Application Brief

Prevent Battery Overdischarge with Precise Threshold Enable Pin

Using a buck-boost converter is a convenient way to obtain a fixed supply voltage within the wide voltage range of typical batteries used in low-power devices such as smart meters, wearables or those in the Internet of Things. In order to extract as much energy as possible from the battery, it helps if the converter can operate at low input voltages.

In non-inverting buck-boost devices such as the TPS63802, the minimum operating input voltage is as low as 1.3 V once the device is started. With most rechargeable batteries, however, such a deep discharge can cause irreversible reduction in capacity or even catastrophic failure and damage to the rest of the system. In such situations, it becomes essential to cut off the battery from the rest of the system at a desired voltage value.

Most DC/DC converters have an input pin to enable or disable the device. However, the threshold voltage at this pin can have a huge tolerance, making it difficult to accurately set the desired cutoff voltage. As an example, according to the datasheet, the threshold voltage of the enable (EN) pin for the TPS63020 is within the range listed in Table 1. In this case, the EN pin voltage threshold can be anywhere between 0.4 V and 1.2 V.

Table 1. EN pin voltage levels for TPS63020

Parameter		Min	Typ	Max	Unit
V_{IL}	EN input low voltage			0.4	V
V_{IH}	EN Input high voltage	1.2			V

This threshold range is fine for on/off control using logic-level signals, but not for setting a precise cutoff voltage derived from the input voltage. To achieve higher accuracy, it is possible to add a comparator and a voltage reference, or a voltage supervisor circuit, but this increases complexity and cost. Instead, it would be more useful if the EN pin has more precisely defined threshold voltages.

The concept of achieving a precise threshold voltage for buck converters was introduced in the application report Achieving a Clean Startup by Using a DC/DC Converter with a Precise Enable-pin Threshold. The new TPS63802 non-inverting buck-boost converter also has a very precise threshold voltage for the EN pin, with approximately 3% tolerance and 100 mV hysteresis, as listed in Table 2.

Table 2. EN pin threshold voltages for TPS63802

Parameter		Min	Typ	Max	Unit
$V_{IT+(EN)}$	Rising threshold voltage for EN pin	1.07	1.1	1.13	V
$V_{IT-(EN)}$	Falling threshold voltage for EN pin	0.97	1	1.03	V

Having precise voltage thresholds, it is possible to easily set a user-defined minimum supply voltage. This is done using a voltage divider connected to VIN pin, EN pin and ground, as shown in Figure 1.

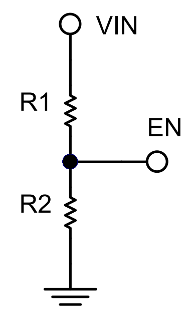

Figure 1. Setting the input cutoff voltage with a voltage divider

Equation 1 calculates the falling threshold supply voltage where the converter is turned off:

$$V_{IT-} = V_{IT-(EN)} \left(1 + \frac{R1}{R2}\right) \quad (1)$$

Equation 2 calculates the rising threshold supply voltage where the converter is turned on:

$$V_{IT+} = V_{IT+(EN)} \left(1 + \frac{R1}{R2}\right) \quad (2)$$

The additional voltage divider will increase the current consumption, therefore, aim for large resistances. Considering that the EN input leakage current for TPS63802 is 0.2 µA maximum, aim for at least 20 µA of current in the voltage divider. The application report

Optimizing Resistor Dividers at a Comparator Input has more details about how to optimize a resistor divider at a comparator input.

As an example, to set the cutoff input voltage to V_{IT-} = 2.5 V, we can first choose R1 + R2 = 125 kΩ to have a 20 µA resistor divider current. Solving Equation 1, we choose R1 = 75 kΩ and R2 = 49.9 kΩ resistors with 1% tolerance. The turn-on input voltage is now V_{IT+} = 2.75 V according to Equation 2.

Figure 2 shows that the achieved cutoff and turn-on input voltages are V_{IT-} = 2.56 V and V_{IT+} = 2.8 V, respectively. This is within the equivalent tolerance of approximately 80 mV (3.1%) caused by the EN pin threshold voltage and resistor tolerances, not taking into account the oscilloscope accuracy. The application report Method for Calculating Output Voltage Tolerances in Adjustable Regulators has more details on calculating equivalent voltage tolerances.

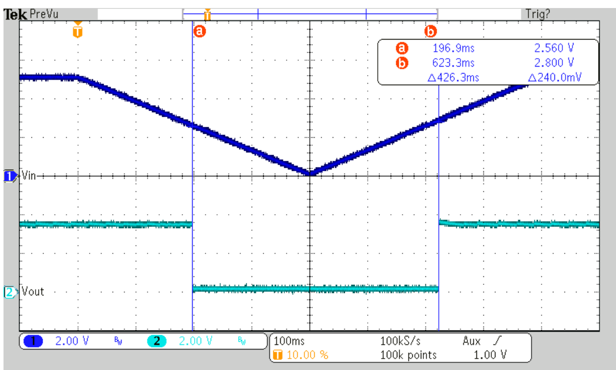

Figure 2. Achieved cutoff and turn-on input voltage thresholds

The previous example shows how simple it is to protect a battery from overdischarge by adding only two resistors. The same solution is applicable not only to buck-boost but also to other buck or boost devices having the precise threshold voltage EN pin.

References

TPS63802 Datasheet

TPS63020 Datasheet

Achieving a Clean Startup by Using a DC/DC Converter with a Precise Enable-pin Threshold

Optimizing Resistor Dividers at a Comparator Input

Method for Calculating Output Voltage Tolerances in Adjustable Regulators

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