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ABSTRACT

Soft start is a common feature used in DC/DC buck converters. Soft start can prevent excessive inrush current and maintain a controlled output voltage during power on. This application note aims to provide a better understanding of TPS56837 soft start. First, this document introduces soft start and covers the general principle of soft start, both internal and external soft start are illustrated. Then, this documents analyzes behaviors related to soft start. Finally, guidance of how to co-lay TPS56837 and TPS56637 is provided.

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1 Why Soft Start is Needed

The soft start function is initiated after EN enable and input voltage reaches UVLO. The soft start circuitry controls the output voltage slope to prevent excessive inrush current, maintain a controlled output voltage, and avoid unwanted voltage overshoots and drops during power management IC start up.

Figure 1-1 shows the difference of output voltage versus time with and without the soft start function. The figure shows that the output voltage overshoots and drops without soft start function. So, soft start is needed for power management IC.

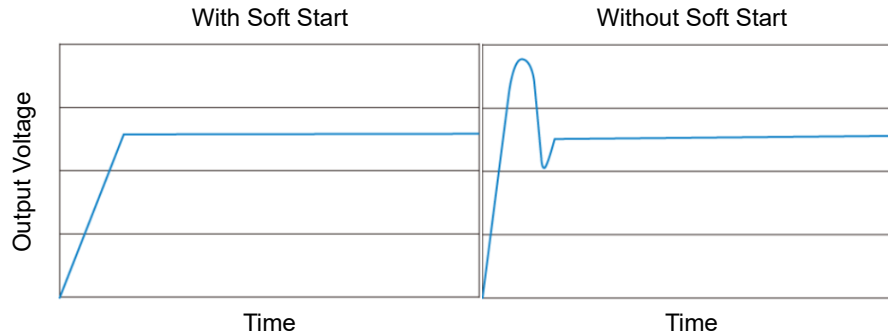


Figure 1-1. Output Voltage With and Without Soft Start Function

2 Soft Start Principle

2.1 General Principle

The general principle of soft start is to use constant pullup current (I_{SS}) to charge the internal or external soft start capacitor (C_{SS}) so as to regulate the capacitor voltage (V_{SS}) ramp-up with designed slope. The reference voltage (V_{REF}) follows V_{SS} until V_{REF} reaches the setting reference voltage. The time ramping to V_{REF} is soft start time (T_{SS}). For TPS56837, I_{SS} is 6 μ A, V_{REF} is equal to 600 mV, T_{SS} can be set by internal or external C_{SS} .

Equation 1 shows T_{SS} based on described general principle:

$$T_{SS} = \frac{C_{SS} \times V_{REF}}{I_{SS}} \quad (1)$$

Figure 2-1 and Figure 2-2 show Simplis circuit and Simplis simulation results of soft start principle, respectively. In Figure 2-1, U7 voltage is clamped to 600 mV as V_{REF} . According to Equation 1, with 6- μ A I_{SS} charging 22-nF C_{SS} to achieve 600-mV V_{REF} , T_{SS} is calculated as 2.2 ms which is the same as Figure 2-2 simulation results.

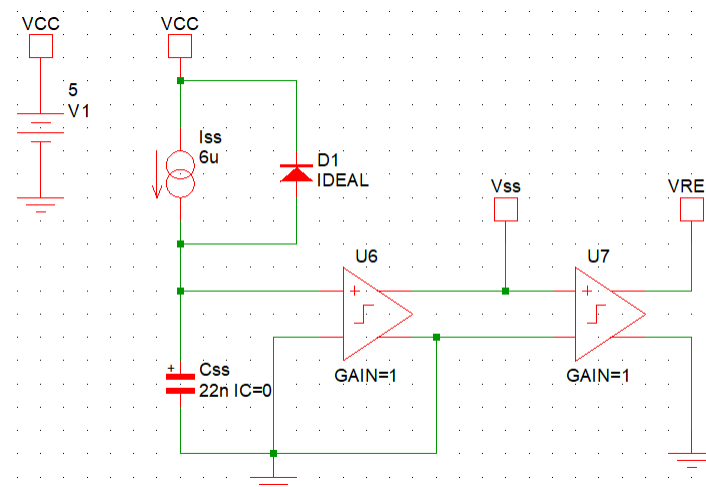


Figure 2-1. Simplis Circuit of Soft Start

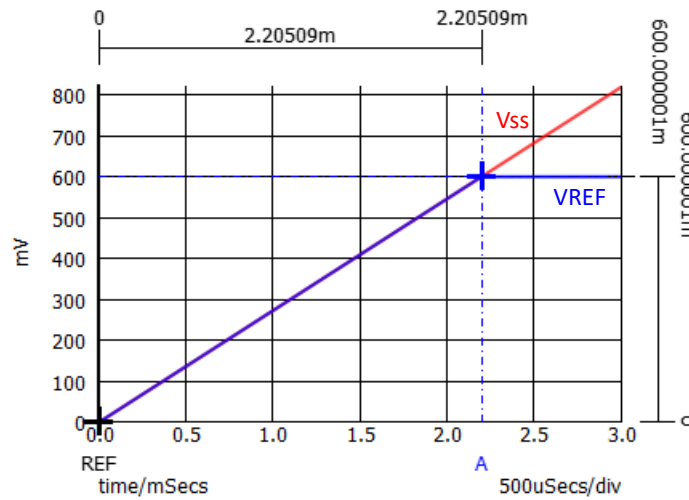


Figure 2-2. Simplis Results of Soft Start

2.2 Internal and External Soft Start

TPS56837 can support both internal and external soft start. Leaving the SS pin floating leads to default internal soft start time. Connecting an external capacitor between SS and AGND leads to external soft start time based on Equation 1.

TPS56837 has a 18-nF internal capacitor C_{SS} inside the device, corresponding to T_{SS} of 1.8 ms with an internal pullup current I_{SS} of 6 μ A. So, TPS56837 can allow the SS pin floating which can save one soft start capacitor and be easy for layout.

If an external capacitor C_{SS} between SS and AGND is connected, the internal pullup current charges both the internal and external capacitor, TPS56837 tracks the lower one between the internal soft start voltage and the external soft start voltage. In other words, T_{SS} follows the slower one. When the external capacitor C_{SS} is smaller than 18 nF, T_{SS} is the default internal soft start time, 1.8 ms. If only the external capacitor C_{SS} is greater than 18 nF, the soft-start time is adjusted to longer T_{SS} based on Equation 1.

Figure 2-3, Figure 2-4 and Figure 2-5 show the T_{SS} measurement results on TPS56837 EVM board with internal C_{SS} , external $C_{SS} = 1$ nF, and external $C_{SS} = 47$ nF, respectively. In Figure 2-3, when leaving the SS pin floating, the soft start time is approximately equal to default internal soft start time, 1.8 ms. Figure 2-4 shows the T_{SS} when connecting an external 1-nF capacitor between SS and AGND. The soft start time is still approximately equal to default internal soft start time, 1.8 ms. In Figure 2-5, an external 47-nF capacitor is connected to the SS pin. The soft start time is 4.7 ms, which equals the calculated results using Equation 1.

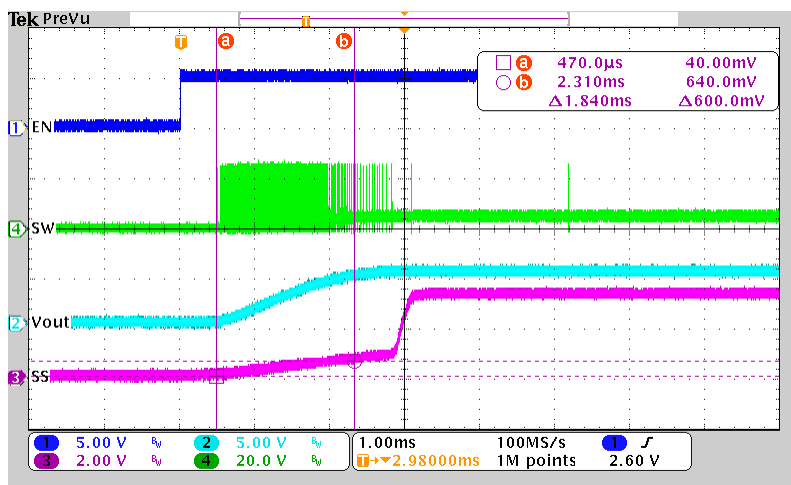


Figure 2-3. Soft Start Time with Internal C_{SS}

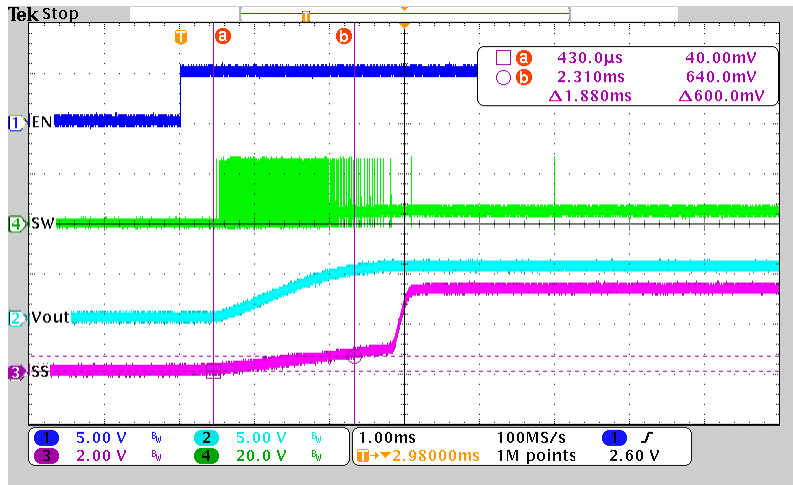


Figure 2-4. Soft Start Time with External $C_{SS} = 1 \text{ nF}$

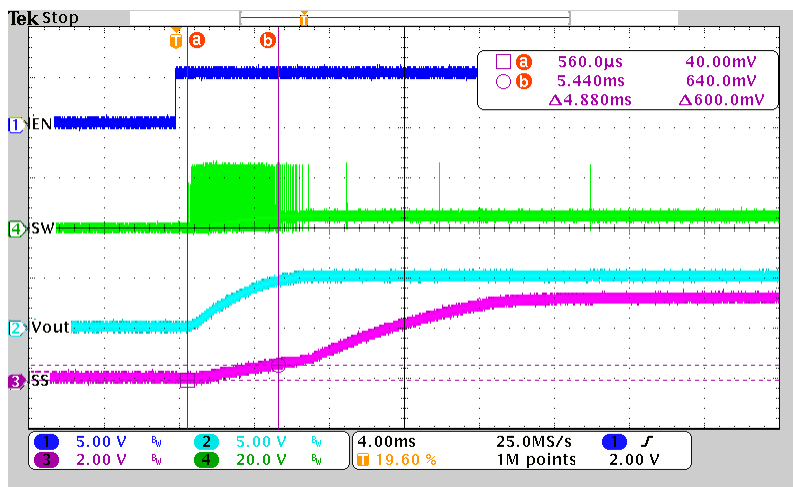


Figure 2-5. Soft Start Time with External $C_{SS} = 47 \text{ nF}$

3 Behaviors Related to Soft Start of TPS56837

3.1 Soft Start Sequence

Figure 3-1 shows the typical soft start sequence of TPS56837. Once the enable signal triggers the EN on threshold, the internal VCC starts to ramp up. After the voltage of internal VCC crosses the UVLO rising threshold, it takes 40-100 μs to finish reading and setting of MODE. Once MODE setting is done, the switching frequency and current limit are latched and do not change until VIN or EN toggles to restart device. Then after a delay of around 64 μs , the soft-start circuitry works as seen in Section 2.1. Vout ramps up smoothly with a set soft start time. When Vout is up to the reference voltage after T_{SS} , PGOOD turns to high after a delay.

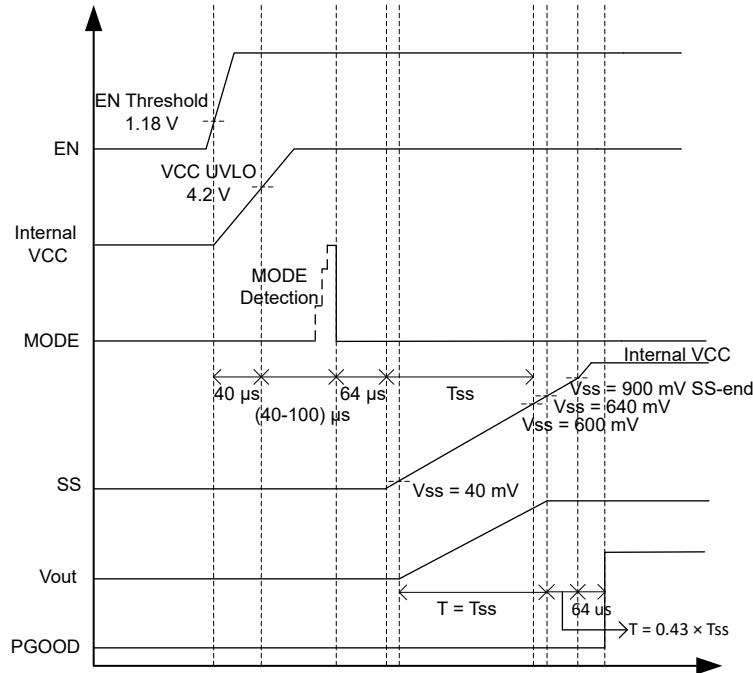


Figure 3-1. Soft Start Sequence

3.2 Soft Start Discharge

If the external soft start capacitor C_{SS} has pre-biased voltage at start-up, the device initially discharges the external capacitor voltage to lower voltage then charge again. This discharge is intended to prevent power up without soft start when the pre-biased voltage is higher than reference voltage.

Figure 3-2 shows TPS56837 soft start waveform when external C_{SS} has pre-biased voltage. Once EN is enabled, TPS56837 begins to discharge the pre-biased C_{SS} . When the voltage of C_{SS} reaches zero, the soft start function begins and V_{out} ramps up smoothly.

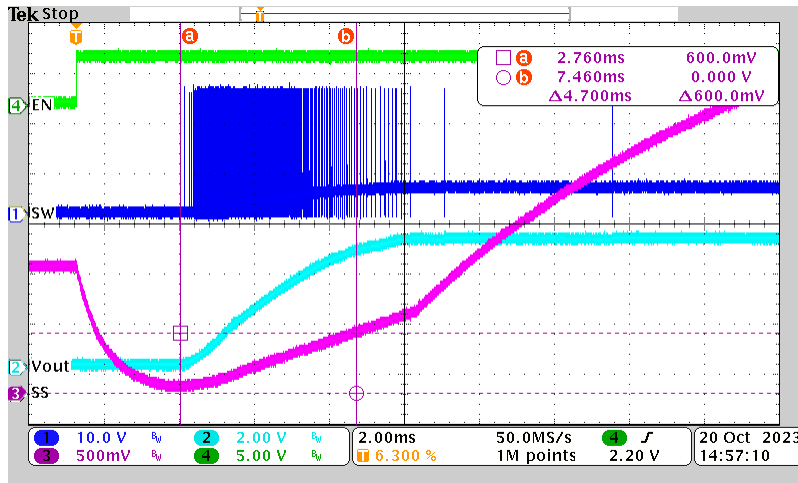


Figure 3-2. Discharge When External C_{SS} has Pre-bias Voltage

3.3 UVP Hiccup Time

The TPS56837 has an under-voltage protection (UVP) feature. When the output voltage falls below 65% of the target voltage, the UVP comparator detects the under-voltage and shuts down the device after a deglitch time of 256 μ s, then re-starts after the hiccup time.

Figure 3-3 is the hiccup waveform of TPS56837 with an internal soft start capacitor C_{SS} . The figure shows that the hiccup time is 7 cycles of internal C_{SS} charge time. During hiccup, the C_{SS} is charged to 900 mV which is 1.5 x 600 mV (V_{REF}) and then pulled up to internal VCC. So one cycle of internal C_{SS} charge time equals 1.5 x T_{SS} . The total hiccup time is 7 x 1.5 x T_{SS} , which is 10.5 cycles of T_{SS} .

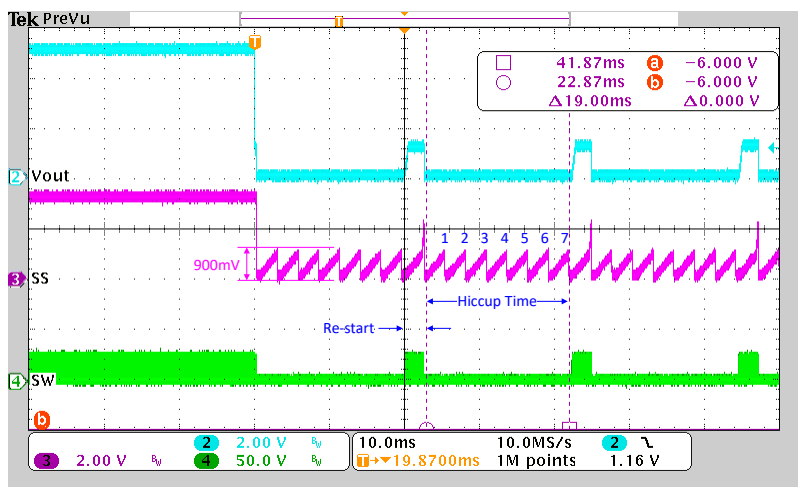


Figure 3-3. Hiccup Time with Internal C_{SS}

Figure 3-4 is the hiccup waveform of TPS56837 with an external 47-nF soft start capacitor C_{SS} . The hiccup time equals 7 cycles of C_{SS} charge time plus 8 cycles of C_{SS} discharge time. But the C_{SS} discharge time is not fixed. The discharge time changes with C_{SS} capacitance value and the biased status of C_{SS} .

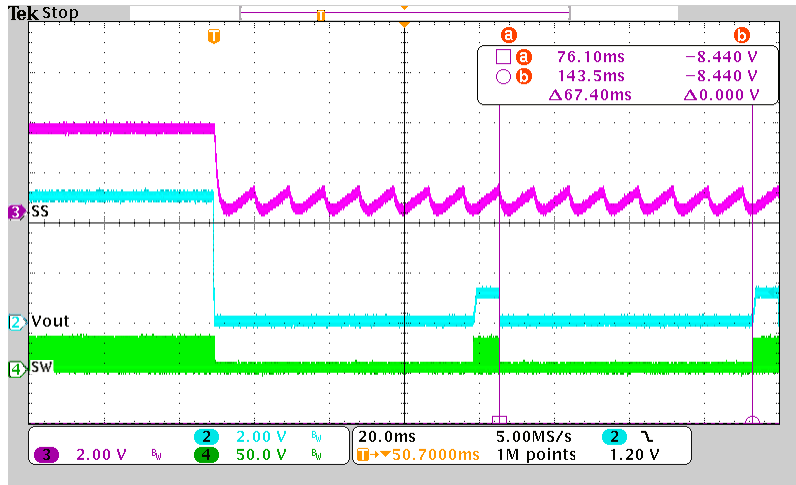


Figure 3-4. Hiccup Time With External $C_{SS} = 47 \text{ nF}$

4 How to Co-Lay TPS56837 and TPS56637

4.1 Pinout Differences of TPS56837 and TPS56637

Both TPS56837 and TPS56637 are 10-pin, VQFN-HR, RPA packages. Figure 4-1 are the pinouts of TPS56837 and TPS56637. The only difference between the two is pin 5.

The pin 5 of TPS56837 is a SS pin, which is the soft-start time configuration pin. Leaving SS pin floating leads to default 1.8-ms soft start time. Connecting an external capacitor between SS and AGND leads to longer soft start time.

The pin 5 of TPS56637 is a NC pin. NC pin must not be connected and stay floating during use.

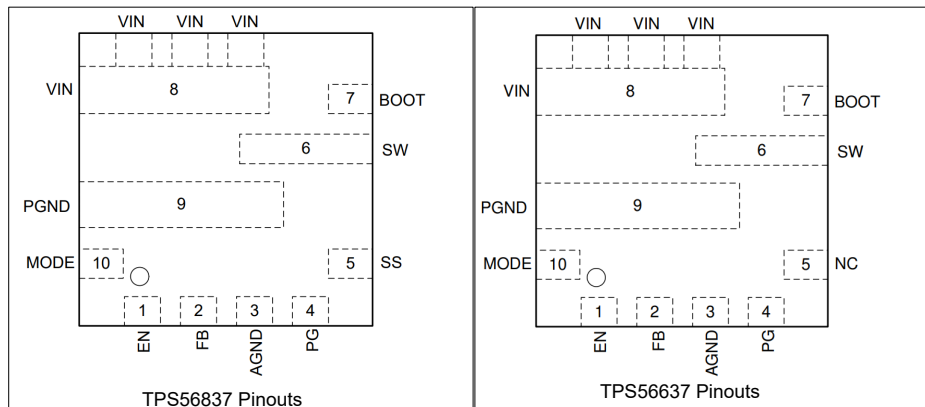


Figure 4-1. Pinouts of TPS56837 and TPS56637

4.2 Co-lay Guidance TPS56837 and TPS56637

TPS56837 can both leave SS pin floating with default 1.8-ms soft start time and connect external capacitor with desired soft start time. TPS56637 NC pin must not be connected and TPS56637 has default internal soft start time 2 ms.

So, TPS56837 and TPS56637 can directly change to each other by using TPS56837 default internal soft start. TPS56837 and TPS56637 can co-lay if longer soft start time of TPS56837 is needed. A place for external soft start capacitor is added and left at NC for TPS56637. Figure 4-2 shows co-lay guidance of TPS56837 and TPS56637 with external soft start capacitor.

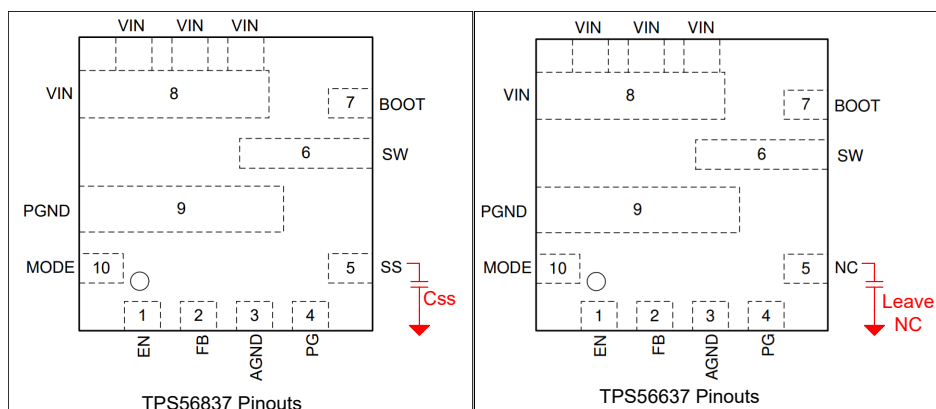


Figure 4-2. Co-lay Guidance

5 Summary

This application note covered TPS56837 soft start, the general principles of soft start, the behaviors related to soft start, and co-lay guidance of TPS56837 and TPS56637.

6 References

- Texas Instruments, [TPS56837 4.5-V to 28-V Input, 8-A Synchronous Buck Converter](#), data sheet.
- Texas Instruments, [TPS56637 4.5-V to 28-V Input, 6-A Synchronous Buck Converter](#), data sheet.

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