An Ultra-Linear Amplifier

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Presenting a new output-stage connection in an otherwise conventional amplifier which provides a degree of listenability which is well above average.

IT HAS BEEN CLAIMED that there is no more room for improvement of power output stages since other elements of a complete sound system—particularly the electro-mechanical ones—are far inferior. There is a prevalent belief that "one good amplifier is only marginally different from another." The proponents of this line of thought imply that significant improvement in power amplifiers is extremely difficult to achieve, and with this idea the authors agree, but the authors disagree as to the *need* for further improvement. Obviously, the weaker links do need improvement, but this alone is no reason for abandoning the further development of stronger links in the chain of audio reproduction—the power amplifier and primarily the power output stage which is the prime generator of distortion in the purely electronic part of the audio system.

Present thinking is very parallel to the views of the 1935 era when it was felt that the principle need was for better program sources and that the transducers and audio amplifiers had reached a stage of near perfection which could hardly be improved. Now, what audiophile would be satisfied with the reproduction standards of sixteen years ago when playing the new LP's or high grade tape? By analogy, therefore, as well as for the never-ending search for a never-attainable perfection, we must continue to seek improvement in *every* link of the audio chain.

The old standards for evaluating amplifier quality have fallen into disrepute. It can be audibly demonstrated that a wide pass band and low harmonic content do not necessarily mean that the amplifier satisfies the critical listener. Newer criteria have been developed such as intermodulation distortion analysis and square wave testing, both of which simulate dynamic conditions to some extent and take into consideration that music and speech are not of a static nature. These new tests produce higher correlation between experimental data and listener preference. Therefore, modern amplifiers sound better than the ones of a few years ago as a general rule. However, these tests do not always separate the wheat from the chaff. Amplifiers which measure well do not necessarily sound well although an amplifier which shows up as poor on measurements will not sound well. Excellent measurements are a necessary but not a sufficient condition for quality of sound. This means that the listening test is the one of most importance—it is the most stringent test of all.

On the basis of listening tests (definitely not on the basis of measurements) the audio school has been divided into two camps—triodes versus tetrodes. There has been shifting between the popularity of the two, but there has always been a distinct cleavage. When the triode-without-feedback was judged superior to the tetrode-without-feedback, the tetrode school added feedback and reaffirmed the merits of this tube type. This was again superseded by the triode-with-feedback, but the beam tetrode still has its followers, presently in the category of a defensive minority among the audio elite.

The very fact that each tube type has ardent supporters is evidence that each has definite points of merit. Possibly the devotees of each type listen for *different* qualities of reproduction, and this causes divergence of opinion. The triode fan usually emphasizes "smoothness" or "sweetness" of sound. The beam power advocates seek "crispness" or "clean sound." Each group obviously desires sound which simulates the original, but each rejects the elusive and unmeasureable distortions which characterize the tube type preferred by the opposition camp. A new type of tube, none of which has been put on the market for many years, might be the thing which could reconcile these diverse views of listeners who all look for the same thing but seek it in different ways.

The requisites for such a new tube can be listed readily:

1. Low internal impedance, such as is offered by the triode.
2. High power sensitivity of the tetrode so as to minimize drive problems.
3. Lower harmonic and intermodulation distortion than either triode or tetrode at both high and low levels of operation.
4. Sufficiently high efficiency to permit adequate output without undue bulk or cost.

Since no such tube is available, the only recourse is to seek a mode of operation of existing type tubes to approximate the desired qualities and then to see whether the theory is justified by listening tests.

Linearizing the Output Stage

The physical difference between the triode and tetrode is, of course, the screen grid. This gives the tetrode its efficiency on the one hand, but also increases the plate resistance and contributes toward the "tetrode sound" which is so violently disliked by triode favorers. Therefore, the screen grid seems to be the element which gives the tetrode its advantages and its disadvantages compared to the triode. In fact, when the screen is connected to the plate, the resultant tube is a triode which is excellent in many respects though handicapped by limited power output and low permissible dissipation. Control of the screen is a logical step toward extracting the favorable attributes of the tube and discarding the unfavorable.

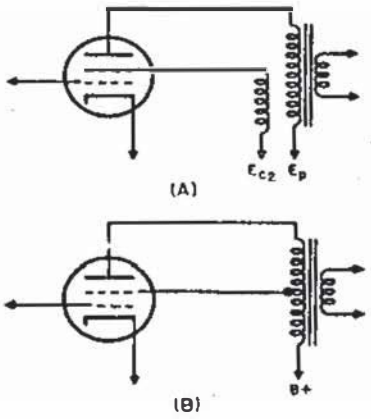

Fig. 1. Arrangements for energizing the screen grid to improve tube linearity.

Experimentally it was found that the goal of improved operation could be achieved through energizing the screen with d.c. through a special winding on the output transformer and combining the effects of both plate and screen current in the output transformer. This is illustrated at (A) in *Fig.* 1 with an alternative and simpler method shown at (B). It has been found that the screens must be fed from a low-impedance source or the benefits of this arrangement cannot be realized. This eliminates the possibility of doing the same job with resistive bridge networks or voltage dividers.

The screen load impedance is somewhat critical if optimum results are desired. As the ratio of screen load impedance varies from zero (tetrode operation) to unity (triode operation), important effects show up:

1. The internal impedance takes a sharp drop and then levels off.
2. Maximum undistorted output drops slightly at first, then decreases rapidly.
3. Intermodulation distortion at high level operation drops to a minimum and then soars upward.
4. Low level IM decreases somewhat and then holds almost level.

The situation is demonstrated graphically in *Fig.* 2 where it can be seen

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