

INSTRUCTION MANUAL  
**MODEL 148A**  
**20 MHz**  
**AM/FM/PM GENERATOR**

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# SECTION 1

## GENERAL DESCRIPTION

### 1.1 THE MODEL 148A

Wavetek Model 148A, 20 MHz AM/FM/PM Generator is a precision source of sine, triangle, square, ramp and pulse waveforms plus dc voltage. The waveforms may be controlled in symmetry as well as amplitude and dc offset. A built-in modulation generator can modulate frequency, phase and amplitude or modulation may be by an external source.

The generator may be run in continuous mode or triggered for a single pulse or gated for a burst of pulses. Triggering and gating may be by the Model 148 built-in modulation generator or by an external source. The triggered and gated waveform start/stop point is selectable from  $-90^\circ$  through  $+90^\circ$ . Start/stop control plus dc offset control gives haverswave capability.






The main output of waveforms may be attenuated and offset. A TTL sync pulse is available at main generator frequencies, and the modulation generator waveforms are available at fixed amplitudes.

Frequency of both the main generator and the modulation generator can be manually controlled at the front panel or electrically controlled by external voltages.

### 1.2 SPECIFICATIONS

#### 1.2.1 Main Generator

##### 1.2.1.1 Waveforms

Selectable sine , triangle , square , positive square , negative square  and dc. A TTL sync pulse is provided on a separate output connector. All can be produced with variable symmetry, amplitude and dc offset.

##### 1.2.1.2 Operational Modes

Continuous: Generator oscillates continuously at the selected frequency.

External Trigger: Generator is quiescent until triggered by an external signal, then generates one cycle at the selected frequency.

External Gate: Same as external trigger, except generator oscillates at the selected frequency for the duration of the positive state of the external signal plus the time to complete the last cycle.




Internal Trigger: Same as external trigger, except that the modulation generator is internally connected to the trigger input of the main generator.






Internal Gate: Same as external gate, except that the modulation generator is internally connected to the trigger input of the main generator.

#### 1.2.1.3 Modulation Modes

##### Internal Modulation

Setting a front panel modulation switch in the INT position routes the selected modulation function from the modulation amplitude control to the selected modulating circuits of the main generator.

Amplitude Modulation (AM):  ,  modulation functions are used in this internal modulation mode. With modulation amplitude ccw, carrier at function output is not amplitude modulated and approximately half of normal (AM OFF) amplitude. Clockwise rotation of modulation amplitude results in increasing amplitude modulation of the carrier to at least 100% AM.

Frequency Modulation (FM) and Sweep:  and  modulation functions are used to linearly sweep the main generator frequency. The frequency dial sets the lower sweep limit and the modulation amplitude control determines the upper frequency limit (not to exceed 2.0 x multiplier). A sweep set mode allows precision setting of upper frequency limit. For frequency deviation, the dial determines the center frequency and modulator ,  or  varies the main generator frequency above and below

center by an amount determined by the modulation amplitude.

-Phase Modulation (PM): As in External Modulation. Amplitude of modulator  $\sim$ ,  $\wedge$ ,  $\sqcap$  functions varies phase up to  $\pm 50^\circ$ .

### External Modulation

A BNC feeds an external signal to the modulating circuits when selected by a front panel modulation toggle switch in the EXT position.

Amplitude Modulation (AM): External modulating signals with zero dc component produce suppressed carrier modulation; i.e., a carrier (at main generator function output) amplitude of zero. The function output modulated signal has an amplitude sensitivity of 3 volts peak (1.5 Vp into 50 $\Omega$ ) per volt peak in. A carrier signal level at the function output can be produced at a sensitivity of 3 Vp (1.5 Vp into 500) per 1 Vp dc component in. Modulating the dc component modulates the carrier level. Percent modulation (AM) will be the ratio of the peak ac to peak dc of the modulating signal. Input impedance is >2.5 k $\Omega$ .

Frequency Modulation (FM) and Sweep: Sensitivity is 20% of frequency range/volt peak. Linear behavior results only when all instantaneous frequencies called for fall within the frequency range (2  $\times$  multiplier to 0.002  $\times$  multiplier). The instantaneous frequency called for is the multiplier and dial setting altered by the instantaneous voltage at the modulation input. Input impedance is 5 k $\Omega$ .

Phase Modulation (PM): Sensitivity is 10 $^\circ$  phase shift/volt peak. Linear behavior results only when all instantaneous transition frequencies called for fall within the frequency range (2  $\times$  multiplier to 0.002  $\times$  multiplier). The instantaneous frequencies called for will depend heavily on the modulation frequency, and waveform. Inoperative at frequency multiplier settings below 100. Input frequencies roll off at 6 dB/octave above one half of full range frequency and above 150 kHz. Input impedance is 10 k $\Omega$ .

#### 1.2.1.4, Frequency Range

**0.0002** Hz to 20 MHz in 10 overlapping ranges with approximately 1% vernier control.

#### 1.2.1.5 Function Output(50 $\Omega$ )

$\sim$ ,  $\wedge$  and  $\sqcap$  selectable and variable to 30V p-p (15V p-p into 50 $\Omega$ ).  $\sqcup$  and  $\sqcap$  up to 15 Vp (7.5 Vp into 50 $\Omega$ ). All waveforms and dc can supply 150 mA

peak current and may be attenuated to 60 dB in 20 dB steps. An additional 20 dB vernier also controls the waveform amplitudes.

#### 1.2.1.6 Adjustable Waveform Start/Stop Point

Approximately  $-90^\circ$  to  $+90^\circ$  to 2 MHz (operative on sine and triangle waveforms only).

#### 1.2.1.7 DC Output and DC Offset

Selectable through function output (50 $\Omega$ ). Controlled by front panel controls to a minimum of  $\pm 14.4$  Vdc ( $\pm 7.2$  Vdc into 50 $\Omega$ ) with signal peak plus offset limited to  $\pm 15$  Vdc ( $\pm 7.5$  Vdc into 50 $\Omega$ ). DC offset and wave form attenuated proportionately by the 60 dB output attenuator.

#### 1.2.1.8 External Modulation Input

AM: Sensitivity of 3 Vp out/Vp (1.5V into 50 $\Omega$ ). Input impedance is >2.5 k $\Omega$ .

FM: Sensitivity of 20% of frequency range/Vp. Input impedance is 5 k $\Omega$ .

PM: Sensitivity of 10 $^\circ$  phase shift/Vp. Input impedance is 10k $\Omega$ .

#### 1.2.1.9 Symmetry

Symmetry of all waveform outputs is continuously adjustable from 1 :19 to 19:1. Varying symmetry provides variable duty-cycle pulses, sawtooth ramps and non-symmetrical sine waves.

#### NOTE

*When SYMMETRY control is used, indicated frequency is divided by approximately 10.*

#### 1.2.1.10 Sync Output (TTL)

TTL level pulse which will drive 10 TTL loads. Frequency and time symmetry are the same as for function output.

#### 1.2.1.11 Trigger and Gate

Input Range: 1V p-p to  $\pm 10$ V.

Input Impedance: 10 k $\Omega$ , 33 pF.

Pulse Width: 25 ns minimum.

Repetition Rate: 10 MHz maximum.

Adjustable triggered signal start/stop point: approximately  $-90^\circ$  to  $+90^\circ$  to 2 MHz.

## 1.2.1 .12 Frequency Precision

### Dial Accuracy

$\pm$  (1 % of setting + 1 % of full range) on x 100 thru x 1 M ranges.

$\pm$  (2% of setting + 2% of full range) on x .01 thru x 10 and x 10M ranges.

### Time Symmetry

$\pm$  0.5% on x, 100 thru x 100k ranges and from 0.2 to 2.0 on dial.

$\pm$  5% on all other ranges and from 0.02 to 2.0 on dial.

## 1.2.1 .13 Amplitude Precision

### Amplitude Change With Frequency

Sine variation less than:

$\pm$  0.1 dB thru x 1 00k ranges;

$\pm$  0.5 dB on x 1 M range;

$\pm$  3 dB on x 10M range.

### Step Attenuator Accuracy

$\pm$  0.3 dB per 20 dB step at 2 kHz.

## 1.2.1.14 Waveform Characteristics

### Sine Distortion

<0.5% on x 100 Hz to x 10 kHz.

< 1 .0% on x .01 to x 10 Hz and x 100 kHz ranges.

All harmonics 30 dB below fundamental on x 1 MHz range.

All harmonics 26 dB below fundamental on x 10 MHz range.

### Square Wave Rise/Fall Times




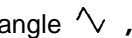
At FUNCTION OUT < 25 ns for 15V p-p into a 50 $\Omega$  load.

### Triangle Distortion




Odd harmonics within 15% of correct value to 2 MHz.

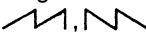
## 1.2.2 Modulation Generator

### 1.2.2.1 Waveforms




Selectable sine , triangle , square , up ramp M and down ramp M .

### 1.2.2.2 Frequency Range

, ,  0.1 Hz to 100 kHz in three 100:1 ranges.

 Sweep: 0.2 Hz to 200 kHz (2 x setting).

## 1.2.2.3 Output (600 $\Omega$ )

,  and  are fixed level 10V p-p balanced about ground. M and M are fixed level 5 Vp from 0 to + 5V.

## 1.2.2.4 Frequency Modulation (FM IN)

Voltage control of modulator frequency with sensitivity of 20% of range per volt. Input impedance is 5 k $\Omega$ .

## 1.2.2.5 Waveform Characteristics

### Sine Distortion

< 5 %

### Time Symmetry

< 1 % from 1 Hz to 10 kHz.

< 5% from 0.1 Hz to 100 kHz.

## 1.2.3 General

### 1.2.3.1 Stability (for amplitude, dc offset and frequency)

Short Term:  $\pm$  0.05% for 10 minutes.

Long Term:  $\pm$  0.25% for 24 hours.

### 1.2.3.2 Environmental

Specifications apply at 25°C  $\pm$  5°C ambient Instrument will operate from 0°C to 50°C ambient temperatures.

### 1.2.3.3 Dimensions

28.6 cm (11 1/4 in.) wide; 13.3 cm (5 1/4 in.) high; 27.3 cm (10 3/4 in.) deep.

### 1.2.3.4 Weight

5 kg (11 lb) net; 6.6 kg (14 1/2 lb) shipping.

### 1.2.3.5 Power

90 to 105V, 108 to 126V, 198 to 231V and 216 to 252V selectable; 48 to 400 Hz; less than 40 watts.

## NOTE

*Unless otherwise noted, all specifications apply from 0.1 to 2.0 on frequency dial when FUNCTION OUT is at maximum and 50 $\Omega$  terminated, with SYMMETRY control at OFF. Symmetry and vernier affect frequency calibration. Maximum possible asymmetry is a function of frequency setting.*

# SECTION 3

## OPERATION

### 3.1 CONTROLS AND CONNECTORS

The following item numbers are keyed to figure 3-1.

#### 3.1.1 Main Generator

- 1 Frequency Dial — The frequency control of the main generator. The setting on this dial multiplied by the **FREQ MULT 12** setting is the basic output frequency of the generator at the **FUNCTION OUT.6** and **SYNC OUT 7** BNCs. The **FREQ VERNIER 12** and, in some cases, the modulation generator also affect the main generator frequency.
- 2 Mode Switch — This outer switch selects the operating mode of the main generator as follows:
  - a. **EXT GATE Mode** — The main generator is quiescent until a proper gate signal is applied at the **EXTTRIG IN** BNC 13 and then outputs the selected signal for the duration of the gate signal, plus the time to complete the last cycle generated.

- b. **EXT TRIG Mode** — Same as for **EXT GATE** mode, except the main generator output is one cycle of selected signal only.

- c. **CONT Mode** — The output signal is continuous.

- d. **INT TRIG** — Same as for **EXTTRIG** mode, except the trigger signal is applied internally by the modulation generator.

- e. **INT GATE** — Same as for **EXT GATE**, except the gate signal is applied internally by the modulation generator.

**TRIGGER LEVEL Control** — This inner control is a continuously variable adjustment of the trigger circuitry firing point. When full ccw, a positive going pulse at approximately  $-7.5V$  is required for triggering (see figure 3-2). In the full cw position, a positive going pulse at approximately  $+7.5V$  or more positive voltage is required for triggering. In the **GATE** modes, the generator will run continuously when the control is cw of 12 o'clock.

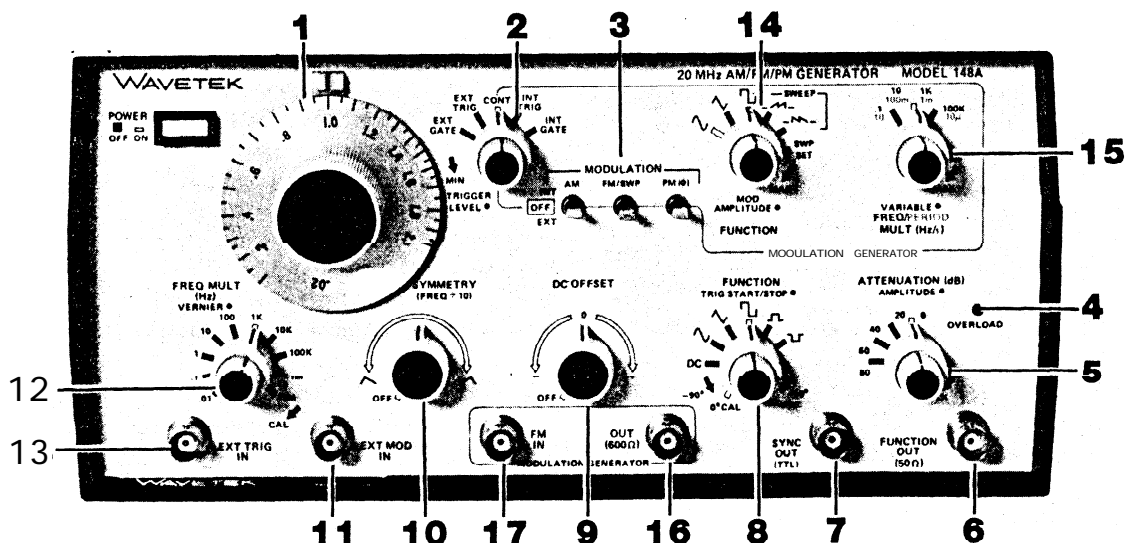


Figure 3-1 Controls and Connectors

### 3.1.2 Modulation Generator

14 FUNCTION Switch – This switch selects the waveform output of the modulation generator. Output is at the OUT BNC connector 16 and is also available internally to the main generator. Waveforms are sine ( $\sim$ ), triangle ( $\nabla$ ), square ( $\square$ ), ramp up (M) and ramp down (N). A SWP SET detent holds the OUT BNC at AMPLITUDE control 14 level; used to set upper sweep frequency.

MOD AMPLITUDE Control – This inner control attenuates the modulation generator signal that is internally fed to the main generator when modulating. It has no effect during internal triggering or gating and it has no effect on the OUT 16 signal.

15 FREQ/PERIOD MULT Switch – This outer switch (with ranges given in both frequency and period) selects the modulation generator frequency/period range.

VARIABLE Control – This inner control sets the frequency/period within a range.

16 OUT (600 $\Omega$ ) Connector – This BNC is the modulation generator waveform output: sine ( $\sim$ ), triangle ( $\nabla$ ) and square ( $\square$ ) fixed level 10V p-p (5V p-p into 600 $\Omega$ ) waveforms balanced about ground and ramp ( $\nearrow, \searrow$ ) fixed level 0 to + 5 Vp waveform.

17 FM IN (5 k $\Omega$ ) Connector – This BNC is the input for frequency modulation of the modulation generator. Sensitivity is 20% of frequency range per volt in.

### 32 OPERATION

For convenience, the generator operation has been grouped in seven basic modes, from which many variations and combinations are possible. The following paragraphs give basic switch positions for each mode and requirements and suggestions for operation.

The basic modes of operation are:

- Continuous – A continuous output signal.
- Triggered – One cycle of waveform for each trigger signal.
- Gated – A “burst” of waveforms for the duration of each gate signal.

- AM – The instantaneous amplitude of the output signal varies with the instantaneous amplitude of the modulation signal.
- FM – The instantaneous frequency of the output signal varies with the instantaneous amplitude of the modulation signal.
- PM – The instantaneous phase of the output signal varies with the instantaneous amplitude of the modulation signal.
- DC – The dc output can be set from + 15 Vdc to – 15 Vdc (+ 7.5 Vdc to – 7.5 Vdc into 50 $\Omega$ ).

### 3.2.1 Continuous Operation

When setting up the generator, it is advisable to observe the output on an oscilloscope. Connect FUNCTION OUT to the scope input using a 500 cable and a 50 $\Omega$  load. For continuous waveform output, select a basic waveform at the desired frequency. Ensure the modulation switches are set to OFF and the mode is set to CONT. The output amplitude can be as great as 15V p.p; attenuate as desired.

#### NOTE

*For best waveform quality, use the ATTENUATION SWITCH for gross attenuation; then use the AMPLITUDE control for fine attenuation.*

The waveform may be skewed to the left or right using the SYMMETRY control; e.g., making a ramp ( $\nearrow$ ) from a triangle ( $\nabla$ ) waveform.

#### NOTE

*The output frequency is divided by 10 when the SYMMETRY control is switched from the OFF position.*

The dc level of the waveform may be varied with the DC OFFSET control, but waveform clipping can occur.

#### NOTE

*Waveform clipping will occur (OVERLOAD LED will light), unless waveform amplitude is decreased so that waveform plus offset is less than 7.5 volts at the waveform peak.*

### 3.2.2 Triggered Operation

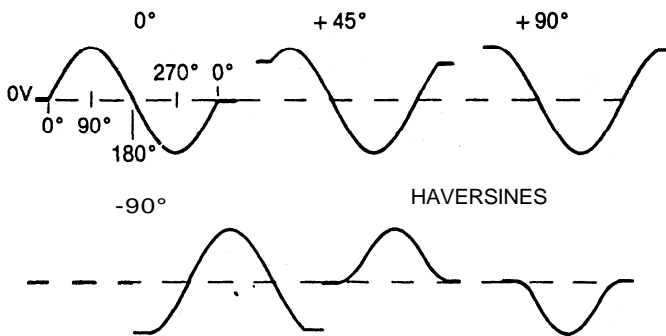
In triggered operation, there is one cycle of output for each trigger signal input. For triggered operation, first

set up the generator for continuous operation (refer to paragraph 3.2.1). The main generator may be triggered internally by the modulation generator or triggered by an external source. If an unmodulated waveform is being output, the modulation generator is free to give the desired triggering frequency and should be selected as the trigger source. Use any modulation generator waveform as the trigger. Set the modulation generator frequency for the desired trigger frequency and sync on the modulation generator output.

**NOTE**

1. Trigger frequency must be slower than the output waveform frequency.
2. The MOD AMPLITUDE control has no effect in INT TRIG and INT GATE modes.

Rotate the TRIGGER LEVEL control to obtain a good trigger. If the waveform start/stop point is to be other than zero degrees, set the TRIG START/STOP control as required. (See figure 3-3.) Haversines can be set up using start/stop control and dc offset control.



**Figure 3-3. Waveform Start/Stop Examples**

If external triggering is to be used, connect a repetitive signal with a positive going transition of greater than one volt to EXT TRIG IN using a 50Ω cable. Adjust the TRIGGER LEVEL control for proper triggering.

**3.2.3 Gated Operation**

In gated operation there is a “burst” of waveforms lasting the duration of the gate pulse plus the time required to complete the last cycle of waveform started. Set up as for triggered operation (refer to paragraph 3.2.2) and select a “trigger” signal whose duty time gives the desired waveform burst.

**3.2.4 Manual Triggering and Gating**

The TRIGGER LEVEL control can also be used for manually triggering or gating the generator. For manually triggering (single cycles), the generator mode should be EXT TRIG with no external signal input at the EXT TRIG IN connector. Each time TRIGGER LEVEL is rotated cw through mid-position, one triggered cycle will be generated. In EXT GATE mode, the generator runs continuously as long as the TRIGGER LEVEL is CW of mid-position.

**3.2.5 AM Operation**

In amplitude modulation, the instantaneous amplitude of the output signal varies with the instantaneous amplitude of the modulation signal.

**NOTE**

*The output waveform will be clipped (OVERLOAD LED will light) if any instantaneous amplitude greater than  $n \pm 15$  volts ( $\pm 7.5$  volts into 50Ω) is produced.*

Set up the generator as for continuous operation (refer to paragraph 3.2.1). Switch to internal or external amplitude modulation. If internal, note that the carrier (main generator waveform) mean amplitude is decreased to half. This is to prevent clipping (overdriving the output amplifier) when the carrier amplitude is modulated (increased and decreased) by another signal. Set the modulation generator frequency to a lower frequency than the main generator and sync the scope to the modulation generator output. Set the modulator amplitude for a desired percentage of amplitude modulation (0 to greater than 100% range) and set the main generator ATTENUATION and AMPLITUDE controls for a desired amplitude of modulated waveform. If external modulation is selected, observe that the carrier (main generator waveform) amplitude drops to zero (null). This is for suppressed carrier mode of amplitude modulation. Connect the modulator OUT (600Ω) to the EXT MOD IN with a coaxial cable. Set the main generator ATTENUATION and AMPLITUDE controls for a desired amplitude of suppressed carrier waveform. For best results when using an external modulation signal at EXT MOD IN, maintain as near as convenient a 5 Vp amplitude (which does not exceed 5 VP); then use the main generator ATTENUATION and AMPLITUDE controls. An external source may also be used for regular AM operation, rather than suppressed carrier operation, by supplying a dc component along with the ac

modulating signal (observing 5 Vp limit) to set the carrier level.

### 3.2.6 FM Operation

In FM operation, the instantaneous frequency of the output signal varies with the instantaneous amplitude of the modulating signal.

#### NOTE

*The output frequency modulation will not be linear when the instantaneous modulated frequency exceeds these range limits.*

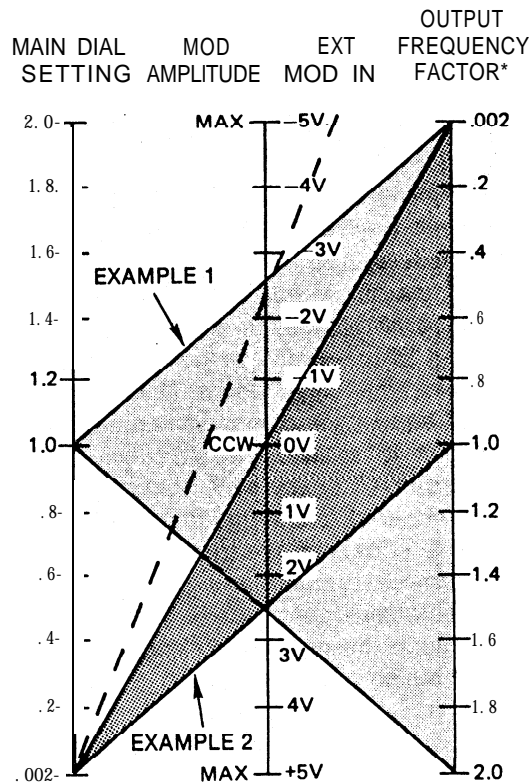
*Upper Limit: 2.0 x FREQ MULT*

*Lower Limit: 0.001 x Upper Limit*

Set up the generator as for continuous operation (refer to paragraph 3.2.1). The frequency setting will be the center frequency from which the modulated signal will vary. Switch to internal or external FM modulation. If internal, set the modulation generator frequency as desired and sync on the modulation generator signal. Set the modulation amplitude for the amount of modulation desired. Because the main generator is limited in frequency range (limited to approximately the dial range for any given multiplier setting), the main generator frequency dial and the modulation amplitude control, must be balanced to stay within that range. The range is shown in figure 3-4 as the OUTPUT FREQUENCY FACTOR, which, when multiplied by the FREQ MULT setting, gives the actual output frequency. Example 1 shows the output being swept over the full frequency range when the main generator frequency dial is set at midpoint (1.0), the MOD AMPLITUDE control set at midrange and the modulation signal is a balanced waveform ( $\sim$ ,  $\sim$  or  $\square$ ); that is, the modulation generator voltage swings both positive and negative. If the MOD AMPLITUDE control is rotated toward ccw, the voltage swing decreases and the angle subtended in the nomograph decreases. If the MOD AMPLITUDE control is rotated toward MAX, the angle subtended would overshoot the OUTPUT FREQUENCY FACTOR range, indicating that saturation is likely.

### 3.2.7 Sweep Operation

For sweep operation, set up the generator for continuous operation (refer to paragraph 3.2.1). The frequency setting will be the lower frequency of the continuously varying (or swept) frequency. Switch FM/SWP to internal or external modulation as desired. If internal set the modulation generator FUNCTION



\*Multiply by FREQ MULT for actual output.

**Figure 3-4. Frequency Modulation Nomograph**

switch to SWP SET, monitor the FUNCTION OUT with a counter or oscilloscope and vary the MOD AMPLITUDE control for exactly the upper frequency desired. Note that the main generator is limited in frequency range (limited to approximately the dial range for any given multiplier setting). Select either  $\nearrow$  for sweep up or  $\searrow$  for sweep down. Select the sweep rate desired. Keep in mind the  $\nearrow$  and  $\searrow$  frequencies are double the indicated frequencies on the FREQ/PERIOD control.

Example 2 shows the output being swept from the bottom of the range to midrange by setting the main dial fully cw and the VERNIER fully ccw for absolute bottom of the range. The MOD AMPLITUDE control was left at midrange and the ramp ( $\nearrow$ ) waveform used as the modulator. The ramp is a positive going only waveform. Had a balanced waveform been used, the angle subtended would have included the dotted line and resulted in saturation. If an external modulation signal is to be used, the EXT MOD IN values in the nomograph indicate the signal level required for the desired results.



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#### NOTE

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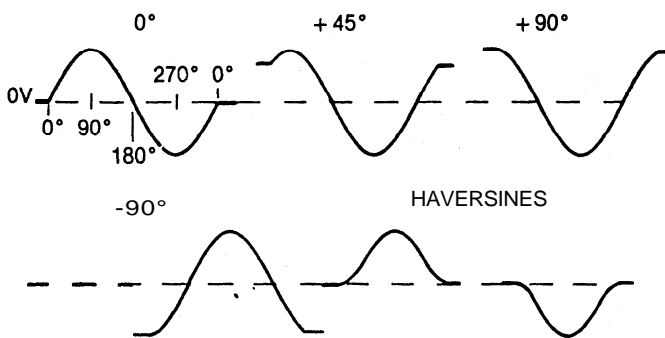
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In gated operation there is a "burst" of waveforms lasting the duration of the gate pulse plus the time required to complete the last cycle of waveform started. Set up as for triggered operation (refer to paragraph 3.2.2) and select a "trigger" signal whose duty time gives the desired waveform burst.

**3.2.4 Manual Triggering and Gating**

The TRIGGER LEVEL control can also be used for manually triggering or gating the generator. For manually triggering (single cycles), the generator mode should be EXT TRIG with no external signal input at the EXT TRIG IN connector. Each time TRIGGER LEVEL is rotated cw through mid-position, one triggered cycle will be generated. In EXT GATE mode, the generator runs continuously as long as the TRIGGER LEVEL is CW of mid-position.

**3.2.5 AM Operation**

In amplitude modulation, the instantaneous amplitude of the output signal varies with the instantaneous amplitude of the modulation signal.

**NOTE**

*The output waveform will be clipped (OVERLOAD LED will light) if any instantaneous amplitude greater than  $n \pm 15$  volts ( $\pm 7.5$  volts into 50Ω) is produced.*

Set up the generator as for continuous operation (refer to paragraph 3.2.1). Switch to internal or external amplitude modulation. If internal, note that the carrier (main generator waveform) mean amplitude is decreased to half. This is to prevent clipping (overdriving the output amplifier) when the carrier amplitude is modulated (increased and decreased) by another signal. Set the modulation generator frequency to a lower frequency than the main generator and sync the scope to the modulation generator output. Set the modulator amplitude for a desired percentage of amplitude modulation (0 to greater than 100% range) and set the main generator ATTENUATION and AMPLITUDE controls for a desired amplitude of modulated waveform. If external modulation is selected, observe that the carrier (main generator waveform) amplitude drops to zero (null). This is for suppressed carrier mode of amplitude modulation. Connect the modulator OUT (600Ω) to the EXT MOD IN with a coaxial cable. Set the main generator ATTENUATION and AMPLITUDE controls for a desired amplitude of suppressed carrier waveform. For best results when using an external modulation signal at EXT MOD IN, maintain as near as convenient a 5 Vp amplitude (which does not exceed 5 VP); then use the main generator ATTENUATION and AMPLITUDE controls. An external source may also be used for regular AM operation, rather than suppressed carrier operation, by supplying a dc component along with the ac

modulating signal (observing 5 Vp limit) to set the carrier level.

### 3.2.6 FM Operation

In FM operation, the instantaneous frequency of the output signal varies with the instantaneous amplitude of the modulating signal.

#### NOTE

*The output frequency modulation will not be linear when the instantaneous modulated frequency exceeds these range limits.*

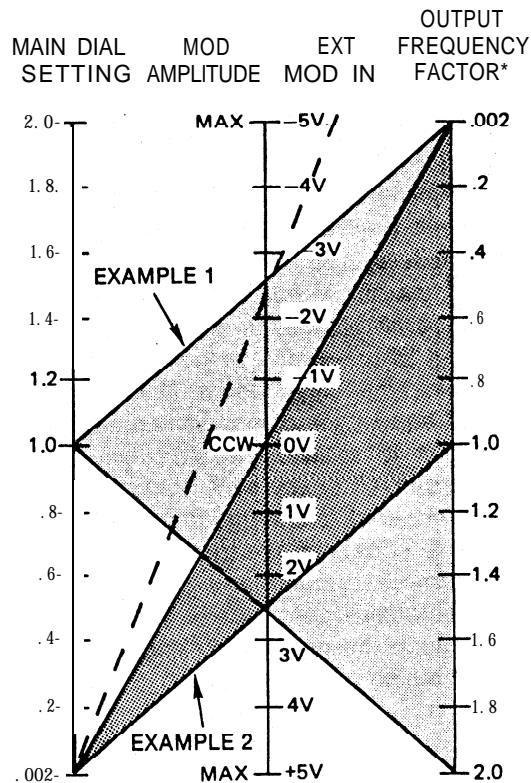
*Upper Limit:  $2.0 \times \text{FREQ MULT}$*

*Lower Limit:  $0.001 \times \text{Upper Limit}$*

Set up the generator as for continuous operation (refer to paragraph 3.2.1). The frequency setting will be the center frequency from which the modulated signal will vary. Switch to internal or external FM modulation. If internal, set the modulation generator frequency as desired and sync on the modulation generator signal. Set the modulation amplitude for the amount of modulation desired. Because the main generator is limited in frequency range (limited to approximately the dial range for any given multiplier setting), the main generator frequency dial and the modulation amplitude control must be balanced to stay within that range. The range is shown in figure 3-4 as the OUTPUT FREQUENCY FACTOR, which, when multiplied by the FREQ MULT setting, gives the actual output frequency. Example 1 shows the output being swept over the full frequency range when the main generator frequency dial is set at midpoint (1.0), the MOD AMPLITUDE control set at midrange and the modulation signal is a balanced waveform ( $\sim$  or  $\square$ ); that is, the modulation generator voltage swings both positive and negative. If the MOD AMPLITUDE control is rotated toward ccw, the voltage swing decreases and the angle subtended in the nomograph decreases. If the MOD AMPLITUDE control is rotated toward MAX, the angle subtended would overshoot the OUTPUT FREQUENCY FACTOR range, indicating that saturation is likely.

### 3.2.7 Sweep Operation

For sweep operation, set up the generator for continuous operation (refer to paragraph 3.2.1). The frequency setting will be the lower frequency of the continuously varying (or swept) frequency. Switch FM/SWP to internal or external modulation as desired. If internal set the modulation generator FUNCTION



\*Multiply by FREQ MULT for actual output.

**Figure 3-4. Frequency Modulation Nomograph**

switch to SWP SET, monitor the FUNCTION OUT with a counter or oscilloscope and vary the MOD AMPLITUDE control for exactly the upper frequency desired. Note that the main generator is limited in frequency range (limited to approximately the dial range for any given multiplier setting). Select either  $\nearrow$  for sweep up or  $\searrow$  for sweep down. Select the sweep rate desired. Keep in mind the  $\nearrow$  and  $\searrow$  frequencies are double the indicated frequencies on the FREQ/PERIOD control.

Example 2 shows the output being swept from the bottom of the range to midrange by setting the main dial fully cw and the VERNIER fully ccw for absolute bottom of the range. The MOD AMPLITUDE control was left at midrange and the ramp ( $\nearrow$ ) waveform used as the modulator. The ramp is a positive going only waveform. Had a balanced waveform been used, the angle subtended would have included the dotted line and resulted in saturation. If an external modulation signal is to be used, the EXT MOD IN values in the nomograph indicate the signal level required for the desired results.

### 3.2.8 PM Operation

In PM operation, the instantaneous phase of the output signal varies with the instantaneous change in amplitude of the modulating signal. The change in phase is made by changing the frequency of the generator until the correct phase angle change is made. The modulation circuit differentiates the modulation signal; that is, its output is proportional to the rate of change of modulation signal amplitude. This voltage is fed to the 'main' generator in exactly the same manner as the FM voltage is. The voltage effects a change in frequency and, in the case of a step function modulation, for example, exists only long enough to cause the desired phase shift. Typically, less than one cycle is required to change the phase. When the phase angle is increased, the frequency increases to achieve it. When the phase angle is decreased, the frequency decreases to achieve it. The frequency required to change the phase also depends upon the modulation frequency and waveform.

#### NOTE

*The output phase will not be linearly modulated when the instantaneous transition frequencies required to effect the phase change exceed these range limits.*

*Upper Limit:  $2.0 \times \text{FREQ MULT}$*

*Lower Limit:  $0.001 \times \text{Upper Limit}$*

Nominally, the phase of the main generator is shifted ten degrees for each volt of instantaneous modulation

signal. When the main generator is set above a range midpoint, the modulation signal begins to lose its effectiveness. The effect is that the input signal is rolling off at 6 dB/octave due to form factor limitations of the input differentiator. This effect also occurs for modulation signal frequencies above 150 kHz.

Set up the generator as for continuous operation (refer to paragraph 3.2.1). Select a range so that the frequency dial can be set, at midpoint or below (for linear operation) and switch to internal or external phase modulation.

#### NOTE

*There is no PM operation for frequency multipliers of 100 or less.*

If internal, set the modulation frequency as desired. (If other than sine waveform is selected, greater than 150 kHz modulation frequencies are possible and the effective roll off must be considered.) Set the modulation amplitude as desired. Full range is 5 Vp and phase shift is 10° per 1 Vp.

#### NOTE

*Because the initial phase reference no longer exists when the phase shifts, phase shift measurement will not be possible with an oscilloscope alone. To measure the phase shift, an additional circuit such as a phase modulator will be necessary to establish a phase angle baseline.*

# SECTION 4

## CIRCUIT DESCRIPTION

### 4.1 FUNCTIONAL BLOCK DIAGRAM ANALYSIS

This section describes the functions of major circuit elements and their relationship to one another as shown in figure 4-1, functional block diagram, and figure 4-2, basic generator and timing diagram. Paragraph 4.2 provides further descriptions relating circuit blocks to schematics in section 7.

As shown in figure 4-1, the main generator VCG (Voltage Control of Generator frequency) summing amplifier receives inputs from the frequency dial, vernier, FM and PM switches which produce a sum current. The PM input is provided with a passive differentiator which produces a voltage proportional to the rate of change of the instantaneous voltage of the modulating signal.

The VCG summing amplifier is an inverting amplifier whose output voltage is used to control a complementary current source and current sink. For symmetrical output waveforms, the currents are equal and directly proportional to the algebraic sum of the VCG inputs. The diode gate, controlled by the hysteresis switch, switches either the current source or sink to the timing capacitor selected by the frequency multiplier control. When the current source is switched in, the charge on the capacitor will rise linearly producing the positive-going triangle slope. Likewise, the current sink produces the negative-going triangle slope.

The triangle amplifier is a unity gain amplifier whose output is fed to the hysteresis switch and to the triangle buffer. The hysteresis switch is a bistable device operating as a window detector with limit points set to the triangle peaks. When the hysteresis switch output is + 2V, the triangle rises to the + 1.25V limit, and the hysteresis switch goes to - 2V. This switches currents at the diode gate and the negative-going triangle slope is started. When the triangle reaches the - 1.25V limit, the hysteresis switch will switch back to positive, repeating the process. As shown in figure 4-2, this repetitive process results in the simultaneous generation of a square wave and a triangle wave at the same frequency.

The output frequency is determined by the magnitude of the capacitor selected by the frequency multiplier

selector and by the magnitude of the currents supplied to and removed from it. Since the currents are linearly proportional to the sum of VCG inputs, so will be the output frequency. The capacitance multiplier provides the bottom four frequency ranges.

When the variable symmetry control is rotated, it first reduces the current sink by a factor of 19, making the negative-going triangle slope 19 times longer than normal. This results in an unsymmetrical waveform output and a frequency division by 10. Continued rotation gradually increases the current sink and reduces the current source in such a way that the period for the triangle to complete one cycle remains constant. This action produces continuously variable symmetry of the output waveforms over a 1:19 to 19:1 range while frequency remains constant at one-tenth of dial and multiplier settings.

The inverted square from the hysteresis switch is fed to the sync amplifier, where it is buffered and converted to a TTL level output, and to the square amplifier, where (if square or pulse functions are selected) a buffered square is sent to the signal shaper for conditioning.

The triangle buffer provides the  $\pm 1.25$  triangle sufficient drive for the signal shaper and presents a small, constant load on the triangle amplifier.

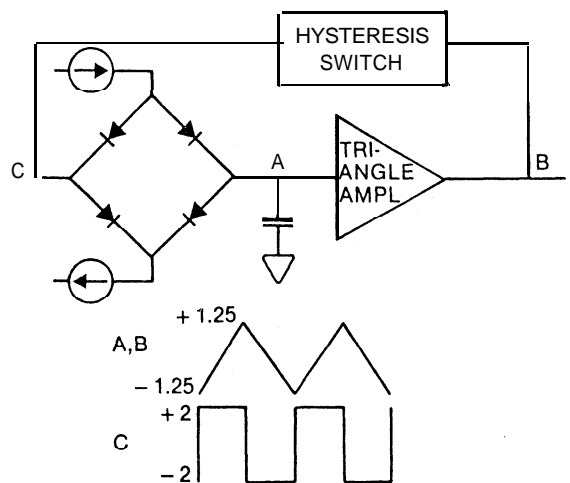


Figure 4-2. Basic Generator Block and Timing Diagram

The signal shaper contains switching elements and a diode array for signal conditioning the buffered triangle and square inputs into the various waveforms controlled by the function switch. The selected waveform is the carrier (+ Y) input to the transconductance multiplier, an integrated circuit, four-quadrant multiplier.

The modulation (+X) input is a positive dc from the control amplifier when the AM switch is off, providing a fixed gain reference for the multiplier. Output currents from the multiplier are applied to the summing node of the preamplifier for conversion to an inverted voltage signal.

The preamplifier output is then attenuated by the front panel amplitude control and fed to the output amplifier summing node along with the dc offset control. The output amplifier is an inverting amplifier whose output is fed into step attenuator and then to the function output connector. The attenuator consists of a distributed network having  $50\Omega$  output impedance. This network provides attenuation in 20 dB (1/10) steps to 60 dB.

For continuous operation of the basic function generator loop (bold path in figure 4-1), the trigger amplifier must maintain a positive level above the most positive charge on the integrating capacitor in order to reverse bias the start/stop diode. Thus, in continuous mode the trigger logic senses the continuous control line from the front panel mode selector and holds the inverting trigger amplifier input low.

In triggered and gated modes the trigger amplifier outputs some level below the positive peak charging level, and the start/stop diode is forward biased to sink the current source and prevent the timing capacitor from charging to the positive peak. This stops waveform generation and holds the triangle output at some dc level called the trigger baseline. The trigger baseline is the level where a triangle, and thus sine, waveform starts and stops when triggered or gated.

The normal trigger baseline is zero volts, analogous to  $0^\circ$  phase of a sine or triangle waveform. The trigger start/stop control offsets the trigger amplifier output and can change the baseline for starting and stopping a sine or triangle waveform from its negative peak ( $-90^\circ$ ) to its positive peak ( $+90^\circ$ ). At the extreme positive peak level setting though, the diode is again reverse biased and generator operation goes continuous, independent of generator mode.

While the integrating capacitor is being held from charging, the start/stop diode must sink the current source, which has a magnitude variable with VCG inputs. Therefore, a compensation is necessary to the voltage level output by the trigger amplifier in order to maintain a constant baseline level as VCG inputs, current source magnitude and forward voltage drop by the start/stop diode are varied. The baseline compensation circuit measures the forward voltage across a diode placed in the current source and injects an off-setting current into the trigger amplifier to maintain an equal voltage differential between the baseline level and trigger amplifier output.

The trigger logic determines that after a waveform starts, it always stops at a complete cycle and at the same phase angle at which it started. The trigger logic receives a trigger stimulus from the signal limiter and latches the trigger amplifier output positive, allowing the generator loop to run. When the negative peak of the last cycle is reached (just one cycle in trigger mode), the square from the hysteresis switch latches the trigger amplifier back to its previous level. The integrating capacitor will charge back to the trigger baseline where the start/stop diode once again forward biases.

The generator mode switch sets the gated control line to determine whether the trigger logic is to latch the generator on for one cycle or for the duration of the trigger stimulus.

The modulation generator board contains the power supplies, the modulation generator and various switching elements to control the source and type of modulation and triggering signals to the main generator.

The modulation generator is an integrated circuit source of sine, triangle and square waveforms, whose frequency is controllable by front panel multiplier switch, variable control, and external voltage at the FM IN input. The triangle and square are applied to a ramp generator consisting of a balanced modulator and buffer amplifier to produce ramp waveforms. A modulation waveform or a SWP SET dc level is sent to the function buffer via the front panel function selector.

The function buffer output is sent to the modulation output ( $600\Omega$ ) connector, the generator mode switch for an internal trigger and gate stimulus, and the amplitude buffer after being attenuated by the front panel amplitude control. The amplitude buffer output goes to the AM, FM and PM switches "internal" positions. The EXT MOD IN connector provides a connec-

tion for an external signal to the switches “external” positions.

The FM and PM switches provide VCG inputs. The AM switch controls the control amplifier and thus the transconductance multiplier. When AM is off, the control amplifier produces a positive dc level giving the multiplier a fixed gain. With internal AM, the dc component from the control amplifier is cut in half, halving the output amplitude to prevent output clipping when modulating. The selected modulation waveform rides on the dc. The ac (modulation signal) has a peak value equal in magnitude to the dc level when the modulation amplitude control is maximum, making the sum of modulator and carrier signals equal to the maximum output capability of the output amplifier, and the difference equal to the zero output level, which is 100% modulation. Then, by varying the modulation signal, a variable 0 to 100% AM of the carrier (main generator) signal is produced. With external AM, the dc component is switched to 0 Vdc, resulting in zero amplitude output, and bipolar signal inputs at the EXT MOD IN connector will produce suppressed carrier (4-quadrant) modulation.

## 4.2 CIRCUIT ANALYSIS

### 4.2.1 VCG Amplifier

Figure 4-3 is a simplified schematic of the VCG circuitry. The value of a resistor “R” is 5 k $\Omega$  and supplies are  $\pm 15$  Vdc. U1 is connected as a summing amplifier to sum the VCG inputs. A top of range input produces 1mA through the feedback resistor resulting in - 5 Vdc at the output of U1

The negative input of U4 is held at the output level of U1 by controlling the current through Q2 as a feedback. One half the output of U1 is buffered by U3 and applied to the wiper of the variable symmetry control. The negative input of U2 is held at 0 Vdc by controlling the current through Q1 as a feedback. As long as the variable symmetry control is off, the two R/2 resistors have equal voltage across them and an equal current through them as through U1 feedback and there is no current at the output of U3. Since an equal current exists in the entire resistor string from + to - supply, the result is a positive control voltage relative to the negative supply at U6 + input and a negative control voltage with respect to the positive supply at U5 + input, each of which is proportional to the sum of the inputs to U1

Similarly, U5 and U6 establish feedback by regulating current through FETs, producing a voltage drop

across series resistors to the supplies equal to the control voltages. The FET currents will be switched at the diode gate into a timing capacitor to produce the triangle waveform.

### 4.2.2 Symmetry Control

Let the source of Q2 be - 5 Vdc, the wiper of the symmetry control, - 2.5 Vdc, and the source of Q1, 0 Vdc. The output of U3 will have no current, each R/2 resistor will have 1 mA, and generator frequency will be at maximum of the range. Open the symmetry switch and set the potentiometer to its electrical center. The output of U3 is still at an equipotential point, but now the total resistance with 5 Vdc across it has changed from R to 10R. Thus, current will drop to 100  $\mu$ A and output frequency will drop to one-tenth of range. If the potentiometer is rotated, current will flow in U3 output to maintain the wiper at - 2.5 Vdc. When the potentiometer is ccw, the wiper is at the positive direction and the upper R/2 will have 2.5V across it with a current source of 1 mA. But the lower R/2 is in series with 9R, which puts 2.5V across 19  $\times$  the normal resistance. Now the current sink will have one-nineteenth the magnitude of the current source. The output waveform for this condition is shown in figure 4-3. Regardless of where the symmetry control is rotated, frequency stays the same (one-tenth of range).

### 4.2.3 Range Switching

For frequency ranges associated with multiplier positions of 100 and 1 K, main board schematic, sheet 1, the value of the current source and current sink setting resistors R326, R38, R48 and R330 is 5 k $\Omega$ , which provides integrating current sensitivity of 200  $\mu$ A per volt of external FM input. With the timing capacitors of 1 and 0.1  $\mu$ F, plus the bulk of the top range timing capacitor and the stray capacitance of the multiplier switch, the generator produces the calibrated output frequency for these ranges. In the top range (multiplier position of 10M), the current setting resistors are paralleled with resistors of one-ninth the value, causing both current sources to run at ten times the usual current, resulting in 2 mA per volt of external FM input. When this current is used with the nominal -90 pF timing capacitor (fixed value plus strays), the top range of frequencies result. For the next three ranges down (multiplier positions 1 M, 100K, 10K), the nominal timing capacitor is the fixed top range capacitor plus strays (i.e., -90 pF) plus the switched values (11 pF, 910 pF, 0.01  $\mu$ F). These result in joint timing capacitors of 101 pF, 1010 pF and 0.0101  $\mu$ F. In these three ranges the positive and negative current sources are boosted by 1 % over the next range down

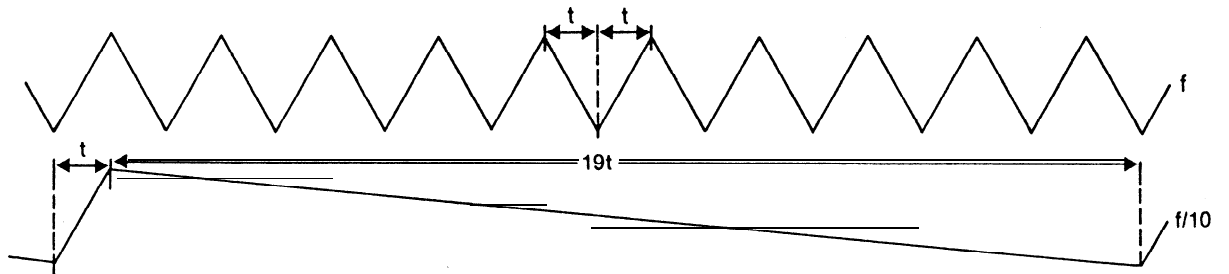
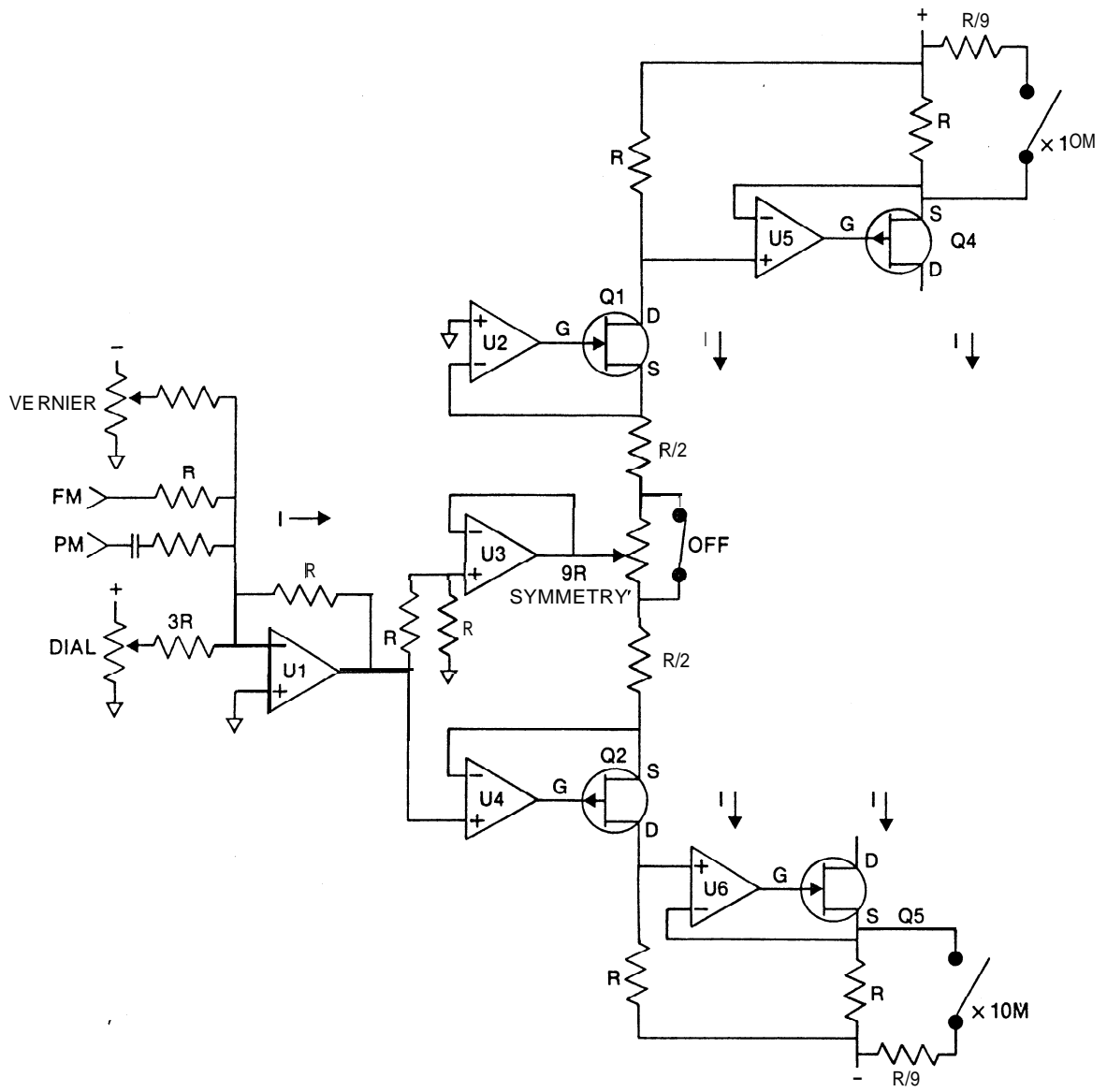


Figure 4-3. VCG Simplified Schematic



(multiplier  $\times$  K) by switching 500 k $\Omega$  resistors in parallel with the 5 k $\Omega$  basic current setting resistors R326, R38, R48 and R330 producing the output frequencies for these ranges. The four ranges below multiplier setting 100 all have the same integrating current and timing capacitor as the 100 multiplier range, but for each of these ranges, 90%, 99%, 99.9% and 99.99% of the integrating current is subtracted by the capacitance multiplier circuit.

#### 4.2.4 Capacitance Multiplier

For the frequency ranges associated with multiplier positions of 10 through 0.01, a capacitance multiplier circuit (main board schematic, sheet 1), senses the timing capacitor charging current and subtracts the appropriate amount so that the effective charging current is a fraction of that delivered by the current sources. This is accomplished by the connection of the capacitance multiplier to the timing capacitor with one input-output terminal through a section of the frequency multiplier switch. The + terminals of U7 and U8 serve as potentiometric input to these amplifiers. U7 has a fixed resistive feedback network, giving it a fixed gain. Capacitor C26 is forced to comply to the triangle voltage wave being generated, because the R54 side is driven at the potential of the input/output terminal and the other side has the same waveform with some fixed gain from U7. Since the side driven at the input/output signal is a summing node, it is fed the necessary current by the feedback resistors R58, R59, R60 and R61. The feedback resistors are selected by the frequency multiplier control, taking on values which give the correct amplitude to the output of U8. This output with respect to common is the input/output waveform with a square wave superimposed; TP1 is the test point where this output can be picked up for signal tracing. The input/output waveform is a triangle wave so the differential across R62 and R63 is a square wave with the correct amplitude to subtract part of the timing capacitor charging current. Since this square wave amplitude is controlled in decades by the frequency multiplier control via R58, R59, R60 and R61, the instrument frequency is divided in decades even though the current sources and timing capacitor remain the same.

#### 4.2.5 Triangle Amplifier

The main board schematic, sheet 2, shows the triangle amplifier; it uses Q8, an FET source follower, to drive Q10, a bipolar emitter follower, for an open loop gain of one. It is a fast, very high input impedance circuit with output impedance low enough to drive the hysteresis switch and the triangle buffer. In series with Q8 is

a matched duplicate FET, Q9. Q9 has the identical drain current as Q8 and, therefore, the same gate-to-source voltage. In series with Q10 is a duplicate emitter follower, Q13. Q13 has the identical collector current as Q10; therefore, it has the same emitter-to-base voltage. Since the gate of the dummy FET, Q9, is connected to the emitter of the dummy emitter follower, Q13, the two terminals have the same voltage. Therefore, within the tolerances of the part parameters and some unaccounted error for base current, the active emitter follower output voltage will be at the value of the input gate. The remaining transistor, Q11, is a second emitter follower for driving the dynamic lead networks at the input of the hysteresis switch. In this role, it needs no dc integrity, as the output is not directly coupled.

#### 4.2.6 Hysteresis Switch

The hysteresis switch (main board schematic, sheet 2) consists mainly of U14, a double input comparator, and Q14/Q15, an output flip-flop. Each differential pair of U14 compares an input voltage to common. The input network provides a positive bias to one and a negative bias to the other; therefore, when the input terminal (output of the triangle amplifier) is at  $\pm 1.25V$ , the flip-flop changes state. The flip-flop selects which input comparator of the hysteresis switch will be activated in preparation for the next change of state. When the timing capacitor is integrating positively, the positive biased comparator is activated. When the timing capacitor voltage reaches + 1.25V, the flip-flop changes state, the negative comparator is activated and the direction of integration is reversed, so that when the timing capacitor signal reaches - 1.25V, the flip-flop switches back and the cycle starts over. In addition to the positive and negative biases at the comparator inputs, there is a dynamic lead network on each one. These lead networks are driven by Q11, a separate emitter follower, from the triangle amplifier. They provide the necessary lead to compensate for the inherent delays of the hysteresis switch, thereby keeping the higher frequency dial nonlinearity and sine distortion to a minimum.

#### 4.2.7 Diode Gate and Timing Capacitor

The diode gate (current switch) and the timing capacitor circuits are shown in the main board schematic, sheet 2. The current source and sink are switched to the timing capacitor by the hysteresis switch via a diode bridge arrangement called the diode gate. Actually, the hysteresis switch is linked to the bridge network by two emitter followers, Q24 and Q25, with independent outputs biased to be at the

same voltage. The simplified timing diagram illustrated in figure 4-2 shows these points as one terminal at C. When the hysteresis switch output is positive, CR16 is forward biased, so that the current sink is sourced by the drive circuit and is ineffective. CR1 3 and CR1 5 are reverse biased, providing isolation between the drive circuit and the timing capacitor. This leaves CR14 forward biased and free to conduct the current source output to the timing capacitor. When the timing capacitor voltage rises to the hysteresis switch point (+ 1.25V), the hysteresis switch output switches low, forward biasing CR13 which back biases CR14 and CR16 and allows the source to be isolated and the sink to discharge the timing capacitor through CR15. This state continues until the negative switch point is reached and reverts to the previous state.

#### 4.2.8 Triangle Buffer

The triangle buffer (main board schematic, sheet 2) is a wide band dc amplifier providing a closed loop gain of one in potentiometric connection. The input differential stage, Q17/Q18, is a monolithic pair. The emitters are fed from a current sink Q19. The active collector load, Q20, is a current source providing greater open loop gain than a resistive load. Following this is an emitter follower, Q21, a zener diode level shifter, CR1 2, and another emitter follower, Q22, for the output stage. The gain is set to one by the 100% feedback to the input pair feedback side, base of Q18.

#### 4.2.9 Signal Shaper

The signal shaper circuit (main board schematic, sheet 3) is uniquely set up for each different waveform by four wafers of the function selector switch. The  $\pm 15$  volt power is switched off in the triangle wave mode and there is virtually no effect on the triangle wave fed to the circuit. In the positive pulse mode, the square wave, rather than the triangle wave, is fed to the circuit and the  $- 15$  volt power is switched off. As a result, the negative swing of the input square wave is clipped off. The negative pulse is formed, when selected by the function switch, in a similar manner. When the square or sine wave is selected, both plus and minus 15 volt power is applied to the circuit. The difference in circuit setup for sine and square is the resistive load at the circuit output and the shape of the signal fed to the input. For the sine wave mode, the matched set of -diodes soft clip the input triangle at three different levels. These signals are resistively summed to produce a sine wave voltage input to the multiplier. For the square wave mode, the input square wave is symmetrically hard-clipped by the

diode network presenting a square wave input voltage to the multiplier.

#### 4.2.10 Transconductance Multiplier

After the main generator signal passes through the function selector switch and the signal shaper circuit, it enters a transconductance multiplier, U15 (main board schematic, sheet 3), where the amplitude is set by dc from the control amplifier or modulated by ac from the modulation generator via the AM switch. Currents in the open collectors of this IC are worked into a current mirror for optimum gain and fed to the pre-amplifier summing node for conversion to a voltage signal at TP7.

#### 4.2.11 Preamplifier

The preamplifier (main board schematic, sheet 3), like the output (power) amplifier, is comprised of a high frequency ac amplifier combined with a low frequency dc amplifier. It converts the current from the multiplier to a voltage signal which is attenuated by the front panel amplitude control and amplified by the output amplifier. The U17 circuit is the dc amplifier and the remaining circuitry is the high frequency amplifier. Again, like the output amplifier, the ac amplifier is symmetrically arranged from the R240/R238 summing node to R246 and R249 at the output stage of the preamplifier. If the input current goes into the node, the voltage at the summing node will rise by a certain amount. By capacitive coupling via C92 and C93, the base voltage of Q40 rises closer to + 15 volts and the base voltage of Q41 rises further away from  $- 15$  volts. Thus, the emitter base junction of Q40 will be less forward biased, thereby reducing the emitter current, while the Q41 emitter current increases. The result is an increase in current in Q42 and a decrease in current in Q43, causing a decreased voltage output in R246/R249. The feedback path through R240 to the summing node tends to cancel the rise in voltage there, causing the output voltage to stabilize. The amount of negative voltage at the output required to pull the summing node back to zero is determined by the value of R240.

#### 4.2.12 Output Amplifier

The output amplifier is comprised of a low frequency dc amplifier and a high frequency ac amplifier. Refer to the simplified circuit of figure 4-4. The U19, Q37 and Q38 circuit is the dc amplifier and the remaining circuitry is the ac amplifier. The ac amplifier is symmetrically arranged, top and bottom. The upper por-

tion amplifies the positive swing of the output, while the lower mirror portion amplifies the negative swing. Operation is class AB; that is, there is independent positive half and negative half amplification, with a small amount of current flow in both sides near zero swing. The amplifier schematic has been simplified in figure 4-4 for the following discussion. Assume that both the input and the output voltages are zero, then the voltage at point A should also be zero. Because of the symmetrical configuration of the amplifier, the current through Q47 and Q49 will be equal and the output will remain at zero. If the input goes positive, the voltage at point A will rise by a certain amount. This will cause the base voltage of Q47 to rise closer to + 24 volts. Thus, the emitter base junction of Q47 will be less forward biased, thereby reducing its emitter current. The result is that the voltage at point B

which is the output voltage, will start to go negative. Finally, when the output has moved far enough negative to pull point A back to zero, by pulling current through the feedback resistor  $R_{fb}$ , the collector current of Q47 and Q49 will again be equal and the output 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  $R_{fb}$  to  $R_{in}$ , and this ratio is the closed loop gain of the output amplifier. The circuit containing U19, Q37, Q38 is a high gain, low frequency amplifier used to bias the high frequency amplifier and to increase the low frequency loop gain. The high frequency amplifier is isolated from low frequency signals at the input by capacitance coupling to the bases of Q47 and Q49. It then employs the low frequency amplifier to bias the emitter of Q47 to obtain the required dc stability and high loop gain.

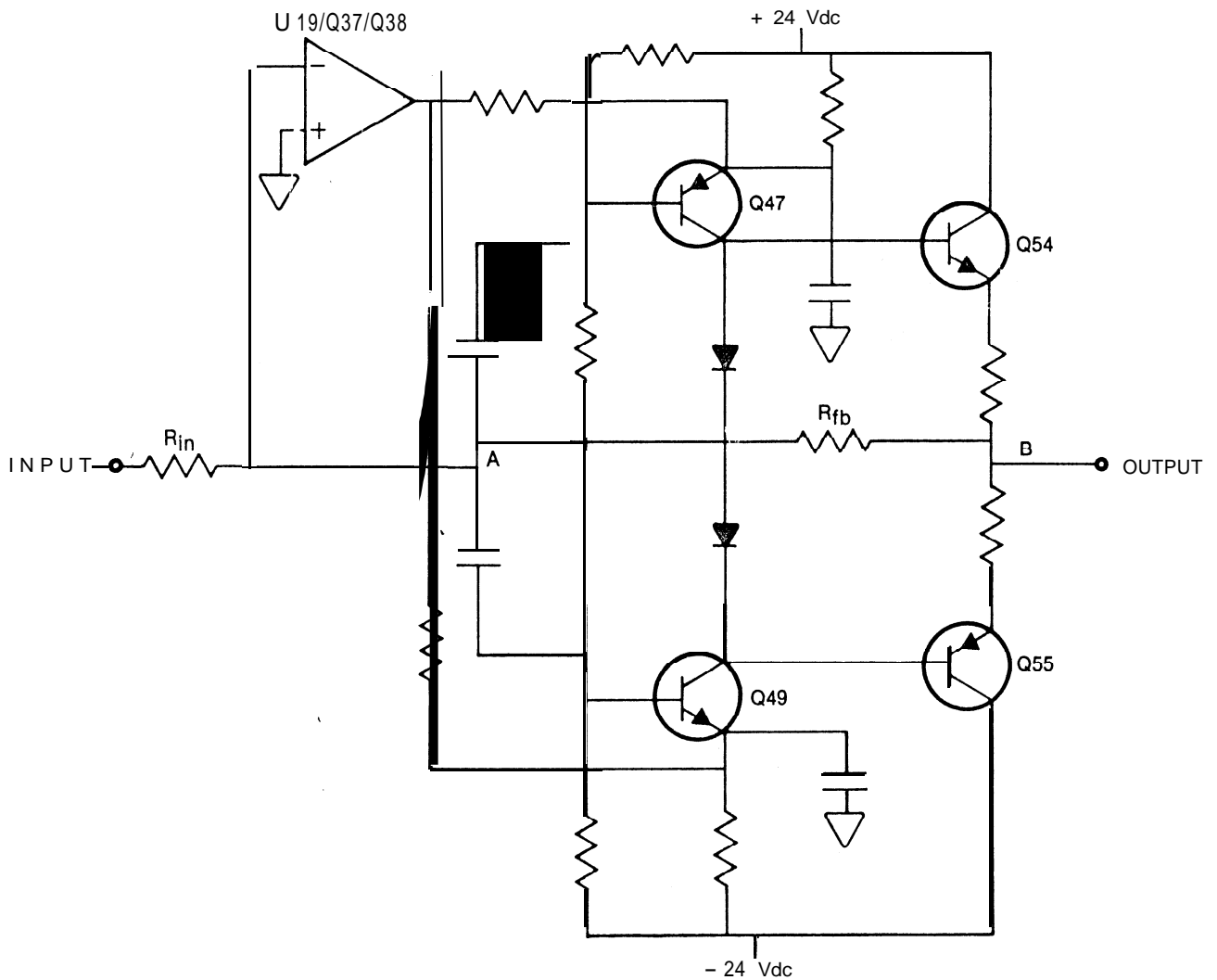


Figure 4-4. Simplified Output Amplifier

Other circuit components are shown on the main board schematic, sheet 3. Emitter followers Q46 and Q48 increase the driving power to the bases of Q47 and Q49. Q51 and Q54 are a harnessed pair sharing the load through R287 and R291 during the positive signal swing. Q51 and Q54 are driven by the collector of Q47. CR40 through CR43 compensate for the emitter-base junction voltage drops of Q51, Q53, Q54 and Q55 to control idling current, reduce crossover distortion and prevent thermal runaway. The two resistor-capacitor networks, R268/C100 and R278/C101 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. VR2 and VR3 are five volt regulators which normally run saturated to supply the output stage current to the collectors of the output transistors. If the output stage should demand an abnormal amount of current through a shorted transistor or output terminal, the current through R295 through R298 will generate five volts of drop. If more current is demanded, the regulators will simply maintain the five volt drop, allowing the output collector voltages to collapse, preventing excessive power dissipation in the amplifier components. The dc offset is fed as a current from the front panel control to the output amplifier summing mode.

#### 4.2.13 Sync Amplifier/Square Amplifier

The side of the hysteresis switch (main board schematic, sheet 2) not used to drive the current switch has an inverted square signal which is used to drive an emitter coupled pair, Q16 and Q23. The collector output of Q23 is biased to provide a TTL level output. The sync out signal is connected to the front panel sync out (TTL) BNC with a coaxial cable.

Next to the sync amplifier, a similar emitter coupled pair, Q57 and Q58, is connected to the same input and biased to output a bipolar square wave to the function switch when square or pulse functions are selected. In other functions, emitter bias is reversed so that the square function remains confined to the hysteresis switch area.

#### 4.2.14 Trigger Signal Limiter

Either an external signal or the modulator function are selected by the generator mode switch (auxiliary generator schematic) and summed through R50 and R51 with the trigger level control. That portion of the trigger signal more positive than the trigger level is

clipped by forward biasing CR1; the negative portion is clipped by CR2. While CR1 is on, Q1 conducts and Q3 switches off to a TTL low level. While CR2 is on, Q1 is off and Q3 saturates to a TTL high level. R57 and R58 provide hysteresis to ensure a clean square wave output.

#### 4.2.15 Trigger Logic/Trigger Amplifier

In continuous mode the continuous control line is low and U13-8 (main board schematic, sheet 2) holds the trigger flip-flop (U12) cleared. U12-3 is low, which is sent by emitter follower Q27 to a diode "AND". A low is sensed at RI 58, the trigger amplifier inverting input. The closed loop gain of the trigger amplifier is set by the ratio of R173 to R158. The trigger amplifier outputs a + 1.5 to + 2 Vdc to reverse bias the start/stop diode CR27 above the most positive charge on the integrating capacitor.

In trigger mode, both control lines are high, and U13 produces a narrow negative pulse, corresponding to a high to low transition of the signal limiter output, to clear U12. In the absence of a trigger stimulus, U12 is clocked by the negative-going edge of the current switch square translated by Q26 to TTL levels. U12-3 goes high and the trigger amplifier goes to a low level, forward biasing CR27 which sinks the VCG current source away from the integrating capacitor. The charge level on the integrating capacitor is held at the voltage drop across CR27 above the trigger amplifier output. Compensation current enters the trigger amplifier summing node through R155 to push its output voltage down exactly the same as the drop across CR27 at a particular magnitude of integrating current. The 0 Vdc trigger baseline may be modified with R4, the front panel start/stop control. Whenever a trigger is received, U13 is cleared and the trigger amplifier output goes high, allowing the integrating capacitor to charge. At the positive triangle peak, the hysteresis switch goes to a negative level and the negative-going triangle slope is generated. The high-to-low hysteresis transition clocks U12-3 high, but the negative portion of the square is also fed into the diode "AND" at CR20 which holds the trigger amplifier output high until the completion of the negative-going slope of the triangle. When the hysteresis switch returns to positive, the trigger amplifier returns to its low output, and the integrating capacitor charges until CR27 forward biases again. The integrating capacitor is again held at the trigger baseline level.

In gate mode, the gated control line is low and U13 produces a negative pulse of the same duration as the signal limiter output. Thus, U12 is held cleared, the





signal at CR24 is held low, and the trigger amplifier output is held high for the trigger duration. The last triangle cycle started is completed through the action explained in trigger mode.

#### 4.2.16 Baseline **Compensation**

CR2 (main board schematic, sheet 1) is in series with the current supplied by the VCG current source. U9-3 is connected to CR2 anode and, since it is a voltage follower, it will have the same potential at its pin 6. U1 O-3 is connected to CR2 cathode and will regulate the current through Q7 to make the same potential at its pin 2; therefore, R64 will have the same voltage across it as the drop across CR2. The current leaving Q7 enters the trigger amplifier summing node, and becomes a voltage offset equal to the drop across CR2, because R64 and the feedback resistor for the trigger amplifier have the same value. Since CR2 and

the start/stop diode are matched and carry equal currents, the trigger baseline will be stable with varying VCG inputs.

#### 4.2.17 **Modulation Generator and Ramp Generator**

The function generator used as a modulation source in the instrument is the Intersil 8038 (U2 on the auxiliary generator board schematic). It is fitted with an auxiliary current balancing circuit (U1) to extend its useful dynamic range. The ramp output which is not built into the chip is developed by amplitude modulating the triangle function with the square function in a balanced modulator (U5). The output signals ( , , , , **M** ) are selected in a function selector switch and fed to the modulation switches where modulation type is selected. The ramp signals have a fundamental frequency of two times that of the other waveforms.