## Voltage-Boosted Output Composite Amplifiers

A number of schemes are useful towards boosting the output swing of standard op amps. This can be either to achieve greater swing (i.e., closer to the rails), or, to develop swings greater than normally possible with standard ICs, i.e., ≈40V swings. In both cases it may also be desirable to increase load drive to 100mA or more.

### Voltage Boosted, Rail-Rail Output Driver

A common requirement in modern system is the rail-rail capable op amp. But all op amps aren't designed with rail-rail outputs, so this may not be possible in all instances. Of course, it makes good sense to utilize standard off-the-shelf rail-rail IC op amps, whenever they meet the application requirements. Nevertheless, it is possible to add an output stage to a standard op amp device that may itself not be rail-rail in function. By using common-emitter (or common-source) discrete transistors external to the op amp, a rail-rail capability is realized. An example designed in this fashion is Figure 6-172 below.

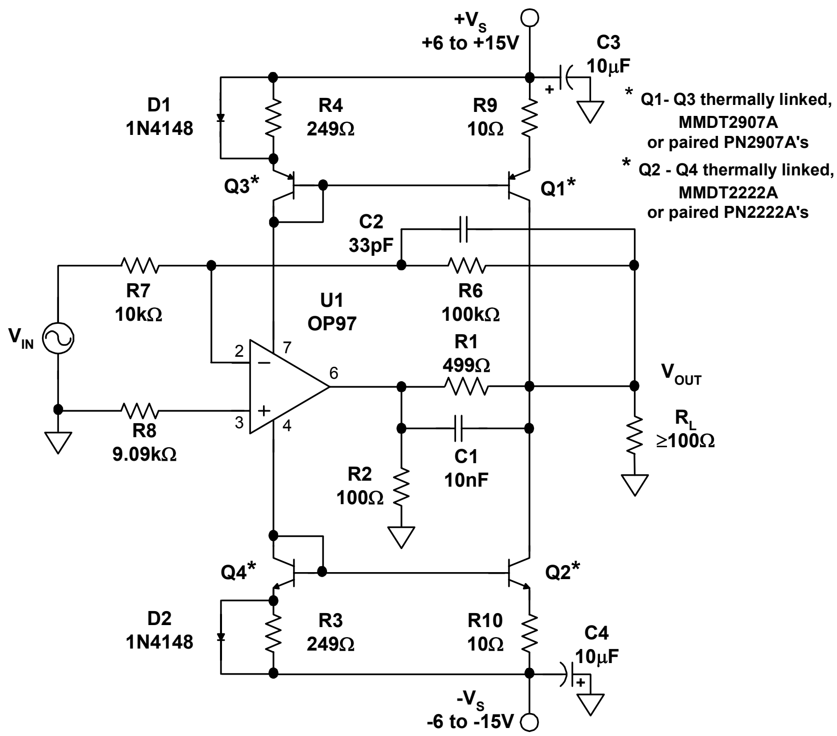


***Figure 6-172:*** *Voltage boosted rail-rail output composite op amp*

Within this circuit Q1 and Q2 are the complementary buffer transistors that provide the rail-rail output swing. The circuit works as follows: Q1 is driven by the voltage drop across R4, and diode-connected Q3. This voltage is developed from the positive rail supply terminal of U1, so the quiescent bias current of Q1 will be related to the quiescent current of U1. Similarly, Q2 is driven from R3 and Q4, via the negative rail terminal of U1. The Q1-Q3 and Q2-Q4 pairs make up current mirrors, developing a quiescent bias current that flows in Q1-Q2. The U1 quiescent current is about 400µA, and with the resistance values shown, the Q1-Q2 bias current is about 10mA.

The output stage added to the U1 op amp adds additional voltage gain, and a current gain boost of 25 times, essentially the ratio of R4/R9 and R3/R10. Thus for a 100mA output from Q1-Q2, U1 only supplies 4mA. The swing across R2 is relatively low, allowing operation on low voltage supplies of ±6V, or up to ±15V.

The simulation data of Figure 6-173 illustrates some salient characteristics of the composite op amp while driving a load of 85Ω. The open loop gain of the circuit is shown by the topmost, or composite gain curve, which indicates a low frequency gain of over 130dB, crossing unity gain at about 630kHz. The intermediate curve is the OP97 op amp gain characteristics. The difference between this and the upper curve is the added gain, which is about 13dB. The lowest curve indicates the closed-loop gain versus frequency characteristics of the composite op amp, which is 20dB in this case, as set by R6 and R7 (as in a standard inverter).

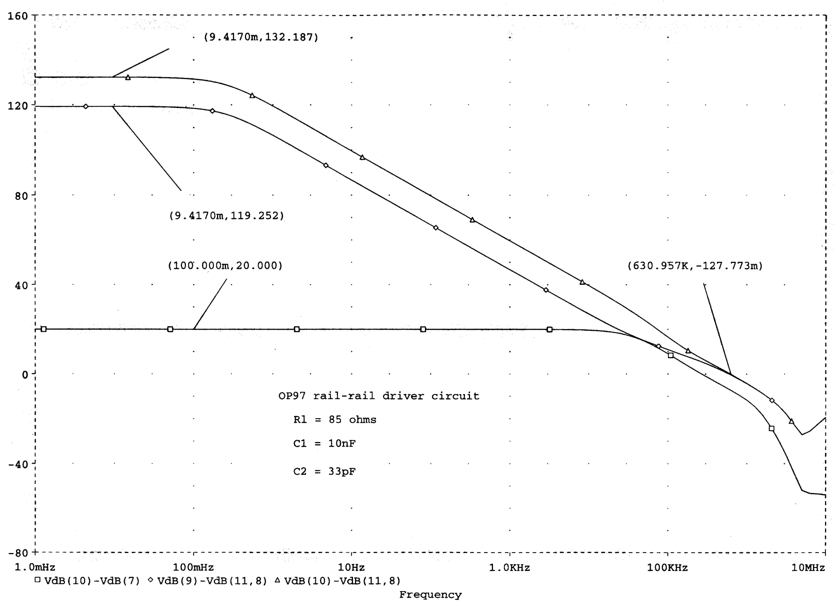


***Figure 6-173:*** *Gain (dB) versus frequency characteristics of Fig. 6-172 composite op amp*

There are a couple of critical points in setting up this circuit. Bandwidth can be controlled by C1 and C2. C1 reduces the added gain at high frequencies, which can be noticed from the composite gain curve, starting below 100kHz. C2 reduces the closed-loop gain, starting about 50kHz. For greater closed-loop gains, C2 may not be needed at all.

Bias control is achieved by the use of thermal coupling between the dual current mirror transistors. The easiest way to accomplish this is to use packaged dual types, either SOT-363 or SM-8 devices (see References 3 and 4). Alternately, TO92 equivalent PN2222A and PN2907A types can be used, with the two flat sides facing and clipped together.

The circuit as shown drives a 100Ω load to within 2V of the rails, limited by the drop across R9 and R10. Current limiting is provided by a shunt silicon diode across R4 and R3, either with 1N4148 diodes, or diode connected transistors. This limits peak output current to about ±60mA. More output current is possible, by adding additional like devices in parallel to Q1 and Q2, with additional 10Ω emitter resistors for each.

A point that should be noted about the booster circuit of Fig. 6-172 is that *the biasing is dependent upon the quiescent current of the op amp*. Thus, this current must be stable within certain bounds, otherwise the idle current in Q1-Q2 could deviate— either too low (causing excess distortion), or too high, causing overheating. So, changing the U1 op amp isn't recommended, unless the biasing loop is re-analyzed for the new device.

Another point is that this type of circuit, which uses the power pins of the op amp for a signal path, *may not model at all in SPICE!* This is due to the fact that many op amp SPICE models do *not* model power supply currents so as to reflect output current— so be forewarned. However, the ADI OP97 model does happen to model these currents correctly, so the reader can easily replicate this circuit with the OP97 (as well as many other ADI models). Discussion of these models can be found in Chapter 7 of this book.

**High Voltage Boosted Output Driver**

With some subtle but key changes to the basic voltage-boosted composite amplifier of Fig. 6-172, output swing can be extended even higher, more than double the standard ±10V swing for ±15V rails. A basic circuit that does this is shown below in Figure 6-174.

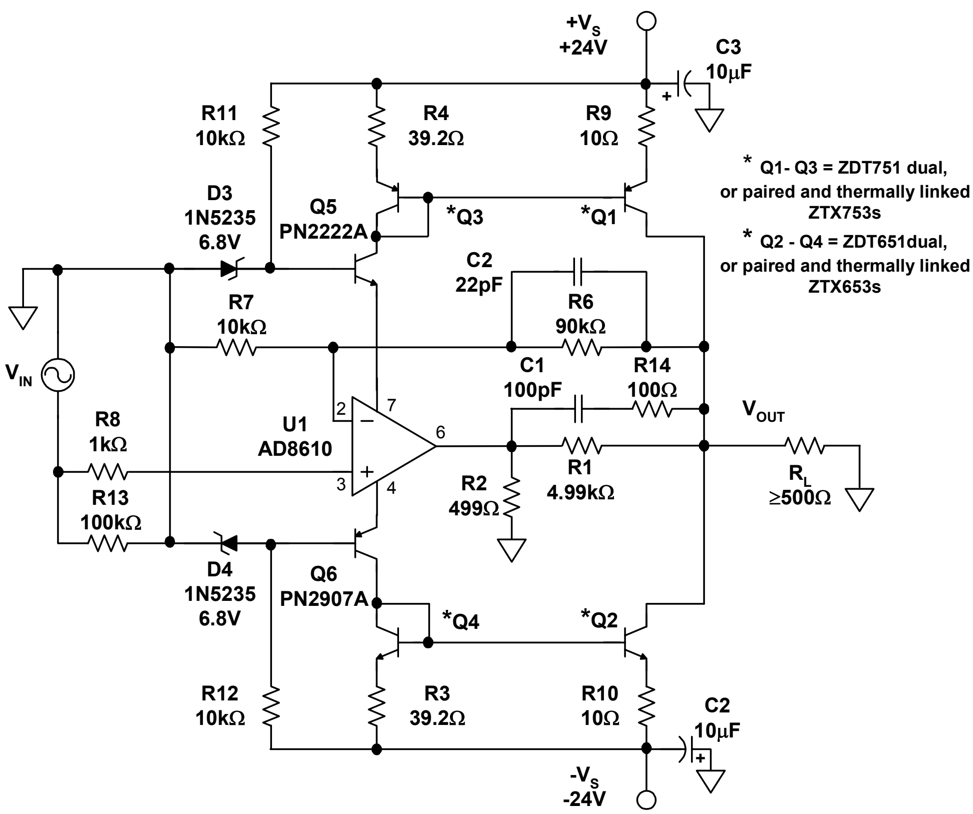


***Figure 6-174:*** *High voltage boosted rail-rail output composite op amp*

This circuit can readily be recognized as being similar to the lower voltage counterpart of Fig. 6-172. To achieve higher voltage capability, the U1 op amp is operated from a pair of combination level-shift/regulator transistors, Q5 and Q6. These are biased in turn from the D3 and D4 zener diodes at their bases, to ±6.8V, respectively. The op amp rails are