INSTRUCTION MANUAL

MODEL 144

HF SWEEP GENERATOR

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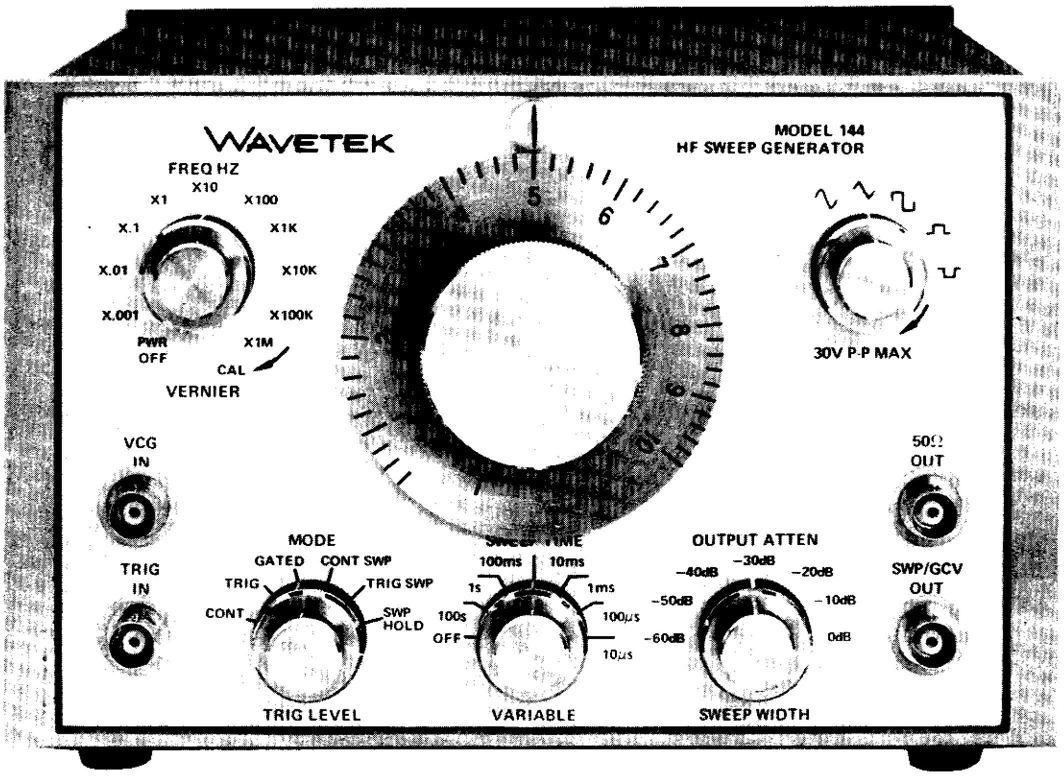


Figure i – Model 144 HF Sweep Generator

SCOPE OF THIS MANUAL

This manual provides descriptive material and instructions for the installation, operation, maintenance, and repair of this instrument. Wavetek's product improvement program ensures that the latest electronic developments are incorporated in all Wavetek instruments by the addition of circuit and component changes as rapidly as development and testing permit. Due to the time required to document and print instruction manuals, it is not always possible to incorporate the more recent changes in the released manual. In this case, data will be found on engineering change sheets at the rear of the manual. If no change sheets are included, the manual is correct as printed.

SECTION 1
INTRODUCTION

1.1 PURPOSE OF THE EQUIPMENT

The Model 144 HF Sweep Generator is a precision 0.0005 Hz to 10 MHz source of sine, triangle, square, positive pulse, and negative pulse waveforms. . .each with variable amplitude, dc offset, and symmetry. Frequency range selection is provided in 10 decades, with a vernier control permitting adjustment of approximately 1% of the selected range. Maximum output amplitude is 30 V p-p into an open circuit (15 V p-p into 50 ohms) with a 60 dB calibrated step attenuator and a 20 dB vernier attenuator (80 dB overall) allowing signal levels as low as 1.5 mV p-p. Both the output waveform and the dc offset are attenuated by the 60 dB calibrated step attenuator.

Six operational modes (continuous, triggered, gated, continuous sweep, triggered sweep, and sweep and hold), plus tone burst capability, are provided by the Model 144. The main output can be internally swept over a 1000:1 ratio at sweep speeds from 10 μs to 100 seconds—or it can be frequency modulated, dc programmed, or externally swept over the 1000:1 ratio by applying an external control signal to the front panel VCG IN connector. A single cycle of output, or one full sweep of the output, can be obtained if an external trigger is applied to the front panel TRIG IN connector.

In addition to the 50Ω main output and a separate rear panel SYNC output, the Model 144 also has a front panel SWP/GCV output. When the main output is not internally swept,.the sawtooth output of the internal sweep generator appears at the SWP/GCV OUT connector. When the main output is internally swept, a GCV output proportional to the instantaneous frequency of the main generator will appear at the SWP/GCV OUT connector. This GCV output (Generator-Controlled-Voltage) can be used to drive X-Y recorders or the vertical and horizontal deflection circuits of oscilloscopes, video monitors, etc.

Varying the triangle symmetry produces a sawtooth or "ramp" signal with a rise or fall time as steep as 50 nanoseconds at a recurring rate of 1 MHz. Pulse outputs as narrow as 50 nanoseconds, with repetition rates as high as 1 MHz (on-off ratios as great as 19:1), can be generated in either polarity. Even the sine wave symmetry may be varied over this 1:19 to 19:1 range if desired. When the output symmetry is not 1:1, the indicated output frequency must be divided by approximately 10.

With this instrument it is possible to simultaneously program or sweep the output frequency, select the output symmetry desired, and manually vary the dc offset. This capability, coupled with the variety of waveforms available and precision output amplitude control, makes the Model 144 an extremely versatile instrument.

1.2 GENERAL PHYSICAL DESCRIPTION

Weighing approximately 9 pounds (13 pounds when shipped) the Model 144 is 8-½ inches wide, 5-¼ inches high, and 11-½ inches deep. Housed in a compact, ruggedized, portable case, the Model 144 is normally shipped with a 10-foot, 3-wire, detachable line cord and one copy of this instruction manual.

1.3 SPECIFICATIONS

1.3.1 Versatility

WAVEFORMS

Selectable sine, square, triangle, positive pulse, and negative pulse. Symmetry of all outputs continuously adjustable from 1:19 to 19:1. Varying triangle symmetry produces sawtooth or output. Separate SWP/GCV OUTput and separate SYNC OUTput with variable symmetry as described below.

OPERATING FREQUENCY RANGE

0.0005 Hz to 10 MHz in the following ranges:

X.001	0.0005 Hz to .01 Hz
X.01	0.005 Hz to 0.1 Hz
X.1	0.05 Hz to 1 Hz
X1	0.1 Hz to 10 Hz
X10	0.1 Hz to 100 Hz
X100	1 Hz to 1 kHz
X1K	10 Hz to 10 kHz
X10K	100 Hz to 100 kHz
X100K	1 kHz to 1 MHz
X1M	10 kHz to 10 MHz

Note: When symmetry control is used, indicated frequency is divided by approximately 10.

MAIN OUTPUT

Sine, Square, triangle, positive pulse, and negative pulse; selectable. Maximum output 30 V p-p into open circuit; (15 V p pulse) calibrated 15 V p-p into 50Ω. Precision output attenuator calibrated in 10 dB steps to −60 dB with 20 dB vernier for overall attenuation of −80 dB. Output impedance is 50Ω. Short circuit current is 150 mA.

SYNC OUTPUT

Amplitude greater than 4 V p-p into open circuit; 2 V p-p into 50Ω. Rise and fall times less than 50 ns. Square waveform for symmetrical outputs, rectangular waveform for pulse and ramp outputs. Sync pulse polarity opposite that of output square wave.

DC Offset
Controlled manually by rear panel control. Adjustable range ±10 Vdc open circuit (±5 Vdc into 50Ω) with peak signal and offset amplitude limited to ±15 Vdc into open circuit (±7.5 Vdc into 50Ω). DC offset and output waveform attenuated proportionately by 60 dB output attenuator.

SWP/GCV OUTPUT

SWP OUTput (0 to +5 V fixed) when in Continuous, Triggered, or Gated modes. GCV OUTput (0 to +5 V maximum) proportional to frequency control settings when in Continuous Sweep, Triggered Sweep, or Sweep and Hold modes.

1.3.2 Operational Modes

Continuous
Operating as a standard VCG (voltage-controlled generator) frequency of 50Ω OUTput is determined by front panel control settings in conjunction with VCG INput signal. Output of internal sweep generator appears at SWP/GCV OUT connector.

Triggered
Only one complete cycle of output appears at 50Ω OUT connector for each pulse applied to TRIG IN connector.

Gated
Same as Triggered mode except that output oscillations continue for duration of gating signal applied to TRIG IN connector.

Continuous Sweep
Main generator is swept by internal sweep generator so that frequency of 50Ω OUTput is swept from a low frequency established by front panel frequency controls to a high frequency determined by SWEEP WIDTH control setting. Sweep rate is determined by SWEEP TIME and VARIABLE controls. GCV OUTput (generator-controlled voltage) appears at SWP/GCV connector.

Triggered Sweep
Same as Continuous Sweep mode except that output is swept only once for each pulse applied to TRIG IN connector. During time between sweeps, main generator oscillates at low frequency determined by frequency control settings.

Sweep and Hold
A gated sweep in which the frequency output is held at maximum at the end of each sweep for the duration of the gate signal at the TRIG IN connector. Between gate signals, the output is the low frequency determined by the frequency control settings.

Tone Burst — Accomplished in Gated mode by connecting ramp output of SWP/GCV OUTput to TRIG INput. Tone burst rate, frequency, and duration can be independently controlled in this configuration.

Trigger Input
1 V peak into 10 kΩ, dc coupled.

Sweep Time
10 μs to 100 seconds.

Sweep Width
Up to 1000:1 with single turn control.

1.3.3 Horizontal Precision

Frequency Dial Accuracy
0.01 Hz to 1 MHz ±(1% of setting +1% of full scale) for symmetrical waveforms.
1 MHz to 10 MHz ±(2% of setting +2% of full scale) for symmetrical waveforms.

Vernier
Permits frequency adjustment of approximately 1% of range.

Time Symmetry
10 Hz to 100 kHz . . . . ±0.5%
0.01 Hz to 500 kHz . . . . ±1.0%

1.3.4 Voltage-Controlled Generator

VCG CONTROL RANGE

Up to 1000:1 frequency change with external voltage input. Upper frequency is limited to maximum of selected range. Required external signal for full voltage control is 5 volts with input impedance of 5 kΩ.

VCG INPUT FREQUENCY

VCG Bandwidth . . . . 100 kHz
VCG Slew Rate . . . . . 2% of range/microsecond

VCG LINEARITY

10 Hz to 100 kHz . . . . ±0.2%
0.001 Hz to 1 MHz . . . . ±0.5%

1.3.5 Vertical Precision

SINE WAVE FREQUENCY RESPONSE

Amplitude change with frequency less than:

0.1 dB . . . . to 100 kHz
0.2 dB . . . . to 1 MHz
2.0 dB . . . . to 10 MHz

STEP ATTENUATOR ACCURACY

±0.25 dB/10 dB

STABILITY

Short term . . . . ±0.05% for 10 minutes
Long term . . . . ±0.25% for 24 hours
Percentages apply to amplitude, frequency, and dc offset.

AMPLITUDE SYMMETRY

All waveforms (except pulse) are symmetrical about ground within ±1% of maximum peak-to-peak amplitude.

1.3.6 Purity

SINE WAVE DISTORTION

10 Hz to 100 kHz . . less than 0.5% (typically 0.25%)
100 kHz to 1 MHz . . . . less than 1.0%
1 MHz to 10 MHz . . all harmonics at least 30 dB down

TRIANGLE LINEARITY

0.002 Hz to 100 kHz . . . . greater than 99%
Linearity defined by best straight line method.

SQUARE WAVE RISE AND FALL TIME (terminated in 50Ω load)

Less than 20 nanoseconds; limited to 500 V/microsecond.

TOTAL ABERRATIONS

Less than 5%.

1.3.7 Environmental

TEMPERATURE

All specifications listed, except for stability, are for 25°C ±5°C. For operation from 0°C to 55°C, derate all specifications by a factor of 2.

1.3.8 Mechanical

DIMENSIONS

8-½ inches wide, 5-¼ inches high, 11-½ inches deep.

WEIGHT

9 pounds net, 13 pounds shipping.

POWER

105 V to 125 V or 200 V to 250 V; 50 to 400 Hz. Less than 40 watts.

1.4 ACCESSORIES AND ASSOCIATED EQUIPMENT

This instrument is normally shipped with a 10-foot, 3-wire, detachable line cord and a copy of this instruction manual. The items listed below are compatible accessories and associated equipment which may be helpful in the user's installation.

RACK ADAPTER KIT. . . . . Wavetek No. 130-602

ADAPTER CABLE(S),
SHIELDED. . . . . . . BNC Female to BNC Female
BNC Female to BNC Male
BNC Female to Dual Banana
BNC Female to Dual Alligator

NOTE
Specifications apply from 1-10 on the frequency dial.

SECTION 2

INSTALLATION AND OPERATION

2.1 MECHANICAL INSTALLATION

After unpacking the instrument, visually inspect all external parts for possible damage to knobs, connectors, surface areas, etc. If damage is discovered, file a claim with the carrier who transported the unit. The shipping container and packing material should be saved in case reshipment is required.

No mechanical installation is required when the instrument is to be used as a portable bench top instrument. If a rack-mounting configuration, or a Rack Adapter Kit (see paragraph 1.4), is provided, the unit may be mounted in a standard 19-inch equipment rack. Instructions for attaching the Rack Adapter Kit are provided with the kit.

2.2 ELECTRICAL INSTALLATION

2.2.1 Power Connection

Connect the ac line cord to the mating connector at the rear of the unit.

NOTICE

Unless otherwise specified at the time of purchase, all Wavetek instruments are shipped from the factory with the power transformer connected for operation on a nominal 115-volt ac line supply, and a 3/8 amp 115 V line fuse.

NOTICE

Conversion for 230-volt operation requires resetting a switch at the rear of the instrument. To reset the 115/230 conversion switch (concealed by the rear panel) remove the rear panel, set the slide switch to 230, and replace the panel. Install a fuse with a rating of 3/16 amp at 230 volts.

2.2.2 Signal Connections

Use 50Ω shielded cables equipped with female BNC connectors to distribute all RF signals when connecting this instrument to associated equipment.

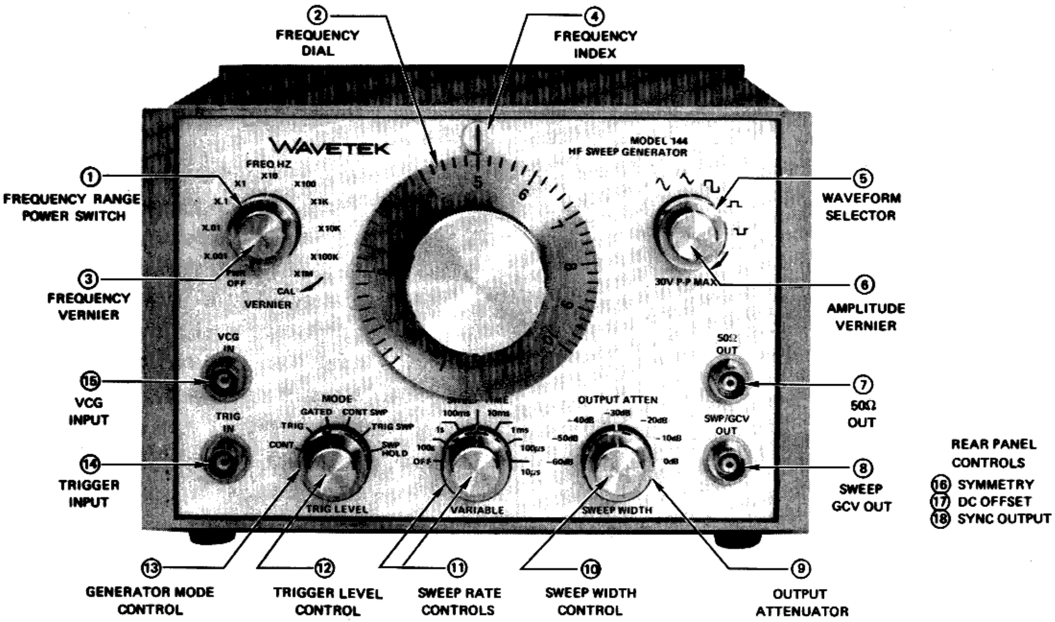


Figure 2-1 - Operating Controls

2.3 OPERATING CONTROLS

The operating controls and electrical connections for the Model 144 are shown in Figure 2-1. The listing below discusses each control and its function.

1. **Frequency Range/Power Switch** – This 11 position switch selects the generator frequency range. The extreme counter-clockwise position is the power off position.

2. **Frequency Dial** – The main frequency control. The setting on this dial multiplied by the frequency range setting (above) equals the output frequency of the generator. The frequency vernier (3) and the symmetry control (11) also affect the generator frequency. Note their effect in the listing below.

3. **Frequency Vernier** – This control allows precision control over the output frequency. A complete turn of this vernier is equivalent to approximately one half of the smallest division on the main frequency dial. When in the full clockwise position (CAL), the settings on the main dial will be accurate.

4. **Frequency Index** – The scribe line indicates the frequency dial setting. The index is illuminated when the unit is on.

5. **Waveform Selector** – This selects the waveform that appears at the 50Ω output connector. The waveforms are sine ∿, triangle ⋀⋁, square ⊓⊔, positive going pulse, and negative going pulse.

6. **Amplitude Vernier** – A vernier control of the output amplitude. Maximum clockwise position gives the full output amplitude of 30 V peak-to-peak into an open circuit or 15 V p-p into a 50Ω load, except positive and negative pulse which are 7.5 V zero to peak amplitude into 50Ω load. Counter-clockwise rotation will continuously reduce the output amplitude. The control gives a minimum of 20 dB variation (10:1). This control operates in conjunction with the output attenuator (9). For maximum amplitude output this vernier must be full clockwise and the output attenuator in the "0 dB" position.

7. **50Ω Out** – This connector provides the selected generator output function. The generator may operate into an open circuit providing 30 V peak-to-peak maximum, or into a 50Ω load providing a 15 V peak-to-peak output.

8. **Sweep GCV Output** – When the generator is in continuous, trigger, or gated mode (control 12) this output provides a fixed 0 to +5 V sawtooth output. The frequency of this output is controlled by the sweep rate controls (11). When the generator is in continuous Swp, Trig Swp, or Swp Hold modes the output becomes the Generator Control Voltage (GCV) that is proportional to frequency. The frequency is controlled by the sweep rate controls (11) and the amplitude is determined by the main frequency dial, VCG input, and sweep width controls.

9. **Output Attenuator** – Attenuates the output from 0 dB (15 V p-p 50Ω max) to –60 dB (15 mV p-p into 50Ω) in six, 10 dB steps. The vernier (6) adds an additional –20 dB, thus, a maximum of –80 dB (1.5 mV p-p into 50Ω).

10. **Sweep width control** – Determines the amount of sweep when in Cont Sweep, Trig Swp, or Swp and Hold modes. Clockwise rotation increases sweep width, counter clockwise rotation decreases sweep width.

11. **Sweep rate control** – Determines the frequency of the 144 ramp generator appearing at the SWP/GCV OUT. The frequency of this generator is independent of the frequency of the main generator. When in any of the sweep modes, this ramp determines the duration of the sweep cycle. The outer dial determines the frequency range and the vernier (inner) dial provides a fine adjustment. Note that the outer switch detent position is located between two time ranges. With the vernier in the full clockwise position, the sweep time is equal to the time to the right of the detent setting. However, moving the vernier to the full counterclockwise results in sweep time approximately 100 times the sweep time to the left of the detent.

12. **Trigger Level Control** – Adjusts the sensitivity of the Trigger Input Circuitry. When in the full counter clockwise approximately –7.5 V is required for triggering. In the full clockwise position approximately +75. V is required for triggering. At the mid point, extremely low voltages will trigger the instrument. By rotating the dial, it is possible to manually trigger the generator. In the gated mode, the generator will begin to run continuously as the control is rotated past the mid-point in a clockwise direction.

13. **Generator Mode Control** – Selects the operating mode of the main generator as follows:

    a) Cont = Continuous Mode – The generator operates at a fixed frequency and runs continuously. The SWP/GCV output is a fixed 0 to 5 V ramp.

b) Trig = Trigger mode — The generator will give one complete cycle of output for each pulse applied to the TRIG IN connector. Since the SWP/GCV output can be operated independently, it can be used as a convenient source. Manual triggering can be accomplished by rotating the Trig Level Control (13) from full CCW to full CW. The SWP/GCV output is a fixed 0 to 5 V ramp.

c) Gated = Gated Mode — Operates the same as triggered mode except that the generator will continue to have output for the full time that the signal at the TRIG IN connector exceeds the GATING Level. See Trig Level (13). The SWP/GCV output is a fixed 0 to 5 V ramp.

d) Cont Swp = Continuous with Sweep Mode — The main generator operates continuously and repetitively sweeps from the minimum to maximum frequency as determined by the sweep controls. In this mode as in the following two sweep modes, the SWP/GCV output becomes the generator control voltage (GCV) which is proportional to the instantaneous frequency of the generator.

e) Trig Swp = Triggered Sweep Mode — The main generator oscillates at the start or low frequency until a trigger signal is applied. The frequency then sweeps to the maximum frequency as determined by sweep width and then returns to the low frequency until another trigger is applied.

f) Swp Hold = Sweep and Hold Mode — The generator operates the same as in triggered sweep mode except that the output remains at the high frequency after sweeping for the duration of the gate pulse. When the gate pulse drops, the output returns to the low frequency as set by the frequency controls.

14. **Trigger Input** — DC coupled input with 10 kΩ input impedance. The trigger level control adjusts the sensitivity of the generator to this input signal.

15. **VCG (Voltage Controlled Generator) Input** — This connector allows external control of frequency. With 0 volts in, the generator output frequency is determined by the frequency range selected and the frequency dial setting. A positive VCG voltage will increase this frequency, and a negative voltage will decrease the frequency. Input impedance is 5 kΩ.

16. **Symmetry Control** — This controls the time symmetry between the positive and negative portions of the output waveform. In the full counter-clockwise (detent) position, the control is disabled and the output waveform has 1:1 symmetry (50-50 duty cycle). Rotating the dial clockwise will vary the symmetry from 1:19 through 19:1. Note: when the symmetry is off the NORM (detent) position, the output frequency is divided by approximately a factor of 10. This allows a minimum pulse width of 50 nanoseconds.

17. **DC Offset** — This rear panel control adjusts the amount of DC or baseline offset above or below signal ground. The Detent position gives normal symmetry and as the control is rotated from the maximum negative offset through zero offset to maximum positive offset.

18. **Sync Out** — This rear panel output provides a square or rectangular output at the same frequency of the main generator. The output amplitude is approximately 2 V p-p into 50Ω. The phase relationship between the sync output and the waveforms from the 50Ω output is as shown in Figure 2-3.

2.4 INSTALLATION CHECKS

This paragraph outlines a quick checkout procedure to determine if the instrument is operating properly. Field calibration and checkout instructions are given in Section 4 to determine compliance with electrical specifications. If electrical deficiencies exist, refer to the warranty on the back of the title page.

Use a Tektronix Model 454 oscilloscope (or equivalent) and a 10 MHz Counter-Timer with 5-digit resolution when performing these installation checks.

1. After connecting the line cord to the ac line, set the front panel controls and switches as follows:

FREQ HZ (switch)	PWR OFF
FREQ DIAL (main dial)	10
WAVEFORM SELECTOR (switch)	∿
30 V P-P MAX (control)	counterclockwise
SYMMETRY (rear panel switch/control)	OFF
DC OFFSET (rear panel switch/control)	OFF
OUTPUT ATTEN (switch)	0 dB
MODE (switch)	CONT
SWEEP TIME (switch)	OFF
VARIABLE (control)	clockwise
SWEEP WIDTH (control)	clockwise

2. Connect the 50Ω OUT connector to the oscilloscope, terminated in a 50-ohm load.

3. Set FREQ HZ to X100. A 1 kHz sine wave with an amplitude of less than 1.5 p-p should be displayed on the oscilloscope.

4. Set the 30 V P-P MAX clockwise. The amplitude of the displayed waveform should be 15 V p-p.

5. Check the minimum and maximum amplitude of each waveform using the WAVEFORM SELECTOR and the 30 V P-P MAX control. Reset WAVEFORM SELECTOR TO ∿ , and 30 V P-P MAX to clockwise position.

6. Observe the oscilloscope display and rotate the FREQ DIAL clockwise to .1 setting. The sine wave frequency should change from 1 kHz to 10 Hz. Check the range to range tracking accuracy with dial setting at 10.

7. With FREQ HZ set to X 100K and FREQ DIAL set to .1, set VERNIER control fully counterclockwise. The output frequency should be less than 1 kHz.

8. Rotate SYMMETRY control slightly clockwise until symmetry function is activated. The output square wave should be unsymmetrical by a ratio of approximately 1:19 and the frequency is divided by approximately 10. Continue rotating the SYMMETRY control through its entire range. The square wave symmetry should vary from 1:19 through 1:1 to 19:1 at the full clockwise extreme.

9. Set 30 V P-P MAX fully counterclockwise and the rear panel DC OFFSET clockwise. The baseline of the output waveform should be approximately –5 volts. Rotate DC OFFSET control from OFF to maximum clockwise; the baseline should shift from –5 V to greater than +5 V. Reset the control to OFF.

10. Set 30 V P-P MAX fully clockwise and rotate OUTPUT ATTEN switch through each position, observing the oscilloscope display to check the output attenuation.

11. With SWEEP TIME set between 10 ms/1 ms and VARIABLE set fully clockwise (1 ms sweep), the SWP/GCV OUT waveform should be a 1 kHz sawtooth. Set VARIABLE fully counterclockwise; the SWP/GCV OUT waveform should be less than 10 Hz.

12. Check the SWP/GCV OUT frequency in all positions of the SWEEP TIME switch, at the clockwise and counterclockwise ends of the VARIABLE control.

13. Using a shielded cable equipped with BNC connectors, connect the SWP/GCV OUT connector to the TRIG IN connector; and connect the scope to the 50Ω OUT connector. Set MODE switch to TRIG and rotate TRIG LEVEL control while observing the oscilloscope. One cycle of the selected output waveform should be displayed.

14. Set MODE switch to GATED and rotate TRIG LEVEL control while observing the oscilloscope. The multiple cycles of the selected output waveform should appear when the TRIG LEVEL control is rotated toward the clockwise extreme and disappear when the control is turned toward the counterclockwise extreme.

15. Set MODE switch to CONT SWP and set FREQ HZ to X 1K. Using a counter, set output frequency to 10 Hz with the FREQ DIAL. Set SWEEP WIDTH fully clockwise and SWEEP TIME to 100s/1s. Displayed output should sweep from 10 Hz to 10 kHz at a 1 Hz rate.

16. Set MODE switch to TRIG SWP and rotate TRIG LEVEL control while observing the oscilloscope. Displayed output should sweep once from 10 Hz to 10 kHz in 1 second.

17. Set MODE switch to SWP HOLD and rotate TRIG LEVEL control while observing the oscilloscope. When TRIG LEVEL is fully counterclockwise, the 10 Hz waveform should be observed. Rotate TRIG LEVEL fully clockwise and the output should sweep from 10 Hz to 10 kHz and hold as long as the TRIG LEVEL is in this position.

18. Disconnect the cable from the TRIG IN connector, and connect the SWP/GCV OUT connector to the oscilloscope input. Set MODE switch to CONT and SWEEP TIME to 10 ms/1ms. The oscilloscope should display a 1 kHz sawtooth waveform.

19. Set MODE switch to TRIG and then to GATED. The same 1 kHz sawtooth waveform should be present in these modes.

20. Set MODE switch to CONT SWP, then TRIG SWP, then SWP HOLD. The SWP/GCV OUT signal should be a GCV signal proportional to the instantaneous frequency of the main generator.

2.5 OPERATING PROCEDURE

No preparation for operation is required beyond completion of the initial installation checks given in paragraph 2.4 of this manual. It is recommended that a one-half hour warm-up period be allowed for the associated equipment to reach a stabilized operating temperature, and for the Model 144 to attain stated accuracies.

2.5.1 Operation as a Function Generator

1. Properly terminate the 50Ω OUT connector.

2. Select desired output waveform using the WAVEFORM SELECTOR switch.

3. Set the generator mode switch to CONT.

4. Set FREQ HZ switch to desired multiplier.

5. Set FREQ DIAL to desired setting by aligning with Index.

6. Set 30 V P-P MAX and OUTPUT ATTEN switch for desired output level and amplitude.

For reference, the following table gives the approximate output amplitude levels at attenuator settings. The output levels of the positive and negative pulse waveforms are one-half of these levels.

TABLE 2-1

Attenuator Position	Peak-to-Peak Output into 50Ω load.	
	Maximum (Vernier full CW)	Minimum
0 dB	15 volts	1.5 V
−10 dB	5 volts	500 mV
−20 dB	1.5 volts	150 mV
−30 dB	500 mV	50 mV
−40 dB	150 mV	15 mV
−50 dB	50 mV	5 mV
−60 dB	15 mV	1.5 mV

7. With DC OFFSET set to 0 detent position and SYMMETRY control set to NORM, the output waveform should be a symmetrical waveform oscillating around a zero dc reference point. (Except when in a positive or negative pulse position.)

8. Select the polarity of dc offset desired and the amount of offset using the rear panel control. If an excessive amount of dc offset is used, waveform clipping may be observed. The sum of peak waveform voltage and the dc offset cannot exceed the maximum rated output of the generator. For example, on the 0 dB attenuator setting the maximum output is 15 V peak-to-peak or 7.5 V peak above and below zero volts. Offset plus peak voltage cannot exceed 7.5 V. See Figure 2-2.

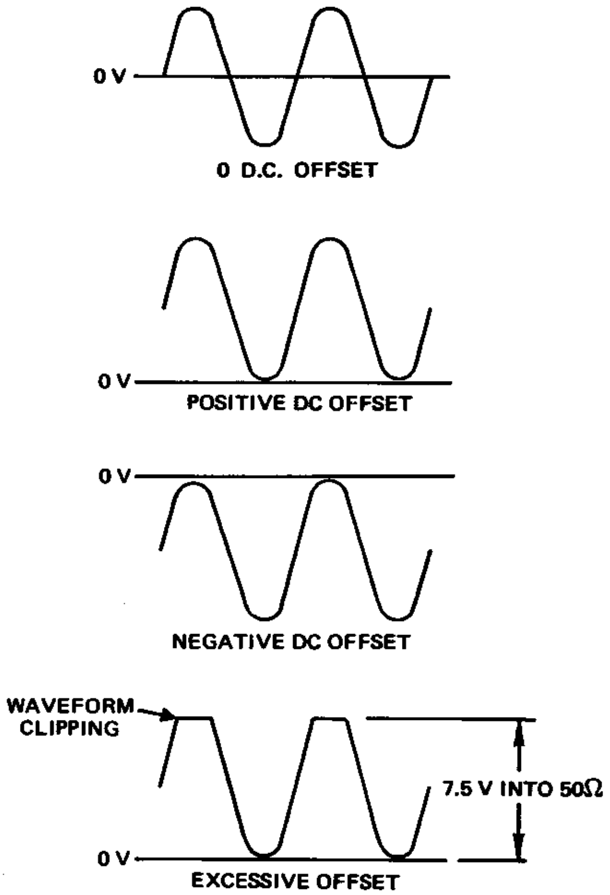


Figure 2-2 - DC Offset Control

9. Set SYMMETRY switch/control for desired symmetry or dissymmetry. The symmetry control can be used to develop ramp waveforms with variable rise fall ratios and pulse trains with variable duty cycle. By using the sine wave with dissymmetry, controllable sine distortion can be developed. Figure 2-3 shows the effect of this control on output waveforms.

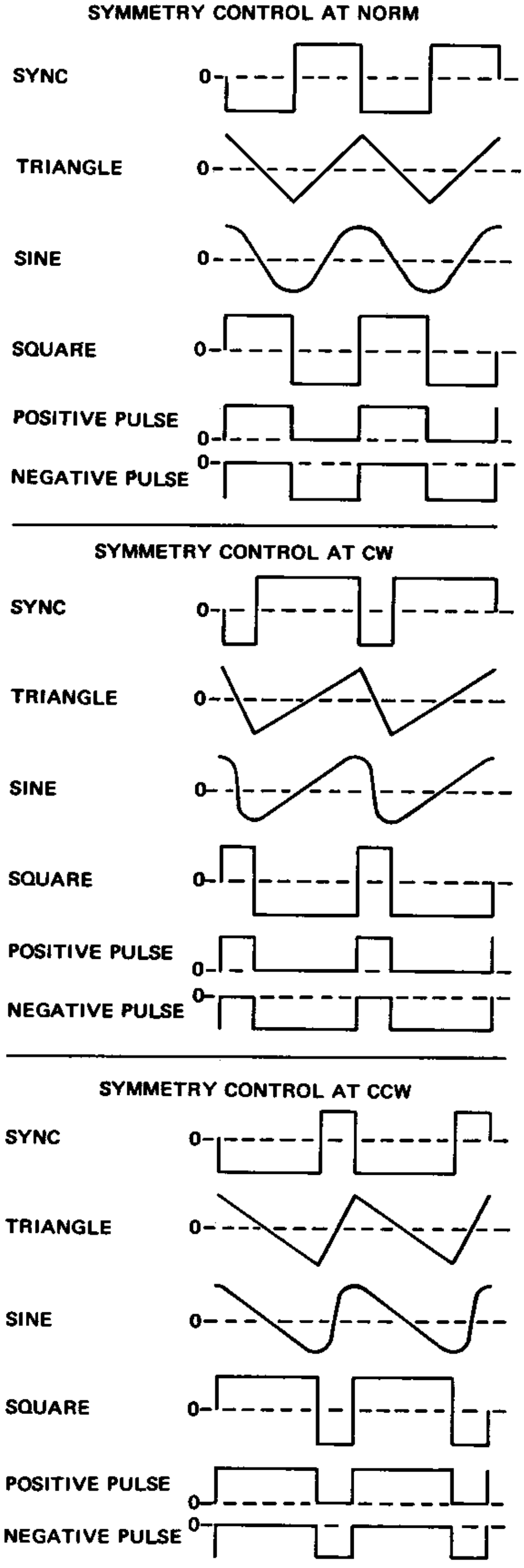


Figure 2-3 - Waveform Phasing and Symmetry Control

2.5.2 Operation as a Voltage Controlled Generator

The VCG input connector can be used to externally control the frequency of the generator. If a positive voltage is applied to the VCG input terminal the frequency will increase from the dial setting. A negative voltage will cause the frequency to decrease from the dial setting. The VCG range of the Model 144 is 1000:1. On any range multiplier setting, the frequency can be controlled from .01 x the multiplier to 10 x the multiplier. The nomograph of Figure 2-4 shows the characteristics of the VCG circuit. Column A gives the frequency dial setting, column B, the VCG voltage and column C, the resultant frequency of the generator.

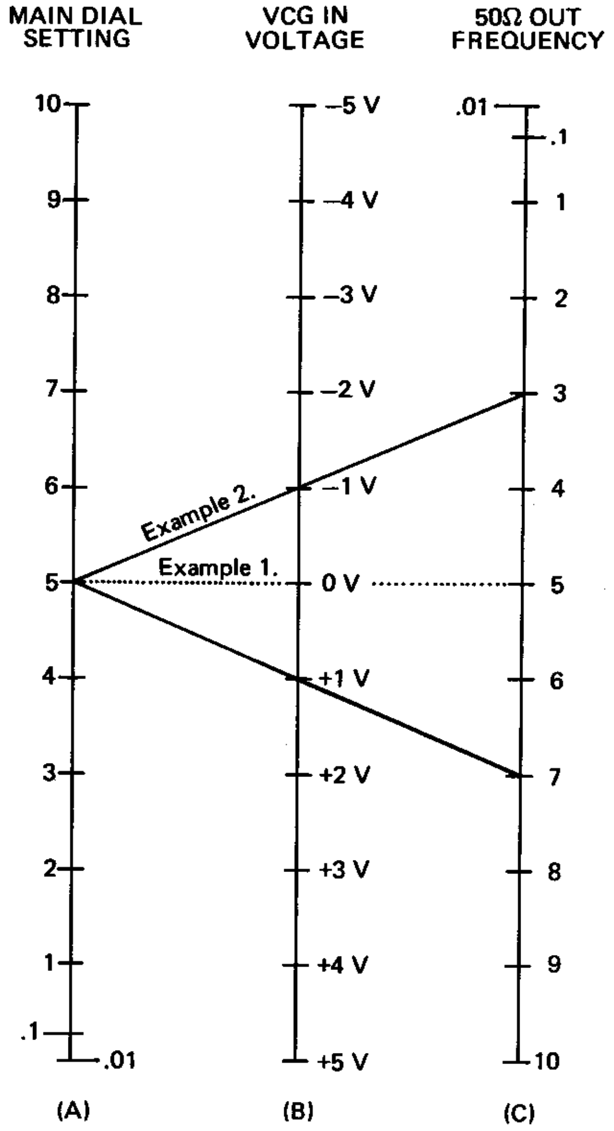


Figure 2-4 - VCG Voltage-to-Frequency Nomograph

In example 1, the dial is set at 5 and 0 volts VCG input voltage is applied. Extend a straight line from 5 (dial setting) through 0 volts (VCG voltage). The result is an output frequency of 5 (multiplied by the range multiplier).

In order to set the generator at .01 x the range multiplier (1/1000 of the range) the following procedure is to be followed:

a) Using the frequency dial and a counter or oscilloscope, set the generator frequency to 0.1 x the range multiplier.

b) By rotating the vernier counter-clockwise, decrease the frequency to .01 x the range multiplier.

As can be seen from the nomograph, a +5 volt VCG input will then cause the frequency to increase to the maximum of 10 x the range (an increase from .01 to 10; i.e., 1000:1).

2.5.3 Operation as a Triggered Generator

1. Select the desired waveform using the waveform selector switch.

2. Set the generator mode switch to trig.

3. Adjust the generator to the desired frequency (or width) using the range switch and the main frequency dial.

4. Apply a signal to the Trig In BNC.
   Note: The SWP/GCV output may be used as a trigger source. In this case the sweep time control determines the repetition rate of the triggered output signal, and the trigger level dial control sets the width, or duration, of the output signal.

2.5.4 Gated or Tone Burst Operation

With the generator adjusted as in trigger operation above, change the mode control to the gated position. The generator output will then be a burst of signals. The duration of the burst is adjustable by the trigger level control, refer to Figure 2-5.

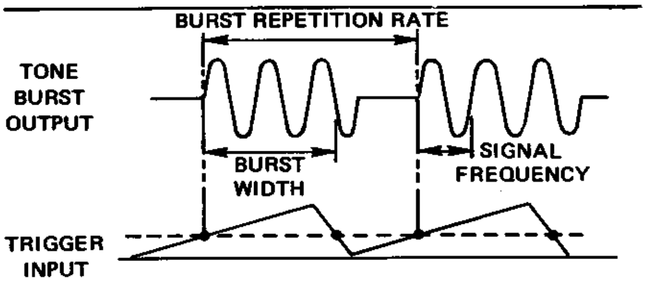


Figure 2-5 - Tone Burst Controls

The generator can be made to free run in this mode at certain settings of the trigger level control. By resetting the trigger level control, normal gated operation can be re-established.

2.5.5 Operation as a Sweep Generator

Three sweep modes are available with the Model 144, continuous with sweep, trigger with sweep and sweep and hold. The operation of these modes can be visualized by the graphs shown in Figure 2-6. These graphs plot the output frequency of the generator as a function of time in the three different sweep modes.

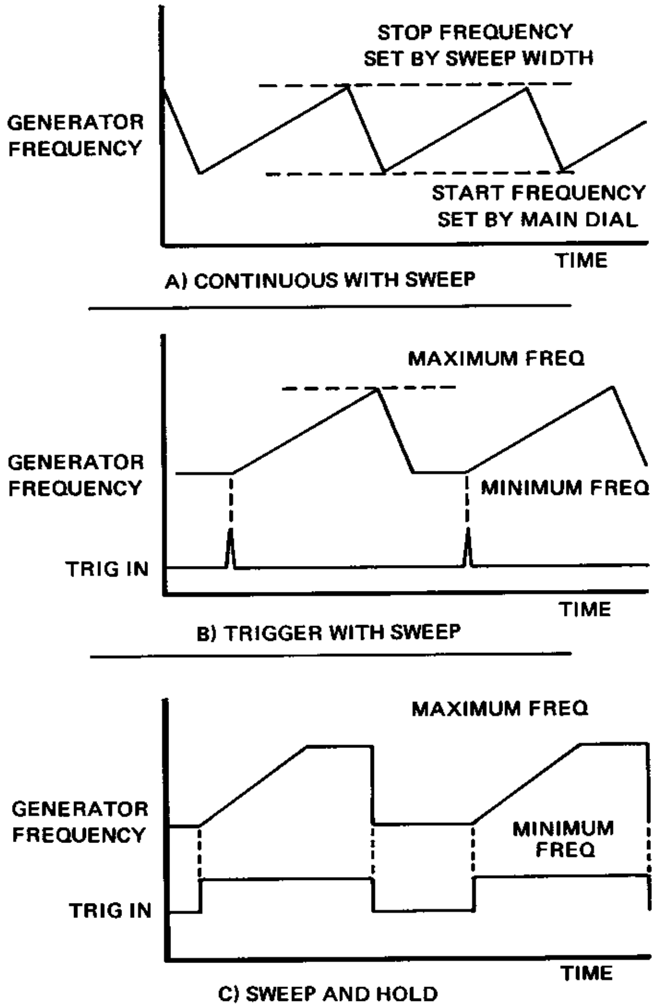


Figure 2-6 - Generator Sweep Modes

These modes together with the GCV output can be used, to accurately adjust the sweep limits over a preselected frequency range. The set-up procedure shown in Figure 2-7 utilizes an oscilloscope, however an X-Y recorder or a counter could be used in a similar manner.

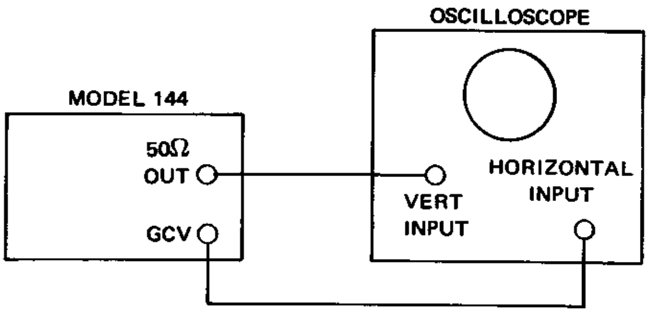


Figure 2-7 - Set-Up Procedure

1. Select the waveform, amplitude and frequency range desired.

2. Switch the generator to trig with sweep mode.

3. Adjust the START frequency to the desired value with the main frequency dial.

4. With the generator connected to the oscilloscope as shown in Figure 2-7, and the oscilloscope in the external horizontal mode, adjust the horizontal position so that the waveform is positioned on the left reticle of the oscilloscope.

5. Turn the main frequency dial to the top frequency desired, and adjust the horizontal gain of the oscilloscope so that the waveform is positioned on the extreme right hand reticle, or any convenient reticle of the screen.

6. Return the generator main dial to the start frequency and switch the mode control to sweep and hold mode. Adjust the sweep width control until the waveform is positioned at the right hand reticle as selected in step 5 above.

   Note: If the sweep width has no effect, it may be necessary to manually trigger the generator by rotating the trigger level control.

7. Switch the generator to cont with sweep mode. The frequency will now sweep between the START frequency, selected by the main dial and the stop frequency as adjusted by the sweep width.

If more detailed calibration of the oscilloscope horizontal axis is required, the main dial can be used. By moving the dial and noting the start point of the sweep, the horizontal axis can be calibrated as a function of frequency.

2.5.6 Floating Output

This instrument is shipped from the factory with the signal ground floating above chassis ground, unless otherwise specified at the time of purchase. If a common signal/chassis ground is desired, perform the following modification:

1. Disconnect the power cord, loosen the two captive thumb screws on the rear panel, and remove the rear panel.

2. Slide the dust cover out from the rear, loosen the two screws on the rear plate and the two screws on the power supply board (at bottom of chassis) and remove the power supply board, flipping it over on the main circuit board.

3. Solder one end of an insulated wire to the ground lugs (green wires of the power connector) and push the other end through the small opening on the main circuit board.

4. Solder the other end of the insulated wire to the ground terminal on the power supply board.

SECTION 3
CIRCUIT DESCRIPTION

3.1 SIMPLIFIED BLOCK DIAGRAM ANALYSIS

3.1.1 Main Generator

Refer to Figure 3-1, the Simplified Block Diagram, and Figure 3-2, the Simplified Timing Diagram, when reading this description. Paragraph 3.2 and its sub-paragraphs provide further descriptions of the functions of the basic circuits in this instrument. This paragraph describes, briefly, the major circuit elements and their relationship to one another.

As shown in Figure 3-1, the VCG Summing Amplifier sums the currents from the FREQ DIAL, VERNIER, and VCG

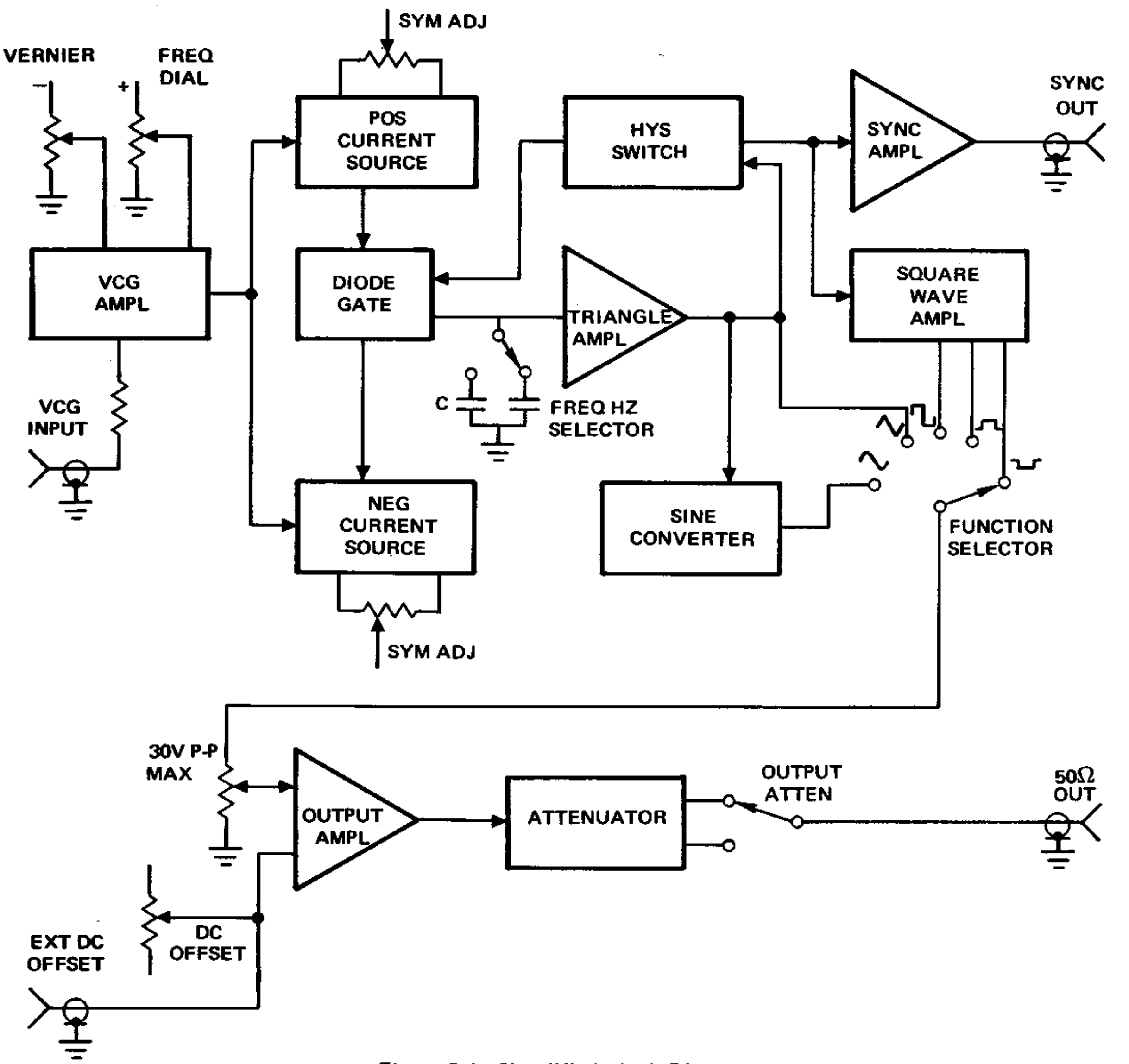


Figure 3-1 - Simplified Block Diagram

IN connector. The VCG Summing Amp is an inverting amplifier whose output voltage is used to control a positive current source and a negative current source. For symmetrical output waveforms, the currents from the two current sources are equal and directly proportional to the voltage of the VCG Summing Amplifier output. The Diode Gate, which is controlled by the Hysteresis Switch, is used to switch the positive current or the negative current to the timing capacitor selected by the FREQ HZ selector. If the positive current is switched into the timing capacitor, the voltage across the capacitor will rise linearly to generate the triangle rise transition. If the current is negative, the voltage across the timing capacitor will fall linearly to produce the fall transition.

The Triangle Amplifier is a unity gain amplifier whose output is fed to the Hysteresis Switch as well as to the Sine Converter. The Hysteresis Switch has two voltage limit points (+1.25 V and −1.25 V).

During the time the output voltage of the Triangle Amplifier is rising, the output voltage of the Hysteresis Switch is positive. But when the output voltage of the Triangle Amplifier reaches +1.25 V, it triggers the Hysteresis Switch causing the switch output to go negative. Once the control voltage into the Diode Gate becomes negative, it will switch the positive current out and switch the negative current in to the timing capacitor, so that the voltage across the capacitor will reverse, starting a linear decrease of the waveform. When the decreasing voltage reaches −1.25 V, the output of the Hysteresis Switch will switch back to positive, reversing the process. This action generates the triangle waveform as shown in Figure 3-2. Since the output of the Hysteresis Switch is a square wave, the result is simultaneous generation of a square wave and a triangle wave at the same frequency.

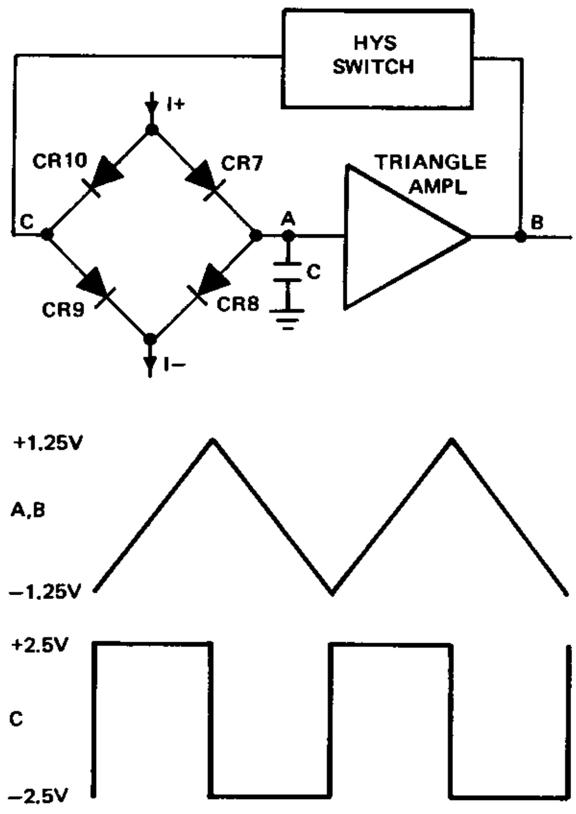


Figure 3-2 - Simplified Timing Diagram

The output frequency is determined by the magnitude of the capacitor selected by the FREQ HZ selector and the magnitude of the positive and negative current sources. Since the current sources are linearly proportional to the control voltage of the VCG circuit, the output frequency will also be linearly proportional to the control voltage.

If the current of the negative current source is decreased by 19 times, the fall time of the triangle will be 19 times longer than the rise time of the triangle; resulting in an unsymmetrical waveform and a division of the frequency by a factor of 10. Gradually increasing the current from the negative current source and decreasing the current from the positive current source in such a way that the period for the triangle to complete one cycle remains constant, the symmetry of the output waveform can be continuously varied while the frequency is held constant.

The inverted output of the Hysteresis Switch is fed to the Sync Amplifier and also the Square Wave Amplifier. The Square Wave Amplifier consists of a shaping circuit which limits the output swing to ±1.25 volts. For positive pulse outputs, it limits the output voltage swing from −1.25 V to 0 V; and for negative pulse outputs, it limits the output swing from 0 V to +1.25 V.

The output signal from the Triangle Amplifier is applied to the Sine Converter, consisting of a sine shaping circuit and a sine amplifier.

The sine, triangle, square, positive pulse, or negative pulse is fed to the Output Amplifier through the WAVEFORM SELECTOR switch and the 30 V P-P MAX control. The Output Amplifier is an inverting amplifier whose output is fed into a step attenuator and then to the output BNC connector.

The Attenuator consists of four pi attenuators, each having a 50-ohm input impedance and a 50-ohm output impedance. There is one −10 dB attenuator, one −20 dB attenuator, and two −30 dB attenuators. By combining them in six different arrangements, these four attenuators provide 10 dB steps of attenuation; from 0 dB to −60 dB.

3.1.2 Sweep Generator and Trigger Logic

CONTINUOUS MODE

In this mode, both the Main Generator and the Sweep Generator operate independently. As shown in Figure 3-3, the Sweep Generator is a passive integrator with a Voltage Controlled Current Source. The output of the Sawtooth Amplifier changes the states of both the Peak and Zero Detectors when either the peak or the zero limit is reached, thus switching on and off the current source output. The result of this charging and discharging of the timing capacitor is a continuous generation of a sawtooth waveform.

The charging and discharging rate of the timing capacitor, also the repetition rate of the sawtooth waveform, is proportional to the amount of current fed into the capacitor and the size of the capacitor. The amount of current output is proportional to the controlling voltage and the current programming resistor. Thus, the repetition rate is controlled by the sweep time VARIABLE control R33 and the SWEEP TIME range selector switch.

The Current Source Switch provides a shunt path to signal ground for the timing capacitor when the sawtooth waveform is in the negative slope region. Switching action is activated by the Peak Detector and the Zero Detector outputs. The Sawtooth Amplifier is a noninverting, high input impedance, high slew rate amplifier providing low output impedance and complete isolation for the passive integrator.

The Peak and Zero Detectors accomplish detection of both extremes of the sawtooth waveform. The outputs of these two detectors, in conjunction with other transistor switches, causes the Current Source Switch to place a shunt path across the Timing Capacitor or remove the shunt path. Thus, the operational loop is completed for the Continuous Mode operation of the Sweep Generator.

TRIGGERED OR GATED MODES

Refer to Figure 3-4. In both the Triggered and the Gated modes, the Main Generator and the Sweep Generator operate independently.

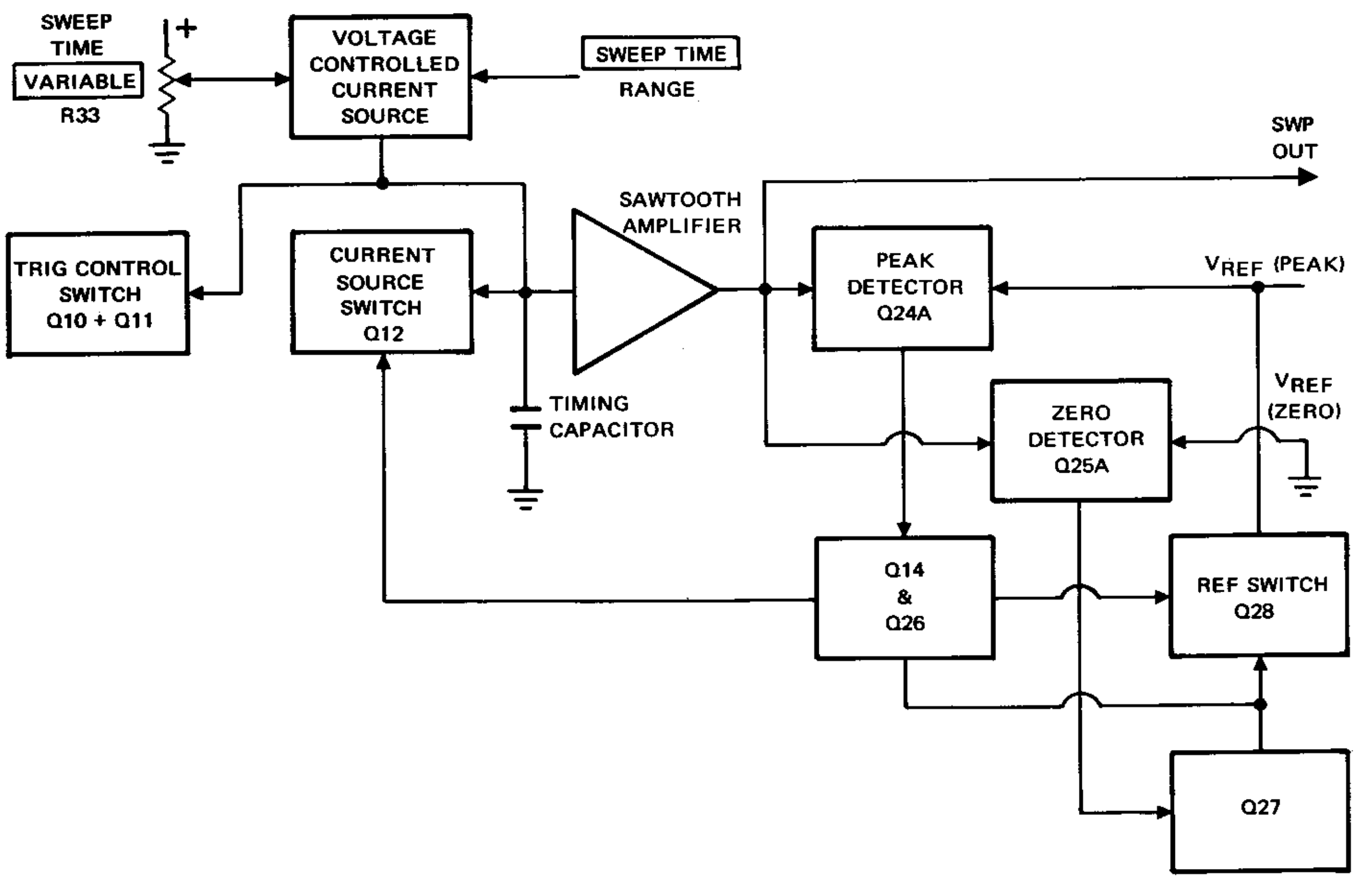


Figure 3-3 – Sweep Generator, Continuous Mode

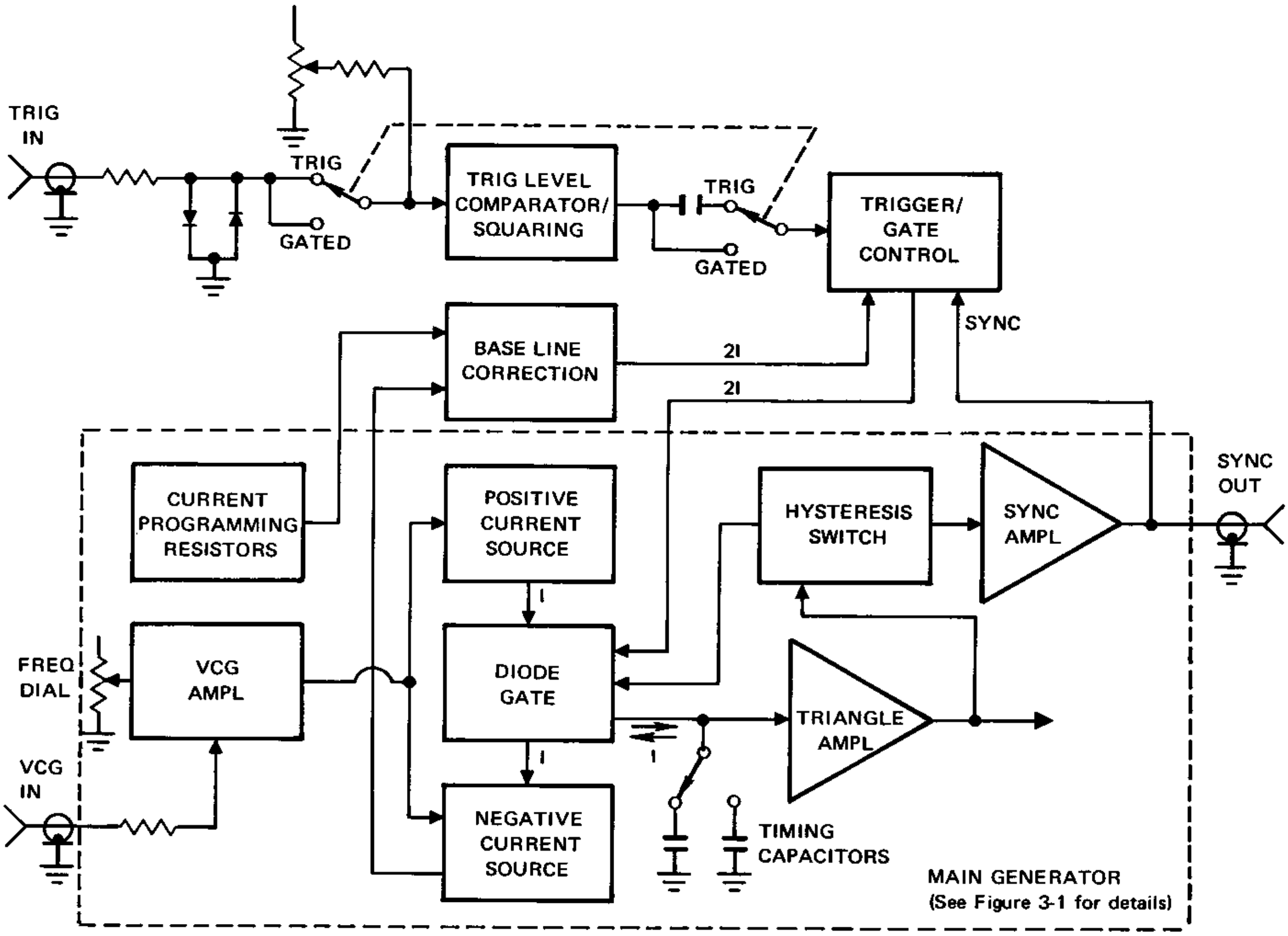


Figure 3-4 — Sweep Generator, Triggered or Gated Modes

When this instrument is in the TRIG mode and ready, the Main Generator Diode Gate is switched off by the Trigger/Gate Control, and the Timing Capacitor is discharged through the shunt path. When a trigger signal arrives at the Trigger/Gate Control, the control flip-flop changes the state, opening the Diode Gate. Current flows into the Timing Capacitor, allowing the passive integrator to generate a triangle waveform. The control flip-flop is reset by the square wave from the Sync Amplifier when the proper phase triggers the flip-flop. The flip-flop output, in conjunction with the level-shift circuit, closes the Diode Gate. Thus, the single cycle generation of a selected waveform is accomplished.

When in the GATED mode, the output of the Trigger Level Comparator/Squaring circuit is coupled directly to the Trigger/Gate Control. The sequence of operation is the same as that of the TRIG mode, except that one or more cycles are generated for the duration of the trigger (gate) signal applied to the TRIG IN connector.

SWEEP MODES

In the SWEEP modes of operation, a third input (the Sweep Generator output) is added to the VCG Amplifiers through the SWEEP WIDTH control. In the CONT SWP mode, the Sweep Generator and the Main Generator run continuously. In the TRIG SWP and SWP HOLD modes, the Main Generator runs continuously at the frequency set by the frequency controls until a trigger or gate pulse appears at the TRIG IN connector.

(a) Continuous Sweep Mode

Refer to Figure 3-5. In the CONT SWP mode, the basic frequency of the Main Generator is set by the FREQ

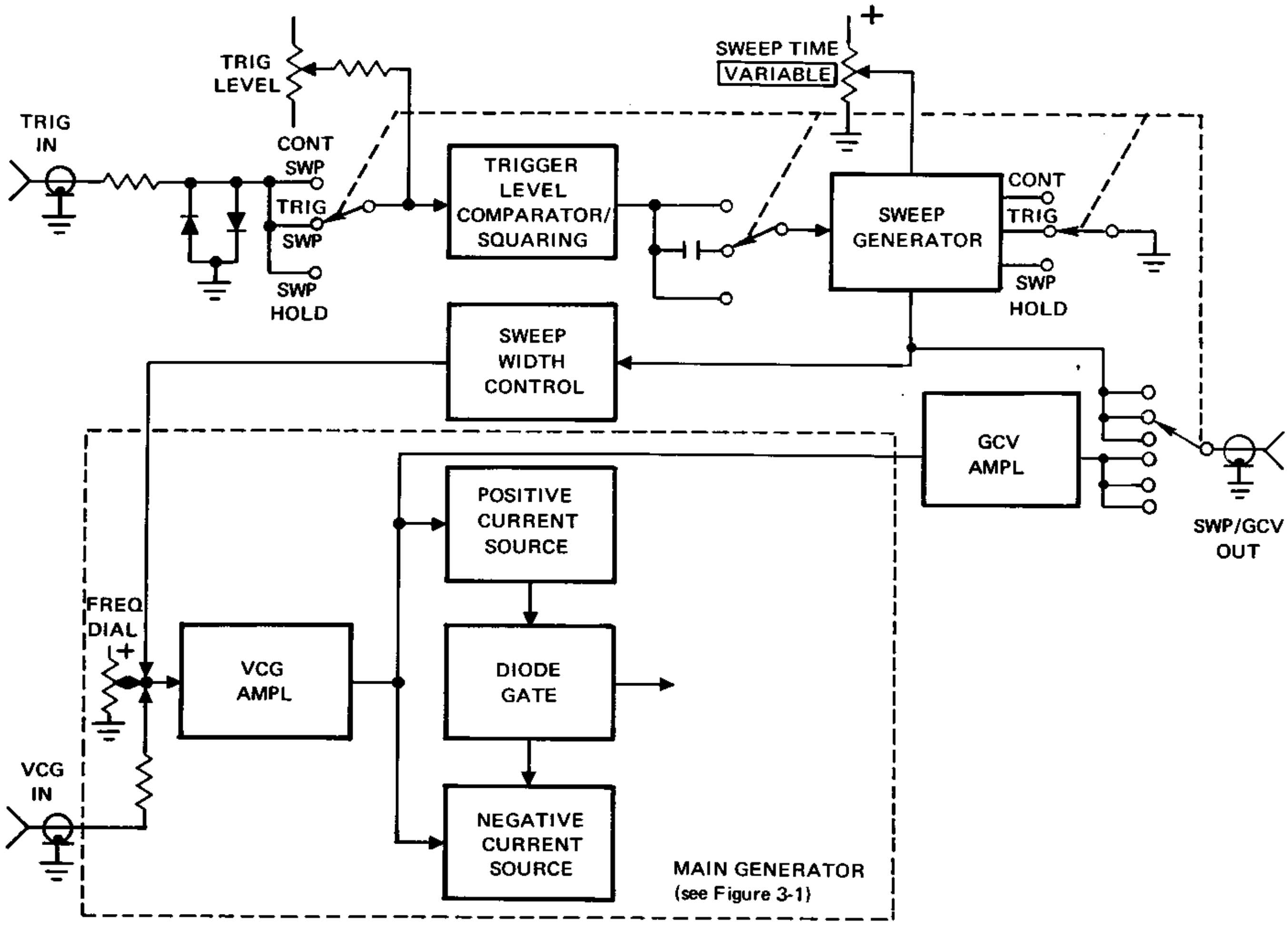


Figure 3-5 – Sweep GEN, CONT SWP, TRIG SWP, & SWP HOLD modes

DIAL, the VERNIER, and the FREQ HZ selector. As the Sweep Generator output starts moving positive, the frequency increases linearly because the output of the Sweep Generator is coupled through the SWEEP WIDTH control to the first VCG Amplifier summing node. Maximum frequency is determined by the basic frequency and the setting of the SWEEP WIDTH control. It should be noted that the maximum SWEEP WIDTH (fully clockwise) is usable only when the basic frequency is set to less than 1/100th of the maximum frequency in the selected range. The swept output waveform repeats for as long as the MODE switch is set to CONT SWP. SWEEP TIME switch and VARIABLE control determine the sweep repetition rate.

(b) Triggered Sweep Mode

Refer to Figure 3-5. In the TRIG SWP mode, the Main Generator runs continuously at the minimum frequency set by the FREQ DIAL, VERNIER, and FREQ HZ selector. The Sweep Generator is, initially, in a standby condition. When an input trigger signal is applied at the TRIG IN connector, the output of the Trigger Level Comparator/Squaring circuit changes the state of the Trigger/Gate Control circuit. The output of the Trigger Level Comparator/Squaring circuit is coupled through a capacitor to release the Sweep Generator Clamp for a single cycle. Thus, a single sweep of the Main Generator is accomplished. The operation of the SWEEP WIDTH control is the same as in the CONT SWP mode.

(c) Sweep and Hold Mode

The operation in this mode is similar to operation in the triggered Sweep Mode except the output of the Trigger Level Comparator/Squaring circuit is not coupled through a capacitor, and the Sweep Generator Clamp is removed for the duration of the trigger (or gate) signal. When the gate signal drops, the Main Generator again runs continuously at the frequency set by the frequency controls.

3.2 FUNCTIONAL BLOCK DIAGRAM ANALYSIS

As each functional block is described, refer to the appropriate block diagram and, if necessary, the appropriate portions of the schematic diagrams at the rear of this manual.

3.2.1 Main Generator

VCG AMPLIFIER AND CURRENT SOURCES

As shown in Figure 3-6, IC2 is connected as a Summing Amplifier to sum the VCG input current through R89, the current from the FREQ DIAL R82, and the current from the VERNIER control R90. IC2 is an inverting

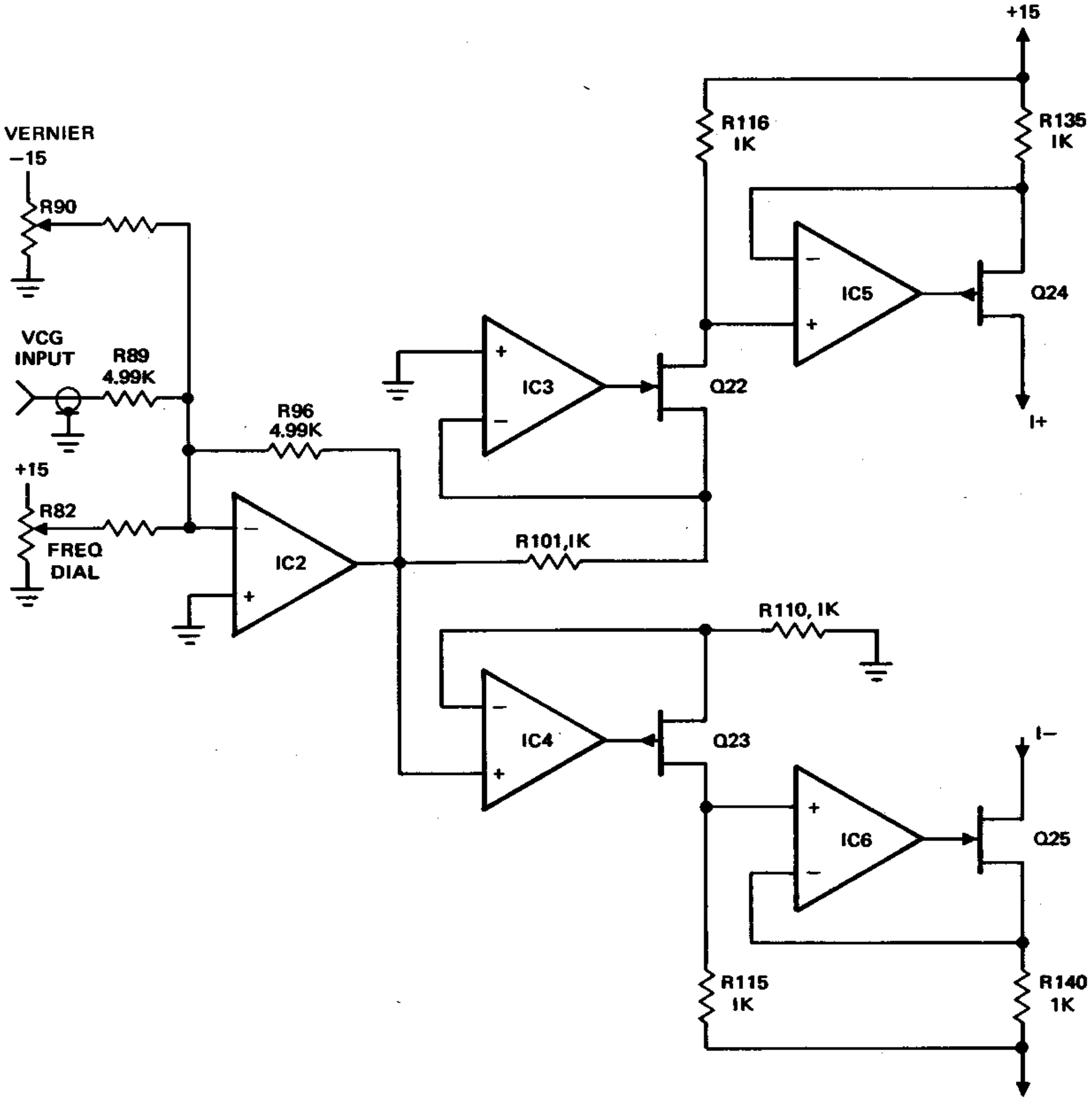


Figure 3-6 – VCG Amplifier and Current Sources amplifier whose output voltage will change between 0 and −5 volts under normal operating conditions. Transistor Q21 limits the output swing to 0 and −7 volts. The output of IC2 is used to control both the positive and negative current sources, IC3 through IC6.

The negative input of IC3 is held at 0 volts by its feedback. The current through R101 would be directly proportional to the output voltage of IC2 if all the source currents of IC3 and IC5 are neglected, and the current through R116 would be equal to the current through R101. Therefore, the voltage drop across R116 would be equal to the voltage drop across R101. Thus, amplifier IC3 is operated as a voltage level shifter to shift the voltage referenced from ground to a voltage referenced from +15 volts.

Due to the feedback control of amplifier IC5, the voltage drop across R135 would be equal to the voltage drop across R116 which in turn is equal to the voltage output of amplifier IC2. Since the positive current output from Q24 is directly proportional to the voltage across R135, it must also be proportional to the control voltage of the VCG amplifier.

Amplifiers IC4 and IC6 are very similar to amplifiers IC3 and IC5 except that IC3 is an inverting amplifier and IC4 is a non-inverting amplifier. If all the 1 kΩ resistors in Figure 3-6 are well matched, the positive output current (I+) and the negative output current (I−) will be equal and directly proportional to the control voltage. These two currents are alternately switched into a timing capacitor to generate a triangle waveform.

By increasing the resistance of R101 by 19 times, the voltage drop across R116 and R135 will be reduced to 1/19th of what it had been. Therefore, the output current (I+) will be 1/19th the negative current (I−). In this condition, a nonsymmetrical triangle with a rise to fall ratio of 19 to 1 and a frequency of 1/10th the original frequency (symmetrical frequency) is generated. If the resistance of R101 is decreased and the resistance of R110 is increased by exactly the same amount, the symmetry ratio will be gradually changed while the output frequency remains constant. Dual potentiometers R99 and R103 provide this SYMMETRY control.

For FREQ HZ multipliers of X10 to X1M, R135 and R140 are 1 kΩ resistors. Changing the FREQ HZ multiplier is accomplished by changing the timing capacitors connected to the diode gate.

For frequency ranges below X10, R135 and R140 are changed instead of changing the timing capacitors. In this case, the current from the current sources will go as low as 50 nA, and the source current of IC5 and IC6 can not be neglected. Therefore, a high impedance buffer amplifier Q26 and Q27 is inserted between Q24 and the negative input of IC5, and another buffer amplifier Q28 and Q29 is inserted between Q25 and the negative input of IC6.

Q27 is connected as a constant current source supplying the bias current to Q26 and minimizing the change of V_{gs} of Q26 with temperature change. R129 provides dc offset adjustment of the buffer amplifier. Q28 and Q29 function exactly like Q26 and Q27.

Refer to the Main Board schematic diagram 142-210 at the rear of this manual. FREQ DIAL control R82 controls the amount of current supplied to the summing node of the VCG amplifier, thus controlling the output frequency. VERNIER control R90 provides fine frequency control. R93 is the zero adjustment for the negative input of IC2, so the VCG input terminal is not dependent on source impedance. R87 provides source current compensation for the negative input of IC2, permitting frequency adjustments at the minimum setting of the FREQ DIAL. The 100 kΩ potentiometers associated with IC3, IC4, IC5, and IC6 are used to zero offset the input terminal of the corresponding amplifiers. Q21 and R100 are used to limit the output voltage swing of the VCG amplifier, IC2, to +0.7 volts and −7.0 volts.

TRIANGLE AMPLIFIER

The Triangle Amplifier consists of transistors Q1 through Q8, with Q1 and Q2 forming a very high input impedance differential pair. Q3 and Q4 supply constant bias currents to the differential pair, increasing the open loop gain of the amplifier. Q5 is connected as a 7-volt zener diode to shift the output level of Q6. The overall Triangle Amplifier is a unity gain amplifier with very low output impedance.

HYSTERESIS SWITCH

The Hysteresis Switch consists of a comparator and a flip-flop. The integrated circuit IC1 (CA3049) is the comparator, consisting of two differential amplifiers. One side of each differential amplifier, pin 7 and pin 10, are connected to ground through 22 ohm resistors. Potentiometers R23 and R12 establish the high and low voltage limits for the comparator. When the output of the Triangle Amplifier reaches +1.25 V, the transistor connected to pin 1 of IC1 will be conducting, and the collector current through pin 12 will be large enough to turn on the tunnel diode CR11, which in turn changes the state of the flip-flop. When the output of the Triangle Amplifier reaches −1.25 volts, the transistor connected to pin 7 of IC1 conducts and its collector current at pin 6 will be large enough to turn on tunnel diode CR13, reversing the state of the flip-flop.

There are three RC networks connected to pin 1 and three RC networks connected to pin 4 of IC1. These six RC networks provide frequency response compensation for IC1 and the entire loop of the Triangle Generator so that it will have a flat frequency response from dc to 10 MHz.

The flip-flop is comprised of transistors Q10 through Q16, with Q12 and Q13 connected as a differential pair. Q14 supplies a constant bias to the differential pair, preventing saturation during their "on" state. Q11 and Q16 are voltage followers whose output is fed back to Q12 and Q13 through R46, R54, and R55 forming the flip-flop configuration. Q9 is connected as a 7-volt zener reference for IC1 and the flip-flop.

In the state where Q13 is conducting and Q12 is cut off, the voltage at the emitter of Q16 is high (+2.5 V) and the voltage at the emitter of Q11 is low (−2.5 V). Once tunnel diode IC13 is turned on by IC1, the V_{be} of Q15 will increase until Q15 turns on and in turn Q13 is turned off. This causes the emitter voltage of Q16 to drop to −2.5 V which, through feedback resistors R47 and R46, keeps Q12 in the on state. Thus the emitter voltage of Q11 will rise to +2.5 volts. Although the tunnel diode CR13 is turned on only a very short time during the peak of the triangle waveform, Q13 will remain in the off state because of the feedback through R46, R47, R54, and R55. The output of Q11 is used to drive the diode gate.

DIODE GATE

As shown in Figure 3-7, the Diode Gate consists of four diodes, CR7 through CR10. Assume that the voltage at point C is +2.5 V. Diodes CR7 and CR9 are then forward biased, and CR8 and CR10 are reverse biased. The negative current source (I−) will draw current from the Hysteresis Switch through CR9, but the positive current source (I+) will charge up the timing capacitor "C" through CR7.

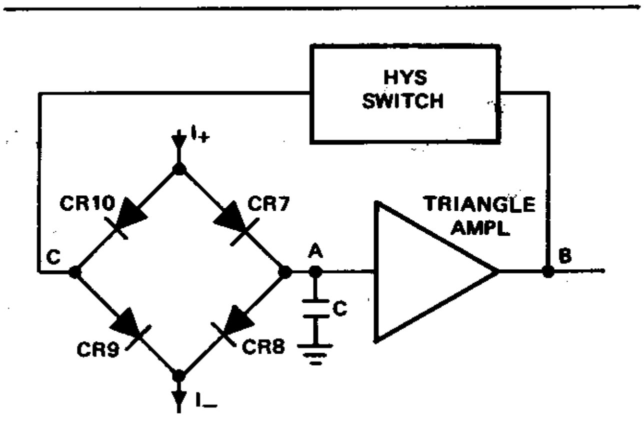


Figure 3-7 - Simplified Diode Gate Diagram

The result is a linear rise of voltage across the timing capacitor. When this voltage reaches +1.25 volts, the output of the Hysteresis Switch will change to −2.5 volts. In this state, CR8 and CR10 are forward biased and CR7 and CR9 are reverse biased. The positive current will be diverted to the Hysteresis Switch through CR10 and the negative current source will draw current from the timing capacitor through CR8. This action causes a linear discharge of the timing capacitor. The process is repeated, thus a triangle waveform is generated.

SINE CONVERTER AND AMPLIFIER

The Sine Converter is a sealed subassembly containing matched diodes and precise current-biasing resistive networks. When a precise triangle wave is fed into the shaping network, through voltage divider R149 and R148, the triangle wave is shaped into a sine wave. Potentiometers R159 and R168 adjust the voltage supplied to the sine converter to obtain minimum sine distortion. The amplitude of the sine converter output is approximately 250 mV p-p. This voltage is amplified to approximately 2.5 V p-p by the Sine Amplifier.

The Sine Amplifier consists of transistors Q30 through Q35 connected as a differential feedback amplifier. The gain of the amplifier is controlled by R165, R164, and R158. R145 and R146 compensate the source current into Q30 to minimize the distortion of the sine converter output.

SQUARE AMPLIFIER

The inverted output from Hysteresis Switch Q16 (±2.5 volt square wave) is fed to the Square Wave Shaper comprised of CR14 through CR19. For a square wave output, CR14 and CR19 are reverse biased. In one state, if the cathode voltage of CR15 is +2.5 volts, CR15 and CR17 will be reverse biased and CR16 and CR18 will be forward biased. The output at the cathode of CR18 is limited to +1.25 volts by the current through R63 and R64 into R69. When the input voltage is switched to −2.5 volts, CR15 and CR17 will be forward biased and CR16 and CR18 will be reverse biased, limiting the output at the cathode of CR18 to −1.25 volts by the current through R66 and R67 into R69.

When the positive pulse output is selected by the WAVEFORM SELECTOR switch, the cathode of CR14 is connected to ground through R61. In this configuration, the output at the anode of CR18 will be limited to a voltage swing of −1.25 and zero. Because the output amplifier is an inverting amplifier, the signal at the 50Ω OUT connector will be a positive pulse. In a similar manner, when the anode of CR19 is connected to ground through R61, the output swing at the cathode of CR18 will be limited to zero and +1.25 volts, resulting in a negative pulse at the 50Ω OUT connector.

C26 is a high frequency filter to filter the high frequency noise on the square wave, resulting in a cleaner signal. At this point, the output signal is buffered by a double emitter follower stage consisting of Q17 and Q18, and the output at the common emitters is applied to the output amplifier through the contacts of the WAVEFORM SELECTOR switch.

SYNC AMPLIFIER

The inverted output signal from Hysteresis Switch Q16 is also applied to another double emitter follower stage consisting of Q19 and Q20. The output at the common emitters of this stage is applied directly to the SYNC OUT connector at the front panel.

OUTPUT AMPLIFIER

The Output Amplifier is comprised of a low frequency dc amplifier and a high frequency ac amplifier. The high frequency amplifier consists of Q50 thru Q55. IC8, an integrated circuit, is the low frequency dc amplifier. A simplified schematic of the Output Amplifier is shown in Figure 3-8. Refer to figure 3-8 during the following circuit description.

Assume that both the input and the output voltages are zero. The voltage at point A should also be zero. Because of the symmetrical configuration of the amplifier, the current through Q52 and Q53 will be equal, and the output will remain at zero.

If the input voltage goes positive, the voltage at point A will rise by a certain amount. This will cause the base voltage of Q52 to rise closer to +28 volts and at the same time cause the base voltage of Q53 to rise further away from −28 volts. Thus, the emitter-base junction of Q52 will be less forward biased therefore reducing its emitter current, while the emitter current of Q53 will increase because of the increased forward bias of its emitter-base junction. The result is that the voltage at point B and the output voltage will start to go negative. Finally, when the output has moved far enough negative to pull point A back to zero, the collector currents of Q52 and Q53 will again be equal and the voltage at point B will stabilize. The amount of negative voltage at the output required to pull point A back to zero is controlled by the ratio of R_{fb} and R_{in}, and this ratio is the gain of the output amplifier.

IC8 is a high gain low frequency amplifier used to bias the high frequency amplifier and to improve the overall open

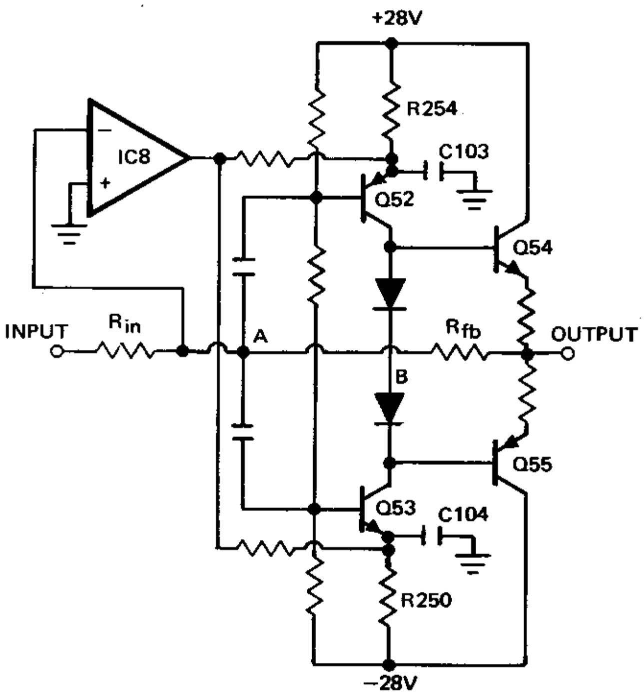


Figure 3-8 — Simplified Output Amplifier

loop gain. Refering back to the main board schematic, the high frequency amplifier is dc isolated from the input by capacitance coupling to the bases of Q50 and Q51, then employs the low frequency amplifier IC8 to bias the emitters of Q52 and Q53 to obtain the required dc stability and high open loop gain. Emitter followers Q50 and Q51 increase the driving power to the bases of Q52 and Q53.

CR34 and CR35 compensate for the emitter-base junction voltage drops of Q54 and Q55 to reduce crossover distortion. The resistor-diode networks CR36, R263 and CR37, R264 serve to reduce the emitter resistance of Q54 and Q55 at high output current level, but maintain a full 10Ω emitter resistance at low output current level to protect Q54 and Q55 from damage due to thermal runaway.

R234, C88, and C89 form a high frequency compensation network which improves the corners of the square wave output at high frequencies. The two resistor-capacitor networks, R252, C103, and R253, C104, are emitter bypass circuits to maintain the high frequency amplifier gain during the transition time prior to the dc amplifier taking effect. This improves the rise time since the dc amplifier requires a few microseconds to respond and stabilize. Another compensation is C97 which bypasses R247 to give the signal a low impedance path during the signal transition allowing faster and more symmetrical rise and fall times.

Potentiometer R228 is used to calibrate the gain of the amplifier and C95 is used to calibrate the overshoot of the square wave output. The 30 V P-P MAX control R172 provides continuous adjustment of the output level over a range of 0 to −20 dB. This is in addition to the attenuation provided by the output step attenuator. Calibration potentiometer R188 is used to zero the offset of the output amplifier, and R167 is the front panel DC OFFSET potentiometer.

OUTPUT ATTENUATOR

The Output Attenuator consists of four pi attenuators with some modification to minimize the number of components used. The four attenuators employed are −10 dB, −20 dB, or two −30 dB attenuators; all with 50Ω input and output impedances. When the OUTPUT ATTENuator control is used to select −10 dB, −20 dB, or −30 dB; only one pi attenuator is used. When −40 dB, −50 dB, or −60 dB is selected; the second 30 dB pi attenuator is used in series with the appropriate attenuator to yield the desired total attenuation.

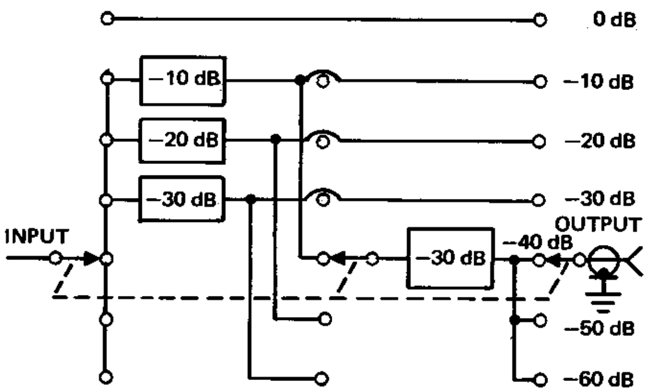


Figure 3-9 – Simplified Output Attenuator

3.2.2 Sweep Generator and Trigger Logic

Refer to Figure 3-10. The TRIG and GATED modes are made possible by the addition of two matched diodes, CR5 and CR6, to the Current Control Diode Bridge of the Main Generator. The remaining control circuits are located on the Sweep Board. Baseline correction circuits, the Diode OR Gate, and the Trigger/Gate Control circuit comprise the remaining circuitry.

In the standby condition, the output of the Triangle Amplifier (point B) is at zero volts. The Hysteresis Switch output is at a negative potential, thus switching off CR7 and CR9.

Current flows out of the baseline correction circuit while being controlled by the Trigger/Gate Control circuit on the Sweep Board. One half of the current flows through CR5 and CR8 to the negative current source (I−) and the other half of the current flows through CR6 to ground. This establishes ground potential at the cathode of CR5. When the anodes of CR5 and CR6 become negative, CR5 and CR6 are switched off, and the triangle generator begins to oscillate normally.

TRIGGER LEVEL COMPARATOR/SQUARING CIRCUIT

Refer to Figure 3-4, 3-10 and the Sweep Board schematic (144-212) at the rear of this manual.

IC1 forms a comparator-amplifier with an integrated constant current source. When the positive portion of an input triggering signal overcomes the trigger level set by TRIG LEVEL control R1, input transistor of IC1 turns on, forcing output transistor of IC1 to turn off. Q3 and Q4 form a pair of Differential Switches to shift the voltage output of IC1 back to the ground reference signal while further speeding up the switching action. When the negative portion of an input triggering signal overcomes the hysteresis established by R6 and R7, input transistor of IC1 turns off, forcing output transistor of IC1 to turn on.

Thus, the output of the Trigger Level Comparator/Squaring Circuit, at the collector of Q3, is a pulse with rapid rise and fall times. This pulse has a duration determined by the width of the input signal applied to the TRIG IN connector and the threshold established by the TRIG LEVEL control, except when a step voltage is applied.

Q5 and Q6 are inverting Saturated Switches for the GATED and the SWP HOLD modes. These Saturated Switches further reduce the rise and fall times of a gating pulse created by the Trigger Level Comparator, Squaring Circuit. In the TRIG or TRIG SWP modes, Q5 and Q6 are coupled through a small capacitor (C3 and C4) to create narrower pulses for triggering the respective circuits.

TRIGGER/GATE CONTROL

The Trigger/Gate Control circuit is best understood by studying the timing relationship shown in Figure 3-10 when the generator is in the GATED mode. When a signal is applied to the TRIG IN connector and the TRIG LEVEL control is adjusted properly, a gating pulse appears at the collector of Q6. This pulse is coupled through the MODE switch to the direct set (pin 9) input of IC6, a J-K flip-flop. The positive signal at pin 9 forces the output $\overline{Q}$ (pin 6) change state to ground potential. The output is shifted in level by Q38 and Q39 to a negative potential. Diodes CR8 and CR11 form an "OR" Gate. As soon as the emitter of Q39 becomes negative, the (2I+) current out of the baseline correction circuit stops flowing through CR5 and CR6, removing the effective shunt path of the integrator in the Main Generator. The integrator output moves

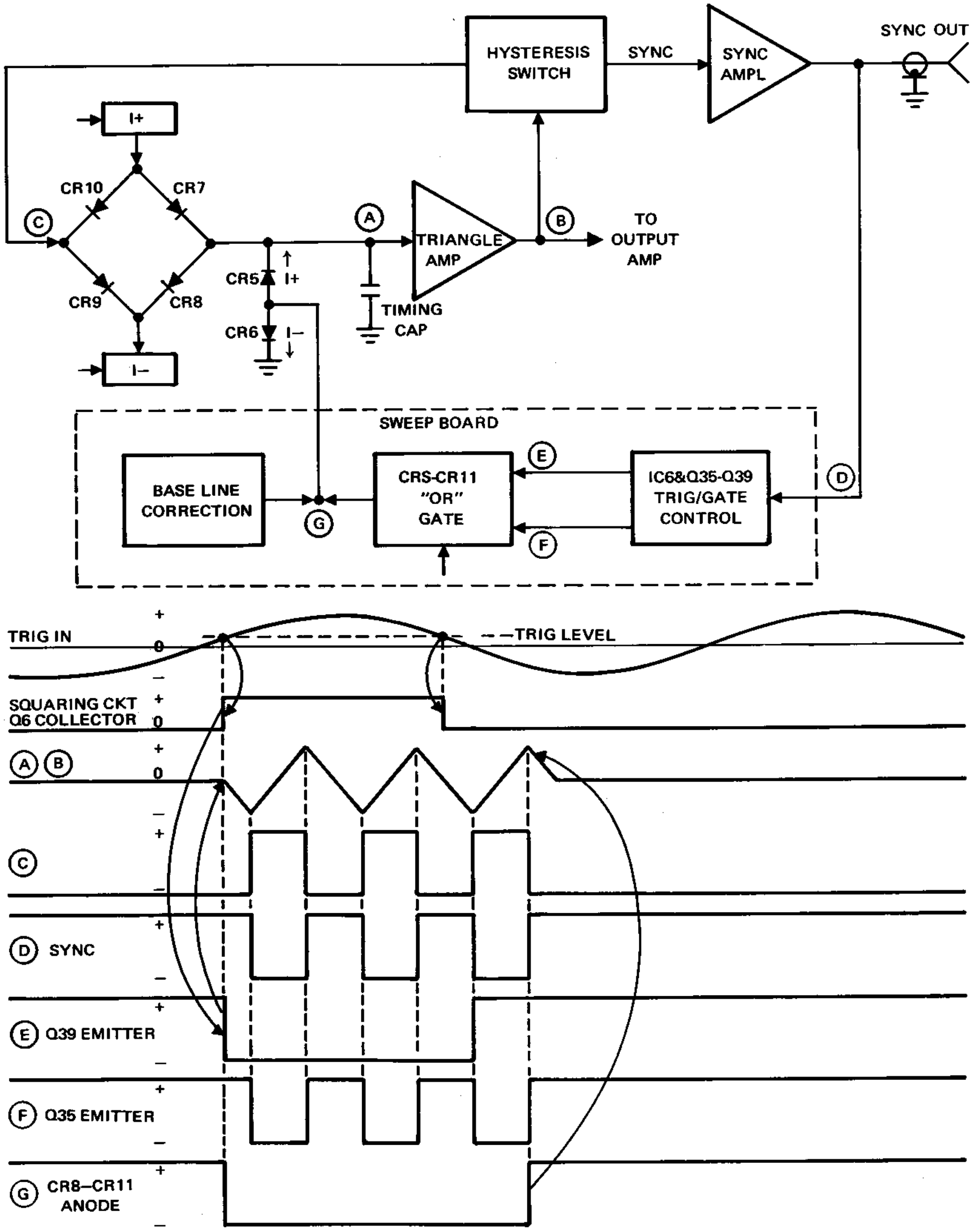


Figure 3-10 – TRIG and GATED Modes

initially positive since the output switch is at a negative potential when the generator is in a standby state.

The Main Generator functions normally, as if in the CONT mode, for the duration of the gating pulse. Although the sync pulse is applied to the clock input of IC6, the input signal is overridden by the positive gating potential at the direct set input (pin 9) and $\overline{Q}$ remains at ground potential. When the gating signal returns to ground potential, IC6 is ready to resume its initial state triggered by the next negative portion of the sync pulse. The output of IC6 is level-shifted and gated with sync output. When both Q39 and Q35 emitters become positive, the anodes of CR8 and CR11 become positive. Thus, (2I+) current out of the baseline correction circuit flows through CR6 to ground. Since point C becomes negative when the sync pulse changes its state, point A moves toward the negative potential until the current through CR8 is completely supplied through CR5, thus clamping point A to ground. See Figure 3-10 for a diagram of the timing relationship.

BASELINE CORRECTION CIRCUIT

The Baseline Correction Circuit is, essentially, a current source as described in the Main Generator description. The purpose of this circuit is to provide twice as much current as the negative current source (I–) for the integrator of the Main Generator, so that the baseline remains at zero volts when the generator is in the standby condition for the TRIG or GATED modes. The output of the negative current source in the Main Generator is used to control this positive current source.

The current at TP9 is fed to the positive input of IC4 through R78. IC4 and Q30 form a voltage follower such that the same amount of current flows through R82 and R83, with CR17 acting as a voltage shifter. Q32, IC5, Q33, and Q34 form another voltage follower which produces twice as much current as the Main Generator negative current source (I–). R85 is provided to adjust the dc offset of the second voltage follower. This adjustment is made when the generator is in the TRIG or the GATED mode. R85 is set to 1/1000th of the maximum frequency for the range, thus, allowing the minimum amount of current flow through the programming resistor.

SWEEP GENERATOR

Voltage Controlled Current Source

Transistors Q7, Q8, and Q9 together with resistors form a current source for the passive integrator. Since the collector of Q7A is held at a constant voltage by the reference diode Q8, the collector of Q7B is a current source for the passive integrator. Since the collector of Q7A is held at a constant voltage by the reference diode Q8, the collector of Q7B is a current source output which is controlled by the range resistors and the VERNIER potentiometer R33. The transistor Q9 is a transistor switch which turns off the current source when the emitter is grounded since Q9 becomes a zener diode and biases the emitter of Q7B to be nearly equal to the base.

Voltage Follower

The transistors Q15 through Q22 form a noninverting isolation amplifier for the passive integrator. The potentiometer R43 adjusts the dc offset of the amplifier. Q17 and Q18 are matched junction field effect transistors which provides high input impedance and wide band response.

Q15 and Q16 are constant current source providing high voltage gain to the Q17 and Q18 stage. The output is buffered and level-shifted by Q19 and Q21. Q20 and Q22 form a push-pull emitter follower in order to provide the low impedance output.

Peak Detector

Q24 is the peak detector. Q24A turns off when the positive peak is reached since the Q24B is referenced to +5 volts. The adjustment of sawtooth peak voltage is accomplished by potentiometer R75. When Q24A turns off, Q26 turns off, thus allowing the Q28 to turn on. Q28 in turn changes the reference voltage of Q24B to zero volt. Q14 also turns off when Q24A turns off. Thus, Q12 turns on, discharging the timing capacitor.

Zero Detector

Q25 is the zero detector. Q25B is referenced to ground. Thus, Q25A turns on only when the sawtooth output reaches near zero volt. When Q25A turns on, Q27 turns on, which in turn turns off Q28, allowing the peak detector reference to return to the normal voltage (+5 volts). Q24B turns off. Then Q24A turns on, causing Q14 to turn on. The discharging path through Q12 for the timing capacitor is removed, allowing the integrator to move toward the positive peak. Thus, continuous generation of the sawtooth wave is accomplished.

When the Model 144 is in the TRIG SWP mode, IC3 output (Q) is positive. Therefore, Q10 and Q11 are on while Q9 is turning off the current source. The timing capacitor is shorted to ground through Q10. When a trigger pulse is applied to the direct clear input (C_D) of the IC3 the output immediately changes the state allowing Q9, Q10, and Q11 to turn off. The integration takes place. When the peak voltage is reached, the output of Q23 emitter follower creates a narrow pulse to toggle the IC3.

The output of IC3 becomes positive turning Q10 and Q11 on. Thus the single sawtooth output is created.

When the Model 144 is in the SWP HOLD mode, emitters of Q26, 27, and 28 are tied to ground through the MODE selector. Therefore, those transistors and the zero detector are not in a part of the operation. It is also to be noted that the peak voltage reference is not switched when the peak voltage is detected. In the standby state, when the trigger input voltage is less than the trigger level setting, the gate of Q10 is forced to ground. The current source is switched off and the timing capacitor is discharged through Q10. Therefore, the output of the sawtooth amplifier is at ground. As soon as the trigger input overcomes the trigger level setting, the ground signal at the gate of Q10 is removed, positive integration takes place and the timing capacitor is charged up to +5 volts. When Q24A detects the voltage, Q12 turns on harder and begins to discharge the timing capacitor. As soon as the capacitor voltage decreases, Q24A begins to turn on harder, forcing Q14 to turn on and Q12 to turn off. The result is a balanced condition at +5 volts as long as the trigger input exceeds the trigger level setting.

GCV Amplifier

Generator controlled voltage (GCV) is provided for all three sweep modes of the Model 144.
IC2 is a unity gain inverting amplifier which converts the VCG amplifier output (0 to −5 volts) to 0 to +5 volts.

Power Supply

AC voltage is coupled from the transformer secondary to the bridge rectifiers CR1 through CR8. Filtering is provided by C1, C2, C10, and C12. Q9 is connected and operated as a zener reference for the +15 V supply. IC1 is a comparator differential amplifier whose output is used to drive transistor amplifier Q4, whose output at the collector is used to drive a Darlington connected pair consisting of Q1 and Q2. The Darlington connected pair provides added current gain; Q3 is a current limiting device. The base voltage of Q3 is a current limiting device. The base voltage of Q3 is biased by voltage divider R5 and R7 to be slightly below +15 volts. Therefore, for normal operation Q3 is reverse biased and no current flows through its collector. However, when the output current from the +15 volts exceeds a certain limit, the voltage drop across R12 will increase to a point exceeding the total voltage across R5 plus the base-emitter voltage of Q3, forward biasing Q3. The current driving the base of Q2 will be diverted to the collector of Q3, causing the power supply voltage to drop below normal operating voltage. As the power supply voltage drops, voltage divider R5 and R7 has more effect on the base of Q2; eventually turning it off completely. When the overload condition is removed, the normal condition will be restored.

The diode, CR9, across the input terminals of IC1 prevents latch-up. Potentiometer R21 is used to calibrate the +15 volt supply. The −15 volt, and ±28 volt supplies have similar circuitry. The −15 volt supply is referenced to the +15 volt supply while the +15 volt supply is referenced to the −15 volts. The −28 volt supply is referenced to the −15 volts, and the +28 volts is referenced to the +15 volt supply.

SECTION 4
MAINTENANCE

4.1 ACCESS INSTRUCTIONS

Removal of the dust cover affords quick access to the majority of components within the unit. However, it may be necessary to remove the Power Supply Board or other parts to gain access to those components not exposed by removing the dust cover.

4.1.1 Removing the Dust Cover

To remove the dust cover (case) from the Model 144, the following procedure should be followed:

1. Unplug the power cord and unscrew the two captive screws on the rear panel.

2. Remove the rear casting and with the instrument setting face down, lift the cover off slowly.

3. Reverse this procedure when replacing the dust cover. Tighten the two captive screws only finger-tight.

4.1.2 Removing the Power Supply Board

1. Remove two screws holding the Power Supply Board to the two side panels.

2. Loosen the two screws (from the outside of the rear plate) which holds the heat sink for the four power supply transistors.

3. Flip the Power Supply Board out of the chassis, toward the rear, and mount the board on the outside of the rear plate using the same two screws and the same two holes used to mount the heat sink.

NOTICE

This instrument can be operated with the power supply board mounted on the outside of the rear plate. However, it should never be operated without having the heat sink of the power supply board connected to the rear plate of the unit, as the rear plate is also used as a portion of the heat sink for the power transistors.

NOTICE

4.1.3 Removing the Sweep Board

1. Remove the front panel knobs labeled TRIG LEVEL, MODE, VARIABLE and SWEEP TIME.

2. Loosen one of the set screw in the shaft-coupler of the SWEEP WIDTH control.

3. Loosen the screws which hold the Sweep Board to the two side panels.

4. Label and disconnect the four wires connected to the TRIG IN and SWP/GCV OUT connectors.

5. Remove the Sweep Board by sliding the Board toward the rear panel.

4.1.4 Removing the Attenuator Bracket

1. Remove the OUTPUT ATTEN knob.

2. Label and unsolder the wires connected from the attenuator to the BNC connector and main circuit board.

3. Loosen the two screws which mount the bracket to the Main Circuit Board.

4.1.5 Replacing Q54 and Q55

1. To remove the transistor, unscrew the nuts holding the transistor to the base of the heat sink and unsolder the transistor leads on the main circuit board. Then remove the transistor.

2. Before replacing the transistor, put some thermal compound or silicon grease along both sides of the bottom edge of the transistor for good thermal contact.

4.1.6 Front Panel Removal

1. Remove the rear panel and dust cover as described above, and unplug all the knobs.

2. Unsolder all BNC connectors, label and unsolder FREQUENCY DIAL potentiometer leads and unscrew the two nuts which hold the power transistors into the heat sinks.

3. Remove bulb from the indicator lamp, and remove four front panel retaining screws.

4. Pull the front panel straight forward to remove it.

4.2 CALIBRATION INSTRUCTIONS

This paragraph provides complete sequential calibration instructions for this instrument. The instructions are concise and are written for the experienced electronics technician or field engineer having a working knowledge of this type of instrumentation.

WAVETEK maintains a factory repair department for those customers not possessing the necessary test equipment or personnel to maintain this type of instrument. If an instrument is returned to the factory for calibration or repair, a detailed description of the specific problem should be attached. This will hasten turnaround time.

4.2.1 Recommended Test Equipment

The following test equipment (or equivalent) is recommended for this calibration procedure. A quick checkout of the instrument can be made by comparing the indicated parameters with those given in the specifications portion of Section 1.

Table 4-1. TEST EQUIPMENT

Name	Required Characteristics	Recommended Manufacturer	Model
Oscilloscope	To 250 MHz	Tektronix	454
Oscilloscope	To 30 MHz	Tektronix	544
Plug-In	Dual Channel	Tektronix	1A1
Plug-In	Peak mV measuring capability	Tektronix	1A5
Distortion Analyzer	To 600 kHz	Hewlett-Packard	334A
Spectrum Analyzer Display	To 50 MHz	Hewlett-Packard	141S
IF Section		Hewlett-Packard	8552A
RF Section		Hewlett-Packard	8553L
Differential Voltmeter	Microvolt dc measurement		
Counter	To 10 MHz	0.1% of reading accuracy	

NOTE

The entire calibration procedure must be read first to determine initial control settings and test equipment connections required before attempting recalibration. The steps of this procedure should be performed in the sequence given, and the parts within each step should also be performed in the same sequence given.

4.2.2 Preliminary Procedures

1. Set the front panel controls to the positions listed:

FREQ Hz	X 100
FREQ DIAL	10
WAVEFORM SELECTOR	Sine
30 V P-P MAX	3/4ths of full CW
DC OFFSET (in rear panel)	OFF
SYMMETRY (in rear panel)	OFF
OUTPUT ATTEN	−10 dB
VERNIER	full CW
MODE	CONT
SWEEP TIME	OFF
SWEEP WIDTH	CCW

4.2.3 Power Supply Regulation

2. Following the instructions in paragraph 4.1.2, attach the Power Supply Board to the rear plate of the instrument.

3. Connect ac power to the instrument, and connect the voltmeter leads to TP1 (common) and TP2 (+15 V) on the Power Supply Board. See Figure 4-5

4. Adjust R21 for a reading of +15 Vdc ±20 mV on the voltmeter.

5. Check the voltage at TP3 for −15 Vdc ±50 mV; at TP4 for +28 Vdc ±400 mV; and at TP5 for −28 Vdc ±400 mV.

6. Replace the board and the dust cover, and allow the generator to warm up for at least 1/2 hour before calibration.

4.2.4 VCG Amplifier — Zero Offset Adjustment

7. Connect a 5.1 kΩ resistor to each test lead of the differential voltmeter for isolation to prevent integrated circuit oscillations.

8. Set FREQ HZ to X 100, FREQ DIAL to full clockwise extreme, FREQ VERNIER to CAL, and SYMMETRY to OFF.

9. Set the voltage between IC3(2), and IC3(3) to 0 Vdc ±100 μV, using R107. See Figure 4-4.

10. Set the voltage between IC4(2), and IC4(3) to 0 Vdc ±100 μV, using R113.

11. Set the voltage between IC5(2), and IC5(3) to 0 Vdc ±100 μV, using R123.

12. Set the voltage between IC6(2), and IC6(3) to 0 Vdc ±100 μV, using R125.

13. With FREQ DIAL still fully clockwise, set the voltage between IC2(2) and ground (at R95) to 0 Vdc ±100 μV, using R93.

14. Set FREQ DIAL to 1 and adjust voltage between TP6 and TP7 to 0 Vdc ±200 μV, using R129.

15. Adjust voltage between TP8 and TP9 to 0 Vdc ±200 μV, using R132.

4.2.5 Triangle Amplitude Adjustment

16. Set FREQ HZ to X 100, FREQ DIAL to 10, WAVEFORM SELECTOR to TRIANGLE, and SYMMETRY to OFF.

17. Connect the oscilloscope probe (a type W or 1A5 plug-in module should be used with the scope) to ∿ position of the WAVEFORM selector switch, SW2, see Figure 4-4.

18. Adjust the triangle amplitude to ±1.25 V ±5 mV, using R12 and R23, see Drawing 142-010.

4.2.6 Sine Distortion

19. Set FREQ HZ to X 100, VERNIER to CAL, WAVEFORM SELECTOR to SINE, FREQ DIAL to 10, and OUTPUT ATTEN to 0 dB.

20. Set 30 V P-P MAX control to 3/4ths of full CW, and connect oscilloscope probe to ∿ position of the WAVEFORM selector switch (SW2), see Figure 4-4.

21. Adjust R153 so that the dc offset of the sine amplifier is zero.

22. Connect the test equipment as shown in Figure 4-1, and adjust R159, R168, and R145 for minimum sine wave distortion.

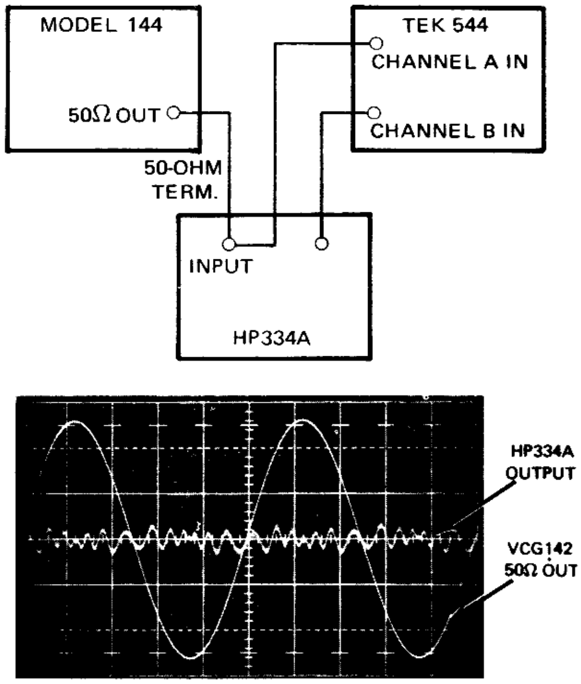


Figure 4-1 - Distortion Analysis Test Set-Up

23. Set FREQ HZ to X 1K and readjust R159, R168, and R145 for optimum sine distortion.

24. Set FREQ HZ to X 100 and readjust R159, R168, and R145 if necessary

25. Alternately perform steps 24 and 25 until the least amount of sine wave distortion is obtained on both ranges — typically .14%.

26. Adjust R165 for a 2.5 V p-p signal output from the sine amplifier ±25 mV.

27. Readjust R153 so that the dc offset of the sine amplifier is 0 V ±5 mV.

28. Connect the Spectrum Analyzer as shown in Figure 4-2, and check the sine wave distortion at frequencies higher than 600 kHz. If distortion does not meet the specification, check calibration of C95, follow procedure 4.2.10.

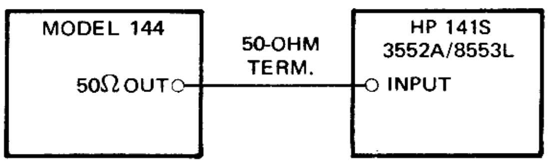


Figure 4-2 - Spectrum Analysis Test Set-Up

4.2.7 Frequency Calibration

29. Set FREQ HZ to X10K, FREQ DIAL to 10, VERNIER to CAL, and adjust R269 to obtain 100 kHz ±100 Hz.

30. With FREQ HZ still at X10K, FREQ DIAL fully clockwise, VERNIER fully counterclockwise, and adjust R87 to obtain an output of 75 Hz ±5 Hz.

31. Rotate VERNIER to CAL position. The output frequency should be less than 1 kHz.

32. Set FREQ HZ to X1M, FREQ DIAL to 9, and adjust C1 to obtain an output frequency of 9 MHz ±10 kHz. Check frequency accuracy from 1 to 10 of the DIAL and readjust C1 to split the error if necessary.

33. Set FREQ HZ to X100K, FREQ DIAL to 10, VERNIER to CAL, and adjust C10 to obtain 1 MHz ±1 kHz at the output. Check frequency accuracy from 1 to 10 of the DIAL and readjust C1 to split the error if necessary.

34. Set FREQ DIAL to 10, VERNIER to CAL.

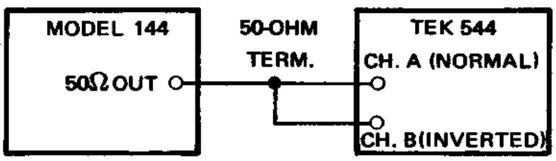
35. Set FREQ HZ to X1K, adjust R268 to obtain 10 kHz ±10 Hz.

36. Set FREQ HZ to X100, adjust R267 to obtain 1000 Hz ±1 Hz.

37. Set FREQ HZ to X10, adjust R84 to obtain 100 Hz ±0.1 Hz.

4.2.8 Time Symmetry Adjustment

38. Refer to the following test set-ups during these calibration instructions.



Trigger: Internal

Display: Alternate

Time Base: .1 ms/division for 1/1000th of X100K range.

Figure 4-3 - Time Symmetry Measurement Test Set-Up

39. With 50Ω OUTPUT connected to the oscilloscope; set FREQ HZ to X 100K, FREQ DIAL to full clockwise extreme, and WAVEFORM SELECTOR to SQUARE WAVE.

40. Adjust the scope controls for a display speed of .1 ms/cm and adjust VERNIER control until the oscilloscope screen is filled by one complete cycle.

41. Alternately adjust R123 and R125 for optimum sine symmetry, while keeping the total time period constant.

4.2.9 Output Amplifier Adjustment

42. With the 50Ω OUT connected to the oscilloscope using a 50Ω ±1% termination; set FREQ HZ to X 100, FREQ DIAL to 10, WAVEFORM SELECTOR to TRIANGLE and step attenuator to 0 dB.

43. Set 30 V P-P MAX control fully counterclockwise, and adjust R188 for amplitude symmetry about ground.

44. Set 30 V p-p control fully clockwise, and adjust R228 for a 15 V p-p output amplitude.

45. Set WAVEFORM SELECTOR to SQUARE WAVE, and adjust R66 for +7.5 V and R63 for −7.5 V peak amplitude. (15.0 V p-p.)

4.2.10 High Frequency Response Adjustment

46. Set FREQ HZ to X 1M, FREQ DIAL to 1, and WAVEFORM SELECTOR to SQUARE WAVE.

47. Adjust C95 for best square wave, without peaking, from 5 V p-p to 10 V p-p output amplitude.

48. Set WAVEFORM SELECTOR to SINE WAVE. FREQ DIAL to 10.

49. Adjust C48 to obtain 14 V p-p output amplitude.

4.2.11 Sweep Board Adjustment

50. Set MODE selector to CONT and SWEEP TIME selector to OFF.

51. Connect oscilloscope probe to the sweep output at the junction of R52 and R53.

52. Adjust R43 to set output at −20 mV.

53. Set SWEEP TIME selector to 100 mS/10 mS and the VARIABLE to fully CW.

54. Adjust R71 to set the lower peak of the sawtooth wave for −10 mV and R75 to set the upper peak of the sawtooth wave for +5.100 volts at SWP/GCV OUT connector.

55. Check for less than 100 mV shift of the lower peak of sawtooth between 10 mS/1 mS 100 mS/10 mS ranges.

56. Set MODE selector to CONT SWP, SWEEP TIME selector to OFF, and frequency dial to 10.

57. Adjust R22 to obtain +5 V ±50 mV at SWP/GCV OUT connector.

58. Connect a cable between SWP/GCV OUT and TRIG IN connectors.

59. Set SWEEP TIME selector to 1 mS/100 μs; variable fully CW; MODE selector to TRIG; frequency range to X 100 kHz and 10 on dial; OUTPUT ATTEN to 0 dB; variable attenuator to fully CW; and waveform to ∿

60. Adjust R4 (on mainboard) to set the base line of the triangle wave to 0 ±25 mV at 50Ω out connector.

61. Set frequency dial fully CW and frequency VERNIER fully CCW, adjust R85 to set the base line to 0 V. Check that the base line should remain within ±50 mV at all frequency dial settings.

62. Set function selection to ∿ and frequency dial at 10.

63. Adjust the base line to 0 ±20 mV by R153 on mainboard.

4.3 CORRECTIVE MAINTENANCE

If the instrument appears to be operating abnormally, and an investigation of input/output connections, as well as a calibration check, do not cure the problem; follow the trouble-shooting procedure outlined below. Localize the fault to a specific stage by following the outline in Table 4-2. Then check the dc operating voltages at the pins of the solid-state devices, and check passive components with a high input impedance ohmmeter (power off) before replacing a suspected semiconductor element.

Table 4-2. TROUBLE-SHOOTING GUIDE

Symptom	Corrective Action
Blown Line Fuse	Replace F1 with a slow blow fuse of the proper amperage. If fuse blows again, check the following: a) Q45 or Q47 may be shorted between the collector and emitter. b) Q1, Q8, Q10, or Q16 on power supply board may be shorted to the heat sink bracket. c) A capacitor or transistor may be shorted. d) Check for loose wires or solder bridges on each printed circuit board.
Power Supply Malfunctions	If there is a symptom of power supply malfunction, disconnect all wires between the power supply board to the main board and sweep board and check the following: a) All power supply output voltages. If all are either too high or too low, the trouble is probably in the +15 V supply as all supplies are directly or indirectly referenced to it. b) Check CR9 through CR12. A defective or incorrectly polarized diode will cause the integrated circuits to latch up. c) Reference voltage at collector of Q9 should be +6.6 V ±0.3 V with +15 V in normal condition.
No Output Signal	a) Power Supply Malfunctions b) For MODE switch at CONT position, disconnect the wire

Symptom	Corrective Action
	connected between the anode of CR5 and Sweep Board. If output is back to normal, trouble is on the Sweep Board. Check for defective Q35, Q39 and other circuitry on the Sweep Board. Otherwise, trouble is on the Main Board.
No Output Signal . . . . but SYNC output normal	The output amplifier is malfunctioning; see Output Amplifier Check outlined below.
No SYNC Output. . . . . but Output normal	The Sync Amplifier is malfunctioning; Check Q19 and Q20 for proper operation.
No SINE Output . . . . TRIANGLE and SQUARE are OK	Sine Amplifier is malfunctioning; See Sine Amplifier Check outlined below.
Badly Distorted SINE Output . . . . TRIANGLE is OK	Sine Module is malfunctioning and should be replaced. First Check Q34 or Q35 for possible trouble.
No SYNC and 50Ω OUTput	The Triangle Generator is not functioning properly. Check Triangle Amplifier, Hysteresis Switch, Diode Gate, and VCG circuits.
SQUARE WAVE Output . . . . has Abnormally Slow Rise or Fall Times	Check all bypass capacitors (C103, C104, C93, C94 and C97) in the Output Amplifier. Check Output Amplifier as outlined below.
TRIANGLE Output has Constant. . . . . Positive Slope with change of Frequency	Check Q23 and Q25 for possible trouble; then check IC4 and IC6 and their associated circuitry.
TRIANGE Output has Constant . . . . Negative slope with Change of Frequency	Check Q22 and Q24 for possible trouble; then check IC3 and IC5 and their associated circuitry.
Checks	
VCG Amplifier & IC3-IC6	With SYMMETRY control set to NORM, slowly turn FREQ DIAL from 0.1 to 10 and observe the following: a) Voltage at emitter of Q21 should move from 0 to −5 volts. b) Source of Q22 remains at 0 and drain moves from +15 V to +10 V. c) Source of Q23 moves from 0 to −5 V and drain moves from −15 V to −10 V. d) Source of Q24 moves from +15 V to +10 V. e) Source of Q25 moves from −15 V to −10 V. f) Voltage at drain of Q27 follows voltage at gate of Q26. g) Voltage at drain of Q29 follows voltage at gate of Q28.
Continue Signal Output at TRIG & GATED MODE . . .	a) Check the proper operation of IC4, IC5, Q32 and the associated circuitry on the Sweep Board. b) Check for the correct logic level according to the proper table below.

Symptom	Corrective Action
No SWP Output at CONT, TRIG & GATED MODE . . .	a) Check the proper operation of ramp amplifier, Q17 through Q22 on Sweep Board. b) Check for defective transistors Q8 through Q28. c) Check the proper logic level following the table of CONT MODE.
No GCV Output at CONT SWP, TRIG SWP, and SWP HOLD MODE	Check the proper operation of IC2 on Sweep Board.
Triangle Amplifier Check	Short the gate of Q1 to ground and check the following: a) Gate of Q2 is at 0 volts. b) Voltage across C14 is approximately 6.6 volts. c) If "a" or "b" is not true, check all transistors in Triangle Amplifier for possible trouble.
Hysteresis Switch Check.	a) Voltage at collector of Q9 is approximately 6.6 volts. b) Voltage at collector of Q14 is approximately 7 volts. c) Voltage at junction of R49 and R50 is approximately −3 volts. d) For normal operation, voltage at the emitters of Q11 and Q16 switches between +2.5 volts and −2.5 volts. If switch does not oscillate, proceed as follows: e) If voltage at gate of Q2 is greater than +1.25 V, the voltage at the emitter of Q16 should be +2.5 V and the emitter of Q11 should be −2.5 V. If the voltage at the gate of Q2 is less than −1.25 V, the voltage at the emitter of Q16 should be −2.5 V and the emitter of Q11 should be +2.5 V or the Hysteresis Switch is malfunctioning. f) Q10 should be saturated if voltage at pin 1 of IC1 is above ground, and Q15 should be saturated if voltage at pin 4 of IC1 is below ground. g) If Hysteresis Switch appears to function normally, and Triangle Amplifier also appears to function normally, but no oscillations are present at the output; check CR7 through CR10, Q24 and Q25.
Sine Amplifier Check	If the voltage at the bases of Q30 and Q31 are not equal, check Q30 through Q35 for possible trouble.
Output Amplifier Check	Check the collector and emitter voltages of all transistors in the Output Amplifier circuit. Some key voltage test points are listed below: a) Voltage at junction of C94 and C93 is zero volt. b) Voltage at base of Q52 is approximately +19 volts. c) Voltage at base of Q53 is approximately −19 volts. d) Voltage at pin 12 of IC8 is between −5 volts to +10 volts.