

oscilloscope audio applications

BY GLEN SOUTHWORTH

INTRODUCTION

The oscilloscope is probably the most useful and versatile of all instruments used in making audio tests and measurements. It may be used as a signal tracer, peak reading voltmeter, phase shift monitor, and for indicating the amount of modulation present in a signal. The oscilloscope may likewise be easily used to detect and interpret harmonic, intermodulation, phase, and transient distortions which may occur in audio equipment. The sensitivity and high impedance input of the HEATHKIT OSCILLOSCOPE makes it extremely useful for stage by stage testing of any part of the audio chain, whether it be amplifier, speaker, phono pickup, or microphone.

USE OF HEATHKIT OSCILLOSCOPE AS A PEAK READING VOLTMETER AND PROGRAM MONITOR

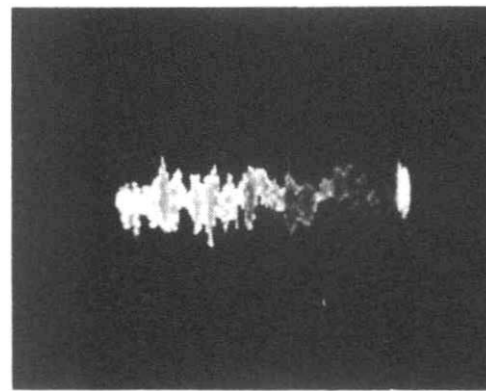
One of the simplest and most interesting uses to which an oscilloscope can be put is to monitor the Output of an audio amplifier carrying program material. In many applications, such as broadcasting or recording, a certain peak voltage level must not be exceeded or excessive distortion will result and the instantaneous indication of the oscilloscope makes it considerably superior to the conventional meter in indicating sudden transient peaks.

One way of using the scope as an overload indicator is to draw two parallel, horizontal, lines on a celluloid screen, separated by some convenient distance, such as three inches, and place the screen over the face of the scope tube. A calibrating voltage is then applied to the scope input and the input level adjusted until the peaks of the signal trace just touch the two parallel lines. If the scope is then used to monitor program material, any traces appearing outside of the two parallel lines indicates instantaneous intensities exceeding that of the calibrating voltage, and the amplifier gain may be reduced accordingly.

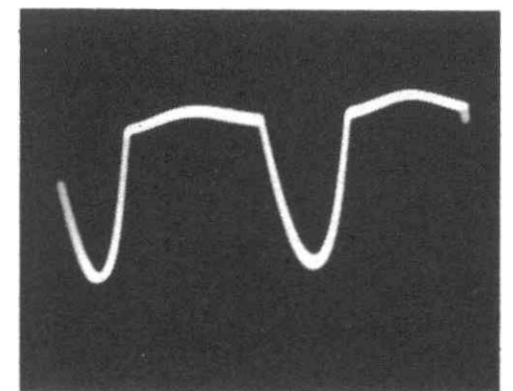
The oscilloscope is useful in many other ways in the monitoring of recordings or broadcasts. It is capable of detecting spurious subsonic or supersonic oscillations and can indicate the character and amplitude of unwanted hum or noise. Likewise, the scope can give visual warning of excessive distortion occurring in the audio system. For example, overloading in previous stages would tend to cause flat tops to be present upon the waveforms traced on the screen. Similarly, severe second harmonic distortion, such as might be caused by lack of proper bias or loss of one of a set of push-pull tubes, will be indicated by traces that appear to go mostly in one direction from the center of the screen (an example of which is shown in figure S-2).

The experimenter, musician, or classroom instructor will find the HEATHKIT OSCILLOSCOPE a valuable aid in analyzing various sounds and noises. If it is wished to make accurate measurements of peak voltages encountered, the

graph screen supplied with the scope may be used, and an accurate calibrating voltage obtained from a source such as the HEATHKIT VOLTAGE CALIBRATOR KIT.



S-1 Scope pattern of a piccolo passage, note complex modulations

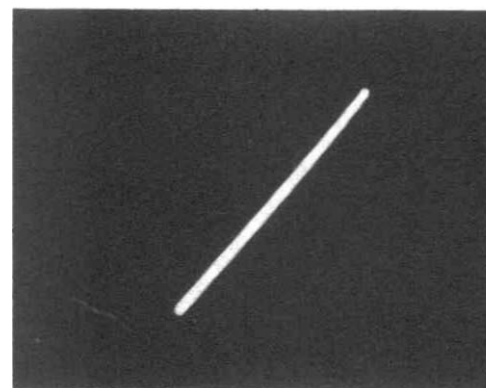


S-2 Scope pattern of sine wave deformed by excessive 2nd harmonic distortion

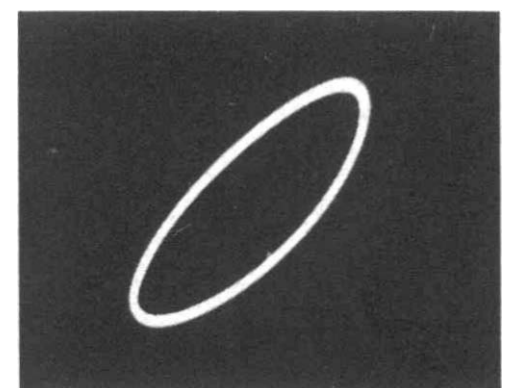
PHASE SHIFT INDICATION WITH THE HEATHKIT OSCILLOSCOPE

A knowledge of phase characteristics is becoming increasingly important in audio design and construction, and the oscilloscope makes an excellent method of detecting phase shift over a range of from zero to one hundred eighty degrees. If identical signals are applied to both the horizontal and vertical amplifiers of an oscilloscope, then a straight diagonal line will be traced upon the screen. When the phase of the signal applied to one of the amplifiers is inverted, then the diagonal line will be traced at right angles to the pattern formed before. This particular relationship is frequently very useful in obtaining the proper phasing of transformers, microphones, speakers, amplifiers, and other audio devices where proper connections must be made to secure optimum results.

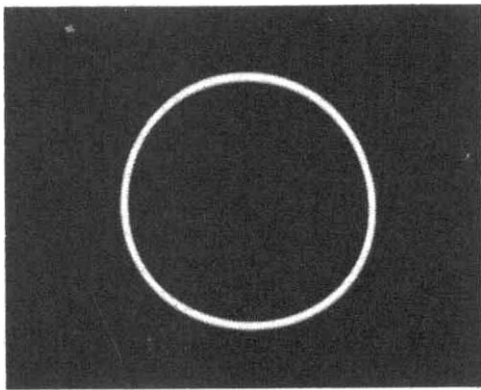
Phase shifts of 180 degrees or less are often of importance in the design of tone controls or amplifiers using inverse feedback. If too much feedback is used, instability or oscillation frequently occurs near the region of ninety degree phase shift. The accompanying scope patterns show some of the typical figures produced by phase shift over a range of zero to 180 degrees.



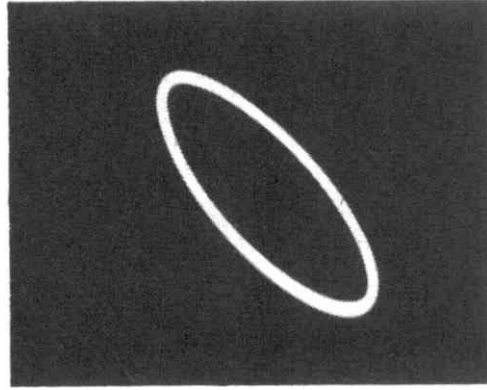
S-3 0 degrees phase shift



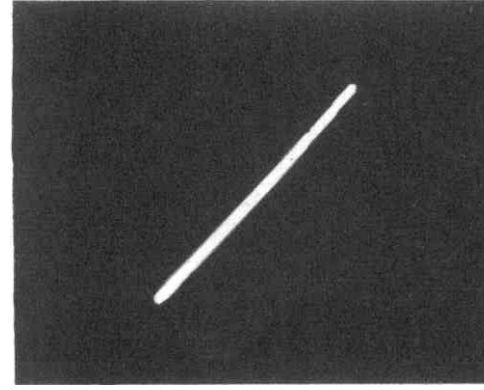
S-4 Approximately 45 degrees phase shift



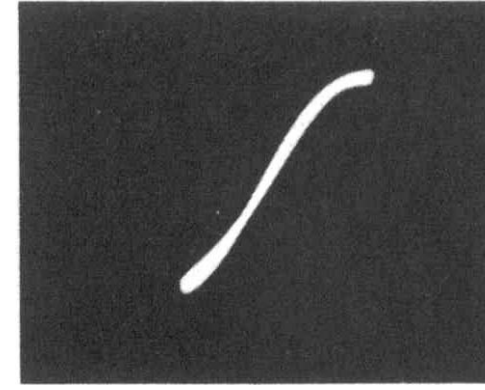
5-5 Ninety degrees phase shift



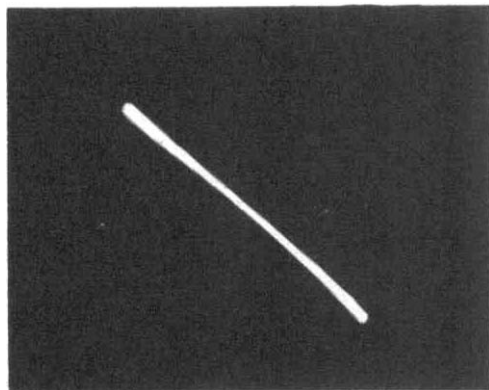
5-6 Approximately 135 degrees phase shift



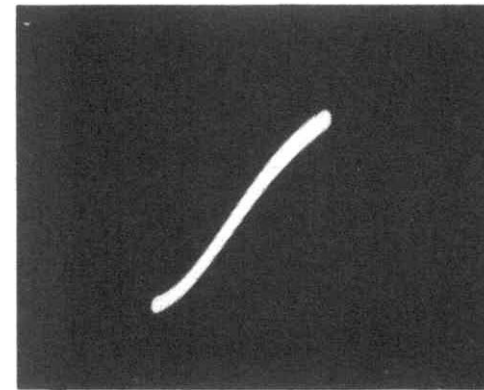
5-10 Trace produced by amplifier having neither phase or harmonic distortion



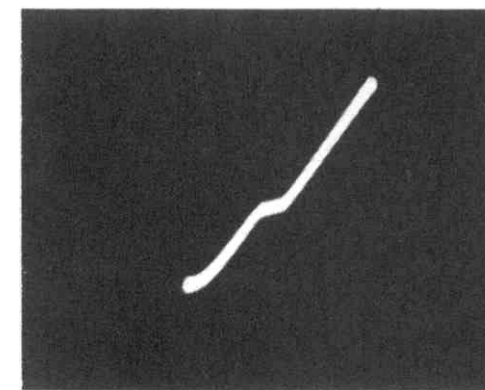
5-11 Trace showing both 2nd and third harmonics



5-7 180 degrees phase shift



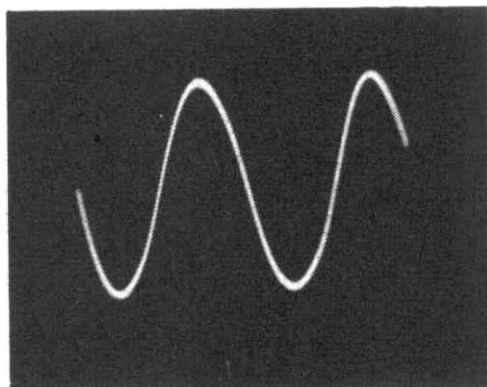
5-12 Trace showing predominately third harmonic distortion



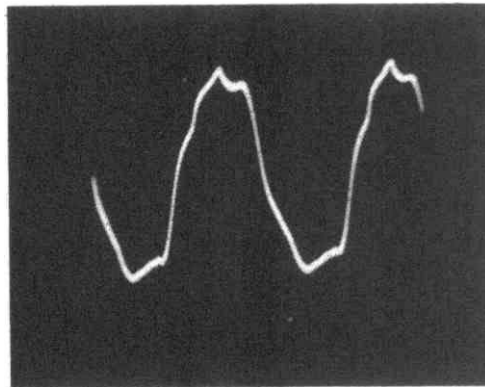
5-13 Trace showing severe high order distortion at low levels as well as overload on positive peaks

DISTORTION MEASUREMENTS WITH THE HEATHKIT OSCILLOSCOPE

The simplest way to examine an amplifier or other piece of equipment for harmonic distortion is to apply a pure sine wave to the input of the device being tested and examine the output with the oscilloscope to see if any obvious deformations of wave shape occur, an example of which is shown below.



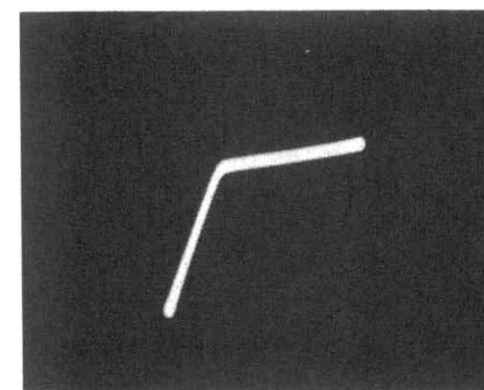
5-8 Input waveform from HEATHKIT, Audio Oscillator



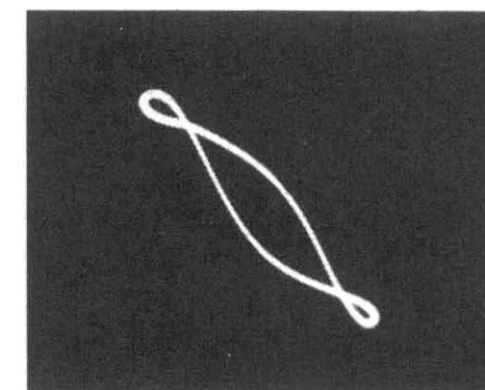
5-9 Output of amplifier under test, showing severe distortion

A test which is capable of considerably greater sensitivity is to apply the signal from the audio oscillator to one deflection amplifier and the output of the unit being tested to the other. If no phase or harmonic distortion is present, then a straight diagonal line will be traced upon the oscilloscope screen, as in the phase shift test outlined previously. However, if harmonic distortion is present, the line will exhibit one or more bends or kinks, and the following scope patterns illustrate some of the various distortions that may be encountered.

By taking a celluloid screen and drawing a straight diagonal line on it with a ruler, and then matching the scope trace as closely as possible to the straight line, it is possible to detect harmonic distortion as low as two or three percent. For greatest ease in detecting distortion, the phase shift present in the system should be as low as possible or an oval trace will result instead of a line. If a low distortion signal source is used, a phase shifting network may be used between the



5-14 Pattern of severe 2nd harmonic distortion or near rectification of signal. Sharpness of bend indicates high order harmonics are also present

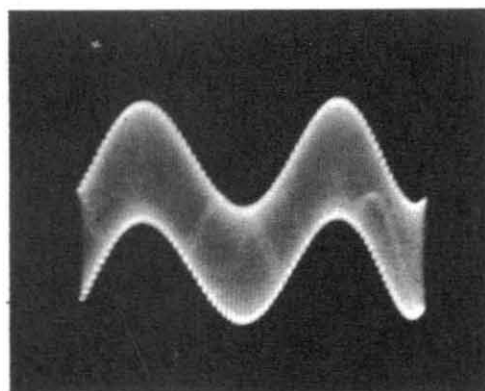


5-15 Scope trace of an amplifier in which phase shift has occurred after 3rd harmonic distortion was produced

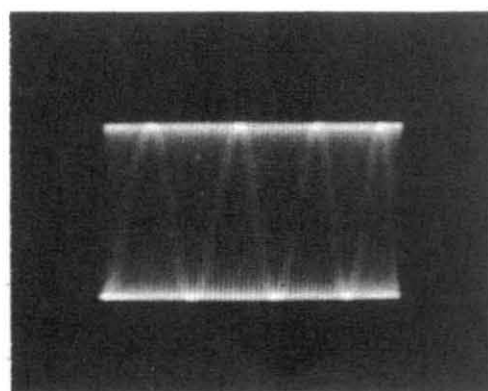
audio oscillator and the scope in order to cancel out phase distortion taking place in the equipment under test, and an example of this is shown in the accompanying schematic.

INTERMODULATION TESTS WITH THE HEATHKIT OSCILLOSCOPE

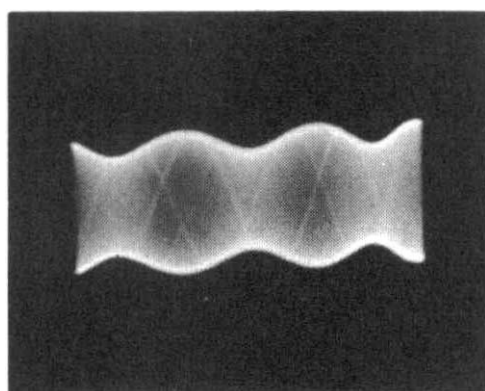
Through the addition of three resistors and three condensers, the oscilloscope can be used as a very effective means of detecting intermodulation distortion occurring in audio equipment. To make intermodulation tests, two tones are applied to the equipment being measured. One of these may be sixty cycles, obtainable from the power line through an isolation transformer, and the other a high frequency tone of between two thousand and ten thousand cycles, such as is readily obtainable from the HEATHKIT AUDIO OSCILLATOR. These two tones are usually mixed together with the low frequency being approximately four times the amplitude of the high frequency. The output of the equipment being tested is then applied to the scope input through a simple RC high pass filter, the complete setup being shown in the accompanying diagram, on page 4, and the pattern traced upon the screen may then be examined for any modulations that may have been produced by the equipment under test. Following are shown three of the typical patterns that may be produced.



5-16 Pattern of test signal with high and low frequencies mixed in one to one ratio



5-17 Output of high pass filter when no distortion has been introduced by equipment under test



5-18 Pattern of intermodulation caused by second harmonic distortion in equipment under test. Approximately 250% distortion

The oscilloscope can indicate several important factors which are not normally discernable with the average inter-modulation meter. It will show whether positive or negative modulation is taking place, and what type of harmonic distortion is apt to be accompanying the 1M distortions. For example, second harmonic distortion will cause the envelope shape to resemble the waveform of the low frequency component, while

third harmonic distortion will make the envelope shape resemble the low frequency component if it had been passed through a full wave rectifier. In addition, the individual cycles of the high frequency component may be examined to see if severe harmonic distortion is occurring here in addition to modulation.

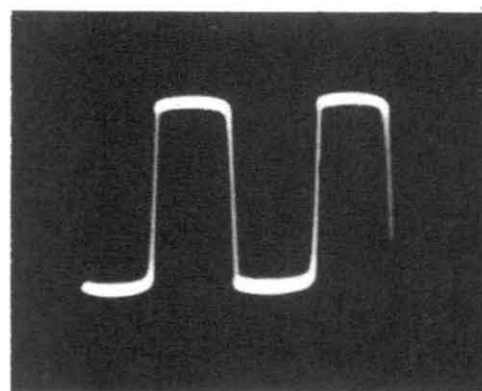
The excellent sensitivity of the HEATHKIT OSCILLOSCOPE means that intermodulation tests may be made at very low power levels as well as at high output. This can be very desirable due to the fact that with modern loudspeakers a signal level of a fraction of a milliwatt may be highly audible and low distortion at such intensities may be essential to good listening. Likewise, the high sensitivity and high input impedance of the HEATHKIT OSCILLOSCOPE mean that voltage amplifier stages and preamplifiers may be tested to locate sources of distortion, or if desired an entire reproducing system may be tested by the intermodulation technique.

For disc, tape, wire, or film recording the simple high pass filter used in the intermodulation test technique may be employed to give an excellent indication of "Flutter" or spurious modulation of a pure high frequency tone, by eliminating hum or unwanted low frequencies that might confuse the scope pattern.

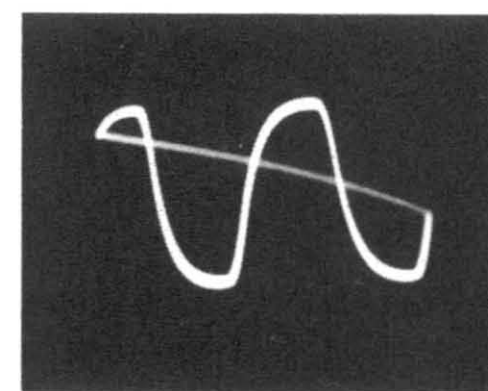
TRANSIENT TESTS WITH THE OSCILLOSCOPE

The oscilloscope is the only instrument used widely in making transient tests. The most common technique is to generate some transient waveform, such as the square wave, and visually examine any distortions that may occur in the equipment being tested. The following pictures of oscilloscope patterns illustrate some of the distortions that may occur frequently.

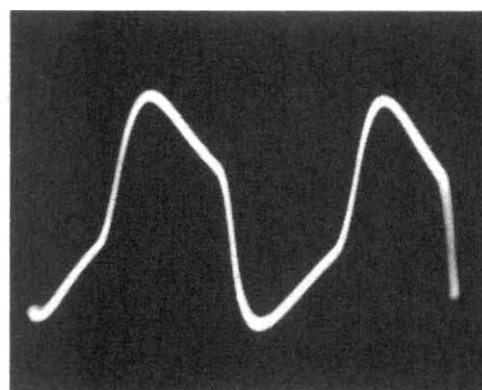
Another test that is finding increasing use is the generation of periodic pulses. These are more like the waveforms actually encountered in speech and music and have several test advantages over the square wave. The first of these is the fact that the asymmetrical character of the pulse very strongly stimulates any reactive component in the equipment being tested,



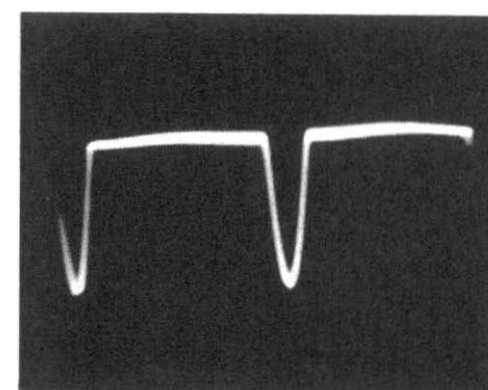
5-19 Square wave input (produced by diode clipping of a sine wave)



5-20 Effect of capacitive circuit element and corresponding loss of high frequency response

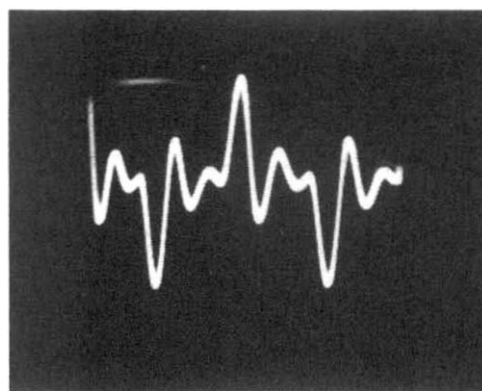


5-21 Effect of inductive circuit element, note corners slightly rounded due to high frequency resonance in coil

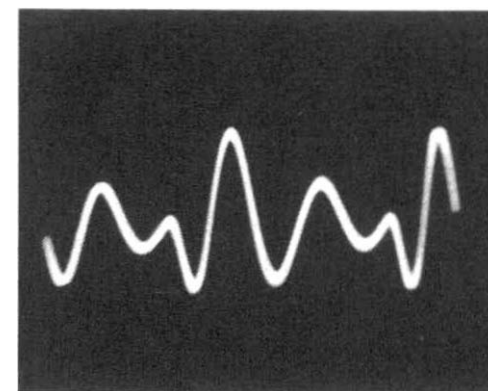


5-22 Ringing produced by resonant circuit

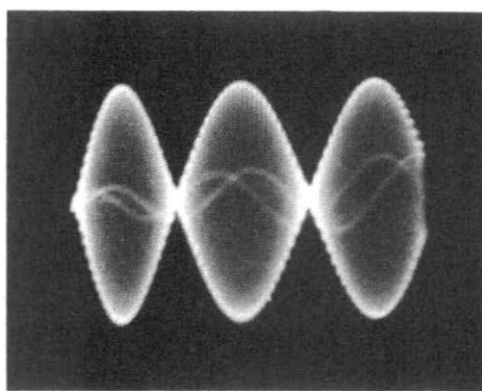
and secondly, those ringing resonances are most strongly stimulated which have a relationship to the pulse repetition rate. The following scope photographs illustrate the initial pulse wave shape and two of the many distortions that may be produced in audio equipment.



5-23 Pulse input signal (produced by peak clipping of sine wave)



5-24 Pulse distortion produced by inductive circuit element



5-25 Ringing caused by resonant circuit element

The various types of transient test that may be used are limited chiefly by the ingenuity of the experimenter. In addition to the two described, experiments may be made with damped wave trains, both of which simulate sounds frequently occurring in nature. If desired, the technique described under harmonic distortion measurements may be used to provide

a means of instantaneous comparison of input and output signals, or the HEATHKIT ELECTRONIC SWITCH be used as a convenient means of displaying both input and output signals upon the oscilloscope screen.

It is usually considered that transient distortions are apt to be the largest in electro-acoustic devices such as loudspeakers, phonograph pickups, and microphones. The excellent

sensitivity of the HEATHKIT OSCILLOSCOPE means that in many cases the electro-mechanical device being tested may be connected directly to the oscilloscope input. For example, the intensity and duration of loudspeaker resonances may be easily indicated by connecting the speaker voice coil terminals to the scope input and tapping the cone sharply. Similarly, any crystal phonograph pickup and most high impedance microphones will have enough electrical output to produce usable scope traces.

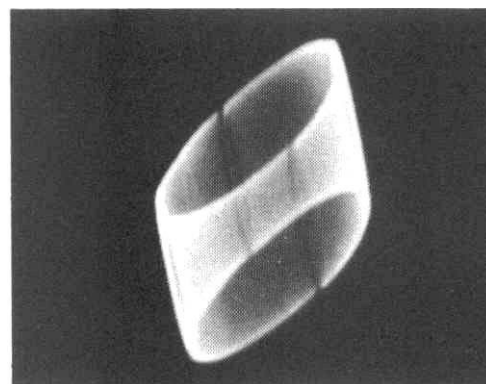
USE OF THE OSCILLOSCOPE AS A FREQUENCY METER

If an accurately calibrated audio oscillator is available, the oscilloscope may be used as a convenient means of determining the frequencies of unknown signals. The simplest way to do this is to set the oscilloscope sweep frequency to its lowest range and mix the unknown signal with that from the audio oscillator in a one to one ratio. The frequency of the audio oscillator is then varied until low frequency beats, such as shown in S-26, appear. The point at which the beats are extremely slow or seems to vanish is the point at which the local oscillator frequency is the same as the unknown. However, in order to avoid mistaken readings, the user should be sure that the beats are not being produced by strong harmonics in either waveform.

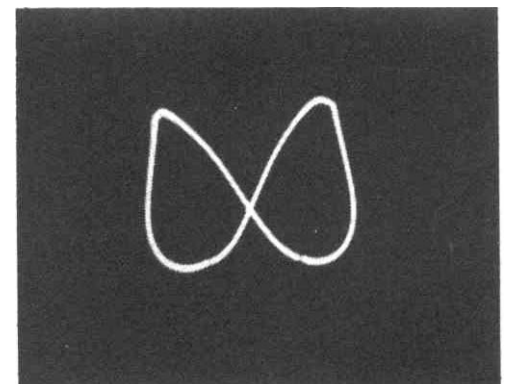
If it is desired to know the various components of a complex wave, for example one containing frequencies of one hundred and five thousand cycles, then the local audio oscillator may be slowly swept through the audio range and the zero beating with various frequency components noted.

A second method of measuring frequency is through use of the Lissajous figures. In this case the unknown signal is applied to the oscilloscope vertical amplifier and the signal from

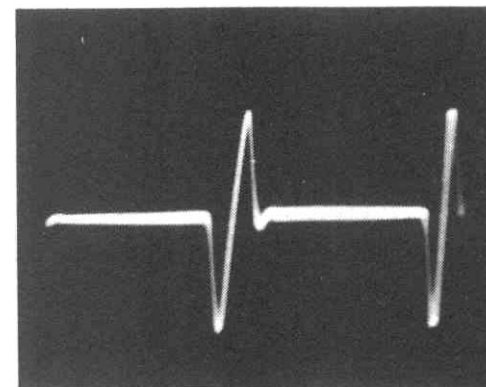
the local audio oscillator to the scope horizontal amplifier. If the local oscillator is tuned to a frequency twice that of the unknown signal, a figure eight will be formed on the screen, while if both frequencies are identical, an oval or circular pattern will be produced. As in the beat method, mentioned previously, a complex wave may be examined by slowly sweeping the local oscillator through the audio range and noting the points at which oval or circular patterns are produced. Below are several examples of patterns produced by beats and Lissajous figures.



5-26 Simple low frequency beats produced by two close frequencies of equal amplitude



5-27 Butterfly pattern of Lissajous figures caused by setting local oscillator at one half the frequency of unknown signal



5-28 Lissajous pattern caused when unknown signal is 60 and 5000 cps and local oscillator frequency is 60 cps

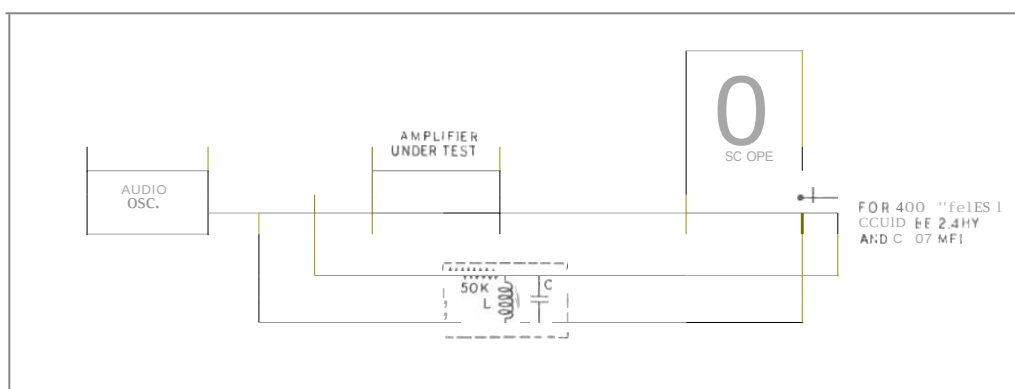


Figure 1 Setup for making phase shift measurements with scope. Same connections are used for making distortion tests, but the three components enclosed in dotted box may be added to cancel out phase distortion and achieve a straight line pattern. Values of Land C will depend upon the test frequency used and the oscillator is tuned slightly high or low to obtain phase cancellation.

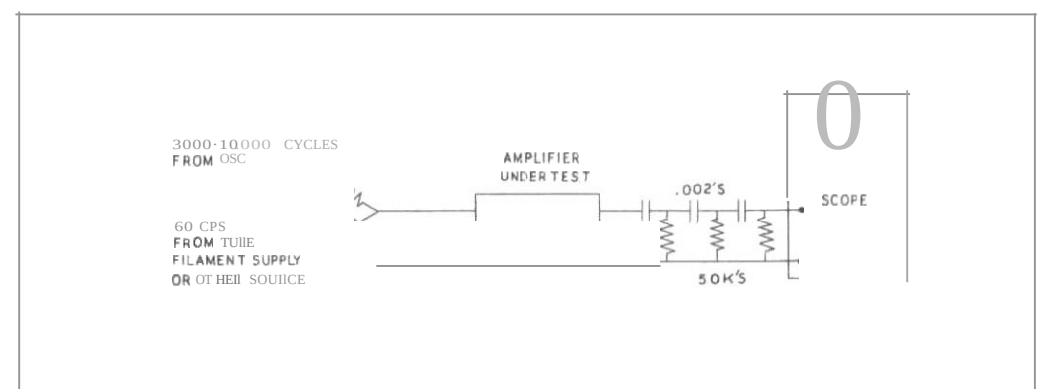


Figure 2 Test setup for making intermodulation tests with an oscilloscope. The high pass filter should be well shielded when making tests of low level, high impedance amplifier stages. When testing for "Flutter", the output of the playback device is connected to the input of the high pass filter.

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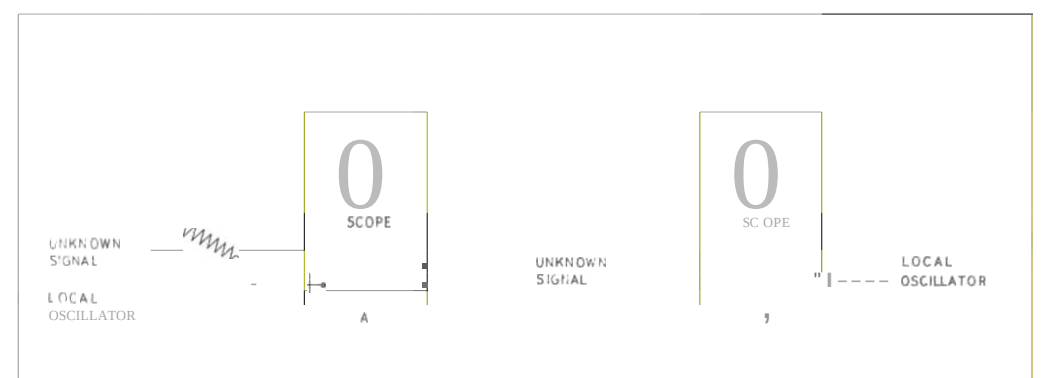


Figure 3 A. is the connection for determining an unknown frequency through the beat method. B. is for determining an unknown frequency through use of Lissajous figures.

checking transformer action with the oscilloscope

BY LOUIS E. GARNER, JR.

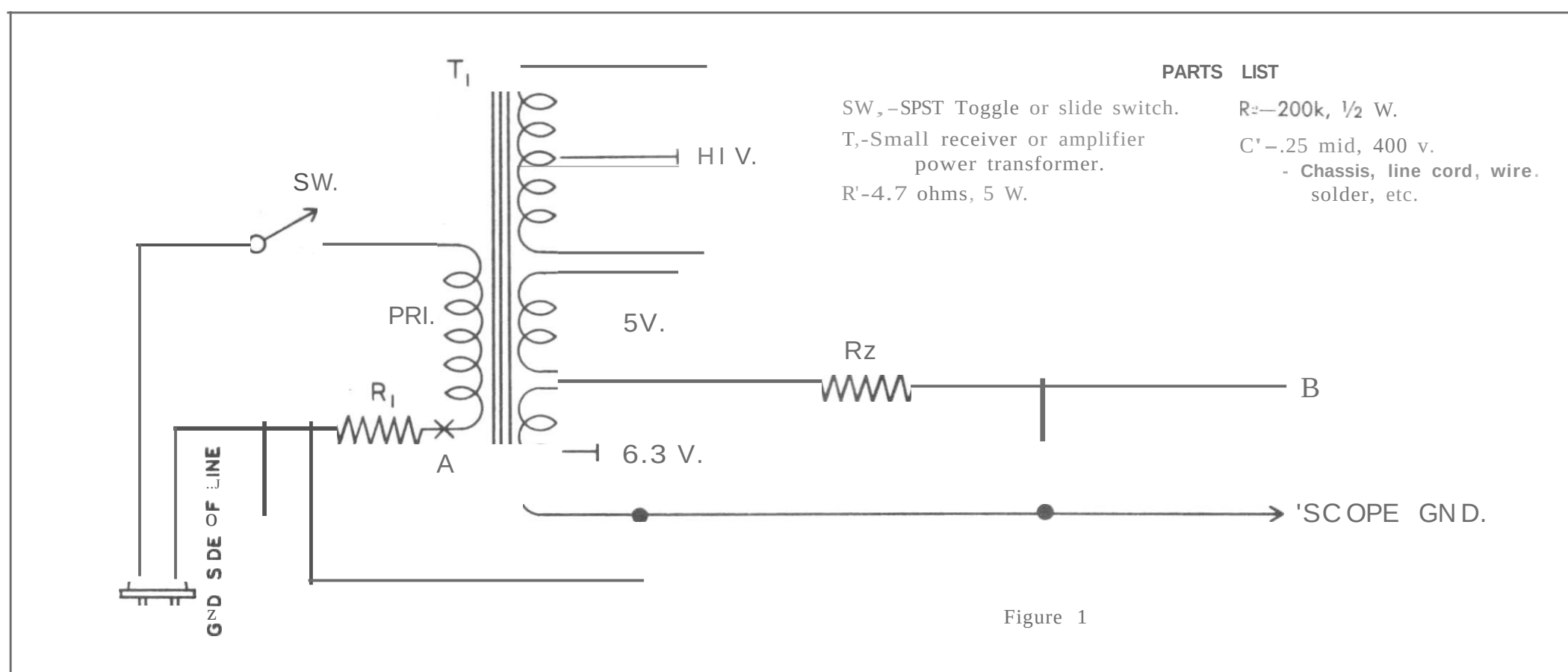
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Your Heathkit OSCILLOSCOPE is a valuable training aid. With it you can study actual circuit operation and thus gain a better insight of theory. In these "Application Notes" an effort will be made to outline a series of experiments you can perform, using standard radio parts and your Heathkit Oscilloscope. These experiments should prove valuable to experimenters, servicemen, hams, and others in giving a better understanding of circuit operation. Schools, too, will find

the experiments worthwhile, either for supplementary study, or for incorporation into a more formal plan of training.

Generally, no effort will be made to explain the theory or math involved in other than a very elementary way. For a further discussion of theory, refer to any of the excellent standard reference texts that are available.

As the first in this series of experiments, power transformer action will be studied.



OBTAINING A B-H OR "HYSTERESIS" CURVE:

The circuit given in Fig. 1 is suitable for obtaining a B-H curve for a transformer or coil. The B-H curve, you may recall, is a curve indicating the number of lines of magnetic flux produced by magnetizing forces of various strength. For most core materials, the curve is S-shaped, with the top and bottom loops indicating magnetic saturation of the core material. If the core material has magnetic hysteresis, the curve will widen, with the area between the sides representing losses due to hysteresis.

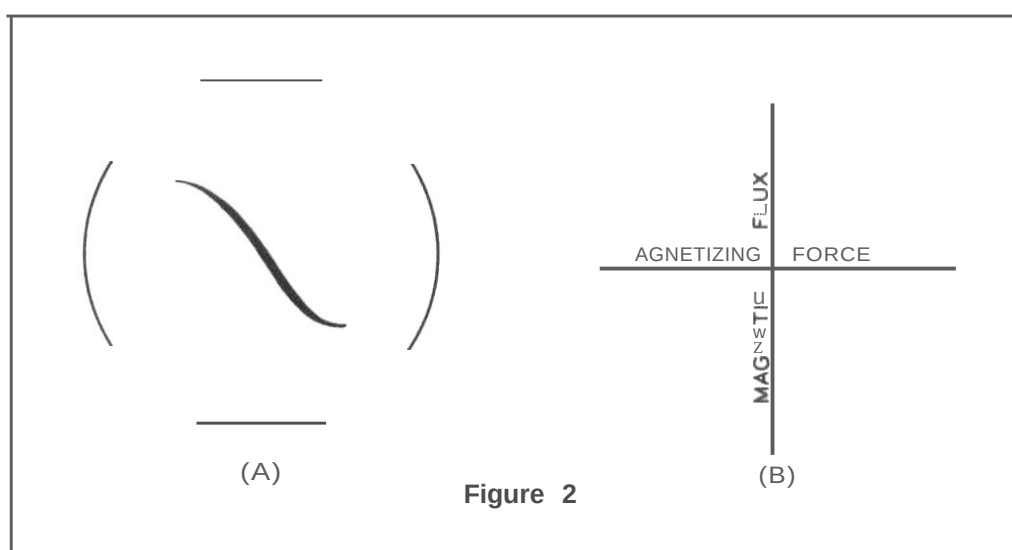
To obtain a B-H curve, two signals are required . . . one proportional to the magnetizing force applied to the sample, and another proportional to the number of lines of magnetic flux produced.

In Fig. 1, the voltage across R₁ is proportional to the current flowing in the transformer primary, and hence proportional to the magnetizing force. To obtain proper deflection, point A is connected to the HOR. INPUT terminal of your 'scope. Switch the selector to HOR. INPUT so that the internal sweep of the 'scope is disconnected.

The voltage across the secondary winding of the transformer is proportional to the turns ratio (between primary and secondary), the number of lines of magnetic flux produced, and the rate of change of the lines of flux. The turns ratio, in this case, is a constant value and so can be neglected. By using an integrating network consisting of R₂ and C₁, a voltage proportional primarily to the number of lines of flux is obtained. Thus, the signal appearing at point B is connected to the VERT. INPUT terminal of your 'scope.

When connecting the circuit shown, pay particular attention to the chassis ground connection. Since one side of the power line is connected to the chassis and to 'scope ground, **make** sure that the line plug is placed in the wall socket so that the chassis is at earth ground potential. **If** in doubt, check between the chassis and earth ground with an a.c. voltmeter, reversing the connections if necessary.

With the 'scope and the circuit in Fig. 1 turned "on", and with the controls of the 'scope properly adjusted, a typical "S" curve similar to the one shown in Fig. 2(a) should be obtained. (NOTE: Depending on which side of the 6.3 volt secondary winding is grounded, the "S" curve may "face" in the opposite direction). The exact shape of the curve will depend on the characteristics of the core material in the transformer, and on the settings of the HORIZONTAL and VERTICAL GAIN controls of your 'scope.



PRIMARY CURRENT IN A TRANSFORMER:

The circuit shown in Fig. 1 is also suitable for studying the primary current in a power transformer. The integrating circuit R_2-C_1 is disconnected and removed. Point A is connected to the VERT. INPUT terminal of the 'scope, and the internal linear sweep of the 'scope used.

The sweep controls are adjusted until two or three cycles appear on the screen of the 'scope.

When the transformer is unloaded, the primary current will appear as shown in Fig. 3(b). The primary voltage (sine-wave) is shown in Fig. 3(a) for comparison purposes. This

may be observed by transferring the lead to the VERT. INPUT terminal of the 'scope to observe the full line voltage (to the transformer side of the "ON-OFF" switch in Fig. 1). Readjustment of the VERTICAL GAIN control will be necessary.

The odd shape of the primary current curve is due to saturation of the transformer core on peaks. As the transformer core is saturated, the rate of change and the number of lines of magnetic flux are sharply reduced, with the instantaneous impedance of the primary winding dropping appreciably. Therefore, more current flows in the primary during the peaks, and a sharply peaked current is obtained.

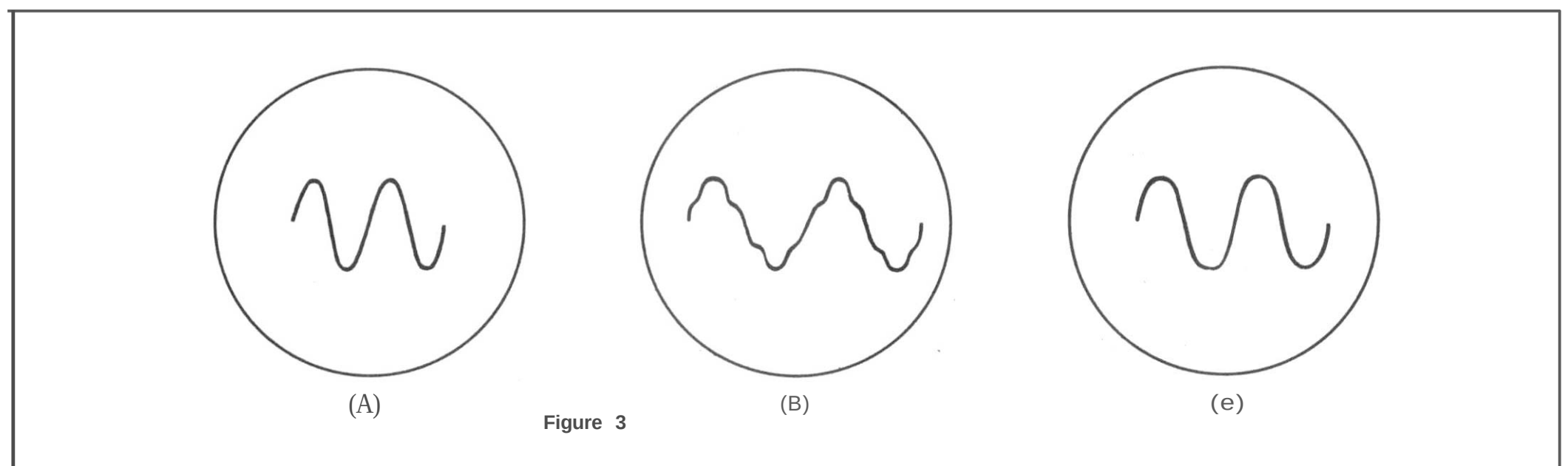
To show how the primary current changes under load, different sized load resistors may be connected across one of the secondary windings. Use 10 W. resistors and choose resistance values to permit light, normal, and heavy loading. Observe how the amplitude of the primary current increases as the secondary winding is loaded and how the wave-shape changes as loading is increased.

If the load resistor is connected across half the high-voltage secondary winding, a good resistance value to use for light loading is from 50,000 to 100,000 ohms. Progressively smaller values can be used to note the effect of additional loading. When the secondary is heavily loaded, the primary current will approach a sine-wave in shape, but will still be somewhat distorted (Fig. 3(c)).

The current flowing in the secondary winding sets up lines of magnetic flux which do two things: (a) tend to cancel the lines of flux set up by the primary current, reducing the effective impedance of the primary and permitting greater primary current flow; (b) reduces the tendency to core saturation, permitting the primary current to more nearly approach a sine-wave in shape.

SECONDARY VOLTAGE PHASE RELATIONSHIPS:

By using the EXT. SYNC provision on your 'scope, it is quite easy to prove that the voltages obtained from each end of a center-tapped secondary winding are 180° out of phase with each other. To do this, the transformer used in the preceding experiments may be employed. The connections are shown in Fig. 4.



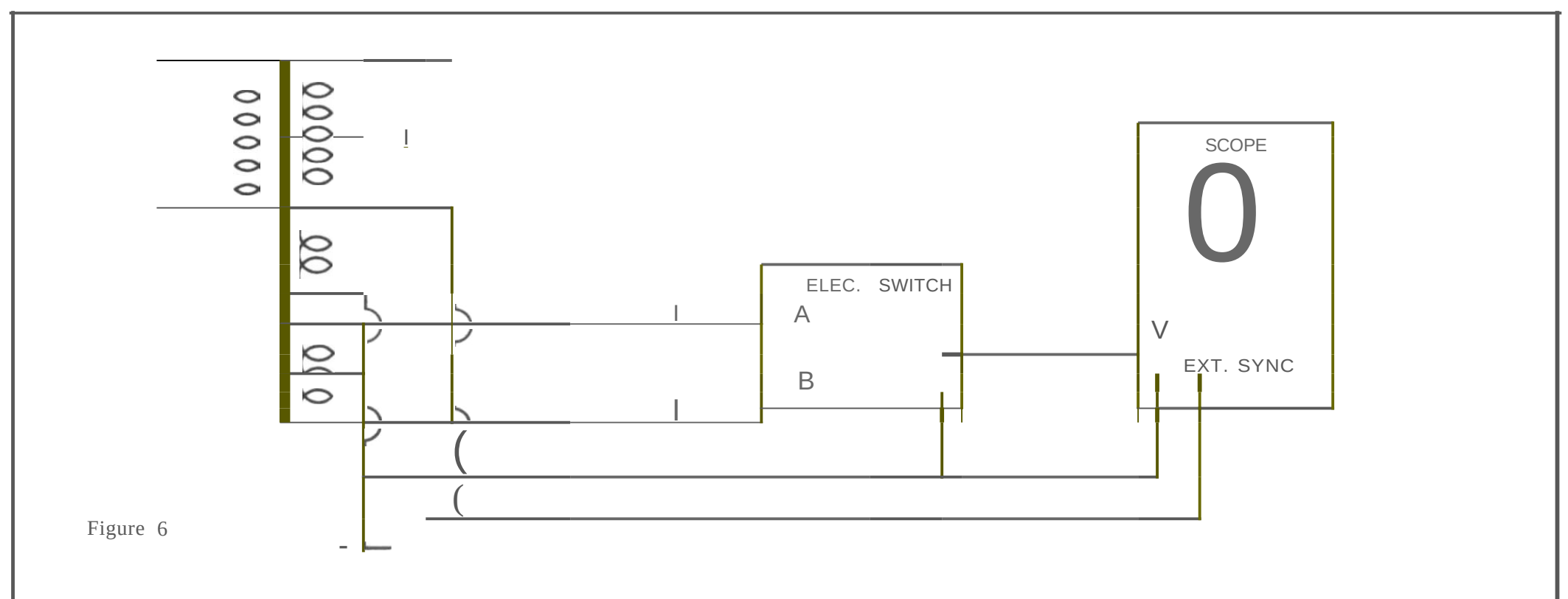
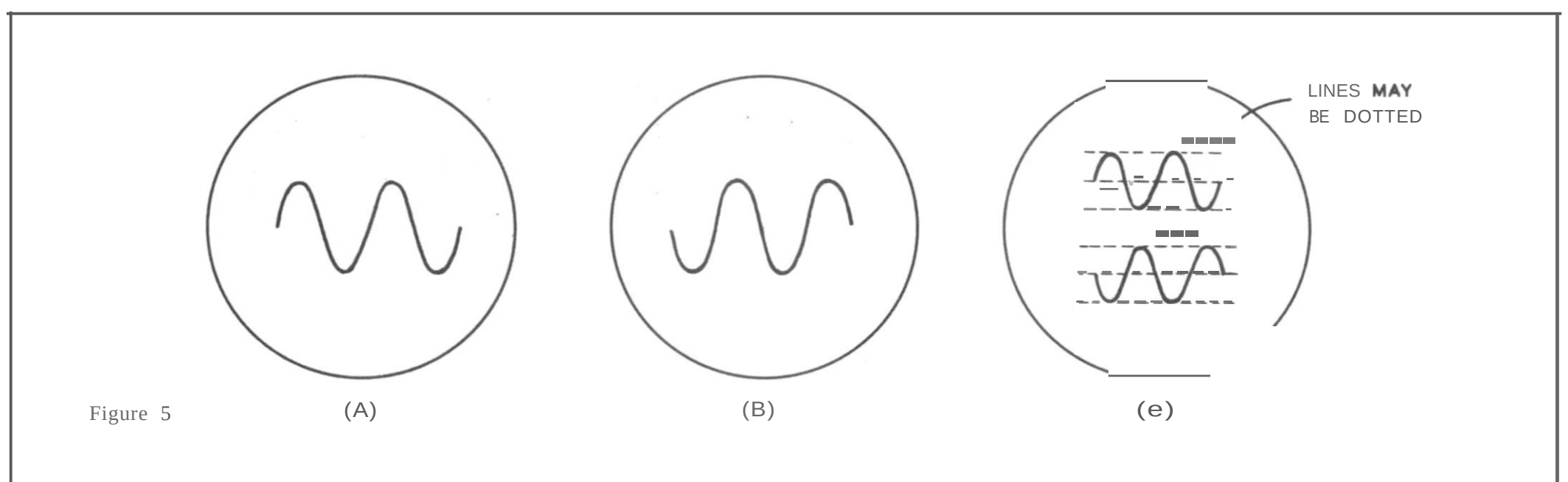
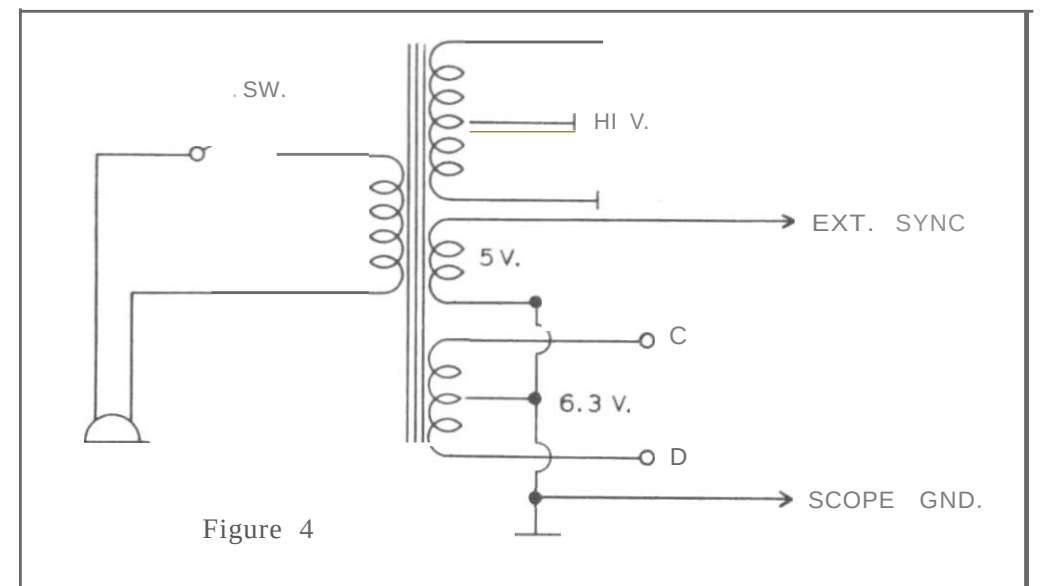
Use the internal sweep of the 'scope, but with external sync, obtained from the 5 volt winding of the power transformer. This provides a steady sync signal which remains 'unchanged regardless of the phase or polarity of the signal applied to the VERT. INPUT of the 'scope.

First observe the sine-wave signal appearing at point C (Fig. 4). Adjust the SWEEP and SYNC controls of the 'scope until two or three complete cycles can be observed. The signal may appear as shown in Fig. 5(a).

Now, *without touching the sync or sweep controls*, transfer the lead to the VERT. INPUT of the 'scope to point D (opposite side of the transformer winding). Note that a sine-wave is again observed, but that the phase relationship has been shifted by 180° .

If you have a Heathkit Electronic Switch available, both signals may be observed at the same time and the phase relationships become even more apparent. See Fig. 6 for block

diagram connections of the Electronic Switch. The general appearance of the two signals, observed simultaneously, is shown in Fig. 5(c).



study of differentiation and integration circuits with 'scope and square-wave generator

BY LOUIS E. GARNER, JR.

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Simple R-C circuits are used for interstage coupling, in high-pass and low-pass filters, and to form differentiation and integration circuits and are used in almost every type of electronic equipment. From this, we can see that a familiarity with R-C circuits is important not only to understanding complex equipment, but also helpful to rapid servicing, whether the equipment is a simple two-tube phonograph or a thirty tube television receiver.

The Heathkit Square-Wave Generator and the Heathkit Oscilloscope may be used to good advantage to study the action of simple R-C circuits. The Heathkit Electronic Switch will also prove useful for certain experiments. In addition to test equipment, clip leads or wire will be needed for connecting the various circuits, and an assortment of small components will be required, as follows: (2) .1 mfd condensers, a .01 mfd condenser, a .001 mfd condenser, a 10 Hy, 40 ma filter choke, and $\frac{1}{2}$ w. resistors having the following values ... 100, 500, 1K, 5K, 10K, 100K, 500K, 1 Megohm (nearest RTMA values will be satisfactory).

R-C DIFFERENTIATION CIRCUITS

The series R-C circuit shown in Fig. 1 may be used either as an interstage coupling network, as a high-pass filter, or as a differentiation circuit, depending on the time constant (product of C in mfd and R in megohms). Where the time constant is large compared to the time for one cycle of applied signals, the circuit is satisfactory for coupling purposes. Where the time constant is large compared to most applied signals, but much smaller for lower frequency signals, the circuit may

be considered a high-pass filter. Finally, where the time constant is small compared to the duration of one cycle of applied signals, we have a differentiation circuit.

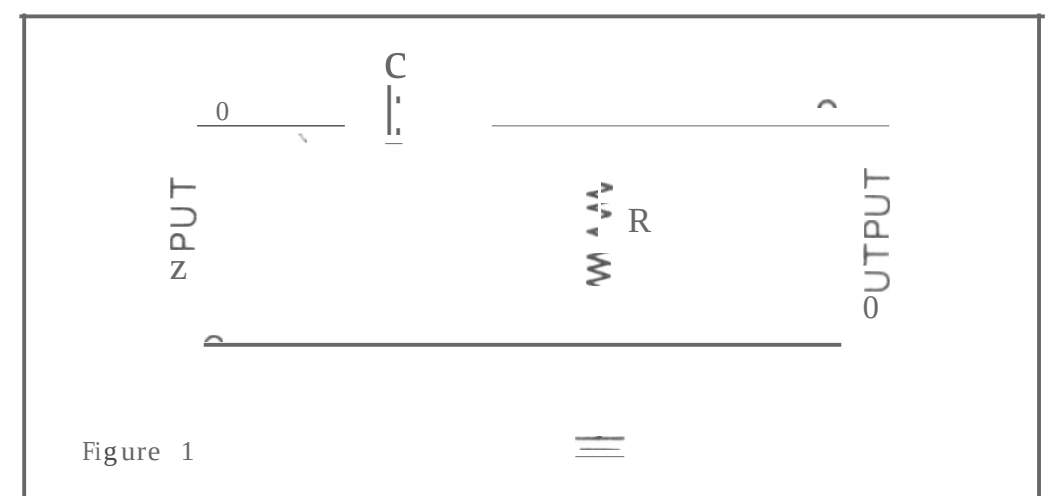


Figure 1

To see how the time constant of the R-C network will affect a square-wave signal, use your Square-Wave Generator to apply a 50 cps signal to the input of the circuit shown in Fig. 1 (.1 mfd for C, and 1 megohm for R). Connect your Oscilloscope to observe the Output signal.

With a 1 megohm resistor for R, there will be little or no distortion of the square-wave signal, although there may be a slight slant to the flat tops, as shown in Fig. 2(a). Now, try progressively smaller resistor values for R (thus changing the time constant of the circuit). Use values of 500K, 100K, 50K, 10K, 5K, 1K, 500 and 100 ohms. As the time constant is reduced, the flat tops of the output signal become more slanted, as shown in Fig. 2(b), and finally become pulsed (Fig. 2(c)). The signal amplitude will also be reduced as R is changed to very small values.

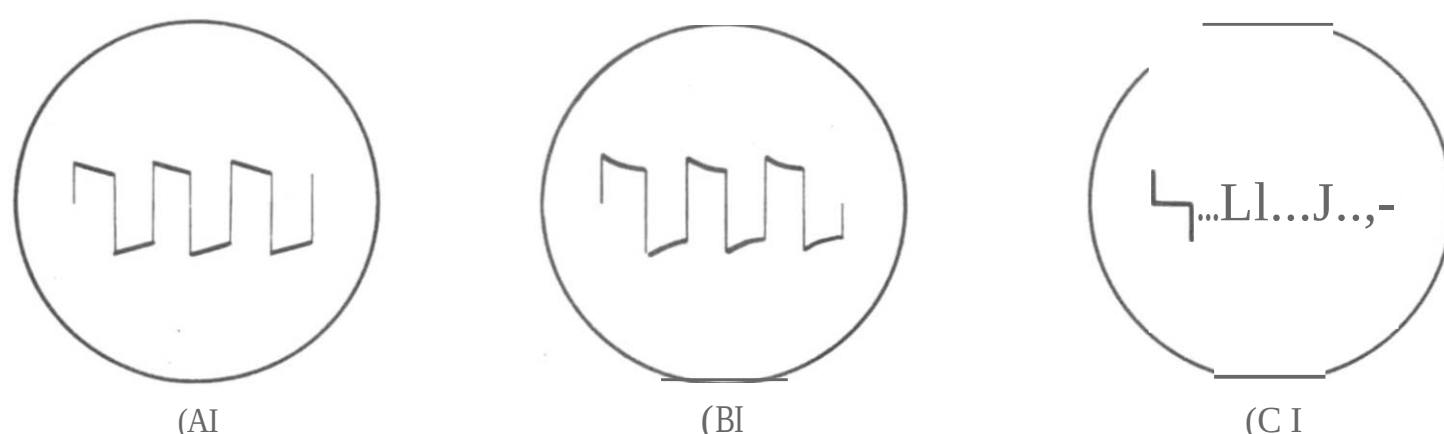
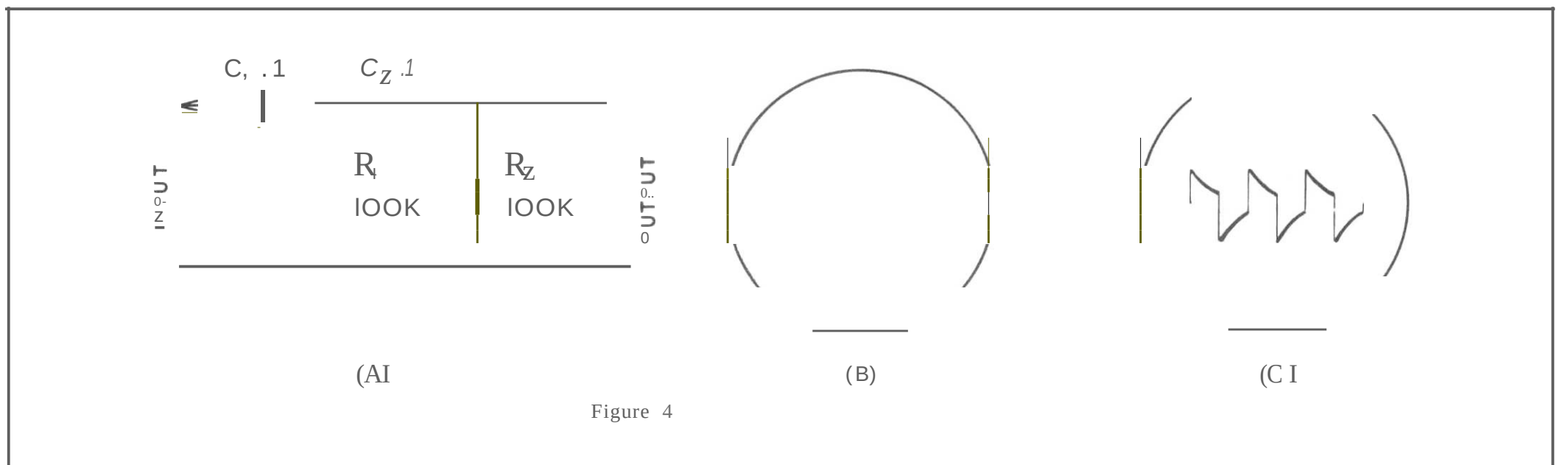
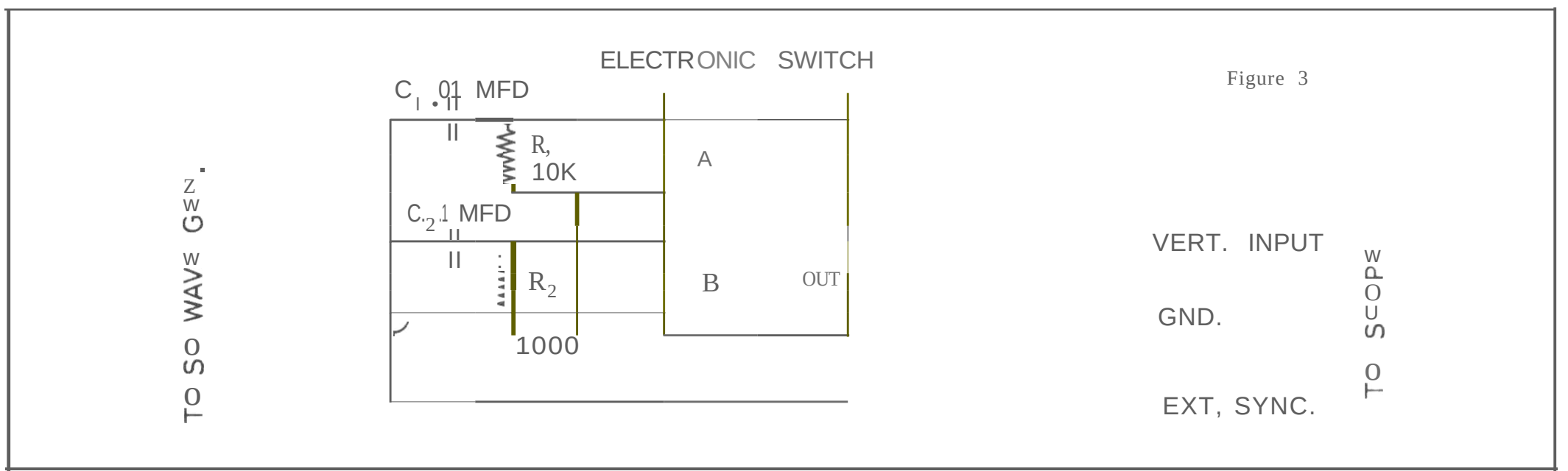


Figure 2



The Electronic Switch may be used in conjunction with the Square-Wave Generator and the Oscilloscope to prove that the R-C time constant and not the individual values of R and C is the important factor in this circuit. To do this, networks having the same time constant, but different values of R and C, are connected to the output of the Square-Wave Generator, with the Electronic Switch permitting both signals to be observed simultaneously on the scope. Use the circuit shown in Fig. 3. Note that the two output signals may be made to overlap perfectly, giving ample proof that both R-C circuits affect the square-wave signal in the same fashion.

To show that the output wave-shape depends on *both* the R-C time constant and the repetition rate (frequency) of the applied signal, use a .01 mfd condenser for C (Fig. 1) and a 100K resistor for R, observing the output wave-shape for a 50 cps signal. Raise the frequency to 500 cps and observe the difference in pattern. Finally, change the time constant of the R-C circuit by the same ratio that the frequency of the applied signal has been changed by substituting a .001 mfd for the .01 mfd condenser. Note that the pattern now obtained with the 500 cps signal is essentially the same as that previously obtained with a 50 cps signal, and with the circuit time constant ten times larger.

CASCADED DIFFERENTIATION

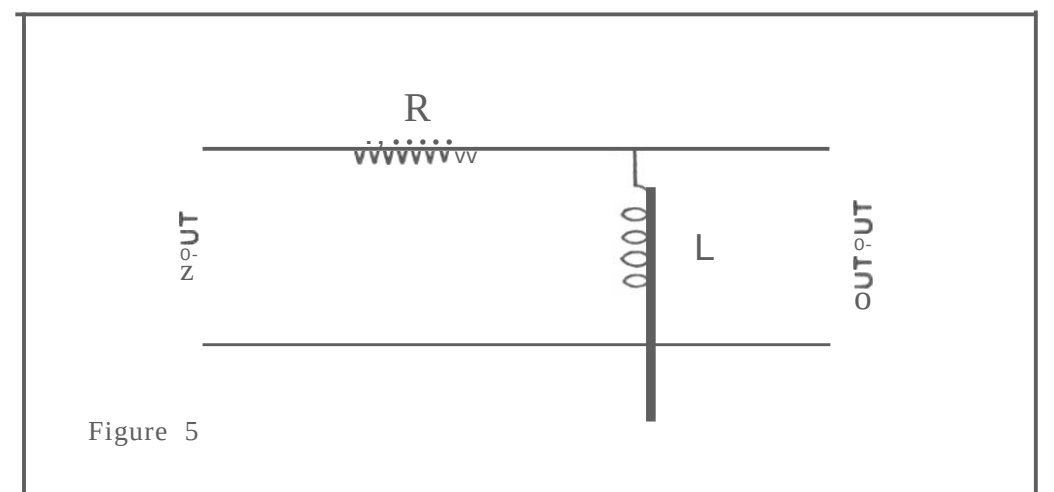
Often, two simple R-C circuits such as we have just studied will be connected in cascade to provide better action. Such a circuit is shown in Fig. 4(a). To observe the effect of cascaded R-C circuits, connect the Square-Wave Generator and adjust for a 50 cps signal. First observe the output signal for

a single stage (across R1). With the values shown, the pattern will appear somewhat as shown in Fig. 4(b). Now observe the output wave-shape with both R-C circuits in the network in Fig. 4 (c).

The use of cascaded circuits is not limited to only two stages. Sometimes three or more stages will be cascaded to obtain the desired operation.

R-L DIFFERENTIATION

A differentiation circuit may also be formed by using a resistor and coil in combination, as shown in Fig. 5. The experiments carried out with the simple R-C differentiation circuit may be repeated with the R-L circuit shown, using a small 10 Hy filter choke and the various sized resistance values previously suggested.



Typical patterns obtained with different resistor values are shown in Fig. 6. With a 100 ohm resistor, there is only a slight degree of tilt (or slant) given a 50 cps square-wave,

as shown in Fig. 6(a). The tilt becomes more pronounced and curved with R changed to $1K$ (Fig. 6(b)), and finally becomes pulsed as R is increased to higher values. With a $50K$ resistor, the wave-shape will be similar to that shown in Fig. 6(c).

R-C INTEGRATION CIRCUITS

The basic integration circuit is similar to the simple differentiation circuit previously shown in that a resistor and condenser in series are used to make up the circuit, but the Output signal is taken across the condenser rather than across the resistor, as shown in Fig. 7.

The operation of the integration circuit is essentially opposite to that of the differentiation circuit. However, the time constant of the circuit is still the important factor as far as the effect of the circuit on the amplitude and wave-shape of an applied signal is concerned.

As in the previous experiments a 50 cps square-wave may be used to study the action of the basic circuit. Again, use a .1 mfd condenser for C and try values of R from 100 ohms to 1 megohm.

The patterns obtained with R having values of 100 ohms, $10K$, and 1 megohm are shown in Figs. 8(a), 8(b), and 8(c) respectively. With a 1 megohm resistor, the amplitude of the output signal drops appreciably, and becomes an almost perfect triangular wave.

CASCADE!) INTEGRATION CIRCUITS

As in the case of the differentiation circuits, it is possible to use two or more basic integration circuits in cascade to obtain a better degree of integration. With the circuit shown in Fig. 9(a), the output patterns of a 50 cps square-wave for single and dual stage integration are given in Figs. 9(b) and 9(c).

R-L INTEGRATION

An R-L circuit may also be used for integration, as shown in Fig. 10. To observe the action of this circuit, the experiments previously carried out may be repeated, again using a number of different resistor values for R . The 10 Hy choke used in the R-L differentiation circuit will be suitable for use in the integration circuit.

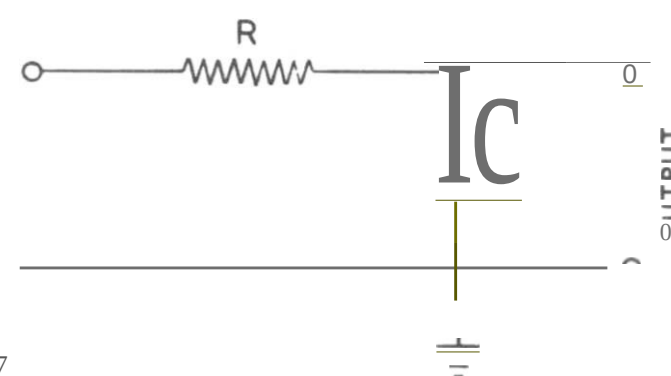
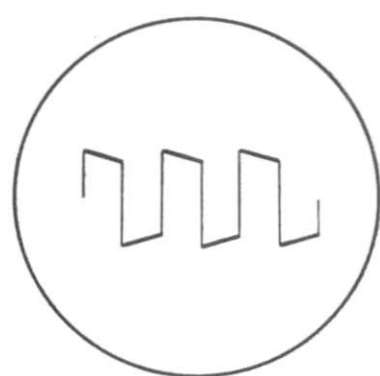
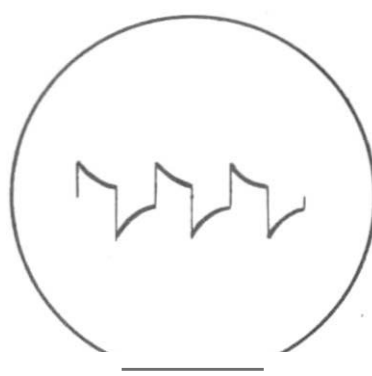


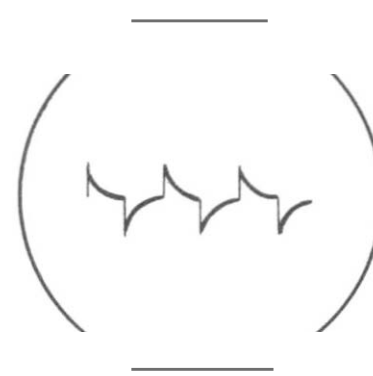
Figure 7



(A)

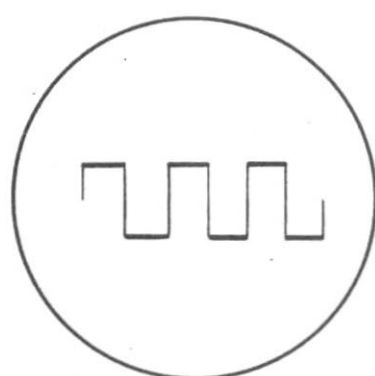


(B)



(C)

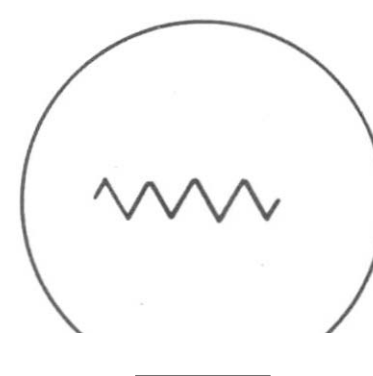
Figure 6



(A)

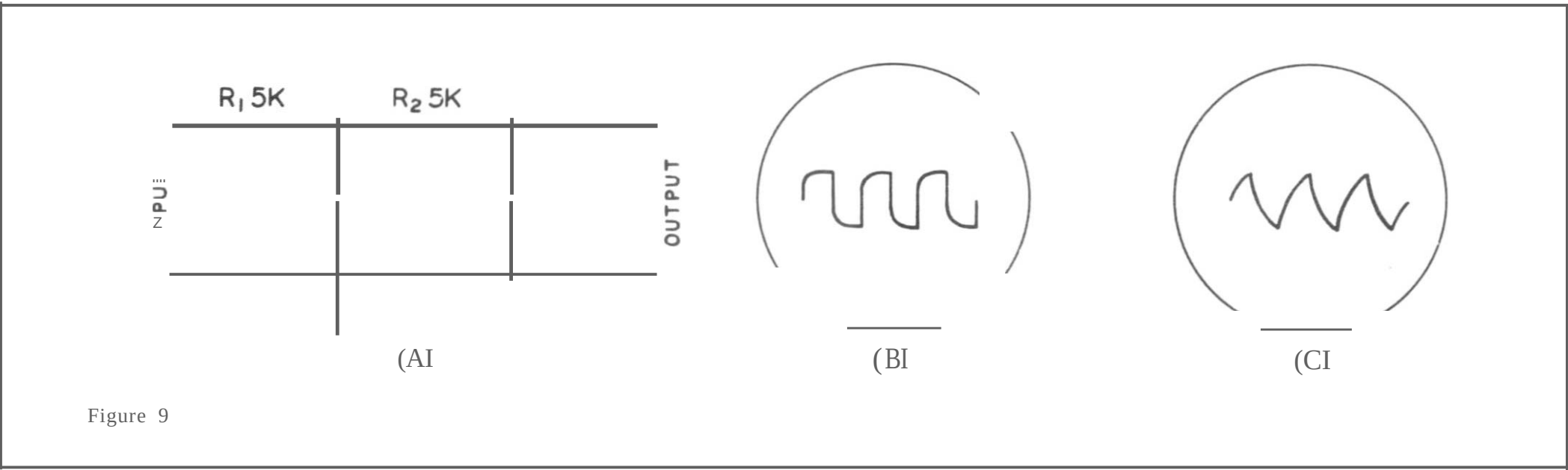


(B)



(C)

Figure 8

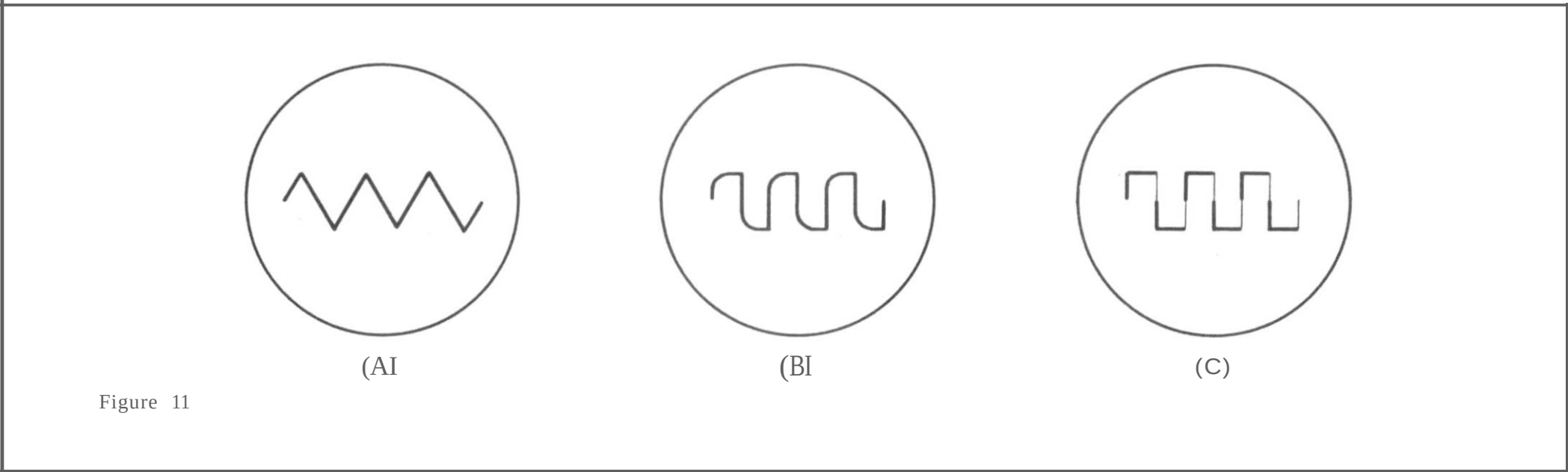
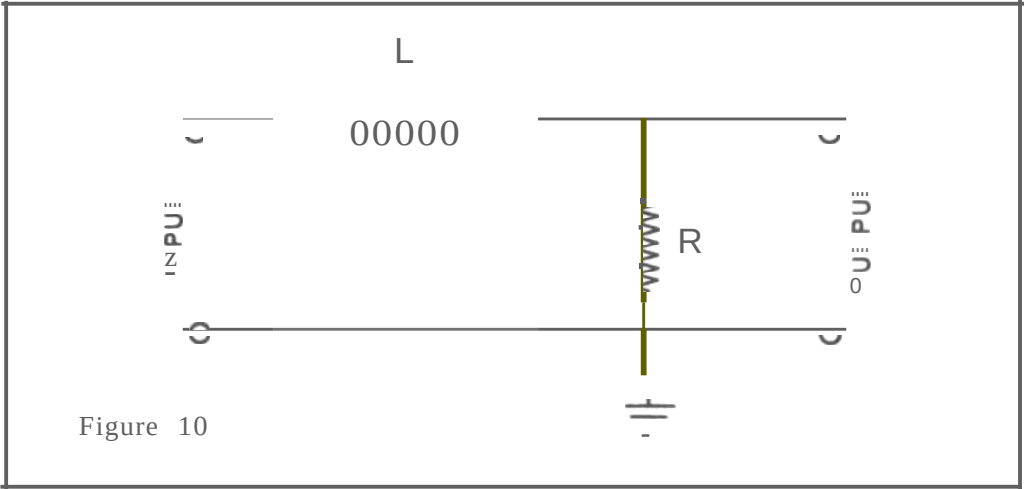


The pattern obtained with R at 100 ohms will be similar to that shown in Fig. 11(a). As R is increased to 10 K, the pattern will approach that given in Fig. 11 (b). Finally, as R is increased to 100K, the output **again** approaches a square-wave in shape, as shown in Fig. 11 (c).

FURTHER EXPERIMENTS

The values suggested for L and C in the experiments given were purposely chosen as easily available, and suitable to demonstrate the action of the circuits using a 50 cps square-wave. Further experiments may be carried Out by using different values of L and C as well as changing R . Different square-

wave signals may be applied and the results observed.



studying power rectifier and filter circuits with the heathkit oscilloscope

BY LOUIS E. GARNER, JR.

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In a previous bulletin we discussed the use of your Heathkit Oscilloscope in studying basic transformer action and in obtaining a B-H curve. We will now see how the Oscilloscope may be used to study the action of half-wave and full-wave rectifiers and choke and condenser input filters. We will see, too, that there are defects which may cause 60 cycle hum to be present in the Output of a full-wave rectifier circuit (even though only 120 cycle ripple would normally be expected).

The small receiver power transformer used in the previous experiments will be satisfactory for the experiments in this bulletin. In addition, you will need a 47 ohm, $\frac{1}{2}$ W. resistor, two 1,000 ohm, $\frac{1}{2}$ W. resistors, a 5,000 ohm, 2 W. resistor, a 15,000 ohm, 2 W. resistor, a 50,000 ohm, 2 W. resistor, a .5 mfd, 400 volt condenser, a 10-10 mfd, 450 volt electrolytic condenser, a 10 Hy, 40 ma choke, a standard rectifier tube (5Y3, 5Y4, 80, 5U4, etc.) with socket to match, and an assortment of paper by-pass condensers.

BASIC RECTIFIER ACTION:

The circuit shown in Fig. 1 is satisfactory for studying the basic action of half-wave and full-wave rectifiers. Later, filter circuits may be added and their effect on ripple wave-shapes observed.

First, use the set-up as a half-wave rectifier by disconnecting one plate lead of the rectifier tube (open the circuit at point A). The ripple wave-shape obtained is observed by connecting point B to the VERT. INPUT terminal of the 'scope, with the 'scope GND to circuit ground. The signal should have a wave-shape similar to the one shown in Fig. 2 (a).

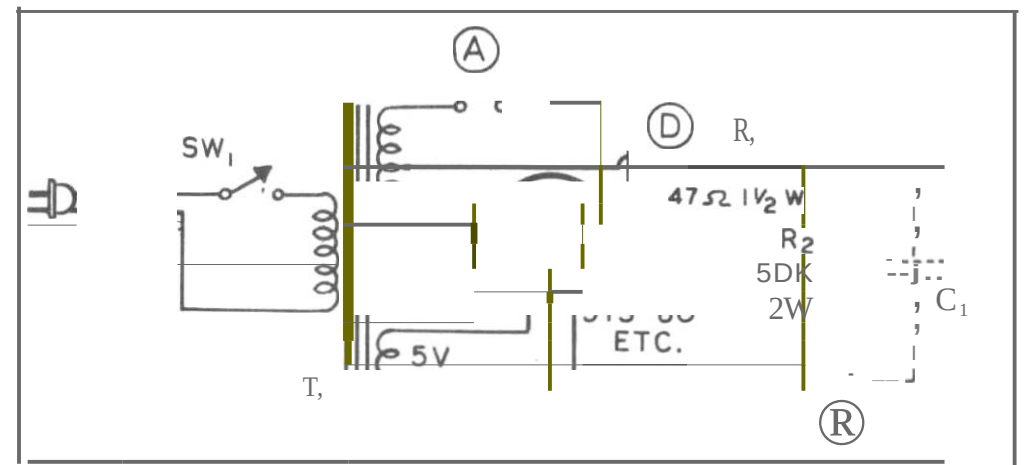
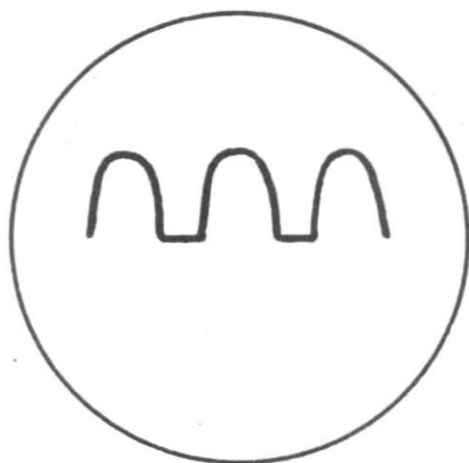


Figure 1

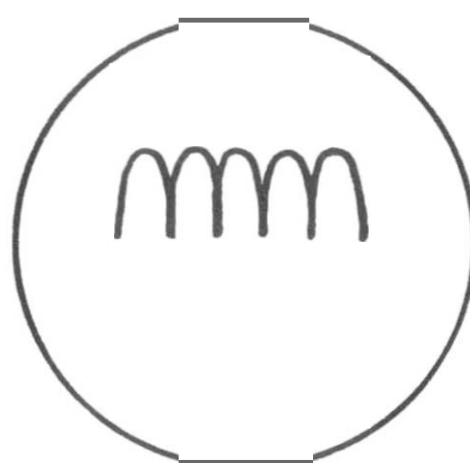
The circuit may now be converted to full-wave rectification by closing the lead at point A. In Fig. 2 (b) is shown the typical pattern obtained with full-wave rectification.

Servicemen sometimes encounter sets using a full-wave rectifier which seems to be in good condition, but in which a low frequency (60 cycle) hum is present. The hum is often difficult to "track down" as power supply ripple in sets using full-wave rectification is normally at 120 cycles. However, an unbalance in the rectification on each "half" of the sine-wave cycle will superimpose a 60 cycle modulation on the 120 cycle ripple signal. Since the filter circuit is designed primarily to remove 120 cycle ripple, the 60 cycle hum can easily "sneak through" and cause considerable trouble in the equipment.

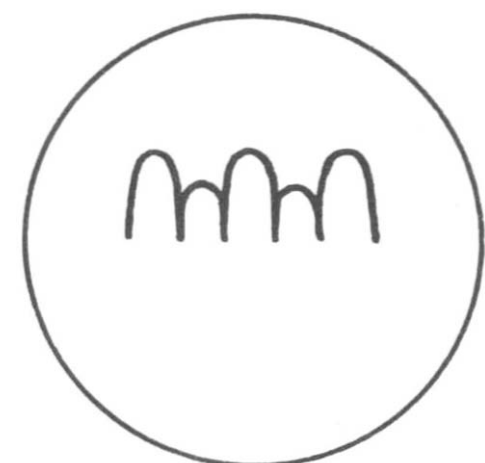
Unbalanced rectification may be caused by such common defects as a defective power transformer or a full-wave rectifier in which one-half of the tube is "weak".



(A)

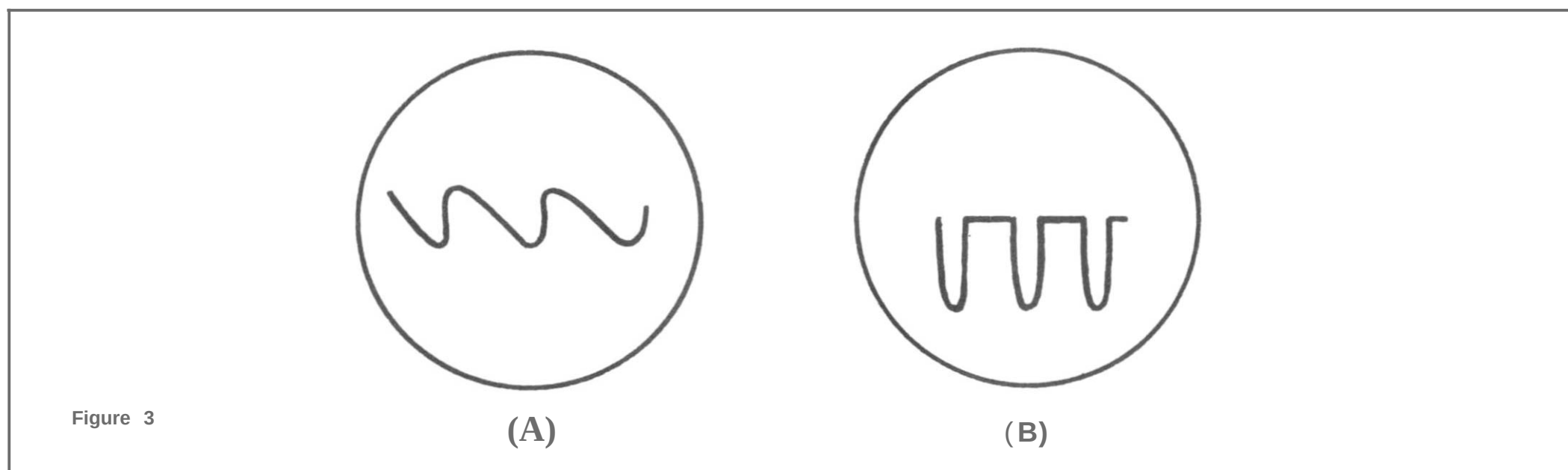


(B)



(C)

Figure 2



To demonstrate the effect of unbalanced rectification, connect a 15,000 ohm, 2 W. resistor in series with one of the plate leads (open point A, Fig. 1, and connect the resistor in series here). Again observe the output wave-shape (Fig. 2 (c)). Note that every other "half-cycle" is higher than the other due to unbalanced rectification.

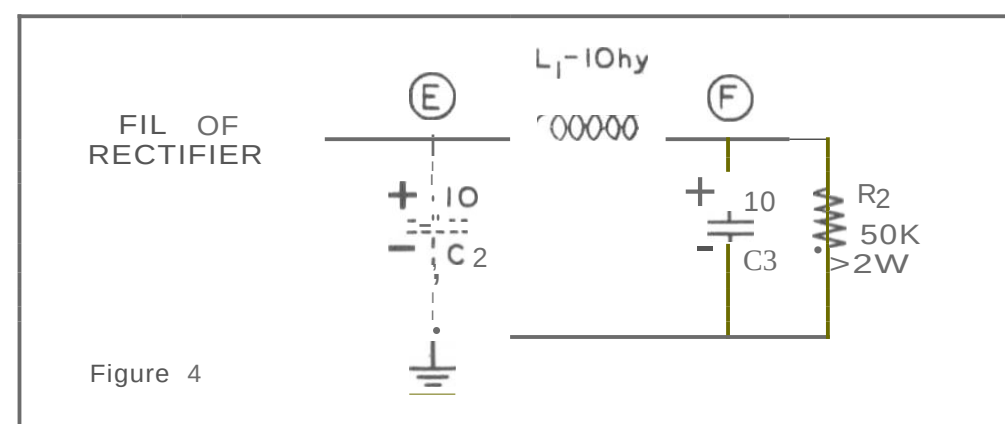
The effect of a condenser across the load resistor may be observed by adding a .5 mfd, 400 volt condenser across R_2 (Fig. 1). The amplitude of the ripple signal observed at point B drops considerably, and approaches a saw-tooth in shape. See Fig. 3 (a).

When a condenser forms part of the rectifier load, the condenser charges on voltage peaks and discharges slowly through the load resistor. From this, we would expect the *current* wave-shape through the composite load (condenser and resistor) to be a fairly narrow pulse.

As you may recall, the 'scope may be used to observe *current* wave-shapes by connecting a small resistor in series with the circuit and observing the voltage appearing across the resistor. Therefore, to observe the 'peaked charging current of the condenser, it is only necessary to transfer the VERT. INPUT lead of the 'scope to point D (Fig. 1). The signal obtained is shown in Fig. 3 (b).

CHOKE INPUT FILTERS:

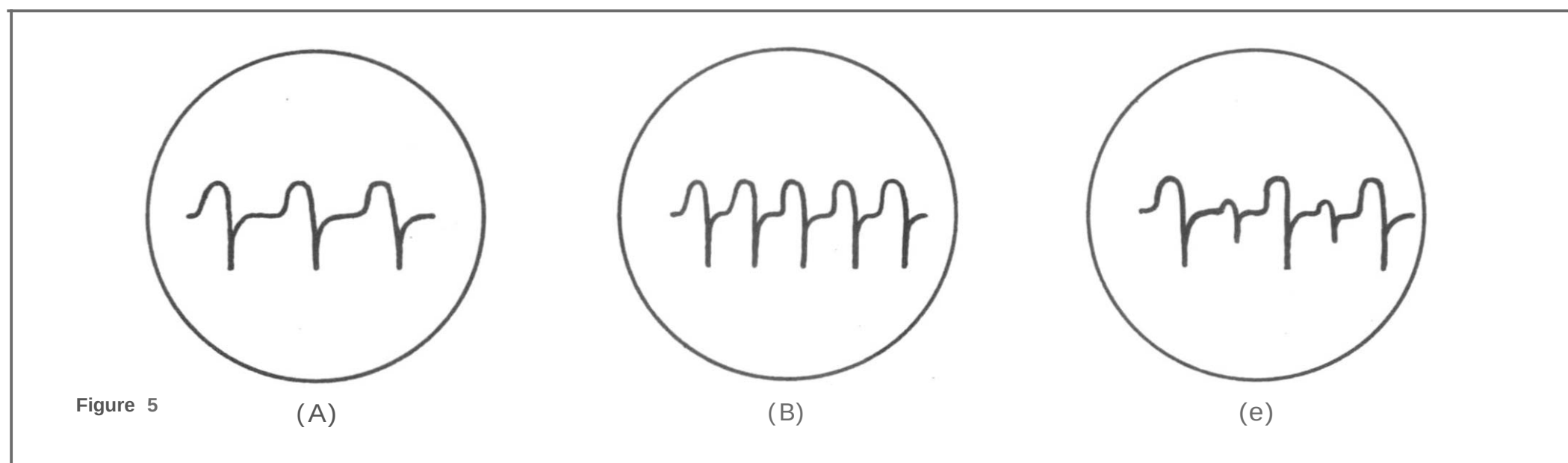
The basic choke input filter circuit shown in Fig. 4 may be used to study filter action. Note that R_2 has been transferred to the output of the filter to act as a load.



The ripple wave-shape should be observed both at the input (point E) and at the output (point F) of the filter circuit. Both full-wave and half-wave rectification may be used. With half-wave rectification, the wave-shape at point E will appear approximately as shown in Fig. 5 (a). The pattern obtained with full-wave rectification is similar except for the amplitude and the number of cycles obtained Fig. 5 (b). Unbalanced rectification will give the pattern shown in Fig. 5 (c). (NOTE: Introduce unbalance by using the 15,000 ohm, 2 W. resistor in series with one plate lead, as described previously.)

Transferring the VERT. INPUT lead of the 'scope to point F (Fig. 4) permits the Output ripple signal to be observed. The pattern will be similar to that shown in Fig. 6 (a) ... conditions are half-wave rectification, choke input.

A 5,000 ohm, 2 W. resistor may be substituted for the 10 Hy choke shown in Fig. 4, and the ripple patterns obtained with an R-C filter seen.



To obtain the maximum benefit from these experiments, you will find it worthwhile to check the relative amplitudes of the ripple signals as the components in the filter circuit are varied in size. In addition, the d.c. output voltage should be checked. Finally, different sized load resistors may be used in place of R_L and the effect of both ripple amplitude and wave-shape observed.

CONDENSER INPUT FILTER:

Another filter condenser may be added to the circuit shown in Fig. 4 (C_2) and the action of a condenser input filter studied. Again, the wave-shape of the ripple signal at both the input (point E) and the output (point F) should be observed. In Fig. 6 (b) is shown the approximate wave-shape of the ripple signal at the input to the filter with full-wave rectification, while the output ripple wave-shape, under similar conditions, is shown in Fig. 6 (c). Note that the signal is more rounded and of considerably lower amplitude.

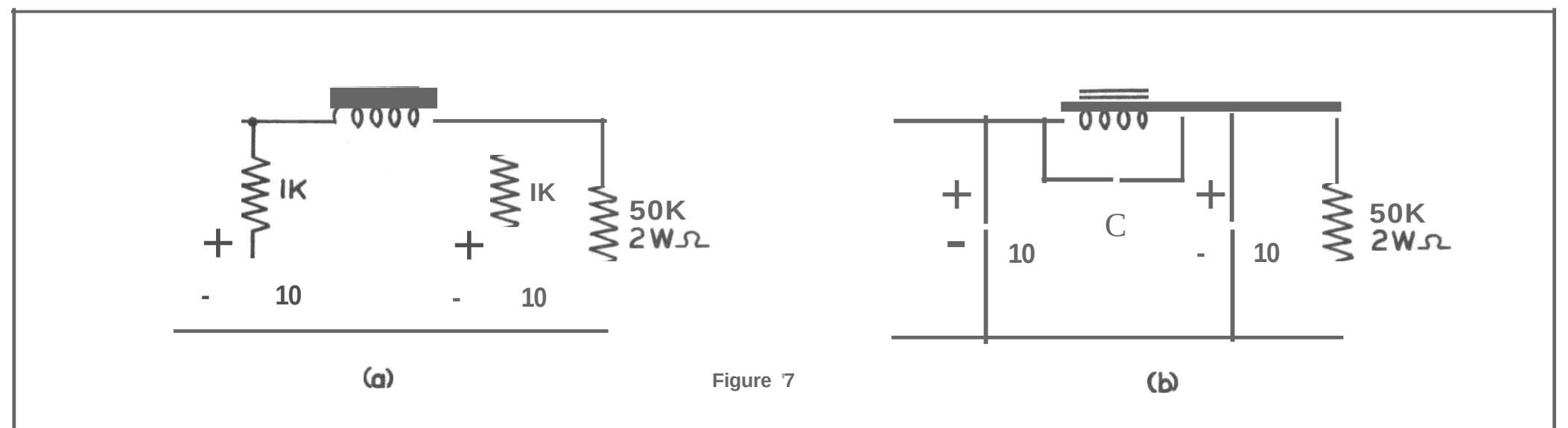
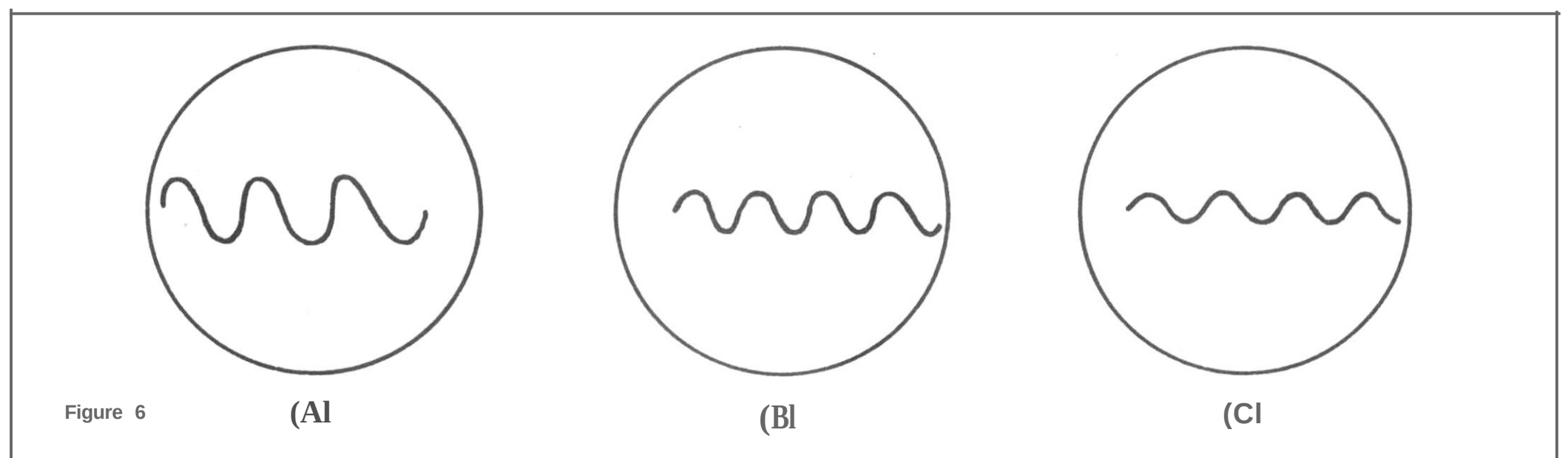
ADDITIONAL EXPERIMENTS:

To demonstrate the effect of condenser power factor on ripple, small resistors (1,000 ohm, $\frac{1}{2}$ W.) may be connected

in series with each condenser in the filter circuit and the ripple wave-shapes again observed. The connections are shown in Fig. 7 (a).

Older radio receivers often used a tuned filter circuit to obtain the maximum reduction in ripple. The operation of such a circuit may be studied by shunting different sized paper condensers across the filter choke, using the circuit shown in Fig. 7 (b). Use values from .05 mfd to .5 mfd, changing by .05 mfd each time. In this way the change in ripple amplitude as resonance is approached may be more easily observed.

The experiments listed have undoubtedly suggested many additional experiments to the reader. For example, the basic techniques of using the 'scope outlined above may also be used for studying the operation of bridge rectifier circuits, two-section filters, and combination R-C and L-C filters. The ripple patterns encountered in voltage-doubler and tripler circuits may also be studied to advantage.



phase shift and frequency measurement with the heathkit oscilloscope

BY LOUIS E. GARNER, JR.

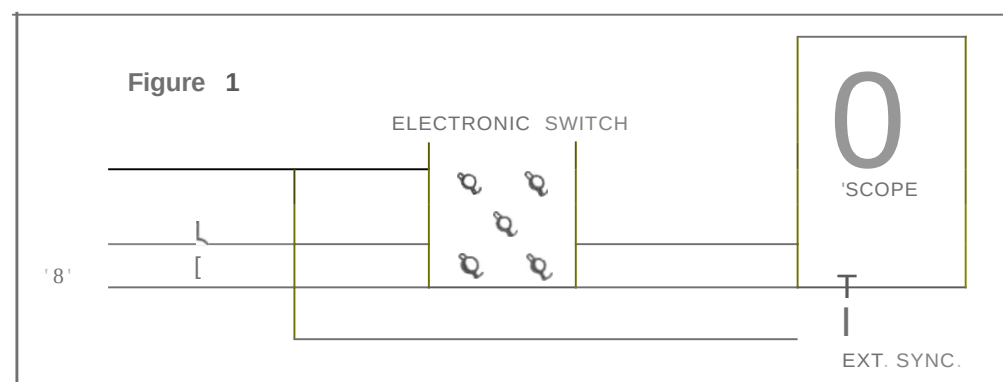
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In another "Application Notes" bulletin we discussed two frequency measuring techniques suitable for use with the Oscilloscope . . . "completed-loop" and "uncompleted-loop" Lissajou figures. In this bulletin we will discuss still a third frequency measuring technique, especially useful where the ratio between the known and unknown signals is large. We will also discuss methods for determining the phase difference between two sine-wave signals at the same frequency.

As we shall see, a special phase-shifting network is utilized in the frequency measuring technique to be described. Therefore, the techniques for measuring phase-shift will be discussed first.

MEASURING PHASE-SHIFT WITH AN ELECTRONIC SWITCH:

If an Electronic Switch is available, two Sine-wave signals may be directly compared for phase shift, using the circuit shown in Fig. 1. When the Electronic Switch and 'scope controls are properly adjusted, the pattern should appear somewhat as shown in Fig. 2.



The phase difference between the signals applied to the "A" and "B" inputs of the Electronic Switch may be approximated by comparison of the signal peaks on the 'scope image. The phase difference is approximated by the relative positions of the peaks, taking the spacing for an entire cycle across the screen of the 'scope into account, and remembering that there are 360° in a complete sine-wave cycle.

Thus, if the distance between peaks (A-B, Fig. 2) is one-tenth the distance for a complete sine-wave cycle, the phase difference between the two signals is $1/10$ of 360° or 36° .

Although this technique is valuable for approximating phase differences, it is not too good for determining small phase differences because of the difficulty in accurately measuring the distance between sine-wave peaks.

However, this technique is quite valuable for study, for experimentation, and for student demonstration. For those experimenters having the Heathkit Electronic Switch available, the technique may be easily demonstrated by using the phase-shifting network shown in Fig. 3. The 60 cy. test signal may be obtained from the 60 CY. TEST terminal of the 'scope.

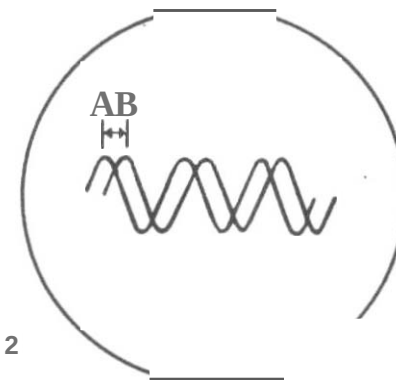


Figure 2

MEASURING PHASE-SHIFT WITH THE ELLIPSE METHOD:

When sine-wave signals having the same frequency and in-phase are simultaneously applied to the horizontal and vertical inputs of an oscilloscope, the resultant pattern is a diagonal slanting line, as shown in Fig. 4 (a). This may be demonstrated on your Heathkit Oscilloscope by switching the SWEEP SELECTOR to HOR. INPUT and connecting the 60 CY. TEST terminal to both the HOR. and VERT. INPUT terminals. If the two signals are exactly 180° out-of-phase, a diagonal slanting line is still obtained, but the slant is in the opposite direction (Fig. 4 (b)).

A phase difference of exactly 90° will result in an almost perfect circle (Fig. 4 (c)) provided the HOR. and VERT. GAIN controls are adjusted for equal deflection. If there is more gain vertically, the circle will become a vertically elongated ellipse. More gain horizontally will result in a horizontally elongated ellipse.

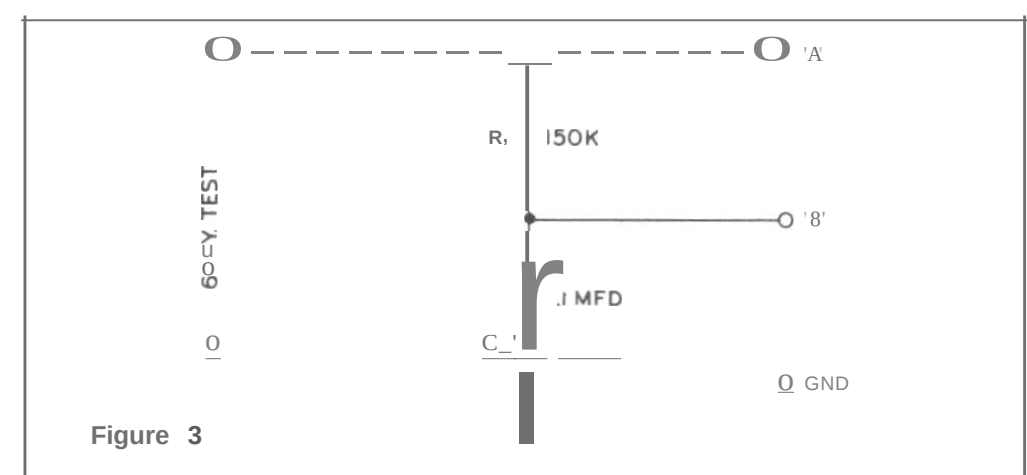
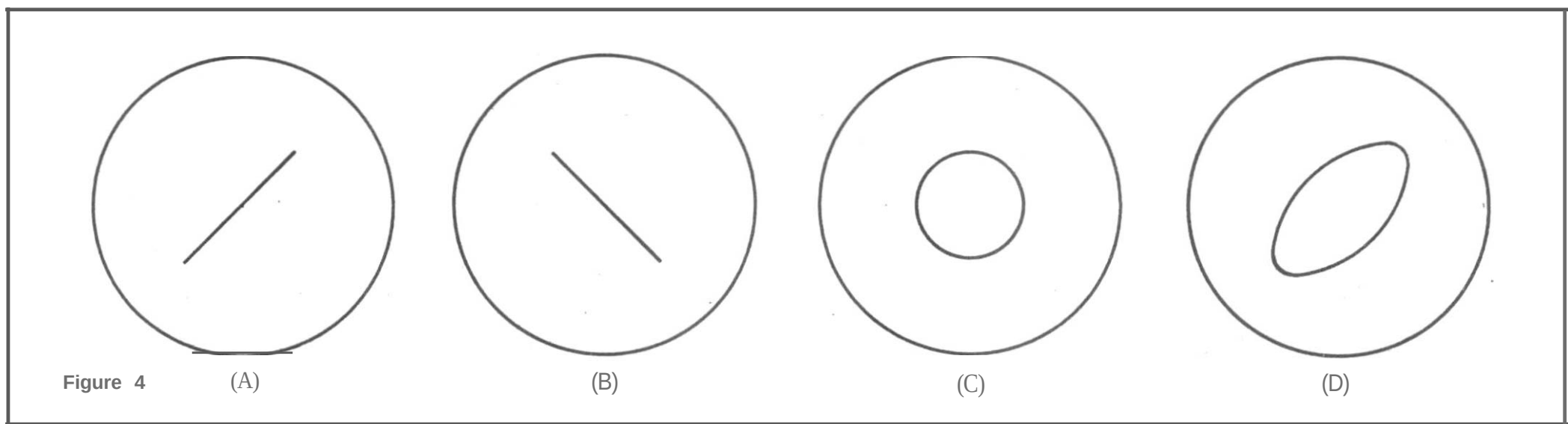
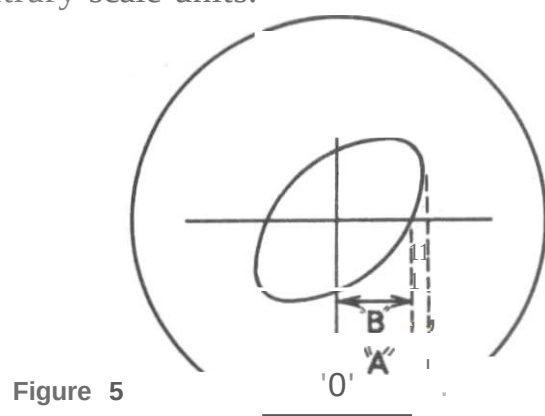


Figure 3



A phase difference of less than 90° will result in an ellipse, the long axis of which is at an angle, as shown in Fig. 4 (d). The ellipse will slant in the opposite direction *if* the phase difference is between 90° and 180° .

It is possible to determine the phase difference between the two sine-wave signals making up an ellipse by using a simple mathematical relationship. Referring to Fig. 5, the ellipse is first centered on the 'scope graph screen, using the centering controls. The distance from "0" to where the ellipse intercepts the horizontal axis is measured ("b" in Fig. 5). This measurement may be in fractions of an inch, in cm, or in any arbitrary scale units.

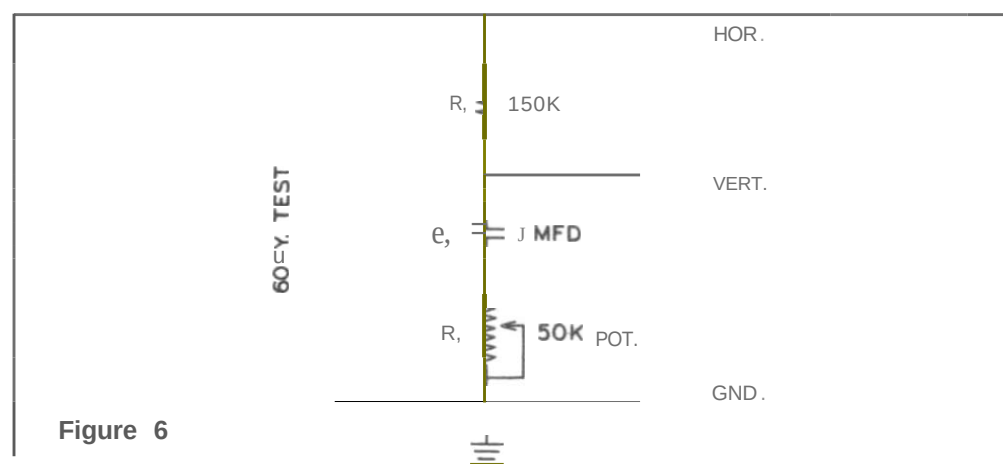


Next, the distance to a tangent to the maximum horizontal point on the ellipse is measured in the same units as before ("a" in Fig. 5). Finally, the ratio of "b" to "a" gives the sine of the phase angle. In other words:

$$b/a = \sin \theta, \text{ where } \theta \text{ is the phase angle.}$$

In Table A is given the sine (to three decimal places) for angles from 0° to 90° , taken 5° at a time. For a more complete table, refer to any standard handbook or set of mathematical tables.

SIN θ	θ	SIN θ	θ	SIN θ	θ	SIN θ	θ	SIN θ	θ
0.000	0°	.342	20°	.643	40°	.866	60°	.985	80°
.087	5	.423	25	.707	45	.906	65	.996	85
.174	10	.500	30	.766	50	.940	70	1.000	90
.259	15	.574	35	.819	55	.966	75		

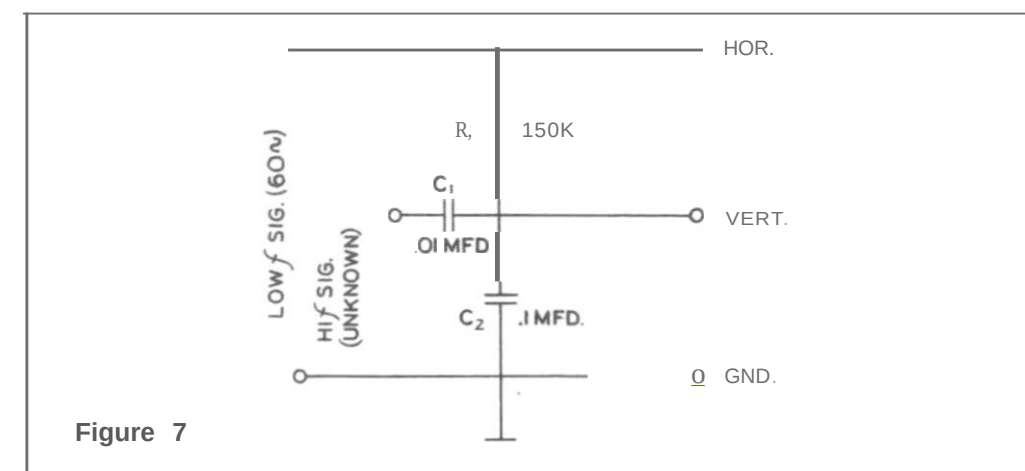


The formation of an ellipse may be demonstrated by using the circuit shown in Fig. 6. As the 50K pot. is adjusted, the shape of the ellipse will vary, demonstrating that the shape depends on the relative phase difference between signals fed to the horizontal and vertical inputs of the 'scope. (NOTE; There will be a change in vertical amplitude as well as a change in the shape of the ellipse as the pot. is adjusted... readjustment of the VERT. GAIN control will correct for this, and still permit the changes in the pattern to be easily observed.)

Of the two methods for measuring phase shift, the first (using an Electronic Switch) is generally used for demonstration purposes, and the second (the ellipse method) for practical laboratory work. As experience is gained in using the second method, many technicians acquire the ability to estimate the phase difference from the general shape of the ellipse, without taking time to actually measure "a" and "b", or to perform the necessary calculations.

ANOTHER FREQUENCY MEASURING TECHNIQUE:

As we have seen, an almost perfect circle may be formed on the screen of an oscilloscope by applying sine-wave signals having a 90° phase difference to the horizontal and vertical inputs. This fact may be used to advantage to form a circular time base for comparing the frequencies of a known and an unknown signal.



The known signal is applied to a simple R-C phase shifting network to obtain signals which are 90° out-of-phase. These signals are applied to the horizontal and vertical inputs of the 'scope to form a circular pattern. The unknown signal is then applied to one input along with the known signal. The resultant is a gear-toothed pattern, with the number of "teeth" on the pattern giving the ratio between the known and unknown signals.

For demonstration purposes, the circuit shown in Fig. 7 may be used. R1 and C2 form a phase-shifting network for the

known low frequency signal. Connections to the oscilloscope are as shown.

The unknown high frequency signal is applied to the VERT. INPUT of the oscilloscope along with the "phase-shifted" low frequency signal. Condenser C_1 permits application of the high frequency unknown signal, yet offers sufficient impedance to the low frequency signal to prevent interaction between circuits. As far as the high frequency signals are concerned, C_1 and C_2 form a simple capacitive voltage divider. (For best results, the amplitude of the high frequency signal should be low compared to the signal used to form the circular time base.)

With the component values given, a 60 cy. signal (obtained from the TEST terminal of the 'scope) may be used as the low frequency signal to form the circular time base. A high frequency signal may be obtained from the Heathkit Sine-Wave Generator.

The pattern formed will appear somewhat similar to the one shown in Fig. 8, with the number of "teeth" in the gear representing the ratio between the frequencies of the signal forming the basic circular pattern and the unknown signal. As can be seen, this method permits comparison of signals having a wide ratio. Ratios of 1:15 and 1:20 are not uncommon. Such ratios would be difficult to determine, to say the least, using conventional Lissajou figures. The pattern would become so complex that analysis would be virtually impossible.

The number of "teeth" are sometimes difficult to determine unless special care is taken to "stop" the tendency of the pattern to rotate. This is best accomplished by very careful adjustment of the exact frequencies of the two signals being com-

pared. If the unknown signal is fixed in frequency, the low frequency signal used to form the basic circular pattern is varied slightly.

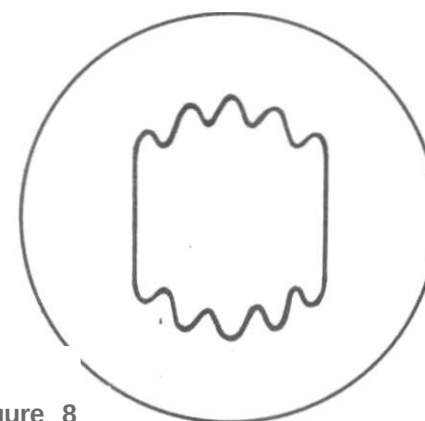


Figure 8

ADDITIONAL EXPERIMENTS:

If the circuit in Fig. 7 is used, and the high frequency signal varied over a wide range, as well as the relative amplitudes of the high and low frequency signals, extremely interesting patterns may be formed. The simple "gear-tooth" pattern may be changed into rings, into elongated cylinders, and into other patterns.

Unusual effects may be obtained by reducing the frequency of the "high frequency" signal until it approaches and becomes equal to the frequency of the low frequency signal used to form the basic circular pattern.

Other effects may be obtained by substituting signals other than sine-waves for the high frequency signal. Square-waves, especially, permit the formation of quite distinctive and unusual patterns.

uSing the heathkit oscilloscope to service amplifiers

BY LOUIS E. GARNER, JR.

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The Heathkit Oscilloscope is a valuable instrument for servicing and testing audio amplifiers ... whether small low power phono amplifiers or powerful public address systems. In this bulletin we will outline many of the basic test techniques used in servicing audio amplifiers. In addition to those techniques to be described here, there are specialized techniques available for testing high fidelity systems ... these will be discussed in other bulletins.

Before describing specific techniques, certain general precautions will be outlined that should always be followed when testing or servicing audio amplifiers:

1. Never operate an amplifier without a load! To do so may ruin the output tube(s) or damage the Output transformer. Where quality tests are being made, the load should be the rated load for the amplifier (speaker or exact equivalent). However, a resistive load may generally be substituted for a speaker (provided impedances are equal) for other tests.

2. If the amplifier is designed to use electrodynamic speakers, be sure all speakers are properly connected *before* turning "on". Where this type of speaker is used, the field coil often serves as the filter choke. To turn on the amplifier with the speaker(s) disconnected may damage the input filter condensers and ruin the rectifier tube.

3. When making quality tests, and connecting a signal source to the amplifier, be sure that the input impedance of the amplifier is properly matched ... otherwise, the results obtained may be meaningless. *This step is particularly important where the amplifier has a low impedance input.* Where a high impedance input is used, it is not as necessary to take special pains to match the input impedance.

4. Do not shift the alignment of input transformers. In audio amplifiers using input transformers, the mounting is usually such that the transformer position may be easily shifted. The transformer is then aligned for minimum hum pick-up during manufacture. If the alignment is shifted by the serviceman, even accidentally, heavy hum may occur which is virtually impossible to eliminate by conventional means, and often difficult to isolate. However, should the alignment of an input transformer be accidentally shifted, realignment may be carried out using a technique to be described later.

SERVICING "WEAK" AND "DEAD" AMPLIFIERS:

If an audio amplifier is either "weak" or "dead", the defective stage may be isolated quite rapidly by using the 'scope as a Signal Tracer.

An audio signal is introduced at the input of the amplifier and the appearance and relative amplitude checked stage-by-stage through the entire circuit, using the oscilloscope. The audio signal may be obtained from an Audio Generator, from the "Audio Output" jack of an R. F. Signal Generator, or, if desired, from the 60 CY. TEST terminal of the 'scope itself.

A "dead" stage is readily spotted by the lack of a signal as that stage is checked.

Since relative gain is approximated by comparison of the input and output signal amplitudes of each stage, a "weak" stage is isolated by the lack of gain (remember, however, that some phase-inverter stages do not supply a gain exceeding 1).

Once the defective stage is isolated, whether it is "dead" or "weak", it is usually a simple matter to identify the defective part, either by visual observation (a burnt resistor is readily spotted, for example) or by making quick voltmeter or ohmmeter tests.

CHECKING FOR HUM AND NOISE:

Here, again, the 'scope is used as a visual Signal Tracer. To properly identify hum, remove the input audio signal and use the 'scope to check directly for the presence of a ripple signal. General practice is to check the Output of the power supply first, as power supply defects cause the majority of "hum" complaints.

Where the power supply Output is free of ripple, the hum has generally been introduced in one of the amplifier stages. A stage-by-stage check with the 'scope soon isolates the offender.

Sixty-cycle hum is usually caused by heater-to-cathode leakage, improper lead dress, an open grid circuit, poor shielding,

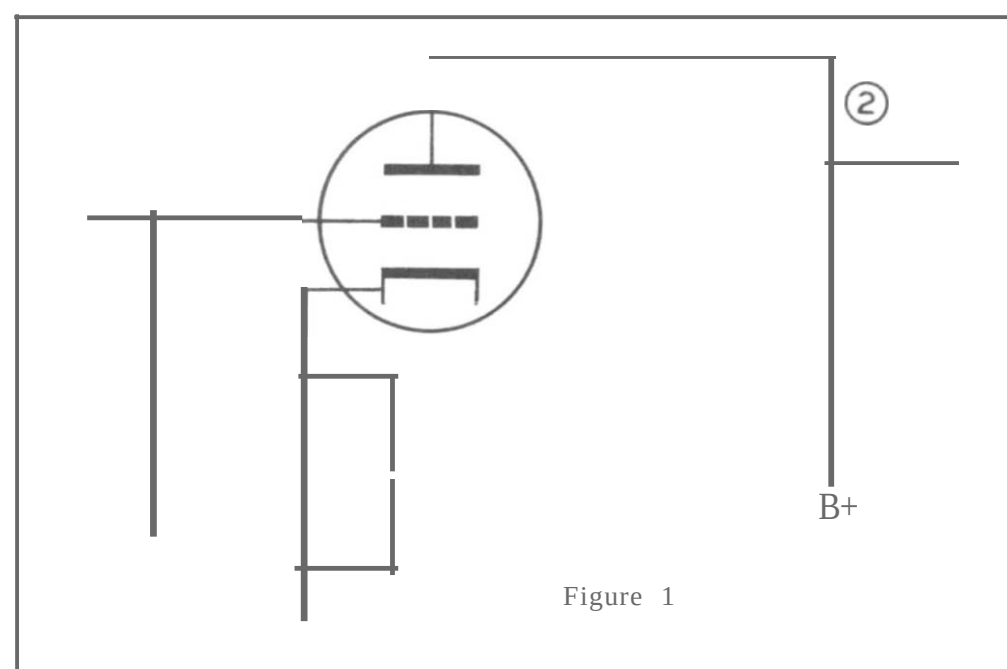


Figure 1

or an unbalance in the power supply circuit (in sets using full-wave rectification). Hum at 120 cycles is generally caused by defective filter condensers or a shorted filter choke.

Heater-to-cathode leakage in a tube is a common cause of 60 cycle hum, and may be readily identified with the 'scope. Referring to Fig. 1, the 'scope is first used to check for the presence of hum on the grid of the stage (point 1). If no hum is present here, but there is hum at the output (point 2), the VERT. INPUT lead of the 'scope is transferred to check for hum on the cathode of the tube (point 3). Hum here often indicates heater-to-cathode leakage in the tube.

ALIGNING INPUT TRANSFORMERS:

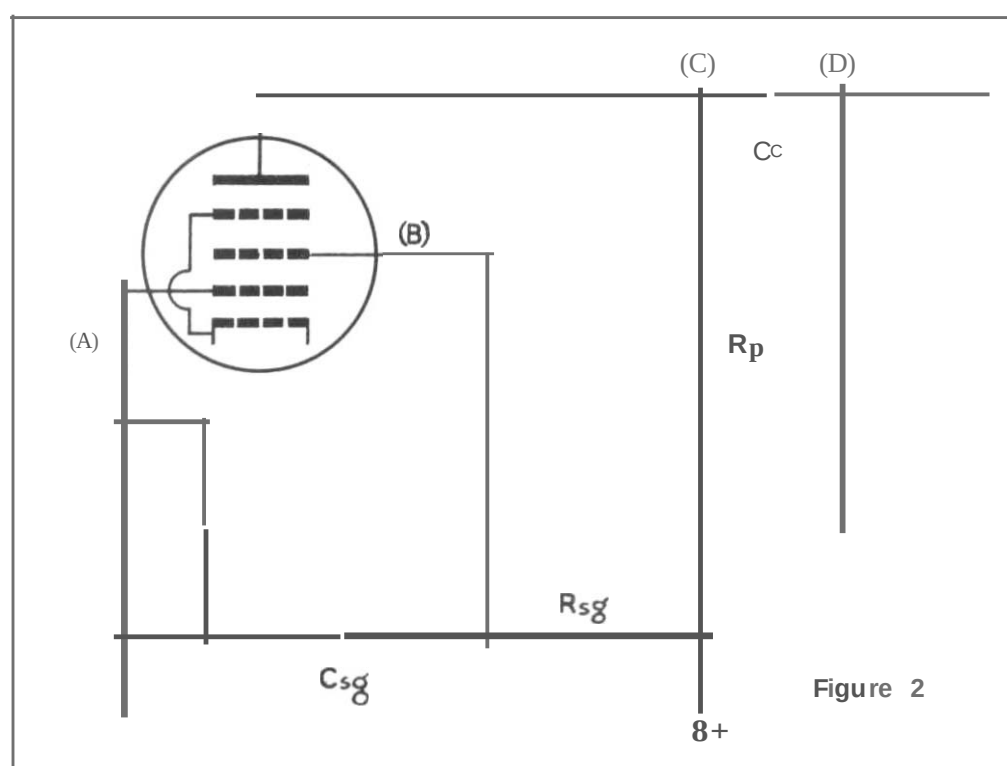
As mentioned previously, a number of commercial audio amplifiers use input transformers. These are generally aligned for minimum hum during equipment manufacture. If their position is accidentally shifted, the following technique may be used for realignment:

1. Connect the 'scope to observe the Output of the amplifier.
2. With *no input signal*, turn amplifier gain controls to maximum. (Use whatever gain is necessary in the 'scope to observe any hum present).
3. Loosen the screw(s) holding the input transformer and gradually shift its position. Pick the position giving a minimum hum signal.
4. Tighten the mounting screws.

This technique is also valuable when designing and building amplifiers. It may be used to select the best position for interstage and Output transformers so that minimum induction hum pick-up will occur.

CHECKING BY-PASS AND COUPLING CONDENSERS:

The effectiveness of by-pass and coupling condensers may be quickly checked by using the 'scope. A typical pentode resistance-coupled amplifier stage is shown in Fig. 2. To check coupling and by-pass condensers in this stage, an audio signal is introduced in the amplifier, as when checking for a "weak" or "dead" stage. Use a signal from 400 to 1000 cps.



The cathode by-pass condenser may be checked by connecting the VERT. INPUT lead of the 'scope to point (a). The presence of a signal here indicates that the condenser is either partially or completely open.

In a similar fashion, a check at point (b) indicates whether the screen-grid by-pass condenser is effectively by-passing the signal to ground.

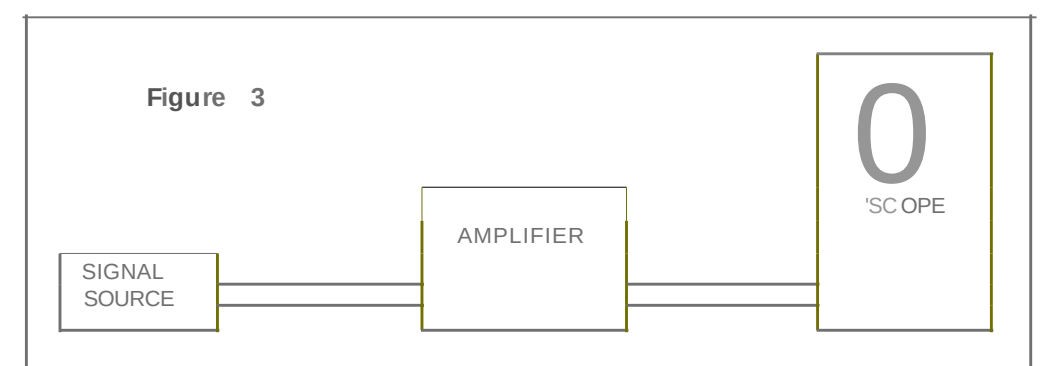
To check the coupling condenser (Cc), note the relative amplitude of the signal at point (c). Then transfer the VERT. INPUT lead to point (d). The lack of an audio signal here (or one of much lower amplitude) is a good indication that the coupling condenser is open.

CHECKING A CONTROL FOR NOISE:

Gain and *Tone* controls may become "noisy" after a period of service. Often a "noisy" control may be located by manipulating the control while listening to the Output of the amplifier. However, where positive identification is desired, the 'scope may be used.

Connect the center arm of the suspected control to the VERT. INPUT terminal of the 'scope. With a low level audio signal applied to the amplifier input, turn the control rapidly back and forth, observing the 'scope pattern. The amplitude of the signal should vary smoothly as the control is manipulated. Erratic variations in amplitude, the presence of "hash", or sudden jumps of the pattern generally indicates the control to be noisy.

Sometimes noise in a control is due simply to the presence of dirt or other foreign matter. In such cases, the control can often be cleaned by using an eye-dropper or hypodermic injector to inject a small amount of carbon tetrachloride and then vigorously rotating the control back and forth. After such an attempt at cleaning, *if* the control is still noisy, *it* should be replaced.



CHECKING FOR AMPLITUDE DISTORTION:

The circuit shown in block diagram form in Fig. 3 is used to check an audio amplifier for amplitude distortion. The "Amplifier" may be either a complete unit or a single stage. The "Signal Source" may be either a sine-wave Audio Generator or any other source of an audio signal having good waveform.

With a sine-wave input signal, the Output, as observed on the screen of the 'scope, should also be a pure sine-wave. Any departure from the sine-wave shape indicates that distortion has taken place in the amplifier.

If the negative peaks of the signal are flattened, as shown in Fig. 4 (a), *it* generally shows too much bias. This permits

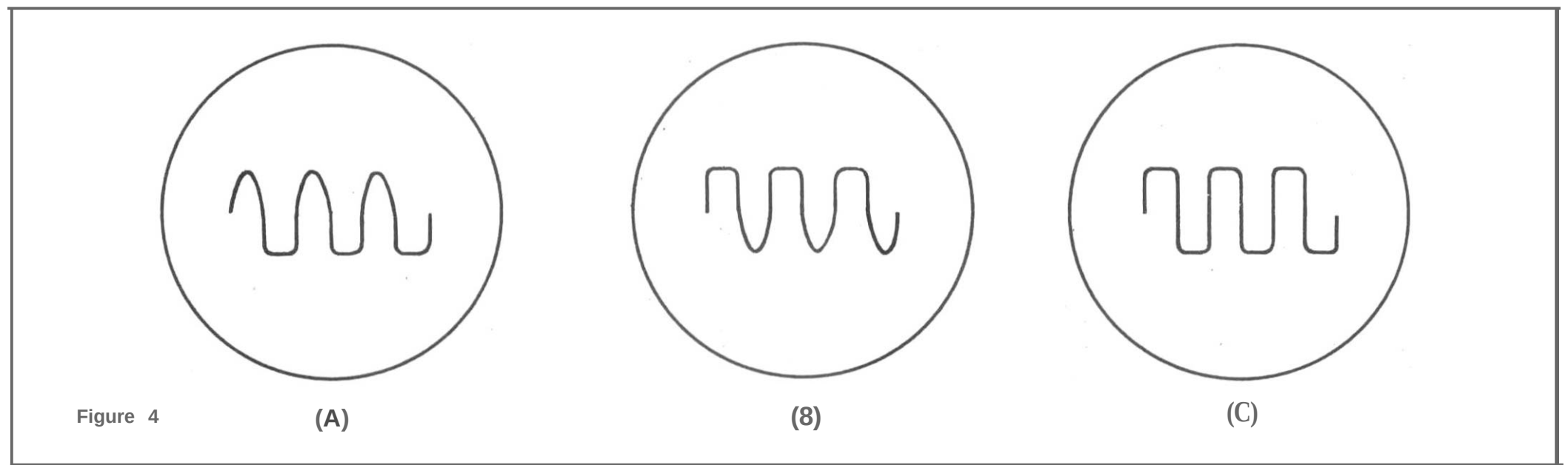
the negative signal peaks to drive a tube into its "cut-off" region. An open grid resistor will sometimes cause a similar effect.

A flattening of the positive peaks, as shown in Fig. 4 (b), indicates either insufficient bias, permitting the positive signal peaks to drive a tube to plate saturation, or else a weak tube. Lower than normal plate or screen voltages will often produce a similar distortion.

If both peaks are flattened, so that the pattern begins to approach a square-wave in shape, excessive overload of a

stage is indicated. As a first step, the input signal level should be reduced.

Should the clipping persist, even with a lower input level, individual stage operating voltages should be checked. Also look out for an extremely weak tube or the wrong tube used in a particular socket.



using the heathkit oscilloscope for frequency measurement with lissaiou figures

BY LOUIS E. GARNER, JR.

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Your Heathkit Oscilloscope may be used for accurate frequency measurement by comparing an unknown signal with a known signal. The two signals are applied to the horizontal and vertical inputs of the instrument and the resulting pattern (known as a "Lissajou Figure") studied.

Lissajou figures may be of two general types ... the "completed loop" type, and the "uncompleted loop" type. A completed loop Lissajou figure is formed when the two signals are both sine-waves (even if slightly distorted). The uncompleted loop figure is formed when one signal is a sine-wave and the other a linear saw-tooth signal. Both types are suitable for frequency measurement, and the choice of which to use is pretty much up to the individual. The techniques used with both types will be discussed in this bulletin.

COMPLETED LOOP LISSAJOU FIGURES:

In general, the completed loop Lissajou figure is preferred by the majority of technicians and engineers for frequency measurement. However, to use the completed loop figures to the greatest advantage requires a rather wide range sine-wave generator for comparison purposes. The basic test set-up used is shown in Fig. 1.

The unknown signal may be connected to either the VERT. or HOR. input of the 'scope, while the known signal, obtained from a sine-wave generator, is connected to the other input. However, general practice is to connect the unknown signal to the VERT. INPUT and the known signal to the HOR.

INPUT, as shown. The frequency of the sine-wave generator is then varied until a stationary and easily recognized pattern is formed. This pattern gives the *ratio* between the known and unknown signals and frequency determination then becomes a matter of simple arithmetic.

To determine the ratio between the two signals, the figure is imagined enclosed in a rectangle. The points of tangency of the loops along the horizontal and vertical sides are then counted. Thus, in Fig. 2 (a), there is one point of tangency along the vertical line (dashed) and three points of tangency along the horizontal line (dashed). The frequency ratio, in this case, is 3:1.

Since three vertical *loops* are formed for one horizontal *loop*, the frequency of the signal applied to the vertical input is 3 times that applied to the horizontal input. If the known signal (horizontal) had a frequency of 150 cps, the frequency of the unknown signal (vertical) would be 450 cps. *Note that the pattern does not depend on the actual frequencies, but simply on their ratio.* A similar pattern would be formed with signals of 250 cps (horizontal) and 750 cps (vertical).

Had the frequency ratio been interchanged (vertical input signal $\frac{1}{3}$ that of the horizontal), the pattern would be the same, but aligned as shown in Fig. 2 (b). The ratio "VERTICAL: HORIZONTAL" now becomes 1:3.

The pattern obtained with a 3:2 ratio is shown in Fig. 2 (c), along with the dotted tangency lines used to determine ratio.

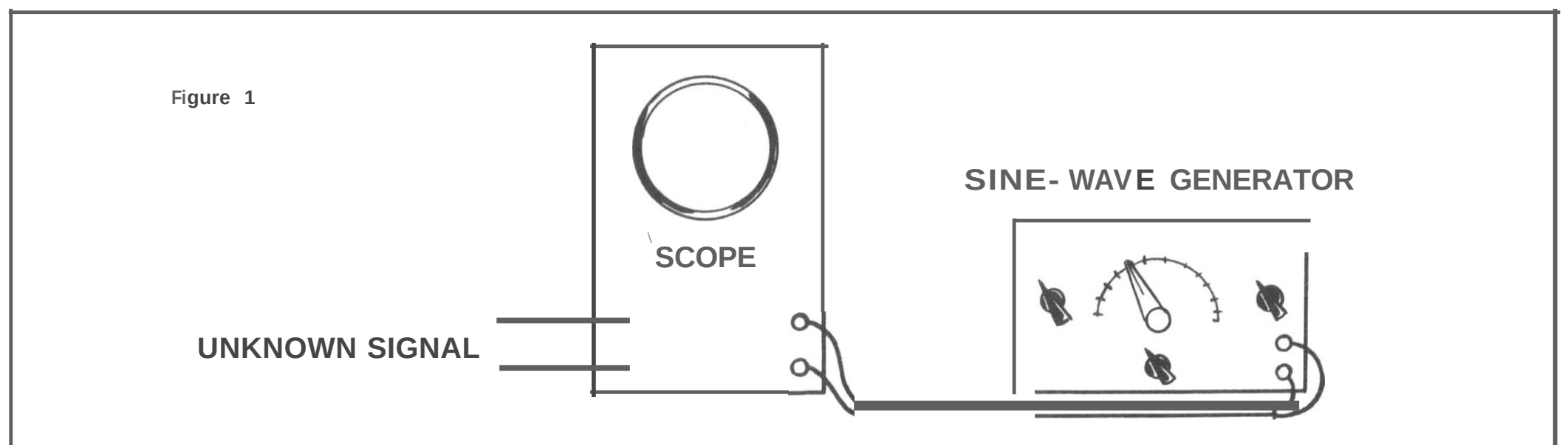
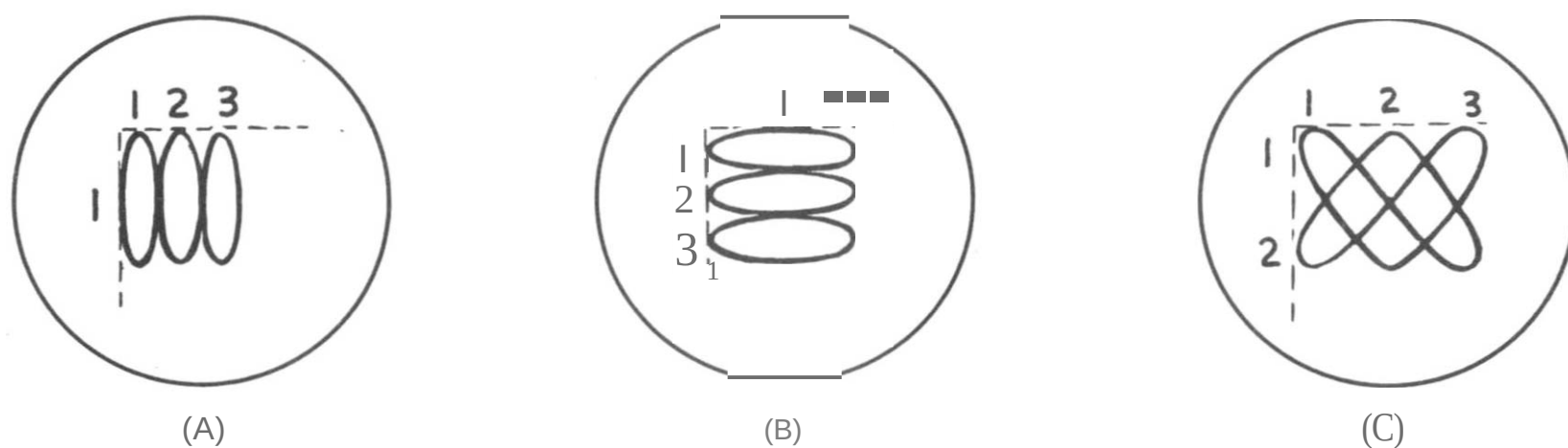


Figure 2



In Fig. 3 are shown examples of a 1:1 ratio (Fig. 3 (a)), a 1:2 ratio (Fig. 3 (b)), a 2:1 ratio (Fig. 3 (c)), and a 6:1 ratio (Fig. 3 (d)). On the basis of these illustrations, the reader should have no difficulty determining the ratio of other figures he may encounter.

Phase Considerations: Care must be taken that the phase relationship of the two signals is such that a recognizable pattern is formed. This is generally accomplished by varying the frequency of the sine-wave generator slightly until the desired pattern is obtained.

Examples of how the phase relationship may change the pattern are given in Figs. 4 (a) to 4 (d) and in Figs. 5 (a) and 5 (b). In addition the 1:1 ratio pattern given in Fig. 3 serves as an example. The elliptical or circular pattern shown in Fig. 3 (a) is obtained only when the two signals are out-of-phase. The circle shown is obtained with a 90° phase difference. When the two signals are in phase (or exactly 180°

out-of-phase), a diagonal slanting straight line pattern is obtained.

The patterns given in Figs. 4 (a) and 4 (b) both represent a 1:2 ratio, but with different phase relationships. The patterns in Figs. 4 (c) and 4 (d) both represent a 3:2 ratio, and the patterns in Figs. 5 (a) and 5 (b) are both for a 4:1 ratio.

Distortion: If one of the signals used to form the completed loop Lissajou figure is a distorted sine-wave, a different pattern is obtained. However, it is usually still possible to determine the frequency ratio.

Examples of figures obtained when a clipped sine-wave (obtained from the Heathkit Voltage Calibrator) is used for horizontal deflection and a normal sine-wave for vertical deflection are given in Figs. 5 (c) and 5 (d). The frequency ratios are 1:1 and 2:1, respectively.

Figure 3

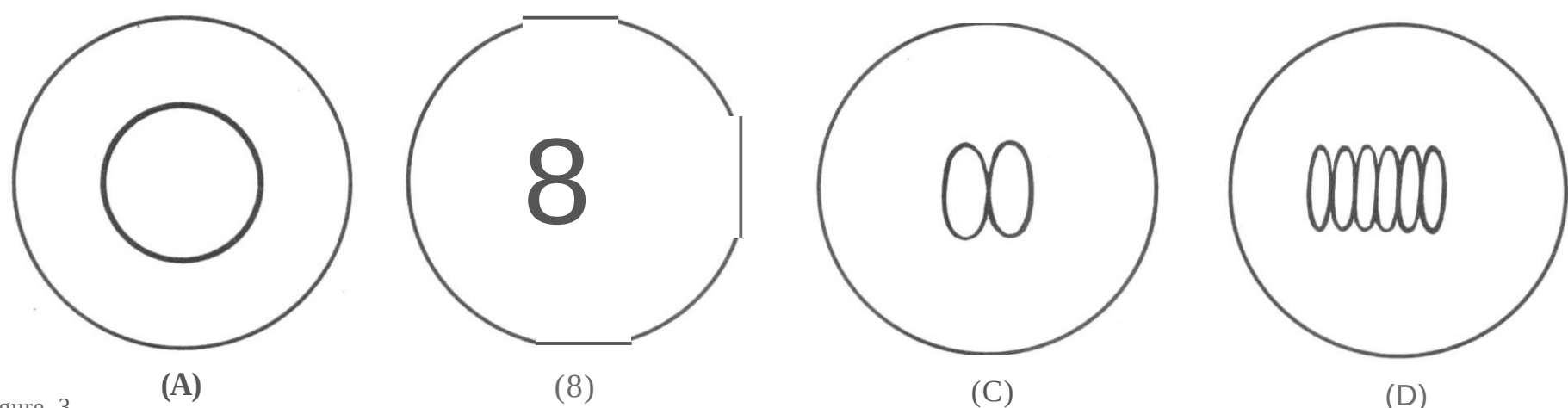
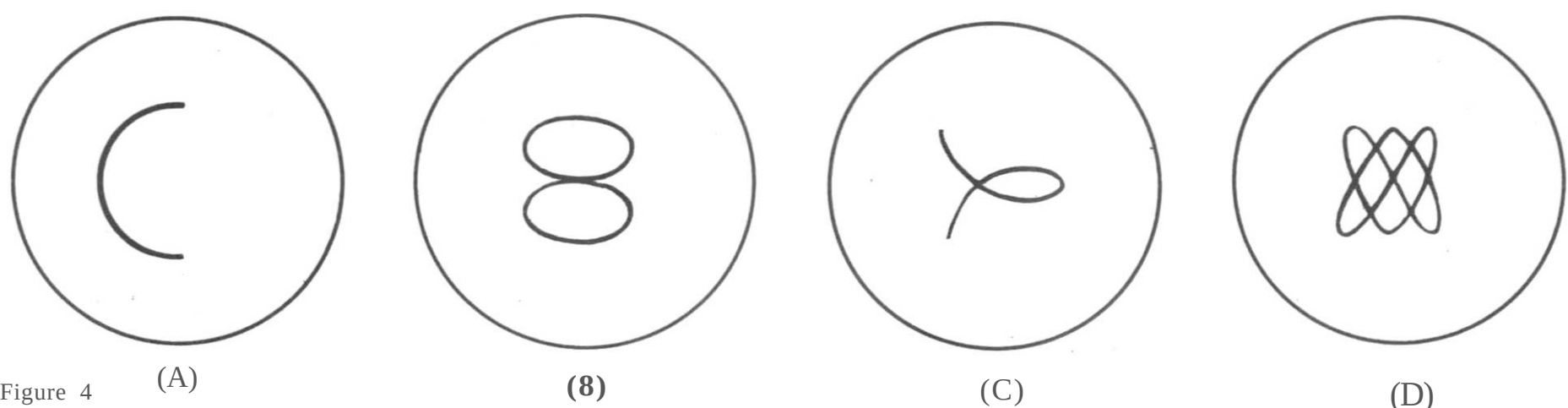
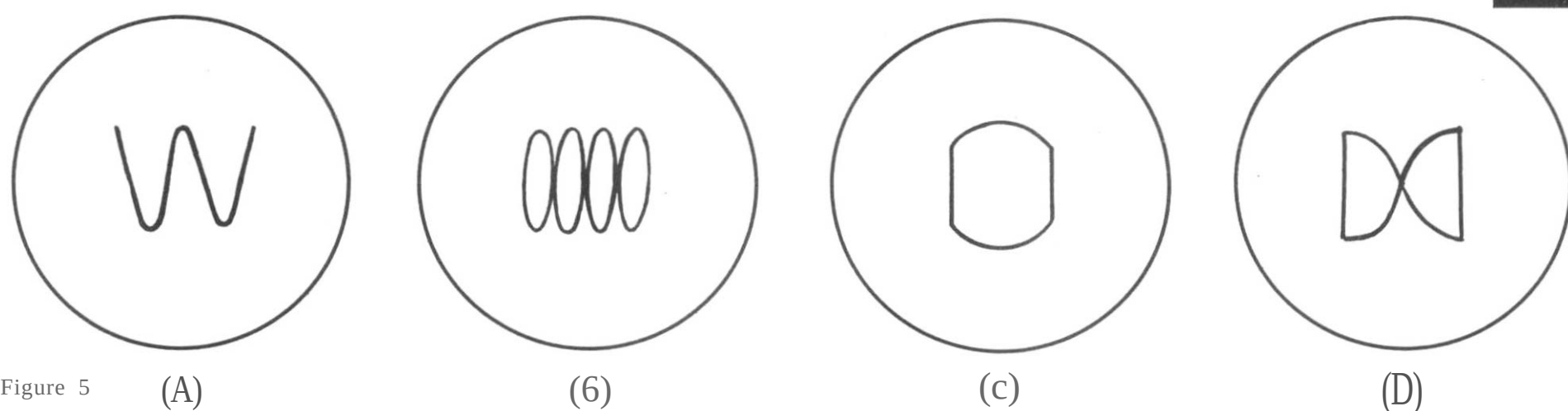


Figure 4





UNCOMPLETED LOOP LISSAJOU FIGURES:

Uncompleted loop figures are formed when sine-wave and saw-tooth signals are used (the saw-tooth signal is generally used to provide horizontal deflection). When these patterns are used for frequency measurement, it is necessary that the frequency of one of the signals be known, for, as in the case of the completed loop Lissajou figures, the pattern obtained simply indicates the ratio between the two signals.

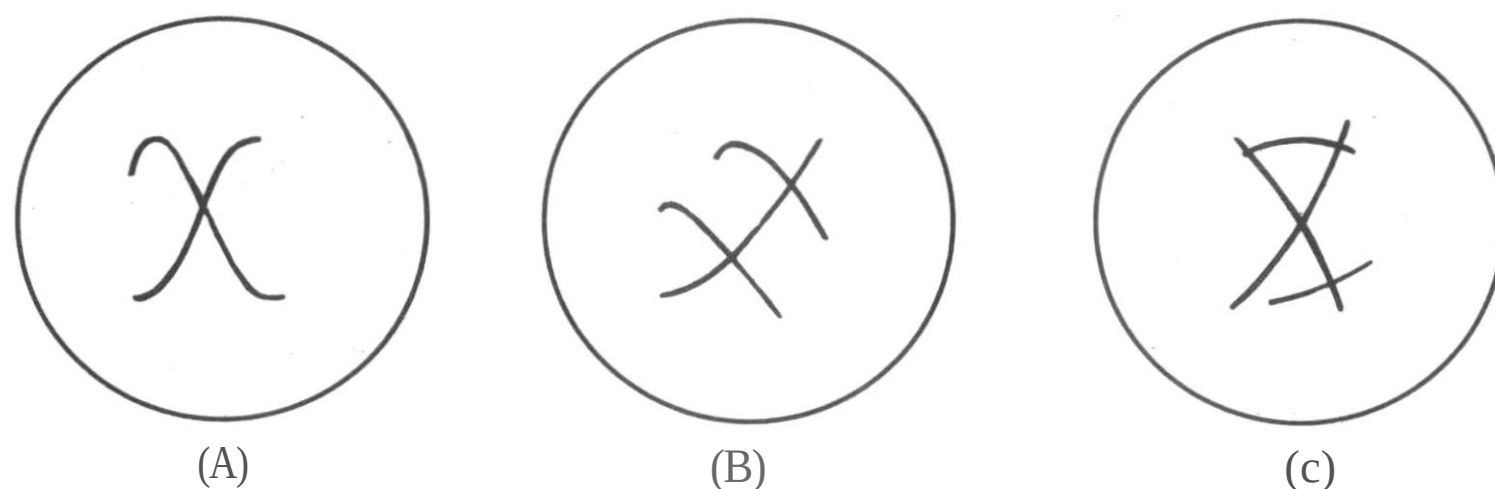
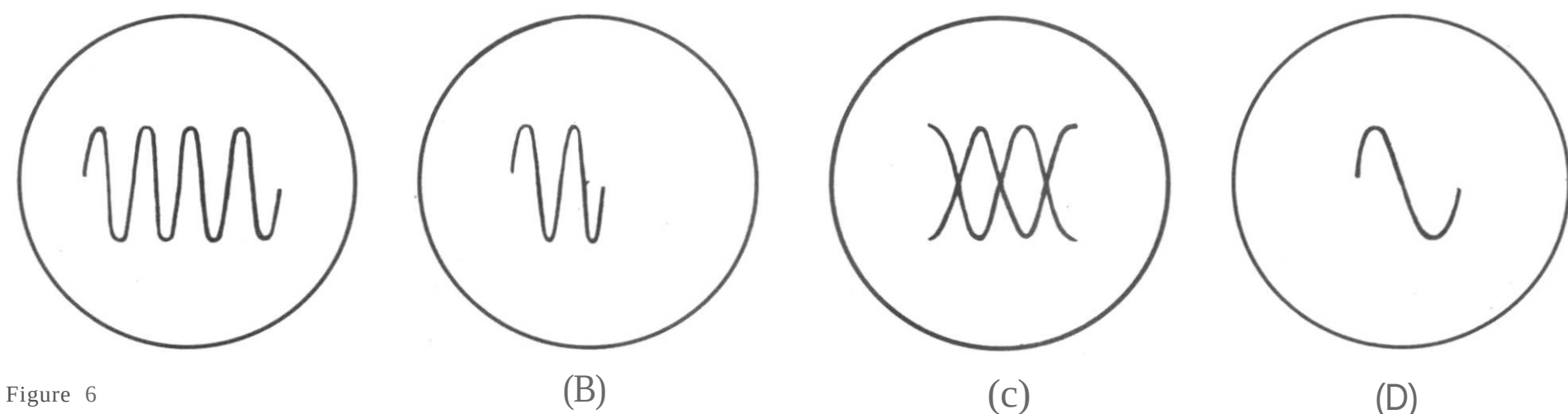
Uncompleted loop figures are often used for calibrating the sweep of an oscilloscope, but may also be used for measuring the frequency of an unknown signal . . . *once the sweep frequency has been set.*

To form the uncompleted loop figure, a sine-wave signal is applied to the VERT. INPUT terminals of the 'scope, and the linear sweep of the 'scope used for horizontal deflection. Examples of the figures obtained with ratios of 4:1, 2:1, 3:2, and 1:1 are given in Figs. 6 (a), 6 (b), 6 (c) and 6 (d), respectively.

When the linear sweep is greater in frequency than the sine-wave, the applied signal is "chopped" into segments. The number of segments making up the pattern may be counted to give the frequency ratio. The actual position of the individual segments will vary with the phase relationships in the same manner that the appearance of the completed loop pattern varied with phase. The patterns obtained with frequency ratios of 1:2, 1:3 and 1:4 are given in Figs. 7 (a), 7 (b) and 7 (c), respectively.

To measure the frequency of an unknown sine-wave signal using the uncompleted loop Lissajou figure method, the linear sweep of the 'scope must either be (a) calibrated, (b) first set to a known frequency, or (c) have its frequency checked after forming a pattern with the unknown signal. Method (b) follows:

1. Connect a known sine-wave signal to the VERT. INPUT and EXT. SYNC terminals of the 'scope. Switch to EXT. SYNC.



2. Adjust the 'scope sweep to the desired frequency by watching the uncompleted loop pattern obtained. For example, if a 60 cy. test signal is used, the 'scope sweep may be set to 30 cy. using the pattern in Fig. 6 (b), to 60 cy. using the pattern of Fig. 6 (d), to 120 cy. (Fig. 7 (a)), to 180 cy. (Fig. 7 (b)), and to 240 cy. (Fig. 7 (c)).

3. Disconnect the known sine-wave signal at the VERT. INPUT terminal; *but leave it connected to the EXT. SYNC terminal to insure that the 'scope sweep maintains the previously set frequency.*

4. Connect the unknown signal to the VERT. INPUT

terminal and observe the pattern obtained. If a stable pattern is obtained, analysis will indicate the frequency of the unknown signal. For example, if the 'scope sweep had been set to 180 cy., and the pattern of Fig. 6 (b) was obtained with the unknown signal, the frequency of the unknown signal would be 360 cps.

Since it is sometimes difficult to obtain a stable pattern in step (4), above, method (c) is sometimes used. This is similar to method (b), except that the role of the known and unknown signals is reversed. In other words, a stable pattern is first obtained with the unknown signal, and then the 'scope sweep frequency determined using a known signal.

the heathkit oscilloscope and laboratory power supply

BY LOUIS E. GARNER, JR.

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OBTAINING CHARACTERISTIC CURVES

Few laboratory measurements are more time consuming than those required to obtain the necessary data to plot characteristic curves, whether for crystals, transistors, or tubes. However, considerable time may be saved by using the Oscilloscope to obtain the desired curves ... when the proper circuit is employed, almost any type of desired characteristic curve may be obtained and *displayed directly on the screen of the CRT*. In this bulletin we will outline the techniques used to obtain characteristic curves for a germanium diode, a vacuum tube diode, triodes and pentodes.

In addition to the Oscilloscope, a d.c. power supply such as the Heathkit Laboratory Power Supply, a few bias batteries, a small filament transformer (6.3 v), a few small components (resistors, tube socket, wire, etc.), and the tube or other component whose characteristic curve is to be obtained will be required.

OBTAINING THE CHARACTERISTIC CURVE FOR A GERMANIUM DIODE

The circuit given in Fig. 1 (a) is satisfactory for obtaining the Voltage-Current characteristic curve for a germanium diode (such as types IN34, IN21, etc.). A 1000 ohm resistor is connected in series with the diode and the entire combination connected across a 6.3 v. (60 cy.) a.c. source.

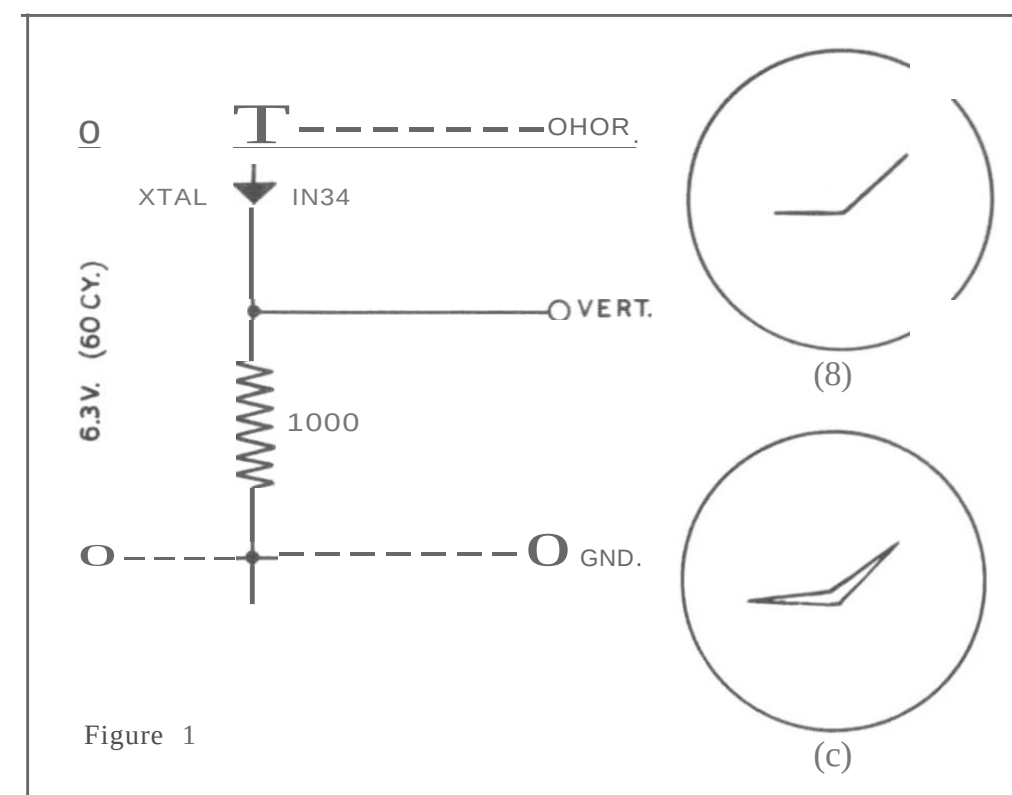
To obtain a horizontal deflection proportional to the applied voltage, the lead to the HOR. INPUT of the 'scope is connected directly to the voltage source, as shown in the schematic diagram.

Any current flowing in the circuit will cause a voltage drop across the 1000 ohm series resistor R_I . This voltage drop is proportional to the amount of current flow in the circuit, and its polarity depends on the direction of current flow. Thus, the voltage drop across R_I may be used for the VERT. INPUT of the 'scope to give a vertical deflection proportional to circuit current flow. With the connections shown, the internal sweep of the 'scope is *not used*.

The curve shown in Fig. 1 (b) is generally obtained. The flat horizontal portion of the curve represents the period of no current flow (or very little **current** flow) while the rising portion of the curve represents current flow through the circuit when the applied voltage reverses polarity. As can be seen, this current flow increases as the voltage increases. (This

rising portion of the curve may point upward or downward, depending on the polarity of crystal connections.)

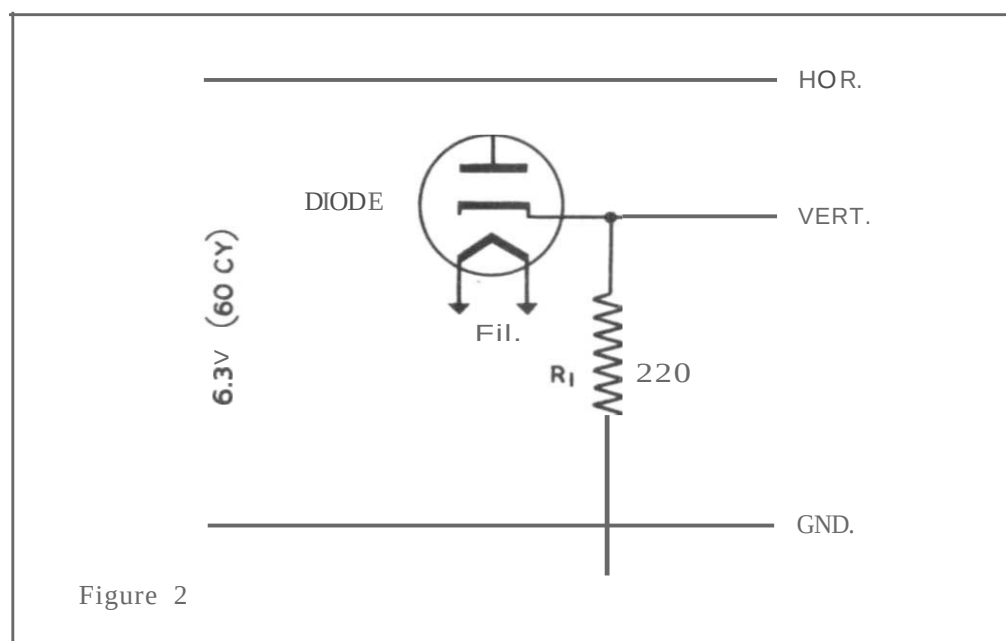
If there is a slight phase shift in the horizontal amplifier of the 'scope, a double-trace may be obtained, as shown in Fig. 1 (c). The double trace does not indicate that the circuit is at fault or that an error in connections has been made, nor does it interfere appreciably with proper interpretation of the characteristic curve obtained.



DIODE CHARACTERISTIC CURVE

The plate voltage vs. plate current ($E - I$) curve for a diode vacuum tube can be obtained using the circuit shown in Fig. 2. Since the internal resistance of the tube is generally low, a smaller **series** resistor (R_I) may be used. (NOTE: In general, a series resistor used to obtain a signal voltage proportional to circuit current flow should be as small as is practicable to insure that circuit action will not be modified by the series resistance.)

The diode curve may be demonstrated either by using a conventional diode such as types 6AL5, 6H6, 6X5, etc., or by diode connecting a triode or pentode tube. However, isolated voltage sources should be used for the filament voltage and the a.c. signal voltage supplied to the diode. If a Heathkit Power Supply is used to supply the signal voltage, a small 6.3 v. filament transformer may be used to supply filament voltage to the tube.



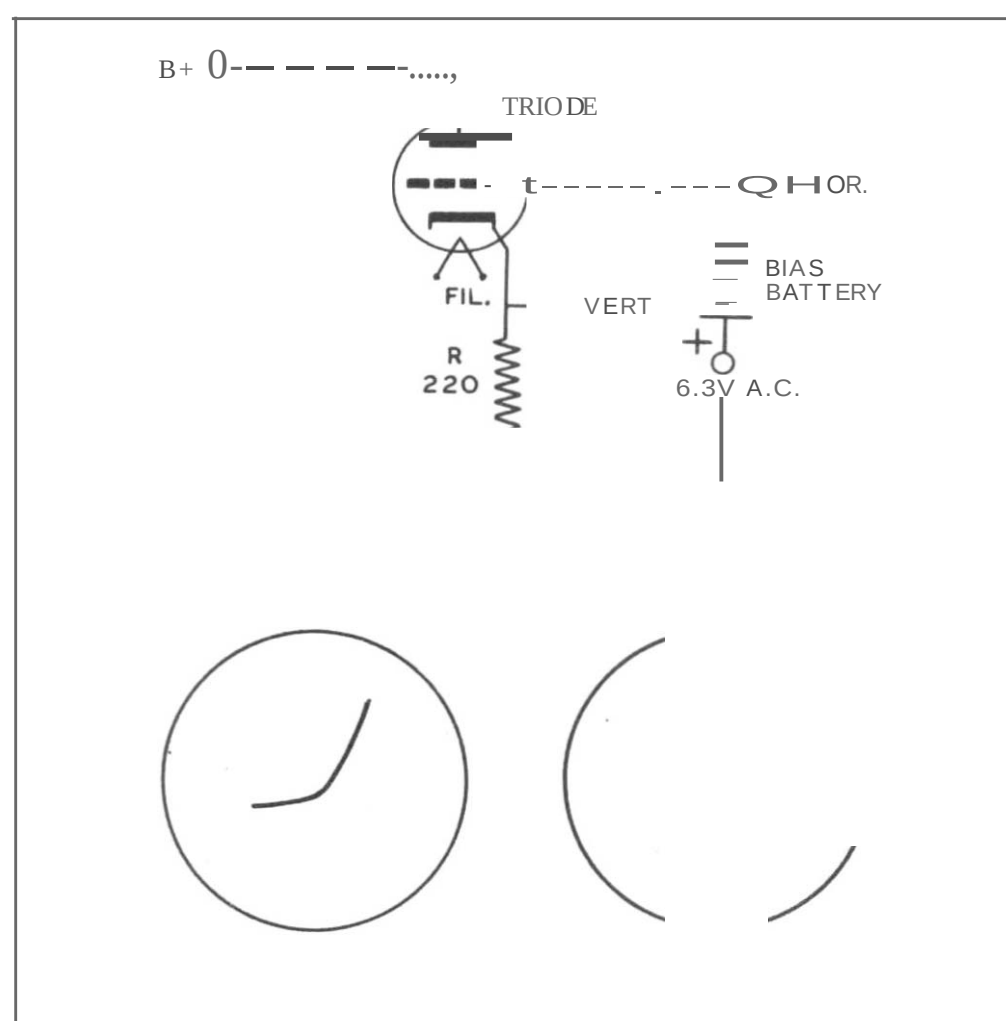
It will be found that the characteristic curve for a vacuum tube diode is quite similar, in general form, to that obtained with the germanium diode (Fig. 1 (b)). An interesting variation of the experiment described above may be obtained by connecting a d.c. voltage in series with the a.c. signal applied to the tube. In this case, the curve obtained represents the tube's response to pulsating d.c.

TRIODE CHARACTERISTIC CURVES

When considering triode tubes, two basic types of characteristic curves may be obtained. The grid voltage vs. plate current curve ($E - I$), and the plate voltage vs. plate current ($E - I$) curve. Both types may be obtained by using the appropriate circuit.

The circuit given in Fig. 3 (a) is satisfactory for obtaining $E - I$ curves. The exact shape of the curve will depend on the constants used. For example, with a fixed bias of -9 volts, the curve shown in Fig. 3 (b) was obtained, using a triode connected 6SJ7 tube. The curve shown in Fig. 3 (c) was obtained when the bias was changed to -1 1/2 volts.

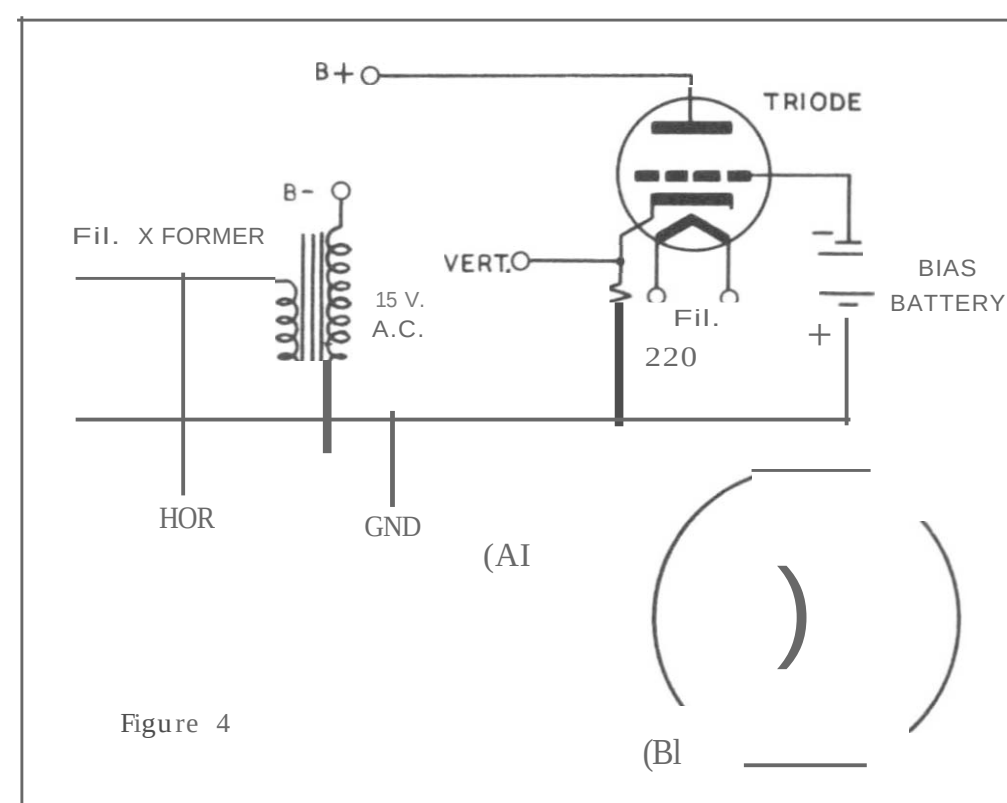
A "family" of curves may be obtained by using different B



voltages, as well as by varying the fixed bias. Therefore, to obtain a true picture of tube operation, both constants should be varied and the resulting changes in the characteristic curves noted.

To obtain an $E - I$ curve for a triode, the circuit shown in Fig. 4 (a) may be used. Since a much wider voltage excursion is required in the plate circuit than in the grid circuit to obtain a satisfactory curve, a 6.3 v. filament transformer is connected "in reverse" so that 115 volts a.c. may be introduced in series with the B supply. Other connections remain the same.

Again, to obtain a "family" of curves, a number of different bias values may be used. A typical curve is shown in Fig. 4 (b). If possible, the B voltage should be adjusted to near 150 or 160 volts (1.41×115) so the plate voltage is reduced to zero on the negative peaks of the applied a.c. voltage. This will insure a truly representative curve.



PENTODE CHARACTERISTIC CURVES

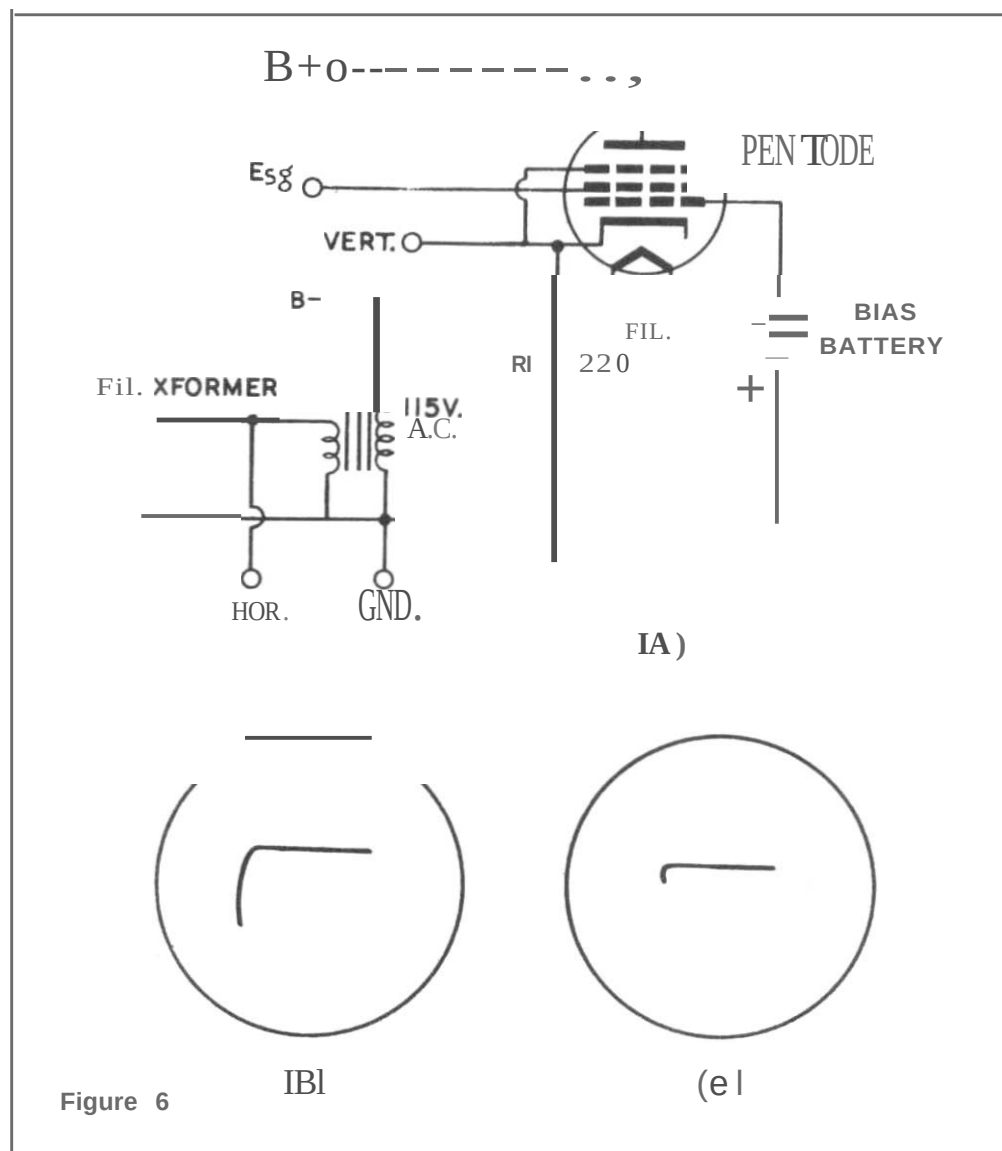
Again, as in the case of the triode tube, both $E - I$ and $E - I$ curves may be considered. A circuit satisfactory for obtaining the $E - I$ curve is illustrated in Fig. 5. Note that screen grid voltage (E_{sg}) in addition to plate voltage must be provided. For best results, this voltage should be obtained from a separate power supply source to prevent changes in screen voltage as the plate voltage is varied.



An interesting experiment may be performed using the circuit shown in Fig. 5. Once a characteristic curve is obtained, the plate voltage should be varied, with all other voltages (screen voltage and grid bias) held constant. It will be found that the characteristic curve, as observed on the screen of the CRT, does not change appreciably, giving ample proof that plate voltage plays a minor role (within limits) in a pentode tube.

To obtain a "family" of curves, different screen grid voltages may be used as well as different fixed bias voltages.

The E -I curve for a pentode may be obtained using the circuit given in Fig. 6 (a). Note that the filament transformer is again used to obtain an isolated high voltage a.c. signal source.



If Fig. 6 (b) is given the characteristic curve obtained using a type 65J7 tube. Fixed B voltage was 160 volts, screen grid voltage was 150 volts, and the fixed bias was $-1\frac{1}{2}$ volts. When the bias was changed to -9 volts, all other voltages remaining the same, the curve shown in Fig. 6 (c) was obtained. As before, to obtain "families" of curves, different screen-grid as well as grid bias voltages may be used.

FURTHER APPLICATIONS

The techniques outlined above may be used to obtain characteristic curves for almost any type of tube. It is necessary to adjust the plate, screen, and bias voltages to suit individual tubes, or course. Characteristic curves obtained using these basic techniques are quite accurate, and may be used for design work when care is first taken to "calibrate" the 'scope, using a Voltage Calibrator or accurate voltmeter.

In other words, where the curves are used for analysis, it is necessary to determine how much deflection (cm or inches) represents a given voltage (or current, or whatever the variables may be) variation. When this step is taken, the curves may be transferred directly from the screen of the 'scope, either by photography or by tracing.

Modifications of the techniques described may be used to obtain characteristic curves for almost any circuit component. It is only essential that certain fundamental rules be followed in setting up the circuit. These are as follows: (a) Horizontal deflection is generally provided by the independent or "x-axis" variable; (b) Vertical deflection is generally provided by the dependent or "y-axis" variable; (c) Voltages (rather than currents) must be used for both horizontal and vertical deflection. Where one of the variables is a current, use a small series resistor to convert this into a corresponding voltage drop. This resistor should be as small as possible so as to have negligible effects on circuit operation. However, its size will be limited by the gain of the 'scope and the magnitude of the currents involved.

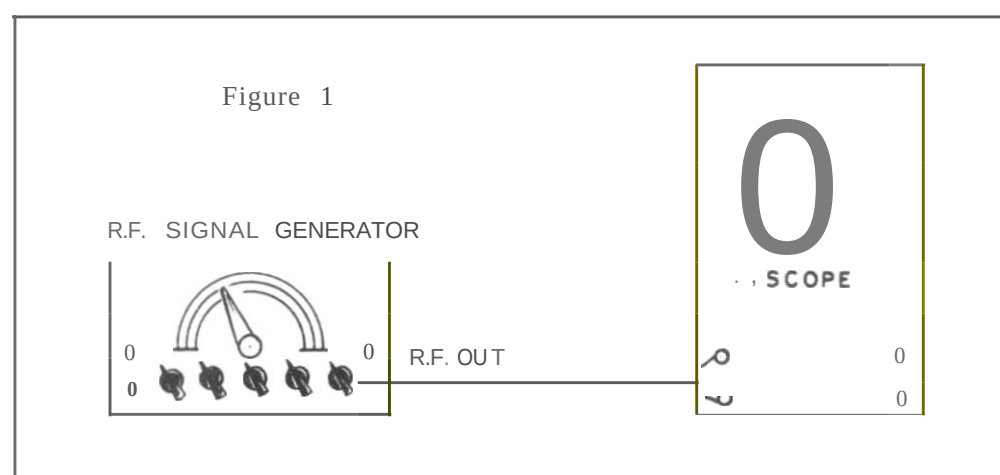
the heathkit oscilloscope and r.f. signal generator

BY LOUIS E. GARNER, JR.

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STUDYING R.F. SIGNALS

Your Heathkit Oscilloscope has an over-all response characteristic sufficient to permit direct observation of R.F. signals through the d. and AM Broadcast bands, provided a signal of reasonable amplitude is available. When used to observe R.F. signals, the 'scope will provide valuable information to many users . . . to the student, a better understanding of R.F. signals, modulation, and other important facts; to the experimenter and technician, simple techniques for checking the quality of low frequency R.F. signals, and for adjusting such devices as carrier current transmitters, phono oscillators, d. signal generators, etc.; and to the Radio-TV serviceman, methods for checking the output of his Signal Generator, and worthwhile additions to his knowledge of test equipment in general.



To observe R.F. signals, simply connect the signal source to the VERT. INPUT terminals of the oscilloscope. Use a low impedance source *if* possible (such as a coupling link). For most tests, the built-in linear sweep of the 'scope may be used.

If available, an ordinary R.F. Signal Generator may be used to become familiar with the basic patterns encountered, and

to gain experience in using the 'scope to observe R.F. signals. The proper connections are shown in Fig. 1.

CHECKING THE QUALITY OF AN R.F. SIGNAL

If a Signal Generator is to be used for the preliminary tests, adjust the controls to provide an Llnmodulated R.F. signal at about 200 KC, and adjust the 'scope sweep so that two or three complete cycles of the R.F. signal may be observed. Use the maximum output of the Signal Generator.

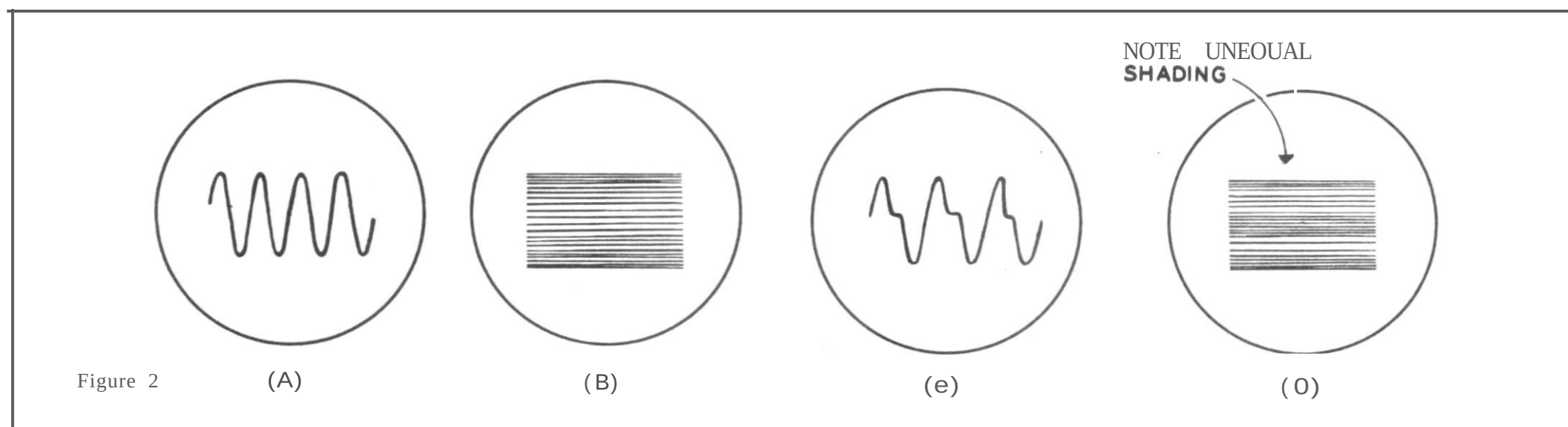
The signal obtained may not be a pure sine-wave (Fig. 2 (a)). This does not indicate that the Signal Generator is defective, however, as many Signal Generators are designed to supply signals rich in harmonics. (NOTE: The presence of harmonics will cause the output signal wave-shape to deviate from the true sine-wave, with the type of distortion depending on the exact harmonics present and their relative amplitudes.)

Now switch the 'scope sweep to a fairly low repetition rate, so that a "rectangle" is obtained on the screen of the CRT, as in Fig. 2 (b). If a pure sine-wave is supplied, the rectangle will have even shading across its height. Should the R.F. signal be distorted, on the other hand, as shown in Fig. 2 (c), the rectangle will be streaked with one or more lighter bands, as in Fig. 2 (d).

This technique is valuable for checking the quality of R.F. signals which are too high in frequency to be observed directly using the built-in sweep of the 'scope.

CHECKING THE FREQUENCY OF R.F. SIGNALS

The frequencies of two R.F. signals may be compared quite easily by means of completed-loop Lissajou figures. A complete discussion of frequency measuring techniques using Lissajou



figures is given in another Heath "Application Notes" bulletin. However, a brief outline of the technique is given below:

The unknown signal is connected to the VERT. INPUT of the 'scope and a standard Signal Generator connected to the HOR. INPUT. The frequency of the Signal Generator is then varied until a stationary single loop pattern is formed (this may be a single slanting line, a circle or an ellipse). The frequency of the Signal Generator is then the same as that of the unknown signal.

When using this technique, care must be taken to adjust the frequency of the standard Signal Generator *very slowly*. Otherwise, it is possible to tune right through the proper frequency without observing the desired pattern.

Due to the response of the 'scope amplifiers, this technique requires a reasonable signal level, and cannot be used at frequencies much above the broadcast band (1500 Kc). However, it is quite satisfactory for checking the frequency of phono oscillators, carrier current transmitters, and R.F. high voltage power supply oscillators.

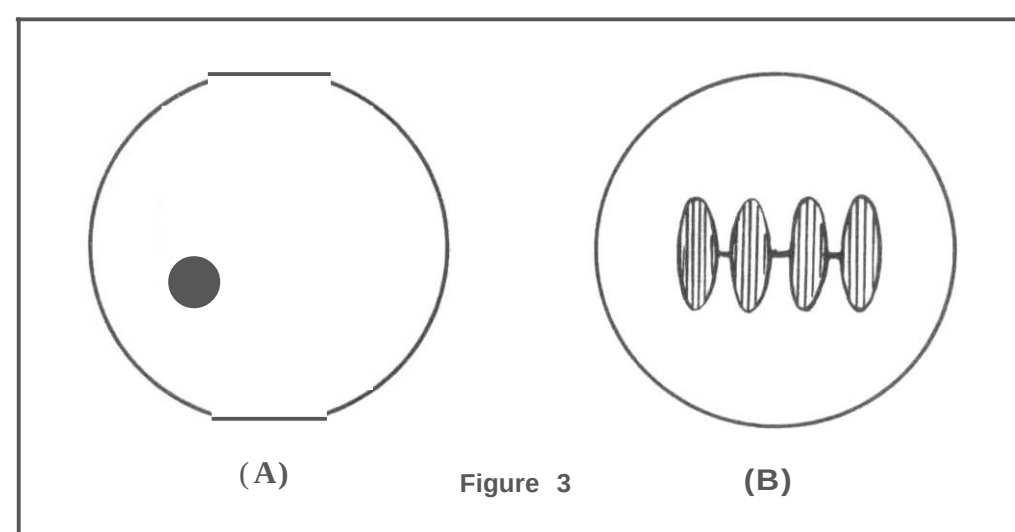


Figure 3

OBSERVING MODULATION PATTERNS

A modulated R.F. signal is generally observed using the built-in linear sweep of the 'scope, with the sweep frequency adjusted to permit observation of the modulation envelope. Since the modulation is generally from 400 to 1000 cps (for an R.F. Signal Generator), the 'scope sweep is set from 100 to 500 cps, depending on the number of modulation envelope cycles to be observed.

To demonstrate the appearance of a modulated R.F. signal, simply switch the Signal Generator controls to supply a MOD. R.F. signal and adjust the sweep controls of the 'scope as indicated above.

With the average R.F. Signal Generator, using from 30% to 50% modulation, the pattern will appear somewhat as shown in Fig. 3 (a). If the modulation exceeds 100%, the pattern will appear as shown in Fig. 3 (b). Overmodulation not only causes severe distortion of the modulating signal (when detected), but where the R.F. oscillator is modulated directly, causes the carrier to shift frequency.

CARRIER HUM

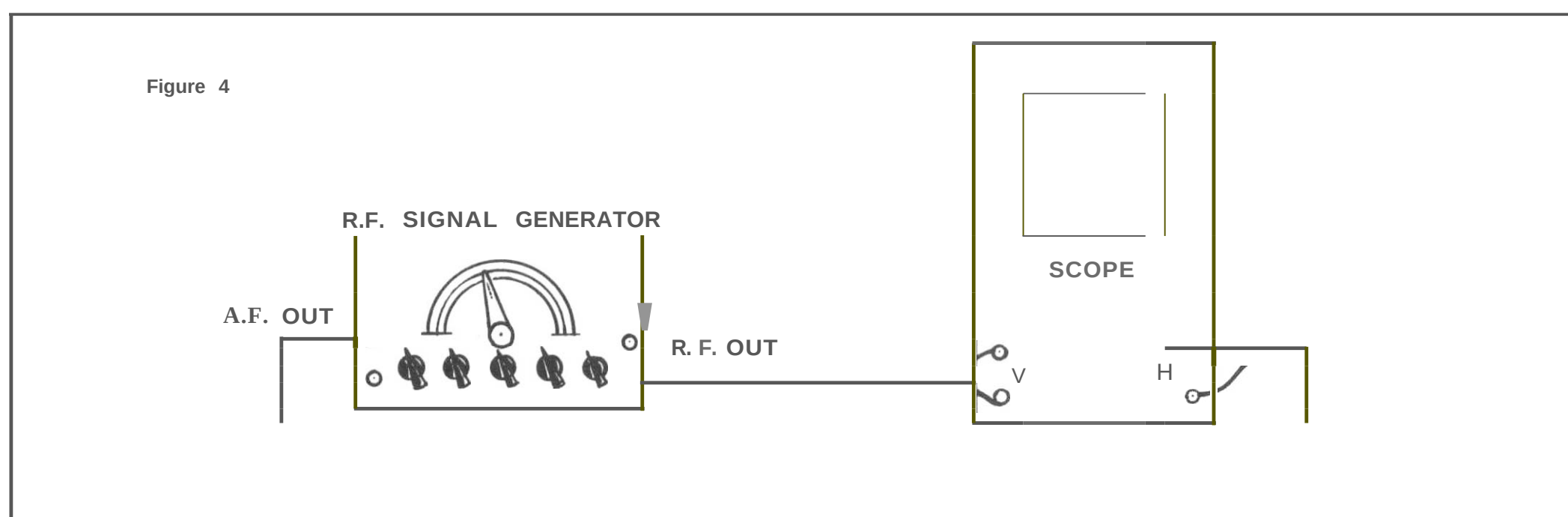
The presence of hum on a carrier R.F. signal may be detected using the technique described above for observing a modulated R.F. pattern. Simply remove the modulation so the carrier is observed alone. With a low frequency horizontal sweep, the R.F. signal should appear as a rectangle, as shown in Fig. 2 (b). If there is hum present, however, a typical modulated R.F. pattern will be obtained, as shown in Fig. 3 (a).

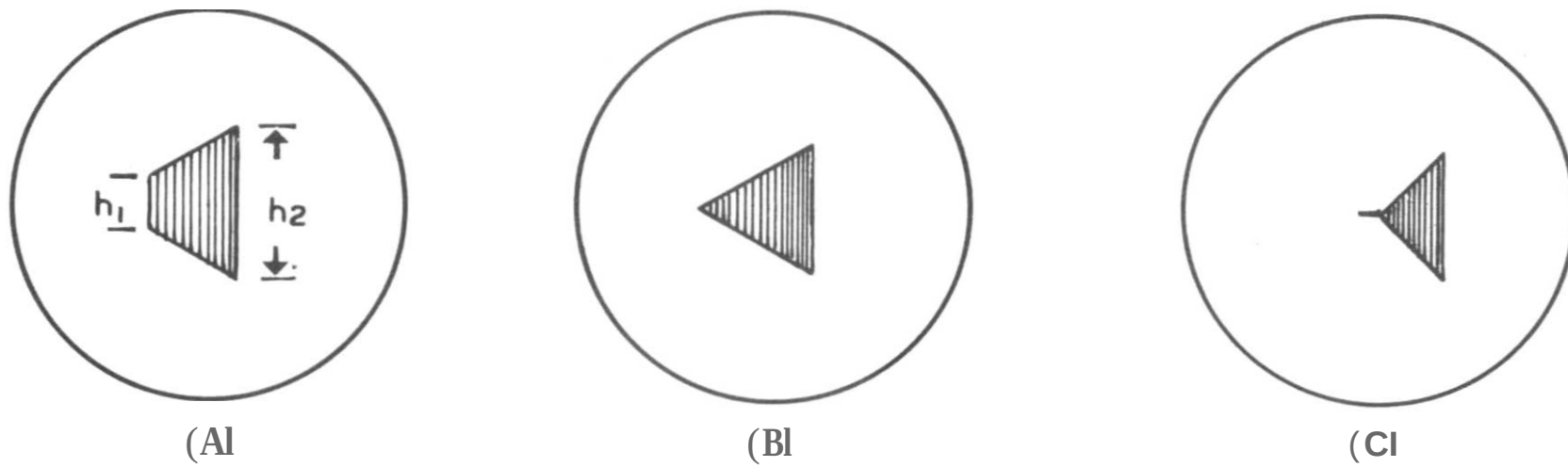
TRAPEZOID PATTERNS

Amateur radio operators ("hams") often use special "monitor" oscilloscopes to check the quality of modulated R.F. signals obtained from their transmitters. A "monitor" 'scope is basically nothing more than a cathode ray tube with appropriate high voltage supply, and positioning, focus, and intensity controls ... sweep amplifiers are generally not provided.

When using a monitor 'scope, hams generally rely on "trapezoidal" patterns for test purposes. A trapezoidal pattern is formed when a modulated R.F. signal is used for vertical deflection and the modulating audio signal used for horizontal deflection. Such a pattern may be demonstrated, using the Heathkit R.F. Signal Generator, with the connections shown in Fig. 4. The R.F. Output lead is connected to the VERT. INPUT terminals of the 'scope, while the AF Out lead is connected to the HOR. INPUT terminals.

The appearance of a typical trapezoidal pattern is given in Fig. 5 (a). As the modulation percentage increases, the pattern becomes more triangular in shape, approaching a





perfect triangle with 100% modulation, as shown in Fig. 5 (b). Overmodulation gives the pattern shown in Fig. 5 (c).

A trapezoidal pattern is useful for determining percentage modulation. The maximum (h_2) and minimum (h_1) heights of the trapezoid are measured, using any convenient units ... the transparent graph scale on the 'scope provides an easy method for measuring the heights. Percentage modulation may then be calculated as follows:

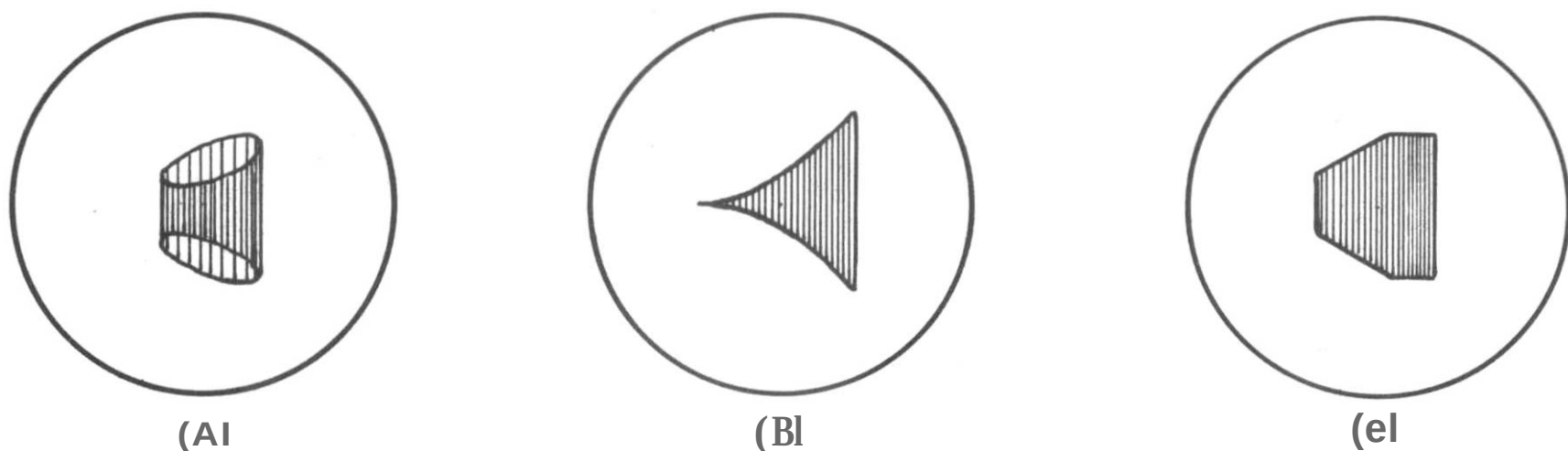
$$\% \text{ Modulation} = (h_2 - h_1 / h_2 + h_1) \times 100.$$

Trapezoidal patterns are also useful for indicating the operational characteristics of R.F. signals obtained from carrier current transmitters, phono oscillators and similar devices. Typical patterns that may be obtained are shown in Fig. 6.

In Fig. 6 (a) is shown the type of pattern obtained with less than 100% modulation, but with phase shift in the audio signal between the point at which the audio signal is taken for 'scope horizontal deflection and the point at which carrier modulation occurs. Such a pattern corresponds, essentially, to the pattern given in Fig. 5 (a). It does not indicate a defect or Improper operation.

In Fig. 6 (b) is given the type of pattern obtained where an improperly operated class C R.F. amplifier is used. Such a pattern may be caused by regeneration, improper neutralization, or excessive bias.

The pattern shown in Fig. 6 (c) may be caused by insufficient R.F. grid drive to a modulated amplifier or a weak amplifier tube. "Saturation" is reached on the modulated peaks, resulting in the flattened appearance.



some applications of the heathkit oscilloscope to audio circuits

BY LAWRENCE FLEMING

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The term "versatile" has been applied to the cathode-ray oscilloscope so often that it has become a cliché. But such time-worn statements usually contain a lot of truth. The oscilloscope is a machine for displaying, in the form of a graph, the relation between any two varying voltages. It can do this about a hundred million times faster than a person can plot a graph by hand, on paper, and about ten thousand times faster than the fastest automatic chart-type recorder. For this reason, it has become the basic instrument in all branches of electronics in which science is concerned with things that happen too quickly for mechanical measuring instruments to follow.

For direct observation, the signals applied to the oscilloscope must be recurrent, repeating themselves continuously at a rate fast enough so that flicker is not objectionable to the eye; 20 times per second or more. Even this limitation can be removed by photography.

In most circuit testing, it is easiest to arrange for the horizontal axis of the graph to represent *time*, by letting the sweep generator in the oscilloscope move the luminous spot across the screen at a constant speed - so many inches per second. By then applying the signal we want to observe to the vertical input terminals, we get a graph showing how this signal varies with time, like the pictures of waveforms in textbooks. The time-base is not the only form of horizontal signal that is easily used and interpreted. Another scheme is to connect the horizontal input of the oscilloscope to the input of the circuit under test, and the vertical input to the output of the circuit under test. The display is then a line showing the relation between the output and input - the transfer characteristic. Circular sweeps, spiral sweeps, and others are used for special purposes.

TYPICAL WAVEFORMS IN AUDIO AMPLIFIERS

In checking the performance of an audio amplifier, the simplest setup is shown in block form in Fig. 1. The source of test signal is desirably an audio generator such as the HEATHKIT Audio Generator, but a 10,000 ohm potentiometer connected across a 6-volt a.c. filament supply will do for many purposes. Across the amplifier output are connected a matched load resistor R and an A.C. VTVM V as well as the vertical input terminals of the oscilloscope. The voltmeter should best be a sensitive electronic meter such as the HEATHKIT A.C. VTVM. For output measurements alone the rectifier-type instrument built into most volt-ohmmeters will do; they are usually flat to 5 kc or so when operated from a low-

impedance source. Moving-iron a.c. voltmeters have very low resistance, around 10 ohms per volt, but can be used on power amplifiers; they are fairly flat to about 2000 cycles. Finally the oscilloscope itself can be used to measure voltage by setting the vertical gain to some convenient value when a known signal is applied, and noting the inches of deflection on the screen per input volt.

Referring to the waveform traces, when a sine-wave a.c. voltage is applied to the amplifier input, the output waveform normally looks like Trace No.1; as the signal level is increased, overloading occurs and the amplifier begins to clip one side of the wave as in Trace No.2. At extreme overload, when the input signal is 5 times the voltage required for normal full output, the amplifier behaves like a square wave generator as in Trace No.3. The frequency in this case is in the middle audio band, 100 to 2000 cycles. The clipping in the amplifier under test occurs in the tubes, by plate-current cutoff and grid-current limiting.

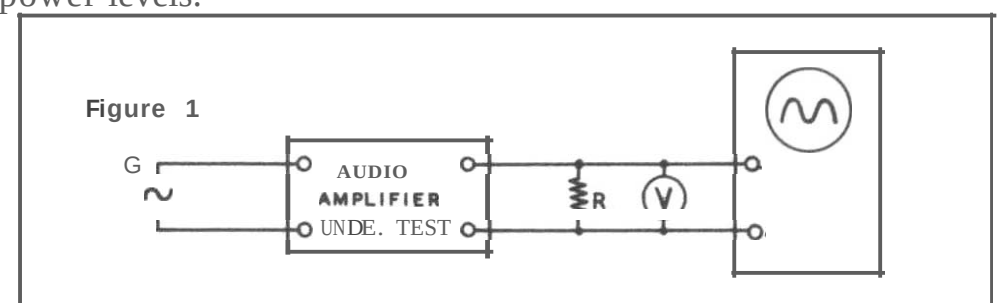
At low frequencies, overloading occurs due to saturation of the core of the output transformer. This produces a wave of the shape shown in trace No.4. With a large output transformer, this type of distortion may not be apparent until the frequency is reduced below 30 or 40 cycles, but with a small transformer saturation distortion may appear as high as 200 cycles.

OUTPUT POWER

Output power of the amplifier is measured by noting the voltage across the load resistor R (Fig. 1) at which distortion of the type of Trace No.2 or Trace No.4 begins to be noticeable. The power in watts is then E^2/R where E is the output

R

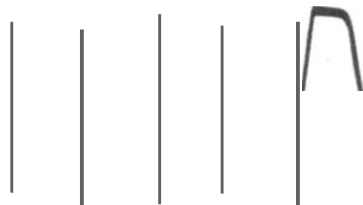
voltage in volts and R the load resistance in ohms. Because the voltage term is squared, a given percent error in measuring the voltage will create twice as large a percent error in the power, hence accuracy is desirable. The maximum power output of most amplifiers falls off more rapidly at extreme low and high frequencies than does the actual gain at moderate power levels.



WAVEFORMS



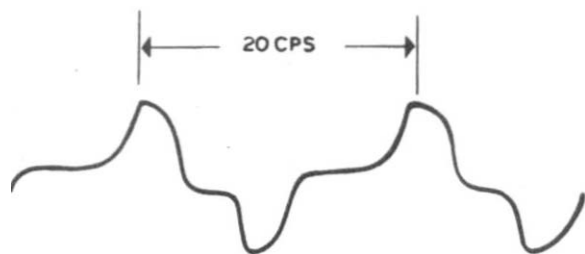
TRACE 1
AUDIO **AMPLIFIER** UNDER TEST-
NORMAL SINE WAVE OUTPUT FROM
VOICE COIL **TERMINALS**.



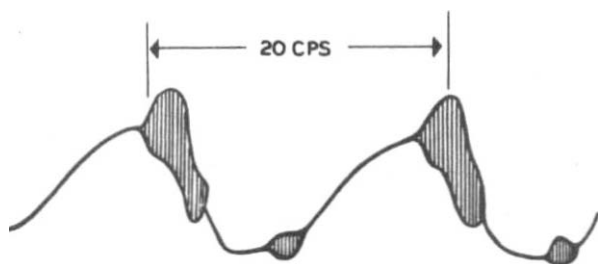
2.
SAME AMPLIFIER-
MODERATE OVERLOAD.



3.
SAME AMPLIFIER-
EXTREME OVERLOAD



4.
TRANSFORMER CORE
DISTORTION.
MAINLY 3RD HARMONIC.



5.
BURSTS OF HIGH-
FREQUENCY OSCILLATION
IN **FEEDBACK** AMPLIFIER.



6.
TRIODE VOLTAGE
AMPLIFIER STAGE,
LARGE SIGNAL **BIAS**
TOO LOW.



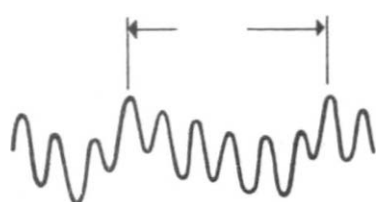
7.
SAME STAGE, **BIAS**
TOO HIGH.



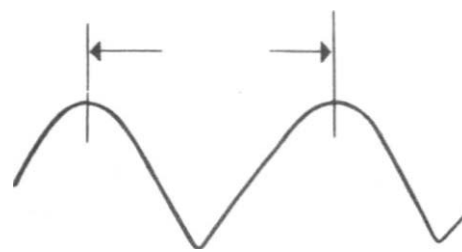
8.
SAME STAGE, **BIAS** OPTIMUM.



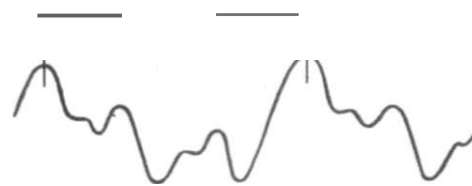
9.
SIGNAL PLUS **HUM**.



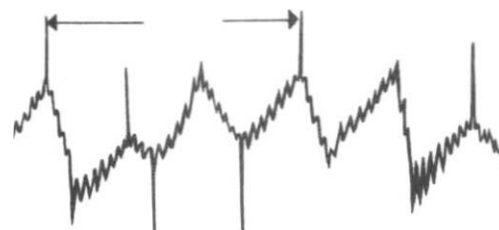
10.
SIGNAL PLUS **HUM**.



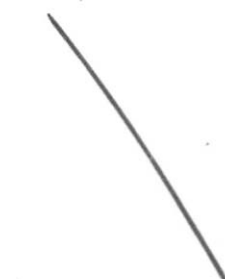
11.
HUM DUE TO **HEATER-**
CATHODE **LEAKAGE** IN TUBE.



12.
INDUCTIVE **HUM** PICKED UP BY
AUDIO **TRANSFORMER** FROM
POWER **TRANSFORMER**.



13.
FLUORESCENT **LAMP**
INTERFERENCE.



14.
X-v TRANSFER CHARACTERISTIC
OF **AMPLIFIER** STAGE OF
FIG. 3 **CORRECT** **BIAS**.



15.
SAME - **BIAS** TOO LOW.



16.
SAME - **BIAS** TOO HIGH.



17.
X-Y TRANSFER CHARACTERISTIC
OF **IN34** CRYSTAL DIODE.



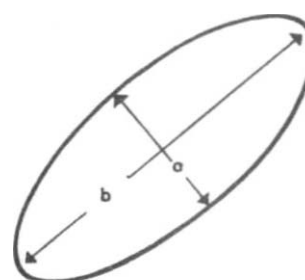
18.
SAME BUT FREQUENCY TOO HIGH.
SHOWING UNDESIRE **PHASE** SHIFT.



19.
PHASE **MEASUREMENT** -
HORIZONTAL SIGNAL ALONE.



20.
VERTICAL **SIGNAL** ALONE.



21.
BOTH SIGNALS TOGETHER.
RATIO OF **AXES** OF **ELLIPSE**
 $\frac{a}{b}$ = **TANGENT** OF HALF THE **PHASE** ANGLE.

FEEDBACK AMPLIFIER OSCILLATION

Negative feedback amplifiers in which the output transformer is included in the feedback loop, are prone to oscillate at high frequencies - 30 to several hundred kilocycles. A wide-band oscilloscope is indispensable in detecting such oscillation. If a continuous oscillation, it is readily noticed on the oscilloscope screen when the input signal is turned off. Sometimes the application of an audio input signal will nearly kill the oscillation, leaving only a slight fuzziness on the peaks of the waves as an indication of trouble. Such oscillation can ruin the listening quality of an amplifier, making it sound fuzzy and rough even though the oscillation frequency is inaudible. It does this by shifting the effective bias on the tubes.

Frequently the oscillation only shows up in the presence of a low-frequency signal. A typical wave of this sort is Trace No. 5. Bursts of high-frequency are superimposed on the audio-frequency wave. Often this phenomenon appears only under overload conditions at very low frequencies, 20 cycles or so. The safest remedy is to reduce the amount of negative feedback. The next most common remedy is to shunt a few hundred mmf of capacitance across the plate circuits of the output tubes. The subject of feedback stability is too large to treat here save from the viewpoint of the oscilloscope's role in detecting instability.

FINDING OPERATING CONDITIONS FOR TUBES

To find the right value of bias resistor for a tube type or plate load or "B" voltage which is not listed in tube manual tables, the oscilloscope is used to detect limiting distortion as in Fig. 2. The bias resistor is made variable. The input signal should be rather large, such that the rms Output voltage will be of the order of 15 percent of the "B" supply voltage. If the bias resistor is too low, grid-current limiting will show up as in Trace No. 6. If too large, plate current cutoff will appear similarly but in opposite phase, as in Trace No. 7. Optimum bias will show up as in Trace No. 8, an undistorted sine wave. All these three traces were taken at the same gain setting, illustrating the fact that the gain of a stage is usually at a maximum when it is biased for lowest distortion.

Any convenient signal frequency can be used, e.g. 60 cycles.

The 100K series grid resistor in Fig. 2 is necessary to simulate actual operating conditions. If it is omitted, the distortion will not show up on this test when bias is too low, but it will appear in actual use of the circuit, unless the signal source happens to have a very low impedance.

The optimum bias point generally corresponds quite closely to a value of plate current that produces a d.c. voltage drop across the tube of about 60% of the plate supply voltage, ex-

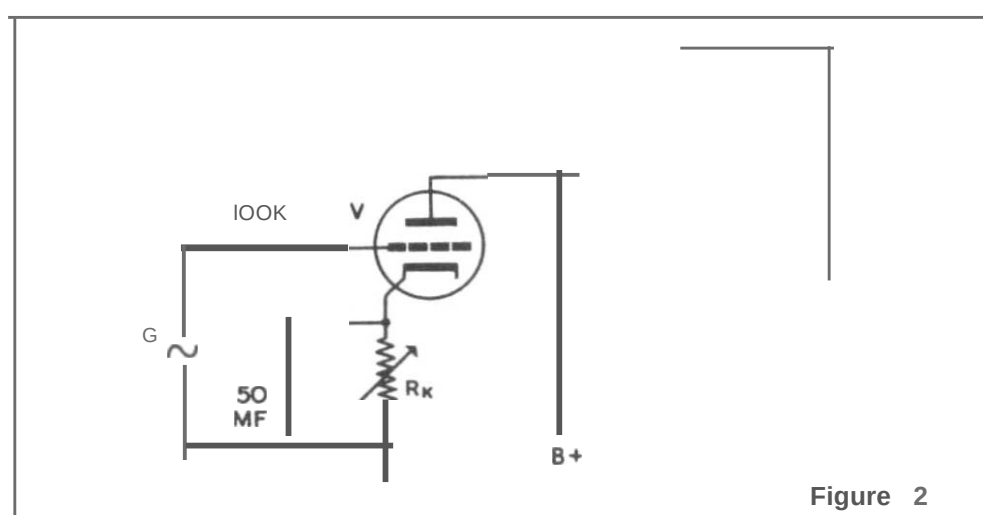
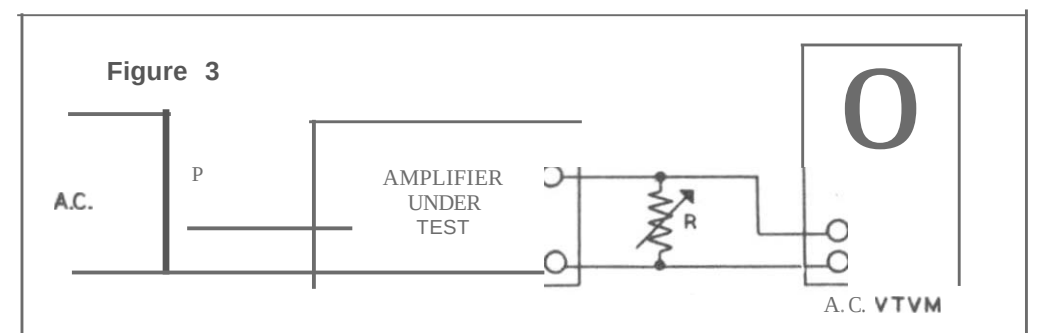


Figure 2

cept when the plate supply voltage is lower than about 200 volts. Thus a good approximation of correct bias can be found by merely connecting a HEATHKIT d.c. vacuum-tube voltmeter from the plate of the tube to ground.

The distortion illustrated in Traces No. 6 and No. 7 is typical second harmonic (cf. Trace No. 4). Pentode voltage amplifiers also generate principally second harmonic distortion when overloaded.

Pentode operating conditions can be determined by the same setup of Fig. 2. Both cathode and screen resistors should be made variable. The procedure is to adjust the cathode bias to the lowest value that avoids grid-current limiting at the highest desired signal level; then adjust the screen resistor to give maximum gain. Cathode d.c. bias should be ordinarily between 1.2 and 2 volts, and the nearest appropriate tube manual resistance-coupled amplifier data used as a starting point.



The "X-Y" type of oscilloscope display can also be used profitably in finding bias and other tube operating constants, and is discussed in a later section.

HUM IN AUDIO CIRCUITS

A sine-wave audio signal contaminated by hum shows the typical oscilloscope pattern of two different frequencies added together, and generally looks like Traces No. 9 or 10. Since the sweep cannot be synchronized to both the signal and the hum frequency, only one component of the pattern can be made to hold still; the other moves.

If the signal is turned off and the hum observed alone on the oscilloscope, the hum waveform offers a clue to the cause. If the hum frequency is 60 cycles, it is not coming from the insufficiently filtered output of a full-wave rectified "B" supply. If the frequency is 120 cycles and the hum waveform is comparatively pure, it probably is due to inadequate "B" supply filtering. This can be checked by temporarily adding an extra large filter capacitor.

Hum due to heater-cathode leakage in low-level audio amplifier stages is usually 60 cycles, and looks like Trace No. 11. To reduce the hum, the cathode should be bypassed with about 50 mfd.

Hum picked up inductively by audio input or other transformers is very rich in harmonics but free from sharp corners or peaks, as in Trace No. 12.

Fluorescent lamp interference is full of very sharp "spikes" and high-frequency hash, as illustrated in Trace No. 13.

To tell quickly whether the frequency observed is 60 or 120 cycles, disconnect the input to the oscilloscope vertical input and touch the input terminal with the finger. The signal thus picked up is 60 cycles.

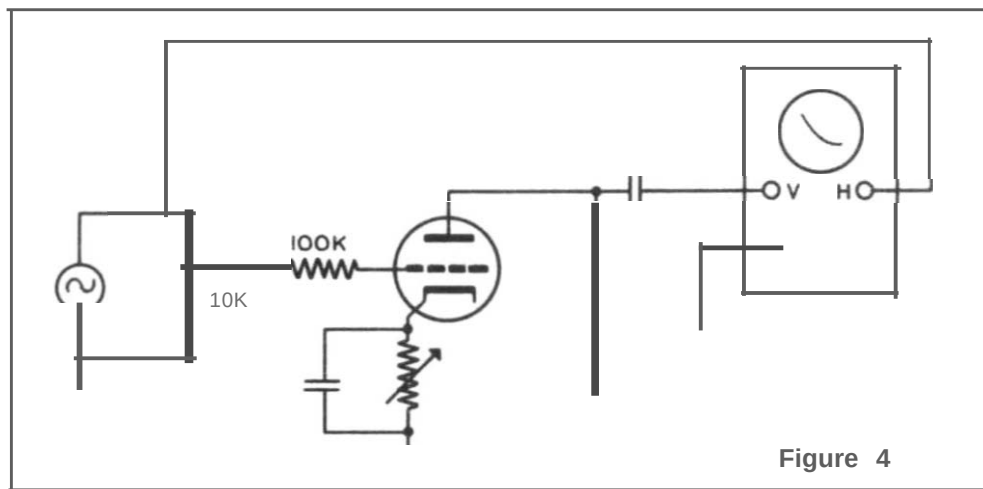


Figure 4

x·y GRAPHS WITH THE OSCILLOSCOPE

Instead of using the sweep circuit built in the oscilloscope, an external signal can be fed into the horizontal amplifier. A display very useful in audio work is produced when the horizontal input is taken directly from the signal source, and the vertical input is taken from the output of some circuit under test, which is fed from the same signal source. Fig. 4 shows a resistance-coupled amplifier stage under test, similarly to Fig. 2 except that it is arranged for an X-Y display. The line appearing on the oscilloscope screen shows the relationship between the input signal and the output signal of the test circuit. When the bias is correct on the tube in Fig. 4, the graph is a straight line, Trace No. 14. When the bias is too low, the curvature of the transfer characteristic is clearly shown in Trace No. 15. Too-high bias gives curvature on the other end, Trace No. 16. This type of display is a more sensitive indication of non-linear distortion than the conventional time-base display..

An audio generator is necessary as a signal source here, because it is necessary to use a frequency at which the phase shift of the test circuit is nearly zero. There is always such a frequency, and it is usually between 200 and 1000 cycles.

Trace No. 17 shows the transfer characteristic of a crystal diode in the circuit of Fig. 5. Trace No. 18 illustrates the degradation of the display by undesired phase shift, in this case due to using a test signal frequency that is too high.

PHASE MEASUREMENT

When two sinusoidal voltages of the same frequency are applied to an oscilloscope, one to each set of deflection plates, the figure on the screen is either a straight line, a circle, or an ellipse. If the two voltages are not derived from the same source, the figure moves; if they are, it stands still.

Fig. 6 shows the general circuit for measuring phase. The circuit in the block can be an amplifier stage, an R-C network,

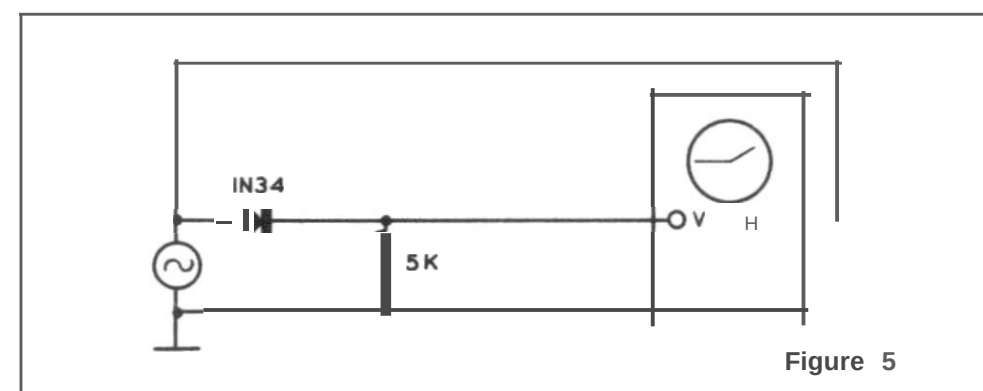


Figure 5

a whole audio amplifier, or practically anything. Phase shift is practically always associated with any deviation from flat frequency response - always in ordinary circuits. Phase shift is detectable before the droop in frequency response can be measured, in nearly all cases.

If the input and output of the test circuit are exactly in phase, the oscilloscope display will be an inclined straight line, similar to Trace No. 14. The direction of inclination will depend on whether or not phase inversion occurs in the test circuit (In Fig. 3, it did).

To measure the phase angle, take the following steps: (1) disconnect the vertical input and adjust the horizontal gain to a value that gives a line on the screen of convenient length; (2) disconnect the horizontal input and adjust the vertical gain to give a vertical line of the same length; (3) reconnect the horizontal gain and measure the length of each axis a and b of the elliptical figure. The phase angle is given by the formula

$$\frac{b}{a} = \tan \frac{1}{2} \phi$$

A table is appended. If the phase angle is 90° , the display will be a circle. For phase angles greater than 90° , the circle thins down into an ellipse again, but with its major (longer) axis inclined the Other way.

Since a slope in gain or transmission loss is nearly always associated with phase shift, it is necessary to readjust the vertical gain to give equal vertical and horizontal deflections on the screen, whenever the frequency is changed.

PHASE ANGLE TABLE

Phase angle ϕ	Ellipse axis ratio $\frac{a}{b}$
	$(= \tan \frac{\phi}{2})$
ϕ	ϕ
5°	.044
10°	.087
15°	.132
20°	.176
30°	.268
40°	.367
50°	.466
60°	.577
70°	.700
80°	.839
90°	1.

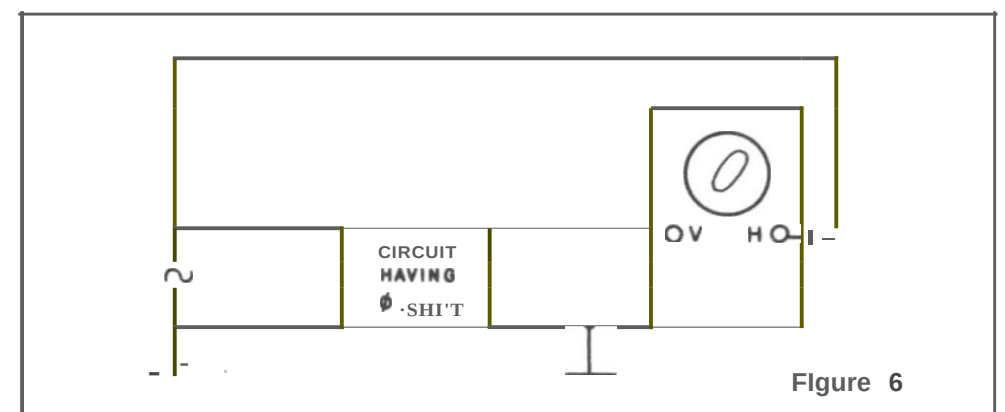


Figure 6

study of r-c oscillator circuits with an oscilloscope

BY LOUIS E. GARNER, JR.

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Most Audio Oscillators can be grouped into one of three major classes: L-C oscillators, Beat Frequency oscillators (BFO), and R-C oscillators. The names of the different classes indicate the method used for frequency determination (tuning).

L-C audio oscillators use a tuned circuit made up of an inductance and a capacity which are generally large and bulky because of the low frequencies involved. Where these oscillators are used in equipment design, they are usually adjusted to a single fixed frequency. This is necessary because of the difficulty of providing variable inductances (or condensers) of large electrical size. L-C audio oscillators may use any of a number of standard circuit arrangements . . . Hartley, Colpitts, "tickler" feedback, etc.

Beat Frequency audio oscillators actually consist of two R.F. oscillators, one fixed and one variable in frequency. The output of the two oscillators are combined in a mixer circuit and the difference or "beat" frequency provides the audio signal. Although this type of circuit is quite popular, and is often used in the design of test equipment, it requires careful engineering. Extreme stability is mandatory in the R.F. oscillators used and, often, is not too easy to obtain. Special care must be taken in layout and circuit arrangement as well as in the choice of electrical components if the completed design is not to suffer from excessive frequency drift.

By far the most popular of the various classes of audio oscillators for all-around use, and especially where a variable frequency range is needed, are the R-C or "resistance-tuned" oscillators. Of the several types of R-C oscillator circuits that have been used, three of the most popular are . . . (a) the Phase-Shift oscillator; (b) the "Wien Bridge" oscillator; (c) the Transitron oscillator.

These three oscillators may be easily assembled by the technician or student and considerable knowledge concerning their operational characteristics gained by performing experimental tests.

ASSEMBLY AND WIRING HINTS

As with the circuits described in previous Bulletins in this series, "breadboard" type construction is recommended to simplify wiring, parts changes, and tests. A separate power supply should be provided. For more detailed construction sugges-

tions, refer to previous Heath "Basic Circuit" Bulletins and specifically to BREADBOARD DESIGN TECHNIQUES.

SUGGESTED TESTS

In each case, your Heathkit Oscilloscope should be used to observe signal waveforms in various parts of the circuit. In addition, d.c. voltage and current measurements may be taken; including a check of plate and screen-grid voltages, plate current, bias voltages, etc.

The frequency of operation and the peak-to-peak output signal amplitude may be checked and these values recorded with the circuit constants to serve as a guide in future experimental work. If the Heathkit Audio Frequency Meter is available to the reader, it may be left connected in each circuit while tests are performed to keep a "running check" on frequency.

SUGGESTED EXPERIMENTS

In each case, the experimenter should wire the circuit described and should carry out the general tests suggested above. Afterwards, parts values and d.c. operating voltages may be changed and any differences in operation noted.

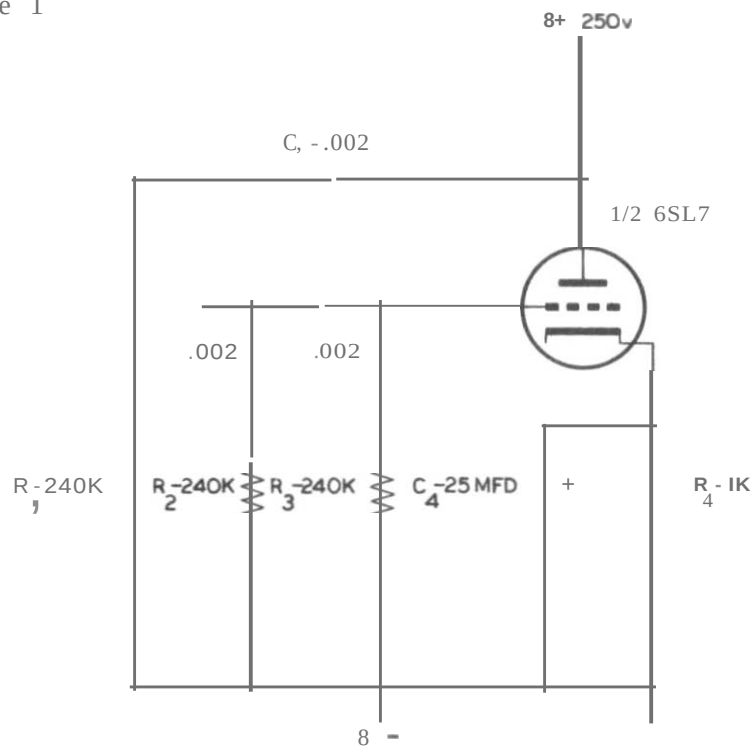
THE PHASE-SHIFT OSCILLATOR

Probably the simplest of the R-C circuits, both from a wiring and an operational viewpoint, is the Phase-Shift oscillator. An experimental circuit suitable for studying the basic characteristics of this oscillator is given in Fig. 1. The tube is $\frac{1}{2}$ of a 6SL7, but many other tubes are suitable . . . $\frac{1}{2}$ of a 12AT7, triode section of a 6SQ7, a 6SF5, or any similar high-mu triode may be used.

An oscillator may be considered as an amplifier in which part of the output signal is fed back to the input with the proper phase relationship to reinforce itself. In the "phase-shift" oscillator, an ordinary single-stage amplifier is used and the signal obtained from the plate circuit is shifted in phase by approximately 180° and applied back to the grid. This is accomplished by a network consisting of three R-C sections, each of which shifts the signal phase by approximately 60° .

(NOTE: In a normal amplifier, the signal in the plate circuit is 180° out-of-phase with the grid signal. A shift of 180° brings the signal "in-phase" with the grid signal, thus permitting oscillation to take place.)

Figure 1



In the circuit given in Fig. 1, this phase-shifting network consists of C_1-R_1 , C_2-R_2 , and C_3-R_3 . Other components in this circuit are the cathode resistor (R_1) with its by-pass condenser (C_4), and the plate load resistor R_L . R_1 and C_4 , together, provide bias for normal operation.

In order for the circuit to oscillate, sufficient signal must be fed back to the grid to overcome circuit losses. This, in turn, means that the tube must provide a certain minimum gain. It has been determined that a gain of around 30 is the minimum necessary to insure operation. Where this much gain is required, it is almost mandatory that several conditions be met, as follows: (1) A high mu tube should be used; (2) the plate load resistor (R_L) must be large enough to utilize a good portion of this potential gain; (3) any loading across R_L must be small so as not to reduce the effective value of this resistor.

Since R_1 , R_2 and R_3 are essentially shunted across R_L as far as a.c. signals are concerned, it follows that these resistors should be appreciably larger than R_L . This means that for a given value of these resistors, R_L must fall within a comparatively narrow range of values . . . large enough to obtain reasonable gain, yet not so large as to permit the phase-shift resistors to act as effective loads. This may be demonstrated by connecting the Heathkit *Resistance Substitution Box* for R_L and experimentally varying the value over a range while the circuit is operating. With the plate voltage and other circuit values as given in Fig. 1, it was found that the circuit oscillated very nicely with R_L at 68K, but that it dropped out of oscillation at 220K and 22K.

(NOTE: When wiring this circuit, it is suggested that one side of the filament supply be connected to circuit ground to minimize hum pick-up.)

With the values given, and R_L at 68K, the output signal closely approached a sine-wave in general form. The measured frequency was 84 cps, with a peak-to-peak amplitude of approximately 50 volts (measured between plate and cathode).

In practical design work, R_1 , R_2 , and R_3 are generally made the same value, as are C_1 , C_2 , and C_3 . Under these conditions, the frequency of operation is determined using the following formula ("R" and "C" in this formula are the values for one resistor and one condenser, respectively, in the phase-shifting network) :

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

The actual frequency will differ somewhat from the calculated value due to parts tolerances.

THE WIEN BRIDGE OSCILLATOR

In the "Wien Bridge" oscillator shown in Fig. 2, a two-stage amplifier is used to obtain a feedback signal having the desired inphase characteristic to sustain oscillation. The R-C networks (R_1C_1 and R_2C_2) are used to insure that this feedback signal has exactly the desired phase relationships *at only one frequency*, and thus act primarily to maintain the frequency of operation.

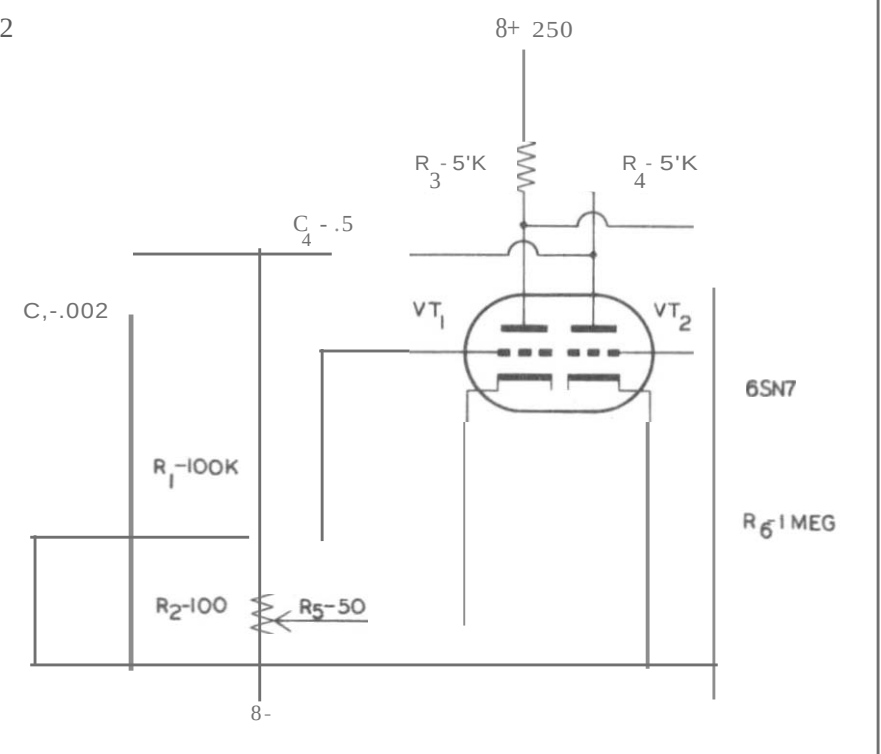
In the circuit shown, a potentiometer (R_1) is used to form one side of the bridge circuit (R_1C_1 and R_2C_2 form the other side) and adjustment of this resistor determines the frequency of operation as well as the signal wave-shape.

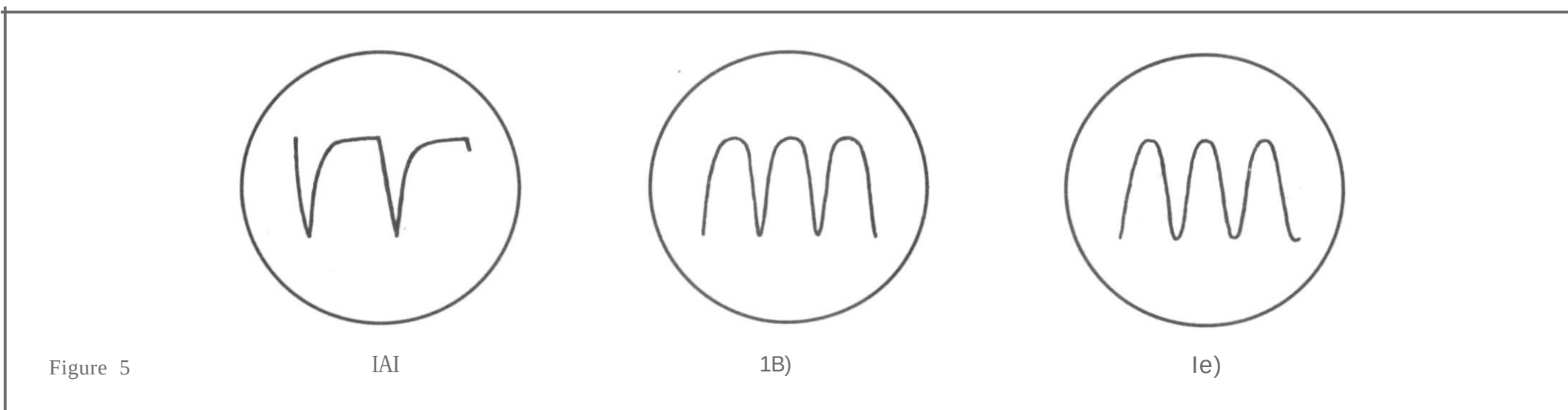
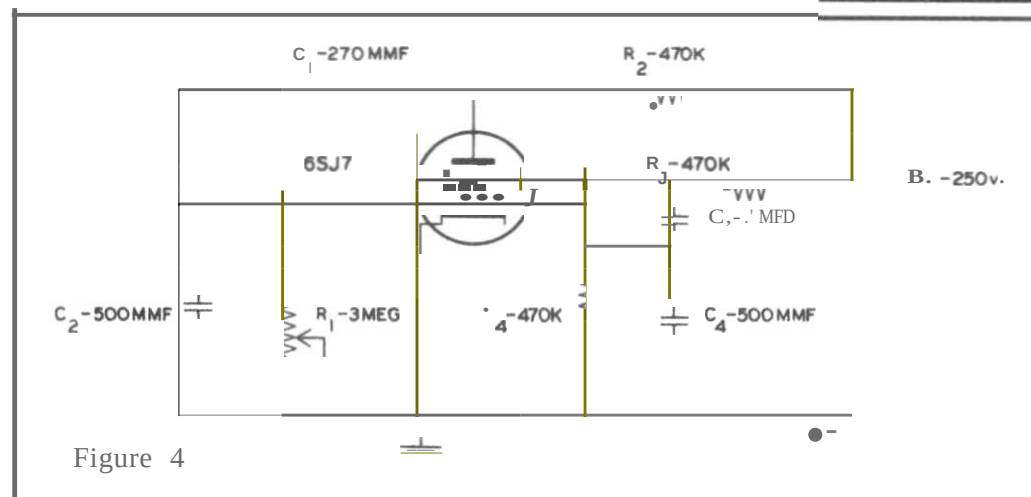
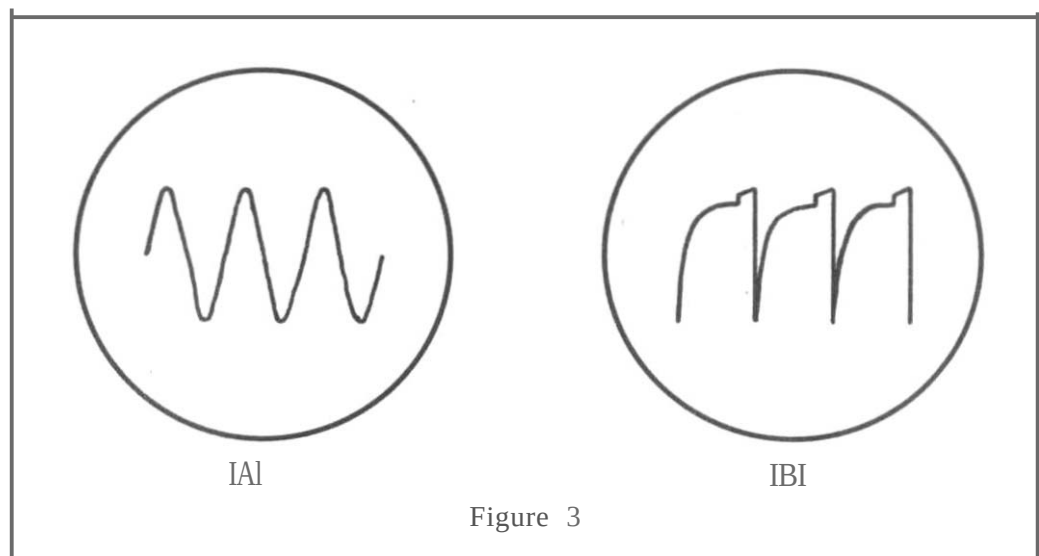
Most of the commercial versions of this circuit, as are used in test equipment design, utilize a tungsten lamp filament as the cathode resistor for the first tube between the center arm of R_1 and ground in Fig. 2). The lamp filament has the proper temperature-resistance characteristic to insure class A operation as the operating frequency is changed, thus maintaining a good sine-wave output signal.

Under "normal" conditions of oscillation, where the output closely approaches a sine-wave, and assuming that the resistors and condensers in the R-C network are of equal value (that is, $R_1=R_2$, and $C_1=C_2$), the frequency of operation is given by the following formula:

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

Figure 2





R and C are the values for a single resistor and condenser in the bridge circuit.

However, with the circuit given in Fig. 2, the setting of R' plays a large part in determining frequency as well as signal wave-shape. With R' set to produce a frequency of about 325 cps, the waveform approaches a sine-wave, as shown in Fig. 3 (a). Peak-to-peak amplitude, in this case, is about 7 volts. When R' is set to supply a signal at about 90 cps, the signal amplitude goes up considerably (exceeding 100 volts), but the wave-shape departs appreciably from the sine-wave form, as shown in Fig. 3 (b).

THE TRANSITRON OSCILLATOR

The "transitron" oscillator utilizes the *negative resistance* characteristic of a tetrode amplifier to sustain oscillation. A suitable experimental circuit for operation at audio frequencies is given in Fig. 4.

Almost all the components in this circuit have some effect on the frequency of operation, but the primary determining

factors are C^1 , C^2 and R^1 . By using a 3 Megohm potentiometer for R' with all other components as shown, a range of from about 18 cps to 14,000 cps may be covered, with the output signal (measured across R') varying from about 50 volts at 14 Kc to over 150 volts at 18 cps (all voltages are peak-to-peak).

Unfortunately, the output signal waveform with this particular circuit is not quite as good as those obtained with the two previous R-C oscillator circuits discussed. Referring to Fig. 5, the signal waveforms shown in Figs. 5 (a), 5 (b) and 5 (c) were obtained at 50 cps, 5 Kc, and 14 Kc respectively. An approach to a sine-wave is made only at the higher frequencies and, even here, the signal waveform is still somewhat distorted.

For this reason, the "transitron" R-C audio oscillator is more often used in applications where the signal waveform is not too important and a sine-wave is not required. One such application is as a code practice oscillator.

relaxation oscillator circuits with the oscilloscope and power supply

BY LOUIS E. GARNER, JR.

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A "Relaxation Oscillator" is one which the frequency of operation is determined primarily by the charge and discharge of a condenser in a simple R-C network, rather than by the relative impedances of resistors and condensers, (as in R-C Oscillators) or by an L-C tuned circuit (as in conventional oscillators ... Hartley, Colpitts, etc.). With this general definition, multivibrator circuits form one of the most important classes of Relaxation Oscillators. However, because of the large number of multivibrator circuits available and their varied application, these have been discussed separately (see Heath Bulletins PLATE-COUPLED MULTIVIBRATORS and CATHODE-COUPLED MULTIVIBRATORS). Here, we will be concerned primarily with other types of Relaxation Oscillators which the experimenter and technician may assemble and study, using his Heathkit equipment as training aids.

The fundamental principle of operation of Relaxation Oscillators may best be understood by considering the simple series R-C network connected to a d.c. voltage source, as shown in Fig. 1 (a).

When SW_1 is closed, condenser C starts to charge slowly through R, and the voltage across C (as measured with voltmeter "V") will gradually increase. The length of time required for the voltage across C to reach a specific value depends on the applied d.c. voltage, the resistance, and the size of the condenser. The time required for this voltage to reach equal to 63% of the applied d.c. voltage is known as the "time constant" of the circuit and is equal to the product of the capacity and the resistance. If the resistance value is in megohms and the capacity in microfarads, the time calculated in this fashion will be in seconds.

Condenser voltage after the closing of SW_1 may be plotted against time and gives the general type of curve shown in Fig. 1 (b). If the condenser is "perfect", the voltage across it will theoretically never equal the supply voltage. From a practical viewpoint, however, the condenser voltage approaches so closely to the supply voltage as to be considered equal to it.

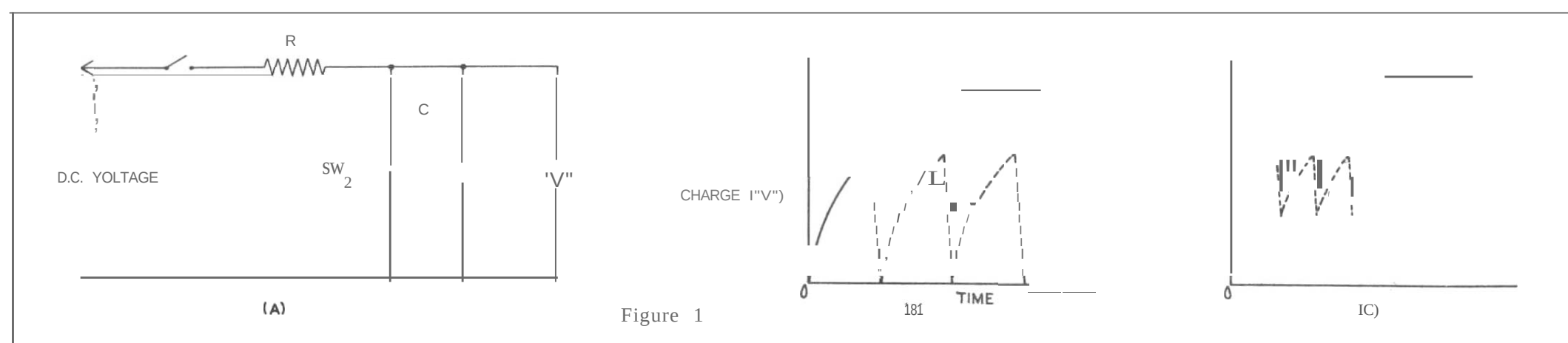
If SW_2 should be closed at some time after C starts to charge, the condenser will be discharged very quickly, as shown by the dotted line in Fig. 1 (b). Thus, SW_2 , when closed, acts as a practical short circuit across C. Should SW_2 be opened after the condenser voltage has dropped to zero, the condenser will then start to charge again. Repeated opening and closing of SW_1 will result in a series of saw-tooth cycles, as shown in Fig. 1 (b).

The same type of signal, but of lower amplitude, may be obtained by opening SW_1 before the condenser voltage drops to zero, as shown in Fig. 1 (c).

Almost all practical relaxation oscillator circuits work on exactly this principle, but with SW_2 replaced by an electronic circuit which accomplishes the same action.

NEON BULB RELAXATION OSCILLATOR

The simplest of Relaxation Oscillators may be formed by connecting a neon bulb across the condenser in place of SW_2 , as shown in Fig. 2 (a). Suitable bulbs are types NE-2 and NE-51, available from most Radio Parts distributors. A .01 mfd condenser may be used for C (although other sizes are also suitable), and the Heathkit Resistance Substitution Box used for R.



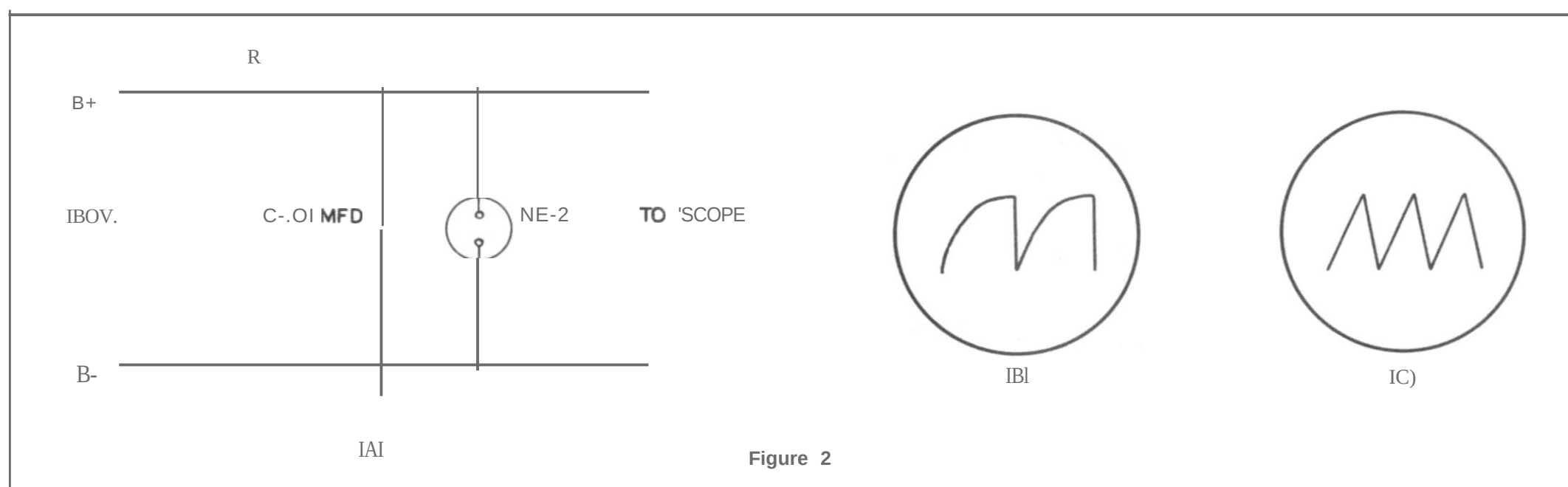


Figure 2

All connecting leads should be kept as short as possible, and it may even be necessary to use a shielded lead to the 'scope to avoid hum pick-up. The Heathkit *Laboratory Power Supply* may be used as the B supply or, if preferred, "B" batteries may be used. If batteries are used, their life will be almost equal to "shelf" life as the current requirement, for this type of circuit, is negligible.

With a B supply voltage of 180, C at .01 mfd, and R at 10 Megohms, the frequency of oscillation will be low enough for the individual pulsations to be observed each time the neon bulb discharges the condenser ... the neon bulb will actually "blink". The signal waveform, as observed on the Heathkit *Oscilloscope* will appear somewhat as shown in Fig. 2 (b).

When the value of R is dropped to 1.5 megohms, other values remaining as above, the signal wave-shape will approach a linear saw-tooth in general form, as shown in Fig. 2 (c). The frequency of oscillation will increase above the "flicker" rate for the eye, so that the neon bulb appears to glow continuously.

Other values of both R and C should be tried, and the signal waveform and frequency checked. In addition, if the *Laboratory Power Supply* is used as a power source, different B voltages may be tried, and the results noted.

As the B voltage is increased, the frequency of oscillation will also increase until the neon bulb is no longer able to discharge the condenser below its own extinction voltage rapidly enough. At this point, the neon bulb will glow continuously and oscillations will cease.

AN INTERLOCKED RELAXATION CIRCUIT

The **relaxation** oscillator circuit shown in Fig. 3 actually consists of two separate oscillators "locked" together so that only one bulb fires at a time. As in the previous circuit, type NE-51 or NE-2 bulbs are satisfactory.

This circuit is often used for novel experiments and attention getting displays as it provides an extremely interesting effect ... V, glows first, goes out, then V, glows, goes out, then V, glows, and so on.

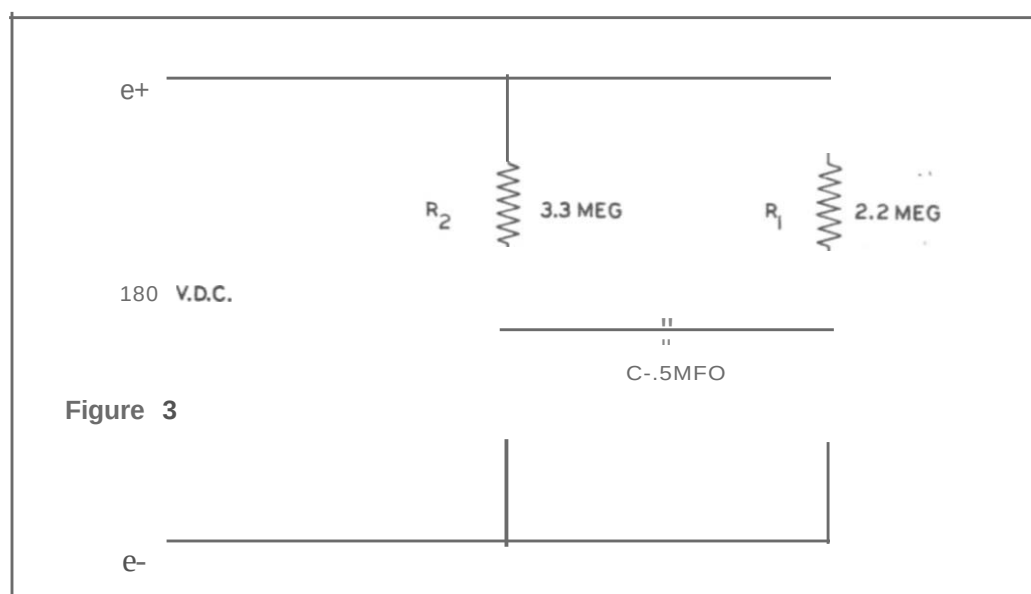
In operation V, fires first, allowing condenser C to charge until V, fires. When V² fires, it effectively short-circuits V¹ dropping the voltage across this bulb below its extinction value (when charged, condenser C can act as a short-circuit between the two neon bulbs). As soon as condenser C has discharged sufficiently, V² goes out, and the entire action is repeated.

A THYRATRON RELAXATION OSCILLATOR

Earlier cathode-ray oscilloscopes (and a number of present-day 'scopes, for that matter) employed a thyratron (gas-filled triode) tube in a relaxation oscillator circuit to supply the linear saw-tooth signal used for horizontal sweep. The basic circuit is illustrated in Fig. 4 (a).

The frequency of operation of this circuit depends primarily on the time constant of the R³-C³ combination (assuming the B supply voltage to be held constant). Bias is provided by cathode resistor R², together with its by-pass condenser, C².

In operation, C³ is charged slowly through R' until V, "fires". When this occurs, C³ is discharged rapidly until the plate voltage of the tube drops below the value necessary to keep the tube conducting. At this point, current flow stops and C³ starts to charge slowly again. The action is then repeated in the same fashion.



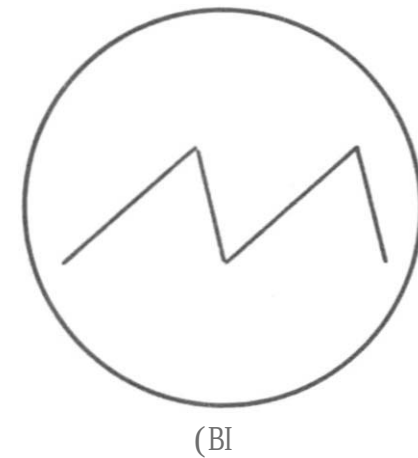
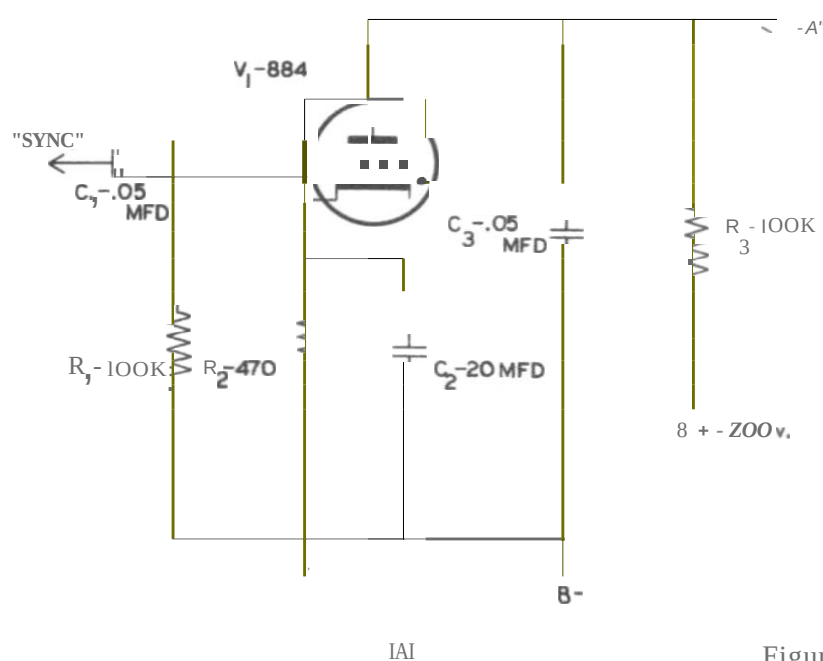


Figure 4

If a small positive signal is applied to the grid of the tube just before the tube is ready to "fire", it can act to initiate the action, and thus serves to *lock-in* or *sync* the oscillator with an external signal. An external "sync" signal is applied through C_1 .

With the values given in Fig. 4 (a), an excellent sawtooth signal is obtained, as shown in Fig. 4 (b). The signal amplitude is approximately 9 volts peak-to-peak, while the operating frequency is approximately 3 Kc.

In practical test equipment circuits, the lower end of C_3 is generally returned to the cathode of the tube, providing a faster retrace or "fly-back" time. Several values of C_3 may be provided, chosen by a selector switch which acts as a "Coarse Frequency" control. R' generally consists of a fixed series resistor together with a potentiometer, which acts as the "Fine Frequency" or "Vernier" control. Finally, a pot. is used in place of a fixed resistor for R_1 , and serves as a "Sync level" control.

BLOCKING OSCILLATOR

The "Tickler Feedback" oscillator (discussed in another Heath Bulletin) may be modified to serve as a Relaxation oscillator. A suitable circuit is given in Fig. 5. T' is a standard interstage plate-to-grid transformer having a 1:3 ratio. R_2 - C_2 forms the familiar resistor-condenser circuit common to all relaxation oscillators.

In this circuit, both the R_1 - C_1 and the R_2 - C_2 combinations affect the operating frequency. With the values shown, the frequency of operation was about 160 cps. The Output signal, as observed at point "A", was a reasonably good sawtooth having an amplitude of about 20 volts peak-to-peak.

When R' was changed to 47K, the frequency of operation dropped to about 110 cps.

Although a considerable control over operating frequency may be exercised by adjusting R_1 - C_1 and R_2 - C_2 , this particular circuit does not lend itself well to operation over wide ranges of frequency . . . at least as far as producing an acceptable saw-tooth is concerned. Because of this, the "blocking oscil-

lator" relaxation circuit is generally employed where a fixed frequency oscillator is needed, and either thyatron or multi-vibrator circuits used where a wide frequency range is to be covered.

Almost any basic oscillator circuit (Hartley, Colpitts, etc.) may be used as a "blocking oscillator" simply by increasing the amount of signal drive and by using a large R-C time constant value in the grid circuit. The addition of the familiar R-C circuit to the plate supply of the tube will then permit the formation of saw-tooth signals.

COMMERCIAL APPLICATIONS

A typical thyatron relaxation oscillator circuit such as was used in many commercial Oscilloscopes is shown in Fig. 6. The values given in this particular circuit were used in the well known Dumont Model 164-E 3" Oscilloscope. The similarity between the circuit given in Fig. 6 and the "Basic Circuit" studied in Fig. 4 (a) should be readily apparent.

The type 885 tube has similar characteristics to the type 884 except for base connections (the type 884 uses an octal base, and was selected for the experimental set-up to fit in with the suggested "breadboard" layout given in another Heath Bulletin).

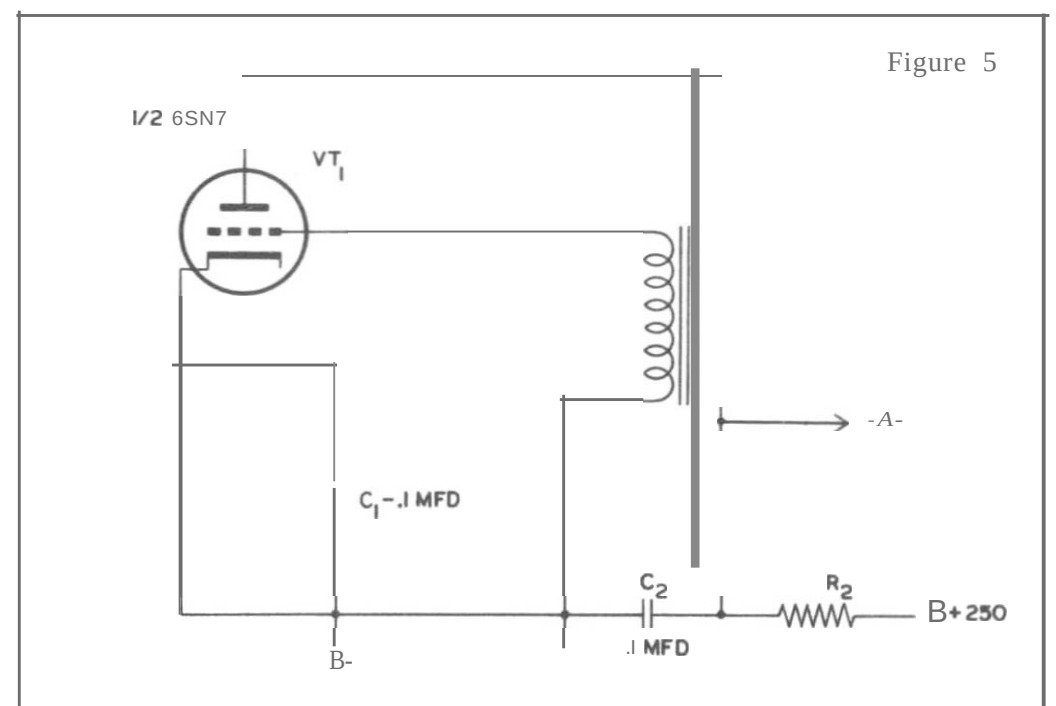
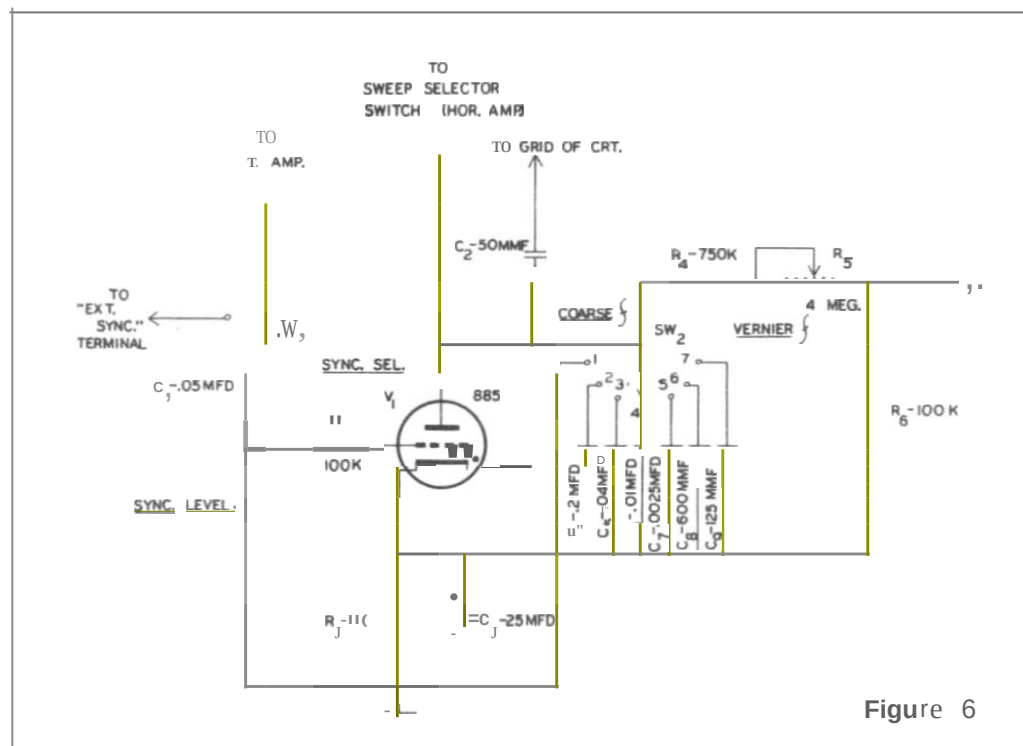


Figure 5



In operation, one of the "discharge" condensers (C_1 to C_6) is charged slowly through the series resistor (R_1 and R_5), then discharged rapidly as V_1 conducts. The lower leads of the "discharge" condensers are returned to the cathode of the tube to provide a faster retrace time.

SW_1 is used to select the proper condenser and acts as a COARSE FREQUENCY control. R_5 , the series resistor, is also variable and acts as a VERNIER FREQUENCY control ... R_1 prevents reducing the series resistance to zero and thus keeps this resistance high enough to sustain oscillation regardless of the setting of R_5 .

With the values shown, the frequency range covered is as follows: SW_1 in position "1"-SWEEP OFF; position "2"-15 to 60 cps; position "3"-60 to 220 cps; position "4"-220 to 900 cps; position "5"-900 to 3,000 cps; position "6"-3,000 to 10,000 cps; position "7"-10,000 to 30,000 cps.

Bias for the stage is provided by cathode resistor R_7 , bypassed by C_7 , and is dependent on the value of this resistor, the average cathode current of the tube, and the "bleeder" current obtained through R_1 .

As we have seen, the operation of this circuit is, in most respects, identical to that of the basic circuit previously described ... however, there are a few additional refinements used to fit this circuit into a Commercial application that require explanation.

First, provision has been made to obtain a "sync" signal from either a separate terminal (EXT SYNC) or from the signal present in the Vertical Amplifier (INT SYNC). The type of "Sync" desired is selected by SYNC SELECTOR switch SW_1 .

Secondly, condenser C_2 permits a portion of the signal appearing on the plate of V_1 to be applied to the grid of the cathode ray tube. Since this condenser has a small value it forms a differentiation circuit with the CRT grid resistor and thus permits a sharp negative pulse to be applied to the CRT during the discharge of the condensers (C_1 to C_6), "blanking" the retrace signal.

study of phase inverter circuits with the scope and power supply

BY LOUIS E. GARNER, JR.

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Wherever a push-pull amplifier is to be used, whether in an Audio amplifier, in a radio transmitter, or in TV and 'scope deflection circuits, it is necessary that signals of equal amplitude but differing in phase by 180° be applied to the grids of the two tubes used. There are several circuits available for accomplishing this action, each having particular advantages and disadvantages.

Your Heathkit Test Equipment may be used advantageously to study various phase-inverter circuits and also to check an existing circuit for proper phase relationships and "balance." Two possible equipment arrangements may be employed, as shown in Figs. 1 and 2.

The technique illustrated in Fig. 1 is preferred, but an *Electronic Switch* is necessary. With this technique, a direct comparison of the two signals is made and a point-by-point check of both phase relationships and signal amplitude is possible.

However, when an *Electronic Switch* is not available, the technique shown in Fig. 2 may be employed. When this method is used, the relative signal wave-shapes must be remembered as SW' is thrown from position 1 to position 2.

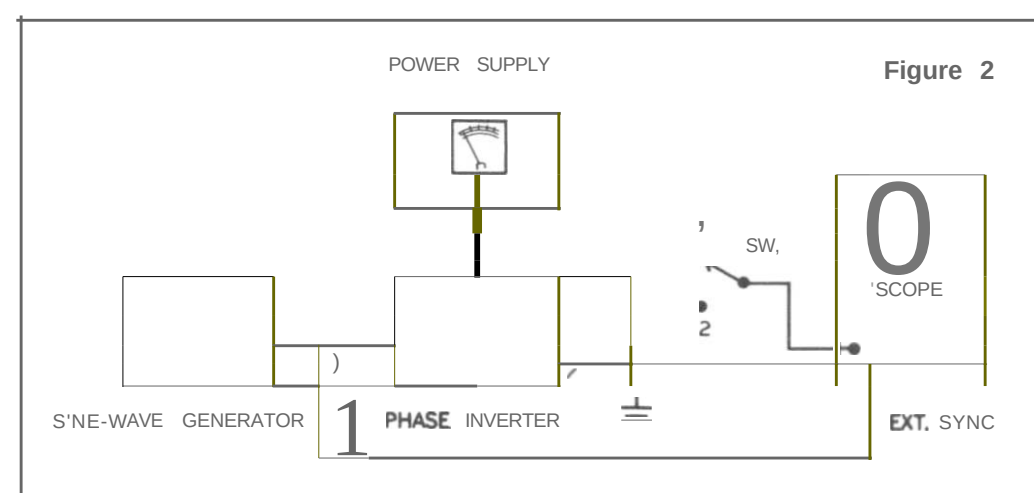
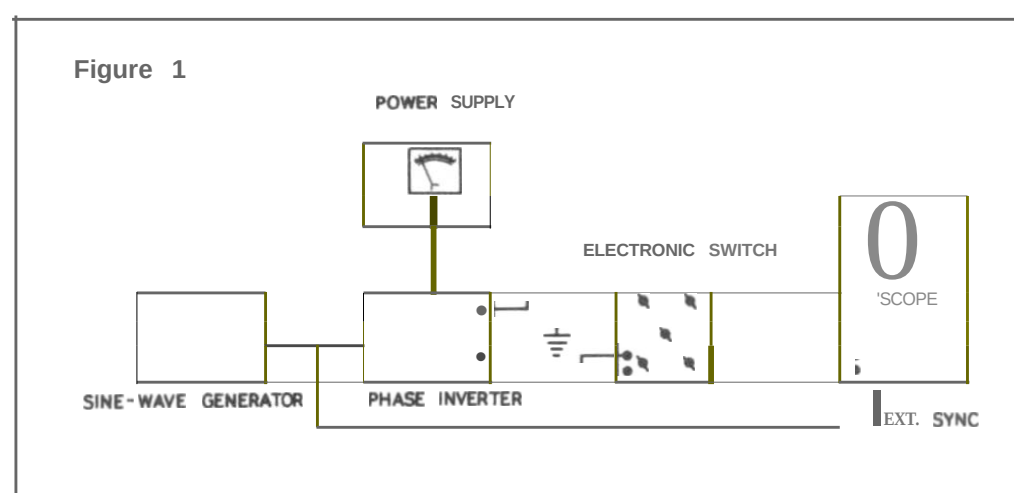
To use the method illustrated in Fig. 1, first connect the "A" and "B" inputs of the *Electronic Switch* in parallel and to the output of one-half of the Phase Inverter circuit. A sine-wave signal may be supplied to the input of the Phase Inverter. The frequency is not too important, and a 60 cycle signal may be used if desired ... however, many technicians prefer to use either a 400 cycle or 1000 cycle signal. The applied signal should be of reasonable amplitude, but not sufficient to overload the Phase Inverter circuit and thus cause clipping and distortion of the sine-wave.

Adjust all test equipment controls until two similar sine-wave signals are observed on the screen of the CRT. Next, adjust the POSITION control of the *Electronic Switch* until these two signals are superimposed. Adjust the "A" and "B" GAIN controls until the two sine-wave signals are of *exactly* equal amplitude. This last step essentially sets the gain of the "A" and "B" amplifiers until equal ... once this step is taken, the "A" and "B" GAIN controls should not be touched during the remainder of the tests, although readjustment of the POSITION control or 'scope controls is permissible.

Finally, remove the parallel connections between the "A" and "B" inputs of the *Electronic Switch*, connecting one output of the phase inverter to the "A" input, and the other to the "B" input, exactly as shown in Fig. 1. With these connections, two sine-wave patterns with differing phase relationships will appear on the screen of the CRT, as shown in Fig. 3 (a). When the phase inverter is properly designed and balanced, these two signals will be of equal amplitude, but will be exactly 180° out-of-phase with each other. If the two signals are not of equal amplitude, the phase inverter circuit is not properly balanced.

If the method shown in Fig. 2 is to be employed, it is only necessary to make the connections shown. No preliminary adjustments are required, except as may be needed to obtain a steady pattern. However, the 'scope VERT. GAIN control must be left fixed in position when changing SW' from position 1 to position 2 (and vice-versa).

Sine-wave patterns should be observed on the 'scope screen as SW' is operated. These patterns should be identical, except as far as phase relationships are concerned, and will probably appear similar to the patterns shown in Figs. 3 (b) and 3 (c).



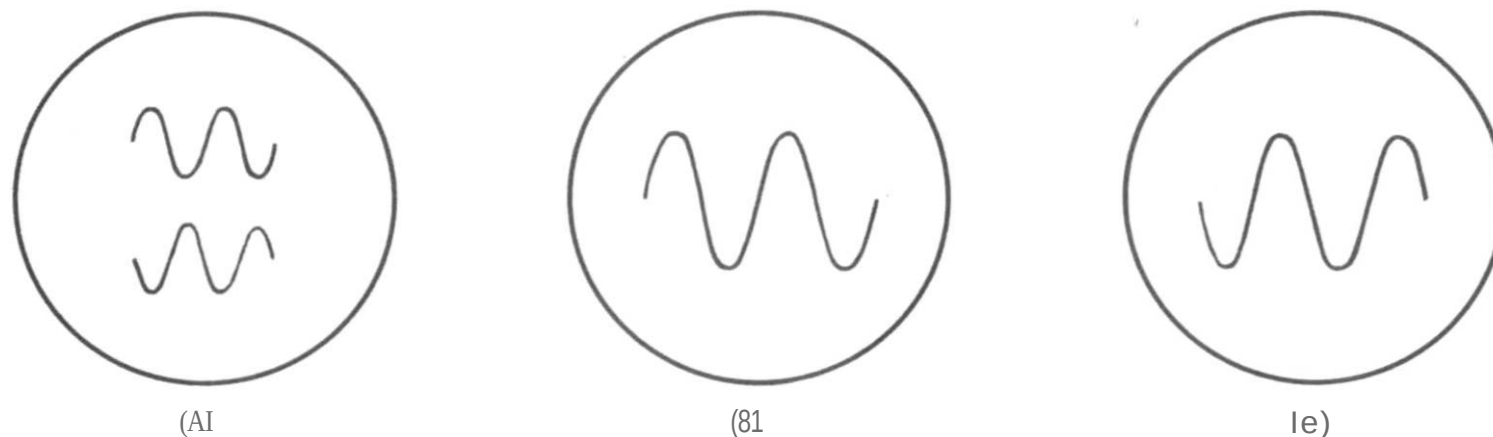


Figure 3

Since two separate patterns are observed at **different** times, the amplitude and phase relationships must be remembered if a comparison is to be made. The transparent graph screen used with the 'scope will aid in doing this.

(NOTE: With either of the methods illustrated, care should be taken that EXT. SYNC is used on the 'scope sweep, as shown ... this step is particularly important if the phase relationships are to be compared with any accuracy.)

In addition to the two techniques outlined above, other techniques may be used for comparing the relative amplitude and phase relationships of two sine-wave signals ... Lissajou figures may be used, for example. In such a case, the resulting pattern will be a diagonal slanting line. However, the techniques given are preferred as far as studying the circuits are concerned.

PRACTICAL PHASE INVERTER CIRCUITS

The Phase Inverter circuits to be shown are typical of those employed in practical design work. All parts values given are practical so the experimenter may actually assemble and test the circuits, carrying out any experiments he may find desirable. If the reader has made it a policy to carry out the previous experiments suggested in the Heath "Basic Circuit" Bulletins, he will find it worthwhile to wire each of the circuits shown, using the techniques described in previous Bulletins.

TRANSFORMER PHASE INVERTER

An amplifier with a transformer output having a center-tapped secondary winding, as shown in Fig. 4, is one of the oldest Phase Inverter circuits. However, it is basically quite an excellent circuit and is often used in modern design ... particularly in high-power audio amplifiers (as used in large

P.A. systems and as modulators for powerful Radiotelephone transmitters). Its chief disadvantage lies in the use of a relatively expensive and sometimes bulky iron-core transformer.

A SNC type IP331 was used in wiring the experimental Circuit given.

TRANSFORMER WITH CENTER TAPPED LOAD

Where a transformer with a center-tapped secondary winding is not available, but where transformer coupling may be desired for other reasons, the circuit shown in Fig. 5 is often employed. This circuit is also used occasionally as a repair technique where the "center-tap" of a transformer (of the type shown in Fig. 4) has opened, but where the secondary winding of the transformer still shows continuity. However, it is not generally used in original design work.

THE PHASE-SPLITTER

The circuit shown in Fig. 6 is basically a combination of a conventional resistance-coupled amplifier and a cathode follower. The signals appearing across R_2 and R_a are of equal amplitude but are 180° out-of-phase.

This circuit is sometimes used in wide-band amplifier design and in circuits where considerable gain is available in previous (or succeeding) stages. The chief advantages of this circuit are simplicity, good balance, and no need for a special iron-core transformer.

For extremely wide-band amplifier work this circuit suffers from one important disadvantage ... the plate-to-ground and cathode-to-ground capacities of most tubes are unequal, resulting in circuit unbalance as far as high frequency signals are concerned, together with some distortion of complex signals.

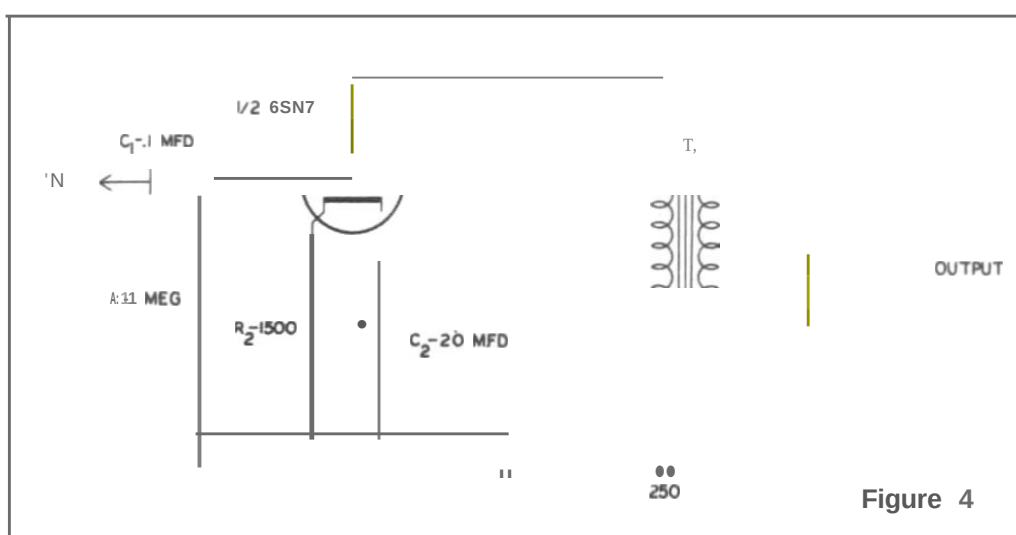


Figure 4

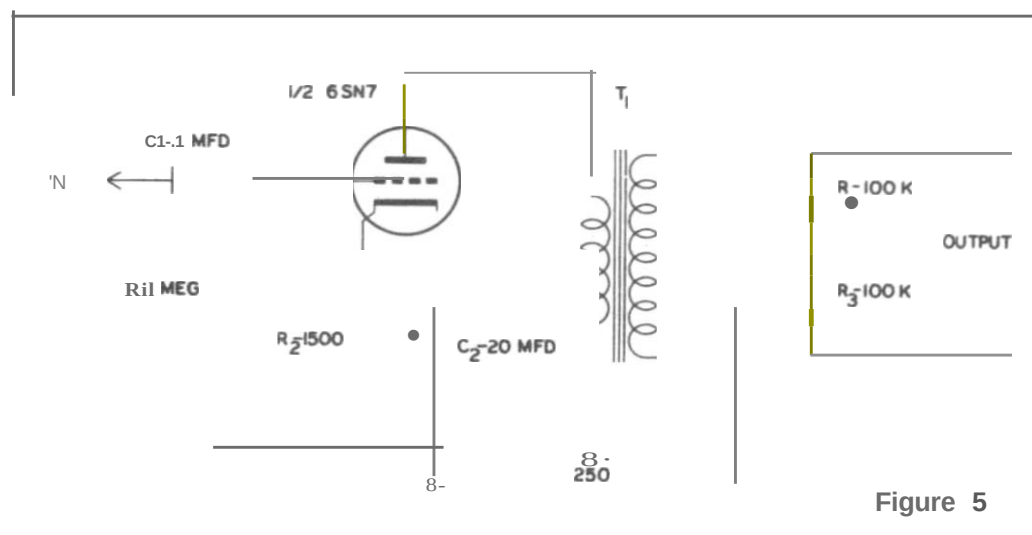


Figure 5

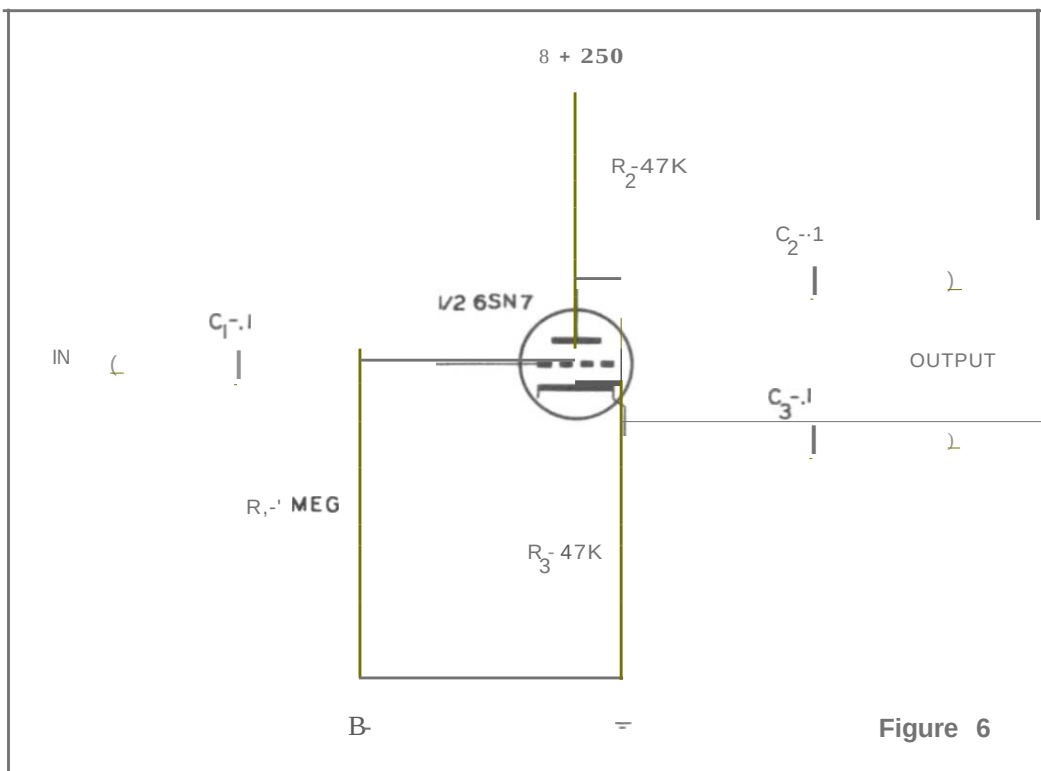


Figure 6

Another disadvantage of this circuit is low gain .. the gain, as far as one-half of the output is concerned, cannot exceed one (that is, over-all gain cannot exceed 2).

Notwithstanding these disadvantages, the circuit is widely used and is quite popular for many types of work.

"CONVENTIONAL" PHASE-INVERTER

The circuit shown in Fig. 7 utilizes an additional tube to provide phase inversion. The signal input to the second tube is adjusted to be approximately equal to the input to the first tube by means of a voltage divider consisting of R_1 and R_0 (where similar tubes are employed), thus assuring a "balanced" output.

Although this circuit is somewhat more complex than the others shown, it offers considerable gain and is probably the most popular of all the types shown in present day design work.

CATHODE-COUPLED PHASE-INVERTER

The circuit shown (Fig. 8) is sometimes used where the phase-inverter stage and output stage must be combined, either for economy or because of space limitations. It is satisfactory for Class "A" work, but is not too good for use where a perfect "balance" is required, as in Class AB and Class B amplifiers.

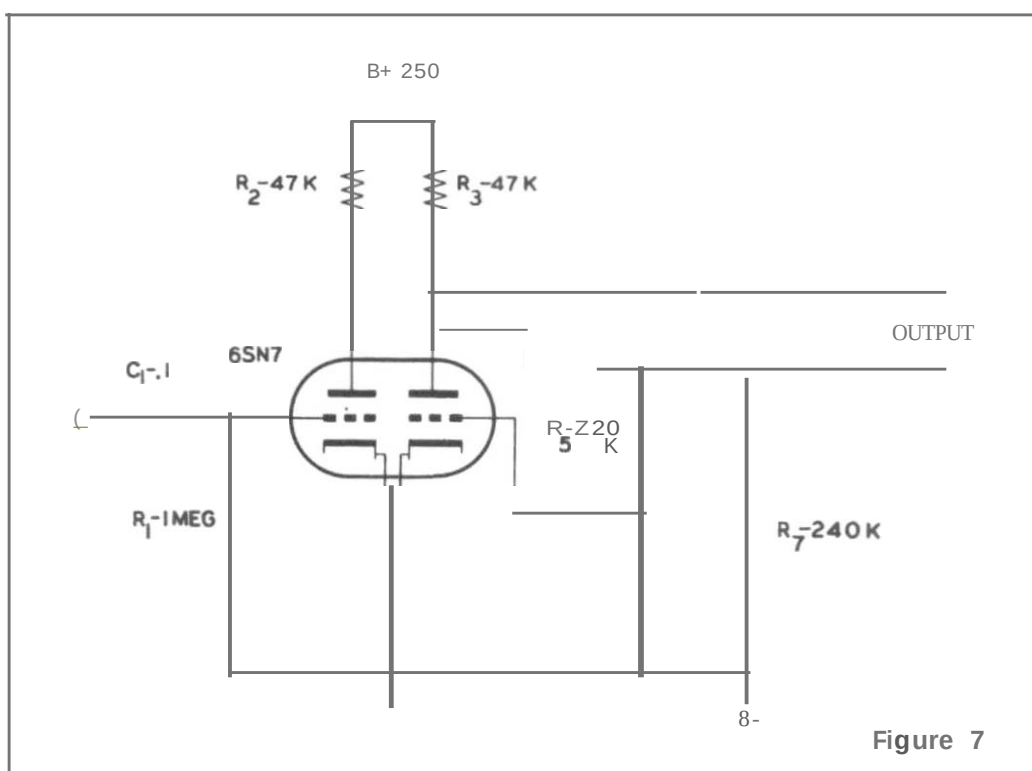


Figure 7

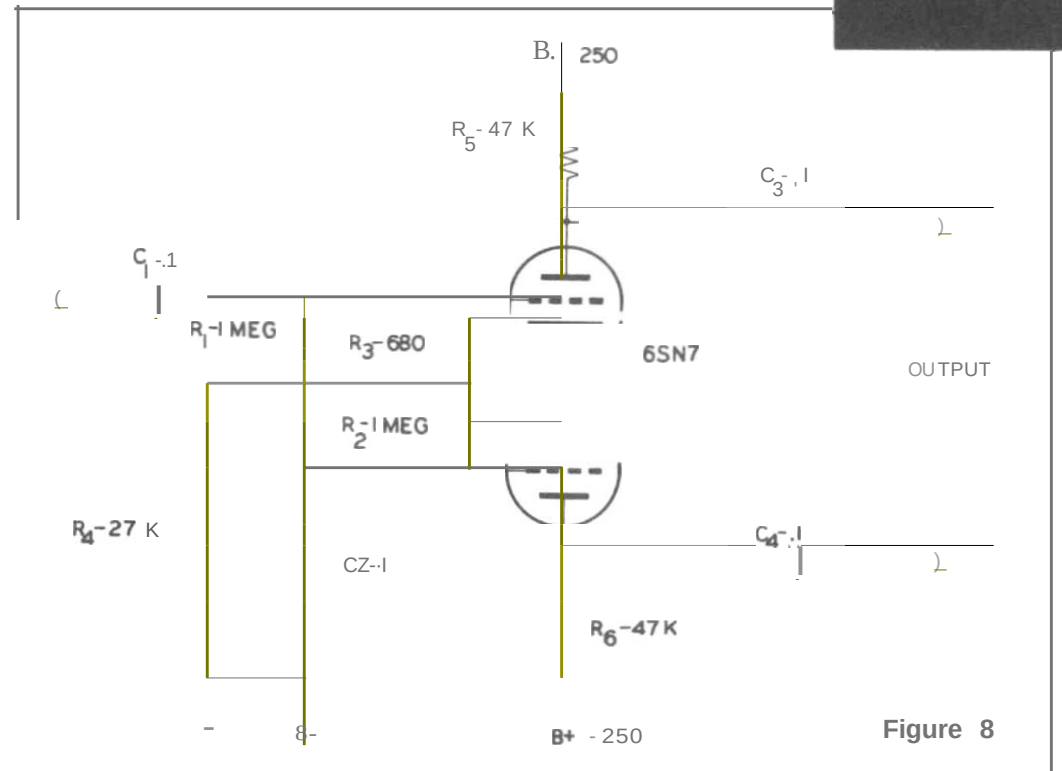


Figure 8

COMMERCIAL APPLICATIONS

Phase Inverter circuits are encountered so often in electronic equipment that the difficulty in giving an example of a "Commercial Application" is not in finding one but, rather, in choosing a "typical" example among the many available. For example, the phase inverter circuit shown in Fig. 6 is used (with different tubes and parts values, of course) in both the Horizontal and Vertical Sweep amplifier circuits of later model Heath *Oscilloscopes*. This circuit is also used in the Heath *Williamson Type Amplifier* and in other Heath Equipment.

The Phase Inverter circuit shown in Fig. 8 is used (in modified form) in the NRI Model 55 Oscilloscope as the final stage in the Horizontal sweep circuit.

While the greatest use of Phase Inverter circuits is to supply two signals having a 180° phase difference to a push-pull amplifier, this is, by no means, the only application of these Circuits.

An interesting application of a Phase Inverter circuit is shown in Fig. 9. This particular circuit is used where it is desired to choose, at will, either the "positive" or "negative" half-cycle of a supplied signal for synchronizing purposes (as when locking-in a sweep oscillator). A modified version of this circuit is used in later model Heath *Oscilloscopes* to sync the horizontal sweep oscillator.

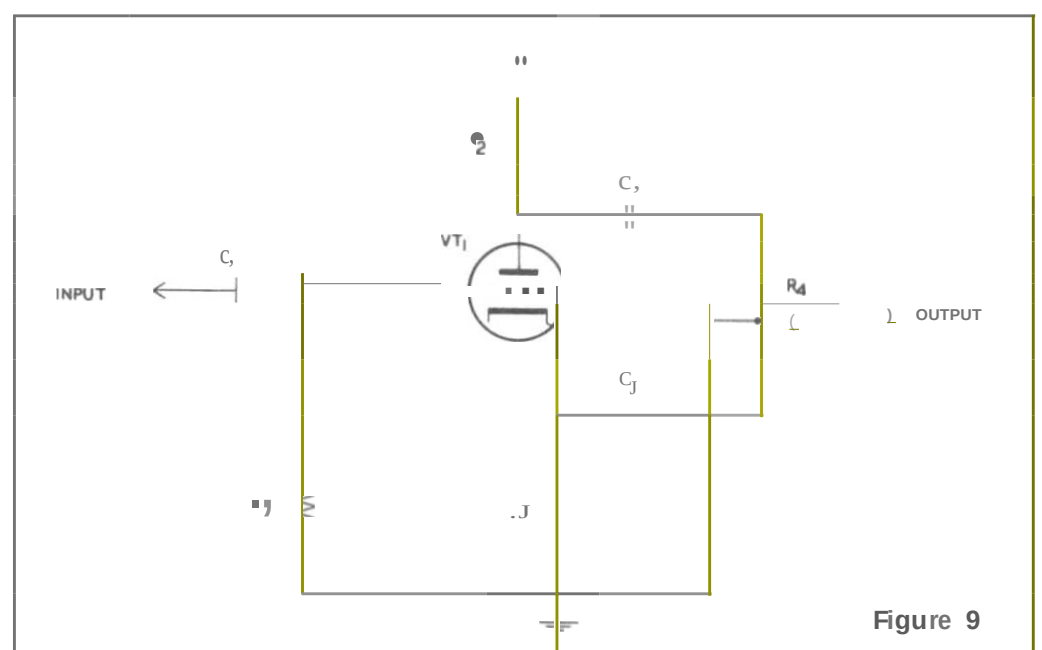


Figure 9

"tickler feedback" audio oscillator experiments with the oscilloscope

BY LOUIS E. GARNER, JR.

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Of all the oscillator circuits available to the engineer, probably no single circuit is more popular than the "tickler feedback" oscillator. Because this circuit is one of the least critical and can be made to operate very easily, it has been used extensively to produce signals at audio, ultrasonic, r.f., v.h.f., and u.h.f. values. However, notwithstanding the circuit's great popularity and wide use, many experimenters do not realize that it may be used to produce a wide variety of signal wave-shapes (other than the common sine-wave) simply by varying the values of different components and the amount of "feedback" employed.

A tickler feedback oscillator to operate at audio frequencies may be assembled quite easily using standard components. After assembly, the different components may be varied and the resulting changes in the output signal wave-shape and amplitude noted, observing the signal on the screen of your Heathkit Oscilloscope. A few hours experimentation in this fashion will enable the experimenter or technician to gain a familiarity with the circuit that is difficult to acquire in any other way.

As in previous Heath Bulletins on "Basic Circuit Experiments," no attempt will be made to enter into detailed mathematical or theoretical discussions on the circuit action or on the results obtained. For those readers desiring a detailed treatment of the academic aspects of the circuit, it is suggested that reference be made to any standard Handbook or Engineering Text.

Assembling the Oscillator: A suitable experimental circuit is shown in Fig. 1. The transformer is a common inexpensive interstage (plate-to-grid) audio transformer having a 1:3 ratio. The tube is one-half of a type 6SN7 ... however, almost any triode or triode-connected pentode may be employed. Such types as 6C4, 6J5, 6O, 12AU7 (one-half), etc. are entirely suitable.

(NOTE: The waveforms shown in the sketches and the experimental results obtained apply specifically to the circuit and components used in the original experiments ... with different transformers and different tubes, the waveforms may not be exactly like those shown.)

The basic oscillator circuit may be assembled on a small metal chassis along with a standard power supply. However,

for ease in making part changes and in making quick tests, it is suggested that the entire circuit be wired on a "breadboard" type chassis (see Heath Bulletin "BREADBOARD DESIGN TECHNIQUES") and that plate voltage and filament power be obtained from a separate unit such as the Heathkit *Laboratory Power Supply*. With such a set-up, it is quite easy to check plate voltage and current at any time, using the built-in meter of the power supply.

Once the oscillator is assembled, but before experiments are started, check the circuit for oscillation ... do this by checking for a d.c. voltage across grid resistor R_1 . A bias of from 15 to 45 volts should be developed here. A test may also be made by using the Oscilloscope to see if a signal is present on either the plate or the grid of the tube. *If the circuit does not oscillate, reverse the connections to either the primary or secondary windings of the transformer (but not both).*

With the circuit shown in Fig. 1, a bias of -33 volts was measured across R_1 , with the plate voltage at 160. The signal observed on the grid of the tube had the general waveform shown in Fig. 2.

Note that a damped oscillation is superimposed on the primary waveform, indicated by the "ripples" following the main pulse (at point A, Fig. 2). This may well be due to a tendency of the oscillator to operate at a higher frequency, but to "block" at the lower rate due to the high level of feedback used.

TESTS TO PERFORM:

To obtain the greatest benefit from the experiments described, the reader will find it worthwhile to carry out a series of systematic tests, recording the results and sketching the various waveforms produced in a notebook. For the technician or experimenter, the resulting notes will serve as a valuable guide whenever it is necessary to use the basic circuit in building or testing equipment. To the engineer or student, the notes (and especially the waveform sketches) will prove valuable as exercises in circuit and waveform analysis. The following tests are suggested:

D.C. Voltage Tests: A record should be kept of B supply voltages and plate current requirements. If the Heathkit *Laboratory Power Supply* is not used as a power source, a separate meter should be provided (a multitester such as the Heathkit *Handitester* may be used).

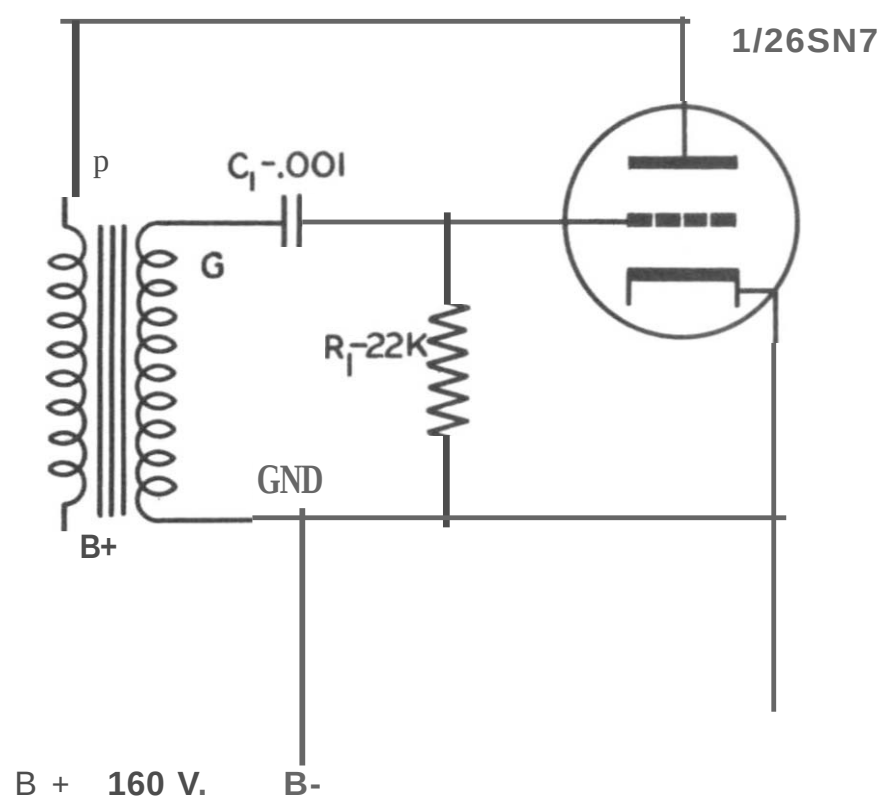


Figure 1

The bias voltage across the grid resistor should be noted as changes are made in the circuit. This voltage may be measured with a conventional d.c. voltmeter, or using a VTVM. The VTVM is preferred, however, but if a regular d.c. voltmeter is used, care must be taken that the d.c. resistance of the meter circuit is at least several times greater than the value of the grid resistor if the meter itself is not to affect circuit operation. Where a multimeter is employed (such as a 1000 ohms/volt meter), the effective meter resistance may be increased by switching to a higher voltage range.

Observing Signal Waveforms: An Oscilloscope should be used to observe the signal waveform at various points in the circuit as experimental changes are made. When using the 'scope, take care that the input is not overloaded, adjusting the VERT. INPUT and VERT. GAIN controls as necessary. Adjust the 'scope HORIZONTAL sweep controls and SYNC

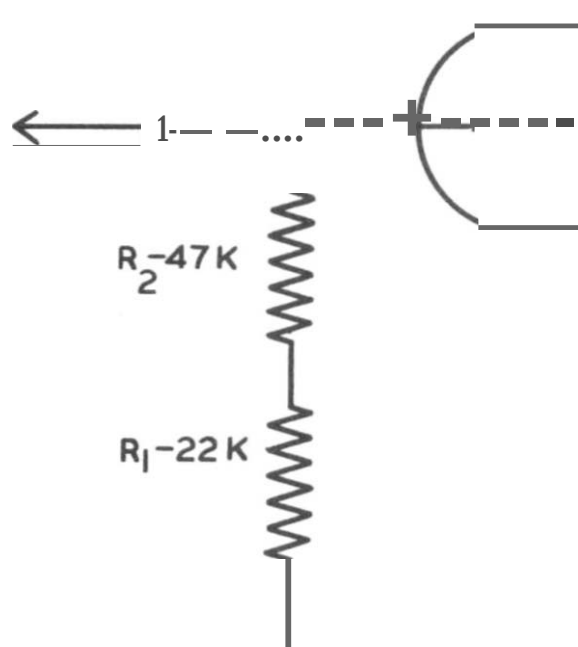
controls so that two or three complete cycles of the signal may be observed. Readjustment of these controls may be necessary occasionally as some circuit changes will cause a shift in the oscillator frequency.

Measuring Signal Amplitude: Since the waveform will seldom be a perfect sine-wave, the signal amplitude can best be measured in terms of peak-to-peak voltages. To do this, use either the Heathkit *Voltage Calibrator* in conjunction with the 'scope or the Heathkit VTVM together with the *Peak-to-Peak Voltage Probe*.

Checking Signal Frequency: With the circuit suggested in Fig. 1, all oscillations will fall in the audio range. Therefore, two equally satisfactory methods are available for checking the frequency of signals produced. The Heathkit *Audio Frequency Meter* may be used, since the accuracy of this instru-



Figure 2



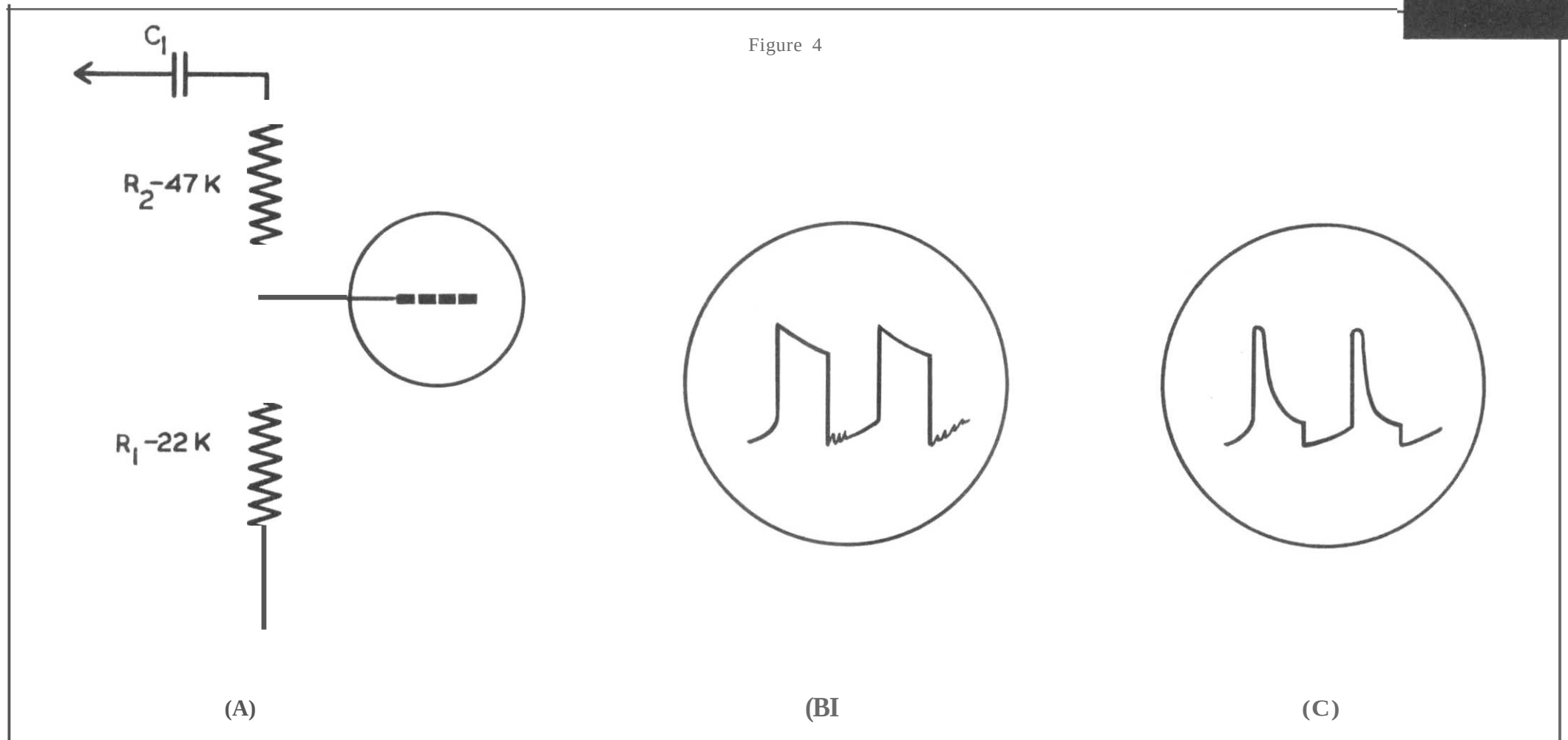
(A)



(B)

Figure 3

Figure 4



ment is unaffected by the wave-shape of the signals applied to its input. Connect the "Ground" lead to circuit ground and the "Hot" lead to the plate of the oscillator.

If preferred, the signal may be compared to a known sine-wave signal, such as might be obtained from the Heathkit *Sine-Wave Generator*, by using completed-loop Lissajou figures (see Heath Bulletin "FREQUENCY MEASUREMENT WITH LISSAJOU FIGURES"). However, since a distorted wave-shape is obtained from the oscillator in most cases, it is almost impossible to recognize frequency ratios other than 1:1. Even here, especial care must be taken when interpreting the pattern to tell if the proper test signal has been used.

SUGGESTED EXPERIMENTS:

As a start, the experimenter should try increasing the value of the grid resistor by connecting another resistor in series

with it (or using a different resistor) ... see Fig. 3(a). With the circuit given, the waveform shown in Fig. 3(b) was obtained.

Transferring the grid connection to the juncture of the two series resistors will reduce grid drive and cause a considerable change in circuit operation. The new connections are shown in Fig. 4(a), while the waveform, as observed on the grid of the tube, is given in Fig. 4(b). The pattern of the signal across both resistors (R_1 and R_2) is given in Fig. 4(c). Measured grid bias (across R_1) was -15 volts.

This part of the experiment may be carried a step further by removing R_1 and substituting a variable resistor (such as a 1 Megohm potentiometer or the Heathkit *Resistance Substitution Box*) and changing the resistance value over a wide range, observing changes in signal amplitude, frequency, waveform, and any variations in grid bias.

Figure 5

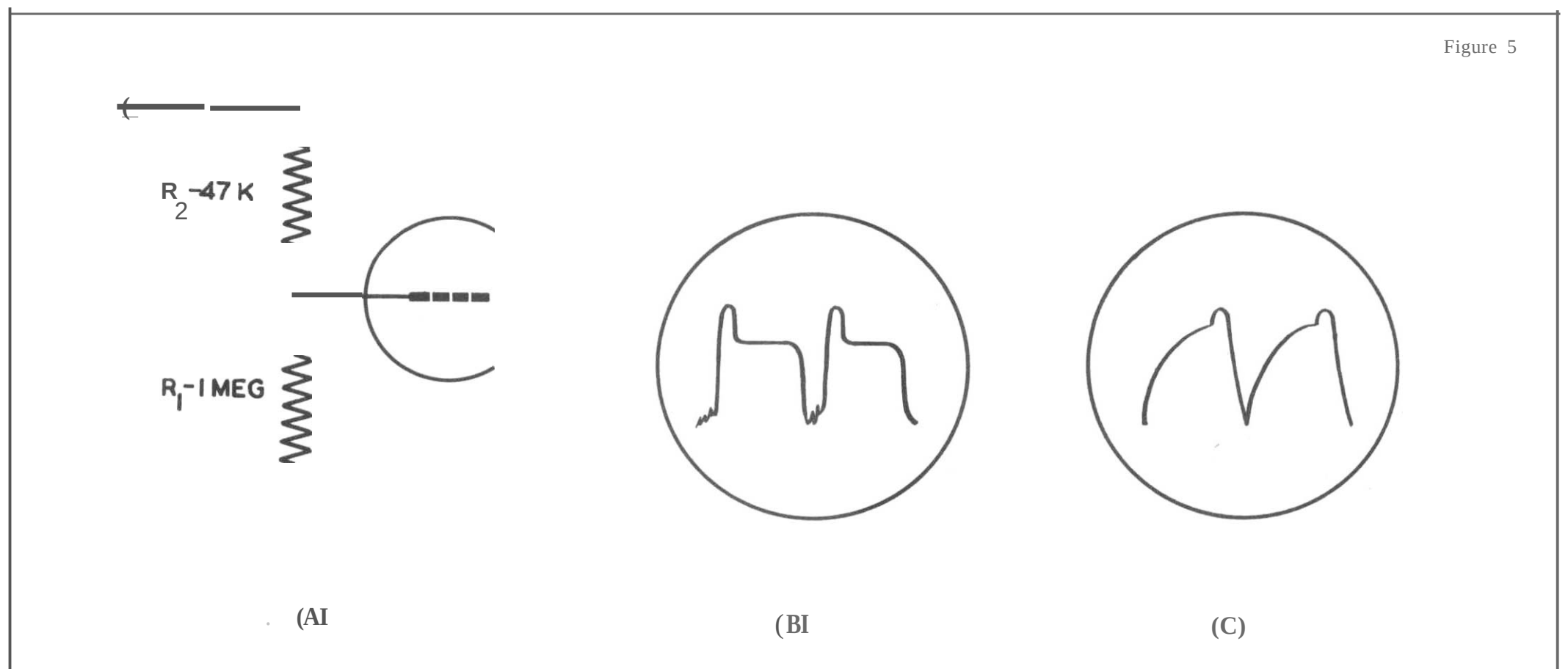
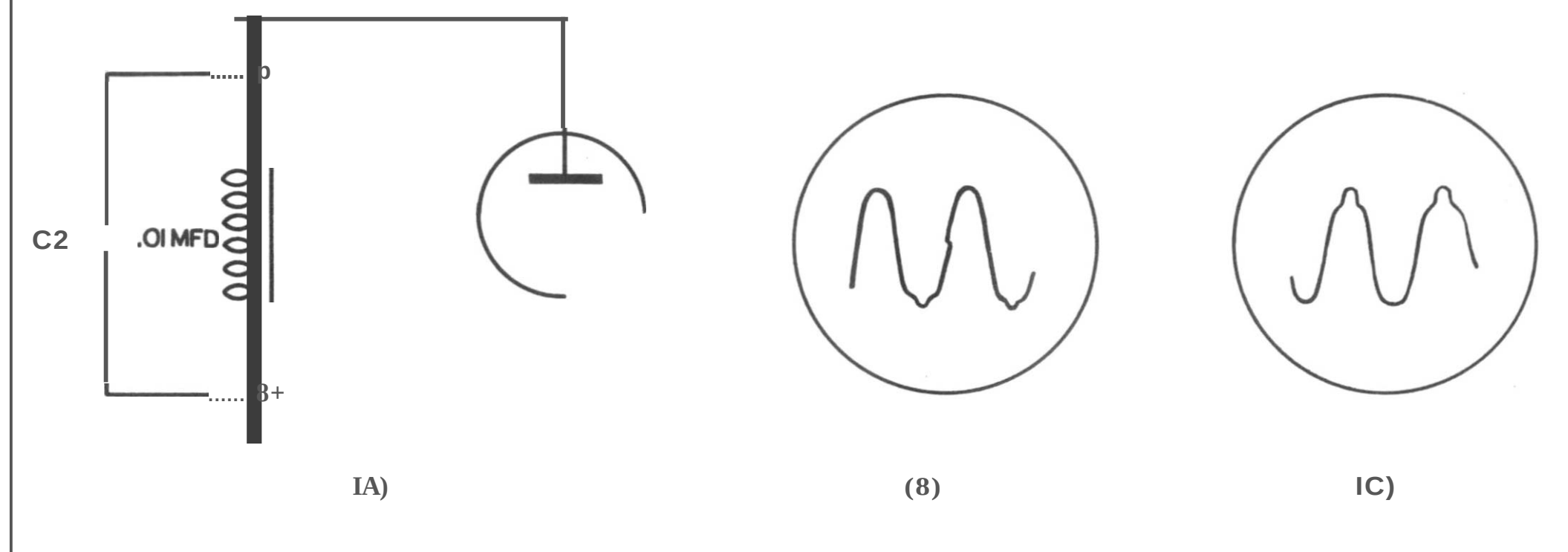


Figure 6



With the arrangement shown in Fig. 5(a), the pattern shown in Fig. 5(b) was observed on the plate of the tube, while the signal at the grid had the waveform shown in Fig. 5(c). The plate signal measured 100 volts, peak-to-peak. Bias (across R_1 , Fig. 5(a)) was found to be -80 volts.

Still another experiment is to try connecting small condensers across either the primary or secondary windings (or both) of the oscillator transformer. With a .01 mfd. paper condenser connected across the primary winding, as shown in Fig. 6(a), the signal shown in Fig. 6(b) was obtained on the plate of the tube, while the signal on the grid had the waveform shown in Fig. 6(c). At the same time, the frequency of oscillation changed from 2600 cps to 1400 cps.

ADDITIONAL EXPERIMENTS:

The experiments suggested above should serve only as a guide to the reader, rather than as a complete and final test. These experiments indicate only a few of the circuit variations possible. In addition to those given, many others probably suggest themselves to the reader... for example, the size of the coupling condenser might be changed, different transformers might be tried, and the plate voltage may be varied over wide ranges. In each case, the suggested measurements may be made and notes kept, permitting a complete record of the oscillator characteristics.

COMMERCIAL APPLICATIONS:

Tickler Feedback oscillators using iron core transformers will be found commercially in Code-Practice Oscillators, in Television receivers and in many other types of equipment.

In most Code Practice Oscillators, the frequency of operation is determined by the L-C values in the circuit, while in TV receivers, the Tickler Feedback oscillator is generally operated as a "blocking oscillator," with the frequency of operation determined by an R-C time constant. (For additional material

on "blocking oscillators," refer to the Heath Bulletin RELAXATION OSCILLATORS.)

A typical application of the Tickler Feedback oscillator in a TV receiver is shown in Fig. 7. This is the circuit of the Vertical Sweep Oscillator used in the Sylvania Model 1-090 Television receiver.

The operation of this circuit is similar to that of the oscillator studied in this Bulletin, except for minor modifications to permit external synchronization (with the Vertical Sync Pulse) and the formation of the desired Output signal waveform. C_6 and R_7 permit the formation of a trapezoidal output signal, which, in turn, is applied to the vertical sweep amplifier.

Since the R-C time constant in the grid circuit controls the frequency of operation, a portion of the grid resistor may be made adjustable to serve as the VERTICAL HOLD control (R_2).

Stage de-coupling is obtained through the use of R_5 and by-pass condenser C_5 .

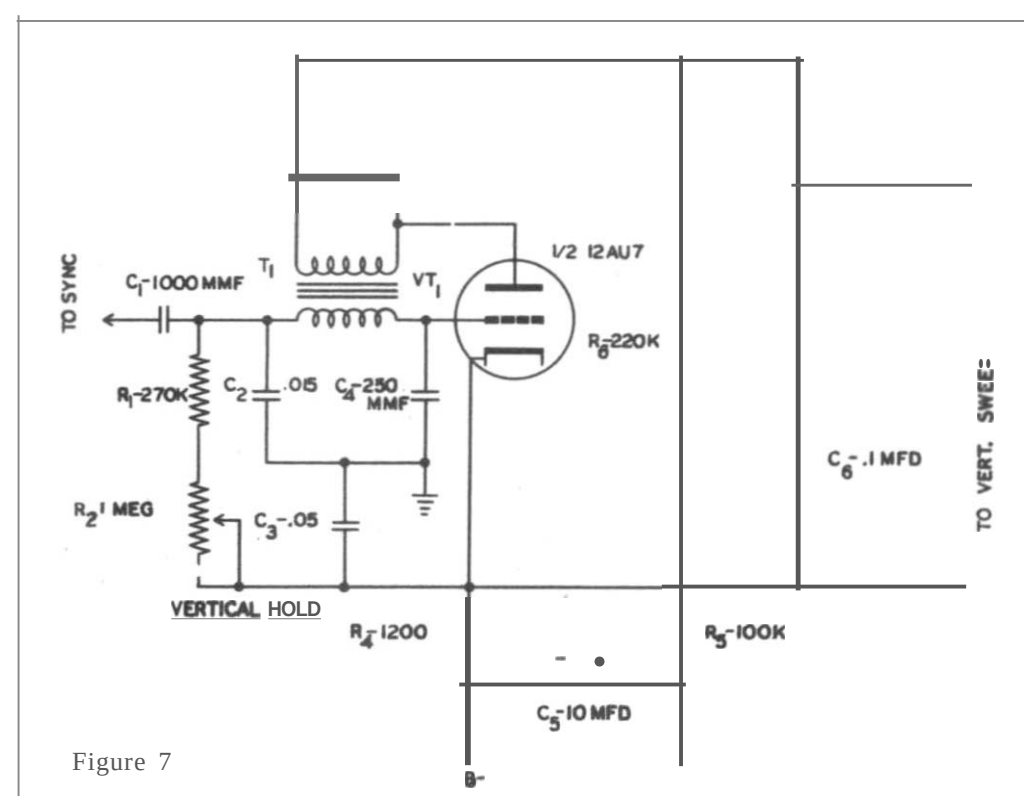


Figure 7

studying basic amplifiers with the oscilloscope and power supply

BY LOUIS E. GARNER, JR.

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For some time, there have been four classes of amplifiers recognized by engineers. The division of amplifiers within each of these classes has been dependent upon grid bias and the amount of signal drive. These classes may be defined as follows:

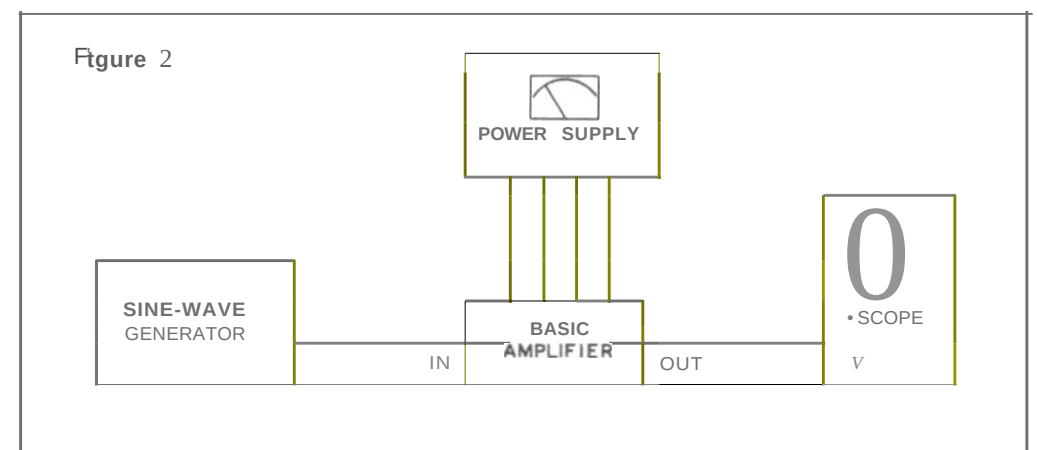
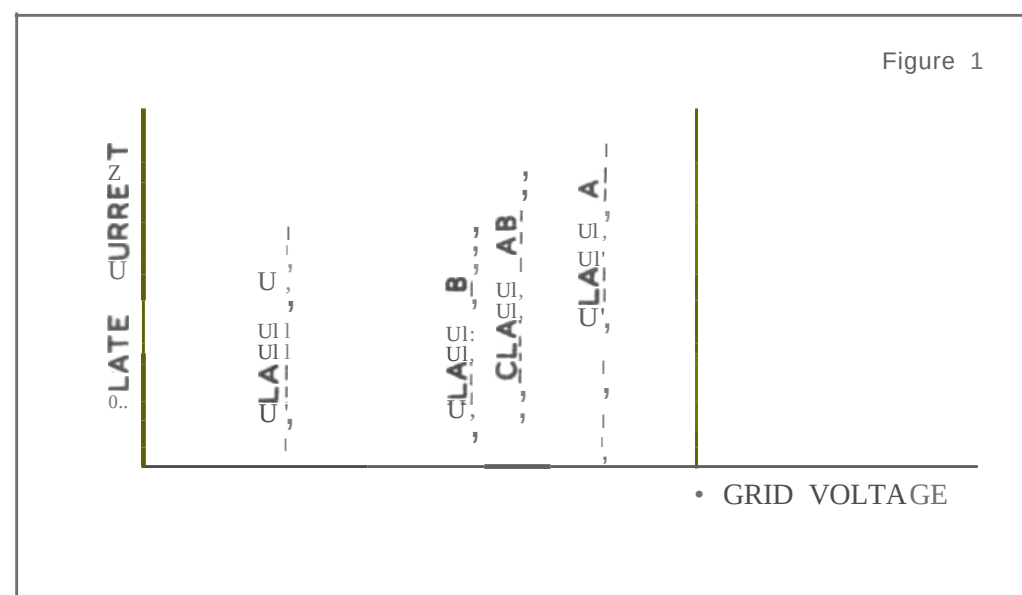
Class A Amplifiers are those in which the grid bias and applied signal voltages are such that plate current flows in the tube at all times. From a practical viewpoint, a Class A amplifier is one in which the grid bias point falls along the linear portion of the tube's characteristic curve, as shown in Fig. 1.

Class AB Amplifiers are those in which the grid bias and applied signal are such that plate current flows for more than half but less than the full cycle of the applied signal. Referring to Fig. 1, Class AB operation would call for an operating point between Class A and Class B, as shown.

Class AB amplifiers are generally further subdivided into Classes AB₁ and AB₂. This additional sub-division is used to indicate whether or not grid current flow occurs during any part of the applied signal... in Class AB₁ grid current does not flow, while in Class AB₂, grid current flow may take place.

Class B Amplifiers are those in which the grid bias is approximately equal to the cut-off value. In these amplifiers, plate current flow occurs during one-half cycle of the applied signal.

Class C Amplifiers are those in which the grid bias is appreciably greater than the plate current cut-off value, so that plate current flow occurs essentially on only the peaks of an applied signal.



All four classes may be used in power amplifiers, but classes A, AB and B are the only ones used for audio work... and, in this application, classes AB and B are only used in push-pull circuits. In R.F. work, where a tuned load is used, classes A, AB, B, and C may be employed.

While these four classifications have been used for many years, a different type of grouping, which depends on the type of circuit associated with the tube, rather than its operating characteristics, has become popular recently. All indications are that this newer method of grouping will be even more extensively used in the future.

With the newer classification, a tube is considered to have two "input" and two "output" terminals, with one of each pair of terminals having a common or "ground" connection. The grouping then depends upon which of the tube's elements is connected to this common point, giving the following classifications... "Grounded Cathode," "Grounded Grid," and "Grounded Plate" amplifiers. The "Grounded Plate" amplifier is more popularly known as a *Cathode Follower*.

Wiring and Testing the Basic Amplifiers: Each of the amplifier schematics to be given is a practical circuit that may be wired by the reader, using the parts values shown. After assembly, experimental tests may be carried out to enable the reader to become familiar with the basic characteristics of the circuit. "Breadboard" type construction is suggested as this lends itself readily to performing quick tests and measurements.

A typical experimental set-up is shown in block diagram form in Fig. 2. Power for the Basic Amplifier circuit is obtained from a Heathkit Laboratory Power Supply. The *Oscilloscope* is used to check the appearance of both the input and output signal waveforms. For most tests, a sine-wave signal is

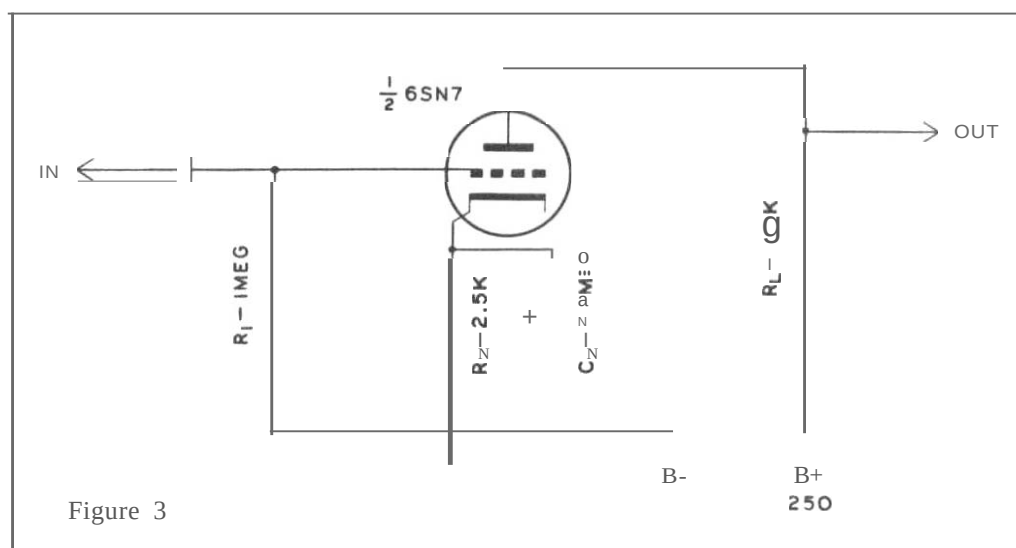


Figure 3

preferred, as this permits a wide variety of tests ... maximum signal drive, distortion, gain, etc. A single frequency is satisfactory unless the experimenter also wishes to complete a frequency response run of each circuit. Some of the possible experimental tests are outlined below:

Gain may be checked by measuring the amplitude of the "input" and "output" signals, and using the following formula:

$$\text{Gain} = \text{Output/Input.}$$

The voltage measurements may be either in terms of RMS or peak-to-peak voltages. RMS voltage readings will be obtained if an A.C. VTVM is used to check the input and output signals, and peak-to-peak readings will be obtained if the Heathkit Voltage Calibrator is used with the 'scope to obtain these measurements.

Maximum Signal Drive may be determined by gradually increasing the input signal level until the output waveform, as observed on the screen of the 'scope, becomes distorted.

Distortion may be observed by using an Electronic Switch to compare the input and output signal waveforms.

D.C. Operating Voltages may be checked using a conventional voltmeter. If notes on the operation of each circuit are to be kept, it is suggested that B supply, actual plate and grid bias voltages, and plate current be recorded.

Frequency Response characteristics may be checked by using a number of different test frequencies, keeping the input signal level constant, and recording the output. If preferred, quick checks may be made using the Square-Wave Generator (refer to the Heath Bulletin EXTENDING AMPLIFIER RESPONSE).

THE GROUNDED-CATHODE AMPLIFIER:

A practical Grounded-Cathode amplifier stage is illustrated in Fig. 3. Although the cathode appears to be above ground potential, by-pass condenser C_2 may be considered as a practical short-circuit as far as a.c. signals are concerned, thus "grounding" the cathode.

This circuit features high gain and high input and output impedances. It is probably the most common of the basic amplifier circuits. The output signal is 180° out-of-phase with the input.

Theoretical gain is given as follows:

$$\text{Gain} = \frac{\mu R_L}{R_L + r_p} \text{ where } \mu \text{ is the amplification factor of the tube, } R_L \text{ is the load impedance, and } r_p \text{ is the plate resistance of the tube.}$$

With the circuit values given in Fig. 3, the measured gain of the circuit was 15 at 1 Kc. As can be determined, the theoretical gain is somewhat higher than the measured value. This will be true in most cases.

THE GROUNDED-GRID AMPLIFIER:

This particular circuit features a low input but high output impedance. High gain is possible with careful design. The output signal is in-phase with the input. The circuit is often used as an "impedance matching transformer" to couple a low impedance to a high impedance circuit, yet providing gain at the same time.

A practical experimental circuit is shown in Fig. 4. With the circuit values given and using a 1 Kc sine-wave signal, the measured gain was twelve.

$$\text{Theoretical gain is given as follows: } \text{Gain} = \frac{(1 + \mu) R_L}{R_L + r_p}$$

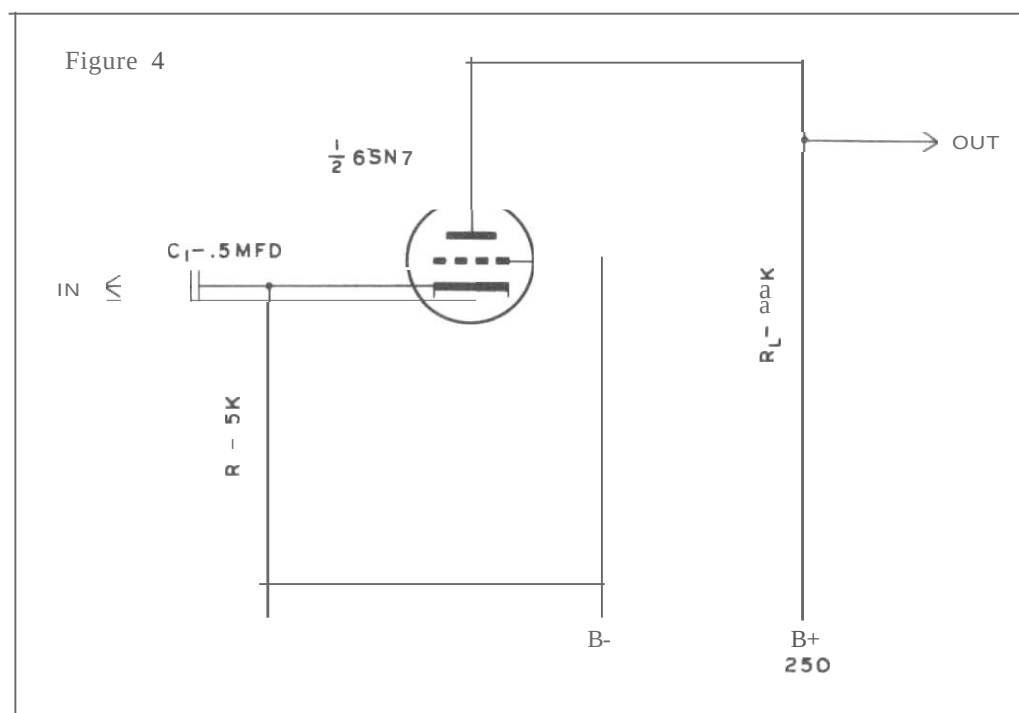
The symbols represent the values given above. It is assumed that the cathode resistor (R_k) is small compared to R_L and r_p .

THE GROUNDED-PLATE AMPLIFIER:

The "Grounded-Plate" amplifier, as shown in Fig. 5, is usually identified by its more popular name of "cathode follower." This particular circuit is not, in the strictest sense, an "amplifier" as the output signal amplitude is always less than the input. Technically, the amplifier can never have a "gain" exceeding one. The output signal is in-phase with the input.

Since this circuit features a high input and low output impedance, it is quite widely used for impedance matching.

$$\text{Theoretical gain is given as follows: } \text{Gain} = \frac{\mu R_L}{r_p + (1 + \mu) R_L}$$



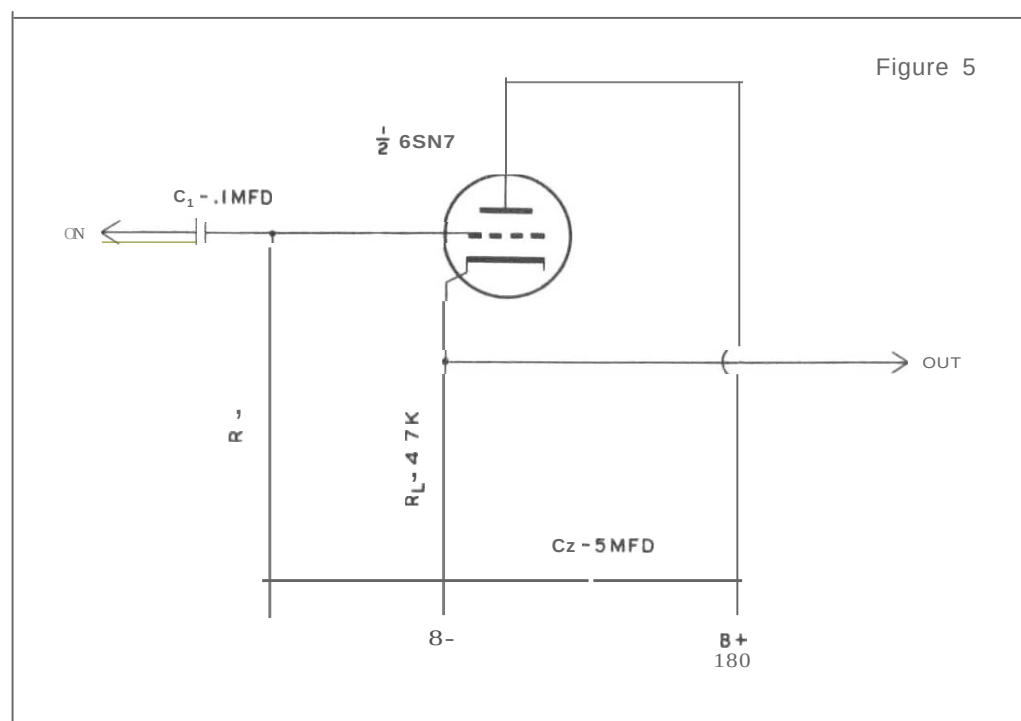


Figure 5

GENERAL CONSIDERATIONS:

The important characteristics of each of the basic amplifiers shown are summed up in tabular form in Fig. 6. This table should serve as a general guide in selecting amplifier circuits for specific applications.

Amplifier	Input Impedance	Output Impedance	Gain	Output Signal Phase
Grounded-Cathode	High	High	High	-180°
Grounded-Grid	Low	High	High	In-Phase
Grounded-Plate	High	Low	Low	In-Phase

Figure 6

In addition to the specific characteristics applying to each amplifier discussed, there are a number of general factors that apply to all the circuits.

In general, the higher the *amplification factor* of a tube, the greater the gain obtained, whereas the higher the *internal resistance*, the lower the potential gain. The best indication of a tube's usefulness as an all-around amplifier is generally in its *mutual conductance* ... the greater the mutual conductance, the better the tube as an amplifier.

Distributed capacities which shunt the output load tend to reduce load impedance and hence circuit gain. For best results in practical circuit design, all wiring and other distributed capacities should be kept to a minimum. This is especially true in the case of wide-band amplifiers.

COMMERCIAL APPLICATIONS:

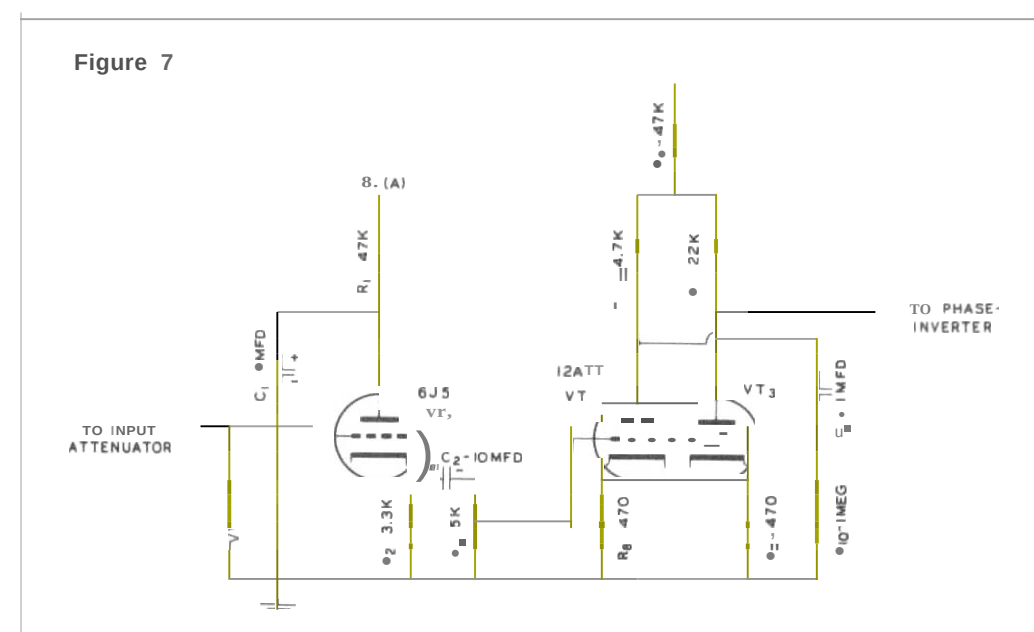
An excellent example of the use of two of the three types of Basic Amplifiers discussed in this Bulletin may be found in your Heathkit *Oscilloscope*. The schematic diagram of the first three amplifier stages in the Vertical Amplifier circuit is given in Fig. 7.

VT1 is a "grounded-plate" or cathode follower stage, while the two following stages may be considered as "grounded-cathode" stages.

The plate of VT1 is essentially at ground potential as far as signals are concerned because of the by-pass action of C_1 . Thus R_2 , in the cathode circuit, becomes the load for this stage. The signal appearing across R_2 is applied to the VERTICAL GAIN control, R_4 , through d.c. blocking condenser C_2 .

The signal is next applied to the grid of VT2, with the amplified output signal appearing across the plate load resistor R_6 . From here the signal is applied to the grid of VT3 through blocking condenser C_3 , appearing across grid resistor R_{10} . Finally, the amplified Output signal appears across the plate load resistor (R_7) of VT3.

Although un-bypassed cathode resistors R_9 and R_8 are used in the cathode circuits of VT2 and VT3, respectively, these resistors are sufficiently small so as not to appreciably affect stage operation. These resistors do provide some bias for the stages, however, and also supply a small amount of degeneration which acts both to improve the over-all response and circuit stability.



oscilloscope study of hartley and colpitts audio oscillators

BY LOUIS E. GARNER, JR.

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In this Bulletin, we will continue our discussion of practical set-ups which will enable the student, the technician, and the experimenter to use his Heathkit equipment as training aids and to gain valuable experience studying and working with basic circuits. As in previous Bulletins in this series, no attempt will be made to discuss the circuits in detail from a theoretical and mathematical viewpoint.

Many technicians and engineers use the names "Hartley" and "Colpitts" synonymously with the term "oscillator." This is undoubtedly due to the fact that the Hartley and Colpitts circuits are, collectively, better known than possibly any other oscillator circuit, even if no more widely used than the very popular "tickler feedback" oscillator.

The operation of these oscillators may best be studied, from a practical viewpoint, by actually wiring them and observing the various signal wave-shapes encountered, using an *Oscilloscope*. If possible, records should be kept of the basic operating characteristics. For detailed suggestions on the measurements to take and other experimental tests, as well as hints on construction and assembly, the reader may refer to the Heath Bulletin THE "TICKLER FEEDBACK" AUDIO OSCILLATOR. However, for the reader not having this Bulletin readily available, the following review is given:

Assembly Hints: Component values may be most easily changed and the circuit arrangement modified if the "bread-board" type of construction is employed. This type of construction also lends itself most readily to tests and measurements.

A separate power supply (such as the Heathkit *Laboratory Power Supply*) is recommended as it allows the B supply voltage to be changed easily, and also permits a quick check of both B voltage and current at any time.

Tests to Perform: In order to put the knowledge gained in the suggested experiments in a form most readily available for future use, the reader will find it worthwhile to keep a notebook record of all results, together with rough sketches of the various waveforms encountered. A record of d.c. operating voltages and **currents** will establish the basic operating conditions for the circuit ... these include the B supply voltage, actual plate voltage, the grid bias voltage (measured across the grid-leak resistor), and plate current. A VTVM should be

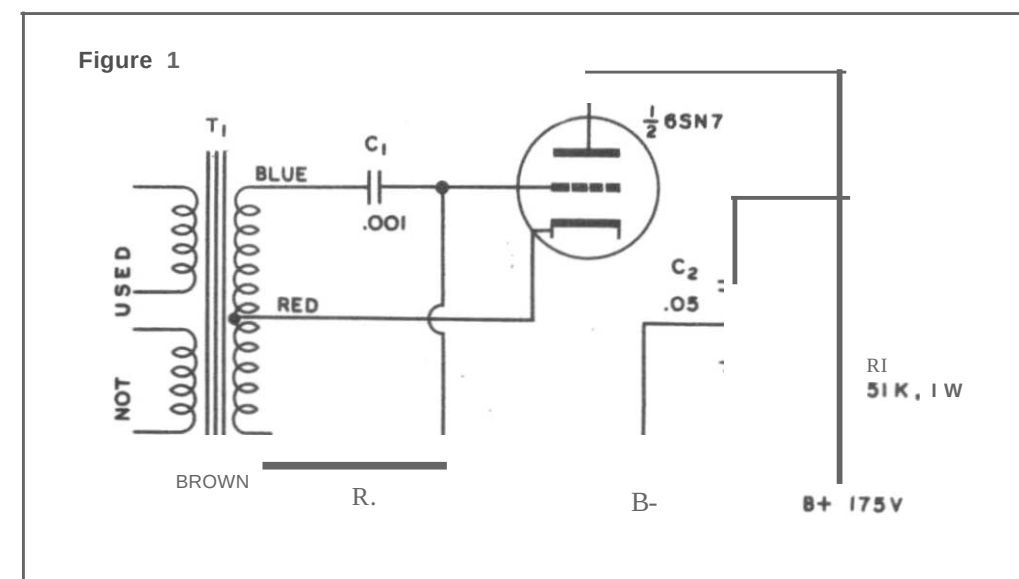
used to check the grid bias voltage to avoid loading the circuit and changing its operating characteristics.

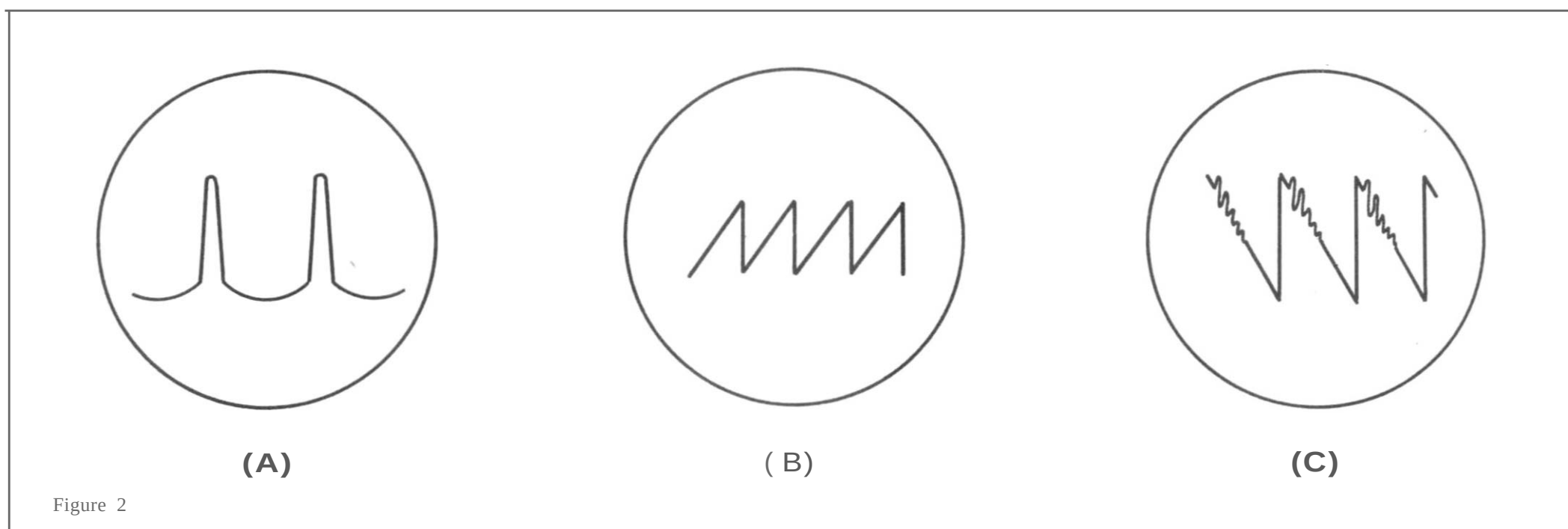
Signal waveforms should be checked on the plate, grid, and cathode of the oscillator tube. In addition, the oscillator frequency and signal amplitude should be noted as changes are made in the circuit. The oscillator frequency can be checked using Lissajou figures or the Heathkit *Audio Frequency Meter*. The signal amplitude may be checked in terms of peak-to-peak voltages, using the Heathkit *Voltage Calibrator* in conjunction with the 'scope. If preferred, these voltages may also be measured using a VTVM and a *Peak-to-Peak Voltage Probe*.

SUGGESTED EXPERIMENTS:

Space limitations make it impractical to give *all* possible experiments for each circuit described. Therefore, it is hoped that the reader will take the suggested experiments only as a guide and will continue to carry out other experiments as might occur to him. In addition, possible experimental modifications of the "standard" circuits given will be found in such sources as Engineering Handbooks and Textbooks and in Laboratory Manuals. By carrying out these additional experiments as they present themselves, the reader should have no difficulty in acquiring a really extensive first-hand knowledge of the circuits shown in these Bulletins.

The Hartley Oscillator: A practical Hartley oscillator circuit is given in Fig. 1. All parts are standard and are easily available at most radio parts supply houses. (The "coil" used in the original experiments is a push-pull plate-to-line transformer, SNC Type No. IP-152 ... the secondary windings are not used.) The tube is one-half of a type 6SN7, in keeping





with the type used in previous Bulletins in this series. However, any equivalent triode should do as well ... types 6C4, 6J5, 6O, etc.

The grid-leak resistor (R_g) should be variable so that different values may be tried during the experiments. A good expedient is to use the Heathkit *Resistance Substitution Box* ... standard resistor values may then be substituted simply by operating a switch.

If the Heathkit *Audio Frequency Meter* is available, a continuous check on frequency may be made by connecting this instrument between the cathode and circuit "ground."

Referring to the schematic diagram (Fig. 1), we can consider T1 simply as a tapped inductance coil. In the basic Hartley oscillator, one end of the tapped coil is connected to the tube's plate, the opposite end to the grid, and the tap to the cathode. Anyone of these three connections may be made through "ground." In the circuit shown in Fig. 1, both grid and cathode may be considered "hot," with the plate essentially at ground potential (through condenser C_2). Since one end of the coil is connected to ground, we can consider that the plate is directly connected to this end of the coil ... at least as far as signal voltages are concerned.

In many other practical circuits, either the grid or the cathode (with the respective coil connection) may be "grounded," with the other tube connections "hot."

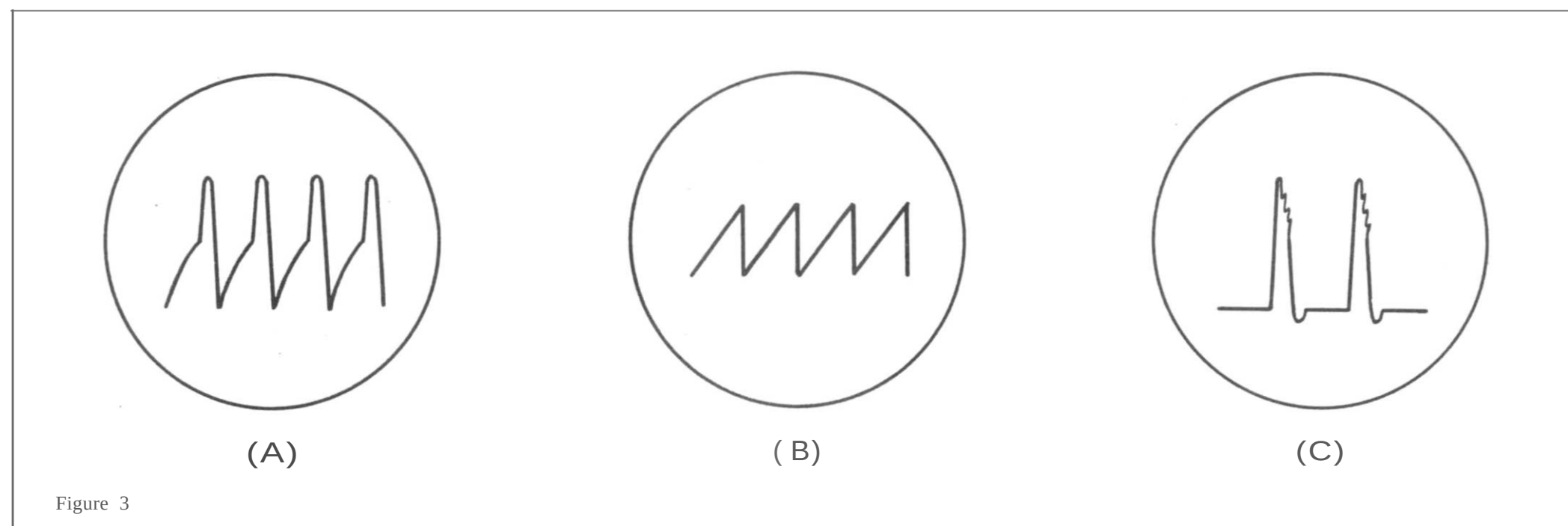
With an Oscilloscope connected to the circuit, and a 47K resistor used for R_g , the pattern shown in Fig. 2(a) was observed on the grid of the tube. The signal amplitude was well over 100 volts, peak-to-peak. The signal between plate and ground, as expected, had a low amplitude ... only about 5 volts peak-to-peak. This signal is shown in Fig. 2(b). Finally, the signal between cathode and ground, given in Fig. 2(c), had an amplitude of almost 100 volts.

The typical saw-tooth pattern observed on the plate of the tube (Fig. 2(b)) is due to the slow charge of C_2 through R_1 and its rapid discharge as the tube conducts heavily on positive grid pulses.

The measured frequency of operation was about 6800 cps, and is due primarily to the time constant of C_1 and R_g ... for the circuit, as shown, operates as a "blocking oscillator."

This can be shown by increasing the value of R_g to 220K ... in which case the patterns shown in Figs. 3(a) (grid, about 200 volts peak-to-peak), 3(b) (plate, about 6 volts peak-to-peak), and 3(c) (cathode, over 100 volts) were obtained. The operating frequency dropped to 1100 cps.

When the value of R_g was reduced to 10K, the frequency jumped to 24,000 cps. The pattern shown in Fig. 4(a) was obtained on the grid of the tube, with a peak-to-peak amplitude of about 40 volts. The signal appearing on the plate, as given in Fig. 4(b), had an amplitude of only 2 volts. In Fig.



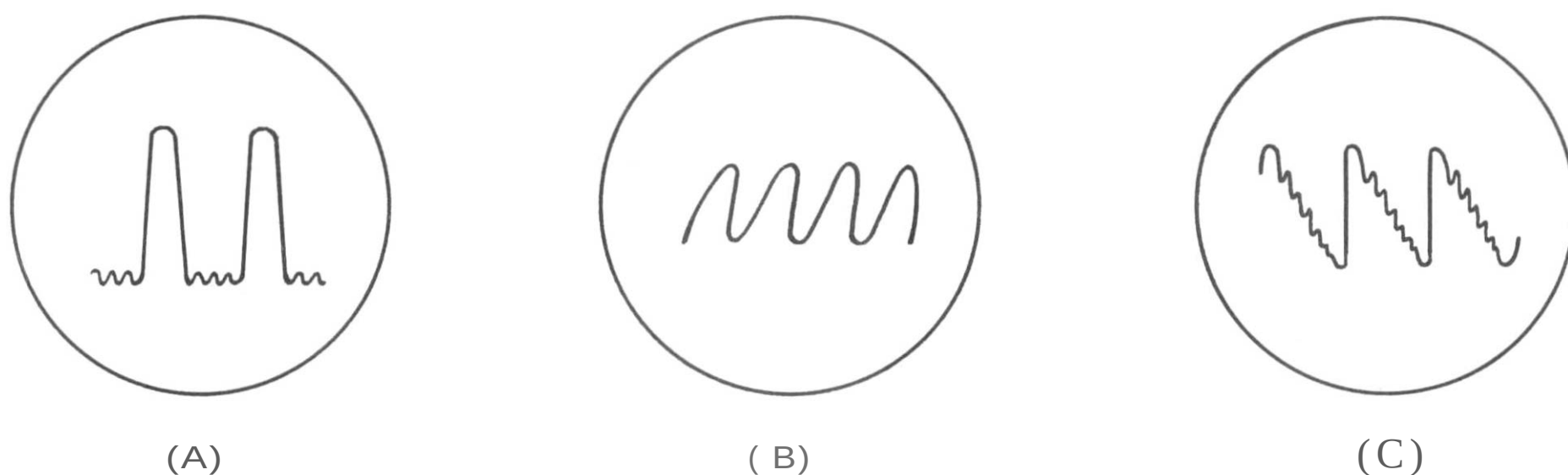


Figure 4

4(c) is given the signal wave-shape appearing between cathode and ground ... amplitude, about 25 volts.

Normally, the Hartley oscillator tries to operate at a frequency determined by an L-C tuned circuit made up of the tapped coil and any capacity across it. However, where the feedback is excessively high, or where the time-constant of the grid condenser-grid-leak resistor combination is large compared to this "natural" frequency, the oscillator will "block" at a rate determined by the R-C time constant. This condition results in the unusual waveforms observed thus far. The "natural" frequency for this circuit is represented by the small "ripples" observed faintly in Figs. 2(c), 4(a), and 4(c).

Where the "natural" operating frequency is reduced to a value comparable to the R-C time constant, the output waveform approaches a sine-wave. This may be demonstrated by shunting a .01 mfd condenser across the coil, as shown in Fig. 5(a). The plate Output signal approaches a **sine-wave** quite closely (Fig. 5(b)), while the operating frequency dropped to 3800 cps.

The Colpitts Oscillator: The Colpitts oscillator is generally considered to be almost the exact equivalent of the Hartley oscillator except that feedback is accomplished by means of a "tapped" condenser (actually two condensers in series) rather than by a tapped inductance coil. A suitable experimental circuit is shown in Fig. 6. L_1 is a 10 Hy, 40 Ma filter choke.

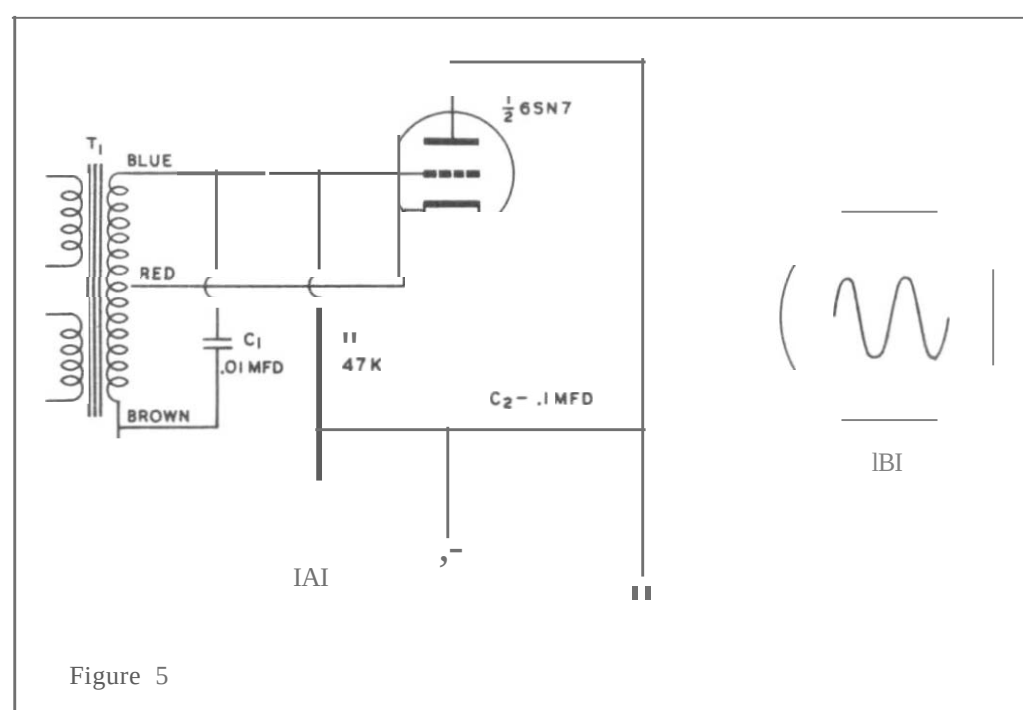


Figure 5

As in the case of the Hartley oscillator, any of the three "terminals" of the "tapped" condenser may be grounded. In the oscillator circuit shown in Fig. 6, the cathode and the "tap" have been connected together through a common ground.

With the circuit shown, and with R_g at 68K, the operating frequency was about 600 cps. The signal waveshapes shown in Figs. 7(a) and 7(b) were observed on the grid and plate of the oscillator tube, respectively. The grid signal had an amplitude of approximately 5 volts, peak-to-peak, while the plate signal amplitude was about 30 volts.

When R_g was raised to 4.7 megohms, the pattern observed on the plate of the tube changed to the general form shown in Fig. 7(c), with an amplitude of about 50 volts peak-to-peak. No attempt was made to observe the grid signal ... 'scope loading would have affected circuit operation in such a case due to the high value of R_g .

COMMERCIAL APPLICATIONS:

Both the Hartley and Colpitts oscillator circuits are so widely used that there is little or no difficulty in finding commercial applications of these circuits. A typical application of the Colpitts circuit is given in Fig. 8 and should be familiar to users of Heathkit equipment.

This is the audio oscillator circuit used in many Heathkit *R. F. Signal Generators*. The switching circuit has been omitted

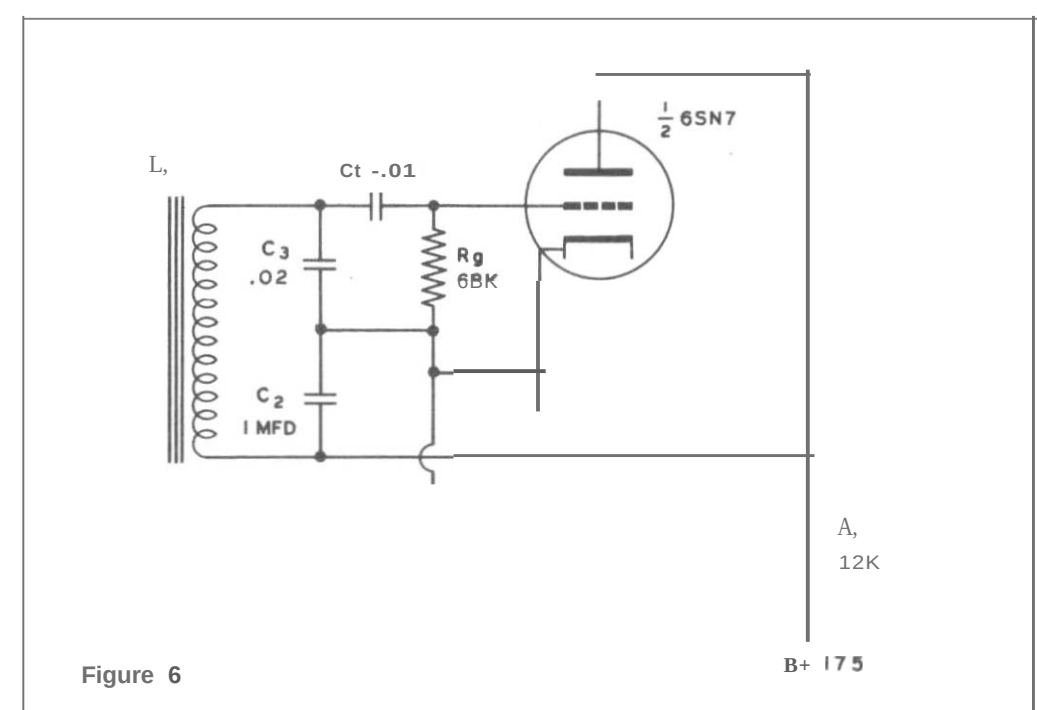
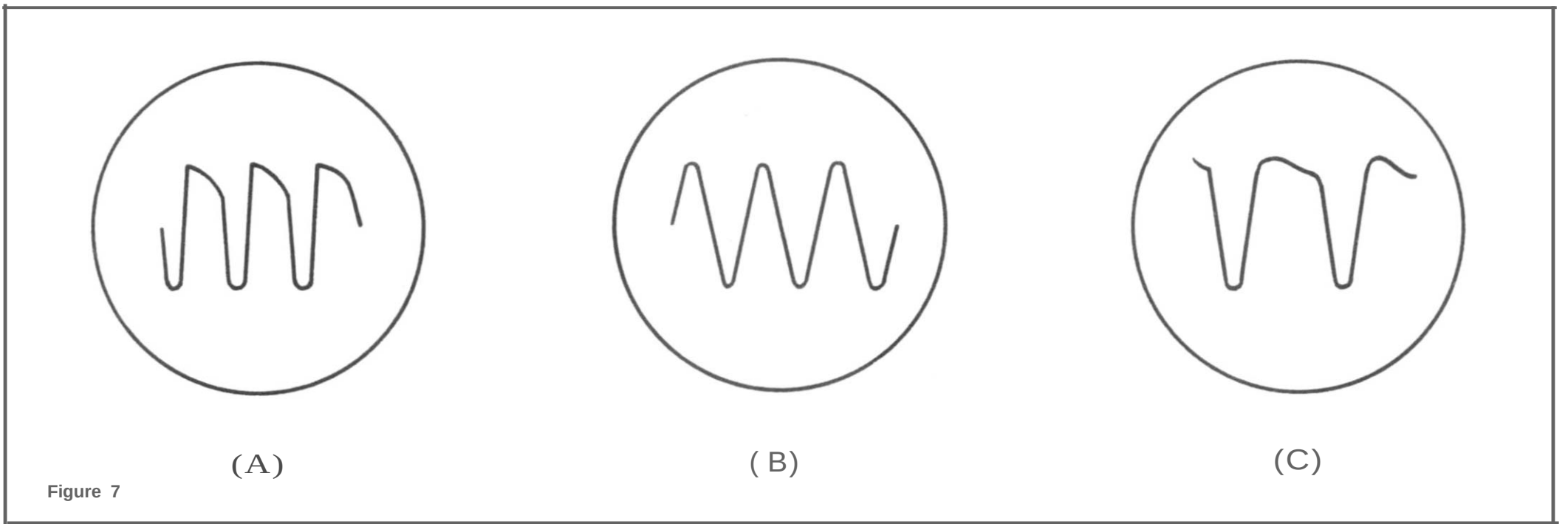
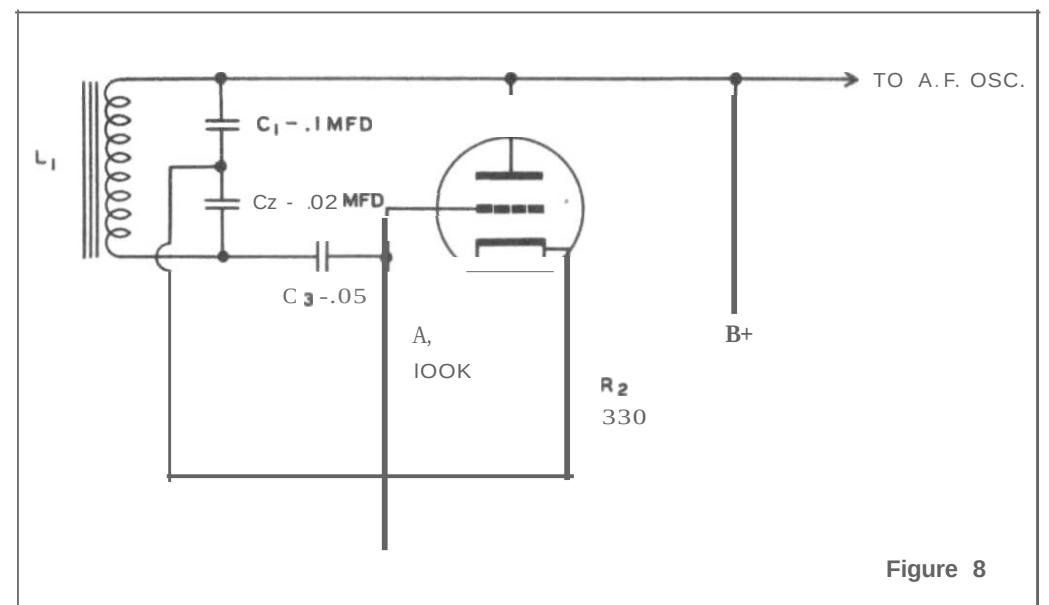


Figure 6



for purposes of clarity. A comparison of this circuit with the experimental Colpitts oscillator shown in Fig. 6 should reveal many points of similarity. Although the parts values and the tube used are not the same, the two circuits are almost identical.

The only major difference between the circuits shown in Figs. 6 and 8 is the use of an un-bypassed resistor in the cathode circuit of the oscillator in Fig. 8. This technique is often used to provide a slight amount of degeneration and thus to improve the wave-shape of the output signal. The circuit shown (Fig. 8) gives an almost perfect sine-wave.



study of plate-coupled multivibrators with the oscilloscope and power supply

BY LOUIS E. GARNER, JR.

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Multivibrator circuits are used extensively in all branches of the Electronics field, not only in such items as TV transmitters and receivers, Radar transmitters and receivers, Electronic Computers, and Electronic Medical Equipment, but also in the Laboratory Test Instruments employed in the design, manufacture, test and servicing of that equipment. In Test Equipment, for example, multivibrators are used in such items as Square-Wave Generators, Counters, Oscilloscopes, Pulse Generators, and Frequency Calibration apparatus. Therefore, a knowledge of the various multivibrator circuits and their characteristics is quite important, not only to the engineer, the technician, and the experimenter, but also to the serviceman who must repair equipment in which these circuits are employed.

In this Bulletin we will continue with the primary objective of the Heath "Basic Circuit" series . . . that is, to outline practical experimental circuits which the reader may assemble and study, using his *Heathkit Test Equipment*. As in other Bulletins in this series, only the basic information necessary to the construction and test of the circuits will be given, and the reader should refer to standard references for detailed theoretical mathematical discussions of the circuits shown.

The multivibrator is basically nothing more than a two-stage resistance-coupled amplifier with the "output" connected back to the "input." Since there is a phase shift of 180° in each stage, the over-all phase shift is 360° , and the signal fed back to the input may be considered as more or less "in phase with itself." In this manner, a necessary condition for oscillation is met . . . that is, amplification of a signal with positive (or "in phase") feedback.

Since there is generally no limit on the amount of feedback occurring, nor are tuned circuits used to select signals at a particular frequency, the resulting oscillation is quite vigorous, resulting not in a sine-wave, but in a complex waveform containing many harmonics. The "frequency" of oscillation depends on the R-C time constants in the coupling circuits employed. These components do not exercise too strong a control on frequency, however, so that most multivibrator circuits are quite unstable and easily "locked-in" or synchronized with an externally applied signal. This last characteristic contributes much to the usefulness of these circuits in test equipment.

Multivibrators may generally be divided into two large classes: (a) Plate-Coupled Multivibrators and (b) Cathode-Coupled Multivibrators. Since there are a number of different circuits in each class, they may be best discussed in separate Bulletins. Here, we will concentrate on some of the more popular *Plate-Coupled Multivibrator* circuits.

Assembly Hints and Suggested Tests: "Assembly and Wiring Hints" have been given in such detail in other Heath Bulletins that it would hardly be profitable to repeat those details here. Suffice to say that "breadboard" construction is recommended and that a separate variable voltage power supply should be used (such as the *Heathkit Laboratory Power Supply*).

The circuit tests to perform will depend largely on the inclinations and available time of the individual experimenter. However, to obtain the greatest amount of useable information from experimental tests, full data on d.c. operating voltages, frequency of operation, signal amplitudes, and signal waveforms should be obtained and recorded for each of the circuits studied.

SUGGESTED EXPERIMENTS:

All parts values will be given in each of the typical circuits shown. The reader should use these values only as a guide,

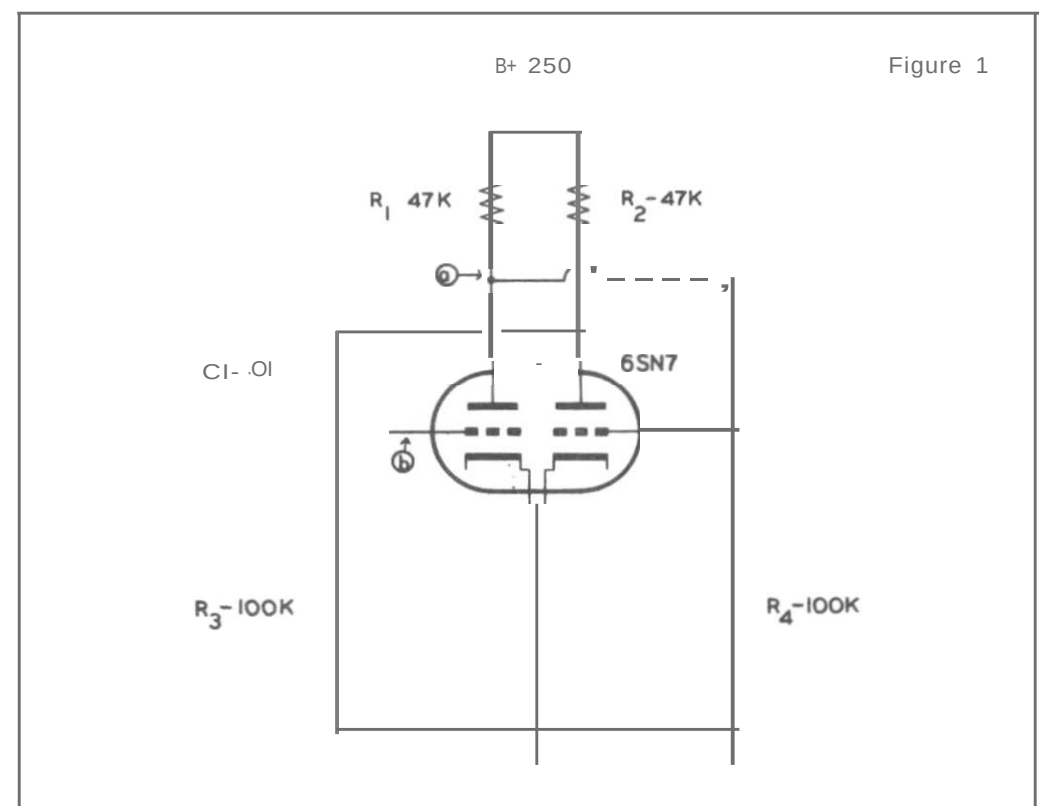


Figure 1

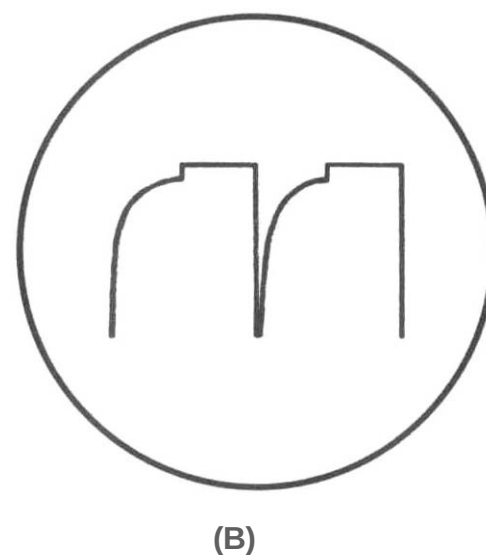
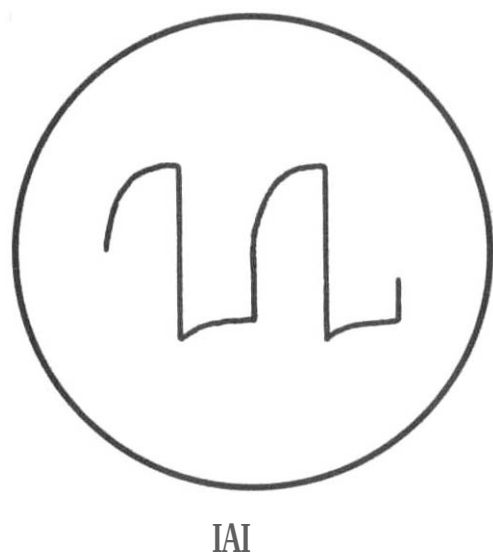


Figure 2

however, and should try different parts wherever practicable, noting any changes in circuit operation or performance.

THE SYMMETRICAL MULTIVIBRATOR:

This particular circuit (Fig. 1) is generally considered as the "basic multivibrator." As can be easily observed, the circuit consists of a two-stage resistance-coupled amplifier with identical value plate load resistors (R_1 , R_2), coupling condensers (C_1 , C_2) and grid resistors (R_3 , R_4) ... hence the name "symmetrical." As mentioned previously, the frequency of operation depends, to a large extent, upon the R-C time constants of the coupling circuits ... C_1 , R_3 , C_2 , R_4 .

With the values given in Fig. 1, the frequency of operation is approximately 170 cps. However, the actual frequency tends to shift back and forth to higher and lower values while the circuit is operating.

The signal waveforms as observed with the Heathkit Oscilloscope at points "A" and "B" (Fig. 1) are given in Figs. 2(a) and 2(b), respectively. Signal amplitudes in both cases are well over 100 volts, peak-to-peak. Note that each "half" of the signal is of equal duration. This is another important characteristic of the Symmetrical multivibrator.

THE ASYMMETRICAL MULTIVIBRATOR:

This particular circuit is basically similar to the Symmetrical multivibrator just discussed, but the time constant of one of the coupling networks is changed so that the two are no longer alike. A suitable experimental circuit is shown in Fig. 3. Note that this circuit is similar to the one given in Fig. 1 except for the value of C_2 .

As can be seen by reference to Fig. 4, this one change results in an appreciable change in signal waveforms. Again, Figs. 4(a), 4(b), 4(c) and 4(d) show the waveforms observed at points "A," "B," "C," and "D" in Fig. 3. The frequency of operation shifted to approximately 500 cps.

The important characteristic of the signal waveforms produced in this case is that the two "halves" of the signal are of unequal time duration. Hence the signal becomes more pulsed. Because of this, Asymmetrical Multivibrators are often used in Pulse Generators.

"SQUARE-WAVE" MULTIVIBRATOR:

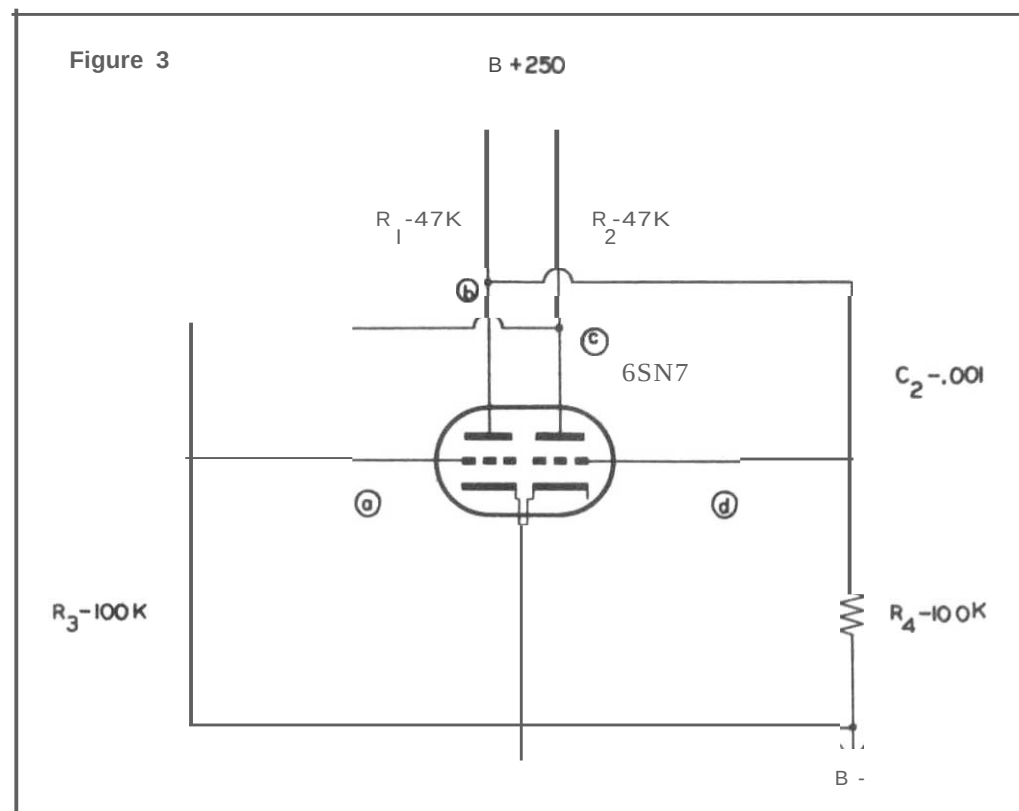
If resistors are connected in series with the grid leads in the basic multivibrator circuit, as shown in Fig. 5, the output signal (point "A") approaches a square-wave in general form, as illustrated in Fig. 6(a). Because of this, the modified circuit is commonly called a "Square-wave" multivibrator.

The addition of these two resistors does not appreciably change the frequency of oscillation. The circuit shown in Fig. 5 operates at approximately 150 cps.

Other signal waveforms encountered in this circuit are also given in Fig. 6. The signal observed at point "B" is given in Fig. 6(b), while the signal pattern observed at point "C" is shown in Fig. 6(c). In each case the signal amplitude is in the neighborhood of 100 volts (peak-to-peak).

MULTIVIBRATOR WITH CATHODE OUTPUT:

In each of the multivibrator circuits given above it was assumed that the Output signal would be taken from one of the plates. In many cases this is permissible, since the multivibrator is used to drive a high impedance circuit. However, there are a good many times when the multivibrator feeds into a low impedance circuit. In such cases, coupling the low impedance



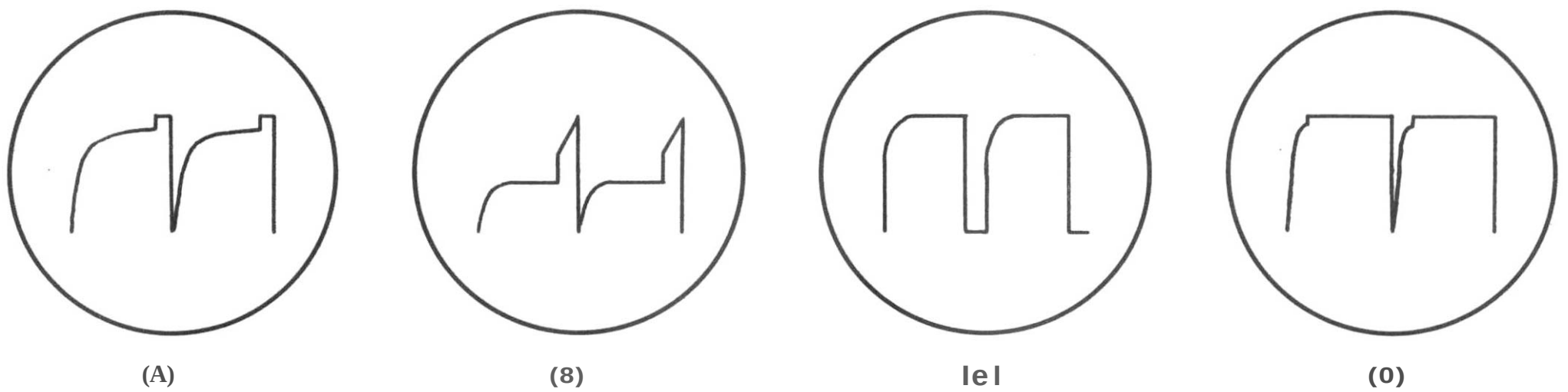


Figure 4

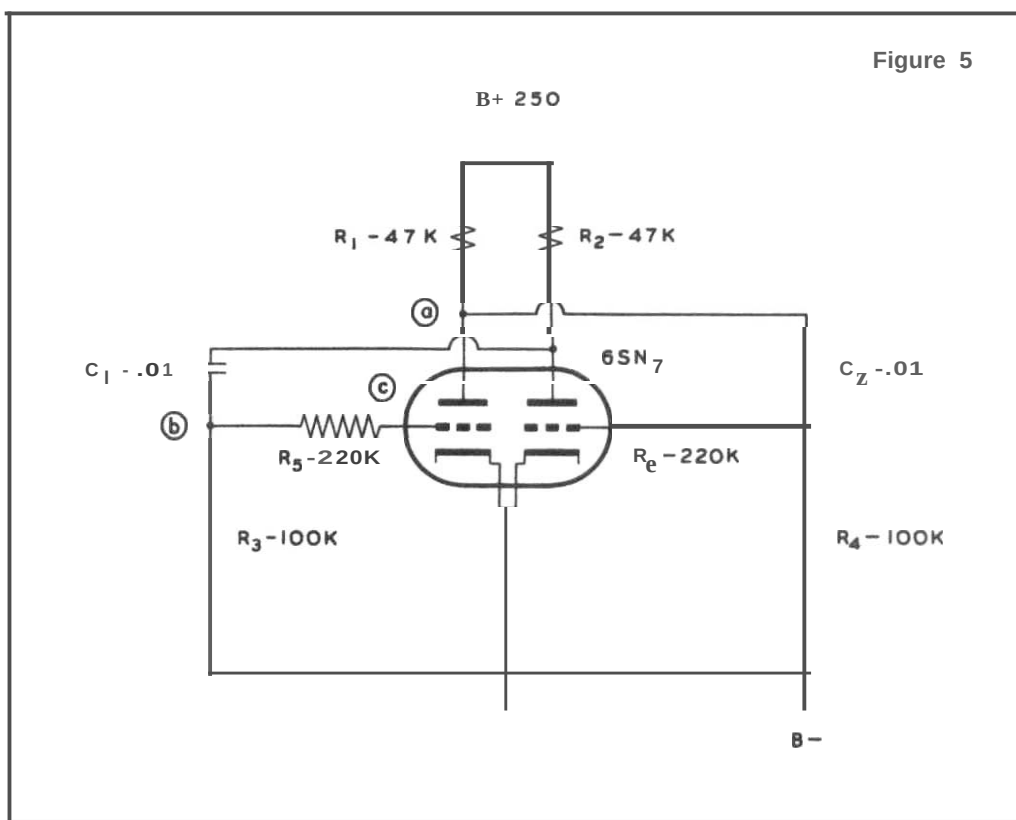


Figure 5

circuit to the plate of the tube will result in undue loading, with a resulting shift in the operating characteristics of the stage. This, in turn, may result in changes in the signal frequency, waveform and amplitude.

One solution is to employ a conventional "cathode follower" stage after the multivibrator. This permits the multivibrator to feed into a high impedance circuit, but, at the same time, permits the final output to be obtained at a low impedance.

There is another solution, however. It has been found that introducing a cathode resistor in one "half" of the multivibrator circuit, as shown in Fig. 7(a), and obtaining the output signal across this resistor, will not appreciably affect the output frequency.

Thus, with the circuit given in Fig. 7(a), the operating frequency remains at 170 cps. The Output waveform, across R_5 , appears as shown in Fig. 7(b), and has an amplitude of approximately 20 volts peak-to-peak.

If a lower output impedance is desired, R_5 may be dropped in value, but with a corresponding drop in output voltage.

Where a high value resistance is used for R_5 , the grid resistor (R_4) should be returned to the cathode rather than to ground. With this connection, the signal amplitude increases, but the waveform changes somewhat.

Thus, with the circuit shown in Fig. 8(a), the output signal across R_5 has an amplitude of approximately 25 volts (peak-to-peak) and the general waveform shown in Fig. 8(b).

COMMERCIAL APPLICATIONS:

Plate-coupled multivibrator circuits are widely used in many types of electronic test equipment. The circuit used in one such application is shown in Fig. 9. This particular multivibrator is used to supply a signal which alternately "blocks" two amplifiers

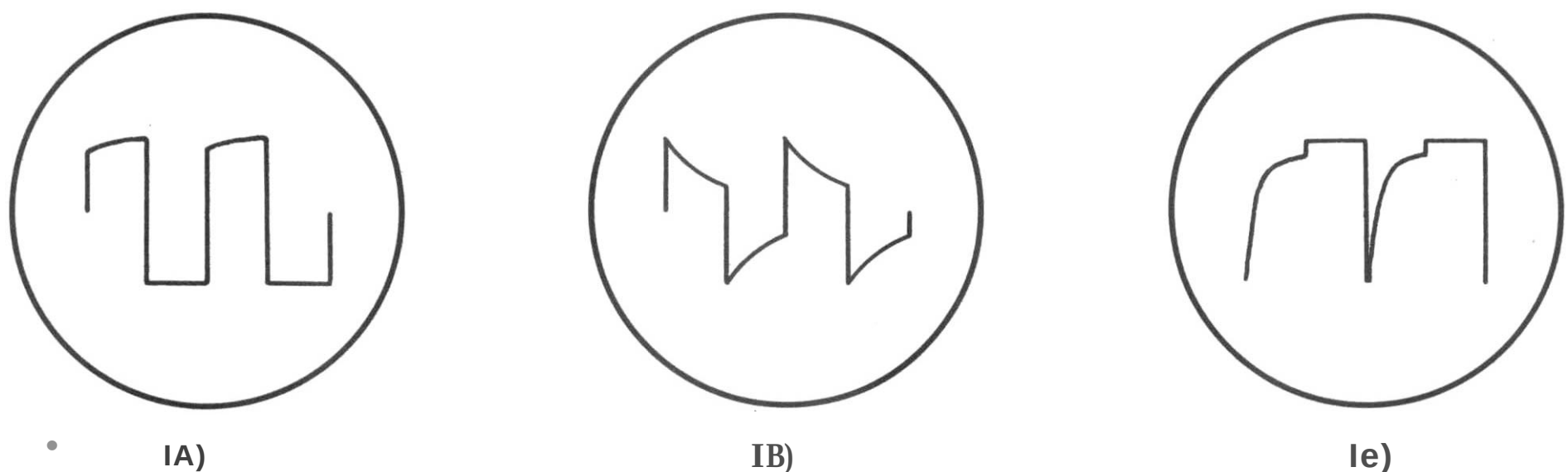


Figure 6

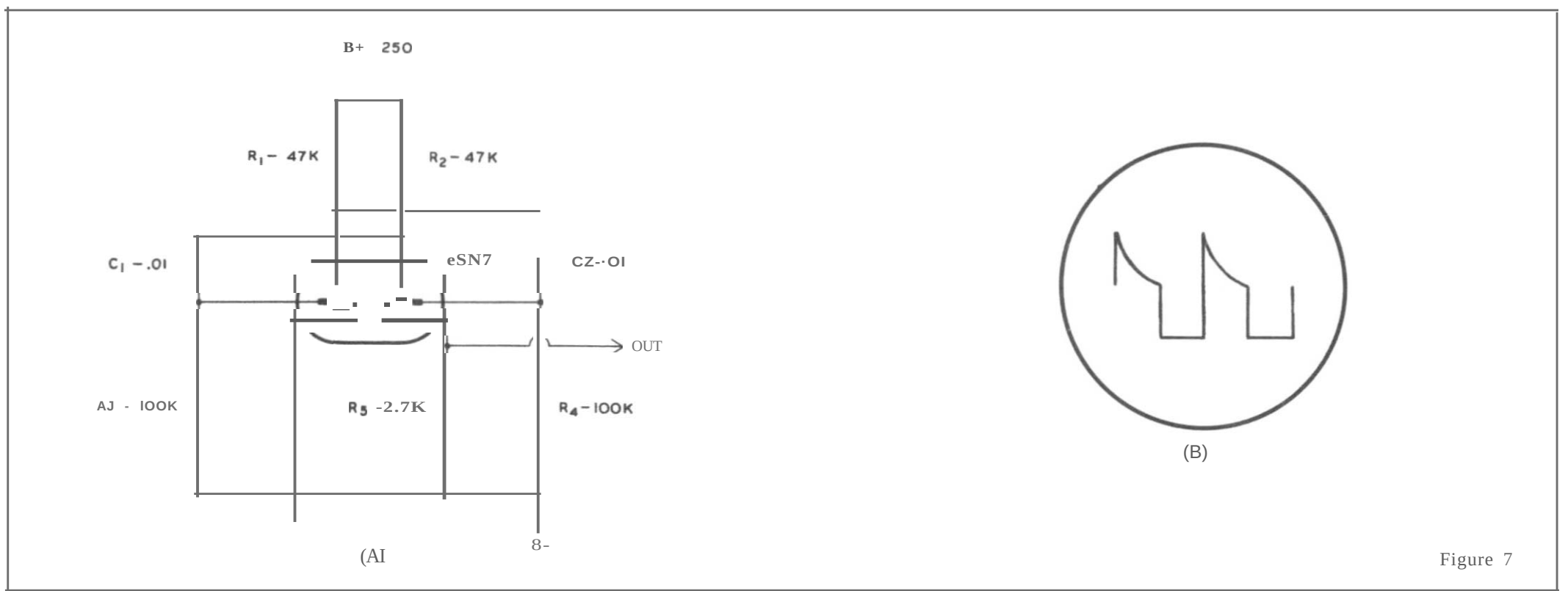


Figure 7

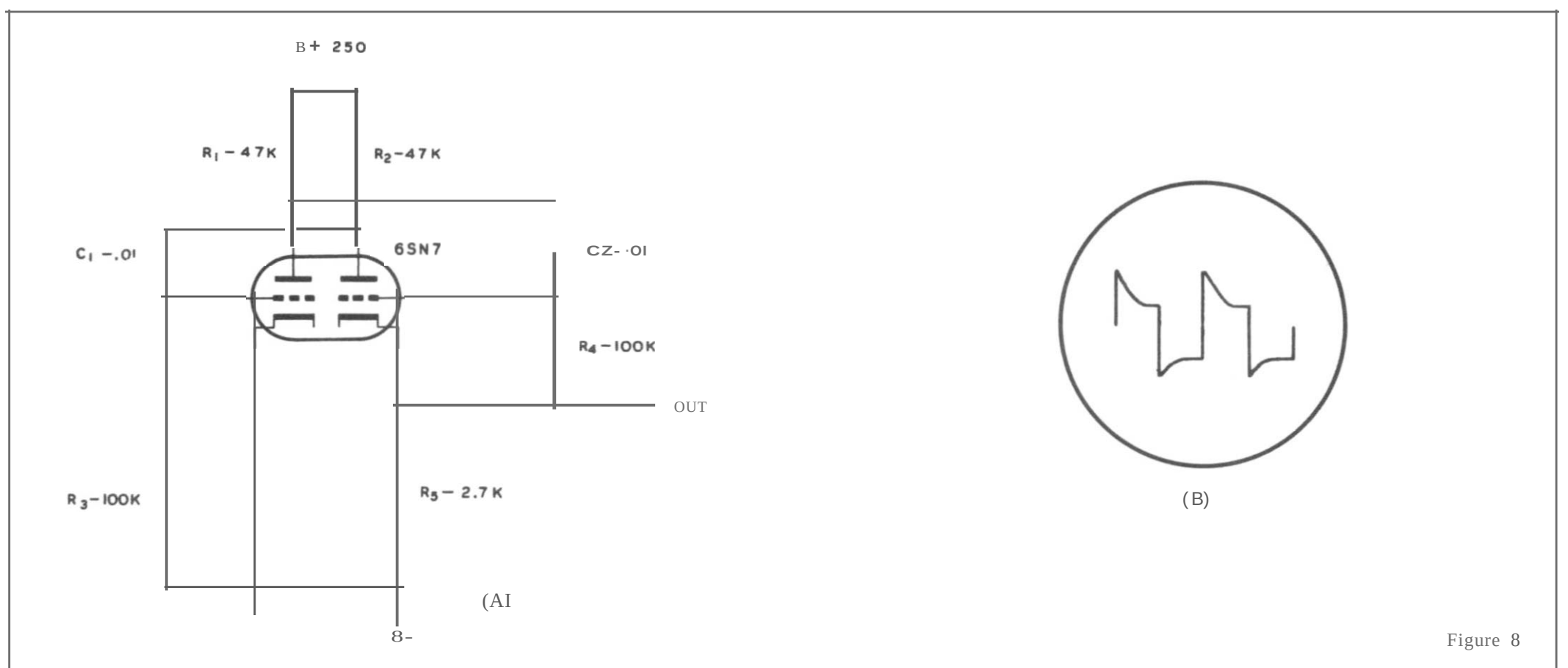


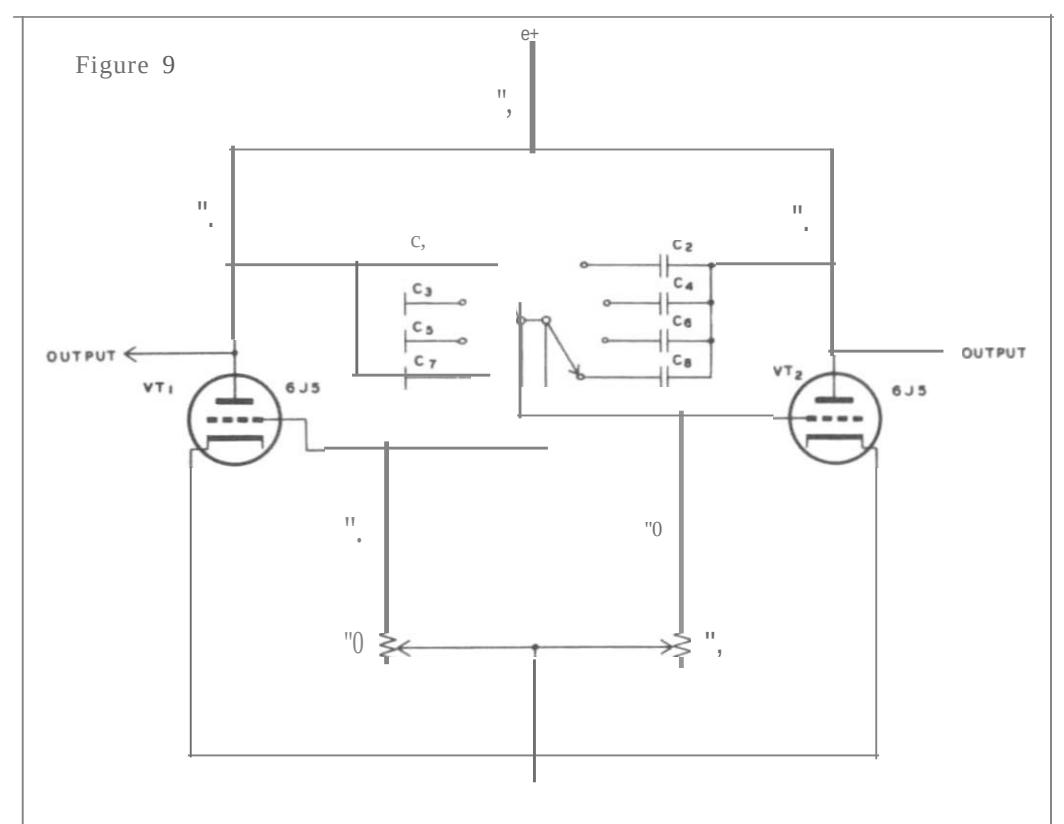
Figure 8

in the Dumont Model 185-A Electronic Switch. Although this is an older model, it is still found in many electronic laboratories and in school laboratories.

In order to provide a wide range of frequency control, SWI is used to select different "pairs" of coupling condensers and serves as a "Coarse" frequency control. Precise adjustment of frequency is obtained by the dual-ganged potentiometer in the grid circuits of the two tubes (R_6 - R_7).

The circuit is used as a Symmetrical Multivibrator and hence corresponding parts values are equal ... that is $R_2 = R_3$, $R_4 = R_5$, $R_6 = R_7$, $C_1 = C_9$, $C_3 = C_6$, etc.

The Heathkit *Electronic Switch* also utilizes a Symmetrical plate-coupled multivibrator in a circuit that differs only slightly from the one given in Fig. 9.



clipper circuit study with the oscilloscope and power supply

BY LOUIS E. GARNER, JR.

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Few circuits are both as simple from a wiring viewpoint and as widely used as the basic clipper. Clippers, in various forms, are used in almost all types of electronic equipment ... in Communication Receivers as noise limiters, in FM receivers to eliminate amplitude modulation, in recording equipment as peak limiters to prevent over-cutting, in Transmitters as peak clipper to prevent over-modulation, and in Test Equipment as amplitude limiters to form square-wave signals. Thus, when considered together, clippers form one of the most interesting groups of circuits. The action of various basic clipper circuits may be easily studied by using your Heathkit *Oscilloscope*.

Basic Clipper Action: The action of any clipper circuit may best be understood by referring to Fig. 1. Several complete cycles of a sine-wave signal are shown in this sketch. If the amplitude of the signal is forcibly restricted to the levels indi-

cated by dotted lines "A" and "B," the positive and negative "peaks" of the sine-wave signal would then be essentially "clipped off."

If only the positive (or negative) peak is removed, rather than both, we can still consider the result as a "clipped signal." In other words, the action of any clipper circuit is to *limit* the amplitude of the positive (or negative, or both) peaks of an applied signal. Because of this, clippers are often called "limiters" ... in most cases, both terms are equally correct. From a practical viewpoint, however, the term "limiter" is generally applied to circuits designed to operate on complex signal waveforms (such as voice signals) and to remove only the peaks, while the term "clipper" is more often applied to circuits used to convert applied signals into rectangular waveforms (or square-waves).

Since Clipper circuits are, in general, so simple to wire, they may be easily set up for experimental study. Once wired, signals of various amplitudes may be applied and the output waveforms studied.

WIRING THE EXPERIMENTAL CIRCUITS:

For ease in making experimental circuit modifications, it is suggested that the circuits to be described be wired on a "breadboard" type chassis (see Heath Bulletin "BREADBOARD" DESIGN TECHNIQUES) and that power be ob-

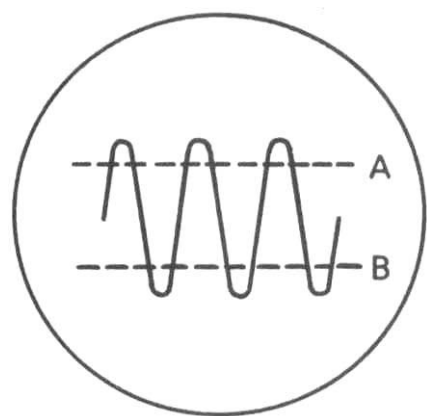


Figure 1

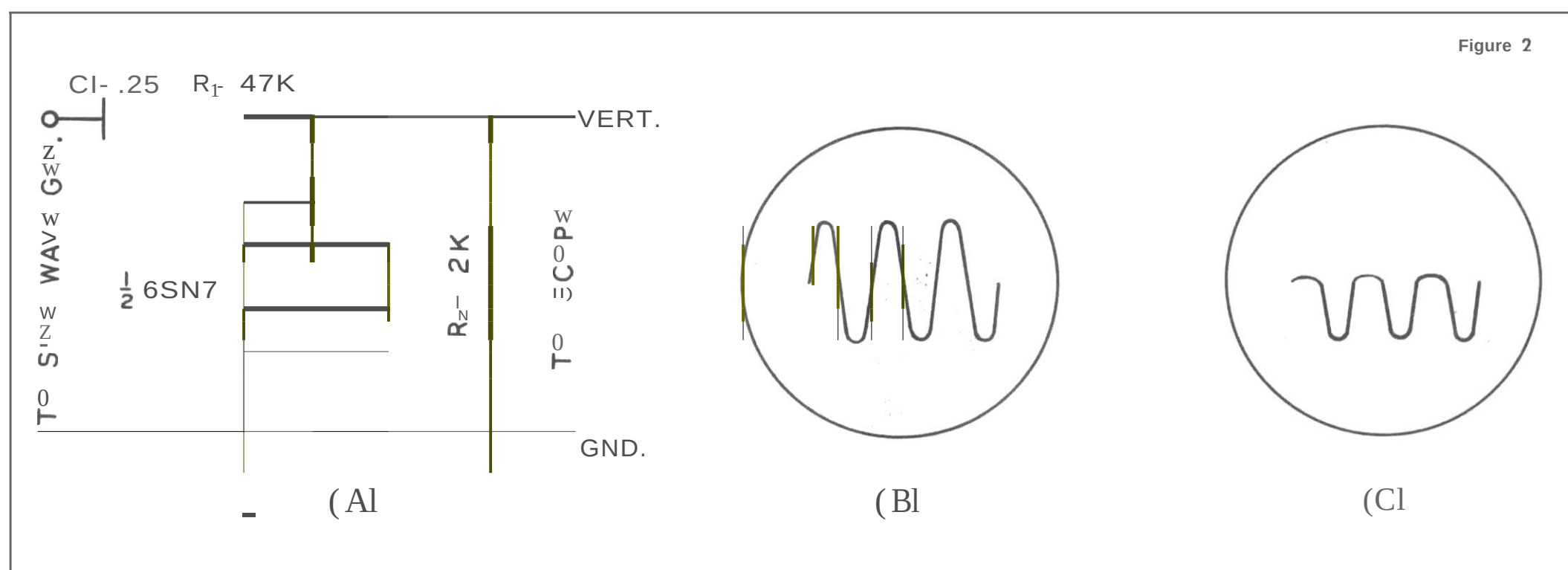


Figure 2

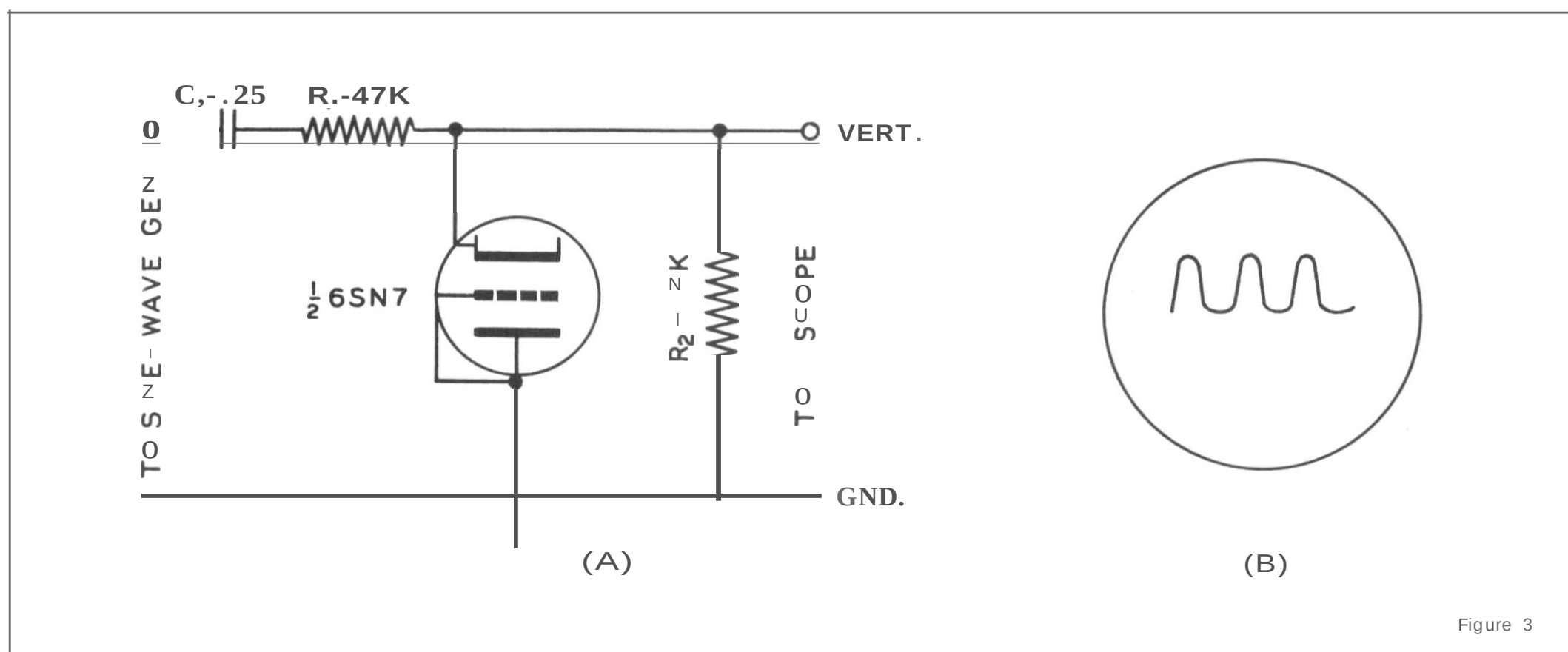


Figure 3

tained from a separate power supply, such as the Heathkit *Laboratory Power Supply*.

However, if the experimenter prefers, the circuits may be assembled on a conventional metal chassis (steel or aluminum).

SHUNT DIODE CLIPPER:

The shunt diode clipper circuit is illustrated in Fig. 2(a). This circuit may be wired using a diode connected triode ($\frac{1}{2}$ 6SN7) or a conventional diode tube ... types 6H6, 6AL5, 6X5, etc. are satisfactory.

To demonstrate the operation of this circuit, connect a sine-wave signal source to the input (Heathkit *Sine-Wave Generator*) and an Oscilloscope to the output, as shown. The exact frequency used is not too important ... 1000 cps is satisfactory. Gradually increase the input signal level, observing the output waveform. It will be found that the sine-wave (Fig. 2(b)) has been changed to the general form shown in Fig. 2(c).

With the circuit connected as shown in Fig. 2(a), the

diode conducts on positive half-cycles, thus acting as a practical short circuit. Because of this, the signal amplitude is dropped across series resistor R_1 . Since this occurs only on positive half-cycles, we find that this "half" of the signal is clipped.

If it is desired to "clip" the negative half-cycles, it is only necessary to interchange plate and cathode connections, as shown in Fig. 3(a). With this circuit, the output waveform appears as shown in Fig. 3(b).

Biased Shunt Diode Clipper: If a small battery is connected in series with the shunt diode clipper, "clipping" will occur over either a greater or smaller portion of the sine-wave cycle, depending on how the battery is connected. With the circuit shown in Fig. 4(a), the diode is conducting even before a signal is applied. Thus, a greater portion of the applied signal is "clipped," resulting in the pattern shown in Fig. 4(b).

On the other hand, if the bias battery connections are reversed, the diode can conduct only on the peaks of the applied signal, and hence only the peaks are clipped, giving the pattern shown in Fig. 4(c).

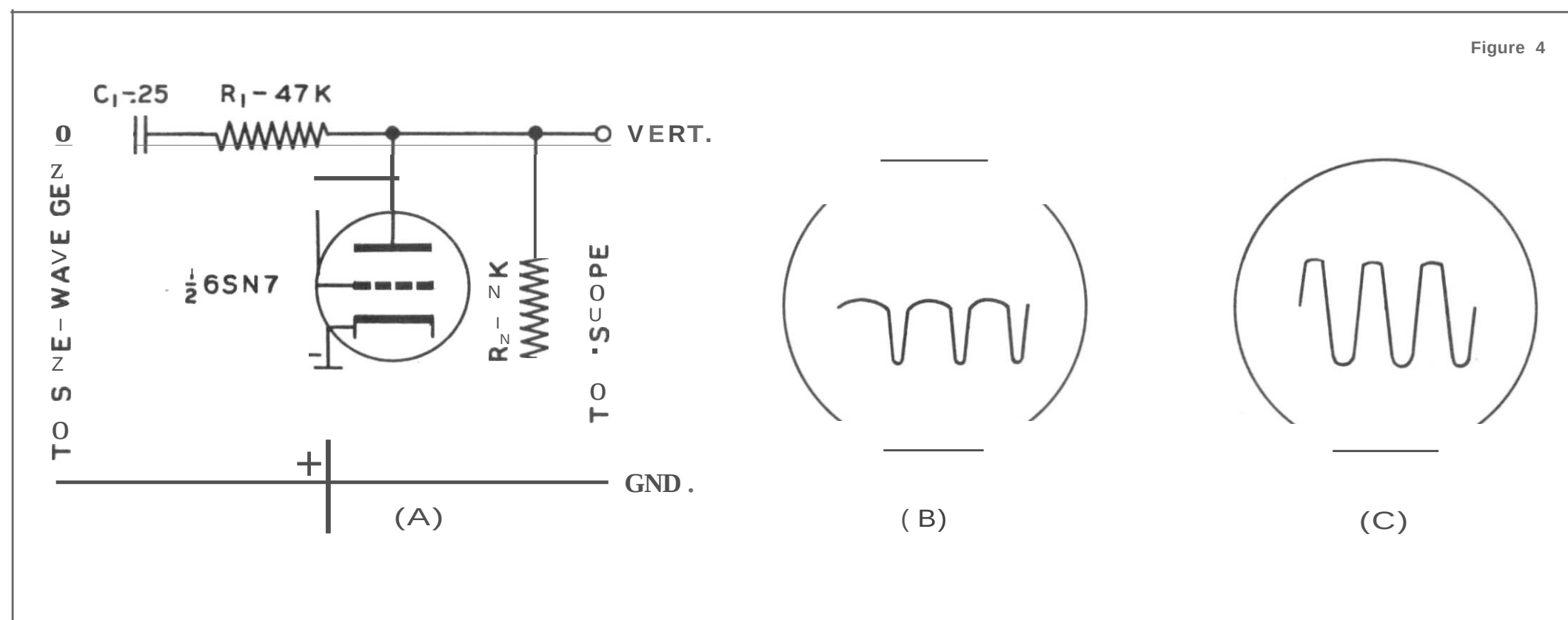


Figure 4

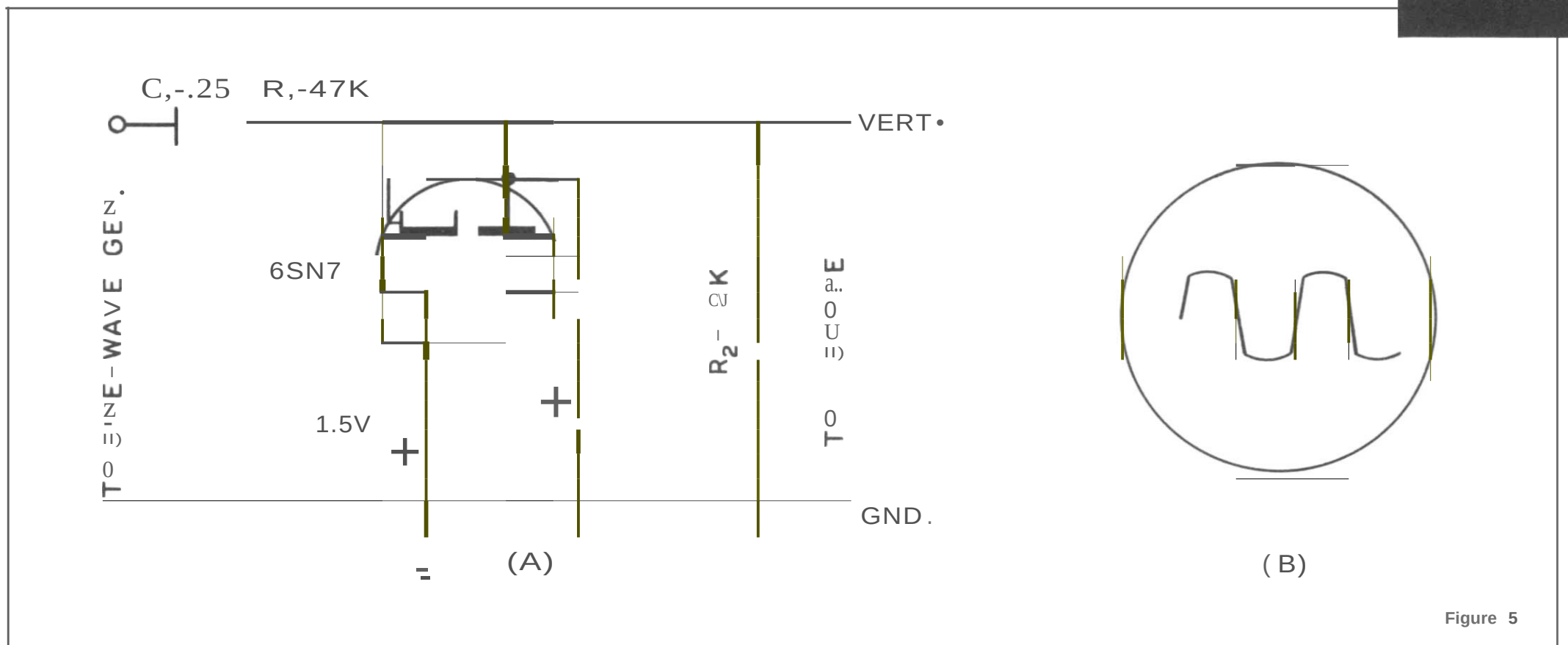


Figure 5

Of course, the actual pattern obtained will depend upon the amount of bias voltage used and upon the amplitude of the applied signal.

Dual Shunt Diode Clipper: Both halves of the applied signal may be clipped by connecting two shunt diode circuits together, as shown in Fig. 5(a). A small amount of bias is used to insure a reasonable output. With this circuit, and with a sine-wave of moderate amplitude applied to the input, the output signal approaches a square-wave in general form, as shown in Fig. 5(b). However, the "flat" portions of the signal are still rounded somewhat.

SERIES DIODE CLIPPER:

If the diode is connected in series with the load rather than across it, the clipping action will still occur. Such a clipper is shown in Fig. 6(a). However, in this case the action of the tube is reversed... that is, the "clipping" action occurs because the tube acts as an open circuit whenever the applied signal is such as to make the plate of the tube negative with respect to its cathode.

The clipping action of the series diode is, in many respects, superior to that of the shunt diode. As seen in Fig. 6(b), the "clipped" portion of the applied signal is much flatter and sharper.

As in the case of the shunt diode clipper, interchanging the plate and cathode connections permits the opposite half-cycles of the applied signal to be clipped. Thus, while the circuit shown in Fig. 6(a) clips the negative half-cycles, reversing the plate and cathode connections results in the positive half-cycles being clipped, giving the pattern shown in Fig. 6(c).

Biased Series Diode Clipper: The Series Diode Clipper may be biased quite easily by connecting a small battery in series with the output load resistor (R_2 in Fig. 6(a)). The action is similar to that observed in the case of the Shunt Diode Clipper except, of course, for the "sharper" clipping.

Dual Series Diode Clipper: Two series diode clippers may be connected "back-to-back" as shown in Fig. 7(a). Such an arrangement forms an excellent square-wave generator, resulting in an output waveform with flat "tops" and sharp corners, as shown in Fig. 7(b).

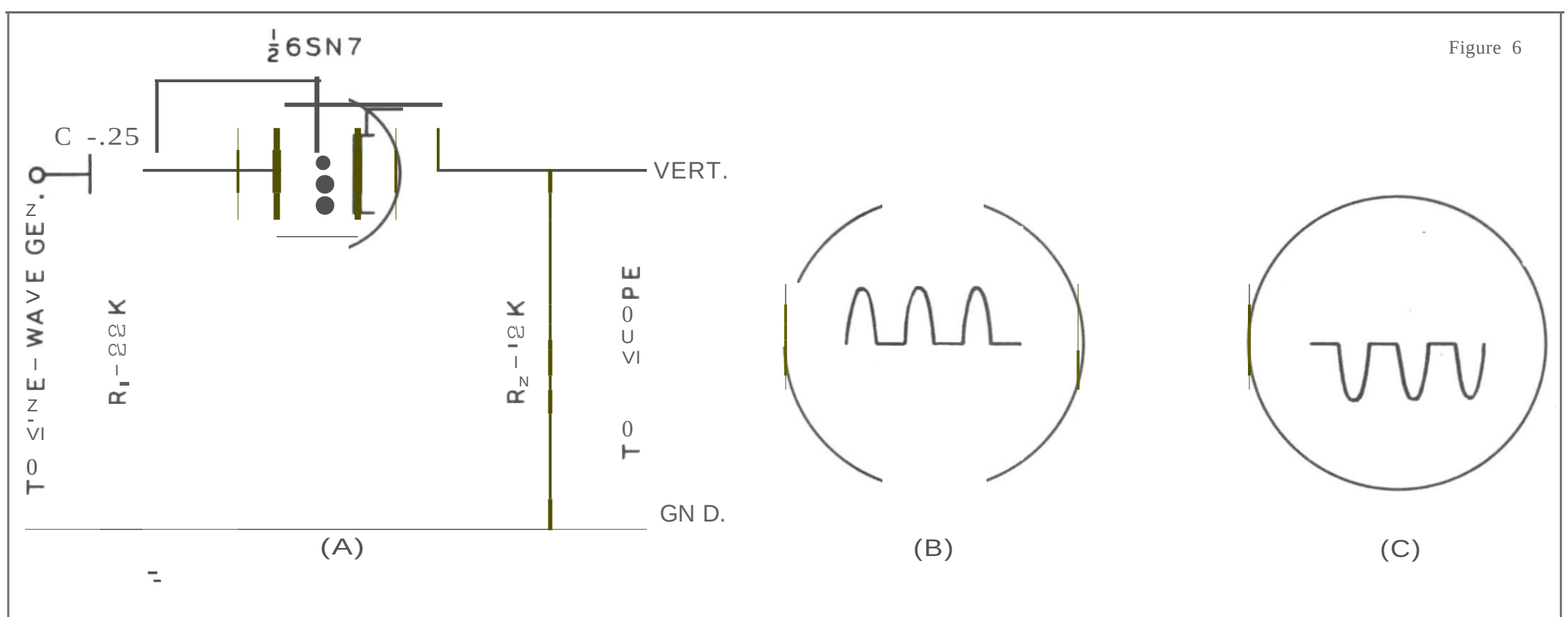
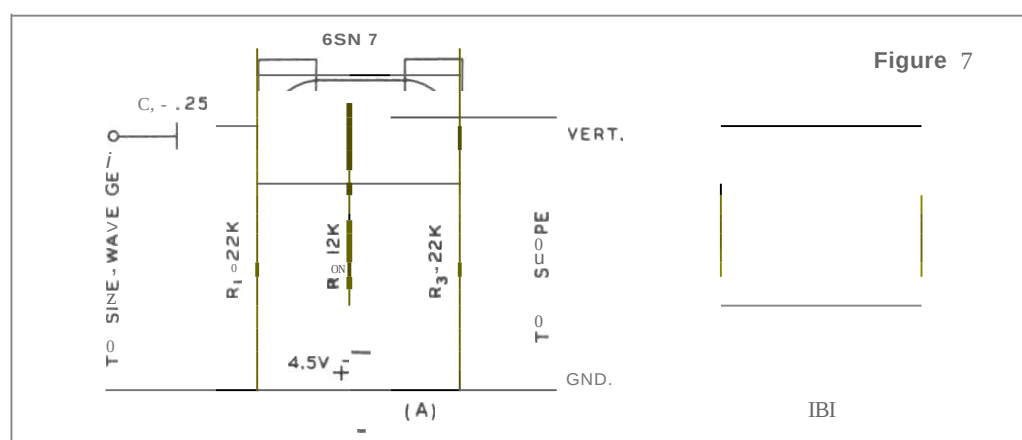


Figure 6



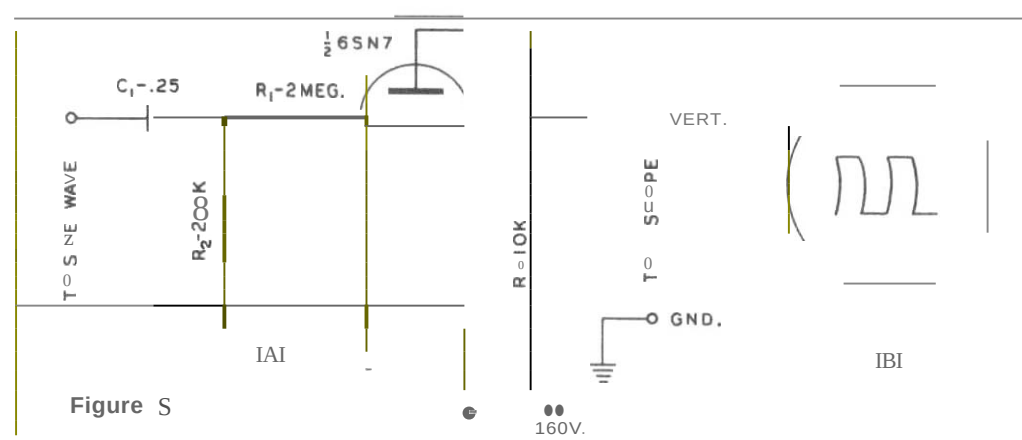
TRIODE CLIPPER:

Triode and pentode vacuum tubes may be used as excellent clippers if desired. Both tubes operate in much the same fashion and their basic action may be demonstrated quite easily using the circuit shown in Fig. 8(a). In this case the 6SN7, used as a diode in previous experiments, is now connected as a conventional triode.

In operation, the grid-cathode circuit acts as a shunt diode clipper, with the grid acting as a diode "plate," and R_1 serving as the series resistor. Thus, the positive half-cycles of an applied signal are "clipped." In addition, the grid current flow through R_1 (which occurs on positive half-cycles) builds up an average bias which, when added to the signal on negative peaks, is sufficient to reduce the plate current to cut-off rather quickly. Less voltage is required for cut-off than normally because of the low plate voltage.

Thus, both positive and negative half-cycles of the applied signal are clipped, resulting in an output signal that closely approaches a square-wave, as shown in Fig. 8(b) (sine-wave applied to the input).

This type of clipper may be "biased" either by using a battery in series with the grid resistor (R_2) or by using a cathode resistor and by-pass condenser.



COMMERCIAL APPLICATIONS:

Clippers are used extensively in TV receivers to remove the "sync pulse" from the composite video signal. One commercially used two-stage clipper circuit is illustrated in Fig. 9. This circuit was used in the popular Dumont Model RA-103 Television receiver and also in the Stromberg-Carlson Model TV-12 and the Crosley 9-407 Series.

Both VT1 and VT2 act to amplify the applied signal as well as to "clip" it. These two stages were used not only to obtain a "pure" sync pulse by repeated clipping, but also to supply a pulse that remained at a more or less constant amplitude regardless of wide variations in the level of the input signal.

In operation, clipping was accomplished in both the VT1 and VT2 stages by virtue of the low d.c. operating voltage. In the case of VT1, a low plate voltage was obtained through voltage division between R_2 and R_4 . In the pentode stage (VT2), screen-grid voltage is more important in determining the operational characteristics of the stage than is plate voltage ... hence the screen-grid voltage was reduced to a low value (to permit clipping to occur) by the voltage divider consisting of R_5 and R_6 .

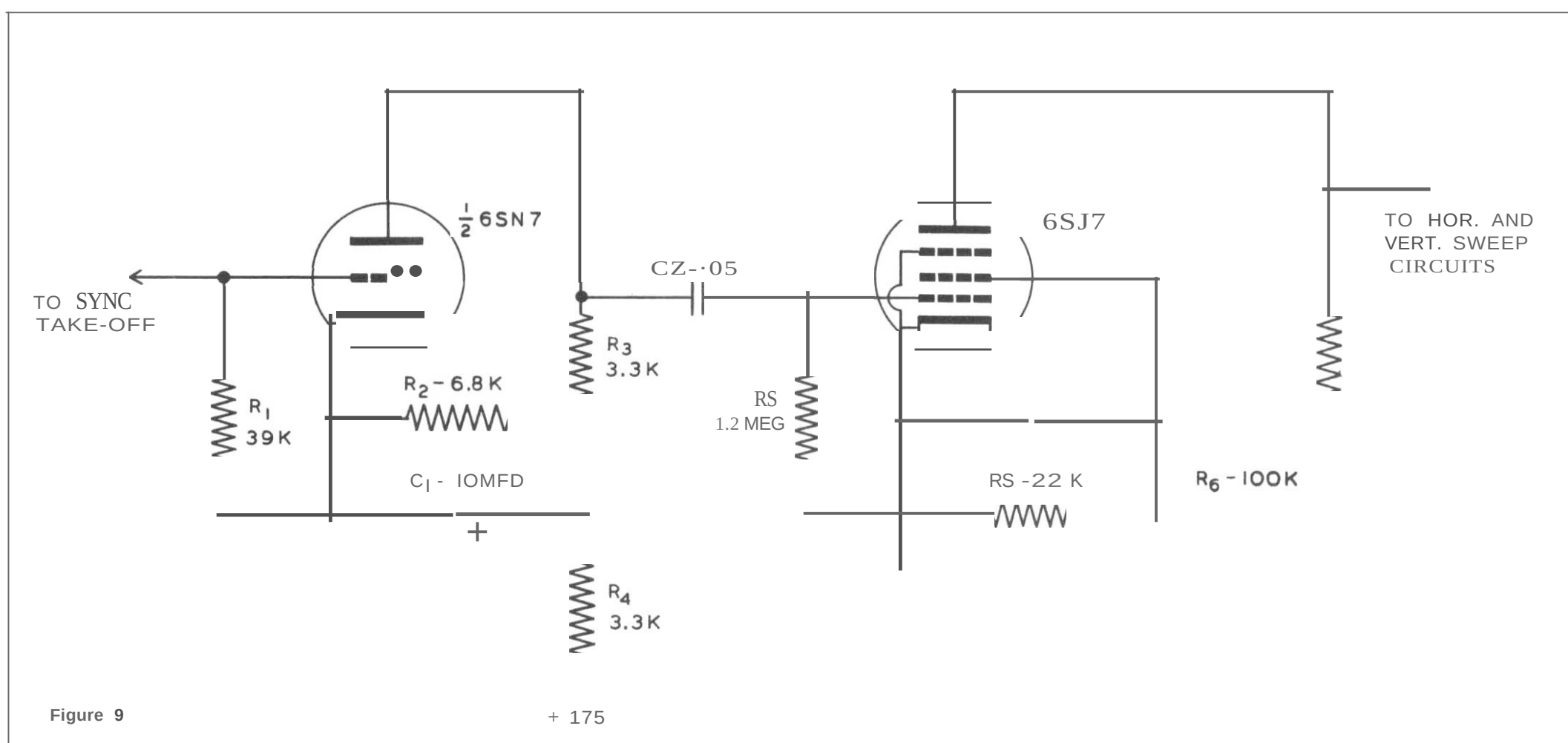


Figure 9

obtaining special signal waveforms with the oscilloscope

BY LOUIS E. GARNER, JR.

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Engineers, Laboratory technicians and experimenters will occasionally require unusual signal waveforms in their laboratory test work. In many cases the signal is used only for a few minutes to test the response of an amplifier or filter to a specific type of signal. In other cases the signal may be needed primarily for comparison purposes to aid in the analysis of an unknown or comparatively complex signal. In still other cases the signal may be used as a practical check of a mathematical calculation or derivation. But seldom is the need pressing enough to justify the construction or purchase of a special signal generator.

However, the laboratory worker may obtain a wide variety of signal waveforms by using his standard Heathkit equipment, a few additional parts, and a little imagination. The "set-up" time required seldom exceeds fifteen minutes.

In this Bulletin we will outline practical techniques that may be used to obtain a variety of signal waveforms. These techniques should serve as a guide to the reader in developing his own methods for obtaining specific wave-shapes.

SINE-WAVE SIGNAL SOURCES:

The reader undoubtedly is familiar with the various sources of Sine-Wave signals. However, a brief review may be of benefit.

Generally, a sine-wave signal is obtained from a conventional *Sine-Wave Generator*, *Audio Oscillator*, or *R.F. Signal Generator*. An *R.F. Signal Generator* may be used as a source of sine-wave signals at R.F. values only over limited ranges, however, since most R.F. Signal Generators are designed to deliver signals rich in harmonics (hence the output wave-shape is a distorted sine-wave rather than "pure").

Where an audio frequency sine-wave signal is desired, the AF OUT jack of the Heathkit *R.F. Signal Generator* may be used.

A 60 cycle sine-wave signal may be obtained from the power line, using a step-down transformer ... or from the "filament" winding of an ordinary **power** transformer in a piece of electronic equipment. Such a signal may also be obtained from the 60 CY TEST terminal of the *Oscilloscope*.

CLIPPED SINE-WAVE SIGNALS:

A clipped sine-wave signal may be obtained by using any sine-wave signal source and applying the Output to a conventional clipper circuit ... suitable "clippers" will be found in the Heath "Basic Circuit" Bulletin entitled CLIPPER CIRCUITS.

The Heathkit *Voltage Calibrator* provides an excellent source of clipped sine-waves at 60 cps. This instrument has the added advantage of supplying a signal of known amplitude.

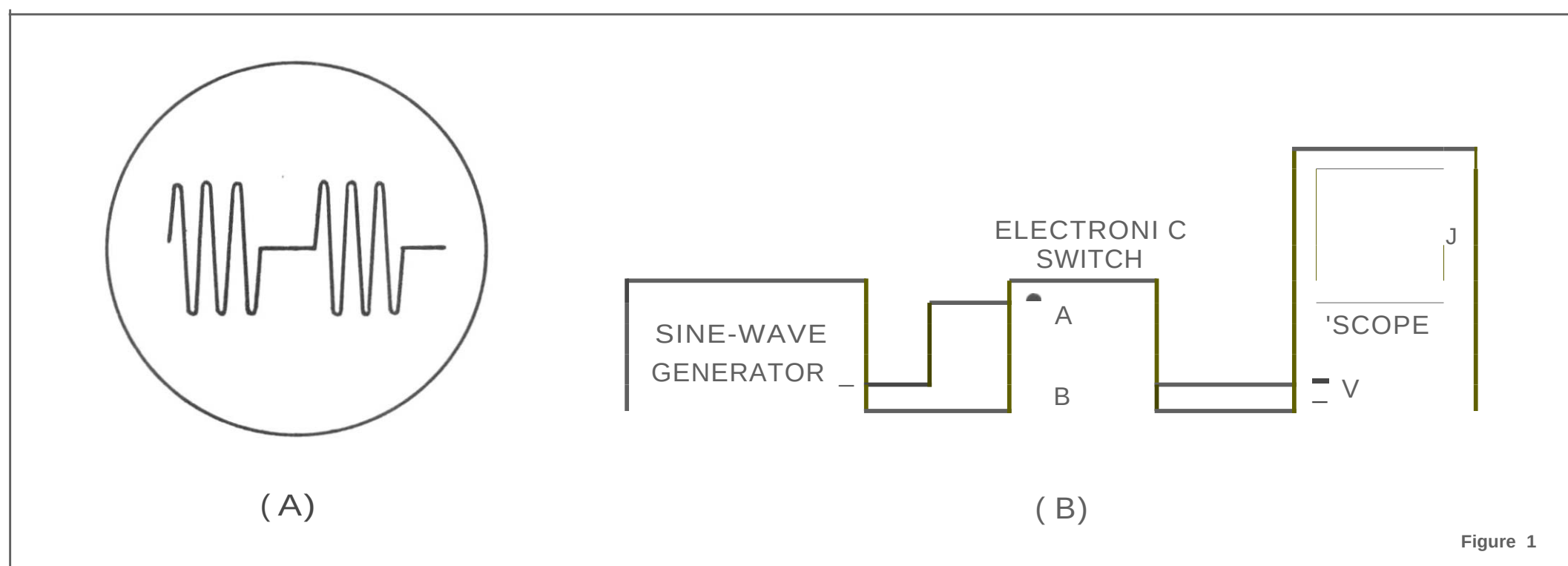
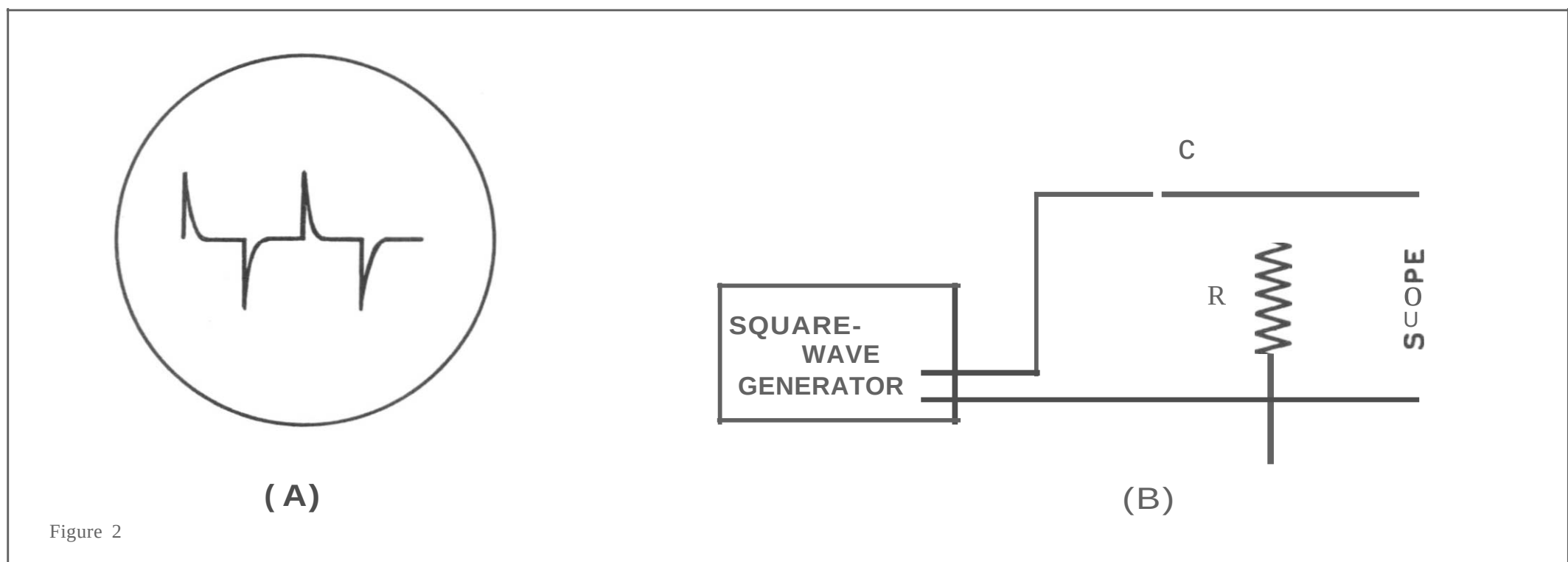


Figure 1



PULSED SINE-WAVE SIGNAL:

The pulsed sine-wave signal, as shown in Fig. 1(a) is often required in laboratory work. Such a signal may be formed by using the equipment set-up shown in Fig. 1(b).

A *Sine-Wave Generator* is connected to the "A" input of an *Electronic Switch* and the "A" Gain control advanced slightly. The "B" Gain control is left turned to "zero gain." The POSITION control is adjusted to bring the two output traces together, as observed on the screen of the 'scope.

To obtain the pattern shown in Fig. 1(a), it is necessary to adjust both the COARSE and FINE frequency controls of the Electronic Switch, as well as the Sweep and Sync controls of the Oscilloscope. For best results, the INT. SYNC. of the 'scope should be used. Therefore, care must be taken when adjusting the frequency controls of the Electronic Switch if a stable pattern is to be obtained. Readjustment of these controls during tests may be necessary.

BI-DIRECTIONAL PULSES:

Bi-directional pulses, as shown in Fig. 2(a), may be formed by using a differentiation circuit and a *Square-Wave Generator*, as shown in Fig. 2(b). The number of pulses obtained per second depends on the frequency of the Square-Wave Genera-

tor, while pulse "sharpness" depends on the R-C time constant of the differentiation circuit. For extremely sharp pulses, a short time constant (small C, small R) must be used.

TRIANGULAR WAVES:

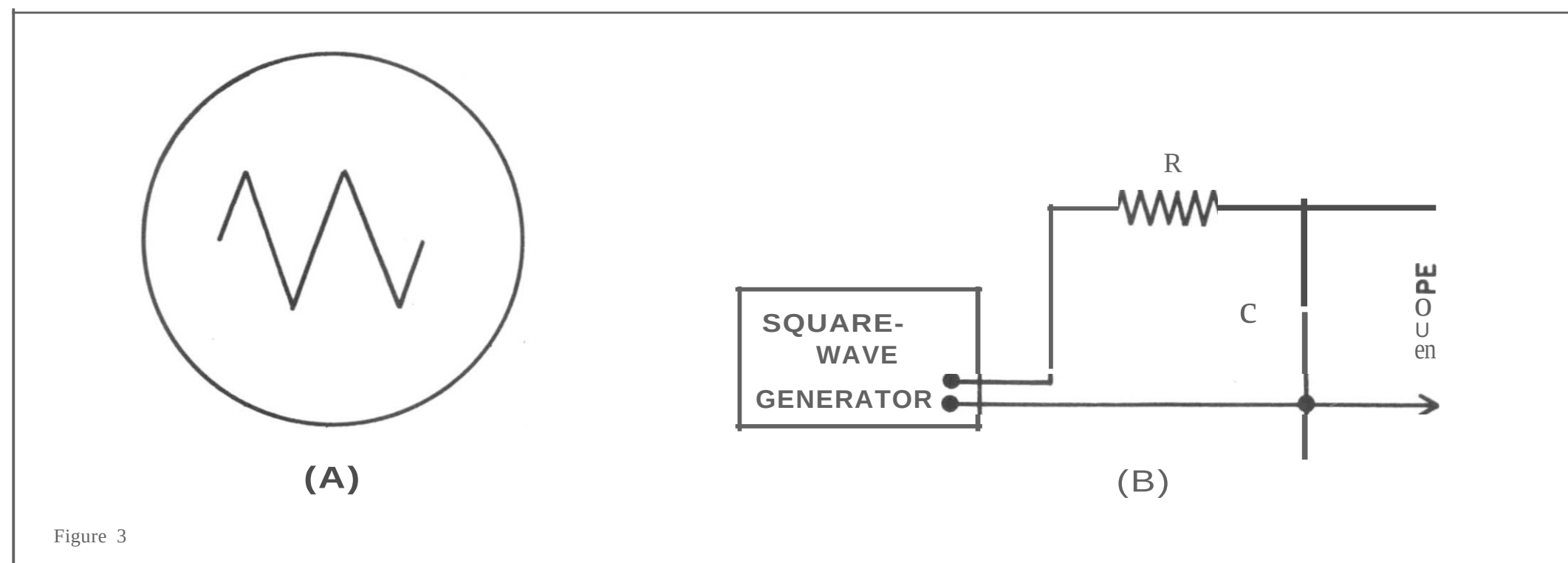
Using an integration network at the output of a Square-Wave Generator as shown in Fig. 3(b) permits the formation of triangular waves Fig. 3(a). In this case, a long time constant (large C, large R) is necessary to the proper formation of the signal waveform.

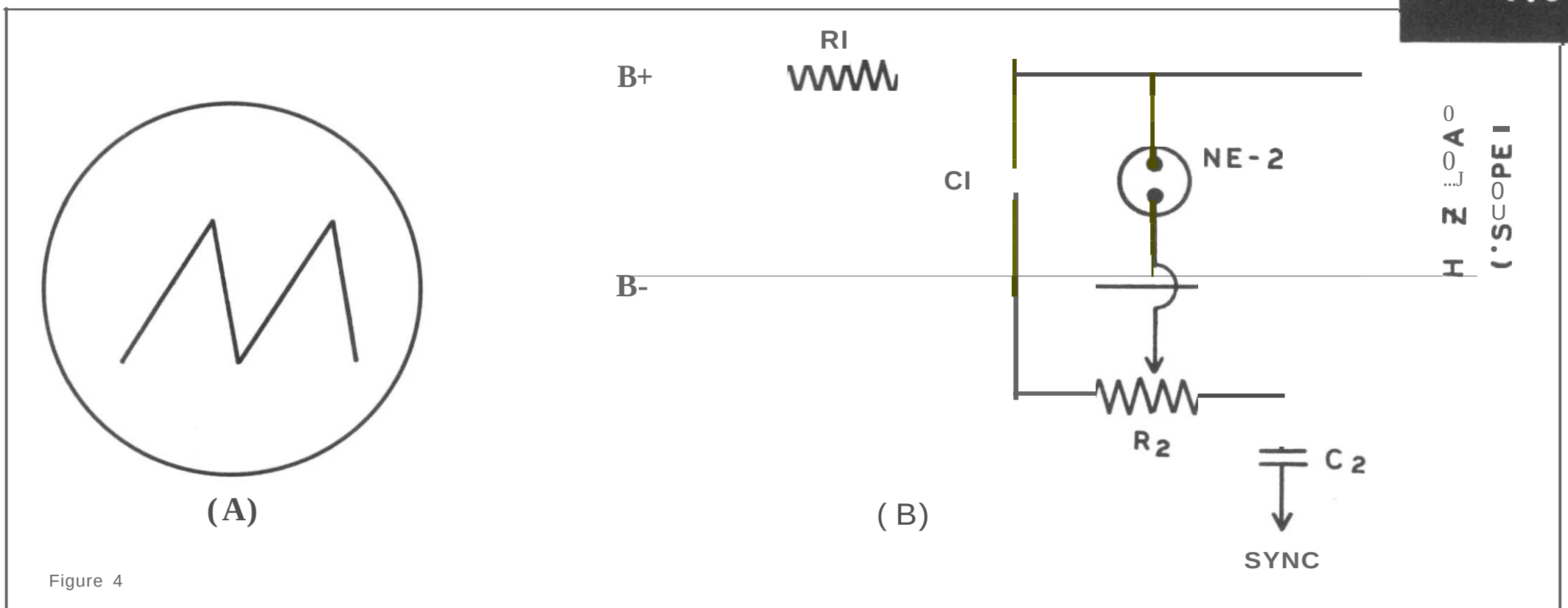
(NOTE: For a more detailed discussion of differentiation and integration networks than is possible here, refer to the Heath Bulletin DIFFERENTIATION AND INTEGRATION CIRCUITS.)

SAW-TOOTH WAVES:

The simplest circuit that may be used to produce linear saw-tooth signals as shown in Fig. 4(a) is the neon-bulb relaxation oscillator. The basic circuit is shown in Fig. 4(b). A type NE-2 or NE-51 neon bulb is satisfactory.

The operating frequency of this circuit depends on the time constant of the R1-C1 combination and on the B supply voltage, as well as on the individual characteristics of the neon





bulb used. Linearity also depends on these factors, and on the amount of circuit loading permitted. For good linearity, the output load must be in excess of several megohms... if necessary a 2 or 3 megohm resistor may be connected in series with the load, or a simple resistance-coupled "buffer" amplifier used between the output and the load. In addition, experimentation with the actual values of R_1 and C_1 (without changing their product or *time constant*) may give a slightly better or more linear signal in a particular case.

The normal frequency range of this circuit is from 10 to 1500 cps, although the maximum frequency will depend on the individual characteristics of the neon bulb used. Trying different bulbs may permit higher frequencies to be obtained.

If desired, the Output saw-tooth may be "synchronized" with an external signal by applying the signal through C_2 to R_2 and adjusting this control.

For saw-tooth signals greater than 1500 cps, a triode gas-tube oscillator circuit may be employed (see Heath Bulletin RELAXATION OSCILLATORS).

STEPPED AND PULSE WAVEFORMS:

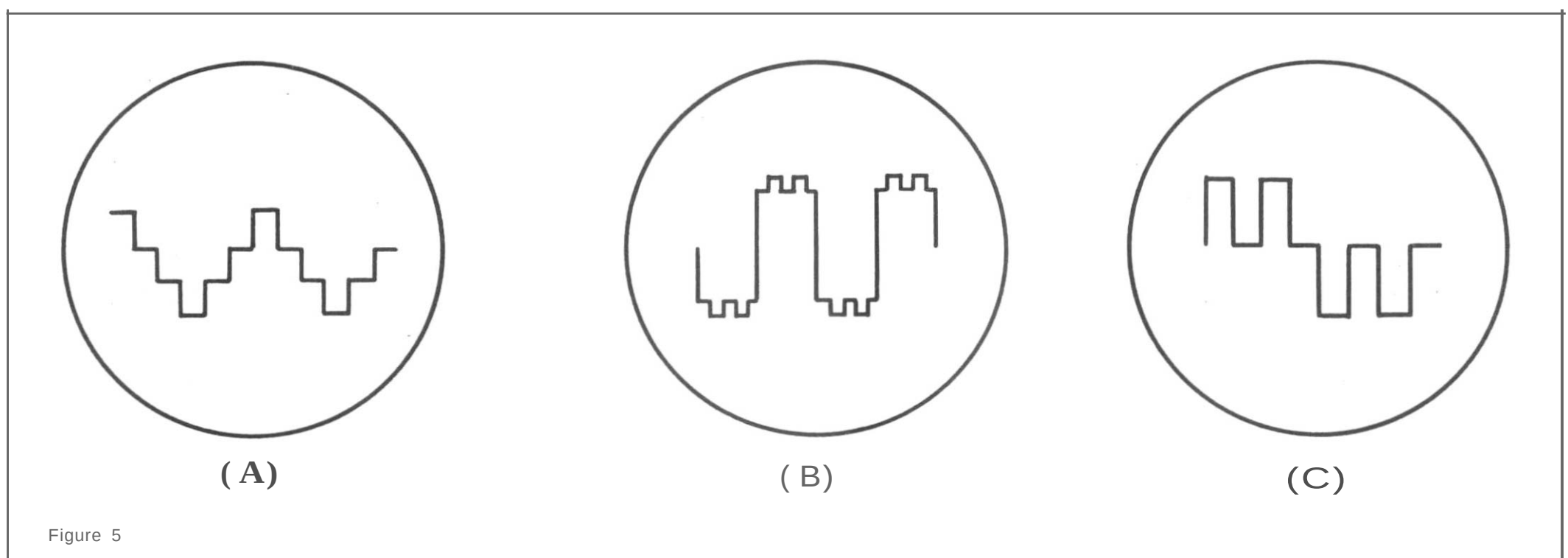
Signal waveforms of the types illustrated in Fig. 5 may be formed by combining Square-wave and rectangular wave sig-

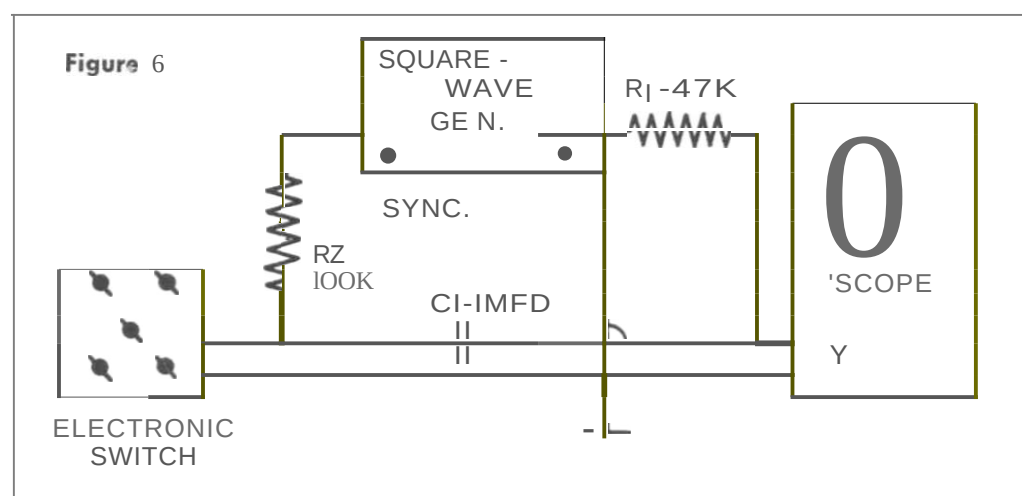
nals. A suitable circuit for accomplishing this is illustrated in Fig. 6. A Heath *Square-wave Generator*, *Electronic Switch*, and *Oscilloscope* are used.

In operation, R_1 prevents the low output impedance of the Square-Wave Generator acting as a short circuit across the Output of the Electronic Switch, and thus serves to isolate the two instruments. C_1 prevents the application of d.c. to the output attenuator of the Square-Wave Generator... a large value condenser must be used here (1 mfd) to avoid signal phase shift. R_2 also serves as an isolation resistor, acting to isolate the "Sync" input and the output of the Square-Wave generator, while still permitting the instrument to be synchronized with the Electronic Switch. These resistor and condenser connections are extremely important if the illustrated waveforms are to be obtained.

The "A" and "B" gain controls of the Electronic Switch are turned fully counter-clockwise and left in this position. The POSITION control serves as an output level control. In this fashion, the Electronic Switch actually performs as an auxiliary square-wave generator.

Using excessive "sync" changes the output signal of the Square-Wave Generator and this new signal, when combined ~~with~~ the output of the Electronic Switch, permits the forma-





tion of the waveform patterns illustrated in Figs. 5 and 7. All the signal waveforms shown were actually produced experimentally, using the circuit connections given in Fig. 6.

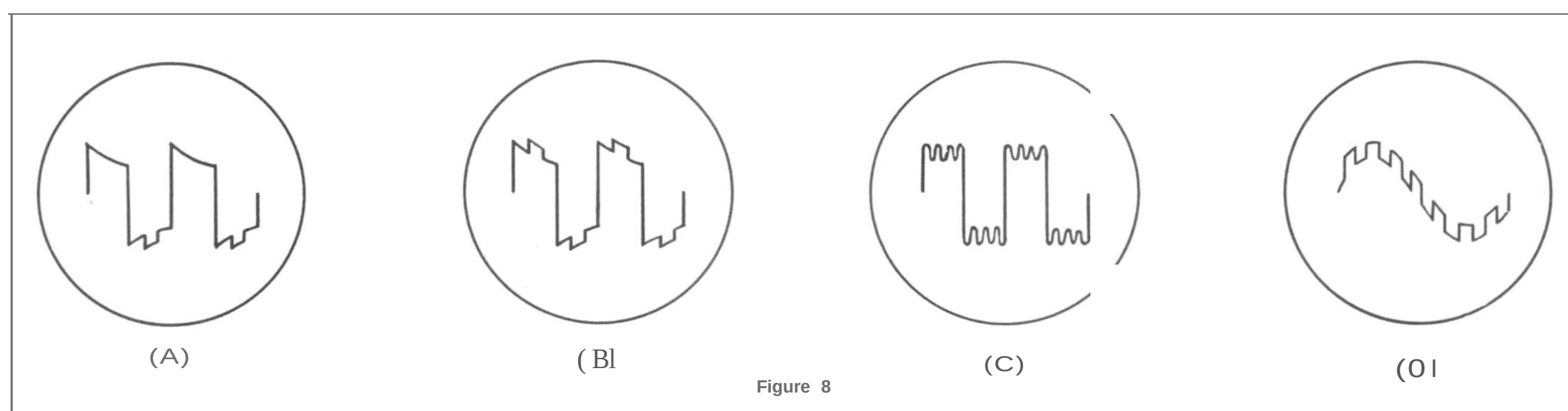
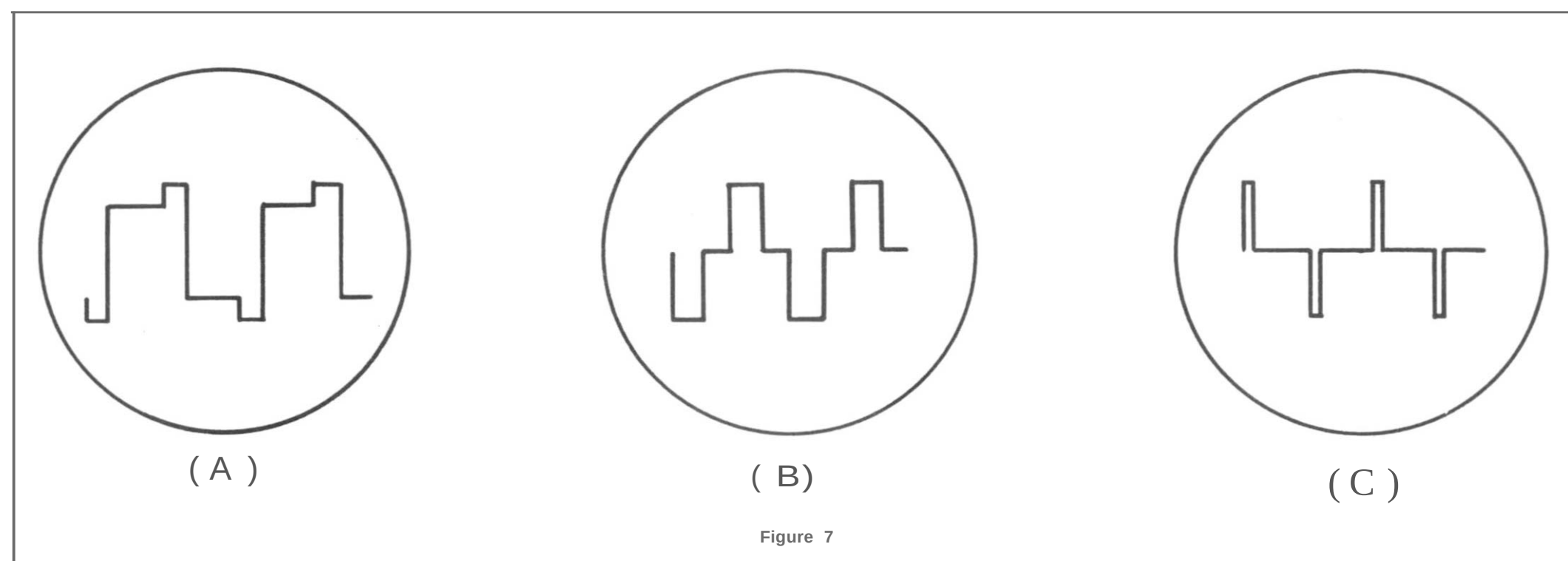
The stepped pulse shown in Fig. 7(a) was changed to produce the double-pulse illustrated in Fig. 7(b) simply by adjusting the OUTPUT control of the Square-Wave Generator. This pattern, in turn, was changed to the narrow rectangular pulse pattern illustrated in Fig. 7(c) by advancing the SYNC. LEVEL control (on the Square-Wave Generator).

COMPLEX PATTERNS:

It is possible to obtain extremely complex patterns by changing the wave-shapes of the individual signals used with the circuit given in Fig. 6. Thus, replacing C_1 with a .05 mfd condenser introduces "tilt" in the Electronic Switch Output, permitting signals of the type shown in Figs. 8(a) and 8(b) to be obtained.

Substituting a *Sine-wave Generator* for the Electronic Switch (all other connections in Fig. 6 remaining the same) permits signals of the types shown in Figs. 8(c) and 8(d) to be obtained.

Because several factors are involved, it is difficult to give exact instructions regarding the instrument control settings used to obtain a specific waveform at a particular frequency. However, if the reader will set up the circuit shown in **Fig. 6**, and experiment with different control settings for a short while, he will soon become familiar with the different waveform combinations possible, and the approximate control settings necessary to obtain a specific pattern.



graphical construction of oscilloscope patterns

BY LOUIS E. GARNER, JR.

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When the built-in linear sweep of the Oscilloscope is used for horizontal deflection at a frequency equal to or lower than the signal applied for vertical deflection, the pattern obtained on the screen of the CRT can generally be recognized. This is true because the pattern on the screen of the 'scope represents the actual waveform of the signal being studied.

On the other hand, when some other type of sweep is used for horizontal deflection, as may be necessary in many laboratory set-ups, the resulting pattern may bear no visible relationship to any recognizable wave-shape. In fact, the same pattern may not always be obtained with signals having identical waveforms because the resultant, as it appears on the screen of the 'scope, depends not only on the frequency and individual wave-shapes of the signals applied for horizontal and vertical deflection, but also upon their phase relationships.

A better understanding of the conditions discussed can be obtained by considering the sketches given in Fig. 1. Fig. 1(a) represents the pattern obtained when a sine-wave signal is used for vertical deflection, and a saw-tooth signal (at $\frac{1}{3}$ the frequency of the sine-wave signal) for horizontal deflection. If the two signals are interchanged (saw-tooth used for vertical deflection), the pattern obtained (Fig. 1(b)), though appearing odd at first, may be easily recognized after a moment's study.

On the other hand, if sine-wave signals are used for *both* horizontal and vertical deflection, the pattern shown in Fig. 1(c) may well result. Note that this pattern is difficult to compare with the pattern shown in Fig. 1(a), even though the same signal is used for vertical deflection in both cases. Even more difficult to correlate with the original sine-wave pattern is the resultant shown in Fig. 1(d) ... *yet this pattern*

may result from the same two signals giving the pattern shown in Fig. 1(c). The only difference is in the phase relationships of the two signals. (NOTE: For an additional discussion of these types of figures, refer to the Heath Bulletin "FREQUENCY MEASUREMENT WITH LISSAJOU FIGURES.")

Fortunately, however, there is a technique available for the graphical construction of practically any pattern that may occur on the screen of an oscilloscope. This technique permits the accurate prediction of the resultant pattern if the waveforms of the "hor." and "vert." signals are known beforehand. More important, in many cases, it may be used to determine the waveform of an unknown signal if the resultant pattern and the waveform of one of the signals making up the pattern is known.

Many technicians, after using the graphical method a few times, acquire sufficient skill at interpreting unusual patterns that they can dispense with actual construction in all except the most complex cases.

The fundamentals of the technique may be best understood by considering the formation of a simple sine-wave pattern, as shown in the graphical construction given in Fig. 2 (sine-wave applied to the VERT. INPUT, with a saw-tooth signal at the same frequency used for horizontal deflection).

The sine-wave signal is drawn along the horizontal axis (x-x) and represents the signal used for vertical deflection. The saw-tooth signal is drawn along the vertical axis (y-y) and represents the signal used for horizontal deflection. The area within the circle represents the oscilloscope screen.

In order to plot the resultant pattern, each signal is divided into a number of sections representing equal time intervals.

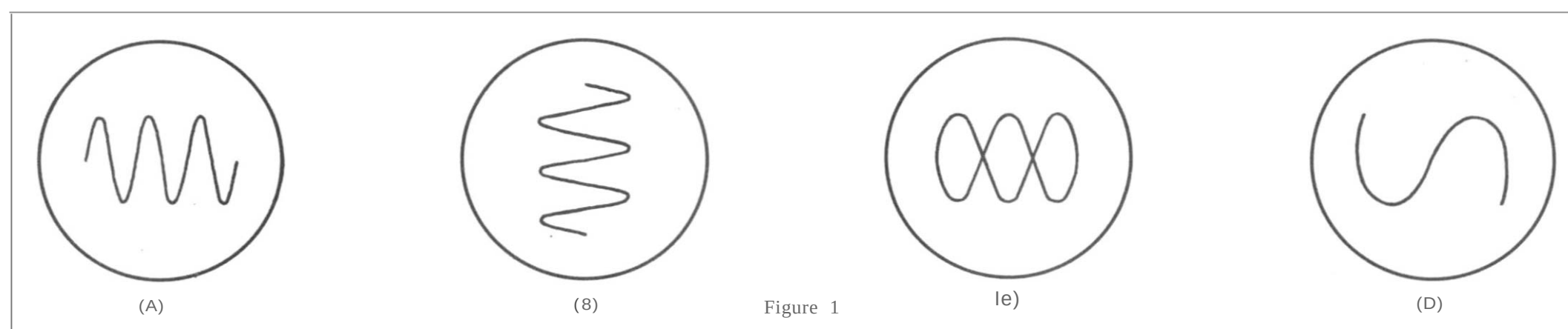


Figure 1

(NOTE: For accuracy, *this must be done carefully*, .. if the frequency of one signal is twice that of the other, two complete cycles would have to be drawn in the distance representing one cycle of the other signal ... and vice-versa.) The number of sections used will equal the number of points given for sketching the "resultant." It is recommended that graph paper be used for plotting the patterns in order to simplify the operation.

We next consider the location of the "electron beam" on the screen of the CRT, both horizontally and vertically, at these corresponding time intervals.

Referring to Fig. 2, at time "A" (" A_1 " is the corresponding point on the saw-tooth signal), the "beam" is at zero vertically, since the amplitude of the sine-wave signal is at zero at this time. However, at the corresponding time on the saw-tooth signal, the beam is displaced horizontally to the left the distance represented by the amplitude of the saw-tooth signal at this point. We can locate these points by drawing a straight dotted line parallel to the corresponding axis, as shown.

At time "B" (and " B_1 "), we find that the beam will be displaced vertically and horizontally as shown. In a similar

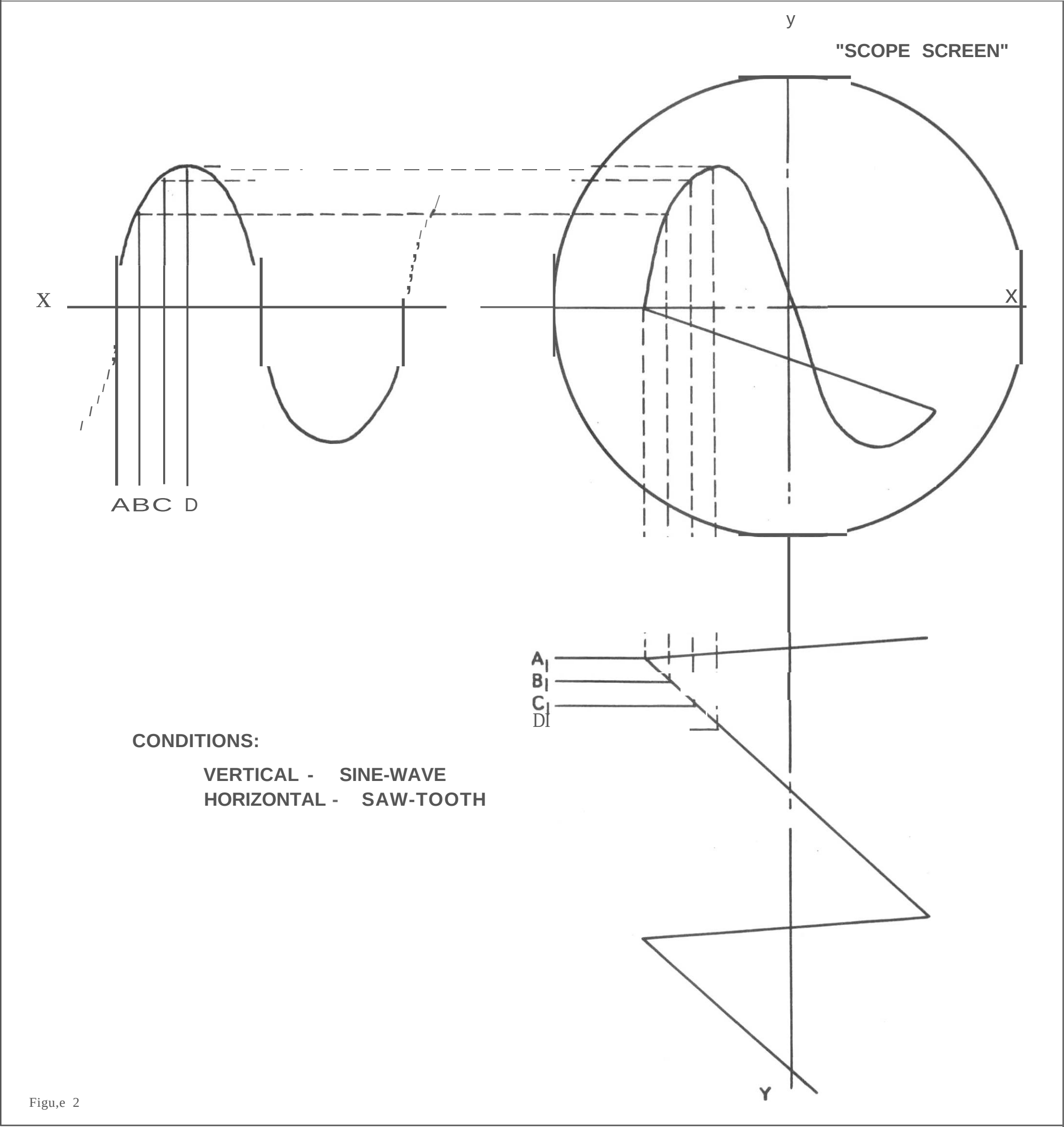
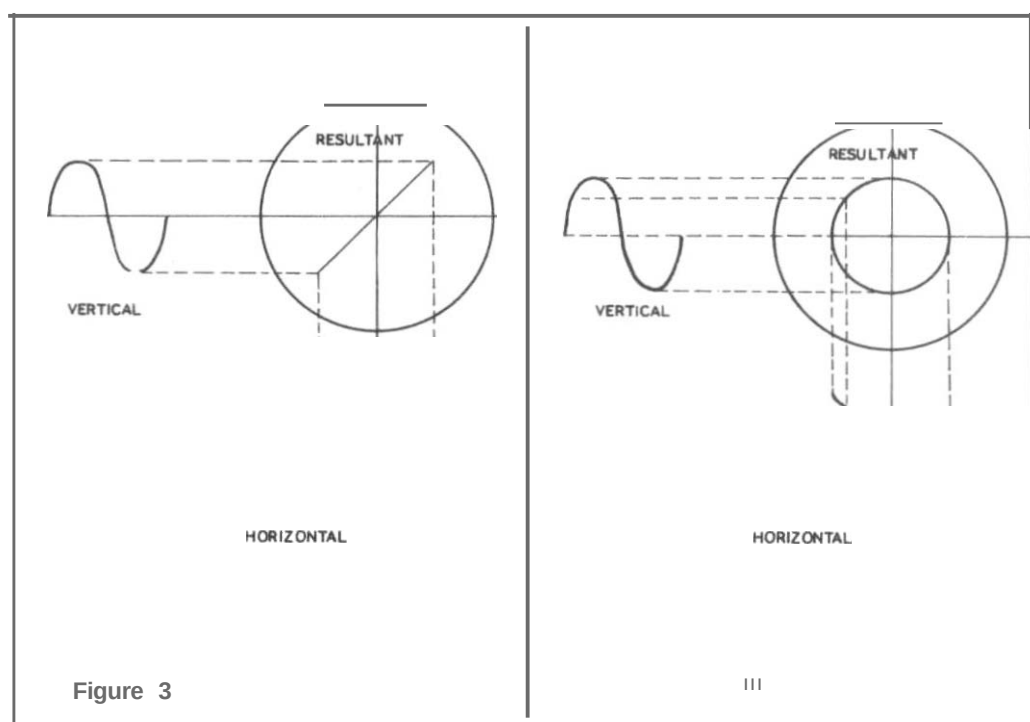


Figure 2



fashion, we can continue to plot points on the "CRT SCREEN" corresponding to additional time intervals... "C" eC_1 "), "D" CD_1 "), etc. Once the entire series of points is plotted, they may be connected by a smooth line, thus giving the resultant pattern.

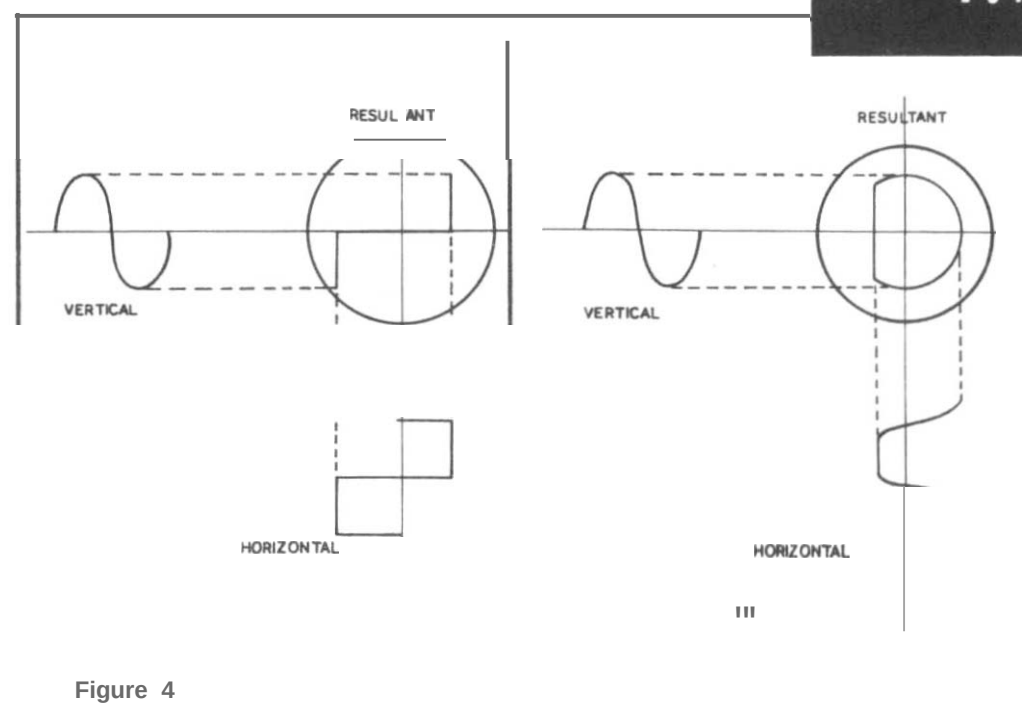
As can be seen from the sketch, the resultant is a typical sine-wave pattern... as was to be expected with the signals used! The "retrace" line is generally very faint or invisible due to the rapid movement of the electron beam during this interval.

To determine the waveform of an unknown signal from the "resultant" and one signal, simply reverse the order of the steps given.

This technique is particularly valuable when phase differences are involved, for it enables an accurate presentation of the pattern obtained even when the phase difference between the two signals involved is very small.

How phase will affect the resultant pattern is shown clearly in Figs. 3(a) and 3(b). In both cases, sine-waves at the same frequency are used for horizontal and vertical deflection, with the only difference being in the phase relationships of the two signals. The pattern formed in Fig. 3(a) results from two sine-wave signals that are in phase, while the pattern formed in Fig. 3(b) results from two signals that are 90° out of phase. In both cases, the patterns predicted graphically may be confirmed by actual laboratory experiment. (NOTE: A technique for measuring the phase difference between two sine-wave signals is given in the Heath Bulletin "PHASE SHIFT AND FREQUENCY MEASUREMENT.")

This same technique may be used even where the signals involved are not simple sine-waves or saw-tooth signals. Two such examples are given in Fig. 4.



The resultant obtained when a sine-wave signal is used for vertical deflection and a square-wave for horizontal deflection is given in Fig. 4(a). Due to the rapid movement of the electron beam in traveling from left to right, the horizontal connecting line may be so faint as to actually disappear in practical work, and the pattern may appear as two short vertical lines, displaced horizontally, and with one above and one below an imaginary centered "zero" line.

In Fig. 4(b) is shown the pattern obtained when a sine-wave and a clipped sine-wave signal are used. In addition, there is a 90° phase difference between the two signals.

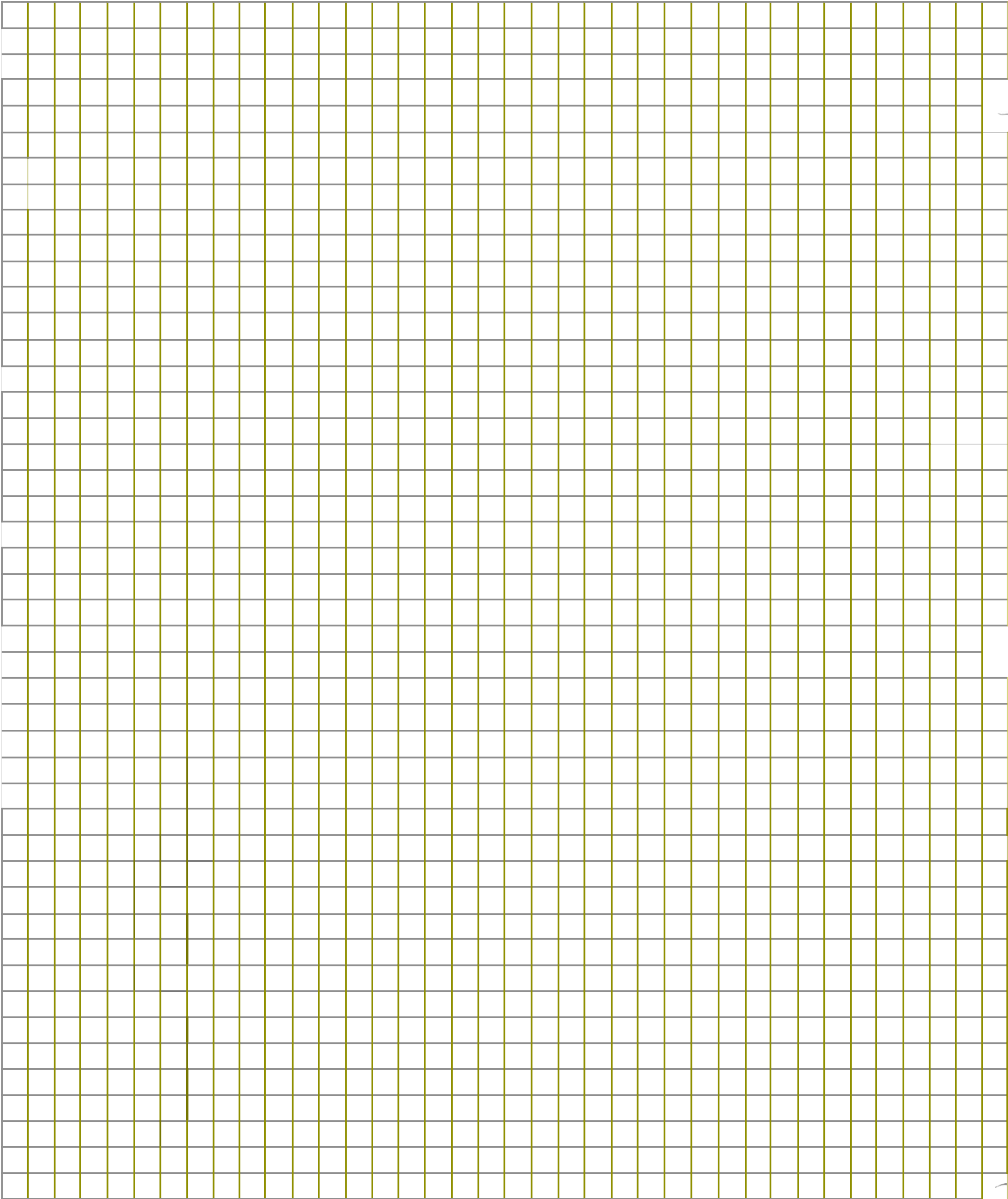
The last page of this Bulletin is laid out as a graph, and may be used by the reader to plot a typical Oscilloscope pattern directly. The experience gained in doing this will help to fix the technique clearly in mind.

Should the reader find it difficult to obtain graph paper locally (to carry out the Construction techniques described), the graph given on the last page may be used over and over... to do this, simply place a piece of tracing paper over the graph scale so that the lines can be seen through the tracing. The pattern may then be traced on the paper directly... when the graphical construction is finished, the completed tracing is removed.

REFERENCES

For the reader desiring to study the technique described in further detail, the following books are suggested:

- (1) ENCYCLOPEDIA ON CATHODE-RAY OSCILLOSCOPES, Rider & Uslan, Published by John F. Rider.
- (2) A GUIDE TO CATHODE RAY PATTERNS, Merwyn Bly, Published by John Wiley.



using the heathkit oscilloscope to accurately calibrate an audio oscillator

BY LOUIS E. GARNER, JR.

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Due to the economic limitations of factory production methods, commercial Audio Oscillators are seldom calibrated to an accuracy exceeding the range between 1% and 5%. While these tolerances are satisfactory for almost all normal experimental tests, the technician or engineer will occasionally require signal frequencies precise to a much greater degree of accuracy for certain types of tests. In such cases, the simplest and least expensive solution is to prepare an accurate calibration chart of an available stable audio oscillator. Where signals over a limited frequency range are needed, as when determining the response of a tuned circuit or a filter network, the calibration chart may be made to cover only the limited range.

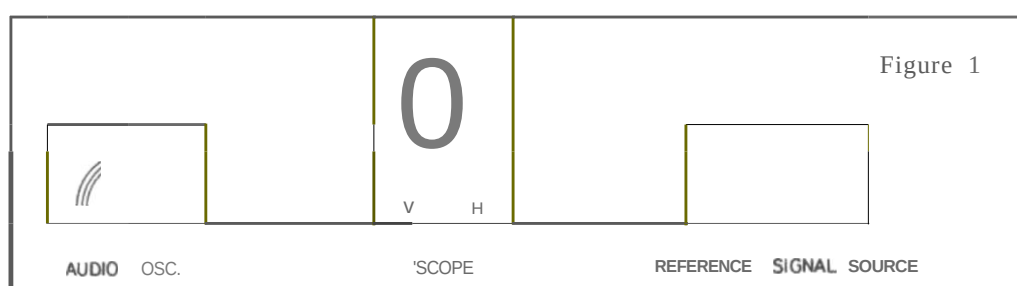
Calibration data is obtained using the Heathkit *Oscilloscope* to compare the output of the Audio Oscillator with an accurately known signal by means of Lissajou Figures (refer to the Heath Bulletin FREQUENCY MEASUREMENT WITH LISSAJOU FIGURES for details of this technique). Once the calibration data is obtained, the actual chart may be prepared in one of two ways.

The "conventional" and simplest method is to prepare a simple 1:1 graph, plotting the calibrated points on a graph scale, then drawing a smooth curve through the average of the plotted points.

A more accurate method, however, is to plot the calibration curve using the statistical *Method of Least Squares*. This particular technique will supply a straight line curve which will best fit all the experimentally obtained data with the highest degree of accuracy. This latter technique will be described in detail.

OBTAINING CALIBRATION DATA

In order to obtain satisfactory calibration points on the dial of the audio oscillator, it is necessary that a known and quite accurate reference frequency be available for test purposes.



It is customary to apply the reference frequency to the HORIZONTAL INPUT of the *Oscilloscope* and the signal from the audio oscillator to the VERTICAL INPUT, as illustrated in Fig. 1.

Since most Electric Power Companies maintain the frequency of the A.C. power quite accurately, the 60 CY TEST terminal of the 'scope (which supplies a signal obtained indirectly from the power line) provides a satisfactory reference signal for checks at low frequencies (up to several hundred cycles per second). Thus, the 60 CY TEST and HORIZONTAL INPUT terminals of the 'scope may be connected together with a short test lead, as illustrated in Fig. 2(a).

For higher frequencies, the audio signal sent by station WWV as part of its Standard Frequency broadcasts is an extremely accurate and quite satisfactory reference, but a communications receiver must be used to obtain this signal. In addition, tuned circuits at 440 cps and 600 cps should be available. The general equipment set-up shown in Fig. 2(b) may be used.

WWV broadcasts are presently made on a 24-hour day basis at 2.5, 5, 10, 15, 20 and 25 mc. The modulation consists of a timed pulse at one-second intervals together with a sine-wave tone modulation of either 600 or 440 cps of four minutes duration spaced alternately between one minute announcements. At present, a 600 cps tone is sent for four minutes after the hour, followed by a 1 minute voice announcement in which the call letters (WWV) and the time (EST) are given. There follows four minutes of a 440 cps tone, another 1 minute announcement, four minutes of the 600 cps tone, etc. The one-second pulses are transmitted during the tone modulation and, for this reason, the use of a tuned circuit to remove the tone is suggested (Fig. 2(b)).

A switch may be provided to permit using either the 440 cps or the 600 cps tuned circuit, depending on which tone is being transmitted. (The design and construction of tuned circuits will be discussed in another Heath Bulletin.) Adjust the receiver output so that the 'scope input is not overloaded (with resulting distortion of the sine-wave signal).

Regardless of the standard frequency source used for reference purposes, the audio oscillator to be calibrated and the 'scope should both be turned "ON" and allowed a sufficient

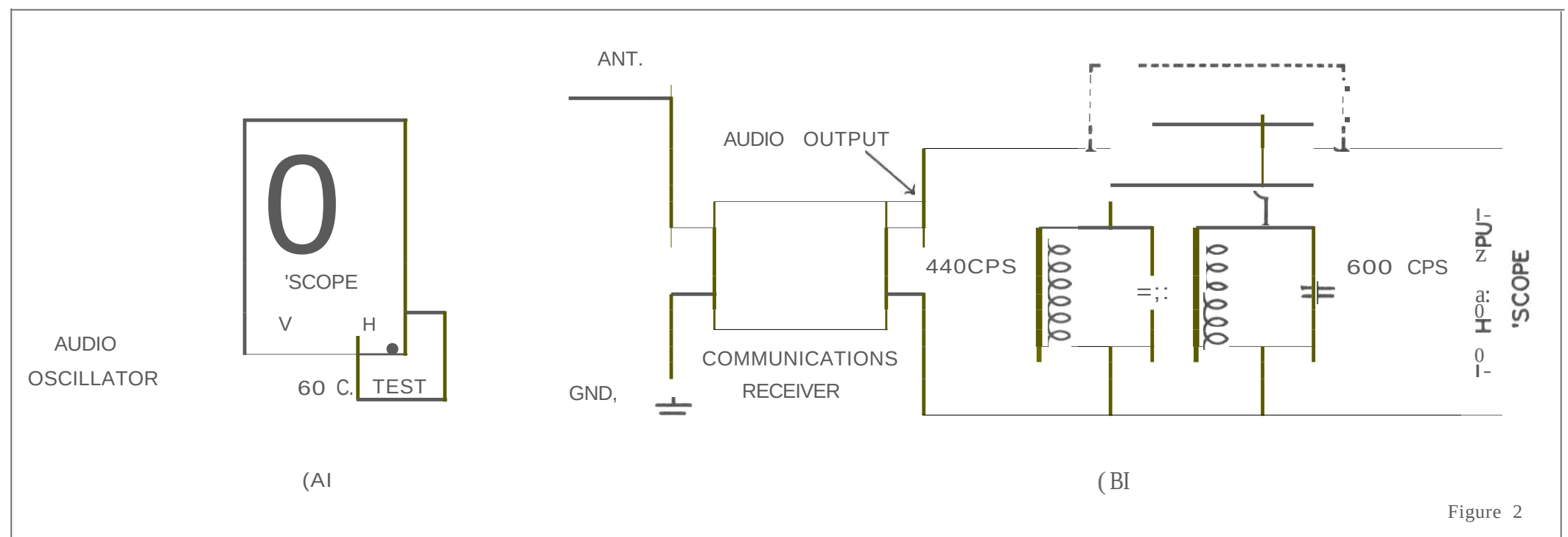


Figure 2

warm-up period to insure stable operation. In the case of the 'scope, a one or two minute "warm-up" is sufficient, but a five to ten minute "warm-up" should be allowed the audio oscillator to minimize any chance of frequency drift.

In addition, for maximum accuracy the line voltage should be checked and noted while calibration is carried out. If the line voltage tends to fluctuate constantly, the use of a voltage-regulating isolation transformer between the audio oscillator and the power line is suggested. Such transformers may be obtained from most Radio Supply Houses.

On the other hand, if the line voltage remains reasonably constant over long periods of time, but has different values at different times during the day (due to changing general loads), a less expensive adjustable auto-transformer may be used between the audio oscillator and the line. In this case, the auto-transformer is set to supply a given voltage (usually 117 volts) during the calibration period...and again whenever the oscillator is used for tests where maximum accuracy is desired.

To obtain the experimental calibration points, the frequency of the audio oscillator is carefully varied over the range (or portion of a range) to be calibrated until recognizable Lissajou patterns are obtained. As each pattern is obtained, it should be allowed to rotate slightly so that no errors in interpretation will be encountered due to phase differences between the two signals.

The dial of the audio oscillator is *carefully* adjusted for a stable pattern to permit the frequency ratio between the oscillator and reference signals to be obtained. A special technique may be used for *accurately* adjusting the dial. The forearm is braced against the top of the workbench and the knob held between the thumb and forefinger. The other three fingers of the hand are extended and braced against the front panel of the instrument.

Record the frequency as given by the oscillator dial setting and the frequency ratio as given by the Lissajou figure for each test point in a table similar to the one given in Table I. The reference frequency used should also be indicated in this table. For maximum accuracy when plotting the final calibration

curve, as many test points should be obtained as is practicable within the range to be calibrated.

Once the table is completed, calculate the actual frequency (from the frequency ratio and the reference frequency values) and record in the table under the column ACTUAL FREQUENCY. The sample values given in Table I were obtained in the course of calibrating an older model Heath Sine-Wave Generator.

Lissajou Pattern Ratio	Reference Frequency	Actual Frequency	Dial Setting
1:3	60	20	21.1
2:5	60	24	25.6
1:2	60	30	32.0
3:5	60	36	38.0
2:3	60	40	42.0
3:4	60	45	47.5
4:5	60	48	50.0
5:6	60	50	52.0
1:1	60	60	62.5
5:4	60	75	78.0
4:3	60	80	82.0
3:2	60	90	92.0
5:3	60	100	102.0

TABLE I

This procedure is then carried through in the same manner until test points are obtained for all the scales to be calibrated. Use other reference frequencies as may be necessary to cover the desired ranges.

PREPARING A SIMPLE CALIBRATION CHART

After obtaining the test points given in Table I, no further experimental tests are necessary. The equipment may now be turned "OFF" and a Calibration Chart prepared for the audio oscillator.

The chart is prepared by plotting the "points" determined above on ordinary graph paper and then connecting the individual points with a smooth line or curve. It is custom-

ary to plot the ACTUAL FREQUENCY as values of "X" and the DIAL SETTING as values of "Y" For a limited range of frequencies, such as is given in Table I, ordinary rectangular coordinates may be used. Log paper will be needed if a wide range is to be plotted on a single curve... however, for maximum accuracy, limited ranges should be plotted as individual curves.

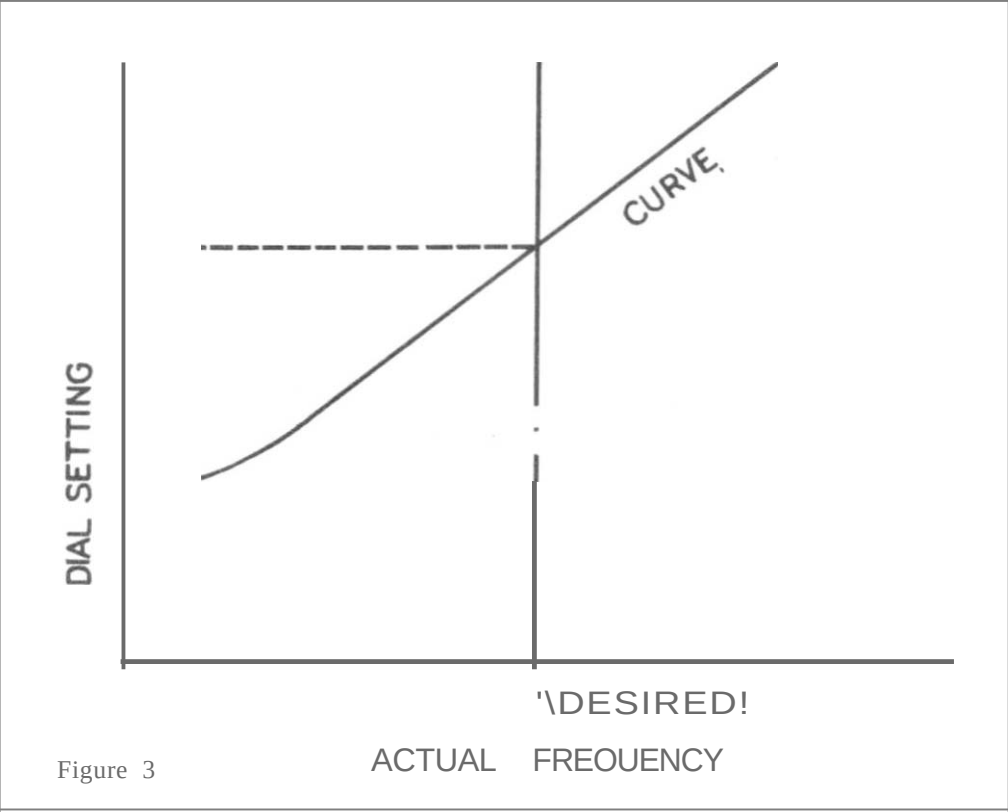
The Calibration Chart prepared in this manner may now be used in a conventional manner. To obtain the DIAL SETTING for any given ACTUAL FREQUENCY, simply locate the desired frequency along the X axis of the graph. Project a vertical line to intersect the plotted curve, and then a horizontal line from this point to the Y axis, indicating the DIAL SETTING necessary to obtain the desired frequency. This technique is illustrated in Fig. 3, and is the standard method of using any Calibration Chart which is in the form of a plotted curve.

The Calibration Chart obtained using the method described above has a number of limitations, all of which tend to restrict its accuracy. First, it will be found almost impossible to fit any standard curve (or straight line) along the plotted points exactly, so that any "average" curve chosen at random represents, at the best, only an approximate compromise...and the compromise chosen may not give the minimum error at all points. Secondly, regardless of the care exercised in obtaining the test points there is bound to be a certain amount of experimental error.

In order to overcome these limitations when plotting a curve where maximum accuracy is desired, the Method of Least Squares may be used to calculate the best fitting curve for the values obtained experimentally. This method also averages the test results obtained, and thus minimizes any experimental errors in making the original readings.

PLOTTING A CALIBRATION CURVE BY THE METHOD OF LEAST SQUARES

To use this technique, first make a preliminary plot of the experimentally determined points to determine the general curve obtained...in the example given (Table I), this is a



straight line. The slope intercept form of the straight line equation, $y = ax + b$, is now used to determine values for each frequency measured, as given in Table II.

Thus, if the dial reading is 21.1 with an actual frequency of 20 cps, the equation becomes $21.1 = 20a + b$.

Next, multiply each equation in Table II by its corresponding frequency, giving a new set of values, as recorded in Table III.

The next step is to add together corresponding sides of the equations determined in Table III, which gives, in this example ...

$46821.9 = 45326a + 698b$ (A)

In a similar fashion, add together the corresponding sides of the equations of Table II, giving ...

$724.7 = 698a + 13b$ (B)

Frequency Measured	Equation
20	$21.1 = 200 + b$
24	$25.6 = 240 + b$
30	$32.0 = 300 + b$
36	$38.0 = 360 + b$
40	$42.0 = 400 + b$
45	$47.5 = 450 + b$
48	$50.0 = 480 + b$
50	$52.0 = 500 + b$
60	$62.5 = 600 + b$
75	$78.0 = 750 + b$
80	$82.0 = 800 + b$
90	$92.0 = 900 + b$
100	$102.0 = 1000 + b$

TABLE II

Equations (A) and (B) may now be solved together as simultaneous linear equations to obtain the values of "a" and "b." (Refer to any High School text on Algebra if the technique of solving simultaneous equations has been forgotten.)

Frequency Measured	Equation
20	$422 \quad 4000 + 20b$
24	$614.4 = 5760 + 24b$
30	$960.0 = 9000 + 30b$
36	$1368.0 = 12960 + 36b$
40	$1680.0 = 16000 + 40b$
45	$2137.5 = 20250 + 45b$
48	$2400.0 = 23040 + 48b$
50	$2600.0 = 25000 + 50b$
60	$3750.0 = 36000 + 60b$
75	$5850.0 = 56250 + 75b$
80	$6560.0 = 64000 + 80b$
90	$8280.0 = 81000 + 90b$
100	$10200.0 = 100000 + 100b$

TABLE III

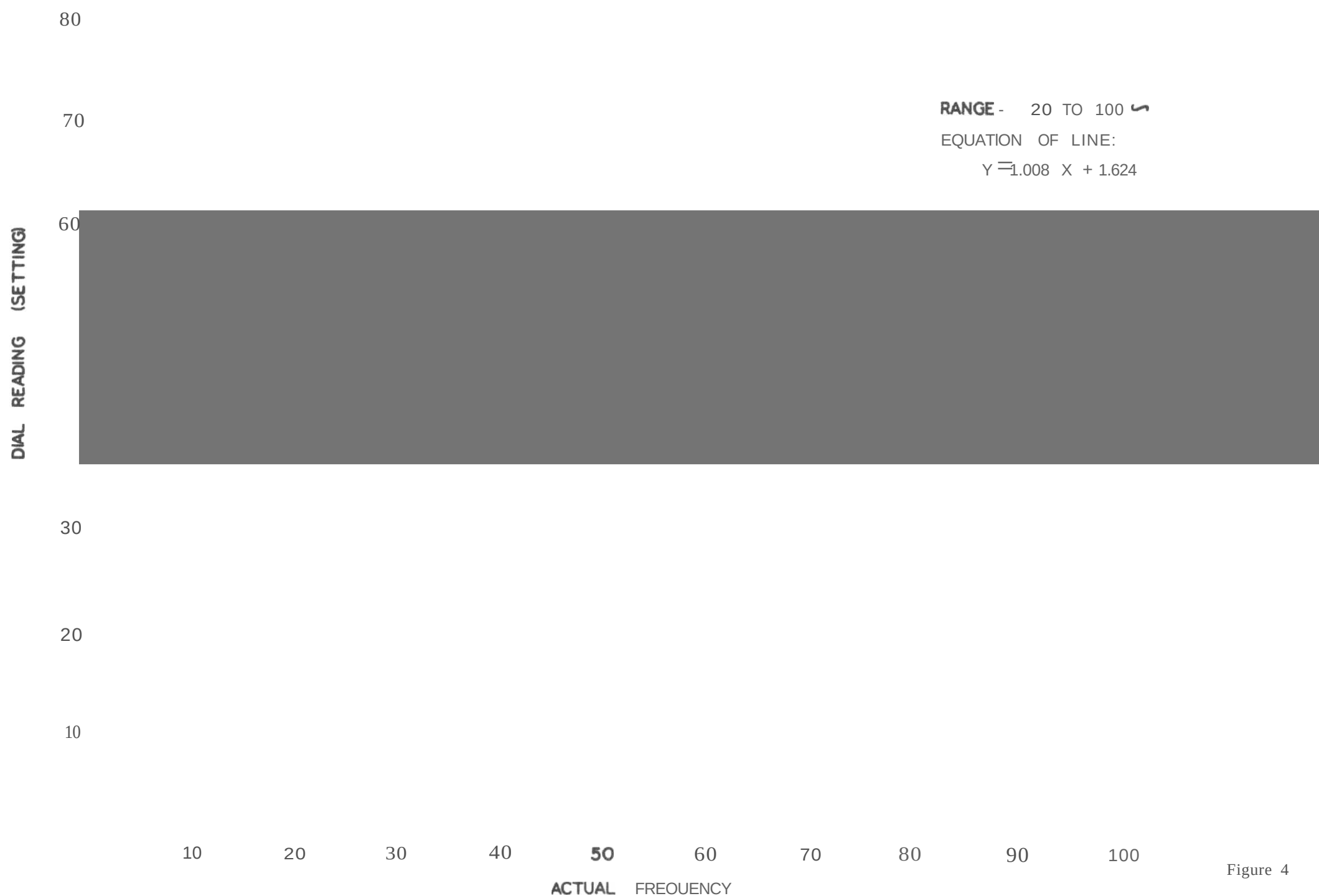


Figure 4

In the example given, it may be determined easily that $a = 1.008$ and that $b = 1.624$. These values are then substituted in the general equation $y = ax + b$, giving ...

$$y = 1.008x + 1.624 \quad (C).$$

All of these computations were to obtain equation (C), which is the equation for the straight-line curve best fitting the experimentally determined points.

Now, in order to obtain the desired curve, it is only necessary to determine two points near the ends of the frequency range, then to plot these two points on the graph scale, and, finally, to draw a straight line through the points, *using an ordinary straight edge or triangle.*

In the example given, we can choose values of 30 cps and 90 cps for "X" (ACTUAL FREQUENCY), giving the following equations:

$$\begin{aligned} y \text{ (DIAL SETTING)} &= (1.008) (30) + 1.624 = 31.86 \\ &\text{and} \\ y \text{ (DIAL SETTING)} &= (1.008) (90) + 1.624 = 92.34. \end{aligned}$$

These values are then plotted on the graph scale and a straight line is drawn through them, giving the final graph shown in Fig. 4.

While the example given applies to a straight line curve, since this was the general type of curve resulting from the experimentally determined results; the same technique may be applied to almost any type of calibration curve that approximates or is equivalent to a known mathematical curve.

In the case of other types of curves, the equation for the particular curve is used in place of the straight line equation (hyperbola, parabola, etc.), with appropriate substitutions and modifications to obtain sufficient points to locate such a curve on a graph. The final curve is then drawn in the form of the equated curve.

ACKNOWLEDGMENT

The author gratefully acknowledges the assistance of Roy W. Loan, Jr., who carried out the measurements for the example given and worked out the necessary calculations.

the oscilloscope in tv servicing

BY LOUIS E. GARNER, JR.

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The Oscilloscope, while quite useful in AM-FM servicing work, is not generally considered as an "essential" instrument in this field. When TV is considered, on the other hand, quite the reverse is true. The 'scope becomes of primary importance, and it is unlikely that any other instrument, with perhaps the single exception of the multimeter (or VTVM), is more necessary to the successful servicing of television receivers.

To obtain the greatest value from the Oscilloscope in TV servicing, the technician should know several things ... (a) what type of test leads to use to connect the 'scope to the TV receiver, (b) where to make the connections in the circuit, (c) how to set the 'scope controls, and (d) the normal wave-forms and signal amplitude at that point. It is virtually impossible to tell the *exact* wave-form and its amplitude without reference to the manufacturer's instruction manual or service notes for the particular set being tested. This is due to the large variety of circuits in use in the hundreds of different model TV receivers that may be encountered in day-to-day service work. However, it is possible to give a GENERAL GUIDE as to the type of signal to be expected at different points in the average TV receiver, as well as an indication of the amplitude range.

TV signal amplitudes are generally measured in terms of "peak-to-peak" voltages. Such voltage measurements may be made by using the Heathkit Voltage Calibrator in conjunction with the Oscilloscope or, if preferred, by using the Heathkit VTVM and the Peak-To-Peak Voltage Probe.

First, let us discuss in a general way the four important factors mentioned. We will then see how these factors apply to actual tests in a TV receiver.

TYPE OF TEST LEADS

The type of leads to use for connecting the Oscilloscope and the TV receiver depends on two items ... (1) the nature of the signal to be observed, and (2) its amplitude. Three basic types of connections are used in most TV service work, as follows:

- A. *Conventional Test Leads*, with either probe or "clip" ends. One lead is generally connected between 'scope ground and the TV chassis and the other lead between the 'scope VERT. INPUT terminal and the point in the receiver where the signal is to be observed.
- B. *'Scope R.F. Demodulator Probe*, used whenever an d. signal is to be checked ... in the video or audio d. stages.
- C. *Heavy Duty Test Leads and Capacitive Voltage Divider*, used where high signal amplitudes are encountered, as in the *Horizontal output* and *High Voltage* sections. The basic capacitive voltage divider is illustrated in Fig. 1, and reduces the signal input to the 'scope by a ratio of 10:1.

WHERE TO MAKE 'SCOPE CONNECTIONS

The electrical connections in the TV receiver are usually made either at the input or at the output of the stage (or section) being tested. The *output* of a particular stage is often considered equivalent to the *input* of the succeeding stage. Exceptions are where a filter network or similar circuit is connected between the two stages.

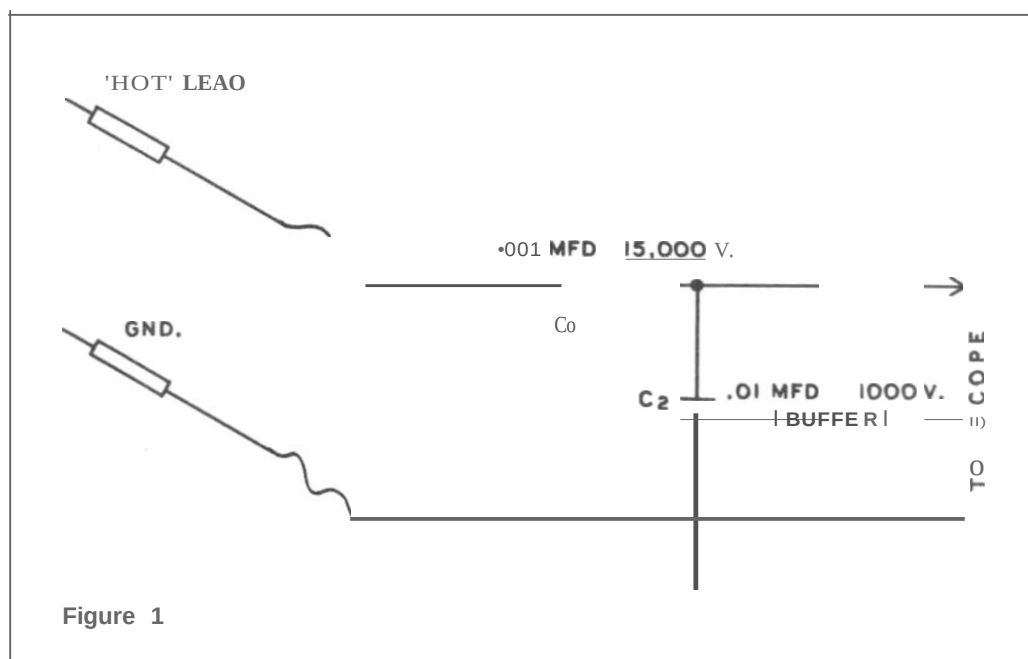
ADJUSTING 'SCOPE CONTROLS

Most of the 'scope controls are adjusted in a conventional fashion. That is, INTENSITY, FOCUS and CENTERING controls are adjusted for a bright, sharp, centered image, while the Horizontal and Vertical GAIN controls are adjusted to give an image of the desired size. However, when viewing video signals, it is often possible to use *two different adjustments* of the Horizontal sweep frequency controls to obtain a steady image. With one adjustment (in the 10-30 cps range), two or three complete *fields* of the video signal are observed, while with the other adjustment (5 Kc to 8 Kc range), *two* or three *line* signals are seen. Later, we will indicate which adjustment to use when checking specific sections of the TV receiver.

WAVE-FORM AND SIGNAL AMPLITUDE

These two items will vary depending on exactly where the tests are made in the receiver and upon the individual characteristics of the set being serviced. Below is given a GENERAL GUIDE for the *average* TV receiver, indicating basic information needed to observe and interpret signal patterns.

To use the GENERAL GUIDE properly, refer to the typical block diagram for a TV receiver given in Fig. 2. In some cases, a section (as indicated on the diagram) may consist of several identical or very similar stages (as in the case of the Video I.F. Amplifiers). In such cases, there will be no individual



break-down into separate stages in the GUIDE. On the other hand, where a section consists of several entirely different stages (as in the case of sweep circuits), each separate stage will be given.

Information on the Type of Test leads to use, the setting of the 'scope horizontal sweep controls, the general *type* of signal encountered and the approximate amplitude range (in peak-to-peak volts) is given. It is assumed that a TV channel is tuned in and that all controls are adjusted for normal operation.

The "normal" output signals for each stage are indicated ... note, however, that only the general *type* of signal is shown in the sketches (Fig. 3) - **not** the *actual waveform* to be observed, as this will vary considerably from one receiver to another. However, where the observed signal is appreciably different from the expected signal, either as to amplitude or wave-shape, there is a good chance that a defect exists in the stage being tested.

I. VIDEO I.F. STAGES.

1. Use R.F. Demodulator Probe.
2. Set 'scope sweep at either *field* (10-30 cps) or *line* (5 Kc to 8 Kc) rate.
3. Video Signals are observed (for *line* signal, see Fig. 3(a)).
4. Amplitude *less than* .5 volts peak-to-peak.

II. VIDEO 2ND DETECTOR.

1. *Input*: R.F. Demodulator probe; *Output*: Reg. Test Leads.
2. Set 'scope sweep at either *field* or *line* rate.
3. Video signals observed.
4. Amplitude from .5 to 2 volts.

III. VIDEO AMPLIFIER.

1. Use Regular Test Leads.
2. Set 'scope sweep at either *field* or *line* rate.
3. Video signals observed.
4. From .5 volts at input to as much as 80 volts at Output.

IV. AUDIO I.F. and RATIO DETECTOR STAGES.

NOTE: The 'scope is not generally needed for troubleshooting these stages. Where used, however, the R.F. Demodulator Probe is necessary. Set the 'scope sweep to permit easy observation of whatever signal is present.

V. AUDIO AMPLIFIER STAGES.

1. Use Regular Test Leads.
2. Adjust 'scope sweep to observe 2 or 3 cycles of signal.
3. Typical audio signal or test tone (see Fig. 3(b)).
4. From .5 volts at Volume Control to as much as 90 volts at Output stage.

VI. SYNC AMPLIFIER (and Sync Separator).

1. Use Regular Test Leads.
2. Set 'scope sweep at either *field* or *line* rate.
3. *Input*: Video Signal; *Output*: Pulse (Fig. 3(c)).
4. From 10 to 50 volts.

VII. HORIZONTAL SWEEP (Horizontal AFC, Horizontal Osc., Hor. Output).

A. Horizontal AFC.

1. Regular Test Leads.
2. Set 'scope sweep to observe *lines*.
3. Special Wave Shape (depending on set).
4. Large variation, depending on set.

B. Horizontal Oscillator (and "discharge" stage).

1. Regular Test Leads.
2. Set 'scope sweep to observe *lines*.
3. Usually a "trapezoid" pattern (Fig. 3(d)), but may approach pulse in wave-form.
4. From 50 to 150 volts.

C. Horizontal Output.

1. Heavy Duty Test Leads and Voltage Divider (Fig. 1).
2. Set 'scope sweep to observe *lines*.
3. Trapezoid or pulse pattern.
4. From 4000 to 10,000 volts.

VIII. VERTICAL SWEEP (Vert. Integrator, Vert. Osc., Vert. Output).

A. Vertical Integrator.

1. Regular Test Leads.
2. Set 'scope sweep to observe *fields*.
3. Pulse wave-form.
4. From 10 to 60 volts.

B. Vertical Oscillator.

1. Regular Test Leads.
2. Set 'scope sweep to observe *fields*.
3. Trapezoid or pulse.
4. From 100 to 300 volts.

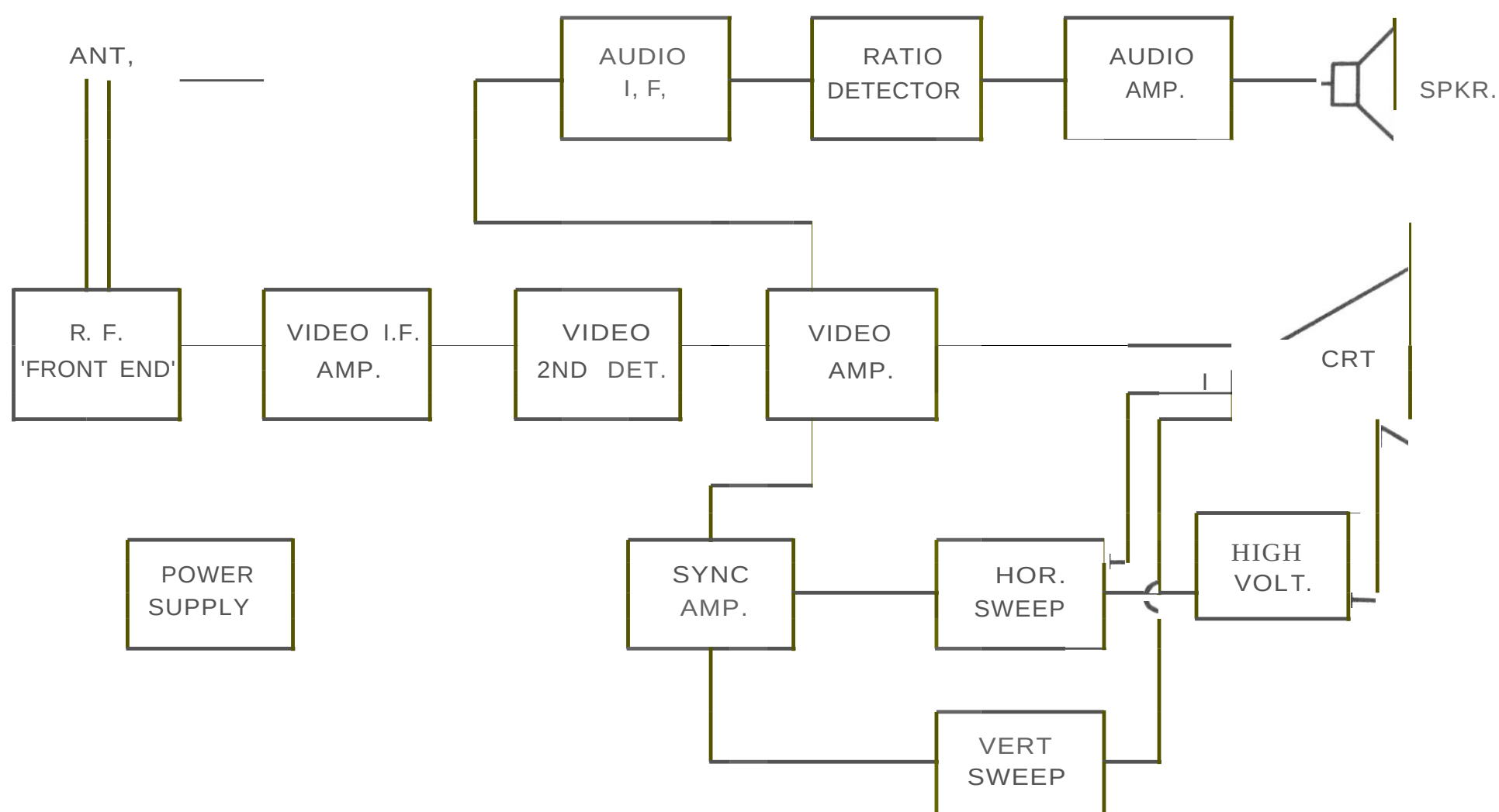


Figure 2

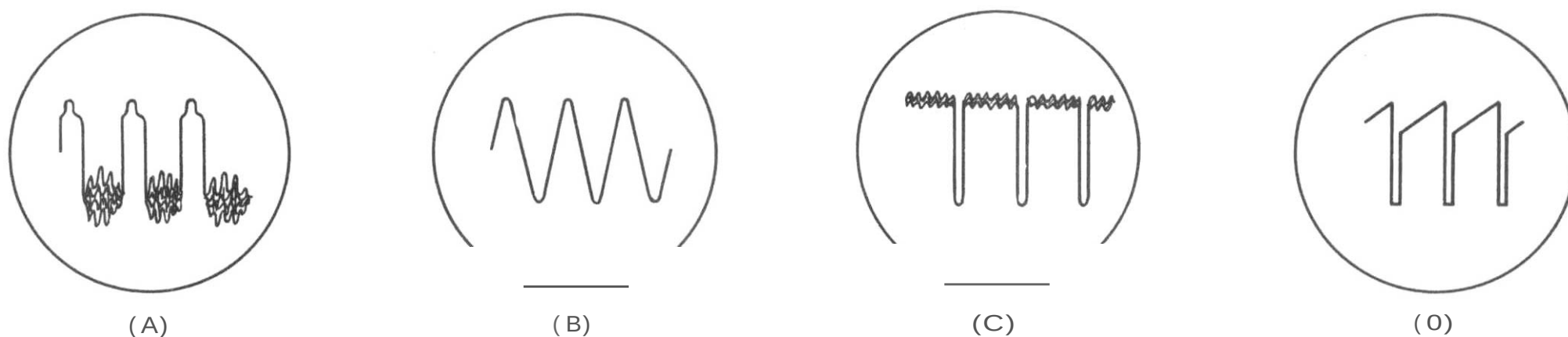


Figure 3

C. Vertical Output.

1. Regular Test Leads in some cases, but Heavy Duty Test Leads and Voltage Divider may be required.
2. Set 'scope sweep to observe *fields*.
3. Trapezoid or pulse.
4. From 500 to 1500 volts.

IX. POWER SUPPLY.

1. Regular Test Leads.
2. Set 'scope sweep in 20-30 cps range.
3. No signal should normally be present. However, excessive hum due to poor filtering may result in typical hum pattern (normal or distorted sine-wave).
4. Signal amplitude depends on the degree of hum ... may be from less than 1 volt to as high as several hundred volts.

INTERPRETING DISTORTED OSCILLOSCOPE PATTERNS

As was pointed out early in this Bulletin, it is virtually impossible to predict exactly what patterns may be expected at various points in a TV receiver without reference to the set Manufacturer's service data. However, once the "normal" pattern is known, certain types of distortion of this pattern indicate, in a general way, the type of defect causing the trouble. A brief review of the **techniques** used when interpreting "distorted" waveform patterns in a TV receiver may prove helpful to the reader.

If **hum** is superimposed on the pattern, it may indicate inadequate filtering in the power supply due to partially open filter condensers. This may be checked by using the 'scope to see if hum is present at the Output of the low voltage B supply.

Hum may also be caused by **heater-to-cathode** leakage in a tube, by incorrect lead dress, or by an open grid return in one of the stages. A check should be made of each possibility.

If the observed pattern is of considerably lower amplitude than is to be expected, it may indicate either a weak tube or lower than normal B voltages. A video signal pattern of lower than normal amplitude may also be caused by improper alignment, poor signal pick-up, or losses in the transmission line.

A pattern in which either the positive or negative "half" (or both) is flattened or "clipped" may be caused by a defective tube, incorrect d.c. operating voltages, or signal overload. Incorrect d.c. operating voltages may result, in turn, from a leaky by-pass condenser or a resistor that has changed value. Leaky

coupling condensers may also cause this type of distortion.

A sweep signal that is considerably off its normal frequency may indicate a change in the value of either a resistor or condenser (in an R-C circuit), improper adjustment of AFC controls, a defective tube, or incorrect d.c. operating voltages.

ALIGNMENT

The Oscilloscope is also used when aligning TV receivers in conjunction with a *TV Sweep Signal Generator*. However, these techniques will be discussed elsewhere.

practical waveform analysis with the oscilloscope

BY LOUIS E. GARNER, JR.

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To obtain the greatest use from the Oscilloscope, the technician should be able to interpret waveform patterns quickly and with reasonable accuracy. Unfortunately, many users find that comparatively common patterns are somewhat difficult to interpret until considerable experience is gained in working with the instrument. For that matter, even experienced engineers and technicians will occasionally encounter an unusual pattern that is extremely troublesome to analyze.

There are mathematical techniques available for attacking the problem. For example, it can be shown, mathematically, that any recurrent waveform may be represented as consisting of a simple fundamental sine-wave together with various harmonics. Using this technique, it has been determined that a square-wave signal consists of a fundamental sine-wave together with odd harmonics of decreasing amplitude. For a "perfect" square-wave, these harmonics extend to infinity, but a practical square-wave seldom contains harmonics past the 21st, and most contain harmonics only to the 11th. The mathematical expression giving the harmonic components making up a complex waveform is known as a "Fourier Series," while the technique is called a "Fourier Analysis."

Although this technique is quite accurate, it requires an appreciable knowledge of mathematics to be used properly. In addition, it is somewhat slow and cumbersome. Thus, for the average laboratory worker, carrying out a series of experimental tests or servicing equipment, a more rapid technique is preferred, even if some accuracy must be sacrificed.

Fortunately, such a technique is available. To properly use the method, the technician need only become familiar with the "basic" waveforms encountered and the principal factors determining the formation of complex wave-shapes.

BASIC WAVEFORMS AND COMBINATIONS

While the common sine-wave (Fig. 1(a)) is "basic" to *all complex waveforms* from a mathematical viewpoint, from a practical level it is much simpler to consider several commonly encountered waveforms as "basic." Other waveforms can then be considered as combinations or modifications of these "basic" signals. The majority of complex waveforms encountered in practical work may be considered in terms of the three signals shown in Fig. 1. Let us discuss these three "basic" signals individually.

The Sine-Wave: This signal may be considered as fundamental to a large variety of commonly encountered wave-shapes. Thus, if one-half of the sine-wave, Fig. 1(a), is clipped, as by half-wave rectification, we have the pattern given in Fig. 2(a). A series of sine-waves of constantly decreasing amplitude forms the typical damped oscillation pattern shown in Fig. 2(b). Varying the amplitude of a steady sine-wave signal in a regular fashion results in the modulation pattern given in Fig. 2(c). And, finally, we can consider the whole class of signals represented by "distorted" sine-waves; a typical pattern representative of this group is shown in Fig. 2(d).

The Rectangular-Wave: Fig. 1(b) shows the basic rectangular waveform. Special modifications of the rectangular wave are the square-wave, Fig. 3(a), and positive-going or negative-going pulses, as shown in Figs. 3(b) and 3(c), respectively.

The Triangular Wave: A very common modification of the basic triangular wave given in Fig. 1(c) is the linear saw-tooth wave, as shown in Fig. 4(a). Other modifications are the clipped triangular wave shown in Fig. 4(b) and the trape-

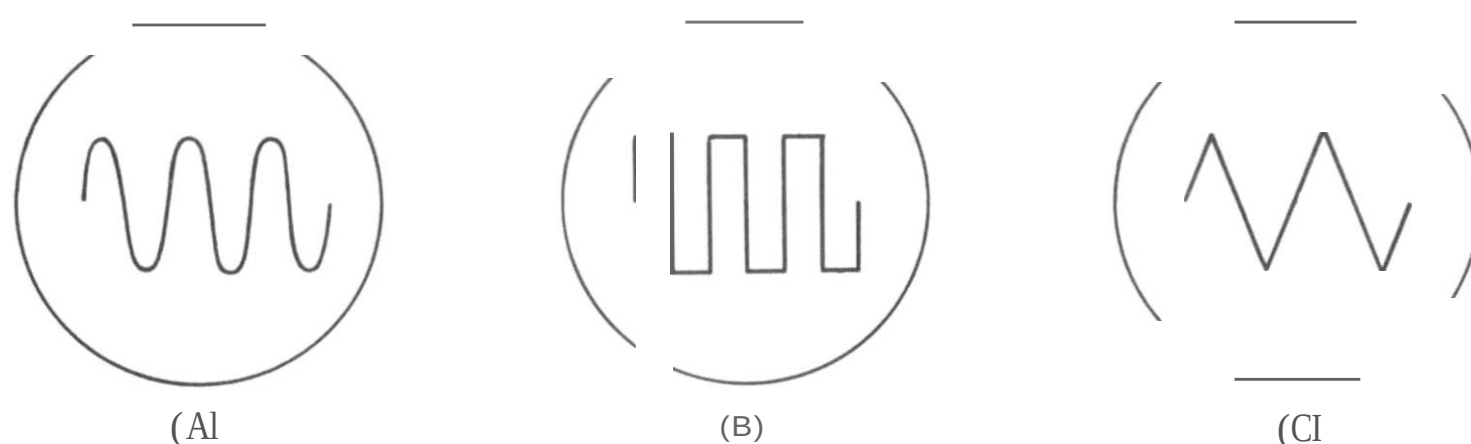


Figure 1

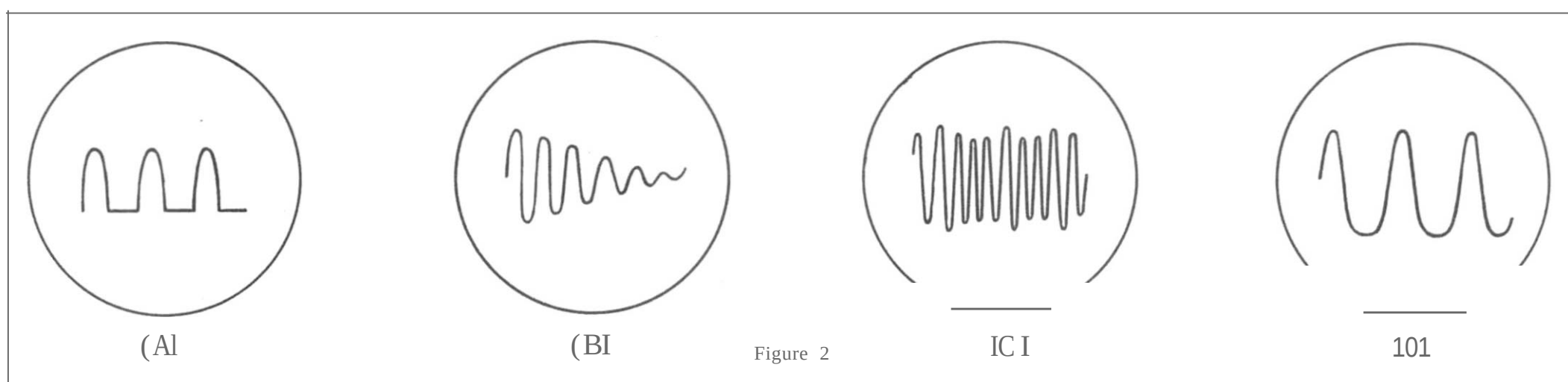


Figure 2

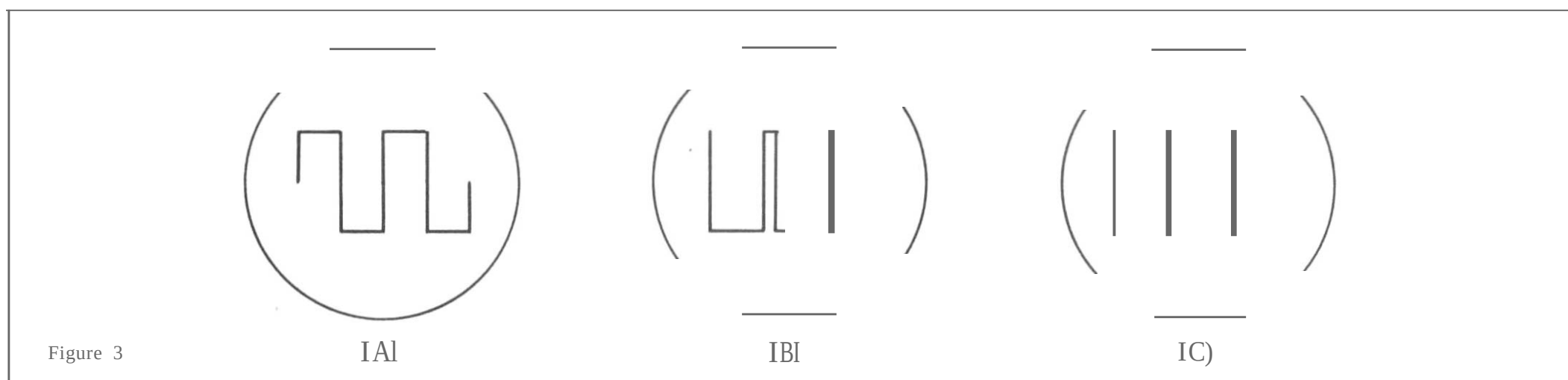


Figure 3

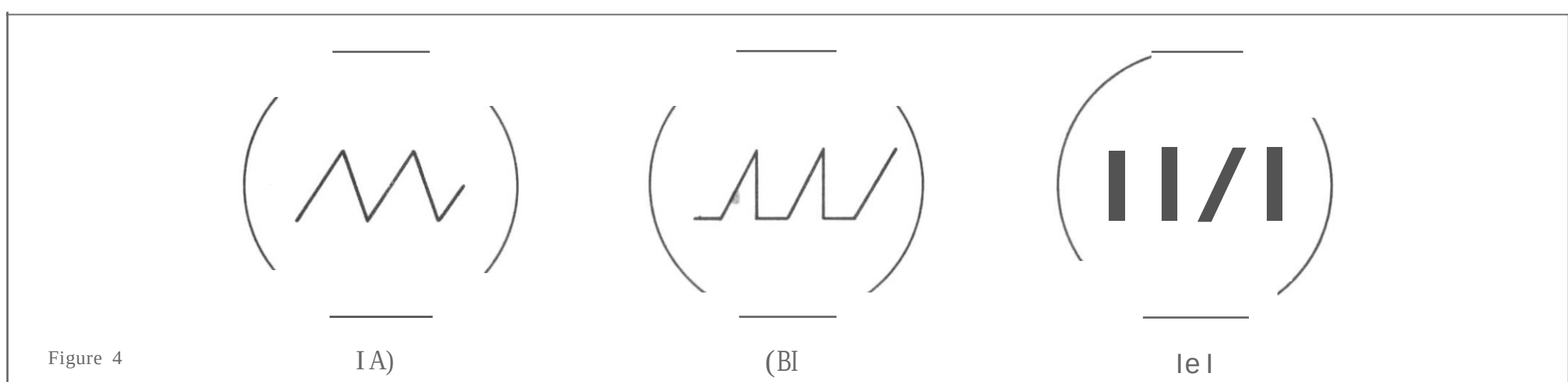


Figure 4

zoidal wave shown in Fig. 4(c). The trapezoidal wave results from "clipping" both sides of the basic triangular or saw-tooth signal.

Combining Basic Waveforms: A large percentage of the more complex waveforms encountered in experimental work may be considered as combinations of the basic wave-shapes given in Fig. 1 (or their modifications).

As an example, the peaked trapezoidal waveform encountered in the horizontal sweep sections of TV receivers may be easily considered as a combination of a pulse (rectangular-wave) and a saw-tooth (triangular-wave), as shown in Fig. 5.

Still another common waveform in TV work is the stepped pulse. This signal, in turn, may be considered as a combination of two pulses or rectangular waves, with one signal of considerably shorter duration than the other. This example is given in Fig. 6.

Additional examples might be given, of course, but these serve to illustrate the basic ideas and the technique of considering complex signals as combinations of simpler signals. Such an approach will aid the technician considerably in recognizing new waveforms and patterns.

ANALYSIS OF COMPLEX WAVEFORMS

While the method just described will help to identify unusual waveform patterns, still another technique is necessary if a practical analysis of the signal is to be made.

As we have mentioned previously, any non-sinusoidal signal, including even such complex signals as the pulsed trapezoid (Fig. 5), may be considered as a combination of a fundamental sine-wave plus sine-wave harmonic signals of varying amplitudes. In most laboratory work requiring the analysis of complex waveforms, it is not necessary to know exactly which harmonic signals are present and their actual amplitude but, rather, whether the higher frequency or the lower frequency harmonics predominate... or, for that matter, whether any are present in the observed pattern.

A practical means of doing this is to carefully observe the pattern obtained, noting the following characteristics: (a) are any changes "sharp" and distinct? (b) can the general shape be clearly identified as one of the basic patterns (or modifications thereof)? (c) is the "body" of the pattern full?

Generally speaking, the "sharpness" of a waveform depends on the presence of high frequency harmonics. The basic shape

depends on the presence of the lower harmonics. And, finally, the "body" of the signal depends on the presence of the fundamental sine-wave (which is at the same frequency as the repetition rate of the complex signal).

A practical example of this type of analysis is given in Fig. 7. A typical "perfect" square-wave is represented in Fig. 7(a). This pattern is of a square-wave signal containing all harmonics in the proper proportion.

If the higher frequency harmonics are missing, the square-wave will tend to become rounded and to lose its "sharp edges" as shown in Fig. 7(b). Note, however, that the basic shape is retained.

On the other hand, if the lower frequency harmonics are missing (or the amplitude of the higher frequency harmonics is accentuated), the square-wave will lose its general "shape" and become peaked as shown in Fig. 7(c).

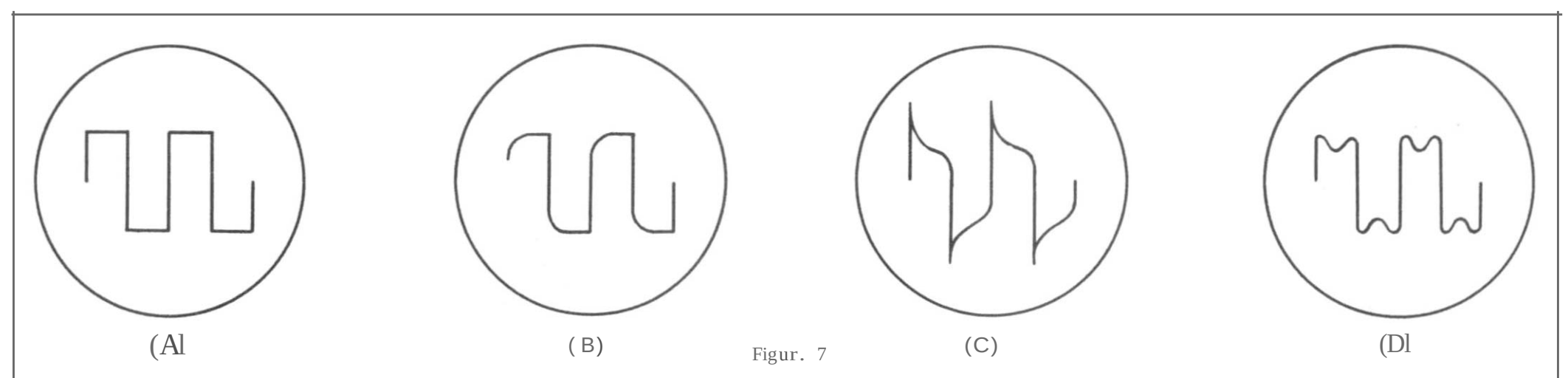
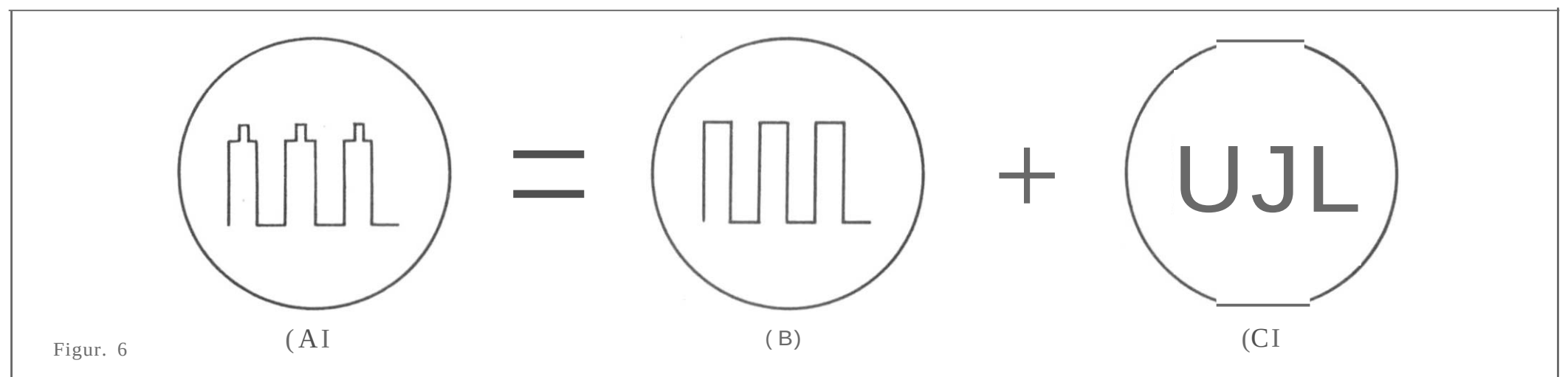
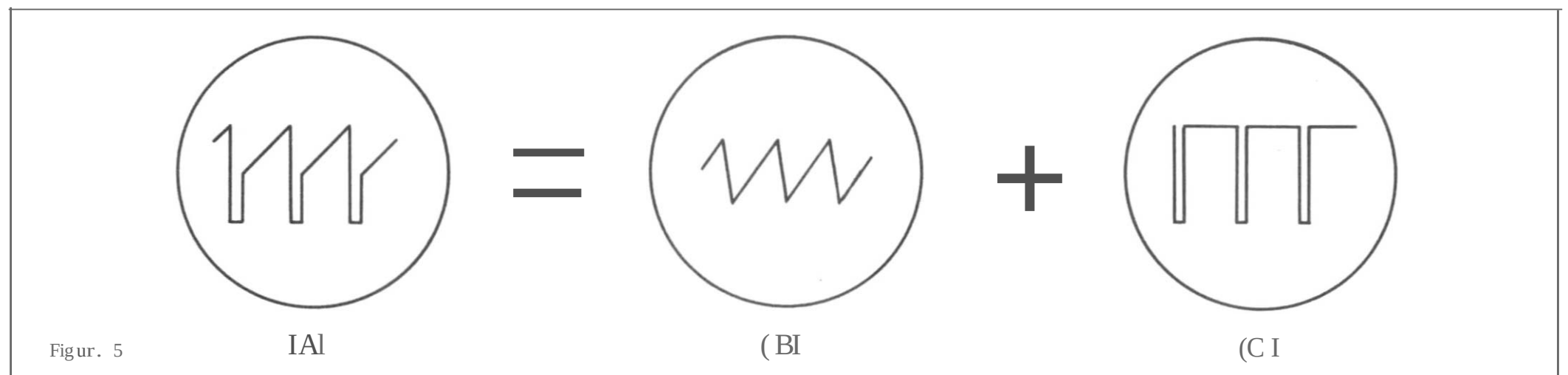
Finally, if the fundamental is of very low amplitude compared to the harmonics, a dip will develop in the square-wave, as shown in Fig. 7(d). In other words, the signal will tend to lose its "body."

Thus, in the example, we have seen how the presence of the higher frequency harmonics affect "sharpness," the lower frequency harmonics affect "shape," and the fundamental affects "body." This is true, in a general way, of the majority of complex waveforms encountered in practical laboratory or experimental work.

REFERENCE

For a detailed review of the technique of "FOURIER ANALYSIS," the reader should refer to *REFERENCE DAYA FOR RADIO ENGINEERS*, 3rd Edition, published by the Federal Telephone and Radio Corporation.

If the reader is interested in studying and applying the basic techniques of the Fourier Analysis, but does not have the necessary background in mathematics, an excellent reference text is *MATHEMATICS OF RADIO COMMUNICATIONS* By T. J. Wang (D. Van Nostrand Co.).



cathode-coupled multivibrator study using the scope & power supply

BY LOUIS E. GARNER, JR.

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AUTHOR'S NOTE

Although this Bulletin is another in the Heath "Basic Circuit" series, it is primarily a continuation of a previous Heath Bulletin on multivibrator circuits... PLATE-COUPLED MULTIVIBRATORS. In the previous Bulletin a few of the many types of equipment in which multivibrator circuits are used were listed. In addition, the fundamental principles of operation were outlined briefly. Finally, several types of Plate-Coupled multivibrator circuits were illustrated and described to serve as a guide to the technician or experimenter wishing to actually wire the circuits and to carry out experimental tests, using his *Heathkit Test Equipment*.

Here we will continue the circuit descriptions in the same manner, but with particular reference to Cathode-Coupled multivibrators. However, the reader should refer to the earlier Bulletin for basic information and to standard Electronic Engineering Handbooks and Textbooks for specific theoretical or mathematical discussions of the circuits.

As may be recalled, the multivibrator is a two-stage resistance-coupled amplifier in which the "output" is coupled back to the "input," providing positive or "in-phase" feedback, and thus fulfilling the basic condition necessary for oscillation. In the Plate-Coupled multivibrators discussed previously this feedback was accomplished by means of direct resistance-capacity coupling. In the Cathode-Coupled multivibrators, the feedback is accomplished through an un-bypassed cathode resistor common to both amplifier stages.

SUGGESTED EXPERIMENTS

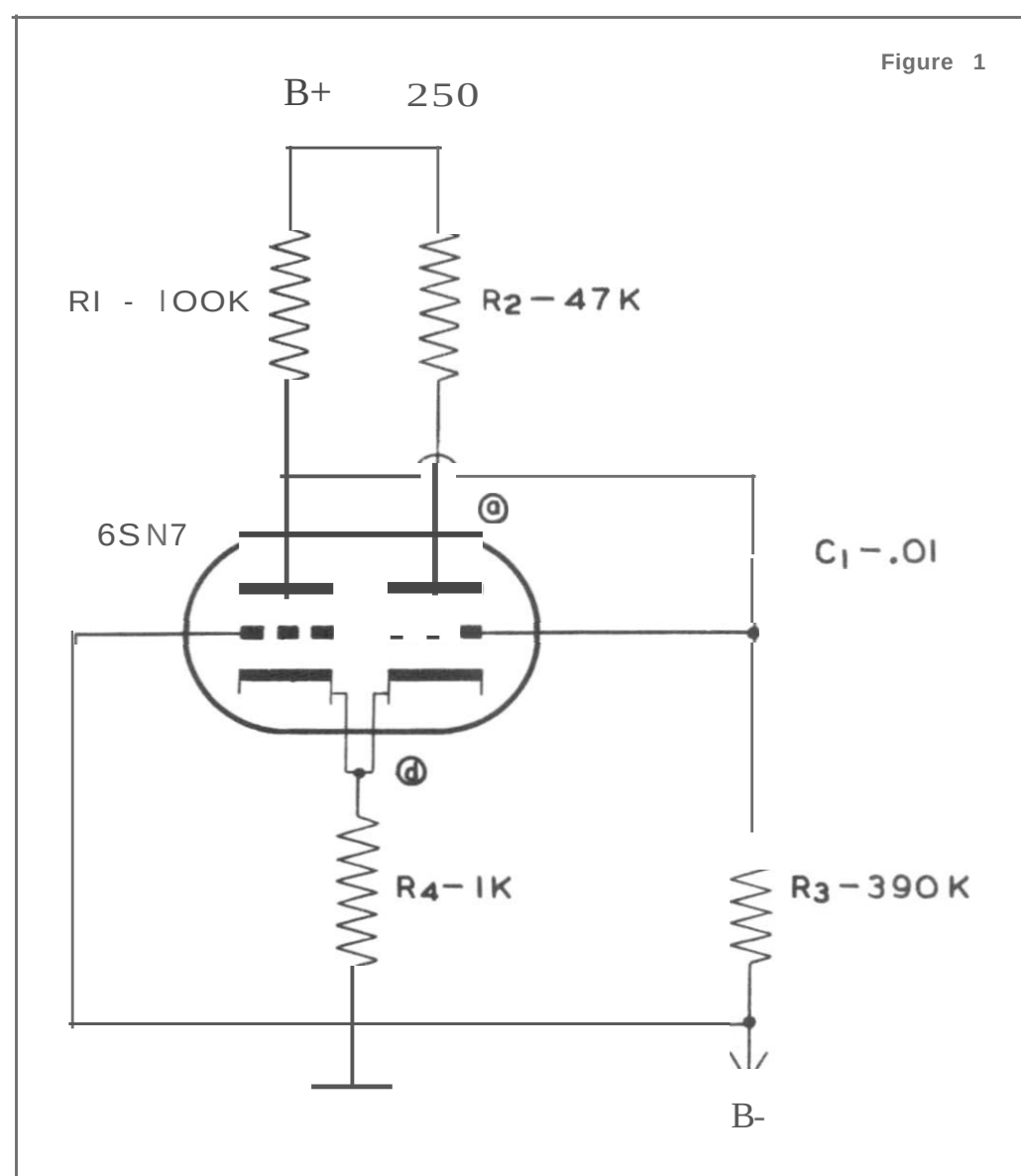
The experimenter should assemble each of the circuits using the parts values shown in the schematic diagrams and should first carry out any tests suggested in the Bulletin. After these preliminary tests are completed, try different part values, different tubes, and different supply voltages, still using the basic circuit given. In this way, the experimenter can become familiar with all phases of the circuit's operation.

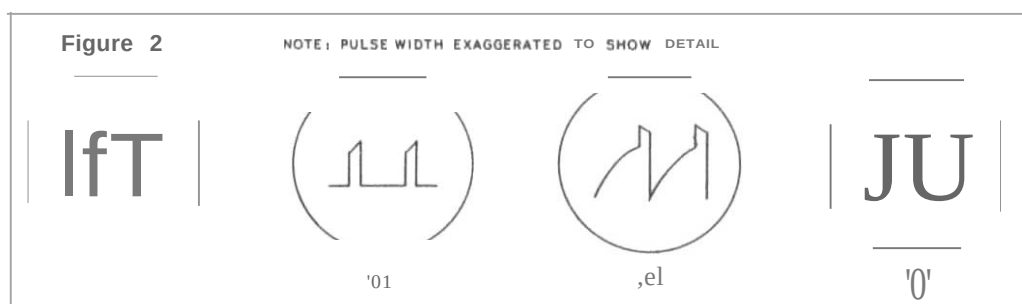
The College or Technical School Student, using these experiments as a supplement to his regular studies, will find it worthwhile to set up the basic mathematical equations relating to each circuit described and to determine, beforehand, the expected results. He may then confirm these results by performing the actual experiments. Where the experimental results do not exactly confirm the predicted action, the student should then determine, by logical reasoning and by experimental tests, the reasons for the differences between predicted and practical results.

Radio & TV Servicemen who are carrying out these experiments to gain a familiarity with the circuits should simulate "defects" that might occur in receivers using these circuits (or their modifications)... leaky or opened condensers, open or changed value resistors, etc. By observing the results obtained with a particular "defect," the Serviceman gains knowledge that will be of real value in his day-to-day servicing work.

CATHODE-COUPLED MULTIVIBRATOR

Although the "Symmetrical Multivibrator" is often considered as *basic* to the whole class of Plate-Coupled multivibrators, an "Asymmetrical Multivibrator" is generally considered as the *fundamental* Cathode-Coupled circuit (Fig. 1). Thus, the Output signal wave-shape is a narrow pulse (see Fig. 2(a)).



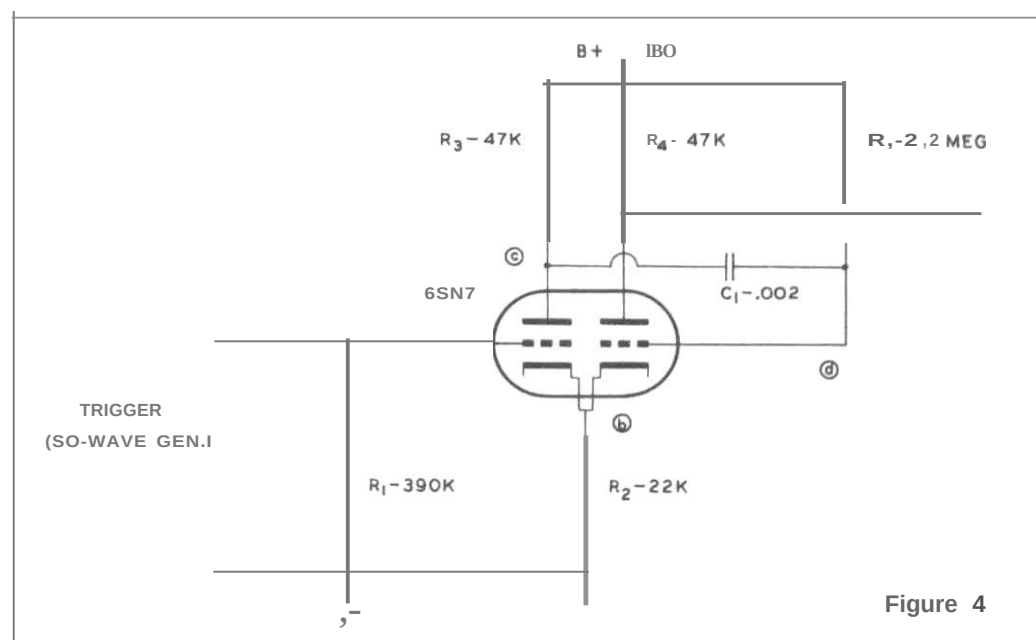
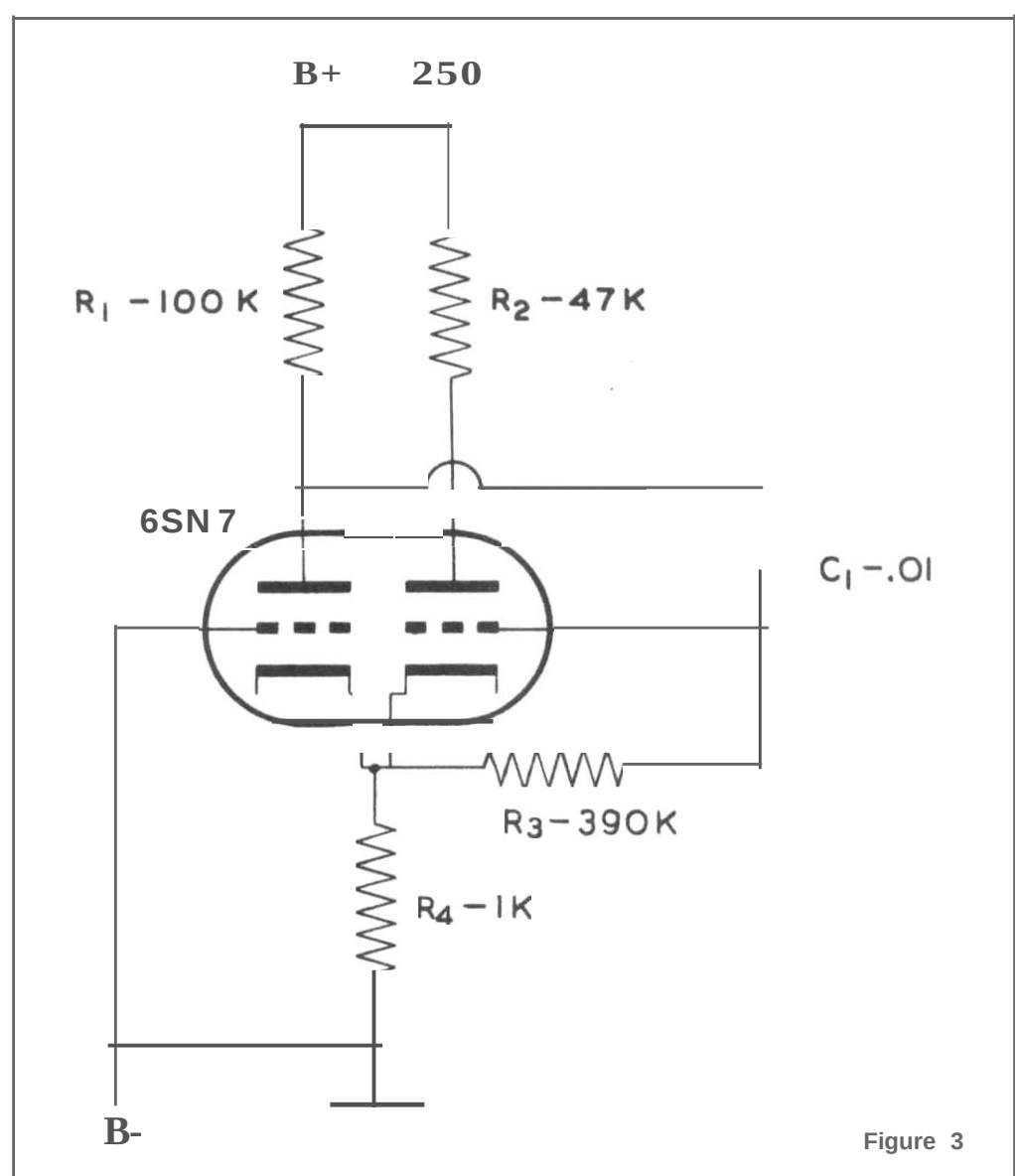


Other signal waveforms in this circuit are shown in Figs. 2(b) and 2(c) and correspond to the patterns observed at points "B" and "C," respectively (using the Heath *Oscilloscope*). The signal amplitude at point "A" is approximately 130 volts, peak-to-peak with the values given in the schematic diagram. At points "B" and "C" the signal amplitude is nearer 60 volts. A pulsed signal appears across the cathode resistor (point "D") and is shown in Fig. 2(d) ... the amplitude is between 4 and 5 volts.

Coupling condenser C_1 and grid resistor R_3 play an important part in determining the operating frequency of this circuit. Where a variable output frequency is desired, a rheostat may be used for R_3 .

The value of the cathode resistor, R_4 , also has considerable control on the operating frequency of the circuit. For example, with the circuit values given in Fig. 1, the operating frequency is approximately 130 cps. When the value of R_4 was dropped from 1000 ohms to 220 ohms, the frequency increased to over 600 cps. At the same time the signal voltage across this resistor dropped to 1.5 volts.

At higher frequencies of operation, the capacity between point "A" and ground becomes important and may even have some control on the frequency of operation. This occurs because the capacity here forms an R-C discharge circuit with plate



resistor R_2 . In some cases, even the input capacity of the 'scope, connected between point "A" and ground, will cause a jump to a much higher operating frequency, together with an appreciable change in signal waveform.

The d.c. B supply voltage does not have too great an effect on operating frequency over quite wide ranges. However, an interesting characteristic of this circuit may be demonstrated quite easily using the Heathkit *Laboratory Power Supply*. With the circuit set up and functioning normally (250 v. B supply), and with the Heathkit *Audio Frequency Meter* connected to the Output (between point "A" and circuit ground), turn the STAND-BY switch of the *Power Supply* to OFF. Observe the operating frequency as indicated on the *Frequency Meter*.

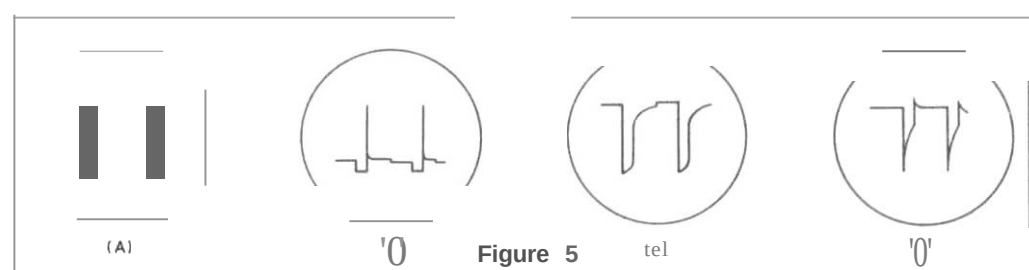
The B voltage, as supplied to the circuit, will not drop to "0" immediately, but will gradually drop as the filter condensers are discharged ... this may be observed by watching the meter on the *Power Supply*. As this happens, the operating frequency of the multivibrator will increase rapidly up to a value several times higher than that noted with 250 volts applied, then will drop back to "0," as the indicated B voltage drops to a very low value.

THE POTTER MULTIVIBRATOR

One variation of the basic cathode-coupled circuit is shown in Fig. 3 ... the only essential difference between this and the preceding circuit is that the grid resistor is returned to the cathode rather than to ground. This particular modification is often used in horizontal sweep circuits in oscilloscopes.

THE "ONE-SHOT" MULTIVIBRATOR

This circuit is not a "free-running" multivibrator in that it normally is in a stable, non-oscillating condition. When a positive-going pulse of sufficient amplitude is applied to the "input" grid, as shown in Fig. 4, this interrupts the stable condition



long enough to permit the circuit to operate through "one cycle." The circuit then returns to its stable condition until another pulse is applied.

Since there is no output signal until a pulse is applied, it is necessary to "drive" this circuit with an external signal. This may best be accomplished by connecting the Heathkit *Square-Wave Generator* to the "input" grid of the tube. With this connection, and an applied signal of about 40 cps, the output waveform (as observed between point "A" and ground) is shown in Fig. 5(a). The amplitude of the signal is about 80 volts, peak-to-peak. (NOTE: "Triggering" of the circuit occurs when the input level is increased to approximately 35 volts peak-to-peak.)

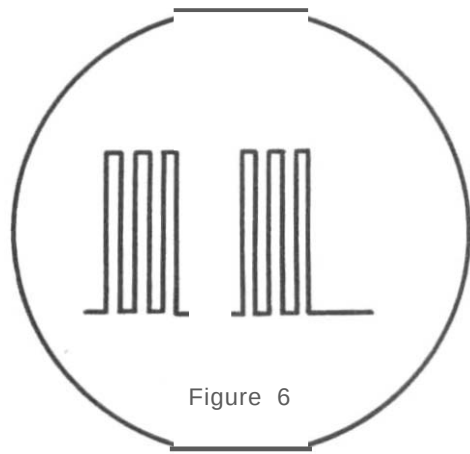


Figure 6

The other signal waveforms in the circuit are shown in Figs. 5(b) (point "B," approximately 20 volts peak-to-peak), 5(c) (point "C," about 70 volts peak-to-peak) and 5(d) (point "D").

If the B voltage applied to this circuit is increased above the value given in Fig. 4, the circuit stability tends to increase and a greater signal input voltage is required to "trigger" it. On the other hand, if the input signal is raised too high for the B supply voltage used, several complete pulses may occur during the period of one-half of the square-wave cycle, giving the output waveform shown in Fig. 6.

The duration or "width" of the pulse shown in Fig. 5(a) stays approximately the same regardless of the number of "trigger pulses" applied per second. The pulse width depends primarily on the circuit constants. Because of this, if a higher frequency square-wave signal is applied to the input, the pulse will occupy a greater and greater percentage of the time for "one cycle" until, at about 500 cps, the output signal approaches a square-wave in general form.

SYNCHRONIZING MULTIVIBRATOR CIRCUITS

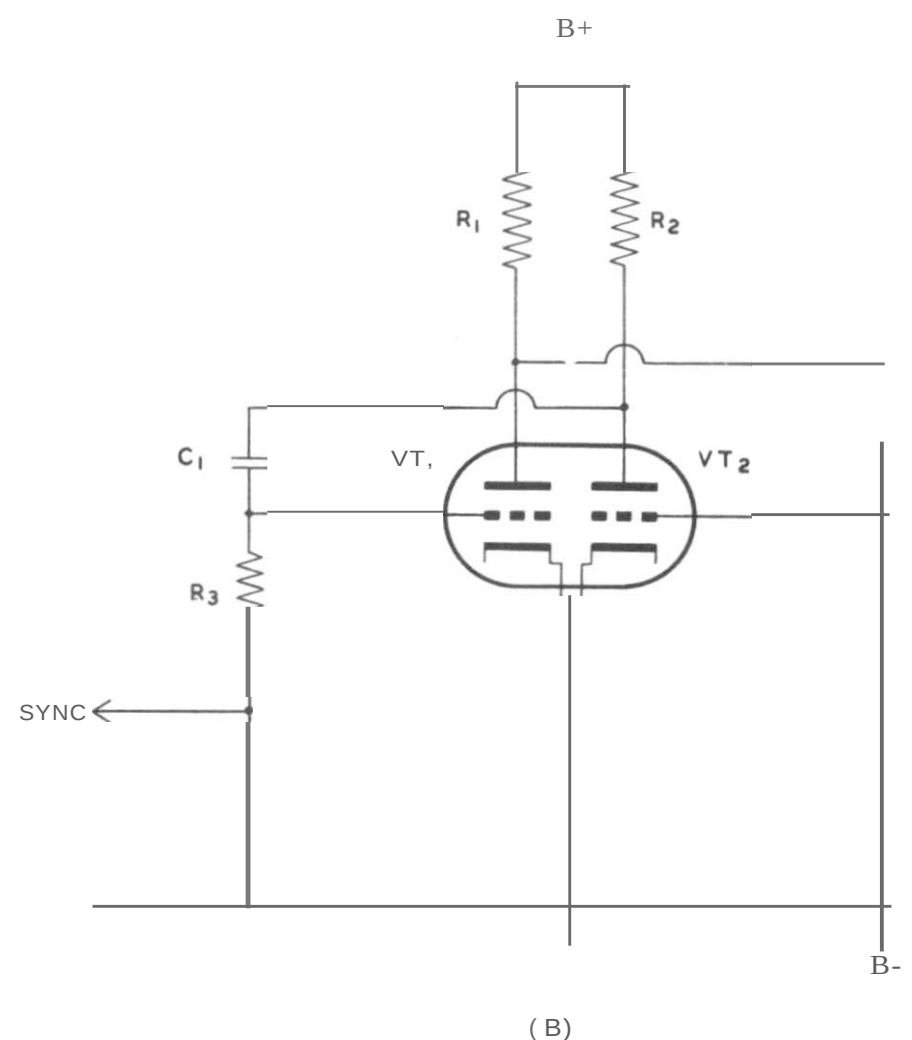
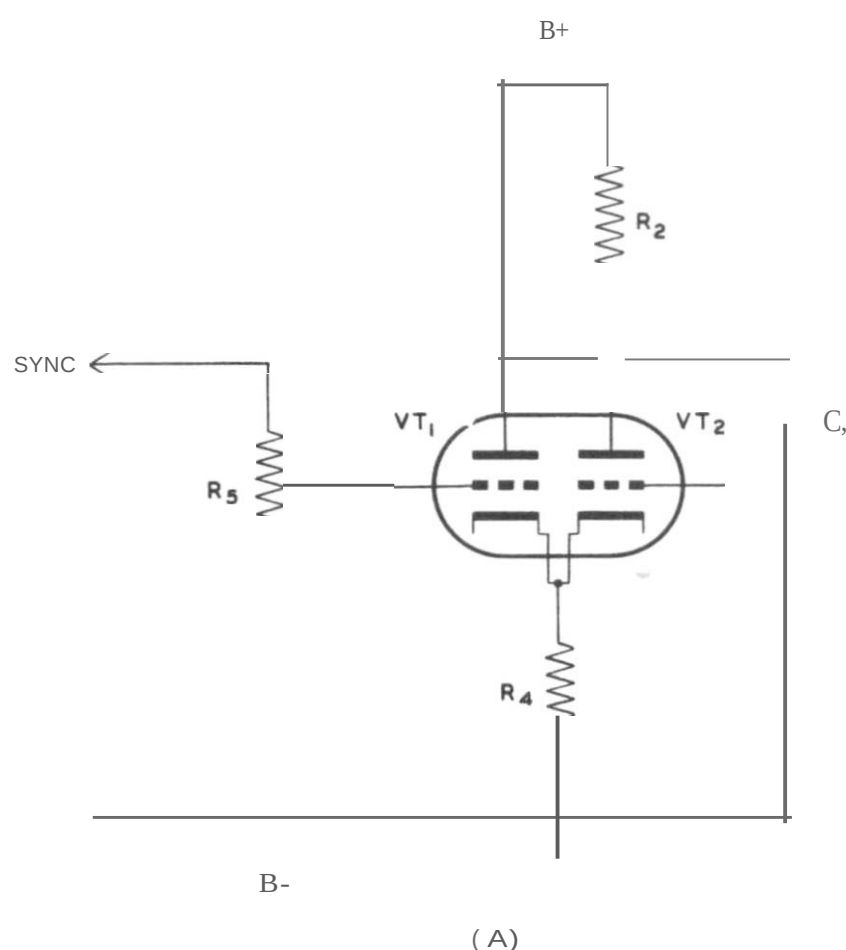
It has been mentioned previously that a multivibrator, as a "free-running" oscillator, tends to be quite erratic in its frequency of operation. Because of this, when multivibrator circuits are used as a signal source in a piece of electronic equipment, they are generally *synchronized* or "locked-in" with another signal.

In the case of the "One-Shot" *Multivibrator* described above, this is no problem... in fact, an external signal is necessary to obtain operation. However, other means are used to "sync" conventional Cathode-coupled and Plate-coupled multivibrators.

The Cathode-coupled multivibrator may be *synchronized* with an external signal by "injecting" the control signal to the normally grounded grid. This is accomplished by connecting a resistor between grid and ground, as shown in Fig. 7(a). If desired, a potentiometer may be used here to provide a "Sync Level" Control.

Plate-coupled multivibrators may be *synchronized* by introducing a signal in series with one of the grids. The circuit shown in Fig. 7(b) is satisfactory for most practical work.

Figure 7



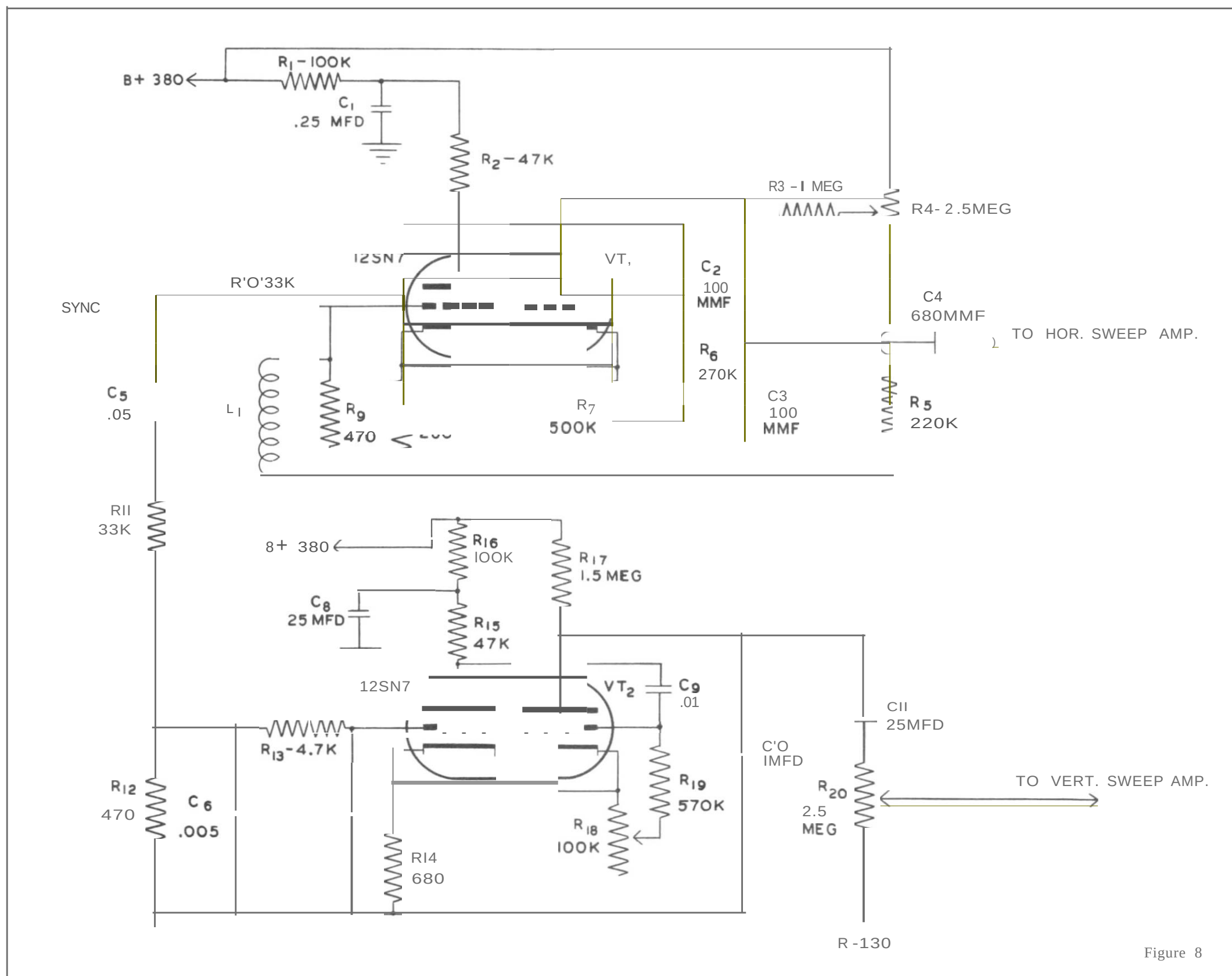


Figure 8

COMMERCIAL APPLICATIONS

Probably one of the best examples of the use of Cathode-Coupled multivibrators in electronic equipment is found in one of the early 7/1 electrostatic TV receivers... the Halli-crafters Model 505. In this set, similar cathode-coupled multi-vibrators are used in *both* the horizontal and vertical sweep circuits. These circuits are illustrated in Fig. 8.

VT1 is the horizontal sweep oscillator and operates at about 15,750 cps. The free-running frequency is controlled by grid resistor R_7 , which acts as the HORIZONTAL HOLD control.

In operation, condenser C_3 is charged slowly through R_3 and R_4 and discharged rapidly by the multivibrator, forming the saw-tooth signal needed for horizontal deflection. This signal is applied through blocking condenser C_4 to one grid of the horizontal sweep amplifier stage.

The amount of voltage applied to C_3 is determined by the setting of R_4 . Since this determines the amplitude of the output signal, R_4 serves as the WIDTH control.

The horizontal sweep oscillator is locked in with the horizontal sync pulses, obtained from the Sync Separator stage

and applied to VT1 through a differentiation circuit consisting of R_{10} , L_1 , and RD' .

As can be readily seen, the vertical sweep oscillator, VT2, is very similar to the horizontal sweep oscillator except for the values of the components used, the method of controlling the output signal level, and the method of applying a sync signal.

In operation, C_{10} is charged slowly through R_{17} and discharged rapidly as the tube shunting it conducts, thus forming a saw-tooth signal. Components in the circuit are chosen so that the free-running frequency is approximately 60 cps.

The saw-tooth signal appearing across C_{10} is applied to R_{20} through blocking condenser C_{11} . R_{20} serves as the vertical amplitude or HEIGHT control.

As in the case of the horizontal sweep oscillator circuit, a variable grid resistor, R_{19} , is used to control the free running frequency of the circuit and thus serves as the VERTICAL HOLD CONTROL.

The vertical sync pulse is applied to the grid of the multivibrator through an integrating circuit consisting of R_{11} , R_{12} , R_{13} , C_6 and C_7 .

r. f. signal generator alignment techniques

BY LOUIS E. GARNER, JR.

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The day-to-day "bread and burrer" job of the Signal Generator is receiver alignment. To save time and money, the serviceman should use a technique which can be applied to the majority of sets encountered in normal work. After using the technique a few times, it becomes a sort of "second nature", and so easily used that the average set may be completely aligned in a matter of minutes. It even becomes feasible to check the alignment of every receiver brought into the shop for service.

Fonunately, receiver design has become sufficiently standardized over the last ten or fifteen years that reference to specific manufacturer's alignment instructions is seldom necessary and the techniques described are applicable, with but little modification, to almost every set encountered.

SINGLE-BAND AM RECEIVER:

In Fig. 1 is given the schematic diagram of the d. and i.f. sections of a small single-band superhetrodyne receiver. The majority of single-band sets use a circuit similar to this one. Modifications likely to be encountered are as follows: (a) use of a loop antenna in place of the antenna coil; (b) use of a separate oscillator rather than a pentagrid converter; (c) iron core tuning of i.f. and/or d. stages in place of the trimmer condensers shown; (d) use of an d. stage ahead of the mixer; (e) more than one i.f. stage. These modifications do not

appreciably affect the alignment technique, however, and the following step-by-step technique may be used directly in most cases (and with slight modifications in a few instances):

1. Turn "on" both the Signal Generator and the Receiver and allow several minutes warm-up time (it is a good idea to leave the Signal Generator "on" during all working hours).

2. Connect an output indicator to the receiver. This may be an a.c. voltmeter connected across the loudspeaker voice coil, but a d.c. VTVM connected to measure AVC voltage ("V" in Fig. 1) is preferred.

3. Short out the local oscillator tuning circuit temporarily (this may be done by clipping a short piece of wire across the lugs of the rotor and stator plates of the oscillator section of the tuning condenser), and set the dial of the receiver to the low frequency end.

4. Connect the Signal Generator to the antenna terminals of the receiver (where the circuit is similar to the one shown in Fig. 1 . . . where an d. stage is used ahead of the mixer, connect the Signal Generator to the injection grid of the mixer stage). Set the Signal Generator to the i.f. value of the set (generally 455 k.c.). Use a modulated signal if an a.c. voltmeter is used as an output indicator and an unmodulated signal if the AVC voltage is used as an output indication.

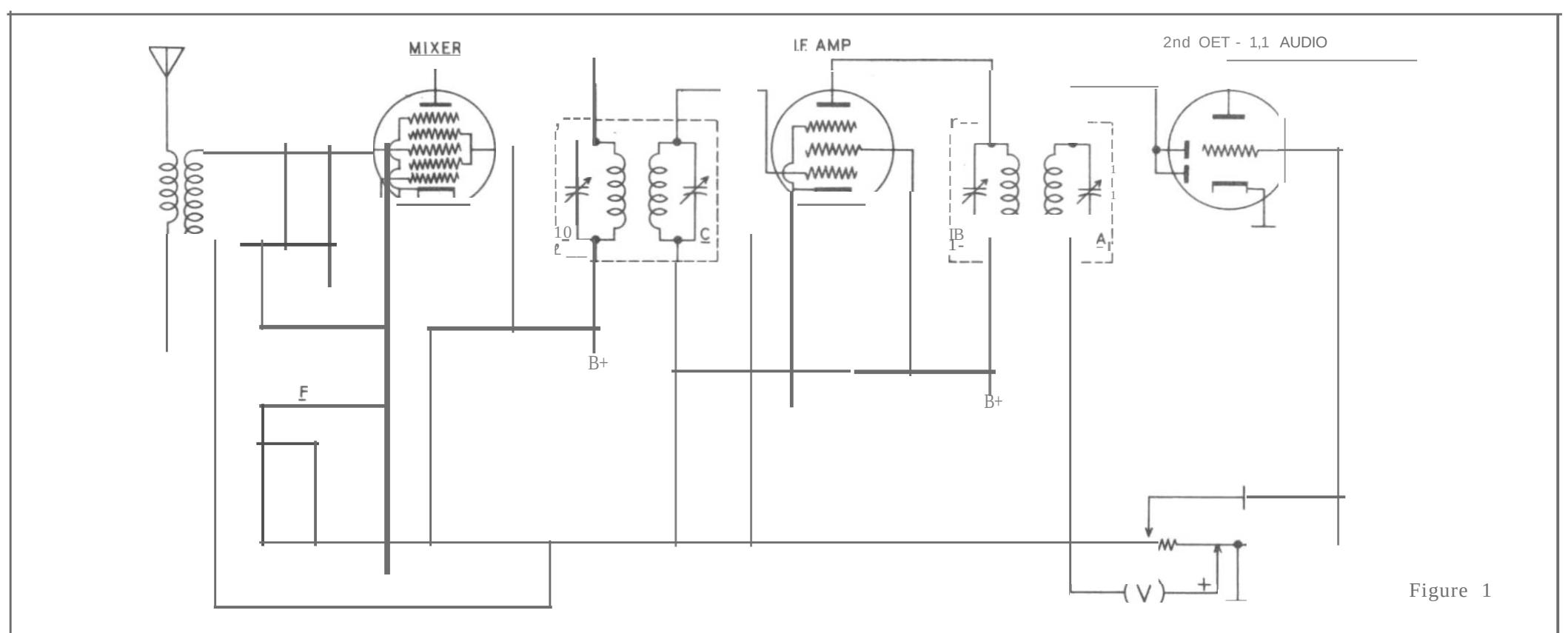


Figure 1

5.' Using the lowest range of the output indicator, increase the Output of the Signal Generator until a reading can just be obtained.

6. Adjust the i.f. transformers for a maximum reading (adjustments A, B, C, and D in Fig. 1) on the output indicator. Reduce the Signal Generator output as necessary to keep a low reading on the Output indicator. Repeat the adjustments at least once to correct for any interaction between primary and secondary windings on the individual transformers. Interaction is more likely to occur in sets where adjustment is by means of iron core slugs than in sets using trimmer condensers.

7. Remove the short across the local oscillator and tune the receiver to its highest frequency dial setting. Set the Signal Generator to the same frequency, and adjust the oscillator trimmer for maximum output (adjustment G in Fig. 1).

8. Tune the receiver and Signal Generator to 1400 kc. and adjust the d. trimmer for maximum Output (adjustment E in Fig. 1)

9. Tune the Signal Generator to 600 kc. Tune the receiver to the low frequency end of the dial. Now, "rock" the receiver tuning condenser while, at the same time, adjusting the padding condenser (adjustment F in Fig. 1) for maximum Output. In sets using especially shaped plates in the oscillator section of the tuning condenser, no padding condenser will be found. Also, in some sets the low frequency oscillator adjustment will be by means of an iron core slug in the oscillator coil rather than by means of a padding condenser.

10. Repeat steps 7, 8, and 9 if readjustment of the padding condenser (or oscillator coil core) was necessary in step 9.

MULTI-BAND AM RECEIVER:

The alignment procedure for a multi-band AM superheterodyne receiver is essentially the same as outlined above for a single-band set. First, the i.f. stages are aligned, using the technique given in steps 1 through 6, above. Next, each d.

band is aligned separately, starting with the highest frequency band and working towards the lowest. The technique given may be used, but with different frequency settings for each band.

If the oscillator and d. trimmer condensers for the different bands are not well identified, a simple technique may be employed to locate the proper adjustments.

Turn the receiver band switch to the highest frequency band and tune in a signal (short-wave station or a signal from the Signal Generator) at the high frequency end of the band. Using an insulated alignment tool, try compressing the different oscillator trimmers until one is found that changes the tuning of the signal. *Don't make a permanent adjustment ... just press the leaves of the condenser together temporarily.* After identifying the oscillator trimmer for the band in this manner, repeat the technique to identify the d. trimmer(s). Turn to the next band and repeat the method, being careful not to touch the trimmers already identified.

Should the oscillator trimmer of the short-wave band(s) have a wide tuning range, it may be possible to pick up and "peak" a signal with two different settings of the trimmer. If this is the case, use the setting with the least capacity to insure that the oscillator is tuned above the incoming signal in frequency.

FM RECEIVERS:

It is standard practice to align the i.f. amplifier of an FM receiver before aligning the d. and oscillator sections, just as in AM sets. However, the exact technique of alignment depends on whether a conventional limiter and discriminator or a ratio detector is used. Where a limiter and discriminator is used, usual practice is to align the i.f. section up to the input of the limiter first, then to align the discriminator as a separate step. When aligning the i.f., d. and oscillator sections, the grid current of the limiter may be used as an output indicator, although the voltage across the limiter grid resistor, as measured with a VTVM, will serve in many cases.

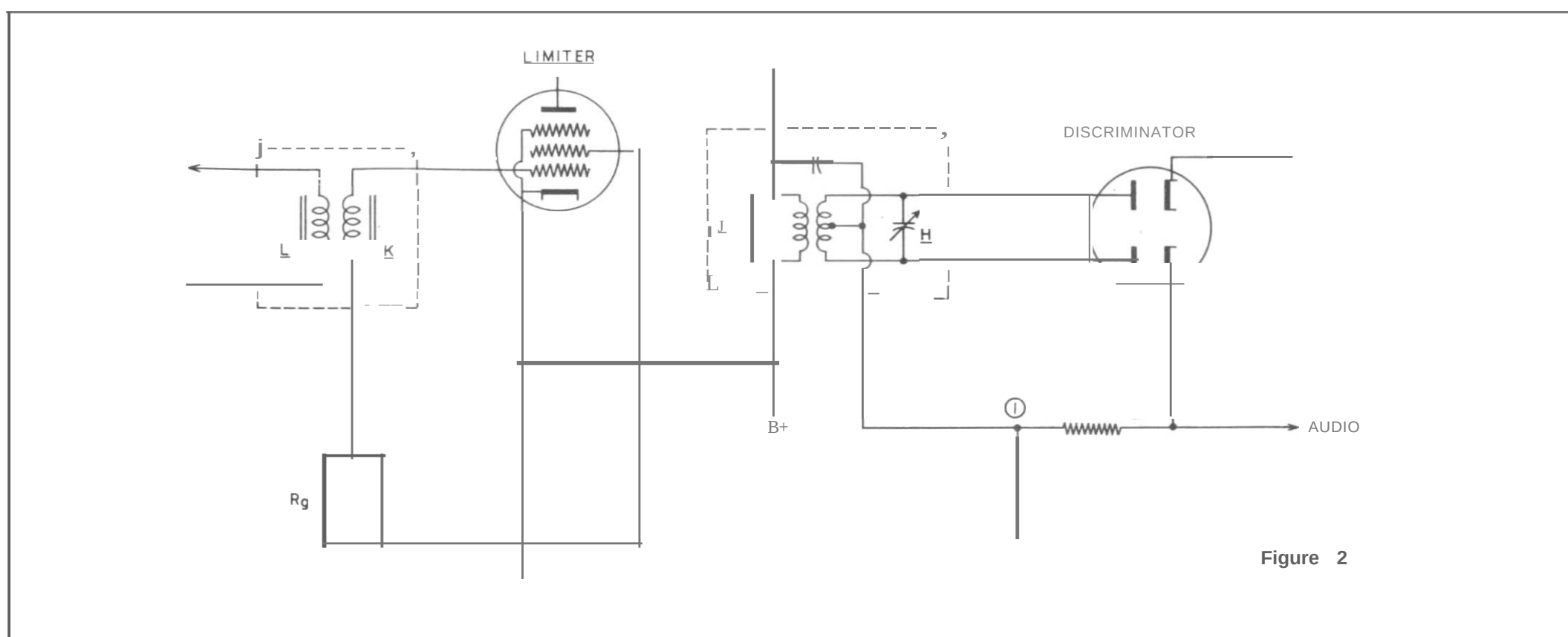


Figure 2

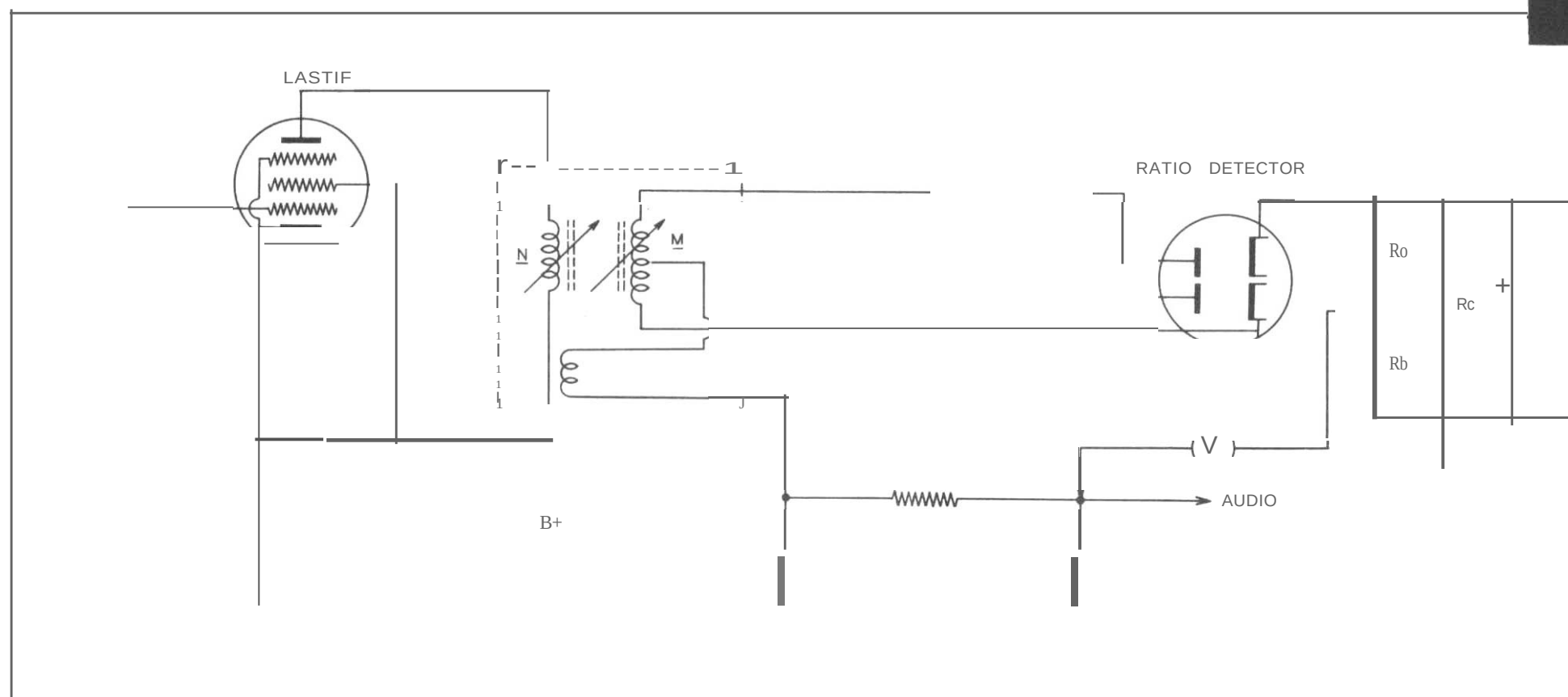


Figure 3

A typical limiter and discriminator stage is given in Fig. 2. Proper alignment technique for the complete FM receiver follows:

1. Connect an output indicator by (a) connecting a VTVM across R_g , or by (b) breaking the circuit at point "X" and inserting a microammeter having a range of from 100 to 150 microamps. If (b) is used, bypass the meter with a .05 mfd molded condenser.

2. Connect the Signal Generator to the input of the mixer stage, and turn "on" both the Signal Generator and the receiver, again allowing a warm-up period. Adjust the Signal Generator to the i.E. value of the set (usually 10.7 me), using an unmodulated d . signal.

3. Peak all i.E. trimmers, in turn, for maximum meter reading. If the i.E. is far out of alignment, so that little meter reading is obtained, it may be necessary to connect the Signal Generator to the last i.E. stage and align this stage first, then to work gradually back towards the mixer stage, rechecking previous i.E. adjustments at each point.

4. Connect a VTVM between point 1 (Fig. 2) and chassis ground and adjust trimmer (or slug) J for a maximum reading, using a low VTVM range.

5. Transfer the VTVM connection to point 2 (Fig. 2) and adjust trimmer H for a minimum voltmeter reading.

6. Transfer the Signal Generator lead to the antenna terminals and align the d . and oscillator trimmers using essentially the same technique as outlined for an AM receiver

(except for frequency settings ... 88 me and 108 me). Output indicator as in step 1. Finally, adjust the antenna trimmer while using the customer's antenna.

RATIO DETECTORS:

Where the FM receiver uses a ratio detector, the following technique may be used for alignment. Refer to Fig. 3.

1. Connect a VTVM or high resistance d.c. voltmeter across R_c .

2. As before, both the receiver and the Signal Generator should be allowed to warm up. The receiver dial should be set to the low frequency end of the dial (88 me) and the Signal Generator adjusted to give an unmodulated signal at the receiver i.E. Connect the Signal Generator to the input of the mixer stage, as before.

3. Adjust all i.E. trimmers (or slugs) for a maximum reading on the meter, using a low range and the least Signal Generator output necessary. Repeat the adjustments at least twice to correct for any interaction.

4. Connect two 100,000 ohm, $\frac{1}{2}$ W. resistors across R_c (R_a and R_h) and connect the voltmeter as shown at V in Fig. 3.

5. Adjust slug (or trimmer) M for a zero output indication on the meter. Slug N should have previously been adjusted for a peak reading (step 3).

6. Align the d . and oscillator stages using the techniques previously described, measuring the voltage across R_c as an output indication.

the heathkit r.f. signal generator In tv servicing

BY LOUIS E. GARNER, JR.

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Using the Heathkit R.F. Signal Generator as a TV service instrument does not, of course, do away with the need for specialized TV service instruments such as the Sweep Generator. However, when properly used, the R.F. Signal Generator permits many TV servicing jobs to be simplified, and others to be speeded up considerably. Proper use of the instrument also permits a better understanding of TV circuit operation which, in turn, leads to greater knowledge and the ability to service with maximum efficiency. As the serviceman becomes familiar with using the Signal Generator in his TV service work, he will soon develop many special techniques himself. However the basic techniques will be covered in this bulletin.

ALIGNMENT

In the majority of TV receivers manufactured during 1946, 1947 and 1948, the required band-width in the video d. stages was obtained by means of "staggered tuning". Even today, many manufacturers still use this technique. This is especially true of the "Custom" sets patterned after the famous RCA 630TS television receiver.

With "stagger tuning", each d. transformer is peaked at a different frequency within the pass-band. By a proper choice of frequencies, and with proper loading to shape the individual response curves, it is possible to obtain a reasonably flat and quite wide over-all response.

Although the Sweep Generator-Oscilloscope method of alignment is generally recommended for TV sets, those receivers in which stagger tuned video iJ. stages are employed

may be satisfactorily aligned using the standard Heathkit R.F. Signal Generator. In addition, the audio d. stages of almost all TV receivers may be aligned with the R.F. Signal Generator, whether or not "stagger tuning" is used in the video d.

The exact frequency at which each iJ. stage is peaked will vary from set to set. The alignment technique, on the other hand, is practically "standard" and the general method described may be used in most cases ... *provided* the d. peaking frequencies are known. Fortunately, most manufacturers supply this data as part of the schematic diagram.

The block diagram for the video and audio d. stages of a typical TV receiver is given in Fig. 1. Note that power supply, sync, sweep and high voltage circuits have been omitted for clarity. The alignment technique follows:

1. Plug in both the TV receiver and Signal Generator. Turn "on" and allow a few minutes warm-up time so all circuits will be stable.
2. Remove the R.F. and Oscillator tubes in the TV receiver "Front-End" (shaded blocks in Fig. 1). Connect the Signal Generator gnd. lead to chassis ground and the "hot" lead to the grid of the Mixer stage through a 50 mmfd decoupling condenser. (NOTE: In sets where a filament "string" is used, the tubes mentioned cannot be removed without opening the filament circuit. In such cases, turn the channel selector to some point on the low band where there is no local TV station.)

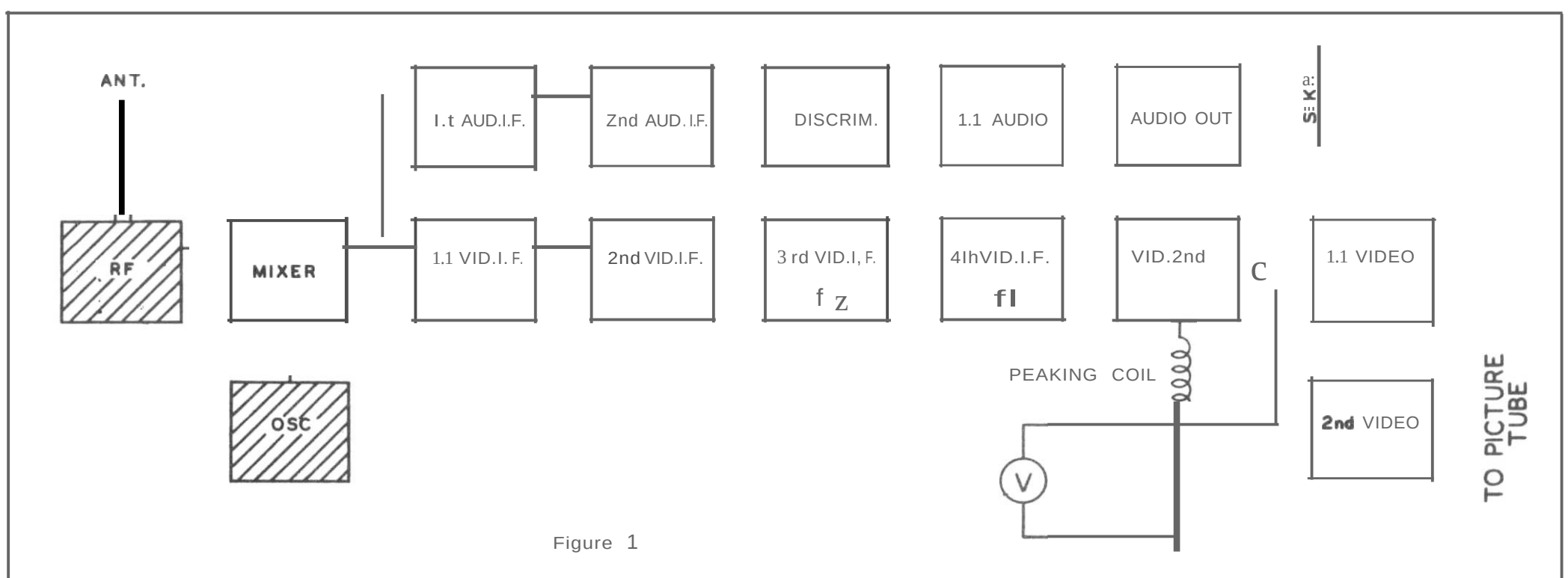
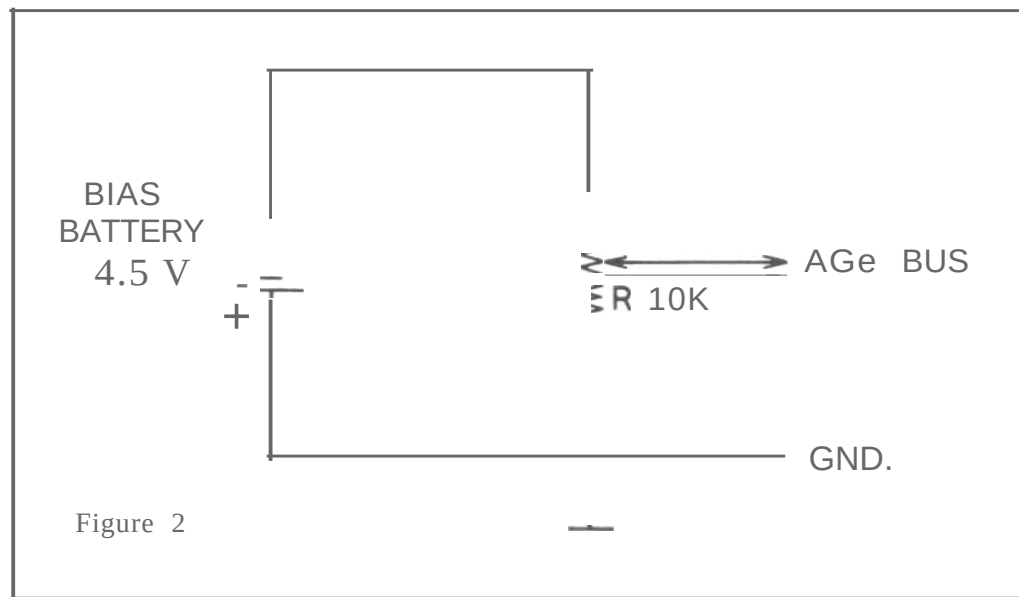


Figure 1

3. Connect a d.c. VTVM to measure the i.f. stage bias (where manually controlled) and adjust to the value suggested by the set manufacturer (for the RCA 630TS, this is -3 volts). Where AGC is used, disconnect the AGC bus and use the substitute AGC bias source shown in Fig. 2 to provide a fixed i.f. bias during alignment. Again, use the bias voltage value suggested by the receiver manufacturer.



4. Connect the d.c. voltmeter across the video 2nd detector load resistor (R_L , Fig. 1).

5. Using the minimum scale on the d.c. voltmeter and the maximum output of the Signal Generator, tune to each i.f. "trap" frequency in turn and adjust the corresponding trap for a *minimum* reading on the meter. (NOTE: I.F. "traps" are not found in all TV receivers, but, where used, are generally tuned to the audio d., and to frequencies corresponding to adjacent channel video and audio d. values.) An unmodulated d. signal is used for this adjustment.

6. Again using an unmodulated d. signal, tune to each of the d. "peaking" frequencies in turn and adjust the corresponding d. coil for a maximum reading across R_L . (These d. values are indicated symbolically in Fig. 1 as f_1 , f_2 , f_3 and f_4 .)

7. Repeat steps 5 and 6 to correct for any inter-action in tuning. However, take especial care that the Signal Generator is set to *exactly* the same frequencies as before.

8. If the receiver is badly out of alignment, oscillation may occur during the alignment procedure. This is indicated by a comparatively high voltmeter reading across R_L (Fig. 1) which remains essentially the same regardless of Signal Generator tuning or output. Should oscillation occur, "load" all d. tuned circuits (except "traps") by shunting with $\frac{1}{2}$ watt carbon resistors (1000 ohms or less). Then carry out the alignment procedure, a stage at a time, as before. Remove the loading resistor of each stage after it is properly adjusted.

9. To align the audio i.f. stages and the discriminator (or ratio detector), simply consider this section of the TV set as the equivalent of the d. and discriminator sections of an FM receiver (except for the i.f. value) and align in the same way. (NOTE: The technique for FM receiver alignment was given in another Heath "Application Notes".)

10. In sets using the "intercarrier" sound system, there may be a 4.5 mc "grain trap" following the video amplifier. To adjust the grain trap, apply a 4.5 mc signal to the first video amplifier ... use the maximum output of the Signal Generator. Now, watching the screen of the picture tube, adjust the "grain trap" until a minimum amount of 'grain' is visible on the screen. "Grain" appears as a coarse texture effect on the picture tube.

MARKER GENERATOR

The R.F. Signal Generator is often used as a "marker" in conjunction with the TV Sweep Signal Generator. When used in such an application it serves to identify the location of the video d. carrier, and of adjacent channel audio and video d. traps.

When the Signal Generator is used as a marker generator, the actual connections to the receiver may be made in one of several ways. First, if the Sweep Signal Generator used has provision for a marker generator connection (usually terminals marked "EXT. MARKER"), the R.F. Signal Generator is connected here. If such provision is not available, the R.F. Signal Generator may be connected in parallel with the Sweep Generator connections to the TV receiver through a small (10 mmf to 50 mmf) decoupling condenser. Some receiver manufacturers suggest that the marker generator be connected either to the stage preceding or the stage following the Sweep Generator connections (to provide additional isolation).

In any case, when properly connected, the marker signal will appear as a small "pip" on the over-all response curve, as shown in Fig. 3. The position of this pip corresponds to the frequency setting of the R.F. Signal Generator. As the Signal Generator tuning is changed, the marker "pip" will move across the response curve.

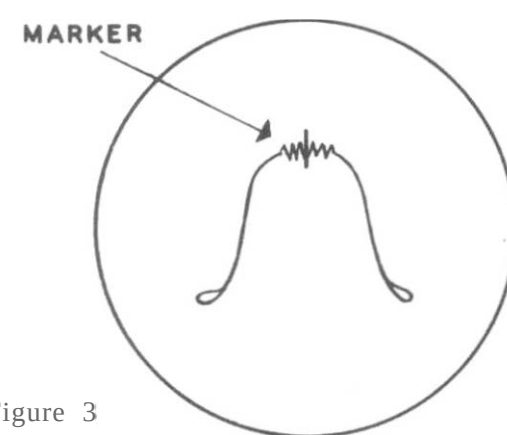


Figure 3

SIGNAL INJECTION TESTS

In a previous bulletin, we discussed the use of "Signal Injection" tests in servicing audio amplifiers and broadcast receivers. The same techniques may be applied, with but simple modification, to checking many stages in a TV receiver.

For tests in the audio and video amplifier sections of the receiver, use the audio signal obtained from the 'AF OUT' jack of the Signal Generator. When checking in the audio stages, this signal will be heard as a tone in the loudspeaker. When checking in the video stages, the signal may be observed as a series of horizontal bars on the screen of the receiver (see Fig. 4).

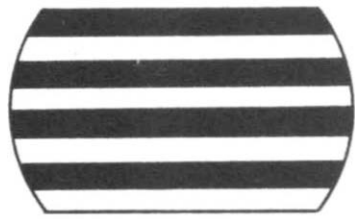


Figure 4

When checking in the audio i.E. sections of the receiver, use a modulated **d.** signal at the audio i.E. value of the receiver. In some sets, having exceptional limiting action, the audio tone will be quite faint, and may disappear entirely when Signal Injection tests are made in the audio i.E. This is due to the fact that TV sound is FM, whereas the modulated signal obtained from the Signal Generator is AM. Under such conditions, the d.c. voltage across the discriminator load resistor may be used as an output indication in lieu of the loudspeaker tone.

A modulated signal at the video i.E. value of the set (or anywhere within the video pass-band) will generally suffice for Signal Injection tests in the video i.E. stages. Again, the output indication will be horizontal bars across the TV screen.

*Be sure to use a small d.c. blocking condenser **in** series with the "hot" Signal Generator lead when making Signal Injection tests.*

In some TV receivers, it may be found impossible to obtain the horizontal bar pattern when checking the last video i.E. stage. This is generally due either to the low gain of the i.E. stage or to de-tuning by the Signal Generator lead. In such cases, the signal may be injected into preceding stages to obtain the additional gain necessary.

VERTICAL LINEARITY ADJUSTMENTS

The horizontal bar pattern produced when Injecting the audio signal into the video amplifier stages (or using a modulated **d.** signal in the video i.E. stages) should consist of equally spaced black-and-white bars. If these bars are not evenly spaced, it indicates need for readjustment of the VERTICAL LINEARITY control of the TV receiver. (NOTE: Adjustment of the VERTICAL HOLD control may be necessary to obtain a pattern of stationary bars.)

In some sets, these adjustments may be made without removing the TV receiver from the cabinet. To do this, disconnect the TV antenna lead and connect the Signal Generator lead in its place. Tune the TV receiver to channel 2 and adjust the R.F. Signal Generator to supply a modulated **d.** signal in the 54-60 mc range. With the CONTRAST control turned up, the horizontal bar pattern should be obtained on the screen of the receiver.

signal injection tests with the heathkit r.f. signal generator

BY LOUIS E. GARNER, JR.

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A valuable technique for trouble-shooting "weak" or "dead" receivers or amplifiers is the "Signal Injection" technique. The basis for this method of defect isolation is to provide a known signal which can be "injected" into various stages of the defective equipment, a stage at a time, until the defective stage is located.

Your Heathkit R. F. Signal Generator provides not only R. F. signals, but also a separate audio signal. Because of this, your instrument is admirably suited to applying this valuable servicing technique.

To see how the Signal Injection servicing technique may be applied to actual servicing problems, let us discuss two different types of equipment that may come into the service shop . . . an audio amplifier and a small AM receiver. We will see how Signal Injection may be used for isolating a "weak" or "dead" stage in each piece of equipment.

THE AUDIO AMPLIFIER:

The block diagram for a typical audio amplifier is given in Fig. 1. We will assume, for the moment, that the amplifier is "dead" due to a defective 2nd audio stage.

In servicing the equipment, the first step, of course, is to check for "obvious" defects such as a lack of B plus, defective tubes, etc. After these preliminary tests, the Heathkit R. F. Signal Generator is used as an audio signal source by plugging the Output cable into the "AF OUT" jack. The level of the audio tone obtained is adjusted by using the "AF IN-OUT"

control. The "MODULATION" control should be set in the "INT." position.

Check the operation of the *output* stages by connecting the ground lead of the Output cable to the chassis of the amplifier and touching the "hot" lead to the grid of first one *output* tube (point A in Fig. 1), then to the other *output* tube (point B in Fig. 1). In this fashion, the operation of each *output* stage is checked individually. As each grid is touched, a clear audio tone should be heard in the loudspeaker.

Next, the operation of the *phase-inverter* stage can be checked by transferring the "hot" lead to the input of this stage (point C in Fig. 1). Again, a clear signal should be heard from the loudspeaker. The tone should be louder than before. If too loud, the volume can be reduced using the "AF IN-OUT" Control.

The *2nd audio* stage is now checked by transferring the "hot" Signal Generator lead to the input of this stage (point D in Fig. 1). If this stage is "dead", no tone will be heard in the loudspeaker. Having isolated the trouble to a specific stage, it is now a simple matter to check d.c. operating voltages and parts until the defective part is found.

As each amplifier stage is checked, working back towards the input stage (*1st audio*), a definite increase in volume should have been noted. It may have even been necessary to reduce the volume using the control mentioned. This, then, provides an additional test technique. A "weak" stage can be identified if little or no increase in volume is heard as the

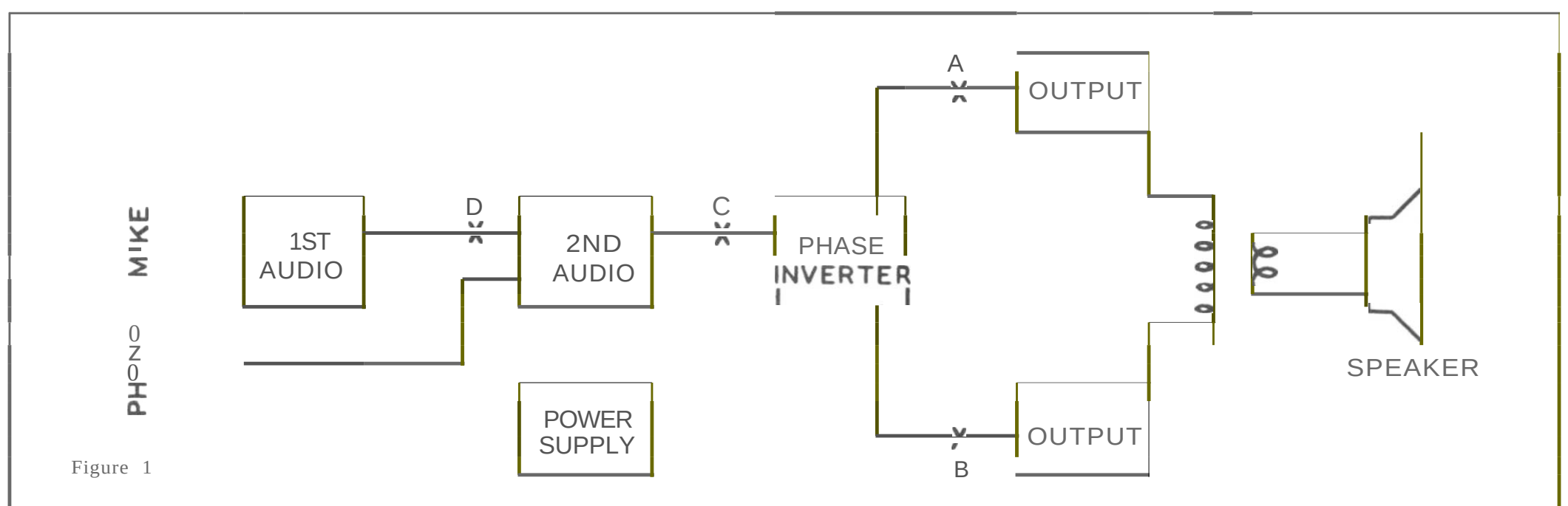


Figure 1

"hot" lead is transferred past the stage. Be careful when interpreting the results of this test for overloading a stage may cause an apparent loss of volume even when the stage, itself, is in good condition. Therefore, when attempting to isolate a "weak" stage, be sure to keep the signal level at a reasonable point.

AN OPEN COUPLING CONDENSER may be isolated using the signal injection technique. Refer to Fig. 2. Part of a conventional resistance-coupled amplifier is shown in the sketch.

If coupling condenser "C," should open, little or no signal would be transferred between stages. To check the condition of the coupling condenser, it is first necessary to connect a small blocking condenser in series with the "hot" lead of the Signal Generator. The condenser may have a value of from .05 mfd to .25 mfd . . . the exact value is not critical. The blocking condenser permits the "hot" lead to be placed on the plate of a tube without danger of the d.c. voltage present injuring circuits within the generator.

If a clear tone is heard when the "hot" lead, is touched to point E, but not when touched to point F (Fig. 2), we are reasonably sure condenser "C," is open.

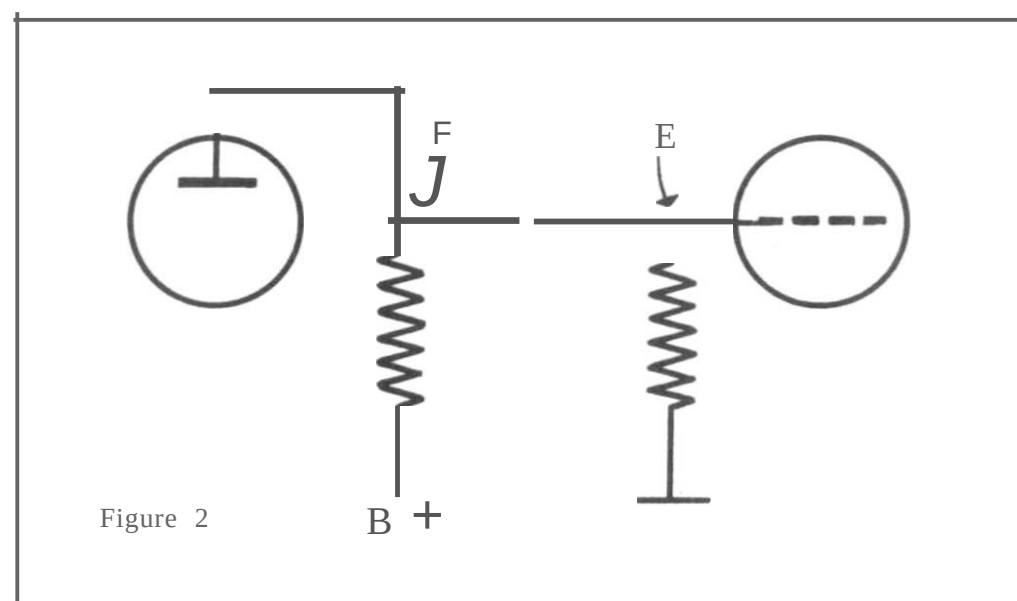


Figure 2

RADIO RECEIVER:

Refer to the block diagram for a typical small AM receiver given in Fig. 3. Again, the technique of Signal Injection is essentially the same as that used in the case of the Audio Amplifier. That is, a substitute signal is injected into each

stage, starting at a convenient point and working back towards the "front" of the equipment. In the case of the Audio Amplifier, we worked towards the input jack of the amplifier. In the case of the radio receiver, we work towards the antenna.

There is one important difference between using the Signal Injection technique on an Audio Amplifier and using the same technique on a receiver. In the case of the amplifier, as we have seen, the audio output signal obtained from the Signal Generator was used exclusively. However, when trouble-shooting a receiver, it becomes necessary to switch to an R. F. signal when checking stages ahead of the 2nd detector. In addition, the frequency of the R. F. signal will have to be changed to match the operating frequency of the stages being checked. But let us refer to our typical example.

A rather common receiver complaint is that "the set is dead". When such a complaint is caused by a defective local oscillator, the trouble may prove somewhat difficult to isolate.

As before, the first step in servicing the equipment is to check for obvious defects. All tubes should be tested and weak or defective ones replaced. A quick check with a d.c. voltmeter will indicate whether or not the power supply is operating.

To isolate the trouble to a stage as rapidly as possible, a technique which experienced servicemen often employ may be used. Instead of stage-by-stage testing, the set is considered to consist of major "sections", and preliminary isolation of the trouble made on this basis.

The audio signal obtained from the Heathkit R. F. Signal Generator may be used to inject a signal at the input of the 1st audio stage (point H in Fig. 3). If a loud, clear tone is heard in the loudspeaker, we know immediately that the entire audio section of the receiver is operating and can forget about these stages.

(On the other hand, if no signal were heard in the loudspeaker as this test were made, we would then know trouble existed in the audio section and could proceed to a systematic stage-by-stage test as described in the case of the Audio Amplifier).

Shift the output cable of the Signal Generator to the "RF OUT" jack and adjust the controls to give a modulated R. F.

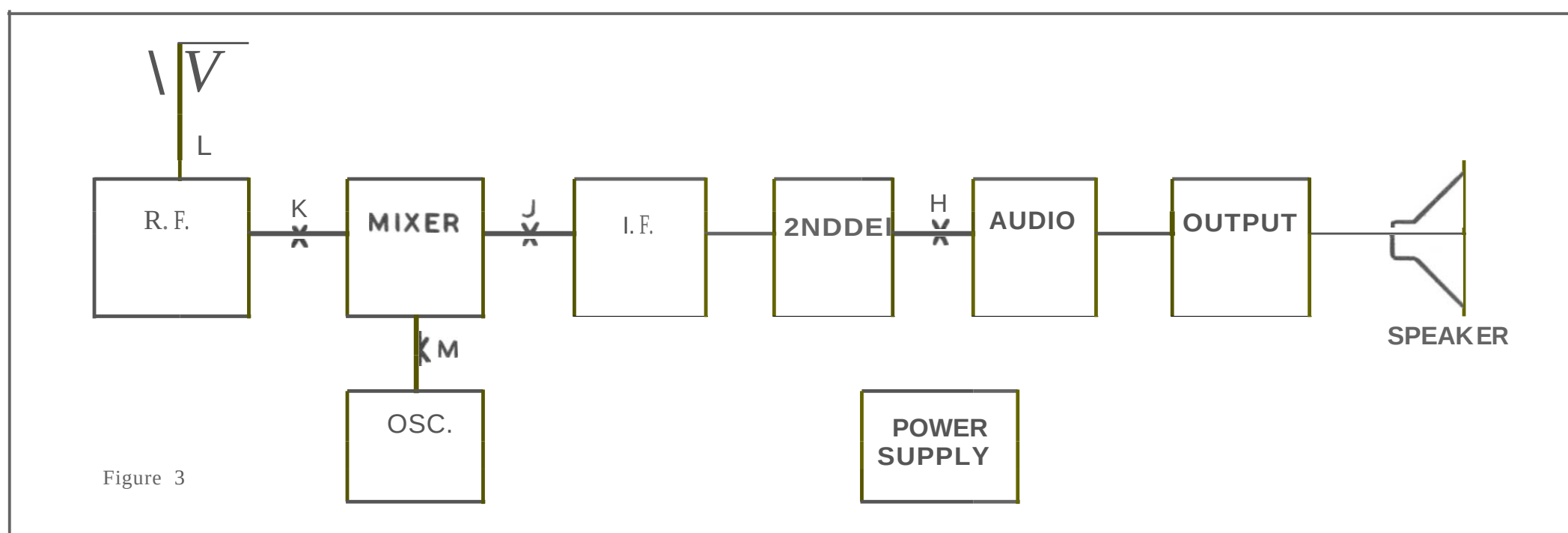


Figure 3

signal at the 1. F. value for the receiver (in most cases, this will be 455 kc). Using a 50 mmf condenser in series with the "hot" lead, injeer the signal at the input of the 1. F. stage (point J in Fig. 3). (NOTE: The use of a small coupling condenser, in this case, is to minimize detuning of the 1. F. and R. F. stages by the Signal Generator lead.) If a tone is again heard in the loudspeaker, we know that the 1. F. stage is o. k.

Transfer the "hot" lead to the input of the *mixer* stage (point K in Fig. 3), again injecting an R. F. signal at the 1. F. value of the set. If the tone is again heard from the loudspeaker, we know that the *mixer* stage is passing a signal satisfactorily. Leaving the lead connection in place, shift the frequency of the Signal Generator so that an R. F. signal of the same frequency to which the receiver is tuned is applied to the input of the *mixer* (refer to the receiver dial setting).

With the local oscillator "dead" there can be no mixing of signals in the *mixer* stage to produce an 1. F. Therefore, with the imagined complaint, no tone will be heard when this last test is made. This gives an indication that the local oscillator is either "dead" or considerably off frequency.

As a further test, the Signal Generator may now be used as a substitute local oscillator. To do this, transfer the "hot" lead to the injection grid of the *mixer* stage (or to the "oscillator" grid if a pentagrid converter is used, with no separate

local oscillator). Turn off the modulation of the Signal Generator.

Tune the receiver to a frequency corresponding to that of a local broadcast station. Now adjust the Signal Generator to a frequency equal to that of the broadcast station plus the 1. F. of the set.

As an example, let us say that the local station has a frequency of 1330 kc, and that the 1. F. of the set is 455 kc. The Signal Generator should be set to 1330 plus 455 or 1785 kc.

Under normal conditions, it should now be possible to receive the local broadcast station. This is final proof that the defect is in the local oscillator stage of the receiver.

Had the defeer been in the R. F. stage or in the antenna circuit, rather than in the local oscillatOr, the Signal Injeerion technique described could again be used to isolate the trouble. A modulated R. F. signal at the frequency to which the set is tuned could be injected at points K and L (Fig. 3) and the results noted.

Variations of the Signal Injeerion technique may be used for servicing FM and TV receivers as well as AM sets and Audio Amplifiers.

special applications of the heathkit electronic switch

BY LOUIS E. GARNER, JR.

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Probably no accessory increases the usefulness of the Heathkit Oscilloscope more than does the Heathkit Electronic Switch. Unfortunately, many technicians fail to utilize the full versatility of this instrument. Sometimes this is due to an unfamiliarity with the possible applications of the instrument, and sometimes due to an hesitancy to take the necessary time to properly "set-up" the equipment. In many cases, however, the time required to connect the Electronic Switch and to set up the necessary circuits is but a fraction of the time saved in conducting a series of tests or experiments.

Several applications of the Heathkit Electronic Switch in carrying out important tests will be discussed in this bulletin. These should serve as an outline guide to the technician wishing to get the greatest use from his instrument.

CHECKING CROSS-OVER NETWORKS:

Cross-over networks are used extensively in high-fidelity audio installations, primarily as frequency dividers for multiple speaker systems. In their simplest form, they consist of high-pass and low-pass filter networks connected in parallel. The high-pass network is used to limit signals fed to the high-frequency speaker or "tweeter", permitting all higher frequencies to pass without attenuation, but attenuating low frequency signals. The low-pass network limits signals fed to the low-frequency speaker or "woofer", attenuating high-frequency signals, but permitting the low-frequency signals to be applied with full intensity.

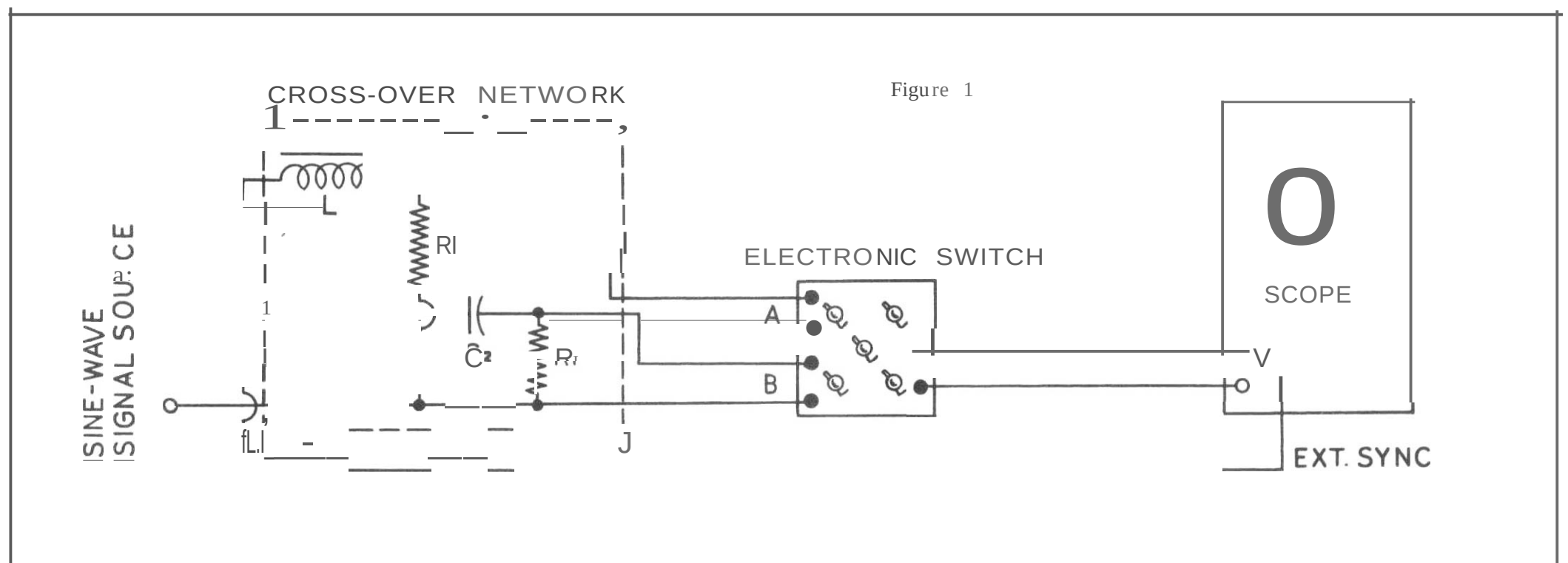
At one frequency in the audio spectrum, known as the "cross-over" frequency, the signal is attenuated equally by both the high-pass and low-pass filters. The cross-over frequency depends on the design of the entire network, and is generally chosen to match the characteristics of the reproducers used as "tweeter" and "woofer" speakers. Thus, a cross-over network design suitable for one speaker system may not give satisfactory results if used with a different system.

The technician will often find it desirable to check the cross-over frequency of any network he plans to use, whether an existing network (perhaps a manufactured unit) or one in the process of design. If the cross-over frequency is not as desired, experimental changes in the circuit may be made until the desired results are obtained.

The cross-over frequency of any network may be determined quite rapidly by using the Electronic Switch in conjunction with an Oscilloscope and an Audio Sine-Wave Generator. The basic circuit used is given in Fig. 1.

Connect the Electronic Switch and scope as shown in Fig. 1. Connect both inputs of the Electronic Switch in parallel and to the Output of the Sine-Wave Generator. A lead should be run from the output of the Sine-Wave Generator to the EXT. SYNC terminal of the scope.

Connect the Electronic Switch and scope as shown in Fig. 1. Connect both inputs of the Electronic Switch in parallel and to the Output of the Sine-Wave Generator. A lead should be run from the output of the Sine-Wave Generator to the EXT. SYNC terminal of the scope.



With a fixed sine-wave input to *both* amplifiers of the Electronic Switch, adjust the *A* & *B* Gain controls until the two sine-wave signals on the screen of the 'scope are of equal amplitude. This step adjusts the gain of the amplifiers until equal. *The Electronic Switch Gain controls are then left fixed in position.*

Remove the parallel connections to the Electronic Switch *A* and *B* inputs, and connect the cross-over network between the output of the Sine-Wave Generator and the inputs to the Electronic Switch, as shown in Fig. 1. (NOTE: A simple type of cross-over network is illustrated in Fig. 1. R_1 and R_2 are resistors with values equal to the impedances of the speakers to be connected to the cross-over network. Test equipment connections are similar even for more complex networks.)

Unless the Sine-Wave Generator is accidentally set at the "cross-over" frequency, sine-wave signals of unequal height will appear on the screen of the 'scope. Adjust the POSITION control on the Electronic Switch until the two sine-wave signals are superimposed, as shown in Fig. 2.

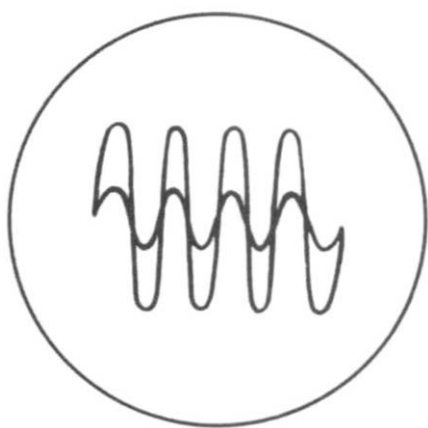


Figure 2

Next, vary the frequency of the Sine-Wave Generator over its range until a frequency is found where the two sine-wave signals become of equal height. This frequency is the "cross-over" frequency for the network, and can generally be found in a matter of seconds once the proper connections and adjustments have been made.

ESTABLISHING A REFERENCE VOLTAGE LEVEL:

When making a series of peak-to-peak signal voltage measurements, approximate, rather than exact, readings are often satisfactory. This is particularly true in TV servicing. Under such conditions, the Heathkit Voltage Calibrator may be used in conjunction with the Electronic Switch and the Oscilloscope to provide an extremely rapid technique for making these voltage tests.

The basic connections used are shown in Fig. 3. However, before the signal voltages are applied to the "A" input of the Electronic Switch, both the "A" and "B" inputs are connected in parallel and the two amplifiers adjusted for equal gain (exactly as in the preceding test). The POSITION control is adjusted until the two wave-forms are superimposed.

The voltage used to adjust the Gain controls should be in the range of voltages to be measured. In other words, if peak-to-peak voltages from 1 volt to 10 volts are expected, the Voltage Calibrator may be used to supply any voltage from 2 to 5 volts for the original adjustments.

Once the Electronic Switch gain controls are set, *they should be left fixed in position* during tests until it is decided to change the reference voltage as supplied by the Voltage Calibrator.

If the signal voltage is a sine-wave, patterns similar to those shown in Fig. 4 will be obtained (assuming the signal voltage to be slightly greater than the Voltage Calibrator reference voltage). If the signal voltage is at a low frequency, permitting a low frequency sweep to be used in the 'scope, the clipped sine-wave pattern formed by the Voltage Calibrator signal may be easily observed, as in Fig. 4 (a). On the other hand, if a high sweep frequency is necessary to permit observation of the signal, the Voltage Calibrator pattern will be chopped into segments and will appear as two bright horizontal lines with a light area between them . . . as in Fig. 4 (b).

In either case, the desired signal may be easily observed, and its amplitude compared to the maximum vertical excursion

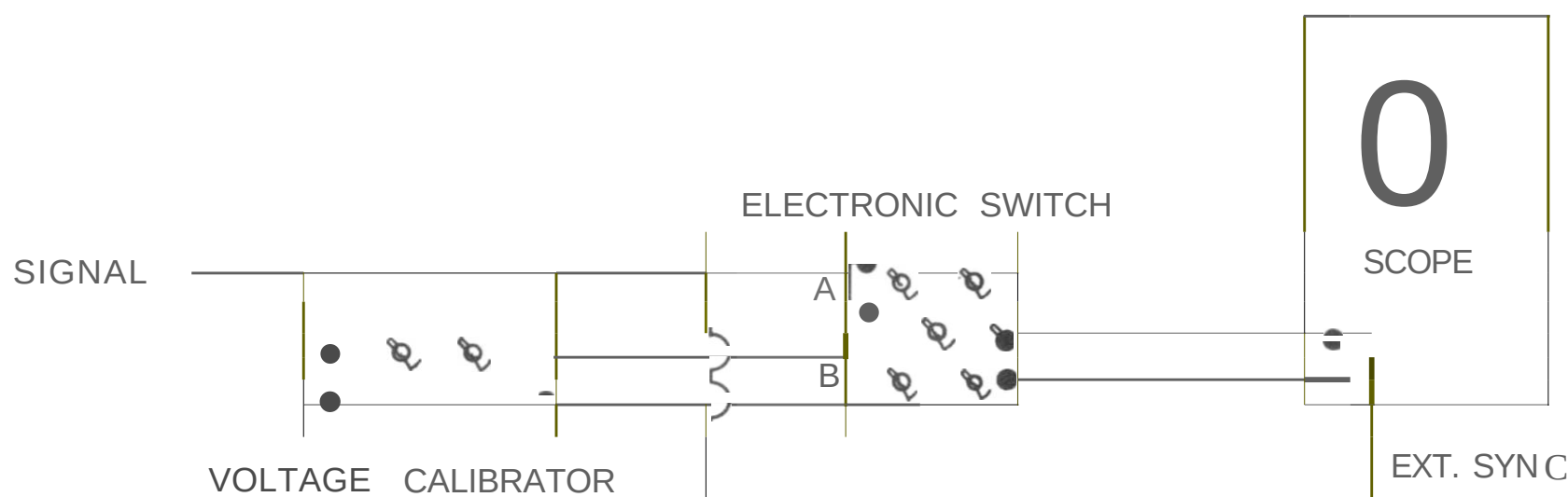


Figure 3

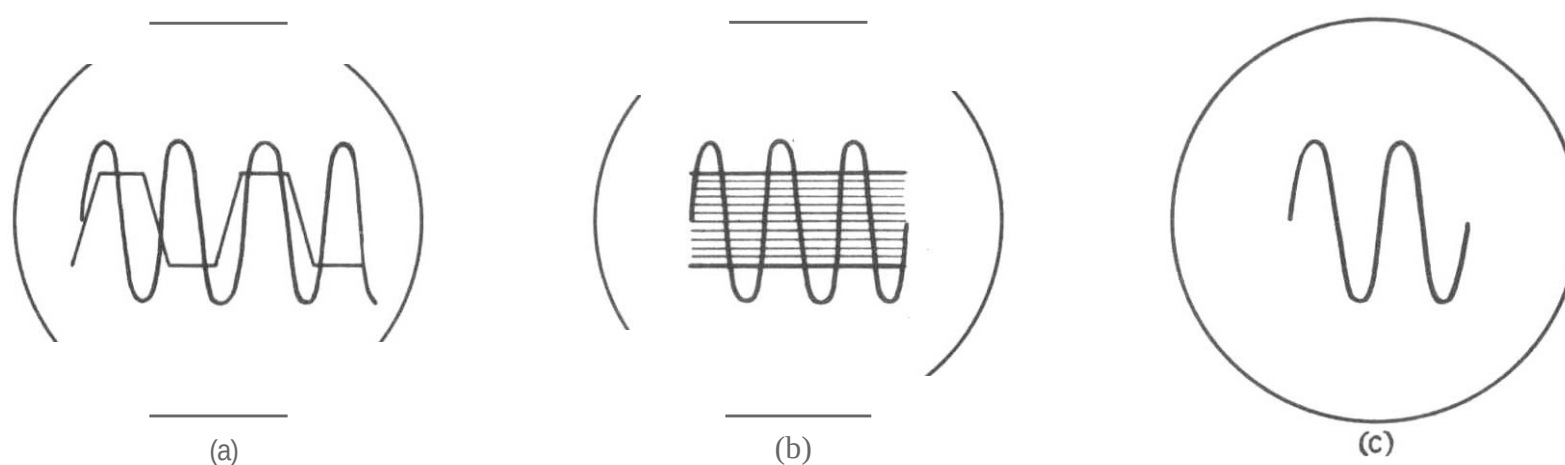


Figure 4

sions of the Voltage Calibrator signal representing a known peak-to-peak voltage. This permits a rapid estimation of the amplitude of the signal in terms of peak-to-peak voltages.

As an example, if the Voltage Calibrator signal gives a deflection of 1" and the unknown signal gives a deflection of 2", the unknown signal has a peak-to-peak voltage exactly twice that shown on the Voltage Calibrator dials. In a similar fashion, a signal amplitude of $\frac{1}{4}$ " represents a peak-to-peak voltage one-quarter that of the Voltage Calibrator. With practice, voltages may be estimated on the basis of approximate height (compared to the easily observed height of the reference voltage) and an exact measurement of height is not necessary.

Note that this technique is accurate *only when the Electronic Switch amplifiers have been preset to supply equal gain.*

ESTABLISHING A ZERO BASE LINE:

A "zero" base line (Fig. 4 (c)) may be obtained simply by turning the Voltage Calibrator Output to zero. Readjustment of the Electronic Switch POSITION control may sometimes prove necessary to bring the base line to the desired position on the screen of the CRT.

CHECKING AMPLIFIER DISTORTION:

The connections suggested in the Instruction Manual on

the Electronic Switch are excellent for checking distortion in an audio amplifier ... either in a single stage or in a complete unit.

A sine-wave input signal is applied to the amplifier and to the "A" input of the Electronic Switch. The output of the amplifier is applied to the "B" input. Thus, both input and output signals may be observed simultaneously on the screen of the CRT and any deviations from the pure wave-form noted.

Extremely accurate checks for distortion may be made by adjusting the respective gain controls until the two signals observed on the screen of the CRT are of equal amplitude, then adjusting the POSITION control until the signals are superimposed. Point-by-point comparison of the two signals is then possible and the least deviation becomes apparent.

OBSERVING THREE SIGNALS:

Three signals may be observed on the screen of a single oscilloscope by using two Electronic Switches. Two of the signals are connected to the "A" and "B" inputs of the first electronic switch. The output of this instrument is connected to the "A" input of the second Electronic Switch (through a .5 mfd coupling condenser), with the third signal to be observed connected to the "B" input. Finally, the output of the second Electronic Switch is connected to the input terminal of the scope.

testing amplifiers with the heathkit voltage calibrator

BY LOUIS E. GARNER, JR.

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The Heathkit Voltage Calibrator, by providing an accurately known, yet easily adjustable a.c. voltage may be used to considerable advantage in practical laboratory work, permitting many tests to be simplified and carried out more rapidly. Most of the tests which may be performed with the instrument can be best applied to audio amplifiers and wide-band resistance-coupled amplifiers (video amplifiers) because of the low frequency of the signal supplied.

In presenting this group of tests, it is hoped that the reader will accept them as a guide rather than as a complete list. Often, the user can modify or adapt an existing technique to a specialized application and, in so doing, establish a completely new method.

MEASURING AMPLIFIER VOLTAGE GAIN:

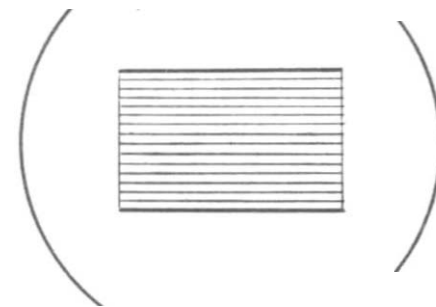
The Heathkit Voltage Calibrator may be used in conjunction with an oscilloscope to provide a rapid method for checking the gain of either a single amplifier stage, or the over-all gain of a complete circuit. The basic technique is illustrated in block diagram form in Fig. 1. The method follows:

1. Connect the voltage Calibrator to the input and an oscilloscope to the output of the amplifier whose gain is to be measured.
2. Turn the amplifier on and allow sufficient "warm-up" time for all circuits to reach stable operating conditions. The Voltage Calibrator and the Oscilloscope may be turned on at the same time.

3. Adjust the Voltage Calibrator to deliver a nominal input signal to the amplifier, but take care that the input is not overloaded. Many technicians prefer to use a decimal multiple of 1 as the test voltage (.01, .1, 1, or 10 volts, depending on the amplifier) to simplify later calculations.

4. Adjust the controls on the 'scope for observation of the output signal. The sweep may be adjusted to permit two or three cycles of the clipped sine-wave to be seen, or may simply be set at a high repetition rate, forming a "band" on the screen of the CRT (Fig. 2). The *Vertical Gain* control is adjusted for a height of 1 or 2 inches (or for any desired amplitude . . . however, the observed height of the signal should be remembered).

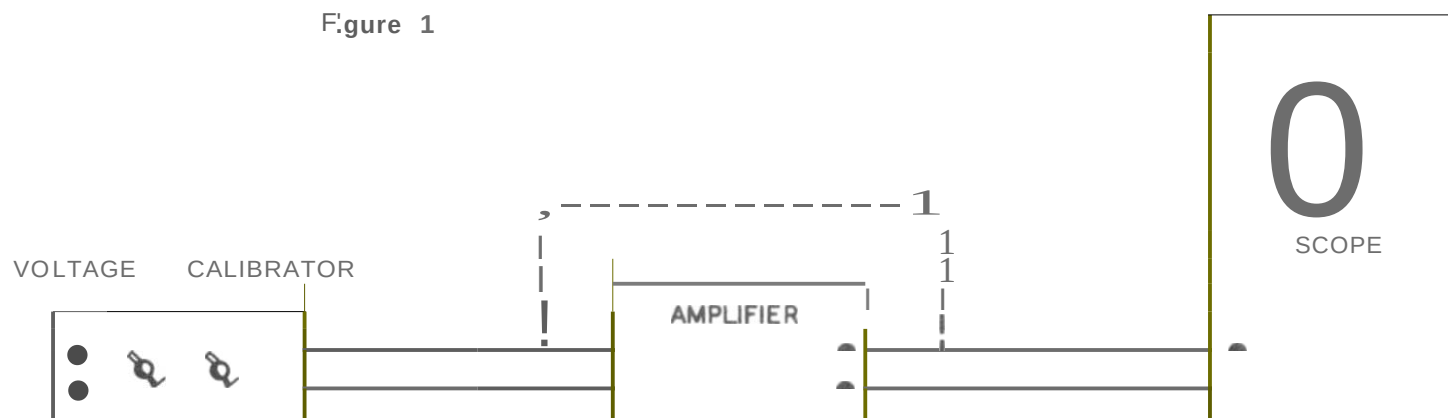
Figure 2



5. Transfer the connections of the Voltage Calibrator to the input of the 'scope, removing the connection to the amplifier (dashed line in Fig. 1).

6. Without touching the *Vertical Gain* control of the 'scope, adjust the Voltage Calibrator until the amplitude of the signal observed on the screen of the CRT is exactly the same as obtained in Step 4. Note the Voltage Calibrator reading.

Figure 1



7. To obtain amplifier gain, divide the voltage reading obtained in Step 6 by the test voltage used in Step 3. As an **example**, if .1 volts had been used in Step 3, and 45 volts had been required in Step 6 to obtain the same deflection, the over-all voltage gain would be $45/.1$ or 450.

8. If db gain is desired, use the following formula:

$$\text{db Gain} = 20 \log Y.G.,$$
 where Y.G. is the voltage gain. In the example given above the db gain would be $20 \log 450$ or approximately 53 db. A "log" table will be found in most handbooks and sets of mathematical tables.

The technique described above is also valuable for determining the minimum and maximum gain obtained as attenuators are adjusted. In addition, it is quite valuable in design work, permitting gain to be checked quickly as changes are made in supply voltages, tubes, and other components.

CHECKING AMPLIFIER GAIN LINEARITY:

An important characteristic of an amplifier is the ability to respond to signals of varying amplitude in a linear fashion. In other words, a good amplifier (not using a Volume Expander or Compressor) should give just as much amplification to a high level signal as is given to a lower level signal. As a practical example, let us say that an amplifier gives an overall voltage gain of 100 with a .1 volt signal applied to the input. This means that the output signal will have an amplitude of $100 \times .1$ or 10 volts. Should a .2 volt **signal** be applied (assuming this to be within the rated maximum input voltage of the amplifier), then a gain of 100 should still be obtained, and the output would be $100 \times .2$ or 20 volts. If more or less than 20 volts Output were obtained in the second case, *the amplifier would not be responding in a linear fashion.*

The Voltage Calibrator **may** be used to test an amplifier for a linear response. The following technique may be used:

1. Use the circuit given in Fig. 1. Turn all instruments on and allow a normal warm-up period.

2. Adjust the Voltage Calibrator to give a low input signal to the amplifier, and adjust the 'scope for a nominal vertical deflection.

3. Increase the input signal level a step at a time by adjusting the Voltage Calibrator. Note the increase in Output level as shown on the 'scope (the actual amount of output is not important in this test . . . only the relative output as compared to the input). The output level should increase in direct proportion to the input level. As an example, if the original input signal was .01 volts, and a deflection of $\frac{1}{4}$ " was obtained on the CRT, then an input signal of .02 volts should give a deflection of $\frac{1}{2}$ ". An input level of .04 volts should give a deflection of 1", etc.

4. Continue increasing the voltage gradually up to the maximum input of the amplifier being tested. If the CRT deflection approaches the maximum permissible on the available screen area, readjust the 'scope *Vertical Gain* control between steps, and then continue. As an example, suppose

an input voltage of .1 volts gives a deflection of $2\frac{1}{2}$ ". With the input left fixed at .1 volts, the 'scope *Vertical Gain* control may be adjusted for a deflection of $\frac{1}{2}$ ", and the tests continued. This new value then becomes the reference for additional steps. In the example given, an input of .2 volts would then give a deflection of 1", .3 volts a deflection of $1\frac{1}{2}$ ", etc. *However, don't readjust the gain control without establishing a new reference.*

In order to properly test an amplifier using the technique given above, it is essential that the 'scope response be linear. Therefore, the vertical amplifier of the 'scope may be checked for linearity before the tests are applied to other equipment. To check the 'scope, use exactly the same technique, but connect the Voltage Calibrator directly to the VERT. INPUT terminals of the 'scope. (NOTE: In many 'scopes, the response will become non-linear after a given deflection is exceeded . . . this does not indicate the 'scope is defective, however. For example, in a 5" 'scope, a non-linear response may be obtained after the deflection exceeds 3". In such a case, use the technique described to determine where the non-linear response of the 'scope occurs, and then confine tests within this maximum deflection, readjusting the *Vertical Gain* control where necessary, as described in Step 4.)

If an oscilloscope is not available, an A.C. voltmeter may be used as an output indicator. Simply remember that the actual voltages measured are not important in this test . . . only the relative increase in output as the input signal level is increased.

Should this test show that the amplifier has a non-linear response, it may indicate that one or more stages are being operated near their overload limit. In such a case, a check of individual amplifier stages may be used to isolate the offending stage.

A non-linear response is generally caused by a weak tube, improper B voltages, or incorrect bias. A tube tester may be used to check the condition of tubes used, while voltages may be checked using a d.c. voltmeter.

Since a non-linear response is desired where a volume expander or compressor is used, this technique is also quite valuable for checking the operation of such circuits. It may also be used to check the point at which limiting occurs in amplifiers employing peak limiters (such as a speech amplifier used with a radio transmitter).

ANOTHER RAPID VOLTAGE MEASURING TECHNIQUE:

In a previous bulletin, a method for rapidly checking peak-to-peak voltages, using the Voltage Calibrator, was described. The technique simply eliminated the need for observing the Voltage Calibrator signal wave-shape.

Where it is not necessary to observe the wave-shape of the signal being checked, an even more rapid technique is available. The test set-up shown in Fig. 3 is used.

The signal obtained from the Voltage Calibrator is applied to both the HOR. and VERT. INPUT terminals of the 'scope

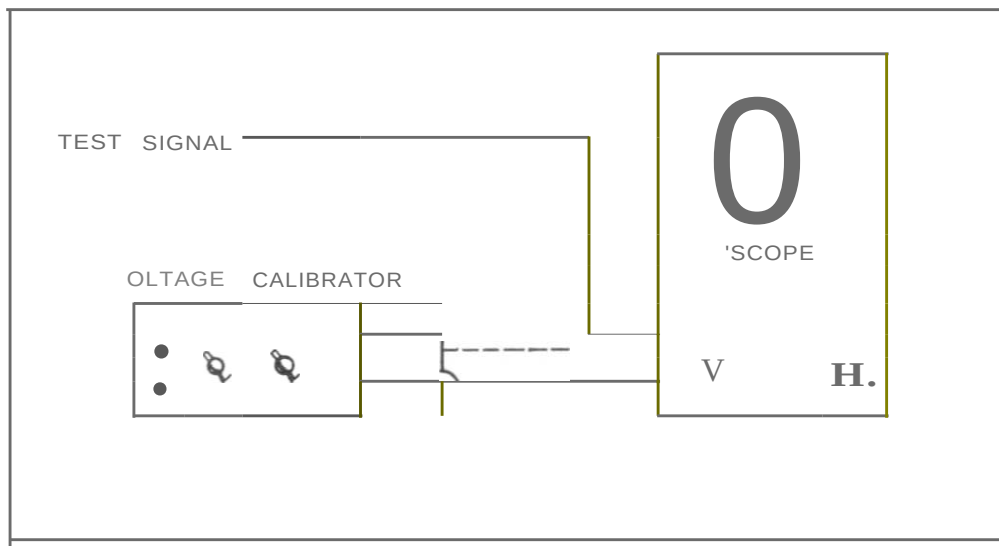


Figure 3

simultaneously (the built-in linear sweep of the scope is *not* used). A diagonal slanting line, as shown in Fig. 4(a), is obtained. The VERT. GAIN and HOR. GAIN controls are adjusted until the height and width (h and w , Fig. 4(a)) of the pattern are equal. The voltage used when making this adjustment should approximate the signal voltages to be measured.

Once the 'scope gain controls are *adjusted*, they are left *fixed in position*. The connection of the Voltage Calibrator to the 'scope VERT. INPUT terminal (dotted line, Fig. 3) is removed, and the signal to be measured applied to the 'scope input, as shown.

Assuming the signal to be measured to be a high frequency signal, and not exactly equal in amplitude to the Voltage Calibrator signal, a rectangle (Fig. 4(b)) will be obtained on the screen of the CRT. The output of the Voltage Calibrator is now adjusted until the rectangle becomes a perfect square ($h = w$, Fig. 4(c)). The peak-to-peak voltage of the unknown signal may now be read directly on the Voltage Calibrator dials.

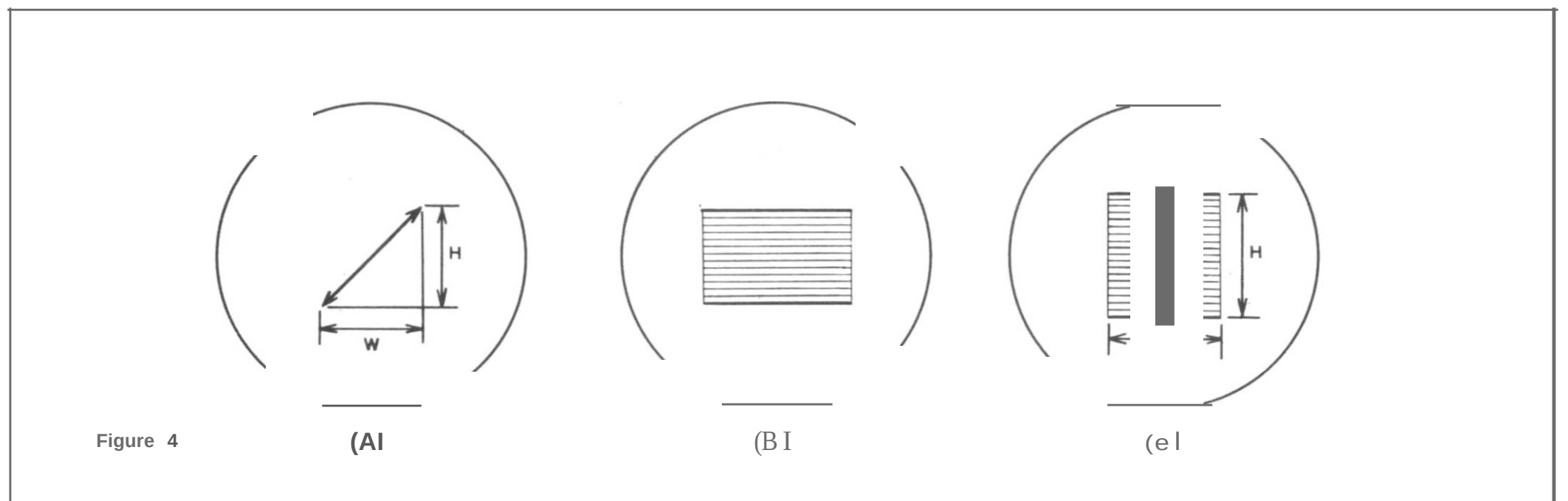


Figure 4

the heathkit yoltage calibrator

BY LOUIS E. GARNER, JR.

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SPECIAL TESTING TECHNIQUES

The Heathkit Voltage Calibrator is designed primarily as an accessory to the cathode ray oscilloscope. It permits substitution of a signal of known and easily adjusted amplitude for a signal of unknown amplitude, and thus permits accurate measurement of the peak-to-peak voltage of any signal wave-shape. Full details on using the Voltage Calibrator for measuring peak-to-peak voltages are given in the Instruction Manual included with the kit.

There are many special test techniques which, when used, make this instrument useful as an all-around piece of laboratory equipment. Undoubtedly, the user will discover some of these techniques himself. However, a brief review of the possible applications of the instrument will serve as a guide to the user.

In developing special applications of the Voltage Calibrator, the user should keep its fundamental characteristics in mind, and not attempt to use the instrument beyond its capabilities. Otherwise, unsatisfactory results may be obtained. Before outlining specific applications of the instrument, it will be worthwhile to review some of the instrument's limitations so that the user, in developing his own techniques, may be cognizant of these factors.

First, it must be remembered that a fixed frequency signal is supplied by the Voltage Calibrator. If the frequency of the test signal is important in the contemplated tests, the Voltage Calibrator should not be used (unless a 60 cycle signal is satisfactory).

Secondly, the instrument supplies a clipped sine-wave. Because of this, it is not too useful for distortion tests. It is often difficult to tell whether additional "clipping" or distortion has occurred.

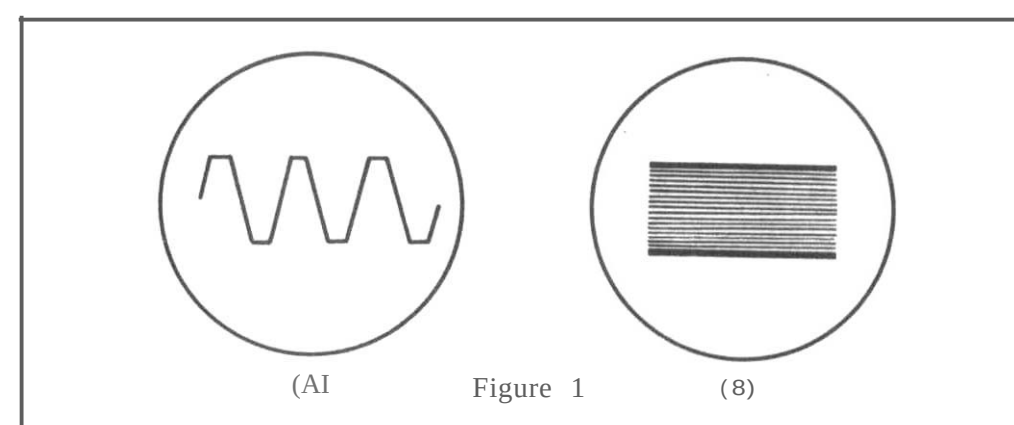
Next, the Voltage Calibrator supplies a maximum signal of 100 volts peak-to-peak. While the instrument may be used for measuring higher voltages, as we shall see later, it will not serve as a signal source if a voltage exceeding this value is required.

Finally, the instrument has a reasonably high output impedance. This characteristic is unimportant when using the calibrator as a signal source for high impedance circuits. However, if an attempt is made to use the instrument to drive low impedance circuits, the dial calibration will no longer be accurate.

RAPID MEASURING TECHNIQUE

If an effort is made to obtain a steady two or three cycle pattern every time a peak-to-peak voltage measurement is made, considerable time may be lost in a day or week of testing simply in adjusting the sweep and sync circuits of the Oscilloscope. To save time, experienced technicians often use a "parallel line" or "band" technique for voltage measurement.

With the conventional method, once the 'scope is adjusted, the clipped sine-wave pattern shown in Fig. 1 (a) is obtained. This is adjusted to the amplitude of the unknown signal (without touching the 'scope gain control), and the peak-to-peak amplitude read directly on the dial scales of the Voltage Calibrator.



To use the rapid technique, simply ignore the settings of the sweep and sync controls on the 'scope. Leave them exactly as set for observing the wave-shape and amplitude of the unknown signal. When the signal from the Voltage Calibrator is applied, the pattern obtained will then depend on the setting of the sweep controls of the 'scope,

In some cases, the clipped sine-wave pattern of Fig. 1 (a) is obtained. However, where the 'scope sweep is set at a high repetition rate, the pattern will appear as two parallel bright lines, with a dimmer "band" between them, as shown in Fig. 1 (b). Simply adjust the Voltage Calibrator until the distance between the two bright lines equals the amplitude of the unknown signal ... then read the dial setting as before,

INTENSITY MODULATION OF 'SCOPE

The Voltage Calibrator is useful in determining the peak-to-peak signal amplitude required to properly modulate the grid (or cathode) of an Oscilloscope. To make this measurement, the connections shown in Fig. 2 may be used.

Adjust the 'scope to a low frequency sweep rate, using the internal sweep. Turn the SYNC control so that a small amount

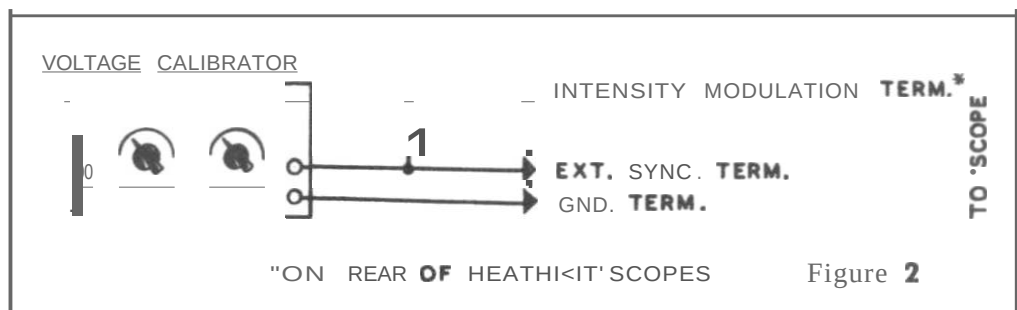


Figure 2

of SYNC signal is applied (note that the switch must be set for EXT. SYNC). No signal is applied to the VERT. INPUT terminals.

Next, adjust the INTENSITY and FOCUS controls until a thin, barely visible, horizontal line is obtained.

Finally, increase the output of the Voltage Calibrator until the solid horizontal line on the screen of the 'scope is changed into a dashed line. The peak-to-peak signal voltage required may then be read directly on the dials of the Voltage Calibrator.

The exact voltage required will vary from 'scope to 'scope, and will also depend, to some extent, on the setting of the INTENSITY control.

SYNC VOLTAGE MEASUREMENT

When using an Oscilloscope for critical tests, EXT. SYNC is often employed so the degree of sync will not depend on pattern amplitude. Under such conditions, it is often important to know approximately how much signal voltage is required to properly sync the 'scope sweep for a specific setting of the SYNC control. Care must be taken that sufficient signal is applied to the EXT. SYNC terminal to insure a stable pattern, and yet without danger of over-syncing.

To determine the voltage required for proper sync at any setting of the SYNC control, use the circuit given in Fig. 3.

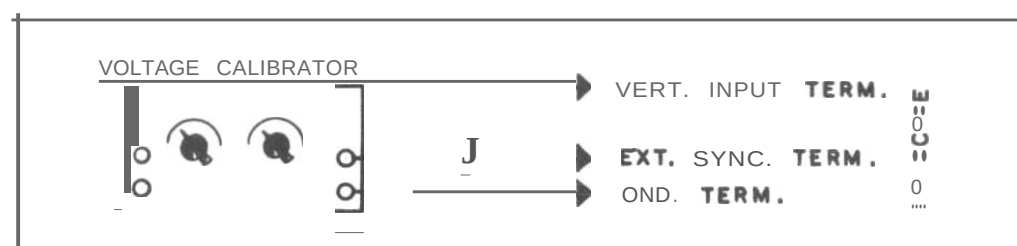


Figure 3

With the 'scope switched to EXT. SYNC, set the SYNC control to the desired position. Gradually increase the voltage applied by the Voltage Calibrator until a stable pattern is obtained (set the VERT. GAIN for a pattern of usable size). The peak-to-peak voltage required for syncing may then be read directly. If desired, the voltage may then be increased until over-syncing occurs and another reading made. The two readings will determine the minimum and maximum voltages required.

A similar technique may be used to properly preset the SYNC control where a signal of known amplitude is to be used for EXT. SYNC purposes. Adjust the Voltage Calibrator to deliver a signal of this amplitude and then increase the degree of sync, using the SYNC control, until a stable pattern is obtained.

MEASURING LOW VOLTAGES

Although the lowest range of the Voltage Calibrator is from

zero to one-tenth of a volt, voltages below .01 volts are difficult to estimate accurately. Where low voltages are to be measured or checked, a simple 10:1 attenuator should be used with the Voltage Calibrator.

Such an attenuator may be assembled using the circuit given in Fig. 4. Precision (1%) resistors may be used, or, if preferred, less expensive resistors may be tried until a pair having the proper ratio are found. However, the overall impedance should be at least 1 megohm.

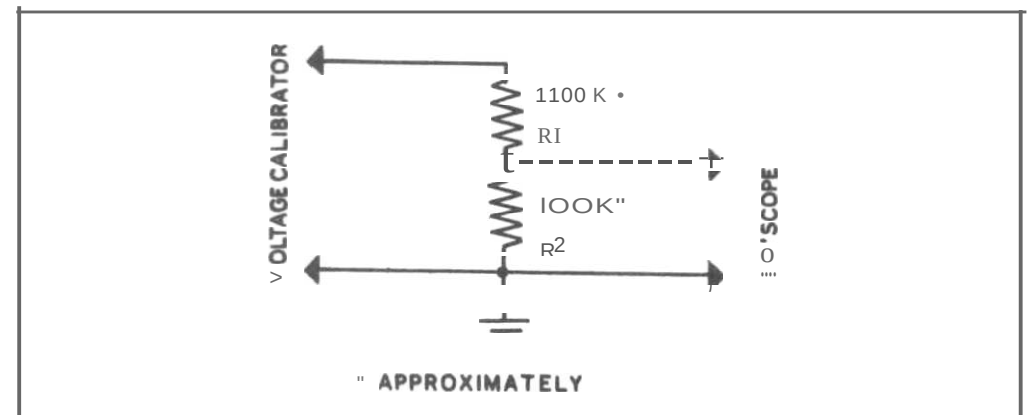


Figure 4

To determine when the proper 10:1 ratio is achieved (and to check attenuator accuracy), apply a 1 volt signal, obtained from the Voltage Calibrator, directly to the VERT. INPUT of the 'scope and adjust for 1" vertical deflection.

Now, apply a ten volt signal across the entire attenuator and observe the signal across R2. Again, 1" deflection should be obtained. If greater deflection is obtained, increase R1 slightly or reduce R2 slightly (or both). If less than 1" deflection is obtained, reduce R1 or increase R2. By using this technique, the proper ratio is soon found.

If preferred, a screwdriver adjusted 1 Megohm pot may be used in place of the two fixed resistors. After adjusting for the proper ratio, the pot adjustment may be left permanently fixed.

This technique is also valuable when designing and building a fixed attenuator or pad to give a specific attenuation ratio ... for use in amplifiers, experimental equipment, etc.

When the attenuator is used with the Voltage Calibrator, divide the dial reading by ten (move the decimal point one place to the left) to obtain the actual voltage reading.

MEASURING HIGH VOLTAGES

Several techniques are available for measuring voltages higher than the maximum available from the Voltage Calibrator. The exact technique to use depends on the amplitude of the signal to be measured, on the 'scope characteristics, and, to some extent, on personal choice. The three most common techniques will be described.

Method A: Using 100 volts, peak-to-peak, adjust the 'scope for a nominal deflection, such as 1/2" or 1". Then, without touching the gain controls of the 'scope, apply the unknown signal to the VERT. INPUT terminals in place of the Voltage Calibrator signal, and observe the deflection obtained.

The amount of deflection is proportional to that obtained with the 100 volt signal. As an example, if the 'scope had

been adjusted for $\frac{1}{2}$ " deflection, and the unknown signal gave a deflection of 3", its amplitude would be 600 volts, peak-to-peak.

When using this method, care must be taken that the 'scope input is not overloaded if accurate results are to be obtained.

Note that this technique is exactly the reverse of the one usually employed. The Voltage Calibrator is used *first* to calibrate the 'scope, and then the unknown signal is measured.

Method B: If a frequency-compensated attenuator is available, it may be used to reduce the amplitude of the unknown signal by a pre-determined amount. Measurement is then carried out in the usual way, with the Voltage Calibrator reading multiplied by the attenuation ratio.

Method C: Some 'scopes are provided with a step attenuator in the vert. amplifier circuit. Where this is the case, first determine the attenuation ratio. Measurement is carried out in the usual fashion, with the step attenuator being used to

attenuate the unknown signal, but not the signal from the Voltage Calibrator. The Voltage Calibrator reading is multiplied by the predetermined attenuation ratio.

To determine the attenuation ratio, apply a fixed signal (50 or 100 volts) to the VERT. INPUT of the 'scope and, with attenuation in the circuit, adjust the VERT. GAIN control for 1" deflection.

Next, turn the attenuation switch to the "off" position and reduce the input signal until 1" deflection is again obtained (don't touch the VERT. GAIN control). Determine the Voltage Calibrator reading and divide this value into the former. This gives the proper multiplying factor to use.

As an example, if 50 volts should be used in the first step, and only 2 volts required in the second step (without attenuation), the ratio would be 25:1 and the multiplying factor 25.

tv servicing with the heathkit square-wave generator

BY LOUIS E. GARNER, JR.

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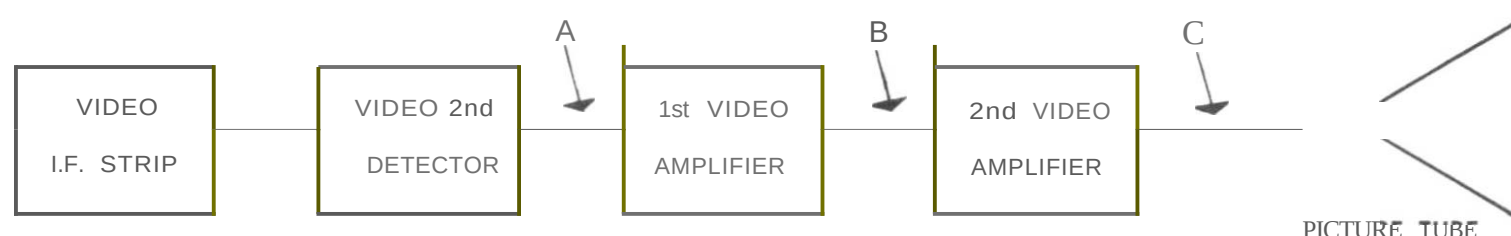
TV receiver defects affecting picture quality may occur in the Front-End, in the video d. section, or in the video amplifier, causing such complaints as poor definition, picture "smear", multiple ghosts, and picture fuzziness. The TV serviceman, on encountering one of the complaints listed, may have some difficulty in determining exactly where the defect has occurred.

However, the Heathkit Square-Wave Generator offers a means of quickly checking the response characteristics of the video amplifier. If this section is found to be in good condition, the alignment of the d. section may be checked and realignment, if necessary, carried out using a Signal Genera-

tor. Once these two sections of the receiver have been checked and known to be in good condition, the Front-end may either be over-hauled or replaced if the complaint still exists. This last step is not generally necessary, however, as the majority of defects affecting picture quality occur either in the video d. or video amplifier sections.

Alignment of TV receivers has been covered in other Heath Bulletins. In this bulletin we will see how the Square-Wave Generator may be used to check the operation of the video amplifier.

Figure 1



CHECKING LOW FREQUENCY RESPONSE

The video amplifier of a TV receiver, in good operating condition, should pass a 60 cycle square-wave signal with no rounding, distortion or tilt. Two methods are available for checking the low frequency response of the video amplifier using a Square-Wave Generator. Both techniques will be discussed.

METHOD A: The Square-Wave Generator is connected to the input of the first video amplifier stage (point A, Fig. 1), and an oscilloscope is connected to the Output of that stage (point B, Fig. 1). With a 60 cycle square-wave signal applied, and with the 'scope controls properly adjusted to observe two or three cycles of the signal, the output should have a good wave-form, as shown in Fig. 2(a). Tilt of the square-wave in either direction, as shown in Figs. 2(b) and 2(c) indicates improper low frequency response. (NOTE: In making these tests, take care that excessive signal is not used to prevent stage over-loading with resultant "clipping". Use the minimum signal necessary to insure a satisfactory pattern. This precaution applies to all tests discussed in this bulletin.)

Tilt as shown in Fig. 2(b) indicates poor low frequency response and *possible* phase shift, while tilt in the opposite direction, as shown in Fig. 2(c) indicates accentuated low frequency response and phase shift in the opposite direction. Both conditions may result in picture "smear".

The same technique may be used to check the operation of the 2nd video amplifier stage (Square-Wave Generator at point B, 'scope at point C), or the over-all response of the entire video amplifier section (Square-Wave Generator at point A, 'scope at point C).

METHOD B: With the second method, no oscilloscope is required. However, the picture tube must be in place in the TV receiver, and all circuits necessary to obtain a raster must be in good operating condition. The connections of the Square-Wave Generator to the receiver are as before.

After connecting the Square-Wave Generator, observe the pattern on the screen of the picture tube, adjusting the VERTICAL HOLD control until a stable black-and-white pattern is obtained. Adjustment of the BRIGHTNESS control may also prove necessary.

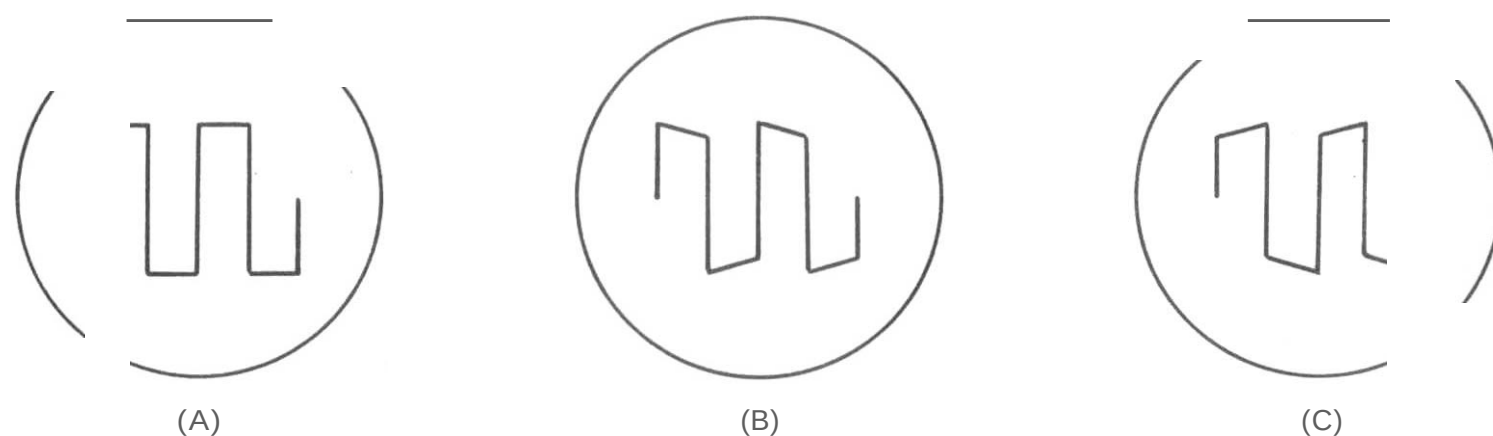


Figure 2

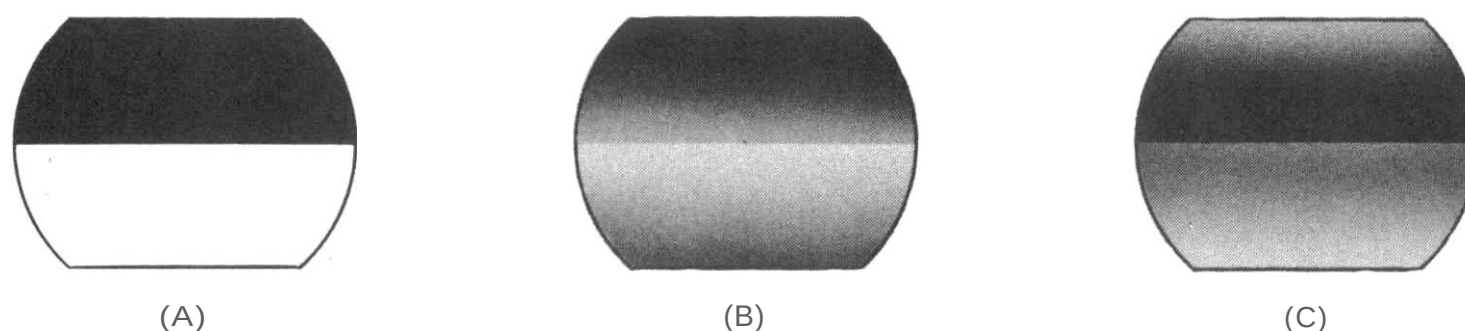
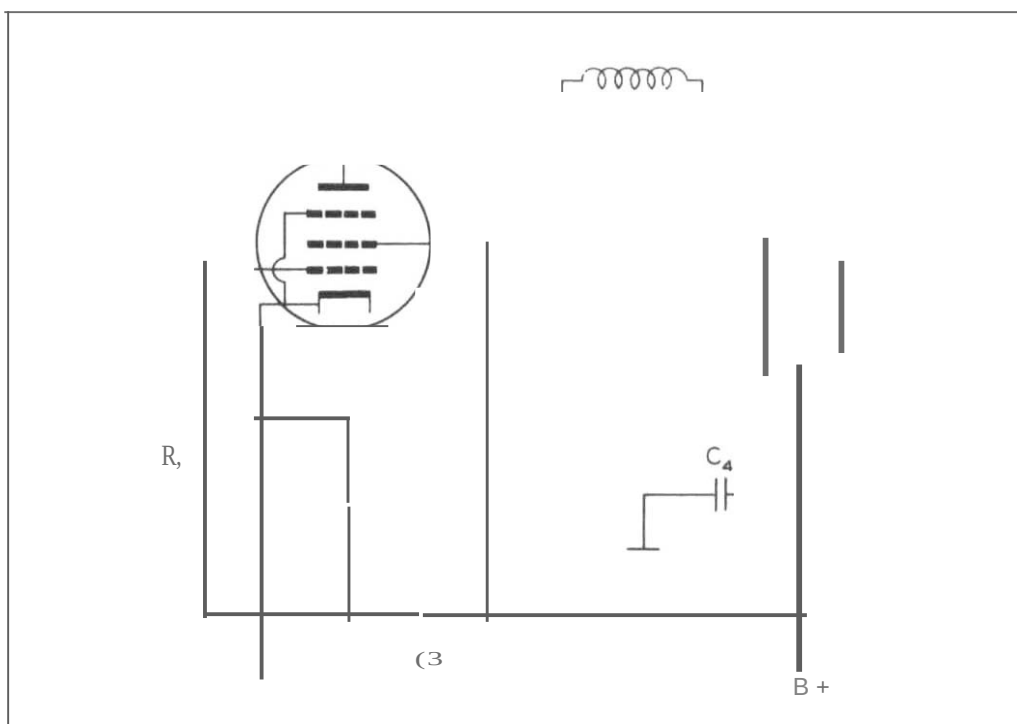


Figure 3

With a 60 cycle square-wave, half the TV screen should be dark, and the other half should be white, as shown in Fig. 3(a). Either the upper or lower half of the screen may be white, depending on how the vertical sweep syncs with the square-wave signal. However, half of the screen should be wholly white, with the other half completely dark.

If there is poor low frequency response, a portion of each half must be "gray", with only the leading edges completely "white" and "black", as shown in Fig. 3(b). Such a condition corresponds to the square-wave pattern shown in Fig. 2(b). Accentuated low frequency response causes just the opposite effect, with the trailing edges completely "white" or "black" and the rest of the pattern gray, as shown in Fig. 3(c). This pattern corresponds to the square-wave response shown in Fig. 2(c).



DEFECTS AFFECTING LOW FREQUENCY RESPONSE

In Fig. 4 is given the schematic diagram for a typical pentode video amplifier stage. C_1 may connect to a preceding amplifier stage or to the output of the video second detector, while C_2 may connect to another video amplifier stage or to the picture tube, depending on the receiver.

Poor low frequency response may be caused by a partial open in C_1 , C_2 or C_3 , by an increase in the value of C_4 , by leakage in C_4 , or by a decrease in the resistance of R_1 or R_2 .

Accentuated low frequency response may be caused by a decrease in the value of C_1 , or by an increase in the value of R_1 . Changes in C_1 may cause either effect, depending on the magnitude of the change.

CHECKING HIGH FREQUENCY RESPONSE

Exactly the same technique is used for checking the high frequency response of a video amplifier, except for the square-wave frequency used and the interpretation of results. Again, two methods are available.

METHOD A: Square-Wave Generator and Oscilloscope connections are made in the video amplifier circuit exactly as before. This time, however, a 100 Kc square-wave signal should be used, and the Square-Wave Generator and 'scope controls appropriately adjusted. If the video amplifier has good high frequency response, the input and output square-wave signals should have exactly the same wave-form, as shown in Fig. 5(a).

If the video amplifier has poor high frequency response, excessive rounding of the square-wave signal will occur, as

shown in Fig. 5(b). Such a condition would result in very poor definition, with considerable "fuzziness".

Poor transient response or excessive peaking at high frequencies will result in overshoots and damped transient oscillation, as shown in Fig. 5(c). Such a condition will cause several "ghosts" immediately following any sharp change in picture contrast. With experience, the serviceman can detect the difference between "ghosts" due to poor transient response (this condition is sometimes called "ringing") and "ghosts" due to external signal reflections.

METHOD B: As before, with the second method no oscilloscope is required. All connections are the same. However, a 100 Kc square-wave signal is used, and the HORIZONTAL HOLD control adjusted for a stable pattern.

In some sets using horizontal AFC, it may prove difficult to obtain a steady pattern by adjusting the HORIZONTAL HOLD control alone. In such cases, use a small coupling condenser to couple a little energy from the horizontal sweep oscillator or horizontal output tube back to the SYNC INPUT terminals of the Square-Wave Generator. In other words, if it is found impossible to obtain a steady pattern, sync the

Square-Wave Generator with the horizontal sweep signal of the TV receiver.

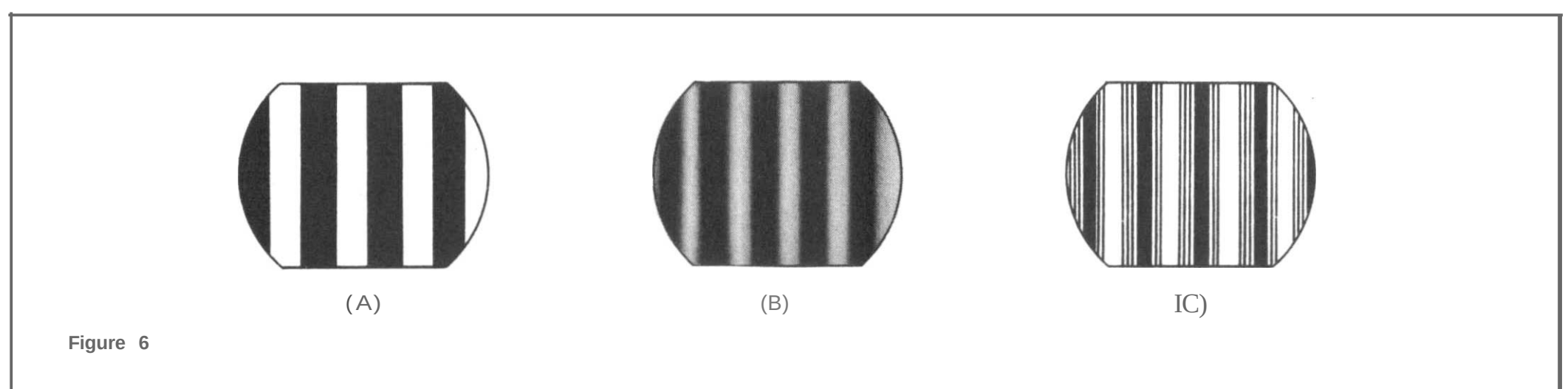
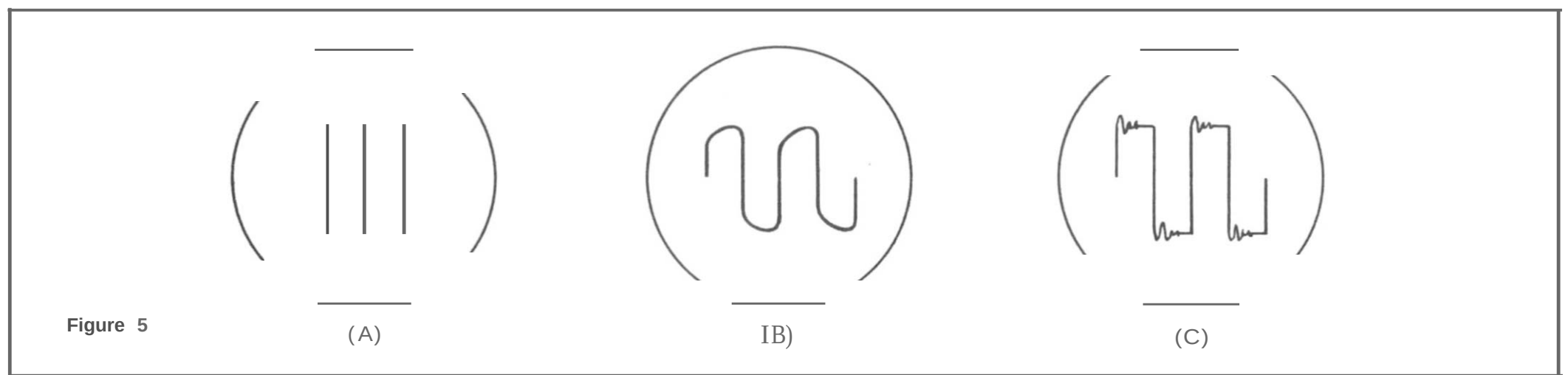
When properly sync'd, a series of vertical black and white bars should be obtained, as shown in Fig. 6(a). Each bar should be distinctly white or black, with clearly defined edges.

Poor high frequency response, giving the square-wave pattern shown in Fig. 5(b), will result in poorly defined edges, with a band of "gray" separating the white and black bars, as shown in Fig. 6(b). Poor transient response will result in a series of fine white or black lines following each change from white to black (and vice-versa) as shown in Fig. 6(c). The corresponding square-wave response was shown in Fig. 5(c).

DEFECTS AFFECTING HIGH FREQUENCY RESPONSE

Referring to Fig. 4, poor high frequency response may be caused by an open peaking coil (L^1 or L^2), by a shorted peaking coil, by an increase in the value of R^5 , and by an open in C^4 .

Poor transient response may be caused by a sharp decrease in the value of R^5 , or by an open peaking coil damping resistor (R^3 or R^0).



square wave generator technique for extending amplifier response

BY LOUIS E. GARNER, JR.

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Since the *Square-Wave Generator* may be used to rapidly check the over-all frequency response characteristic of an amplifier (or a single stage, for that matter), it is of great value in the experimental design of wide-band amplifier circuits. In this Bulletin we will consider some of the factors affecting low and high frequency response and will see how the *Square-Wave Generator* may be used in the practical design of wide-band amplifier circuits.

THE BASIC AMPLIFIER:

A basic resistance-coupled amplifier stage is shown in Fig. 1(a). This general circuit is used in almost all amplifier design work, whether for simple phono amplifiers or multiple-stage wide-band pulse amplifiers. The response curve of such an amplifier will appear somewhat as shown in Fig. 1(b).

To check the over-all response of such an amplifier, using a *Square-Wave Generator*, connect the generator to the input (C_1) and an *Oscilloscope* to the Output (C_5). Apply square-wave signals at different "sPOt" frequencies over the range of the instrument and observe the patterns obtained. The amplitude of the signal should be adjusted carefully so as to avoid possible overload of the amplifier stage. *If in doubt as to the amount of signal necessary, use the minimum output of the Square-Wave Generator that will still give a usable pattern on the screen of the CRT.*

At low frequencies (10 to 60 cps), the output signal will appear somewhat as shown in Fig. 2(a), indicating a drop-off in low frequency response, together with some phase-shift. At frequencies in the middle of the response curve, the output square-wave will be perfectly "flat" with sharp corners, as

shown in Fig. 2(b). As higher frequencies are used, the square-wave will become more rounded, as shown in Fig. 2(c). The waveform shown in Fig. 2(d) will be obtained at frequencies near the upper limit of the response curve.

In order to pass a low-frequency square-wave without "tilt," the amplifier must pass, without phase-shift or drop-off in amplitude, signals down to the fundamental of the square-wave signal used. Thus, an amplifier which permits a 50 cycle square-wave to pass without tilt or slant may be considered reasonably "flat" to 50 cps.

In order to pass a high-frequency square-wave without noticeable rounding, the amplifier must pass, without appreciable drop-off, signals to the 11th harmonic of the square-wave signal used. Thus, an amplifier which permits a 5 Kc square-wave to pass without rounding may be considered "flat" to 55 Kc. For practical work, the "tenth" harmonic is usually considered as the upper limit, although a "perfect" Square-wave *does not contain even harmonic signals* (in the example given, the amplifier would be considered "flat" to 50 Kc).

FACTORS AFFECTING LOW FREQUENCY RESPONSE:

The low frequency response depends on the size of the coupling condensers (C_1 and C_5), the size of the grid resistor (R_1), the size of the cathode by-pass condenser (C_2) and the size of the screen-grid by-pass condenser (C_3). In general, the larger these components are made, from an electrical viewpoint, the better the low frequency response.

Most designers consider the size of the coupling condenser and the grid resistor together, and thus work from the "R-C

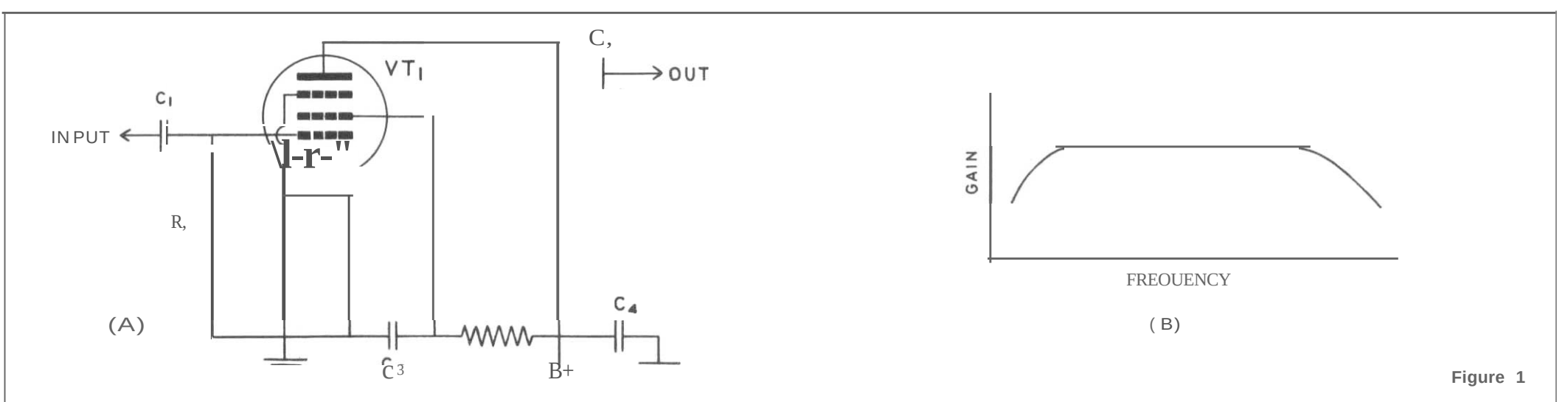
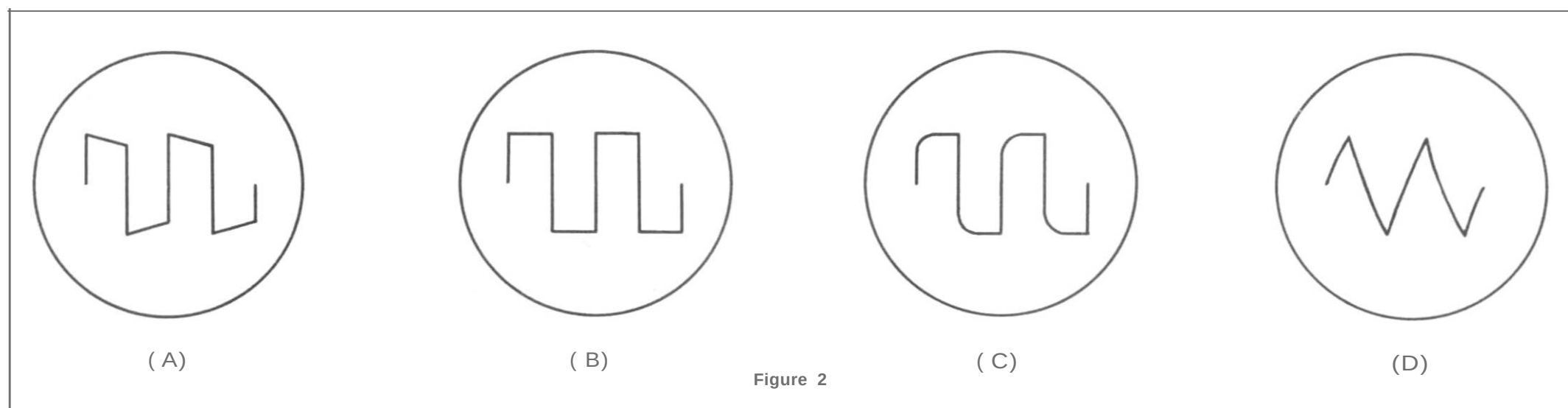


Figure 1



time constant" as far as the coupling circuits are concerned (in the example, product of R_1 and C_1). In such a case, the larger the R-C Time Constant, the better the low frequency response.

The "ideal" as far as low frequencies are concerned is where the coupling capacity is infinitely great and the grid resistor infinite in size. From a practical viewpoint, however, the grid could not be allowed to "float." The closest practical approach is where direct coupling is employed. Thus, where extreme low frequency response is desired, direct-coupled amplifiers are usually employed. Such amplifiers may be designed to have a response down to "zero" cycles per second ... i.e., d.c. voltage changes.

The cathode by-pass condenser (C_2) may be increased in value by using large value electrolytic condensers. However, somewhat better low frequency response is often obtained by using bias cells to supply bias rather than a cathode resistor, as shown in Fig. 3(a). In such cases, the cathode may be connected directly to ground, completely eliminating the need for a by-pass condenser. Such an arrangement is also helpful in eliminating hum, especially when due to heater-to-cathode leakage.

In a similar fashion, large capacity electrolytic by-pass condensers may be used in the screen-grid circuit. However, since many electrolytics fail to give proper by-pass action at high frequencies due to residual inductance, they are often by-

passed, in turn, by paper, mica, or ceramic condensers, as shown in Fig. 3(b).

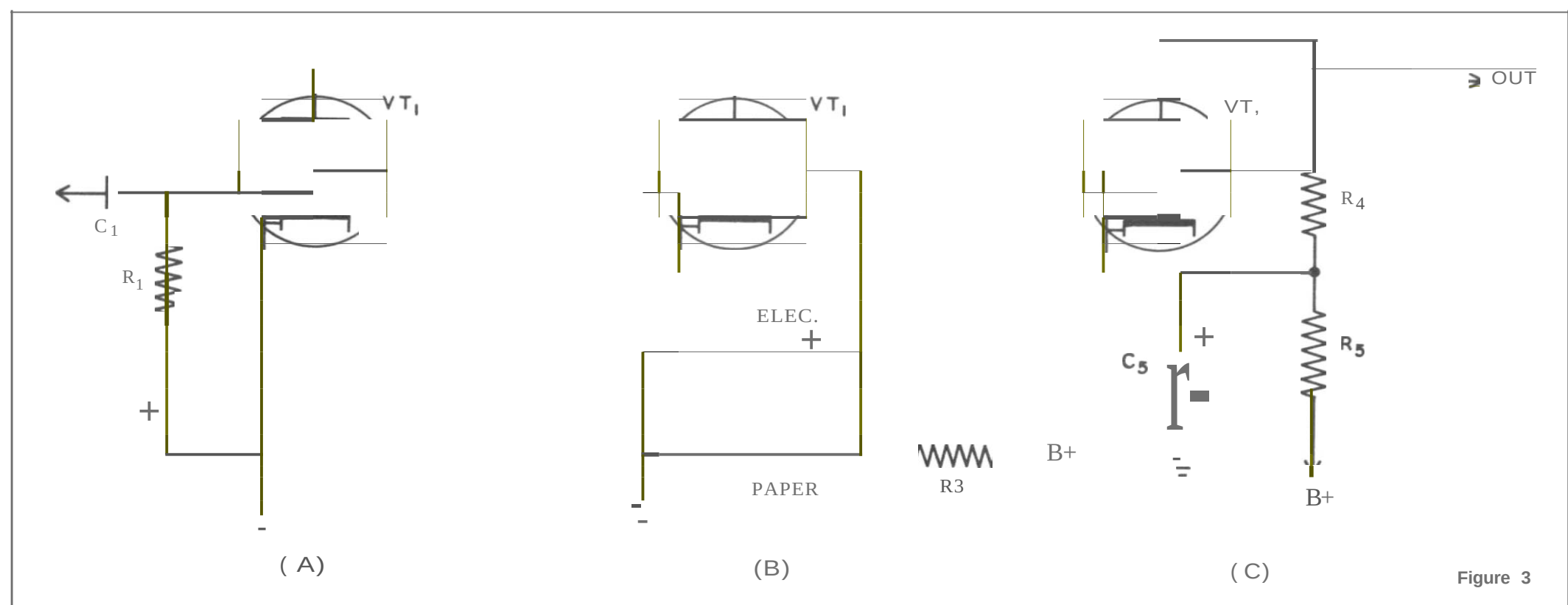
Where the techniques just mentioned are impractical, either for reasons of space requirements, economy, or general design necessity, a low-frequency "compensation" circuit may be employed. Such a circuit is shown in Fig. 3(c).

In operation, the R_5 - C_5 time constant is chosen so that R_5 starts to become part of the load at low frequencies, and thus increases amplifier gain at this point. When R_5 and C_5 are properly chosen, a low-frequency square-wave showing a decided "tilt," as illustrated in Fig. 4(a), may be straightened to produce a near "perfect" response, as shown in Fig. 4(b). However, a certain amount of care must be exercised in choosing the R_5 - C_5 combination. If C_5 is made too small (or R_5 too large), over-compensation may result, giving a tilt in the opposite direction, as shown in Fig. 4(c).

The C_5 - R_5 values may be chosen quickly in a practical circuit by applying a square-wave signal at the desired frequency and experimentally choosing different values until the desired response is obtained.

FACTORS AFFECTING HIGH FREQUENCY RESPONSE:

The high frequency response of a resistance-coupled amplifier normally drops off due to voltage division between the internal tube resistance and plate-cathode capacities. These capacities are made up of distributed wiring capacities, plate-



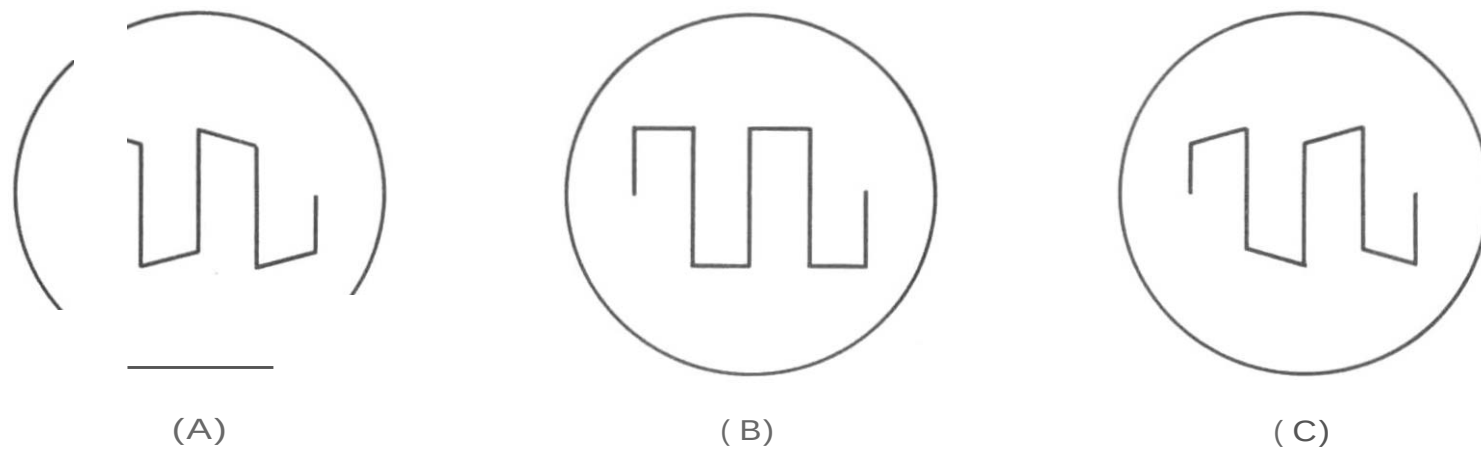


Figure 4

cathode capacity within the tube itself, and the grid-cathode capacity of the succeeding stage.

At higher frequencies, the impedance offered by these distributed capacities drops below the value of the plate load (R_4). Since these capacities are essentially in shunt with the plate load, the effective load drops, resulting in a drop in stage gain.

In general, the best solution is to lower the size of the plate load resistor (adjusting plate and bias voltages accordingly). This results in a lower over-all gain, but a much wider frequency response, as shown in Fig. 5(a).

Where this technique has been carried to its practical limit, the next step is to introduce either series or shunt "peaking coils," as shown in Figs. 6(a) and 6(b), respectively. Sometimes both types of "peaking" are employed.

The action of either of these "peaking coils" is similar. The coil forms a resonant circuit with distributed wiring capacities, boosting the amplifier gain at higher frequencies, and thus "extending" the response curve.

If the resonant frequency is properly chosen, the action of the peaked resonant curve is to "lift" the high frequency response at the expense of a more rapid drop-off, as shown in Fig. 5(b). The high frequency square-wave response, under such circumstances, will no longer be rounded as shown in Fig. 2(c), but will become "sharper," as shown in Fig. 7(a).

Should the resonant frequency of the tuned circuit fall within the "flat" portion of the *normal* response curve, the over-all response will become "peaked" as shown in Fig. 5(c). This will result in a peaked square-wave response, as shown in

Fig. 7(b). Under some circumstances, a damped transient oscillation may take place, resulting in the pattern shown in Fig. 7(c).

Patterns similar to those shown in Figs. 7(b) and 7(c) may also be obtained if the resonant circuit formed has high "Q." Under these conditions, a "damping" resistor is often connected in shunt with the peaking coil, as shown in Fig. 6(c).

If the resonant frequency of the tuned circuit formed by the "peaking coil" is too high, the over-all response may appear as shown in Fig. 5(d). The square-wave response with this condition will appear as shown in Fig. 7(d).

Because of the difficulty in determining distributed capacities exactly, the peaking coil is generally made variable, and is adjusted to give the desired response under practical operating conditions.

PRACTICAL CONSIDERATIONS:

Thus far we have considered simply the basic factors affecting the low and high frequency response of an amplifier stage in terms of circuit design. Of equal importance to the choice of the electrical sizes of the components used in an amplifier is the choice of component types, and the actual wiring and layout of the circuit. Poor layout or wiring may reduce or limit the over-all frequency of an amplifier as severely as improper choice of electrical components. Therefore, a review of practical considerations may prove of value to the reader.

Choosing Components: Once the electrical sizes of resistors, condensers, and peaking coils have been determined, the engineer or technician should "follow through" in suggesting particular types of components... in some cases, a selection by manufacturer's name and type number may even be desirable.

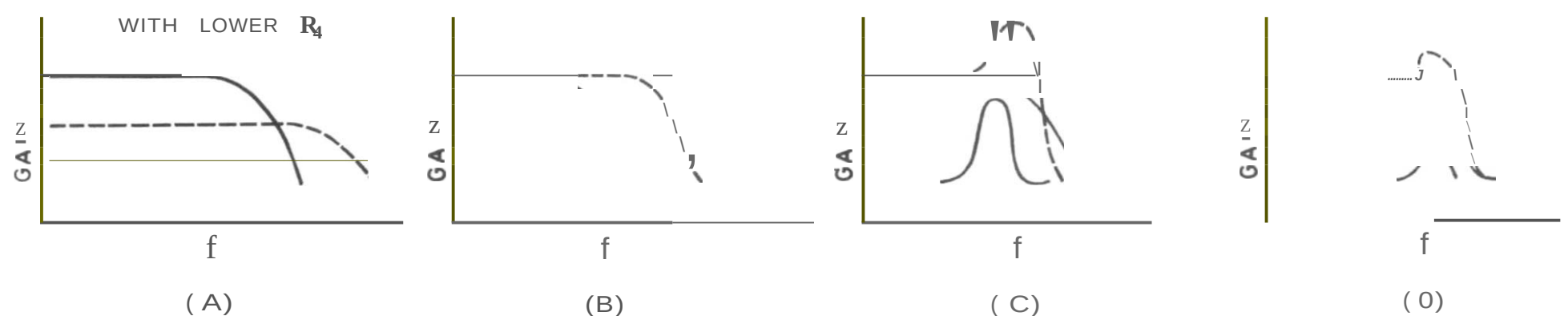
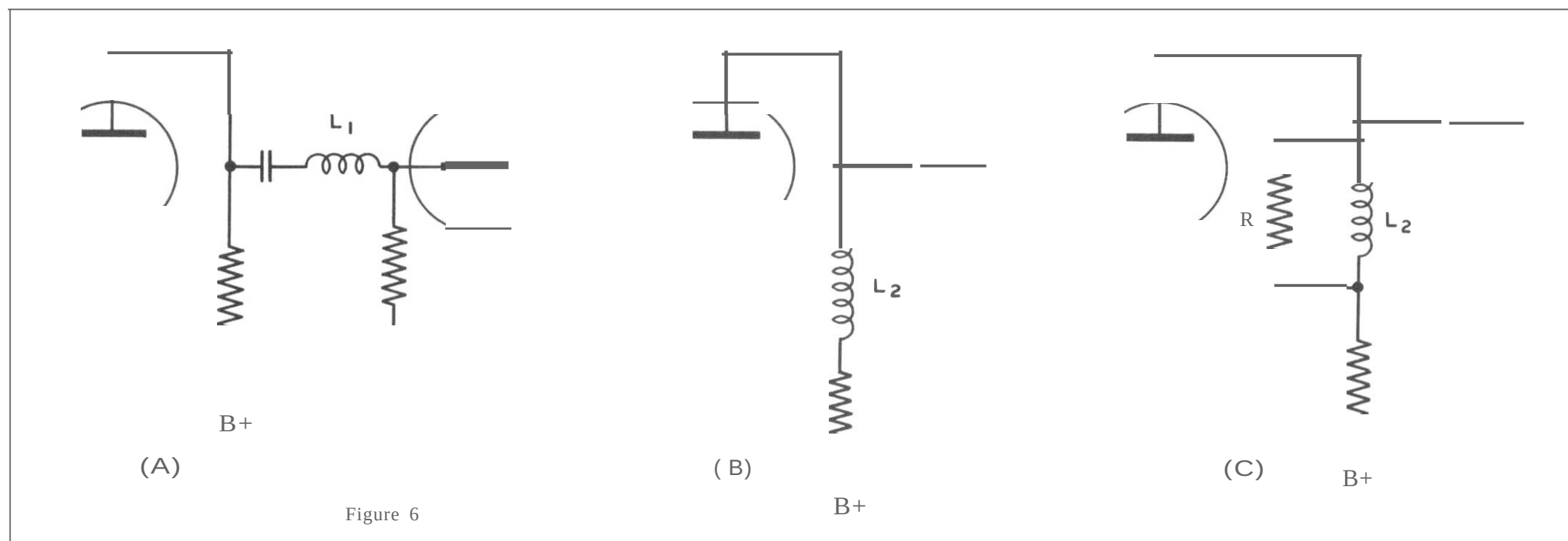


Figure 5



When choosing a tube for a wide-band amplifier, a high value of mutual conductance is more desirable than high μ . In high-gain circuits, low microphonics and low values of heater-to-cathode leakage are very important. For circuits requiring extreme stability, especially selected tubes may be employed... as an alternate, the tubes may be "aged" before being put into service.

A good general guide for selecting an iron-core coupling or Output transformer, where good low frequency response is desired, is the amount of "iron" in the transformer core. Of course the quality of the core material is as important as the quantity... but judging a transformer by its weight provides a good "rule-of-thumb." From a high frequency viewpoint, the amount of distributed capacity in the transformer winding is important... for best results, these distributed capacities should be low.

Large value coupling condensers should have high leakage resistance, especially where the coupling is to a high resistance grid circuit. Where the frequency response of the amplifier is important, these condensers should have a small physical size to reduce distributed capacities to ground and stray coupling to other circuits. In this respect, the new "metallized" paper condensers may be used to obtain the maximum capacity in a small volume of space. All condensers used should have low residual inductance.

Electrolytic condensers used for by-pass purposes should generally be chosen to have a small "minus" but large "plus"

tolerance. However, where these condensers are used in a low frequency compensation circuit, much closer tolerances are mandatory.

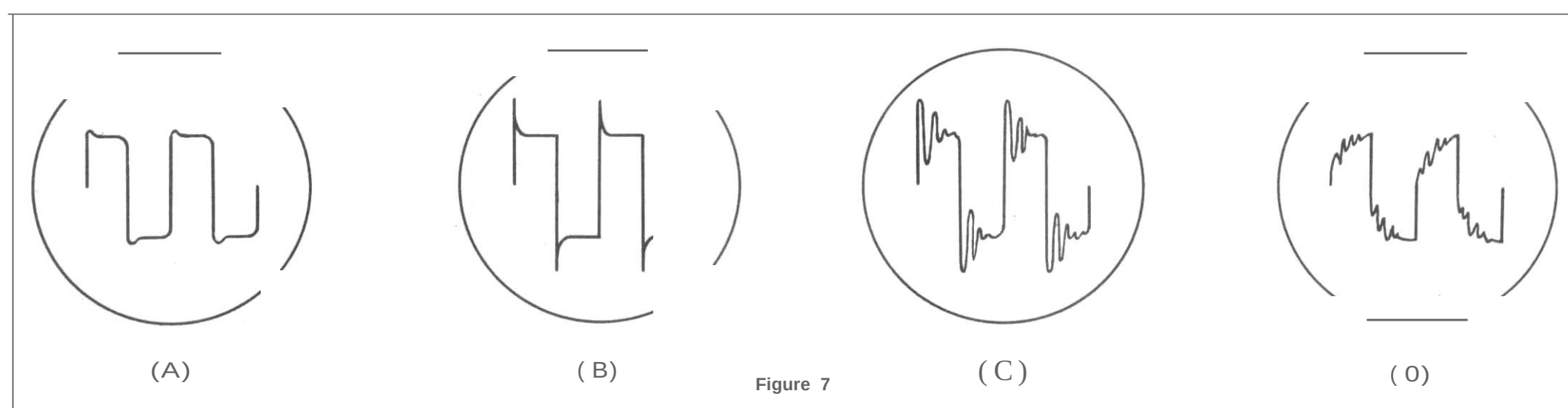
In most cases, a moderate to low "Q" peaking coil is preferred to a high Q coil. However, the peaking coil should not have so low a Q as to defeat its purpose. Peaking coils should be physically small... some manufacturers even wind these coils on small forms about the size of a 1/2 watt carbon resistor.

Carbon resistors should be chosen that have low "noise," particularly when used in high-gain circuits. Unless non-inductive, wire-wound resistors *should not* be used as load resistors in wide-band amplifiers. The exception is where the inherent inductance of the resistor can be taken into account in the design and used to assist "peaking."

Layout and Wiring: In high-gain circuits, ample separation should be provided to prevent interstage coupling... however, the individual stages should not be located so far apart as to require excessively long signal leads.

To minimize hum pick-up and stray coupling, signal leads and coupling condensers may be kept close to the chassis. On the other hand, in wide-band circuits, this step may lead to increased capacities to ground. Therefore, a certain amount of compromise will often prove necessary.

In general, all component leads and connecting wires should be kept as short and direct as possible.



a vibration pick-up with the heathkit audio frequency meter

BY LOUIS E. GARNER, JR.

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One method of using the Heathkit Audio Frequency Meter to measure the mechanical vibration of a piece of machinery is illustrated in Fig. 1. An ordinary microphone (crystal or dynamic) is placed close to the machinery and connected to a high gain audio amplifier. The output of the amplifier is connected to the input terminals of the Heathkit Frequency Meter. (NOTE: If a P.A. type amplifier is used, a resistive load should be substituted for the loudspeaker to prevent possible damage to the output tubes and output transformer by operating the amplifier without a load.)

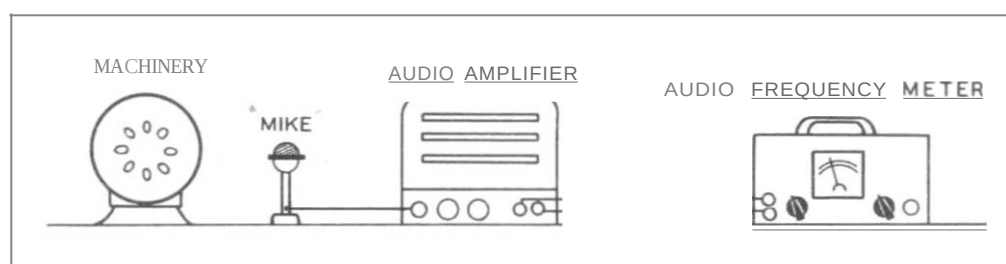


Figure 1

Unfortunately, this technique has several disadvantages. Several pieces of equipment must be interconnected. Great care must be taken in locating the microphone to insure proper pick-up of the desired vibration sounds ... even then, it is

still possible for extraneous noises to be picked up, resulting in erroneous measurements.

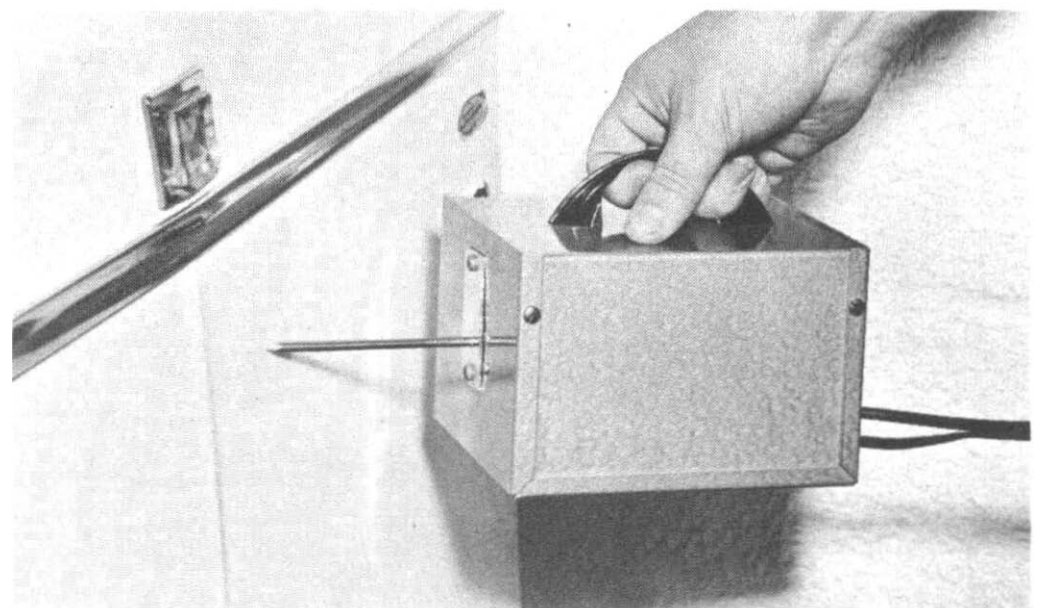


Figure 2

A Pick-Up capable of detecting the vibrations directly is much to be preferred over one depending on sound pick-up, as the possibility of error due to stray noise and unwanted sounds is considerably reduced. Such a Vibration Pick-Up is illustrated in Fig. 2, where it is being used to check the vibration frequency of an automatic washing machine. This Pick-Up

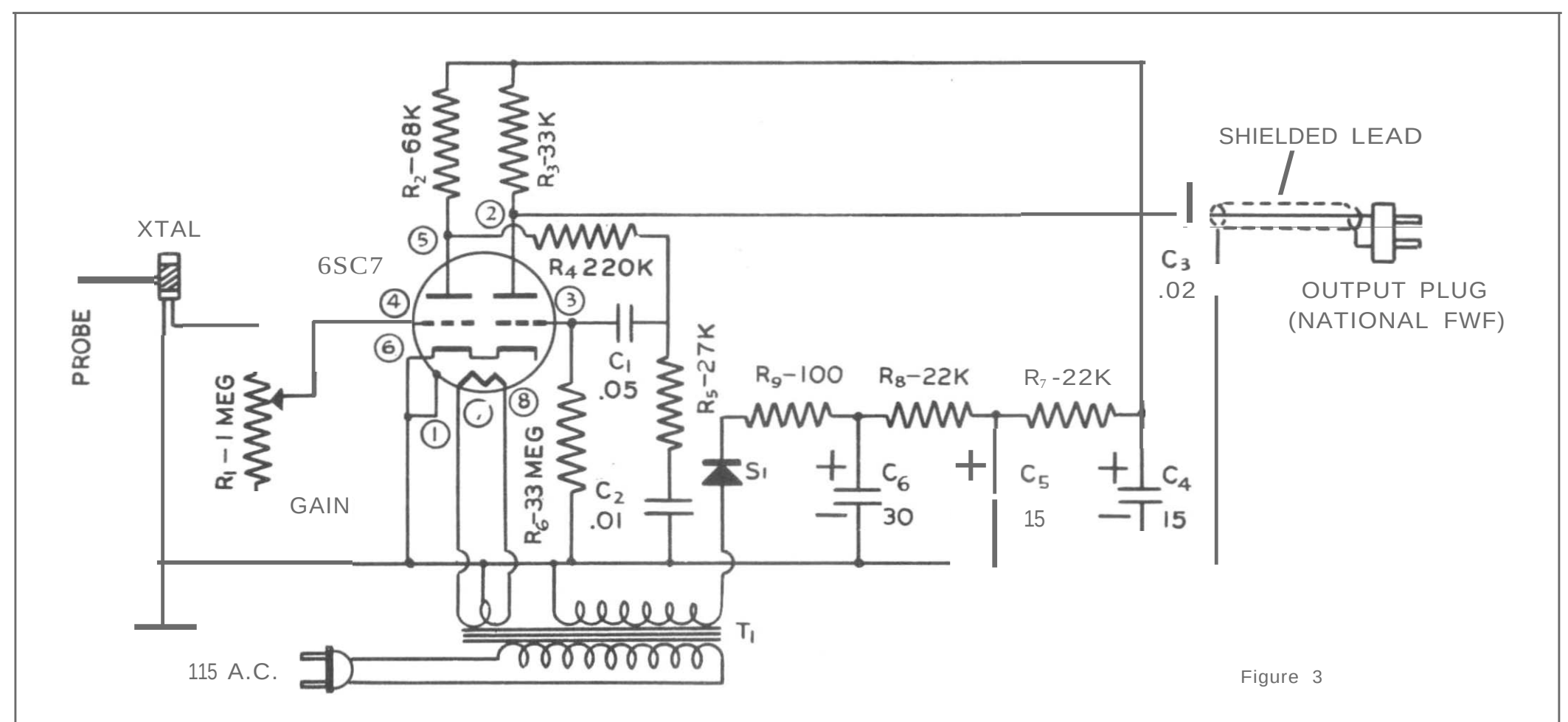


Figure 3

is quite adequate for ordinary measurements and incorporates a self-contained pre-amplifier, permitting direct connection to the Audio Frequency Meter and eliminating the need for complicated connections.

The Pick-Up shown may be easily assembled by the average skilled technician in a few hours time, with the total cost not exceeding \$25.00 for material. The complete schematic diagram is given in Fig. 3, while an interior view, showing details of assembly and construction, is given in Fig. 4. To simplify wiring and to reduce construction time, a standard GE self-powered phono preamp has been used as the basic amplifier.

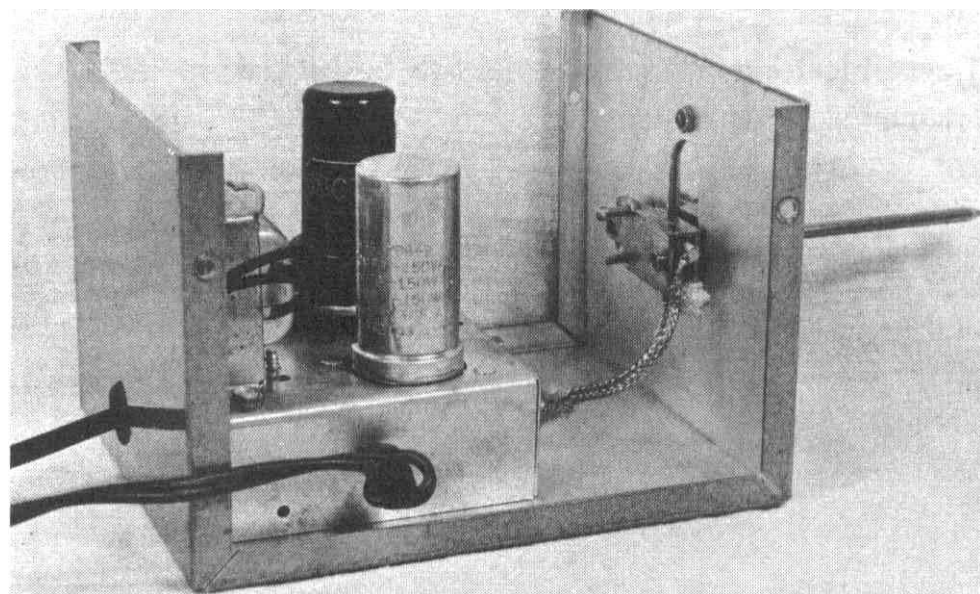


Figure 4

CIRCUIT DESCRIPTION:

Referring to Fig. 3, a signal voltage is developed by the phonograph crystal cartridge (XTAi) due to its mechanical vibration. This voltage appears across the 1 Megohm GAIN control R_t , and a portion of the signal is applied to the grid of one triode section of the 6SC7.

An amplified signal voltage appears across the plate load resistor R_2 and is applied to the grid of the second triode section through R_4 and C_1 , appearing across R'' . R_4 , R_5 , and C_2 form a special equalizing network, used in the original phono preamp. Since this network emphasizes low frequency signals, it has been left in place (most mechanical vibrations are comparatively low in frequency).

Additional amplification takes place in the second stage, with the Output signal appearing across R_3 . This is fed to the output plug (and hence to the Audio Frequency Meter) through blocking condenser C_3 .

A conventional half-wave rectifier power supply circuit is used. It is a standard transformer and is part of the original phono preamp, as is the small selenium rectifier, St . R_0 is a small resistor used to prevent damage to the selenium rectifier due to heavy current drain during the charging of C_4 . Adequate filtering is provided by the cascaded dual pi filter consisting of R' , R' , C_4 , C' and C_4 .

The output connector is a National type FWF plug, chosen because it is a dual banana type plug, with the spacing exactly fitting the INPUT connection terminals on the Audio Frequency Meter.

CONSTRUCTION HINTS:

In Fig. 3, the connections and components within the dotted lines represent the only circuit modifications necessary in the original GE Model UPX-003 Phono Preamp (available at most radio parts distributors). When adding the shielded Output lead, at least a three foot cable should be used to facilitate connections to the Audio Frequency Meter.

As can be easily seen by reference to Fig. 4, the entire unit has been assembled in a small Bud "Minibox" (No. CU-210n). A handle has been mounted on top of the box to simplify one-hand use of the instrument.

The Vibration Pick-Up assembly itself consists of an inexpensive crystal phonograph cartridge and a probe made of a common sixteen penny nail. A shielded lead should be run from the phono cartridge to the pre-amp chassis.

Almost any type of phono cartridge may be used, but a metal cased cartridge is preferred. For maximum sensitivity, a high output cartridge (3 to 9 volt) should be employed. *An expensive phono cartridge is not necessary.* As long as the two basic requirements outlined above are met, the less expensive cartridges are the best for this application.

The assembly of the phono cartridge and the sixteen penny nail is shown in cross-sectional view in Fig. 5. Note that the head of the nail bears directly against the case of the cartridge. This is to insure maximum transfer of vibrational motion from the probe (nail) to the cartridge case.

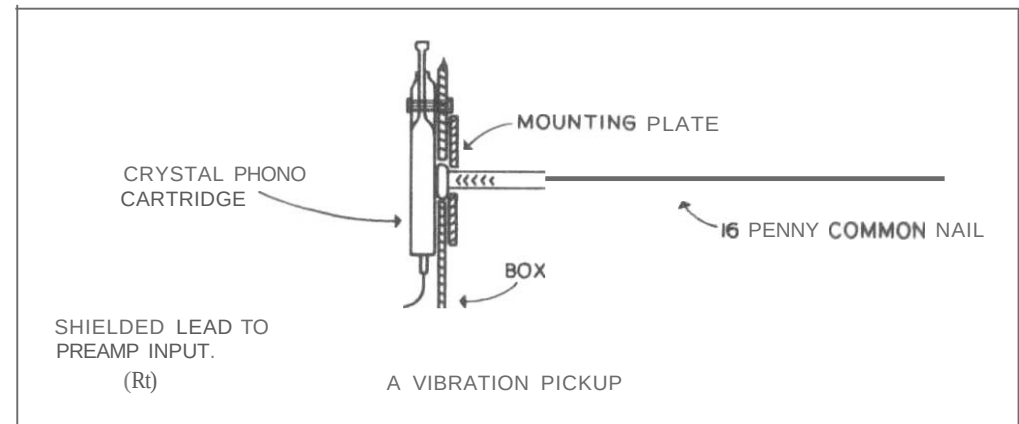


Figure 5

Thus, the crystal phono cartridge acts as a type of inertia pick-up. Vibrations picked up by the probe are transferred to the cartridge case, which tends to vibrate around the crystal (within the cartridge case). The inertia of the crystal prevents it following the rapid vibrations exactly, and thus a bending or twisting motion is set up in the crystal. These motions, in turn, generate an a.c. signal proportional to the original vibrations.

ADJUSTMENT AND APPLICATION:

Once the wiring and assembly has been completed, the Vibration Pick-Up should be tested and the GAIN control adjusted. Almost any piece of machinery having reasonable mechanical vibration may be used to test the unit and to make the original adjustments.

Insert the Vibration Pick-Up Output Plug into the input terminals of the Audio Frequency Meter. Both instruments

should be allowed a short "warm-up" time before an attempt is made to use the Pick-Up,

Now, hold the probe tip tightly against the housing of the machinery (whose vibration is to be measured) and note the reading on the Audio Frequency Meter. Adjust the RANGE switch if necessary. Next, gradually turn up the GAIN control on the Pick-Up until no further increase in the reading of the Frequency Meter is obtained. This insures that sufficient signal is delivered to the input of the Frequency Meter to maintain accurate readings.

Once the GAIN control has been set in this fashion, it may be left fixed in position for all future measurements involving mechanical vibrations on the same order of magnitude (or larger). However, if vibrations of smaller amplitude are to be measured, the GAIN control may have to be readjusted.

, The final reading of the Audio Frequency Meter indicates

the number of *vibrations per second*. To convert to *vibrations per minute*, multiply the scale reading by 60,

In some cases, it may be desirable to **observe** the wave-shape of the vibration as well as to measure its frequency. In such cases, leads may be run directly from the INPUT terminals of the Frequency Meter to the VERT. INPUT terminals of an Oscilloscope. Thus, both the Frequency Meter and the 'scope are connected in parallel.

Where the vibrations of heavy equipment are to be measured, the Frequency Meter and the Vibration Pick-Up may be easily carried to the job for field use. A long extension cord with a cube tap is used to supply a.c. line voltage to operate both instruments. The Frequency Meter may be held in one hand and the Vibration Pick-Up in the other.

the heathkit audio frequency meter

BY LOUIS E. GARNER, JR.

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AN RPM INDICATOR

By adding an easily built accessory to your HEATHKIT Audio Frequency Meter, it becomes possible to measure the revolutions per minute (RPM) of a fan, small airplane propeller, spoked wheel, or similar objects,

The accessory is a compact photo-tube pick-up together with a preamplifier. The entire unit is assembled in a small metal utility box. See Fig. 1.

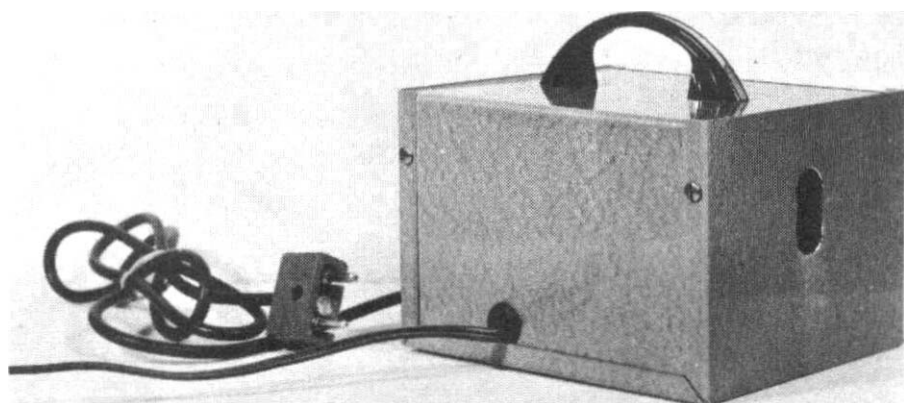


Figure 1

In order to simplify construction, a standard GE Phono Preamplifier is used and modifications made in its circuit. The schematic diagram of the phono preamp is given in Fig. 2, while the necessary circuit changes are shown in Fig. 3.

The complete parts list follows:

- I-240K, $\frac{1}{2}$ W. Carbon resistor
- I-GE Phono Pre-amp, Model No. UPX-003
- I-Type 927 Photo-electric tube
- I-3-pin socket for above
- I-CU-2107 Bud Minibox (4' x 5' x 6")
- 1-1 Megohm carbon potentiometer (taper not critical)
- 2- $\frac{1}{2}$ " rubber grommets
- I-National FWF Insulated plug
- I-Small handle (purchase at dime store or hardware store)
- 3'-Single conductor shielded cable
- Misc.: wire, solder, hdwe., etc.

The total cost of all parts necessary should be less than \$25.00, if purchas'd at regular wholesale prices at a local distributor. If some of the items are already available in the "junk box", the cost will be reduced further.

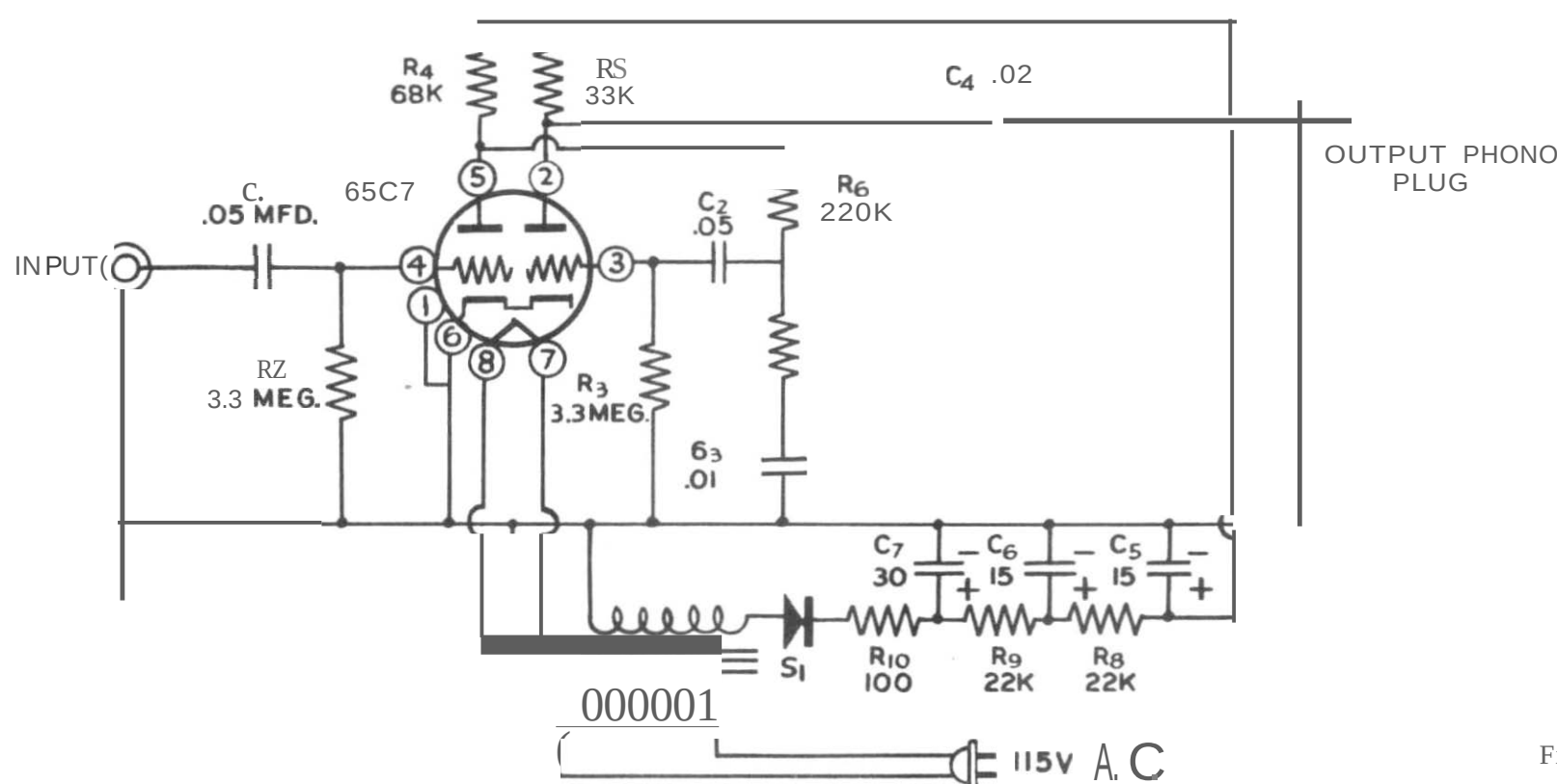


Figure 2

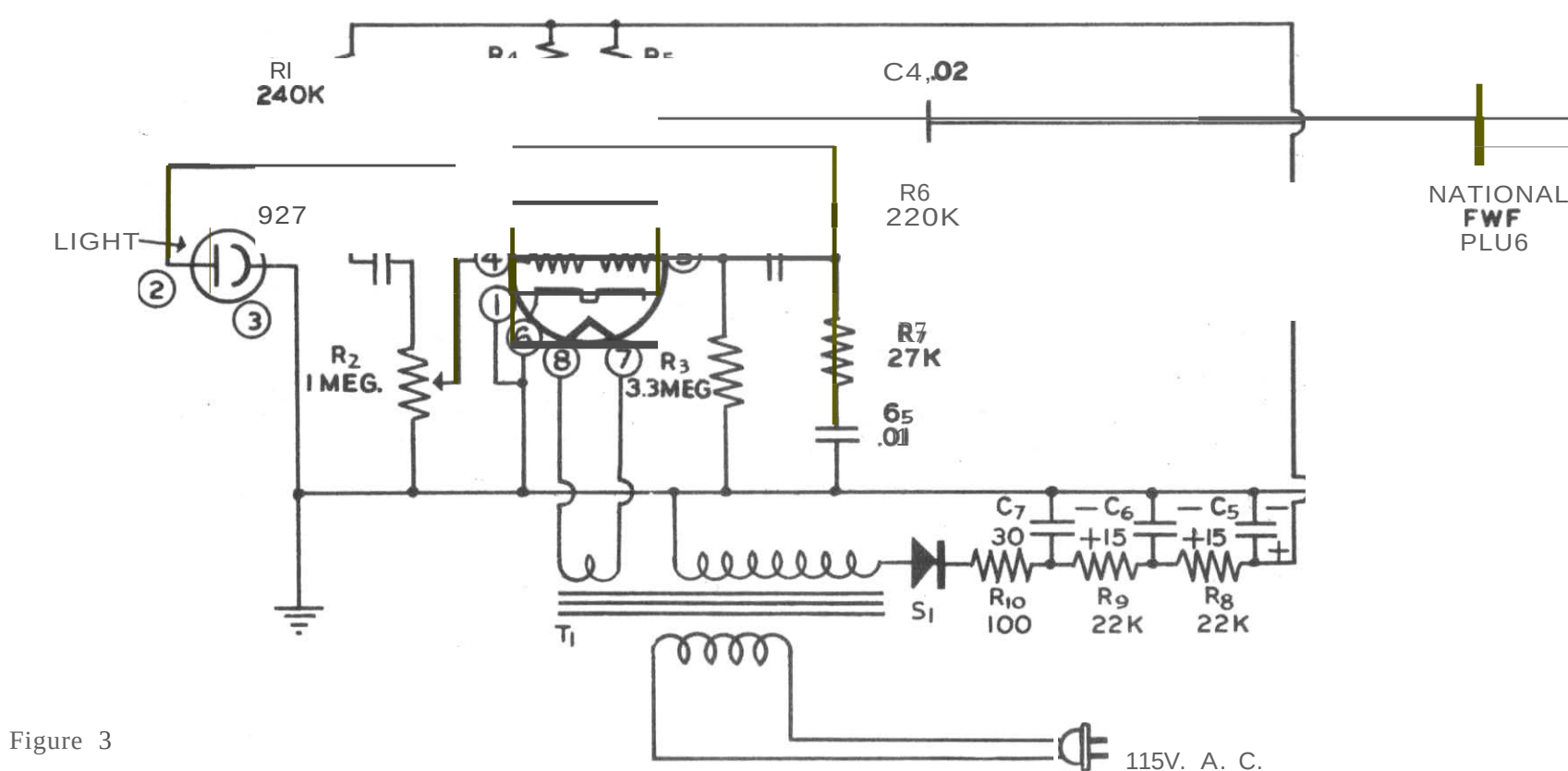


Figure 3

CIRCUIT DESCRIPTION

Refer to the modified schematic diagram given in Fig. 3. As a varying light strikes the 927 photo-tube, its resistance varies, with corresponding changes in the voltage across R' . Thus, the voltage across R' becomes a pulsating d.c. voltage having both an a.c. and a d.c. component. The a.c. component is removed by blocking condenser C^1 and applied to the sensitivity control R_2 .

A portion of the signal voltage across R^2 is applied to the input of a conventional two-stage resistance-coupled amplifier, with the output voltage appearing across R' . Condenser C^1 serves as an output blocking condenser.

Since the current requirements for the photo-tube are small, power is obtained directly from the built-in power supply of the pre-amp.

CONSTRUCTION HINTS

In modifying the pre-amp circuit, the input resistor, R^2 , is replaced by a 1 megohm pot. There is room to place this pot. on the existing chassis provided one of the small pots is used. If a larger pot. is used, it may be necessary to employ an external bracket.

The phono-type output plug and shielded lead is replaced by a 3' shielded cable terminating in a standard National plug. This plug consists of two banana plugs so mounted and spaced that the entire assembly plugs directly into the input binding posts on your HEATHKIT Audio Frequency Meter.

If additional gain is desired, R' and R' may be replaced by 240K, $\frac{1}{2}$ W. carbon resistors, and the compensating network consisting of R_6 , R_7 , and C^3 removed. C^2 then connects between pins 3 and 5 of the tube socket.

The photo-tube socket is mounted directly on the pre-amp chassis and the whole assembly mounted within the 4"x5"x6" Minibox. An oblong hole is cut at one end of the Minibox

in line with the photo-tube. The entire arrangement is clearly visible in Fig. 4. This photograph should serve as a guide for assembly. Compare this view with the external view of the assembly given in Fig. 1.

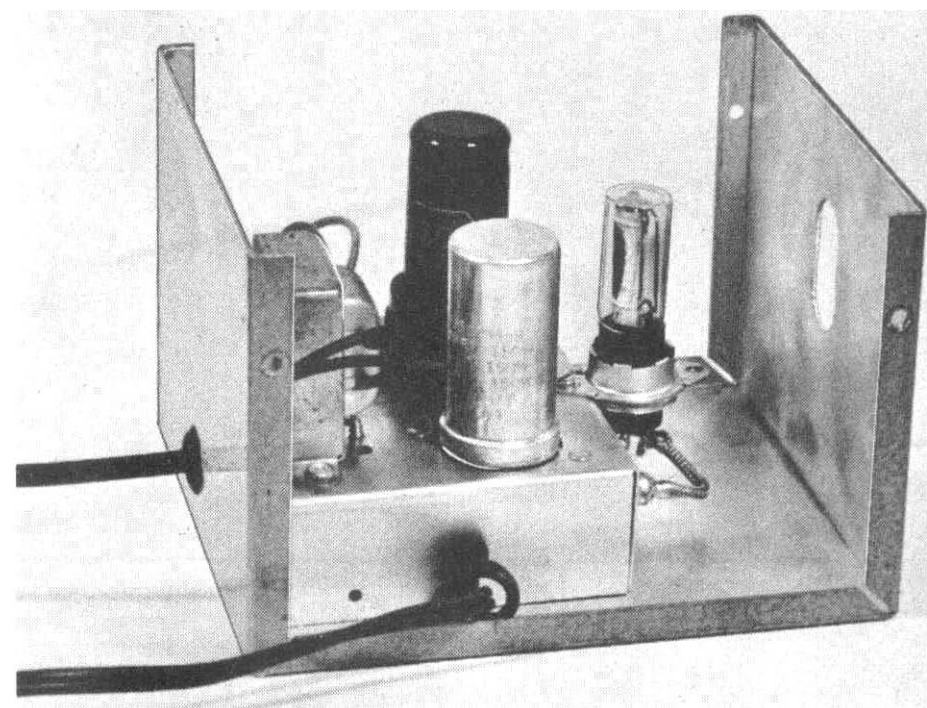


Figure 4

ADJUSTMENT AND OPERATION

To use the accessory as an RPM indicator, place the photo-tube pick-up on one side of the object whose RPM you wish to measure. We will assume, for the moment, that the RPM of an electric fan is to be measured. If this is the case, the set-up will be somewhat as shown in Fig. 5. A light source is placed on the opposite side of the fan and arranged so that its light strikes the opening in the Minibox in direct line with the photo-tube. An ordinary flashlight makes a satisfactory light source. *Be sure that the light source and photo-tube pick-up are arranged so that the fan blades interrupt the light.*

The output plug of the photo-tube pick-up assembly is plugged into the HEATHKIT Audio Frequency Meter, and both units

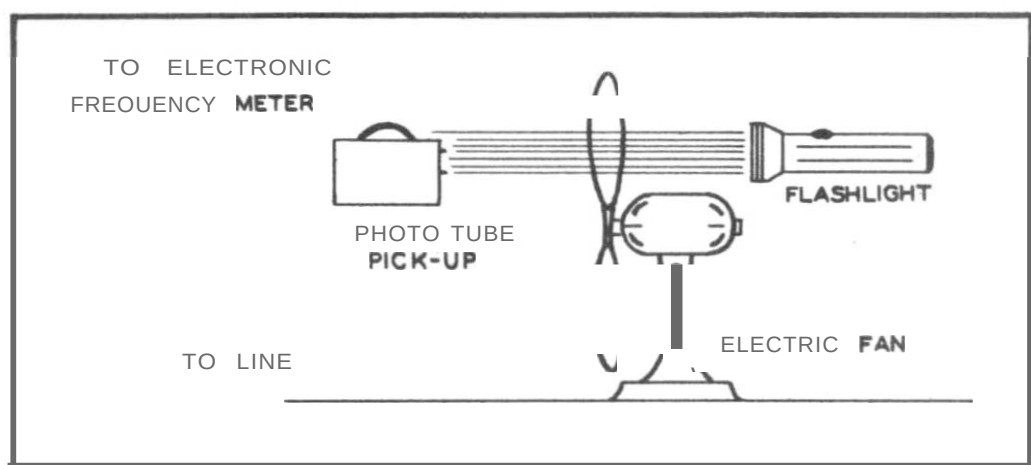


Figure 5

turned on. After allowing time for both units to warm up, turn on the fan and the light source, and adjust the "RANGE" switch of the Frequency Meter for a normal reading (refer to your Instruction Manual).

The sensitivity control (R') should be adjusted for the intensity of the light source used. Gradually turn this control up until the reading on the Frequency Meter no longer increases. Use no more gain than necessary.

The reading on the Frequency Meter indicates the cp.s. of the a.c signal applied to its input. To convert this value to cp.m. (cycles per minute), multiply the meter reading by 60.

Since each "cycle" represents a single passage of a fan blade in front of the photo-tube pick-up, and every blade of the fan interrupts the light source once during each revolution, it is then necessary to divide the cp.m. by the number of blades on the fan to obtain RPM.

In a typical electric fan, having four blades, the actual Frequency Meter reading obtained was 140 cps. Multiplying this by 60 gives a total of 8400 cp.m. Since there are four blades on the fan, we divide the cp.m. figure by 4, giving the value 2100 RPM.

If it is desired to measure the RPM of a device not having a fan or a spoked wheel, a small blade may be temporarily mounted on the shaft of the device in order to obtain a reading. The fan blade may be cut out of **stiff** cardboard or plastic, using the outline shown in Fig. 6. With the number of blades shown, it is only necessary to multiply the Electronic Frequency Meter reading by 10 to obtain RPM.

The wave-shape of the signal obtained at the output of the photo-tube pick-up will depend on the shape of the fan blades. This wave-shape may be easily observed by connecting the output plug of the pick-up to the VERT. INPUT terminals of a Heathkit Oscilloscope, and adjusting the sweep controls for a stable pattern. The wave-shape of the signal obtained from a typical fan blade is shown in Fig. 7.

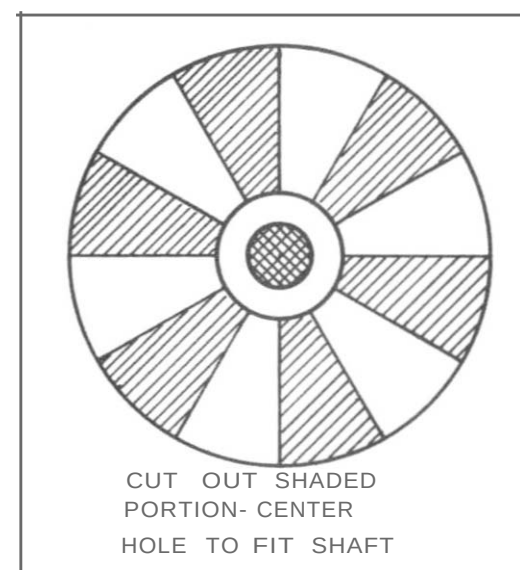


Figure 6

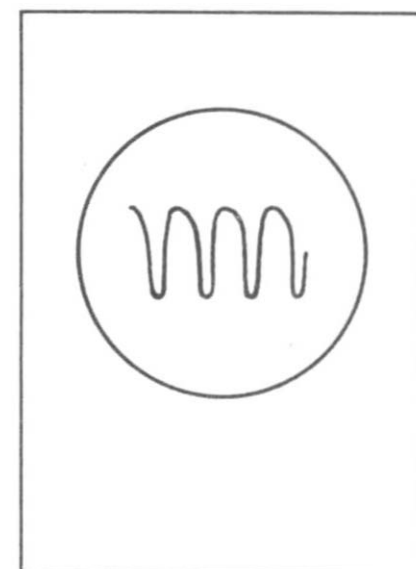


Figure 7

checking musical signals with the audio frequency meter and oscilloscope

BY LOUIS E. GARNER, JR.

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Those readers who are musically inclined or who have more than a passing interest in music and musical instruments may carry out a number of interesting experiments by using their Heathkit equipment to check and observe musical signals. The basic equipment used is as follows: the *Oscilloscope*, the *Audio Frequency Meter* and the *A.C. VTVM*. In addition, a high-gain amplifier, and both a conventional and a vibration type microphone should be available. The Brush VM-1 Vibromike is an excellent vibration pick-up for this work, and is available through most Radio-Electronic supply houses.

However, there are other suitable contact microphones available, and these may be preferred or more easily obtained by the reader... suitable types are the Amperite Model SKH and Electro-Voice Model 805.

As far as the regular microphone is concerned, good results may be obtained with any standard "mike"... suitable types are the Electro-Voice Model 920, Model 911, and Model 628, Shure Models 710A, 520, and 708A, Astatic Models JT-30, 200, and EX, etc.

Setting Up The Test Instruments: The basic equipment arrangement used is illustrated in diagrammatic form in Fig. 1. For professional tests a high fidelity amplifier and high-quality "mike" should be used, but an ordinary P.A. or high-gain phono amplifier is suitable for most experimental and demonstration work.

R_1 is a load resistor used in place of the loud-speaker normally connected to the amplifier's Output. The value of this resistor should be chosen to provide a proper impedance match

Figure 1

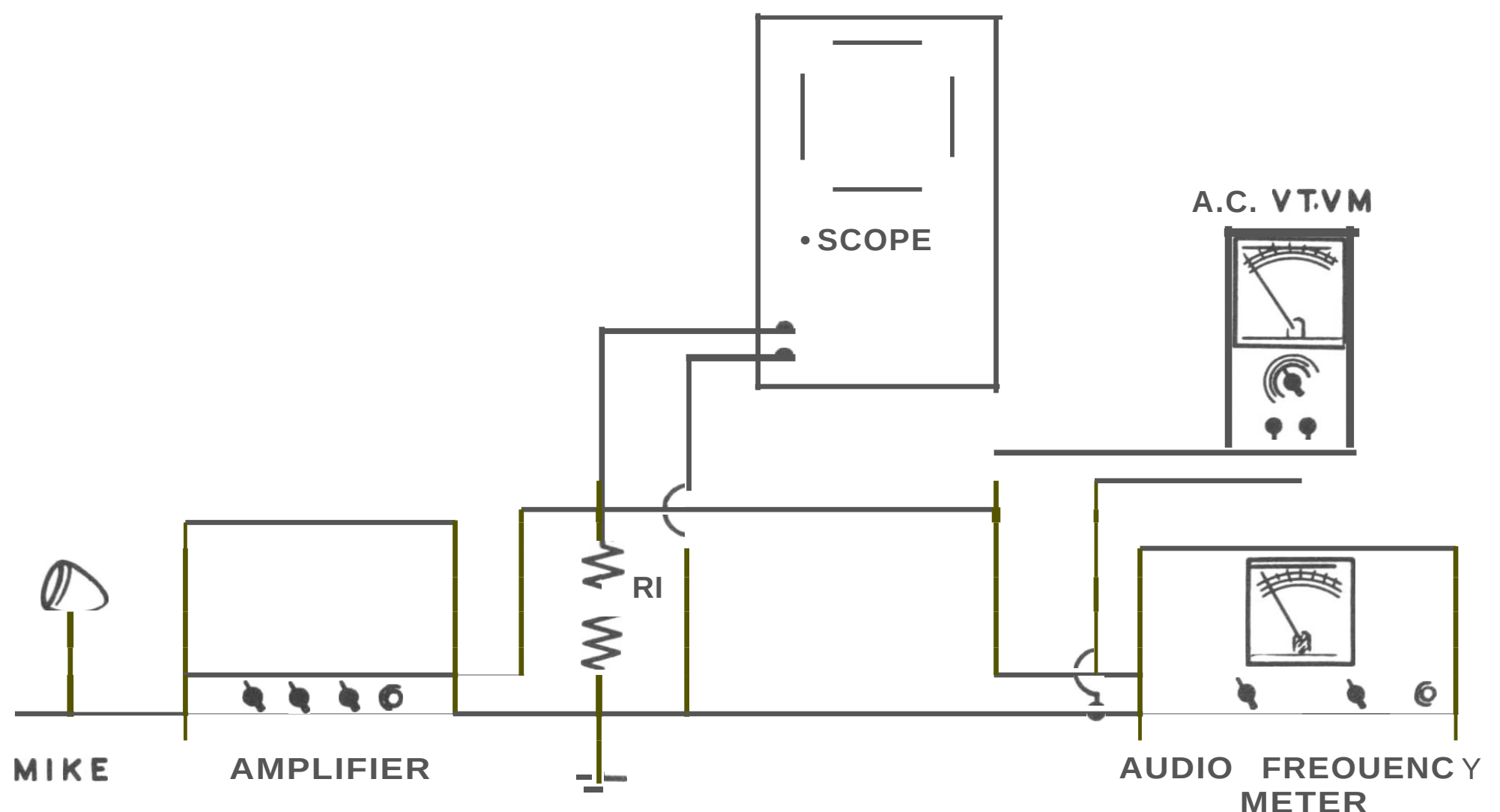




Figure 2

to the amplifier, and its wattage rating sufficient to handle the output without overheating. In most cases, a five or ten watt resistor is ample.

The A.C. VTVM is used primarily to insure that sufficient signal is delivered to the *Audio Frequency Meter* to obtain accurate readings. A minimum of 2 volts (RMS, based on a sine-wave signal) must be supplied, and the GAIN control of the Amplifier should be adjusted accordingly. For best results, the GAIN control may be turned up so that well in excess of 2 volts is supplied under average conditions. (NOTE: Up to 300 volts may be supplied to the input of the *Frequency Meter*.)

If the Amplifier has a low Output impedance (2 to 16 ohms), use either the 10 Volt or 30 Volt range of the A.C. VTVM. The 100 Volt or 300 Volt range should be used if the output impedance is fairly high (500 or 600 ohms).

The *Oscilloscope* serves two important purposes...first, it permits direct observation of the music waveform and, secondly, it permits a check at all times on the quality of the signal, to determine if the amplifier has been overloaded, with resulting "clipping" and distortion of the musical signal. The 'scope VERT. GAIN controls should be adjusted so that two or three inches deflection is obtained with the average input signal. The Sweep frequency SELECTOR and VERNIER controls should be adjusted to deliver a sweep between 10 and 20 cps for most signals, but a higher frequency sweep may be used where a number of high pitched tones are to be observed. A moderate amount of SYNC is employed.

Set the RANGE switch of the *Audio Frequency Meter* first to the 0-10 Kc range, then switch to lower ranges after tests have actually started. If possible, the range selected for any particular test should permit the actual reading to fall on the upper third of the meter scale.

HOW TO CONDUCT THE TESTS

The regular microphone should be used for instruments such as the Ocarina, Harmonica, Flute, Clarinet, Piano, Cornet, Trumpet, Trombone, Saxophone, etc. For low volume instru-

ments, such as the Ocarina and Harmonica, the instrument should be held reasonably close to the "mike," as shown in Fig. 2. A spacing of from six inches to two feet is satisfactory and permits good pick-up while, at the same time, excluding most extraneous sounds and noise.

For the more powerful instruments, such as the Trumpet, Trombone, Bugle, etc., the instrument should be located at a somewhat greater distance from the microphone (2 to 6 feet) to avoid "blasting." For best results, the "mike" may be placed slightly to one side of the horn rather than directly in front of it.

A more distant spacing between the musical instrument and the microphone is also preferred for the larger instruments such as the Piano, Xylophone and Organ. In this case, the greater spacing is used both to prevent excessive vibration and also to insure equal pick-up of different notes.

For small stringed instruments, such as the Guitar, Violin, Banjo, Mandolin, and "Uke," the vibration type microphone should be employed. A small spring clamp is provided with the *Vibromike* and may be used to simplify mounting it on the musical instrument. However, the pick-up may also be mounted by using a small strip of "Scotch" tape or ordinary adhesive tape. As far as the mounting location is concerned, [his is best determined by experiment...the unit may be mounted on the bridge of the instrument, under the tailpiece, or at any other location where good pick up is obtained without adversely affecting the quality of the signal obtained. The mounting location shown in Fig. 3 was used successfully on an inexpensive Guitar.

In order to carry out tests with the stringed instruments, it is generally necessary to sound each musical note a minimum of three times. The first time the various controls on the test equipment are adjusted...the Amplifier GAIN control, the RANGE switch on the *Audio Frequency Meter*, and the VERT. GAIN and sweep controls on the *Oscilloscope*. The second and third times the note is sounded, the signal waveform and frequency characteristics may be observed.

Figure 3



With the wind instruments, the user can generally hold a single note long enough to permit instrument adjustments and tests.

INTERPRETING THE TESTS

The frequency of the signal is read directly on the scale of the *Frequency Meter*. However, this reading must be used as a guide only...not as an exact indication of the particular note sounded.

First, normal tolerance and reading errors are sufficient to prevent an exact frequency check. Most musical notes do not contain an "even" or integral number of cycles per second. This can be seen by reference to Table A, where the frequencies of several "octaves" of musical notes are given, based on a frequency of 440 cps for the musical pitch "A." All the frequencies given are in cycles per second, and are based on the notes of a piano keyboard.

C ₂ - 65.41	C ₁ -130.81	C-261.63
D ₂ - 73.42	D ₁ -146.83	D-293.66
E ₂ - 82.41	E ₁ -164.81	E-329.63
F ₂ - 87.31	F ₁ -174.61	F-349.23
G ₂ - 98.00	G ₁ -196.00	G-392.00
A ₂ -110.00	A ₁ -220.00	A-440.00
B ₂ -123.47	B ₁ -246.94	B-493.88
O-523.25	C ₂ -1046.50	
D ₁ -587.33	D ₂ -1174.70	
E ₁ -659.26	E ₂ -1318.50	
F ₁ -698.46	F ₂ -1396.90	
G ₁ -783.99	G ₂ -1568.00	
A ₁ -880.00	A ₂ -1760.00	
B ₁ -987.77	B ₂ -1975.50	

TABLE A

Secondly, the musical notes produced by some instruments are quite complex, containing several overtones. In many cases, the "overtones" may be of greater intensity than the fundamental. An example of this is given in Fig. 4.

Where the signal has the waveform shown in Fig. 4(a), the *Frequency Meter* will give a good indication of the actual frequency. The Ocarina and a few other wind instruments may give a pattern similar to this one.

A stringed instrument, on the other hand, may well produce a signal having the waveform shown in Fig. 4(b), particularly on the lower frequency notes. The *Frequency Meter*, amplifying and "clipping" this signal, will indicate the frequency of the "overtone" rather than that of the fundamental.

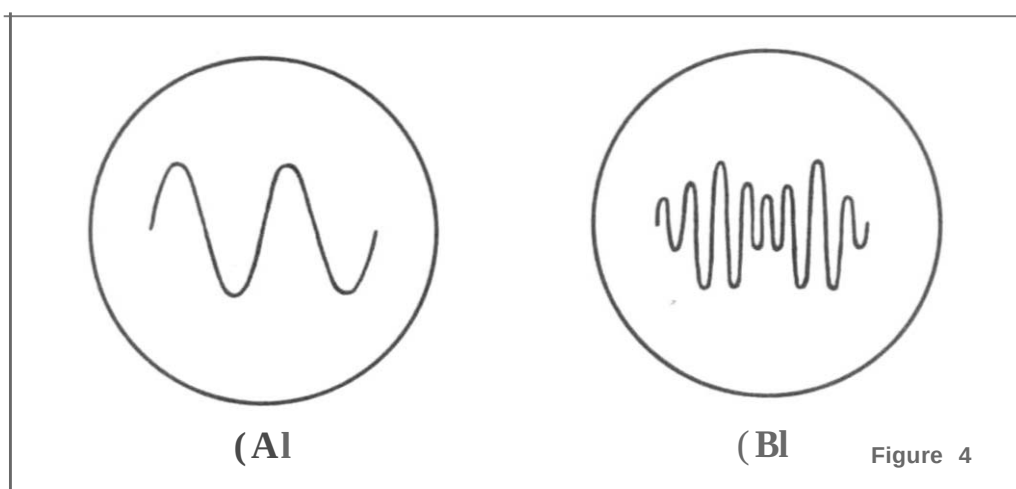
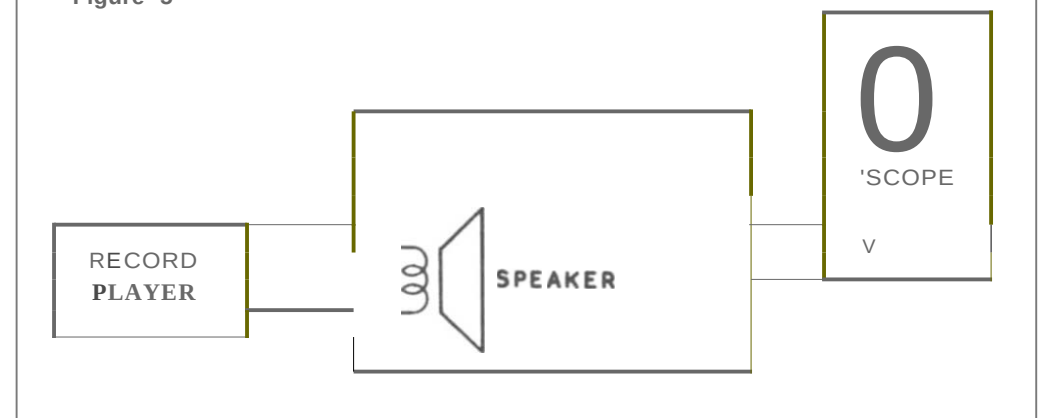


Figure 5



ing and "clipping" this signal, will indicate the frequency of the "overtone" rather than that of the fundamental.

Thus, we see that observing the signal waveform on the screen of the 'scope is mandatory if the proper interpretation is to be given the *Frequency Meter* reading. In addition, the signal waveform conveys other information concerning the characteristics of the musical instrument.

For example, the more complex the signal waveform or the greater the departure from a "pure" sine-wave, the greater the number of overtones produced by the instrument. A complex signal is said to be "rich" in overtones.

If several different instruments are available, the same note may be sounded on each instrument and the differences in tone quality observed.

A stringed instrument, on the other hand, may well produce a signal having the waveform shown in Fig. 4(b), particularly on the lower frequency notes. The *Frequency Meter*, amplifying and "clipping" this signal, will indicate the frequency of the "overtone" rather than that of the fundamental.

Thus, we see that observing the signal waveform on the screen of the 'scope is mandatory if the proper interpretation is to be given the *Frequency Meter* reading. In addition, the signal waveform conveys other information concerning the characteristics of the musical instrument.

ADDITIONAL EXPERIMENTS

With the set-up shown in Fig. 1, it is interesting to observe the voice patterns produced as various individuals say the same word or sing the same note. Differences in tone quality and pitch are graphically displayed on the screen of the CRT.

Still another interesting experiment is to sound the same musical note simultaneously on several different instruments, observing the complex resultant pattern obtained. Or an entire musical selection might be played, so the interplay of complex signal waveforms produced might be easily observed.

For those readers who may not have a musical instrument available, but who may still be interested in observing some of the interesting waveforms produced by musical instruments, the set-up shown in Fig. 5 may be used. The *Oscilloscope* is connected across the loud-speaker voice coil of an ordinary record player. In order to simplify observing the patterns produced by different instruments, the record selections played should feature "soloists" sometime during the rendition of the musical piece.

Still another experiment is to use the equipment arrangement shown in Fig. 1 and to try whistling into the microphone, noting both the frequency as indicated on the *Electronic Frequency Meter*, and the *Oscilloscope* pattern. With a little practice it is possible to produce an almost "pure" sine-wave signal by whistling.

The set-up shown in Fig. 5 is also valuable as an attention-getting display for the Radio-TV Service-shop... particularly where the speaker is arranged so that passers-by may hear the music as well as observe the 'scope patterns. Another variation of this method of attracting potential customers is to substitute a "mike" and amplifier for the record player, using a window display streamer with the following invitation:

STEP INSIDE AND *SEE* YOUR VOICE!

measuring inductance and capacity with the heathkit a.c. voltmeter or oscilloscope and voltage calibrator

BY LOUIS E. GARNER, JR.

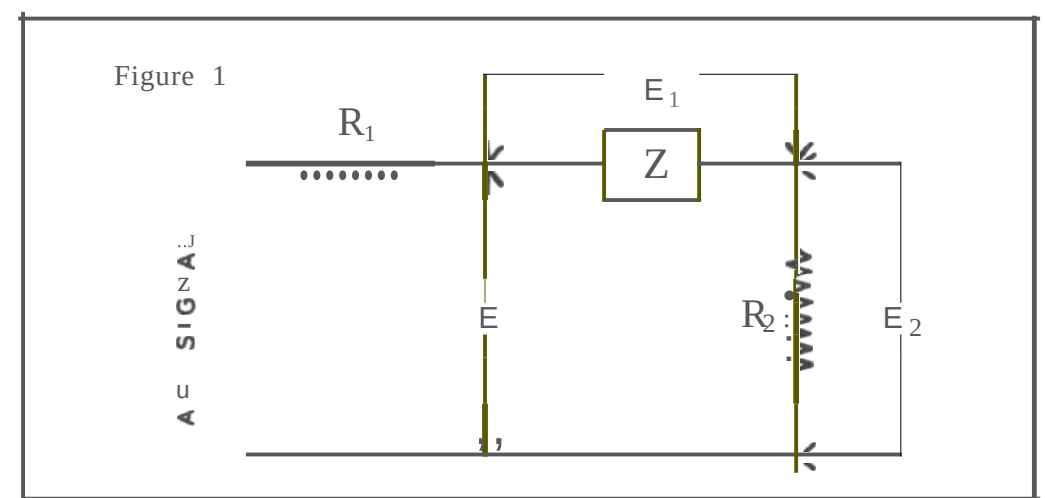
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Although an Impedance Bridge is preferred for measuring inductance and capacity, such an instrument may not always be available. However, it is possible to determine the inductance or capacity of a component, where the values are reasonably large, by using vector relationships, graphical construction, and a few simple calculations. The measurements necessary may be made with either a high impedance A.C. voltmeter, or with an Oscilloscope and Voltage Calibrator.

The basic circuit used to obtain the necessary measurements is shown in Fig. 1. R_1 is an isolating resistor to minimize the effects of the a.c. voltage source on the circuit. Z is the component to be measured, and R_2 is a standard resistor used for establishing a reference. For most measurements, a value of 1000 ohms is satisfactory for R_1 . R_2 is determined by the impedance of Z ... the value of R_2 should be high enough to give an easily measured voltage drop, and may be determined experimentally (the Heathkit Decade Resistance Box is excellent for use here).

The technique used is given in step-by-step form below:

1. Using the circuit given in Fig. 1, apply an a.c. voltage at the frequency at which the measurements are to be made. This signal may be obtained from a sine-wave generator, or, if a 60 cy. signal is to be used, from a power transformer.
2. Using either a high impedance A.C. Voltmeter or an Oscilloscope and Voltage Calibrator, measure the voltage across Z and R_2 (E), across Z alone (E') and across R_2 alone (E''). Record these values. Also note the resistance of R_2 . The voltage measurements may be either RMS (as obtained with



a voltmeter) or peak-to-peak (as obtained with the 'scope). Either is satisfactory for the calculations, *but all measurements should be of the same type.*

3. Establish a scale and draw a horizontal vector proportional to the voltage across R_2 (E'') as shown in Fig. 2 (a). Graph paper is useful for drawing these vectors, as a scale is readily established. However, if graph paper is not available, plain paper may be used, and the scale established using an ordinary ruler.

4. Using a compass, draw an arc with a radius proportional to the value of E' , using the scale previously established. Use the point at the right-hand end of the E_2 vector as a center, as shown in Fig. 2 (b).

5. Draw another arc with a radius proportional to the value of E , this time using the point at the left-hand end of the E_2 vector as a center, as shown in Fig. 2 (c). This arc should intersect the one previously drawn.

Figure 2

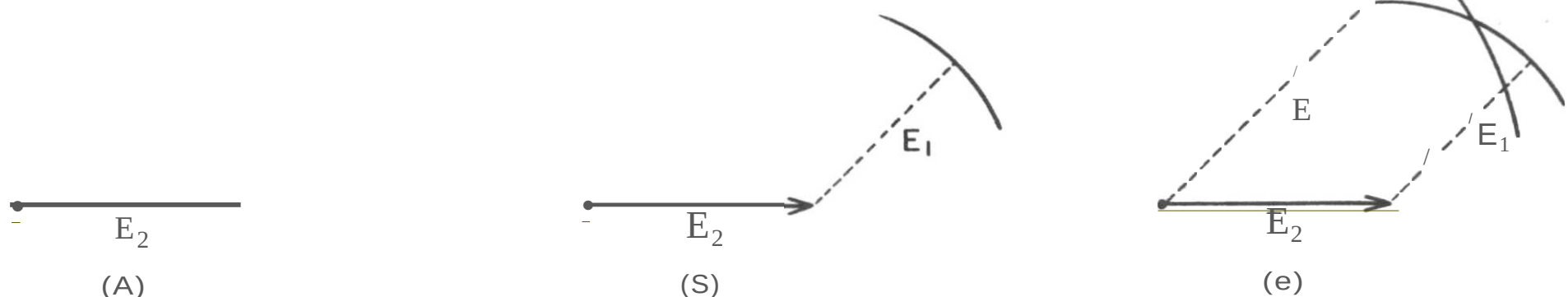
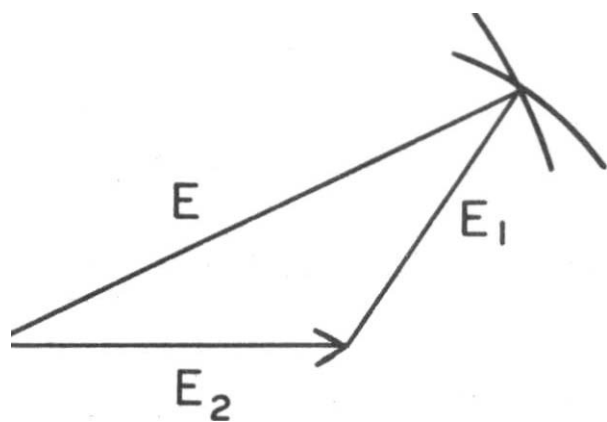


Figure 3



6. Connect the left-hand and right-hand ends of vector E' with the point of intersection of the two arcs, as shown in Fig. 3. This establishes the vector diagram for the circuit.

7. Extend vector E' and drop a perpendicular from the intersection of the two arcs to the extension of E' , forming a right-angle triangle, as shown in Fig. 4. If care has been taken in construction, considerable information concerning the impedance may be derived from this diagram.

The total distance along the extended horizontal vector (distance AC in Fig. 4) is proportional to the voltage drop in the circuit due to resistance alone, with E' (AB in Fig. 4) representing the voltage drop due to R' and BC representing the drop due to the a.c. resistance of Z. The perpendicular, CD, represents the voltage drop due to the reactance of Z. Angle θ represents the phase angle for the entire circuit, while angle θ_1 represents the phase angle for Z alone. To determine the actual phase angles, simply measure these angles with a protractor.

TO DETERMINE THE A.C. RESISTANCE OF Z:

Measure the distance BC (Fig. 4) accurately. Using the scale previously established, convert this measurement into terms of voltage drop (E_{Zr}).

Now, determine the circuit current by dividing the voltage across R' (E') by the resistance. That is,

$$I = E' / R'. \quad (1), \text{ with } E \text{ in volts, } R \text{ in ohms,} \\ I \text{ is given in amperes.}$$

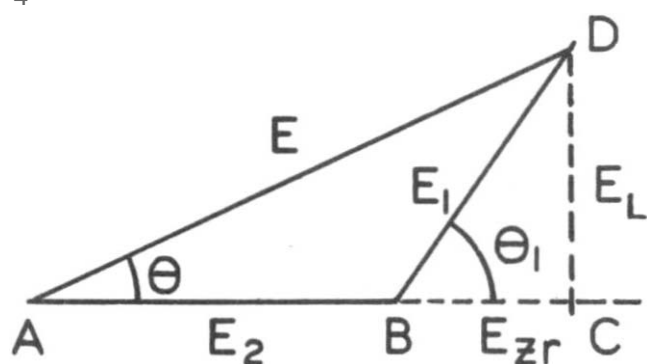
The a.c. resistance of Z may now be determined by dividing the voltage drop due to a.c. resistance (E_{Zr}) by the circuit current ...

$$R_z = E_{Zr} / I. \quad (2)$$

If desired, formulae (1) and (2) may be combined, so that

$$R_z = E_{Zr} R' / E'. \quad (3), \text{ with } R_z \text{ in ohms.}$$

Figure 4



TO DETERMINE INDUCTIVE REACTANCE:

If the impedance (Z) is an inductance coil, the inductive reactance may be determined by dividing the voltage due to reactance (CD, Fig. 4) by the circuit current. Thus,

$$X = E_L / I. \quad (4), \text{ or, combining formula (4)} \\ \text{with formula (1),} \\ X_L = E_L R' / E'. \quad (5), \text{ with } X_L \text{ in ohms.}$$

TO DETERMINE INDUCTANCE:

Use the value for X_L determined above (4) in the following formula:-

$$L = X_L / 2 \pi f. \quad (6), \text{ where } \pi \text{ is 3.14, and } f \\ \text{is the frequency of the signal voltage used for making the tests} \\ \text{in cps, } L \text{ will be in henrys.}$$

TO DETERMINE Q:

The Q of the coil may be determined by using the values obtained for a.c. resistance (2) and inductive reactance (4) as follows:

$$Q = X_L / R_z. \quad (7) \\ \text{Circuit } Q \text{ is determined by adding the value of } R', \text{ or} \\ \text{Circuit } Q = X_L / R_z + R'. \quad (8).$$

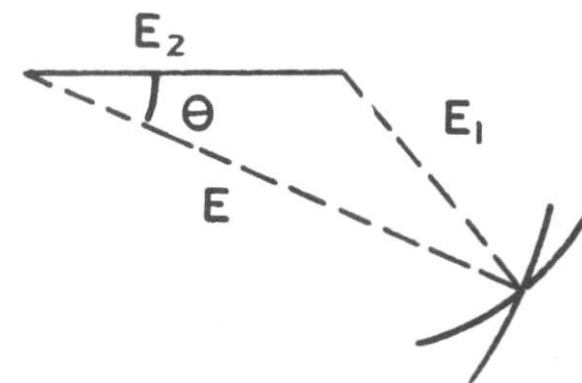


Figure 5

TO DETERMINE CAPACITIVE REACTANCE:

If the impedance being measured in Fig. 1 is a condenser, rather than a coil, the vector diagram should be drawn as shown in Fig. 5, with the arcs intersecting below the horizontal line. This is done simply to illustrate the proper phase relationships. In an inductive circuit, the voltage *leads* the current. In a capacitive circuit, the voltage *lags* the current.

Since the voltage and current are *in phase* in a resistive circuit, the voltage drop across R' (E') is *in phase* with the current through it (I). R' , however, is part of a series circuit, and the current throughout a series circuit is always the same. Therefore, vector E' , representing the voltage drop across R' , establishes the base line (E and I in phase) for the circuit.

Drawing the impedance voltage vector (E_L) and the circuit voltage vector (E) above the axis to be *leading* circuit current. Drawing these voltage vectors below the base line, as in Fig. 5, indicates these voltages to be *lagging* circuit current.

However, the technique of extending vector E' and erecting a perpendicular to the intersection of the arcs is the same for both cases, as is the technique of measuring θ with a protractor to determine the phase angle.

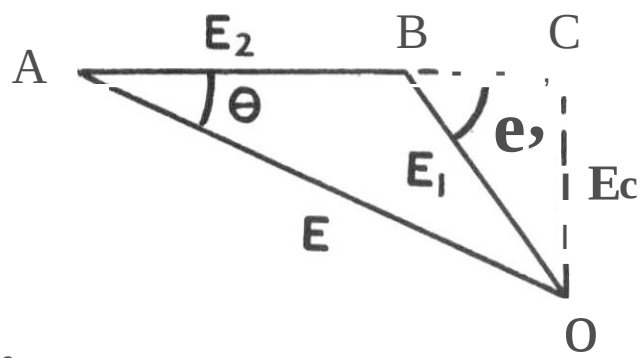


Figure 6

To determine **capacitive** reactance, refer to the vector diagram for a capacitive circuit given in Fig. 6. The length CD is proportional to the voltage drop due to capacitive reactance (E_c). This may be converted into terms of actual voltage using the scale to which the figure has been drawn, and

$$X_c = E_c / I. \quad (9), \text{ where circuit current, } I,$$

has been determined as before (formula (1)). X_c is in ohms.

TO DETERMINE CAPACITY:

The value for X_c as determined with formula (9) is substituted in the following formula:

$$C = 1/2 \pi f X_c, \quad (10), \text{ where } \pi \text{ is } 3.14,$$

and f is the frequency of the applied voltage in cps, C will

be in Farads. To change to the more common micro-farads (mfd), simply multiply by 1,000,000 (10^6), or

$$C \text{ (mfd)} = 10^6 / 2 \pi f X_c. \quad (11).$$

TO DETERMINE DISSIPATION FACTOR:

The dissipation factor (D) of a condenser may be determined with the information derived above. First, calculate the *a.c. resistance* of the condenser, using formula (2). Then,

$$D = R_z / X_c. \quad (12), \text{ where } X_c \text{ is calculated using formula (9), is given above.}$$

RESONANT CIRCUITS AND L-C-R CIRCUITS:

The technique described above may be applied equally well to L-C-R circuits and to series resonant circuits. However, for the results to be accurate, the impedance of the voltage measuring device (whether 'scope or A.C. Voltmeter) must be quite high compared to the impedances being measured.

For most measurements, frequencies of 60 cps, 400 cps, or 1000 cps are used. In some cases, tests may be made at a series of frequencies to determine the effect of frequency on such characteristics as Q , D , and *a.c. resistance*. In most cases, it will be found that the *a.c. resistance* increases with frequency. (NOTE: The "a.c. resistance" referred to is the equivalent resistive component of the impedance ... this may generally be considered a small resistance in series with the reactance.)

applications of the a.c. vtvm

BY LAWRENCE FLEMING

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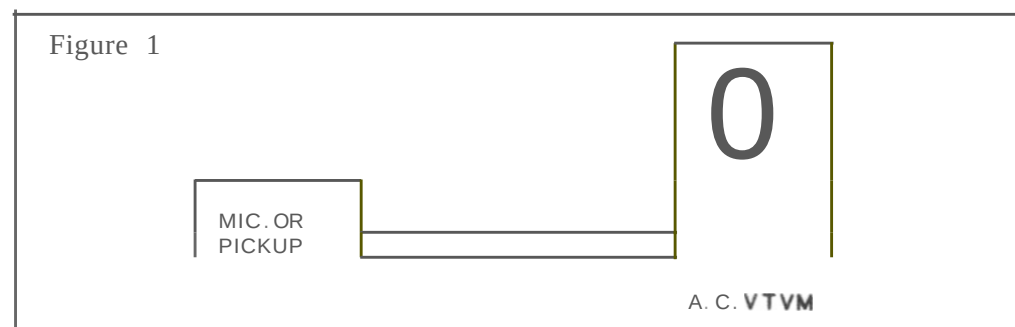
The *Heathkit* A.C. V.T.V.M. has four special characteristics that determine its applications: high input impedance, wide frequency range, **very** high sensitivity, and a very wide voltage range. It is the last two characteristics that make the amplifier-type VTVM unique in the family of electronic instruments. No other device can measure accurately a voltage as small as 1 millivolt at high impedance, or cover a range of 300,000 to 1 (1 millivolt to 300 volts).

The instrument can be used for all the purposes of an ordinary a.c. voltmeter, but is not intended to replace the more basic types of meters for such use-power transformer voltages and the like. Remember that the metal cabinet is connected to the low side of the input, as it must be in a high-gain device. Precautions against shock must be taken if the "low" input terminal is connected to a high-potential point.

While an audio oscillator is necessary in making frequency response measurements, and desirable in most other applications, the AC VTVM alone is useful in much experimental and service work.

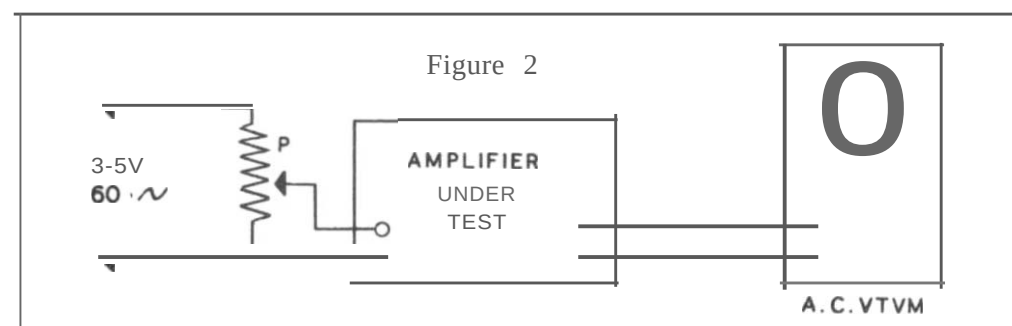
APPLICATIONS WITHOUT OSCILLATOR OUTPUT OF MICROPHONES AND PHONOGRAPH PICKUPS

The AC VTVM will read directly the output voltage of a microphone or phonograph pickup connected directly to the input terminals, Fig. 1. Crystal and dynamic microphones give outputs of 3 to 15 millivolts at ordinary speaking levels and distances. Variable-reluctance pickups generate around 10 millivolts; crystal pickups from about 0.5 to several volts. In making the low-level measurements it is important to use shielded leads and to see that the microphone housing and transformer case (if any) are grounded to the low side of the input.



AUDIO AMPLIFIER GAIN AND HUM LEVEL

Gain at 60 cycles, and hum and noise levels of amplifiers can be determined easily with the set-up shown in Fig. 2. A 60 cycle test signal is taken from the filament supply of the amplifier under test, or from a filament transformer. A volume control P varies the voltage of the test signal. The input voltage applied to the amplifier may be found by temporarily



connecting the "high" input terminal of the AC VTVM to the arm of control P, or alternatively, the control P can be calibrated and the 3 volts or 6 volts a.c. applied to it may be monitored with an ordinary a.c. voltmeter. Control P may be any value over 200 ohms, except that for low-impedance inputs it should not be over 500 ohms or so.

Amplifier output voltages may be measured directly at the plate of any stage, or power output may be found by loading the voice coil terminals with the proper resistor, e.g. 4 ohms, and using the relation

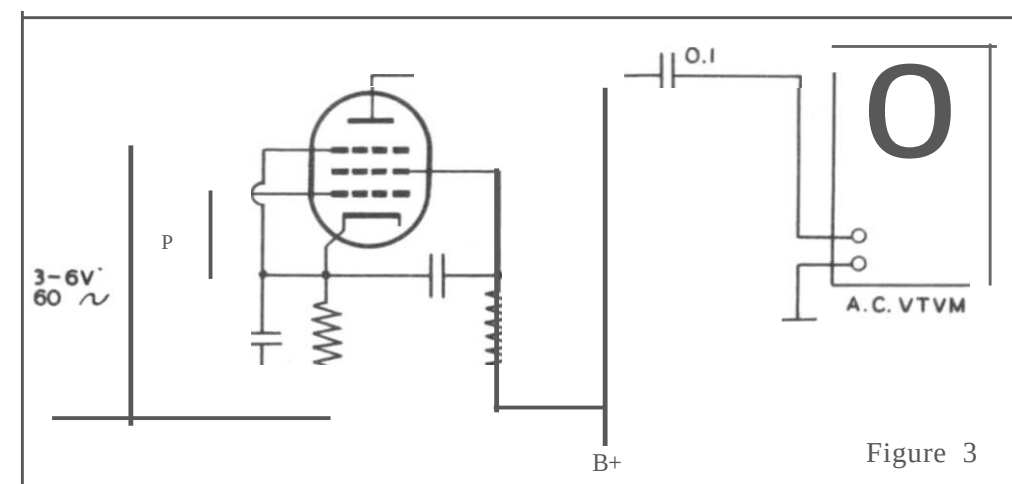
$$W = \frac{E^2}{R}$$

where W is power output in watts, E is output voltage in volts, and R is load resistance in ohms.

Hum level is found by reducing the input to zero. In a good amplifier, hum voltages across the voice coil terminals range around 1 to 10 millivolts. To locate a source of hum, try shorting the input; if the hum disappears, it is a faulty control P or hum pickup in the input wiring. If the hum persists, try shorting the inputs of successive stages in the amplifier, working toward the output. Ripple voltage in the "B" supply may be measured by connecting the audio voltmeter to B plus, through a 0.1 mf condenser.

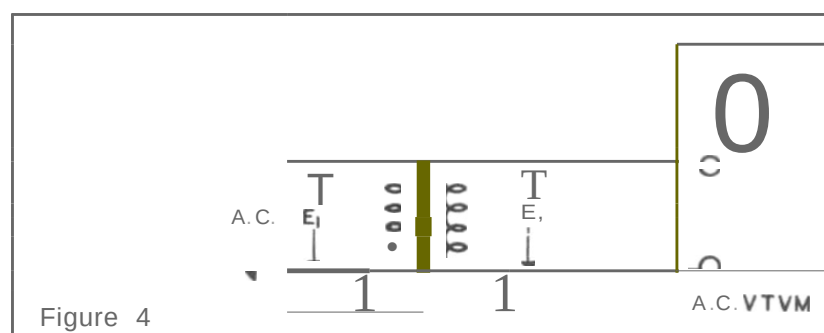
STAGE GAIN

Values of bias resistors, screen resistors, and the like to get maximum gain in experimental circuits, are readily found by trial when the gain can be measured. A typical set-up is indicated in Fig. 3, using the same method described above.



TRANSFORMER RATIOS

The wide voltage range of the AC VTVM enables it to measure turns ratios of all the types of transformers used at power and audio frequencies. Apply an a.c. voltage to one winding, measure it with the AC VTVM, then measure the voltage across the other windings. The voltage ratio will equal the turns ratio, e' . See Fig. 4.



The a.c. test voltage applied should not exceed the voltage for which the winding is rated, but may be less, provided it is not so small that the meter readings are contaminated by induced hum. From 1 to 10 volts is satisfactory for high-impedance windings of audio transformers, e.g. output transformer plate windings, input transformer grid windings, and either side of an interstage transformer. Transformers may be measured in either direction, but it is generally preferable to apply the test voltage to the highest impedance winding.

Unknown transformer types can usually be **identified** by checking the color code of the leads, making a guess from the appearance of the unit, measuring the winding d.c. resistances with an ohmmeter, and then finding the turns ratios by the method above. The RMA color code and some typical ohmmeter readings are given below:

Power Transformer Color Code

115 v. primary-Black
High voltage secondary-Red
High voltage center tap-Red and Yellow
6.3 volt secondary-Green
5 volt secondary-Yellow

Interstage Transformer Color Code

Primary-plate-Black
Primary-B+-Red
Secondary-grid (or grids)-Yellow
Secondary center-tap-Green

Sample Ohmmeter Readings on Transformers

1. Small Filament Transformer
 - 115 v. primary-200 ohms d.c.
 - 6.3 v. 1 A. sec.-1 ohm
2. Small Power Transformer
 - 115 v. primary-IS ohms
 - 600 v. CT, 40 ma secondary---600 ohms overall
 - 6.3 v. 2.5 A secondary-0.2 ohms
 - 5 v. 2 a. secondary-.05 ohm
3. Larger Power Transformer
 - 115 v. primary-3 ohms
 - 700 v. CT, 120 ma. secondary-200 ohms overall
 - 6.3 v. 4 a. secondary-.030hm
 - 5 v. 3 a. secondary-.03 ohm

4. Audio Transformer, Single Plate to Push-Pull Grids, Class A
 - Primary-1500 ohms d.c.
 - Secondary-5000 ohms overall
5. Output Transformer, single 6V6 to 4 ohm voice coil
 - Primary--400 ohms
 - Secondary-1 ohm

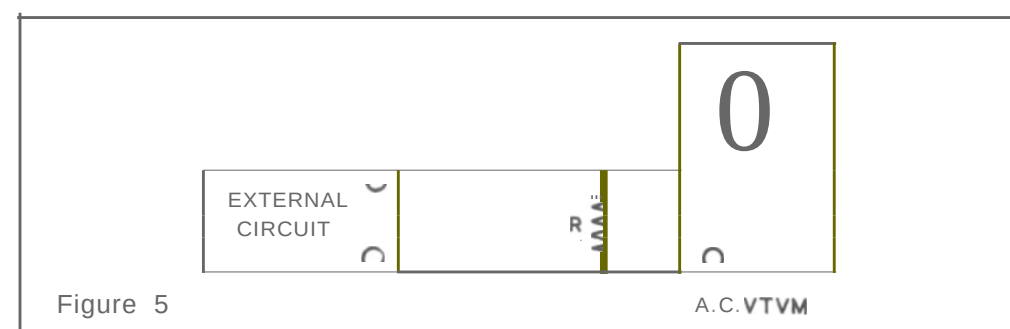
Readings on different makes and models will vary widely; the above is given only as a guide to identification.

TRANSFORMER IMPEDANCE RATIOS

The impedance ratio of a transformer is the square of the voltage ratio. Voltage ratio is the same as the turns ratio, for practical purposes. *Example:* Suppose it is desired to identify a small strap-mounted unit with four leads. The ohmmeter reads a couple of hundred ohms on one winding and less than 1 ohm on the other. Six volts a.c. is then applied to the high winding and 0.27 volts measured across the low winding. The voltage ratio is thus $6/.27 = 22.3$. The square of 22.3 is about 500, so the impedance ratio is 500:1. The ohmmeter readings suggest an output transformer, and the impedance ratio would fit a unit designed to couple a 1500-ohm plate to a 3-ohm voice coil. It is not a filament transformer because the turns ratio is wrong; a 115-volt to 6.3-volt unit would have a turns ratio of 18.3.

A.C. MILLIAMMETER

The AC VTVM can be used as an a.c. milliammeter or ammeter by shunting its input with a resistor, indicated at R in Fig. 5. The voltage drop across the shunt R should be small compared to the drop in the external circuit. This means that the resistance of the shunt should be low — 1/ 10 or less that of the circuit being measured. For a 1-ohm shunt, the AC VTVM will read 1 millivolt when 1 milliampere is flowing through the shunt, and so on. It is preferable to measure in the ground side of the external circuit. If this is not practicable, the low side of the AC VTVM input should be connected to a signal-ground point in the external circuit. If that point is B plus, be careful to avoid shocks from the voltmeter case.



All power-transformer-operated instruments have a capacitance of the order of 100 mmf between the instrument case and the power line, due to the capacitance between the power transformer primary and the core. Hence the meter cannot be used "floating" in the high side of high-impedance circuits without introducing both shunt capacitance and hum.

MEASURING CAPACITANCE

Capacitance can be measured with the AC VTVM at 60 cycles, although the availability of higher audio frequencies from an oscillator will extend the utility of the method. All

that is needed, besides the AC VTVM, is a source of a.c. such as a filament winding, a potentiometer of a few hundred ohms, and some capacitors of known value, arranged as in Fig. 6.

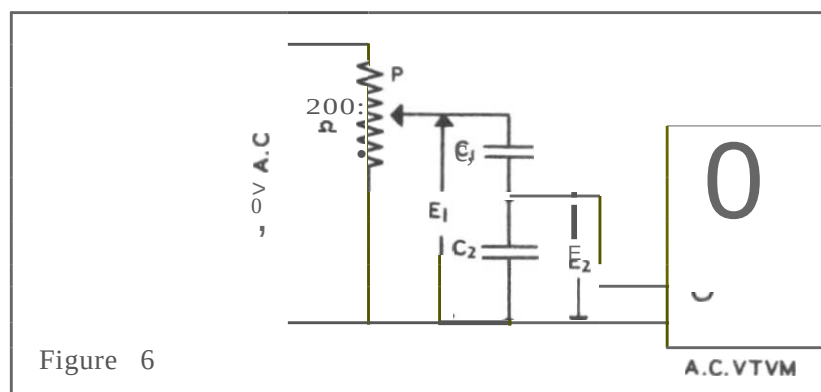


Figure 6

The known and unknown capacitors are connected as a voltage divider. The capacitance ratio is the inverse of the measured voltage ratio: in Fig. 6,

$$\frac{C_1}{C_1 + C_2}$$

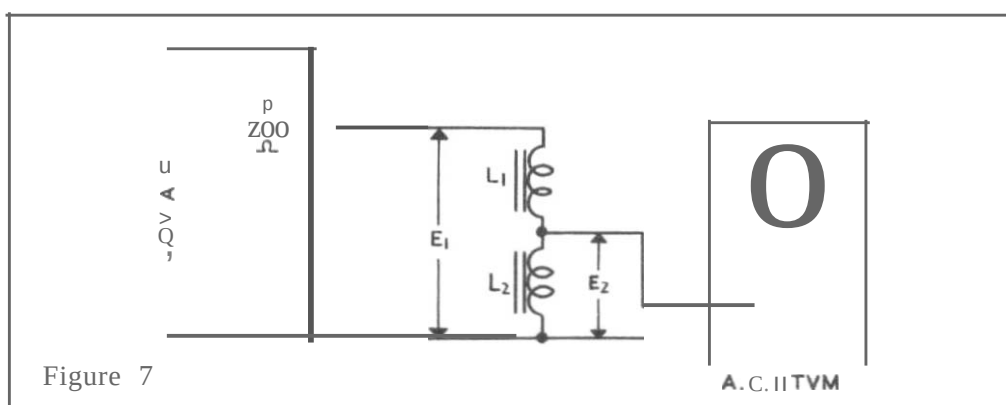


Figure 7

C_2 must be large enough so that its reactance at the measuring frequency is small (say less than 10%) compared to the input impedance of the AC VTVM. At 60 cycles, C_0 should be .05 mf or larger.

A more convenient form of the formula is

$$C' = C_0 \left(1 - \frac{k}{k} \right)$$

where k is the voltage divider ratio, or the ratio of the measured and applied voltages e_0 .

e'

Example: Suppose C_2 is 0.1 mf, the applied voltage e' is 1 volt, and the measured voltage e_0 is 0.3 volt. Then k is 3.3 and C_1 is $0.1 \times \frac{3.3}{6.6} = .05\text{mf}$.

If C_2 is 0.1 mf, e' is 10 volts, and the reading e_0 is .008 volts, then k is $\frac{.008}{10}$ or .0008. Then

$$C_1 = 0.1 \left(1 - \frac{.0008}{.0008} \right)$$

The denominator is less than a tenth of a percent different from 1, so we can call it 1 for simplicity. Then the unknown capacitance is $0.1 \times .0008 = .00008$ mf or 80 mmf. As this second example indicates, when C_2 is a lot smaller than C_1 , the formula can be simplified to

$$C_1 = C_2 k.$$

INDUCTANCE MEASUREMENT

Inductances can be measured by a similar method, shown in Fig. 7. The formula is similar but inverted.

$$L_1 = L_2 \left(\frac{K}{1-K} \right)$$

where k is the ratio of the applied and the measured voltages $\frac{e_0}{e'}$ as before.

At 60 cycles, this method is good only for iron-core filter and audio chokes, and transformers. R.F. coils have so little inductive reactance at power and audio frequencies that their impedance is mainly due to their d.c. resistance.

A 10-henry filter choke makes a good "standard".

Inductance is another helpful guide in identifying transformers. Output transformer primaries measure from 1 henry for a small unit designed for a 1500-ohm plate load, to 10 henries or more for push-pull 8000-ohm plates. Interstage audio transformers usually measure around 20 henries primary and 100 henries secondary. The principle is that the inductive reactance of a winding should be somewhat larger than the rated load resistance, at the lowest audio frequency that the transformer is to pass with good fidelity. This "design frequency" varies with cost and application considerations. It may be as low as 20 cycles for high-fidelity units, and as high as 200 or 300 for midget radio transformers. Hence the inductance of similarly-rated windings will vary widely between audio transformers of different size and cost.

A transformer primary measuring 10 henries, for example, will have an inductive reactance of $6.28 \times 10 \times 60$ at 60 cycles, or 3800 ohms. It could be either a good quality unit designed to work out of a 25L6 plate, or more likely, a lower grade transformer intended to couple a 6V6 plate.

AMPLIFIER OUTPUT IMPEDANCE

The output impedance of an amplifier is readily measured by the set-up shown in Fig. 8. Apply an input signal to the amplifier as before, and provide a variable load resistance R across the output. With load resistor R disconnected, set the input signal level so that some convenient output voltage is measured, say 1 volt. Then connect the load R , and vary it until the output voltage has dropped to half its original value. The resistance R is now equal to the internal resistance looking back into the amplifier.

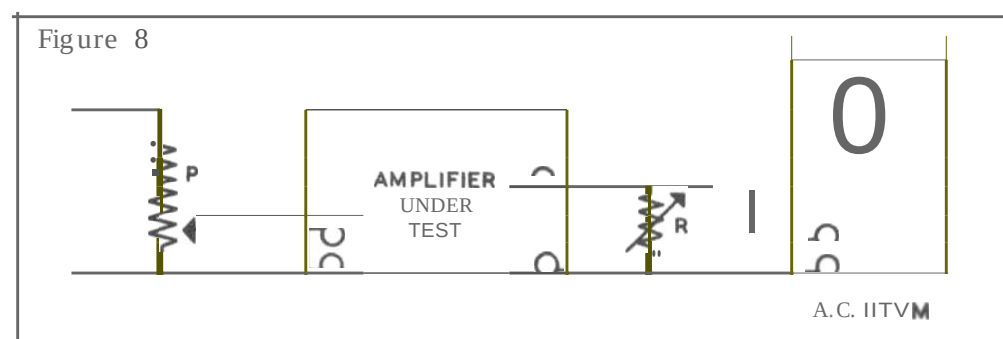
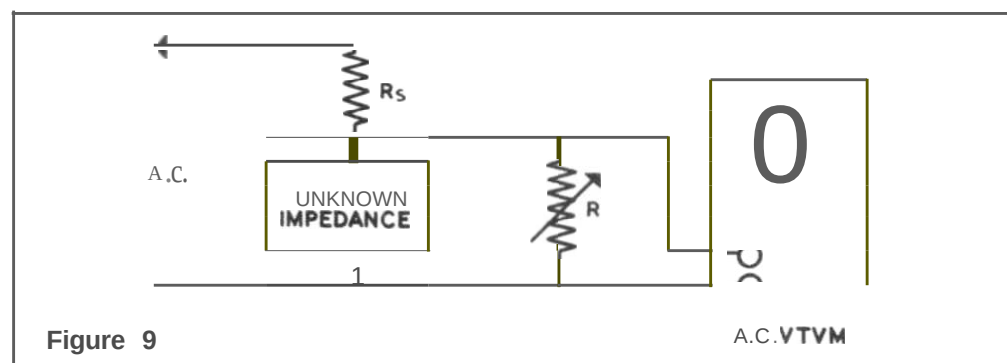


Figure 8

The reading will be in error if the amplifier is overloading. It is advisable to repeat the process at a lower signal level, say 0.1 volt, if there is any doubt.

An alternative method is shown in Fig. 9, applicable to amplifiers or any other circuit whose internal impedance is known to be predominantly resistive. The test signal is applied to the output of the amplifier, or to the circuit terminals, through a high resistance R_s . This "supply resistor" R_s must be at least 10 times higher in value than the circuit impedance being measured. The value does not matter, so long as it is high enough, so that the circuit is not loaded by the source.



Again, measure the a.c. voltage across the unknown impedance with load resistor R disconnected, then connect R

and vary it until the AC VTVM reading drops to half its former value. Load resistance R then equals the unknown impedance.

Plate resistance of triodes and output impedances of cathode followers can be measured this way. Voice coil impedance of speakers can also be measured by this method but an oscillator is needed, because speaker impedances are always very low at 60 cycles and vary a great deal with frequency.

Impedance measurements made at 60 cycles on amplifiers having small output transformers are likely to give an answer that is lower than the impedance at higher frequencies, because of the inductive reactance of the output transformer shunting the reflected resistance.

Instead of varying a load resistor until it equals the circuit impedance, it is just as correct to use a load of any value that will produce a pronounced change in the voltage, then calculate the unknown impedance using the parallel resistor formula.

applications of the ac vtvm and audio generator

BY LAWRENCE FLEMING

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The combination of an audio generator and a VTVM is required for performing frequency response measurements on all audio-frequency circuits. Response curves can be plotted on amplifiers, portions of amplifier circuits, equalizers, tone controls, transformers, and filters. The range of capacitance and inductance measurement is extended. The Q of coils can be determined. Still other types of measurements can be performed with the addition of simple accessories, such as a good microphone, which completes the instrumentation needed for taking frequency response curves on loudspeakers.

In nearly all work with an audio generator and an A.C. VTVM, an oscilloscope is a highly desirable accessory. Its main purpose is to monitor the waveform of the voltage being measured, as a check against noise, hum, and overloading in the circuit being tested. If an oscilloscope is not available, it is recommended that the signal input to the A.C. VTVM be monitored with a simple amplifier and a pair of headphones or a speaker, to see that the signal being measured has the same character as the signal fed in from the audio generator. This precaution is not necessary in measuring passive networks, that is, transformers, filters, R-C networks, capacitances, and inductances; but it saves time by reducing errors, in measuring any circuit that contains vacuum tubes.

AMPLIFIER FREQUENCY RESPONSE

The frequency response of an ordinary audio amplifier is determined with the straightforward set-up indicated in block form in Fig. 1. An oscilloscope is shown connected across the A.C. VTVM terminals to monitor the waveform. The frequency response of the amplifier under test is found simply by varying the generator frequency and noting the readings of the A.C. VTVM.

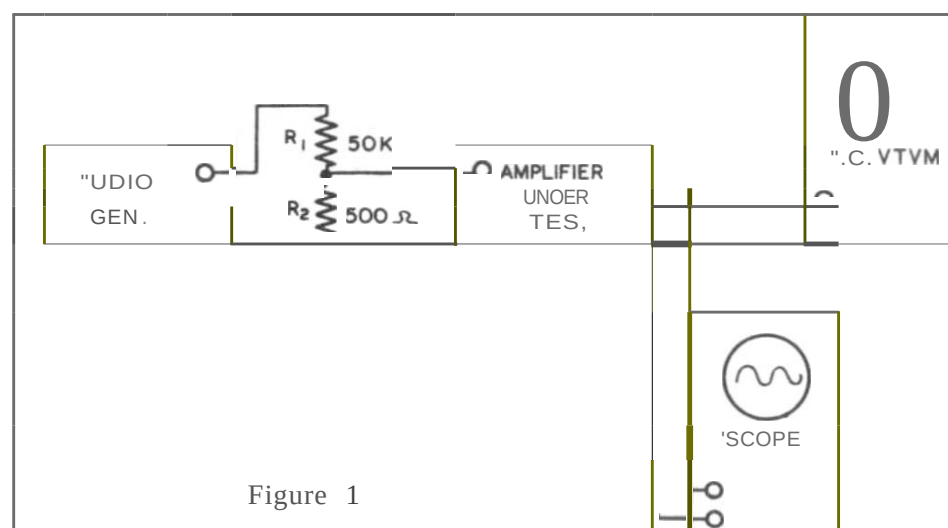


Figure 1

The following precautions are important. The input signal level from the audio generator should be around the middle of the dynamic range of the amplifier—well below the overload level and well above the hum level. To find the gain, check the input level initially by temporarily connecting the A.C. VTVM input to the amplifier input. With any good audio generator, the voltage will stay constant within 1 db over the entire range of frequencies.

For amplifier input circuits rated at 1 volt input or so, such as radio tuner and phonograph inputs, the generator terminals may be connected directly to the amplifier input. For feeding low-level inputs such as microphone inputs, the generator output should be first attenuated about 100 to 1 by a pair of resistors R_1 , R_2 . The exact values are not important. This attenuation permits the generator output control to be operated well up on its range, and preserves a good signal-to-hum ratio in the generator output, since it attenuates the hum as well as the signal. All audio generators deliver a few millivolts of hum even when the output control is turned down to zero, except certain models which have built-in output attenuators.

Besides the ordinary response curve, a maximum-output curve provides important information about an amplifier. This curve plots the maximum undistorted output against frequency. The procedure is to plot each point along the frequency scale by measuring the output voltage level at which waveform distortion begins to be noticeable on the oscilloscope. Fig. 2 illustrates an ordinary low-level response curve and a maximum-output curve for the same amplifier. The low-level response was broadened by negative feedback, which also caused the peak at 30 kc. Feedback or equalization have no effect, however, on the maximum power an amplifier can deliver.

TESTING BREADBOARD CIRCUITS

In measuring gain and frequency response of experimental audio circuits, it is well to measure each stage by itself before stringing together the whole system. Fig. 3 illustrates the test arrangement for a typical voltage amplifier stage. The set-up is similar to Fig. 1 except for the series grid resistor R_1 .

Gain and frequency response are measured in the same way as before, and with the grid resistor R_1 shorted out with a switch SW or a clip lead. Following this, it is necessary to check for grid current. The generator is set at some low

frequency below 200 cycles and resistor R_1 unshorted. If the reading of the A.C. VTVM drops appreciably or if flat-tops appear on the oscilloscope waveform, or if the tone in the headphones changes from pure to buzzy, it indicates that grid-current limiting is taking place in the stage. Cause is too-low bias or too high a signal level. If this check is omitted, the other measurements can lead to spurious values for the bias, gain, and output capability of the tube. Tubes generally work better at very low or zero bias with a low impedance signal source than they do under more normal conditions, but do so only because the source is supplying power to the grid.

The reason for using a low test frequency is that the combination of the input capacitance of VI and the series resistance R_1 will attenuate high frequencies. At 15 kc the insertion of 100,000 ohms in series with a triode grid will drop the signal output some 3 db.

An input coupling capacitor C_2 and grid leak R_2 are advisable here because a fraction of a volt of d.c. exists across the terminals of many audio generators, due to leakage in the output coupling capacitor in the instrument. A check for leakage voltage with a d.c. VTVM can obviate this precaution.

INPUT IMPEDANCE

Figs. 4 and 5 indicate how to measure the input impedance of an amplifier or similar circuit. The method is exact if the

impedance is resistive, approximate if it is reactive. Audio generators have output impedances ranging from about 50 to 800 ohms. For measuring input impedances that are high compared to the generator output impedance, use the arrangement of Fig. 4.

The generator is set at a low frequency, such as 20 cycles, resistance R' shorted out, and the signal level set to give any convenient reading on the A.C. VTVM, such as 1 volt. Then R_1 is varied until the meter reading drops to half its former value. R' is then equal to the unknown impedance at that frequency. Decreases in the measured impedance at high frequencies will be due to the input capacitance. At, say, 20 cycles the measurement will give the resistive term, unless there is a small coupling capacitor in the amplifier to raise the impedance at extreme low frequencies. Input resistances up to several hundred megohms can be measured by this method.

For low input impedances, of the order of a few hundred ohms or less, use the arrangement of Fig. 5. Fixed series resistor R_2 is 10 or more times higher than the input resistance to be measured (value not important if high enough). The output voltage as read by the A.C. VTVM is set as before, with the shunt variable resistance R_3 disconnected. The input resistance is equal to that value of R_3 which reduces the measured voltage by half.

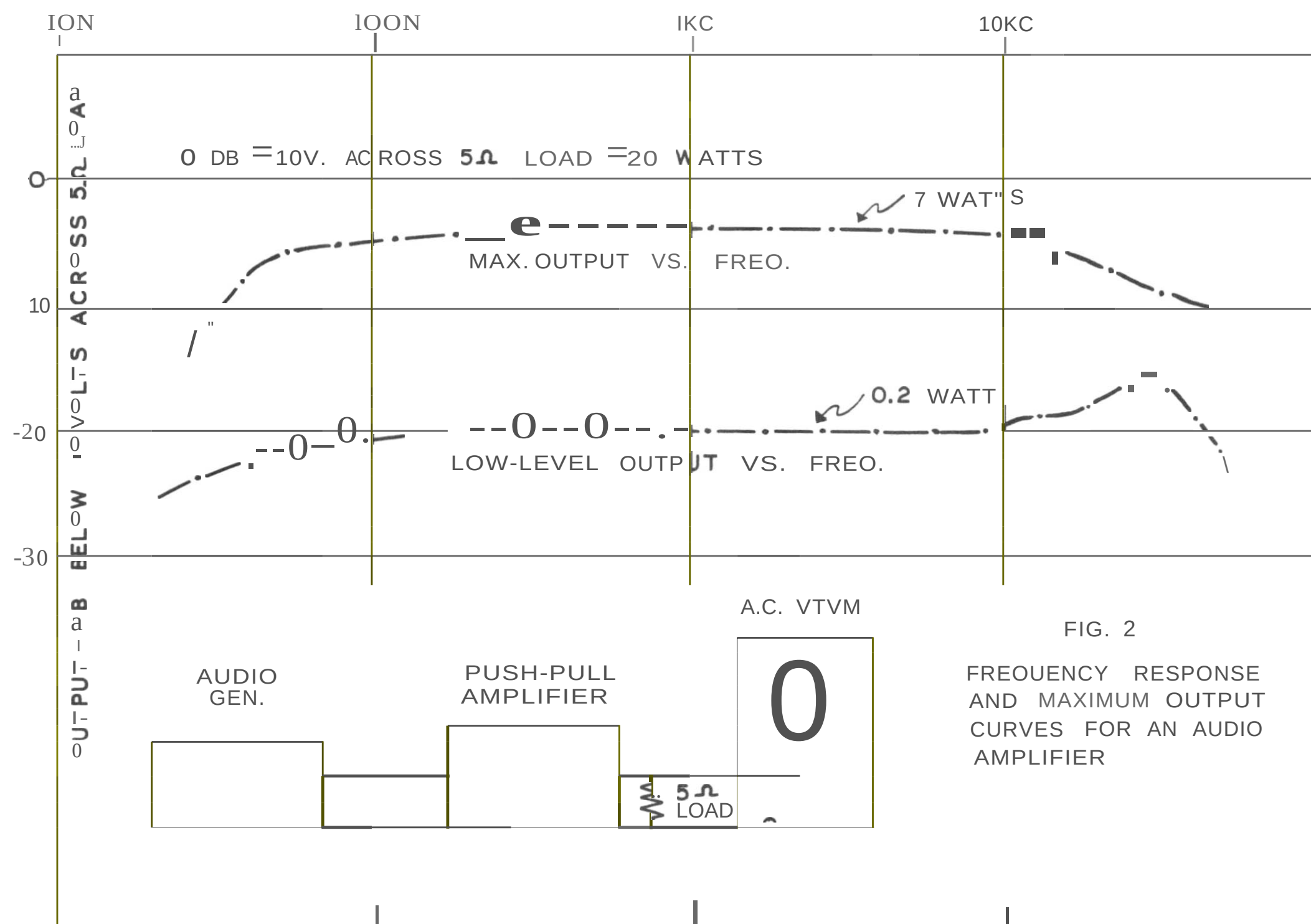
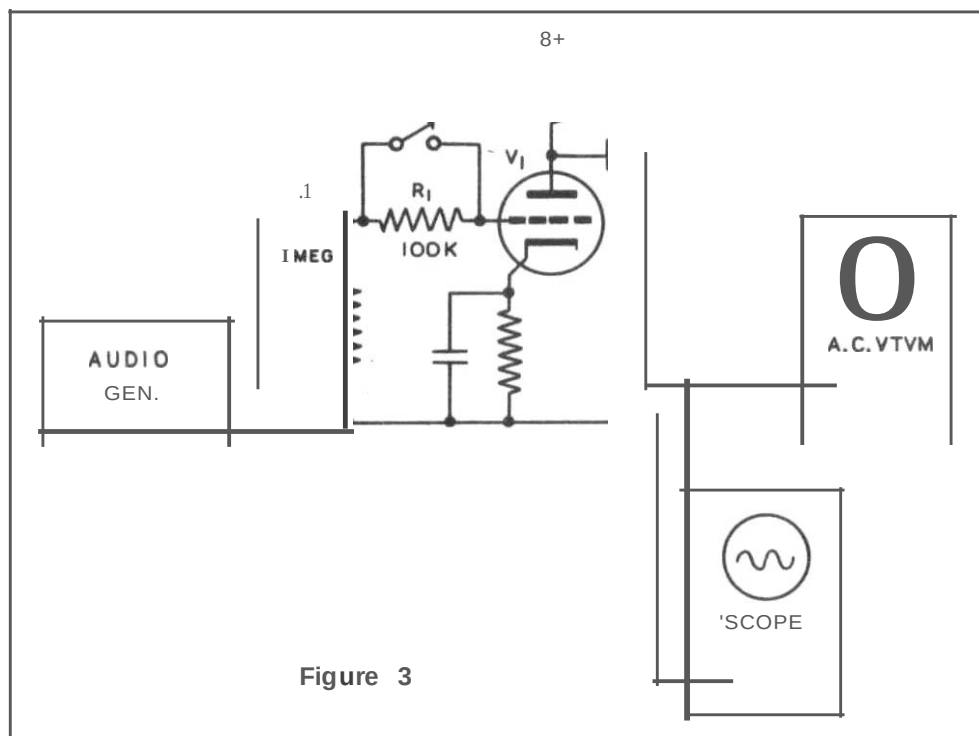


FIG. 2

FREQUENCY RESPONSE
AND MAXIMUM OUTPUT
CURVES FOR AN AUDIO
AMPLIFIER



OUTPUT IMPEDANCE

Output impedance of audio amplifiers is measured by a similar shunting method, using the set-up shown in Fig. 6 except that the audio generator replaces the 60-cycle source. It is desirable to find such output impedances at several frequencies far apart, because the output impedance looking into the terminals of an Output transformer tends to drop at low frequencies and rise at high frequencies, due to transformer characteristics.

Output impedance of a resistance-coupled amplifier stage or a cathode follower is measured the same way. The test frequency should be high enough so that the coupling capacitor reactance is low compared to the impedance being measured. Take care that the signal level is low enough to avoid overloading.

LOUDSPEAKER AND MICROPHONE IMPEDANCES

Speaker voice coil impedances can be measured exactly as above, or by the method indicated in Fig. 7. This latter method is more convenient for impedances which vary a lot with frequency, because no manipulation of controls is needed besides the generator dial itself. The series resistance R is made about 100 times higher than the unknown is likely to be, and the generator voltage is set at some value that gives a convenient value of a.c. current through R and the unknown. Since R is high, the current will be comparatively unaffected by reasonable changes in the unknown, and the unknown impedance will be closely equal to the A.C. VTVM reading divided by the current. For voice coil measurements, a handy set of values is 10 volts out of the generator, and a series resistor R of 1000 ohms. Then each 10 millivolts measured across the voice coil corresponds to 1 ohm impedance.

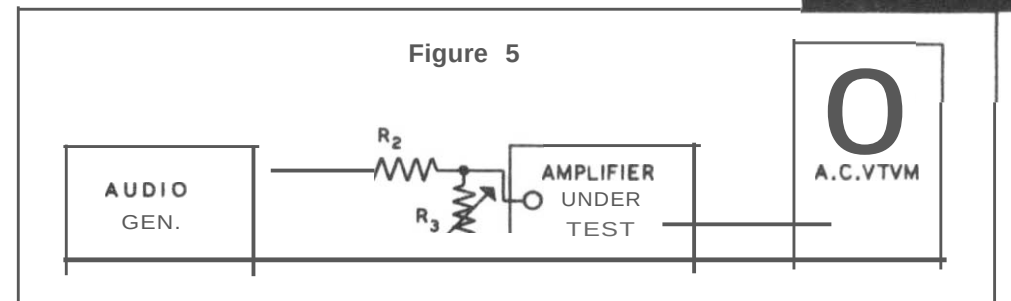
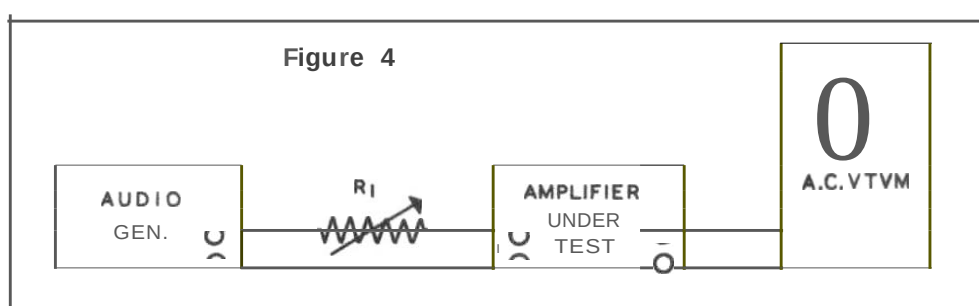


Fig. 8 is a typical voice coil impedance curve taken in this way. The speaker was an 8-inch replacement type. The impedance at low frequencies reflects the degree of restriction of cone movement; the bass resonant peak is very high when the speaker is not baffled at all, (solid curve) but is small when the speaker is mounted in a small closed-back baffle (dotted curve). The 200-cycle peak is a resonance of the box. Baffling has no effect on the impedance at higher frequencies. The high-frequency rise is mainly due to the inertia of the voice coil. The nominal or rated impedance is the value in the flat region around 400 cycles, in this case 3.2 ohms.

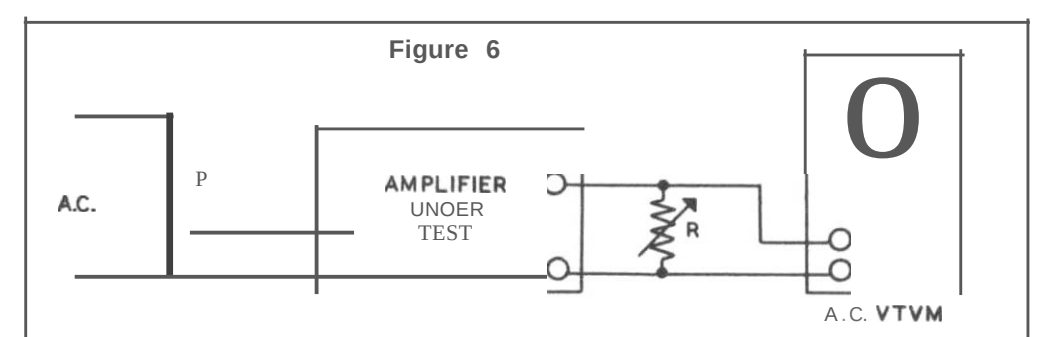
Crystal microphones and pickups are nearly pure capacitances, usually between 200 and 5000 mmf, and are measured the same as condensers. Dynamic and ribbon microphones and magnetic phonograph pickups are inductive with a low Q , and are measured accordingly. Or the method used for voice coils will give an approximate answer at 400 cycles.

SMALL CAPACITANCES

Interelectrode capacitances of tubes and other small direct capacitances upwards of 1 mmf can be measured readily with the set-up of Fig. 9. The method is the same as shown in Fig. 10 for use at 60 cycles, but the use of a higher test frequency permits measuring smaller capacitances. The test frequency is not critical - it need only be high enough so that the reactance of shunt capacitor C is low compared to the input resistance of the A.C. VTVM. 10 kc is suitable.

With the particular values given in Fig. 9, the unknown capacitance C^2 in mmf will be equal to the reading of the A.C. VTVM in millivolts. The method is accurate within 1 percent (exclusive of meter errors) below 100 mmf, and within 10 percent to 1000 mmf. Some care, but not much, is necessary to see that the meter reading is not affected by hum pickup. The unknown capacitor should be connected directly to the A.C. VTVM "high" terminal, and not touched by the hand while the reading is taken.

Reducing the shunt capacitor to 1000 mmf will raise the sensitivity to 0.1 mmf per millivolt, but increases hum pickup problems slightly and introduces 2 or 3 percent extra error due to the input capacitance of the meter.



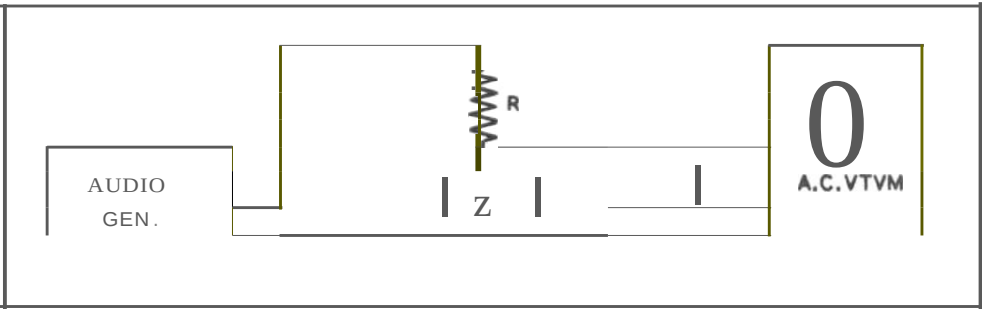


Figure 7

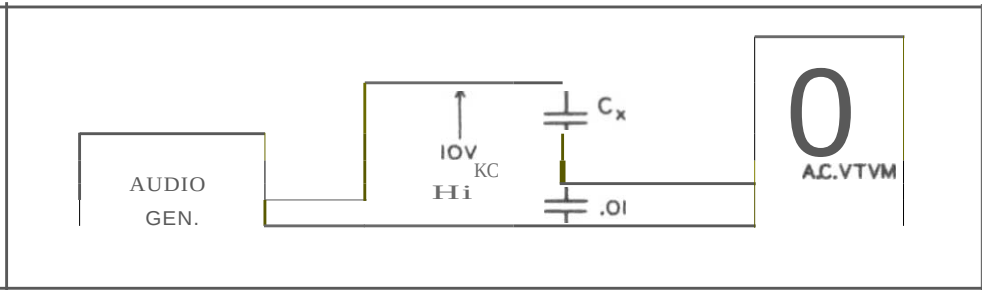


Figure 9

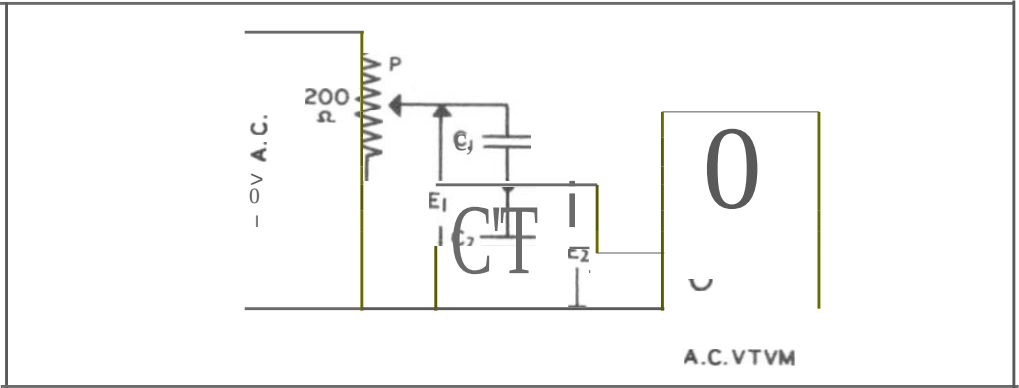
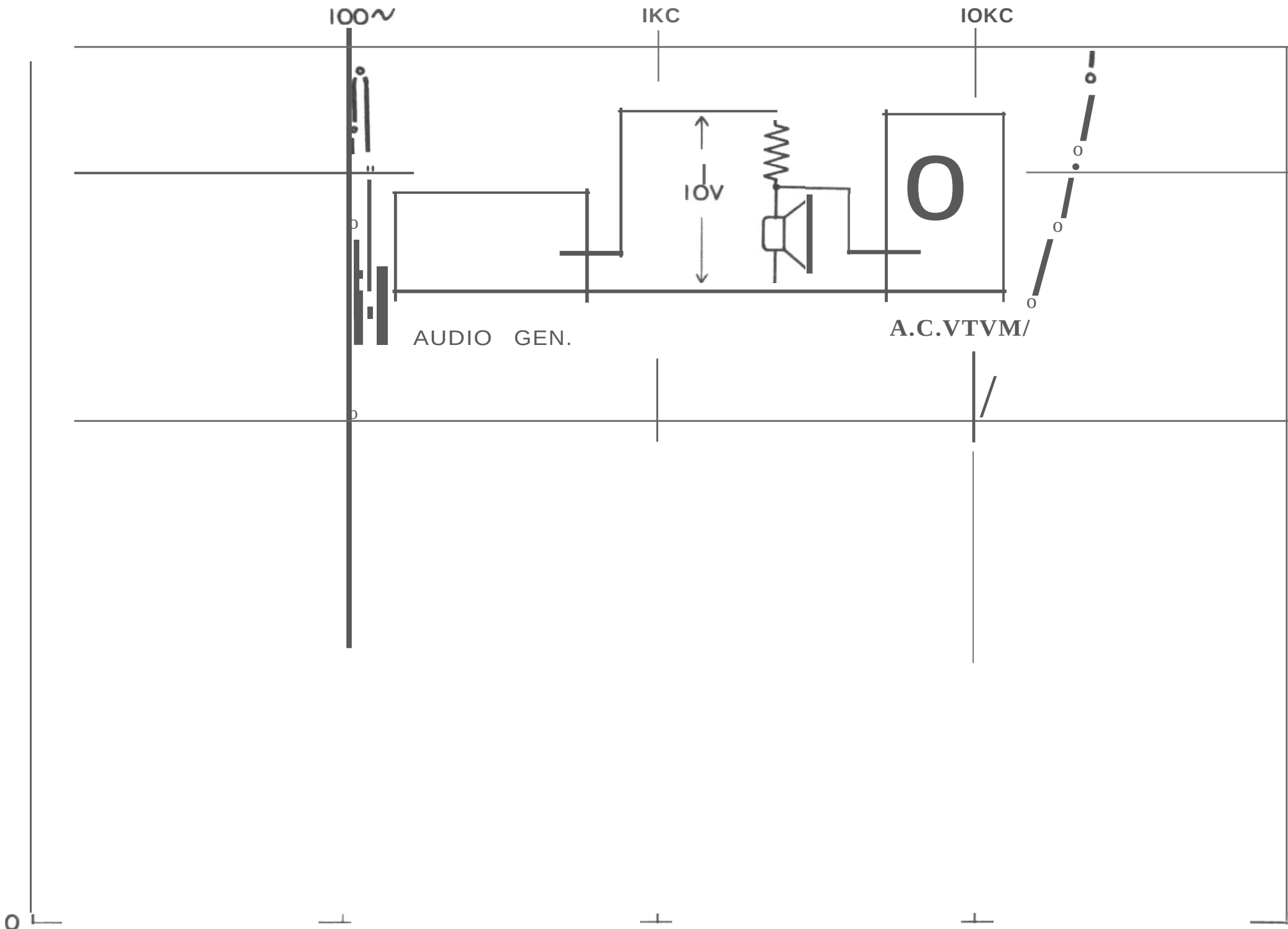


Figure 10

applications of the a. c. vtvm

BY LOUIS E. GARNER, JR.

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The possible applications of the A.C. VTVM, like those of many other electronic test instruments, are virtually unlimited. However, the majority of these applications are very specific, relating to specialized tests on individual types of equipment. In many cases, the user must exercise considerable ingenuity in adapting the A.C. VTVM to a particular test technique. Therefore, listing a few of the more common applications of this instrument should aid the user and serve as a guide to him in developing his own special methods.

CHECKING POWER SUPPLY RIPPLE

The amount of ripple voltage present in the output of a d.c. power supply is quite important in the design of electronic equipment. Some types of equipment can tolerate a much higher ripple level than others. Because of this, the engineer or technician must exercise a reasonable degree of judgment designing power supply filters for specific applications.

To incorporate a "perfect" filter in a power supply for equipment that can tolerate a fairly high ripple content may mean needless expense as well as much larger space and weight requirements for the completed design. On the other hand, permitting more than the "minimum" ripple in a high-gain audio system may lead to an extremely high hum level with resulting unsatisfactory performance ... a case of "expensive economy."

Generally speaking, the permissible ripple content ranges from about 0.1% for high-gain audio amplifiers to as high as 5% for CW R.F. Transmitters. The following technique may be used to determine "percent ripple" in a power supply Circuit:

1. With the power supply turned "Off," connect a d.c. voltmeter to measure the d.c. output voltage.

2. Connect the GROUND terminal of the A.C. VTVM to the common side of the power supply. This may be either the negative or the positive terminal, depending on which is grounded. In some cases, a connection from this point to a good "earth ground" may be desirable to minimize stray pick-up. (NOTE: If this test is conducted on the "transformerless" type of supply, make sure that the line connection

is such that the common side of the supply Circuit is at ground potential.)

3. Connect a .5 mfd condenser *in series with the INPUT voltmeter lead*, and, with the meter turned to the 300 Volt range, connect the free end of the condenser to the ungrounded side of the power supply. (NOTE: This "blocking" condenser should always be used where d.c. is present as well as the a.c. signal.)

4. Turn "On" the power supply. After a steady reading is obtained on the d.c. voltmeter, turn the A.C. VTVM RANGE switch to lower ranges until any a.c. ripple present may be easily read on the meter scale.

5. Percent Ripple is then determined as follows:

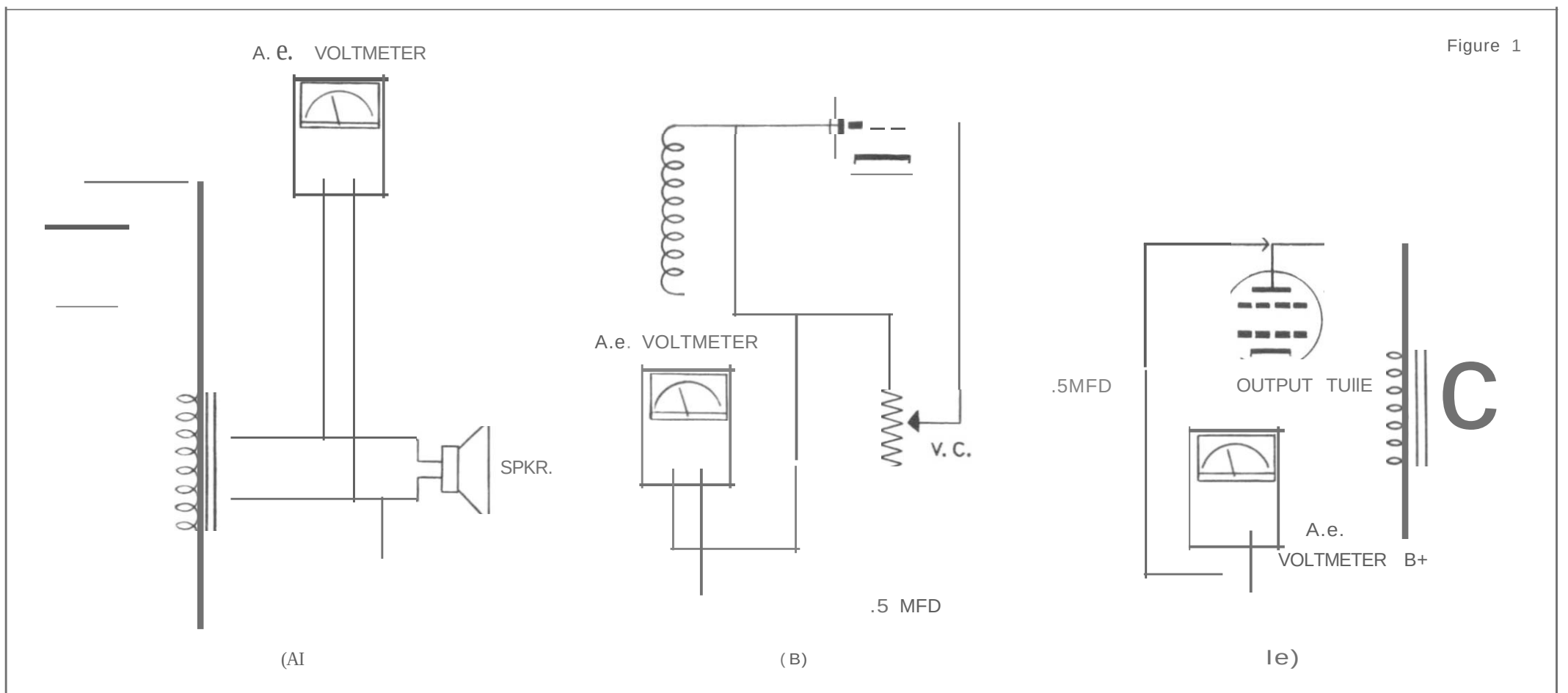
$$\text{Percent Ripple} = \frac{\text{A.C. Voltage (Ripple)}}{\text{D.C. Voltage (Output)}} \times 100.$$

6. *Special Cases ...* (a) Power supplies normally subject to a continuous drain, as those permanently connected in a circuit, should be checked under "full load" conditions; (b) power supplies subject to several different loads should be checked under each load condition ... or, as a minimum, under "no load" and "full load" conditions; (c) Percent Ripple in variable voltage power supplies should be checked under different output voltages as well as under varying load conditions.

AN OUTPUT METER

The A.C. VTVM serves as an excellent Output Meter for use when aligning AM Broadcast and Communication receivers. The meter may be connected directly across the loudspeaker voice coil, as shown in Fig. 1(a). If a .5 mfd "blocking" condenser is used in series with the INPUT terminal, the meter may then be connected to measure the audio signal across the volume control (Fig. 1(b)) or across the primary of the output transformer (Fig. 1(c)).

When the A.C. VTVM is used as an output indicator for aligning sets using AVC, the AVC circuit should be disconnected and a substitute d.c. voltage source used to supply a fixed bias ... a small bias battery is excellent for this purpose.



A NULL INDICATOR

When the A.C. VTVM is used as a Detector in a.c. bridge circuits, it serves as an excellent Null Indicator. Not only is the voltmeter far more sensitive than the headphones generally used for this application, but the needle movement permits a more positive indication of the "null" or balanced adjustment.

When used in this application, care should be taken that the RANGE switch is set to one of the higher voltage ranges as preliminary adjustments are made. The more sensitive ranges should be used *only* as balance is approached.

CHECKING ATTENUATORS

The degree of attenuation obtained from a particular "T," "H," "pi," or similar attenuator network may be determined quite easily by applying a small a.c. signal (obtained from a Sine-Wave Generator or similar source) to the input and using the A.C. VTVM to check the input and output voltage levels. For accuracy, the attenuator or "pad" should be terminated in its normal load impedance.

Where a "line" pad is used (600 ohm impedance), the signal level may be measured directly in "standard" decibels, using the db scale of the meter. The degree of attenuation, in db, is then the difference between the input and Output measurements.

The attenuation *ratio*, on the other hand, is obtained by dividing the *input voltage* by the *output voltage*. As an example, suppose the measured input level is 0.55 volts, while the Output is 0.05 volts. The attenuation ratio is then .55;.05 or 11:1.

MEASURING A.C. CURRENTS

The Heathkit A.C. VTVM may be used as a sensitive a.c. current meter by measuring the voltage across a small known

resistor connected in series in the circuit to be checked. Because of the high sensitivity of the voltmeter, a resistor value can be chosen that is small enough not to adversely affect the circuit's operation. Once the voltage drop across the resistor is known, circuit current is easily determined using Ohm's law.

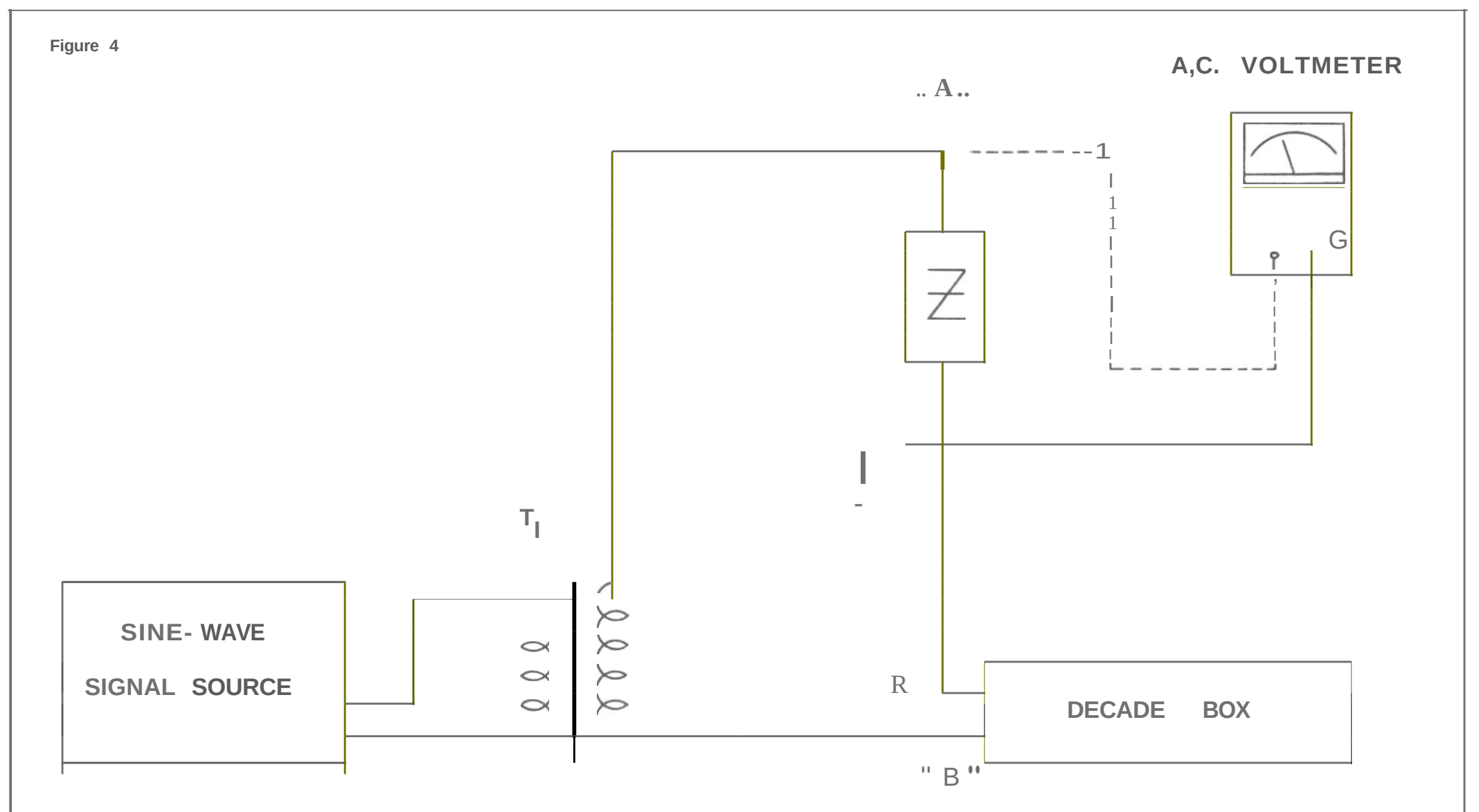
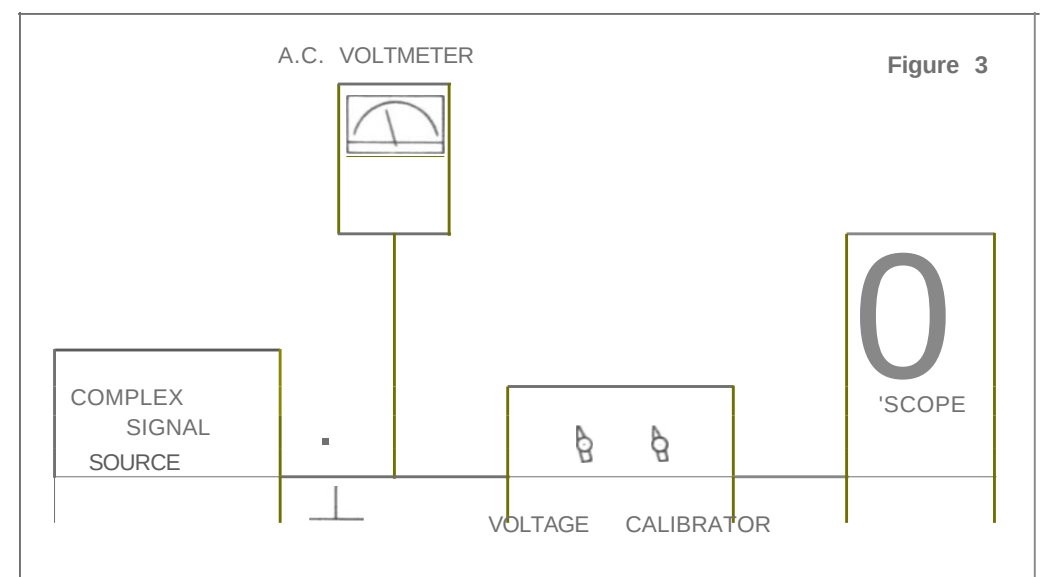
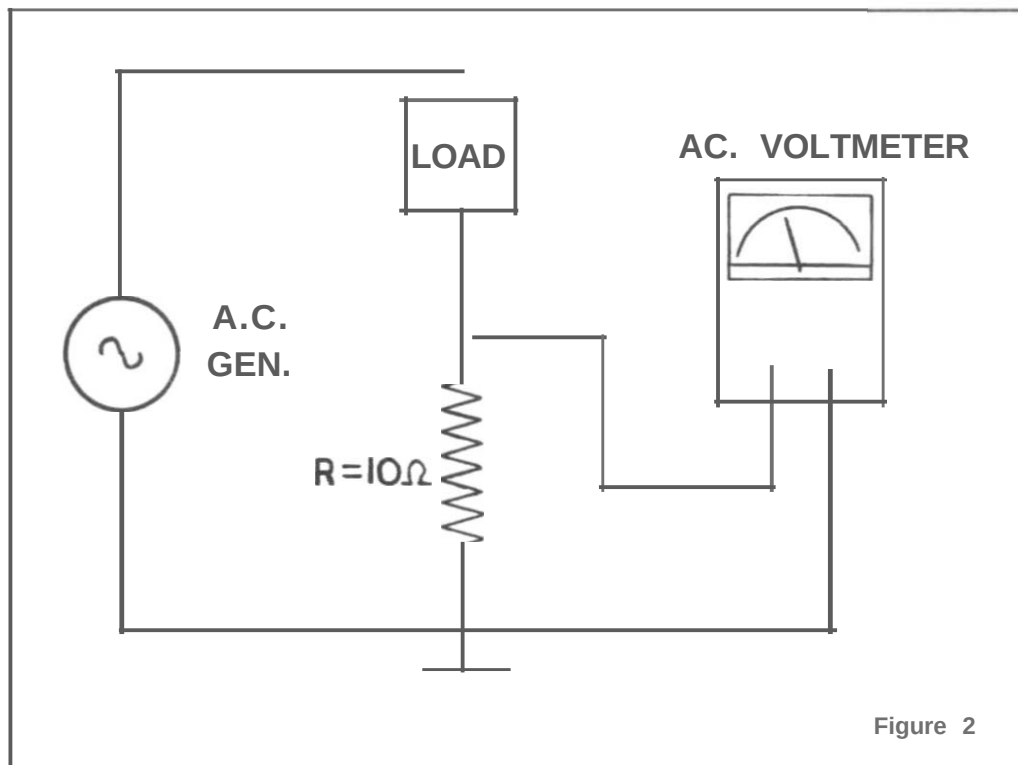
The resistor size should be as small as will still give a readable indication on the meter. If possible, the resistor value should be a multiple of "ten" so that the final calculation becomes simply a matter of adjusting the decimal point of the voltage reading. Values such as .001, .01, .1, 10, 100 and 1000 ohms are satisfactory ... for accuracy, precision resistors should be used.

An example of this technique is illustrated in Fig. 2. In this case a 10 ohm resistor has been used. (NOTE: In many electronic circuits, resistor values as high as 100, or even 1000, ohms may often be used without affecting circuit operation.) Let us assume that the meter reading is .003 volts, using the .01 Volt Range. Circuit current is then determined using Ohm's law ... that is,

$$I = E / R.$$

Substituting in this formula, we find that $I = .003/10$ or .0003 amperes. Converting to more familiar values, we find that the current is .3 milliamperes or 300 microamperes. This example gives some indication of the sensitivity possible. However, if R had been 100 ohms, and the same voltage reading were obtained, the current would then have been $I = .003/100 = .00003$ amperes ... that is, .03 ma or 30 microamperes!

On the other hand, large currents may be measured just as easily ... if a .01 ohm resistor were used, with a measured voltage drop of .05 volts, the current would be $I = .05/.01$, or 5 amperes.



MEASURING SIGNAL VOLTAGES HAVING COMPLEX WAVEFORMS

Your Heathkit A.C. VTVM is calibrated to indicate the RMS value of a pure sine wave ... that is, 70.7% of the peak voltage. Since the meter deflection is proportional to the average value of the input waveform, this calibration will not hold for signals having complex waveforms ... such as pulses, square-waves, and similar signals. In most cases, signals of this type are measured in terms of "peak-to-peak" voltages, using an Oscilloscope and Voltage Calibrator or a peak-to-peak voltmeter.

The 'scope and Voltage Calibrator method may prove time consuming where a large number of voltage measurements are

to be made of signals having identical waveforms ... as when checking individual stages in a pulse amplifier. In such a case, considerable time may be saved by using the A.C. VTVM to make the individual voltage measurements after determining the proper "multiplying factor."

The "multiplying factor" is the ratio between the peak-to-peak voltage and the voltage as indicated on the A.C. VTVM for a particular signal wave-shape. This ratio is determined using the 'scope and Voltage Calibrator, as follows:

1. Referring to Fig. 3, the A.C. VTVM, Oscilloscope, and Voltage Calibrator are connected to the complex signal source as shown. The signal may be a bi-directional pulse, a sawtooth, or any similar complex signal.

2. Using a fixed output, a voltage reading is obtained on the A.C. VTVM and recorded. As an example, let us assume that this is 16 volts.

3. Without changing the output level, the peak-to-peak voltage of the signal is now measured, using the 'scope and voltage calibrator. This value is also recorded. We will assume this to be 48 volts in the example.

4. To determine the "multiplying" or "correction" factor for the A.C. Voltmeter for the particular signal waveform checked, simply find the ratio between the two voltage readings, as obtained in steps 2 and 3 ... in the example used, the ratio would be $48/16 = 3$. This means that as long as the same signal waveform is checked, it is only necessary to multiply the actual AC VTVM reading by three to obtain the peak-to-peak voltage.

5. Do not attempt to use the "multiplying factor" determined in Step 4 with other signal waveforms. Where additional tests are necessary, with a different signal, determine a new "multiplying factor," as outlined.

MEASURING IMPEDANCES

The A.C. VTVM may be used in conjunction with a sine-wave signal source and the Heathkit *Decade Resistance Box* to determine an unknown impedance, using the circuit shown in Fig. 4.

Transformer T₁ may be omitted if the sine-wave source used supplies a signal that is isolated from ground. However, where used, an ordinary interstage coupling transformer is satisfactory for almost all audio work.

To make the measurement, the A.C. VTVM is used to check the voltages across the unknown impedance (Z) and across the known resistor (R - the Heath *Decade Resistance Box*) ... in Fig. 4, this is accomplished simply by transferring the "hot" or INPUT lead from point A to point B.

The resistance value is then changed until the two voltages measured are equal ... at this point, the resistance as indicated by the setting of the Decade Box is equal, in ohms, to the impedance of the unknown.

If it is desired to measure the impedance of the unknown at several different frequencies, the technique may be repeated as often as is desired ... changing the frequency of the supplied sine-wave signal each time.

servicing with the heathkit condenser checker

BY LOUIS E. GARNER, JR.

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Since resistors and condensers comprise the major portion of fixed components in electronic equipment, it is not surprising that the majority of troubles encountered are due to defects in these two types of components (excluding troubles due to defective tubes). A defective resistor or condenser might even result in a relatively expensive part (such as a power transformer) becoming damaged.

Practically every common complaint encountered in radios, amplifiers, or TV, such as distortion, intermittent operation,

hum, oscillation, weak operation, or even a "dead" set may be caused by either defective resistors or condensers. Often, the defect is cumulative ... a leaky or shorted condenser may result in a resistor burning open. The open resistor, in turn, may reduce the current drain from the power supply sufficiently to increase the B voltage (where the power supply has poor regulation), and this, in turn, may result in another condenser breaking down.

Thus, the Resistor-Condenser Checker, permitting the serviceman to accurately check the condition of these important components, becomes an extremely valuable test instrument.

However, to obtain the greatest value from the Resistor-Condenser Checker in servicing work, the instrument should be used as an aid to other servicing techniques, not as a substitute. When servicing a piece of equipment, *do not start by testing every resistor and condenser in the set*. Instead, first isolate the trouble as a defect in a specific stage, using conventional test techniques such as Signal Tracing, Signal Injection, circuit disturbance tests, etc. Then the Resistor-Condenser Checker may be used to advantage to test suspected components in that stage.

Finally, when a service job is completed and the equipment again in normal operating condition, the Resistor-Condenser Checker should be used to check the capacity, power-factor and leakage of *all electrolytic condensers* in the set, as well as

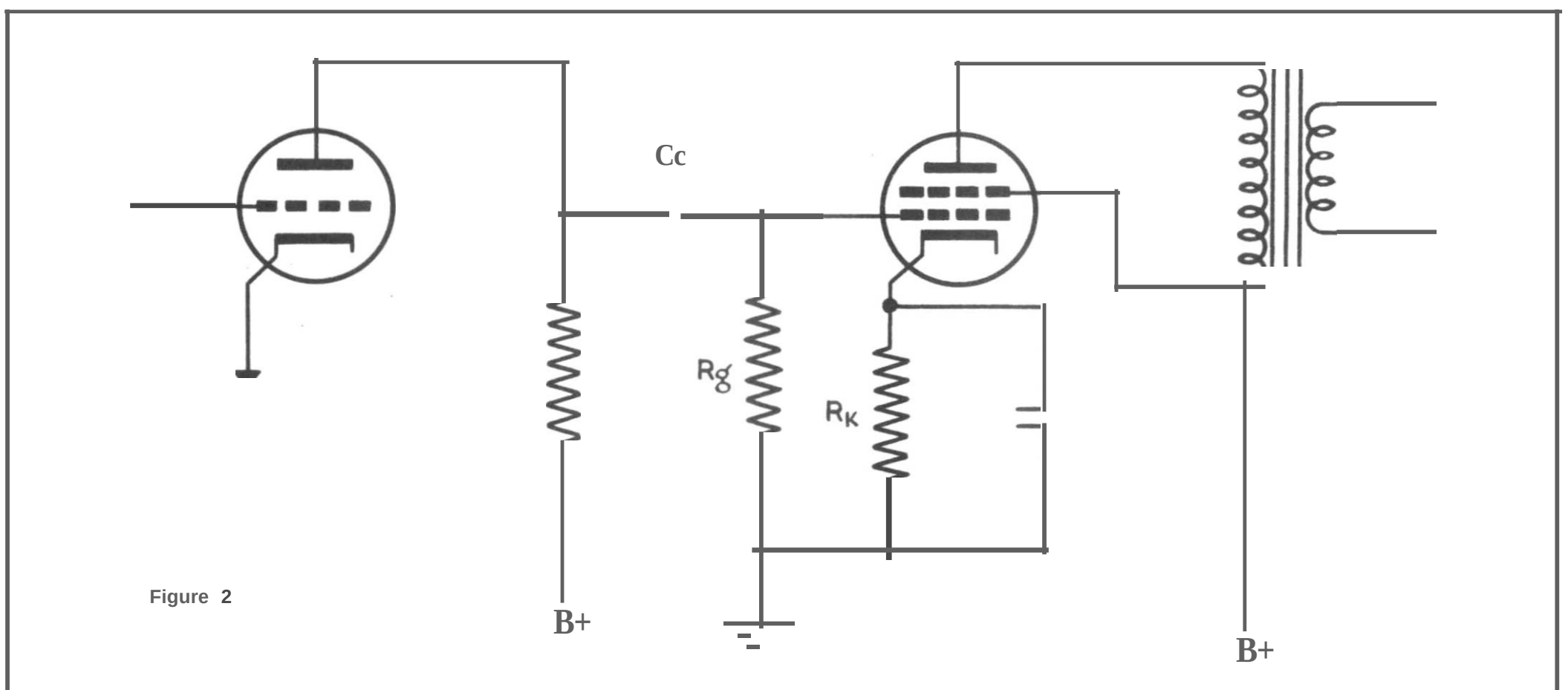
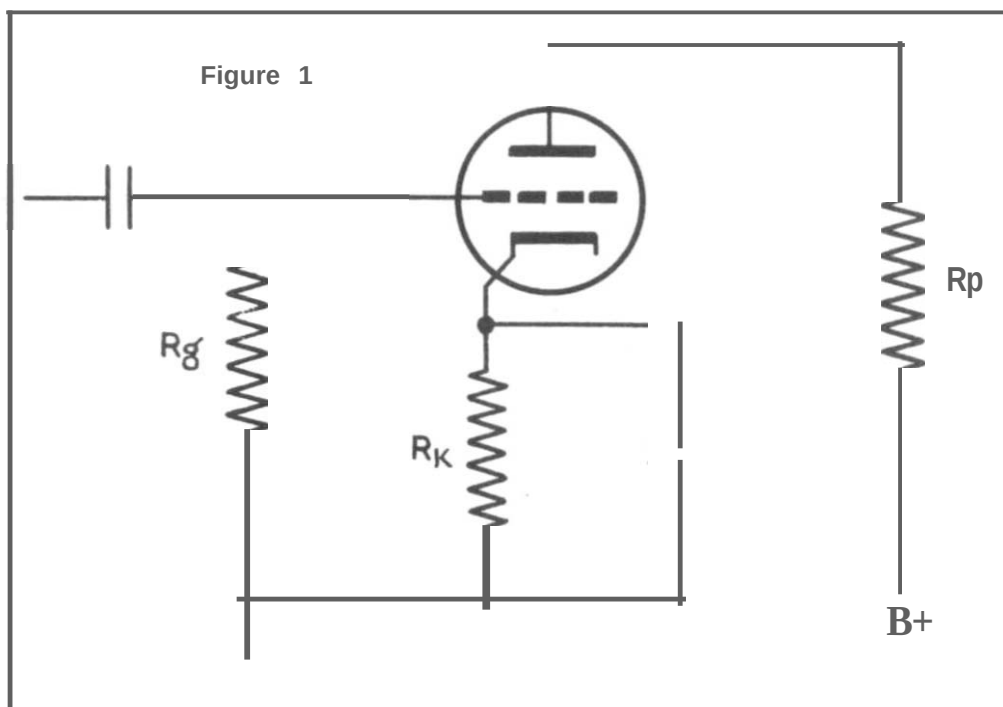


TABLE A: RESISTOR DEFECTS

RESISTOR	DEFECT	EFFECT ON RECEIVER
Ballast or Line	Open	Tubes don't light-set dead!
	Short	Tubes glow bright-burn out often-line fuse may blow.
	Change Value	Tubes light too bright or not enough-depends on change-set weak-distortion.
Bleeder Resistor	Open	Screen and Plate voltages high-oscillation-possible breakdown of filters.
	Short	Low screen, plate voltages-heavy power drain may damage rectifier or transformer-set dead.
	Change Value	Either of above-depends on change-weak, dead, oscillation, or distortion.
Filter Resistor	Open	No B plus-set dead-input filter may short.
	Short	Hum-high B plus-distortion.
	Change Value	Either of above-in less degree.
Plate Resistor	Open	No plate voltage on stage-stage dead.
	Short	Little stage gain (weak), high plate voltage.
	Change Value	Either of above-also distortion.
Screen Resistor	Open	No screen voltage-stage may be dead, weak, or distorted.
	Short	High screen voltage-may ruin tube-oscillation or distortion.
	Change Value	Either of above.
Cathode Resistor	Open	Stage usually dead-if cathode by-pass condenser breaks down-distortion.
	Short	Incorrect bias on stage-may introduce distortion, oscillation or motorboating.
	Change Value	Either of above.
Grid Resistor	Open	Motorboating-hum-oscillation-distortion-may even cause set to be "dead".
	Short	Stage dead.
	Change Value	Either of above.
Diode Load	Change Value	Distortion or "dead set".

the condition of the more critical resistors and other condensers. All components nor up to standard should be replaced. By taking this important step, the serviceman can often protect himself against costly "call-backs"

RESISTOR-CONDENSER DEFECTS:

In Tables A and B are listed many of the major complaints

caused by defective resistors and condensers. Note that only the more common complaints are listed, and that many of the complaints may also be caused by defects in other components. However, once the tubes in the equipment are tested and eliminated as a possible cause of the complaint, there is a good chance that the trouble is due to a defect in one of these two types of components.

TABLE B: CONDENSER DEFECTS

CONDENSER	USUAL TYPE	DEFECT	EFFECT ON RECEIVER
line (117v)	P	Open	Noise, hum.
		Short	Blows line Fuse.
		Change Val.	Usually little or no effect.
Filter	El	Open	Hum-distortion-if input, low B plus.
		Short	No B plus- dead-may damage rectifier or power transformer.
		Change Val.	Hum- distortion- different B plus.
		Hi Power Fac.	Hum-distortion- lower B plus.
		Leakage	Lower B plus- set weak.
Plate by-pass' (output)	P	Open	"Tinny" sound-set may oscillate.
		Short	No plate voltage- set dead- output transformer may be damaged.
		Change Val.	Decrease-similar to open. Increase- hi notes loss- tendency to "boom".
		Leakage	Low plate voltage- stage weak.
Screen By'pass	A.F.-P,C R.F.-P,C,M	Open	Oscillation- hum-distortion.
		Short	No screen voltage- set weak or dead-screen grid resistor may burn out.
		Change Val.	Oscillation- distortion.
		Leakage	Low screen voltage-signal weak or distorted.
Cathode By-pass	A.F.-EL R.F.-P,C,M	Open	Degeneration-stage gain reduced-if common to two or more tubes, oscillation may result.
		Short	Incorrect bias- distortion.
		Change Val.	Decrease- low notes lost-degeneration. Increase-little change.
		Hi Power Fac.	Similar effect to value decrease.
		Leakage	Similar to short, but some leakage is tolerable.
Coupling	A.F.-P,C R.F.-P,C,M	Open	Set dead or very weak.
		Short	Set may be dead-or heavy distortion- tube in following stage damaged- if output tube, power supply may be overloaded.
		Change Val.	Decrease-weak operation. Increase- little change or oscillation.
		Leakage	Distortion- if to output tube, may cause tube to become gassy- in a.c.-d.c. receivers may cause rectifier tube to be damaged due to power supply load.

LEGEND:

A.F. - Audio Frequency Stages.
El - Electrolytic condenser.
C - Ceramic condenser.

RF. - Radio Frequency Stages.
P - Paper condenser.
M - Mica condenser.

The Tables given apply specifically ta AM and FM receivers. However, similar defects will cause correspond. ing effects in TV receivers . . . particularly in the video and audio iJ. stages, and in the audio section. In addition, resistors and condensers in sync, sweep, and high voltage sections may cause many additional effects, ranging from mere loss of sync to complete loss of picture and raster, or a badly distorted picture.

In Table A common resistors encountered are listed in the first column, with defects in the second column, and the effect of each defect on equipment operation in the last column. Table B is similar except for the addition of a column listing the usual type of condenser.

QUICK TESTS:

In many cases a voltmeter serves to give a quick test of a part while still in the circuit, thus determining whether a further test with the Resistor-Condenser Checker is justified. Where possible, such quick tests should be made before removing the suspected part.

A conventional resistance-coupled amplifier stage is shown in Fig. 1. If the plate resistor, R_P , should short, the full B plus voltage will be measured at the plate of the tube (rather than a lower voltage due to resistance drop). The same symptom may occur even if the resistor is in good condition should the tube not be drawing plate current (a defective tube or an open cathode resistor could cause this). However, a check of the tube condition with the Heathkit Tube Tester would soon eliminate the tube as a possible cause of trouble. The defect would then be either in the cathode resistor or the plate resistor (assuming normal B voltage available, and the tube socket to be o.k.).

An open resistor, on the other hand, would remove the plate voltage, even though B plus is available. The same condition could be caused by a shorted tube or a physical short in the circuit wiring. Again, a tube tester check would eliminate the tube, leaving the resistor to be checked with the Resistor-Condenser Checker.

Two common defects causing essentially the same complaint from an operational viewpoint are a leaky coupling condenser and a gassy tube. Referring to Fig. 2, in which is shown the output stage of a typical receiver, distortion of essentially the same type will occur if the output tube becomes gassy or if coupling condenser C becomes leaky. To identify the defect causing the complaint, a d.c. voltmeter is used to check for voltage across the grid resistor, R_G . A d.c. voltage, with the grid end positive, indicates definitely that one or both of the two conditions exist.

To further identify which defect is present, the coupling condenser is disconnected at the grid end. Again a voltmeter check is made across R_G . If the d.c. voltage is still present, the tube is gassy and should be replaced. If the voltage has disappeared, chances are the coupling condenser is leaky. A final test may then be made with the Resistor-Condenser Checker.

audio generator applications

BY GLEN SOUTHWORTH

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INTRODUCTION

The audio generator is the basic signal source for practically all tests of audio equipment. It may be used for continuity tests or signal tracing, for gain measurements and frequency response tests over the complete range of hearing. The audio generator is also the signal source in detection and measurement of linearity, harmonic, intermodulation, difference tone, and some transient distortions that may occur in any part of a sound reproducing chain. In addition, the extended high frequency range of the HEATHKIT Audio Generator makes it useful in connection with work on supersonic frequencies and in the test and alignment of AM receivers.

GAIN MEASUREMENTS WITH THE HEATHKIT AUDIO GENERATOR

The output is controlled by two attenuators, thus making it possible to obtain accurate output levels over a range of 100 microvolts to ten volts. This range may be extended below 100 microvolts by means of external attenuators. The wide range of output voltages makes the audio generator very convenient in making gain measurements of high or low level audio equipment.

Gain measurements may be made over a single tube stage or over an entire amplifier. For greatest accuracy, the output of the Audio Generator should be measured when connected to the amplifier or equipment under test. The output of the equipment being tested is then measured, a high impedance AC voltmeter such as the HEATHKIT AC VTVM being used in both cases, and the gain of the equipment under test may be obtained by dividing the output voltage by the input voltage.

Preferably, gain measurements should be made at high, medium, and low input levels, as, if distortion occurs in the equipment under test, the gain may vary appreciably, depending upon the level of the input signal. In the case of audio amplifiers, it is frequently desirable to know the maximum power output available, and the ten volt output of the HEATHKIT Audio Generator should make it possible to

drive nearly any amplifier having two or more stages to full output. In testing output capabilities, it is useful to make tests over a wide frequency range, as it frequently happens that maximum power available at very high and very low frequencies is considerably less than that obtainable at mid frequencies.

FREQUENCY RESPONSE MEASUREMENTS

Frequency response measurements are one of the commonest audio tests, and may be applied to individual components or a complete audio chain. In the case of a unit, such as the power amplifier, it is usually desired to achieve a "Flat" response curve over the range of human hearing or beyond, while in phonograph preamplifiers or tone control systems it may be desired to achieve emphasis or de-emphasis of certain frequencies. In either case, measurements with an audio generator indicate how closely the design objective has been achieved, and what further steps, if any, are necessary.

When making frequency response measurements several precautions should be taken. Care should be exercised that the device under test is not overloaded, either in the first or later stages. Likewise, it should be noted whether excessive noise or hum is generated which might produce misleading results. Both input and output of the device under test should be properly terminated with the correct impedance, and although the output of the audio generator is designed to be essentially uniform over the audio band, it may be desirable to measure the output of the generator at various frequencies to insure that the loading of the associated equipment does not alter the frequency response.

When making frequency response tests, it is wise to do so at several different input levels, as linearity distortion in the equipment under test may greatly alter the apparent response curves obtained. An example is shown in the accompanying response curve of a push-pull amplifier using a high quality Output transformer. Note that though the frequency response is excellent at high output levels, attenuation at low frequencies becomes severe at levels of a milliwatt or so, and together with

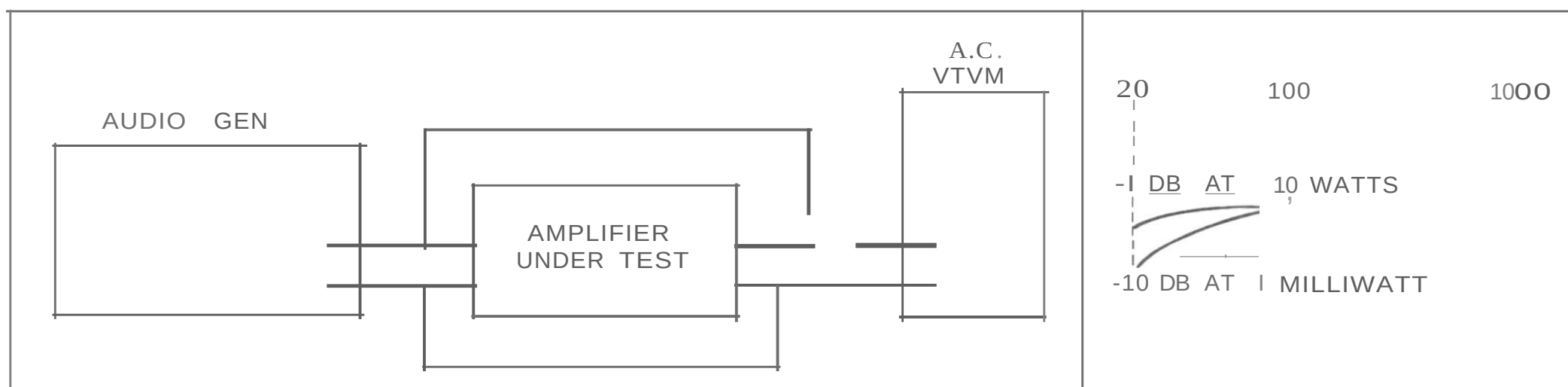


Figure 1

Test setup for making gain measurements, frequency response runs, or linearity tests.

Figure 2

Frequency response of high quality output transformer at two different outputs.

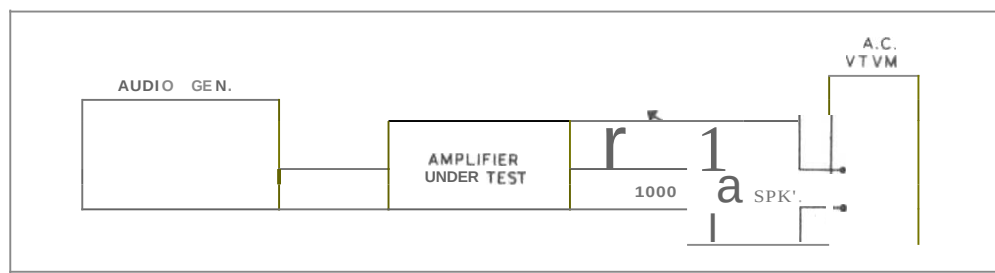


Figure 3

Test setup for determining amplifier output regulation or the speaker-baffle characteristics reflected back to voice coil.

the serious distortion produced leads to an apparent lack of bass in low level listening. This change in low frequency response appears to be a characteristic of many of the more expensive push-pull output transformers, but can be reduced by the application of inverse feedback. On the other hand, cheap output transformers may exhibit the opposite characteristic and measure better at low levels than at high ones, but this may not be correctable by means of inverse feedback.

In making frequency response tests of power amplifiers designed to drive a varying load, such as a loudspeaker or cutting head, it may be wise to test the response characteristics under different load conditions in order to insure optimum performance. Tests of other parts of the audio chain, such as speakers, microphones, recording equipment, etc., may likewise be made with the HEATHKIT audio generator, but usually require additional equipment of known quality. For example, frequency response measurements of disc cutting equipment would require a "Flat" playback pickup and pre-amplifier, while measurements of loudspeaker performance in a given acoustic environment would require a high quality microphone and preamplifier in order to convert the acoustic output to electrical energy measurable by an AC voltmeter.

A test which is frequently useful is to connect a high impedance AC voltmeter, across the voice coil terminals of a loudspeaker and then examine the changes in output level as the audio generator is slowly swept through the audio range. In a high quality amplifier, having a high damping factor, the change in level may be very small, while in a poor amplifier a very large change in response may occur. Usually, a peak occurs at the primary resonance of the speaker and the level increases at high frequencies. By isolating the speaker from the amplifier by means of a thousand ohm resistor, the changes in frequency response produced by the speaker are emphasized and this may be used as a convenient way of detecting transient distortions, through peaks or dips in the response curve, or as a convenient means of adjusting the port in a bass reflex inclosure.

DISTORTION MEASUREMENTS WITH THE HEATHKIT AUDIO GENERATOR

The generator is the basic signal source for numerous types of distortion measurements. The simplest of these is the linearity test, or a means of determining whether the device being examined has the same ratio of input to output signals at all power levels. The precision step attenuator incorporated in the HEATHKIT audio generator makes it ideal for tests of this kind when used in conjunction with the HEATHKIT AC VTVM. For example, in testing an amplifier, the output of the audio generator might be set to the ten volt scale and the variable attenuator adjusted so that the amplifier output provided some convenient deflection of the AC VTVM, such as zero decibels. The range switch of the generator may then be changed to the one volt scale, providing an attenuation of 20 db., and the sensitivity of the meter then increased by 20 db. If no linearity distortion is present, the AC meter will again read zero db. If linearity distortion, such as would pro-

duce volume expansion, is present, the meter will read low, while if volume compression occurs the meter will read high. In practice, measurements of this nature should be made over as wide a range as possible, and the construction of the HEATHKIT audio generator is such as to provide 80 decibels of gain variation in four steps. Likewise, measurements of linearity distortion should be made at low, medium, and high frequencies, as in many cases the amount of distortion present will vary with the frequency. Similarly, precautions should be taken that extraneous hum or noise do not cause misinterpretation of meter readings.

Linearity tests may be easily applied to any element in the audio reproducing chain and appear to give a good indication of the tonal effects that will be produced. A system which introduces volume compression may have a warmer and bassier sound, while a system which produced instantaneous volume expansion would tend towards harshness and high frequency noise emphasis.

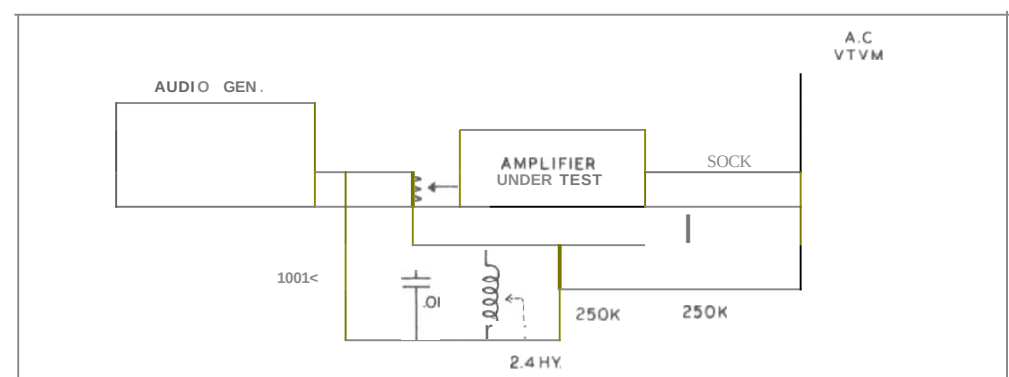


Figure 4

Test arrangement for making distortion tests by the cancellation method. Signals from the audio generator and the amplifier output must be exactly out of phase for accurate readings. First the 250k potentiometer is opened up and the audio generator tuned to about 1000 cps to get maximum meter deflection. Pot is then closed and amplifier output adjusted for desired meter deflection. After this, the 250K pot is gradually opened till minimum meter deflection occurs, and the frequency of the audio generator gradually varied for further reduction of meter reading. The setting of the 250K pot and the frequency of the generator interact to some degree, and several adjustments may be necessary for the minimum meter reading, which will indicate the percentage of distortion present. If it is of importance, residual distortion in the audio generator may be detected by the same test by removing the amplifier from the circuit and using a phase inverter, such as a transformer.

HARMONIC DISTORTION MEASUREMENTS

More commonly used in audio measurements is the harmonic distortion analysis. There are two main types of harmonic measurements, one in which the total strength of all harmonics are measured simultaneously, and another in which the relative intensity of individual harmonic components are measured separately. In the first type of test, the strength of the signal from the output of the device under test is measured, and then the fundamental frequency is removed, either by a filter or by cancellation, and the remaining harmonic components measured. The accompanying block diagram shows one method of doing this by cancelling out the fundamental with an out-of-phase voltage from the audio generator. As the voltage from the audio generator must be exactly 180 degrees out of phase for perfect cancellation, a phase shifting network in the form of a resonant circuit is used to provide greater accuracy of measurement. The values given for the resonant circuit are approximately for 1000 cycles and phase shift over a considerable range may be obtained by varying the audio generator slightly above or below this frequency. Once a 180 degree phase relationship has been achieved, the cancellation voltage from the generator is gradually increased until a minimum reading is found, and this will indicate the percentage of total distortion occurring.

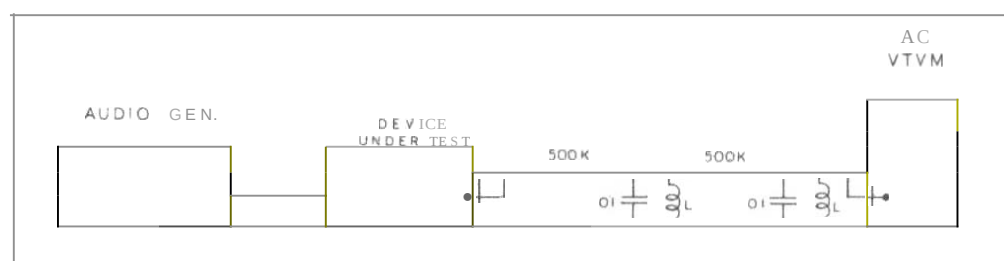


Figure 5

Test arrangement for measuring individual harmonics in a signal. High "Q" inductances must be used and CHICAGO 2.4 hy. noise suppressor chokes are recommended. With the values of capacitance shown, this will give a fundamental frequency of approximately 1000 cycles. Selectivity is such that .1% third harmonic distortion can be detected.

The second method of measuring harmonic distortion may be accomplished by setting up a simple, highly selective, resonant circuit, such as shown in the accompanying diagram. The values given are for a resonant peak of approximately 1000 cycles. In operation, the generator is first tuned to 1000 cps and maximum meter deflection set at some convenient figure. The generator is then tuned to 500 cycles, at which point the output of the tuned circuit will indicate second harmonic distortion of the 500 cycle signal. The generator may then be tuned to 333 cps and the third harmonic component of the signal read, and so on to lower frequencies and correspondingly higher order harmonic components.

The advantage of measuring individual harmonic components is that they give an indication of where the trouble is occurring. For example, second harmonic components of appreciable strength could indicate unbalanced push-pull tubes or improper bias on single ended stages. Third harmonic distortion might indicate wrong bias on push-pull tubes or overdriving of some stage. High order distortion usually indicates something seriously wrong, such as a short circuit, extreme overdriving, or incorrect tube voltages. As mentioned earlier, for a comprehensive test of equipment performance, measurements should be made at all power levels, at different frequencies, and under different load conditions. Similarly, residual distortion in the audio generator, itself, must not be neglected when making precise measurements.

INTERMODULATION DISTORTION MEASUREMENTS WITH THE AUDIO GENERATOR

Intermodulation distortion measurements consist of applying both a high and a low frequency to the audio equipment being tested and measuring the degree of interaction that takes place due to nonlinearity. In the HEATHKIT Intermodulation Analyzer, these frequencies are 60 and either 3000 or 7000 cycles, from self contained sources. Somewhat more comprehensive measurements can be made by using the HEATHKIT audio generator as an external signal source to provide a low frequency signal of from twenty to four hundred cycles, or as a high frequency signal variable from 2000 to twenty kilocycles. The advantage of this is that equipment performance may change decidedly when different test frequencies are used, and in some instances it may be desired to make intermodulation tests on equipment which does not have good low frequency response, making it necessary to use a signal of appreciably higher frequency than sixty cycles.

DIFFERENCE TONE MEASUREMENTS

An interesting, but not too widely used, distortion measurement may be made by applying two high frequency tones, separated by only a hundred cycles or so, to the equipment under test and measuring any spurious low frequency signals that may be generated by the interaction of the two high frequencies. A diagram of the test setup used is shown, and

includes two audio generators, the amplifier or other device being tested, a simple low pass filter, and the HEATHKIT AC VTVM. The outputs of the two generators are set to the same level and the output of the device being tested is measured for a reference level. The output of the low pass filter is then measured and indicates the percentage of difference tone distortion occurring. The two generators may be slowly swept through the region from one thousand to 20 or 30 kilocycles and the percentages of distortion measured at various points. To insure that the frequency difference of the two generators lies within the operating range of the low pass filter, one of the generators may be set at a given frequency and the other slowly swept about it until maximum deflection from the low pass filter occurs. In addition, the efficiency of the low pass filter may be checked at any frequency by merely disconnecting one of the generators and noting any residual output from the low pass filter. Similarly, precautions should be taken against hum pickup, as this would cause erroneous readings.

Excessive difference tone distortion in equipment appears to cause several disagreeable listening effects. It may give rise to excessively audible noise in disc or especially rape reproduction due to the fact that beats or modulations in supersonic components then generate audible frequencies. and the elimination of this type of distortion pays great dividends in listening comfort. Similarly, on some complex musical passages, difference tone distortion may produce a very rough or garbled tone, with the spurious low frequency tone sometimes being plainly audible in flute, soprano, or other high frequency passages. It should be noted that difference tone tests may give considerably different results than intermodulation tests, as it gives information regarding interaction between two high frequencies, while IM tests state the interaction between a high and a low frequency.

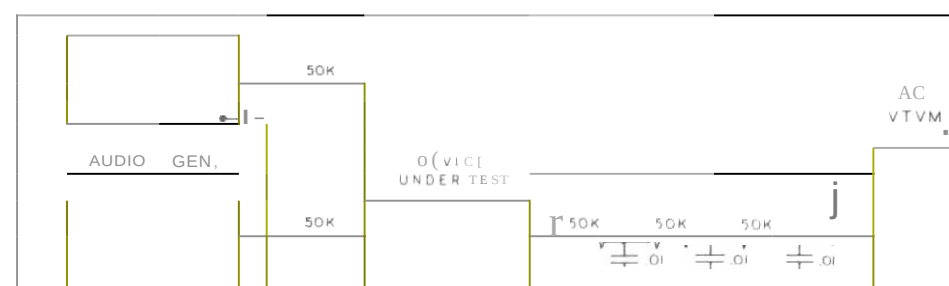


Figure 6

Use of two separate audio generators for making difference tone distortion tests. With the filter shown, percentages of .1% or less can be measured above 3000 cps, but output of filter is at maximum when frequencies are separated by 50 cycles or less. Difference tone measurements may be made at wider frequency separations through means of resonant filters, such as shown in figure 5.

TRANSIENT DISTORTION TESTS WITH THE HEATHKIT AUDIO GENERATOR

Although the audio generator is essentially thought of as a device for steady state measurements, its output waveform may be altered to provide non-sinusoidal waveforms. A simple circuit is shown in the accompanying schematic which allows pulses to be produced from the audio generator. Essentially, it is a device which clips off and passes only the peaks of the sine wave output from the generator. Pulses of either positive or negative polarity, or a combination of both may be obtained in this way, and the relative width of the pulses obtained is determined by the output level of the audio generator. For broad pulses, the full output of the audio generator is applied to the clipping circuit, for narrow pulses, the output of the

generator is attenuated until it barely exceeds the bias voltage supplied by the flashlight batteries. Pulse repetition rate is determined by the frequency setting of the audio generator.

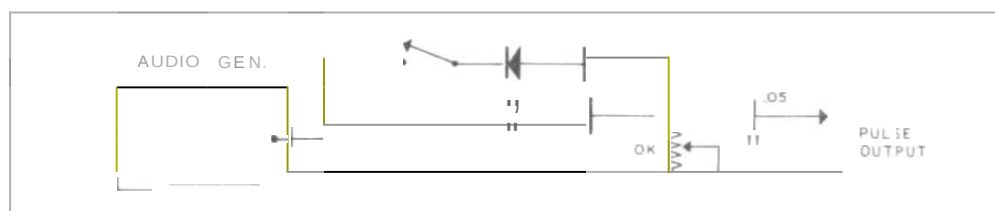


Figure 7

A simple circuit for obtaining pulse output from a sine wave generator. Small $1\frac{1}{2}$ volt flashlight batteries are used for bias voltages. Rectifiers are miniature germanium types. A variable load is used across the output to minimize capacitive distortions at high frequencies.

An oscilloscope is almost essential in making tests of transient response. The simplest procedure is to first observe the output waveshape from the pulse generator, and then observe the output of the device being tested. If the pulse repetition rate is very slow, such as twenty cycles, then ringing resonances and their corresponding damped wave trains are easily observable. In other cases, such as amplifiers and tone controls, it may be desirable to use a high pulse repetition rate, as this produces a correspondingly narrower pulse and makes easier the observation of distortions occurring in reactive elements. A test which is sometimes of significance is to apply a sine wave at the same time as the pulse, and then

observe the oscilloscope screen for any intermodulation distortion that may take place following the pulse. Similarly, the output level of the sine wave should be checked both before and after the pulses are applied, as the pulses may cause a change in tube biasing and a resultant change of gain.

MISCELLANEOUS APPLICATIONS OF THE HEATHKIT AUDIO GENERATOR

The extended high frequency range makes it very useful in the field of supersonics, for tests and adjustment of bias voltages in tape or wire recorders, and in troubleshooting and alignment of AM receivers. In many cases there will be sufficient harmonic radiation to make the generator useful as a signal source at frequencies well above one megacycle.

The audio generator may also be used for special sound effects in radio or stage productions. The use of two or more generators and pulse forming networks can produce a large number of tonal effects. Other, more specialized, uses include the use of the generator for impedance measurements or determining the "Q" of resonant circuits. Unknown frequencies can be identified by "Zero beating" the local oscillator with them.

The HEATHKIT AC VTVM is recommended as an ideal companion instrument to the audio generator, and a large number of measurements and experiments can be made with these two units.

measuring audio filters with an audio generator and ac vtvm

BY LAWRENCE FIEMING

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MEASURING AUDIO FILTERS

The subject of filter design is too large for more than a few brief comments here, but the practical technique of measuring the pass-band characteristics of filters involves some simple considerations that are not covered in the usual texts. The following notes relate to L-C filters of the classical types.

Assuming that we have a filter and know its characteristic impedance, the response curve is found with the set-up of Figs. 1 or 2. The filter must look into resistances equal to its characteristic impedance at each end. To this purpose, resistors are provided in the same way as for transformers. For high impedance filters, use Fig. 1, and for low impedance filters Fig. 2. In the latter figure the input series resistor is high compared to the filter impedance, the input shunt resistor equal to the filter impedance. Values are not critical.

The measurement is now merely a matter of varying the generator frequency and reading the AC VTVM. Signal level is not critical. A convenient practice is to set the generator output so that the AC VTVM reads 1 volt in the flat part of the filter pass band. The actual generator voltage will then be around 2.2 volts or 7 db higher —6 db due to the unavoidable loss in the matching resistors, and 1 db or so insertion loss in the filter itself.

If the impedance of the filter is not known, the right value can often be found by trial. Try pairs of terminating resistance of different values until a smooth pass band characteristic is obtained, free from peaks at the edges or excessively droopy shoulders. Mismatched filters usually exhibit peaks at the band edge, before they start to cut off. Fig. 3 shows some curves illustrating the effects of mismatching on the response of a simple low-pass filter.

DESIGN OF SOME SIMPLE FILTERS

Once the tools for measuring a filter are available, it is quite feasible to construct many types of filters out of easily available parts. The design formulas for "constant-K" high-

pass and low-pass filters are included here for the filter configurations that use the smallest numbers of inductors.

The low-pass circuit or "configuration" is given in Fig. 4A for one section and Fig. 4B for more than one section. The formulas are:

$$L = \frac{R}{\pi f_c}$$

$$C = \frac{L}{R^2}$$

where L is inductance in henries, C is capacitance in microfarads, R is the characteristic impedance in kilohms, and f_c the cutoff frequency in kilocycles. L and C, incidentally, will tune to $\frac{1}{2} f_c$.

The shunt condensers at the ends of a low-pass filter should be half the value of C that the formula gives, as indicated in the Figures; the intermediate condensers in multi-section filters are the full value of C.

For high-pass filters, Figs. 4C and D,

$$L = \frac{R}{4\pi f_c}$$

$$C = \frac{L}{R^2}$$

the symbols having the same definitions as before. The condensers at the ends are twice the formula value of C; intermediate condensers in multi-section filters are equal to C. L and C will tune to $2f_c$, this fact is useful in finding experimentally the correct value for C.

In all "constant-K" filters the rate of attenuation beyond the cutoff frequency is 6 db per octave times the number of reactive components in the filter. For Fig. 4A or 4C, the rate is $6 \times 3 = 18$ db per octave. For Fig. 4B or 4D, it is 30 db per octave. This applies to all filters which do not incorporate tuned circuits which give a rejection peak at some frequency.

Figure 1

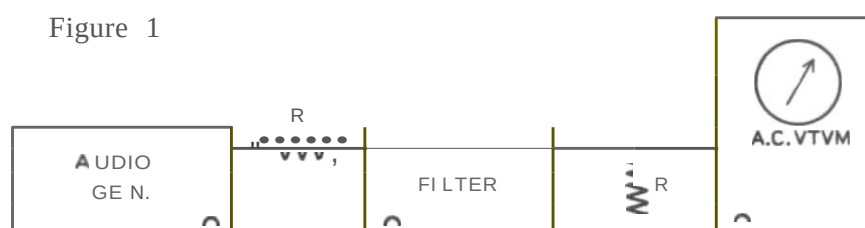
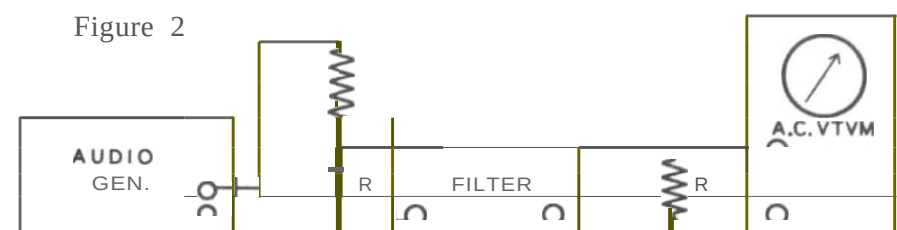


Figure 2



The effect of Q of the inductors is principally at the edges of the pass band, provided Q is at least 5 or 6. 10w-Q units tend to droop or round-off the curve before it gets to the true cutoff frequency.

In the formulas above, note that inductance L, cutoff frequency f_c , and impedance R are interdependant. While it may be customary to start a design with some given value of impedance R and tailor L and C to the desired cutoff frequency, it is not mandatory. It is equally possible to start with the value of L from a choke that is available and tailor the impedance R and the capacitance C to get the desired cutoff frequency f_c . This is perfectly feasible for amateur and much audio work, because R can be varied over a considerable range when the filter is driven from a tube and operates into another tube.

Example: Suppose a 1 henry choke is on hand and it is desired to make an 8000-cycle low-pass filter. For convenience, transpose the formula

$$L = \frac{R}{\pi f_c}$$

to $R = \pi f_c L$,

and substitute in the values $L = 1$ and $f_c = 8 \text{ kc}$.
Then $R = 3.14 \times 8 \times 1 = 25 \text{ K ohms}$.

Finding the capacitance from the formula

$$C = \frac{1}{R^2}$$

C is $\frac{1}{(25)^2}$ or 1 or .0016 mfd.

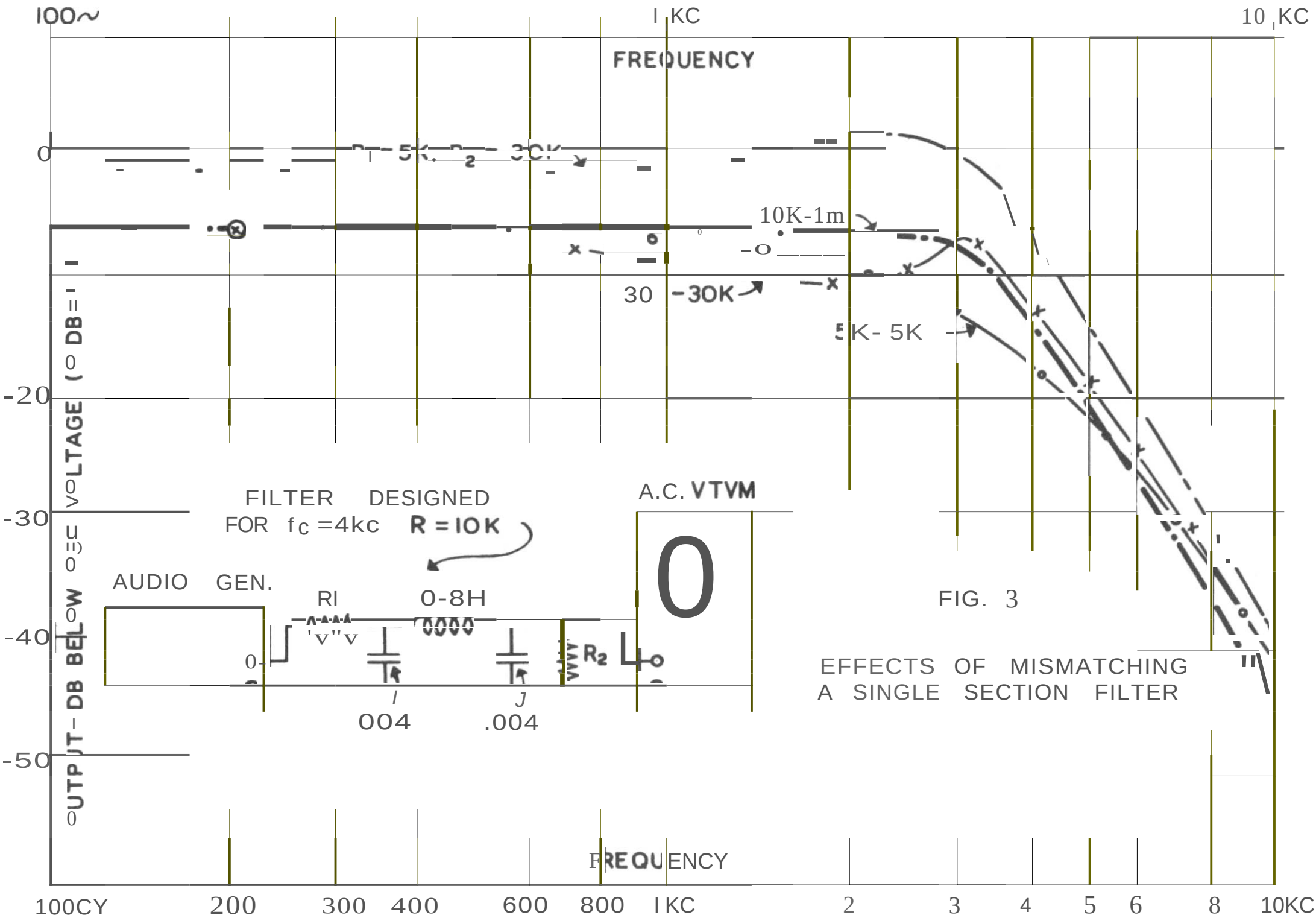
If the filter is a single section, both condensers will be .0008 mfd each; if two-section, the end condensers will be .0008 and the middle one .0016.

FILTER COMPONENTS

Ordinary paper condensers are satisfactory for filters. Tolerances are large on paper capacitors; usually they must be measured and the proper value made up by paralleling two or more units.

Toroidal inductors are the best, and sometimes can be salvaged from surplus filters in a variety large enough to yield some useful inductance values. Rewinding is too tedious to be practical except for very low inductances.

Ordinary filter chokes wound on silicon steel laminated cores can form the basis of good audio filters. The inductance can be varied by changing the air gap width. A typical radio replacement type choke rated at 10 henries, 40 milliamperes has an air gap of around .02" and measures 6 henries with



a Q of 5 to 8 at 1 kc. By removing the frame strap the "I" laminations can be pulled out of the core stack and the fiber air gap spacer replaced with a thicker or thinner one made of cardboard. The change has little effect on the Q , even to the point of removing the "I" laminations entirely. The inductance can typically be raised to 15 henries at no air gap, and reduced to 2 or 3 henries by removing the "I" laminations. Small chokes have as good Q as larger ones at 1 kc.

Laminated-core chokes *pick up* hum from nearby power transformers, and should not be used at signal levels much below 1 volt. Toroids are almost entirely free from this trouble.

Cheap output transformers such as are used with 35L6 and similar tubes have a primary inductance of from 1 to 3 or 4 henries. The same air-gap variation technique can be applied. Interleaved cores can be taken apart and restacked to provide an air gap. Interleaved cores provide maximum inductance but distinctly lower Q than air-gap cores.

The capacitors in a filter should always be several times larger than the distributed capacitance of the inductor. 100 mmf is a typical value for distributed capacitance of a 10-henry radio replacement choke. If the calculations yield a capacitance lower than 1000 mmf or so, a lower inductance and impedance must be used.

R.F. chokes have very low Q at audio frequencies and should not be used unless the Q is checked first.

OPERATING FILTERS FROM VACUUM TUBES

Fig. 5 illustrates the equivalence of some different practical circuits for driving filters. The signal source for the filter can either look like a high-impedance generator (labeled "G" in Fig. 5A) shunted by a resistor equal to the characteristic impedance of the filter, R , or it can look like a low-impedance generator (Fig. 5B) with the resistor R in series. The resistance as seen by the filter is the same for either arrangement.

Practical types of tube circuits are shown in Figs. 5C, D, and E. In Fig. 5C, the cathode follower is a comparatively low impedance source, and a filter of, say 5000 ohms or more impedance may be fed from the follower through the resistor R . At lower values the internal resistance of the cathode follower should be taken into account. This internal resistance is approximately 1 divided by the gm of the tube, typically 500 or 1000 ohms. To drive a 2000-ohm filter, the external series resistance R would be around 1000 or 1500 ohms.

A filter designed for an impedance of around 15,000 ohms may be driven directly by the plate circuit of a triode such as type 6J5 or 6C4, Fig. 50. Additional series resistance may be inserted to match higher impedance filters.

The high-impedance generator of Fig. 5A is realized in practice by using a pentode such as type 6AU6, the plate load resistor being made equal to the filter impedance, Fig. 5E.

When driving low impedance filters from tubes, care must be taken that the tube does not overload. The plate current of the tube must be enough to develop the desired voltage across the load with a margin of safety of at least 2 or 3.

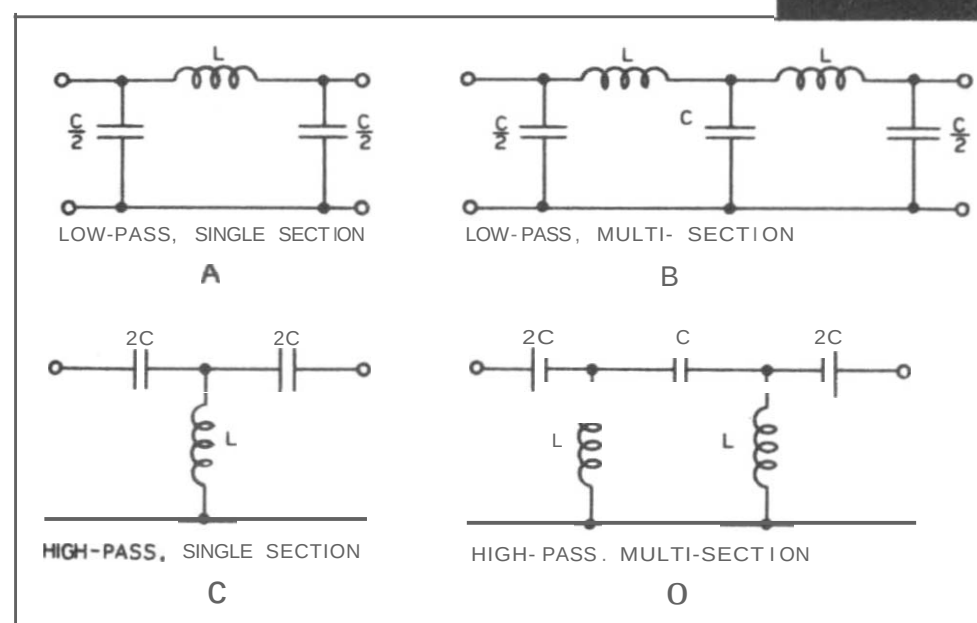


Figure 4

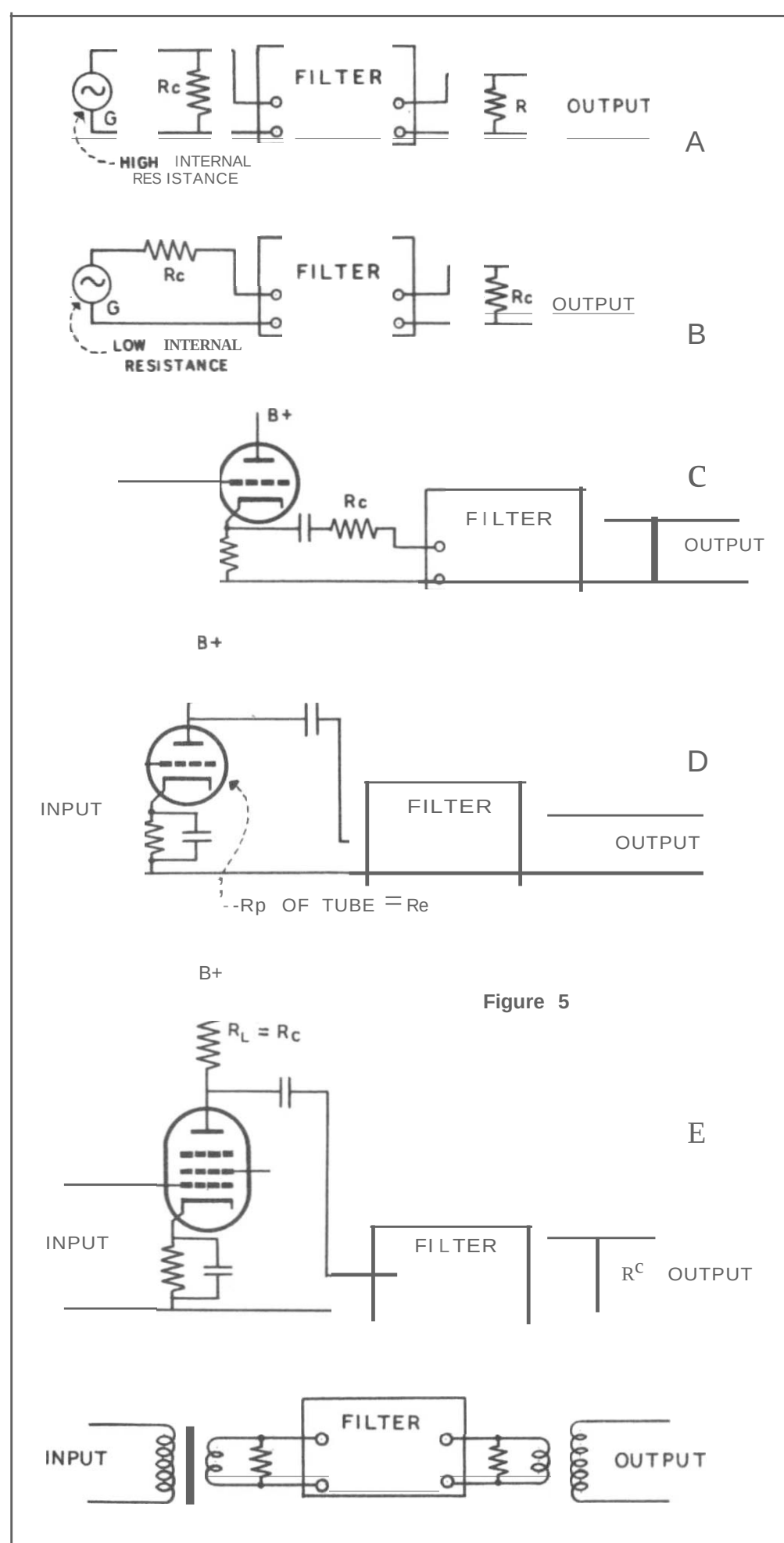


Figure 5

The most efficient way to match filters is with transformers, Fig. 5F, but at impedance levels over about 1000 ohms it is ordinarily cheaper and better to do it directly from a tube. Matching resistors may be applied at either side of a transformer, with allowance being made for the impedance ratio of the transformer.

When it feeds a grid, the output end of the filter is terminated simply by shunting the correct resistance across it.

Filter terminations can often be varied as much as 2 or 3 to 1 without upsetting badly the shape of the response curve, and the terminations need not be exactly equal. Any combination that gives a satisfactory measured curve will work the same way. Sometimes it is possible to compensate for the drooping shoulder on a curve by "fudging" the terminations enough to produce a slight peak at the same place.

ACCESSORIES

The following items have been found convenient by many laboratory workers for use with instruments in making measurements of the type described in these notes:

1. Reactance slide rule (Available from Shure Brothers, 225 West Huron St., Chicago, 35c postpaid).
2. Slide rule. In inexpensive makes, (selling for about a dollar) the "Mannheim" type is all that is needed.
3. Several potentiometers mounted on small metal bases and fitted with calibrated scales. Radio volume controls are satisfactory. The best way to draw the scales is to paint the base with light colored auto enamel, mark with india ink, and cover with clear lacquer.
4. An assortment of clip leads in 6", 12", and 2-ft. lengths, and 3 or 4 cables 2 feet long made of flexible red and black wire, twisted, and fitted with a double banana plug at one end and clips at the other. One similar cable made of crystal microphone cable or other low-capacitance shielded wire.
5. Graph paper, semi-logarithmic, 4-cycle, K&E No. 359-91 or similar, for plotting response curves of db versus frequency.

inductance measurement by resonance with an audio generator and ac vtvm

BY LAWRENCE FLEMING

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INDUCTANCE MEASUREMENT BY RESONANCE

A popular method of measuring inductance is by connecting a known capacitance across the unknown inductor and finding the frequency at which they resonate. The advantage over other methods is that no standard inductances are required. Fig. 1 shows the arrangement. The tuned circuit containing the unknown inductance is fed through a resistor R. The only requirements on the value of resistor R are that it must be high enough to avoid seriously loading the tuned circuit, but low enough to produce a readable voltage across the tuned circuit. 100,000 ohms usually works well. The value of R is about right when the audio voltage across the tuned circuit at resonance is about 1/10 the voltage coming out of the audio generator.

The only real precaution is to use a value for the known capacitance that is large compared to the distributed capacitance of the inductance L. For layer-wound iron-core audio chokes and transformers, C should be at least .002 mfd. Values of C of .01 to 0.1 mfd are typical for measuring such inductors. For smaller inductances or for toroidal or universal-wound coils, C may be as small as .0002 mfd.

When the resonant frequency is found, the inductance can be calculated from the formula

$$f = \frac{1000}{2\pi\sqrt{LC}}$$

or in more convenient form,

$$L = \frac{63,100}{f^2 C}$$

where L is inductance in henries, f is frequency in cycles per second, and C is capacitance in *microfarads*.

The arithmetic can be circumvented by using a reactance chart or, better, a reactance slide rule. An "Inductance Finder" chart is appended.

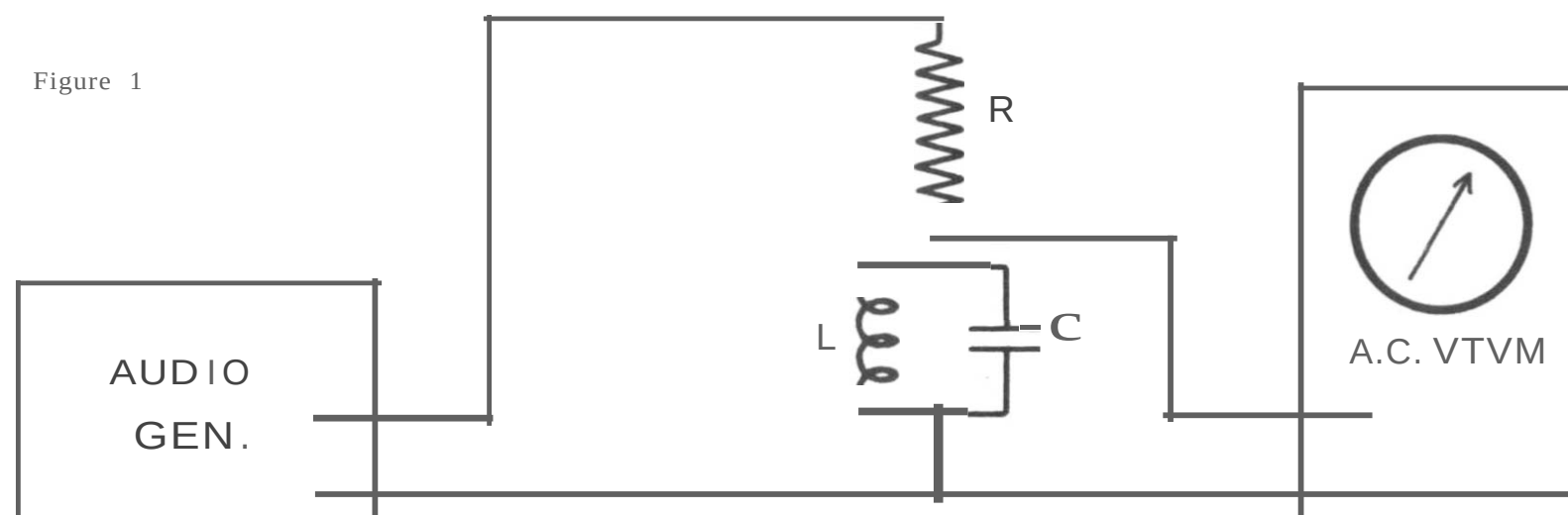
It is a peculiarity of inductances with laminated iron cores that their inductance varies somewhat with frequency, being higher at low frequencies. A filter choke having an inductance of 10 henries at 60 cycles may typically measure around 6 henries at 1000 cycles. The effect is more pronounced with high-permeability alloy cores, but is decreased by the presence of air gaps.

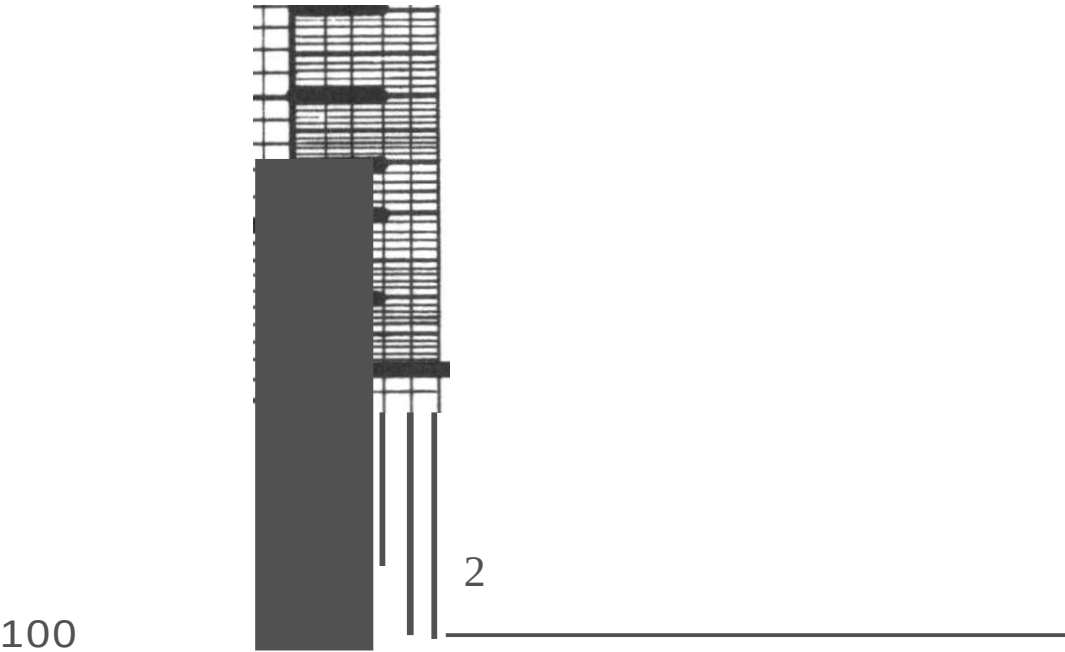
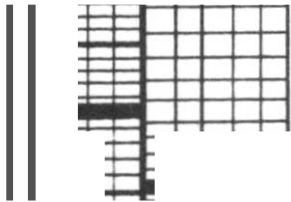
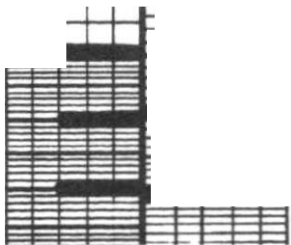
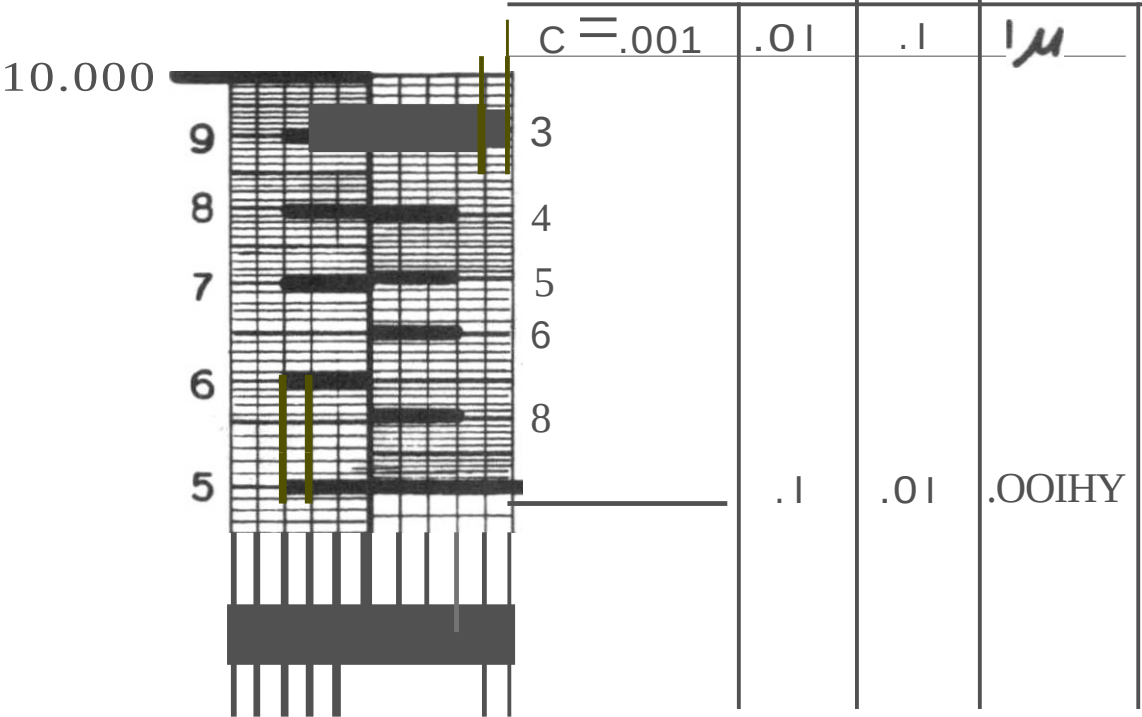
Q OF INDUCTANCES

The Q of a tuned circuit is equal to the resonant frequency divided by the bandwidth 30% down from the peak voltage at resonance. Hence Q can be found with the same setup, Fig. 1, used for inductance measurement by resonance at any frequency within the range of the generator and A.C. VTVM.

The Q of the inductance is for practical purposes the same as the Q of the tuned circuit, since the losses in a coil are, essentially, always much greater than the losses in a condenser. Good paper condensers are satisfactory for capacitances above

Figure 1





about .01 mfd. Mica, not ceramic, should be used for lower values.

The Q of all actual coils varies considerably with frequency. Q is defined as the ratio of reactance to resistance. At low frequencies, inductive reactance is low and Q drops. At high frequencies, copper losses become small compared to inductive reactance, but other losses appear - core losses and distributed capacitance losses. The Q of every coil goes through a broad maximum at some frequency, dropping on both sides. Hence Q should be measured, if practicable, somewhere near the frequency at which the coil is intended to be used.

In the actual measurement, the first step is to pick a condenser that will resonate the inductor at the desired frequency. The series resistor should be at least 10 times higher than the resonant impedance of the tuned circuit (which $= 2\pi fLQ$), i.e. circuit resonant voltage should be not over 1/10 the generator voltage. It may be anything less.

Tune the generator to resonance and note the frequency. Set the generator output control to give a convenient reading on the A.C. VTVM, e.g. 1 volt or 0.1 volt.

Then retune the generator until the A.C. VTVM reading drops to 70% of its former reading, note the frequency, and repeat the process on the other side of resonance. The Q is equal to the frequency at resonance divided by the difference in frequency between the two 70% points. For example, if the tuned circuit resonates at 1000 cycles and is down to 70%

voltage at 950 and 1050 cycles, the Q is $\frac{1000}{1050 - 950} = 10$.

The accuracy of this method is best at lower values of Q.

TRANSFORMER FREQUENCY RESPONSE

Frequency response of audio transformers is measured with the generator, A.C. VTVM, and appropriate load and source resistors connected as in Figs. 2 and 3. Where the rated primary impedance of the transformer is considerably higher than the internal impedance of the generator, e.g. 2000 ohms or more, use Fig. 2. When the transformer primary impedance is lower, e.g. 50 or 500 ohms, use Fig. 3. The impedance viewed by the transformer primary should, in any case, be equal to the value it will see in service. The value is not critical; within 30% is close enough. If the transformer is to operate out of a tube, the resistance seen by the primary should equal the plate resistance of that tube. If out of a crystal microphone, use Fig. 2 with a condenser, or the microphone itself, in place of the series resistor. If out of a magnetic pickup or similar device, replace the resistor with an inductance. The pickup itself will serve.

The secondary load resistor R_2 is made equal to the operating load, e.g. 4 or 8 ohms for a voice coil winding, no resistor for a grid winding.

In Fig. 3, resistor R_3 is made high compared to the transformer primary impedance and R_4 equal to that impedance.

Figure 3

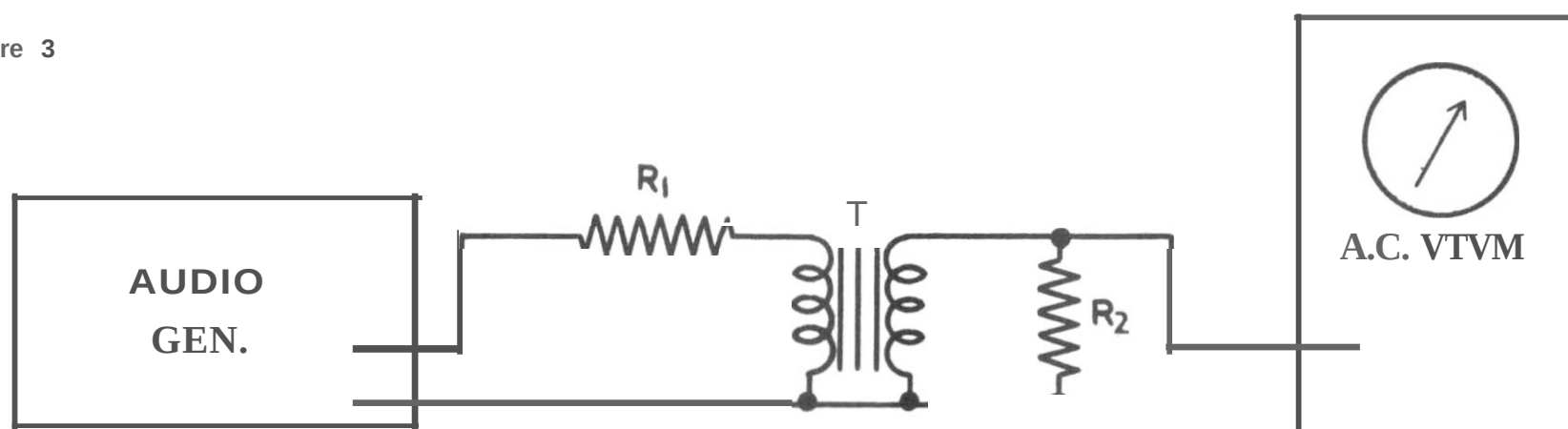
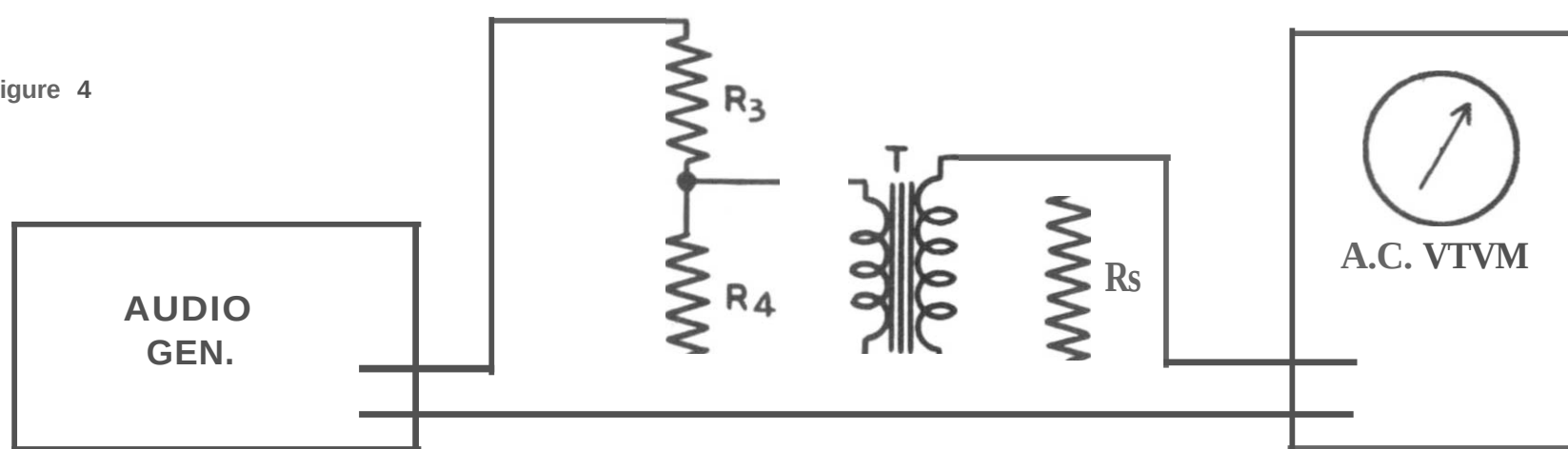


Figure 4



For a 50-ohm primary, good values would be $R_p = 5000$ ohms, $R_s = 50$ ohms.

The turns ratio of the transformer is the ratio of voltage across the secondary to voltage across the primary, at any frequency in the range of flat response. In the case of Fig. 2, it will be found that the generator signal voltage is a little higher than the primary voltage. The difference, due to the drop across resistor R_1 is usually 1 or 2 db, and is the *insertion loss* of the transformer.

It is permissible to operate audio transformers under impedance conditions different from their ratings, provided the

measured ratio and frequency response are satisfactory, and that ratings of d.c. primary current and power level are not exceeded. For a given transformer, the lower the source impedance, the better the bass response. For example, an output transformer rated at 8000:16 ohms, 6 watts, 30 ma. d.c., would work satisfactorily as a 2000:4 ohm unit at the same or lower d.c. and power levels. Bass response would be better than at the higher impedance.

Interstage or line-to-grid transformers having silicon steel cores often have a peak at the high-frequency limit, which can be smoothed off by shunting a resistance of the order of 0.1 megohm across the secondary.

the heathkit laboratory power supply

BY LOUIS E. GARNER, JR.

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SPECIAL APPLICATIONS OF THE POWER SUPPLY

The most popular application of the Heathkit Power Supply in the laboratory is as a power source for experimental circuits. However, this is, by no means, the only important application of this instrument. In fact, the Power Supply may well serve as a valuable piece of test equipment in its own right. A number of possible applications will be discussed, in detail, in this bulletin. These should serve as a guide to the user in developing applications of his own.

CHECKING RELAYS

Many relay coils, particularly a.c. relays, are rated in terms of operating voltage. Thus, there are 6 v. and 115 v. a.c. relays. Sensitive d.c. relays, on the other hand, are generally rated by their coil resistance. Such relays are used extensively in electronic circuits ... photo-rube circuits, capacity relay circuits, remote control circuits, etc.

When designing a circuit where a sensitive d.c. relay is to be used, it is important to know the "pull-in" and "drop-out" currents of the relay as well as the d.c. resistance of the coil. The d.c. resistance may be easily measured using an ohmmeter. The "pull-in" and "drop-out" currents may be determined using the Heathkit Power Supply.

The circuit given in Fig. 1 is satisfactory for making these tests. Resistor R' is chosen so the current flow with minimum voltage is not sufficient to close the relay. Its size may be calculated (using Ohm's law), or the Heathkit Resistance Decade Box may be used, and the value determined experimentally.

To determine the "pull-in" current of the relay, switch the power supply meter to read circuit current. Now, gradually

increase the voltage applied to the circuit, noting the current flow at the same time. The circuit current at the instant the relay closes is the "pull-in" current for the relay.

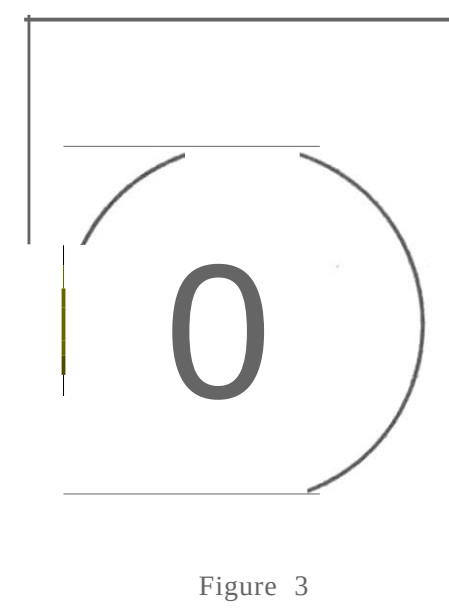
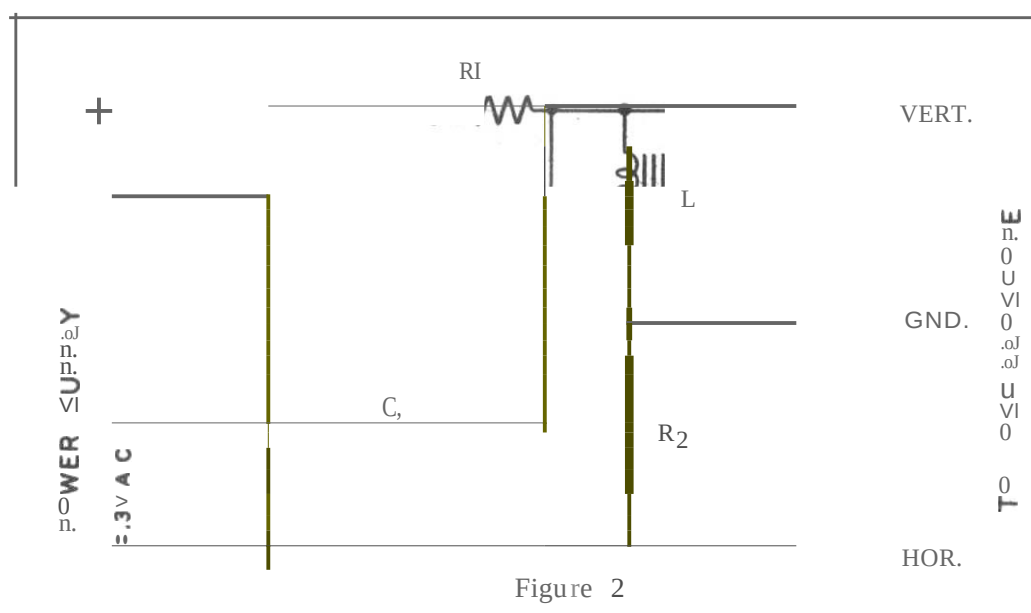
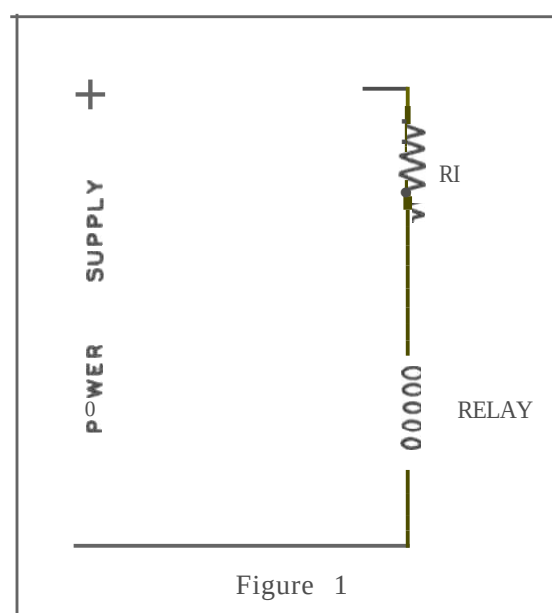
The opposite technique is used to determine "drop-out" current. The voltage is gradually reduced (reducing circuit current) until the relay opens, and circuit current noted at that instant. The "drop-out" current is generally much smaller than the "pull-in" current.

The technique described is also useful for adjusting the sensitivity of a relay to pre-determined values. To adjust the relay, vary the voltage until the circuit current is at the desired "pull-in" value. Then adjust the spring tension and the armature position until the armature just closes. The "drop-out" current value is adjusted in a similar manner. In some cases it may become necessary to compromise on the spring tension, and to adjust only the armature position (by properly spacing the contacts) until the desired sensitivity is achieved.

DETERMINING THE D.C. SATURATION CURRENT OF A CHOKE

The true inductance of an iron-core choke will vary considerably from its "rated" value as the d.c. through the choke changes. For example, a choke rated at 10 Hys, 40 ^{ma} may have from 50% to 100% more inductance when the d.c. through the choke is very low. On the other hand, the inductance may drop to only 3 or 4 Hys. if the d.c. appreciably exceeds the rated value of 40 ma.

When using iron core chokes in experimental work, either as power supply filters or for impedance coupling in amplifiers, it is often important to know the maximum d.c. that may



be passed through the choke windings before the inductance drops appreciably ... that is, when core saturation occurs.

This value can be determined quite easily using the Heathkit Power Supply and an Oscilloscope. The circuit is given in Fig. 2.

Resistor R' is a current limiting resistor and is chosen to permit sufficient current to flow so core saturation will occur as the output voltage of the Power Supply is increased above its minimum value. If the choke coil (L) ratings are known approximately, the value of R' may be calculated using Ohm's law. Otherwise, determine the value experimentally.

To determine the value of R^2 , measure the d.c. resistance of the coil (L) using an ohmmeter. Choose a value for R^2 that will approximate this d.c. resistance (an exact match is not necessary).

In operation, a 60 cycle a.c. voltage is applied through d.c. blocking condenser C_1 to the series circuit consisting of L and R^2 . R^2 serves both as a current limiting resistor and as an isolation resistor to prevent the low Output impedance of the Power Supply shorting the a.c. voltage.

As long as the d.c. through L and R^2 is low, so that core saturation is not approached, L will have appreciable inductance. This means that the coil impedance, due to both the inductive reactance and its resistance, will be considerably higher than the resistance of R^2 (purposely chosen so that its resistance is the same as the d.c. resistance of the coil). Therefore, the a.c. voltage drop across L will be much higher than the drop across R^2 .

As the d.c. through the circuit is increased and core saturation is approached, the impedance of L will drop (due to the drop in inductive reactance), with a resulting drop in the a.c. voltage appearing across it. When the a.c. voltage across L is at a minimum, core saturation has been reached or closely approached. Under such conditions, the impedance of L will be only slightly greater than the resistance of R^2 (the a.c. resistance of a choke is generally greater than its d.c. resistance).

With the connections shown in Fig. 2, a pattern similar to that shown in Fig. 3 will be obtained on the screen of the 'scope when the d.c. through the circuit is at a minimum and the 'scope controls are properly adjusted.

Switch the Power Supply meter to read circuit current and gradually increase the output voltage (thus increasing the current). When the vertical deflection of the 'scope pattern reaches a minimum, and the pattern becomes elliptical or "flattens", core saturation has been reached. The circuit current may then be read directly.

FORMING ELECTROLYTICS

Your Heathkit Power Supply is useful for reforming electrolytic condensers which have lost their usefulness due to shelf storage. Condensers with a nominal d.c. working voltage of from 200 to 450 v. may be connected directly across the d.c. output terminals of the Power Supply. For lower voltage

electrolytics, a resistive voltage divider may be used to obtain the necessary voltage.

Before attempting to "form" an electrolytic, check the condenser for a short or excessive leakage, using either a Resistor-Condenser tester or an ohmmeter. Otherwise, the Power Supply may be overloaded. Also be sure to observe proper polarity when connecting the condenser. Start with the minimum voltage available and gradually increase the voltage as the condenser leakage current drops. The leakage current may be checked simply by switching the Power Supply meter to indicate circuit current. Keep increasing the applied voltage until the working voltage of the condenser is reached.

Don't try to hurry the forming process ... some electrolytics may take from 20 minutes to an hour to form properly.

DESIGNING A METER MULTIPLIER

A simple voltmeter is made by using a milliammeter (or microammeter) together with a series multiplying resistor. The value of the resistor depends on the basic meter range and the desired maximum voltage range.

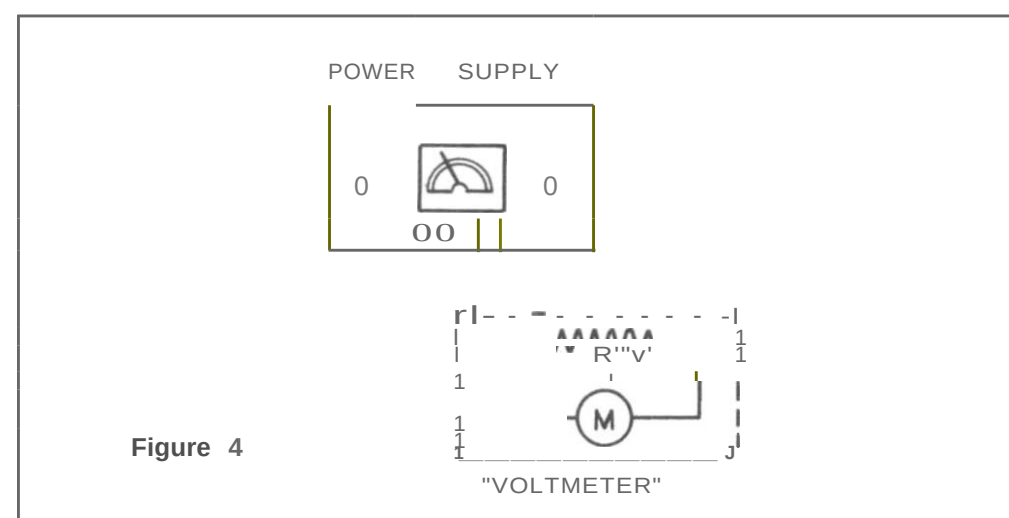
The following formula may be used to determine the proper series resistance to use:

$$R = E / I,$$

where R is the series resistor, E is the maximum voltage range desired, and I is the full-scale current of the meter. Meter resistance is not taken into account in this formula since the meter resistance is usually very small compared to the multiplier resistance.

Once a resistor value has been chosen, it is connected in series with the meter and the "voltmeter" thus formed compared with a standard. The meter scale and calibration may thus be checked for possible error. Sometimes it is necessary to try different resistor values until one having exactly the right resistance is found (due to tolerances). The circuit given in Fig. 4 is suitable for checking a voltmeter against the built-in voltmeter in your Heathkit Power Supply. R' is the series multiplying resistor and M is the basic meter movement. Be sure to observe the proper polarity when making connections.

If the test meter reads *higher* than the Power Supply meter, it indicates that R' should be increased. A *lower* reading indicates that R' is too large.



DESIGNING A SHUNT

To increase the range of a milliammeter or ammeter, a shunt resistance is connected in parallel with the meter. The value of the shunt resistance needed, may be calculated using the following formula:

$$R_s = R_M / K - 1,$$

where R_s is the required shunt resistance, R_M is the meter resistance, and K is the desired multiplying factor.

In most cases, the resistance value will be quite low . . . often only a fraction of an ohm. Because of this, it is difficult to obtain standard resistors having the desired value, and it becomes necessary for the individual to wind his own shunt. Resistance wire, such as nichrome, may be used for the higher resistance shunts, and fine copper wire for the lower values. The shunt should be wound on a flat fiber strip and terminals provided for easy connection to the meter as shown in Fig. 5 (a). Refer to wire resistance tables to determine the amount of wire necessary for a given shunt (these will be found in most handbooks).

Once the shunt has been wound and mounted, the Circuit in Fig. 5 (b) may be used to check the calibration of the

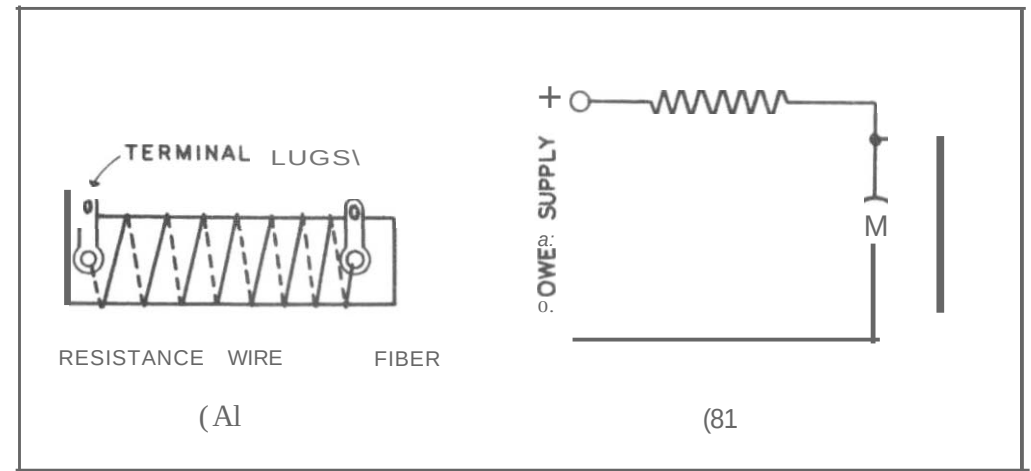


Figure 5

meter and to make final adjustments of the shunt resistance. The meter is checked against the milliammeter in the Power Supply.

Resistor R' is used to limit current flow and may be chosen by using Ohm's law. The value is not critical, however, as the final adjustment of circuit current may be made by adjusting the voltage applied.

an experimental r.f. high voltage supply using the laboratory power supply

BY LOUIS E. GARNER, JR.

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When performing breakdown tests on condensers, insulators and similar components, a High Voltage, low current power source is mandatory. Such a power source is also needed for engineering "mock-ups" of test oscilloscopes, modulation monitors (CRT type), and TV receivers. Thus, a d.c. High Voltage power supply becomes a useful addition to the experimental laboratory even if not used "100%" of the time.

There are several factors to take into account when selecting a High Voltage supply for the laboratory . . . (a) relative safety, (b) COST, (c) space requirements, and (d) versatility. By "versatility" is meant the ability to deliver a variable output voltage suitable for a large number of applications. Probably no single type of High Voltage power supply meets all of these requirements as well as the R.F. type supply. If such a unit is assembled as an accessory to the *Heathkit Laboratory Power Supply*, it provides an inexpensive, yet valuable, addition to the lab.

The basic schematic diagram for a suitable R.F. High Voltage Power Supply is given in Fig. 1. This supply can be assembled and tested in a few hours time and, when used with the *Heathkit Power Supply*, can be easily and quickly adjusted to deliver *from less than 1000 to as high as 6000* volts with a maximum current of 250 microamperes (enough for almost all general applications). The complete parts list (referring to Fig. 1) follows:

- L^1 - L^2 - L^3 - L^4 -Miller Type 4525 R.F.H.V. Transformer.
- L^1 —2.5 MHY, 100 MA R.F. Choke.
- C^1 -350-1000 mmf Padder Condenser.
- $C', C,$ - .05 mfd., 600 v. paper condensers.
- C^4 -.001 mfd., paper or mica condenser.
- C', C' - .0005 mfd., 6000 v. molded paper condensers.
- R' -39K, 2 W. Carbon resistor.
- R' --47K, 1 W. Carbon resistor.
- R' -100K, 1 W. Carbon resistor.
- VT' —6V6 or 6AQ5 tube.
- VT' -1B3 tube.
- MISc. -Tube sockets, grid cap, terminal strips, wire, solder, screws and nuts, chassis and shield (if used), etc.

CIRCUIT DESCRIPTION

As can be seen by reference to the schematic diagram (Fig. 1), VT' is used in a conventional "tickler feedback" R.F.

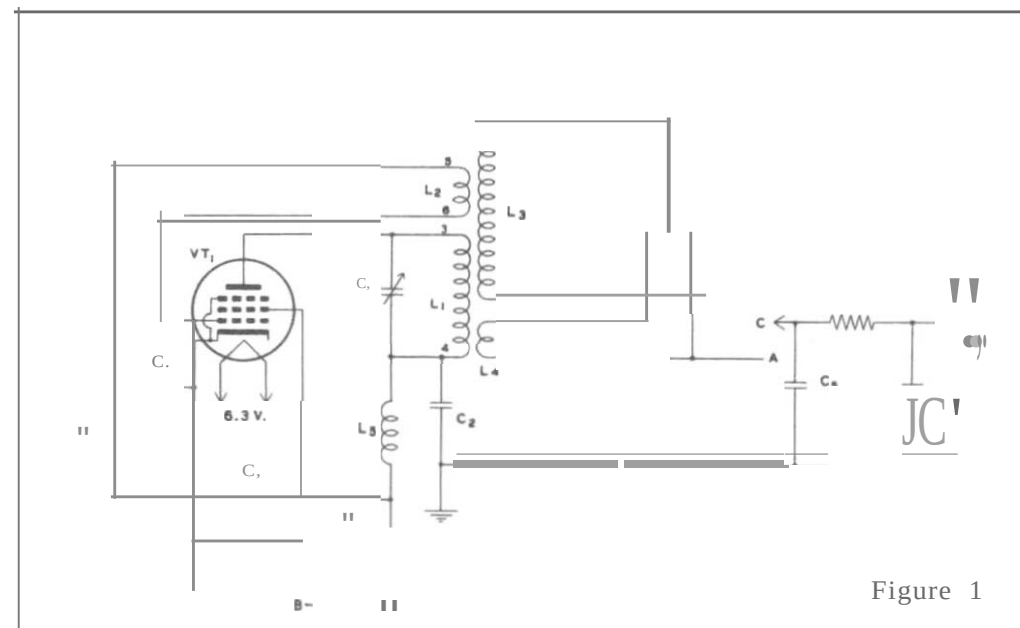


Figure 1

oscillator circuit. L^2 is the feedback coil and is connected to the grid of the tube. C^4 and R^3 are the grid condenser and grid-leak resistor, respectively.

Screen voltage is obtained through screen dropping resistor R' , with C^3 acting as the screen by-pass condenser. L^5 and C^2 form a plate de-coupling circuit and, together, prevent R.F. from feeding back into the low voltage d.c. power supply CkrCult.

A high R.F. voltage is developed across L^3 , partially due to the turns ratio between it and the "primary" winding (L^1), and partially due to a resonant step-up. A resonant voltage step-up is obtained by adjusting the oscillator frequency to equal the resonant frequency of L^3 plus its distributed capacities (including wiring capacities and the plate-cathode capacity of VT'). This is accomplished by means of padder condenser C^1 , which forms a resonant circuit with L^1 and thus controls the oscillator frequency.

The high R.F. voltage across L^3 is rectified by VT' and filtered by an R-C "pi" network consisting of R' , C^5 and C^6 . This filter may be connected either in the cathode circuit (connection "A") or the plate circuit (connection "B") of the rectifier tube, and thus permits obtaining a d.c. voltage which is either positive or negative with respect to ground, at the choice of the user. Because R.F. is used, adequate filtering of "ripple" is provided by low capacity condensers (.0005 mfd.).

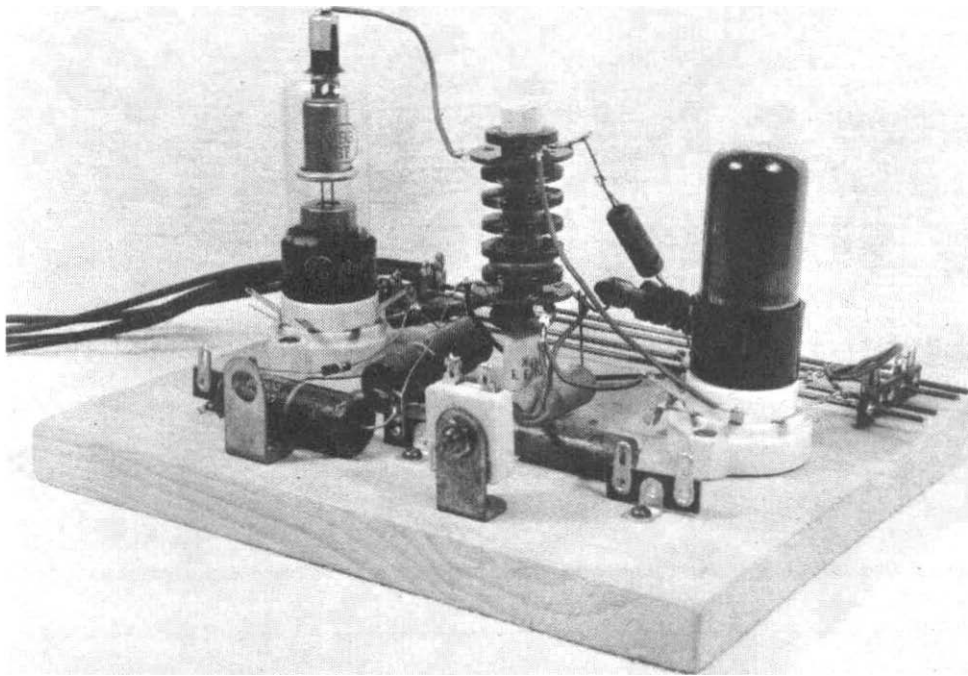


Figure 2

An R.F. voltage is used for the filament of the rectifier tube and is obtained from a single turn loop on the R. F. Transformer (L^1).

When properly adjusted, the operating frequency of the oscillator is between 200 and 300 Kc.

CONSTRUCTION HINTS

If the High Voltage Power Supply is to be assembled only for experimental use, it may well be wired on a "breadboard" type chassis as shown in Fig. 2. However, if it is to be wired as an additional item of laboratory equipment, a conventional metal chassis should be used. In addition, in order to prevent d. interference with nearby radio and television receivers, or other instruments in the laboratory, a complete shield should be provided.

The metal chassis and shield type of construction is illustrated in Fig. 3. The shield cover has been removed and placed to one side to permit the general layout to be seen. (NOTE: A different R.F. coil has been used in this supply, together with an oscillator tube of the miniature type.)

The filament winding of the r.f. transformer (L^1) is not supplied as part of the commercially available coil and must be added by the builder. This winding consists of a single turn of wire wound between the first and second "pi" windings of L^3 and is clearly visible in Fig. 2. The wire used should have high voltage insulation . . . heavy test lead wire is used in the model shown.

For best results, as much spacing as practicable should be provided between the R.F. transformer and between all high voltage connections and the shield (or chassis). A good quality socket should be used for the IB3 (a ceramic socket is preferred . . . do *not* use a wafer socket here.).

To prevent corona discharge, don't leave projecting sharp points in the high voltage circuit (as when hook-up wire is cut with diagonal pliers). If the supply is to be wired for permanent use, all high voltage terminals may be coated with Anti-Corona Lacquer (such as Walsco No. 195) for best results.

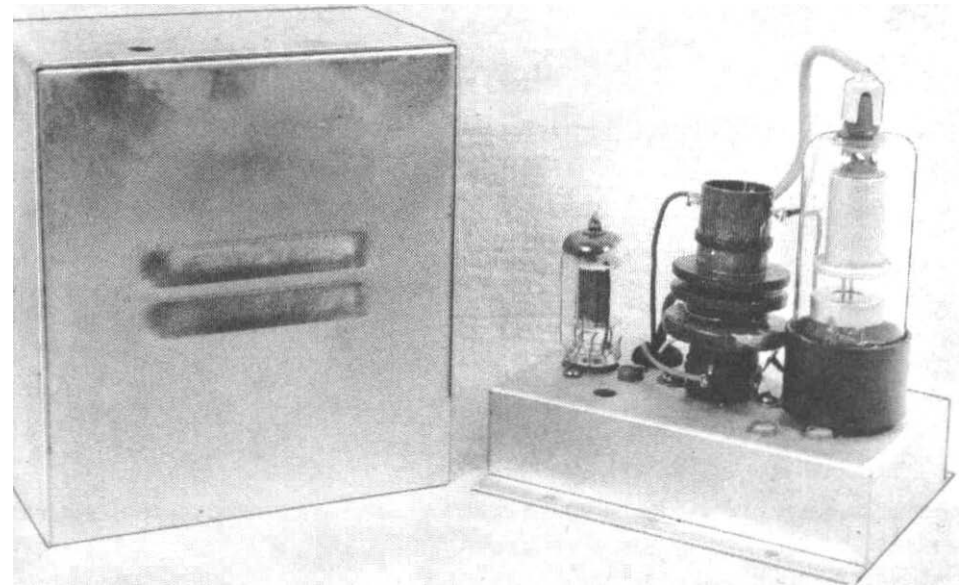


Figure 3

The padder condenser, C^1 , should be mounted so it may be easily adjusted after wiring is completed. If the "breadboard" type construction is used, this padder may be mounted on one of the upright brackets, as shown in Fig. 2. If the chassis type of construction is used, the padder should either be mounted on one of the sides or on the top of the chassis, or a hole should be provided to permit screw-driver adjustment even when the unit is in use . . . and, preferably, even with the shield cover in place.

If an output voltage which is positive with respect to "ground" is desired, connect the filament of the rectifier tube (point "A", Fig. 1) to the input of the filter circuit (point "C") and connect the lower terminal of L^3 (point "B" to ground. On the other hand, if an output voltage negative with respect to ground is preferred, connect point "A" to ground and connect points "B" and "C" together. The high d.c. output voltage is obtained from the Output of the filter, as shown.

If an intermediate ground connection is needed, a voltage divider made up of ten 2 Megohm, 1 Watt carbon resistors may be used, and the connections shown in Fig. 4 employed. Ground connection may then be made at any point along the resistor "chain", as needed.

TESTING AND ADJUSTMENT

Once the wiring is completed, place the oscillator tube in its socket, *but not the rectifier tube*. Connect the filament, low B plus, and low B minus leads to the low voltage power supply and apply power . . . use about 200 volts d.c. Check the oscillator for operation either by checking for a d.c. voltage across the grid resistor (R^2) or by holding a neon test bulb (such as types NE-2 or NE-51) close to the "hot" end of L^3 . If the oscillator is not working (no d.c. voltage across R^2 , or neon bulb doesn't light), reverse the connections to L^2 .

Finally, turn off the low voltage power supply and place the IB3 in its socket, connecting the plate lead.

Using a VTVM and High Voltage Probe, connect the leads to measure the high d.c. output voltage. Again turn the power on. The output voltage may now be adjusted to the desired

value by a combination of two steps ... (a) by adjusting the low d.c. supply voltage, and (b) tuning C_1 . In general, it is best to set the low voltage supply to deliver about 250 v. and then to adjust C_1 for the desired output voltage.

However, with the components used, it may sometimes be difficult to obtain the desired output voltage unless the low voltage supply is adjusted to deliver more (or less) than 250 volts. In Fig. 5, the low voltage supply is delivering almost 300 volts, and over 5000 volts is being obtained by adjustment of C_1 .

When both factors are adjusted, it is possible to obtain any desired voltage from less than 1000 to as high as 6000 volts ... more than 6000 volts is possible under "no-load" conditions, but it is not recommended that this high a voltage be obtained with the parts listed ... a component breakdown is possible.

APPLICATIONS

A few of the possible applications of the High Voltage Supply in the laboratory were mentioned briefly at the beginning of this Bulletin. However, one or two additional suggestions may prove helpful to the reader.

INSULATION BREAKDOWN TESTS

When performing insulation breakdown and similar tests, the high d.c. voltage should not be directly applied to the sample for preliminary checks. Rather, a lower d.c. voltage should first be applied, and this voltage gradually increased until breakdown occurs. (The output voltage of the High Voltage Supply may be adjusted as indicated above.) In this way, the exact point at which breakdown first occurs may be easily determined.

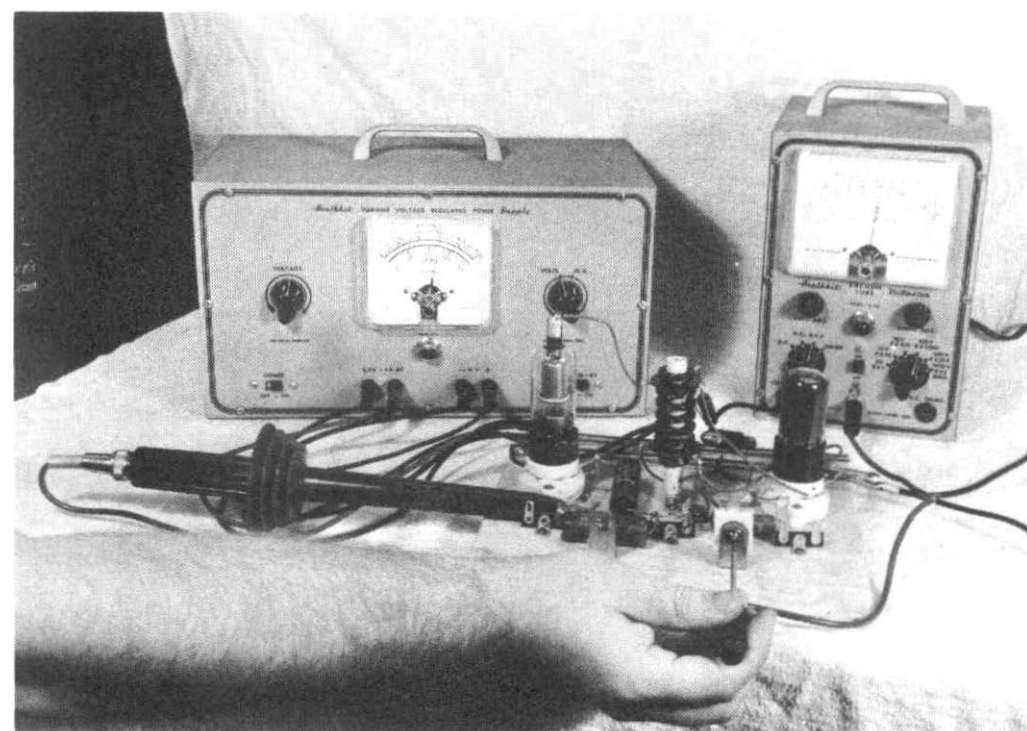
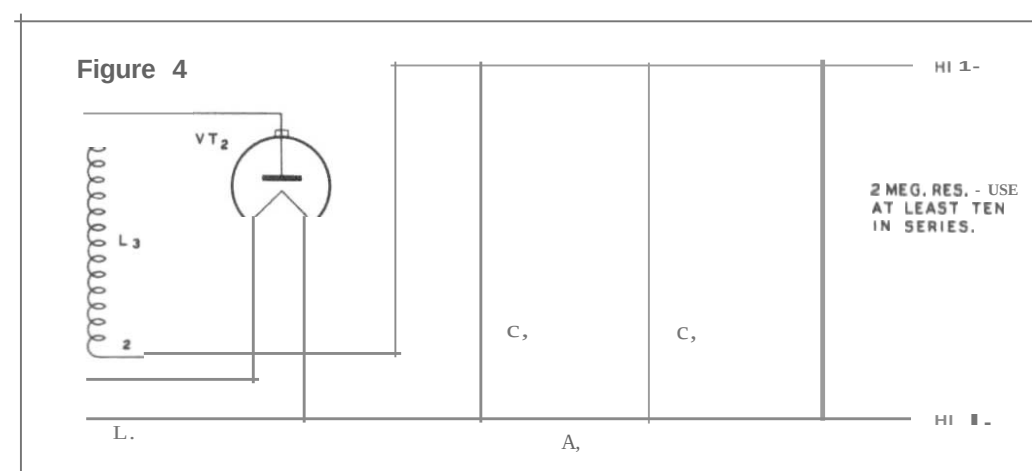


Figure 5

If a low-current meter is to be used to determine leakage current, this meter should be in series with the "grounded" rather than with the "hot" side of the d.c. supply. A series resistor may prove desirable to prevent accidental overload of the meter should the insulation or dielectric being tested breakdown and short.

Care should be taken that all physical constants which might affect the insulation resistance be recorded along with data on the sample and the breakdown voltage. Such information should include ambient temperature, relative humidity, and similar data.

CRT MOCK-UPS

The High Voltage Supply is useful when making an experimental set-up using a Cathode Ray Tube. Where such "mock-ups" are to be used for simple experimental work or for demonstrations (as in the class-room), the actual high voltage used is generally not too important as long as sufficient voltage is obtained to permit the formation of a sharp and bright image.

However, where the "mock-up" is used to obtain engineering data, as when designing a new Oscilloscope or checking CRT characteristics, care should be taken that the proper d.c. voltage is obtained. In such cases, the output of the High Voltage Supply *should be checked and adjusted under load*.

voltage multiplier circuits with the laboratory power supply

BY LOUIS E. GARNER, JR.

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At one time, transformerless Voltage Multiplier power supplies were used extensively in table model radio receivers. As newer tubes were designed that could deliver as much gain as the older tubes, but with lower plate voltages, the use of Voltage Multiplier circuits dropped off and the majority of sets manufactured just before the second World War utilized the "standard" half-wave rectifier power supply circuit (Fig. 1). This supply is capable of delivering output voltages only slightly above line voltage.

This trend would probably have continued after the War had it not been for the advent of Television. With an increasing public demand for lower cost TV receivers and the ready availability of inexpensive selenium rectifiers, the use of transformerless Voltage Multiplier circuits was revived and expanded. Today, Voltage Multiplier circuits are not only used in low voltage B supplies, but also in High Voltage supply circuits, designed to furnish accelerating voltage for large cathode ray tubes. Voltage Multiplier circuits delivering 30 KV and higher have been successfully manufactured as production items.

With the present day wide use as well as future potentialities in mind, every technician, serviceman, and engineer should be familiar with the practical operation of at least the "fundamental" versions of these circuits. Continuing with the objective of the Heath "Basic Circuit" Bulletins, a number of practical Voltage Multiplier circuits will be presented in this Bulletin. Students, technicians, and experimenters will find it comparatively easy to wire the circuits shown and to

become familiar with their operational characteristics by performing simple experiments.

FULL WAVE VOLTAGE-DOUBLER:

An easily wired Full-Wave Voltage Doubler circuit is illustrated in Fig. 2. A type 6SN7 tube is shown diode connected in this circuit, but any suitable dual diode may be used instead...such tubes as types 6H6 and 6ALS are equally satisfactory for experimental tests. (NOTE: The 6SN7 will be used in other Heath "Basic Circuit" experiments, however, and is used in this application only to "standardize" on tube types.)

In commercial versions of the circuit, one side of the circuit may be connected directly to the power line...thus affording a chance of possible shock to the experimenter. In order to avoid this danger, a 6.3 volt filament transformer is connected to the filament supply "in reverse" to act as an isolation transformer (T₁). Approximately 100 volts RMS is obtained from the secondary. The 6.3 volt supply terminals on the Heathkit *Laboratory Power Supply* provide a good source of both filament voltage for the tube and supply voltage for T₁.

T₁ will not be shown in later schematics and only a "100 v. a.c." source will be indicated. In each case, however, it is assumed that the isolation transformer is used.

In operation, tube VT₁ conducts when the cathode is made negative with respect to its plate, charging C₁ to the peak supply voltage (in this case, about 141 volts). Since the plate of VT₂ is negative with respect to its cathode during the same half-cycle, no conduction can take place through this tube.

Figure 1

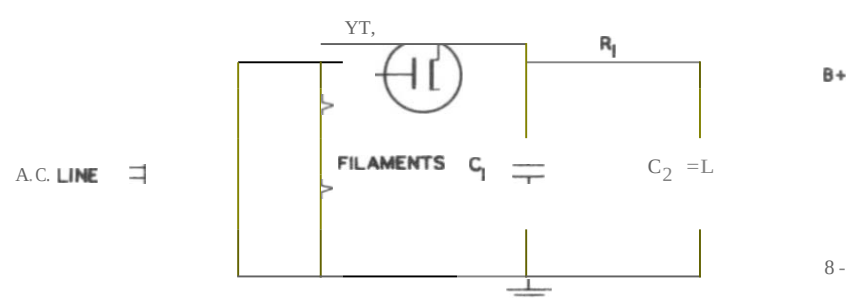
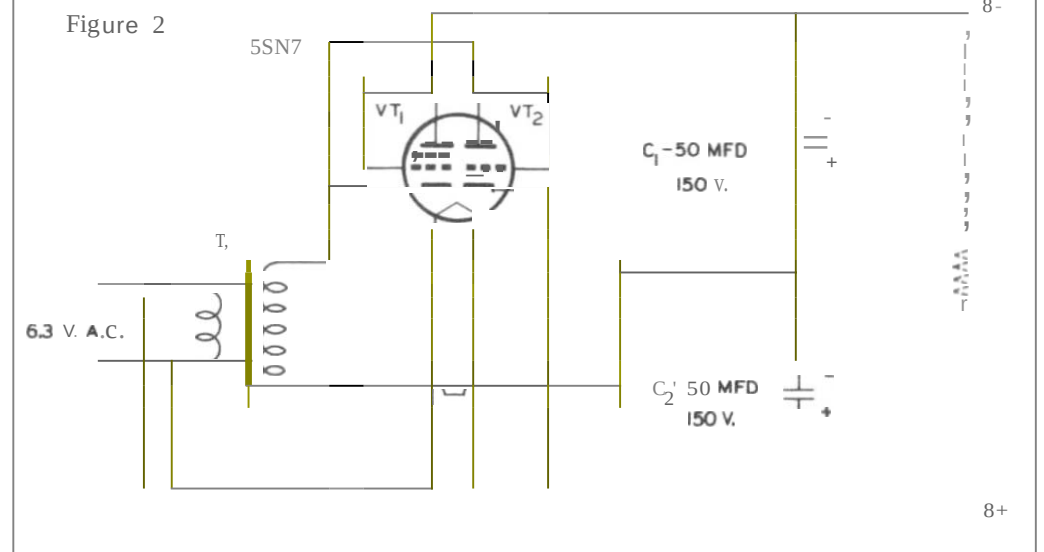
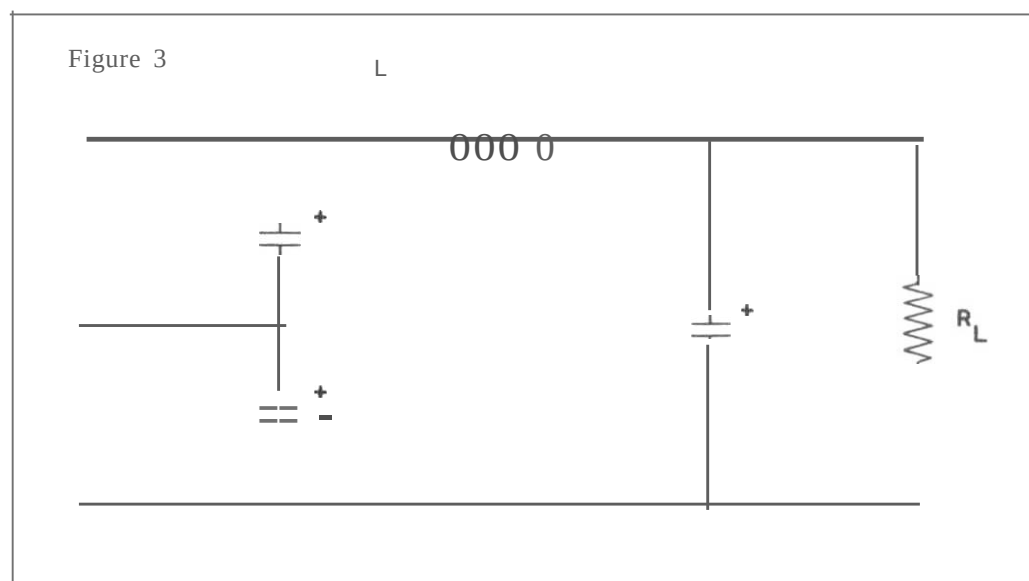


Figure 2





During the next half-cycle, however, VT1 cannot conduct as its cathode becomes positive with respect to its plate. But, at this time, the plate of VTz is positive with respect to its cathode and conduction can take place, charging C_Z to the peak supply voltage.

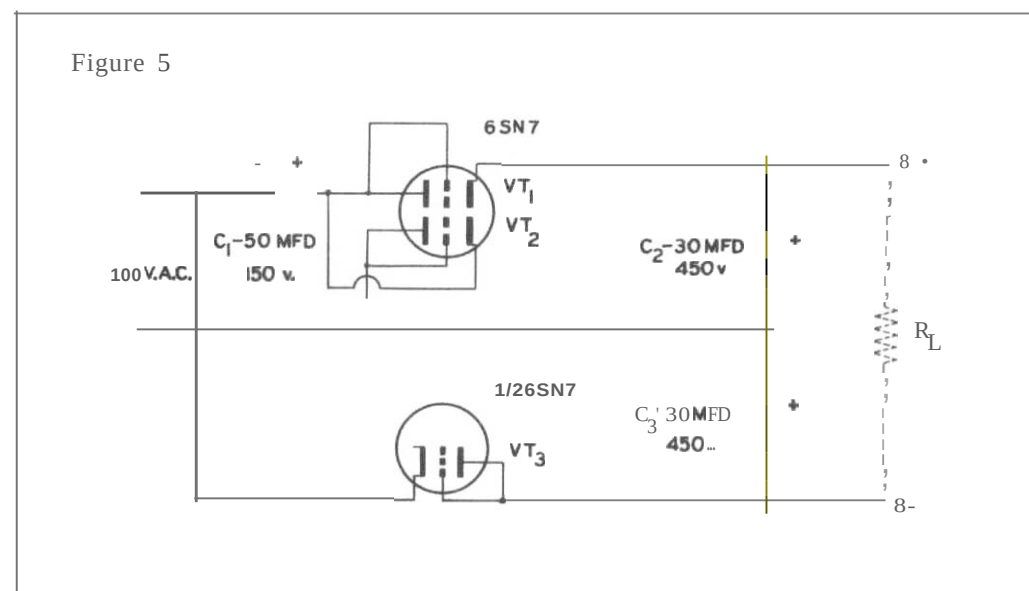
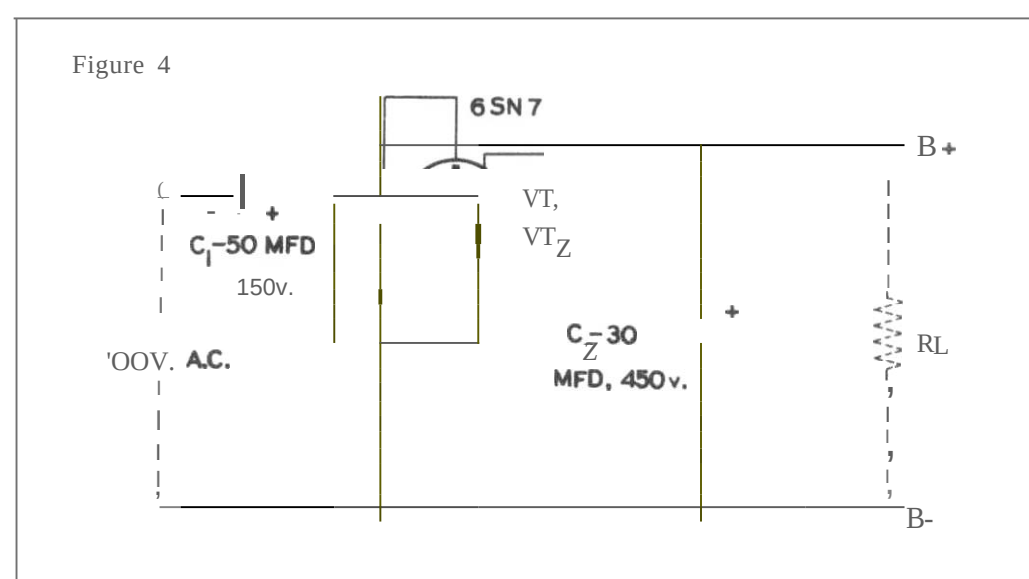
Since the two condensers (C_1 and C_Z) are essentially "in series" as far as their output is concerned, the total d.c. voltage available (across R_L) is equal to the sum of the individual voltages, or approximately twice the peak of the applied a.c. voltage (about 282 volts in this case). The actual voltage will be less than this "theoretical" value due to voltage drop in the transformer and in the tubes. With the values given in Fig. 2, the measured output under *No-Load* conditions was 270 volts.

Condensers C_1 and C_Z , in addition to being an essential part of the circuit, may also be considered as the "input" condensers of a filter network. In commercial circuits, a conventional filter network will be connected between the Output and C_1 - C_Z and R_L , as shown in Fig. 3.

While C_1 and C_Z need only be rated at 150 volts d.c. (in the circuit given), the output filter (C_3 , Fig. 3) should have a d.c. working voltage of at least twice this value ... at least 300, and preferably 350 volts.

HALF-WAVE VOLTAGE DOUBLER:

While the "full-wave" voltage doubler circuit described above supplies current to the load on both "half-cycles" of the applied a.c. voltage, the "half-wave" voltage doubler circuit shown in Fig. 4 supplies current to the load only on alternate half cycles.



Referring to Fig. 4, when the applied voltage is such that the cathode of VTz is negative with respect to its plate, conduction takes place and charges C_1 to the peak of the applied voltage. On the next half-cycle, the voltage across C_1 is in series with the applied a.c. voltage, thus doubling the peak voltage applied to VT1'. Since the polarity is now such the VT1 can conduct, C_Z is charged to this higher voltage.

In actual practice, the voltage across C_Z will be less than in the case of the full-wave voltage doubler circuit since the charge given C_Z depends, in part, on the charge of C_1 ... that is, the charge of C_1 is "divided." In addition, the voltage drop through the rectifier tube will be slightly greater when VT1 is conducting due to the higher total applied voltage and the consequently larger current flow.

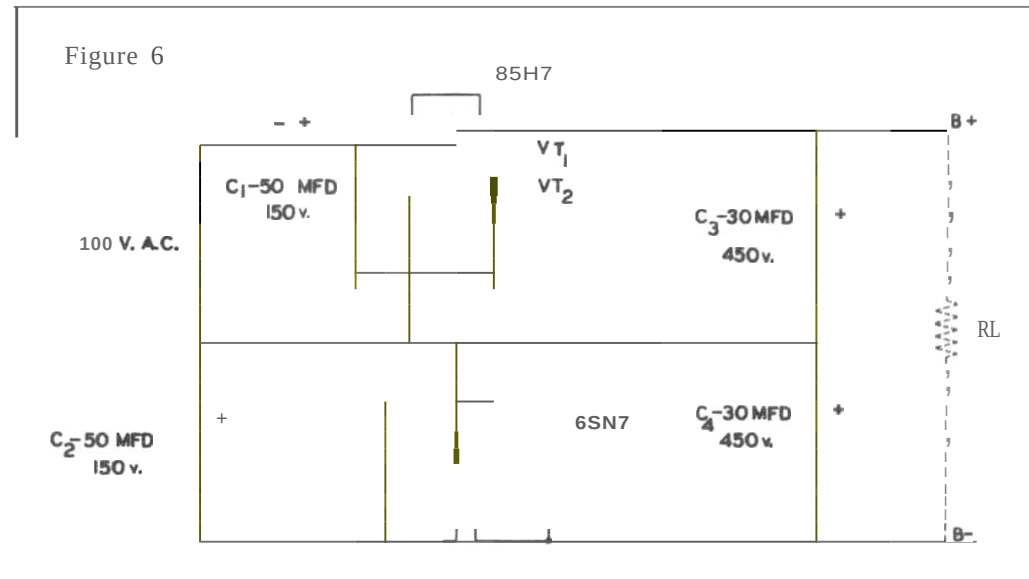
As can be seen from this brief analysis, the "output" (C_Z) is supplied with current only when VT1 is conducting ... on alternate half-cycles.

Since the "doubled" voltage is applied to C_Z , this condenser should have at least twice the d.c. voltage rating of C_1 .

VOLTAGE TRIPLER CIRCUIT:

One of the more popular of the voltage "trippler" circuits is shown in Fig. 5. As can be seen, this circuit is quite similar to the half-wave voltage doubler circuit shown in Fig. 4 except for the addition of a conventional half-wave rectifier circuit.

The upper portion of the circuit (VT1-VTz) operates as a voltage doubler, charging C_Z to twice the peak applied voltage. The lower portion of the circuit (VT3) operates as a





conventional half-wave rectifier, charging C_3 to the peak of the applied voltage. Since C_2 and C_3 are connected in series-adding as far as the load (RL) is concerned, the total voltage obtained is approximately three times the peak applied voltage.

The conventional vacuum tubes shown in the schematics may be replaced with selenium rectifiers without difficulty and, in many commercial circuits, a combination of tubes and dry-disc rectifiers may be used.

Two half-wave voltage doubler circuits may be connected "back-to-back" to form a voltage quadrupler circuit, as shown in Fig. 6. The analysis of this circuit is the same as for the former circuit, with the sum of the voltages across C_3 and C_4 applied to the load.

GENERAL CONSIDERATIONS:

As we have seen, practical voltage multiplier circuits depend on the charge held by a condenser(s) to obtain the high output

voltage. Because of this, the regulation is quite poor unless large value condensers are used, and the output voltage will drop off rapidly with increases in load. This fact has lead to voltage multiplier circuits being used primarily in fairly limited applications . . , (a) where high voltage and comparatively low current requirements exist (accelerating voltage for cathode ray tubes), and (b) where the load is reasonably constant.

Because electrolytic condensers are used (to obtain the high capacity necessary), care should be taken that the polarities indicated in Figs. 2, 4, 5 and 6 be observed when the circuits are wired for experimental tests.

LOAD	D.C. OUTPUT WITH 100 V. RMS. INPUT			
	FIG. 2	FIG. 4	FIG. 5	FIG. 6
(RL)				
"No-Load"	270	260	395	540
100K	255	250	360	460
47K	240	238	330	410
10K	195	190	230	260

TABLE A

The d.c. output voltages for the circuits described, under different load conditions, are given in Table A. These figures apply only to the circuit values given in the schematic diagrams ... if condensers having higher capacity are used, the voltage drop-off will not be as rapid as the load is increased. On the other hand, if the condensers have appreciably less capacity than shown, the output drop-off under load will be even greater.

In order to obtain the values given in Table A, the load resistor was connected directly across the "output," with no filter network used.

COMMERCIAL APPLICATIONS:

As was mentioned at the beginning of this Bulletin, Voltage Multiplier circuits are widely used in modern Television receivers. One such application is shown in Fig. 7. This is the low voltage power supply circuit used in the Hallicrafters Model T-54 Television receiver. The T-54 was one of the most popular of the early 7" Electrostatic receivers. Although the T-54 is no longer manufactured, the circuit is typical of many that have been used and serves as an excellent example of the Commercial application of Voltage Multiplier circuits.

In operation, s1 (a selenium rectifier) serves simply as a half-wave rectifier power supply circuit, giving a positive output voltage at approximately line voltage. R_a prevents a heavy current drain that would damage s1 as C₇ charges. C₇, 'L₁ and C₆ form a conventional "pi" type filter circuit.

VTa also serves as a conventional half-wave rectifier, but supplying a negative voltage with respect to ground. Again, C_s, R₂ and C₄ are a simple "pi" type filter network. The output voltage of this circuit is somewhat higher than that obtained from the "s1" circuit due to the lower current drain.

VT2, operating with the s1 circuit, forms a voltage doubler, supplying a higher output voltage. In operation, C_a charges through VT2 to the peak line voltage plus the d.c. voltage across C₇. R₁ and C₂ form the output filter.

Finally, VT₁, supplied by the doubled output voltage of the VT2 circuit, forms a voltage tripler, giving the highest d.c. output voltage.

"breadboard" design techniques with the laboratory power supply

BY LOUIS E. GARNER, JR.

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Probably the best way to determine final parts values and performance characteristics in an experimental circuit is to actually wire the circuit and check its performance as various changes are made in parts values. This technique is not only valuable as a practical check of the accuracy of engineering calculations, but also permits the rapid design of circuits where a complete and detailed mathematical analysis might require hours.

In order to save time when assembling test circuits, many engineers and experimenters use a special chassis for temporary wiring until the final circuit design is determined. Then a new layout is made on a separate chassis. Although the use of a metal chassis for assembling test circuits offers several advantages, it is often necessary to drill or punch additional holes in order to mount transformers, volume controls, tube sockets, or other components. In such cases, the time required for mechanical work may exceed that required for actual wiring and test.

Considerable time may be saved in wiring experimental circuits by using a separate *Laboratory Power Supply* and a "breadboard" layout. (NOTE: To newcomers in the field, a word of explanation may be necessary. In the early days of radio, it was customary to assemble complete equipment circuits on a wooden base or breadboard. Later, this practice

was confined only to experimental circuits, with the final equipment assembled on a conventional metal chassis. As time went by, it became customary to refer to any temporary or experimental circuit, even if wired on a conventional chassis, as a "breadboard" layout. However, strict interpretation of the expression refers only to circuits assembled on a wooden base.) A typical breadboard "chassis" is illustrated in Fig. 1. This "chassis" is suitable for a wide variety of experimental circuits and may be assembled easily in less than an hour by the average worker. The complete parts list follows:

- 1 — #1 White Pine, 8"x9"x1" (larger size is satisfactory).
- 2 — Octal "above chassis" sockets (ICA # 300).
- 1 — 4-Prong "above chassis" socket for coil form (ICA #2480).
- 2 — 4-Terminal "tie point" terminal strips.
- 3 — 2-Terminal "tie point" terminal strips.
- 2 — Volume control mounting brackets (see below).
- 36" — #12 Tinned bus bar.
- 36" — Flexible Test Lead Wire (red).
- 36" — Flexible Test Lead Wire (black).
- 4 — Banana plugs (2 red, 2 black).
- 13 — Small wood screws.

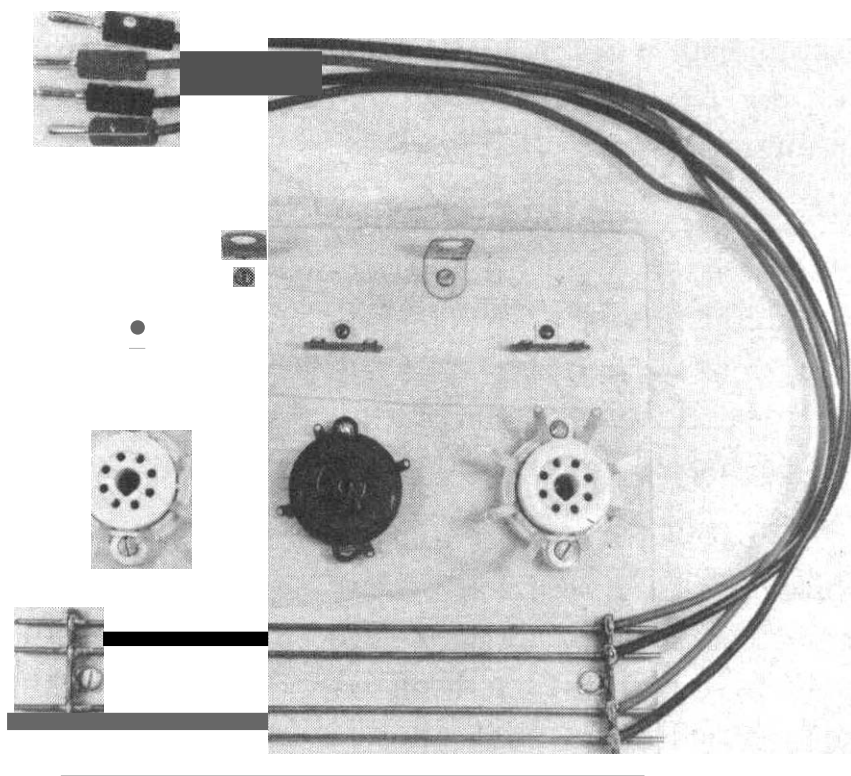
Assembling The Breadboard Chassis: The approximate layout of the experimental breadboard chassis is shown clearly in Fig. 1, and this will serve as a guide to the experimenter. However, it is not necessary that this basic layout be followed exactly. As experiments are carried out, it will often be found desirable to change the position of the various tube sockets, terminal strips, and mounting brackets.

The 4-Terminal terminal strips are mounted close to one edge of the "breadboard" so that corresponding terminals are in line. The #12 tinned bus bar is then straightened, cut into four 9" pieces and soldered in place between the terminals, as shown.

To straighten the bus bar, clamp one end in a bench vise (which should be securely clamped or screwed in place on a heavy workbench), grasp the other end with a pair of heavy electrician's pliers and give a good, strong "yank." As the pull is increased, the bus bar will not only straighten, but will also stretch slightly and become stiffer.

The flexible Test Lead wire is cut into 18" lengths and attached to form flexible extensions of the four lengths of

Figure 1



bus bar, as shown. The banana plugs are then connected to the free ends of the Test Lead wire. These four leads serve to connect the breadboard chassis to the *Power Supply* terminals (2 leads for filament connections, 1 lead for B plus, 1 lead for B minus).

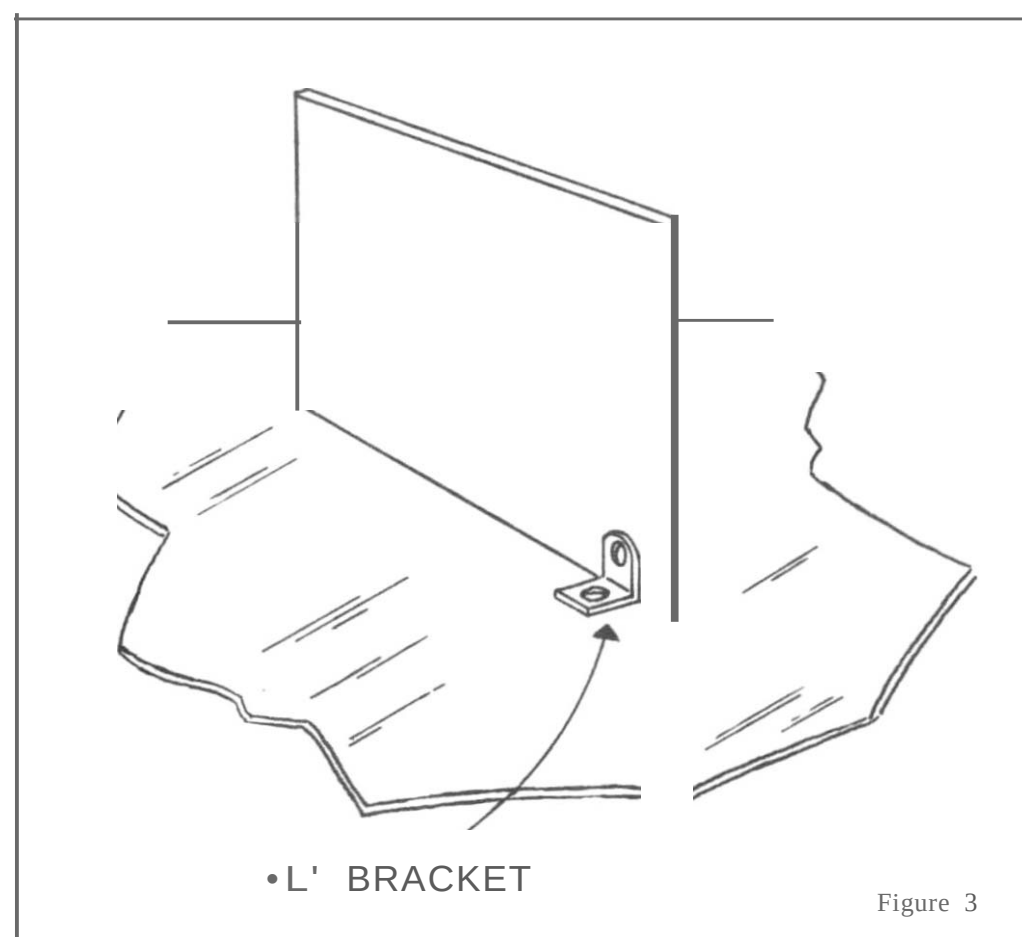
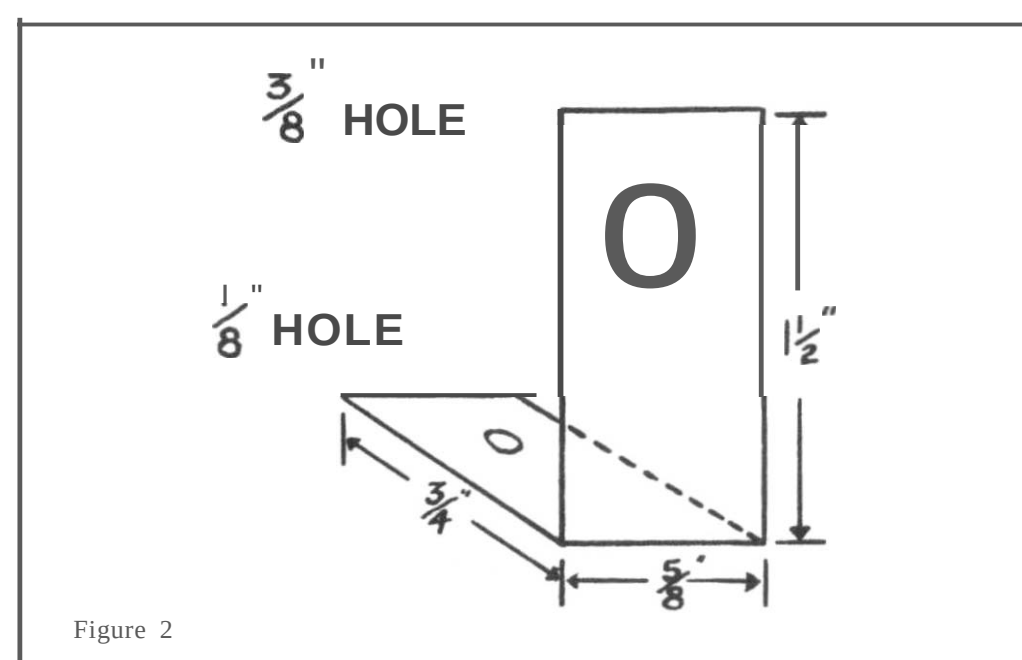
Small metal brackets are provided for mounting volume controls, switches, variable condensers, or similar components. Two of these brackets are used in the chassis illustrated (Fig. 1) but more may be provided where needed.

Construction details of the metal brackets are given in Fig. 2. Most dimensions are not too critical, and the bracket may be made either larger or smaller, as desired. However, the large hole size is critical, as this is standard for most volume controls, rotary switches, and variable condensers.

Either steel or aluminum may be used for making the bracket, of sufficient thickness to impart stiffness to the bracket (at least .050 aluminum or 20 gauge steel). Brass may also be used, if desired, but copper is too soft.

Shielding Techniques: On occasion it becomes necessary to shield experimental circuits in order to carry out desired tests. Because of this, many technicians use a standard metal chassis for experimental work even though the wooden breadboard "chassis" offers many advantages from the viewpoint of time saved in wiring and in making layout and circuit modifications. However, it is possible, with but little additional effort, to obtain shielding that is satisfactory for most work, yet retaining the advantages of a wooden base. The method used is given below.

Remove all parts mounted on the wooden base (simply by removing the wood screws). Cut out a piece of heavy household aluminum foil slightly larger than the wooden base and secure this sheet to the base using ordinary rubber cement. Lap the excess foil along the edges of the base. (NOTE: To use the rubber cement properly, first coat the top surface of the wooden base with cement and allow to dry. Also put one coat on the aluminum foil on the side to be secured to the "chassis." Spread a second coat on each surface and, while still wet, place the foil against the wood. Use a plastic rod or



wooden dowel to roll out any air bubbles and to leave a smooth surface.)

Now, remount the tube sockets, brackets and other parts previously removed, driving the wood screws right through the thin aluminum foil. Electrical connections to the foil may be made by screwing conventional ground lugs in place at the desired points and soldering to the lugs.

Individual parts or circuits may be shielded by using large i.e. transformer shield cans, held in place by "L" brackets and screws. Holes should be cut in the cans to permit circuit leads and other connections to be brought through. Some experimenters even use discarded "tin cans" for shielding.

Interstage shielding is provided by using rectangular pieces of thin sheet metal (steel, copper, or aluminum) held in place with small "L" brackets and wood screws as shown in Fig. 3. These shields may be bent or otherwise formed for special purposes, as required. It is even possible to use aluminum foil in this application if care is taken in forming the shield and mounting it.

Individual wires may be shielded by using conventional shielding braid, or by wrapping the wire in thin strips of aluminum foil.

Accessories: A number of test leads of varying lengths should be prepared for quickly connecting other circuits or pieces of equipment to the breadboard chassis. These test leads are made up using flexible Test Lead wire, clips and plugs. Most experimenters prefer to make up the leads in "pairs," using one red and one black lead of a specific length for each pair.

Two pairs of test leads are shown in Fig. 4. The upper pair is made up using ordinary banana plugs and the lower pair is made with insulated alligator clips (Mueller type 60HS). The separate clips shown are designed to slip right on the banana plugs (Mueller type 60S) and may be used to convert banana plug test leads to clip leads.

The Heathkit RESISTANCE SUBSTITUTION BOX or the DECADE RESISTANCE BOX both serve as valuable accessories to the breadboard chassis described.

Wiring Hints: All connections should be made using simple "lap" joints as illustrated in Fig. 5. This type of soldered connection is not only quickly made, but is even more quickly disconnected. Thus, considerable time may be saved in disassembling experimental circuits.

The four bus bars are used for all power connections, with the flexible leads serving as connectors' to the Heathkit LABORATORY POWER SUPPLY. The banana plugs may be replaced by spade lugs or alligator clips to suit special requirements.

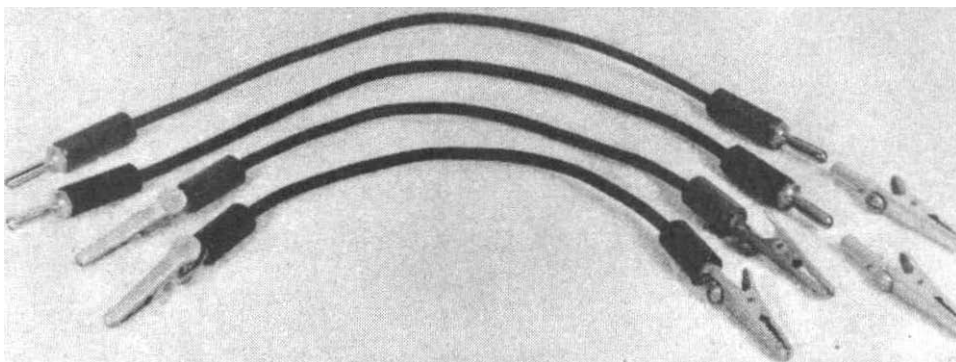
Although octal sockets (for tubes) and a four prong socket (for a standard coil form) are used in the "chassis" shown (Fig. 1), any of these sockets may be removed and other types installed. Small transformers or chokes may be easily mounted directly on the base. The number of terminal strips and their location may be changed to meet individual circuit requirements.

A typical arrangement of two tubes, a coil form, a volume control, and a variable condenser is illustrated in Fig. 6. Connections to the *Power Supply* are also shown in this photograph. This set-up is typical of those that may occur in experimental work.

LIMITATIONS OF BREADBOARD LAYOUTS

The experimental Breadboard "Chassis" described above is useful for many types of laboratory work, and is especially valuable in carrying out experimental tests. Students and teachers, particularly, will find that the layout described is helpful in carrying out experimental demonstrations. However, like any laboratory technique, there are certain limitations on its use. Therefore, to obtain the greatest value from Breadboard layouts, the reader should take reasonable care that these layouts are used within their limitations ... in no case should a "bread-

Figure 4



board" layout of the type described be used where the results obtained cannot be applied directly to the final design.

In design work, a Breadboard layout will give valuable information when checking the characteristics of one or two stages, or when determining optimum values in a new circuit. Such layouts are valuable in industrial electronic work, in designing audio stages, in checking sweep oscillators, counters, and similar circuits, and in determining tube characteristics. However, there are certain types of work where a conventional metal chassis "Breadboard" layout is preferred to the more easily used wooden base described. Several of these are given below:

R.F.-I.F. Circuits: Distributed wiring capacitances and stray component capacities to ground will often determine the tuning and "Q" of an R.F. or I.F. circuit. Because of this, the final experimental design of such circuits should be carried out using a layout as near as possible to the one employed in the completed equipment.

However, for simple demonstrations and classroom work, the wooden base type of breadboard layout is still valuable for studying such circuits. In many cases the effects of distributed capacities can be readily demonstrated by using small mica, ceramic, or "gimmick" condensers to ground.

Multi-Stage Circuits: Where the inter-actions between a number of stages must be considered, wooden base breadboard layout is definitely *not recommended*. There are two reasons for this.

First, one persistent "bug" often encountered is Inter-stage coupling due to common ground "loops." This particular trouble cannot be eliminated experimentally until the equipment is in close to final form. Therefore, a wooden base type of breadboard layout will give little information of value in determining whether the trouble will be encountered, or how to eliminate it.

Secondly, mere space requirements alone make the wooden base type of breadboard layout impractical for multi-stage circuits. An ordinary Television receiver, if laid out "Breadboard" fashion, for example, would occupy a fairly large workbench by itself ... leaving little or no room for test equipment, tools, work space, etc.

uH.F. Circuits: The difficulties encountered in applying the results of tests conducted on a breadboard layout of an R.F. or I.F. circuit apply many times over to U.H.F. and higher frequency circuits. Not only must distributed capacities be taken into account, but also the effect of lead inductances.

At some frequencies, a two inch lead of #20 copper wire may well act as an appreciable inductance ... or even as an R.F. Choke.

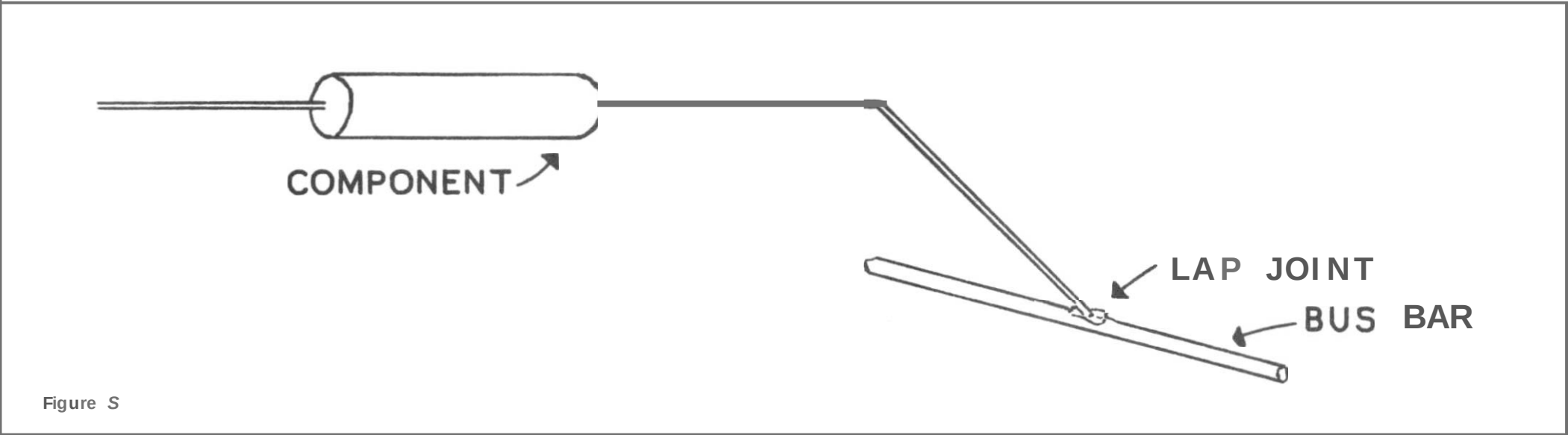
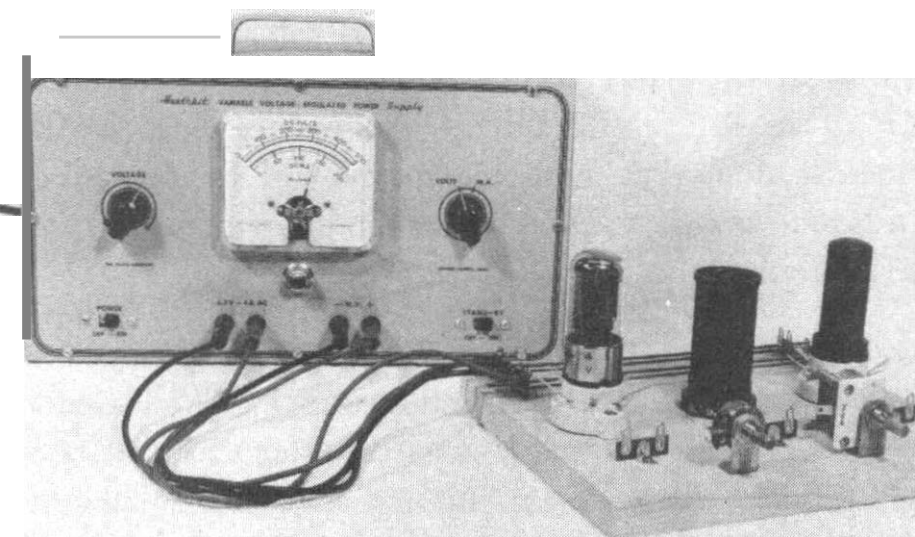


Figure 6



In addition, much better shielding of these circuits are required to eliminate the effects of body capacity. While adequate shielding for many types of work may be achieved using a breadboard layout (with the methods described above), a high degree of shielding is generally difficult to obtain unless a conventional metal chassis is used.

However, if the reader will keep these few limitations in mind, he should have no difficulty in applying Breadboard Layouts to his work ... where applicable, these techniques may save considerable laboratOry time.

(NOTE: The breadboard "chassis" described in this bulletin is used to carry out "basic circuit" experiments described in other Heath bulletins.)

intermodulation analyzer applications

BY GLEN SOUTHWORTH

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GENERAL USAGES

The HEATHKIT Intermodulation Analyzer is a versatile instrument for measuring the degree of interaction between two signals caused by a specific piece of apparatus or chain of equipment. It is primarily designed for tests of audio equipment, but may be used in other fields as well. In the sound reproduction field the HEATHKIT Intermodulation Analyzer may be used to make tests of any or all parts of the reproducing chain, including microphones, records and recording equipment, phonograph pickups, amplifiers, and loudspeakers. In addition to intermodulation tests, the Intermodulation Analyzer may be used with little or no modification as a sensitive AC voltmeter, as a flutter meter for checking tape, disc, or optical recordings, as a high pass noise meter for adjusting tape bias, cutting needle pitch, or other applications, and when used with a suitable signal generator the IM-1 may be used to indicate transient distortions at frequencies above approximately 2000 cycles.

INTERMODULATION TESTS OF AUDIO AMPLIFIERS

The audio amplifier is the piece of equipment to which intermodulation test procedures are most frequently applied. The test commonly used is to set the low frequency tone (60 cycles in the case of the HEATHKIT Intermodulation Analyzer) to an amplitude four times as great as that of the high frequency signal (either 3000 or 7000 cycles in the case of the HEATHKIT Intermodulation Analyzer) and then the intermodulation percentages are measured over a power range of approximately one watt to the maximum output of the amplifier when working into an optimum resistive load. With a typical amplifier this test will usually indicate a gradually increasing intermodulation percentage up to the point of amplifier overload at which the distortion percentages rapidly increase due to clipping of the high frequency during low frequency peaks. An example of this is shown in figure 1.

Much more comprehensive tests may be made than the standard one outlined above. In the first place, few amplifiers work into perfectly matched load impedances and Intermodulation tests of power amplifiers should preferably be made under conditions of at least 100 percent mismatch as well

as with optimum load impedances. In the case of a nominal eight ohm impedance this would mean tests with a four ohm load and a sixteen ohm load as well as with the correctly matched resistance. Typical distortion curves are shown in figure 2.

A second factor of importance is to make tests at very low levels as well as at outputs of a watt or more. In many applications the average power output of an amplifier may be held to a few milliwatts and significant sounds may be reproduced at levels much lower than this. The sensitivity of the HEATHKIT Intermodulation Analyzer is such that measurements down to two milliwatts may be made across an eight ohm Output impedance, and measurements at much lower levels may be made across five hundred ohm outputs. Figure 3 illustrates the characteristics of an amplifier having rising 1M percentages at low levels. Such a condition is frequently typical of gaseous tubes or cross modulation in the output stages caused by insufficient power supply filtering.

Although the use of a four to one ratio between high and low frequencies is standard practice, the masking characteristics of the human ear indicate that interactions between frequencies having ratios as high as one hundred to one may be of significance when the test frequencies are as widely separated as sixty and seven thousand cycles. Assuming good design, such a test will indicate twice the power Output available from an amplifier than would be obtainable with a test using high and low frequencies mixed in a one to one ratio, due to the difference between the peak and average power contained in the two complex waves.

Another nonstandard test, which is very convenient to use, is to set the high frequency test signal at a relatively low level and gradually increase the intensity of the low frequency signal through use of a separate signal source and associated attenuator. This technique has the advantage that the high frequency carrier level, once set, needs no further adjustment and the entire output range of the amplifier may be continuously observed without the necessity for the constant resetting of levels and point by point checking required when a constant difference in levels is maintained between the two

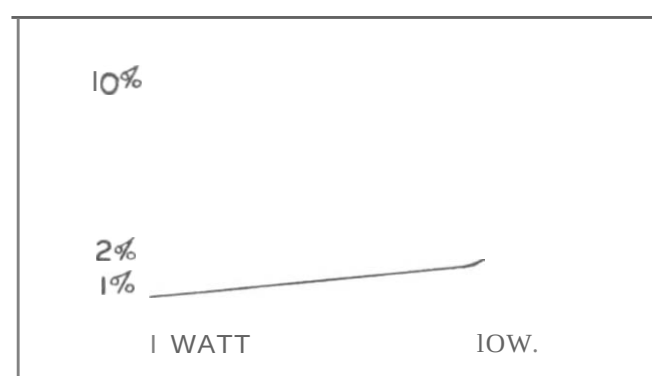


Figure 1

Typical 1M distortion of a high quality amplifier.

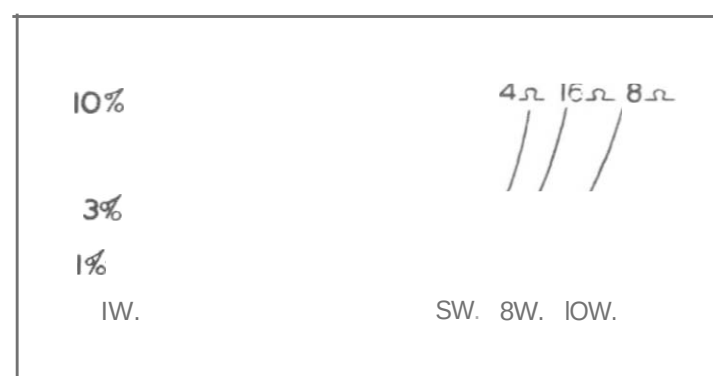


Figure 2

Effects of different load impedances on 1M distortion and power output of amplifier.

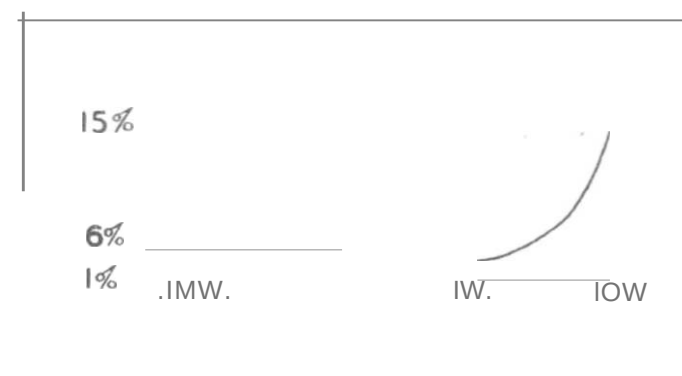


Figure 3

1M distortion curve over 50db. range of power amplifier.

test frequencies. The ability to make continuous observations rather than point by point checks is occasionally of appreciable **importance** due to the fact that some amplifiers may break into parasitic oscillations over a narrow power output range and this effect might go unnoticed in the case of point by point tests.

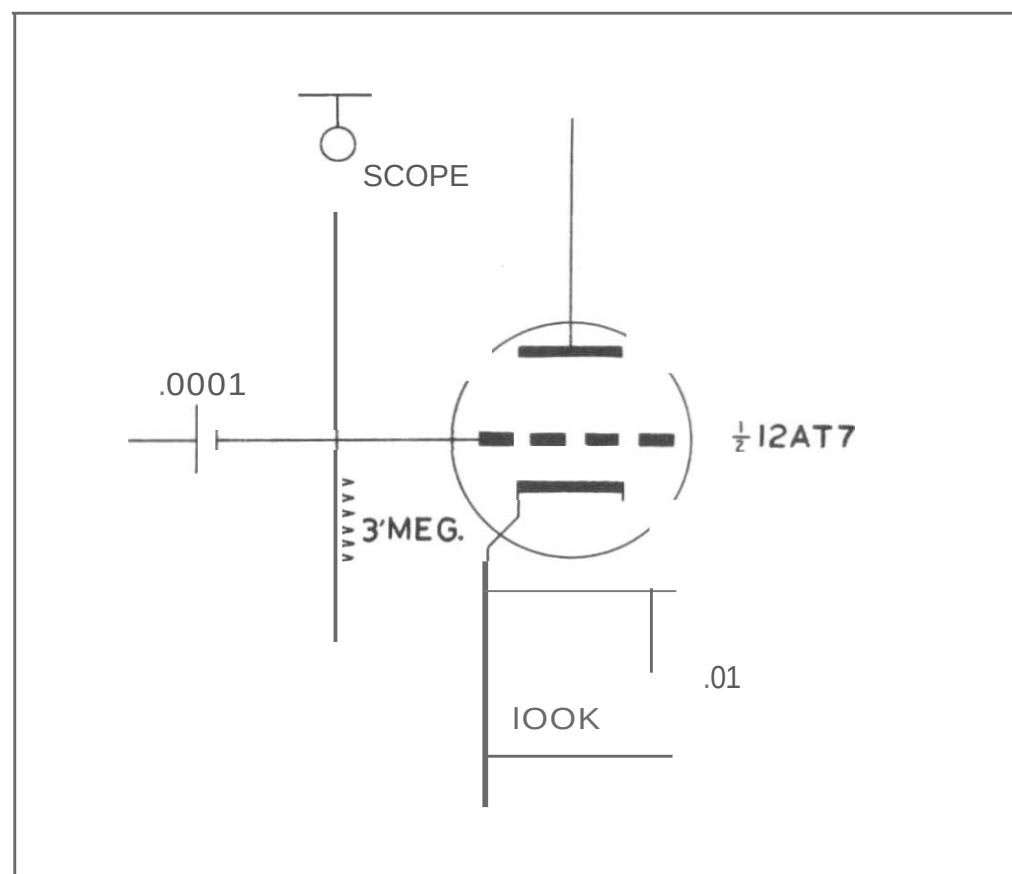


Figure 4

Partial diagram of HEATHKIT Intermodulation Analyzer showing point to connect an oscilloscope for visual observation of high frequency modulation. "Carrier Set" level should be 50% or less.

USE OF AN OSCILLOSCOPE WITH 1M ANALYZER

The oscilloscope is a very useful instrument in interpreting the probable causes and aural effects of various types of intermodulation distortion. In general, the experimenter is most likely to encounter the distortions of the high frequency carrier shown in the accompanying oscilloscope photos made with the aid of the HEATHKIT Oscilloscope. The first of these is symmetrical modulation, such as occurs in an AM transmitter, and is caused by the same conditions that give rise to second harmonic distortion in the amplifier, faulty bias in single ended stages, unbalance in push pull stages, etc. The second of these is positive modulation of the carrier at a frequency twice that of the low frequency signal. This effect is caused by conditions which likewise produce in-phase odd order harmonic components in the amplifier output. Aural sensations resulting may be of harshness and high frequency brilliance.

The third type of modulation likely to be encountered is negative modulation of the high frequency carrier by condi-

tions that tend to produce out-of-phase odd order harmonic components. Aural sensations in this case may be of mellow-ness and bassiness due to the increased masking of the highs by the low frequencies: Either positive or negative modulation may be indicated to some extent with the IM-1 alone by first setting the high frequency carrier level with the meter on carrier set and then applying the low frequency test tone. An apparent increase in carrier level indicates that positive modulation is occurring, while a decrease indicates negative modulation products.

A fourth, and very significant, type of intermodulation distortion is not detectable by the conventional 1M meter but is very obvious with an oscilloscope. In this case, high order harmonic distortion of the carrier frequency may occur and in some cases may be aurally much more distressing than the sum and difference tones generated by true intermodulation. Figure four shows the simple connection that may be made in order to observe carrier modulation on an oscilloscope.

INTERMODULATION TESTS OF OTHER REPRODUCING ELEMENTS

In general, the same techniques that apply in testing amplifiers are used in testing other elements of the audio chain. If electro acoustic or electro-mechanical tests are to be made, it will first be necessary to obtain accurate transducing elements such as microphones or phonograph pickups. In testing microphones, probably the most satisfactory way is to use two separate speakers and power amplifiers to provide the test signals, and frequencies of 200 and 3000 cycles are simpler to generate acoustically than 60 and 7000 cycles. The two speakers should be separated to reduce acoustic interaction, and the microphone preamplifier should have as low inherent distortion as possible. The ratio between the high and low frequencies should preferably be measured at the Output of the microphone preamplifier as the electrical input to the loudspeakers is not a very good indication of actual acoustic output.

Once a microphone of reasonably low distortion has been secured, it may be used to make intermodulation tests of loudspeakers and again two separate power amplifiers may be used to feed a single speaker in order to obtain a low distortion signal source. However, it should be noted that many variables occur when making tests of loudspeakers and it may be difficult to obtain significant results.

In the case of phonograph components, pickups may be measured through use of a standard Intermodulation test disc, several of which are currently available. However, care should be taken that the frequencies used fall within the range of the analyzer. In the operation of the HEATHKIT Intermodu-

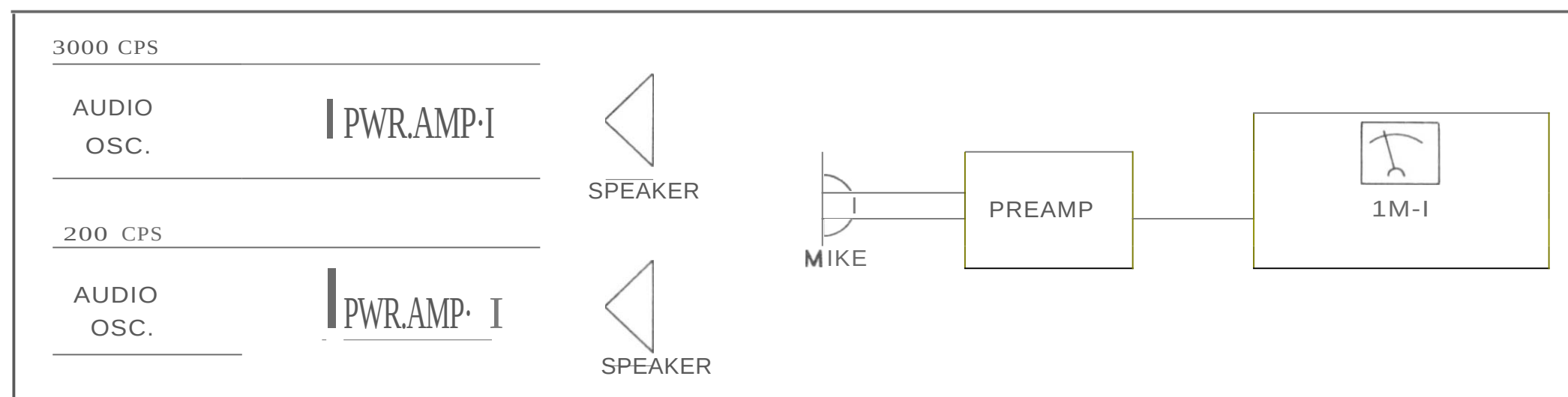


Figure 5

Setup for making 1M tests of microphones. Use of separate power ampli-

fiers and speakers minimizes possibility of 1M distortion occurring elsewhere than in the microphone and preamp.

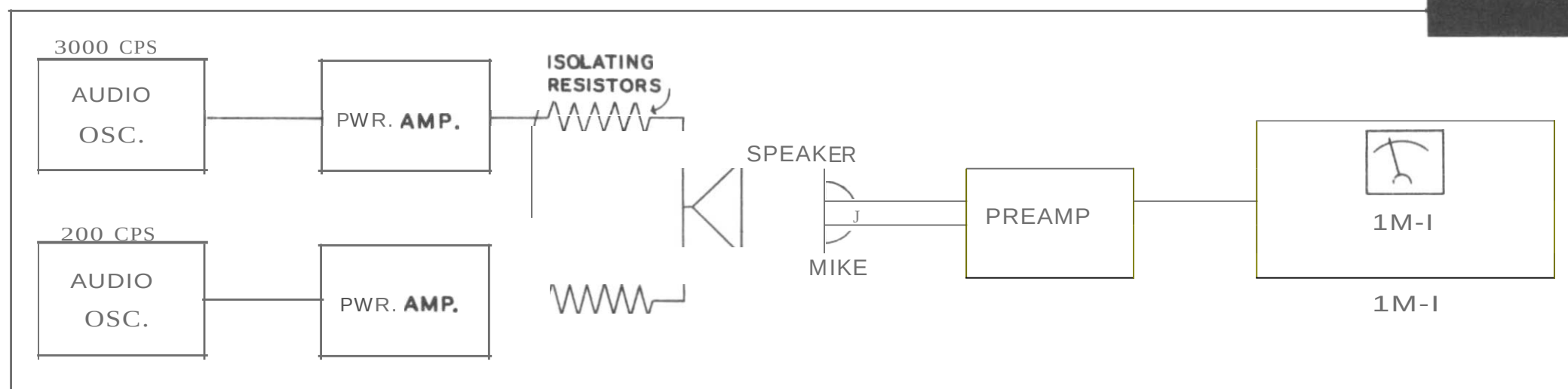


Figure 6

Setup for making 1M tests of loudspeakers. A low distortion microphone and preamp should be used.

lation Analyzer, this will mean a low frequency of from 60 to 200 cycles and a *high* frequency signal between 3000 and 7000 cycles. Once a suitable pickup has been obtained by this test, measurements may be made of cutting head performance by recording mixed *high* and low frequencies and playing back with a low distortion pickup through the IM-1 analyzer. In testing either pickup or cutting head performance it is desirable to check for modulation of a pure *high* frequency signal by turntable rumble or motor hum.

Overall performance of tape or film recorders may be readily tested by recording the two tone signal and applying the output of the playback amplifier to the HEATHKIT Intermodulation Analyzer. As in the case of phonograph recordings it is wise to make a preliminary test of spurious modulation of a pure high frequency tone that may be produced by tape or film flutter. Likewise, a system which shows good overall performance does not necessarily mean that each component is distortion free, as in some instances distortion in one element may be partially cancelled by distortion of an *opposite* nature in another part of the reproducing chain.

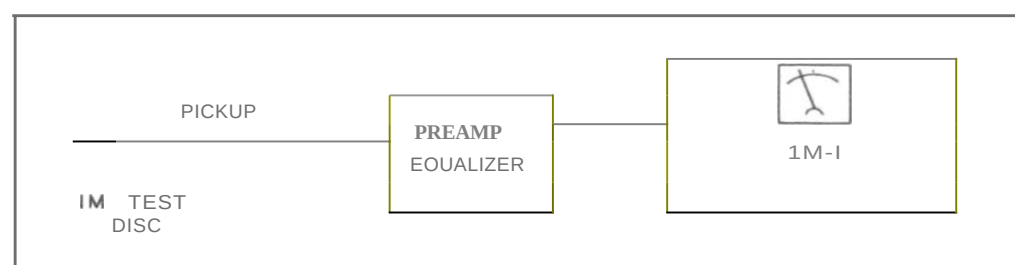


Figure 7

Setup for 1M tests of phonograph pickups. Test disc with proper frequencies must be used with HEATHKIT Intermodulation Analyzer. After low distortion pickup and **preamplifier-equalizer** has been obtained, the same setup may be used for measuring distortion generated by a disc recorder.

SPECIAL MEASUREMENTS WITH THE HEATHKIT INTERMODULATION ANALYZER

Due to the design features included in the Intermodulation Analyzer, it may be used for a number of useful tests Other than intermodulation measurements. For example, a *high* input impedance, AC voltmeter is included which may be used for frequency response measurements, amplifier power output capabilities, and gain or loss of audio amplifier stages, equalizer networks, or other circuit elements. An external multiplier may be used to read voltages higher than the 30 volt range provided by the HEATHKIT Intermodulation Analyzer.

Another very useful application is the use of the Intermodulation Analyzer as a *high* frequency noise meter. This may be done by setting the controls at "Operate" and "Carrier Set" and thus making use of the *high* pass circuits of the

analyzer in conjunction with the AC voltmeter. For greatest precision, the input attenuator should be opened all the way and external calibrating and multiplier resistances used. Once set up in this way, the instrument is very useful in judging the relative *high* frequency noise levels in high gain amplifiers and *disc* or tape recordings without spurious indications being produced by hum or rumble. The meter indication is a very convenient way of adjusting *high* frequency bias for minimum tape *hiss* in magnetic recordings or of adjusting needle *pitch* and groove depth for *minimum* noise in *disc* recordings.

A third application, briefly mentioned earlier, is the use of the HEATHKIT Intermodulation Analyzer as a flutter meter. In this case a pure high frequency tone, from 3000 to 7000 cycles, is fed to the recording equipment under test and the Output of the equipment is applied to the analyzer. Carrier set adjustments are made in precisely the same manner as in 1M tests and then the percentage of mechanical or other modulation introduced by the equipment under test may be read directly upon the 30, 10, or three percent range of the analyzer.

A fourth use which may be made of the analyzer, is the measurement of the change of modulation depth in an amplitude modulated way that may occur due to transient "Ring-ing" in some part of the reproducing chain or acoustic environment. For tests of this nature, a high frequency signal modulated approximately 15 to 20 percent is required. This signal may be obtained by means similar to that used in the initial calibration of the Intermodulation Analyzer. or by use of a simple modulator. The modulation **frequency** should be fixed for all measurements and may be in the range of 60 to

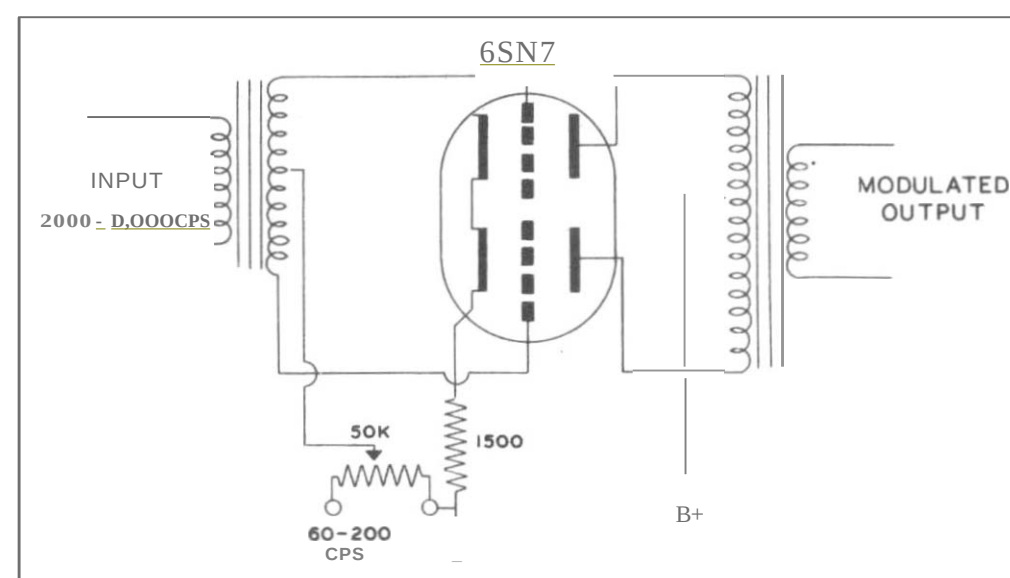
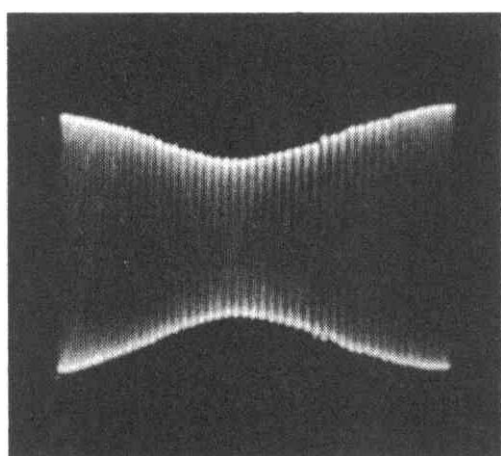


Figure 8

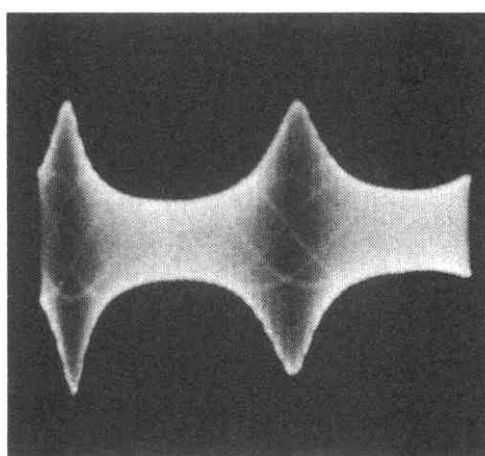
Diagram of simple balanced modulator that may be used to supply a signal for transient distortion tests.

200 cycles. The modulation percentage of the initial signal is first established with the IM-1 and then the output of the device under test is then measured for modulation percentage. Lowered modulation percentages indicate transient ringing, the greater the apparent "Q" of the ringing element, the greater the loss of modulation. An increase in apparent modulation percentage may be the result of serious phase distortion in some reproducing element or acoustic environment. Like-

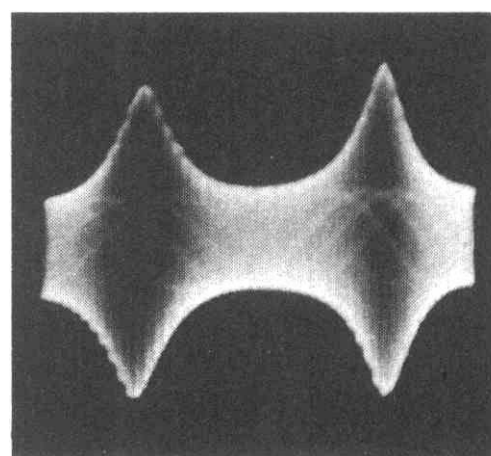
wise, an apparent increase or decrease in modulation percentage may result from non-linearity in the equipment under test. Aurally ringing, due to live room acoustics, apparently tends to reduce the disagreeable effects of modulations such as shown in the first three accompanying oscilloscope photos, but accentuate the irritating effects of transient harmonic distortions such as shown in the fourth photo. The reverse appears to be the case in a dead acoustic environment.



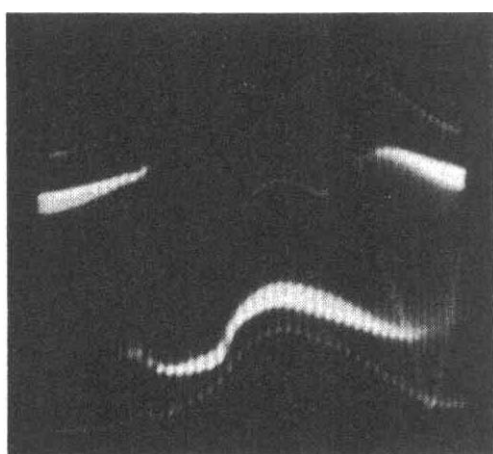
A. Symmetrical modulation of 3000 cycle carrier produced by 2nd harmonic distortion. Low frequency and scope sweep rate of 60 cycles.



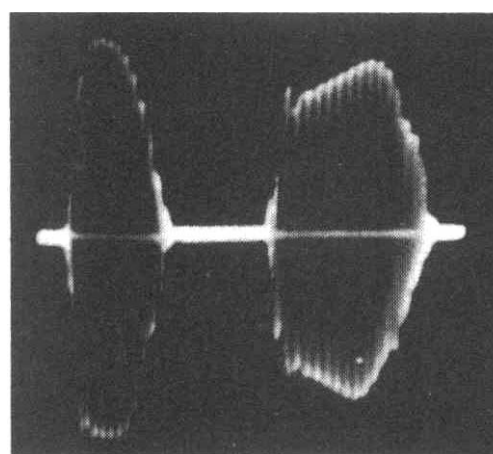
B. Positive modulation of 3000 cycle carrier caused by in-phase third harmonic components. Both positive and negative peaks of low frequency wave cause an increase in amplitude of high frequency tone.



C. Negative modulation of 3000 cycle carrier generated by linearity curve causing out-of-phase third harmonics. Positive and negative peaks of low frequency cause a decrease in the amplitude of the high frequency tone.



D. Example of serious harmonic distortion that may accompany intermodulation. Both second and high order harmonics are shown.



E. Example of amplifier in which the intensity of the low frequency tone is sufficient to run the tubes past cutoff on positive and negative peaks.

using the signal tracer to save servicing time

BY LOUIS E. GARNER, JR.

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The Heathkit *Signal Tracer* has sufficient gain to permit tracing a signal in a receiver from the antenna right through to the loud-speaker voice coil...allowing each individual stage to be checked for proper operation. Because of this, many technicians who use the instrument in servicing will tend to "follow" the signal through the equipment stage-by-stage and point-by-point, regardless of the defect. This technique is quite valuable to the beginner or student as it enables him to obtain a clearer understanding of circuit operation and a greater familiarity with his test equipment.

However, while a stage-by-stage check will generally enable the isolation of a defect in a receiver, this method may be needlessly time consuming to the Radio-TV Serviceman who must, literally, "make every minute count."

A serviceman, of necessity, must consider each service job as made up of two major parts... (a) finding the defect (diagnosis) and (b) correcting the defect (repair). Since it is often difficult to reduce the time required for actual repair (usually replacing a part), every effort should be made to minimize the time required for isolating the defect. It is in this **part** of the job that the Heathkit *Signal Tracer* may be used to save time and effort (and hence to save money).

In this Bulletin we will review practical techniques of applying the *Signal Tracer* to common servicing jobs, with particular emphasis on time-saving methods. The professional serviceman will find it worthwhile to use these methods only as a guide, however, and to make every effort to work out his own short-cut techniques. In addition, the more experienced serviceman should call on his knowledge of the "weaknesses" of various commercial receivers to go directly to the "heart" of the trouble where possible, thus saving additional time.

GENERAL CONSIDERATIONS

First, think of the receiver as consisting of several major sections rather than as individual stages. A defect is then isolated in three steps... (1) Section; (2) Stage; (3) Part. The block diagrams given in Figs. 1 and 2 will aid in developing this concept.

A conventional block diagram for a superheterodyne receiver is illustrated in Fig. 1. This receiver consists of eleven "stages"... the antenna, r.f. amplifier, mixer, local oscillator, 1st I.F. amplifier, 2nd I.F. amplifier, 2nd detector, 1st audio amplifier, audio output, loudspeaker, and power supply.

The same receiver, considered in major sections, is shown in block diagram form in Fig. 2. Only five major sections are

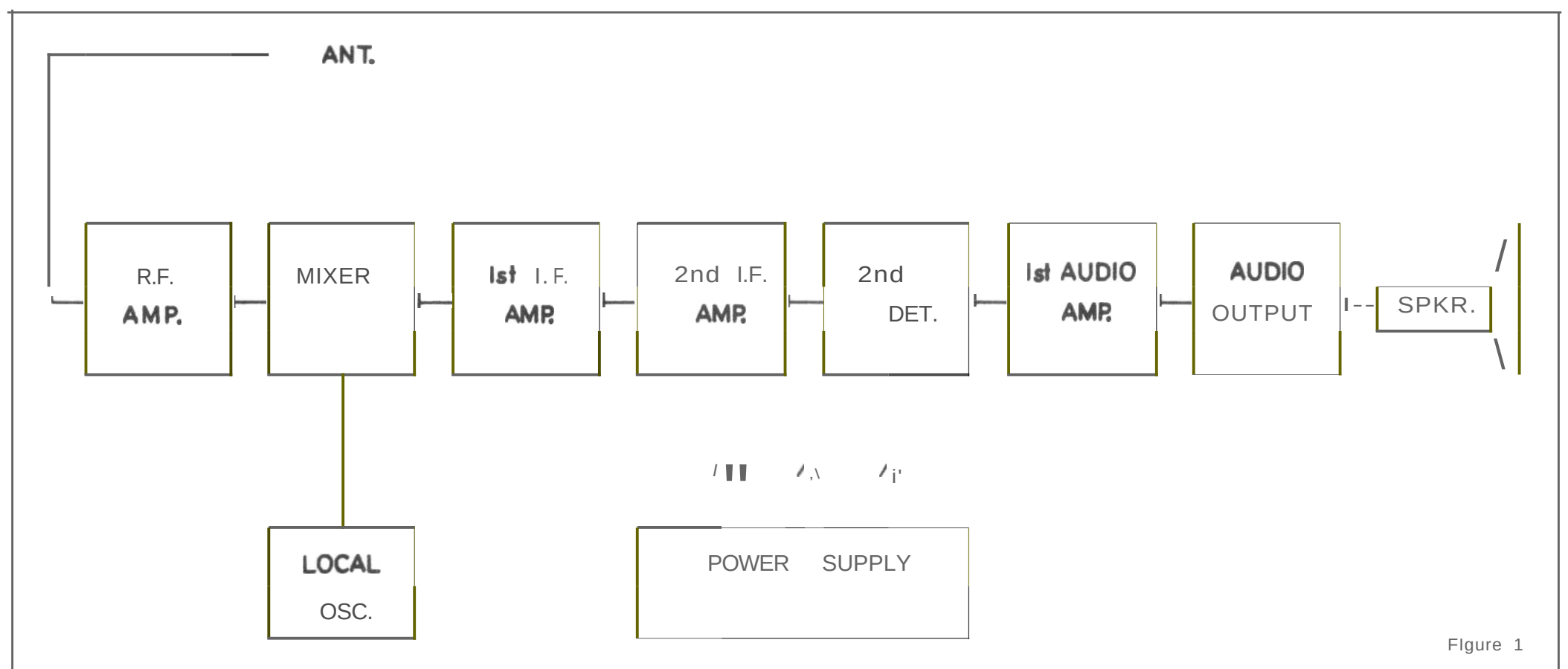
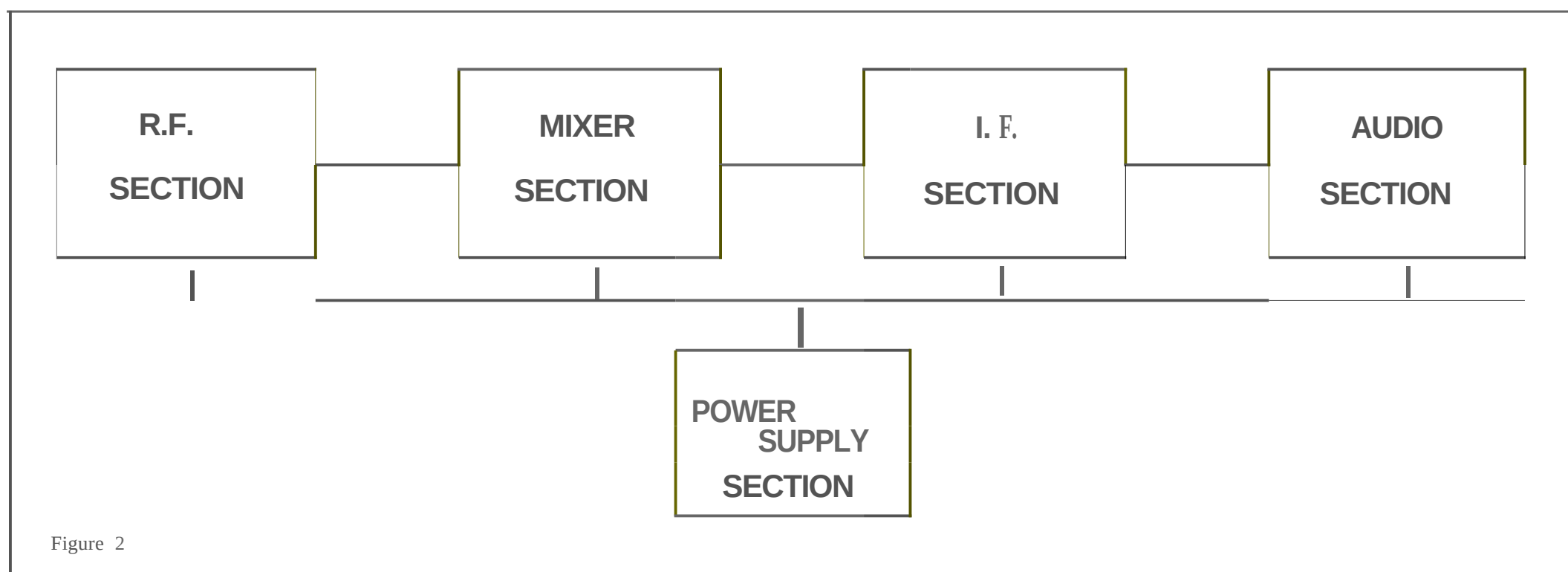


Figure 1



involved ... the R.F. section, consisting of all stages up to the converter; the Converter or Mixer section, consisting of the mixer and local oscillator; the I.F. section, consisting of all I.F. amplifiers and the 2nd detector; the Audio Section, consisting of all audio stages (including the loudspeaker); and the Power Supply section. *This breakdown into five sections would apply even to a receiver having a greater number of stages than the one shown in Fig. 1.* (For example, two or more d. amplifiers, additional audio stages, etc.)

Regardless of the complaint, and before attempting to use the *Signal Tracer*, the serviceman should first check for "obvious" defects ... that is, defects that may be readily spotted by visual observation and without making electrical tests. Such defects include burnt-out tubes (don't light or become warm to the touch), defective line cords or plugs (no power supplied to the receiver), torn or ripped speaker cones (where the complaint is "distortion"), burnt out resistors (identified both by observation and odor), and smashed or damaged parts (such as bent or broken tuning condenser plates). Many defects may be spotted in a matter of seconds without making a single test.

DEAD RECEIVER

Section Isolation: Assuming that the preliminary visual check for defects (as out-lined above) has been made, the receiver should be turned on and the tuning dial set to the frequency of a reasonably strong local station.

Plug the AUDIO probe into the AUDIO jack of the Heathkit *Signal Tracer* and turn this instrument "on." After a few minutes warm up, check for the presence of an audio signal at the Output of the 2nd detector.

If there is an audio signal at the output of the 2nd detector, it indicates that all stages ahead of this point are operating normally and these stages *need not be checked individually*. The defect is probably in the Audio Section.

If there is no audio signal at this point, it indicates that the defect is ahead of this point or in the power supply. Check the operation of the power supply by checking for the presence of d.c. operating voltages, using the Heathkit *Handitester* or VTVM. If normal supply voltages are available, the

defect is in the R.F., Converter, or I.F. sections. If no supply voltages are available, the defect is in the power supply section.

Assuming the power supply to be operating normally, the isolation procedure may be carried further by using the R.F. PROBE of the *Signal Tracer* and checking for the presence of a signal at the input to the I.F. section.

If a signal is present at this point, the defect is in the I.F. section. If not, the defect is either in the Converter section or the R.F. section.

Next, check for the presence of a signal at the input to the Converter section by transferring the probe to this point (and adjusting the *Signal Tracer* GAIN control, if necessary).

Again, *if a signal is present at this point*, the defect is in the Converter section. If not, the defect is in the R.F. section.

(NOTE: An alternative test technique is to check the individual sections from the Antenna on ... however, the Audio section is still checked first.)

Stage Isolation: Having isolated the defect to a major section, use the *Signal Tracer* to follow the signal through each stage of that section, working from the input towards the output. Use the AUDIO probe for checking stages in the Audio section and the R.F. probe for checking the operation of stages in the I.F., Converter, or R.F. sections.

If the trouble had been isolated to the Power Supply section, use a multimeter such as the *Handitester* or VTVM for isolating defects in this section.

Part Isolation: In many cases, the defective part will be "spotted" as soon as the defective stage is isolated. If not, additional tests in the defective stage are necessary.

In most cases, a "dead" receiver is caused by an "open" or "shorted" part (as contrasted to a part that has changed value slightly). Because of this, the final isolation of a trouble to a specific defective part is generally made by using a voltmeter or ohmmeter (again, the Heathkit *Handitester* or VTVM). The voltmeter is used to check for correct plate, screen-grid, and bias voltages in the stage, while the ohmmeter is used to check individual parts for continuity and possible

shortS. USE THE OHMMETER ONLY WITH THE SET POWER TURNED "OFF."

If the trouble has been isolated to the Converter section, the usual cause of a "dead" section is failure of the local oscillator to operate. In many instances it will be found almost impossible to determine if the local oscillator is working by using the *Signal Tracer* alone.

As an alternative, the technique shown in Fig. 3 may be used to check the local oscillator for operation ... simply check for a d.c. voltage across the oscillator grid resistor. A VTVM is preferred for this test.

If there is no d.c. voltage across the oscillator grid resistor, the oscillator is not working ... check for d.c. voltages on the anode grid (and the plate and screen-grids). Check the tube, trying a new one if available. Check for a short in the tuning condenser, and make sure the oscillator coil is in good condition.

WEAK RECEIVER

Section Isolation: The defective section causing a receiver to have poor sensitivity ("weak," low volume, etc.) is isolated using much the same technique that is employed when the set is "dead," with but one important modification. Since the receiver is working, a signal will be present in every section ... but it may be of considerably less than "normal" amplitude.

In order to effectively use the *Signal Tracer* in isolating a "weak" section, the serviceman should have a general idea of the signal level to expect in different sections of the receiver. This knowledge may best be acquired by experience ... try checking the signal level in various sections of receivers known to be in good operating condition. Note about how much it is necessary to advance the GAIN control in order to close the "eye" or to obtain sufficient speaker volume for comfortable listening.

As in the case of a "dead" receiver, the first check should be to see if a normal signal is obtained at the output of the 2nd detector. If a normal signal is present here, the defect is in the Audio section. If not, the defect is either in the Power Supply, I.F., Converter or R.F. sections. The Power Supply section may be checked as before ... by checking for normal d.c. operating voltages.

Should the defect be in the I.F., Mixer or R.F. sections, isolation to one of these sections is obtained when a signal of "normal" amplitude is noted at the input to a section, with a weak signal at the Output. Note that each stage (except the 2nd detector) should supply some gain.

Stage Isolation: Once the defective section is identified, the individual stage is isolated by checking the input and Output signal levels of each stage in that section and noting relative gain. Again, the serviceman should have some idea of the gain to expect and, as before, this knowledge is best acquired by actual tests on similar sets in good operating condition.

Part Isolation: After isolating the defective stage, the first step should be to check the tube in that stage (if not done previously). Check d.c. operating voltages on the stage (low plate and screen-grid voltages are common causes of weak operation), and, finally, check individual parts.

DISTORTION

Section Isolation: As before, an effort is first made to isolate the defect to a particular section. However, care must be taken that the *Signal Tracer* loudspeaker, rather than the "eye," is used in tracing the signal so that the *quality* of the signal may be noted at each test point.

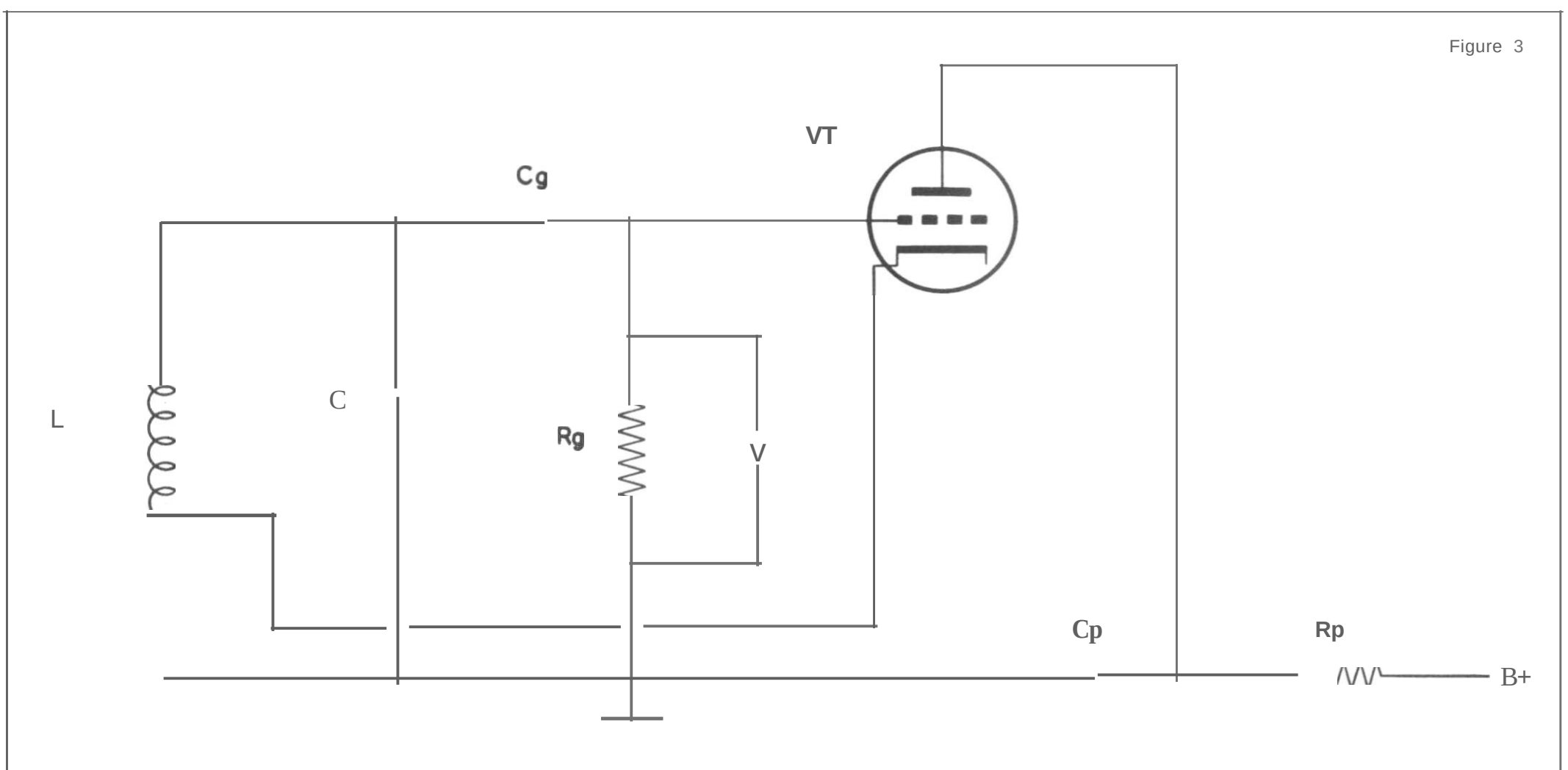


Figure 3

In many cases, *distortion is caused by a defect in the Audio section* of the receiver. Because of this, the check on the quality of the signal at the Output of the 2nd detector is primarily for confirmation. In those few instances where the signal at the output of the 2nd detector is distorted, additional tests may be necessary to complete the isolation of the trouble to a section.

Stage Isolation: The defective stage is isolated simply by listening to the signal at the input and output of each stage. If a clear signal is obtained at the input of a particular stage, but a distorted signal at the Output, the defective stage has been isolated.

A warped loudspeaker frame or cone is a common cause of distortion. Often, some trouble in isolating the trouble may be saved by checking the signal at the speaker voice coil before attempting stage isolation tests. If a good quality signal is obtained at this point, the chances are that the loudspeaker is defective ... full confirmation of this may be obtained by using the speaker in the *Signal Tracer* as a substitute.

Part Isolation: With the trouble isolated to a specific stage, continue to use the *Signal Tracer* to check the operation of any by-pass condensers in that stage. Also check for the presence of an audio signal in the d.c. supply circuit (high power factor in power supply electrolytics is a common cause of distortion). Finally, use the *Handitester* or *VTVM* to check all d.c. operating voltages applied to the stage ... look Out for improper bias voltages. Also check for leaky coupling condensers and gassy tubes.

HUM

Section Isolation: Where the complaint is "hum," a good deal of isolation is possible simply by noting the operation of the receiver. If the hum is *tunable* (comes and goes with the station signals and not present between stations), it is "modulation hum," and is due to a defect in the R.F., Converter or I.F. sections. If the hum is only present when the volume control is turned up, regardless of whether a station is tuned in, it is due to a defect in some stage following the last I.F. amplifier, but ahead of the volume Control. If the hum is always present, and adjusting the volume control has little or no effect on its intensity, it is due to a defect either in the Audio or Power Supply sections.

Stage Isolation: The next step depends on the results of the preliminary isolation tests described above.

If *tunable hum* is encountered, use the R.F. Probe with the *Signal Tracer* and check for the presence of a hum signal in each stage, starting at the antenna and working towards the 2nd detector. Be sure a station is tuned in when carrying out this test.

If hum is only present with the volume control turned up, and remains whether or not a station is tuned in, use the AUDIO probe with the *Signal Tracer* and check all stages between the 2nd detector and the volume control.

If *general hum* is present, diminishing little, if any, when the volume control is turned back, use the AUDIO probe with the *Signal Tracer*. First check for the presence of "ripple" hum at the output of the Power Supply section. Hum here generally indicates defective filter condensers. If the output of the Power Supply is free of hum, check individual stages in the Audio section, working from the volume control towards the loudspeaker.

Part Isolation: Again, the technique to use for isolating the specific defect depends on the results of previous tests. If the hum originates in the power supply, it is generally due to defective filter condensers (these may be checked by substitution or by using the *Heathkit Condenser Checker*). However, hum in this section may also be caused by a defective rectifier tube, a defective filter choke, or unbalance in the power transformer secondary (where a center-tapped secondary is used).

If the hum is found to originate in a specific stage, whether in the Audio or other sections of the receiver, it may be caused by a defective part, connection or tube. In such a case, check for poor lead dress or shielding, or by an open grid circuit.

OTHER COMPLAINTS

In addition to the major complaints outlined in detail above, there are a number of other servicing problems that are likely to be encountered, although not with the frequency of the "major" complaints. Two of the most common are discussed below:

Noise or interference is generally isolated using the techniques described under "HUM." If the complaint is "Noise," and it can be isolated to a particular stage in the receiver (Other than at the antenna ... the "input"), it is generally caused by a defective part, connection or tube. In such a case, the NOISE TEST provision of your *Heathkit Signal Tracer* is quite helpful in finding the specific defect.

Oscillation or Squealing are usually difficult to isolate using the *Signal Tracer* directly, as the complaint tends to become general and to appear in all stages. In such cases, it is often worthwhile to combine Signal Tracing with another valuable servicing technique ... "Stage Blocking." To use the Stage Blocking technique, "short" the input of the suspected stage by connecting a large value condenser between the grid and cathode of the tube. (This technique is also useful for isolating sections of the receiver to prevent interaction when conducting other tests.)

using the heathkit tube checker to identify and "salvage" defective tubes

BY LOUIS E. GARNER, JR.

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Whenever a tested radio tube shows an internal "short" or gives a "BAD" indication on a quality test, the natural impulse is to discard the tube ... to "throw it away". Too often, from a serviceman's viewpoint, the defective tube will be one that is in short supply, with a replacement difficult, if not impossible, to obtain. This may mean a disappointed customer, with the possible loss of future business. To the experimenter or "ham", any defective tube means a financial loss ... a strain on an already limited budget.

Fortunately, not all "defective" tubes are a total loss. Sometimes it is possible to "repair" a defective tube and to obtain at least a few more weeks or months service from it. In other cases, where repairs are impossible, the defective tube may often be used in other work. In this Bulletin, we will try to summarize the most popular and useful salvaging techniques that may be applied to defective tubes. Many of the techniques to be discussed are old, and have been known to servicemen and technicians for years. Others are comparatively new. However, it is hoped that bringing these various methods together in one Bulletin will help the serviceman, experimenter, "ham", and technician to obtain more use from his tubes.

GENERAL SUGGESTIONS

To obtain the greatest use from "salvaged" tubes, the technician should obtain a supply of blank tube cartons (these may be purchased from many radio parts jobbers). Any repaired or salvaged tubes should be kept sorted in the cartons, with the tube type number, the defect, and the repair (if any) indicated on the carton.

While the experimenter or technician may use salvaged tubes at will, *the Radio-TV serviceman, as a matter of good business practice, should use salvaged tubes to repair customer's sets only when a new replacement is not available. When used, the serviceman should not charge the customer for the tube, but should carefully explain the situation, offering the salvaged tube as a gesture of good-will.* A typical explanation may be as follows:

"The trouble you've had with your receiver, Mr. Smith, is caused by a burnt-out 50L6 tube. Unfortunately, these tubes are a little hard to get at present, and I don't have one available ... nor do any of the near-by parts distributors have this tube in stock."

"I'll try to obtain a new tube and will call you as soon as it comes in."

"In the meantime, I've installed a salvaged tube in your receiver which should give you some service and permit you to enjoy your set until a new tube is available. However, don't expect the salvaged tube to last indefinitely ... using it is a temporary expedient only. The tube may fail after a few hours service or may last for several months ... it's hard to tell."

"I'm only making my regular service charge on this set ... there is no charge for the salvaged tube ... it's yours to use until a new replacement is available."

Preliminary Tests: Before deciding whether a defective tube is to be discarded, saved, or "repaired", it is necessary to determine the nature of the defect. Most tube defects fall into one of several general classes ... (a) Noisy or microphonic; (b) Low Emission; (c) Internal shorts between elements; (d) Open Element; (e) Gassy; (g) Mechanically damaged. In addition, almost any of the defects may be intermittent.

Some of the defects listed above may be apparent from the tube's operation in the equipment. Others will be indicated by tests performed using the Heathkit *Tube Checker*. Still others require special tests. We will discuss each type of defect in turn and will see how the defect may be identified and what repair or salvage technique (if any) may be applied.

NOISY AND MICROPHONIC TUBES

A noisy or microphonic tube is generally identified rather quickly by its performance in the equipment where the complaint occurs. In a radio receiver, a microphonic tube may cause squealing or howling which takes place on the audio peaks ... reducing the set volume may temporarily minimize the trouble. In a TV receiver, a microphonic tube may cause squealing or howling if in the audio section, loss of sync if in the sweep circuits, and streaks, "snow" or "hash", and sound bars if in the video sections.

If there is any question as to whether a particular tube is microphonic, the tube may be tapped lightly while in the equipment, using the eraser end of a lead pencil (or one of the special Tube Tappers sold by the Hytron Corporation). This technique is quite easy to carry out and may well be applied to all the tubes in a receiver without difficulty.

Salvage ... In most cases, it is virtually impossible for the technician to repair a microphonic or noisy tube. About the only practical technique to use in such cases is to identify the tube properly and to save it for use in circuits where noise or a microphonic condition will not adversely affect circuit operation. Such circuits include Code Practice Oscillators, power supply rectifiers, etc.

LOW EMISSION TUBES

A tube having low emission will generally be indicated by the *Tube Checker* Quality test as a reading in the Yellow (?) or Red (BAD) areas, but with no tube elements showing an "open" (refer to the Instruction Manual furnished with the *Tube Checker*).

Low emission generally occurs when a tube is nearing the end of its useful life and will usually cause "weak" operation if used as an amplifier in a radio or TV receiver. Where the tube is used in an oscillator circuit, low emission will generally prevent the circuit from operating.

Salvage ... An amplifier stage is sometimes more tolerant of a low emission tube than is an oscillator. Because of this, tubes which show low emission should be saved and, where necessary, tried in other circuits. A low emission tube which fails to operate in one set may give acceptable results in another piece of equipment.

Some of the local oscillator circuits used in table model receivers, in TV sets, and in portable receivers may be especially critical as far as the tube characteristic⁶ are concerned. *There are cases where a tube checking GOOD on the Tube Checker will still fail to operate and it may even be necessary to try several new tubes before satisfactory operation is obtained.* In such cases, the old tube may be saved for use in less critical circuits (unless "burnt out" or otherwise defective).

Rejuvenation of low emission tubes is sometimes possible by operating the tube at higher-than-normal filament voltages for a short period of time. This may be done using your Heathkit *Tube Checker* by turning the SET LINE control clockwise or by switching to the next Filament Voltage position.

The length of time at which the filament must be operated at a higher-than-normal voltage will vary greatly from tube to tube and can best be determined by actual experiment. How-

ever, this technique will not always give satisfactory results, and should generally be used only where absolutely necessary, as there is some danger of opening the mbe's filament. It should not be used on low-voltage battery type tubes.

INTERNAL SHORTS

A partial or complete short between one or more tube elements may cause many different complaints, depending on the tube, the particular elements that are shorted, and the circuit in which the tube is used. Such defects may cause complaints ranging from weak operation to a "dead" set, distortion, oscillation, etc.

Leakage between tube elements is indicated by a glow in the neon bulb on the Heathkit *Tube Checker* as the "Short" test is carried out. The tube element that is shorted may be identified by reference to a tube manual for the tube's pin connections, and by noting the lever that is moved when the neon lamp glows (the levers on the *Tube Checker* connect to pins corresponding to their alphabetical order... lever "A" to pin 1, lever "B" to pin 2, etc.).

Salvage ... If the shorted elements are two that are likely to be connected together in some circuits, the tube may simply be saved and used in such circuits. As an example, pentode tubes are often "triode" connected in certain types of equipment. If a pentode having a short or leakage between the screen-grid and plate is used in a circuit where the pentode is "triode" connected, its operation will be satisfactory. Such a circuit is illustrated in Fig. 1(a).

Often, a tube having heater-to-cathode leakage will cause considerable hum in equipment in which the cathode is above ground, but will work satisfactorily in circuits where the cathode is grounded. This can best be determined by actual experiment.

If the internal leakage or short is caused by a "hair wire" inside the mbe, as is often the case, the defect may sometimes be corrected by temporarily applying a high a.c. voltage between the shorted elements. The resulting high current flow through the short burns it open. This technique is illustrated in Fig. 1(b).

A SPST push-button switch is connected in series with the primary of a power transformer. Leads are taken from one-

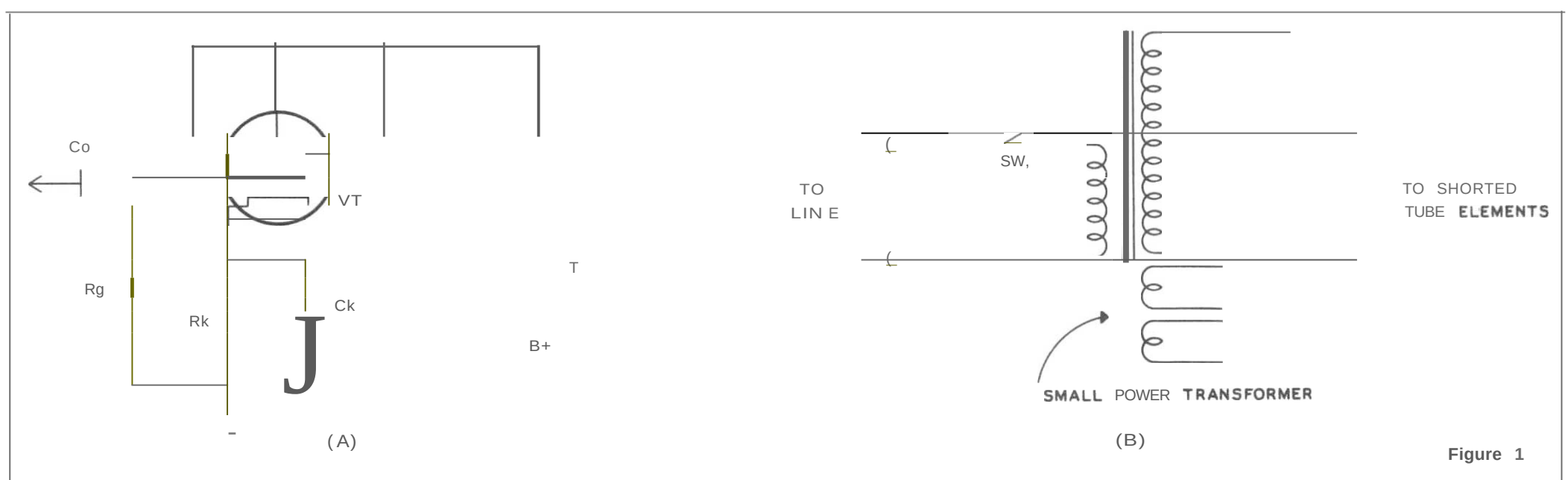


Figure 1

half of the high voltage secondary winding and connected to the tube pins of the shorted elements. With the transformer primary connected to the power line, the switch is depressed for a second or two, then released. The tube should then be checked again on the *Tube Checker* to see if the "short" still exists ... if this defect has been cleared up, the tube may be given the regular quality check. In addition, a check for "open" elements should be made (refer to the Instruction Manual for the *Tube Checker*). This last test is necessary for this technique may sometimes "open" an element lead instead of burning out the short.

A variation of the last described technique is to charge a high-capacity (50-100 mfd) high voltage (450 V.) electrolytic condenser, using a d.c. source (such as the Heathkit *Laboratory Power Supply*), and then to connect the condenser leads to the shorted elements, discharging it through the "short". The resulting high current flow is often sufficient to burn open the short without damaging tube elements.

HOWEVER, NOTE THAT THESE LAST TWO TECHNIQUES MAY NOT ALWAYS WORK ... THEY SHOULD BE USED ONLY WHERE ABSOLUTELY NECESSARY OR WHERE NO OTHER ALTERNATIVE IS POSSIBLE.

OPEN ELEMENTS

If the filament of a tube is open, the stage in which the tube is used becomes "dead". An open filament will show up quickly when the tube is checked on the *Tube Checker* either by a lack of glow or by the tube not becoming warm (in the case of metal tubes). With some battery tubes, the lack of a filament glow may be difficult to spot, as the filament does not become very bright even when good ... in such cases, the defect will show up immediately when a "Quality" test is given, as the needle will not move up-scale even slightly.

If one of the other tube elements is open, the symptoms will vary greatly, depending on which element is open, the tube itself, and the circuit in which the tube is used. In most cases, however, these symptoms will be those resulting from either a "dead" or "weak" stage.

In any case, the open element may be identified by using your Heathkit *Tube Checker* and by following the suggestions given in the Instruction Manual accompanying the kit.

Salvage ... In tubes having hollow pin bases (4-pin tubes, octal tubes, etc.), an element will sometimes open due to the wire lead running from the tube proper to the pin breaking loose. In such cases, the tube may be repaired by flowing hot solder into the pin to re-establish the connection.

To do this job use a well-tinned hot soldering iron. Melt sufficient solder on the tip of the iron to form a small globule. Next, hold the end of the tube pin against the soldering iron tip until the pin is heated sufficiently for solder to flow inside it by capillary action. Remove the iron quickly to prevent forming a "glob" of solder on the tube pin.

If the tube has an open filament, a repair may sometimes be made by momentarily applying a high voltage to the filament

pins (using the techniques outlined above for "burning Out" a short). The high voltage causes an arc between the open ends of the filament and the heat generated "welds" the two ends together. This technique seems to work best with high voltage filament tubes such as the 3SZS, SOBS, 6X4, 6X5, etc.

HOWEVER, LIKE THE TECHNIQUE FOR BURNING OPEN A SHORT, THIS METHOD DOES NOT ALWAYS WORK.

Even where an open filament repair is made, there is no guarantee that the repair will be permanent. A filament "welded" using this last technique may last for only a few minutes use ... on the other hand, it might be possible to obtain several months additional service from the tube.

In tubes having a tapped filament section for use in operating a pilot lamp, such as the 3SZS, an open in the tapped (low voltage) section will not prevent the tube from operating if circuit continuity is restored. The simplest repair is to short Out the tapped section by connecting a piece of hook-up wire between the tube pins. Another technique is to substitute a higher current pilot bulb for the one normally connected across the tapped section. Still another method is to use a small resistor in place of the tapped section ... determine the proper value by using Ohm's law.

GASSY TUBES

A small amount of gas in a vacuum tube may cause appreciable distortion if there is a high resistance in the grid return lead of the tube. If the grid return has low d.c. resistance, on the other hand, "gas" in the tube may have no noticeable effect on the operation of the equipment.

Unfortunately, it is often difficult to tell whether a tube is "gassy" with a simple *Tube Checker* test. Instead, the following technique may be used:

Referring to the typical output stage shown in Fig. 2, use a high resistance d.c. voltmeter to check for a voltage across the grid resistor R_g . (The equipment in which the tube is used should be ON and operating, of course.)

If there is a d.c. voltage across the resistor, with the grid end positive, disconnect one end of the coupling condenser C_c . Should the d.c. voltage across R_g disappear, the coupling condenser is leaky and should be replaced (this may be confirmed by a further test using the Heathkit *Condenser Checker*). HOWEVER, IF THE D.C. VOLTAGE ACROSS R_g REMAINS, EVEN WITH C_c DISCONNECTED, THE TUBE IS PROBABLY DEFECTIVE ... the tube is either "gassy" or there is leakage between one or more of the tube's elements. Should a test on the *Tube Checker* indicate there are no internal shorts, the tube is gassy.

Salvage ... A tube with a small amount of "gas" may be saved for use in circuits where there is little d.c. resistance in the grid return (for example, in transformer-coupled amplifiers), or for use in oscillator circuits where waveform is not

critical (as in code practice oscillatOrs). Tubes having considerable "gas" are generally suitable for experimental work only.

MECHANICAL DAMAGE

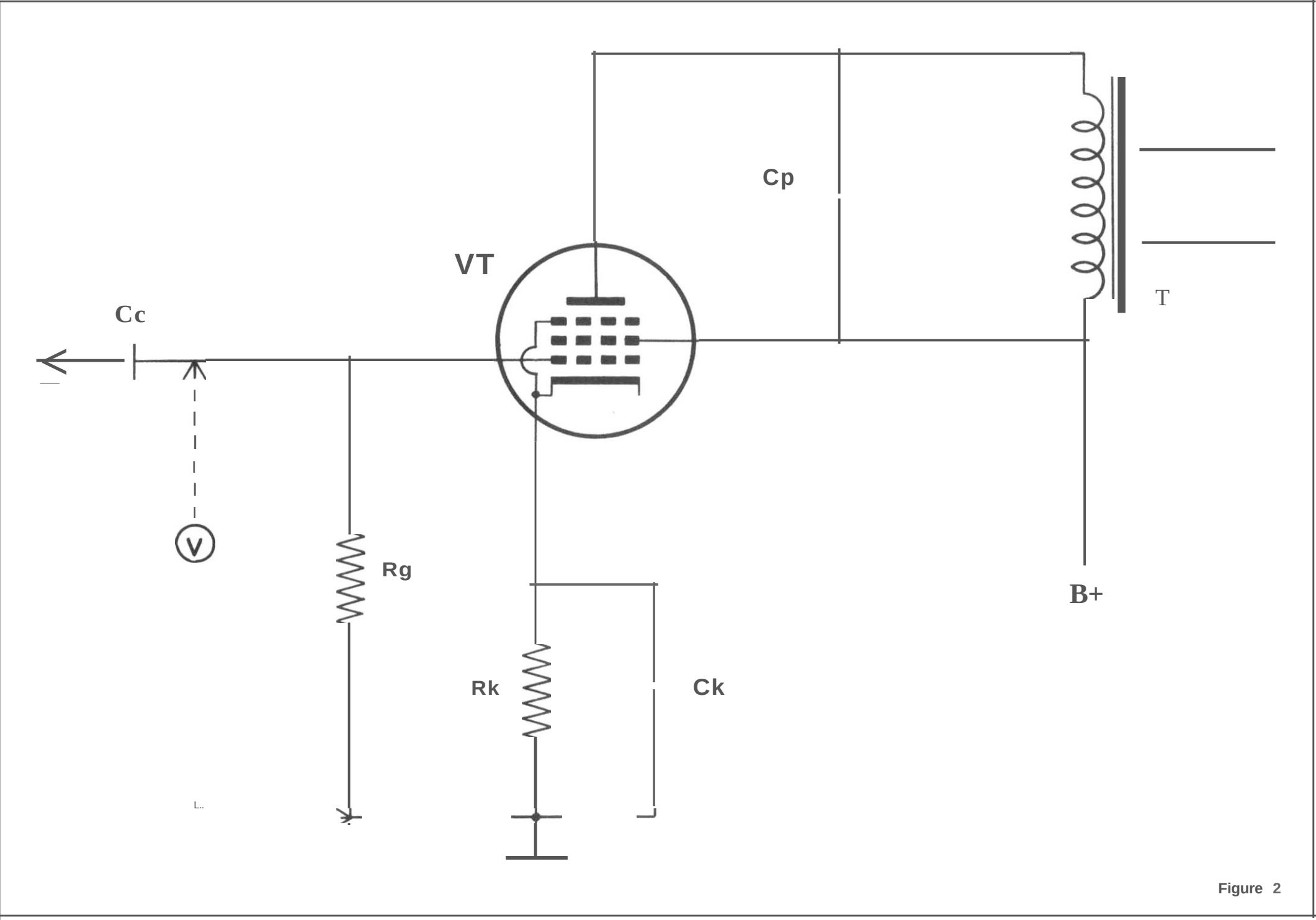
Mechanical damage to a tube may take anyone of several forms. Many of these do not affect the tube's electrical characteristics or its operation in a circuit. A number of the more common defects are listed below, tOgether with repair hints.

*Cracked base:-*The bakelite or plastic base of a tube may often become cracked without affecting the glass envelope. In some cases the envelope may even break loose from the base and the tube be held in place only by the element leads. The general repair technique is to flow Radio Service Cement or Bakelite cement into the crack and to allow it to set. Care should then be exercised when removing or replacing the tube in its socket.

*Bent Pins:-*This defect is more often encountered with 7-pin and 9-pin miniature tubes. The "Standard Cure" is to simply re-straighten the pins, using any of the standard jigs that are available. Such jigs are made by General Cement, Hytron and others, and may be purchased at most Radio Supply Houses.

*Loose Top Cap:-*This defect is often encountered on glass tubes. As long as the glass envelope is not cracked, it is only necessary to cement the tOp cap back in place and to resolder the wire lead to the metal cap.

*Broken "Key":-*A common mechanical damage occurring to octal tubes is for the bakelite "key" to become broken. This is minor damage indeed and may be left unrepaired if care is taken to properly align the tube when replacing it in its socket. Otherwise, cement the key back in place using Bakelite cement ... *be sure the key is properly aligned when doing this.* Allow plenty of time for the cement to set before using the tube again.



getting the most from your vtvm

BY LOUIS E. GARNER, JR.

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All around versatility makes the *Vacuum Tube Voltmeter* an extremely valuable piece of test equipment. In fact, this instrument is generally considered to be one of the "required" items for every electronic laboratory, experimenter's workshop, Ham Shack, and Radio-TV Repair Shop. But this versatility lies not so much in the instrument itself as in the skill and knowledge of the user. Therefore, an outline of a few of the more basic application techniques should prove valuable ... not only for the information given directly, but as an aid to the user in obtaining greater familiarity with the instrument, and hence the ability to use it successfully in a larger number of applications.

HINTS ON MAKING VOLTAGE MEASUREMENTS

The VTVM is an extremely sensitive instrument and may well give erroneous readings if used "above ground." Therefore, all voltage measurements are best made with respect to the chassis or "ground" of the equipment under test.

This requires that special techniques be used to measure some voltages. For example, to measure the d.c. voltage drop across the plate load resistor in a resistance-coupled amplifier stage (Fig. 1), two readings would be taken. First, the voltage between B plus and ground would be checked. Next, the plate voltage (between P and ground, Fig. 1) would be checked. The difference between these two readings will give the voltage drop across R_p .

As a practical illustration, let us assume that B plus is 250 volts, and that the plate voltage measures 225 volts. The difference of 25 volts represents the drop across R_p .

Checking Bias Voltages in H.P. Circuits: Sometimes when a check of d.c. grid voltage is made in a high frequency circuit, the capacity of the test lead itself may cause a change in the operating characteristics of the stage. This is particularly true in the case of oscillator stages. This effect is reduced in your Heathkit VTVM by the 1 megohm resistor in series in the d.c. probe.

However, there is sufficient exposed lead and tip length ahead of the one megohm resistor to occasionally cause trouble in high frequency circuits.

In such cases, any capacity effects may be minimized by cutting one of the leads of a 47K, $\frac{1}{2}$ W. carbon resistor very

short (about $\frac{1}{4}$ " maximum) and making a temporary lap soldered connection to the point where the voltage measurement is to be taken. The VTVM probe is then touched to the long free lead of the resistor to take the actual measurement.

Although the 47K resistor acts to provide effective isolation as far as high frequency signals are concerned, its value is small compared to the resistance of the VTVM and hence it will not affect the d.c. voltage reading obtained.

(NOTE: Make the soldered connection as quickly as possible ... if care is not taken, the resistor may be overheated due to the short lead length involved.)

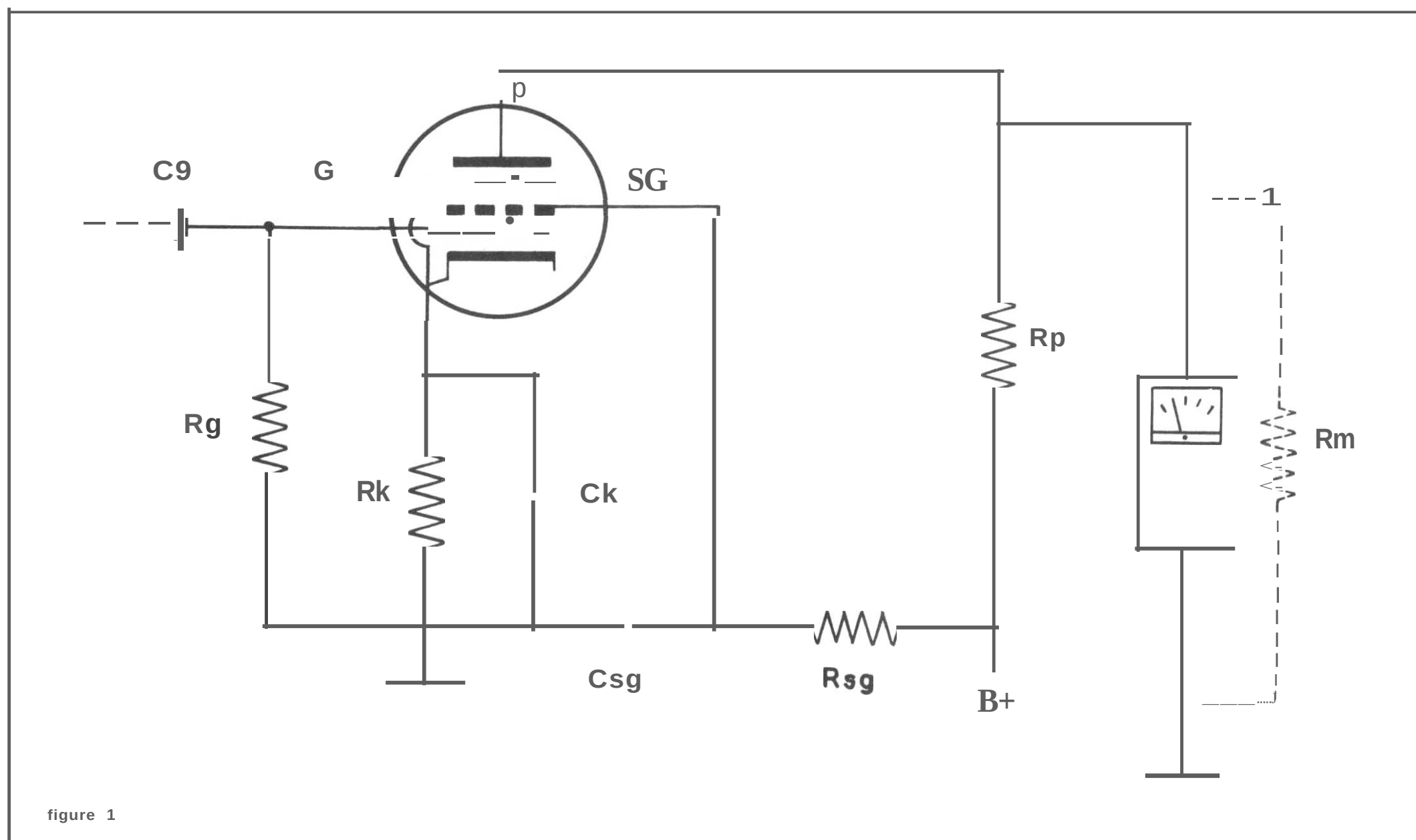
Checking Tube Electrode Voltages: Another point where difficulty may be encountered is when checking various electrode voltages in vacuum tube circuits. Regardless of the voltage measured between any particular element and ground, the important voltage, as far as tube operation is concerned, is that between each electrode and the tube's cathode.

Returning to the circuit given in Fig. 1, let us assume that the cathode resistor, R_k , has opened, but that the cathode bypass condenser has not broken down. In this case, a check between the plate and ground would indicate that full B voltage is available. In many cases, the technician might take this to indicate that plate voltage was "normal" and might well go to another stage in an attempt to isolate the defect. However, a check between cathode and ground would indicate a high voltage between these two points rather than normal bias voltage.

Therefore, when checking tube voltages with a VTVM, be sure to check the voltage between every electrode and ground, including the cathode.

Interpreting Voltage Readings: Equipment manufacturers often give a list of "normal" voltages in the Instruction Manual supplied with their equipment or in separate Service Notes. If actual measurements are to be compared with the voltages given in such a chart, the type of instrument used to establish the original "normal" readings should be known.

In military equipment, the voltage readings are usually those obtained with either a 1000-ohms/volt or 20,000-ohms/volt meter. In many cases both sets of readings will be given. Schematic diagrams of older radio receivers usually give the voltage readings as measured with either a 1000-ohms/volt



or a 20,000-ohms/volt meter, *but seldom both*. Finally, service notes of modern radio and TV receivers more often give the voltage readings as obtained with a standard VTVM.

Where the readings given in the "voltage chart" are those obtained with a VTVM, no difficulty will be encountered. Where the readings are those obtained with a 1000-ohms/volt meter, the VTVM measurements will be higher than those given in the chart. Finally, where the readings are those obtained with a 20,000-ohms/volt meter, the VTVM measurements *may be either higher or lower than those given in the chart*, depending on the voltmeter range used,

How these possible discrepancies may occur can be seen by reference to Fig. 1. If a meter is used to check the plate voltage of the tube, as shown, the meter resistance R_m acts to form a simple voltage divider with R_p . Hence the meter resistance will affect the reading obtained. As long as R_m is high compared to R_p , the difference between the "true" voltage and the meter reading will be slight ... but R_p , in many cases, is likely to have a high value.

A practical example will better illustrate the conditions involved. An often encountered value for R_p is 250,000 ohms. A 1000-ohms/volt meter, on the 250 volt scale, has a resistance (R_m) of 250,000 ohms and hence this meter would immediately drop the voltage to about half its true value. A 20,000-ohms/volt meter, on the same scale, has a resistance of 5 megohms, and will give a higher and more nearly correct reading. The VTVM, finally, with a resistance of 11 megohms, will give the highest reading.

However, under some circumstances, the 20,000-ohms/volt meter may actually give a higher reading than a VTVM. On

the 1000 volt scale, for example, the 20,000-ohms/volt meter has a resistance of 20 megohms ... nearly twice that of a VTVM.

MEASURING CIRCUIT CURRENTS

Although your Heath VTVM is basically a Voltmeter-Ohmmeter, it still may be used for determining circuit currents by measuring the voltage drop across resistors and applying Ohm's law ...

$$I = E / R,$$

where I is the current in amperes, E the voltage (volts) drop, and R the resistance in ohms. Where the resistance value is unknown, it may be determined using the VTVM as an ohmmeter.

For example, to determine the plate current in a stage, measure the voltage drop across the plate load resistor. Then divide this value by the resistance of the plate load. If the drop across the plate load is 50 volts and the resistance of the plate load is 25,000 ohms, plate current is $I = E / R = 50 / 25,000 = .002$ amps ... this value may be converted into milliamperes by moving the decimal point three places to the right ... that is plate current is 2 ma.

In a similar fashion, screen-grid current may be determined by measuring the voltage drop across the screen-grid resistor and applying Ohm's law. Total cathode current is determined by measuring the d.c. voltage across the cathode resistor and again applying Ohm's law.

CHECKING CONDENSERS FOR LEAKAGE

The Heathkit *Condenser Checker* is preferred for checking

the condition of condensers. However, where this instrument is not available, or for quick field tests, the Ohmmeter ranges of your VTVM may be used.

If the condenser to be checked is wired in a piece of equipment, turn OFF the power and "discharge" the condenser by shorting its leads together. Disconnect one lead so that no other component will shunt it while the Ohmmeter test is made.

Next, connect the test leads across the condenser leads or terminals and check its resistance. The needle will drop to a low value and then move up-scale to the final reading.

Mica, paper, or ceramic condensers below .1 mfd in value should have a resistance well above 20 megohms. Paper condensers greater than .1 mfd in value should have leakage resistances above 10 megohms.

When checking electrolytic condensers, take one reading, then reverse the ohmmeter leads and take another reading... the higher resistance reading is the correct one. Electrolytic condensers should, in general, have a leakage resistance in excess of 100,000 ohms. However, leakages as low as 25,000 ohms are permissible in the case of high-capacity, low-voltage condensers (such as are used in cathode by-pass applications).

An approximate indication as to the *capacity* of larger condensers may be obtained by observing the time taken for the needle to reach the final resistance value. In order to estimate these values, the user should try checking the resistance of several known condensers of different values, noting the approximate time taken in each case to obtain a final "steady" reading.

CHECKING BATTERIES

A VTVM check of a battery under "no-load" conditions is of little value as an indication of the battery's condition. If at

all possible, battery tests should be made with the Heathkit *Battery Tester*. However, if the proper instrument is not available, and a VTVM must be used, either of the following techniques will generally give satisfactory results:

Method A: Turn on the equipment in which the battery is used (hearing aid, portable receiver, farm radio, etc.) and allow the equipment to operate for five to ten minutes. Then, while the equipment is still on, check the battery voltage. If the voltage is ten percent below its normal rated value, the battery is probably weak. A difference of 15% indicates the battery should definitely be replaced.

Method B: If the battery cannot be easily identified, or its "normal" voltage is not known, a slightly different technique is used. Connect the VTVM to the battery terminals while the equipment is turned "off." Check the no-load voltage and then turn the equipment "on." After five to ten minutes operation, the battery voltage should not have dropped appreciably more than 5%. A 10% to 15% drop indicates that the battery should be replaced.

IDENTIFYING POWER TRANSFORMER WINDINGS

Small power transformers, having anywhere from 6 to 14 leads, may often prove difficult to properly identify unless the color code is known. Where the color code is not known, or where none is used, the technique given below may be employed:

1. Set up the VTVM for use as an ohmmeter and connect the COMMON lead to anyone of the transformer terminals (or leads).
2. Using the ohmmeter probe, touch the other transformer terminals until continuity is found to exist to the terminal

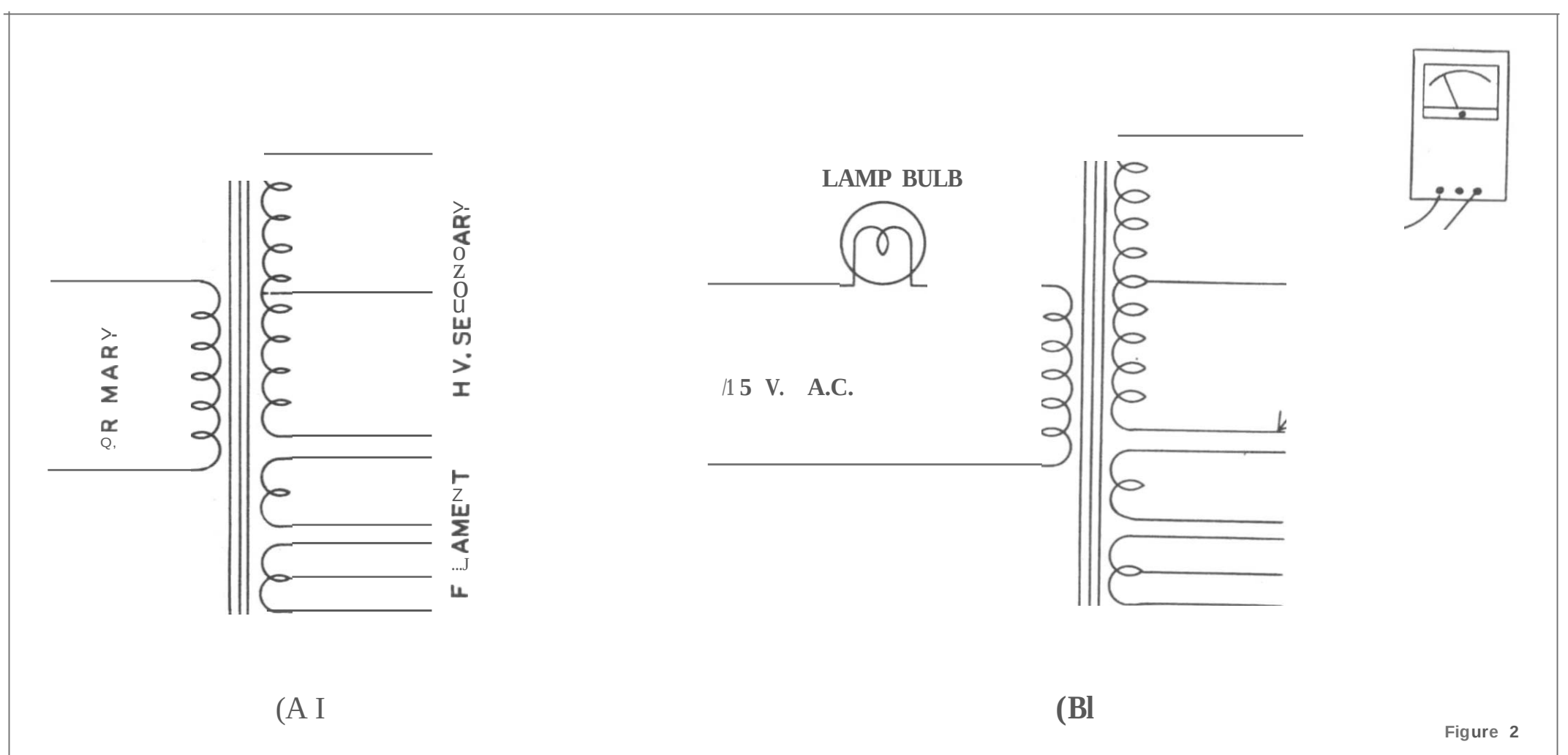


Figure 2

having the COMMON lead connection. Identify these two leads using tape, a card or string, or simply by noting the color code. Also note the measured resistance between the two terminals. (NOTE: If continuity is found to more than one other lead, there is a good chance that the winding is tapped...in this case, note the maximum resistance value.)

3. Choose another unidentified terminal and transfer the COMMON ohmmeter lead to this one. Repeat step 2, identifying the leads of another winding.

4. Continue until all of the windings of the transformer have been isolated and their individual resistances noted. If no continuity can be found between one or more terminals, there is a possibility that one winding is "open"...simply make a note of this fact.

5. The individual windings may now be identified as follows: (a) The pair of leads having the *highest resistance* (usually anywhere from over 1000 to less than 100 ohms, depending on the current rating) are connected to the *high voltage winding*; (b) the pair of leads having the *next highest resistance* (from over 100 to less than 10 ohms, again depending on the rating) are connected to the *primary winding*; (c) those pairs of leads having *very low resistances* (usually less than 1 ohm) are the *filament windings*. In most small power transformers, the high-voltage secondary and one or

more of the filament windings will be center-tapped (see Fig. 2(a)).

6. Having identified the windings in step 5, connect a 115 volt lamp in series with the "primary" winding as shown in Fig. 2(b). Use a 25 or 50 W. bulb for small transformers and also W. bulb (or larger) for transformers of the size used in large P.A. amplifiers and TV receivers. Apply 115 volts a.c. to the circuit and observe the brightness of the bulb...the bulb should light somewhat, but with far from normal brilliance. If the bulb lights almost to normal brilliancy, it indicates that there is either a short in one of the transformer windings, or that the wrong winding has been chosen as the "primary".

7. Assuming that the bulb glows dimly in step 6, use the VTVM as an a.c. voltmeter and carefully check the voltages across each of the windings. The voltages across the secondary windings should bear the same proportion to their "normal" values that the measured primary voltage bears to line voltage. If these relationships are what may be expected, remove the series lamp bulb and connect the primary directly to the line. The a.c. voltmeter may then be used to determine final secondary voltages. (NOTE: Expected "normal" filament winding voltages are 2.5, 5, 6.3. while the high voltage may be from 150 to 400 volts on each side of center-tap...depending on the individual transformer. Do not attempt to measure secondary voltages in excess of 1000 volts!)

applications of the heathkit impedance bridge

BY LOUIS E. GARNER, JR.

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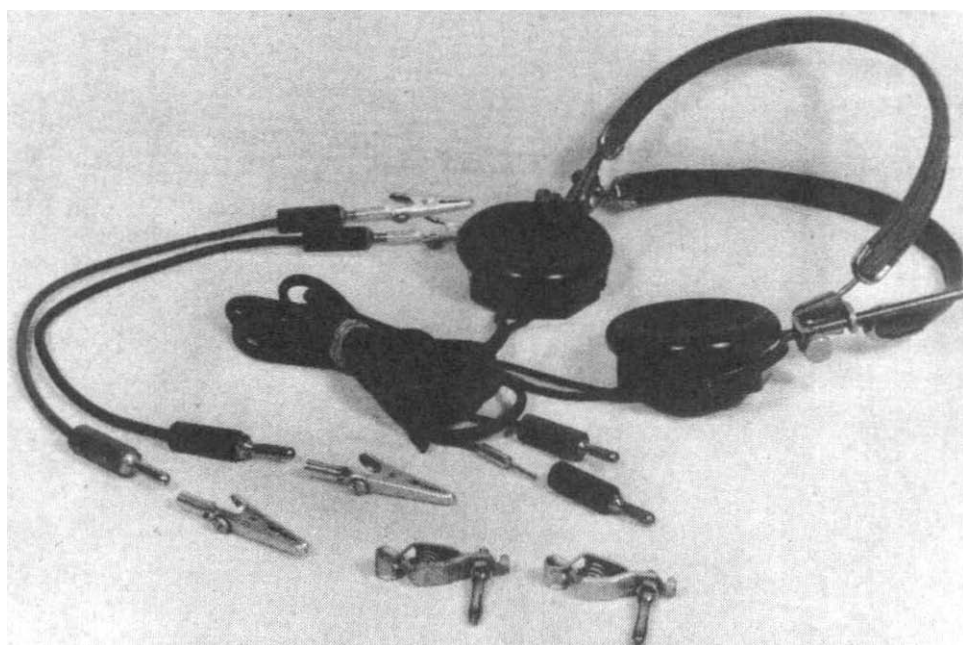
The basic techniques of using the Heathkit *Impedance Bridge* to measure inductance, capacity and resistance are fairly straightforward and are outlined in detail in the instruction manual accompanying the instrument. In addition, there are a number of special techniques which will help considerably to simplify many types of measurements. Several of these techniques will be reviewed in this Bulletin in the hope that the reader will find additional uses for his instrument and will be encouraged to work out special methods to simplify his own measurement problems.

ACCESSORIES

A carefully selected assortment of accessories will help to minimize the time required to "set-up" the impedance bridge to make a group of tests. Several popular accessories are illustrated in Fig. 1 and discussed individually below.

Headphones are used as a null indicator when making A.C. measurements (also see the section on NULL INDICATORS below). For maximum sensitivity, high impedance (crystal) headphones are recommended. Considerable time may be saved in connecting and disconnecting the Headphones if they are fitted with banana plugs in place of the conventional phone tips. The "solderless" type of banana plug shown in the illustration is sized so that the regular phone tip fits right into the

Figure 1



"wire" opening, making it unnecessary to remove the ups supplied with the Headphones.

Short test leads, fitted with banana plugs at one end and alligator clips at the other are useful for connecting heavy iron core chokes and large paper condensers to the Bridge terminals. In order to minimize the possibility of erroneous readings due to lead resistance, use heavy flexible test lead wire ... a minimum of 18 gao and preferably larger (16, 14, or 12 ga.).

Alligator clips fastened to banana plugs are useful for production testing of small components ... resistors, condensers, and small chokes or coils. Several variations of the type shown in the illustration are possible, depending on the types of clips and plugs used.

Special jigs may sometimes be assembled by the individual user to simplify the testing of large quantities of a single type of component. Such jigs may take a wide variety of forms, depending on the requirements, problems, and ingenuity of the user, and hence no specific type is shown in Fig. 1.

However, a type of construction often employed in making up special jigs is illustrated in Fig. 2. A V-shaped bracket is fitted unto a standard banana plug.

When a pair of such jigs are used, small components having straight wire leads may be checked in rapid succession by holding the component in one hand such that the leads are caught in the "vees," while balancing the bridge with the other hand. "Tolerance" tests of large numbers of components may be made easily and quickly. (NOTE: This technique cannot be used on small value condensers or Other components where an error might be introduced by body capacity ... in such cases clips are necessary so that the component becomes self-supporting during the test.)

For the maximum speed in making production line "tolerance" tests, the tolerance limits may be indicated directly on the bridge dial by using short strips of black Scotch tape, as shown in Fig. 3. The tape may be removed at any time or shifted to establish new limits.

NULL INDICATORS

When making A.C. measurements, a number of different Null Indicators may be employed, depending on the inclina-

tions of the user and the degree of sensitivity desired. Several different indicators are listed below, together with notes on their use.

Headphones, as mentioned previously, are satisfactory for the majority of measurements. However, sensitivity is somewhat limited, even where high impedance 'phones are used, making it difficult to establish an accurate "null point" in some tests. Better results are often obtained if a high gain audio amplifier is used between the EXT. DET. terminals and the headphones.

The A.C. Voltmeter is an excellent null indicator and permits extremely accurate adjustments of the bridge. To use this instrument, start with a higher voltage range and turn to lower ranges only as a "null" is approached. After completing the measurement, the AC Voltmeter should be turned to a high range before removing the component (being checked) or turning the Bridge GENERATOR switch to EXT. (to avoid "banging" the Voltmeter needle).

The Oscilloscope is also an excellent null indicator, but certain precautions are necessary when using this instrument. To use the Oscilloscope as a null indicator, connect the EXT. DET. terminals of the Bridge to the VERT. INPUT terminals of the 'scope.

With the Bridge set up and ready for final balancing adjustments, adjust the scope Sweep and Sync controls until two or three complete cycles of the a.c. signal may be observed. Now, adjust the Bridge for the minimum vertical amplitude of the observed signal, regardless of signal waveform, adjusting the VERT. GAIN control as necessary to increase 'scope sensitivity. In many cases, it will be found that the waveform pattern as well as the signal amplitude will change as the Bridge is balanced (depending on the component being checked).

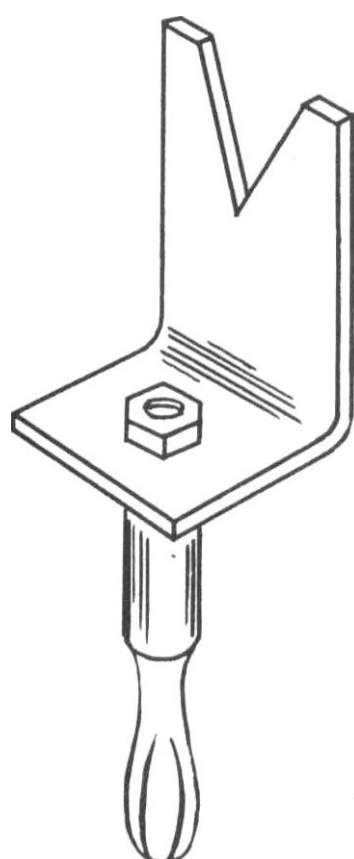


Figure 2

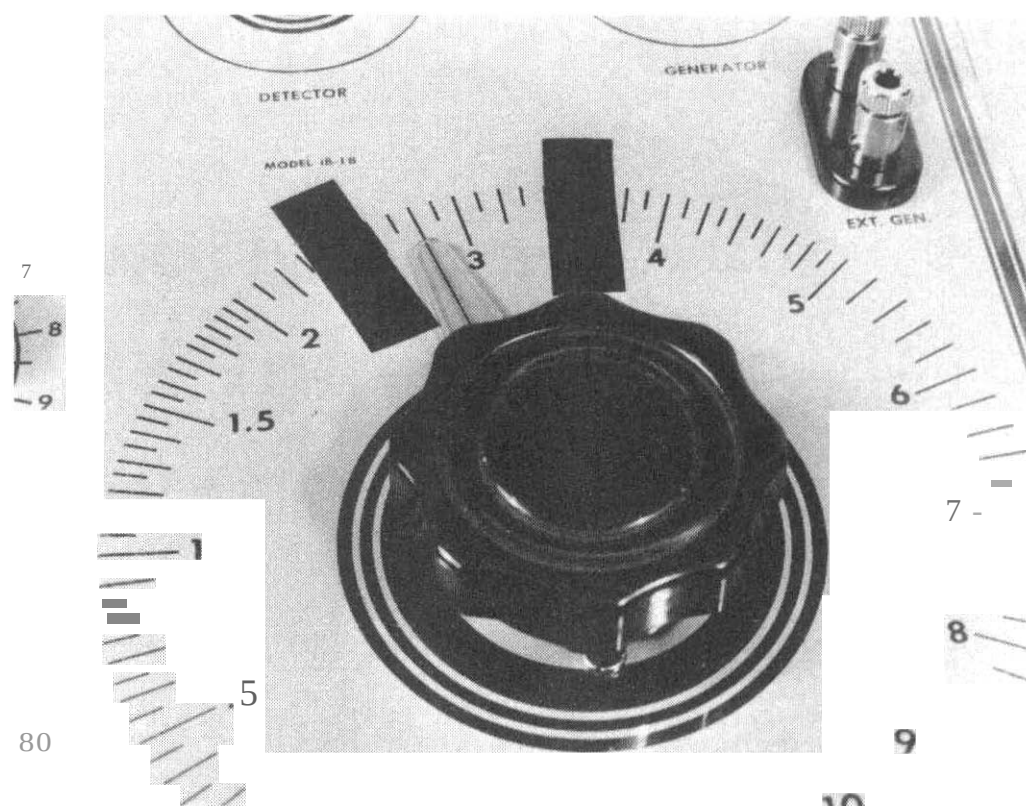


Figure 3

Two waveform patterns obtained while checking a 700 MHy iron core choke are illustrated in Fig. 4. The built-in 1 Kc generator of the *Impedance Bridge* was used.

EXTERNAL GENERATORS

As mentioned in the Instruction Manual, AC Bridge measurements at other than 1 Kc may be made by switching the GENERATOR switch to EXT. and connecting an AC signal source to the EXT. GEN. terminals.

Many AC measurements, especially those involving filter condensers and iron core chokes, are made at 60 cycles. A 60 cycle AC signal may be obtained from the filament winding of a power transformer... an excellent source is the 6.3 Volt Output of the Heathkit *Laboratory Power Supply*.

For AC measurements at other than 60 cps or 1 Kc, use an *Audio Oscillator* or the AUDIO OUTPUT of an R.F. *Sine-Wave Generator*.

If greater indicating accuracy is desired when making DC resistance measurements, an external battery together with a series resistance may be used, *provided the main eRL dial is not turned below 1*. The maximum permissible battery voltages and recommended minimum series resistances are given in the Instruction Manual, and are repeated below for the convenience of the reader:

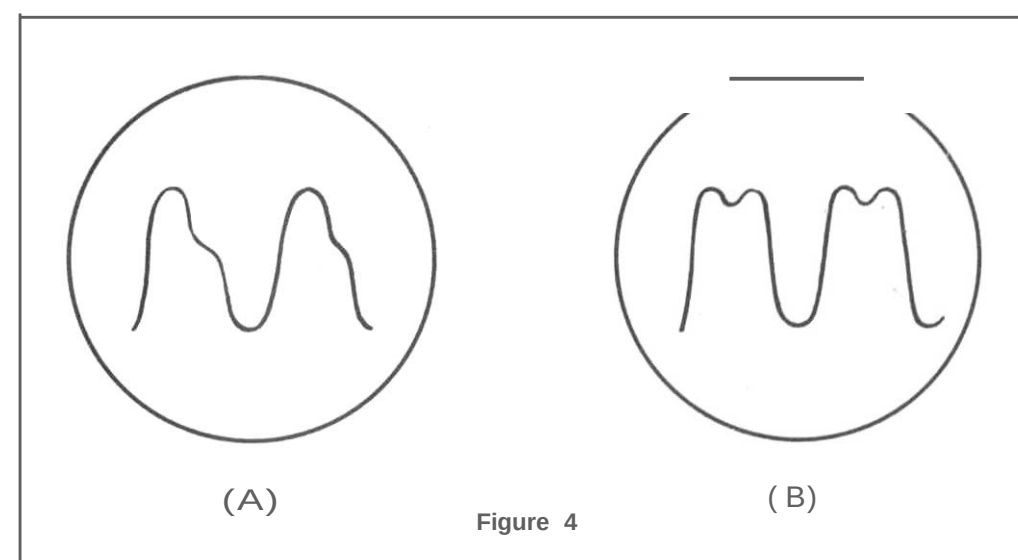


Figure 4

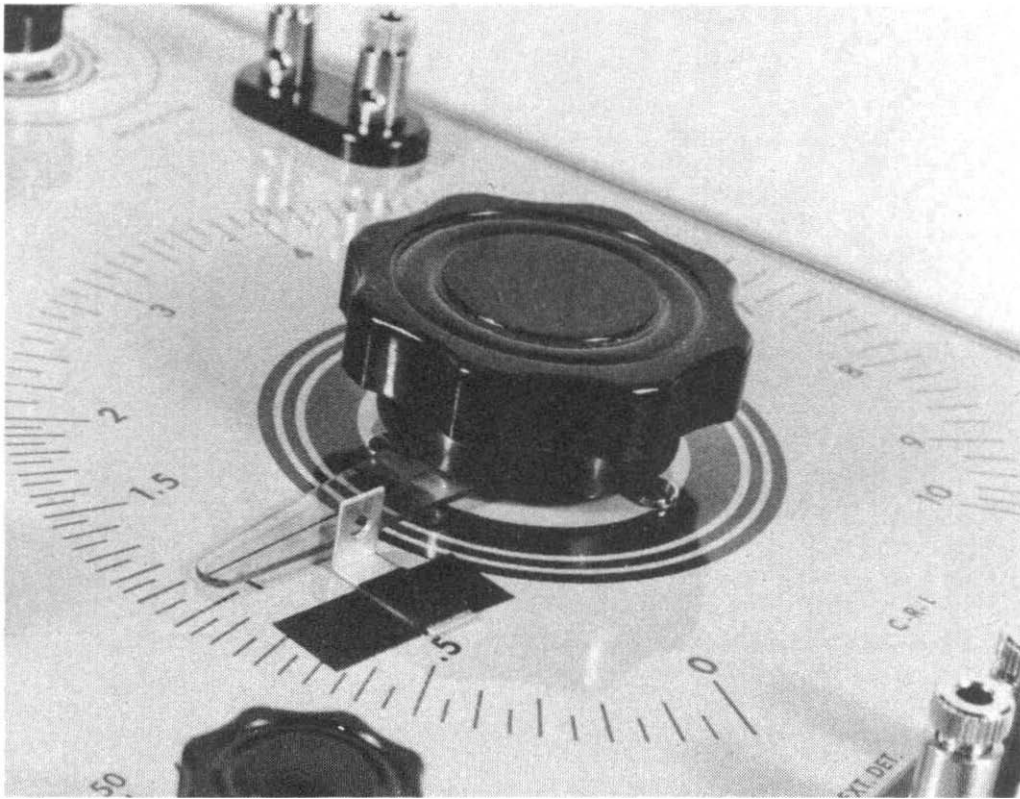


Figure 5

ON MULTIPLIERS	NOT MORE THAN	IN SERIES WITH
0.1, 1.0, 10, 100	67½ V.	not less than 1500 ohms
1K	135 V.	not less than 4000 ohms
10 K, 100 K, 1 Meg.	202½ V.	not less than 6500 ohms

In order to avoid turning the CRL dial below 1 when using an external battery, the technique illustrated in Fig. 5 may be employed. A small "L" bracket is fixed in place with Scotch tape to act as a "Stop" on the rotation of the dial pointer. Since tape is used, the mounting is only temporary and may be removed at any time for regular tests.

PERMEABILITY TESTS

Accurate tests of the permeability of a material require special techniques beyond the scope of this Bulletin. For information on such techniques, the reader should refer to standard engineering handbooks and reference texts.

However, relative checks on the permeability of various core materials may be made quite easily by using the *Impedance Bridge* to check the inductance of a given coil with an air core and the same coil with a core of the material to be tested. The increase in coil inductance is proportional to the permeability of the core material used.

In order to obtain a satisfactory coil for such tests without the trouble and expense of winding a special one, a small iron-core filter choke may be disassembled, giving the component parts shown in Fig. 6. For best results, a choke having low d.c. resistance should be used.

After disassembly, the inductance of the coil alone may be checked and indicated on a tag left permanently attached to it. It is suggested that the following information be obtained and recorded: D.C. Resistance; Inductance @ 60 cps; Q @ 60 cps; Inductance @ 1 Kc; Q @ 1 Kc.

The "core" and "keeper" (Fig. 6) may be used as templates for cutting out solid cores or core laminations of the material

whose relative permeability is to be checked. After the new core has been accurately cut out, the coil may be mounted on it, and the "keeper" and mounting bracket reassembled.

Finally, the inductance of the reassembled coil may be checked and compared to the inductance obtained with an "air" core. Some indication of the relative losses sustained with the test core material may be obtained by noting any changes in coil Q.

INDUCTANCE MEASUREMENTS

The "apparent" inductance of a large coil, as indicated on the *Impedance Bridge*, may often differ considerably from the actual value due to the distributed capacity in the coil. Where the inductance measurement is made at a frequency less than 0.1 the natural resonant frequency of the coil, errors will be less than 1 per cent, and no special correction need be made in the *Impedance Bridge* reading.

However, where the natural resonant frequency of the coil is low, or where the frequency used when checking the coil inductance is high, the possibility of error (as the natural resonant frequency of the coil is approached) should be taken into account, and the necessary correction made.

In order to see if correction is necessary, the "natural" resonant frequency should be determined. The technique illustrated in Fig. 7 may be used. "L" is the coil whose "natural" frequency is to be checked. R is a series resistance used to indicate when resonance has been reached ... the value of R should be kept as low as will permit a reasonable reading on the *A.C. Voltmeter*. This resistor may best be chosen experimentally for the particular coil used. (NOTE: The Heathkit *Resistance Substitution Box* may be used to advantage here.)

To determine the resonant frequency of the coil, vary the output frequency of the *Sine-Wave Generator* until a dip occurs

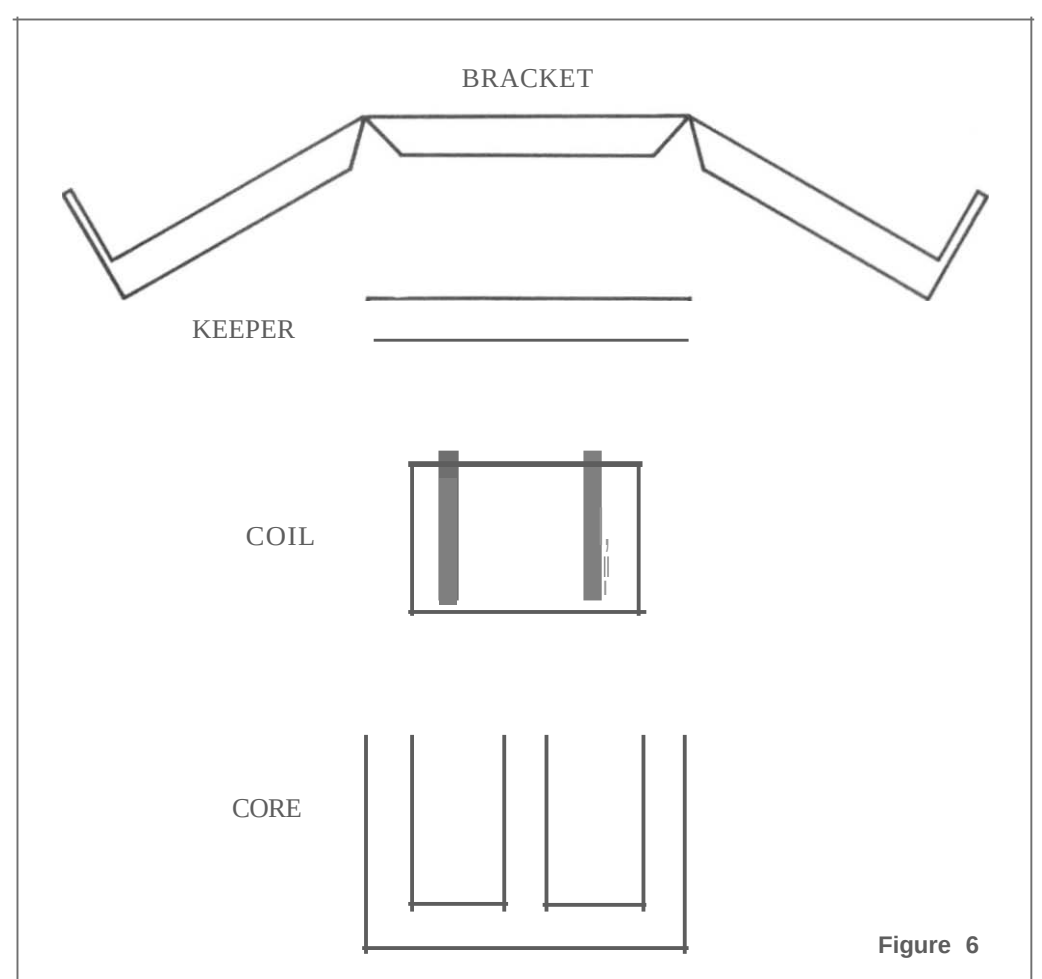
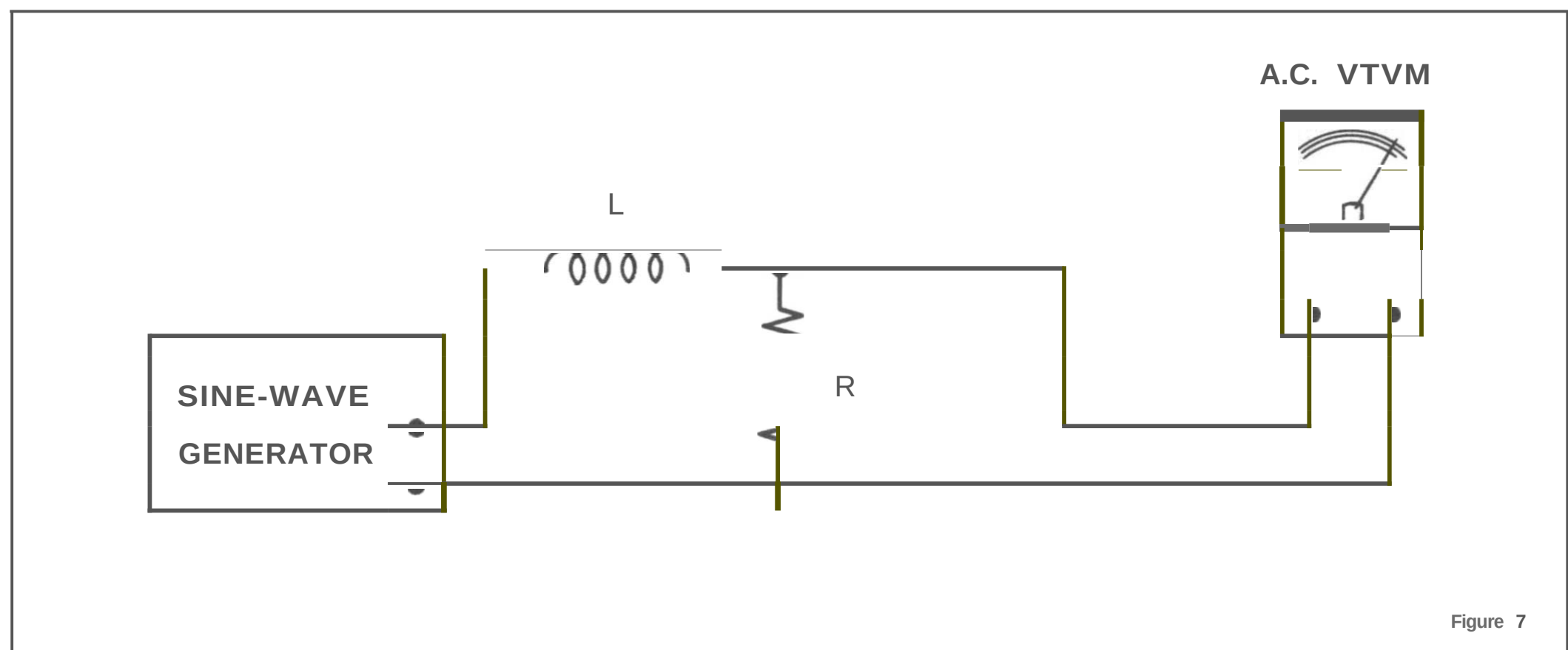


Figure 6



in the voltage reading across R. The point at which the minimum voltage reading occurs is the resonant frequency of the coil. The Sine-Wave Generator should have reasonably constant output if accurate results are to be obtained.

Once the resonant frequency of the coil has been determined, the following relationship, given in Terman's RADIO ENGINEERS' HANDBOOK, may be used to calculate the inductance of the coil:

$$\text{APPARENT INDUCTANCE OF COIL} = \frac{L}{1 - m^2}$$

(Measured on the Bridge)

where L is the true inductance of the coil and m is the ratio of the frequency at which the measurement is made to the "natural" resonant frequency of the coil, as determined above (Fig. 7).

CAPACITY MEASUREMENTS

When measuring small capacities, an accurate check becomes difficult to obtain because of the stray capacities associated with the bridge circuit and with connections to the "unknown."

In such cases, somewhat more accurate results may be obtained by first connecting a larger condenser across the Bridge terminals and checking its capacity, then connecting the small "unknown" condenser *in parallel* with the larger condenser and checking the *total capacity* of both components. *The difference in the two readings is the capacity of the small condenser.*

The Heath *Decade Condenser Box* is helpful when using this last technique.

The instruments discussed in the HEATHKIT TECHNICAL **APPLICATION** BULLETIN series are listed in alphabetical sequence and each instrument has been assigned a numerical designation. For example, Oscilloscope 1.A, 1.B, 1.e, etc. Signal Generator 2.A, 2.B, etc. In the listing below, the designation for each Instrument Bulletin is given and for further reference convenience Bulletin numbers are given whenever the specific instrument is again mentioned in Technical Bulletins dealing with other instruments.

AC VTVM

7.A, 7.8, 7.C, 7.0, 9.A, 9.B, 9.C

AUDIO FREQUENCY METER

6.A, 6.B, 6.C, **1.N**

AUDIO GENERATOR

9.A, 9.B, 9.C, 10.G, **1.N**, 10.R, 10.S, 10.U, 3.A, 7.C

CONDENSER CHECKER

s.A

ELECTRONIC SWITCH

3.A, 1.B, 1.C, 1.E, 1.M, 1.S, 7.A

IMPEDANCE BRIDGE

15.A

INTERMODULATION ANALYZER

11.A, 1.A, 9.A

OSCILLOSCOPE

1.A, 1.B, 1.C, 1.0, 1.E, 1.F, 1.G, 1.H, 1.I, 1.J, 1.K, 1.L, 1.M, **1.N**, 1.0, 1.P, 1.Q, 1.R, 1.S, 1.T, 1.U, 1.V, 1.W, 1.X, 3.A, **4.A, 4.B**, 5.A, 5.8, 6.C, 7.A, 7.8, 7.0, 11.A

POWER SUPPLY

10.A, 10.B, 10.C, 1.H, 1.I, 1.M, **1.N**, 1.0, 1.P, 1.Q, 1.R, LX, 10.0

SIGNAL GENERATOR

2.A, 2.B, 2.C, 1.I, 1.S

SIGNAL TRACER

12.A

SQUARE WAVE GENERATOR

5.A, 5.B, 1.C

TUBE CHECKER

13.A

VACUUM TUBE VOLTMETER

14.A, 1.N, 1.0, 1.P, **2.A**, 2.8, 10.B

VOLTAGE CALIBRATOR

4.A, 4.8, 7.0

The third series of **twelve Bulletins** and Index Sheet concludes the material supplied under the terms of the original \$2.00 offer. When future technical Bulletins are available they will be announced in Heathkit Flyers. Additional Bulletins can be added to this Index Sheet.

The availability of HEATHKIT TECHNICAL APPLICATION BULLETINS represents a sincere effort on the part of the Heath Company to assist kit purchasers in obtaining

maximum performance and usefulness from **their** instruments through intelligent application thereby realizing a greater return on their investment. These Bulletins have been prepared **by** recognized technical authorities and are general in their concept. The material is not necessarily applicable only to specific instruments or models as the information provided is truly **basic**.

If this material has been helpful to you we will feel well repaid for the expense and effort involved.



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