

MODEL **IG-18 Sine-Square
Audio Generator**

HEATHKIT®
ASSEMBLY MANUAL



PRICE \$2.00



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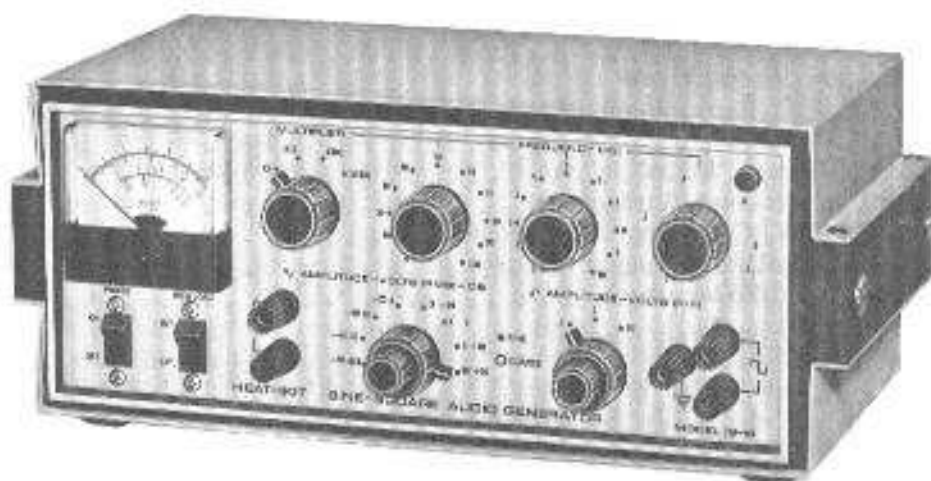
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Assembly and Operation of the



SINE-SQUARE AUDIO GENERATOR

MODEL IG-18



HEATH COMPANY
BENTON HARBOR, MICHIGAN 49022

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INTRODUCTION

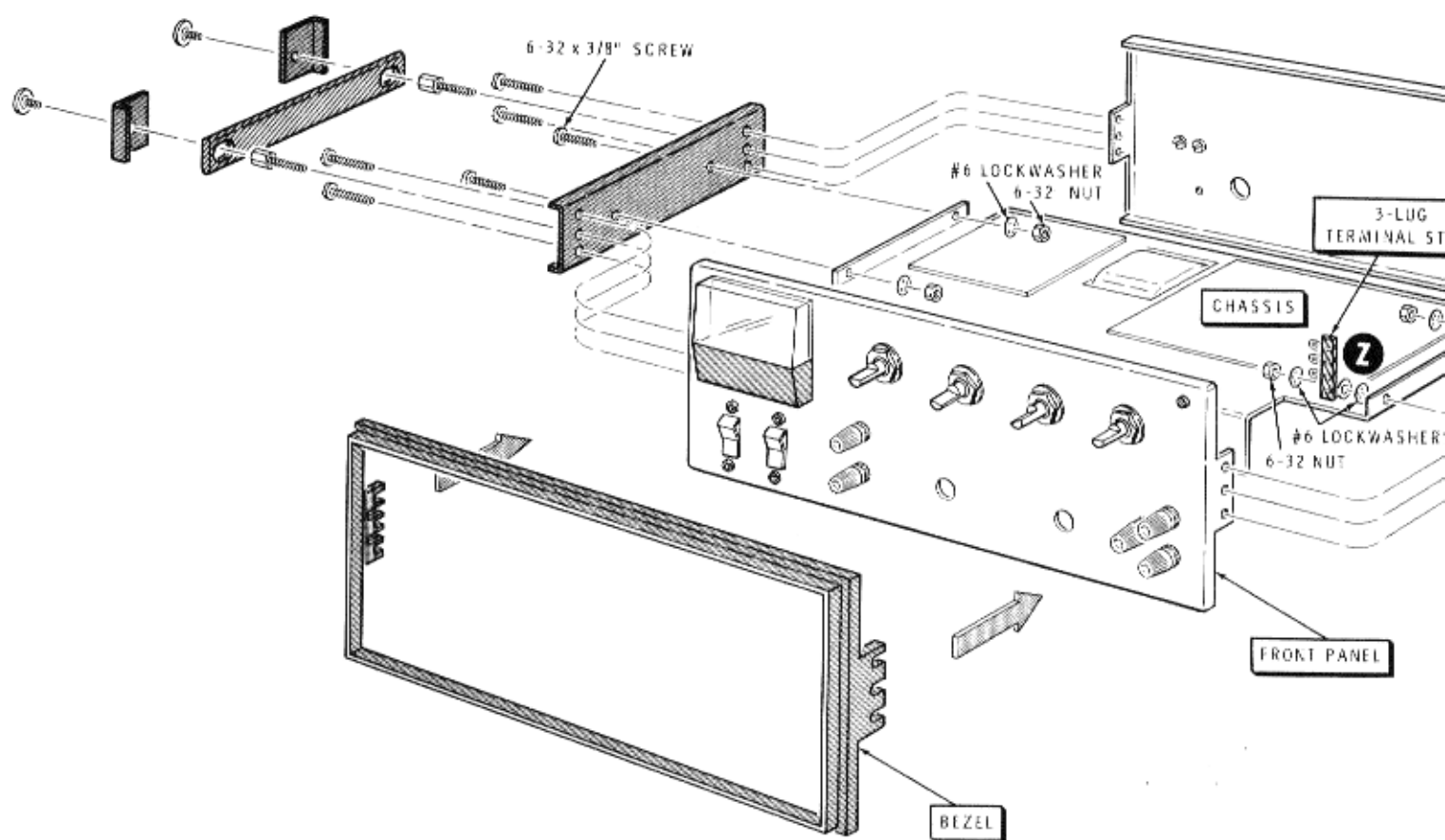
The Heathkit Model IG-18 Sine-Square Audio Generator has been designed for laboratory use as well as for service and testing. Sine wave signals are available between 1 Hz and 100 kHz. Low distortion (less than .1%) sine wave signals are available from 10 Hz to 100 kHz. The output is stepped from .003 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.

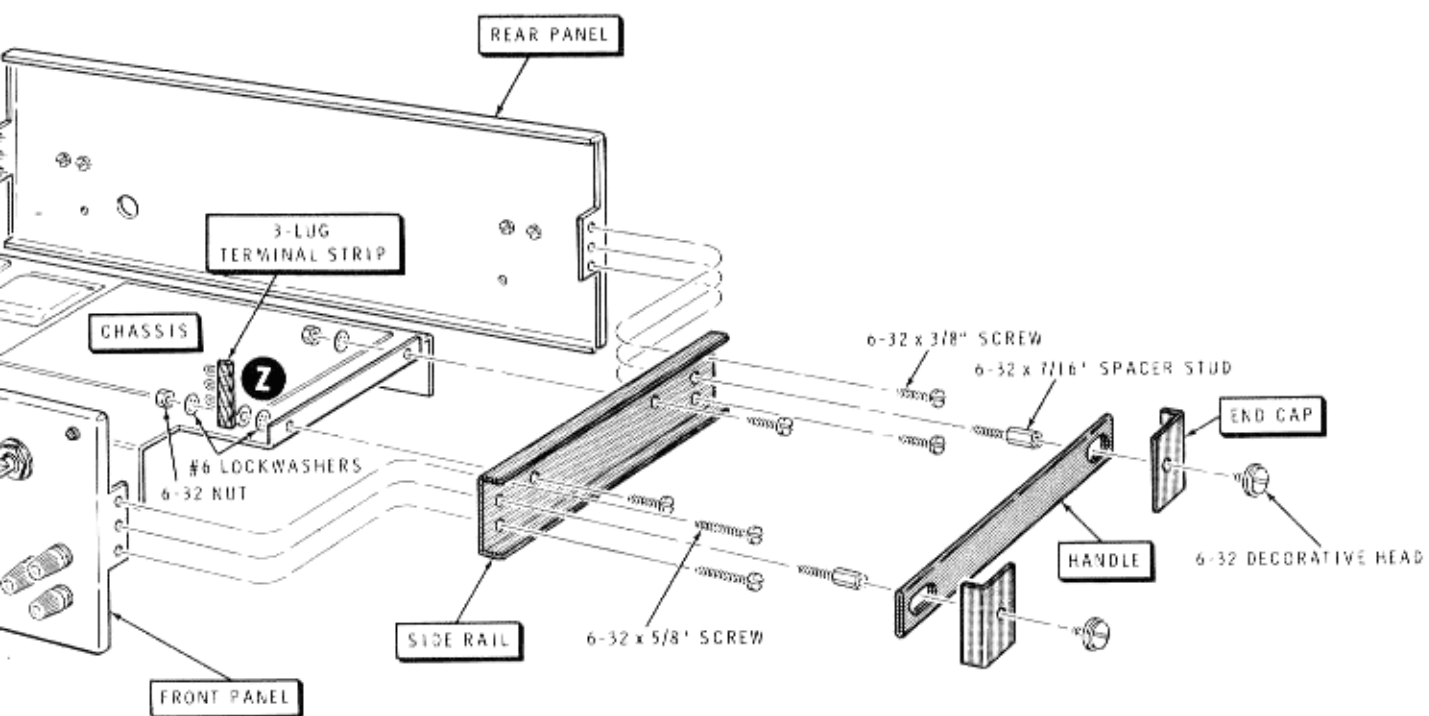
The sine and square wave frequencies are identical and the level of each is independently adjustable. Both signals may be used either simultaneously or independently.

The sine wave output will operate into high impedance loads (10 k Ω 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 you with a versatile, accurate, and attractive signal source. It will be a valuable and useful addition to your laboratory or workbench.



PICTORIAL



PICTORIAL 16

- (✓) At the other end of this twisted pair, connect the black wire to lug 2 (NS) of terminal strip
- (✓) Connect the brown wire to lug 1 of the power transformer (NS).

NOTE: A flat 3-lead line cord is supplied with this kit that is approved for use in the U.S.A. and in some other countries. If this cord is not approved for your locality, obtain locally an approved cord and proceed with the following steps, making changes where necessary.

The flat 3-lead line cord supplied with this kit has one of its outer leads marked with ribs in the insulation along its edge. The other lead is smooth, and the third lead is color coded green.

- (✓) Separate the three line cord leads for a distance of about 1-1/2" from the stripped ends. Twist together and apply a small amount of solder to the small wires at the end of each lead. This will hold the separate strands together.
- (✓) Pass the line cord through the hole in the rear panel.
- (✓) Connect the green line cord lead to the solder lug of Y (S-1).
- (✓) Connect the ribbed line cord lead to lug 4 of the power transformer (NS).
- (✓) Connect the smooth line cord lead to lug 1 of terminal strip Y (NS).
- (✓) Connect one lead of the fuse to lug 1 of terminal strip Y (S-2).
- (✓) Connect the other fuse lead to lug 2 of terminal strip Y (S-2).

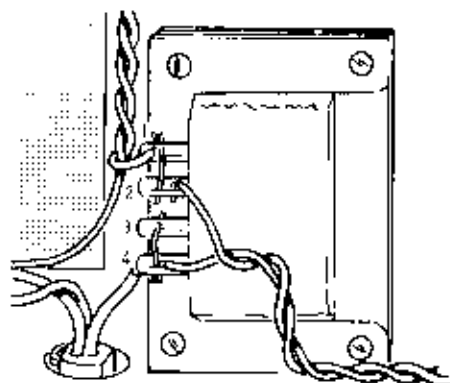
120-240 VAC WIRING ALTERNATIVE

Two sets of line voltage wiring instructions are given below: one for 120 VAC line voltage, and the other for 240 VAC line voltage on Page 34. In the U.S.A., 120 VAC is most commonly used, while in some other countries 240 VAC is more common. USE ONLY THE INSTRUCTIONS THAT AGREE WITH THE LINE VOLTAGE IN YOUR AREA.

120 VAC Wiring

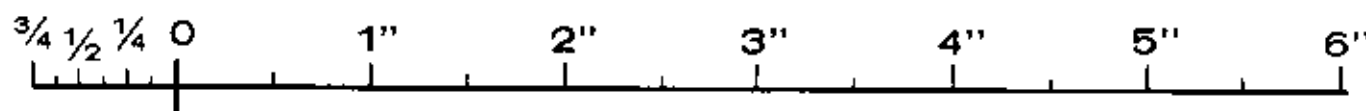
Refer to Detail 18B for the following steps.

- (✓) Remove the insulation from two 1" lengths of hookup wire.
- (✓) Connect a 1" bare wire from lug 1 (S-2) to lug 2 (S-2) of the power transformer.
- (✓) Connect a 1" bare wire from lug 3 (S-1) to lug 4 (S-3) of the power transformer.



120 VAC WIRING

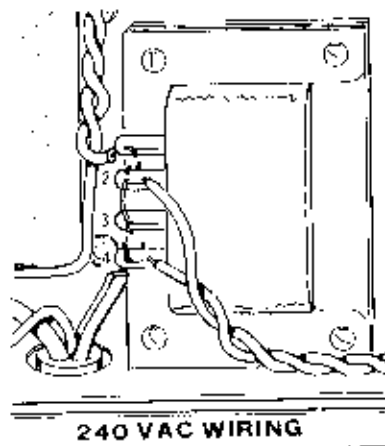
Detail 18B



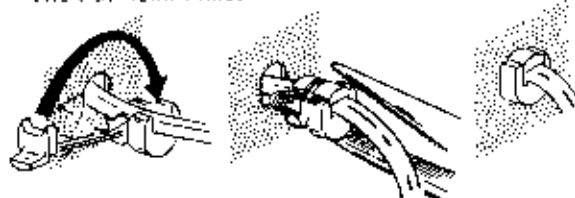
240 VAC Wiring

Refer to Detail 18C for the following steps.

- () Remove the insulation from a 1" length of hookup wire.
- () Connect a 1" bare wire from lug 2 (S-2) to lug 3 (S-1) of the power transformer.
- () Solder transformer lug 1 (S-1).
- () Solder transformer lug 4 (S-2).



Detail 18C

BACK OF REAR PANEL

1. PULL SLACK OUT OF CORD.
2. CRIMP STRAIN RELIEF ON CORD ABOUT ONE INCH FROM REAR PANEL.
3. COMPRESS STRAIN RELIEF SO THAT IT WILL PASS INTO HOLE IN REAR PANEL. LINE-UP FLATS ON STRAIN RELIEF WITH STRAIGHT SIDES OF HOLE.
4. PULL LINE CORD ON INSIDE OF INSTRUMENT TO EXPAND STRAIN RELIEF.

Detail 18D

NOTE: In the following step, if you have used the flat 3-lead line cord supplied with this kit, install strain relief #75-71. If you have used a round line cord (not supplied with this kit), install strain relief #75-30.

- (✓) Refer to Detail 18D and install the line cord strain relief on the line cord.

This completes the wiring of your Heathkit Sine-Square Audio Generator. Carefully inspect all solder joints for unsoldered wires or loose connections. Remove any wire clippings or solder splashes that may be lodged in the wiring. Then proceed to the Knob Installation section.

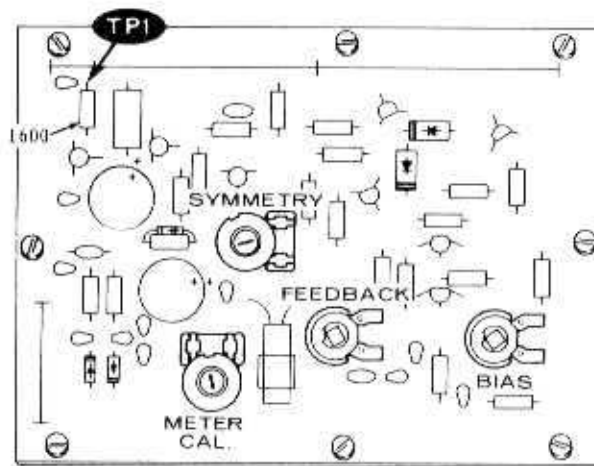
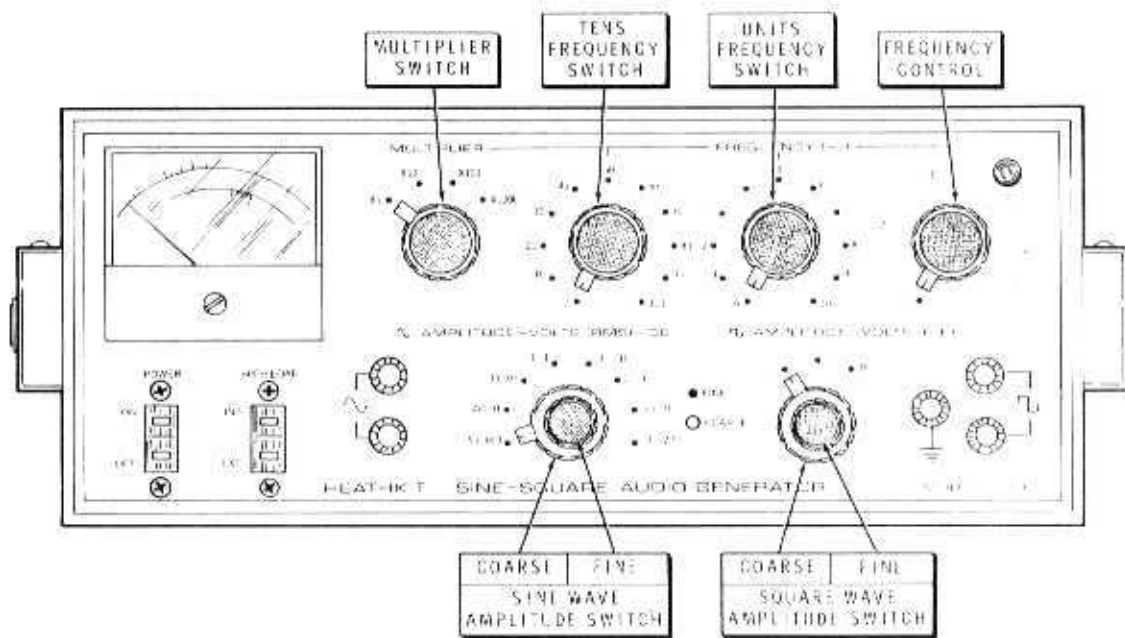


FIGURE 1

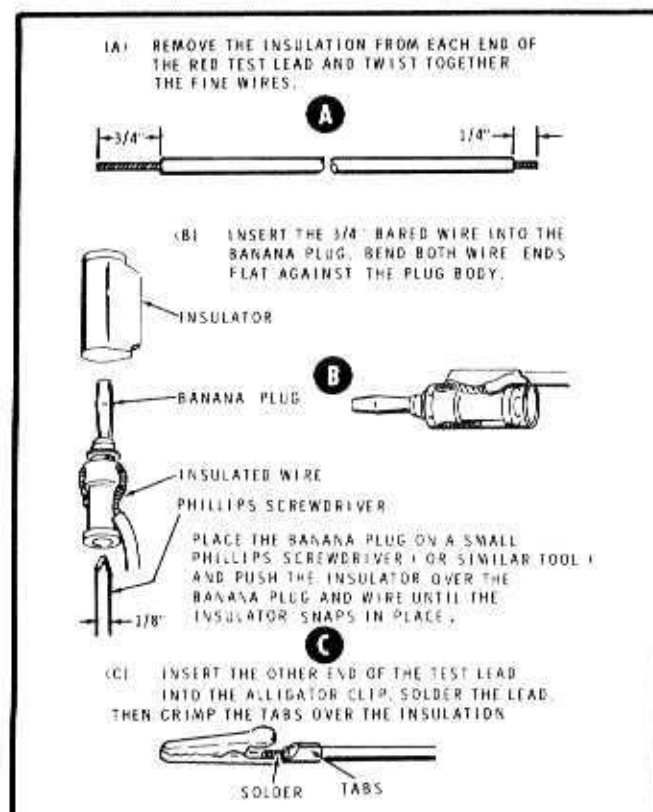


PICTORIAL 19

TEST LEAD ASSEMBLY

- () Prepare the black and the red test lead as shown in Pictorial 20. Use the black insulator with the black test lead and the red insulator with the red test lead.

This completes the Step-By-Step Assembly. Proceed to the Tests And Adjustments.



PICTORIAL 20

TESTS AND ADJUSTMENTS

TESTS

If you do not obtain the correct results in any of the following tests, turn the equipment off. Then refer to the chart following the step. These charts list the Condition of the malfunction, and the Possible Cause. Review the items listed in the Possible Cause column and correct the condition before proceeding to the next step. The information in the In Case Of Difficulty section (Page 57) of the Manual may also be helpful in locating trouble in the kit.

Refer to Figure 1 (on fold-out from Page 36) for the following step.

- (✓) Connect the common lead of an ohmmeter to either black binding post of the Generator. Connect the other ohmmeter lead to test-point (TP1) on the wave generator circuit board. The ohmmeter should indicate a resistance of at least 1500 Ω , when the pointer stops.

DIFFICULTY	POSSIBLE CAUSE
Resistance measured considerably less than 1500 Ω .	Short circuit on wave generator circuit board: 1. Check positioning of transistors. 2. Check values of resistors. 3. Check for solder bridges between circuit board foils.
Resistance measured considerably more than 1500 Ω .	Open circuit(s) on wave generator circuit board: 1. Check solder connections. 2. Check resistor values. 3. Check for broken component leads.

- (✓) Measure the resistance between the two flat prongs of the AC line cord plug. With the POWER switch off, the resistance should read infinite. With the POWER switch on, the resistance should be 20 Ω or more.

DIFFICULTY	POSSIBLE CAUSE
Resistance measured 20 Ω or more with POWER switch off and infinite with POWER switch on.	POWER switch installed upside down.
Resistance measured near zero ohms.	POWER switch connected directly across line cord.

- (✓) Check the resistance between each line cord plug prong and the chassis. The resistance should measure infinite for both prongs.

- (✓) Check the resistance between the round ground prong of the line cord plug and the chassis. This resistance should be near zero ohms.

DIFFICULTY	POSSIBLE CAUSE
Resistance not as described.	Line cord not wired properly. Check line cord connections.

- (✓) Set the voltmeter to read a DC+ voltage of about 43 volts.

- (✓) Connect the voltmeter common lead to either black binding post. Connect the other voltmeter lead to TP1.

- (✓) Turn the POWER switch OFF, and plug the line cord into a 120 VAC outlet.

- (✓) Turn the POWER switch ON. The voltmeter reading should gradually increase to about 43 volts and stay there.

DIFFICULTY	POSSIBLE CAUSE
Measured voltage less than 43 VDC but more than zero.	1. Diode D5 or D6 installed backwards. 2. Poor solder connections. 3. Capacitors C1, C2, C3, or C4 installed backwards.
No voltage.	1. Transistor improperly installed. 2. Open circuit or short circuit on power supply circuit board.
Measured voltage about 50 volts.	1. Zener diode D7.

(✓) Turn the POWER switch off.

This concludes the tests. Proceed to the Adjustments.

ADJUSTMENTS

Two methods for adjusting the Audio Generator are provided below. The first method uses only an AC voltmeter, and the second method (on Page 42) 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.

ADJUSTMENTS WITH AC VOLTMETER ONLY

Set the switches and controls as follows:

- (✓) POWER SWITCH: OFF.
- (✓) MULTIPLIER: X10.
- (✓) TENS FREQUENCY: 10.
- (✓) UNITS FREQUENCY: 0.
- (✓) 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.

- (✓) SINE WAVE AMPLITUDE switch (coarse): 10 volts.
- (✓) SINE WAVE AMPLITUDE control (fine): Fully clockwise.
- (✓) SQUARE WAVE AMPLITUDE switch (coarse): 10 volts.
- (✓) SQUARE WAVE AMPLITUDE control (fine): Fully clockwise.
- (✓) 600 Ω LOAD SWITCH: EXT.

NOTE: The following controls are located on the wave generator circuit board. Refer to Figure 1 for their location. Position each control at its center of rotation.

- (✓) BIAS.
- (✓) FEEDBACK.
- (✓) SYMMETRY.
- (✓) METER CAL.

- (✓) Plug the line cord into an AC outlet.
- (✓) Turn the POWER switch ON.
- (✓) Adjust the FEEDBACK control until the panel meter reads between 6 and 8 on the 0-10 scale.
- (✓) Set the external voltmeter to read 10 volts AC.
- (✓) 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.
- (✓) Rotate the METER CAL control clockwise until the panel meter reads the same, on the 0-10 scale, as the voltmeter.
- (✓) 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.

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

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

- (✓) Readjust the FEEDBACK control until the panel meter indicates 10 volts.

This completes the adjustments of the Audio Generator. Turn off the power and remove the AC plug from the socket. Proceed with the Final Assembly on Page 45.

ADJUSTMENTS WITH AC VOLTMETER AND OSCILLOSCOPE

Set the controls and switches as follows:

- () POWER SWITCH: OFF.
- () MULTIPLIER: X100.
- () TENS FREQUENCY: 10.
- () UNITS FREQUENCY: 0.
- () 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.

- () SINE WAVE AMPLITUDE switch (coarse): 10 volts.
- () SINE WAVE AMPLITUDE control (fine): Fully clockwise.
- () SQUARE WAVE AMPLITUDE switch (coarse): 10 volts.
- () SQUARE WAVE AMPLITUDE control (fine): Fully clockwise.
- () 600 Ω LOAD: EXT.

NOTE: The following controls are located on the wave generator circuit board. Refer to Figure 1 (fold-out from Page 36) for their location. Position each control at its center of rotation.

- () BIAS.
- () FEEDBACK.
- () SYMMETRY.
- () METER CAL.

- () Plug the line cord into an AC outlet.
- () Turn the POWER switch ON.
- () Adjust the FEEDBACK control until the panel meter reads between 6 and 8 on the 0-10 scale.
- () Set the external voltmeter to read 10 volts AC.
- () 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.
- () Adjust the METER CAL control until the panel meter reads the same, on the 0-10 scale, as the voltmeter.
- () Disconnect the external voltmeter.
- () Set the oscilloscope to display a 1000 Hz waveform at an amplitude of 10 volts.
- () Connect the oscilloscope to the sine wave output binding posts.
- () 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.
- () Turn the MULTIPLIER switch to each position, X1 through X1000. Leave the switch in the position where the panel meter indicates the lowest voltage.
- () Readjust the FEEDBACK control so that the panel meter indicates 10 volts.
- () Reset the FREQUENCY and MULTIPLIER switches for a 1000 Hz output at 10 volts (MULTIPLIER at X100, TENS FREQUENCY at 10).
- () Connect the oscilloscope to the square wave output binding posts. Set the oscilloscope input switch to AC.

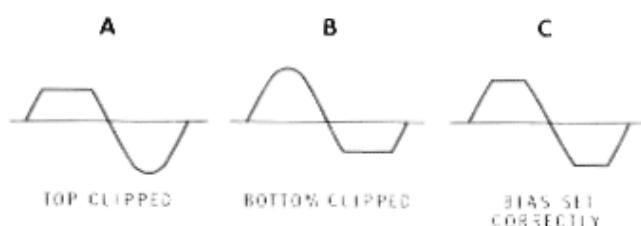


Figure 2

- () 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 2.
- () Adjust the BIAS control so both halves of the waveform are clipped equally, as shown in Part C of Figure 2.
- () Adjust the FEEDBACK control until the panel meter indicates 10 volts.
- () 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.

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.

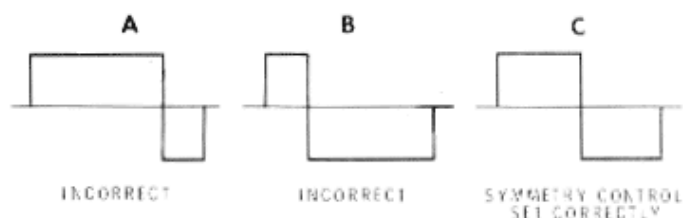
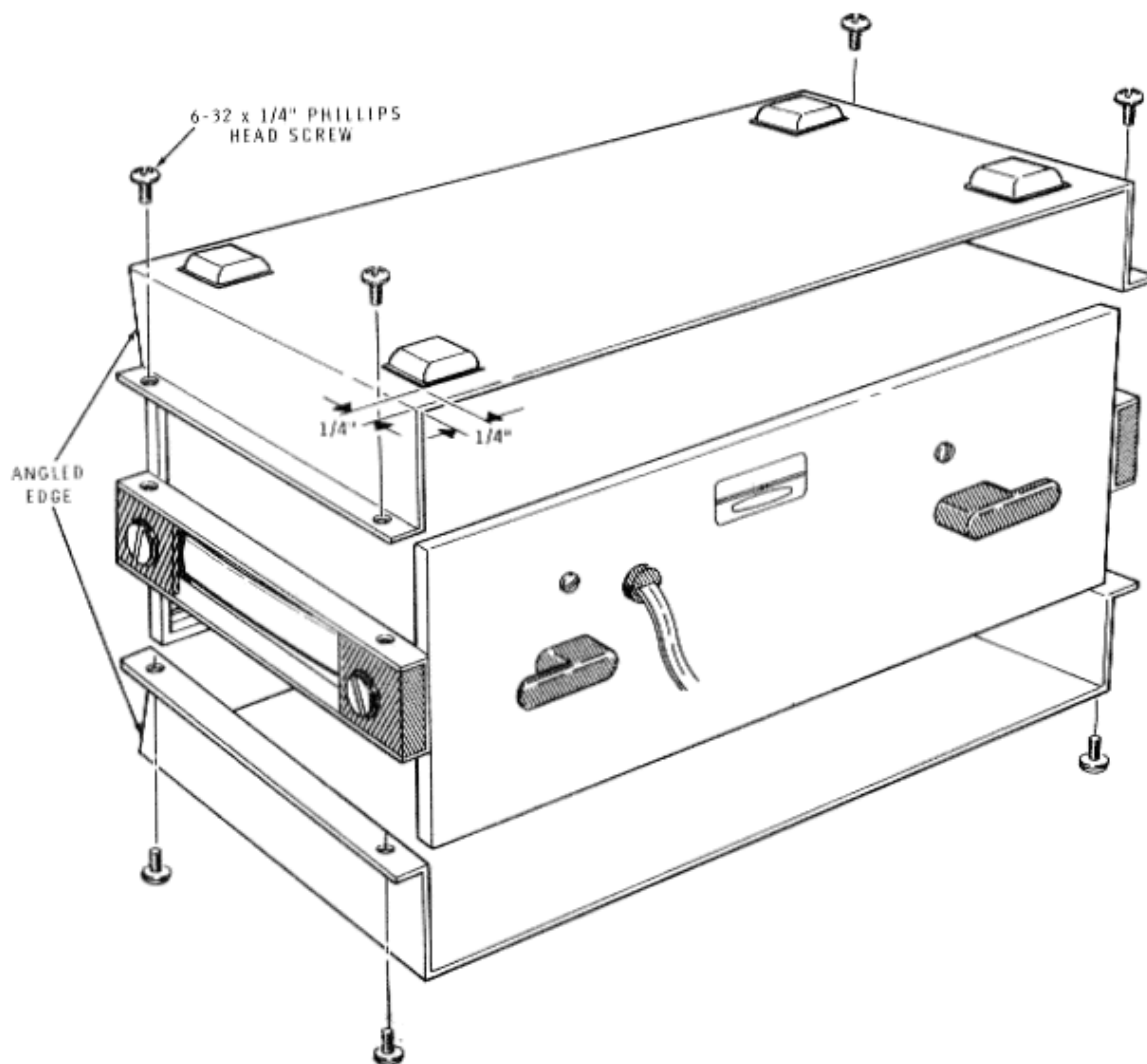


Figure 3

- () Rotate the SYMMETRY control until the positive and negative halves of the square waveform are equal, as shown in part C of Figure 3.

This completes the adjustments. Turn off the power and remove the AC plug from the socket. Proceed to Final Assembly.



PICTORIAL 21

FINAL ASSEMBLY

Refer to Pictorial 21 for the following steps.

Locate eight 6-32 x 1/4" phillips head screws, two cabinet half shells, and four plastic feet.

(✓) Turn the instrument upside down and install one of the cabinet half shells with four 6-32 x 1/4" phillips head screws. The angled edge of the cabinet is the front; this edge should protrude over the bezel.

(✓) Remove the backing paper from a plastic foot. Affix the foot about 1/4" from both edges at one corner of the cabinet bottom.

(✓) Likewise, affix the remaining three feet on the other three corners of the cabinet bottom.

(✓) Turn the instrument over and install the other cabinet half shell with four 6-32 x 1/4" phillips head screws.

(✓) Remove the protective paper from the blue and white label and affix it to the rear panel as shown.

This completes the assembly of the Sine-Square Audio Generator.

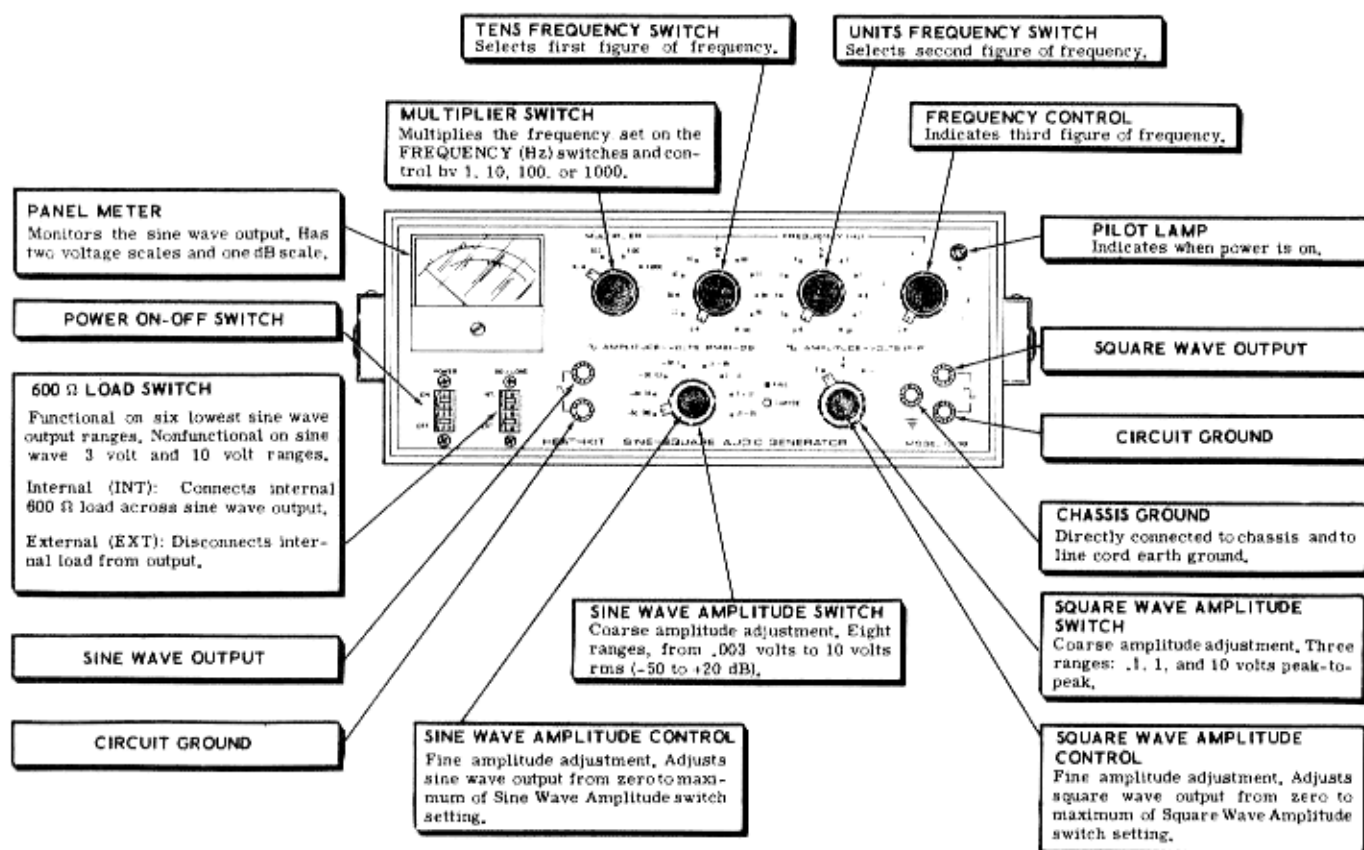


Figure 4

OPERATION

Refer to Figure 4, which describes each of the front panel controls and terminals, before you read the remaining material in this section.

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

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 k Ω 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.

CAUTION: The square wave generator output is DC-coupled to avoid poor low frequency response (see "Square Wave Testing" on Page 52). The output is a DC signal that varies from zero to some positive value when measured at the

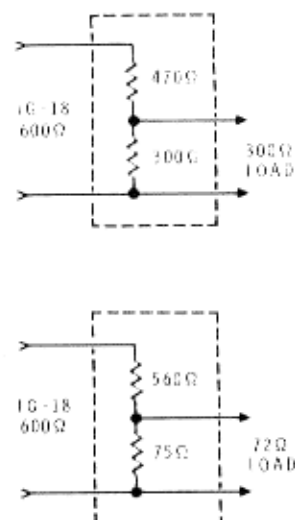


Figure 5

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 5. 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:

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

Since $P = EI$ and $I = \frac{E}{R}$, the above

equation may be restated as:

$$\text{dB} = 10 \log \frac{\frac{E_1^2}{R_1}}{\frac{E_2^2}{R_2}}$$

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:

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

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

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

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 $E = .775$ 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

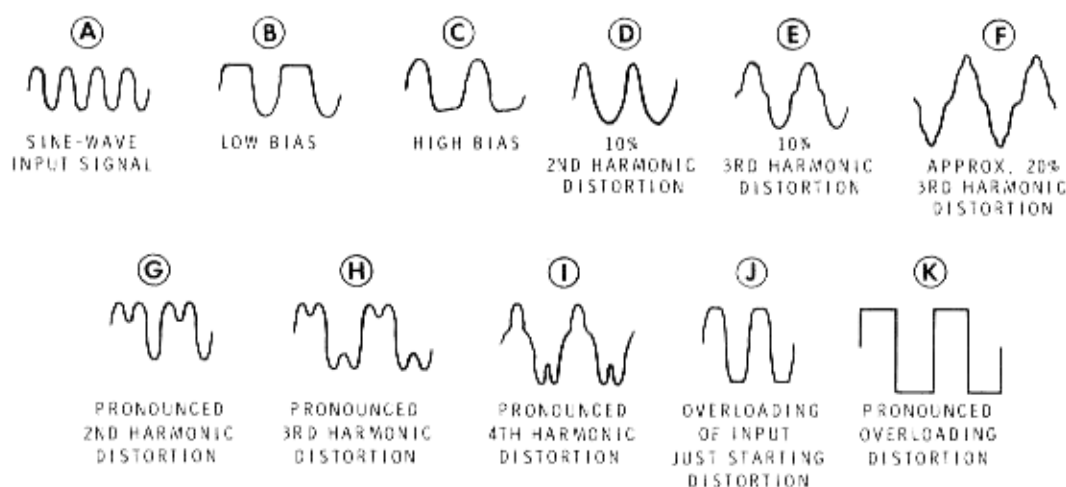
SINE WAVE TESTING

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.

Figure 7 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 48. 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.

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 6 shows waveforms of several kinds of distortion.



TYPICAL DISTORTION PATTERNS OBTAINED IN AUDIO AMPLIFIER TESTING

Figure 6

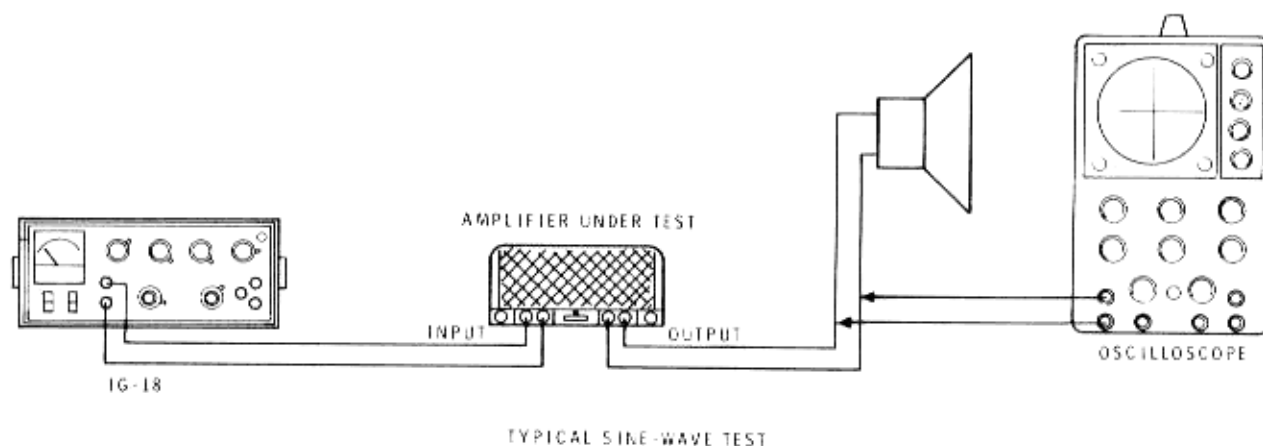
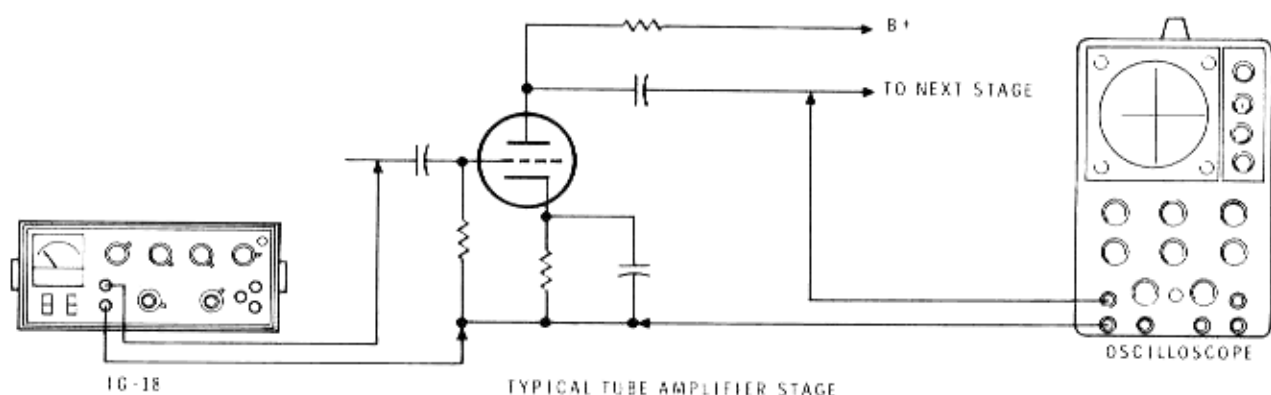
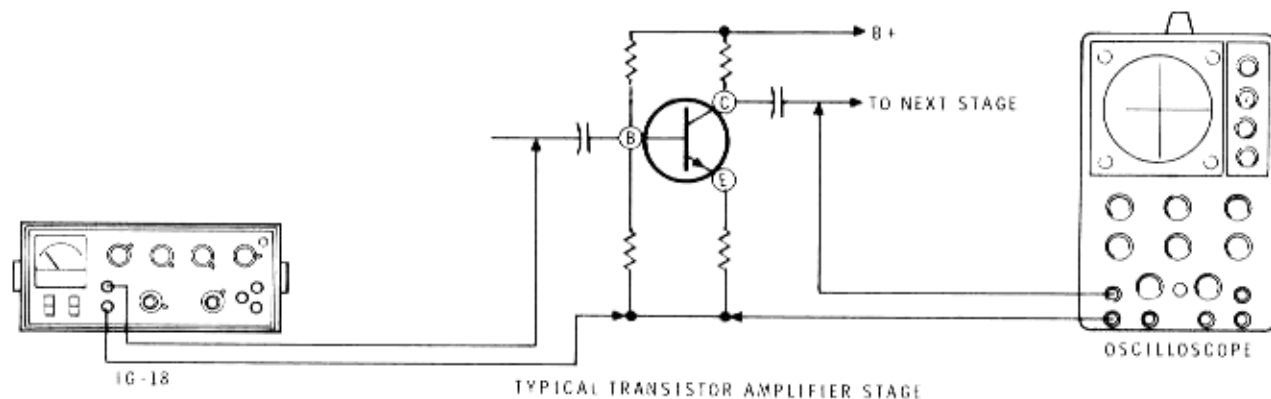


Figure 7

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 the frequency response of an amplifier from 10 Hz to 100,000 Hz.

Figure 8 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 os-

cilloscope 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.

SPECIAL GENERATOR APPLICATIONS

Impedance Measurements

Figures 9A and 9B 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 9A. It may be necessary to use variable resistors of several different values, such as 10 k Ω , 100 k Ω , 1 M Ω , and 5 M Ω , to obtain the correct indication on the external AC meter.

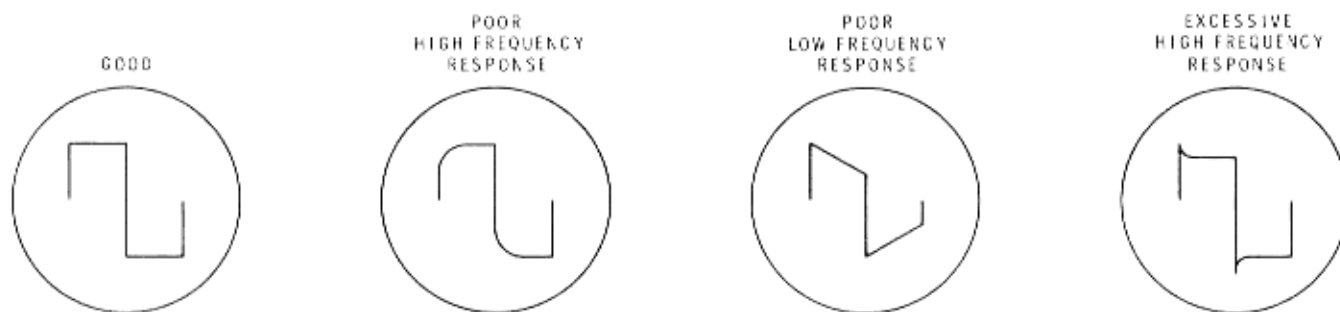


Figure 8

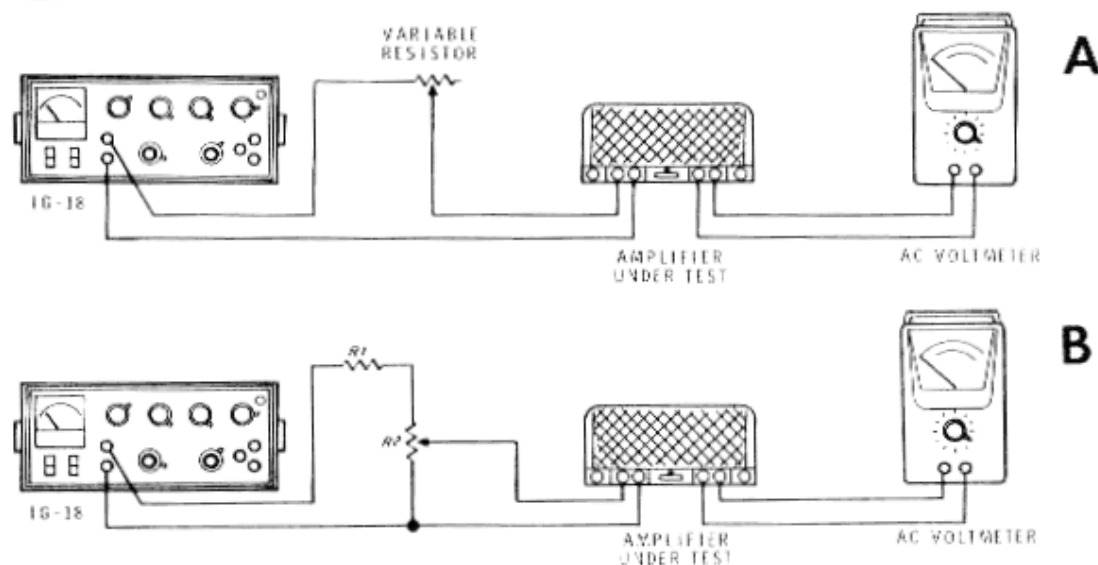


Figure 9

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 would appear to be smaller because some of the signal would be 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 9B. Fixed series resistor R_1 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 R_2 disconnected.

When R_2 is connected again, it is adjusted until the meter reading drops to half of the former value. The resistance of variable resistor R_2 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 use 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 Lissajous figures will be seen on the oscilloscope. Interpreting these waveforms correctly will show the frequency of the unknown signal.

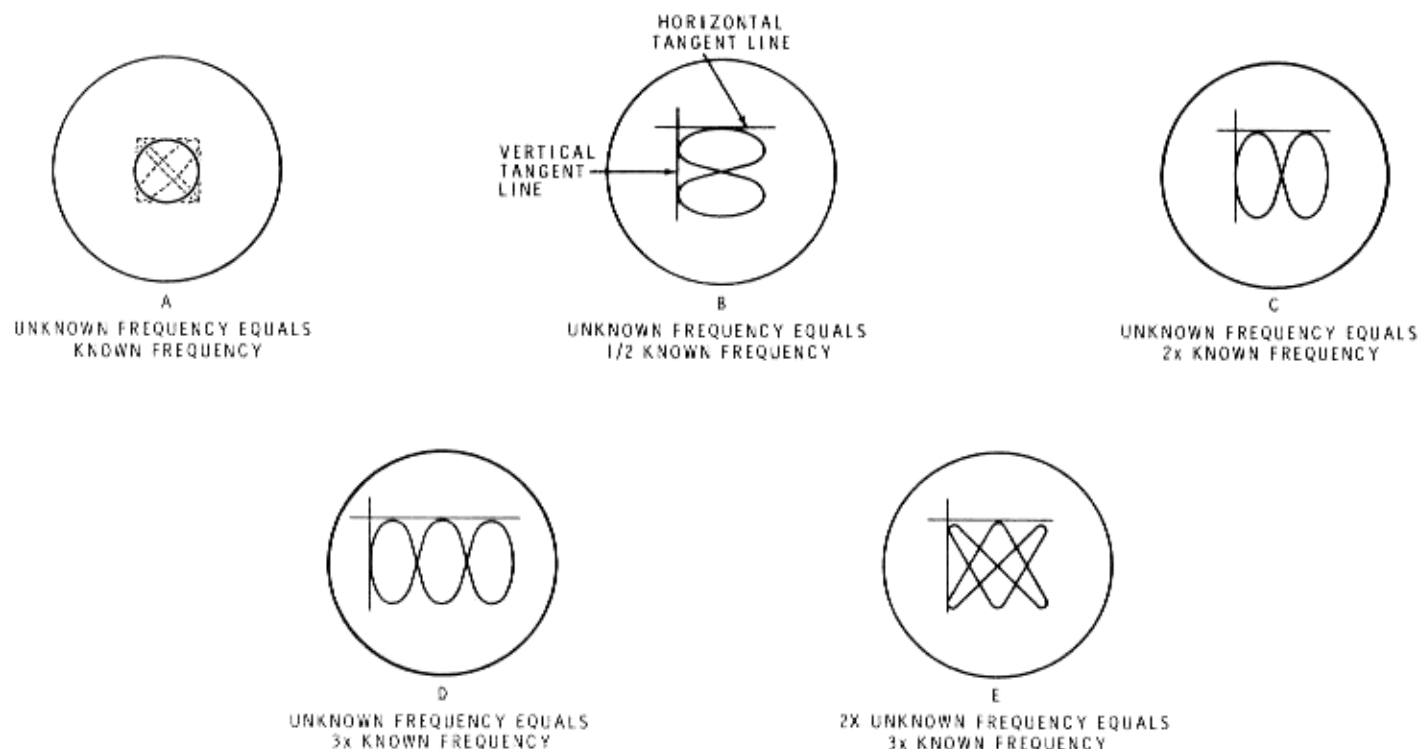


Figure 10

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 10. 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 10. 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.

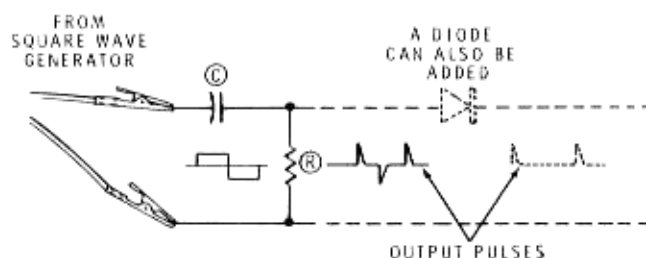


Figure 11

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 11. 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 $\times 1/10$ = 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" ($1 \mu\text{F} = .000001$ 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 k Ω resistor and .0005 μF capacitor will give the desired 5 microsecond pulse.

$$500 \times 10^{-12} \text{ (capacitance, .0005 } \mu\text{F)} \times 1 \times 10^4 \text{ (resistance, 10 k}\Omega\text{)} =$$

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

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

$$.0000000005 \text{ (capacitance, .0005 } \mu\text{F)} \times 10,000 \text{ (resistance, 10 k}\Omega\text{)} = .000005 = 5 \text{ microseconds}$$

IN CASE OF DIFFICULTY

1. Recheck the wiring. Trace each lead in colored pencil on the Pictorial as it is checked. It is frequently helpful to have a friend check your work. Someone who is not familiar with the unit may notice something consistently overlooked by the builder.
2. About 90% of the kits that are returned for repair do not function properly due to poor connections and soldering. Therefore, many troubles can be eliminated by reheating all connections to make sure they are soldered as described in the Soldering section of the Kit Builders Guide.
3. Check to be sure that all transistors are in their proper locations. Make sure each transistor lead is connected to the proper point.
4. Check the values of the parts. Be sure the proper parts have been wired into each circuit as shown in the Pictorial Diagrams. It

would be easy, for example, to install a 62 k Ω (blue-red-orange) resistor where a 620 k Ω (blue-red-yellow) resistor should have been installed.

5. Check for bits of solder, wire ends, or other foreign matter which may be lodged in the wiring, or on the circuit board foil.
6. If the trouble still is not located and a voltmeter is available, check the voltage readings against those shown on the Schematic Diagram. A review of the Circuit Description may help you locate the trouble.

NOTE: Refer to the Circuit Board X-Ray Views on Page 67 and Photographs on Page 69 for the physical location of parts.

NOTE: In an extreme case where you are unable to resolve a difficulty, refer to the "Customer Service" information inside the rear cover of the Manual. Your Warranty is located inside the front cover of the Manual.

TROUBLESHOOTING CHART

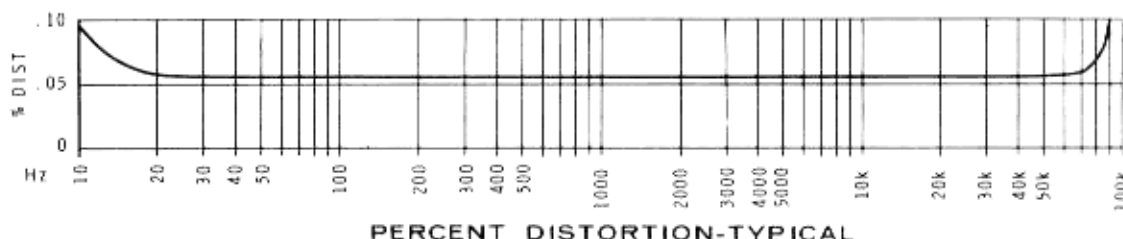
DIFFICULTY	POSSIBLE CAUSE AND SUGGESTED CURE
Pilot lamp lights. No sine or square wave output.	<ol style="list-style-type: none"> 1. All controls set at zero. 2. Measure the B+ voltage at point A on the generator circuit board. If the voltage is low or there is no voltage, refer to the next Difficulty on this Chart. 3. Feedback control not set properly. (Refer to Adjustments section on Page 41.) 4. Check transistors Q1, Q2, Q5, Q4, and Q3 in that order. 5. Open filament in lamp L1. 6. Wrong part value, improper connection, or faulty part in notch filter circuits (units and tens switches). (Make checks at other frequency settings to test this possibility.)
B+ voltage low or no B+ voltage.	Measure the resistance of the generator circuit board at TP1 as described in the step under "Tests" on Page 39. If this resistance is less than 1500 Ω , apply the checks on the previous page to the generator circuit board. If the resistance is 1500 Ω or greater, check the following: <ol style="list-style-type: none"> 1. Transistor Q10. 2. Diodes D5 and D6. 3. Zener diode D7. 4. Capacitors C1, C2, C3, and C4. 5. Transformer primary windings.
No sine wave output. Square wave output ok.	<ol style="list-style-type: none"> 1. Short circuit or excessive load at sine wave output terminals. 2. Check control R106. 3. Check capacitor C6.
No square wave output. Sine wave output ok.	<ol style="list-style-type: none"> 1. Short circuit or excessive load at square wave output terminals. 2. Symmetry trimmer not adjusted properly. 3. Check transistors Q6, Q7, and Q8. 4. Check control R101. 5. Check capacitor C8. 6. Frequency set too low.
Bottom of square wave goes below zero.	<ol style="list-style-type: none"> 1. D8 open.

DIFFICULTY	POSSIBLE CAUSE AND SUGGESTED CURE
<p>Meter inoperative. Sine wave output ok.</p>	<ol style="list-style-type: none"> 1. Check diodes D3 and D4. 2. Check control R21. 3. Meter pointer stuck. 4. Meter coil open. <p>WARNING: When testing the meter for continuity, use <u>only</u> the highest resistance range of the ohmmeter.</p>
<p>Sine wave distorted.</p>	<ol style="list-style-type: none"> 1. Feedback control set too high. 2. Bias control not set correctly. 3. Check Q10. 4. Check Q5, Q4, Q1, Q2, and Q3. 5. Improper ground connections between Generator and associated equipment. 6. Low line voltage.

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.	$\pm 10\%$ of full scale with proper load termination.



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 $\pm 5\%$ of first and second digit.
Power Requirements.	105-125 VAC or 210-250 VAC, 50/60 Hz, 6 Watts.
Dimensions.	5-1/8" high x 13-1/4" wide x 7" deep.
Net Weight.	7 lbs.

The Heath Company reserves the right to discontinue instruments and to change specifications at any time without incurring any obligation to incorporate new features in instruments previously sold.

CIRCUIT DESCRIPTION

Refer to the Block Diagram on Page 65 and to the Schematic Diagram (fold-out from Page 75) 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 circuit consists 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

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

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 $R_x = 5000 \Omega$, for 40 Hz the two 2500 Ω resistors are selected and $R_x = 2500 \Omega$, for 60 Hz both the 5000 Ω and the 2500 Ω resistors are selected in parallel and $R_x = 1670 \Omega$.

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 voltage divider that consists of resistors R5 and R6, and control R7. (Resistor R3 decreases the gain of the differential amplifier to make it more stable.) The voltage at the lower end of this divider, and therefore at the bases of Q1 and Q2, is made adjustable by being connected to the arm of Bias control R9, which is connected in a DC voltage divider with R8 and R10.

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

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

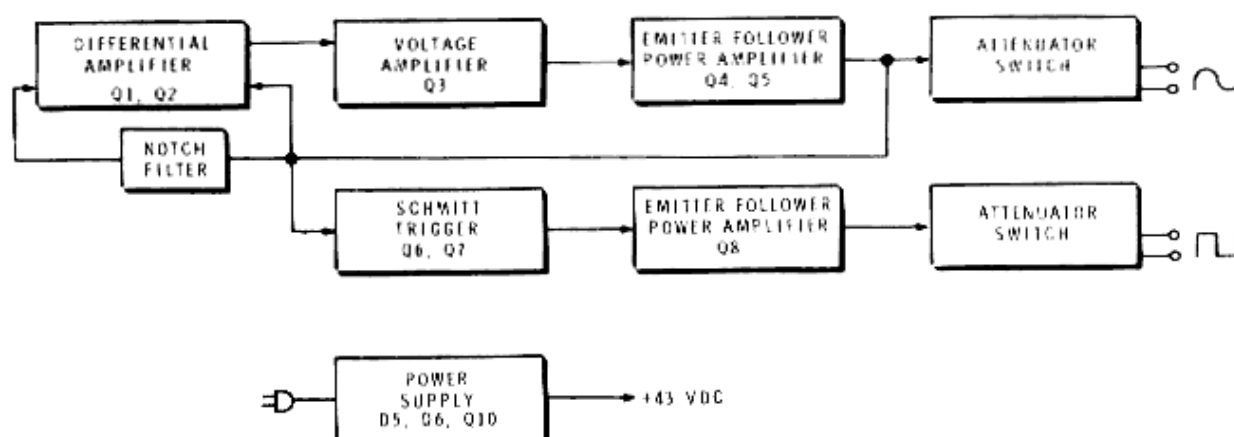
SINE WAVE OUTPUT ATTENUATOR

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.

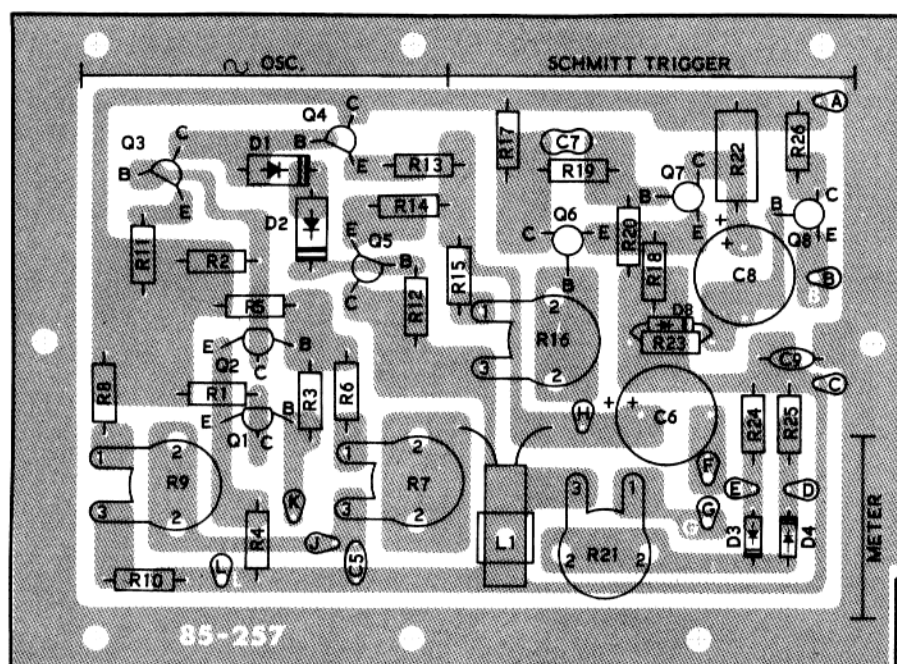
The Schmitt trigger output from the collector of transistor Q7 is coupled through capacitor C8 to the base of emitter follower transistor Q8, which provides a low impedance output with no voltage gain. D8 protects the base of Q8 from excessive negative voltage. The output from Q8 passes directly to Square 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

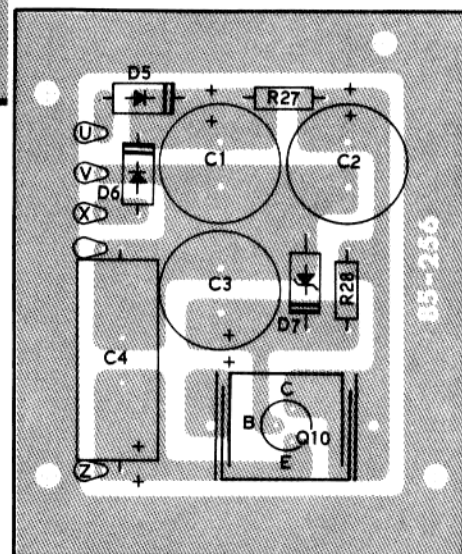
Dual-primary power transformer T1 can be wired to operate from either 120 VAC or 240 VAC. The output from the secondary of T1 is rectified by diodes D5 and D6 in a full wave rectifier circuit, and filtered by the pi filter consisting of capacitors C1 and C2 and resistor R27.

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.

CIRCUIT BOARD X-RAY VIEWS

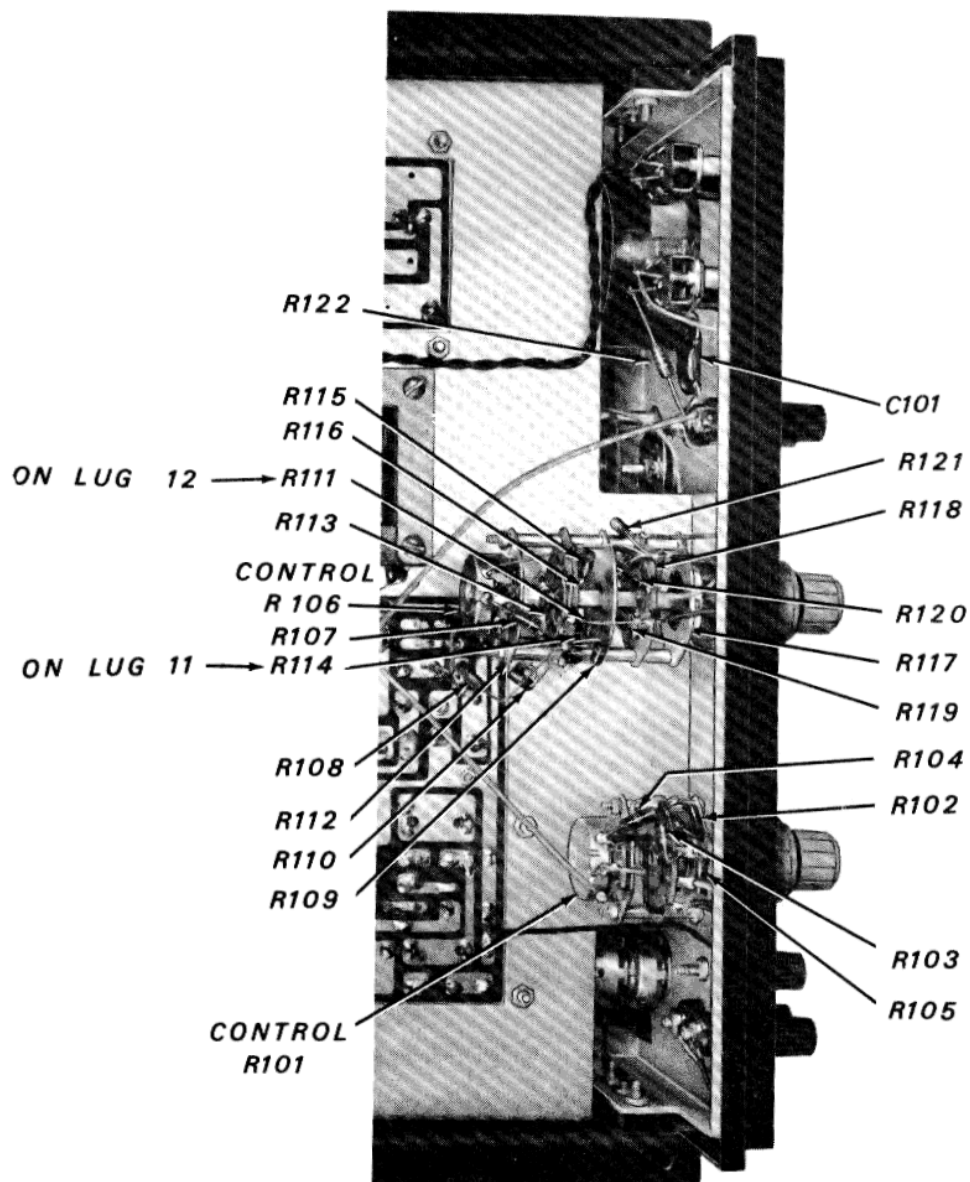


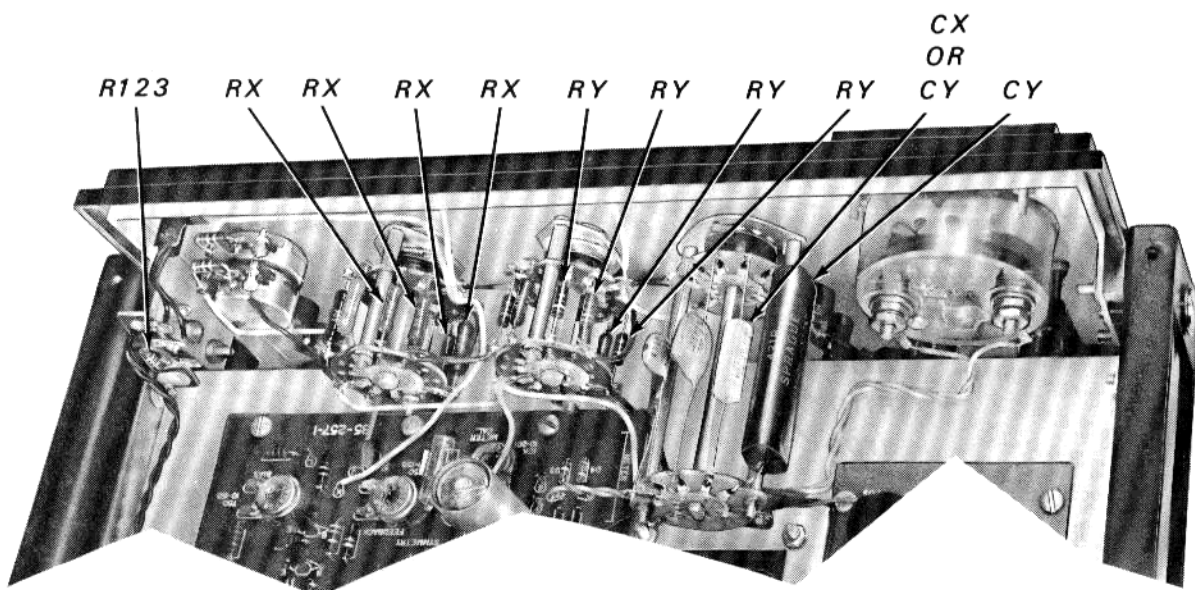
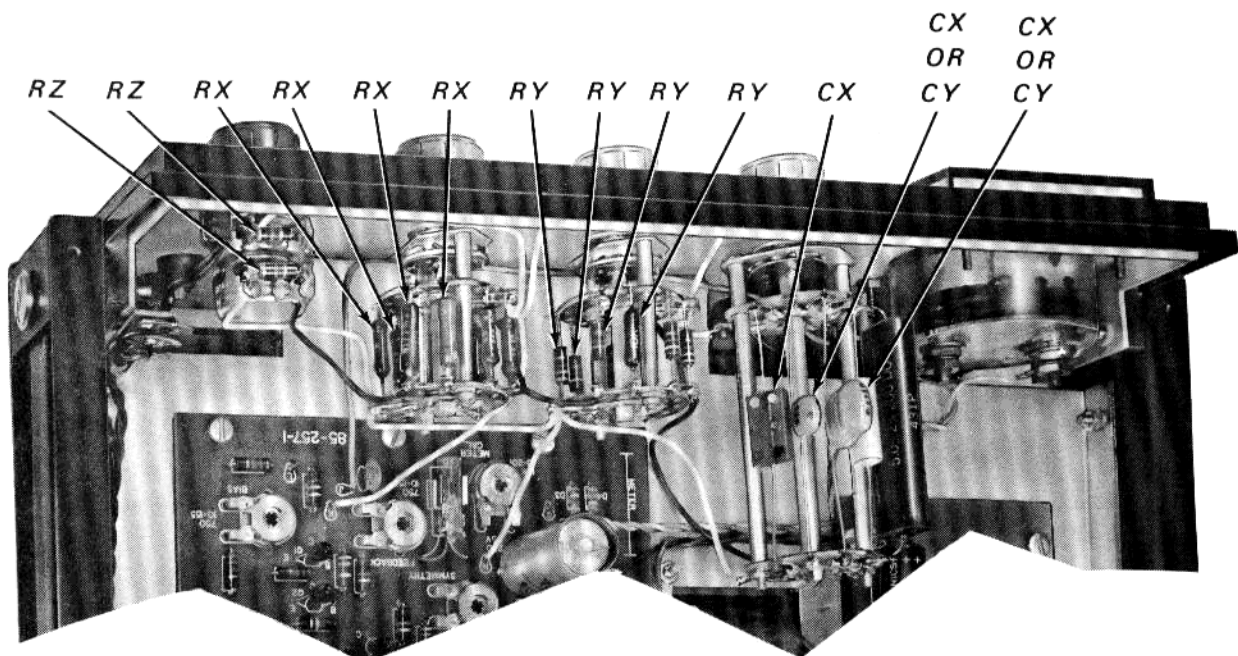
WAVE GENERATOR CIRCUIT BOARD
(VIEWED FROM FOIL SIDE)



POWER SUPPLY
CIRCUIT BOARD
(VIEWED FROM FOIL SIDE)

CHASSIS PHOTOGRAPHS





REPLACEMENT PARTS PRICE LIST

WAVE GENERATOR

The following prices apply only on purchases from the Heath Company where shipment is to a U.S.A. destination. Add 10% (minimum 25 cents) to the price when ordering from an authorized Service Center or Heathkit Electronic Center to cover local sales tax, postage and handling. Outside the U.S.A. parts and service are available from your local Heathkit source and will reflect additional transportation, taxes, duties and rates of exchange.

To order parts, use the Parts Order Form furnished with this kit. If a Parts Order Form is not available, refer to Replacement Parts in the "Kit Builders Guide".

PART No.	PRICE Each	DESCRIPTION
-------------	---------------	-------------

RESISTORS

1/2 Watt

1-54	.15	15 Ω
1-66	.15	150 Ω
1-97	.15	1100 Ω
1-98	.15	1600 Ω
1-89	.15	2400 Ω
1-16	.15	4700 Ω
1-20	.15	10 k Ω
1-47	.15	56 k Ω
1-29	.15	220 k Ω

1 Watt

1-56-1	.15	1200 Ω
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CAPACITORS

20-128	.55	470 pF resin
21-16	.15	.01 μ F disc
25-146	.70	100 μ F electrolytic

PART No.	PRICE Each	DESCRIPTION
-------------	---------------	-------------

CONTROLS

10-155	1.00	750 Ω
10-201	1.00	10 k Ω

DIODES-TRANSISTORS

56-26	.40	Crystal diode
56-56	.30	Silicon diode
57-65	.30	Silicon diode
417-94	1.00	2N3416 transistor
417-154	1.65	2N2369 transistor
417-201	.50	X29A829 transistor

HARDWARE

250-89	.05	6-32 x 3/8" screw
254-1	.05	#6 lockwasher
259-1	.05	#6 solder lug
252-3	.05	6-32 nut
250-175	.05	2-56 x 3/8" screw
254-7	.05	#3 lockwasher
252-51	.05	2-56 nut

MISCELLANEOUS

206-24	.70	Lamp clip
412-66	1.15	Lamp
85-257-2	1.90	Wave generator circuit board
331-6	.25	Solder
200-516	2.10	Chassis
	2.00	Manual (See front cover for part number.)
490-5	.15	Nut starter

POWER SUPPLY

PART No.	PRICE Each	DESCRIPTION
-------------	---------------	-------------

RESISTORS-CAPACITORS

1-1	.15	47 Ω 1/2 watt resistor
1-89	.15	2400 Ω 1/2 watt resistor
25-126	.75	50 μ F capacitor

DIODES-TRANSISTOR

56-66	1.35	VR 43 zener diode
57-65	.30	Silicon diode
417-178	1.55	40389 transistor

PART No.	PRICE Each	DESCRIPTION
-------------	---------------	-------------

HARDWARE

250-89	.05	6-32 x 3/8" screw
254-1	.05	#6 lockwasher
252-3	.05	6-32 nut

MISCELLANEOUS

54-205	5.25	Power transformer
85-256-2	1.90	Power supply circuit board
344-50	.05/ft	Black wire
344-52	.05/ft	Red wire

SWITCH PARTS

PART No.	PRICE Each	DESCRIPTION
-------------	---------------	-------------

RESISTORS

1-83	.15	56 Ω
1-84	.15	62 Ω
1-66	.15	150 Ω
1-94	.15	390 Ω
1-63	.15	510 Ω
1-131	.15	620 Ω
1-96	.15	750 Ω
1-97	.15	1100 Ω
1-98	.15	1600 Ω
1-89	.15	2400 Ω

1/2 Watt, 1%

2-249	1.00	2500 Ω (2.5 k Ω)
2-248	1.00	3300 Ω (3.3 k Ω)
2-247	1.00	5000 Ω (5 k Ω)
2-50	1.00	10 k Ω
2-97	1.00	25 k Ω
2-98	1.00	33.3 k Ω
2-99	1.00	50 k Ω
2-11	1.00	100 k Ω

CAPACITORS

20-55	.30	500 pF
27-84	1.80	.005 μ F

PART No.	PRICE Each	DESCRIPTION
-------------	---------------	-------------

Capacitors (cont'd.)

27-83	2.40	.05 μ F
27-82	2.95	.5 μ F
27-81	5.00	5 μ F

SWITCHES-CONTROL NUT

63-485	5.25	8-position rotary with 5000 Ω control
63-1252	5.25	3-position rotary with 600 Ω control
63-487	3.55	11-position rotary
63-488	3.25	4-position rotary
252-7	.05	Control nut

WIRE

344-50	.05/ft	Black wire
344-51	.05/ft	Brown wire
344-53	.05/ft	Orange wire
344-54	.05/ft	Yellow wire
344-55	.05/ft	Green wire
344-56	.05/ft	Blue wire
344-59	.05/ft	White wire

CHASSIS PARTS

PART No.	PRICE Each	DESCRIPTION
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RESISTORS

1-95	.15	560 Ω
1-23	.15	27 k Ω
1-102	.15	82 k Ω

ELECTROLYTIC CAPACITORS

25-193	.90	250 μ F
25-205	1.95	300 μ F
27-110	.30	.047 μ F Mylar

CONTROL-SWITCHES

12-96	2.40	1 M Ω dual control
60-24	.75	Rocker switch

PLASTIC PARTS

70-10	.25	Black test lead insulator
70-11	.25	Red test lead insulator
75-17	.15	Binding post base insulator
75-30	.15	Line cord strain relief, round cord
75-71	.15	Line cord strain relief, flat cord
100-16-2	.15	Binding post cap, black
100-16-18	.15	Binding post cap, red
100-699	.25	Binding post cap, green
207-3	.15	Cable clamp
261-28	.10	Plastic foot
413-10	.15	Red pilot lamp lens
261-30	.20	Line cord retainer

HARDWARE

#6 Hardware

250-227	.05	6-32 x 7/8" phillips head screw
250-26	.05	6-32 x 5/8" screw
250-304	.15	6-32 x 7/16" spacer stud
250-89	.05	6-32 x 3/8" screw
250-229	.05	6-32 x 1/4" phillips head screw
250-535	.25	6-32 x 1/4" decorative head screw
250-475	.05	#6 x 1/4" sheet metal screw
254-1	.05	#6 lockwasher
254-27	.05	#6 external-internal lockwasher
255-15	.05	#6 x 1/2" spacer
259-1	.05	#6 solder lug
252-3	.05	6-32 nut

PART No.	PRICE Each	DESCRIPTION
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Other Hardware

252-7	.05	Control nut
253-10	.05	Control flat washer
254-4	.05	Control lockwasher
252-32	.05	Speednut
427-3	.15	Binding post base

METAL PARTS

90-401-2	3.90	Cabinet half shell
100-769	2.35	Front panel
100-770	2.25	Rear panel
100-771	1.30	Side rail
204-759-1	.55	End cap
210-35	4.35	Bezel
211-32	.55	Handle

WIRE

Hookup Wire

344-50	.05/ft	Black
344-51	.05/ft	Brown
344-54	.05/ft	Yellow
344-55	.05/ft	Green
344-57	.05/ft	Violet
344-58	.05/ft	Gray

Other Wire

89-23	1.25	Line cord
341-1	.10/ft	Black test lead
341-2	.10/ft	Red test lead





KNOBS AND BUSHINGS



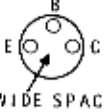

455-50	.15	Single knob bushing
455-51	.15	Inner shaft knob bushing
455-52	.15	Outer shaft knob bushing
462-245	.40	Single knob
462-247	.55	Outer shaft knob
462-276	.40	Inner shaft knob

MISCELLANEOUS

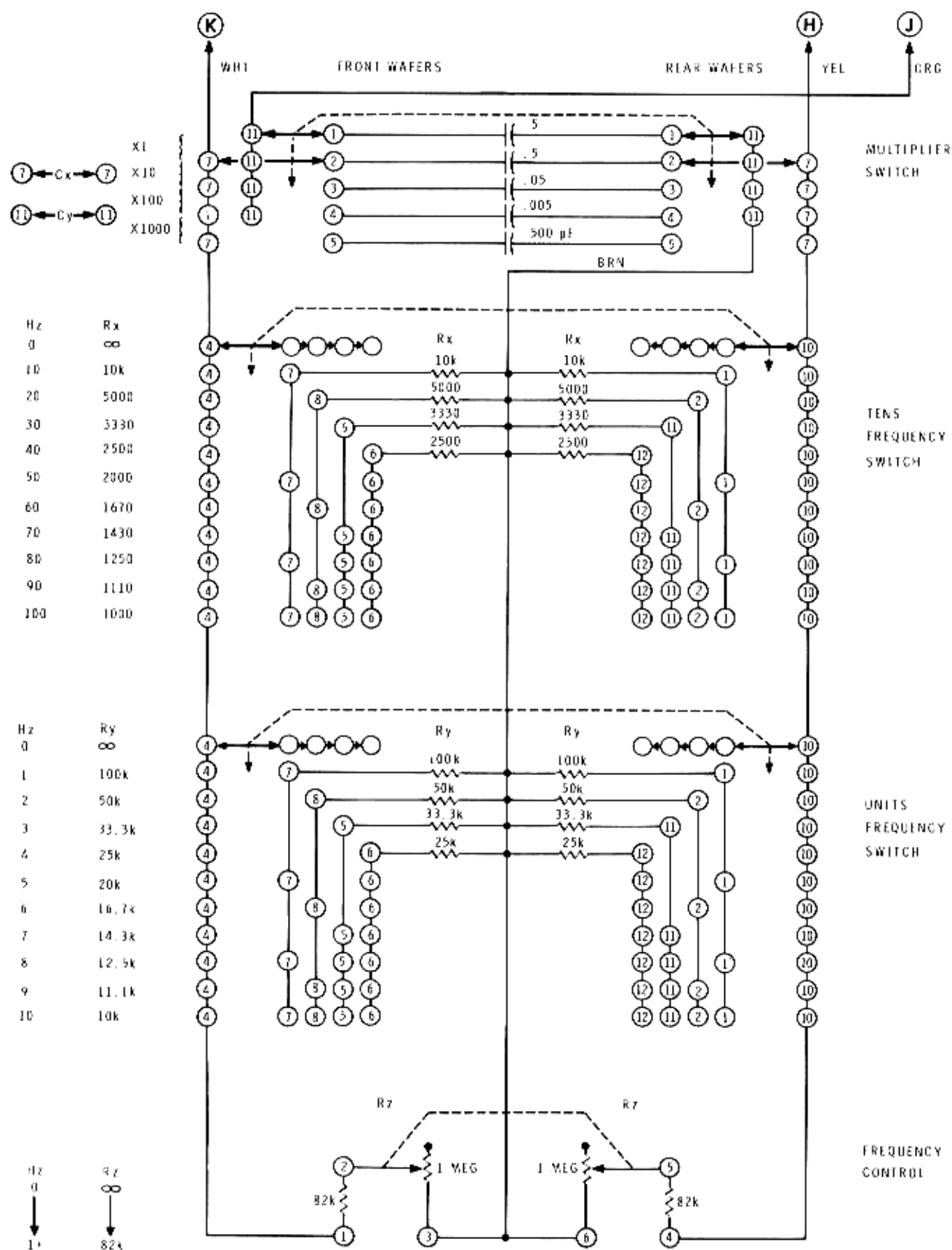
253-85	.05	Felt washer
260-16	.10	Alligator clip
407-131	17.55	Meter
412-15	.30	Neon lamp
431-41	.15	2-lug terminal strip
431-35	.15	7-lug terminal strip
438-47	.20	Banana plug
259-20	.05	Solder pin
421-22	.65	3/4 ampere slow-blow fuse

NOTES

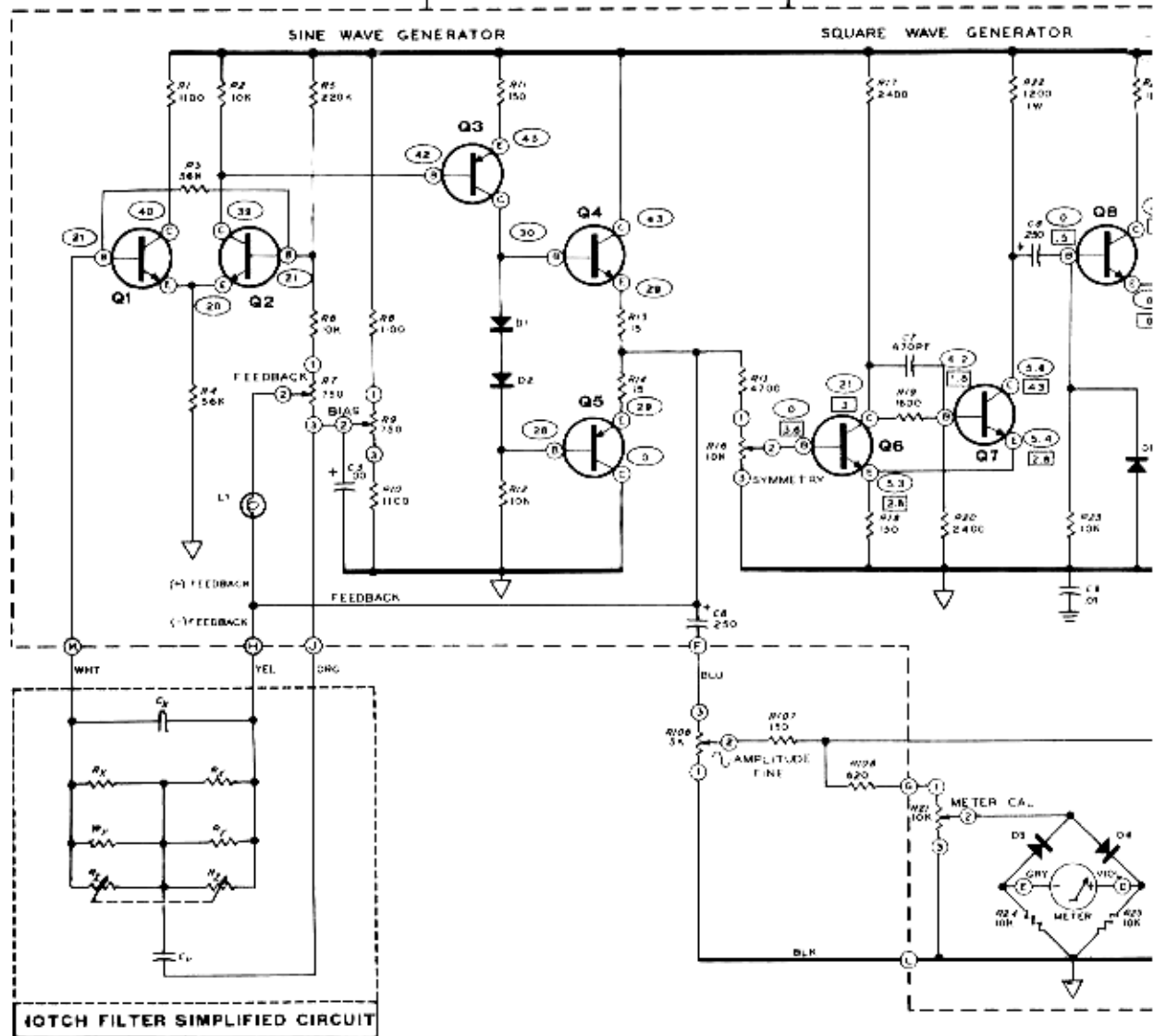
1. RESISTORS AND CAPACITORS, EXCEPT THOSE IN THE NOTCH FILTER CIRCUIT, ARE NUMBERED IN THE FOLLOWING GROUPS:
 0-99 PARTS MOUNTED ON CIRCUIT BOARDS.
 100-199 PARTS MOUNTED ON CHASSIS.
2. ALL RESISTORS ARE 1/2 WATT UNLESS MARKED OTHERWISE. RESISTOR VALUES ARE IN OHMS (K=1000).
3. ALL CAPACITORS ARE IN μ F UNLESS MARKED OTHERWISE (pF=PICOFARAD).
4. ALL SWITCHES SHOWN IN FULL COUNTERCLOCKWISE POSITION WHEN VIEWED FROM THE KNOB END.
5.  INDICATES COMMON CIRCUIT GROUND.
6.  INDICATES CHASSIS GROUND.
7. REFER TO THE CHASSIS PHOTOGRAPHS AND CIRCUIT BOARD X-RAY VIEWS FOR THE PHYSICAL LOCATION OF PARTS.
8.  +DC VOLTAGES TO EITHER COMMON OUTPUT TERMINAL. ALL CIRCUIT BOARD CONTROLS FULLY CCW. ALL FREQUENCY SWITCHES AND CONTROL CCW, ALL AMPLITUDE SWITCHES AND CONTROLS FULLY CW. VOLTAGES $\pm 10\%$.
9.  +DC VOLTAGES, THE SAME AS ABOVE, EXCEPT SYMMETRY CONTROL FULLY CW.

TRANSISTOR, DIODE	PART NUMBER	MAY BE REPLACED WITH	BASING DIAGRAM
Q1, Q2, Q4	417-94	2N3416	
Q3, Q5	417-201	2N2386	
Q6, Q7, Q8	417-154	2N2369	
Q10	417-178	40389	
D1, D2, D5, D6	57-65	SILICON 100 PIV, 100 mA	
D3, D4	56-26	1N191	
D7	56-66	ZENER VR43 1 WATT	
D8	56-56	1N4149	

FRONT WAFERS



WAVE GENERATOR CIRCUIT BOARD



POWER SUPPLY CIRCUIT BOARD

