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A SIMPLIFIED ELECTRONIC CIRCUIT FOR ULTRASONIC INSPECTION

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ABSTRACT

A simplified electronic circuit was developed for use in ultrasonic inspection instruments. The circuit was designed to utilize barium titanate transducers in a transmission system. The high-voltage pulser and high-gain amplifier required with quartz transducers were eliminated in the new circuit.

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A SIMPLIFIED ELECTRONIC CIRCUIT FOR ULTRASONIC INSPECTION

INTRODUCTION

An instrument was developed at the Savannah River Laboratory to detect unbonded areas in fuel elements by the attenuation they produce in an ultrasonic beam.[1] The instrument had quartz transducers which required a 3000-volt pulser and a high-gain amplifier. As a result, the electronic circuitry was rather involved and difficult to adjust.

The availability of barium titanate transducers with ten times the coupling coefficient of quartz made it possible to consider a new electronic system. This report covers the development of a new electronic circuit.

SUMMARY

A simplified electronic circuit was developed which utilizes barium titanate transducers. The need for a high-voltage pulser and a high-gain amplifier was eliminated, thus reducing the number of electronic components to one-third of the number required with previous instruments.

The simplified circuit is more stable and requires less maintenance than the previous circuits. It can be used with any of the fuel element feeders[1][2] developed previously.

The output signal of the instrument is used with an appropriate readout system to give either a map record of the unbonded area or a digital reading which represents the integrated area of the unbonded sections.

DISCUSSION

A circuit has been developed which utilizes barium titanate transducers for the inspection of the bond in fuel elements. The transmitting transducer is pulsed by a blocking oscillator requiring a 300-volt power supply. This system eliminates the need for the 3000-volt pulser required with quartz transducers. In addition, no amplification is required, as the signal developed at the receiving transducer is large enough to be fed directly to a discriminator. The operation of the circuit can best be understood by referring to Figure 1, which contains a block diagram together with sketches of the various pulses developed.

The tester detects unbonded areas and other defects in fuel elements by the attenuation they produce in an ultrasonic beam transmitted through the samples by a pulsed barium titanate transducer. The ultrasonic beam is detected by a second barium titanate transducer and the electrical signal is sent to a discriminator. If this

signal is above a preset threshold level, an output pulse is developed by the discriminator. The discriminator pulse reverses the state of a flip-flop circuit and closes an electronic gate which had been opened by the original signal from the pulser. When an unbonded area is present, the ultrasonic signal is attenuated below the threshold level and the discriminator does not develop an output pulse. The state of the flip-flop is not changed and the gate controlled by the flip-flop passes the next pulse from the pulser. Thus the gate tube passes a pulse each time the received ultrasonic signal is attenuated below a set level by an imperfection in the sample. These pulses can then be counted as the sample is scanned at a uniform rate and the total count registered is a measure of the unbonded area.

The state of the flip-flop can also be used to control a recorder by which the defective areas are mapped on electrosensitive recording paper.

A more detailed description of the instrument follows:

PULSER

A blocking oscillator, diagrammed in Figure 2, is used to pulse the transmitting element. The oscillator is free-running and is adjusted to give approximately 1000 pulses/sec. The pulse rate can be increased or decreased by changing the value of the grid resistor. A pulse transformer (Freed MPF-11) is used to provide a transformer-coupled output to the barium titanate element. A variable inductor, connected in parallel with the output terminals of the transformer, is tuned so that the output circuit resonates at the natural frequency of the transducer. Under these conditions, the blocking oscillator acts as a "ringing" oscillator and the mechanical vibrations of the transducer build up to a very high amplitude.

TRANSDUCERS

The transmitting and receiving transducers are piezoelectric ceramics of barium titanate manufactured by the Erie Resistor Corporation. Both transducers are identical and have a natural frequency of approximately 900 kc. They are mounted in stainless steel blocks, as shown in Figure 3, which are attached to a mechanical feeder. Coaxial cables connect the transducers to the instrument chassis.

DISCRIMINATOR

The discriminator is similar to one developed by Kandiah[3]. The pulse from the receiving transducer is detected by a vacuum diode which is connected to provide a negative signal to the grid of the first discriminator tube. If the pulse is of sufficient amplitude, the first tube is momentarily cut off and the second tube draws additional current. The negative signal produced at the plate of the second tube is used to cut off the "A" section of the flip-flop.

FLIP-FLOP

The flip-flop circuit is shown in Figure 4. A signal from the pulser cuts off the "B" section and the output from the discriminator cuts off the "A" section. The positive swing of the pulser signal is clipped with a crystal diode to prevent it from cutting the "B" section back on in the absence of a discriminator pulse. The "A" section remains in a conducting state until it receives a pulse from the discriminator. The time required for the ultrasonic pulse to traverse the sample under inspection is sufficient to allow the initial pulse from the blocking oscillator to change the state of the flip-flop before the discriminator pulse develops.

GATE

The gate circuit is also shown in Figure 4. Part of the bias voltage on the gate tube is provided by a voltage divider connected to the plate of the "B" section of the flip-flop. The gate tube has a large cathode resistor and is thus cut off when the "B" section of the flip-flop is conducting. When the "B" section is cut off, the higher plate voltage raises the bias of the gate tube so that the next pulse of the blocking oscillator is passed. The gate tube passes a pulse each time the amplitude of the received ultrasonic pulse falls below the preset discriminator level.

RECORDER READOUT

The "B" section plate voltage of the flip-flop can be used to control the current in the recording circuit shown in Figure 5. The recorder "writes" on "Teledeltos L-39" electrosensitive paper. If the "B" section of the flip-flop remains cut off, the high plate voltage biases the writing tube in a conducting state. The capacitor in the grid circuit of the writing tube retards the voltage rise on the grid so that the tube will not conduct during the short time that the "B" section is normally cut off, but will allow the tube to conduct if the "B" section remains cut off.

The recorder pen may be connected mechanically to the scanning system so that the defective areas are mapped as the sample is scanned. Figure 6 shows typical recordings made with this system. The unbonded areas show up as dark areas.

OPERATION WITH DIGITAL READOUT

The complete circuit of a detector for digital readout is shown in Figure 7. The instrument is adjusted by tuning L1 and L2 until the voltage across L2 is a maximum. The discriminator level is then set by adjusting P1 and P2 until the discriminator will fire when a well-bonded slug is between the transducers. Figure 8 is a photograph of the transducer heads and limit-switch assembly. The slug is rotated and translated between the transducers. Every time the transmitted signal falls below the set level of the discriminator, a pulse is sent to the counter. When the count reaches a preset

number, a "reject" alarm is sounded. Limit switches exclude the inspection of the end caps, which give rise to spurious counts. The switches also serve to reset the counter before the next slug is scanned.

PERFORMANCE

The performance of the instrument indicates that the tester can be used on elements of any shape to which a transmission technique can be applied. The electronic circuit is stable and requires a minimum of servicing.

The electronics for a slug tester with a digital readout is shown in Figure 9. The equivalent circuit using quartz crystals requires approximately twice the rack space as well as 3000-volt underwater probes.

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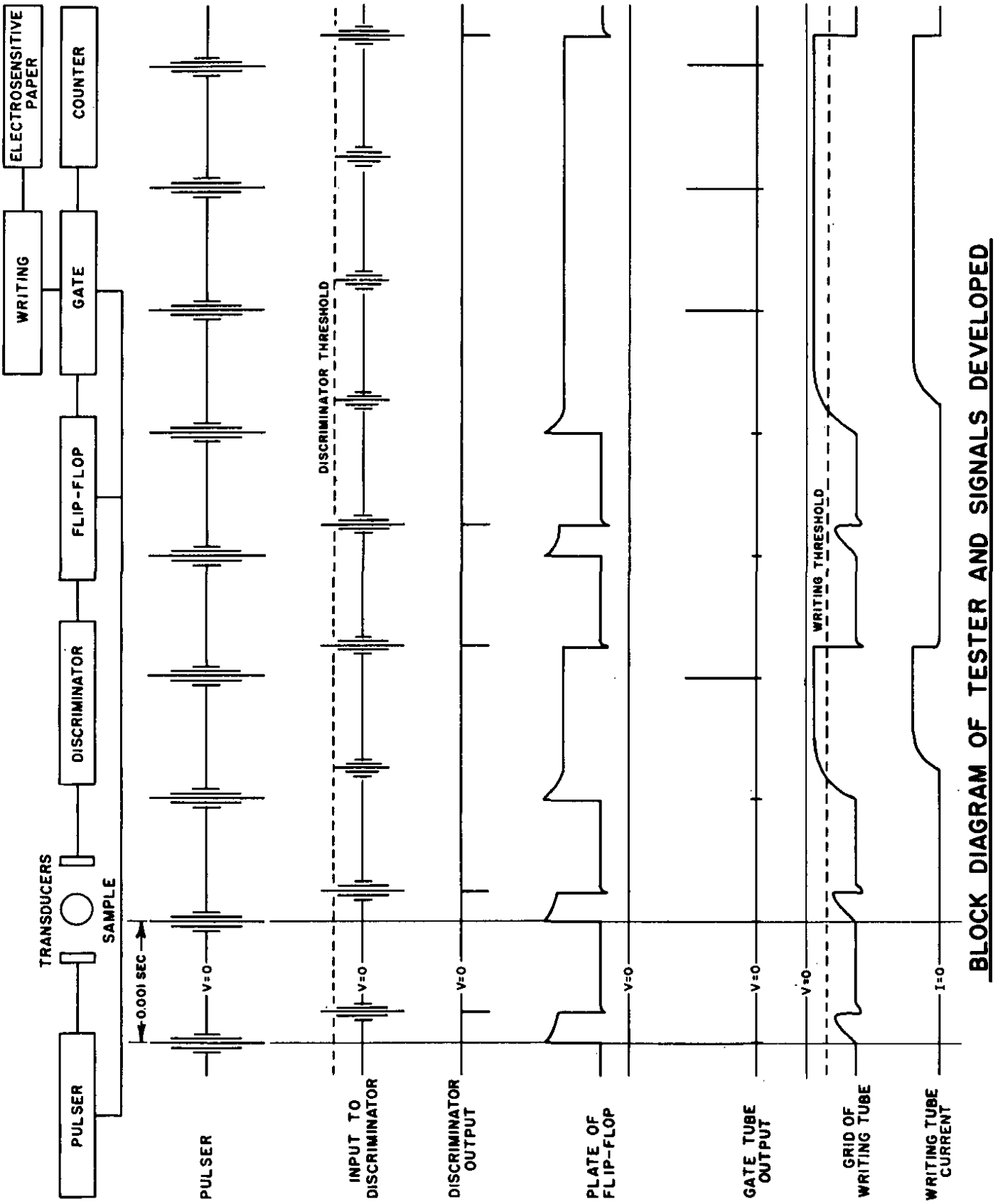
2. Blucke, W. L. E. I. du Pont de Nemours & Co., DP-66, July 1954 (classified report).

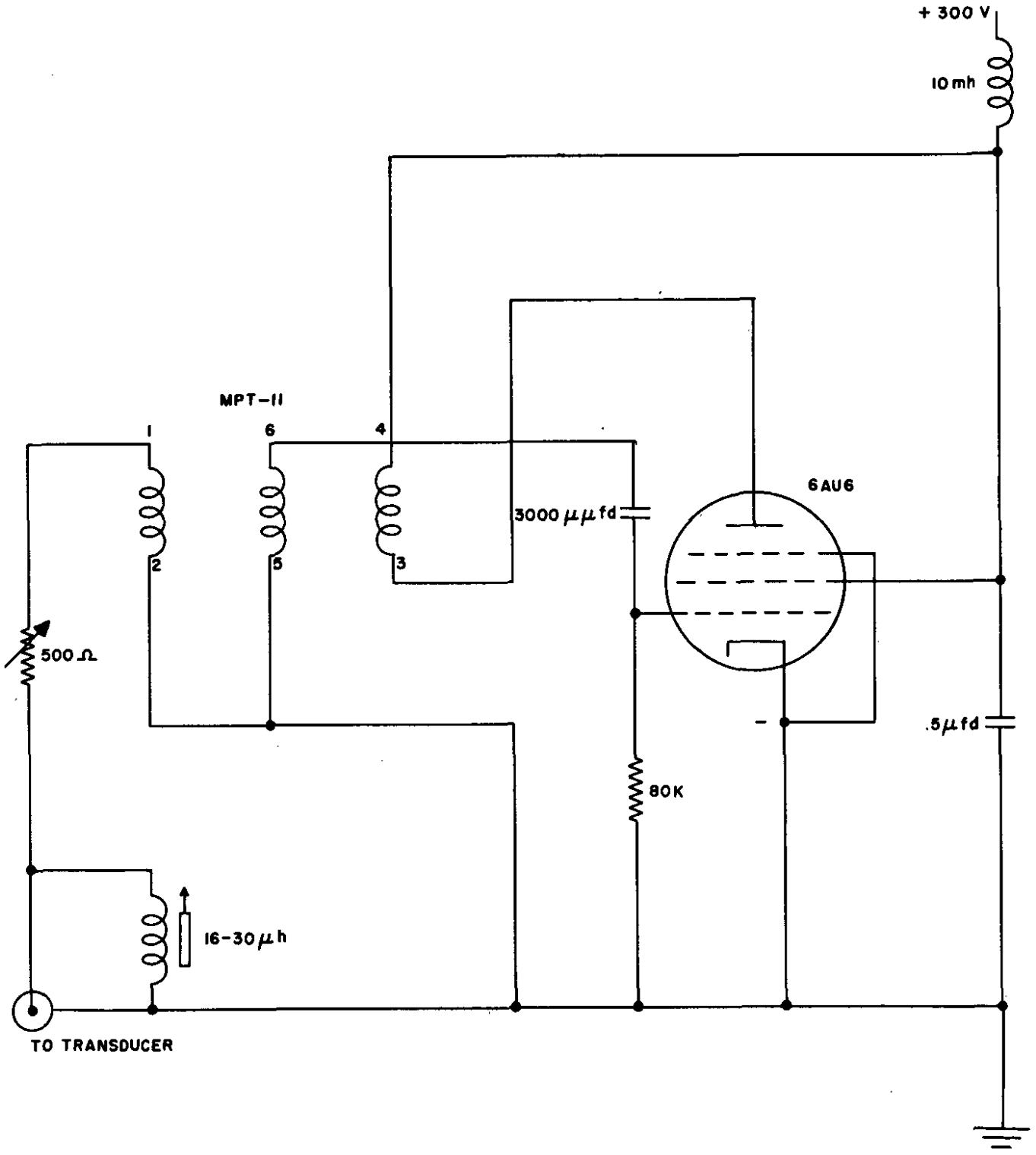
3. Kandiah, K. "A Sensitive Pulse Trigger Circuit With a Stable Threshold." Proc. IEE Part II, Vol. 81, p. 239.

FIGURE 1



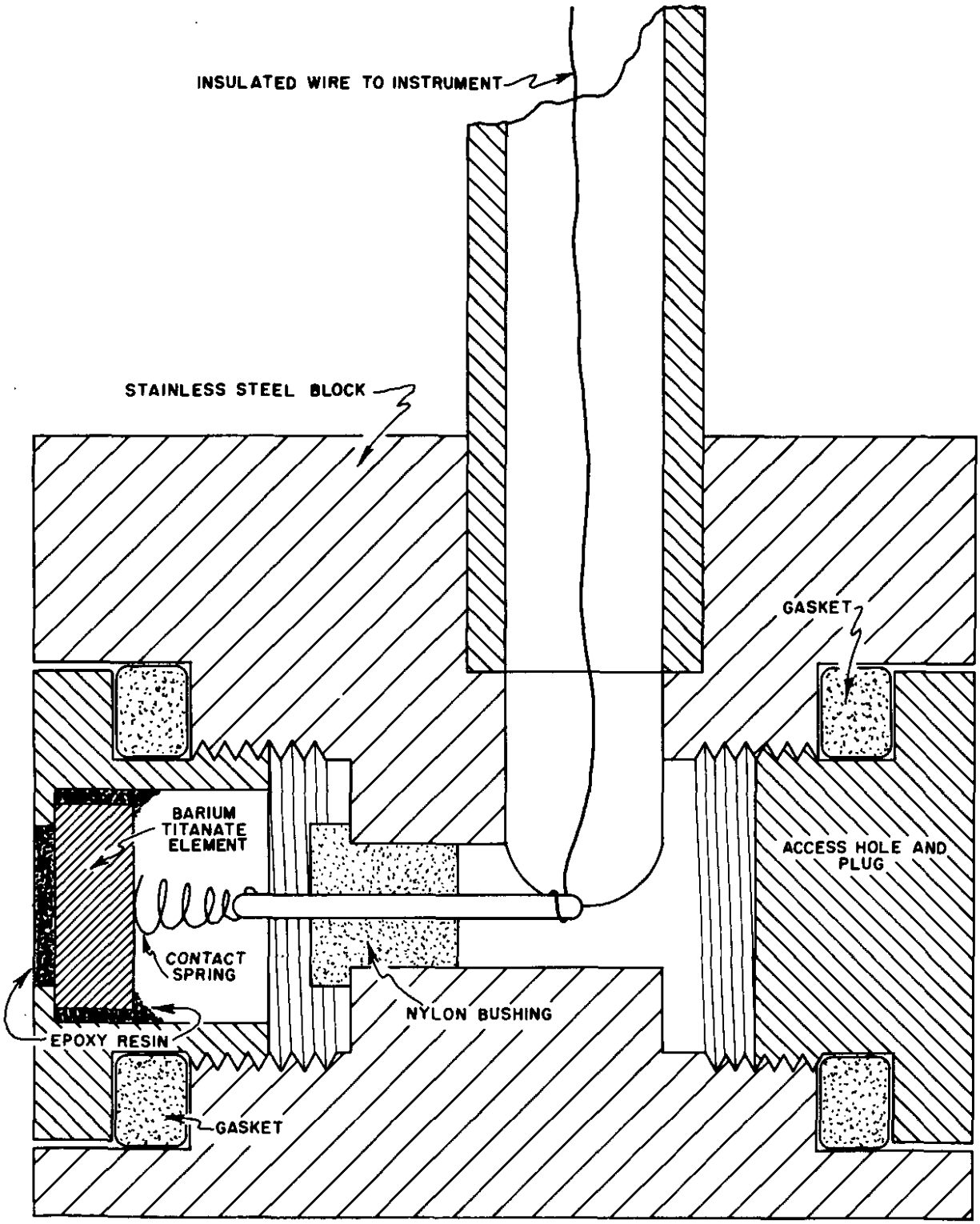
BLOCK DIAGRAM OF TESTER AND SIGNALS DEVELOPED

FIGURE 2



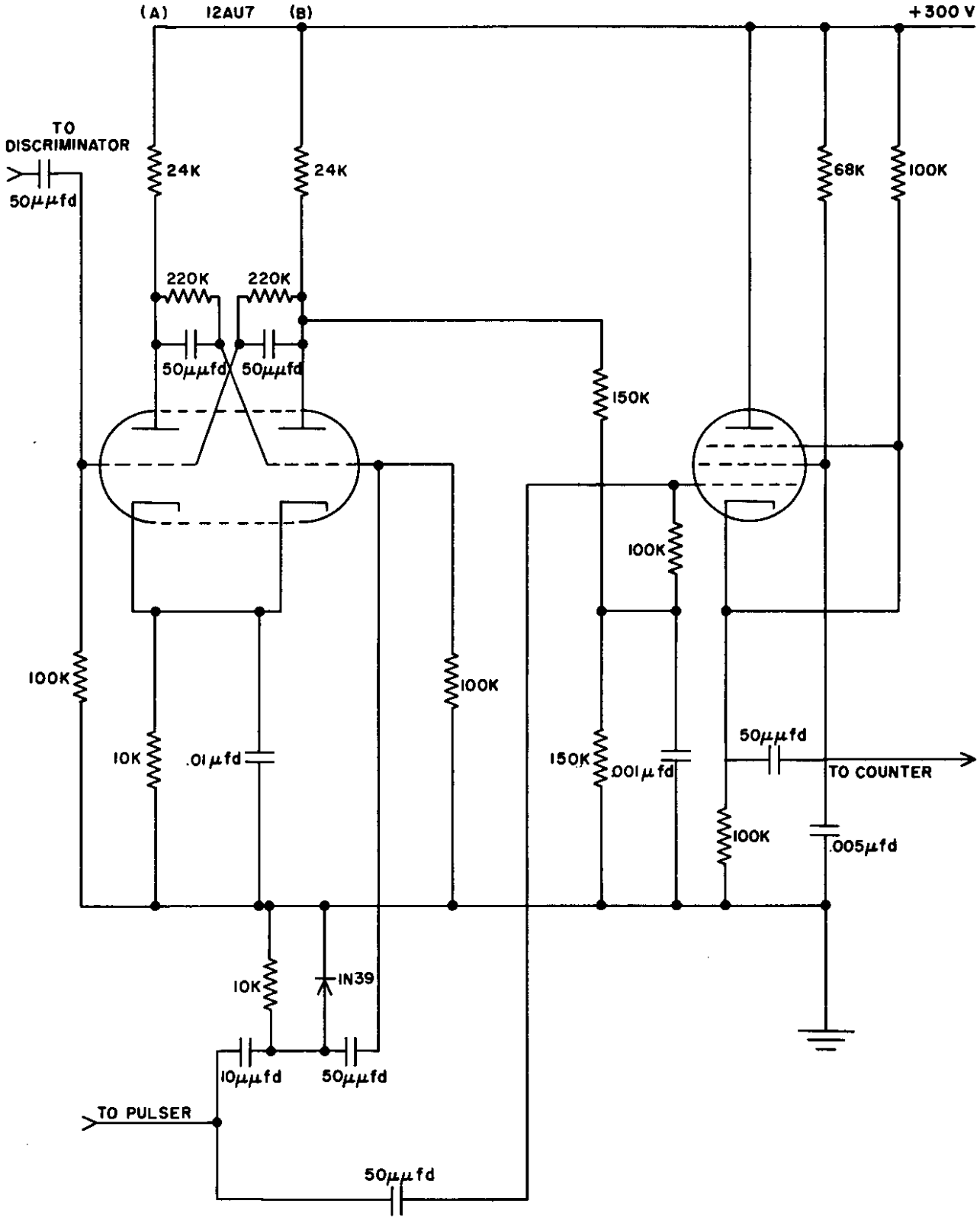
CIRCUIT DIAGRAM OF PULSER

FIGURE 3



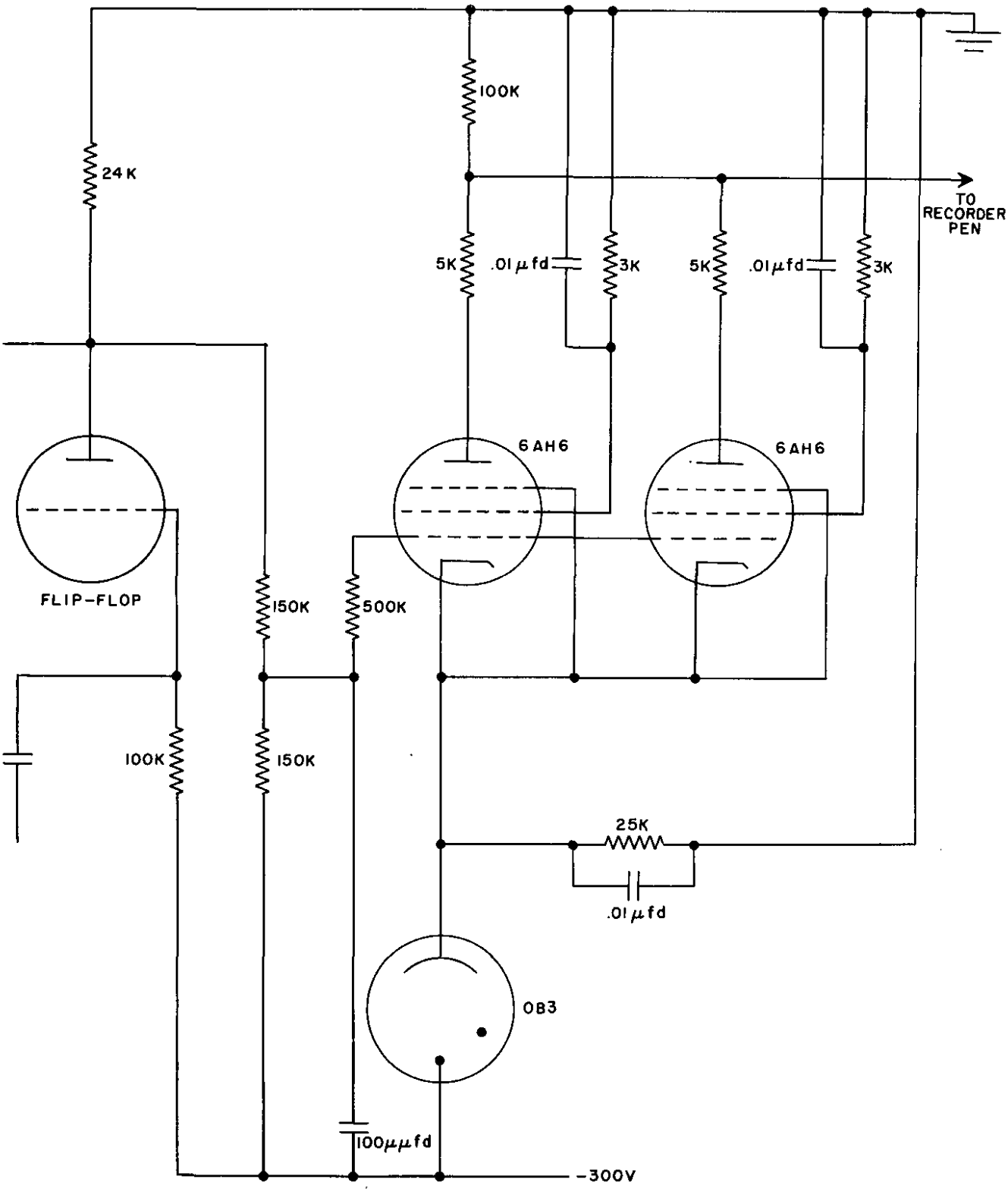
TRANSDUCER ASSEMBLY

FIGURE 4



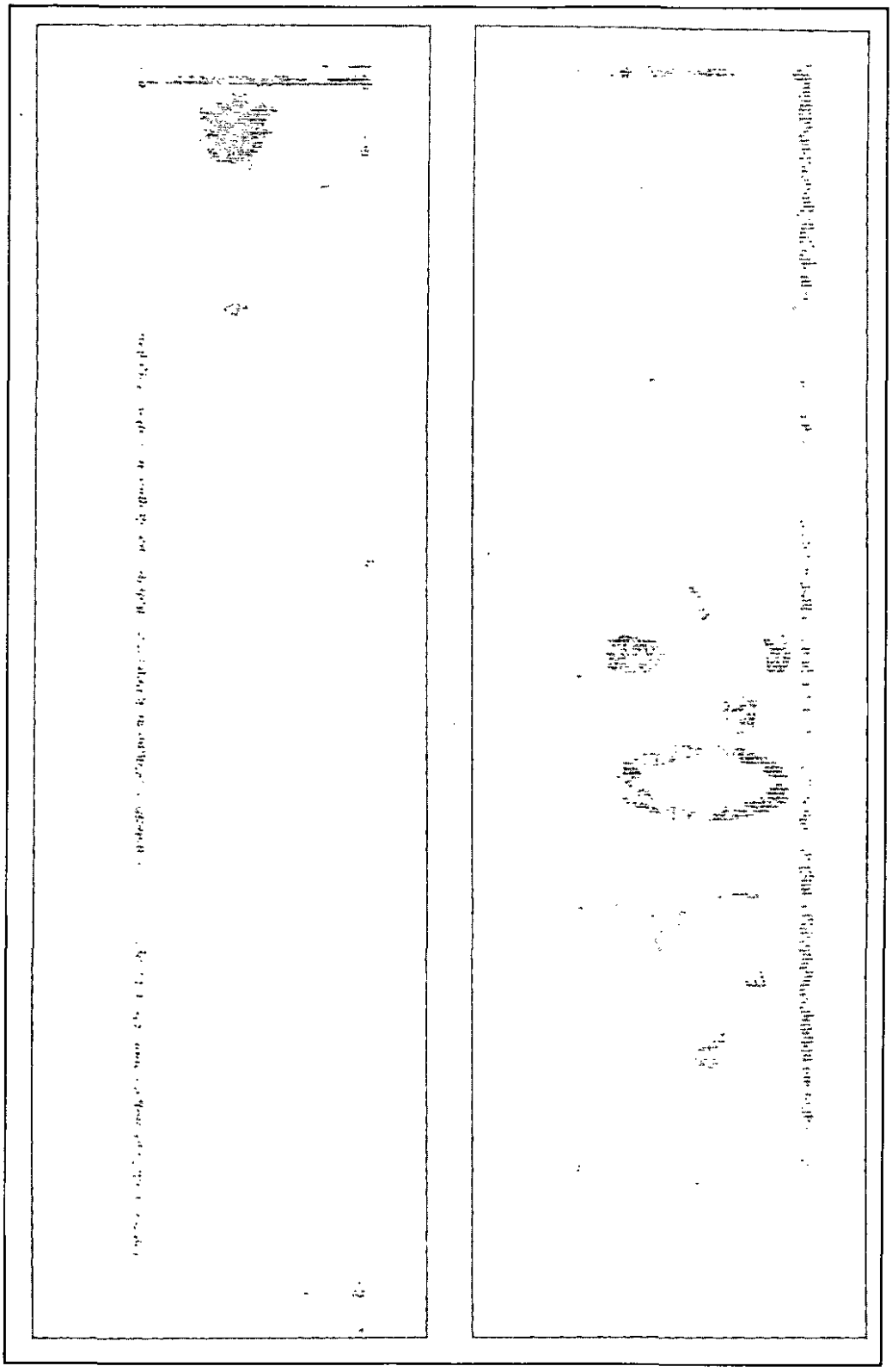
FLIP-FLOP AND GATE CIRCUIT

FIGURE 5



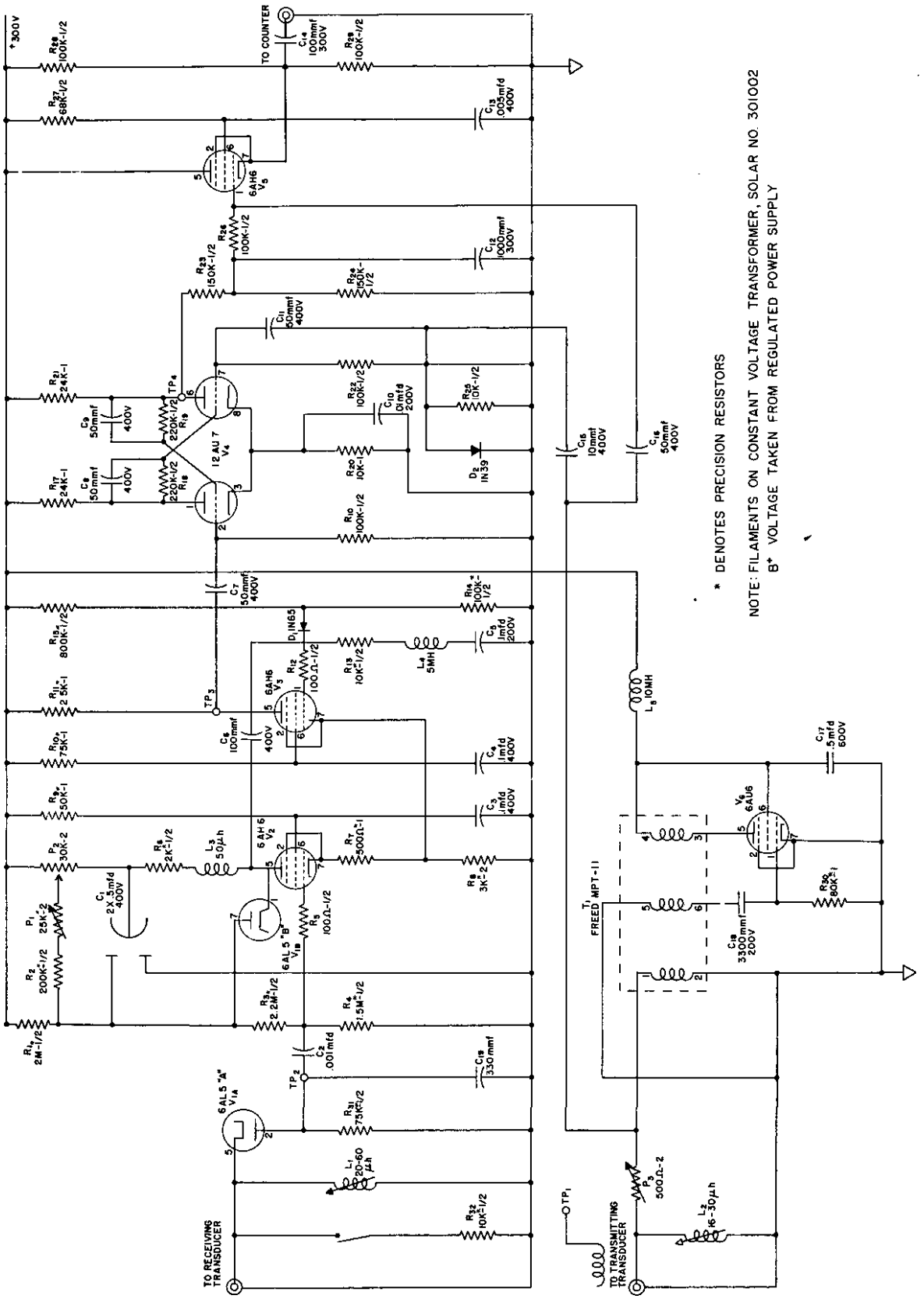
RECORDER CIRCUIT

FIGURE 6



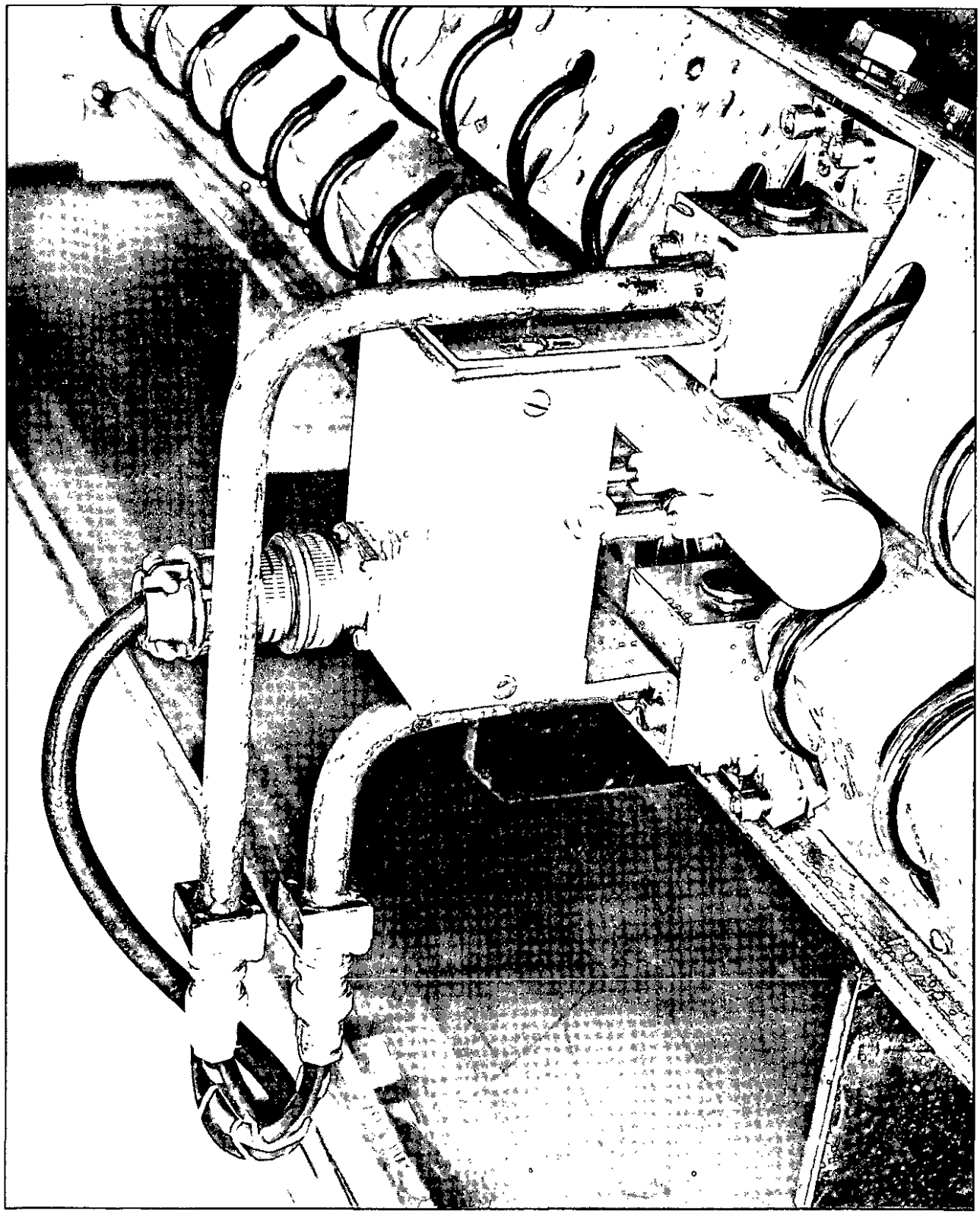
NONBOND RECORD ON ELECTROSENSITIVE PAPER

FIGURE 7



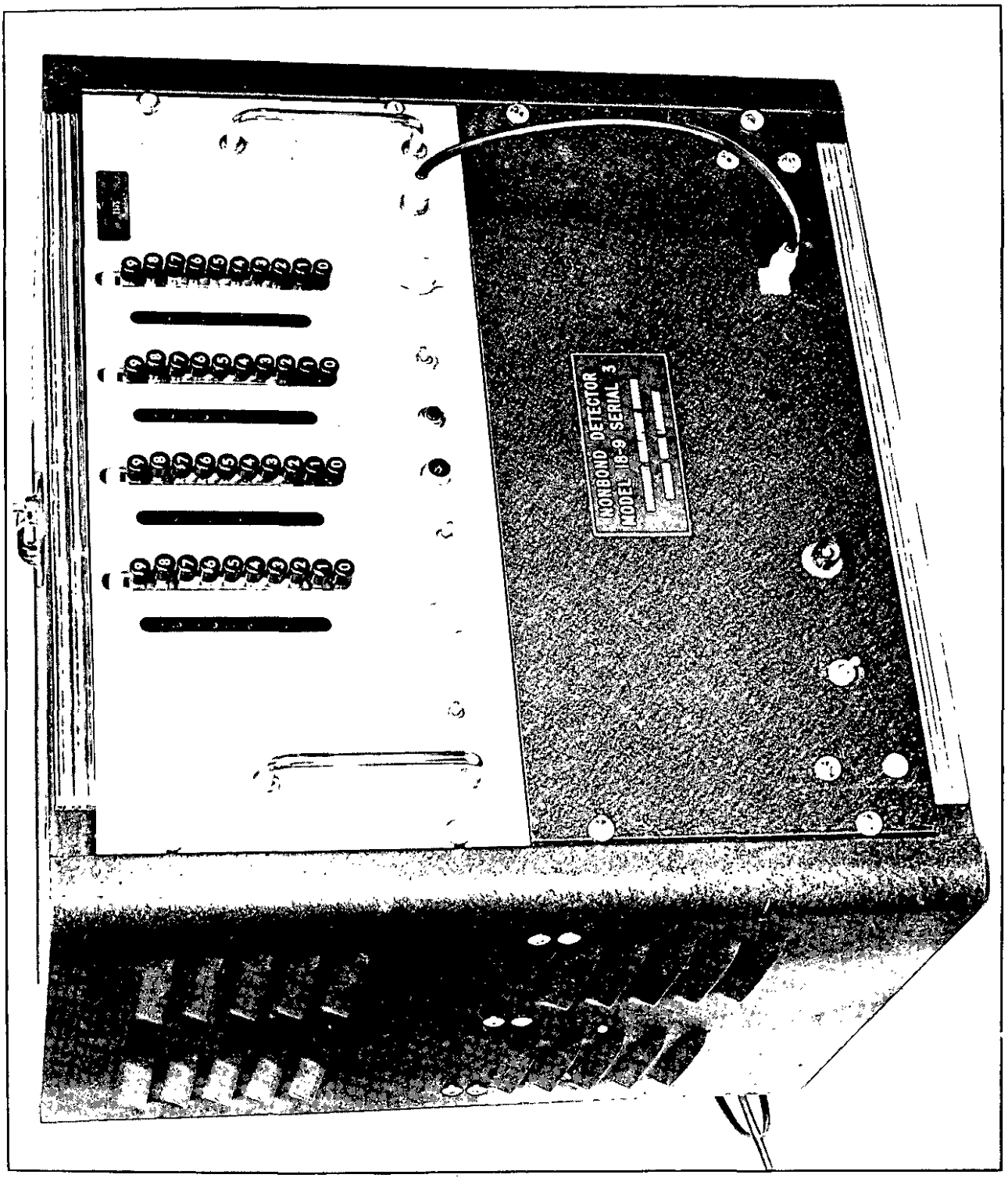
CIRCUIT DIAGRAM OF COMPLETE TESTER

FIGURE 8



PHOTOGRAPH OF MOUNTED TRANSDUCERS

FIGURE 9



PHOTOGRAPH OF TESTER