Shunt regulator serves as inexpensive op amp in power supplies

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Developed as a three-terminal shunt regulator, the popular and multiple-sourced TL431 IC offers designers many intriguing possibilities beyond its intended application. Internally, the TL431 comprises a precision voltage reference, an operational amplifier, and a shunt transistor (**Figure 1a**). In a typical voltage-regulator application, adding two external resistors, R_A and R_B, sets the shunt-regulated output voltage at the lower end of load resistor R_S (**Figure 1b**).

In today's power-supply market, cost reduction drives most designs, as evidenced by Asian manufacturers that have resorted to shaving pennies off their power-supply products by using single-sided pc boards. This Design Idea shows how a three-terminal shunt regulator can replace a more expensive conventional operational amplifier in a power-converter design.

A switched-mode power supply uses a galvanically isolated feedback portion of a PWM circuit (**Figure 2**). In designs that omit a voltage amplifier, a shunt regulator can serve as an inexpensive op amp. Resistors R_I and R set the power supply's dc output voltage, and optocoupler IC_2 provides galvanic isolation. Resistor R_1 provides bias for the optocoupler and the TL431, IC_1. Resistor R_3 and zener diode D_1 establish a fixed bias voltage to ensure that bias resistor R_1 does not form a feedback path. Resistors R_1 and R_2 control the gain across the optocoupler. In most designs, the ratio of R_2 to R_1 is roughly 10-to-1.

Components C_P, C_Z, and R_Z provide frequency compensation for the control loop. The optocoupler includes a high-frequency pole, f_P, in its frequency response, an item that most optocouplers' data sheets omit. You can use a network analyzer to determine the location of the high-frequency pole or estimate that the pole occurs at approximately 10 kHz. The following **equation** describes the compensation network's small-signal transfer function:

$$G_C(s)=\frac{\Delta V_{ERR}}{\Delta V_{OUT}}=\frac{(s\times R_Z\times C_Z+1)}{s\times R_I(C_Z+C_P)\left(\frac{s\times R_Z\times C_P\times C_Z}{C_P+C_Z}+1\right)}\times\frac{R_2}{R_1}\times\left(\frac{1}{\left(\frac{s}{2\times\pi\times f_P}+1\right)}\right).$$

Note that, under some circumstances, adding a bypass capacitor across diode D_1 may be necessary for output-noise reduction. EDN

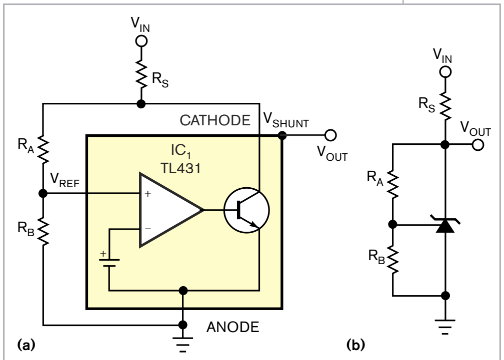

Figure 1 Despite the block diagram, the TL431 is internally complex (a), but you need only three external resistors to use the TL431 in a basic shunt-regulator circuit (b).

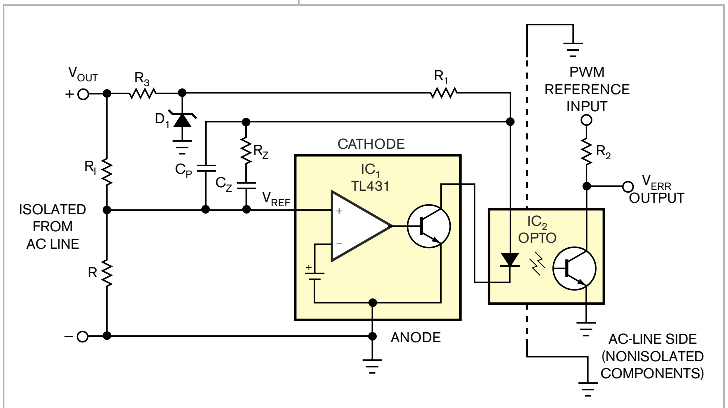

Figure 2 A TL431 replaces a more expensive operational amplifier in this power supply's PWM feedback-regulator circuit.