DO NOT CIRCULATE
Retention Copy

UNCLASSIFIED

[redacted]

PUBLICLY RELEASABLE
LANL Classification Group
[signature]
5/2/96

LA REPORT 114

[redacted] c3

July 27, 1944

This document contains 16 pages

PULSE HEIGHT ANALYZER - MODEL A

WORK DONE BY:

D. K. Froman

W. A. Higinbotham

B. Rossi

REPORT WRITTEN BY:

W. A. Higinbotham

Instrumentation

CLASSIFICATION CANCELLED
For The Atomic Energy Commission
by the Declassification Officer
per Bruce Harlow/JS

This [redacted]
ing of the Espionage Act U.S.C. 50 31 and 32, its
tr [redacted]

[redacted]

UNCLASSIFIED

[redacted]

ABSTRACT

The circuit consists of three discriminators, an anti-coincidence circuit, two delay circuits, a shorting circuit on the input, scalers and power supply. It is designed for fast positive pulses corresponding in speed to those from electron collection or proportional counters, and for slow positive pulses from ion collection chambers. One discriminator is set to fire on all pulses that rise an arbitrary amount above noise. The other two determine the upper and lower boundaries of a channel whose width is adjustable from 1.5 to 7.5 volts. The position of this channel is adjustable from 0 to 50 volts. The delay and shorting circuits make the chance of spurious measurements small, even at relatively high counting rates. Measurements made with apparatus will be described in a forthcoming report by Philip G. Koontz.

[redacted]

[redacted]

PULSE HEIGHT ANALYZER - MODEL A

GENERAL DISCUSSION OF THE PROBLEM AND CIRCUITS

Fig. 1 shows a block diagram of the whole apparatus. The detector and amplifier are any of the conventional models. The rest of the circuits, including a meter and power supply, are mounted on two chasses and one 10½" panel.

Figs. 2,A and B show two general types of pulse which will be delivered by the amplifier. The rise time will always be considerably shorter than the tail. To measure heights correctly successive pulses must not overlap. This can be avoided either by taking counts so slowly that overlap is improbable or by making the circuit insensitive for a time after each pulse. The latter scheme was chosen in the interest of counting speed. The output of the amplifier passes through a clamping circuit as shown in Fig. 1 and then to the discriminators. Discriminator 1 is set to fire on small pulses. When it fires it triggers delay 1 (T_1) which triggers delay 2 (T_2) at some time, d (Fig. 2, E). This clamps the input to a point slightly below ground as shown in Fig. 2, C. If another pulse occurs in the interval T_2 (as shown in Fig. 2, H) it is attenuated as shown at I and thus does not register. It is important that the pulse rate be low enough that the probability of overlap in the rise time or the time of delay 1 (T_1) be negligible. Since the delay time (T_2) is always considerably greater than the rise time or (T_1) the addition of the clamping circuit gives a very appreciable gain in counting speed. Because of the type of clamping circuit used, there must be no overshoot at the input. If the input wave-form has overshoot like that in Fig. 2, B the amplifier should have a clip-

[redacted]

[redacted]

ping circuit installed. Finally, the output of the amplifier should have a very low impedance (such as a cathode follower).

The arrangement of the discriminators is shown in Fig. 3. The bias of discriminator 1 is adjustable for pulses from 0 to 50 volts. Discriminators 2 and 3 are adjusted simultaneously from one potentiometer. The interval between them is set by a tapped battery. The rheostats R_1, R_2, R_3 are provided to match the zero settings of the three discriminators.

Discriminators 2 and 3 feed the anti-coincidence circuit. The waveforms at the output of these discriminators are shown in Fig. 2, F and G, respectively. The time b, c will vary with pulse shape but all discriminators flip back at approximately the same time (d). So the anti-coincidence circuit works on pulses differentiated from the rear of F and G. It is possible that discriminator 3 may recover between f and d. For this reason the time (T_1) should be adjusted with a scope for any particular setup, to make the time f-d as short as possible. Also keeping f-d short reduces the chance of a second pulse falling in the time (T_1).

The output of the anti-coincidence circuit is, then, equal to the number of pulses whose heights fall between the setting of discriminators 2 and 3. This is called the differential count. Discriminator 1 must be set to count all pulses because it triggers the delay circuits. This is called the integral count. A scale of 8 and a driver for a cyclotron type register follows the anti-coincidence circuit and a scale of 32 and driver follows discriminator 1.

TECHNICAL CIRCUIT DISCUSSION

The complete circuit drawings will be found in Figs. 4 and 5.

[redacted]

[redacted]

The Clamping Circuit

The input shorting circuit (see left-central portion of Fig. 4) consists of a condenser in series with the input, a diode to a positive potential and a triode which, when conducting, provides a shunt path for the signal to a slightly lower potential. Series capacity is chosen to avoid loss of high frequencies. The impedance of the shunt path can be made as low as 100 ohms. The residual of a pulse that occurs during clamping is proportional to the speed of rise multiplied by the series capacity and inversely proportional to the impedance of the clamping tube. To keep this quantity small different size condensers are used for slow and fast pulses. To achieve low resistance in the triode the following precautions are necessary: Use a high Gm tube such as 6AC7, 6AG7, or 6J6. Keep some voltage across the triode. In this case the diode is biased about 20 volts positive relative to the triode cathode which is at plus 150. Finally one must draw a considerable grid current. In this case the grid is direct coupled to the delay circuit and draws 3 ma. when conducting. The clamps are followed by a cathode follower to drive the discriminators. Capacities of the clamp circuit should be kept low because the total stray capacity and the series capacity form a divider on the input. The loss due to this and the cathode follower is about 30 percent in the fast position and negligible in the slow position, with the constants shown. If the rise time of fast pulses does not exceed 100 volts per microsecond the series capacity may be increased to 200 mmfd.

Operation of Clamping Circuit

With this circuit well in mind the operation will be described again in more detail. The input wave-form of Fig. 2, A or B will trigger discriminator 1 and the shunt tube will be conducting from time d to e. The wave-form after

[redacted]

[redacted]

the clamp will be that shown at C. Note that the clamp pulls the signal below the normal baseline. If a second pulse occurs in the time interval d-e, as shown at H there will be a slight feed-through as shown in I. This should be lower than the normal baseline and the firing point of discriminator 1. Without the clamp the second pulse would have been measured wrong by an amount q-p (Fig. 2, H). The tail of this second pulse will extend beyond time e but as long as it has a negative slope the series condenser will be charged through the diode and the baseline maintained. A third pulse falling after e will be counted and the height will be wrong by the quantity s-r. However, this is a triple coincidence, the probability of which is negligible.

The maximum counting speed will be limited, in most cases by the probability that a second pulse will start during the time (T_1) or include the time e. A second pulse whose rise includes e will be counted and measured wrong. This has the same probability as that of a pulse falling in (T_1) and both should be avoided. If the input is allowed to have an overshoot as shown in Fig. 2, B it will cause no error in measuring single pulses as long as it is completely recovered by time e. But a second pulse starting between d and e may have a positive slope after e which shoves the baseline up. It is recommended, therefore, that overshoot be clipped off somewhere in the amplifier.

Discriminators

The discriminators (Figs. 3 and 4) are a type of trigger circuit. The feedback path is from the plate of the left pentode to the control grid of the right pentode and back through the cathodes to the grid circuit of the left hand tube. The right hand tube is normally conducting. A pulse raises the input grid until the left tube starts to conduct. Then the control grid of the right hand tube drops by an amount determined by the left plate resistor, the plate current

[redacted]

[redacted]

and the resistor divider. As the pulse continues to rise, the grid, screen and cathode of the left tube act as a cathode follower. No grid current will be drawn unless the input pulse exceeds 70 volts. Therefore, RC coupling is permissible at the inputs to the discriminators. This RC must be large compared to the longest value of (T_1) (Fig. 2). The cathode following continues over the top of the pulse and down the other side. Because of the reduced potential of the right control grid due to conduction in the left tube, the pulse must fall to a value slightly below that at which it triggered the discriminator before the right hand control grid regains control and the original condition is restored. The amount of this "hysteresis" may be controlled by varying the plate resistor of the first tube. In this circuit it amounts to about two volts. This means that the discriminators won't work on pulses less than two volts because they will flip and not recover. The small by-pass condenser (grid to plate) is very important to increase the feedback at high frequencies.

The variable bias has been described. One meter is provided on the panel and may be switched to measure the bias setting of either potentiometer relative to plus 105. To make the zero settings correspond, the following procedure may be used. Connect the input to a source of pulses of constant known height. Set P_1 (Fig. 3) so the meter reads this amount. Turn the rheostat R_1 (Fig. 3) until it is touch and go whether the discriminator fires or not. Repeat with discriminators 3 and 4 with the battery switch at 0 volts.

Anti-coincidence Circuit

If discriminator 3 fires, the wave-form at the plate of the right tube is that shown at G (Fig. 2). This goes through a condenser to a diode and G3 of a 6L7 (Fig. 4). The condenser is charged during the time the discriminator is flipped. This may be a very short time so the diode is necessary. At the end

[redacted]

[redacted]

of the pulse, G3 of the 6L7 is driven below cut-off.

Discriminator 2 causes a triode to conduct while it is flipped. At the end of the pulse, (Fig. 2, F) the triode is cut off. A sharp pulse is developed across the inductance in the triode plate and this is coupled to G1 of the 6L7. If discriminator 2 is triggered but discriminator 3 is not, there is a signal in the plate of the 6L7 which goes to the differential scaler. Note that there is actually some slope where the pulse is cut off at d so the cut-off signal to G3 of the 6L7 occurs just before the firing signal to G1. Also, the recovery time of G3 is made long enough to take into account the fact that discriminator 3 may recover between f and d (Fig. 2, A).

Delay Circuits

Discriminator 1 feeds through a coupling tube to delay 1. When delay 1 recovers it triggers delay 2 which applies the clamping pulse to the input. The delay circuits shown in Fig. 4 are a modification of a circuit developed at the Radiation Laboratory, M.I.T., Cambridge, Massachusetts. It is described in their reports 320 and 334. It has the advantage that the width can be controlled linearly over a wide range by a d.c. voltage. Thus, in this case, the ratio of delay 1 to delay 2 is fixed by the grid RC's and both are controlled by one potentiometer. However, it required a lot of empirical work to make the delays track over the two ranges. If anyone should ever consider duplicating this circuit I would recommend using conventional biased multivibrators with separate controls on delay 1 and delay 2. This part of the circuit should be carefully checked with a double pulser. Decoupling tubes between stages are quite necessary and, even so, the shape of the triggering pulses is quite critical. Also, it will probably be found that if a second pulse triggers the delay circuits shortly after delay 2 has recovered, the length of the second delay 2 will be considerably less than it was the first

[redacted]

[redacted]

time. This is a phenomenon common to all types of multivibrators. It is due to the fact that the plate to grid condenser does not get fully recharged between cycles. The effect can be minimized by keeping the plate resistors as low as possible. In some cases it may pay to drive this condenser from a cathode follower.

The rise time of a pulse (Fig. 2, a-f) depends on the chamber, the amplifier, etc. The decay time constant (preferably a single RC) is from 3 to 10 times the rise time. Pulse shapes must be carefully examined to determine the proper ratio of (T_1) to (T_2). In our work we have been using a ratio of 1 to 25. The delays cover the following ranges;

	Delay 1	Delay 2
For Fast Pulses	2-20 microseconds	50-100 microseconds
For Slow Pulses	100-1000 "	2.5-25 milliseconds

Selection of the proper setting for each experiment is made while observing actual pulses on a triggered sweep oscilloscope. (LA Report 99 describes suitable sweep circuits and delay line).

GENERAL REMARKS

The power supply and voltage regulator circuit in Fig. 4 is conventional. No bias supply was required. However, a high plate potential is required by the cathode follower that succeeds the clamp. This is obtained ahead of the regulator and requires good filtering.

Fig. 5 shows the scaler and output chassis. Plug in scaler units, (Fig. 7) are used. This chassis 17" x 12" x 2" was mounted "up side down" to the top of the panel. Actually the whole outfit gets too hot and should be made

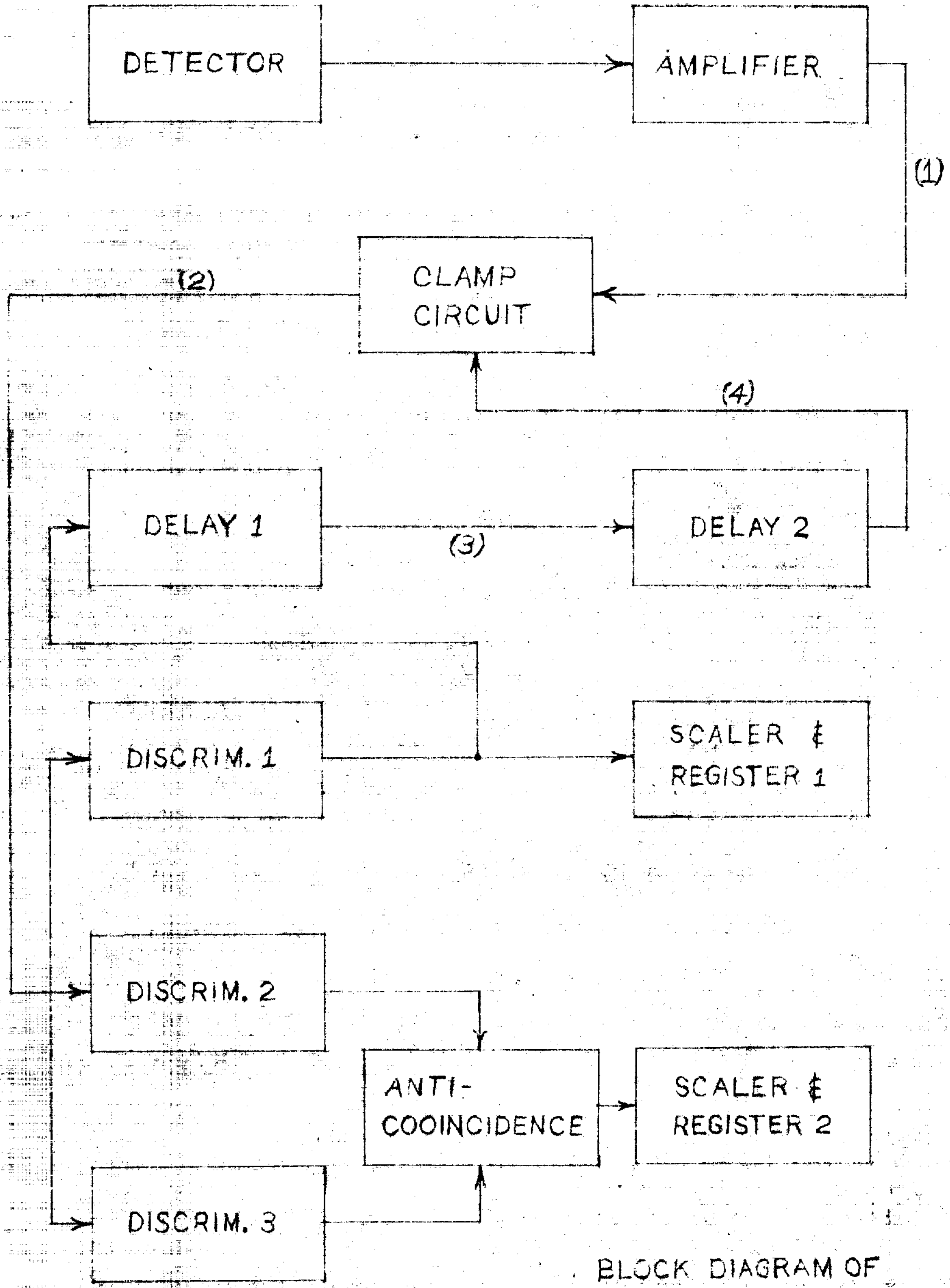
[redacted]

up in two separate chasses. Precision wire wound resistors and wire wound potentiometers are used throughout the discriminator part of the circuit.

Mr. Otto Frisch has recently suggested the use of a shorted delay line to produce pulses of a uniform rectangular shape (LA-107). Such a pulse shape makes the elaborate timing circuits, described in this article, unnecessary. A ten channel analyzer using the delay line will be described in a forthcoming report.

[redacted]

FIG. 1 [redacted]

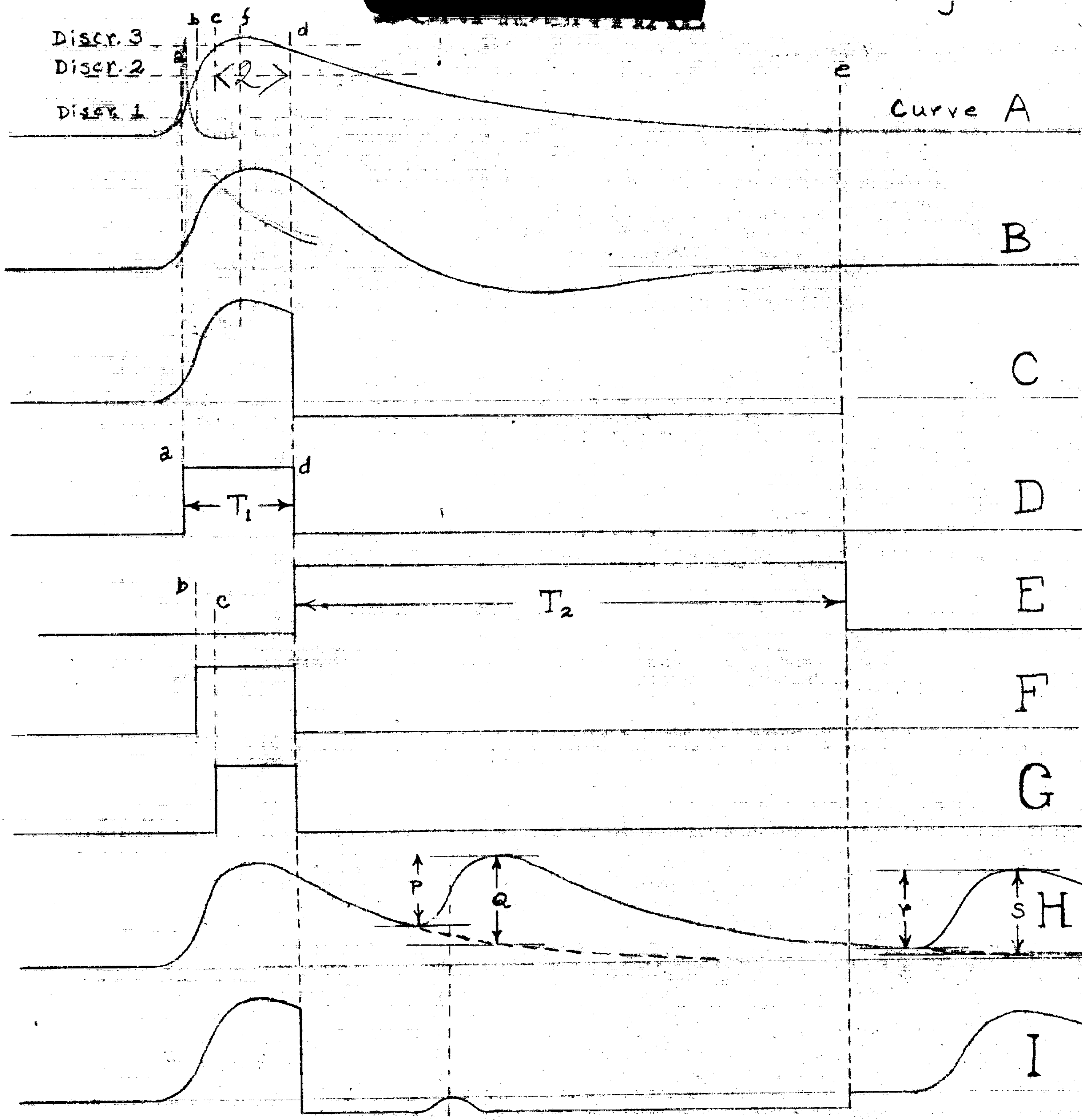


BLOCK DIAGRAM OF
PULSE ANALYZER A
DWG. NO. 354-A
BY HIG.
DATE 7-15-44

[redacted]

[redacted]

Fig. 2

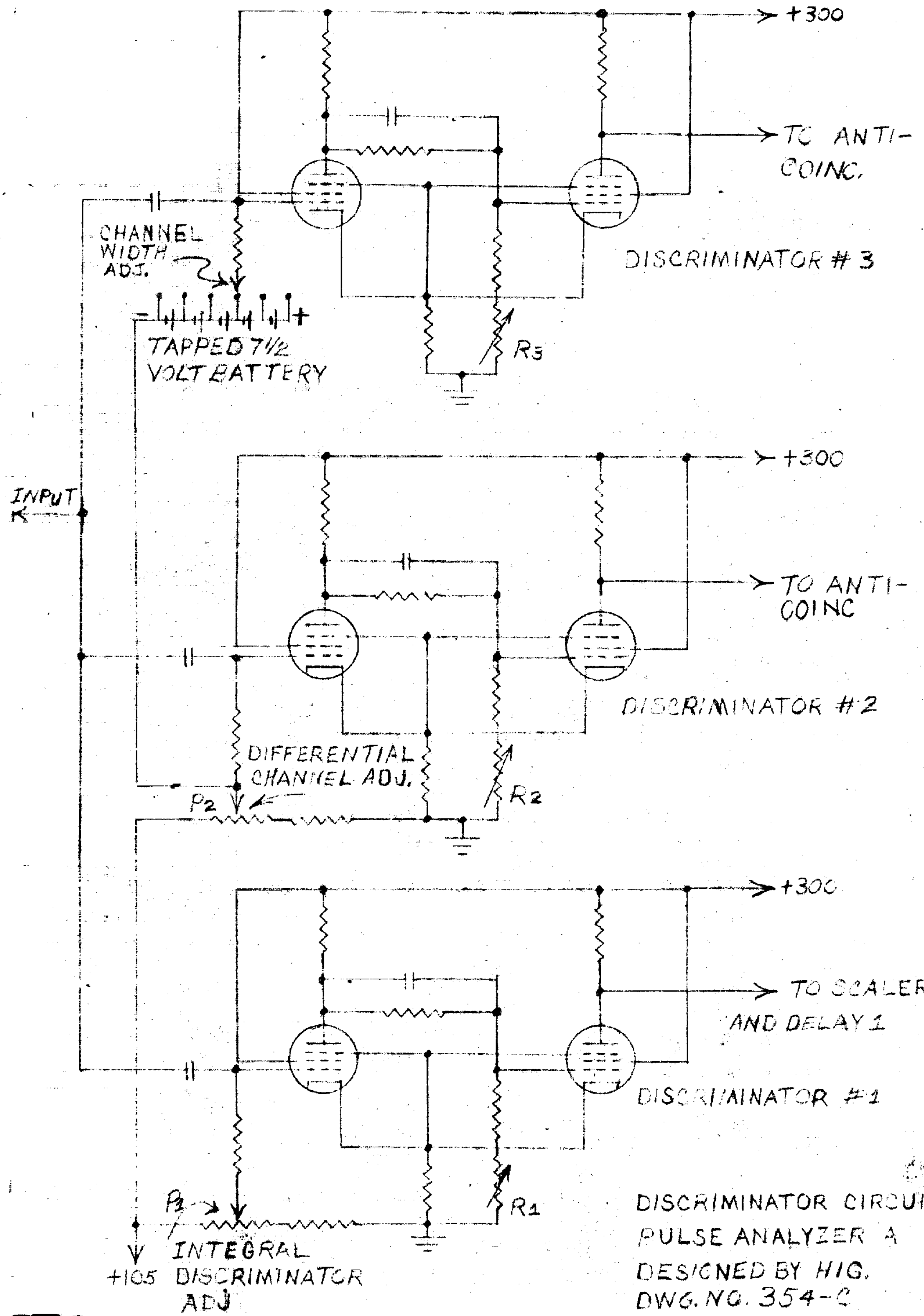


Waveforms
Pulse Analyzer A
7-19-44

Dwg. no. 354-B

[redacted]

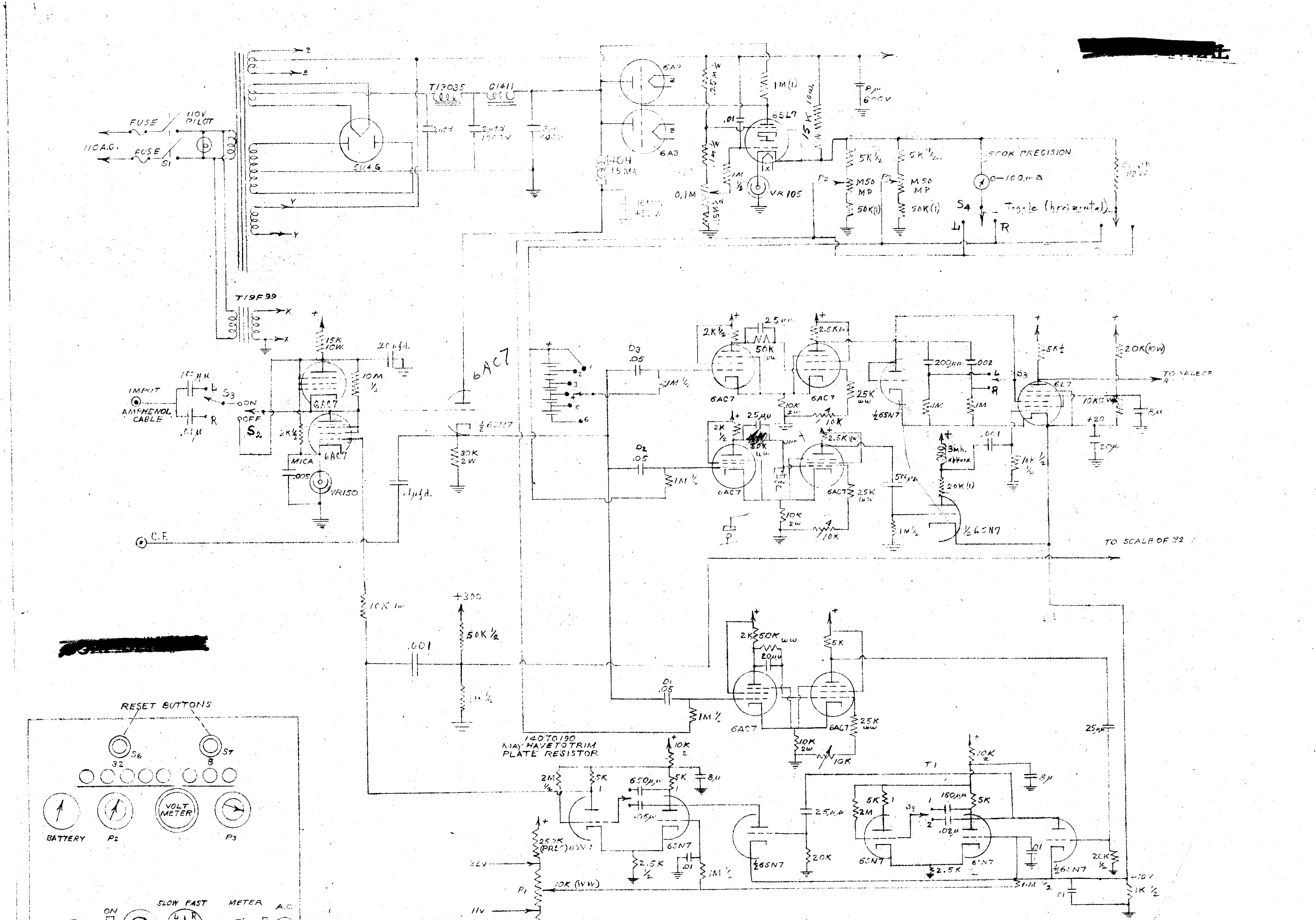
FIG. 3 [redacted]



DISCRIMINATOR CIRCUIT
PULSE ANALYZER A
DESIGNED BY H.I.G.
DWG. NO. 354-C
DATE - 7/17/44

[redacted]

[redacted]

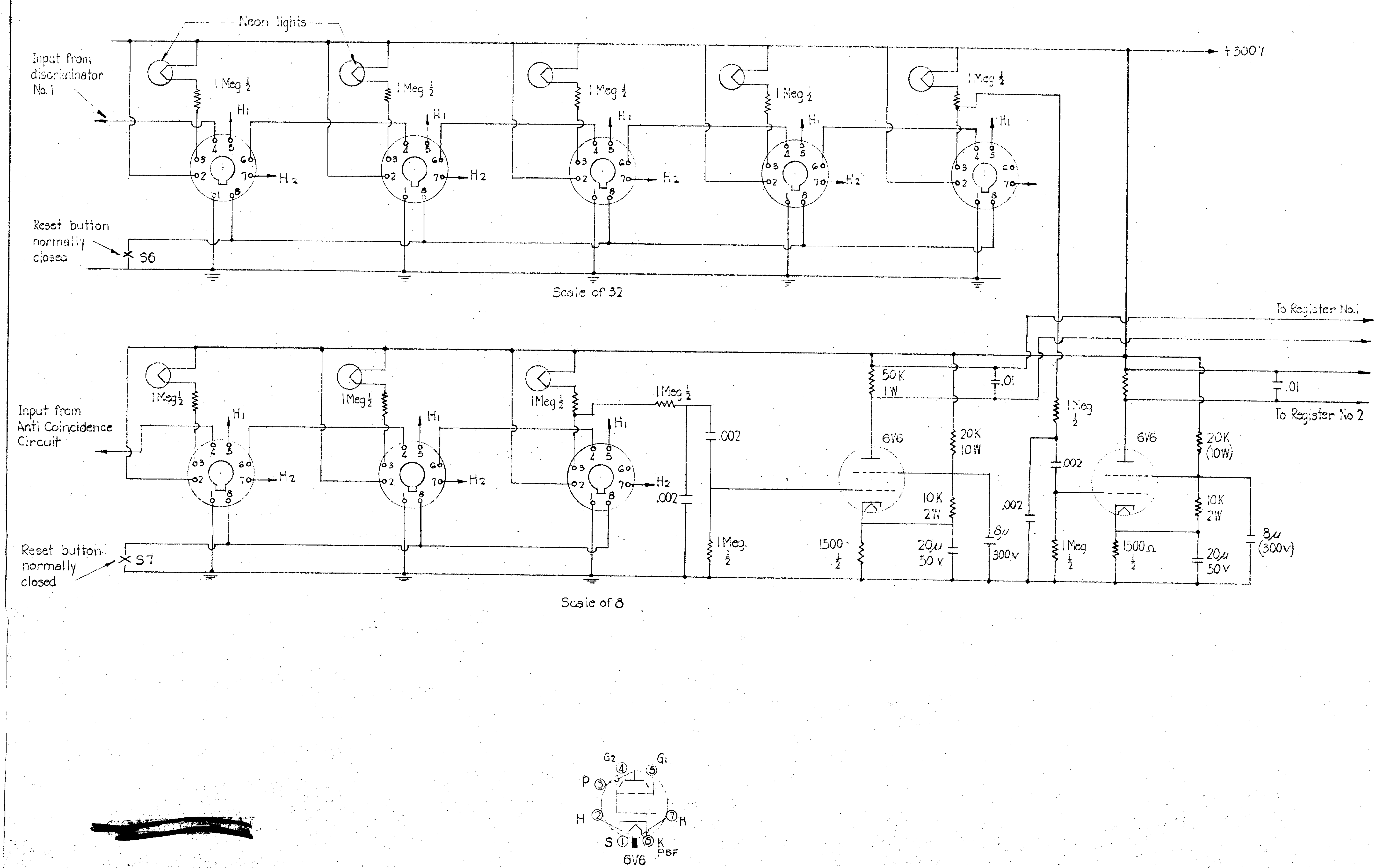


[redacted]

FIG 4

LOS ALAMOS	DRAWING NUMBER
3 CHANNEL PULSE ANALYSER	P-4-262,A

[redacted]



[redacted]

FIG 5

LOS ALAMOS HIGINBOTHAM 3CH. PULSE ANALIZER	DRAWING NUMBER 1-31-44 P4—22B	D3663

[redacted]

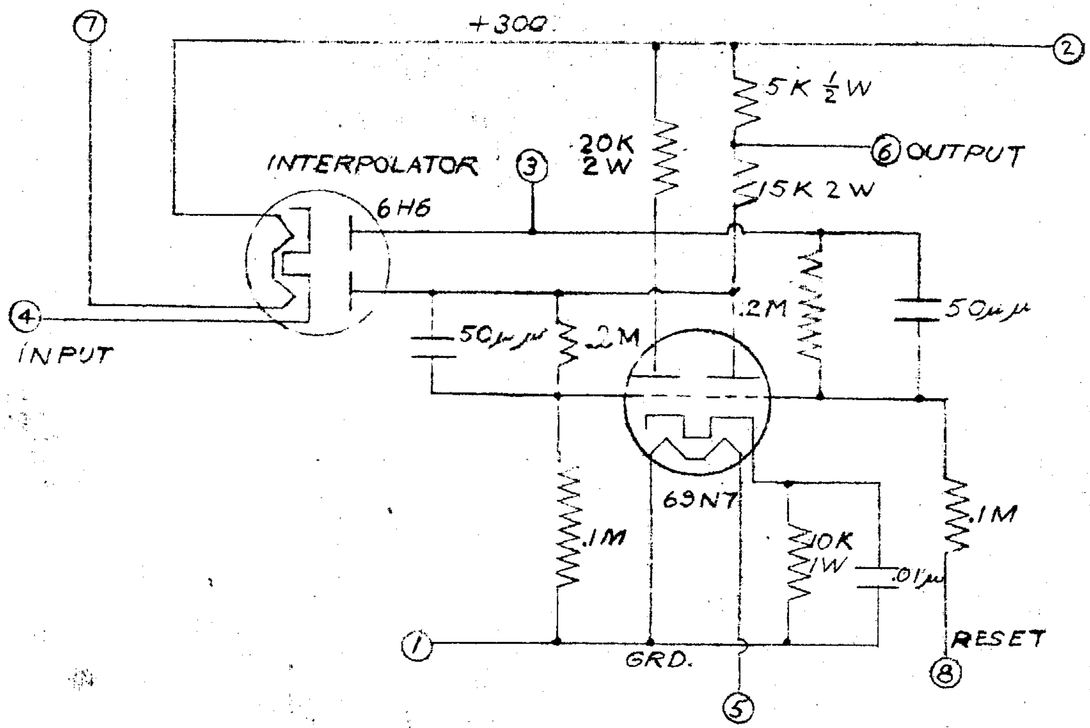


FIG 6

[redacted]

LOS ALAMOS	DRAWING NUMBER
SCALER UNIT CIRCUIT P4 — 247-01	1-8-44

D35/2 MH

UNCLASSIFIED

APPROVED FOR PUBLIC RELEASE