H-F Equalization for Magnetic Pickups

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Methods of using shunt capacitance to provide low-pass filter action and NAB or LP compensation.

ONCE THE OUTPUT of a magnetic pickup has been equalized so that the response up to the transition frequency is a realistic reproduction of the original recorded material, the listener next turns to the other end of the spectrum in an attempt to eliminate noise or to match the recording characteristic. The methods of equalizing the low-frequency response were discussed in the preceding article, and such methods are equally applicable to most of the high-quality low-level magnetic pickups that are available. These pickups are of the high-impedance type, designed to work directly into the grid of a vacuum tube. The electrical characteristics are similar, and the same methods of high-frequency equalization can be applied to all.

In order of importance, the three principal reasons for equalizing the high-frequency end of the audio band are:

1. To reduce surface noise
2. To eliminate distortion

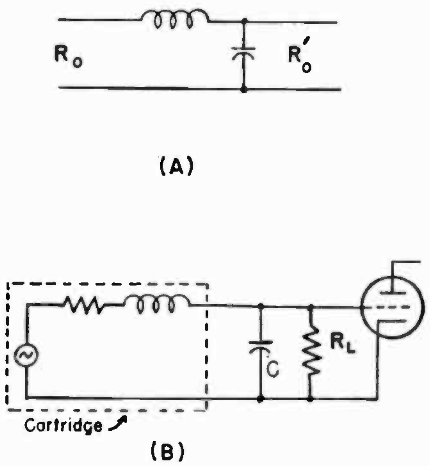

Fig. 1. (A) Conventional L-section low-pass filter configuration. (B) Circuit of magnetic pickup shunted by capacitor C and terminated by resistor R_L, feeding grid of amplifier tube.

3. To compensate for the recording characteristic

The reasons for this order will be apparent from the discussion.

The first of these listings is the one most noticed by the layman, who is often the person for whom the equipment is being designed. He is apt to be conscious of noise much before his notice of distortion, and favorite records—usually played more than others—are likely to be the most worn and consequently the greatest offenders.

The second reason becomes more apparent as the ear acquires training. The effect is noticed on many records as a definite "muddiness" and "smearing" in the high-level, full-orchestra passages, probably as a result of cutting at an average level which is too high for the amplifier equipment, the cutting head, or the record material. Consequently, when peak passages are reached, system distortion rises considerably. A higher over-all distortion *which remains constant* is less objectionable than low distortion throughout parts of the recording, with great distortion on high-level passages.

Compensation for the recording characteristic is likely to be considered by many as the most important of the three listed reasons. Without diverting into a discussion of recording characteristics—which are definitely not standardized among the various manufacturers, or even in one manufacturer's own studios—let it be said that some degree of high-frequency equalization is generally employed in the recording studio, as measured from the microphone to cutting head. However, this does not necessarily mean that the individual record that you buy is going to reproduce with that increased h-f response. It is recognized that one stamper is capable of producing about 1,000 records before it is discarded. The first record may be excellent, but what about the 999th? One more record and the stamper will be discarded. In the writer's opinion, very few commercial records are on the market today with any excess of high-frequency response—certainly not to the extent that they cannot be compensated for easily by usual "tone control" circuits. Therefore, with the exception of compensation for the NAB characteristic, no "sloping" circuits will be discussed. Reproduction from the record will be assumed to be correct as far as frequency response is concerned, and since both of the high-quality magnetic pickups in growing use are capable of performance up to 10,000 cps, it will be further assumed that the electrical output from the pickup is directly proportional to the velocity of the stylus tip.

Correction Methods

The simplest method of reducing the response of any electrical circuit to a desired maximum frequency is by means of a low-pass filter. In proper designs, practically any shape of curve can be obtained. However, in high-impedance circuits the series inductances reach large proportions, and they do pick up hum. Consider a simple low-pass filter such as that shown in *Fig. 1A*. It consists of a series inductance and a shunt capacitor. The equivalent circuit of a magnetic pickup is essentially a generator in series with an inductance equal to that of the coil, and with a resistance equal to the resistance of the coil. Thus, if a capacitor is shunted across the output of the pickup, as in *Fig. 1B*, the net result is that a low-pass filter section is formed. It is only necessary to choose the correct value for the capacitor and the correct value for the terminating resistance, after the cut-off frequency is selected.

L-P Filter Circuits

The configuration for the low-pass filter used in connection with these magnetic pickups is now seen to consist of the inductance of the pickup itself shunted by a capacitor, with the combination working into a suitable load resistance. Without considering the actual cut-off frequencies, the general circuit is developed first from the formulas for a constant-k low-pass filter, which will provide the values for C when the inductance L and the cut-off frequency are known. The cut-off frequency, f_c, is that at which the response is down 3 db.

By further rearrangement of the formulas, the value for the terminating resistance is given in terms of L and C. To simplify the determination of these capacitance values, they are shown in chart form in *Fig. 2*. The inductance of the

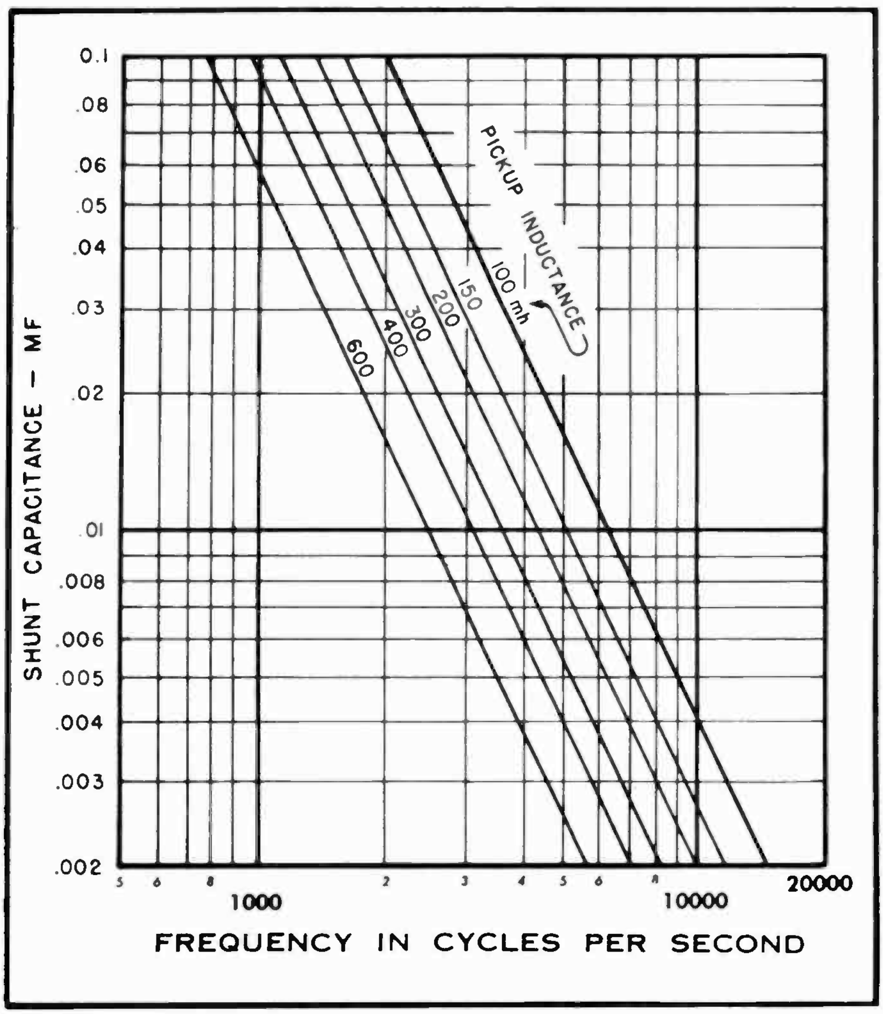

Fig. 2. Chart for determining capacitance to be shunted across magnetic pickup to provide low-pass filter action.

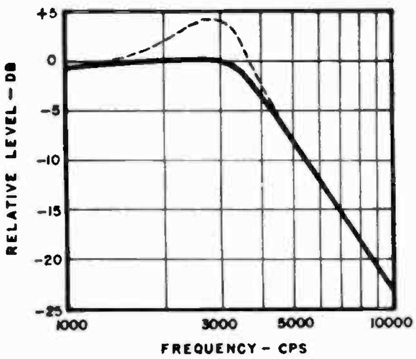

Fig. 3. Shape of response curve for $f_c = 3850$ cps. Dotted curve indicates peak due to improper terminating resistance.

various available pickups ranges from about 100 mh for the early GE models to approximately 600 mh for some of the more recent designs. For this reason, the curves have been redrawn to accommodate this range of inductances. To use the chart, follow the diagonal line for the inductance of the pickup to the frequency of the desired cutoff, and read capacitance at the left.

Response Curves

A typical response curve obtained by the use of a properly terminated capacitance shunt across the output of a magnetic pickup is shown by the solid curve of *Fig. 3*, while the dotted curve shows the effect of operating the combination into a load resistance equal to three times the optimum value. The smoother response of the solid curve is much to be preferred, and the use of a filter with sharper cut-off characteristics is generally undesirable for high quality audio circuits. Empirical values for the terminating resistance are given by the simple relation

$$R = 1.2 f_c$$

where R is in ohms and f_c is the selected cutoff frequency (3 db down). The response is flat up to approximately 80 per cent of the cut-off frequency, is down 3 db at f_c, and decreases at the rate of approximately 15 db per octave above f_c.

Any resistance in series with the capacitor does not affect the curve up to a frequency of approximately $2f_c$. Above this point, the curve tends to flatten off. Therefore it is recommended that the capacitor be connected directly across the pickup, and shunted by the correct load resistor. For flexibility, and to provide for wide-open response when record surfaces and distortion content permit, a switch may be arranged to connect either of two or more capacitors across the circuit as desired, each capacitor having its own resistor permanently connected across it. Using this arrangement, cut-off frequencies anywhere in the band can be chosen at will. For ordinary use on commercial shellac pressings, a three-position switch providing cut-off frequencies of 3,500 and 6,000 cps, together with one wide-open position, has proven quite satisfactory, although a more elaborate arrangement would obviously give a wider range of control.

NAB and LP Roll-Off

Professional users of these pickups often have need for a circuit which will provide the proper roll-off for the high frequencies for correct reproduction of LP records and transcriptions using the NAB recording characteristic. This curve is shown by the solid heavy line of *Fig. 4*, together with the equalization provided by the low-frequency equalizing circuits previously described, and the simple capacitance droop to correct for the high end. The resulting range of control provides for a response at 100 cps anywhere between +6 and –2db, together with an approximately flat response above 1,000 cps.

The droop resulting from the shunting of a capacitor across a line of a certain impedance is a gradual deviation from flat

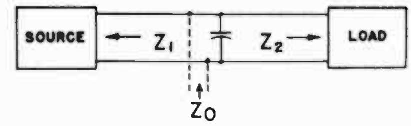

Fig. 5. Impedance Z_0 of any point in a circuit is composed of Z_1 and Z_2 in parallel.

to a loss of 3 db at approximately three times the frequency at the point of deviation, with a further droop at a rate of 6 db per octave above that point. However, this does not apply to capacitor shunted directly across an inductive source such as a pickup. The capacitor must be shunted across a circuit which is essentially resistive. A simple method of determining the correct capacitance to provide equalization for the NAB curve is given by the following:

$$C = \frac{75\ (Z_1 + Z_2)}{Z_1 Z_2}$$

where Z_1 and Z_2 refer to the impedances indicated in *Fig. 5*. This is a modification of the standard formula employed in some broadcasting plants which is $C = 100/Z_0$, where Z_0 is the impedance at any given point in a circuit. Thus, the impedance at any point on a 600-ohm line equals 300 ohms, since the source and load—each being 600 ohms—are in parallel. The value of 100 gives a roll-off which is somewhat greater than required to provide flat response.

Adaptations to Preamplifier

The preamplifier suggested for low-frequency compensation is readily adapted to provide the required roll-off to compensate for the NAB curve. The logical place to insert the shunt capacitor is across the output circuit, at which point the impedance consists of the load resistance shunted by the plate resistance, and both shunted by the grid leak of the following stage. Assuming that the grid leak is 1 meg or more, the impedance at this point is numerically of the order of 40,000 ohms, resulting in a shunt capacitance value of $0.0018 \mu f$.

When the connections from the preamplifier to the succeeding circuits must be fairly long, the capacitance of the shielded lead is apt to cause a droop in the response. This may be corrected easily by the addition of a capacitor across R_4 in *Fig. 1* of the preceding article on page 47. With a value of 0.27 meg. for this resistor, the capacitance to be placed across this resistor is equal to $0.59/f$, where f is the frequency at which the response is down 3 db. This same method of equalization may be used to bring the high-frequency response of a poor pickup up to flat at any desired frequency by the application of this formula, if the particular cartridge droops appreciably. The output of the better cartridges is held to a tolerance of $\pm$ 2 db to 10,000 cps, and further correction should not be necessary.

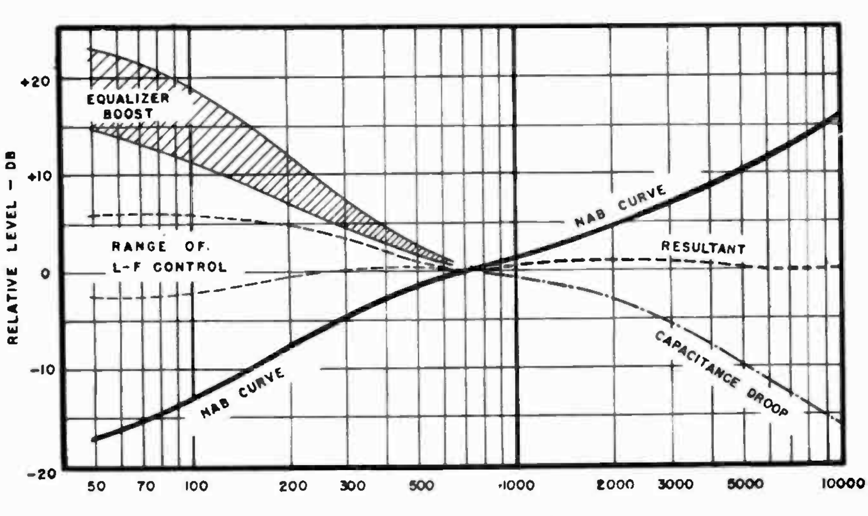

Fig. 4. NAB recording characteristic related to equalized preamplifier and to capacitance roll-off to provide control over low-frequency response and a flat high-frequency response.