Title

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Author

Nakamura, Michiyuki.

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ABSTRACT

A compact, portable pulse generator with output pulses in the millimicrosecond (mμsec) region at high repetition rates is described. The generator has repetition rates of up to 10^7 pulses per second, pulse rise times of less than 2.5 mμsec, and pulse widths adjustable from 2.5 to 25 mμsec. The output pulse is negative in polarity and is adjustable over an amplitude range of from 0 to 12 volts into 125 ohms output impedance. The instrument has provisions for gating, single pulsing, and operation with drive from an external signal source.

A MILLIMICROSECOND PULSE GENERATOR CAPABLE OF 10 MILLION PULSES PER SECOND*

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INTRODUCTION

Mercury-relay-type pulse generators[1] with output pulses of less than 1 millimicrosecond rise time are available, but these generators are usually limited to repetition rates of less than a few hundred cycles per second. Pulse generators capable of rates above 1 Mc generally have output pulse rise times on the order of 10^{-8} second or slower. Some generators have faster rise times at repetition rates of more than 1 Mc, but their output levels are on the order of less than 1 volt.

The pulse generator described here is a unit with an output pulse rise time of less than 2.5 mμsec and repetition rates of up to 10^7 pulses per second. The output pulse amplitude is 0 to 12 volts. The pulse width is adjusted by the use of external clipping lines from 2.5 to 25 mμsec. The instrument employs circuitry and techniques that require a minimum of circuit complexity and power-supply demands, resulting in a small, portable unit.

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* Work done under the auspices of the U. S. Atomic Energy Commission.

[1] Val Fish, Jr., A Coaxial Mercury Relay for Fast Pulse Generation, UCRL-3602, July 1955.

SPECIFICATIONS AND OPERATION OF THE PULSE GENERATOR

The repetition rate of the pulser may be controlled by an internal generator, a single-pulse push button, or an external signal source. Positive pulses from an external signal source of at least 5 volts amplitude will trigger the pulse generator from 0 to 10^7 pulses per second. Sine-wave input from an external source may be used, but the input amplitude requirement varies with input frequency, as shown in Fig. 1. The internal generator frequency is controlled by a six-decade coarse-frequency selector switch and a fine-frequency control. The internal generator frequency range is 10 cps to 10 Mc.

A positive 20-volt pulse, 50 mμsec wide, precedes the output pulse by approximately 10 mμsec for initiating timing or triggering oscilloscopes.

The instrument has provisions for gated operation. For "ungated" operation the gate is open, and all pulses are allowed through. For "gated" operation the gate remains closed if no signal (i.e. a 0-volt signal) appears at the gate input. The gate is opened by a positive 20-volt signal and may be turned on or off in less than 0.1 microsecond. Figure 2 shows a burst of pulses obtainable when the gating feature of the instrument is used in conjunction with the internal generator. Because there is no provision for synchronizing the gate with the internal generator, the first and last pulses in the train of pulses may not always be full amplitude. Bursts of pulses are useful for simulating operation with pulsed accelerators and checking equipment for such items as repetition-rate sensitivity, base-line shift, and pile-up.

The output of the instrument is designed to operate into 125-ohm impedance. Three output channels are available that are coincident in time. The output pulse in each of the channels is independently adjustable for amplitude and pulse width. The output pulse is of negative polarity, 0 to 12 volts in amplitude when feeding a 125-ohm system. The instrument could, with some changes in circuit parameters, be modified to operate into other impedance levels. The pulse width is adjustable from 2.5 to 25 mμsec by means of external clipping lines. Output wave forms are shown in Fig. 3 by means of multiple exposures indicating the range in pulse widths attainable. The rise time of the leading edge is not affected with changes in output amplitude. These signals are displayed directly on the deflection plates of a cathode-ray tube in a Tektronix 517 oscilloscope. With the rise-time limitations of the cathode-ray tube (1.2 mμsec rise time) and the interaction of the signal with the horizontal sweep accounted for, the rise time of the output pulse is calculated as approximately 2mμsec. (Tolerance variations in commercially available components, however, are such that this may be conservatively stated as less than 2.5 mμsec.)

Because of the use of clipping lines for determining the output pulse widths, there is no reverse terminating resistor in the instrument. This feature necessitates the use of good termination in the output circuit if reflections are to be eliminated.

The input power requirement varies with output repetition rate. When the output repetition rate is 10^7 pulses per second, the power requirement is approximately 200 watts at 117 volts ac.

CIRCUIT DESCRIPTION

A simplified block diagram of the instrument is shown in Fig. 4. The tubes associated with each function are indicated. The schematic circuit diagrams are shown in Figs. 5, 6, 8, 9, and 10. In these diagrams all resistor wattage ratings are 1/2 watt unless noted. The capacitor values less than one are in microfarads, and those greater than one are in micromicrofarads unless otherwise indicated.

The single-pulse and external-drive input signals trigger a square-wave generator (SWG) (V1, V2, and V3A) when the coarse-frequency range-selector switch is in position 7. This switch is the four-deck switch shown in Fig. 5. In switch position 7 the SWG becomes a monostable multivibrator. The SWG is basically the same switching circuit used in a 40-Mc scaler.[2] This switching circuit is capable of very fast switching speeds[3] and is partly responsible for the simplicity of circuit design in the instrument. The SWG may be triggered at a rate up to 10^7 per second by positive pulses of at least 5 volts amplitude. With external-drive input pulses or single pulses there is no lower limit on the repetition rate. With sine-wave input signals the required input-signal amplitude for triggering the SWG varies with input frequency as described before.

In the other six positions of the switch (positions 1 through 6) the SWG becomes an astable multivibrator. The coarse-frequency range of the astable multivibrator is determined by the RC timing networks selected. By returning the resistors in the RC timing network to an adjustable potential, one can vary the frequency of the SWG over a 10-to-1 range for any selected RC timing network. The frequency range of the internal generator from 10 to 10^7 pulses per second is covered by six decade steps in conjunction with the fine-frequency control.

The SWG is capable of fast switching speeds with a resultant output-signal rise time on the order of 25 mμsec. This fast rise time allows sharp differentiation of the square-wave signal. The reason for differentiating the signal sharply is to keep the duty factor of the amplifiers that follow from

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[2] M. Nakamura, "Forty-Megacycle Scaler," Rev. Sci. Instr. <u>28</u> 1015-1020 (1957).

[3] Melvin Brown, "Greater Gain Bandwidth in Trigger Circuits," Rev. Sci. Instr. <u>30</u>, No. 3, 169-175 (1959).

becoming excessive at the high repetition rates. The fast rise time also contributes to the simplicity of the instrument, since a smaller number of amplifying stages is required.

The gate (V3B) employs a cathode follower coupling the differentiated signal from the SWG to the first amplifier V4 (Fig. 6.) When the gate switch is in the "ungated" position, the cathode follower biases V4 just beyond cutoff. In this "ungated" position the signals from the SWG are sufficient to bring V4 into conduction from just beyond cutoff. When the gate switch is in the "gated" position, V4 is biased well beyond cutoff, and signals from the SWG cannot bring the grid of V4 into conduction. A positive 20-volt signal to the gate(V3B) is required to bring the grid of V4 to a bias level such that signals from the SWG can be amplified.

The pulse-shaping amplifiers V5 through V7 (Fig. 6) are each biased beyond cutoff and are driven into conduction by the signal. Signal inversion between each amplifier stage is accomplished by pulse transformers. The transformer windings, a 2-to-1 step-down, reduce the capacitive and grid loading of the following grid input to the preceding stage. The signal drives each amplifier stage from cutoff into heavy conduction, progressively steepening the rise time of the signal. Figure 7 indicates this process of steepening the signal wave form. The input signal is of sufficient amplitude that it overcomes the bias level beyond cutoff and drives the grid of the amplifier well into conduction. The value "a" indicated in Fig. 7A is slow-rising and is not amplified. The portion of the signal labeled "b" is that part of the signal which is amplified. Figure 7B indicates the improved wave form obtainable from such an operation.

The reasons for using this method of bringing the amplifiers from cutoff into conduction with the aid of inverting step-down transformers are fourfold: (a) the steepest portion of the input pulse may be selected for amplification;

(b) the input-stage loading to the preceding stage is reduced; (c) more anode current is available when the grid is driven positive; and (d) the power-supply requirements are minimized because large quiescent currents in the amplifiers are not required.

Because each amplifier is driven well into conduction, the plate dissipation of the amplifiers at high repetition rates can be kept within tube ratings only by limiting the duty factor. This is done by differentiating the signal from the SWG, thus narrowing the signal pulse width. This differentiation limits the maximum pulse width obtainable from the instrument to 25 mμsec.

The positive trigger-output signal is taken from the grid of V5 and isolated from the amplifier stages by an output pulse amplifier with a pulse-transformer output. See Figs 6 and 8.

Figure 9 shows a typical output amplifier circuit showing V8 and V9 only. Output amplifiers V9, V11, and V13 are fed from the same source and driven into conduction from cutoff. The amplitude of the output signal is a function of the plate and screen voltages of the output amplifier tubes. These voltages are controlled by the corresponding cathode followers V8, V10, and V12, whose cathode potentials are independently adjustable. The output pulse is of negative polarity, 0 to 12 volts in amplitude when fed into 125 ohms impedance. Had the instrument been designed to feed into other impedance levels, the output amplitude would have been different.

The output pulse width is fixed by the double transit time in the clipping lines, which are externally connected to the instrument; 125-ohm cable such as RG 63/U must be used in this instrument for clipping lines because 125-ohm cable is used within the instrument. The average velocity of propagation in RG 63/U is 9.9 inches per mμsec. Because the rise time of the pulse is less than 2.5 mμsec, the minimum pulse width may be clipped to approximately 2 mμsec. The maximum pulse width of 25 mμsec is limited by the pulse within the instrument. The positive overshoot of the signal resulting from the clipping action is eliminated from the output by a combination of series and shunt diodes. The G111A diodes are manufactured by Hewlett-Packard Company, Palo Alto, California. The Q6-100 diodes are manufactured by Qutronic Semiconductor Corporation.[4]

If positive output signals are desired, or if output impedance levels other than 125 ohms are required, transformers[5] similar in construction to the interstage transformers may be used for inversion or impedance transformation. The transformer core material is Ferroxcube type 102, style 203F250. The turns ratio are shown on the schematic diagram. The Ferroxcube Corporation is located in Saugerties, New York.

The unit has a self-contained power supply, which is shown in Fig. 10. Because of the simple circuitry and the small power-supply requirements, the instrument is small and compact. The portable pulse generator is packaged in a box approximately 14-1/2 × 11 × 11-1/4 inches and weighs 40 pounds.

ACKNOWLEDGMENTS

The author would like to thank Mr. Frank Evans, who has previously shown that output pulses of fast rise time could be attained by using techniques similar to those described here. The author would also like to thank Mr. Dick A. Mack for his helpful discussions and suggestions.

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[4] Qutronic Semiconductor Corporation, 525 Broadway, New York 12, New York.

[5] N. Winningstad, Nanosecond Pulse Transformers, IRE Trans. on Nuclear Sci. (paper presented at Meeting at San Mateo, California, Nov. 6-7, 1958).

LEGENDS

Fig. 1. External-drive input requirements for sine-wave signals vs. frequency.

Fig. 2. Bursts of 10-Mc pulses obtained when gating feature is used (vertical sensitivity = 16 volts/cm; horizontal sweep = 0.25 μsec/cm).

Fig. 3. Multiple exposures of output wave forms showing output pulse-width variations (vertical sensitivity = 16 volts/cm; horizontal sweep = 5 mμsec/cm).

Fig. 4. Simplified block diagram of pulse generator.

Fig. 5. Circuit diagram of square-wave generator (SWG) and gate.

Fig. 6. Pulse-shaping amplifiers.

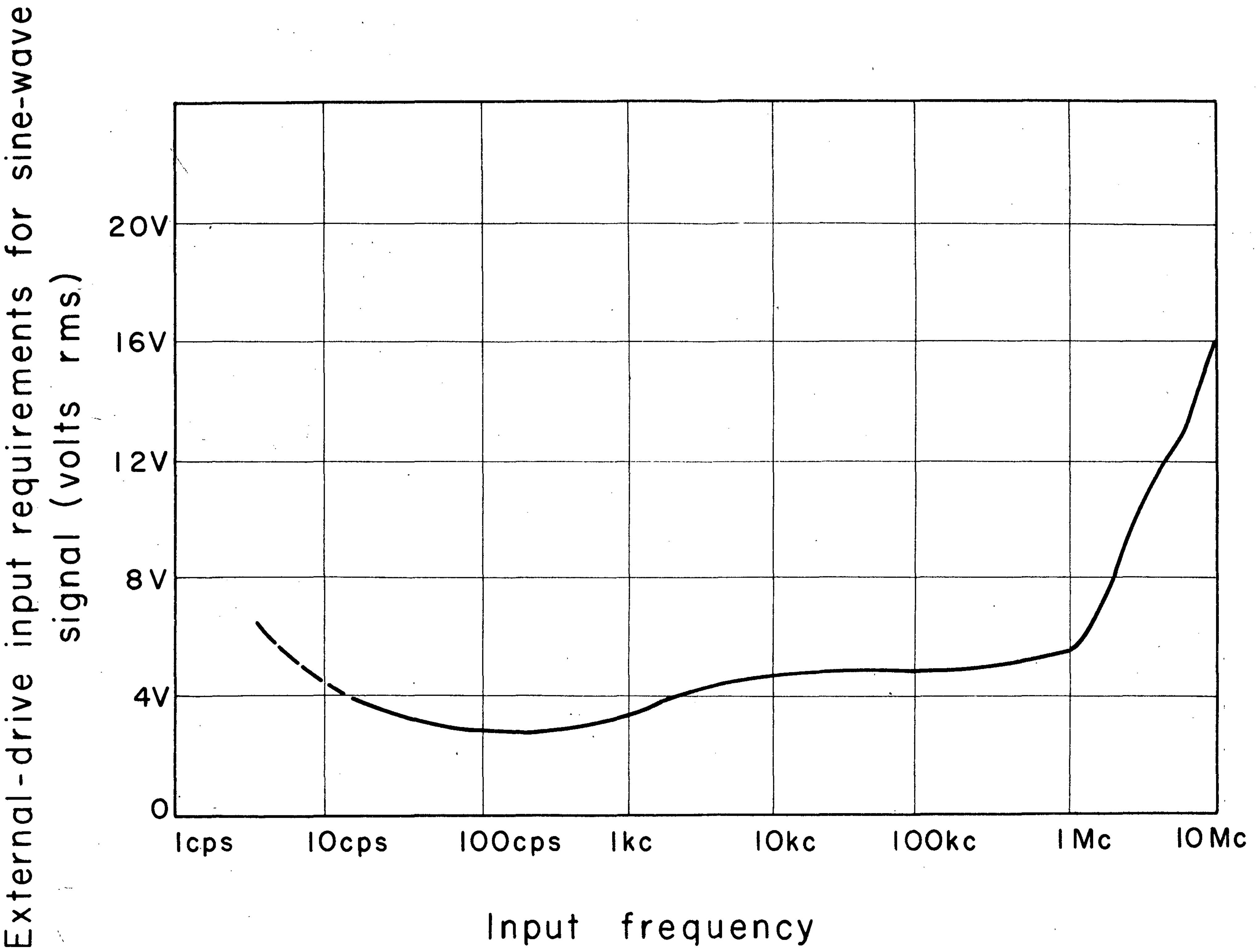
Fig. 7. Wave forms for amplifier input (A) and output (B), indicating steepening of pulse rise time (wave forms not necessarily to same scale).

Fig. 8. Trigger-output amplifier. The turns ratio of the pulse transformer is 1:1. PCA Electronics, Inc. is located in Sepulveda, California.

Fig. 9. Typical output amplifier circuit.

Fig. 10. Circuit diagram of power supply for pulse generator.

d9



55152-2

MU-16710

FIG 1 55,152-2

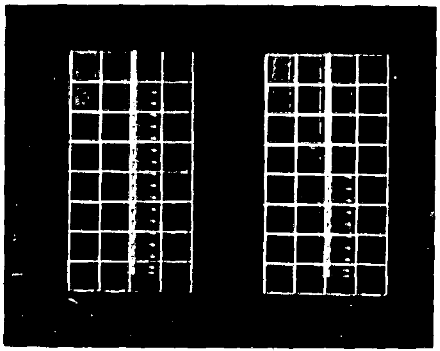


Fig. 2.

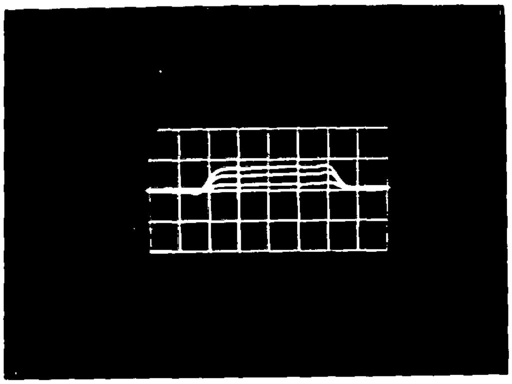


Fig 3A

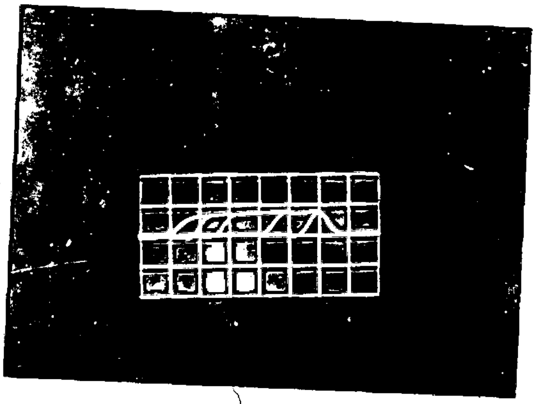
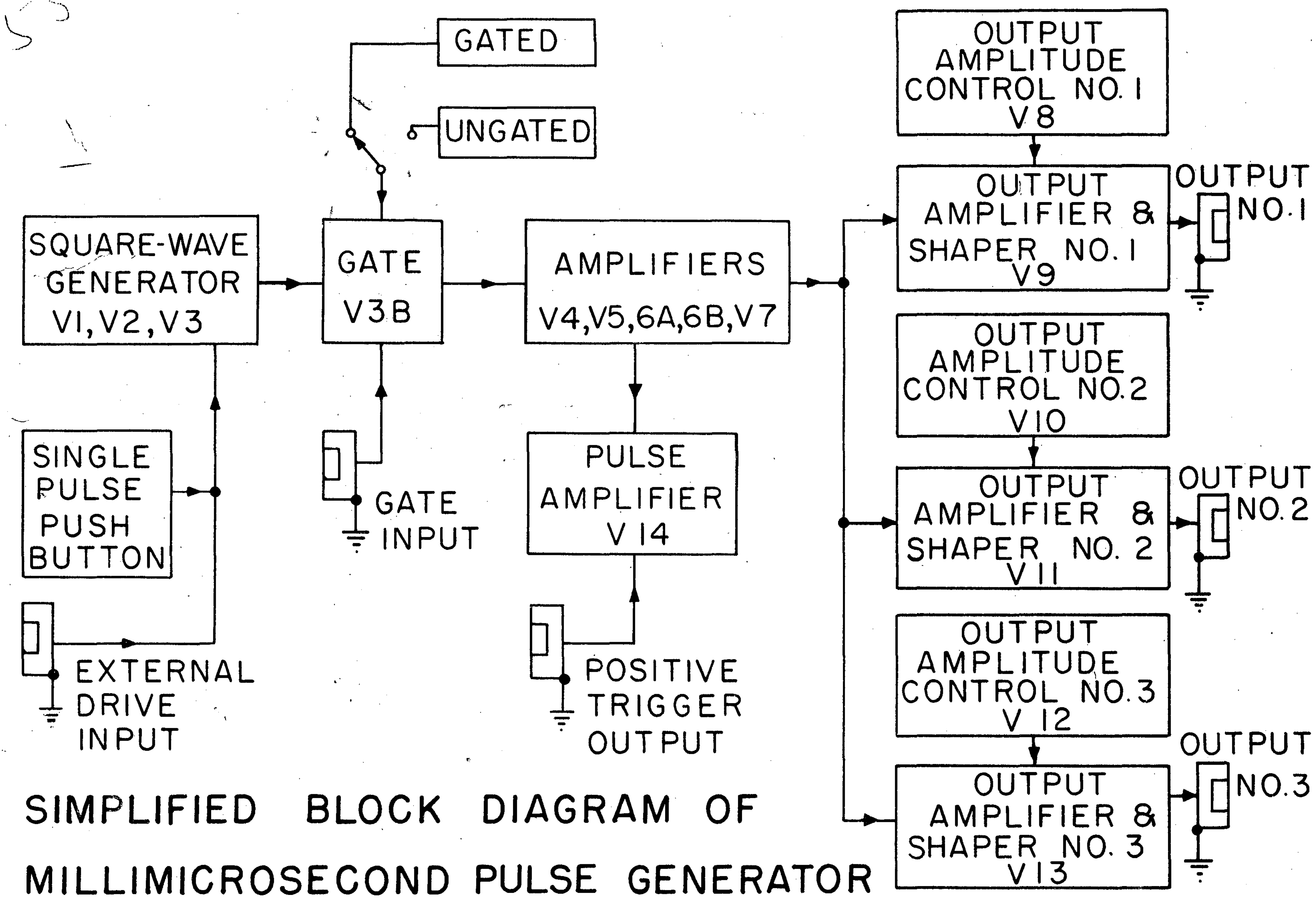


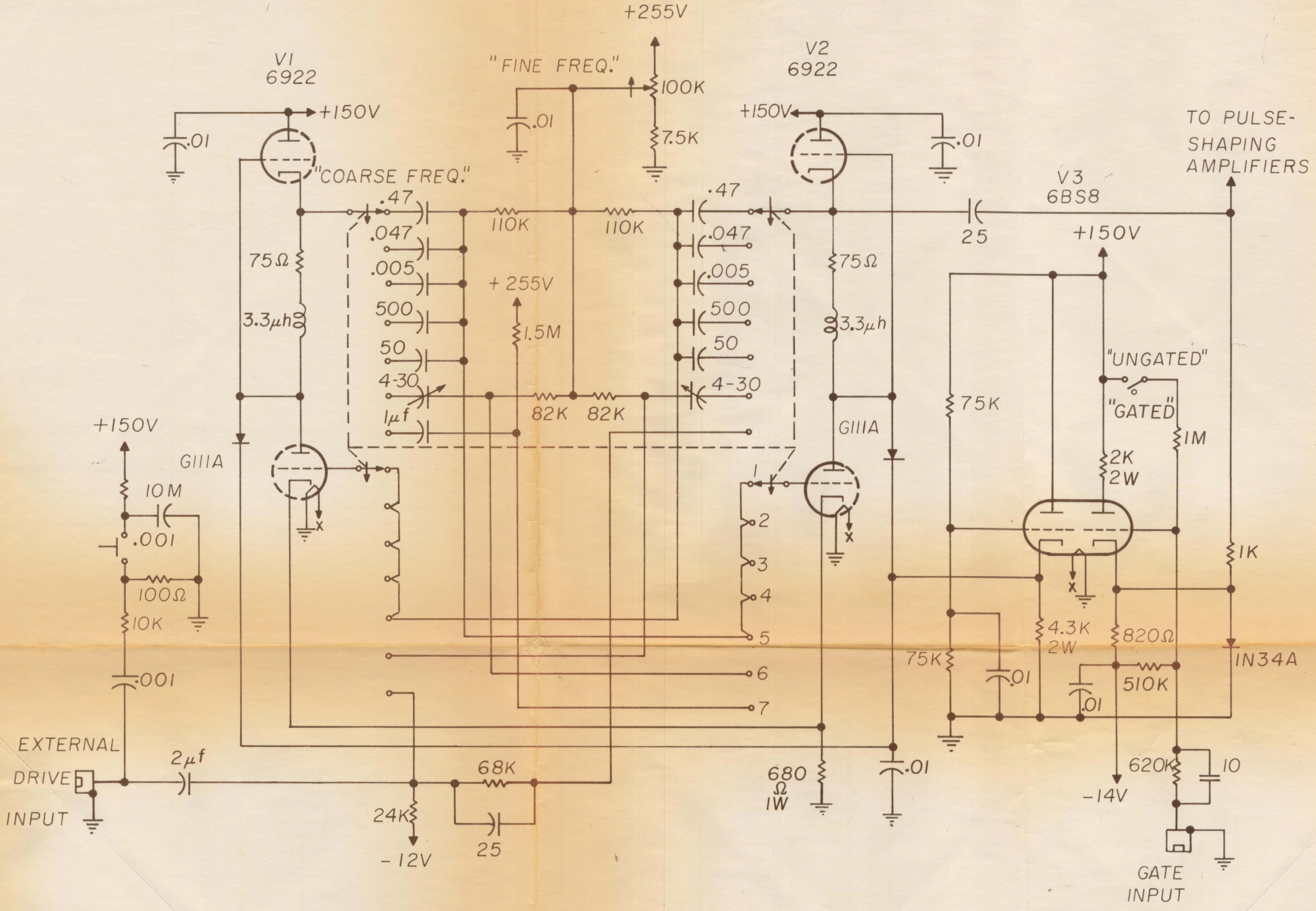
Fig 3B

55



SIMPLIFIED BLOCK DIAGRAM OF
MILLIMICROSECOND PULSE GENERATOR

Fig 4
55,024-2



V1
6922
+150V
.01
"COARSE FREQ."
"FINE FREQ."
+255V
100K
7.5K
.01
V2
6922
+150V
.01
TO PULSE-
SHAPING
AMPLIFIERS
V3
6BS8
.47
.047
.005
500
50
4-30
1μf
110K
110K
.47
.047
.005
500
50
4-30
25
+150V
75Ω
3.3μh
+ 255V
1.5M
82K
82K
75Ω
3.3μh
"UNGATED"
"GATED"
75K
1M
2K
2W
G111A
G111A
+150V
G111A
10M
.001
100Ω
10K
1
2
3
4
5
6
7
1K
4.3K
2W
820Ω
75K
.01
.01
510K
IN34A
.001
EXTERNAL
DRIVE
INPUT
2μf
68K
24K
-12V
25
680
Ω
1W
.01
620K
10
-14V
GATE
INPUT

Fig. 5

55,384-3

Box 56

~~1 Drawing~~

~~UCRL - 8445~~

BOX - 55

UCRL - 8588 Rev

1 Drawing

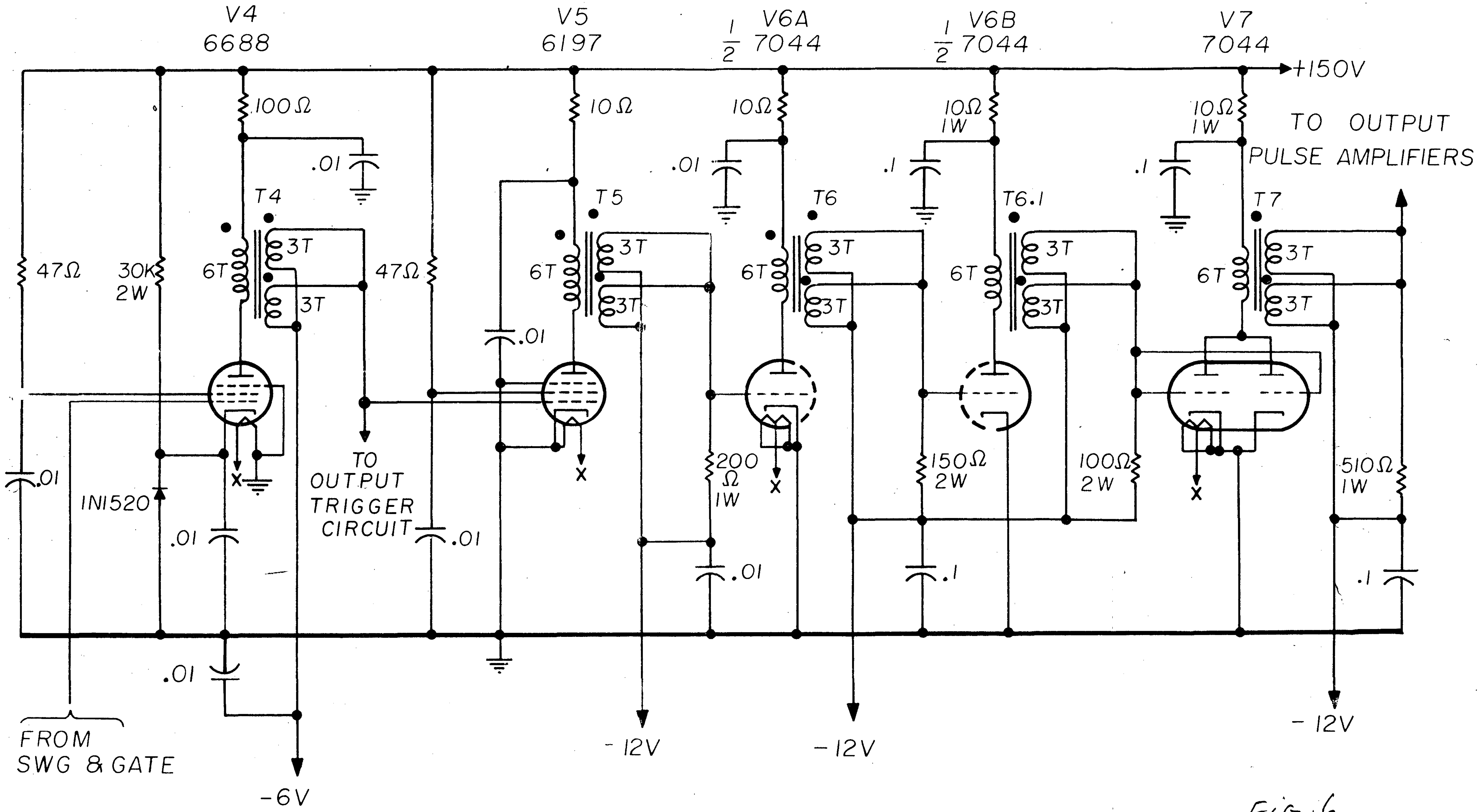
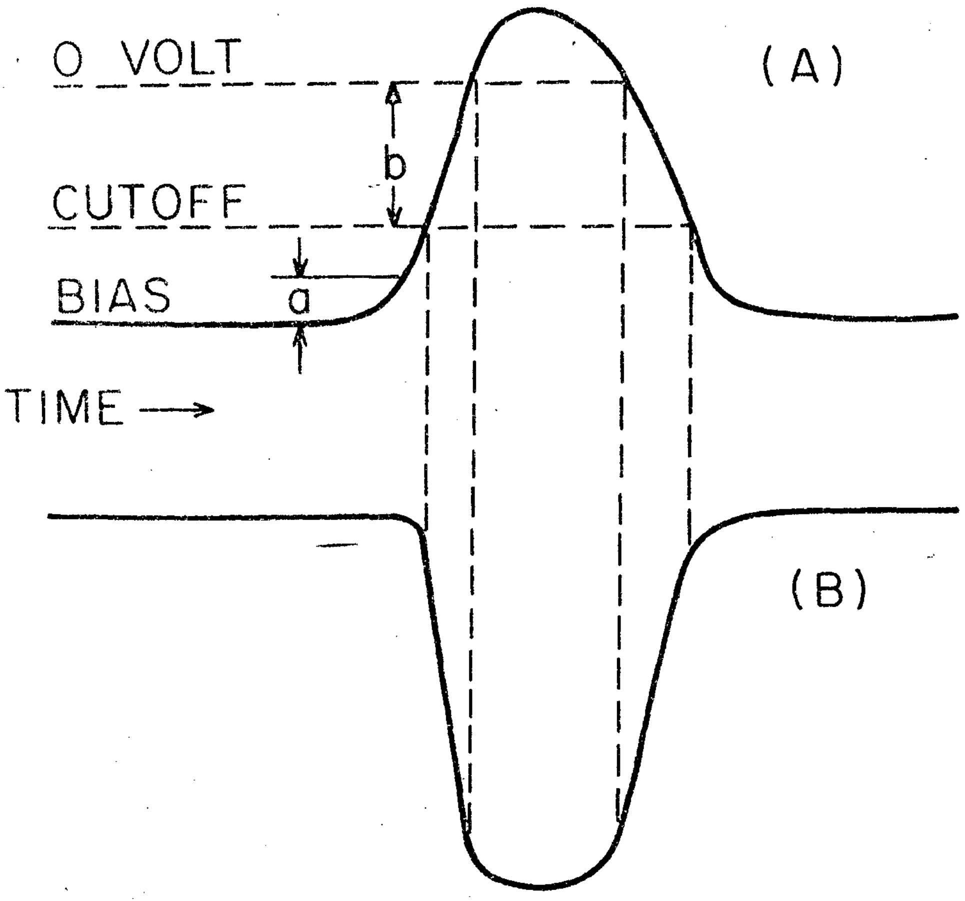

V4
6688
V5
6197
1/2 V6A 7044
1/2 V6B 7044
V7
7044
+150V
100Ω
10Ω
10Ω
10Ω 1W
10Ω 1W
TO OUTPUT PULSE AMPLIFIERS
.01
.01
.1
.1
T4
T5
T6
T6.1
T7
6T
3T
47Ω
30K 2W
47Ω
.01
.01
1N1520
.01
TO OUTPUT TRIGGER CIRCUIT
.01
X
200 Ω 1W
150Ω 2W
100Ω 2W
510Ω 1W
.01
.1
.1
.01
FROM SWG & GATE
-6V
-12V
-12V
-12V

Fig. 6
55,385-2



AMPLIFIER INPUT (A) & OUTPUT (B) WAVEFORMS, INDICATING STEEPENING OF PULSE RISE TIME (WAVEFORMS NOT NECESSARILY TO SAME SCALE)

55025-1

Fig 7

55,025-1

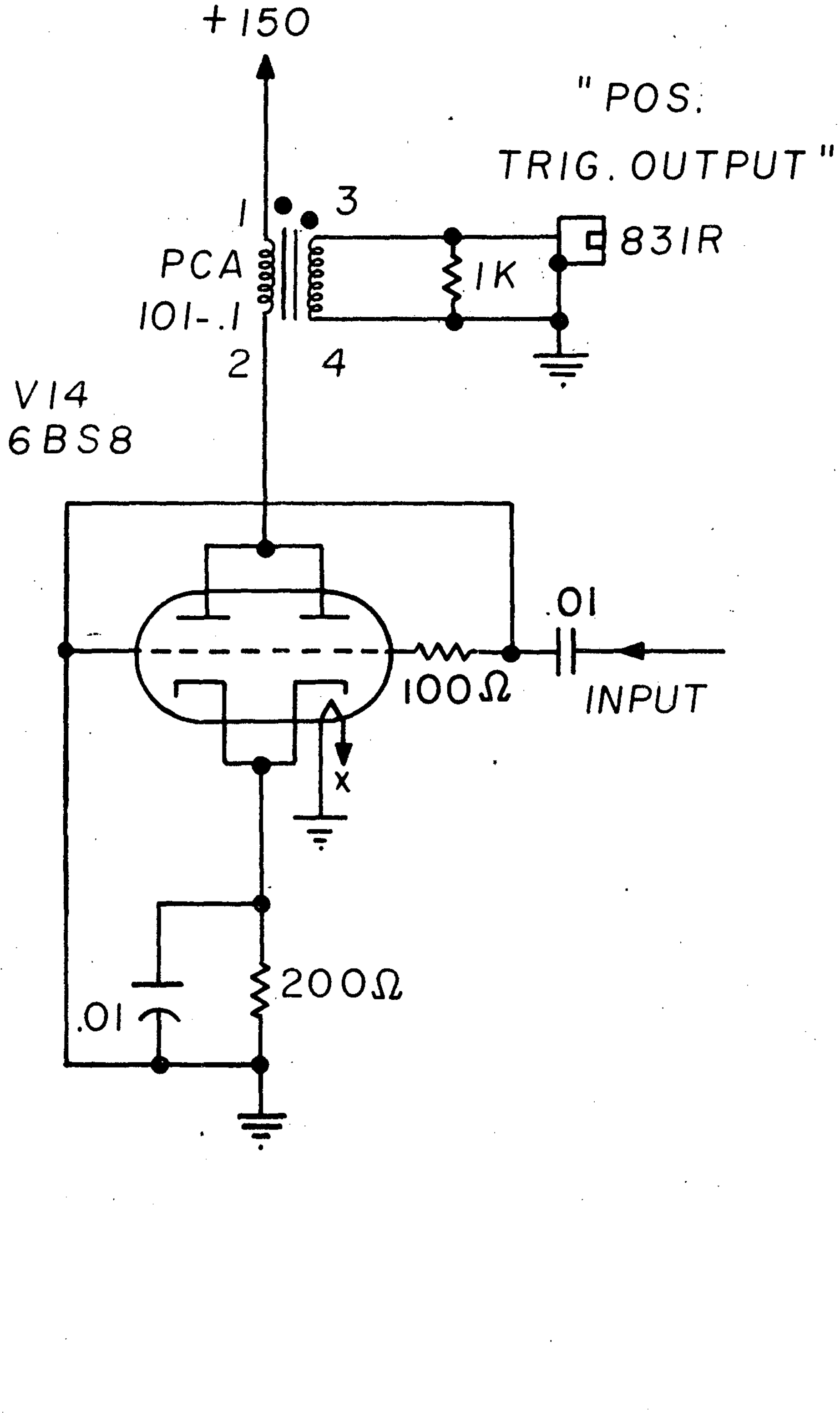

+150
"POS.
TRIG. OUTPUT"
1
3
PCA
101-.1
2
4
1K
831R
V14
6BS8
.01
100Ω
INPUT
X
200Ω
.01

Fig 8

55,558-1

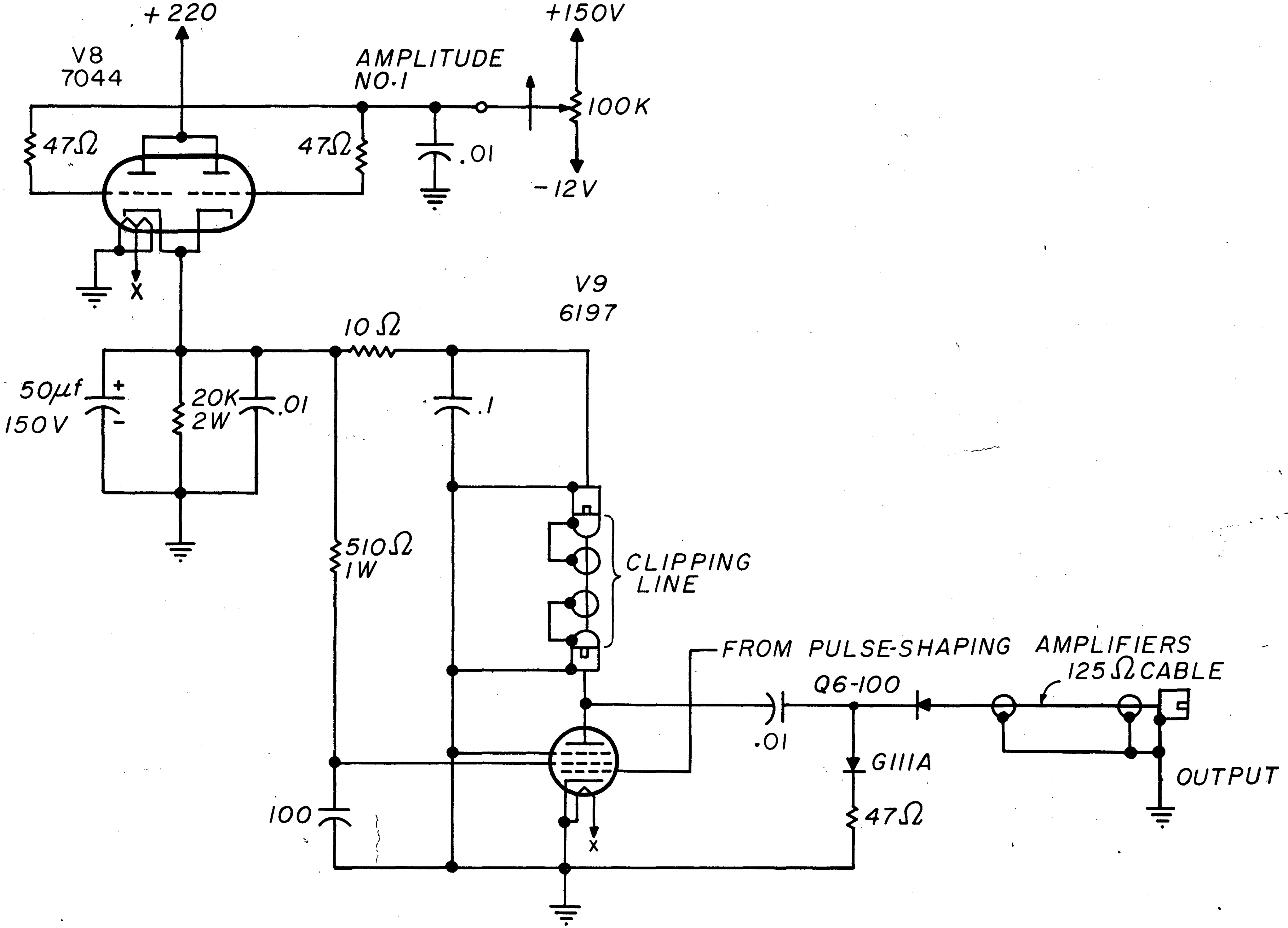

+220
V8
7044
47Ω
47Ω
AMPLITUDE
NO·1
.01
+150V
100K
-12V
X
V9
6197
10Ω
50μf
150V
+
-
20K
2W
.01
.1
510Ω
1W
CLIPPING
LINE
FROM PULSE-SHAPING AMPLIFIERS
125Ω CABLE
Q6-100
.01
G111A
47Ω
100
X
OUTPUT

Fig 9
55,386-2

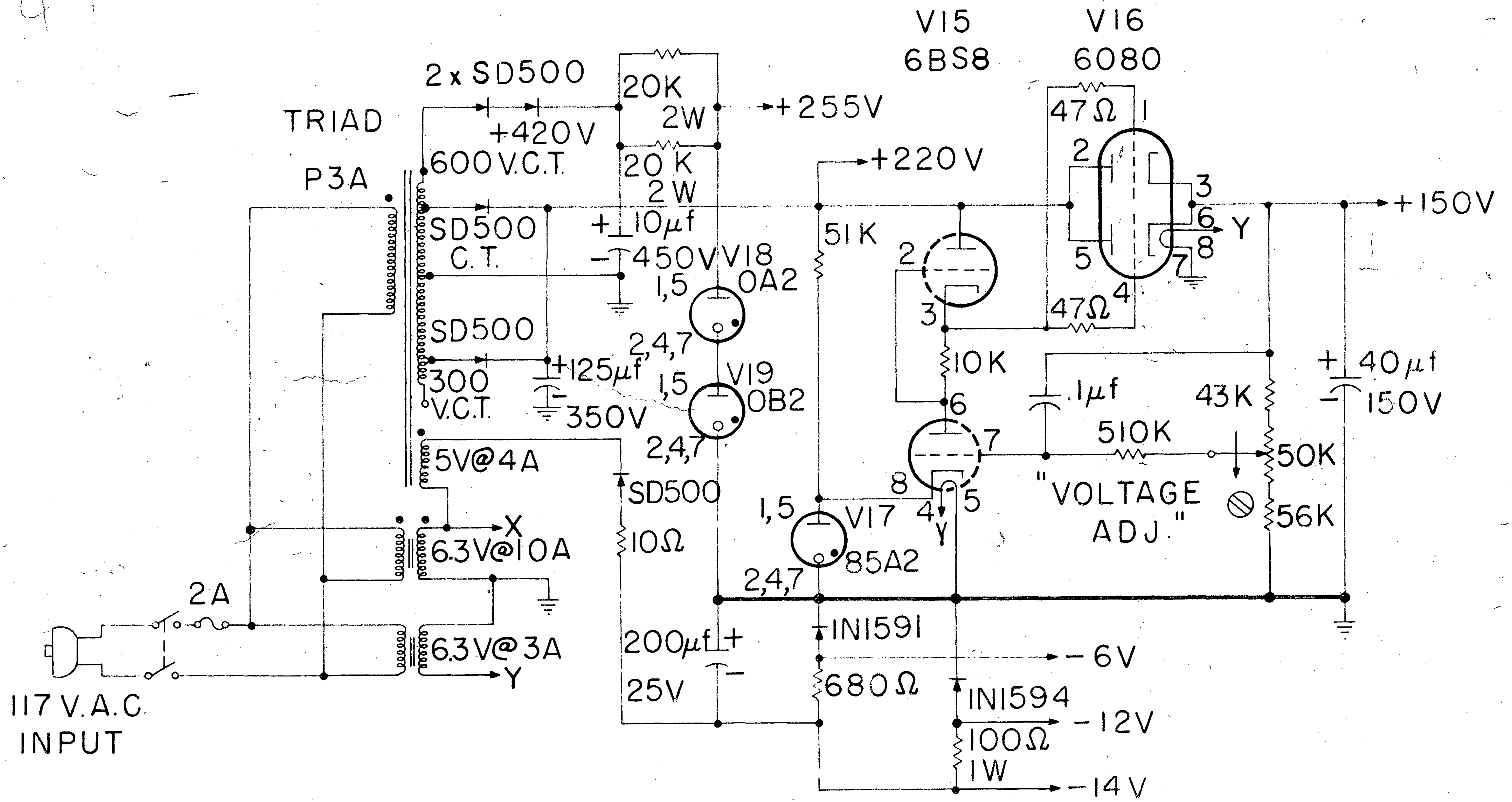


FIG 10
55162-2