

Set quiescent current with  $R_{20}$  and increase  $R_{21}$  until there is a small increase in current.

The only part still to be described is the biasing chain  $R_7$ - $D_4$ - $D_5$ - $R_8$ - $C_3$ . This provides the half supply voltage for the base of  $Tr_1$  (decoupled by  $C_3$ ), a load for the class A stage  $Tr_2$ , and sets devices  $Tr_4$  and  $Tr_5$  at the minimum conduction level required for good phase response during cross-over—by using the voltage across  $D_1$  and  $D_2$ . By increasing the value of  $C_3$  it is possible to reduce the rate of charging of the speaker coupling capacitor, eliminating 'thump', but capacitor size becomes very large.

Returning for a moment to the input section,  $Tr_2$  is in a similar position to that used in many amplifiers, but instead of driving another stage ( $Tr_3$ ) which only requires a limited voltage swing, it is the prime mover for the output section. To have sufficient drive capability the quiescent current in this stage may well need to be 10mA—instead of the 1mA in mine—and the voltage swing on the collector will be the full supply voltage (50 volts).

It now seems clear why the distortion of many amplifiers rises at low frequencies. The dissipation change of this device during a voltage cycle could be 500mW pk-pk in the case I have quoted giving an emitter-base voltage change at low frequencies of about 100mV. This change, even if we assumed it is basically a linear function of voltage, will cause a non-linear change in the input device and hence a considerable rise in distortion at low frequencies. In my amplifier the maximum dissipation change in  $Tr_2$  will be less than 1mW, thus eliminating this form of distortion and improving intermodulation performance.

## Performance

The measurement of distortion created some difficulties especially when con-

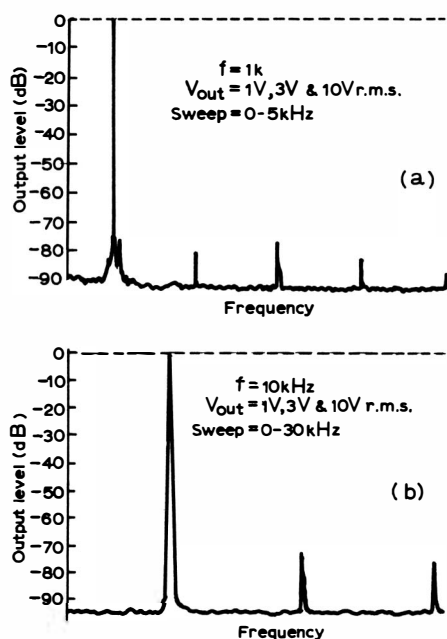


Fig. 4. Spectra made with a wave analyser showed no difference between spectra of outputs from oscillator and amplifier. Plots were made with (a) 1kHz and (b) 10kHz signals and were identical at all three power levels.

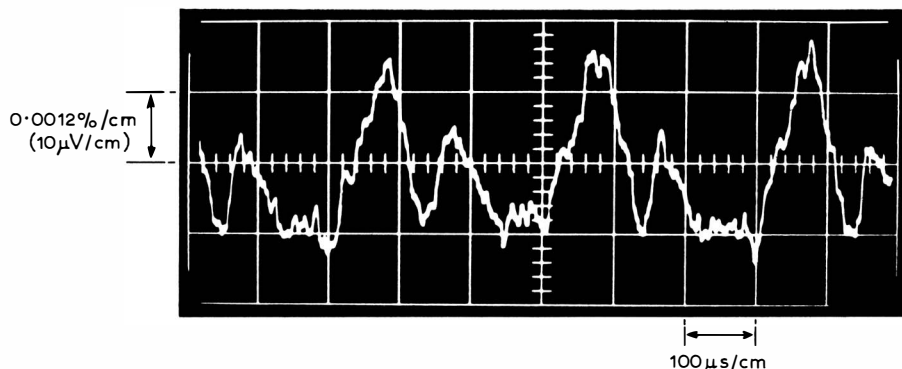


Fig. 5. Null method of assessing amplifier distortion shows distortion products to be well down in the noise. Deflection of 4cm represents 0.003% peak distortion at 10 watts (3kHz, 15Ω load).

sidering the range of frequencies over which this amplifier operates. The methods employed can be separated into two distinct techniques—spectrum analysis and nulling methods. To realize the first technique, an oscillator with a pure, single-line spectrum was needed, but the only one available at the time, approaching a reasonable performance, was the Si 451 produced by J. Sugden & Co, having a range up to 30kHz. This was found (excellent as it is) to be inadequate to permit the measurement of amplifier distortion.

So difficult in fact was the problem that it is impossible to publish distortion curves with any degree of confidence in their truth, but it can be said that using the Hewlett Packard 3590 wave analyser there was *no discernible difference* between a plot of the distortion of the oscillator and that taken after the oscillator output had been passed through the amplifier. Plots were taken over the frequency range 100Hz to 20kHz and powers of 100mW to 25W. As a matter of interest the spectrum plots of the amplifier are shown in Fig. 4 for 1kHz and 10kHz and at several power levels. The second method attempted was rather more successful but unfortunately does not present information in a usable form because it involves a comparison of output and input signals. It is also not a sequential test as in the previous method and as a result problems were encountered in successfully nulling the output against the input of the amplifier, due to the phasing of the signals and the earth loops generated by the measurement method. After considerable adjustment of the phase compensation and spurious pick-up difficulties the photograph Fig. 5 was obtained. Here the distortion generated is right in the noise (−120dB down from 20V r.m.s.) and the total deflection of 4cm represents 0.003% peak distortion at 10 watts and a frequency of 3kHz, chosen for easiest phase cancellation. The spikes usually evident in the difference waveform with this type of amplifier are completely absent, even with reactive loads, indicating that stability in the cross-over region must be excellent.

## Intermodulation performance

The use of these two techniques is limited in one way or another to the evaluation of

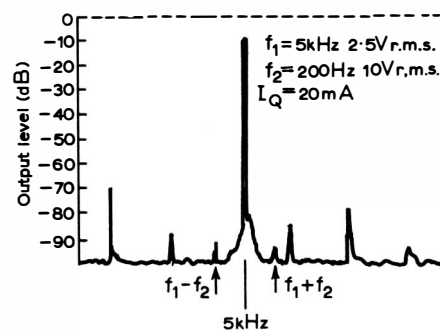


Fig. 6. Result of feeding 5kHz and 200Hz signals in a 16:1 power ratio into amplifier. Intermodulation products  $f_1 + f_2$  and  $f_1 - f_2$  are 90dB below 200 Hz signal. Other spectral lines are due to generator distortion.

amplifier linearity. The main advantage is, of course, that a direct numerical value of distortion is obtained which can be used in comparison with other amplifiers.

The intermodulation test does not rely on low-distortion oscillators of signal cancelling techniques—in fact the only component which limits the measurement accuracy is the wave analyser itself. The real drawback is seen when an interpretation of the results is necessary! The method adopted is to “sweep” the transfer characteristic of the amplifier with a low-frequency signal of large amplitude, and to “measure” the slope of the characteristic with a low-level high-frequency signal. The two frequencies selected were 200Hz and 5kHz in a power ratio of 16:1.

The results not only ease the assessment of the amplifier performance in an absolute sense but also give some form of subjective measurement for comparison with other elements in the system. The results obtained in Fig. 6 indicate an excellent performance, the intermodulation products  $f_1 + f_2$  and  $f_1 - f_2$  are −90dB below the sweeping signal (200Hz) all other spectral lines being due to generator distortion.

## Amplitude-frequency response

The type of frequency compensation used for this amplifier is unusual, mainly as a result of the system design. The open-loop gain begins to fall off at about 4kHz and continues on a 6dB/octave roll-off to about