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A UNIFIED DISPLAY FOR COUNTERMEASURES RECEIVERS

[UNCLASSIFIED TITLE]

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ABSTRACT

In order to secure complete intercept information, a countermeasures operator must observe three separate and often widely spaced cathode-ray-tube displays. To reduce operator fatigue, improve the threshold for a wide range of signal types and increase the amount of reliable information obtained from an intercept, a countermeasures indicator has been developed, utilizing a multigun cathode-ray tube, that simultaneously displays signal-analysis, direction-finding and panoramic oscilloscope (panscope) information.

The signal analysis is presented on a 0-5 μsec exponential sweep, a 5-500 μsec two-decade approximately logarithmic sweep and a 500-50,000 μsec two-decade approximately logarithmic sweep. The direction-finder bearing is presented on two linear scales. The panscope display is presented in the usual manner. Provisions have been made to gate the intensities of the displays to allow photography to be used as a means of data recording.

The direction-finding indication works with any standard microwave antenna rotating at 0 to 720 rpm in either direction and gives a bearing on cw as well as modulated signals.

Future microwave intercept systems based on high-resolution superheterodyne receivers should include the techniques described in this report to insure the maximum utilization of the intercept data by providing a unified display.

PROBLEM STATUS

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

AUTHORIZATION

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A UNIFIED DISPLAY FOR COUNTERMEASURES RECEIVERS
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BACKGROUND

One of the aims of the Countermeasures Branch of the Naval Research Laboratory has been the development of techniques applicable to the improvement of countermeasures intercept equipment. The major efforts are directed toward improving the threshold of interception for a wide range of signal types and/or increasing the amount of reliable information obtained from each intercept. At the same time techniques are developed to simplify intercept equipments and to reduce their power and space requirements.

From an operational standpoint, the countermeasures intercept operator has a difficult task. Signal analyzers such as the AN/SLA-1, AN/SLA-2, and the AN/APA-74 have made the operator's job considerably easier, and they have increased the amount of reliable information obtained and improved the threshold of interception for a wide range of signal types. Even with these equipments, however, the operator must look at one scope to tune the receiver, look at a second scope for direction-finding information, and observe a third scope for signal-analysis information. Often the position of these scopes with respect to each other and with respect to the operator is disadvantageous.

Narrow-band panoramic systems (panscopes) such as those contained in the AN/APR-9, AN/BLR-1, AN/SLR-2, etc., have relatively good response to cw signals and wide-pulse high-repetition-rate signals. A multisweep signal analyzer with wideband circuits and multiple time-base presentations is superior to the panscope with regard to narrow-pulse response and response to extremely short bursts (1).

To eliminate the multiplicity of scopes the operator must face and to provide all the displays necessary for the satisfactory interception of all types of signals, the Countermeasures Branch undertook the development of a unified indicator which would present the signal analysis, direction finding, and receiver panscope displays simultaneously on a single scope.

The first attempt at a unified indicator might have been combining a signal analyzer using five slave sweeps, such as the types previously mentioned, with a linear direction-finding display and the receiver panscope. It is believed that it would have been possible to develop the seven-gun cathode-ray tube required for such an indicator, if time sharing were not to be used. There would be two major disadvantages to a seven-sweep presentation: the cathode-ray tube would be quite large and the operator would have difficulty observing seven sweeps. Since excellent five-gun cathode-ray tubes had been developed (7XP2, 7YP2) and were in use by the armed forces, the first attempt would be to use such a tube.

If a five-gun cathode-ray tube were used, it would require that only three sweeps be used for signal analysis. Sweeps of various shapes were investigated and it was found that a linear or exponential sweep and 2 two-decade logarithmic sweeps would theoretically be suitable for use in a three-sweep signal analyzer (2). At the same time several circuits using only passive components were proposed for the generation of two-decade approximately logarithmic sweeps. A signal analyzer was successfully designed and constructed using a 0-5 μsec exponential sweep, a 5-500 μsec approximately logarithmic sweep and a 500-50,000 μsec approximately logarithmic sweep (3). Tests on the three-sweep analyzer indicated it was stable, reasonably accurate and practical (4).

UNIFIED INDICATOR

A unified indicator, using three sweeps for a signal-analysis display, one sweep for a df display, and one sweep for the receiver panscope display, was developed. The complete schematic of the unified indicator is given as Plate 1 at the end of this report.

Signal Analyzer Section

The circuitry of the three-sweep signal analyzer that had been developed previously and reported in references 2 and 3 was used as a basis for the signal-analyzer circuitry in the unified indicator. Three changes were made in the circuit techniques. The circuits of the signal-analyzer section of the unified indicator are given as Figs. A-1 to A-6 in Appendix A.

Originally, a diode was used in the 500-50,000 μsec sweep circuit to reduce the recovery time by discharging the 0.01055 μf capacitor, C_1 (Fig. 1a). The diode discharged the capacitor to within about 3/4 volt of the plate potential of V504A. If the sweep was not triggered, the remaining 3/4 volt would discharge through the 0.957M resistor until the voltage across C_1 equalled the plate voltage of V504A. When the sweep was triggered, C_1 would start to charge toward the supply potential; at the end of the sweep the diode would discharge C_1 to within 3/4 volt of the plate voltage of V504A. If the sweep was triggered again as soon as the lockout would allow, C_1 would charge toward the supply potential but would have started charging from a higher potential than the previous time; thus the shape of the sweep would be changed. A pulse occurring a given time after the start of the sweep would not always appear in the same position on the screen because of the change in sweep shape. To eliminate this difficulty a system of double gating was devised. In this system, (Fig. 1b and A-5), C_1 is always discharged through V504B to the same potential. Although this potential is not the same as the plate potential of V504A, it differs by a constant voltage, and consequently the shape of the charging curve (the sweep voltage) is constant. The effect of the incomplete recovery of C_1 was more apparent in the unified indicator for two reasons. The analysis sweeps in the unified indicator are 4 inches long while in the three-sweep analyzer (3) they were only 2-1/2 inches. Secondly, the amplitude of sweep waveform required in the analyzer section of the unified indicator is only 75% of that required by the other analyzer. Thus the effect of the residual 3/4 volt was amplified.

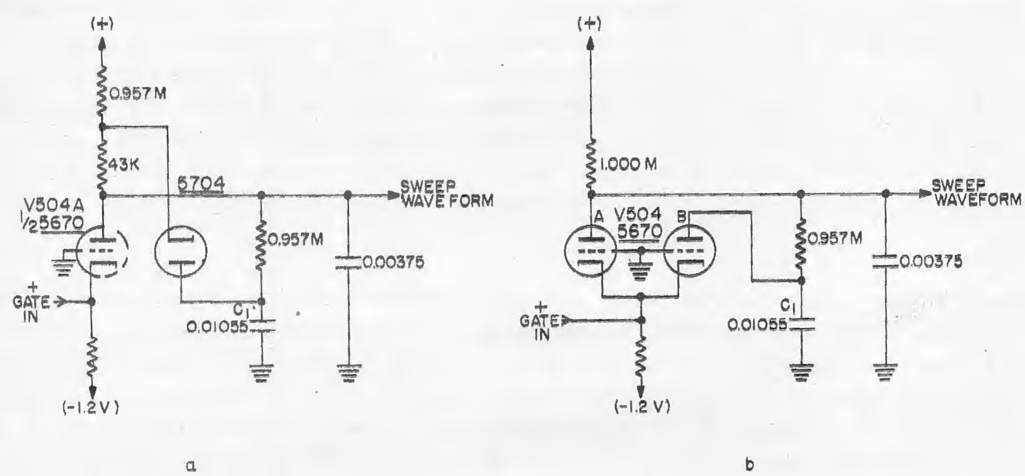


Fig. 1 - Sweep-capacitor recovery networks

The second change in circuit technique was in the pulse-stretcher circuits. Experience with the three-sweep analyzer showed that the pulse stretching near the center of the approximately logarithmic sweeps was inadequate. The waveform used to vary the impedance of the discharge pentodes (V204 and V205, Fig. A-2) was an integrated negative gate. Near the center of the sweep the gate was not negative enough. To eliminate this difficulty a small portion of the negative-going sweep waveform was obtained from taps on the plate load resistors of the deflection amplifiers (V404A, Fig. A-4 and V505A, Fig. A-5). This waveform was used to control the stretching pentode. Figure 2 shows the difference in shapes of these waveforms on the grid of pentode V204 in the 5-500 μsec pulse stretcher.

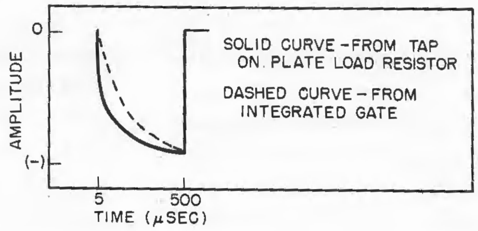


Fig. 2 - Waveforms to control pulse stretching

From the very start of the work with nonlinear sweeps it had been realized that the intensity tailoring might be a problem when changing cathode-ray tubes or cathode-ray tube types. The networks used (pages 5 and 6 of reference 3) to provide tailoring of the intensity of the nonlinear sweeps on a type K1115P2 cathode-ray tube were duplicated in the intensity circuits for the signal-analysis sweeps of the unified indicator. These tailoring networks are in the grid circuits of V1501B and V1501C, Fig. A-6. Several 7YP2 cathode-ray tubes were tried in the combined indicator, but satisfactory intensity tailoring for all tubes was not secured. Further investigation showed that the shapes of the tailored gates were satisfactory but the amplitudes had to be varied for different cathode-ray tubes. A potentiometer was added to the circuit to control the amplitude of the 5-500 μsec rectangular gate delivered to the intensity-tailoring network; this potentiometer is in the cathode circuit of V403A (Fig. A-4). Adjustment of the potentiometer provided proper intensity tailoring for the 5-500 μsec sweep on all cathode-ray tubes. A similar control in the cathode circuit of V503B (Fig. A-5) serves the same purpose for the 500-50,000 μsec sweep.

Signal analyzers such as the AN/SLA-1 and AN/SLA-2 indicate the presence of amplitude-modulated signals. The signal may be amplitude modulated to transmit information or the modulation may be caused by the varying signal strength from a lobe-switching or conical-scanning radar. Often it is desired to know what the modulating signal is. In the AN/SLA-1 or AN/SLA-2 analyzers this could sometimes be determined by reducing the video gain until the circuits synchronized on the highest pulse under the envelope. If the internal sync level control in the analyzer was set at a low value, the video amplitude had to be reduced considerably to stabilize the display.

To remove the difficulty of trying to interpret such a low signal, a front panel sync level control was incorporated in this analyzer. This control changes the level at which the Schmitt circuit in the signal analyzer triggers. Thus by adjusting the sync level control it is possible to trigger the analyzer on the highest pulse under an envelope without reducing the amplitude of the signal. The sync level control varies the bias of the signal-analyzer Schmitt circuit. This control is shown on the schematic diagram (Fig. A-3). The variable resistor (sync range control) in series with the sync level control is adjusted so that, with no signal present, adjustment of the sync level control does not cause the Schmitt circuit to trigger.

The changes described in the remainder of this section do not represent changes in basic techniques but are modifications to improve the performance or decrease the complexity of the instrument.

A fixed pulse stretcher circuit, V202C and V207A, was added to the original variable stretcher circuits shown in Fig. A-2. The output of the fixed stretcher is used to drive the audio stretcher (V209) and the audio output circuit (V210). With this audio stretching system (5), even a single 0.1 μsec pulse produces a loud click in the headphones. The output of the fixed stretcher is also used in the DF system which will be described later in this report.

Countermeasures signal analyzers in the past have been designed to be used with several types of receivers. Some of these receivers have positive video outputs while others have negative video outputs. Consequently, the video amplifiers in the signal analyzers had a video polarity switch. Since the unified indicator was designed to be used either with the AN/SLR-2, AN/BLR-1, or the AN/APR-9 as modified by Root (6), all of which have a positive wideband video output, the phase inverter and polarity switch were eliminated from the video amplifier circuit. The cathode follower, V102 (Fig. A-1), is used to isolate the high input capacity of the 418A (V103), from the plate circuit of the 5847/404A (V101).

Solem (3) treated the subject of gate coupling affecting the sweep shape and indicated the effect could be minimized by using cathode gating. The effect of gate coupling is to change the speed of the start of the sweep. Cathode gating reduced the effect of gate coupling across the interelectrode capacity of the sweep tube, but the capacity of the circuits adjacent to the tube causes considerable gate coupling. Initially, it was thought the effect could be removed sufficiently by shielding the lead from the plate of V403B (Fig. A-4) to the grid of V404A. This was not sufficient so a grounded shield was soldered across the socket of V403. The shield passes between pins 2 and 3, is soldered to center shield, pin 7, and ground, and passes between the components of the sweep-generating network and gate-carrying components (Fig. 3). To reduce the coupling further, the intensity-gate lead from the cathode circuit of V403 is run on the opposite side of the chassis plate from the other components.

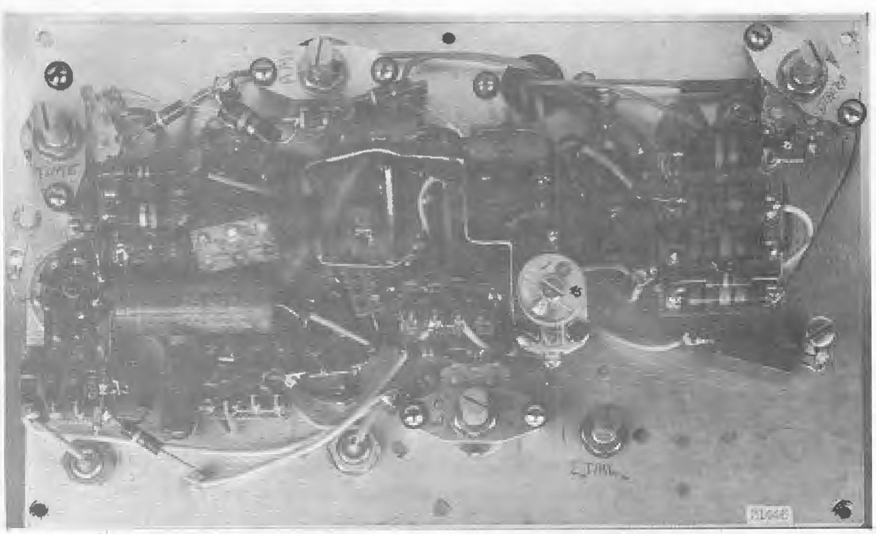


Fig. 3 - 5-500 μsec chassis, showing location of shield used to reduce gate coupling

 [redacted]

Other changes of a minor nature were made in the signal-analyzer circuits, such as the elimination of 5% resistor sizes wherever possible and a change in some tube types. The −105 volt supply was changed to a −90 volt supply so that the heaters of the pentodes, V204 and V205 (Fig. A-2), in the stretcher circuits could be run from the grounded heater lines without exceeding the heater-cathode voltage ratings of the tubes. The high writing speed at the start of the 0-5 μsec sweep causes the trace intensity to be low. To increase the intensity of this sweep the accelerating potential was raised to 5000 volts (+2500 volts and −2500 volts with respect to ground).

Linear Direction Finder

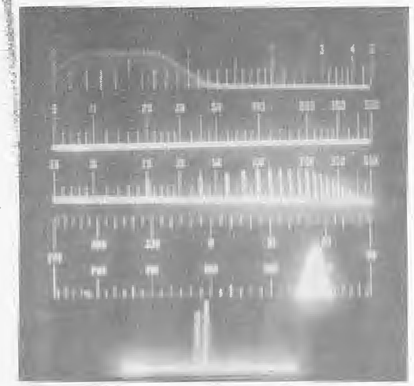
A linear direction-finding presentation was chosen for two reasons; first, to conserve display area, and second, because the sensitive deflection plates in the cathode-ray tube limit the vertical deflection to two inches and so do not permit the generation of an adequate polar display. There are numerous ways to generate a linear sweep from a rotation. A modulated-carrier system was chosen for its long rotational life, freedom from noise, and high order of resolution.

Briefly, the linear direction-finding presentation is as follows: two horizontal traces, one 3/4 inch above the other, are traced out by a moving spot on the face of the cathode-ray tube. The upper trace represents rotation of the antenna from 270° to 0° to 90° (Fig. 4). The lower trace represents rotation of the antenna from 90° to 180° to 270°. Assume the antenna is rotated slowly in a clockwise direction; 0° is the center of the upper trace, and the spot moves to the right to the 90° position. At the 90° position the spot drops suddenly to the lower trace and moves to the left, past 180° at the center of the bottom trace, to the 270° position at the left of the bottom trace. At the 270° position the spot jumps suddenly to the upper trace and moves towards 0° in the center. The spot is effectively direct-coupled to the antenna and indicates the angular position of the antenna whether the antenna is stopped or is rotating at rates up to 720 rpm in either direction. Signals received when the antenna angular position corresponds to a position on the upper trace are displayed downward from the trace. Signals received when the antenna angular position corresponds to a position on the lower trace are displayed upward from the trace. A few examples of signals displayed on the df sweep are shown in Fig. 4.

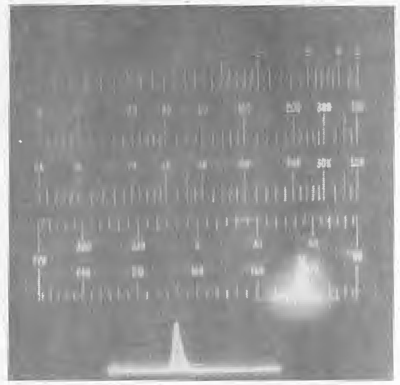
Horizontal Sweep Generator – The basic principle involved in the generation of the linear direction-finding indication is related to the shape of the function ($|\sin\theta| - |\cos\theta|$). This function closely represents the symmetrical triangular waveform required to produce a bidirectional linear sweep. If a two-phase resolver is used to modulate a carrier, the amplitudes of the two outputs are the sine and cosine functions of the shaft angular position. If the two outputs are amplitude detected and their envelopes subtracted, the result is the ($|\sin\theta| - |\cos\theta|$) function. For each 360° of resolver shaft rotation two symmetrical triangular waveforms are generated. To produce the DF display only one waveform is required for each 360° of antenna rotation. To secure the desired relationship between the antenna and the DF display the resolver is driven at one half the antenna rotation rate.

The basic circuit of the demodulator and difference amplifier is show in Fig. 5. The basic circuit was modified to obtain a better output waveform and the circuit shown in Fig. 6 was used.

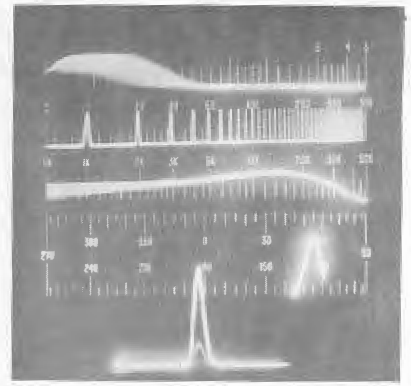
The cathode followers are used to isolate the resolver from the detectors and to prevent the loading of the resolver or transformers. The transformers step up the voltage outputs of the resolvers to allow the crystal diodes to operate over a larger portion of their linear range. The full-wave connection is used to make the filtering easier. The filters were chosen to give good filtering of the carrier frequency without affecting the carrier-envelope waveform. In practice, the differential amplifier is the deflection amplifier for the cathode-ray tube.



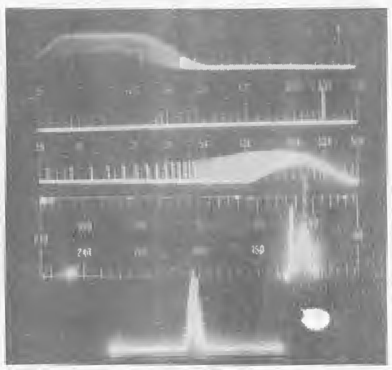
(a) - Pulse signal: pulse width 0.75 μsec, pulse period 2050 μsec, bearing 126°



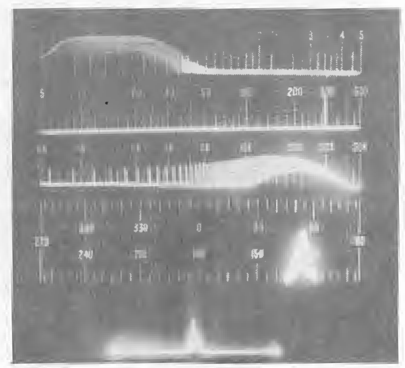
(b) - CW signal: bearing 126°



(c) - Pulse signal: pulse width 0.65 μsec, pulse period 10 μsec, bearing 126°



(d) - Pulse signal: pulse width 0.8 μsec, pulse period 295 μsec, bearing 126°



(e) - Same as (d) but DF narrow-band display switch opened

Fig. 4 - Photographs of signals displayed on the unified indicator

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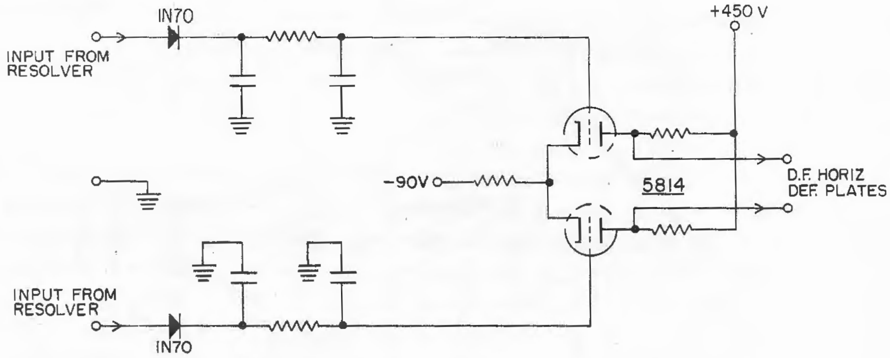

Fig. 5 - Original demodulators and sweep amplifier

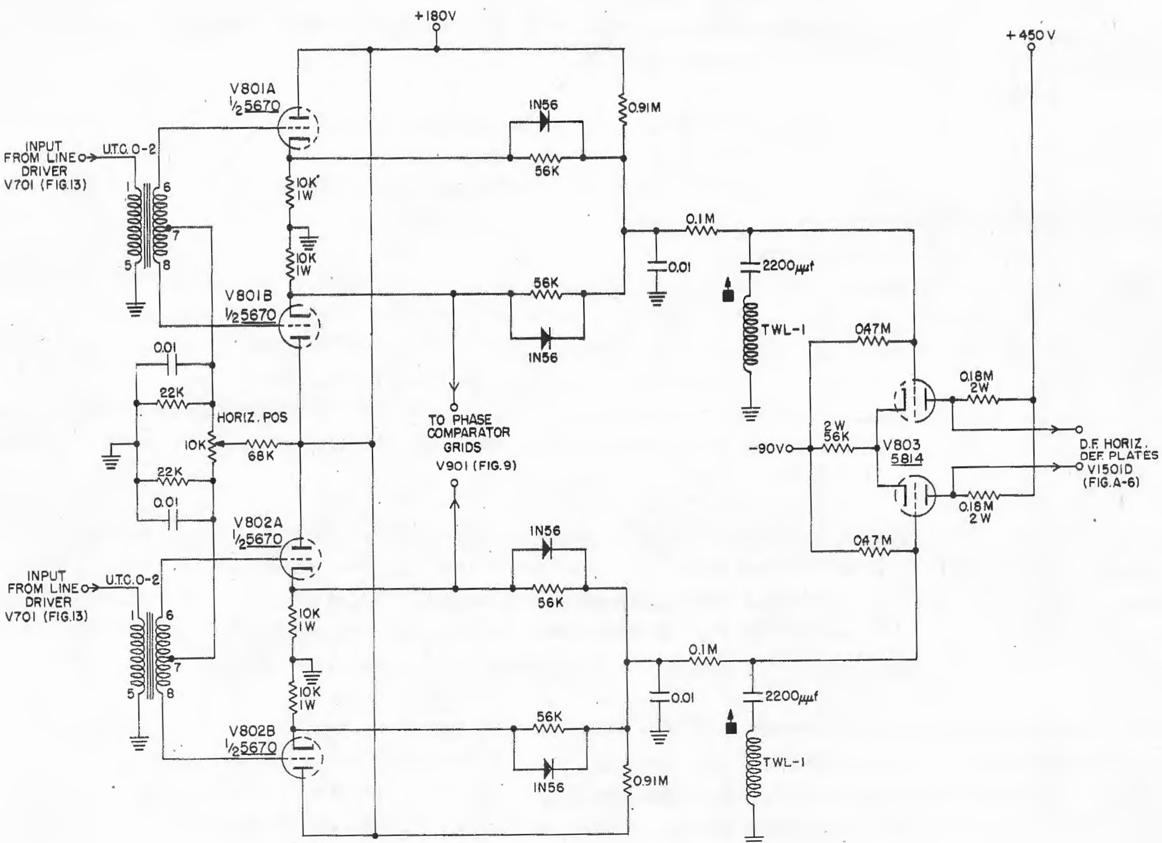

Fig. 6 - Demodulators and sweep am[redacted]

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From Fig. 6 it can be seen that for any position of the resolver there are two outputs at the carrier frequency. The relative amplitudes of these two outputs depend upon the angular position of the resolver shaft. Each of these output voltages is stepped up by the transformers and rectified by the crystal diodes. At the grids of the differential amplifier there are dc voltages the magnitudes of which depend upon the angular position of the resolver shaft. The plates of the differential amplifier are direct-coupled to the cathode-ray tube horizontal deflection plates. This circuit is effectively direct-coupled from the resolver shaft to the deflection plates.

The original sweep-generating circuit was similar to that of Fig. 6 except that 1N70 crystal diodes were used and no positive bias voltage was applied to the crystals. The output of this circuit was plotted and compared to the theoretical waveform. It was found that the tips of the waveform were rounded considerably. It was first thought that the rounding was caused by the resolver having a high voltage output at the null points. The resolvers were replaced with a type having a very low null output, Kearfott Type 235-1-A, with only a slight improvement in the output waveshape. The 1N70 diodes were replaced by 1N56 diodes. Again the output waveshape improved slightly. To operate these diodes at a more favorable portion of their rectification curves, a bias voltage was provided by returning the cathodes of each pair of diodes to +180 volts through a 0.91M resistor as shown in Fig. 6.

The basic waveform for the engraved direction-finding scale is the $(|\sin\theta| - |\cos\theta|)$ curve. However, the spacing of the last five degrees at each end of the sweep was halved to correct for the poor low-signal ability of the crystals in the peak detectors.

When the output waveform of the sweep generator is compared to the desired waveform represented by the engraved DF scales the errors in the generated sweep can be determined (Fig. 7). From Fig. 7, the maximum error observed is 3-1/2 degrees at the 275-degree position. Exeept for the last 5 degrees at each end of the DF scales the observed error is less than 2 degrees.

The lowest carrier frequency that can be used is a function of the highest modulating frequency and of the accuracy desired. At least one Navy antenna, the AN/BPA-1, is capable of rotating at 720 rpm. Thus the highest modulating frequency is 12 cps, which corresponds to 4320 degrees per second. For an accuracy of one-half degree the sampling should occur at least twice each half degree, or 17,280 times a second. When full-wave detection is used, the effect is to double the sampling frequency. Thus a carrier frequency of 8640 cps is the required minimum. For convenience a 10 kc carrier was chosen.

The 10 kc carrier oscillator must be capable of driving the impedance of the resolver as well as the capacity of the lines to the resolver, must have a means of varying the output amplitude, and must maintain a stable output at the set amplitude. The amplitude (width) of the sweep is determined by the carrier amplitude and can be changed by varying the carrier amplitude. An automatic gain-control circuit is included in the oscillator to stablize the carrier output and the sweep width.

The carrier oscillator (Fig. 8) uses half of a 5814, V601A, in a Colpitts circuit. The inductance used in this circuit and the other DF circuits is Chicago Transformer type TWL-1 variable inductors with a maximum inductance of about 30 mh. The oscillator output is fed to a 5725 dual-control pentode, V602, the gain of which is controlled by the suppressor voltage. This harmonic content of the output is filtered by a resonant circuit. The signal from the resonant filter is compared with the output signal in a 5751 differential amplifier, V603. The low output impedance required to drive the capacity of the lines and the input impedance of the resolver is obtained by using half a 5687, V604A, as an output cathode follower and employing negative feedback from the output to the grid of the preceeding stage, V603B. The input to the cathode follower is from the differential amplifier. The final output is fed to a biased detector as well as to the resolver. The biased detector, V601B, one half of a 5814 connected

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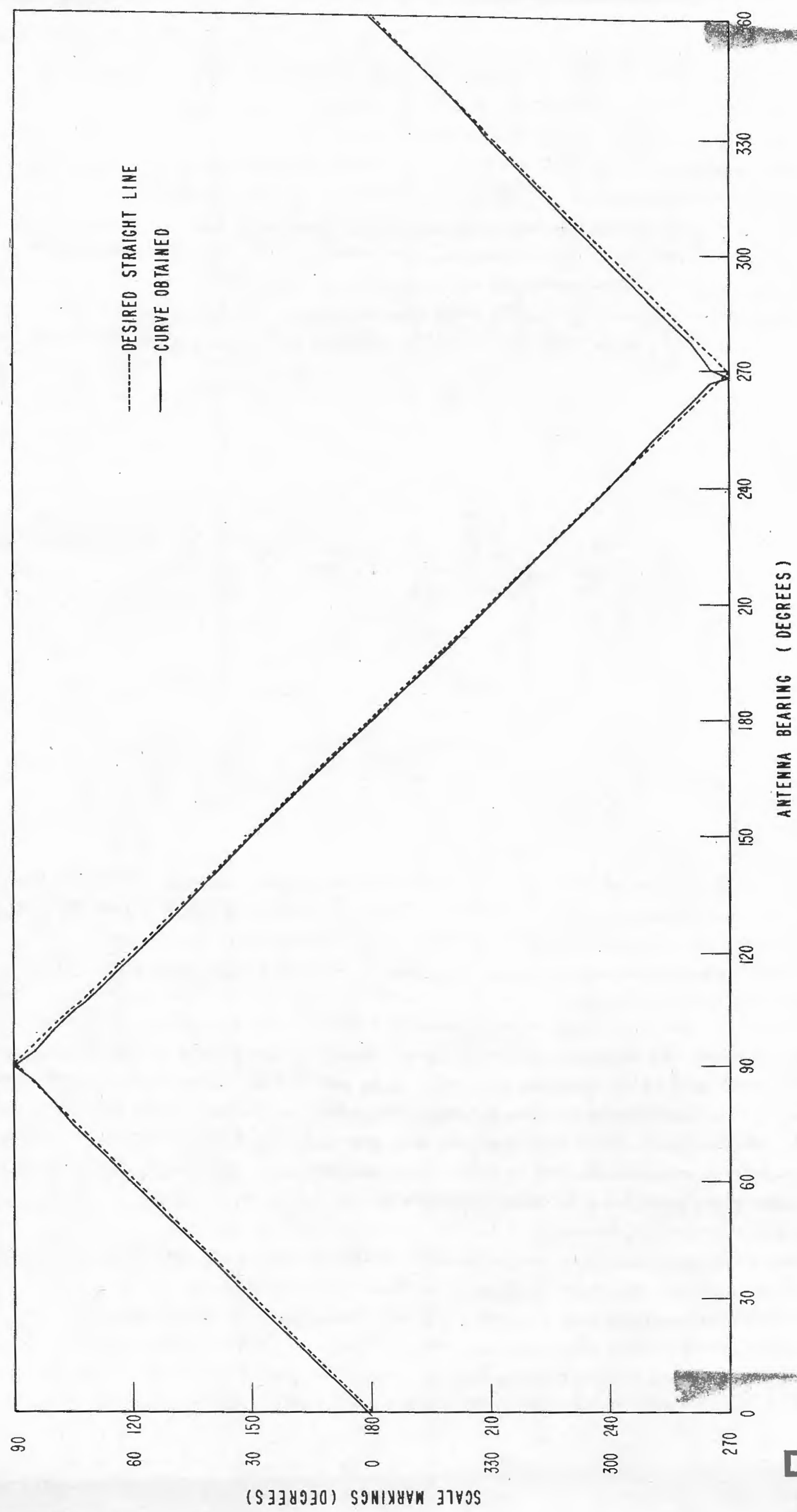

Fig. 7 - DF accuracy curve

as a diode, rectifies the output waveform. The rectified voltage is filtered and applied to the suppressor grid of the 5725. The effect of this circuit is to maintain a constant-amplitude output. The actual output [redacted] is determined by the bias voltage on the detector.

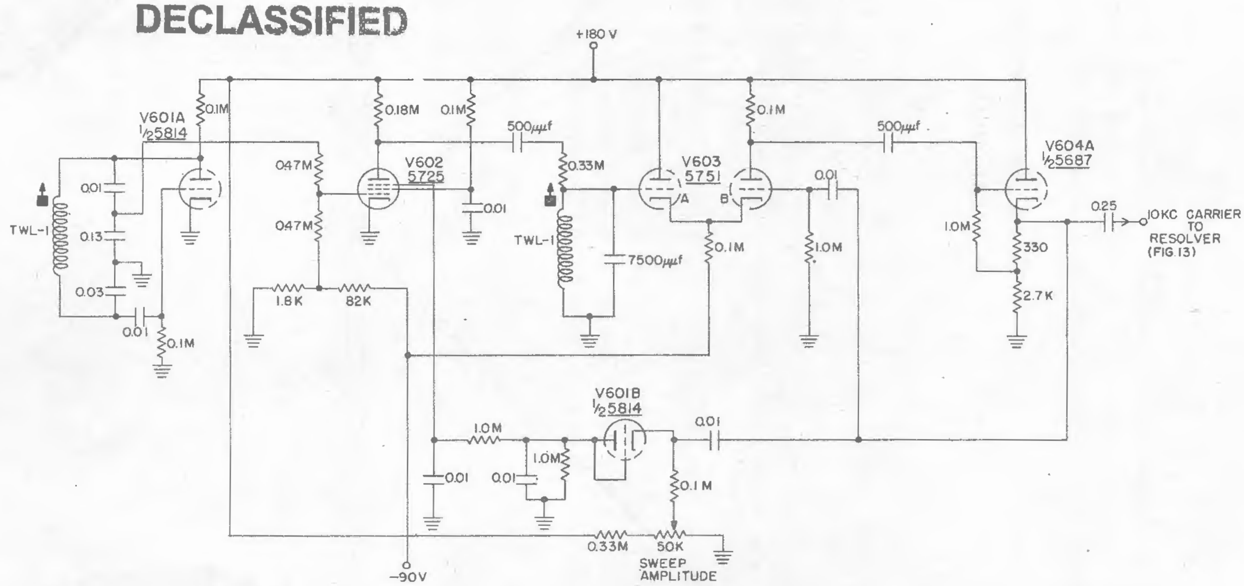

Fig. 8 - Oscillator and amplifier

Vertical Signal Inverter

Control voltage generator - The circuits just described produce the required horizontal deflection. If just the horizontal position of the spot were used to indicate the antenna angular position, every portion of the trace except the end points would correspond to two possible antenna positions. It was necessary to develop a means of eliminating this ambiguity. It was initially proposed to display the received signal vertically from the df trace. Signals received during one half rotation of the antenna would be displayed vertically upward, while signals received during the other half rotation would be displayed vertically downward. To do this a control signal or voltage had to be derived; this control voltage must sense in which half of its rotation the antenna is operating. Each time an output of the resolver passes through a null the phase of the output carrier changes. This means that the phases of the carrier outputs are alike for one half rotation of the antenna and opposite for the other half rotation. From the phase relationships between the carriers from the resolver rotor windings, it can be determined in which half of its angular rotation the antenna is operating.

There are undoubtedly several types of phase detectors that could be used to give an indication of whether the phases of the carriers are alike or opposite. In this application it is desirable to have an indication as close as possible to the points where the phases change. At these points the output of one resolver stator is a maximum while the output of the other is a minimum. If the antenna is rotated until the phases change again (180°) the relative amplitudes of the two carriers are reversed. The phase detector chosen gives an indication, within a fraction of a degree, of the point where the phases change.

[redacted]

[redacted]

A portion of each of the carrier outputs, taken from the cathodes of V801B and V802A (Fig. 6), is squared by successive amplifying and clipping. Figure 9 is the circuit diagram of the clipper stages, phase comparator and control voltage generator. Each of the resulting square waves has the same phase as one of the carriers. The square waves produced are either in phase or 180° out of phase with each other. These square waves are applied to the grids of a differential amplifier, V906. The differential waveform appearing from plate to plate of this stage is applied to the primary of a transformer. When the two square waves are in phase there is no signal on the secondary of the transformer; when the square waves are out of phase an amplified, approximately square wave is developed across the secondary of the transformer. The signal from the secondary of the transformer is rectified and filtered to provide a dc voltage. For one half rotation of the antenna there is a dc output from the filter and for the other half rotation the output is zero. The polarity of the dc depends upon which way the rectifiers are connected.

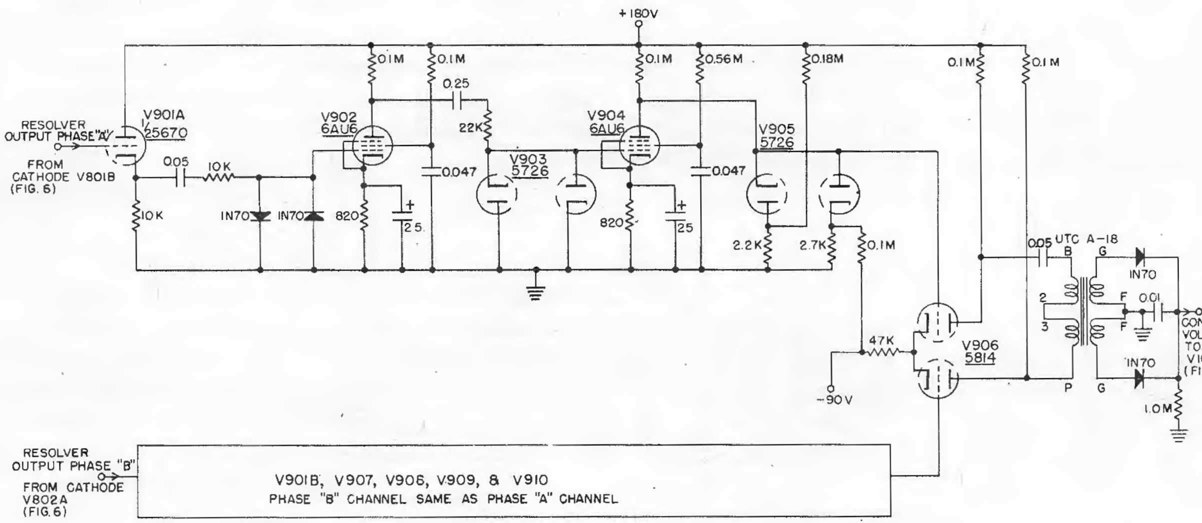

Fig. 9 - Phase comparator and control voltage generator

DF video switch - Each vertical deflection plate of the electron gun that is used for the direction-finding indication is direct-coupled to the plate of a pentode amplifier (Fig. 10). The video signals to be displayed are fed to the parallel-connected control grids of the pentodes. The pentodes used are 5915's, a dual-control type in which the suppressor grids also have control of the plate current. If one pentode is cut off by the suppressor and a signal is fed to the parallel-connected control grids, the other pentode conducts, amplifies, and deflects the electron beam of the cathode-ray tube. In this circuit the input video polarity is positive, so the amplified signal is negative. When the negative signal is applied to the upper vertical deflection plate the deflection is downward, and when it is applied to the lower vertical deflection plate the deflection is upward. The deflection can be made to be upward or downward depending upon which dual-control pentode is conducting. If the suppressor grids of the dual-control pentodes are connected to a voltage source so arranged that only one of the dual-control tubes is allowed to conduct at a time and so that the selection of which tube is conducting is determined by the control voltage, then the correct presentation will result.

To produce the waveforms required at the suppressors of the 5915's from the control voltage available, a cathode-coupled bistable multivibrator (Schmitt circuit), V1001 [redacted]. When the positive control

[redacted]

voltage is applied to the grid of V1001A, this section conducts and the other section, V1001B, is cut off. When the control voltage is decreased, the circuit flips rapidly to the other stable state in which the input section is cut off and the other section is conducting. The waveforms at the plates of the Schmitt circuit are direct-coupled to the suppressor grids of the 5915 dual-control pentodes, (V1003 and V1002, Fig. 10). The direct coupling allows the correct direction of deflection to be maintained when the antenna rotation is stopped. The cathodes of the 5915's are connected to +120 volts; the plate supply is about 235 volts. The plate supply for the Schmitt circuit is +120 volts. The plate voltage of the conducting section in the Schmitt circuit is about +90 volts. Through the direct-coupling to the 5915's one suppressor of the 5915's is therefore at +90 volts. This means that one suppressor is -30 volts with respect to its cathode and that this 5915 is cut off. The plate voltage of the nonconducting section in the Schmitt circuit and, consequently, the voltage on the suppressor grid of the other 5915 is about +120 volts. The suppressor-to-cathode voltage is therefore zero, and this tube conducts.

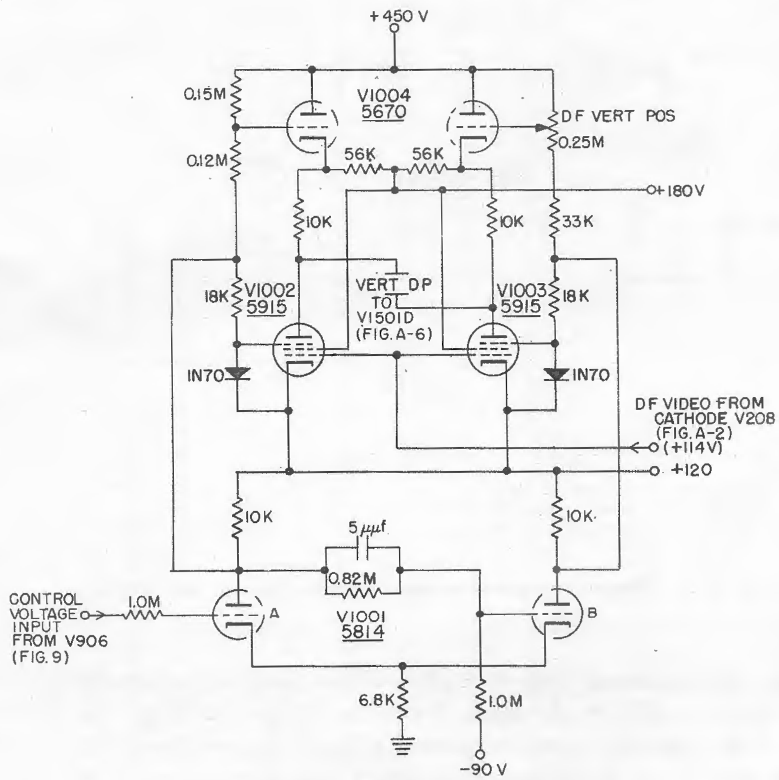

Fig. 10 - DF video switch

Because of the various bleeder circuits attached to the plates in the Schmitt circuit it does not operate symmetrically. The plate voltages in the Schmitt circuit are given in Table 1. The difference in the voltage at the plates when each half of V1001 is conducting is unimportant since the potential is sufficiently less than +120 volts to insure cutting the 5915 tube off. When a Schmitt-circuit section is cut off, its plate potential affects the conductance of the attached 5915. To minimize the effect of the difference in suppressor voltages, a germanium diode was connected from suppressor to cathode of each tube in such a manner to prevent the suppressor potential from rising above the cathode potential. The 18K resistors prevent the 1N70's from drawing excessive current.

[redacted]

TABLE 1
Schmitt-Circuit Plate Potentials

Test Point	Potential (volts)	
	V1001A Conducts	V1001B Conducts
Plate V1001A	85	127
Plate V1001B	130	89

In summary, the factors that determine the direction of the video display are the following: The resolver carrier outputs are either in phase of 180° out of phase, depending in which half of its rotation the antenna is operating. The phase comparator and control-voltage generator give a positive dc voltage output when the carriers are out of phase and a zero dc output when the carriers are in phase. When the control voltage is zero, the input section (V1001A, Fig. 10) in the Schmitt circuit is cut off and the other section (V1001B) conducts. The 5915 (V1002) with its suppressor connected to the plate of the Schmitt circuit input section conducts, while the other 5915 (V1003) is cut off. When the control voltage is positive the input section (V1001A) of the Schmitt circuit conducts; the other section (V1001B) in the Schmitt circuit is cut off and, therefore, the 5915 (V1002) is cut off and the 5915 (V1003) conducts. The direction of the display depends upon which 5915 conducts. When V1002 conducts the deflection is downward and when V1003 conducts the deflection is upward.

The plate voltage for each 5915 is obtained from a section of cathode follower V1004. The grid voltage of one cathode follower is set by a fixed divider; the grid voltage of the other cathode follower is set by a potentiometer to allow vertical positioning of the trace. Each cathode-follower grid has a portion of the Schmitt-circuit plate waveforms applied to it. This gives a dynamic positioning of the trace. When the video deflection is downward, the trace is positioned above the undeflected spot position, and when the video deflection is upward, the trace is positioned below the undeflected spot position. The magnitude of trace displacement is controlled by varying the basis potential on the control grids of V1002 and V1003.

Video Circuits - It was felt that the df display should be capable of giving the bearing of cw signals as well as pulse signals so that a maximum amount of information could be obtained from the combined indicator.

When the receiver is tuned to a cw signal its narrow-band output (Panscope Video) effectively consists of a series of pulses. These pulses are caused by the heterodyne action between the sweeping oscillator and the cw signal. These pulses are the same as the envelope shape seen on the panscope. This video can be used to give a DF indication on cw signals. To give an indication on all type signals it is necessary to add the wide- and narrow-band video outputs. All except the very-narrow-pulse signals appear in both the wide- and narrow-band video outputs. To prevent the generation of odd waveshapes by the addition of wide- and narrow-band video, an integrating network is used in the narrow-band feed. The integrating network removes narrow-pulse signals and high-frequency noise from the narrow-band video but allows the relatively low-frequency cw video to pass. The adding circuit consists of the two cathode followers V208A and V208B (Fig. A-2). The wide-band video is stretched a fixed amount by the diode V202C and the resistor-capacitor combination in the grid circuit of V207A. The output of the cathode follower V207A is clamped by V207B to the potential selected by the bias potentiometer. The clamped video is fed to a cathode follower V208A. The integrated narrow-band video is clamped by the germanium diode in the grid circuit of the cathode follower V208B. Since the grids of the cathode followers are tied to the same potential, the cathode potentials are equal. The resistor divider between the cathodes of this tube provides wide- and narrow-band video signals of about equal amplitude at the tap. For average signals, the wide-band video amplitude is less than the narrow-band video amplitude so the tap on the divider is set closer to V208A. The amplitude of the wide- and narrow-band video signals can be independently adjusted. The DF wide-band video amplitude is varied by adjusting the potentiometer in the cathode circuit of V207A. The DF narrow-band video amplitude is varied by adjusting the amount of signal fed to the grid of the video amplifier in the panscope circuit, V1101B (Fig. 11). The signal from the tap on the divider between the cathodes of V208 is dc coupled to the paralleled grids of the 5915's in the video switch (Fig. 10). Since the cathodes of the 5915's are tied to +120 volts, the bias is set by the grid potential. The 5915 grid potential is set by the bias potentiometer in the grid circuit of the adding circuit (V208, Fig. A-2). The bias should be adjusted to give proper trace separation in the DF display. The best performance is usually at about +114 volts at the 5915 grids.

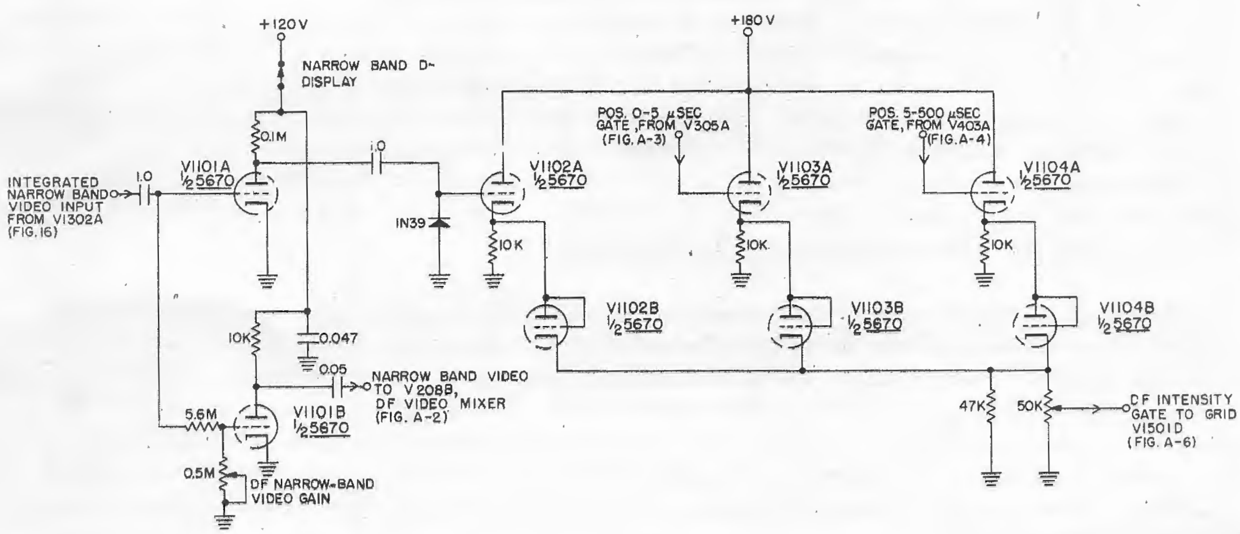

Fig. 11 - DF intensity chassis

During the development of the DF video switch, type 5725 (6AS6) tubes were used and found to have several drawbacks. The gain of 5725's varied widely from tube to tube and the No. 1 grid cutoff voltage seemed to vary greatly from tube to tube. The 5915's seemed to be more closely matched than the 5725's and were used in place of 5725's in this circuit.

Intensity Circuits - Video intensification is used on the direction-finding indication to allow the baseline to be suppressed, reduce operator fatigue, and allow the display to be photographed. The usual photographic procedure is to operate the equipment in a darkened room, open the camera shutter and wait for a signal to flash on the screen. After the flash the shutter is closed. If the baseline were not suppressed, it might overexpose the film and possibly fog the entire negative. If the baseline were not suppressed and the antenna rotation were stopped, the spot on the cathode-ray tube would probably burn the screen.

Three cathode followers (V1102A, V1103A and V1104A, Fig. 11) are used in the intensifying circuit. Each cathode follower is diode coupled to a common resistive load. The three coupling diodes are V1102B, V1103B, and V1104B. A portion of signal developed across the common resistance is used to drive the intensity grid of the DF gun of the cathode-ray tube. Each cathode follower is fed with a different intensifying signal. V1102A is fed with the integrated narrow-band video that has been clipped

[redacted]

and inverted by V1101A. This waveform intensifies cw signals. V1103A and V1104A are fed respectively by the 0-5 μsec and 5-500 μsec positive gates from the signal-analyzer section. These gates intensify the display of the stretched pulse signals.

DF Narrow-Band Display Switch - There is one presentation on the DF display that warrants further explanation. If the repetition rate of a pulse signal is sufficiently high that the time of the stretch, in the narrow-band panscope video circuit, is greater than the time between pulses, pulse detection occurs. Photographs of such a signal displayed on the combined indicator are shown in Figs. 4d and 4e. The panscope display shows the detection. After being integrated, the narrow-band video has the pulses removed, but the detected envelope remains and is added to the wide-band video and displayed on the DF sweep. The extra spike on the left side of the DF pattern is caused by the narrow-band detected output. The position of this spike on the DF pattern varies since the panscope sweeps through the signal at different portions of the antenna pattern on successive sweeps. The appearance of the spike is a normal occurrence with high-repetition-rate signals. To some operators the presence of the spike is objectionable and a handicap in reading the bearing. To alleviate this difficulty a switch was installed to allow the operator to shut off the narrow-band video to the DF display. The switch removes the plate voltage of V1101 when the operator chooses to use the wide-band video only on DF. This DF narrow-band display switch is a normally closed spring-returned type. The use of a spring-returned switch precludes the possibility of accidentally missing a cw intercept because the switch was left open.

DF Calibrator - If one channel of the DF sweep generator were to malfunction, it is possible that the operator of the equipment might think that the amplitude and centering had shifted. Readjustment of the amplitude and centering controls would produce a sweep that would appear to be correct but would actually be very nonlinear. Therefore, a DF calibrator circuit was incorporated to facilitate alignment of the DF sweep.

Twelve thin steel fins were inserted at 30 degree intervals into the gear that drives the synchros in the antenna pedestal. An electromagnetic pickup was mounted so that the fins would pass close to the end of the pickup when the antenna is rotating. Each fin, as it passes, generates a voltage in the pickup. This voltage is used to trigger a blocking oscillator.

The blocking-oscillator cathode is returned to ground through the video-amplifier input circuit. When the blocking oscillator is triggered, the pulses from the cathode circuit are amplified by the video amplifier and presented on the signal analyzer and DF sweeps. The DF sweep is adjusted until these marks coincide with the 30 degree scale markings. A switch is used to remove the plate voltage from the blocking oscillator except when the DF sweep is being calibrated. The circuit is shown in Fig. 12.

DF Antenna and Control System - The DF Antenna now being used with the unified indicator is an AN/SLA-3(XN-1). The servo control system is an experimental manufacturer's prototype. Although this prototype is not completely representative of field equipments, the differences are such that the following comments apply to the production models as well as the prototype.

There are two basic modes of operation, a continuous rotation in either direction with a speed from 0 to 320 rpm or a servo operation in which the antenna servos to any bearing set by a pointer on the front panel of the control unit. In the control unit there is a 5F synchro follower that repeats the antenna bearing.

For operation with the unified indicator the resolver used to generate the linear DF sweep is geared to the 5F synchro in such a manner that the resolver revolves at half the antenna speed. The accuracy of the DF display is dependent upon the ability of the synchro to follow the antenna. It was discovered that in the AN/SLA-3 (XN-1) the series of flexible couplings used to drive the synchro generator in the antenna pedestal had several degrees of backlash in their operation. It was necessary to replace these couplings with an antibacklash flexible coupling before the DF system would operate successfully. Although an examination of the similar production antenna, AS-570/SLR, has not been made, the instruction book for it shows a similar series of flexible couplings in the synchro drive train. It is strongly recommended that these couplings be replaced with an antibacklash type. Provisions are included for operating the synchros either from the ship's gyro source or from the power mains to provide true and relative bearings respectively.

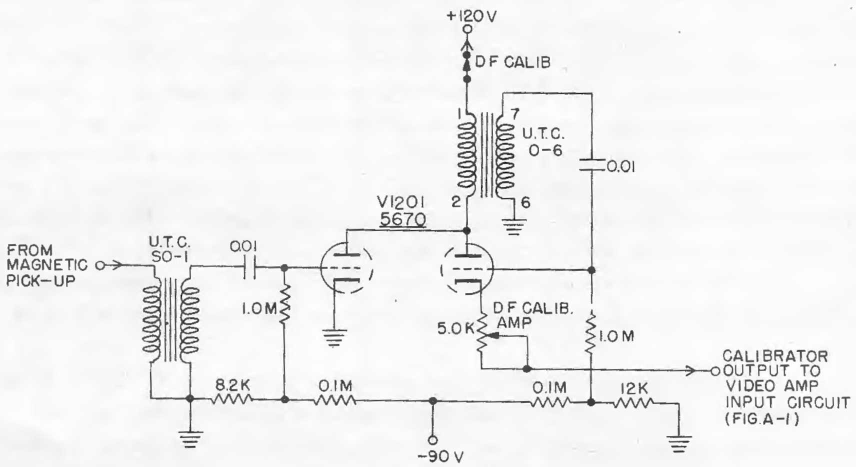

Fig. 12 - DF calibrator

The resolver is located in the antenna control unit and the resolver outputs are fed to the demodulators in the combined indicator. To isolate the capacities of the interconnecting cables from the resolver, cathode followers were installed in the control unit (V701A and V701B, Fig. 13). The plate voltage supply for the cathode followers is the unregulated +300-volt line from the servo amplifier. An 0A2 regulator tube is used to stabilize the plate voltage of V701A and V701B. The balancing control is adjusted for equal maximum output signals. The outputs of the cathode followers are fed to the demodulators.

Some antennas belonging to the same antenna group (0A-473/SLR) as the AS-570/SLR consist of two antennas mounted back to back. One antenna is vertically polarized, the other is horizontally polarized. A switch on the control unit allows the operator to select the vertically or the horizontally polarized antenna. When switching polarization it is also necessary to shift the bearing indication 180° since the antennas face opposite directions. To change the bearing indication it is necessary to reverse two pairs of leads. The leads from the resolver to the two 0-2 transformers (Fig. 6) must be reversed and the primary connections of one of the 0-2 transformers must also be reversed. These leads can be switched with a relay connected as shown in Fig. 14. The coil is connected in parallel with the coils of relays K201 and K202 in the control unit C-1213/SLR and is energized by 115-volts 60-cps ac when the polarization switch is in the horizontal position.

It is possible that the unified indicator might be used with a less complicated antenna assembly and control system, for example the AN/APA-69. In this system the resolver is driven directly from the antenna. It is necessary to install the proper gearing between the resolver and the antenna so that the resolver operates at one half the speed of the antenna. It is also suggested that the resolver in the AN/APA-69 be replaced by the Kearfoot Type 235A-1 resolver. The 235A-1 is more suitable for use with the 10 kc carrier than the original resolver. The same switching circuit as described for the

 [redacted]

OA-473/SLR antenna (Fig. 14) is also necessary for us[redacted]since it too has vertically and horizontally polarized antennas mounted back to back. The relay coil is energized by 28 volts dc when the polarization switch on the AN/APA-69 control unit is in the vertical position.

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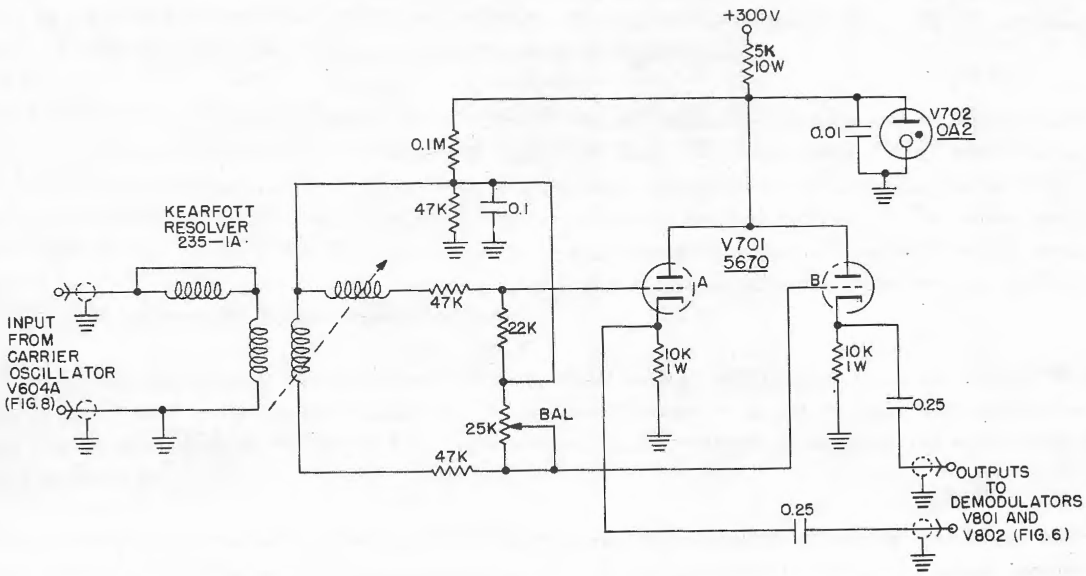

Fig. 13 - Resolver and line drivers added to antenna control AN/SLA-3

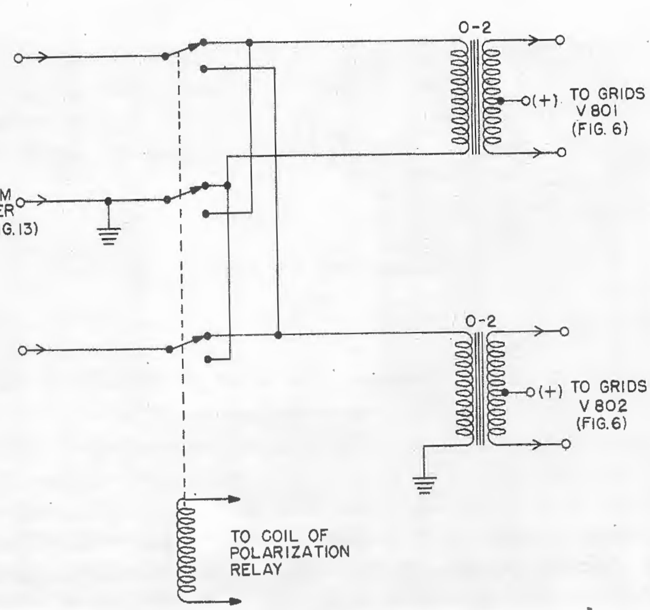

Fig. 14 - Circuit to correct bearing whe[redacted]
changing polarization

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When the linear DF display is used with an AN/APA-69 antenna some additional circuitry is required to produce a true bearing indication. The two outputs of the resolver are fed to driver amplifiers. The low-impedance outputs of the amplifier are used to drive a second resolver. The outputs of the second resolver are fed to the demodulators. The second resolver is driven by a synchro follower on the flux-gate compass line. This resolver is geared to the synchro so that it rotates at one half the synchro speed. The relative amplitudes of the carriers reaching the demodulators depend upon the angular position of both resolver shafts. As the second resolver shaft rotates, the spot moves in the same manner as when the first resolver shaft rotates. One resolver causes displacement of the spot corresponding to antenna motion; the other resolver causes spot displacement corresponding to a change in course of the aircraft. The additional circuitry required for true bearing indication is shown in Fig. 15. The driving amplifier has two identical channels, each of which is similar to the output amplifier of the carrier oscillator.

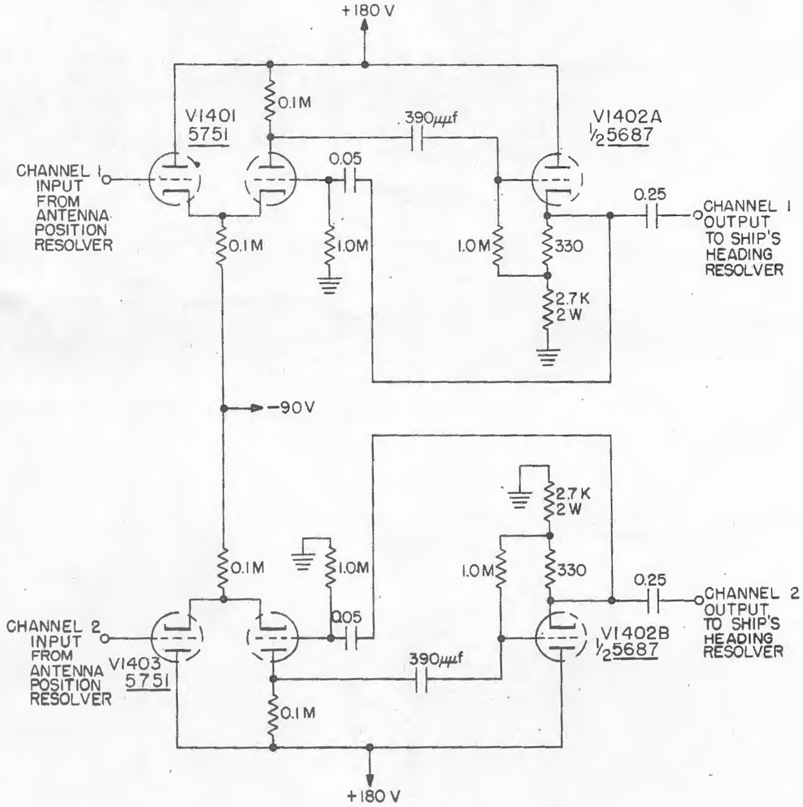

Fig. 15 - Driver amplifier

Panoramic Display

The horizontal-sweep voltage for the panoramic presentation is generated in the receiver (AN/APR-9) and is available as a push-pull signal. In the combined indicator the horizontal sweep voltage is coupled to a dual-potentiometer gain control (Fig. 16). The outputs of the gain control are coupled by 1.0-μf capacitors to the grids of the deflection amplifier. Capacitors as large as 1.0 μf are required to pass the waveform without objectional phase shift. The grid returns of the horizontal deflection amplifier, V1301, have the horizontal centering potentials applied to them. The plates of the deflection amplifier are directly coupled to the horizontal deflection plates of the cathode-ray-tube gun. The

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500-$\mu\mu$f capacitor connected from plate to plate of the deflection amplifier has no effect on the sweep waveform but removes some objectionable transients picked up by the long leads to the deflection plates.

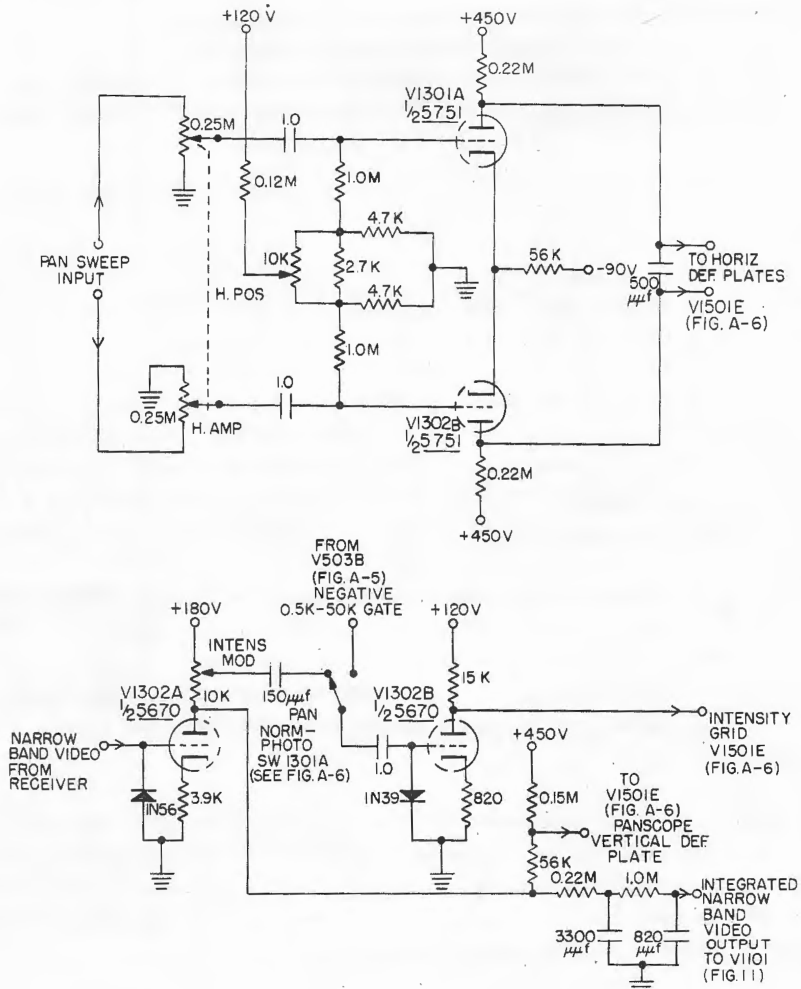

Fig. 16 - Panscope amplifiers

The AN/SLR-2 and the AN/BLR-1 receivers have positive narrow-band video outputs. The AN/APR-9, when modified (6), has a positive stretched narrow-band video output. The narrow-band video is clamped by the 1N56 germanium diode in the grid circuit of V1302A and is amplified and inverted by V1302A. The output of this stage is used in three ways. The output is applied through a voltage divider to the lower vertical deflection plate of the gun of the cathode-ray tube used to give the panscope presentation. The voltage divider is used to bring the deflection plate to the proper dc potential to minimize astigmatism. A portion of the output is amplified and inverted by V1302B and used as video intensification (intensity modulation) on the panscope display. The amount of intensification is controllable from the front panel by adjustment of the intensity-modulation control. The output also is passed through an integrating network to the amplifier and clipper V1101A and to the amplifier V1101B. The signal from V1101A is used in the DF Intensifying circuits (Fig. 10). The signal from V1101B is fed to the DF Video mixer (V208B, Fig. A-2).

When photography is used as a means of data recording, the panoramic sweep might fog or overexpose the negative. To prevent this from occuring provision was made to gate the intensity of the panoramic sweep. The panscope normal-photo switch in the grid circuit of V1302B allows the choice of two signals for intensification. In the normal position the amplified video from V1302A is used for intensification, while in the photographic position the 500-50,000 μsec negative gate from the signal analyzer is used for intensification. In the normal position the panoramic-display baseline intensity is controlled from the front panel; in the photo position the baseline intensity is set by a screwdriver adjustment. With the switch in the photo position the panoramic display is not visible until the signal analyzer is triggered.

Video Balancing

It has long been the opinion of the Countermeasures Branch at NRL that the video gain control in the signal analyzer should remain fixed and the receiver gain control be varied to secure the best display.

To display a signal properly, if the analyzer gain control is set too low, the receiver gain has to be increased. As the receiver gain is increased, a point is reached where the last i.f. stage in the receiver is overdriven and clipping results. When a clipped signal is displayed on a signal analyzer, erroneous rise time and pulse widths result, the wave shape of signals other than pulses can be considerably distorted, and any amplitude modulation of the signal might be clipped off.

In view of the serious errors that are possible if the gain controls are misadjusted, the video gain control in the unified indicator was made an internal screwdriver adjustment. To set the signal-analyzer video gain control, the receiver gain control is advanced until noise covers the baseline of the panscope. The sync level control is set at the most sensitive end and the signal analyzer video gain is increased until the sweeps are triggered almost continiously by the noise. This is the correct setting for the video gain control.

To obtain the correct relative amplitudes of pulse signals on the analyzer and DF sweeps, the receiver is tuned to a pulse signal with a repetition rate of about 1 kc and pulse width of about 1 μsec. The receiver gain control is adjusted until the signal on the analyzer sweeps has the correct amplitude (i.e., about 3/4 inch), and then the DF wide-band gain control is adjusted until the signal on the DF sweep has the same amplitude as on the analyzer sweeps.

To obtain the correct relative amplitude of signals on the panscope and DF displays, the receiver is tuned to a cw signal, the receiver gain control is adjusted so that the highest portion of the panscope display does not overlap the DF scales, and the DF narrow-band video gain control is adjusted until the signal amplitude is just short of touching the opposite DF scales.

After these internal gain controls have been set, the signal level is adjusted by using only the receiver gain control.

Power Supply

The range of signals that might be present across the output of any of the power supplies is quite wide. Two extremes might be 0.1-μsec signals caused by the change in plate current of the final video amplifier and pulses 49,500 μsec long from the 500-50,000 μsec multivibrator. To prevent interaction between circuits all power supplies must have low internal impedances. In all regulator circuits, except the positive and negative 2500-volt supplies, the use of a single amplifier stage did not provide a low

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enough internal impedance, and multiple-stage amplifiers were used. Since many circuits are dc coupled, it is essential that the voltages be stable.

The heaters of all the tubes in the unified indicator require 140 watts. Table 2 lists the power-supply dc voltages and the current drawn from each.

TABLE 2
Power-Supply Requirements

Voltage (v)	Current (ma)
+450	45
+180	220
+120	85
-90	70
+2500 (for CRT)	0.05
-2500 (for CRT)	6.0

DESIGN CONSIDERATIONS

Considerable thought was given to the choice of tube types used in the unified indicator. The type 5670 was used for multivibrators because of its stability, high transconductance, low heater power, internal shield, and uniformity of characteristics from tube to tube. In clamp-tube applications the 5670 was chosen because of its sharp cutoff characteristics, stability and uniformity. Low-mu tubes, (5814's), were used as deflection amplifiers since they were stable and minor variations in the grid circuits were not amplified as much as they would have been with high-mu tubes like the 5751, 5670 or 12AT7.

In several portions of the circuits nonstandard tube types were used. In all cases these tube types can be replaced with standard tube types. The video amplifier uses a 5847/404A and a 418A. The video amplifier described by Markell (5) has the same performance characteristics while using a 6AH6, a 5763 and three 5654's. In the pulse stretcher circuits a 6BC7 triple diode is used (V202A,B,C). This could be replaced by standard types in the following manner: replace V202A and V202B with a 5726, replace V202C and V209A with a 5726, replace V207B with a 1N39 crystal diode, and combine V207A and V209B in a single 5670. This does not increase the number of tubes required.

Stable precision resistors were used in the signal-analysis sweep-generating networks of the unified indicator, as recommended in reference 4. Temperature changes during warm-up cause no noticeable change in the shape of the signal-analysis sweeps.

A change in the lengths of all the sweeps and a slight drift in the positioning has been noticed. This is a long-term change, taking up to an hour to stabilize. It is felt that these drifts should be and could be eliminated by the use of stable resistors in the following parts of the unified indicator: signal-analysis sweep-generating networks (as already mentioned), timing multivibrator circuits, amplitude-control divider networks, positioning-control divider networks, deflection-amplifier plate loads and cathode resistors, and the sampling divider resistors in the regulated power supplies.

POSSIBLE APPLICATIONS

The unified indicator was designed to work with existing equipments with as few modifications as possible to the existing equipments. Specifically, this indicator was designed to be used with an AN/APR-9 receiver and an AN/SLA-3 antenna. The circuit techniques are also applicable to the development of a unified indicator for use with the AN/BLR-1 and AN/SLR-2 receivers and such antenna groups as the AN/SLR-2, AN/APA-69 and AN/BPA-1. It must be remembered that with all antennas the resolver in the DF circuit must be driven at one half the antenna speed.

The AN/APR-9 receiver, with each of its major units on a separate chassis and interconnected by cables with plugs, is particularly well suited for laboratory use. To use a unified indicator of this type with an AN/APR-9 receiver modified as by Root (6), the cable from the mixer amplifier to the AN/APR-9 indicator is disconnected at the indicator and reconnected to the unified indicator. The cable from the AN/APR-9 power unit to the AN/APR-9 indicator is discarded and a new cable is run from the unified indicator to the AN/APR-9 power unit. The main reason for this is to eliminate the now unused −1100 volt lead from the connector on the unified indicator.

The frequency-indicating Veeder counter with the reset switch and lamp used in the AN/APR-9 indicator is duplicated in the unified indicator. From this discussion it can be seen that the unified indicator can be used with an AN/APR-9 receiver without modifications of the receiver other than those described by Root (6).

All the information available from the AN/APR-9 indicator is available from the combined indicator. In addition the signal analysis and direction-finding information is available from the scope presentations. The front panel of the combined indicator also has a data card, true relative bearing indicator, and a clock (Fig. 17).

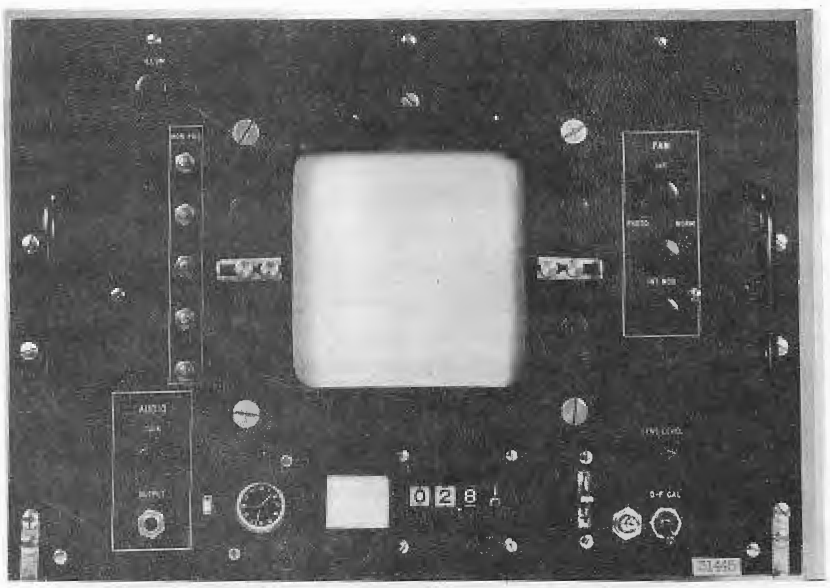

Fig. 17 - Front panel unified indicator

Rapidly scanned receivers, such as described by Wald (7), can be used with the unified indicator by modifying only the driving circuits for the frequency-indica[redacted]eeder counter.

SUMMARY

A linear direction-finding display, with a maximum error of 3-1/2 degrees, and with less than 2 degrees over 340 degrees of the scan, can be successfully generated using the circuits described. The unifying of the signal-analysis, direction-finding, and panoramic displays involves only straightforward circuit techniques. When used, for example, with an AN/APR-9 receiver this unified indicator replaces the indicator of the AN/APR-9, the indicator of the AN/APA-69 direction finder, and the AN/APA-74 signal analyzer. The advantages of the unified display are conservation of space, reduction of operator fatigue, improvement in the threshold for the interception of a wide range of signal types, and increased reliability of the information obtained. If a camera were designed to photograph the clock, data card, and frequency indicator as well as the scope display, a single photograph would provide complete intercept information on a given signal. Future microwave intercept systems based on high-resolution superheterodyne receivers should include the techniques described in this report to insure optimum utilization of the intercept data by providing a unified display.

* * *

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4. Hendrickson, A. H., and Solem, R. J., "Stability Characteristics of Nonlinear Sweeps for Signal Analyzers," NRL Report 4285 (Confidential), January 21, 1954
5. Markell, J. H., "Refinements in Countermeasures Signal Analyzer Techniques," NRL Report 4341 (Confidential), April 27, 1954
6. Root, W. B., "Improved Performance Characteristics of Modified Countermeasures Microwave Intercept Receivers," NRL Memorandum Report 200 (Confidential), August 10, 1953
7. Wald, B., "Rapid Scanning Techniques for Countermeasures Receivers," NRL Report 4410 (Confidential), September 8, 1954

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APPENDIX A
Signal Analyzer Circuits

The following figures give the circuitry for the signal-analyzer section of the unified indicator. All capacitor values are in microfarads unless otherwise noted. All resistors are one-half watt unless otherwise noted.

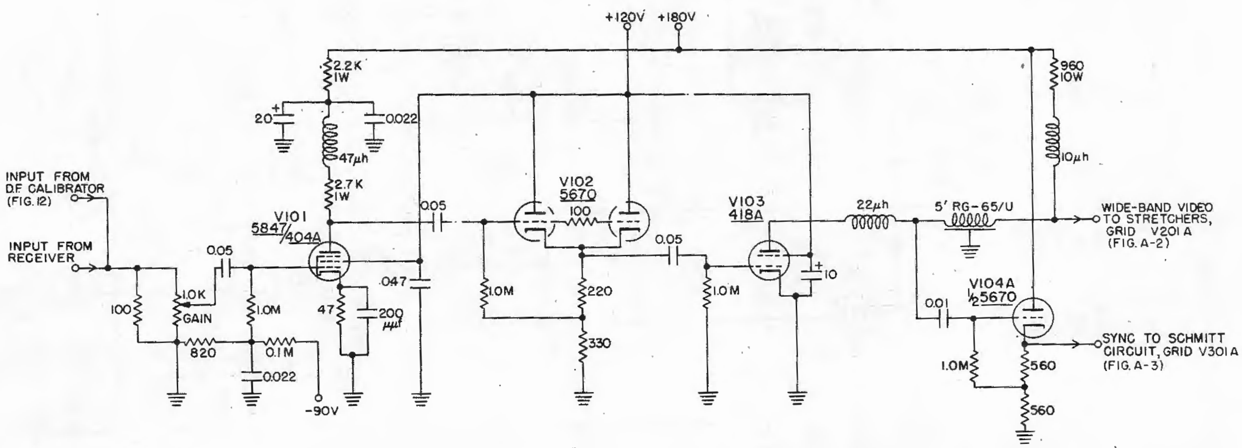

Fig. A-1 - Wide-band video amplifier

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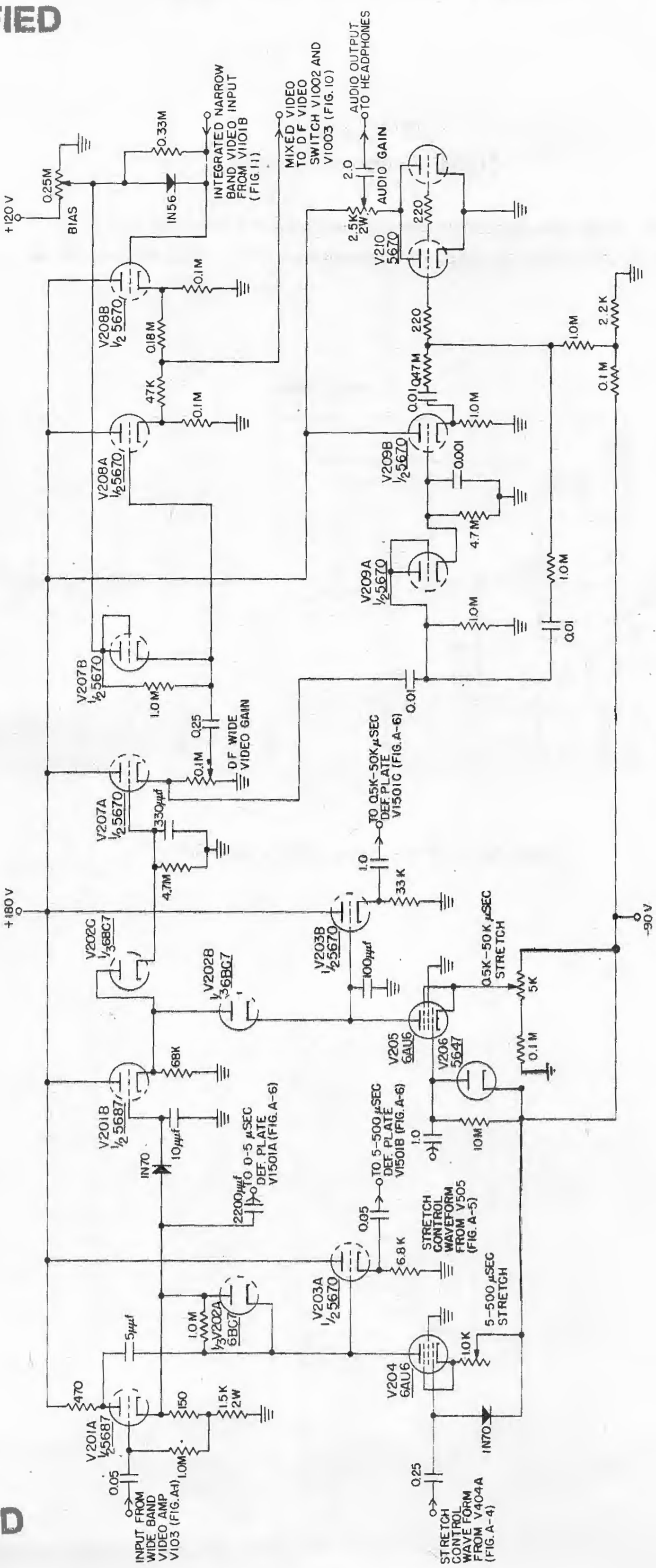

Fig. A-2 - Pulse stretchers and DF video mixer

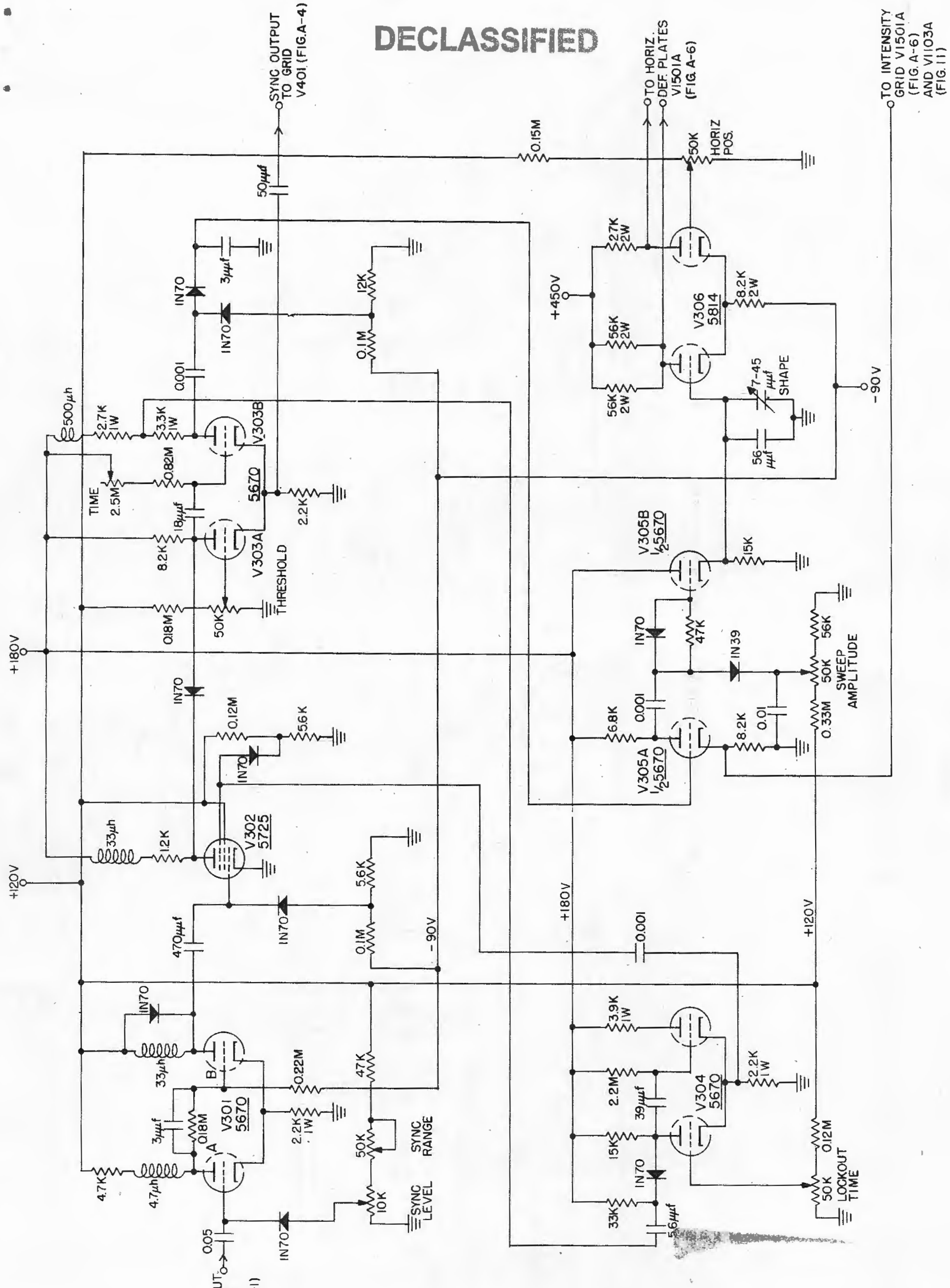

Fig. A-3 - 0-5 μsec sweep circuit

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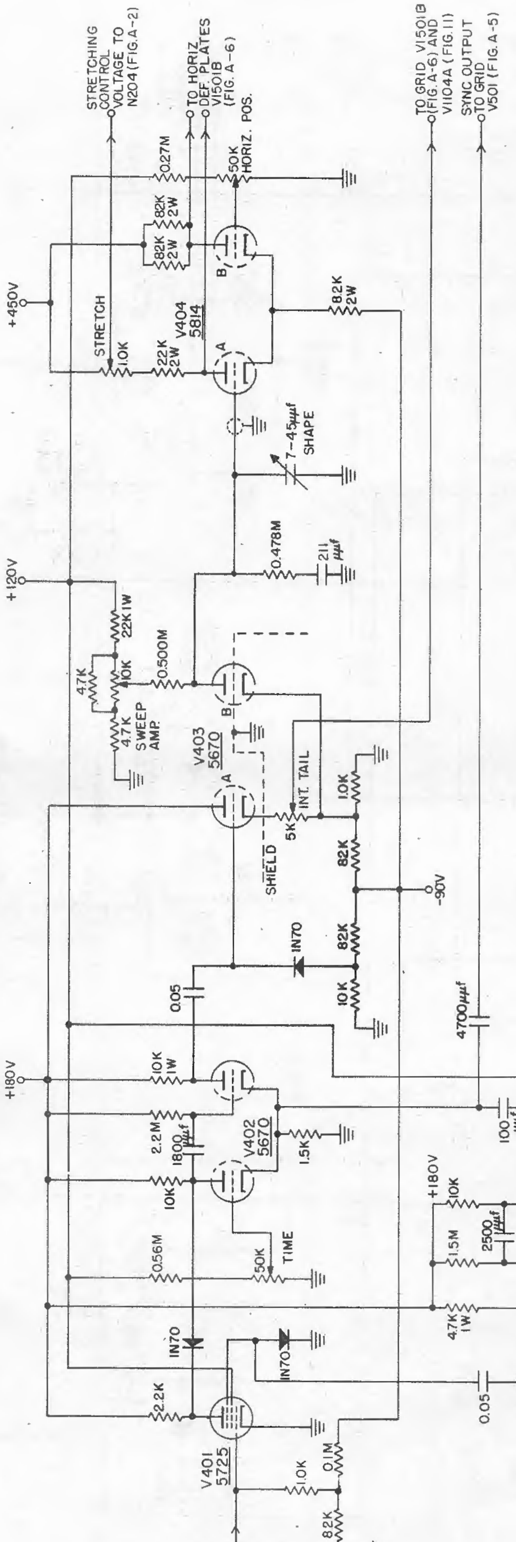

Fig. A-4 - 5-500 μsec sweep circuit

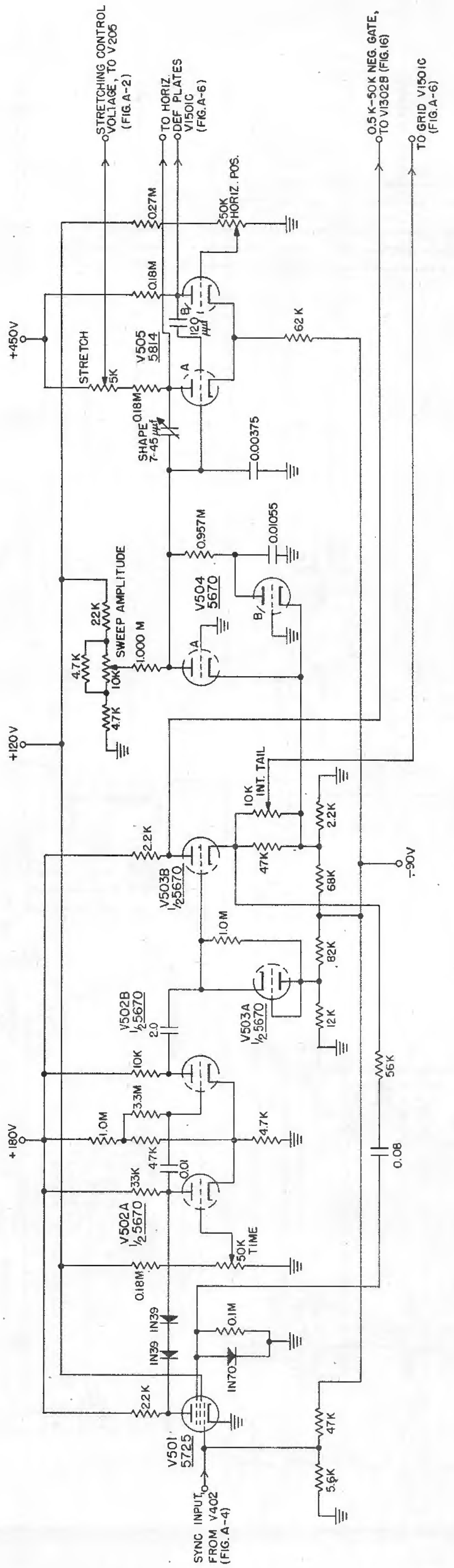

Fig. A-5 - 500-50,000 μsec sweep circuit [redacted]ENTIAL

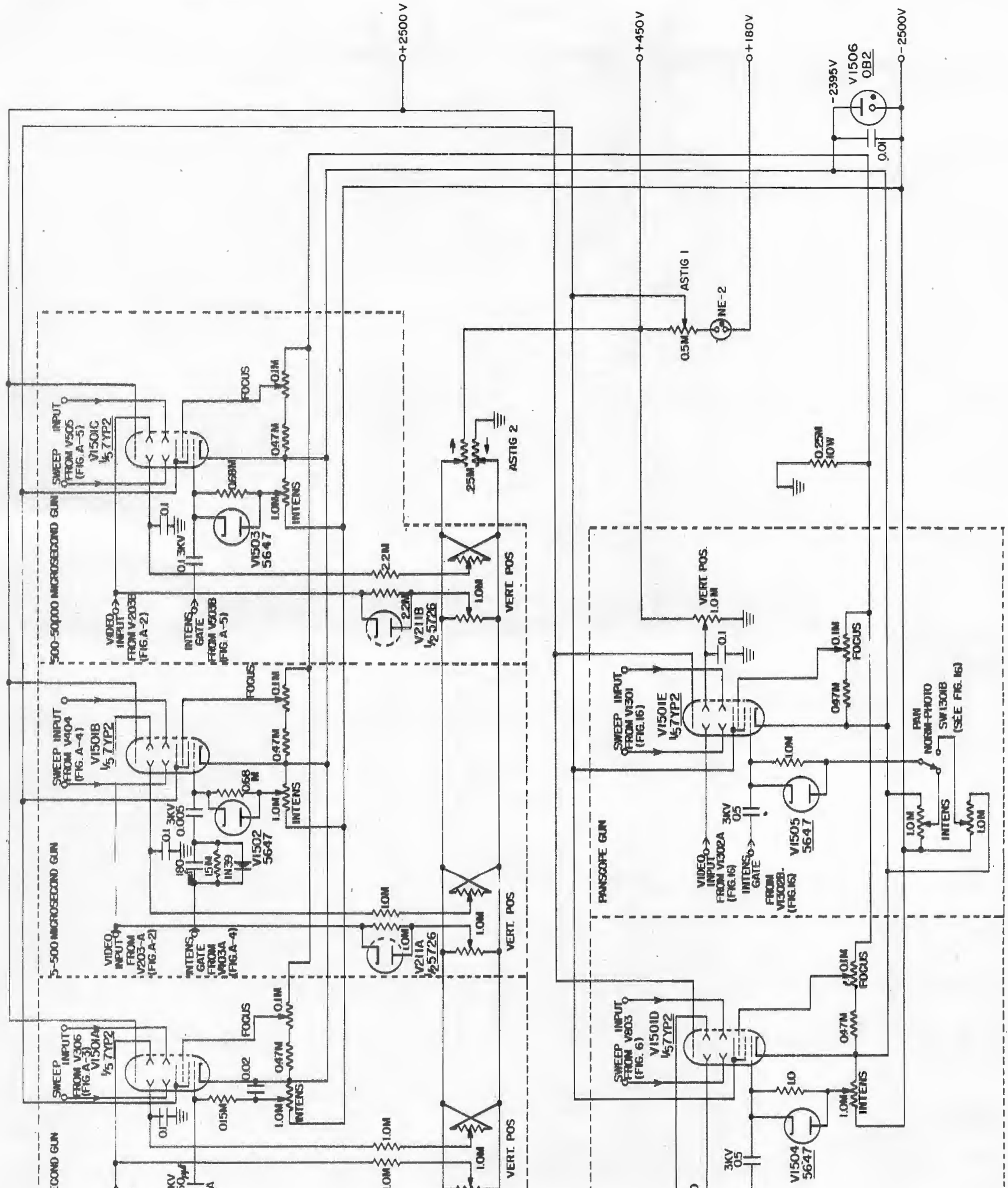

Fig. A-6 - Cathode-ray-tube circuit

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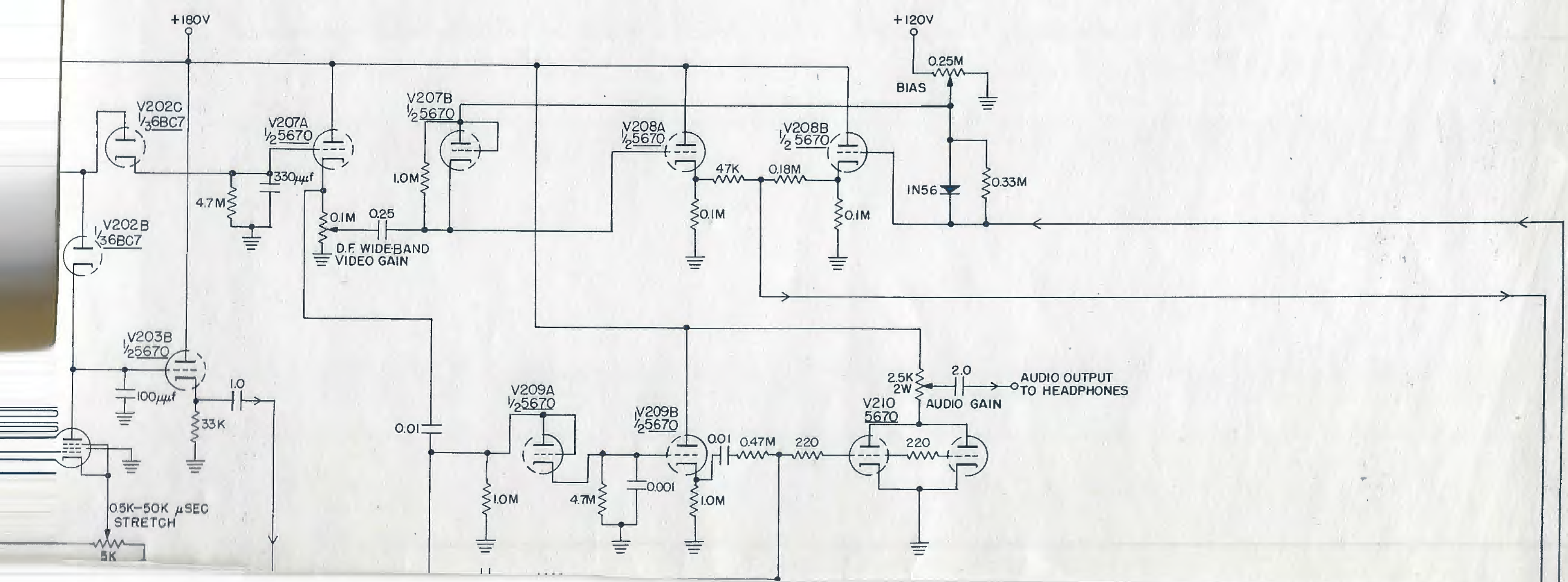
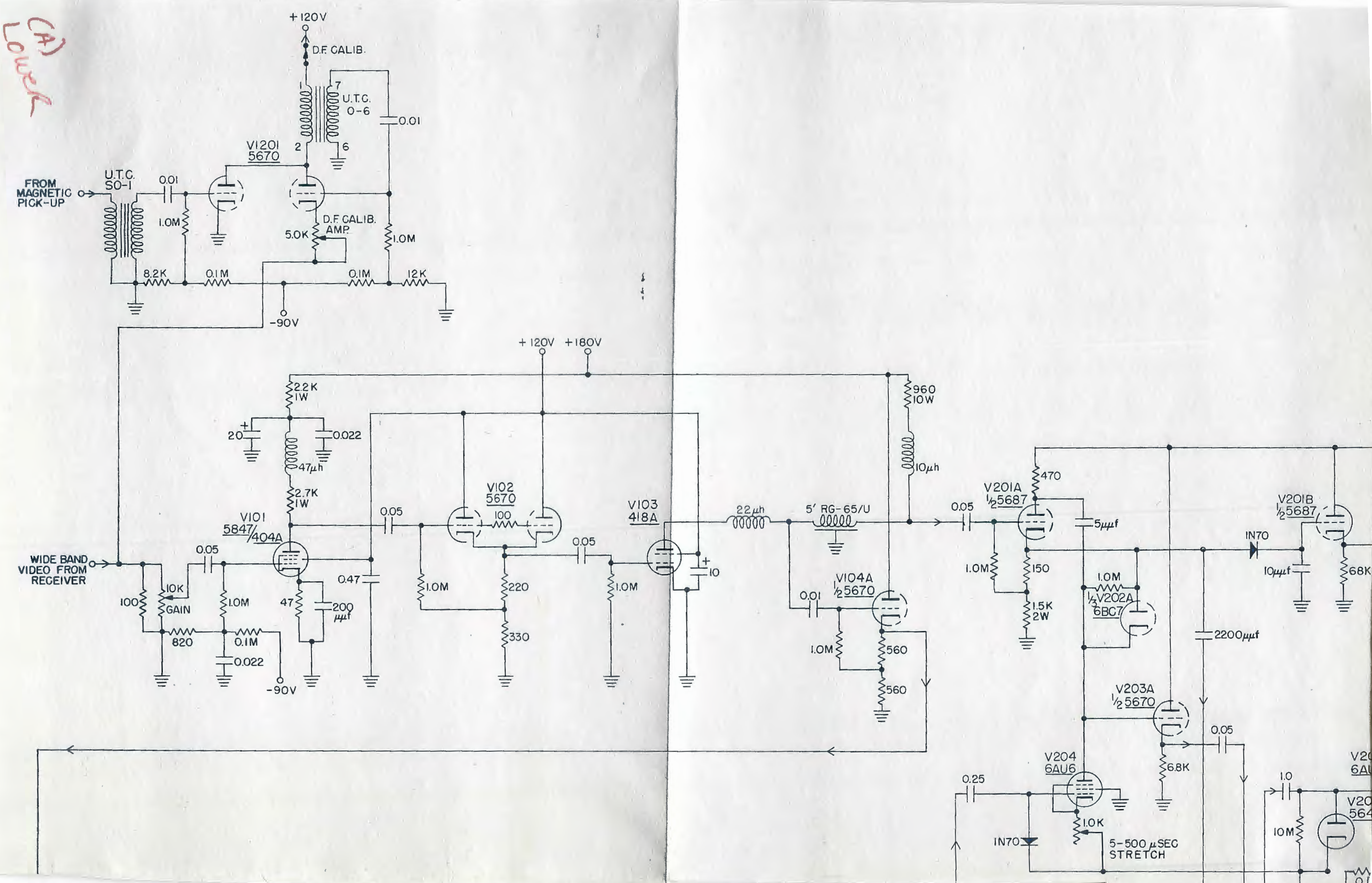
Plate 1 (A) upper




(A) Lower
FROM MAGNETIC PICK-UP
U.T.C. SO-1
0.01
1.0M
8.2K
0.1M
V1201 5670
+120V
D.F. CALIB.
U.T.C. O-6
0.01
D.F. CALIB. AMP.
5.0K
1.0M
0.1M
12K
-90V
+120V +180V
2.2K 1W
20
0.022
47μh
2.7K 1W
V101 5847/404A
WIDE BAND VIDEO FROM RECEIVER
100
10K GAIN
820
0.05
1.0M
0.1M
0.022
-90V
47
200 μμf
0.47
0.05
V102 5670
100
1.0M
220
330
0.05
1.0M
V103 418A
10
22μh
5' RG-65/U
960 10W
10μh
V104A 1/2 5670
0.01
1.0M
560
560
0.05
V201A 1/2 5687
470
1.0M
150
1.5K 2W
5μμf
1.0M
1/3 V202A 6BC7
V203A 1/2 5670
6.8K
2200μμf
0.05
V204 6AU6
0.25
IN70
1.0K
5-500 μSEC STRETCH
IN70
10μμf
V201B 1/2 5687
68K
1.0
10M

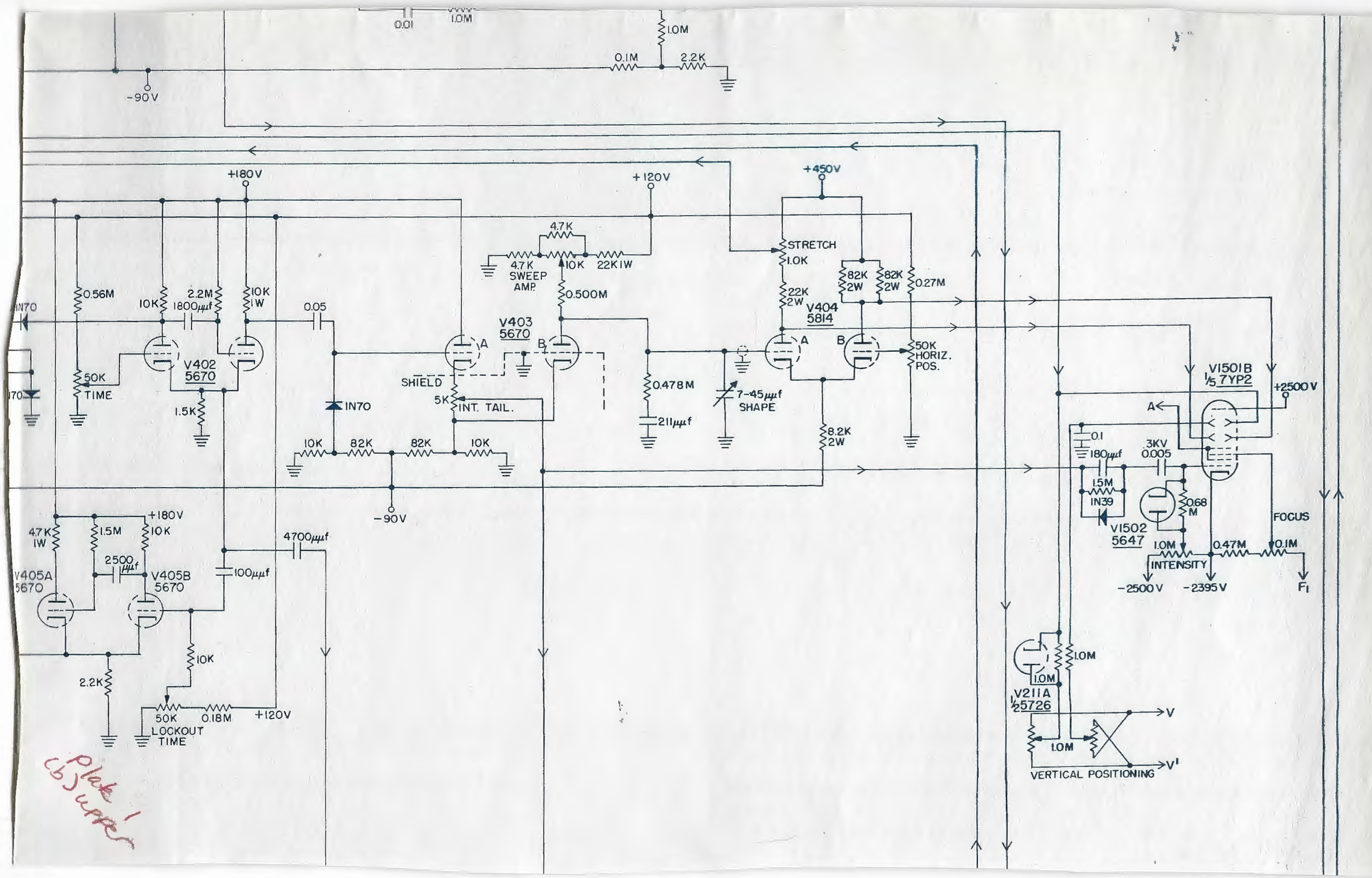
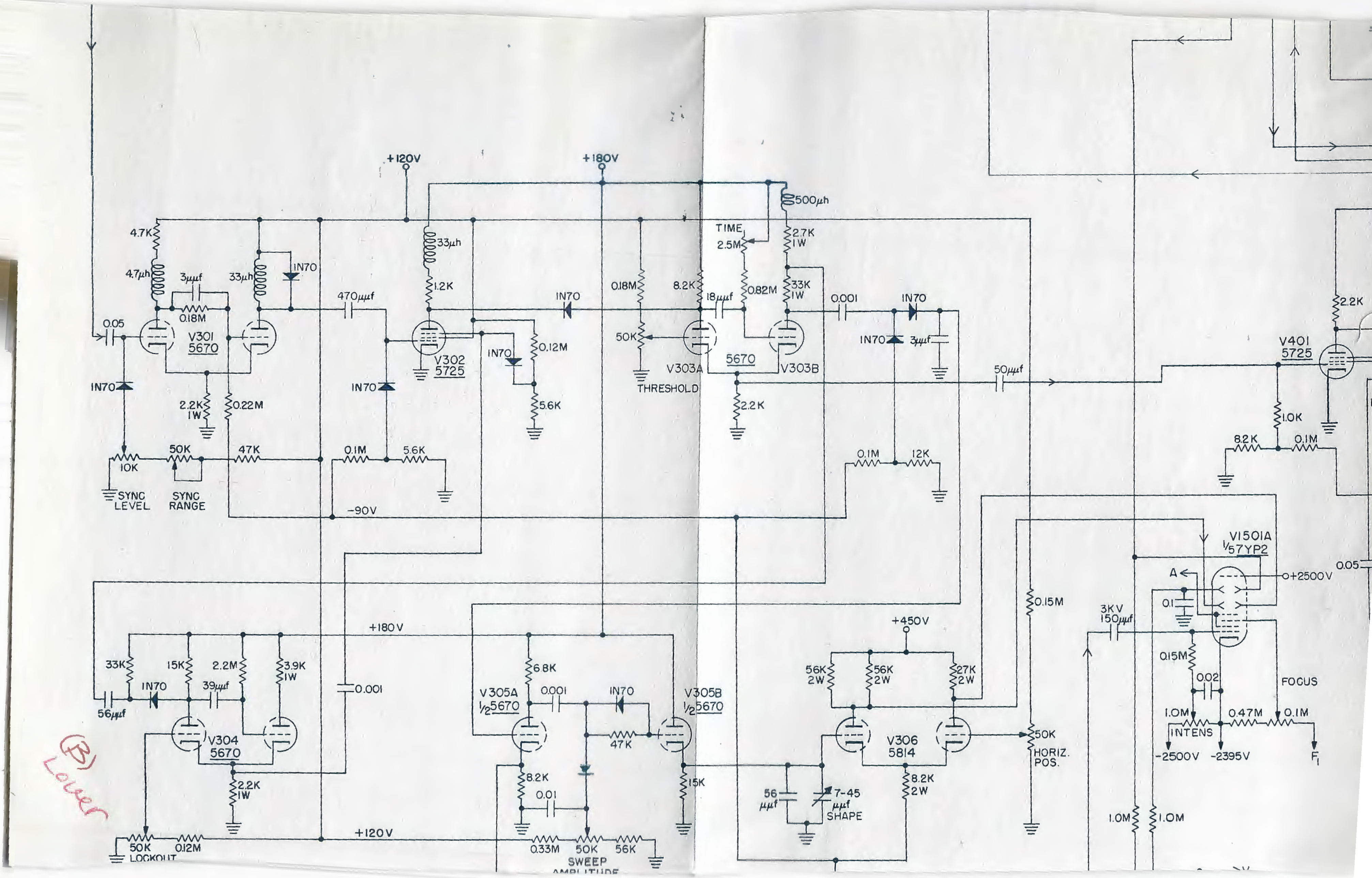
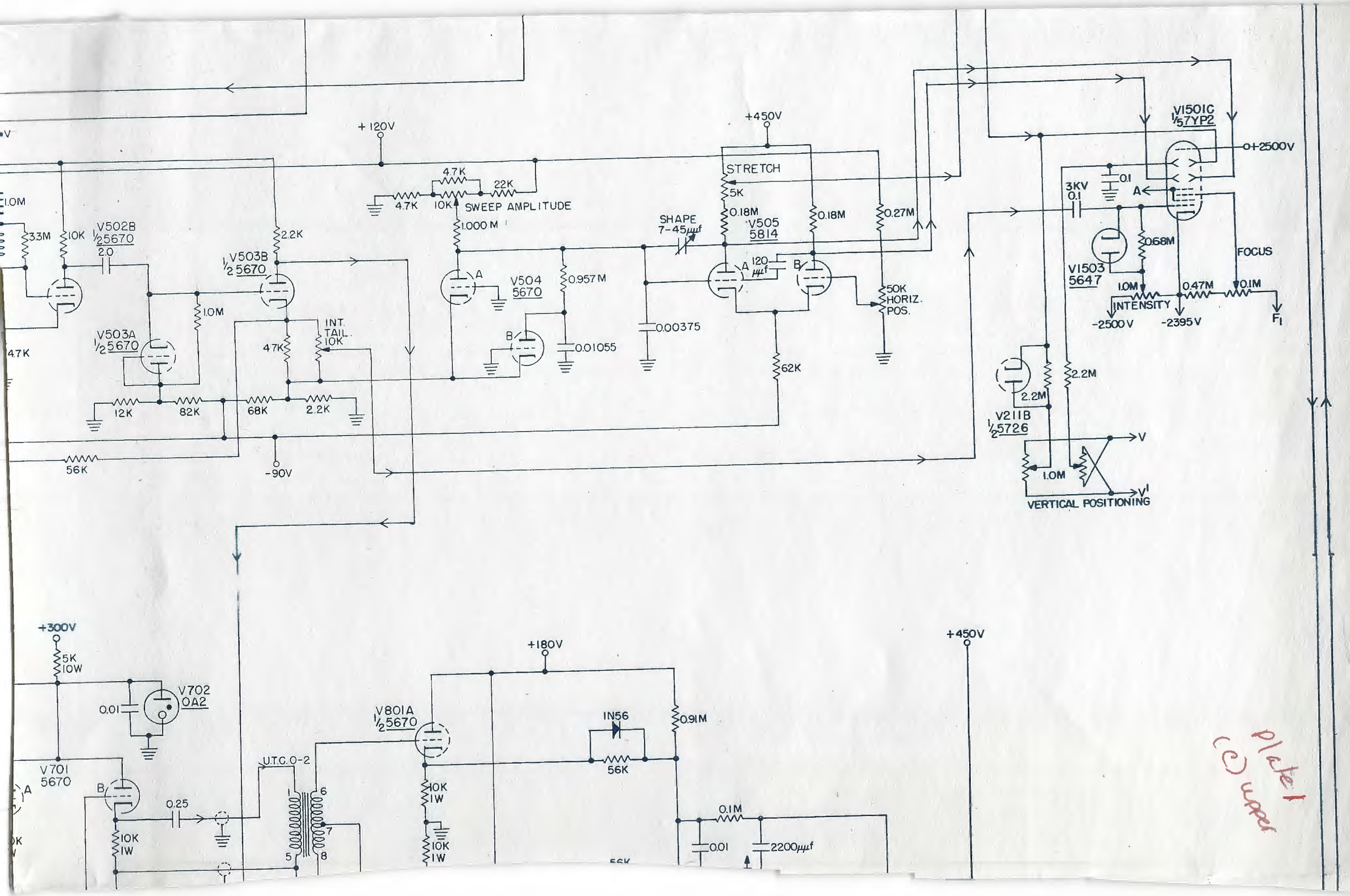


Plate 1 (b) upper

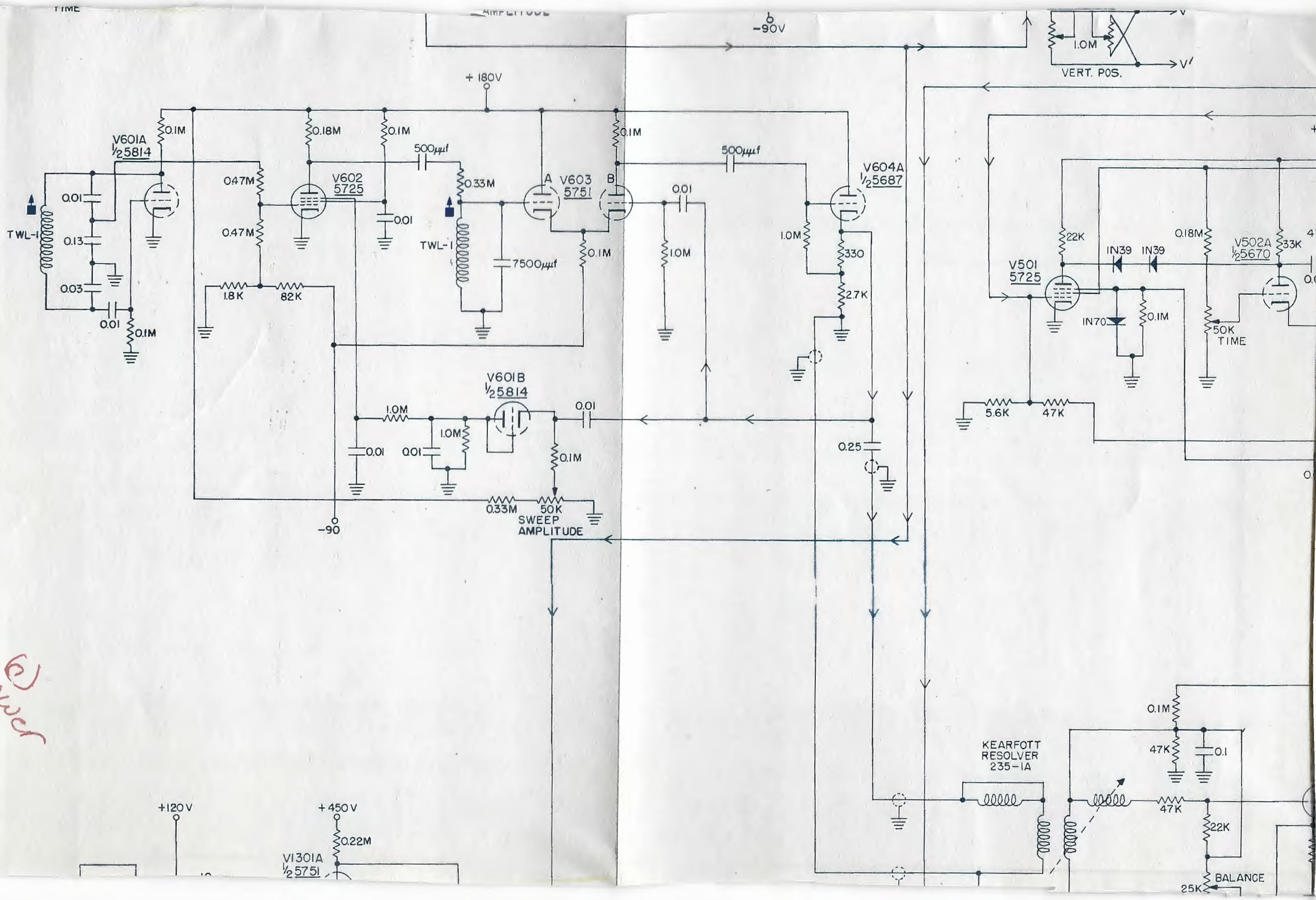


+120V
+180V
4.7K
4.7μh
3μμf
0.18M
33μh
IN70
0.05
V301
5670
2.2K
1W
0.22M
10K
50K
47K
SYNC LEVEL
SYNC RANGE
470μμf
1.2K
V302
5725
0.1M
5.6K
-90V
0.12M
0.18M
8.2K
18μμf
TIME
2.5M
0.82M
500μh
2.7K
1W
33K
1W
V303A
5670
V303B
THRESHOLD
0.001
3μμf
50μμf
12K
V401
5725
2.2K
1.0K
8.2K
V1501A
1/5 7YP2
A
0.1
+2500V
0.05
3KV
150μμf
0.15M
0.02
FOCUS
1.0M
INTENS
0.47M
-2500V
-2395V
F1
+180V
33K
15K
2.2M
39μμf
3.9K
56μμf
V304
5670
LOCKOUT
0.12M
+120V
V305A
1/2 5670
6.8K
V305B
1/2 5670
0.01
0.33M
SWEEP
56K
15K
+450V
56K
2W
27K
V306
5814
7-45
μμf
SHAPE
56
HORIZ. POS.

(B) Lower

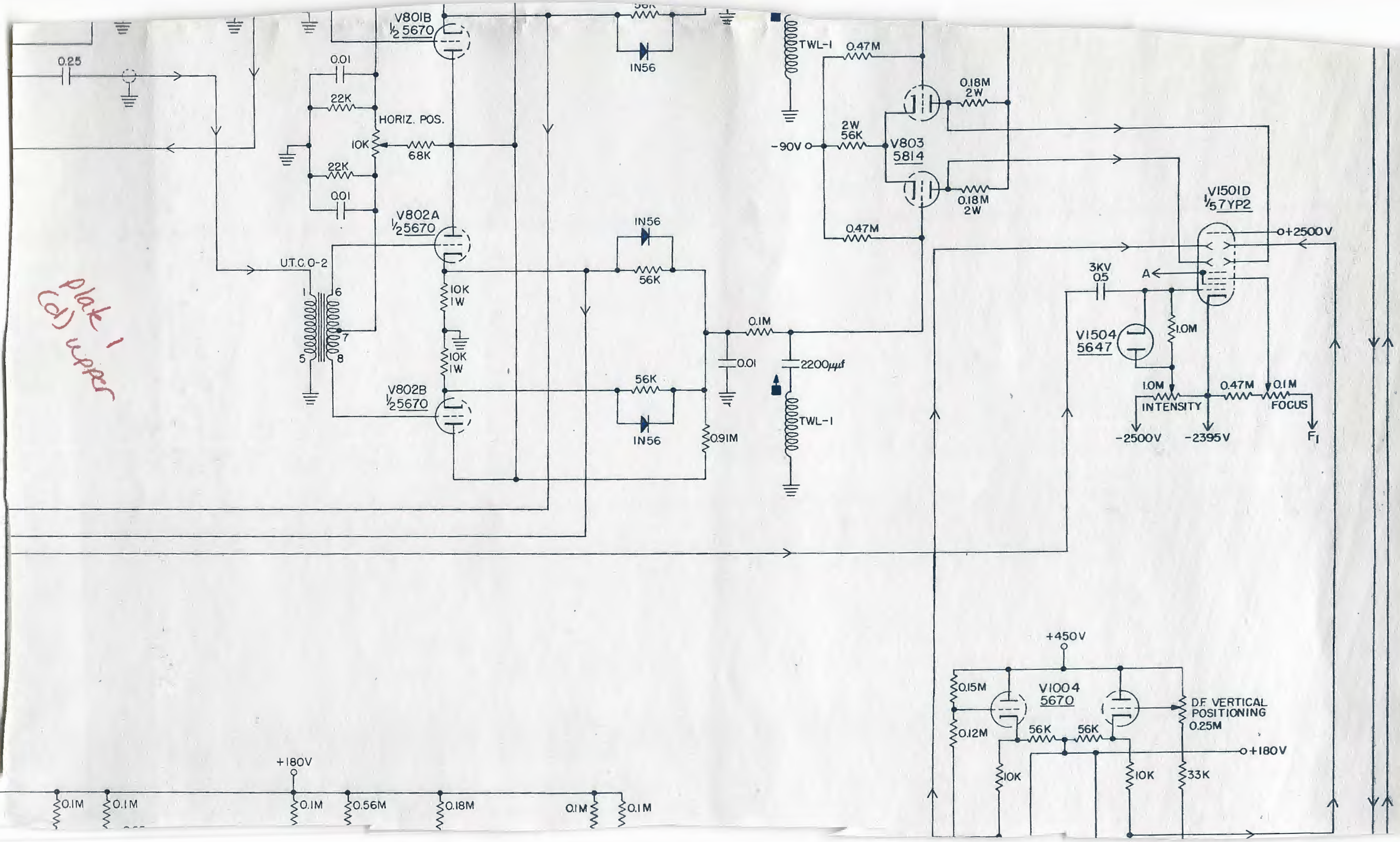


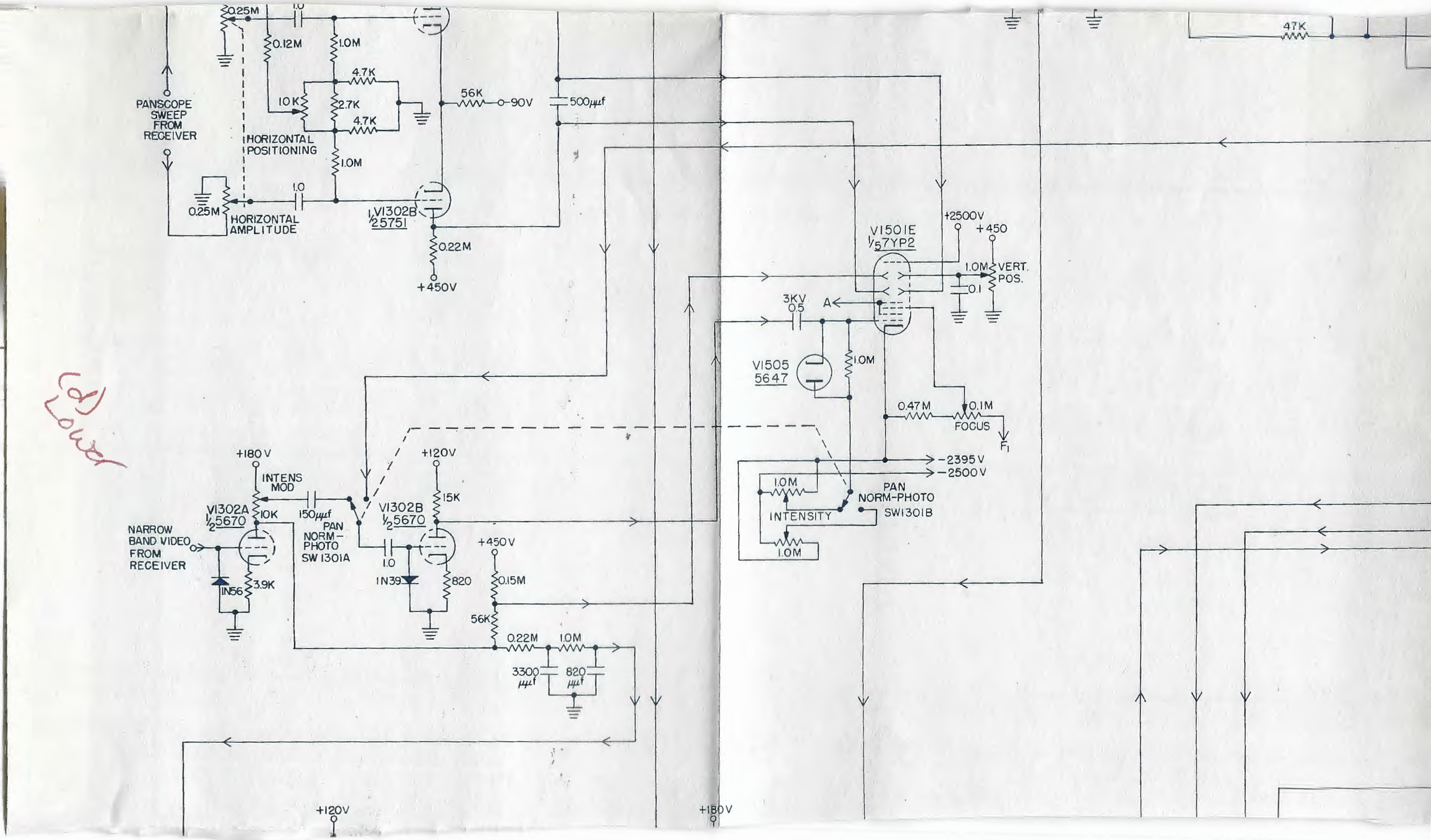
V501C
1/5 7YP2
+2500V
FOCUS
0.1M
F1
0.47M
-2395V
INTENSITY
1.0M
-2500V
0.68M
V1503
5647
0.1
3KV
0.1
A
2.2M
V
V'
1.0M
VERTICAL POSITIONING
2.2M
V211B
1/2 5726
+450V
STRETCH
5K
0.18M
V505
5814
0.18M
0.27M
120 μμf
50K
HORIZ.
POS.
62K
SHAPE
7-45μμf
0.00375
0.957M
0.01055
V504
5670
+120V
4.7K
10K
22K
SWEEP AMPLITUDE
1.000 M
2.2K
V503B
1/2 5670
INT.
TAIL
10K
47K
2.2K
68K
-90V
82K
12K
1.0M
V503A
1/2 5670
V502B
1/2 5670
2.0
10K
33M
1.0M
4.7K
56K
+300V
5K
10W
V702
OA2
0.01
V701
5670
0.25
10K
1W
U.T.C.O-2
V801A
1/2 5670
10K
1W
+180V
IN56
56K
0.91M
0.1M
0.01
2200μμf
+450V
Plate 1
(c) upper



V601A
½5814
TWL-1
0.01
0.13
0.03
0.1M
0.47M
1.8K
82K
0.18M
V602
5725
500μμf
0.33M
7500μμf
+180V
V603
5751
V604A
½5687
330
2.7K
1.0M
0.25
V601B
½5814
0.33M
50K
SWEEP
AMPLITUDE
-90
-90V
VERT. POS.
V501
5725
1N39
1N70
22K
V502A
½5670
33K
50K
TIME
5.6K
47K
KEARFOTT
RESOLVER
235-1A
BALANCE
25K
+120V
+450V
0.22M
V1301A
½5751

(c) Lower


V801B
½ 5670
0.25
0.01
22K
HORIZ. POS.
10K
68K
22K
0.01
V802A
½ 5670
U.T.C. O-2
1
6
7
5
8
10K
1W
10K
1W
V802B
½ 5670
IN56
56K
IN56
56K
56K
IN56
0.91M
0.1M
0.01
2200μμf
TWL-1
TWL-1
0.47M
0.18M
2W
-90V
2W
56K
V803
5814
0.18M
2W
0.47M
V1501D
⅕ 7YP2
+2500V
3KV
0.5
A
V1504
5647
1.0M
1.0M
INTENSITY
0.47M
0.1M
FOCUS
-2500V
-2395V
F1
+450V
0.15M
V1004
5670
0.12M
56K
56K
D.F. VERTICAL
POSITIONING
0.25M
+180V
10K
10K
33K
+180V
0.1M
0.1M
0.1M
0.56M
0.18M
0.1M
0.1M
plak 1
(d) upper



0.25M
1.0
0.12M
1.0M
4.7K
10K
2.7K
4.7K
PANSCOPE SWEEP FROM RECEIVER
HORIZONTAL POSITIONING
1.0M
56K
-90V
500μμf
1.0
0.25M
HORIZONTAL AMPLITUDE
1/2 V1302B 2575I
0.22M
+450V
47K
+2500V
+450
V1501E 1/5 7YP2
1.0M
VERT. POS.
0.1
3KV 0.5
A
V1505 5647
1.0M
0.47M
0.1M
FOCUS
F1
-2395V
-2500V
1.0M
INTENSITY
1.0M
PAN NORM-PHOTO SW1301B
+180V
INTENS MOD
V1302A 1/2 5670
10K
150μμf
PAN NORM-PHOTO SW1301A
+120V
V1302B 1/2 5670
15K
NARROW BAND VIDEO FROM RECEIVER
IN56
3.9K
1.0
IN39
820
+450V
0.15M
56K
0.22M
1.0M
3300 μμf
820 μμf
+120V
+180V

(d) Lower

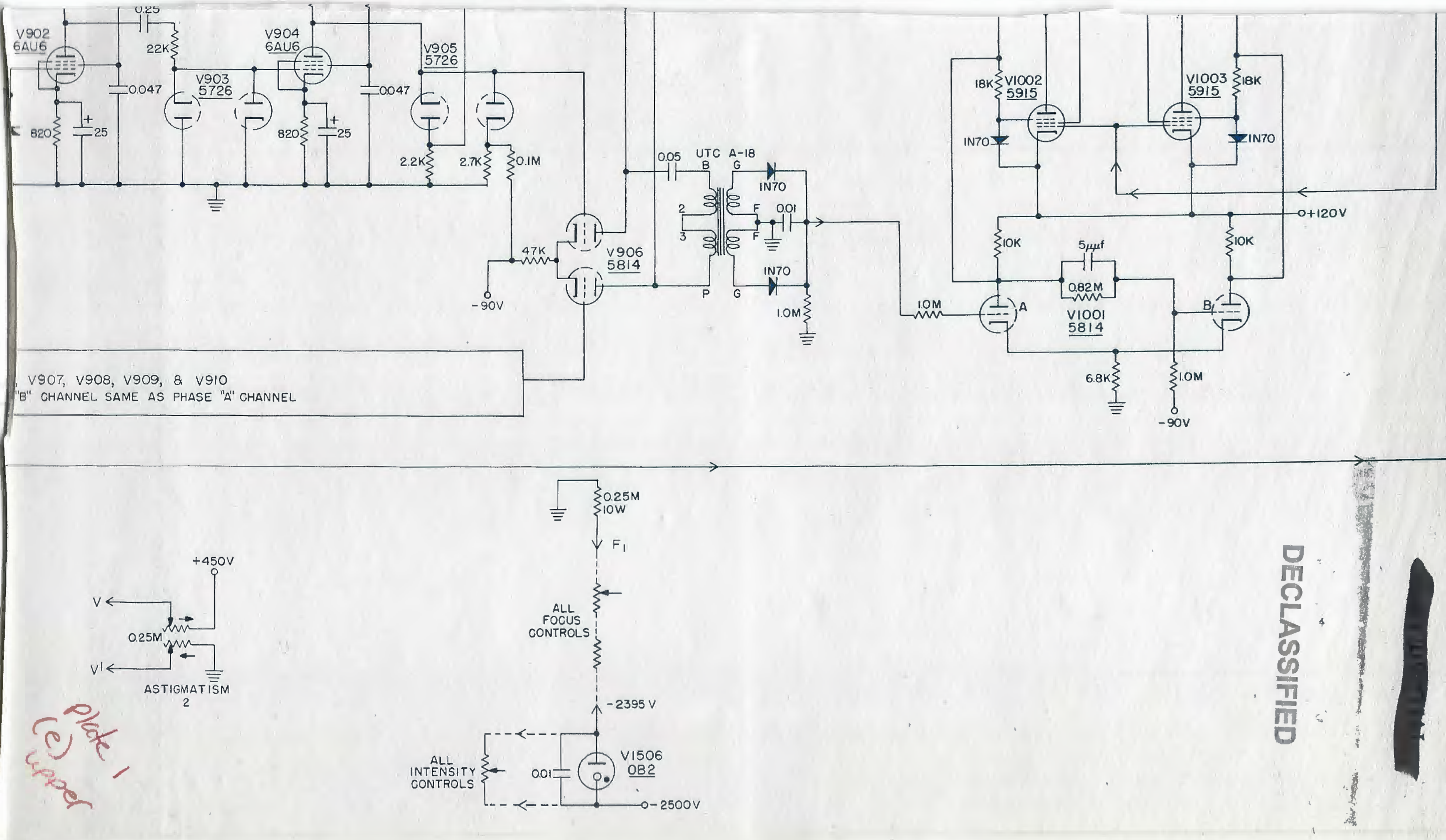


Plate 1 (e) upper

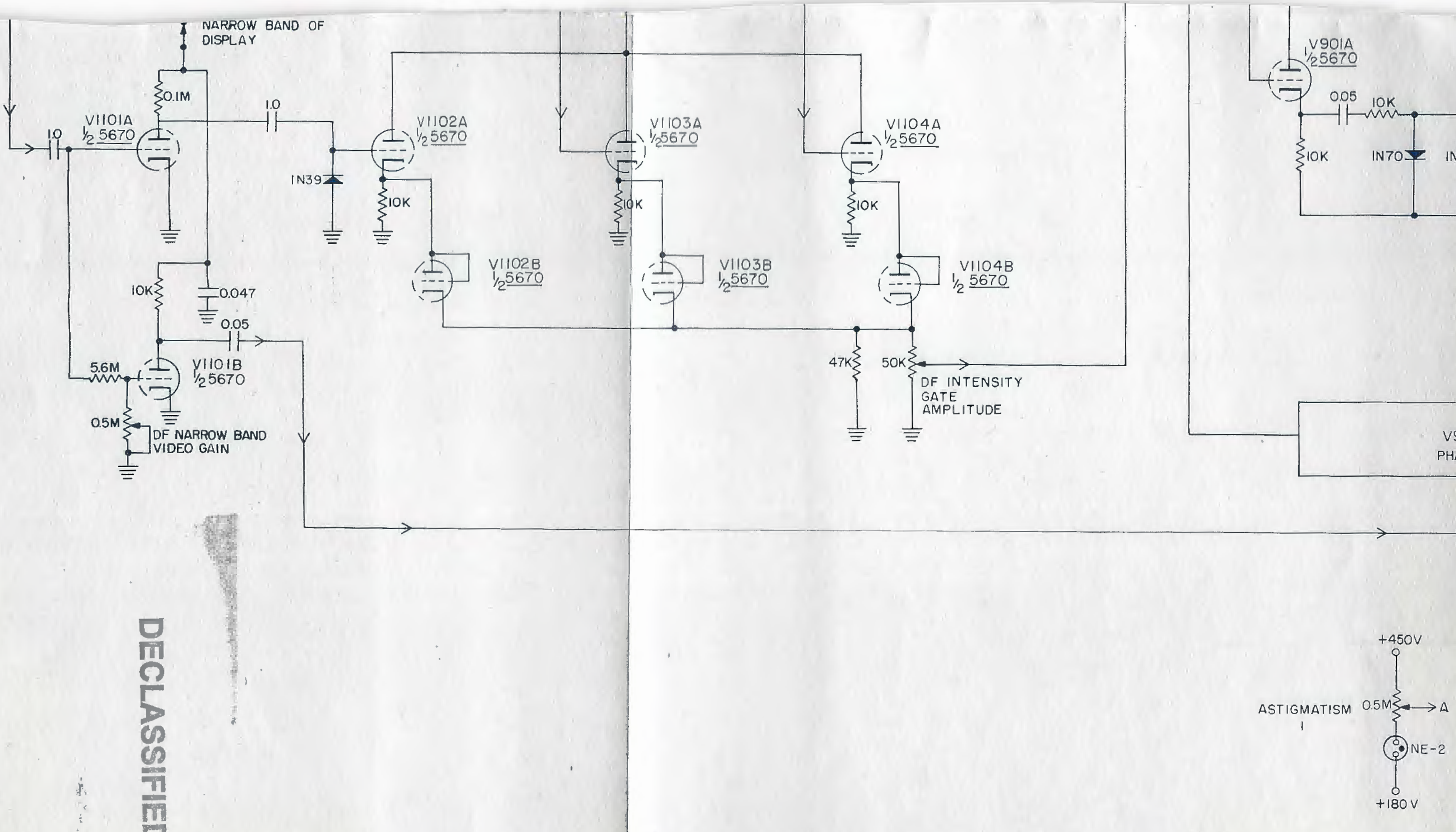


PLATE 1 — UNIFIED INDICATOR SCHEMATIC

(e) Lower

[redacted]