A fresh design approach to a

300W Amplifier

Yes, it's finally happened. We have produced a really high power amplifier. As a prelude to presentation of the full circuit next month, designer Richard Tymerski outlines some of the principles involved in the new amplifier which will deliver 200 watts RMS into 8-ohm loads and 300 watts RMS into 4 ohm loads.

Following the discussion presented in the October 1979 issue concerning the design problems of high power audio amplifiers, this article looks more generally at the desirable features such amplifiers should have and an amplifier design philosophy is expounded.

The ensuing discussion is not only concerned with measures taken to achieve amplifier ruggedness and reliability but also with measures taken to achieve very low distortion, both Transient Intermodulation Distortion (TIM) and Total Harmonic Distortion (THD).

As shown in the October 1979 article, the fact that loudspeaker loads have appreciable reactance dictates the requirements for a large Safe Operating Area (SOA) for the amplifier output transistors. The requirement is such that the load-line of the loudspeaker should not exceed the limits of the SOA. This end can be met by the use of parallel-operated output transistors and load-line limiting.

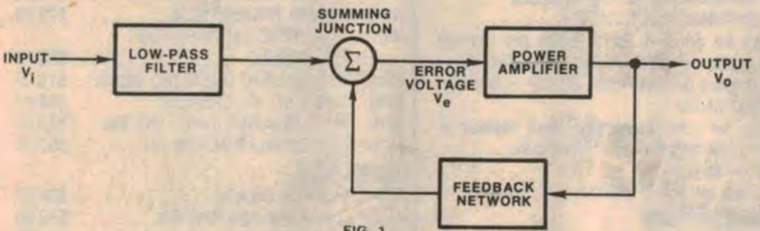


FIG. 1

Due to the power derating at high collector-emitter voltages imposed by secondary breakdown on bipolar devices, paralleling of the output transistors, to increase the SOA, is necessary. The greater the number of output transistors, the greater the power that the amplifier can deliver reliably into the load. Parallel operation relies on current sharing to effect power dissipation sharing. To ensure even current sharing large emitter resistors should be employed. These resistors, however, dissipate some of the power that would otherwise be delivered to the load. Nevertheless, it is important that they should be reasonably large otherwise current "hogging" in individual transistors may occur, thus rendering ineffective the aim for an increased SOA. If the output transistors are arranged in an emitter follower configuration, large emitter resistors also help to provide good bias stability.

To ensure that operation is within the designated limits once a certain SOA has been established, load line or voltage-current (V-I) limited should be employed. It operates by monitoring the voltage across and current through the output transistors and when a potentially unsafe combination is reached, drive to the output transistors is interrupted, thus avoiding possible output transistor destruction. The V-I limiting locus is usually placed just inside the SOA boundaries.

Another provision to ensure the reliability of an amplifier, is that of designing for unconditional stability despite changes in the load. To achieve this, a load stabilising circuit may be used. This circuit serves to keep the amplifier stable in spite of changes in the output load which, in an audio amplifier, are completely out of the hands of the designer, can be extreme and often contribute considerably to poor performance of an otherwise good amplifier.

Equally important as the aim for reliability in a high power amplifier are the requirements for low total harmonic distortion (THD) and low transient intermodulation distortion (TIM). Until recently, it was thought that these two requirements were conflicting but this is not so. It is possible to design an amplifier with very low THD and low TIM.

Let us recap on how TIM is produced. Fig. 1 shows a typical feedback amplifier system. It consists of a low pass filter at the input placed there simply as recognition of the fact that any real life program material that is fed into the feedback amplifier is of limited bandwidth. The cut-off frequency of the input filter is at a frequency designated as F(1). Following this input filter is the feedback power amplifier. It is represented by the power amplifier block in the forward path with a feedback network from the output to the input summing junction. The feedback amplifier has an open loop cut-off frequency at F(0) and it is assumed that the rate of roll-off is first-order, ie, 6dB/octave. Assume also for the moment that the input filter is also first-order.

Now, let us look at the error voltage of the amplifier, ie, Ve, when the input signal, Vi, is a perfect square wave. Let's consider, in particular, the error voltage response to the leading edge of the square wave input. This is depicted in Fig. 2. It shows that an overshoot occurs when F(1) is greater than F(0). There is no such overshoot when F(1) is equal to or less than F(0).

If the overshoot is of sufficient amplitude to overload the input stage of the amplifier, the input signal no longer has control of the output. This blockage of signal may be quite long and during this time, 100% intermodulation occurs. This is known as TIM and is believed to be the reason why some amplifiers featuring excellent THD specifications fail to "audition" well. Much of the harshness previously thought to be due to crossover distortion is now attributed to TIM.

Finnish amplifier designer, Matti Otala (1) has performed a detailed investigation of the error voltage, Ve, for various combinations of the ratio F(1) to F(O) and feedback factor for the system of Fig. 1. His conclusion was that increasing overall feedback made TIM worse. Furthermore, Otala stated that, to obviate the production of TIM an amplifier should be designed for a wide open-loop bandwidth and overall feedback should virtually be kept to a minimum.

Otala's "open-loop" bandwidth specification states that if high fidelity reproduction requires a 20kHz upper cut-off frequency in an amplifier, the amplifier should reach it without feedback, ie, F(0) should be equal to at least 20kHz. And so it has been along these lines that a number of amplifiers purporting to feature low TIM have been designed.

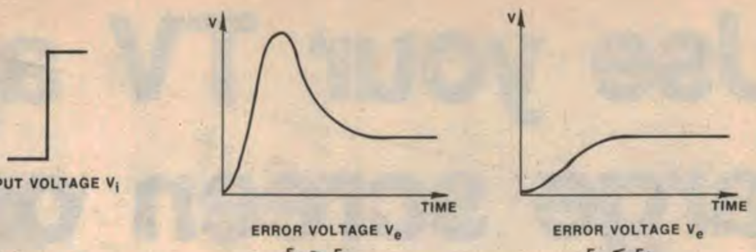
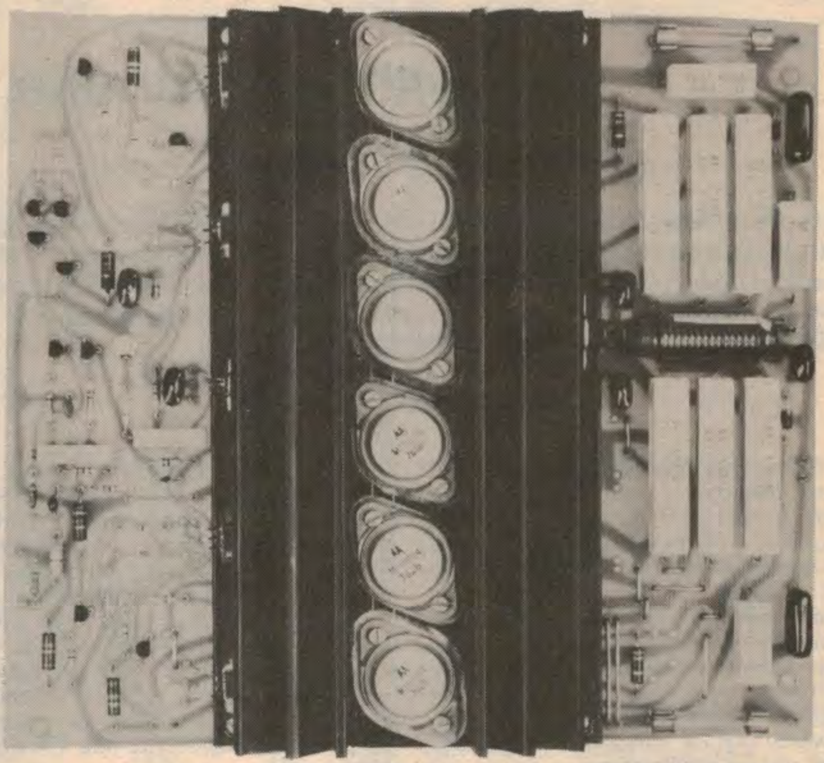


FIG. 2



Rugged, reliable and easy-to-build, this amplifier will be featured next month.

In order that these amplifiers have wide open-loop bandwidths and low overall feedback, local negative feedback in the amplifier stages is employed (usually in the form of emitter degeneration). This also results in giving the amplifier a good linear open-loop characteristic and with the modest amount of overall feedback, THD is reduced to an acceptable level. However, large over-all feedback is more effective in reducing THD than repeated use of local feedback with a modicum of overall feedback.

More recently, a design philosophy which permits large overall feedback without jeopardising TIM performance has been developed by Peter Garde (2). His approach relies on designing the input stage of the feedback amplifier with a sufficient overload margin, such that any realistic input signal to the amplifier will not cause TIM.

The overload characteristic of the input stage is directly proportional to the stage operating current and inversely proportional to the stage transconductance (ie, gain expressed in amps/volt). Therefore, for a sufficient overload margin, the first stage is designed with a greater than usual operating current and a low transconductance. This low transconductance may be achieved by emitter degeneration of the bipolar transistor stage or by employing JFETs, as they have an inherently low transconductance characteristic.

Whichever approach is used, provided a low transconductance input stage with generous overload margin is used, considerable overall feedback can be applied to the amplifier to achieve very low orders of THD while still maintaining freedom from TIM.

If "lag" compensation is employed to achieve amplifier stability, the above measures, used to achieve an adequate overload margin also increase the Slew Rate capability of the amplifier. In fact, the requirement for the prevention of TIM also relates to the amplifier Slew Rate and the nature of the input signal.

If we define the term, Signal Slope, as the "maximum rate of change of signal voltage with respect to time" then to avoid Slew Rate limiting, the Slew Rate capability of the amplifier should be greater than the output Signal Slope of all possible signals the amplifier will handle.

Note that limiting the bandwidth of program material reduces the maximum signal slope. Therefore, it is advantageous to have a filter at the input (if the program material has a wide bandwidth). It should also be noted that the maximum signal slope from a first order low pass filter is directly proportional to its corner frequency. Therefore, for a given maximum input voltage input (ie, the input voltage at which the amplifier output stage starts to clip) the maximum signal slope is limited to that resulting from a 20kHz corner frequency (which is the lowest applicable to high fidelity amplifiers).

If however, we adopt a second-order filter (with Bessel alignment) with identical -3dB frequency to the first order filter, we find that the maximum Signal Slope is about half that of the first-order filter.

The second-order filter also offers greater cancellation of treble boost from tone controls, which tend to worsen TIM. Thus, we see that this approach has merit considering the cost and the ease of implementation in the amplifier design.

Let us now summarise all that has been said above. We have seen that to ensure amplifier ruggedness and reliability consideration must be given to the nature of loudspeaker loads and an appropriate number of output transistors should be used. When these transistors are operated in parallel, reasonably large emitter resistors should be employed to ensure equal current sharing. V-I limiting and load stabilisation can further enhance reliability. To achieve very low dynamic (TIM) and static (THD) distortion performance in an amplifier we have seen that large overall feedback can be used when due attention has been paid to the design of the amplifier input stage. This stage should be operated at a reasonably high current and feature low transconductance. The inclusion of an input filter reduces the maximum Signal Slope fed to the amplifier and this lowers the dynamic distortion. The lower Signal Slope from a second order filter makes it preferable to a first order filter.

Next month we will present the full circuit and constructional details.

REFERENCES:

(1) Otala, M., "Transient Distortion in Transistorised Audio Power Amplifiers", Transactions IEEE, Vol. AU-18, No. 3, September 1970, pp234-239.

(2) Garde, P., "Transient Distortion in Feedback Amplifiers", Proc. IREE, Vol. 38, No. 10, October 1977.