Disc Recording Characteristics

STANDARDIZATION AT LAST? SOME NOTES ON B.S. 1928: 1955

By J. D. SMITH, B.Sc.

THERE has in the past been much controversy over the subject of recording characteristics. Numerous writers have quoted characteristics, often with considerable divergencies of opinion. Indeed the very mention of "recording characteristic" has been sufficient to unleash a spate of correspondence in the technical Press. In view of this it is very surprising that the revised British Standard 1928:1955*, issued over a year ago, has provoked almost no comment other than brief notices of its existence. Can it be that the new Standard settles once and for all every possible argument on the subject, or is the recording-characteristic-conscious section of the public largely unaware of its existence? Be this as it may, it is perhaps worth while to examine this new characteristic, in view of the fact that the specification or its equivalent is now being adopted by many record manufacturers in this country and abroad.

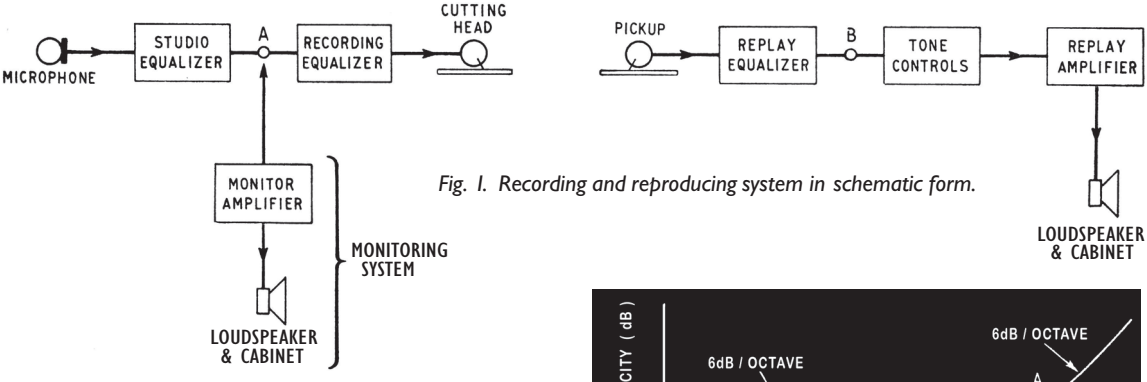


Fig. 1. Recording and reproducing system in schematic form.

Limitations of Standardization.—B.S.1928 covers most aspects of recording and reproducing gramophone records and transcription recordings on discs. Speeds of rotation and various dimensional features of discs and reproducing equipment are specified. This much is relatively straightforward but the question of standardizing recording characteristics is very much more involved as the committee responsible for the Standard have been at pains to point out in an appendix.

The nature of these difficulties becomes apparent on examining Fig. 1, in which a complete recording and reproducing system is shown schematically. The studio equalizer is adjusted to compensate for studio and microphone deficiencies and to obtain the desired balance between high and low frequencies. The electrical signal at point A is then such that when reproduced by means of a specified monitor chain consisting of amplifier, loudspeaker and listening room, it has the balance and quality that the manufacturer desires: presumably a subjective judgment. To prevent adjacent grooves from overlapping at low frequencies, and to improve signal/noise ratio at high frequencies, this electrical signal is equalized to a known recording characteristic before being fed to the cutting head. During replay the output from the pickup is fed via an equalizer having a response which is the inverse of the recording characteristic, so that, save for any deficiencies in the system, the signal at B will be a replica of that at A. Then, if the *same* monitor chain as before were connected to B, the sound would be exactly as the manufacturer intended. In practice the signal at B is reproduced by a different system, usually incorporating yet another equalizer, the "tone controls," by which the listener introduces his personal preferences. The sound as finally reproduced may, therefore, differ from what the manufacturer had intended, but it does so in a manner determined by the listener.

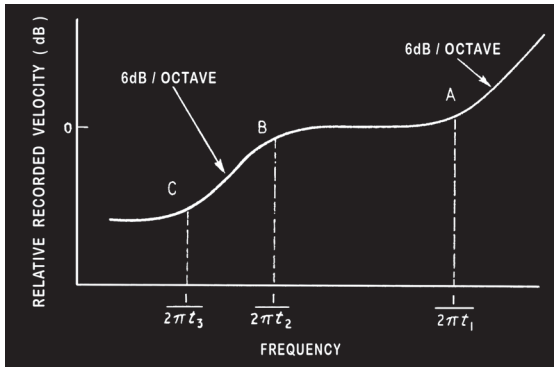


Fig. 2. General form of standard recording characteristic.

Now if a second manufacturer were to make a record of the same performance he would, in general, use a different monitor system and would equalize to produce a balance which *he* regarded as satisfactory. The signal at A would, therefore, differ from that produced by the first manufacturer at that point. The same is true of the replayed signal at

* British Standard 1928 : 1955. "Gramophone Records, Transcription Disk Recordings and Disk Reproducing Equipment." Revised May, 1955. Obtainable from British Standards Institution, 2, Park Street, London, W.1.

TABLE 1.

Time constant	Coarse groove	Fine groove
Treble rise t_1	50 μsec	75 μsec
Bass fall t_2	450 μsec	318 μsec
Bass rise t_3	3180 μsec	3180 μsec

B, provided that matched recording and replay characteristics be used (though not necessarily similar to those used in the first case). This signal at B would have to be reproduced by the second manufacturer's monitor system in order to obtain the sound as intended by him.

Thus the whole picture becomes somewhat confused and all that standardization can do at present is to specify recording and replay characteristics which could be adopted by all manufacturers. This ensures that the listener can with certainty obtain at point B in his reproducing chain the electrical signal intended by the manufacturer. This the British Standard does and no more. Having done this there are still the differences between the various manufacturers' monitor systems: as pointed out in the Standard, it would be highly desirable to standardize these but at present this is impracticable. The manufacturer's preferences in the matter of balance and so forth must be regarded as part of the actual performance and as such may not be subjected to standardization; the same is true of adjustments made by the listener.

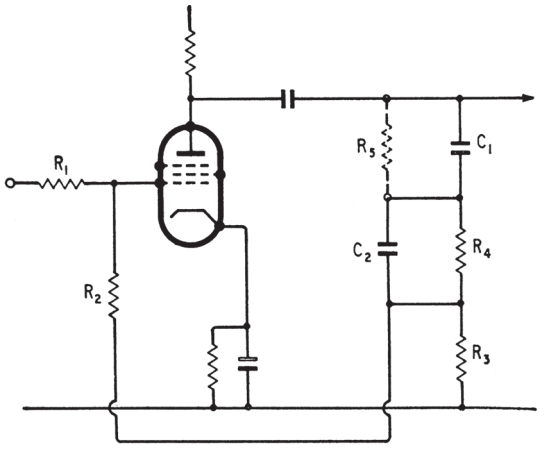
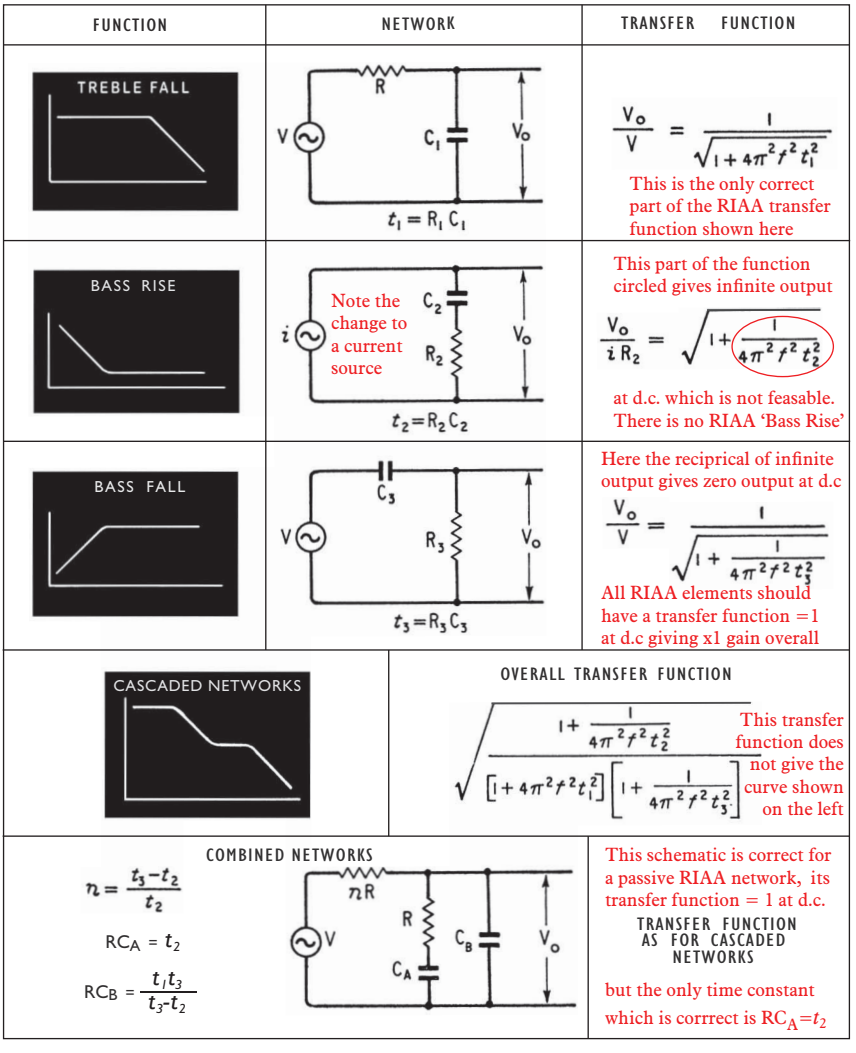


fig. 4. Equalizer employing negative feedback. The resistor R_5 (shown dotted) is normally omitted, but may be included if necessary to limit the low-frequency boost.

Fig. 3. Basic passive networks comprising a replay equalizer.



The above discussion seems to suggest that there are still many loopholes in the Standard. There is perhaps some truth in this but nevertheless it is a great step forward to have two characteristics, one for "coarse groove" and one for "fine groove" recordings, clearly and simply defined so that the listener is no longer at the mercy of opinion in this matter. It is certainly to be hoped that all manufacturers will adopt them.

The New Standards.—The new standard characteristics are very conveniently defined in terms of the time-constants of equalizing networks. Fig. 2 shows diagrammatically a recording characteristic. There are three portions to this curve: at A there is a treble rise defined by time-constant, tu so that at high frequencies the curve rises at a rate of 6 dB per octave. At B

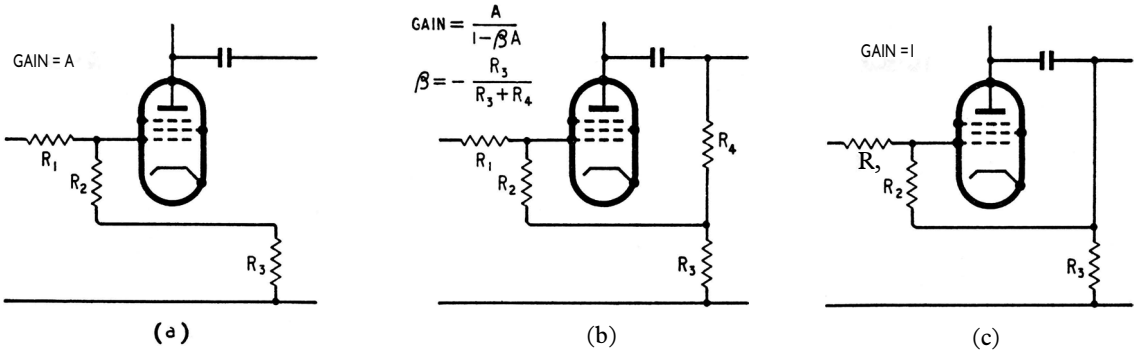


Fig. 5. Equivalent circuits of Fig. 4 at (a) low, (b) mid-band, and (c) high frequencies.

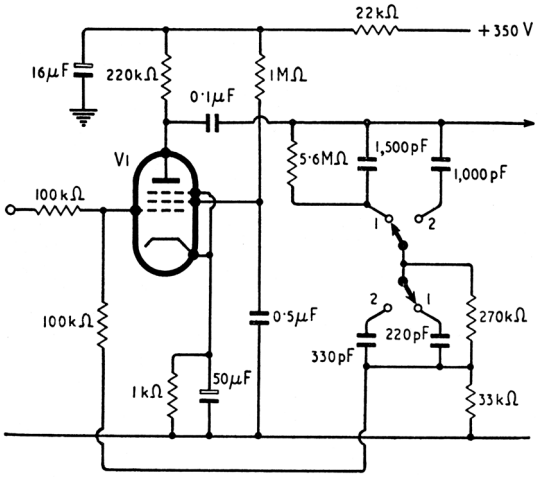


Fig. 6. Complete equalizer for B.S.S. 1928: 1955 characteristics. V1 may be Z729, EF86, 6BR7, etc. Mid-band gain approx. 10. Switch positions: 1—B.S.S. Coarse Groove, 2—B.S.S. Fine Groove.

there is a bass fall and a second time-constant, t_2, defines this. At low frequencies the response does not fall away indefinitely because a bass rise of time-constant, t_3, is included. Table 1 gives the values of the time-constants as set out in the Standard.

Replay Equalizers.—A replay equalizer could be constructed using passive networks chosen to give the appropriate time-constants, remembering that a rise in recording characteristic must be matched by a fall in replay characteristic. The three networks must be cascaded in such a manner that they do not interact one with another; alternatively a single passive network incorporating all the necessary time-constants may be used. Such networks are shown in Fig. 3.

It is preferable, however, to use a valve with selective feedback to provide equalization and to incorporate the time-constants in the feedback loop. Fig. 4 shows such a circuit. In Fig. 5 are shown the three circuit conditions at low, mid-band and high frequencies. Notice that, as Fig. 5(a) shows, the gain at low frequencies, where maximum boosting is required, is limited to that available from the valve. In this way the required bass fall is provided without actually including a further time-constant: the ratio of the effective time-constant of this bass fall to that of the bass rise is the ratio of the maximum gain of the stage to that at mid-band, where a moderate amount of feedback is applied as shown in Fig. 5(b). If in a particular circuit this ratio is too great, R_5 may be included to provide a small amount of feedback at low frequencies. In a similar way there is a limitation of the high-frequency attenuation when the condition of Fig. 5(c) is reached, the gain then being unity (if $R_1 = R_2$). However, this undesired limitation is not serious in a properly designed circuit. The actual time-constants are given by $C_1(R_3 + R_4)$ for bass rise and C_2R_4 for treble fall.

Fig. 6 shows a circuit with suitable component values. Note that the switch may have as many positions as desired so as to incorporate equalization for older recordings. The load on this stage should not be heavier than 1 megohm or the available gain will be reduced and full bass boost will not be provided. If the stage must be more severely loaded it is possible by reducing R_2 to obtain the necessary bass boost at the expense of overall gain.

Notes by; Keith Snook

There is no *'Bass Rise'* defined in the RIAA characteristic as indicated in Fig.3 above. Any cascaded networks or combined network used for fine groove (RIAA) and course groove record reply should have a total transfer function that is 1, not 0 or ∞, at 0Hz.

There may be capacitive coupling in the amplifiers associated with the equalisation network which will give an additional high pass function or *'Bass Fall'* but the equalisation function will still require 3 time constants as defined in BS 1928 or by the RIAA as listed in table 1 above. The correct overall transfer function written in the same form as Fig.3 should be:–

$$\sqrt{\frac{1+4\pi^2f^2t_2^2}{\left[1+4\pi^2f^2t_1^2\right]\left[1+4\pi^2f^2t_3^2\right]}}$$

W. H. Livy of "Abbey Road Studios" responded to this article *(WW letters january 1957).* The authors reply did not address the fundamental mistake but did introduce a 4th time constant above t_1, long before Allen Wright of Vacuum State Electronics, told us we need a t_4 to "*restore much of the air and naturalness that's on the master tape*". Which, I assume, has to be tape machine introduced harmonics and hiss.

LETTERS TO THE EDITOR

The Editor does not necessarily endorse the opinions expressed by his correspondents

Is Distortion Unpleasant?

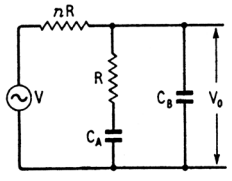
AS A. J. Hickman points out (December, 1956, issue), one can get used to anything: vibrato, dominant seventh chords, even deliberately mistuned "jazz" pianos, are sought after and give pleasure if not overworked.

The point is that all these effects are under the control of the musician, but the products of non-linearity are not.

Hindhead. HENRY MORGAN.

Disc Replay Equalizers

THE article by J. D. Smith on "Disc Recording Characteristics" in the November 1956 issue gives incorrect formulæ for the components of the combined network in Fig. 3. It can be shown that the correct formulæ should be as follows:-

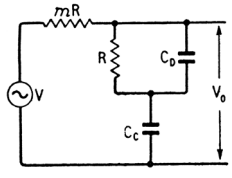


$$n = \left(t_1 + t_3 - t_2 - \frac{t_1 t_3}{t_3}\right)\frac{1}{t_2}$$

$$RC_A = t_2$$

$$RC_B = \frac{t_1 t_3}{t_1 + t_3 - t_2 - \frac{t_1 t_3}{t_2}}$$

Another network which will give an identical frequency response curve is: -



$$m = \frac{t_1 + t_3 - t_2}{t_2 - \frac{t_1 t_3}{t_1 + t_3 - t_2}}$$

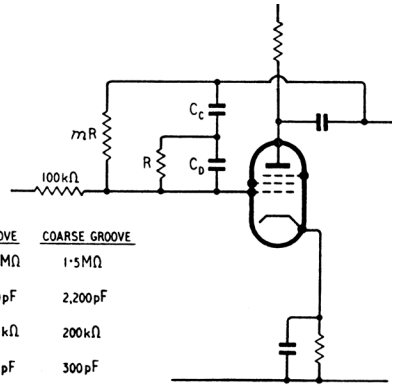
$$RC_C = t_2 - \frac{t_1 t_3}{t_1 + t_3 - t_2}$$

$$RC_D = \frac{t_1 t_3}{t_1 + t_3 - t_2}$$

The error in Mr. Smith's formulæ may explain why his feedback circuit shown in Fig. 4 does not appear to conform to the combined network diagram.

It can be easily demonstrated that the frequency response V_0/V of the combined networks above is exactly the same as the variation with frequency of the impedance seen looking back into the output terminals of the network, so that these networks can be used directly in the feedback loop of an amplifier to get the desired replay characteristic. A third network is also available giving the same impedance variation.

A practical circuit would be:-



FINE GROOVE	COARSE GROOVE
$mR = 3{\cdot}3M\Omega$	$1{\cdot}5M\Omega$
$C_C = 860pF$	$2{,}200pF$
$R = 270k\Omega$	$200k\Omega$
$C_D = 300pF$	$300pF$

If the gain of the valve is not enough to prevent the bass response from flattening off due to the feedback becoming inoperative, then the value of mR may be increased or even omitted.

E.M.I=Studios, London, N.W.8. W. H. LIVY.

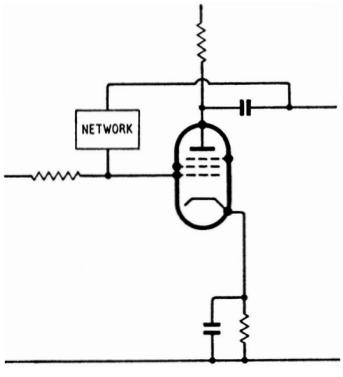
The Author Replies:

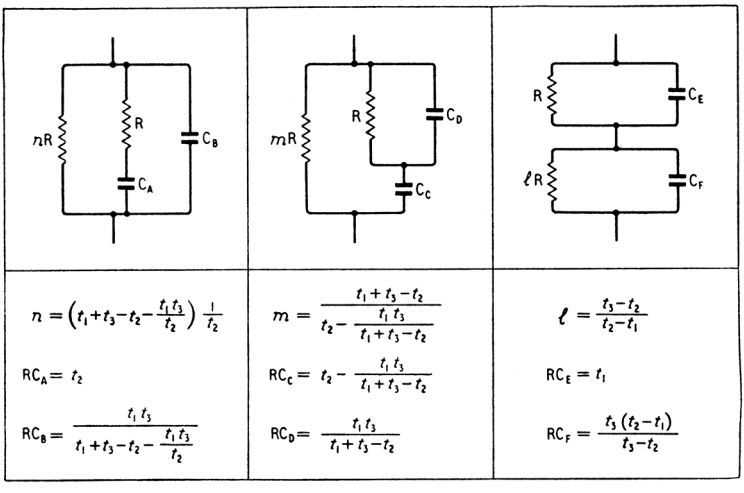
YOUR correspondent is quite right in taking me to task for misquoting the formulæ in Fig. 3. It will be noted that the expressions I gave are in fact approximations to the correct ones, since that for n may be rewritten as $n = \left(\frac{t_3 - t_2}{t_2}\right)\left(1 - \frac{t_1}{t_2}\right)$ which reduces to $\frac{t_3 - t_2}{t_2}$ as given, when $t_1 \ll t_3$. In either case $RC_B = \frac{t_1 t_3}{nt_2}$. Since Fig. 3. is intended to illustrate formal networks, I must apologize for quoting the approximate formulæ.

The approximation is valid when pre-emphasis is applied sparingly, as has been the practice in the past but which is scarcely true with the B.S.S. characteristics: the approximation is fair for the coarse groove case but somewhat gross for fine groove. The major inaccuracy is in the limitation of bass boost and does not exceed 2 dB, which for many purposes is sufficiently accurate.

The circuit of Fig. 4 of my article is not derived

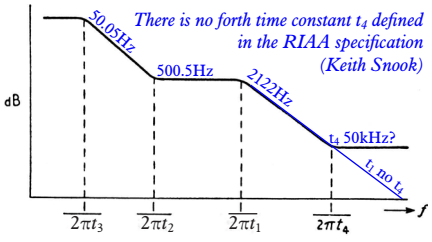
And another 4th network using 2 resistors and 2 capacitors at www.keith-snook.info





$n = \left(t_1 + t_3 - t_2 - \frac{t_1 t_3}{t_2}\right)\frac{1}{t_2}$	$m = \frac{t_1 + t_3 - t_2}{t_2 - \frac{t_1 t_3}{t_1 + t_3 - t_2}}$	$\ell = \frac{t_3 - t_2}{t_2 - t_1}$
$RC_A = t_2$	$RC_C = t_2 - \frac{t_1 t_3}{t_1 + t_3 - t_2}$	$RC_E = t_1$
$RC_B = \frac{t_1 t_3}{t_1 + t_3 - t_2 - \frac{t_1 t_3}{t_2}}$	$RC_D = \frac{t_1 t_3}{t_1 + t_3 - t_2}$	$RC_F = \frac{t_3 (t_2 - t_1)}{t_3 - t_2}$

directly from this combined network. Only two of the required time constants, t_1 and t_2, are included in the feedback network itself; the third appears by virtue of the finite gain of the valve which limits the bass boost. (If a circuit is to be used for equalizing several characteristics, some of which require less boost, this can be reduced by means of R_5.) There is a fourth time constant, t_4 due to the fact that the h.f. cut does not continue indefinitely. Hence, the overall response is of the form:-



In practice, this highest time constant is not observed since it occurs beyond the pass-band of the amplifier. The conditions giving the three plateau regions were shown in Fig. 5. It is clear that the design of the equalizer involves a knowledge of the gain of the stage and even then is not quite straightforward because the feedback network provides frequency-dependent loading on the anode circuit, so modifying the response in a manner which tends to increase both the bass boost and treble cut and should be allowed for (most readily by experiment).

Note that under the bass boost condition the stage is working without feedback so that the maximum mid-band gain is realized. Against this it must be admitted that the limiting boost is dependent on valve parameters and therefore liable to change with ageing, etc.

The two practical circuits cannot be directly compared as they fulfil different operational requirements. The one given by your correspondent employs more feedback and hence gives equalization accurately controlled by the network elements, but at the expense of overall gain. In many instances, greater gain is required and this is achieved by raising the network impedance until the bass boost is limited by the available valve gain and not by the network itself. Under these conditions it is often convenient to include redundant resistors in order to avoid the use of inconveniently large values and the circuit may then take a form similar to that which I gave (which is in fact a derivative of the third network given in Mr. Livy's letter).

Watford. J. D. SMITH.

Scale Distortion Again

" M. G. L. " ends his review of a high-fidelity test record (December issue) by saying of loudness controls that they try " to reproduce an orchestra as it would be heard a long way away with the frequency balance as it would be audible much closer; and this cannot possibly lead to natural results ".

The problem of scale distortion (loss in the ear of bass and treble at loudness levels less than natural) cannot be solved by ignoring it. The Fletcher and Munson curves show the loss of bass to approach 14 dB per octave at very low levels, and compensation is essential to hear the bass at all. Reproduction of an orchestra at full volume cannot be tolerated in ordinary rooms, and would be unnatural anyway. Reduction by ordinary (uncompensated) volume-control in effect removes the orchestra " a long way away " with loss of bass and treble, and makes the music thin, monotonous and tiring to listen to.

Reduction by compensated volume-so-called loudness-control effectively leaves the orchestra at its proper distance, but playing quieter (or with fewer members, if you will) *as would be expected* within the confines of an ordinary listening room, and therefore IS more natural.

Absolute fidelity in the home cannot be hoped for, due to the many well-known causes, but compensation for scale distortion is a valuable aid to the illusion of naturalness and the pleasure of listening-the real aim.

Walsall, Staffs. STANLEY MAY.

The Reviewer Replies :

I CANNOT agree with Stanley May's statement that " reproduction of an orchestra at full volume cannot be tolerated in ordinary rooms and would be unnatural anyway." The aim of correct reproduction is surely to produce in the ear the same sound pressures as would be produced in the ear in the concert hall. Subject to the usual distortions this can be achieved, and in the opinion of many people, including myself, leads to the most natural results. Many of us who share a belief in this standard think that music is often reproduced too loud by " hi-fi " addicts.

If an orchestra were to play quietly or with fewer members in the concert hall, owing to the scale distortion Mr. May mentions, the frequency bahnce heard would be different from that of a normal orchestra. Thus, even if for some reason we wish to reproduce our music as it would be played by such a smaller orchestra at the same distance as usual, it would be unnatural to compensate in the living room for a change which would remain uncompensated in the concert hall.

It is, however, possible that reproduction sounding like an orchestra which is the wrong size and has an incorrect frequency balance may be preferable to reproduction sounding like an orchestra of correct size and balance which is too far away. If we are restricted to these alternatives there may be some justification for Mr. May's use of a " loudness " control, but neither of these alternatives attempts to provide the correct reproduction that can to a large extent be achieved.

M.G. L.

The UL Circuit

I NOTED Grant's application (September, 1956, issue) of the UL circuit to single-sided pentodes with some interest. My company suggested this to a magazine editor here in the U.S. and he turned down the suggestion with the argument that it would not pay commercially since there is a patent licence problem.

A tap is required on a small and low-cost output transformer, and an engineer at one of the transformer companies was of the opinion that the tap cost would exceed that of an RC network for a conventional inverse feedback loop. Hence the UL circuit for a single-sided pentode doesn't seem to appear commercially attractive. However, in my opinion, it should work out better than an RC loop since there should be less trouble with poor " phase bandwidth " produced by a cheap output transformer.

Great Neck, L.I., U.S.A. TED POWELL.

Audio Demonstrations

THE letters from C. Streatfield and H. Glover published in your October issue criticize the Radio Show demonstrations of sound-reproducing equipment and, in particular, the choice of programme material.

Perhaps the manufacturer who has the listener's ear for only a few minutes can be forgiven for trying to produce impressive rather than natural sounds. But if a test of naturalness is required, I, personally, remain convinced that speech is the best material. When well reproduced at the correct volume level the illusion of reality is, to me at least, greater than with other sounds well reproduced. But equipment which produces impressive bangs, crashes and tinkles doesn't necessarily seem to reproduce speech naturally.

London, N.W.7. W. J. CLUFF.