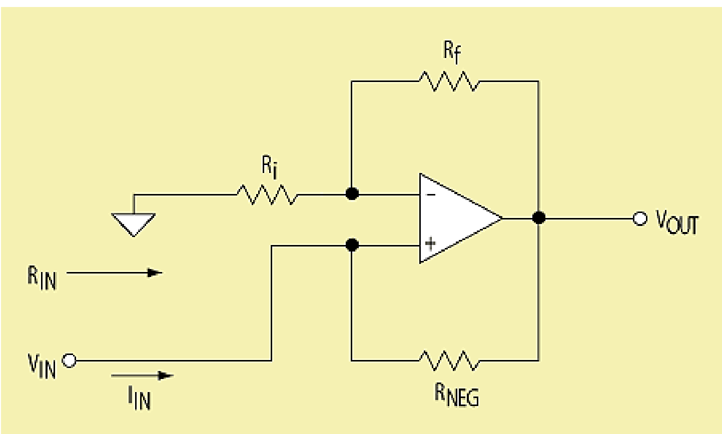
Negative-Resistance Load Canceller Helps Drive Heavy Loads

Contributing Author
ED Online ID #4128
March 19, 2001

Though not difficult, driving a load from a voltage reference IC requires some attention. After determining the supply voltage and output voltage, various other design parameters need to be considered. These include the output-voltage temperature coefficient, initial accuracy, drift, noise, line and load regulation, package size and type, power consumption, stability with various capacitive loads, and the required source and sink capabilities.

The need to source or sink more current than the voltage reference can provide is a common problem. A precision unity-gain buffer amplifier offers an adequate solution in applications that can tolerate its additional drift, noise, and gain inaccuracy. One serious drawback, however, is the buffer's potential instability when driving capacitive loads (such as the well-bypassed reference inputs of an analog-to-digital or digital-to-analog converter). Attempting to guarantee the buffer's stability by introducing an isolation resistor (between op-amp output and capacitive load) further degrades the reference circuit's accuracy.

Another alternative approach is to cancel the load, that is, to make it seem like a sizable resistance. If load resistance is made to appear large, the remaining load is then composed of any capacitance that may be in parallel with the load resistance. The load may be cancelled by placing a negative resistance in parallel with the load's positive resistance. If the magnitudes of these positive and negative resistances can be made equal, the effective load resistance becomes infinite. Unlike a buffer amplifier, this negative-resistance circuit adds negligible output error (Fig. 1).



1. By matching this circuit's negative resistance (between the VIN terminal and ground) with the load, the load will appear infinite.

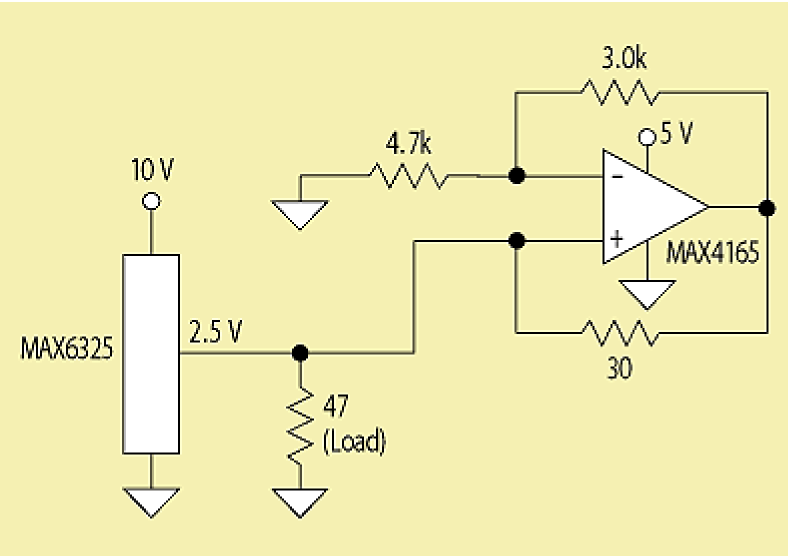
The input resistance from V_{IN} to ground is negative, and can be calculated as follows:

$$I_{IN} = \frac{V_{IN} - V_{OUT}}{R_{NEG}} = \frac{V_{IN} - V_{IN}\left(1 + \frac{R_f}{R_i}\right)}{R_{NEG}}$$

$$= \frac{-\frac{R_f}{R_i} V_{IN}}{R_{NEG}}$$

$$R_{IN} = \frac{V_{IN}}{I_{IN}} = -R_{NEG} \frac{R_i}{R_f}$$

Adding this circuit to the output of an ultra-stable reference able to drive ±15 mA (Fig. 2) lets the reference drive ±50 mA or more. With perfectly matched components, the reference would source negligible dc current. When 1% resistors are used in the negative-resistance circuit, the required worst-case output current is ±2 mA. Load cancellation improves the output accuracy by lowering the error created by the reference output resistance. It also minimizes any drift due to self-heating, particularly when the output current is large and the difference between the output voltage and reference-supply voltage also is substantial. In addition, the circuit is unconditionally stable with any capacitive load.



2. Placing the circuit from Figure 1 in parallel with the load of a voltage reference (47 W in this case) cancels most of the reference's resistive load. Effectively, only the capacitive load will remain.