stability. Unfortunately, the converse is not always true. However, as mentioned earlier, these are the parameters which concern the designers of high quality solid-state circuitry, in which a very much higher standard has already been reached than was practicable with the valve designs of the late '50s. What would be possible in the light of present knowledge, with the use of hybrid valve-transistor designs using transistors for the small-signal stages for which they are ideally suited, and power output valves coupled to high quality toroidal output transformers to minimise hf phase-shift, is an interesting field for speculation, but it seems unlikely to attract commercial interest.

PREAMPLIFIERS

If anywhere, this is the field where the transistor and, in the near future, the monolithic integrated circuit, has really come into its own, with the elimination of heater-circuit wiring, the facility of the use of npn and pnp devices (for right-way-round and upside-down usage), junction and mos field-effect transistors for very high input impedance applications and the minimisation of circuit stray capacitances by virtue of the small physical dimensions of the elements in use. Also, because of the absence of heater circuit and cathode-heater capacitance complications, much greater freedom is available to the designer in the choice of signal and feedback injection paths. As ever, the requirements remain for good signal-to-noise ratios, low hum and radio-break-through pick-up, good linearity and good overload margins to cope with inadvertent maladjustment of the gain controls. Only in this latter context has the thermionic valve a significant advantage over the solid-state device and this advantage, stemming from the limited voltage capability of the low-noise small-signal transistor, is being eroded by design improvements. A circuit arrangement giving a very low input noise level, a low distortion factor, and an output of up to 30 V rms, is shown in Fig. 11.

For very low noise levels, the impedance of the input circuit is of primary importance, in order to minimise the thermal noise originating at this point. At the moment, discrete transistors offer a significantly better performance than the best of the available integrated circuits, and pnp bipolar transistors are better than npn devices because of their lower surface recombination noise. With good small-signal transistors, device input noise values over the 10 Hz-20 kHz bandwidth of the order of 0.15 μV have been claimed, but under circumstances where the input circuit itself would introduce some 0.5 μ V of wide band noise.

With practical devices, and low input-impedance arrangements, a figure of the order of 0.25 μV, referred to the input would appear to be the lower practical limit. Such circuits must use series feedback configurations, of the type shown in Fig. 10, in order to take advantage of the low input impedance offered by, say, a microphone transformer. This leads to the penalty, as shown previously, that the distortion with feedback will be higher than with a shunt feedback arrangement.[18, 19] This arises because of 'common mode' failure in the feedback path, but can be substantially reduced, as in Fig. 10, with a single input transistor, if the input device is operated in 'cascade' to minimise the extent to which the feedback voltage applied at the emitter is able to modulate the emitter-collector voltage. Also, as shown earlier,[20] the distortion in the bipolar transistor is an input characteristic function, and decreases

Power output: 270W, continuous power, into 4 ohms. (500W + in bridge connection into 8 ohms).
Frequency response: dc – 40 kHz (–3 dB point).
Harmonic distortion: Less than 0.01% at maximum and lesser powers, 10 Hz-3 kHz. No crossover products detectable at max output – 3 dB.
Settling time: $<5\ \mu$s.
Output impedance: (1 kHz) 0.02 ohms.
No instability or alteration of square-wave response on reactive loads up to 2μF + 4 ohms. Unaffected by o/c operation, system closes down and draws negligible power from power supply if s/c or improperly low impedance load is connected across outputs.
S/N ratio: –90 dB ref max output.

Fig. 11. This amplifier produces 270 watts (continuous power into four ohms) with a frequency response within 3 dB from dc to 40 kHz. Distortion is less than 0.01%.