APPENDIX F

OUTPUT STAGES

Some applications may require outputs other than the text circuit's 0V to 5V range. The simplest variation is a bipolar output, shown in Figure F1. The circuit, a summing inverter, subtracts the DAC output from a reference to obtain a bipolar output. Resistor and reference values may be varied to obtain different output excursions. The LT1010 output buffer provides drive capability and the chopper stabilized amplifier maintains 0.05µV/°C stability. The resistors introduce a 0.3ppm/°C error contribution[1]

Figure F2 yields voltage gain by dividing the DAC output prior to its application to the feedback A-to-D. In this case, the 1:1 divider ratio sets a 10V output, assuming an A-to-D reference of 5V. As in Figure F1, the resistors add a slight temperature error, about 0.1ppm/°C for the ratio set specified.[2]

Figure F3 uses active devices for voltage outputs as high as ±100V. The discrete high voltage stage is driven in closed-loop fashion by a chopper stabilized amplifier. Q1 and Q2 furnish voltage gain, and feed the Q3-Q4 emitter follower outputs. Q5 and Q6 set current limit at 25mA by diverting output drive when voltages across the 27Ω shunts become too high. The local 1M-50k feedback pairs set stage gain at 20, allowing LTC1152 drives to cause full ±120V output swing. The local feedback reduces stage gain-bandwidth, making dynamic control easier. This stage is relatively simple to frequency compensate because only Q1 and Q2 contribute voltage gain. Additionally, the high voltage transistors have large junctions, resulting in low f_ts, and no special high frequency roll-off precautions are needed. Because the stage inverts, feedback is returned to the amplifier's positive input. Frequency compensation is achieved by rolling off the amplifier with the local 0.005µF-10k pair.

Heating and voltage coefficient errors are minimized in the feedback term by using four individual resistors. Trimming involves selecting the indicated resistor for exactly 100.0000V output with the DAC at full scale.

Figure F4 increases output current capability with a current gain stage inside the DAC output amplifier's feedback loop. This stage replaces the LT1010 150mA buffer shown in the text. The figure shows two options, differing in output capacity. It is worth noting that as output current rises, wiring resistance becomes a large potential error term. For example, at only 10mA output, 0.001Ω of wiring resistance introduces 10µV drop—a 2ppm error. Because of this, heavy loads should be supplied via short, highly conductive paths and remote sensing employed.

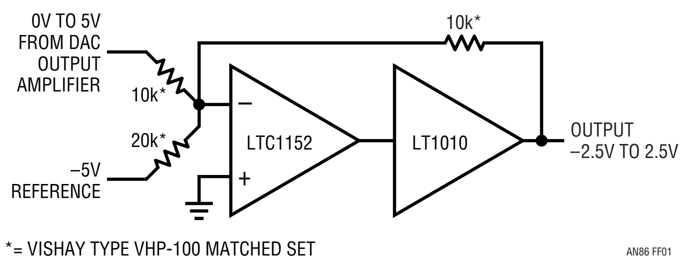

Figure F1. Precision Resistors and Chopper Stabilized Output Amplifier Allow Bipolar DAC Output. Trade-Off Is ≈0.3ppm/°C Additional Resistor Based Error

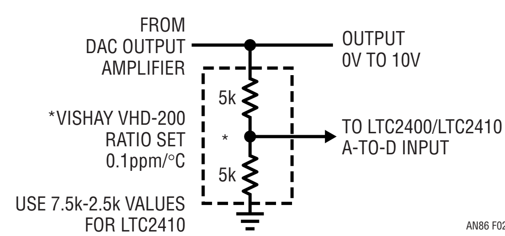

Figure F2. ×2 Voltage Gain Obtained By Feedback Division at A-to-D. Slight Increase in Overall Temperature Coefficient Results

Note 1: See Note 1 in Appendix E.

Note 2: See above footnote.

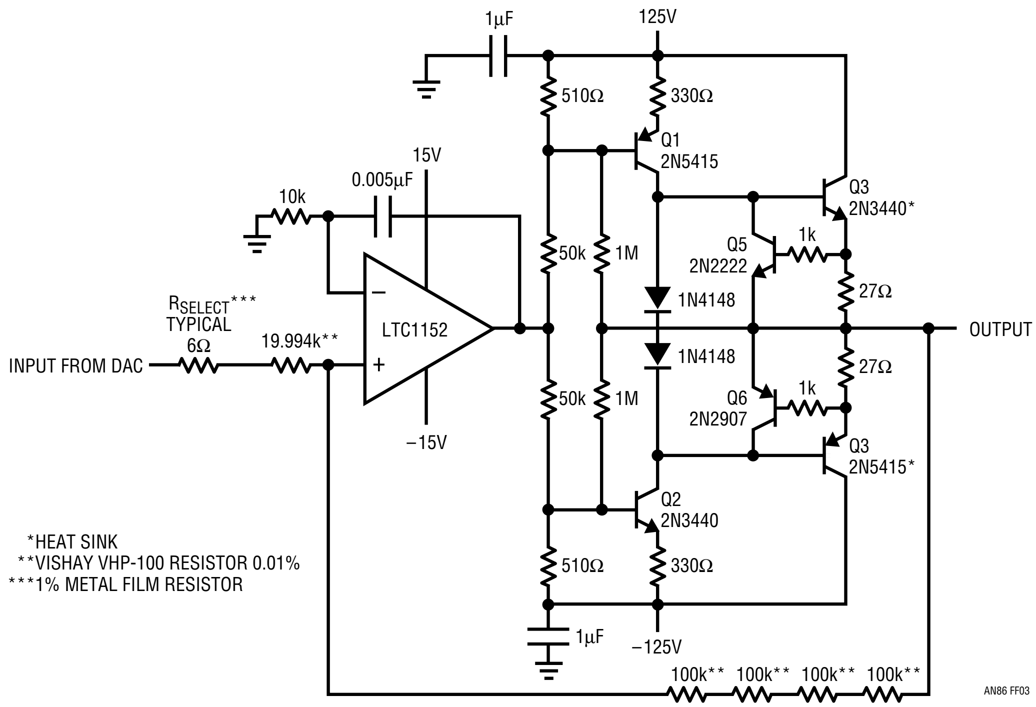

Figure F3. High Voltage Output Stage Delivers ±100V at 25mA. Multiple Feedback Resistors Minimize Dissipation and Voltage Coefficient Effects

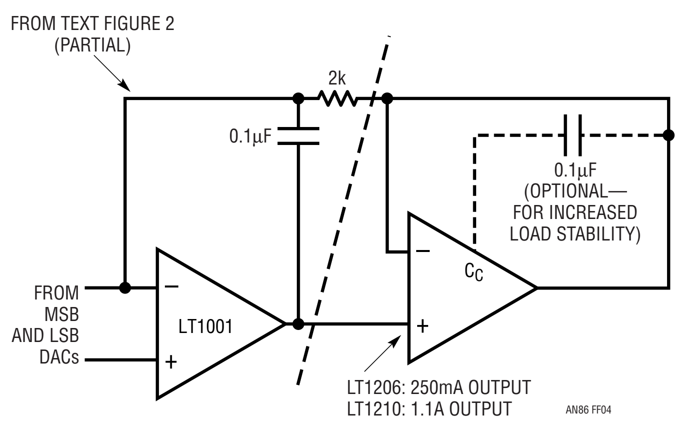

Figure F4. LT1206/LT1210 Output Stages Supply 250mA and 1.1A Loads, Respectively. Remote Sensing Is Usually Necessary to Compensate IR Drops