Application Report
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TPS65311-Q1/TPS65310A-Q1 GPFET Soft Start Using a Capacitor Between GPFET Pin and PMOS-Protection Switch Source Pin

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ABSTRACT

TPS65311-Q1 and TPS65310A-Q1 devices are High-Voltage Power-Management Integrated Circuits (ICs) for use in Automotive Applications such as Advanced Driver Assistance Systems (ADAS). These devices provide the gate drive signal for the external PMOS-protection switch, which connects input voltage to the BUCK1 external-switching MOSFET. With the help of a small capacitor connected from the source of the external PMOS-protection switch to the gate drive pin (GPFET pin), it is possible to adjust the turnon time of this external PMOS-protection switch to reduce the inrush current when PMOS-protection switch turns on.

This application report provides guidelines for choosing the optimum soft-start capacitor between the GPFET pin and external PMOS-protection switch source pin to reduce the inrush current during turn on. This method was verified on the TPS65311-Q1 device. However, this part of the circuit is identical between TPS65310A-Q1 and TPS65311-Q1 devices and the results are applicable to the TPS65310A-Q1 device also.

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1 Introduction

The TPS65311-Q1/TPS65310A-Q1 devices have an external PMOS gate drive output (GPFET), which turns on and off the main input supply (VINPROT) and BUCK1 input supply with the help of an external PMOS switch based on certain device operating conditions. The *TPS65311-Q1* datasheet provides further details related to GPFET pin operating conditions.

Internal to the device, a PMOS transistor connected from VIN pin to GPFET pin pulls the GPFET pin high (to Vin voltage level) to keep the external PMOS switch in off condition. During the turn on process of the external PMOS switch, the internal PMOS switch connected from Vin to GPFET is turned off and GPFET pin is pulled low with the help of 20-µA (typical) pulldown current source. Detailed specifications of the GPFET pin is provided in Table 1.

As shown in Figure 1, with the help of an external soft-start capacitor (Css_gpfet) connected between source pin of external PMOS-protection switch and GPFET pin, it is possible to adjust the turn on characteristics of the external PMOS-protection switch connected to the GPFET pin.

Table 1. GPFET Pin Specifications From TPS65311-Q1 Datasheet (SLVSCA6 Rev B)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
EXTERNAL PROTECTION						
VCLAMP	Gate to source clamp voltage	VIN – GPFET, 100 µA	14		20	V
IGPFET	Gate turn on current	VIN = 14 V, GPFET = 2 V	15		25	µA
RDSONGFET	Gate driver strength	VIN = 14 V, turn off			25	Ω

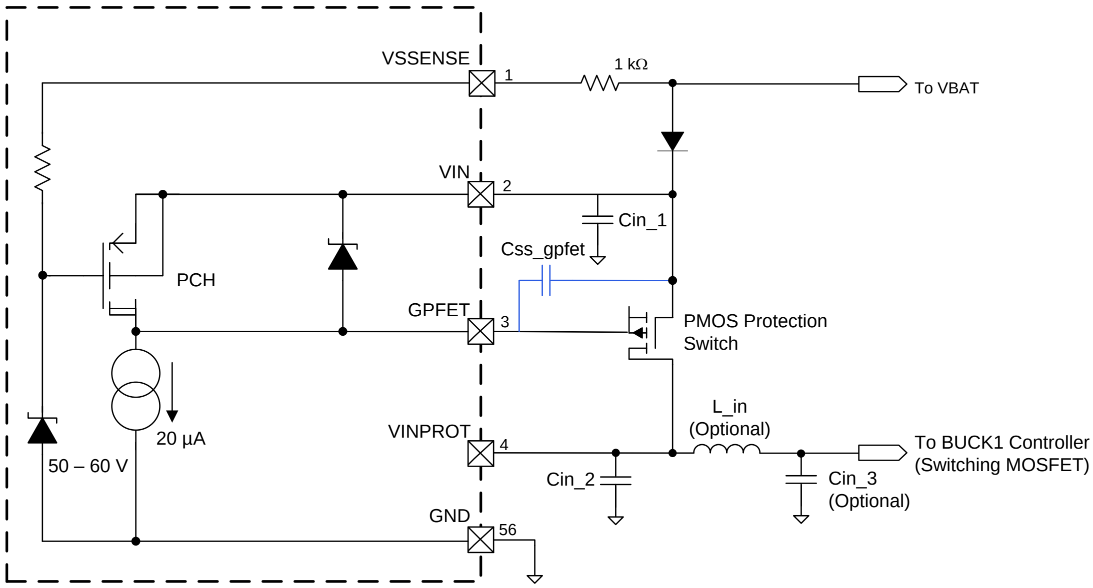


Figure 1. GPFET PMOS Switch Drive Control Circuitry With Css_gpfet

2 Test Setup and Procedure

A TPS65311EVM was used to check the effect of Css_gpfet with the following test conditions:

- Vbat (Input supply) = 12 V (Bench-top power supply with 4-A current rating)
- BUCK1 Output Voltage, VBUCK1 = 3.3 V
- External PMOS switch: SI7461DP
- Lout_BUCK1 = 10 µH
- Cout_BUCK1 = 100 µF (total capacitance)
- Input LC filter inductor value (L_in) = 10 µH
- Input capacitor values are as follows:
  - Cin_1 = 22 µF
  - Cin_2= 47 µF
  - Cin_3= 47 µF

Functionality is tested at room temperature with no external load conditions.

3 Test Procedure and Measurement Results

To understand the effect of the Css_gpfet capacitor on overall system behavior, different measurements were done as below.

- TPS65311-Q1 start-up behavior with Vbat ramped from 0 V to 12 V is captured without an external Css_gpfet capacitor as a reference as shown in Figure 2.
- The measurement is repeated with the following different Css_gpfet values: 1 nF, 2.2 nF,4.7 nF, 10 nF, 15 nF, 100 nF, and 470 nF.
- For each case, different timing measurements are taken and listed in Table 2.
- Input inrush current during start up is measured and its rise time and peak current are tabulated in Table 3. Timing diagram for this measurement is shown in Figure 3.
- Shutdown behavior is also measured to see the effect of Css_gpfet on device shutdown.

3.1 Device Start Up Behavior Measurement Results

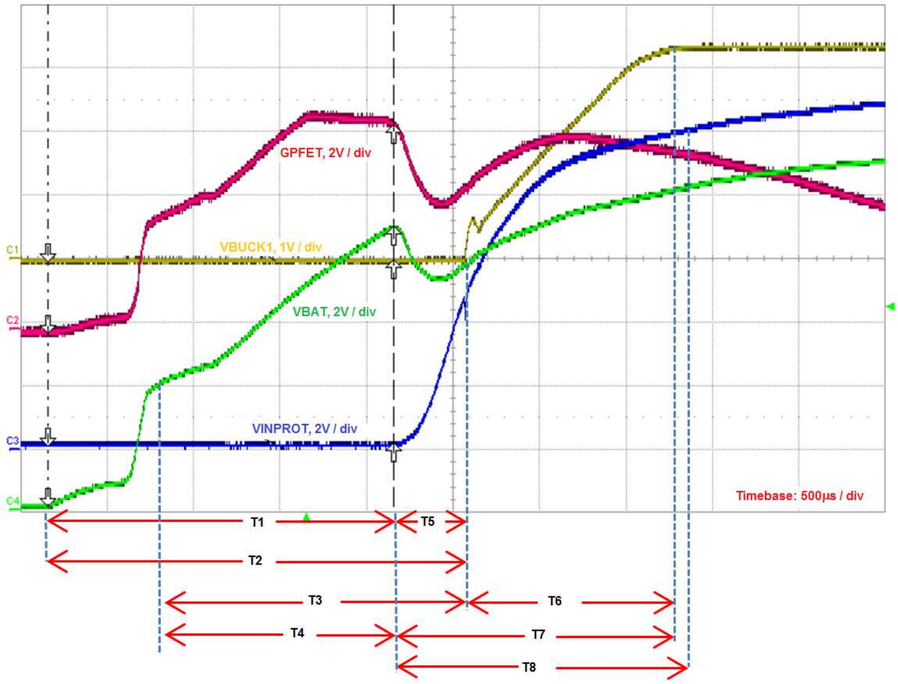
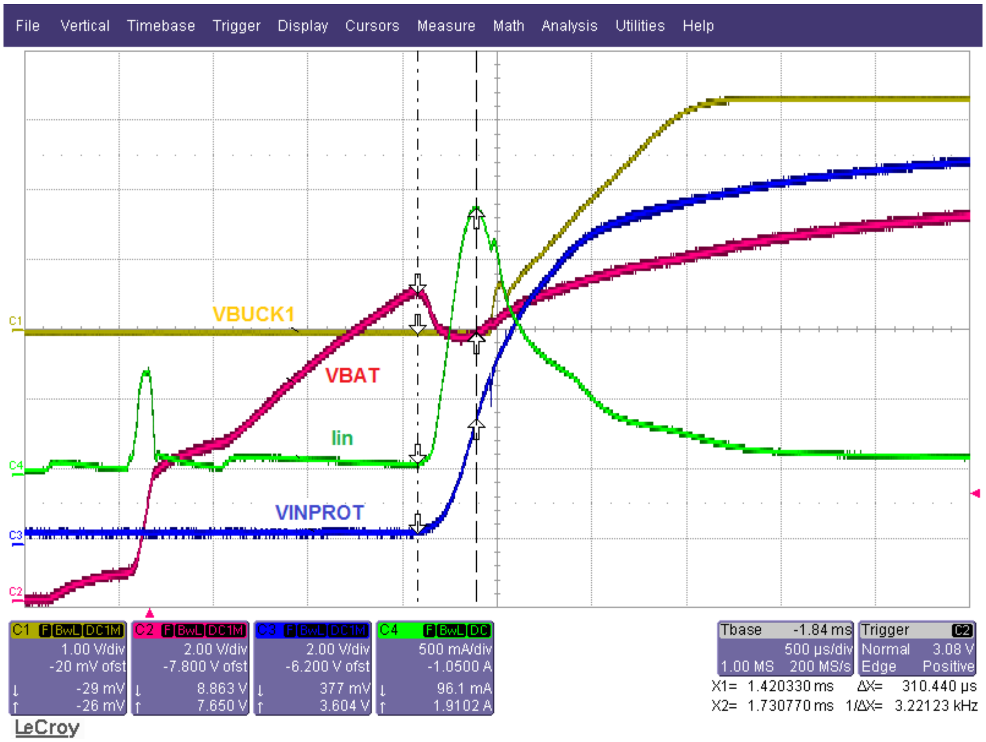


Figure 2. Start-up Timing Diagram

Table 2. Timing Measurement Results With Different Soft-Start Capacitors Across GPFET Pin and External PMOS Switch Source Pin

Css_gpfet	T1 (ms)	T2 (ms)	T3(ms)	T4 (ms)	T5 (µS)	T6 (ms)	T7 (ms)	T8 (ms)
No Css_gpfet	2.001	2.404	1.741	1.339	404.32	1.214	1.603	1.665
1nF	2.105	2.513	1.867	1.460	431.32	1.219	1.630	1.691
2.2nF	2.234	2.649	1.995	1.578	447.56	1.215	1.645	1.645
4.7nF	2.473	2.964	2.300	1.827	483.43	1.212	1.694	1.527
10nF	2.994	3.544	2.892	2.342	537.95	1.201	1.743	1.293
15nF	3.467	4.204	3.555	2.819	737.33	1.214	1.945	1.373
100nF	11.577	13.673	12.974	10.646	2276.06	1.216	3.363	3.115

3.2 Input Inrush Current Measurement Results



C1 (Yellow): VBUCK1 output voltage (3.3 V)

C2(Red): Vbat voltage

C3(Blue): VINPROT voltage

C4(Green): Input (Vbat) inrush current

Trise_Iin: Inrush current rise time measured from ~100 mA current to its peak value

Figure 3. Start-up Timing Diagram With Input Inrush Current

Table 3. Input Inrush Current Measurement Results With Different Css_gpfet Capacitors

Css_gpfet	Trise_Iin (µs)	Peak Inrush Current (A)
No Css_gpfet	310	1.9
1 nF	337	1.8
2.2 nF	382	1.8
4.7 nF	408	1.8
10 nF	553	1.7
15 nF	614	1.6
100 nF	1949	0.8

3.3 Device Shutdown Behavior Results

For each case (No Css_gpfet, Css_gpfet = 1 nF, 2.2 nF, 4.7 nF, 10 nF, 15 nF, and 100 nF), device shutdown behavior is checked to see whether Css_gpfet influences the shutdown behavior. Based on the measurement results, it is clear that this capacitor does not have much influence on the shutdown behavior. This is also expected per design due to the presence of a strong internal pullup transistor (with max Rdson resistance = 25 ohm) between GPFET pin and VIN pin. Figure 4 and Figure 5 show the shutdown behavior without Css_gpfet and with Css_gpfet = 100 nF, respectively.

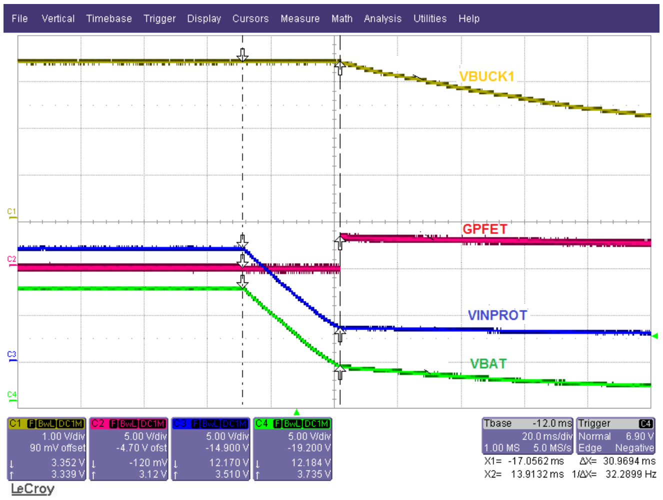


Figure 4. Shutdown VINPROT High to Low - No Css_gpfet

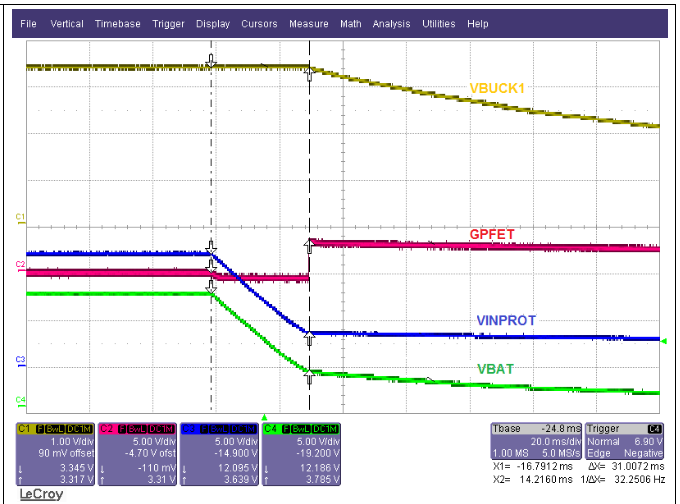


Figure 5. Shutdown VINPROT High to Low - With Css_gpfet = 100 nF

3.4 Device Start Up Behavior With Large Css_gpfet Capacitor

Since the external PMOS-protection switch is turned off with the help of a weak pulldown current source (20 µA, typical, internal to the GPFET pin), a very large Css_gpfet may prevent the PMOS-protection switch from turning on. To check this behavior, Css_gpfet value was increased to 470 nF. With this capacitor value, the external PMOS-protection switch does not turn on correctly as shown in Figure 7.

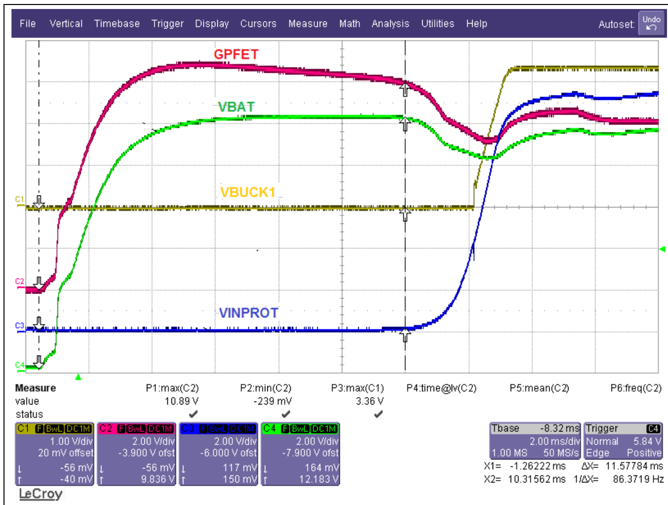


Figure 6. Start-up behavior With Css_gpfet = 100 nF

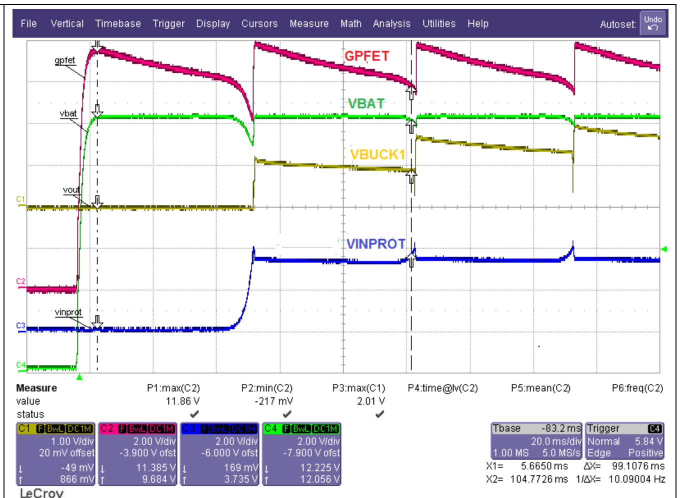


Figure 7. Start-up behavior With Css_gpfet = 470 nF

4 Observations and Conclusions

Measurement results show that with the help of Css_gpfet capacitor, it is possible to control the turnon characteristics of external P-MOS protection switch to reduce the inrush current during its turn on. An optimum Css_gpfet capacitor value depends mainly on external application conditions, hence the exact value of this capacitor cannot be provided. Select this capacitor value based on measurements done on the actual application. Use this application note only as a reference document for optimizing the Css_gpfet capacitor.

Based on the measurements done with the application condition mentioned in the *Section 3* section, the following observations and conclusions are made:

- With a Css_gpfet capacitor (less than 100 nF) between GPFET pin and source of external PMOS transistor, it is possible to adjust the timing between start of BUCK1 output or start of VINPROT voltage with respect to Vbat.
- With the help of Css_gpfet capacitor, input inrush current magnitude and its slew rate can be reduced.
- Rise time of BUCK1 output is not affected by Css_gpfet.
- Rise time of VINPROT, with reference to the time at which VBUCK1 reaches 3.3 V, is slowed down with increasing Css_gpfet.
- Higher value capacitors, like 470 nF for Css_gpfet, will not allow GPFET to turn on since the 20 µA pulldown current source is too weak to pull the GPFET pin sufficiently low.
- Shutdown behavior does not change much with different Css_gpfet values.
- Since the effect of Css_gpfet mainly depends on actual components (Example: Cout, Lout, LC filter, PMOS-protection switch, and so forth) used on the board, it is recommended to finalize this capacitor value based on actual measurements done on the customer board. Keep this capacitor as small as possible.
- Also, results may vary depending on the input power supply used. The recommendation is to use a real car battery for more accurate measurements.
- All timing specifications related to device power-up sequencing in the datasheet are specified without considering the Css_gpfet capacitor and some of the power-up timing parameters may change with the addition of Css_gpfet capacitor. For example, t_{START} timing (*TPS65311-Q1* datasheet, *Figure 24. Power-up Sequencing*) may be changed with addition of Css_gpfet capacitor.

Revision History

DATE	REVISION	NOTES
November 2016	*	Initial Release

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