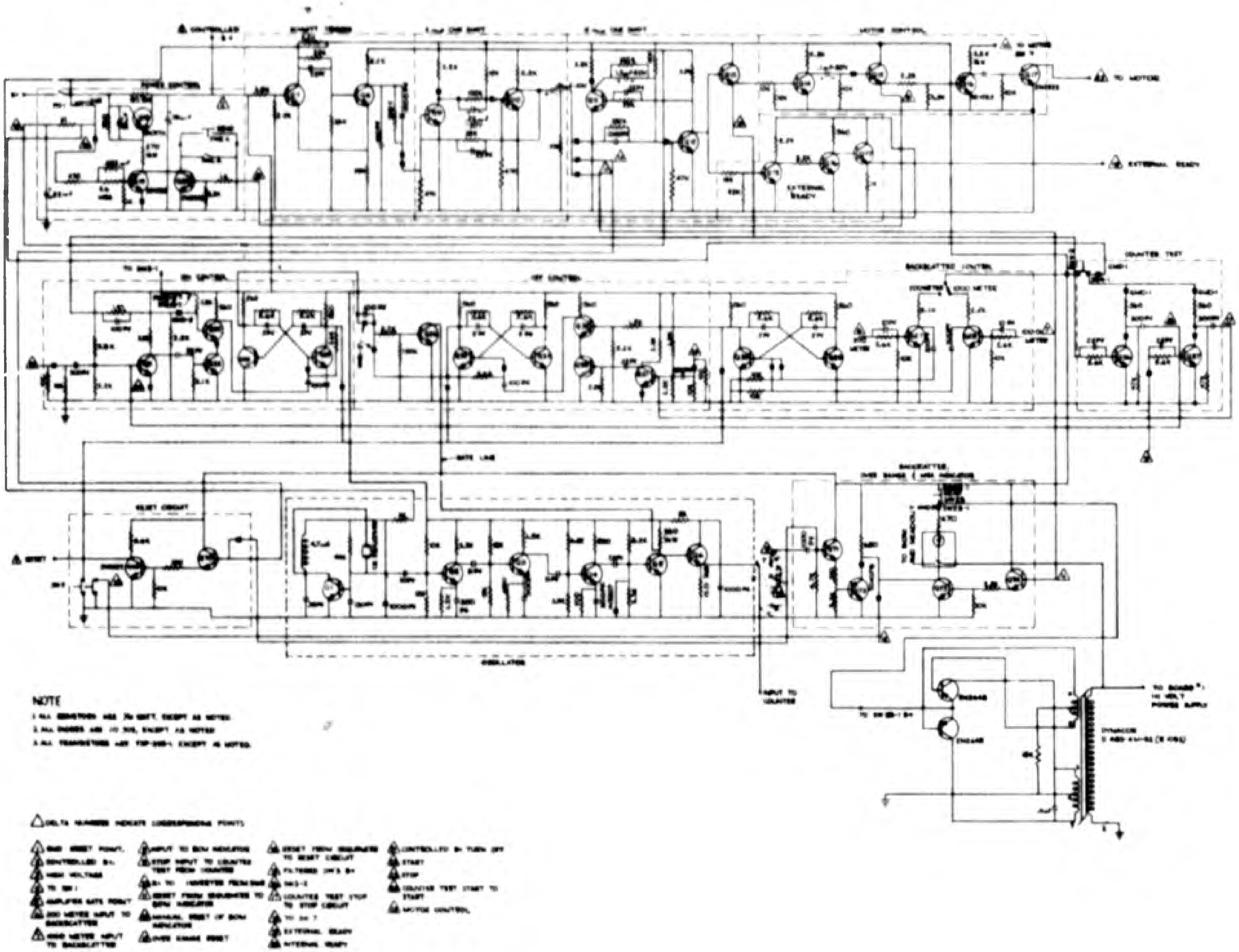


Figure 22. Dc-to-ac converter



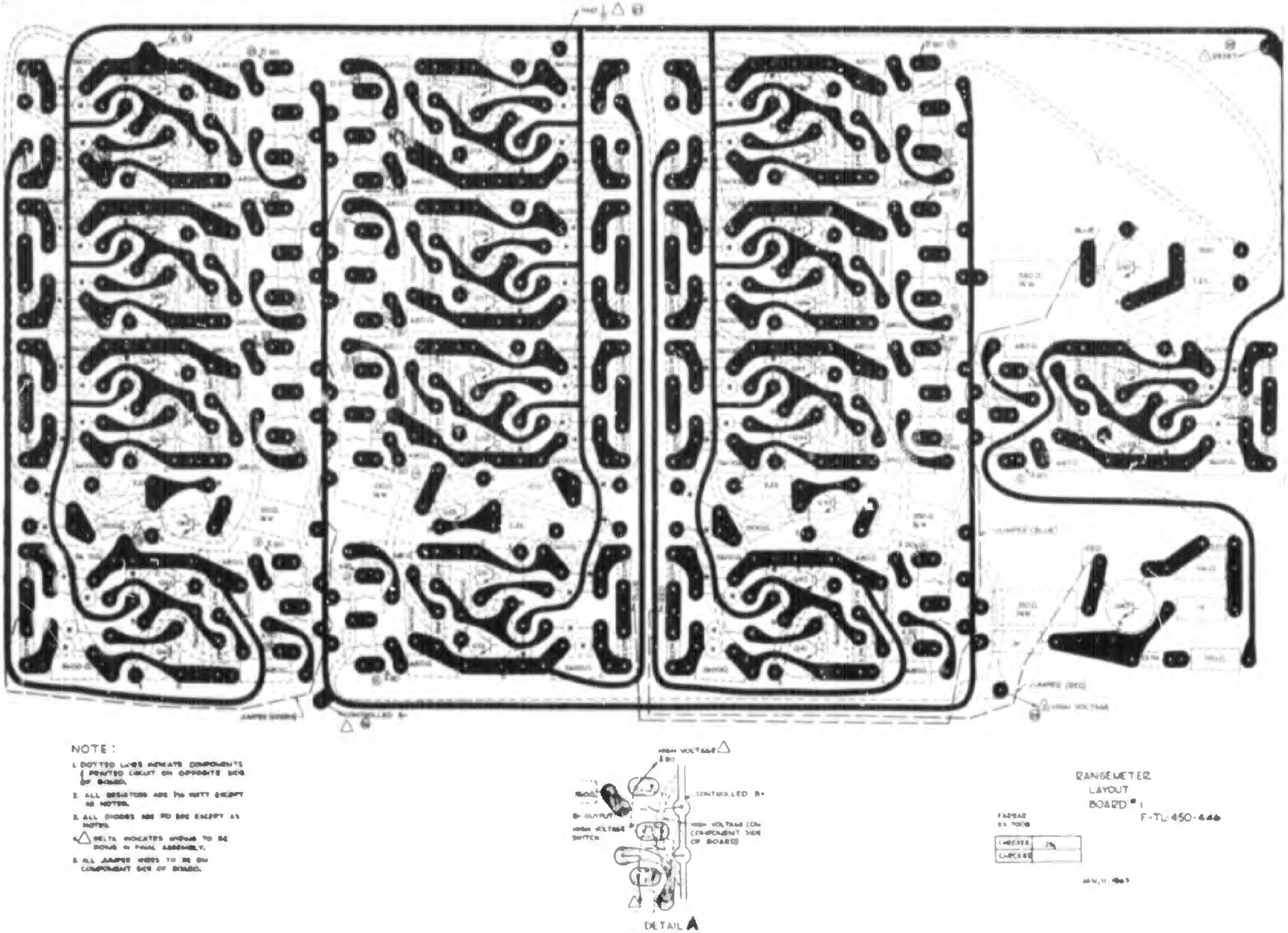
2013-63

Figure 23. Counting circuitry on printed circuit board No. 1.



2015-63

Figure 24. Circuitry on printed circuit board No. 2.



2014-63

Figure 25. Printed circuit board No. 1.

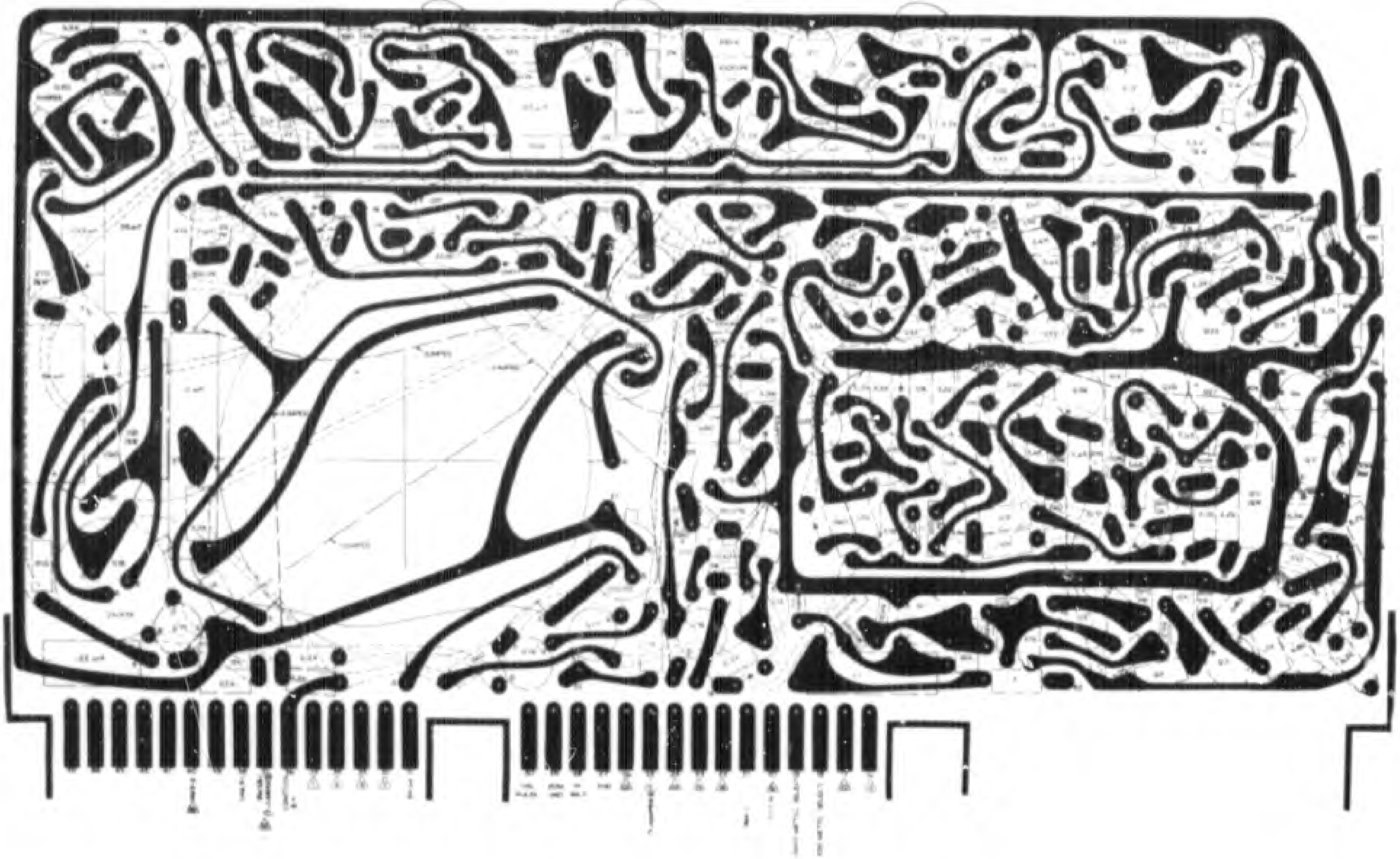


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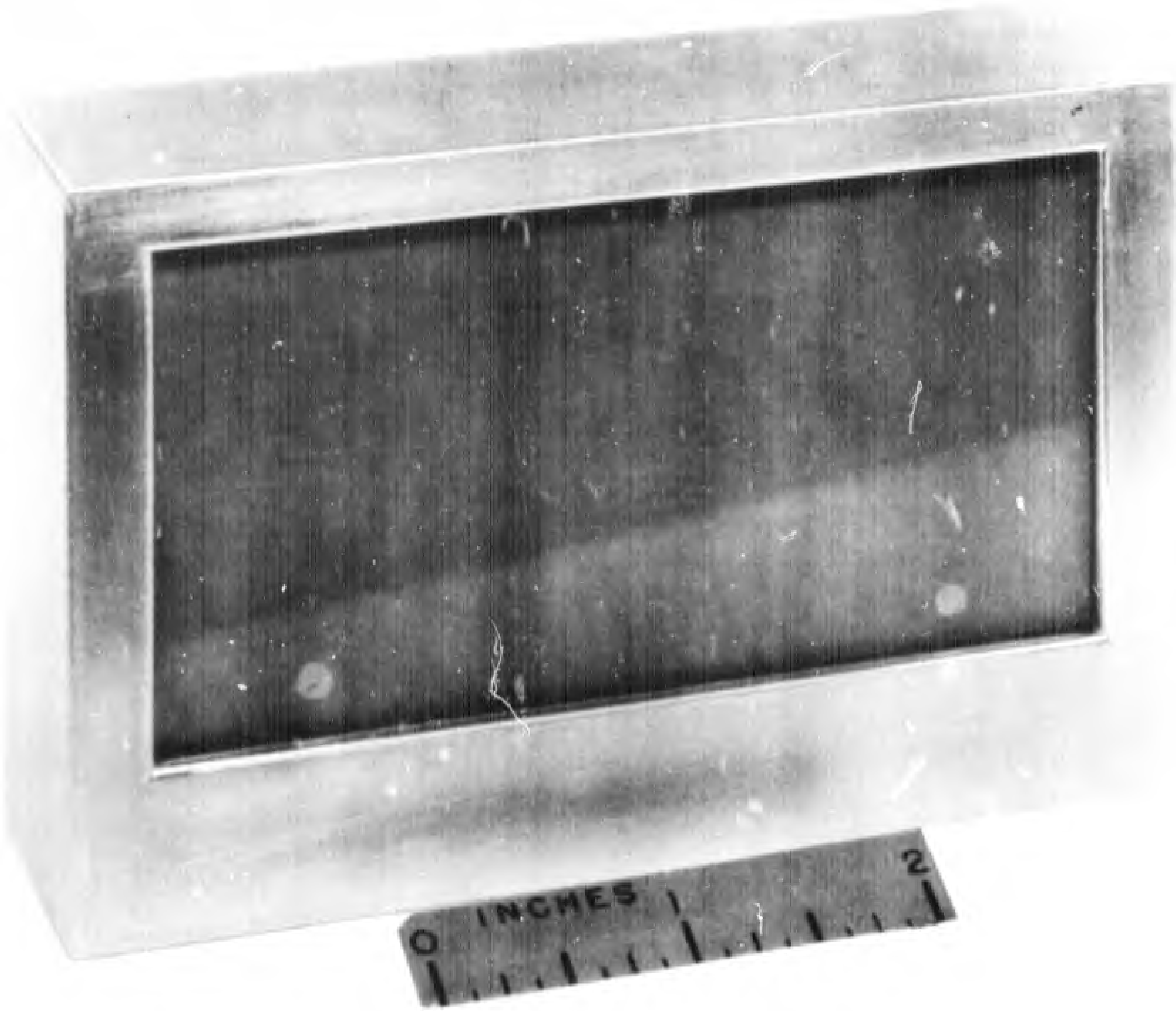
Figure 26. Printed circuit board No. 2.



1638-63

Figure 27. Completely assembled rangemeter for XM23 laser rangefinder.

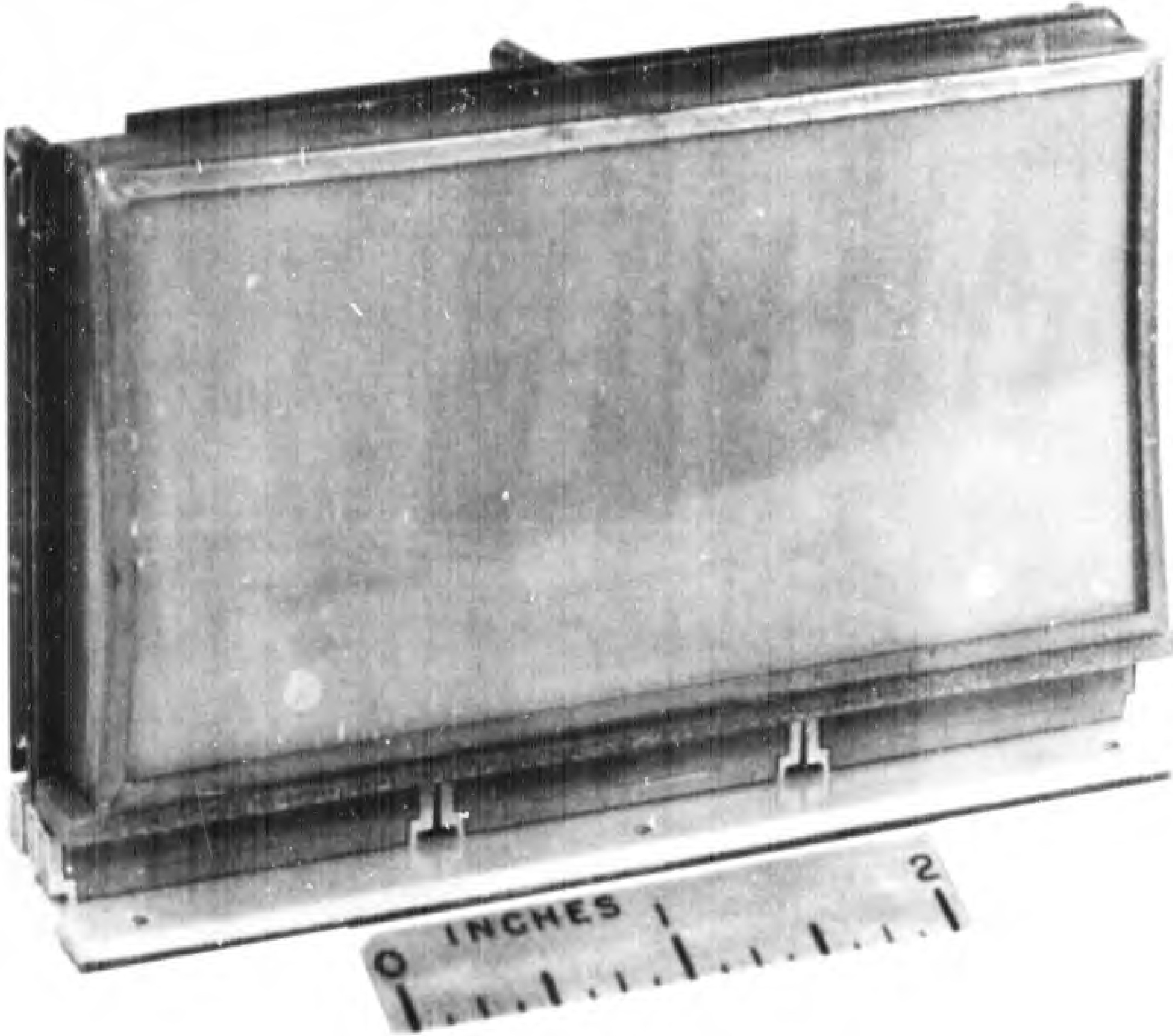


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Figure 28. Rangemeter on mother board.

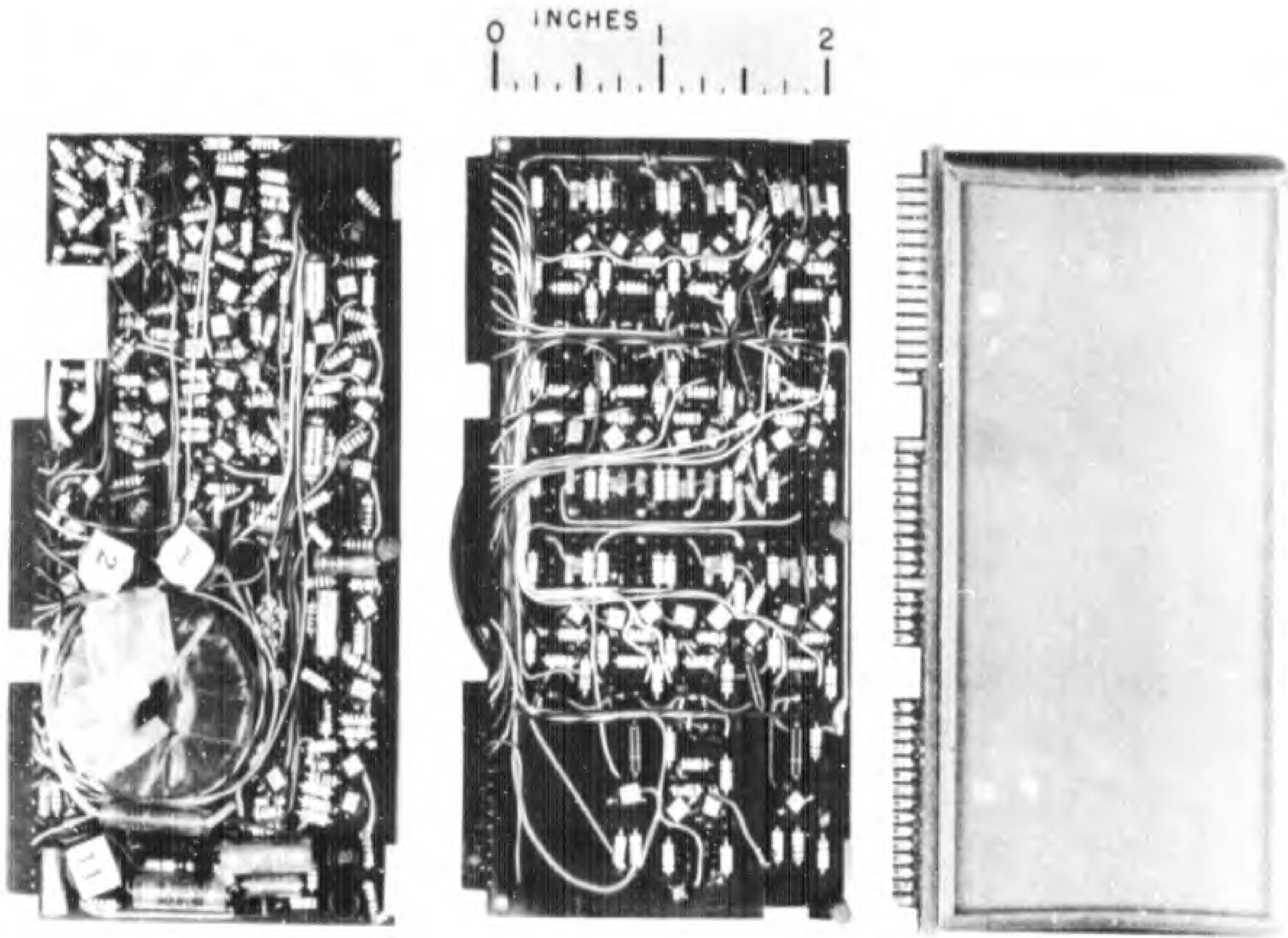
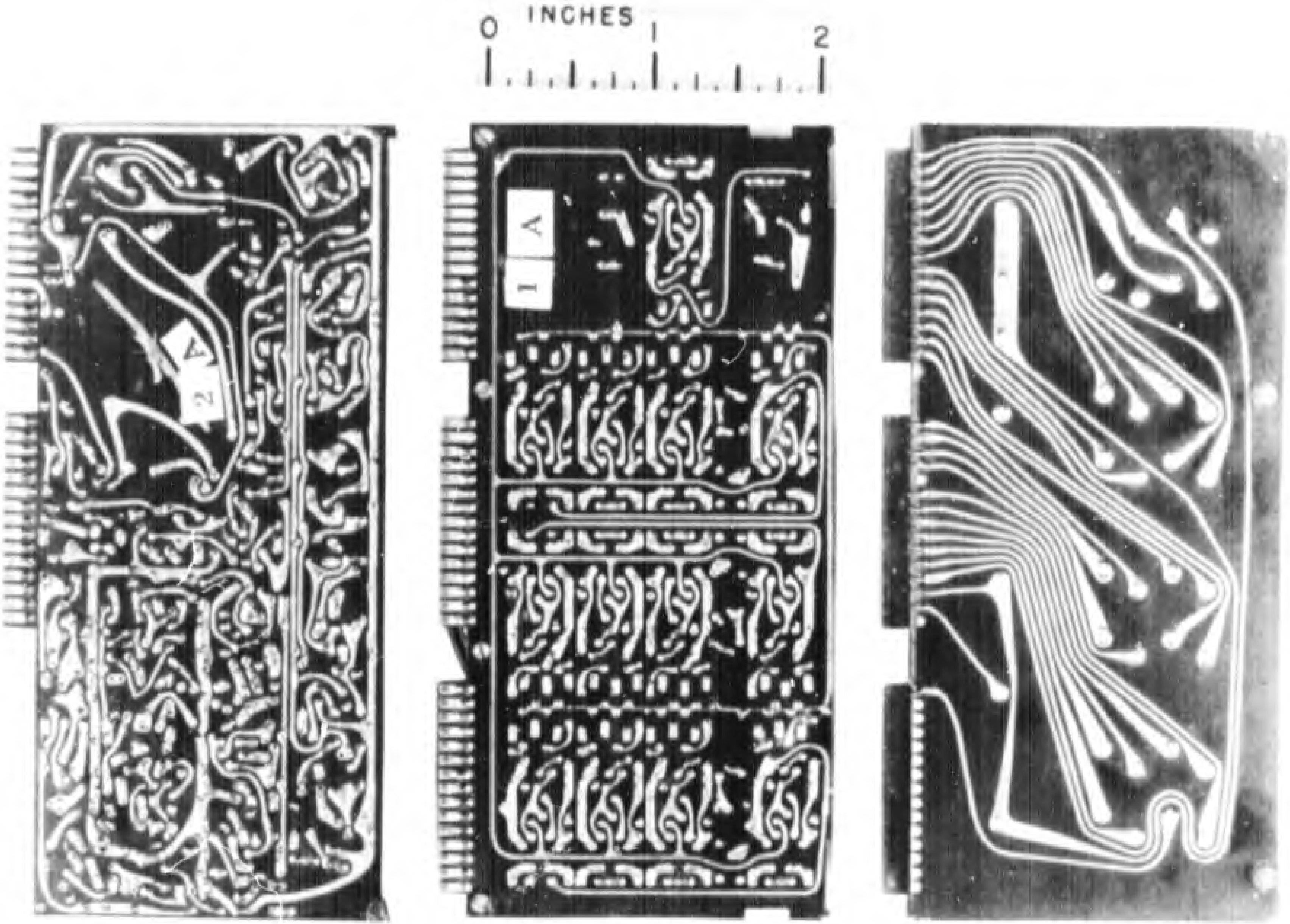
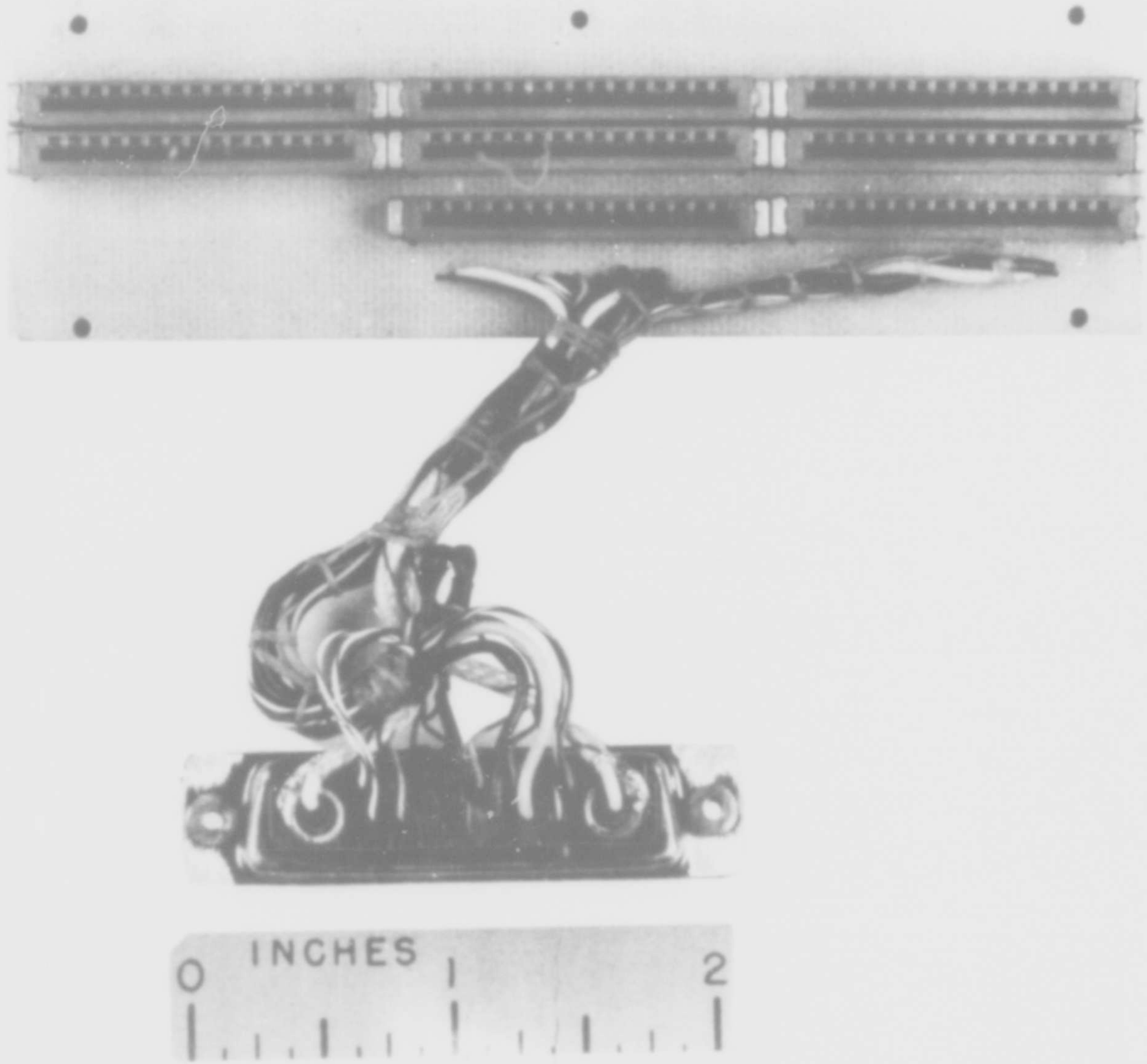


Figure 29. Electronics and readout - front view.



1641-63

Figure 30. Electronics and readout - rear view.



1639-63

Figure 31. Mother board and wiring harness.