Measuring and Matching Tape Playback and Microphone Preamplifiers

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Optimum performance from a tape playback head and a microphone are ensured by measuring their response through the amplifier. Suitable equalizer circuits can then be introduced.

1. TAPE PLAYBACK CHARACTERISTICS

THE FREQUENCY RESPONSE characteristics of the tape playback head are similar to those of the constant-velocity phonograph cartridge. Thus, if a tape were magnetized equally at all frequencies and played on a tape machine, the output from the playback head would rise linearly with freqnency at the rate of 6 db per octave. This rise would continue to the frequency limits of the head if several factors didn't intervene to upset this convenient state of affairs.

In the recording process, the degree of tape magnetization theoretically is proportional to the current passing through the recording head. At high frequencies this characteristic is altered because of the close proximity of the tiny magnets which make up the recorded tape. The opposite poles adjacent to each other "cancel" some of the magnets.

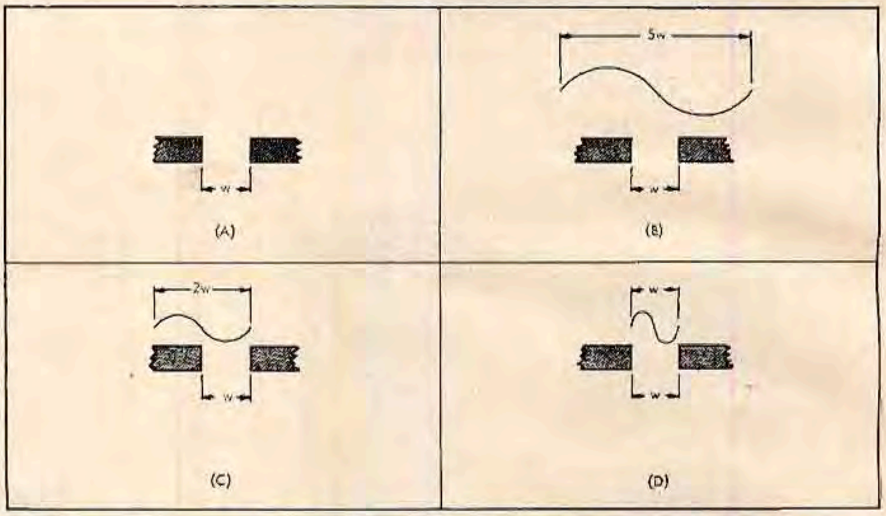

Fig. 1. Effect of gap width on current through playback head: (A) Head gap is **w**; (B) a portion of the cycle is sampled; (C) when wavelength is twice gap width, half the cycle is sampled at any one moment; (D) when wavelength is equal to gap width, output is zero.

Another loss is due to insufficient depth in the recording layer. The frequencies at the treble end of the spectrum are recorded at the surface of the magnetic material while the lower frequencies penetrate the recording layer to a greater degree.

It can also be demonstrated that the recording bias current has a definite relationship to the recorded signal appearing on the tape. Excessive current tends to decrease the high frequencies more than it does the low end of the band. On the other hand insufficient bias will cause excessive distortion. A compromise between the two extremes must be chosen to make a good recording.

Deviation from a standard relationship (for the particular head) between recorded flux and audio signal power fed to the record head, can be related to power losses in the head. This is particularly true at high frequencies. The standard ratio assumes that equal magnetic fields are set up for equal head currents, at all frequencies. This is not the case. There is more power dissipated in the head at high frequencies than at low frequencies. As a result, less high-frequency power remains to magnetize the tape.

Although high-frequency losses are of primary significance in the recording process, losses at both extremes of the audio band are important in playback.

If the opposing magnetic poles, which result when a recording is made on tape, lie near the head gap, the output will be high. At very low frequencies, because of the large wavelengths, the poles may be far from the head gap and the output will tend to decrease.

The width of the gap in the playback head is significant for high-frequency response. This can be explained with the help of *Fig.* 1.

Assume that tape passes over a gap of width w. If the recorded wavelength is greater than w, let us say $5w$, the gap sees only a portion of the recorded waveshape at any one instant of time as the tape passes over the head. Each portion sets up a different current through the head coil until the entire sine wave is traced. As the wavelength is decreased, a greater portion of the cycle appears across the gap at any one instant. When the wavelength recorded on the tape is twice the gap width, the current through the head represents the average[1] current of a half cycle or $2I_{peak}/\pi$. When the gap width is equal to a complete cycle, the average output current in the playhead is zero. The output increases again, with frequency, after the null. At the null frequency, the gap width equals the recorded wavelength.

[1] The average current of a curve is equal to the area under the curve divided by the length along the X (or w) axis. Thus, for the sine wave function $i = I_p \sin\theta$, the area under the curve for a half cycle is $\int_0^\pi I_p \sin\theta \, d\theta$, and the distance along the x axis is $\pi - 0$. The equation for the average area under half a sine wave is

$$\frac{1}{\pi} I_p \int_0^\pi \sin\theta \, d\theta = \left[\frac{I_p}{\pi}(-\cos\theta)\right]_0^\pi = \frac{I_p}{\pi}(1+1) = \frac{2I_p}{\pi}$$

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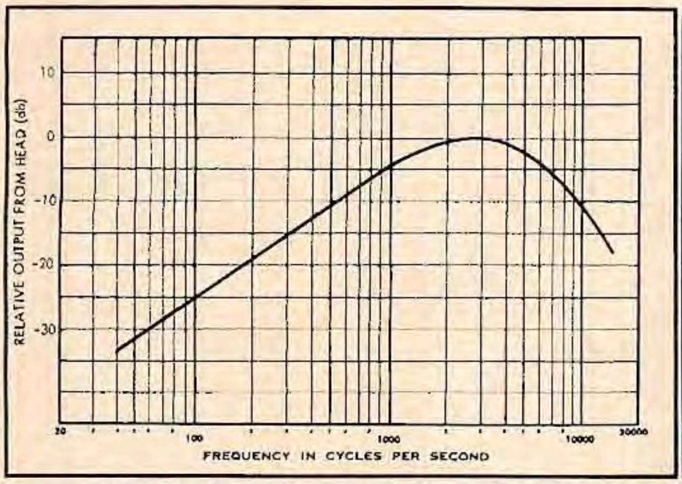

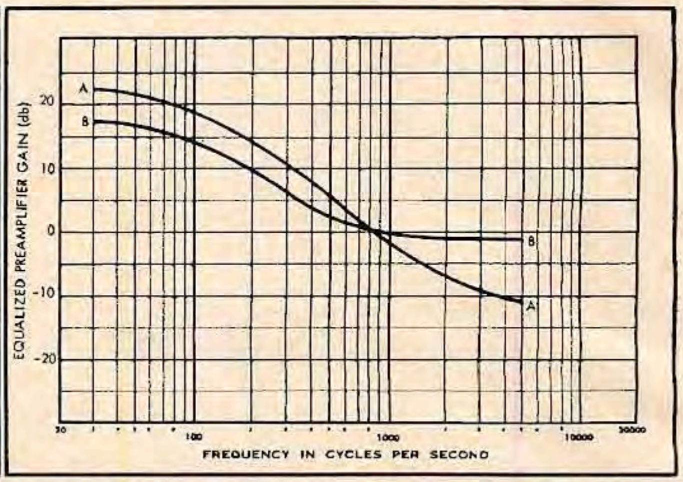

Fig. 2. (left) Output from playback head reproducing a constant-current recording at 7½ ips. Gap width is 0.0002-in. although effective gap is greater. Fig. 3. (right) Standard preamplifier equalization curves: A-A is the curve for 7½ ips; B-B is the curve for 3¾ ips.

This leads to two commonly assumed factors. First, the usable wavelength is double the gap width of the playback head, for only then is there sufficient compensateable output from the head. Second, for the same gap width, the usable upper frequency is less at slow speeds than at high speeds, because the recorded wavelength, *w*, is reached at a lower frequency when recording at slow speeds than at high speeds.

Finally, the usable bandwidth can be calculated from the gap width. The null in output is at the frequency when the recorded wavelength is equal to the gap width. The recorded wavelength can be derived from the equation

$$\lambda = vt = \frac{v}{f} \qquad Eq.\ (1)$$

where λ is the wavelength, v is the velocity of the tape, t is the period or the time duration of one cycle, and f is the frequency in cycles per second.

The null frequency is then:

$$f = \frac{v}{\lambda} \qquad Eq.\ (2)$$

As an example, use a velocity of 3.75 ips and a wavelength of 0.0001 inches per cycle. The wavelength is numerically equal to the gap width. Substituting these into *Eq. (2)* yields:

$$f = \frac{3.75 \text{ ips}}{0.0001 \text{ ips}} = 37{,}500 \text{ cps.}$$

The usuable upper limit of the reproducible band is 37,500/2 or about 18,000 cps. This limit is seldom realized for the effective gap is usually greater than the mechanical gap. The imperfections at the edge of the gap across which the tape rides is a major factor in producing this discrepancy. A typical playback curve resulting from a constant-current recording is shown in *Fig. 2*. The roll-off frequency is a function of the gap width, tape speed, and tape resolution characteristics.

To produce a flat playback response from a constant-current recording, the playback preamplifiers are equalized in accordance with the curves shown in *Fig. 3*, accepted as a standard by the industry. In order to determine the resultant frequency response due to the preamplifier and the playback head combination, the curve in *Fig. 2* (head characteristics) must be added to one of the equalization curves in *Fig. 3*. An example of this procedure at the 7½-ips speed is shown in *Fig. 4*.

Figure 4 indicates that there is insufficient boost at the high and low frequencies of the audible band. This should be compensated for in the recording process and thus is of no interest here.

The preamplifier must provide the characteristic shown in *Fig. 3*. The test setup shown in *Fig. 5* can be used in the testing procedure. For a discussion of the test circuit and the correct test procedure, read "Measuring and Matching the Phono Equalization Curve" in August AUDIO.

2. MICROPHONE CHARACTERISTICS AND REPRODUCTION

Piezoelectric microphones used in high fidelity applications, usually fall into two groups. The first group utilizes crystal or ceramic elements which operate on the piezoelectric principle. They are designed so that the resonant frequency is above the audible range. The output voltage will then be substantially constant, for a uniformly applied signal at all frequencies. Equalizing networks, similar to the type used with constant-amplitude phonograph cartridges, can be used to flatten the response as required over the audio spectrum.

The equivalent circuit of the crystal and ceramic microphone is a voltage source in series with a capacitor which should work into an essentially resistive load at the microphone preamplifier. All this is shown in *Fig. 6*.

The equation for the circuit in *Fig. 6* is:

$$\frac{e_{out}}{e_{in}} = \frac{R}{R + \frac{1}{j\omega C}} = \frac{jR\omega C}{jR\omega C + 1} \qquad Eq.\ (3)$$

The numerator in the equation indicates that the output for a zero frequency (d.c.) input is zero. The 3-db rolloff point is determined by the denominator when

$$jR\omega C = j \text{ or } f_1 = \frac{1}{2\pi RC} \qquad Eq.\ (4)$$

The curve described by this equation is shown in *Fig. 7*.

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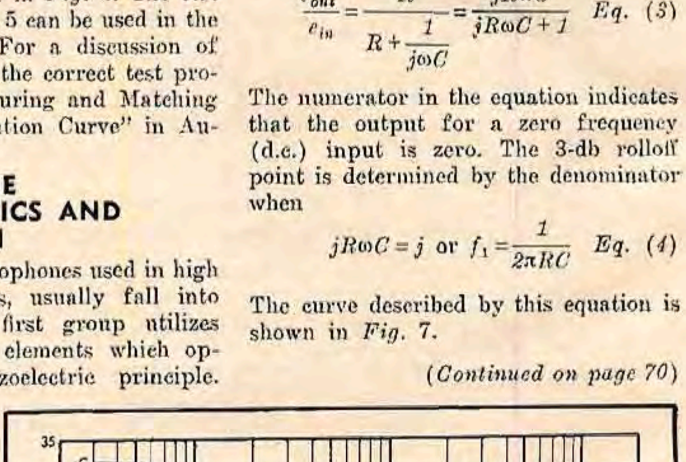

Fig. 4. Playback curves at 7½ ips; A-A from constant-current recording; B-B is result when A-A is added to C-C; C-C equalization for 7½ ips.

MICROPHONE PREAMPLIFIERS

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At the frequency f_1, the output from the microphone is down 3 db. At $2f_1$, the output is down 1 db, while at $4f_1$, the output may be considered as not having dropped off at all. The proper procedure for choosing f_1 is to select the lowest frequency which must be reproduced without any rolloff, consistent with the quality of the microphone used. This frequency is $4f_1$. The frequency f_1 in *Eq.* (4) is ¼ of the lowest frequency requiring a nominally flat amplification. Substitute this value for f_1 into *Eq.* (2), as well as the capacitance of the microphone, *C*, and solve for the resistor *R*. (The capacitance of crystal microphones varies from 500 pf to 15,000 pf.) The exact value should be obtained from the manufacturer of the particular microphone in question. If the actual value cannot be obtained from the manufacturer, assume it to be 500 pf.

In the test procedure, use the circuit shown in *Fig.* 5. Insert a capacitor, equal in value to the equivalent microphone capacitance, in series with the lead connecting the signal generator to the preamplifier.

Dynamic. The second popular type of microphone is the moving coil, or dynamic, variety. Here, a diaphragm is set in motion by the air pressure emanating from a sound signal. A coil is attached to this diaphragm. This coil moves in a strong magnetic field causing current to be generated in its winding.

The output from this microphone normally would rise with frequency for a constant signal pressure. Careful and proper choice of the mechanical resonant frequency can provide an output uniform with frequency over most of the audible spectrum.

The preamplifier used with each category of microphone should be characterized by a uniform frequency response. Because few microphones can reproduce the extremes of the band, and in the interest of stability, many amplifiers will roll off the upper and lower ends of the spectrum. It is not uncommon to find that 50 and 10,000 cps in one amplifier, or 40 and 15,000 cps in a second amplifier, are 3 db down from the maximum output level.

The procedure for testing microphone preamplifiers varies only slightly from that performed for tape-head or phonograph-cartridge units. In the AUX position, the amplifier is adjusted to perform at its most linear frequency capabilities. The switch is then thrown to the lower output PHONO, TAPE HEAD, and MIC positions. Adjust the level control to about 5 db below the maximum undistorted output at 1000 cps. Proceed to check the relative gain at all other frequencies, using this point as the reference level.

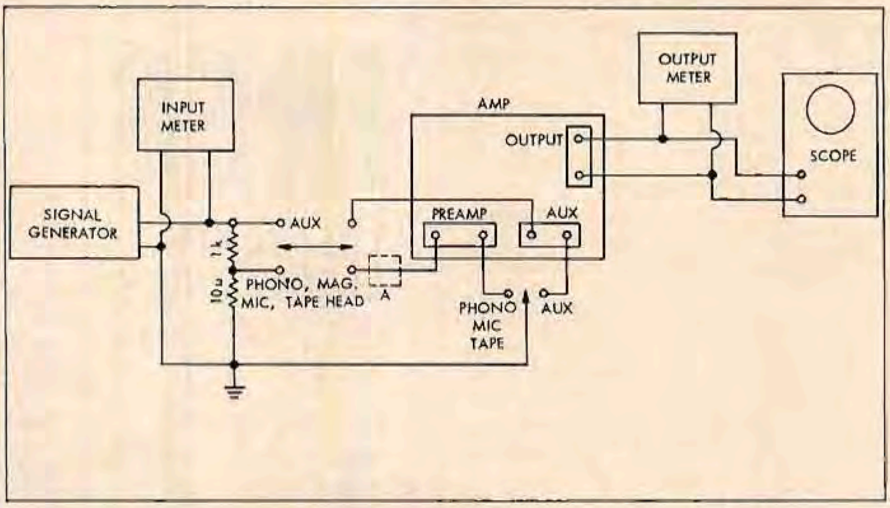

Fig. 5. Setup for measuring phono, microphone, and tape head equalization curves. Transducer is inserted at "A" when it is used in the test circuit.

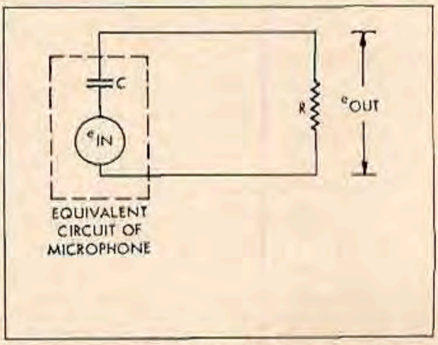

Fig. 6. Equivalent circuit of a ceramic microphone working into a resistive load.

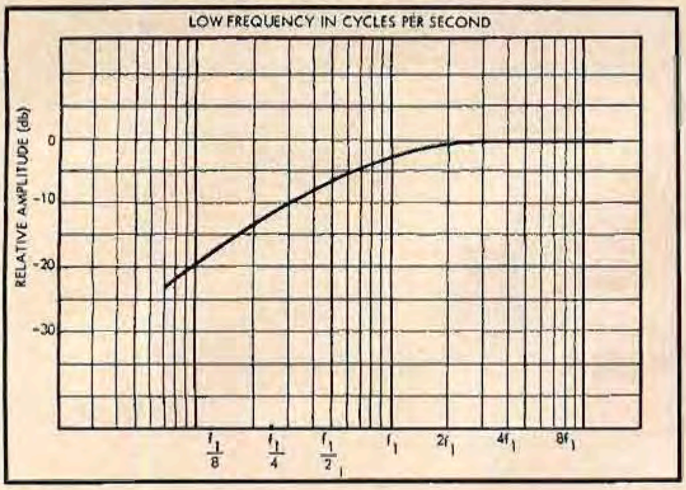

Fig. 7. Response of circuit shown in Fig. 6.

Precise Testing

Just as in the case of the constant-velocity phonograph cartridge, the tape head and dynamic microphone used should be included as an integral component in the test setup. This would take into account the effect of the inductance of these components as well as the effect of the input inpedance of the preamplifier. However, several precautions must be taken to make valid readings (refer to *Fig.* 5):

1. The resistor connected to ground in the divider network at the signal generator, must be small in value. It must be negligible compared to the impendance of the transducers under test.
2. The resistors in the divider network must be non-inductive.
3. The leads from the generator should be of the low-capacitance shielded type.
4. The transducer must be connected in series with the "hot" lead from the generator.
5. The transducer must be shielded so that it does not pick up stray electrical or acoustical signals.
6. The signals fed to the preamplifier through the cartridge, tape head, or microphone must be of the order of magnitude of the signal normally expected out of the particular transducer involved.

Isolation between the signal source and the transducer may be difficult to accomplish. Phono cartridges and tape heads should be placed in magnetically shielded boxes. Microphones should be housed in acoustically as well as magnetically shielded containers. The leads from these transducers should be shielded from stray field pickup.

One further precaution. The divider network should be at the generator. Use 3 feet of stretched shielded lead to connect the generator to the transducer. This will maintain the signal in the shielded lead at a low level, minimizing the probability of stray fields being set up and induced into the transducer. Placing the transducer 3 feet away from the signal generator minimizes direct induction from the generator into the transducer.

The importance of the transducer in the test circuit cannot be overemphasized. In *Fig.* 8, note the different curves resulting from the test made on the transistorized playback preamplifier used in the EICO model RP100 tape deck. Note the difference in the curves with and without the playback head in the test setup. The curve adheres closely to the standard when the head is used in the more accurate method of testing, just discussed. Æ

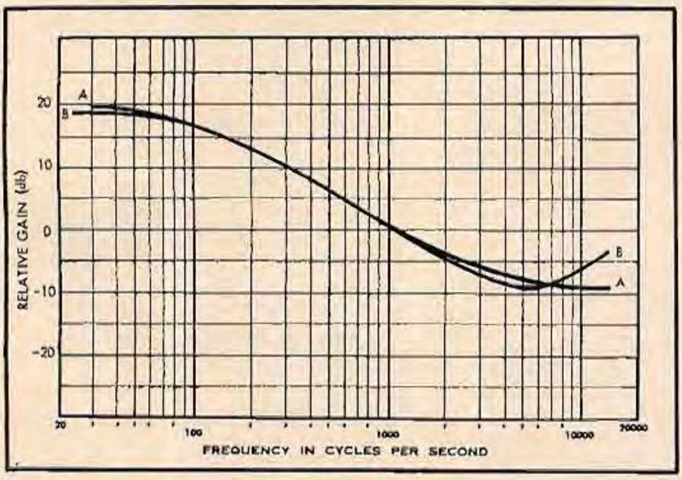

Fig. 8. Response of circuit shown in Fig. 5: A-A with head in setup and; B-B without head in setup. Notice how much closer curve with head approaches standard curve.