[Regulate a 0 to 500V, 10-mA power supply in a different way]

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Contemporary power supplies use switching techniques to achieve the desired output voltage from the primary source. Switching power supplies, however, are often too noisy to be used in sensitive analog circuits. You may find linear power supplies to be preferable in these cases.

A standard practice for a linear voltage regulator is shown in **Figure 1**. A higher-than-desired, unstable voltage is connected to the input, V_{IN}, and the series-pass transistor, Q_1, reduces the voltage to the desired level at output V_{OUT}. An error amplifier, IC_1, compares a fraction of V_{OUT} with a reference voltage, V_R, and controls Q_1 to keep the output fixed regardless of the load current, I_{OUT}, and variations of V_{IN}. Such a circuit is suitable only for a small range of output voltages.

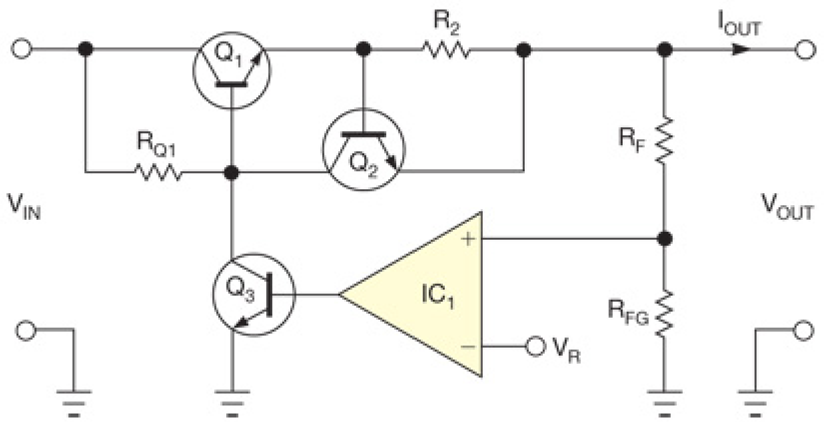

Figure 1 A standard linear voltage regulator connects the feedback directly to the series-pass transistor, Q_1.

When a wide range of output settings is desired, as in laboratory power supplies, the value of resistor R_{Q1} must be small enough to allow sufficient base current for transistor Q_1 at the high end of the output voltage range, but excessive power is dissipated at this resistor and transistor Q_3 when output voltage is reduced. Additionally, Q_3 must withstand the maximum V_{IN}.

You can use the circuit in **Figure 2** to overcome these problems. Two standard transformers, T_1 and T_2 (220V ac to 6V ac, 10W), are used to make an isolated replica of the mains supply, V_M. This replica is doubled and rectified using D_1, D_2, C_1, and C_2 to get about 560V at V_{IN} from 220V ac at V_M. As in the standard **Figure 1** connection, a series-pass transistor, Q_1 ([BU508A]), is used to reduce the unstable V_{IN} down to a fixed V_{OUT}, and IC_1 compares the divided V_{OUT} with V_R. Potentiometer R_3 sets V_R to allow for the adjustment of V_{OUT}, as given by the following **equation**: $V_{OUT}=V_R\times[(R_{FG}+R_F)/R_{FG}]$, where $R_F=R_{F1}+R_{F2}$ … R_{Fn}.

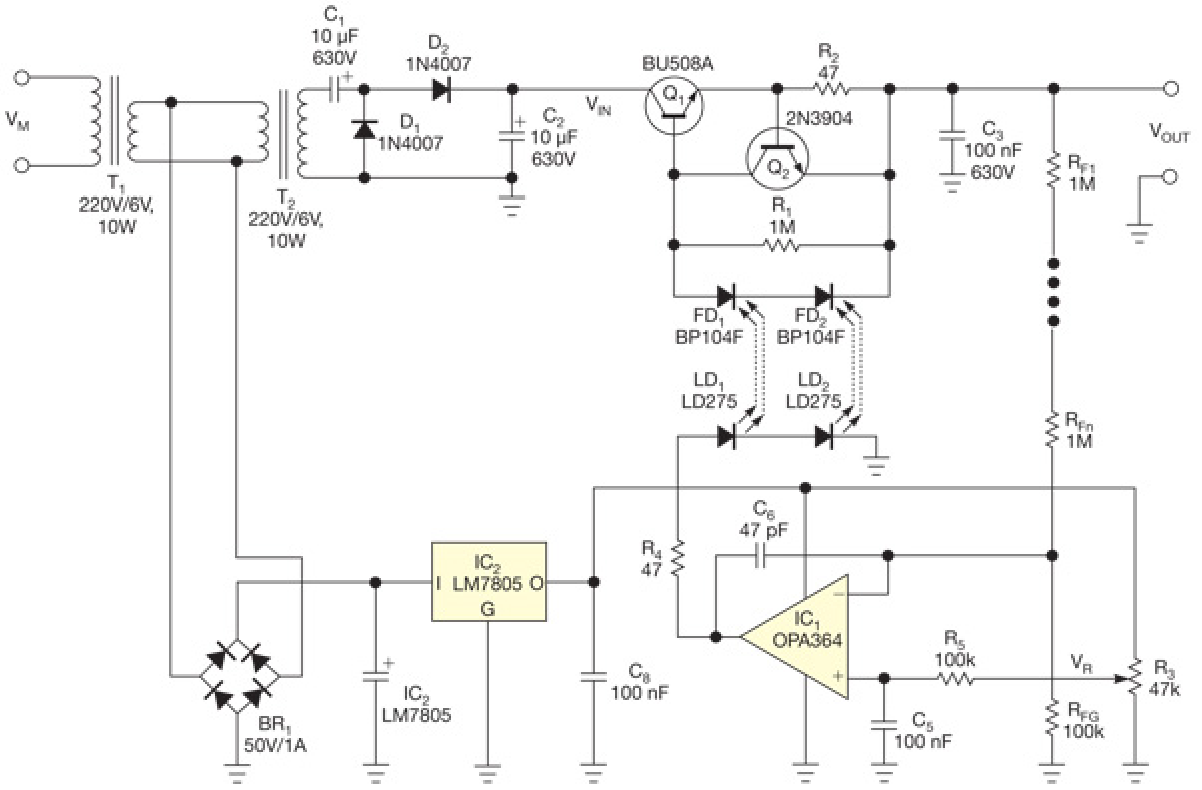

Figure 2 Optical coupling isolates the high voltage at Q_1 from the op-amp output.

With 10 resistors (1 MΩ each) connected in series to form R_F and a maximum reference voltage of 5V, the output voltage can be set from 0 to 505V. The OPA364 operational amplifier is a rail-to-rail input type to allow proper operation, with V_R ranging from 0 to 5V, and is able to source a current of up to 40 mA.

To reduce the power dissipation caused by driving a series-pass transistor and expand the output voltage range, the driving of transistor Q_1 is done in an unconventional way using optical isolation. Two photodiodes, FD_1 and FD_2, operating in photovoltaic mode, provide the driving current for the base of transistor Q_1. Light falling on the photodiodes causes a current flow into the base of Q_1.

The maximum voltage from a single photodiode working in photovoltaic mode is not sufficient to drive the base; therefore, two photodiodes are connected in series. Photodiodes for infrared light at 870 to 950 nm are used, and two IR LEDs, LD_1 and LD_2, illuminate them. The LEDs are standard 5-mm, plastic-encapsulated types. To improve the transfer ratio of the current through the LED versus the current generated by the photodiode, cut off the tops of the LEDs and polish them to form a flat surface. Place the photodiodes in proximity to the surfaces obtained. The transfer ratio of this homemade optocoupler is about 0.05. (The current of 20 mA through the LED causes a current of 1 mA through the photodiode.) Alternatively, you can use a commercially available linear optocoupler—for example, an IL300, which houses two photodiodes. Its current transfer ratio is only about 0.007, so you should use several such components in parallel.

The current-limiting circuit formed by Q_2 and R_2 simply shorts the FD_1 and FD_2 photodiodes when the output current exceeds Q_2's turn-on threshold, and the limit is independent of the output voltage. Capacitor C_6 is added for compensation, and transistor Q_1 should be fitted with a heat sink of at least 5°C/W. The power supply for the operational amplifier and the reference voltage is provided from the ac signal between the two transformers using bridge rectifier BR_1 (50V, 1A); two filtering capacitors, C_7 and C_8; and voltage regulator IC_2 (LM7805). A shutdown of the output voltage can be made by a simple short circuit across capacitor C_5, making V_R equal to 0.

Those living in a 110V ac region can use locally available transformers, but they should modify the circuit to achieve 500V by adding yet another transformer, T_3 (the same as T_1 and T_2, all 110V ac to 6V ac, 10W), in such a way that the low-voltage windings are connected in parallel, while the high-voltage windings of transformers T_2 and T_3 are connected in series. The operation of the high-voltage windings can be verified using an ac voltmeter; if the voltmeter reads zero, the ends of the windings from T_3 must be exchanged. Alternatively, if a 220V/6V transformer is available, keep T_2 as 220V/6V and use 110V/6V at T_1.

Editor's note: High voltages of 500V and the available current of several milliamps can be lethal; exercise caution when building, testing, and using this circuit.