Moving Iron Pickups

Effect of Inductance on Frequency Response

By E. H. FRANCIS

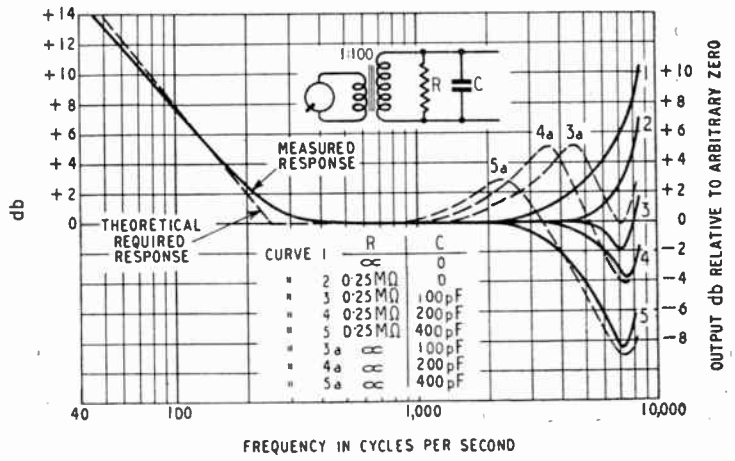

Fig. 1. Frequency response of pickup (including bass compensation) for various loads on secondary of coupling transformer.

IT is the purpose of this article to underline certain features of miniature moving-iron pickups which should be appreciated to obtain most satisfactory results. These important features are: (1) The frequency response of the pickup; (2) the impedance/frequency characteristic in association with the input transformer; (3) the frequency correction necessary for playing ordinary recordings.

Some experiments with the E.M.I. Type 12 ("Hypersensitive") pickup may serve to draw attention to the importance of the inductive reactance of the pickup winding, and the necessity for care in choice of coupling component values.

Dealing first with the H.F. end (i.e., frequencies above 1,000 c/s), curve 1 of Fig. 1 shows the output with the secondary of the step-up transformer (as supplied with the Type 12 pickup; ratio approximately 1:100) connected directly to a medium-slope triode amplifier. The curves of Fig. 1 were taken using H.M.V. test records DB4034 to 4037 and with the transformer feeding into an amplifier whose gain/frequency response was flat between 1,000 and 10,000 c/s. The output of the amplifier was measured with a meter accurately calibrated in decibels. The zero level is an arbitrary one, and small fluctuations of the order of ±1 db have been smoothed out as they were not likely to be due to the pickup.

The point to note is that the output increases considerably above 4,000 c/s due mainly to the needle resonance which occurs at 9 to 10 kc/s, and due also to some extent to resonance in the transformer secondary circuit. The reason for the transformer resonance will be seen in a moment.

Turning now to the impedance of the pickup; its winding resistance is approximately 6 ohms, but there is also inductance of the order of one millihenry. Fig. 2 shows the impedance, and also the reactive component, over the frequency range at the pickup terminals, and also on the secondary of the 1:100 transformer. Taking 8,000 c/s by way of example, the secondary impedance contains 500,000 ohms (approximately) of inductive reactance, and thus a circuit stray capacitance (i.e., total of winding capacitance and valve input capacitance) of only 40 pF approximately is required to give resonance at this frequency. The equivalent circuit at the transformer secondary is shown in Fig. 3; the increased gain at the resonant frequency is due to the resonant rise in voltage across the

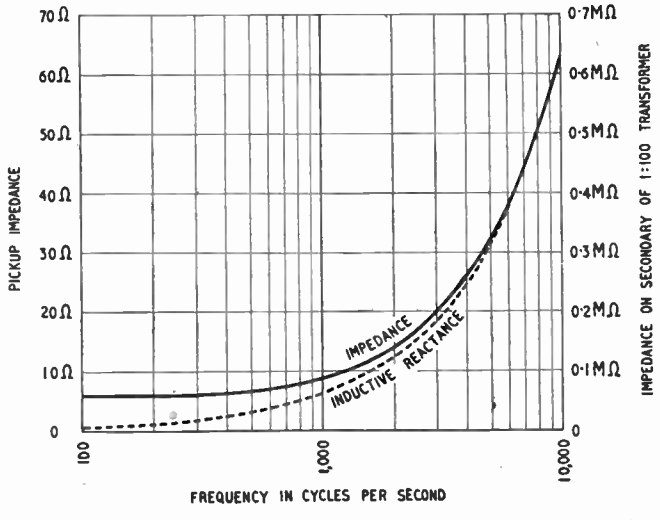

Fig. 2. Impedance and inductive reactance curves above 100 c/s.

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circuit capacity C_s being applied to the valve grid. Curves 3a, 4a and 5a of Fig. 1 show the effect more clearly when the capacity C_s is increased by the addition of 100, 200 and 400 pF condensers respectively.

Top Cut

Allowing for the deficiency of the average speaker above 5 kc/s, the rising response of the pickup aided by the secondary circuit resonance might appear to be an advantage. In practice this is not so, and surface noise and higher frequencies are unduly prominent. It is necessary therefore to take steps to attenuate the higher frequencies, in fact to avoid the distortion which occurs on the louder passages of almost all recordings it is necessary to aim at the sharpest possible cut-off. The makers of the pickup recommend the use of filters to give the following characteristics:—

Frequency (kc/s)		Attenuation (db)
New Records	Old Records	
6	4	6
7	5	15
10	7	30

Only a proper low-pass filter comprising coil and condenser networks (difficult to construct and test for the amateur) could give such a sharp cut-off, but if one assumes some discrimination will be used in rejecting inferior quality or worn recordings, a less sharp cut-off can be allowed with corresponding improvement in reproduction.

Fortunately, for this purpose the resonance referred to above comes in useful, as referring to Fig. 3 it will be seen that the circuit is similar to that of a half-section low-pass filter. Referring again to Fig. 1, curves 2 to 5 show the effect of a 0.25 MΩ shunt resistance and various capacities connected in parallel across the secondary terminals of the transformer. A capacity of 200 pF with 0.25 MΩ shunt in parallel gives a curve which is very satisfactory in practice, but as will be seen from the curve, the output begins to rise again above 7 kc/s. If desired a filter circuit in the amplifier (tuned to 9 kc/s) may be used to ensure further attenuation of frequencies above 7 kc/s. Suitable circuits are described later.

The final circuit of a gramophone pre-amplifier stage used by the author is shown in Fig. 4. Points to note are that the top cut-off condenser C_1 has been made 300 pF variable, further top-cut is given by C_2, a value of 0.002 μF being suitable. A tone control of the variable resistance-capacity type has been included (R_6, C_3). This latter control operates lower in the scale than C_1 and C_2 and forms a useful control of tonal balance, as some recordings, notably American, appear to have pre-emphasis of the higher frequencies. The components R_3, R_4, R_5 and C_5 comprise the main correction circuit for the L.F. recording characteristic giving about 10 db lift at 50 c/s. Additional lift of about 4 db at 50 c/s is given by R_1, R_2 and C_4. R_1 and R_2 also provide the 0.25 MΩ closing resistance for the transformer. The measured L.F. curve including this correction is shown in Fig. 1. This shows more than the calculated lift, due to the effect of the fundamental tone arm mechanical resonance at about 20 c/s.

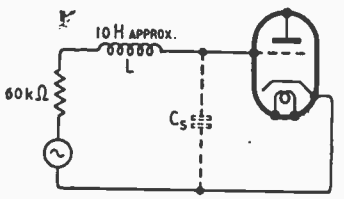

Fig. 3. Equivalent circuit at secondary of coupling transformer (ratio 1 : 100).

V_1 is a triode of about 10,000 Ω impedance. Should a higher impedance triode be used R_3 should be omitted. If higher gain is required from this stage a pentode may be used. In this case R_3 and R_4 should be omitted, and the anode load resistance made 100 kΩ; suitable other components are, cathode resistor and condenser 1,500 Ω and 25 μF, screen resistor and condenser 470 kΩ and 0.5 μF.

One final word on the operation of the control in the pre-amplifier (Fig. 4). On most new English recordings R_6 needs adjustment for maximum top and on good recordings C_1 may be adjusted to allow the full frequency range. On worn records or records with pre-emphasis R_6 is used to reduce surface noise and high frequencies and C_1 will help in these respects and also to eliminate the higher frequency products of distortion. If the bass appears to be too heavy, the components R_1, R_2 and C_4 may be replaced by a 0.25 MΩ resistor connected directly across the transformer, or C_4 may be short-circuited with a switch to form a bass control.

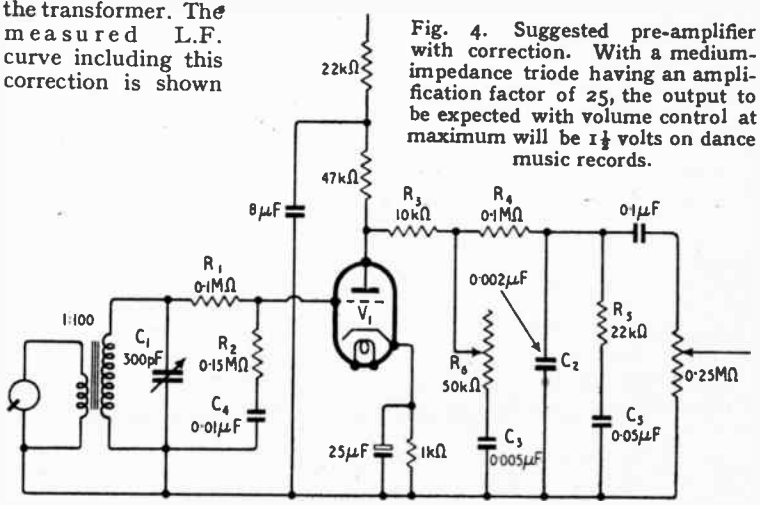

Fig. 4. Suggested pre-amplifier with correction. With a medium-impedance triode having an amplification factor of 25, the output to be expected with volume control at maximum will be 1½ volts on dance music records.