INSTRUCTION MANUAL

Serial Number ____________

TYPE 491/R491

SPECTRUM ANALYZER

Tektronix, Inc.
S.W. Millikan Way ● P. O. Box 500 ● Beaverton, Oregon 97005 ● Phone 644-0161 ● Cables: Tektronix

070-0598-00 267

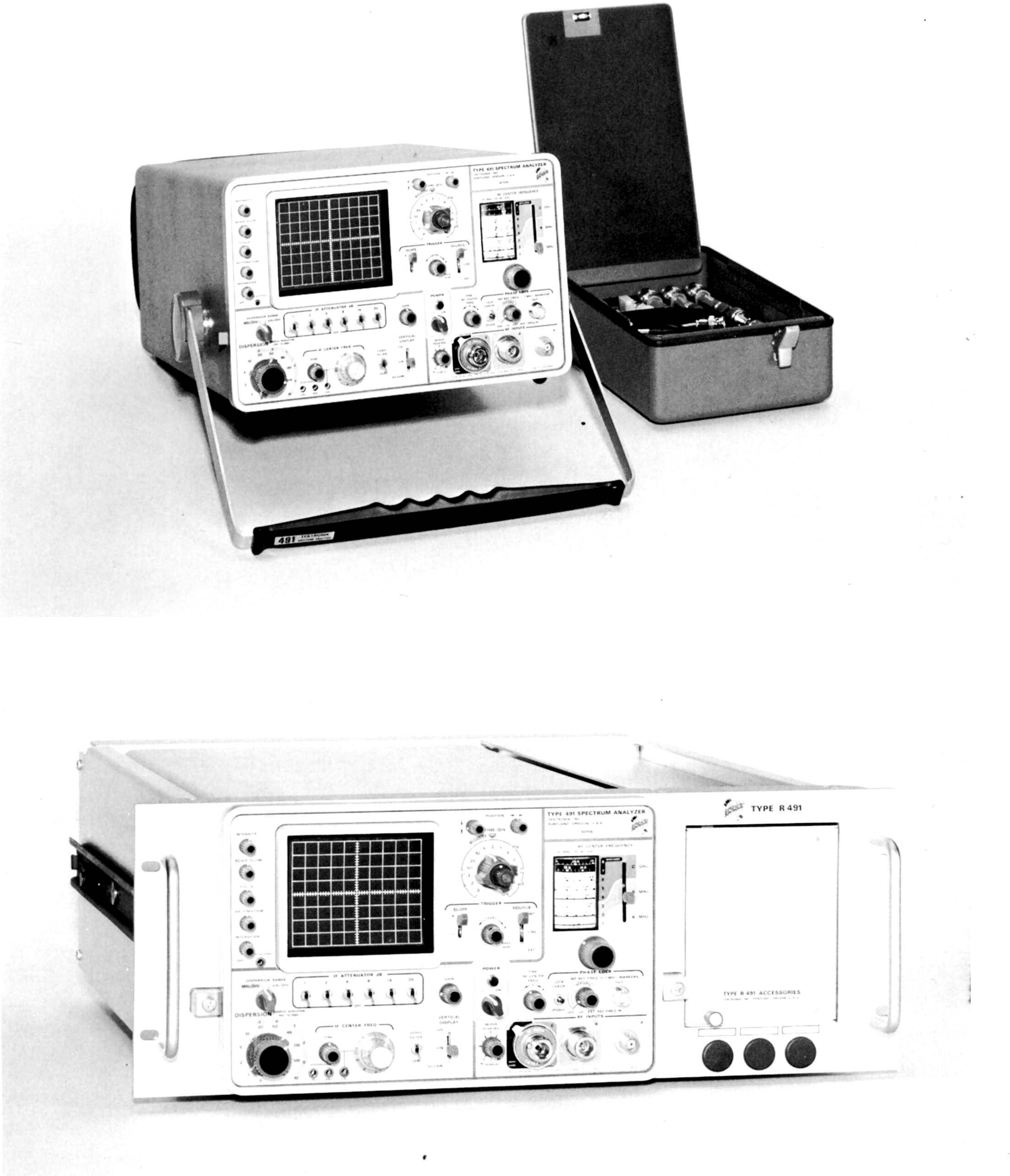


Fig. 1-1. The Type 491/R491 Spectrum Analyzer.

SECTION 1

CHARACTERISTICS

The Type 491 Spectrum Analyzer is a wide band, general purpose portable spectrum analyzer with an RF center frequency range from 10 MHz to 40 GHz. The analyzer displays signal amplitude as a function of frequency for a selected portion of the spectrum, Frequency is displayed along the horizontal axis (dispersion) and signal amplitude on the vertical axis of a self-contained system.

The following electrical characteristics apply at an ambient temperature of 25° C (±5°C) after an initial warmup period of approximately 20 minutes.

ELECTRICAL CHARACTERISTICS

Characteristic	Performance Requirement	Supplemental Information
RF Center Frequency Range	10 MHz to 40 GHz—See Table 1-1	
CW Sensitivity (S + N = 2 N)	See Table 1-1	
Dial Accuracy	Within ± (2 MHz +1% of dial reading)	IF CENTER FREQ central at 000, FINE IF CENTER FREQ control and FINE RF CENTER FREQ controls centered.

TABLE 1-1

Minimum CW Sensitivity (S + N = 2N)

Band and Scale	RF CENTER FREQUENCY	1 kHz RESOLUTION	100 kHz RESOLUTION	Supplemental Information
A-1	10-275 MHz	–100 dBm	–80 dBm	
B-2	275-900 MHz	–110 dBm	–90 dBm	
3	800-2000 MHz	–105 dBm	–85 dBm	
C-4	1.5-4.0 GHz	–110 dBm	–90 dBm	
5	3.8-8.2 GHz	–100 dBm	-80 dBm	50 Ω source impedance.
6	8.0-2.4 Ghz	–95 dBm	–75 dBm	
7	12.4-18.0 GHz	–90 dBm	–70 dBm	
8	18.0 -26,5 GHz	–80 dBm	-60 dBm	All voltages are RMS.
	26.5-40.0 GHz	–70 dBm	-50 dBm	

TABLE 1-2

DISPERSION/DIV		Remarks
Setting	Accuracy	
10MHz	±3% (±0.3 MHz/Div)	Over the ±25 MHz of the IF Center FREQ control except the 10 MHz/DIV position (± 10 MHz). The DISPERSION CAL adjust can be reset to improve the accuracy at a specific IF CENTER FREQ control setting by using the front panel 1 MHz CAL MARKERS OUT as a calibrated signal.
5 MHz	±3% (±0.15 MHz/Div)	
2 MHz	±5% (±0.1 MHz/Div)	
1 MHz	±7% (±70 kHz/Div)	
.5 MHz	±10% (±50 kHz/Div)	
.2 MHz	±15% (±30 kHz/Div)	Measured over the center 8 divisions of the graticule.

ELECTRICAL CHARACTERISTICS (cont)

Characteristic	Performance Requirement		Supplemental Information
Dispersion MHz/DIV RANGE Range	.2 MHz/Div to 10 MHz/Div		In a 1-2-5 seauence
Accuracy	See Table 1-2		
Linearity	±3% (over an 8 division display)		
kHz/DIV RANGE Range	1 kHz/Div to 500 kHz/Div in a 1-2-5 sequence and zero dispersion.		
Accuracy	±3% of each setting		Over the ±2.5 MHz range of the IF CENTER FREQ control. Measured over the center 8 divisions of the graticule.
Linearity	±3% (over an 8 divisions display)		
Resolution	≤1 kHz to ≥100 kHz; in 11 uncalibrated steps.		May be coupled with the DISPERSION control or switched separately.
IF Center Frequency Control Range"	IF CENTER FREQ	FINE	
1 kHz/DIV to 500 kHz/DIV Dispersion	≥(+ and – 2.5 MHz)	≥(+ and – 50 kHz)	
0.2 MHz/DIV to 5 MHz/DIV	≥(+ and – 25 MHz)	≥(+ and – 1 MHz)	
10 MHz/DIV	≥(+ and – 10 MHz)	≥(+ and – 1 MHz)	
IF Attenuation Range	0 to 51 dB		In combinations of 1, 2, 4, 8, 16 and 20 dB.
Accuracy	±0.1 dB/dB		
IF GAIN Control Range	≥50 d B		
Display Flatness with IF CENTER FREQ at 000	3 dB maximum amplitude variations from 10 MHz to 12.4 GHz. 6 dB maximum amplitude variations from 12.4 GHz to 40 GHz		Band 1 (10 MHz to 275 MHz) 50 MHz dispersion. Bands 2 through 8 (275 MHz to 40 GHz] 100 MHz dispersion.
Incidental FM IF	≤200 H z		Typically 100 Hz. Up to 400 Hz if power line frequency drops to 48 Hz.
IF + LO	≤300 Hz (at LO fundamental and with phase lock operation)		
Phase Lock Internal Markers	1 MHz ±0.1% (Control next to OFF position.)		
INT REF FREQ Range	At least 1 kHz but not more than 1.3 kHz above measured frequency with the INT REF FREQ control counterclockwise (next to OFF position.)		Instrument must be inside the dust cover.
Stability; Ref. Osc. (Short term FM)	≤1 port in 10^7.		
External Phase Lock Reference Input Frequency	1 MHz to 5 MHz		
Voltage	1 to 5 volts peak to peak.		
Display Functions Dynamic Range LOG	≥40 dB with 8 division display		
LIN	≥26 dB with 8 division display		
SQ LAW	≥13 db with 8 division display		
Maximum Input Power	-30 dBm for linear operation +15 dBm diode mixer, power limit		See Fig. 2-8

TIME BASE

Characteristic	Performance Requirement	Supplemental Information
RECORDER Output	≥4 mV per displayed division amplitude of signal in LIN made.	Rear panel connector
Sweep Range	10 μs/div to 0.5 s/div	In a 1, 2, 5 sequence
Sweep Accuracy	± 3 %	Measured within the center 8 divisions
VARIABLE Time/Div	≥2.5:1	An uncalibrated control provides continuously variable sweep rates from 10 μs/div to approximately 1.25 s/div.
Sweep Length	10.5 divisions ±0.2 div.	
Sawtooth Output	70 mV to 90 mV (P-P)	Rear panel connector

TRIGGERING

Trigger Sensitivity		
Internal	≤0.2 division, 20 Hz to 100 kHz	
External	≤0.2 volt, 20 Hz to 100 kHz	
Maximum Input Voltage	100 volts (DC + peak AC)	

POWER REQUIREMENTS

Input Voltage 115-volt range	LOW- 90 to 110 VAC MED- 104 to 126 VAC HIGH- 112 to 136 VAC	Line voltage ranges provide regulated DC voltages, when line contains less than 2% total harmonic distortion.
230-volt range	LOW- 180 to 220 VAC MED- 208 to 252 VAC HIGH- 224 to 272 VAC	
Line Frequency	48 to 440 Hz	
Input Power	55 watts maximum	

CATHODE RAY TUBE

Characteristic	Information
Tube Type	T4910-7-1
Phosphor	P7
Accelerating Potential	Approximately 3.75 kV
Graticule Type	internal
Area	8 divisions vertical by 10 divisions horizontal Each division equals 0.8 cm.
Illumination	Variable edge lighting
Unblinking	Deflection type, DC coupled

MECHANICAL CHARACTERISTICS

Construction	Alluminum-alloy chassis, panel and cabinet Glass laminate etched-circuit boards
Finish	Anodized panel, blue vinyl-coated cabinet
Overall Dimensions [measured at maximum points]	7¼" high, 12½" wide, 23½" long (includes panel cover and carrying handle)

ENVIRONMENTAL CHARACTERISTICS

The following environmental test limits apply when tested in accordance with the recommended test procedure. This instrument will meet the electrical performance requirements given in this section, following an environmental test.

Characteristic	Performance Requirement	Supplemental Information
Temperature		
Operating	-15° C to +55° C	Automatic resetting thermal cutout protects instrument from overheating.
Non-operating	-55° C to +75° C	
Altitude		
Operating	15,000 feet maximum	Altitude referred to sea level. Operating temperature capabilities decline 10 C per 1000 feet altitude above sea level.
Non-operating	50,000 feet maximum	May be tested during non-operating temperature test.
Humidity		
Non-operating	Five cycles (120 hours) of Mil-Std-202C, Method 106B	Exclude freezing and vibration.
Electromagnetic Interference (EMI)		
Radiated Interference	150 kHz to 1000 MHz	Tested within an electrically shielded enclosure with the CRT mesh filter installed. Within the limits described in MIL-I-6181D, Figs. 7, 8, 14 and 16.
Conducted Interference	150 kHz to 25 MHz	Conducted interference through the power cord.
Vibration		
Operating	Resonant searches along all 3 axes at 0.025 inches, frequency varied fram 10-55 c/s. All major resonances must be above 55 c/s.	Instrument secured to vibration platform during test. Total vibration time, about 55 minutes.
Shock		
Operating and non-operating	One shock of 30 G, one-half sine, 11 millisecond duration each direction along each major axis.	Guillotine-type shocks. Total of 12 shocks.
Transportation		
Package vibration	Meets National Safe Transient type of test when correctly packaged. One hour vibration slightly in excess of 1 G.	Package should just leave vibration surface
Package drop	30 inch (18-inches for R491) drop on any corner, edge or flat surface.	

SECTION 3
CIRCUIT DESCRIPTION

Introduction

The Type 491 Spectrum Analyzer is a swept IF type analyzer covering the frequency range from 10 MHz to 40 GHz. This section first presents a block diagram analysis, then a more detailed circuit description of each major section.

Basic Description

A block diagram of the Type 491 is shown in Fig. 3-1 and the Diagrams section.

Signals within the frequency range of the Type 491 that are applied to the RF INPUT are converted by the heterodyne process to the first intermediate frequency. This is a wide band IF of 150 MHz to 250 MHz. Three selectable local oscillators, in combination with selected mixers, provide the 10 MHz to 40 GHz frequency coverage for the instrument. A phase lock circuit locks the local oscillator to a stable (internal or external) reference frequency. This provides the required stability necessary for narrow dispersion displays.

One or two [depending on the selected bond) low pass filters (265 MHz and 235 MHz] plus the 150 MHz to 250 MHz bandpass filter between the first mixer and the wide band IF amplifier, attenuate and isolate local oscillator frequencies which would generate spurious signals when mixed with the second local oscillator frequency.

The wide band (150 MHz to 250 MHz) IF response is then swept, in the second mixer, by a swept frequency to generate a second IF of 75 MHz. The swept frequency rate of the oscillator is synchronized to the sweep rate so the CRT display becomes frequency based with a dispersion window that depends on how much the oscillator is swept.

Center frequency of the swept oscillator is 275 MHz. The amount the oscillator sweeps depends on the selected dispersion. At maximum dispersion the oscillator sweeps 225 MHz to 325 MHz, which converts all signals within the wide band IF to the second 75 MHz IF.

Calibrated attenuation is steps of 1 to 51 dB is provided by the IF attenuator, The signal is then amplified and applied to the 3rd mixer stage, where it is mixed with 70 MHz to produce a 3rd IF frequency of 5 MHz, The bandwidth of this 5 MHz IF is varied by means of the variable resolution circuit which provides resolution control from approximately 100 kHz to less than 1 kHz.

Video signals from the detector are amplified by the vertical amplifier, then applied to the CRT vertical deflection plates and to the trigger circuit for the sweep generator, provided the Trigger SOURCE selector is in the INT position. The sweep generator will free run, or it can be triggered from any one of three selectable sources; line, external and internal.

The signal from the sweep generator is applied to both the sweeper oscillator through the variable dispersion circuit and to the horizontal amplifier circuit for the horizontal sweep on the CRT. The horizontal CRT beam movement and the frequency scan in the 2nd mixer are therefore synchronized. This provides the calibrated dispersion and a linear display of the frequency spectrum on either side of the dial center frequency.

The 1st or tunable local oscillator is phase-locked to a stable crystal-controlled reference frequency by the phase locking circuit. This stabilizes the local oscillator frequency and permits narrow 1 kHz/div dispersion settings.

RF Section

The RF section contains three local oscillator assemblies, for each band, and their respective mixers. Two low-pass filters (235 and 265 MHz) are switched in series with the signal path between the band A mixer and the IF band-pass filter. Only the 265 MHz low-pass filter is used for bands B and C, The band selector switch SW70 selects the filters and connects only one oscillator circuit to the +150 volt supply, Only one oscillator is operating for a given band switch position. The 235 MHz low pass filter attenuates the low frequency end of the band A oscillator.

Heater voltage for the oscillators is supplied by the +10 volt regulated supply. Thus, oscillator frequency drift due to heater voltage variation is minimized. The heater supply line to V40 and V41 includes a series dropping resistor, R45 and R46, to reduce the voltage far these tubes to 6 volts.

Lossy cables (such as W10-W34, etc.) are used to reduce SWR caused by slight impedance mismatch between circuits. Impedance mismatches may be due to coaxial connectors or other discontinuities.

NOTE

Lossy cables use steel wire for the center conductor. These cables are factory-installed and used to optimize response flatness and sensitivity. The lossy cable is identified by the white insulation coating; the standard 50 W coaxial cable has the clear insulation. Do not interchange these cables.

Band A: The oscillator frequency for band A is 200 MHz above the RF input dial reading and has a tunable range of 210 to 475 MHz. The oscillator uses a ceramic planer triode. The tuned circuits are ganged together and tuned by the RF CENTER FREQUENCY control. Frequency tracking of the RF dial is adjusted by variable L and C trimmers, if required.

The band A local oscillator output is applied through a transmission line transformer T14, to the diodes or balanced section of the mixer. Adjustment of R13, C14 and C16 for balance greatly reduces local oscillator feed-through. The desired difference frequency is coupled to the IF amplifier through the 235 MHz filter.

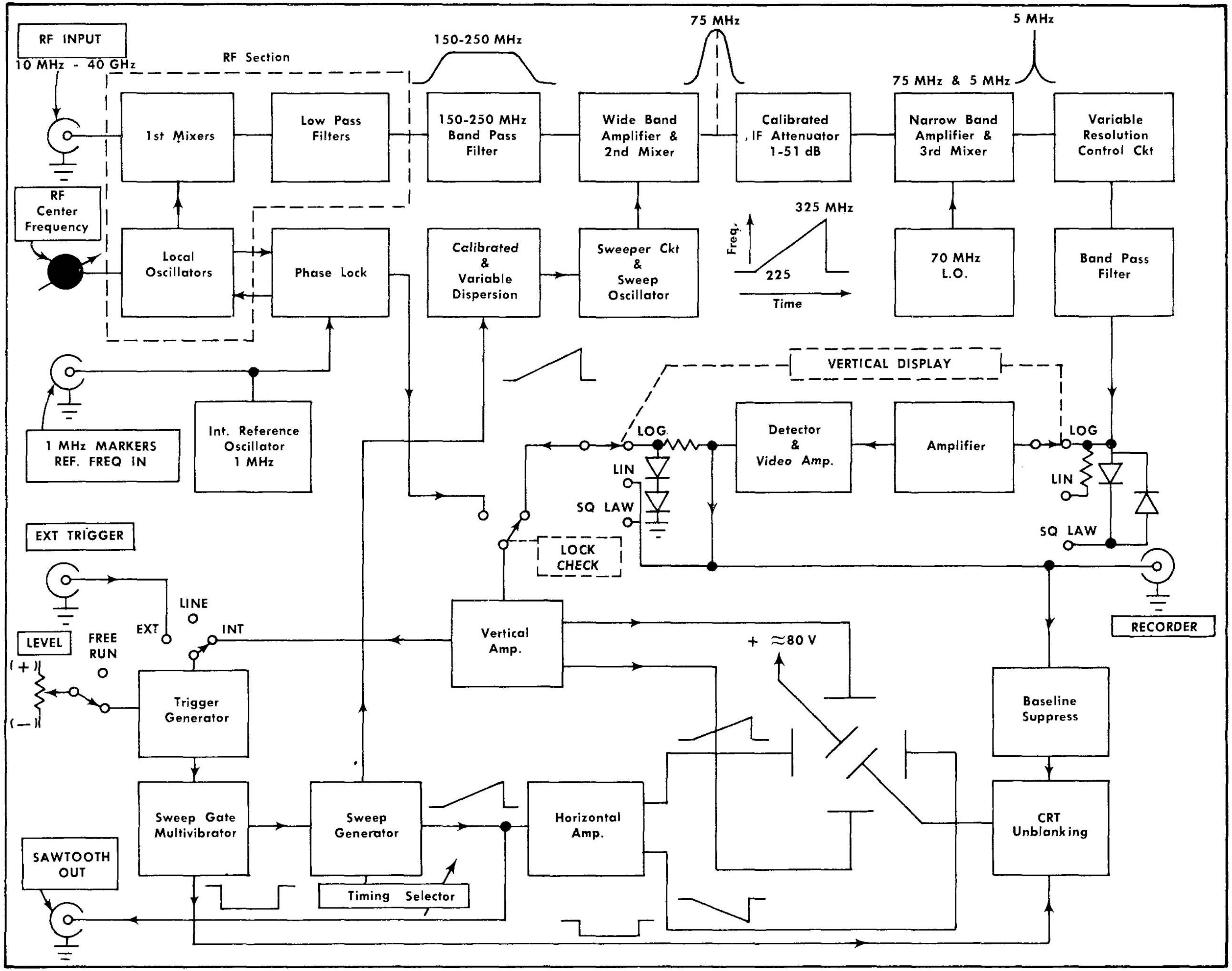


Fig. 3-1. Function block diagram of the Type 491.

Band B: The oscillator for band B is similar to band A oscillator. The fundamental frequency range 470 MHz to 1100 MHz and the 2nd harmonic of the oscillator is used for the frequency range 270 MHz to 2000 MHz for scales 2 and 3.

The mixer for this band is a crystal diode. Input RF is applied through a 1 dB isolation pad to the diode. C68, in series with R68, is tuned for response flatness. An RF choke L67, isolates the IF and provides a DC path for the MIXER PEAKING circuit.

Band C: The oscillator for band C is a triode oscillator connected to tunable transmission lines which are tuned by the RF CENTER FREQUENCY control. The oscillator fundamental frequency range is 1.7 GHz to 4.2 GHz. Harmonics through the 10th and the fundamental are used to heteradyne with the input RF to provide the input frequency range from 1.5 to 40 GHz.

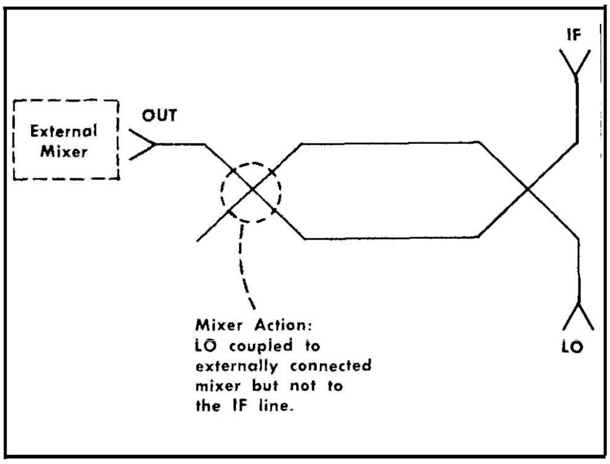


Fig. 3-2. Simplified equivalent of the hybrid directional coupler.

The oscillator output is applied to a hyrid directional coupler or diplexer; see Fig. 3-2. The diplexer couples the LO signal to the mixer port (OUT] and the mixer output to the IF port. The mixer action is therefore in an externally connected mixer, which may be either coaxial or waveguide, and the 200 MHz IF is then coupled through the diplexer to the IF connector.

The C band frequency range requires the following four mixers: One coaxial mixer for the frequency range 1.5 to 12.4 GHz, and three wave guide mixers with frequency ranges of 12.4 to 18 GHz, 18.0 to 26.5 GHz and 26.5 to 40 GHz.

The IF output is applied through a 1 dB attenuator pad and the 265 MHz law-pass filter. DC return for the mixer is through the 1 dB attenuator to the mixer peaking circuit. The mixer peaking circuit has two modes of operation, a search mode and a manual mode. In the search mode, the sweep voltage from the sweep generator circuit is applied to the base of Q65 and Q51. This varies the collector-to-emitter resistance and establishes a variable mixer diode current so that optimum mixer peaking is provided at some point through the sweep scan.

If the local oscillator is slowly tuned through a frequency range, signals above the specified sensitivity level will appear above the noise when they reach this optimum point. This ensures optimum search capability, and when a signal is intercepted, the operator then switches to manual tuning and optimizes the mixer for the given RF center frequency.

Phase Lock Circuit

The phase lack circuit synchronizes the local oscillator frequency with a stable reference frequency. This reduces oscillator drift and incidental frequency modulation, permitting narrow dispersion settings for signal analysis.

The phase detector samples the instantaneous RF voltage generated by the tunable local oscillator at a rate determined by the reference frequency. The sample voltages are then intergrated and applied to a comparator which generates a corrective voltage to feed back to the local oscillator.

When the local oscillator frequency is an exact multiple of the reference frequency, the phase detector output is a DC voltage that is proportional to the instantaneous potential of the sampled oscillator voltage. If the local oscillator phase drifts, the phase detector output changes. This change is amplified through Q1170-Q1180 and applied as a corrective voltage to a voltage-controlled capacitance diode in the oscillator tuned circuit. This shifts the phase of the oscillator so it remains lacked with the reference frequency. See Fig. 3-3.

The corrective signal from the comparator and amplifier is also applied to the vertical circuit when the LOCK CHECK button SW889 is depressed. This provides a beat frequency signal indication on the CRT so the operator can locate a lock point. Beat frequency displays appear on the CRT screen as the local oscillator is tuned (see Operating section). A reference voltage related to the position of the FINE RF CENTER FREQ control is also applied to the vertical deflection circuit and is used to center the error signal within the dynamic operating range of the comparator amplifier Q1170-Q1180. Phase lock operation should be set within the dynamic range of the amplifier, preferably in the center of the dynamic range. This dynamic range is visually displayed on the CRT as a vertical displacement of the display.

Circuit Analysis

Turning the INT REF FREQ control clockwise closes SW1106 so collector voltage is applied to Q1100. The crystal controlled 1 MHz oscillator will now operate. The output 1 MHz signal from the emitter of Q1110 is applied to the trigger generator circuit. Diodes D1122 and D1123 set the quiescent current through the tunnel diode D1124 and couple the signal to the 1 MHz MARKER OUT connector J1120; or, if an external reference signal is applied, they couple the signal to the trigger generator circuit.

Frequency of the reference oscillator Q1100 is primarily controlled by the crystal Y1104, inductor L1104, and the capacitance of diodes D1116 and D1117. Diode D1116 is back biased to act as a voltage-controlled capacitance diode; however, when signal amplitude across crystal Y1104 becomes excessive, D1116 will conduct on the peak signal swing. D1117 then becomes back biased and acts as the capacitance diode.

The back bias across D1116 is controlled by INT REF FREQ control R1106. This change in back bias increases or decreases the diode capacity and shifts the resonant frequency of crystal Y1104. The pulling range on the crystal frequency by the INT REF FREQ control is about 1 kHz. This is sufficient to maintain phase lock condition through frequency gaps that occur above 1 GHz when the oscillator shifts phase lock mode,

When the local oscillator shifts to a different lock mode, the fundamental frequency of the oscillator shifts 1 MHz. This produces frequency gaps in the upper scales which will shift the signal off screen with dispersions of 100 kHz/div or less. The INT REF FREQ control shifts the reference oscillator frequency about 0.1% (1 kHz). This shifts the local oscillator by the same percentage, so the frequency gaps between lock modes are filled. If the observed signal should shift off screen, it can be returned on screen or slid along the display by the INT REF FREQ control.

The pulse generator consists of tunnel diode D1124, driving amplifier Q1120. The quiescent current of tunnel diode D1124 is approximately 2.5 mA. The positive-going portion of the input reference signal switches the tunnel diode to its high state and a fast rise positive pulse is generated. The pulse is amplified and differentiated by Q1120 and the short RC time constant in the emitter circuit.

The output pulse of Q1120 is transformer coupled through T1128 to Q1121. The positive portion of the coupled pulse is of sufficient amplitude to trigger Q1121 into avalanche, and the resulting collector current sweeps out the stored charge of diodes D1134 and D1139. When the charge has dissipated, the diodes generate a fast recovery step. This recovery step is differentiated and coupled through transmission line transformer T1140, T1150 and T1160 to the phase detector as a series of equal amplitude positive and negative strobe pulses.

The phase detector (Fig. 3-4) consists of a two diode gate and a low pass filter network. The diode gate is turned on by the combined application of the local oscillator signal and the very narrow strobe pulses, During the on time, the phase detector samples the amplitude and phase of the local oscillator signal and develops a voltage at the output of the filter (C, and the junction of R_1, R_2) that approximately equals the instantaneous value of the local oscillator signal.

The sample of the local oscillator signal has a finite width determined by the duration of the strobe pulse. The phase detector operates on either the positive or negative slope of the local oscillator signal, depending on the total difference between the detector output voltage and the phase of the local oscillator signal. The strobe pulse width, therefore, must not exceed one-half period of the highest local oscillator input frequency, which is 4.2 GHz. This period is 0.21 ns.

If the input local oscillator frequency is not a harmonic of the reference frequency, the output of the phase detector is approximately zero. However, as the local oscillator frequency approaches a harmonic of the reference frequency, an AC or beat frequency signal is developed at the detector output. This is amplified and applied through the LOCK

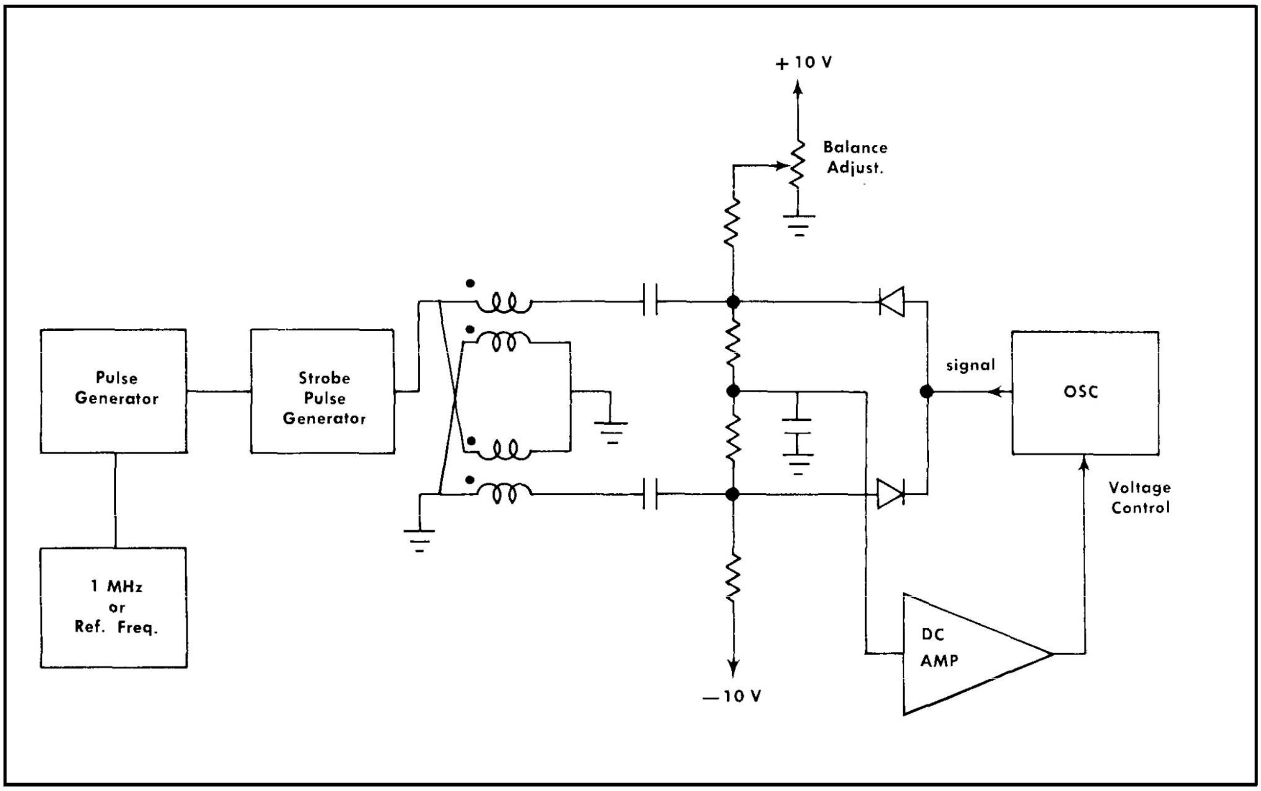


Fig. 3-3. Phase lock block diagram.

CHECK switch to the vertical deflection system. At zero beat, the output signal amplitude snaps to a minimum and the circuit locks the local oscillator to the reference frequency by feeding a corrective voltage to a Varactor diode in the oscillator circuit.

FINE RF CENTER FREQ control R1182 tunes the local oscillator over a limited range by changing the DC output level of Q1180. When the circuit is in a lock condition, any small shift of the FINE RF CENTER FREQ control is counteracted by the phase lock circuit. If the control is further moved the circuit will lose the lock and the oscillator will jump to a different frequency lock point. This jump in frequency is easily seen as a shift in signal position at dispersion settings of 500kHz/div or less,

An isolation switch is used to minimize the loading affect of the lower band (A & B) phase detectors on the band C phase detector. The junction at diodes D1170 and D1174 is returned, through a filter network and the Band selector switch SW70, to +150V. The diodes are forward biased when the Band selector switch is in the A or B position. When the switch is changed to the C position, the diode switch is open.

Band C Bal and Bands A & B Bal adjustments correct any imbalance between the phase detectors so the DC output level of the amplifier remains balanced as the Band selector is switched between bands. The FINE RF CENTER FREQ control must be centered for this adjustment.

Sweeper Circuit

This circuit (see Fig. 3-5) provides a swept frequency, centered at 275 MHz, to the wide band mixer amplifier. The swept frequency amplitude is constant and the dispersion can be varied from about O Hz to 100 MHz.

A positive-going sawtooth voltage from the sweep generator circuit is applied through pin AE to the emitter of Q200. Q200 is configured as a long-tail amplifier. It converts the sawtooth voltage input signal to a linear current ramp, which is applied through the DISPERSION attenuator to one side of comparator amplifier Q220-Q230.

The output DC level of the current ramp from Q200 is set by Sweep Center adjustment R203. Dispersion CAL adjustment R208, shunts the dispersion attenuator. It calibrates the dispersion for the 10 MHz/div position of the DISPERSION selector by adjusting the output amplitude of the current ramp from Q200. The remaining positions the selector are then within instrument specifications.

Two dispersion ranges (MHz/DIV and kHz/DIV) are provided by the DISPERSION RANGE selector R210, which selects a different range of resistance values for each position of the DISPERSOIN selector.

Sweep Comparator. The sweep comparator containing Q220 and Q230 compares the current ramp from the dispersion attenuator against a current ramp applied to the base of Q230. The signal applied to the base of Q230 is the

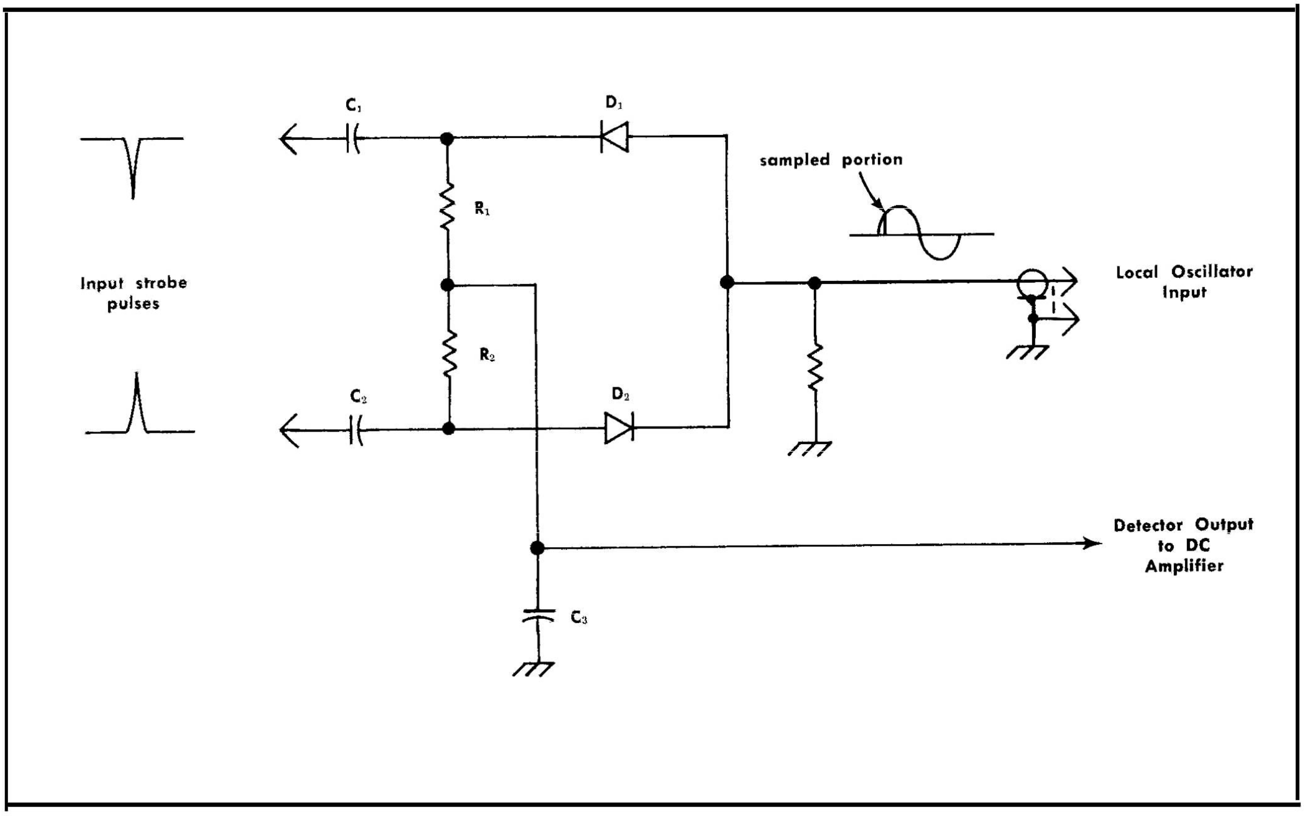


Fig. 3-4. Simplified phase detector circuit.

resultant feedback signal from a frequency to voltage converter and ramp generator. Any differential between the two signals is a voltage output that controls the bias on frequency-determining capacitance diode D314. D314 is part of the swept oscillator circuit which shifts the swept oscillator frequency by an amount proportional to the signal output from the comparator.

Q240 is the constant current source for the sweep comparator. About 3.4 mA of current through the comparator is set by the bias of Q240. Output DC level at the collector of Q230 is set by the IF Center Freq Range adjustments in the collector circuit of Q260.

Sweep Oscillator. The oscillator frequency is primarily a function of the L (L314) and C (diode D314 in series with blocking capacitor C314) in the collector circuit of Q310. Capacitance of diode D314 is varied by the signal from comparator Q230-Q220. An increase in back bias decreases the capacitance of the diode and increases the frequency of the swept oscillator. Capacitance change of the diode is not proportional to the voltage ramp, but high gain in the discriminator feedback loop to the comparator reduce this non-linearity. At maximum dispersion, the oscillator sweeps from 225 MHz to 325 MHz.

Output signal from the oscillator is tapped across the partial winding of L314 and capacitively coupled to transformers T330 and T331. The transformers step the voltage up about 2:1 and converts the single-ended signal to a balanced push-pull drive signal for the output amplifier Q340 and Q350.

Fig. 3-6 is a simplified drawing of the transformer circuit. The oscillator is the signal source or generator which supplies the signal voltage (e). The input windings of T330 and T331 are connected in series; therefore, the voltage across each winding equals e/2 (assuming an ideal transformer). The polarity of the signal at a particular instant of time is shown in Fig. 3-6. This voltage, across the input windings, produces an equal voltage (e/2) across the output windings with the polarity as indicated in Fig. 3-6.

The generator, or source, is in series with the output winding for T331, therefore, the voltage ot the output with reference to point A equals 3e/2. This voltage adds to the voltage output of T330 to provide a total output signal of 4e/2 or 2e.

If the reference point is changed to the common side of the input windings of T330 and T331 (shown os a phantom ground on the simplified drawing) the impedance looking into the output terminals of the transformers is balanced,

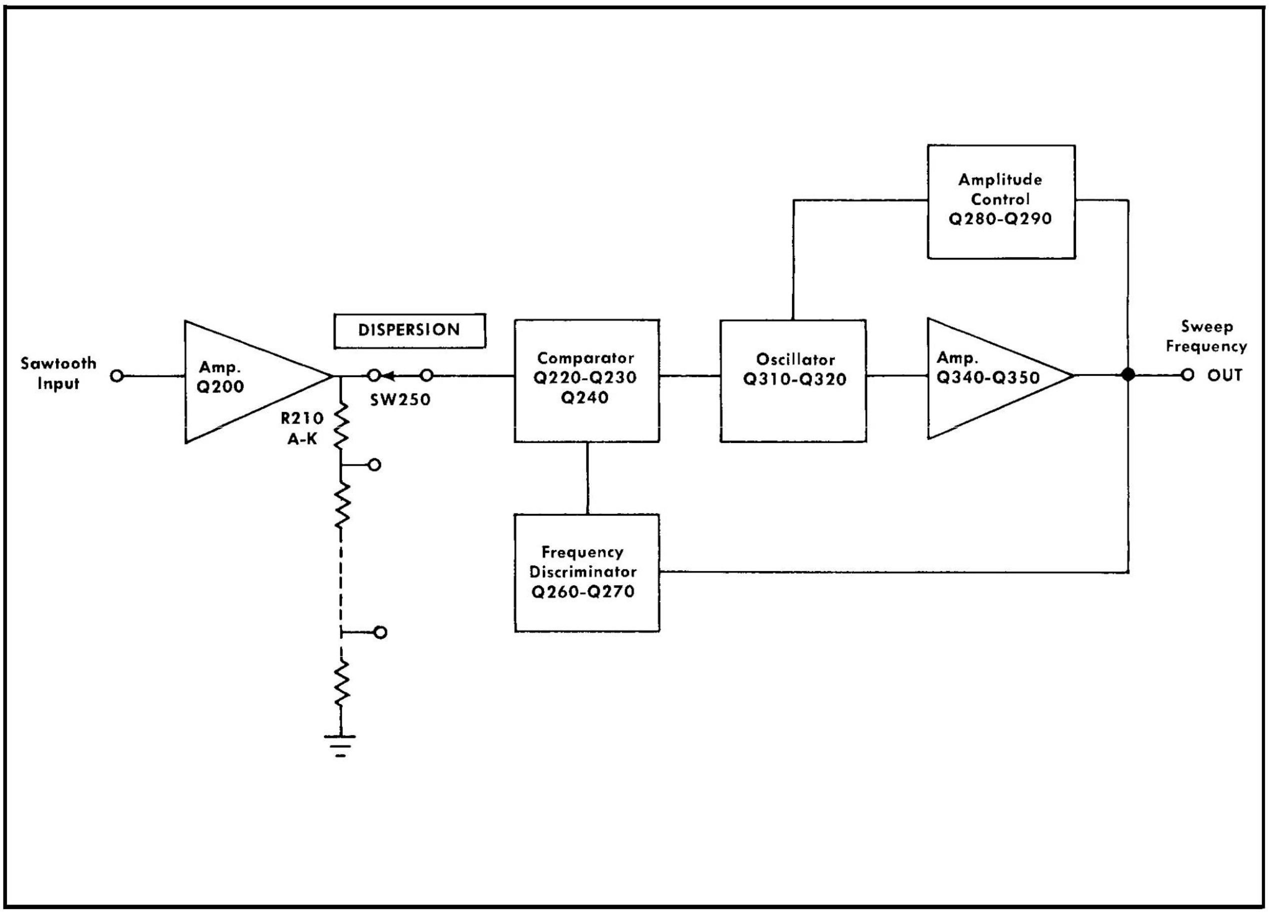


Fig. 3-5. Block diagram of sweeper circuits.

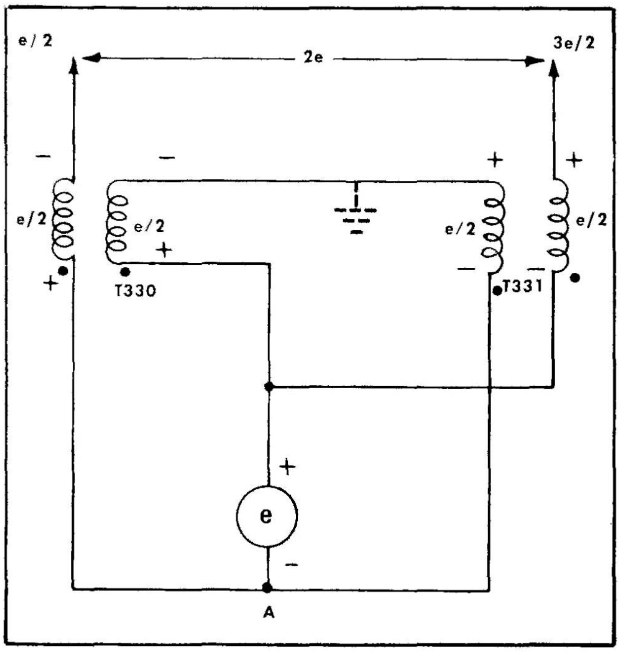


Fig. 3-6. Simplified diagram of the transformer (T330-T331) circuit from the swept oscillator to the push-pull amplifier Q340-Q350.

so the dirve signal to the amplifiers is a balanced push-pull signal.

Transformers T343 and T354 in the collector circuit of Q340 ond Q350 provide a 4:1 impedance transformation from the collectors of the transistors to the output transformer T347.

Transformer T347 converts the push-pull signal to a single-ended output signal. Push-pull amplification, plus filtering through the low pass filter circuit of L358-C358 and L348-C348 reduces the harmonic content in the swept frequency output signal.

Diode D334 in the base voltage divider circuit provides the temperature compensation for transistors Q340-Q350.

The single-ended output signal is coupled through a 2:1 impedance transformer T363, to the mixer in the Wide Band IF. The output signal is also applied, through two feedback loops, to frequency ond amplitude control circuits.

Frequency Discriminator. Two frequency discriminators for each position of the DISPERSION RANGE selector SW365 provide an output voltage signal to the frequency discriminator comparator Q260. The output voltage from the comparator is a ramp voltage that is proportional to the sweep oscillator frequency. It is applied to one side of the comparator Q230-Q220.

The MHz/Div discriminator consists of two matched diodes, D373 and D376, at the input ends of two transmission lines. The transmission lines are $^1/_8$ wavelength long at the center frequency (275 MHz). One line is open ended and appears capacitive, the other line is shorted and appears inductive, at the center frequency. As the input frequency to the discriminator increases, the transmission line input impedance nears the characteristics of a ¼ wavelength line. The shorted transmission line input impedance increases, the open ended line input impedance decreases. This produces proportionate changes to the output signal from the diodes. Signal output from diode D376 becomes more negative, and signal output from D373 becomes less negative. This push-pull drive is applied to the comparator Q260 and converted to a single ended output signal for the sweep comparator.

Thermal balance is achieved by balancing the current differential through both sections of the transistor. The common emitters are connected to a constant current source Q270. Current (approximately 3 mA) is established by the voltage drop across the emitter resistance R274.

The IF CENTER FREQ (R256) and the FINE (R259) controls sum in a DC voltage with the differential signal from the comparator to allow positioning of the IF center frequency (200 MHz or a frequency close to 200 MHz) to the center of the horizontal sweep.

The amplitude of the ramp signal to the sweep comparator is a function of the DISPERSION RANGE switch SW210 and the DISPERSION selector SW365 setting. This amplitude determines the frequency deviation swing of the sweep oscillator band.

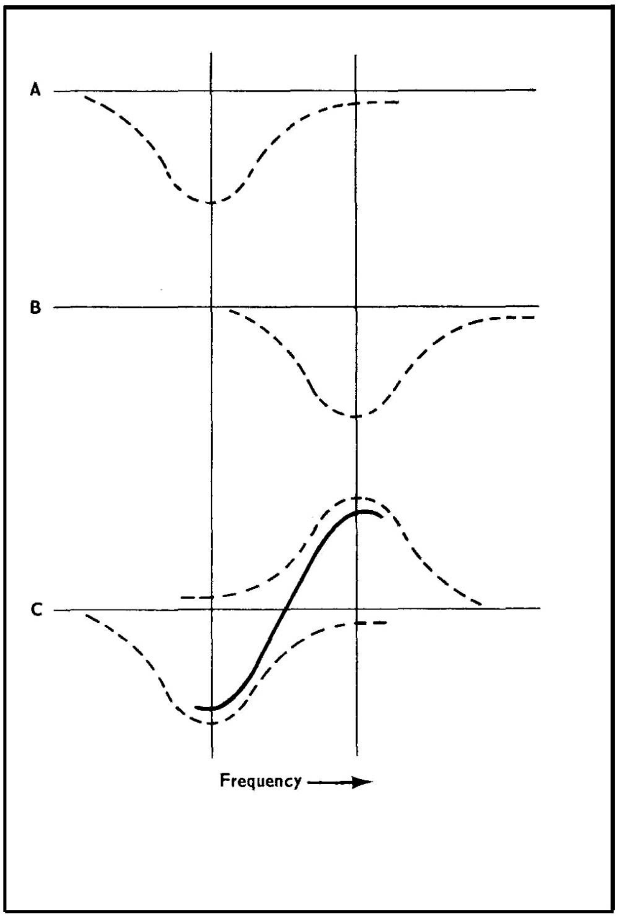


Fig. 3-7. Frequency vs Voltage curves for kHz/DIV discriminator circuit.

The discriminator for the kHz/DIV position of the DISPERSION RANGE switch consists of tuned circuits which operate much like the tuned transmission lines for the MHz/div discriminator. The parallel circuit L384-C384 is tuned slightly below the center frequency, and the circuit L385-C385 is tuned above the center of the sweep oscillator frequency. The output of the detectors is shown in Fig. 3-7. When the detector output is applied to the comparator, a voltage versus frequency curve similar to Fig. 3-7C is the resultant output. The circuit operates over the linear portion of the curve. The kHz/div Cal adjustment R368 calibrates this range.

Diodes D277 and D279 isolate the narrow band discriminator tuned circuit when the Type 491 is operating in the MHz/DIV dispersion *range*. They prevent parasitic oscillation due to circuit coupling between the wide band and narrow band discriminators. The diodes are forward biased when the DISPERSION RANGE switch is in the MHz/DIV position and the current through the diodes lowers or spoils the Q of the tuned discriminator circuit. When the DISPERSION RANGE switch is in the kHz/DIV position, the diodes are backbiased and disconnected from the low dispersion discriminator circuit.

Ampliude Comparator. Uniform sensitivity and linearity over the dispersion range is maintained by controlling or regulating the oscillator output amplitude. This is accomplished by the RF amplitude comparator circuit, Q290 and Q280. The RF output signal is detected by diode D361 and applied through diode D362 to the base of Q280. This rectified RF signal on the base of Q280 is compared against a reference voltage set by the RF Ampl adjustment R290. The differential output signal is fed back as a voltage to control the forward bias of Q320. Q320 is the current source for the oscillator circuit. Amplitude changes in the oscillator output are fed back as correction signals to the current regulator to regulate oscillator current or output power.

To summarize the sequence of operation for the sweeper circuit, assume the output from the sweep comparator Q220-Q230 is a positive-going ramp. This voltage ramp increases the bias on the capacitance diode and decreases the circuit capacitance so the socillator output frequency will increase. This increase in output frequency is fed back to the discriminator, and detected as an increasing negative voltage output from D376 (assuming the DISPERSION RANGE switch is in the position shown in the schematic diagram) and a decreasing negative voltage from D373. The differential output from comparator Q260 is a positive-going ramp to the base of Q230, where it is compared against the input ramp on the base of Q220. The differential signal output from the sweep comparator, synchronizes the sweep oscillator with the horizontal sweep generator sawtooth signal and the dispersion is a function of the DISPERSION RANGE and DISPERSION selector positions.

DISPERSION RANGE BAL adjustment R234 provides IF center frequency balance adjustment between the MHz/Div and kHz/Div dispersion positions. Center Freq Range adjustment (R251) and CAL (R250) calibrate the frequency range of the IF CENTER FREQ control over the IF center frequency.

Wide Band (1 50-250 MHz) Amplifier and Second Mixer

The wide band amplifier contains an input 150-250 MHz band-pass filter, two amplification stages and a mixer ampilifer with its output tuned to 75 MHz, Gain through the amplifier is approximately 20 dB.

The wide band response from the RF section is applied through a 150-250 MHz band-pass filter to the input amplifier Q120. The band-pass filter is a combination constant-k type filter, modified with m-derived input and output sections to provide a constant 500 input and output impedance through the pass band. Series-tuned circuits L101-C101 and L107-C107, are tuned to the low end of the band; L102-C102 and L108-C108 primarily control the high frequency response characteristic of the filter. All of the adjustments interact and are adjusted for optimum response flatness over the pass band.

Toroid transformers T120, T125 and T134 provide the wide band characteristics for the input and output coupling. L124-C124 form a 75 MHz trap to provide additional attenuation (approximately 60 dB) to any 75 MHz signal that may push through the filters.

C137 in the emitter and L134 in the collector of Q130 are peaking adjustments and adjusted for optimum flatness of the IF response. C137 compensates for the transistor rolloff toward the high end of the band; however, because of the low Q in the collector circuit; due to R134 and circuit loading, the overall effect of both adjustments (L134 and C137) is seen as a bandpass response adjustment.

The output from Q130 is applied through transformer T134 to the base of mixer amplifier Q140. The swept oscillator output is coupled to the emitter of Q140. The collector output load (L144 and C143) is tuned to 75 MHz so the difference frequency of 75 MHz is coupled through the 65 MHz trap to the attenuator circuit as the 2nd IF frequency, The 65 MHz trap (L147-C147) attenuates or rejects 65 MHz signal component from feeding through to mix with the 70 MHz oscillator. Any 65 MHz signal would mix with 70 MHz to generate a 5 MHz signal for the narrow band IF amplifier and would appear as an undesirable spurious response on the output display.

IF Attenuator

The IF attenuator is a six section network that provides a total signal attenuation of 51 dB. The input and output impedances to the attenuator are maintained at a constant 50 Ω regardless of the IF ATTENUATOR switch setting, Input and output filter sections (C151-L151-C152 and C187-L188-C188) at the input and output of the attenuator form a low pass filter to prevent high frequency signals from feeding into the 75 MHz amplifier.

Narrow Band IF Amplifier

This circuit contains two stages of 75 MHz IF amplification, a stable 70 MHz oscillator, a mixer amplifier with its output tuned to 5 MHz and a stage of amplification for the 5 MHz IF frequency,

Input to the amplifier is AC coupled from the IF attenuator to the base of Q420, The 75 MHz IF amplifiers are Q420 and Q430. The IF transformers are tuned to the IF frequency by adjusting the capacitance of C425 and C435. Gain of the amplifier is varied by changing the forward bias of Q420, which then sets the bias of Q430 through the DC return of its base to emitter Q420. A feedback winding on T424, to the hose of Q420, provides the neutralization far the collector-to-base capacitance.

The 75 MHz IF and the output from o crystal controlled 70 MHz oscillator Q440, are applied to the mixer amplifier Q450. The collector output circuit of Q450 is T454, which is tuned to 5 MHz and couples the signal to the 5 MHz IF amplifier Q460. Diode D454 in the collector load of Q450 improves the overload characteristics of the amplifier. Output of the 5 MHz IF signal is applied through an insulated connector J470 to the input of the variable resolution amplifier.

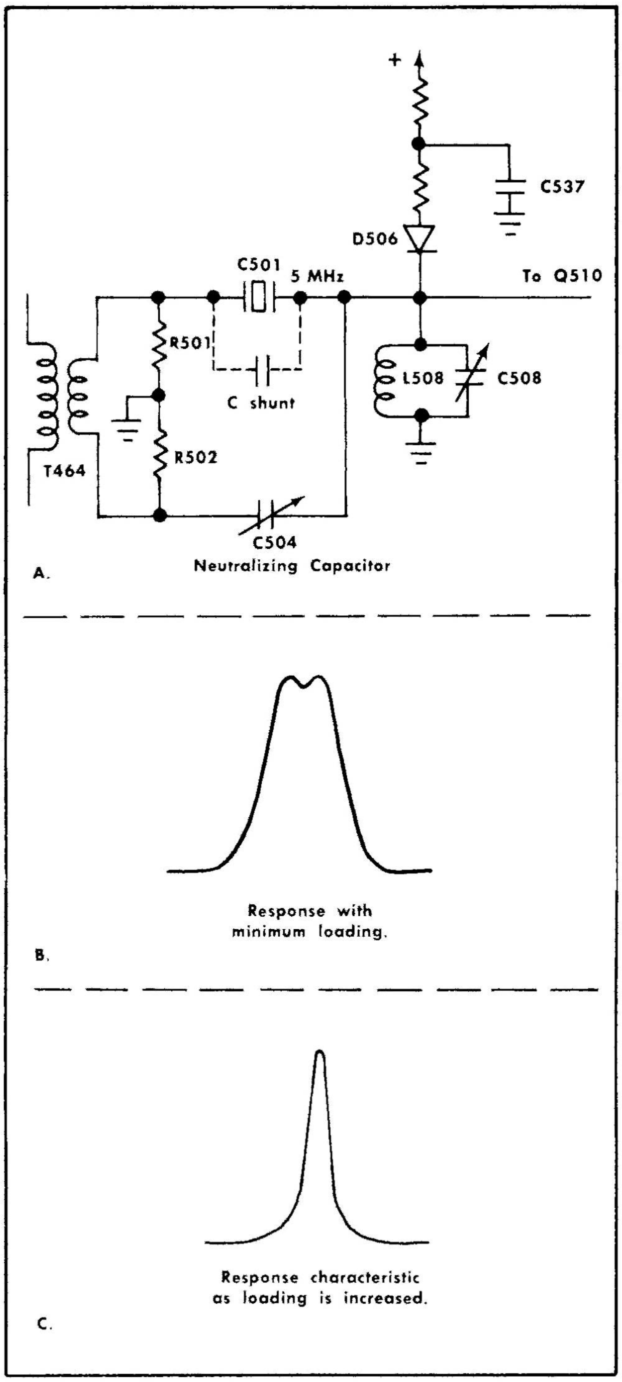


Fig. 3-8. Crystal variable resolution filter.

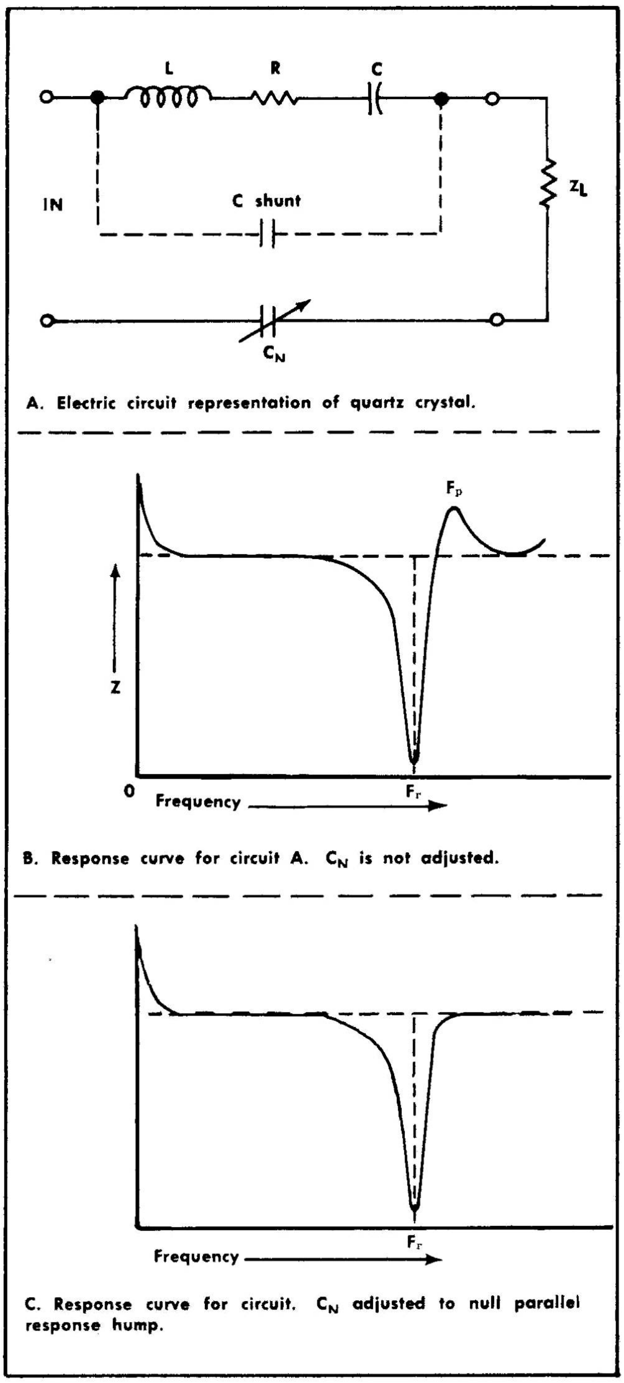


Fig. 3-9. Crystal filter, equivalent circuit and impedance response curves.

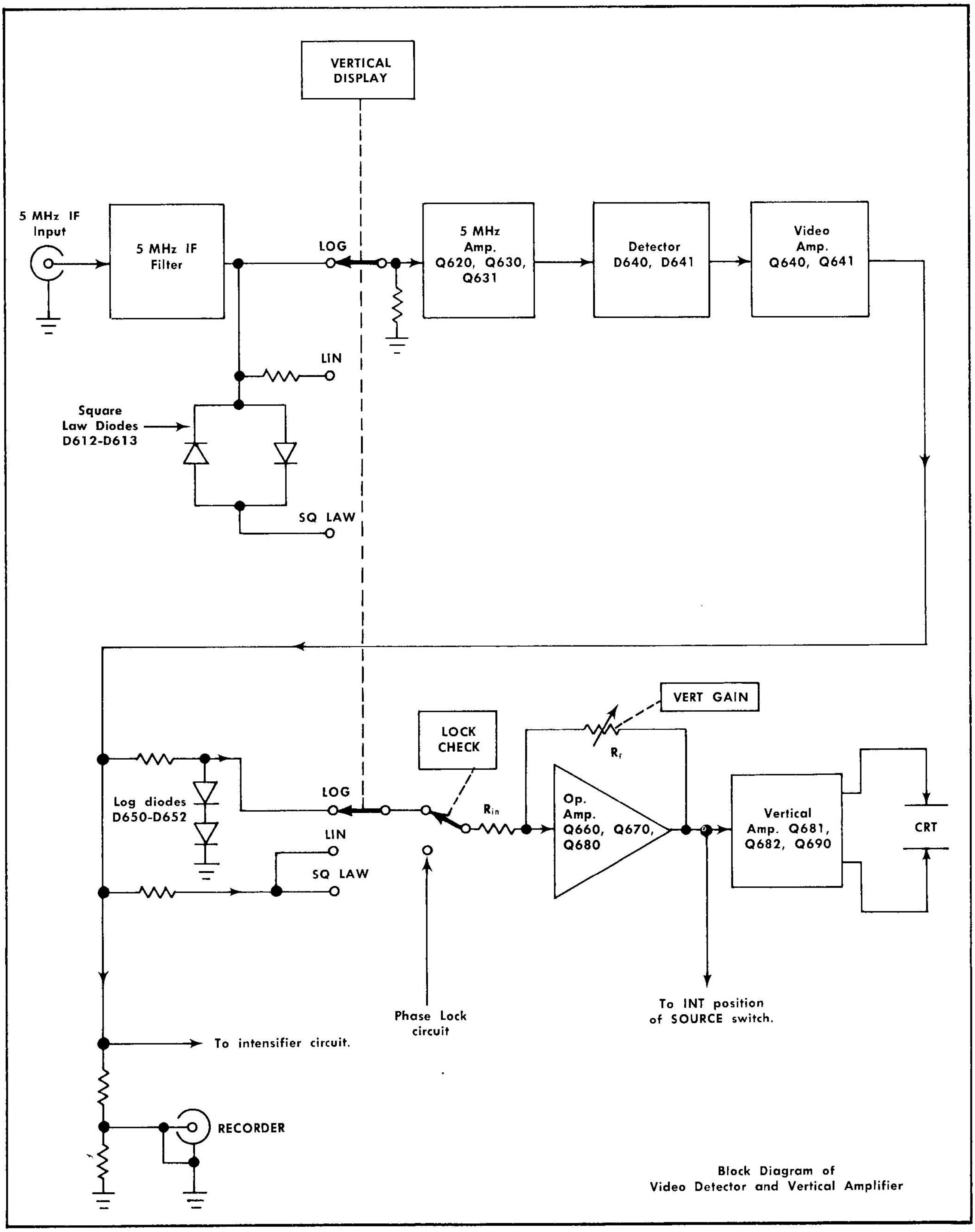


Fig. 3-10. Block diagram of the video detector and vertical amplifier.

Variable Resolution Amplifier

The variable resolution amplifier is designed to vary the bandwidth of the 5 MHz IF from approximately 100 kHz to less than 1 kHz, Bandwidth of the circuit is a function of the output load for a crystal filter network. By varying the output load a variable resolution bandwidth is obtained.

The signal input to the variable filter circuit is insulated from chassis ground and connects across R501-R502. Crystal Y501 is a 5 MHz crystal, connected in series between the input and the parallel resonant circuit L508-C508. Bandwidth or resolution of the circuit is dependent on the characteristic response of the crystal at its series resonant frequency and the Q of the parallel resonant circuit L508-C508.

Fig. 3-8 illustrates the impedance response versus frequency curve of a quartz crystal. Capacitor C504 neutralizes the stray shunt capacitance around the crystal so the response of the crystal is equivalent to a series tuned circuit with a very narrow band-pass[1]; see Fig. 3-9.

The bandwidth of the filter network is a function of the crystal output load, which is primarily the parallel resonant circuit; therefore, bandwidth becomes a function of the Q for the resonant circuit. The Q of the output load circuit for the crystal is varied by changing the bias of diodes D506, which changes the shunt loading across the parallel-tuned circuit.

As the forward bias of D506 is increased, the Q of the parallel resonant circuit decreases and the response characteristic of the crystal becomes the dominant factor in determining the bandwidth of the filter network. The crystal response is very narrow, so the display resolution is increased as the diode forward bias increases.

SW550, the RESOLUTION selector, is coupled to the DISPERSION selector and when coupled, provides normal resolution for each position of the DISPERSION selector. However, by pulling the control knob, the RESOLUTION selector is uncoupled and any desired resolution within the range of the control can be obtained for a given DISPERSION selector setting.

The 100 MHz Resol Cal adjustment R543, adjusts the resolution bandwidth to approximately 100 kHz with the RESOLUTION control at the fully clockwise position, and to 60 kHz at the —6dB point in the next position. The other RESOLUTION control positions are not calibrated. However, the bandwidth at each step provides adequate resolution for most displays.

Emitter followers Q510-Q520 isolate the high impedance of the filter network from the relatively low output impedance, thus minimizing circuit loading on the filter network. Q530 is a grounded-emitter operational amplifier with a relatively low output impedance to provide the signal amplitude required to drive the Log and Sq Law circuits.

[1] (Ref: F. Langford-Smith RAC Radiotron Designer's Handbook; 4th edition.)

Video Detector and Vertical Amplifier (Fig. 3-10)

The 5 MHz IF response from the variable resolution amplifier is applied to a band-pass filter circuit to shape the response and attenuate spurious signals. VERTICAL DISPLAY switch SW600 selects one of three possible displays; LOG, LIN and SQ LAW.

The LOG position applies the signal directly to the base of the amplifier Q620. This direct coupling, with no signal attenuation, provides the full dynamic range required for the LOG diode circuit at the output of the video amplifier and a logarithmic display.

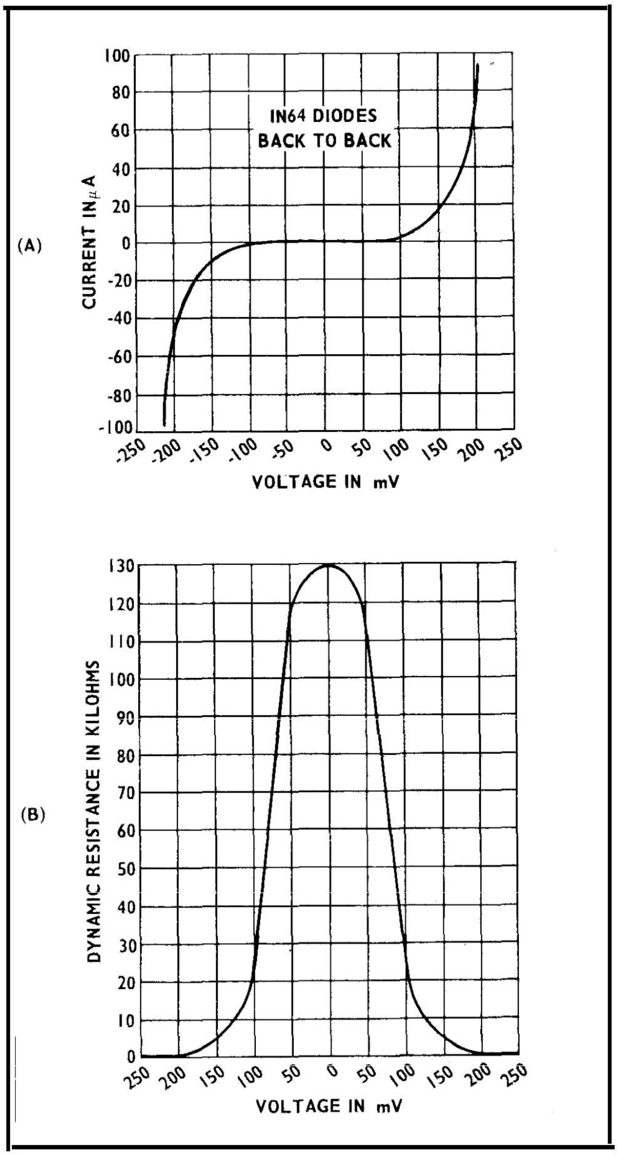


Fig. 3-11. Characteristic curves for 1N64 diodes; (A) voltage vs current; (B) voltage vs dynamic resistance.

The input signal is attenuated through R617 and the input impedance to Q620, so that an approximate 5 division display in the LIN position will provide approximately the same signal amplitude when the switch is changed to either of the other two positions.

In the SQ LAW position the signal is applied through two germanium diodes, D612-D613, to the base of Q620. The diodes are connected back to back to form a square-law voltage divider. Signal voltage to the amplifier Q260 in the SQ LAW mode becomes a function of the diode's dynomic resistance as shown in Fig. 3-11.

Note that diode resistance exceeds 100 kΩ for very low (mV) input signals. The divider ratio is approximately 200:1 so 0.5% of the signal will be applied to Q620. With a 150 mV signal the dynamic resistance of the diode decreases to approximately 5 kΩ, so approximately 10% of the signal will be applied to Q620. The circuit will normally have about 70 mV signal for full screen display so the diodes operate along the steep portion of the dynamic resistance curve.

This no-linear dynamic resistance of the divider produces a display which emphasizes small signal level differences between signals. The vertical response for the SQ LAW display is approximately proportional to the signal power.

Q620 is a high gain amplifier driving the complementary amplifier Q630-Q631. The complementary amplifier provides the drive for the step-up transformer T640. This provides the voltage gain required to drive the LIN detector, the log circuit, the recorder and the intensifier circuit. The signal to the RECORDER output connector is a linear signal in the LIN and LOG positions of the VERTICAL DISPLAY switch, and square law in the SQ LAW position.

The video detector diodes D640 and D641 are connected as a voltage doubler for maximum efficiency The output video signal is then amplified through the emitter followers Q640 and Q641 and applied through the VERTICAL DISPLAY switch SW600 to the vertical amplifier. Q641 is long-tailed through R657 to the -10 V supply to provide a constant DC output level to drive the vertical amplifier, the baseline suppress circuit and the RECORDER output connector. This provides minimum baseline shift when the VERTICAL DISPLAY selector is switched between positions.

The logarithmic circuit consisting of R650, R651, R653, D650 and D652 provides a logarithmic display when the VERTICAL DISPLAY switch is in the LOG position.

Low amplitude video signal voltages appear across D650 with little or no attenuation. As the amplitude increases, the current through the diode becomes an exponential function of the voltage across the diode, R650 becomes the current source for the diode, so the voltage out becomes a logarithmic function. As the signal amplitude incrases the diode current approaches the linear region of the voltage-current characteristic curve; however, this current through R653 develops sufficient voltage across D652 to turn this diode *on* and the two diodes operate in series to extend the logarithmic range of the circuit.

Vertical Amplifier. The vertical amplifier consists of an operational amplifier driving a paraphase output amplifier. The operational amplifier consists of the grounded base amplifier Q660, driving the emitter follower Q670 and the inverter amplifier Q680. Output signal from the collector of Q680 is fed back to the input of the amplifier, through R672 (Vert Gain adjustment) in series with R671, to the emitter of Q660. Gain of the amplifier is a function of the ratio R_f/R_{in}. R_f is controlled by the Vert Gain adjustment.

POSITION control R665, sets the input DC level to the operational amplifier which is reflected as a DC shift in the output level to the vertical output amplifiers. Diodes D670 and D671 do not normally conduct They limit the overdrive and speed up the recovery of the amplifier.

The low impedance signal output from the operational amplifier drives the vertical amplifier output stage. The output amplifier is connected as a paraphase amplifier to convert the single-ended input signal to a push-pull drive for the vertical deflection plates of the CRT, The common emitters of the output amplifer are connected to a constant current source Q690, which supplies approximately 2.5 mA to each output side of the amplifier (or 5 MA total).

Trigger Generator, Sweep Generator and Horizontal Amplifier

The sweep generator will free run or it may be triggered by the internal video signal, the line frequency or an externally applied triggering signal.

Sweep rates in a 1-2-5 sequence may be selected for 0.5 s/div to 10 µs/div. The sweep voltage generated by the sweep generator is amplified by the horizontal amplifier and applied as a push-pull sawtooth to the horizontal deflection plates of the CRT.

If the sweep generator is triggered, the selected trigger signal is amplified and shaped by a trigger amplifier then applied to the trigger generator. Trigger signal level and slope can be adjusted and selected.

The trigger pulse from the trigger generator switches a sweep gating multivibrator to generate the unblinking gate for the CRT during sweep time and initiates the operation of the sweep generating circuit.

The sweep generator supplies a linear and timed ramp signal to the horizontal amplifier plus a feed-back signal to the trigger generator. This feed-back signal locks out or holds off the trigger signals to the sweep gating multivibrator until the sweep has run and the circuit is ready again to be triggered.

Trigger Generator. The selected trigger signals from the SOURCE siwtch are AC coupled through C701 to an operational amplifier Q700, Q710 and Q720. The output of this operational amplifier is a low impedance signal that drives one side of a comparator amplifier Q730-Q731.

The input DC level to the operational amplifier is set by the trigger LEVEL control R702, and the Trig Level Center adjustment R724. This input DC level to the operational amplifier also governs the output DC level of the amplifier which is the input level to the comparator Q730-Q731,

One side of the comparator is referenced through the SLOPE switch SW720 to ground, while the other side is connected through the SLOPE switch to the output of the operational amplifier. The Trigger LEVEL control adjust the DC level, on the signal side of the comparator, to a voltage potential above or below ground. The input trigger signal must overcome this unbalance to trigger the trigger generator circuit. Triggering becomes a funtion of the trigger signal amplitude and the slope of the trigger signal.

The Trig Level Centering R724 is adjusted with the Trigger LEVEL control set to zero volts. It is adjusted so a low amplitude input signal will trigger the trigger generator with the SLOPE switch in either the + or - position.

The trigger generator consists of the comparator Q730-Q731, the tunnel diode D737 and the amplifier Q740. In the quiescent state, with the trigger generator ready to be triggered, the comparator is unbalanced so Q730 is conducting most of the current. The current of Q731 sets the tunnel diode between its low operating and threshold state.

If the current through Q731 is increased by the application of a trigger signal (negative-going signal on the base of C2730 or positive-going signal on the base of Q731) the tunnel diode will shift to its high state. When the TD shifts to its high state, a fast-rise pulse is generated at the base of the amplifier Q740, This generated trigger pulse is amplified, inverted and applied us a positive-going pulse to the sweep gating multivibrator Q750-Q751. The output waveform of the multi vibrator is the sweep gate to the sweep circuits and the CRT unblanking signal.

Sweep Gating Multivibrator. The positive-going input pulse from the collector of Q740 turns Q750 on and flips the multivibrator. This applies a negative-going gate to the emitter follower Q752 which provides the unblinking pulse for the CRT blanking plates and the sweep gate signal to the emitters of the gated comparator Q770-Q771. The sweep gating multivibrator is a bistable oscillator so it will remain in this state until a signal is applied to the circuit to switch the multivibrator back to its pretriggered state.

The sweep gate signal steps the emitter potential of the gated compartor Q770-Q771 from approximately 1 volt to 0 volt. The DC level on the base of Q771 is approximately 300 mV (set by the voltage divider R779 and R778). The base voltage of Q770 is approximately 1.3 volts (set by the 10:1 voltage divider R770 and R771). Both sides of the comparator are therefore back biased when the negative-going gate is applied to the emitters. The collector of Q771 steps down abruptly, gate diode D781 disconnects and the Miller runup circuit action is initiated.

Sweep Generator. When diode D781 disconnects, collector current from Q771 is interrupted so the base of Q790 starts toward the -10 volt supply.

The Miller runup circuit is essentially a high gain amplifier employing negative feedback, The positive-going voltage at the collector of Q791 is fed back through runup emitter follower Q800 and coupled through the timing capacitor C785 to the base of Q790. This feedback voltage opposes the tendency for the base to swing negative. Because the gain of the amplifier Q790-Q791 is high, a very linear rate of charge is maintained on the timing capacitor C785. Timing current through R785 almost equals the charging current of C785 so the base of Q790 moves only a very small amount during runup.

The linear voltage rise at the emitter of Q800 rises to approximately 7.5 volts (set by the Sweep Length adjustment R759) and pulls up the base of Q751 to its forward bias state. At this point the gating multivibrator is flipped to its pretriggered state. The emitter of Q752 now steps up to approximately +9 volts.

When the emitter voltage of Q752 steps up, Q771 is turned on hard. This applies forward bias to the disconnect diode, and timing current plus extra base current is now supplied by Q771. The Miller circuit now starts to run down and will continue to run down until diode D770 is forward biased. This occurs when the emitter potential is approximately 0.6 volts more negative than the 1.3 volt potential on the base of Q770. This turns Q770 on. It now shares part of the available current. The rundown of the Miller circuit levels off and a condition of equilibrium is maintained. The output voltage level of the Miller circuit remains near O V until the next gate is applied to the gate comparator, when it again runs up to generate another sweep ramp.

Diode D782 conducts if the positive voltage excursion on the base of Q790 should be excessive. This prevents the Miller circuit from hanging up.

Holdoff Circuit. When the sweep gate is applied to the emitters of the gated comparator, the collector of Q770 steps down from approximately 0 volts to -1.4 volts (drop across D767 and D768). The negative-going gate to the base of Q761 is amplified and applied to Q760 as a positive-going gate. This turns Q706 on hard. The resultant current demand of Q760 through R741 pulls the emitter of the trigger amplifier Q740 down far enough to cut Q740 off. No trigger signal can now get through from the trigger generator to the sweep gating multivibrator.

When the sweep gating multivibrator is flipped to its pretriggered state by the sweep ramp on the base of Q751, the positive-going gate at the emitter of Q752 is not sufficient to turn Q770 on. The sweep ramp must run down to approximately 0.6 volts to turn D770 on. After a time delay period, established by the RC feedback network (C761 and R762 between the collector and base of Q760), the collector current of Q760 will decrease. This increases the forward bias of Q740 to the point where it again conducts and an applied trigger signal to the amplifier will now go through the amplifier to trigger the sweep gate multivibrator and initiate another sweep.

Sweep rate is a function of the timing resistors R785 and timing capacitors C785. R786 is the VARIABLE control which provides an approximate 2.5 times sweep rate change between the TIME/DIV selector (SW785) positions.

Horizontal Amplifier. The sawtooth voltage at the emitter of Q800 drives the paraphase amplifier Q810-Q820 which converts the single-ended sweep from the sweep generator to a push-pull drive signal for the horizontal deflection plates. The paraphase output amplifier is long-tailed to the constant current source Q830 and Q831. Horizontal gain is provided by the GAIN adjustment R813. Horizontal trace positioning is provided by the POSITION control R823 which shifts the DC output level to the horizontal deflection plates.

CRT and Blanking Circuit

This circuit contains the high voltage generating and regulating circuits for the accelerating potentials on the CRT, plus an unblinking circuit, and a baseline suppressed or intensifier circuit.

High Voltage Circuit. The high voltage oscillator Q1003 drives the primary windings of the high voltage transformer T1010. The high voltage rectifier circuit, containing D1014 and D1016, is configured as a voltage doubler. The circuit provides approximately -3700 volts for the cathode of the CRT and is the reference voltage for the half-wave rectifier D1020, which develops an additional -150 volts (approximately) for the CRT grid to cathode bias.

A sample of the high voltage is taken from the voltage divider circuit and applied to an error sensing and amplifier circuit, Q1000, Q1001 and Q1002. This circuit controls the current through the high voltage oscillator to regulate the high voltage output.

Q1003, with the primary windings of T1010 plus the distributed circuit capacitance, comprise the high voltage oscillator. Q1002, in shunt with the emitter-base winding of the oscillator, regulates the oscillator current.

Q1000 compares a sample of the high voltage with the -10 volt regulated supply. The error voltage is amplified through the complementary amplifier and regulator Q1001 and Q1002.

The emitter of Q1002 or output of the regulator is connected through R1009 to the +10 volt supply, This provides the initial forward bias to the base of Q1003. Positive feedback from the collector winding to the base-emitter winding causes the circuit to oscillate. Frequency of oscillation is dependent on transformer winding capacitance, including reflected reactance of the secondary windings, Frequency of oscillation is approximately 50 kHz.

The voltages supplied by the secondary windings of T1010 are: +175 V for the +150 volt regulator circuit in the low voltage power supply; -3700 V for the CRT cathode; 6.3 VAC for the CRT heater, and grid bias voltage for the CRT. All of these voltages are regulated by the regulator circuit. The amplitude of the oscillator output signal, or the transformer primary voltage, is dependent on drive voltage to the base of Q1003. The DC base voltage of Q1003 is set by the base voltage of Q1002.

The HV Adjust R1001 sets the forward bias for the amplifier Q1000. This sets the current through Q1001 and Q1002. Far example: A decrease in the high voltage load (current demand decreases) will decrease the forward bias of Q1000 and a positive-going signal is applied to the base of Q1001. This decreases the DC voltage at the base of Q1003. The feedback therefore decreases the oscillator output and the output high voltage will remain constant, Ripple reduction is a factor of the amplifier gain.

R1032 (Intensity Range) and R1033 (INTENSITY level control) provide a range from 0 to approximately 100 volts bias for the CRT to vary the CRT beam current. FOCUS R1028 and ASTIGMATISM R1038 controls provide a variable positive (with respect to the cathode) control voltage to the focusing anode and astigmatism grid. These two controls are normally adjusted in sequence for optimum beam focus over the CRT graticule area.

Trace Rotation. The Trace Rotation control provides means to align the horizontal trace on the CRT with the graticule lines. The Trace Rotation adjustment R1035 varies the magnetic field about the coil around the CRT. It will rotate the horizontal beam approximately +3°.

Blanking Circuit. Blanking in this CRT is dependent on the voltage difference between the deflection blanking plates. When the voltage difference between the plates is significant, few electrons strike the phosphor and the CRT is blanked,

The voltage on one defection blanking plate (pin 9) is fixed at approximately +80 volts by the voltage divider R1040-R1042. The voltage on the other plate (pin 7) is dependent on the output level of the operational amplifier Q1080 and Q1081.

The quiescent level (no-trace period) of Q1080 collector is about +10 V and the electron stream from the cathode of the CRT is deflected to the side because of the voltage difference between the plates, No beam or trace is visible on the screen. During sweep time, a negative unblinking pulse is applied to the base of Q1081 This raises the operational amplifier DC output level to the voltage level on the other blanking plate so the electron stream can now poss through to the CRT screen, The beam or trace is now visible.

Intensifier Circuit. Signal intensification or hose line suppression provides increased contrast between spectrum signals and the baseline of the display.

The video signal is applied through diodes D1050 and D1051 to one side of a comparator amplifier Q1050 and Q1051. The input video signal is compared against a DC level set by the INTENSIFIER control R1013 and the resultant differential output is applied across the base-emitter junction of Q1070.

The positive-going input video from the detector circuit produces an output voltage from the comparator amplifier which will decrease the forward bias of Q1070. This produces a negative-going voltage at the collector of Q1070. This voltage is applied through the CONTRAST control R1075 to the input of the operational amplifier Q1081 ond Q1080. A negative-going signal from the intensifier circuit adds to the unblinking voltage signal and modulates the CRT blanking plates so that the CRT beam is intensity modulated (Z axis modulation),

Diode D1073 provides a reference voltage to ground for the collector of Q1070. With no signal input, the collector potential of Q1070 is approximately +10 volts, The INTENSIFIER control sets the quiescent current through the intensifier circuit, which sets the DC level at which intensification begins, CONTRAST control R1075 adjusts the amplitude of the moduating signal to the unblinking circuit. This determines the contrast between the suppressed baseline and the video signal.

Low Voltage Power Supply

The low voltage power supply in the Type 491 (see Power Supply schematic diagram) consists of three inter-related supplies that operate together as a system. This system delivers regulated and filtered voltages of -10, +10 and +150 volts, A common power transformer T900 supplies the input power to each of the supplies. The input circuit to the power transformer primary can be altered so the Type 491 will operate through a voltage range from 90 VAC to 136 VAC. A second plug-in connector switches the transformer primary winding from 115 V nominal to 230 V nominal line voltage by connecting the windings in series for 230 VAC operation or in parallel for 115 VAC operation, The Operating section of the manual describes connector switch positions for each voltage range. Unless otherwise specified, the Type 491 is shipped with T900 connected for 115 VAC input.

Overload protection is provided by fuse F900 ond F902. Thermal cutout TK902 in the primary circuit of T900 opens the transformer primary circuit if the temperature inside the analyzer rises above a safe level. TK902 resets automatically when the temperature returns to normal.

-10 Volt Supply. This is the reference voltage for the other voltage supplies and the comparator circuits in the Type 491. Reference voltage for the -10 volt supply is set by zener diode D964, to approximately -0.9 V on one side of a comparator Q960-Q961. The voltage to the other half of the comparator is obtained from the voltage divider R967, R968 (-10 volts), R969 and diodes D967-D968. When R968 is properly adjusted the output voltage from the regulator is exactly -10 volts.

Error voltage signal is sensed by the comparator Q960-Q961 and applied as a correction signal through the complementary amplifier Q952-Q951 to the base of the regulator Q960. For example, an increased current demand by the -10 volt supply load would tend to develop a negative-going error signal on the error side of the comparator. This produces a positive-going correction signal to the base of Q950 and the extra current demand of the load is supplied.

The regulator circuit can never completely compensate for changes in output voltage, because there must be an error input for the circuit to operate. However, any error in the output is reduced by a factor equal to the loop gain of the regulator circuit.

+10 Volt Supply and Regulator. Error sensing far the +10 volt supply is accomplished by the amplifier Q930. A sample of the +10volt supply is applied from the voltage divider, R934-R935 in series with the regulator Q920, to the base of Q930. This voltage sample is compared with the -10 volt emitter reference voltage. D932 provides thermal compensation for Q930.

The amplified error signal from Q930 is emitter-coupled through Q922 to the base of the regulator Q920. Q921 is connected in cascade with Q922 and isolates the collector of Q922 from the rectifier output. This reduces the amount of the power supply ripple couple into the regulator circuit.

The +10 volt supply provides power for the POWER indicating light B948. Current is also supplied from the +10 V unregulated supply, through transistor Q940 to the scale illumination lights. The SCALE ILLUM control R940 sets the current through the illumination circuit and controls lamp brightness.

Line signal for the LINE position of the SOURCE switch is provided from pin 17 of the secondary winding of T900.

+150 Volt Regulated Supply. Error sensing for the +150 volt supply is provided by Q911. Error signal voltage in the +150 volt supply is amplified by the cascode amplifier Q911-Q910 and applied through the emitter follower Q900 to the base of the regulator Q901 as a corrective signal.

Diodes D904 and D905 protect Q900 from excessive voltage transients between the collector and emitter of Q900.

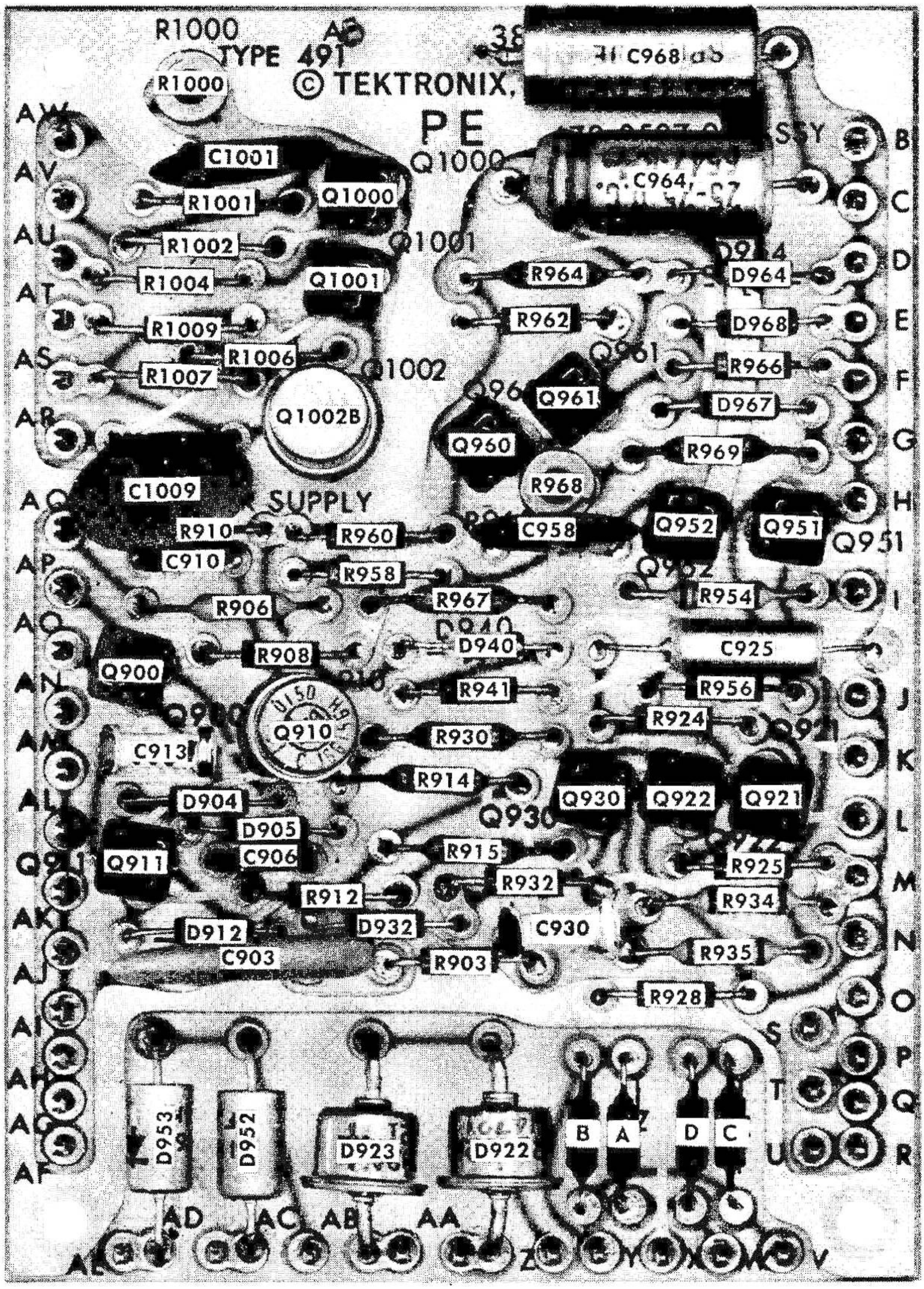


Fig. 4-22. Power supply board assembly with component call out.

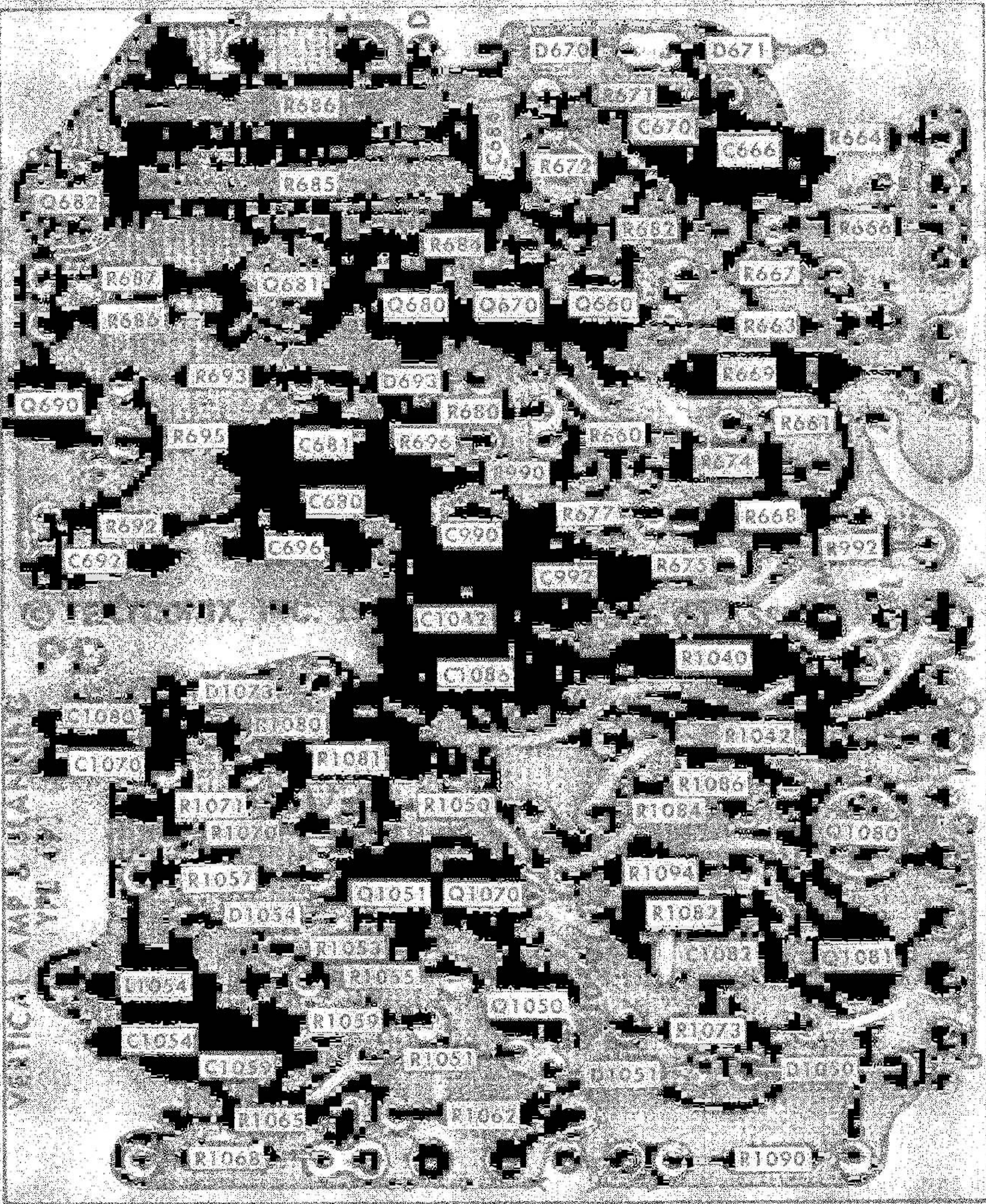


Fig. 4-23 Vertical Amplifier and Blanking board assembly with component call out.

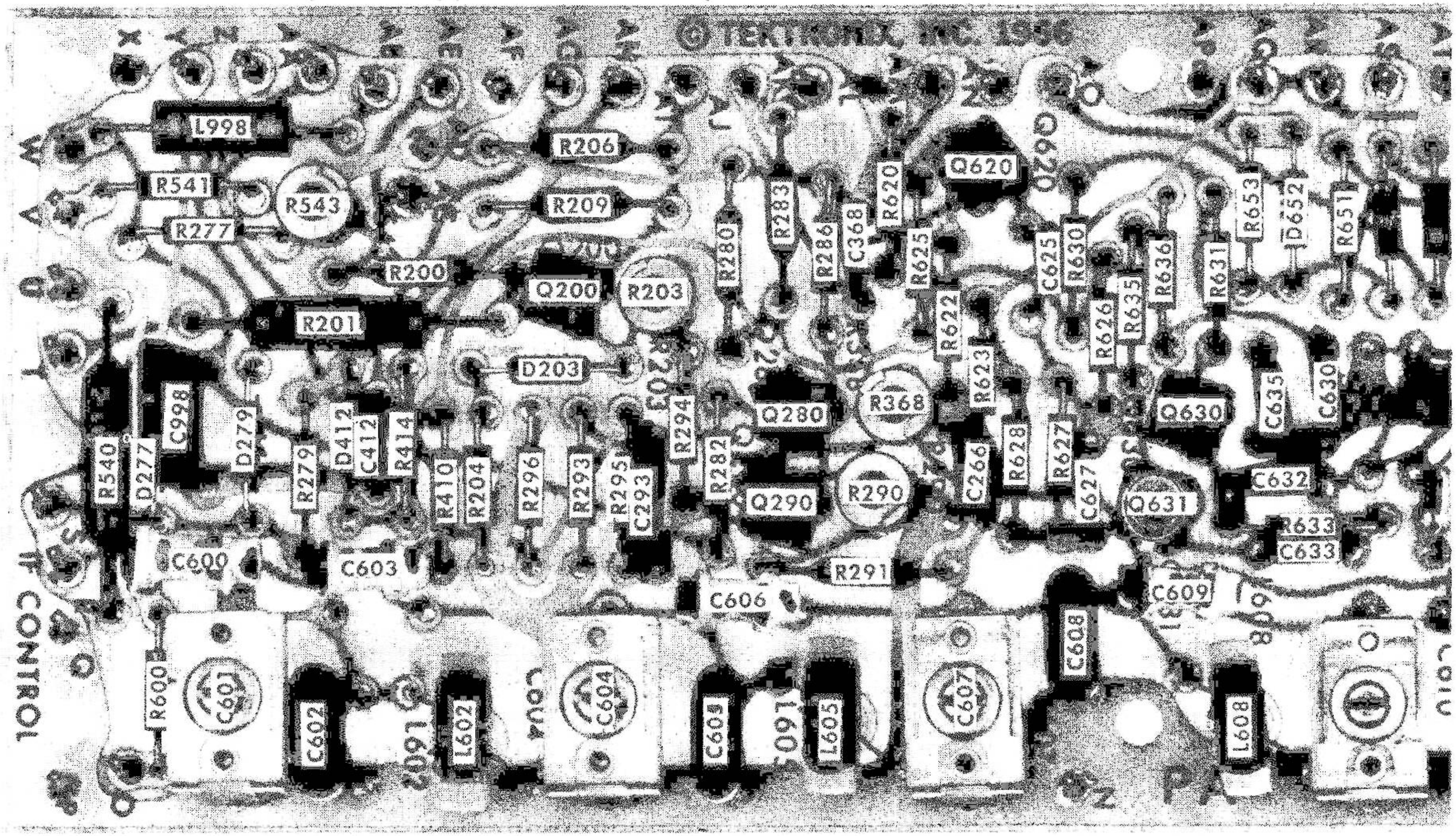


Fig. 4-24. IF control board assembly with component call out.

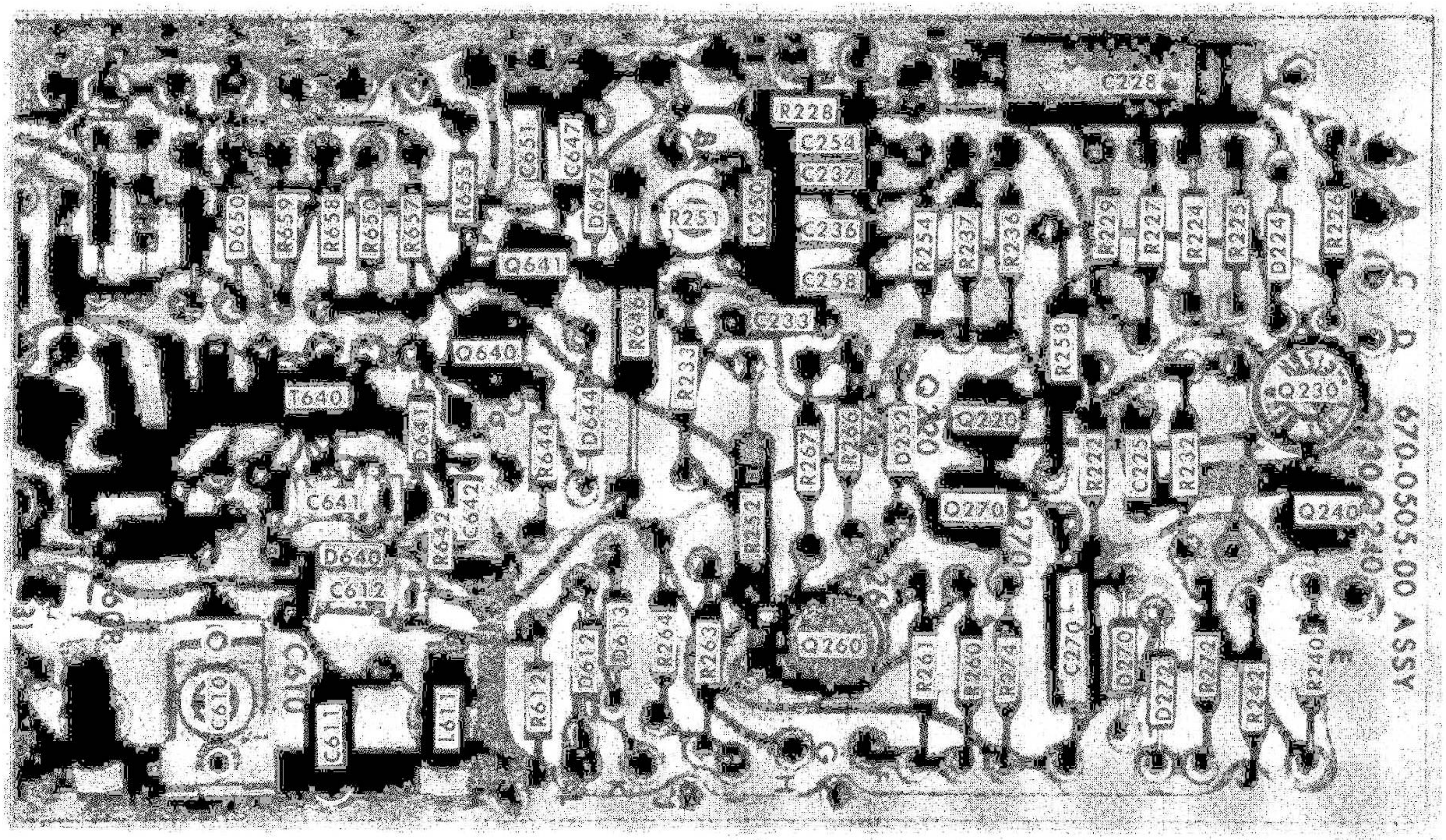


Fig. 4-24. IF control board assembly with component call out.

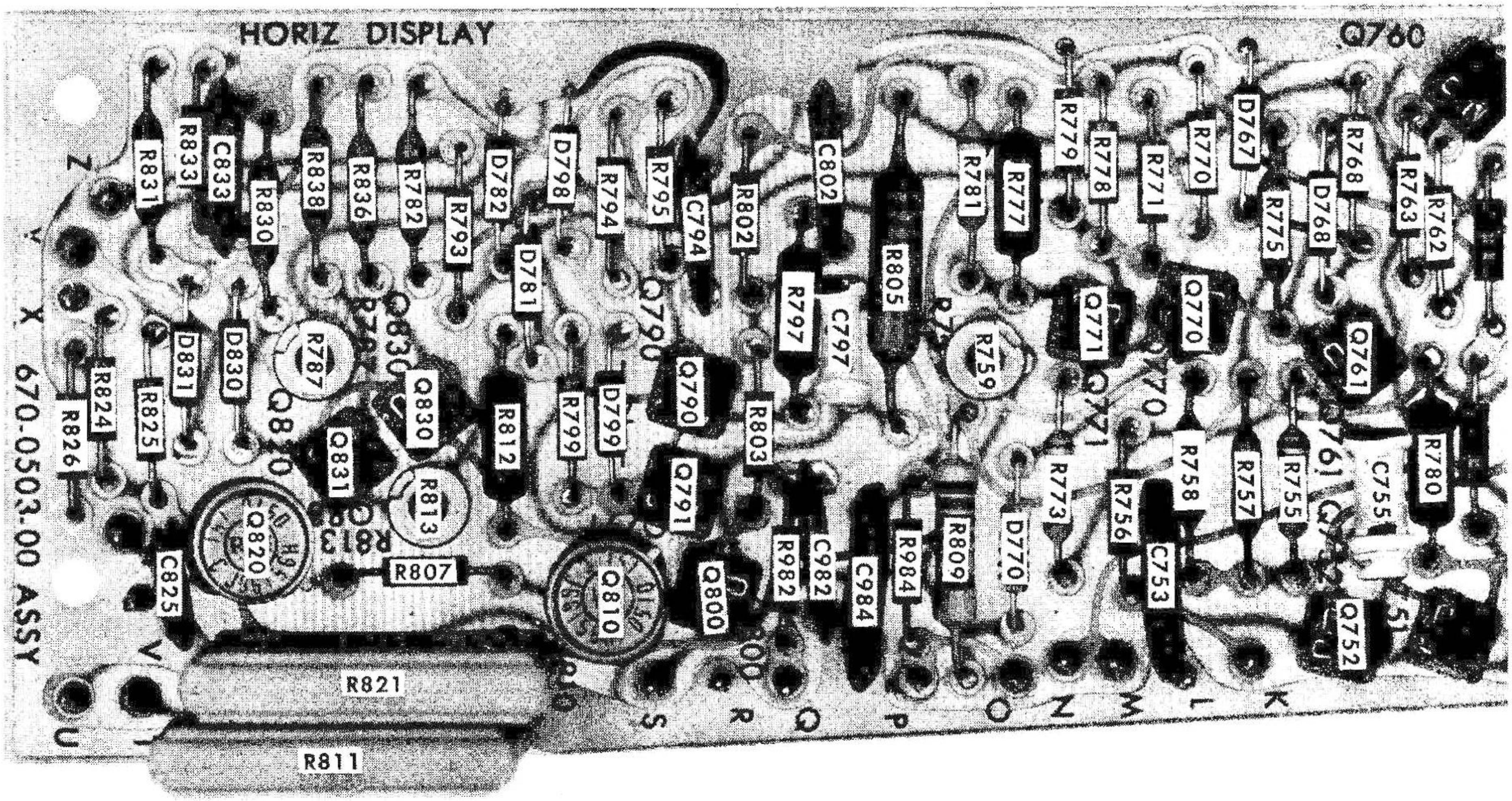


Fig. 4-25. Horizontal display board with component call out.

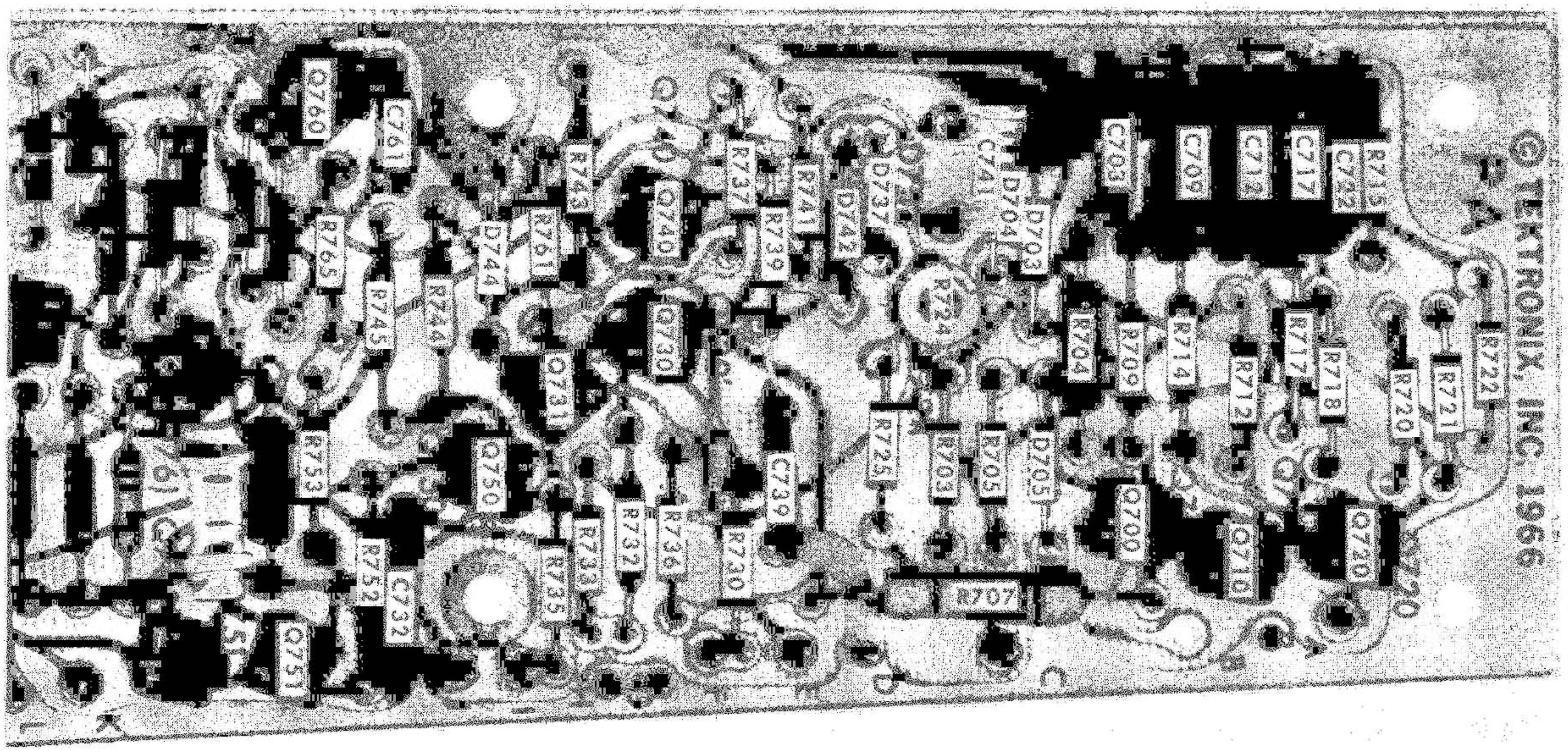


Fig. 4-25. Horizontal display board with component call out.

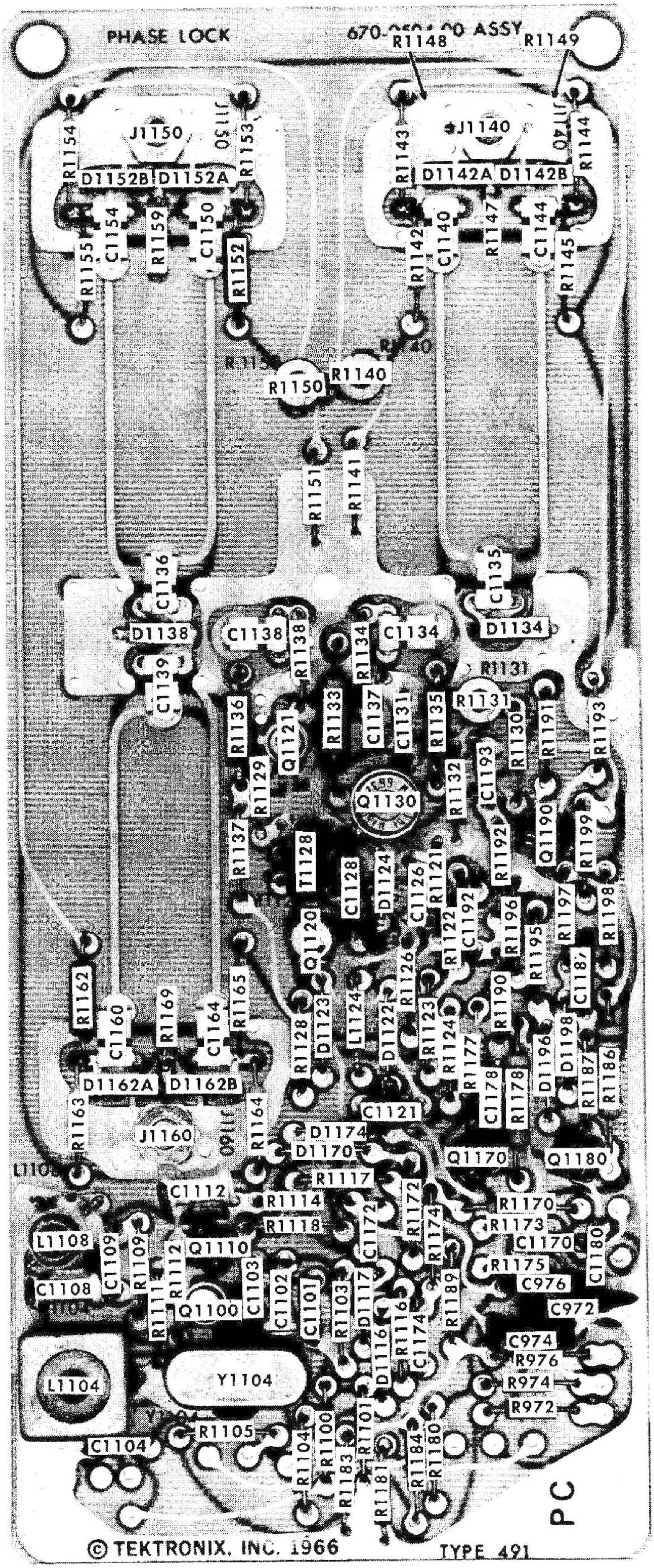
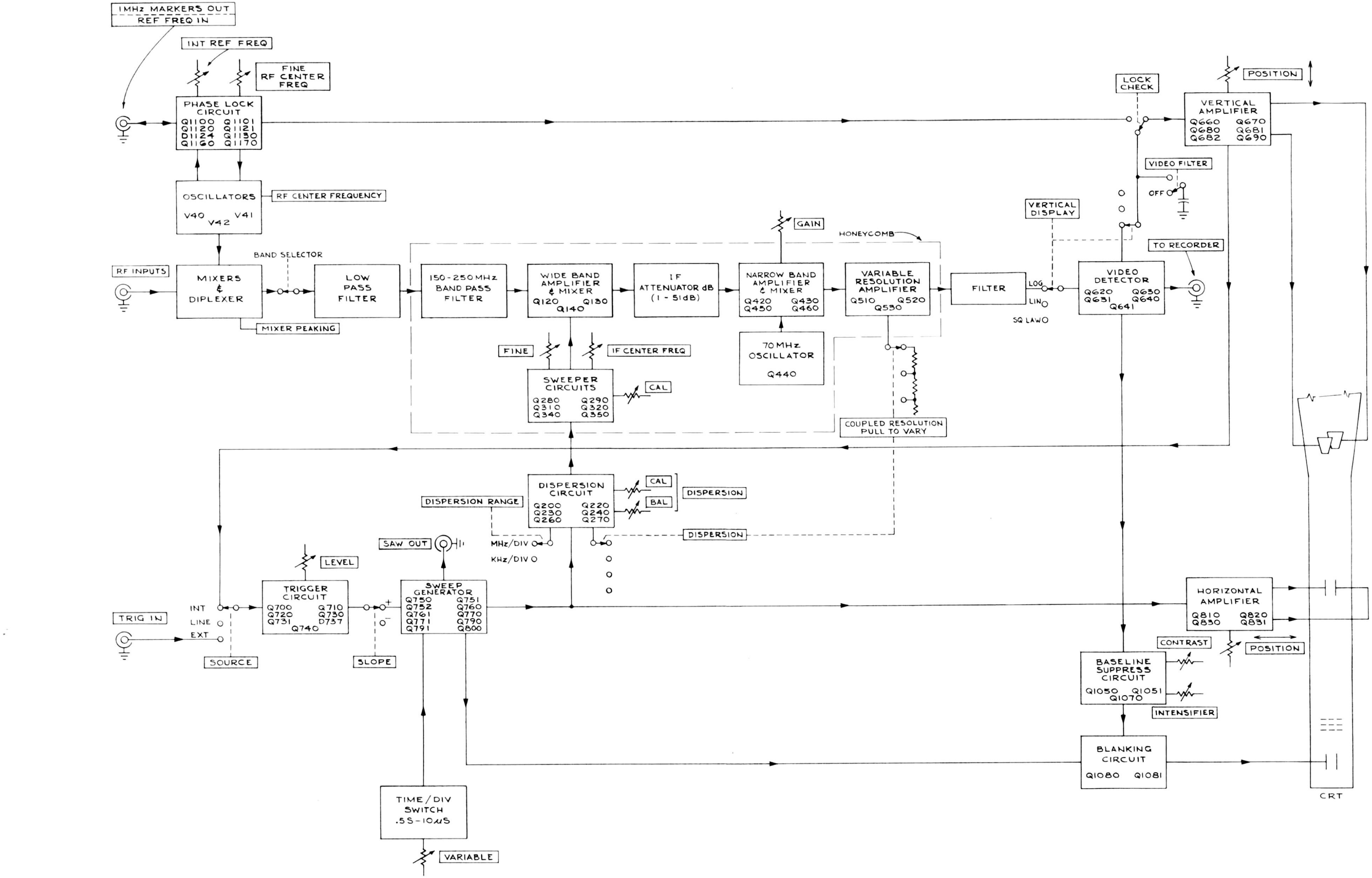
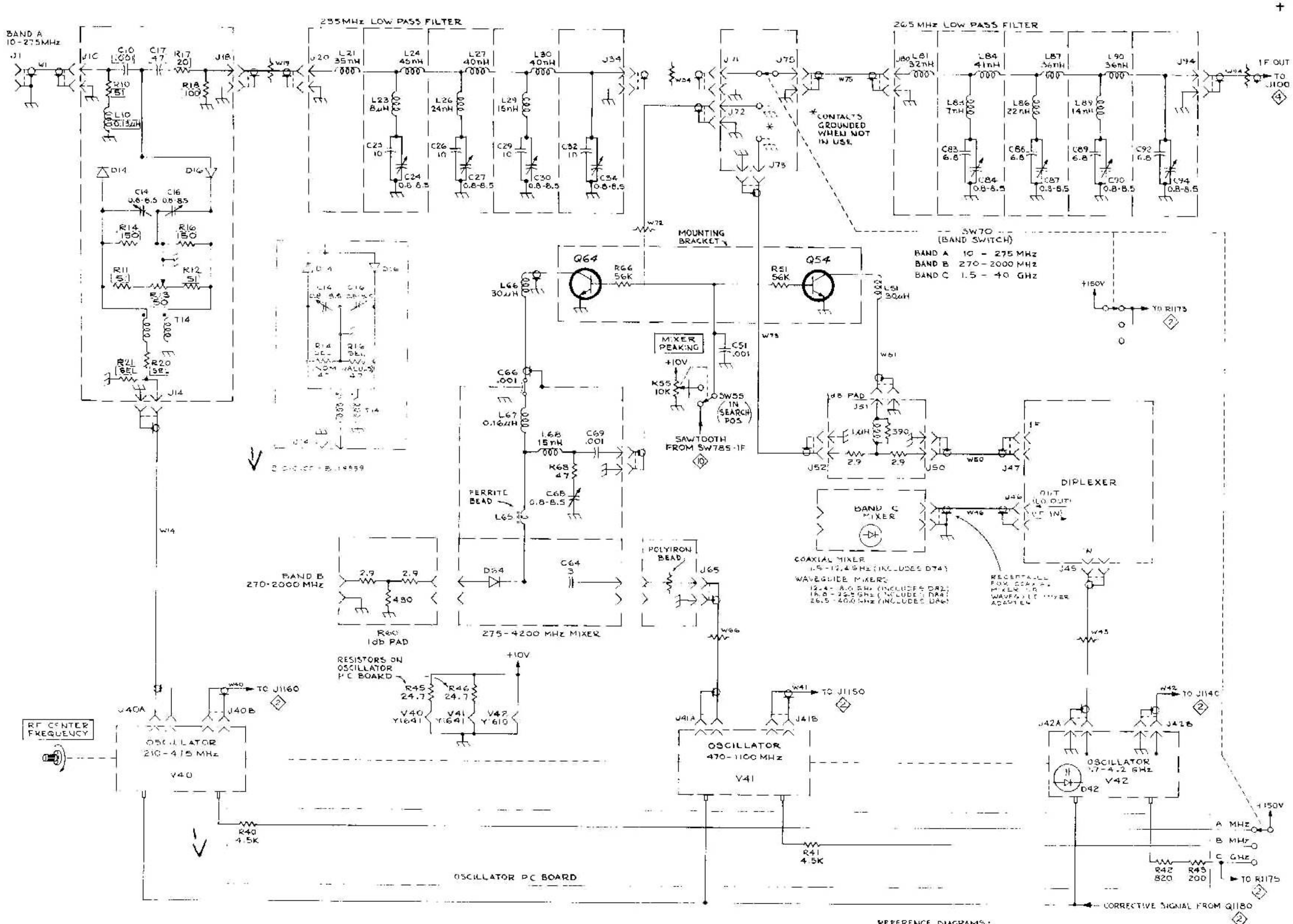


Fig. 4-26. Phase lock board with component call out.



TYPE 491 SPECTRUM ANALYZER A BLOCK DIAGRAM MRH 1066

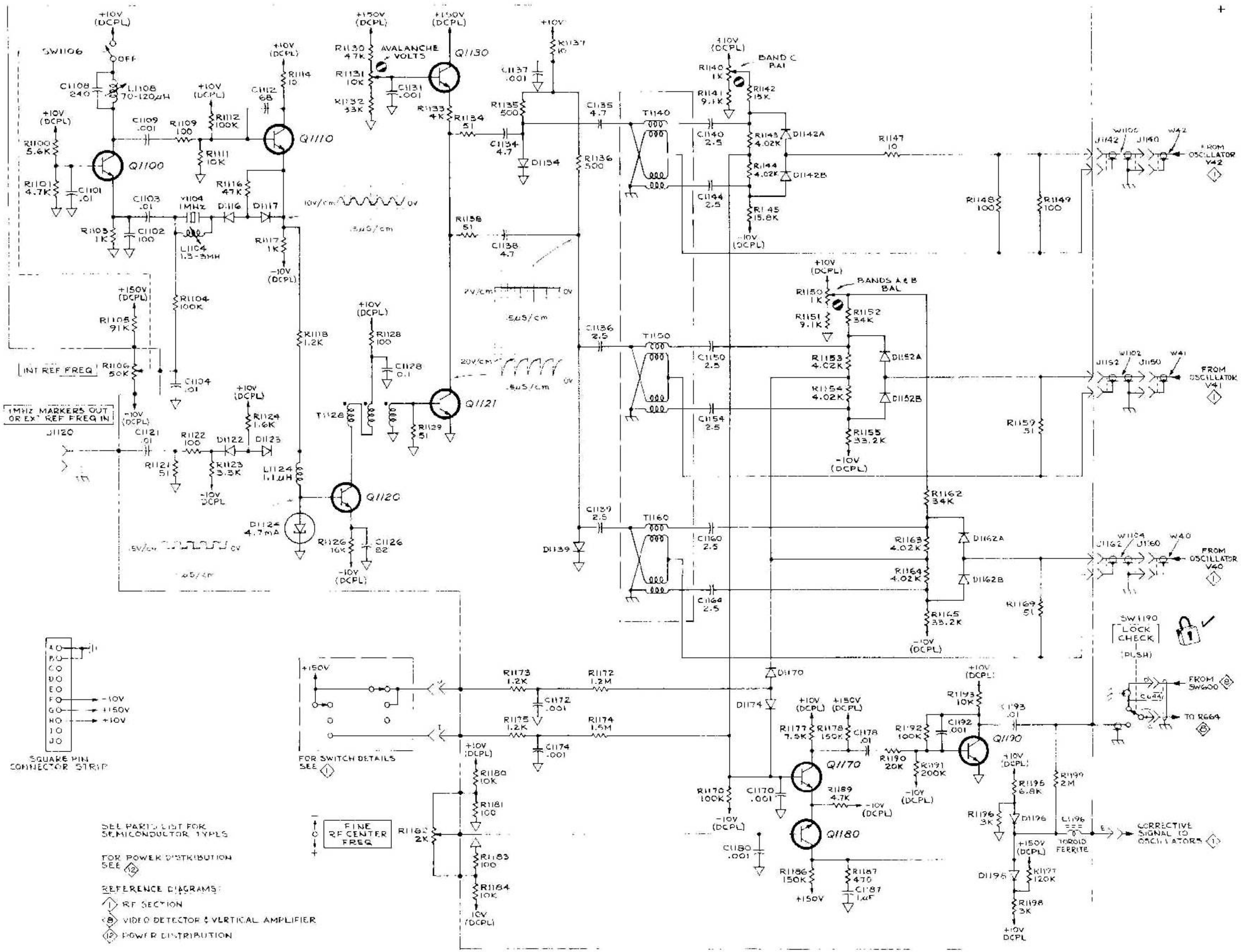


SEE PARTS LIST FOR SEMICONDUCTOR TYPES

FOR POWER DISTRIBUTION SEE ⑫

REFERENCE DIAGRAMS:
② PHASE LOCK CIRCUIT
④ WIDE BAND AMPLIFIER
⑩ TIMING SWITCH
⑫ POWER DISTRIBUTION

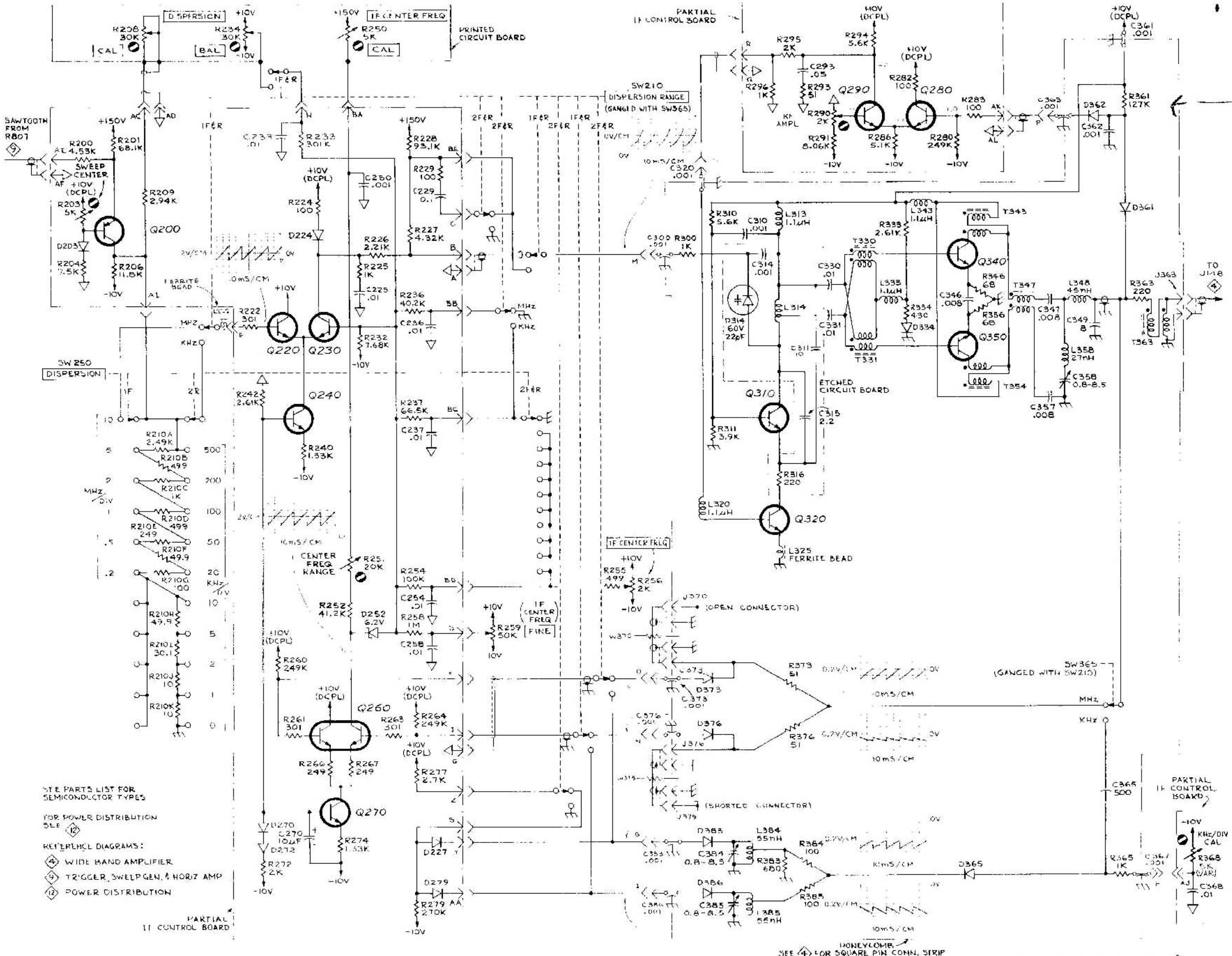
ⓥ See parts list for earlier values and serial number ranges of parts, also all component values encircled are included.

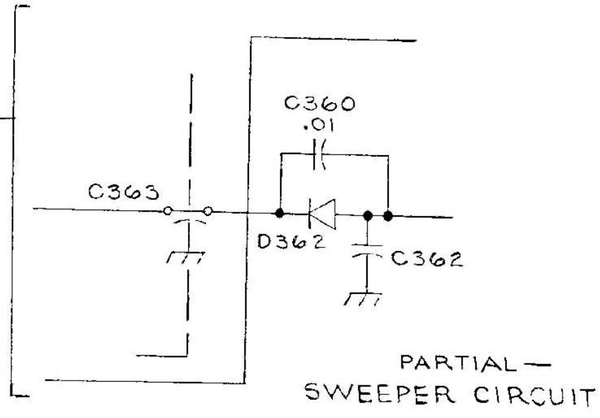


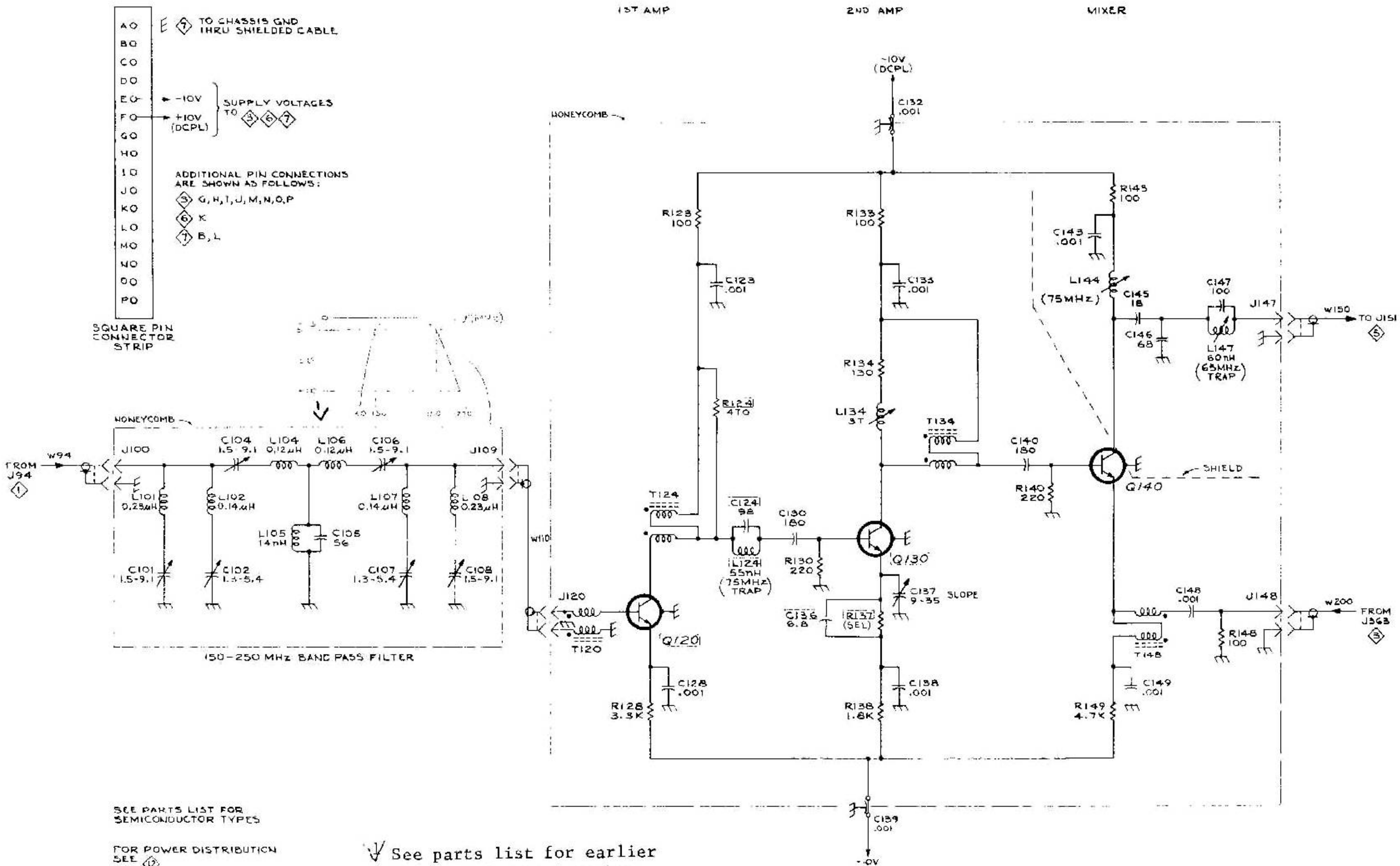
TYPE 491 SPECTRUM ANALYZER

PHASE LOCK CIRCUIT ②

SCHEMATIC CORRECTION







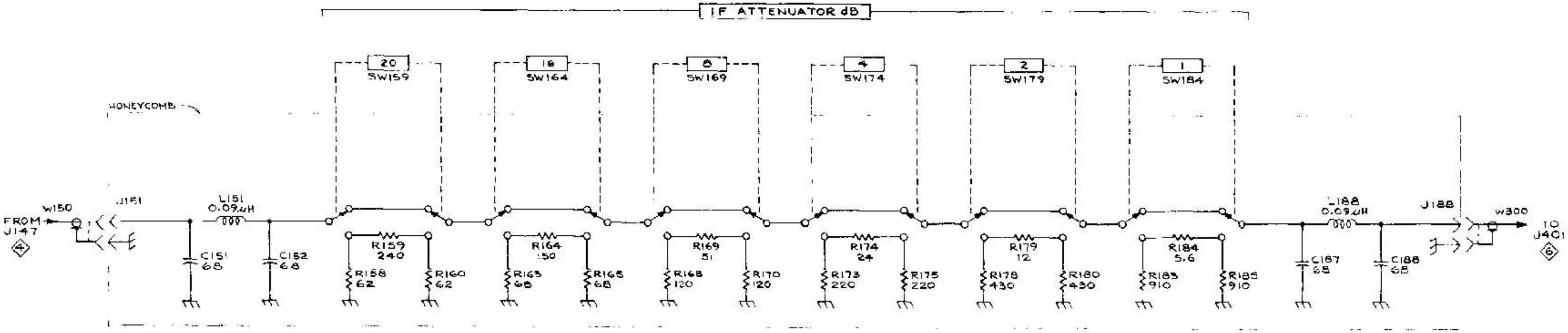
SEE PARTS LIST FOR SEMICONDUCTOR TYPES

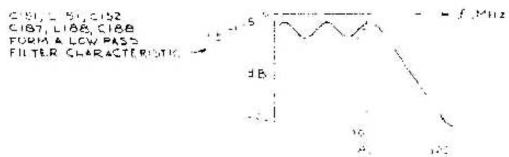
FOR POWER DISTRIBUTION SEE 12

REFERENCE DIAGRAMS:

- 1 RF SECTION
- 3 SWEEPER CIRCUITS
- 5 IF ATTENUATORS
- 6 NARROW BAND AMPLIFIER
- 7 VARIABLE RESOLUTION AMPLIFIER
- 12 POWER DISTRIBUTION

√ See parts list for earlier values and serial number ranges of parts, also component values encircled are included.

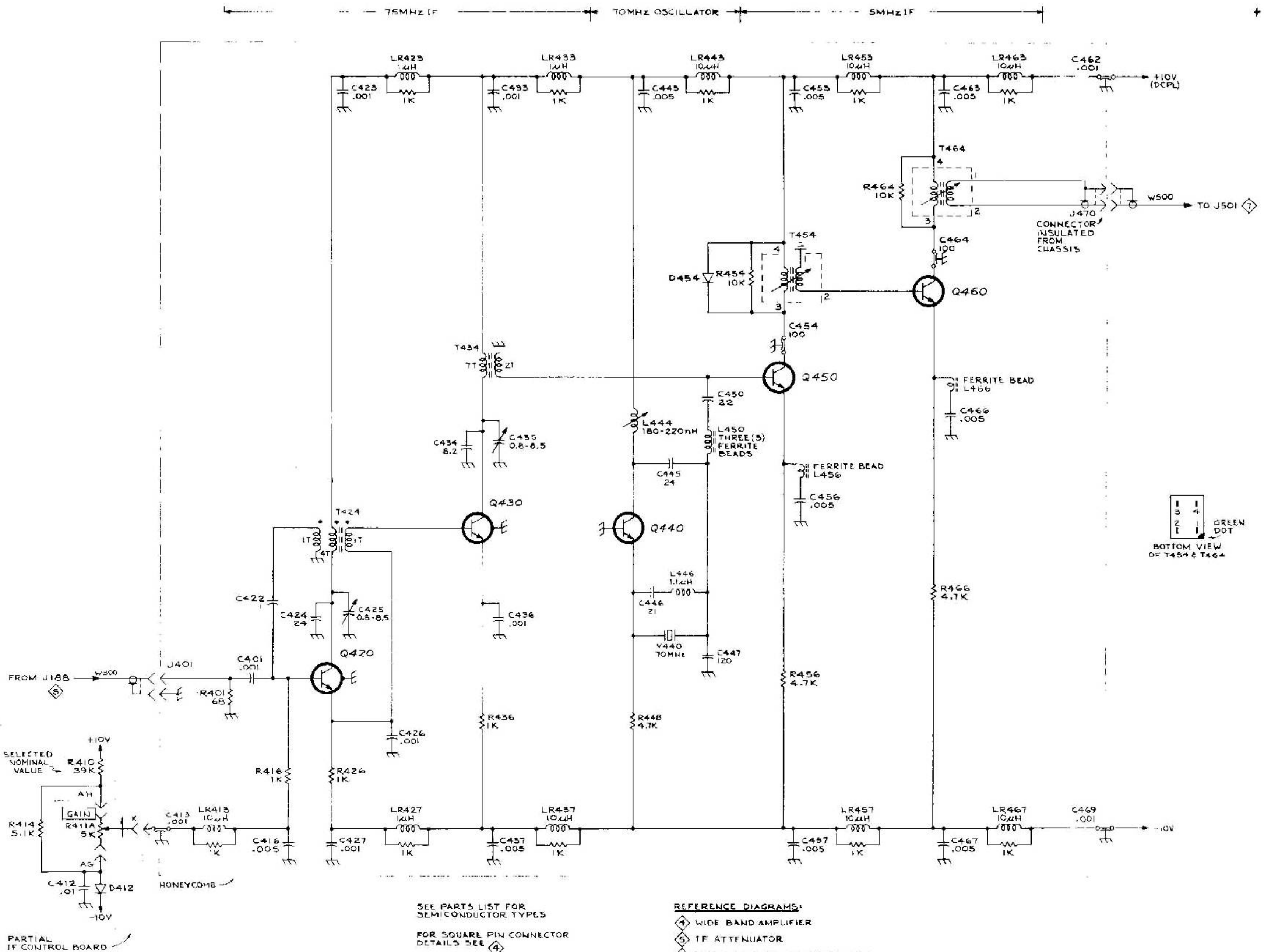




REFERENCE DIAGRAMS:

④ WIDE BAND AMPLIFIER

⑥ NARROW BAND AMPLIFIER



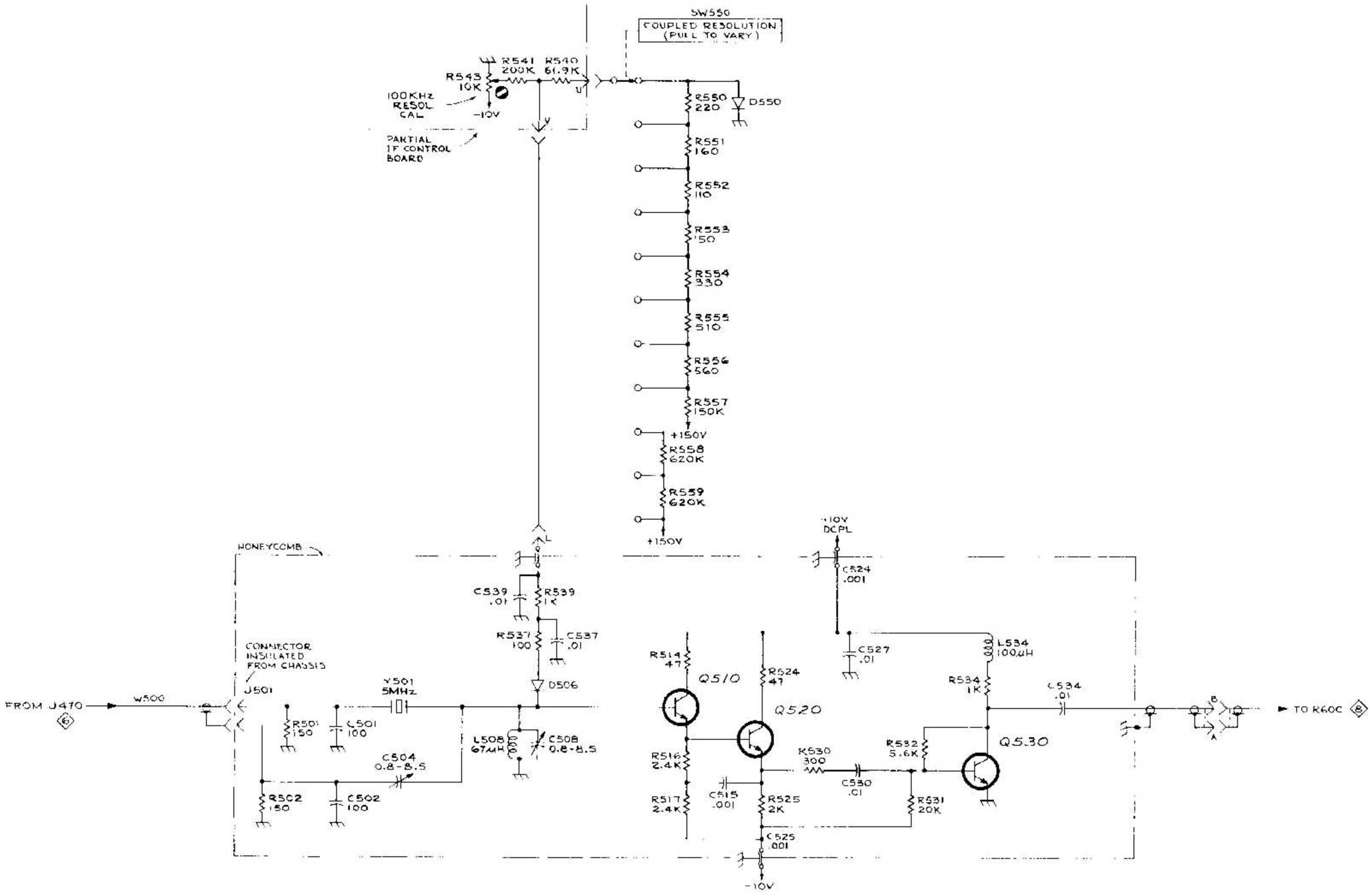
SEE PARTS LIST FOR SEMICONDUCTOR TYPES

FOR SQUARE PIN CONNECTOR DETAILS SEE ⟨4⟩

FOR POWER DISTRIBUTION SEE ⟨12⟩

REFERENCE DIAGRAMS:

⟨4⟩ WIDE BAND AMPLIFIER
⟨5⟩ IF ATTENUATOR
⟨7⟩ VARIABLE RESOLUTION AMPLIFIER
⟨12⟩ POWER DISTRIBUTION



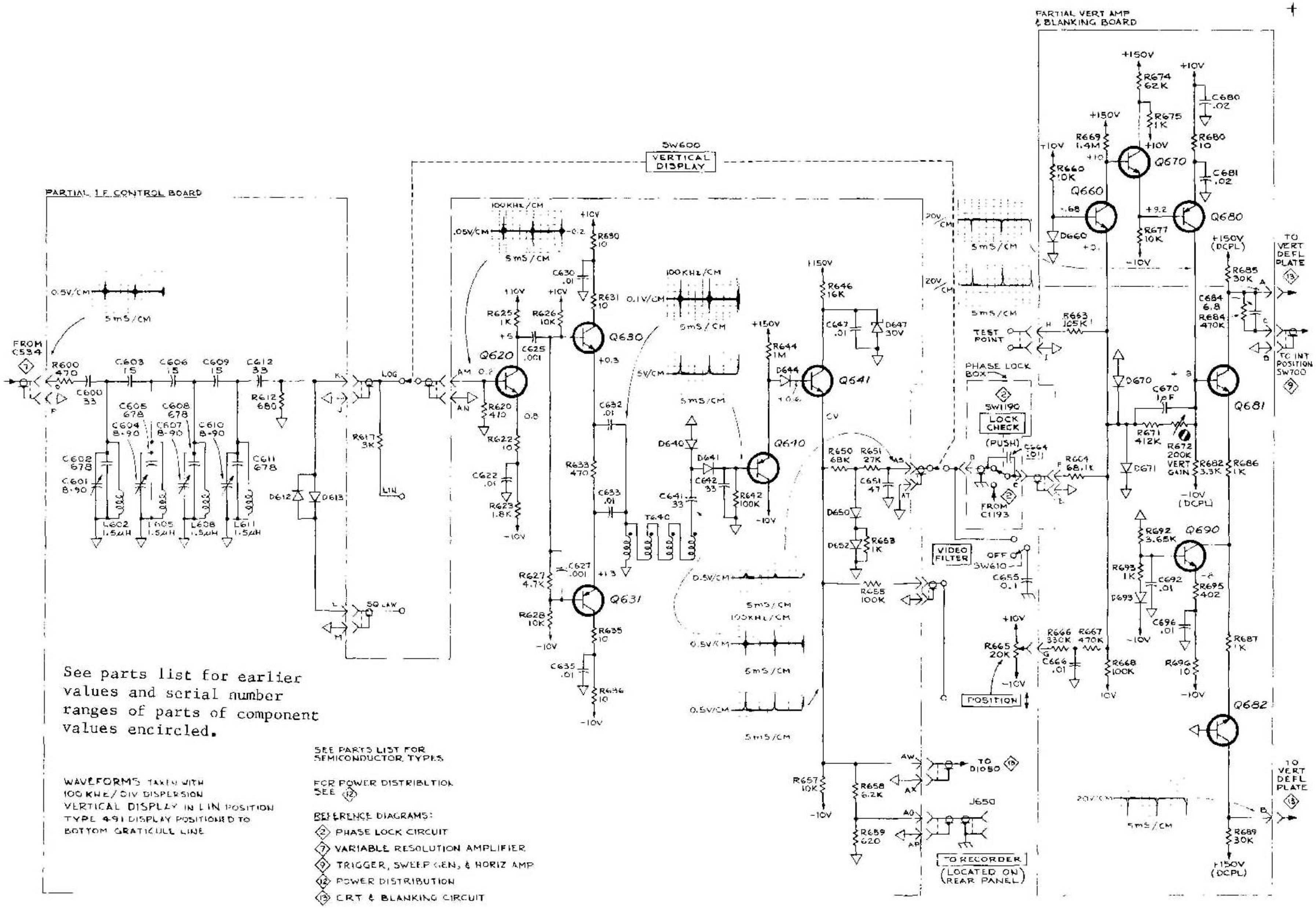
SEE PARTS LIST FOR SEMICONDUCTOR TYPES

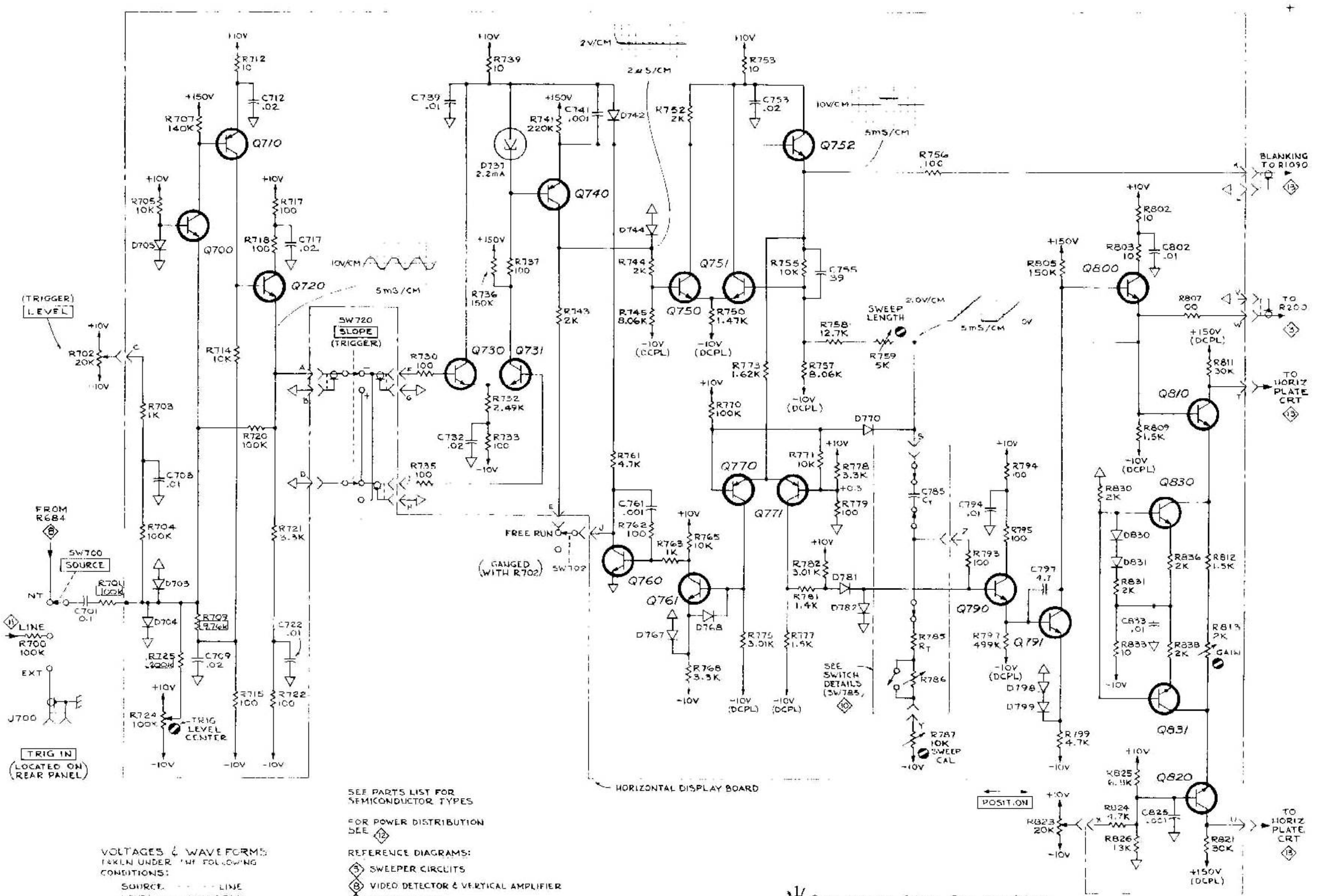
FOR SQUARE PIN CONNECTOR DETAILS SEE ⟨4⟩

FOR POWER DISTRIBUTION SEE ⟨12⟩

REFERENCE DIAGRAMS:

⟨4⟩ WIDE BAND AMPLIFIER
⟨6⟩ NARROW BAND AMPLIFIER
⟨8⟩ VIDEO DETECTOR & VERTICAL AMPLIFIER
⟨12⟩ POWER DISTRIBUTION


PARTIAL VERT AMP & BLANKING BOARD
PARTIAL I.F. CONTROL BOARD
SW600
VERTICAL DISPLAY
FROM C534
TO VERT DEFL PLATE
TO INT POSITION SW700
TEST POINT
PHASE LOCK BOX
SW1190
LOCK CHECK
(PUSH)
FROM C1193
VIDEO FILTER
SW610
POSITION
TO D1050
J650
TO RECORDER
(LOCATED ON REAR PANEL)
See parts list for earlier values and serial number ranges of parts of component values encircled.
WAVEFORMS TAKEN WITH 100 KHz/DIV DISPERSION
VERTICAL DISPLAY IN LIN POSITION
TYPE 491 DISPLAY POSITIONED TO BOTTOM GRATICULE LINE
SEE PARTS LIST FOR SEMICONDUCTOR TYPES
FOR POWER DISTRIBUTION SEE 12
REFERENCE DIAGRAMS:
2 PHASE LOCK CIRCUIT
7 VARIABLE RESOLUTION AMPLIFIER
9 TRIGGER, SWEEP GEN, & HORIZ AMP
12 POWER DISTRIBUTION
13 CRT & BLANKING CIRCUIT



SEE PARTS LIST FOR SEMICONDUCTOR TYPES

FOR POWER DISTRIBUTION SEE ⑫

REFERENCE DIAGRAMS:

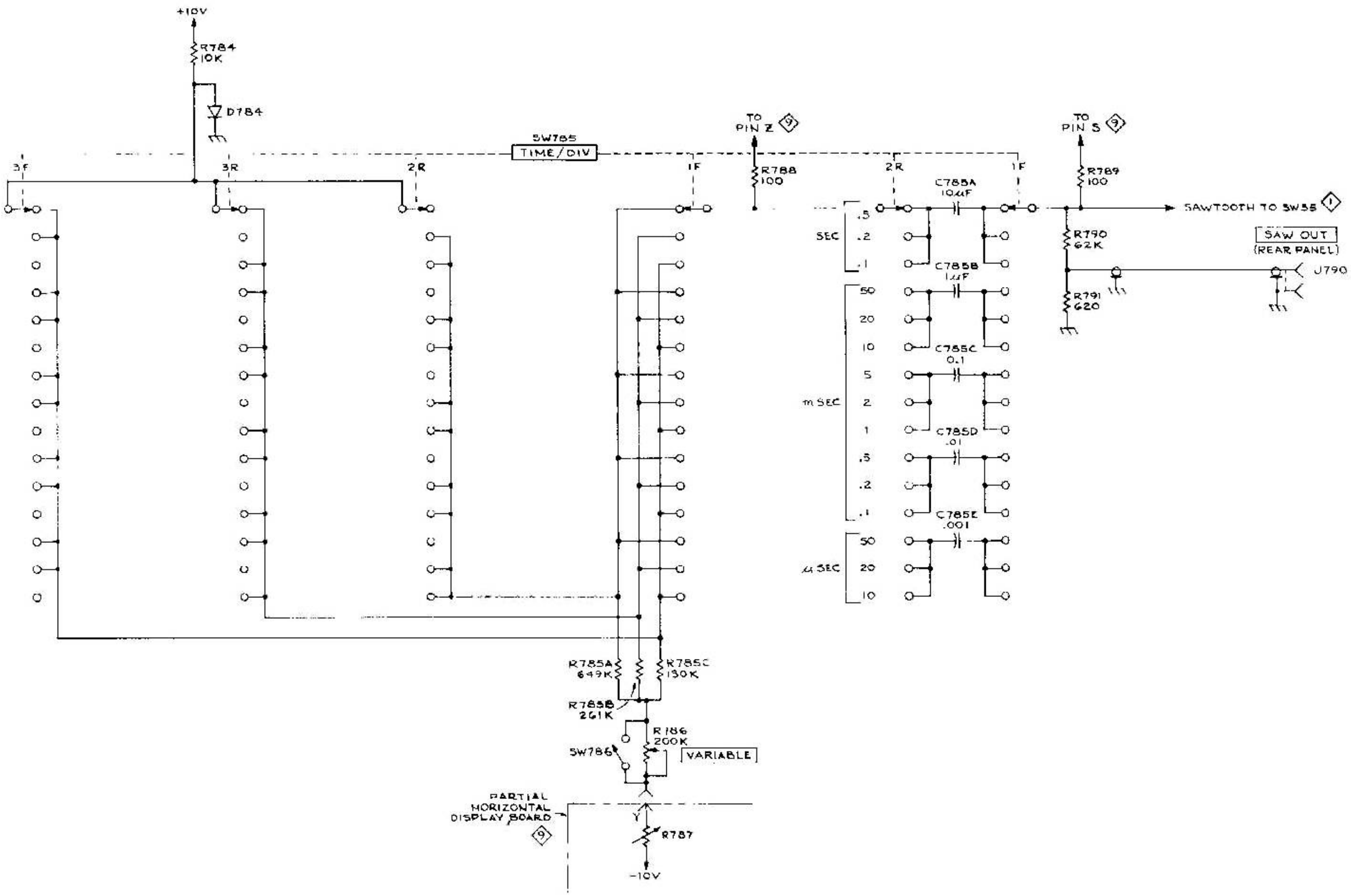
- ③ SWEEPER CIRCUITS
- ⑧ VIDEO DETECTOR & VERTICAL AMPLIFIER
- ⑩ TIMING SWITCH
- ⑪ POWER SUPPLY
- ⑫ POWER DISTRIBUTION
- ⑬ CRT & BLANKING CIRCUIT

VOLTAGES & WAVEFORMS TAKEN UNDER THE FOLLOWING CONDITIONS:

SOURCE	LINE
LEVEL	CENTERED
SLOPE	+
TIME / DIV	2mS

1 See parts list for earlier values and serial number ranges of parts, also component values encircled.

TRIGGER, SWEEP GEN, & HORIZ AMP ⑨



SEE PARTS LIST FOR SEMICONDUCTOR TYPES.

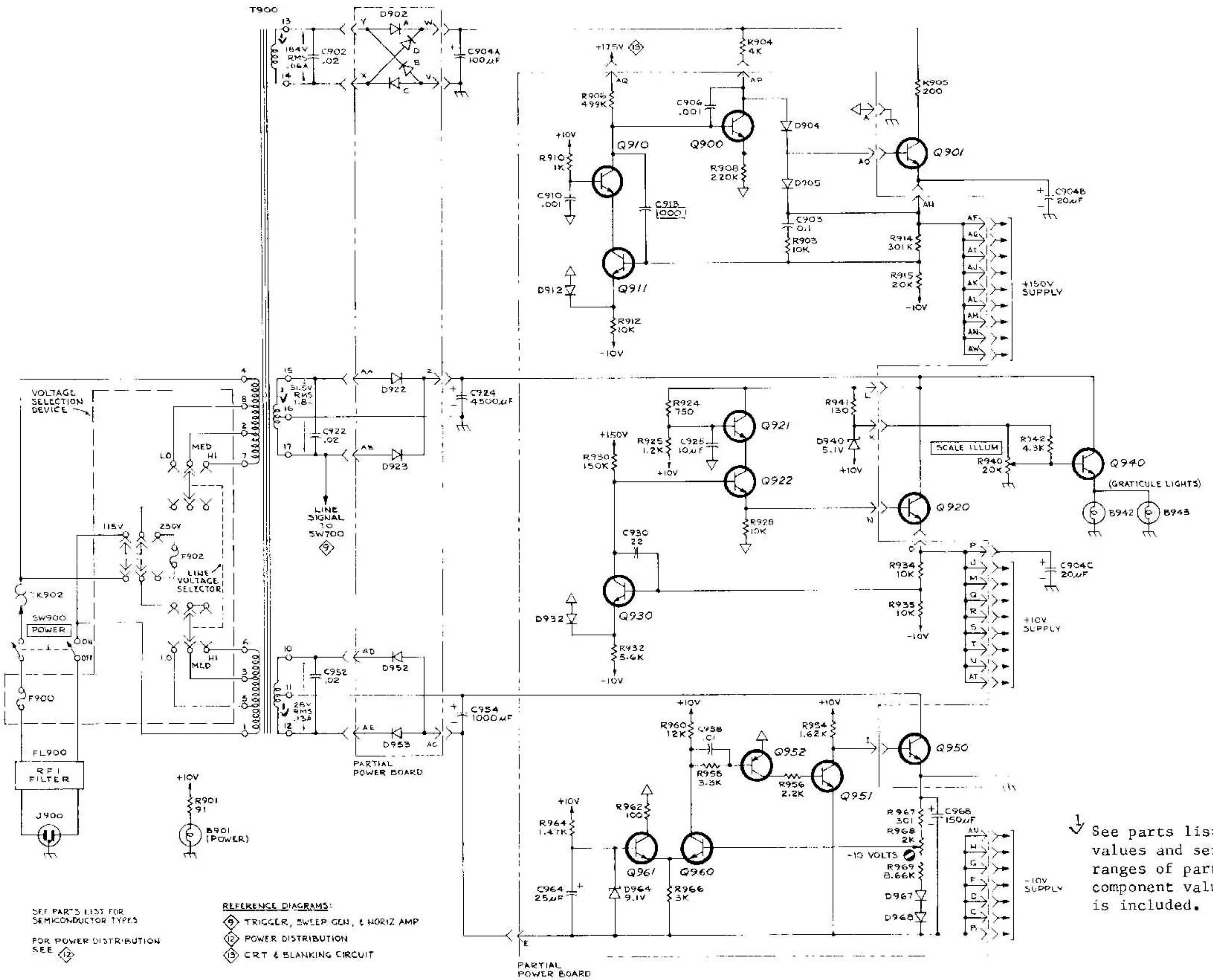
FOR POWER DISTRIBUTION SEE 12

REFERENCE DIAGRAMS:

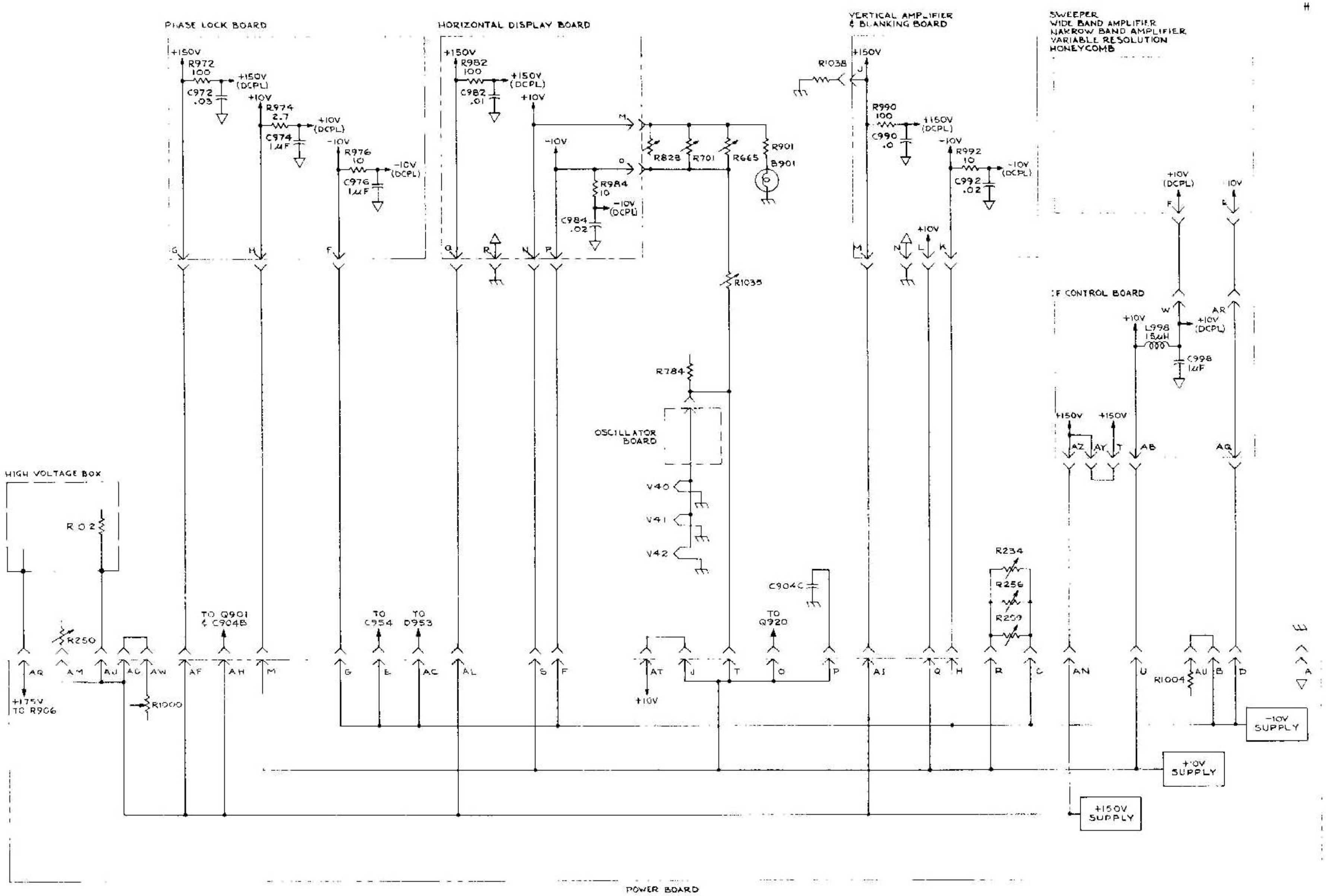
1 RF SECTION

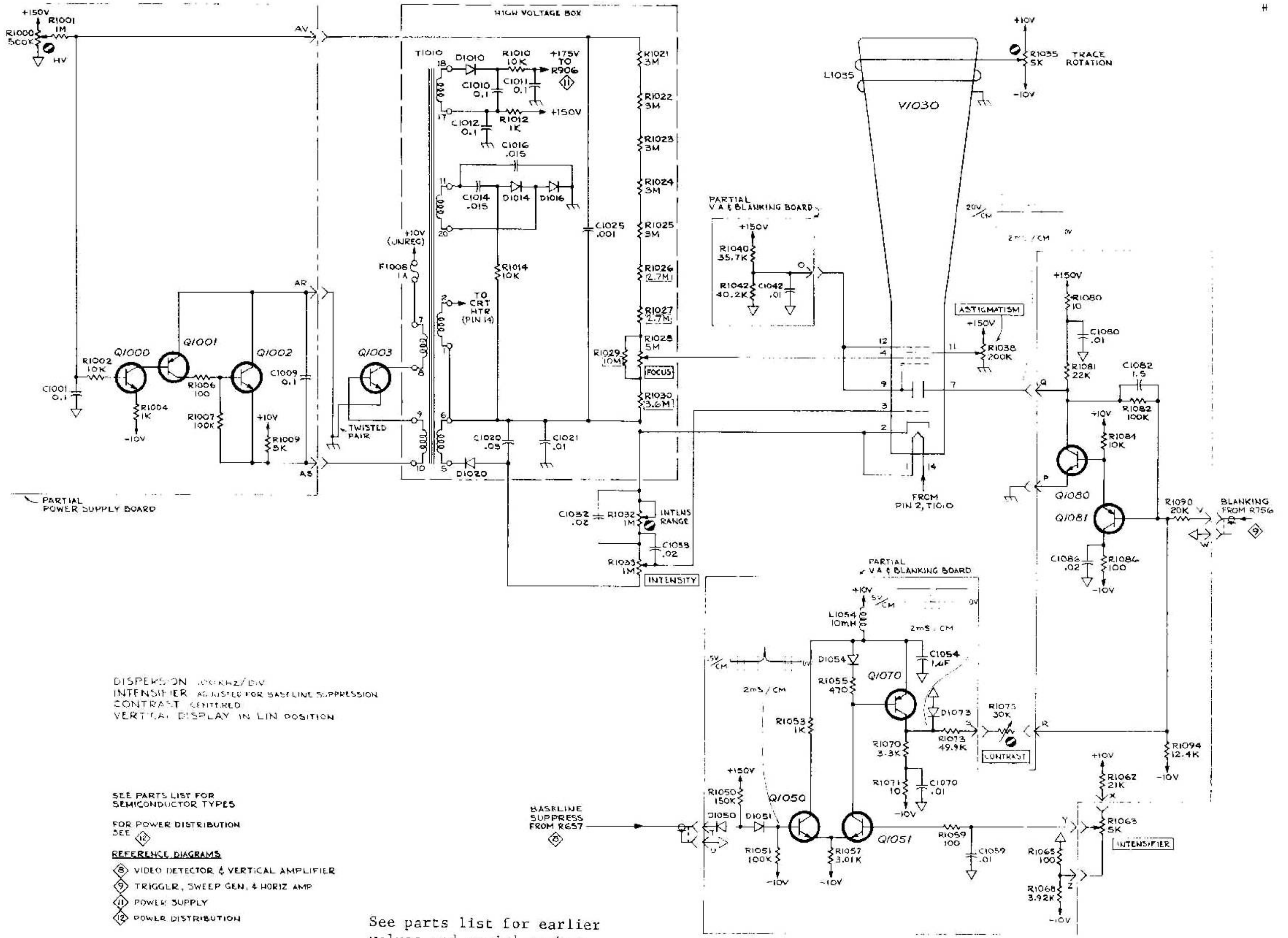
9 TRIGGER, SWEEP GEN & HORIZ AMP

12 POWER DISTRIBUTION



See parts list for earlier values and serial number ranges of parts, also component value encircled is included.


PHASE LOCK BOARD
HORIZONTAL DISPLAY BOARD
VERTICAL AMPLIFIER & BLANKING BOARD
SWEEPER
WIDE BAND AMPLIFIER
NARROW BAND AMPLIFIER
VARIABLE RESOLUTION
HONEYCOMB
IF CONTROL BOARD
OSCILLATOR BOARD
HIGH VOLTAGE BOX
POWER BOARD
-10V SUPPLY
+10V SUPPLY
+150V SUPPLY
+175V TO R906
TO Q901 & C904B
TO C954
TO D953
TO Q920



DISPERSION 100 kHz/DIV
INTENSIFIER ADJUSTED FOR BASELINE SUPPRESSION
CONTRAST CENTERED
VERTICAL DISPLAY IN LIN POSITION

SEE PARTS LIST FOR SEMICONDUCTOR TYPES

FOR POWER DISTRIBUTION SEE ⑫

REFERENCE DIAGRAMS

⑧ VIDEO DETECTOR & VERTICAL AMPLIFIER
⑨ TRIGGER, SWEEP GEN, & HORIZ AMP
⑪ POWER SUPPLY
⑫ POWER DISTRIBUTION

See parts list for earlier values and serial number ranges of parts of component values encircled.