Negative Feedback

Q. What is negative feedback, and what is its purpose? John Ivers, St. Louis, Mo.

A. By negative (inverse) feedback we mean that condition wherein a portion of the output is returned to a previous stage in phase opposition to the input signal. It may be looked upon as a peculiar kind of tug-of-war in which the output does nothing until the input receives a signal. Then the input voltage is opposed by what we call the feedback voltage. The main input signal voltage always wins the game, since it is impossible to reintroduce sufficient signal to the input circuit to cancel it completely.

Figure 1 shows a single audio-frequency

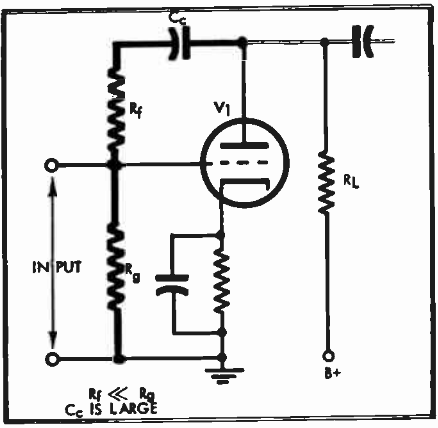

Fig. 1.

stage in which feedback is applied from plate to grid. There are two paths from the plate of V_1. One leads to a succeeding stage, while the other leads back to the input grid. The latter path delivers the signal to the input, and is known as the feedback loop.

From what has been said so far, it is obvious that a signal can be returned from output back to input with no difficulty. In order that we may call this signal *negative* feedback it must be in such a direction that it cancels some of the input signal. This circuit meets this requirement. At some portion of the input cycle the grid is made more positive with respect to ground. The tube draws more plate current, and the voltage dropped across the plate-load resistor, R_l, increases. This causes the plate to become less positive than it was with no signal applied to the grid. What I'm saying is that the plate and grid signals behave oppositely. Therefore, when the signal from the plate is fed back to the grid of the same stage, it is in such a direction as to cancel a portion of the input signal.

Not only is it important to be sure of the direction of the feedback, but it is also important to be sure of the *degree* of feedback. An examination of *Fig.* 2 will show that less feedback will be available to the input stage than was the case in *Fig.* 1. because the feedback resistor, R_F and the grid resistor, R_G form a voltage divider whose action is more severe in *Fig.* 2 than in *Fig.* 1.

Negative feedback is used for many different purposes, some of which will be given here.

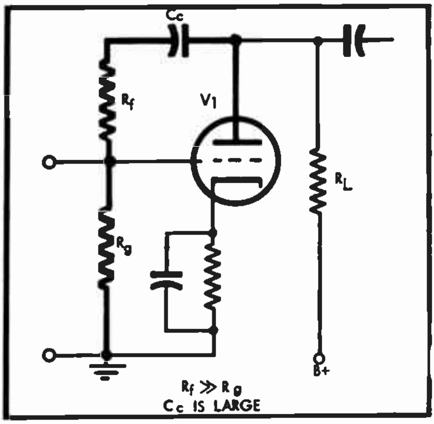

Fig. 2.

Negative feedback is used to correct frequency response. For example, if there is amplitude distortion present in an amplifier, the voltage produced at the distorting frequency will be greater (or less) than any other voltage fed to the feedback loop. (I am assuming, of course, that all voltages fed into the amplifier are equal.) Because the voltage of the distorting frequency at the output of the loop is greater (or less) than any other voltage at the output of the feedback loop, more of this voltage will be fed back to the input stage of the loop than at any other frequency. Thus, more (or less) of the distorting frequency signal will be canceled, and by this means response tends to level off. Notice I said "*tends* to level off." There is always present some error, much like that occurring in the governor mechanism of the old spring phonographs, wherein changes in spring tension were only partially compensated for by changes in the centrifugal force of the weights, and hence friction of the drum against its brake pads.

Another use for negative feedback is that of frequency compensation of the character found in tape and phonograph reproducers. The compensation is accomplished by making the feedback loop frequency sensitive. If what is needed is a circuit which will boost the lows, it is necessary to feed back more highs than lows, leaving the lows more or less unattenuated while the highs are considerably reduced in intensity. To accomplish this merely insert a small capacitor, C_C in series with the loop, as in *Fig.* 3. Because the reactance of the capacitor is high as compared to that of the feedback resistor, most of the lows are lost across the capacitor. The reactance to the highs, on the other hand, is small compared to that of the feedback resistor, and therefore, most of the voltage at these frequencies is available as feedback. If you desired to feed back more lows than highs, which you might in pre-emphasis networks, insert a small bypass capacitor in the loop. This will shunt the highs to ground, thereby bypassing the loop. This capacitor offers a low reactance path back to ground.

Sometimes the elements in these frequency compensating networks are made variable. When this is done we have a tone-control circuit most often referred to as the Baxandall type. Such variable networks are also the means by which many phono preamplifiers achieve the various record compensation curves.

Still another use for inverse feedback is that of making an amplifier more nearly linear. This is accomplished in a manner similar to that discussed in connection with frequency correction. Any instantaneous peak or dip in a wave shape is automatically compensated for by an increase or decrease in the amount of feedback applied. This doesn't mean that all frequencies fed into the equipment will be converted automatically into sinewaves. This would be highly undesirable, since much of the transient nature of program material consists of steep wavefronts. The feedback removes the discrepancy between the signal being

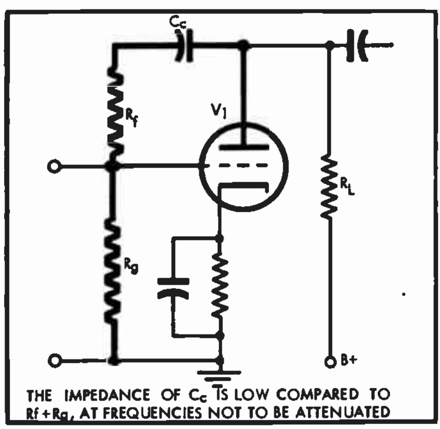

Fig. 3.

fed into the equipment and that which is reproduced in its output. This use of negative feedback will become increasingly important as more and more transistorized equipment comes on the market, because such amplifiers are operated Class B. Such operation is extremely nonlinear and can be overcome only by applying tremendous amounts of feedback.

Outside the field of sound reproduction feedback finds a wide variety of uses. Atomic reactors use feedback to control the rate at which neutrons are accelerated toward their targets. Such feedback is used in automation to reconcile differences between programmed work and the actual work produced. Various computer operations make use of the error signal from feedback as a means of arriving at the proper answer to the problem fed to the computer.

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