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TB2

TECHNICAL BULLETIN

RECEIVER TESTING: Maximum Current Modulation

REALISTIC TESTING

We're always searching for a better way to measure receiver response and distortion. The reason is simple: as component and circuit design improve, we must improve test methods to match.

However, it's unrealistic to test a receiver for performance beyond the limits already imposed by other elements in the system, such as the amplifier and power supply. Our goal instead is to test under conditions and limits more like those of actual use.

The MCM (Maximum Current Modulation) test described in this bulletin incorporates those conditions and limits. What's more, it meets three other important requirements: it is strict, it is relatively simple, and it is practical for incoming inspection testing.

MAXIMUM CURRENT MODULATION DEFINED

The term Maximum Current Modulation itself describes a condition in which the peak current value of the AC signal equals the value of the DC bias current passing through the receiver, but does not exceed it. This peak value is the maximum current the receiver could experience in an actual hearing aid without the *amplifier* distorting excessively.[1]

Since nonlinear distortion in a receiver is directly related to current, a test with this signal should then reveal the maximum distortion the receiver (with the acoustic load used in the test) would add to total hearing aid distortion. Therefore, a receiver may be considered distortion-free if it linearly reproduces an AC signal limited to the MCM value corresponding to the desired DC bias current. Figure 1 shows a simplified circuit for such a test.

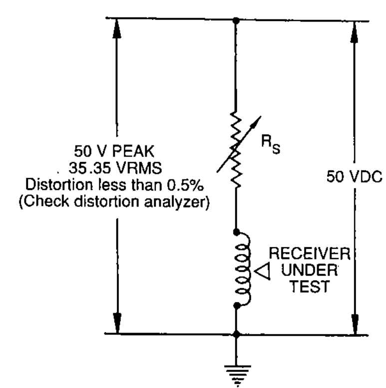

FIGURE 1

[1] See Appendix

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DEVELOPMENT OF A TYPICAL MCM TEST CIRCUIT

In this circuit the AC and DC sections are balanced. The AC source signal - checked with a distortion analyzer to make sure it is within the limits shown - should be adjusted so its *peak* voltage equals the DC voltage. Then once each cycle the current in the receiver leg of the circuit will vary from zero to twice the average value (see Figure 2).

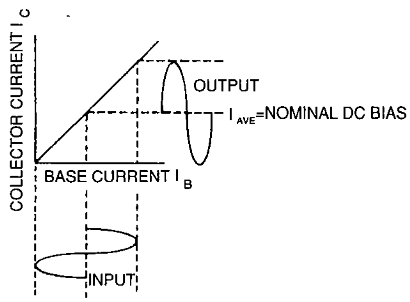

FIGURE 2

To approximate the transistor circuit's high source impedance compared to the receiver's, resistance R_s should be large - at least 20 times the receiver's maximum impedance in the frequency range under study[3]. This will also impose constant-current conditions, so-called because changes in receiver impedance like those in Figure 3 will not noticeably affect the signal current[4].

CIRCUIT DETAILS

Figure 4 shows the test circuit in more detail. The capacitor and choke isolate the AC and DC sources from each other; resistor R_1 balances the DC resistance of the choke (R_L) so that, if AC peak voltage and DC voltage are equal at their respective sources, they will be equal at junction "A" (the capacitor is chosen so it will have little effect on the AC signal).

The peak value of sinusoidal AC can be measured by a voltmeter placed across resistor R_T. The value (1 x $\sqrt{2}$, or 1.414, ohms) of this resistor permits us to read this peak current direct with an RMS-indicating voltmeter. Its location in the circuit makes this metering easier (R_T and the meter have a common ground with the AC and DC sources) and, since it has a low value, it will not affect measurements.

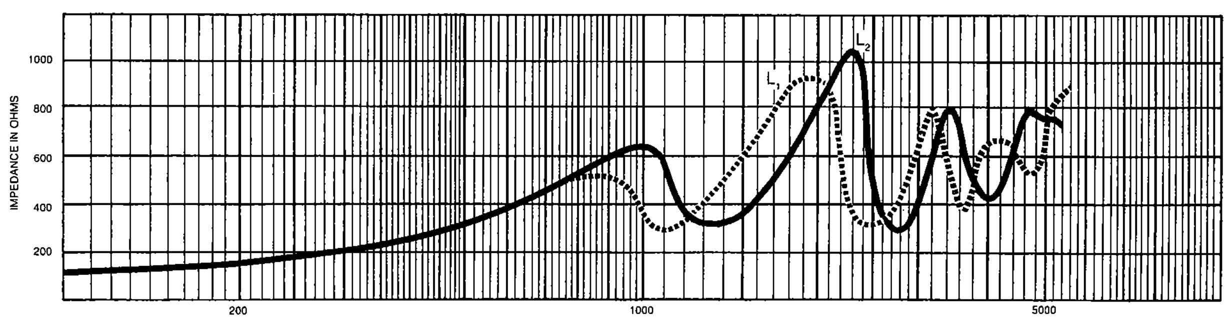

FIGURE 3 Variation of impedance with frequency. For 2 different lengths of No. 13 tubing ($L_1 = 1.5L_2$) coupling the receiver to a 2cc cavity (ASA S3.3 1960 Type HA2; IEC Standard 126, Figure 1).

[2] If the signal is a low-distortion sinusoid, we can assume the peak voltage to be 1.414 times the RMS value indicated on a standard meter.

[3] By contrast, a Maximum Available Power (ASA Constant Available Power) test requires the source and load impedance be equal, a rarity in silicon-transistor hearing aid circuits.

[4] Notice in Figure 3 that the *maximum impedance could be double the nominal value at 1000 Hertz;* also, a change in coupling tube length would change both values.

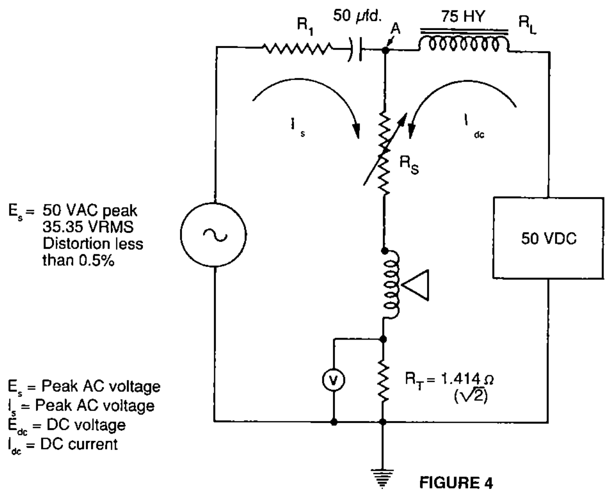

FIGURE 4

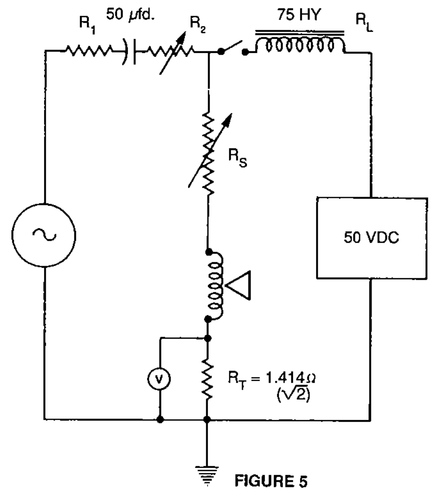

FIGURE 5

We have already mentioned that R_s should be at least 20 times the maximum receiver impedance. In practice, the ratio is usually even greater because the 50-volt power supplies dictate a value for R_s between 25K and 75K ohms to keep currents reasonable. Thus, in calculating current, the receiver impedance and DC resistance (as well as R_T) can be neglected without any great loss in accuracy:

$$R_L + R_s = \frac{E_{dc}}{I_{dc}} \qquad R_1 + R_s = \frac{E_s}{I_s}$$

Since R_1 and R_L are equal and E_s and E_{dc} are equal, it can be seen that, no matter what value we assign to R_s to adjust current, the AC peak will remain equal to the DC - the criterion for Maximum Current Modulation. For flexibility, you may wish to add other items to the test circuit, as in Figure 5. Here the switch allows us to cut off DC entirely to test centre-tapped or other zero-bias receivers. The variable resistor R_2 permits adjustment of the AC signal independently of DC bias. If desired, we can then reduce the AC signal below MCM conditions.

CONCLUSIONS

The MCM test yields upper-limit distortion data. At the same time, it duplicates the typical constraints of a hearing aid in the frequencies where distortion tends to be highest[5]. It is therefore both strict and realistic.

And, as the schematics show, the circuit is relatively uncomplicated. Finally, since the circuit is good for sensitivity measurements, too, it is practical for production-line use.

To the extent random sound does not produce a pure sinusoidal wave form, even the MCM test signal is artifical. Even though it imposes a severe test condition, this test signal, too may someday have to be refined to take into account the transient characteristics of everyday sounds. In the meantime, however, it is useful to us to the extent it meets the above critertia of strictness, realism, simplicity, and practicality.

[5] See Appendix.

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APPENDIX

This supplement explains in greater detail the philosophy behind MCM testing.

CONDITIONS AND LIMITS OF USE

How is the receiver used in a hearing aid today? In the typical single-ended circuit, it is in the collector leg of the output stage of a transistor amplifier. Supply voltage is about 1.4 volts DC, the average current some value between 0.3 and 2.0 ma. Under these conditions, there are limits on both the current and voltage signals the amplifier can supply to the receiver.

The collector current is modulated through transistor action. This modulation cannot exceed 100%: the current cannot be less than zero. Therefore, the maximum *undistorted* signal the amplifier can supply is one with a peak AC value equal to the quiescent, or average, collector current (Figure 2). The latter is set by the DC bias. If the peak signal exceeds it, clipping will occur on the negative half cycle (Figure 6).

A similar limit applies to the voltage across the transistor: it may not drop below zero. In fact, the limit is slightly above zero, at the saturation voltage. Further, the average current flowing through the DC resistance of the receiver coil causes an additional voltage drop. These two factors, saturation voltage and voltage loss in the coil, prevent the signal from equalling the battery voltage. Thus, the maximum excursion of the voltage signal is governed by the equation:

$$E_s = E_B - E_{sat} - I_cR$$

where E_S = the peak value of the signal
E_B = battery voltage
E_{sat} = collector saturation voltage
I_C = average collector current = DC bias
R = DC resistance for the receiver coil

If the supply voltage is assumed to be 1.4 volts and the saturation voltage 0.2 volts, the equation can be reduced to:

$$E_S = 1.2 - I_CR$$

Signal current, then, is limited by the average collector current, signal voltage by that factor and the coil DC resistance. In either case, for a given receiver coil resistance, *the maximum undistorted signal the amplifier can supply is related to the DC bias.*

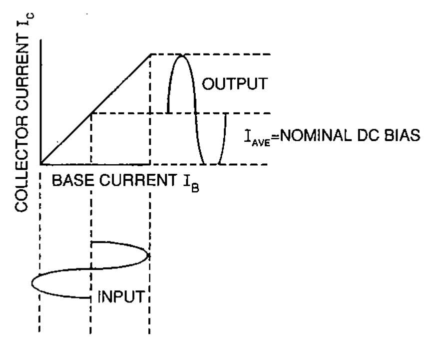

FIGURE 6

WHICH TEST TO CHOOSE?

The most stringent test would seem to be one conducted at both the voltage and current limits. However, except at a few discrete frequencies, these limits will not be reached simultaneously. This is because current and voltage are related by receiver impedance (that is, E = I Z), which depends on both frequency and the acoustic load (refer back to Figure 3).

Further, the receiver is a current-sensitive device. Therefore, its distortion is closely related to the amount of current flowing through the winding. Usually maximum distortion will then be noted at the highest current signal levels.

When will these high currents occur? As frequency increases, the receiver impedance generally increases (again see Figure 3): in many circuits the voltage limit will be reached before 100% current modulation is achieved. However, at lower frequencies, the impedance is less and the full current modulation can be applied before the voltage limit is reached.

In summary:

1. The maximum distortion in the receiver will usually occur at the highest current signal levels.
2. The highest undistorted signal current the amplifier can provide occurs at the lower frequencies.
3. The limit on this signal is set by the average current, or DC bias.

It follows that a strict, yet realistic test would include an AC signal with a peak current value equal to, but not exceeding, the DC bias current - hence the term Maximum Current Modulation.