101 WAYS

to use your...

AUDIO TEST EQUIPMENT

by
ROBERT G. MIDDLETON

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by ROBERT G. MIDDLETON

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PREFACE

Most of my friends in electronics today are interested in audio. Some are "fanatics," just as I was a wireless fanatic way back when. Their enthusiasm is infectious.

Modern audio test instruments, such as harmonic-distortion meters and intermodulation analyzers look complicated and difficult to use. Actually, most audio test equipment is easier to operate than a scope.

This book answers the basic questions most often asked about audio instruments. However, it does not cover such generalized equipment as volt-ohm-milliammeters and vacuum-tube voltmeters. Readers who wish this background information are referred to the other books in this series.

As you leaf through these pages, you will see that this is a completely practical handbook. It gets right down to brass tacks and shows how to do the job. Audio theory is not discussed. You will find, as you learn how to make audio tests, that you automatically acquire a lot of valuable theory without realizing it.

If the readers of this book are as enthusiastic as those who have read the manuscript and have discussed what they would like to see in the book, I will feel that my efforts have been well worthwhile.

Good luck!

Bob Middleton

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INTRODUCTION

Readers of the preceding volumes in this series have requested additional information about audio-amplifier testing. The number of inquiries indicates a definite need for a how-to-do-it book in this field.

Some of the test instruments used in radio and television test work are also essential in audio test work. Such instruments as the VOM, VTVM, oscilloscope, and square-wave generator are basic to both fields. On the other hand, harmonic-distortion meters, intermodulation-distortion analyzers, audio wattmeters, audio VTVM's, and tone-burst generators (or their equivalent) are also widely used in audio test work.

Still other instruments, such as wow and flutter meters, are very useful in audio test work, although they may be too expensive for the average shop. Fortunately, much of the information afforded by the more costly instruments can be obtained with the more basic instruments, plus a bit of ingenuity. This book endeavors to show you how you can get the maximum results from the instruments you are likely to have at hand.

Audio sweep generators, like wow and flutter meters, are rather expensive. However, a gliding-tone frequency test record or tape can be made to do much of the work expected of an audio sweep generator. Also, since high-fidelity amplifiers are often driven from AM tuners, we find use for AM signal generators in audio work.

Like the companion volumes, this is not a theory book nor a textbook. It is a practical *working* handbook for the professional audio technician, engineer, and serious audiophile. You will find each application categorized and cross-referenced for quick location.

Necessary practical information, precautions, and required equipment and connections, are given for each test. Where questions might arise in evaluation of results, typical data are included to guide the user to correct conclusions.

It is obviously impossible to cover all the applications for audio test equipment in this volume. However, much additional information will be found in companion volumes of this series. For example, you will find discussions of square-wave interpretations in *101 Ways to Use Your Oscilloscope*; additional discussions of decibel measurements and techniques are given in *101 Ways to Use Your VOM and VTVM*; and alignment procedures for AM tuners are discussed at length in *101 Ways to Use Your Signal Generator*.

EQUIPMENT CHECKS

U1

To Check the Output Uniformity of an Audio Oscillator or Square-Wave Generator

Equipment: AC VTVM.

Connections Required: Connect equipment as shown in Fig. 1.

Procedure: Adjust generator attenuator and meter controls to indicate voltage of output signal. Switch the generator to its various bands successively, and turn the tuning dial through its range on each band. Observe any changes in meter reading.

Evaluation of Results: A good audio oscillator or square-wave generator will have little variation in output level over the various frequency ranges. If the level is not constant, this must be considered when the frequency response of an amplifier is being checked.

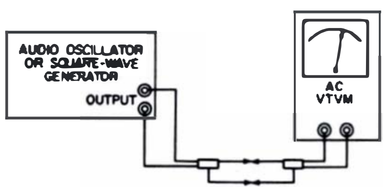


Fig. 1. Test setup.

NOTE 1

Audio-Oscillator Hum Is Highest on Low-Frequency Range of RC Bridge-type Oscillator

Sixty-cycle hum, when present in the output from an audio oscillator, will usually be most troublesome on the lowest frequency range of an RC bridge-type oscillator. This is due to the oscillator circuit resistance being very high on the low-frequency range—the grid resistance normally is 15 to 20 megohms. Consequently, the grid circuit is susceptible to pickup of stray 60-cycle fields. The remedy is better shielding of the high-resistance grid-circuit components.

U2

To Check the Output of an Audio Oscillator or Square-Wave Generator for Hum Voltage

Equipment: Oscilloscope.

Connections Required: Connect equipment as shown in Fig. 2.

Procedure: Display sine- or square-wave pattern on scope screen. Tune generator near—but not exactly to—60 cycles. Observe pattern on screen.

Evaluation of Results: The pattern should be completely steady. Any writhing of the waveform on the scope screen indicates the presence of hum.

The vertical amplifier of the scope must also be free from hum before a valid test can be obtained.

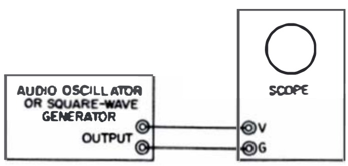


Fig. 2. Test setup.

NOTE 2

Output From Square-Wave Generator Sometimes Is Unstable

When certain types of square-wave generators are tested by feeding the generator output to a scope, the waveform displayed is sometimes unstable and distorted, and will change when the operator grasps a test lead. This is more evident when the generator attenuator is operated at maximum. The instability and distortion often can be remedied by connecting a water-pipe ground to the cases of the instruments. (See Fig. 3 for illustration of typical unstable waveform.)

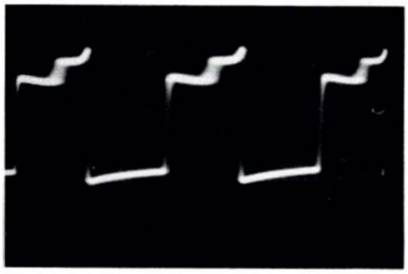


Fig. 3. Typical unstable output waveform from square-wave generator.

U3

To Check the Output From an Audio Oscillator for Distortion

Equipment: Audio oscillator and harmonic-distortion meter.

Connections Required: Connect equipment as shown in Fig. 4.

Procedure: Tune audio oscillator to a low frequency, such as 100 cycles. Adjust meter controls to read percentage of harmonic distortion. Repeat test for medium frequency, such as 3,000 cycles, and for high frequency, such as 15 kc.

Evaluation of Results: The meter reading should be very low. Subtract this measured distortion figure from the total distortion figure indicated when low-distortion amplifiers are being checked. If the audio oscillator has appreciable harmonic output, use a low-pass filter to minimize the harmonic distortion. A simple RC filter like the one in Fig. 5 is helpful. The values of R and C depend upon the test frequency. The lower the frequency, the larger the values must be. Figs. 6, 7, and 8 show how the fundamental waveform is suppressed by a harmonic-distortion meter. The meter then indicates the voltage of any harmonic in the waveform under test.

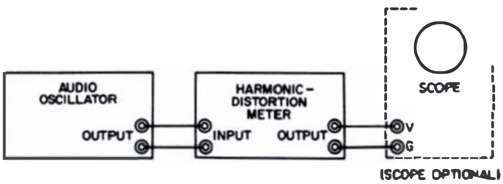


Fig. 4. Test setup.

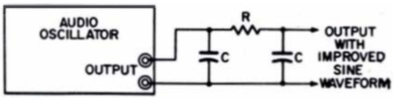


Fig. 5. An R-C low-pass filter for removing harmonics from audio-oscillator output.

(A) With second harmonic.

(B) With third harmonic.

(C) With fourth harmonic.

(D) With fifth harmonic.

Fig. 6. Fundamental sine wave with harmonics.

(A) Second-harmonic distortion.

(B) Third-harmonic distortion.

(C) Fourth-harmonic distortion.

(D) Fifth-harmonic distortion.

Fig. 7. Amplifier output distorted by harmonics.

(A) Second harmonic.

(B) Third harmonic.

(C) Fourth harmonic.

(D) Fifth harmonic.

Fig. 8. Harmonic sine-wave voltages measured by harmonic-distortion meter.

NOTE 3

A Filter Can Improve Output Waveform From Audio Oscillator

A filter consisting of a Class-A amplifier with a parallel-T RC negative-feedback loop (Fig. 9) can be used to improve the waveform from an audio oscillator. The network operates like a trap. Negative feedback occurs at all frequencies except the null frequency of the network. Therefore, the network passes one frequency only. Since there is no negative feedback at the pass frequency, considerable demand is placed upon the Class-A amplifier for distortion-free amplification. The tube must introduce negligible distortion into the signal; otherwise, the purpose of the filter will be defeated. The feedback loop can be designed to pass any audio frequency, according to the formula:

$$R_1 = R_2 = 2R_o$$
$$C_1$$
$$R_1$$
$$f = \tfrac{1}{2}\pi R_1 C_1$$

where,

R and C notations are as in Fig. 9,
f is the resonant frequency of the network.

The values for a complete null at the resonant frequency are quite critical. It is advisable to use two potentiometers, one as R_1
other as R_o.
be adjusted critically, to provide a complete null at the chosen frequency.

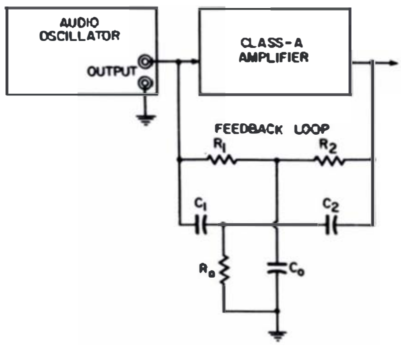


Fig. 9. An audio filter to improve the waveform from an audio oscillator.

NOTE 4

Audio-Oscillator Calibration Can Be Checked Against WWV Transmissions

We seldom need to accurately know the output frequency from an audio oscillator. However, if this becomes desirable, the instrument can be zero-beat against the WWV transmission at 440 and 4,000 cycles. Other harmonic and subharmonic frequencies can be calibrated with Lissajous patterns.

To Check an Audio Oscillator for Load Sensitivity

Equipment: AC VTVM and assorted fixed capacitors.

Connections Required: Connect equipment as shown in Fig. 10.

Procedure: Set audio oscillator for 10- or 15-kc output. Set attenuator for maximum output. Observe meter reading. Then shunt progressively larger capacitors across output terminals of audio oscillator. Again observe any change in meter reading. Repeat test with attenuator set at ⅔, ½, and ⅓ maximum.

Evaluation of Results: A load-sensitive audio oscillator will show a drop in output with relatively small shunt capacitances across the output terminals. Load sensitivity usually is most troublesome at lower attenuator settings and higher operating frequencies. It must be taken into account when audio signals are injected into circuits having shunt capacitances that can affect generator characteristics.

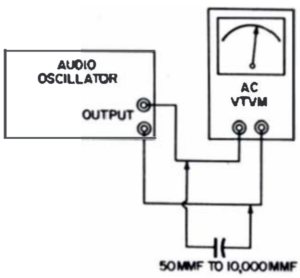


Fig. 10. Test setup.

U5

To Check a Square-Wave Generator for Load Sensitivity

Equipment: Oscilloscope and assorted fixed capacitors.

Connections Required: Connect equipment as shown in Fig. 11.

Procedure: Set square-wave generator controls for high-frequency square-wave output, such as 10 or 15 kc. Set generator attenuator for maximum output. Observe waveform on scope screen. Then shunt progressively higher capacitances across generator-output terminals until diagonal corners of square wave are noticeably rounded, as shown in

Fig. 12. Repeat test with generator attenuator set at ⅔, ½, and ⅓ maximum.

Evaluation of Results: A load-sensitive square-wave generator will show corner rounding when comparatively small capacitances are shunted across the generator-output terminals. In general, load sensitivity is greatest at low attenuator settings and at high frequencies. Load sensitivity must be taken into account when square-wave signals are injected into circuits having shunt capacitances that are high enough to affect generator characteristics.

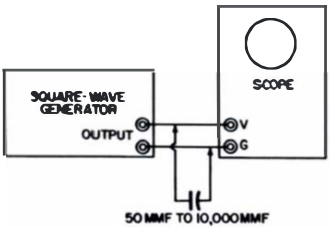


Fig. 11. Test setup.

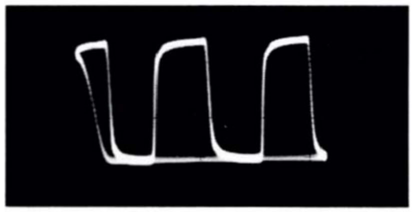


Fig. 12. Square-wave pattern with diagonal corners rounded.

U6

To Check the Accuracy of an Audio Wattmeter

Equipment: Amplifier, audio oscillator, terminating resistor, and AC VTVM.

Connections Required: Connect equipment as shown in Fig. 13.

Procedure: Drive amplifier with moderate output from audio oscillator, to avoid waveform distortion in amplifier output. Note scale readings on wattmeter and VTVM. Reduce output from audio oscillator in steps, and note scale readings on both instruments. Repeat the tests to obtain checks at low, medium, and high frequencies.

Evaluation of Results: The VTVM should be read in rms values. (If peak or peak-to-peak voltages are indicated by the VTVM, convert to rms values.) The power in the load resistor is given, in each test, by E^2/R, when E is in rms volts. The value of E^2/R should correlate closely with the reading on the wattmeter scale in each test.

Both the VTVM reading and the wattmeter are subject to waveform error. Hence, they should be checked with a good audio oscillator and amplifier. The output waveform from the amplifier can be tested with a harmonic-distortion meter. Typical audio wattmeters have an input resistance of 10,000 ohms. An amplifier load resistor of 16 ohms, for example, will not have its value changed appreciably when the wattmeter is connected. On the other hand, some wattmeters have low input resistances. If so, calculate the actual load resistance as the wattmeter input resistance and the terminating resistance in parallel.

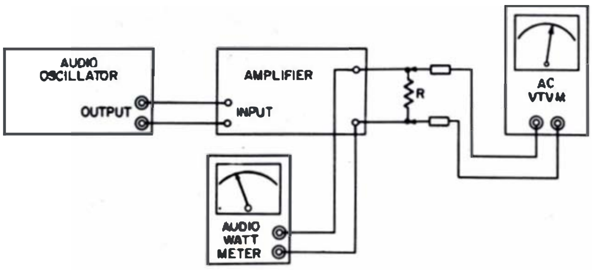


Fig. 13. Test setup.

U7

To Measure the Rejection Characteristic of a Harmonic-Distortion Meter

Equipment: Audio oscillator and AC VTVM.

Connections Required: Connect equipment as shown in Fig. 14.

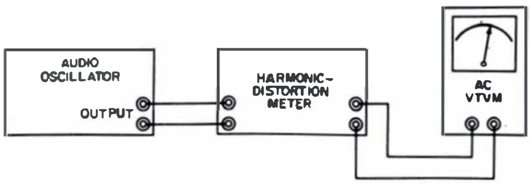
Procedure: Set harmonic-distortion meter controls to eliminate the fundamental at a given frequency, such as 400 cycles. Then tune the audio oscillator slowly (or in small steps) from 100 to 600 cycles. Observe voltage readings on VTVM.

Evaluation of Results: The rejection characteristic starts at the frequency at which the VTVM reading first starts to drop off. The characteristic goes through zero and then rises again. The rejection characteristic ends at the frequency at which the VTVM reading returns to its original value. If the meter movement in the harmonic-distortion meter is known to be accurate, the AC VTVM will not be required.

If desired, the rejection characteristic can be plotted on a sheet of graph paper as voltage *versus* frequency.

A very narrow rejection characteristic is undesirable. On the other hand, the characteristic should not be so broad that the second harmonic of the fundamental is appreciably attenuated. This would cause false readings of total harmonic distortion. It is advisable to check the rejection characteristic at a low frequency, such as 60 cycles; at a medium frequency, such as 1,000 cycles; and at a high frequency, such as 15,000 cycles.

Fig. 14. Test setup.

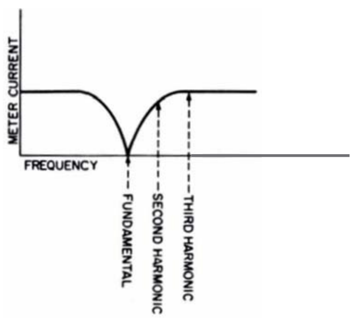


NOTE 5

Rejection-Frequency Curve of Harmonic-Distortion Meter

When tuned to the fundamental frequency, a harmonic-distortion meter suppresses the fundamental of a waveform. The rejection-frequency curve is made as broad as possible without appreciably attenuating the second harmonic. This insures that the rejection circuit will not ring a waveform excessively. Fig. 15 shows a typical rejection-frequency curve for a harmonic-distortion meter. The trap characteristic could be quite narrow. However, the narrower the characteristic, the greater the ringing imposed on a waveform.

Fig. 15. Typical rejection-frequency curve for a harmonic-distortion meter.



U8

To Check the Frequency Response of a Harmonic-Distortion Meter

Equipment: Audio oscillator and oscilloscope.
Connections Required: Connect equipment as shown in Fig. 16.
Procedure: Set controls of harmonic-distortion meter so as to switch the filter out of the instrument circuit. This is commonly termed the Set Level function. Adjust audio oscillator and instrument level control to obtain ½ or ¾ full-scale indication on the harmonic-distortion meter. Vary audio-oscillator frequency from 60 cycles to an upper frequency at which the vertical deflection on the scope screen begins to decrease.
Evaluation of Results: The point at which the vertical deflection begins to decrease is the upper frequency limit of the amplifiers in the harmonic-distortion meter. Past this frequency, the instrument is not useful.

Observe also the harmonic-distortion meter indication relative to the vertical deflection on the scope screen. If the meter indication starts to fall off first, this point must be taken as the highest useful frequency for the harmonic-distortion meter. Note also that, to provide a valid test, the audio oscillator must have a uniform output. The audio oscillator can be connected directly to the scope input terminals for a cross check.

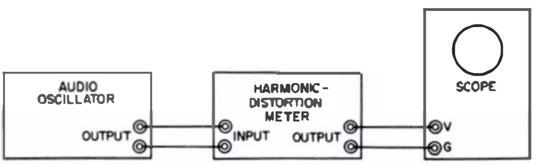


Fig. 16. Test setup.

U9

To Check the Consistency of Distortion Scale Indication in a Harmonic-Distortion Meter

Equipment: Audio oscillator.
Connections Required: Connect equipment as shown in Fig. 17.

Procedure: Apply low-frequency output, such as 60 cps, from audio oscillator to harmonic-distortion meter. Adjust level control of meter for full-scale indication, with sensitivity switch set at the 100% position (or Set-Level position). Then tune the filter until a very low reading, such as 1% or 2%, is obtained (Fig. 18). Finally turn the sensitivity switch progressively to the 30%, 10%, and 3% positions. Note meter reading each time on appropriate scale. Repeat tests at 400 cycles and at 10 kc.

Evaluation of Results: The meter reading should be the same on all ranges. In actual practice, however, considerable inaccuracy may occur at very low scale positions. The accuracy of the average distortion meter will usually be higher when readings are taken on the upper ⅔ or ¾ of the scale.

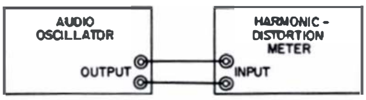


Fig. 17. Test setup.

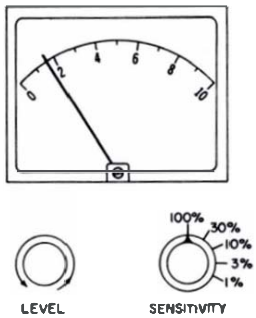


Fig. 18. Appearance of controls when operation of a harmonic-distortion meter is being checked.

NOTE 6

Reversing Power Plug Often Reduces Residual Hum Level in Harmonic-Distortion Meter

When a harmonic-distortion meter is set for high-sensitivity indication, such as the 1% range, the pointer does not rest at zero. Instead, it fluctuates about an average position—normally 1/10 full scale. If the power plug in the outlet is reversed, the pointer will often rest nearer zero, because the residual hum level in the meter will have changed.

NOTE 7

Three Types of Scales Are Provided on Conventional Harmonic-Distortion Meters

A harmonic-distortion meter usually has three scales—VTVM, percentage of total harmonic distortion, and decibels. The VTVM ranges generally measure from zero to approximately 30 volts. The decibel ranges in most meters have a reference level of 1 milliwatt in 600 ohms.

NOTE 8

Peak Voltage of Fundamental in Square Wave Is Greater Than Peak Voltage of Square Wave

When a square wave is passed through a harmonic-distortion meter (Fig. 19) and the instrument is tuned to trap out the fundamental, the waveform of the residual voltage will be as shown in Fig. 20. The troughs of the removed fundamental sine wave cross the zero-volt axis. This is due to the peak voltage of the fundamental frequency in a square wave being 1.27 times the peak voltage of the square wave itself. The harmonic-distortion meter reads a typical 28.5% on the residual voltage. Ordinary harmonic-distortion meters are not highly accurate when the harmonic content of a waveform is large.

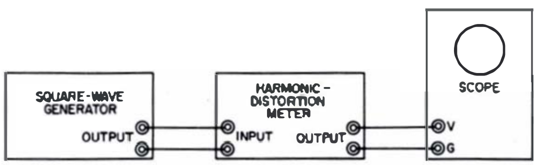


Fig. 19. Test setup.

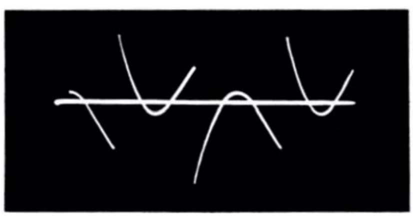


Fig. 20. Position of zero-volt level with respect to fundamental, when harmonic-distortion meter is tuned for indication of complete fundamental elimination.

U10

To Measure the Cathode Currents of the Output Tubes in an Audio Amplifier

Equipment: DC milliammeter and phone plug.

Connections Required: Make connections as shown in Fig. 21.

Procedure: Turn milliammeter controls for high-current range. Insert plug into jack 1 of amplifier. Reduce range setting on meter until ½ or ⅔ full-scale reading is obtained. Then repeat procedure at jack 2.

Evaluation of Results: A cathode current of approximately 60 ma can be expected in a normally operating amplifier. The current will change if the amplifier is driven into overload. The current readings at both jacks should be equal, and should not exceed the maximum ratings for the tubes in the amplifier. If the current readings are not equal, the amplifier balance control (or controls) should be adjusted.

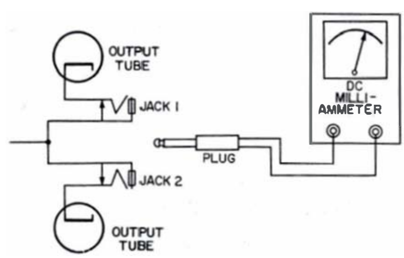


Fig. 21. Test setup.

NOTE 9

Distortion Increases When Push-Pull Stages Are Unbalanced

The push-pull output stage of an audio amplifier should be balanced to within 5%, and preferably 2%, on a cathode-current basis. When the tubes are unbalanced, hum, harmonic distortion, and intermodulation distortion increase. Sometimes output tubes must be selected which will provide a satisfactory balance adjustment. A tube tester usually will indicate whether a pair of tubes have reasonably similar characteristics. If balance cannot be obtained when similar tubes are used, check the circuit components.

NOTE 10

Hum in Amplifier Output Arises from Various Sources

Hum in the output of an audio amplifier is not always due to faulty filter capacitors or inductors. A common offender is heater-cathode leakage in tubes which have cathodes operating above ground. Tube selection is helpful, particularly in low-level stages. Some amplifiers have a hum-balance control in the heater circuit. If so, adjust the control for minimum hum. Poor ground connections, or improperly grounded units which cause circulating ground currents, are sometimes responsible. High-impedance, low-level grid circuits can pick up stray hum fields. To check, go through the amplifier, stage by stage, and shunt each grid to ground in succession with a large bypass capacitor. This will show whether a grid circuit is picking up hum. Sometimes a low-level audio cable needs to be grounded at one end only. At other times, hum can be reduced by grounding both ends.

U11

To Test the AC Balance of the Push-Pull Output Stage in an Audio Amplifier

Equipment: AC VTVM and audio oscillator.

Connections Required: Connect equipment as shown in Fig. 22.

Procedure: Adjust audio oscillator to provide nearly maximum rated output from amplifier. Tune oscillator for standard test frequency, such as 400 cycles. Apply VTVM lead, in turn, from plate 1 to ground and plate 2 to ground. Note meter readings.

Evaluation of Results: The two readings should be nearly equal. If not, check the DC voltage readings from plate 1 to ground and plate 2 to ground. If the DC voltage readings are nearly equal but the AC voltage readings are not, check the drive circuits to the output stage. If both the AC and the DC voltage readings are unequal—and the balance control(s) are adjusted as accurately as possible—check the components in the output stage.

Unequal AC voltage readings can be expected at very low and very high audio frequencies. Here the circuit reactances begin to show up as unequal drive voltages to the grids of the push-pull tubes.

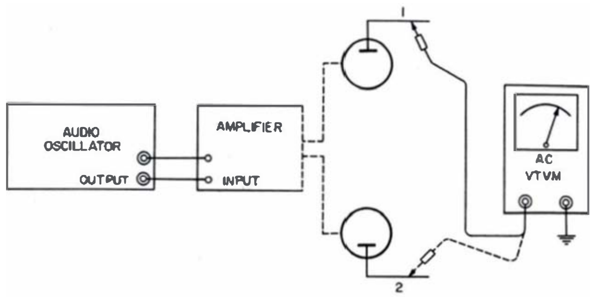


Fig. 22. Test setup.

U12

To Measure the Frequency Response of an Audio Amplifier

Equipment: Audio oscillator, AC VTVM, power resistor, and toggle switch or clip lead.

Connections Required: Connect equipment as shown in Fig. 23.

Procedure: Set audio-oscillator controls for 50-cycle output and for maximum rated power level across load resistor R. Measure voltages at points 1 and 2. Then advance generator frequency to 200 cycles. Check voltage at point 2, and reset audio-oscillator attenuator, if necessary, for same input voltage as before. Then measure the output voltage from the amplifier at point 1 again. Repeat the procedure at progressively higher frequencies, to obtain complete frequency response of amplifier.

Evaluation of Results: Plot or tabulate the voltage-*vs.*-frequency measurements, and compare them with the manufacturer's amplifier specifications.

A more complete test of amplifier frequency response is obtained by repeating the procedure for low- and medium-level input voltages. The power in load resistor R can be easily found from Ohm's law:

$$W = E^2/R$$

where,

W is the power in watts,
E is the rms voltage across R,
R is the load resistance in ohms.

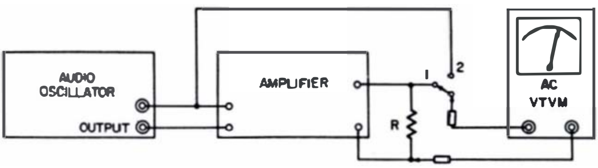


Fig. 23. Test setup.

NOTE 11

Resistor Used as Amplifier Load Must Have Adequate Power Rating

A resistor or combination of resistors used as an amplifier load during tests must have a large enough power rating to handle the output from the amplifier. Two resistors can be connected in series or parallel to double the power-handling capability. Three resistors connected in series or parallel will triple the power-handling capability of an individual resistor. Thus, two 5-watt, 8-ohm resistors can be connected in series to provide a 10-watt, 16-ohm resistive load. Or, two 5-watt, 32-ohm resistors can be connected in parallel to provide a 10-watt, 16-ohm load.

NOTE 12

Octave Is a Harmonic-Frequency Relation

Amplifiers are sometimes rated in terms of db roll-off per octave. This means the response is down this number of db for each time the frequency is doubled. The term *octave* in musical work designates the tone interval, e.g., from one C note on the piano to the next C note. There are eight intervals, or one octave, between the two C notes. The two notes are practically in harmonic-frequency relation on the modern, tempered scale. Thus, if an amplifier has a roll-off of 6 db per octave past 10 kc, the response will be down 50% at 20 kc.

To Measure the Total Harmonic Distortion of an Amplifier

Equipment: Audio oscillator, harmonic-distortion meter, and optional terminating resistor for amplifier.

Connections Required: Connect equipment as shown in Fig. 24. Use the rated value of terminating resistor for the amplifier, if the speaker is disconnected.

Procedure: Set harmonic-distortion meter to Set Level position. Tune audio oscillator to a standard test frequency, such as 400 cycles. Adjust input signal level for full-scale meter indication. Then switch harmonic-distortion meter to suitable test position, and tune out the 400-cycle fundamental. Observe meter reading, using a higher-sensitivity range if necessary.

Evaluation of Results: The meter scale of a typical harmonic-distortion meter indicates the percentage of distortion voltage, with respect to the output voltage of the amplifier.

Standard test procedure is to adjust the input signal level to the amplifier for maximum rated power output. Percentage distortion will usually be lower at lower power-output levels. For good-quality sound reproduction, total harmonic distortion should be less than 2%. (Up to 5% is considered acceptable.) Note also that an audio oscillator can have greater distortion than a low-distortion amplifier. We cannot subtract the audio-oscillator distortion from the total amplifier distortion, because we do not know whether the audio-oscillator distortion voltages are in phase, out of phase, or at some other phase to the amplifier distortion voltages. A good audio oscillator must then be used, or its output must be filtered.

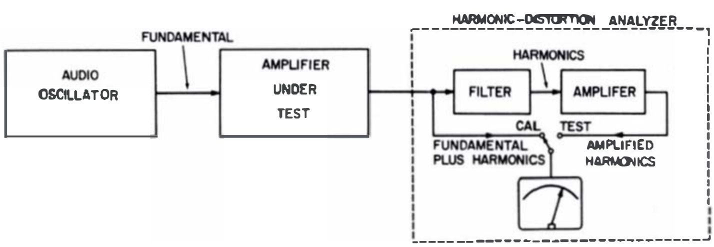


Fig. 24. Test setup.

NOTE 13

Oscilloscope Can Display Waveform of Voltage Measured by Harmonic-Distortion Meter

Many harmonic-distortion meters have a pair of output binding posts to which a scope can be connected (Fig. 25). The scope shows the waveform of the distortion voltage measured by the meter. This is often useful for showing whether the distortion voltage is principally second harmonic, third harmonic, etc. Fig. 26 shows the change in shape of a harmonic-distortion waveform as the distortion meter is tuned through the null point.

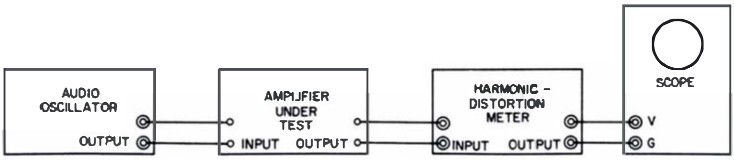


Fig. 25. Test setup for U13, using oscilloscope.

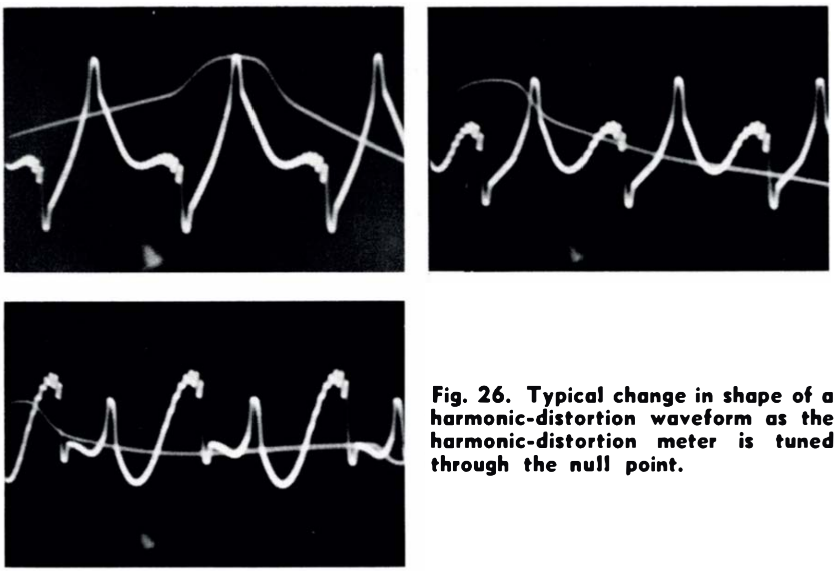


Fig. 26. Typical change in shape of a harmonic-distortion waveform as the harmonic-distortion meter is tuned through the null point.

NOTE 14

Advantage of Using a Scope With a Harmonic-Distortion Meter

There is no definite relationship between percentage of total harmonic distortion and quality of sound, as judged by the listener. Two amplifiers can have the same percentage of total harmonic distortion; yet, listeners will quickly agree that one amplifier has better quality of reproduction than the other. One theory to explain this lack of correlation is that clipping, for example, though causing a small percentage of harmonic distortion, is highly objectionable to the listener because it occurs over a small portion of the cycle only. Our ears respond more like the beam of an oscilloscope than like the pointer in a harmonic-distortion meter. In a scope pattern we sometimes can detect objectionable distortion, which would pass unnoticed in a harmonic-distortion meter test. The general rule is:

1. A harmonic-distortion meter can measure various forms of objectionable harmonic distortion, which cannot be seen on the scope screen. A typical example is a simple mixture of a third-harmonic voltage with a fundamental voltage.
2. A scope can make visible other objectionable forms of harmonic distortion which cannot be properly evaluated on a harmonic-distortion meter. A typical example is peak clipping or compression of a fundamental voltage.

Clipping is the most objectionable form of harmonic distortion. A small discontinuity that causes clipping does not cause a proportionally large increase in total harmonic distortion. Thus, in evaluating a total harmonic-distortion figure, it is important to know whether clipping distortion is included. A total harmonic-distortion figure that is acceptable in the absence of clipping can be unacceptable if it refers to clipped waveforms. A clipped sine wave is shown in Fig. 27.

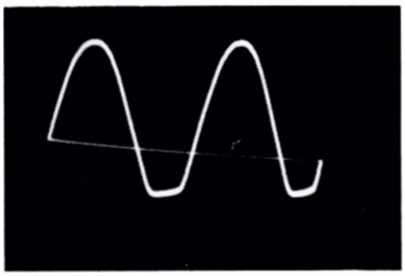


Fig. 27. Unsymmetrical clipping of a sine wave.

NOTE 15

Different Types of Filters Are Used in Harmonic-Distortion Meters

Harmonic-distortion meters commonly used in audio work have either a high-pass filter, or a rejection filter which eliminates only the fundamental frequency from the amplifier output signal. In general, the fundamental-rejection filter gives a higher meter reading because it does not eliminate circuit noise and hum voltage. Both types of harmonic-distortion meters measure what is called total harmonic distortion. Although the total harmonic-distortion voltage is applied to the meter, the reading is not exactly a true total harmonic voltage. The inaccuracy of indication results from the contact rectifiers, which respond to the average value of the total harmonic voltage. The average value can vary appreciably, depending upon the phases of the distortion voltages. A completely accurate measurement of total harmonic distortion is time consuming. It requires a sharply-tuned pass filter to measure the various distortion voltages, one by one. Each value is then squared, and the sum of all the squares is computed. Finally the square root of the sum of the squares is taken. The square root gives the true total harmonic-distortion voltage. It is possible to use a thermocouple or a square-law VTVM indicator in a harmonic-distortion meter, to provide true indications of total harmonic-distortion voltages. However, a thermocouple is delicate and easily burned out, and a square-law VTVM is not as stable nor as easy to keep in calibration as the simpler AC meters. Hence, contact rectifiers are generally used. Ordinary total harmonic-distortion meters are very useful for comparative tests on amplifiers, although the actual reading may not be exactly correct.

NOTE 16

Harmonic-Distortion Measurements More Meaningful When Made Over a Wide Range of Operating Conditions

It is customary to give the total harmonic-distortion percentage for an amplifier under one or two conditions of power into a resistive load. However, more meaningful data are provided by determining the total harmonic-distortion percentage over a wide range of operating conditions. Measurements should include: (1) low output level, (2) medium output level, (3) high output level, (4) low input frequency, (5) medium input frequency, (6) high input frequency, (7) low gain-control setting, (8) medium gain-control setting, (9) high gain-control setting, and (10) typical speaker, instead of resistive, load in all of the foregoing tests.

NOTE 17

Total Harmonic-Distortion Figure Is Inconclusive

Amplifiers cannot be compared solely on the basis of total harmonic distortion. The reason is that high-order harmonic distortion is more objectionable to the listener. Accordingly we need to know the percentages of second, third, fourth, fifth, etc., harmonic distortions. To avoid this difficulty, compare the amplifiers on the basis of intermodulation distortion, in order to obtain a better evaluation of reproduction quality.

NOTE 18

Noise and Hum in Output Signal Can Be Measured in Scope Pattern

Fig. 28 shows noise and hum voltages superimposed on the output waveform from an amplifier. The vertical excursion of the "fuzz" riding on top of the waveform can be measured if the scope is calibrated. The excursion of the complete waveform also corresponds to a certain voltage, which can be measured when the deflection sensitivity of the scope is known.

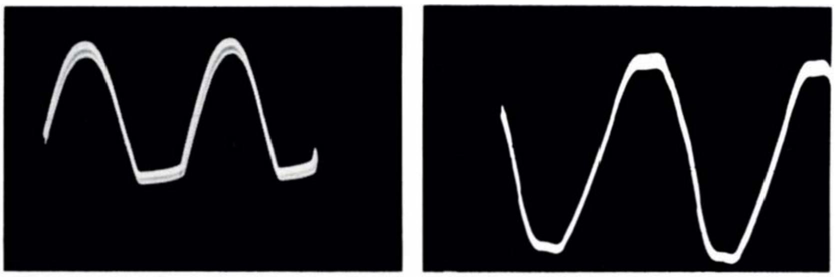


Fig. 28. Examples of large hum and noise voltages in the distorted output from an amplifier.

U14

To Check for Amplifier Distortion With a Scope

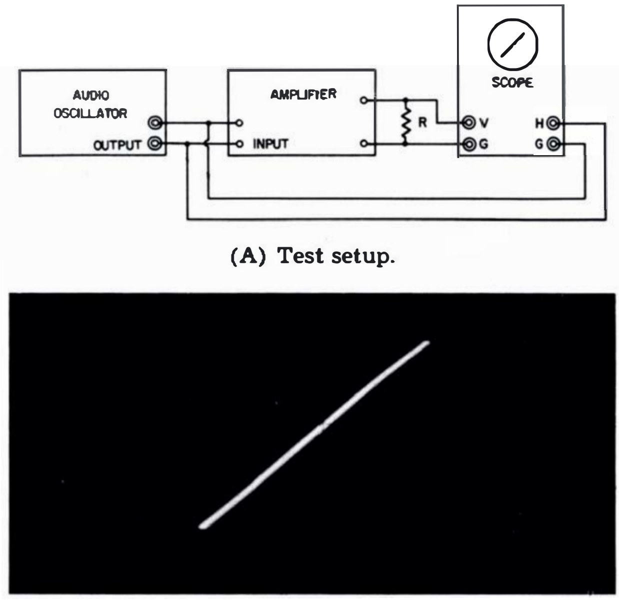
Equipment: Audio oscillator, terminating resistor, and oscilloscope.

Connections Required: Connect equipment as shown in Fig. 29A.

Procedure: Advance output from audio oscillator until the straight line on the scope screen just begins to curve at one or both ends, as shown in Fig. 29B. Then, using calibrating facilities of scope, determine the voltage across terminating resistor R.

Evaluation of Results: According to a rule of thumb, there will be approximately 1% harmonic distortion in the amplifier output when the straight line just begins to curve noticeably. The power in the load at this point is given by the formula, $W = E^2/R$. Power measurements are made by calibrating the scope in rms values.

The frequency or frequencies of test must not exceed the capability of the scope, if a narrow-band scope is used. The horizontal amplifier in the scope is usually the limiting factor. For audio work, a scope with identical vertical and horizontal amplifiers is preferred.



(A) Test setup.

(B) Waveform with harmonic distortion just noticeable.

Fig. 29. Checking amplifier distortion.

U15

To Measure Amplifier Phase Shift With an Electronic Switch

Equipment: Audio oscillator, electronic switch, oscilloscope, and terminating resistor.

Connections Required: Connect equipment as shown in Fig. 30.

Procedure: Adjust audio-oscillator output for desired operating level, below maximum rated output of amplifier. Set electronic-switch and scope controls for convenient pattern display. Tune audio oscillator through the passband of the amplifier, while watching the two sine-wave displays for shift along the horizontal base line.

Evaluation of Results: In the midband range an audio amplifier will show an output waveform which is either in phase or 180° out of phase with the input waveform. On the other hand, at the low-frequency and high-frequency ends of the passband, the output waveform will progressively lag or lead the input waveform (see Fig. 31). Lag or lead often occurs in the midband range because of faulty crossover or feedback networks.

Phase shift can be disregarded in amplifiers not designed for high-quality reproduction. On the other hand, discriminating listeners find phase shift objectionable in high-fidelity amplifiers.

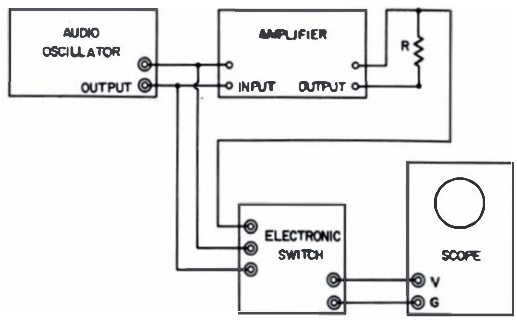


Fig. 30. Test setup.

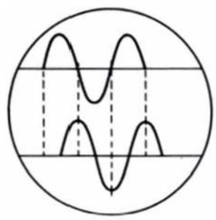


Fig. 31. Typical waveform, showing phase shift through an amplifier.

U16

To Measure the Maximum Power Output From an Amplifier (Harmonic-Distortion Meter Method)

Equipment: Audio oscillator, harmonic-distortion meter, terminating resistor, and AC VTVM.

Connections Required: Connect equipment as shown in Fig. 32.

Procedure: Advance output from audio oscillator in successive steps, each time checking the total harmonic distortion with the harmonic-distortion meter. When the percentage of harmonic distortion reaches a chosen maximum, such as 1%, observe the VTVM reading.

Evaluation of Results: The power in the load is given by Ohm's law—$W = E^2/R$—where W is the power in watts, E is the voltage in rms volts, and R is the resistance of the terminating resistor in ohms.

When the maximum total harmonic distortion chosen is small, a good audio oscillator must be used. Otherwise, the audio oscillator can have more distortion than the amplifier. The output waveform from an audio oscillator can be improved by using the low-pass filter shown earlier in Fig. 5.

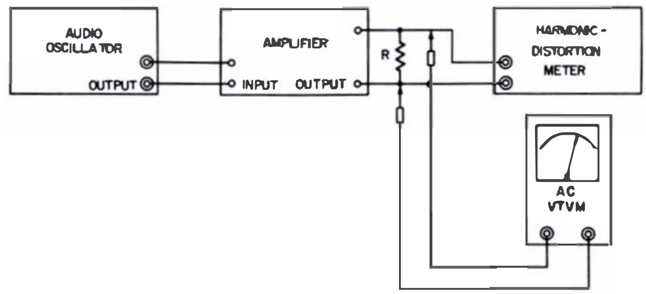


Fig. 32. Test setup.

NOTE 19

Input Circuit of Harmonic-Distortion Meter Has No Blocking Capacitor

A blocking capacitor ordinarily is not provided in the input circuit of a harmonic-distortion meter. Hence, the test leads must not be connected to the plate of an amplifier tube or other source of DC voltage. The input circuit is commonly a 500-ohm potentiometer, and is suitable for connection to low-impedance sources only. If a blocking capacitor is required, it must be large enough to pass the lower audio frequencies without attenuation. For example, to couple a 60-cycle signal into a 500-ohm potentiometer with only 10% loss requires a coupling capacitor of approximately 500 mfd.

To Measure the Intermodulation Distortion of an Amplifier

Equipment: IM distortion meter.

Connections Required: Connect equipment as shown in Fig. 33.

Procedure: Set load switch of IM meter to terminate amplifier correctly. (If IM meter does not have load facilities, an external load resistor must be provided.) Set IM test signal to a desired level not exceeding the rated maximum power output of the amplifier. Preliminary IM tests are usually made at the maximum rated output. Adjust IM distortion-meter control to the set-level reference position. Switch the IM distortion meter to %IM on the function dial. Advance range switch as required for ½ or ⅔ full-scale reading.

Evaluation of Results: Compare percentage of IM distortion on meter scale with value specified by receiver manufacturer. Note that IM distortion often increases rapidly if the maximum rated output of the amplifier is exceeded.

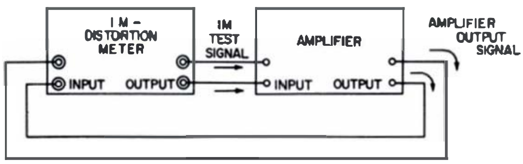


Fig. 33. Test setup.

NOTE 20

Conventional Method of Measuring Harmonic Distortion Not Always Accurate

The conventional method of measuring harmonic distortion is reasonably accurate when the distortion voltage has a sine waveform. On the other hand, if the distortion voltage is nonsinusoidal, the total harmonic-distortion indication may be greatly in error. Hence, intermodulation measurements are preferred over conventional harmonic-distortion measurements.

NOTE 21

No Correlation Between Distortion Figures Obtained by Total Harmonic Distortion and Intermodulation Test Methods

An amplifier with practically no intermodulation distortion can have considerable harmonic distortion. There is no known basis of comparison between the figures obtained by the two methods. Hence, a thorough test of amplifier distortion must include both methods. Each is helpful in comparing the performance of other amplifiers.

NOTE 22

Instruments With Full-Wave Contact Rectifiers Indicate AC Voltages Which Depend Upon Waveform

For accurate measurements, the effect of the waveform must be observed on readings of instruments having contact rectifiers. The values shown in Fig. 34 are those indicated by meters with full-wave contact rectifiers. The pointer indicates the effective value on the scale. The meter movement responds to the average value of the waveform. The waveforms illustrated (sine, triangular, and square) have equal peak voltages. On the other hand, note how the indicated (effective) values differ. In general, meters with contact rectifiers indicate true rms voltages for pure sine waves only.

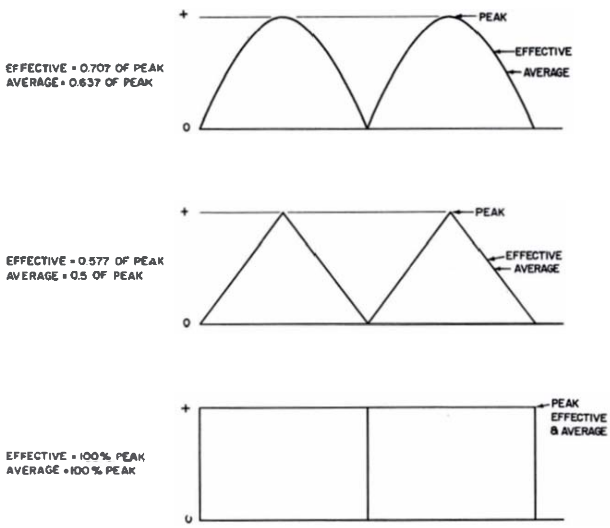


Fig. 34. The peak, effective, and average values of various waveforms when passed through equipment using full-wave contact rectifiers.

NOTE 23

Mixture of Second Harmonic With Fundamental Gives Some Result as Clipping the Fundamental

Clipping a sine wave results in the generation of even harmonics. This fact can be readily demonstrated by mixing a fundamental with a second-harmonic voltage, as from a pair of audio oscillators. The mixed waveform (Fig. 35) has the shape of a fundamental that has been clipped while passing through an amplifier.

Whether second-harmonic distortion is noticeable or not depends upon the amplifier input signal. A pure sine wave can undergo considerable second-harmonic distortion before the listener finds the distortion objectionable. On the other hand, if two sine-wave voltages are applied to the amplifier, a relatively small amount of second-harmonic distortion will become objectionable. The difference is due to generation of intermodulation frequencies by the two sine-wave voltages while passing through the amplifier.

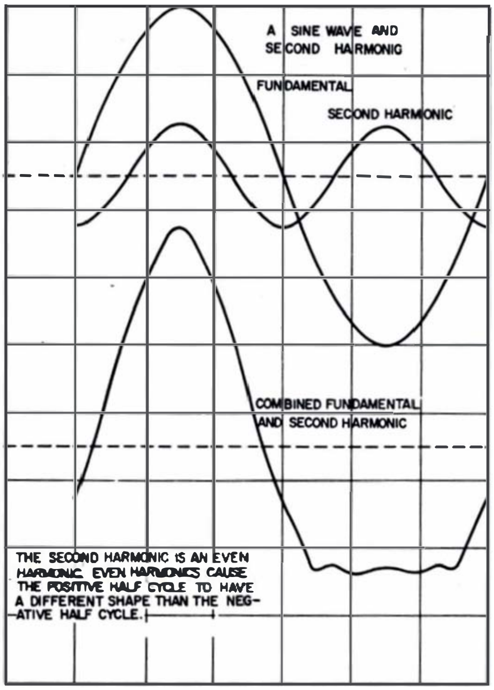


Fig. 35. A fundamental sine wave distorted by the second harmonic.

NOTE 24

How Amplitude Nonlinearity Causes Intermodulation Distortion

Intermodulation is the modulation of one frequency by another frequency. It occurs whenever the amplitude is nonlinear. The nonlinearity is not necessarily in an amplifier tube or transistor. Speakers, for example, have amplitude nonlinearity, particularly when operated at high output. A basic example of intermodulation occurs when a waveform is clipped, as illustrated in Fig. 36. This waveform consists of two frequencies—60 and 2,000 cycles. The 2,000-cycle voltage is reduced in amplitude during the clipping interval, and sideband frequencies are generated. The 2,000-cycle tone from the amplifier is mixed with a 2,060- and a 1,940-cycle frequency. These intermodulation frequencies are more objectionable to the listener than harmonic-distortion frequencies.

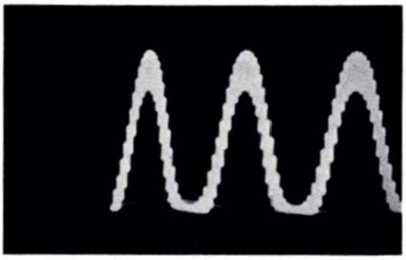


Fig. 36. A waveform with intermodulation distortion.

U18

To Determine Whether the Output Signal From an Amplifier Is in Phase or Out of Phase with the Input Signal

Equipment: Audio oscillator, oscilloscope, terminating resistor, 10K resistor, 1K resistor, and 100K potentiometer.

Connections Required: Connect equipment as shown in Fig. 37.

Procedure: Apply a medium-level signal, such as 1,000 cycles, to the amplifier. Vary the potentiometer adjustment while watching the scope pattern.

Evaluation of Results: If adjusting the pot reduces the vertical deflection to zero, the output signal is 180° out of phase with the input signal. On the other hand, if the vertical deflection is not reduced to zero (no null point on the pot), the output signal is in phase with the input signal.

When one is assembling units for a stereophonic amplifier, this test is useful for phasing the speakers correctly. An audio amplifier supplies an output signal that is either in phase or 180° out of phase with the input signal. The output phase depends upon the number of stages and the types of circuits in the amplifier.

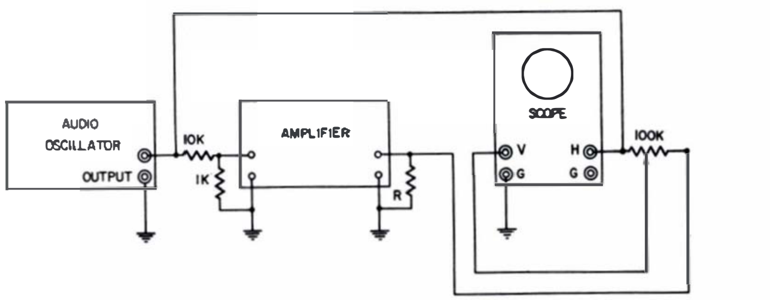


Fig. 37. Test setup.

NOTE 25

Direct-Reading Phase-Shift Meter

A direct-reading phase-shift meter is a simple device using the typical circuit shown in Fig. 38. This instrument has a special scale calibrated in degrees of phase shift. To use the instrument, feed the signal input of an amplifier under test to the Signal 1 terminals. Feed the output signal from the amplifier to the Signal 2 terminals. Adjust the attenuators of the phase-shift meter to give equal readings when the switch is turned from position 1 to position 2. Throw the switch to position 3. The reading on the meter scale at this position is the degrees of phase shift.

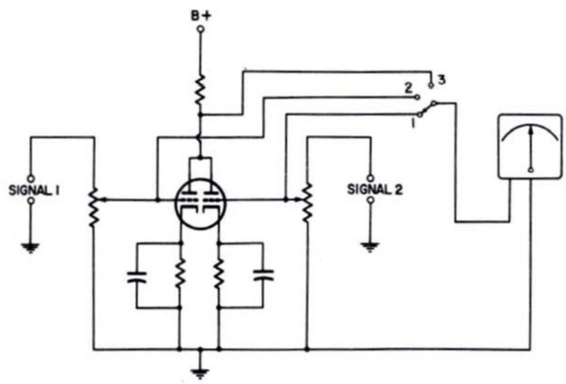


Fig. 38. Typical circuit configuration for a direct-reading phase-shift meter.

To Make a Square-Wave Test of an Audio Amplifier

Equipment: Square-wave generator, oscilloscope, switch or clip lead, and terminating resistors.

Connections Required: Connect equipment as shown in Fig. 39.

Procedure: Adjust output of square-wave generator to approximately the normal operating level of amplifier. Tune generato to a low frequency, such as 50 cycles. Observe output and input waveforms on scope screen, by throwing the switch from position 1 to position 2. Repeat test, at progressively higher frequencies, to approximately 10 kc.

Evaluation of Results: A good amplifier will not show appreciable ringing or overshoot at any square-wave frequency. In almost any amplifier, tilt will occur at very low test frequencies, and corner rounding will occur at very high test frequencies.

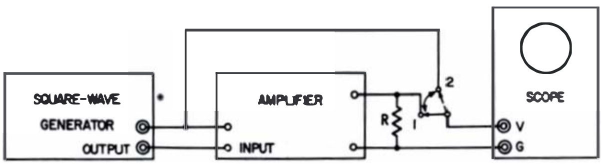


Fig. 39. Test setup.

NOTE 26

Overshoot and Ringing of Amplifier Should Be With Reference to Rise Time of Square-Wave Generator

The amount of overshoot and ringing in an audio amplifier depends greatly upon the rise time of the square-wave generator. If the generator has a slow rise time, the amplifier will be free from overshoot and ringing. On the other hand, the same amplifier can overshoot and ring strongly when tested with a generator having a fast rise time. Hence, a statement that an amplifier has an overshoot of 10% needs to be correlated with the rise-time figure of the square-wave generator. The amplifier should be tested at a rise time corresponding to the minimum rise time of transients in the signals normally handled by the amplifier. This is determined primarily by the frequency response or bandwidth of the signal source, whether it is a record player, a tape recorder, a wire recorder, an instrument pickup, or an FM or AM receiver.

To Localize Distorting Stage By Signal-Injection Method

Equipment: Audio oscillator, blocking capacitor, and harmonic-distortion meter.

Connections Required: Connect equipment as shown in Fig. 40.

Procedure: First measure the total harmonic distortion for the complete amplifier, in the usual manner. If the distortion figure is high for the particular amplifier, proceed with signal-injection tests. Stage-by-stage tests can often be made in order to localize the source of distortion. Connect a blocking capacitor in series with the audio-oscillator output lead; then check progressively from grid to grid, as indicated in the diagram. The output voltage from the audio oscillator should be adjusted in each case to provide the same Set Level reading on the harmonic-distortion meter.

Evaluation of Results: The signal-injection method permits the increased distortion contributed by each stage in the amplifier to be measured. Thus, a stage which contributes excessive distortion can be localized.

The signal-injection method becomes uncertain in amplifiers having over-all feedback, because the impedance of the audio-oscillator output cable disturbs the normal input voltage to the grid.

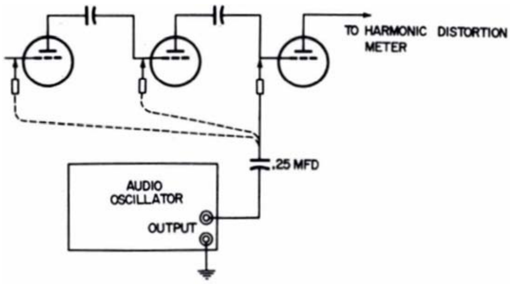


Fig. 40. Signal-injection method for locating the distorting stage.

NOTE 27

Signal Tracing Can Be Accomplished With Over-all Feedback Loop Opened

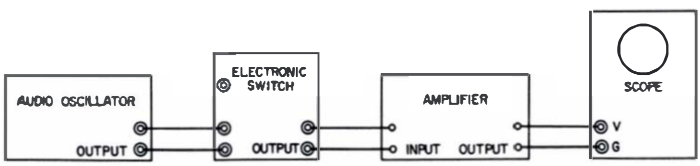
When a scope is used to signal-trace an amplifier, a faulty stage can sometimes be located more easily by opening the over-all feedback loop. The gain goes up; the input signal to the amplifier must be reduced accordingly, to avoid overload. Disconnecting the over-all feedback loop also increases the distortion. In a typical amplifier the distortion figure doubles whenever the feedback loop is opened. Keep this in mind when checking the amplifier.

U21

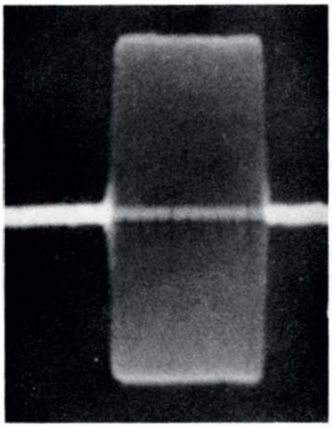
To Make a Tone-Burst Test of an Amplifier

Equipment: Audio oscillator, electronic switch, and oscilloscope.
Connections Required: Connect equipment as shown in Fig. 41A.
Procedure: Tune audio oscillator to a suitable test frequency, such as 10 kc. Adjust electronic switch to supply tone bursts of the approximate form shown in Fig. 41B. Observe pattern on scope screen for distortions of tone-burst waveshape.
Evaluation of Results: The tone-burst signal places more exacting demands upon the ability of the amplifier to reproduce transients than the ordinary square-wave test does. The tone-burst signal shows the amplifier response to a suddenly applied AC voltage as well as to a suddenly applied DC voltage.

Tone-burst tests are more informative when the tone-burst frequency is varied over a wide audio range. This helps to locate regions of faulty response in crossover and feedback networks. It is also good practice to check the tone-burst pattern for distortion at low-, medium-, and high-input signal levels.



(A) Test setup.



(B) Typical tone-burst signal.

Fig. 41. Tone-burst test of an amplifier.

NOTE 28

Double-Ended Scope Required When Both Sides of Voice Coil Operate Above Ground

In some audio amplifiers, both ends of the voice coil operate above ground. A single-ended scope cannot be used to check the voltage across the voice coil, because the amplifier may be seriously disturbed or damaged. A double-ended scope must be used instead.

U22

To Check an Amplifier for Parasitic Oscillation

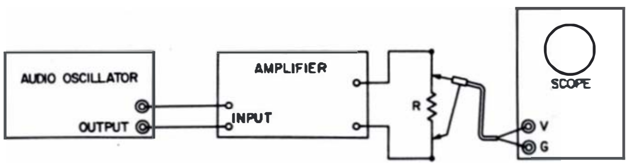
Equipment: Audio oscillator, oscilloscope, and terminating resistor.

Connections Required: Connect equipment as shown in Fig. 42A.

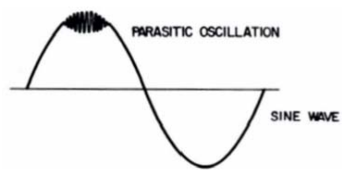
Procedure: Adjust audio-oscillator controls for low-frequency output, such as 60 cycles, and low-level input to the amplifier. Adjust amplifier controls for normal operation. Adjust scope controls to display sine-wave pattern on screen. Then advance output voltage from audio oscillator, and reduce attenuator setting of scope. Observe pattern for "ballooning" at any point, particularly on the peaks (Fig. 42B). Repeat test at several levels until the amplifier is delivering its maximum rated output. Repeat the test again at medium and at high audio frequencies.

Evaluation of Results: When a "balloon" or "bulge" appears in the trace, parasitic oscillation is occurring during the "bulge" interval. This oscillation is most likely to occur when grid current flows in an amplifier circuit.

A complete check for parasitic oscillation can be made by using a speaker load instead of a resistive load for the amplifier, and by repeating the test for different settings of the amplifier controls. Parasitic oscillation can usually be eliminated by connecting 50- to 500-ohm resistors in series with the tube electrodes in the circuit in which the oscillation is occurring.



(A) Test setup.



(B) Appearance of parasitic oscillation on a sine wave.

Fig. 42. Checking an amplifier for parasitic oscillation.

NOTE 29

Signal Tracing an Amplifier With Parasitic Oscillation

Parasitic oscillation causes "rattle" in the sound. To localize the tube causing the parasitic oscillation, use a scope to check through the amplifier from grids to plates of successive tubes. Often, the output stage is the offender. It is advisable to use a low-capacitance probe with the scope, because the input capacitance of a direct cable can be sufficient to "kill" the parasitic oscillation and falsely indicate that the stage is functioning normally.

U23

To Measure the Output Impedance of an Amplifier

Equipment: Audio oscillator, variable power rheostat, and AC VTVM.

Connections Required: Connect equipment as shown in Fig. 43.

Procedure: Set switch to position 1 and amplifier controls to normal operating positions. Adjust audio-oscillator output to avoid excessive output voltage, which could cause arc-overs or breakdown. With VTVM switched to AC function, note scale reading. Then set switch to position 2. Adjust rheostat for half of first scale reading.

Evaluation of Results: Measure resistance of rheostat. This resistance is equal to the output impedance of the amplifier.

For a comprehensive test, repeat the foregoing procedure for low-, medium-, and high-frequency output from the audio oscillator. This method of measuring output impedance is based upon the connection of the load rheostat in series with the amplifier output impedance. Thus, the rheostat and the output impedance are a voltage divider. When both values are equal, the VTVM will read half voltage.

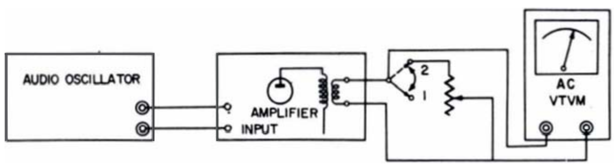


Fig. 43. Test setup.

U24

To Measure the Damping Factor of an Amplifier

Equipment: Audio oscillator, AC voltmeter, and 15-ohm wire-wound variable resistor.

Connections Required: Connect output from audio oscillator to input terminals of amplifier. Connect AC voltmeter across amplifier output terminals, as shown in Fig. 44. In second part of test, also connect resistor across amplifier output terminals.

Procedure: Apply relatively low output voltage from audio oscillator to amplifier (to avoid overload and possible arc-over on open-output circuit). A 60-cycle test frequency is suitable. Observe voltmeter reading. Next adjust the wirewound resistor to the nominal impedance of the amplifier. Connect resistor across amplifier output terminals, and again note meter reading. The nominal impedance of the amplifier is the value of load into which the amplifier normally works. The recommended nominal impedance is often marked on the amplifier. In any event, the nominal impedance is the value of the actual load impedance used with the amplifier.

Evaluation of Results: The damping factor of the amplifier is equal to the full-load voltage divided by the difference between the no-load and the full-load voltages.

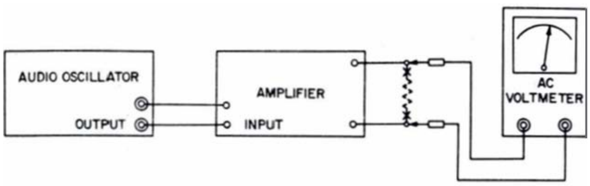


Fig. 44. Test setup.

U25

To Measure the Input Impedance of an Amplifier

Equipment: Audio oscillator, rheostat, SPDT switch, AC VTVM, and terminating resistor.

Connections Required: Connect equipment as shown in Fig. 45.

Procedure: Set switch to position 1. Adjust amplifier controls for normal operation. Note reading on meter scale. Then set switch to position 2. Adjust rheostat for half of first meter reading.

Evaluation of Results: Measure the rheostat resistance. This is the amplifier input impedance.

In transistor amplifiers the output resistance of the common circuits is changed by the generator and rheostat resistance. Hence, the load resistor chosen must terminate the amplifier correctly, taking into account the generator and rheostat resistance. The rheostat resistance and the generator resistance add together to increase the output resistance of a transistor amplifier.

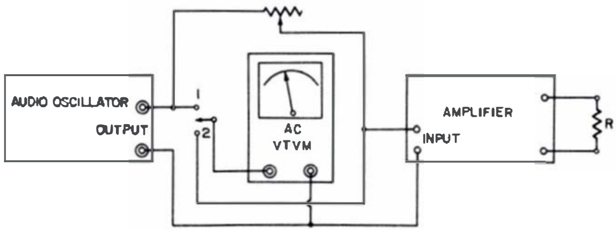


Fig. 45. Test setup.

NOTE 30

Amplifier Input Impedance Often Differs at Low and High Frequencies

The input impedance of an amplifier often changes with frequency. Hence, for a comprehensive test of input impedance, measure at a low, a medium, and a high frequency. As a rule we are concerned with only the magnitude of the input impedance; we do not break the input impedance down into its resistive and reactive components. However, it is the reactive component that causes the input impedance to change with frequency.

U26

To Measure the Noise Level of an Amplifier

Equipment: Audio oscillator, harmonic-distortion meter, and terminating resistor.

Connections Required: Connect equipment as shown in Fig. 46.

Procedure: R should have the recommended value for terminating the amplifier. The voltage across R can be read directly on most harmonic-distortion meters. To measure the noise level of the amplifier, select a suitable reference power level for the amplifier. For example, this might be 4 watts or 5.7 volts across 8 ohms. Note db reading on distortion meter scale. Then turn audio oscillator off. Switch distortion meter to higher sensitivity position, to obtain db reading of noise-voltage output from the operating amplifier. Again note db reading.

Evaluation of Results: Take the ratio of the two db readings. This is the noise level of the amplifier. It is customarily expressed as so many db below so many watts (for example, 61 db below 4 watts).

Most distortion meters in audio work have contact rectifiers, with a meter that responds to the average value of the rectified waveform. See Note 22.

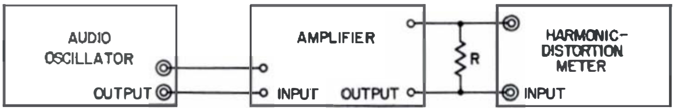


Fig. 46. Test setup.

NOTE 31

Relationship of Dbm and VU Measurements

A dbm measurement is a decibel measurement of a sine-wave voltage, made with a db meter having a reference level of 1 milliwatt in 600 ohms. A VU (volume unit) measurement is a decibel measurement of a complex voltage. It is made with a db meter having a reference level of 1 milliwatt in 600 ohms, and with such damping that pointer overshoot is not greater than 1.5% in response to a suddenly applied voltage. That is, a dbm measurement is made on a steady sine-wave signal; thus, meter damping is not important. On the other hand, a VU measurement is made on musical or vocal waveforms; meter damping must be controlled before a valid level indication can be obtained.

As a general rule, most harmonic-distortion meters have a dbm scale. The db scale (or scales) on a harmonic-distortion meter may have a zero-db reference level of 1 milliwatt in 600 ohms. When this reference level is used, the scale readings are often called *dbm* instead of *db*. The term *dbm* refers to the reference level.

NOTE 32

Correction of Db Reading When Measuring Across Different Load Impedances

The db scales on a harmonic-distortion meter can be used in measuring db gain or loss across any load impedance, provided suitable correction factors are applied. The individual measurements are not necessarily correct. However, the *difference* between the two db measurements will be the correct number of db, after a suitable correction factor is taken from the chart in Fig. 47.

Example: The db scales of the harmonic-distortion meter are calibrated for a reference level of 1 milliwatt in 600 ohms. If we measure db at the input and output of an amplifier, we might find 1 db at the input terminals and 1 db at the output terminals. If the input impedance of the amplifier is 100,000 ohms and the output impedance is 500 ohms, the ratio of the impedance is 200-to-1. From the chart, we see that 23 db must be added to the difference between the two db readings (1—1+23 = 23-db gain).

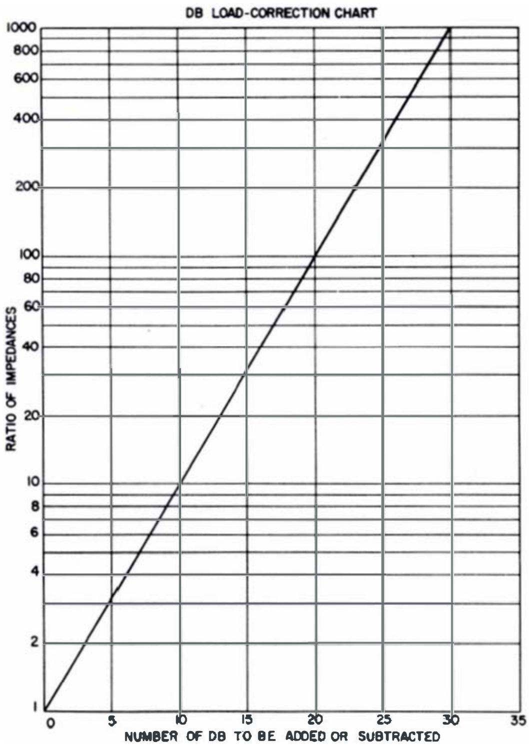


Fig. 47. Db load-correction chart.

U27

To Monitor an Audio Amplifier for Circuit Loading During Voltage Checks

Equipment: Oscilloscope, VTVM, and audio oscillator.
Connections Required: Connect equipment as shown in Fig. 48.

Procedure: Observe scope pattern before and after VTVM probe is applied at a test point in the amplifier circuit.

Evaluation of Results: Any change in the scope pattern indicates the amplifier operation is disturbed by application of the VTVM.

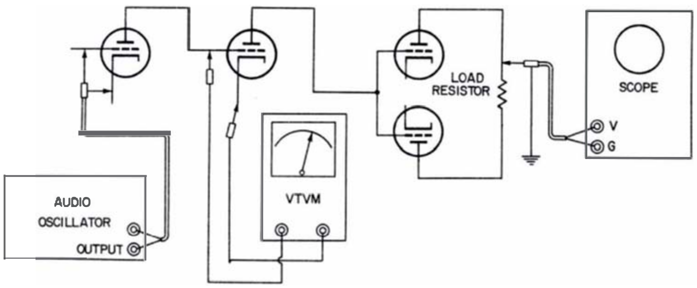


Fig. 48. Test setup.

U28

To Use Two Audio Oscillators as Signal Sources for Intermodulation-Distortion Tests

Equipment: Two audio oscillators (at least one with double-ended output), four 300-ohm resistors, and an oscilloscope.

Connections Required: Connect resistors into a bridge circuit. Connect audio oscillators to bridge, as shown in Fig. 49.

Procedure: Tune audio oscillators to test frequencies chosen. The low-frequency signal may be 50 to 100 cycles, and the high-frequency signal may be 1,000 to 6,000 cycles. (In another method, two high frequencies are used, such as 3,000 and 3,200 cycles.) Set the high-frequency signal to one-fourth the voltage of the low-frequency signal, or use equal voltages.

Evaluation of Results: With a scope, check the output waveform from the bridge, in order to observe the voltage ratios of the two signals.

The bridge circuit is particularly useful for mixing when the two generators are set to approximately the same frequency. The bridge minimizes the tendency of the generators to "pull," to "lock," or to supply a distorted waveform. One generator must have double-ended output, to prevent the bridge from being grounded out.

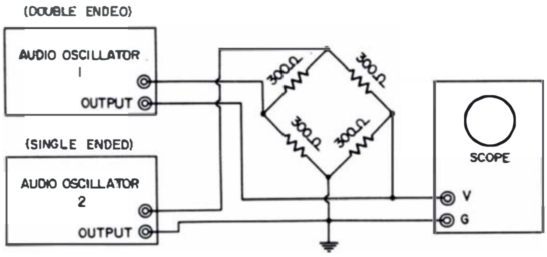


Fig. 49. Bridge connections used to minimize "pulling" and "locking" of two audio oscillators.

NOTE 33

Audio Analyzers Combine Functions of Several Testers

Instead of individual audio test instruments, an audio analyzer can be used to minimize the number of test leads and connections required to check out an amplifier. A typical audio analyzer is a package unit containing an audio VTVM, audio wattmeter, intermodulation meter, and two fixed-frequency signal sources. Standard terminating resistors are provided inside the analyzer. The VTVM has dbm scales. Thus, practically all necessary amplifier tests, except harmonic-distortion measurements, can be made with the one instrument.

U29

To Measure the Hum and Noise Output Voltage from an Amplifier

Equipment: Audio VTVM, and resistor with a value equal to the normal source impedance for amplifier.

Connections Required: Connect equipment as shown in Fig. 50.

Procedure: The amplifier should be normally loaded by a speaker, or by a terminating resistor of a suitable value. Set amplifier controls to normal operating positions. Observe reading on scale of audio VTVM. The input resistor, if of high value, is susceptible to hum pickup from stray fields. This can result in abnormally high meter readings.

Evaluation of Results: The meter reading is useful chiefly as a basis for comparing different amplifiers. It can be stated as the number of db below rated maximum power output of the amplifier, noting also the output load impedance and power output.

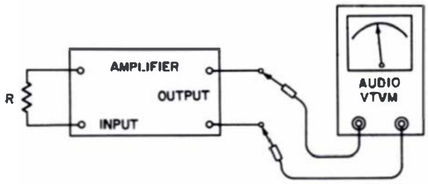
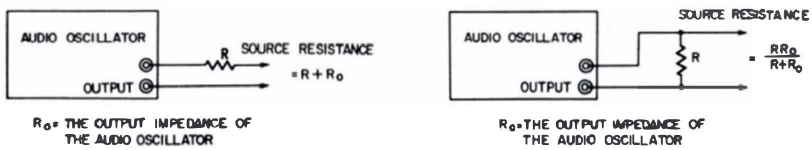


Fig. 50. Test setup.

NOTE 34

Amplifier Input Impedance May Differ from Recommended Source Impedance Value

It is desirable to operate high-fidelity amplifiers from a driving source having an impedance equal to the amplifier input impedance. On the other hand, higher gain can often be obtained by mismatching the driving source impedance to the amplifier input impedance. Thus, the rated input impedance for some amplifiers may differ from the measured input impedance. To determine whether impedance mismatching causes appreciable distortion, check the frequency response and total harmonic distortion, using impedance-transfer pads, as depicted in Fig. 51.



(A) Increasing the source resistance. (B) Decreasing the source resistance.

Fig. 51. Changing the source resistance of the audio oscillator.

NOTE 35

How to Measure the Source Resistance of an Audio Oscillator

The source resistance of an audio oscillator can be easily measured, as shown in Fig. 52. The potentiometer is first opened and the reading noted on VTVM. Then the potentiometer is connected and adjusted for half the original voltage reading. The resistance of the potentiometer is then equal to the source or internal resistance of the audio oscillator. This measurement must often be made if the attenuator setting is changed, because some audio oscillators do not have a constant source resistance at all attenuator settings.

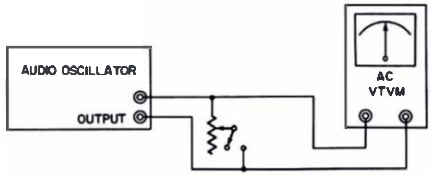


Fig. 52. Test setup.

NOTE 36

Two Impedances Can Be Matched to Each Other With an L Pad

L pads (Fig. 53) can be used to match two impedances to each other in an audio circuit. The high impedance to be matched is R_1; the low impedance is R_2. The series resistor in the L pad is R_A; the shunt resistor is R_B. The required values of R_A and R_B are found from the basic formulas:

$$R_1 = \frac{R_A(R_B + R_2) + R_B R_2}{R_B + R_2}$$

$$R_2 = \frac{R_B(R_A + R_1)}{R_A + R_B + R_1}$$

or,

$$R_A = \sqrt{R_1(R_1 - R_2)}$$

$$R_B = \sqrt{\frac{R_1}{R_1 - R_2}}$$

Fig. 53. L pads, used for impedance matching.

U30

To Check the Frequency Response of an Amplifier With Transformer Input

Equipment: Audio oscillator, matching resistor, terminating resistor, AC VTVM, and switch or clip lead.

Connections Required: Connect resistor of suitable value in series or shunt with audio-oscillator output, to match input impedance of amplifier (see Figs. 54 and 51). Connect terminating resistor of rated value across amplifier output terminals. Connect VTVM and switch, as shown in Fig. 54.

Procedure: Adjust audio-oscillator output for maximum rated power output of amplifier. Make first test at a low frequency, such as 50 cycles. Switch VTVM from position 1 to position 2 for comparative readings. Then increase audio-oscillator frequency in progressive steps, each time checking the input voltage (switch in position 2). If necessary, reset the audio-oscillator attenuator in order to maintain the same input voltage on each test.

For a more complete frequency checkout, repeat the foregoing procedure at medium- and low-output levels.

Evaluation of Results: The output voltages can be plotted against frequencies on a sheet of graph paper. In this way an overall picture of the amplifier frequency response can be obtained. Providing correct source impedance from the audio oscillator to a transformer input amplifier applies also to total harmonic-distortion and intermodulation tests. Otherwise, the test results may be misleading. In general, the apparent distortion of a transformer input amplifier increases as the impedance of the driving source differs from the matching value.

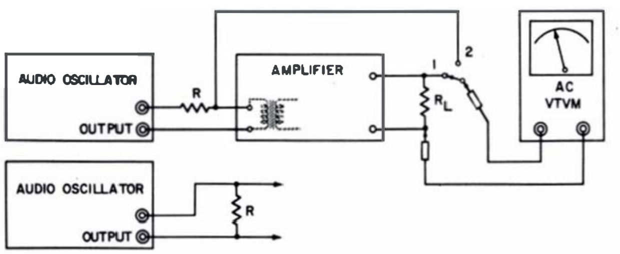


Fig. 54. Test setup.

U31

To Check an Amplifier for Cross Talk Between Inputs

Equipment: Audio oscillator, AC VTVM, and terminating resistor.

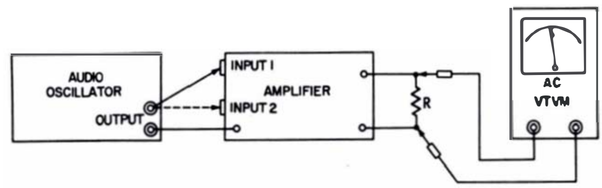
Connections Required: Terminate amplifier with the proper load. Connect VTVM across load as shown in Fig. 55. In first test, connect audio-oscillator output to input 1 of amplifier. In second test,. connect audio-oscillator output to input 2 of amplifier.

Procedure: With audio oscillator connected to input 1, switch amplifier to input 1. Advance output from audio oscillator for rated power output from amplifier. Tune audio oscillator to 1 kc. Test for cross talk by switching amplifier to input 2. Observe meter reading, if any. In second test, connect audio oscillator to input 2. With amplifier switched to input 2, adjust the audio-oscillator output for rated power output from amplifier. Test for cross talk by switching amplifier to input 1. Observe meter reading, if any.

Evaluation of Results: Cross talk is given by the number of db difference between meter readings when the amplifier is switched from one input to the other.

Some amplifiers are designed to operate with one input shorted when the other input is in use. Other amplifiers have signal sources connected to each input, so that one input is not shorted when the other is in use.

Fig. 55. Test setup.



U32

To Check for Cross Talk Between Stereophonic Amplifiers

Equipment: Audio oscillator, two terminating resistors, and AC VTVM.

Connections Required: Connect equipment as shown in Fig. 56.

Procedure: Adjust audio oscillator for rated power output from amplifier. With audio oscillator connected to input A, run a frequency response for amplifier A (VTVM connected to output of amplifier A). Then connect VTVM to output of amplifier B. Without changing the audio-oscillator output, note the output voltage (if any) from amplifier B, and run a frequency response. Repeat the procedure with the audio-oscillator output connected to input B.

Evaluation of Results: The cross-talk figure is the number of db difference between the two VTVM readings at the frequency of maximum cross talk.

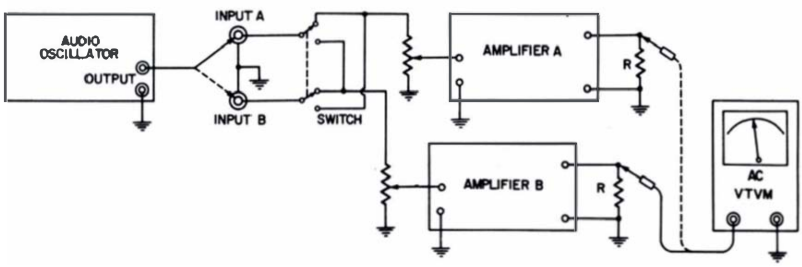


Fig. 56. Test setup.

U33

To Check the Load Tolerance of an Amplifier

Equipment: Audio oscillator, assortment of power resistors to terminate amplifier, and AC VTVM.

Connections Required: Connect equipment as shown in Fig. 57.

Procedure: Terminate the amplifier with the rated resistance. Adjust level of audio-oscillator signal to provide maximum rated output from the amplifier. Run a frequency response. Then change the rated load resistance (R) 20%. Again adjust the audio oscillator for maximum rated amplifier output. Run a frequency response with the changed load resistance. Repeat test with rated load resistance 40% higher and 40% lower. If amplifier has several output impedances, the test can be repeated at each output.

Evaluation of Results: In general, the frequency response of an amplifier is best when the amplifier is working into its rated load resistance. In some instances, however, a variation of the recommended resistance will improve the frequency response because of component tolerances.

A speaker provides a varying load value at different frequencies. Accordingly, if a speaker is used to load the amplifier, the results of the frequency run will usually be poorer than if a resistive load is used. The impedance of a speaker at various frequencies is affected by the type of enclosure.

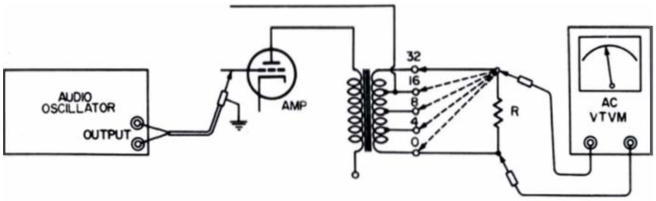


Fig. 57. Test setup.

U34

To Check the Regulation of the Power Supply in an Amplifier

Equipment: Square-wave generator, oscilloscope, and terminating resistor.

Connections Required: Connect equipment as shown in Fig. 58.

Procedure: Adjust square-wave generator for normal input voltage to amplifier. Tune generator to low frequency such as 20 cycles. Observe the pattern on the scope screen.

Evaluation of Results: The amplitude of any distorted square-wave pattern on the scope screen shows how incomplete the regulation of the power supply is. Note, however, that complete regulation is not required for satisfactory amplifier operation. The test is useful for comparison, when poor regulation is suspected as a cause of distortion.

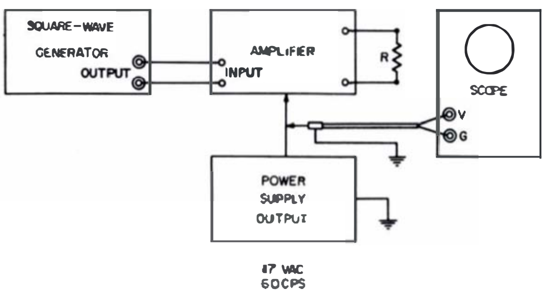


Fig. 58. Test setup.

To Determine the Line-Voltage Tolerance of an Amplifier

Equipment: Audio oscillator, harmonic-distortion meter, Variac, and terminating resistor.

Connections Required: Connect equipment as shown in Fig. 59.

Procedure: Set Variac for 117 volts output. Adjust audio-oscillator level to obtain rated power output from amplifier, as indicated on VTVM range of harmonic-distortion meter. Tune audio oscillator to 400 cycles. Measure harmonic distortion. Then reduce output voltage from Variac in steps of 10%. Readjust audio-oscillator output for rated power output from amplifier. Recheck harmonic distortion on each step.

Evaluation of Results: Harmonic distortion generally increases when the amplifier supply voltage is reduced beyond a certain level. The line-voltage tolerance is the amount the amplifier supply voltage can vary before the harmonic-distortion level increases appreciably.

For a more complete test, make a frequency run on each step. (Use the VTVM function of the harmonic-distortion meter as an output indicator.)

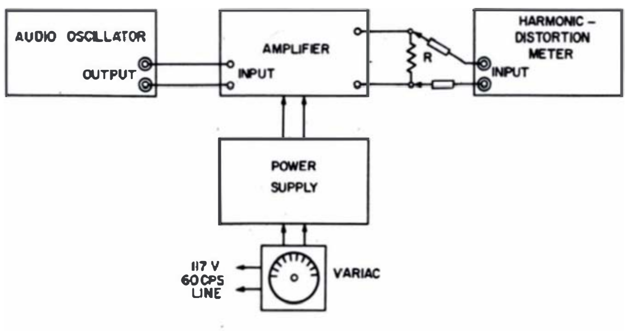


Fig. 59. Test setup.

NOTE 37

Automatic Line-Voltage Regulating Transformer Stabilizes Amplifier Operation

When an amplifier is susceptible to line-voltage variation and must be operated with varying supply voltage, an automatic line-voltage regulating transformer is helpful. The transformer must be of the automatic saturable-reactor type. An adjustable transformer is of little value, because it requires attention each time the line voltage changes. The transformer must also have an adequate power-output rating for the amplifier. When noise is present in the line and interference feeds through into the amplifier circuits, an automatic line-voltage regulating transformer will also help suppress the noise.

U36

To Check the Amplitude Linearity of an Amplifier

Equipment: Audio oscillator, AC VTVM, terminating resistor, and switch or clip lead.

Connections Required: Connect equipment as shown in Fig. 60.

Procedure: Set audio oscillator to a very low output, and tune to 400 cycles. Measure input voltage (position 2). Then measure the output voltage at position 1. Repeat test as output from audio oscillator is varied in equal steps, up to the maximum rated output of the amplifier.

Evaluation of Results: If the amplifier is free from amplitude distortion, the same ratio of output/input readings will be obtained in each test.

This is a useful check when a harmonic-distortion or IM meter shows excessive signal distortion. If amplitude distortion is present, check the resistances and operating voltages in the amplifier circuits.

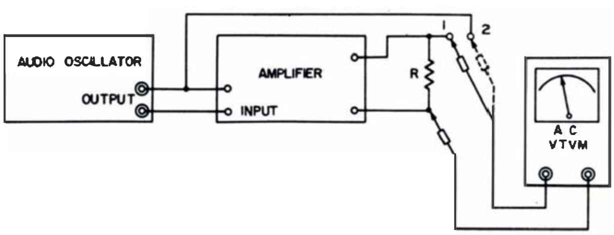


Fig. 60. Test setup.

NOTE 38

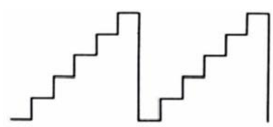
Amplitude Distortion Sometimes Caused by Poor Power-Supply Regulation

When the power-supply regulation is poor, the Class-AB or -B amplifier tubes operate at lower plate and screen voltages, since current drain increases with an increasing level. Bias voltages often change also. The amplification factor of some tube types varies with supply-voltage changes. In turn, amplitude nonlinearity results. Hence, when amplitude nonlinearity is found, do not forget to check the regulation of the power supply. Regulation can be improved by using larger filter and decoupling capacitors.

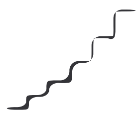
NOTE 39

Staircase Generator Provides a Rapid Amplitude-Distortion Check

Amplitude-distortion checks by input-output measurements are time consuming. Therefore, a busy shop may prefer to use a staircase generator. This generator supplies the waveform shown in Fig. 61A. The voltage output has a square waveform, and increases in amplitude equally at each step. A scope is used as an indicator at the amplifier output. If the amplifier is free from amplitude distortion, the output amplitude will increase equally at each step. If amplitude nonlinearity is present, the steps of the output waveform will be unequal in height, as shown in Fig. 61B.



(A) Output waveform from staircase generator.



(B) Typical amplifier output waveform when amplitude distortion is present.

Fig. 61. Staircase generator may be used to check for amplitude distortion in an amplifier.

U37

To Measure the Effect of a Reactive Load on an Amplifier

Equipment: Audio oscillator, terminating resistors, assorted capacitors and inductors, and harmonic-distortion meter.

Connections Required: Connect equipment as shown in Fig. 62.

Procedure: Adjust audio oscillator for maximum rated power output from amplifier. Measure the harmonic distortion without the reactor in the load circuit. Check at a low, a medium, and a high frequency. Then connect the reactor in the load circuit and repeat the measurement. Finally repeat tests with larger values of reactors, to determine the tolerance of the amplifier to reactive loads. The total harmonic-distortion test just described should be supplemented by a frequency run and by IM distortion and square-wave tests. They will provide a complete evaluation of the amplifier tolerance to reactive loads. In certain feedback amplifiers, reactive loads also affect the amplitude linearity.

Evaluation of Results: The total harmonic-distortion rating of many amplifiers is for resistive loads only. The inclusion of small reactances can give some amplifiers a higher total harmonic-distortion figure than the rated value. On the other hand, other amplifiers are quite tolerant to reactive loads.

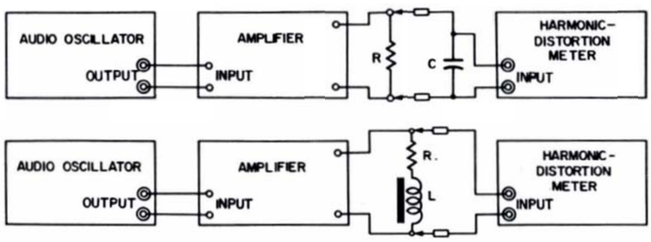


Fig. 62. Test setup.

U38

To Make a Peak-Overload Test of an Amplifier

Equipment: Oscilloscope, terminating resistor, capacitor, and square-wave generator that can provide an unsymmetrical square-wave (pulse) output.

Connections Required: Connect equipment as shown in Fig. 63.

Procedure: Adjust output from generator to provide 50% greater peak voltage across load resistor than for rated power output. Tune generator to a frequency differentiated by the capacitor, so that the amplifier is driven with a sharply peaked pulse. Observe pattern on scope screen.

Evaluation of Results: The same waveshape should be observed at the input and output of the amplifier. If the spike is clipped or changed in shape, the amplifier does not have peak-overload capability, and cannot reproduce musical transients without distortion.

This type of test is preferred over the steady-state test of peak-overload capability, because the pulse simulates actual requirements. Critical listeners object to amplifiers which clip peak overloads during the reproduction of musical passages, although average listeners often overlook this form of distortion.

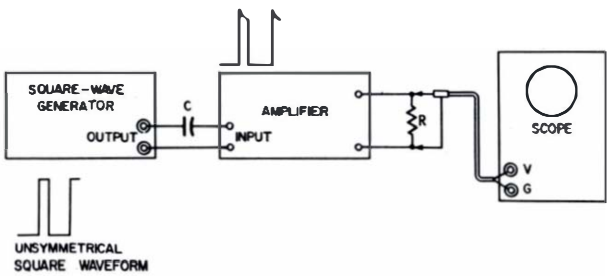


Fig. 63. Test setup.

NOTE 40

Differentiated Square Wave Can Be Used in Peak-Overload Test

An ordinary square-wave generator can be used to make a peak-overload test if an unsymmetrical square-wave generator is not available. Adjust the value of C (Fig. 63) to provide a sharply peaked waveform, as illustrated in Fig. 64. Follow the procedure outlined in U38.

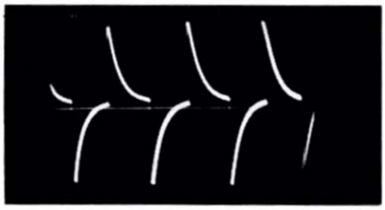


Fig. 64. A differentiated square wave.

U39

To Use an Audio Analyzer as a Signal Source in a Harmonic-Distortion Test

Equipment: Audio analyzer, harmonic-distortion meter, and terminating resistor.

Connections Required: Connect equipment as shown in Fig. 65.

Procedure: Switch output signal from audio analyzer to Low Frequency Test. Measure total harmonic distortion with the harmonic-distortion meter, in the usual manner. Then switch output signal from audio analyzer to High Frequency Test. Again measure total harmonic distortion with the distortion meter, in the usual manner.

Evaluation of Results: This method gives measurements of total harmonic distortion at two frequencies only, e.g., 60 cycles and 6 kc. However, it is quite useful when an audio oscillator is not available.

Some audio analyzers do not provide low-distortion test signals for IM testing. Hence, before using these signals for total harmonic-distortion tests, check the signal purity, as explained in Note 41.

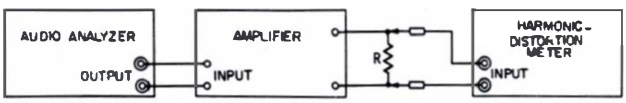


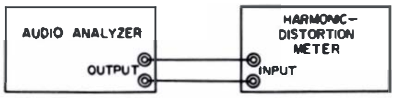
Fig. 65. Test setup.

NOTE 41

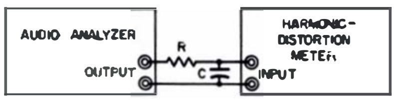
Checking and Improving Waveform from Audio Analyzer

To check the output waveform from an audio analyzer, connect the signal output directly to a harmonic-distortion meter, as shown in Fig. 66A. If the total harmonic distortion is high (e.g., 2% or 3%), it can be reduced considerably by using an RC filter (Fig. 66B). If the improvement is not great enough to test a low-distortion amplifier, use an audio filter, as shown in Fig. 66C. Placing an RC filter ahead of the audio filter (Fig. 66D) will lessen the burden on the audio filter.

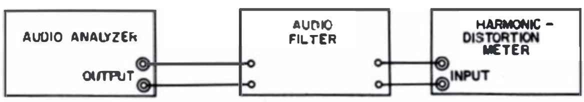
Some audio analyzers have cross talk between the high- and the low-frequency signals. One way of killing the cross talk is to pull the high-frequency oscillator tube while using the low-frequency output signal. A low-pass filter or an audio filter will also reduce cross talk to a negligible level. If a reading is objectionably high when the audio-analyzer signal is being checked with a harmonic-distortion meter, cross talk can be suspected.



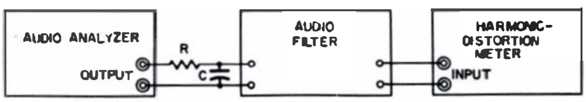
(A) Signal from audio analyzer connected for check of total harmonic distortion.



(B) Addition of an R-C filter results in a lower total harmonic-distortion figure.



(C) A good audio filter will greatly improve a waveform with a high harmonic-distortion figure.



(D) Additional waveform improvement is obtained by using both an R-C filter and an audio filter.

Fig. 66. Improving the output signal from an audio analyzer.

To Measure the Amplifier Input Resistance

Equipment: Audio oscillator, AC VTVM, terminating resistor, and potentiometer (approximately 1 meg for high-impedance amplifiers; or if low-impedance input, approximately 1,000 ohms).

Connections Required: Connect equipment as shown in Fig. 67.

Procedure: Set audio oscillator to a low frequency, such as 60 cycles. Reduce potentiometer resistance to zero, and note meter reading. Then turn potentiometer arm until meter reading drops to one-half.

Evaluation of Results: Disconnect pot and measure its resistance. This is the input resistance of the amplifier.

The test does *not* measure the *input impedance* of the amplifier. It measures the *resistive component* of the input impedance, because the test frequency is 60 cycles and the reactive components are negligible.

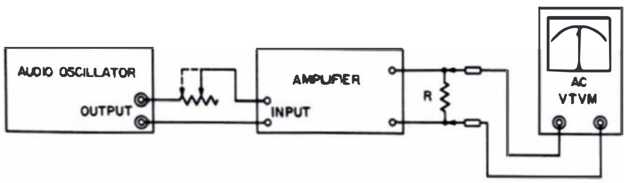


Fig. 67. Test setup.

U41

To Measure the Input Capacitance of an Amplifier

Equipment: Audio oscillator, AC VTVM, terminating resistor, and trimmer capacitor.

Connections Required: Connect equipment as shown in Fig. 68.

Procedure: Tune audio oscillator to approximately 10 kc. Short trimmer capacitor, and note meter reading. Then remove short from trimmer capacitor, and adjust it for one-half the original reading.

Evaluation of Results: Measure trimmer capacitance on a capacitor testor or bridge. This is the input capacitance of the amplifier.

The input *capacitance* of the amplifier must be distinguished from the input *impedance*. The input capacitance is the reactive component of the input impedance. The input impedance is a combination of the input resistance and the input capacitance. The ohms of input impedance will differ at each frequency. For rapid calculation of reactance, a reactance slide rule (like the one manufactured by Shure Brothers) is recommended.

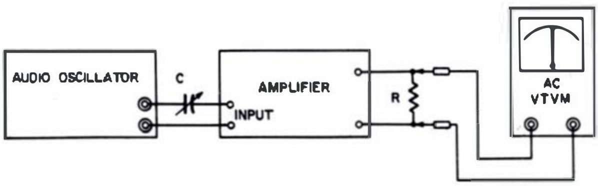


Fig. 68. Test setup.

U42

To Measure the Input Resistance and the Capacitance or Inductance of an Amplifier With Transformer Input

Equipment: Impedance bridge and terminating resistor.
Connections Required: Connect equipment as shown in Fig. 69.
Procedure: Turn amplifier on. Adjust bridge controls for impedance balance. Switch bridge to resistive and reactive functions, to determine the input resistance and the value and sign of input reactance.
Evaluation of Results: The measurement is valid for only the test frequency of the bridge and the test-signal level applied by the bridge. However, it is a good, average test.

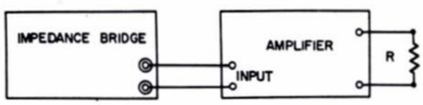


Fig. 69. Test setup.

U43

To Check an Amplifier For Crossover and Notch Distortion

Equipment: Audio oscillator, oscilloscope, and terminating resistor.

Connections Required: Connect equipment as shown in Fig. 70.

Procedure: Adjust audio oscillator for maximum power output from amplifier, as measured on screen of calibrated scope. Tune audio oscillator to approximately 3,000 cycles. Observe pattern on scope screen.

Evaluation of Results: Crossover and notch distortion occur near the zero-volt line of the output waveform. Crossover distortion is symmetrical and occurs on each side of a half cycle. On the other hand, notch distortion occurs on only the negative-going portion of the waveform. Crossover distortion indicates excessive bias on the push-pull output tubes. Notch distortion is caused by the leakage reactance in the output transformer resonating with the stray capacitance in the primary circuit.

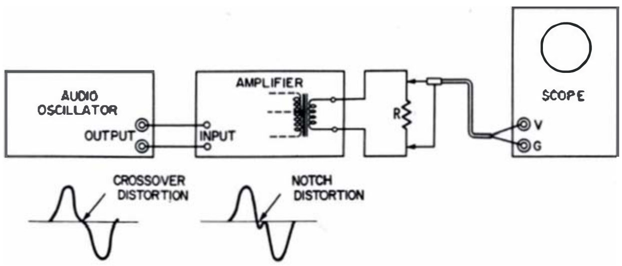


Fig. 70. Test setup.

U44

To Test a Phase Inverter for Distortion and Unbalance

Equipment: Audio oscillator, oscilloscope with low-capacitance probe, and terminating resistor.

Connections Required: Connect equipment as shown in Fig. 71.

Procedure: Advance output from audio oscillator for maximum rated output from amplifier. Apply low-capacitance probe at points (1) and (2). Observe waveform and peak-to-peak voltages. Also check at points (3) and (4). Repeat checks at low, medium, and high audio frequencies.

Evaluation of Results: A good sine waveform should be observed. Peak-to-peak voltages should also be practically the same at the four test points. If distortion or unequal voltages are found, check the associated circuit components.

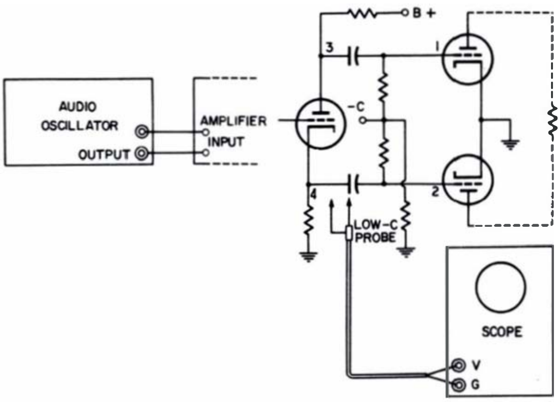


Fig. 71. Typical phase-inverter circuit. Test at indicated points in order to localize distortion and unbalance.

U45

To Measure the Phase Shift Around a Feedback Loop

Equipment: Audio oscillator, oscilloscope (preferably with identical vertical and horizontal amplifiers), and two low-C probes.

Connections Required: Connect equipment as shown in Fig. 72.

Procedure: Adjust audio-oscillator output for normal amplifier operation. Observe scope pattern as audio-oscillator frequency is varied from 60 cps to upper frequency at which no more output is obtained from amplifier.

Evaluation of Results: At certain frequencies the scope will display an inclined line. This shows there is no phase shift through the feedback and amplifier systems. At other frequencies (particularly at high frequencies), ellipses will be observed. They may open into circles and back into ellipses with opposite inclination. Excessive phase shift causes regeneration or oscillation (positive feedback) and resulting instability. Phase shift can be caused by reactive components anywhere within the feedback loop and amplifier circuit.

Use low-capacitance probes when testing at high frequencies, to avoid misleading indication due to circuit loading.

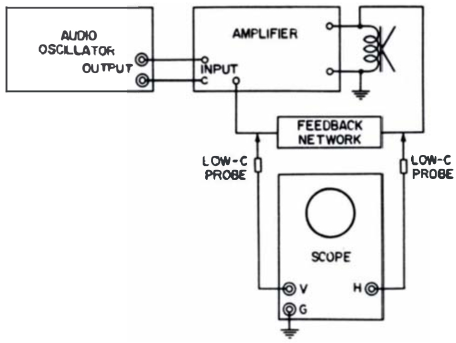


Fig. 72. Test setup.

NOTE 42

Individual Feedback Loops Can Be Opened to Determine Phase Shift of Each

If multiple feedback loops are used in the amplifier in U45, excessive phase shift can be located by opening each loop and observing the change in phase shift. Whenever a feedback loop is opened, the output from the audio oscillator must be reduced to prevent amplifier overload.

U46

To Check the Balance of a Phase Compressor

Equipment: Audio oscillator, harmonic-distortion analyzer, oscilloscope, and terminating resistor.

Connections Required: Connect audio-oscillator output to amplifier input terminals. Connect terminating resistor, harmonic-distortion meter, and scope, as shown in Fig. 73.

Procedure: Apply standard test frequency, such as 400 cycles, to amplifier. Adjust audio oscillator for maximum rated output from amplifier. Tune harmonic-distortion meter to eliminate fundamental (400 cycles). Observe scope pattern.

Evaluation of Results: No discernible second-harmonic output should appear in scope pattern. Third- and fifth-harmonic residues will be visible at high scope gain. If second and other even-harmonic residues appear, check the circuit for faulty components causing the unbalance.

The phase-compressor type of output stage has R-C circuitry to cancel even harmonics, just as push-pull transformer coupling cancels even harmonics.

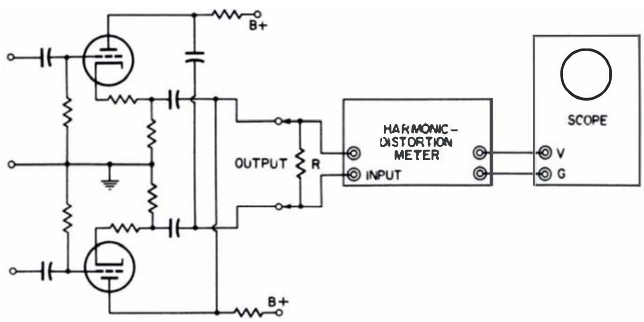


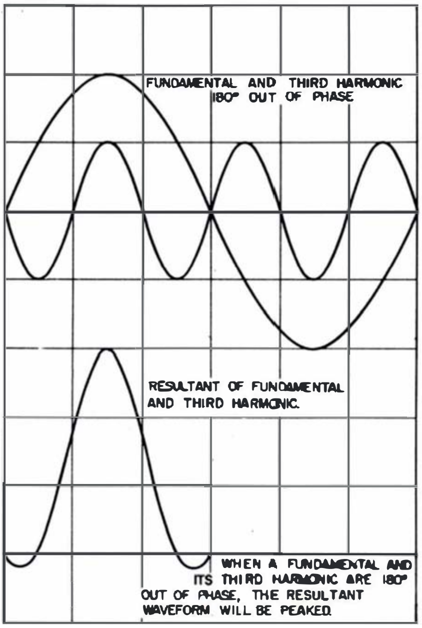
Fig. 73. Test setup.

NOTE 43

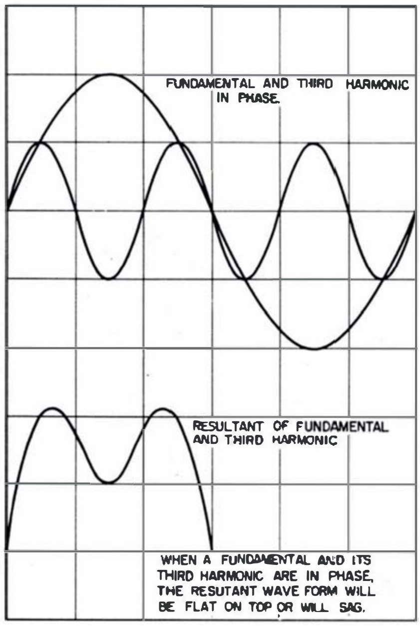
Waveshape of Distortion Signal at Output of Harmonic-Distortion Meter Differs from Waveshape in Input Signal

The waveshape of the distortion signal at the output of a harmonic-distortion meter differs from the one at the input. The change in waveshape is caused by phase shift in the filter circuit of the meter. The filter removes the fundamental from the input signal and passes the second harmonic. However, in passing the second harmonic, the filter circuit shifts its phase. The third harmonic is likewise shifted in phase, although not as much as the second harmonic. Thus, the output signal has phase distortion. In turn, the meter indication is not entirely accurate. The reason is that phase shifts of the components in a complex waveform can vary the reading —10 to +16% in a full-wave contact-rectifier instrument. Fig. 74 shows how phase shift of a third harmonic, with respect to the fundamental, changes the waveshape. To measure the phase shift of a harmonic passing through a harmonic-distortion meter, use the test setup in Fig. 75.

The audio oscillator is tuned to 1000 cycles, for example, and the harmonic-distortion meter is tuned from 2,000 to 8,000 cycles. An elliptical scope pattern shows phase shift.



(A) Fundamental and its third harmonic 180° out of phase.



(B) Fundamental and its third harmonic in phase.

Fig. 74. Phase relationships between the fundamental and third-harmonic frequencies.

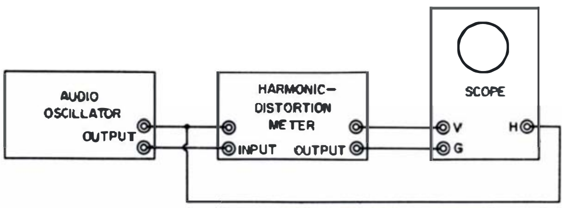
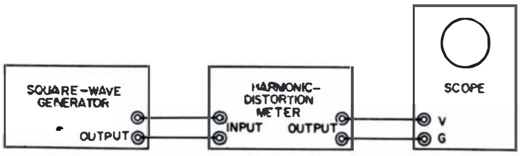


Fig. 75. Test setup.

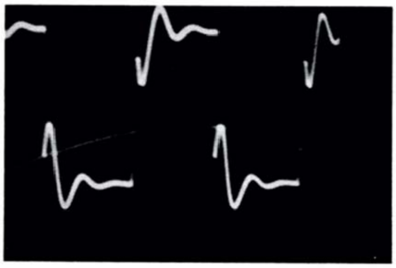
NOTE 44

Filter Phase Shift in Harmonic-Distortion Meter Can Cause Strong Ringing in Transient Voltages

The phase shift caused by the filter in a harmonic-distortion meter can cause strong ringing in transient voltages. Phase shift is present, even though the filter is tuned to a frequency lower than the fundamental of the transient. Thus, if a 2-kc square wave is applied to a typical harmonic-distortion meter (Fig. 76A), good reproduction of the waveform will be obtained when the filter is switched out of the amplifier circuit. On the other hand, with the filter switched into the circuit, strong ringing may be observed (Fig. 76B), regardless of the filter tuning.



(A) Test setup.



(B) Ringing in square waveform.

Fig. 76. To check for ringing in transient voltage, caused by filter phase shift in harmonic-distortion meter.

U47

To Check an Amplifier Tube for Grid-Current Flow

Equipment: Audio oscillator, DC VTVM, and terminating resistor.

Connections Required: Connect equipment as shown in Fig. 77.

Procedure: Advance audio-oscillator output until meter reading starts to rise. Note meter reading. Then advance audio-oscillator attenuator to obtain maximum rated power output from amplifier. Again note meter reading.

Evaluation of Results: Grid current starts to flow at the signal level at which meter reading first starts to rise. The grid-current flow can be calculated from Ohm's law if the grid-leak resistance is known.

When capacitive coupling is used to the grid, damping on positive signal peaks can cause considerable distortion unless the capacitor is large enough to supply the grid-current demand. An oscilloscope check at the grid will reveal whether the positive signal peaks are flattened during the grid-current interval.

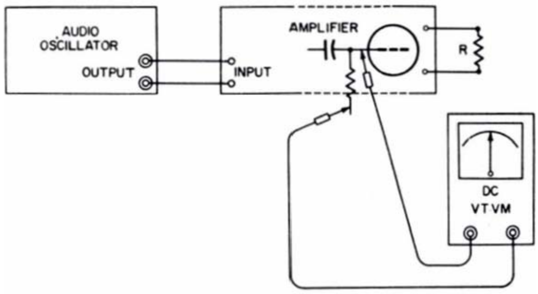


Fig. 77. Test setup.

NOTE 4S

Classes of Amplifier Operation

Audio-amplifier tubes operate in Class A, AB, or B. Class-A tubes operate over the complete cycle (at maximum power output) without plate-current cutoff. Class-AB tubes operate at higher bias than Class A. They are used only in push-pull circuits which balance out the even-harmonic distortion. Class-B tubes are biased almost to plate-current cutoff. Class-A amplifiers are designated Class A_1 or Class A_2 (at maximum power output). A Class-A_1 tube draws no grid current. A Class-A_2 tube draws grid current over part of the signal cycle. Similarly, a Class-AB_1 tube draws no grid current, and a Class-AB_2 tube draws grid current on positive signal peaks.

U48

To Determine Whether Screen Bypassing Is Adequate

Equipment: Audio oscillator, oscilloscope, and terminating resistor.

Connections Required: Connect equipment as shown in Fig. 78.

Procedure: Tune audio oscillator to a low frequency, such as 60 cycles. Advance audio-oscillator output for maximum rated amplifier output. Measure the peak-to-peak screen voltage on a calibrated scope.

Evaluation of Results: AC voltage at the screen grid lowers the gain at the test frequency and reduces the shielding effect of the grid. The AC voltage can be reduced by increasing the value of the screen bypass capacitor.

The same test can be used to check the effectiveness of decoupling capacitors between the amplifier circuits and the power supply.

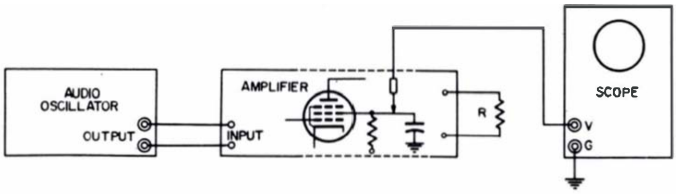


Fig. 78. Test setup.

U49

To Check for Equality of Time Constants in the R-C Circuits of an Amplifier

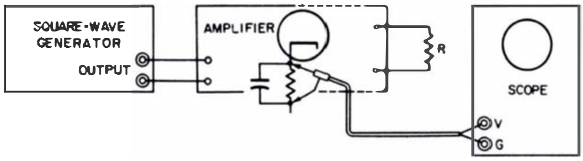
Equipment: Square-wave generator, oscilloscope, and terminating resistor.

Connections Required: Connect equipment as shown in Fig. 79A.

Procedure: Advance square-wave generator output for maximum rated power output from amplifier. Tune generator to a low frequency, one at which a differentiated square wave (Fig. 79B) will be seen on the scope screen when the scope is applied across an R-C circuit in the amplifier. Check, in turn, each of the cathode bypass, screen bypass, and decoupling bypass capacitors in the amplifier.

Evaluation of Results: The same differentiated square wave should be observed at each R-C circuit. If greater or lesser differentiation occurs at various R-C circuits, the transient response of the amplifier will not be optimum on peak overloads. The time constants can be adjusted by choosing suitable capacitor values.

(A) Test setup.



(B) Desired scope pattern.

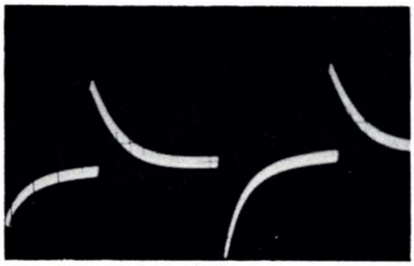


Fig. 79. Checking the equality of R-C time constants in an amplifier circuit.

U50

To Measure the Relative Hum and Distortion Voltages From an Amplifier

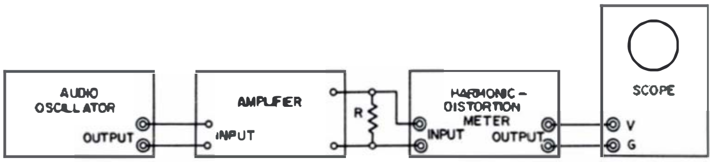
Equipment: Audio oscillator, harmonic-distortion meter, oscilloscope, and terminating resistor.

Connections Required: Connect equipment as shown in Fig. 80A.

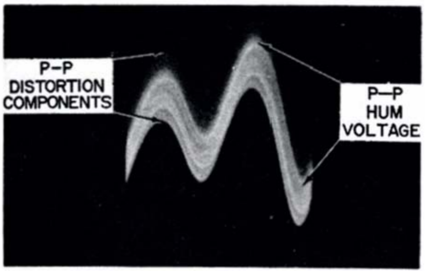
Procedure: Tune audio oscillator to standard test frequency, such as 400 cycles. Adjust output voltage to chosen level of test. Tune out fundamental on harmonic-distortion meter. Set scope controls for 30- or 60-cycle horizontal deflection.

Evaluation of Results: The audio residue has a much higher frequency than the hum voltage, and appears as a thickening of the pattern. Fig. 80B shows the relative hum and distortion voltages present in the waveform.

The relative proportions of hum and distortion voltages vary widely from one amplifier to another. However, the same method of evaluation applies in each case.



(A) Test setup.



(B) Distorted waveform.

Fig. 80. Relative hum and distortion voltage measurement in an amplifier.

U51

To Test an Amplifier for Grid-Blocking Distortion

Equipment: IM signal source, oscilloscope, and terminating resistor.

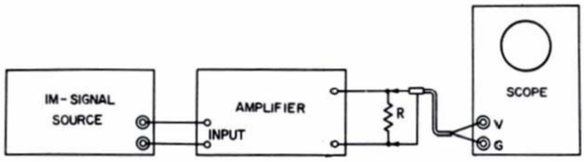
Connections Required: Connect equipment as shown in Fig. 81.

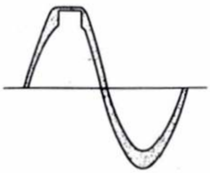
Procedure: Set signal input level to obtain maximum rated power output from amplifier. Observe waveform on scope screen.

Evaluation of Results: The output waveform from the amplifier may appear as shown in Fig. 82. If the high-frequency component disappears along the falling excursion of the waveform, grid blocking is occurring in one of the stages.

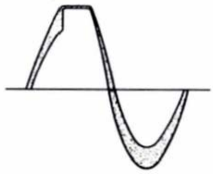
Grid blocking results from grid-current flow on positive signal peaks, combined with a relatively slow recovery time. In other words, if a tube is driven far into grid current and the time constant of the grid-capacitor and grid-leak circuits is long, the grid will remain blocked by the high negative bias left after the signal peak has passed.

Fig. 81. Test setup.





(A) Clipping and no grid blocking.



(B) Clipping and grid blocking.

Fig. 82. Grid clipping and blocking distortion.

U52

To Measure the Reduction in Hum and Harmonic Distortion Resulting from Negative Feedback

Equipment: Audio oscillator, harmonic-distortion meter, oscilloscope, and terminating resistor.

Connections Required: Connect equipment as shown in Fig. 83.

Procedure: In the first test, leave the feedback loop (or loops) connected, and measure as explained in U50. In the second test, open the feedback loop (or loops), and reduce the audio-oscillator output to provide the same power output as before. If necessary, retune the harmonic-distortion meter in order to obtain a minimum reading.

Evaluation of Results: Compare the peak-to-peak voltages of the hum and distortion components in the two patterns. The ratios between the voltages give the reduction in hum and distortion resulting from negative feedback.

To measure the reduction in hum and distortion caused by negative feedback across an unbypassed cathode resistor, eliminate the negative feedback by shunting the resistor with a large bypass capacitor, as shown in Fig. 84.

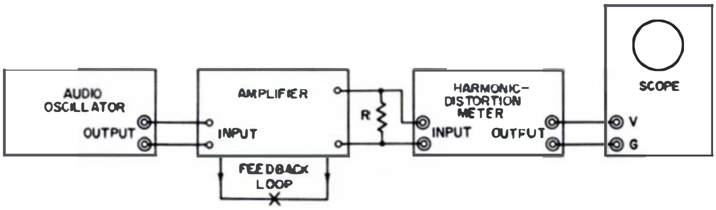


Fig. 83. Test setup.

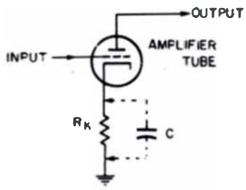
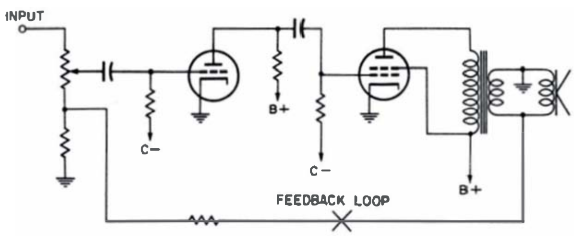


Fig. 84. Method of eliminating negative feedback.

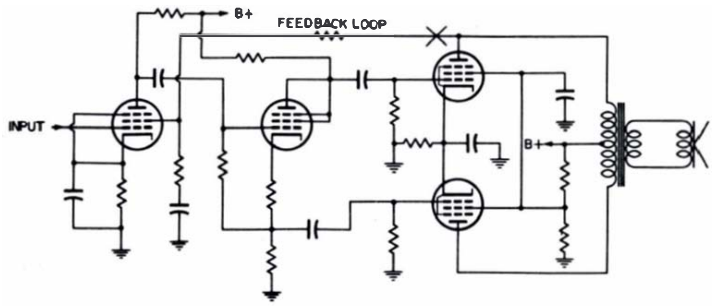
NOTE 46

Feedback Loops May Supply B+ Voltage to Tube Electrodes

In some amplifier circuits, the feedback loop also conducts DC supply voltage to a tube electrode. If so, the feedback lead cannot merely be open-circuited. It must be connected to a suitable DC voltage source, so that the tube will operate properly. For example, the feedback loop in Fig. 85A can be open-circuited without considering the DC voltage. The loop operates in an AC-coupled circuit. On the other hand, the loop in Fig. 85B not only feeds back AC signal voltage to the screen grid of the input tube, but also supplies DC voltage to the screen. In this example, open the loop at X, and then connect it at a suitable point in the power supply. This will provide normal operating voltage to the screen grid. The feedback loop can be connected to the B+ line, at the center tap on the output-transformer primary.



(A) Loop operated in AC-coupled circuit.



(B) Loop that is also part of the DC supply line.

Fig. 85. Opening the feedback loop.

NOTE 47

Normal Operation of Feedback Loop Can Depend Upon Correct Generator Source Resistance

When negative feedback is made to the input circuit of an amplifier, the audio oscillator may be included in the feedback network, as seen in Fig. 86. If so, the generator must have the same source resistance as the driver circuit or the unit which the generator replaces. A resistor (R) can be added in series with the audio-oscillator output lead, for example, to provide a higher source resistance. See also U25, Note 30, Note 34, Note 35, Note 36, U30, U40, U41, and U42.

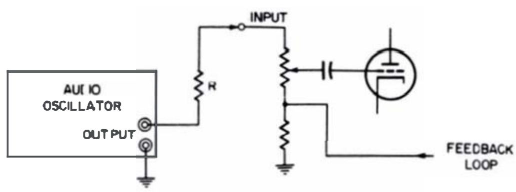


Fig. 86. Audio oscillator connected within the feedback network.

U53

To Check the Loudness-Control Response in a Preamplifier

Equipment: Audio oscillator, AC VTVM, and terminating resistor.

Connections Required: Connect equipment as shown in Fig. 87.

Procedure: Set preamplifier controls for flat response. Set loudness control to extreme end of its range. Adjust the audio oscillator and the preamplifier volume control for normal output from the amplifier. Determine the frequency response of the preamplifier. Then reset loudness control to progressively higher positions. Maintain same amplifier output by readjusting the volume control. Determine the frequency response of the preamplifier for each setting of the loudness control.

Evaluation of Results: Unlike the volume control, the loudness control does not have a flat frequency response. It is a special type of compensated volume control which normally provides a progressive bass boost as it is set for higher sound output (and may also provide a certain amount of treble boost at higher output settings). Typical Fletcher-Munson curves are shown in Fig. 88.

The *phon* is the unit of loudness as sounds are heard by the ear. We normally do not hear low frequencies as well at low volume levels as we do at high levels. Since a disc is generally recorded at a different level than it is reproduced, the loudness control makes the frequency response at the reproduction level correspond to the ear's response at the recording level.

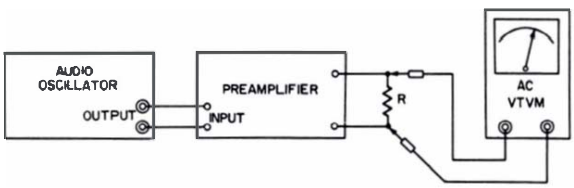


Fig. 87. Test setup.

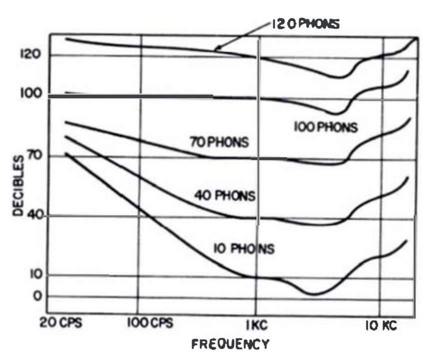


Fig. 88. Typical Fletcher-Munson curves.

NOTE 48

Loudness Is a Judgment, Not a Direct Knowledge of Sound Energy

Do not suppose that the loudness of a sound is anything other than a mental judgment. For instance, if a speaker is operating in a room and you stop up one ear, does the loudness of the sound change? Not one bit! Yet only half as much sound energy is entering your ears. It is the same as if you close one eye while reading this page. Does the brightness of the page change? Again, not a bit! Yet only half as much energy is entering your eyes. The loudness of a sound corresponds to sound waves in the air. However, we do not need sound waves in order to perceive sound. In conversations "heard" in our dreams, we experience sound—including softness and loudness—but these experiences obviously have no basis in air vibrations. Likewise, if we take heavy doses of certain drugs, we experience buzzing and ringing sounds of varying loudness; yet these sounds, too, have no basis in air waves. Thus, we conclude that hearing and sound are mental judgments. They do not give us direct knowledge of the physical data with which we work.

U54

To Check the Response of a Scratch Filter in a Preamplifier

Equipment: Audio oscillator, AC VTVM, and terminating resistor.

Connections Required: Connect equipment as shown in Fig. 89.

Procedure: Switch scratch filter on. Set preamplifier controls for flat response. Adjust the audio oscillator and the preamp volume control for normal output. Run a frequency response of the preamplifier.

Evaluation of Results: The high-frequency response should be approximately as shown in Fig. 90. There should be noticeable attenuation, starting at 7 kc and falling to approximately −35 db at the 10-kc point.

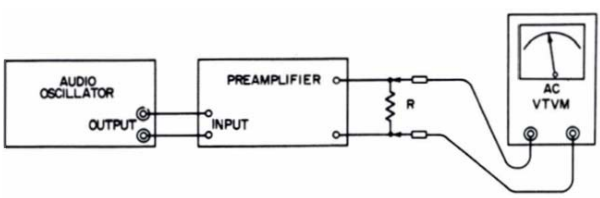


Fig. 89. Test setup.

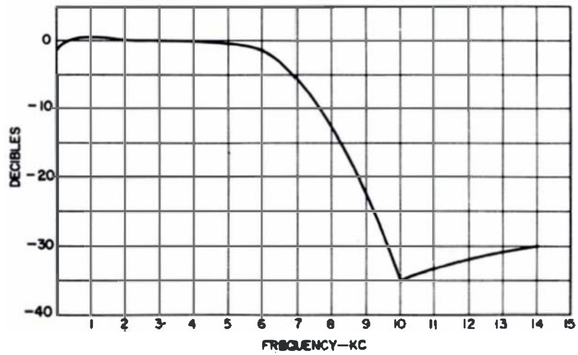


Fig. 90. Typical frequency response for a commercial scratch filter.

U55

To Check the Response of a Rumble Filter in a Preamplifier

Equipment: Audio oscillator, AC VTVM, and terminating resistor.

Connections Required: Connect equipment as shown in Fig. 91.

Procedure: Switch rumble filter on. Set preamplifier controls for flat response. Adjust the audio oscillator and the preamplifier volume control for normal output. Run a frequency response of the preamplifier.

Evaluation of Results: The low-frequency response should be approximately as in Fig. 92, with an initial slope of 10 or 12 db per octave. (From 10 cycles to 20 cycles, for example, is one octave.) The high-frequency response should not be affected by the rumble filter.

Rumble is heard as either a low-frequency tone or a series of slow, random pulses from substandard or faulty record players. Arm resonance or mechanical-drive vibration can also cause rumble. The rumble filter in a preamplifier attenuates or eliminates the rumble distortion, but at the expense of low-frequency response. However, the acoustic effect is not as severe as might be concluded from Fig. 92. The reason is that the ear can generate a synthetic bass when harmonics of a bass tone are passed by the amplifier. Synthetic bass, however, becomes less evident at lower volume levels.

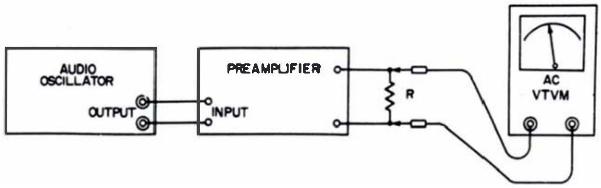


Fig. 91. Test setup.

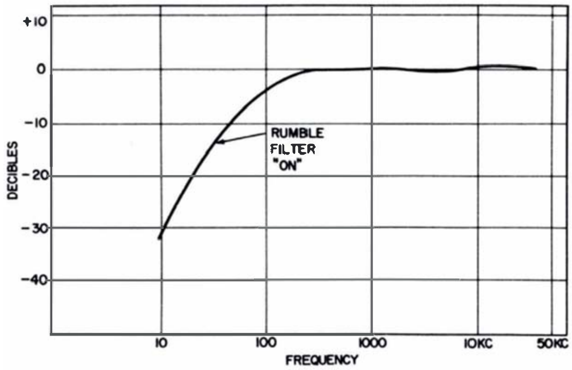


Fig. 92. Normal frequency response for a preamplifier with rumble filter operating.

U56

To Check the Response of a Presence Control in a Preamplifier

Equipment: Audio oscillator, AC VTVM, and terminating resistor.

Connections Required: Connect equipment as shown in Fig. 93.

Procedure: Switch presence control on. Set preamplifier controls for flat response. Adjust the audio oscillator and the preamplifier volume control for normal output. Run the frequency-response curve of the preamplifier.

Evaluation of Results: The low-frequency response should be essentially flat, although a rising midrange response of 5 or 6 db should appear, as indicated in Fig. 94. The high-frequency response should be about the same as with the presence control switched off.

A rising midrange response, as provided by a presence control, is sometimes desired when vocal selections with a musical background are being reproduced. Since this actually departs from true high fidelity, its use involves artistic judgment.

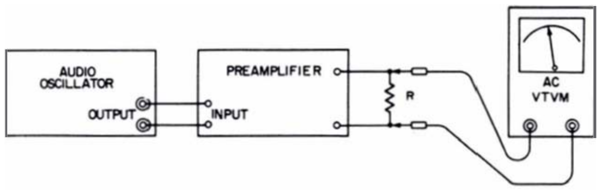


Fig. 93. Test setup.

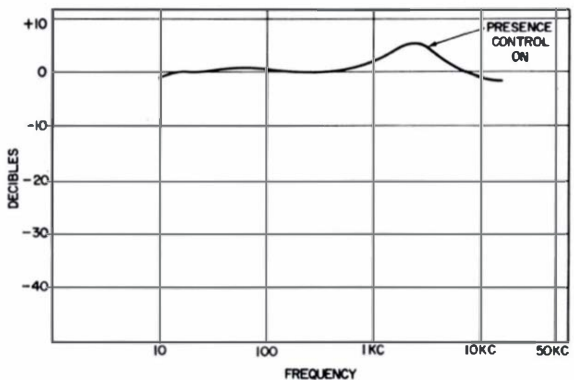


Fig. 94. Typical frequency-response curve for a preamplifier, with tone controls set for flat response and the presence control turned on.

NOTE 49

Distinction Between Loudness- and Presence-Control Characteristics

The beginner must not confuse loudness-control with presence-control characteristics. As shown in Fig. 94, a presence control provides a typical midrange boost, but does not affect the low-frequency response. A loudness control, on the other hand, provides a low-frequency boost, but does not affect the high-frequency response (Fig. 95). In addition to the low-frequency boost, some loudness controls in elaborate amplifiers provide a small high-frequency boost. The high-frequency boost makes the loudness characteristic conform more closely to the Fletcher-Munson curves. However, high-frequency boost is not too important to most listeners. For this reason, it is often omitted.

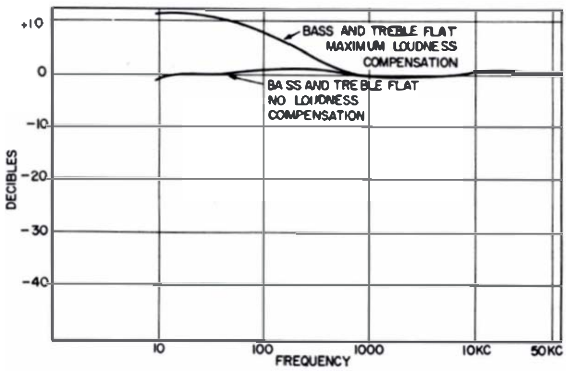


Fig. 95. Typical frequency-response curve for a preamplifier, with tone controls set for flat response and the loudness control at maximum.

U57

To Check the Response of Bass-Boost, Bass-Cut, Treble-Boost, and Treble-Cut Controls

Equipment: Audio oscillator, AC VTVM, and terminating resistor.

Connections Required: Connect equipment as shown in Fig. 96.

Procedure: Adjust all preamplifier controls for a flat response, except the control under test. Adjust the audio oscillator and the preamplifier volume control for normal output. Run a frequency response of the preamplifier.

Evaluation of Results: Typical frequency responses for boost and cut tone controls are shown in Fig. 97. Observe that treble boost is not the same as bass cut, nor is bass boost the same as treble cut. The difference can be heard distinctly if the preamplifier controls are varied while music is playing. The frequency distortions caused by bass and treble boosts and cuts are a matter of artistic judgment and individual preference.

The frequency responses in Fig. 97 are free from interaction between tone controls. In other words, bass boost and cut controls do not affect the treble response. Nor do the treble boost and cut controls affect the bass response. In some preamplifiers the bass and treble controls will interact noticeably.

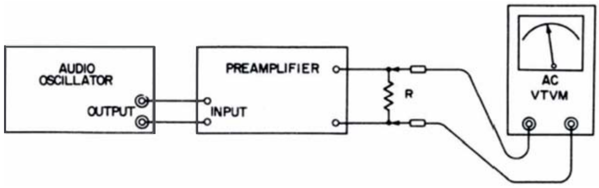


Fig. 96. Test setup.

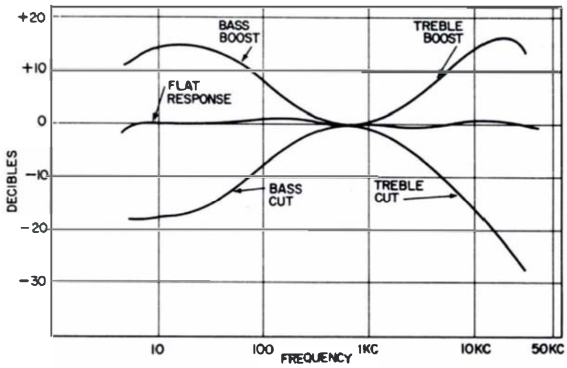


Fig. 97. Typical frequency-response curves for the bass and treble tone controls.

U58

To Measure the Frequency Response of a Crossover Network

Equipment: Audio oscillator, VOM, and terminating resistors.

Connections Required: Connect output terminals of audio oscillator to input terminals of amplifier. Connect suitable values of terminating resistors in place of the woofer and the tweeter. In first test, connect VOM across one terminating resistor. In second test, connect VOM across the other terminating resistor. (See Fig. 98.) A VOM should be used in place of a VTVM, because of ground capacitance.

Procedure: Adjust audio oscillator for maximum rated output from amplifier. First run a frequency-response curve for the woofer load. Then run a frequency-response curve for the tweeter load.

Evaluation of Results: Compare the roll-off characteristics of the crossover network with the manufacturer's specifications.

Roll-off rates are chosen at widely different values by various designers. The important point is that the high-frequency and low-frequency roll-offs should be consistent, so that the over-all frequency response will be flat. You will find roll-off rates from 6 db to 18 or 24 db per octave. In general, transient response is better with slow roll-off, although a greater demand is placed upon the tweeter for power output.

A speaker is not a purely resistive load. Hence, the roll-off characteristic, when measured with a load resistor, may not be quite the same as when measured with a speaker as the load.

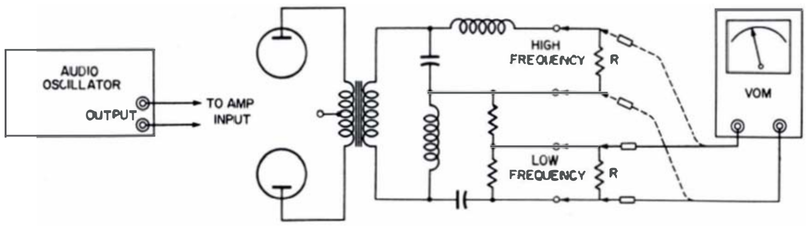


Fig. 98. Test setup.

NOTE 50

Variations in Crossover Network Design and Triple-Output Systems

In some amplifiers the crossover network is connected to intermediate stages instead of directly to the speakers. Likewise, a few amplifiers have electronic crossovers instead of LC filters, as shown in Fig. 98. However, the same test is appropriate for both. Elaborate systems have a woofer, midrange (squawker), and tweeter arrangement. In such systems, run three frequency-response curves instead of two. The combined responses should always show an over-all flat frequency characteristic.

U59

To Measure the Weighted Noise Level of an Amplifier

Equipment: An R-C differentiating network with a 1-millisecond time constant (Fig. 99); and a db meter that has an amplifier with a bandwidth of 15 to 15,000 cycles and a frequency response flat within ±1 db.

Connections Required: Short circuit the input terminals of the amplifier, preferably with a shielded connector. Terminate the amplifier in a rated load, if required. Connect R-C circuit across load. Connect output from R-C circuit to input terminals of meter amplifier.

Procedure: Set amplifier controls at predetermined positions for maximum rated output from amplifier. Measure noise voltage on db meter.

Evaluation of Results: The weighted noise level is the number of db below the normal output voltage from the amplifier. Compare measured value with manufacturer's specifications.

Preamplifiers are often rated for weighted noise level from more than one input. Switch amplifier to various inputs, as required. Thus, a preamp might be rated with a weighted noise level of better than 80 db below 2 volts for one input, and better than 54 db below 2 volts for another input. The weighted noise input is considered to be more in accordance with acoustic values than a noise measurement without low-frequency attenuation.

Weighted noise-level ratings of preamplifiers are often given on the basis of total noise and hum. However, many engineers prefer to separate the two. If a scope is connected across the noise meter, the ratio of noise voltage to hum voltage can be evaluated. When checking manufacturer's specifications, distinguish between the two rating methods.

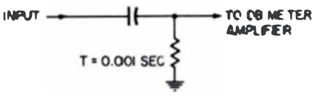


Fig. 99. An R-C differentiating network used to measure the weighted noise level of an amplifier.

U60

To Test the Operation of a Bridging Control in a Preamplifier

Equipment: Audio oscillator, terminating resistors, and AC VTVM.

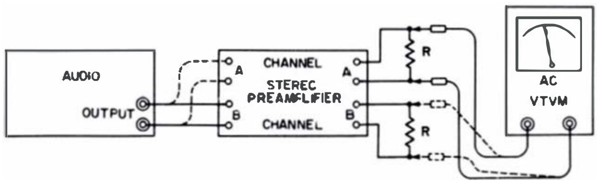
Connections Required: Connect equipment as shown in Fig. 100.

Procedure: Set preamplifier controls for normal output level. Run a frequency response of the preamplifier with the bridging control set at low, medium, and high positions. Repeat test with signal input connected to channel A and meter connected to the output of channel B.

Evaluation of Results: The output voltage should increase proportionally with the setting of the bridging control. The frequency response of the amplifier should be within rated limits at any setting of the bridging control.

The purpose of the bridging control is to intermix the two stereo channels. This minimizes or eliminates the "hole in the middle" due to speaker placement or recording characteristics.

Fig. 100. Test setup.



U61

To Check the Equalization-Control Characteristic in a Preamplifier

Equipment: Audio oscillator, AC VTVM, and terminating resistor.

Connections Required: Connect equipment as shown in Fig. 101.

Procedure: Adjust all preamplifier controls for flat response, except for the equalization control, which is set to AES response. Adjust audio oscillator and volume control for normal output. Run a frequency response of the preamplifier.

Evaluation of Results: The frequency response should correspond to Fig. 102. Both the treble and bass end of the characteristic can be varied by adjusting the boost and cut controls, although not sufficiently to match the characteristics of some older recordings. Fig. 103A is the RIAA recording curve. The equalizer in the preamp has the opposite characteristic, so that a flat frequency response is obtained from the record to the equalizer output.

Fig. 103B shows the standard RIAA playback curve. When the frequency response of an equalizer is being checked on the RIAA position, this curve should be reproduced within ±2 db.

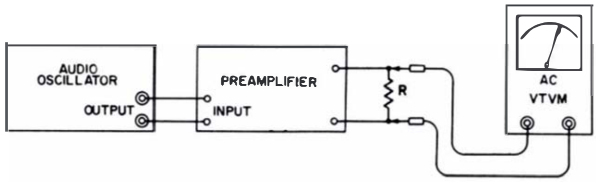


Fig. 101. Test setup.

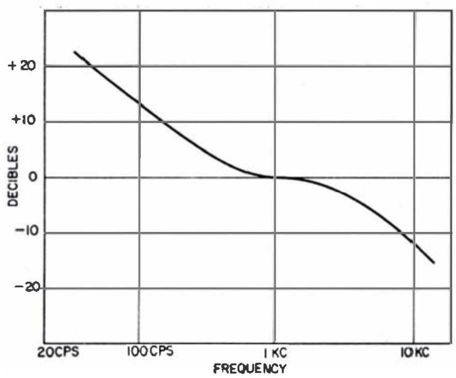
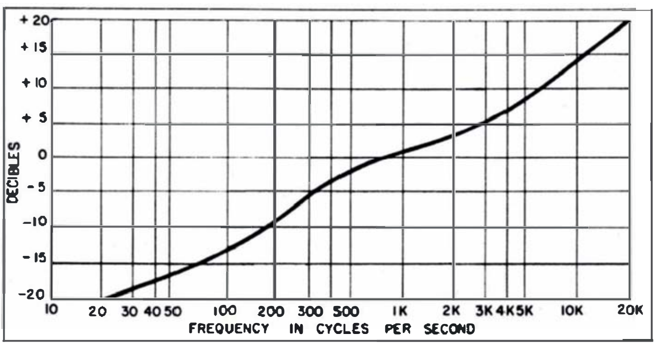
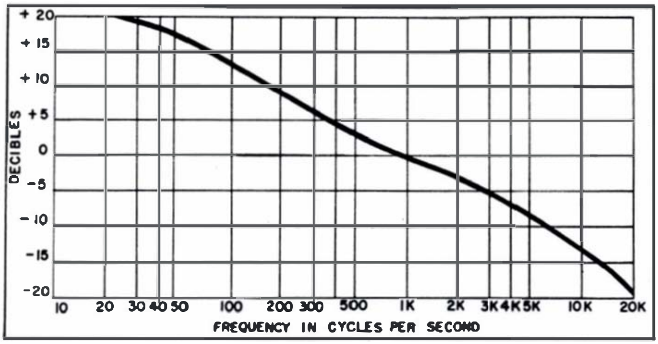


Fig. 102. Equalization characteristic recommended by the AES for record playback.



(A) RIAA recording curve.



(8) RIAA playback curve.

Fig. 103. Standard RIAA curves.

U62

To Test an Amplifier for Microphonics

Equipment: Audio oscillator, terminating resistor, and audio VTVM.

Connections Required: Disconnect speaker from amplifier. Connect load resistor of suitable value across amplifier output terminals. Connect audio VTVM across load resistor. Connect output from audio oscillator to speaker terminals. (See Fig. 104.)

Procedure: Drive speaker over the audio-frequency range, and note any reading on the VTVM. Place stylus in a record groove. (Do not operate record player, because the test is for checking reproduction of vibrations from speaker.)

Evaluation of Results: If the amplifier and player are free from microphony, the meter reading does not increase when the speaker is energized.

To test the amplifier by itself, disconnect the pickup and substitute a suitable fixed resistor.

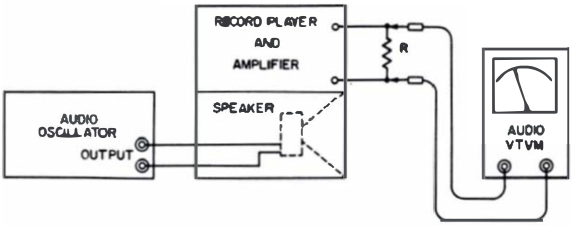


Fig. 104. Test setup.

U63

To Check for Regeneration in an Over-all Feedback Loop

Equipment: DC milliammeter.

Connections Required: Insert milliammeter in the B+ lead to the output transformer (Fig. 105). ***Caution:*** Set meter to high current range first.

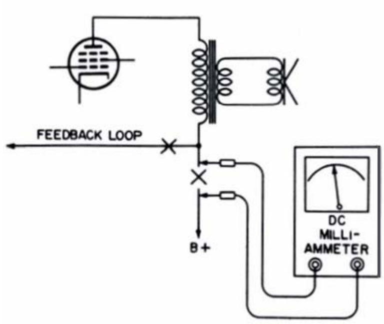
Procedure: Disconnect the feedback loop, and observe the meter reading.

Evaluation of Results: If the B+ current to the output stage decreases when the feedback loop is disconnected, look for incorrect component values in the feedback circuit.

Regeneration (positive feedback) occurs in a negative-feedback loop when component values change and introduce a phase shift at certain frequencies; this phase shift makes the feedback positive instead of negative. Unsuspected phase shifts can occur in the amplifier components themselves, and can cause regeneration when all components in the feedback loop have correct values. Some amplifiers have extended high-frequency response beyond the audible range. Unless carefully controlled, stray capacitances can cause regeneration in such amplifiers.

Negative feedback is often expressed in db. That is, an amplifier may be said to have 25 db negative feedback. This means the amplifier has 25 db less gain than if the negative feedback were removed. For example, if an over-all feedback loop is used, the amplifier gain will increase 25 db when the feedback loop is opened. In turn, the amplifier response will be much poorer without negative feedback.

Fig. 105. Milliammeter inserted in B+ line to output transformer.

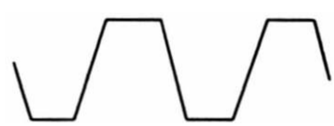


NOTE 51

Negative Feedback Cannot Reduce Clipping Distortion

Clipping distortion cannot be reduced by negative feedback; instead, the clipped waveform corners are sharpened. This inability to correct the waveform results from the fact that the amplifier gain is suddenly reduced to zero during the clipping interval. Clipping is heard as a knocking sound. The only remedy for clipping is to operate the amplifier below the overload point. Fig. 106 shows some clipped waveforms. Whether even harmonics (Fig. 106A) or odd harmonics (Fig. 106B) are generated depends upon the waveshape of the distorted signal.

(A) Unsymmetrical clipping generates even harmonics.



(B) Symmetrical clipping generates odd harmonics.

Fig. 106. The generation of harmonics by distorted waveshapes.

COMPONENT TESTS

U64

To Check the Output From a Phono Cartridge

Equipment: Audio VTVM and test record.

Connections Required: Connect the audio VTVM across the normal load resistor for the cartridge, as shown in Fig. 107.

Procedure: Inspect the stylus with a 50-power stylus inspection microscope. If it shows signs of wear, replace it before playing the test record. Set the audio VTVM to a suitable range, such as 30 millivolts. Place the test record on the changer, and observe the reading on the VTVM.

Evaluation of Results: A variable-reluctance cartridge should provide 0.01- to 0.03-volt output; a ceramic cartridge, 0.5 to 1.2 volts; and crystal cartridges, 0.5 to 5 volts. To determine the frequency response of a cartridge, check the comparative output voltages obtained from the various frequency ranges of the test record.

The frequency response of a good ceramic or crystal cartridge should extend from 50 cycles to 12 or 15 kc. Some types of high-output cartridges have a frequency response to only 7 or 8 kc. Variable-reluctance cartridges should have a response to 15 or 20 kc.

The frequency response of a pickup is affected by the shunt capacitance of the connecting cable, the value of the load resistance, and—with some designs, such as variable-reluctance pickups—the inductance of the unit itself. Hence, if the frequency response of a pickup is unsatisfactory, it is often worthwhile to try different values of load resistance and different diameters of connecting cable.

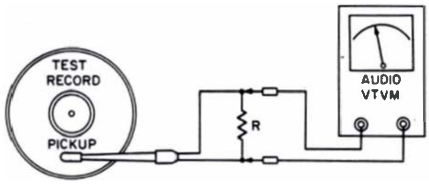


Fig. 107. Test setup.

NOTE 52

Most Pickup Cartridges Operate on the Velocity Principle

In a record that is cut to have equal velocities at all frequencies, the movement of the needle perpendicularly to the grove is inversely proportional to the frequency. In other words, the cut is small at low frequencies and large at high frequencies. The high frequencies are boosted. This gives a good signal-to-noise ratio at high frequencies, and avoids overcutting of the groove walls at low frequencies. The low frequencies contain most of the sound energy. The db output from an RIAA (Recording Industry Association of America) record *versus* frequency is shown in Fig. 103A. An equalizer with an inverse characteristic is used to provide a flat response from a pickup cartridge. The equalizer is usually contained in the preamplifier. Most modern records will be played in the RIAA position of the equalizer, since they are based upon the characteristic shown in Fig. 103A.

U65

To Check for Optimum Needle Pressure

Equipment: Needle-pressure gauge.

Connections Required: None.

Procedure: Place gauge under stylus, and read pressure on grams scale.

Evaluation of Results: As a preliminary step, check the scale reading against the manufacturer's specifications. Thus, if

6 to 8 grams is specified, any reading between these limits is acceptable. On the other hand, an IM analyzer may show less tracking distortion (e.g., when the pressure is 8 grams rather than 6 grams). No set rules can be stated. Optimum pressure (within specified limits) can be determined only by measurement with a test record and an IM analyzer.

Even if the needle pressure is optimum, distortion will occur if the stylus angle is incorrect. It is good practice to check the stylus angle against the manufacturer's specifications.

The needle-pressure gauge should be so placed that it indicates the normal playing level of the pickup. This level may vary in a changer; however, the pressure can be measured at the average playing level. The needle should rest freely in the cup. The pressure usually increases as the pickup is raised and decreases as the pickup is lowered. However, a variation of more than 2 grams (or 25% of rated pressure) indicates a fault in the arm assembly.

NOTE 53

Low-Distortion Reproduction Requires Correct Tracking Angle

An ideal tone arm and pickup would track a record so that the stylus always moved perpendicularly to the tangent at the groove. In practice, this can occur at only one point on the record, since the pickup moves on a curve from the outer to the inner grooves. A reasonably good test of the tracking angle is to place the stylus at the outer grooves, then at an intermediate groove, and finally at an inner groove, and observe whether the edge of the cartridge is reasonably tangent to the groove. A tracking error of 3° or 4° is normally expected at the outer and inner grooves. (An experienced eye is required to evaluate such a small tracking error.) Large tracking errors are plainly visible. Excessive errors in tracking angle cause second-harmonic distortion in reproduction, as illustrated in Fig. 108.

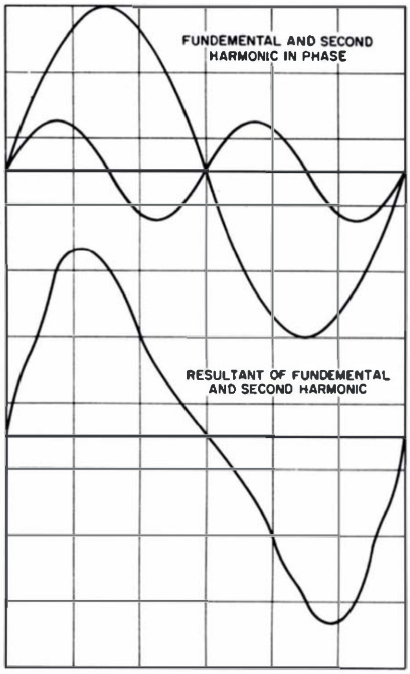


Fig. 108. Second-harmonic distortion, caused by error in tracking angle.

U66

To Measure the Intermodulation Distortion of the Pickup and Preamplifier

Equipment: Two-tone test record, preamplifier, and intermodulation-distortion meter.

Connections Required: Connect equipment as shown in Fig. 109.

Procedure: Measure percentage of IM distortion (in the same manner as if a two-frequency signal were being applied to the preamplifier).

Evaluation of Results: Evaluate the percentage of IM distortion in the light of the preamplifier IM distortion (if measureable), plus any wow and flutter contributed by the player. Make separate measurements to determine these factors.

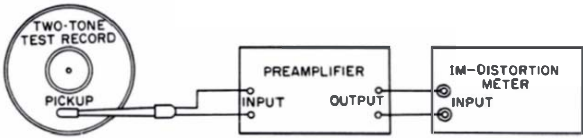


Fig. 109. Test setup.

U67

To Measure the Static Compliance of a Stylus

Equipment: Calibrated shadowgraph and sensitive balance.

Connections Required: None.

Procedure: Mount pickup in shadowgraph, and project image of stylus on screen. Load stylus laterally with a small loop of wire (or other convenient weight) to obtain a readily measurable deflection on the screen. Then measure the weight with a sensitive balance.

Evaluation of Results: The static compliance is given in centimeters of deflection per dyne of force. In other words, divide the deflection measured on the screen by the applied force required to produce the deflection. A dyne is 1/980 gram when acted upon by gravity.

NOTE S4

Arm Resonance Is Related to Compliance of Stylus

Distortion at low audio frequencies can be caused by unsuitable combinations of pickups and arms. Arm resonance is the resultant of the mass and construction of the arm with respect to the compliance of the stylus. Any arm resonance is objectionable. Therefore, if a frequency-response check (described in U64) shows that a resonant rise occurs at a frequency higher than 25 cycles, it is advisable to try another combination of pickup and arm. If a test record with frequencies low enough to check for arm resonances is not available, any record can be run at a slower speed. If a record is run at half the speed at which it was recorded, for example, all recorded frequencies will be halved.

To Measure Turntable Speed

Equipment: Stroboscopic disc and 60-cycle lamp.
Connections Required: None.
Procedure: Place stroboscopic disc (Fig. 110) on turntable. Set player at desired speed. Observe disc under 60-cycle lighting.
Evaluation of Results: The markings that appear to stand still show the exact speed of the turntable. If the markings appear to move clockwise, the speed is too fast. If they appear to move counterclockwise, the speed is too slow.

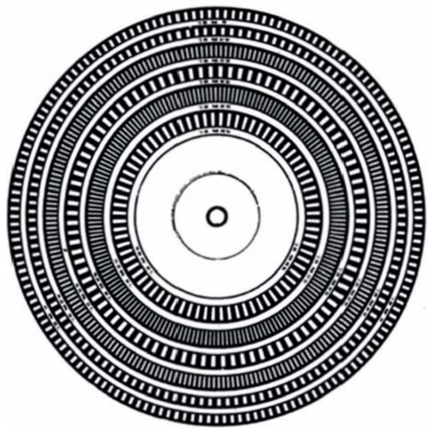


Fig. 110. A typical stroboscopic disc.

U69

To Measure the Intermodulation Distortion of a Pickup

Equipment: Two-tone test record, IM analyzer, terminating resistor, and preamplifier (optional).
Connections Required: Connect equipment as shown in Fig. 111. Omit preamp if pickup has sufficient output to drive IM analyzer effectively. If the preamp is omitted, however, the pickup must work into its normal load resistance with a specified equalizer.
Procedure: Operate IM analyzer in the same manner as if an amplifier were being tested with two audio oscillators.

Evaluation of Results: Any nonlinearity in the pickup response is a corresponding percentage of IM distortion. In most cases the IM distortion of the preamp is low enough to be neglected. On the other hand, if the preamp has measurable IM distortion, the test results will be in error. Intermodulation distortion rises rapidly with poor tracking. This is the best test when you are adjusting stylus pressure to a critical optimum value.

It is not practical to subtract preamplifier IM distortion from pickup distortion, for this reason. We do not know whether the two distortion residues are in phase, out of phase, or combined at some intermediate phase angle.

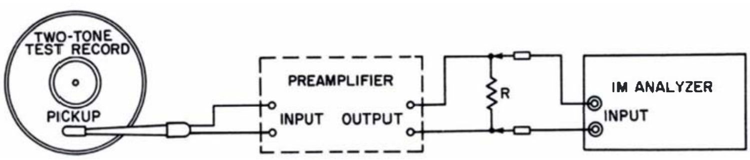


Fig. 111. Test setup.

U70

To Check a Record Player for Rumble

Equipment: Test record, audio VTVM, preamplifier, and terminating resistor.

Connections Required: Connect terminating resistor to preamplifier output (if required). Connect VTVM to preamp output terminals, as shown in Fig. 112.

Procedure: Reproduce the 1-kc tone from the test record. Set preamp controls for flat response. Adjust volume control for normal output from preamp. Then place the needle in an unrecorded groove. Increase VTVM sensitivity, until a reading is obtained. Finally, lift pickup from record, and note any change in VTVM reading. (See also U71.)

Evaluation of Results: The difference between VTVM readings with the needle in an unrecorded groove and with the pickup lifted from the record can be regarded as a rough measure of rumble. The measurement can be expressed as the number of db below rated amplifier output.

Rumble becomes noticeable in normal reproduction as a noise "like furniture moving around upstairs" during low-volume passages or while the needle is in an unrecorded groove. Rumble is a series of random pulses (not a cyclic low-frequency interference); it can thus be distinguished from wow and flutter. To avoid confusing rumble with wow and flutter, connect a sensitive scope at the amplifier output. The waveform will show whether the interference is random or cyclic. Rumble is caused by vibrations within the record player.

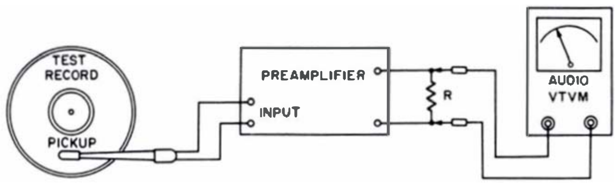


Fig. 112. Test setup.

U71

To Check a Record Player for Rumble (Filter Method)

Equipment: Low-pass filter with a cutoff frequency of approximately 300 cycles, test record, audio VTVM, and terminating resistors. (See Note 55.)

Connections Required: Connect equipment as shown in Fig. 113.

Procedure: First disconnect low-pass filter. Reproduce 1-kc tone from test record. Adjust preamp controls for maximum rated output and flat response. Then connect filter. Increase VTVM sensitivity until a reading is obtained. Observe readings as tone bands from 1 to 10 kc are fed to the preamp. Finally, lift pickup from record, and observe any change in reading.

Evaluation of Results: The difference between the VTVM readings with the needle tracking the test record and with the pickup lifted from the record is an approximate measure of rumble. The rumble interference is expressed as the number of db below maximum rated output from the amplifier.

This test is somewhat more accurate than the one in U70, because the low-pass filter eliminates any spurious midrange and high-frequency output. To distinguish between random rumble interference and wow or flutter, use a sensitive scope, as noted in U70.

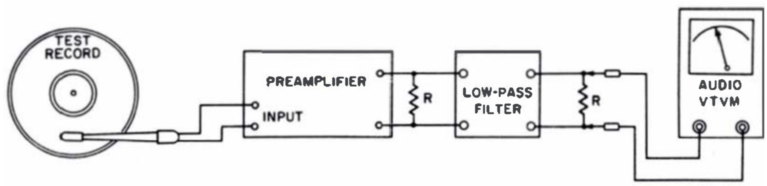


Fig. 113. Test setup.

NOTE 55

Construction of Low-Pass Filters

Simple T-section low-pass filters can be easily constructed in the shop. The circuit and component values for a low-pass T-section filter are shown in Fig. 114. Note carefully that required values of L and C depend upon the value of filter terminating resistor R. To obtain a sharp cutoff characteristic, use several T sections connected in series and terminated with R. Mount the coils in the sections at right angles, or shield them, so that they do not couple into one another. The value of L can be determined with an inductance bridge. Close-tolerance capacitors are readily available. Different values can be connected in series or parallel, if necessary, for an accurate odd value.

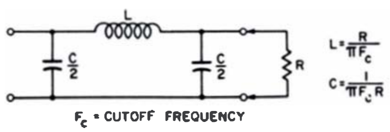


Fig. 114. A low-pass T-section filter.

U72

To Measure the Wow and Flutter of a Record Player

Equipment: Test record, and wow and flutter meter.

Connections Required: Connect output from phono cartridge (through suitable equalizer) to wow and flutter meter. (See Fig. 115.)

Procedure: Reproduce the 1-kc tone band of the test record. Adjust controls on wow and flutter meter, as required.

Evaluation of Results: The meter reads "per cent of flutter." The reading is given as:

$$\%\ \text{flutter} = \frac{\text{maximum frequency} - \text{minimum frequency} \times 100}{\text{average frequency}}$$

where,

maximum frequency is the highest deviation from average frequency,

minimum frequency is the lowest deviation from average frequency due to wow or flutter.

A reading of less than 1% is considered acceptable. A good player may show a reading of as low as 0.1%.

Wow and flutter meters are complex instruments, and are usually beyond the budget of the average shop. However, a person with a critical and experienced ear can roughly estimate wow and flutter by listening to a 1-kc tone from a test record. Wow and flutter are essentially similar distortions, except that wow is low-frequency FM, and flutter is higher-frequency FM variation in tone reproduction. Both wow and flutter are caused by imperfect mechanical-drive systems in the player. (A more remote cause of wow is an off-center record).

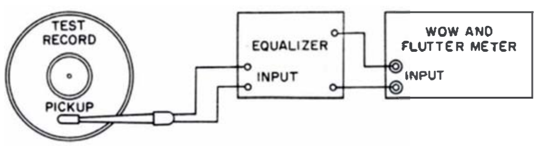


Fig. 115. Test setup.

U73

To Check the Phasing of Speakers

Equipment: Flashlight cell or an ohmmeter.

Connections Required: Connect 1.5-volt source to speaker voice coil, as shown in Fig. 116.

Procedure: Note whether cone moves out or in when current flows through the voice coil. Reverse connection, if necessary, to make cone move out when current is applied. Then mark the positive terminal on the speaker. Repeat procedure for each speaker to be operated in parallel with the first speaker.

Evaluation of Results: The marked terminals are a guide to correct phasing of the speakers. Feed all marked terminals from the same bus, and all unmarked terminals from the other bus.

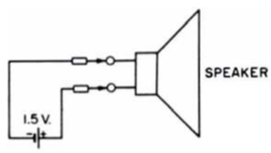


Fig. 116. Test setup.

NOTE 56

Pseudo-Bass Fundamental Generated by the Ear

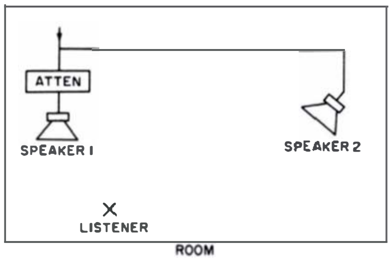
If the fundamental is removed from a bass tone and the remaining overtones (harmonics) fed to a loudspeaker, the fundamental does not seem to disappear entirely. An illusion exists that the fundamental is still present. This is called pseudo-bass, and is a characteristic of the hearing process. It can be compared with the illusion of three dimensions on a television screen. Both the seeing process and the hearing process strive to complete the visual or auditory clues provided.

NOTE 57

Proper Placement of Two Speakers Gives Pseudo-Stereophonic Sound

When two speakers are fed from the same source and are properly placed with respect to the listener, a pseudo-stereophonic effect results. (See Fig. 117.) The listener must be much closer to one speaker than to the other, and the levels must be suitably adjusted. The essential feature is the time delay imposed upon one of the sound sources. Because of room acoustics, speaker locations are critical and must be determined experimentally.

Fig. 117. Typical arrangement for producing pseudo-stereophonic sound.



U74

To Measure the Impedance of a Speaker

Equipment: Audio oscillator, audio VTVM, 30-ohm wirewound rheostat, and toggle switch or clip leads.
Connections Required: Connect equipment as shown in Fig. 118.
Procedure: Tune audio oscillator to 400 cycles. Set attenuator for approximately 1-volt output to speaker voice coil. Throw switch from position 1 to position 2. Adjust rheostat R until the voltage reading is the same in both switch positions. Then disconnect R and measure its resistance.
Evaluation of Results: The resistance of the rheostat is the impedance of the speaker at 400 cycles. The speaker impedance can be similarly evaluated at steps over the complete audio range.

The impedances measured at different frequencies depend upon the baffle or enclosure used with the speaker. Hence, this method is useful for comparing the merit of one enclosure with another. This technique gives the magnitude of the impedance, which is of chief interest.

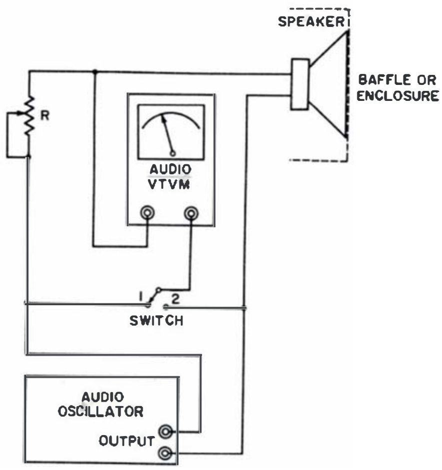


Fig. 118. Test setup.

U75

To Measure the Critical Damping Resistance of a Speaker

Equipment: Oscilloscope, crystal diode, 120K resistor, 0.5-mfd capacitor, 50-ohm wirewound rheostat, SPST switch, and dry cell.

Connections Required: Connect equipment as shown in Fig. 119.

Procedure: Alternately vary the rheostat, and open and close the switch. Observe any change in the ringing pattern on the scope screen.

Evaluation: The critical damping point is reached when the rheostat is adjusted to a point at which the pulse pattern on the scope shows no ringing when the switch is opened. The critical damping resistance is then the resistance of the rheostat at that particular setting.

For the most accurate determination, the speaker should be enclosed in its baffle.

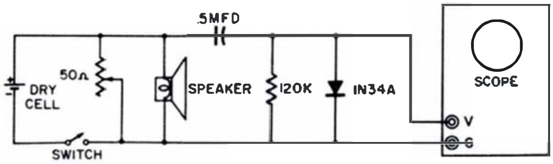


Fig. 119. Test setup.

NOTE 58

Damping-Factor Control Used in Some Amplifiers To Adjust Speaker Damping

Speaker damping is controlled principally by the source resistance from the output stage. This source resistance is coupled to the voice coil of the speaker (in most cases) through the output transformer. If the source resistance is low, the speaker damping will be large. On the other hand, if the source resistance is high, little damping will be imposed upon the speaker. This is electrical damping, as distinguished from mechanical damping imposed by air in the speaker enclosure. Variable damping is used in some amplifiers. This damping is provided by changing the amount of negative feedback in the amplifier system. The source resistance presented by the output stage varies with the amount of feedback. The damping factor can be changed in either direction by varying the amount of current feedback and voltage feedback. A typical circuit with a damping-factor control is shown in Fig. 120. Negative feedback occurs in the current-feedback circuit, which is connected from the common (C) tap, through R1B, to ground. When R1B is moved toward the cathode, current feedback is decreased as R1B is progressively shorted out. Damping increases as negative-current feedback decreases. Negative feedback also occurs in the voltage-feedback circuit, which is connected from the top (16-ohm tap) of the output transformer, through feedback resistor R2, to control R1A. As the control is turned toward the cathode, negative-voltage feedback increases, and even more damping is obtained. Controls R1A and R1B are ganged, for easier damping-factor adjustment.

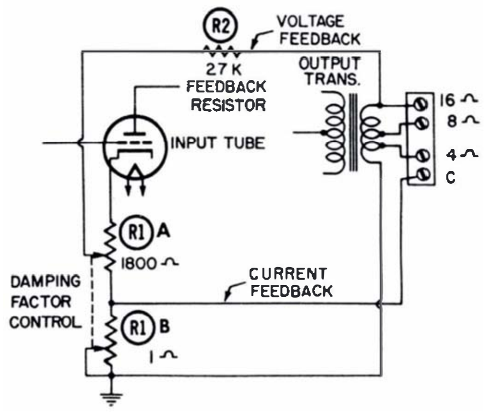


Fig. 120. Amplifier stage using a ganged damping-factor control.

To Check the Frequency Response of a Volume Control

Equipment: Audio oscillator and AC VTVM.
Connections Required: Connect equipment as shown in Fig. 121.
Procedure: Adjust audio oscillator and VTVM controls for approximately ¾ full-scale reading when volume control is set to its maximum position. Then vary audio-oscillator frequency from, for example, 60 cycles to 15 kc. Observe any variation in meter reading. This is the reference-frequency response. Next reduce setting of volume control to around ⅔ of maximum. Advance output from audio oscillator for approximately ¾ full-scale reading on the VTVM. Again vary audio-oscillator frequency over the range selected. Observe any variation in meter reading. Repeat the test with the volume control at about midrange and ⅓ of maximum.
Evaluation of Results: If the volume control has no frequency distortion, the reference-frequency response will be found at each control setting.

This is a particularly useful test when a shielded cable from a volume control is very long. The cable shunts capacitance across the control. If the capacitance is excessive, compared with the resistance of the control, the frequency response will be different at each control setting. The remedy is to reduce either the shunt capacitance or the resistance of the volume control.

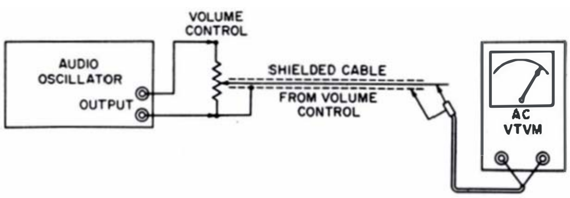


Fig. 121. Test setup.

U77

To Measure the Impedance of an Audio Component

Equipment: Audio oscillator, AC milliammeter, and AC VTVM.
Connections Required: Connect equipment as shown in Fig. 122.

Procedure: Set audio oscillator to a standard test frequency, such as 400 or 1000 cycles. Keep output from oscillator at a relatively low level, in order to avoid waveform distortion due to generator loading, and core saturation when testing components with iron cores. Note VTVM and milliammeter readings.

Evaluation of Results: The impedance of the component is given by the formula:

$$Z = E \div I$$

An audio VTVM has lower voltage scales than ordinary service VTVM's. On the other hand, at extremely low levels the measurement can become inaccurate because of stray-field pickup by the VTVM. Hence, when using an audio VTVM, make sure the test-signal level is not so low that stray pickup becomes noticeable. Note also that the impedance value at 400 cycles will not be the same as the impedance value at 1000 cycles, unless the component is purely resistive.

When an AC milliammeter is not available, an AC VTVM can be used in combination with a resistor to determine the amount of current flow, as shown in Fig. 123. Thus, if R is equal to 1000 ohms, the VTVM will indicate one volt for each milliampere of current. The accuracy of the measurement is no better than the accuracy of the resistor. Hence, a precision resistor should be used.

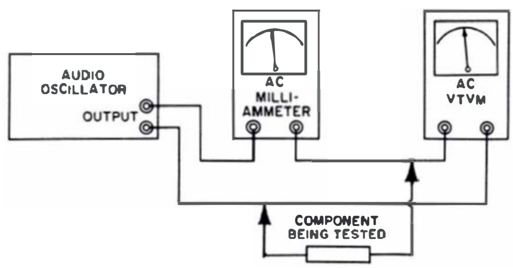


Fig. 122. Test setup.

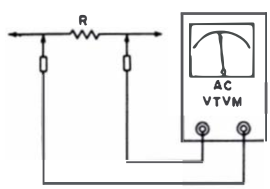


Fig. 123. Determining the amount of current flow with an AC VTVM.

To Measure the Phase Angle Between Voltage and Current in an Audio Component (Direct-Reading Electronic Phase-Meter Method)

Equipment: Audio oscillator, small value resistor, and electronic phase meter.

Connections Required: Connect equipment as shown in Fig. 124.

Procedure: Use the smallest value series resistor possible in order to minimize measurement error. Tune audio oscillator to desired test frequency, such as 400 cycles. Adjust phase-meter attenuators to equalize input voltages. Switch meter to the Read position. Observe scale reading.

Evaluation of Results: The phase-shift meter indicates the angle between voltage and current directly in degrees.

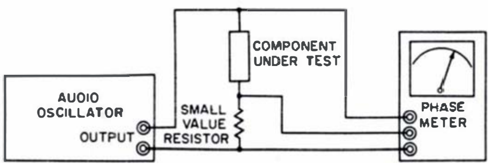


Fig. 124. Test setup.

U79

To Measure the Phase Angle Between Voltage and Current in an Audio Component (Oscilloscope Method)

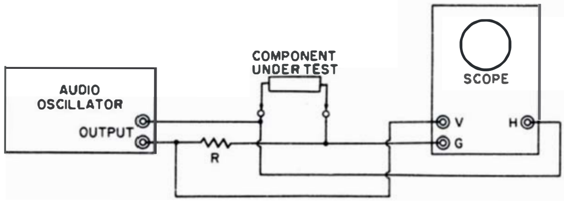
Equipment: Audio oscillator, oscilloscope, and small value resistor.

Connections Required: Connect equipment as shown in Fig. 125.

Procedure: Use the smallest value resistor possible in order to minimize measurement error. Adjust scope gain controls for convenient pattern width and height. Set audio oscillator to desired test frequency (400 cycles is a standard test frequency). An ellipse should appear on the scope screen.

Evaluation of Results: The proportions of the ellipse give the phase angle between voltage and current.

Fig. 125. Test setup.



U80

To Measure the Bass Resonant Frequency of a Speaker

Equipment: Audio oscillator, AC VTVM, and resistor with a value approximately ten times the nominal speaker impedance.

Connections Required: Connect equipment as shown in Fig. 126.

Procedure: Vary the frequency applied to the amplifier input in steps, noting the VTVM reading on each step. If desired, plot the readings *versus* frequency on a sheet of graph paper.

Evaluation of Results: A definite peak (or peaks) will appear somewhere at the low-frequency end of the audio range. A typical frequency response for a small speaker is shown in Fig. 127. If the speaker is not mounted in a baffle or enclosure, the curve will show the actual resonant frequency of the speaker. On the other hand, if the speaker is in a baffle or enclosure, the response will be modified.

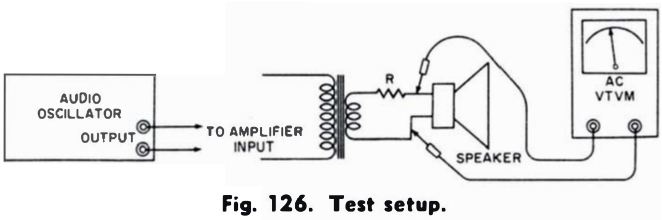
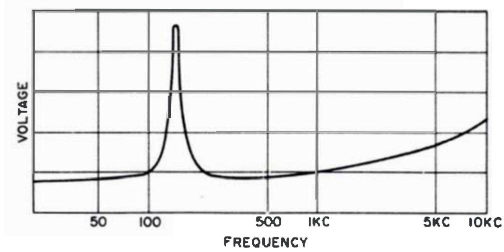


Fig. 126. Test setup.

Fig. 127. Typical bass-resonant response curve for a small speaker.



U81

To Measure the Compliance of a Speaker

Equipment: Audio oscillator; AC VTVM; resistor with a value about ten times the nominal speaker impedance; and an additional known weight, such as a dime (2.5 grams).

Connections Required: Connect equipment as shown in Fig. 128.

Procedure: Measure the bass resonant frequency of the speaker, as explained in U80. Then tape a known weight (such as a dime, 2.5 grams) to the cone, near the voice coil. Again measure the bass resonant frequency.

Evaluation of Results: The compliance of the speaker is given by:

$$C = \frac{(F_r/F_{rw})^2 - 1}{4\pi^2 m F_r^2}$$

where,

C is the compliance in cm/dyne,
F_r is the unloaded resonant frequency,
F_{rw} is the loaded resonant frequency,
m is the added mass in grams,
$\pi = 3.1416$.

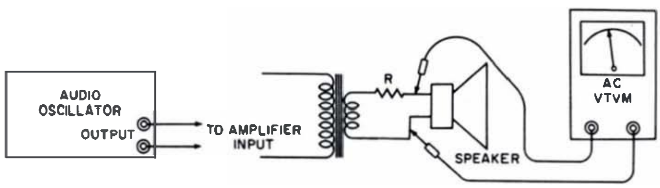


Fig. 128. Test setup.

U82

To Measure the Intermodulation Distortion of a Speaker

Equipment: IM signal source (may be contained in an audio analyzer, or use two audio oscillators), low-distortion amplifier, good-quality microphone, microphone amplifier (low-distortion type), and IM distortion analyzer.

Connections Required: Connect equipment as shown in Fig. 129.

Procedure: Make test in open air, to avoid reflection of sound from possible nonlinear reflecting surfaces. Drive speaker from IM signal source at normal output. Place microphone on speaker axis, and at a distance, to obtain normal output. Measure percentage of IM distortion with IM distortion analyzer.

Many speakers have a relatively high percentage of intermodulation distortion. The distortion increases rapidly with high sound output. However, the amplifiers in the test must have a much lower IM distortion figure than the speaker. Otherwise, the test results will be invalid. A laboratory-quality microphone is not required; a good broadcast-type microphone will have a much better characteristic than most speakers.

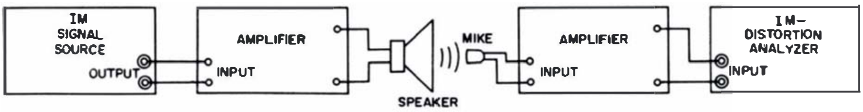


Fig. 129. Test setup.

U83

To Measure the Erase Current in a Tape Recorder

Equipment: Audio VTVM and 100-ohm precision resistor.

Connections Required: Open the ground lead to the erase head, and insert the 100-ohm resistor. Connect the audio VTVM across the resistor (Fig. 130).

Procedure: Note rms voltage reading on VTVM scale.

Evaluation of Results: Use Ohm's law to determine the erase current. Each volt drop across the 100-ohm resistor corresponds to 10 ma of current flow. Compare current value with manufacturer's specifications. If more than 20% low, check circuit components. Typical erase-current values range from 15 to 75 ma, depending upon design.

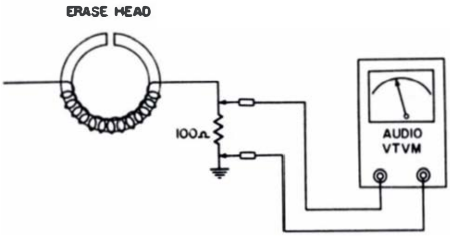


Fig. 130. Test setup.

U84

To Measure the Bias Current in the Recording Head

Equipment: Audio VTVM and 100-ohm resistor.

Connections Required: Open the return lead from the recording head, and insert a precision 100-ohm resistor. Connect audio VTVM across resistor, as shown in Fig. 131.

Procedure: Note the rms voltage reading on the VTVM scale.

Evaluation of Results: Calculate the bias current from Ohm's law. Each volt dropped across the 100-ohm resistor corresponds to 10 ma. Compare the value of bias current with the value recommended by the recorder manufacturer. The correct bias current ranges from less than 1 ma to several ma, depending upon the design of the recording head.

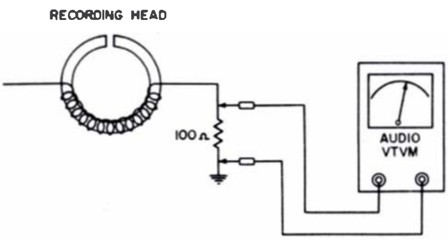


Fig. 131. Test setup.

U85

To Check for an Open or Shorted Coil in a Recording Head

Equipment: Audio oscillator, oscilloscope, and 100-ohm resistor.

Connections Required: Connect output terminals of audio oscillator to input terminals of recorder preamp. Connect vertical-input terminals of scope across the recording head, as shown by solid line in Fig. 132. Pull bias-oscillator tube; otherwise, a false pattern will be displayed on the scope screen.

Procedure: Drive the preamp with approximately one volt at 400 cycles from the audio oscillator. Observe pattern on scope screen.

Evaluation of Results: No signal on the scope screen indicates a short in the winding. To check for an open, connect the 100-ohm resistor in series with the ground lead of the head. Apply the scope across the resistor. No signal on the scope indicates an open winding.

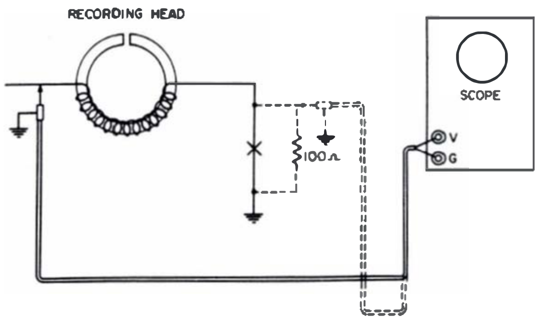


Fig. 132. Test setup.

U86

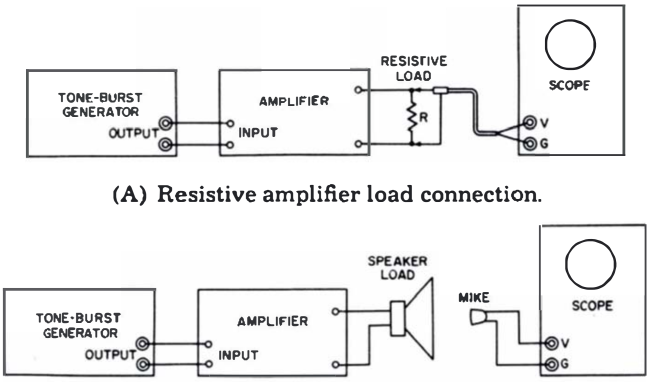
To Make a Tone-Burst Test of a Speaker

Equipment: Tone-burst generator (or audio oscillator and electronic switch), terminating resistor, broadcast microphone, and oscilloscope.

Connections Required: Connect a suitable value load resistor across amplifier output terminals, and connect scope across resistor. Connect output from tone-burst generator to amplifier input terminals, as shown in Fig. 133A. In second test, replace load resistor with speaker. Connect scope input terminals to microphone (Fig. 133B).

Procedure: With amplifier terminated in the load resistor, observe the tone-burst response of the amplifier. If noticeable distortion occurs, note the waveform. Check at steps over the complete audio-frequency range. Next, with speaker and microphone connected (Fig. 133B), repeat the tone-burst tests.

Evaluation of Results: If the speaker has no tone-burst distortion, the patterns will be identical in the two tests. On the other hand, most speakers show appreciable tone-burst distortion. The better the speaker, the more nearly the same are the patterns in the two tests.



(A) Resistive amplifier load connection.

(B) Speaker as amplifier load.

Fig. 133. Test setups for a tone-burst test of a speaker.

U87

To Test a Matched Pair of Audio-Output Tubes

Equipment: AC VTVM, audio oscillator, and terminating resistor.

Connections Required: Connect equipment as shown in Fig. 134.

Procedure: Adjust audio oscillator for a frequency of approximately 1 kc. Drive amplifier to maximum rated output, and observe reading on VTVM. Then interchange tubes T1 and T2. Again observe meter reading. ***Caution:*** Turn amplifier off when interchanging tubes.

Evaluation of Results: If the tubes are exactly matched, the VTVM reading does not change when the tubes are interchanged.

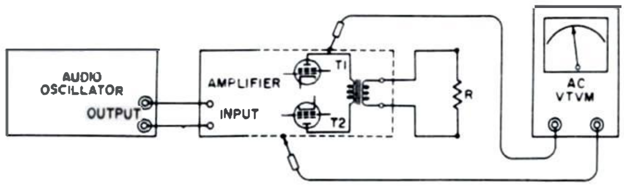


Fig. 134. Test setup.

SYSTEM CHECKS

U88

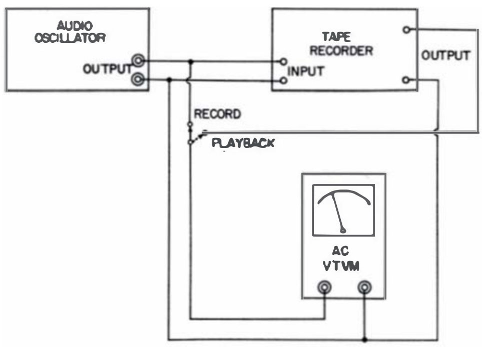
To Check the Frequency Response of a Tape Recorder

Equipment: Audio oscillator, AC VTVM, and switch or clip lead.

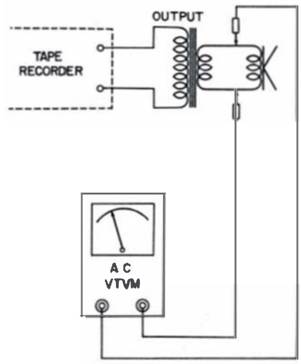
Connections Required: Connect audio-oscillator output to amplifier input in tape recorder. Connect VTVM to audio-oscillator output in first part of test (Fig. 135A). Connect VTVM across speaker voice coil (or load resistor) in second part of test (Fig. 135B).

Procedure: Adjust audio-oscillator output to normal recording level, avoiding excessive input. Tune audio oscillator to a low frequency, such as 50 cycles. Record the signal, and note VTVM reading. Next tune audio oscillator to successively higher frequencies, and record the signals at the original level indicated by the VTVM. Finally connect VTVM to amplifier output (Fig. 135B), and play the tape back. Note VTVM readings as the recording frequency changes.

Evaluation of Results: If the system has a flat frequency response, the VTVM readings will be constant. The measured frequency response depends upon the setting of the tone control. Hence, a complete test includes frequency runs at different settings of the tone control.



(A) AC VTVM connected across audio-oscillator output.



(B) AC VTVM connected across speaker voice coil.

Fig. 135. Frequency-response check of a tape recorder.

U89

To Measure the Low-Frequency Noise from a Record Player, Preamplifier, and Amplifier

Equipment: Decibel meter, terminating resistor, and test record.
Connections Required: Connect equipment as shown in Fig. 136.
Procedure: Use the 1000-cycle tone of the test record. Adjust the volume so that the amplifier operates within its power limit. Turn the bass control to zero. The initial measurement should be such that the meter can indicate at least −50 db less output. Note db reading. Then place the stylus in an unrecorded groove. Turn the bass control up to normal setting. Do not change the amplifier gain. Again note the db reading.
Evaluation of Results: The db reading obtained with the 1000-cycle tone is the reference db reading. The db reading obtained with the unrecorded groove is the comparative low-frequency noise level. Subtract the two readings to obtain the low-frequency noise level in db below the reference level.

Since the db measurements are made across a fixed terminating resistor, the difference in db readings will be the actual number of db below the reference level. On the other hand, neither of the individual db readings is necessarily correct by itself.

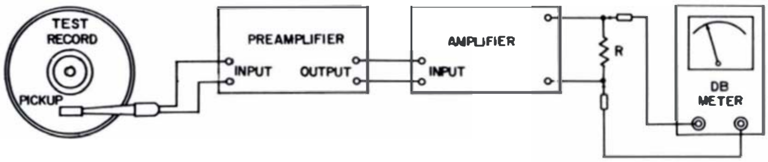


Fig. 136. Test setup.

U90

To Make a Sweep-Frequency Test of a Record Player, Preamplifier, and Amplifier System

Equipment: Gliding-tone test record, terminating resistor, and AC VTVM or scope.

Connections Required: Connect equipment as shown in Fig. 137.

Procedure: Adjust amplifier controls for normal output. Observe meter reading or scope deflection as gliding-tone record drives the preamp through the audio-frequency range.

Evaluation of Results: The variation in instrument indication shows the flatness (or lack of flatness) of the combined pickup, preamp, and amplifier system.

A gliding-tone test record is an audio-frequency sweep-signal source. A typical record starts at 14 kc and ends at 10 cps. Another starts at 10 kc and ends at 50 cps. Still another has five 1-kc bands at increasing output levels, followed by alternate gliding and constant frequencies from 3 kc to 30 cps. Numerous other combinations are available for making any specialized tests desired.

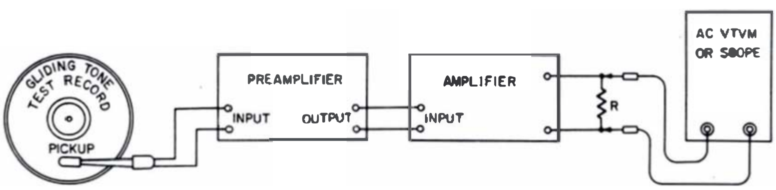


Fig. 137. Test setup.

To Test the Over-all Transient Response of a Tape Recorder

Equipment: Square-wave generator and oscilloscope.

Connections Required: Connect output from square-wave generator to mike-input connector of recorder. Connect vertical-input terminals of scope to voice-coil terminals of speaker. (See Fig. 138.)

Procedure: Set square-wave generator output for normal recording level. Run recorder. Vary square-wave generator frequency slowly from 20 cps to 10 kc. Then play back, and observe scope pattern. Increase the horizontal-deflection rate as the square-wave frequency increases.

Evaluation of Results: The scope pattern shows the system response to transient voltages. Typical distortions are tilt, curvature, corner rounding, overshoot, and ringing.

Better square-wave reproduction is observed when the speaker is disconnected and a suitable load resistor substituted. This eliminates the distortion introduced into the pattern by the motional impedance of the speaker.

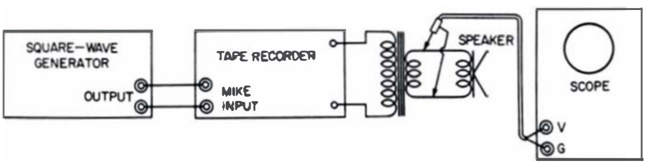


Fig. 138. Test setup.

U92

To Test the Over-all Tone-Burst Response of a Tape Recorder

Equipment: Tone-burst generator and oscilloscope.

Connections Required: Connect output from tone-burst generator to mike-input connector of recorder. Connect vertical-input terminals of scope to voice-coil terminals of speaker. (See Fig. 139.)

Procedure: Set tone-burst generator output for normal recording level. Run the recorder. Vary tone-burst generator frequency slowly from 20 cps to 10 kc. Then play back, and observe scope pattern. Increase the horizontal-deflection rate as the tone-burst frequency increases.

Evaluation of Results: The tone-burst pattern observed on the scope screen corresponds in a general way to the patterns observed in a square-wave test. However, the tone-burst test is a more critical test, since the tone signal exalts a given harmonic in the square wave, and provides a more pronounced reaction to minor defects in the tape-recorder system.

To obtain a more comprehensive evaluation of tone-burst response, gradually vary the tone-burst frequency from a low value to the upper limit at which the amplifier output starts to fall off. Some amplifiers will distort a tone burst at a certain frequency, but will pass an undistorted burst at other frequencies.

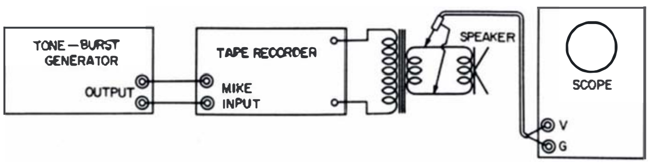


Fig. 139. Test setup.

U93

To Measure the Peak-Overload Capability of a Tape Recorder

Equipment: Square-wave generator, R-C differentiating network, terminating resistor, and oscilloscope.

Connections Required: Connect differentiating network between square-wave generator and microphone-input jack of tape recorder. Use suitable R and C values, to obtain approximately 50% decay of the square wave (as shown by a scope check). Terminate the playback amplifier with a suitable load resistor. Connect scope input terminals across load resistor. (See Fig. 140.)

Procedure: Record on tape the differentiated square wave in progressively higher voltage steps, noting the recorder-level indication on each step. Next play the tape back, and observe pattern on scope screen.

Evaluation of Results: The level at which the top of the reproduced waveform is no longer pointed, but rounded or clipped, is the peak-overload capability of the recorder.

Use of a load resistor instead of a speaker eliminates excessive noise during the test. On the other hand, the peak-overload capability is generally less with a speaker. The speaker has a reactive component of impedance, which causes the load line on the output-tube characteristic to become an ellipse instead of a straight line. In turn, the tube starts to overload and distort earlier than with a resistive load.

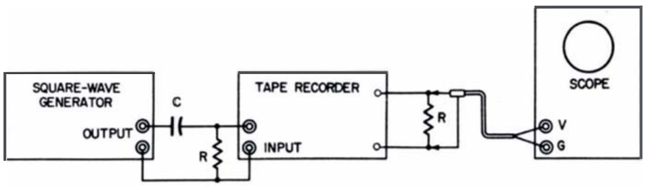


Fig. 140. Test setup.

U94

To Measure the Total IM Distortion of a Tape-Recorder System

Equipment: IM signal source (may be obtained from audio analyzer or from two audio oscillators and a bridge mixing network, as shown in Fig. 141), broadcast-quality microphone, good preamplifier, and IM distortion meter.

Connections Required: Connect equipment as shown in Fig. 141.

Procedure: Record output from IM signal source at maximum recording level. Then play the tape back at normal output level. Place microphone on axis of speaker and back far enough for normal operating level of microphone. (Test is preferably made in open air.) Measure percentage of IM distortion on IM distortion meter.

Evaluation of Results: The percentage of IM distortion read on the IM distortion meter is the resultant of the individual system distortions. It is the most useful IM measurement, because it represents the total IM distortion in the actual operation of the recorder.

The percentage of IM distortion read on the meter is not the simple sum of the individual IM distortions. The individual distortions can be combined by the system networks in phase, out of phase, or in some intermediate phase. If the audio-signal sources are variable (as when two audio oscillators are used), it is helpful to make total IM distortion readings at different frequencies. In the first test, set one generator at a low audio frequency and the other at a high audio frequency. In the second test, set both generators to different high frequencies, if the IM meter permits.

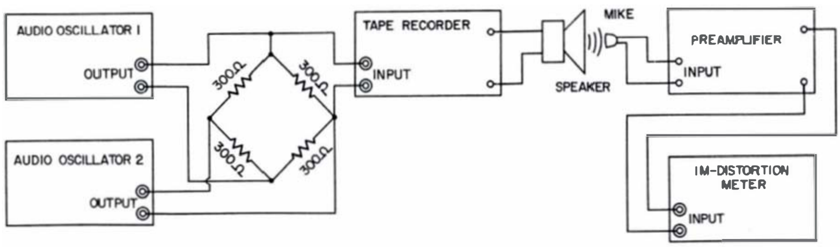


Fig. 141. Test setup.

U95

To Measure the Total Harmonic Distortion of a Tape-Recorder System

Equipment: Audio oscillator, broadcast-quality microphone, good-quality preamplifier, and harmonic-distortion meter.

Connections Required: Connect equipment as shown in Fig. 142.

Procedure: Record audio tone at maximum recording level. Then play tape back. Place microphone on axis of speaker, at the distance for normal microphone output when recorder is reproducing at normal output. Measure percentage of total harmonic distortion on harmonic-distortion meter.

Evaluation of Results: The reading on the harmonic-distortion meter gives the resultant of the system harmonic distortions. This is not necessarily the simple sum of the individual distortions. It is the most useful measurement of harmonic distortion, because it represents the total harmonic distortion encountered in actual operation of the recorder.

The percentage of total harmonic distortion generally varies with the test frequency. Hence, make tests at low, medium, and high audio frequencies. The reading on the harmonic-distortion meter often varies greatly at different recording levels and at different settings of the volume control. Therefore, these factors should also be determined in a complete test run.

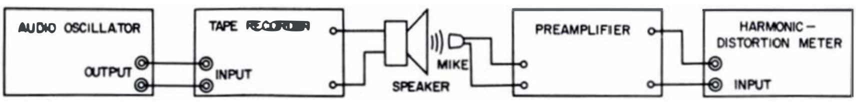


Fig. 142. Test setup.

U96

To Check a Stereophonic System for Balance

Equipment: Audio test record and stereo balance meter (or noise-level meter).

Connections Required: None.

Procedure: Place meter in position of the listener, in front of the two speakers, as shown in Fig. 143. Reproduce a 400- or 1000-cycle tone from the test record at normal level. Apply the tone signal to each channel in turn, and observe meter readings. Adjust the stereo balance control for equal readings.

Evaluation of Results: A midrange balance is obtained when meter readings are equal at a midrange test frequency. However, other settings of the stereo balance control may be necessary at low and high audio frequencies. An average balance setting can be determined from three tests made at 100, 1000, and 8000 cycles.

A block diagram of a basic stereo amplifier, with a pair of identical sound channels, ganged controls, a balance network, and function switch, is shown in Fig. 144. The balance-control circuit used between stereo preamplifier channels is illustrated in Fig. 145.

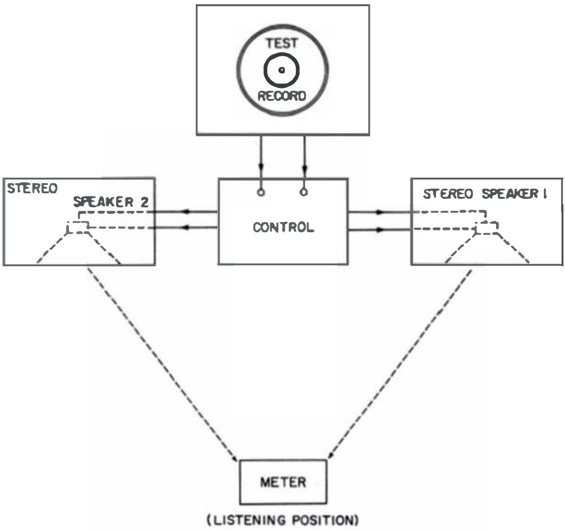


Fig. 143. Test setup.

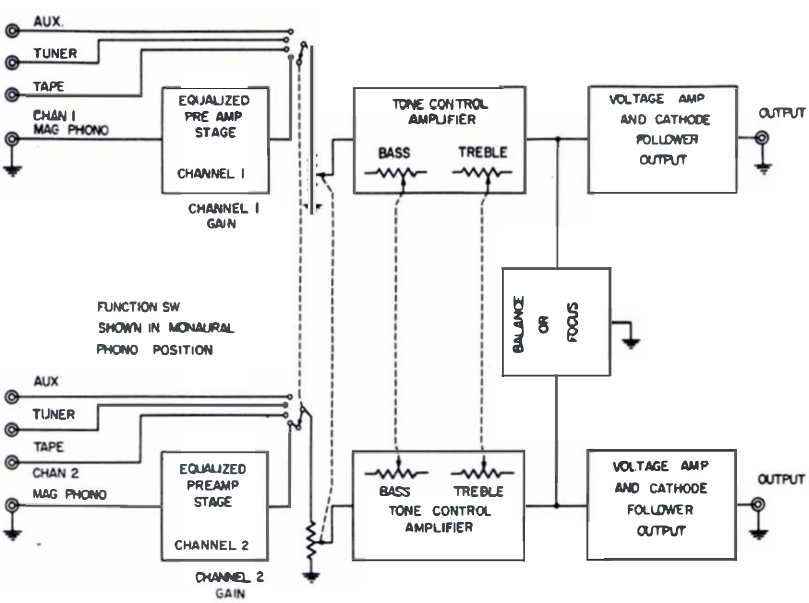


Fig. 144. Block diagram of a basic stereo amplifier.

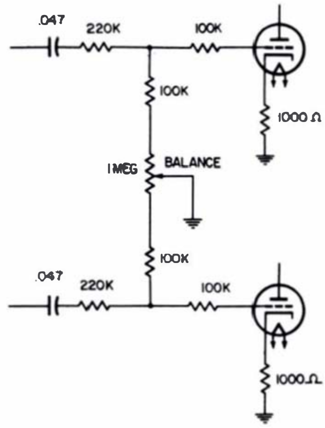


Fig. 145. Circuit diagram for a balance control between stereo preamplifier channels.

U97

To Check the Frequency Response of an AM Tuner and Hi-Fi Amplifier

Equipment: Audio oscillator, RF signal generator, terminating resistor, and AC VTVM.

Connections Required: Connect equipment as shown in Fig. 146.

Procedure: Adjust output from audio oscillator for approximately 30% modulation of the RF signal. Set signal generator for average input to AM tuner (avoid overload). Tune generator to suitable frequency. Vary audio-oscillator frequency in steps, from 50 cycles to 15 kc. Observe meter readings at each step.

Evaluation of Results: The frequency response should be reasonably flat up to 10 kc. If the high-frequency response is poor, check the RF tuner alignment.

For accurate test results, the modulator section of the RF signal generator must not distort the audio signal and must have flat frequency response through the audio range.

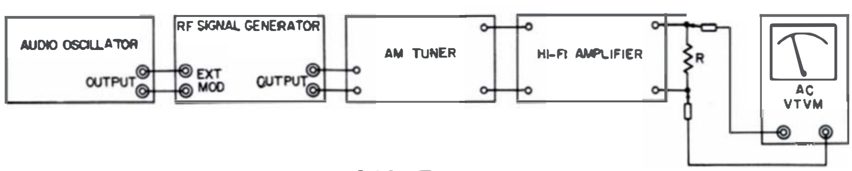


Fig. 146. Test setup.

U98

To Measure the Total Harmonic Distortion of an AM Tuner and Hi-Fi Amplifier

Equipment: AM signal generator, terminating resistor, and harmonic-distortion meter.

Connections Required: Connect equipment as shown in Fig. 147.

Procedure: Set generator for 30% internal modulation. Set output level from generator for normal operation of tuner (avoid overload). Tune generator and AM tuner to the same frequency. Adjust amplifier for normal output. Measure percentage of total harmonic distortion on harmonic-distortion meter.

Evaluation of Results: If a good AM tuner is used, the reading of the harmonic-distortion meter will not be much higher than the reading of the amplifier alone. Note that some AM generators have substandard internal modulators. They can introduce more harmonic distortion than the tuner and amplifier.

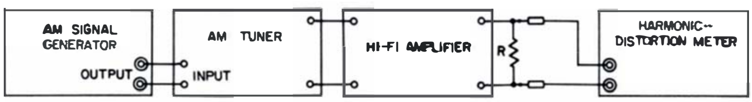


Fig. 147. Test setup.

U99

To Measure the Total Intermodulation Distortion of an AM Tuner and Hi-Fi Amplifier

Equipment: IM signal source, RF signal generator, IM distortion meter, and terminating resistor (unless IM distortion meter contains internal load resistors).

Connections Required: Connect equipment as shown in Fig. 148.

Procedure: Adjust output from IM signal source for 30% modulation of the RF signal generator. Set output level from generator for normal operation of AM tuner. Tune generator to same RF frequency as AM tuner. Adjust hi-fi amplifier for normal output. Measure total IM distortion on IM distortion meter.

Evaluation of Results: This method gives the total IM distortion of the system, exclusive of the speaker. To include the speaker distortion, connect the speaker at the amplifier output in place of the terminating resistor. With a broadcast-quality microphone, pick up the speaker output and feed it to a good-quality preamplifier. Measure the total distortion from the preamp with the IM distortion meter.

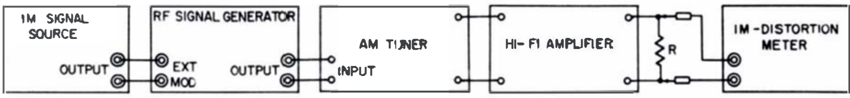


Fig. 148. Test setup.

U100

To Make a Tone-Burst Test of an AM Tuner and a Hi-Fi Amplifier

Equipment: Tone-burst generator (or audio oscillator and electronic switch), RF signal generator, oscilloscope, and terminating resistor.

Connections Required: Connect equipment as shown in Fig. 149.

Procedure: Adjust output from tone-burst generator to obtain 30% modulation of the RF signal. Set output from RF signal generator for normal operation of the AM tuner. Tune generator and AM tuner to the same RF frequency. Set hi-fi amplifier for normal output. Observe tone-burst pattern on scope screen.

Evaluation of Results: The tone-burst pattern should be almost the same as when the amplifier is tested by itself. For a complete check, vary the tone-burst frequency through the audio range. At the low end of the RF band, the AM tuner response sometimes differs from the response at the high end. Hence, this should also be checked.

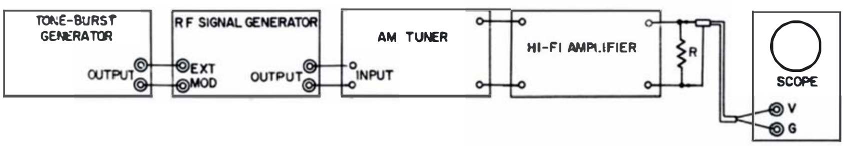


Fig. 149. Test setup.

To Test the Square-Wave Response of an AM Tuner and Hi-Fi Amplifier

Equipment: Square-wave generator (or audio oscillator and electronic switch), RF signal generator, oscilloscope, and terminating resistor.

Connections Required: Connect equipment as in Fig. 150.

Procedure: Adjust output from square-wave generator to obtain 30% modulation of the RF signal. Set output from RF signal generator for normal operation of the AM tuner. Tune generator and AM tuner to the same RF frequency. Set hi-fi amplifier for normal output. Observe square-wave pattern on scope screen.

Evaluation of Results: The square-wave reproduction of the AM tuner and hi-fi amplifier should be almost as good as the square-wave reproduction of the hi-fi amplifier by itself. If the square-wave distortion is excessive, check the AM tuner alignment.

FM tuners are often used to drive high-fidelity amplifiers; however, the foregoing tests are impractical in the average service shop because of the inavailability of true FM signal generators. Therefore, an FM tuner should be checked out as an individual unit, using a sweep generator and an oscilloscope.

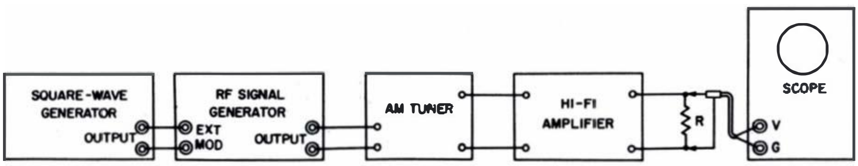


Fig. 150. Test setup.

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ABOUT THE AUTHOR

BOB MIDDLETON was born in Watsonville, Calif., in 1908. He spent his early years on a farm in the Bay region. Becoming interested in wireless in 1919, he operated a "bootleg" spark transmitter until he was old enough to become a licensed operator. In 1921, he held the state record for long-distance reception on a cats-whisker detector. Bob operated his own radio service business for a number of years and later entered design engineering. In 1948, he moved into field engineering and technical lecturing. He has become well known also for his writing on service problems and instrumentation. Bob is a senior member in the I. R. E., and his biography appears in "Who's Who in the Midwest." He has written four previous companion volumes —*101 Ways to Use Your Sweep Generator, 101 Ways to Use Your Oscilloscope, 101 Ways to Use Your VOM and VTVM,* and *101 Ways to Use Your Signal Generator*.

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