Feedback and Loudspeaker Damping

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The author proposes a solution to the problem of obtaining a feedback signal which is equivalent to the movement-generated e.m.f. of a speaker voice coil.

THE RELATIVELY RECENT articles on positive current feedback used to improve loudspeaker damping have, to this reader, been most engrossing. In spite of studies made of the articles and arguments on this subject he has, until quite recently, felt much in the dark when it came to feeling able to claim much of an opinion of his own on the relative merits of such a system. It seemed that such a subject should be resolved into simpler contradictions than any presented so far in order to make one feel he has made a wise choice of one opinion or another.

This need has led to this attempt to reduce the subject into simpler terms by digging into the fundamental aspects of the subject. The author feels that the analysis which is here presented can show some things not apparent in foregoing discussions, and finally may offer amends to those who think they disagree, as well as to make some proposals that the engineers more actively engaged may find promising.

According to Lenz's law, the voltage induced in a coil due to its passage through a magnetic field is always of a polarity such as to produce a current which would oppose the motion. In other words, an e.m.f. due to coil motion in a field tends to stop the motion. This presumes, however, a closed circuit at the coil ends, for this e.m.f. can only act if it can act to cause or influence current through the coil. When such a coil is a voice-coil there is always such a closed circuit existing. The path is around through the windings of the output transformer secondary. This closed circuit can nearly constitute a short-circuit for the coil, permitting much current to flow with just a small movement-generated coil e.m.f. The more current which flows as a result of this e.m.f. the better will be the dynamic braking of the movement, that is, the quicker will the movement cease. But even with a short-circuited coil moving in a magnetic field the cuurrent through it is definitely limited. It is limited by the resistance of the coil itself. A method to overcome this limitation and further enhance the dynamic braking action is most desirable. Such a method, to be successful, would have to permit a greater current flow than a short-circuited arrangement would allow. At first any such method might seem impossible for it would seem that nothing could allow more current than a short circuit. But on second thought it should be realized that a second source of voltage in series with the voice-coil could be provided to increase the current above what simply a short-circuited voice-coil would allow. This suggests a circuit employing as a second source of voltage one greater but proportional to the movement-generated e.m.f. and in phase with it having also a lower source impedance, as in *Fig.* 1. So far we have spoken only of movement-generated voltages. In the case of a loudspeaker, where it is voice-coil current which causes the motion in the first place, movement-generated e.m.f. is still present and acts to oppose the voice-coil current. In this way it influences the actual current and always acts to stop the motion the same as if some physical force was causing the motion. However, generally under these circumstances the movement-generated e.m.f. itself causes no current to flow. It only acts to influence the voice-coil current which is moving the voice-coil, by subtracting from the voltage causing it. This is true all the time except during "hangover" periods. During these periods the physical forces of inertia or suspension compliance cause the movement-generated e.m.f. to exceed the driving voltage and so cause its own reverse current to flow. Notice here that this is a "reverse current," one of opposite polarity to that originally causing the motion. This reverse current then will act on its own and damp the motion and so limit the hangover effect. Since positive feedback—whether voltage feedback or current feedback—tends to increase the output signal, at this time if positive current feedback were introduced it would increase the current limiting the hangover effect so as to squelch it quicker.

From this the main point may be apparent but it is simply that positive current feedback does not oppose voice-coil movement until the movement-generated e.m.f. exceeds the driving voltage and produces a reverse current. At this time there is a phase reversal which, in effect, changes positive feedback to negative feedback. If this point is not made clear there is yet much room for controversy. It should be noted that the comparison was said to be only an ***effect*** similar to inverse feedback. The e.m.f. generated by a coil moving in a magnetic field *is* inverse feedback. Any voltage which aids that voltage is, with regards to it, a positive feedback voltage, but with regards to the total effect it is a negative feedback voltage. There is a good comparison in the rather familiar circuit of an amplifier using a positive feedback loop connected to the cathode end of an unbypassed cathode resistor. The feedback voltage is definitely positive with respect to the signal voltage appearing across the cathode resistor, but just as definitely negative with respect to the over-all effect.

But the story doesn't end here. To some, the advantage of improved damping during hangover periods will be thought to be too highly paid for by the inherent disadvantages existing the rest of the time, since the rest of the time the in-phase feedback is regenerative.

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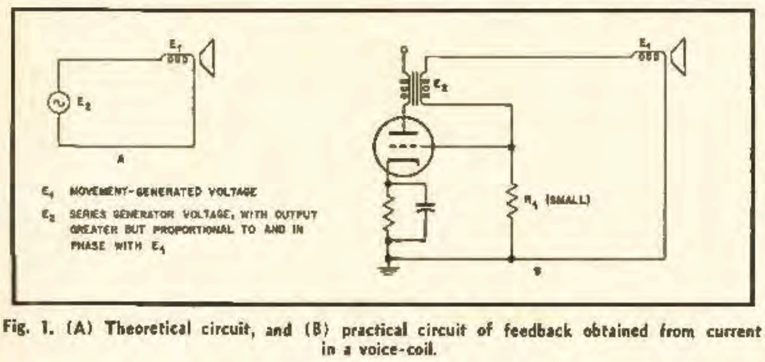

Fig. 1. (A) Theoretical circuit, and (B) practical circuit of feedback obtained from current in a voice-coil.

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The basic problem is one of separating the movement-generated voltage from the driving voltage so that only and at all times will the feedback signal resemble the actual cone movement, in-phase current feedback succeeds in doing this part of the time only. True it serves best during those critical periods of hangover, but hangover is only part of realism. It follows usually in the wake of transients which themselves would be much improved if motional feedback could be put to work on a full-time job.

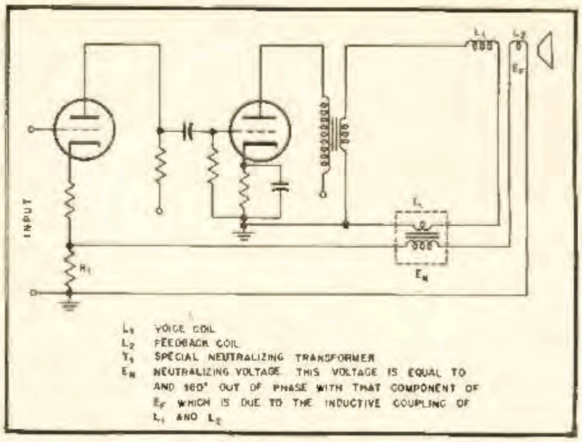

Fig. 2. Typical circuit employed a movement - generated feedback voltage. The use of resistor R_1 is optional, since the feedback could be applied in any of a number of ways.

Source of Feedback Signal

It is not difficult to produce separate and independent movement-generated voltages. Every microphone does it. A separate winding on the voice-coil former suggests itself but this is only a partial answer for it will have some mutual inductance with the voice-coil that will mean voltage will be induced in it other than that due to motion. The apparent solution is to shield the windings from each other magnetically. This seems a difficult problem since the pick-up windings should be as close as possible to the voice-coil from the standpoint of minimizing time lag between driving voltage and pick-up voltage. Such a time lag is due, of course, to sound traveling at a rather slow speed even through a solid. If it were not kept at a minimum serious phase shifts would occur at the higher frequencies and would limit the introduction and effectiveness of feedback. Another approach suggests itself and this is likely the simplest solution: use of neutralizing voltage. Feedback windings wound over a voice-coil, or near one end would be the same as a transformer; current through the voice-coil would induce a voltage in them. If another simple transformer of special design were used in series with the voice-coil to allow the same voice-coil current to produce a secondary voltage equal to that induced in the feedback windings it could be used to cancel the voltage so induced. This transformer could have a low-impedance primary since the secondary can consist of many turns to produce the right voltage. By this device then, it should be possible and feasible to use motional feedback with all the advantages that the principle implies. *Figure 2* shows a suggested circuit.

Although the author has believed for some time now that a feedback signal due to voice-coil movement would be considerably better to use than any signal existing within an amplifier itself, this positive feedback discussion has helped to stimulate and crystallize thinking on the subject. It can be seen that theoretically the resulting improvements of using an independent feedback signal as described would not be limited to improved damping. It would act to make the voice-coil and cone follow more exactly whatever voltage waveshape was applied, and at all times.

It is felt that much credit belongs to Warner Clements who seems to have stirred up this thing in the first place and to Ulric Childs who gave him some good arguments.