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APPLICATION NOTE 4474

4.096V, 80mA Precision Reference

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Abstract: You can boost the output-current capability of a voltage-reference IC without degrading its output accuracy, by adding an NPN-transistor buffer in the feedback loop of the IC's error amplifier. The circuit shown enables a MAX6033A reference to deliver as much as 80mA.

This design idea appeared in the December 1, 2006 issue of *EDN* magazine.

Large analog systems with many loads on the reference voltage can easily demand more current than a single reference IC can deliver. If your reference has FORCE and SENSE terminals, however, you can easily add a buffer inside the feedback loop. The buffer has no effect on reference accuracy, and the overall circuit can have (for example) the same 0.04% initial accuracy and 7ppm/°C temperature coefficient as does a stand-alone MAX6033 (the IC in **Figure 1**). The 4.096V precision reference described below includes a buffer circuit that delivers 80mA.

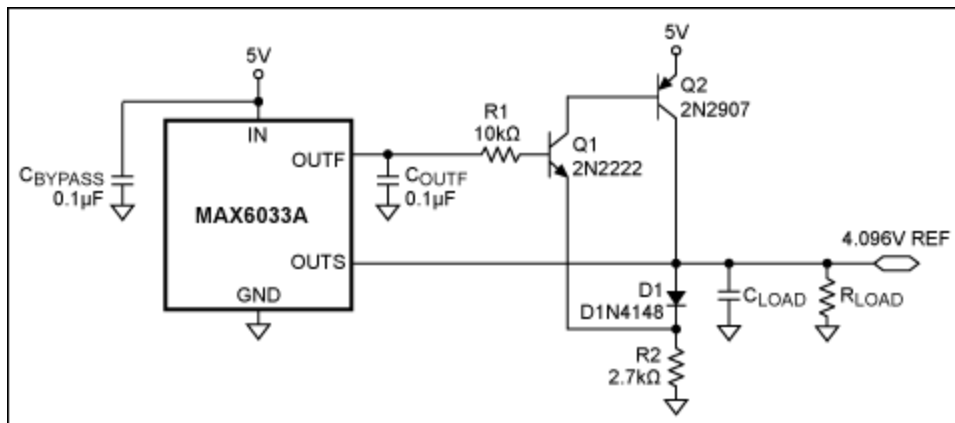


Figure 1. Adding a 2-transistor output buffer to this 4.096V, 15mA reference IC boosts the output current to 80mA or higher.

One must keep the following issues in mind when designing a buffer stage for the FORCE-SENSE control loop:

- Supply-voltage head room
- No phase inversion
- Unity voltage gain

The simplest buffer circuit is an NPN emitter follower, which requires a drive voltage that is higher (by one transistor V_{be}) than the reference output voltage. When you also consider the minimum required

power-supply voltage and the maximum allowed V_{be} voltage, this configuration runs out of head room. A PNP drive stage can solve the headroom problem, but that arrangement inverts the output voltage and prevents the FORCE-SENSE loop from working. You can cancel the inversion by adding another PNP stage, but two PNP transistors destabilize the FORCE-SENSE loop by adding too much gain.

The modified "complementary Darlington" configuration of Figure 1 (also called a Sziklai connection) solves these problems. The circuit acts like an emitter follower, so it provides unity voltage gain with no inversion. The output PNP stage has plenty of head room, but the NPN stage does not. To overcome that drawback, we add a diode (D1) that shifts the NPN emitter voltage down by one diode drop. Thus, the diode drop and transistor V_{be} cancel one another (to a first approximation), leaving plenty of voltage headroom.

The maximum output current for this circuit (80mA) is a consequence of limited beta in the Q2 transistor shown (2N2907). By substituting other transistors, you can increase the output current to any reasonable level.

For stability, the MAX6033 requires 0.1 μ F ceramic capacitors on its IN and OUTF pins. The OUTF capacitor determines the circuit's response speed. Otherwise, the transistor buffer has no significant effect on transient response. Because the transient response of most dc references cannot deal with a fast step load, you must rely on this circuit's output capacitor (C_{LOAD}) to supply fast current spikes. The circuit is stable for C_{LOAD} values up to 10 μ F.

Related Parts

[MAX6033](#)

Ultra-High-Precision SOT23 Series Voltage Reference

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