**TEKTRONIX®**

# FUNCTION GENERATOR

## FG 501

## INSTRUCTION MANUAL

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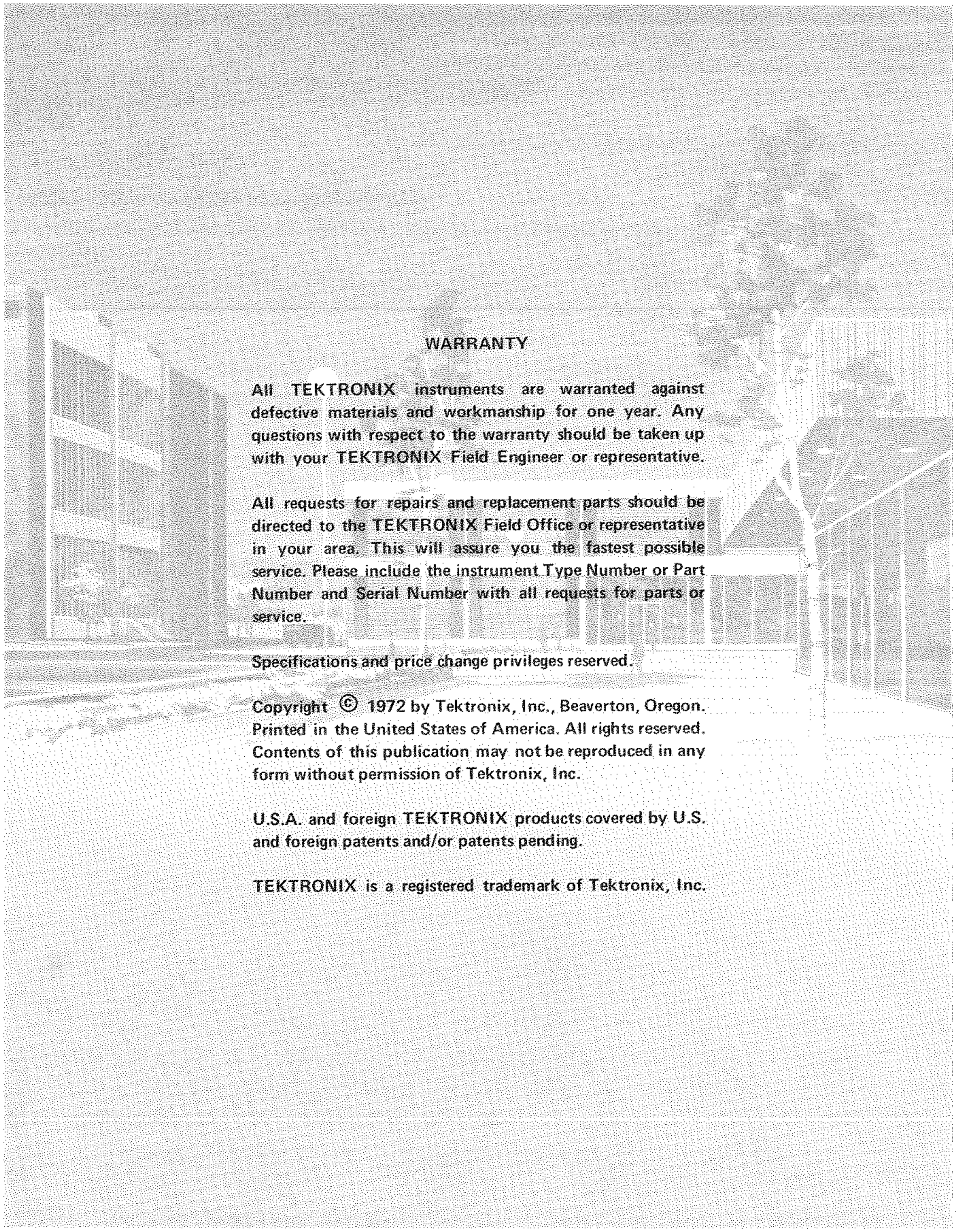

## WARRANTY

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 repairs 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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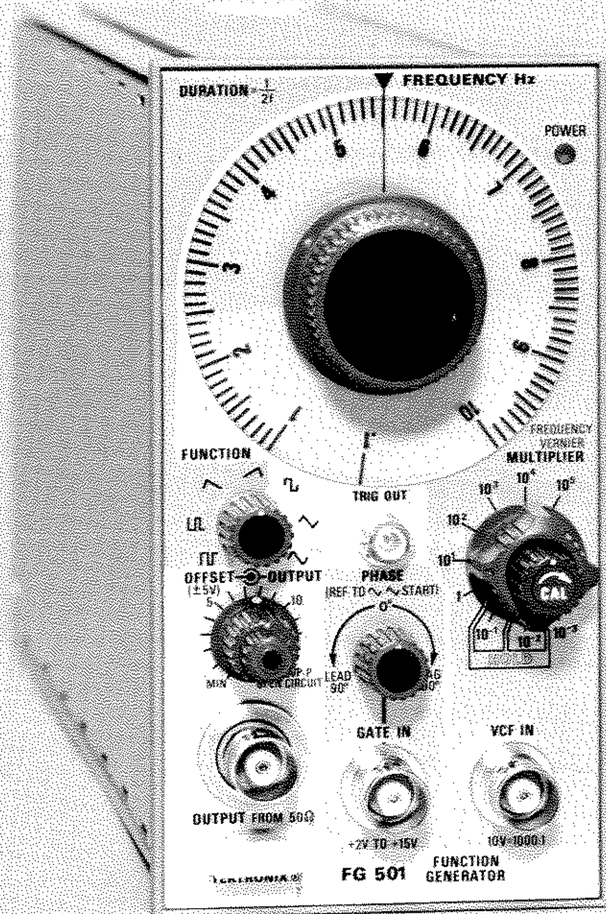
FREQUENCY Hz
POWER
FREQUENCY VERNIER
MULTIPLIER
FUNCTION
TRIG OUT
OFFSET
OUTPUT
PHASE
GATE IN
VCF IN
OUTPUT FROM 50Ω
+2V TO +15V
FG 501
FUNCTION GENERATOR

# SECTION 1 OPERATING INSTRUCTIONS

## INSTRUMENT DESCRIPTION

The FG 501 Function Generator is designed to operate in a TM 500 Series Power Module. Low distortion sine, square, triangle, pulse and ramp waveforms from 0.001 Hz to 1 MHz as well as a +2.5 V square-wave trigger are available at the front panel. Variable DC offset of ±5 V is also provided. A "hold" feature allows the generator output to be abruptly halted at its instantaneous voltage level and held there until manually switched on again.

A voltage-controlled frequency (VCF) input is provided to control 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 which allows the generator to be turned on 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 phase (start level) of the waveform burst can be varied ±90° by a front-panel control.

The variety of swept and modulated signals available from the FG 501 make it especially useful for such applications as testing servo-system or amplifier response, distortion and stability; FM generation and frequency multiplication, or simply used 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

### Introduction

The FG 501 is calibrated and ready for use when received. It is designed to operate in any compartment of a TM 500 Series Power Module only. Refer to the Power Module Instruction Manual for line voltage requirements and Power Module operation.

### Installation and Removal

**CAUTION**

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

1. Install the FG 501 in the Power Module by aligning the upper and lower rails of the FG 501 with the Power Module tracks. Insert gently until the FG 501 front panel is flush with the Power Module front panel.

2. Remove the FG 501 from the Power Module by pulling the release latch at the bottom of the front panel and sliding the unit straight out of the Power Module.

### Turn-On Procedure

1. Check that the FG 501 is fully inserted into the Power Module.

2. Pull the PWR switch on the front panel of the Power Module to apply power to the FG 501. Observe that the POWER indicator light on the FG 501 comes on.

# OPERATING CONSIDERATIONS

*NOTE*

*Before using the FG 501 for the first time, read the Operating Considerations in this section and the description of the front-panel controls, connectors, and indicators on the Controls and Adjustments foldout page at the back of this manual.*

## Output Connections

The output of the FG 501 is designed to operate as a voltage source in series with 50 Ω and 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 is less likely to occur at the lower frequencies (especially with sine and triangle waveforms). However, to insure that waveform purity is preserved, observe the following precautions:

1. Use quality 50 Ω coaxial cables and connectors.

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

3. Use 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, i.e., 6 feet or more.

5. Insure that attenuators, terminations, etc. have adequate power handling capabilities for the output waveform (approximately 0.5 W into a 50 Ω load).

Power output is determined by the selected waveform, its amplitude, and the amount of offset voltage selected.

The physical and electrical characteristics of the pulse transmitting cable determine the characteristic impedance, velocity of propagation, and amount of signal loss. Signal loss, due to energy dissipation in the cable dielectric, is proportional 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.

## Risetime and Falltime

If the output pulse from the FG 501 is used for measuring the rise or falltime of a device, the risetime characteristics of associated equipment may have to be considered. If the risetime of the device under test is at least 10 times greater than the combined risetimes of the FG 501 plus the monitoring oscilloscope and associated cables, the error introduced will not exceed 1% and generally can be ignored. If the rise or falltime of the test device, however, is less than 10 times as long as the combined risetimes of the testing system, the actual risetime of the device will have to be determined from the risetime of each component making up the system. This equals the square root of the sum of the squares of the individual risetimes. Conversely, the risetime of the device under test can be found from the same relationship if the actual risetimes in the system are known except that of the device under test.

## Impedance Matching

**Reflections** As a pulse travels down a transmission line, each time it encounters a mismatch, or different impedance than 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.

**Matching Networks.** The following describes methods for matching impedance networks into relatively low impedances. If the FG 501 is driving a high impedance, such as the 1 MΩ input impedance of the vertical input for an oscilloscope, the transmission line must be terminated into a 50 Ω attenuator and 50 Ω termination at the oscilloscope input. The attenuator isolates the input capacity of the device. Distortion can be caused by this input capacity.

A simple resistive impedance-matching network, that provides minimum attenuation, is illustrated in Fig. 1-1. 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:

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

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

$$\text{and } R_2 = Z_1\sqrt{\frac{Z_2}{Z_2 - Z_1}}$$

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:

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

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

When constructing such a device, the environment surrounding the components should also be designed to provide a transition between the impedances. Keep in mind that 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. $z_o = 138/\sqrt{\epsilon} \log_{10} D/d$, where D is the inside diameter of the outer conductor, and d is the outside diameter of the inner conductor. $\epsilon$ is the dielectric constant (1 in air).

**Attenuation Ratios.** Though the network in Fig. 1-1 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 ($A_1$) which 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 ($A_2$) which 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

$$A_2 = \frac{96.8}{64.6} + \frac{96.8}{50} + 1 = 4.44$$

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 $R_2$.

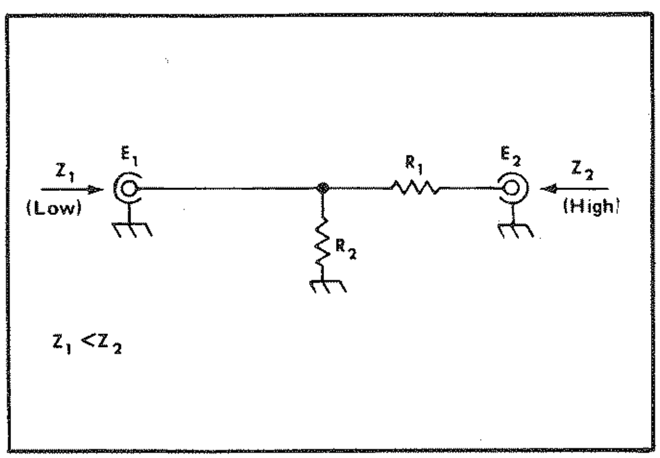


**Fig. 1-1. Impedance matching network that provides minimum attenuation.**

### Duration of Ramps and Pulses

The duration of ramp and pulse waveforms is always equal to the half-cycle time of the sine, square, or triangle waveform frequency. For MULTIPLIER settings of 1 or greater, the retrace/off time is such that the waveform has a duty cycle of approximately 80%, i.e., frequency equals approximately 1.6X FREQUENCY Hz dial setting. For MULTIPLIER settings less than 1, the retrace/off time is from 10 ms to 100 ms which results in duty cycles approaching 100%, i.e., frequency equals approximately 2X FREQUENCY Hz dial setting.

# OPERATION

### Free-Running Output

The following procedure provides a free-running waveform output with variable frequency and amplitude.

1. Set the OUTPUT control to the fully ccw position and the OFFSET control to the 0 (centered) position. Check that the PHASE control is pushed in (off).

2. Set the FUNCTION selector to the desired waveform (see Fig. 1-2).

3. Select the desired frequency with the MULTIPLIER selector and FREQUENCY Hz dial. For example, if the MULTIPLIER selector is set to the $10^5$ position and the FREQUENCY Hz dial is at 5, output frequency is 500 kHz, i. e., MULTIPLIER setting X FREQUENCY Hz setting. The output frequency is calibrated when the FREQUENCY VERNIER control is in the fully cw position. The duration of ramp and pulse waveforms is dependent on the MULTIPLIER setting. See Duration of Ramps and Pulses under Operating Considerations for further information.

4. Connect the load to the OUTPUT connector and adjust the OUTPUT control for the desired output amplitude.

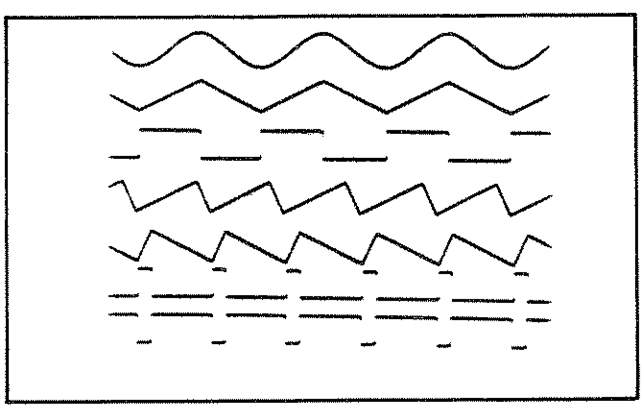

Fig. 1-2. Output waveforms available from the FG 501.

### Variable DC Offset

Adjust the OFFSET control to position the DC level (baseline) of the output waveform ± 5 V about ground. For example, +5 V of offset will increase the DC + peak AC

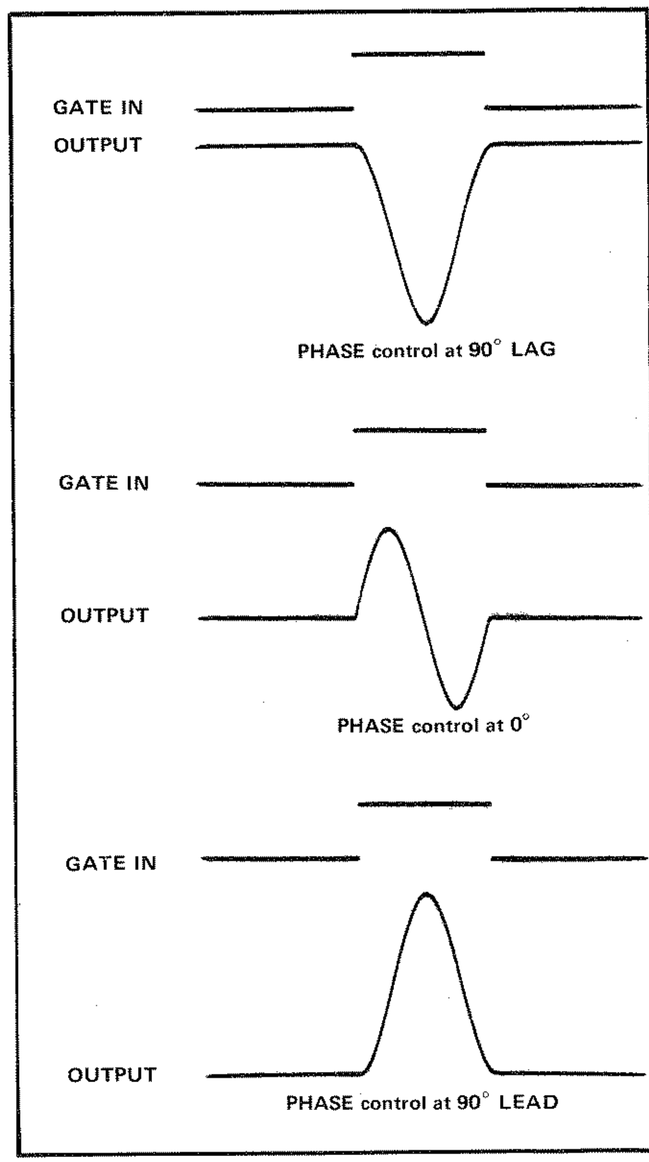


Fig. 1-3. Single cycle output with variable phase



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voltage of a 7.5 V P-P output to 12.5 V DC + peak AC while −5 V of offset will reduce the DC + peak AC output to 2.5 V.

## Gated (Burst) Output and Variable Phase

A gating signal of at least 2 to 15 V amplitude applied to the GATE IN connector with the PHASE control pulled out will provide a burst of cycles at the OUTPUT connector. The duration of the burst and number of cycles in the burst depends on the gating signal duration and the output frequency selected. When the gating signal goes to the zero level, the generator completes its last cycle and remains quiescent until the next gating signal.

Single cycles can be obtained by applying a gating signal with a period approximately equal to the period of the FG 501 output waveform. The number of cycles per burst can be approximated by dividing the gating signal duration by the period of the FG 502 output frequency.

The phase (start level) of the waveform burst can be varied ±90° by pulling out and turning the PHASE control either ccw or cw from the 0 (centered) position (see Fig. 1-3). The phase of the output burst is referenced to the sine or triangle waveform 0° start point.

Output frequency can be varied during the burst duration by applying a voltage controlled frequency (VCF) signal to the VCF IN connector.

## Voltage—Controlled Frequency (VCF) Output

The output frequency of any selected waveform can be swept within a range of 1000:1 by applying a 0 to 10 V signal to the VCF IN connector. The polarity of the VCF input signal determines which direction the output frequency sweeps from the frequency set by the MULTIPLIER selector and FREQUENCY Hz dial, i. e., a + signal sweeps the frequency upward as shown in Fig. 1-4(A), a − signal sweeps the frequency downward as shown in Fig. 1-4(B).

The maximum swept frequency range of 1000:1 encompasses the sensitive uncalibrated range of the FREQUENCY Hz dial, i. e., < .1 to 1. Therefore, to insure that the frequency does sweep at least a range of 1000:1, it is recommended that the FREQUENCY Hz dial be set at 10 and a 0 to −10 V signal be applied to the VCF IN connector. The output will thus sweep downward at least 1000:1 from a FREQUENCY Hz dial setting of 10 as shown in Fig. 1-4(B). It may be necessary to vary the CAL control to obtain the full 1000:1 swept range or the lowest swept frequency desired.

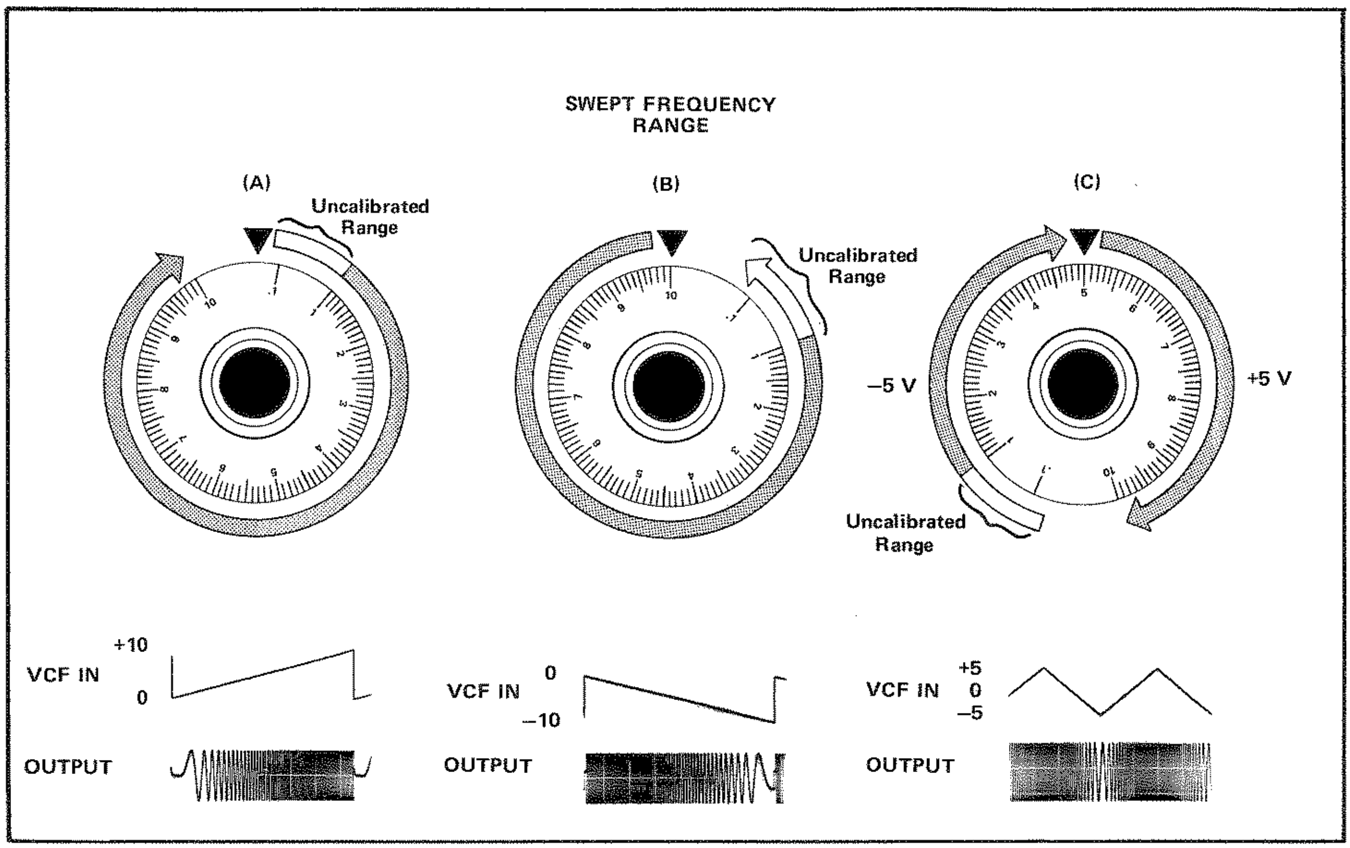


Fig. 1-4. Swept Frequency range with 10 V signals applied to VCF IN connector.

An input signal that varies symmetrically about a 0 V level will also sweep the generator symmetrically about the center frequency set by the MULTIPLIER selector and FREQUENCY Hz dial as shown in Fig. 1-4(C).

Since the VCF input amplitude vs frequency is a linear relationship, the frequency output range can be determined from the VCF input amplitude.

## Hold Mode

Three detented HOLD positions are provided between the lowest three MULTIPLIER selector positions. By switching to any one of the HOLD positions, the generator can be stopped at its instantaneous voltage level and held there until the MULTIPLIER selector setting is changed.

## Trigger Output

A TTL-compatible +2.5 V square wave is available from the TRIG OUT connector. The frequency of the trigger output is determined by the output frequency selected by the MULTIPLIER selector and FREQUENCY Hz dial.

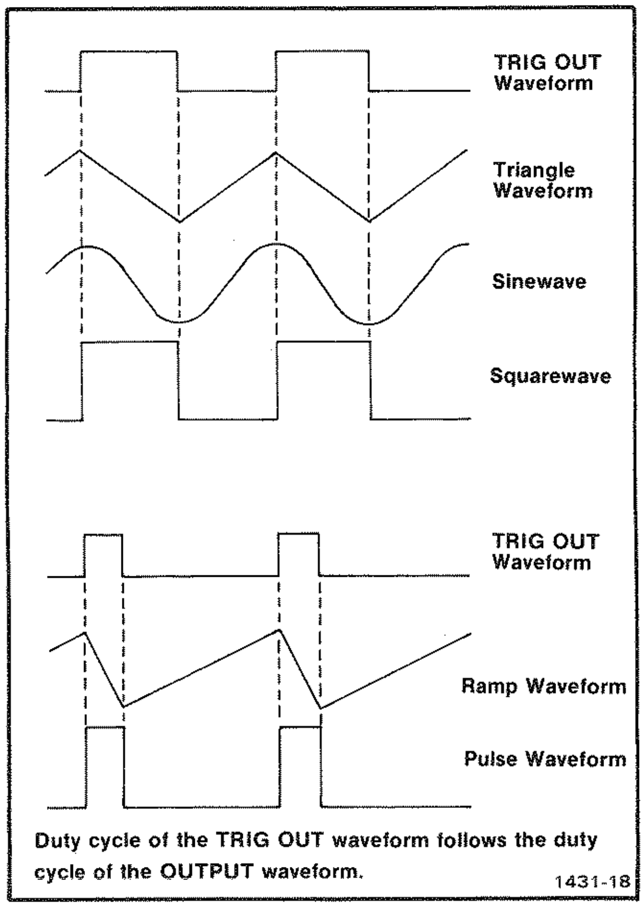


Fig. 1-5. Phase relationships between various OUTPUT waveforms and the TRIG OUT waveform.

# APPLICATIONS

## Response Analysis

The FG 501 is particularly suited for determining response characteristics of circuits or systems. This application utilizes the VCF input of the FG 501 to sweep the generator over a range of frequencies. By applying the desired waveform from another FG 501 Waveform Generator, or equivalent, 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 501. 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).

3. Apply the desired waveform to the VCF IN connector. (A positive-going waveform will sweep the frequency upwards from the FREQUENCY Hz dial setting while a negative-going waveform will sweep downwards.)

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 and reading that frequency on the FREQUENCY Hz dial.

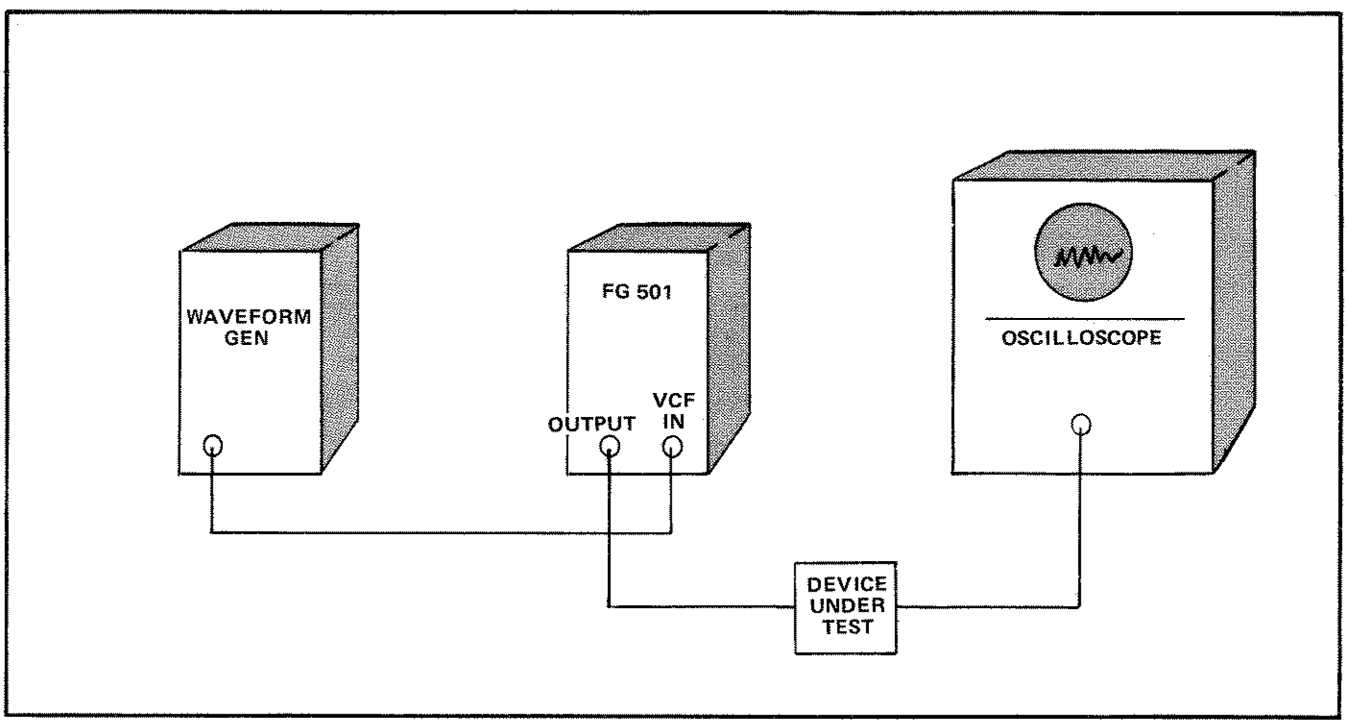


Fig. 1-6. Analyzing circuit or system response.

## Tone-Burst Generation or Stepped Frequency Multiplication

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

The following procedure describes a technique for obtaining a tone-burst or frequency multiplied output from the FG 501. Refer to the Gated (Burst) Output and Variable Phase and the Voltage-Controlled Frequency (VCF) Output discussions under Operation for additional information.

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

2. Pull out the FG 501 PHASE control. 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.

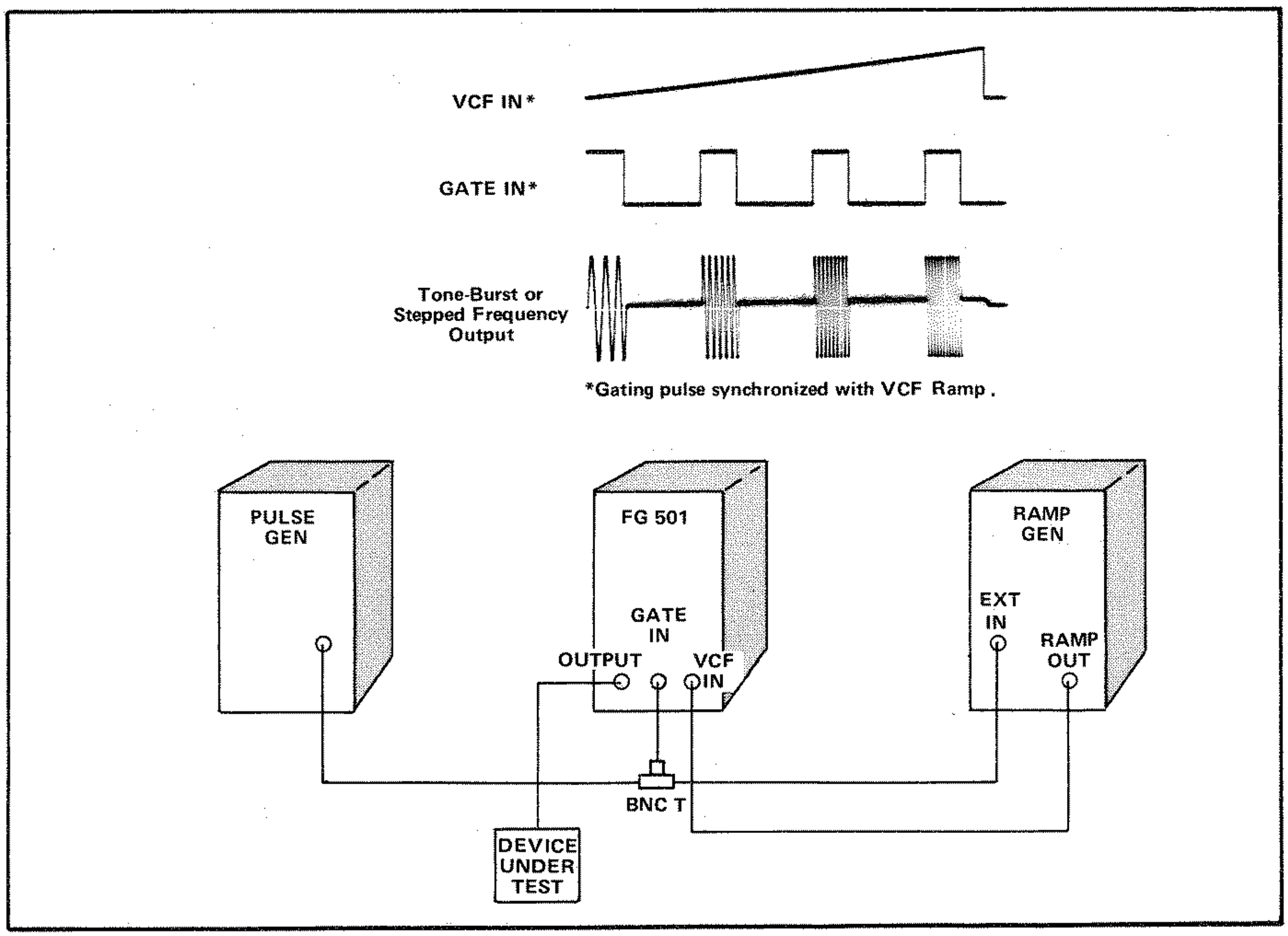


Fig. 1-7. Tone burst generation or stepped frequency multiplication.

# ELECTRICAL CHARACTERISTICS

## Performance Conditions

The electrical characteristics are valid only if the FG 501: (1) has been calibrated at an ambient temperature between +20°C and +30°C and (2) is operating at an ambient temperature between 0°C and +50°C unless otherwise noted.

OUTPUTS: Sine, triangle, square, ramp, and pulse waveforms selectable by the front panel FUNCTION selector. Also +2.5 V square-wave trigger from front-panel TRIG OUT connector.

AMPLITUDE (EXCLUDING OFFSET): 15 V P-P open circuit. 7.5 V P-P into 50 Ω load. Sine, triangle and square-wave amplitudes within 5% for single setting of OUTPUT control.

OFFSET RANGE: + and −5 V open circuit. + and −2.5 V into 50 Ω load.

FREQUENCY RANGE: 0.001 Hz to 1 MHz in 9 decade steps.

FREQUENCY RESOLUTION: 1 part in $10^4$ of full scale with FREQUENCY VERNIER control.

DIAL RANGE AND ACCURACY: 1 to 10 within 3% of full scale (.1 to <1 uncalibrated).

TIME SYMMETRY: Within 1% from 0.001 Hz to 1 MHz on calibrated portion (1 to 10) of FREQUENCY Hz dial. Within 10% on uncalibrated portion (0.1 to 1) of FREQUENCY Hz dial from 20°C to 50°C.

HOLD MODE STABILITY: Within 5% of output voltage in 1 hour at +25°C on 0.001 Hz range.

FREQUENCY AND AMPLITUDE (INCLUDING OFFSET) STABILITY: Temperature—Within 2% from 0.1 Hz to 1 MHz. Within 10% from 0.001 Hz to < 0.1 Hz. Time—Within 0.1% for 10 minutes. Within 0.25% for 24 hours.

### TRIANGLE/RAMP OUTPUT

LINEARITY: Within 1% from 0.001 Hz to < 100 kHz. Within 2% from 100 kHz to 1 MHz.

RAMP DURATION: $\frac{1}{2f}$ (see Operating Considerations).

### SINE WAVE OUTPUT

DISTORTION: 1% or less from 0.001 Hz to 1 Hz 0.5% or less from > 1 Hz to 20 kHz. 1% or less from > 20 kHz to 100 kHz. 2.5% or less from > 100 kHz to 1 MHz. Applies to calibrated portion of dial only. Valid from 10°C to 40°C.

### SQUARE WAVE/PULSE OUTPUT

RISETIME: 100 ns or less.

ABERRATIONS: 5% or less measured P-P with output amplitude at 7.5 V P-P into external 50 Ω load.

PULSE DURATION: $\frac{1}{2f}$ (see Operating Considerations).

### EXTERNAL GATE INPUT

INPUT SIGNAL: 0 V to at least +2 V square wave not to exceed +15 V. Bursts are synchronous with the gate.

BURST LENGTH: Determined by selected output frequency and gating pulse width.

PHASE: Continuously variable from −90° to +90° referred to 0° sine and triangle start points.

INPUT IMPEDANCE: ≈ 1 kΩ.

### EXTERNAL VOLTAGE-CONTROLLED FREQUENCY (VCF) INPUT

OUTPUT FREQUENCY RANGE: At least 1000:1 with 10 V VCF input. Negative-going voltage decreases frequency; positive-going voltage increases frequency. $f_{max}$ = 10X MULTIPLIER setting, $f_{min} = \frac{\text{MULTIPLIER setting.}}{100}$

SLEW RATE: ≈ 1/2 V/μs.

### TRIGGER OUTPUT

AMPLITUDE: +2.5 V square wave into a 600 Ω load.

# SECTION 2 THEORY OF OPERATION

## Introduction

The following is a description of the electrical circuits in the FG 501. Refer to the simplified block diagram and the detailed schematic diagrams on the foldout pages at the back of the manual to aid in understanding this description.

# LOOP GENERATOR

### Triangle Waveform Generation

Operational amplifiers U45 and U48 in conjunction with Q45A/B and Q48A/B are voltage followers. Thus, the voltage at pin 3 of U45 and U48 is also present at the emitters of Q45A/B and Q48A/B. Switch S50 (MULTIPLIER) and resistance network R53 through R60 provide constant current to the emitters of Q45A/B which, together with U45, comprise a positive current source that charges the timing capacitor selected by S50 (C72 through C79). Resistor network R63 through R70 provides constant current to the emitters of Q48A/B which, together with U48, comprise a negative current source that also charges the timing capacitor selected by S50.

The current sources for the operational amplifiers and the timing capacitor are separate. Thus, input current requirements of the amplifiers have little effect upon the timing current supply. Q45A and Q45B are identical current sources. Q45A supplies approximately 70 nA to U45 input (the remaining current goes to ground), while Q45B supplies charging current to the timing capacitor.

The current switch, composed of CR100 through CR103 and emitter-coupled transistors Q85 and Q90, determines whether the positive current source or negative current source charges the timing capacitor. For example, if CR100 is turned off, all the current from Q45B goes through CR102 to charge the timing capacitor in the positive direction at a linear rate. Emitter follower Q138 passes the linear ramp through divider network R190/R191 and to pins 3 and 5 of upper and lower level comparators U195A/B. The voltage at pin 2 of U195A sets the upper hysteresis. The voltage at pin 6 sets the lower hysteresis. With CR100 off, U195A is in the negative state until the ramp at pin 3 reaches +1.77 V; then the output at pin 10 goes positive. The output of inverting amplifier U80C then goes negative, which causes nor gate U80D output to go positive, Thus, pin 9 of lower-level comparator U195B goes positive, which enables lower-level comparator U195B. Consequently, emitter-coupled switch Q85 turns on. The collector of Q85 moves in the negative direction, which turns on CR100 and turns off CR101. Thus, the negative current source now charges the timing capacitor and the ramp starts to go negative at a linear rate. Again, the ramp is applied to the divider network R190/R191, and to pin 5 of U195B. When the ramp reaches P1.77 V, the output at pin 10 of U195B goes negative. This causes the output of U80C to go positive, pin 13 of U80D goes negative, Q85 turns off, and Q90 turns on. CR101 turns on again, while CR100 turns off. This action is repeated to form a triangle waveform output from the loop generator. The slope (frequency) of the triangle is determined by how much current the positive and negative current sources provide to the timing capacitors.

Potentiometer R25 (FREQUENCY Hz) provides 0 V to approximately 10 V to pin 3 of voltage follower U30. The output of U30 is fed to pin 2 of voltage summing amplifier U15 where it is summed with an offset voltage (approximately −7 V) from potentiometer R38 (X1 Cal) and any VCF input applied to J10. Voltage summing amplifier U15 has an output range of +7 to +17 V which drives the positive current source. This 10 V swing across the timing resistors provides a wide current (frequency) range.

The negative current source is also driven by the positive voltage output of U15. However, the polarity is reversed by inverting amplifier U40. Thus, the voltage change at pin 3 of U48 in the negative current source very closely tracks that at pin 3 of U45 in the positive current source. Low frequency symmetry is adjustable by potentiometer R45 (X.1 Sym).

## Frequency Switching

Frequency (decade) switching from 1 Hz to 1 MHz is accomplished by changing timing capacitors and from 1 Hz to 0.0001 Hz by changing timing resistors.

## External Voltage-Controlled Frequency (VCF) Mode

Voltage-controlled frequency is accomplished by applying a voltage to J10 (VCF IN) which is summed with the voltage set by R25 (FREQUENCY Hz). Subsequently, the current to the timing capacitor is changed, which changes the generator output frequency as described under Triangle Waveform Generation.

## Level Shifting

Level shifting occurs in the circuit composed of Q125 and Q130. Q130 is a current source for Q125. Q130 also assures that any bias across source follower Q120 is dropped across R127, which shifts the level of the input to the sine shaper circuit (Q150 and Q170) with respect to 0 V (+5 V to −5 V).

## Sine Waveform Generation

The sine shaper is composed of Q150, Q170 and an associated divider-diode network. The resistor network composed of R155, R156, R158, R160, and R162 forms a voltage divider with a diode connected to each junction. In series with the diodes are resistors R157, R159, R161, and R163. A positive-going ramp from the emitter of Q138 will turn on the diode with the least current first, in this case, CR162. Diode CR162 has the least effect on the incoming ramp. Each successive diode has a greater effect. CR155 has the maximum effect since there is no resistor at its anode end. Thus, the peaks of the triangle waveform are clipped harder than are the remaining portions. The reverse is true of the negative half of the sine shaper, i.e., Q170 and its associated divider-diode network. Potentiometers R150 (Upper Level) and R170 (Lower Level) at the bases of Q150 and Q170 adjust for minimum distortion of the sine shaper output. Thus, a sine waveform is derived from the triangle waveform.

## Square Waveform Generation

A square waveform output is derived by taking the available square waveform from the collector of current switch driver Q90 and feeding it through divider R102-R105 and to switch S250 (FUNCTION).

## External Gate Mode

Gating is accomplished by applying an external signal to J215 (GATE IN) and closing S245 (PHASE). As long as pin 12 of nor gate U80D is near ground, the loop generator is functioning. However, a positive voltage at pin 12 of U80D will disable the loop generator.

In normal operation with no external gating signal at J215 (GATE IN), transistors Q80 and gate amplifier Q225 are on (saturated), which holds phase clamp switch Q230 off. When Q230 is off, the phase clamping circuit (composed of U235 and current boosting transistors Q240 and Q242) does not affect the gate of source follower Q120. Assume that switch S245 (PHASE) is closed and a squarewave is applied to J215 (GATE IN). During the positive transition of the gating signal, the loop generator continues to run, since Q80 and Q225 are already on. However, when the gating signal goes negative, Q80 turns off, since the input impedance of the gating input drops to 1 k (R220 vs R81), thereby turning off Q80 and Q225. Pin 12 of U80D is pulled up and the loop generator is disabled. Simultaneously, Q230 turns on, which also turns on diodes CR245 through CR248. The gate of source follower Q120 is now clamped to the voltage set by U235 and associated current-boosting transistors Q240 and Q242. By adjusting the input to pin 3 of U235 with potentiometer R235 (PHASE), the clamping voltage to the gate of Q120 can be shifted to start the triangle waveform anywhere from +90° to −90° from the sine and triangle 0° start point.

## Hold Mode

Cam switch S50 (MULTIPLIER) has three positions between the three lowest frequency range settings that stop the triangle waveform at its instantaneous voltage level (i.e., the timing capacitor charge holds at its instantaneous level) until S50 is switched back to a range position. The hold contacts on cam switch S50 are normally closed.

# OUTPUT AMPLIFIER

Cam switch S250 (FUNCTION) selects a triangle, square, or sine waveform and feeds it to the output amplifier.

Transistors Q250 and Q255 are complementary emitter followers which offset any differential between the input and output voltage and provide temperature compensation.

Assume that a triangle waveform is selected by S250 (FUNCTION). The triangle waveform voltage applied to the output amplifier is varied in amplitude by potentiometer R260A (OUTPUT), then summed with the voltage selected by potentiometer R260B (OFFSET). The output amplifier is basically an operational amplifier. Its gain is determined by input resistor R279 and feedback resistor R281. Transistor Q270 provides the positive input. Now, when Q270 turns on, i.e., a positive voltage is applied to its base; Q290 turns on which turns on Q295 and pulls the output up. If Q276 turns on, i.e., Q270 turns off when a negative voltage is applied to its base; Q280 turns on, which turns on

Q285. Consequently, Q298 turns on and pulls the output down. R298 establishes the source impedance of the output.

### Pulse and Ramp Generation

Switch S250 (FUNCTION) also applies pulses and ramp waveforms to the output amplifier.

When a positive or negative ramp waveform is selected by S250, a lower resistance is switched into the positive or negative current sources, depending on the polarity of the selected ramp waveform. For instance, if the positive current source had the least resistance, then current would increase in that source and consequently increase the slope of that particular side of the ramp. The reverse is true if the negative current source has the least resistance.

Positive or negative pulses are obtained by changing the duty cycle of the square waveform. The output pulse is derived from the "on" portion of the square waveform. The triangle generator frequency determines the frequency of the square waveform and, thus, the pulse frequency.

# POWER SUPPLIES

### +20 V Reference Supply

The +20 V supply is the reference for all the supplies. Diode bridge network CR400 and capacitor C400 convert the raw 25 V AC from the Power Module to +33 V DC, which is then fed to the +20 V reference supply. Field effect transistor Q400 along with R405 comprise a constant current source for 6.2 V zener diode VR405. VR405 is temperature compensated at approximately 7 mA when potentiometer R400 (Reference Current) is adjusted for 7 V across R405, which then establishes the 6.2 V reference for non-inverting operational amplifier U410. Negative feedback is provided through resistor network R410-R415. Potentiometer R415 (+20 Volts) is adjusted for +20 V output. When output current exceeds 200 mA, sensing resistor R417 in the emitter of series pass transistor Q410 turns Q415 on, which pulls down the base of Q410 and shuts the +20 V supply off.

### +20 V Decoupled Supply

Voltage follower U420, in conjunction with current booster Q420, drives the series pass transistor in the Power Module. Current sensing resistor R424 turns on Q424 when output current exceeds 400 mA, which pulls down the base of Q420 and shuts off the +20 V decoupled supply.

### –20 V Reference Supply

The –20 V supply consists of inverting operational amplifier U480. Input resistor R481 and feedback resistor R482 are 0.1%, thereby assuring that the –20 V reference supply accurately follows the +20 V reference supply. As in the +20 V reference supply, series pass transistor Q488, current sensing resistor R487, and transistor Q485 provide overcurrent shutdown (in excess of 200 mA).

### –20 V Decoupled Supply

Voltage follower U470 with its associated current booster Q472 and current sensing resistor R473 operate identically to the +20 V decoupled supply.

### +17 V Supply

Voltage follower U430 with voltage divider R430/R431 comprise the +17 V supply. Divider R430-R431 establishes +17 V at pin 3 of U430, while feedback is supplied to pin 2 from current booster Q430. There is no current sensing resistor in the 17 V supply since the voltage for the 17 V supply is supplied by the +20 V reference supply, which has overcurrent protection.

### –17 V Supply

The –17 V supply consists of inverting operational amplifier U460, current booster Q468 and 0.1% resistors R464 and R465 which provide an accurate –17 V with respect to the +17 V Supply.

### +5 V Supply

Divider R441-R442 provides +5 V to pin 3 of voltage follower U440. If excessive current is drawn, current sensing resistor R446 turns on Q447 which pulls down the base of current booster Q445 and shuts off the +5 V supply. The collector of Q445 connects to the unregulated +11.5 V from the Power Module.

### –5 V Supply

The –5 V supply consists of emitter follower Q450. No current limiting is provided since the collector is tied to the current limited –20 V reference supply. Diode CR450 provides temperature compensation for Q450.

# SECTION 3 SERVICING INFORMATION

## Contents

This section of the manual contains information necessary to service the FG 501. Adjustment procedures are provided on the Controls and Adjustments foldout page with supporting illustrations that show internal adjustment locations and describe front-panel control functions. Also included is the electrical parts list with an illustration on the Component Location foldout page that shows the physical location of components on the etched circuit board with an alpha-numeric grid keyed to the electrical parts list (see Grid Loc column in the parts list). A schematic diagram is located opposite both the electrical parts list and the circuit board illustration to further facilitate the location of components. Rear connector pin assignments are listed in Table 3-1.

Mechanical parts are listed at the rear of this section with an exploded view of the instrument. A list of standard accessories and a carton assembly drawing are on the back of the exploded view foldout page.

## Maintenance

General system maintenance procedures are provided in the Power Module instruction manual, i.e., preventive maintenance, troubleshooting aids, parts removal and replacement procedures, parts ordering information, etc.

## Service Available

Tektronix, Inc. provides complete instrument repair and calibration at local Field Service centers and at the Factory Service Center. Contact your local TEKTRONIX Field Office or representative for further information.

# ADJUSTMENT PROCEDURE

## Introduction

The adjustment procedure on the Controls and Adjustments foldout page is intended to return the circuits of the FG 501 within their designed operating capabilities. Adjustment is generally required after a repair has been made, or after long time intervals in which normal aging of components may affect instrument accuracy. Before making adjustments, verify instrument operation by performing the procedure described under Operation in Section 1.

## Test Equipment Required

The following test equipment and accessories or the equivalent, are required for complete adjustment of the FG 501. Specifications given for the test equipment are the minimum necessary for accurate adjustment. Therefore, some of the specifications listed may be less rigorous than the actual performance capabilities of the test equipment. All test equipment is assumed to be correctly calibrated and operating within their listed specifications.

If other test equipment is substituted, control settings or set-up may need altering to meet the requirements of the equipment used. Detailed operating instructions for the test equipment are not given in this procedure. Refer to the instruction manual for the test equipment if more information is needed.

1. Oscilloscope. TEKTRONIX 7403 with 7A15 Single-Trace Amplifier and 7B50 Time Base plug-ins recommended.

2. Digital Voltmeter. ±10 V to ±20 V within 0.5%.

3. 10X Probe. TEKTRONIX P6053 recommended.

4. 50 Ω Termination. TEKTRONIX Part No. 011-0049-01 recommended.

5. Plug-in Extension. TEKTRONIX Calibration Fixture 067-0645-02. Note: Do not use this extension to plug the FG 501 into any instrument other than the TM 500 series Power Module.

6. 10 kHz Notch Filter (or Distortion Analyzer). Construct Notch Filter as shown in Fig. 3-1, for performing sine waveform upper and lower level adjustments (R150 and R170):

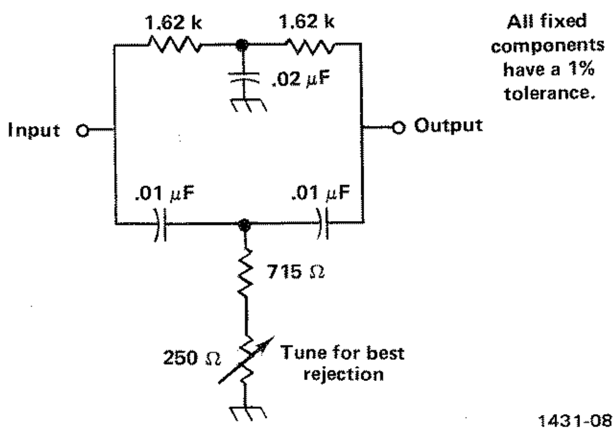


Fig. 3-1. 10 kHz Notch Filter.

## Preliminary Considerations

Read the Operating Considerations in Section 1 before adjusting the FG 501.

This instrument should be adjusted at an ambient temperature between +20 °C and +30°C (+68°F and +86°F) for best accuracy.

Do not preset internal controls unless they are known to be significantly out of adjustment, or unless repairs have been made in the circuit. In these instances, the internal adjustments can be set to midrange.

## Preparation

1. Remove the cover from the left side of the FG 501 and, if necessary, blow off accumulated dust with low-pressure compressed air.

2. Connect the FG 501 to the Power Module through the Plug-in Extension.

3. Apply power to the Power Module. Check that the POWER indicator on the FG 501 is lit.

4. Refer to the Controls and Adjustments foldout page in this section for internal adjustment procedures.

*NOTE*

*If a malfunction is detected during adjustment, refer to system maintenance in the Power Module instruction manual for troubleshooting techniques, parts removal and replacement procedures, parts ordering information, etc.*

## Repackaging for Shipment

If the Tektronix instrument is to be shipped to a Tektronix Service Center for service or repair, attach a tag showing: owner (with address) and the name of an individual at your firm that can be contacted, complete instrument serial number and a description of the service required.

Save and re-use the package in which your instrument was shipped. If the original packaging is unfit for use or not available, repackage the instrument as follows:

1. Obtain a carton of corrugated cardboard having inside dimensions of no less than six inches more than the instrument dimensions; this will allow for cushioning. Refer to the following table for carton test strength requirements.

2. Surround the instrument with polyethylene sheeting to protect the finish of the instrument.

3. Cushion the instrument on all sides by tightly packing dunnage or urethane foam between carton and instrument, allowing three inches on all sides.

4. Seal carton with shipping tape or industrial stapler.

**SHIPPING CARTON TEST STRENGTH**

| Gross Weight (lb) | Carton Test Strength (lb) |
|---|---|
| 0-10 | 200 |
| 10-30 | 275 |
| 30-120 | 375 |
| 120-140 | 500 |
| 140-160 | 600 |

TABLE 3-1

Rear Connector Pin Assignments

| Pin No. | Left (A) | Right (B) |
|---|---|---|
| 28 | Output | Trigger Output Common |
| 27 | Output Common | Trigger Output |
| 26 | Not Used | Not Used |
| 25 | Not Used | Gate In Common |
| 24 | Not Used | Gate In |
| 23 | Not Used | Not Used |
| 22 | Not Used | VCF In Common |
| 21 | Not Used | VCF In |
| 14 through 20 | Not Used | Not Used |
| 13 | 25 VAC Winding | 25 VAC Winding |
| 12 | +33.5 V Filtered DC | +33.5 V Filtered DC |
| 11 | Base of Series Pass PNP Transistor | Collector of Series Pass PNP Transistor |
| 10 | Emitter of Series Pass PNP Transistor | Not Used |
| 9 | +33.5 V Common | +33.5 V Common |
| 8 | –33.5 V Filtered DC | –33.5 V Filtered DC |
| 7 | Emitter of Series Pass NPN Transistor | Collector of Series Pass NPN Transistor |
| 6 | Base of Series Pass NPN Transistor | Not Used |
| 5 | Not Used | Not Used |
| 3 and 4 | +11.5 V Common | +11.5 V Common |
| 2 | +11.5 V Filtered DC | +11.5 V Filtered DC |
| 1 | 25 VAC Winding | 25 VAC Winding |