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NRL REPORT 3569

FR-3569

SSD DUMMY SIGNAL AND NOISE GENERATOR

DECLASSIFIED: By authority of
NRL Classification Change Notice
No. 29-61 Dated 2 May 61
Dresda Jean Lambert 2028
Entered by NRL Code

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Date: 17 JAN 2017
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SSD DUMMY SIGNAL AND NOISE GENERATOR

Harry L. Clark

UNCLASSIFIED

October 18, 1949

Approved by:

Dr. J. A. Sanderson, Superintendent (Acting), Optics Division

NAVAL RESEARCH LABORATORY

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CONTENTS

ABSTRACT

The need for an artificial source of signal and noise which would simulate the actual output from a pulse-type thermal-radiation detector led to the development of the SSD Dummy Signal and Noise Generator. This unit generates positive and negative lobed pulses of proper shape, duration, and magnitude and thereby reproduces the behaviour of a thermal detector as it crosses a surface target at various ranges. Semiconductor noise of adjustable magnitude is generated and can be mixed with the signal in any proportion. Variable tuning is also provided. Signal-noise combinations are available up to 40 volts peak at a sufficiently low impedance to drive a chemical recorder.

PROBLEM STATUS

This report concludes the work on that phase of the problem assigned by the Bureau of Ships correspondence. The general problem of infrared detection is continuing as an NRL problem.

AUTHORIZATION

Problem No. N07-02R as modified by BuShips letter NObsr-42257, Serial No. 947-1160 dated 27 September 1948. (NE 120-711)

SSD DUMMY SIGNAL AND NOISE GENERATOR

INTRODUCTION

Thermal radiation or far infrared-detection systems being developed by the Navy fall into two categories. The first, the steady-state type, depends for its signal upon a steady interruption of the target radiation falling upon the detector element; the second, the pulse type, depends for its signal upon the occasional passage of the target's image across the detector element.

The steady-state type of detection system is represented by such units as the Navy's PBF (Passive Bearing Finder)[1] and PND (Portable Nan Detector)[2,3] whereas the pulse type of system is represented by a unit such as the SSD (Stabilized Ship Detector).[4,5]

Signal presentation in the steady-state type of system is simple and straightforward. The signal voltage is employed to frequency-modulate and/or amplitude-modulate a local oscillator and the resultant tone is presented aurally. Presentation of the signal pulses in the pulse-type of system is more difficult. Because the pulse repetition rate is so low, use cannot be made of any type of cathode-ray-tube presentation, such as is employed in radar systems, without a loss in signal-to-noise ratio due to the decay characteristic of the phosphor.[6] Other schemes are therefore employed.

For example, in the SSD, the signal generated by sweeping the optical system over the target (Figure 1a) consists of a single pulse with both positive and negative lobes (Figure 1b). During amplification this pulse is purposely modified and assumes the shape of a ram's head (Figure 1c). Application of the ram's-head pulse to the biased electrodes of a chemical recorder produces a black and-white spot (Figure 1d) on a normally grey trace on the recorder paper. The intensity distribution in the spot is determined by the amplitude distribution in the pulse and its position across the paper is determined by the bearing of the target. As successive sweeps are made across the target, successive traces are

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[1] *BuShips Instruction Manual for Passive Bearing Finder (Confidential), NObs-21176.*

[2] *Becker, J. A., et al., Portable Nan Detector or PDN Model 3, OSRD 4168, 29 May 1944.*

[3] *NDRC, Div. 16, Summary Technical Report, Vol. 3, Nonimage Forming Infrared, pp. 290-2[illegible] , 1946 (Confidential).*

[4] *Stabilized Ship Detector (SSD), OSRD 5985, 31 December 1945.*

[5] *NDRC, Div. 16, Summary Technical Report, Vol. 3, Nonimage Forming Infrared, pp. 332-345, 1946 (Confidential).*

[6] *A storage tube similar to the Haeff tube would be satisfactory if a greater range in writing intensities were available.*

put on the recorder paper, one below the other. The result is a sharply defined trace representing the target's course (Figure 2). Noise likewise appears on the recorder paper but is randomly distributed. Because of the orderly arrangement of target signals on the recorder paper and the disorder of the noise, signals whose peak magnitude is as small as 1/4 the peak magnitude of the noise can be observed. Thus this method of signal presentation improves the signal-to-noise ratio considerably.

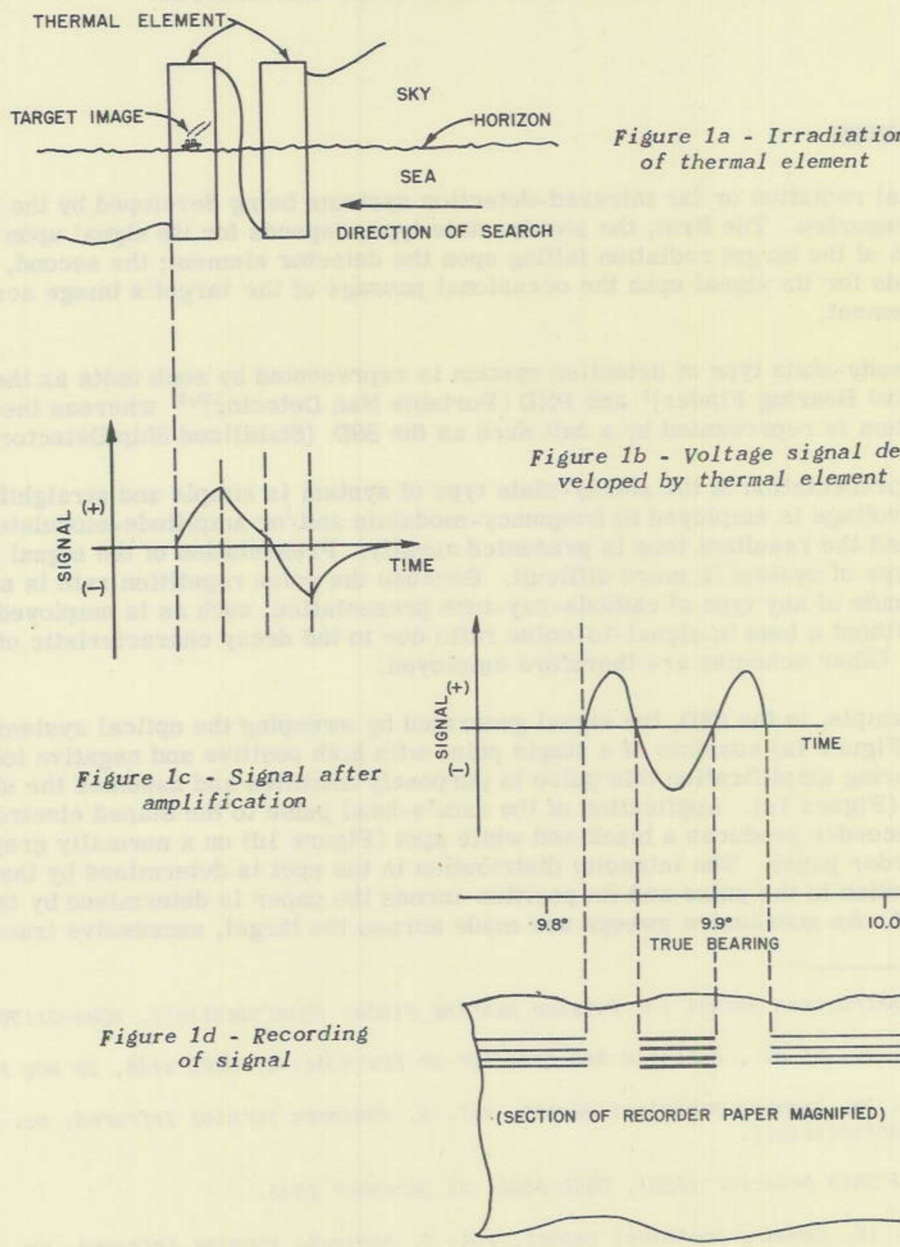

Figure 1a - Irradiation of thermal element

Figure 1b - Voltage signal developed by thermal element

Figure 1c - Signal after amplification

Figure 1d - Recording of signal

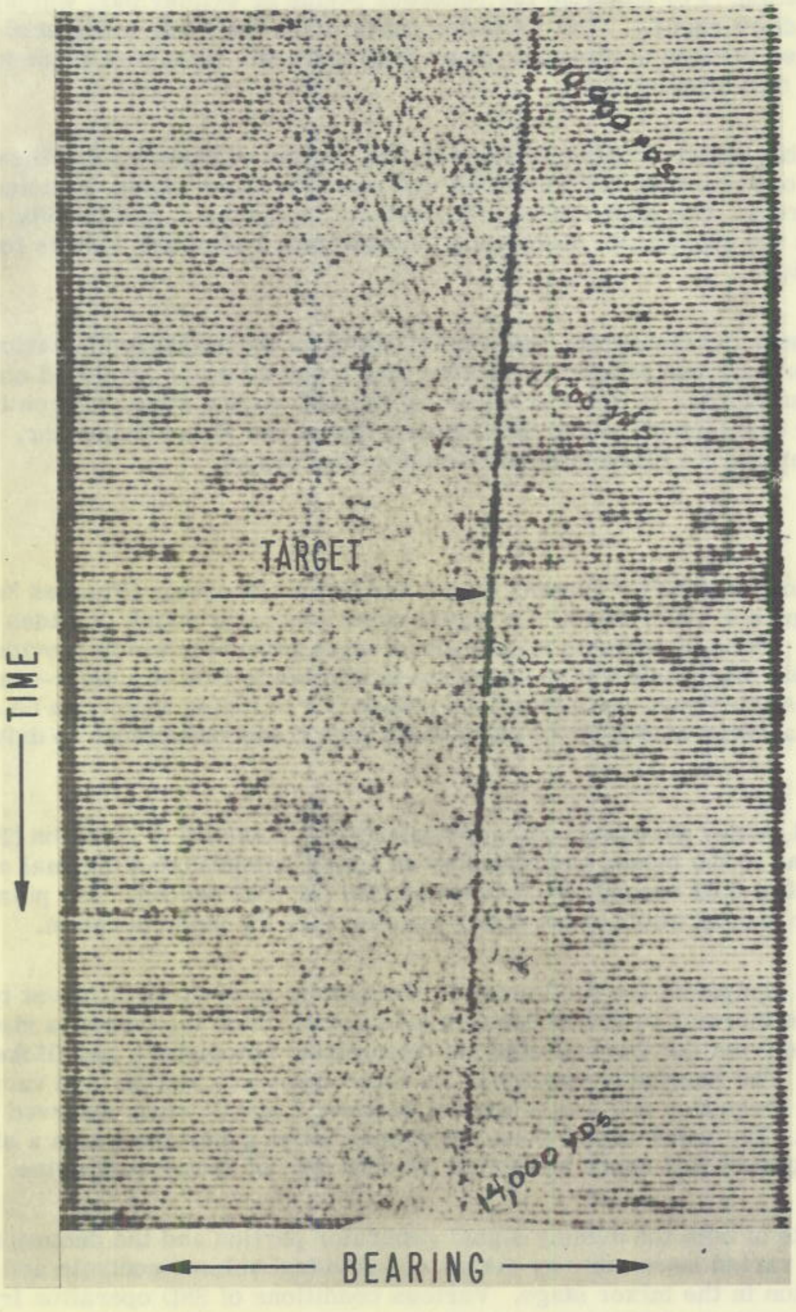

Figure 2 - Typical SSD recording

Certain practical difficulties, however, are associated with the chemical method of signal presentation. For example the recorder stylus or printer bar, whichever is employed, wears down rapidly. The recorder paper dries out while being used and deteriorates during prolonged periods of storage. Some improvements have been made in the recorder paper but it is still troublesome.

Considerable effort is being directed by the Bureau of Ships toward the development of other types of recording devices which will yield the same signal-to-noise ratio as the chemical recorder. One such device, for example, employs a multiplicity of magnetic tapes on which the signals are stored and incorporates a playback feature for cathode ray tube presentation.

In all of these developments, the need to simulate the shipboard behaviour of the SSD within the laboratory had arisen. A system was required which produced controllable signal and noise similar to those produced by the SSD during actual search operation. This led to the development of the SSD Dummy Signal and Noise Generator. A description of the generator and its function is presented in this report.

FUNCTIONS

The functions of the SSD Dummy Signal and Noise Generator (Figures 3a and 3b) are depicted in Figure 4. It consists of a signal pulse generator which provides positive and negative lobed pulses of variable magnitude; a noise generator which provides low-frequency noise of variable magnitude whose spectrum is similar to that of a semi-conductor; a mixer which combines the signal and noise; four stages of r-c tuning which can be switched in one at a time; and a power amplifier of sufficiently high transconductance to drive a chemical recorder.

The signal pulses generated are approximately 0.1 second in duration (Figure 5). They correspond to the pulses generated by an actual compensated thermal element with a time constant of 0.02 second which is irradiated for 0.02 second. The pulse repetition rate is one per second which is ten times greater than the pulse duration.

In the SSD equipment the total noise in the system is of three different types, "optical noise" from the thermal radiation background against which the target is viewed, semi-conductor noise from the thermal element (thermister bolometer), and flicker noise from the input tube. The frequency spectra of all three types are similar and vary as $1/f^n$ (where f is the frequency and n is a number between 1 and 2) when observed with a constant unit bandwidth. The noise output from the dummy noise generator bears a similar relationship to the frequency and hence simulates the SSD type of background noise.

The outputs of both the dummy signal generator portion and the dummy noise generator portion can be varied separately by means of individual volume controls and can be mixed in any proportion in the mixer stage. Various conditions of SSD operation from that of scanning over a target at close range to that of operating at threshold range and beyond can therefore be reproduced.

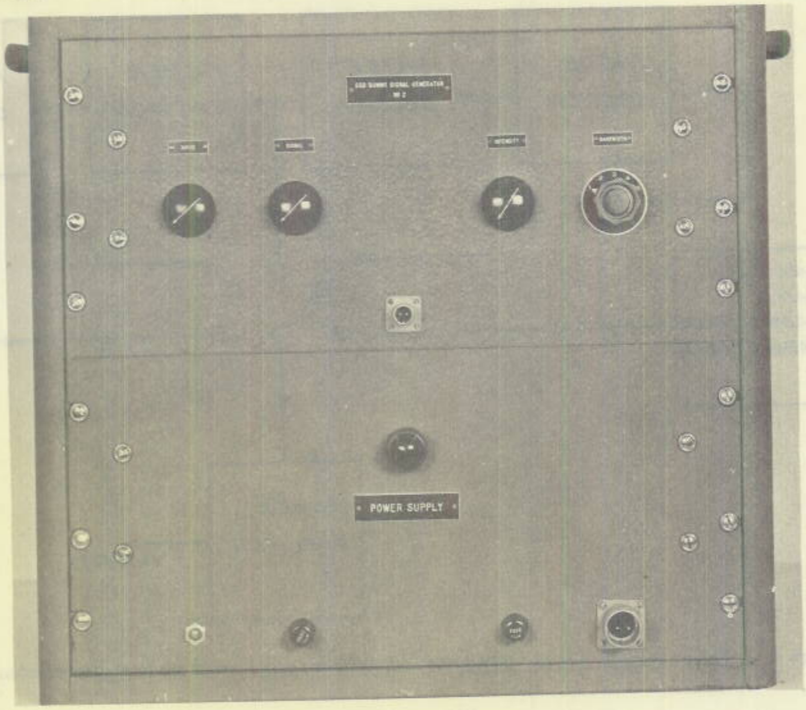

Figure 3a - SSD dummy signal and noise generator (front view)

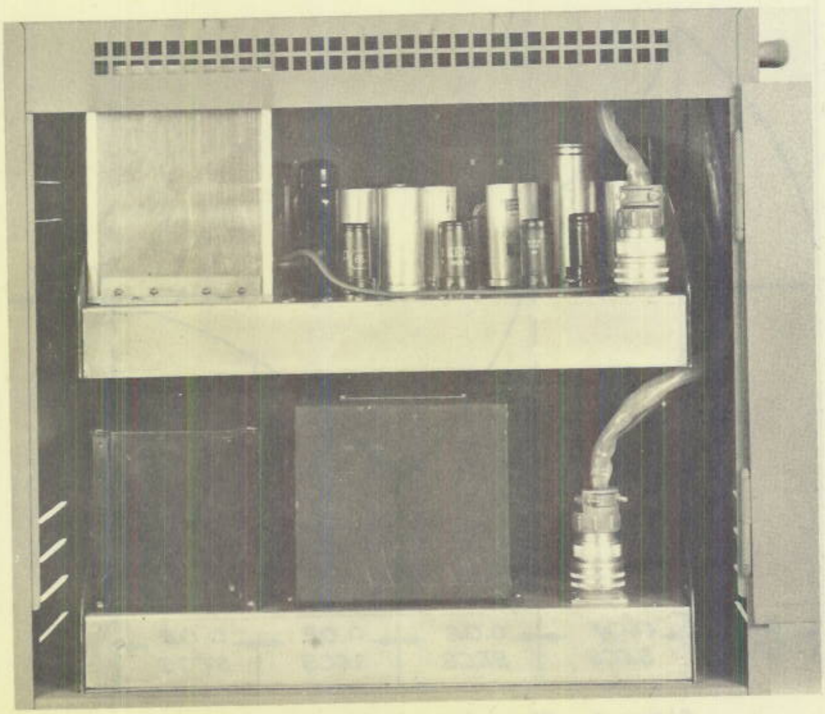

Figure 3b - SSD dummy signal and noise generator (rear view)

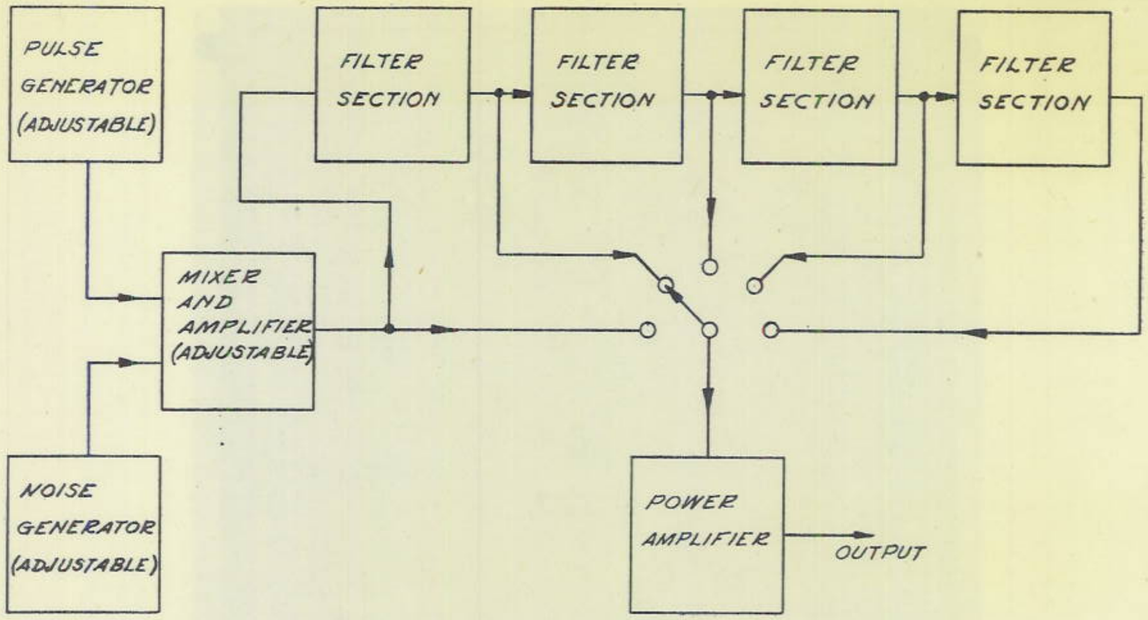

Figure 4 - Functional block diagram of SSD signal and noise generator

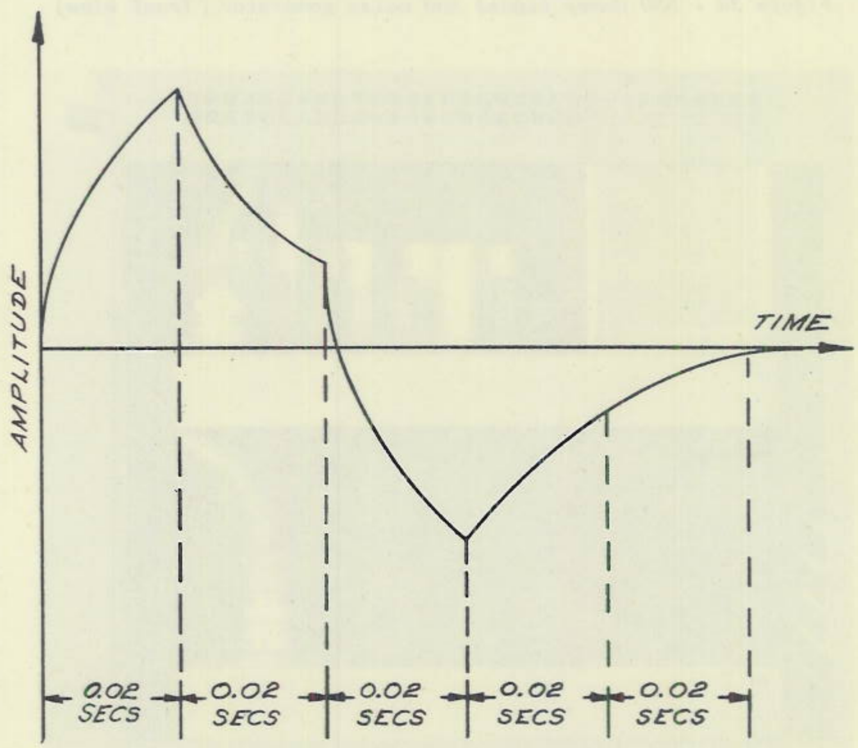

Figure 5 - Character of signal pulses generated by dummy signal generator

Four identical stages of tuning which can be switched in or out one or more at a time provide a means for observing the effect of various bandwidths on the signal-to-noise ratio, signal definition, and target bearing at the recorder. Typical results are shown in Figures 6a and 6b through Figures 10a and 10b. In Figure 6a, the signal output of the entire equipment is compared with the signal produced by the signal generator portion in the absence of tuning and noise. Figure 7a shows the effect of one stage of tuning; Figure 8a, two stages; Figure 9a, three stages; and Figure 10a, four stages. A similar set of comparisons is made for the noise. In Figure 6b, the noise output of the entire equipment is compared with the noise produced by the noise generator portion in the absence of tuning and a signal. Figure 7b shows the effect of one stage of tuning; Figure 8b, two stages; Figure 9b, three stages; and Figure 10b, four stages. Figure 11 shows a typical combination of signal and noise before and after one stage of filtering.

The magnitude of the signal and noise combination observed at the output of the entire equipment is also variable. A maximum peak output of 40 volts across a 1000-ohm load is available with lesser amounts for smaller load resistances. The maximum peak no-load output is 100 volts.

CIRCUIT CHARACTERISTICS

The wiring diagram of the SSD Dummy Signal Noise Generator and its power supply are shown in Figures 12 and 13. Component layouts for the generator section are shown in Figures 14a and 14b and those for the power supply are shown in Figures 15a and 15b.

Generation of the signal pulses is accomplished with a mechanical shutter-lamp-photocell combination (Figures 16a and 16b). The shutter is driven at 60 rpm in front of a 1″ x 1/16″ uniformly illuminated slit. The resulting variations in light appear as voltage pulses of the desired shape and duration at the output terminals of the photocell. Illumination of the slit is provided by a d-c 110-volt lamp operating behind a ground-glass screen. Pulses of other shapes or durations may be obtained by employing different shutters.

A germanium-crystal diode operating with a +6-volt bias is employed to generate noise. Because it is a semiconductor, its noise spectrum is very similar to spectra of the various noises in the SSD system.

Mixing of the signal and noise is done in the conventional manner with a twin triode. Since volume controls in the output portions of the signal generator and of the noise generator allow a wide variation in signal and noise magnitudes, the proportion in which the signal and noise are mixed is also variable.

The signal-noise combination resulting from the mixing is amplified and then presented to the filter section. The magnitude of the combination can be varied by means of a third volume-control located immediately after the amplifier stage.

Variable filtering of the signal-noise combination is accomplished with four identical pentode stages employing identical r-c tuning in each stage. The response characteristic of each stage is given by curve B in Figure 17. The result of employing any or all of the stages in tandem is also shown in Figure 17. Thus A represents the frequency response of the system with no tuning; curve B, with one stage; curve C, with two stages; curve D, with three stages; and curve E, with four stages.

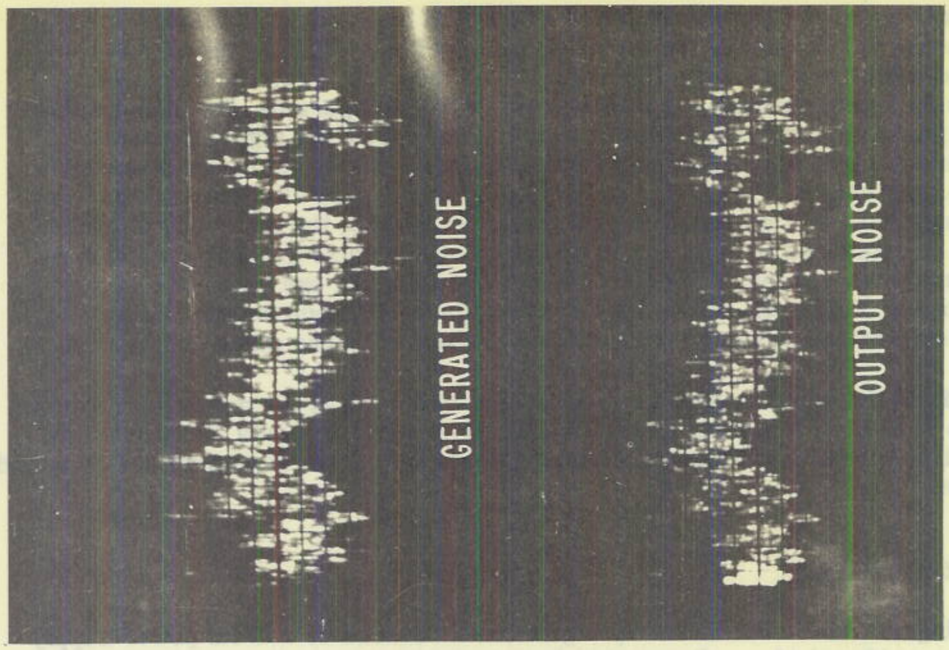

Figure 6b - Noise with no tuning

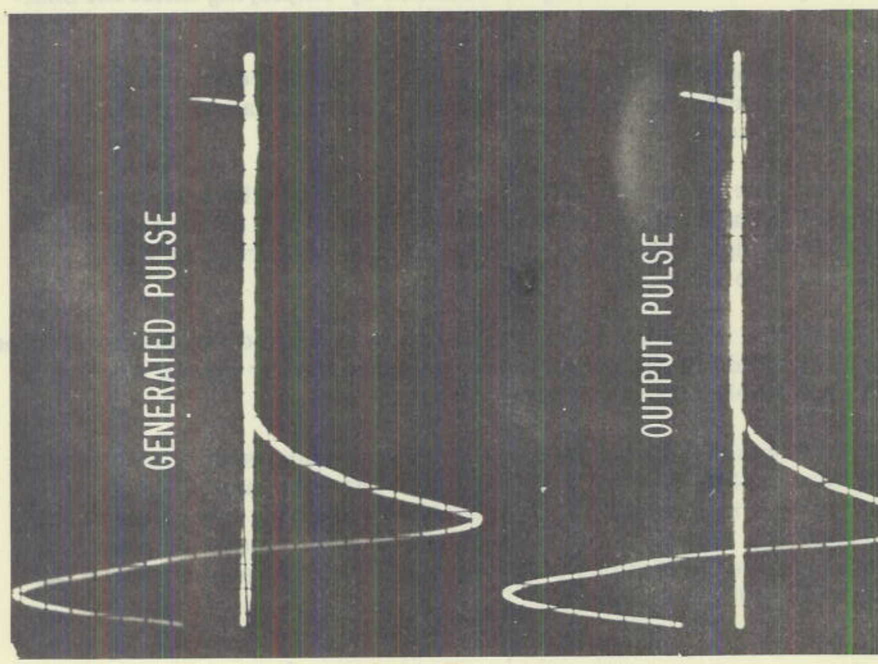

Figure 6a - Signal pulse with no tuning

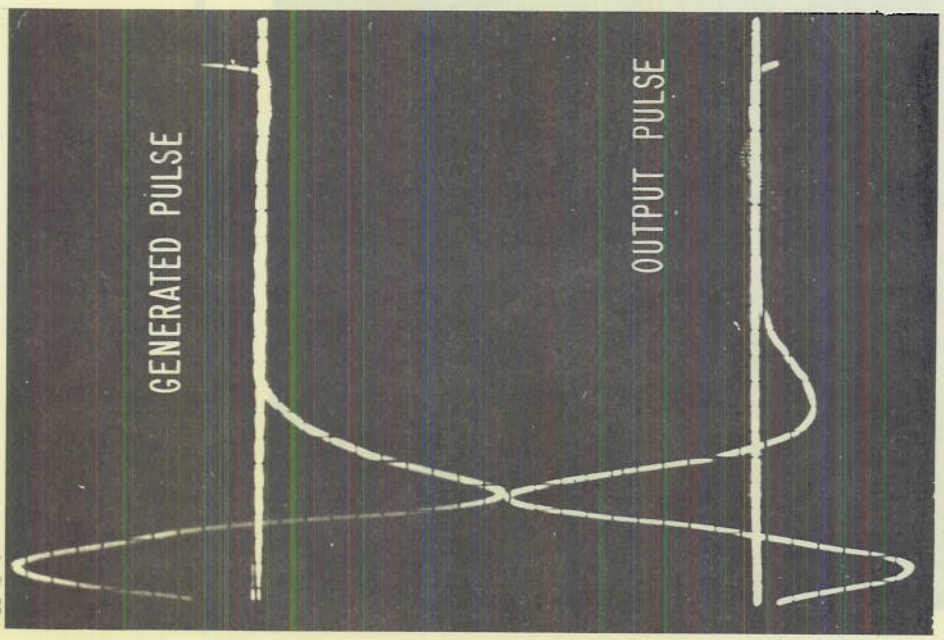

Figure 7a - Signal pulse with one stage of tuning

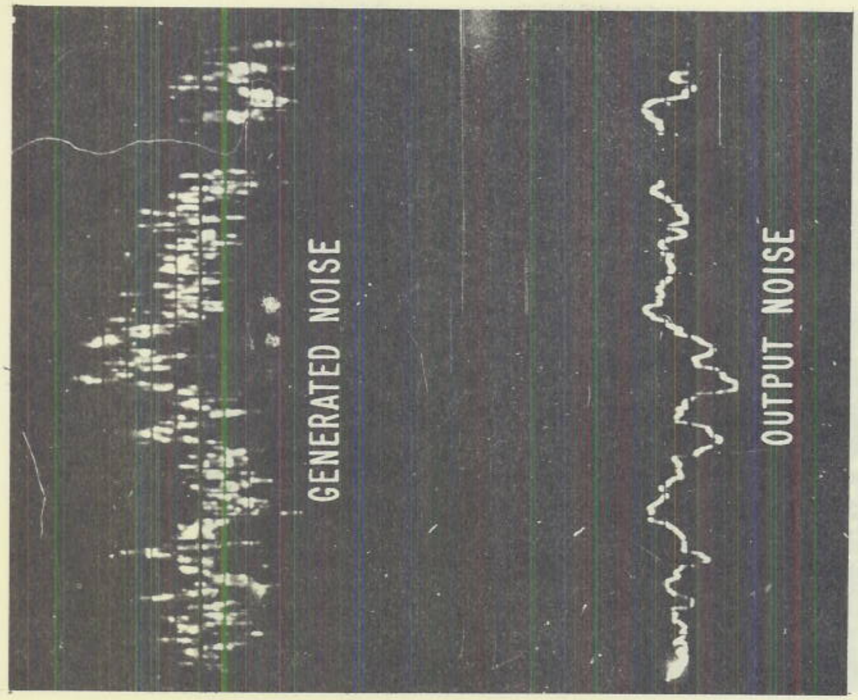

Figure 7b - Noise with one stage of tuning

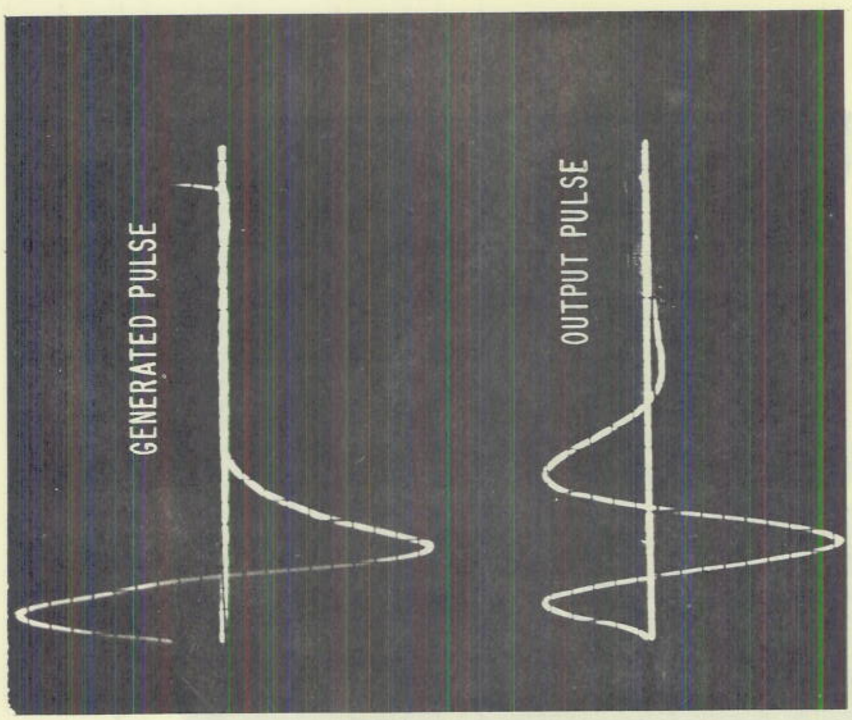

Figure 8a - Signal pulse with two stages of tuning

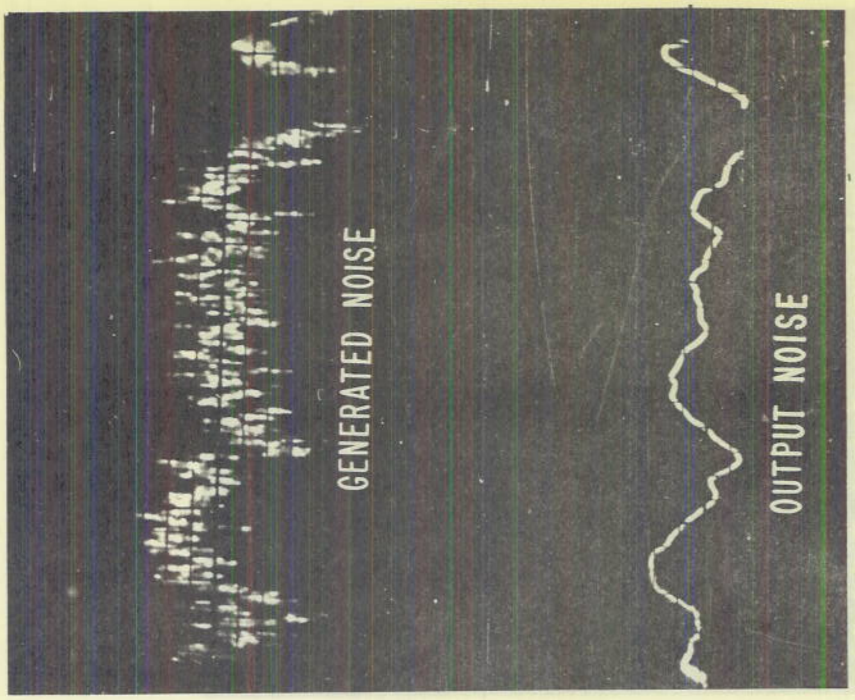

Figure 8b - Noise with two stages of tuning

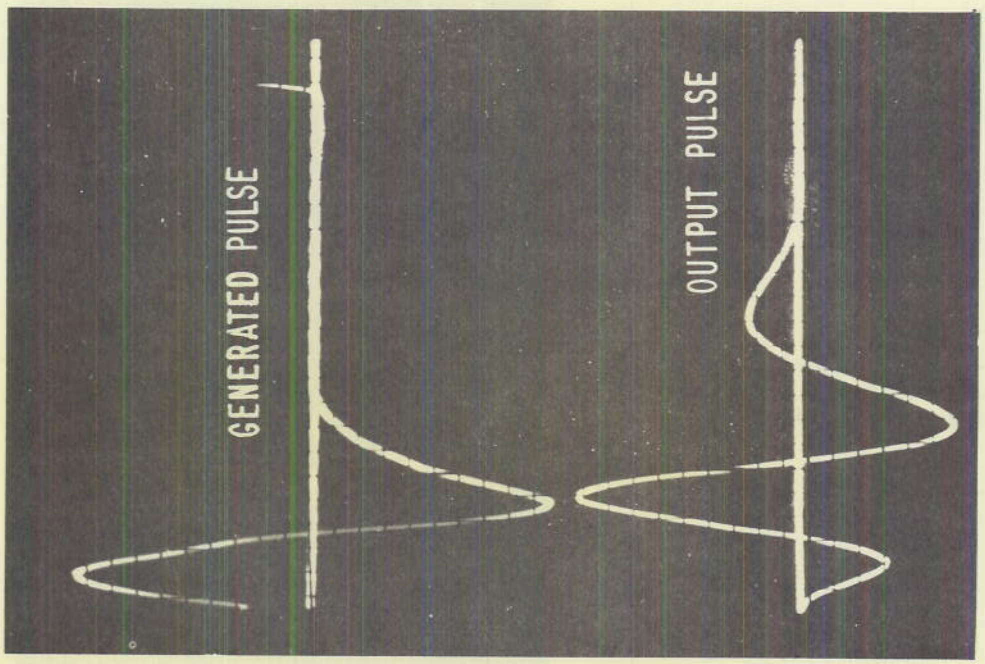

Figure 9a - Signal pulse with three stages of tuning

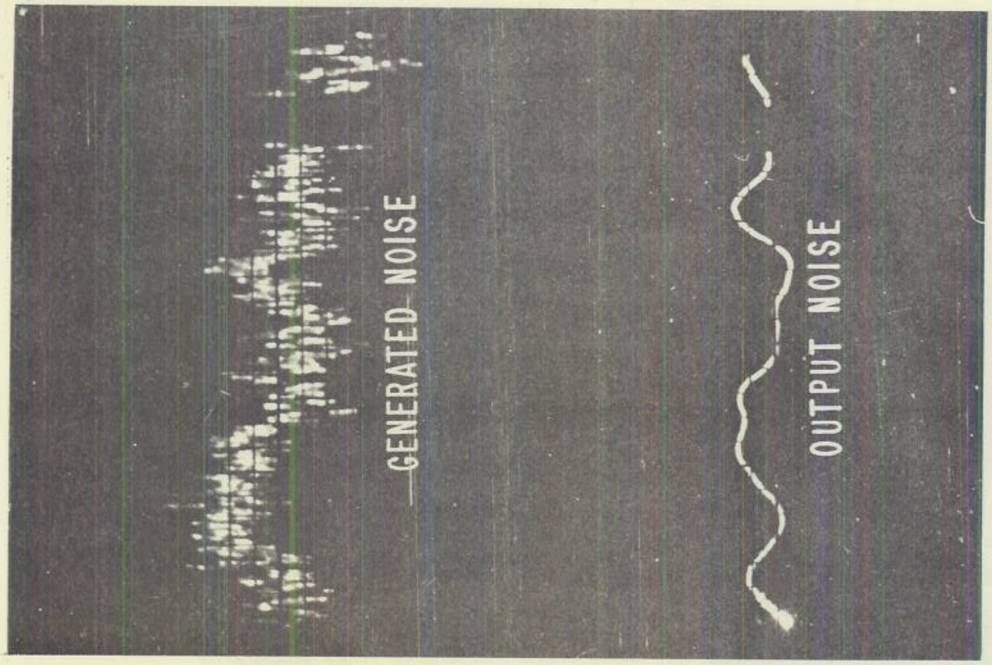

Figure 9b - Noise with three stages of tuning

[redacted]

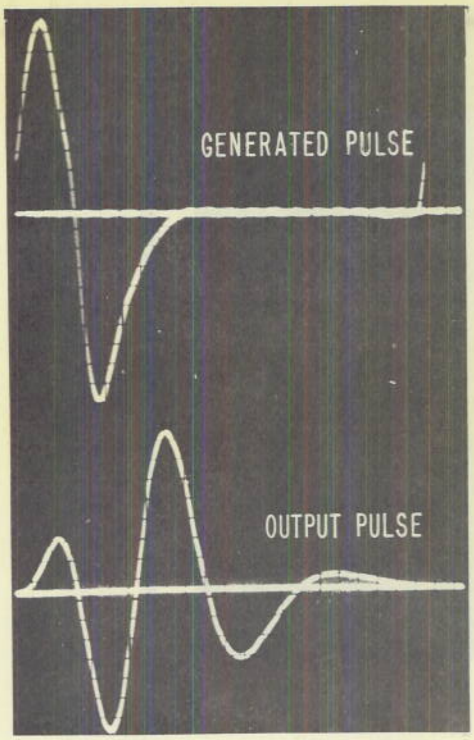

Figure 10a - Signal pulse with four stages of tuning

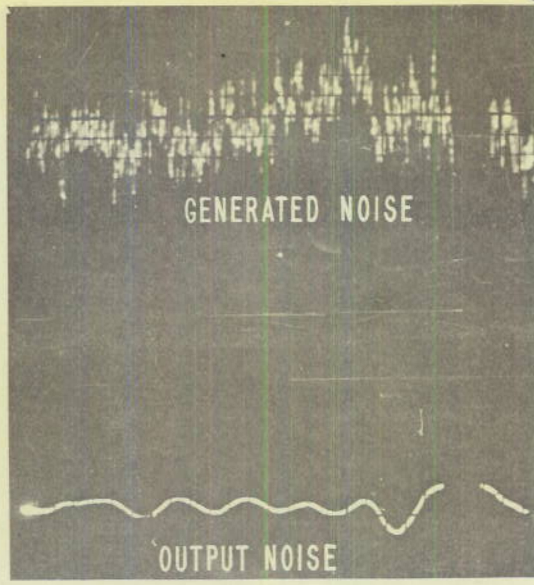

Figure 10b - Noise with four stages of tuning

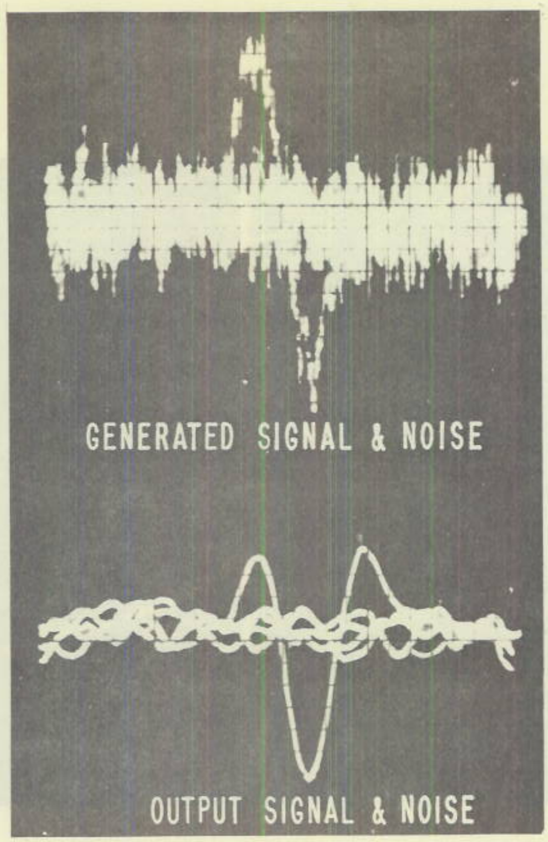

Figure 11 - Typical signal and noise combination before and after one stage of filtering

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[redacted]

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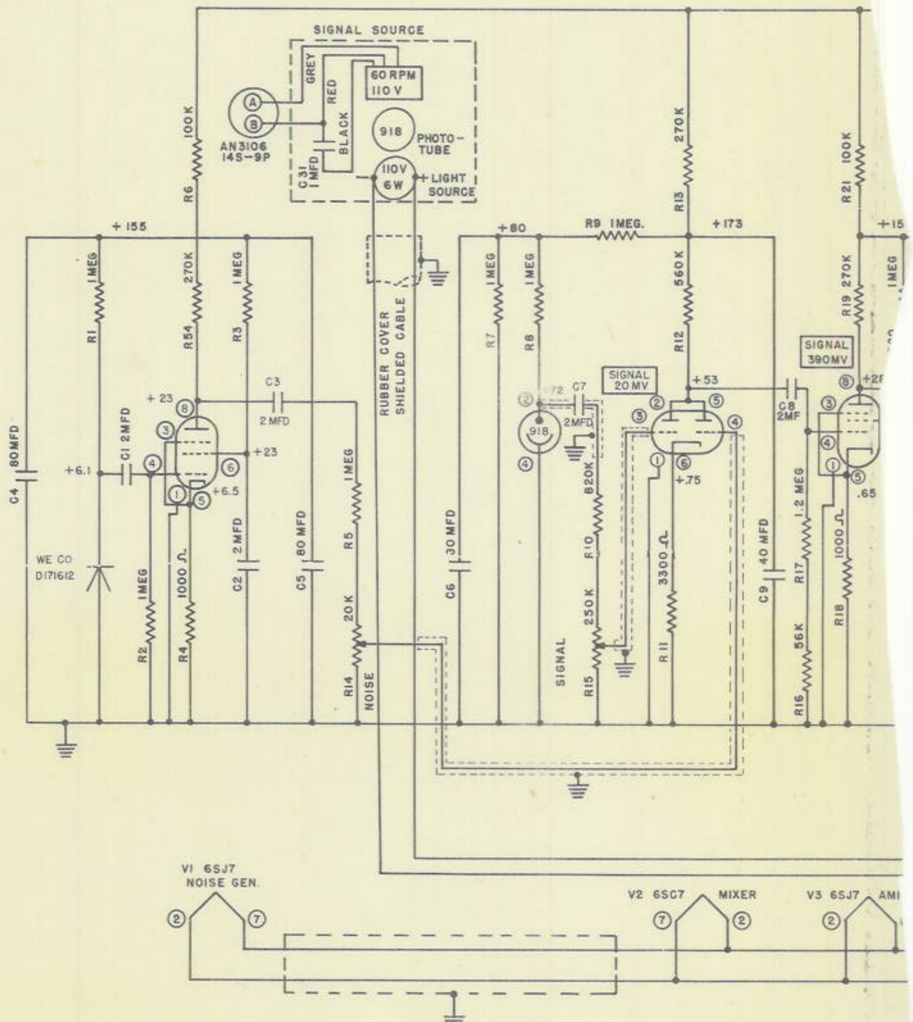
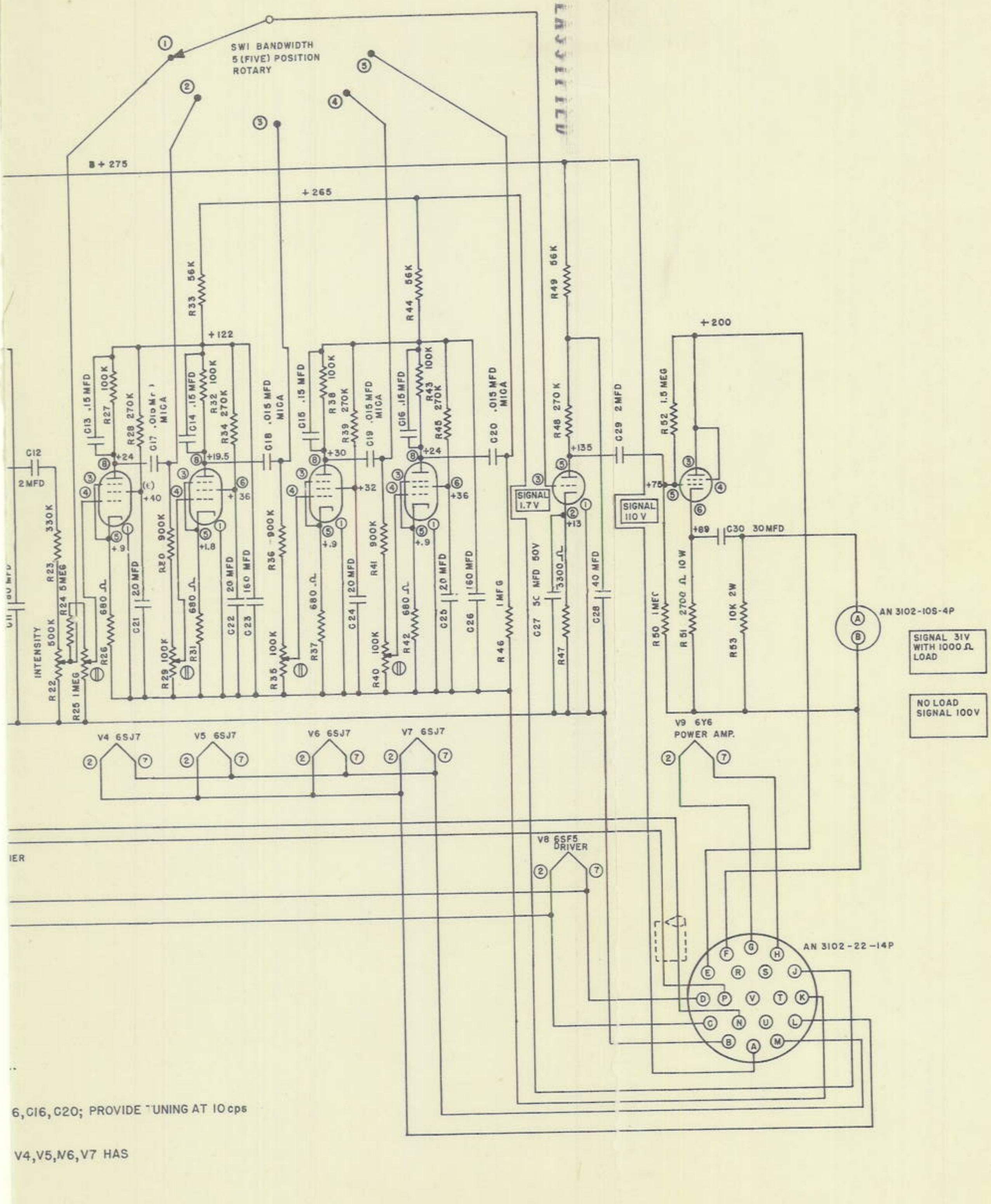


NOTES

1. SYMBOL ⦶ SIGNIFIES SCREW DRIVER ADJUSTMENT. (SEE NOTE (SIX)6)
2. (B-) IS GROUNDED AT ONE POINT ONLY NEAR THE NOISE GEN. TUBE V1-6SJ7.
3. CRYSTAL DIODE USED FOR NOISE SOURCE IS INSTALLED IN NONCONDUCTING POSITIO
4. ALL RESISTORS 1(ONE) WATT EXCEPT WHERE SPECIFIED
5. V4-R27,R29,R30,C13,C17, V5-R32,R35,R36,C14,C18; V6-R38,R40,R41,C15,C1; V7-R43,R
   AND ARE SELECTED WITH ± 1% OF STATED VALUES.
6. LOCKING TYPE POTENTIOMETER R25,R29,R35,R40 ARE ADJUSTED SO EACH STAGE
   UNITY GAIN AS OBSERVED AT SWITCH TAPS 2,3,4,5.
7. VALUES OF SIGNAL VOLTAGE ARE rms WITH A STEADY SINEWAVE SIGNAL APPLIED.

Figure 12 - Wiring diagram of S

[redacted]



6,C16,C20; PROVIDE TUNING AT 10cps

V4,V5,N6,V7 HAS

SD dummy signal and noise generator


R20
C10
2 MFD
PLIF

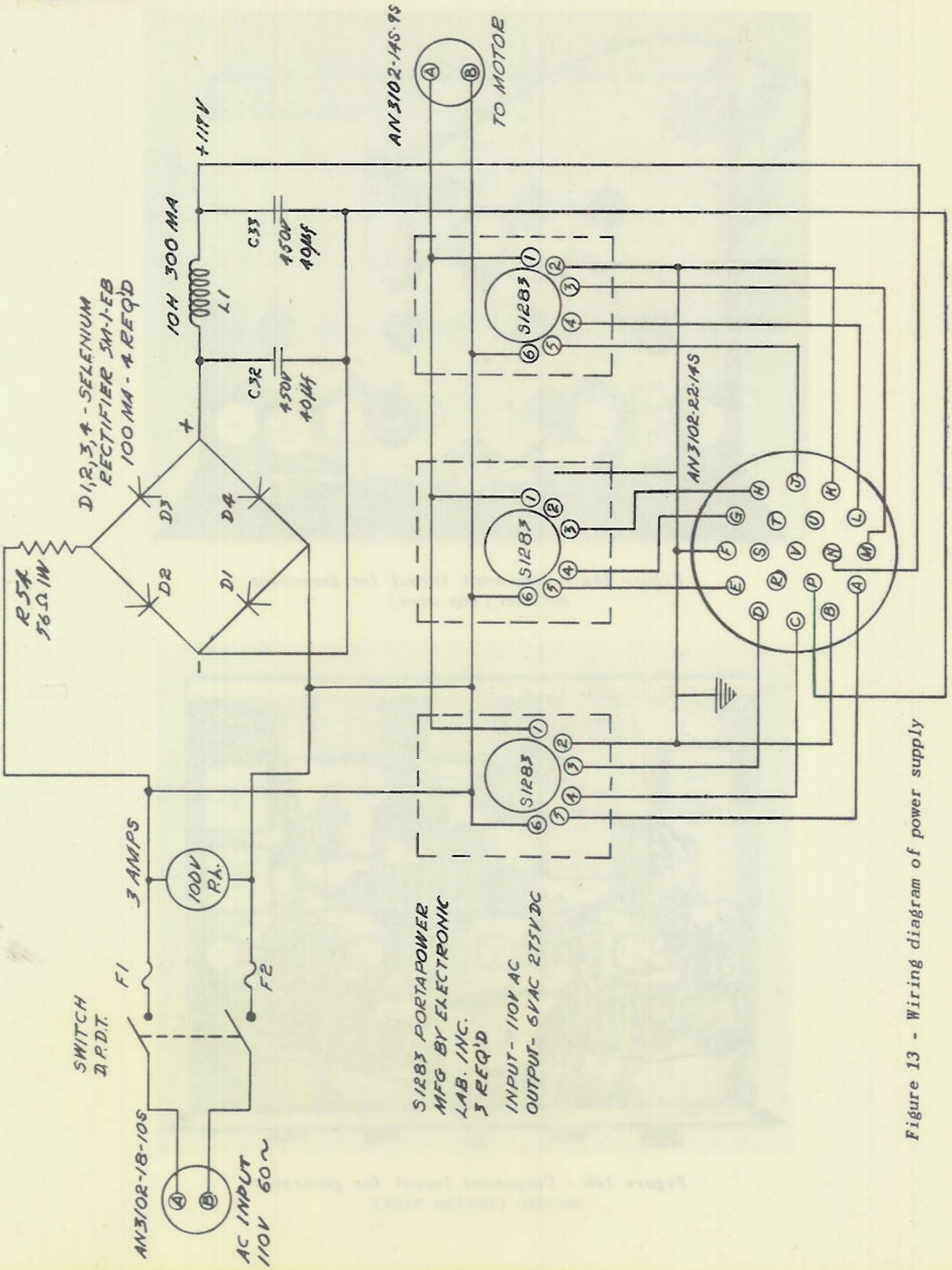


Figure 13 - Wiring diagram of power supply

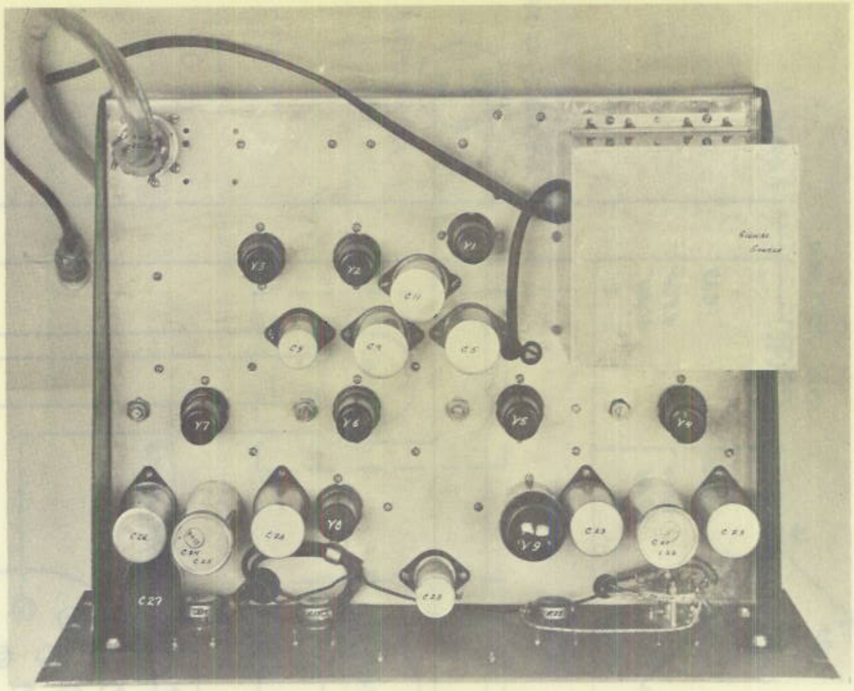


Figure 14a - Component layout for generator section (top view)

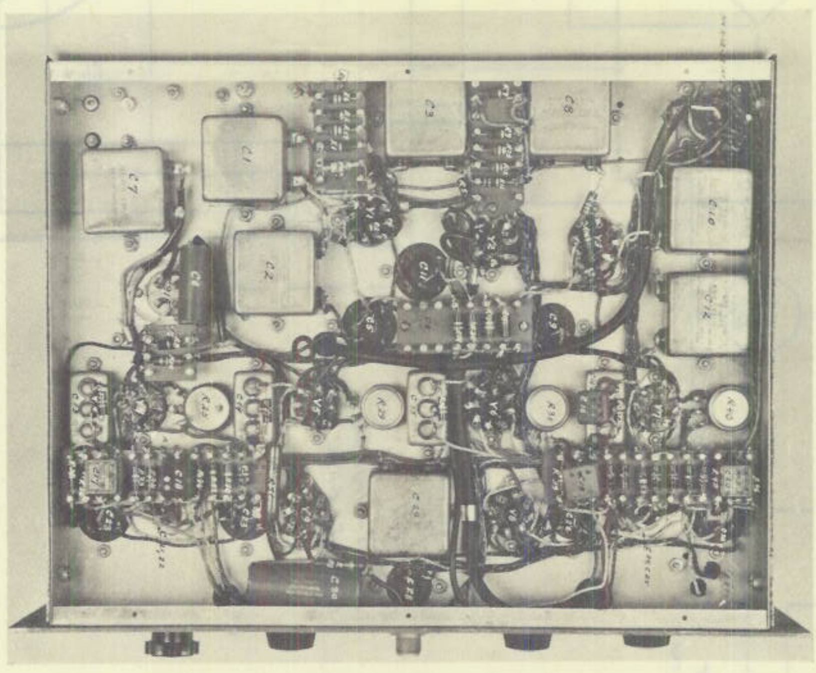


Figure 14b - Component layout for generator section (bottom view)

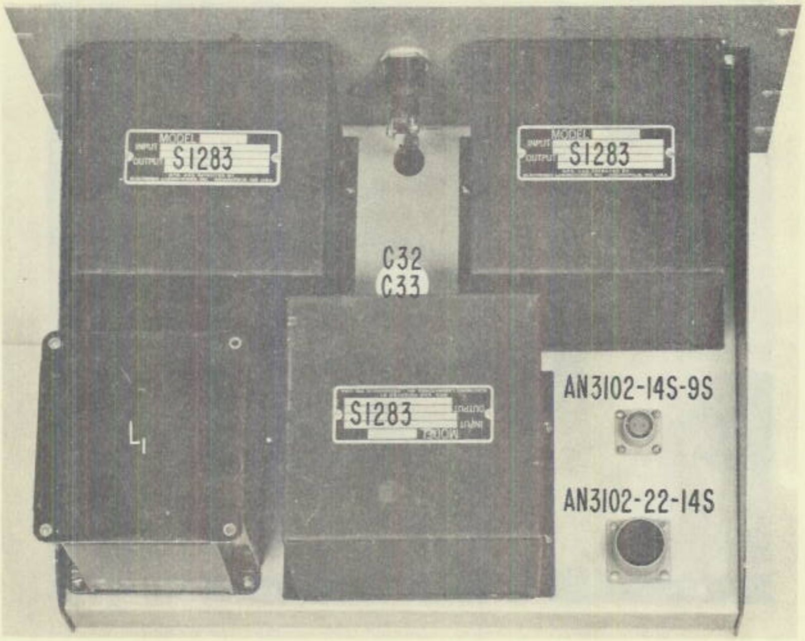


Figure 15a - Component layout for power supply (top view)

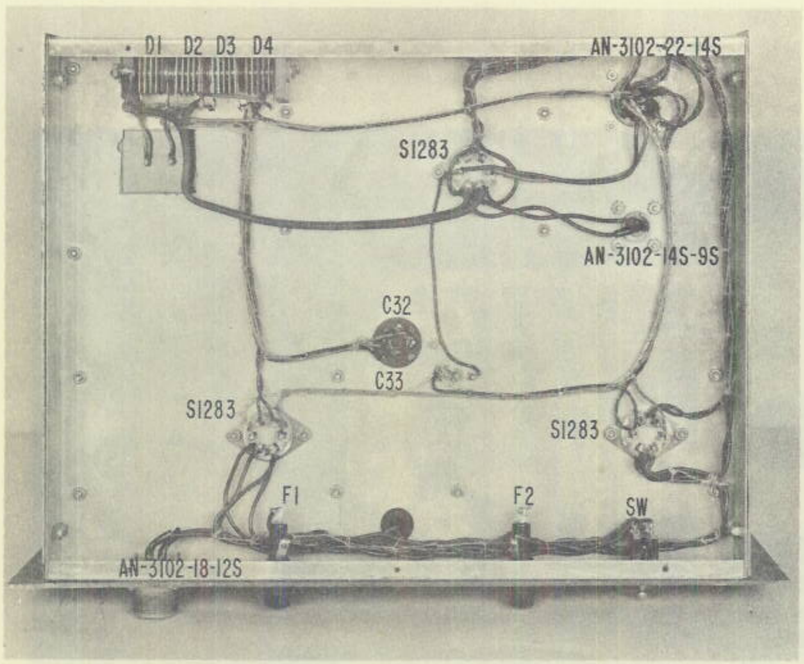


Figure 15b - Component layout for power supply (bottom view)

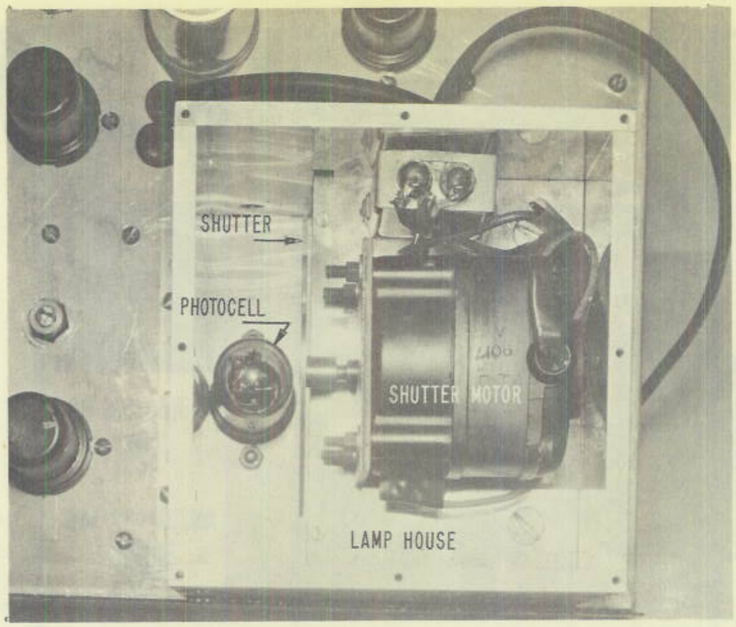


Figure 16a - Signal generator (cover removed)

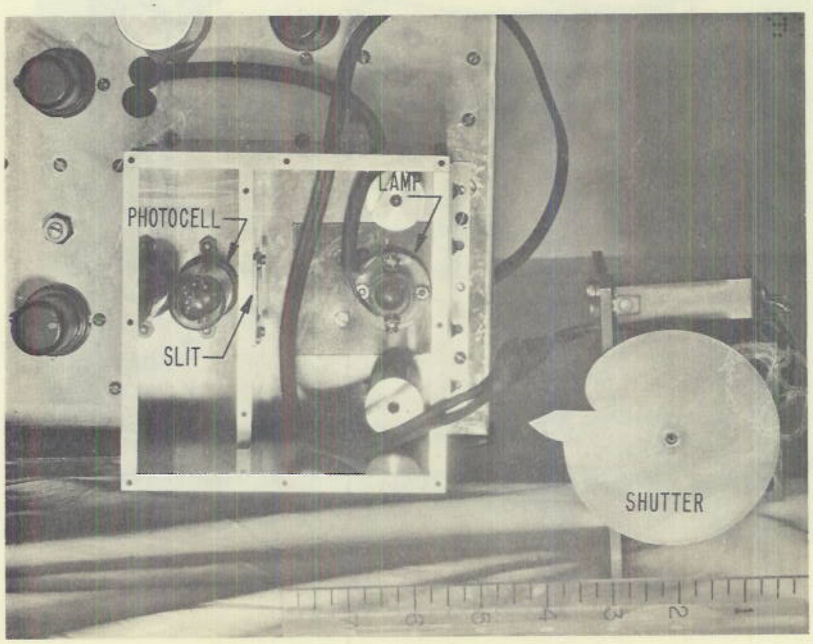


Figure 16b - Signal generator (shutter motor removed)

STAGE OF TUNING	CURVE NO.	SWITCH POSITION
0	A	1
1	B	2
2	C	3
3	D	4
4	E	5

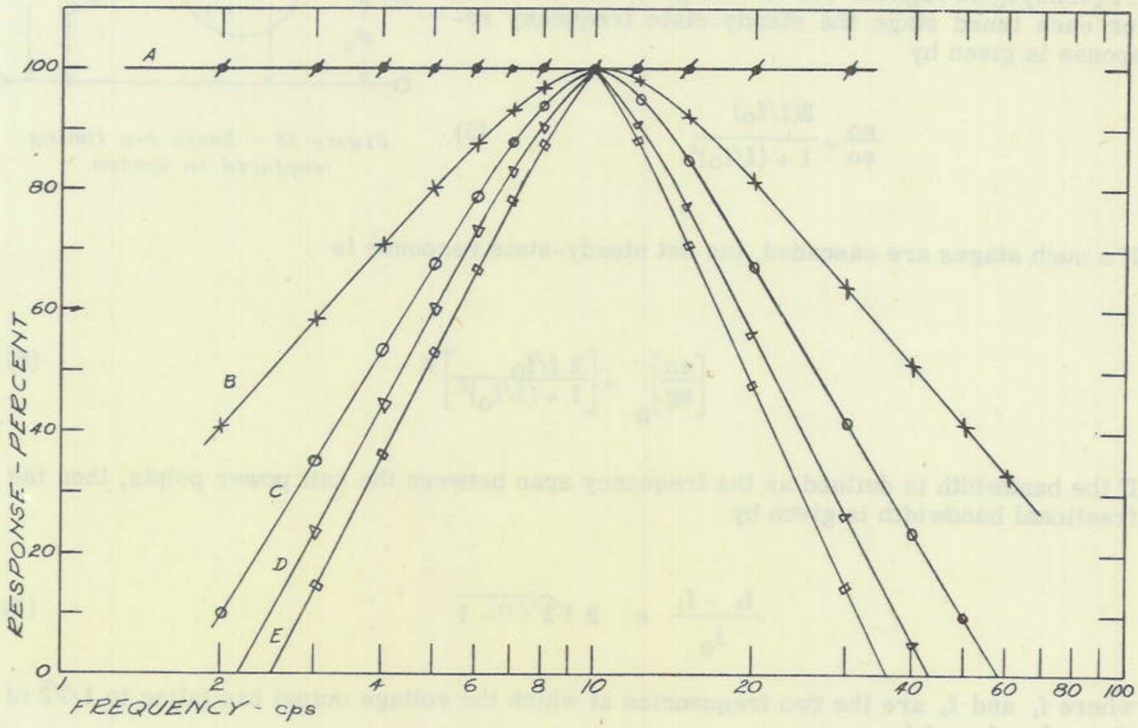


Figure 17 - Frequency characteristics of the system

R-C tuning of this type is illustrated by the simplified diagram of Figure 18.

If

$$R_g \geq 10\, R_L \tag{1}$$

and

$$R_g C_g = R_L C_L \tag{2}$$

then the frequency of peak response, f_o, is

$$f_o = \frac{1}{2\pi \sqrt{R_g C_g R_L C_L}} = \frac{1}{2\pi R_g C_g} = \frac{1}{2\pi R_L C_L} \tag{3}$$

and the steady-state response at any frequency, f, is

$$\frac{eo}{eg} = R_L g_m \frac{(f/f_o)}{1 + (f/f_o)^2} \qquad (4)$$

where g_m is the transconductance of the pentode. In this application, the over-all steady-state gain of each single-tuned stage is made equal to unity at the peak frequency f_o through the use of voltage dividers. Thus for each tuned stage the steady-state frequency response is given by

$$\frac{eo}{eo} = \frac{2(f/f_o)}{1 + (f/f_o)^2} \qquad (5)$$

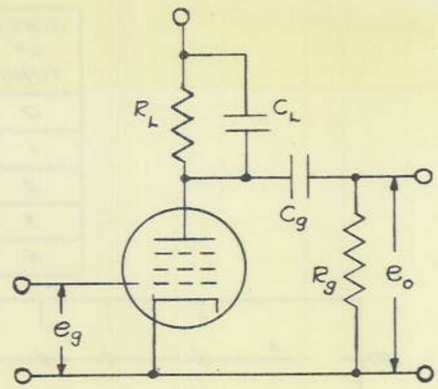


Figure 18 - Basic r-c tuning employed in system

If n such stages are cascaded, the net steady-state response is

$$\left[\frac{eo}{eg}\right]_n = \left[\frac{2\, f/f_o}{1 + (f/f_o)^2}\right]^n \qquad (6)$$

If the bandwidth is defined as the frequency span between the half power points, then the fractional bandwidth is given by

$$\frac{f_2 - f_1}{f_o} = 2\sqrt{2^{1/n} - 1} \qquad (7)$$

where f_1 and f_2 are the two frequencies at which the voltage output has fallen to $1/\sqrt{2}$ of its peak value at f_o.

In the event that the shape of the mechanical shutter is changed so that pulses of durations other than 0.1 second are provided, the tuning in the four tuned-stages should also be changed. If the new pulse has a positive and negative lobe and is of duration T_2, the new peak frequency is given by

$$\text{(pos. plus neg. lobe)} \qquad f_o \approx \frac{1}{T_2} \,. \qquad (8)$$

On the other hand, if the pulse has only a single positive or negative lobe and is of duration T_1, the new peak frequency is given by

$$\text{(pos. or neg. lobe)} \qquad f_o \approx \frac{1}{2T_1} \,. \qquad (9)$$

The peak frequency can be changed by altering the values of C_{13}, C_{14}, C_{15}, C_{16} and C_{17}, C_{18}, C_{19}, C_{20} (Figure 12) in accordance with equation (3). The values of the plate-load resistances and grid-leak resistances should not be altered. In later models of this equipment (SSD Dummy Signal Generator No. 3), the tuning condensers for each stage are mounte in a can which can be plugged into the circuit from the top of the chassis. Such an arrangement obviates the necessity of changing soldered connections.

After passing through the filter sections the signal-noise combination is further amplified and is then applied to the grid of a cathode follower. The output of the cathode follower is coupled to the system's load, which might be an indicating device or recorder under test, by a 30 mfd electrolytic condenser. Large external voltages placed across the output terminals of system should therefore be avoided.

The system's power supply consists of four separate units. One unit supplies d-c voltage to the lamp in the pulse generator section. A second unit provides plate and filament voltages for all tubes in the pulse generator section, noise generator section, and mixer-amplifier section. A third unit provides plate and filament voltages to all tubes in the filter sections. The fourth unit provides similar voltages to the cathode follower and its driver. The entire system operates from a 110-volt, 60-cps, single-phase line with a current drain of less than 3 amperes.

APPLICATIONS

The SSD Dummy Signal and Noise Generator has been utilized extensively in this Laboratory for checking the performance of pulse amplifiers employed in various experimental thermal-detection systems.

One unit was used extensively by the Alden Products Co. of Brockton, Mass. during their work on chemical recorder papers for the Bureau of Ships.

Another unit is now being employed by the Armour Research Foundation of Chicago for checking signal-to-noise ratios of a multiple magnetic-tape recorder being developed for the Bureau of Ships for use in the SSD system.

Other units are being used for experimental work by the Underwater Sound Laboratory of New London in conjunction with their infrared program.

ACKNOWLEDGMENT

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in a can which can be plugged into the circuit from the top of the chassis. Such an arrangement obviates the necessity of changing soldered connections.

After passing through the filter sections the signal-noise combination is further amplified and is then applied to the grid of a cathode follower. The output of the cathode follower is coupled to the system's load, which might be an indicating device or recorder under test, by a 50 mfd electrolytic condenser. Large external voltages placed across the output terminals of system should therefore be avoided.

The system's power supply consists of four separate units. One unit supplies d-c voltage to the tubes in the pulse generator section. A second unit provides plate and filament voltages for all tubes in the pulse generator section, noise generator section, and mixer-amplifier section. A third unit provides plate and filament voltages to all tubes in the filter sections. The fourth unit provides similar voltages to the cathode follower and its driver. The entire system operates from a 110-volt, 60-cps, single-phase line with a current drain of less than 2 amperes.

APPLICATIONS

The 280 Dummy Signal and Noise Generator has been utilized extensively in this Laboratory for checking the performance of pulse amplifiers employed in various experimental thermal-detection systems.

One unit was used extensively by the Alden Products Co. of Brockton, Mass. during their work on chemical recorder papers for the Bureau of Ships.

Another unit is now being employed by the Armour Research Foundation of Chicago for checking signal-to-noise ratios of a multiple magnetic-tape recorder being developed for the Bureau of Ships for use in the 280 system.

Other units are being used for experimental work by the Underwater Sound Laboratory of New London in connection with their infrared program.

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