OPERATING INSTRUCTIONS

TYPE 1900-A

WAVE ANALYZER

1900-A

1900-A

GENERAL RADIO COMPANY

A

OPERATING INSTRUCTIONS

TYPE 1900-A

WAVE ANALYZER

AND

TYPE 1910-A

RECORDING WAVE ANALYZER

Form 1900-0100-B
May, 1965

GENERAL RADIO COMPANY
WEST CONCORD, MASSACHUSETTS, USA

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SPECIFICATIONS

FREQUENCY

Range: 20 to 54,000 cps. The frequency is indicated on a counter and a dial with a linear graduation, 1 division/10 cps.

Accuracy of Calibration: ±(½% +5 cps) up to 50 kc; ±1% beyond 50 kc.

Incremental-Frequency Dial (△F): ±100 cps. Accuracy is ±2 cps below 2 kc, ±5 cps up to 50 kc.

Automatic Frequency Control: At frequencies below 10 kc, the total range of frequency lock is at least 400 cps for the 50-cycle band and at least 150 cps for the 10-cycle band, as defined by 3-db drop in response from full-scale deflection. At 50 kc the lock ranges decrease to about half of these values.

Selectivity: Three bandwidths (3, 10, and 50 cps) selected by switch.

Effective bandwidth for noise equal to nominal bandwidth within ±10% for 10- and 50-cycle bands and ±20% for 3-cycle band.

3-Cycle Band: At least 30 db down at ±6 cps from center frequency, at least 60 db down at ±15 cps, at least 80 db down at ±25 cps and beyond.

10-Cycle Band: At least 30 db down at ±20 cps, at least 60 db down at ±45 cps, at least 80 db down at ±80 cps and beyond.

50-Cycle Band: At least 30 db down at ±100 cps, at least 60 db down at ±250 cps, at least 80 db down at ±500 cps and beyond.

INPUT

Impedance: One megohm on all ranges.

Voltage Range: 30 microvolts to 300 volts full scale in 3, 10 series. A decibel scale is also provided.

Voltage Accuracy: After calibration by internal source, the accuracy up to 50 kc is ±(3% of indicated value +2% of full scale) except for the effects of internal noise when the attenuator knob is in the maximum-sensitivity position. In that position the internal noise is about 5% of full scale for the 3- and 10-cycle bands and 10% of full scale for the 50-cycle band. From 50 to 54 kc, the above 3% error becomes 6%.

***Residual* Modulation Products and Hum:** At least 75 db down.

OUTPUT

100-kc Output: Amplitude is porportional to amplitude of selected component in analyzer input signal. With the Type 1521 Graphic Level Recorder connected through the adaptor cable supplied, at full-scale meter deflection, output is at least 3 volts. Dynamic range from overload point to internal noise is >80 db with attenuator knob fully clockwise.

Recording Analyzer: The analyzer in combination with the Type 1521 Graphic Level Recorder produces continuous, convenient records of frequency spectra over the complete range of the analyzer. The end frames of the bench models can be bolted together to form a rigid assembly.

DC Output: One milliampere in 1500 ohms for full-scale meter deflection, one side grounded.

Filtered Input Component: Output at least 1 volt across 600-ohm load for full-scale meter deflection with output control at maximum.

Tracking Generator: 20 cps to 54 kc; output is at least 2 volts across 600-ohm load with output control at maximum.

GENERAL

Terminals: Input, Type 938 Binding Posts; output, telephone jacks.

Power Requirements: 105 to 125 (or 210 to 250) volts, 50 to 60 cps, approximately 40 watts.

Accessories Supplied: Type 1560-P95 Adaptor Cable Assembly, phone plug, Type CAP-22 Power Cord, spare fuses.

Other Accessories Available: Type 1900-P1 Link Unit for coupling to Type 1521 Graphic Level Recorder.

Cabinet: Rack-bench.

Dimensions: Bench model—width 19, height 16¼, depth 15¼ inches (485 by 415 by 390 mm), over-all; rack model—panel 19 by 15¾ inches (485 by 400 mm), depth behind panel 13¼ inches (340 mm).

Net Weight: 59 pounds (27 kg).

Shipping Weight: 140 pounds (64 kg).

TYPE 1910-A RECORDING WAVE ANALYZER

Dimensions: Width 19, height 25¼, depth 15¼ inches (485 by 645 by 390 mm), over-all. Supplied with end frames for bench mounting and support sets for installation in a standard 19-inch relay rack.

Net Weight: 109 pounds (50 kg).

Shipping Weight: 204 pounds (93 kg).

Figure 1-1. Type 1900-A Wave Analyzer.

SECTION 1

INTRODUCTION

1.1 PURPOSE.

The Type 1900-A Wave Analyzer (Figure 1-1) or the Type 1910-A Recording Wave Analyzer (Figure 2-2) can be used to measure and to analyze a spectrum of complex electrical signals, including replicas of acoustic noise or mechanical vibrations. Incorporating excellent selectivity, the analyzer is especially useful for the separation and measurement of the individual components of periodic complex waveforms, such as harmonic and intermodulation distortion. It is particularly well suited for the analysis of noise, because its bandwidth, in cycles per second, is independent of the center frequency. Thus the required averaging time is constant and the calculation of spectrum level is simple. In addition, the required averaging time is reasonably short when the 50-cycle bandwidth of the analyzer is used.

The analyzer can also serve as a tunable, narrow-band filter, so that any component of a complex input signal can be used to drive other instruments (such as a frequency counter) when a highly accurate measurement of the component frequencies is desired.

In the "tracking generator" mode of operation, the output is a sine-wave signal, tunable over the 54-kc range and always in tune with the analyzer. When this signal is used to drive a bridge or other network, the output can be measured by the analyzer, whose selectivity reduces the interference from extraneous noise, hum, or distortion.

For automatic waveform analysis, outputs are provided on the analyzer to drive the Type 1521 Graphic Level Recorder or a 1-ma dc recorder.

1.2 GENERAL DESCRIPTION.

The Type 1900-A Wave Analyzer is a heterodyne voltmeter. The level of the input signal is adjusted by means of a calibrated attenuator (see Figure 1-2); the signal is then heterodyned, in a balanced modulator, with the voltage from a local oscillator. The frequency of this local oscillator is adjusted so that the difference between it and the desired component of the input signal is 100 kc. The resulting 100-kc heterodyne component then passes through a highly-selective quartz-crystal filter, whose bandwidth can be set to either 3, 10, or 50 cps. The level of the 100-kc filter output is amplified and is then adjusted by means of a second calibrated attenuator. The signal is then indicated on a meter. The direct current flowing through the meter is available at panel terminals for use in driving a 1-ma dc recorder. The amplified 100-kc signal is also available at panel terminals to drive the Type 1521 Graphic Level Recorder.

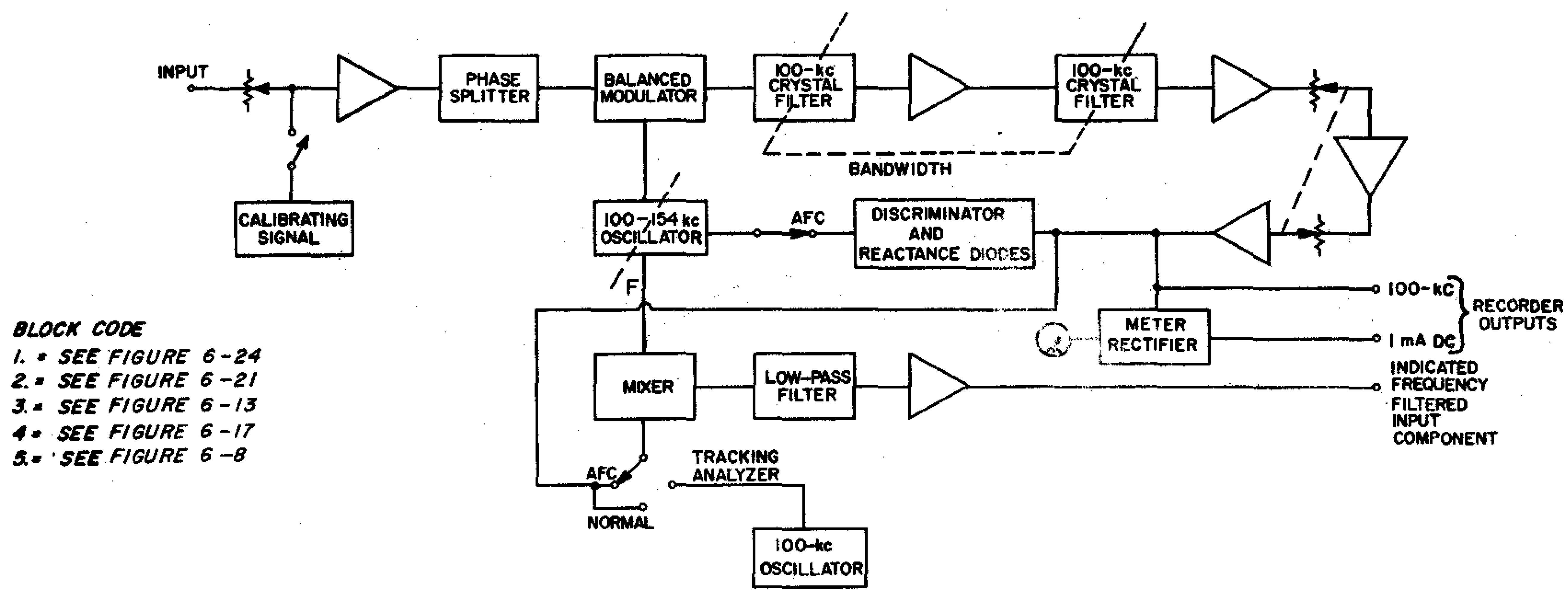


Figure 1-2. Block diagram of the analyzer.

In one mode of operation, the output is heterodyned back to the original frequency, and it is available at panel terminals marked FILTERED INPUT COMPONENT. In another mode, the local oscillator beats with a 100-kc, quartz-crystal-oscillator signal and the combination functions as a beat-frequency oscillator. This output is also available at panel terminals marked TRACKING GENERATOR. Both of these final outputs can be adjusted by the LEVEL control.

The frequency of the local oscillator is adjustable from 100 kc to 154 kc by means of the two large coaxial FREQUENCY knobs, and the difference between the actual oscillator frequency and 100 kc is indicated on the counter-dial combination. A capacitor in the oscillator circuit, with a dial marked ΔF, can be used to change the indicated frequency by any amount up to ±100 cps at any setting of the FREQUENCY controls.

A panel switch provides adjustment of the meter response speed to either SLOW, MEDium, or FAST. The slower speeds are well suited for noise analysis.

The panel GAIN control can be used to set the gain at any desired value with respect to a reference component. By means of a screw-driver adjustment, the gain can be set in terms of a calibrating signal derived from the power line, so that the meter indicates directly in volts.

Controls are provided to adjust the balanced modulator and to set the frequency of the local oscillator.

1.3 CONTROLS AND CONNECTORS.

Table 1-1 lists the controls and connectors on the Type 1900-A Wave Analyzer.

TABLE 1-1 CONTROLS AND CONNECTORS.

Figure 1-3 Ref No.	NAME	TYPE	FUNCTION
1	POWER (OFF)	2-position toggle switch with pilot light	Turns instrument on or OFF.
2	FREQUENCY (CPS)	Two coaxial, continuous, rotary controls with counter and dial	Control local-oscillator frequency, to tune analyzer from 20 to 54,000 cps. Larger knob gives coarse control; smaller knob gives fine control. NOTE **These controls have no stops. The uncalibrated portion of the range is marked by a red flag on the left-hand-perimeter indicator; in addition, the range from 54,000 to 60,000 cps is not calibrated. However, no damage will result if the dial is turned through its range.**
3	ΔF (CPS)	Continuous rotary control with calibrated dial	Controls frequency of local oscillator over a span of ±100 cps from the frequency indicated by the FREQUENCY counter and dial.
4	F ZERO (PUSH TO ENGAGE)	Continuous rotary control	Adjustment of local-oscillator frequency.
5	CARRIER BALANCE (PUSH TO ENGAGE)	Pair of continuous rotary controls	Adjusts modulator balance to reduce carrier feed-through at low frequencies.
6, 7, 8	FULL SCALE	Two coaxial step selector switches	Larger dial sets input attenuator; smaller dial provides percentage and db scales ; inner knob sets analyzer attenuator.
9	BANDWIDTH (CPS)	3-position selector switch	Selects bandwidth of quartz-crystal filter.
10	METER SPEED	3-position selector switch	Selects response speed of meter.
11	READING	2-position selector switch	Permits panel control of gain or internal CAL control.
12	CAL	Rotary control with slotted shaft (under snap button)	Provides screw-driver adjustment of internal gain of analyzer.
13	GAIN	Continuous rotary control	Sensitivity adjustment.
14	MODE	3-position selector switch	Selects mode of operation (refer to text).
15	LEVEL	Continuous rotary control	Adjusts amplitude of beat-frequency oscillator output or filtered-signal output.
16	INPUT (1 MEGOHM)	Jack-top binding-post pair	To connect signal to be analyzed.
17	OUTPUT (RECORDER) (1 mA DC)	Phone jack	To connect dc recorder.
18	OUTPUT (RECORDER) (100 KC)	Phone jack	To connect 100-kc output from analyzer to graphic level recorder.
19	OUTPUT (GENERATOR OUTPUT) (FILTERED INPUT COMPONENT)	Phone jack	Output from beat-frequency oscillator or filtered-signal output is available at this jack.
		3-terminal male connector	For connection to power source; located at rear of instrument. Two fuse holders are located beside the connector.

1.4 ACCESSORIES SUPPLIED.

Table 1-2 lists the accessories supplied with the Type 1900-A Wave Analyzer.

In addition to those listed in Table 1-2, the accessories listed in Table 1-3 are supplied with the Type 1910-A Recording Wave Analyzer.

TABLE 1-2
Accessories supplied with the Type 1900-A Wave Analyzer.

Quantity	Name	Part Number
1	Type 1560-P95 Adaptor Cable Assembly	1560-9695
1	Type CDMP-22 Phone Plug	4220-2000
1	Type CAP-22 Power Cord	4200-9622
2	Type FUF-1 Fuses Two 0.5-amp for 115-volt model or two 0.25-amp for 230-volt model	 5330-1000 5330-0700

TABLE 1-3
Additional accessories supplied with the Type 1910-A Recording Wave Analyzer.

Quantity	Name	Part Number
1	Type 1521 Graphic Level Recorder (with 60-rpm motor)	
1	Type 1521-P3 80-db Potentiometer[1]	
1	Type 1900-P1 Link Unit	
1	Type 1521-P10B Drive Unit	
10	Rolls of Chart Paper	1521-9464
10	Rolls of Chart Paper	1521-9465

[1] The 80-db potentiometer is supplied in addition to the 40-db unit installed in the recorder.

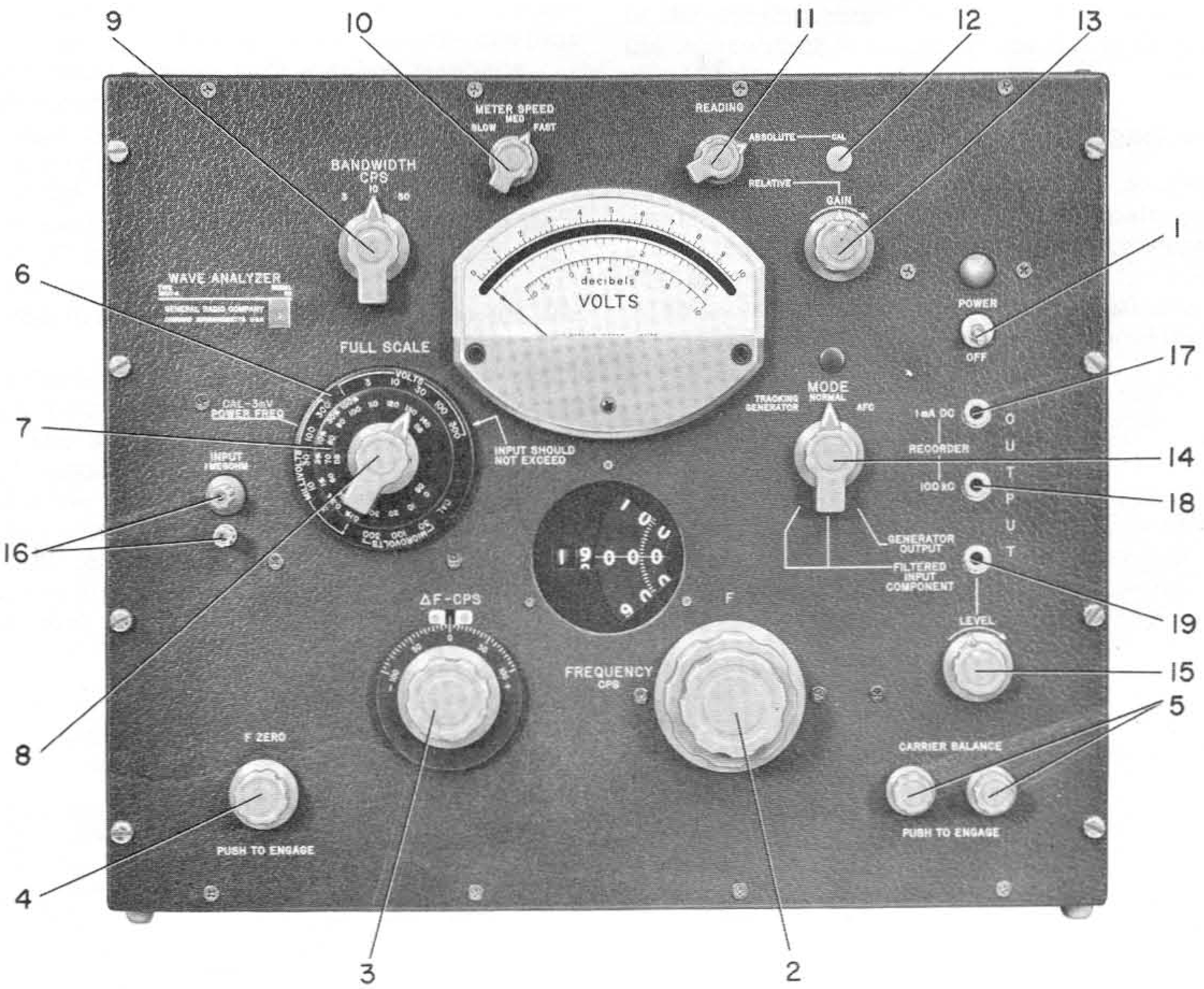


Figure 1-3. Panel view of the analyzer. Numbers refer to Table 1-1.

1.5 OTHER ACCESSORIES AVAILABLE.

Table 1-4 lists the other accessories available for the Type 1900-A Wave Analyzer.

TABLE 1-4. Other Accessories Available.

Type Number	Name	Function
1900-P1	Link Unit	Couples the analyzer to the Type 1521 Graphic Level Recorder.
1900-P3	Link Unit	Couples the analyzer to the Type 1521 Graphic Level Recorder.
1521-9464	Chart Paper	For use on Type 1521 Graphic Level Recorder, to record output of analyzer. Calibrated 0 to 10 kc, linear, repeating every 20 inches.
1521-9465	Chart Paper	For use on Type 1521 Graphic Level Recorder when analyzer is used on 50-cycle bandwidth only. Calibrated 0 to 50 kc, linear, 10 inches, repeating every 16 inches.
1521	Graphic Level Recorder	To record 100-kc output of analyzer and automatically plot spectrum.
1150-B	Digital Frequency Meter	To measure accurately the frequency of the selected components.

SECTION 2

INSTALLATION

2.1 MOUNTING THE TYPE 1900-A WAVE ANALYZER.

The instrument is available for either bench or relay-rack mounting. For bench mounting (Type 1900-AM), aluminum end frames are supplied to fit the ends of the cabinet. Each end frame is attached to the instrument with four panel screws with fiber washers and four No. 10-32 round-head screws with notched washers.

For rack mounting (Type 1900-AR), special rack-mounting brackets are supplied to attach the cabinet and instrument to the relay rack (see Figure 2-1).

To install the Type 1900-AR in a relay rack:

a. Attach each mounting bracket (A) to the rack with two No. 10-32 round-head screws (B). Use the inside holes on the brackets.

b. Slide the instrument onto the brackets as far as it will go.

c. Insert the four panel screws with attached washers (C) through the panel and the bracket, and thread them into the rack. The washers are provided to protect the face of the instrument.

d. Toward the rear of each bracket, put a thumbscrew (D) through each slot in the bracket and into the hole in the side of the cabinet.

Reverse the above procedure to remove the instrument from the relay rack.

To remove the Type 1900-AR Wave Analyzer from the cabinet, set the instrument on its back (panel up) on two or more blocks, so that it will not rest on the projecting power plug. Remove the eight panel screws, four at the top and four at the bottom of the panel. By means of the overhanging side edges of the panel, carefully lift the instrument straight up, until it is free of the cabinet.

2.2 MOUNTING THE TYPE 1910-A RECORDING WAVE ANALYZER.

The Type 1910-A Recording Analyzer, which includes both the Type 1900-A Wave Analyzer and the Type 1521 Graphic Level Recorder, is shipped with aluminum end frames, completely assembled for bench mounting. Also included are supports for installation in a standard 19-inch relay rack. Follow the mounting instructions given in paragraph 2.1, above.

2.3 CONNECTION TO POWER SUPPLY.

Connect the analyzer to a source of power as indicated by the legend at the input socket at the rear of the instrument; use the power cord provided. While instruments are normally supplied for 115-volt operation, the power transformer can be reconnected for 230-volt ser-

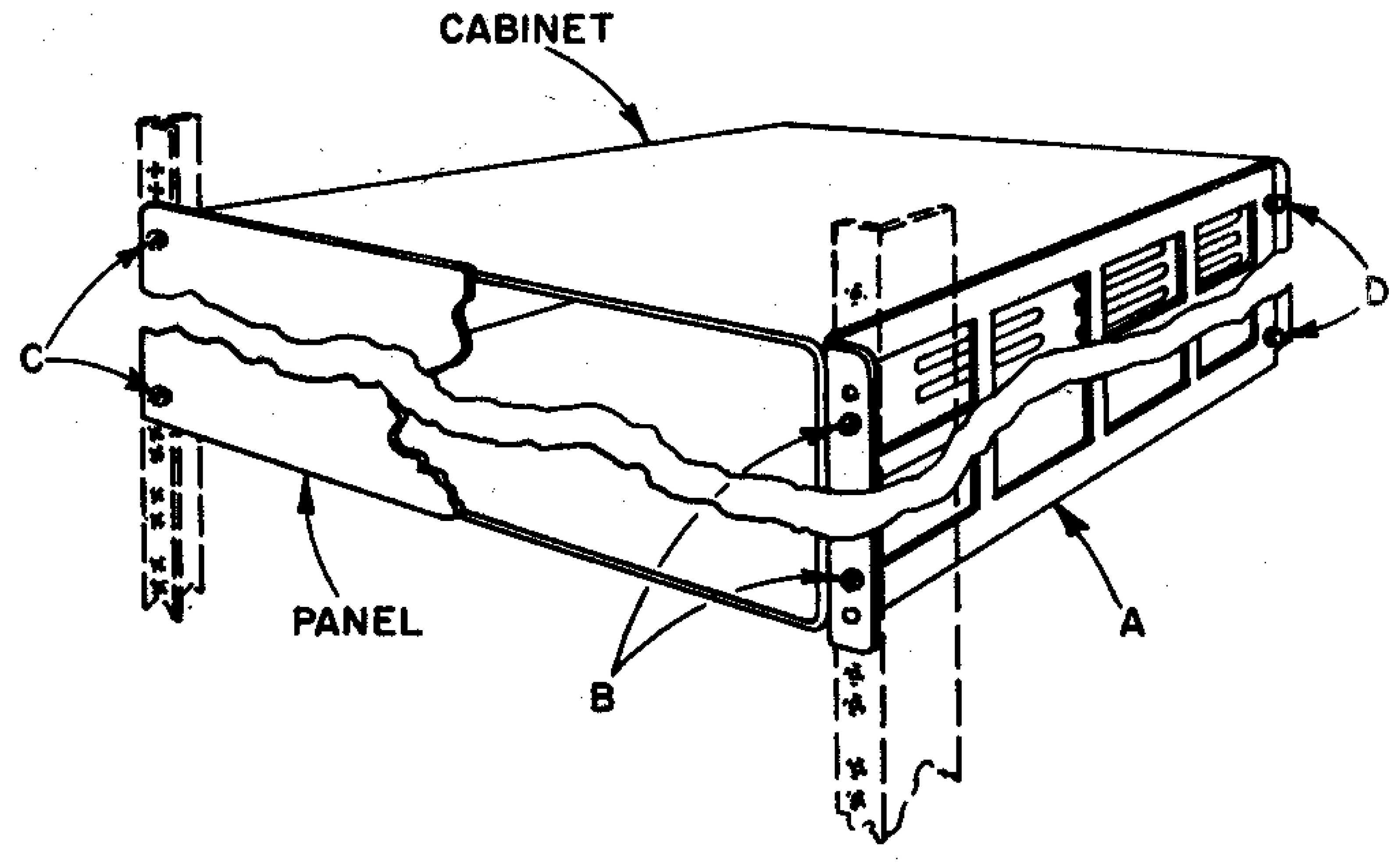


Figure 2-1. Installation of relay-rack model, Type 1900-AR.

vice (see schematic diagram, Figure 6-8). When changing connections, be sure to replace line fuses with those of current rating for the new input voltage (refer to Parts List). Appropriate measures should be taken so that the legend indicates the new input voltage. On instruments changed from 230 to 115 volts, this simply means removal of the 210- to 250-volt input plate; a 105- to 125-volt legend is marked beneath. For instruments changed to 230 volts, a 210- to 250-volt plate (Type 5590-1664) may be ordered from General Radio.

2.4 INSTALLATION WITH TYPE 1521 GRAPHIC LEVEL RECORDER.

2.4.1 GENERAL.

The analyzer can be combined with the Type 1521 Graphic Level Recorder, as in the Type 1910-A, for automatic recording of the frequency components of a signal. In addition to the two instruments, a Type 1521-P10 Drive Unit and a Type 1900-P1 or -P3 Link Unit are required to complete the analyzer-recorder assembly.

Either rack- or bench-mounted models can be used in the combination. End frames, furnished with the bench-mounted units, can be bolted together to form a rigid assembly without the use of a rack (Figure 2-2).

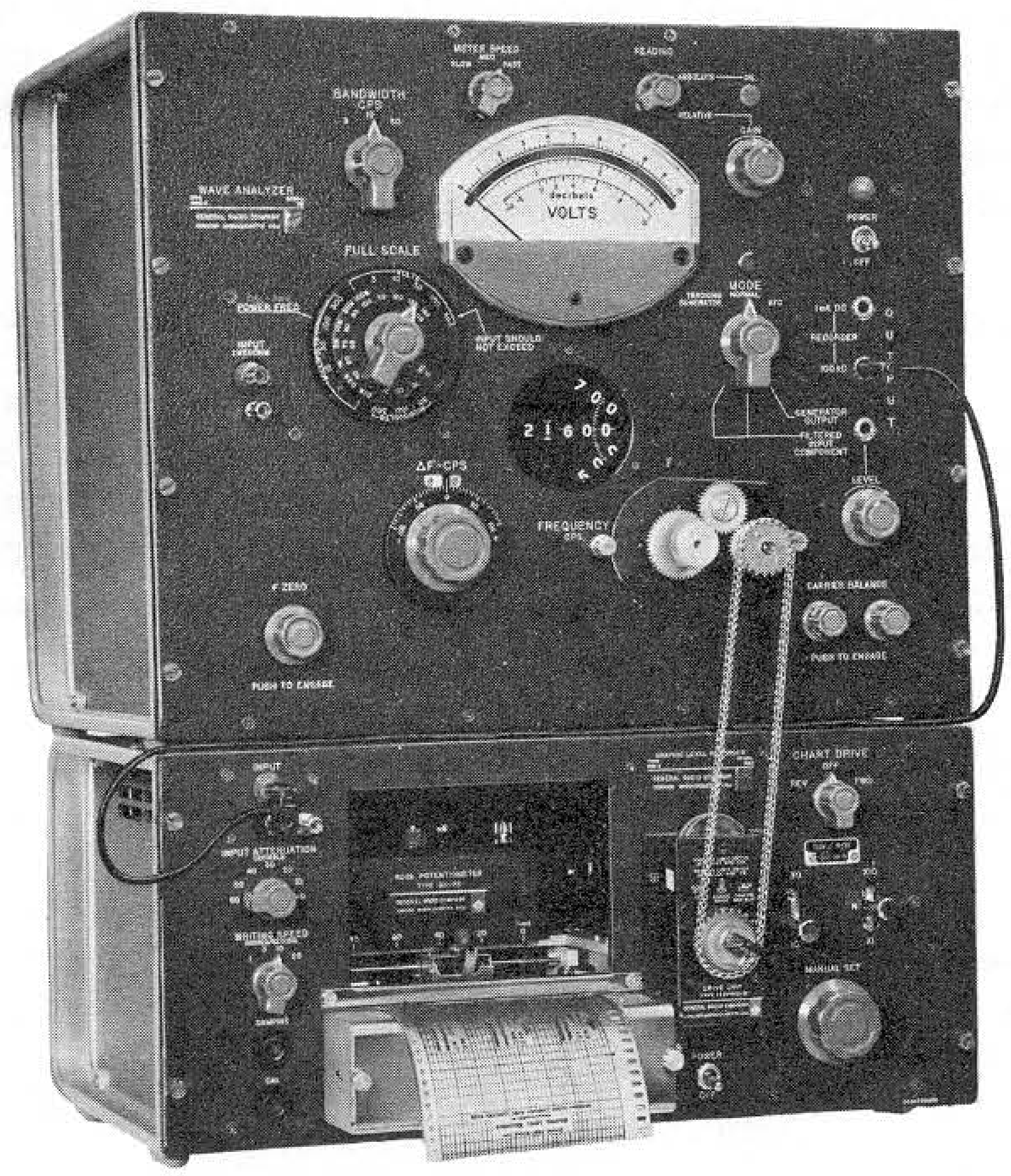


Figure 2-2. The mechanical connections between the analyzer and the Type 1521 Graphic Level Recorder. These two instruments and the accessories listed in Tables 1-2 and 1-3 are included in the Type 1910-A Recording Wave Analyzer.

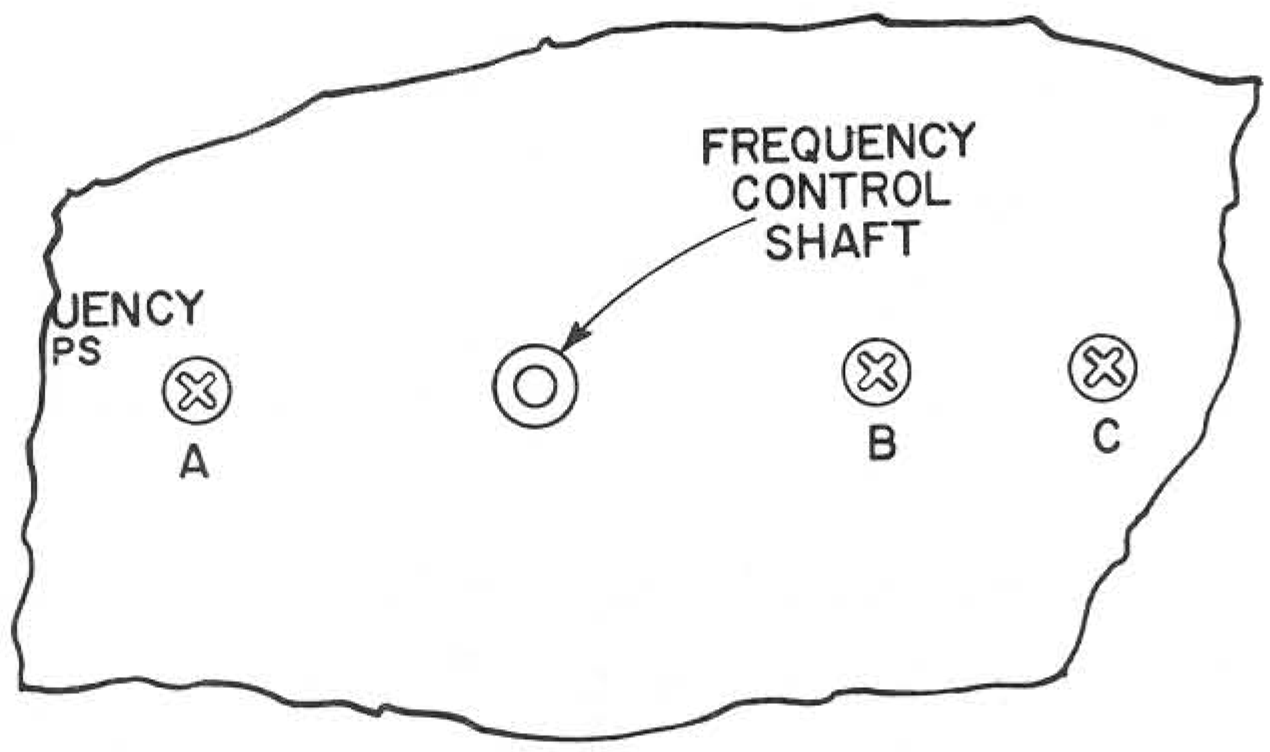


Figure 2-3. The three panel screws shown must be removed before the Type 1900-P1 or -P3 Link Unit is mounted on the analyzer.

The combination can be set up with either instrument above the other. However, the analyzer is normally placed above the recorder, since, with this arrangement, the drive chain linking the two units does not interfere with the manipulation of any controls.

2.4.2 INSTALLATION PROCEDURE.

2.4.2.1 General. For rackmounting, place the two instruments in the same relay rack, one above the other, and follow the procedure described in paragraph 2.1 of this book and in Section 2 of the Operating Instructions for the Type 1521 Graphic Level Recorder.

For bench use, place one instrument above the other with the panels in the same plane. Bolt the end frames together on each side of the instruments (bolts supplied.

CAUTION

Because of torque limitations do not attempt to drive the analyzer with the high-speed (300-rpm) motor in the recorder.

2.4.2.2 Type 1521-P10 Drive Unit. Mount the Type 1521-P10 Drive Unit on the Type 1521 Graphic Level Recorder as described in the Operating Instructions for the latter. The Microswitches (used to turn the motor off at the ends of the sweep) will seldom be needed; therefore, the internal toggle switch (behind the panel, near the socket for the drive-unit plug) should be snapped toward the rear, away from the panel of the recorder.

2.4.2.3 Type 1900-P1 Drive Unit. To mount the Type 1900-P1 Link Unit on the analyzer, proceed as follows:

a. Loosen the setscrews in the two FREQUENCY control knobs. Slide the knobs off the shaft.

b. Remove the three panel screws (A, B, and C, Figure 2-3) that are near and in line with the exposed shaft.

c. Remove the two thumbscrews (with their washers) from the two threaded storage holes in the main plate of the link unit and place the plate so that the FREQUENCY control shaft is inserted in the 3/8-inch bushing. Screw the thumbscrews into the two panel-

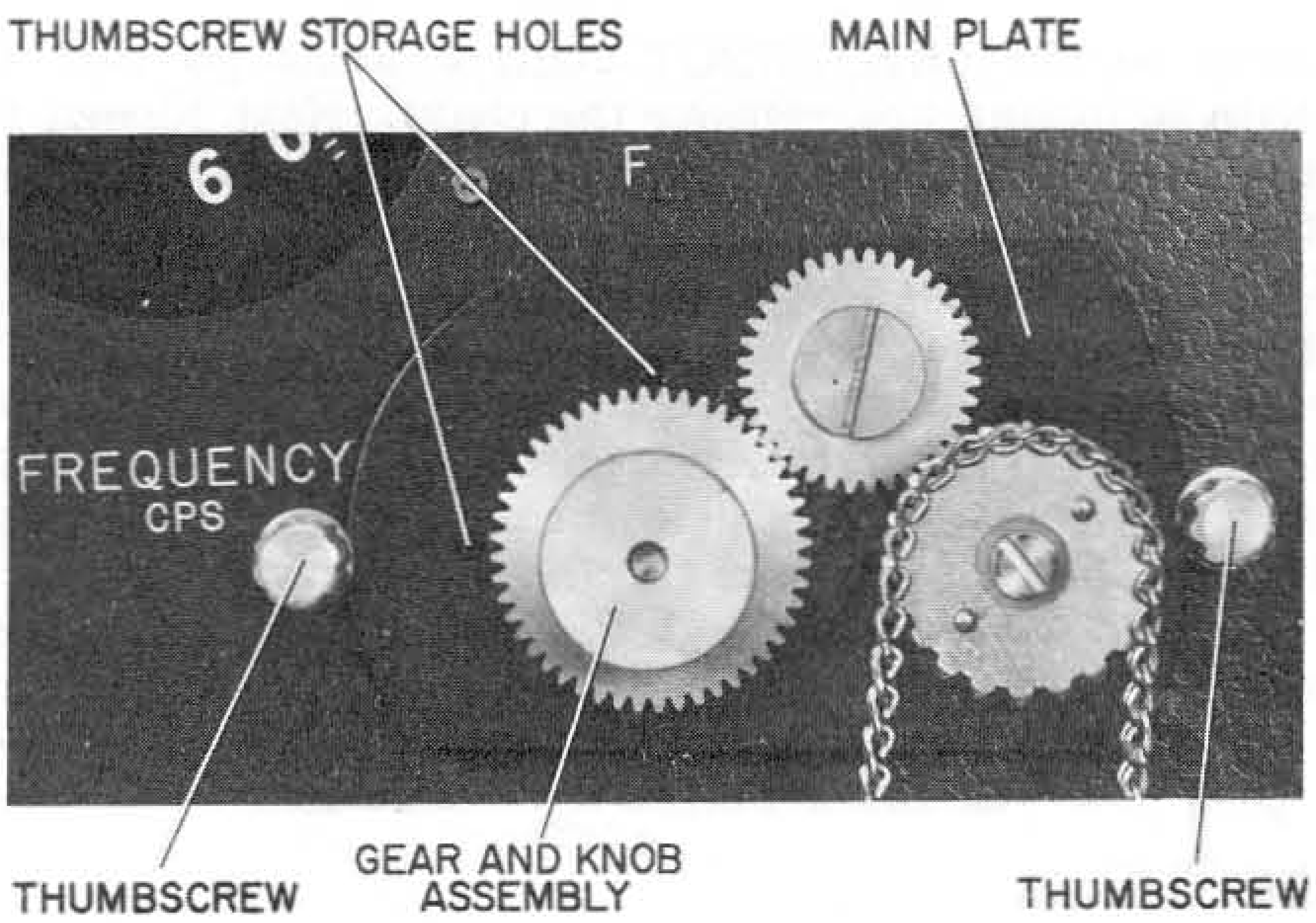


Figure 2-4. Method of mounting the Type 1900-P1 Link Unit on the analyzer.

screw holes (A and C) that are farthest from the shaft. The washers must straddle the main plate, as shown in Figure 2-4, to lock the plate in place.

d. Determine which of the two gear-and-knob assemblies (both are supplied) is to be used. The one with setscrews near the *knurled* end of the knob drives the small-diameter FREQUENCY control shaft and covers a span of 1 kc per revolution. This assembly is designed for use on any of the three bandwidths, with Type 1521-9464 Chart Paper, which covers 10 kc in 20 inches. The recorder can be operated so that the second 20-inch section of paper corresponds to the next 10-kc span. (The 10-kc units must be marked on the paper for identification.)

To attach this assembly, slip the knob over the shaft end and mesh the gear with the one on the main plate of the link unit, as shown in Figures 2-2 and 2-4. Tighten both setscrews in the knob.

e. The gear-and-knob assembly with setscrews near the gear end of the knob drives the larger control shaft and covers a span of 10 kc per revolution. Use this assembly only when the 50-cycle bandwidth is to be used exclusively and only with the Type 1521-9465 Chart Paper, which covers 50 kc in 10 inches. (The drive with this connection is not smooth enough to give accurate results with bands narrower than 50 cps. Also, the resolution of the chart paper is not adequate to justify its use with the narrower bandwidths.)

To attach this assembly, first remove the E-type retaining ring and the washer from around the 3/16-inch FREQUENCY control shaft. Push the shaft in about 1/8 inch, so that the internal gears are no longer in mesh. Slip the knob over the shaft end and mesh the gear with the one on the main plate of the link unit, as shown in Figures 2-2 and 2-4. Tighten both setscrews in the knob.

When the selected knob-and-gear assembly is in place, slip the appropriate length of chain (two are supplied) over the sprockets on both the link unit on the analyzer and the drive unit on the recorder. Use the short chain when the analyzer is placed on top of the recorder and the long chain when the recorder is above the analyzer. Loosen the two thumbscrews that hold the main plate of the link unit and swing the plate on the FREQUENCY control shaft to take up the slack in the chain. Then tighten the thumbscrews.

2.4.2.4 Type 1900-P3 Link Unit. To mount the Type 1900-P3 Link Unit on the Type 1900-A Wave Analyzer, proceed as follows (see Figure 2-5):

a. Loosen the setscrews in the two FREQUENCY control knobs of the wave analyzer. Slide the knobs off the shaft.

b. Remove the three panel screws (A, B, and C, Figure 2-3) that are near and in line with the exposed shaft.

c. Remove the two thumbscrews (with their washers) from the two threaded storage holes in the rear of the link unit. Make certain that the gear-shift pin is pulled out and inserted into the middle position and that the gear-and-knurled-knob assembly is free, with the setscrews that are at the front of the knurled knob backed off.

d. Place the link unit so that the FREQUENCY control shaft is inserted in the 3/8-inch bushing and into the captive-gear-and-knurled-knob assembly.

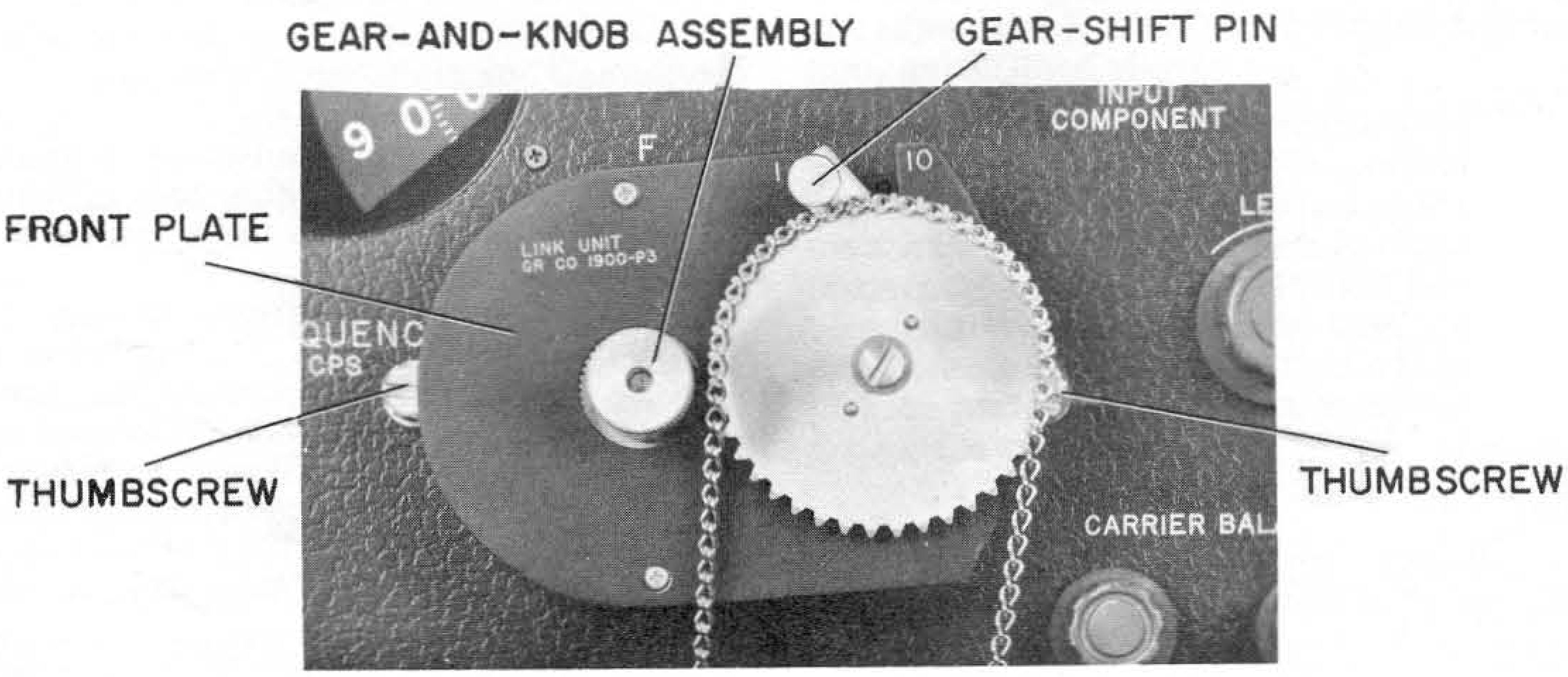


Figure 2-5. Method of mounting the Type 1900-P3 Link Unit on the analyzer.

e. Screw the thumbscrews into the two panel-screw holes (A and C) that are farthest from the shaft. The washers must straddle the rear plate, to lock it in place.

f. Tighten the setscrews in the captive-gear-and-knurled-knob assembly.

g. Slip the chain provided onto the large sprocket by tipping it under the gear-shift pin and, with an upward push on the pin, slide it into place.

h. Loosen the two thumbscrews holding the rear plate of the link unit so that the unit can swing down to allow the chain to be placed over the sprocket of the Type 1521-P10 Drive Unit. Then swing the link unit to take up the slack in the chain and tighten the thumbscrews.

2.4.2.5 Completing the Installation. Use the Type 1560-P95 Cable Assembly to connect the wave analyzer to the recorder, with the ribbed section of the plug at the top (the shield in the lower terminal). Insert the telephone plug in the 100 KC RECORDER OUTPUT jack on the analyzer. (Use the 1 mA DC RECORDER OUTPUT jack for dc recordings.)

The analyzer-recorder combination is now ready for use. Refer to the Operating Procedure, Section 3 of this book and to the Operating Instructions for the Type 1521 Graphic Level Recorder.

2.4.3 RESTORING MANUAL CONTROL.

2.4.3.1 Removing the Type 1900-P1 Link Unit. To remove the Type 1900-P1 Link Unit, first remove the two thumbscrews (Figure 2-4). This will allow the unit to swing on the FREQUENCY control shaft so that the chain is loose; then remove the chain. Next loosen the two setscrews in the knob-and-gear assembly and slide it off the shaft. Remove the two thumbscrews and withdraw the link unit from the analyzer. Then replace the three panel screws. If the inner shaft (3/16-inch diameter) has been pushed in (as described in e., paragraph 2.4.2.3), pull it out to its original position, at the same time rotating it slightly to mesh the internal gears. Then replace the washer and the retaining ring.

Slip the two original FREQUENCY control knobs onto the shaft and tighten all four setscrews in the knobs.

The analyzer is now ready for manual control.

2.4.3.2 Removing the Type 1900-P3 Link Unit. To remove the Type 1900-P3 Link Unit, first remove the two thumbscrews with their washers (Figure 2-5). Swing the link unit so that the chain is loose, and remove the chain. Next loosen the two setscrews in the captive-gear-and-knob assembly; then slide the link unit off of the FREQUENCY control shaft. Screw the two thumbscrews, with their washers, into the two threaded storage holes in the rear plate of the link unit.

Replace the three panel screws (A, B, and C, Figure 2-3). Then slip the two original FREQUENCY control knobs onto the shaft and tighten all four setscrews in the knobs.

The analyzer is now ready for manual control.

SECTION 3

OPERATING PROCEDURE

3.1 INITIAL ADJUSTMENT.

3.1.1 GENERAL.

After installation (refer to Section 2), snap the POWER switch on. For most measurements the analyzer is ready to use after a one-minute warm-up period.

When the instrument is first set up, adjust the F ZERO control as described in paragraph 3.1.2. Repeat this procedure whenever an accurate calibration of the low end of the FREQUENCY dial is desired. More frequent adjustment of the F ZERO control is usually unnecessary, because the frequency drift after warm-up is small.

Also, when the instrument is first turned on, adjust the CARRIER BALANCE controls as described in paragraph 3.1.3. Thereafter, check and adjust the balance occasionally, particularly when low-level, low-frequency components are to be measured. Ordinarily these controls require adjustment only once every day or two.

3.1.2 ADJUSTMENT OF F ZERO CONTROL.

To standardize the frequency calibration, first set the controls at zero frequency. At this point the local oscillator is actually operating at a frequency of 100 kc, which is the center of the filter passband. Part of the signal from the local oscillator is fed through the filter, and then is used to produce an indication on the meter.

Use the following procedure to tune the oscillator frequency to the center of the filter passband. Do not connect a signal to the INPUT terminals for this adjustment.

Set the controls as follows:

FREQUENCY dial to 00000 by means of the two large concentric knobs below and to the right of the dial.

ΔF dial to 0.

FULL SCALE attenuator

Larger dial fully counterclockwise (INPUT SHOULD NOT EXCEED arrow at 300 VOLTS).

Knob fully clockwise (300 VOLTS).

BANDWIDTH knob to 10.

METER SPEED knob to FAST.

READING knob to ABSOLUTE.

MODE knob to NORMAL.

Push the F ZERO knob in toward the panel to engage the flexible coupling, and rotate the knob until maximum indication is noted on the meter; release the knob at this point. The F ZERO control is now properly adjusted.

Some special situations may require slight modifications of this basic approach, as follows:

If the indication is not great enough for satisfactory tuning, turn the attenuator knob one or two steps counterclockwise from the full-clockwise position.

NOTE

If the meter indicates beyond full scale even with the attenuator knob in the 300 VOLTS position, make a preliminary carrier balance (refer to paragraph 3.1.3), then proceed with the adjustment of the F ZERO control.

An attempt to make the adjustment with the carrier nearly balanced may yield two maximum meter deflections, one on each side of the correct F ZERO point, so that the carrier should be slightly unbalanced, as follows:

If the maximum meter indication is near zero with the FULL SCALE attenuator knob at 30 VOLTS, push one of the CARRIER BALANCE knobs in, so that it engages the flexible coupling, and rotate it slightly to obtain a meter indication near midscale. Then proceed with the adjustment of the F ZERO control.

For maximum precision in setting the frequency of the local oscillator, set the BANDWIDTH switch to 3 CPS and adjust the F ZERO knob for maximum meter indication, as outlined above.

3.1.3 CARRIER BALANCE ADJUSTMENT.

When the FREQUENCY controls are set near zero, any signal from the local oscillator that passes through the filter may interfere with the measurement of a low-frequency signal. The CARRIER BALANCE controls can be adjusted to reduce the oscillator signal sufficiently to eliminate this difficulty. This adjustment also ensures that the main mixer circuit is operating properly. The procedure is as follows:

Set the F ZERO control as described in paragraph 3.1.2.

Without disturbing the FREQUENCY controls, adjust the CARRIER BALANCE knobs for a minimum meter indication. Push each knob in to engage its flexible coupling and rotate each in turn until the minimum possible indication is obtained. Tune each knob alternately several times for a successively closer approach to a null. It is usually unnecessary to balance the signal to better than a full-scale meter deflection with the FULL SCALE attenuator knob in the 30 VOLTS position (larger dial set to INPUT SHOULD NOT EXCEED 300 VOLTS). If a very precise balance is attempted, the meter indication will not reach a stable null. The disturbing fluctuations are caused by very low frequency noise (sometimes called "flicker effect") in the mixer and preceding amplifier. This noise is troublesome only when the FREQUENCY controls are set near zero.

Some drifting of the balance will occur, although the CARRIER BALANCE controls can be readjusted at any time. If it is desirable to maintain the balance for several hours or longer, allow a 10-minute warm-up period and adjust the controls to give a meter indication of less than half scale. No readjustment should be necessary for several hours. Even if the power to the instrument is turned off temporarily, with the attenuator knob in the 30 VOLTS position, the balance should give a reading less than full scale shortly after the instrument is turned on again.

3.1.4 CALIBRATING FOR DIRECT READING IN VOLTS.

An internal calibrating signal is provided to standardize the sensitivity of the instrument so that the amplitude of a component can be measured directly in volts.

After the F ZERO control has been adjusted as in paragraph 3.1.2, set the other controls as follows:

FREQUENCY dial to 00060 (00050 if the powerline frequency is 50 cps).

ΔF dial to 0.

FULL SCALE attenuator

Larger dial fully clockwise, with CAL opposite CAL-3mV POWER FREQ.

WARNING

When the larger dial is set fully clockwise, the electronic circuits are disconnected from the input signal.

Knob to 3 MILLIVOLTS.

BANDWIDTH knob to 10 (or to the bandwidth that is to be used for subsequent measurements).

NOTE

For the 50-cycle bandwidth, complete the CARRIER BALANCE adjustment of paragraph 3.1.3 before proceeding with this calibration.

METER SPEED knob to FAST.

READING knob to ABSOLUTE (or to RELATIVE, if the sensitivity is to be standardized by means of the panel GAIN control).

MODE knob to NORMAL.

To be sure the frequency tuning is correct, adjust the ΔF dial for maximum indication on the meter, which should read 3 millivolts. If it does not, adjust the sensitivity by means of the screw-driver control under the panel snap button marked CAL (or by the GAIN control knob if the READING knob is in the RELATIVE position).

For the greatest accuracy, repeat this standardization procedure just before a measurement is made.

The sensitivity of the analyzer for the three bandwidths has been equalized at the factory. Therefore, if the gain is set for the 3-cycle bandwidth, it will be nearly the same for either the 10- or the 50-cycle bandwidth. The small differences that may exist are due to the fact that the insertion loss of the highly selective filter drifts at a different rate for each of the three bandwidths.

If it is essential, for a given set of measurements, that two bandwidths have exactly the same maximum response, the calibration can be set to read correctly for one bandwidth with the READING knob at ABSOLUTE, (by means of the CAL screwdriver control) and for the other bandwidth, with the READING knob at RELATIVE, (by means of the panel GAIN control).

3.2 MEASUREMENT OF COMPONENTS OF PERIODIC SIGNALS.

3.2.1 GENERAL.

A wide variety of periodic signals can be analyzed, as shown in Figures 3-1,a and 3-1,b.

The settings to be used for the various controls on the analyzer depend upon the nature of the applied signal. Quite often, enough is known about the signal so that the controls can be set directly. However, if very little is known, the controls should be set in a manner to permit successively better settings after a preliminary analysis. The settings are not critical unless use of the full capabilities of the analyzer is required.

3.2.2 ANALYSIS PROCEDURE.

After the initial adjustments have been made (paragraph 3.1), proceed as follows:

a. Set the FULL SCALE attenuator larger dial fully counterclockwise (the INPUT SHOULD NOT EXCEED arrow at 300 VOLTS), or to a value such that the peak voltage of the signal (if it is known) is not more than about 1.4 times the chosen INPUT SHOULD NOT EXCEED value, in which case omit paragraphs e, f, and g of this procedure.

WARNING

When the larger dial is set fully clockwise, the electronic circuits are disconnected from the input signal.

b. Connect the signal to be analyzed to the INPUT terminals.

c. Set the controls as follows:

ΔF dial to 0.

METER SPEED knob to FAST.

READING knob to ABSOLUTE.

MODE knob to NORMAL.

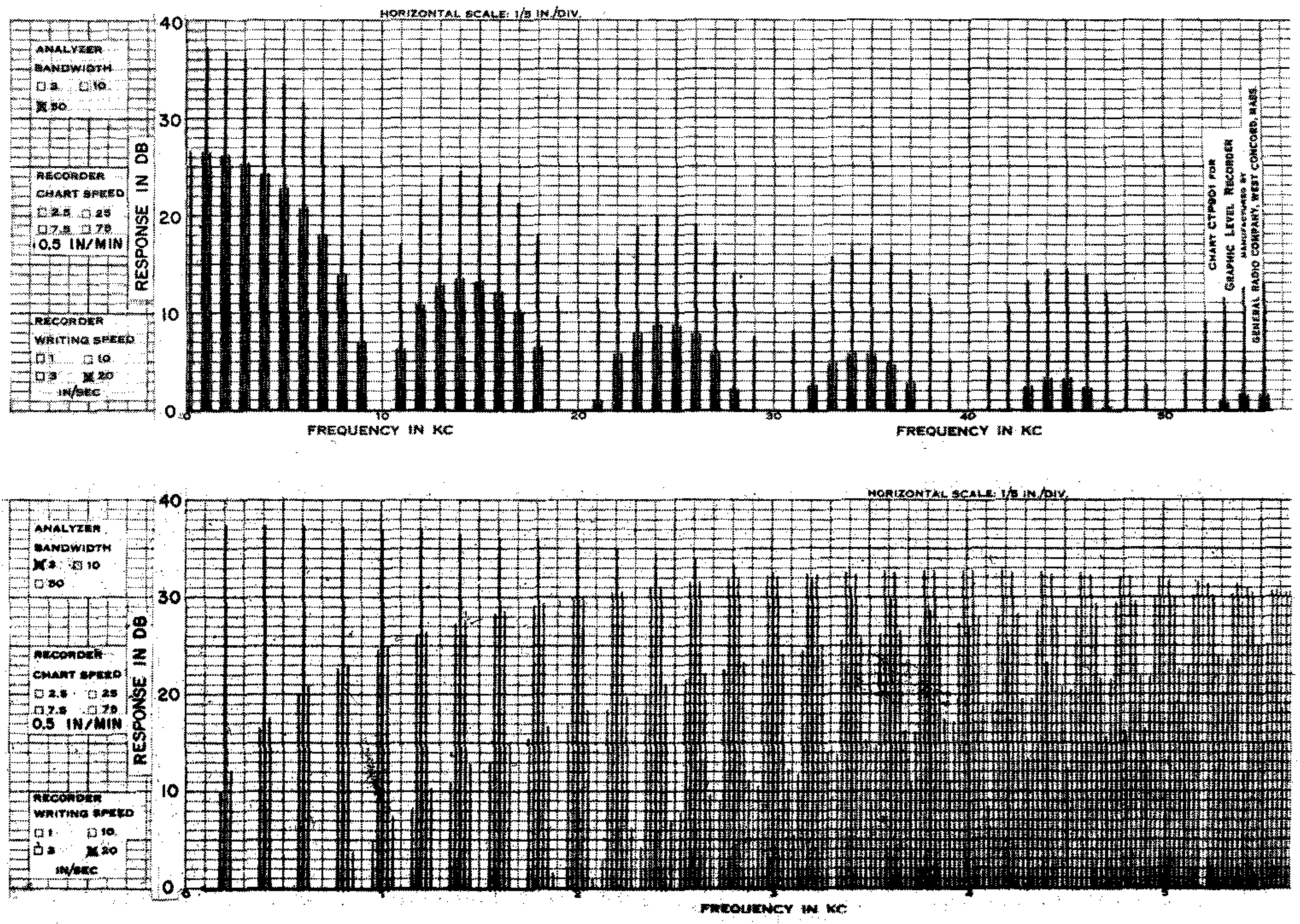


Figure 3-1. Plots of pulse waveforms made on the recording analyzer: (a, top) 100-μsec pulse at 1-kc repetition rate. Pulse was amplitude modulated from ¼ to full amplitude by a 200-cycle, non-coherent sine wave. (b, bottom) 20-μsec pulse at an average repetition rate of 200 cps. The pulse was position modulated at a 25-cycle rate.

d. Set the BANDWIDTH knob to 50 CPS for a preliminary scan of the spectrum, or to a narrower band if necessary.

e. Turn the FULL SCALE attenuator knob two steps from its maximum clockwise position.

f. Scan the frequency range from 00000 to 54000 by turning the FREQUENCY control knob. Note the approximate amplitudes and frequencies of any components of the input signal by deflections of the meter. Turn the FULL SCALE attenuator knob a step or two clockwise whenever a meter deflection beyond full scale is discovered. (The unbalanced carrier signal will produce a deflection in the vicinity of 00000 on the FREQUENCY dial. Ignore this signal during the preliminary scan.) If no deflection of the meter is located (except in the vicinity of 00000), rotate the FULL SCALE attenuator larger dial two steps clockwise (increasing sensitivity) and again scan the range from 00000 to 54000. Continue to increase the sensitivity until the components of the incoming signal are located. (If the rotation of the attenuator larger dial has a significant effect on the meter deflection near 00000, a low-frequency component is indicated.)

g. Add together all the actual observed voltages of the major components; ignore those that are less than about 1/10 the amplitude of the largest component. Set the FULL SCALE attenuator larger dial so that the INPUT SHOULD NOT EXCEED arrow points to a value greater than the sum of the major components. This setting ensures that spurious components introduced by the mixer are at least 75 db below the level of the largest component. Such a setting is desirable when a low-distortion, sine-wave signal is to be analyzed. When a pulse or other wave that is composed of many nearly equal components is analyzed, a setting one step clockwise from that calculated above is often desirable. This reduces the effects of internal noise. Usually distortion is not noticeable.

h. Tune through the desired range of frequencies and note the value of each component. Adjust the sensitivity for each, by means of the FULL SCALE attenuator knob, to give a meter indication slightly less than full scale.

NOTE

Do not change the setting of the attenuator larger dial once it has been set either as described in paragraph g, above, or according to the peak value.

The actual component voltage amplitude is indicated by the meter deflection. Read the meter scale that corresponds to the full-scale voltage indicated on the larger dial of the attenuator by the setting of the FULL SCALE attenuator knob.

i. Use the 10- or 3-cycle bandwidth if component frequencies below 100 cps are to be measured or if the component frequencies are quite close to each other. The rate of tuning must be much slower for the narrower bandwidths so that no significant components will be overlooked as the frequency range is scanned. Therefore, for a preliminary check, use of the 50-cycle bandwidth offers the quickest survey of the range. In the region where a component is located. the narrower bands can be used, to determine whether or not more than one component is present.

The actual frequency of a so-called periodic signal fluctuates somewhat. For most signals the fluctuations are small and can be ignored for purposes of analysis. Some signals, however, fluctuate in frequency enough to produce serious errors in the determination of the amplitude of the components when a narrow band (such as 3 cps) is used. Therefore always use the widest band commensurate with the required selectivity and noise rejection (refer to paragraph 4.12).

3.2.3 PERCENTAGE READINGS (MEASUREMENT OF DISTORTION).

In the measurement of the distortion of a nearly sinusoidal signal, it is often desirable to measure the amplitude of the distortion component as a percentage of the fundamental. To make percentage measurements, follow the instructions as given above for analysis procedure (paragraph 3.2.2, steps a through g), but in step h tune the FREQUENCY controls to the fundamental frequency. Select a bandwidth that is small compared with this fundamental frequency and adjust the FREQUENCY controls for maximum meter response. Set the FULL SCALE attenuator knob fully clockwise. Hold the larger dial stationary with one hand and, with the other, rotate the smaller dial until the knob points to 100%. Set the READING knob to RELATIVE, and adjust the GAIN control to give a full-scale meter deflection on the 10 scale, regardless of the setting of the larger dial. (If it is impossible to obtain a full-scale deflection, rotate both FULL SCALE attenuator knob and the inner dial one step counterclockwise. Do not change the setting of the larger dial. Then adjust the GAIN control for a full-scale deflection of the meter.) Now use the FREQUENCY knobs to tune in the various distortion components. In each case adjust the FULL SCALE attenuator knob to give a convenient on-scale deflection of the meter. Read the meter scale indicated by the pointer of the attenuator knob on the scale of the smaller dial; the meter scale indicates directly in percent.

To measure the harmonic components of a low-frequency fundamental, choose a bandwidth that is narrow enough to provide adequate discrimination between fundamental and harmonic components. For instance, do not attempt to measure the distortion of a 20-cycle wave with the 50-cycle-bandwidth filter.

To measure harmonics greater than one percent, use the 50-cycle bandwidth down to about 150 cps, the 10-cycle bandwidth to 30 cps, and the 3-cycle bandwidth to 10 cps. For 0.1-percent harmonics, use the 50-cycle bandwidth to 250 cps, the 10-cycle bandwidth to 50 cps, and the 3-cycle bandwidth to 20 cps.

NOTE

The analyzer is so sensitive that the noise in the mixer and in the preceding amplifier stages can be readily observed on the more sensitive ranges. This is particularly so when the GAIN control is set fully clockwise. The noise limits the ultimate range of analysis. Therefore, for the maximum usable range, set the FULL SCALE attenuator larger dial as far clockwise as is permitted by the peak input voltage. Then, for signals of 0.1 volt or more, it is possible to observe components as much as 90 db below the fundamental signal, if the selectivity is adequate.

3.2.4 MEASUREMENT OF COMPONENTS AT FREQUENCIES BELOW 20 CPS.

The response is uniform within 1 db down to 10 cps and within 2 db down to 5 cps. Thus measurements can be made at these low frequencies, but, for the best use of the analyzer, particular care must be taken when certain adjustments are made. For measurements at these low frequencies:

Allow the instrument to warm up for at least 20 minutes before the measurement is made.

Set the F ZERO control as described in paragraph 3.1.2, but with the BANDWIDTH control set to 3 CPS.

Then adjust the CARRIER BALANCE controls as in paragraph 3.1.3, but adjust them so that the carrier indication on the meter is less than 1/10 of full scale with the FULL SCALE attenuator knob in the 30 VOLTS position.

Proceed as in paragraph 3.2.2, except use the ΔF dial for frequency tuning.

3.2.5 MEASUREMENT OF HUM COMPONENTS.

The internal hum components in the analyzer have been kept small by careful design, and the instrument is well shielded to reduce the effects of extraneous fields. Because the analyzer can measure very low voltages, the stray magnetic fields from transformers, motors, or similar devices that are located near the input of the analyzer can introduce appreciable components at the power-line frequency or at multiples thereof. These devices (especially blowers) may be located in instruments that are being used near the analyzer. Therefore, when low-level hum components are to be measured, such troublesome devices should be either turned off or removed from the vicinity of the analyzer.

3.3 ANALYSIS OF NOISE.

3.3.1 GENERAL.

The settings to be used for the various controls of the analyzer depend on the fineness of detail that is desired, on the over-all signal level involved, and on the accuracy required. Suggestions for the selection of the BANDWIDTH and the METER SPEED are given throughout this section, and Section 5 gives an extended discussion of noise-measuring techniques.

3.3.2 ANALYSIS PROCEDURE.

After the initial adjustments have been made, proceed as follows:

a. Set the FULL SCALE attenuator larger dial so that the rms value of the noise signal is less than the indicated INPUT SHOULD NOT EXCEED value. This setting is not critical; an estimate within 3 to 1 of the correct value is usually adequate. The rms value can be measured with an rms-type voltmeter, or, for random noise, with a simple rectified average-type voltmeter.

If the output of a Type 1551 Sound-Level Meter or a Type 1558 Octave-Band Noise Analyzer is to be analyzed, set the attenuator larger dial to INPUT SHOULD NOT EXCEED 1 VOLT; if the output of a Type 1553 Vibration Meter is to be analyzed, set the larger dial to INPUT SHOULD NOT EXCEED 3 VOLTS. If, during the analyzing procedure, a band level is found that is greater than 1 or 3 volts, respectively, the larger dial must be rotated one stop further counterclockwise.

If there is no convenient way in which to measure the over-all signal, set the FULL SCALE attenuator larger dial fully counterclockwise and make progressively better settings by following the procedure given in steps d and e of this section.

b. Connect the input signal to the INPUT terminals.

c. Set:

ΔF dial to 0.
BANDWIDTH knob to 50 CPS (unless it is known that a narrower band is necessary).
METER SPEED knob to MED.
READING knob to ABSOLUTE.
MODE knob to NORMAL.
FULL SCALE attenuator knob two steps counterclockwise from the fully clockwise position.

Omit steps d and e, unless there is no convenient way in which to measure the over-all signal. In the latter case, set the FULL SCALE attenuator larger dial fully counterclockwise and make progressively better settings by following the procedure given in steps d and e.

d. Sweep slowly through the entire frequency range in question and note the regions where the greatest deflections occur. Adjust the attenuator knob as necessary to obtain a convenient meter deflection. In the vicinity of 00000 on the FREQUENCY dial, the unbalanced carrier will produce a meter deflection. Discount this carrier level as described in paragraph 3.2.2.

e. Estimate the rms value of the total signal as follows:

If the band level of noise is uniform within a few decibels over the entire range of 54 kc, multiply the average voltage by 30 to obtain the rms value. If the frequency span over which the noise band level is a maximum and reasonably uniform is only about 5 kc, multiply this band level voltage by 10 to obtain the rms value. If this maximum span is only about 500 cps, multiply the voltage by 3.

f. Tune slowly through the range of frequencies from 00100 to the desired maximum. Adjust the FULL SCALE attenuator knob to obtain a meter deflection near full scale for each significant band.

NOTE

Do not readjust the FULL SCALE attenuator larger dial after it has been set according to the rms value.

Use a rate of tuning slower than 50 cps per second. (Refer to Section 5 for an extended discussion of noise-measurement techniques.)

Note the average noise in each band that is significant to the problem at hand. In some cases it may be necessary to note only the maximum levels. If a detailed study is necessary, a recording with a Type 1521 Graphic Level Recorder is to be preferred (refer to paragraph 3.8).

g. When taking a reading at any given frequency, observe the behavior of the pointer on the meter and select an average value. This value will be more reliable if the SLOW METER SPEED is used, but this necessitates a wait of at least 30 seconds before the reading is taken. Use of the SLOW position, with its 5-second time constant, requires at least a 20-second observation of the pointer. The time constants for the MEDium and FAST meter speeds are approximately 0.5 and 0.15 second, respectively; thus less time is required when readings are taken at these speeds. However, the selected average value is then less reliable (refer to paragraph 5.4.2). Therefore a choice must be made between the reading time required and the reliability of the selected value.

3.3.3 NOISE MEASUREMENTS AT FREQUENCIES BELOW 100 CPS.

Ordinarily, either the 10- or the 3-cycle bandwidth should be used for analysis at frequencies below 100 cps. The 50-cycle bandwidth is too wide to offer good resolution. Also, the carrier feedthrough may be enough to obscure the noise level at low frequencies unless the more selective bands are used.

The carrier balance can be consistently maintained about 40 db below the INPUT SHOULD NOT EXCEED voltage. If the level at low frequencies is important, set the attenuator larger dial to the lowest possible value. As much as 10 db overload is permissible (that is, with the larger dial set so that the INPUT SHOULD NOT EXCEED arrow is at 1/3 the value of the rms input-signal voltage) if the required range of analysis is not greater than 60 db.

The carrier must be carefully balanced and the input attenuator setting must be wisely chosen when a measurement within two bandwidths of zero frequency is to be made.

3.4 ANALYSIS OF PERIODIC COMPONENTS IN NOISE.

Most signals are combinations of periodic components and noise. When only the periodic components are of interest, the use of a narrow band helps to reduce the relative importance of the noise. Therefore, if the frequency stability of the periodic component is adequate, and if sufficient time is available, the 3-cycle bandwidth can be used to obtain maximum noise suppression. Otherwise a compromise is necessary in the selection of the bandwidth.

When both the periodic components and the noise are to be considered (for example, as shown in Figures 3-2, a, and 3-2, b), the choice of bandwidth is usually based on the particular application for which the analysis is being attempted.

In some instances it is well to make two separate analyses, one with the 3-cycle bandwidth, to obtain the amplitudes of the discrete components, and the other with the 50-cycle bandwidth, to obtain the spectrum level of the noise.

3.5 FILTERED INPUT COMPONENTS.

The components of the input signal within the selected pass band of the analyzer are available at the OUTPUT jack labeled FILTERED INPUT COMPONENT when the MODE switch is in either the NORMAL or the AFC position. The output amplitudes of these components are directly proportional to their input amplitudes and depend upon the settings of the FULL SCALE attenuator and the LEVEL controls.

Terminate this output in 600 ohms, to minimize unwanted carrier-frequency components.

This output can be used to drive a counter, such as the Type 1150 Digital Frequency Meter, to measure the frequency of the selected input component.

WARNING

When this output is used, it should be carefully shielded from the input to the analyzer, to avoid undesirable feedback.

3.6 TRACKING GENERATOR.

To obtain a sinusoidal signal from the analyzer, set the MODE switch to TRACKING GENERATOR; the output is then available at the panel GENERATOR OUTPUT jack. The amplitude is controlled by the LEVEL knob; the frequency is controlled by the FREQUENCY and ΔF controls and the F ZERO knob.

The frequency of the tracking generator follows the frequency of the analyzer as they are tuned by the FREQUENCY control. Thus the analyzer can be used as the output voltmeter for a system or device that is being supplied by the tracking generator. The analyzer and the generator are synchronized at the factory.

Because some residual signal is transferred internally from output to input, use the following procedure when in the TRACKING GENERATOR mode:

Always set the FULL SCALE larger dial as far clockwise as the level of the input signal will allow. Also, always use an input signal large enough so that with the FULL SCALE attenuator knob four steps from the clockwise end, the meter indicates beyond full scale.

To measure and set the tracking generator output, connect a Type 546 Microvolter to the GENERATOR OUTPUT jack by means of the Type 1560-P95 Adaptor Cable (supplied). Adjust the LEVEL control to obtain the necessary 2.2 volts (0 db) on the microvolter. The voltage is then supplied from the OUTPUT terminals of the microvolter to the device under test.

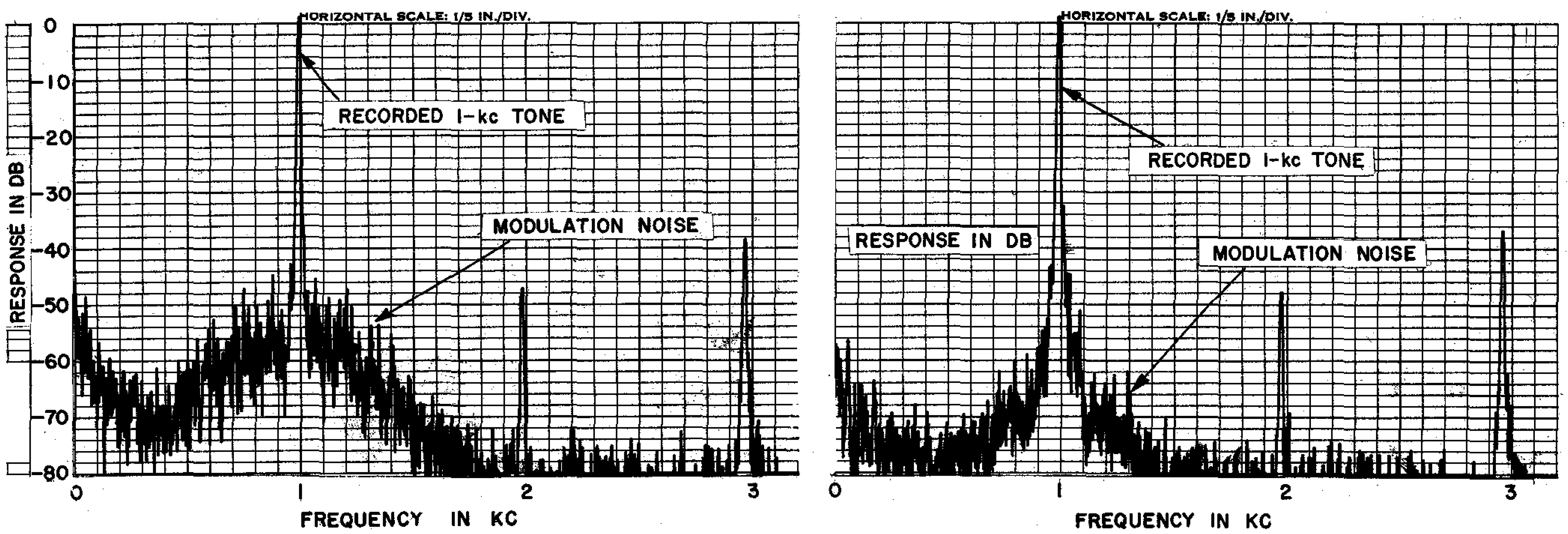


Figure 3-2. Charts of modulation noise on a 1-kc tone for two different types of magnetic tape. Note that one is about 10 db better than the other. Such measurements can be made easily with the recording analyzer, due to its 80-db dynamic range. For these records, chart speed was 2.5 inches per minute; writing speed, 10 inches per second; bandwidth, 10 cps.

Because the TRACKING GENERATOR output is obtained by mixing two signals, some small-amplitude components having frequencies that are different from that of the main output signal are also present in the output. Ordinarily, these are small enough so that their presence causes no trouble. The frequencies (in cps) of some of these components are as follows: 100,000, 100,000 plus the FREQUENCY dial reading, 100,000 x a ± b x the FREQUENCY dial reading (where a and b are integers). When the FREQUENCY dial is set near 50,000, 33,333, or 25,000, a small effect on the output is noticeable as a sort of modulation, because one of the spurious components approaches zero beat. Even though the high-frequency components are small, they can affect the operation of some counters if an attempt is made to measure the frequency of the TRACKING GENERATOR at low frequencies (refer to paragraph 5.6). The output should have a resistance of 600 ohms across it, and if frequencies below 1 kc are the only ones of interest, an additional shunt capacitor of about 0.1 μf can be used to reduce the amplitude of the stray components.

3.7 AUTOMATIC FREQUENCY CONTROL.

In order to stabilize the tuning of the wave analyzer to a particular component of a signal for an extended period, it is often convenient to use the automatic frequency control feature. The procedure is as follows:

Adjust the analyzer as described in the previous paragraphs, with the MODE switch in the NORMAL position. Use the widest possible bandwidth.

Tune in the desired component.

Set the attenuation and GAIN controls to give a meter indication near full scale.

Turn the MODE switch to AFC.

The analyzer is now locked to the selected component. To check the lock-in range, turn the FREQUENCY control dial slowly back and forth, and leave it near the middle of the lock-in range.

If the ambient temperature is markedly different from the normal room temperature, the AFC capture range may be shifted sufficiently to require retuning in the NORMAL position of the MODE control so that the analyzer frequency will lock with that of the selected component signal.

NOTE

This possible shift in the capture range is particularly noticeable with the 3 CPS bandwidth, and in this case it is frequently necessary to readjust the FREQUENCY control knob to "capture" the component, even at normal temperatures. Vary the frequency back and forth very slowly until the properly tuned setting is found. Because of this very limited capture range and because of the serious effects of small drifts with this narrow bandwidth, no specifications are given for AFC with the 3-cycle bandwidth. This readjustment is sometimes also necessary for the 10 CPS bandwidth, because of aging effects.

WARNING

Do not use AFC when a signal is being analyzed as a function of frequency, either by hand or by recording. The AFC will distort the frequency scale and will give misleading values for the frequencies of the components.

3.8 ANALYSIS RECORDING WITH THE TYPE 1521 GRAPHIC LEVEL RECORDER.

3.8.1 GENERAL.

Instructions for the use of this recorder are given in the Operating Instructions for the Type 1521. Some additional directions that apply to its specific use with the Type 1900-A Wave Analyzer are included here.

CAUTION

Do not attempt to use the high-speed (300-rpm) motor in the recorder to drive the analyzer.

3.8.2 INITIAL ADJUSTMENTS.

3.8.2.1 General. After installation (refer to Section 2) turn on the POWER switch on the Type 1900-A and allow the analyzer to warm up.

3.8.2.2 Operating the Type 1900-P3 Link Unit. Mounting instructions for the Type 1900-P3 Link Unit are given in paragraph 2.4.2.4. When this link unit is used, a choice of operating conditions is available, as follows:

a. Neutral Position. When the gear-shift pin is in the middle position, the drive from the recorder is disengaged. The FREQUENCY dial of the wave analyzer can then be set to the desired frequency by means of the knurled knob. The chart paper of the recorder should also be set to the desired position with the gear-shift pin in neutral and the chart-drive right-hand lever in N (neutral).

b. Normal Drive. To put the link unit in the normal drive position, pull the gear-shift pin out of the center hole, shift it to the left, and then push it into the left-hand hole in the back plate. As the pin is moved to the left, it may be necessary to rotate the knurled knob slightly to permit the gears to engage. With the pin in the left-hand position, the drive rate is correct for the Type 1521-9484 Chart Paper with a scale of 100 cps for each division. The setting of the FREQUENCY dial is simplified by the use of the neutral position.

c. Expanded Scale. To obtain a 10-to-1 expansion of the chart scale, pull the gear-shift pin out and insert it into the right-hand hole in the back plate. Again, it may be necessary to rotate the knurled knob slightly to permit the gears to engage.

With the pin to the right, the drive rate is such that, for the Type 1521-9464 Chart Paper, one division corresponds to 10 cps. The frequency scale should therefore be divided by 10.

This expanded-scale position provides a display of the full resolution of which the 3-cycle bandwidth is capable. (The expansion is great enough so that there is no point in using the 50-cycle bandwidth for this drive.) It is possible to estimate the relative position of a frequency component on the chart to about 1 cps. Since the calibration accuracy of the drive is only ± (1/2% + 5 cps), the resolution is significantly better than the accuracy. It does, however, permit display of the components that are closely spaced in frequency, and it simplifies the reading of small differences in frequency; but the basic accuracy limitations of the FREQUENCY control must always be considered when the results are interpreted.

With this expanded scale, the rate at which the frequency is swept is also reduced by a factor of ten for a given chart speed. This factor should be taken into account in setting the chart speed. For best accuracy in the display of frequency and amplitude of a component selected by the 3-cycle band, the frequency sweep rate should be slow, preferably below 100 cycles per second per minute.

3.8.2.3 Other Adjustments. Select and install the potentiometer to be used in the Type 1521 to record the desired component levels. The potentiometer with the lowest range that covers the levels to be recorded will give the greatest recording accuracy.

Raise the pen from the paper and set the WRITING SPEED control to a SLOW position (1 or 3 inches per second). This setting reduces the banging of the coil assembly on the stops due to turn-on transients.

Turn ON the power switch of the recorder.

Make certain that the connecting cable from the Type 1521 Graphic Level Recorder is plugged into the 100 KC RECORDER OUTPUT jack of the Type 1900-A Wave Analyzer, unless the DC OUTPUT is to be recorded (refer to paragraph 3.8.10). Make the adjustments described in paragraphs 3.1.2 and 3.1.3. If the drive-unit clutch is in the idle position, the chain can be driven by hand to set the FREQUENCY dial to the desired point for the initial adjustment.

Be sure the MODE switch on the analyzer is in the NORMAL position.

WARNING

The input leads to the analyzer must be well shielded to avoid pickup from the 100 KC RECORDER OUTPUT connection to the recorder. Open leads, if they must be used, should be as short as possible and should be kept well away from the connection to the recorder.

3.8.3 SYNCHRONIZATION OF FREQUENCY DIAL AND RECORDING PAPER.

The frequency dial can be synchronized conveniently with the paper either at this point or after the procedure of paragraph 3.8.5.

With the analyzer controls set according to paragraphs 3.1.2 and 3.1.3 and with the drive-unit clutch in the idle position, proceed as follows:

a. Set the INPUT ATTENUATION control of the Type 1521 to 60.

b. Set the right-hand chart-speed lever to N, and turn the MANUAL SET control so that the "0" line on the chart paper is directly under the pen.

c. Set the right-hand chart-speed lever on the recorder to either the upper or lower position. (Be sure the FREQUENCY dial on the analyzer is set at 00000.)

d. Throw the clutch into the NON-SLIP position.

The chart paper and the FREQUENCY dial are now synchronized sufficiently well for most purposes; however, due to backlash, some slight error in synchronization may still exist.

If exceptionally accurate positioning of the zero is desired, use the ΔF dial to correct the error. The procedure is as follows:

a. Set the chart-speed lever to the lower position.

b. Set the CHART DRIVE to REV and let the motor drive the FREQUENCY control backwards a few hundred cycles; then switch the CHART DRIVE to OFF.

c. Change the CHART DRIVE to FWD and switch it to OFF just before the recording pen reaches the zero frequency line on the paper.

d. Set the pen in place and note the number of cycles on the chart before the pen reaches zero. This value we will call f_1.

e. Lift the pen.

f. Adjust the ΔF dial to obtain a deflection on the meter due to the residual carrier. Note the reading of the ΔF dial, ΔF_1, for which the maximum deflection from the residual carrier is obtained.

g. Set the ΔF dial to $\Delta F_1 - f_1$.

h. Now use the motor to drive the analyzer slowly through the zero frequency mark on the chart paper. The residual carrier will be recorded at zero frequency.

Some displacement of the true zero will occur, because of the finite time necessary for the analyzer and the pen to respond to the signal. A further correction can be made for this effect by setting the ΔF dial slightly higher than the setting given by $\Delta F_1 - f_1$.

3.8.4 RESIDUAL CARRIER.

The residual carrier recorded at zero frequency is a useful marker for the 0 point on the chart. Sometimes it may be desirable to unbalance the carrier slightly to obtain this marker. On the other hand, it may sometimes be desirable to avoid recording this carrier, to prevent misinterpretation of the recorded signal. In this latter case, balance the carrier very carefully just before recording. However, if the 40- or 80-db potentiometer is used, a complete balance will not be possible and some fluctuations of the pen will occur as the best balance is approached. These fluctuations are the result of residual noise (refer to paragraph

3.1.3). If a sufficiently good balance is not readily obtained, start the recording or set the pen on the paper only when the FREQUENCY dial is far enough beyond 00000 so that no deflection due to the residual carrier is observed.

3.8.5 ADJUSTMENT OF RECORDER INPUT CONTROL.

Apply a signal to the Type 1900-A Wave Analyzer and adjust the controls to obtain a full-scale indication on the meter. The internal calibrating signal (at the power frequency) can be used (refer to paragraph 3.1.4).

NOTE

The ΔF dial can be used to tune in the calibrating signal so that the main FREQUENCY control need not be disturbed. However, be sure to return the ΔF dial to its original position before a recording is made.

For the 20- and 40-db potentiometers, set the INPUT ATTENUATION control and the CALibration adjustment of the Type 1521 Graphic Level Recorder to give maximum deflection of the recording pen (refer to Table 3-1); i.e. the pen should be at the top of the chart paper.

If the 80-db potentiometer is used and if the entire 80-db dynamic range of the analyzer is needed, set the controls of the Type 1521 so that the pen position is up to 10 db below the top of the chart paper for full-scale deflection of the meter. The analyzer can handle a sine-wave output signal about 10 db beyond full scale; thus overloading will not occur within the recorded range, provided the FULL SCALE attenuator larger dial is set correctly.

If all the components of the analyzer signal are significantly less in magnitude than the total signal, rotate the FULL SCALE attenuator knob counterclockwise to increase the recorded level of the components. This increases the background noise level, but even with the knob two positions counterclockwise from the fully clockwise position, the internal noise level will usually be below the 0-db level of the 80-db potentiometer. Further shifting of the knob will increase the noise and reduce the dynamic range.

TABLE 3-1

Type 1521 Input Attenuation settings for maximum pen deflection.

Potentiometer Type	Range	Type 1521 Input Attenuation Decibels Settings
1521-P3	80 db	0 or 10
1521-P2	40 db	30
1521-P1	20 db	50
1521-P4*	dc	0

*Shunt the recorder input with 3500 to 4000 ohms for full-scale adjustment, and feed it from the 1 mA DC RECORDER OUTPUT jack (refer to paragraph 3.8.10).

3.8.6 PERIODIC COMPONENTS.

Set the WRITING SPEED to 20 INCHES PER SECOND on the recorder and choose the widest possible BANDWIDTH on the analyzer (refer to paragraph 3.2.2, i). Select a chart speed according to Table 3-2.

The values in the table are to be used with a 40-db potentiometer. With an 80-db potentiometer divide the given chart speeds by 2.

TABLE 3-2

Chart speeds to be used with a 40-db potentiometer for the measurement of periodic components.

Bandwidth	Chart Speed
50	⩽25 IN/MIN
50	⩽ 1.5 IN/MIN*
10	⩽2.5 IN/MIN
3	⩽0.5 IN/MIN

*For Type 1521-9465 Chart Paper.

This table illustrates the great advantage in chart speed obtainable by use of the wide band.

3.8.7 NOISE.

Set the WRITING SPEED and CHART SPEED according to Table 3-3.

TABLE 3-3

Chart and writing speeds for the measurement of noise.

Bandwidth	Chart Speed	Writing Speed
50	⩽1.5 IN/MIN	1 IN/SEC
50	⩽5 IN/MIN	3 IN/SEC
50	⩽0.5 IN/MIN*	⩽3 IN/SEC
10	⩽0.5 IN/MIN	⩽3 IN/SEC

*For Type 1521-9465 Chart Paper.

NOTE

The 3 CPS BANDWIDTH is not recommended for recording noise measurements, because of the wide fluctuations encountered in the recording.

3.8.8 PERIODIC COMPONENTS AND NOISE.

If both periodic components and noise are included in the signal, set the WRITING SPEED and CHART SPEED according to Table 3-3.

If only periodic components are of interest, but appreciable noise is present, try the 10 CPS BANDWIDTH, 3 IN/SEC WRITING SPEED, and ⩽0.5 IN/MIN CHART SPEED.

3.8.9 SETTING THE ANALYZER CONTROLS.

The control settings to be used in any analysis are best determined by making a preliminary recording with the controls set as outlined in paragraphs 3.2 and 3.3. This preliminary recording is then used as the basis for a final setting of the controls. One can quickly discover if any components go beyond the maximum of the recorder, or if some components of interest are too low. Thus the recorded analysis can be used to set the controls for paragraphs 3.2.2, f, and 3.3.2, d.

Ordinarily, the settings of the FULL SCALE attenuator larger dial and knob should not be changed during a recording. The level recorder provides the changes in sensitivity that are necessary to plot the full range of the potentiometer.

It is often necessary to tune in certain components to determine the proper settings of the input attenuator controls. Use the motor drive to sweep quickly to the desired point, and then tune in the component accurately by means of the ΔF control. Return the ΔF dial to 0 or to the value selected in paragraph 3.8.3 before a recording is made.

3.8.10 DC RECORDING.

If a linear plot is desired, rather than a logarithmic plot, the 1 mA DC RECORDER OUTPUT can be recorded on a 1 ma dc recorder that has an input resistance of 1500 ohms or less. A servo-type dc recorder with a sensitivity of 1.5 volts or better can also be used if its input is shunted by the proper value of resistance to give a net of 1500 ohms or less.

NOTE

The external circuit (connected by a phone plug) is in series with the meter circuit when it is plugged into the 1 mA DC jack; therefore the dc resistance of the external circuit should be 1500 ohms or less, to avoid upsetting the operation of the analyzer.

If the dc recording feature of the Type 1521-A Recorder is used, shunt the INPUT with a resistor whose value gives a full deflection of the recorder pen when the meter of the analyzer indicates full scale. The required shunt resistance is about 3500 ohms.

The direct current provided by the 1 mA DC OUTPUT is essentially linearly proportional to the input voltage. It is linear to ±0.2% of full scale over the wide range from full scale to 1% of full scale. To improve the linearity at the low end, offset the zero of the recorder in a positive sense by about .002 times full scale.

Simple, direct-writing, 1-ma, moving-coil recorders usually operate slowly enough to seriously limit the speed with which an analysis can be made. This limitation should be taken into account with a recorder of this type and a slow-speed drive should be used. Check the operation by recording a signal first with the analyzer tuned to the signal, then with the analyzer sweeping through the tuned position. A comparison of the two recorded amplitudes will indicate whether or not the sweep rate is slow enough to give the desired accuracy.

SECTION 4

PRINCIPLES OF OPERATION

4.1 GENERAL.

The general principles of operation are discussed in paragraph 1.2. In this section the various component parts of the analyzer will be described (see the block diagram, Figure 1-2). The principles involved will be discussed to the extent that they may help the operator to use the instrument more effectively and to maintain proper operation.

4.2 INPUT ATTENUATOR.

The compensated, resistive, 1-megohm attenuator at the INPUT (controlled by the FULL SCALE attenuator larger dial) covers an 80-db range. It is used to set the signal level at the input to the first amplifier stage as high as possible to maintain a good signal-to-noise ratio, but not high enough for the amplifier to distort the signal significantly.

4.3 INPUT AMPLIFIER AND FILTER.

The input cathode follower provides the high impedance required at the input and the low output impedance for a filter. The filter attenuates any component whose frequency is 100 kc or higher. This reduces any possible errors that might occur due to input components that are outside the normal range of the instrument. This precaution is necessary because the subsequent system (mixer, 100-kc filter, and amplifier) is sensitive to any 100-kc signal and to the image at 200 kc plus the frequency selected by the FREQUENCY controls, as well as to the fundamental to which the FREQUENCY control is tuned, which is the only response desired.

4.4 PHASE SPLITTER.

The phase splitter transforms the single-ended circuit to provide the balanced signal required for the balanced modulator. A potentiometer in the circuit permits adjustment of the relative outputs from each side of the circuit, to minimize even-order-harmonic distortion.

4.5 BALANCED MODULATOR.

The balanced modulator consists of a balanced cascode mixer with a twin triode driving a pair of grounded-base transistors. The signal from the local oscillator is applied to the two cathodes in parallel, and the balanced input signal from the phase splitter is applied to the grids in push-pull. The transistors have a low input impedance; thus the signal level at the plates of the twin triodes is very low. The output transformer, which is tuned to 100 kc, transforms the output signal from push-pull to single-ended, to feed the 100-kc crystal filter.

4.6 100-154 KC OSCILLATOR.

The main oscillator supplies the local-oscillator signal for the balanced cascode mixer. It is a series-tuned Vackar oscillator. This circuit produces exceptionally stable performance when it is used with stable low-loss capacitors and inductors. Compensating capacitors are used to reduce the frequency drift during warmup.

The plates of the main tuning capacitor are shaped to produce an essentially linear frequency variation as the capacitor is rotated. A rotor plate with movable sectors is adjusted at the factory to correct for residual deviations from linearity.

A separate tuning capacitor, connected to the oscillator circuit through a set of carefully selected divider capacitors, provides a frequency control (ΔF) that changes the oscillator frequency by a number of cycles per second that is reasonably independent of the setting of the main tuning capacitor.

A level-controlled circuit is included to control the voltage to the balanced-modulator cathodes and to make the amplitude of this voltage reasonably independent of the setting of the main tuning capacitor.

The voltage from a separate pickup coil, wound on the same bobbin as that used for the mixer coil, is amplified and compared with the voltage from a reference diode. The difference voltage controls a series regulating transistor in the plate supply.

Only a small fraction of the oscillator voltage (carrier) that is applied to the balanced modulator appears in the output of the latter because the oscillator voltage is applied to the two halves of the twin triode in parallel, and the output is in push-pull. If the two halves of the twin triode circuit were identical, no oscillator voltage would be produced. In practice, some balance adjustment is necessary, and this adjustment is provided in the oscillator compartment. A coarse balance is obtained by adjustment of the cathode-bias resistor; a finer balance is provided at the panel by adjustment of the amplitude of two carrier components approximately 90 degrees out of phase with each other. These are fed into the output circuit of the modulator.

Variable-capacitance diodes control the frequency of the oscillator in the AFC mode, over a limited range. These diodes are switched out and are replaced by a fixed capacitor when the MODE switch is turned to NORMAL or to TRACKING GENERATOR.

4.7 THE 100-KC CRYSTAL FILTER.

This filter is composed of two similar units. Each consists of a pair of quartz crystals, coupled together and followed by an isolating amplifier. The bandwidth of each pair is controlled by the capacitances that shunt the points at which the crystals of each pair connect. The values of these capacitances are changed as the BANDWIDTH setting is changed.

The terminating, tuning, and damping elements in the filter are also switched by the BANDWIDTH control. These elements are adjusted to center the pass band at 100 kc and to make the over-all response slightly rounded at the top. The pass bands are adjusted to make the response band of the first pair slightly narrower than that of the second pair. Thus, the over-all response provides effective bandwidths of 3, 10, and 50 cps. The 3-db bandwidth is then about 5% less than the effective bandwidth.

4.8 INTERMEDIATE-FREQUENCY AMPLIFIER, ATTENUATOR, AND 100-KC OUTPUT.

The filtered signal is amplified or attenuated to the desired output level by a cascade of stabilized amplifier stages and attenuators. The latter are controlled by the FULL SCALE attenuator knob and ordinarily are set to give a usable meter deflection for the selected frequency component.

One transistor stage (Q655), at the end of this cascade, provides an output of the filtered 100-kc signal. This stage is coupled through an autotransformer for operation with a Type 1521 Graphic Level Recorder. The tuning of the stage is adjusted to include the capacitances of the recorder input and the Type 1560-P95 Connecting Cable.

Either of two equivalent panel controls, selected by the READING knob, can be used to adjust the gain of one section of the cascade. One of these controls (CAL, R654, behind a snap button) is screwdriver operated and can be adjusted to set the calibrated gain, with little danger of its being inadvertently disturbed. The other control (GAIN, R653, a knob on the panel) can be readily adjusted at any time.

The range of the external gain controls can be set by means of an internal gain adjustment (R665) in the output amplifier. Once set, this adjustment should not require resetting; therefore it is not accessible from the panel.

Another internal control (R674) sets the 100-kc output obtained when the meter indicates full scale and ordinarily requires no readjustment.

4.9 METER RECTIFIER AND DC OUTPUT.

The output from one of the 100-kc amplifier stages drives a full-wave rectifier from a source impedance that is high at 100 kc. The rectified output flows through the 1-ma dc panel meter and through a series resistor of 1500 ohms that is grounded at one end. The 1 mA DC OUTPUT jack is connected across this resistor so that, when an external device is plugged in, the latter replaces the resistor in the circuit.

The meter response in the SLOW and MEDium positions of the METER SPEED switch is controlled by capacitors connected across the series combination of meter and 1500-ohm resistor. In the FAST position, the response speed is essentially that of the meter, fed through a moderate source impedance.

A reference diode, in parallel with the series combination of meter and 1500-ohm resistor, limits the maximum current to about 2.5 ma. The rectifier circuit itself is linear to beyond 5 ma, so that noise peaks are correctly rectified. The meter capacitors smooth out these peaks and reduce them for the reference diode.

4.10 AUTOMATIC FREQUENCY CONTROL.

When the MODE switch is in the AFC (automatic-frequency-control) position, the frequency of the 100- to 154-kc oscillator is controlled, over a limited range, by the filtered 100-kc signal. At the meter amplifier stage, this signal drives a cascade of two clipping amplifiers that, in turn, drive a frequency discriminator. This discriminator includes a quartz crystal; it is set to give, over a limited range, dc output proportional to the deviation of the frequency from 100 kc. The dc output is applied to the variable-capacitance diodes in the 100- to 154-kc oscillator circuit to control the oscillator frequency. The filtered signal then remains at 100 kc.

The rate at which the afc action occurs and the extent of the control are different for each of the three bandwidths, to maintain a stable control system. Because the center frequency of the control circuit does drift somewhat, readjustment of the tuning of the 100- to 154-kc oscillator is sometimes necessary for optimum afc operation. This drift may be great enough for the afc to control at a frequency sufficiently far from the center frequency of the 3-cycle bandwidth so that the control is not usable. Because of this drift, the instrument is not rated for afc operation with the 3-cycle bandwidth.

Internal tuning adjustments are provided to set the frequency of the afc discriminator.

4.11 FILTERED INPUT COMPONENT.

When the MODE switch is in the NORMAL or AFC position, another balanced modulator mixes the filtered and amplified 100-kc signal with a signal from the 100- to 154-kc oscillator. The lower frequency component of the modulation is selected by a low-pass filter and is amplified by a stabilized transistor amplifier. The output is available at the panel jack labeled FILTERED INPUT COMPONENT OUTPUT. The LEVEL knob on the panel operates a potentiometer between the low-pass filter and the amplifier and controls the output. The modulation process restores the filtered-signal component to its original frequency.

4.12 TRACKING GENERATOR.

When the MODE switch is in the TRACKING GENERATOR position, the second balanced modulator is used to mix a signal from the 100- to 154-kc oscillator with a 100-kc signal from a crystal-controlled oscillator. The crystal used for the discriminator in the AFC mode is used to control this 100-kc oscillator. As long as the frequency of this oscillator is at the center frequency of the crystal filter, the beat-frequency component resulting from the modulation will be at the frequency to which the input system is tuned. The same low-pass filter, potentiometer, and amplifier used in the NORMAL mode are used here to amplify and control this beat-frequency output.

The frequency of the crystal-controlled oscillator is adjustable over a small range by means of a variable capacitor in series with the crystal. This capacitor is accessible from the front panel, through the hole covered by the snap button just above the MODE switch.

4.13 CALIBRATING SIGNAL.

Voltage from one secondary of the power transformer is applied, through a resistor, to a series pair of oppositely connected reference diodes. These diodes are so chosen that the resulting clipped voltage is reasonably independent of the ambient temperature. A fraction of this voltage appears across a 100-ohm output resistor, part of a resistive divider that includes a potentiometer for adjustment. The fundamental component of this output wave (nearly a square wave) varies slightly with the input voltage. To balance out this variation over a wide range of input voltages, a small current is fed to the output resistor from the oppositely phased winding of the same secondary.

The voltage from the output resistor is fed to the most clockwise step of the FULL SCALE attenuator switch (controlled by the larger dial). When the larger dial is set fully clockwise, the calibrating signal is applied directly to the input vacuum tube and the normal input circuit is disconnected. The attenuator sensitivity is the same as when the dial is set one position from fully clockwise.

The potentiometer in the resistive divider is adjusted at the factory so that when the gain of the instrument is set to give a meter indication of 3 millivolts for the fundamental component of the CAL signal, the analyzer is then standardized to read directly in volts.

4.14 POWER SUPPLY.

In addition to the calibrating signal, five regulated dc voltages are obtained from the power supply. The 190- and 85-volt supplies, for the plates of the vacuum tubes, are regulated by a simple shunt regulator that includes a voltage-regulator tube and a reference diode. A selected fraction of the voltage developed by the diode is used as a reference for the other regulated supplies, which are the series regulator type. The transistor supplies are set to approximately 35 volts. The heater supply is set to 12 volts, with a somewhat lower actual voltage at the heaters. This lower-than-normal, regulated, heater voltage ensures a long, stable life for the vacuum tubes.

SECTION 5

APPLICATIONS

5.1 GENERAL.

Some relatively simple applications of the Type 1900-A Wave Analyzer require only a superficial knowledge of the analysis procedure to give satisfactory results. However, the analysis of some signals is so greatly affected by the operator's technique that a detailed knowledge of the inherent limitations of analysis is quite necessary. In this section we will discuss a wide variety of applications and the problems involved, so that the analyzer may be used more effectively.

5.2 PERIODIC SIGNALS.

5.2.1 HARMONIC DISTORTION.

The classic applications of the wave analyzer are concerned with periodic signals such as the harmonic distortion of a sinusoidal wave, a modulated signal, etc.

The analyzer can be used to measure, selectively, the components of a wave, as shown in Figure 5-1. If these components consist of the fundamental and its harmonics, a comparison of the amplitudes of the harmonic components with the fundamental amplitude is a measure of the harmonic distortion. Paragraph 3.2.3 explains how these components can be measured as a direct percentage of the fundamental.

Two basic factors limit the minimum distortion that can be measured on the analyzer: the inherent distortion present in the analyzer, and the selectivity characteristic. The former depends upon the applied signal. If the incoming signal is below the selected value indicated by the INPUT SHOULD NOT EXCEED arrow, the inherent distortion is at least 75 db below the amplitude of the input signal (less than .018%). For most practical purposes, this inherent distortion can be neglected.

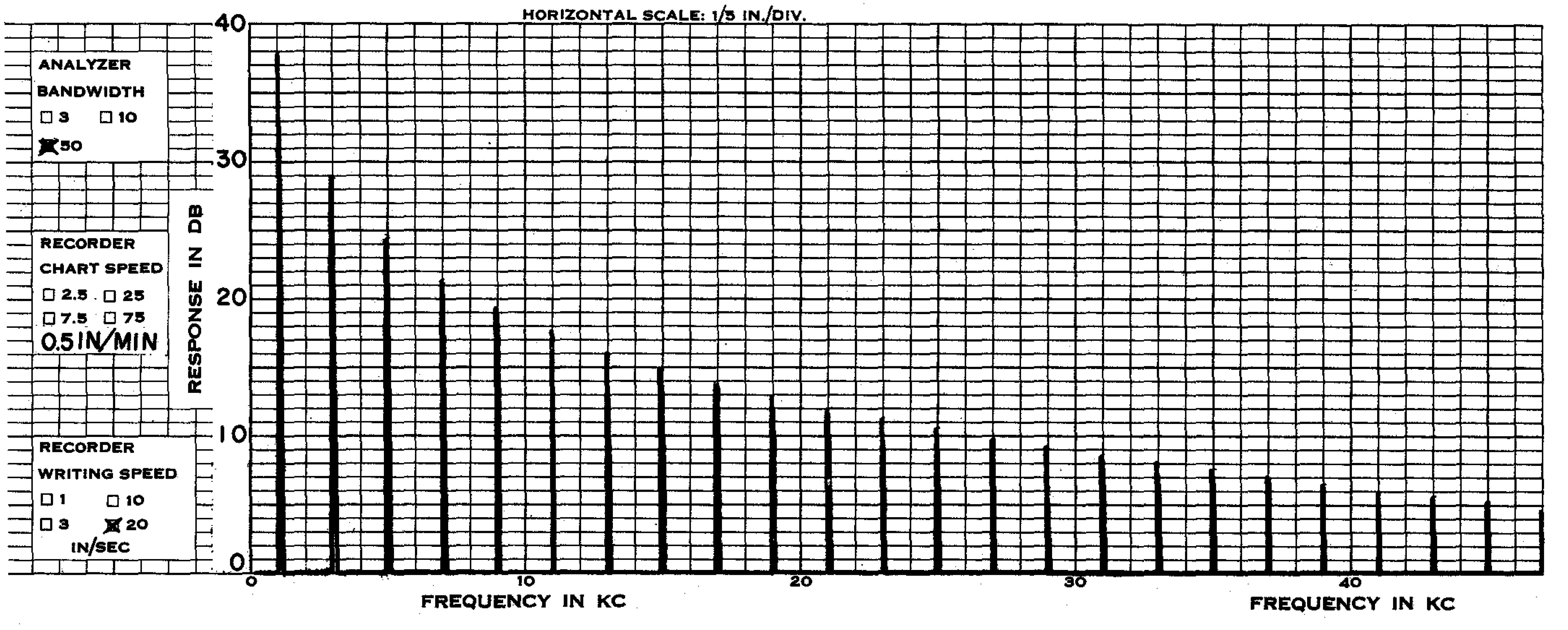


Figure 5-1. The harmonic components of a 1-kc square wave. The absence of even harmonics shows that the wave is symmetrical.

This distortion in the analyzer consists mainly of second and third harmonics. The percentage distortion will decrease as the input signal is reduced. Thus, for those unusual applications where distortion components of the order of .02% or less must be measured, the input attenuator can be set to a value somewhat higher than is normally required, and the inherent distortion will be reduced. This procedure is effective only to the point where the inherent noise or ultimate filter attenuation (about 90 db, or .003%) limits the result.

5.2.2 INTERMODULATION DISTORTION.

The measurement of intermodulation distortion on a wave analyzer is similar to the measurement of harmonic distortion, in that individual components are measured in each case. But the frequencies of the intermodulation-distortion components are the sums and differences of integral multiples of the frequencies of the main components. The required selectivity is generally determined by the minimum distortion to be measured and by the lowest frequency of the main components or by the difference in frequency between the main components.

But other components may also affect the choice of bandwidth. For any given measurement, it is relatively easy to list the possible component frequencies and thus to decide on the critical frequency separation. As a general rule, the 10-cycle bandwidth is adequately selective for audio-frequency intermodulation-distortion measurements.

If low-frequency intermodulation components are to be measured, the effect of the wave-analyzer oscillator signal may have to be considered when the bandwidth is selected. The oscillator signal, observed as a maximum on the meter at 00000 FREQUENCY setting, is attenuated as the FREQUENCY control is turned from 00000. The amount of this attenuation depends on the bandwidth and on the change in tuning from 00000. If measurements are to be made of a component at 30 cps, for example, adequate attenuation of the wave-analyzer oscillator signal can usually be obtained with the 10-cycle bandwidth. But for still lower frequencies it may be necessary to use the 3-cycle bandwidth.

5.2.3 PULSES.

The analysis of periodic pulses is often very simple, but some knowledge of what to expect should be helpful.

The basic repetition rate sets the frequency spacing of the components. Thus a pulse that repeats 20 times per second will have components a minimum of 20 cps apart, as shown in Figure 5-2. If a pattern of pulses is produced, the minimum spacing is determined by the rate at which the entire pattern is reproduced.

If the frequency spacing of the components is large compared with the selected analyzer bandwidth, the response of the analyzer will increase as its tuning approaches the frequency of a component. The response reaches a maximum at the frequency of the component and decreases to a very low value as the tuning proceeds away from that frequency. In effect, the response characteristic of the filter is traced, as shown in Figure 5-3.

If the frequency spacing of the components is comparable to that of the bandwidth, the change in response will be much less, as the tuning is varied. Some energy from each component is passed by the analyzer and the response is higher than with only one component present. This effect is particularly noticeable halfway between two nearly equal components, as shown in Figure 5-2. This again illustrates the need for adequate selectivity, obtained by choice of the correct bandwidth for a given analysis, as described in paragraphs 3.2 and 5.2.2.

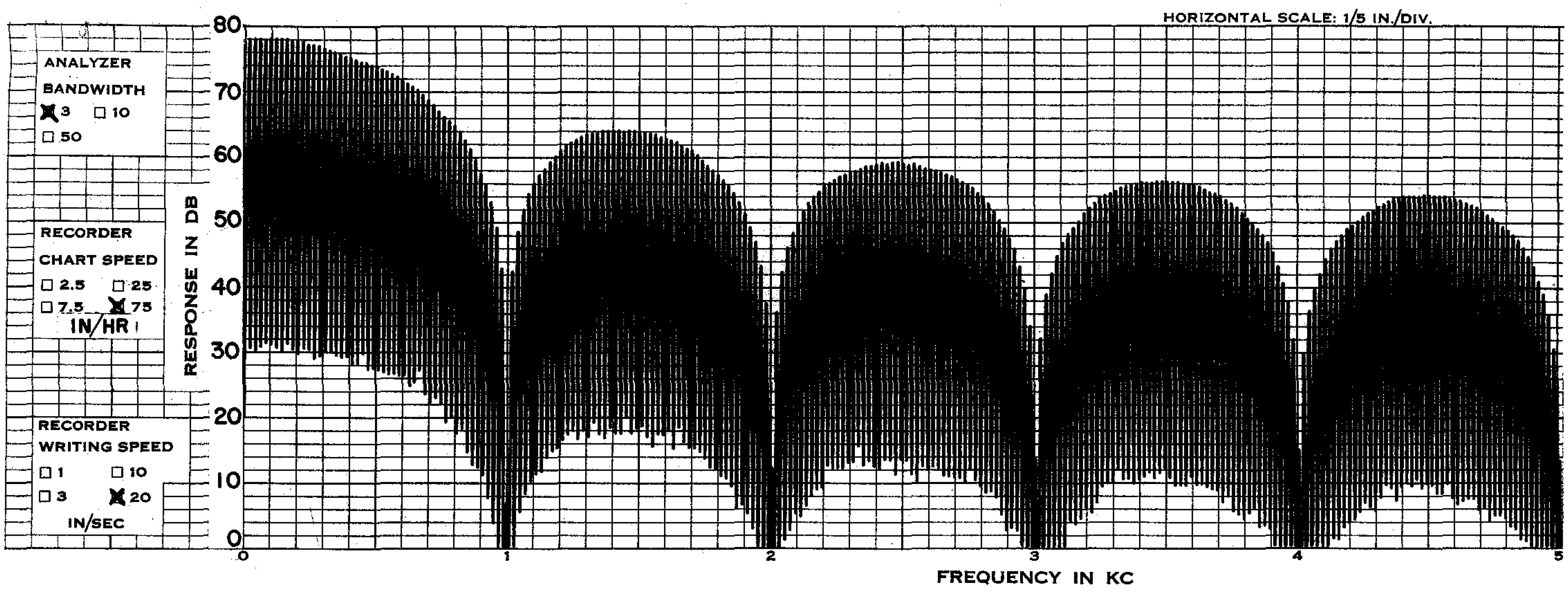


Figure 5-2. Analysis of a 1-msec pulse with a 20-cps repetition rate.

Selectivity requirements for the analysis of pulses usually are not as severe as for distortion measurements. Adjacent components of a pulse often have nearly the same amplitude, so that a filter attenuation of 20 db or more at the component-frequency spacing from the center frequency is adequate. However, this may not be sufficient for pulse-modulation signals.

Marked fluctuations in the response of the analyzer, as a component is tuned in, usually are the result of jitter of the pulse (refer to paragraph 5.2.6).

5.2.4 MODULATED SIGNALS.

Some modulated signals are within the frequency range of the analyzer, for example, telemetering subcarriers and the stereo multiplex system that has sidebands extending to 54 kc. When such systems are modulated by a sine wave, the components of the resultant modulated signal can be selectively measured by the wave analyzer. The choice of bandwidth depends on the frequencies involved, particularly the modulating frequency. In general, the 10-cycle bandwidth should be used for this application.

When the sideband components in the immediate vicinity of a carrier are to be measured, it is often convenient to set the main FREQUENCY control to the carrier. Then the ΔF dial is used to locate the sideband components on either side of the carrier.

If the modulating signal is not periodic, the analysis problem is similiar to that of noise analysis (refer to paragraph 5.4).

5.2.5 EFFECT OF SWEEP RATE.

The rate at which the FREQUENCY control is turned has an important effect on the output. There are two aspects of this effect: the response of the analyzing filter itself and the response of the indicating device.

As previously noted, if the FREQUENCY control is turned or driven very slowly through the region of maximum response to an isolated component, the output of the analyzer varies in accordance with the filter response characteristic. The response when the control is left at the setting for maximum meter indication (the "static response") and the corresponding FREQUENCY dial reading are taken as the amplitude and frequency, respectively, of the measured component. If the FREQUENCY control is turned rapidly, the maximum response differs somewhat from the static response, and the frequency at which the maximum occurs is shifted a small amount in the direction of the dial rotation. If the rate of tuning is rapid enough, secondary peaks in the response may also appear beyond the main maximum response.

These effects are most noticeable on the 3-cycle bandwidth, since the behavior is a function of the square of the bandwidth. Thus, as far as the response of the filter is concerned, tuning can be accomplished on the 50-cycle bandwidth about 250 times as fast as on the 3-cycle bandwidth.

This behaviour can readily be observed by trial with a sine-wave input signal. Practice with such a signal will show how rapidly the tuning can be accomplished without causing a serious error.

When a signal is tuned in manually, the FREQUENCY control is turned back and forth until the maximum response is found. For the 3-cycle bandwidth, the maximum response observed when the control is turned very slowly is higher than the static response by a few percent. This transient effect is critically dependent on the response characteristic of the filter. If the response is symmetrical, the transient behavior will give mirror images for the two directions of tuning, and in each case the peak will occur just beyond the center of the response. The correct setting for the FREQUENCY con-

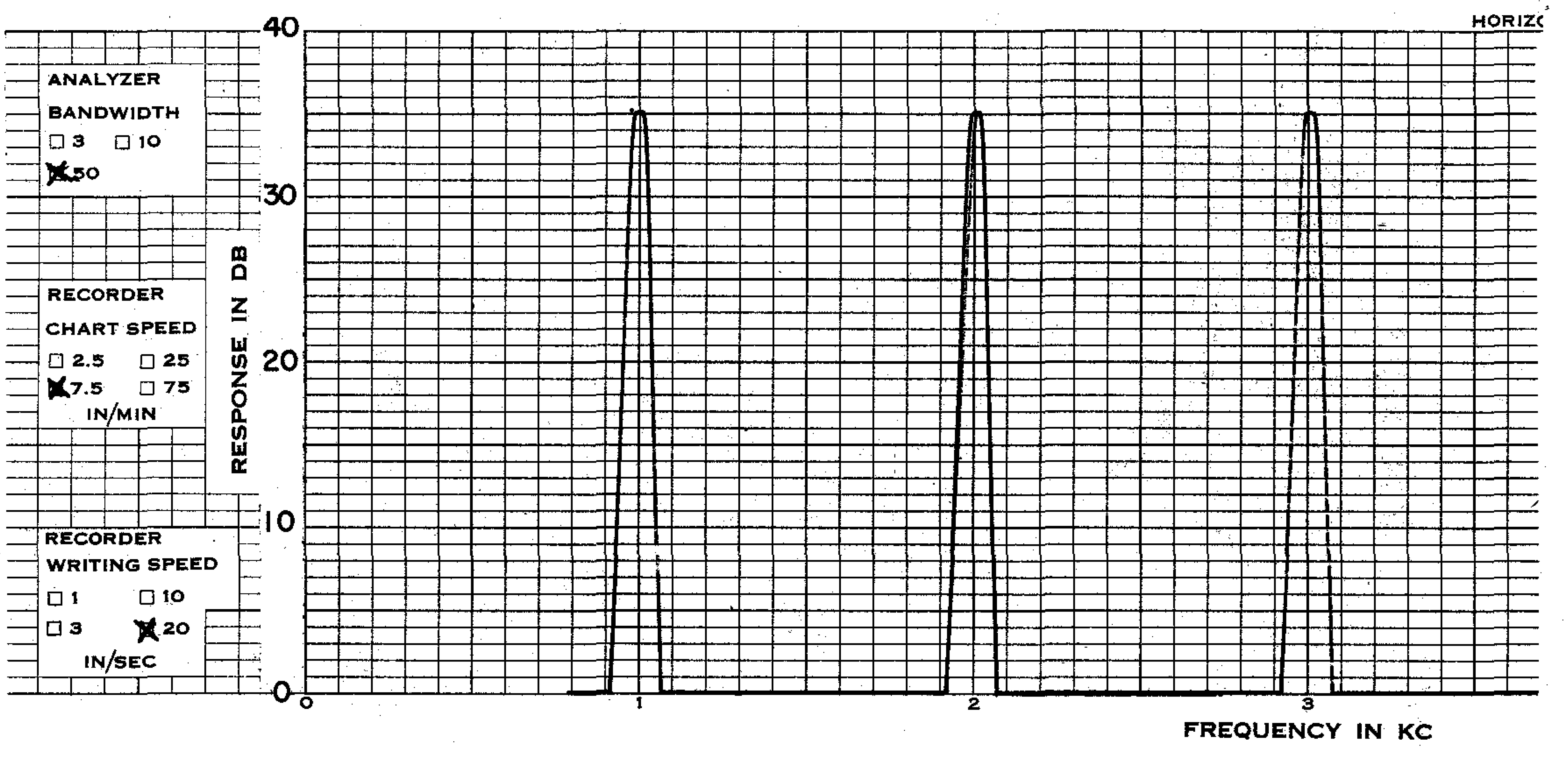


Figure 5-3. The first three components of a 20-μsec pulse repeated every millisecond. The response of the 50-cycle band is traced out in the process of recording the individual components.

trol is between the two response peaks. Since even a slight dissymetry in the static-pass-band response will produce a noticeable difference in the dynamic response in the two directions of tuning, the ideal mirror-image behavior will not ordinarily be observed. Some slight difference between the maximum responses in the two directions will be noted, but this difference usually is not more than a fraction of a decibel. The slower the tuning, the smaller both the transient effect and the difference between the maximum responses in the two directions will be.

The effect of the characteristics of the output indicator or the recording device on the transient response when the FREQUENCY tuning is swept through the frequency of a component can be highly significant, as shown in Figure 5-4. Ordinarily a fast indicator response is desirable (except for noise measurements, as noted in paragraph 5.4) so that the indicator will show the maximum response of the analyzer output when its frequency is tuned to that of the component. Therefore, when the recorder is used, the METER SPEED should be set at FAST. With a recorder, use the fastest possible recorder speed.

Most dc recorders are slow in response, which seriously limits the speed with which a recording can be made. The Type 1521 Graphic Level Recorder has a relatively fast response and therefore permits a more rapid analysis and recording when the wider bands are used.

5.2.6 JITTER, WOW, AND FLUTTER.

The indicated amplitude of a component of a constant-amplitude, constant-frequency, periodic signal is steady. Many electrical signals are of this type; that is, they are sufficiently constant in amplitude and frequency so that the component amplitudes produce a steady meter deflection. However, many others, such as random noise (refer to paragraph 5.4), do not behave in this way. Another of this latter type is a signal intended to be uniformly periodic, but which has enough variation in frequency, called jitter, wow, or flutter, to permit the sharp selectivity of the analyzer to reproduce these frequency fluctuations. If possible, use the 50-cycle bandwidth for these signals; for most practical problems this will be adequate. However, it is sometimes desirable, for purposes of demonstration, to measure or record high-order harmonics of pulses with a low-frequency repetition rate, for example, the harmonics in the vicinity of 50 kc for pulses occurring at a 20-cycle rate. Usually the 3-cycle bandwidth is selected to separate these harmonics. But ordinary pulse generators do not have an oscillator that is stable enough to permit such a measurement. It is often necessary to use a crystal-controlled source; the output of the pulse generator can be locked to the output of a time-mark generator, to give the required stability.

As a component is tuned in, the effect of jitter is different at different points of the filter characteristic. Jitter is most noticeable when the analyzer is tuned to give a response for a component that is a few decibels less than the maximum response; at this point the response is most sensitive to slight changes in frequency. The jitter is less noticeable at the frequency setting that gives maximum response.

Because of this fluctuation due to jitter on the input signal when the analyzer is tuned slightly off the peak of the response characteristic, special adjustments may be necessary for a recorded analysis when jitter is present. For instance, the pen drive should be critically damped, or even slightly overdamped, to avoid excessive excursions of the pen as a jittery component is tuned in. Also, the analysis must be made more slowly than with stable components, to permit a more precise recording of the component amplitudes. With a slower sweep-frequency rate, a slower pen speed can be used, and the resulting recording will show less of the effects of jitter.

Figure 5-4. A recording of the first few components of a 50-μsec pulse at a 500-cps repetition rate. The 3-cycle bandwidth of the analyzer and the fastest recorder writing speed were used. The first four components were recorded at 1¼ kc per minute. Then the analysis was repeated, to the fifth component at a rate of 3¾ kc per minute, again to the sixth at 12.5 kc per minute, and again to the seventh at 37.5 kc per minute. The chart shows the displacement in apparent center frequency, the reduction in amplitude, and some secondary responses that occur when the tuning is swept too rapidly.

Some frequency fluctuations are periodic. They may be intentionally so, or, as in the case of wow or flutter from a tape recorder, they may be unavoidably introduced by mechanical eccentricities in the tape-drive mechanism. In the latter case, the frequencies of the resulting fluctuations correspond to the speeds of the eccentric mechanisms or some combination of such speeds. When a taped signal is analyzed, components can be found spaced the flutter rate away from the main components, if the flutter is great enough.

Some of the jitter or flutter is random; this is a frequency-modulation noise. One must decide whether or not it is to be treated as a frequency "broadening" of the signal and, in a sense, is to be ignored whenever possible. Or, if the jitter must be determined, it can usually be translated by means of a linear discriminator (such as the Type 1142-A Frequency Meter and Discriminator) into a signal that varies in amplitude. The output of the discriminator is then analyzed and the components of the jitter are determined.

5.3 TUNABLE FILTER.

5.3.1 GENERAL.

When the MODE switch is in the NORMAL or AFC position, the analyzer functions as a tunable, highly selective filter and amplifier. The input of the filter is available at the INPUT terminals and the output is available at the phone jack labeled FILTERED INPUT COMPONENT. The gain of the filter is determined by the settings of the FULL SCALE attenuator dial and knob, and the GAIN and LEVEL controls.

The applications for this mode of operation are generally those for a highly selective filter, for example, isolation of an individual component of a signal for an accurate determination of its frequency, or for the production of an accurate band of noise.

When this output is used, it should be carefully shielded from the input to the analyzer, to avoid undesirable feedback.

5.3.2 TRANSIENT RESPONSE.

As a filter, the analyzer has the inherent advantages, as well as the limitations, of a minimum-phase network with its response characteristic. Thus the transient response is such that the build-up time in seconds is approximately the reciprocal of the bandwidth in cps. The rounded shape of the filter pass band results in an overshoot of about one-half decibel when a tone is suddenly applied, and a similar amount of ringing when the tone is turned off.

When the filter output is monitored by a meter or recorder with a time constant that is not short compared with that of the filter, the response time of the system is then longer than that of the filter alone. The overshoot and ringing also may be altered radically by the output indicator.

5.4 RANDOM NOISE.

5.4.1 GENERAL.

The meter indication produced by an applied random-noise signal (such as that generated by thermal agitation in a resistance, by random fluctuations in thermionic emission, and by gaseous discharges) is not a steady indication. Actually, all signals contain some random-noise energy and in some it is sufficient to produce significant fluctuations of the meter reading. The fluctuations in level are not a result of erratic behavior of the analyzer, but rather they reflect irregularities in the process of noise production. The measurement of such noise can be treated on a statistical basis.

In the measurement of a random noise, the average power level is of first importance. Because the signal voltage, rather than the power, is measured, and because an analysis of finite bandwidth is used, the equivalent voltage for a one-cycle band is often calculated. This is called the root-mean-square voltage spectral density, or, simply, the spectral density. In practice the wave analyzer measures the absolute value of the instantaneous voltage, averaged by an RC smoothing circuit. This value is then divided by the square root of the bandwidth in cps and is corrected for the ratio of rms to average for a Gaussian distribution. These concepts will be discussed in greater detail.

5.4.2 AVERAGING PROCEDURE AND CONFIDENCE LIMITS.

Figure 5-5 shows the behavior of the pointer of the indicating instrument as a function of time during measurement of a random noise. These charts were made with the 50-cycle bandwidth, for FAST, MEDium, and SLOW meter speeds, and with samples of the same noise measured in each case. It can be seen that the average value is essentially the same for all samples, but the fluctuations are markedly greater for the faster meter speeds. The charts also show that little significance can be attached to a maximum or minimum reading for a noise signal. For a given bandwidth and voltage level, the maximum or minimum depends upon the meter speed used and the length of time the meter is observed. However, the fluctuations have some significance in the statistical estimate of the confidence given to the selected average value.

As seen from the charts, it is much easier to estimate the average value when the SLOW meter speed is used. But because of the rise time of the metering circuit, 25 to 30 seconds must elapse before an average reading is selected. For the MEDium meter speed, a preliminary estimate can be obtained in two or three seconds, but a better average can be selected if the meter is observed for a somewhat longer period. With the FAST meter speed, it is difficult to make a good estimate of the average value, due to the large fluctuations produced.

If the narrower bandwidths are used, even greater fluctuations make it more difficult to obtain an average value. For this reason, use only the SLOW meter speed for noise measurements with the 3-cycle bandwidth. The principle involved is relatively simple: The narrow band gives fineness of detail; the finer the desired detail, the more time is needed to obtain the result to a certain degree of confidence. This principle can be expressed in quantitive terms by the use of statistical theory[1].

If a particular meter reading is selected as the noise voltage, the selected value may not be the best estimate of the average value. The degree of confidence in any such value can be expressed in statistical terms. Thus, if a reading is selected for a random noise when the 50-cycle bandwidth and the SLOW meter speed are used, the chances are only 1 in 10 that the long-time average differs from the selected value by more than 4%; the chances are 1 in 100 that the difference is more than 6%. These values are called the 90% and 99% confidence limits, respectively. The limits are not strictly symmetrical. For example, for the FAST meter speed, the chances are only 1 in 100 (99% confidence limits) that the ratio of the long-time average value to the selected value will be beyond the 0.75 to 1.47 range. Table 5-1 gives a list of these confidence limits.

These ranges of uncertainty can be reduced by the use of the average of a number of independent readings. The reduction in the range is approximately inversely proportional to the square root of the number of independent observations. Thus the average of four observations reduces the uncertainty to about one-half the values in the table.

The range of uncertainty is frequently called the statistical error.

If the fluctuations in readings are observed for a time and an estimate of the average value is made, the extent of the reduction of the uncertainty is limited by the fact that all the observations are not independent, and one can remember and use only a small portion of the total observed behavior. The observations are not independent, because of the finite time required for the pointer to assume a new value. An interval of two or three time constants should be allowed between observations. The approximate time constants for the different meter speeds are:

0.15 second for FAST,
0.5 second for MEDium,
5 seconds for SLOW.

TABLE 5-1.

Confidence limits of 99% on voltage (one chance in 100 that the ratio of the long-time average value to a selected meter reading will be beyond the range shown in the table).

BANDWIDTH CPS \ METER SPEED	FAST	MED	SLOW
50	0.75 to 1.47 (-2.5 to +3.3 db)	0.85 to 1.22 (-1.4 to +1.7 db)	0.94 to 1.06 (-0.5 to +0.5 db)
10	0.57 to 3.0 (-5.1 to +9.5 db)	0.71 to 1.64 (-3 to +4.3 db)	0.89 to 1.13 (-1 to +1.1 db)
3	0.43 to 14 (-7.3 to +23 db)	0.57 to 3.0 (-5.1 to +9.5 db)	0.82 to 1.27 (-1.7 to +2.1 db)

If a recorder is used on the 100 KC OUTPUT to record the output of the filtered noise, the response time (or writing speed) of the recorder, not the meter speed of the analyzer, is the significant factor that sets the averaging time by which the extent of the fluctuations is determined.

With a dc recorder, its response time is affected by the setting of the METER SPEED switch, because the dc recorder is connected in series with the indicating device of the analyzer.

5.4.3 SPECTRAL DENSITY.

To compare measurements of random noise made with two different bandwidths, the measured value is converted to an equivalent value for a 1-cycle bandwidth. The equivalent voltage varies as the square root of the

[1] R.B.Blackman and J.W.Tukey, "The Measurement of Power Spectra", Dover, New york, 1958.
T.P.Rona, "Instrumentation For Random Vibration Analysis", pp 7-27 to 7-30, RANDOM VIBRATION, edited by S.H.Crandall, Technology Press, Cambridge, Massachusetts, 1958.

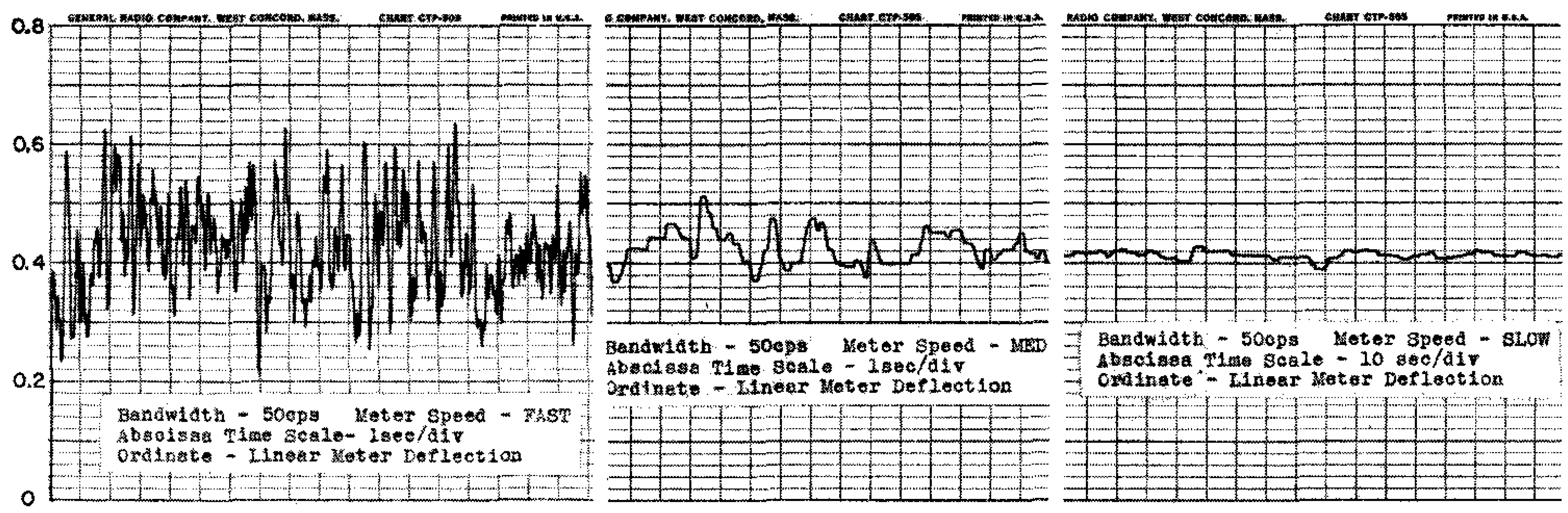


Figure 5-5. Charts of the analyzer meter current (dc output) as a function of time, for random noise, with a 50-cycle bandwidth, and with FAST, MEDium, and SLOW METER SPEED switch settings. The fluctuations are the greatest for the fast speed, moderate for the medium speed, and smallest for the slow speed. With the 50-cycle bandwidth, it is possible to select a reasonably good average value, even for the fast meter speed.

bandwidth; thus the conversion is a simple factor for each bandwidth. It is also customary to specify the voltage as an rms value. Therefore an additional correction factor of 1.1284 is used to convert the rectified average value, calibrated with a sine wave, to the rms value of a Gaussian noise. Thus the over-all correction ratios to convert to a 1-cycle bandwidth are:

0.159 (-15.9 db) for the 50-cycle bandwidth,
0.357 (-9 db) for the 10-cycle bandwidth,
0.65 (-3.7 db) for the 3-cycle bandwidth.

This conversion to a 1-cycle bandwidth is significant only if the noise spectrum is continuous and is essentially uniform within the measured band and if the noise does not contain prominent pure-tone components. For this reason, the results of this conversion must be interpreted with great care to avoid false conclusions. In particular, when a noise is measured at a center frequency that is not much greater than the bandwidth, the conditions for a significant conversion to a 1-cycle equivalent spectrum density probably will not be met.

5.4.4 EFFECT OF SWEEP RATE.

Considerable time is required to obtain a reliable measurement of a noise signal at a given frequency, and a correspondingly greater time is required to measure noise at a number of frequencies. The time is proportional to the number of measurements. If a spectrum is recorded as a continuous plot, the time is proportional to the number of bandwidths included in the range being covered. Since the time required for one measurement with a given degree of confidence is inversely proportional to the bandwidth, the total time required to cover the frequency range is inversely proportional to the square of the bandwidth. Therefore, always use the widest possible bandwidth for this analysis.

Some examples of the effects of different sweep rates are shown in Figures 5-6, 5-7, 5-8, and 5-9.

5.4.5 DURATION OF A SAMPLE.

The uncertainty resulting from the limited observation time compared with the detail desired in the frequency analysis occurs for other time limitations as well. Moreover, some of these limitations may not come under the operator's control. For example, a noise source may not be uniform over an extended period of time. The noise may be a transient effect, such as the acoustic noise produced at the launching of a rocket. Such transient noises are usually recorded on a magnetic tape recorder and are played back in short samples, for analysis. These samples are cut from the recording and are formed into loops, to run continuously in the recorder. This procedure directly limits the possible fineness of detail in the analysis and also limits the accuracy with which the actual level in any one frequency band can be determined. This latter limitation results from the fact that the maximum time during which independent information can be obtained is the sample duration.

The confidence limits for the SLOW meter speed in Table 5-1 can be used as a guide to the reliability of the results if the sample duration is of the order of 5 seconds. Similarly, for a 0.5-second sample, the figures for MEDium meter speed in the table can be used as a guide. As the sample time becomes even shorter, the spectrum obviously becomes a discrete one, with a component spacing at the repetition rate of the sample if a 3-cycle bandwidth is used. Thus the continuous nature of the spectrum is lost.

If the noise is sufficiently uniform with time, a longer sample offers increased accuracy; or measurements on a number of samples can be averaged. Because of the inherent variability of random noise, analyses of distinct samples of the same noise do not yield identical results. The range of values predicted by statistical theory can be used as a guide in judging whether the results of such analyses agree well enough to be useful. Unless this inherent variability is appreciated, useful data or a useful analysis system may be rejected, or too much reliance may be placed on a particular measurement.

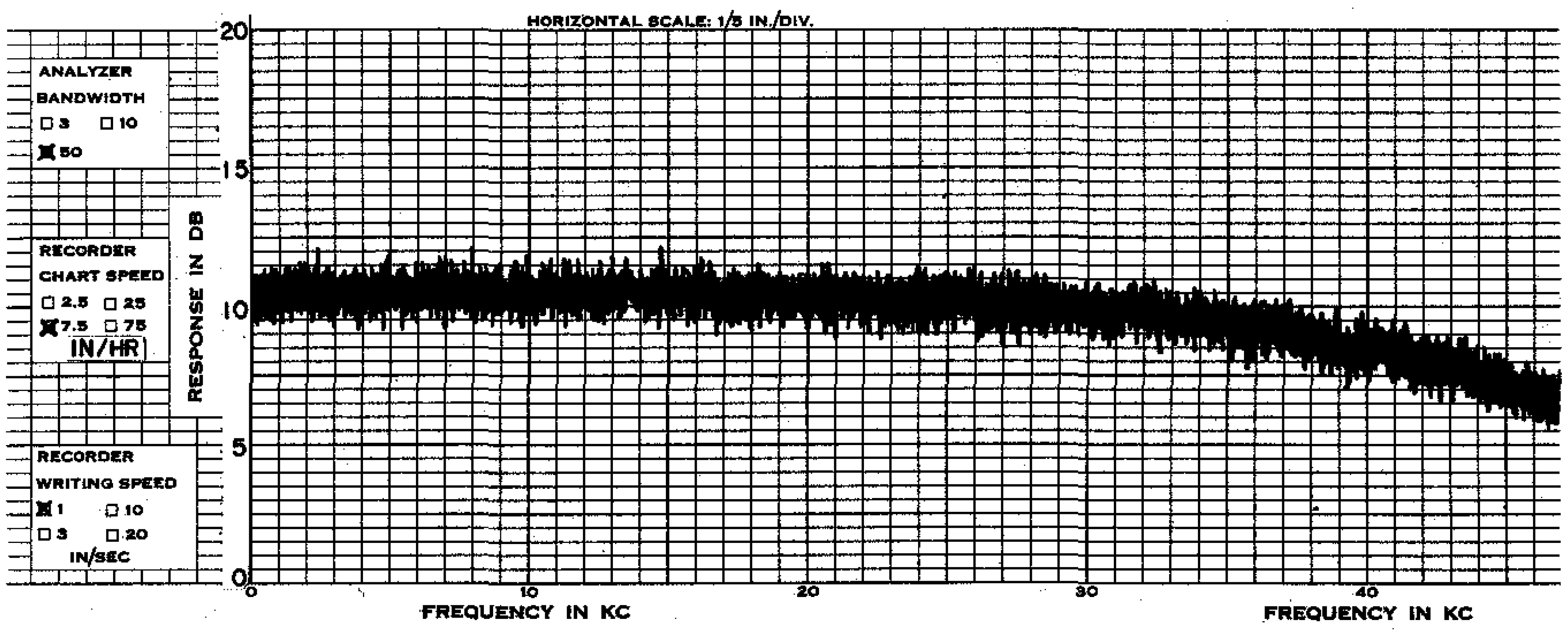


Figure 5-6. Chart of 0- to 20-kc output of the Type 1390 Random-Noise Generator, as recorded with a 50-cycle bandwidth. The wide bandwidth, the slow chart speed, and the slow writing speed combine to give a small fluctuation in level, and they make possible an accurate estimate of the uniformity of the spectrum. Since each division on the ordinate is 0.5 db, the spectrum to 20 kc is shown to be uniform to 0.25 db, or better.

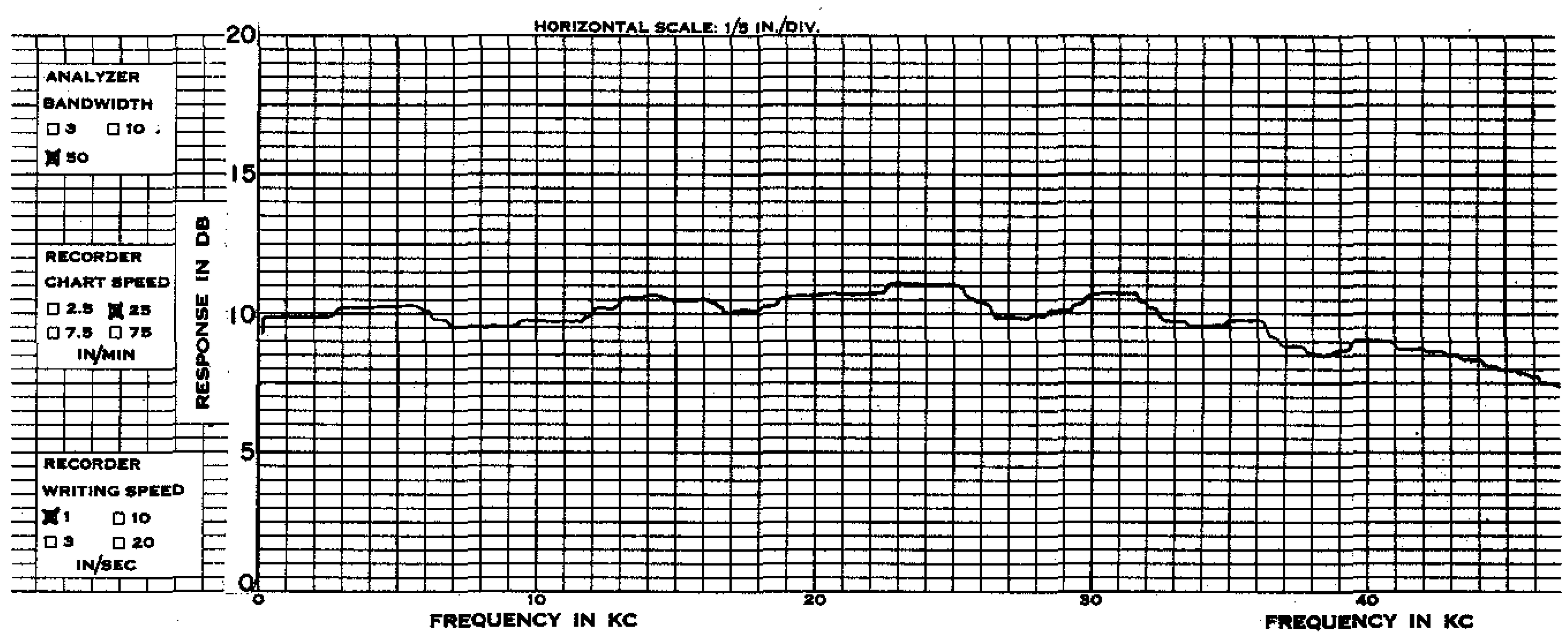


Figure 5-7. If the chart speed is increased much more (to reduce the required analysis time), the resulting record becomes more difficult to interpret. In this recording, the fluctuations have now been spread out so much that one might be led to the incorrect conclusion that, in the spectrum to 20 kc, there are variations of a decibel or more in amplitude.

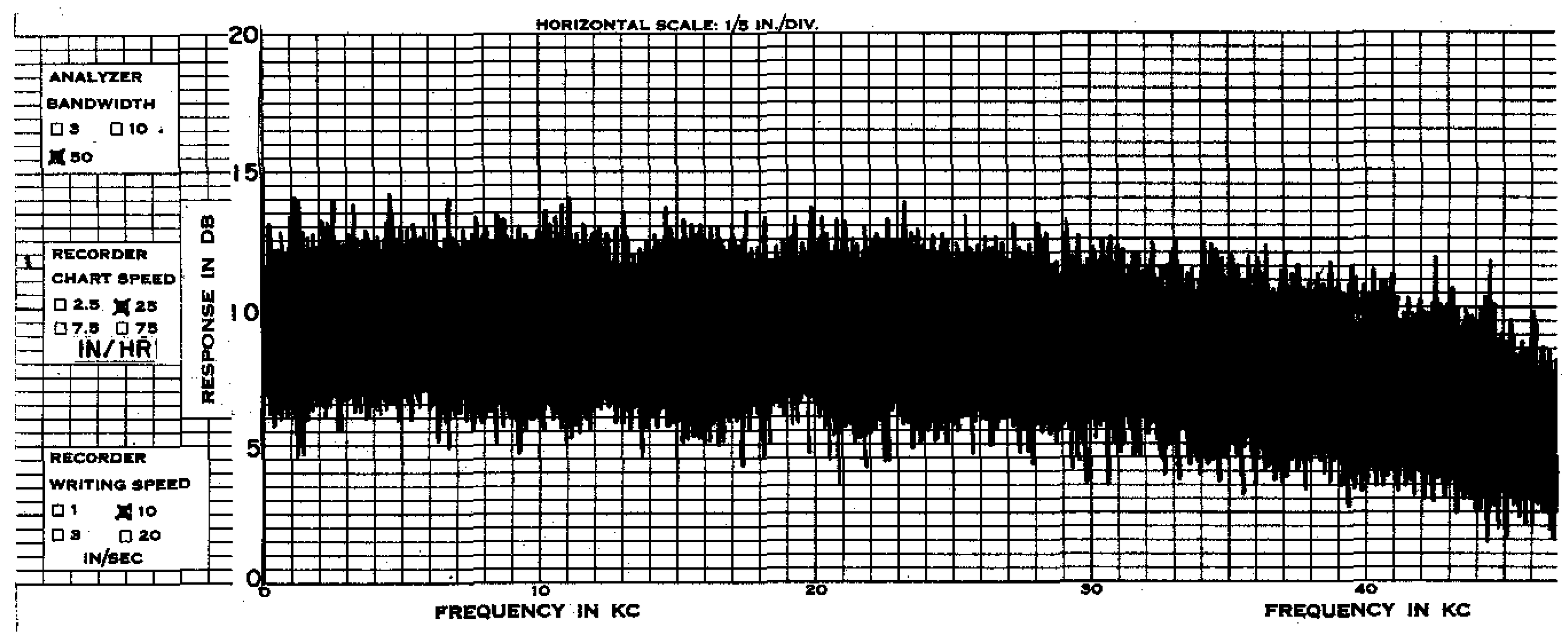


Figure 5-8. If the writing speed is increased, the fluctuations increase. In this recording, the uniformity of the spectrum is still apparent, because of the slow chart speed. Thus, in effect, many samples of the noise are recorded for each bandwidth. When the fluctuations are as large as shown here, however, the correct long-time average is not simply midway along the dense part of the chart. It is actually somewhat higher, because the fluctuations from the average in the negative direction are inherently greater than those in the positive sense.

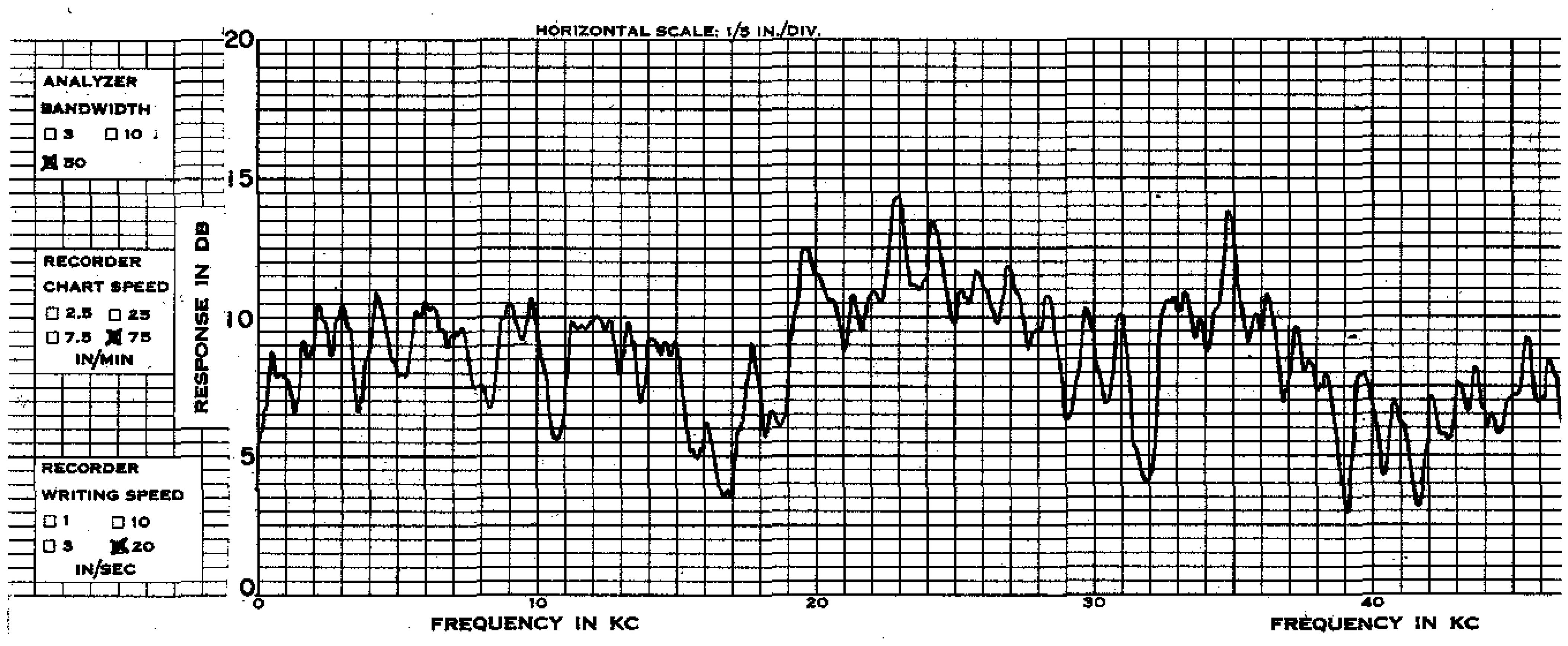


Figure 5-9. Here the chart speed is such that the 50-kc range is covered in 8 seconds. If it is not realized that such time is insufficient for obtaining a spectrum analysis in which some confidence can be placed, one assumes, from this chart, that large variations in spectrum level were present. This speed of analysis is comparable to that of many display-type spectrum analyzers. It indicates how misleading the analysis of noise on such a device can be.

5.4.6 DISTINGUISHING NOISE FROM PERIODIC COMPONENTS.

Occasionally, the spectrum of a signal may show what appears to be a discrete component, but it is actually a random signal that is very narrow in bandwidth because of resonance in the system from which the signal is obtained. To distinguish between the random signal and one that is truly periodic, note the effect of changing the bandwidth. The indicated amplitude of a true sinewave signal is unaffected by a change in the bandwidth. The random-noise signal, however, will be affected if the band of noise is wider than the widest bandwidth used. If the noise is narrower than the narrowest band used, there will be no apparent difference with the various bandwidths. In this case, the statistical behavior of the indicated amplitude will reveal whether or not the signal is random. The fluctuations of the meter are large for noise as narrow as 3 cps, even with the SLOW meter speed. Thus it should be obvious whether the signal is a steady component or a noise component.

The possibility of the component being relatively discrete, but with some jitter or fluctuation in frequency, should also be considered. Usually this type of component can be distinguished by the change in behavior as it is tuned in (refer to paragraph 5.2.6).

5.4.7 NARROW-BAND NOISE SOURCE.

If a broad-band noise generator, such as the Type 1390 Random-Noise Generator, is connected to the INPUT terminals, a narrow band of noise is obtained at the OUTPUT jack labeled FILTERED INPUT COMPONENT. (Set the MODE switch to NORMAL, the LEVEL control fully clockwise, and the other controls as though the applied noise was to be analyzed.) The center frequency of this noise is tunable by means of the FREQUENCY control. This type of signal is useful for some measurements. For example, it can be converted into an audible noise by a loudspeaker; it can also be used for some psychoacoustic tests and for reverberation and acoustic-transmission measurements.

5.5 ACOUSTIC NOISE AND VIBRATION.

The Type 1900-A Wave Analyzer is well suited to the analysis of many types of acoustic noise and vibration, particularly those produced by rotating or reciprocating machinery, such as gear trains, electric motors, and turbines. Acoustic noise and vibration measurements are discussed in detail in the "Handbook of Noise Measurement," available from General Radio.

5.6 FREQUENCY MEASUREMENT OF A COMPONENT.

The analyzer can be used to select a signal component whose frequency is to be measured more accurately than the accuracy of the FREQUENCY dial will allow. The output at the jack labeled FILTERED INPUT COMPONENT is used to drive a Type 1142 Frequency Meter and Discriminator or a counter (such as the Type 1150 Digital Frequency Meter or the Type 1151 Digital Time and Frequency Meter). Be sure the impedance across the output is approximately 600 ohms; the output filter then operates effectively to reduce stray signals that might interfere with the frequency measurement. At frequencies below 1 kc, adjust the output LEVEL control on the analyzer or the amplitude control on the counter so as to reduce the residual stray signals. Set the amplitude just high enough to obtain reliable operation of the counter.

5.7 BRIDGE SOURCE AND DETECTOR.

In the TRACKING GENERATOR mode, the analyzer provides the generator and detector for ac impedance bridge measurements. The excellent selectivity of the analyzer helps to avoid trouble from interfering signals. The 2-volt output from the TRACKING GENERATOR and the high sensitivity of the analyzer are adequate for most bridge measurements.

However, in this case one limitation is due to a small amount of energy from the tracking generator that is transferred in the instrument to the analyzing section. Although this transfer is less than one part in 100,000, this internal crosstalk can produce an error when an attempt is made to use the instrument alone, with a bridge that will balance to better than .01%. The use of external amplifiers helps to avoid this limitation in this rather unusual case.

For bridge measurements, set the FULL SCALE larger dial to INPUT VOLTS SHOULD NOT EXCEED 100 MILLIVOLTS, the setting for maximum sensitivity of the input attenuator. As the bridge approaches a balance, turn the FULL SCALE attenuator knob counterclockwise to further increase the sensitivity. If the meter indication is beyond full scale with the knob fully clockwise, rotate the attenuator larger dial counterclockwise as far as necessary for an on-scale reading. As the bridge is balanced, rotate the dial clockwise until the 100 MILLIVOLT position is reached. Then use the knob to increase the sensitivity further.

5.8 RESPONSE MEASUREMENTS OF TAPE RECORDERS.

Some tape recorders are designed to permit simultaneous record and playback functions. The response of such a recorder can be measured automatically with the Type 1900-A Wave Analyzer and Type 1521 Graphic Level Recorder. Use the analyzer in the TRACKING GENERATOR mode (refer to paragraph 3.6). Couple the graphic level recorder to the analyzer both mechanically and electrically, and record the 100 KC OUTPUT. The GENERATOR OUTPUT supplies the signal to the tape recorder, and the output from the tape recorder is applied to the INPUT of the analyzer. Vary the frequency slowly, and plot the response on the graphic level recorder. A decided advantage of this process is obtained from the fact that the analyzer eliminates much of the background noise and most of the spurious signals generated in the tape recorder.

One complication involved in this measurement is the delay between record and playback. In a typical recorder, the two heads are 1.5 inches apart. At 15 inches per second, the corresponding delay is 0.1 second. Thus, if the analyzer frequency is swept at a rate of 12 kc per minute or 200 cps per second, the recorded signal frequency will be 20 cps higher than the reproduced signal frequency. If the 50-cycle bandwidth is used, the analyzer will respond reasonably well to the signal that is displaced 20 cps.

To take advantage of the 10-cycle-bandwidth selectivity, a slower sweep rate should be used. Thus, at 1.2 kc per minute, the displacement is only 2 cps, and the 10-cycle bandwidth is usable. As a further refinement, the frequency of the crystal oscillator used for the TRACKING GENERATOR mode can be altered to compensate for this frequency displacement (refer to paragraph 4.12). However, the range of adjustment is limited to about 4 cps; thus the compensation is not adequate for high sweep rates.

Because some residual signal is transferred internally from output to input, use the following procedure when in the TRACKING GENERATOR mode:

Always set the FULL SCALE larger dial as far clockwise as the level of the input signal will allow. Always use an input signal large enough so that, with the FULL SCALE attenuator knob four steps from the clockwise end, the meter indicates beyond full scale.

SECTION 6

SERVICE AND MAINTENANCE

6.1 GENERAL.

We warrant that each new instrument sold by us is free from defects in material and workmanship, and that, properly used, it will perform in full accordance with applicable specifications for a period of two years after original shipment. Any instrument or component that is found within the two-year period not to meet these standards after examination by our factory, district office, or authorized repair agency personnel, will be repaired, or, at our option, replaced without charge, except for tubes, or batteries that have given normal service.

The two-year warranty stated above attests the quality of materials and workmanship in our products. When difficulties do occur, our service engineers will assist in any way possible. If the difficulty cannot be eliminated by use of the following service instructions, please write or phone our Service Department (see rear cover), giving full information of the trouble and of steps taken to remedy it. Be sure to mention the type and serial numbers of the instrument.

Before returning an instrument to General Radio for service, please write to our Service Department or nearest district office, requesting a Returned Material Tag. Use of this tag will ensure proper handling and identification. For instruments not covered by the warranty, a purchase order should be forwarded to avoid unnecessary delay.

6.2 PRELIMINARY CHECKS.

6.2.1 GENERAL.

The following preliminary checks are included to familiarize the user with the wave analyzer and to assure him of the normal operation of its various sections. The instrument need not be dismantled for these preliminary checks.

6.2.2 LOCAL OSCILLATOR.

Turn on the POWER switch and allow the instrument to warm up for several minutes. Set the panel controls as follows:

ΔF dial to 0
BANDWIDTH switch to 10 CPS
METER SPEED switch to FAST
READING switch to ABSOLUTE
MODE switch to NORMAL
FULL SCALE attenuator
  Larger dial — fully CCW
  Knob — fully CW

Turn the main FREQUENCY dial through zero frequency (00000) and note any indication on the meter. If the indication is small, increase the sensitivity by rotating the FULL SCALE attenuator knob one or two steps counterclockwise, to give a greater meter reading (refer to paragraph 3.1.2). A meter indication near 00000 on the dial signifies that the local oscillator is operating properly.

6.2.3 FREQUENCY DIAL CALIBRATION.

With the FREQUENCY dial set to 00000, push in the F ZERO knob (to engage its tuning capacitor), and rotate it until a maximum indication is obtained on the meter. Disengage the F ZERO knob. The FREQUENCY dial is now correctly calibrated.

6.2.4 ΔF DIAL CALIBRATION.

For an approximate calibration check of the ΔF dial, set the panel controls as follows:

FREQUENCY dial to 00000
ΔF dial to 0
BANDWIDTH switch to 3 CPS
METER SPEED switch to FAST
READING switch to ABSOLUTE
MODE switch to NORMAL
FULL SCALE attenuator
  Larger dial — fully CCW
  Knob — for convenient meter indication.

Engage the F ZERO knob and tune it for maximum meter indication. (The narrow bandwidth requires slow tuning.) Carefully disengage the F ZERO knob without disturbing the setting. Turn the FULL SCALE attenuator larger dial fully clockwise (CAL). Turn the attenuator knob to 3 MILLIVOLTS. Use the meter as an indicator, and tune the ΔF dial to the internal calibrating signal. This signal, at the power-line frequency, should be observed at -60 and +60 on the ΔF dial (or -50 and +50, if a 50-cycle power line is used). This is an approximate check on the calibration of the ΔF dial.

Reset the ΔF dial to 0.

6.2.5 CARRIER BALANCE.

Set the panel controls as in paragraph 6.2.2 and obtain a meter indication (produced by the carrier from the local oscillator) at 00000 on the FREQUENCY dial (refer to paragraph 3.1.3). Adjust the two CARRIER BALANCE controls for a minimum meter indication: push each knob in to engage its flexible coupling and rotate one and then the other. Turn the FULL SCALE attenuator knob two steps counterclockwise and reduce the meter indication to less than full scale (sufficient for most measurements) by means of the CARRIER BALANCE controls.

6.2.6 SENSITIVITY.

To check the sensitivity, proceed as follows:

Set the panel controls as in paragraph 6.2.4, but set the FREQUENCY dial at the power-line frequency (either 60 or 50 cps). Tune the ΔF dial for a maximum meter indication, which should be approximately 3 mv. A slight readjustment of R654, the screwdriver control behind the panel snap button labeled CAL, will correct a small error.

Change the BANDWIDTH switch from 3 CPS to 50 CPS, and then to 10 CPS. In each case the meter reading should be approximately 3 mv, and should differ very little from the reading at 3 CPS. Reset the level to 3 mv for any of the three bandwidths by means of R654 for the ABSOLUTE position of the READING switch and by means of the panel GAIN control for the RELATIVE position.

6.2.7 TRACKING GENERATOR MODE.

To determine that the TRACKING GENERATOR mode of operation is functioning properly, connect a pair of headphones (or a frequency counter or oscilloscope) to the GENERATOR OUTPUT jack. Set the MODE switch to TRACKING GENERATOR and the LEVEL control fully clockwise. With the phones, an audible signal, whose frequency corresponds to the setting of the main FREQUENCY dial, will be heard (the frequency must not be in the ultrasonic region). A frequency counter or oscilloscope will also indicate the presence of this signal.

6.2.8 NORMAL MODE.

With headphones or other indicating device connected as in paragraph 6.2.7, set the MODE switch to NORMAL. There should be a signal at the OUTPUT jack whenever a signal is present in the passband of the crystal filter. The CAL signal is convenient to use for this purpose. Set the FULL SCALE attenuator larger dial fully clockwise (with the CAL position opposite the CAL - 3 mV POWER FREQ line). Set the attenuator knob to 3 MILLIVOLTS. As the FREQUENCY dial is tuned through the power-line frequency (60 or 50 cps), the meter should indicate a signal, which should also be present at the OUTPUT jack.

The calibrating signal is approximately a square wave; therefore the odd-harmonic (3rd, 5th, 7th, etc.) components should also be present as the FREQUENCY dial is tuned through these frequencies.

6.2.9 AFC OPERATION.

Automatic frequency control (afc) is used to hold a slowly-drifting signal within the passbands of the crystal filter. The operation of this circuit can be checked as follows:

Set the BANDWIDTH switch to 10 CPS and the ΔF dial to 0. Apply an external audio signal (at approximately 1 kc) to the INPUT terminals and tune in this signal with the FREQUENCY controls. Adjust the FULL SCALE attenuator larger dial and knob to obtain an on-scale reading of the meter. Set the READING switch to RELATIVE and adjust the GAIN control for a full-scale indication on the meter. Use the ΔF dial to measure the effective bandwidth between the 3.5-db points (down 3.5 db from the maximum). This bandwidth should be approximately 10 cps. Set the ΔF dial to 0; then set the MODE switch to AFC. Turn the ΔF dial slowly, to keep the signal within the lock-in range, and note that the apparent bandwidth is now much greater than the 10 cps noted above. This apparent bandwidth at the 3-db points should now be about 150 cps.

Change the BANDWIDTH switch setting to 50 CPS. The observed bandwidth, at the 3-db points, should be approximately 400 cps.

6.2.10 RECORDER OUTPUT, 1 mA DC.

Two RECORDER OUTPUT jacks are available on the panel. One, labeled 1 mA DC, is for dc recording; the other provides a 100-kc output, to drive a graphic level recorder, such as the General Radio Type 1521.

To check the dc output, connect a 5-ma, dc meter, in series with a 1500-ohm resistor, to the 1 mA DC OUTPUT jack, through a telephone plug.

Set: BANDWIDTH switch to 10 CPS
METER SPEED switch to FAST
READING switch to ABSOLUTE
FULL SCALE attenuator
Larger dial to CAL (fully CW)
Knob to 3 MILLIVOLTS

Tune to the power-line frequency (60 or 50 cps). The analyzer meter should read approximately full scale; the external dc meter should read approximately 1 ma. Turn the attenuator knob two steps CCW, to increase the sensitivity. The external meter should now read approximately 2.5 ma, if the limiting diode in the meter circuit is functioning properly. Remove the meter and the 1500-ohm resistor.

6.2.11 RECORDER OUTPUT, 100 KC.

Reset the panel controls as in paragraph 6.2.10, but set the FULL SCALE attenuator larger dial to OUTPUT SHOULD NOT EXCEED 1 VOLT. Set the attenuator knob to 1 volt. Apply an external 1-kc signal to the input of the Type 1900-A, and, with the FREQUENCY dial, tune in the signal and adjust its level for a full-scale indication on the meter. Plug the Type 1560-P95 Connecting Cable, terminated in 10 kilohms, into the 100 KC RECORDER OUTPUT jack. Connect an oscilloscope across the termination and note that a signal (at 100 kc) is present.

6.2.12 INPUT ATTENUATOR.

Set: BANDWIDTH switch to 10 CPS
METER SPEED switch to FAST
READING switch to RELATIVE

Set the input attenuator larger dial one step from fully clockwise and the knob fully clockwise (100 MILLIVOLTS). Apply a convenient low-frequency signal (e.g. 100 cps) to the INPUT terminals and tune in this signal on the FREQUENCY dial. Adjust the level of the incoming signal to give any convenient, near-full-scale meter reading (e.g. +8 db) to use as a reference level, and note the reading. Then turn both the attenuator larger dial and the knob one step counterclockwise. The meter reading should now be within ±0.25 db of the original reading. Repeat this test for each step of the attenuator. (In the last position, with the knob and dial fully counterclockwise, some amplifier noise will be noted in addition to the signal.)

The above method of checking the input attenuator involves two separate circuits, with two separate attenuators. As attenuation is added in one circuit, an equal amount is subtracted in the other; thus the indicated level should remain the same. Separate tests for each of the attenuators are described in paragraph 6.8.2.

NOTE

This completes the preliminary checks on the various circuits in the analyzer. More detailed servicing procedures, requiring removal of the instrument from its cabinet, are described in the following paragraphs. To avoid unnecessary servicing, be sure that all cable connectors are securely in place before proceeding.

6.3 POWER SUPPLY.

Five different dc voltages and a square-wave calibrating signal are provided by the power supply.

Diode CR509 develops a regulated voltage for the variable oscillator and provides reference voltages for the 12-, 34-, and 35-volt supplies (for the tube heaters, the output amplifier, and the i-f amplifiers, respectively). Potentiometer R516 sets the level of the 12-volt supply and R513 sets that of the 35-volt supply. Regulation of the 190-volt supply is obtained by the combination of V501 in series with CR509.

The nominal values for these voltage supplies should be obtained with normal loads and with 105 to 125 (or 210 to 250) line volts. If any of these values are found to be incorrect, the following voltage checks will help to localize the trouble. Measure the voltages to ground, with a vacuum-tube voltmeter (such as the GR Type 1806) and with a power-line voltage of 115 (230) volts.

TABLE 6-1
Power-supply test voltages.

Test Point	DC Voltage
T P 501	210 v
T P 502	190 v
T P 503	85 v
T P 504	42 v
T P 505	16 v
T P 506	21 mv, peak-to-peak square wave, at line frequency, measured with a CRO.
T P 507	35 v, regulated dc voltage, adjusted to ±2%.
T P 508	12 v, regulated dc voltage, adjusted to ±2%.

To measure transistor voltages, first remove the top shelf of the power supply in the following manner:

Turn the POWER off. Remove the three screws on each edge of the power-supply shelf and swing the latter out carefully, to expose the wiring on the underside (see Figure 6-7). Turn the POWER on. Measure the transistor voltages to ground, using a vacuum-tube voltmeter. The measured values should approximate those given in Table 6-2. Use a power-line voltage of 115 (230) volts.

TABLE 6-2
Transistor voltages for the power supply.

Transistor	Collector (Volts)	Emitter (Volts)
Q501	+42	+35
Q502	+42	+36
Q503	+12	+16
Q504	+12	+15
Q505	+15	+12
Q507	+42	+34

6.4 VARIABLE OSCILLATOR.

6.4.1 GENERAL.

The normal tuning range of the local oscillator is 100 kc to 154 kc. This corresponds to 00000 to 54000 on the main FREQUENCY dial. The oscillator tube is V201, Type 12AY7. Oscillator amplitude control is accomplished by means of Q201 (an rf amplifier) and Q202 (a series regulator). The amplified oscillator signal is rectified by CR203, referred to reference diode CR204, and used as a bias voltage for Q202, which controls the plate voltage of the oscillator tube. Potentiometer R210 sets the oscillator level.

Incremental tuning of ±100 cps is possible by use of the ΔF dial (C203), the tuning range of which can be adjusted by C204.

When the analyzer is operated in the AFC mode, variable-capacitance diodes are used for frequency correction of the oscillator. The capacitance of these diodes is replaced by capacitors C225 and C228 when the instrument is operated in the NORMAL mode.

The low-frequency end of the variable oscillator is set by means of the adjustable, slotted core of L201, accessible through a hole in the cover of the oscillator compartment, at the right (see Figures 6-6 and 6-9).

The high-frequency end of the tuning range is calibrated by means of C202 and C226, a coarse and a fine adjustment, respectively. These trimmer capacitors are accessible from the right-hand end of the oscillator compartment.

6.4.2 VARIABLE OSCILLATOR CALIBRATION.

To calibrate the variable oscillator, remove the instrument from its cabinet and proceed as follows:

Turn the POWER on and connect a vacuum-tube voltmeter to TP201, at the lower left-hand end of the oscillator compartment. Adjust R210 (at the upper left-hand end of the oscillator section) to give 0.6 volt. Disconnect the voltmeter and connect a frequency counter to TP201. Set the ΔF dial to 0 and the F ZERO control (PUSH TO ENGAGE) to the middle of its range, as determined by frequency measurements. Use the main FREQUENCY dial to tune to an oscillator frequency of about 101,000 cps. The total span of the ΔF dial (C203) must be 200 ±2 cps. If the span is outside these limits, adjust C204 (at the left-hand end of the oscillator housing). Increasing the capacitance of C204 reduces the span, and vice versa. When the span is correct, reset the ΔF dial to 0.

Set the BANDWIDTH switch to 50 CPS and the MODE switch to AFC. Measure the oscillator frequency. Switch to the NORMAL mode and again measure the frequency. Adjust trimmer C225 (at the right-hand end of the oscillator section) so that the frequencies are identical. Then set the MODE switch to NORMAL.

Reset the FREQUENCY dial to 00000. Adjust the core of L201 to obtain a frequency of 100,000 cps. Turn the FREQUENCY dial to 50000, and, by means of C202 (coarse adjustment) and C226 (fine adjustment), set the oscillator frequency to 150,000 cps. Returne the FREQUENCY dial to 00000 and, if necessary, reset the frequency to 100,000 cps by means of the core adjustment of L201. Again measure the frequency at 50000 on the dial and repeat the procedure if necessary.

When both ends of the dial have been calibrated, measure the frequency at various points over the entire range of the dial. They must be within ±0.5% ±5 cps to 150,000 cps and within ±1% to 154,000 cps.

If any point on the dial is outside these limits, the main tuning capacitor should be recalibrated. This requires removal of the outer shield cover, for access to the interior of the oscillator compartment. Turn the POWER off. Disconnect the cable with the multipoint connector and the three shielded leads marked GY (gray), CL (clear), and BL (blue), at the rear left-hand side of the compartment. Remove the screws holding the cover and slide it off. Reconnect the cable and the three shielded leads and turn the POWER on.

The complete procedure for realignment of the main tuning capacitor is as follows:

Determine that the span of the ΔF dial is correct to ±1 cps. Be sure the oscillator frequency, at about 101,000 cps, is the same for both NORMAL and AFC positions of the MODE switch, with the BANDWIDTH switch set to 50 CPS. Use capacitor C225 to correct any difference in the NORMAL position.

Turn the analyzer upside down on the bench. Set the main FREQUENCY dial to 00000, the ΔF dial to 0, the MODE switch to NORMAL, and, by visual inspection, set the F ZERO capacitor to the middle of its range. Adjust the core of L201 so that the frequency of the oscillator is 100,000 cps. Do not remove the cylindrical shield from the coil for this adjustment.

Reset the FREQUENCY dial to 50000. Set C226 in the middle of its range and adjust C202 for an oscillator frequency of 150,000 cps. Make the final adjustment with C226, for better resolution. Repeat this procedure until an adjustment at one end of the frequency range has a minimum effect at the other end.

The linearity of the main tuning capacitor is adjusted by means of slotted rotor-plate segments, the positions of which are varied by individual adjusting screws.

The frequencies at dial settings of 54000, 53000, 52000, and 51000 must be within ±1%. The 50000 point should be exact (previously set with trimmers C202 and C226).

Start with the FREQUENCY dial at 50000 and decrease the reading until the next whole adjustable plate segment is in mesh with the stator. Use the adjusting screw for this segment, to set the frequency (as read on the counter connected at TP201) to 100,000 plus the dial reading in cps. Set the frequency within ±0.3% of the dial reading.

Reset the dial so that the next whole segment is in mesh with the stator and adjust this segment to give a frequency corresponding to the dial reading. Follow this procedure for each segment in turn. Points between 09000 and 00000 on the dial must be within ±0.3% ±5 cps. Recheck the end points (00000 and 50000) and the complete dial linearity. Readjust the segments, if necessary, to obtain minimum deviations within the above limits.

Replacement of the oscillator shield cover will have some effect on the calibration. To correct for this, set the main dial at 50000, the ΔF dial at 0, and the F ZERO capacitor at the center of its tuning range. Readjust C202 or C226 so that the oscillator frequency is 150,000 cps. Turn the main dial to 00000; if the oscillator frequency is not 100,000 cps, readjust the core of L201. Repeat this procedure until the adjustment at each end of the frequency range is correct. The intermediate points on the dial should then check within ±0.5% ±5 cps.

6.4.3 VOLTAGE TABLE.

TABLE 6-3
Variable-oscillator voltages, measured to ground with a vacuum-tube voltmeter.

Tube	Pin	DC Volts
V201	1	+58
	2	0
	3	0
	4	+12
	5	0
	6	+58
	7	0
	8	0
	9	+6

Transistor	Collector (DC Volts)	Emitter (DC Volts)
Q201	+ 7.5	+23
Q202	+57	+79

6.5 OUTPUT AMPLIFIER.

6.5.1 GENERAL.

The output amplifier is located in a shielded box at the upper right-hand side of the instrument (see Figure 6-5). It consists of two cascaded transistor amplifiers, each containing two transistors in a feedback circuit. The second amplifier drives a full-wave rectifier for the meter circuit. A separate transistor amplifier supplies a 100-kc signal for use with a graphic level recorder.

6.5.2 METER CIRCUIT.

The meter circuit is driven from a tunable transformer, T651. It is tuned to resonance in the following manner:

Tune in the internal CAL signal (or an external signal) and adjust the level for a convenient on-scale meter indication. Adjust the core of T651 for maximum meter indication.

6.5.3 RECORDER OUTPUT, 1 mA DC.

The meter circuit is driven by a full-wave rectifier, CR651 and CR652. The meter is in series with a 1500-ohm resistor, which is switched out automatically when a dc recorder is connected to the 1 mA DC RECORDER OUTPUT jack. This resistor simulates the input resistance of many dc recorders.

A limiting diode, CR653, is used to limit the current through the meter and the external dc circuit. This diode limits the maximum dc to about 2.5 ma, without affecting the dynamic ac range of the amplifier.

6.5.4 RECORDER OUTPUT, 100 KC.

Transistor Q655 feeds a resonant autotransformer, T652, that is tuned to 100 kc and is used to drive a graphic level recorder, such as the GR Type 1521. The capacitance of the connecting cable is part of the circuit and affects the tuning; therefore this transformer is peaked with a Type 1560-P95 Adaptor Cable Assembly plugged into OUTPUT jack J652 (100 KC RECORDER OUTPUT). Terminate the cable with 10 kilohms. Connect a sensitive vacuum-tube voltmeter across the 10-kilohm resistor and adjust T652 for maximum output.

With the transformer tuned to resonance, set R674 for an output of 5 volts when the meter reads full scale. Remove the input signal. The voltmeter must read more than 70 db below 5 volts.

6.5.5 METER SPEED CIRCUITS.

The METER SPEED switch (with three positions, marked SLOW, MED, and FAST) changes capacitors to vary the time constant of the meter. The circuit capacitance is 2000 μf in the SLOW position, 200 μf in the MEDium position, and 1 μf in the FAST position.

6.5.6 CIRCUIT GAIN ADJUSTMENTS.

The READING switch, S651, selects either of two circuits and the corresponding level control. One control, R654, sets the gain accurately in terms of an internal standardizing signal, for ABSOLUTE readings. This control is accessible through a hole in the panel, under the snap button marked CAL. The other control is adjusted by the panel knob marked GAIN, and is used when the READING switch is in the RELATIVE position. It permits measurement of relative values, such as harmonic distortion in percent.

Set the READING switch to RELATIVE and the GAIN control to minimum. Tune in the CAL signal and note the meter reading. Change the READING switch to ABSOLUTE, and by means of the CAL control, R654, obtain a meter reading approximately 5 db higher than that noted above. With the FULL SCALE attenuator knob set to 3 MILLIVOLTS, adjust R665 for a 3-mv reading on the meter.

Potentiometer R665 (see Figure 6-14) sets the over-all gain of the amplifier and may require a slight readjustment after the input mixer has been set for minimum distortion (refer to paragraph 6.10).

6.5.7 SERVICING THE ETCHED-CIRCUIT BOARD.

For convenience in trouble shooting, the output-amplifier shelf is hinged. Remove the two screws at the two front corners and swing the board up, for access to the etched circuits (see Figure 6-14).

Transistor voltages are given in Table 6-4.

TABLE 6-4
Output-amplifier voltages, measured to ground with a vacuum-tube voltmeter.

Transistor	Collector (DC Volts)	Emitter (DCVolts)
Q651	+17	+23
Q652	+11.5	+17
Q653	+11.5	+30
Q654	+34	+11
Q655	0	+27.5

6.6 CRYSTAL FILTER ALIGNMENT.

6.6.1 PRELIMINARY ADJUSTMENTS.

WARNING

Only qualified personnel, with the recommended test equipment, should attempt to align the crystal filter.

NOTE

The proper response characteristics for the three bands can be obtained over a range of settings of the individual crystal circuits. The settings outlined below have been found to be the most suitable for the following step-by-step procedures, but the factory-adjusted settings of the individual circuits in a particular instrument may deviate somewhat from those given.

Alignment of the crystal filter (Figure 6-18) requires a stable 100-kc signal source whose frequency can be varied somewhat about this nominal value. Some means of attenuating the signal to the necessary low levels must be provided. A General Radio Type 546-C Microvolter is recommended as an attenuator. A frequency counter with resolution of 0.1 cps is also required.

Remove the covers from the left side and top of the crystal filter shelf. Preset the controls as follows:
R403 and R406 — 90° from the clockwise stop;
R401 — 180° from the counterclockwise stop.

Center all other variable controls, including 18 potentiometers and 10 trimmer capacitors. Replace the shield cover on the left side. Use the top cover to partially shield the two compartments; allow room for test-lead connections.

Set the BANDWIDTH switch to 50 CPS, the attenuator larger dial fully counterclockwise, and the attenuator knob to 30 VOLTS. Feed a 5- to 10-mv signal at 100 kc to TP155 (in the input section) and tune T151 for maximum indication on the Type 1900-A meter.

6.6.2 ALIGNMENT OF FIRST CRYSTAL (X301).

Connect the high side of PL601 (brown, coaxial cable connecting to J451, in the upper, right-hand, rear corner of the crystal filter assembly) to the stator of C309 (at AT307 or AT314). Tune the 100-kc signal source for a peak indication on the analyzer meter. Adjust the GAIN control so that the meter indicates some convenient reference point, such as +9 db. Lower the frequency of the incoming signal until the meter reads 3 db below the peak and note the frequency, f_L, as read on the counter. Then increase the frequency similarly, and note the frequency, f_H, at which the meter reads 3 db below the peak, on the high side of the resonance. Determine the bandwidth between the 3-db points ($f_H - f_L$), and adjust R305 so that this bandwidth is 39 ±1 cps. The center of the 50-cycle-bandwidth response curve of X301 should be at 99,980 ±3 cps (determined by $\frac{f_L + f_H}{2}$).

Change the BANDWIDTH switch setting to 10 CPS. Tune the signal source to exactly 99,996.0 cps and adjust C305 for maximum meter indication. Again adjust the GAIN control for a reading of +9 db (or any convenient reference point), and measure the bandwidth at points 3 db down from the peak, as before. Adjust R304 and C305 to give a bandwidth of 8.6 ±0.2 cps, centered at 99,996.0 ±0.1 cps.

Similarly, set the BANDWIDTH switch to 3 CPS, tune the signal source to 99,998.8 cps, and adjust C306 for maximum meter indication. Again using the 9-db reference point, adjust R303 and C306 so that the bandwidth at the 3-db points is 2.8 ±0.2 cps, centered at 99,998.8 ±0.1 cps.

6.6.3 ALIGNMENT OF SECOND CRYSTAL (X302).

Connect the high side of PL601 to AT352 (switch S401, terminal 110F). Terminate the test source in 50 ohms and connect it to the stator of C309 (at AT307 or AT314).

Set the BANDWIDTH switch to 50 CPS. Adjust the signal source and the FULL SCALE attenuator knob for a convenient reference reading on the meter. Use the procedure outlined in paragraph 6.6.2 and adjust R308 to obtain a bandwidth of 39 ±1 cps at the 3-db points. The center of the 50-cycle-bandwidth response curve of X302 should be at 99,985 ±3 cps.

Set the BANDWIDTH switch to 10 CPS. Tune the signal source to exactly 99,996.0 cps and adjust C314 for a peak reading of the meter. Adjust R309 and C314 so that the bandwidth at the 3-db points is 8.6 ±0.2 cps wide, centered at 99,996.0 ±0.1 cps.

Similarly, set the BANDWIDTH switch to 3 CPS, tune the signal source to 99,998.8 cps, and adjust C316 for maximum meter indication. Adjust R310 and C316 so that the bandwidth at the 3-db points is 2.8 ±0.2 cps, centered at 99,998.8 ±0.1 cps.

6.6.4 ADJUSTMENT OF FIRST COMBINATION (CRYSTALS X301 AND X302).

Set the BANDWIDTH switch to 50 CPS. Connect the signal source to TP155 (with the 50-ohm termination removed), and tune it for a peak reading on the analyzer meter. Adjust the GAIN control on the Type 1900-A to obtain a meter indication of +9 db. Lower the frequency of the incoming signal until the meter reads 3 db below the peak, and note the frequency, as read on the counter. Increase the frequency of the signal by 56 cps and adjust C309 so that the meter reads 3 db below the peak. The bandwidth at these 3-db points must be 56 ±4 cps, centered at 100 kc ±2 cps. Adjust C309 so that both these limits are met.

Set the BANDWIDTH switch to 10 CPS. In the same manner, measure the bandwidth at the 3-db points. It must be 11.3 ±0.3 cps, centered at 100 kc ±0.2 cps[1], and symmetrical.

Repeat this procedure with the BANDWIDTH switch at 3 CPS. The bandwidth at the 3-db points must now be 3.4 ±0.3 cps, centered at 100 kc ±0.1 cps[1], and symmetrical.

[1] The centering of these bandwidths may be improved by a slight readjustment of the circuit associated with the second crystal of each combination (X302 or X402). The bandwidth will also be affected by this adjustment. Both the bandwidth and the center frequency of the combination must be within the specified limits when the final adjustments have been completed.

6.6.5 ALIGNMENT OF THIRD CRYSTAL (X401).

Connect the high side of PL601 (brown) to the stator of C405 (at AT407 or AT408). Also, connect the test-signal source to TP302. Set the BANDWIDTH switch to 50 CPS, and, in the same manner as before, measure the bandwidth at the 3-db points to be 70 ±4 cps, centered at 99,974 ±5 cps. Adjust R401, if necessary.

Set the BANDWIDTH switch to 10 CPS. Tune the signal source to 99,995.3 cps and adjust C401 for a peak indication on the analyzer meter. Adjust R404 and C401 so that the bandwidth at the 3-db points is 9.2 ±0.2 cps, centered at 99,995.3 ±0.1 cps.

Set the BANDWIDTH switch to 3 CPS. Tune the signal source to 99,998.8 cps and adjust C403 for a peak meter indication. Adjust R405 and C403 so that the bandwidth at the 3-db points is 3.4 ±0.2 cps, centered at 99,998.8 ±0.1 cps.

6.6.6 ALIGNMENT OF FOURTH CRYSTAL (X402).

Connect PL601 to J451 (normal connection). Terminate the signal source in 50 ohms, and connect it to the stator of C405.

With the BANDWIDTH switch at 50 CPS, the bandwidth at the 3-db points must be 30 ±2 cps, centered at 99,985 ±2 cps. Adjust R407, if necessary.

Set the BANDWIDTH switch to 10 CPS. Tune the signal source to 99,995.3 cps and adjust C409 for a peak indication on the meter. Adjust R408 and C409 so that the bandwidth at the 3-db points is 9.2 ±0.2 cps, centered at 99,995.3 ±0.1 cps.

Set the BANDWIDTH switch to 3 CPS. Tune the signal source to 99,998.8 cps and adjust C411 for a peak indication on the meter. Adjust R409 and C411 so that the bandwidth at the 3-db points is 3.4 ±0.2 cps, centered at 99,998.8 ±0.1 cps.

6.6.7 ADJUSTMENT OF SECOND COMBINATION (CRYSTALS X401 AND X402).

Remove the 50-ohm termination from the test source. Set the BANDWIDTH switch to 50 CPS. Connect the signal source to TP302 and tune it for a peak reading on the analyzer meter. Adjust the GAIN control on the Type 1900-A for a meter indication of +9 db. Lower the frequency of the incoming signal until the meter reads 3 db below the peak, and note the frequency, as read on the counter. Increase the frequency of the signal by 64 ±2 cps and adjust C405 so that the meter reads 3 db below the peak. The bandwidth at these 3-db points must be 64 ±2 cps, centered at 100 kc ±2 cps.

Set the BANDWIDTH switch to 10 CPS. In the same manner as before, measure the bandwidth at the 3-db points. It must be 13.1 ±0.3 cps, centered at 100 kc ±0.2 cps[1], and symmetrical.

Repeat this procedure, with the BANDWIDTH switch at 3 CPS. The bandwidth must now be 3.9 ±0.2, centered at 100 kc ±0.1 cps[1], and symmetrical.

6.6.8 ALIGNMENT OF COMPLETE CRYSTAL FILTER (X301, X302, X401, X402).

Connect the test-signal source to TP155. The top cover of the crystal compartment should be in place, but not fastened.

Set the BANDWIDTH switch to 50 CPS. Measure the bandwidth at frequencies that give meter readings 3.5 db down on each side of the peak reading. This bandwidth must be 50 ±5 cps, centered at 100 kc ±10 cps[1], and symmetrical. (Adjust R407 only, to improve the symmetry.) A slight tilt to the flat top can be corrected by careful readjustment of T151.

Set the BANDWIDTH switch to 10 CPS. The bandwidth at the 3.5-db points must be 10 ±1.0 cps, centered at 100 kc ±1 cps[1], and symmetrical.

Set the BANDWIDTH switch to 3 CPS. The bandwidth at the 3.5-db points must be 3 ±0.6 cps, centered at 100 kc ±1 cps[1], and symmetrical.

Tune the FREQUENCY dial for maximum indication on the meter.

With the signal peaked in the 3-cycle band, set the BANDWIDTH switch to 50 CPS, and adjust the GAIN control for any convenient meter indication as a reference. Change the BANDWIDTH switch setting to 10 CPS and adjust R403 to obtain the same meter indication. Change the BANDWIDTH switch setting to 3 CPS and adjust R406 to obtain a meter indication approximately 0.1 db higher than the reference.

Remove the test-signal connections and fasten the top shield cover in place.

6.6.9 REMOVAL OF CRYSTAL-FILTER UNIT.

The crystal-filter unit can be removed from the sub-panel for trouble-shooting. The procedure is as follows:

Remove the BANDWIDTH switch knob. Disconnect the multipoint power connector and the three shielded cables (BROWN, RED, and ORANGE). Loosen the set-screws in the bead-chain driven pulley. Use an offset screwdriver to remove the four screws holding the filter unit to the sub-panel. Hold the pulley and chain in place with one hand and slide the unit away from the panel. Insert a rod (such as a screwdriver) through the hole in the panel, to keep the pulley and chain in position until the unit is replaced.

To expose the etched circuits, simply remove the bottom plate.

Reverse the above procedure to reinstall the filter unit.

6.6.10 CRYSTAL-FILTER AMPLIFIER VOLTAGES.

TABLE 6-5
Crystal-filter amplifier voltages, measured to ground with a vacuum-tube voltmeter.

Tube	Pin	DC Voltage	Tube	Pin	DC Voltage
V351	1	+160	V451	1	+150
	2	0		2	+5
	3	+1.2		3	+6
	4	+12		4	+12
	5	0		5	0
	6	+150		6	+150
	7	0		7	0
	8	+0.9		8	+0.9
	9	+6		9	+6

Transistor	Collector	Emitter
Q351	+14	+3
Q451	+18	+9

[1] Refer to footnote, page 35.

6.7 TRACKING-GENERATOR SECTION.

6.7.1 GENERAL.

The circuits for the TRACKING GENERATOR, NORMAL, and AFC modes of operation are located in the tracking generator section of the instrument (see Figure 6-5).

6.7.2 TRACKING-GENERATOR CIRCUIT.

When the MODE switch is in the TRACKING GENERATOR position, a signal at the frequency indicated by the main FREQUENCY dial setting is present at the panel GENERATOR OUTPUT jack. The level of this signal is adjusted by the LEVEL control. A variable and a fixed signal beat together to produce this signal. The variable signal, supplied by the local oscillator, is adjustable from 100 kc to 154 kc. The fixed signal is obtained from a 100-kc quartz-crystal oscillator (including crystal X251, located behind the etched-circuit board, and transistor Q251). The two signals are fed to a double, balanced mixer (V251, Q254, and Q255). The difference frequency is filtered and then is amplified by Q256 and Q257.

To adjust the tracking generator, proceed as follows: Remove the rear shield cover (see Figure 6-5). Set the MODE switch to TRACKING GENERATOR and the LEVEL control fully clockwise. Set capacitor C250 (behind the snap-button, above the MODE switch) at approximately half capacitance (with the slot in the end of the shaft in a vertical position). Connect a frequency counter to TP202 on the etched-circuit board and adjust C251 (Figure 6-11) to give a frequency of 100 kc.

As an alternate method, feed the signal from the GENERATOR OUTPUT jack to the INPUT terminals of the analyzer. Set the BANDWIDTH switch to 3 CPS, the LEVEL control at maximum, and adjust the FULL SCALE attenuator controls for an on-scale meter reading. Then adjust C251 for maximum meter indication. Remove the connection between the OUTPUT jack and the INPUT terminals.

Connect a 600-ohm load to the OUTPUT jack (LEVEL control at maximum) and observe the output from the jack on an oscilloscope. Adjust the output level by means of R259 (a screwdriver adjustment on the etched-circuit board, Figure 6-11) for maximum output without clipping. At least 3 volts should be present.

Set the MODE switch to NORMAL. Temporarily remove transistor Q254 from its socket. Set the LEVEL control to maximum and adjust the oscilloscope for high sensitivity. Set the FREQUENCY dial to 05000. Tune C274 (on the etched-circuit board) for minimum output. (A second-harmonic signal may be present when the fundamental is balanced out.)

Reset the FREQUENCY dial to 58000, and adjust C275 for minimum output.

Replace Q254 in its socket. Set the MODE switch to TRACKING GENERATOR, and tune the main dial to about 100 cps. Remove the 600-ohm load at the OUTPUT jack and adjust the CRO to give a greatly enlarged trace of the 100-cycle signal so that the fine structure can be observed. This structure represents the two oscillator signals whose difference is the output signal. Adjust R280 for minimum high-frequency oscillator signals.

Reconnect the 600-ohm load to the OUTPUT jack, and connect a vacuum-tube voltmeter across the output. Monitor the level over the complete tuning range (00000 to 54000 cps). The level is affected slightly by the settings of capacitors C276, C277, and C278.

6.7.3 NORMAL-MODE CIRCUIT.

In the NORMAL mode of operation, a signal from the local oscillator is heterodyned with one from the 100-kc IF amplifier to provide an output signal. Thus, the latter signal will be obtained only when a signal is present in the passband of the i-f amplifier.

To check this circuit, set the FULL SCALE attenuator larger dial to CAL and the knob to 3 MILLIVOLTS. With the BANDWIDTH switch at 10 CPS, tune the main FREQUENCY dial to the power-line frequency and obtain maximum indication on the meter. A signal at the power-line frequency will appear at the FILTERED INPUT COMPONENT jack. Tune the FREQUENCY dial through the third harmonic of the power-line frequency. Again, a corresponding signal will appear at the jack, as determined with headphones or an oscilloscope. This output signal should be at least 1 volt across 600 ohms, with a full-scale indication on the meter. If no such signal is present with input indicated on the meter, make the following tests:

Determine that:

a. Plug PL252 (BK) is connected to jack J656.

b. Plug PL253 (BL) is connected to jack J205.

c. A 100-kc signal is present at jack J656 when a signal is present in the i-f band.

d. The local-oscillator signal is present at anchor terminal AT258 (see schematic diagram, Figure 6-13). Its frequency will be between 100 and 154 kc (depending upon the setting of the FREQUENCY dial), with an amplitude of 0.6 volt.

e. An unfiltered beat signal is present at AT257, connected to the output of the mixer. The filtered beat signal will be present at AT255.

6.7.4 AFC CIRCUIT.

When automatic frequency control (AFC) is used, a signal from the 100-kc i-f amplifier is fed to a tuned, limiting amplifier (Q252 and Q253) and is then applied to a discriminator that uses a 100-kc quartz crystal, X251. The output from the discriminator is rectified, filtered, and applied as a dc correction voltage to a variable-capacitance diode circuit in the local oscillator.

With no input signal, the dc voltage from the discriminator is about 35 volts. With an input signal applied, this voltage rises to between 55 and 60 volts on one side of resonance and drops to 10 to 15 volts on the other side.

To align the discriminator, a dc vacuum-tube voltmeter, a frequency counter, and an external audio-signal source are needed. Connect the counter to TP201, at the left-hand end of the variable oscillator housing. Set the BANDWIDTH switch to 50 CPS and the MODE switch to AFC. Tune the FREQUENCY dial to about 01000 and measure the frequency of the local oscillator. (Do not apply a signal to the input of the analyzer.) Do not change the FREQUENCY dial setting, but set the MODE switch to NORMAL, and again measure the frequency. Adjust capacitor C225 (at the right-hand end of the oscillator housing) to give the same frequency for both the NORMAL and AFC positions of the MODE switch. Repeat both measurements after each adjustment.

Temporarily disconnect the lead from terminal #5 of plug PL251 at AT265, (on the etched-circuit board). Set the MODE switch to NORMAL. Connect the dc vacuum-tube voltmeter to AT265. With no signal at the analyzer input, note the dc voltage level for future reference (about 35 volts).

Set the ΔF dial to 0 and the MODE switch to AFC. Connect a stable audio signal (e.g. 1000 cps), whose frequency is known within 1 cps, to the INPUT terminals of the analyzer. With the counter connected to TP201, use the FREQUENCY dial to tune in the input signal. The frequency of the local oscillator should be 100,000 cps plus the frequency of the input signal. If the test-signal frequency is 1000 cps, set the oscillator frequency to 101,000 cps. Use the FULL SCALE input attenuator controls (or an external adjustment) to give a full-scale meter reading. Temporarily disregard the incorrect main FREQUENCY dial reading.

Tune the ΔF dial slowly through its range. The vacuum-tube voltmeter should indicate the usual S-shaped discriminator characteristic. On the low-frequency side of zero, the voltage should peak between 50 and 60 volts. On the high side, a minimum between 10 and 20 volts should be found. Set the ΔF dial for this minimum, and adjust the core of L252 for a minimum meter indication (see Figure 6-11). Reset the ΔF dial to 0, and note whether or not the dc voltage is near the reference level of 35 volts. If not, retune the discriminator circuit by means of C262 and C264 so that the reference-voltage point is in the middle of the discriminator characteristic when the ΔF dial is at 0. Change the MODE switch to NORMAL and remove the input signal; then recheck the dc reference level. When the voltage at the center of the discriminator characteristic coincides with this reference level, the discriminator is properly tuned.

Disconnect the vacuum-tube voltmeter and resolder the lead from terminal #5 of PL251 to AT265.

With an input signal connected to the analyzer and the MODE switch at AFC, a full-scale signal in the audio range, once it is captured, should remain locked in over a total range of approximately 400 cps in the 50-cycle band. The range for the 10-cycle band is approximately 150 cps. This lock-in range is the total frequency span between points 3 db down from the maximum.

NOTE

These figures for lock-in range apply to frequencies below 10 kc; the range is reduced to about half these values at the high-frequency end of the tuning range.

6.7.5 SERVICING THE ETCHED-CIRCUIT BOARD.

The underside of the etched-circuit board can be made accessible for servicing by the removal of the two screws in the upper corners (Figure 6-11). The hinged board may then be swung out. This procedure also provides access to the fixed-oscillator quartz crystal, X251.

TABLE 6-6
Voltages for the tracking-generator section, measured to ground with a vacuum-tube voltmeter.

Tube	Pin	DC Volts
V251	1	+65
	2	0
	3	+1.7 to +3.0*
	4	+12
	5	0
	6	+65
	7	0
	8	+3.0 to +1.7*
	9	+6

Transistor	Collector	Emitter
Q251	+3.5 to +5.0†	+1.5 to +2.4†
Q252	+30	0
Q253	+16	+32
Q254	0	+1.7 to +3.0*
Q255	0	+3.0 to +1.7*
Q256	+23	+3.5
Q257	+18	+24

* Depends on the setting of R280.
† Depends on the setting of R259.

6.8 INPUT CIRCUITS.

6.8.1 GENERAL.

The INPUT terminals of the analyzer are connected to a 70-db attenuator with 10 db of attenuation per step. The signal from this attenuator is fed to a twin-triode amplifier, V151. The input section of this tube is a cathode-follower circuit that drives a low-pass filter whose series elements are L151 and L152. The filter feeds the second half of V151, which operates as a phase splitter. The input signal appears as a push-pull output signal at TP154 and TP155. The signals at these points should be approximately equal, but their values depend on the setting of R160, a balancing control, whose adjustment is described in paragraph 6.10.

Tube V152 is a balanced modulator that operates with a push-pull signal applied to its grids and an in-phase local-oscillator signal applied to its cathodes. The push-pull arrangement of the plate circuit causes the local-oscillator signal to be balanced out, leaving the upper ($f_o + f_s$) and lower ($f_o - f_s$) sidebands, where f_o is the frequency of the local oscillator and f_s is the frequency of the input signal. The lower sideband is selected by the 100-kc crystal filter and is amplified in later stages.

If a signal is applied to the INPUT terminals and the FREQUENCY dial is tuned for the corresponding meter reading, a modulated wave with a scallop-shaped envelope will appear at TP151.

Transformer T151 is tuned to 100 kc, the intermediate frequency, by adjustment of a screw-type core with a left-hand thread. Use the meter as an indicator and tune the transformer to resonance on the 10-cycle band (for best resolution). This adjustment may tilt the flat-top characteristic of the 50-cycle-filter pass-band. A slight readjustment of T151 should correct this condition, with little effect on the 10-cycle band (refer to the crystal-filter adjustments, paragraph 6.6).

6.8.2 INPUT ATTENUATOR.

(See the simplified circuit diagram, Figure 6-1.)

Use the following procedure to check the input attenuator. An external audio-signal source (such as the GR Type 1304-B Beat-Frequency Audio Generator) and an accurate step attenuator (such as the GR Type 1450-TB Decade Attenuator) are required.

Set the audio generator to 1 kc with an output of 50 volts and connect it to the external attenuator (properly terminated in 600 ohms). Set the attenuator for an 80-db attenuation and connect its output to the analyzer INPUT terminals. Set the FULL SCALE attenuator larger dial one step from maximum clockwise (INPUT SHOULD NOT EXCEED 100 MILLIVOLTS) and the attenuator knob to 3 MILLIVOLTS. Set the BANDWIDTH switch to 10 CPS and the READING switch to RELATIVE. Tune in the signal by means of the FREQUENCY controls and adjust the GAIN control for a convenient reference reading on the meter, e.g. +8 db.

Rotate the attenuator larger dial one step counterclockwise and remove 10 db of attenuation from the external attenuator. The meter should now read +8 ±0.2 db. Repeat the procedure for each step of the input attenuator; add attenuation with the larger dial and remove the same amount in the external attenuator. Each step should provide 10 ±0.2 db of attenuation.

It is convenient to check the 100-kc attenuator at this point in the procedure. This attenuator is operated by the FULL SCALE attenuator knob. (The circuit is discussed in paragraph 6.9.)

With the audio-signal source and the external attenuator connected as before, set:

READING switch to RELATIVE
FULL SCALE attenuator
Larger dial to INPUT SHOULD NOT EXCEED 10 VOLTS
Knob fully CW
External attenuator to 10 db.

Tune in the audio signal and use the GAIN control to obtain a convenient indication on the meter, e.g. +8 db. Add 10 db of external attenuation and turn the FULL SCALE attenuator knob one step counterclockwise. The meter should indicate 8 ±0.2 db. Repeat this procedure for all other steps of the 100-kc attenuator; each step should provide attenuation of 10 ±0.2 db. The meter will indicate slightly higher in the most sensitive position of the attenuator, due to residual noise in the amplifier.

6.8.3 CARRIER BALANCE.

Capacitors C166 and C167 (see Figure 6-22) are used to balance out the carrier. They are adjusted in the following manner:

a. Set the FULL SCALE attenuator larger dial fully counterclockwise and the main FREQUENCY dial to 00000. Do not connect a signal to the INPUT terminals. Using the F ZERO dial (PUSH TO ENGAGE), tune the local oscillator to the 100-kc i-f frequency as indicated by the maximum reading of the meter. Adjust the attenuator knob to maintain an on-scale meter deflection. Using a high-sensitivity oscilloscope as an indicator, adjust C166 for minimum signal at TP154 and adjust C167 for minimum signal at TP155.

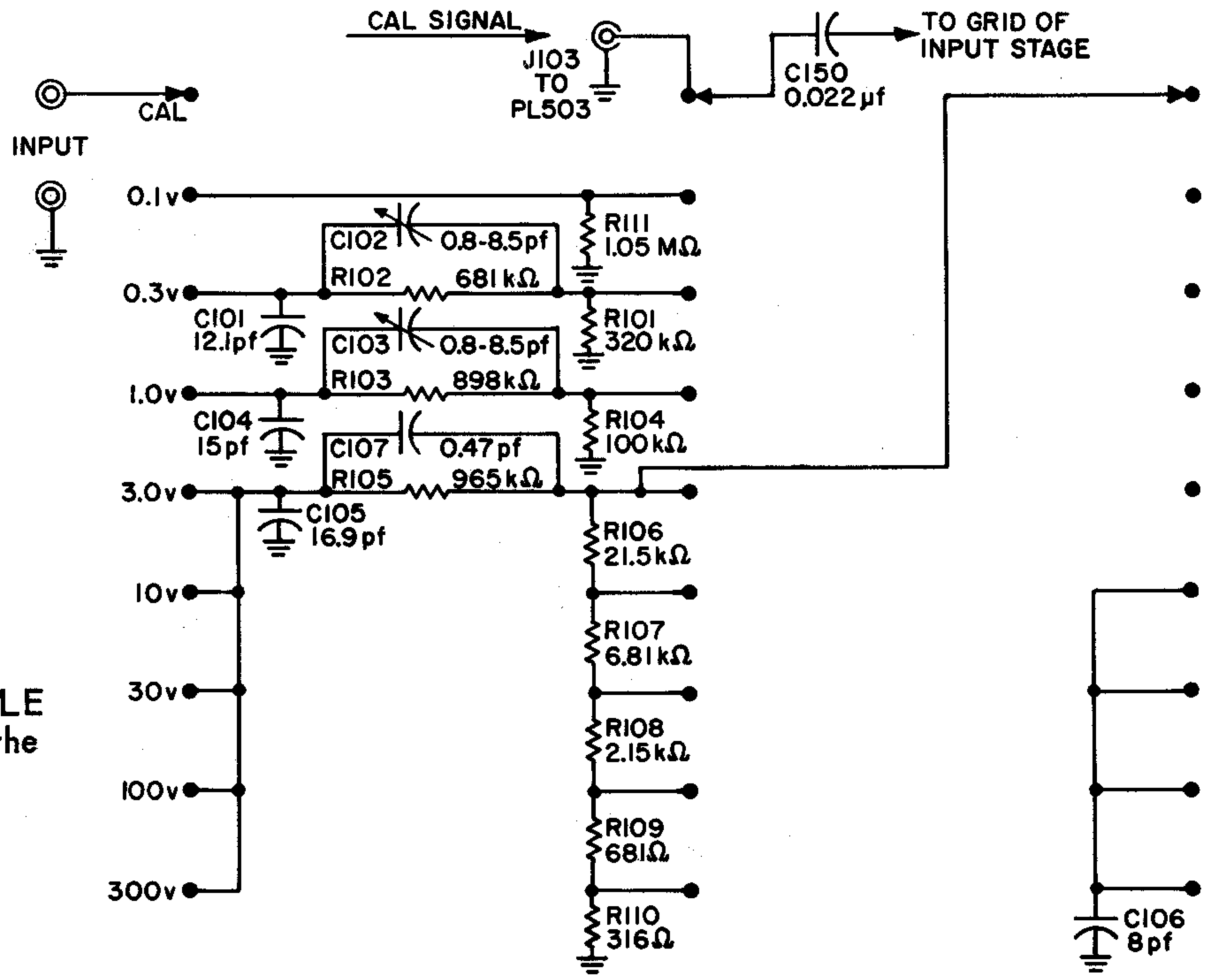


Figure 6-1. Circuit for the FULL SCALE input attenuator (S101), operated by the larger dial.

6.8.4 LOW-PASS FILTER.

NOTE

Inductors L151 and L152 have been adjusted to 30 mh and 48 mh, respectively, and should not be disturbed.

The low-pass input filter is adjusted as follows:

a. Apply an external signal, whose frequency can be tuned to the 100-kc i-f frequency of the analyzer, to the INPUT terminals of the Type 1900-A.

b. Adjust the FULL SCALE attenuator knob and dial to give a convenient on-scale meter indication.

c. Set the BANDWIDTH switch to 10 CPS and adjust the frequency of the incoming signal for maximum meter indication.

d. Adjust C159 (see Figure 6-22) for minimum indication (maximum rejection).

e. Set the external signal frequency to 205 kc. Tune in this image frequency at about 05000 on the main FREQUENCY dial.

f. Adjust C158 for minimum meter indication.

g. Connect the clipper circuit shown in Figure 6-2 between the GENERATOR OUTPUT jack and the INPUT terminals of the analyzer.

h. Set the MODE switch to TRACKING GENERATOR and turn the LEVEL control fully clockwise.

i. Set the FULL SCALE attenuator larger dial one step from maximum clockwise and turn the knob fully clockwise.

j. Set the FREQUENCY dial to 01000 and the READING switch to RELATIVE.

k. Adjust the GAIN control to give a convenient meter indication (e.g. +8 db) for a reference.

l. Reset the FREQUENCY dial to 40000 and adjust C161 for the reference as noted in step k. Change the dial to 50000 and adjust C157 for the same reference. At 55000 on the dial, adjust C163 for the same reference.

m. Repeat this entire procedure, to correct for some interaction between adjustments.

6.8.5 FREQUENCY-COMPENSATION ADJUSTMENTS OF THE INPUT ATTENUATOR.

a. Reset the main FREQUENCY dial to 50000 and note the meter reading (with the other controls set as in the preceding paragraph).

b. Turn both the attenuator dial and the knob one step counterclockwise; adjust C102 on the attenuator (Figure 6-22) for the meter reading noted in step a.

c. Turn the attenuator dial and knob one additional step counterclockwise, and adjust C103 for the meter reading noted in step a.

This completes the compensation adjustments of the input attenuator.

6.8.6 INPUT-SECTION VOLTAGES.

Table 6-7 gives the dc voltages for the input section, measured to ground with a vacuum-tube voltmeter.

TABLE 6-7

DC voltages for the input section, measured to ground with a vacuum-tube voltmeter.

Tube	Pin	DC Volts
V151	1	+150
	2	+38
	3	+40
	4	+12
	5	0
	6	+110
	7	+40
	8	+41
	9	+6
V152	1	+105 to +165*
	2	0
	3	+2.8 to +8.8*
	4	0
	5	+12
	6	+105 to +165*
	7	0
	8	+2.8 to +8.8*
	9	+6
Transistor	**Collector DC Volts**	**Emitter DC Volts**
Q151	+150 to +185*	+130 to +175* (TP153)
Q152	+150 to +185*	+130 to +175* (TP152)

* Depends on setting of R216.

6.9 IF AMPLIFIER AND ATTENUATOR (100 KC).

6.9.1 GENERAL.

The cylindrical shield can, mounted on the rear of the housing for the input section (see Figures 6-5 and

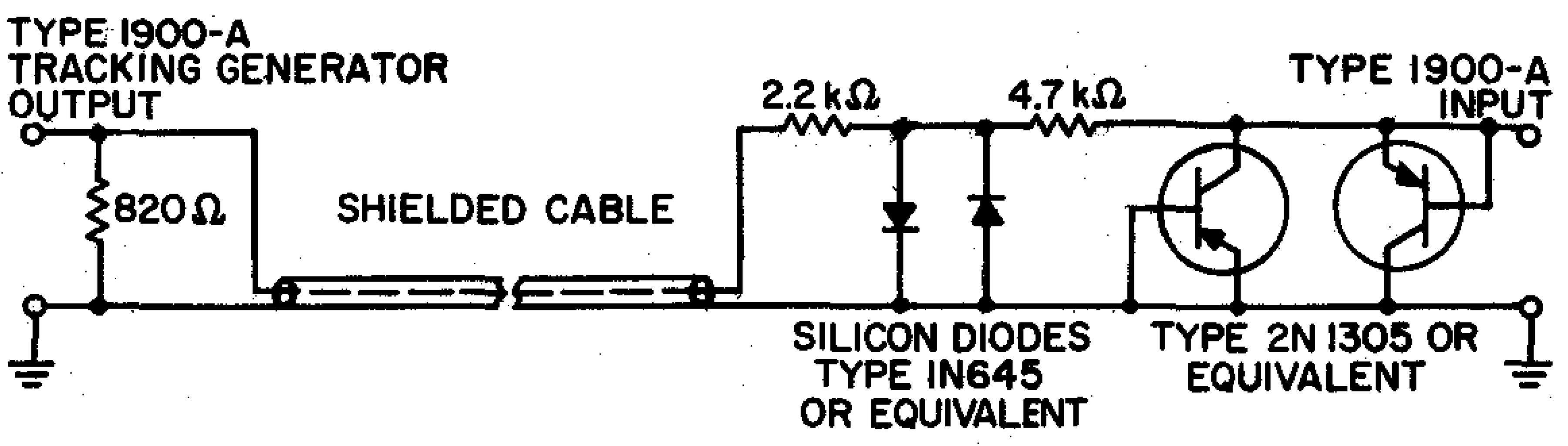


Figure 6-2. Clipper circuit to be used with the signal from the TRACKING GENERATOR, to adjust the frequency-response characteristic of the analyzer input circuits.

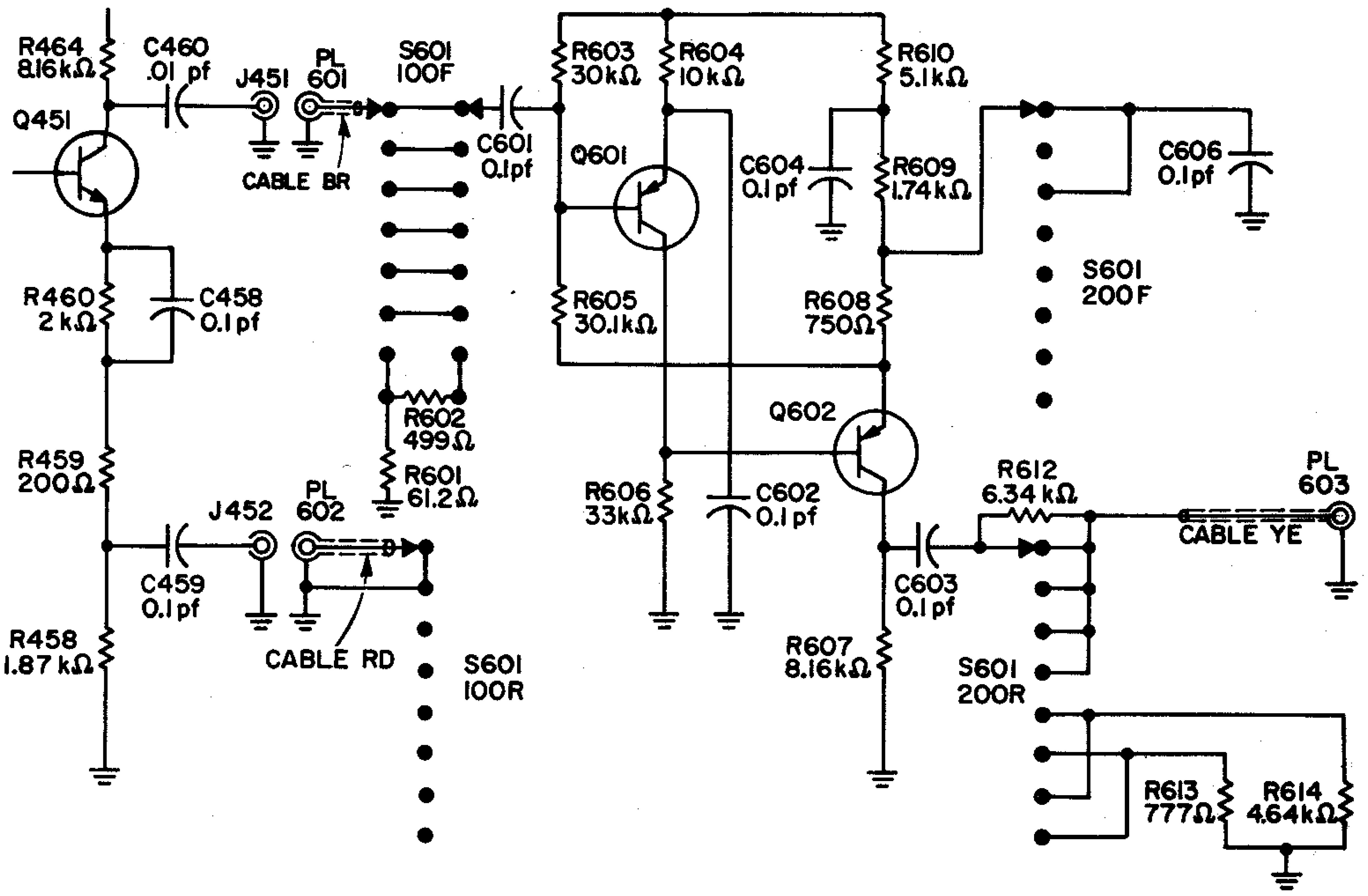


Figure 6-3. Circuits for the 100-kc attenuator and amplifier. The circuits switched by S601, shown in the counterclockwise position, are controlled by the FULL SCALE attenuator knob.

6-22), contains a two-stage transistor amplifier and a 70-db attenuator in several sections. The control shaft of this attenuator is coaxial with the FULL SCALE input attenuator switch; it is controlled by the attenuator knob. Both the amplifier and the attenuator operate at 100 kc, the i-f frequency.

Transistors Q601 and Q602 are current sources in a stabilized feedback amplifier. The former presents a low input impedance to the signal source, and the latter appears as a high-impedance source for the next amplifier stage.

Current-divider attenuators operate at both the input and the output of the amplifier. Attenuation of 10 db is provided when capacitor C606 is disconnected from R608 and R609. Similarly, 20 db of attenuation is produced when C459 is disconnected from R458 and R459. Another 20 db of attenuation is provided when the network of R601 and R602 is switched into the circuit; R612 and R614 give an attenuation of 10 db; R612 and R613 provide 20 db.

Figure 6-3 shows the circuit connections for each position of the FULL SCALE attenuator switch, S601, which is controlled by the attenuator knob. Table 6-8 gives the attenuation for each switch position.

6.9.2 VOLTAGE TABLE.

Table 6-9 gives the dc voltages for the intermediate amplifier and attenuator section, measured to ground with a vacuum-tube voltmeter.

6.10 DISTORTION ADJUSTMENTS.

To adjust the analyzer for minimum distortion, a low-distortion audio-signal source is required. The General Radio Type 1304-B Beat-Frequency Audio Generator or the Type 1311 Audio Oscillator is recommended. Additional filtering should be used with these instruments; this consists of a high-Q, series-resonant

TABLE 6-8

Attenuation inserted for each position of the attenuator knob.

S601 Switch Position	100 F	100 R	200 F	200 R	Total Att.
1 (CCW)	0	0	0	0	0 db
2	0	0	10 db	0	10 db
3	0	20 db	0	0	20 db
4	0	20 db	10 db	0	30 db
5	0	20 db	10 db	10 db	40 db
6	0	20 db	10 db	20 db	50 db
7	20 db	20 db	10 db	10 db	60 db
8	20 db	20 db	10 db	20 db	70 db

TABLE 6-9

DC voltages for the i-f section, measured to ground with a vacuum-tube voltmeter.

Transistor	Collector DC Volts	Emitter DC Volts
Q601	+20	+27
Q602	+15	+20

circuit that includes a .03- to .04-µf capacitor, an adjustable decade inductor of 600 to 850 mh (such as the GR Type 1490-C Decade Inductor), a 600-ohm resistor, and a 10-ohm resistor. The circuit is shown in Figure 6-4. The adjustment procedure is as follows:

a. For proper mixer operation, the oscillator level at TP201 should be 0.6 volt. Adjust, if necessary, by means of R210. Both TP201 and R210 are located at the left-hand end of the oscillator compartment.

b. Adjust capacitors C166 and C167, in the input section, to give minimum 100-kc signal at TP154 and TP155, respectively (see Figure 6-22).

c. Set the panel controls on the analyzer as follows: BANDWIDTH switch to 10 CPS
FREQUENCY dial to 00000
FULL SCALE attenuator larger dial fully CCW (INPUT SHOULD NOT EXCEED 300 VOLTS)
READING switch to ABSOLUTE
ΔF dial to 0
METER SPEED switch to FAST
FUNCTION switch to NORMAL

d. Tune in the local-oscillator signal by means of the F ZERO knob (PUSH TO ENGAGE).

e. Adjust the attenuator knob as necessary for a convenient meter indication.

f. Temporarily disconnect plug PL203 (violet-and-white cable) from jack J152, at the rear of the input section.

g. Adjust R206, at the left-hand end of the oscillator compartment, for minimum carrier, as indicated on the meter. Readjust the attenuator knob as necessary.

h. Reconnect PL203 to jack J152 and, by means of the CARRIER BALANCE controls, again obtain a minimum carrier signal.

i. Connect the 1-kc signal source, with the series tuned circuit of Figure 6-4, to the INPUT terminals of the analyzer. (Use the 5-volt range on the Type 1304-B or the 3-volt range on the Type 1311-A.)

j. Set the FULL SCALE attenuator knob fully clockwise and the attenuator dial to INPUT SHOULD NOT EXCEED 300 MILLIVOLTS.

k. Tune in the 1-kc signal and resonate the tuned circuit by adjusting the inductor, L.

l. Set the signal level at the source, if necessary, to maintain an on-scale meter indication. At resonance (peak meter indication), adjust the incoming signal to obtain a full-scale reading on the meter.

m. Tune the analyzer to the second harmonic of the input signal, at about 02000 on the main FREQUENCY dial. Measure the level of the second harmonic. Increase the sensitivity, as necessary, by rotating the attenuator knob. Also, measure the third harmonic in the same manner. Each of these harmonics must be at least 75 db below the fundamental. If the second harmonic only does not meet this requirement, adjust potentiometer R160 by means of the slotted extension shaft at the rear of the input section (see Figure 6-5). It may be possible to reduce the level of the second harmonic sufficiently to meet this limit by this adjustment. Then remeasure the third harmonic.

n. If either harmonic still does not meet this requirement, proceed as follows:

Set the attenuator knob fully clockwise, tune in the 1-kc signal, and adjust its level for a full-scale meter reading. Then tune the analyzer to the second harmonic.

o. Temporarily set the FULL SCALE attenuator larger dial one step clockwise (INPUT SHOULD NOT EXCEED 100 MILLIVOLTS). Turn the attenuator knob counterclockwise if necessary, to obtain an on-scale meter indication.

p. Set potentiometer R216 (at the left-hand end of the oscillator compartment) fully clockwise. Alternately adjust R216 and R160 for minimum distortion, favoring the clockwise end of R216.

q. Turn the attenuator dial one step counterclockwise (INPUT SHOULD NOT EXCEED 300 MILLIVOLTS). The level of the second harmonic should be at least 75 db below that of the fundamental.

r. Tune the analyzer to the third harmonic, at about 03000. The level of this harmonic must also be at least 75 db below that of the fundamental.

s. Any appreciable change in the setting of R216 will affect the gain of the instrument. If necessary, readjust the full-scale sensitivity of the fundamental signal and remeasure the second and third harmonics.

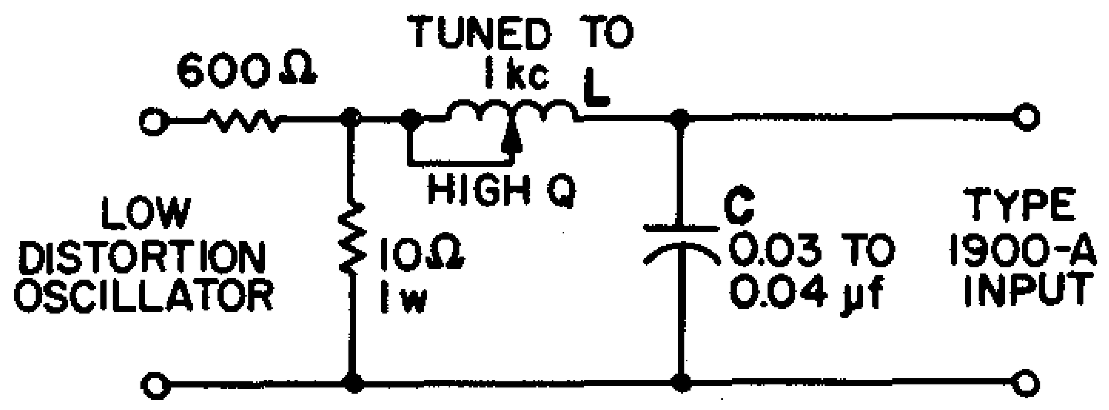


Figure 6-4. Additional filtering, to be used with low-distortion audio generators.

6.11 SENSITIVITY CALIBRATION.

6.11.1 GENERAL.

The analyzer supplies an internal calibrating signal to standardize the voltage sensitivity of the instrument. When the larger attenuator dial is in the CAL position, this signal is connected directly to the input amplifier and the normal input circuit is disconnected.

6.11.2 CALIBRATION PROCEDURE.

Set the attenuator knob to 3 MILLIVOLTS and the READING switch to ABSOLUTE; tune the main FREQUENCY dial to the power-line frequency. The analyzer meter should now indicate 3 mv. Adjust R654 (the potentiometer behind the snap button marked CAL, on the panel) to obtain this value.

6.11.3 STANDARDIZATION OF THE CALIBRATING SIGNAL.

The above adjustment of R654 assumes that the factory setting of R521, on the power-supply shelf, has not been changed. If it has, it must be reset before accurate absolute measurements can be made. This recalibration of the CAL signal requires a test signal at some convenient frequency between 50 and 1000 cps, at an accurately determined level of 10 millivolts. Connect this signal to the INPUT terminals.

a. Set the panel controls on the analyzer as follows:

BANDWIDTH switch to 10 CPS
READING switch to RELATIVE
GAIN control fully CCW
FULL SCALE attenuator
Larger dial one step from fully CW
Knob to 10 MILLIVOLTS.

b. Tune in the signal and note the reading of the analyzer meter.

c. Change the READING switch to ABSOLUTE and, by means of the CAL control, adjust the meter reading to a value 5 db higher than that previously noted.

d. Adjust R665, in the output-amplifier section (Figure 6-14), for a meter reading of exactly 10 millivolts.

e. Turn the larger dial of the attenuator to the CAL position (fully clockwise) and set the main FREQUENCY dial to the internal calibrating signal, at the power-line frequency. (This is a clipped sine-wave signal; be sure to use the fundamental, not a harmonic.)

f. Tune for the maximum meter indication and adjust R521 (on the power-supply shelf) for a reading of 3 millivolts.

NOTE

A signal level of about 10 mv, actually 9.487 mv, is used to calibrate the meter scales. The 9.487-mv point on one scale coincides with the 3-mv point on the other; for convenience, the 3-mv point is used. In the CAL position of the input attenuator, the full-scale sensitivity is actually 10 mv, not the apparent 3 mv indicated by the attenuator dial and knob. For this reason, a calibrating signal of 9.487 mv is used.

6.12 TUBE REPLACEMENT.

The replacement of most of the tubes in the analyzer will not affect the operation of the instrument. However, changing the mixer tube, V152, or the input tube, V151, may necessitate some readjustment of the circuits. If either of these tubes is replaced, follow the procedure given in paragraph 6.10.

PARTS LISTS AND SCHEMATICS

The following pages contain parts lists, photographs, etched-board layouts, and schematic diagrams. They are arranged by circuit, in the following order:

Rotary switch sections are shown as viewed from the panel end of the shaft. The first digit of the contact number refers to the section. The section nearest the panel is 1, the next section back is 2, etc. The next two digits refer to the contact. Contact 01 is the first position clockwise from a strut screw (usually the screw above the locating key), and the other contacts are numbered sequentially (02, 03, 04, etc), proceeding clockwise around the section. A suffix F or R indicates that the contact is on the front or rear of the section, respectively.

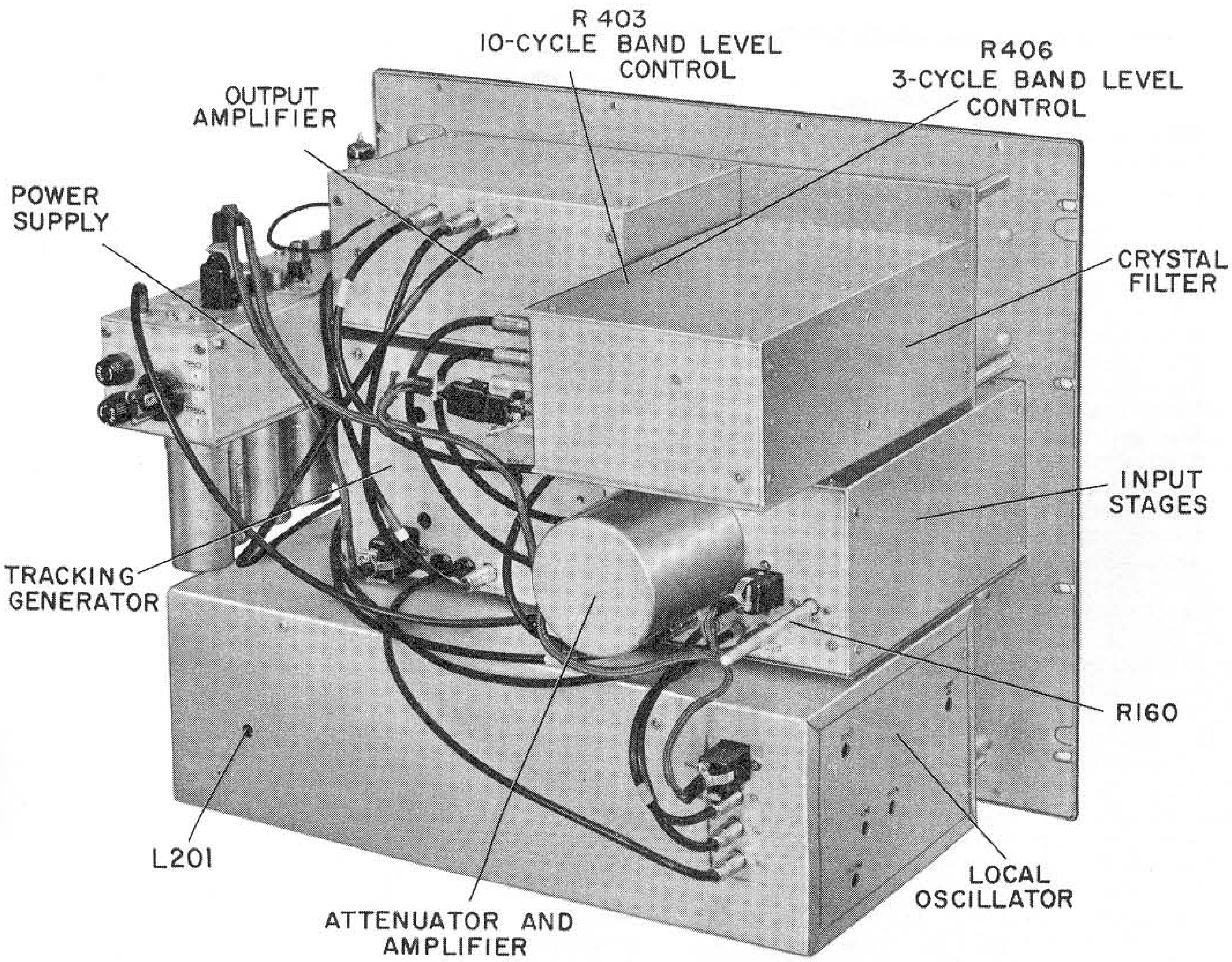


Figure 6-5. Rear interior view of the Type 1900-A Wave Analyzer.

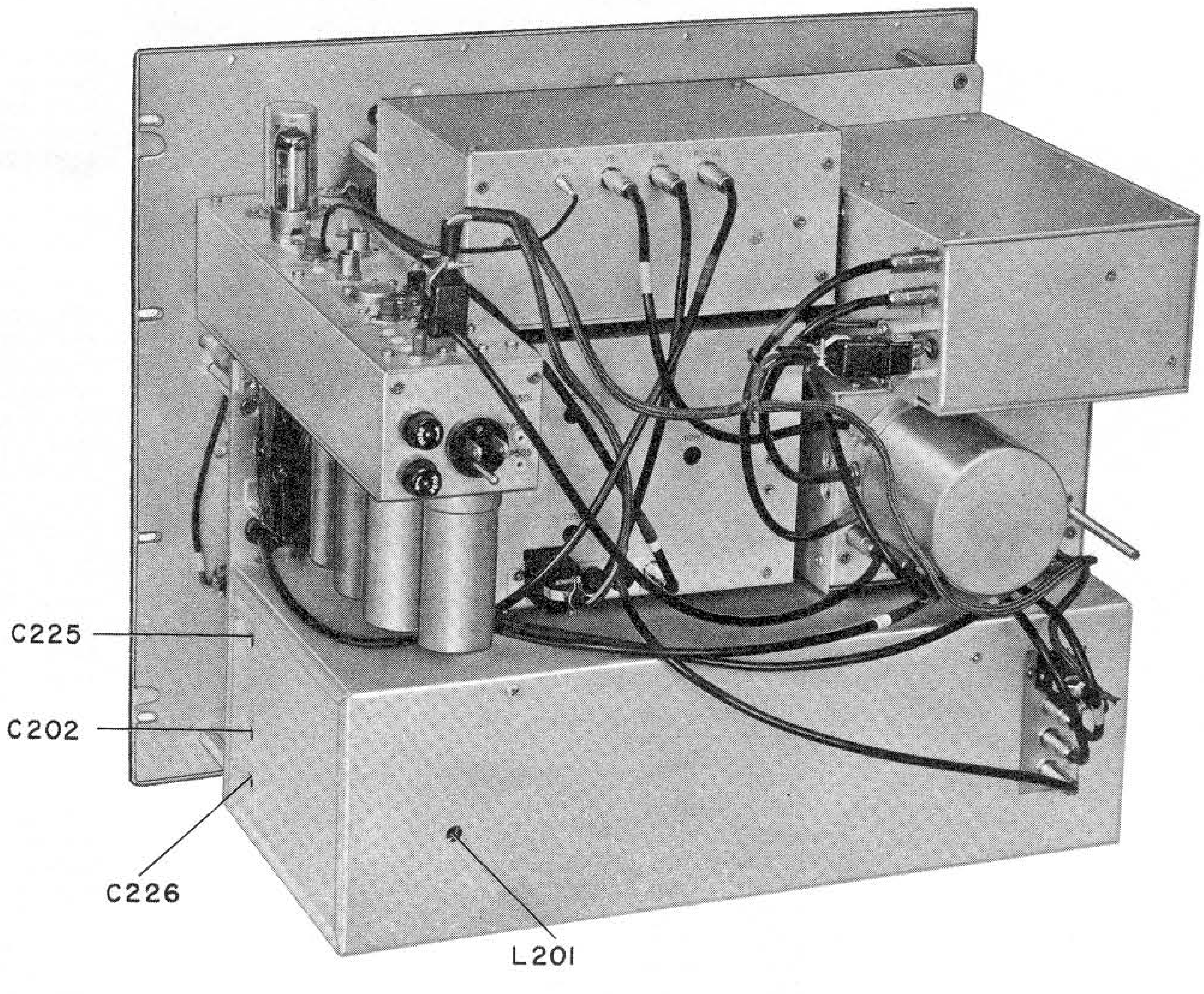


Figure 6-6. Interior view of the analyzer showing adjustments for the variable oscillator.

PARTS LIST FOR THE POWER SUPPLY CIRCUITS.

REF NO.		PART NO.
	CAPACITORS	
C501	Ceramic, .01 µf +80-20% 500 v	4406-3109
C502	Ceramic, .0068 µf +80-20% 500 v	4406-2689
C503A C503B	Electrolytic, 25 µf 200 v	4450-3300
C504A	Electrolytic, 50 µf 450 v	4450-0800
C504B	Electrolytic, 25 µf 450 v	4450-0800
C504C	Electrolytic, 25 µf 450 v	4450-0800
C505A	Electrolytic, 90 µf 300 v	4450-3400
C505B	Electrolytic, 30 µf 300 v	4450-3400
C505C	Electrolytic, 30 µf 300 v	4450-3400
C506A	Electrolytic, 300 µf 150 v	4450-5602
C506B	Electrolytic, 150 µf 150 v	4450-5602
C506C	Electrolytic, 150 µf 150 v	4450-5602
C507	Electrolytic, 10 µf 50 v	4450-3100
C508	Electrolytic, 10 µf 50 v	4450-3100
C509A	Electrolytic, 1500 µf 25 v	4450-0700
C509B	Electrolytic, 750 µf 25 v	4450-0700
C509C	Electrolytic, 750 µf 25 v	4450-0700
C510	Electrolytic, 25 µf 25 v	4450-3000
C511	Electrolytic, 50 v	4450-3900
	RESISTORS	
R500	Composition, 10 kΩ ±5% 1/2 w	6100-3105
R501	Power, 1.5 kΩ ±5% 3 w	6680-2155
R502	Power, 1.5 kΩ ±5% 3 w	6680-2155
R503	Power, 1.5 kΩ ±5% 3 w	6680-2155
R504	Composition, 1 kΩ ±5% 1/2 w	6100-2105
R505	Composition, 680 Ω ±5% 1/2 w	6100-1685
R506	Composition, 680 Ω ±5% 1/2 w	6100-1685
R507	Composition, 200 Ω ±5% 1/2 w	6100-1205
R508	Composition, 56 Ω ±5% 1/2 w	6100-0565
R509	Composition, 56 Ω ±5% 1/2 w	6100-0565
R510	Composition, 1 kΩ ±5% 1/2 w	6100-2105
R511	Composition, 6.8 kΩ ±5% 1/2 w	6100-2685
R512	Composition, 47 kΩ ±5% 1/2 w	6100-3475
R513	Potentiometer, Composition, 10 kΩ ±10%	6010-0900
R514	Composition, 33 kΩ ±5% 1/2 w	6100-3335
R515	Composition, 43 kΩ ±5% 1/2 w	6100-3435
R516	Potentiometer, Composition, 2.5 kΩ ±10%	6010-0700
R517	Composition, 5.6 kΩ ±5% 1/2 w	6100-2565
R518	Composition, 5.1 kΩ ±5% 1/2 w	6100-2515
R519	Precision, 59 kΩ ±1% 1/2 w	6731-2590
R520	Composition, 18 MΩ ±5% 1/2 w	6100-6185
R521	10 kΩ	0971-4200
R522	Precision, 100 Ω ±1% 1/2 w	6731-1100
R523	Power, 1.5 Ω ±5% 5 w	6660-9155
R524	Power, 56 Ω ±5% 5 w	6660-0565
R525	Wire-wound 6.8 Ω ±10% 2 w	5600-0700
R526	Composition, 220 Ω ±5% 1/2 w	6100-1225
	MISCELLANEOUS	
CR501	Diode, 1N3254	6081-1002
CR502	Diode, 1N3254	6081-1002
CR503	Diode, 1N3254	6081-1002
CR504	Diode, 1N3254	6081-1002
CR505	Diode, 1N753A	6083-1006
CR506	Diode, 1N753A	6083-1006
CR507	Diode, 1N3253	6081-1001
CR508	Diode, 1N3253	6081-1001
CR509	Diode, 1N3005A	6083-1022
Q501	Transistor, 2N1984	8210-1040
Q502	Transistor, 2N169A	8210-1692
Q503	Transistor, 2N176	8210-1760
Q504	Transistor, 2N1374	8210-1374
Q505	Transistor, 2N169A	8210-1692
Q507	Transistor, 2N1984	8210-1040
V501	Tube, 0B2	8300-0450
F501 F502	Fuse, 0.5 amp 115 v	5330-1000
F501 F502	Fuse, 0.25 amp 230 v	5330-0700
J501	Jack	4260-1280
P501	Pilot light	5600-0700
PL501	Plug	4240-0600
PL502	Plug	4220-4900
PL503	Plug	1900-0300
S501	Switch	7910-1300
SO501	Socket	4230-3500
T501	Transformer	0485-4003

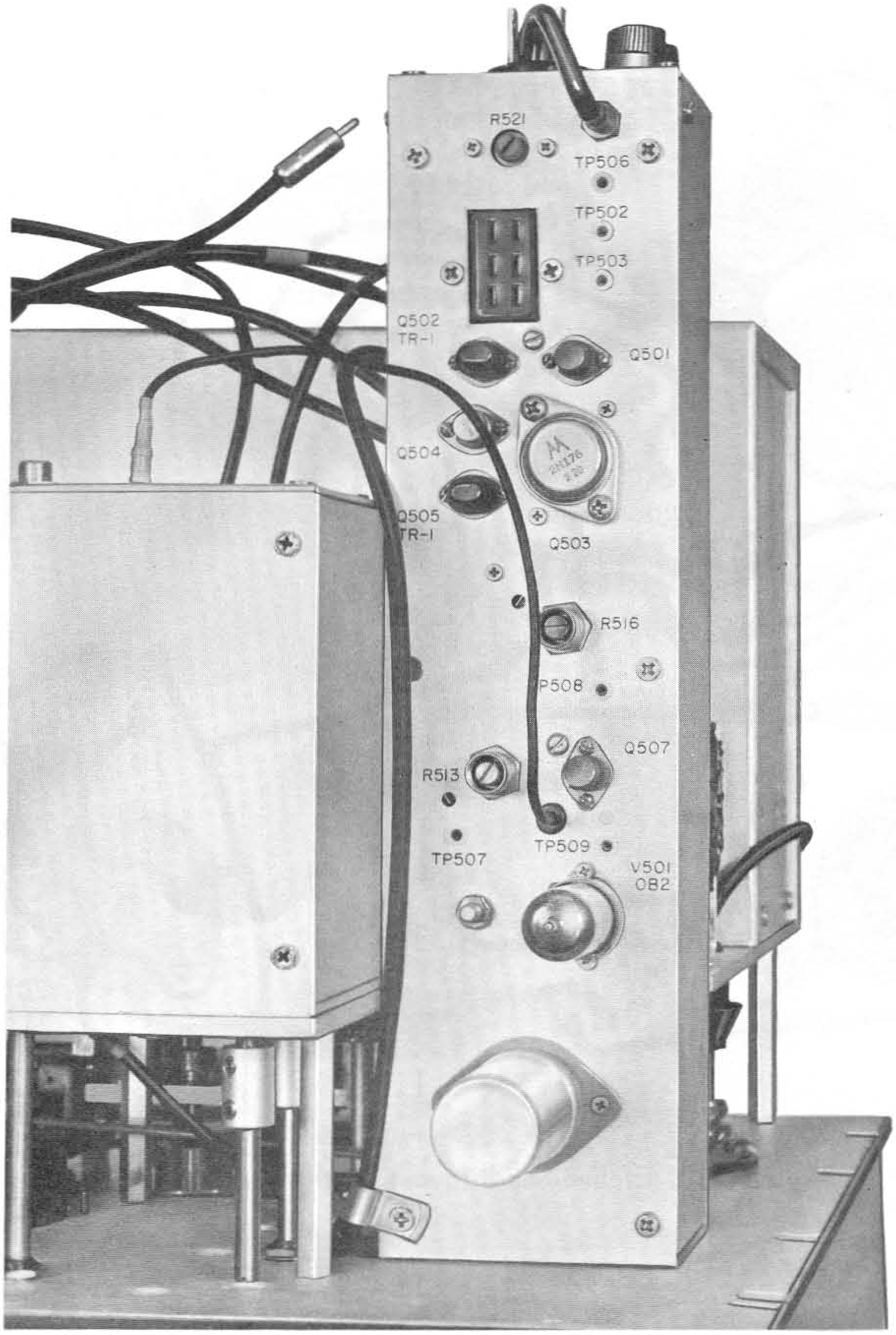
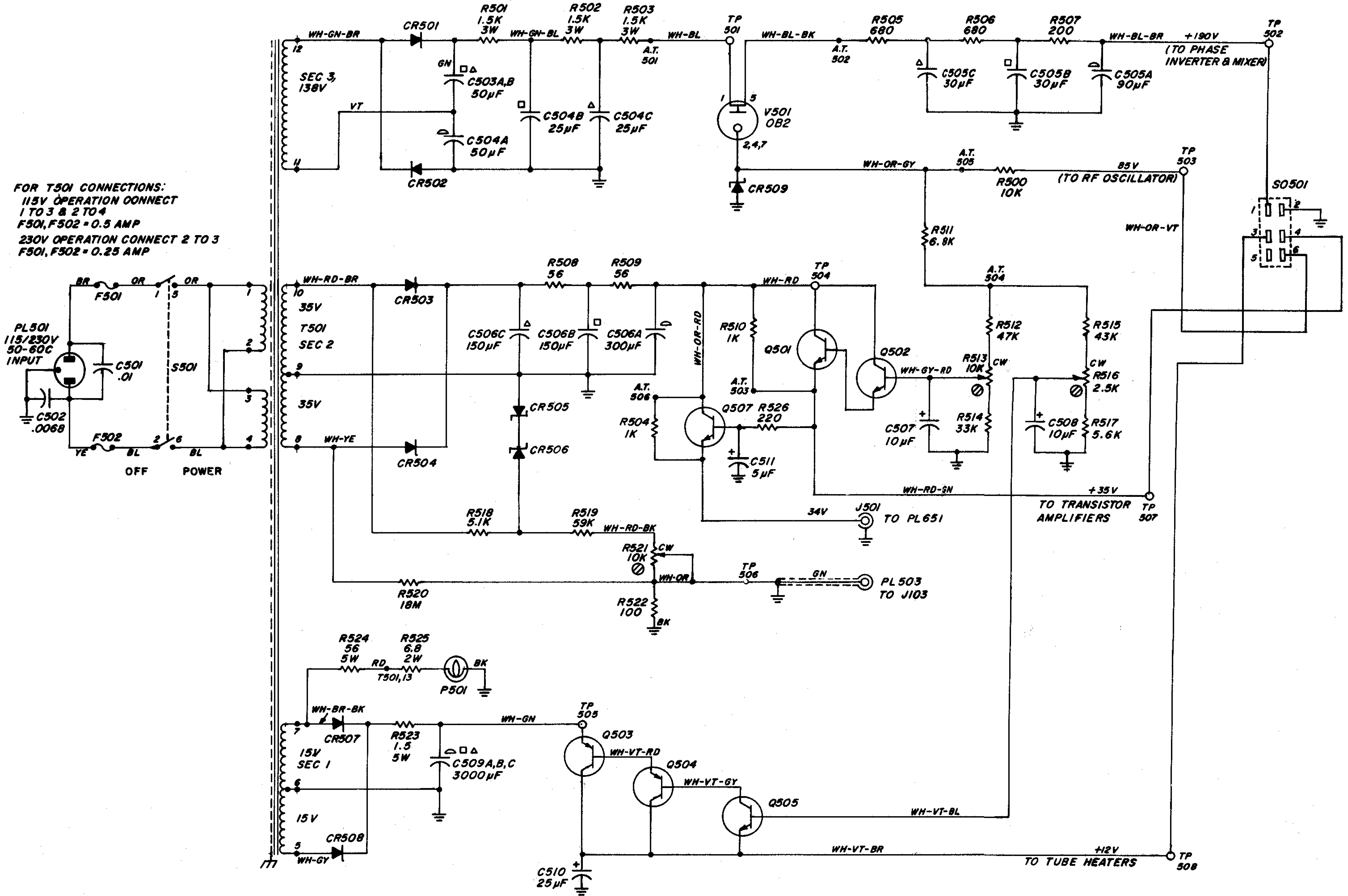
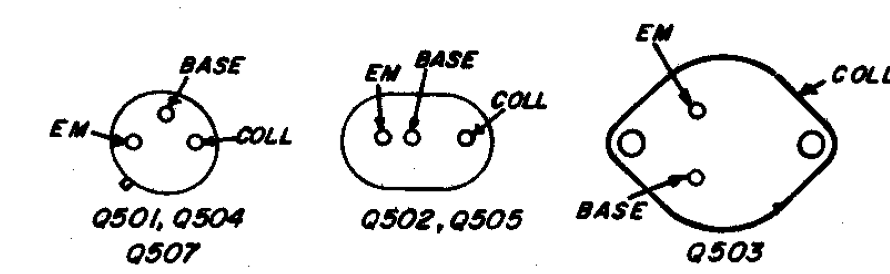
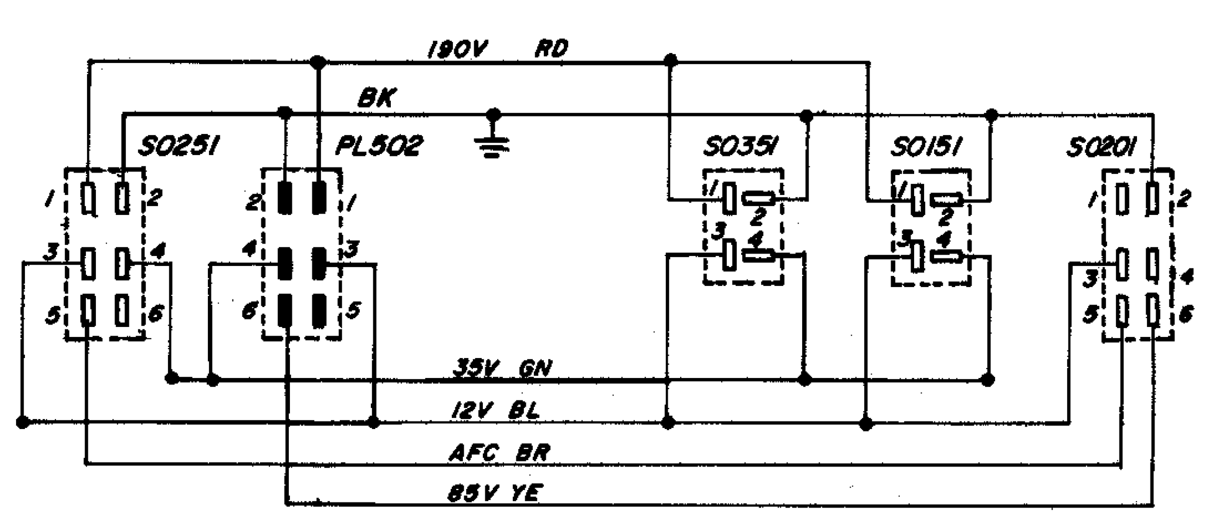


Figure 6-7. Power supply.







NOTE UNLESS SPECIFIED

1. POSITION OF ROTARY SWITCHES SHOWN COUNTERCLOCKWISE.
2. CONTACT NUMBERING OF SWITCHES EXPLAINED ON SEPARATE SHEET SUPPLIED IN INSTRUCTION BOOK.
3. REFER TO SERVICE NOTES IN INSTRUCTION BOOK FOR VOLTAGES APPEARING ON DIAGRAM.
4. RESISTORS 1/2 WATT.
5. RESISTANCE IN OHMS K = 1000 OHMS M = 1 MEGOHM
6. CAPACITANCE VALUES ONE AND OVER IN PICOFARADS. LESS THAN ONE IN MICROFARADS.
7. ○ KNOB CONTROL
8. ⊘ SCREWDRIVER CONTROL
9. AT - ANCHOR TERMINAL
10. TP - TEST POINT

ANCHOR TERMINALS USED: A.T. 501-506
TEST POINTS USED: TP 501-504, 506-508

Figure 6-8. Schematic diagram of the power-supply circuits.

PARTS LIST FOR THE VARIABLE-OSCILLATOR, TRACKING-GENERATOR, AND AFC CIRCUITS

CAPACITORS

REF NO.	CAPACITORS	PART NO.
C201		0539-4150
C202	Air, 4-50 pf	4380-0400
C203		1420-3100
C204	Air, 3.9-75 pf	4380-3300
C205	Mica, .001 µf ±1% 500 v	4600-1100
C206	Mica, 768 pf ±1% 500 v	4710-0768
C207	Mica, 100 pf ±1% 500 v	4710-0010
C208	Mica, 100 pf ±1% 500 v	4710-0010
C209	Mica, .00221 µf ±1% 500 v	4600-1201
C210	Air, 2.8-16 pf	4380-3400
C211	Mica, .01 µf ±2% 500 v	4550-0102
C213	Mica, 47 pf ±10% 500 v	4700-0380
C214A C214B	Electrolytic, 300 µf 15 v	4450-2400
C216	Plastic, 0.47 µf ±10% 100 v	4860-8248
C217	Ceramic, .01 µf ±20% 500 v	4406-3109
C218	Ceramic, .01 µf ±20% 500 v	4406-3109
C219	Ceramic, .01 µf ±20% 500 v	4406-3109
C220	Plastic, 0.1 µf ±10% 100 v	4860-8250
C222	Electrolytic, 10 µf 150 v	4450-3100
C223	Electrolytic, 60 µf 25 v	4450-2900
C224	Mica, 590 pf ±2% 500 v	4700-0730
C225	Air, 2.9-35 pf	4380-3300
C226	Air, 1.7-8.7 pf	4380-3600
C227	Ceramic, .01 µf ±20% 500 v	4406-3109
C228	Mica, 75 pf ±5% 500 v	4700-0375
C229	Ceramic, 220 pf ±5% 500 v	4417-1225
C230	Ceramic, 22 pf ±5% 500 v	4417-0225
C250	Air, 2.9-35 pf	4380-3000
C251	Trimmer, 8-50 pf	4910-1170
C252	Mica, 75 pf ±5% 500 v	4700-0375
C253	Mica, .002 µf ±5% 500 v	4580-0400
C254	Mica, .002 µf ±5% 500 v	4580-0400
C255	Mica, .002 µf ±5% 500 v	4580-0400
C256	Ceramic, 0.1 µf +80-20% 50 v	4403-4100
C257	Ceramic, 0.1 µf +80-20% 50 v	4403-4100
C258	Ceramic, .0047 µf ±20% 500 v	4406-2479
C259	Mica, 270 pf ±1% 500 v	4710-0450
C260	Mica, 499 pf ±1% 500 v	4710-0570
C261	Plastic, .047 µf ±10% 200 v	4860-7869
C262	Trimmer, 8-50 pf	4910-1170
C263	Mica, 33 pf ±5% 500 v	4700-0301
C264	Trimmer, 8-50 pf	4910-1170
C265	Plastic, 1 µf ±10% 100 v	4860-8274
C266	Plastic, 3.3 µf ±10% 100 v	4860-8400
C267	Plastic, 3.3 µf ±10% 100 v	4860-8400
C268	Ceramic, 0.1 µf +80-20% 50 v	4403-4100
C269	Ceramic, 0.1 µf +80-20% 50 v	4403-4100
C270	Ceramic, 0.1 µf +80-20% 50 v	4403-4100
C271	Ceramic, .01 µf ±20% 500 v	4406-3109
C272	Ceramic, .01 µf ±20% 500 v	4406-3109
C273	Mica, 47 pf ±5% 500 v	4700-0247
C274	Trimmer, 8-50 pf	4910-1170
C275	Trimmer, 8-50 pf	4910-1170
C276	Trimmer, 5-25 pf	4910-1150
C277	Trimmer, 5-25 pf	4910-1150
C278	Trimmer, 8-50 pf	4910-1170
C279	Mica, 249 pf ±1% 500 v	4710-0429
C280	Mica, 487 pf ±1% 500 v	4710-0558
C281	Mica, 261 pf ±1% 500 v	4710-0441
C282	Electrolytic, 4 µf 300 v	4450-3200
C283	Electrolytic, 16 µf 150 v	4450-0200
C284	Electrolytic, 10 µf 25 v	4450-3800
C286	Electrolytic, 60 µf 25 v	4450-2900
C287	Electrolytic, 100 µf 25 v	4450-2300
C288	Plastic, .00402 µf ±2% 100 v	4860-7378
C289	Plastic, .0013 µf ±5% 200 v	4860-7315
C290	Electrolytic, 25 µf 50 v	4450-3000
C291	Electrolytic, 60 µf 25 v	4450-2900
C292	Electrolytic, 60 µf 25 v	4450-2900
C293	Ceramic, 0.1 µf +80-20% 50 v	4403-4100

RESISTORS

REF NO.	RESISTORS	PART NO.
R201	Composition, 1 MΩ ±5% 1/2 w	6100-5105
R202	Composition, 560 kΩ ±5% 1/2 w	6100-4565
R203	Composition, 51 kΩ ±5% 1/2 w	6100-3515
R204	Potentiometer, Composition, 10 kΩ ±10%	6000-0600
R205	Potentiometer, Composition, 10 kΩ ±10%	6000-0600
R206	Potentiometer, Wire-wound, 500 Ω ±10%	6050-1100
R207	Wax, 300 Ω ±5% 2 w	6760-1305
R208	Wax, 300 Ω ±5% 2 w	6760-1305
R209	Composition, 750 kΩ ±5% 1/2 w	6100-4755
R210	Potentiometer, Composition, 50 kΩ ±10%	6010-1400
R211	Composition, 220 kΩ ±5% 1/2 w	6100-4225
R212	Composition, 10 kΩ ±5% 1/2 w	6100-3105
R213	Composition, 100 kΩ ±5% 1/2 w	6100-4105
R214	Composition, 68 kΩ ±5% 1/2 w	6100-3685
R215	Composition, 3.3 kΩ ±5% 1/2 w	6100-5335
R216	Potentiometer, Wire-wound, 2.5 kΩ ±10% 1/2 w	6050-1500
R217	Composition, 22 MΩ ±5% 1/2 w	6100-6225
R218	Composition, 2.2 MΩ ±5% 1/2 w	6100-5225
R251	Composition, 51 kΩ ±5% 1/2 w	6100-3515
R252	Composition, 75 kΩ ±5% 1/2 w	6100-3755
R253	Composition, 5.6 kΩ ±5% 1/2 w	6100-2565
R254	Composition, 12 kΩ ±5% 1/2 w	6100-3155
R255	Composition, 30 kΩ ±5% 1/2 w	6100-3305
R256	Composition, 10 kΩ ±5% 1/2 w	6100-3105
R257	Composition, 5.1 kΩ ±5% 1/2 w	6100-2515
R258	Composition, 30 kΩ ±5% 1/2 w	6100-3305
R259	Potentiometer, Composition, 100kΩ ±20% 1/2 w	6040-0900
R260	Composition, 110 kΩ ±5% 1/2 w	6100-4115
R261	Composition, 2 kΩ ±5% 1/2 w	6100-2205
R262	Composition, 3.3 kΩ ±5% 1/2 w	6100-2335
R263	Composition, 15 kΩ ±5% 1/2 w	6100-3155
R264	Composition, 8.2 kΩ ±5% 1/2 w	6100-2825
R265	Composition, 2.7 MΩ ±5% 1/2 w	6100-5275
R266	Composition, 2.7 MΩ ±5% 1/2 w	6100-5275
R267	Composition, 1 MΩ ±5% 1/2 w	6100-5105
R268	Composition, 10 kΩ ±5% 1/2 w	6100-3105
R269	Composition, 2.7 MΩ ±5% 1/2 w	6100-5275
R270	Composition, 22 MΩ ±5% 1/2 w	6100-6225
R271	Composition, 510 kΩ ±5% 1/2 w	6100-4515
R272	Composition, 2.2 MΩ ±5% 1/2 w	6100-5225
R273	Composition, 1 kΩ ±5% 1/2 w	6100-2105
R274	Composition, 36 kΩ ±5% 1/2 w	6100-3365
R275	Composition, 1 kΩ ±5% 1/2 w	6100-3365
R276	Composition, 1 kΩ ±5% 1/2 w	6100-2105
R277	Composition, 1.5 MΩ ±5% 1/2 w	6100-5155
R278	Composition, 1.5 MΩ ±5% 1/2 w	6100-5155
R279	Composition, 20 kΩ ±5% 1/2 w	6100-3205
R280	Potentiometer, Composition, 25 kΩ ±20%	6040-0800
R281	Composition, 20 kΩ ±5% 1/2 w	6100-3205
R282	Composition, 2.2 MΩ ±5% 1/2 w	6100-5225
R283	Composition, 2.2 MΩ ±5% 1/2 w	6100-5225
R284	Potentiometer, Composition, 100 kΩ ±10%	6000-0900
R285	Composition, 51 kΩ ±5% 1/2 w	6100-3515
R286	Film, 12.1 kΩ ±1% 1/2 w	6450-2121
R287	Composition, 240 kΩ ±5% 1/2 w	6100-4245
R288	Composition, 100 Ω ±5% 1/2 w	6100-1105
R289	Composition, 20 kΩ ±5% 1/2 w	6100-3205
R290	Composition, 300 Ω ±5% 1/2 w	6100-1305
R291	Composition, 1.3 kΩ ±5% 1/2 w	6100-2135
R293	Composition, 1 kΩ ±5% 1/2 w	6100-2105

MISCELLANEOUS

REF NO.	MISCELLANEOUS	PART NO.
CR201	Diode, 1N952	6084-1003
CR202	Diode, 1N952	6084-1003
CR203	Diode, 1N191	6082-1008
CR204	Diode, 1N746	6083-1005
CR205	Diode, 1N952	6084-1003
CR251	Diode, 1N191	6082-1008
CR252	Diode, 1N191	6082-1008
Q201	Transistor, 2N1373	8210-1373
Q202	Transistor, 2N398A	8210-3981
Q251	Transistor, 2N338	8210-1021

REF NO.		PART NO.
Q252	Transistor, 2N338	8210-1021
Q253	Transistor, 2N1374	8210-1374
Q254	Transistor, 2N508	8210-1012
Q255	Transistor, 2N508	8210-1012
Q256	Transistor, 2N338	8210-1021
Q257	Transistor, 2N1131	8210-1025
V201	Tube, 12AY7	8370-0925
V251	Tube, 5814A	8380-5814
J203	Jack	4260-1280
J204	Jack	4260-1280
J205	Jack	4260-1280
J251	Jack	4260-1280
J252	Jack	4260-1500
L201A		
L201B	Inductor,	1900-3160
L201C		
L203	Inductor, 250 mh	0119-0020
L204	Inductor, 10 mh ±10%	4300-6300
L205	Inductor, 100 µh ±10%	4300-3500
L251	Inductor, 10 mh ±10%	4300-6394

REF NO.		PART NO.
L252	Inductor,	1900-2220
L253	Inductor, 10 mh ±10%	4300-6300
L254	Inductor, 4.7 mh ±10%	4300-6387
L255	Inductor, 30 mh	1900-2820
L256	Inductor, 35.2 mh	1900-2250
L257	Inductor, 680 µh ±10%	4300-4600
L258	Inductor, 100 µh ±10%	4300-3500
PL201	Plug	4220-4500
PL202	Plug	1900-0308
PL203	Plug	1900-0308
PL251	Plug	4220-4500
PL252	Plug	1900-0303
PL253	Plug	1900-0303
PL254	Plug	1900-0305
S201	Switch	7890-2590
S251	Switch	7890-2570
S252	Switch	7890-2580
SO201	Socket	4230-0100
SO251	Socket	4230-0102
X251	Crystal	1900-2300

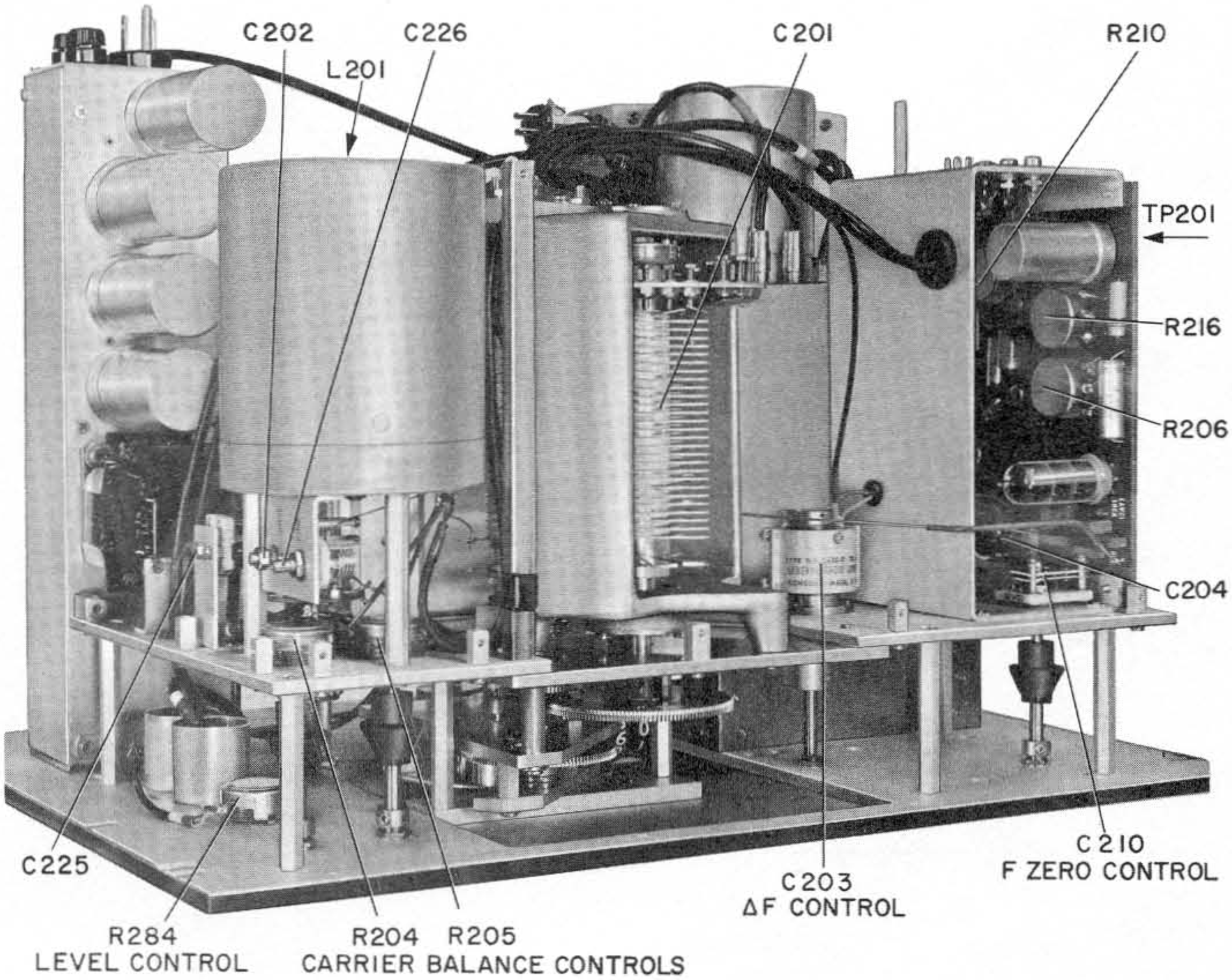


Figure 6-9. Variable oscillator.

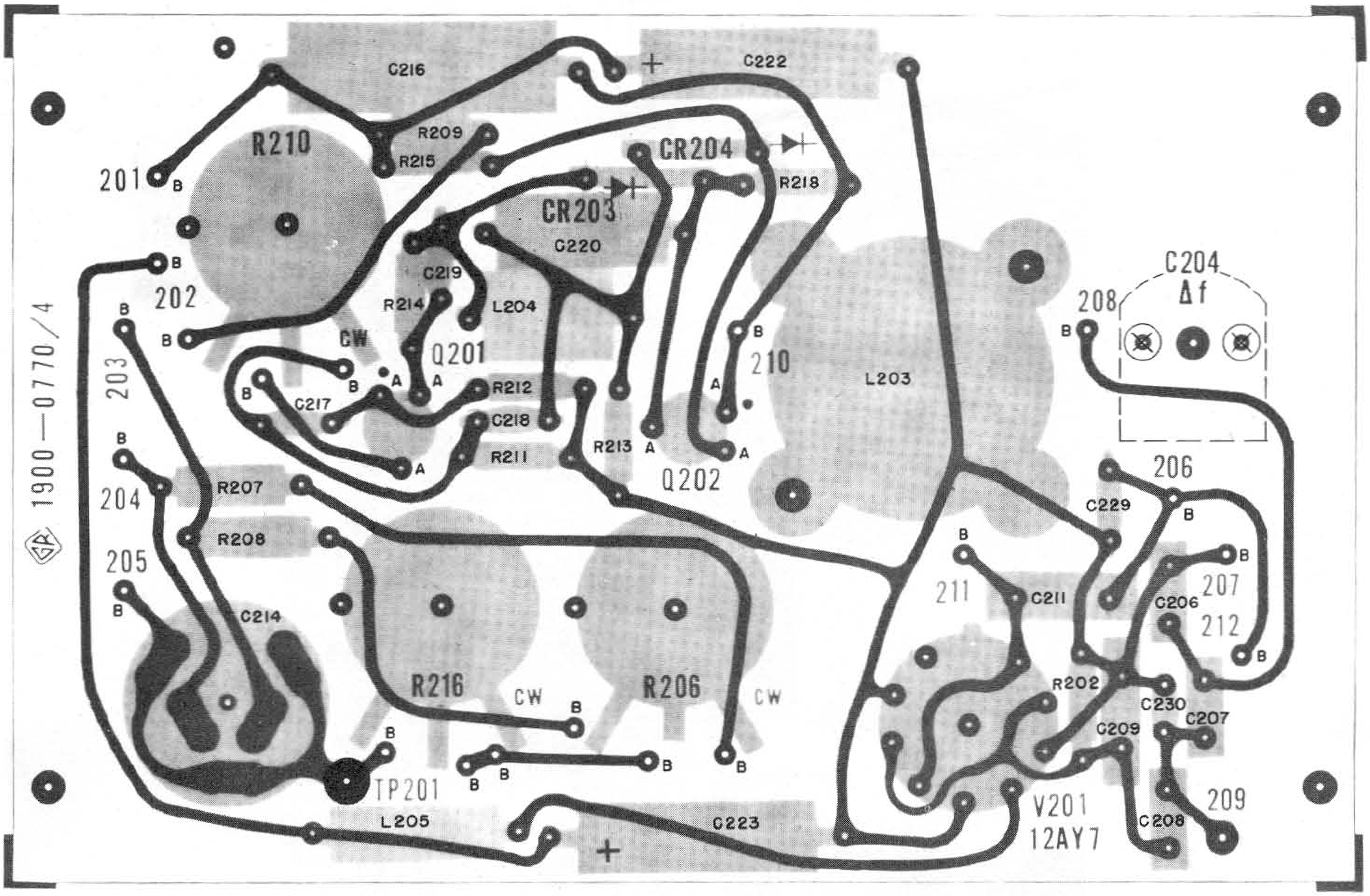


Figure 6-10. Etched-board layout for the variable oscillator.

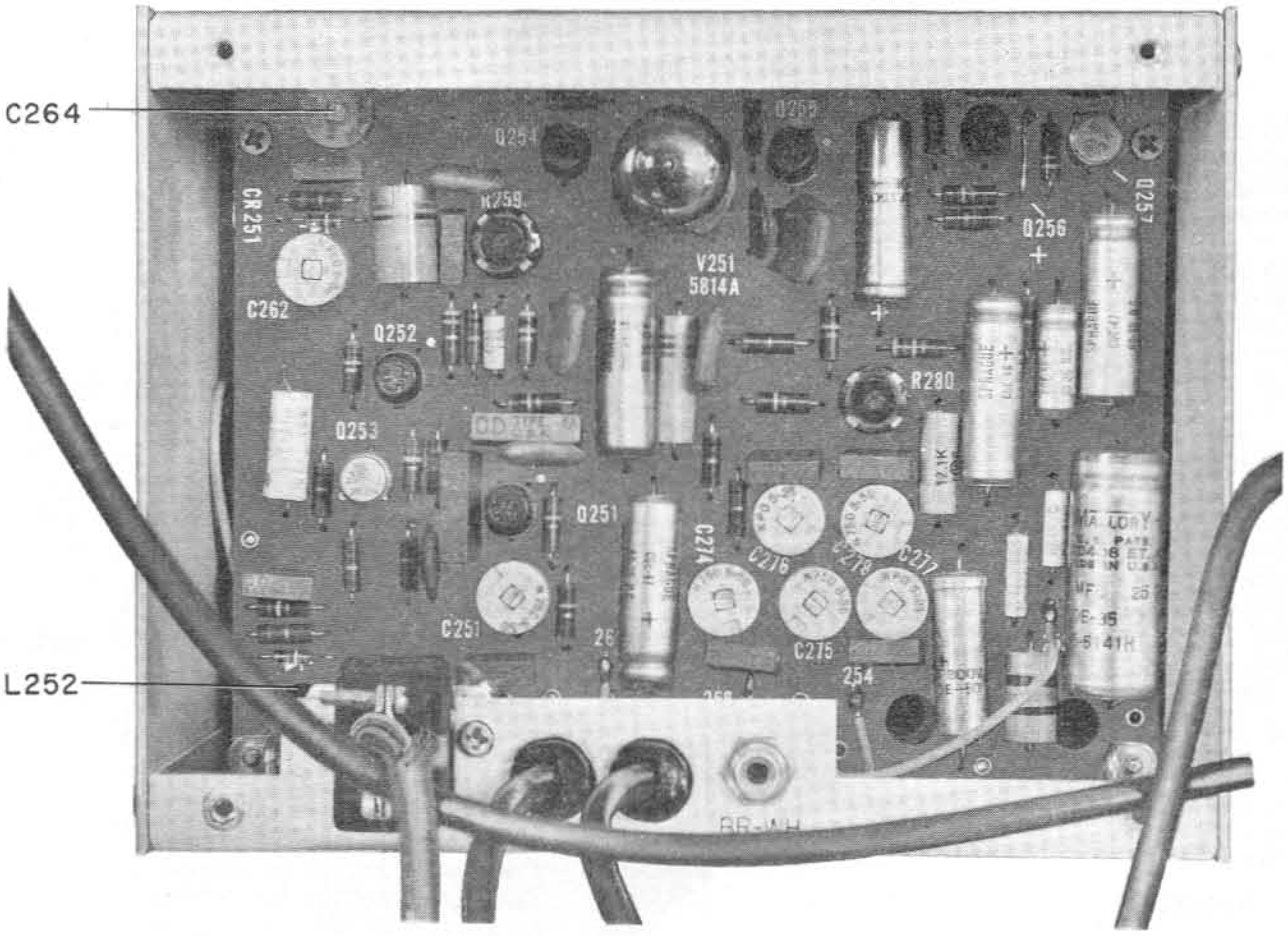


Figure 6-11. Tracking generator.

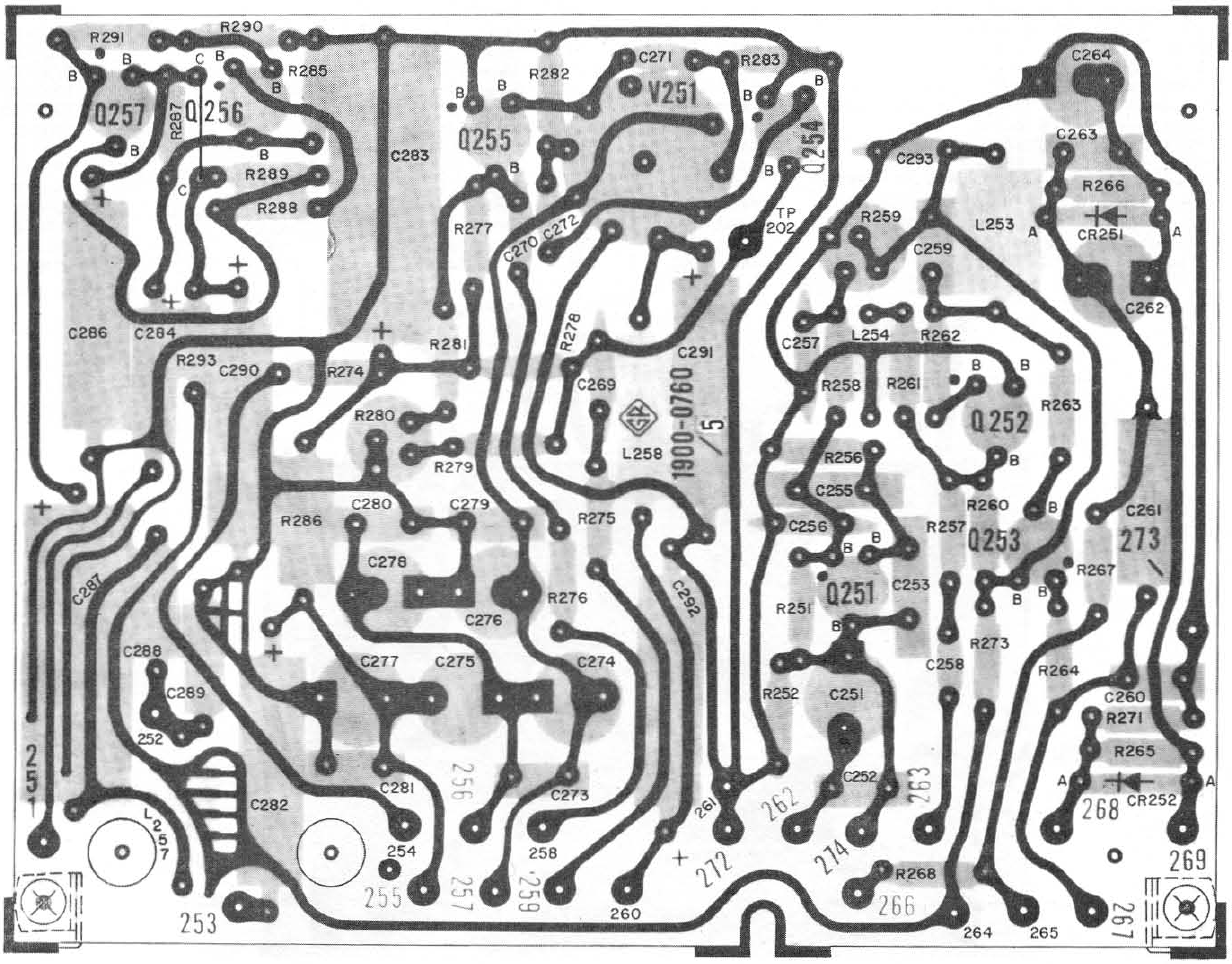
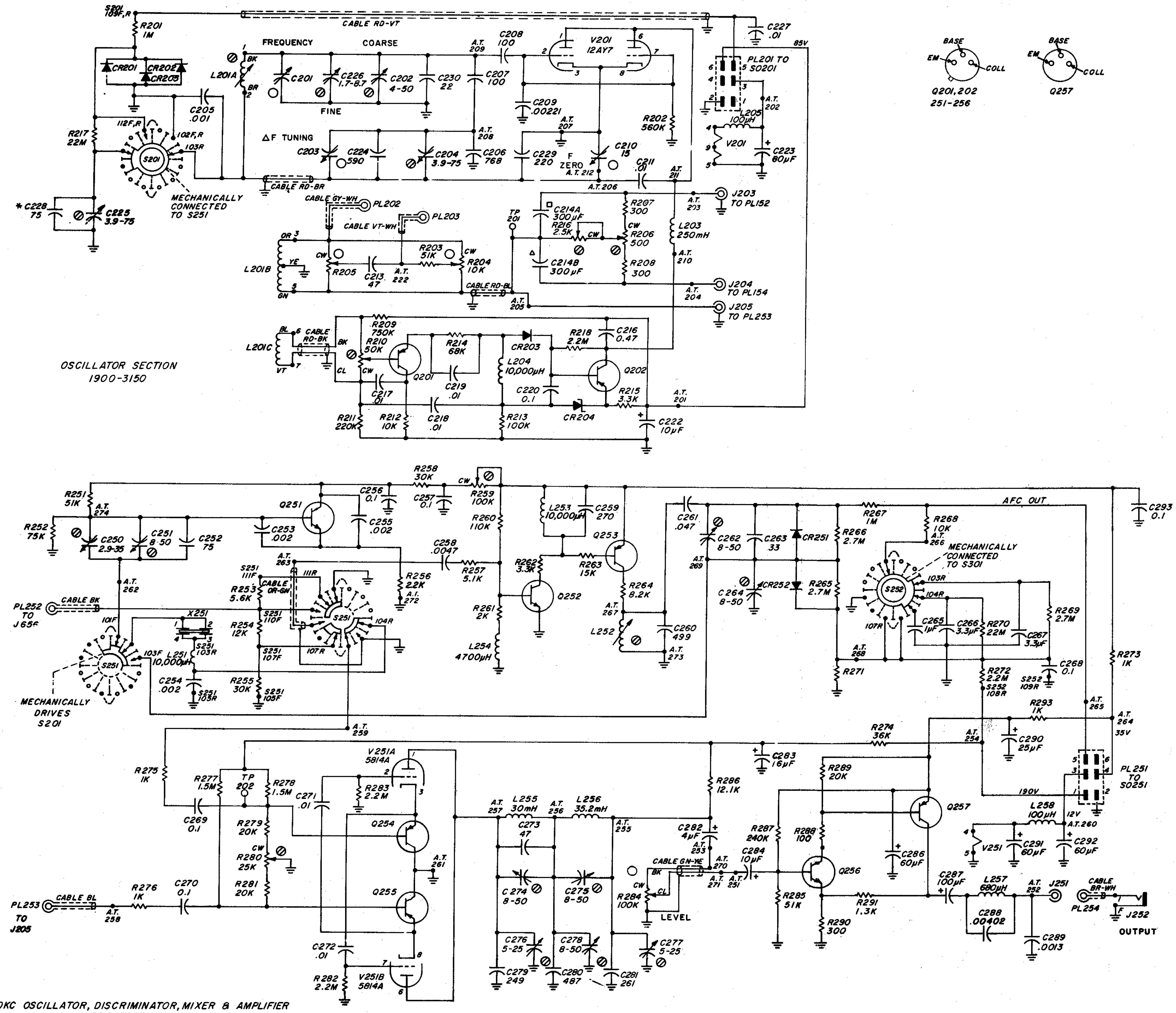
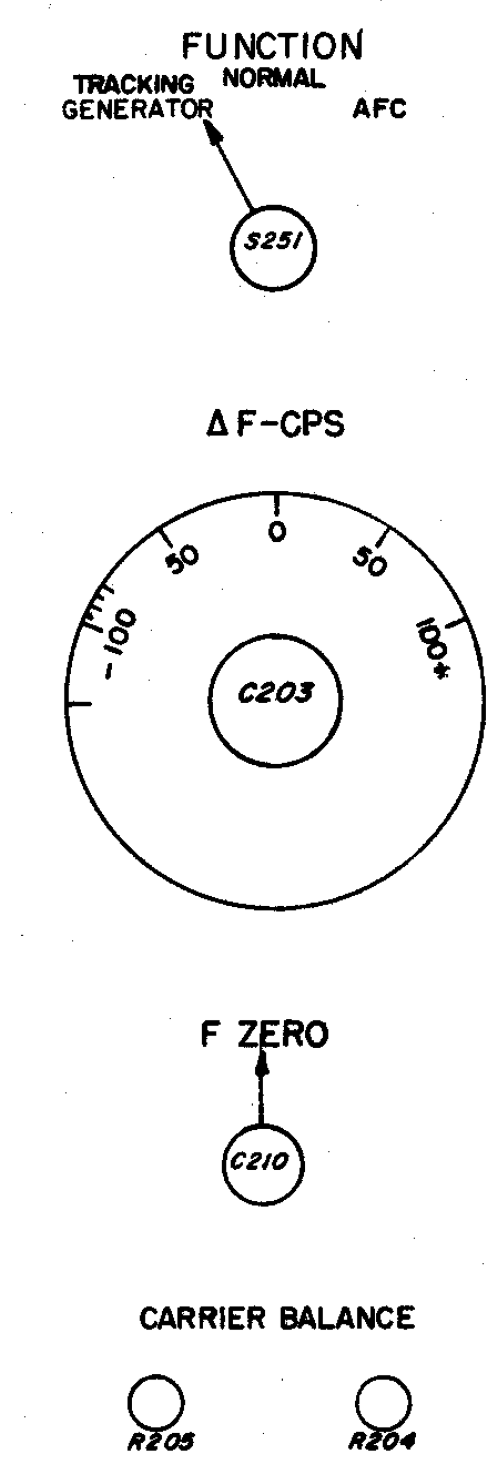


Figure 6-12. Etched-board layout for the tracking-generator and afc sections.





NOTE UNLESS SPECIFIED	
1. POSITION OF ROTARY SWITCHES SHOWN COUNTERCLOCKWISE.	5. RESISTANCE IN OHMS K = 1000 OHMS M = 1 MEGOHM
2. CONTACT NUMBERING OF SWITCHES EXPLAINED ON SEPARATE SHEET SUPPLIED IN INSTRUCTION BOOK.	6. CAPACITANCE VALUES ONE AND OVER IN PICOFARADS. LESS THAN ONE IN MICROFARADS.
3. REFER TO SERVICE NOTES IN INSTRUCTION BOOK FOR VOLTAGES APPEARING ON DIAGRAM.	7. ◯ KNOB CONTROL
4. RESISTORS 1/2 WATT.	8. ⊘ SCREWDRIVER CONTROL
	9. AT - ANCHOR TERMINAL
	10. TP - TEST POINT

ANCHOR TERMINALS USED: A.T. 201-212, 222, 251-274
TEST POINTS USED: TP201, TP202

Figure 6-13. Schematic diagram for the variable-oscillator, tracking-generator and afc circuits.

*VALUES TO BE ALTERED BY LAB IF NECESSARY

PARTS LIST FOR THE OUTPUT-AMPLIFIER CIRCUITS

REF NO.		PART NO.
	CAPACITORS	
C601	Ceramic, 0.1 µf +80-20% 50 v	4403-4100
C602	Ceramic, 0.1 µf +80-20% 50 v	4403-4100
C603	Ceramic, 0.1 µf +80-20% 50 v	4403-4100
C604	Ceramic, 0.1 µf +80-20% 50 v	4403-4100
C605	Electrolytic, 5 µf	4450-3900
C606	Ceramic, 0.1 µf +80-20% 50 v	4403-4100
C651	Ceramic, 0.1 µf +80-20% 50 v	4403-4100
C652	Ceramic, 0.1 µf +80-20% 50 v	4403-4100
C653	Ceramic, 0.1 µf +80-20% 50 v	4403-4100
C654	Plastic, 0.22 µf ±10% 100 v	4860-7981
C655	Electrolytic, 5 µf 50 v	4450-3900
C656	Ceramic, 0.1 µf +80-20% 50 v	4403-4100
C657	Ceramic, 0.1 µf +80-20% 50 v	4403-4100
C658	Mica, 220 pf ±10% 500 v	4700-0518
C659	Ceramic, 0.1 pf +80-20% 50 v	4403-4100
C660	Electrolytic, 5 µf 50 v	4450-3900
C661	Mica, .01 µf ±2% 500 v	4550-0102
C662	Mica, 680 pf ±5% 500 v	4680-2800
C663	Ceramic, .01 µf ±20% 500 v	4406-3109
C664	Ceramic, .01 µf ±20% 500 v	4406-3109
C665	Plastic, 1 µf ±10% 100 v	4860-8274
C666A C666B	Electrolytic, 1000 µf 3 v	4450-2450
C667	Electrolytic, 200 µf 12 v	4450-0400
C668	Mica, .00196 µf ±2% 500 v	4590-0825
C669	Electrolytic, 5 µf 50 v	4450-3900
C670	Electrolytic, 5 µf 50 v	4450-3900
	RESISTORS	
R601	Film, 61.2 Ω ±0.5% 1/2 w	6450-9612
R602	Film, 499 Ω ±1% 1/2 w	6450-0499
R603	Composition, 30 kΩ ±5% 1/2 w	6100-3305
R604	Composition, 10 kΩ ±5% 1/2 w	6100-3105
R605	Film, 30.1 kΩ ±1% 1/8 w	6250-2301
R606	Composition, 33 kΩ ±5% 1/2 w	6100-3335
R607	Film, 8.16 kΩ ±0.5% 1/2 w	6450-1816
R608	Film, 750 Ω ±1% 1/2 w	6450-0750
R609	Film, 1.74 kΩ ±1% 1/2 w	6450-1174
R610	Composition, 5.1 kΩ ±5% 1/2 w	6100-2515
R611	Composition, 1 kΩ ±5% 1/2 w	6100-2105
R612	Film, 6.34 kΩ ±1% 1/2 w	6450-1634
R613	Film, 777 Ω ±0.5% 1/2 w	6450-0777
R614	Film, 4.64 kΩ ±1% 1/2 w	6450-1464
R651	Composition, 30 kΩ ±5% 1/2 w	6100-3305
R652	Composition, 5.6 kΩ ±5% 1/2 w	6100-2565
R653	Potentiometer, Composition, 100 kΩ ±10%	6020-0700
R654	Potentiometer, Composition, 100 kΩ ±10%	6020-0700
R655	Film, 30.1 kΩ ±1% 1/2 w	6450-2301
R656	Composition, 10 kΩ ±5% 1/2 w	6100-3105
R657	Composition, 27 kΩ ±5% 1/2 w	6100-3275
R658	Composition, 2.4 kΩ ±5% 1/2 w	6100-2245
R659	Wire-wound, 560 Ω ±5% 2 w	6760-1565
R660	Film, 825 Ω ±1% 1/2 w	6450-0825
R661	Composition, 1.8 kΩ ±5% 1/2 w	6100-2185
R662	Composition, 1.6 kΩ ±5% 1/2 w	6100-2165
R663	Composition, 1 kΩ ±5% 1/2 w	6100-2105
R664	Composition, 3.9 kΩ ±5% 1/2 w	6100-2395
R665	Potentiometer, Composition, 1 kΩ ±20%	6040-0400
R666	Composition, 5.6 kΩ ±5% 1/2 w	6100-2565
R667	Composition, 12 kΩ ±5% 1/2 w	6100-3125
R668	Wire-wound, 180 Ω ±5% 2 w	6760-1185
R669	Wire-wound, 330 Ω ±5% 2 w	6760-1335
R670	Composition, 510 Ω ±5% 1/2 w	6100-1515
R671	Composition, 1.5 kΩ ±5% 1/2 w	6100-2155
R672	Film, 511 Ω ±1% 1/2 w	6450-0511
R673	Wire-wound, 75 Ω ±5% 2 w	6760-0755
R674	Potentiometer, Composition, 100 Ω ±20%	6040-0100
R675	Wire-wound, 560 Ω ±5% 2 w	6760-1565
R676	Wire-wound, 15 Ω ±10% 2 w	6760-0159
	MISCELLANEOUS	
CR651	Diode, 1N695	6082-1014
CR652	Diode, 1N695	6082-1014
CR653	Diode, 1N750	6083-1003
Q601	Transistor, 2N2188 (or 2N1395)	8210-1045
Q602	Transistor, 2N2188 (or 2N1395)	8210-1045
Q651	Transistor, 2N2188 (or 2N1395)	8210-1045
Q652	Transistor, 2N2188 (or 2N1395)	8210-1045
Q653	Transistor, 2N1373	8210-1373
Q654	Transistor, 2N1984	8210-1040
Q655	Transistor, 2N1311	8210-1025
J651	Jack	4260-0400
J652	Jack	4260-1500
J653	Jack	4260-1280
J654	Jack	4260-1280
J656	Jack	4260-1280
M651	Meter	5730-1310
PL601	Plug	1900-0302
PL602	Plug	1900-0302
PL603	Plug	1900-0302
PL651	Plug	1900-0309
PL652	Plug	1900-0305
S601	Switch	7890-2550
S651	Switch	7890-2530
S652	Switch	7890-2540
T651	Transformer	1900-2610
T652	Transformer	1900-2630

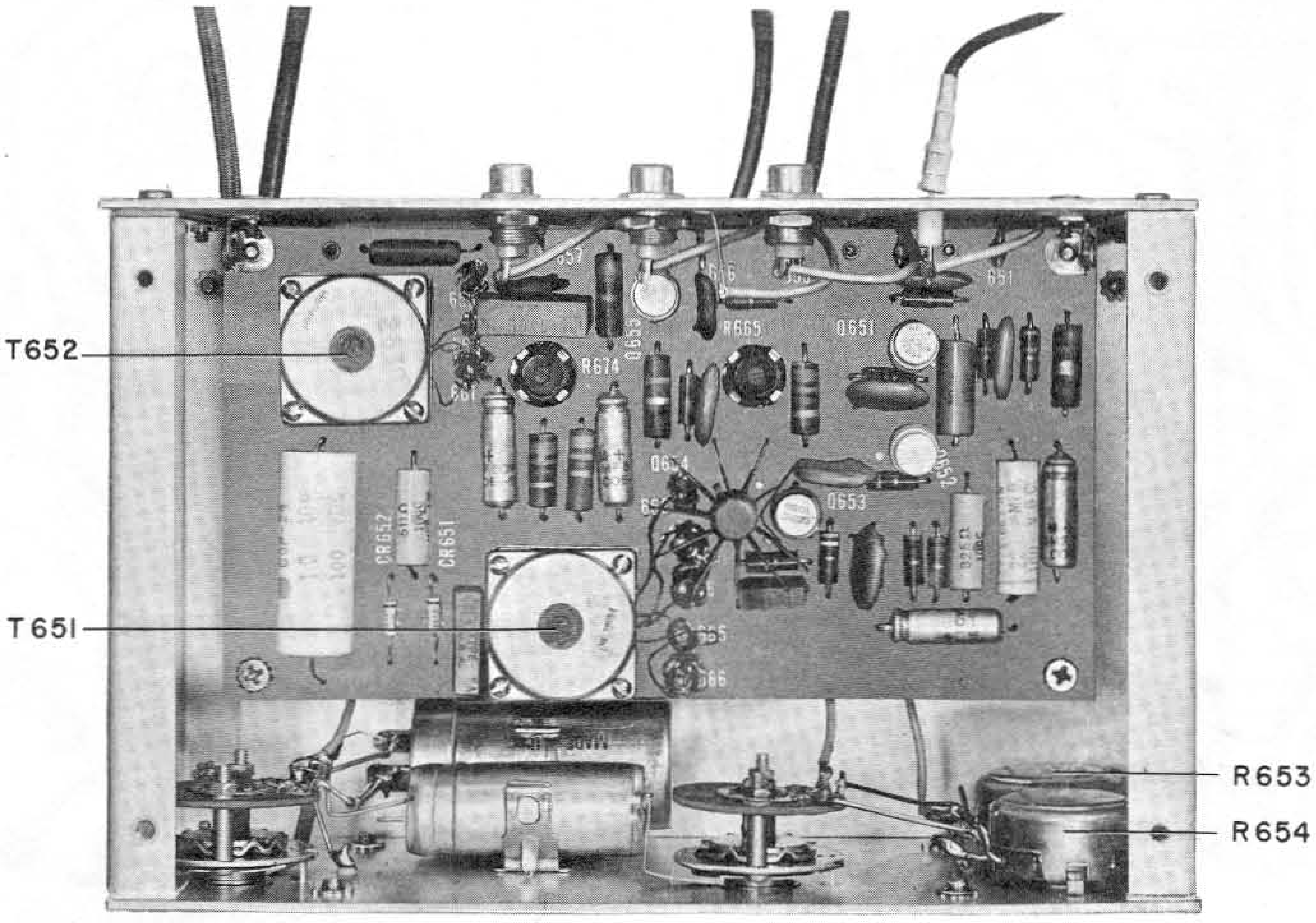


Figure 6-14. Output amplifier.

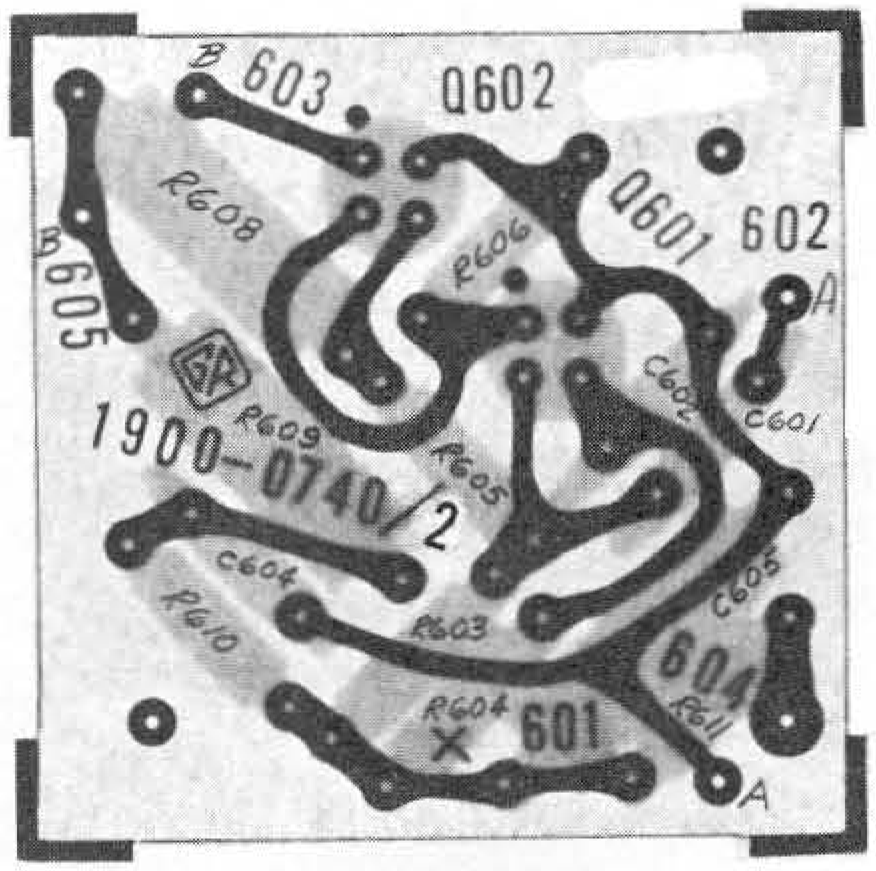


Figure 6-15. Etched-board layout for the 100-kc amplifier.

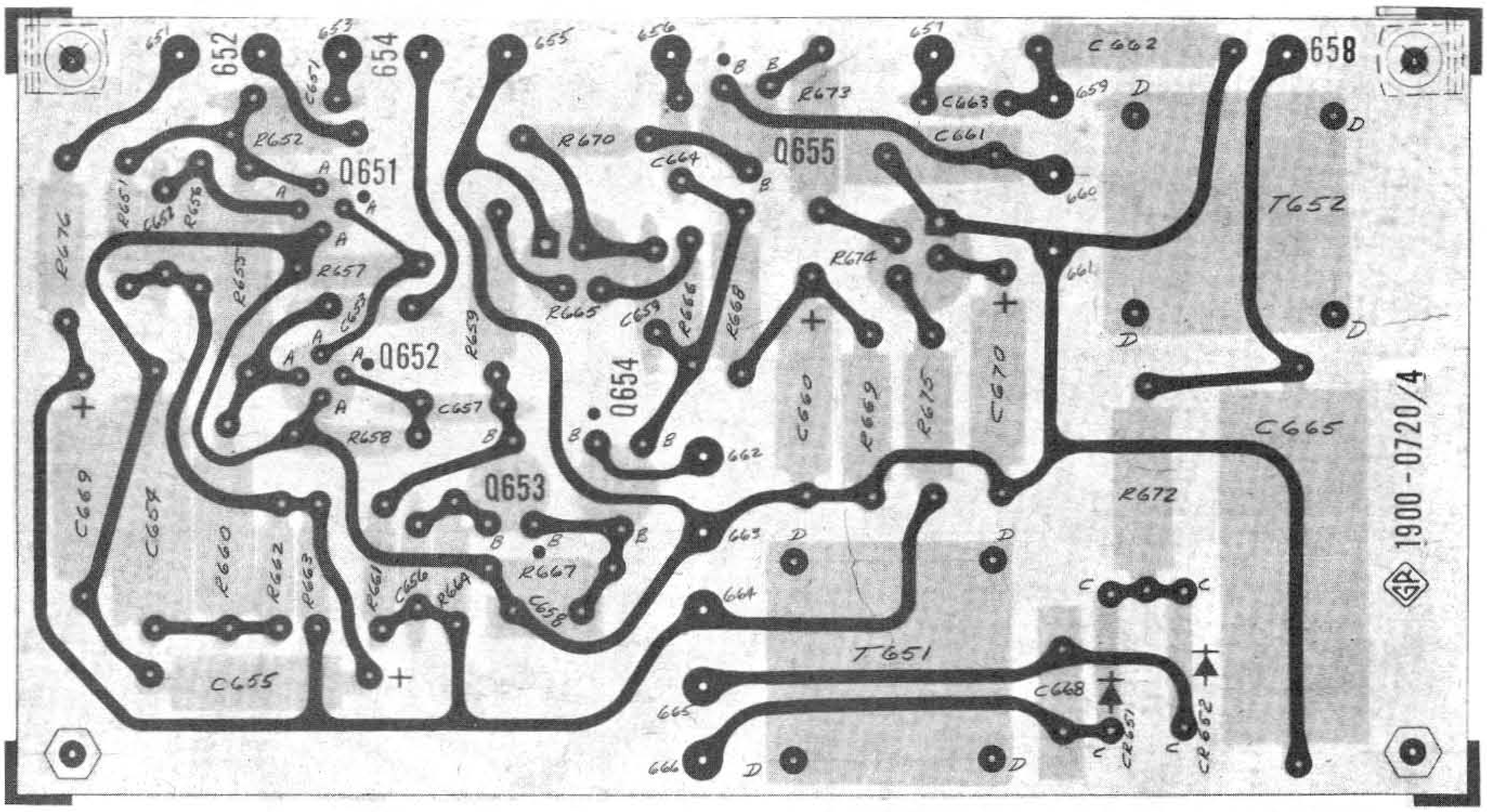
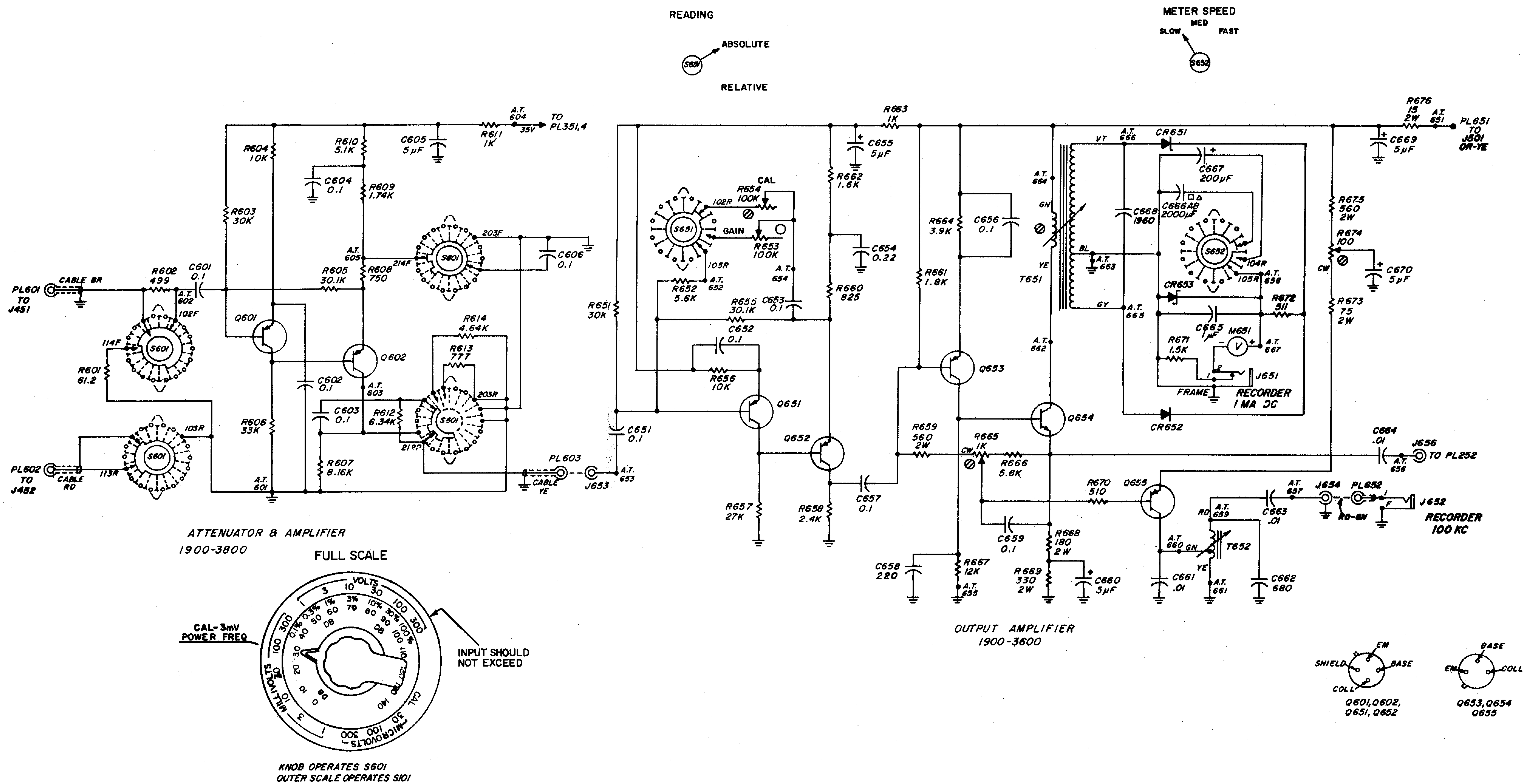


Figure 6-16. Etched-board layout for the output amplifier.



NOTE UNLESS SPECIFIED	
1. POSITION OF ROTARY SWITCHES SHOWN COUNTERCLOCKWISE.	5. RESISTANCE IN OHMS K - 1000 OHMS M - 1 MEGOHM
2. CONTACT NUMBERING OF SWITCHES EXPLAINED ON SEPARATE SHEET SUPPLIED IN INSTRUCTION BOOK.	6. CAPACITANCE VALUES ONE AND OVER IN PICOFARADS, LESS THAN ONE IN MICROFARADS.
3. REFER TO SERVICE NOTES IN INSTRUCTION BOOK FOR VOLTAGES APPEARING ON DIAGRAM.	7. ○ KNOB CONTROL
	8. ⊘ SCREWDRIVER CONTROL
4. RESISTORS 1/2 WATT.	9. AT - ANCHOR TERMINAL
	10. TP - TEST POINT

ANCHOR TERMINALS USED: A.T. 601-605, 651-667

Figure 6-17. Schematic diagram for the output-amplifier circuits.

PARTS LIST FOR THE CRYSTAL-FILTER CIRCUITS

FIRST SECTION

REF NO.		PART NO.
	CAPACITORS	
C302	Mica, .00237 ±2% 500 v	4590-0871
C303	Mica, .001 µf ±2% 500 v	4590-0690
C304	Mica, .001 µf ±2% 500 v	4590-0900
C305	Air, 3-32 pf	4380-3725
C306	Air, 3-32 pf	4380-3725
C307	Mica, 16 pf ±5% 500 v	4700-0210
C308	Mica, 10 pf ±5% 500 v	4700-0203
C309	Air, 3-32 pf	4380-3725
C311	Mica, 220 pf ±5% 500 v	4640-0700
C312	Mica, 820 pf ±5% 350 v	4680-3100
C313	Mica, 47 pf ±5% 500 v	4700-0247
C314	Air, 3-32 pf	4380-3725
C315	Mica, 27 pf ±5% 500 v	4700-0235
C316	Air, 3-32 pf	4380-3725
C317	Mica, 100 pf ±5% 500 v	4700-0660
C318	Ceramic, .0022 µf ±20% 500 v	4405-2229
C351	Ceramic, 0.1 µf +80-20% 50 v	4403-4100
C352	Ceramic, 470 pf ±20% 500 v	4404-1479
C353	Ceramic, .022 µf ±20% 500 v	4407-3229
C354	Ceramic, .01 µf ±20% 500 v	4406-3109
C355	Ceramic, .01 µf ±20% 500 v	4406-3109
C356	Ceramic, 0.1 µf +80-20% 50 v	4403-4100
C357	Electrolytic, 5 µf 50 v	4450-3900
C358	Ceramic, .01 µf ±20% 500 v	4406-3109
C359	Mica, 75 pf ±5% 500 v	4700-0375
C360	Ceramic, .01 µf ±20% 500 v	4406-3109
	RESISTORS	
R301	Composition, 27 kΩ ±5% 1/2 w	6100-3275
R302	Composition, 10 kΩ ±5% 1/2 w	6100-1105
R303	Potentiometer, Composition, 10 kΩ ±20%	6040-0600
R304	Potentiometer, Composition, 25 kΩ ±20%	6040-0800
R305	Potentiometer, Composition, 25 kΩ ±20%	6040-0800
R307	Composition, 15 kΩ ±5% 1/2 w	6100-3155
R308	Potentiometer, Composition, 25 kΩ ±20%	6040-0800
R309	Potentiometer, Composition, 25 kΩ ±20%	6040-0800
R310	Potentiometer, Composition, 10 kΩ ±20%	6040-0600
R311	Composition, 1 kΩ ±5% 1/2 w	6100-1105
R351	Composition, 100 kΩ ±5% 1/2 w	6100-4105
R352	Composition, 2.7 kΩ ±5% 1/2 w	6100-2275
R353	Composition, 470 kΩ ±5% 1/2 w	6100-4475
R354	Composition, 1.5 kΩ ±5% 1/2 w	6100-2155
R355	Composition, 27 kΩ ±5% 1/2 w	6100-3275
R356	Composition, 75 kΩ ±5% 1/2 w	6100-3755
R357	Composition, 4.7 kΩ ±5% 1/2 w	6100-2475
R358	Composition, 220 kΩ ±5% 1/2 w	6100-4225
R359	Composition, 15 kΩ ±5% 1/2 w	6100-3155
R360	Composition, 2 kΩ ±5% 1/2 w	6100-2205
R361	Composition, 1 kΩ ±5% 1/2 w	6100-2105
R362	Composition, 220 kΩ ±5% 1/2 w	6100-4225
R363	Film, 200 Ω ±1% 1/2 w	6450-0200
R364	Composition, 1 kΩ ±5% 1/2 w	6100-2105
	MISCELLANEOUS	
Q351	Transistor, 2N338	8210-1021
V351	Tube, 12AX7	8370-0900
L301	Inductor, 33 mh ±10%	4300-6391
L302	Inductor, 22 mh ±10%	4300-6393
L351	Inductor, 100 µh ±10%	4300-3500
PL301	Plug	1900-0301
PL351	Plug	4220-4400
S301	Switch	7890-2510
SO351	Socket	4230-0100
X301	Crystal	1900-2300
X302	Crystal	1900-2300

SECOND SECTION

REF NO.		PART NO.
	CAPACITORS	
C401	Air, 3-32 pf	4380-3725
C402	Mica, 16 pf ±5% 500 v	4700-0210
C403	Air, 3-32 pf	4380-3725
C404	Mica, 10 pf ±5% 500 v	4700-0203
C405	Air, 3-32 pf	4380-3725
C407	Mica, 200 pf ±5% 500 v	4640-0650
C408	Mica, 750 pf ±5% 500 v	4680-2900
C409	Air, 3-32 pf	4380-3725
C410	Mica, 36 pf ±5% 500 v	4700-0240
C411	Air, 3-32 pf	4380-3725
C412	Mica, 20 pf ±5% 500 v	4700-0228
C413	Mica, 100 pf ±5% 500 v	4700-0660
C451	Ceramic, .0022 µf ±20% 500 v	4405-2229
C452	Ceramic, 0.1 µf +80-20% 50 v	4403-4100
C453	Ceramic, 470 pf ±20% 500 v	4404-1479
C454	Ceramic, .01 µf ±20% 500 v	4406-3109
C455	Ceramic, .022 µf ±20% 500 v	4407-3229
C456	Ceramic, .01 µf ±20% 500 v	4406-3109
C457	Ceramic, .01 µf ±20% 500 v	4406-3109
C458	Ceramic, 0.1 µf +80-20% 50 v	4403-4100
C459	Ceramic, 0.1 µf +80-20% 50 v	4403-4100
C460	Ceramic, .01 µf ±20% 500 v	4406-3109
C461	Electrolytic, 5 µf 50 v	4450-3900
C462	Mica, 75 pf ±5% 500 v	4700-0375
	RESISTORS	
R401	Potentiometer, Composition, 25 kΩ ±20%	6040-0800
R402	Composition, 10 kΩ ±5% 1/2 w	6100-3105
R403	Potentiometer, Composition, 10 kΩ ±20%	6040-0700
R404	Potentiometer, Composition, 25 kΩ ±20%	6040-0800
R405	Potentiometer, Composition, 10 kΩ ±20%	6040-0600
R406	Potentiometer, Composition, 5 kΩ ±20%	6040-0600
R407	Potentiometer, Composition, 25 kΩ ±20%	6040-0800
R408	Potentiometer, Composition, 25 kΩ ±20%	6040-0800
R409	Potentiometer, Composition, 10 kΩ ±20%	6040-0600
R410	Composition, 2.4 kΩ ±5% 1/2 w	6100-2245
R411	Composition, 10 kΩ ±5% 1/2 w	6100-3105
R451	Composition, 470 kΩ ±5% 1/2 w	6100-4475
R452	Composition, 2.7 kΩ ±5% 1/2 w	6100-2275
R453	Composition, 100 kΩ ±5% 1/2 w	6100-4105
R454	Composition, 1 MΩ ±5% 1/2 w	6100-5105
R455	Composition, 75 kΩ ±5% 1/2 w	6100-3755
R456	Composition, 1.5 kΩ ±5% 1/2 w	6100-2155
R457	Composition, 220 kΩ ±5% 1/2 w	6100-4225
R458	Film, 1.87 kΩ ±.5% 1/2 w	6450-1187
R459	Film, 200 Ω ±1% 1/2 w	6450-0200
R460	Composition, 2 kΩ ±5% 1/2 w	6100-2205
R461	Composition, 62 kΩ ±5% 1/2 w	6100-3625
R462	Composition, 150 kΩ ±5% 1/2 w	6100-4155
R463	Composition, 4.7 kΩ ±5% 1/2 w	6100-2475
R464	Film, 8.16 kΩ ±0.5% 1/2 w	6450-1816
R465	Composition, 1 kΩ ±5% 1/2 w	6100-2105
R466	Composition, 1 kΩ ±5% 1/2 w	6100-2105
	MISCELLANEOUS	
Q451	Transistor, 2N338	8210-1021
V451	Tube, 12AX7	8370-0900
J451	Jack	4260-1280
J452	Jack	4260-1280
L401	Inductor, 33 mh ±10%	4300-6398
L402	Inductor, 22 mh ±10%	4300-6393
L451	Inductor, 100 µh ±10%	4300-3500
S401	Switch	7890-2520
X401	Crystal	1900-2300
X402	Crystal	1900-2300

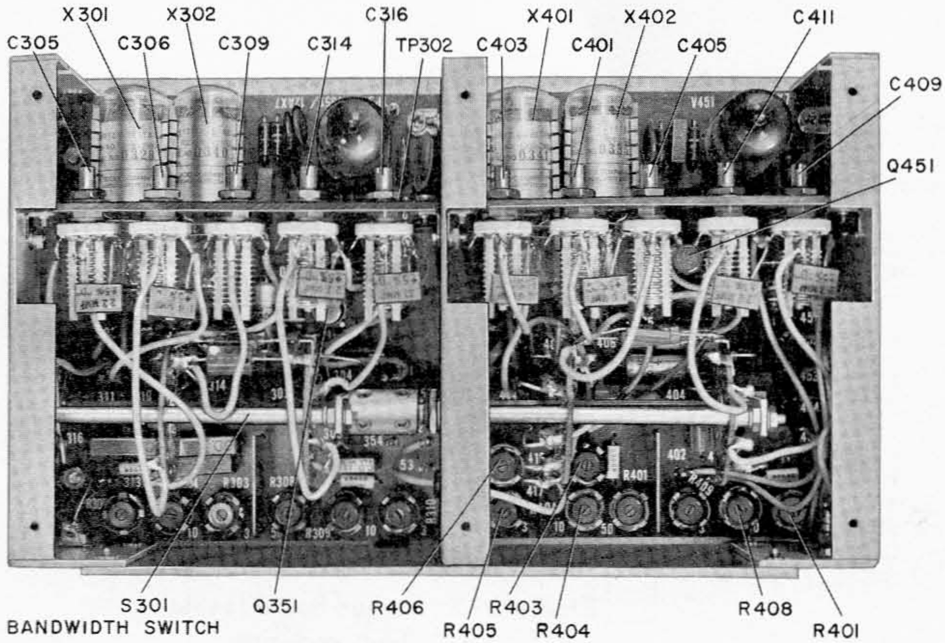


Figure 6-18. Crystal filter.

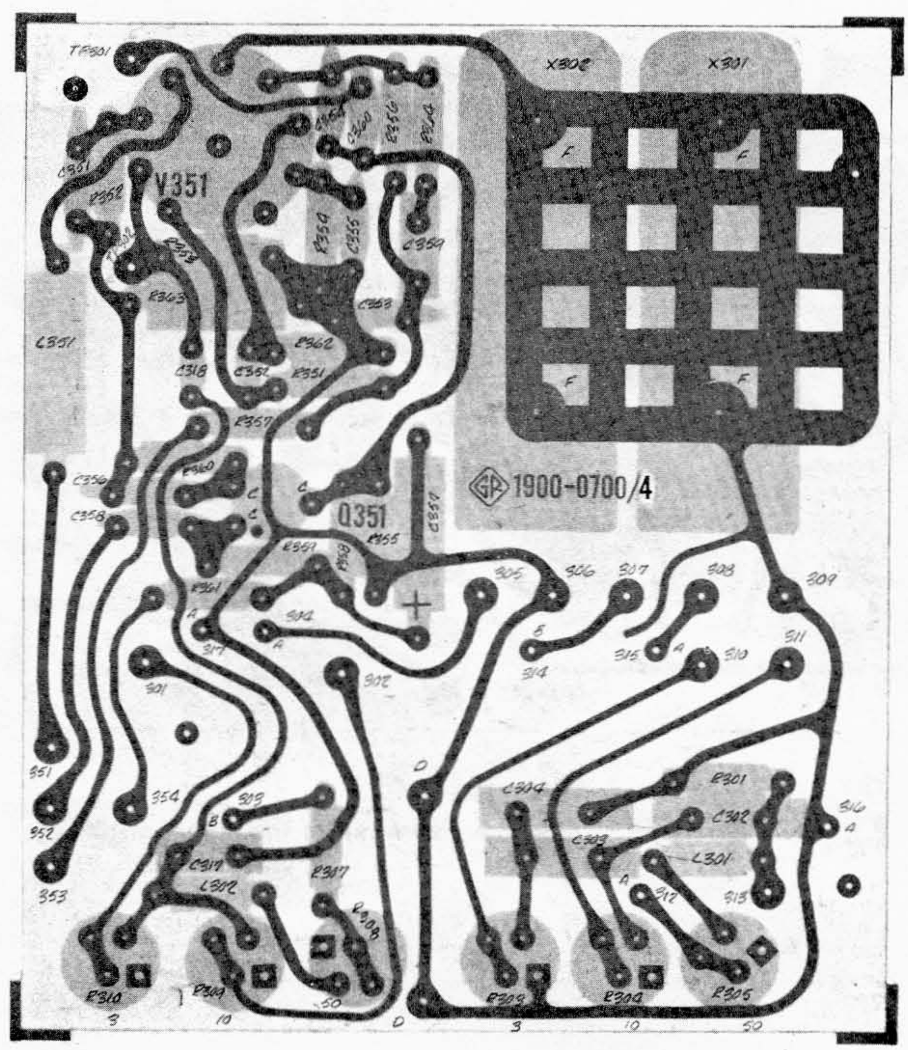


Figure 6-19. Etched-board layout for the crystal filter, first section.

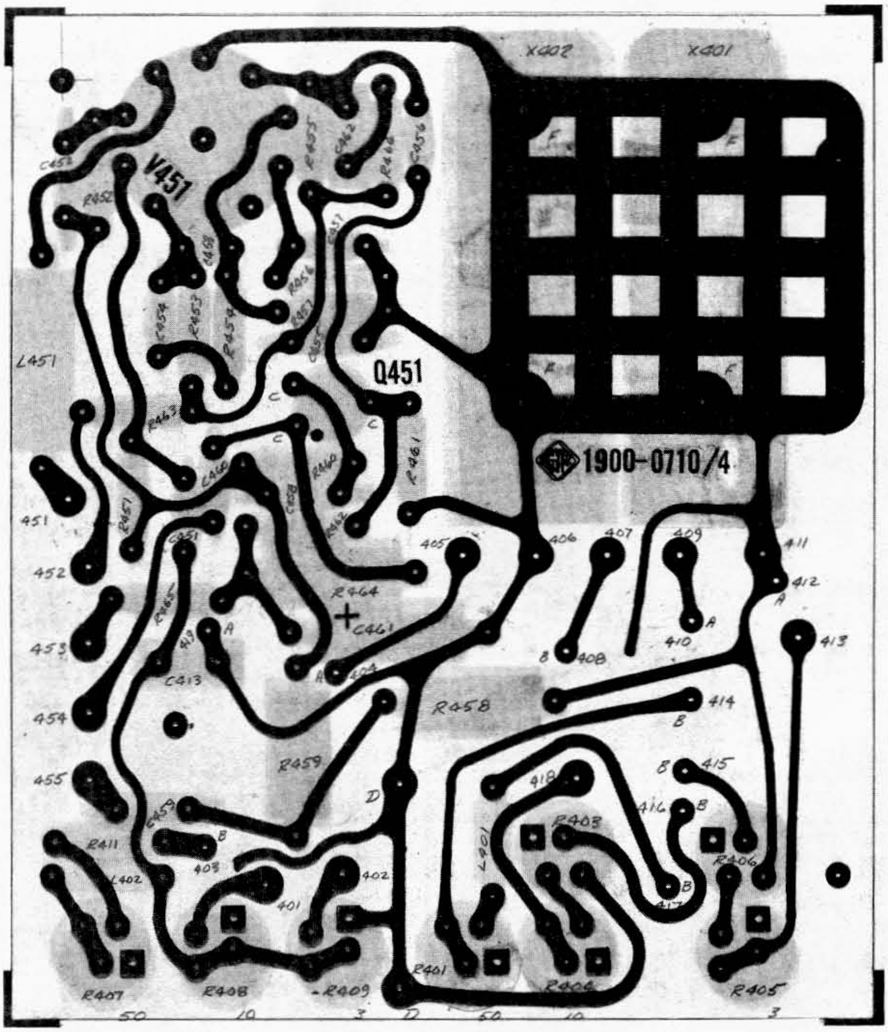


Figure 6-20. Etched-board layout for the crystal filter, second section.

SECOND IF AMPLIFIER

Figure 6-21. Schematic diagram for the crystal-filter circuits.

ANCHOR TERMINALS USED: A.T. 301-317, 351-354, 401-419, 451-455
TEST POINTS USED: TP301, 302

PARTS LIST FOR THE INPUT-SECTION CIRCUITS

REF NO.		PART NO.
	CAPACITORS	
C101	Ceramic, 12.1 pf ±2% 500 v	4400-3201
C102	Trimmer, 0.8-8.5 pf	4910-1100
C103	Trimmer, 0.8-8.5 pf	4910-1100
C104	Ceramic, 15 pf ±1% 500 v	4400-3301
C105	Ceramic, 16.9 pf ±2% 500 v	4400-3410
C106	Ceramic, 8 pf ±10% 500 v	4400-2980
C107	Ceramic, 0.47 pf ±10% 500 v	4400-1200
C150	Ceramic, 0.022µf ±20% 500 v	4407-3229
C151	Plastic, 0.1 µf ±10% 200 v	4860-8253
C152A C152B	Electrolytic, 15 µf 350 v	4450-3500
C153	Plastic, 0.47 µf ±10% 100 v	4860-8248
C154	Mica, 68 pf ±2% 500 v	4650-0119
C155	Mica, 68 pf ±2% 500 v	4650-0119
C157	Trimmer, 8-50 pf	4910-1170
C159	Trimmer, 8-50 pf	4910-1170
C160	Mica, 75 pf ±2% 500 v	4650-0160
C161	Trimmer, 8-50 pf	4910-1170
C162	Electrolytic, 10 µf 150 v	4450-3100
C163	Trimmer, 3-12 pf	4910-1130
C164	Plastic, 0.022 µf ±10% 200 v	4860-7855
C165	Electrolytic, 10 µf 150 v	4450-3100
C166	Trimmer, 1.5-7 pf	4910-1110
C167	Trimmer, 1.5-7 pf	4910-1110
C168	Plastic, 0.022 µf ±10% 200 v	4860-7855
C169	Electrolytic, 50 µf	4450-2200
C170	Electrolytic, 50 µf	4450-2200
C171	Ceramic, 0.01 µf ±20% 500 v	4406-3109
C172	Mica, 787 pf ±2% 500 v	4590-0570
C174	Electrolytic, 15 µf 15 v	4450-3700
C176	Ceramic, 0.01 µf ±20% 500 v	4406-3109
	RESISTORS	
R101	Film, 320 kΩ ±.5% 1/2w	6450-3320
R102	Film, 681 kΩ ±1% 1/2 w	6450-3681
R103	Film, 898 kΩ ±.5% 1/2 w	6450-3898
R104	Film, 100 kΩ ±1% 1/2 w	6450-3100
R105	Film, 965 kΩ ±.5% 1/2 w	6450-3965
R106	Film, 21.5 kΩ ±1% 1/2 w	6450-2215
R107	Film, 6.81 kΩ ±1% 1/2 w	6450-1681
R108	Film, 2.15 kΩ ±1% 1/2 w	6450-1215
R109	Film, 681 Ω ±1% 1/2 w	6450-0681
R110	Film, 316 Ω ±1% 1/2 w	6450-0316
R111	Film, 1.05 MΩ ±1% 1/2 w	6450-4105

REF NO.		PART NO.
R151	Composition, 2.2 MΩ ±5% 1/2 w	6100-5225
R152	Composition, 1.3 MΩ ±5% 1/2 w	6100-5135
R153	Composition, 2.7 MΩ ±5% 1/2 w	6100-5275
R154	Composition, 1 MΩ ±5% 1/2 w	6100-5105
R156	Composition, 15 kΩ ±5% 1/2 w	6100-3155
R157	Film, 10 kΩ ±1% 1/2 w	6450-2100
R158	Film, 24.9 kΩ ±1% 1/2 w	6450-2249
R159	Composition, 30 kΩ ±5% 1/2 w	6100-3305
R160	30 kΩ	0971-4170
R161	Composition, 30 kΩ ±5% 1/2 w	6100-3305
R162	Film, 24.9 kΩ ±1% 1/2 w	6450-2249
R163	Film, 20 kΩ ±1% 1/8 w	6250-2200
R164	Film, 10 kΩ ±1% 1/2 w	6450-2100
R165	Composition, 2.2 MΩ ±5% 1/2 w	6100-5225
R165	Composition, 2.2MΩ ±5% 1/2 w	6100-5225
R166	Composition, 2.2 MΩ ±5% 1/2 w	6100-5225
R167	Composition, 6.8 kΩ ±5% 1/2 w	6100-2685
R168	Composition, 62 kΩ ±5% 1/2 w	6100-3625
R169	Composition, 62 kΩ ±5% 1/2 w	6100-3625
R170	Composition, 6.8 kΩ ±5% 1/2 w	6100-2685
R171	Composition, 22 kΩ ±5% 1/2 w	6100-3225
R172	Composition, 3.9 kΩ ±5% 1/2 w	6100-2395
	MISCELLANEOUS	
Q151	Transistor, 2N338	8210-1021
Q152	Transistor, 2N338	8210-1021
V151	Tube, 12AY7	8370-0925
V152	Tube, 5814A	8380-5814
J101	Jack	4060-2400
J102	Jack	4060-1800
J103	Jack	4260-1280
J151	Jack	4260-1280
J152	Jack	4260-1280
J155	Jack	4260-1280
L151	Inductor, 30 mh	1900-2820
L152	Inductor, 48 mh	1900-2840
L153	Inductor, 33 mh ±10%	4300-6398
L154	Inductor, 33 mh ±10%	4300-6398
L155	Inductor, 100 µh ±5%	4300-6392
PL151	Plug	4220-4400
PL152	Plug	1900-0304
PL154	Plug	1900-0304
S101	Switch	7890-2560
SO151	Socket	
T151	Transformer	1900-2880

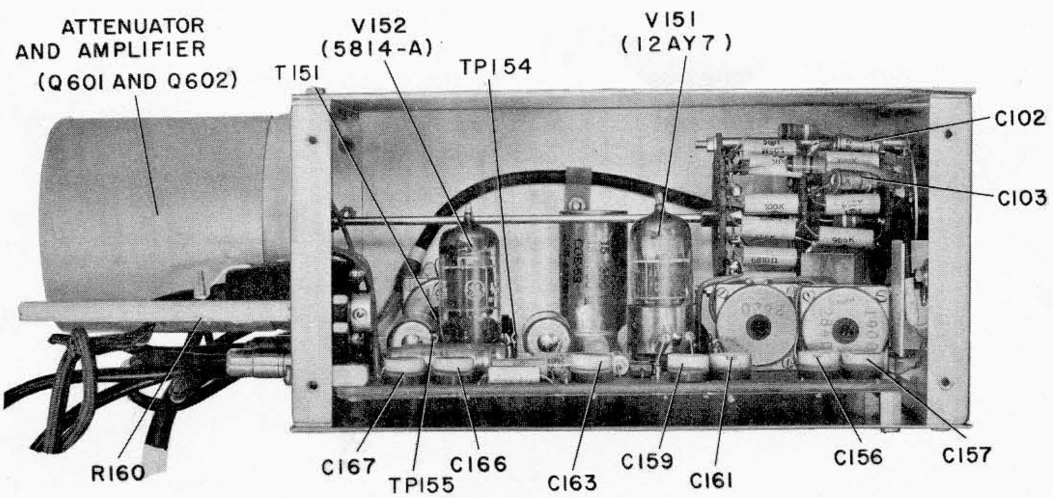


Figure 6-22. Input section.

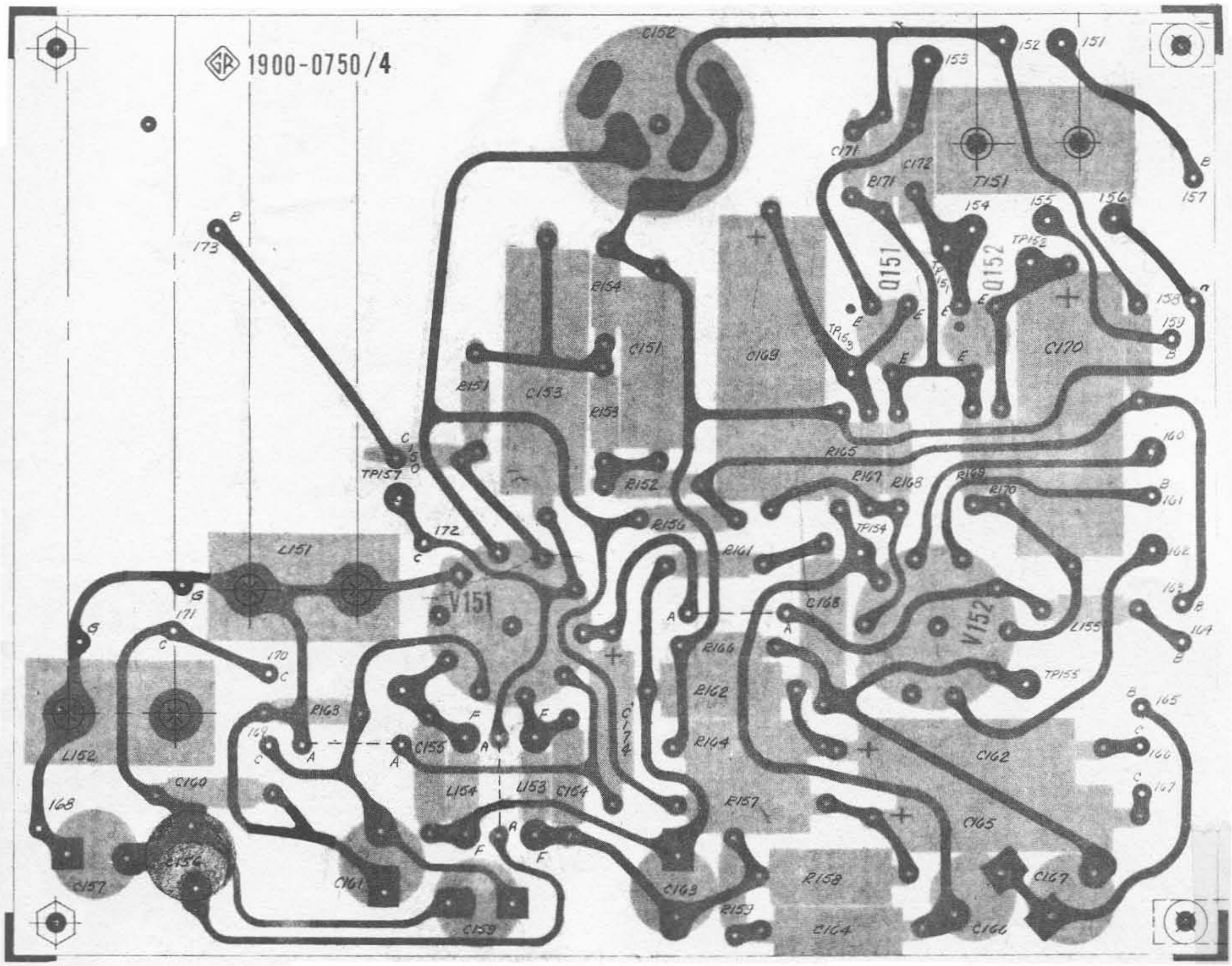
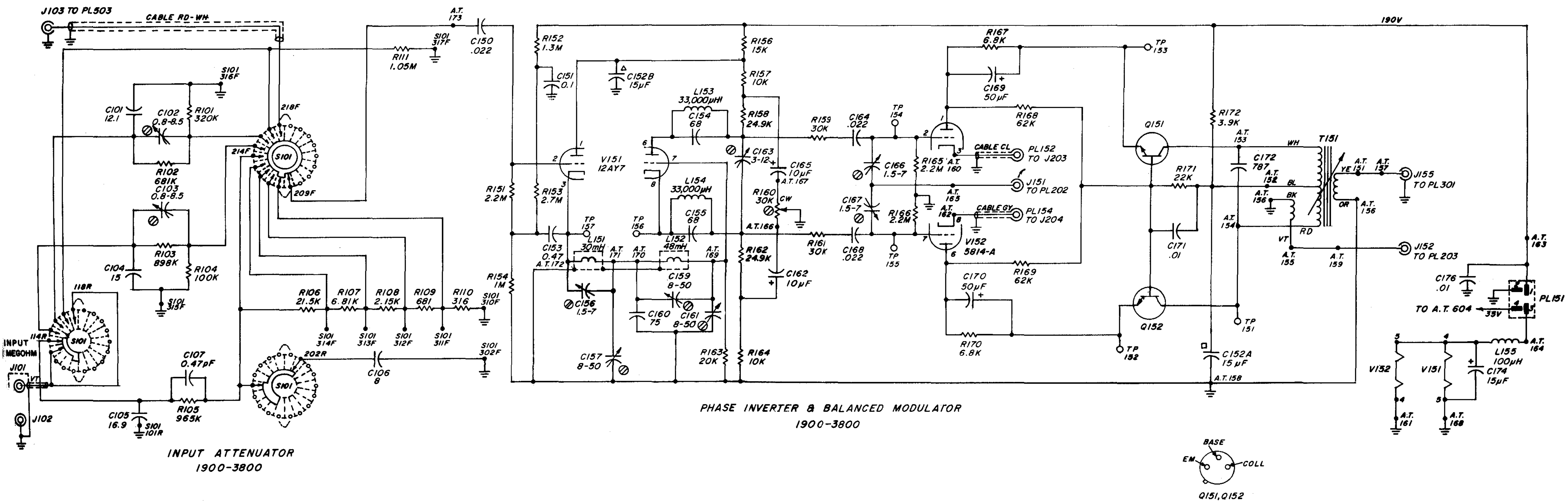


Figure 6-23. Etched-board layout for the input section.

NOTE UNLESS SPECIFIED

1. POSITION OF ROTARY SWITCHES SHOWN COUNTERCLOCKWISE.
2. CONTACT NUMBERING OF SWITCHES EXPLAINED ON SEPARATE SHEET SUPPLIED IN INSTRUCTION BOOK.
3. REFER TO SERVICE NOTES IN INSTRUCTION BOOK FOR VOLTAGES APPEARING ON DIAGRAM.
4. RESISTORS 1/2 WATT.
5. RESISTANCE IN OHMS K = 1000 OHMS M = 1 MEGOHM
6. CAPACITANCE VALUES ONE AND OVER IN PICOFARADS, LESS THAN ONE IN MICROFARADS.
7. ○ KNOB CONTROL
8. ⊘ SCREWDRIVER CONTROL
9. AT - ANCHOR TERMINAL
10. TP - TEST POINT

ANCHOR TERMINALS USED: A.T.151-173
TEST POINTS USED: TP151-157



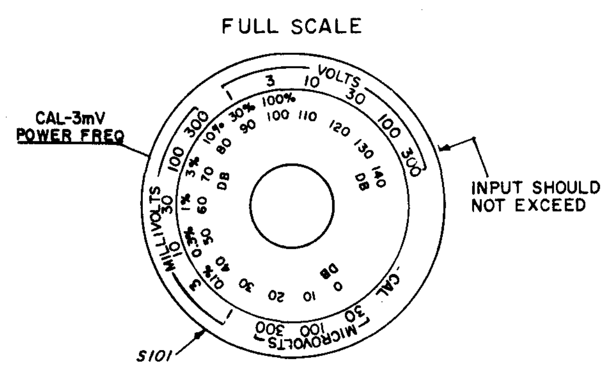


Figure 6-24. Schematic diagram for the input-section circuits.

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