A NOVEL OUTPUT STAGE WITH SUPERIOR PERFROMANCE

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Bryston's amplifier circuitry has always been a result of careful evaluation of the most linear methods of amplifying a signal. The output stage employed in Bryston's power amplifiers is an example.

Shown below is a simplified depiction of three similar output stages all using complementary bipolar output transistors. Each of the diagrams shows a type of output configuration known as an "output triple" due to the cascading of 3 stages of current gain.

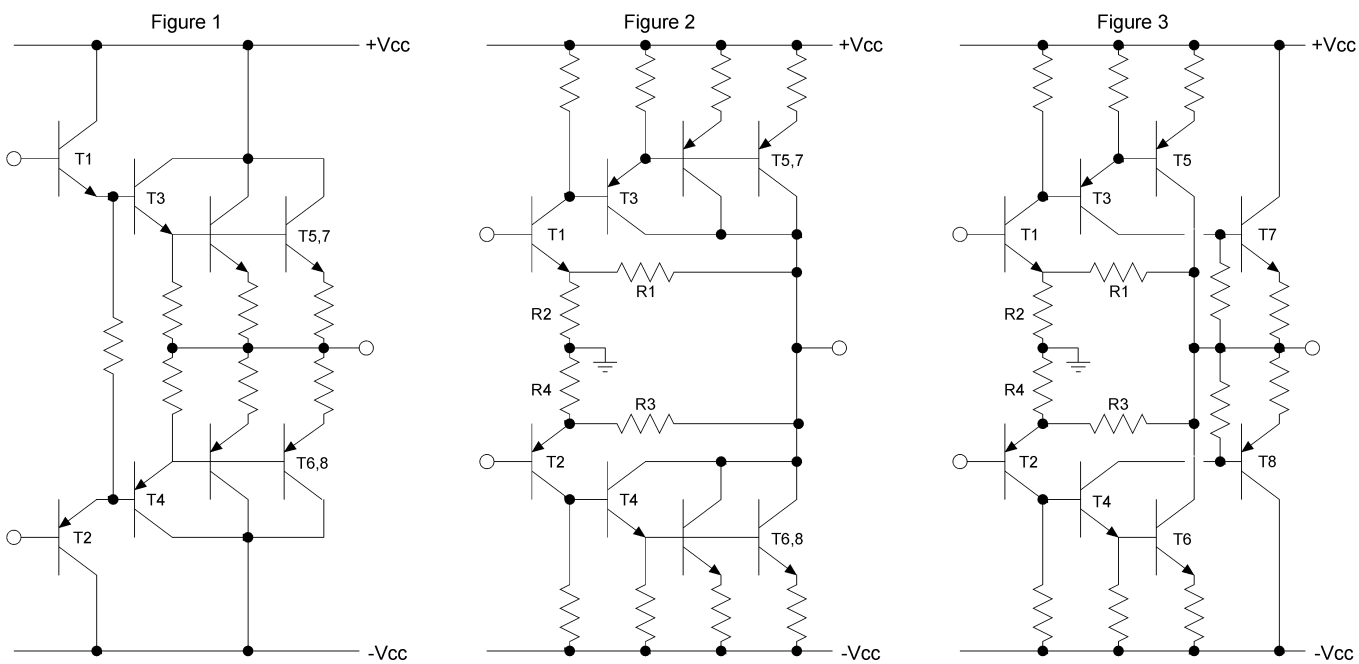

Figure 1 is a classic triple Darlington stage where each successive transistor is driven from the emitter of the previous stage. This arrangement features a current gain of approximately 10 and a voltage gain of 1. It is reasonable linear but has a few limitations:

1: The 1:1 voltage gain requires the preceding low current voltage gain stage(s) to swing the full power supply to drive it to full output. This increases distortion at all frequencies, especially at high output levels.

2: The driver transistors, T3 and T4, have to supply current to the combined input capacitance of the dual output transistors, T5/T7 and T6/T8. This limits the bandwidth of the driver devices and increases distortion at high frequencies. The drive current from T3 and T4 gets split between the output devices 50-50 as well. At high output current levels the drivers may be straining to supply the required input current.

3: Although the NPN devices on the top half are nominally complementary to the PNP transistors on the bottom half of the stage, there are some substantial differences. The bandwidth and gain-current curves do not match and even the "on-voltages" of the output devices differ by about 10%. This means the transfer functions of this output stage do not match at zero-crossing which makes crossover distortion a problem.

Figure 2 shows an earlier Bryston output stage which solves at least one of the above limitations. The output stage has been changed into a common emitter section by virtue of the driver transistors connecting to the collectors of the pre-drivers T1 & T2. This allows a small Voltage gain, (a factor of two, for example), to be developed in the output stage, with the assistance of a local feedback loop (Rl/R2 and R3/R4). That in turn means the input stages need not swing the full power supply voltage at high output levels, reducing distortion. The other limitations still apply, however.

Figure 3 shows Bryston's proprietary output stage, which we call "Quad-Complementary". This output section, although only slightly different in layout from the other two, shows some important advantages:

1: The finite voltage gain of Fig. 2 is retained, with the resulting reduction in overall distortion.

2: The input capacitance of the output devices, T5~T8, is reduced by a factor of four. The reason for this is that the junctions of T5 and T7, for example, are now actually in series with each other, with the driver between them. Since the value of series capacitance is divided rather than multiplied, the total is one-half, rather than twice, the average value, substantially increasing bandwidth and decreasing high-frequency distortion. A similar consideration applies for the drive current to the output devices, which now does 'double duty'. The total input current is half the amount required in Figs. 1 & 2. The drivers thus have less strain to supply high input current, further reducing distortion.

3: Perhaps most important, the complementary characteristics of the upper and lower halves of this output configuration are almost ideally matched. The gain and bandwidth curves of both halves are now the conglomerate characteristics of both NPN and PNP type transistors, as is the 'on-Voltage' of the output devices. Thus the transfer function meets almost seamlessly at zero-crossing, virtually eliminating crossover distortion.

Bryston' s Quad-Complementary output section requires close matching of output transistor gain values, not only between similar types, but between opposite types. Since Bryston products are already hand-built from critically selected components, this is no serious disadvantage to our manufacturing. There is also a slight increase in the complexity of the biasing considerations for this type of output section, since the normal V_{BE} multiplier bias string, (not shown in the diagrams), is not accurate enough to track the several stages of distributed current-gain-with-voltage-gain which make up this circuit. Bryston thus has bias-tracking thermal links in more than one location. In practice, this works very well and quite predictably once the engineering considerations are understood.

In our opinion, the slight increases in required engineering investigation are far outweighed by the overall improvement in wide-band accuracy of this type of output section. The result is that almost mythical *best-of-all-worlds*, where, with no substantial increase in cost or parts-complexity, a truly better design is possible, with superior performance and listening quality.

The overall harmonic distribution of Bryston' s Quad-Complementary output stage closely approaches an ideal Class-A output, except that the overall distortion is actually much lower. (True class-A power amplifier output stages suffer from relatively high current-induced distortion levels, though consisting of mostly lower order harmonics). The listening characteristics display a high degree of transparency without harshness or grain. The annoyances previously ascribed to *transistor sound* are absent and the amplifier seems to combine the seductive lushness of tube equipment with the focus and accuracy of solid-state.