HEATH
Schlumberger

MODEL SG-5218

SINE-SQUARE AUDIO GENERATOR

595-1979

HEATH COMPANY
BENTON HARBOR, MICHIGAN 49022
a Schlumberger company

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INTRODUCTION

This Sine-Square Audio Generator has been designed for laboratory use as well as for service and testing. Sine wave signals are available between 1 Hz and 100 kHz. Low distortion (less than .1%) sine wave signals are available from 10 Hz to 100 kHz. The output is stepped from .003 volt to 10 volts. These high quality sine wave signals make it ideal for such applications as testing audio amplifiers for gain and frequency response, as a signal source for harmonic distortion measurements, or as an external modulator for an RF signal generator.

Square wave signals with a rise time of 50 nanoseconds are available from 5 Hz to 100 kHz at output levels up to 10 volts. These clean square wave signals can be used for checking frequency response in audio equipment, or as a trigger for testing digital instruments.

The sine and square wave frequencies are identical and the level of each is independently adjustable. Both signals may be used either simultaneously or independently.

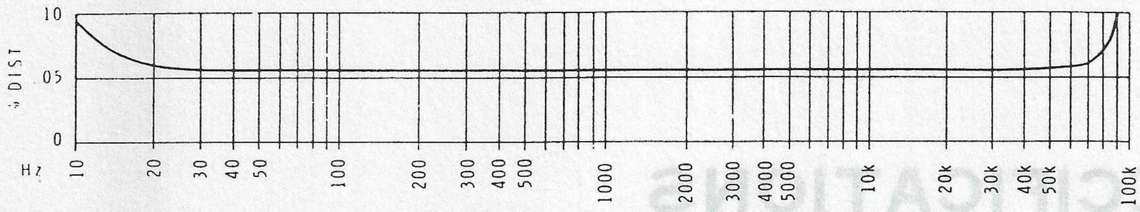
The sine wave output will operate into high impedance loads (10 kΩ or higher) in all output ranges, or it will operate into 600 ohm loads in ranges up to 1 volt. The square wave output is designed to operate into loads of 2000 ohms or greater.

Other features include: A panel meter for monitoring the sine wave output; repeatable selection of any frequency; switch-selected 600 ohm internal load; and all solid-state circuitry for maximum reliability. All of these features combine to provide a versatile, accurate, and attractive signal source.

SPECIFICATIONS

SINE WAVE OUTPUT

Frequency Range	1 Hz to 100 kHz.
Output Voltage Ranges	0 – .003 0 – .01 0 – .03 0 – .1 0 – .3 0 – 1 0 – 3 0 – 10
Internal Load	Internal 600 Ω load available on .003, .01, .03, .1, .3, and 1 volt ranges.
dB Ranges	−62 to +22 dB. −12 to +2 dB on meter. −50 to +20 dB in eight 10 dB switch positions. +2 dB maximum into 600 Ω load.
Output Variation	±1 dB from 10 Hz to 100 kHz.
Output Indication	Two voltage scales and one dB scale on front panel meter.
Output Impedance	10 volt range: 0-1000 Ω. 3 volt range: 800-1000 Ω. 1 volt range and lower: 600 Ω.
Meter Accuracy	±10% of full scale with proper load termination.



PERCENT DISTORTION-TYPICAL

Distortion	Less than .1% from 10 Hz to 20 kHz.
Type of Circuit	Differential amplifier with complementary pair output. Notch filter frequency determination.

SQUARE WAVE OUTPUT

Frequency Ranges	5 Hz to 100 kHz.
Output Voltage Ranges	0–.1 V, 0–1 V, and 0-10 V zero-to-peak into 2000 Ω or higher load.
Output Impedance	52 Ω on .1 V and 1 V ranges; Up to 220 Ω on 10 V range.
Rise Time	Less than 50 nanoseconds.

GENERAL

Frequency Selection	First two significant figures on 0–100 and 0–10 switches each in ten steps. Third figure on 0–1 control. Multiplier switch: X1, X10, X100, X1000.
Frequency Error	Within ±5% of first and second digit.
Power Requirements	105-125 VAC or 210-250 VAC, 50/60 Hz, 6 Watts.
Dimensions	5.12″ high x 13.25″ wide x 7″ deep. (13 cm high x 33.6 cm wide x 17.8 cm deep.)
Net Weight	7 lbs. (3.18 kgs.)

210-260 VOLT PRIMARY WIRING

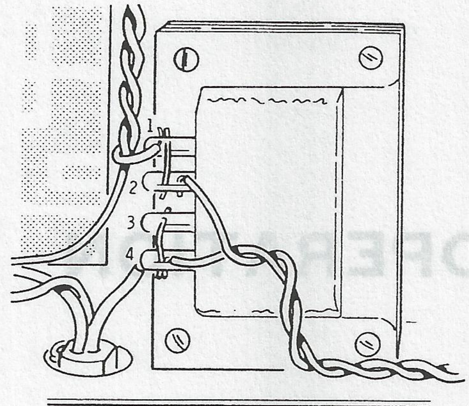
When shipped, this instrument is ready for operation from a 105-130 volt ac source. If 210-260 volt ac operation is desired, remove the top cover of the generator. Perform the following instructions:

1. Refer to Figure 2A and remove the two jumper wires from the terminals located on the power transformer.

2. Refer to Figure 2B and install an insulated jumper wire between tabs #2 and #3. Solder these connections.

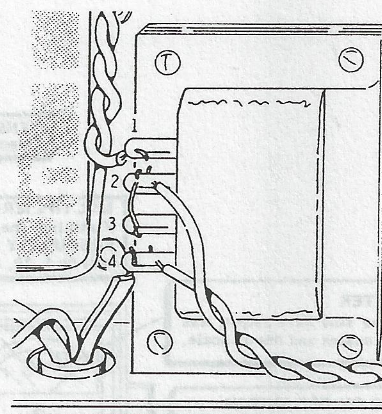
3. Reinstall the top cover.

NOTE: Electrical regulations in some areas require a special line cord and/or plug for 240-volt operation. Replace if necessary.



120 VAC WIRING

Figure 2A
120-VOLT PRIMARY



240 VAC WIRING

Figure 2B
240-VOLT PRIMARY

FREQUENCY SELECTION

To select a given frequency, set the TENS and UNITS FREQUENCY switches to correspond with the first two figures of the frequency. If a third figure is required, set the FREQUENCY control to the correct number. Then set the MULTIPLIER switch to the appropriate position to multiply the switch and control settings by the required multiplying factor.

EXAMPLES:

SWITCH AND CONTROL SETTINGS

SELECTED FREQUENCY	MULTIPLIER	TENS FREQUENCY	UNITS FREQUENCY	FREQUENCY CONTROL
60 Hz	X1	60	0	0
60 Hz	X10	0	6	0
400 Hz	X10	40	0	0
1520 Hz	X100	10	5	.2
15.2 kHz	X1000	10	5	.2

OPERATION

This section will first present alternate primary power transformer wiring for operation from a 210-260 volt ac power source, followed by detailed instructions on proper instrument usage. Refer to Figure 1 for a description of each of the front panel controls and terminals, before you read the remaining material in this section.

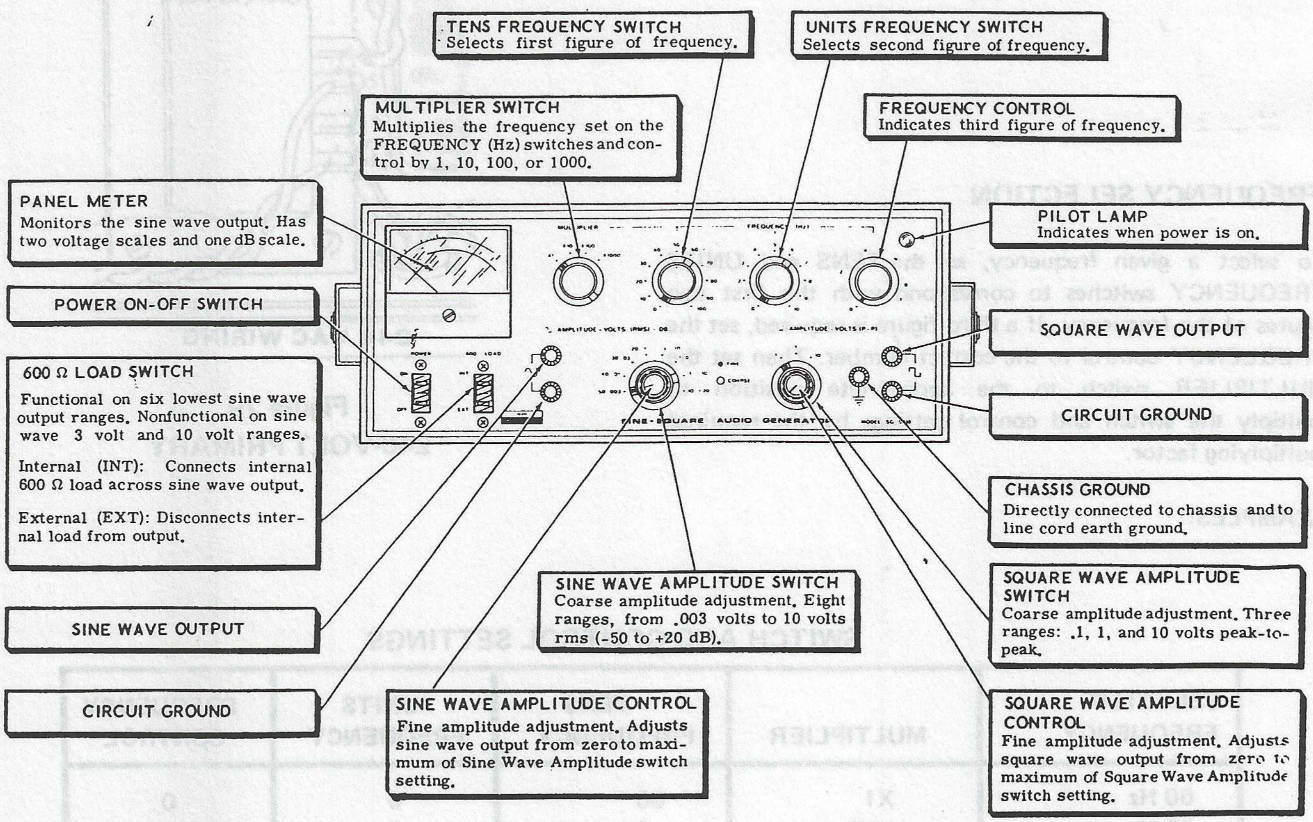


Figure 1 Front panel controls and terminals

SINE WAVE AMPLITUDE

The output of the Audio Generator must be properly terminated to obtain accurate meter indications.

To obtain correct meter readings with a high impedance load (10 kΩ or more); set the 600 Ω LOAD switch to INT, and set the SINE WAVE AMPLITUDE switch to the nearest full scale value above the desired output level. Then adjust the SINE WAVE AMPLITUDE control to give the desired output on the proper meter scale. EXAMPLE: For an output voltage of 7.3 volts, set the SINE WAVE AMPLITUDE switch to 10 volts. Then turn the SINE WAVE AMPLITUDE control to give a 7.3 reading on the 0-10 scale of the meter. EXAMPLE: For an output of .025 volt, set the SINE WAVE AMPLITUDE switch to .03 volt. Then turn the SINE WAVE AMPLITUDE control to give a 2.5 reading on the 0-3 meter scale.

To obtain correct meter readings with an external 600 Ω load (1 volt maximum output signal level): set the LOAD switch to EXT and proceed as before.

SQUARE WAVE AMPLITUDE

To select a square wave output level, set the COARSE SQUARE WAVE AMPLITUDE switch to the lowest range that includes the desired voltage. Then adjust the FINE SQUARE WAVE AMPLITUDE control until the required voltage is produced. The front panel voltage ranges (.1v, 1v, and 10v) are for loads of 2000 Ω impedance or more. Output level may be measured with a high impedance AC voltmeter or with an oscilloscope. Remember that a square wave is measured in peak-to-peak volts and that most AC voltmeters indicate rms volts.

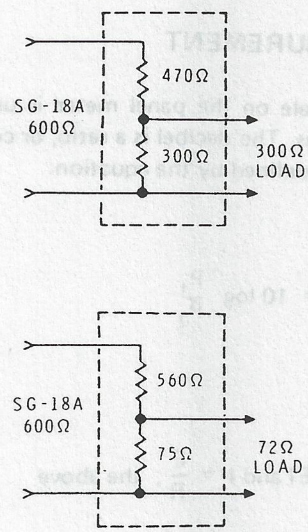


Figure 3 Impedance matching

CAUTION: The square wave generator output is DC-coupled to avoid poor low frequency response (see "Square Wave Testing" on Page 13). The output is a DC signal that varies from zero to some positive value when measured at the output terminals. Do not connect this generator output into DC circuitry without using capacitive coupling. (Observe proper capacitor polarity.) Do not short the output terminals at maximum (10.0v) output.

IMPEDANCE MATCHING

In general, impedance matching is not critical in test work. However, if close matching is required, matching pads may be constructed using composition resistors as shown in Figure 3. This Figure shows two examples for matching the 600 Ω output to different input leads. Since these pads also act as voltage divider networks, the input voltage will be less than the voltage indicated by the panel meter.

dB MEASUREMENT

The red scale on the panel meter is used for decibel (dB) comparisons. The decibel is a ratio, or comparison, of power levels. It is defined by the equation:

$$dB = 10 \log \frac{P_1}{P_2}$$

Since $P = EI$ and $I = \frac{E}{R}$, the above equation may be restated as:

$$dB = 10 \log \frac{\left(\frac{E_1^2}{R}\right)}{\left(\frac{E_2^2}{R_2}\right)}$$

While the decibel is basically a relative expression between two power levels, it can be used as a quantitative expression if one of the levels is defined as a standard level.

After various levels in several industries were partly accepted as "standard levels", the audio industry settled on a standard level of 1 milliwatt of power into a 600 ohm load. This standard level may be used in 600 ohm circuits only. In these circuits R_1 and R_2 in the above equation are equal and cancel out, simplifying the expression to:

$$dB = 10 \log \frac{E_1^2}{E_1^2}\text{, or}$$

$$dB = 10 \log \left(\frac{E_1}{E_2}\right)^2\text{, or}$$

$$dB = 20 \log \frac{E_1}{E_2}.$$

Accordingly, with the standard 600 Ω load across the signal output, you can read relative power on a voltmeter, such as the front panel meter on the Generator or any other voltmeter with the appropriate calibration (dB scale).

As zero dB is defined as 1 milliwatt in a 600 Ω load, and $P = \frac{E^2}{R}$, then $.001 = \frac{E^2}{600}$, or $E = \sqrt{.6}$, or $E = .755$ V.

It is for this reason that the zero dB mark is in line with the 7.75 mark on the 0-10 meter scale.

APPLICATIONS

SINE WAVE TESTING

Gain and distortion checks are probably the most common types of sine wave tests that you will make with this Generator. Usually these tests are performed on an amplifier. In either of these tests, a single amplifier stage may be tested separately, or the entire amplifier may be tested.

To test for distortion, the output signal from an amplifier can be displayed on an oscilloscope and compared with the input sine wave from the Sine-Square Generator. This test will indicate if distortion is present and, if so, what kind. Figure 4 shows waveforms of several kinds of distortion.

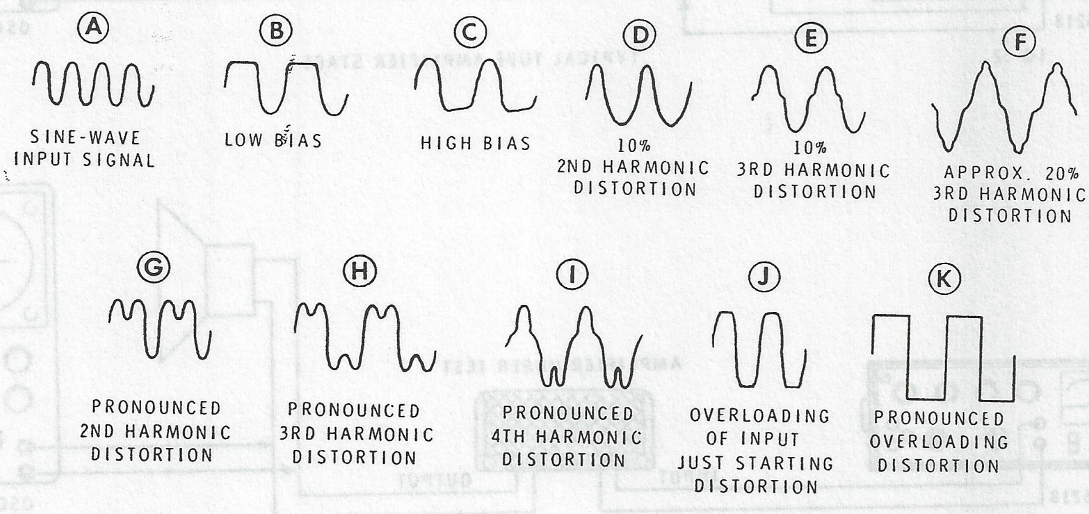


Figure 4 Typical distortion patterns obtained in Audio Amplifier testing

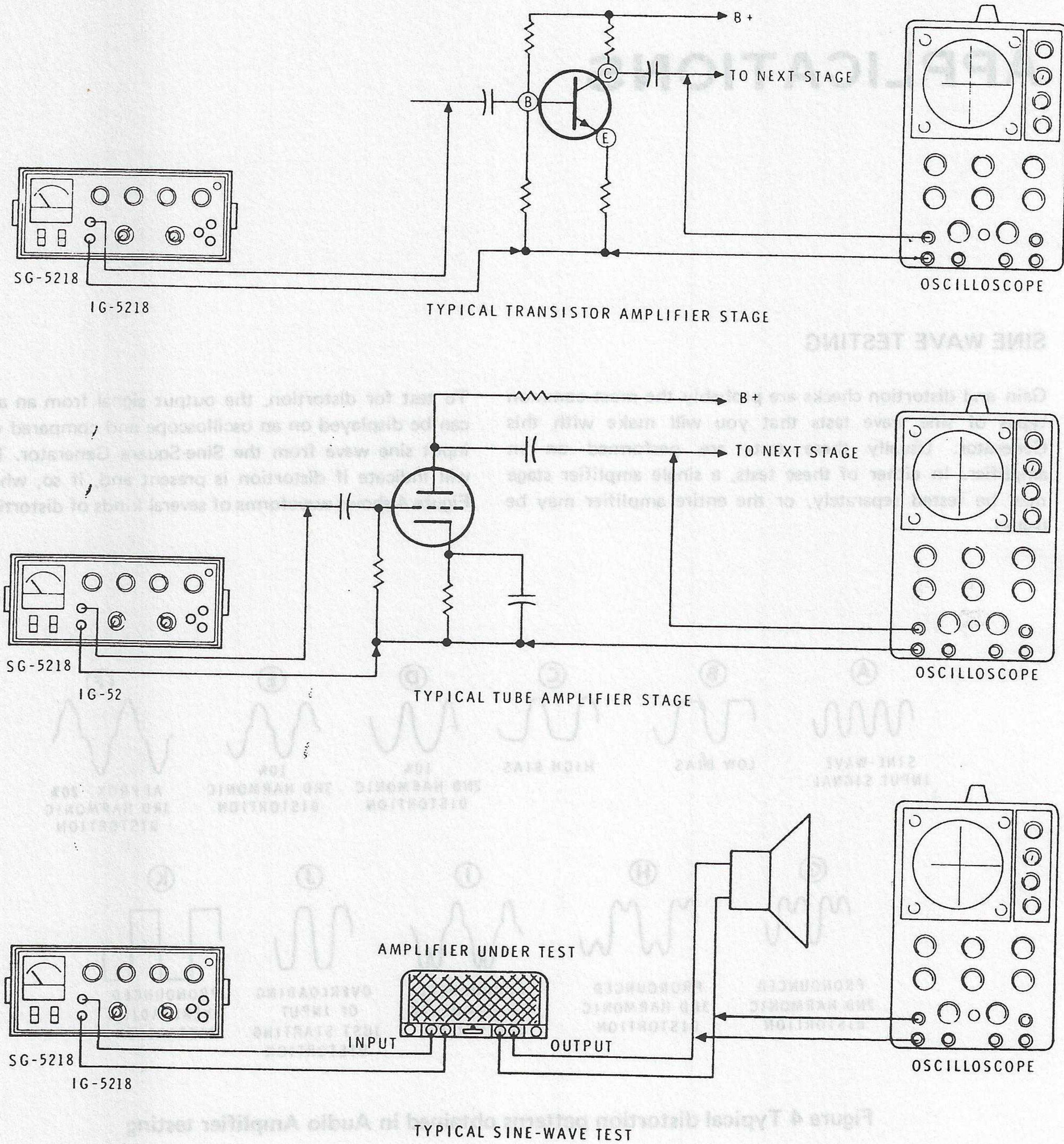
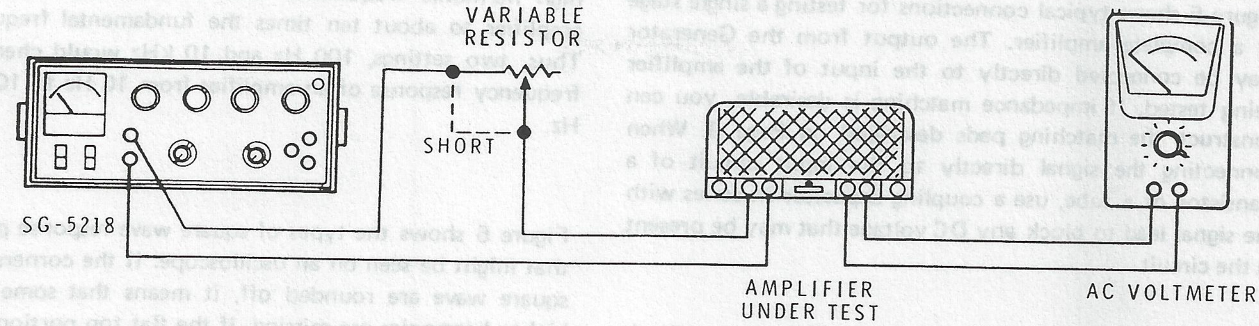


Figure 5 Typical connections for testing.



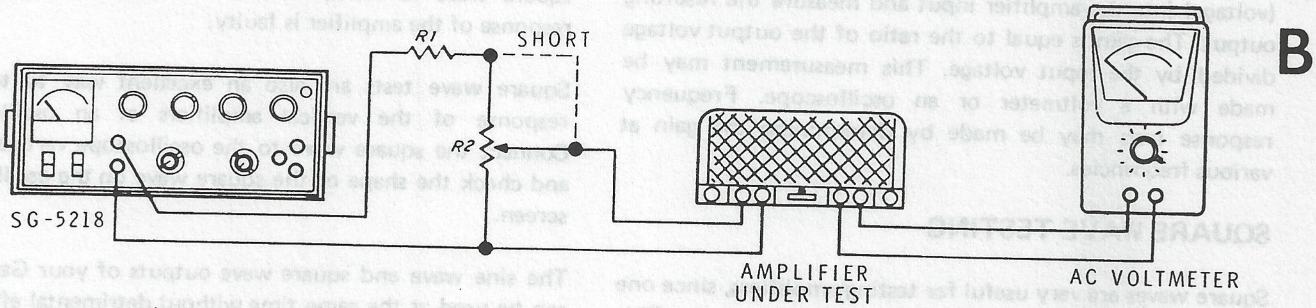


Figure 7 Connections for impedance tests.

SPECIAL GENERATOR APPLICATIONS

Impedance Measurements

Figures 7A and 7B show how to measure the input impedance of an amplifier or of a similar circuit. The method is exact if the impedance is resistive, approximate if it is reactive. For measuring input impedances that are high compared to the Generator output impedance, use the arrangement shown in Figure 7A. It may be necessary to use variable resistors of several different values, such as 10 kΩ, 100 kΩ, 1 MΩ, and 5 MΩ, to obtain the correct indication on the external AC meter.

Set the Generator to a low frequency, such as 20 Hz, short out the variable resistor, and set the signal level of the Generator to give a convenient reading on the AC voltmeter. Remove the short from the variable resistor. The value of the variable resistor is then adjusted until the reading on the meter drops to 1/2 of the former value. The resistance of the variable resistor is then equal to the unknown input impedance of the amplifier. The resistance of the variable resistor can be measured with an ohmmeter. If this same check were made at higher frequencies, the input impedance ould appear to be smaller because some of the signal would shorted out by the input capacitance of the amplifier.

For low input impedances, of a few hundred ohms or less, connect the circuit as shown in Figure 7B. Fixed series resistor R1 should be at least ten times the input resistance to be measured. The value of this resistor is not important if it is made large enough. The output voltage is set to some convenient value, as before, with variable resistor R2 disconnected.

When R2 is connected again, it is adjusted until the meter reading drops to half of the former value. The resistance of variable resistor R2 is then equal to the input resistance of the amplifier.

FREQUENCY MEASUREMENTS

An oscilloscope and the Generator can be used to measure the frequency of an unknown signal. Place the oscilloscope horizontal frequency selector in the horizontal input position. Connect a sine wave from the Generator to the horizontal input of the oscilloscope. Connect the unknown frequency to the vertical input of the oscilloscope. Do not used square waves to make these tests.

When the size of the generator signal is adjusted to approximately the same size as that of the unknown signal, and the oscilloscope is properly adjusted, waveforms called

Figure 5 shows typical connections for testing a single stage or a complete amplifier. The output from the Generator may be connected directly to the input of the amplifier being tested. If impedance matching is desirable, you can construct the matching pads described on Page 9. When connecting the signal directly to the input circuit of a transistor or a tube, use a coupling capacitor in series with the signal lead to block any DC voltage that may be present in the circuit.

To test the voltage gain, feed a signal of known amplitude (voltage) into the amplifier input and measure the resulting output. The gain is equal to the ratio of the output voltage divided by the input voltage. This measurement may be made with a voltmeter or an oscilloscope. Frequency response tests may be made by determining the gain at various frequencies.

SQUARE WAVE TESTING

Square waves are very useful for testing amplifiers, since one square wave will perform several tests simultaneously. This occurs because the square wave is actually a complex waveform made up of many sine waves, which are the fundamental frequency and all of the odd harmonics of that frequency. Therefore, in one operation, the square wave tests a circuit at many different frequencies, from one tenth to ten times the fundamental frequency.

The flat top of the square wave tests the low frequency response of a circuit. This happens because the flat top more closely resembles low frequencies, or short burst of DC voltage. The vertical portion of the square wave contains high harmonic frequencies that test the response of the amplifier to about ten times the fundamental frequency. Thus, two settings, 100 Hz and 10 kHz would check frequency response of an amplifier from 10 Hz to 100,000 Hz.

Figure 6 shows the types of square wave response patterns that might be seen on an oscilloscope. If the corners of the square wave are rounded off, it means that some of the higher harmonics are missing. If the flat top portion of the square wave is tilted, it means that the low frequency response of the amplifier is faulty.

Square wave tests are also an excellent way to test the response of the vertical amplifiers of an oscilloscope. Connect the square wave to the oscilloscope vertical input and check the shape of the square wave on the oscilloscope screen.

The sine wave and square wave outputs of your Generator can be used at the same time without detrimental effects to either waveform. This makes the use of recurrent sweep oscilloscopes especially easy with this instrument.

For example, when making stage gain measurements on an amplifier with an oscilloscope, connect the sine wave output of the Generator to the input of the stage being measured. Connect the square wave output to the external sync connector of the oscilloscope. Measurements can now be made through a number of amplifier stages without readjusting the oscilloscope sync controls, regardless of how small or how large the signal is.

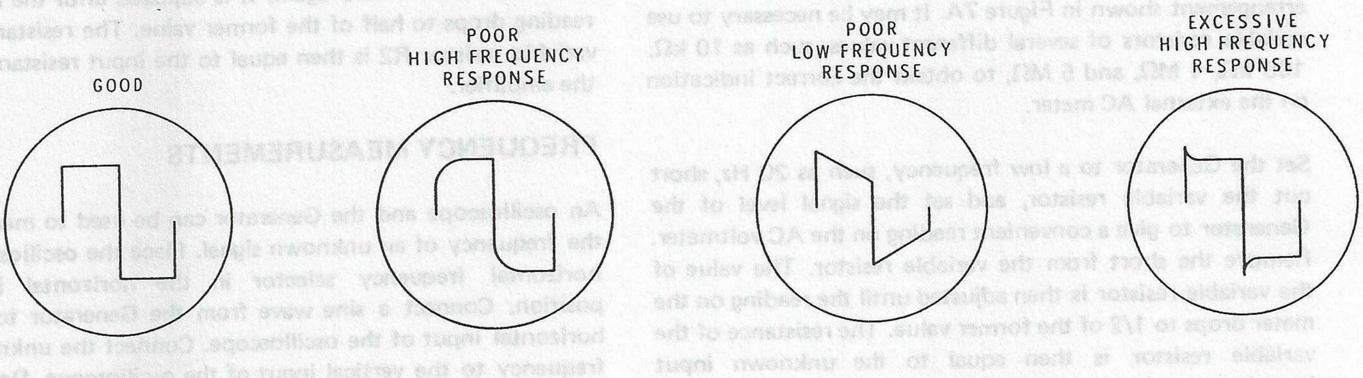


Figure 6 Response patterns

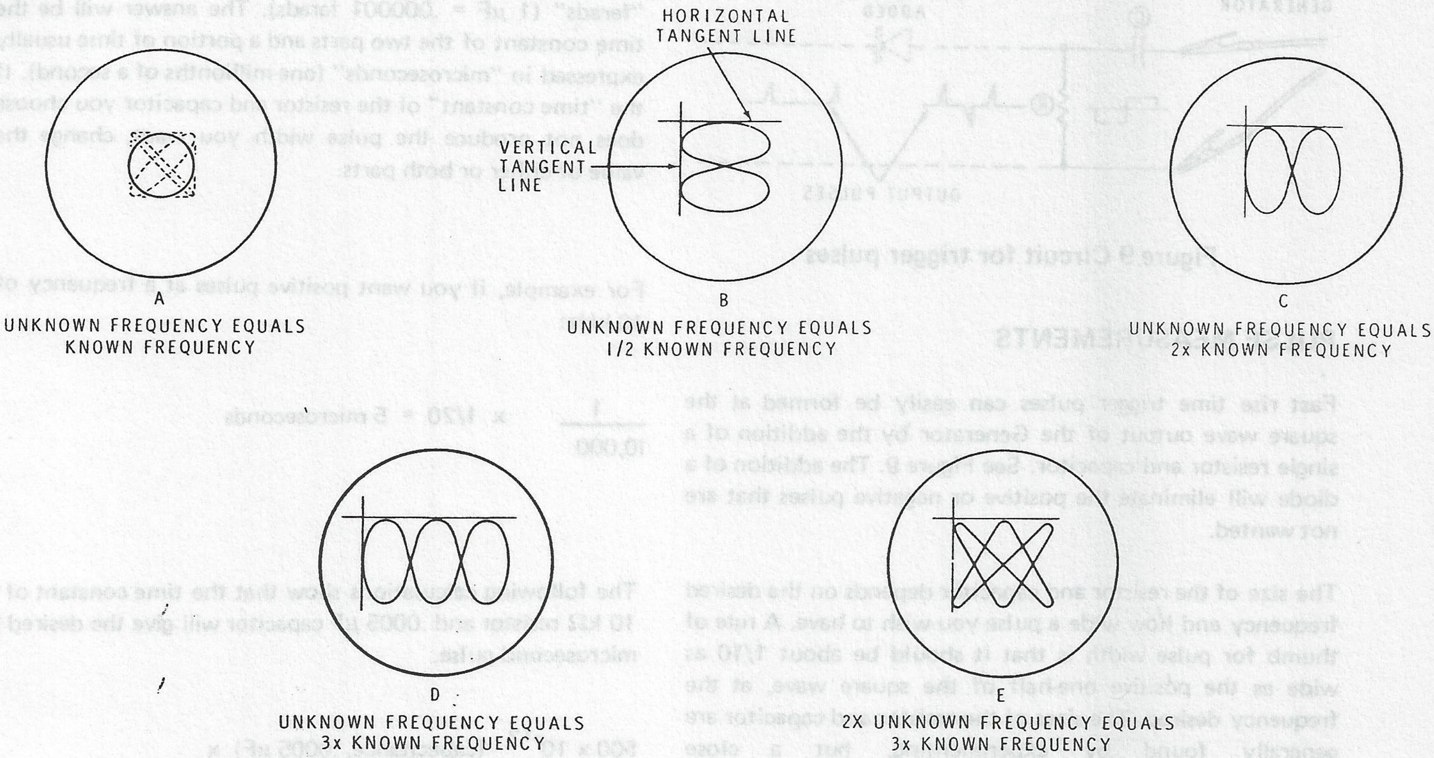


Figure 8 Typical Lissajous figures.

Lissajous figures will be seen on the oscilloscope. Interpreting these waveforms correctly will show the frequency of the unknown signal.

To measure an unknown frequency, adjust the Generator frequency until the pattern comes as close as you can adjust it to the circle shown in Part A of Figure 8. This circle may appear to revolve in such a way that it alternately assumes each of the following forms: a slanting line to the left, an ellipse, a circle, an ellipse, again, a slanting line to the right, an ellipse, etc. Often, it will be almost impossible to keep the circle from revolving.

When the circle is displayed on the oscilloscope screen, the frequency of the unknown signal is then exactly equal to the frequency of the Generator, as shown on the Generator dial. The accuracy of the measurement is the same as the accuracy of the Generator frequency.

Unknown frequencies that are beyond the frequency limits of the Generator can be measured by using more complex Lissajous patterns, such as the ones shown in Parts B, C, D, and E of Figure 8. In these cases, the pattern shown on the oscilloscope gives the ratio between the frequency of the Generator signal and the frequency of the unknown signal. Determining the frequency of the unknown signal then becomes a matter of simple arithmetic. The frequency of the unknown signal can be calculated using the following formula:

$$\text{Unknown Frequency} = \frac{T_h \times F}{T_v}$$

In the above formula, T_h is the number of loops that touch the horizontal tangent line; F is the Generator frequency; and T_v is the number of loops which touch the vertical tangent line.

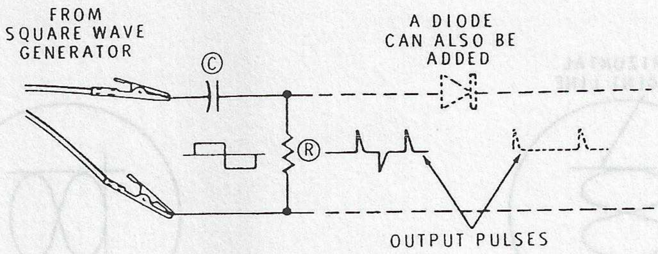


Figure 9 Circuit for trigger pulses

PULSE MEASUREMENTS

Fast rise time trigger pulses can easily be formed at the square wave output of the Generator by the addition of a single resistor and capacitor. See Figure 9. The addition of a diode will eliminate the positive or negative pulses that are not wanted.

The size of the resistor and capacitor depends on the desired frequency and how wide a pulse you wish to have. A rule of thumb for pulse width is that it should be about 1/10 as wide as the positive one-half of the square wave, at the frequency desired. The sizes of the resistor and capacitor are generally found by experimenting, but a close approximation can be found in the following manner:

$$\frac{1}{\text{freq. of square wave}} \times 1/2 = \text{time of 1/2 cycle of square wave}$$

The above x 1/10 = width of average pulse quantity in fractions of a second

Collecting the above together we get:

$$\frac{1}{\text{freq. of square wave}} \times 1/20 = \text{time of pulse width for average pulse.}$$

To find the size of the pulse that a resistor and capacitor will give, multiply the resistance in ohms by the capacitance in "farads" (1 μF = .000001 farads). The answer will be the time constant of the two parts and a portion of time usually expressed in "microseconds" (one-millionths of a second). If the "time constant" of the resistor and capacitor you choose does not produce the pulse width you want, change the value of either or both parts.

For example, if you want positive pulses at a frequency of 10 kHz:

$$\frac{1}{10{,}000} \times 1/20 = 5 \text{ microseconds}$$

The following calculations show that the time constant of a 10 kΩ resistor and .0005 μF capacitor will give the desired 5 microsecond pulse.

500×10^{-12} (capacitance, .0005 μF) x
1×10^{4} (resistance, 10 kΩ) =

$500 \times 10^{-8} = 5 \times 10^{-6} = .000005$
= 5 microseconds

Another way this time constant can be caluclated is as follows:

.0000000005 (capacitance, .0005 μF)
x 10,000 (resistance, 10 kΩ) =
.000005 = 5 microseconds

CIRCUIT DESCRIPTION

Refer to the Block Diagram on Page 19 and to the Schematic Diagram (fold-out from Page 29) while reading this Circuit Description.

The circuit of the Sine-Square Audio Generator includes three principal sections: The Sine Wave Generator (including the meter and output attenuator circuits), the Square Wave Generator, and the Power Supply. Each of these Sections will be described separately.

SINE WAVE GENERATOR

The sine wave oscillator circuits consist of differential amplifier transistors Q1 and Q2; voltage amplifier transistor Q3; power amplifier transistors Q4 and Q5; and the positive and negative feedback loops. Positive (regenerative) feedback comes from the common emitter output of transistors Q4 and Q5, and is coupled to the base of transistor Q2 through the lamp L1, the arm of feedback control R7, and resistor R6. Negative (degenerative) feedback comes through the notch filter and is directly coupled to the base of transistor Q1.

Oscillation occurs due to the positive feedback. Without negative feedback, the circuit would oscillate at some indeterminate frequency; however, the notch filter, which passes all frequencies except the one to which it is tuned, provides the negative feedback to the base of transistor Q1. This negative feedback prevents oscillation at all frequencies except the one that is not passed, permitting the system to oscillate at only the selected frequency.

The tuned frequency of the RC notch filter circuit may be calculated by the general formula:

$$F = \frac{1}{2\pi RC}$$

where F is frequency in hertz, R is resistance in ohms, and C is capacitance in farads. However, since this notch filter is a specialized RC network in which there are two resistances and two capacitances, the formula for this network then becomes:

$$F = \frac{1}{2\pi\sqrt{R_1 \; R_2}\sqrt{C_1 \; C_2}}\,.$$

Since R_1 and R_2 will always be equal, the formula simplifies to:

$$F = \frac{1}{2\pi R\sqrt{C_1 \; C_2}}\,.$$

In the notch filter in the Sine-Square Audio Generator R may consist of one or several resistors in parallel; or

$$R = \frac{1}{\frac{1}{R_x} + \frac{1}{R_y} + \frac{1}{R_z}}; \quad C_1 = C_x; \text{ and } C_2 = C_y .$$

R_x represents the resistance value selected by the Tens Frequency switch for a particular frequency. This resistance may consist of one resistor, or a parallel combination of several resistors. For example; for 20 Hz the two 5000 Ω resistors are selected and R_x = 5000 Ω, for 40 Hz the two 2500 Ω resistors are selected and R_x = 2500 Ω, for 60 Hz both the 5000 Ω and the 2500 Ω resistors are selected in parallel and R_x = 1670 Ω.

R_y represents the resistance value selected by the Units Frequency switch for a particular frequency. The operation of this switch is identical to that of the Tens Frequency switch, except that the resistance values are ten times those of the Tens Frequency switch.

R_z represents the resistance value of the Frequency control when adjusted for a particular frequency.

C_x and C_y represent the capacitors on the Multiplier switch. The value of C_y will always be 10 times larger than the value of C_x for all positions of the Multiplier switch.

As shown in the general formula $F = \frac{1}{2\pi RC}$, the tuned frequency of a notch filter is inversely proportional to the value of its resistances and capacitances. Therefore, to achieve an increase in frequency the resistance must decrease. Likewise, for a tenfold increase in frequency, by using the Multiplier switch, the capacitance must decrease tenfold.

Any tendency of the oscillator to produce signals of increasing amplitude is controlled by lamp L1. If the oscillator output increases, more current is fed through the feedback circuit and through lamp L1. This increased current causes the filament of the lamp to heat slightly, which causes its resistance to increase. This increase in resistance attenuates the feedback signal to the base of transistor Q2. The result is a regulated output from transistor Q2.

DC base bias is provided to Q1 and Q2 through a volt divider that consists of resistors R5 and R6, and control (Resistor R3 decreases the gain of the differential amplifie to make it more stable.) The voltage at the lower end of thi divider, and therefore at the bases of Q1 and Q2, is mad adjustable by being connected to the arm of Bias contrc R9, which is connected in a DC voltage divider with R8 an R10.

The signal from the differential amplifier is direct couple from the collector of Q2 to the base of voltage amplifi transistor Q3. From the collector of Q3, the signal is dire coupled to the base of Q4, and through diodes D1 and D2 t the base of Q5. These diodes maintain a 1.2 volt differenc between the bases of transistors Q4 and Q5.

Q4 and Q5 form an emitter follower complementary-pa amplifier with no voltage gain and a low impedance outpu The output signal from this stage is coupled to the squar wave circuits as a trigger signal and to the sine wave outpu attenuator.

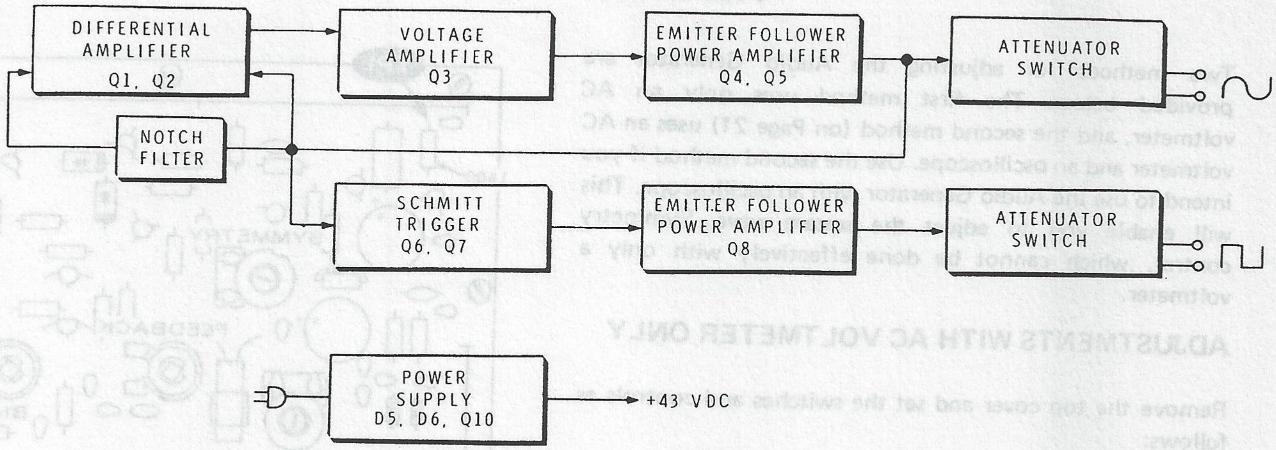
SINE WAVE OUTPUT ATTENUATOR

The sine wave signal from Q4 and Q5 is coupled through capacitor C6 to Sine Wave Amplitude control R106. From R106, the signal is coupled through isolating resistor R107 to the meter circuit and to the Sine Wave Amplitude switch.

The resistor network on two sections of this switch comprise an eight-step voltage divider (R109 to R121) which proportionately divides the signal into steps of 10 dB each. The selected voltage level is applied to the sine wave output terminals. The remaining section of the switch permits internal load resistor R122 to be connected across the output terminals in the six lowest output ranges.

METER CIRCUIT

Resistor R108 and meter calibration control R21 comprise a voltage divider through which some of the signal from resistor R107 is bypassed for monitoring by the panel meter. Diodes D3 and D4, and load resistors R24 and R25 form a half-wave bridge rectifier circuit for the output meter.



BLOCK DIAGRAM

SQUARE WAVE GENERATOR

The square wave section consists of a Schmitt trigger circuit Q6 and Q7, a power amplifier Q8, and the square wave attenuator. The square wave is produced by the Schmitt trigger circuit, which is triggered by a sine wave signal that is coupled through resistor R15 and Symmetry control R16 to the base of Q6.

The Schmitt trigger circuit has two stable states: one in which Q7 is conducting and Q6 is cut off, and the other in which Q6 is conducting and Q7 is cut off. The switching time between these two states is extremely short, which permits the circuit to produce a square wave with a very fast rise time.

The switching is controlled by the voltage on the base of Q6. This voltage varies with the rising and falling voltage of the sine wave input. Symmetry control R16 is adjusted to produce time intervals between switching on and switching off that are of equal length; therefore, producing a symmetrical square wave.

The Schmitt trigger output from the collector of transistor Q7 is coupled through capacitor C8 to the base of emitter follower transistor Q8, which provides a low impedance output with no voltage gain. D8 protects the base of Q8 from excessive negative voltage. The output from Q8 passes directly to Square Wave Amplitude control R101. From R101, the square wave is applied through the attenuator network on the Square Wave Amplitude switch to the square wave output terminals.

POWER SUPPLY

Dual-primary power transformer T1 can be wired to operate from either 120 VAC or 240 VAC. The output from the secondary of T1 is rectified by diodes D5 and D6 in a full wave rectifier circuit, and filtered by the pi filter consisting of capacitors C1 and C2 and resistor R27.

Zener diode D7 provides a regulated reference voltage for the base of voltage regulator transistor Q10, which regulates the DC output at 43 volts. Capacitor C4 grounds AC feedback from the sine wave generator at high frequencies.

RECALIBRATION

Two methods for adjusting the Audio Generator are provided below. The first method uses only an AC voltmeter, and the second method (on Page 21) uses an AC voltmeter and an oscilloscope. Use the second method if you intend to use the Audio Generator with an oscilloscope. This will enable you to adjust the square wave Symmetry control, which cannot be done effectively with only a voltmeter.

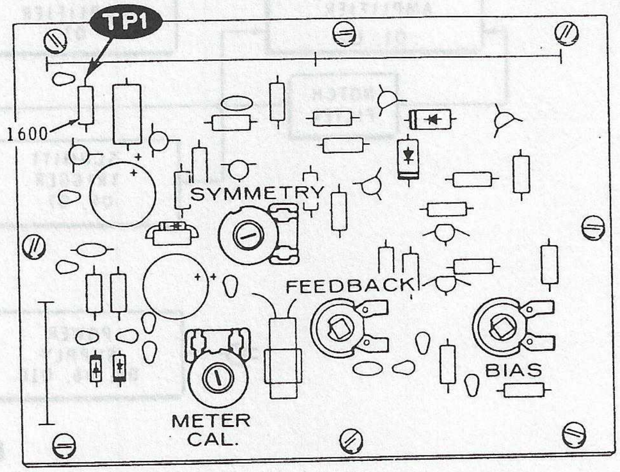


Figure 10 Location of test point and adjustments.

ADJUSTMENTS WITH AC VOLTMETER ONLY

Remove the top cover and set the switches and controls as follows:

1. POWER SWITCH: OFF.
2. MULTIPLIER: X10.
3. TENS FREQUENCY: 10.
4. UNITS FREQUENCY: 0.
5. FREQUENCY control: 0.

NOTE: The word FINE on the front panel refers to the small knob on each of the AMPLITUDE controls. COARSE refers to the large knob on each of the AMPLITUDE switches.

6. SINE WAVE AMPLITUDE switch (coarse): 10 volts.
7. SINE WAVE AMPLITUDE control (fine): Fully clockwise.
8. SQUARE WAVE AMPLITUDE switch (coarse): 10 volts.
9. SQUARE WAVE AMPLITUDE control (fine): Fully clockwise.
10. 600 Ω LOAD SWITCH: EXT.

NOTE: The following controls are located on the wave generator circuit board. Refer to Figure 10 for their location. Position each control at its center of rotation.

1. BIAS.
2. FEEDBACK.
3. SYMMETRY.
4. METER CAL.
5. Plug the line cord into an AC outlet.
6. Turn the POWER switch ON.
7. Adjust the FEEDBACK control until the panel meter reads between 6 and 8 on the 0-10 scale.
8. Set the external voltmeter to read 10 volts AC.
9. Connect the external voltmeter common lead to the black sine wave output binding post. Connect the other voltmeter lead to the red sine wave output binding post.
10. Rotate the METER CAL control clockwise until the panel meter reads the same, on the 0-10 scale, as the voltmeter.
11. Disconnect the external voltmeter.

NOTE: During the following adjustments the panel meter pointer may seem to vary erratically. This is normal. If you encounter difficulties, make the control adjustments in small increments and allow the instrument time to stabilize after each adjustment.

12. Turn the SINE WAVE AMPLITUDE control (fine) to approximately the 3 o'clock position.
13. Adjust the BIAS control until you obtain a maximum panel meter reading.

14. Turn the SINE WAVE AMPLITUDE (fine) control fully clockwise.

15. Adjust the FEEDBACK control until the panel meter reads 10 volts.

NOTE: In the following two steps, if no change can be detected in the panel meter reading, it will not be necessary to readjust the feedback control.

16. Turn the TENS FREQUENCY switch to each position, 10 through 100. Leave the switch in the position where the panel meter indicates the lowest voltage.

17. Turn the MULTIPLIER switch to each position, X1 through X1000. Leave the switch in the position where the panel meter indicates the lowest voltage.

18. Readjust the FEEDBACK control until the panel meter indicates 10 volts.

This completes the adjustments of the Audio Generator. Reinstall the top cover.

ADJUSTMENTS WITH AC VOLTMETER AND OSCILLOSCOPE

Remove the top cover and set the controls and switches as follows:

1. POWER SWITCH: OFF.

2. MULTIPLIER: X100.

3. TENS FREQUENCY: 10.

4. UNITS FREQUENCY: 0.

5. FREQUENCY control: 0.

NOTE: The word FINE on the front panel refers to the small knob on each of the AMPLITUDE controls. COARSE refers to the large knob on each of the AMPLITUDE switches.

6. SINE WAVE AMPLITUDE switch (coarse): 10 volts.

7. SINE WAVE AMPLITUDE control (fine): Fully clockwise.

8. SQUARE WAVE AMPLITUDE switch (coarse): 10 volts.

9. SQUARE WAVE AMPLITUDE control (fine): Fully clockwise.

10. 600 Ω LOAD: EXT.

NOTE: The following controls are located on the wave generator circuit board. Refer to Figure 10 for their locations. Position each control at its center of rotation.

1. BIAS.

2. FEEDBACK.

3. SYMMETRY.

4. METER CAL.

5. Plug the line cord into an AC outlet.

6. Turn the POWER switch ON.

7. Adjust the FEEDBACK control until the panel meter reads between 6 and 8 on the 0-10 scale.

8. Set the external voltmeter to read 10 volts AC.

9. Connect the external voltmeter common lead to the black sine wave output binding post. Connect the other voltmeter lead to the red sine wave output binding post.

10. Adjust the METER CAL control until the panel meter reads the same, on the 0-10 scale, as the voltmeter.

11. Disconnect the external voltmeter.

12. Set the oscilloscope to display a 1000 Hz waveform at an amplitude of 10 volts.

13. Connect the oscilloscope to the sine wave output binding posts.

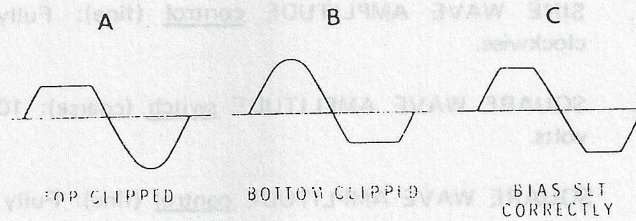


Figure 11 Bias adjustment waveforms.

14. Rotate the FEEDBACK control fully clockwise. Note that the positive or negative half of the waveform is clipped as shown in part A or B of Figure 11.

15. Adjust the BIAS control so both halves of the waveform are clipped equally, as shown in part C of Figure 11.

16. Adjust the FEEDBACK control until the panel meter indicates 10 volts.

17. Disconnect the oscilloscope.

NOTE: In the following two steps, if no change can be detected in the panel meter reading, it will not be necessary to readjust the feedback control.

18. Turn the TENS FREQUENCY switch to each position, 10 through 100. Leave the switch in the position where the panel meter indicates the lowest voltage.

19. Turn the MULTIPLIER switch to each position, X1 through X1000. Leave the switch in the position where the panel meter indicates the lowest voltage.

20. Readjust the FEEDBACK control so that the panel meter indicates 10 volts.

21. Reset the FREQUENCY and MULTIPLIER switches for a 1000 Hz output at 10 volts (MULTIPLIER at X100, TENS FREQUENCY at 10).

22. Connect the oscilloscope to the square wave output binding posts. Set the oscilloscope input switch to AC.

NOTE: The very fast rise time (leading edge) of the square wave signal is very rich in harmonics, extending into the megahertz range. Low frequency oscilloscopes may respond in various ways to this signal. The leading edge may be "rounded off" through the roll-off characteristics of the oscilloscope, or frequency compensation (with peaking coil, for instance) may lead to "ringing" or "overshoot". Even the leads between the generator and oscilloscope may affect the pattern displayed.

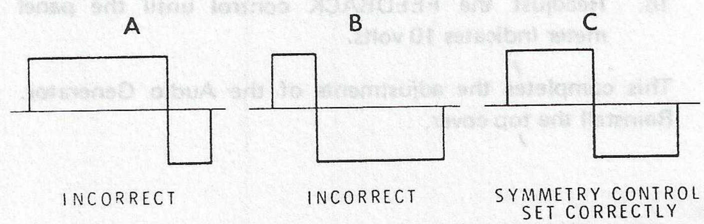


Figure 12 Symmetry adjustment waveforms.

23. Rotate the SYMMETRY control until the positive and negative halves of the square waveform are equal, as shown in part C of Figure 12.

This completes the adjustments. Reinstall the top cover.

PARTS LIST

The Key numbers relate to the X-Ray Views, Chassis Photograph, and Schematic.

WAVE GENERATOR CIRCUIT BOARD

RESISTORS

(All resistors are 1/2-watt, 10% unless otherwise specified.)

KEY No.	PART No.	DESCRIPTION
R1	1-97	1100 Ω
R2	1-20	10 kΩ
R3	1-47	56 kΩ
R4	1-47	56 kΩ
R5	1-29	220 kΩ
R6	1-20	10 kΩ
R7	10-155	750 Ω control
R8	1-97	1100 Ω
R9	10-155	750 Ω control
R10	1-97	1100 Ω
R11	1-66	150 Ω
R12	1-20	10 kΩ
R13	1-54	15 Ω
R14	1-54	15 Ω
R15	1-16	4700 Ω
R16	10-201	10 kΩ control
R17	1-89	2400 Ω
R18	1-66	150 Ω
R19	1-98	1600 Ω
R20	1-89	2400 Ω
R21	10-201	10 kΩ control

KEY No.	PART No.	DESCRIPTION
Resistors (cont'd.)		
R22	1-56-1	1200 Ω, 1-watt
R23	1-20	10 kΩ
R24	1-20	10 kΩ
R25	1-20	10 kΩ
R26	1-98	1600 Ω

CAPACITORS-LAMP

C5	25-146	100 µF electrolytic
C6	25-193	250 µF electrolytic
C7	20-128	470 pF resin
C8	25-193	250 µF electrolytic
C9	21-16	0.01 µF ceramic
L1	412-66	Lamp

DIODES-TRANSISTORS

D1	57-65	1N4002
D2	57-65	1N4002
D3	56-26	1N191
D4	56-26	1N191
D8	56-56	1N4149
Q1	417-94	2N3416
Q2	417-94	2N3416
Q3	417-201	X29A829
Q4	417-94	2N3416
Q5	417-201	X29A829
Q6	417-154	2N2369
Q7	417-154	2N2369
Q8	417-154	2N2369

POWER SUPPLY CIRCUIT BOARD

RESISTORS-CAPACITORS

KEY No.	PART No.	DESCRIPTION
R27	1-1	47 Ω
R28	1-89	2400 Ω
C1	25-205	300 μF electrolytic
C2	25-205	300 μF electrolytic
C3	25-205	300 μF electrolytic
C4	25-126	50 μF electrolytic

DIODES-TRANSISTOR

KEY No.	PART No.	DESCRIPTION
D5	57-65	1N4002
D6	57-65	1N4002
D7	56-66	VR-43 (1N3035) 43-volt zener
Q10	417-178	40389

NOTCH FILTER COMPONENTS

(All resistors are 1/2-watt, 1% unless otherwise specified.)

KEY No.	PART No.	DESCRIPTION
R_X	2-50	10 kΩ
	2-247	5000 Ω
	2-248	3300 Ω
	2-249	2500 Ω
R_Y	2-11	100 kΩ
	2-99	50 kΩ
	2-98	33.3 kΩ
	2-97	25 kΩ
R_Z	12-96	1 MΩ dual control
	1-102	82 kΩ, 10%
C_X	27-81	5 μF Mylar*
	27-82	0.5 μF Mylar*
	27-83	0.05 μF Mylar*
	27-84	0.005 μF Mylar*
	20-55	500 pF ceramic

CHASSIS COMPONENTS

RESISTORS-CAPACITOR

(All resistors are 1/2-watt, 10% unless otherwise specified.)

KEY No.	PART No.	DESCRIPTION
R101	63-1252	600 Ω control (part of switch)
R102	1-63	510 Ω
R103	1-63	510 Ω
R104	1-84	62 Ω
R105	1-83	56 Ω
R106	63-485	5000 Ω control (part of switch)
R107	1-66	150 Ω
R108	1-131	620 Ω
R109	1-89	2400 Ω
R110	1-94	390 Ω
R111	1-97	1100 Ω
R112	1-98	1600 Ω
R113	1-98	1600 Ω
R114	1-97	1100 Ω
R115	1-97	1100 Ω
R116	1-98	1600 Ω
R117	1-98	1600 Ω
R118	1-98	1600 Ω
R119	1-97	1100 Ω
R120	1-97	1100 Ω
R121	1-96	750 Ω
R122	1-95	560 Ω
R123	1-23	27 kΩ
C101	27-110	0.047 μF Mylar*

GENERAL COMPONENTS

KEY No.	PART No.	DESCRIPTION
	54-205	Power transformer
	60-24	Load switch
	60-24	Power switch
	63-485	Amplitude switch
	63-486	Coarse amplitude switch
	63-487	Tens switch
	63-487	Units switch
	63-488	Multiplier switch
	407-131	Meter
	412-15	NE-2H power lamp
	421-40	3/16-ampere fuse (slow-blow)

*DuPont registered trademark.