Texas Instruments

Application Report

SLUA585–September 2011

How to Review a Multicell Switching Charger Schematic

Roger Liang and Wang Li *BMS-High Cell & Emerging*

ABSTRACT

This application report provides a checklist for reviewing a switching charger schematic and explains each item in the list.

Before beginning the checklist, it is prudent to obtain the following charger information:

1. Battery chemistry information
2. How many cell in parallel or series?
3. Charge current rate, voltage rate
4. Does the charger have system load? Does the charger system need power path management? Does the charger need a dynamic power management?
5. Input voltage range and transience
6. Output voltage range and transience
7. What is the final product using the charger? Does it have any special requirement?
8. Host control or stand-alone charger
9. Smart charger or non-SMBus charger

After a multicell switching charger solution is selected, several general common design guide lines are applicable. The following paragraphs pertain to the checklist for schematic review. If anything violates the rule or is unclear, contact TI technical support.

1 PGND and AGND

PGND means power ground; it serves as a ground connection for a high-current power converter node. On a printed-circuit board (PCB) layout, it must be connected directly to the source of low-side power MOSFET.

AGND means analog ground; it serves as ground connection for low-current sensitive analog and digital signals. On a PCB layout, it must be connected to the analog ground plane, and only connect to PGND through the Power Pad underneath the integrated circuit (IC).

To make PCB ground layout clear, the PGND and AGND are separated and are connected with a short jumper wire on the schematic.

2 Common and Differentiate Mode Capacitor Around Current Sense

Place a 0.1-μF ceramic capacitor from ACN/CSSN/SRN/CSON to ACP/CSSP/SRP/CSOP to provide differential mode filtering. Place an optional 0.1-μF capacitor from ACP/CSSP/SRP/CSOP or ACN/CSSN/SRN/CSON to GND for common-mode filtering.

3 Vcc Filter; Resistor Package

Place a 1-μF ceramic capacitor from PVCC to PGND pin close to the IC. To reduce the overvoltage spike or high dv/dt on the Vcc pin, add a 10-Ω 1206 package resistor in front of the Vcc capacitor to give a 10-μs RC time constant. Another pair of RC value can also be used on this filter, 0.47-μF capacitor and 20-Ω 0805 package resistor.

4 Input Snubber

During the adapter hot plug-in, the input FETs have not been enabled, the ac switch is off, and the simplified equivalent circuit of the input is shown in Figure 1.

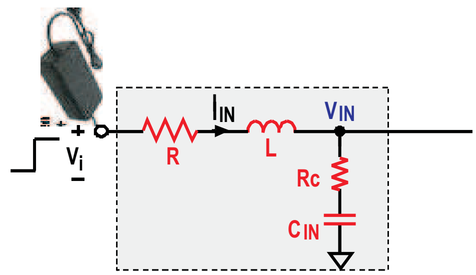


Figure 1. Simplified Equivalent Circuit During Adapter Insertion

Figure 2 depicts the recommended input filter design for a typical wall notebook adaptor input source. The measured input voltage and current waveforms are shown in Figure 3. The input voltage spike has been well damped by adding a 2-Ω resistor, while keeping the capacitance low.

If the input is not a typical notebook adaptor, the resistor and capacitor value may be changed according to the test result.

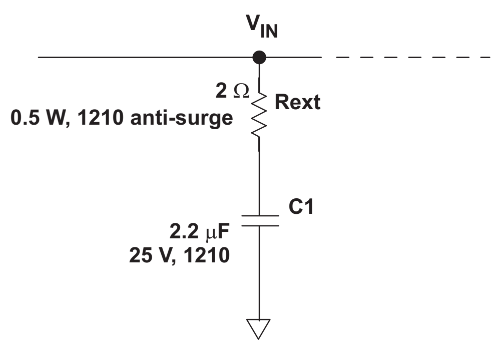


Figure 2. Recommended Input Filter Design

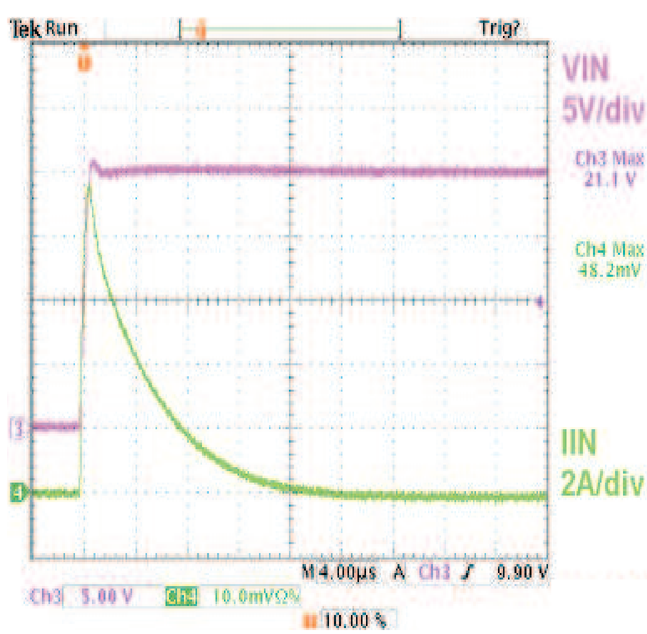


Figure 3. Adapter dc Side Hot Plug-in Test Waveforms

5 Charge Pump Circuit

If the switching charger has a charge pump circuit for driving the high-side FET, place a bootstrap capacitor close to the IC. Typically, a 0.047-µF capacitor and a Schottky bootstrap diode are used in most application circuits (the Cg of high-side MOSFET is less 4.7 nF).

6 Reverse Input Protection

If a reverse input source is plugged in, the charger should survive. Every IC pin must be protected for that condition. In Figure 4, the input has a pair of back-to-back P-channel MOSFETs, which is driven by $\overline{\text{ACDRV}}$. It provides the reverse input protection. All IC pins are isolated by ACFET.

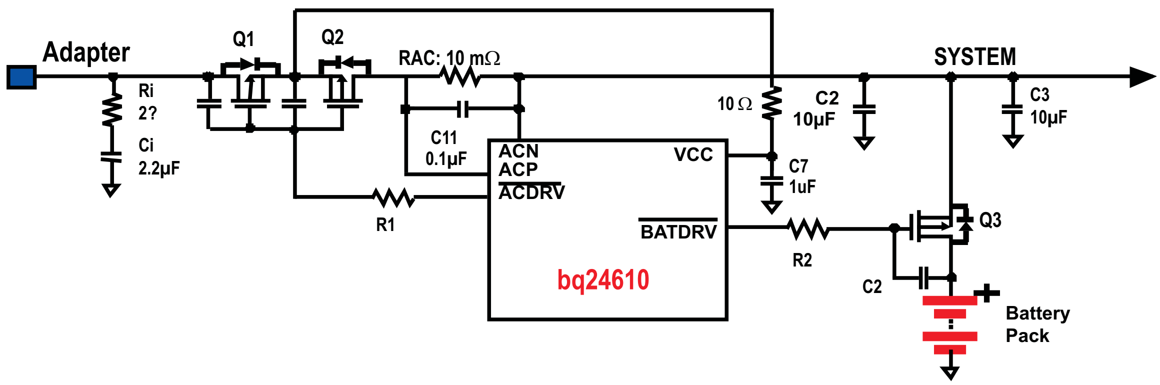


Figure 4. P-FETs Reverse Input Protection

In Figure 5, the new charger IC drives the N-Channel MOSFETs. The external reverse input protection circuit (Q6, R6 and R7) has to turn off the RBFET (Q2) and limit the current flowing out from CMSRC and ACDRV. In normal operation, Q6 is turned off by negative Vgs. When adapter voltage is reversed, Q6 Vgs is positive. As a result, Q6 turns on to short gate and source of Q2 so that Q2 is off. Q2 body diode blocks negative voltage to system. However, the CMSRC and ACDRV pins need R3 and R4 to limit the current due to the ESD diode of these pins when turned on. Q6 must have low Vgs threshold voltage and low Qgs gate charge so it turns on before Q2 turns on. R3 and R4 must have enough power rating due to power dissipation when the ESD diode is on. In Figure 6, the Schottky diode D3 gives the reverse adapter voltage protection, no extra small MOSFET or resistors are needed.

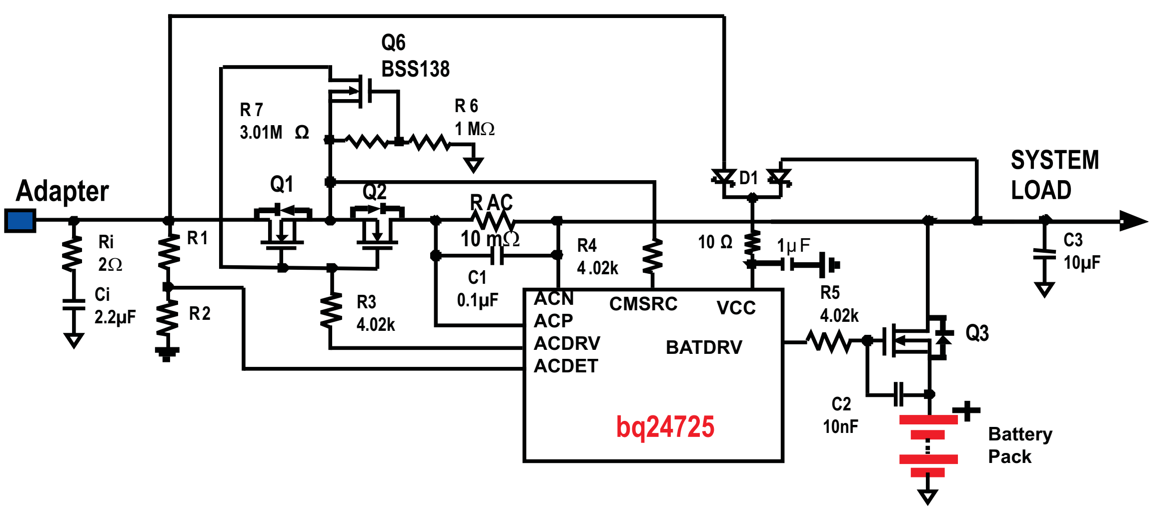


Figure 5. N-FETs Reverse Input Protection

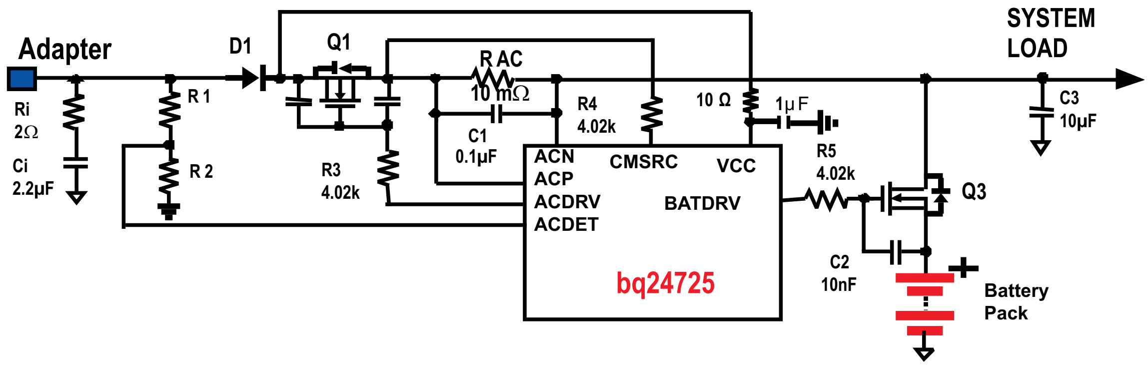


Figure 6. One Diode Reverse Protection

7 Input FET and BATFET Gate Drive Capability

If there is an internal charger pump that drives the N-Channel input FET or BATFET, such as the bq24725 (see Figure 5 and Figure 6), the minimum load resistance between BATDRV and SRN or minimum load resistance between ACDRV and CMSRC is 500kΩ because of the gate drive (charge pump circuit) capability.

8 Capacitor Voltage Rate and Material

Ceramic capacitors show a dc-bias effect. This effect reduces the effective capacitance when a dc-bias voltage is applied across a ceramic capacitor, as on the input capacitor of a charger. This effect may lead to a significant capacitance drop, especially for high input voltages and small capacitor packages. See the manufacturer’s data sheet about the performance with a dc bias voltage applied. It may be necessary to choose a higher voltage rating or nominal capacitance value in order to get the required value at the operating point.

Check the REGN or PVCC capacitor voltage rating.

9 Check Current Limit Type, Cycle-by-Cycle Current Limit or Average Current Limit

The bq24725/707/726, bq24745/747/765, bq246xx, and bq2417x/13x have cycle-by-cycle current limit. The output capacitance must be placed between the outside of current sense resistor and the battery package terminal. An optional 0.1-µF capacitor between SRP or CSOP and ground is for common mode filtering. Meanwhile, the capacitance on SRP must not be higher than 0.1 µF in order to properly sense the voltage across SRP and SRN for cycle-by-cycle under-current and over current detection.

The bq2410x/11x/12x, bq24702/703, bq24704/605, and bq2475x have average current limit. The charge-current sense resistor R_{SR} must be positioned with half or more of the total output capacitance placed before R_{SR}, contacting both R_{SR} and the output inductor; and the remaining capacitance placed after R_{SR}. The output capacitance must be divided and placed on either side of R_{SR}. A ratio of 50:50 gives the best performance, but the node in which the output inductor and R_{SR} connect must have a minimum of 50% of the total capacitance. This capacitance provides sufficient filtering to remove the switching noise and give better accuracy.

10 Add Series Resistor in Front of ACDRV and BATDRV

To limit the in-rush current on ACDRV pin, BATDRV pin, and CMSRC pin, a few kilo-ohm resistor is recommended on each of the three pins. Refer to Figure 4, Figure 5, and Figure 6. Also, set the VCC or PVCC filter RC time constant much smaller than this ACDRV or BATDRV RC time constant.

11 HIDRV Turnon Speed to Reduce EMI

If the product has an EMI concern on switching charger circuit, reserve a resistor between the IC's high-side gate drive pin and MOSFET's gate. The resistor can slow down the high- side FET turnon speed and reduce the spike and ringing on switch node voltage waveform.

12 Check That Inductor Ripple Does Not Hit Current Limit

Calculate the maximum peak to peak inductor ripple current at worst condition.

Iripple_p-p = (Vin_max-Vout) × Vout / (Vin_max × Lmin x fs_min)

Vin_max: maximum input voltage,
Fs_min: minimum switching frequency,
Lmin: minimum inductance
Vout: pick the possible output voltage that close to half maximum input voltage

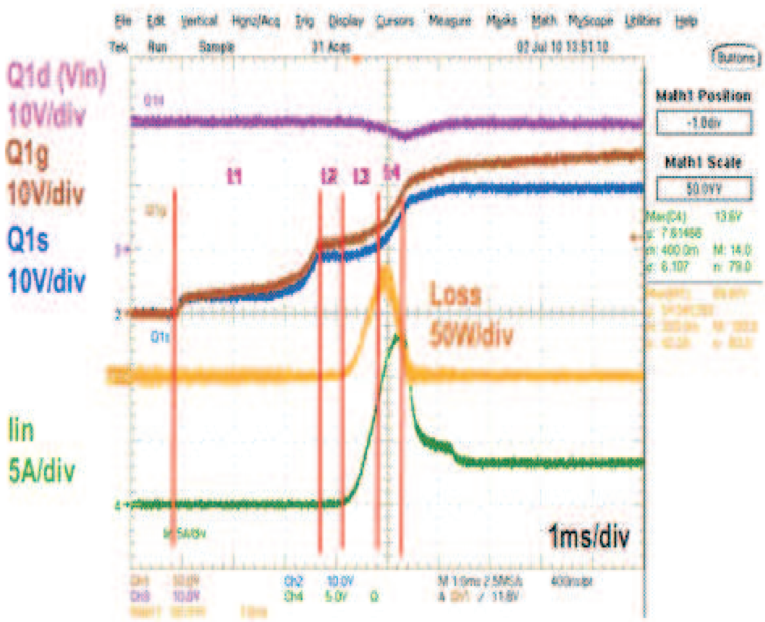
The IC has a charge over current limit threshold, Voc that is 145% or 165% of Rsns × IREG_CHG. Please make sure the Iripple_p-p is lower than 2 x (Voc- Rsns x I_{REG_CHG}). So, the charge current can run at IREG_CHG without triggering over current protection first.

13 Input FET Power Rating and In-Rush Current Control

A large volume system capacitor or system load needs high-power rating input FET to handle the power dissipation during a soft start (inrush current control).

Figure 7 is soft start waveform on Figure 8 circuit. Use "transient thermal impedance" chart from data sheet to verify the junction temperature. If the junction temperature is lower than Tj_max, the input FET is safe.

9V Battery, Adapter Insert, 60 W Load



Peak loss 90 W

Figure 7. Input FET Power Loss During Soft Start

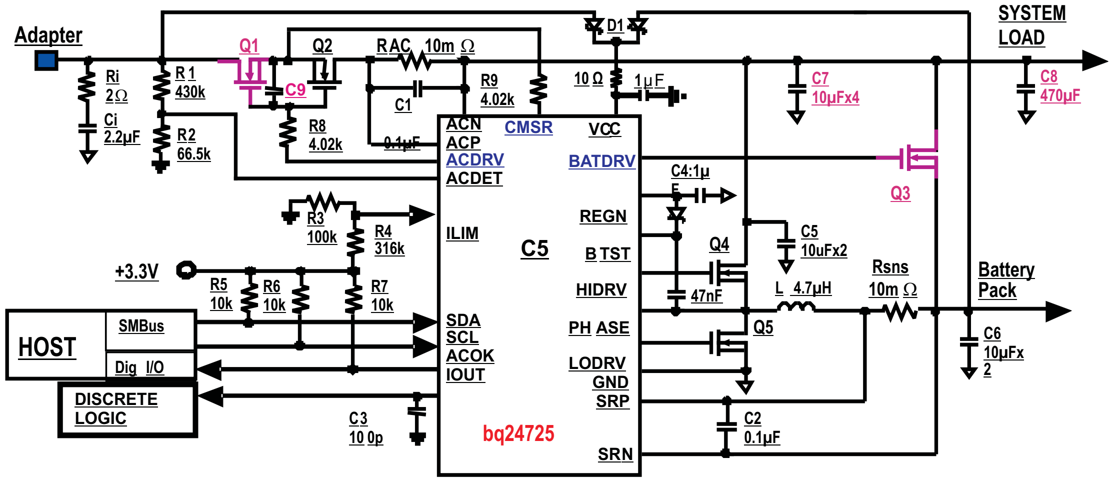


Figure 8. A Typical Charger Circuit With Power Path Management

14 BAT Output Capacitor or Resistance is Out of Range

For host control charger, a data sheet will give a recommended inductor and capacitor value base on the LC resonant range.

For stand-alone charger, it not only has a LC resonant range, but also has Cmax_wake or Cmax_dis calculation which is derived from the battery detection parameter [see bq24610 data sheet (SLUS892)]. If the output capacitor is over Cmax, the status pin will flash even when battery is absent.

Also, if the resistance is too high between charger output and battery terminal, the charger will run in and out of charger termination.

Rbat_max = Vrch/Iterm
Vrch: Recharge threshold voltage; mV/Cell
Iterm: Termination current.

15 Iout Stability 100 pF

For bq24725/707/726, place a 100-pF or less ceramic decoupling capacitor from IOUT pin to GND.

For bq2475x; bq24704/705 and bq740/741, place a 100-pF or less ceramic decoupling capacitor from IADAPT pin to GND.

For bq24745/747/765, place a 100-pF or less ceramic decoupling capacitor from VICM pin to GND.

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products		**Applications**	
Audio	www.ti.com/audio	Communications and Telecom	www.ti.com/communications
Amplifiers	amplifier.ti.com	Computers and Peripherals	www.ti.com/computers
Data Converters	dataconverter.ti.com	Consumer Electronics	www.ti.com/consumer-apps
DLP® Products	www.dlp.com	Energy and Lighting	www.ti.com/energy
DSP	dsp.ti.com	Industrial	www.ti.com/industrial
Clocks and Timers	www.ti.com/clocks	Medical	www.ti.com/medical
Interface	interface.ti.com	Security	www.ti.com/security
Logic	logic.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Power Mgmt	power.ti.com	Transportation and Automotive	www.ti.com/automotive
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Mobile Processors	www.ti.com/omap		
Wireless Connctivity	www.ti.com/wirelessconnectivity		
		TI E2E Community Home Page	e2e.ti.com

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265