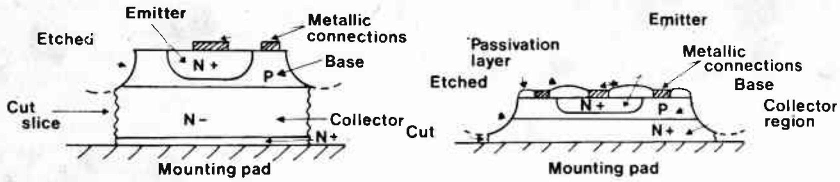
Fig 1 POWER TRANSISTOR CONSTRUCTIONAL TECHNIQUES



'Triple diffused Mesa' power transistor.

The 'N+' contact layer, 'P' base and 'N+' emitter layers are successively diffused into the high resistivity 'N-' collector material

'Epitaxial base' power transistor.

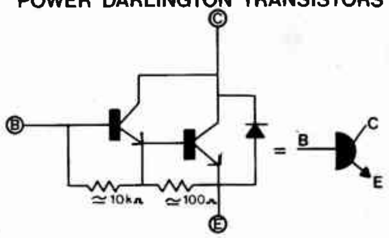
The 'P' base is grown in the vapour phase on the high conductivity 'N+' collector material. The 'N+' emitter layer is then diffused into the base. Note the thinner collector region with a higher thermal conductivity

sized reservoir capacitor is used. This is also desirable from the point of view of HT line voltage regulation. The actual current rating (which should be the 'DC' value) chosen will depend upon whether it is thought likely that the amplifier will be driven, or tested, for protracted periods at power output levels close to its maximum rating. For myself, I thought that this would be unlikely, and chose a rather cheaper mains transformer with a 2 amp rating. This is, however, a matter of personal choice. With a large sized reservoir capacitor, adequate current will still be available on peaks to provide a transient (tone-burst) power output well in excess of the rated 30 watt level for the probable duration of most musical peaks, while the thermal inertia of the transformer will allow continuous power outputs of the rated value for a minute or two, without serious overheating.

Having decided the HT voltage level and the power output requirements, the next necessary decision is the type of circuit to be employed, and the type of output devices. At the moment, by far the best ratio of performance to cost is obtained from a class-AB push-pull output system using conventional junction transistors. It is also useful at this stage to decide whether to use 'complementary' (*n-p-n/p-n-p*) output devices, or whether to use one of the improved 'quasi-complementary' (*n-p-n/n-p-n*) arrangements. The choice is not as clear cut as it is sometimes suggested, since *n-p-n* and *p-n-p* devices can never be truly equivalent in their characteristics, especially at high frequencies, so one is left to decide whether it is better to have good symmetry at LF (complementary) or an improved balance at the HF end of the spectrum (improved quasi-complementary), where the ability of the negative feedback to straighten out the non-linearities is, in any case, much less good.

In general, though, it is easier to make a simple circuit behave well with complementary devices, and this therefore seemed the best bet. The next stage was to contemplate catalogues and price lists to decide on the actual devices to be used, bearing in mind the decision, already taken inwardly, not to use any form of electronic overload protection circuit if this could be avoided. Since these fast-acting protection circuits tend to come into operation prematurely on certain types of LS load (giving rise to unexpected—and definitely unwanted—

Fig 2 INTERNAL CONNECTIONS OF POWER 'DARLINGTON' TRANSISTORS



clipping under circumstances in which the output transistors, whose well-being they have at heart, are not really at risk), if they can be eliminated, then so much the better. However, this does demand fairly robust output devices with a generous 'safe operating area' rating.

Once again, the best performance-to-cost ratio in rugged, complementary power transistors with reasonable HF characteristics and safe-operating-area ratings is provided by those of 'epitaxial-base' construction (fig. 1). In these devices, the 'base' region, which is very important in determining the HF performance, the destructive 'secondary breakdown' levels, and the symmetry of the PNP/NPN performance, is formed by vapour-phase growth onto a plain slice of silicon whose structure has already been tailored to make it have a good performance as the 'collector' region of the finished device. Selective diffusion through a photographically deposited 'mask' then allows the generation of the emitter regions of a large number of transistors side-by-side on the same silicon slice, from which they can be separated by cutting. This is an economical manufacturing process which allows the construction of devices with a closely matched performance, which are much less affected by the vagaries of the diffusion process than for earlier types of power transistors. From the point of view of the circuit designer, this is very good news, in that it ensures a greater degree of consistency in the performance of the final circuit.

Although the market situation has now changed, at the time this circuit was designed complementary pairs of 'epitaxial-base' Darlington transistors (devices in which the driver and output transistors are fabricated simultaneously, along with the necessary interconnections and base-emitter resistors, on the same individual chip fig. 2), were a lot more expensive than their simpler single transistor equivalents. They are now only a little more expensive.

The reason for the relatively low cost of this particular type of device is that it is made in large quantities specifically for the output stages of audio amplifiers as shown schematically in fig. 3. Unfortunately, there is a snag stemming directly from the fact that both driver and output transistors are on the same chip. When the output transistors are driven hard, the increase in temperature is communicated directly to the driver devices, so that instead of just two forward-biased base-emitter junctions getting hot, and requiring a lower bias voltage for the same collector current, there are now four. This, in turn, makes the accurate control of quiescent operating current—on which the elimination of crossover distortion depends—a nearly impossible task. I conclude, with regret, that the semiconductor manufacturers have much lower standards for acceptable performance than I would consider reasonable in the light of present knowledge.

Happily, there is a simple way around this problem, by turning the output transistors upside-down and using a separate small-signal transistor to drive each half, thereby making an output triplet (fig. 4a). I first suggested this scheme in an article (*Studio Sound* April 1975), and it remains, in my view, the best way of using these devices. Once again, though, there is a snag, in that the triplet so formed will oscillate merrily at a few MHz, due to the inherent phase shifts within each device making an elegant HF phase-shift oscillator. This can be avoided by the introduction of the two resistors R_a and R_b in each half (fig. 4b), which limit the gain and minimise the HF phase-shift in the first stage. (If an increased degree of correction is required, the values of both R_a and R_b can be reduced, while keeping the ratio the same, and R_a can also be bypassed with a phase-lead capacitor).

Because of the very high degree of internal feedback within the triplet, the linearity of each of these output stage halves is very good indeed, and this linearity is preserved up to a frequency of several hundred kHz. Moreover, the input impedance is so high, and the drive power requirements so small, that the preceding class-A amplifier stages need to do very little work, which reduces the difference between high-power and medium-power THD levels. Again, this is a good thing.

Fig 3 SCHEMATIC ARRANGEMENT OF AUDIO OUTPUT STAGE USING POWER 'DARLINGTON' TRANSISTORS