TEKTRONIX®

FG 502
FUNCTION GENERATOR

INSTRUCTION MANUAL

Tektronix, Inc.
P.O. Box 500
Beaverton, Oregon 97005

Serial Number _____

070-1766-00

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WARRANTY

All TEKTRONIX instruments are warranted against defective materials and workmanship for one year. Any questions with respect to the warranty should be taken up with your TEKTRONIX Field Engineer or representative.

All requests for repair and replacement parts should be directed to the TEKTRONIX Field Office or representative in your area. This will assure you the fastest possible service. Please include the instrument Type Number or Part Number and Serial Number with all requests for parts or service.

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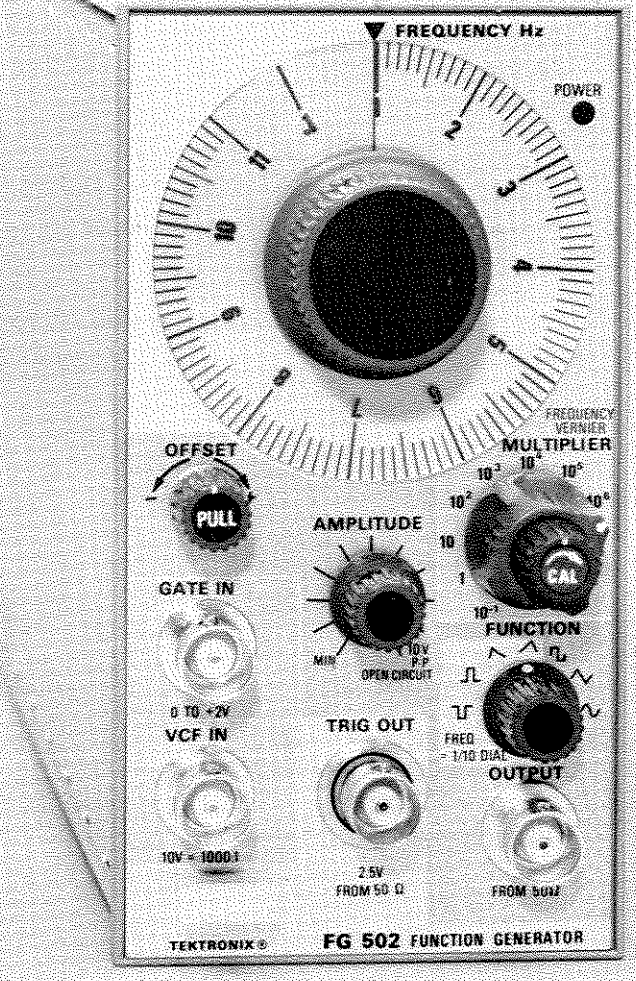


OPERATING INSTRUCTIONS

INSTRUMENT DESCRIPTION

The FG 502 Function Generator is designed to operate in a TM 500 series power module. Low distortion sine, square, triangle, positive and negative pulse and ramp waveforms from 0.1 Hz to 11 MHz, are available at the front panel. A +2.5 V square wave trigger also is available at the front panel. Variable DC offset of ±5 V is also provided.

A voltage-controlled frequency (VCF) input controls the output frequency from an external voltage source. The output frequency can be swept above or below the selected frequency, to a maximum of 1000:1, depending on the polarity and amplitude of the VCF input and the selected output frequency.

Also included is an external gate input that allows the generator to operate for the duration of an externally applied gating signal. This mode provides either a single cycle output, or a train (burst) of preselected waveforms, depending on the gating signal width and the generator frequency setting.

The variety of swept and modulated signals available from the FG 502 make it especially useful for such applications as testing servo-system or amplifier response, distortion and stability. It is also useful for FM generation, frequency multiplication, or as a variable beat-frequency oscillator, repetition-rate, or tone-burst generator. The square wave trigger output can be used as a source for TTL logic, or to synchronize an external device such as an oscilloscope or counter.

PREPARATION FOR USE

Initial Operation

CAUTION

Turn the Power Module off before inserting the plug-in; otherwise, damage may occur to the plug-in circuitry.

The FG 502 is calibrated and ready for use when received. It is designed to operate in any compartment of the TM 500 series power module. Refer to the power module instruction manual for line voltage requirements and power module operation. See Fig. 1-1 for installation-removal procedure. Check that the FG 502 is fully inserted in the power module. Pull the PWR switch on the power module. Check that the green POWER light on the FG 502 is on. The Controls, Connectors and Adjustments foldout page in Section 3 gives a complete description of the front panel controls and connectors.

Functions Available At Rear Connector

Refer to the rear connector assignment illustration in the Service Section of this manual for pin assignments.

A slot between pins 23 and 24 on the rear connector identifies the FG 502 as a member of the signal source family. A barrier may be inserted in the corresponding position of the power module jack, to prevent other than signal source plug-ins from being used in that compartment. This protects the plug-in should specialized connections be made to that compartment. Consult the Building A System section of the power module manual for further information.

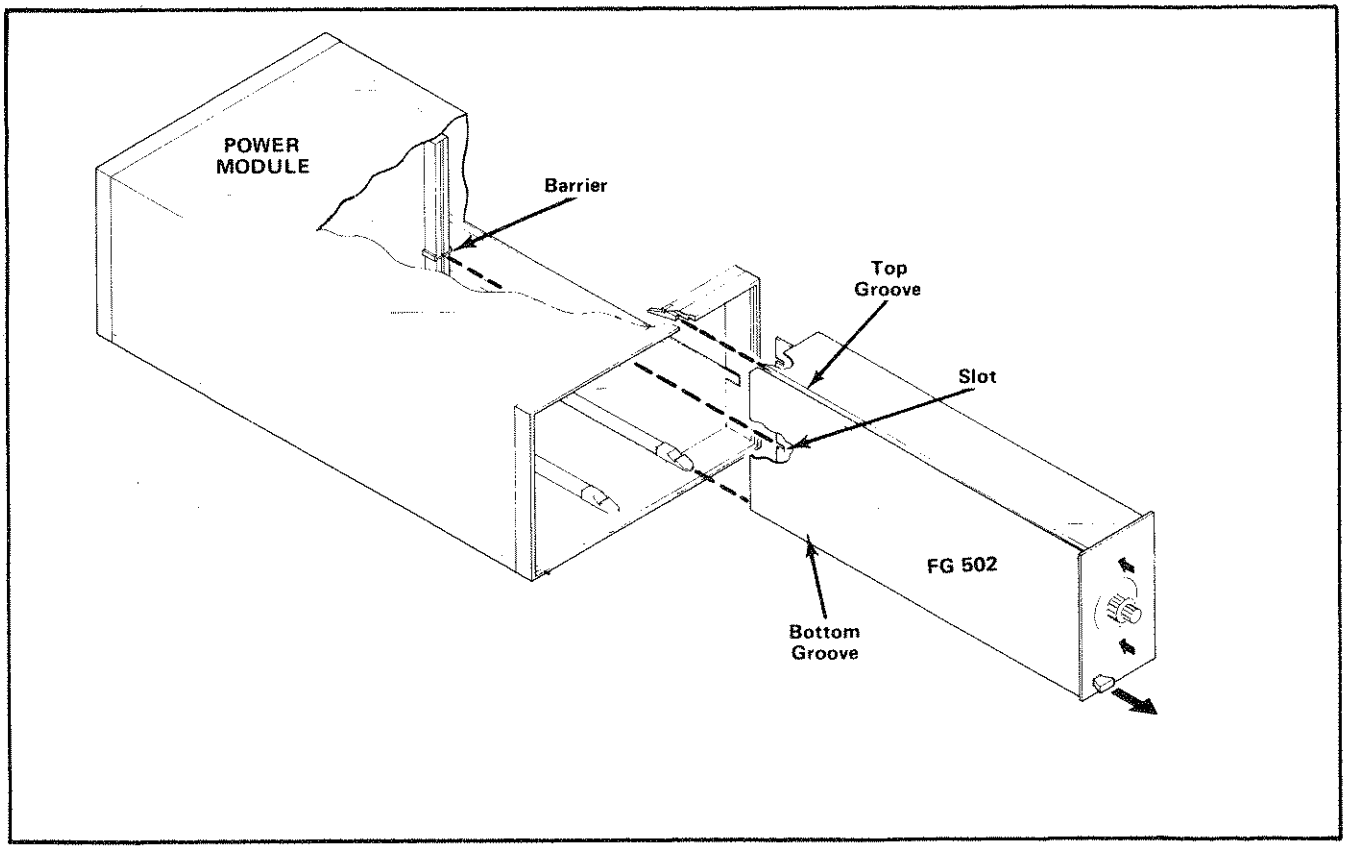


Fig. 1-1. FG 502 Installation and removal.

OPERATING CONSIDERATIONS

Output Connections

The output of the FG 502 is designed to operate as a 50 Ω voltage source working into a 50 Ω load. At the higher frequencies, an unterminated or improperly terminated output will cause excessive aberrations on the output waveform (see Impedance Matching discussion). Loads less than 50 Ω will reduce the waveform amplitude.

Excessive distortion or aberrations, due to improper termination, are less likely to occur at the lower frequencies (especially with sine and triangle waveforms). To ensure waveform purity, observe the following precautions:

1. Use good quality 50 Ω coaxial cables and connectors.

2. Make all connections tight and as short as possible.

3. Use good quality attenuators, if necessary to reduce waveform amplitude to sensitive circuits.

4. Use terminators or impedance-matching devices to avoid reflections when using long cables (6 feet or more).

5. Ensure that attenuators, terminations, etc. have adequate power handling capabilities for the output waveform.

Risetime and Falltime

If the output pulse from the FG 502 is used to measure the rise or falltime of a device, consider the risetime characteristics of the associated equipment used. If the risetime of the device under test is at least 10 times greater than the combined risetimes of the FG 502 plus the monitoring oscilloscope and associated cables, the error introduced will not exceed 1%. This error can generally be ignored. When the rise or falltime of the test device is less than 10 times as long as the combined risetimes of the testing system, the actual risetime of the device must be determined. This is found from the risetime of each component making up the system. The total risetime equals

the square root of the sum of the squares of the individual risetimes. $R_T = \sqrt{(R_1)^2 + (R_2)^2 + (R_3)^2 + \ldots}$. Conversely, the risetime of the device under test can be found, from the same relationship, if the actual risetimes in the system are known.

The physical and electrical characteristics of the pulse transmitting cable determine the characteristic impedance, velocity of propagation, and amount of signal loss. Signal loss, is related to the frequency; therefore, a few feet of cable can attenuate high frequency information in a fast-rise pulse. It is important therefore, to keep these cables as short as possible.

When signal comparison measurements or time difference determinations are made, the two signals from the test device should travel through coaxial cables with identical loss and time delay characteristics.

If there is a DC voltage across the output load, the output pulse amplitude will be compressed, or in some cases (if the voltage exceeds ±10 V), it may short the output. To prevent this from occurring, the output must be coupled through a DC blocking capacitor to the load. The time constant of the coupling capacitor and load must be long enough to maintain pulse flatness.

Impedance Matching

As a pulse travels down a tranmission line, each time it encounters a mismatch, or different impedance than that of the transmission line, a reflection is generated and sent back along the line to the source. The amplitude and polarity of the reflections are determined by the amount of the encountered impedance in relation to the characteristic impedance of the cable. If the mismatch impedance is higher than the line, the reflection will be of the same polarity as the applied signal. If it is lower, the reflection will be of opposite polarity.

If the reflected signal returns before the pulse is ended, it adds to or subtracts from the amplitude of the pulse. This distorts the pulse shape and amplitude. If the FG 502 is driving a high impedance such as the 1 MΩ input impedance (paralleled by a stated capacitance) of the vertical input to an oscilloscope, connect the transmission line to a 50 Ω attenuator, 50 Ω termination, and then the oscilloscope input. The attenuator isolates the input capacitance of the device, and the FG 502 is properly terminated.

A simple resistive impedance-matching network, that provides minimum attenuation, is illustrated in Fig. 1-2. To match impedance with the illustrated network, the following conditions must exist:

$$\frac{(R_1 + Z_2)\,R_2}{R_1 + Z_2 + R_2} \text{ must equal } Z_1$$

and

$$R_1 + \frac{Z_1 R_2}{Z_1 + R_2} \text{ must equal } Z_2.$$

Therefore:

$$R_1 R_2 = Z_1 Z_2; \text{ and } R_1 Z_1 = R_2(Z_2 - Z_1)$$

or

$$R_1 = \sqrt{Z_2(Z_2 - Z_1)}$$

and

$$R_2 = Z_1 \sqrt{\frac{Z_2}{Z_2 - Z_1}}.$$

For example, to match a 50 Ω system to a 125 Ω system, Z_1 equals 50 Ω and Z_2 equals 125 Ω.

Therefore:

$$R_1 = \sqrt{125(125 - 50)} = 96.8 \text{ ohms}$$

and

$$R_2 = 50\sqrt{\frac{125}{125-50}} = 64.6 \text{ ohms.}$$

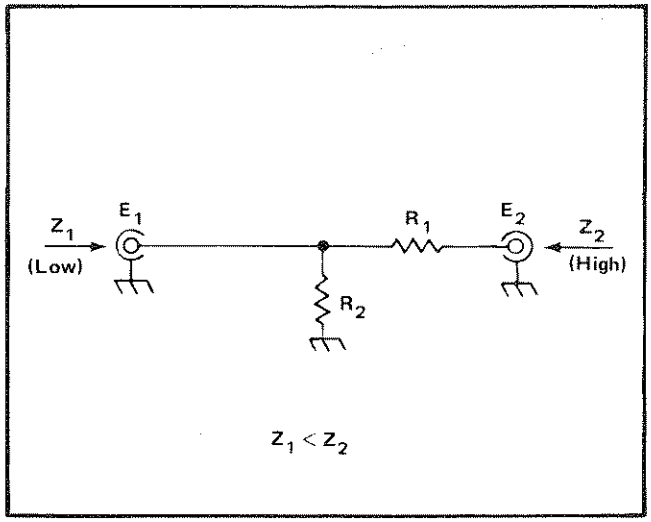


Fig. 1-2. Impedance matching network that provides minimum attenuation.

When constructing such a device, the environment surrounding the components should be designed to provide a transition between the impedances. The characteristic impedance of a coaxial device is determined by the ratio between the outside diameter of the inner conductor to the inside diameter of the outer conductor

$$(Z_O = \frac{138}{\sqrt{\Sigma}} \log_{10} D/d).$$

D is the inside diameter of the outer conductor, d is the diameter of the inner conductor, and Σ is the dielectric constant (1 in air).

The network in Fig. 1-2 provides minimum attenuation for a purely resistive impedance-matching device. The attenuation as seen from one end does not equal that seen from the other end. A signal (E_1) applied from the lower impedance source encounters a voltage attenuation (A_1) that is greater than 1 and less than 2, as follows:

$$A_1 = \frac{E_1}{E_2} = \frac{R_1}{Z_2} + 1$$

A signal (E_2) applied from the higher impedance source (Z_2) encounters a greater voltage attenuation (A_2) that is greater than 1 and less than $2(Z_2/Z_1)$:

$$A_2 = \frac{E_2}{E_1} = \frac{R_1}{R_2} + \frac{R_1}{Z_1} + 1 .$$

In the example of matching 50 Ω to 125 Ω,

$$A_1 = \frac{96.8}{125} + 1 = 1.77$$

and

$$A_2 = \frac{96.8}{64.6} + \frac{96.8}{50} + 1 = 4.43 .$$

The illustrated network can be modified, to provide different attenuation ratios, by adding another resistor (less than R_1) between Z_1 and the junction of R_1 and R_2.

OPERATION

Free-Running Output

Set the AMPLITUDE control fully clockwise, and make certain the OFFSET control is pushed in. Set the FUNCTION selector to the desired waveform. See Fig. 1-3. Select the desired frequency with the MULTIPLIER and FREQUENCY Hz dials. Note the ramp and pulse frequencies are one-tenth the FREQUENCY Hz and MULTIPLIER dial settings. The output frequency is calibrated when the FREQUENCY VERNIER control is in the full clockwise position. Connect the load to the OUTPUT connector and adjust the AMPLITUDE control for the desired output amplitude. Pull and adjust the OFFSET control to position the DC level (baseline) of the output waveform above or below 0 V as desired.

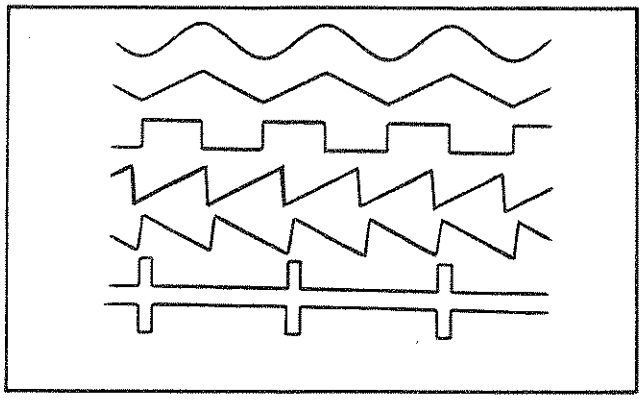


Fig. 1-3. Output waveforms available from the FG 502.

Gated Output

A gating signal of at least 0 V to +2 V applied to the GATE IN connector provides gated waveforms. The duration of the output waveforms depends upon the duration of the gating signal. The number of cycles during the burst depends upon the FREQUENCY Hz and MULTIPLIER dial settings. Single cycles can be obtained by applying a gating signal with a period approximately equal to the period of the FG 502 output. The number of cycles per burst may be approximated by dividing the gating signal duration by the period of the FG 502 output.

Output frequency can be varied during the burst duration by applying the proper voltage to the VCF IN connector. See Voltage-Controlled Frequency (VCF) Output following.

Voltage-Controlled Frequency (VCF) Output

The output frequency of the FG 502 can be swept over a frequency range of 1000:1, depending on the MULTI-

PLIER setting, by applying a 0 V to 10 V signal to the VCF IN connector. It may be necessary to vary the CAL control to obtain the full 1000:1 swept range or the lowest swept frequency desired. See Fig. 1-4 for maximum VCF range for each MULTIPLIER setting.

The polarity of the VCF input signal determines the direction the output frequency is swept from the frequency set by the MULTIPLIER, FREQUENCY Hz, and VERNIER controls. A positive-going voltage raises the frequency, while a negative-going voltage lowers the frequency. A voltage that varies symmetrically about 0 V sweeps the output frequency symmetrically about the center frequency determined by the frequency controls. See Fig. 1-5.

Since the VCF input amplitude versus frequency is a linear relationship, the frequency output range may be determined from the VCF input amplitude. Refer to the following test under the heading Response Analysis for a typical application using the VCF feature.

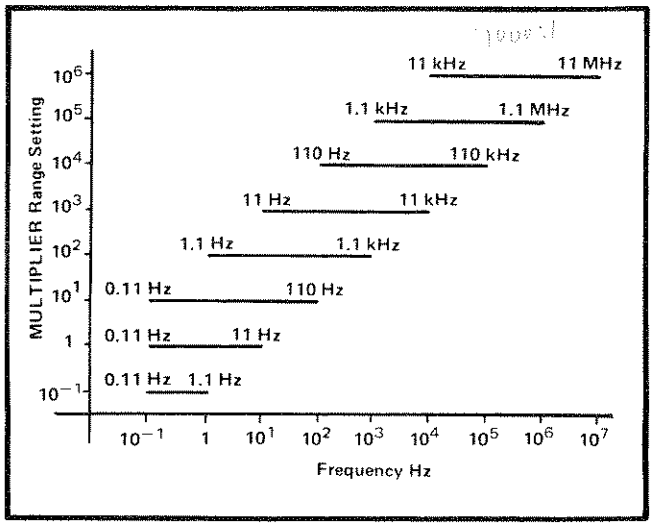


Fig. 1-4. Graph showing range of frequencies for each MULTIPLIER setting that can be swept with a 0 to 10 V signal applied to the VCF input.

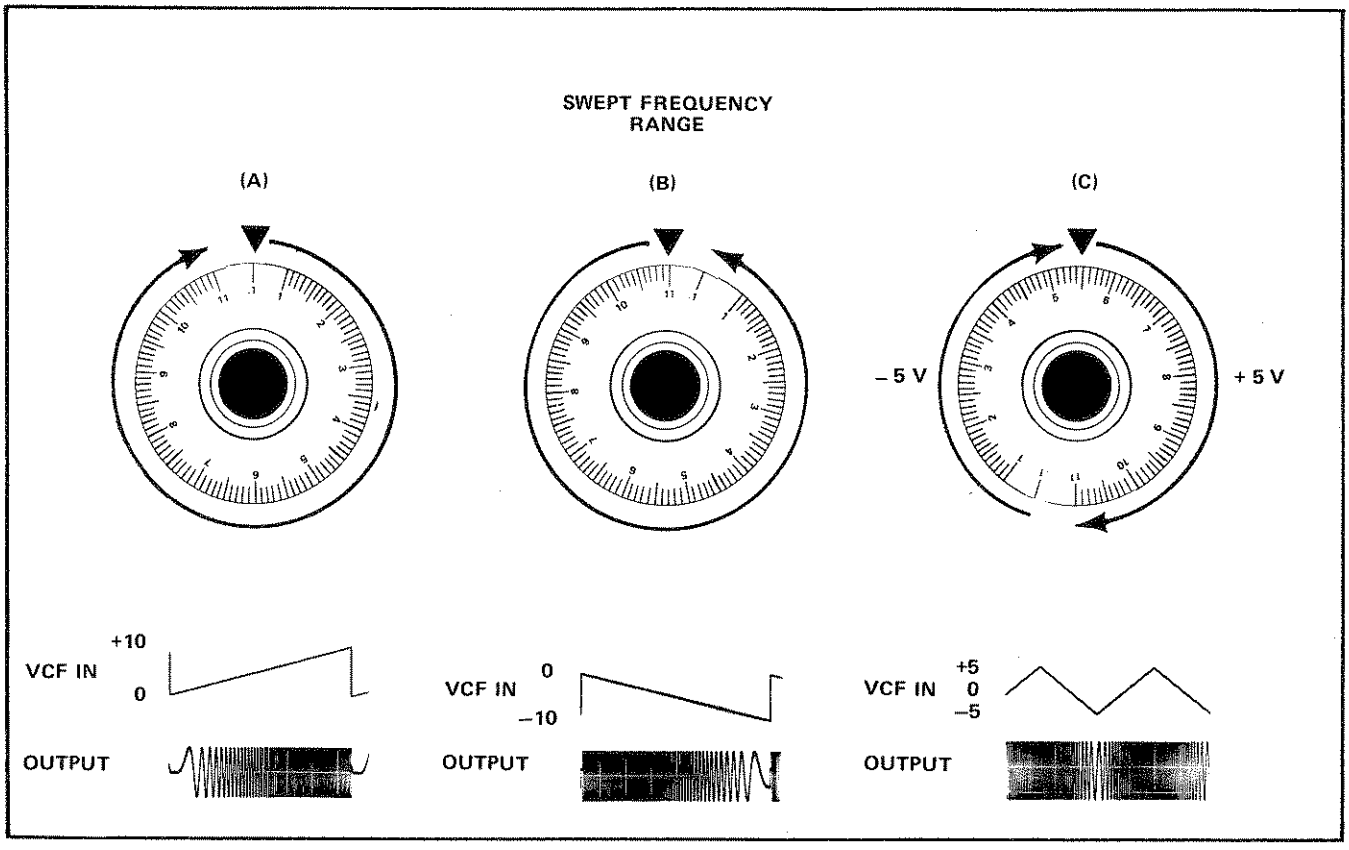


Fig. 1-5. Swept Frequency range with 10 V signals applied to VCF IN Connector.

APPLICATIONS

Response Analysis

The FG 502 is particularly suited for determining response characteristics of circuits or systems. This application utilizes the VCF input of the FG 502 to sweep the generator over a range of frequencies. By applying the desired waveform from the FG 502 to a device under test, and sweeping the waveform frequency over a selected range, various response characteristics can be observed on a monitoring oscilloscope.

The following procedure describes a technique for determining response characteristics of any frequency sensitive device that operates within the frequency range of the FG 502. Refer to the Voltage-Controlled Frequency (VCF) Output discussion under Operation for additional information.

1. Connect the equipment as shown in Fig. 1-6.

2. Set the MULTIPLIER selector and FREQUENCY Hz dial for the desired upper or lower frequency limit (depending on the direction you wish to sweep). See Fig. 1-4 for VCF ranges and MULTIPLIER settings.

3. Apply the desired waveform to the VCF IN connector.

4. Adjust the amplitude of the VCF input waveform for the desired output frequency range.

5. Observe the response characteristics on the monitoring oscilloscope.

The frequency at which a displayed response characteristic occurs can be determined by first removing the VCF input waveform, then manually adjusting the FREQUENCY Hz dial to again obtain the particular characteristic observed in the swept display. Then read the frequency on the FREQUENCY Hz dial.

Tone-Burst Generation or Stepped Frequency Multiplication

The FG 502 can be used as a tone-burst generator or frequency multiplier for checking tone-controlled devices. This application utilizes a Pulse Generator, such as the Tektronix PG 501, as a gating signal source and a Ramp Generator, such as the Tektronix RG 501, as a VCF signal source.

The following procedure describes a technique for obtaining a tone-burst or frequency multiplied output from the FG 502. Refer to the Gated (Burst) Output and the Voltage-Controlled Frequency (VCF) Output discussions under Operation for additional information.

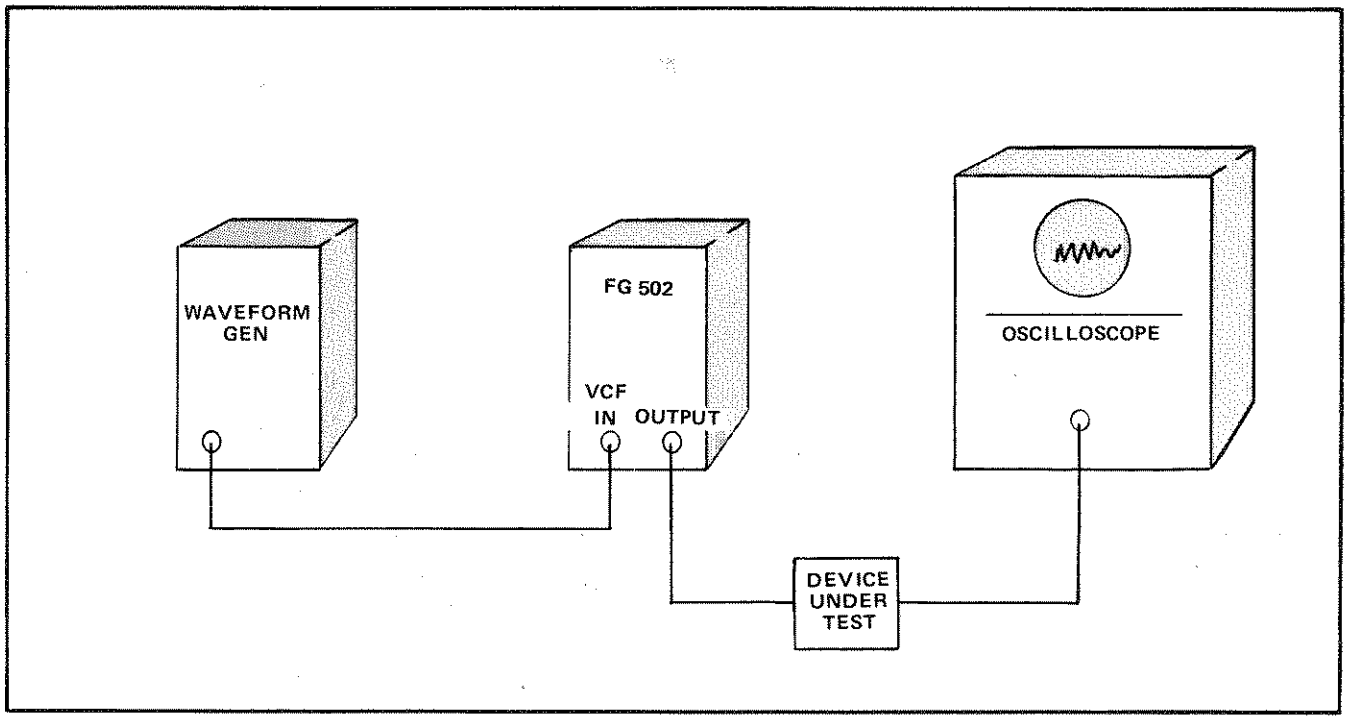


Fig. 1-6. Analyzing circuit or system response.

1. Connect the equipment as shown in Fig. 1-7.

2. Set the Ramp Generator for the desired ramp duration and polarity.

3. Adjust the Pulse Generator period for the desired number of bursts within the selected ramp duration. Adjust the Pulse Generator duration for the desired burst width.

4. Select the sweep frequency range by adjusting the FREQUENCY Hz dial for one end of the swept range (upper or lower limit depending on the polarity of the ramp). Then adjust the Ramp Generator amplitude for the other swept frequency limit.

Various other tone-burst or frequency multiplied characteristics can be obtained by using different gating input waveforms, i.e. triangle, sine, square, etc.

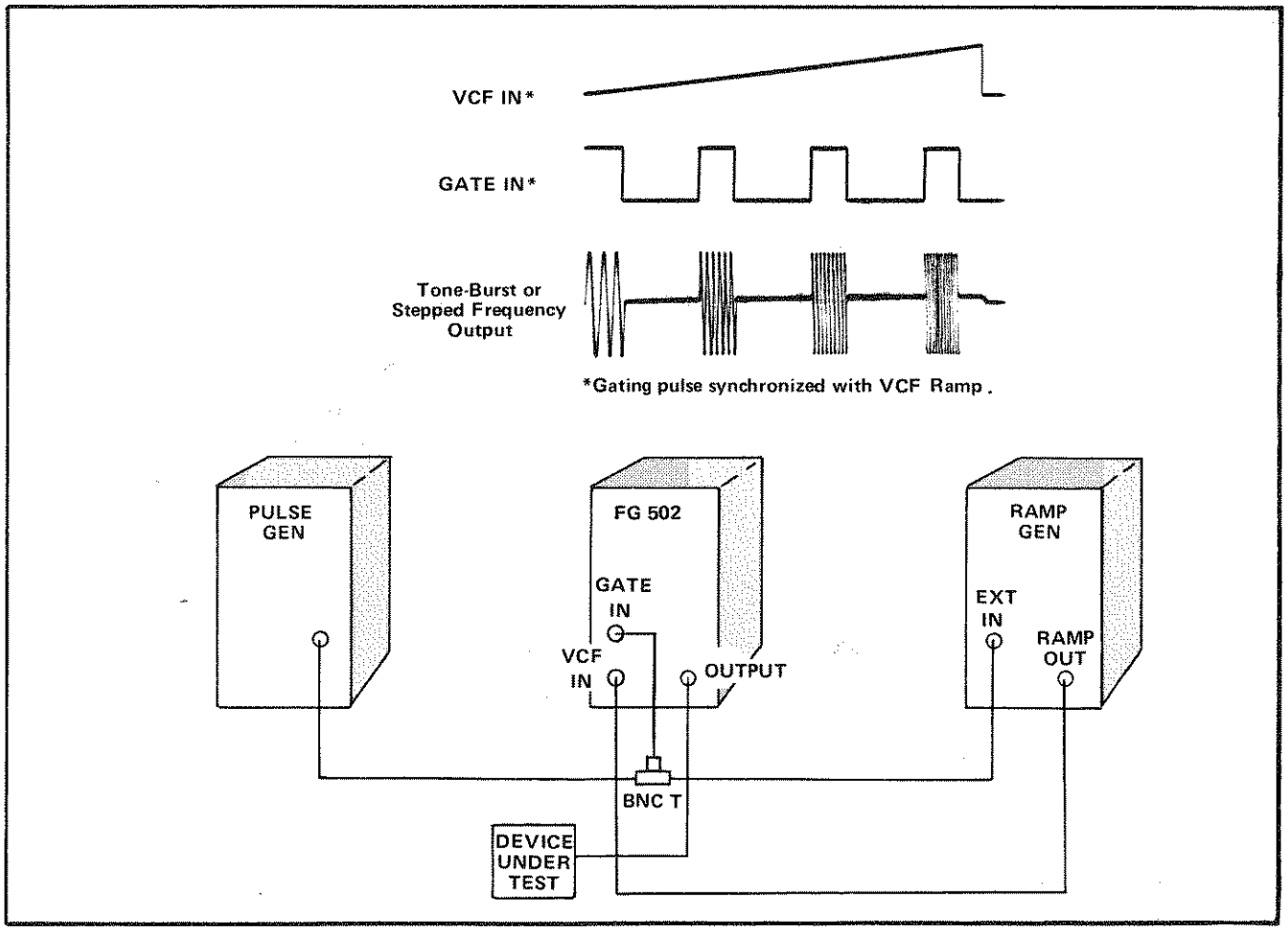


Fig. 1-7. Tone burst generation or stepped frequency multiplication.

ELECTRICAL CHARACTERISTICS

Performance Conditions

The electrical characteristics are valid only if the FG 502 is calibrated at an ambient temperature between +20°C and +30°C, and operated between 0°C and +50°C, unless otherwise noted.

WAVEFORMS:

Sine, triangle, square, ramp and pulse.

FREQUENCY RANGE:

0.1 Hz to 11 MHz.

FREQUENCY RESOLUTION:

1 part in 10^6 of full scale setting using the FREQUENCY VERNIER control.

FREQUENCY STABILITY:

≤0.1% for 1 hour, ≤0.5% for 24 hours. Dial must be on calibrated portion and ambient temperature must be 25°C ±5°C.

PULSE AND RAMP FREQUENCY:

1/10 triangle frequency.

DIAL RANGE:

1 to 11 calibrated, 0.1 to 1 uncalibrated.

DIAL ACCURACY:

≤3% of full scale from 0.1 Hz to 1 MHz.

≤5% of full scale from 1 MHz to 10 MHz.

11 MHz setting not less than 11 MHz.

AMPLITUDE:

10 V P-P open circuit, 5 V P-P into a 50 Ω load, excluding offset, referenced at 10 kHz.

AMPLITUDE FLATNESS:

Sine Wave: ≤ ±1.5 dB referenced at 10 kHz.

Square and triangle to sinewave amplitude ≤ ±3 db.

OFFSET RANGE:

±5 V open circuit, ±2.5 V into a 50 Ω load.

SINE WAVE DISTORTION:

Equal to or less than 0.5% from 10 Hz to 50 kHz. Harmonics > −30 dB down at all other frequencies. Dial must be on calibrated portion, and ambient temperature must be 25°C ±5°C.

TRIANGLE SYMMETRY:

Within 1% from 0.1 Hz to 1.1 MHz, within 3% from 1.1 MHz to 11 MHz using 10^6 MULTIPLIER setting. Dial must be on calibrated portion. Ambient temperature must be 25°C ±5°C.

TRIANGLE LINEARITY:

Within 1.0% from 0.1 Hz to 110 kHz, within 3% from 100 kHz to 1.1 MHz using 10^5 MULTIPLIER setting, within 5% from 1 MHz to 11 MHz using 10^6 MULTIPLIER setting.

SQUARE WAVE and PULSE OUTPUT:

Risetime: ≤20 ns.

Aberrations: ≤3% P-P at full amplitude into a 50 Ω load.

PULSE AND RAMP ASPECT RATIO:

95/5.

VOLTAGE CONTROLLED FREQUENCY INPUT:

Range: A 10 V signal shifts frequency ≥ 1000:1 where maximum frequency ≤11X MULTIPLIER setting and minimum frequency ≥0.011X MULTIPLIER setting.

Slew Rate: ≥0.5 V/μs.

EXTERNAL GATE INPUT:

0 V to ≥+2 V, not to exceed +15 V. Baseline of output waveform during off period within 500 mV measured from 0 V. Input impedance is 1 kΩ. Usable on the 10^6 MULTIPLIER setting only for sine, triangle, or square waveform outputs.

TRIGGER OUTPUT:

+2.5 V from 50 Ω.

POWER CONSUMPTION:

15 watts.

THEORY OF OPERATION

Introduction

The triangle waveform is the basic waveform in the FG 502. The ramp waveforms are triangle waveforms with non-equal runup and rundown times. The sine wave is derived from the triangle waveform, using a four step approximation. The square and pulse waveforms are generated by the triangle generator control circuitry.

Refer to the simplified Block Diagram, and the circuit diagrams in the pullout pages of this manual along with the following discussion, for a complete understanding of the FG 502 operation.

Triangle Generator

Operational amplifier U140, with Q140, and the positive timing resistors, form a positive constant current source. U175, Q175, and the negative timing resistors form a negative constant current source. These constant current sources supply the current (either positive or negative) to charge the timing capacitor, generating the triangle waveform.

To understand the operation of this circuit, assume the junction of CR140 and CR170 is positive with respect to ground. CR140 is off and CR170 is conducting. CR175 is off, and the capacitor is charging from the positive current source through CR145. Q292 is off, clamping the junction of CR140 and CR170 at approximately 5 V above ground. This action occurs through CR300, CR304, CR308 and CR312. Current to hold the junction of CR140 and CR170 positive is supplied via R155, connected to the +17 V supply.

In this state CR248 is on, CR245 is off, and the voltage level at the base of Q232 (not conducting) is set by the current flowing through R245, CR246, and R240.

The ramp, moving in the positive direction, appears in the same polarity at the base of Q230B. This is accomplished through the action of source follower Q220, with its constant current source Q202. Q204 and Q210, complementary emitter followers, drive the AC compensated attenuator RT224, C224, and R220.

When the base of Q230B (now conducting) reaches the same voltage as the base of Q230A (Q230A and Q230B form a comparator) Q230B stops conduction and Q230A turns on. The collector of Q230A goes positive, turning Q292 on and Q290 off. The collector of Q292 goes negative, limited to about −5 V by diodes CR302, CR306, CR310 and CR314. This action turns diodes CR248 and CR246 off, setting the level at the base of Q232 slightly below ground. The negative voltage at the junction of CR140 and CR170 turns CR175 on and CR170 and CR145 off. This action disconnects the positive current source from the timing capacitor and connects the negative current source through CR175, causing the ramp to go in the negative direction. The action continues until Q230B turns on, by the negative ramp at its base, and the entire cycle is repeated. R250 sets the voltage at the base of Q230A and therefore, the DC level of the triangle waveform.

The frequency of the triangle waveform is controlled by two factors: (1) the value of the timing capacitor, and (2) the amount of current available to charge it. The current is varied by changing the value of the timing resistors, (the larger the value of the timing resistors and capacitors, the slower the rate of rise), and the voltage across the timing resistors.

The voltage across the timing resistors is essentially the voltage at pin 3 of operational amplifiers U140, in the positive current source, and U175, controlling the negative current source. The voltage at pin 3 of U140 is controlled by summing amplifier U135. The voltage at pin 3 of U175 is controlled by summing amplifier U170. Input voltage to these summing amplifiers is controlled by the FREQUENCY Hz dial through U100, or the voltage present at the VCF IN front panel connector. When the voltage at pin 3 of U100 goes more positive by increasing the FREQUENCY Hz dial setting, or through the VCF IN input, the voltage at pin 6 of U140 goes negative, and pin 6 of U175 positive. This action increases the voltage across the timing resistors. The value of the timing resistors and timing capacitor is selected by the front panel MULTIPLIER switch. R170 improves low frequency symmetry by compensating for bias currents in the operational amplifiers when operating at low voltage levels. Voltage levels through this circuit are 0 to about +10 V at the input of U100. This is translated at about +7 V to +17 V at pin 6 of U135.

During non-gated operation, the base of Q332 is two diode drops above ground. Q332 is off and Q330 is conducting. Q325 is on and Q315 off, back biasing CR315, and allowing normal operation of the triangle generator. When the proper level gating signal is applied to the front panel GATE IN connector, the base of Q332 alternates with the gating signal. When the gating signal is low (ground potential) Q332 conducts. This action translates to conduction in Q315 and forward biasing CR315. This locks the junction of CR140 and CR170 at the level set by R155, causing these diodes to conduct the timing capacitor charging current to ground, through Q315. Operation of the triangle generator is inhibited by this action. When the gating signal goes positive CR315 is back biased, and the generator functions normally.

Ramp waveforms are generated by changing the value of either the positive or negative timing resistor, to create different rise and fall times.

The square wave that controls charging of the timing capacitor is picked off at the collector of Q290, to operate the trigger out amplifier. The impedance looking into the emitter of Q268 is about 51 Ω. The same waveform operates the isolation diode bridge CR260, CR262, CR264, and CR266. The output from this bridge is the square or pulse waveforms. The triangle waveform, to the output amplifier and sine shaper, is taken from the emitter of Q210.

Sine Shaper

This circuitry provides a four step approximation of a sine wave, from the triangle waveform, by use of a diode ladder configuration. This circuit consists of four bridges. All inputs to these bridges are connected to R350, and all outputs are connected to their common load resistor R395. Each bridge is supplied by current from the +17 V and −17 V supplies through different value resistors, R358, R368, R378, R388 and their equal value complementary resistors in the negative supply leads.

As the triangle waveform increases in voltage, each bridge reaches a current limit whereby it can no longer increase current through the load resistor, R395. These current limits are set by R382, R384, R388, and similar resistances for the other bridges. R350, and R250 are set for minimum sine wave distortion.

Sine Wave Buffer

This circuit operates as an inverting operational amplifier, with a gain of about three or four. The sine wave output from the shaper is fed to the base of Q400. A negative-going signal at the base of Q400 causes its collector to go positive and the collector of Q410 negative. The collectors of Q420 and Q430 respond in the opposite polarity. Q440 inverts the waveform at the collector of Q420, and the bases of Q442 and Q444 are driven in the same polarity. Output and negative feedback are taken from the junctions of R442 and R444. R450 in the negative feedback loop sets the DC gain, and C450 sets the AC gain.

Output Amplifier

This circuit operates as an inverting operational amplifier. The selected waveform is applied to the base of Q480 through the AMPLITUDE control, R465. Q480 and Q490 operate as an emitter-coupled amplifier. The collector of Q480 drives the base of Q500. The base of Q515 is driven by the collector of Q500. The collector of Q490 drives the base of Q506. The polarities are such that the collectors of Q515 and Q506 move in phase. Their collectors drive the parallel output stage Q530, Q532, Q540, and Q542. The bypassed resistors in the emitter circuit of the output transistors limit the output current. R550, R552, R555, and R556 provide a back termination of 50 Ω. Negative feedback is taken from the junction of the current limiting resistors in the output stage. R566, in the feedback loop, sets the DC gain while C564, C566, C568, and C574 adjust the AC gain. R475, the OFFSET control, places an adjustable DC bias on the input of the amplifier.

Power Supplies

The diode bridge, CR600, rectifies 25 V AC from the power module. The full wave rectified DC is filtered by C602 and applied as regulated +20 V DC to the circuitry in the FG 502, through the series pass transistor located in the power module.

VR610 sets the voltage at pin 3 (+ input of an operational amplifier) of U615. U615 has a gain of approximately three. The output at pin 6 therefore, is about 20 V. Emitter follower Q620 drives the base of the series pass transistor. Should the +20 V load increase, pin 2 of U615 (through R623 and R625) goes negative. This causes pin 6 to go positive, increasing current flow and restoring the +20 V to its previous level. Should the current drawn increase, so the voltage across R632 is sufficient to turn Q622 on, current limiting occurs. Q620 reduces conduction, reducing the current through the series pass transistor to a safe level. CR632 protects the +20 V supply, should it short to the minus supply.

U664 is an operational amplifier with a gain of about one. The reference voltage is the +20 V applied at pin 2. The output at pin 6 (−20 V) drives emitter follower Q662. Q662 drives the series pass transistor located in the power module. Current limiting takes place in conjunction with

Q660 and R655. Feedback occurs through R678. The action of this circuit is similar to the +20 V regulator. CR655 protects this supply, should a short occur to +20 V.

The +17 V is referenced to the +20 V. U635, with a gain of about one, controls Q635, the series pass transistor for this supply. Feedback occurs at pin 2 of U635. Current limiting in the +20 V supply protects this circuit.

The −17 V supply is referenced to the +17 V at pin 2 of U650. The gain of U650 is about one. Q650 serves as the series pass transistor for this supply. Feedback occurs through R640. Current limit for this supply is the +20 V supply.

The regulatory action of the +17 V and −17 V supplies is similar to that in the 20 V supplies.

SERVICE INFORMATION

SYMBOLS AND REFERENCE DESIGNATORS

Electrical components shown on the diagrams are in the following units unless noted otherwise:

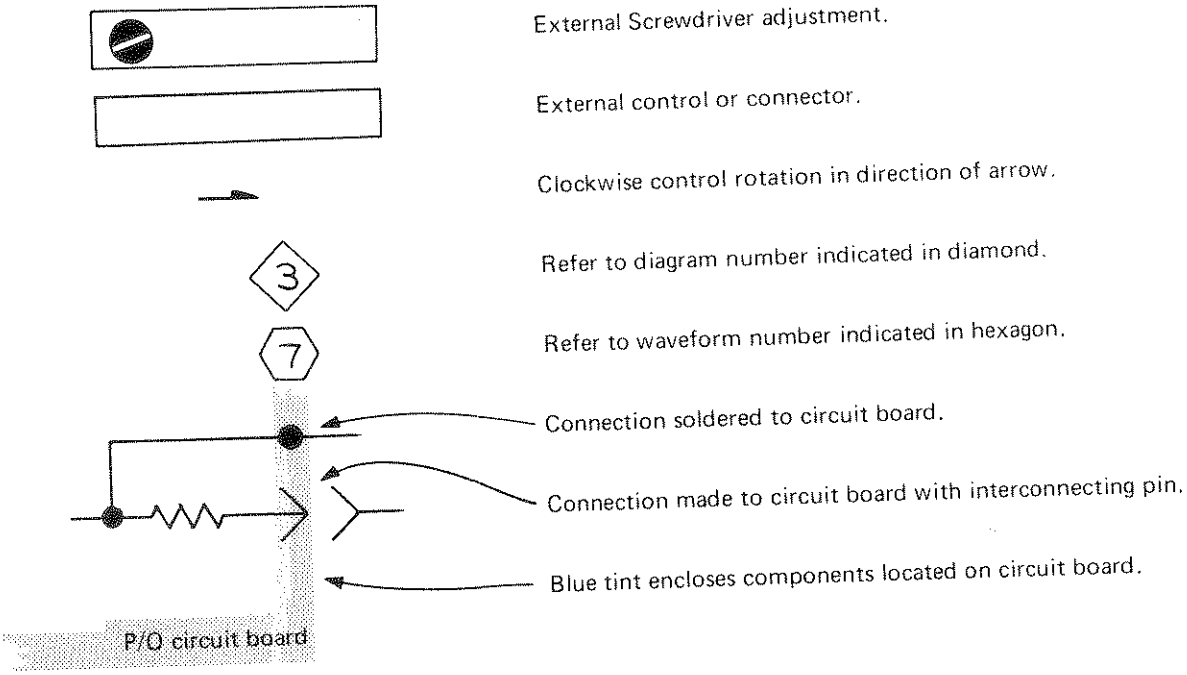
Capacitors = Values one or greater are in picofarads (pF).
Values less than one are in microfarads (μF).

Resistors = Ohms (Ω)

Symbols used on the diagrams are based on ANSI Y32.2 – 1970.

Logic symbology is based on MIL-STD-806B in terms of positive logic. Logic symbols depict the logic function performed and may differ from the manufacturer's data.

The following special symbols are used on the diagrams:



External Screwdriver adjustment.

External control or connector.

Clockwise control rotation in direction of arrow.

Refer to diagram number indicated in diamond.

Refer to waveform number indicated in hexagon.

Connection soldered to circuit board.

Connection made to circuit board with interconnecting pin.

Blue tint encloses components located on circuit board.

REAR CONNECTOR PIN ASSIGNMENTS

TABLE 2-1

	B		A	
Trigger Output Common	28		28	Output
Trigger Output	27		27	Output Common
	26	Signal source plug-in barrier slot	26	
Gate In Common	25		25	
Gate In	24		24	
	23		23	
VCF In Common	22		22	
VCF In	21		21	
	20		20	
	19		19	
	18		18	
	17		17	
	16		16	
	15		15	
	14		14	
* 25 VAC Winding	13		13	* 25 VAC Winding
+33.5 V Filtered DC	12		12	+33.5 V Filtered DC
* Collector lead of PNP Series-Pass Transistor	11		11	* Base lead of PNP Series-Pass Transistor
Transformer Shield	10		10	* Emitter lead of PNP Series-Pass Transistor
33.5 V Common	9		9	33.5 V Common
−33.5 V Filtered DC	8	TM 500 barrier slot	8	−33.5 V Filtered DC
* Collector lead of NPN Series-Pass Transistor	7		7	* Emitter lead of NPN Series-Pass Transistor
Not Used	6		6	* Base lead of NPN Series-Pass Transistor
17.5 VAC Winding	5		5	17.5 VAC Winding
+11.5 V Common	4		4	+11.5 V Common
+11.5 V Common	3		3	+11.5 V Common
+11.5 V Filtered DC	2		2	+11.5 V Filtered DC
* 25 VAC Winding	1		1	* 25 VAC Winding
	B		A	

Rear-view of plug-in

Assignments listed for pins 1A—13A and 1B—13B are available in all power modules; however only those pins marked with an asterisk (*) are used by the FG 502.

REPLACEABLE ELECTRICAL PARTS

PARTS ORDERING INFORMATION

Replacement parts are available from or through your local Tektronix, Inc. Field Office or representative.

Changes to Tektronix instruments are sometimes made to accommodate improved components as they become available, and to give you the benefit of the latest circuit improvements developed in our engineering department. It is therefore important, when ordering parts, to include the following information in your order: Part number, instrument type or number, serial number, and modification number if applicable.

If a part you have ordered has been replaced with a new or improved part, your local Tektronix, Inc. Field Office or representative will contact you concerning any change in part number.

Change information, if any, is located at the rear of this manual.

SPECIAL NOTES AND SYMBOLS

X000	Part first added at this serial number
00X	Part removed after this serial number

ITEM NAME

In the Parts List, an Item Name is separated from the description by a colon (:). Because of space limitations, an Item Name may sometimes appear as incomplete. For further Item Name identification, the U.S. Federal Cataloging Handbook H6-1 can be utilized where possible.

ABBREVIATIONS

ACTR	ACTUATOR	PLSTC	PLASTIC
ASSY	ASSEMBLY	QTZ	QUARTZ
CAP	CAPACITOR	RECP	RECEPTACLE
CER	CERAMIC	RES	RESISTOR
CKT	CIRCUIT	RF	RADIO FREQUENCY
COMP	COMPOSITION	SEL	SELECTED
CONN	CONNECTOR	SEMICOND	SEMICONDUCTOR
ELCTLT	ELECTROLYTIC	SENS	SENSITIVE
ELEC	ELECTRICAL	VAR	VARIABLE
INCAND	INCANDESCENT	WW	WIREWOUND
LED	LIGHT EMITTING DIODE	XFMR	TRANSFORMER
NONWIR	NON WIREWOUND	XTAL	CRYSTAL

CROSS INDEX MFR. CODE NUMBER TO MANUFACTURER

MFR.CODE	MANUFACTURER	ADDRESS	CITY,STATE,ZIP
00853	Sangamo Electric Co., S. Carolina Div.	P. O. Box 128	Pickens, SC 29671
01121	Allen-Bradley Co.	1201 2nd St. South	Milwaukee, WI 53204
01295	Texas Instruments, Inc., Semiconductor Group	P. O. Box 5012	Dallas, TX 75222
02111	Spectrol Electronics Corp.	17070 East Gale Ave.	City of Industry, CA 91745
02735	RCA Corp., Solid State Division	Route 202	Somerville, NY 08876
04713	Motorola, Inc., Semiconductor Products Div.	5005 E. McDowell Rd.	Phoenix, AZ 85036
07263	Fairchild Semiconductor, A Div. of Fairchild Camera and Instrument Corp.	464 Ellis St.	Mountain View, CA 94042
07910	Teledyne Semiconductor	12515 Chadron Ave.	Hawthorne, CA 90250
12040	National Semiconductor Corp.	Commerce Drive	Danbury, CT 06810
14193	Cal-R, Inc.	1601 Olympic Blvd.	Santa Monica, CA 90404
14936	General Instrument Corp., Semiconductor Products Group	600 W. John St.	Hicksville, NY 11802
24931	Specialty Connector Co., Inc.	3560 Madison Ave.	Indianapolis, IN 46227
28480	Hewlett-Packard Co., Corporate Hq.	1501 Page Mill Rd.	Palo Alto, CA 94304
56289	Sprague Electric Co.		North Adams, MA 01247
71744	Chicago Miniature Lamp Works	4433 Ravenswood Ave.	Chicago, IL 60640
72136	Electro Motive Corp., Sub of International Electronics Corp.	South Park and John Streets	Willimantic, CT 06226
72982	Erie Technological Products, Inc.	644 W. 12th St.	Erie, PA 16512
73138	Beckman Instruments, Inc., Helipot Div.	2500 Harbor Blvd.	Fullerton, CA 92634
75042	TRW Electronic Components, IRC Fixed Resistors, Philadelphia Division	401 N. Broad St.	Philadelphia, PA 19108
80009	Tektronix, Inc.	P. O. Box 500	Beaverton, OR 97077
80031	Electra-Midland Corp., Mepco Div., A North American Phillips Co.	22 Columbia Rd.	Morristown, NJ 07960
81483	International Rectifier Corp.	9220 Sunset Blvd.	Los Angeles, CA 90069
90201	Mallory Capacitor Co., Div. of P. R. Mallory Co., Inc.	3029 E. Washington St.	Indianapolis, IN 46206
91637	Dale Electronics, Inc.	P. O. Box 609	Columbus, NB 68601
91836	Kings Electronics Co., Inc.	40 Marbledale Road	Tuckahoe, NY 10707

Ckt No.	Tektronix Part No.	Serial/Model No. Eff	Dscont	Name & Description	Mfr Code	Mfr Part Number
A1	670-2595-00	B010100	B029999	CKT BOARD ASSY:FUNCTION GENERATOR	80009	670-2595-00
A1	670-2595-01	B030000	B031238	CKT BOARD ASSY:FUNCTION GENERATOR	80009	670-2595-01
A1	670-2595-02	B031239		CKT BOARD ASSY:FUNCTION GENERATOR	80009	670-2595-02
C148				10UF		
C150				1UF		
C152	295-0126-00	B010100	B010160	CAP.,SET,MTCHD:0.1UF	80009	295-0126-00
C154				0.01UF		
C148				10UF		
C150				1UF		
C152	295-0164-00	B010161		CAP.,SET,MTCHD:0.1UF	80009	295-0164-00
C154				0.01UF		
C156				950PF		
C156	283-0645-00	B010100	B010160X	CAP.,FXD,MICA D:790PF,1%,100V	00853	D151E791F0
C157	283-0600-00	B010100	B010437X	CAP.,FXD,MICA D:43PF,5%,500V	00853	D10E430J0500
C158	281-0125-00	B010100	B010160X	CAP.,VAR,MICA D:90-400PF,175V	72136	T51917-1
C158	281-0509-00	XB010438		CAP.,FXD,CER DI:15PF,+/-1.5PF,500V	72982	301-000C0G0150K
C160	281-0540-00	B010100	B010112	CAP.,FXD,CER DI:51PF,5%,500V	72982	301-000U2J0510J
C160	283-0600-00	B010113		CAP.,FXD,MICA D:43PF,5%,500V	00853	D10E430J0500
C162	281-0205-00			CAP.,VAR,PLSTC:5.5-65PF,100V	80031	C010GA/60E
C190	290-0572-00			CAP.,FXD,ELCTLT:0.1UF,20%,50V	56289	196D104X0050HA1
C192	290-0534-00			CAP.,FXD,ELCTLT:1UF,20%,35V	56289	196D105X0035HA1
C204	281-0504-00			CAP.,FXD,CER DI:10PF,+/-1PF,500V	72982	301-000C0G0100F
C224	283-0604-00	B010100	B010437	CAP.,FXD,MICA D:304PF,2%,300V	00853	D153F3040G0
C224	283-0646-00	B010438		CAP.,FXD,MICA D:170PF,1%,100V	00853	D151E171F0
C240	283-0646-00	B010100	B010112	CAP.,FXD,MICA D:170PF,1%,100V	00853	D151E171F0
C240	283-0598-00	B010113	B010437	CAP.,FXD,MICA D:253PF,5%,300V	00853	D153E2530J0
C240	283-0672-00	B010438		CAP.,FXD,MICA D:200PF,1%,500V	00853	D155F201F0
C245	283-0024-00			CAP.,FXD,CER DI:0.1UF,+80-20%,30V	56289	273C16
C247	283-0648-00	B010100	B010437X	CAP.,FXD,MICA D:10PF,5%,100V	00853	D151C100DC
C247	283-0611-00	XB030000		CAP.,FXD,CER DI:2.7UF,+80-20%,30V		
C268	283-0615-00			CAP.,FXD,MICA D:33PF,5%,500V	00853	D155E330J0
C272	290-0536-00			CAP.,FXD,ELCTLT:10UF,20%,25V	90201	TDC106M025FL
C287	281-0064-00			CAP.,VAR,PLSTC:0.25-1.5PF,600V	72982	530-002
C288	283-0663-00			CAP.,FXD,MICA D:16.8PF,+/0.5PF,500V	00853	D155C1689D0
C292	283-0024-00			CAP.,FXD,CER DI:0.1UF,+80-20%,30V	56289	273C16
C332	283-0600-00			CAP.,FXD,MICA D:43PF,5%,500V	00853	D10E430J0500
C350	281-0207-00			CAP.,VAR,PLSTC:2-18PF,100V	80031	HT10EA-218
C351	290-0536-00	B010100	B010112X	CAP.,FXD,ELCTLT:10UF,20%,25V	90201	TDC106M025FL
C352	283-0618-00			CAP.,FXD,MICA D:130PF,2%,300V	00853	D153E131G0
C390	290-0534-00			CAP.,FXD,ELCTLT:1UF,20%,35V	56289	196D105X0035HA1
C392	290-0534-00			CAP.,FXD,ELCTLT:1UF,20%,35V	56289	196D105X0035HA1
C395	281-0589-00			CAP.,FXD,CER DI:170PF,5%,500V	72982	301-057Z5D0171J
C405	290-0534-00			CAP.,FXD,ELCTLT:1UF,20%,35V	56289	196D105X0035HA1
C418	290-0534-00			CAP.,FXD,ELCTLT:1UF,20%,35V	56289	196D105X0035HA1
C420	283-0024-00			CAP.,FXD,CER DI:0.1UF,+80-20%,30V	56289	273C16
C428	283-0024-00			CAP.,FXD,CER DI:0.1UF,+80-20%,30V	56289	273C16
C430	283-0615-00			CAP.,FXD,MICA D:33PF,5%,500V	00853	D155E330J0
C432	281-0518-00			CAP.,FXD,CER DI:47PF,+/-9.4PF,500V	72982	301-000U2J0470M
C442	290-0534-00			CAP.,FXD,ELCTLT:1UF,20%,35V	56289	196D105X0035HA1
C450	281-0204-00			CAP.,VAR,PLSTC:2-22PF,100V	80031	C010EA-20E
C452	283-0600-00			CAP.,FXD,MICA D:43PF,5%,500V	00853	D10E430J0500
C460	283-0629-00			CAP.,FXD,MICA D:62PF,1%,500V	00853	D105E620F0
C462	283-0672-00			CAP.,FXD,MICA D:200PF,1%,500V	00853	D155F201F0

Ckt No.	Tektronix Part No.	Serial/Model No. Eff	Dscont	Name & Description	Mfr Code	Mfr Part Number
C480	281-0504-00			CAP.,FXD,CER DI:10PF,+/-1PF,500V	72982	301-000C0G0100F
C494	281-0523-00			CAP.,FXD,CER DI:100PF,+/-20PF,350V	72982	301-000U2M0101M
C498	283-0024-00			CAP.,FXD,CER DI:0.1UF,+80-20%,30V	56289	273C16
C504	283-0024-00			CAP.,FXD,CER DI:0.1UF,+80-20%,30V	56289	273C16
C512	283-0691-00			CAP.,FXD,MICA D:650PF,1%,300V	72136	DM15F651F0300
C530	290-0534-00			CAP.,FXD,ELCTLT:1UF,20%,35V	56289	196D105X0035HA1
C532	290-0534-00			CAP.,FXD,ELCTLT:1UF,20%,35V	56289	196D105X0035HA1
C536	290-0536-00			CAP.,FXD,ELCTLT:10UF,20%,25V	90201	TDC106M025FL
C540	290-0534-00			CAP.,FXD,ELCTLT:1UF,20%,35V	56289	196D105X0035HA1
C542	290-0534-00			CAP.,FXD,ELCTLT:1UF,20%,35V	56289	196D105X0035HA1
C546	290-0536-00			CAP.,FXD,ELCTLT:10UF,20%,25V	90201	TDC106M025FL
C552	283-0003-00	B010100	B010112	CAP.,FXD,CER DI:0.01UF,+80-20%,150V	56289	20C205A1
C552	283-0268-00	B010113	B031238X	CAP.,FXD,CER DI:0.015UF,10%,50V	72982	8131N075W5R153K
C564	283-0636-00	B010100	B010112	CAP.,FXD,MICA D:36PF,+/-0.5PF	00853	D151E360D0
C564	283-0600-00	B010113	B031238X	CAP.,FXD,MICA D:43PF,5%,500V	00853	D10E430J0500
C566	281-0207-00			CAP.,VAR,PLSTC:2-18PF,100V	80031	HT10EA-218
C568	281-0207-00			CAP.,VAR,PLSTC:2-18PF,100V	80031	HT10EA-218
C574	281-0202-00	B010100	B031238X	CAP.,VAR,PLSTC:1.5-5.5PF,100V	80031	C010EA-5E
C602	290-0324-00			CAP.,FXD,ELCTLT:750UF,+75-10%,40V	56289	39D757G040HJ4
C632	290-0559-00			CAP.,FXD,ELCTLT:22UF,20%,35V	56289	196D226X0035MA1
C635	290-0559-00	XB010150		CAP.,FXD,ELCTLT:22UF,20%,35V	56289	196D226X0035MA1
C640	290-0559-00	XB010438		CAP.,FXD,ELCTLT:22UF,20%,35V	56289	196D226X0035MA1
C655	290-0559-00			CAP.,FXD,ELCTLT:22UF,20%,35V	56289	196D226X0035MA1
C680	290-0324-00			CAP.,FXD,ELCTLT:750UF,+75-10%,40V	56289	39D757G040HJ4
CR140	152-0457-00			SEMICOND DEVICE:SILICON	28480	5082-2671
CR145	152-0457-00			SEMICOND DEVICE:SILICON	28480	5082-2671
CR170	152-0457-00			SEMICOND DEVICE:SILICON	28480	5082-2671
CR175	152-0457-00			SEMICOND DEVICE:SILICON	28480	5082-2671
CR204	152-0141-02	XB030000		SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR230	152-0322-00			SEMICOND DEVICE:SILICON,15V	01295	A1108
CR232	152-0322-00			SEMICOND DEVICE:SILICON,15V	01295	A1108
CR245	152-0141-02			SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR246	152-0141-02			SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR248	152-0141-02			SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR250	152-0141-02			SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR260	152-0141-02			SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR262	152-0141-02			SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR264	152-0141-02			SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR266	152-0141-02			SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR268	152-0457-00			SEMICOND DEVICE:SILICON	28480	5082-2671
CR300	152-0141-02			SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR302	152-0141-02			SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR304	152-0141-02			SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR306	152-0141-02			SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR308	152-0141-02			SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR310	152-0141-02			SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR312	152-0141-02			SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR314	152-0141-02			SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR315	152-0141-02			SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR318	152-0141-02	XB010438		SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR332	152-0141-02			SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR334	152-0141-02			SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR336	152-0141-02			SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220

Ckt No.	Tektronix Part No.	Serial/Model No. Eff	Dscont	Name & Description	Mfr Code	Mfr Part Number
CR338	152-0141-02			SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR352	152-0141-02	B010100	B029999	SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR352	152-0333-00	B030000		SEMICOND DEVICE:SILICON,55V,200MA	80009	152-0333-00
CR354	152-0141-02	B010100	B029999	SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR354	152-0333-00	B030000		SEMICOND DEVICE:SILICON,55V,200MA	80009	152-0333-00
CR356	152-0141-02	B010100	B029999	SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR356	152-0333-00	B030000		SEMICOND DEVICE:SILICON,55V,200MA	80009	152-0333-00
CR358	152-0141-02	B010100	B029999	SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR358	152-0333-00	B030000		SEMICOND DEVICE:SILICON,55V,200MA	80009	152-0333-00
CR362	152-0141-02	B010100	B029999	SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR362	152-0333-00	B030000		SEMICOND DEVICE:SILICON,55V,200MA	80009	152-0333-00
CR364	152-0141-02	B010100	B029999	SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR364	152-0333-00	B030000		SEMICOND DEVICE:SILICON,55V,200MA	80009	152-0333-00
CR366	152-0141-02	B010100	B029999	SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR366	152-0333-00	B030000		SEMICOND DEVICE:SILICON,55V,200MA	80009	152-0333-00
CR368	152-0141-02	B010100	B029999	SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR368	152-0333-00	B030000		SEMICOND DEVICE:SILICON,55V,200MA	80009	152-0333-00
CR372	152-0141-02	B010100	B029999	SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR372	152-0333-00	B030000		SEMICOND DEVICE:SILICON,55V,200MA	80009	152-0333-00
CR374	152-0141-02	B010100	B029999	SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR374	152-0333-00	B030000		SEMICOND DEVICE:SILICON,55V,200MA	80009	152-0333-00
CR376	152-0141-02	B010100	B029999	SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR376	152-0333-00	B030000		SEMICOND DEVICE:SILICON,55V,200MA	80009	152-0333-00
CR378	152-0141-02	B010100	B029999	SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR378	152-0333-00	B030000		SEMICOND DEVICE:SILICON,55V,200MA	80009	152-0333-00
CR382	152-0141-02	B010100	B029999	SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR382	152-0333-00	B030000		SEMICOND DEVICE:SILICON,55V,200MA	80009	152-0333-00
CR384	152-0141-02	B010100	B029999	SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR384	152-0333-00	B030000		SEMICOND DEVICE:SILICON,55V,200MA	80009	152-0333-00
CR386	152-0141-02	B010100	B029999	SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR386	152-0333-00	B030000		SEMICOND DEVICE:SILICON,55V,200MA	80009	152-0333-00
CR388	152-0141-02	B010100	B029999	SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR388	152-0333-00	B030000		SEMICOND DEVICE:SILICON,55V,200MA	80009	152-0333-00
CR430	152-0141-02			SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR432	152-0141-02			SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR520	152-0141-02			SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR522	152-0141-02			SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR524	152-0141-02			SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR600	152-0488-00			SEMICOND DEVICE:SILICON,200V,1500MA	14936	KBP-02-8
CR632	152-0066-00			SEMICOND DEVICE:SILICON,400V,750MA	02735	1N3194
CR642	152-0141-02			SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR644	152-0141-02			SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR655	152-0066-00			SEMICOND DEVICE:SILICON,400V,750MA	02735	1N3194
CR664	152-0141-02			SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR666	152-0141-02			SEMICOND DEVICE:SILICON,30V,150MA	07910	CD8220
CR680	152-0488-00			SEMICOND DEVICE:SILICON,200V,1500MA	14936	KBP-02-8
DS630	150-0109-00			LAMP,INCAND:18V,26MA	71744	CM7220
J125	131-0955-00			CONNECTOR,RCPT,:BNC,FEMALE	24931	28JR200-1
J280	210-0774-00			EYELET,METALLIC:0.152 OD X 0.245 INCH L,BRS	80009	210-0774-00
J285	131-0274-00			CONNECTOR,RCPT,:BNC	91836	KC79-67
J340	131-0955-00			CONNECTOR,RCPT,:BNC,FEMALE	24931	28JR200-1
J555	131-0955-00			CONNECTOR,RCPT,:BNC,FEMALE	24931	28JR200-1

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P280	131-1003-00			CONNECTOR BODY,:CKT BD MT,3 PRONG	80009	131-1003-00
Q140	151-0188-00			TRANSISTOR:SILICON,PNP	04713	2N3906
Q175	151-0190-00			TRANSISTOR:SILICON,NPN	04713	2N3904
Q200						
Q202	151-1042-00			SEMICOND DVC SE:MATCHED PAIR FET	01295	2N5245
Q204	151-0301-00			TRANSISTOR:SILICON,PNP	04713	2N2907A
Q210	151-0160-00			TRANSISTOR:SILICON,NPN	07263	S16223
Q230	151-0301-00	B010100	B010112X	TRANSISTOR:SILICON,PNP	04713	2N2907A
Q230A,B	151-0261-00	XB010112		TRANSISTOR:SILICON,PNP,DUAL	12040	NS7410
Q232	151-0301-00	B010100	B010112X	TRANSISTOR:SILICON,PNP	04713	2N2907A
Q268	151-0302-00			TRANSISTOR:SILICON,NPN	04713	2N2222A
Q290	151-0302-00	B010100	B010437	TRANSISTOR:SILICON,NPN	04713	2N2222A
Q290	151-0424-00	B010438		TRANSISTOR:SILICON,NPN	07263	2N5769
Q292	151-0302-00	B010100	B010437	TRANSISTOR:SILICON,NPN	04713	2N2222A
Q292	151-0424-00	B010438		TRANSISTOR:SILICON,NPN	07263	2N5769
Q315	151-0190-00			TRANSISTOR:SILICON,NPN	04713	2N3904
Q318	151-0188-00	B010100	B010437X	TRANSISTOR:SILICON,PNP	04713	2N3906
Q325	151-0190-00			TRANSISTOR:SILICON,NPN	04713	2N3904
Q330	151-0188-00			TRANSISTOR:SILICON,PNP	04713	2N3906
Q332	151-0188-00			TRANSISTOR:SILICON,PNP	04713	2N3906
Q400	151-0188-00			TRANSISTOR:SILICON,PNP	04713	2N3906
Q410	151-0188-00			TRANSISTOR:SILICON,PNP	04713	2N3906
Q420	151-0302-00			TRANSISTOR:SILICON,NPN	04713	2N2222A
Q430	151-0302-00			TRANSISTOR:SILICON,NPN	04713	2N2222A
Q440	151-0301-00			TRANSISTOR:SILICON,PNP	04713	2N2907A
Q442	151-0302-00			TRANSISTOR:SILICON,NPN	04713	2N2222A
Q444	151-0301-00			TRANSISTOR:SILICON,PNP	04713	2N2907A
Q480	151-0188-00			TRANSISTOR:SILICON,PNP	04713	2N3906
Q490	151-0188-00			TRANSISTOR:SILICON,PNP	04713	2N3906
Q500	151-0302-00	B010100	B031238	TRANSISTOR:SILICON,NPN	04713	2N2222A
Q500	151-0103-00	B031239		TRANSISTOR:SILICON,NPN	04713	2N2219A
Q506	151-0302-00	B010100	B031238	TRANSISTOR:SILICON,NPN	04713	2N2222A
Q506	151-0103-00	B031239		TRANSISTOR:SILICON,NPN	04713	SN2219A
Q515	151-0301-00	B010100	B031238	TRANSISTOR:SILICON,PNP	04713	2N2907A
Q515	151-0134-00	B031239		TRANSISTOR:SILICON,NPN	04713	2N2904
Q530	151-0103-00			TRANSISTOR:SILICON,NPN	04713	2N2219A
Q532	151-0134-00			TRANSISTOR:SILICON,PNP	04713	2N2905A
Q540	151-0103-00			TRANSISTOR:SILICON,NPN	04713	2N2219A
Q542	151-0134-00			TRANSISTOR:SILICON,PNP	04713	2N2905A
Q620	151-0190-00			TRANSISTOR:SILICON,NPN	04713	2N3904
Q622	151-0190-00			TRANSISTOR:SILICON,NPN	04713	2N3904
Q635	151-0311-01			TRANSISTOR:SILICON,NPN	04713	MJE340
Q650	151-0324-00			TRANSISTOR:SILICON,PNP	04713	SJE915
Q660	151-0188-00			TRANSISTOR:SILICON,PNP	04713	2N3906
Q662	151-0188-00			TRANSISTOR:SILICON,PNP	04713	2N3906
R100	321-0251-00			RES.,FXD,FILM:4.02K OHM,1%,0.125W	75042	CEAT0-4021F
R105	311-1560-00			RES.,VAR,NONWIR:5K OHM,5%,0.50W	73138	91A-5000M
R110	311-1576-00			RES.,VAR,WW:10K OHM,3%,2W	02111	152BS103H
R115	311-0258-00			RES.,VAR,NONWIR:100 OHM,10%	01121	WAIG024510lUA
R116	315-0100-00			RES.,FXD,COMP:10 OHM,5%,0.25W	01121	CB1005
R120	321-0289-00			RES.,FXD,FILM:10K OHM,1%,0.125W	75042	CEAT0-1002F
R122	315-0102-00			RES.,FXD,COMP:1K OHM,5%,0.25W	01121	CB1025
R125	321-0289-00			RES.,FXD,FILM:10K OHM,1%,0.125W	75042	CEAT0-1002F
R127	321-0286-00			RES.,FXD,FILM:9.31K OHM,1%,0.125W	75042	CEAT0-9311F
R129	321-0240-00			RES.,FXD,FILM:3.09K OHM,1%,0.125W	75042	CEAT0-3091F

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R130	311-1567-00			RES.,VAR,NONWIR:100 OHM,20%,0.50W	73138	91A-100R0M
R131	321-0114-00	B010100	B029999	RES.,FXD,FILM:150 OHM,1%,0.125W	75042	CEAT0-1500F
R131	321-0106-00	B030000		RES.,FXD,FILM:124 OHM,1%,0.125W	75042	CEAT9-2212C
R135	321-0289-00			RES.,FXD,FILM:10K OHM,1%,0.125W	75042	CEAT0-1002F
R137	315-0332-00			RES.,FXD,COMP:3.3K OHM,5%,0.25W	01121	CB3325
R139	315-0152-00			RES.,FXD,COMP:1.5K OHM,5%,0.25W	01121	CB1525
R140	317-0511-00			RES.,FXD,COMP:510 OHM,5%,0.125W	01121	BB5115
R142	321-0346-00			RES.,FXD,FILM:39.2K OHM,1%,0.125W	75042	CEAT0-3922F
R144	321-0226-00	B010100	B010112	RES.,FXD,FILM:2.21K OHM,1%,0.125W	75042	CEAT0-2211F
R144	321-0913-03	B010113	B010437	RES.,FXD,FILM:2.22K OHM,0.25%,0.125W	91637	MFF1816D22200C
R144	321-0649-00	B010438		RES.,FXD,FILM:2.19K OHM,0.25%,125W	75042	CEAT2-2191C
R146	321-0442-00			RES.,FXD,FILM:392K OHM,1%,0.125W	75042	CEAT0-3923F
R148	321-0322-00	B010100	B029999	RES.,FXD,FILM:22.1K OHM,1%,0.125W	75042	CEAT0-2212F
R148	321-0643-00	B030000		RES.,FXD,FILM:22.1K OHM,0.25%,0.125W		
R150	315-0395-00			RES.,FXD,COMP:3.9M OHM,5%,0.25W	01121	CB3955
R152	321-0418-00			RES.,FXD,FILM:221K OHM,1%,0.125W	75042	CEAT0-2213F
R155	315-0821-00	B010100	B010437	RES.,FXD,COMP:820 OHM,5%,0.25W	01121	CB8215
R155	301-0821-00	B010438		RES.,FXD,COMP:820 OHM,5%,0.50W	01121	EB8215
R157	315-0100-00	B010100	B010437X	RES.,FXD,COMP:10 OHM,5%,0.25W	01121	CB1005
R160	321-0289-07			RES.,FXD,FILM:10K OHM,0.1%,0.125W	75042	CEAT9-1002B
R162	321-0289-07			RES.,FXD,FILM:10K OHM,0.1%,0.125W	75042	CEAT9-1002B
R164	315-0152-00			RES.,FXD,COMP:1.5K OHM,5%,0.25W	01121	CB1525
R169	321-0277-00			RES.,FXD,FILM:7.5K OHM,1%,0.125W	75042	CEAT0-7501F
R170	311-1175-00			RES.,VAR,NONWIR:100 OHM,10%,0.50W	73138	66WR-101K-SM
R171	321-0277-00			RES.,FXD,FILM:7.5K OHM,1%,0.125W	75042	CEAT0-7501F
R175	317-0511-00			RES.,FXD,COMP:510 OHM,5%,0.125W	01121	BB5115
R178	321-0346-00			RES.,FXD,FILM:39.2K OHM,1%,0.125W	75042	CEAT0-3922F
R180	321-0226-00	B010100	B010112	RES.,FXD,FILM:2.21K OHM,1%,0.125W	75042	CEAT0-2211F
R180	321-0913-03	B010113	B010437	RES.,FXD,FILM:2.22K OHM,0.25%,0.125W	91637	MFF1816D22200C
R180	321-0649-00	B010438		RES.,FXD,FILM:2.19K OHM,1%,0.125W	75042	CEAT-2191C
R182	321-0442-00			RES.,FXD,FILM:392K OHM,1%,0.125W	75042	CEAT0-3923F
R184	321-0322-00	B010100	B029999	RES.,FXD,FILM:22.1K OHM,1%,0.125W	75042	CEAT0-2212F
R184	321-0643-00	B030000		RES.,FXD,FILM:22.1K OHM,0.25%,0.125W	75042	CEAT9-2212C
R186	315-0395-00			RES.,FXD,COMP:3.9M OHM,5%,0.25W	01121	CB3955
R188	321-0418-00			RES.,FXD,FILM:221K OHM,1%,0.125W	75042	CEAT0-2213F
R190	315-0100-00			RES.,FXD,COMP:10 OHM,5%,0.25W	01121	CB1005
R192	315-0100-00			RES.,FXD,COMP:10 OHM,5%,0.25W	01121	CB1005
R200	315-0821-00			RES.,FXD,COMP:820 OHM,5%,0.25W	01121	CB8215
R204	315-0202-00			RES.,FXD,COMP:2K OHM,5%,0.25W	01121	CB2025
R208	315-0101-00			RES.,FXD,COMP:100 OHM,5%,0.25W	01121	CB1015
R210	315-0101-00			RES.,FXD,COMP:100 OHM,5%,0.25W	01121	CB1015
R214	315-0100-00			RES.,FXD,COMP:10 OHM,5%,0.25W	01121	CB1005
R216	301-0271-00			RES.,FXD,COMP:270 OHM,5%,0.50W	01121	EB2715
R218	301-0241-00			RES.,FXD,COMP:240 OHM,5%,0.50W	01121	EB2415
R220	315-0201-00			RES.,FXD,COMP:200 OHM,5%,0.25W	01121	CB2015
R226	315-0241-00			RES.,FXD,COMP:240 OHM,5%,0.25W	01121	CB2415
R228	315-0153-00			RES.,FXD,COMP:15K OHM,5%,0.25W	01121	CB1535
R230	315-0102-00	B010100	B010112	RES.,FXD,COMP:1K OHM,5%,0.25W	01121	CB1025
R230	315-0302-00	B010113		RES.,FXD,COMP:3K OHM,5%,0.25W	01121	CB3025
R234	315-0102-00	B010100	B010112	RES.,FXD,COMP:1K OHM,5%,0.25W	01121	CB1025
R234	315-0302-00	B010113		RES.,FXD,COMP:3K OHM,5%,0.25W	01121	CB3025
R236	315-0102-00	B010100	B010112	RES.,FXD,COMP:1K OHM,5%,0.25W	01121	CB1025
R236	315-0302-00	B010113		RES.,FXD,COMP:3K OHM,5%,0.25W	01121	CB3025

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R240	321-0096-00			RES.,FXD,FILM:97.6 OHM,1%,0.125W	75042	CEAT0-97R60F
R245	321-0239-00			RES.,FXD,FILM:3.01K OHM,1%,0.125W	75042	CEAT0-3011F
R247	316-0565-00	B010100	B010437X	RES.,FXD,COMP:5.6M OHM,10%,0.25W	01121	CB5651
R248	315-0222-00	B010100	B010112	RES.,FXD,COMP:2.2K OHM,5%,0.25W	01121	CB2225
R248	321-0228-00	B010113		RES.,FXD,FILM:2.32K OHM,1%,0.125W	75042	CEAT0-2321F
R250	311-1563-00	B010100	B010112	RES.,VAR,NONWIR:1K OHM,20%,0.50W	73138	91A-10000M
R250	311-1564-00	B010113		RES.,VAR,NONWIR:500 OHM,20%,0.50W	73138	91A-500R0M
R255	311-1565-00	B010100	B010147	RES.,VAR,NONWIR:250 OHM,20%,0.50W	73138	91A250R0M
R255	311-1567-00	B010438		RES.,VAR,NONWIR:100 OHM,20%,0.50W	73138	91A-100R0M
R256	321-0100-00	B010100	B010437	RES.,FXD,FILM:107 OHM,1%,0.125W	75042	CEAT0-1070F
R256	321-0106-00	B010438		RES.,FXD,FILM:124 OHM,1%,0.125W	75042	CEAT0-1240F
R260	321-0215-00			RES.,FXD,FILM:1.69K OHM,1%,0.125W	75042	CEAT0-1691F
R262	321-0215-00			RES.,FXD,FILM:1.69K OHM,1%,0.125W	75042	CEAT0-1691F
R268	315-0242-00			RES.,FXD,COMP:2.4K OHM,5%,0.25W	01121	CB2425
R272	301-0151-00	B010100	B010437	RES.,FXD,COMP:150 OHM,5%,0.50W	01121	EB1515
R272	301-0101-00	B010438		RES.,FXD,COMP:100 OHM,5%,0.25W	01121	EB1015
R274	301-0151-00	B010100	B010437	RES.,FXD,COMP:150 OHM,5%,0.50W	01121	EB1515
R274	301-0101-00	B010438		RES.,FXD,COMP:100 OHM,5%,0.25W	01121	EB1015
R278	315-0510-00			RES.,FXD,COMP:51 OHM,5%,0.25W	01121	CB5105
R280	315-0240-00			RES.,FXD,COMP:24 OHM,5%,0.25W	01121	CB2405
R282	315-0102-00			RES.,FXD,COMP:1K OHM,5%,0.25W	01121	CB1025
R284	308-0685-00			RES.,FXD,WW:1.5 OHM,10%,1W	75042	BW20-1R500J
R290	315-0102-00	B010100	B010437	RES.,FXD,COMP:1K OHM,5%,0.25W	01121	CB1025
R290	301-0821-00	B010438		RES.,FXD,COMP:820 OHM,5%,0.25W	01121	EB8215
R292	315-0201-00	B010100	B010437	RES.,FXD,COMP:200 OHM,5%,0.25W	01121	CB2015
R292	301-0161-00	B010438		RES.,FXD,COMP:160 OHM,5%,0.50W	01121	EB1615
R294	315-0100-00			RES.,FXD,COMP:10 OHM,5%,0.25W	01121	CB1005
R298	315-0471-00			RES.,FXD,COMP:470 OHM,5%,0.25W	01121	CB4715
R318	315-0751-00	XB010438		RES.,FXD,COMP:750 OHM,5%,0.25W	01121	CB7515
R319	315-0911-00	B010100	B010437	RES.,FXD,COMP:910 OHM,5%,0.25W	01121	CB9115
R319	315-0202-00	B010438		RES.,FXD,COMP:2K OHM,5%,0.25W	01121	CB2025
R320	311-1563-00	B010100	B010437	RES.,VAR,NONWIR:1K OHM,20%,0.50W	73138	91A-10000M
R320	311-1560-00	B010438		RES.,VAR,NONWIR:5K OHM,5%,0.50W	73138	91A-5000M
R321	315-0153-00	B010100	B010437	RES.,FXD,COMP:15K OHM,5%,0.25W	01121	CB1535
R321	315-0622-00	B010438		RES.,FXD,COMP:6.2K OHM,5%,0.25W	01121	CB6225
R325	315-0102-00			RES.,FXD,COMP:1K OHM,5%,0.25W	01121	CB1025
R327	315-0393-00			RES.,FXD,COMP:39K OHM,5%,0.25W	01121	CB3935
R328	315-0751-00			RES.,FXD,COMP:750 OHM,5%,0.25W	01121	CB7515
R330	315-0752-00			RES.,FXD,COMP:7.5K OHM,5%,0.25W	01121	CB7525
R332	315-0104-00			RES.,FXD,COMP:100K OHM,5%,0.25W	01121	CB1045
R338	315-0103-00			RES.,FXD,COMP:10K OHM,5%,0.25W	01121	CB1035
R340	315-0303-00			RES.,FXD,COMP:30K OHM,5%,0.25W	01121	CB3035
R342	315-0102-00			RES.,FXD,COMP:1K OHM,5%,0.25W	01121	CB1025
R350	311-1567-00			RES.,VAR,NONWIR:100 OHM,20%,0.50W	73138	91A-100R0M
R351	315-0131-00	B010100	B010112X	RES.,FXD,COMP:130 OHM,5%,0.25W	01121	CB1315
R352	321-0354-00			RES.,FXD,FILM:47.5K OHM,1%,0.125W	75042	CEAT0-4752F
R354	315-0100-00	B010100	B010112	RES.,FXD,COMP:10 OHM,5%,0.25W	01121	CB1005
R354	321-0117-00	B010112		RES.,FXD,FILM:162 OHM,1%,0.125W	75042	CEAT0-1620F
R356	311-1565-00	B010100	B010112X	RES.,VAR,NONWIR:250 OHM,20%,0.50W	73138	91A250R0M
R358	321-0354-00			RES.,FXD,FILM:47.5K OHM,1%,0.125W	75042	CEAT0-4752F
R362	321-0304-00			RES.,FXD,FILM:14.3K OHM,1%,0.125W	75042	CEAT0-1432F
R364	315-0101-00	B010100	B010112	RES.,FXD,COMP:100 OHM,5%,0.25W	01121	CB1015
R364	321-0150-00	B010113		RES.,FXD,FILM:357 OHM,1%,0.125W	75042	CEAT0-3570F

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R366	311-1565-00	B010100	B010112X	RES.,VAR,NONWIR:250 OHM,20%,0.50W	73138	91A250R0M
R368	321-0304-00			RES.,FXD,FILM:14.3K OHM,1%,0.125W	75042	CEAT0-1432F
R372	321-0307-00			RES.,FXD,FILM:15.4K OHM,1%,0.125W	75042	CEAT0-1542F
R374	315-0100-00	B010100	B010112	RES.,FXD,COMP:10 OHM,5%,0.25W	01121	CB1005
R374	321-0067-00	B010113		RES.,FXD,FILM:48.7 OHM,1%,0.125W	75042	CEAT0-48R70F
R376	311-1567-00	B010100	B010112X	RES.,VAR,NONWIR:100 OHM,20%,0.50W	73138	91A-100R0M
R378	321-0307-00			RES.,FXD,FILM:15.4K OHM,1%,0.125W	75042	CEAT0-1542F
R382	321-0289-00			RES.,FXD,FILM:10K OHM,1%,0.125W	75042	CEAT0-1002F
R384	315-0101-00	B010100	B010112	RES.,FXD,COMP:100 OHM,5%,0.25W	01121	CB1015
R384	321-0110-00	B010113		RES.,FXD,FILM:137 OHM,1%,0.125W	75042	CEAT0-1370F
R386	311-1567-00	B010100	B010112X	RES.,VAR,NONWIR:100 OHM,20%,0.50W	73138	91A-100R0M
R388	321-0289-00			RES.,FXD,FILM:10K OHM,1%,0.125W	75042	CEAT0-1002F
R390	315-0100-00			RES.,FXD,COMP:10 OHM,5%,0.25W	01121	CB1005
R392	315-0100-00			RES.,FXD,COMP:10 OHM,5%,0.25W	01121	CB1005
R395	315-0820-00			RES.,FXD,COMP:82 OHM,5%,0.25W	01121	CB8205
R397	315-0222-00			RES.,FXD,COMP:2.2K OHM,5%,0.25W	01121	CB2225
R400	315-0101-00			RES.,FXD,COMP:100 OHM,5%,0.25W	01121	CB1015
R402	315-0512-00			RES.,FXD,COMP:5.1K OHM,5%,0.25W	01121	CB5125
R405	315-0100-00			RES.,FXD,COMP:10 OHM,5%,0.25W	01121	CB1005
R408	315-0512-00			RES.,FXD,COMP:5.1K OHM,5%,0.25W	01121	CB5125
R410	315-0222-00			RES.,FXD,COMP:2.2K OHM,5%,0.25W	01121	CB2225
R412	315-0101-00			RES.,FXD,COMP:100 OHM,5%,0.25W	01121	CB1015
R415	315-0912-00			RES.,FXD,COMP:9.1K OHM,5%,0.25W	01121	CB9125
R418	315-0100-00			RES.,FXD,COMP:10 OHM,5%,0.25W	01121	CB1005
R422	315-0220-00			RES.,FXD,COMP:22 OHM,5%,0.25W	01121	CB2205
R424	315-0431-00			RES.,FXD,COMP:430 OHM,5%,0.25W	01121	CB4315
R426	315-0220-00			RES.,FXD,COMP:22 OHM,5%,0.25W	01121	CB2205
R436	315-0431-00			RES.,FXD,COMP:430 OHM,5%,0.25W	01121	CB4315
R438	315-0431-00			RES.,FXD,COMP:430 OHM,5%,0.25W	01121	CB4315
R442	315-0220-00			RES.,FXD,COMP:22 OHM,5%,0.25W	01121	CB2205
R444	315-0220-00			RES.,FXD,COMP:22 OHM,5%,0.25W	01121	CB2205
R450	311-1563-00			RES.,VAR,NONWIR:1K OHM,20%,0.50W	73138	91A-1000M
R452	315-0102-00			RES.,FXD,COMP:1K OHM,5%,0.25W	01121	CB1025
R460	311-1565-00			RES.,VAR,NONWIR:250 OHM,20%,0.50W	73138	91A250R0M
R462	315-0101-00			RES.,FXD,COMP:100 OHM,5%,0.25W	01121	CB1015
R465	311-1427-00			RES.,VAR,NONWIR:2K OHM,20%,0.50W	01121	10M458
R467	315-0101-00			RES.,FXD,COMP:100 OHM,5%,0.25W	01121	CB1015
R470	315-0180-00			RES.,FXD,COMP:18 OHM,5%,0.25W	01121	CB1805
R472	315-0512-00	B010100	B029999	RES.,FXD,COMP:5.1K OHM,5%,0.25W	01121	CB5125
R472	321-0260-00	B030000		RES.,FXD,FILM:4.99K OHM,1%,0.125W	75042	CEAT0-4991F
R475[1]	311-1602-00			RES.,VAR,NONWIR:5K OHM,10%,1W	01121	12M566
R480	315-0222-00			RES.,FXD,COMP:2.2K OHM,5%,0.25W	01121	CB2225
R485	311-1565-00			RES.,VAR,NONWIR:250 OHM,20%,0.50W	73138	91A250R0M
R486	315-0912-00			RES.,FXD,COMP:9.1K OHM,5%,0.25W	01121	CB9125
R490	315-0512-00			RES.,FXD,COMP:5.1K OHM,5%,0.25W	01121	CB5125
R492	315-0512-00			RES.,FXD,COMP:5.1K OHM,5%,0.25W	01121	CB5125
R494	315-0222-00			RES.,FXD,COMP:2.2K OHM,5%,0.25W	01121	CB2225
R498	315-0101-00			RES.,FXD,COMP:100 OHM,5%,0.25W	01121	CB1015
R500	315-0241-00			RES.,FXD,COMP:240 OHM,5%,0.25W	01121	CB2415
R502	315-0300-00			RES.,FXD,COMP:30 OHM,5%,0.25W	01121	CB3005
R504	315-0241-00			RES.,FXD,COMP:240 OHM,5%,0.25W	01121	CB2415
R510	315-0221-00			RES.,FXD,COMP:220 OHM,5%,0.25W	01121	CB2215
R512	315-0200-00			RES.,FXD,COMP:20 OHM,5%,0.25W	01121	CB2005

[1]Furnished as a unit with S475.

Ckt No.	Tektronix Part No.	Serial/Model No. Eff	Dscont	Name & Description	Mfr Code	Mfr Part Number
R515	315-0121-00			RES.,FXD,COMP:120 OHM,5%,0.25W	01121	CB1215
R518	315-0112-00			RES.,FXD,COMP:1.1K OHM,5%,0.25W	01121	CB1125
R520	315-0100-00			RES.,FXD,COMP:10 OHM,5%,0.25W	01121	CB1005
R522	315-0470-00			RES.,FXD,COMP:47 OHM,5%,0.25W	01121	CB4705
R530	315-0330-00			RES.,FXD,COMP:33 OHM,5%,0.25W	01121	CB3305
R532	315-0330-00			RES.,FXD,COMP:33 OHM,5%,0.25W	01121	CB3305
R536	315-0100-00			RES.,FXD,COMP:10 OHM,5%,0.25W	01121	CB1005
R540	315-0330-00			RES.,FXD,COMP:33 OHM,5%,0.25W	01121	CB3305
R542	315-0330-00			RES.,FXD,COMP:33 OHM,5%,0.25W	01121	CB3305
R546	315-0100-00			RES.,FXD,COMP:10 OHM,5%,0.25W	01121	CB1005
R550	303-0470-00			RES.,FXD,COMP:47 OHM,5%,1W	01121	GB4705
R552	303-0470-00			RES.,FXD,COMP:47 OHM,5%,1W	01121	GB4705
R555	303-0470-00			RES.,FXD,COMP:47 OHM,5%,1W	01121	GB4705
R556	303-0470-00			RES.,FXD,COMP:47 OHM,5%,1W	01121	GB4705
R560	315-0303-00			RES.,FXD,COMP:30K OHM,5%,0.25W	01121	CB3035
R564	321-0253-00	B010100	B031238	RES.,FXD,FILM:4.22K OHM,1%,0.125W	75042	CEAT0-4221F
R564	321-0192-00	B031239		RES.,FXD,FILM:976 OHM,1%,0.125W	75042	CEAT0-9760F
R566	321-0203-00			RES.,FXD,FILM:1.27K OHM,1%,0.125W	75042	CEAT0-1271F
R568	315-0200-00			RES.,FXD,COMP:20 OHM,5%,0.25W	01121	CB2005
R574	315-0132-00	B010100	B031238X	RES.,FXD,COMP:1.3K OHM,5%,0.25W	01121	CB1325
R600	308-0710-00			RES.,FXD,WW:0.27 OHM,10%,1W	75042	BW20-R2700J
R602	308-0710-00			RES.,FXD,WW:0.27 OHM,10%,1W	75042	BW20-R2700J
R610	315-0332-00			RES.,FXD,COMP:3.3K OHM,5%,0.25W	01121	CB3325
R612	315-0432-00			RES.,FXD,COMP:4.3K OHM,5%,0.25W	01121	CB4325
R614	321-0261-00			RES.,FXD,FILM:5.11K OHM,1%,0.125W	75042	CEAT0-5111F
R616	315-0100-00			RES.,FXD,COMP:10 OHM,5%,0.25W	01121	CB1005
R618	315-0470-00			RES.,FXD,COMP:47 OHM,5%,0.25W	01121	CB4705
R620	315-0202-00			RES.,FXD,COMP:2K OHM,5%,0.25W	01121	CB2025
R623	321-0289-00			RES.,FXD,FILM:10K OHM,1%,0.125W	75042	CEAT0-1002F
R625	311-1561-00			RES.,VAR,NONWIR:2.5K OHM,20%,0.50W	73138	91A-25000M
R630	315-0201-00			RES.,FXD,COMP:200 OHM,5%,0.25W	01121	CB2015
R632	308-0755-00			RES.,FXD,WW:0.75 OHM,5%,2W	75042	BWH-R7500J
R635	321-0239-00			RES.,FXD,FILM:3.01K OHM,1%,0.125W	75042	CEAT0-3011F
R636	321-0312-00			RES.,FXD,FILM:17.4K OHM,1%,0125W	75042	CEAT0-1742F
R638	321-0289-07			RES.,FXD,FILM:10K OHM,0.1%,0.125W	75042	CEAT9-1002B
R640	321-0289-07			RES.,FXD,FILM:10K OHM,0.1%,0.125W	75042	CEAT9-1002B
R642	315-0152-00			RES.,FXD,COMP:1.5K OHM,5%,0.25W	01121	CB1525
R650	315-0512-00			RES.,FXD,COMP:5.1K OHM,5%,0.25W	01121	CB5125
R655	308-0755-00			RES.,FXD,WW:0.75 OHM,5%,2W	75042	BWH-R7500J
R662	315-0470-00			RES.,FXD,COMP:47 OHM,5%,0.25W	01121	CB4705
R664	315-0202-00			RES.,FXD,COMP:2K OHM,5%,0.25W	01121	CB2025
R666	315-0152-00			RES.,FXD,COMP:1.5K OHM,5%,0.25W	01121	CB1525
R670	321-0261-00			RES.,FXD,FILM:5.11K OHM,1%,0.125W	75042	CEAT0-5111F
R672	315-0100-00			RES.,FXD,COMP:10 OHM,5%,0.25W	01121	CB1005
R676	321-0289-00			RES.,FXD,FILM:10K OHM,1%,0.125W	75042	CEAT0-1002F
R678	321-0289-00			RES.,FXD,FILM:10K OHM,1%,0.125W	75042	CEAT0-1002F
R680	308-0710-00			RES.,FXD,WW:0.27 OHM,10%,1W	75042	BW20-R2700J
R682	308-0710-00			RES.,FXD,WW:0.27 OHM,10%,1W	75042	BW20-R2700J
RT224	307-0126-00			RES.,THERMAL:100 OHM,10%	14193	2D21-101K
S150	263-1001-00			ACTR ASSY,CAM S:--FUNCTION	80009	263-1001-00
S155	263-1002-00			ACTR ASSY,CAM S:--MULTIPLIER	80009	263-1002-00
S475[1]						

[1]Furnished as a unit with R475.

Ckt No.	Tektronix Part No.	Serial/Model No. Eff	Dscont	Name & Description	Mfr Code	Mfr Part Number
U100	156-0067-00			MICROCIRCUIT,LI:OPERATIONAL AMPLIFIER	07263	UA741
U135	156-0067-00			MICROCIRCUIT,LI:OPERATIONAL AMPLIFIER	07263	UA741
U140	156-0067-00			MICROCIRCUIT,LI:OPERATIONAL AMPLIFIER	07263	UA741
U170	156-0067-00			MICROCIRCUIT,LI:OPERATIONAL AMPLIFIER	07263	UA741
U175	156-0067-00			MICROCIRCUIT,LI:OPERATIONAL AMPLIFIER	07263	UA741
U615	156-0067-06			MICROCIRCUIT LI:OPERATIONAL AMPLIFIER	80009	156-0067-06
U635	156-0067-00			MICROCIRCUIT,LI:OPERATIONAL AMPLIFIER	07263	UA741
U650	156-0067-00			MICROCIRCUIT,LI:OPERATIONAL AMPLIFIER	07263	UA741
U664	156-0067-06			MICROCIRCUIT,LI:OPERATIONAL AMPLIFIER	80009	156-0067-06
VR139	152-0279-00			SEMICOND DEVICE:ZENER,0.4W,5.1V,5%	07910	1N751A
VR164	152-0279-00			SEMICOND DEVICE:ZENER,0.4W,5.1V,5%	07910	1N751A
VR610	152-0166-00			SEMICOND DEVICE:ZENER,0.4W,6.2V,5%	81483	69-9035

Services Available

Tektronix, Inc. provides complete instrument repair and adjustment at local Field Service Centers and at the Factory Service Center. Contact your local Tektronix Field Office or Representative for further information.

Maintenance

Refer to the TM 500-series power module manual for maintenance information.

Test Equipment

For complete calibration, the following equipment is recommended:

TM 500 Series Power Module.

Digital voltmeter with ranges greater than ±20 V dc, Tektronix DM 501 or equivalent (accurate within 0.1%).

Digital counter capable of measuring frequencies to 11 MHz, such as a Tektronix DC 501 or equivalent.

Complete 50 MHz oscilloscope system with two 1X probes and 1 mV/div sensitivity, such as a Tektronix 5403 mainframe, 5A48 Vertical plug-in, 5A20 Differential Amplifier plug-in, 5B42 Time Base, and 2 P6011 1X probes, or equivalent.

Distortion analyzer or 10 kHz notch filter constructed as shown in Fig. 3-1.

Square-wave generator capable of 0 V to 8 V at 1 kHz, Tektronix FG 501, FG 502, FG 503 or equivalent.

Spectrum Analyzer, Span/Div 10 MHz or greater, Tektronix 1401A or equivalent.

Two 50 Ω Terminations with bnc connectors, Tektronix Part No. 011-0049-01 or equivalent.

50 Ω X10 attenuator with bnc connectors, Tektronix Part No. 011-0059-02 or equivalent.

Two 50 Ω, 42 inch coaxial cables with bnc connectors, Tektronix Part No. 012-0057-01 or equivalent.

General

The FG 502 can be calibrated either installed in a TM 500-series power module, or connected to a TM 500-series power module via a flexible plug-in extender (Tektronix Part No. 067-0645-01). Remove the power module cabinet to make adjustments to the FG 502. Allow 20 minutes warm-up time, or until the operating temperature is 25°C ±5°C.

@

PROCEDURE

1. Adjust +20 V Supply

Connect the positive lead of the voltmeter (set to read +20 V) to the +20 V TP and the negative lead to the GND TP. Adjust R625 (+20 V Adj.) for a reading of 20 V ±1%.

2. Check Power Supply Voltages

Connect the negative lead of the voltmeter (set to read 20 V) to the −20 V TP and the positive lead to the GND TP. Check that the reading is 20 V ±1%. Move the negative lead to the −17 V TP and note the reading. Now measure the +17 V by switching the negative lead to the GND TP and the positive lead to the +17 V TP. The absolute values of these voltages must be within 2% of each other.

3. Check Power Supply Ripple

On the FG 502, set the MULTIPLIER knob to 10^{-1}, the FREQUENCY Hz dial to 0.1, and the FUNCTION switch to the triangular waveform. Using the differential amplifier in the oscilloscope, set the vertical sensitivity to 1 mV/Div and set both inputs for ac coupling. Using 1X probes, connect one input of the Differential amplifier to any of the GND TP connectors in the FG 502. Connect the other 1X input probe in turn to the +20 V, −20 V, +17 V, and −17 V supplies at their respective test points. Check that the ripple is less than 300 μV peak-to-peak at each of the test points. Ripple shows up as a broadening of the oscilloscope trace. Disregard the humps caused by generator feedback when checking the minor supplies for ripple.

4. Adjust Waveform Symmetry

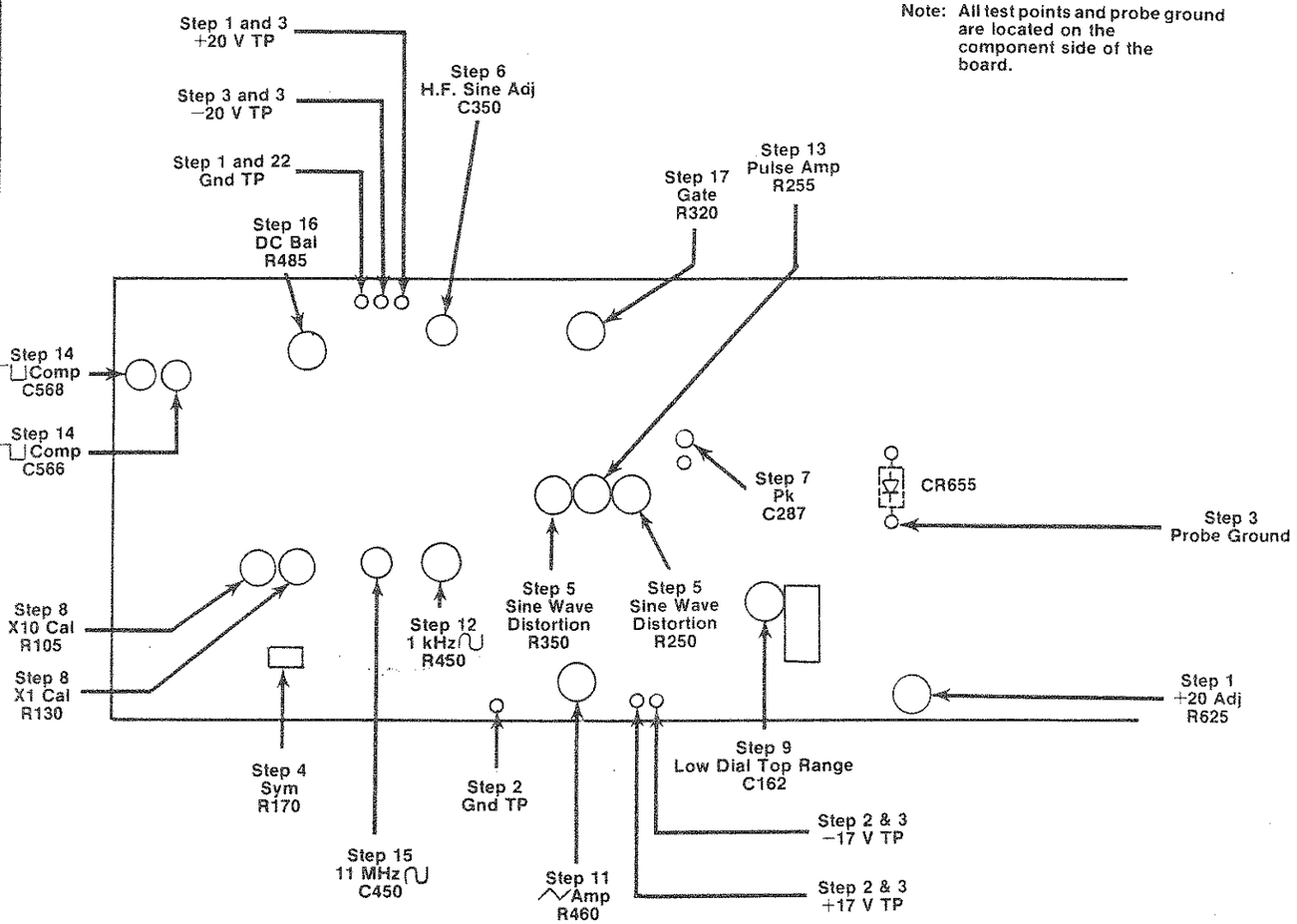
Connect the FG 502 output through a 50 Ω coaxial cable terminated in 50 Ω to the oscilloscope input. Adjust the FG 502 for an approximate 10 kHz square-wave with the AMPLITUDE control at Maximum (10 V p-p). Set the oscilloscope to show 1 cycle in 10 divisions of display. Now adjust R170 (Sym) for best square-wave symmetry.

5. Adjust Sinewave Distortion

Connect the FG 502 output to the input of the distortion analyzer or the notch filter with a 50 Ω cable. Connect the output of the distortion analyzer or notch filter with another 50 Ω cable to the oscilloscope. Set the FUNCTION switch for sinewave output. Set the FREQUENCY Hz dial at 1 and the MULTIPLIER knob at 10^{4}. If the notch filter is used, terminate the coaxial cable from the FG 502 at the notch filter, and adjust the FREQUENCY Hz dial so that the output frequency is directly in the notch (minimum display amplitude). Now adjust R250 (DC Level) and R350 (Sine Drive) for minimum distortion, or minimum display on the oscilloscope. Repeat several times, since considerable interaction exists.

INTERNAL ADJUSTMENT PROCEDURE

B031170-up



6. Adjust High Frequency Sine Distortion

Change the FG 502 MULTIPLIER knob to 10^6 and reset the FREQUENCY Hz dial to 1. Connect the output of the FG 502 to the oscilloscope via a 50 Ω coaxial cable, 10X attenuator, and 50 Ω termination. Obtain a stable sinewave display on the oscilloscope. Adjust C350 (HF Sine Adj.) for the smoothest and best looking sinewave peaks.

7. Adjust Triangle Peak

Connect the FG 502 output to the oscilloscope with terminated 50 Ω cable. Set the FG 502 FREQUENCY Hz dial to .1 and FUNCTION switch to triangle. Adjust the oscilloscope so the top portion of the triangle is displayed (positive 1/2 cycle in 8 divisions). Adjust C287 for linear slopes and equal rise and fall times on the triangle peaks.

8. Adjust Low Frequency Timing

Connect the FG 502 to the counter with 50 Ω terminated cable. Set the FG 502 MULTIPLER knob to 10^3, the FREQUENCY Hz dial to 11, the AMPLITUDE control fully cw, and the FREQUENCY VERNIER dial to the CAL position. Adjust R105 (X10 Cal) for a counted frequency of 11 kHz. Set the FREQUENCY Hz dial to 1. Adjust R130 (X1 Cal) for a counted frequency of 1 kHz. Repeat both adjustments until the timing is within specifications.

9. Adjust High Frequency Timing

Set the FG 502 MULTIPLIER knob to 10^6 and the FREQUENCY Hz dial to 10. Adjust C162 (Low Dial Top Range) for 10 MHz on the counter. Set the FREQUENCY Hz dial to 11 and check for 11 MHz count or greater.

10. Check Timing Accuracy

Check all MULTIPLIER ranges with the FREQUENCY Hz dial at 1 and 11 for accuracy to specifications (3% of full scale from 0.1 Hz to 1 MHz, 5% of full scale from 1 MHz to 10 MHz, and 11 MHz not less than 11 MHz).

11. Adjust Triangle Amplitude

Set the MULTIPLIER knob for 10^4, the FREQUENCY Hz dial to 1, the AMPLITUDE control fully cw, and the FUNCTION switch to triangle. Connect the FG 502 output to the oscilloscope using a 50 Ω coaxial cable without termination. Adjust R460 (Triangle Amp) for exactly 10 V peak-to-peak signal. Install a 50 Ω termination between the cable and oscilloscope and check the signal to be within specifications (between 5.0 and 5.2 volts peak-to-peak).

12. Adjust Sinewave Low Frequency Amplitude

Set the FUNCTION switch to sinewave. Remove the 50 Ω termination between the cable and oscilloscope. Leave all other controls as in the previous step. Adjust R450 (Sinewave Amp) for exactly 10 V peak-to-peak. Reinstall the 50 Ω termination between the cable and oscilloscope and check as in the preceding step.

13. Adjust Square-Wave Low Frequency Amplitude

Set the FUNCTION switch for a square-wave. Remove the 50 Ω termination between the cable and oscilloscope. Leave all other controls as in the preceding step. Adjust R255 (Pulse Amp) for exactly 10 V peak-to-peak, and check as in steps (11) and (12).

14. Adjust Square-Wave Compensation

Connect the FG 502 to the oscilloscope through a 50 Ω coaxial cable, a 10X attenuator, and a 50 Ω termination. Set the MULTIPLIER knob to 10^5, the FREQUENCY dial to 1 (100 kHz), and the AMPLITUDE control to maximum. Adjust the oscilloscope for 1 cycle in 10 divisions. Adjust C566 and C568 (Square-Wave Comp) for a fast rising edge and square corner. Check that the rise time is less than 20 ns, and aberrations are less than 3% peak-to-peak.

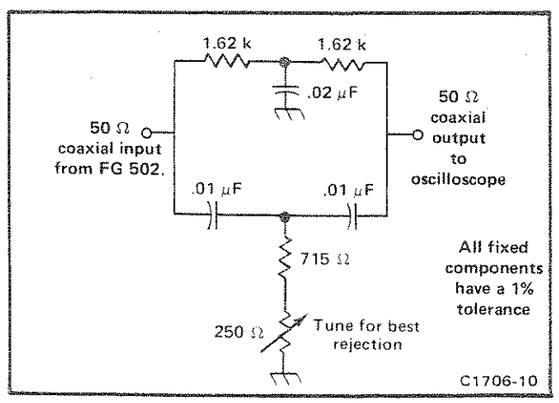


Fig. 3-1. 10 kHz notch filter.

15. Check Sinewave High Frequency Amplitude and Distortion

Connect the FG 502 to the oscilloscope through a terminated 50 Ω coaxial cable. Set the MULTIPLIER knob to 10^6 and the FREQUENCY Hz dial to 11 MHz. Check that the amplitude of the sinewave is 5 divisions ±0.8 division (±1.5 dB referenced at 10 kHz). Disconnect the cable from the oscilloscope, and remove the 50 Ω termination. Connect a cable from the FG 502 to the spectrum analyzer. Set the spectrum analyzer Frequency Span/Div control for 10 MHz. Check that the second and third harmonic frequencies are at least 30 dB below the fundamental frequency. Adjust C450 for the maximum 11 MHz sinewave amplitude with the second and third harmonics still 30 dB below the fundamental frequency amplitude. Set the FG 502 FREQUENCY Hz dial to 10 and the MULTIPLIER knob to 10^5. Set the spectrum analyzer Frequency Span/Div control to 1 MHz. Check that the second and third harmonic frequencies are at least 30 dB below the fundamental freqeuncy amplitude. Set the FG 502 MULTIPLIER knob to 10^4, the spectrum analyzer Frequency Span/Div control to 0.1 kHz, and check that the second and third harmonic frequencies are at least 30 dB below the fundamental frequency amplitude.

16. Adjust Output Amplifier DC Balance

Connect the FG 502 through a terminated 50 Ω coaxial cable to the oscilloscope. Set the FUNCTION switch to triangle, the AMPLITUDE control for minimum amplitude, the MULTIPLIER knob to 10^3, and the FREQUENCY Hz dial to 11. Set the vertical deflection factor on the oscilloscope for 0.1 V/Div. Ground the vertical input of the oscilloscope momentarily to establish a 0 V dc reference for the display. Adjust R485 (DC Bal) so that the output waveform is centered around the 0 V reference level.

17. Adjust Baseline

Connect the square-wave generator (set for at least a 0 V to +2 V, 1 kHz square-wave) to the GATE IN connector on the FG 502. Set the FG 502 FUNCTION switch for a sinewave and the FREQUENCY Hz dial to 5 with the MULTIPLIER Knob at 10^3 for 1 kHz bursts of the 5 kHz waveform. Adjust R320 to position the baseline exactly half way between the positive and the negative sinewave peaks.

18. Check VCF

Set the FREQUENCY Hz dial to 10 and the MULTIPLIER knob to 10^5. Connect a 1 kHz, 0 V to −8 V square-wave to the VCF connector. Check that the display shows a double display of approximately 1 cycle per division and 2 cycles per 10 divisions.

19. Check Trigger Out

Disconnect all test equipment from the FG 502. With a X1 probe or an unterminated 50 Ω cable, check for a signal on the bnc TRIG OUT connector on the FG 502. Minimum signal here should be 2.5 V but 5 V is more common. A terminated cable will show approximately 2/3 of the unterminated amplitude.

Services Available

Tektronix, Inc. provides complete instrument repair and adjustment at local Field Service Centers and at the Factory Service Center. Contact your local Tektronix Field Office or Representative for further information.

Maintenance

Refer to the TM 500 series power module manual for complete maintenance information.

Test Equipment

For complete calibration, the following equipment is recommended:

Digital voltmeter with ranges greater than ±20 V DC, Tektronix DM 501 or equivalent.

Digital counter capable of measuring frequencies to 11 MHz, Tektronix DC 501 or equivalent.

Complete 50 MHz oscilloscope system with 1X probe and 1 mV/div sensitivity, Tektronix 5403 main frame, 5A48 vertical plug-in, 5B42 time base, and P6011 1X probe, or equivalent.

Distortion analyzer or 10 kHz notch filter constructed as shown in Fig. 3-1.

Square wave generator capable of 0 V to ≥2 V at 1 kHz, Tektronix FG 501, FG 502 or equivalent.

50 Ω termination, BNC connectors, Tektronix Part Number 011-0049-01.

50 Ω 10X attenuator, BNC connectors, Tektronix Part Number 011-0059-02.

Two 50 Ω 42 inch coaxial cables, BNC connectors, Tektronix Part Number 012-0057-01 or equivalent.

General

The FG 502 can be calibrated either fully installed in a TM 500 series power module, or connected to the power module via a flexible plug-in extender (Tektronix Part No. 067-0645-01). Remove the power module cabinet to make adjustments to the FG 502 inside the power module.

1. Adjust +20 V Supply

Connect the positive lead of the voltmeter set to read +20 V to the +20 V TP and the negative lead to the Gnd TP. Adjust R625, +20 Adj., for a reading of 20 V ±1%.

2. Check Power Supply Voltages

Connect the negative lead of the voltmeter set to read −20 V to the −20 V TP and the positive lead to the Gnd TP. Check that the reading is +20 V ±1%. Move the negative lead to the −17 TP and note the reading. Now measure the +17 V by switching the negative lead to the Gnd TP and the positive lead to the +17 V TP. The absolute value of these voltages must be within 0.1% of each other.

3. Check Power Supply Ripple

Connect a 1X probe to the vertical input of the oscilloscope, AC coupled, 1 mV/div sensitivity. Clip the ground strap of the probe to the TP labeled Probe Ground in the illustration. Check the +20 V, −20 V, +17 V, and −17 V, at their respective test points, for less than 100 μV of ripple, measured peak to peak.

4. Adjust Triangle Symmetry

Connect the output of the FG 502 through a 50 Ω coaxial cable, terminated in 50 Ω, to the oscilloscope input. Set the MULTIPLIER at 10^5, the FREQUENCY Hz dial near .1, the oscilloscope time base at 1 ms/div, and the FUNCTION switch for a triangle waveform. Set the AMPLITUDE control for maximum amplitude. The OFFSET control must be in. After obtaining a stable triangle display on the oscilloscope, adjust the FREQUENCY Hz dial and the FREQ VERNIER control for a 1 kHz triangle frequency. Now adjust R170, Sym., for best triangle symmetry.

5. Adjust Sine Wave Distortion

Connect a distortion analyzer to the output of the FG 502 using coaxial cable, or the notch filter in series with the output of the FG 502 and the oscilloscope. Set the FUNCTION switch for sine wave output. Set the FREQUENCY Hz dial at 1 and the MULTIPLIER at 10. If the notch filter is used, terminate the coaxial cable from the FG 502 at the notch filter, and adjust the FREQUENCY Hz dial so that the output frequency is directly in the notch (minimum display amplitude). Now adjust R250, DC Level, and R350, Sine Drive, for minimum distortion, or minimum display on the oscilloscope. Go over these controls several times, since considerable interaction exists. To arrive at the percent distortion, divide the amplitude of the sine wave without the notch filter, and multiply by 100.

6. Adjust High Frequency Sine Distortion

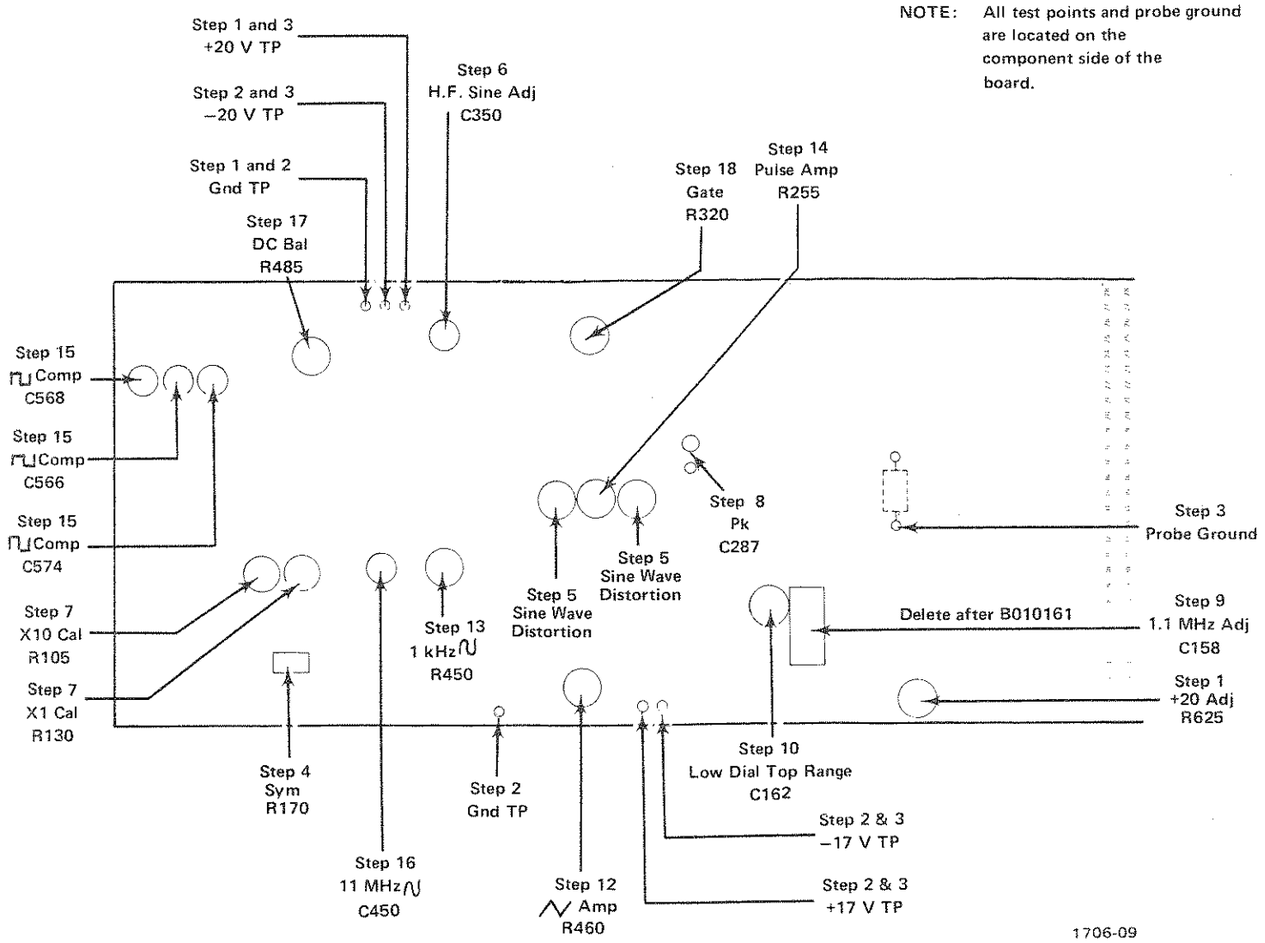
Change the MULTIPLIER to 10^5 and set the FREQUENCY Hz dial at 1. Connect the output of the FG 502 to the oscilloscope using a 50 Ω coaxial cable, 10X attenuator, and 50 Ω termination. Obtain a stable sine wave display. Adjust C350, HF Sine Adj., for the smoothest and best looking sine wave peaks.

7. Adjust Low Frequency Timing

Transfer the output of the FG 502 to the counter. Set the MULTIPLIER to 10^4, and the FREQUENCY Hz dial to 1. The FREQ VERNIER control must be in the CAL position. Set the FUNCTION switch for triangle output at

ADJUSTMENTS

B010162-B031169



maximum amplitude. Adjust R130, X1 Cal., for an output frequency of 10 kHz. Now set the FREQUENCY Hz dial at 11 and adjust R105, X10 Cal., for an output frequency of 110 kHz. Go back and repeat both adjustments until accuracy within specifications is achieved.

8. Adjust Triangle Peak

Set the MULTIPLIER at 10^6 and the FREQUENCY Hz dial at 0.1. Set the FG 502 at maximum amplitude. Set the FUNCTION switch for triangle waveforms, and connect the FG 502 to the oscilloscope through a 50 Ω coaxial cable, 10X attenuator, and 50 Ω termination in that order. Adjust the oscilloscope for easily visible triangle peaks. Adjust C287, Pk., for the best looking and most uniform triangle peaks.

9. Adjust 1.1 MHz Timing (B010100-B010161 ONLY)

Change MULTIPLIER to 10^5 and FREQUENCY Hz dial to 11. Adjust C158, 1.1 MHz Adj., for an output frequency of 1.1 MHz.

10. Adjust High Frequency Timing

Change MULTIPLIER to 10^6 and FREQUENCY Hz dial to 10. Adjust C162, Low Dial Top Range, for an output frequency of 10 MHz.

11. Check Timing Accuracy

Check all MULTIPLIER ranges with the FREQUENCY Hz dial at 1 and 11 for accuracy to specifications.

12. Adjust Triangle Gain

Set the MULTIPLIER control to 10^4, FREQUENCY Hz dial to 1, AMPLITUDE control fully cw, and FUNCTION switch to triangle. Connect the FG 502 to the oscilloscope as in the previous step. Adjust R460, ⩘ Amp., for exactly a 5 V P-P triangle amplitude on the oscilloscope.

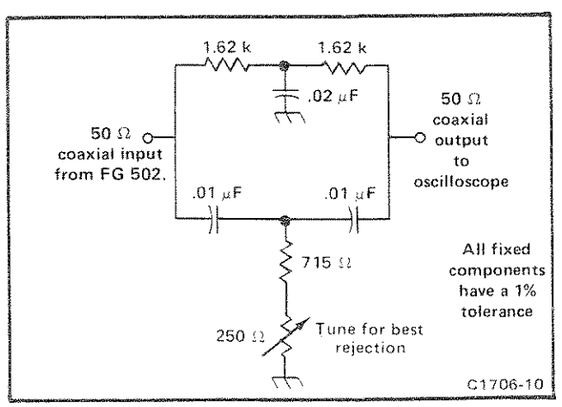


Fig. 3-1. 10 kHz notch filter.

13. Adjust Sine Wave Low Frequency Amplitude

Set the MULTIPLIER to 10^3 and the FREQUENCY Hz dial to 1. Connect the FG 502 to the oscilloscope, as in the previous step, with the FUNCTION switch set for triangle output. Adjust the vertical sensitivity of the oscilloscope and the output amplitude of the FG 502 (near maximum) for a five division reference output. Now change the FUNCTION to sine output, and adjust R450, 1 kHz, for a sine wave amplitude exactly equal to the reference amplitude of the triangle waveform.

14. Adjust Square Wave Low Frequency Amplitude

Using the setup as in the previous step, switch the FUNCTION selector to square wave output. Adjust R255, Pulse Amp., for a square wave output exactly equal to the amplitude of the triangle waveform.

15. Adjust Square Wave Compensation

Using the same setup as in the previous step, set the MULTIPLIER to 10^6, FREQUENCY Hz dial to 1 and the AMPLITUDE control at maximum. Adjust the oscilloscope for an easily viewed display. Adjust C566, C568, and C574, ⊓⊔ Comp., for the best looking front corner on the square wave. After completing these adjustments, check that the rise and fall time of the square wave is ⩽20 ns.

16. Adjust Sine Wave High Frequency Amplitude

Using the same setup as in the previous step, set the FUNCTION switch for sine wave output. Set the MULTIPLIER at 10^3 and the FREQUENCY Hz dial at 10. Adjust the AMPLITUDE control for a five division display, with the oscilloscope vertical sensitivity at 0.1 volts/div. Now change the MULTIPLIER to 10^6 and the FREQUENCY Hz dial to 11. Adjust C450, 11 MHz, for an amplitude of exactly five major divisions.

17. Adjust Output Amplifier DC Balance

Using the same setup as in the previous step, remove the 50 Ω termination, 10X attenuator, and reconnect the coaxial cable to the oscilloscope. Set the FUNCTION switch for triangle output and the AMPLITUDE control for minimum amplitude. Set the vertical deflection factor of the oscilloscope at 0.1 volts/div, the FREQUENCY Hz dial at 11 and the MULTIPLIER at 10^3. Ground the input of the oscilloscope vertical to establish 0 V. Now adjust R485, DC Bal., so that the output waveform is centered around the 0 V DC reference level established on the oscilloscope.

18. Adjust Baseline

Connect a square wave generator, set for a 0 V to at least +2 V, 1 kHz square wave, to the GATE IN connector. Set the FG 502 for a sine wave output of 5 kHz. While viewing the 5 kHz sine wave bursts, adjust R320, Gate, to place the baseline exactly half way between the positive and negative sine wave peaks.

Services Available

Tektronix, Inc. provides complete instrument repair and adjustment at local Field Service Centers and at the Factory Service Center. Contact your local Tektronix Field Office or Representative for further information.

Maintenance

Refer to the TM 500 series power module manual for complete maintenance information.

Test Equipment

For complete calibration, the following equipment is recommended:

Digital voltmeter with ranges greater than ±20 V DC, Tektronix DM 501 or equivalent.

Digital counter capable of measuring frequencies to 11 MHz, Tektronix DC 501 or equivalent.

Complete 50 MHz oscilloscope system with 1X probe and 1 mV/div sensitivity, Tektronix 5403 main frame, 5A48 vertical plug-in, 5B42 time base, and P6011 1X probe, or equivalent.

Distortion analyzer or 10 kHz notch filter constructed as shown in Fig. 3-1.

Square wave generator capable of 0 V to ⩾2 V at 1 kHz, Tektronix FG 501, FG 502 or equivalent.

50 Ω termination, BNC connectors, Tektronix Part Number 011-0049-01.

50 Ω 10X attenuator, BNC connectors, Tektronix Part Number 011-0059-02.

Two 50 Ω 42 inch coaxial cables, BNC connectors, Tektronix Part Number 012-0057-01 or equivalent.

General

The FG 502 can be calibrated either fully installed in a TM 500 series power module, or connected to the power module via a flexible plug-in extender (Tektronix Part No. 067-0645-01). Remove the power module cabinet to make Adjustments to the FG 502 inside the power module.

1. Adjust +20 V Supply

Connect the positive lead of the voltmeter set to read +20 V to the +20 V TP and the negative lead to the Gnd TP. Adjust R625, +20 Adj., for a reading of 20 V ±1%.

2. Check Power Supply Voltages

Connect the negative lead of the voltmeter set to read −20 V to the −20 V TP and the positive lead to the Gnd TP. Check that the reading is −20 V ±1%. Move the negative lead to the −17 TP and note the reading. Now measure the +17 V by switching the negative lead to the Gnd TP and the positive lead to the +17 V TP. The absolute value of these voltages must be within 0.1% of each other.

3. Check Power Supply Regulation

Connect a 1X probe to the vertical input of the oscilloscope, AC coupled, 1 mV/div sensitivity. Clip the ground strap of the probe to the TP labeled Probe Ground in the illustration. Check the +20 V, −20 V, +17 V, and −17 V, at their respective test points, for less than 100 μV of ripple, measured peak to peak.

4. Adjust Triangle Symmetry

Connect the output of the FG 502 through a 50 Ω coaxial cable, terminated in 50 Ω, to the oscilloscope input. Set the MULTIPLIER at 10^5, the FREQUENCY Hz dial near .1, the oscilloscope time base at 1 ms/div, and the FUNCTION switch for a triangle waveform. Set the AMPLITUDE control for maximum amplitude. The OFFSET control must be in. After obtaining a stable triangle display on the oscilloscope, adjust the FREQUENCY Hz dial and the FREQ VERNIER control for a 1 kHz triangle frequency. Now adjust R170, Sym., for best triangle symmetry.

5. Preset Triangle DC Level Adjustment

Change the MULTIPLIER setting to 10^3, and the FUNCTION to sine wave. Set the FREQUENCY Hz dial to 1. Adjust R250, DC Level, for the best looking positive and negative sine wave peaks.

6. Adjust Sine Wave Distortion

Connect a distortion analyzer to the output of the FG 502 using coaxial cable, or the notch filter in series with the output of the FG 502 and the oscilloscope. Set the FUNCTION switch for sine wave output. Set the FREQUENCY Hz dial at 1 and the MULTIPLIER at 10^4. If the notch filter is used, terminate the coaxial cable from the FG 502 at the notch filter, and adjust the FREQUENCY Hz dial so that the output frequency is

ADJUSTMENTS

B010100-B010161

directly in the notch (minimum display amplitude). Now adjust R250, DC Level, R350, Sine Drive, R356, R366, R376, and R386, Sine Shapers, for minimum distortion, or minimum display on the oscilloscope. Go over these controls several times, since considerable interaction exists. To arrive at the percent distortion, divide the amplitude of the display, using the notch filter, by the amplitude of the sine wave without the notch filter, and multiply by 100.

7. Adjust High Frequency Sine Distortion

Change the MULTIPLIER to 10^6 and set the FREQUENCY Hz dial at 1. Connect the output of the FG 502 to the oscilloscope using a 50 Ω coaxial cable, 10X attenuator, and 50 Ω termination. Obtain a stable sine wave display. Adjust C350, HF Sine Adj., for the smoothest and best looking sine wave peaks.

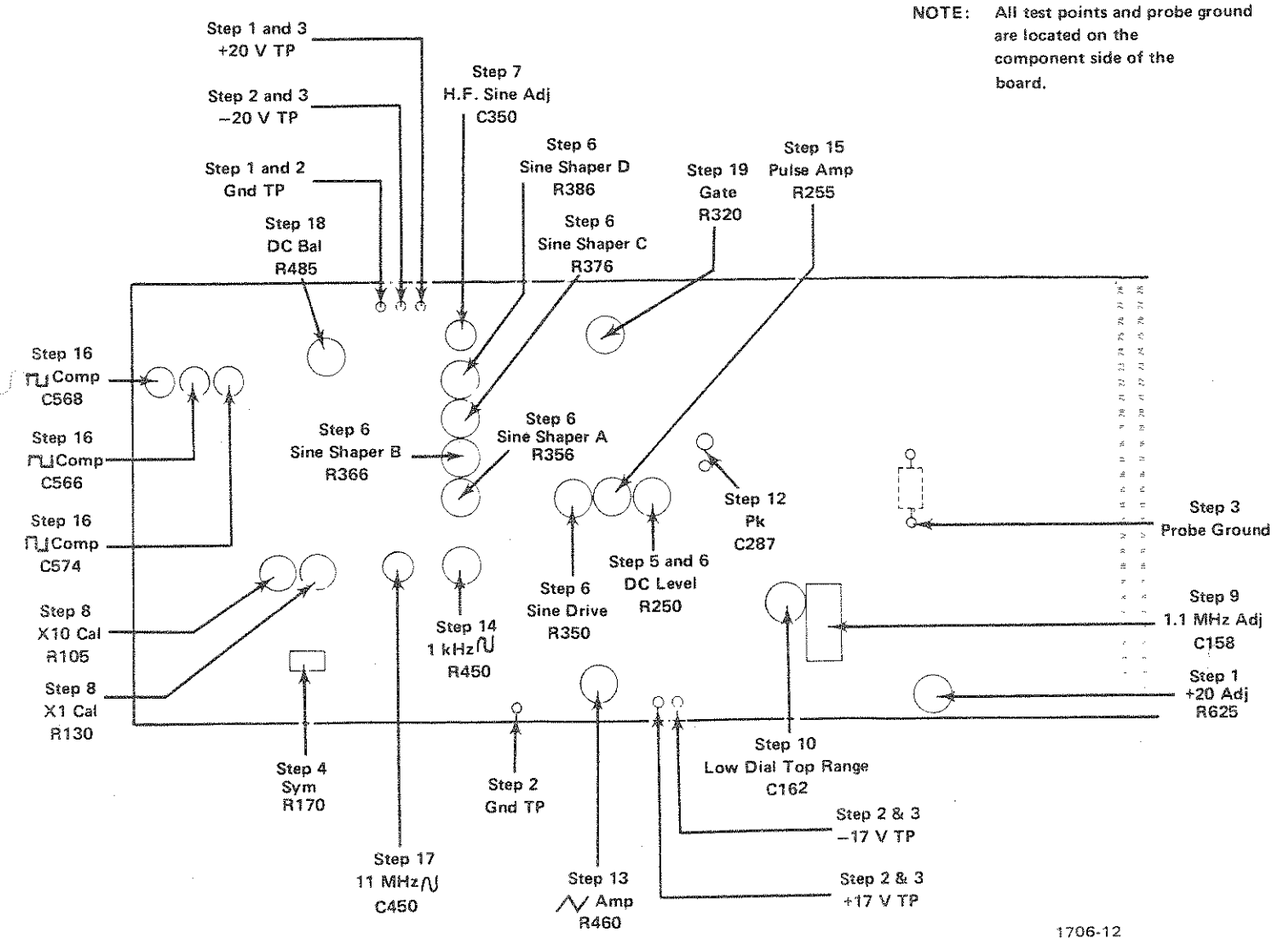
8. Adjust Low Frequency Timing

Transfer the output of the FG 502 to the counter. Set the MULTIPLIER to 10^4, and the FREQUENCY Hz dial to 1. The FREQ VERNIER control must be in the CAL position. Set the FUNCTION switch for triangle output at maximum amplitude. Adjust R130, X1 Cal., for an output frequency of 10 kHz. Now set the FREQUENCY Hz dial at 11 and adjust R105, X10 Cal., for an output frequency of 110 kHz. Go back and repeat both adjustments until accuracy within specifications is achieved.

9. Adjust 1.1 MHz Timing

Change MULTIPLIER to 10^5 and FREQUENCY Hz dial to 11. Adjust C158, 1.1 MHz Adj., for an output frequency of 1.1 MHz.

NOTE: All test points and probe ground are located on the component side of the board.



10. Adjust High Frequency Timing

Change MULTIPLIER to 10^6 and FREQUENCY Hz dial to 1. Adjust C162, Low Dial Top Range, at 11 MHz. Repeat step 8 and this step until accuracy within specifications is achieved.

11. Check Timing Accuracy

Check all MULTIPLIER ranges with the FREQUENCY Hz dial at 1 and 11 for accuracy to specifications.

12. Adjust Triangle Peak

Set the MULTIPLIER at 10^6 and the FREQUENCY Hz dial at 0.1. Set the FG 502 at maximum amplitude. Set the FUNCTION switch for triangle waveforms, and connect the FG 502 to the oscilloscope through a 50 Ω coaxial cable, 10X attenuator, and 50 Ω termination in that order. Adjust the oscilloscope for easily visible triangle peaks. Adjust C287, Pk., for the best looking and most uniform triangle peaks.

13. Adjust Triangle Gain

Set the MULTIPLIER control to 10^4, FREQUENCY Hz dial to 1, AMPLITUDE control fully cw, and FUNCTION switch to triangle. Connect the FG 502 to the oscilloscope as in the previous step. Adjust R460, ∿ Amp., for exactly a 5 V P-P triangle amplitude on the oscilloscope.

14. Adjust Sine Wave Low Frequency Amplitude

Set the MULTIPLIER to 10^3 and the FREQUENCY Hz dial to 1. Connect the FG 502 to the oscilloscope, as in the previous step, with the FUNCTION switch set for triangle output. Adjust the vertical sensitivity of the oscilloscope and the output amplitude of the FG 502 (near maximum) for a five division reference output. Now change the FUNCTION to sine output, and adjust R450, 1 kHz, for a sine wave amplitude exactly equal to the reference amplitude of the triangle waveform.

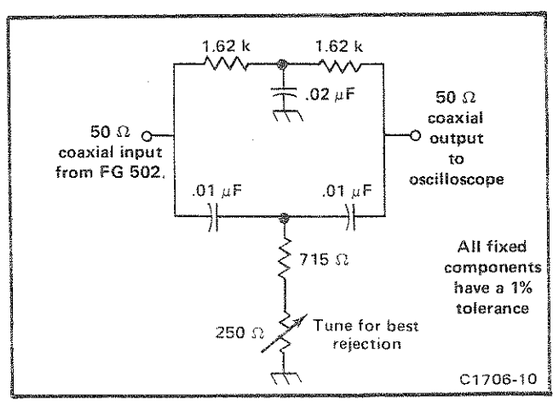


Fig. 3-1. 10 kHz notch filter.

15. Adjust Square Wave Low Frequency Amplitude

Using the setup as in the previous step, switch the FUNCTION selector to square wave output. Adjust R255, Pulse Amp., for a square wave output exactly equal to the amplitude of the triangle waveform.

16. Adjust Square Wave Compensation

Using the same setup as in the previous step, set the MULTIPLIER to 10^6, FREQUENCY Hz dial to 1 and the AMPLITUDE control at maximum. Adjust the oscilloscope for an easily viewed display. Adjust C566, C568, and C574, ⊓⊔ Comp., for the best looking front corner on the square wave. After completing these adjustments, check that the rise and fall time of the square wave is ⩽20 ns.

17. Adjust Sine Wave High Frequency Amplitude

Using the same setup as in the previous step, set the FUNCTION switch for sine wave output. Set the MULTIPLIER at 10^3 and the FREQUENCY Hz dial at 10. Adjust the AMPLITUDE control for a five division display, with the oscilloscope vertical sensitivity at 0.1 volts/div. Now change the MULTIPLIER to 10^6 and the FREQUENCY Hz dial to 11. Adjust C450, 11 MHz, for an amplitude of exactly four major divisions.

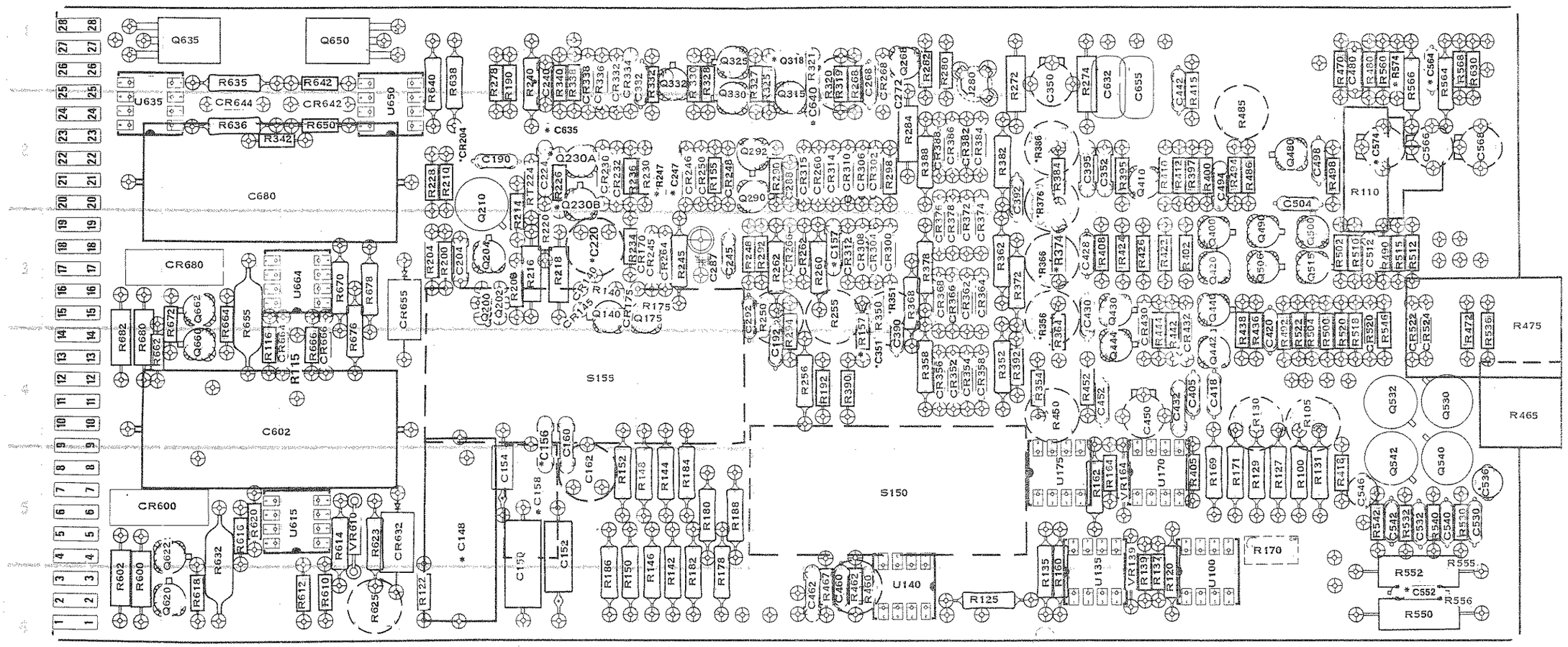
18. Adjust Output Amplifier DC Balance

Using the same setup as in the previous step, remove the 50 Ω termination, 10X attenuator, and reconnect the coaxial cable to the oscilloscope. Set the FUNCTION switch for triangle output and the AMPLITUDE control for minimum amplitude. Set the vertical deflection factor of the oscilloscope at 0.1 volts/div, the FREQUENCY Hz dial at 11 and the MULTIPLIER at 10^3. Ground the input of the oscilloscope vertical to establish 0 V. Now adjust R485, DC Bal., so that the output waveform is centered around the 0 V DC reference level established on the oscilloscope.

19. Adjust Baseline

Connect a square wave generator, set for a 0 V to at least +2 V, 1 kHz square wave, to the GATE IN connector. Set the FG 502 for a sine wave output of 5 kHz. While viewing the 5 kHz sine wave bursts, adjust R320, Gate, to place the baseline exactly half way between the positive and negative sine wave peaks.

PARTS LOCATION GRID

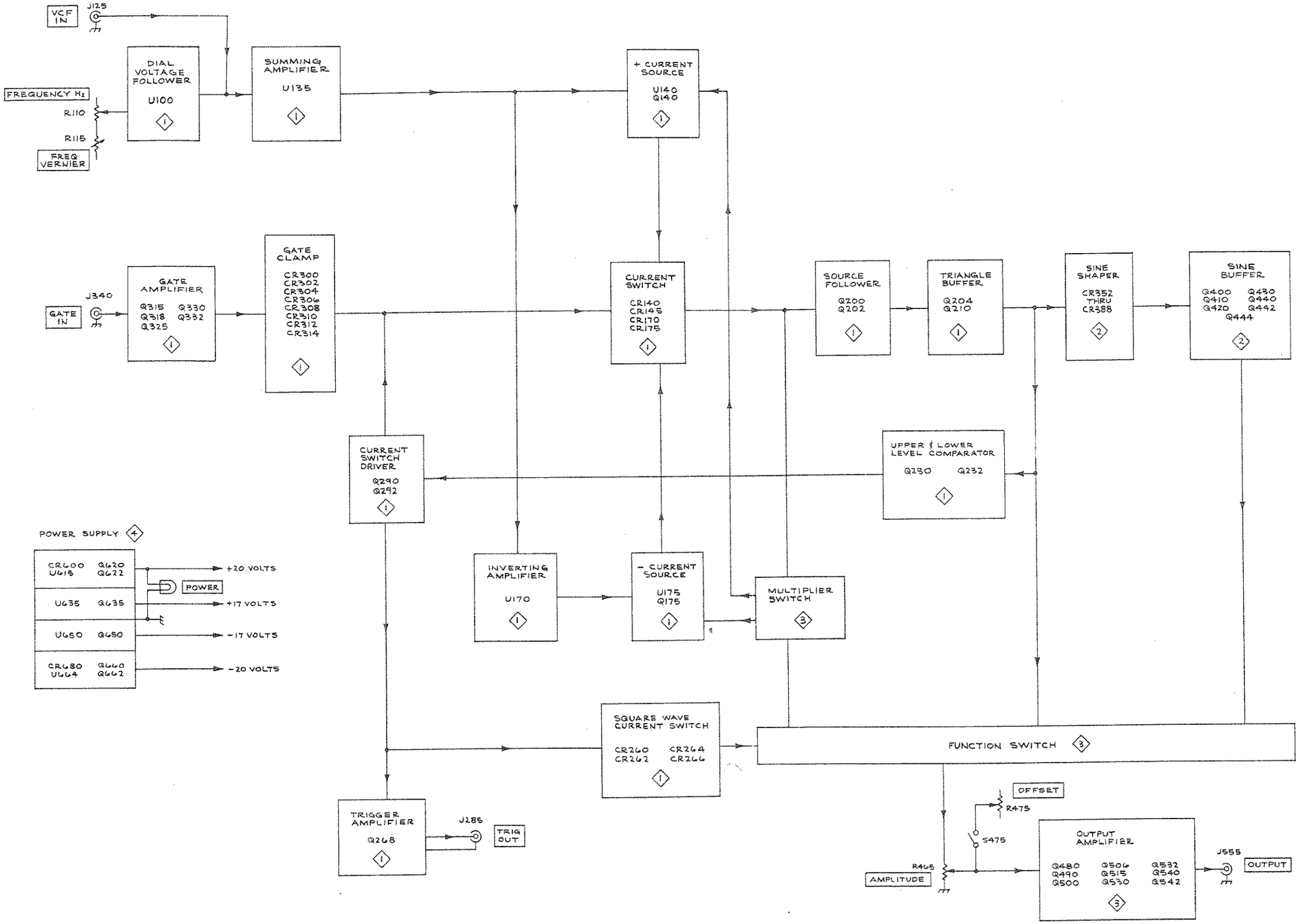


*See Parts List for serial number ranges.

1706-11

R318
CR318
C148
R115
C156
} * Located on back of board.

CKT NO	GRID LOC	CKT NO	GRID LOC	CKT NO	GRID LOC	CKT NO	GRID LOC	CKT NO	GRID LOC	CKT NO	GRID LOC	CKT NO	GRID LOC
C148	D5	CR140	E3	Q140	E3	R152	E5	R332	E1	R510	L3	U140	H6
C150	E5	CR145	E3	Q175	F3	R155	F2	R338	E1	R512	L3	U170	J5
C152	E5	CR170	F3	Q200	D3	R157	G4	R340	E1	R515	L3	U175	I5
C154	D5	CR175	E3	Q202	D3	R160	I6	R342	B2	R518	L4	U615	C5
C156	E4	CR204	D2	Q204	D3	R162	I5	R350	H3	R520	K4	U635	A2
C157	G3	CR230	E2	Q210	D2	R164	I5	R351	H3	R522	K4	U650	C2
C158	E5	CR232	E2	Q230A	E2	R169	J5	R352	I4	R530	L5	U664	C3
C160	E4	CR245	F3	Q230B	E2	R170	K5	R354	I4	R532	L5		
C162	E5	CR246	F2	Q232A	E2	R171	K5	R356	I3	R536	M4		
C190	D2	CR248	F2	Q232B	E2	R175	F3	R358	H4	R540	L5	VR139	J6
C192	G4	CR250	F2	Q268	H1	R178	F6	R362	I3	R542	L5	VR164	J5
C204	D3	CR260	G2	Q290	F2	R180	F5	R364	I4	R546	L4	VR610	C5
C220	F3	CR262	G3	Q292	F2	R182	F6	R366	I3	R550	L6		
C224	E2	CR264	F3	Q315	G2	R184	F5	R368	H3	R552	L6		
C240	E1	CR266	G3	Q318	G1	R186	E6	R372	I3	R555	M5		
C245	F3	CR268	H1	Q325	F1	R188	F5	R374	I3	R556	M5		
C247	F2	CR300	H3	Q330	F1	R190	D1	R376	I2	R560	L1		
C268	G1	CR304	H3	Q332	F1	R192	G4	R378	H3	R564	L1		
C272	H1	CR306	G2	Q400	J3	R200	D3	R382	I2	R566	L1		
C287	F3	CR308	G3	Q410	J2	R204	D3	R384	I2	R568	L1		
C288	G2	CR310	G2	Q420	J3	R208	D3	R386	I2	R574	L1		
C292	F3	CR312	G3	Q430	J3	R210	D2	R388	H2	R600	A6		
C332	F1	CR314	G2	Q440	J3	R214	D2	R390	G4	R602	A6		
C350	I1	CR315	G2	Q442	J4	R216	E3	R392	I4	R610	C6		
C351	H4	CR318	G1	Q444	J4	R218	E3	R395	J2	R612	C6		
C352	I2	CR332	F1	Q480	K2	R220	E3	R397	J2	R614	C5		
C390	H4	CR334	E1	Q490	K3	R226	E2	R400	J2	R616	B5		
C392	I2	CR336	E1	Q500	K3	R228	D2	R402	J3	R618	B6		
C395	I2	CR338	E1	Q506	K3	R230	F2	R405	J5	R620	B5		
C405	J4	CR352	H4	Q515	K3	R234	E3	R408	I3	R623	C5		
C418	J4	CR354	H4	Q530	L4	R236	E2	R410	J2	R625	C6		
C420	K4	CR356	H4	Q532	L4	R240	E1	R412	J2	R630	M1		
C428	I3	CR358	H4	Q540	L5	R245	F3	R415	J1	R632	B5		
C430	I3	CR362	H3	Q542	L5	R247	F2	R418	K5	R635	B1		
C432	J4	CR364	H3	Q620	B6	R248	F3	R422	J3	R636	B2		
C442	J1	CR366	H3	Q622	B5	R250	G3	R424	J3	R638	D1		
C450	J4	CR368	H3	Q635	B1	R255	G3	R426	J3	R640	D1		
C452	I4	CR372	H3	Q650	C1	R256	G4	R436	K4	R642	C1		
C460	G6	CR374	H3	Q660	B4	R260	G3	R438	K4	R650	C2		
C462	G6	CR376	H3	Q662	B3	R262	G3	R442	J4	R655	B3		
C480	L1	CR378	H3			R268	G1	R444	J4	R662	A4		
C494	J2	CR382	H2	R100	K5	R272	I1	R450	I4	R664	B3		
C498	K2	CR384	H2	R105	K4	R274	I1	R452	I4	R666	C4		
C504	K2	CR386	H2	R110	L2	R278	D1	R460	G6	R670	C3		
C512	L3	CR388	H2	R116	B4	R280	H1	R462	G6	R672	B3		
C530	M5	CR430	J3	R120	J6	R282	H1	R465	M4	R676	C4		
C532	L5	CR432	J4	R122	D6	R284	H2	R467	G6	R678	C3		
C536	M5	CR520	L4	R125	H6	R290	G2	R470	K1	R680	A4		
C540	L5	CR522	L4	R127	K5	R292	G3	R472	M4	R682	A4		
C542	L5	CR524	L4	R129	K5	R294	G4	R475	M3				
C546	L5	CR600	A5	R130	K4	R298	H2	R480	L1	RT224	E2		
C552	L6	CR632	C5	R131	K5	R318	G1	R485	K2				
C564	L1	CR642	C2	R135	I6	R319	G1	R486	K2				
C566	L2	CR644	B2	R137	J6	R320	G1	R490	L3	S150	H5		
C568	M2	CR655	D3	R139	J6	R321	G1	R492	K4	S155	E4		
C574	L2	CR664	B4	R140	E3	R325	G1	R494	K2	S475	L3		
C602	B4	CR666	C4	R142	F6	R327	G1	R498	K2				
C632	I1	CR680	B3	R144	F5	R328	F1	R500	K4				
C635	E2	J280	H1	R146	F6	R330	F1	R502	K3	U100	J6		
C640	G1			R148	F5			R504	K4	U135	I6		
C655	J1			R150	E6								
C680	B2												



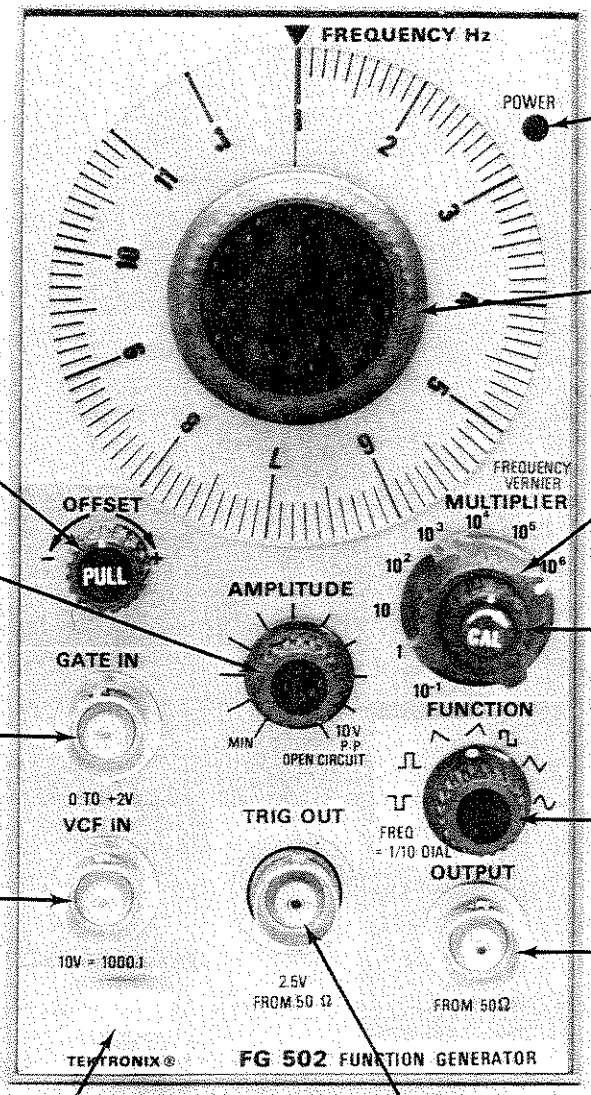
FG 502

(A)

BLOCK DIAGRAM

DEH 1073

CONTROLS AND CONNECTORS



POWER On Pilot Light

Illuminated when power is applied to unit.

FREQUENCY Hz Dial

Multiply dial reading by MULTIPLIER setting for frequency out.

OFFSET Control

Pull and adjust for output waveform DC offset.

MULTIPLIER Switch

Sets basic frequency range.

AMPLITUDE Control

Adjusts amplitude of output waveform.

VERNIER Control

Allows fine adjustment of output frequency.

GATE IN Connector

Voltage applied permits gating of output waveform.

FUNCTION Switch

Selects output waveform.

VCF IN Connector

Applied external voltage changes output waveform frequency.

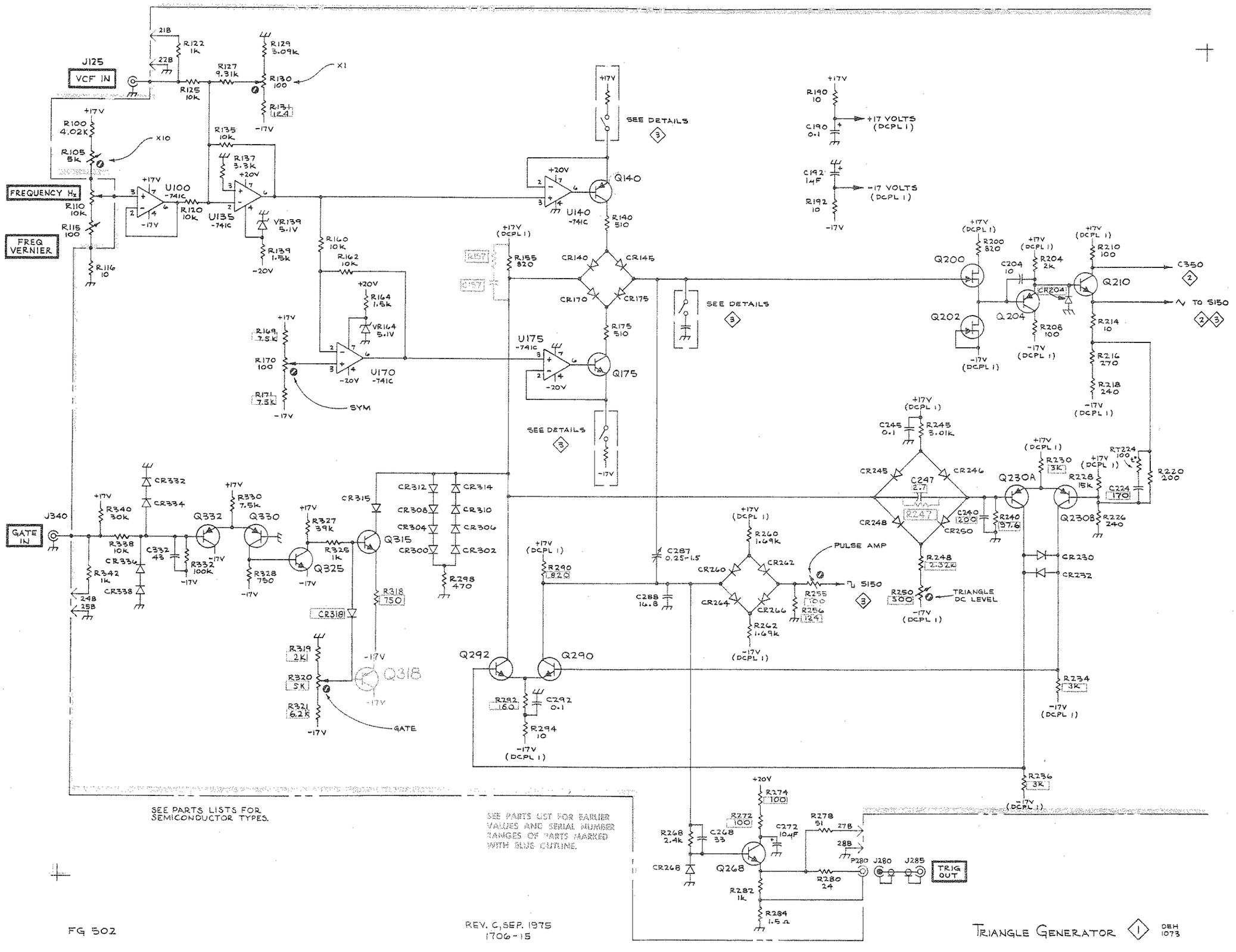
OUTPUT Connector

BNC connector for waveform output.

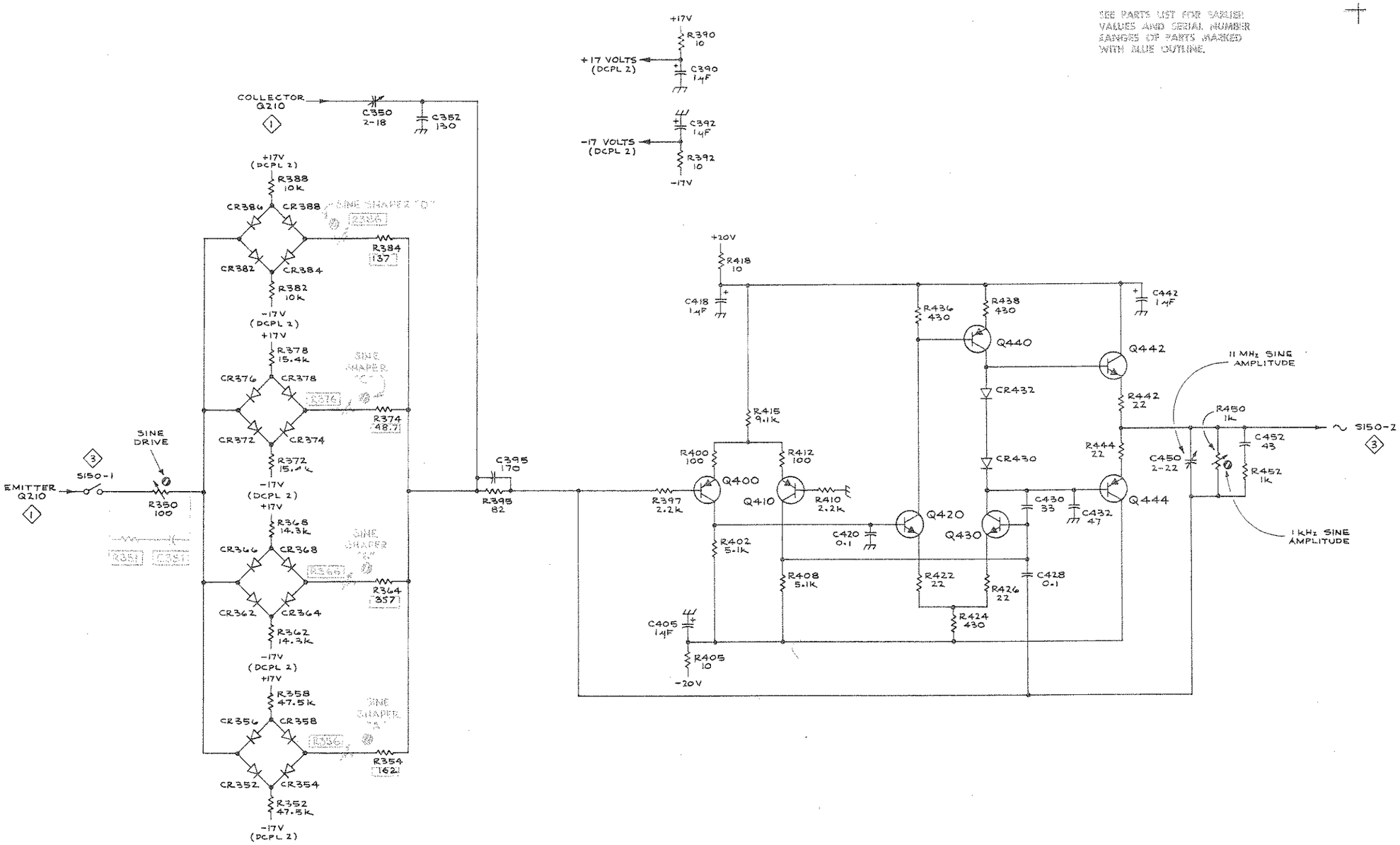
Latch. Pull to remove plug-in.

TRIG OUT Connector

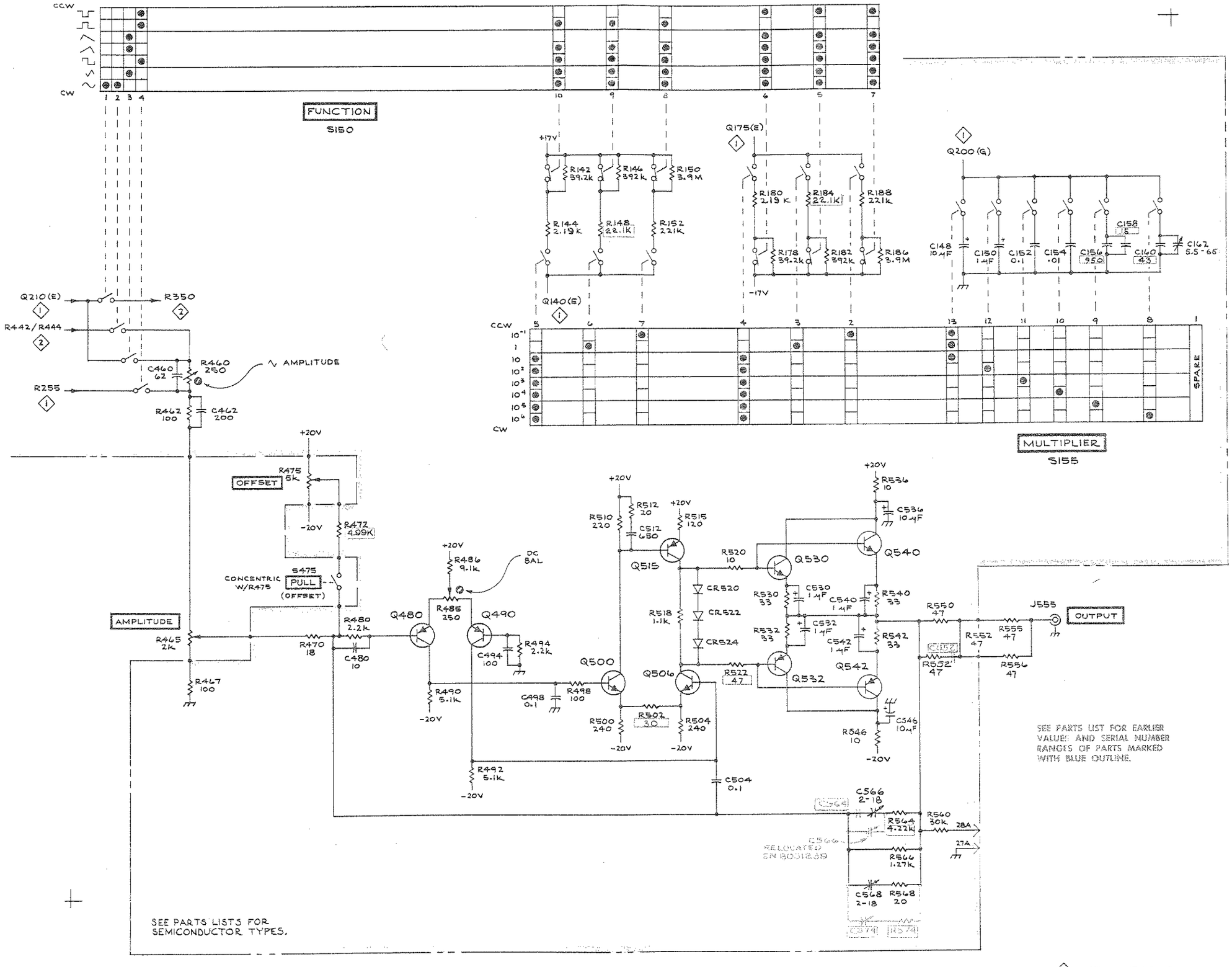
Square-wave output for applications requiring an external trigger.


J125
VCF IN
21B
22B
R122 1k
R127 9.31k
R125 10k
R129 3.09k
R130 100
X1
R131 12.4
-17V
+17V
R100 4.02K
R105 5K
X10
FREQUENCY Hz
R110 10K
R115 100
FREQ VERNIER
R116 10
R135 10K
R137 3.3k
+20V
U100 -741C
U135 -741C
R120 10K
VR139 5.1V
R139 1.5k
-20V
R160 10K
R162 10K
+20V
R164 1.5k
VR164 5.1V
U170 -741C
R169 7.5K
R170 100
R171 7.5K
SYM
U175 -741C
SEE DETAILS
3
Q140
U140 -741C
R140 510
R155 820
C157
CR140
CR145
CR170
CR175
R175 510
Q175
SEE DETAILS
3
R190 10
C190 0.1
+17 VOLTS (DCPL 1)
C192 1uF
R192 10
-17 VOLTS (DCPL 1)
Q200
R200 820
C204 10
R204 2K
CR204
Q204
R208 100
Q202
R210 100
Q210
C350
2
TO 5150
2 3
R214 10
R216 270
R218 240
C245 0.1
R245 3.01K
CR245
CR246
C247 2.7
R247
CR248
CR250
C240 200
R240 37.6
Q230A
Q230B
R230 3K
R228 15K
C224 170
RT224 100
R220 200
R226 240
CR230
CR232
R248 2.32K
R250 500
TRIANGLE DC LEVEL
PULSE AMP
R255 100
R256 124
5150
3
C287 0.25-1.5
C288 16.8
R260 1.69K
CR260
CR262
CR264
CR266
R262 1.69K
R234 3K
R236 3K
J340
GATE IN
R340 30K
R338 10K
R342 1K
248
258
CR332
CR334
CR338
Q332
Q330
R330 7.5K
R332 100K
R328 750
C332 43
R327 39K
R325 1K
Q325
Q315
CR315
CR312
CR314
CR308
CR310
CR304
CR306
CR300
CR302
R298 470
R318 750
CR318
R319 2K
R320 5K
R321 6.2K
Q318
GATE
Q292
Q290
R292 160
C292 0.1
R294 10
R290 820
R274 100
R272 100
R278 51
27B
28B
R268 2.4K
C268 33
C272 10uF
CR268
Q268
R280 24
P280
J280
J285
TRIG OUT
R282 1K
R284 1.5Ω
SEE PARTS LISTS FOR SEMICONDUCTOR TYPES.
SEE PARTS LIST FOR EARLIER VALUES AND SERIAL NUMBER RANGES OF PARTS MARKED WITH BLUE OUTLINE.
FG 502
REV. C, SEP. 1975
1706-15
TRIANGLE GENERATOR 1 DEH 1073
GENERATOR

SEE PARTS LIST FOR EARLIER VALUES AND SERIAL NUMBER RANGES OF PARTS MARKED WITH BLUE OUTLINE.



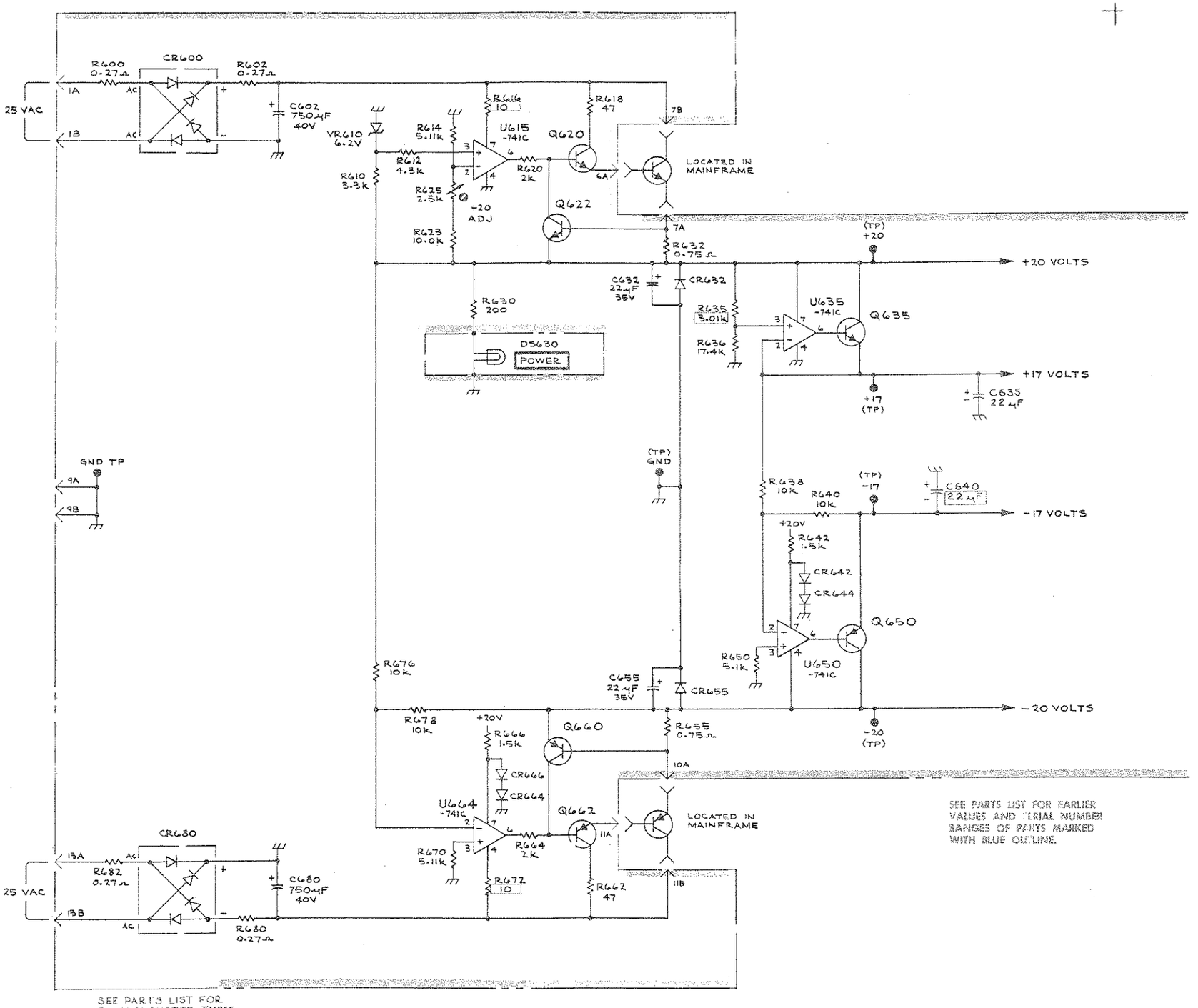
SEE PARTS LISTS FOR SEMICONDUCTOR TYPES.



FG 502

REV C, APRIL 1976

OUTPUT AMPLIFIER AND SWITCH DETAILS 3 DEH 1073 1706-17



REPLACEABLE MECHANICAL PARTS

PARTS ORDERING INFORMATION

Replacement parts are available from or through your local Tektronix, Inc. Field Office or representative.

Changes to Tektronix instruments are sometimes made to accommodate improved components as they become available, and to give you the benefit of the latest circuit improvements developed in our engineering department. It is therefore important, when ordering parts, to include the following information in your order: Part number, instrument type or number, serial number, and modification number if applicable.

If a part you have ordered has been replaced with a new or improved part, your local Tektronix, Inc. Field Office or representative will contact you concerning any change in part number.

Change information, if any, is located at the rear of this manual.

SPECIAL NOTES AND SYMBOLS

X000	Part first added at this serial number
00X	Part removed after this serial number

FIGURE AND INDEX NUMBERS

Items in this section are referenced by figure and index numbers to the illustrations.

INDENTATION SYSTEM

This mechanical parts list is indented to indicate item relationships. Following is an example of the indentation system used in the description column.

1 2 3 4 5 *Name & Description*

Assembly and/or Component
Attaching parts for Assembly and/or Component
- - - * - - -
Detail Part of Assembly and/or Component
Attaching parts for Detail Part
- - - * - - -
Parts of Detail Part
Attaching parts for Parts of Detail Part
- - - * - - -

Attaching Parts always appear in the same indentation as the item it mounts, while the detail parts are indented to the right. Indented items are part of, and included with, the next higher indentation. The separation symbol - - - * - - - indicates the end of attaching parts.

Attaching parts must be purchased separately, unless otherwise specified.

ITEM NAME

In the Parts List, an Item Name is separated from the description by a colon (:). Because of space limitations, an Item Name may sometimes appear as incomplete. For further Item Name identification, the U.S. Federal Cataloging Handbook H6-1 can be utilized where possible.

ABBREVIATIONS

"	INCH
#	NUMBER SIZE
ACTR	ACTUATOR
ADPTR	ADAPTER
ALIGN	ALIGNMENT
AL	ALUMINUM
ASSEM	ASSEMBLED
ASSY	ASSEMBLY
ATTEN	ATTENUATOR
AWG	AMERICAN WIRE GAGE
BD	BOARD
BRKT	BRACKET
BRS	BRASS
BRZ	BRONZE
BSHG	BUSHING
CAB	CABINET
CAP	CAPACITOR
CER	CERAMIC
CHAS	CHASSIS
CKT	CIRCUIT
COMP	COMPOSITION
CONN	CONNECTOR
COV	COVER
CPLG	COUPLING
CRT	CATHODE RAY TUBE
DEG	DEGREE
DWR	DRAWER
ELCTRN	ELECTRON
ELEC	ELECTRICAL
ELCTLT	ELECTROLYTIC
ELEM	ELEMENT
EPL	ELECTRICAL PARTS LIST
EQPT	EQUIPMENT
EXT	EXTERNAL
FIL	FILLISTER HEAD
FLEX	FLEXIBLE
FLH	FLAT HEAD
FLTR	FILTER
FR	FRAME or FRONT
FSTNR	FASTENER
FT	FOOT
FXD	FIXED
GSKT	GASKET
HDL	HANDLE
HEX	HEXAGON
HEX HD	HEXAGONAL HEAD
HEX SOC	HEXAGONAL SOCKET
HLCPS	HELICAL COMPRESSION
HLEXT	HELICAL EXTENSION
HV	HIGH VOLTAGE
IC	INTEGRATED CIRCUIT
ID	INSIDE DIAMETER
IDENT	IDENTIFICATION
IMPLR	IMPELLER
IN	INCH
INCAND	INCANDESCENT
INSUL	INSULATOR
INTL	INTERNAL
LPHLDR	LAMPHOLDER
MACH	MACHINE
MECH	MECHANICAL
MTG	MOUNTING
NIP	NIPPLE
NON WIRE	NOT WIRE WOUND
OBD	ORDER BY DESCRIPTION
OD	OUTSIDE DIAMETER
OVH	OVAL HEAD
PH BRZ	PHOSPHOR BRONZE
PL	PLAIN or PLATE
PLSTC	PLASTIC
PN	PART NUMBER
PNH	PAN HEAD
PWR	POWER
RCPT	RECEPTACLE
RES	RESISTOR
RGD	RIGID
RLF	RELIEF
RTNR	RETAINER
SCH	SOCKET HEAD
SCOPE	OSCILLOSCOPE
SCR	SCREW
SE	SINGLE END
SECT	SECTION
SEMICOND	SEMICONDUCTOR
SHLD	SHIELD
SHLDR	SHOULDERED
SKT	SOCKET
SL	SLIDE
SLFLKG	SELF-LOCKING
SLVG	SLEEVING
SPR	SPRING
SQ	SQUARE
SST	STAINLESS STEEL
STL	STEEL
SW	SWITCH
T	TUBE
TERM	TERMINAL
THD	THREAD
THK	THICK
TNSN	TENSION
TPG	TAPPING
TRH	TRUSS HEAD
V	VOLTAGE
VAR	VARIABLE
W/	WITH
WSHR	WASHER
XFMR	TRANSFORMER
XSTR	TRANSISTOR

CROSS INDEX MFR. CODE NUMBER TO MANUFACTURER

MFR.CODE	MANUFACTURER	ADDRESS	CITY,STATE,ZIP
08261	Spectra-Strip Corp.	7100 Lampson Ave.	Garden Grove, CA 92642
08928	Abbott Screw and Mfg. Co.	6525 North Clark	Chicago, IL 60626
10539	Jackson Bros., London, Ltd.		Croyden, Surrey, England
22526	Berg Electronics, Inc.	Youk Expressway	New Cumberland, PA 17070
23499	Gavitt Wire and Cable, Division of RSC Industries, Inc.	455 N. Quince St.	Escondido, CA 92025
24931	Specialty Connector Co., Inc.	3560 Madison Ave.	Indianapolis, IN 46227
45722	USM Corp., Parker-Kalon Fastener Div.	1 Peekay Drive	Clifton, NJ 07014
73743	Fischer Special Mfg. Co.	446 Morgan St.	Cincinnati, OH 45206
74445	Holo-Krome Co.	31 Brook St. West	Hartford, CT 06110
77250	Pheoll Manufacturing Co., Division of Allied Products Corp.	5700 W. Roosevelt Rd.	Chicago, IL 60650
78189	Illinois Tool Works, Inc. Shakeproof Division	St. Charles Road	Elgin, IL 60120
78471	Tilley Mfg. Co.	900 Industrial Rd.	San Carlos, CA 94070
79136	Waldes, Kohinoor, Inc.	47-16 Austel Place	Long Island City, NY 11101
79807	Wrought Washer Mfg. Co.	2100 S. O Bay St.	Milwaukee, WI 53207
80009	Tektronix, Inc.	P. O. Box 500	Beaverton, OR 97077
82647	Texas Instruments, Inc., Control Products Div.	34 Forest St.	Attleboro, MA 02703
83385	Central Screw Co.	2530 Crescent Dr.	Broadview, IL 60153
91836	Kings Electronics Co., Inc.	40 Marbledale Road	Tuckahoe, NY 10707
98978	International Electronic Research Corp.	135 W. Magnolia Ave.	Burbank, CA 91502

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Dscont	Qty	1 2 3 4 5 Name & Description	Mfr Code	Mfr Part Number
1-1	337-1399-00			2	SHLD,ELECTRICAL:SIDE	80009	337-1399-00
-2	366-1007-01			1	KNOB:ROUND,GRAY,W/SETSCREW	80009	366-1007-01
	213-0153-00			2	. SETSCREW:5-40 X 0.125 INCH,HEX SOC.STL	74445	OBD
-3	354-0437-03			1	RING,KNOB SKIRT:CLEAR PLASTIC	80009	354-0437-03
					(ATTACHING PARTS)		
-4	211-0088-00			2	SCREW,MACHINE:2-56 X 0.281",82 DEG,FLH STL	77250	OBD
	210-0978-00			1	WASHER,FLAT:0.375 ID X 0.50 INCH OD STL	78471	OBD
					- - - * - - -		
-5	366-1031-03			1	KNOB:RED,--CAL,W/SETSCREW	80009	366-1031-03
	213-0153-00			1	. SETSCREW:5-40 X 0.125 INCH,HEX SOC.STL	74445	OBD
-6	366-1170-01			1	KNOB:GRAY,4 SIDED,W/SETSCREW	80009	366-1170-01
	213-0153-00			2	. SETSCREW:5-40 X 0.125 INCH,HEX SOC.STL	74445	OBD
-7	366-0494-00			2	KNOB:GRAY WITH SETSCREW	80009	366-0494-00
	213-0153-00			1	. SETSCREW:5-40 X 0.125 INCH,HEX SOC.STL	74445	OBD
-8	366-1023-03			1	KNOB:GRAY,--PULL,W/SETSCREW	80009	366-1023-03
	213-0153-00			1	. SETSCREW:5-40 X 0.125 INCH,HEX SOC.STL	74445	OBD
-9	214-1840-00			1	PIN,KNOB SECRG:	80009	214-1840-00
-10	366-1422-01			1	KNOB:LATCH	80009	366-1422-01
-11	131-0955-00			2	CONN,RCPT,ELEC:BNC,FEMALE	24931	28JR200-1
-12	131-0955-00			1	CONN,RCPT,ELEC:BNC,FEMALE	24931	28JR200-1
					(ATTACHING PARTS)		
-13	210-0255-00			1	TERMINAL,LUG:0.391" ID INTTOOTH	80009	210-0255-00
					- - - * - - -		
-14	131-0274-00			1	CONN,RCPT,ELEC:INSULATED BNC,FEMALE	91836	KC79-67TR5
-15	----- -----			1	RESISTOR,VAR:(SEE R475/S475 EPL)		
					(ATTACHING PARTS)		
-16	210-0583-00			1	NUT,PLAIN,HEX.:0.25-32 X 0.312 INCH,BRS	73743	2X20319-402
-17	210-0940-00			1	WASHER,FLAT:0.25 ID X 0.375 INCH OD,STL	79807	OBD
					- - - * - - -		
-18	----- -----			1	RESISTOR,VAR:(SEE R465 EPL)		
					(ATTACHING PARTS)		
-19	210-0583-00			1	NUT,PLAIN,HEX.:0.25-32 X 0.312 INCH,BRS	73743	2X20319-402
-20	210-0940-00			1	WASHER,FLAT:0.25 ID X 0.375 INCH OD,STL	79807	OBD
					- - - * - - -		
-21	358-0378-00			1	BUSHING,SLEEVE:PRESS MOUNT	80009	358-0378-00
-22	333-1729-00			1	PANEL,FRONT:FG502	80009	333-1729-00
-23	214-1513-01			1	LCH,PLUG-IN RET:	80009	214-1513-01
					(ATTACHING PARTS)		
-24	213-0254-00			1	SCR,TPG,THD CTG:2-56X0.25"100 DEG,FLH STL	45722	OBD
					- - - * - - -		
-25	----- -----			1	RESISTOR,VAR:W/HARDWARE(SEE R110 EPL)		
-26	200-0935-00			1	BASE,LAMPHOLDER:0.29 OD X 0.19" L,BK PLSTC	80009	200-0935-00
-27	378-0602-00			1	LENS,LIGHT:GREEN	80009	378-0602-00
-28	352-0157-00			1	LAMPHOLDER:WHITE PLASTIC	80009	352-0157-00
-29	407-1274-00			1	BRKT,RES. MTG:	80009	407-1274-00
					(ATTACHING PARTS)		
-30	211-0559-00			1	SCREW,MACHINE:6-32 X 0.375"100 DEG,FLH STL	83385	OBD
					- - - * - - -		
-31	401-0161-00			1	DRIVE,TURNS RED:6:1 REDUCTION	10539	4511/DAF
					(ATTACHING PARTS)		
-32	213-0138-00			2	SCR,TPG,THD FOR:4-40 X 0.188 INCH,PNH STL	83385	OBD
					- - - * - - -		
-33	386-2555-00	B010100 B031699		1	SUBPANEL,FRONT:PLASTIC	80009	386-2555-00
	386-2555-01	B031700		1	SUBPANEL,FRONT:PLASTIC	80009	386-2555-01
					(ATTACHING PARTS)		
-34	213-0229-00			4	SCR,TPG,THD FOR:6-20X0.375 100 DEG,FLH STL	83385	OBD
					- - - * - - -		
-35	337-1794-00			1	SHLD,ELECTRICAL:FRONT SUBPANEL	80009	337-1794-00
-36	384-0126-00			1	EXTENSION SHAFT:4.6 INCHES LONG	08928	A3417
-37	384-1258-00			1	EXTENSION SHAFT:9.6 INCHES LONG	80009	384-1258-00
	672-0067-00			1	CKT BOARD ASSY:WITH CAM SWITCH	80009	672-0067-00
					(ATTACHING PARTS)		
-38	213-0146-00			4	SCR,TPG,THD FOR:6-20 X 0.313 INCH,PNH STL	83385	OBD
-39	210-0202-00			1	TERMINAL,LUG:SE #6	78189	2104-06-00-2520N
					- - - * - - -		

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Dscont	Qty	1 2 3 4 5 Name & Description	Mfr Code	Mfr Part Number
1-	----- -----			-	. CKT BOARD ASSY W/CAM SWITCH INCLUDES:		
-40	----- -----			1	. CKT BOARD ASSY:--MAIN(SEE A1 EPL)		
	----- -----			-	. . CKT BOARD ASSY INCLUDES:		
-41	131-0604-00			23	. . CONTACT,ELEC:0.025 SQ X 0.365 INCH LONG	80009	131-0604-00
-42	131-1003-00			1	. . CONN,RCPT,ELEC:CKT BD MT,3 PRONG	80009	131-1003-00
-43	136-0252-04			4	. . SOCKET,PIN CONN:0.188 INCH LONG	22526	75060-001
-44	136-0514-00			9	. . SOCKET,SEMICOND:MICROCIRCUIT,8 PIN INLINE	82647	C930802
-45	214-0269-00	B010100	B031238	5	. . HEAT SINK,ELEC:0.312 ID X 0.750" LONG	98978	TXD032-075
	214-0269-00	B031239		8	. . HEAT SINK,ELEC:0.312 ID X 0.750" LONG	98978	TXD032-075
-46	214-0693-00	B010100	B031238	7	. . HEAT SINK,ELEC:0.250 ID X 0.750" LONG	98978	TXD017-075
	214-0693-00	B031239		4	. . HEAT SINK,ELEC:0.250 ID X 0.750" LONG	98978	TXD017-075
-47	214-0579-00			6	. . TERM,TEST PT:0.40 INCH LONG	80009	214-0579-00
-48	376-0051-01			1	. . CPLG,SHAFT,FLEX:FOR 0.125 INCH DIA SHAFTS	80009	376-0051-01
	----- -----			-	. . . COUPLING INCLUDES:		
	376-0049-00			1	. . . CPLG,SHAFT,FLEX:PLASTIC	80009	376-0049-00
	354-0251-00			2	. . . RING,COUPLING:	80009	354-0251-00
	213-0048-00			4	. . . SETSCREW:4-40 X 0.125 INCH HEX SOC STL	74445	OBD
-49	----- -----			1	. . RESISTOR,VARIABLE:(SEE R115 EPL)		
					(ATTACHING PARTS)		
-50	210-0583-00			1	. . NUT,PLAIN,HEX.:0.25-32 X 0.312 INCH,BRS	73743	2X20319-402
-51	210-0046-00			1	. . WASHER,LOCK:INTL,0.26 ID X 0.40" OD,STL	78189	1214-05-00-0541C
-52	407-0579-00			1	. . BRKT,RES. MTG:	80009	407-0579-00
					- - - * - - -		
-53	----- -----			1	. . TRANSISTOR:(SEE Q650 EPL)		
					(ATTACHING PARTS)		
-54	211-0097-00			1	. . SCREW,MACHINE:4-40 X 0.312 INCH,PNH STL	83385	OBD
-55	210-1122-00			1	. . WASHER,LOCK:DISHED,0.12 ID X 0.375"OD STL	78189	4704-04-02
-56	210-0921-00			1	. . WASHER,MICA:0.50 X 0.141 X0.005 INCH THK	80009	210-0921-00
-57	210-0406-00			1	. . NUT,PLAIN,HEX.:4-40 X 0.188 INCH,BRS	73743	2X12161-402
					- - - * - - -		
-58	----- -----			1	. . TRANSISTOR:(SEE Q635 EPL)		
					(ATTACHING PARTS)		
-59	211-0097-00			1	. . SCREW,MACHINE:4-40 X 0.312 INCH,PNH STL	83385	OBD
-60	210-1122-00			1	. . WASHER,LOCK:DISHED,0.12 ID X 0.375"OD STL	78189	4704-04-02
-61	210-0921-00			1	. . WASHER,MICA:0.50 X 0.141 X0.005 INCH THK	80009	210-0921-00
-62	210-0406-00			1	. . NUT,PLAIN,HEX.:4-40 X 0.188 INCH,BRS	73743	2X12161-402
					- - - * - - -		
	263-1002-00			1	. ACTR ASSY,CAM S:--MULTIPLIER	80009	263-1002-00
					(ATTACHING PARTS)		
-63	211-0116-00			4	. SCR,ASSEM WSHR:4-40 X 0.312 INCH,PNH BRS	83385	OBD
					- - - * - - -		
	----- -----			-	. . ACTUATOR ASSY INCLUDES:		
-64	200-1586-00			1	. . COVER CAM SW:	80009	200-1586-00
-65	354-0219-00			1	. . RING,RETAINING:FOR 0.25 INCH INCH SHAFT	79136	5103-25-MD-R
-66	214-1127-00			2	. . ROLLER,DETENT:0.125 DIA X 0.125 INCH L	80009	214-1127-00
-67	214-1704-01			2	. . SPRING,FLAT:CAM SW DETENT,0.008 INCH THK	80009	214-1704-01
-68	210-0406-00			4	. . NUT,PLAIN,HEX.:4-40 X 0.188 INCH,BRS	73743	2X12161-402
-69	401-0155-00			1	. . BEARING,CAM SW:FRONT	80009	401-0155-00
-70	105-0493-00			1	. . DRUM,CAM SWITCH:	80009	105-0493-00
-71	401-0156-00			1	. . BEARING,CAM SW:REAR	80009	401-0156-00
	263-1001-00			1	. ACTR ASSY,CAM S:--FUNCTION	80009	263-1001-00
					(ATTACHING PARTS)		
-72	211-0116-00			4	. SCR,ASSEM WSHR:4-40 X 0.312 INCH,PNH BRS	83385	OBD
					- - - * - - -		
	----- -----			-	. . ACTUATOR ASSY INCLUDES:		
-73	200-1631-00			1	. . COVER CAM SW:	80009	200-1631-00
-74	354-0219-00			1	. . RING,RETAINING:FOR 0.25 INCH INCH SHAFT	79136	5103-25-MD-R
-75	214-1127-00			2	. . ROLLER,DETENT:0.125 DIA X 0.125 INCH L	80009	214-1127-00
-76	214-1704-00			1	. . SPRING,FLAT:CAM SW DETENT,0.006 INCH THK	80009	214-1704-00
-77	214-1704-01			1	. . SPRING,FLAT:CAM SW DETENT,0.008 INCH THK	80009	214-1704-01
-78	210-0406-00			4	. . NUT,PLAIN,HEX.:4-40 X 0.188 INCH,BRS	73743	2X12161-402
-79	401-0155-00			1	. . BEARING,CAM SW:FRONT	80009	401-0155-00
-80	105-0494-00			1	. . DRUM,CAM SWITCH:	80009	105-0494-00
-81	401-0156-00			1	. . BEARING,CAM SW:REAR	80009	401-0156-00
-82	426-0724-04			1	FR SECT,BOTTOM:	80009	426-0724-04
-83	214-1061-00			1	SPRING,GROUND:FLAT	80009	214-1061-00
-84	426-0725-05			1	FRAME SECT,TOP:	80009	426-0725-05
-85	175-0825-00			FT	WIRE,ELECTRICAL:2 WIRE RIBBON	23499	TEK-175-0825-00
-86	175-0826-00			FT	WIRE,ELECTRICAL:3 WIRE RIBBON	08261	TEK-175-0826-00
-87	210-0774-00			1	EYELET,METALLIC:0.152 OD X 0.245 INCH L,BRS	80009	210-0774-00
-88	210-0775-00			1	EYELET,METALLIC:0.126 OD X 0.23 INCH L,BRS	80009	210-0775-00

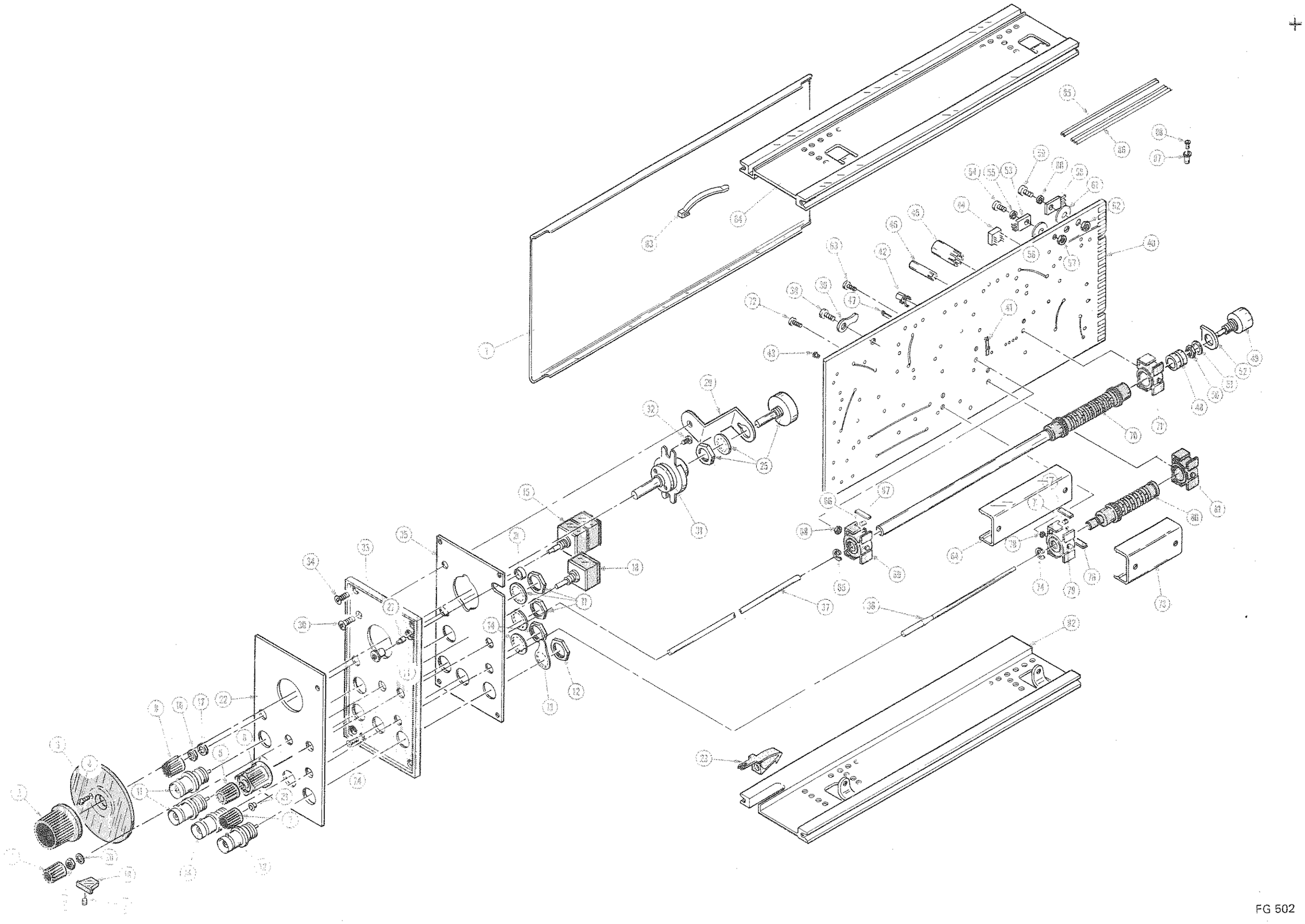


FIG. 1 EXPLODED

FG 502

Fig. & Index No.	Tektronix Part No.	Serial/Model No. Eff	Dscont	Qty	1 2 3 4 5	Name & Description	Mfr Code	Mfr Part Number
	070-1706-00			1		MANUAL,TECH:SERVICE	80009	070-1706-00

MANUAL CHANGE INFORMATION

At Tektronix, we continually strive to keep up with latest electronic developments by adding circuit and component improvements to our instruments as soon as they are developed and tested.

Sometimes, due to printing and shipping requirements, we can't get these changes immediately into printed manuals. Hence, your manual may contain new change information on following pages.

A single change may affect several sections. Since the change information sheets are carried in the manual until all changes are permanently entered, some duplication may occur. If no such change pages appear following this page, your manual is correct as printed.

SERVICE NOTE

Because of the universal parts procurement problem, some electrical parts in your instrument may be different from those described in the Replaceable Electrical Parts List. The parts used will in no way alter or compromise the performance or reliability of this instrument. They are installed when necessary to ensure prompt delivery to the customer. Order replacement parts from the Replaceable Electrical Parts List.

CALIBRATION TEST EQUIPMENT REPLACEMENT

Calibration Test Equipment Chart

This chart compares TM 500 product performance to that of older Tektronix equipment. Only those characteristics where significant specification differences occur, are listed. In some cases the new instrument may not be a total functional replacement. Additional support instrumentation may be needed or a change in calibration procedure may be necessary.

Comparison of Main Characteristics

DM 501 replaces 7D13		
PG 501 replaces 107	PG 501 - Risetime less than 3.5 ns into 50 Ω.	107 - Risetime less than 3.0 ns into 50 Ω.
108	PG 501 - 5 V output pulse; 3.5 ns Risetime.	108 - 10 V output pulse; 1 ns Risetime.
111	PG 501 - Risetime less than 3.5 ns; 8 ns Pretrigger pulse delay.	111 - Risetime 0.5 ns; 30 to 250 ns Pretrigger Pulse delay.
114	PG 501 - ±5 V output.	114 - ±10 V output. Short proof output.
115	PG 501 - Does not have Paired, Burst, Gated, or Delayed pulse mode; ±5 V dc Offset. Has ±5 V output.	115 - Paired, Burst, Gated, and Delayed pulse mode; ±10 V output. Short-proof output.
PG 502 replaces 107		
108	PG 502 - 5 V output	108 - 10 V output.
111	PG 502 - Risetime less than 1 ns; 10 ns Pretrigger pulse delay.	111 - Risetime 0.5 ns; 30 to 250 ns Pretrigger pulse delay.
114	PG 502 - ±5 V output	114 - ±10 V output. Short proof output.
115	PG 502 - Does not have Paired, Burst, Gated, Delayed & Undelayed pulse mode; Has ±5 V output.	115 - Paired, Burst, Gated, Delayed & Undelayed pulse mode; ±10 V output. Short-proof output.
2101	PG 502 - Does not have Paired or Delayed pulse. Has ±5 V output.	2101 - Paired and Delayed pulse; 10 V output.
PG 506 replaces 106	PG 506 - Positive-going trigger output signal at least 1 V; High Amplitude output, 60 V.	106 - Positive and Negative-going trigger output signal, 50 ns and 1 V; High Amplitude output, 100 V.
067-0502-01	PG 506 - Does not have chopped feature.	0502-01 - Comparator output can be alternately chopped to a reference voltage.
SG 503 replaces 190, 190A, 190B	SG 503 - Amplitude range 5 mV to 5.5 V p-p.	190B - Amplitude range 40 mV to 10 V p-p.
191	SG 503 - Frequency range 250 kHz to 250 MHz.	191 - Frequency range 350 kHz to 100 MHz.
067-0532-01	SG 503 - Frequency range 250 kHz to 250 MHz.	0532-01 - Frequency range 65 MHz to 500 MHz.
TG 501 replaces 180, 180A	TG 501 - Marker outputs, 5 sec to 1 ns. Sinewave available at 5, 2, and 1 ns. Trigger output - slaved to marker output from 5 sec through 100 ns. One time-mark can be generated at a time.	180A - Marker outputs, 5 sec to 1 μs. Sinewave available at 20, 10, and 2 ns. Trigger pulses 1, 10, 100 Hz; 1, 10, and 100 kHz. Multiple time-marks can be generated simultaneously.
181	TG 501 - Marker outputs, 5 sec to 1 ns. Sinewave available at 5, 2, and 1 ns.	181 - Marker outputs, 1, 10, 100, 1000, and 10,000 μs, plus 10 ns sinewave.
184	TG 501 - Marker outputs, 5 sec to 1 ns. Sinewave available at 5, 2, and 1 ns. Trigger output - slaved to marker output from 5 sec through 100 ns. One time-mark can be generated at a time.	184 - Marker outputs, 5 sec to 2 ns. Sinewave available at 50, 20, 10, 5, and 2 ns. Separate trigger pulses of 1 and .1 sec; 10, 1, and .1 ms; 10 and 1 μs. Marker amplifier provides positive or negative time marks of 25 V min. Marker intervals of 1 and .1 sec; 10, 1, and .1 ms; 10 and 1 μs.
2901	TG 501 - Marker outputs, 5 sec to 1 ns. Sinewave available at 5, 2, and 1 ns. Trigger output - slaved to marker output from 5 sec through 100 ns. One time-mark can be generated at a time.	2901 - Marker outputs, 5 sec to 0.1 μs. Sinewave available to 50, 10, and 5 ns. Separate trigger pulses, from 5 sec to 0.1 μs. Multiple time-marks can be generated simultaneously.

NOTE: All TM 500 generator outputs are short-proof. All TM 500 plug-in instruments require TM 500-Series Power Module.

REV. A, OCT 1975

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MANUAL CHANGE INFORMATION

PRODUCT FG 502
070-1706-00

CHANGE REFERENCE C7/876
DATE 8-25-76

CHANGE:	DESCRIPTION

TEXT CORRECTION

Page 1-5 ADD new Fig. 1-6 after Fig. 1-5. Renumber existing Fig. 1-6 and Fig. 1-7 to Fig. 1-7 and Fig. 1-8 respectively. Increment by one the figure references on page 1-7.

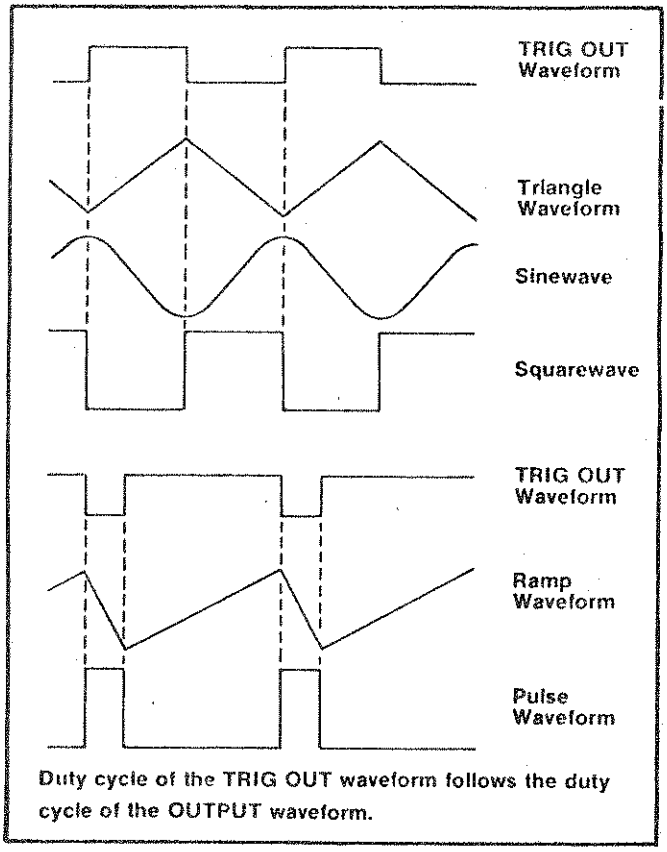

Fig. 1-6. Phase relationships between various OUTPUT waveforms and the TRIG OUT waveform.

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MANUAL CHANGE INFORMATION

PRODUCT FG 502
070-1706-00

CHANGE REFERENCE M32184
DATE 8-18-77

CHANGE:	DESCRIPTION

EFF SN B034786

ELECTRICAL PARTS LIST AND SCHEMATIC CHANGES

CHANGE TO:

A1	670-2595-03	CKT BOARD ASSY:FUNCTION GENERATOR
C247	281-0658-00	CAP.,FXD,CER DI:6.2PF(NOMINAL VALUE)SEL
CR245	152-0153-00	SEMICOND DEVICE:SILICON,10V,50MA,FD7003
CR246	152-0153-00	SEMICOND DEVICE:SILICON,10V,50MA,FD7003
CR248	152-0153-00	SEMICOND DEVICE:SILICON,10V,50MA,FD7003
CR250	152-0153-00	SEMICOND DEVICE:SILICON,10V,50MA,FD7003

The above parts are shown on diagram 1 TRIANGLE GENERATOR.