A better bootstrap/bias supply circuit

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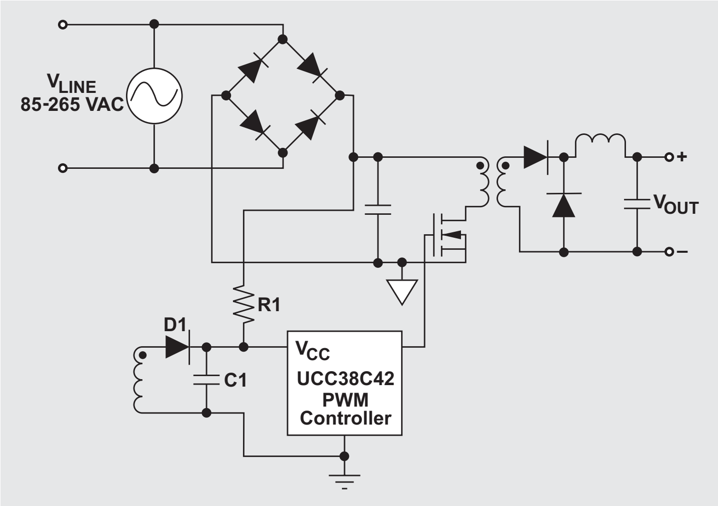
In some power-supply applications, the pulse width modulator (PWM) controller is powered up by the configuration in Figure 1 from an auxiliary winding tapped off the power stage's transformer. This technique is used to reduce power loss and keep the overall efficiency high. The auxiliary winding, D1, and C1 provide power and hold-up energy for the PWM. Resistor R1 is used to trickle charge C1 off the input voltage. C1 has to be sized to hold up the supply voltage (V_{CC}) long enough for the PWM to start switching the gate of the power MOSFET, causing energy to be stored in the power transformer and delivered to the PWM's V_{CC} through the auxiliary winding. This technique is known as bootstrapping. However, at light-load conditions this circuit is problematic for the power-supply designer.

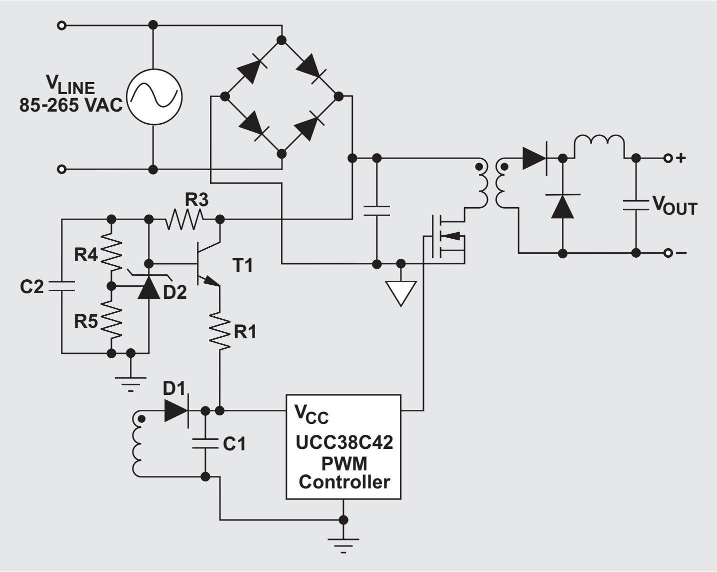
Figure 1. Traditional bootstrapping/bias supply



Problems with traditional bootstrapping/bias supply scheme

Under light-load conditions, C1 has to supply all the energy. C1 generally has to be large enough to hold up V_{CC} for at least 10 switching cycles. However, under light-load and no-load conditions, the current into the PWM (I_{CC}) will discharge V_{CC} to the point that the PWM will go into undervoltage lockout (UVLO), causing the output to become unstable. The designer might think that he can reduce the size of R1 or increase the size of C1. Reducing the size of R1 only increases losses and decreases the overall efficiency. Increasing the size of C1 only decreases the start-up time of the PWM. The circuit in Figure 2 will reduce the size of the hold-up capacitor and provide power under no-load conditions while maintaining high efficiencies at the converter's full output power.

Figure 2. Adding series-pass regulator reduces size of C1



Theory of operation

Electrical components C2, D2, R3, R4, R5, and T1 form a series-pass regulator that provides power to the PWM's V_{CC} under light- to no-load conditions. Resistor R1 provides current limiting to protect the series-pass transistor (T1). All of these components together form a bootstrap/bias supply circuit. The series-pass regulator is designed to supply a bias voltage that is less than the bias voltage developed by the auxiliary winding. When the auxiliary winding starts to supply V_{CC} voltage, it produces a voltage large enough to back bias the base emitter junction of T1, causing the series-pass regulator to turn off. This circuit enables the designer to take advantage of lower losses from powering the PWM with an auxiliary winding and also supplies energy to the control circuitry at light loads.

Setting up the circuit

First we set up the shunt regulator voltage. Knowing the voltage from the auxiliary supply (V_{AUX}), we can use the following equation to calculate the shunt voltage (V_{SHUNT}):

$$V_{SHUNT} = V_{AUX} - 1\text{ V}$$

It is important to note that V_{SHUNT} minus V_{AUX} should not exceed the maximum reverse voltage of the base-to-emitter junction of T1. This information can be found in the transistor's data sheet.

Once we have decided on the shunt voltage, we can easily set up the series-pass regulator. To minimize losses, R3 is typically sized to allow just enough current to bias the shunt regulator. Typically this is set for twice the shunt regulator's minimal bias current (I_{D2}):

$$R3 = \frac{V_{IN} - V_{SHUNT}}{2 \times I_{D2}}$$

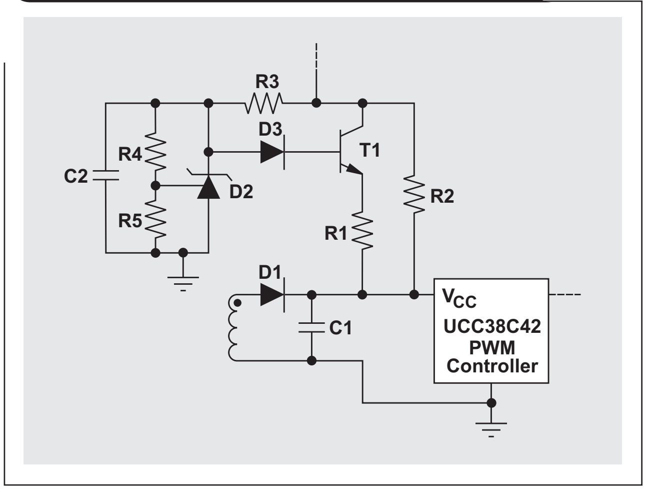
R4 and R5 program the shunt voltage. R4 can be selected by choosing a resistor for R5 and plugging the reference voltage (V_{REF}) into the following equation:

$$R4 = R5 \times \frac{V_{SHUNT} - V_{REF}}{V_{REF}}$$

R1 limits the current through T1, protecting it from overcurrent conditions. It can easily be selected based on the maximum current rating (I_{max}) and Ohm's law:

$$R1 = \frac{V_{SHUNT} - V_{BE}}{I_{max}}$$

Figure 3. Lower bias voltage provided by R3 and D3



C1 is typically sized for hold-up time (t_{HOLDUP}) and can be sized by knowing V_{BIAS} and the PWM's UVLO and operating current (I_{CC}):

$$C1 = \frac{I_{CC} \times t_{HOLDUP}}{V_{BIAS} - \text{UVLO}}$$

C2 is a hold-up and filtering capacitor for most applications. A 1-µF ceramic capacitor will work fine for this electrical component.

In some applications, due to efficiency requirements, the power-supply designer may want the bias voltage to run lower than the PWM integrated circuit's turn-on threshold. This would require an extra resistor and diode (see Figure 3). R2 is a trickle-charge resistor used for bootstrapping the PWM. It allows capacitor C1 to charge up to the PWM's turn-on threshold voltage. Diode D3 is required to ensure that T1's maximum reverse base-to-emitter voltage is not exceeded. It is also worth mentioning that the shunt voltage would have to be adjusted to accommodate the forward voltage drop of D3.

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