# Shunt regulator eases power-supply-start-up woes

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The popular and multiply sourced TL431 three-terminal shunt regulator offers designers considerable versatility in its applications. **Figure 1a** illustrates the TL431's internal circuitry, which comprises a precision voltage reference, an operational amplifier, and a shunt transistor (**Reference 1**). In a typical voltage-regulator application, two external resistors, $R_A$ and $R_B$, determine the shunt-regulated output voltage at the lower end of load resistor $R_S$ (**Figure 1b**). By way of illustration, the TL431 and a few external active and passive components can serve as a low-power auxiliary power supply for an SMPS (switched-mode-power-supply) PWM (pulse-width-modulated) controller. In some power-supply designs, an auxiliary winding on the step-down transformer supplies power to the PWM controller. Under light output loads, the auxiliary winding may supply inadequate power to the PWM controller. For example, the converter circuit in **Figure 2** derives power for PWM controller $IC_1$ through an auxiliary bias winding, $W_{AUX}$, which is part of transformer $T_1$. Resistor $R_T$ and capacitor $C_{HOLD}$ form a trickle-charge circuit that supplies start-up power to $IC_1$. To conserve energy, resistor $R_T$ supplies just enough current to trickle-charge $C_{HOLD}$ to voltage $V_{AUX}$. Once the circuit starts, it

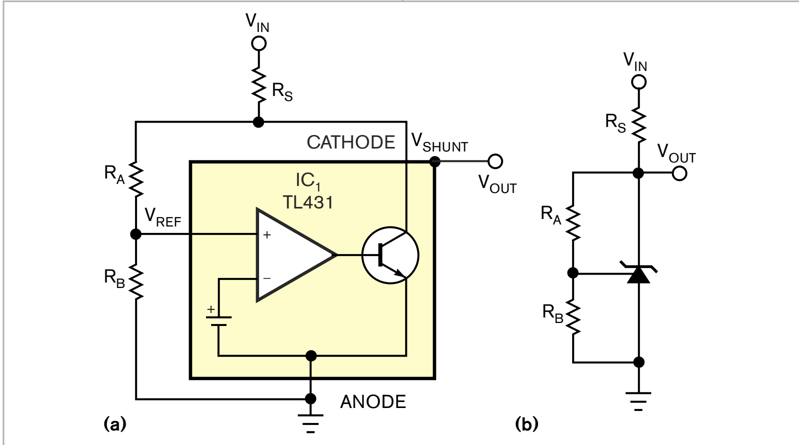


Figure 1 An uncomplicated block diagram (a) conceals the TL431's internal complexity, but you need only three external resistors to use the TL431 in a basic shunt-regulator circuit (b).

operates as you would expect and delivers output power to the load, and the auxiliary winding and its components power the PWM controller.

However, removing the output load reduces the energy supplied to the auxiliary bias winding, depleting the charge on $C_{HOLD}$ and causing $IC_1$ to turn off, which in turn upsets output-voltage regulation and causes the power supply to operate erratically. A low-power bias-supply circuit supplies light-load start-up power and then switches off to conserve power whenever the auxiliary winding can supply enough energy to PWM controller $IC_1$ (**Figure 3**). In this circuit, a series-pass regulator turns on under light-load conditions and turns off when the bias winding can supply the energy to the PWM controller, thus conserving energy under load and improving converter efficiency.

Resistors $R_A$ through $R_D$, shunt regulator $IC_1$, diode $D_1$, and transistor $Q_1$ form the low-load series-pass-regulated bias supply. You select these components to produce a voltage at $Q_1$'s emitter that falls between $IC_1$'s turn-off voltage and the nominal voltage produced by rectifying the auxiliary bias winding's output, $V_{AUX\_NOM}$. In effect, the voltage at $IC_1$'s $V_{CC}$ pin follows in wired-OR fashion whichever is higher: $V_{AUX\_NOM}$ or the voltage at transistor $Q_1$'s emitter. When the auxiliary bias winding and its components deliver sufficient power, $Q_1$'s emitter sees a reverse bias, and $Q_1$ shuts off to conserve energy. Conversely, $Q_1$ supplies power when $V_{AUX}$ decreases below $V_{AUX\_NOM}$ due to a light output load. Note that the circuit still must include trickle-charge resistor $R_T$ because most PWM controllers incorporate undervoltage lockout, the ability to start at a higher than nominal supply voltage.

To design the series-pass regulator, select resistor $R_C$ to supply sufficient operating current to $IC_2$, and select resistor $R_D$ to maintain $Q_1$'s collector voltage and current within its safe operating area. Select resistors $R_A$ and $R_B$ to set the series regulator's output voltage above $IC_1$'s start-up voltage and below the nominal voltage supplied by the auxiliary winding's rectified output. Choose bypass capacitor $C_A$ to minimize ripple voltage across $IC_2$.

You can use the following **equation** to adjust the voltage divider formed by resistors $R_A$ and $R_B$:

$$\frac{V_{REF}}{R_B} = \frac{V_{AUX\_NOM} - V_{D1} - V_{BE(Q_1)} - V_{REF} - 1V}{R_A}.$$

The voltage at $Q_1$'s emitter must fall below the nominal auxiliary voltage, which the auxiliary bias winding supplies. $V_{REF}$ represents shunt regulator $IC_2$'s internal nominal reference voltage of 2.495V, and $V_{D1}$ and $V_{BE(Q1)}$ represent $D_1$'s voltage drop and $Q_1$'s forward base-emitter voltage, respectively. **EDN**

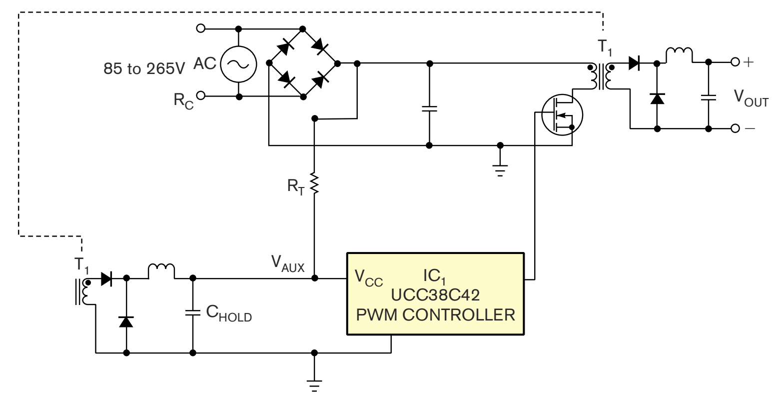


Figure 2 An auxiliary winding supplies power to the supply's PWM controller.

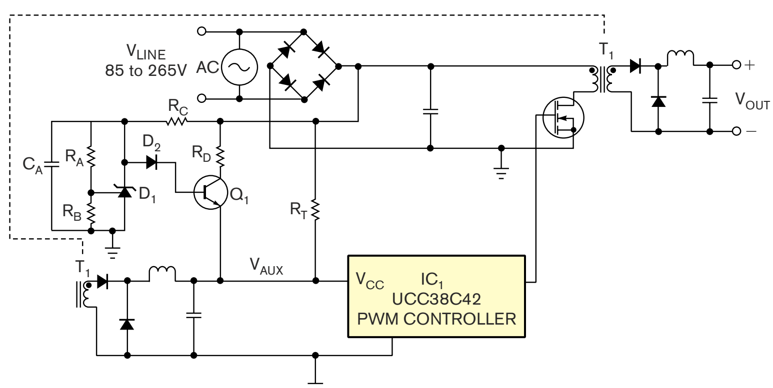


Figure 3 In this improved design, pulse-width-controller $IC_1$ derives its power from $R_T$ for start-up, auxiliary winding $W_{AUX}$ for normal operation, and shunt-regulator circuit $IC_2$ and $Q_1$ for low-load operation.

## REFERENCE


1. O'Loughlin, Michael, "Shunt regulator serves as inexpensive op amp in power supplies," *EDN*, Sept 15, 2005, pg 96, www.edn.com/article/CA6255051.