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NRL REPORT 3847

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IMPROVED COUNTERMEASURES PULSE ANALYZER TECHNIQUES

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ABSTRACT

In the analysis of an intercepted pulse signal, it is desirable for countermeasures purposes to determine the modulation characteristics of the received signal as well as the frequency and direction to the transmitting source.

Because of the advance of the art of pulse modulation in new radar and communication systems, requirements on the abilities of countermeasures pulse analyzers have become more stringent. The capabilities of the new pulse analyzer described in this report are such that the modulation characteristics of many of these new systems can be qualitatively determined. In addition, a quantitative analysis can be performed for simple pulse modulations as well as for some of the more complex forms.

PROBLEM STATUS

This is an interim report; work is continuing on this problem.

AUTHORIZATION

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NR 506-110

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IMPROVED COUNTERMEASURES PULSE ANALYZER TECHNIQUES

INTRODUCTION

In the analysis of an intercepted pulse signal, it is desirable for countermeasures purposes to determine the modulation characteristics of the received signal as well as the frequency and direction to the transmitting source. Analyzers in use at the present time, which are capable of measuring the width and repetition frequency of pulse signals, include the RDJ, AN/APA-64, and AN/SLA-1.[1] The advantages of the latter type over the others have been evaluated.[2] Certain limitations of the circuitry of the original models of the AN/SLA-1 have led to the investigation of improved circuit techniques.

The AN/SLA type of pulse analyzer described in this report contains a five-gun cathode-ray tube on which pulse analysis information is simultaneously displayed on five traces, each of which has a different time base. The display gives almost instantaneously the characteristics of an unknown pulse modulation. The unit has a wide-band video amplifying system, and five sweep channels which are automatically synchronized with the incoming pulse signal.

GENERAL DESCRIPTION

The unit, shown in block form in Figures 1 and 2, operates from the video output of any standard intercept receiver. The indicator was designed to operate from either positive or negative video signals and to permit calibration by an audio oscillator.

The wide-band video amplifier was designed to perform two functions, to amplify the video information for presentation on the face of the five-gun cathode-ray tube and to provide the synchronizing pulse to trigger the 5-μsec sweep channel. The 50-, 500-, and 5,000-μsec sweep channels were triggered by the unblanking pulse from the 5-μsec channel in order to maintain a constant video/sync ratio. To alleviate the synchronization problem of the 50,000-μsec sweep, this channel was triggered by the unblanking pulse of the 50-μsec sweep.

The sweep traces are calibrated to read pulse width in microseconds and pulse repetition frequency in cycles. In the past, units of this nature have been calibrated as shown in Figure 3. However, considering the advanced nature of this analyzer and the complexity

[1] Gall, James E., "An Instantaneous Pulse-Signal Analyzer," NRL Report No. R-3435 (Confidential), 22 March 1949. (The design of the AN/SLA-1 was based on the techniques that were reported in this report.)

[2] Medrow, Karl R., "Joint Air Force Navy Tests on the Comparisons of Three Pulse Analyzer Techniques," NRL Ltr Report No. C-3940-1/50 (Confidential), 26 January 1950

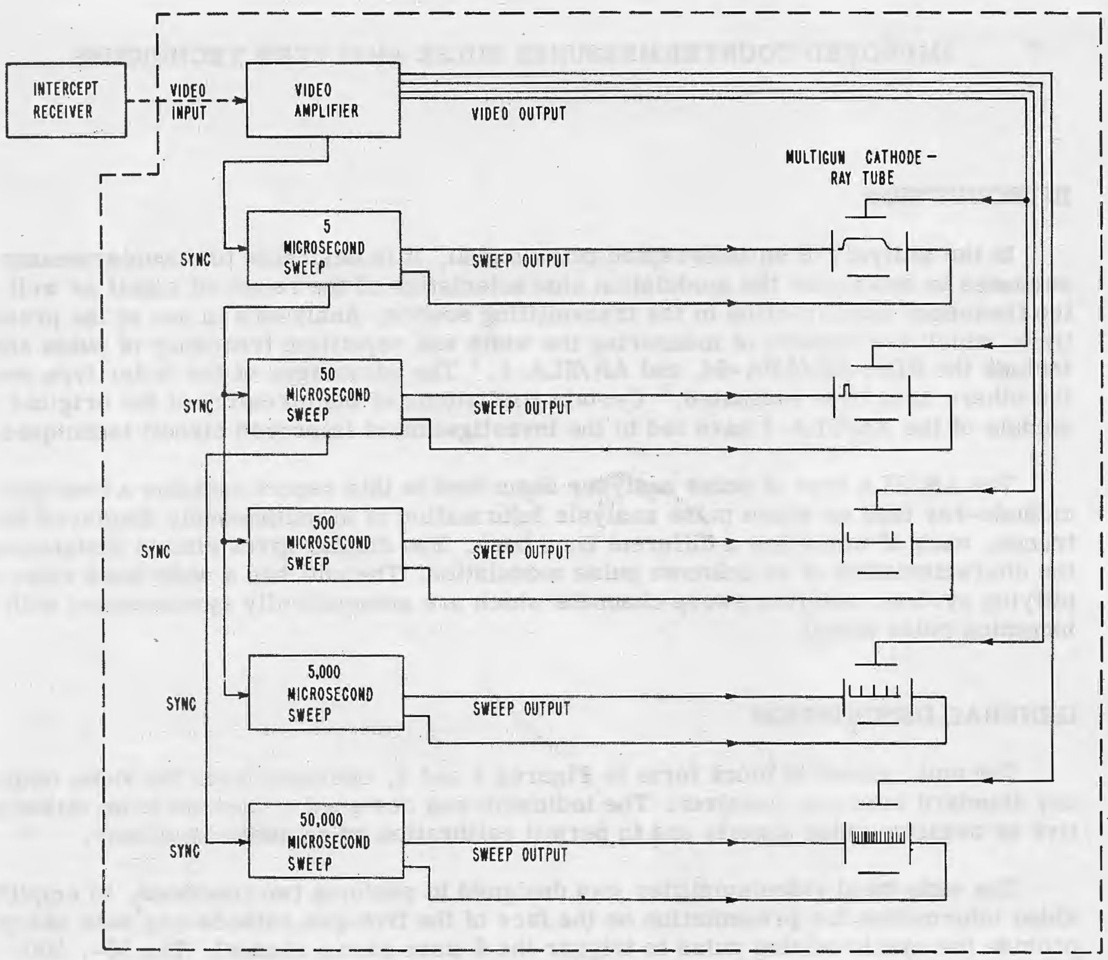

Figure 1 - Pulse analyzer block diagram

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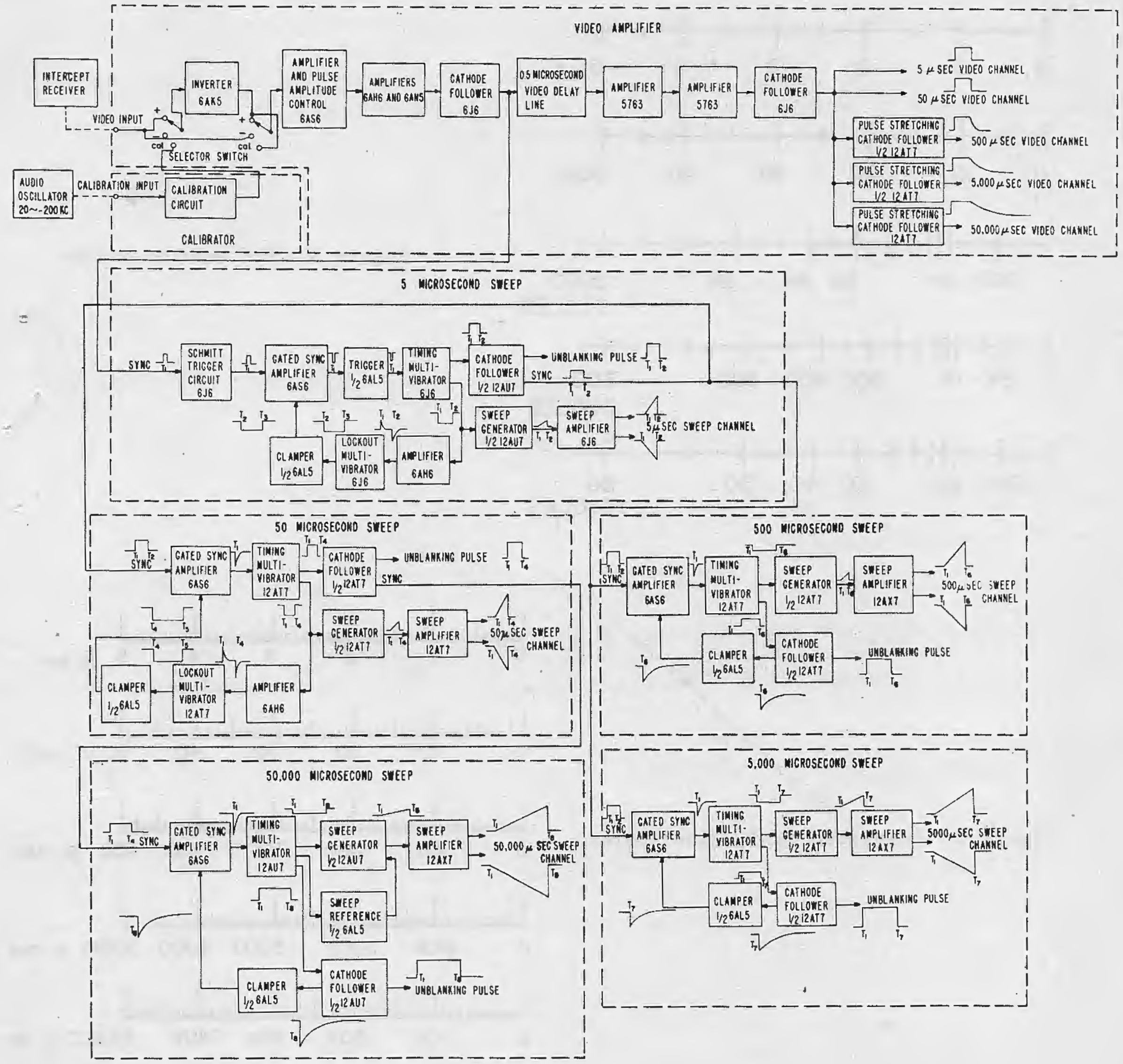

Figure 2 - Pulse analyzer detail block diagram

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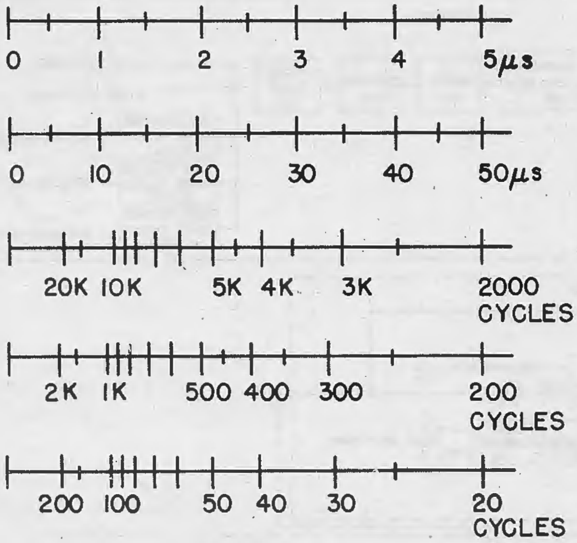

Figure 3 - Calibration scales

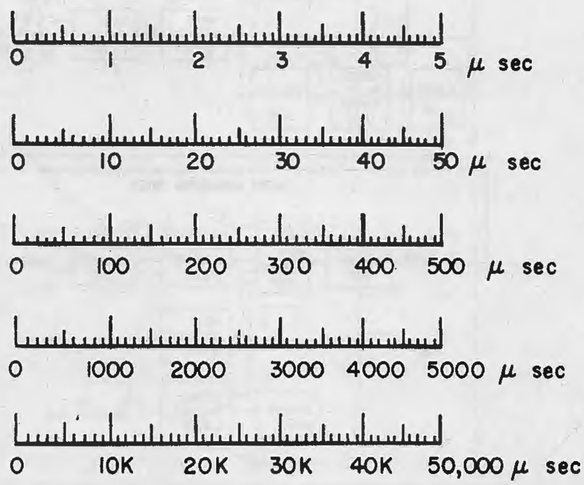

Figure 4 - Suggested calibration scales

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of signals that might be intercepted, it is believed that the scales should be calibrated in time, as shown in Figure 4.

To analyze a simple radar interception on this indicator, utilizing the scales of Figure 3, the following procedure is used. Depending upon the width of the pulse, the pulse width is measured on either of the top two traces. The repetition frequency can be read from the calibrated scale at the position of the second pulse on any sweep containing two or more pulses, but greatest accuracy is obtained by using the trace having the greatest spacing between the first two pulses.

If the scales of Figure 4 are used, pulse periods are read directly instead of repetition frequencies. The major advantage gained by this scaling is in the determination of the time spacings of pulse groups, such as occur in some of the more complex forms of pulse modulation.

CIRCUIT DESCRIPTION

Video-Amplifier

The video-amplifier was designed so that when operated with the AN/APR-9 countermeasures receiver, the over-all rise time would not exceed 0.1 μsec. When connected to receiving equipments having narrower video bandwidths, the over-all passband will be essentially that of the associated equipment.

From the instruction book it was determined that the video bandwidth of the AN/APR-9 was 4 Mc. Therefore, with this bandwidth a rectangular pulse at the input of the receiver should be passed with a rise time of 0.088 μsec. Thus for an over-all rise time of 0.1 μsec the video-amplifier of the associated pulse analyzer must have a rise time not exceeding 0.048 μsec.[3] It is desirable, in addition, that the video-amplifier be designed to have no overshoot. It is evident that an increase in the bandwidth of the receiver video-amplifier would permit a considerable saving in power in the analyzer amplifier through reduction in the bandwidth required to provide an over-all rise time of 0.1 μsec.

In the design of a video-amplifier the gain-to-rise-time ratios of the stages suitable to use in combinations must be considered. Necessary polarities, current ranges, and cutoff characteristics must be kept in mind so that suitable voltages will be developed across the load resistors and the grid circuits will not be driven into conduction or to cutoff, since it is desired to observe the whole pulse amplitude with minimum distortion of the pulse shape. The completed design of the video-amplifier is shown in Figure 5. This amplifier has a measured rise time of 0.045 μsec and an over-all amplification of approximately one hundred. This gain is adequate to display the output noise from both the RDO and the AN/APR-9 receivers.

The input or pulse-inverter stage utilizes a 6AK5 tube. Its gain is one, and only positive signals are applied to it. If the input signal is negative, the whole circuit is by-passed by use of a double-pole switch, and the input goes directly to the next stage.

A 6AS6 is employed in the second or gain-control stage. It is desirable to have this stage as near the input as possible since the input-signal amplitude range is contemplated at 50:1. The suppressor is a convenient element for control since the transconductance of

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[3]Valley, G. E., and Wallman, H., "Vacuum Tube Amplifiers," New York, McGraw-Hill, 1948, pp. 77-80

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the tube can be varied by suppressor voltage-adjustment without disturbing the input or output impedances. Another important characteristic is that operation of the gain control does not change the dynamic range of grid No. 1. The maximum signal-input capabilities are limited by the cutoff characteristics of the 6AS6 because only negative-going signals are to be applied to this circuit. The gain-to-rise-time ratio is calculated on the basis of full gain, and the plate load-resistance determined and compensated for the proper rise time improvement without overshoot. Maximum calculated gain of this stage is 2. The performance characteristics of this gain-control stage are presented in Figures 6 and 7. In these figures the sensitivity of the vertical-deflection system of the cathode-ray tube was assumed to be 70 volts per inch.

The next two stages are necessary to increase the signal amplitude to a sufficient value to give a six-volt positive sync-pulse. The first amplifier is a 6AH6 tube. This tube was selected because of its high transconductance and low plate-current characteristics. Following the 6AH6 is a 6AN5 tube operating with a plate voltage of 180 volts and a screen voltage of 105 volts. A 6AH6 tube was tried, but with screen voltage of 105 volts and a plate current of the order of 9 milliamperes, the output of the tube was limited to a value which was not sufficient to drive the 6J6 cathode-follower delay-line tube satisfactorily.

A type 6J6 twin triode with both sections in parallel is used as a cathode follower to drive the delay line. The synchronizing signal is removed at the cathode and the video signal passes through the delay line, thereby being delayed approximately 0.5 μsec.

Of equal importance for good operation of the video amplifier is the characteristic of the delay line. The delay line must delay the pulse as well as preserve its shape. A six-inch section of General Electric distributed line is used in this amplifier. Published information indicates that the pass characteristic is 2 Mc. Measured in the laboratory with sinusoidal waves, the half-power point for this particular section proved to be approximately 7 Mc. The phase-delay characteristic of this line, however, is not satisfactory for operation with rise times of the order of 0.1 μsec. Improvement of the video-amplifier would be possible with a more suitable delay line to pass the specified narrow pulse.

The first tube following the delay line circuit is a 5763. This tube was selected in order that sufficient current would be available to develop the necessary voltage in the plate resistor. This circuit serves merely to invert the positive polarity from the cathode follower so that the proper polarity signal will be available to drive the next stage negatively. The gain of this amplifier is approximately 2.

The output video-amplifier tube selected is a 5763. It is operated with equal screen and plate voltages of approximately 250 volts and at zero grid bias, since a positive-going signal is desired in the output. The plate resistor is 1,000 ohms and is compensated to prevent overshoot. The gain of this amplifier is approximately 4, with a maximum output voltage of approximately 70 volts. Since the amplification of the cathode-follower stage V8 is approximately 0.9 this provides a maximum deflection potential of only about 60 volts, somewhat less than enough for one-inch deflection on the K1052P2 cathode-ray tube. From the foregoing it is obvious that the use of high-sensitivity deflection plates in the cathode-ray tube would lessen the requirements of the amplifier stage V7.

The remaining tubes in the video amplifier are triodes used as cathode followers. The triode used to drive the pulse-width deflection plates and the cathode followers for indicating the pulse repetition-frequency is a 6J6 with both sections of the triode connected in parallel. The remaining three triodes are sections of 12AT7 tubes. These tubes drive the pulse repetition-frequency deflection plates, and pulse stretching is obtained by utilizing

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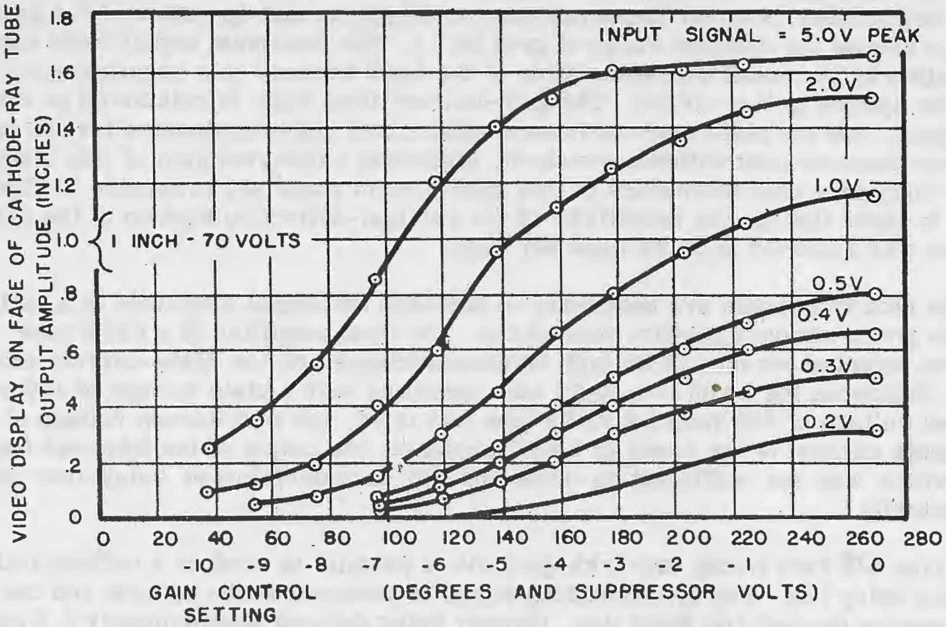

Figure 6 - Operating characteristics for gain control circuit

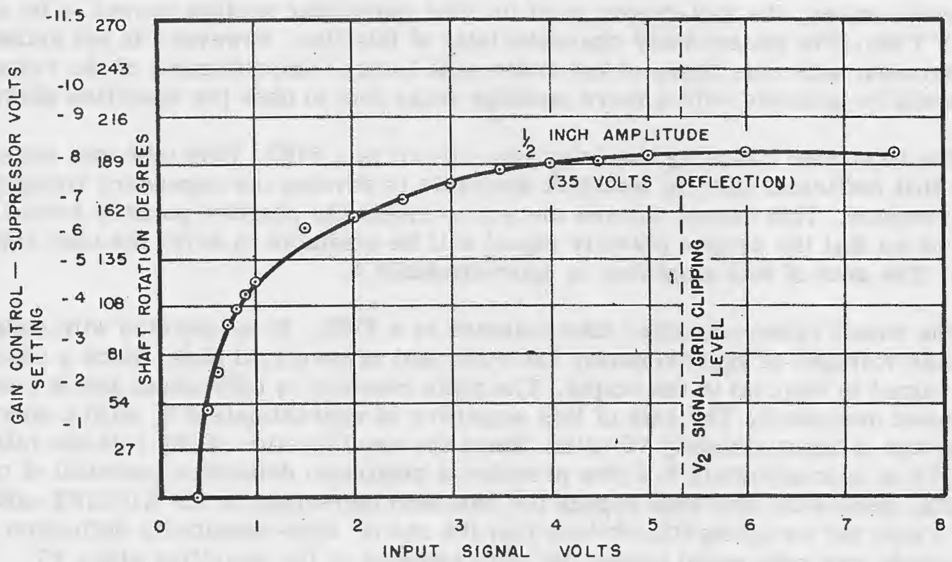

Figure 7 - Dynamic range of video gain control circuit

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the cathode-to-ground capacitances in conjunction with the cathode resistors in order to set up the appropriate discharge time-constants. The networks of the pulse-stretching circuits of the 500-, 5,000-, and 50,000-μsec channels have exponential decay time-constants of the order of 5, 50, and 350μsec respectively. The pulse-stretching circuit was incorporated in the unit in order to permit observation of narrow pulses on the low repetition-rate scales. An interesting feature of this pulse-stretching circuit is that with pulse signals of varying amplitude, the circuit acts as a cathode-follower detector[4] and presents the pulse-amplitude variations on the face of the cathode-ray tube.

Comparisons of total plate-power consumptions show that the video-amplifier, as described, uses more power than is necessary for the operation of the five sweep-generating circuits to be described. This power requirement could be materially reduced if the cathode-ray deflection sensitivity were improved by a factor of at least two, and if intercept receivers, such as the AN/APR-9, AN/BLR, and AN/SSQ-11, were designed with adequate video passbands and greater video output.

Sweep Circuits

In order to provide complete analysis information, the indicator sweep circuits are required to synchronize with signals over a wide frequency range. The successful performance of this analyzer depends upon the synchronization of the five traces with single pulses or with repetitive pulses at rates up through 2 Mc without any observable "jitter" or horizontal movement of the traces.

When conventional sweep circuits are triggered by high-frequency pulses, these circuits are unstable. The factor that causes this instability is the inability of the sweep circuits to achieve complete recovery to their initial equilibrium before they are triggered again. To insure complete recovery of the sweep circuits, an automatic "lockout" circuit was designed so that no triggering pulses would reach the sweep-timing circuits until the circuits had recovered. Two types of sweep "lockout" circuits for the channels were designed. In the 5- and 50-μsec channels, as indicated in Figure 2, the negative date of a "lockout" multivibrator is used to eliminate the trigger pulses from the output of the gated sync-amplifier during the period when these circuits are relaxing. The time when this action occurs is at the end of the time-base cycle. In the 500-, 5,000-, and 50,000-μsec channels, as indicated in Figure 2, the negative exponential portion of the differentiated unblanking pulse is used to eliminate the trigger pulses from the gated sync-amplifier output. This negative exponential occurs during the period when the sweep circuits are relaxing.

5-Microsecond Channel—The first stage, V1, in Figure 8, is a basic Schmitt trigger circuit.[5] This stage enables the sweep circuit to be triggered regardless of the slopes of the front edges of the video pulses, which are obtained from practical receivers. This stage can be synchronized with single pulses or with repetitive pulses at rates up through 2 Mc. It can be synchronized with sine waves or any other wave form passed by the video-amplifier up through 2 Mc. A test synchronizing signal from the video amplifier is shown in Figure 9. (In Figures 9 through 25, times are defined as in Figure 2.) The sync output of the Schmitt circuit is shown in Figure 10. The output of the Schmitt circuit is differentiated by the RC coupling-network in the grid of the gated sync-amplifier, V2, to produce the signal in Figure 11.

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[4]Chance, B., et al., "Waveforms," New York, McGraw-Hill, 1949, p. 507
[5]Puckle, O. S., "Time Bases.....," London, Chapman & Nall, 1943, p. 57

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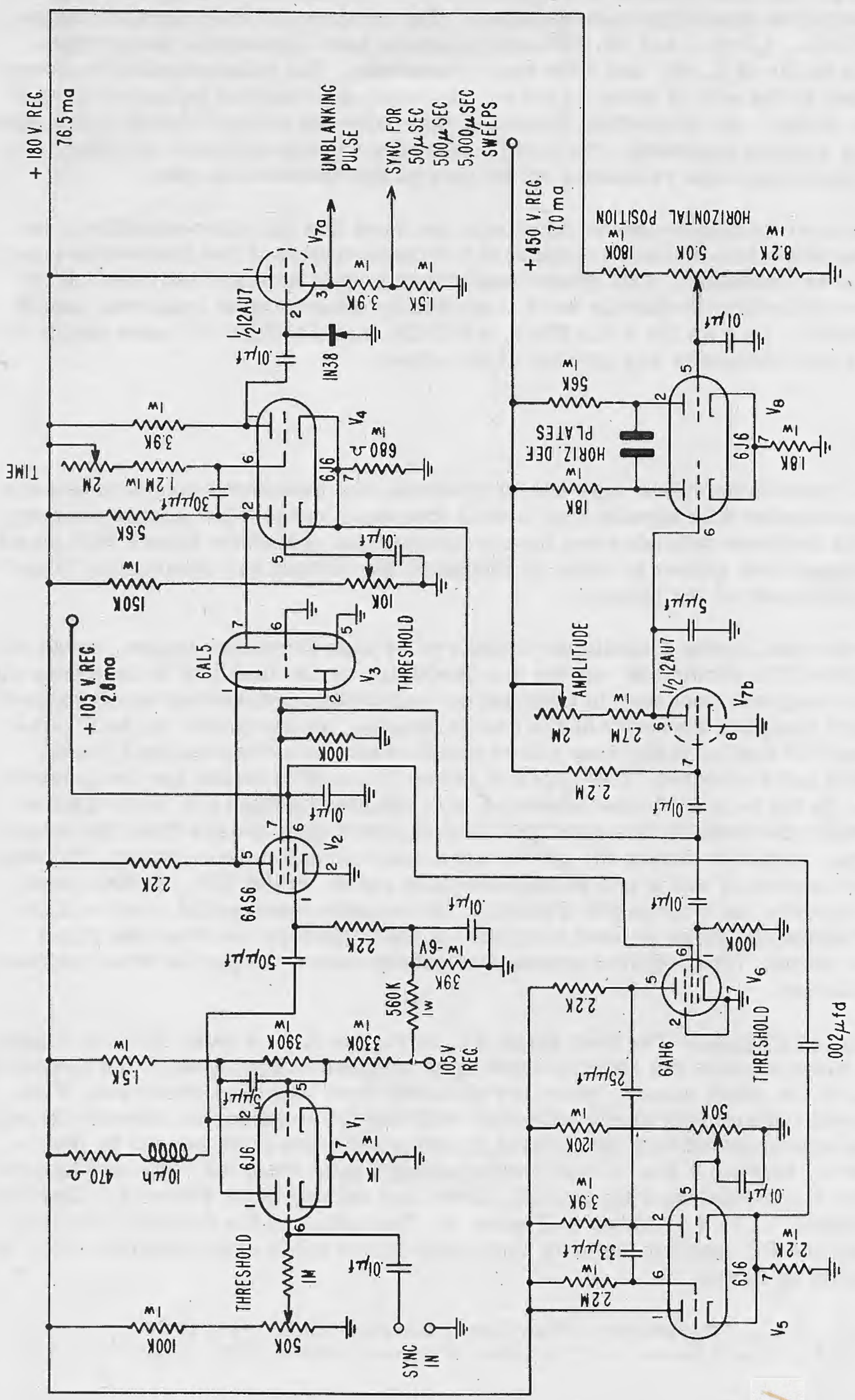

Figure 8 - Circuit for 5-microsecond sweep

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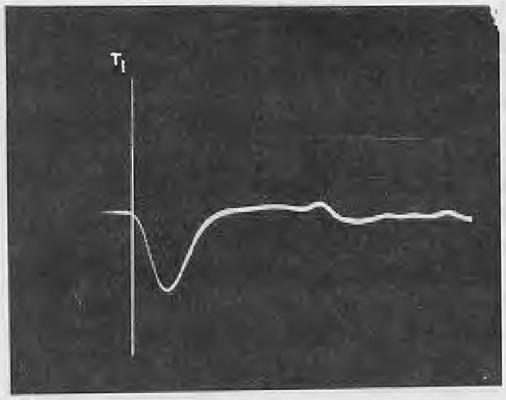

Figure 9 - Synchronizing signal from video-amplifier (positive pulse; sweep time-base 1 μsec; at "sync in" terminal)

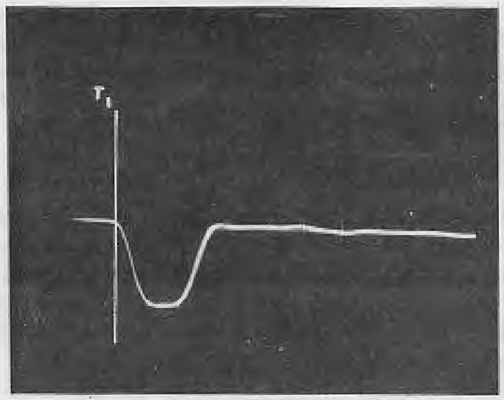

Figure 10 - Sync output of Schmitt circuit (positive pulse; sweep time-base 1 μsec; Pin #2 of V1)

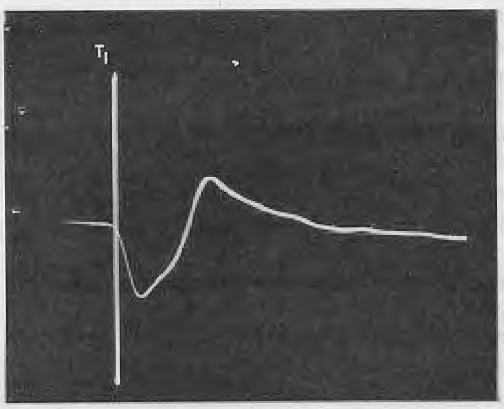

Figure 11 - Differentiated sync signal (positive pulse; sweep time-base 1 μsec; Pin #1 of V2)

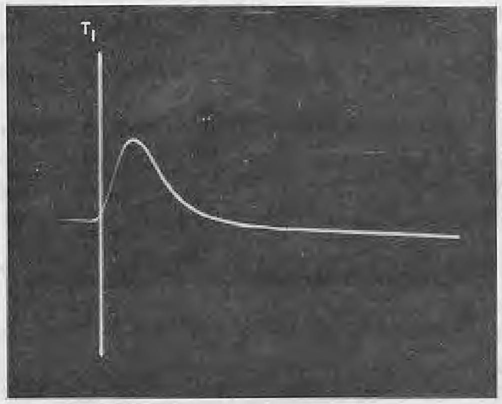

Figure 12 - Output of gated sync amplifier (negative pulse; sweep time-base 1 μsec; Pin #5 of V2)

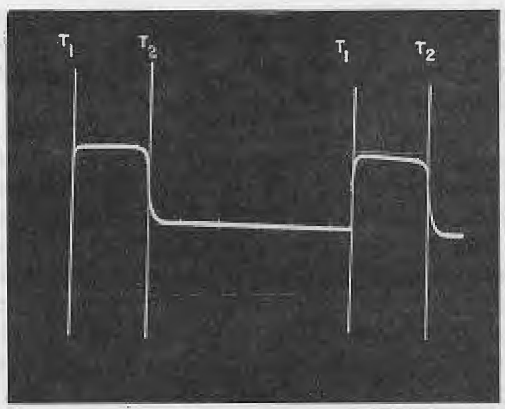

Figure 13 - Negative gate of timing multivibrator (Pin #2 of V4)

The observable jitter of the 5-μsec sweep is a function of the width of the sync pulse. To minimize jitter this pulse should be as narrow as multivibrator V4 will tolerate. The shape of the pulse can be improved by designing the Schmitt trigger circuit to utilize tubes such as the 5687 or a pair of 6AH6's, which have a higher transconductance than the 6J6.

The gated sync-amplifier stage, V2 in Figure 8, has two functions, to amplify and invert the trigger pulses, and to act as a gate tube to allow the sweep circuit to achieve complete recovery to its original equilibrium before it is triggered again. This lockout function is obtained by utilizing the cutoff characteristic of the suppressor grid of V2 in Figure 8. A negative gate is applied to this grid at the end of the timing cycle, which is the start of the relaxation period of the sweep timing-circuits. The amplifier sync-pulse output is shown in Figure 12.

One half of the dual diode, V3 in Figure 8, is used to provide isolation between the gated sync amplifier and the timing multivibrator; the other half clamps the positive excursion of the negative waveform on the suppressor grid of V2 in Figure 8 to ground.

The timing multivibrator produces one square pulse of fixed time-width each time it is triggered. Waveforms of the negative and positive gates are shown in Figures 13 and 14. The width of the negative gate at the cathode of the timing multivibrator, as shown in Figure 15, determines the displayed sweep time.

The sawtooth for the sweep is obtained by utilizing a small percentage of the exponential curve of the RC charging-network which is in the plate circuit of V7b. The negative gate used to cut off the sweep-generator tube, V7b, is obtained from the cathode of the timing multivibrator and is shown in Figure 16.

The sweep-amplifier stage, V8 in Figure 8, amplifies the generated sawtooth. The outputs of the amplifier stage are direct-coupled to the horizontal deflection plates of the cathode-ray tube. Waveforms of this stage are shown in Figures 17, 18, and 19. The use of direct-coupled sweeps eliminates the undesirable time constant caused by conventional dc restoring circuits. Thus this method prevents horizontal shift of the sweep trace on the face of the cathode-ray tube when the sweep circuit is triggered by one or a few pulses.

The sweep amplifier was originally designed to display the sweep on a 5-inch multigun cathode-ray tube. Since the cathode-ray tube was changed to a 7-inch multigun tube, which requires a larger sweep amplitude, and since the sweep amplifier is being operated at its maximum limit, it may be necessary to change the design of this stage to a stage consisting of two pentodes. The design will depend upon the sensitivity of the cathode-ray tube used and the desired linearity of the sweep trace.

The unblanking pulse applied to the grid of the cathode-ray tube is obtained from the cathode-follower stage, V7a in Figure 8. Waveforms of this stage are shown in Figures 20 and 21. The cathode resistor network also provides sync signals for the 50-, 500-, and 5,000-μsec channels. In this manner only one sync-to-video ratio is obtained for all the sweeps since all the sweeps are slave to the 5-μsec sweep and the threshold of the Schmitt circuit. The sweeps could be triggered independently from the same source in the video amplifier. This method of triggering would be undesirable since each sweep channel would have a separate threshold adjustment and consequently would produce uncertainty of firing in the various sweep circuits.

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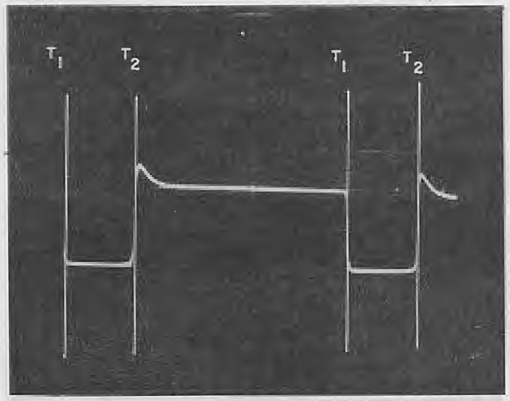

Figure 14 - Positive gate of timing multivibrator (Pin #1 of V4)

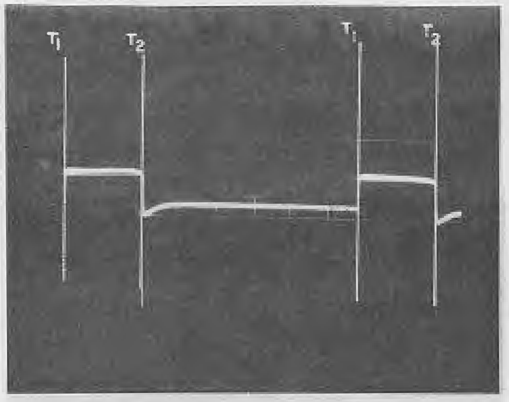

Figure 15 - Negative gate at cathode of timing multivibrator (Pin #7 of V4)

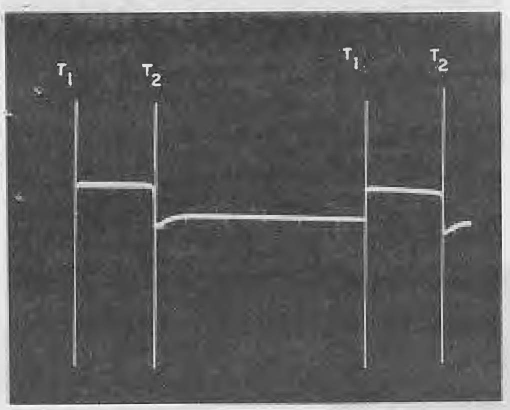

Figure 16 - Negative gate on grid of sweep tube (Pin #7 of V7)

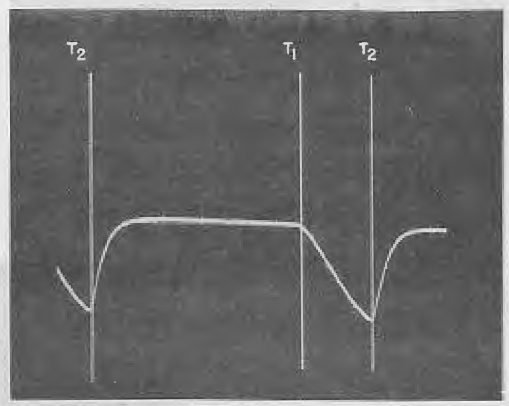

Figure 17 - Positive sweep output (Pin #2 of V8)

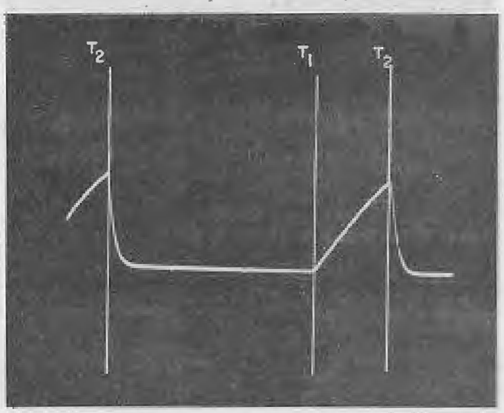

Figure 18 - Negative sweep output (Pin #1 of V8)

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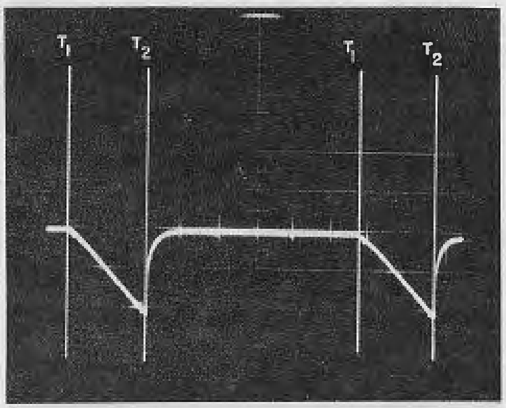

Figure 19 - Cathode of sweep amplifier stage (Pin #7 of V8)

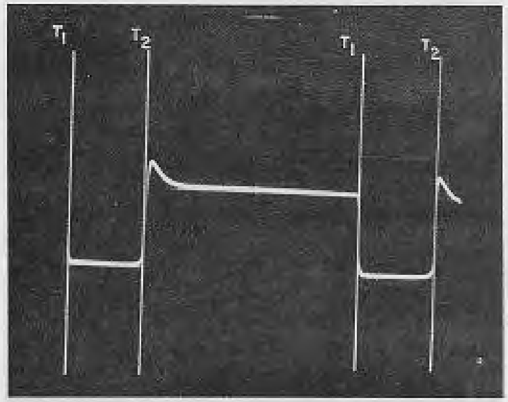

Figure 20 - Positive gate on grid of cathode follower (Pin #2 of V7)

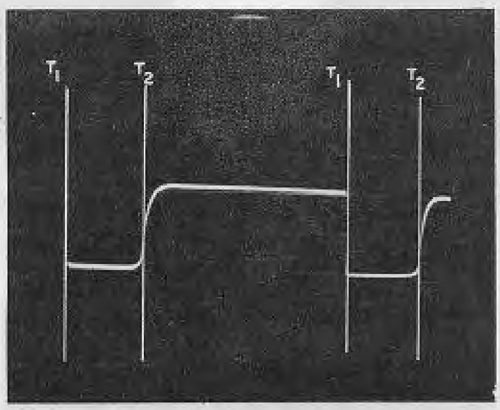

Figure 21 - Positive unblanking pulse (Pin #3 of V7)

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Stage V6 in Figure 8 amplifies the negative cathode-gate. The waveforms of this stage are shown in Figures 22 and 23. This stage also provides the necessary isolation between the lockout multivibrator and the timing multivibrator.

The lockout multivibrator, V5, is triggered by the differentiated amplified gate-pulse. The negative excursion of the differentiated waveform, which is at the end of the timing cycle, is used to trigger the multivibrator. The negative gate on the cathode of the lockout multivibrator is coupled to the suppressor grid of the gated sync amplifier, V2 in Figure 8, thus providing the lockout period. The waveforms of multivibrator V5 are shown in Figures 24 and 25. It is important that the negative gate of the lockout period be deep enough to cut off the suppressor grid of V2, and that the back edge of the gate be as sharp as is reasonably possible. In the original design it was necessary to exceed the power-dissipation rating of the conducting triode of the lockout multivibrator in order to obtain a satisfactory lockout gate, but new tubes such as the 5687, or paralleled triodes of a 6J6, can be used to overcome this problem.

50-Microsecond Channel—The design of this channel is similar to the 5-μsec channel, except that the timing multivibrator, V2a and V3a of Figure 26, is triggered by a different method by the gated sync amplifier, V1. The trigger from V1 is applied through a 470K - 0.01 μf coupling-network instead of through a diode. By use of this network, the negative gate from the timing multivibrator is coupled back to the plate of the gated sync amplifier, stage V1. This negative gate depresses the plate of V1 below ground during the timing cycle of the multivibrator. This action prevents triggering from occurring before the end of the timing cycle, and thus changing the time of the negative gate.

In order to eliminate observable jitter in this sweep it is important that a narrow sync-pulse be used and that the back edge of the lockout gate-pulse be as sharp as is reasonably possible.

500-, 5,000-, and 50,000-Microsecond Channels—The basic designs of the 500-, 5,000-, and 50,000-μsec channels are similar to that of the 50-μsec channel. The circuits of these channels are shown in Figures 27, 28, and 29. However, the lockout function of these circuits is obtained by using a negative exponential waveform instead of a negative gate. This negative exponential waveform is obtained by differentiating the positive gate of the unblanking pulse. The negative-exponential lockout waveforms for the 500-μsec channel are shown in Figure 30.

In the various sweep channels, the design of the coupling network from the cathode of the timing multivibrator to the grid of the sweep-generator stage has been varied in accordance with the requirements of each channel in order to provide a minimum sweep recovery-time. It is essential that the magnitude of the time constant of this coupling network be as small as possible, and still be able to pass the negative gate-pulse. To provide a stable time-base, this network must recover completely between sweeps. In the 50,000-μsec sweep channel (Figure 29), because of the large time constant involved, a dc coupling-network is utilized to pass the negative gate.

In the 50,000-μsec sweep channel, a short recovery time between sweeps could not be obtained because of the long discharge time-constant formed by the 1-μf sweep capacitor and the impedance of the sweep-generator tube, V2b in Figure 29. By use of a sweep-reference diode, V5b, both the maximum and the quiescent potentials across the sweep capacitor are increased by the same amount, but the discharge curve is still referenced to the same minimum potential by V2b. When the potential reaches the conducting point of the diode, the discharge is terminated, thus reducing the time of discharge to a portion of a time constant rather than to many time constants. This decrease in relaxation-

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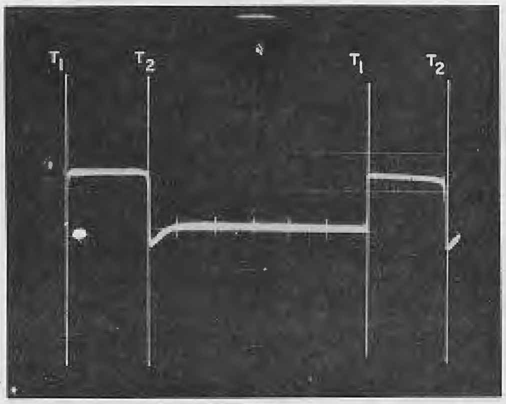

Figure 22 - Negative gate on grid of amplifier stage (Pin #1 of V6)

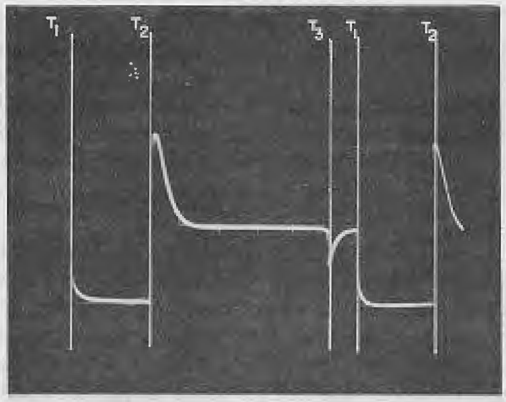

Figure 23 - Plate of amplifier stage (Pin #5 of V6; positive is down)

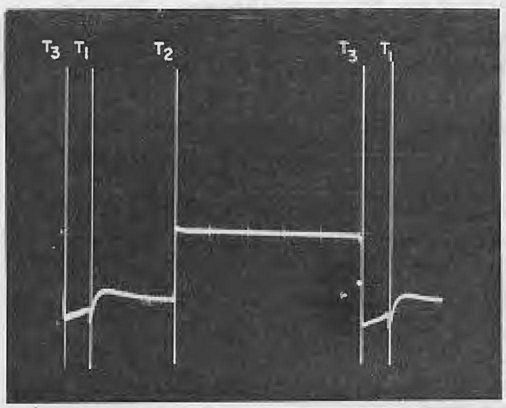

Figure 24 - Negative gate of "lockout" multivibrator (Pin #7 of V5; positive is down)

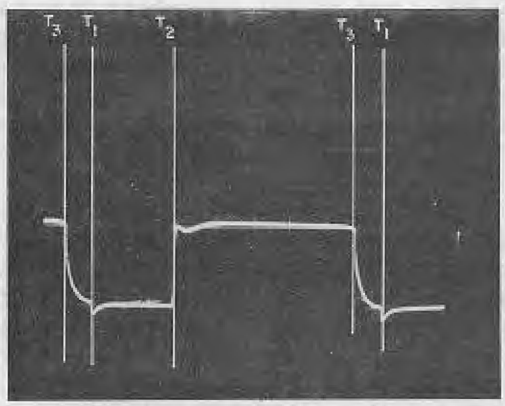

Figure 25 - Negative gate of "lockout" multivibrator (Pin #2 of V5)

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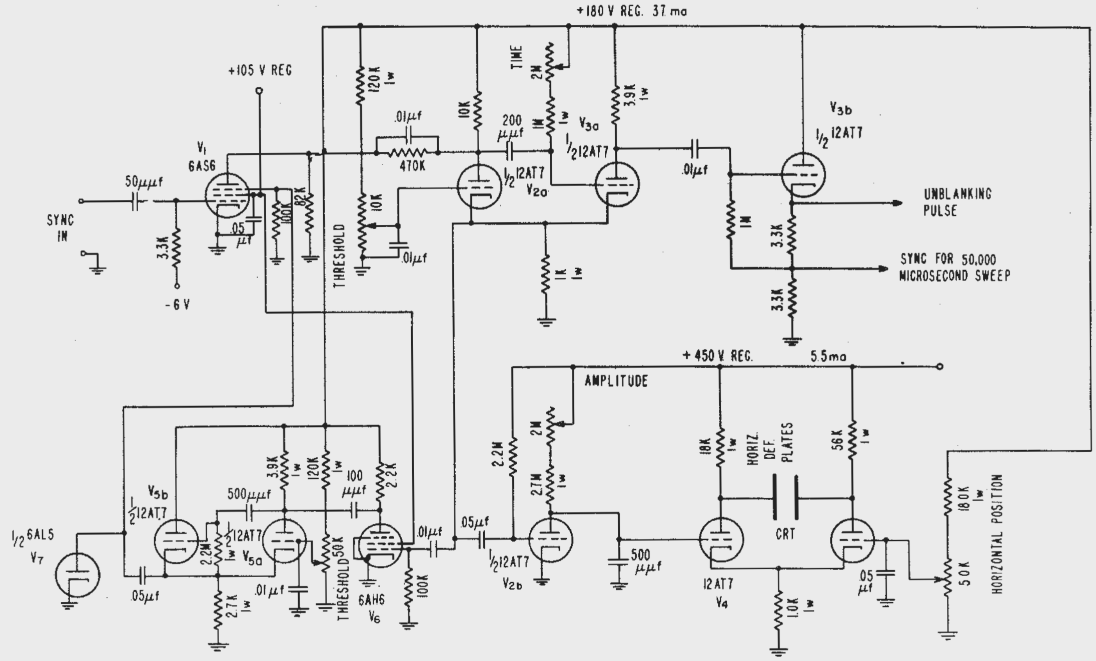

Figure 26 - Circuit for 50-microsecond sweep

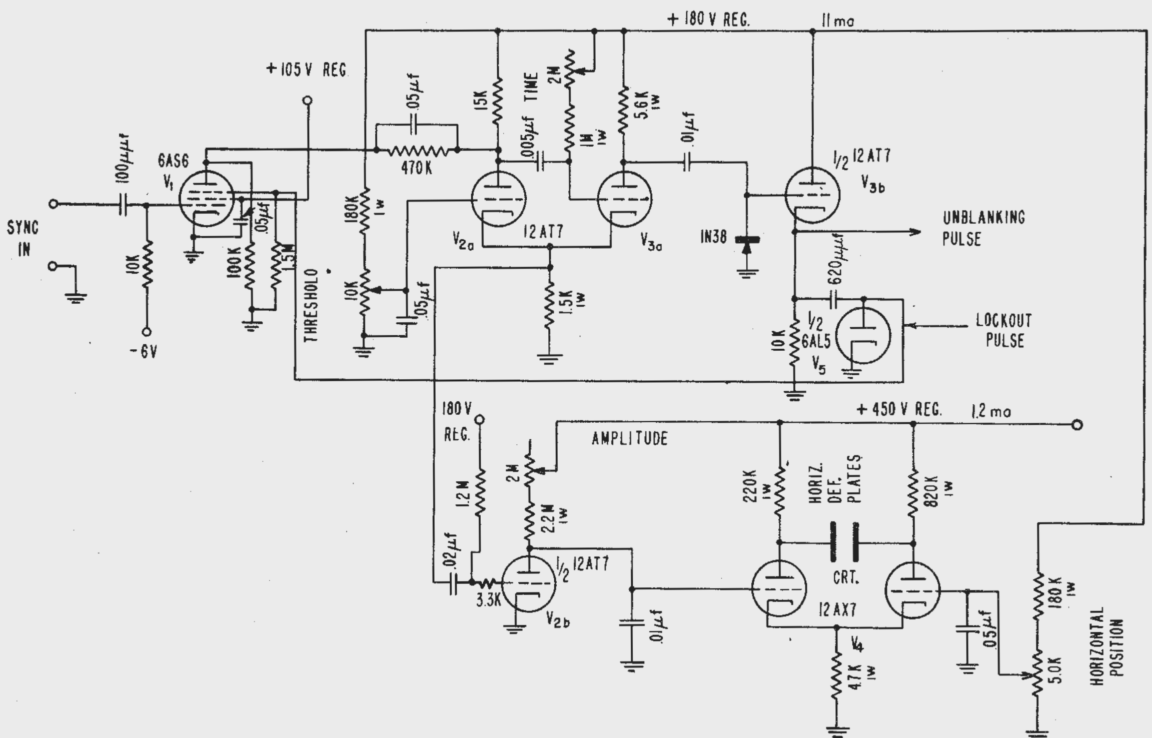

Figure 27 - Circuit for 500-microsecond sweep

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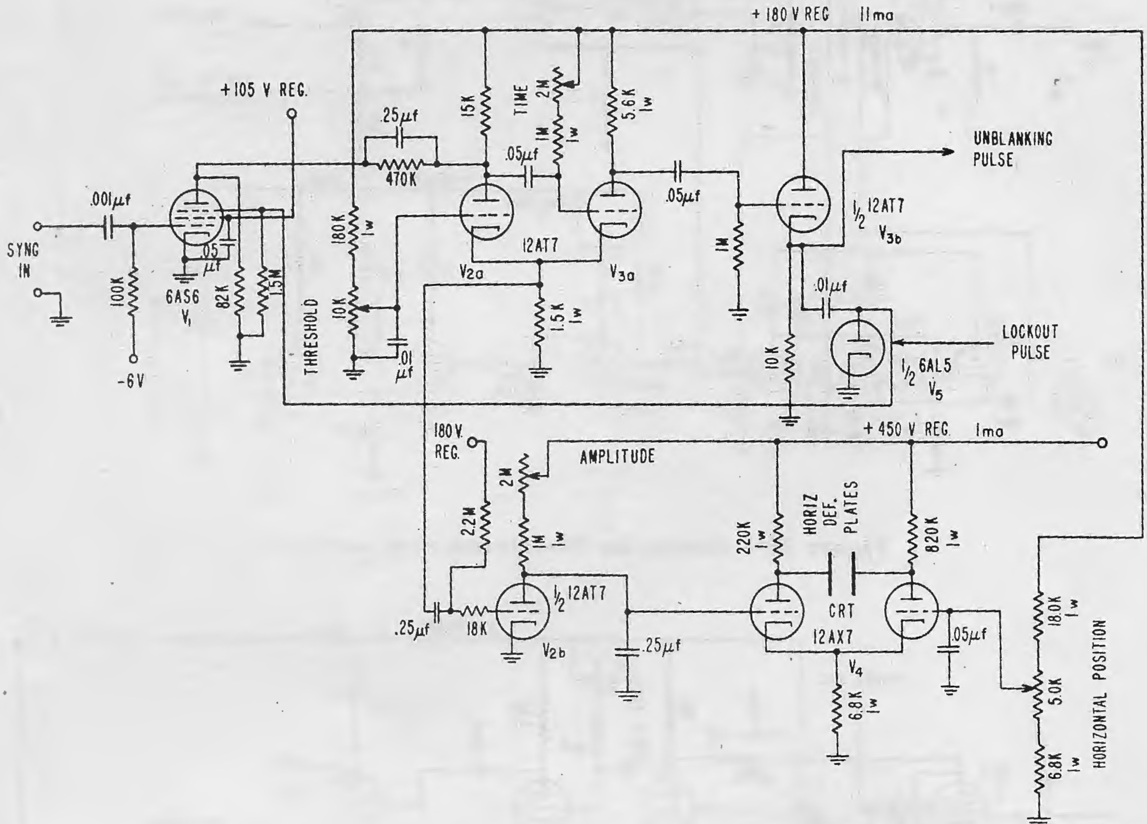

Figure 28 - Circuit for 5,000-microsecond sweep

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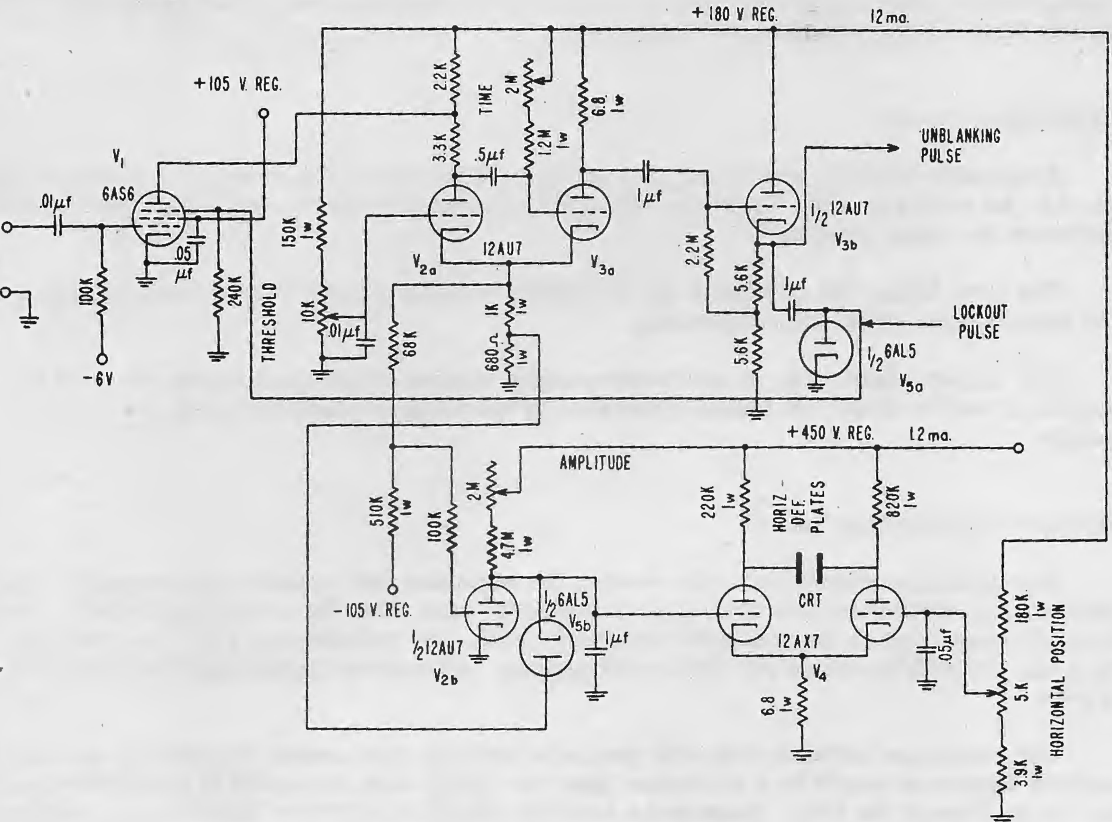

Figure 29.- Circuit for 50,000-microsecond sweep

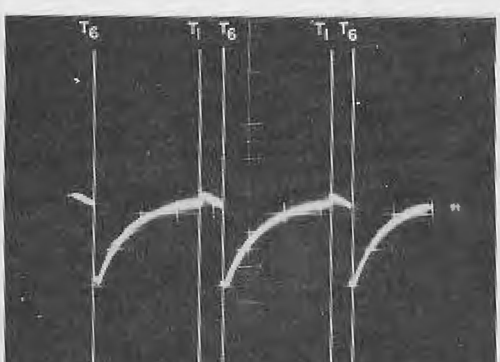

Figure 30 - Negative exponential lock-out waveform for the 500-microsecond sweep (suppressor pin, V1; down is negative)

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time permits appreciable increase in the maximum possible rate of the sweep. The discharge time curves are shown in Figure 31.

Calibration Circuit

A tentative circuit, which may be used for calibration of the sweep, is shown in Figure 32. An external audio oscillator or signal generator must be used with this circuit to calibrate the pulse analyzer.

The first stage, V1 of Figure 32, is a basic Schmitt circuit.[6] This circuit generates the basic 1-μsec pulse for calibration.

The second stage, V2, is a cathode-coupled clipper circuit and serves to limit the amplitude and to shape the pulses generated by the Schmitt circuit into square 1-μsec pulses.

Multigun Cathode-Ray Tube

The multigun cathode-ray tube used in the indicator unit contains five separate, individual gun-structures electrically isolated from each other by an internal shield. To prevent modulation of the traces by external fields, the cathode-ray tube was shielded by a mu-metal tube-mount so that low-frequency, extraneous fields would not affect the traces.

The particular cathode-ray-tube gun to be used on each sweep was chosen so that the pattern distortion would be a minimum when the sweep was presented in the desired sector on the face of the tube. Experience with the 7Z5P2 (Electronic Tube Corp.) multigun cathode-ray tubes has indicated in the past that projecting the electron beam straight forward presents the least trapezoidal distortion of the pattern, but in the K1052P2 (DuMont) it was found to be desirable to reverse the relative positions of the traces with respect to the guns in the cases of the 5- and 50-μsec sweeps, as is shown in Figure 33. It is possible that the constriction of the glass envelope beyond the ring base of this tube may account for the distortion encountered when the traces and guns were aligned in direct correspondence.

The cathode-ray tube, five sweep channels, and the video amplifier were incorporated into an experimental model. The circuit of this unit is shown in Figure 34. The indicator model is shown in Figures 35, 36, and 37.

Power Supply

An electronically regulated power supply was designed and constructed to provide low-impedance, stabilized, low-potential sources for the indicator unit. The circuit schematic is shown in Figure 38, and the unit is shown in Figures 39, 40, and 41. The circuit was designed to use components available at the time when the design was considered. Total primary power consumption is 460 watts.

In the design of the voltage-regulating circuits, the impedances of the power-supply circuits were made as low as reasonably possible to reduce the coupling between units of

[6] Ibid.

[redacted]

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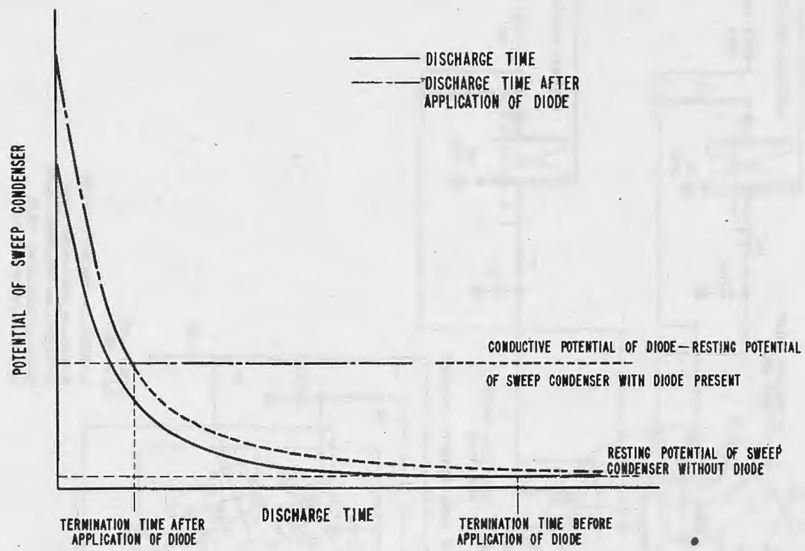

Figure 31 - Discharge time curves for 50,000-microsecond sweep-condenser

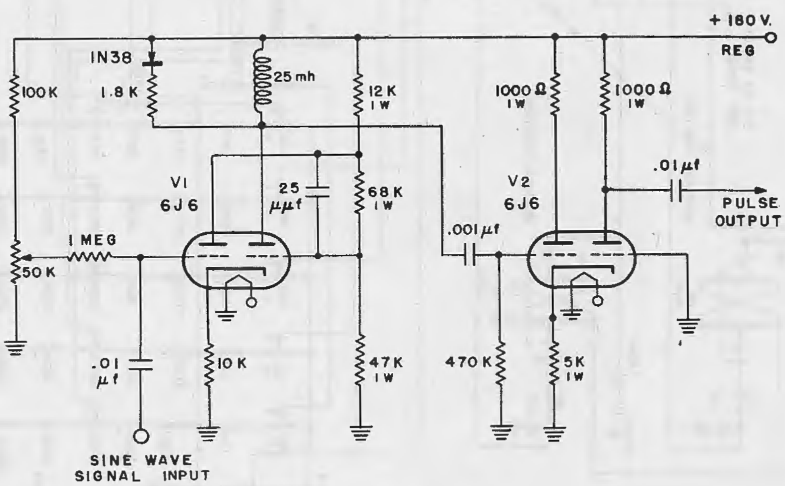

Figure 32 - Tentative calibration circuit

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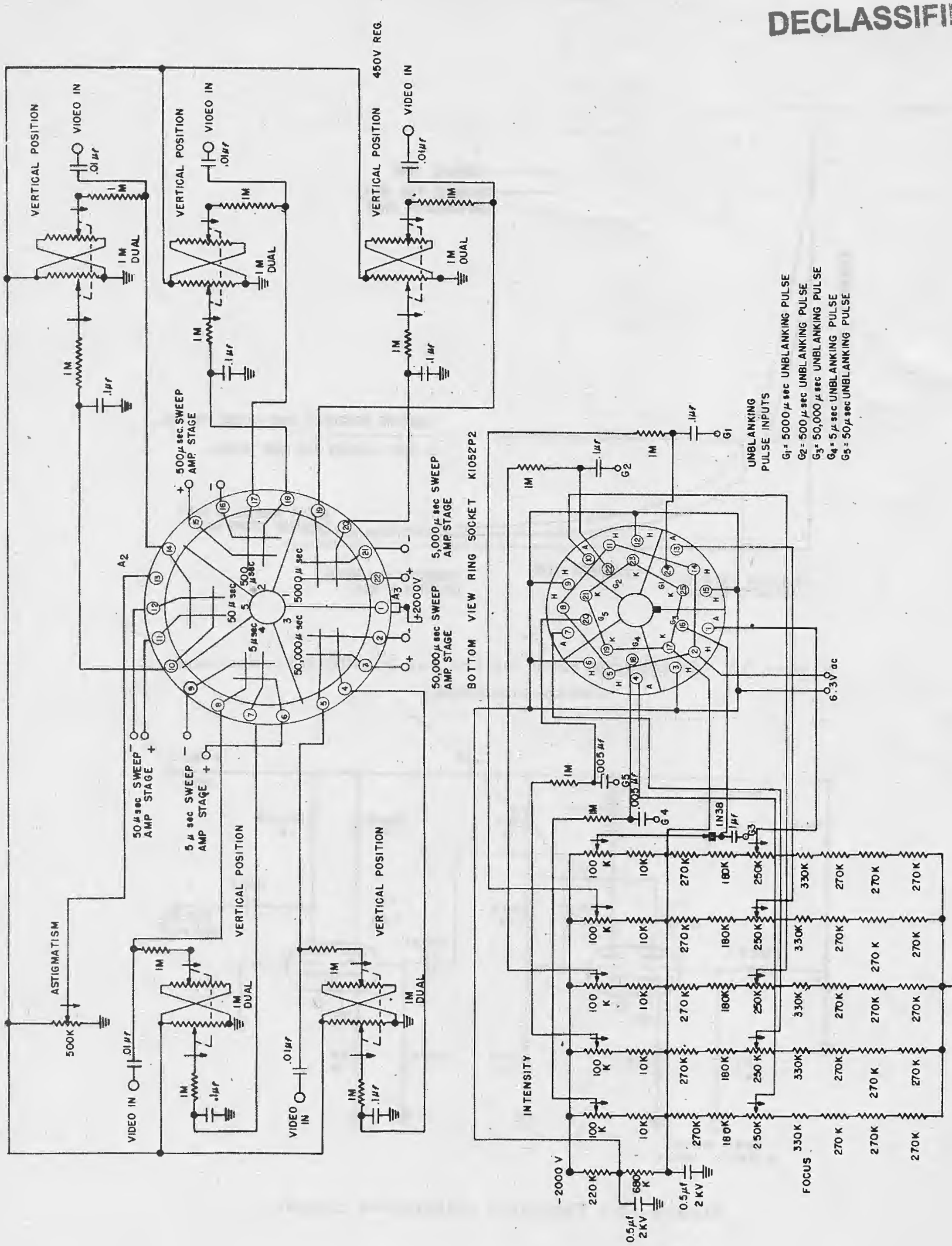

Figure 33 - Cathode-ray tube circuit

[redacted]

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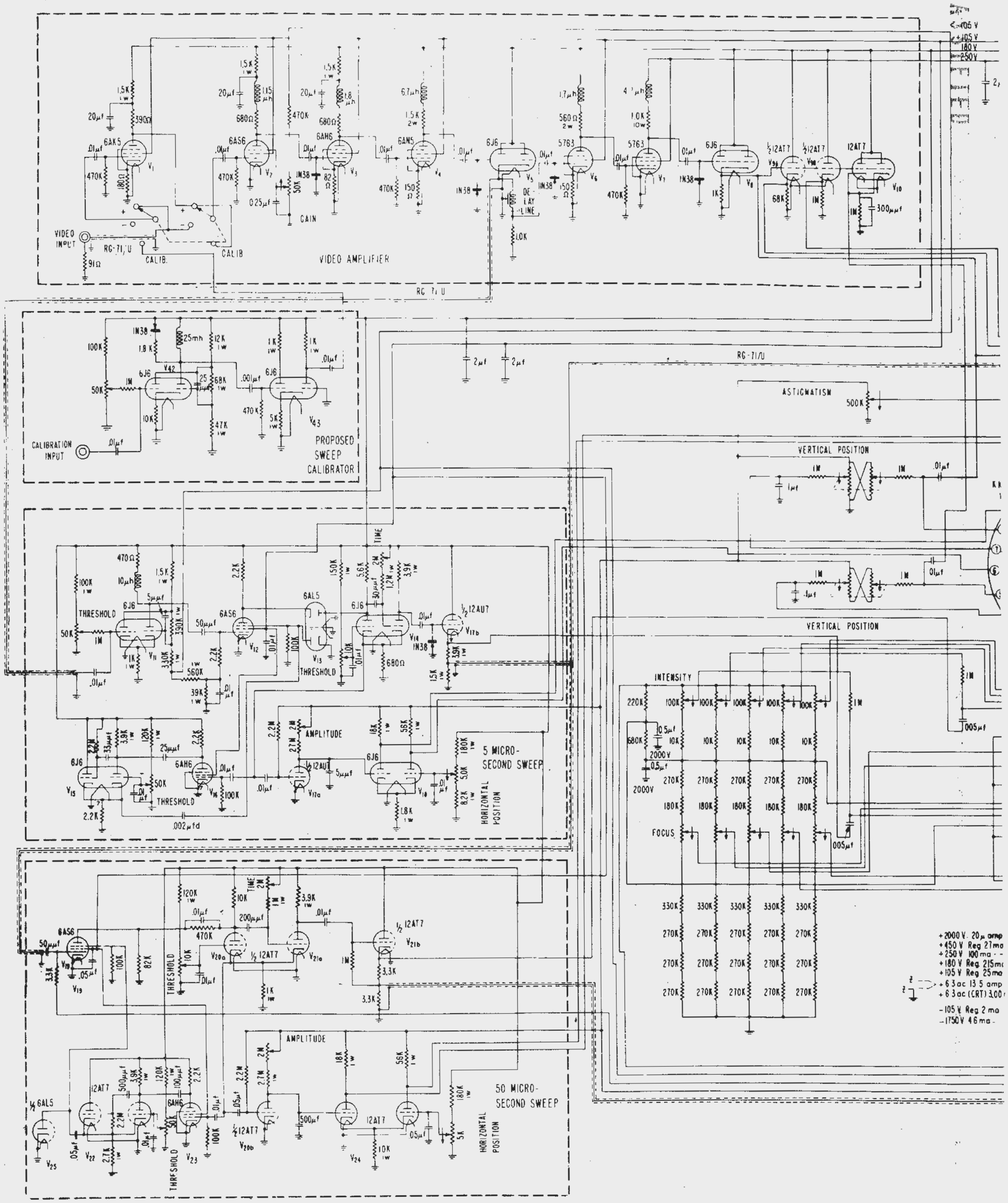

Figure 34 - Pulse analyzer

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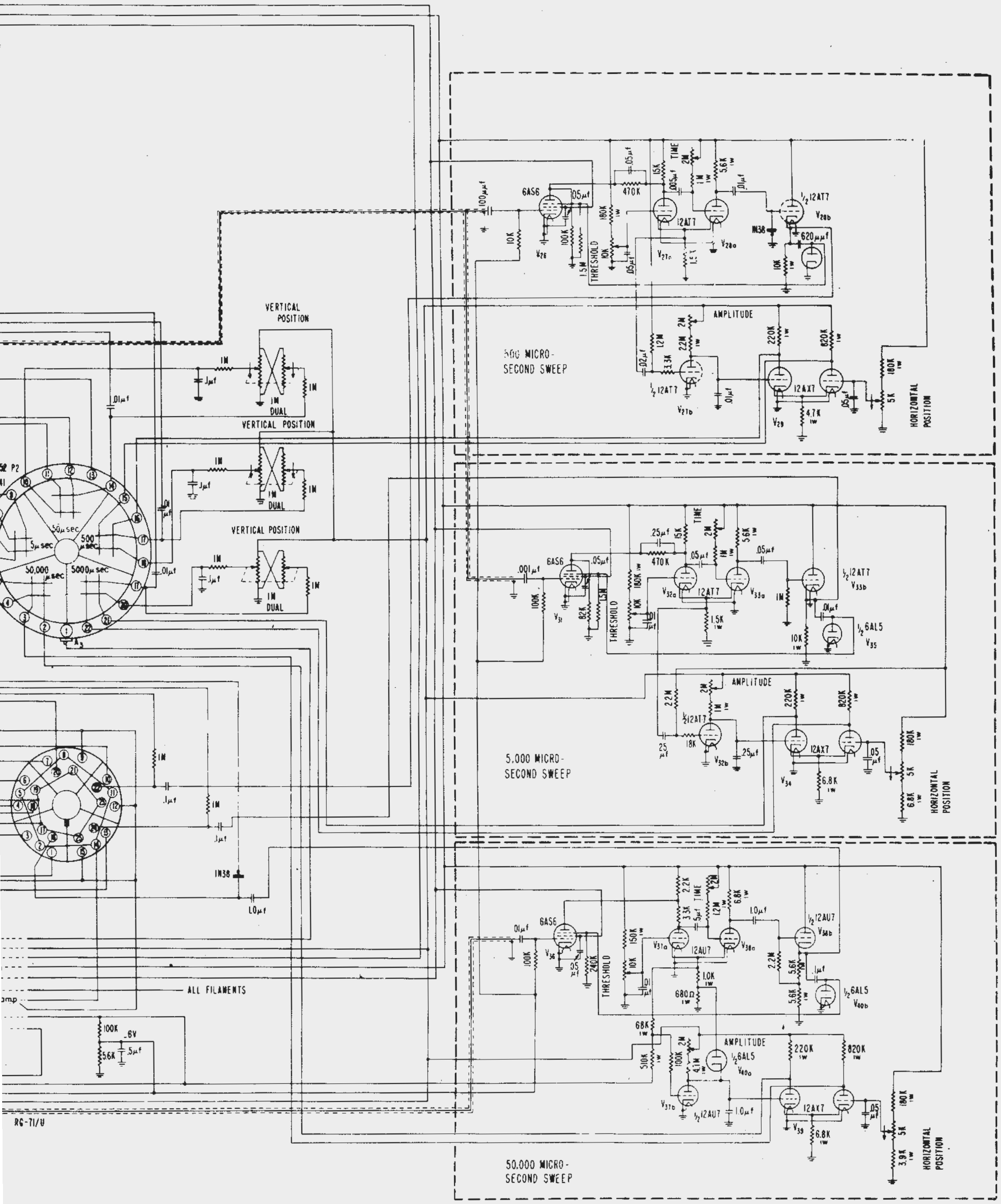

schematic diagram

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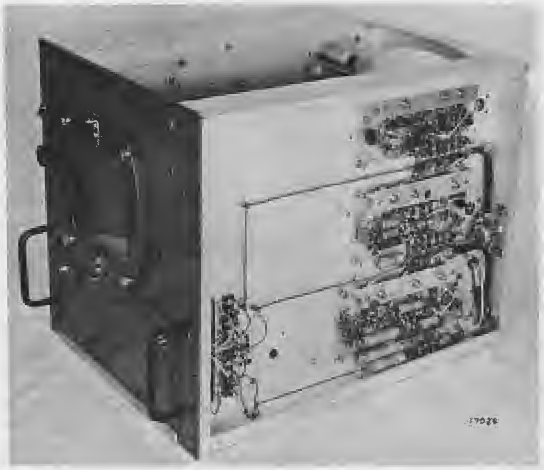

Figure 35 - Oblique view of indicator unit

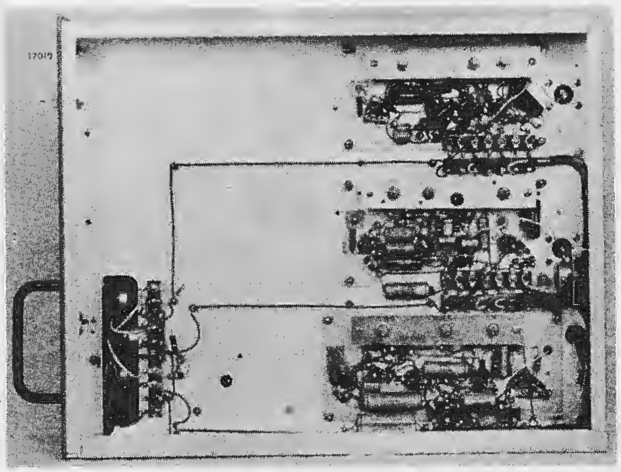

Figure 36 - Right side view of indicator unit

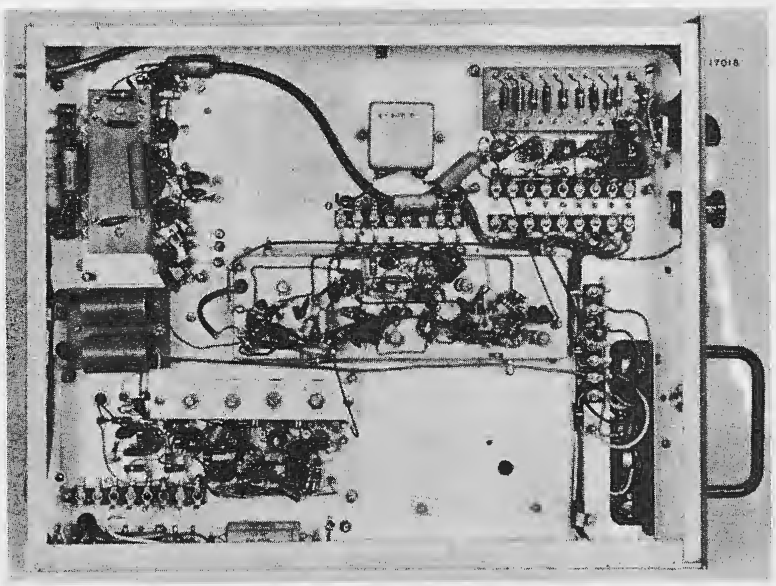

Figure 37 - Left side view of indicator unit

[redacted]

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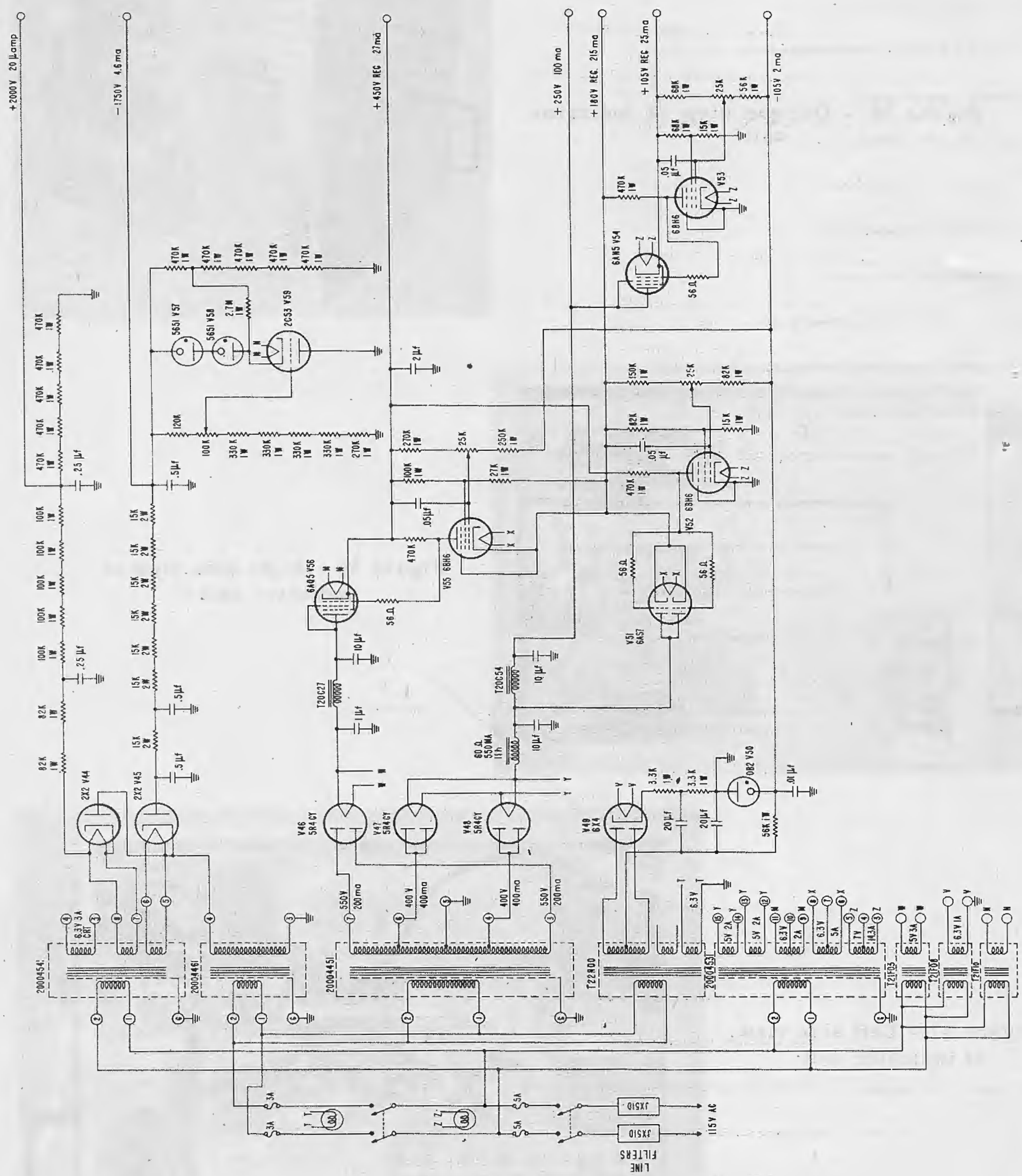

Figure 38 - Pulse analyzer 60-cycle power supply

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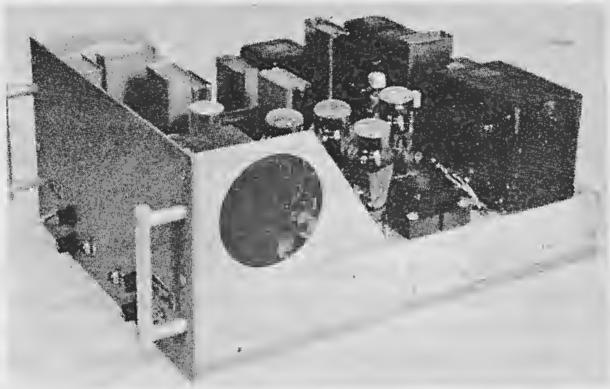

Figure 39 - Oblique view of power supply

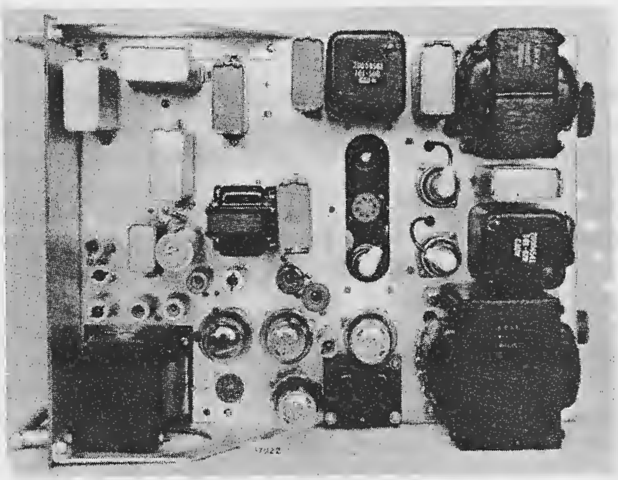

Figure 40 - Top view of power supply

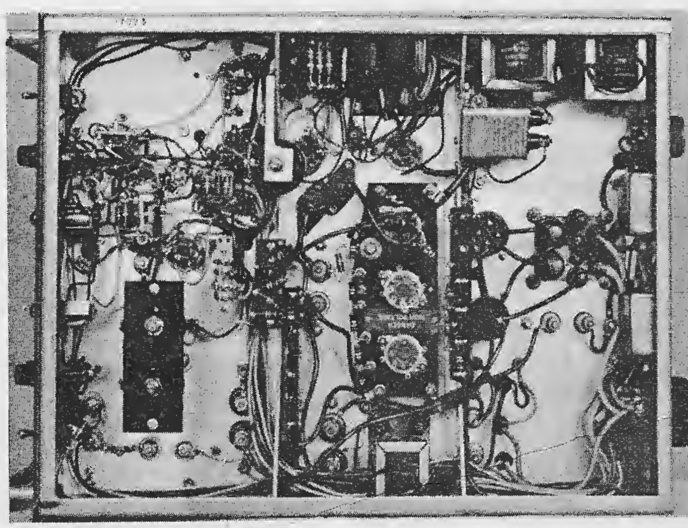

Figure 41 - Bottom view of power supply

[redacted]

 [redacted]

the analyzer. In the design of the 180-volt source, greater gain in the amplifier stage, V52, was obtained by connecting the amplifier plate-load resistor to the 450-volt regulated potential instead of to the 180-volt regulated potential. Simplification of the circuit was obtained by utilizing various regulated voltage sources as reference potentials in the design of the regulated power-supply circuits. Thus the need for individual reference tubes for each of the individual regulated-voltage circuits was eliminated. Regulation of the negative 1750-volt source improved the trace-length stability in the presence of line-voltage fluctuations.

In the power supply, the wiring of the paralleled rectifiers (V47, V48) for the 180- and 250-volt potentials should be changed so that each potential has its own individual full-wave rectifier and filtering system. In this manner better isolation could be obtained between these two potentials, and the ripple content of the 250-volt source, due to current surges from the 50,000- and 5,000-μsec sweep circuits, could be decreased. When high-sensitivity, deflection-plate, 5-gun tubes become available, the requirements on the video amplifier will be reduced to a point where the 250-volt power source will not be required.

PERFORMANCE

The circuits were synchronized with single groups of pulses[7] or with repetitive pulses[8] at rates up through 2 Mc. Synchronization with a 0.1-μsec pulse whose frequency varied from 20 cycles through 2 Mc is demonstrated by Figures 42 through 47. Since the maximum ratio of the sweep speeds of the time bases is 10,000-to-1, photographing these traces is a difficult problem. The unblanking pulses of the time bases have been adjusted in amplitude to present an optimum intensity when the unit is triggered through the entire synchronization range.

The analyzer was connected to an AN/APR-9 countermeasures receiver to analyze several signals that were being transmitted in the adjoining area. A typical rotating radar presentation is shown by Figure 48. The effect of the pulse-stretching circuits, designed to display visually narrow pulses on the longer time bases, can be noticed on the lower two traces, and, on the bottom trace can be seen the antenna pattern of the intercepted radar beam. In long-distance interception of a narrow-beam radar, if the duration of the amplitude variation of the intercepted signal does not exceed the time base of the bottom trace, the antenna pattern of the intercepted radar can be approximated by observing the displayed pattern on the bottom trace and measuring the time between consecutive bursts.

The proximity of a powerful radar installation causes echoes, (e.g., from buildings or other reflecting surfaces) to be displayed on the indicator. This is shown in Figure 49.

The modulation characteristics of many modulated pulse systems[9] can be displayed by this analyzer.

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[7] Young, J. D., "Pulse-Train Control System," NRL Report No. 3502 (Confidential), 7 July 1949

[8] Young, J. D., "Generation of Very Short Pulses at Megacycle Rates," NRL Report No. 3678 (Confidential), 7 June 1950

[9] Young, J. D., "Simulation of Complex Pulse Modulation," NRL Report No. 3832, 27 April 1951

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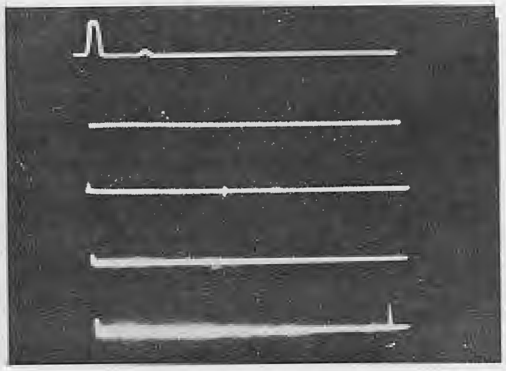

Figure 42 - Indicator presentation of 0.1 μsec pulses with a repetition rate of 20 cycles

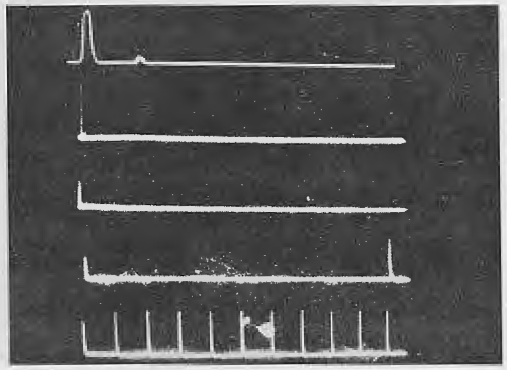

Figure 43 - Indicator presentation of 0.1 μsec pulses with a repetition rate of 200 cycles

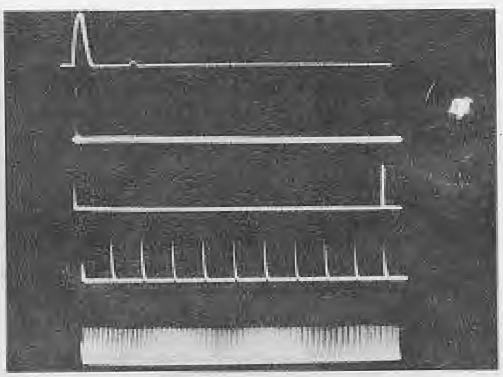

Figure 44 - Indicator presentation of 0.1 μsec pulses with a repetition rate of 2000 cycles

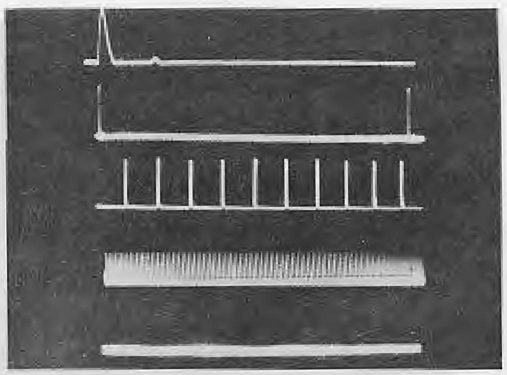

Figure 45 - Indicator presentation of 0.1 μsec pulses with a repetition rate of 20 kc

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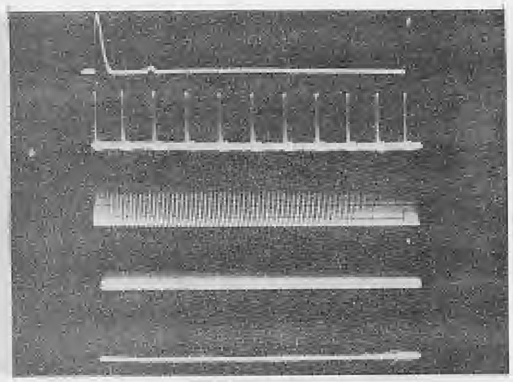

Figure 46 - Indicator presentation of 0.1 μsec pulses with a repetition rate of 200 kc

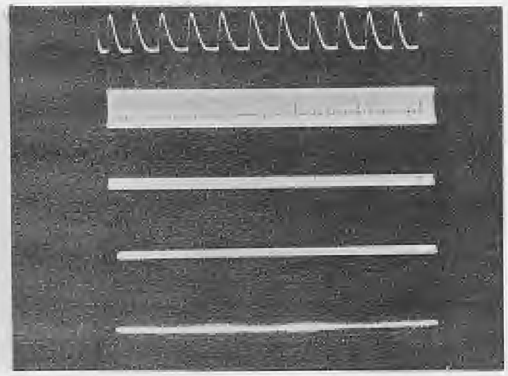

Figure 47 - Indicator presentation of 0.1 μsec pulses with a repetition rate of 2 Mc

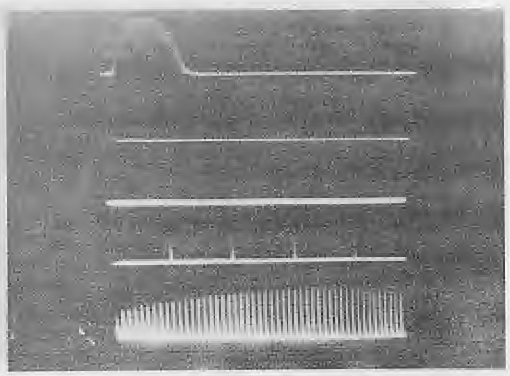

Figure 48 - Typical rotating radar presentation (pulse width, 1.25 μsec; repetition rate, 920 cycles)

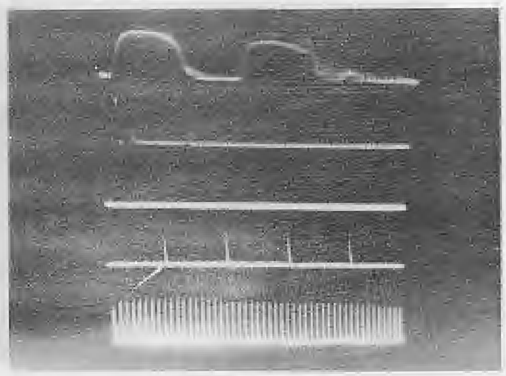

Figure 49 - Typical rotating radar presentation (pulse width, 1.25 μsec; repetition rate, 920 cycles; with echoes from nearby buildings displayed)

[redacted]

[redacted]

In Figure 50, a simple pulse system is displayed. The pulse width is 6-μsec and the pulse repetition-frequency is 14 kc. In Figure 51 the effect of pulse repetition-frequency modulation of the system presented in Figure 50 is displayed. On the middle trace a progressive increase in the variation of the pulses caused by the pulse repetition-frequency modulation can be noticed; on the second trace from the bottom, a bunching effect caused by the pulse repetition-frequency modulation can be detected.

Figure 52 shows the effect of pulse amplitude modulation of the system displayed in Figure 50. Amplitude variation of the signal can be noticed on all the traces.

In Figure 53 a double-pulse system is displayed by the analyzer. This figure shows on the top trace a 4-μsec pulse which is amplitude modulated. On the next trace two pulses are displayed. The first pulse is the 4-μsec amplitude-modulated pulse, followed 13 μsec later by a pulse whose width is modulated. The width of the second pulse varies from 7 to 9 μsec. The repetition frequency of the pulse group is 14 kc.

In Figure 54 a pulse group system is illustrated. This display shows a group of 0.5-μsec pulses spaced 10 μsec apart. The group repetition frequency is 3100 cycles.

Figure 55 illustrates the display of pulse group modulation. On the middle trace the variation of the numbers of pulses in the groups is indicated.

Figure 56 shows the presentation of a multichannel system. The top trace of the display shows a 0.5-μsec pulse, the next shows the 0.5-μsec pulse followed by an amplitude-modulated pulse 10 μsec wide. The amplitude-modulated pulse is followed by a pulse whose position is modulated. On the middle trace the repetition frequency of 14 kc is displayed.

Figure 57 shows the presentation of another multichannel system. The top trace of the display shows a 0.5-μsec pulse followed 2.5 μsec later by an amplitude-modulated pulse 8 μsec wide. The next trace shows the first two pulses followed 20 microseconds later by a width-modulated pulse. The width of this pulse varies from 4 to 6 microseconds. The amplitude modulation is best illustrated on the longer time bases.

CONCLUSIONS

The performance characteristics of the pulse analyzer described in this report have substantially proved the merit of its circuits. The operation of the unit has shown the practicality of the synchronizing and lockout circuits as a device permitting stable synchronization of the sweep circuits with signals having a wide range of waveforms, repetition rates, and duty cycles. The use of a single clamp-tube sweep circuit followed by a dc amplifier for sweep deflection produces a pattern which has a minimum of drift with duty cycle and therefore provides the maximum trace integration for photographic purposes.

Experience gained during design and operation of the circuits described in this report supports the following statements:

a. The low vertical-deflection sensitivity of present five-gun cathode-ray tubes compared to that possible with new deflection structures makes the design of an efficient wide-band, high-gain, video amplifier a difficult problem and one which is expensive in terms of power required.

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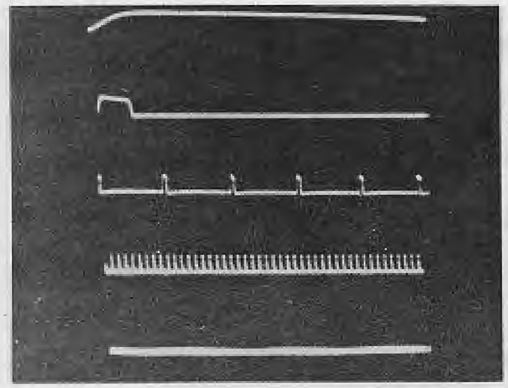

Figure 50 - Pulse width and pulse repetition rate presentation

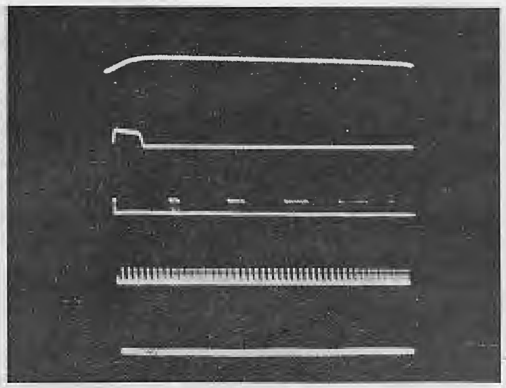

Figure 51 - Pulse repetition-frequency modulation

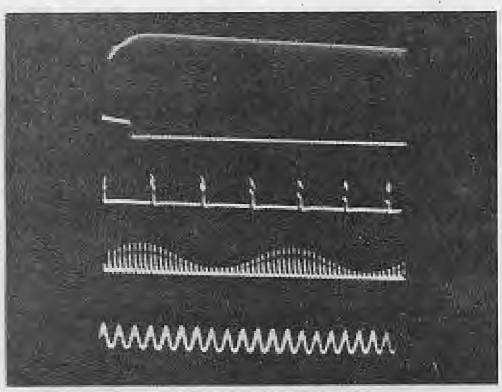

Figure 52 - Pulse amplitude modulation

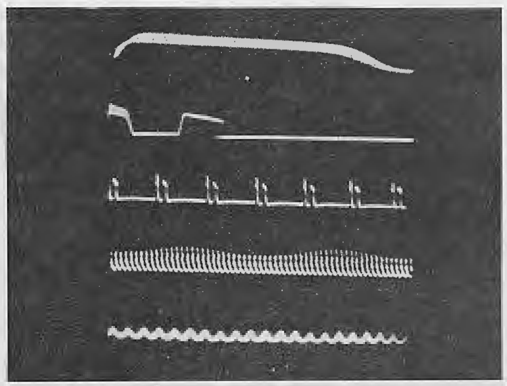

Figure 53 - A double pulse system; First pulse amplitude modulated; Second pulse width modulated

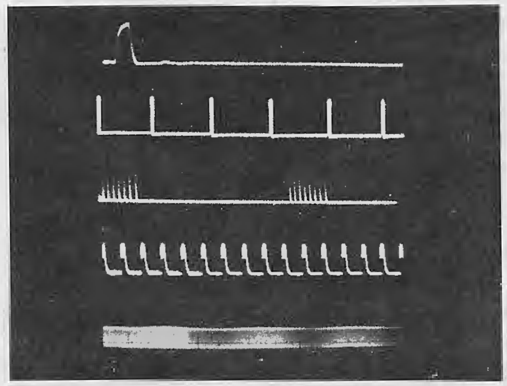

Figure 54 - Pulse group presentation

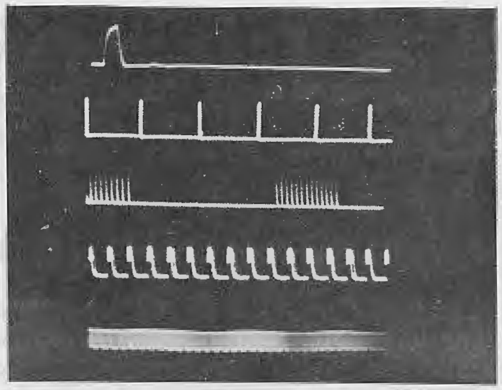

Figure 55 - Pulse group modulation

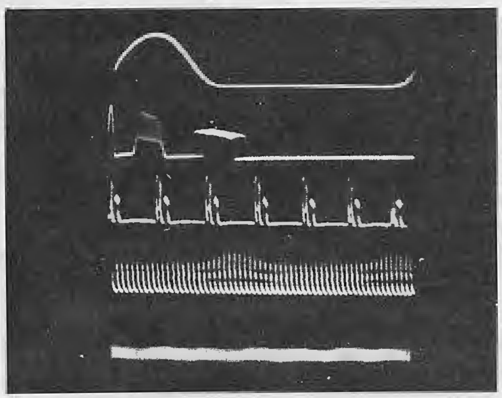

Figure 56 - A multichannel system consisting of a sync pulse, an amplitude modulated pulse and a position modulated pulse

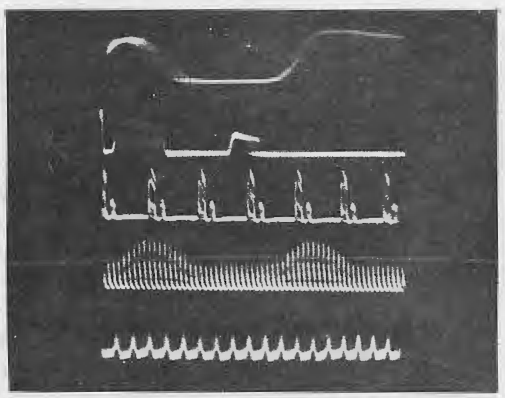

Figure 57 - A multichannel system consisting of a sync pulse, an amplitude modulated pulse and a width modulated pulse

b. The low horizontal-deflection sensitivity of present five-gun cathode-ray tubes increases the difficulty of designing sweep amplifiers capable of producing the deflection required with adequate linearity.

c. The inadequate video bandwidths and output video levels of modern microwave receivers, as represented by models of the AN/APR-9 available at NRL, make difficult the design of the video-amplifiers in analyzers to be employed with these receivers, in that such associated amplifiers are required to provide far greater than their proportionate share of both bandwidth and amplification.

The modulation characteristics of many modulated-pulse systems can be determined by this analyzer. The following types of pulse modulation can be distinguished: pulse amplitude, pulse number, pulse width, pulse repetition-frequency, pulse group, and pulse position.

Photographs in this report show that although equipment of the AN/SLA type does permit analysis of the modes of pulse modulation and the time and amplitude characteristics of most pulse signals, it does not always completely analyze the intelligence transmitted. Ambiguity can arise in certain cases. These limitations of present equipment indicate the need for continued research to determine improved methods of analysis for complex pulse modulations in order to provide adequate intercept data necessary for the development and operation of new countermeasures devices for action against an enemies' complex transmissions.

RECOMMENDATIONS

It is recommended that the circuits in new countermeasures pulse analyzers be based on the circuit techniques used in the NRL experimental unit described. To alleviate the design problems associated with the video- and sweep-deflection amplifiers, it is further recommended that the following improvements be made in the associated receivers and cathode-ray tubes:

a. All AN/APR-9 receivers now in the field should be modified to provide increased video output and a video bandwidth of at least one-half the i-f amplifier bandwidth. All specifications for new receivers such as improved models of the AN/APR-9, the AN/BLR, and the AN/SSQ-11 should be prepared with this recommendation in mind.

b. The deflection sensitivity of the five-gun cathode-ray tubes used in this analyzer should be improved. It is suggested that:

1. The vertical deflection sensitivity be improved by use of deflection structures similar to that employed in the 5XP (DuMont) cathode-ray tubes.

2. The horizontal-deflection sensitivity be improved by decreasing the spacing of the horizontal-deflection plates to the limit permitted by the required centered range of deflection. The increase in capacity caused by this change is considered of minor importance in connection with the speed of sweeps employed.

The use of a cathode-ray tube with square face should be investigated in order to reduce the mechanical size of the tube and still retain the advantages of a large screen. Decreasing the curvature of the tube face should be considered in order to reduce the parallax that occurs with present tubes.

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For countermeasures operations it would be desirable to have all the pertinent information centered in front of the intercept operator for ease and swiftness of operation. Therefore future research should include investigation of nonlinear sweeps, such as logarithmic types, to consolidate the pulse analysis information on three or less sweeps. This would leave two or more cathode-ray traces available for panoramic, direction-finding and other pertinent indications on the same display.

ACKNOWLEDGMENT

Acknowledgment for the pioneer work in the early developmental stages of this technique should be given to J. E. Gall and C. C. Mezger - formerly of the Countermeasures Branch. Karl R. Medrow, formerly of the Countermeasures Branch, designed the video amplifier and calibration circuit. Appreciation is extended to the following staff members of the Countermeasures Branch: to H. K. Weidemann for his encouragement, suggestions, and constructive criticisms; to J. S. Tomczak for his work in laying out and constructing the indicator and power supply units; and to J. H. Markell for his suggestions and assistance in preparing this report.

* * *

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NAVY-DPPO PRNC, WASH., D.C.