Precise Start-Up Delay Using Enable Pin with Precise Voltage Threshold

Milos Acanski

Sometimes, a DC/DC converter needs to be started with a certain delay after the input voltage supply is provided. For example, some processors require specific power-up sequencing of different voltage domains. Another reason to use delayed start-up is to spread the inrush current peaks due to the start-up of multiple DC/DC converters.

Most DC/DC converters have an enable (EN) input pin to enable or disable the device. To delay the start-up of the converter, an RC network shown in Figure 1 can be used.

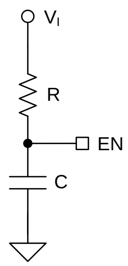

Figure 1. Delaying Start-up via EN Pin

If the threshold voltage of the EN pin $V_{TH;EN}$ is known for the device, use Equation 1 to calculate the start-up delay t_d.

$$t_d = R \cdot C \cdot \ln\left(\frac{V_I}{V_I - V_{TH;EN}}\right) \quad (1)$$

However, the threshold voltage at this pin can have a huge tolerance, making it difficult to precisely pinpoint the desired start-up time. As an example, according to the datasheet, the threshold voltage of the EN pin for 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 intended for on and off control using logic-level signals, not for setting a precise start-up delay. To achieve a precise start-up delay, it is possible to add a timer circuit, but this increases complexity and cost. Instead, it is more useful if the EN pin can have a more precisely defined threshold voltage.

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

Table 2. EN Pin Threshold Voltages for TPS63802

PARAMETER		MIN	TYP	MAX	UNIT
$V_{THR;EN}$	Rising threshold voltage for EN pin	1.07	1.1	1.13	V
$V_{THF;EN}$	Falling threshold voltage for EN pin	0.97	1	1.03	V

For the purpose of achieving delayed start-up, only the rising voltage threshold $V_{THR;EN}$ is important. Rewriting Equation 1, the R and C values need to satisfy Equation 2. To keep Equation 2 accurate, the delay time t_d must be larger than 1 ms, otherwise the neglected internal timing of the device starts affecting the start-up delay. Additionally, too long input voltage ramp-up can also affect the start-up delay t_d.

$$R \cdot C = \frac{t_d}{\ln\left(\frac{V_I}{V_I - V_{THR;EN}}\right)} \quad (2)$$

To decrease the size of the capacitor, a natural solution is to use the largest possible value for the resistor. Considering that the EN pin leakage current I_{lkg} for TPS63802 is typically 0.01 µA, aim for at least 1 µA of resistor current when the EN pin voltage is close to $V_{THR;EN}$. Equation 3 gives the recommendation for the resistance value.

$$R \leq \frac{V_I - V_{THR;EN}}{100\, I_{lkg}} \quad (3)$$

As an example, to achieve a start-up delay of t_d = 50 ms in a system with V_I = 3.3 V, you can choose a resistor R = 1.20 MΩ with 1% tolerance, and a capacitor C = 100 nF with 5% tolerance. Figure 2 shows the achieved start-up delay of just under 49 ms. This is well within the equivalent tolerance of approximately 3 ms, or around 6%, caused by the resistor, capacitor, and EN pin threshold tolerances, not taking into account the input voltage and oscilloscope accuracy. If the same RC circuit was used with the TPS63020, the start-up delay could be anywhere between 16 ms and 54 ms.

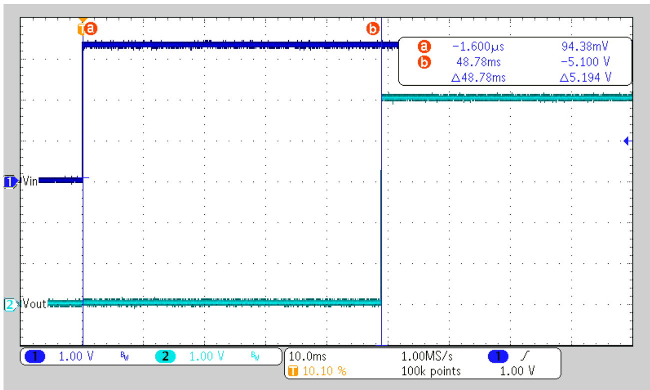

Figure 2. Achieved Start-up Delay of 50 ms

The previous example shows how simple it is to achieve precise start-up delay by adding only a resistor and a capacitor. The same solution is applicable not only to buck-boost converter but also to other buck or boost devices having the precise threshold voltage EN pin. If it is expected that the input voltage can cycle fast enough to influence the start-up delay, a diode can be put in parallel to the resistor in order to quickly discharge the capacitor, as shown in Figure 3.

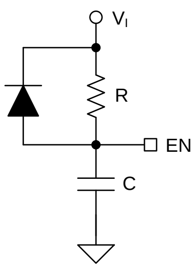

Figure 3. Adding Diode to Quickly Discharge C

Additionally, the start-up delay can be achieved together with the resistor divider described in the *Prevent Battery Overdischarge with Precise Threshold Enable Pin Application Report* in order to disable the device at a desirable minimum input voltage, as shown in Figure 4.

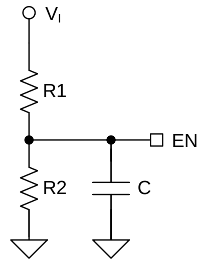

Figure 4. Setting Input Cutoff Voltage and Delayed Start-up

In this case, the component selection starts from selecting the values for the voltage divider. The capacitance value is then selected according to Equation 4.

$$C = \frac{t_d}{R_{eq} \cdot \ln\left(\frac{V_{eq}}{V_{eq} - V_{THR;EN}}\right)} \tag{4}$$

Where:

$$R_{eq} = \frac{R1 \cdot R2}{R1 + R2} \tag{5}$$

$$V_{eq} = V_I \frac{R2}{R1 + R2} \tag{6}$$

References

- *TPS63802 2-A, High-Efficient, Low IQ Buck-Boost Converter with Small Solution Data Sheet*
- *TPS6302x High Efficiency Single Inductor Buck-boost Converter with 4-A Switches*
- *Achieving a Clean Startup by Using a DC/DC Converter with a Precise Enable-pin Threshold Technical Brief*
- *Prevent Battery Overdischarge with Precise Threshold Enable Pin Application Note*