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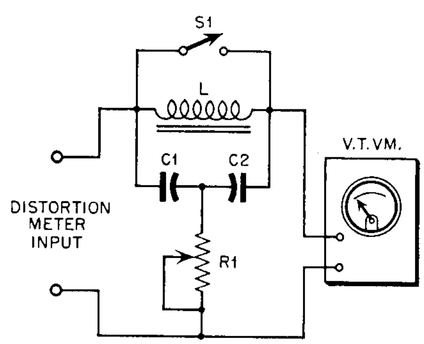
Audio Frequency Distortion Measurements

Part 2, A Practical Distortion Analyzer

By the Engineering Department, Aerovox Corporation

Part 1 of this series contained a discussion of the nature of audio frequency distortion and a survey of the methods employed in making quantitative distortion measurements on audio equipment. The present article details the design and construction of a simple and practical distortion analyzer which is a very useful adjunct to any amplifier service shop or audio high fidelity experimenters bench. The instrument is compact, easy to adjust and use, and costs little to build. Yet, the results obtained are sufficiently accurate to permit evaluation of the performance of most audio equipment and observation of the results of even minor design changes.

As was pointed out in Part 1, the simplest form of distortion meter employs a null bridge to suppress the fundamental test frequency being amplifier under test and a vacuum tube voltmeter to read the amplitude of any signals which pass unattenuated through the null bridge. If the signal input to the amplifier is a pure sine wave of frequency equal to the null frequency of the bridge, the only signals indicated by the voltmeter will



BASIC DISTORTION METER
FIG.1

be the harmonics introduced by distortion in the amplifier being tested. If the response of the voltmeter is linear, it is easy to express the total harmonic content thus indicated as a percentage of the amplifier output.

The Distortion Analyzer

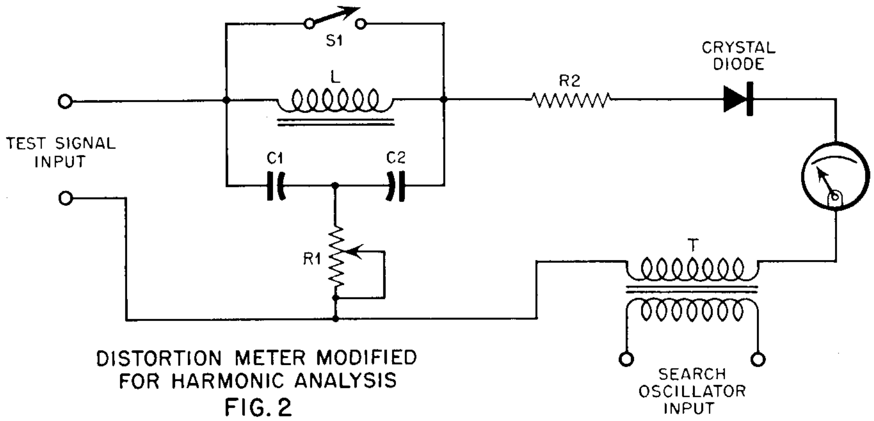
The major shortcoming of the null bridge type of distortion meter, as it is usually employed, lies in its inability to identify the order of the harmonic content indicated. It reads *total* percentage of distortion and thus may only be classed as a distortion *meter*. To be considered a distortion *analyzer,* the instrument should be capable of indentifying each harmonic component present and indicating their relative amplitudes. Commercial distortion analyzers which accomplish this are both complicated and costly. However, a simple system is available which is not appreciably more complicated than the common null bridge distortion meter, but is capable of considerablly better results. Its use is predicated upon the availability of a second audio oscillator.

The circuit of a typical null bridge distortion meter is shown in Fig. 1. The components L, C1, C2 and R1 constitute the null bridge network which suppresses the frequency at which L and the series combination of C1 and C2 are resonant, as given by:

(1)

$$\text{Null frequency } (f) = \frac{1.414}{2\pi\sqrt{LC}} \text{ cycles per sec.}$$

Where: L is the choke inductance in henries.
C = C1 = C2 is the capacitance of each unit in farads.



DISTORTION METER MODIFIED FOR HARMONIC ANALYSIS
FIG. 2

The circuit configuration will be recognized as the "bridge-T" type of network. The resistance (R1) is used to adjust the null reading to minimum. If the circuit constants are chosen properly, and distributed capacitance is minimized, virtually zero transmission will occur at the null frequency. If the null circuit "Q" is high, the null will be very sharp and nearby frequencies will be very slightly affected. The voltmeter is used to measure both total amplifier output and harmonic output by shunting out the bridge circuit with the switch (S1) during the former measurement. A vacuum tube voltmeter may be employed, or as shown by $Turner_1$, a simple crystal diode voltmeter may be used with only a slight sacrifice in accuracy.

To convert the distortion meter of Fig 1 to a distortion analyzer, the modification shown in Fig. 2 is made. An audio transformer is added to permit the insertion of a sine wave signal from a second audio oscillator. This signal is used to identify individual harmonic components present in the bridge output by the beat method. To accomplish this, the second oscillator is swept through the frequency range containing the harmonics of the fundamental test signal. Fig. 3 is a block diagram of the complete test set up. Near the frequency of each harmonic present, a "beat" will be observed in the distortion meter reading. The amplitudes of the beats are indicative of the relative magnitude of each harmonic component identified. Thus, a quantitative indication of harmonic content, as well as total harmonic percentage, is obtained.

As an example, suppose that the test frequency is 400 cycles and the distortion meter indicates a total harmonic distortion of 10% before the introduction of the "search" oscillator. If there is both second and third harmonic distortion, an amplitude beat will be observed when the second oscillator is swept through 800 and 1200 cycles. If the second harmonic predominates, the beat at 800 cycles will be greater than the one at 1200 c.p.s. in the same proportion. Knowing the total harmonic distortion, it is easy to evaluate the percentage of each harmonic component. The search oscillator frequency should be adjusted close enough to the harmonic frequency to give nearly zero beat, so that the meter needle can follow. The oscillator used for searching should be relatively free of harmonic output.

Construction Details

The practical circuit diagram of the distortion analyzer is given in Fig. 4. Since no vacuum tubes or power sources are required for its operation, the unit may be assembled in very compact form. A crackle-finish metal cabinet measuring 6"x6"x6" affords more than sufficient space to mount all components. No chassis is used; all parts are mounted on the front panel except the choke (L) and the audio transformer (T) which are supported by a sheet-metal shelf fastened to the back of the removable front panel by means of the shaft bushings of R1, R2, and S2 (Fig. 4). The dimensions of this shelf and the approximate locations of the parts mounted on it are shown in Fig. 5. The suggested front panel lay-out is shown in Fig. 6.

To assure maximum versatility, three null bridge frequencies; 400, 1000 and 5000 cycles, are provided. These frequencies are selected by substituting the proper capacitance values for C1 and C2. Capacitor switching is done with a two-circuit, three-position wafer switch. If additional or alternative test frequencies are required, the necessary capacitor values may be computed from:

$$(2) \quad C1 = C2 = \frac{1}{158 f^2} \text{ farads} \quad (\text{for 8 henry choke})$$

Where: f is the desired null frequency.

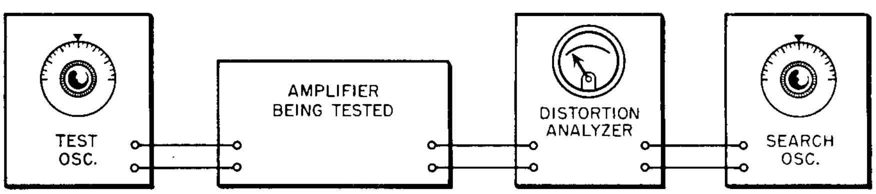
For most routine amplifier testing, the three frequencies for which values are given in Fig. 4 will be sufficient.

For effective fundamental frequency rejection with low harmonic frequency attenuation, the "Q" of the null bridge components must be high. Best quality components should be used for the resonant circuit comprising C1, C2 and 1. The choice of the choke is important since the resistance as well as the inductance of this unit is critical. The resistance of the choke will adversely affect the "Q" of the null circuit if too high.

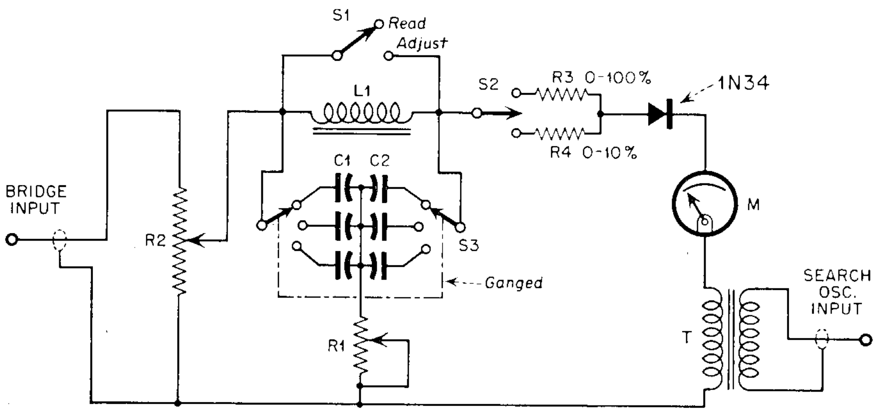
Some selection of capacitors may be necessary to arrive at any given test frequency, although for most practical purposes it is not necessary to measure distortion at exactly the frequencies specified.

The null resistor (R1) is a variable one megohm potentiometer mounted on the front panel and provided with a small knob. This control is used to adjust the null response to minimum at each of the test frequencies. The setting of R1 usually remains fixed for any given frequency.

The crystal diode voltmeter uses a 1N34 or any of the germanium crystals as a rectifier. It gives a response that is aproximately linear with input voltage if a high sensitivity meter is used. A O-100 microampere meter is ideal, since the scale calibration can be used to indicate distortion percentage directly. Otherwise, any meter requiring less than about 250 microamperes for full scale deflection may be employed. Above this current, the average crystal diode characteristic departs markedly from linearity.



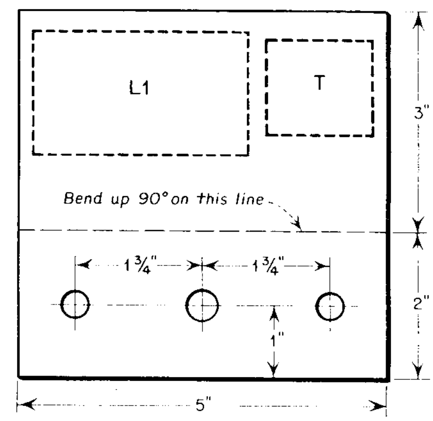
TEST SET-UP FOR DISTORTION MEASUREMENTS
FIG. 3



R1 - 1 megohm, carbon.
R2 - 1000 ohm, wire wound.
R3 - 30,000 ohms, ½ watt carbon.
R4 - 2000 ohms, ½ watt carbon. (Approx.)
S1, S2 - S.P.D.T. toggle switch. ↖See text.
S3 - 2gang, 3position wafer switch.

L1 - 8 hy. 150 ohm choke.
T - See text. M - 0-100 microamperes.
CRYSTAL - 1N34 or equivalent.
C1, C2 - 400 C.P.S. .04 µfd (Aerovox Type 489)
- 1000 C.P.S. .006 µfd (Aerovox Type 1089)
- 5000 C.P.S. .00025 µfd (Aerovox Type 1468)

PRACTICAL DISTORTION ANALYZER
FIG. 4



DETAILS OF SHELF
FIG. 5

Two meter ranges are provided to allow more accurate reading of distortion percentages. These ranges, O-100% and O-10%, are selected by switching meter multiplier resistors R3 and R4 by means of a toggle switch (S2). The multiplier resistor for the O-10% scale is selected to give full scale deflection at 1/10th the rms input voltage required to give full scale reading on the O-100% range.

The audio transformer (T) may be almost any unit of good quality which the experimenter might have available. The characteristics are not critical, since this transformer is used merely to introduce a small audio voltage from the search oscillator into the voltmeter circuit. A good 3:1 interstage audio transformer will usually be found satisfactory.

The audio input cable to the bridge circuit, as well as the external lead to the search oscillator, are run through holes in the left hand side of the metal cabinet and wired permanently to the circuit. These leads are of standard single-conductor shielded audio cable and are fitted with alligator clips at the input ends. The cabinet holes should be fitted with rubber grommets.

Using the Distortion Analyzer

The use of the instrument is relatively simple. After the construction has been completed, the operation of the null bridge circuit is tested at each of the test frequencies. To do this, the bridge input cable is connected directly to the output terminals of the test oscillator. With the toggle switch S1 in the "Adjust" position and the test oscillator and frequency selector switch set at the proper test frequency, the output of the test oscillator and the gain control (R2) are adjusted to give full scale deflection of the distortion meter. Then, when S1 is thrown to the "Read" position, the meter reading should drop to a very low value. To minimize the reading, the null resistor (R1) and the test oscillator frequency must be varied simultaneously. If the null bridge is functioning properly, the adjusted null at some frequency near the desired test frequency will be quite sharp and the meter reading will be very nearly zero.

If an incomplete null is obtained, the bridge components are faulty or the test oscillator has some harmonic output which is being indicated on the meter. The nature of this residual reading can be readily determined by the use of the search oscillator. With the distortion meter operating as above in the "Read" position, the search oscillator is connected to the audio transformer input leads and enough search signal is injected to about double the residual reading on the meter. The frequency range of the test signal and its harmonics is then explored by varying the frequency dial of the search oscillator slowly. If there is a large beat fluctuation of the meter pointer at the fundamental frequency and little at its multiples, the residual reading is caused by imperfect bridge balance. If the converse is true, the harmonic content of the test oscillator is to blame for the incomplete null. The harmonic output of the test oscillator should be carefully recorded so that it can be discounted when actual amplifier tests are being made.

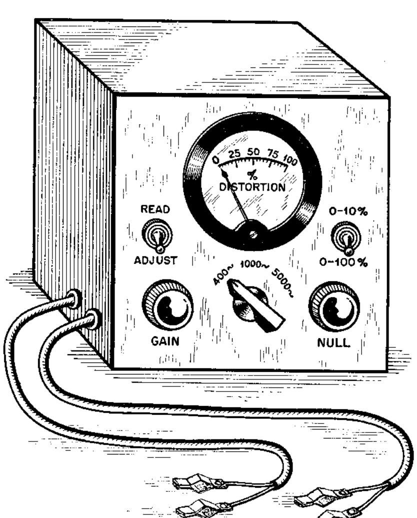


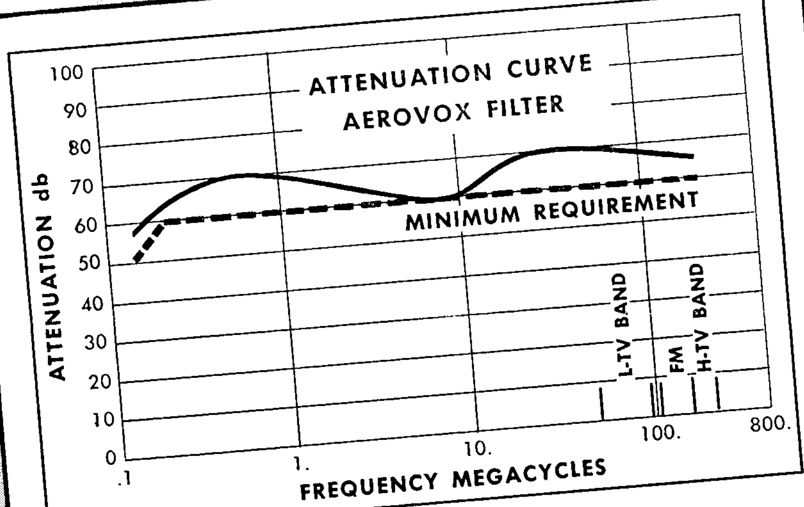
FIG. 6

In using the bridge to analyze the distortion introduced by an amplifier, the procedure followed is the same as that used above for determining the distortion content of the oscillator except that the amplifier is introduced between the test oscillator and the bridge, as shown in Fig. 3. The bridge input leads are connected directly across the speaker voice coil or other normal amplifier load. The gain of the amplifier is set to the value at which it is desired to determine the distortion. The null reading is then obtained as above and, expressed as a percentage of the full scale reading of the meter minus the residual reading, is the total distortion percentage introduced by the amplifier. The harmonic components may then be individually identified by the use of the search oscillator. Each beat noted indicated a component of that frequency (read from the search oscillator) and relative magnitude present in the output of the amplifier.

1—R. F. Turner, Radio and Television News, Nov. '48, p. 69.

Uncle Sam's latest jeep as quiet as proverbial mouse, because of AEROVOX

Interference Filters



● The chart sums it up. Note how radio interference generated by the ignition system and other electrical equipment is suppressed well in excess of requirements.

Uncle Sam's new jeep includes The Electric Auto-Lite Company's 24-volt waterproof electrical equipment. It must operate efficiently even *under water*. And radio interference must be minimized in the interests of dependable military communications.

Long hours of cooperative research and engineering were spent on this noise-suppression problem. The main considerations were filters to minimize interference originating with the voltage regulator, the generator and the ignition system. Aerovox finalized the complete answer based on the three major units here presented.

• • •

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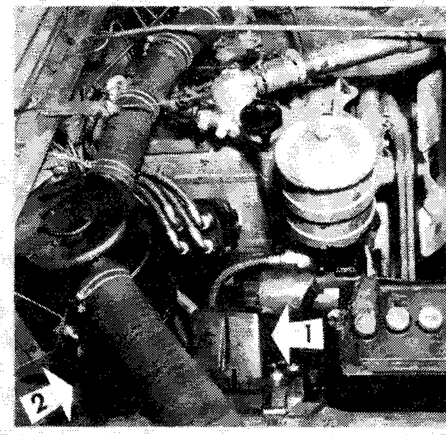
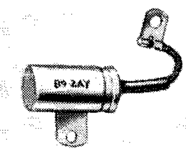
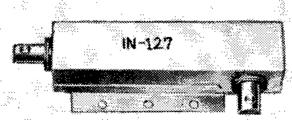
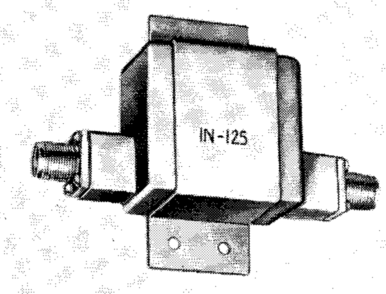




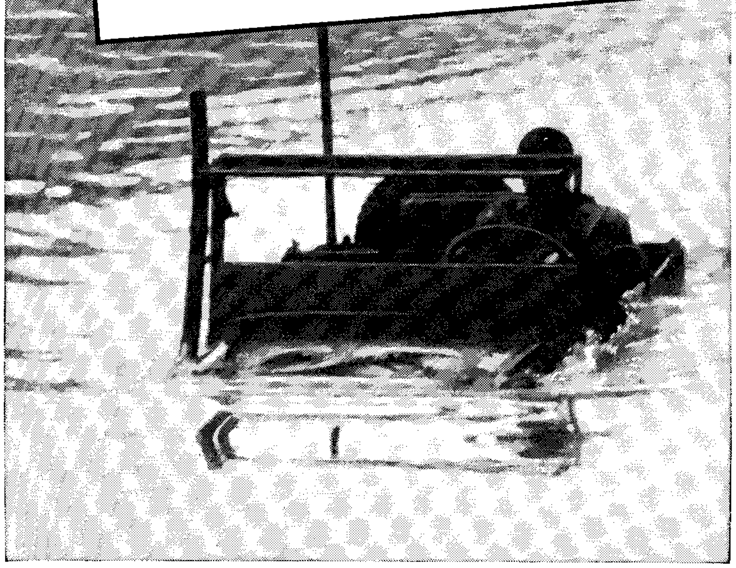
Aerovox Type 89ZAY using a metallized-paper capacitor and mounting inside voltage regulator case to work in conjunction with IN-127.



Aerovox Type IN-127 mounted inside voltage regulator (Arrow No. 1) and acting as interference eliminator for voltage regulator and generator systems.



Aerovox IN-125 which mounts on bulkhead of jeep (Arrow No. 2) and suppresses interference originating in ignition system.



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