Application Report
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Plug-In Modules: Understanding Margining and Prebias Start-Up

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ABSTRACT

Power supply systems for most of today's latest applications must be able to manage how multiple output voltages rise after input power is applied. These power supplies must also be capable of starting up into preexisting external voltages present at the output. Another important requirement is supply voltage margining, i.e., the ability of the power supply to momentarily adjust the output voltages to test the load circuit over its supply voltage tolerances.

Board-mounted power modules, often referred to as plug-in modules, are offered by innovatively packaging high-efficiency, synchronous rectifiers in order to minimize the printed-circuit board area. These are available in surface-mount, vertical through-hole and horizontal through-hole styles. Features built into these modules make it easy to include the preceding capabilities into the power supply. This application report explains how these modules are able to meet the latest power system requirements with just a few external components.

1 Margining

Margining is the process of dynamically testing the load circuit over its supply voltage range. This testing demonstrates the load circuit's ability to tolerate small changes in the power supply voltages that may occur over time and temperature. It ensures the rated performance with the supply voltage at the threshold limits of its regulation band. The testing typically is performed by forcing the power supply modules in the system to ±5% of their nominal output voltage. Once the supply voltage has settled at the margined voltage, the system performance is evaluated.

To better understand how margining is done, one must understand the circuit that is used to set the output voltage in the plug-in modules. Figure 1 shows a portion of an output voltage divider and feedback circuitry that is used for most modules. The output voltage is adjusted by a divider consisting of resistors R1, R2, and RSET. The midpoint of the divider (R1 and R2+RSET) is connected to the inverting input of the operational amplifier, which is used to process the error voltage between the internal reference voltage Vref and the divider voltage. The voltage control loop of the module regulates the output voltage so as to maintain the voltage at the midpoint of the divider equal to the reference voltage. By connecting an external resistor between the Trim pin and GND, the divider ratio is changed, thus allowing adjustment of the output voltage.

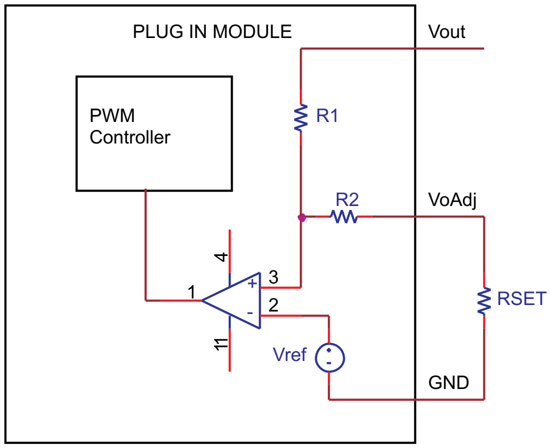

Figure 1. PTH Module Feedback System

The value for RSET is calculated based on the following formula:

$$RSET = R1k\Omega \times \frac{Vref}{Vout - Vref} - R2k\Omega \tag{1}$$

Because the values of reference (Vref), R1 and R2 are internal to the module, the equation of RSET varies from module to module.

For example in PTH03010W, the formula is:

$$RSET = 10\ k\Omega \times \frac{0.8}{Vout - 0.8} - 2.49\ k\Omega \tag{2}$$

In PTH08T230W, the formula is:

$$RSET = 10\ k\Omega \times \frac{0.69}{Vout - 0.69} - 1.43\ k\Omega \tag{3}$$

To implement margining, the divider is changed by small amounts to obtain the desired margining voltages. The PTHxx060W, PTHxx010W, PTHxx020W, and PTHxx030W plug-in modules incorporate Margin Up and Margin Down control inputs. These controls allow the output voltage to be adjusted momentarily, either up or down, by a nominal 5%. The ±5% change is applied to the adjusted output voltage, as set by the external resistor, Rset at the Vo Adjust pin. The 5% adjustment is made by pulling the appropriate margin control input directly to the GND terminal. A simple n-channel MOSFET is recommended for this purpose (see Figure 2). Adjustments of less than 5% can also be accommodated by adding series resistors Ru and Rd to the control inputs. The value of the resistors can be calculated using the following formula.

$$Ru = \frac{499}{\Delta\%} - 99.8\ k\Omega \qquad Rd = \frac{499}{\Delta\%} - 99.8\ k\Omega \tag{4}$$

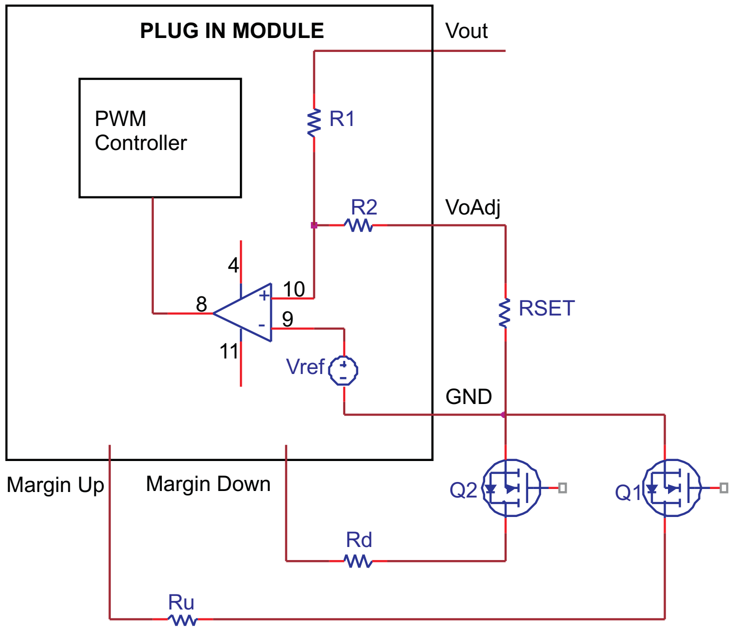

Figure 2. PTH Module With Margin Up and Margin Down

If the modules do not have margining pins, use the circuit arrangement as shown in Figure 3. A resistor Ru is connected in series with a n-channel FET Q1 between the trim pin and ground to margin up or slightly increase the output voltage. A p-channel FET in parallel with a resistor Rd which is in series with the RSET to between TRIM and ground helps to margin down or slightly decrease the output voltage. Under normal operation, both FETs are kept off. Because the input on the gate is low under normal conditions, Q2 is on and allows normal operation. Table 1 summarizes the truth table.

Table 1. Truth Table

Q1	Q2	Output
Low	Low	Vout
High	Low	Margined Up Voltage
Low	High	Margined Down Voltage

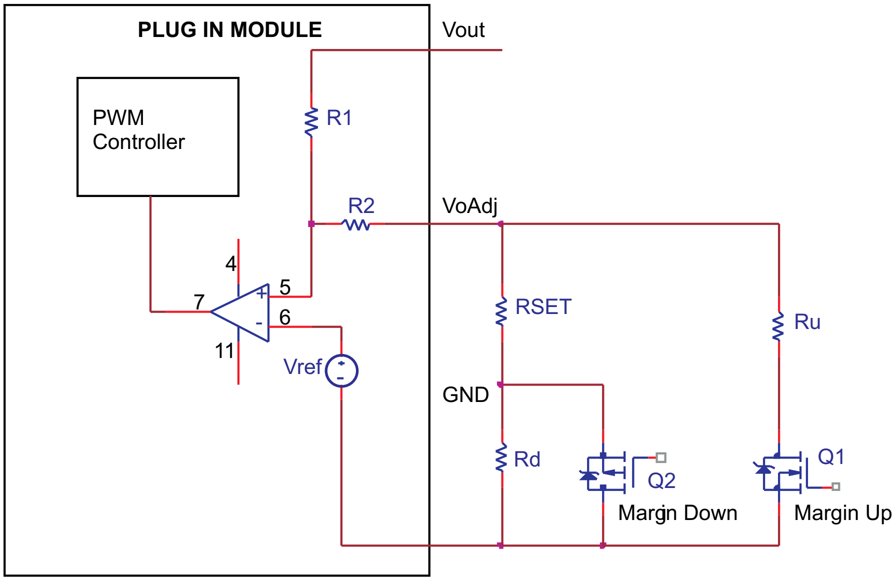

Figure 3. PTH Module with Margin Up and Margin Down

The values of Rd and Ru are determined using the following equations. Use the RSET equation from PTR08100 data sheet (SLTS284) as an example.

$$RSET = \frac{1.165}{Vout - 0.591}\ k\Omega$$

$$RSET + Rd = \frac{1.165}{\left(Vout - \left\{\frac{\Delta\% \times Vout}{100}\right\}\right) - 0.591}\ k\Omega$$

$$\frac{RSET \times Ru}{RSET + Ru} = \frac{1.165}{\left(Vout + \left\{\frac{\Delta\% \times Vout}{100}\right\}\right) - 0.591}\ k\Omega \quad (5)$$

Similar equations can be derived for other modules depending on the RSET equation.

2 Prebias Start-Up

A prebias start-up condition occurs as a result of an external voltage being present at the output of a power module prior to its output becoming active. Consider a basic synchronous buck converter as shown in Figure 4.

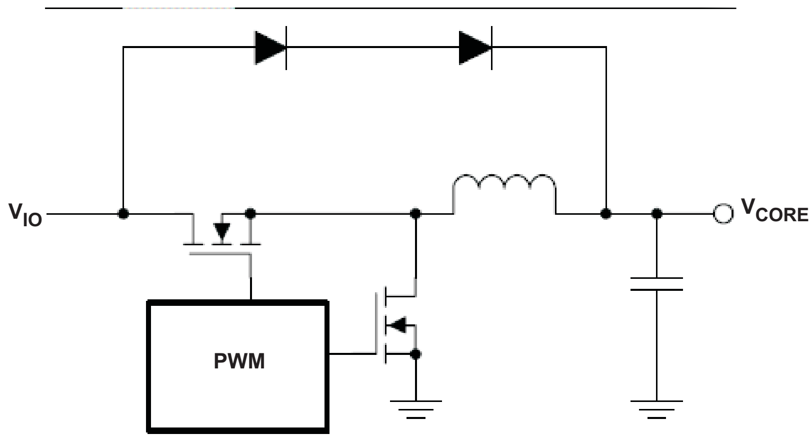

Figure 4. Application Circuit for Prebias Start-Up

V_{IO} comes up first, and applies core voltage through the series diodes before the core's converter is enabled. This is a prebias condition. When the converter's PWM controller is enabled, it soft-starts the high-side FET, and its duty cycle (D) ramps gradually from zero to that required for regulation. However, if during soft-start, the synchronous rectifier (SR) FET is on when the high-side FET is off (SR FET duty cycle = 1 - D), the SR sinks current from the output (through the inductor), tending to cause both the core and I/O voltages to drop.

Figure 5 shows another typical application circuit of PTH08T230W. This often occurs in complex digital systems when current from another power source is backfed through a dual-supply logic component, such as an FPGA or ASIC. Another path may be via clamp diodes as part of a dual-supply, power-up sequencing arrangement.

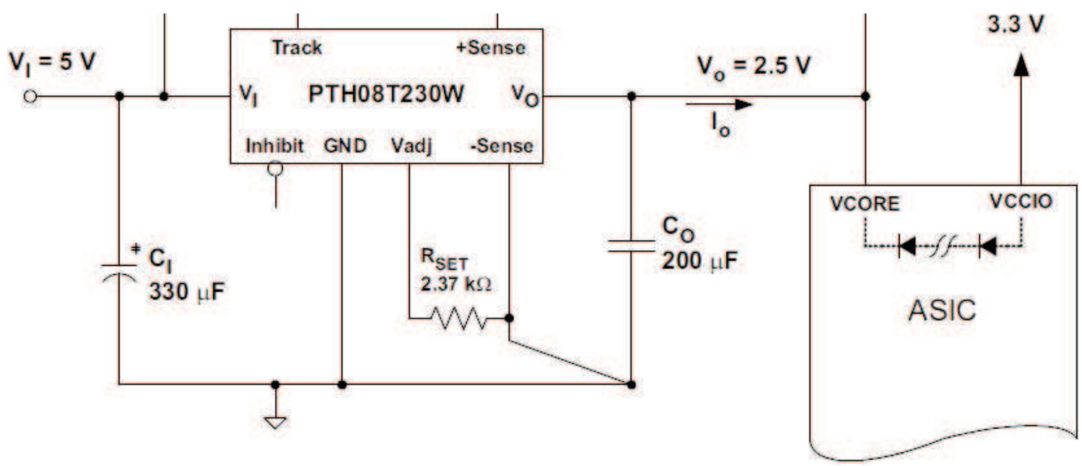

Figure 5. Application Circuit of PTH08T230W for Prebias Start-Up

Most of the plug-in modules from Texas Instruments incorporate synchronous rectifiers, but do not sink current during start-up, or whenever the Inhibit pin is held low. During start-up, the output current is negligible until the output voltage rises above the voltage backfed through the intrinsic diodes. However, to ensure satisfactory operation of this function, certain conditions must be maintained. When the module is under Auto-Track control, it sinks current if the output voltage is below that of a back-feeding source. That is why this feature is incompatible with Auto-Track.

To ensure a prebias holdoff, one of the following two approaches must be used when input power is applied to the module.

1. The Auto-Track function must be disabled or
2. The module's output held off (for at least 50 ms) using the Inhibit pin.

Either approach ensures that the Track pin voltage is above the set-point voltage at start-up. The following list ensures a start-up into prebias condition.

1. Start-up includes the short delay (approximately 10 ms) prior to the output voltage rising, followed by the rise of the output voltage under the module's internal soft-start control. Start-up is complete when the output voltage has risen to either the set-point voltage or the voltage at the Track pin, whichever is lowest.
2. To ensure that the regulator does not sink current when power is first applied (even with a ground signal applied to the Inhibit control pin), the input voltage must always be greater than the output voltage throughout the power-up and power-down sequence.
3. The Auto-Track function can be disabled at power up by immediately applying a voltage to the module's Track pin that is greater than its set-point voltage. This can be easily accomplished by connecting the Track pin to V_I.

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