Application Report

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Buck Boost Charger with Power Path for Super Cap

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ABSTRACT

Super Cap is becoming very popular in many applications since its unique feature like more recharge cycle, better transient capacity, simpler charger management and less environment pollution. Typical multi-cell Cap in series requires buck boost topology to charge from empty to full when V_{IN} is below 5 V. BQ25703A is good device which can perform quick charging, power path and protection function in single chip. This paper discusses how to use it and some considerations in real application.

Contents

List of Figures

List of Tables

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1 Typical Application Requirements

1.1 Application Example

- V_{IN}: 4.5~5.5 V.// Power source current limit is 0.5 A for USB and 2 A for Adaptor.
- CAP : Two cell in series.//25F/2.7 V for single cell.
- V_{BAT}: 0 V —4.8 V.// CAP from empty(0V) to full (V_{CHG} = 4.8 V).
- V_{SYS} range: 2.8 V~4.8 V.// V_{sysmin} = 2.8 V, V_{CHG} = 4.8 V.
- Cell balancer function.// 10 k Resistor in parallel with each Cap cell for passive balance.
- Power path function.// When ultra-low V_{BAT} and connect to AC, system start up instant.
- V_{IN} DPM function.// Protect V_{IN} from big drop when reach current limit.
- Cap OVP threshold: 5.2 V (MAX to 5.4 V).//Hardware OVP protection.
- Charge time: USB V_{IN} 120 s / Adaptor V_{IN} 30 s.// From V_{sysmin} to V_{CHG}.
- Working temp: -40~65 ℃ (up to 85 ℃)

1.2 Test Equipment

- Agilent E3644 A 5 V / 3 A Power supply
- Tektronix MSO4054 Oscilloscope
- Agilent 34401 A Multi-meter
- TI BQ25703A EVM Board
- EV2400 USB to any board
- TI Battery Management Studio software
- Nesscap Two cell 25 F Super Cap

2 Super Cap Charger Based on BQ25703A

2.1 BQ25703A Key Features

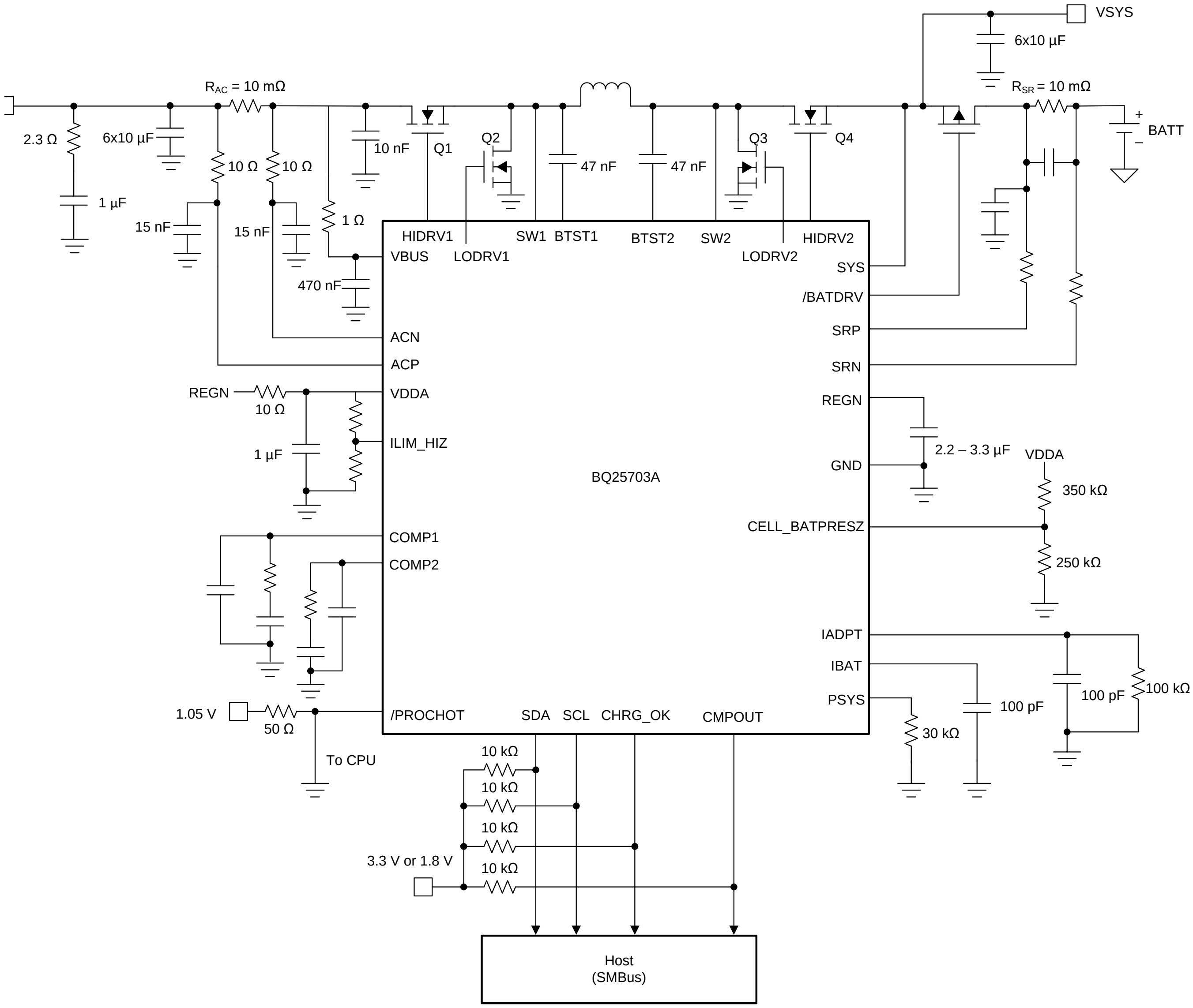

Figure 1. Buck Boost Charger With BQ25703A

BQ2570x series provide the flexibility for different application option, which shows as Table 1.

Table 1. BQ2570x Series Buck Boost Charger

	BQ25700A	BQ25703A	BQ25708	BQ25710	BQ25713	BQ25713B
Interface	SMBus	I2C	SMBus	SMBus	I2C	I2C
Device Address	09h	6Bh	09h	09h	6Bh	6Ah
VAP for IMVP9	No	No	No	Yes	Yes	Yes
Pass Through Mode	No	No	No	Yes	Yes	Yes
OTG Mode	Yes	Yes	No	Yes	Yes	Yes
OTG Voltage Range	4.48 V — 20.8 V	4.48 V — 20.8 V	N/A	3 V — 20.8 V	3 V — 20.8 V	3 V — 20.8 V

Table 1. BQ2570x Series Buck Boost Charger (continued)

	BQ25700A	BQ25703A	BQ25708	BQ25710	BQ25713	BQ25713B
OTG Voltage Resolution	64 mV	64 mV	N/A	8 mV	8 mV	8 mV
Charging Voltage Resolution	16 mV	16 mV	16 mV	8 mV	8 mV	8 mV

BQ25703A key features list below make it good single chip solutions for two cell super cap buck boost charger with full addition function.

- Large V_{IN} range: 3.5 V ~ 24 V.
- Buck-boost controller flexible for Multi-cell charging (Li-ion or CAP).
- NVDC power path – Instant-On with deeply discharged CAP.
- High charge current up to 6 A.
- DPM function against power source overload.
- High efficiency and Low Battery Quiescent Current
- IC Safety OVP/OCP/OT protection and integrated comp for flexible protection.
- High accuracy voltage (0.5%) and current regulation (2%).
- Integrated AMP/ADC to monitor charge status easily.

2.2 Typical Charging Profile

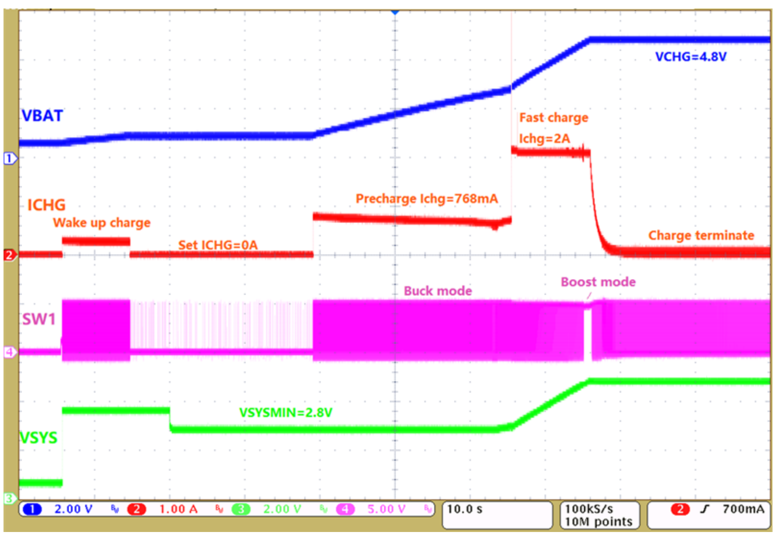

Figure 2. Adapter Charging Profile with Pre-Charge and Fast-Charge

Setup and Software Configure:

- * Chose Power supply is adapter 4.5 V ~ 5.5 V / 3 A.
- * Using Rsr = 5 mΩ for this example.
- * Set CELL_BATPRESZ for 1 Cell start up.
- * Power up. This would automatically enable 256 mA wake up charging current for 30 min. (128 mA for 10 mΩ); V_{SYS} would keep 3.58 V default value.
- * Set I_{CHG} = 0 A (REG0x03/02) would stop wake up charging. And wait software configure.
- * Set V_{SYSMIN} = 2.8 V (REG0x0D/0C), V_{SYS} would change from to 2.8 V immediately.
- * Set V_{BAT} = 4.8 V (REG0x05/04). Full voltage of two cell cap. One cell can set up to 5 V.
- * Check the I_{LIM_HIZ} when higher I_{CHG} > 2 A. Or disable I_{LIM_HIZ} pin to set input current limit. (REG0x33/32

bit 7=0)

- * Set I_{CHG} = 2.048 A (REG0x03/02 = 1.024 A for 10 mΩ) would start charging.

2.3 Speed Up Pre-Charge Stage

With the default setting, the pre-charge current is about 384 mA for 10 mΩ, the charge time from empty to full would reach up to above 100 s. This pre-charge current is fixed in device, two methods we can take to increase it and speed up charge process.

1) Use smaller Rsr = 2 mΩ.

Compared with 10 mΩ, the pre-charge current would increase by 5 times which up to 1.9 A. When fast stage set to 2 A (REG: 0.4 A for 10 ohm), the charging time from empty to full would about 20 s.

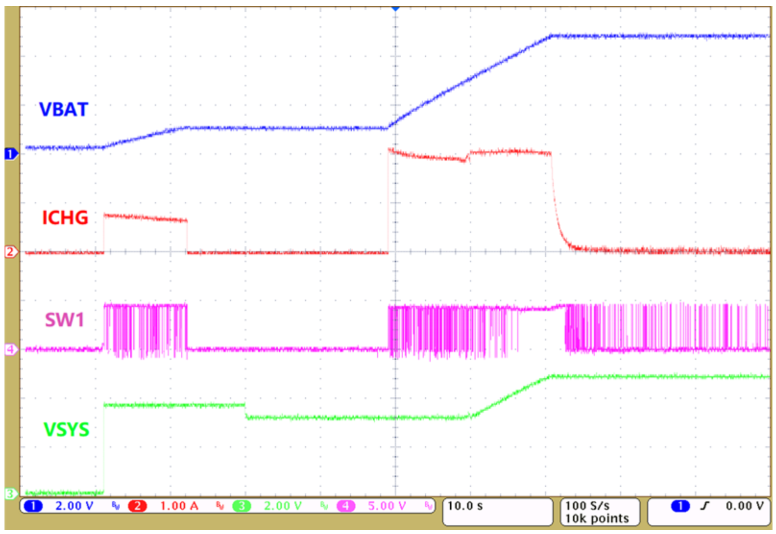

Figure 3. Rsr = 2 mΩ

2) Disable LDO Mode

The main reason why pre-charge current small is IC working in LDO mode to key V_{sysmin} when ultra low battery voltage. Disable LDO mode can increase the pre-charge current but this would lose regulate high V_{sysmin}, and the current is controlled by Vsr , V_{BAT} and Cap internal resistance. The charge time would reduce to 40 s.

Figure 6. Disable LDO Mode

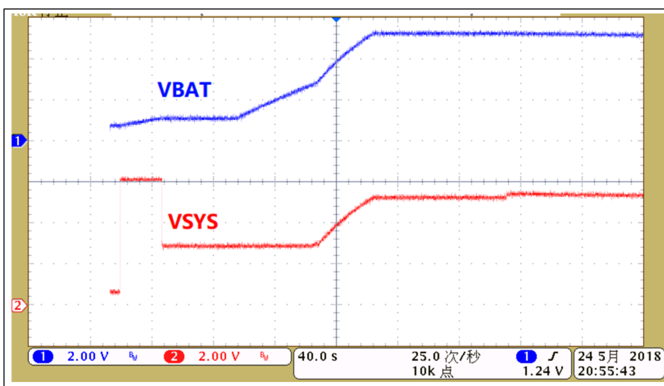

Figure 4. LDO Mode

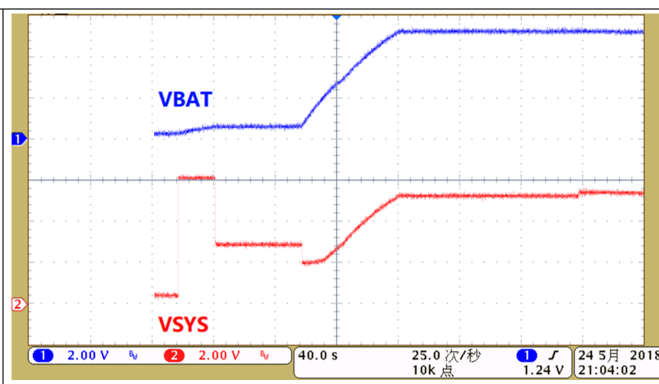

Figure 5. Bypass Mode

2.4 *USB 0.5 A Charge*

Some power supply current capacity is low, like USB 2.0 of computer which only have 0.5 A current limit. In these case, when high current charge process would make the V_{IN} drop out and system crashed. Two method can be taken to avoid V_{IN} big drop.

1) Reduce Precharge Current and Fast Charge Current

Suggest using large Rsr > 5 mΩ to limit the pre-charge current below 0.5 A.

$$\mathrm{Min}\left(\mathrm{Rsr}\right) = 10\ \mathrm{m}\Omega \times \frac{2.8\ \mathrm{V} \times 384\ \mathrm{mA}}{5\ \mathrm{V} \times 0.5\ \mathrm{A} \times 0.9} = 4.7\ \mathrm{m}\Omega \quad (1)$$

Set I_{CHG} < 0.4 A to limit fast charge current below 0.5 A

Below is Rs r = 5 mΩ and I_{CHG} = 0.4 A, which could maintain V_{IN} keep 5 V not drop.

Figure 9. USB Charging with Lower Current

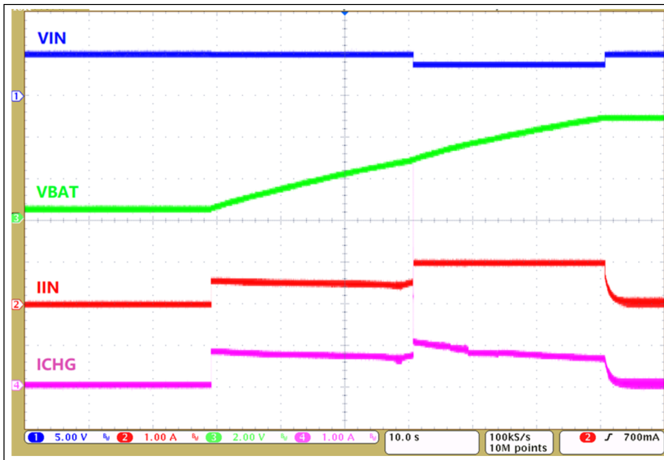

Figure 7. 1 A Fast Charge

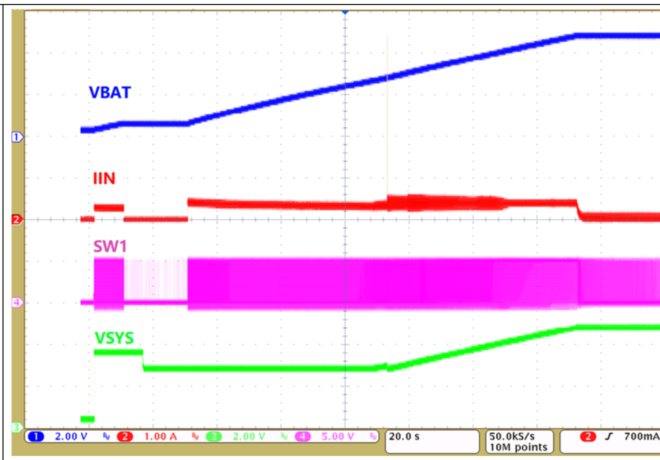

Figure 8. 0.4 A Fast Charge

2) Use Integrated DPM Function

Figure 12 shows when DPM enabled and IIN is reach up to 0.5 A , the charge current would reduce quick to maintain V_{IN} not drop. DPM function can make full use of any power source supply and avoid system crashed when input power is limited.

Figure 12. Charger with V_{IN} DPM Function

Figure 10. Without DPM

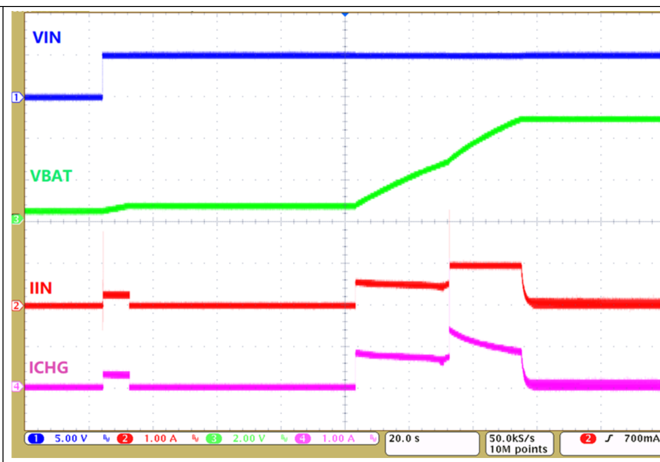

Figure 11. With DPM

2.5 Cell Passive Balance

Cell balance function is important when mismatch between cells since manufacture and long term running. This could prevent one cell over charge while the other under charge to improve the life cycle of the super cap. Active balancer performance and efficiency are good while the control is complicated and cost is high. Passive balancer is simple and lower cost with tradeoff efficiency.

For 10 K ohm parallel resistance, there would be about 250 uA sell loss current. But compared with a typical 0.5 A current system, this small trickle can be ignored. For longer standby time or lower system current, suggest higher parallel resistance. The test waveform is as Figure 4 which shows cell voltage match well each other when charging.

Figure 15. Passive Cell Balance Function

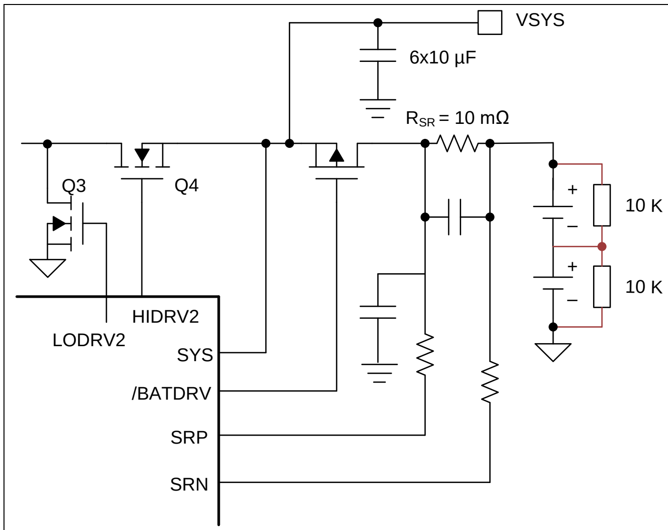

Figure 13. Passive Balance circuit example

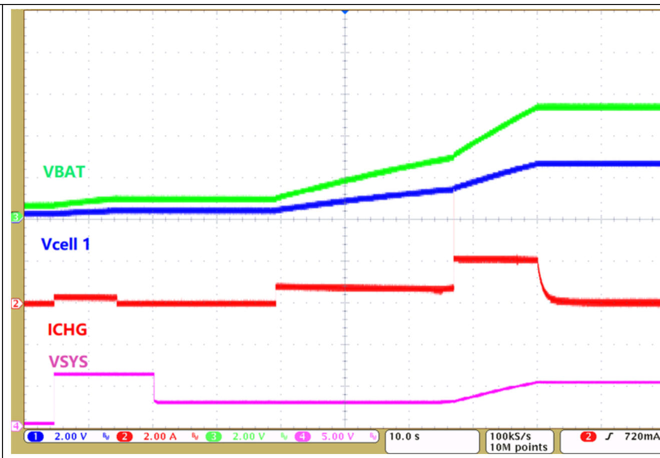

Figure 14. Additional OVP circuit with HIZ

2.6 Hardware OVP Protection

BQ25703A have integrated Battery Overvoltage Protection (BATOVP). The BATOVP threshold is 104% (1 s) or 102% (2 s to 4 s) of regulation voltage set in REG0x05/04().

But in some case, when wrong high V_{CHG} setting or software control crashed, you need a additional way to protect OVP protection. BQ25703A have one internal comparator which is very suitable for addition protection like OVP,OCP and thermal protection. One method is using HIZ mode to disconnect V_{IN} when OVP. External control to cut off BATFET is another method to consider.

Figure 18. HIZ Mode OVP Protection

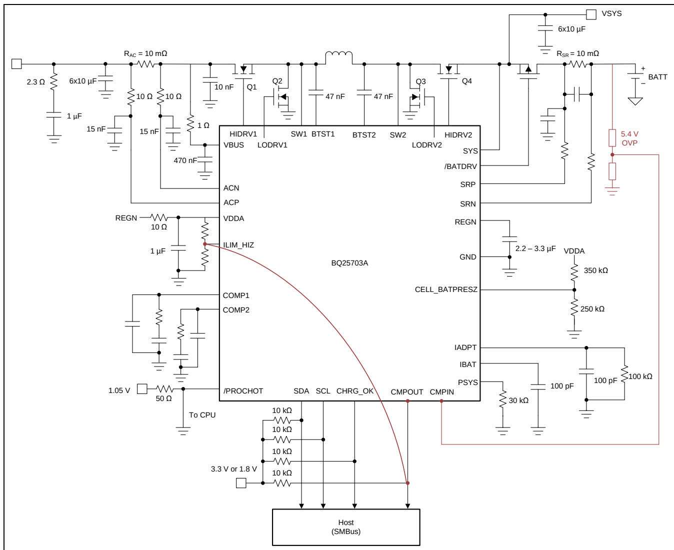

Figure 16. Charging with Cell Balance

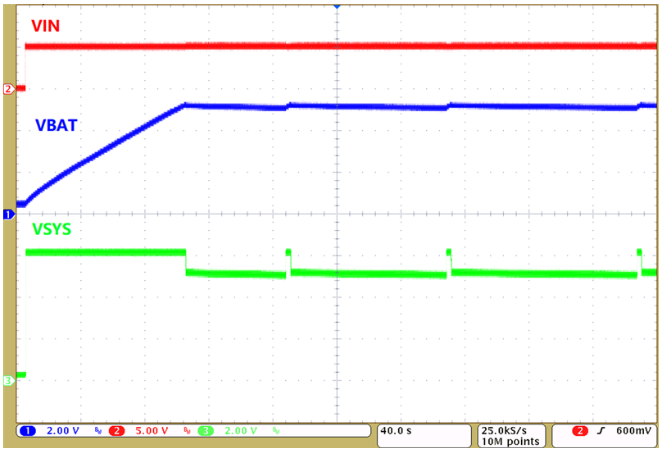

Figure 17. Charging OVP Test

3 Summary

BQ25703A is a good device as buck boost charger for super cap application. Its NVDC power path, DPM function can make system works smarter and not add any cost. Additional feature like hardware OVP and passive balancer make solutions safer in real system.

4 References

- 1. Texas Instruments, SLUSCU1A, BQ25703A product datasheet.
- 2. Texas Instruments, SLUUBG6, "BQ2570x Evaluation Module" User's Guide.