Application Note

BQ25171-Q1 Quick Start Guide

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ABSTRACT

This application note discusses common standalone circuits for the BQ25171-Q1 device. The BQ25171-Q1 is an automotive rated linear battery charger capable of charging at up to 800 mA for 1 cell to 2 cell Li-Ion, Li-Polymer, and LiFePO4 chemistries and 1-cell to 6-cell NiMH. The device has an input voltage operating range of 3 V to 18 V and is highly integrated requiring a minimum number of external parts.

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Trademarks

1 Introduction

The following sections first provide an overview of the external parts required to configure the device, then three reference circuit designs are introduced: 700-mA/70-mA Variable Charge Li-Ion Fast Charge, 200-mA NiMH Time Charge, and 45-mA LiFePO4 Fast Charge. These designed can be implemented as is or modified to meet your design specifications. Note this is a simple explanation of the device and descriptions are brief. For a full explanation of the device and its features refer to the BQ25171-Q1 data sheet.

2 BQ25171-Q1 Design Decisions

The device requires a minimum number of external parts to implement a charging solution. The standard solution only requires the selection of three external resistors to configure the device to given charge specifications.

1. CHM_TMR – Resistor value to select battery chemistry and charge timer, see table 7-1 in Data sheet.
2. VSET – Resistor value to program charge voltage and enable optional intermittent charge (for NiMH only), see table 7-2 in Data sheet.
3. ISET – Resistor value to set fast charge current, see Table 7-1 in this application note.
4. Other connections:
   a. TS – NTC to monitor battery temperature, typically 10 kΩ.
   b. Cin and Cout – 1 µF effective capacitance connection to ground at both IN and OUT
   c. STAT1 and STAT2 – Open collector status outputs (optional connections)
   d. /CE – Charge enable input (optional connection)

3 700 mA/70 mA Variable Charge Current Li-Ion Fast Charge Design

Figure 3-1 provides a solution that will charge a Li-Ion battery at 700 mA or 70 mA with charge current selection controlled by a GPIO pin on a host device and termination at 10% of the selected charge current.

- R-ISET1 will set fast charge current to 70 mA, 4.2 kΩ.
- R-ISET2 will combine with R-ISET1 in parallel to set fast charge current to 700 mA, 480 Ω.
- The external NMOS transistor with gate voltage controlled by a host GPIO pin will set fast charge current to 700 mA when turned on.
- R-CHM_TMR will set chemistry to Li+ with a 10 hour safety timer, 82 kΩ.
- R-VSET will set the number of cells and regulation voltage to 1 cell Li-Ion 4.2 V, 18 kΩ.
- Charge enable (/CE) pin is connected to host MCU for external device control.
- R-TS is required, a 10 kΩ NTC in battery pack is connected to pin.
- STAT1/STAT2 LEDs are used together to indicate charge status and faults, they are optional.

This application supports enhanced charge current flexibility.

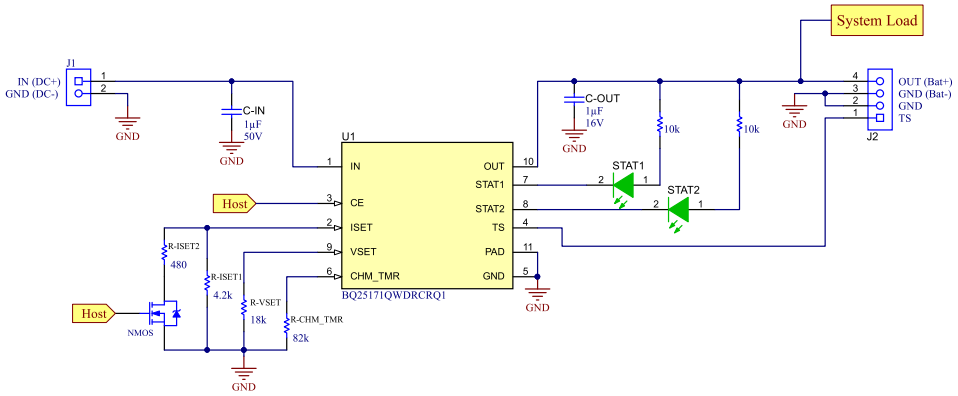

Figure 3-1. BQ25171-Q1 700-mA/70-mA Fast Charge

4 200 mA Time Charge 3S NiMH Design

Figure 4-1 provides a solution that will charge 3 series NiMH battery cells at 200 mA for 14 hours.

- R-ISET will set fast charge current to 200 mA, 1.5 kΩ.
- R-CHM_TMR will set chemistry to NiMH with a 14 hour charge timer, 11 kΩ.
- R-VSET will set the cell count to 3 and enable optional intermittent charge, 18 kΩ.
- /CE pin is connected to host MCU for external device control.
- R-TS is required, a 10 kΩ resistor is connected to GND to disable this function.
- STAT1/STAT2 LEDs are used together to indicate charge status and faults, they are optional.

This application supports medium capacity multi-cell NiMH batteries.

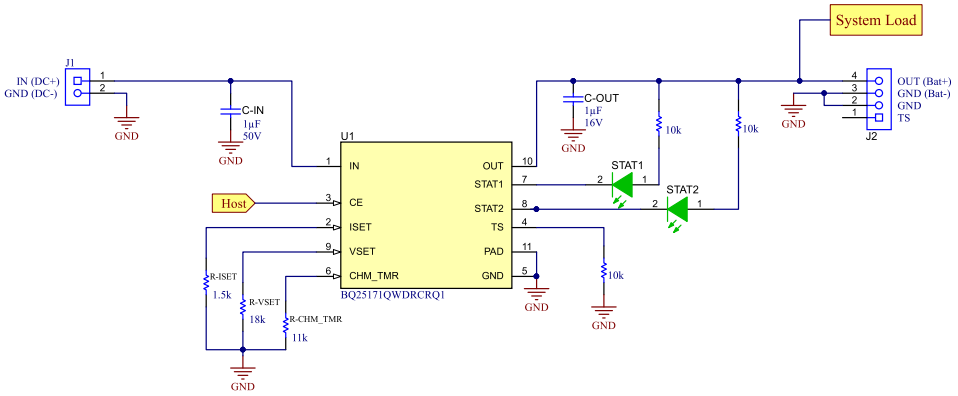

Figure 4-1. NiMH 200-mA Time Charge Design

5 45 mA Fast Charge LiFePO4 Design

Figure 5-1 provides a solution that will charge at 45 mA and demonstrates the required resistors to modify the allowable battery temperature range.

- R-ISET will set fast charge current to 45 mA, 6.6 kΩ.
- Following the recommendation from Data Sheet section *ISET Pin Detection,* a RC circuit has been added in parallel with R-ISET to achieve a more stable current signal.
- R-CHM_TMR will set chemistry to Li+ with the safety timer disabled, 62 kΩ.
- R-VSET will set the output voltage to 3.7 V for a 1 cell LiFePO4 battery, 62 kΩ,
- R-TS is required, a 10 kΩ NTC in battery pack is connected to pin. Add Rs and Rp to adjust temperature range. RS 1.9 kΩ and RP 400 kΩ sets range to 0°C to 60°C.
- STAT1/STAT2 LEDs are used together to indicate charge status and faults, they are optional.
- /CE pin is left floating; IC operation is enabled by default.

This application supports smaller capacity batteries.

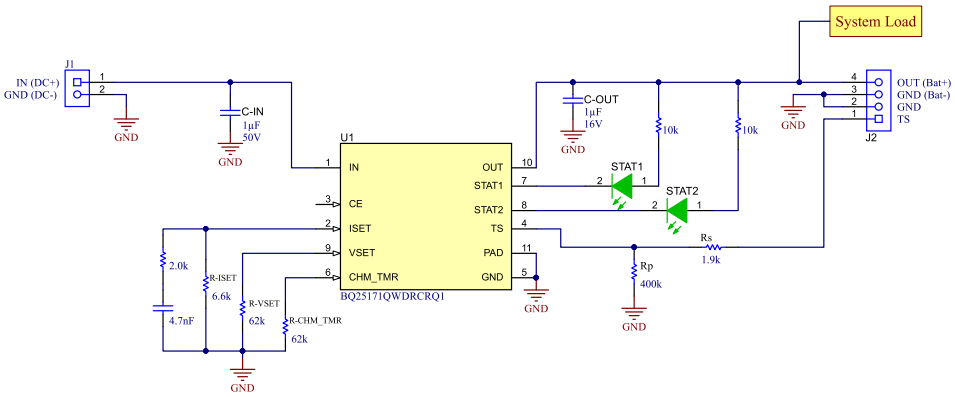

Figure 5-1. LiFePO4 45-mA Fast Charge Design

6 Pin Configuration

Table 6-1 provides a summary of the pins on the device.

Table 6-1. BQ25171-Q1 Pin Configuration

Pin - Name	I/O	Description	Comments
Pin 1 – IN	P	Input power supply	Operating range to 18 V, Absolute Max 40 V
Pin 2 – ISET	I	Resistor R-ISET sets fast charge current	ICHG = K-ISET/R-ISET, K-ISET= 300 AΩ, 375 Ω = 800 mA
Pin 3 – $\overline{CE}$	I	Active Low Charge Enable pin, IC in shutdown mode when $\overline{CE}$ is high	IC enabled by default when pin is floating
Pin 4 – TS	I	Battery temperature input, connect a 10 kΩ NTC thermistor	Connect 10 kΩ resistor from TS to gnd if TS function is not used
Pin 5 – GND	-	Ground terminal	
Pin 6 – CHM_TMR	I	Resistor R-CHM_TMR sets chemistry and charge time	Resistor range 3.6 kΩ to 100 kΩ
Pin 7 – STAT1	O	Open drain charge status	
Pin 8 – STAT2	O	Open drain charge status	
Pin 9 – VSET	I	Resistor R-VSET sets out pin regulation voltage	Resistor range 3.6 kΩ to 100 kΩ
Pin 10 – OUT	P	Battery/ system load connection	
Thermal Pad	-	Exposed thermal pad	Connect thermal pad to board gnd plane

7 R-ISET Common Values

Calculations for resistor ISET are provided in the data sheet. Table 7-1 provides a reference of calculated resistor values for various fast charge currents. Resistors with ±1% tolerance or better are recommended to minimize charge current error.

Table 7-1. Calculated Resistor Values

ICHG (mA)	R-ISET (Ω)	Closest Standard Resistor (Ω)
10	30 k	30.1 k
30	10 k	10.0 k
50	6000	6040
100	3000	3010
200	1500	1500
300	1000	1000
400	750	750
500	600	604
600	500	499
700	429	432
800	375	374

Tables 7-1 and 7-2 in section 7.3.1 in Data Sheet provide appropriate resistor values to use to set CHM_TMR and VSET pins.

8 Common Questions: Tips and Tricks

- Changes to ISET, VSET, and CHM_TMR pin values on the fly.
  - The ISET pin is monitored while charging and changes to R-ISET during operation will immediately change the charge current.
  - The VSET and CHM_TMR pins are not continuously monitored during charge. Changes to these pins will not be acknowledged by the device until the input supply or /CE pin is toggled.
- ISET, VSET, CHM_TMR pins short/open protection
  - A short/open circuit condition detected on VSET or CHM_TMR results in a non-recoverable fault. Toggle /CE or input power supply to reset device
  - A short circuit condition detected on ISET results in a non-recoverable fault.
  - An open circuit condition on ISET causes charger to start charging with 0 A charge current.
- NiMH charging profile
  - Device does not support fast charging NiMH.
  - The duration of the time based charge is set by CHM_TMR and the current is set by ISET.
  - Device charges NiMH battery in constant current mode only, option for additional intermittent charges set by VSET pin.
  - Intermittent charging enables a shortened charge cycle 25% of the charge timer set by CHM_TMR to replenish natural self-discharge, but not overcharge the battery.
  - The intermittent charge is initiated when battery voltage falls below V_{RECHG} (1.3 V).
- Disable automatic recharge with charge enable (/CE) pin
  - Under standard operation device automatically restarts the charge cycle following a battery voltage drop below the recharge threshold (V_{RECHG}).
  - Disable the charger by pulling the /CE pin high from a host device to prevent the automatic start of a charge cycle.
  - Ensure your system has a method to re-enable charging when desired as device will not monitor battery voltage when disabled.
- ISET as an output current monitor
  - Voltage developed on the R-ISET resistor maps to output current at a 300 to 1 ratio and can be monitored by an external circuit.
- Output current regulation at low battery voltage

  - For Li-Ion battery voltage less than VBAT_SHORT (2.2 V), and LiFePO4 battery voltage less than 1.2 V the output current is limited to IBAT_SHORT (16 mA). Device is in trickle charge phase.
  - For Li-Ion battery voltage between VBAT_SHORT and VBAT_LOWV (2.2 V and 2.8 V), and LiFePO4 battery voltage between 1.2 V and 2.0 V output current is limited to the precharge current set to 20% of ISET value.
  - Battery voltage must rise above VBAT_LOWV threshold within the 30 minute precharge timer. Otherwise the timer expiration ends the charge cycle and a toggle of the input supply or /CE pin is required to restart charging.
- Operation at low charge current
  - ICHG can be set as low as 10 mA via ISET, for ICHG below 50mA TI recommends adding a RC circuit in parallel with R-ISET for greater signal stability. R = 2 kΩ and C = 4.7 nF recommended. Refer to Figure 5-1 above for implementation of RC circuit.
  - Precharge and termination current accuracy may be lower at very low charge currents,
- Operation at very low charge current
  - The recommended minimum fast charge current is 10 mA, but ISET can be set less than 10 mA.
  - Charge current accuracy can no longer be guaranteed at less than 10 mA, current may drop to 0 A.
  - There is no fault indication for charging at 0 A STAT1 and STAT2 outputs will continue to indicate charge in progress.
- STAT1/STAT2 pins
  - Open drain outputs, combination of STAT1 and STAT2 indicate charge complete, charge in progress, recoverable fault, or non-recoverable fault.
- Open battery operation
  - When no battery is present the device will cycle in and out of charging and provide an output voltage equal to the VSET regulation voltage.
  - Device does not perform a battery detection routine at startup.
- Efficiency of charge, how to reduce power dissipation
  - The closer Vin is to Vout the better the efficiency and lower the power dissipation. Be aware Vin will need to be larger than Vout + VDO (dropout voltage) to account for voltage loss internal to the IC.
  - Required power dissipation in IC is greatest during fast charge with a low battery voltage and a high input voltage.
- Input/output protection
  - Device has input overvoltage protection, but does not have IN-DPM (voltage fold back protection).
  - Device has output overcurrent and overvoltage protection. The overcurrent condition will require a toggle of /CE or power supply to resume charging.
- During Vin OVP unit cannot operate
  - Max input voltage without damaging device is 40 V.
  - Unit will enter standby mode above VIN_OV (18 V) until the input voltage recovers below the overvoltage threshold.
- Safety timer reset events
  - Cycle input power, safety timer resets.
  - Toggle the /CE pin, safety timer resets.
  - Battery voltage falls below V_{RECHG}, safety timer resets.
  - Battery voltage crosses the VBAT_LOWV threshold, safety timer resets.
  - For NiMH with intermittent charge enabled, VBAT falls below recharge threshold, charge timer resets.
- Safety timer expiration
  - Timer expiration for Li+ charging results in non-recoverable fault.
  - Timer expiration for NiMH charging is the expected termination. A fault occurs if VOUT < V_{RECHG} at timer expiration.
- Charge is not terminating before safety timer expiration
  - Confirm CHM_TMR is set for the appropriate safety timer length, confirm VSET and ISET match the battery manufacturer specs.
  - A system load in parallel with the battery drawing a large % of the available charge current may cause charging to be incomplete at safety timer expiration.
- Safety timer extension scenarios

  - When the device is in thermal regulation the safety timer is extended and counts at half clock rate for the duration of thermal regulation,
  - When a recoverable fault occurs the safety timer is suspended until charge is automatically resumed.
  - If the charge cycle is restarted safety timer will reset.
- TS pin in battery temperature application
  - Device is in normal operation when TS pin voltage is between Vcold and Vhot, typically corresponds to 0°C to 45°C.
  - TS pin voltage outside the acceptable range results in a recoverable fault. Device stops charging and enters standby state until battery temperature returns to operational range.
  - Hot and cold thresholds can be modified using series and parallel resistors Rs and Rp between the TS pin and the NTC thermistor.
- Thermal Regulation and shutdown
  - Device monitors internal junction temperature independent of TS pin battery temperature monitor.
  - Thermal regulation limits charge current when IC temperature exceeds T_{REG} (125°C).
  - Thermal shutdown turns off unit if IC temperature exceeds T_{SHUT} (150°C). Device resumes charge when temperature falls below T_{SHUT} falling threshold of 135°C

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