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STABILITY OF AMPLIFIER SYSTEMS CONNECTED TO THE BL MICROPHONE

Each of the BL-series microphones requires a biasing voltage. Since the voltage is usually supplied by connection to the amplifier power supply, the microphone power supply regulation requirements must be considered in the design of the amplifier system to avoid oscillations and other undesired side effects. The problems of stability in using the BL microphone are not new but are a repetition of the old problems of biasing a high gain transistor amplifier. It is necessary to remember that the supply regulation fluctuations can reach the amplifier input via the microphone.

In applying the BL microphone to the hearing aid amplifier, the problem can be divided into two fairly distinct classes: (1) Amplifiers containing an odd number of inverting stages, and (2) Amplifiers containing an even number of inverting stages (disregarding emitter follower, Darlington, or other non-inverting stages in each case).

Class 1: THE AMPLIFIER WITH AN ODD NUMBER OF STAGES is the simplest application because in this configuration the feedback that passes through the microphone produces degeneration in the center of the passband. Unless it contains an excessive number of coupling capacitors or is used at a very high gain, the amplifier will usually be stable. It will suffer a loss in gain as the internal resistance of the battery increases near the end of its life. This effect can be minimized by the use of a decoupling network in the supply lead to the microphone. We recommend, to prevent excessive loss in supply voltage to the microphone, that the decoupling resistor not exceed 2,000 ohms. The value of the bypassing capacitor will set the frequency above which the degeneration is to be eliminated. Thus, as battery resistance increases, the sensitivity below the frequency determined by the decoupling network will decrease.

Figure 1 shows an experiment which was run with a moderate gain, 3-stage amplifier hearing aid using a BL microphone, a BK receiver, and a battery with a 10 ohm internal resistance. The decoupling network consisted of a 2000 ohm resistor in series with the microphone, and a range of values of capacitance shunting the microphone bias terminals. The decoupling capacitance was varied from zero microfarad through 1.5 microfarad. Then, the decoupling network was removed, and the BL microphone was biased with a separate battery of equivalent terminal voltage; this simulated an ideally decoupled power supply. It is to be noted that increasing the value of the decoupling capacitance maintained the sensitivity to a lower frequency.

Other than spurious difficulties (such as mechanical vibration transmission, acoustic leakage between the receiver and the microphone, or inadvertent "common path" coupling in the wiring), the principal cause of instability in this class of circuit is apt to be excessive phase shift introduced by series coupling capacitiors in the amplifier. This can normally be controlled by not having more than two interstage coupling capacitors. Regardless of the number of coupling capacitors, however, the amplifier will be stable if the phase shift stays under 180 degrees until the loop gain due to power supply impedance feedback falls below unity. In practice, this means that only one coupling capacitor should be used to provide the basic low frequency rolloff: all other coupling capacitors should be large enough so they are unimportant (i.e., produce negligible phase shift) until the frequency is reached at which the loop gain falls below unity. The other coupling capacitors can then be used to further limit the low frequency response.

Class 2: THE AMPLIFIER WITH AN EVEN NUMBER OF STAGES is a more critical problem in that the feedback caused by battery impedance is positive and tends to produce oscillation. To assure stability, the product of amplifier transconductance (G_a), the source resistance of the battery (R_b), and the attenuation in the microphone (A_m) must be less than unity: $G_a R_b A_m < 1$. When the amplifier gain is appreciable, it may be necessary to increase the microphone attenuation in the amplifier passband

TECHNICAL BULLETIN

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to obtain stability. Since decoupling by a resistor-capacitor combination will become ineffective at a low enough frequency, it is necessary to deliberately decrease the amplifier gain to a safe value at and below this low frequency. This should be done by selecting one coupling capacitor to produce the needed low frequency rolloff and providing generous enough capacity in any others so that they cannot contribute a significant amount of phase shift in the frequency region where the stability is still in doubt.

The frequency responses shown in Figure 2 illustrate the effect of using too small a decoupling capacitor for the value of the dominant interstage coupling capacitor. Excessive sensitivity at a low frequency can result. The same effect is illustrated in Figure 3 where amplifier gain control has been varied on a similar set-up that has insufficient decoupling for use at the higher gain settings. With larger values of coupling and decoupling capacitors, this can be at a very low frequency (in the region of a few Hertz). The circuit values chosen for illustration place the effect within the audible band. In practice, the response anomalies may occur at very low frequencies where the effect is more likely to result from acceleration rather than acoustic signals.

The microphone output impedance and the attenuation of power supply modulation are constant and without appreciable phase shift throughout most of the audio frequency range. However, at low frequencies (between 1 and 10 Hertz), there can be a phase shift in the attenuation of as much as 60° lead. This phase shift, like the attenuation, is dependent on the internal amplifier and the circuit adjustment necessary to standardize the mid-band performance of the microphone. As frequency is lowered through this range, the output impedance of the microphone will decrease, and the attenuation of the power supply feed-through signal will increase. The two effects are related, and those devices exhibiting the higher phase shifts will exhibit greater increases of attenuation and lower very-low-frequency output impedance. The additional very-low-frequency attenuation may be only a few dB or as much as 20dB. Most devices will exhibit phase shifts and attenuations less than the above extremes.

In the attenuation transition range, the internal low frequency phase shift is in the same direction as that due to the use of an additional coupling capacitor.

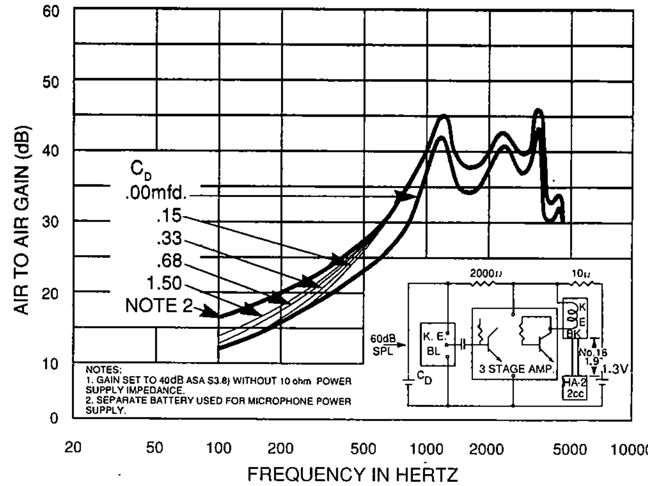

FIGURE 1

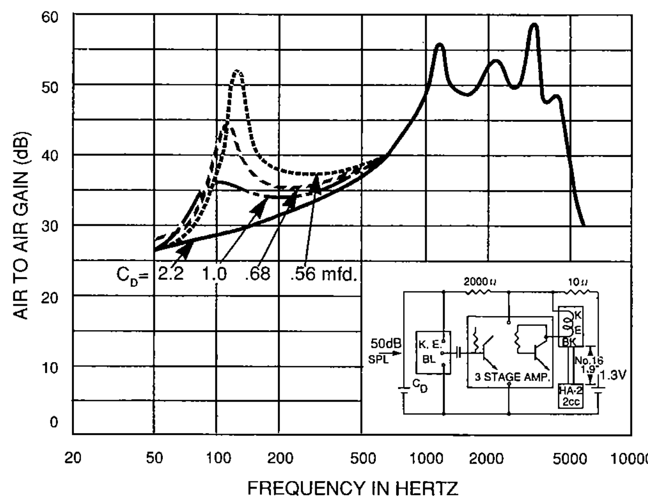

FIGURE 2

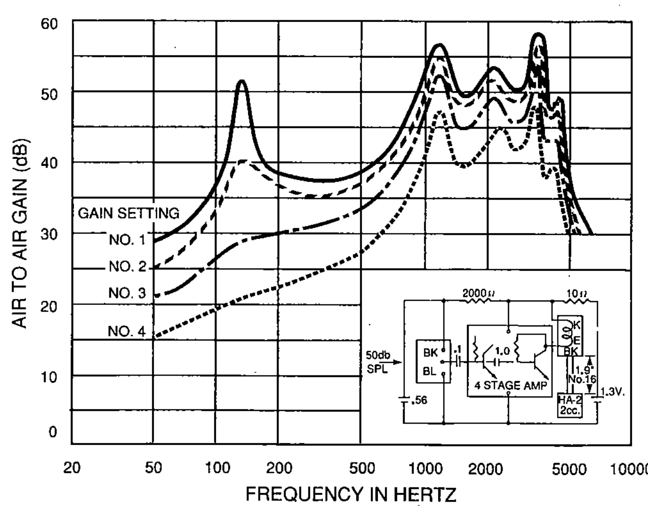

FIGURE 3