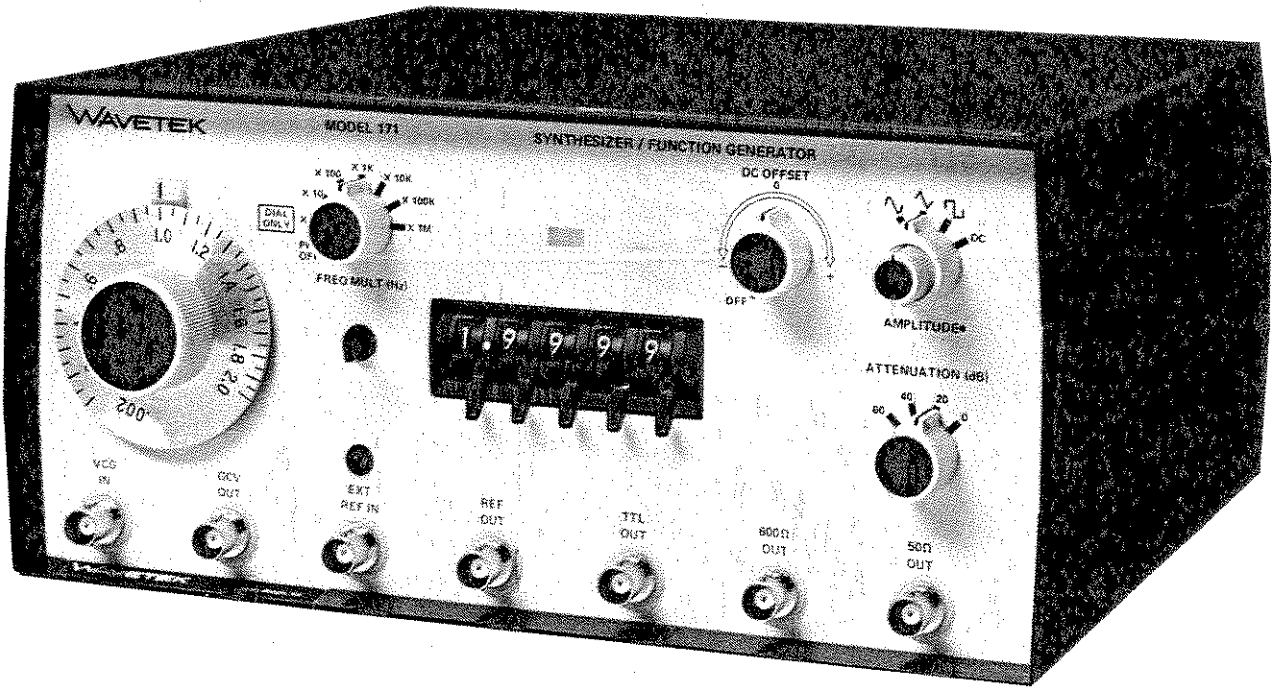
MODEL 171
SYNTHESIZER/FUNCTION GENERATOR



WAVETEK

SECTION 1
INTRODUCTION

1.1 THE MODEL 171

The Wavetek Model 171 Synthesizer/Function Generator is a precision source of sine, triangle and square waveforms and dc voltage. The generator combines the precision frequency of a synthesizer with the versatility and operating convenience of a function generator. The two major modes of operation are synthesizer and function generator.

Function generator output frequency can be varied from 0.1 Hz to 2 MHz in seven ranges manually by dial and remotely by an applied voltage. In addition to this analog control of frequency, the Model 171 has a 4½ digit switch for synthesizer control of function generator frequency. The synthesizer gives precision (0.005%) frequency accuracy and stability (0.0001%/°C) from 1.000 Hz to 1.9999 MHz in six ranges. When the synthesizer is used to set the frequency, in addition to greater frequency accuracy and stability, the waveform purity is improved over that of the function generator alone.

Amplitude of the waveform is continuously variable from 10V peak-to-peak in a matching termination load (50Ω or 600Ω) down to 10 mV peak-to-peak in four ranges of attenuation (0, 20, 40, 60 dB). DC reference of the waveforms can be offset positively and negatively. The synthesizer can be locked to its own internal reference or to an external 1 MHz reference.

1.2 SPECIFICATIONS

The available waveforms, frequencies, amplitudes, operating modes, precision (accuracy) and purity (quality) are listed in the following paragraphs.

1.2.1 Versatility

Output Signals
Sine ∿ , triangle ⋀ , square ⊓ and DC selectable. TTL pulse ⎍ , 1 MHz reference pulse ⎍ and GCV signal proportional to output frequency are also available.

Control
Generator operates in continuous mode. Frequency is controlled manually by dial or digital switch, or externally thru VCG input voltage. Digital switch is operable between 0.1000 and 1.9999 settings and works with all frequency multipliers except X 1.

Frequency Range
0.1 Hz to 2 MHz in seven overlapping ranges.

Operating Frequency Ranges

FREQ MULT	Range	Digital Resolution
X 1	0.1 Hz to 2 Hz	N. A.
X 10	1 Hz to 20 Hz	0.001 Hz
X 100	10 Hz to 200 Hz	0.01 Hz
X 1K	100 Hz to 2 kHz	0.1 Hz
X 10K	1K Hz to 20 kHz	1.0 Hz
X 100K	10K Hz to 200 kHz	10 Hz
X 1M	100K kHz to 2 MHz	100 Hz

NOTE

Digital switch valid with all frequency multipliers except X 1 (first range). Frequency ratio of 1000:1 on dial, 20:1 on digital switch.

Main Output
∿ , ⋀ , ⊓ ; variable to 20V p-p into open circuit and 10V p-p with matching load at either 50Ω OUT or 600Ω OUT. DC offset of waveform (or DC if selected) is adjustable to ±10 volts open circuit and ±5 volts into matching load. Waveform plus offset is limited to ±10V peak (open circuit).

Output waveforms can be attenuated from 0 dB to 80 dB: 60 dB in 20 dB steps plus a 20 dB vernier for continuous variation (20 dB vernier does not affect offset or DC output).

Optional output protection circuit of zeners and fuses protect both output and common sides from inadvertent connection to external voltage or ac line.

DC Offset and DC Output
DC offset of waveform and DC output are selectable and variable thru ±10V (±5V into matching load). Waveform plus offset is limited to ±10V peak (open circuit). Step attenuator attenuates dc level.

Generator Frequency TTL Output
TTL pulse has an approximately 50% duty cycle at generator frequency and can drive up to 20 TTL loads.

Optional TTL buffer circuit provides high power TTL compatible signal capable of driving load impedances as low as 50Ω.

GCV (Generator Controlled Voltage) Output
0 to +2V (nominal, open circuit) proportional to frequency of main generator. Output impedance 600Ω.

VCG (Voltage Controlled Generator) Input
In function generator mode only, VCG voltage as well as dial settings select generator frequency. Frequency may be dc-programmed or ac-modulated by external 0 to 2V signal. Input impedance is 2 kΩ. VCG input can change generator output 1000:1 in function generator mode on all ranges (limited by a minimum VCG frequency of 0.1 Hz).
VCG Input Signal Bandwidth: 100 kHz.
VCG Slew Rate: 0.1 V/μs.

External Reference Input
1 MHz sine or square wave external reference clock signal of 1 Vrms to 10 Vrms. 5 kΩ input impedance.

Reference Output
TTL level 1 MHz pulse train output when in the synthesizer mode.

Optional TTL buffer circuit provides high power TTL compatible signal capable of driving load impedances as low as 50Ω.

1.2.2 Operating Modes

Synthesizer
Operates as a synthesizer with function generator outputs locked to the synthesizer frequency. The frequency is determined by the frequency multiplier switch and the digital switch settings. The digital switch is operable from 0.1000 and 1.9999 on all ranges above the X 1 range.

Voltage Controlled Generator (VCG)
Operates as a conventional VCG. The frequency is controlled by the dial, multiplier switch and external VCG voltage on all ranges.

1.2.3 Frequency Precision

Synthesizer Operation
Accuracy: 0.005% of setting.
Stability: 1 ppm per degree C.
Internal Frequency Standard: 4 MHz crystal with an aging rate of 20 ppm per year.
Locking Time: Within 10% of final frequency in < 100 ms; within 0.01% of final frequency on X 1K, X 10K, X 100K and X 1M ranges in < 300 ms, X 100 in < 2s, X 10 in < 20s.

Dial/VCG Operation
Dial Accuracy: ±3% of full scale for 0.1 Hz to 200 kHz; ±5% of full scale for 200 kHz to 2 MHz.
Time Symmetry
±1% on all ranges except X 1M range.

1.2.4 Amplitude Precision

Amplitude Change With Frequency (Sine)
Less than ±0.1 dB on all ranges thru X 100K.
Less than ±0.5 dB on X 1M range.

1.2.5 Waveform Purity

Harmonic Distortion
Less than 0.5% to 20 kHz (typically 0.2%).
Less than 1.0% to 200 kHz (typically 0.5%).
All harmonics 30 dB below fundamental on X 1M range.

Spurious Signals
Typically 70 dB below fundamental to 20 kHz and 40 dB below fundamental to 2 MHz (in synthesizer mode only).

Integrated Signal to Phase Noise
Typically 30 dB to 200 kHz measured over ±15 kHz bandwidth excluding carrier ±10 Hz (in synthesizer mode only).

Square Wave Rise and Fall Time
Less than 75 ns.

Triangle Linearity
Greater than 99% to 200 kHz.

TTL Pulse Rise and Fall Time
Less than 25 ns (15 ns typical).

1.2.6 Environmental

Specifications apply at 23°C ± 5°C. Instrument will operate from 0°C to +50°C.

1.2.7 Mechanical

Dimensions
11¼ in./28.6 cm wide; 5¼ in./13.3 cm high; 10¾ in./27.3 cm deep.

Weight
8.5 lb/3.85 kg net; 12 lb/5.5 kg shipping.

1.2.8 Power

90 to 110V, 105 to 125V, 180 to 220V or 210 to 250V; 50 to 400 Hz; less than 20 watts.

NOTE

All specifications apply when frequency dial is between 0.1 and 2.0 or digital switch is between 0.1000 and 1.9999, amplitude is at 10V p-p and output is from the 50Ω BNC into a 50Ω load.

SECTION 2
INITIAL PREPARATION

2.1 UNPACKING INSPECTION

After carefully unpacking the instrument, inspect the external parts for damage to knobs, dials, indicators, surface areas, etc. If there is damage, file a claim with the carrier who transported the instrument. Retain the shipping container and packing material for use in case reshipment is required.

2.2 PREPARATION FOR USE

Before connecting the instrument to line power, be sure the rear panel 115/230V and HI/LO switches are set to the value nearest the line voltage and that the fuse is correct for the switch setting. Be sure that the plug on the power cord is the proper mate for the line receptacle.

AC Line Voltage	Switch A	Switch B	Fuse (SB)
90 - 110	115	LO	3/8 amp
105 - 125	115	HI	3/8 amp
180 - 220	230	LO	3/16 amp
210 - 250	230	HI	3/16 amp

2.3 ELECTRICAL ACCEPTANCE CHECK

This checkout procedure verifies the generator operation. If a malfunction is found, refer to the Warranty in the front of the manual. An oscilloscope, counter, three short lengths of 50Ω coax cable, a 50Ω feedthru load and a 0 to ±2V voltage source are required (figure 2-1). Circled numbers index controls and connectors to figure 3-1.

1. Preset the generator front panel controls as follows:

Control	Position
Frequency Dial (1)	1.0
FREQ MULT	X 1K
Digital Switch (4)	1.9999
DC OFFSET	OFF
Waveform Selector (6)	∿
AMPLITUDE	Full cw
ATTENUATION	0
Dial/Digital Switch (2)	Toward Dial

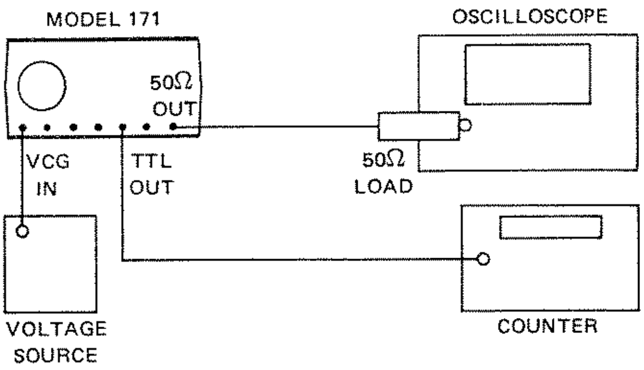


Figure 2-1. Performance Checkout Setup

Table 2-1. Performance Checkout

Step	Control	Position/Operation	Observe
Function			
1	Adjust the oscilloscope for several cycles of sine wave.		
2	Waveform Selector	⋀ , ⊓⊔ , DC, ∿	Waveform changes from ∿ to ⋀ to ⊓⊔ to a 0V dc level then ∿ .
Amplitude			
1	AMPLITUDE	Ccw to 12 o'clock	Waveform amplitude reduces.

Table 2-1. Performance Checkout (Continued)

Step	Control	Position/Operation	Observe
2	DC OFFSET	9 o'clock, then slowly to full cw (return to OFF)	Waveform offset negatively, then positively (clipping may occur).
3	ATTENUATION	20, 40, 60 (return to 0)	Waveform amplitude decreases with each step.
Outputs			
1	Remove 50Ω load and reconnect cable. Remove the 50Ω OUT connection and place it on the 600Ω OUT BNC.		Unloaded 50Ω OUT and 600Ω OUT are identical.
2	Remove the 600Ω OUT connection and place it on the TTL OUT.		Square pulse at 1 kHz.
3	Remove the TTL OUT connection and place it on the REF OUT. Flip dial/digital switch selector to digital switch side.		1 MHz pulse.
4	Remove the REF OUT connection and place it on the GCV OUT.		2 Vdc level.
5	Flip dial/digital switch selector to dial side.		1 Vdc level.
Frequency			
1	Remove GCV OUT connection and place on 50Ω OUT.		
2	FREQ MULT	Use each multiplier X 1 thru X 1M (return to X 1).	Observe an increase in frequency while stepping from X 1 to X 1M.
3	Dial	Vary from 2.0 to .2 (return to .2).	Observe a corresponding change in frequency.
4	Connect a 0 to ±2V source to the VCG IN BNC. Vary the voltage positively.		Observe a change in frequency proportional to the change in VCG voltage.
5	Dial	2.0	
6	Voltage Source	Vary the voltage negatively.	Observe a change in frequency proportional to the VCG voltage.
7	Disconnect the voltage source.		
8	Dial/Digital Switch Selector	Switch toward the digital switch.	1.9999 kHz.
9	Digital Switch	Set each position of the digital switch.	Observe counter readout corresponding to set of digital switch.

SECTION 3
OPERATION

3.1 CONTROLS AND CONNECTORS

The generator front panel controls and connections shown in figure 3-1 are keyed by circled numbers to the following descriptions.

(1) **Frequency Dial**

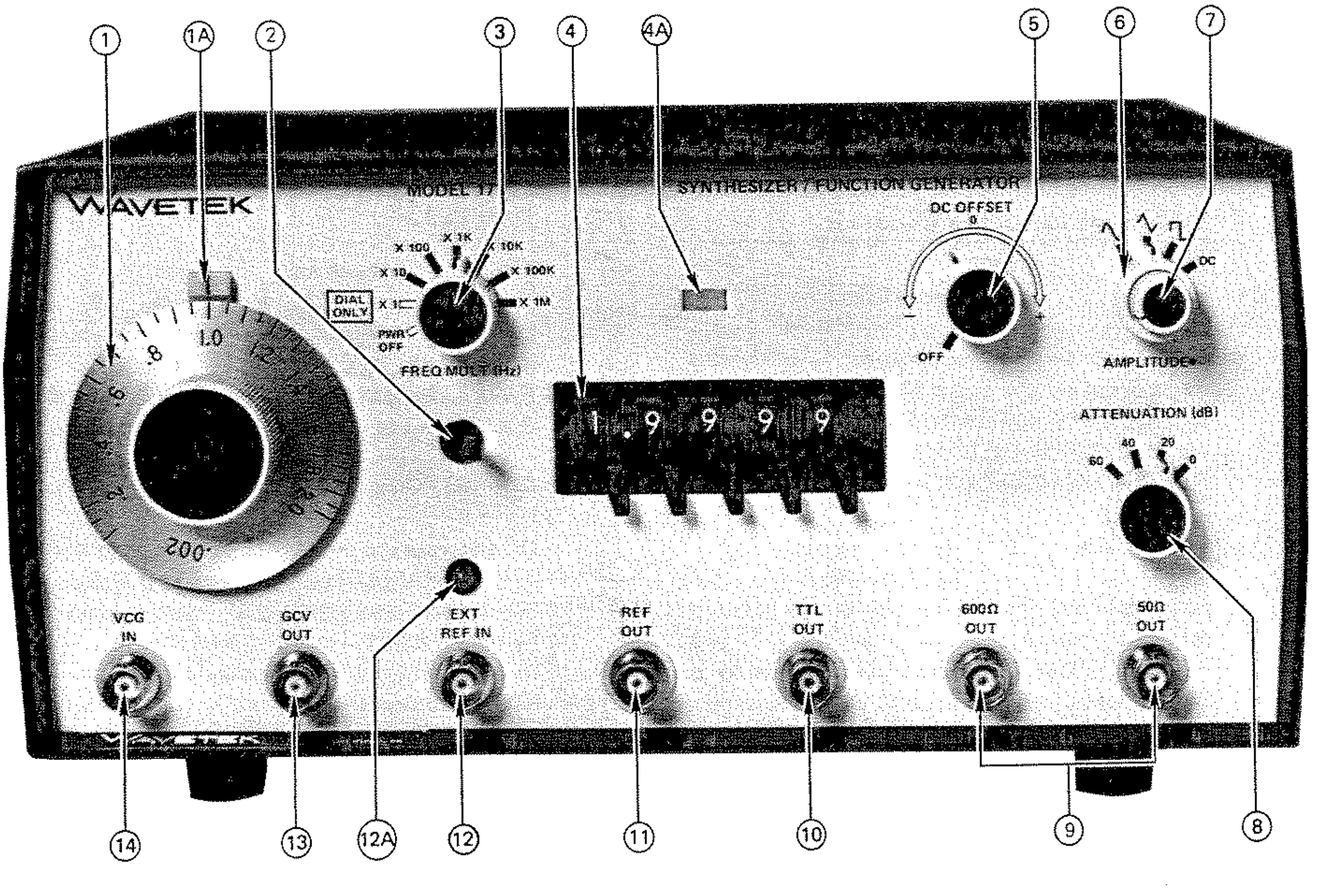
When the frequency dial is selected by the dial/digital switch selector (2) the index (1A) lights and the frequency output is determined by the dial, FREQ MULT (3) and VCG (14) voltage.

(2) **Dial/Digital Switch Selector**

Places the instrument in either function generator (dial controlled) or synthesizer (digital switch controlled) mode. Respective dial index (1A) or digital switch index (4A) lights to indicate operation mode.

(3) **FREQ MULT (Hz)**

Power is turned on when frequency range is selected at FREQ MULT. The multipliers are for the dial (1) and digital switch (4) readings and the VCG (14) voltage.



④ **Digital Switch**

When the digital switch is selected by the dial/digital switch selector ② the index 4A lights and the frequency output is determined by the digital switch and the FREQ MULT.

⑤ **DC OFFSET**

Rotating DC OFFSET clockwise past 12 o'clock offsets dc output or dc center reference of the output waveform positive; when counterclockwise, negative. When OFF, the dc output is signal ground or the output waveform is balanced around signal ground (0V in figure 3-2).

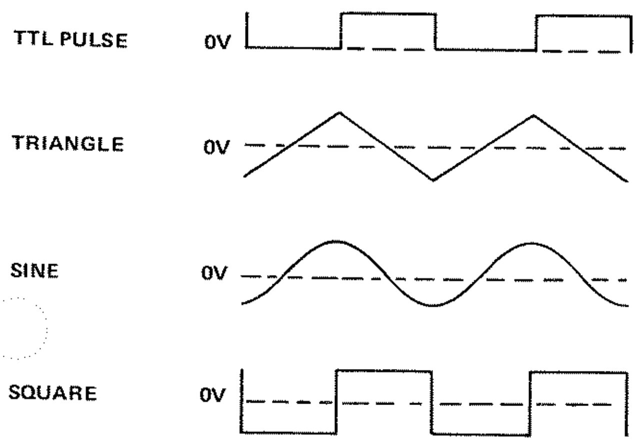


Figure 3-2. Output Waveforms

⑥ **∿ , ∧ , ⊓ and DC (Waveforms)**

Sine ∿ , triangle ∧ and square ⊓ waveforms are selected by the larger of the two concentric controls; the DC position provides a dc voltage output controlled by DC OFFSET. Outputs appear at 50Ω OUT and 600Ω OUT.

⑦ **AMPLITUDE**

Rotating AMPLITUDE fully clockwise provides maximum peak-to-peak output at 50Ω OUT and 600Ω OUT; rotating counterclockwise gives up to 20 dB attenuation. Also see ATTENUATION ⑧. AMPLITUDE does not affect dc offset or dc output.

⑧ **ATTENUATION**

With a 600Ω load on the 600Ω OUT connector or a 50Ω load on the 50Ω OUT connector, output voltage for each attenuation is:

	Amplitude Control	
Attenuation	**Full cw**	**Full ccw**
0	10V p-p	1V p-p
20	1V p-p	100 mV p-p
40	100 mV p-p	10 mV p-p
60	10 mV p-p	(Not specified)

⑨ **600Ω OUT and 50Ω OUT Connectors**

600Ω OUT and 50Ω OUT provide variable frequency and amplitude ∿ , ∧ , ⊓ and DC. Maximum signal amplitude is 10V p-p with matching loads (20V p-p into open circuit).

⑩ **TTL OUT Connector**

A fixed amplitude Transistor-Transistor Logic (TTL) square pulse train of the output frequency. (TTL levels are 0V to 0.4V for a logic low and 2.4V to 5V for a logic high.) The output can drive up to 20 TTL loads. The pulse train can also be used as a synchronizing reference to 50Ω OUT and 600Ω OUT. Phase of output waveforms relative to the TTL pulse is shown in figure 3-1.

⑪ **REF OUT Connector**

A fixed amplitude Transistor-Transistor Logic (TTL) pulse train of 1 MHz whose origin is an internal clock oscillator or, if indicator 12A is lit, the external reference signal of 1 MHz.

⑫ **EXT REF IN Connector**

Input for a 1 MHz sine or square wave external reference clock signal. The signal must be at least 1 Vrms. Synthesizer frequencies are referenced to this signal when indicator 12A is lit.

⑬ **GCV OUT Connector**

DC excursions at the Generator Controlled Voltage output (GCV OUT) of 0V to about 2V proportionally represents frequency within the range indicated by FREQ MULT.

⑭ **VCG IN Connector**

DC excursions at the Voltage Controlled Generator input (VCG IN) proportionally control frequency within the range determined by FREQ MULT. Positive voltage increases the frequency set by the dial ① ; negative voltage decreases the frequency. Use in function generator mode only.

3.2 OPERATION

Operation is described as function generator operation and synthesizer operation. The generator is ready to operate as soon as a frequency multiplier is selected.

3.2.1 Signal Termination

Proper signal termination, or loading, of the generator connectors is necessary for its specified operation. For example, the proper termination of the 50Ω OUT connector is shown in figure 3-3. Placing the 50 ohm terminator, or 50 ohm resistance, in parallel with a higher impedance, matches the receiving instrument input impedance to the generator output impedance, thereby minimizing signal reflection or power loss on the line due to impedance mismatch.

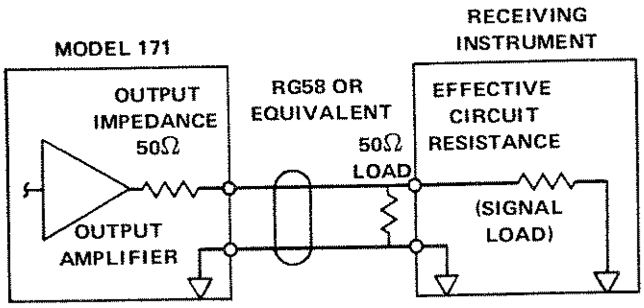


Figure 3-3. Signal Termination

The input and output impedances of the generator connectors are listed below:

Connector	Impedance
50Ω OUT	50Ω
600Ω OUT	600Ω
TTL OUT	*
REF OUT	*
VCG IN	2 kΩ
GCV OUT	600Ω
REF IN	5 kΩ

*The TTL OUT connector can drive up to 20 Transistor-Transistor Logic (TTL) loads (low level between 0V and 0.4V, and high level between 2.4V and 5V). REF OUT can drive up to 3 TTL loads. Addition of the TTL buffer option gives these outputs the capability of driving a 50Ω load.

3.2.2 Manual Function Generator Operation

For basic operation, select the waveform frequency and amplitude. The following steps demonstrate manual control of the function generator. (Circled numbers are keys to figure 3-1.)

Step	Control/Connector	Setting
1	50Ω OUT or 600Ω OUT	Connect circuit to either output (refer to paragraph 3.2.1).
2	Dial/Digital Switch Selector (2)	Set toward the dial.
3	FREQ MULT	Set to desired range of frequency.
4	Frequency Dial (1)	Set to desired frequency within the range.
5	Waveform Selector (6)	Set to desired waveform.
6	DC OFFSET	Set as desired. Limit waveform amplitude to prevent clipping (see figure 3-4).
7	AMPLITUDE and ATTENUATION	Select for desired amplitude.

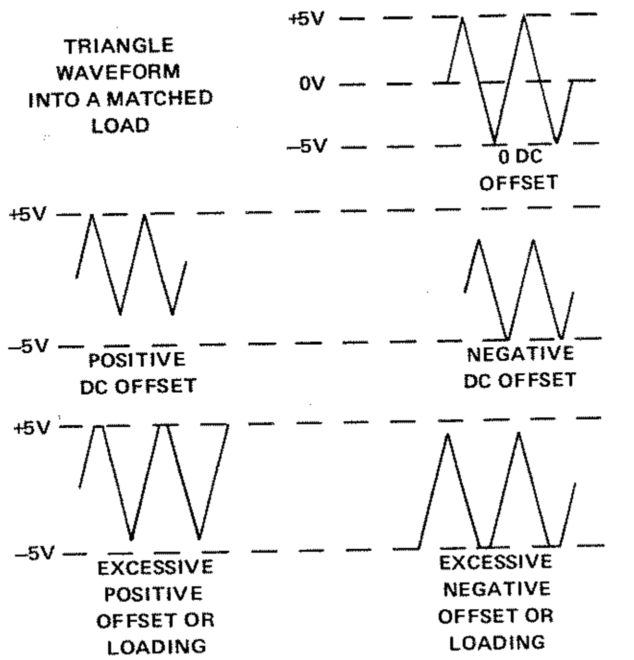


Figure 3-4. DC OFFSET Control

3.2.3 Voltage Controlled Function Generator Operation

Operation as a voltage controlled function generator (VCG) is as for a manually controlled function generator, only the frequency within particular ranges is additionally controlled with dc levels (±2V excursions) injected at the VCG IN connector. Perform the steps given in paragraph 3.2.2, only set the frequency dial to determine a reference from which the frequency is to be voltage controlled.

1. For frequency control with positive dc inputs at VCG IN, set the dial for a lower frequency limit.

2. For frequency control with negative dc inputs at VCG IN, set the dial for an upper frequency limit.

3. For modulation with an ac input at VCG IN, set the dial at the desired center frequency. Do not exceed the maximum dynamic range of the selected frequency range.

Figure 3-5 is a nomograph with examples of dial and voltage effects. Example 1 shows that with 0V VCG input, frequency is as determined by the main dial setting, 1.0 in this example. Example 2 shows that with a positive VCG input, output frequency is increased. Example 3 shows that with a negative VCG input, output frequency is decreased. (Note that the Output Frequency Factor column value must be multiplied by a frequency range multiplier to give the actual output frequency.)

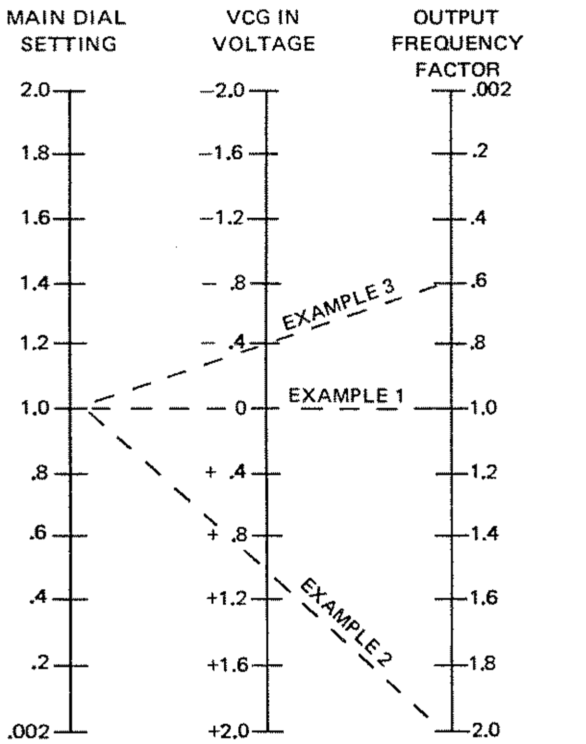


Figure 3-5. VCG Voltage-to-Frequency Nomograph

NOTE

Nonlinear operation results when the VCG input voltage is excessive; that is, when the attempted generator frequency exceeds the range setting (2 times the multiplier setting) or in the other direction, 1/1000th of the range setting.

The up to 1000:1 VCG sweep of the generator frequencies available in each range results from a 2V excursion at the VCG IN connector. With the frequency dial set to 2.0, excursions between −2V and 0V at VCG IN provide the up to 1000:1 frequency sweep. With the dial set to .002, excursions between 0V and +2V at VCG IN provide the up to 1000:1 sweep within the set frequency range.

3.2.4 Synthesizer Operation

For synthesizer operation, select the waveform, frequency and amplitude. The following steps demonstrate synthesizer control. (Circled numbers are keys to figure 3-1.)

Step	Control/Connector	Setting
1	50Ω OUT or 600Ω OUT	Connect the circuit to either output (refer to paragraph 3.2.1).
2	Dial/Digital Switch Selector 2	Set toward digital switch.
3	FREQ MULT	Set to desired range of frequency.
4	Digital Switch 4	Set to desired frequency within the range.
5	Waveform Selector 6	Set to desired waveform.
6	DC OFFSET	Set as desired. Limit waveform amplitude to prevent clipping (see figure 3-4).
7	AMPLITUDE and ATTENUATION	Select desired amplitude.

Synthesizer frequencies are normally referenced to an internal crystal oscillator. However, an external 1 MHz sine or square wave reference signal can be applied at REF IN; the indicator 13A will light, indicating a proper external reference in use.

3.2.5 Monitoring the Synthesizer/Function Generator

Besides the 50Ω OUT and 600Ω OUT main generator outputs, the GCV OUT connector supplies a voltage proportional to the generator frequency, the TTL OUT connector supplies a TTL compatible pulse train at the generator frequency, and the REF OUT supplies a TTL compatible 1 MHz pulse train.

The GCV OUT signal is used to drive the frequency axis of an X-Y recorder or oscilloscope; the generator frequency TTL OUT signal is used to synchronize other devices to the generator or to drive TTL level inputs, and the REF OUT signal is used to reference other 171's to a master crystal oscillator.