# AUDIANA

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# Recording Characteristics—1

A discussion of the various characteristics employed in making phonograph records, together with the reasons for their use.

THAT THE ULTIMATE in disc recording is to make the reproduced signal as near as possible to the original seems to go without further elaboration. This applies, of course, to any recording, but this discussion is solely about disc recording systems. To achieve faithful reproduction, therefore, it would seem that if all the components were made as perfect as it is possible to make them, it would suffice to record the signal and play it back with completely *flat* equipment. However, due to a number of limitations, this is not feasible, and the curve employed in recording is definitely not flat; consequently the curves employed in reproduction must deviate from uniformity. It is the purpose of this discussion to elaborate on the reasons for deviation in both the recording and the reproducing operations.

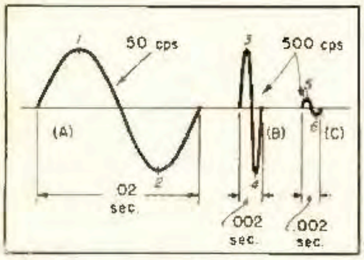

Fig. 1. Comparison between sine-wave signal plotted for 50 and 500 cps: at same amplitude, (A) and (B); and at same velocity, (A) and (C).

The principal variations from flatness in the recording process are due to mechanical limitations. In order to provide as high a signal-to-noise ratio as possible, it is desirable that the recorded level on the disc shall approach the maximum permissible value without overloading. Any further discussion of this problem necessitates defining certain recording terms, which will be done shortly.

It may be said, however, that low-frequency equalization is employed to reduce the possibility of overloading and that the high-frequency equalization is resorted to in order to reduce surface noise. The resulting recording curve is one in which the low frequencies are reduced in level at a constant rate, beginning at some predetermined point called the "turnover" frequency, and that the high frequencies are increased in level at some predetermined rate. The high-frequency equalization is commonly called "pre-emphasis" and must be compensated for in reproduction just as the low-frequency equalization is.

### Low-Frequency Equalization

There are two basic types of recording. One of these is known as "constant amplitude" and the other as "constant velocity." Both terms apply to the tip of the recording or reproducing stylus as it traces the groove. In constant-amplitude recording, the stylus tip at a given signal level moves a fixed distance each side of its center or rest position for any frequency. Thus the amplitude of the swing of the stylus tip is constant.

In constant-velocity recording, the maximum velocity of the stylus tip at a given signal level remains constant for any frequency. Considering a sine wave as being applied to the recording head, the maximum velocity occuring during each cycle is as the stylus tip is crossing its center or rest position. *Figure* 1 is used to clarify this point. (A) shows a sine wave at a frequency of 50 cps, requiring a period of time .02 sec. in length. (B) shows a sine wave at a frequency of 500 cps, requiring a period of time of .002 sec. Both of these are shown at the same amplitude, or displacement, of the stylus from its rest position. From these diagrams, it is seen that the stylus requires .01 sec. to move from *1* to *2* in (A), and .001 sec. to move from *3* to *4* in (B), and that both of these distances are the same. Therefore, the velocity of the stylus point must be 10 times as great for the higher frequency since it must move over the same distance in 1/10 the time. If the velocity of the stylus were held constant, then the displacement or amplitude of the swing would be re-

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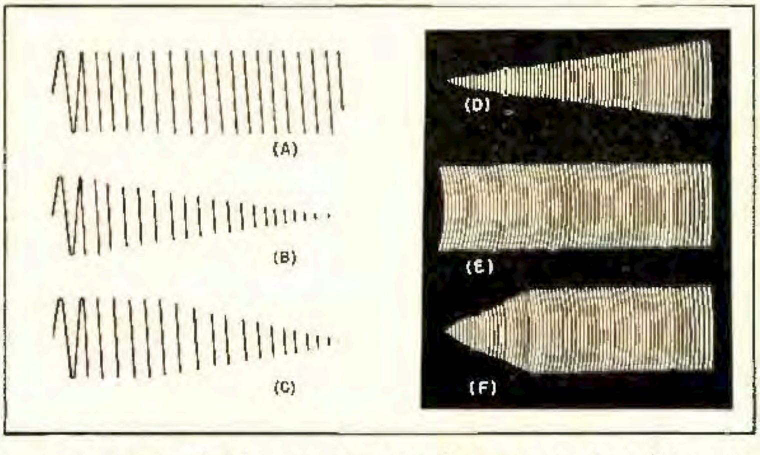

Fig. 2. Amplitude of stylus swing for swept-frequency signal at: (A) constant amplitude; (B) constant velocity; (C) commercial constant velocity. Corresponding light patterns are shown at (D), (E), and (F).

# AUDIANA

*[from page 20]*

duced to one tenth of its previous amount, as at (C).

Thus, in a constant-amplitude recording the velocity increases with frequency, although the displacement of the stylus point remains constant. In a constant-velocity recording, the amplitude decreases with frequency, but the peak velocity of the stylus point remains constant. In all of this discussion, it is assumed that the signal level is held at a given fixed point.

Practically all phonograph records and transcriptions are made with a combination of these two characteristics, with the change from one to the other occuring at the turnover point. In order to limit the swing of the stylus at the low frequencies, recordings are normally made at constant amplitude from the lowest frequency up to the turnover point, and at constant velocity above the turnover point. *Figure* 2 shows a typical groove for a swept-frequency signal from 50 to 10,000 cps at constant amplitude at (A), at constant velocity at (B), and at "commercial constant velocity" at (C). Commercial constant velocity is the term given to a curve which is at constant amplitude up to the turnover, and at constant velocity above. If the actual record were viewed with a distant light illuminating the grooves, the pattern due to (A) would appear as at (D); that for (B) would appear as at (E); and that for (C) is shown at (F). This latter is the familiar "Christmas tree" pattern which is almost universally used to evaluate performance of recording apparatus. It is characteristic of this method of illumination that a constant-*velocity* recording will produce a light band of fixed width, and thus the width of the band at any point may be used to compare the actual "velocity" of the groove throughout the frequency spectrum.

**Pickup Response**

Different types of pickups respond to the recording methods in different ways. A velocity-actuated device—such as a magnetic pickup—will produce a constant voltage output from a constant-velocity recording. This is due to the fact that the voltage is generated by the movement of a conductor through a magnetic field, or by the variation of a magnetic field which passes through a coil. Since the voltage generated in this manner is proportional to the velocity with which the lines of force and the conductor move with respect to each other, the voltage output from a magnetic pickup is flat over the constant-velocity portion of a recording, and droops at the rate of 6 db per octave over the constant-amplitude portion of the recording. Conversely, the voltage output from a crystal pickup is flat over the constant-amplitude portion of the recording, because the voltage generated by a crystal pickup is directly proportional to the *displacement* of the crystal, which is in turn actuated by the stylus.

There are a number of other factors which enter into the actual voltage output from a pickup, but these are functions of the mechanical characteristics of the device. The masses and compliances of the stylus and its supporting structure, of the pickup arm, and of any other moving elements, affect the output by introducing mechanical resonances which show up as peaks and dips in the frequency response of the pickup.

To clarify one point, however, it must be said that if a recording were made with a crystal cutter without any equalization, and played back with a crystal pickup, also without equalization, the output would be exactly like the input, provided both cutter and pickup were perfect. Similarly, if a recording were made with a magnetic cutter without equalization, and played back with a magnetic pickup—also without equalization—the output would again be exactly like the input, assuming that both pickup and cutter were perfect. However, pickups and cutters are not perfect, and in addition, the equalization previously referred to is normally applied, so some equalization must also be applied in the reproduction.

**Equalization Required**

Practically all commercial recordings are made with magnetic cutters, and consequently there is a certain amount of equalization introduced to limit the excursion of the stylus, during the recording, up to the turnover point. Thus the recording is constant amplitude up to this frequency, and essentially constant velocity above. Therefore, the reproduction by a crystal pickup is flat from the lowest frequency up to the turnover point without any equalization, and droops at the rate of 6 db per octave above that point. This demands that crystal pickups be equalized on the high end only, since it is a characteristic of these devices that they reproduce flat from a constant-amplitude signal. In order that they should actually be flat over the low end, the equivalent circuit of a crystal pickup as a generator must be investigated. The crystal may be considered as a constant-voltage generator in series with a capacitance equal to that of the pickup itself. This capacitance is of the order of .0015 μf, and therefore the load resistance must be chosen so that there is adequate transmission of the low frequencies. The circuit may be likened to that of the coupling capacitor between two amplifier stages, and it is remembered that the size of the capacitor affects the low-frequency response.

The capacitor and the grid leak or load resistor may be considered as a voltage divider, with the reactance of the capacitor acting as the top section and the load resistance as the lower, as shown in *Fig.* 3. At the frequency where the reactance of the capacitor equals the resistance of the load resistance, the response is down 3 db from the maximum. This accounts for the requirement that the load resistor for a crystal pickup shall be relatively high in value, usually at least 0.5 meg. and in many instances more than this. It also accounts for the statement that the low-frequency response may be controlled by the value of the load resistor.

To equalize the response above the turnover point, some arrangement similar to that of *Fig.* 3 (B) is generally employed. Assuming that the turnover frequency is 500 cps, the response at 1000 cps is down from the 500-cps level by 6 db; at 2000 cps it is down 12 db; at 4000 cps it is down 18 db; and at 8000 cps it is down 24 db. Thus if it is desired to equalize completely up to 8000 cps, it is necessary to introduce 24 db of loss to the low frequencies by means of a voltage divider $R_1$ and $R_2$. This requires that $R_2/(R_1 + R_2)$ must equal 1/16, since this is the voltage ratio corresponding to a 24-db loss. Then, the low frequencies are reduced in level to the 8000-cps level, but this

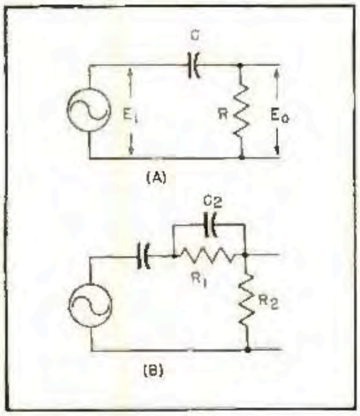

Fig. 3. Crystal pickup circuits. (A) is equivalent circuit when crystal pickup having capacitance C works into the load resistance *R*. (B) shows usual method of compensating for high-frequency droop.

would also introduce a similar loss at 8000 cps, so this effect is counteracted by shunting a capacitor across $R_1$ with its reactance at the 3-db point being equivalent to the resistance $R_1$.

Considering actual and typical values, let us assume that $R_2$ is taken as 0.1 meg; therefore, $R_1$ must be 0.1 meg. x (16−1), or 1.5 megs. For the case under discussion, the curve is flat at 500 cps, and down 6 db at 1000 cps. By drawing this curve on a sheet of graph paper, it will be observed that the curve is down 3 db at approximately 700 cps. Thus it is determined that the reactance of the capacitor $C_2$ must equal 1.5 megs at a frequency of 700 cps. The actual value of the capacitance may then be calculated from the relation $C = 1/2\pi fX_c$, or it may be obtained from an inspection of a reactance chart (such as that on page 13). In this case, the required capacitance is approximately 130 $\mu\mu$f, and this value will give complete equalization for a crystal pickup at high frequencies up to 8000 cps, when used with these resistance values.

There is just one thing wrong with this equalization, however. Records are not normally cut with a flat frequency response all the way up from the turnover point. The NAB curve, for example, as well as the standard LP curve, are both cut on the basis of a pre-emphasis of 100 $\mu$sec, of which more later. With this curve, then, the recorded signal is already boosted by approximately 14 db at 8000 cps, and the required equalization is thus reduced to only 10 db at this frequency, and the calculations must be revised.

This discussion should give a rough idea of how equalization is arranged for one type of pickup. Let it be said that if the response of any given pickup is known for a flat frequency record, it is fairly simple to determine exactly the equalization required to obtain flat response. It then becomes necessary to know the exact recording characteristic in order to make a good match. These characteristics differ appreciably, although there are a number of more or less definite curves in common use today.

Turning for a moment to the magnetic pickup, it will be remembered that the response for constant amplitude recording droops at the rate of 6 db per octave below the turnover point. This requires a boost of the low frequencies, in direct contrast to the crystal pickup, but for a flat recording above turnover, no high-frequency equalization is required. Actually this does not obtain in practice because of the pre-emphasis employed, and some high-frequency droop must be introduced intentionally.

Low-frequency equalization for magnetic pickups may be obtained in a variety of ways, all of them about equally effective, but differing appreciably in circuit design. The output signal from these pickups is usually quite low—ranging from 10 to 100 millivolts—and some amplification is required to boost the signal up to the level of radio tuner outputs, in order to facilitate switching. The common methods of equalization for magnetic pickups will be discussed in Part II of this series.

## CATHODE FOLLOWER

[from page 15]

in A if an additional stage is included within the feedback loop.

If we add such a stage to the cathode follower (as in *Fig.* 5) we run into the same problem of ground reference for our input signal that we had with *Fig.* 3B and encounter rather serious power supply problems for this stage. If, however, we had a stage within the feedback loop for the conventional amplifier (as in *Fig.* 6) we would then have a solution to the problem which would provide the same improvement in