Application Report

SLUA508 – April 2009

Achieving Different Charge Voltage for bq2408x

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PMP - BMS Battery Charge

ABSTRACT

By changing standard 4.2-V charge voltage to 4.1 V or lower, rechargeable lithium-ion (Li-Ion) battery cycle life can be extended at low temperature. New chemistry batteries such as the $LiFePO_4$ rechargeable battery requires a 3.6-V charge voltage. All these new applications need a nonstandard charge voltage. This application report gives examples of using the 4.2-V bq24085 charger to achieve different charge voltage.

The bq24085/6/7/8 series are highly integrated Li-ion and Li-polymer linear chargers, targeted at space-limited portable applications. The bq2408x series offers a variety of safety features and functional options, while still implementing a complete charging system is a small package. Multiple versions of this device family enable easy design in cradle chargers or in end equipment, while using low-cost or high-end ac adapters.

However, these linear chargers can only provide a standard 4.2-V charge voltage, while many of the new applications need a nonstandard charge voltage. For example, at low temperature, users prefer to reduce charge voltage to 4.1 V or lower to extend battery cycle life. The new chemistry battery, like the recently developed $LiFePO_4$ battery, needs 3.6 V instead of a 4.2-V charge voltage. This application report gives examples of using the 4.2-V bq24085 charger to achieve different charge voltage.

Figure 1 shows the circuit implementation to change charge voltage to 4.1 V when temperature is low. The bq24085 has an internal voltage reference of 4.2 V. This internal voltage reference is used for voltage loop control so that output voltage is regulated to 4.2 V. To change the output voltage, two resistors, R1 and R2, are used. The R1 and R2 values are selected so that the BAT pin is 4.2 V, whereas the OUT pin is 4.1 V. This requires a voltage source higher than 4.2 V connected to R2. R4 and the 4.7-V Zener diode Z1 are used for this higher voltage source. T1 is a PNP transistor used to control the voltage level switch from 4.2 V at normal temperature to 4.1 V at low temperature. R3 is the base bias resistor for T1. R3 and Z1 are connected to a host OC gate.

At normal temperature, the host OC gate is off. As a result, T1 is off so that R2 does not have an impact on regular charger operation. When temperature is low, the host turns on the OC gate to pull down R3 and Z1, so that R1 and R2 together provide feedback voltage to the BAT pin.

Assume that the input is 5 V and Z1 gives approximately 4.6 V, using the superposition principle gives the following equation.

$$V_{O(REG)} = V_{OUT} \times \frac{R_2}{R_1 + R_2} + V_Z \times \frac{R_1}{R_1 + R_2},$$

Where $V_{O(REG)}$ = 4.2 V, V_{OUT} = 4.1 V, and V_Z = 4.6 V.

Solving the equation gives the following answer:

$$R_2 = \frac{V_Z - V_{O(REG)}}{V_{O(REG)} - V_{OUT}} \times R_1 = \frac{4.6 - 4.2}{4.2 - 4.1} \times R_1 = 4R_1$$

Select R1 = 390 , then R2 is 1.54 kΩ. Select R4 = 124 to provide approximately a 3-mA bias current for Z1 at a 5-V input voltage. R3 can be a large resistor such as 133 kΩ to minimize bias current but not large enough to let T1 exit from the saturation state. Select the Z1 4.7-V Zener diode BZX84C4V7. Select the T1 15-V PNP transistor ZXTP25015 which has very high gain so that the saturation voltage drop is only in the several mV range which can be ignored.

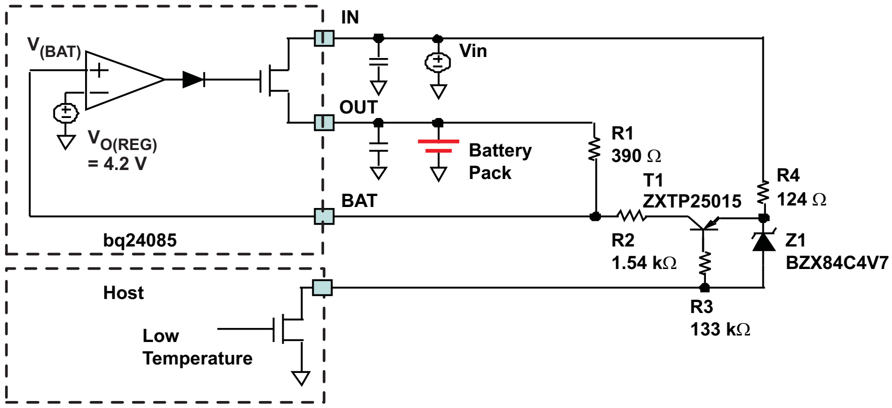

Figure 1. Circuit Implementation to Change Charge Voltage to 4.1 V by Using Zener Diode

Table 1 summarizes the test result. When input is changed from 4.5 V to 6.5 V, the output voltage is reduced from 4.163 V to 4.026 V, which is due to the Zener diode breakdown voltage change when bias current changes. If a very accurate voltage source (must be higher than 4.2 V) is available in the system, then connect this voltage source to the T1 emitter, and R4 and Z1 can be saved.

Table 1. Test Result of Zener Diode Circuit

Vin (V)	Vo (V)	Vz (V)	Iz (mA)
4.5	4.163	4.34	1.3
5	4.096	4.62	3.1
5.5	4.059	4.77	5.9
6	4.039	4.85	9.3
6.5	4.026	4.90	12.9

To improve the voltage regulation accuracy, an operational amplifier can be used to adjust the output voltage. Figure 2 shows the circuit implementation to change the charge voltage to 4.1 V when temperature is low. At normal temperature, the host OC gate is off. As a result, U1 is a voltage follower that does not impact regulation voltage at 4.2 V. When temperature is low, the host turns on the OC gate to pull R1 down to ground; U1 is a noninverting amplifier. The output voltage regulation changes according to the following equation.

$$V_{OUT} = V_{O(REG)} \times \frac{R_1}{R_1 + R_2}$$

Where $V_{O(REG)}$ = 4.2 V, V_{OUT} = 4.1 V

Solving the equation gives the following result.

$$R_1 = \frac{V_{OUT}}{V_{O(REG)} - V_{OUT}} \times R_2 = \frac{4.1}{4.2 - 4.1} \times R_2 = 41R_2$$

Select R1 = 10 kΩ, then R2 is 410 kΩ. Select standard 412 kΩ. Select U1 for low-power supply current with an extremely low input bias current operational amplifier such as TLV2241. Table 2 summarizes the test result. When input is changed from 4.5 V to 6.5 V, the output voltage only changes 16 mV, which is much smaller than the Zener diode circuit.

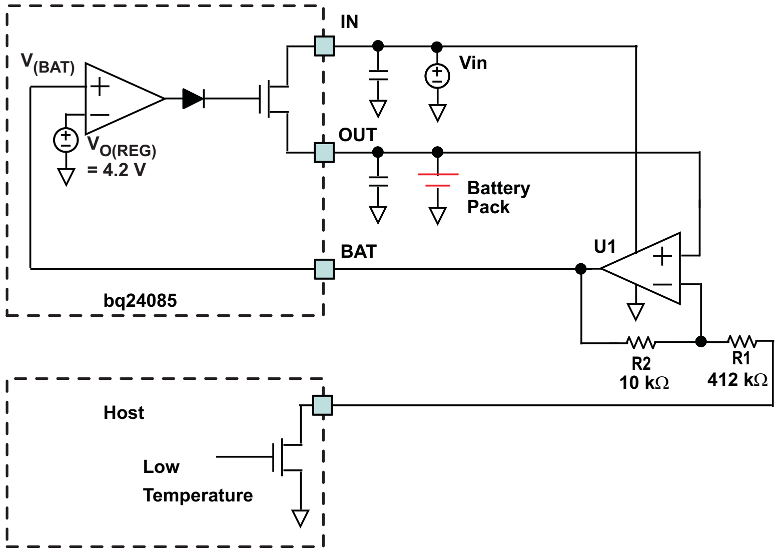

Figure 2. Circuit Implementation to Change Charge Voltage to 4.1 V by Using an Operation Amplifier

Table 2. Test Result of Operational Amplifier Circuit

Vin (V)	Vo (V)
4.5	4.117
5	4.101
5.5	4.102
6	4.102
6.5	4.103

A new chemistry battery, like the recently developed $LiFePO_4$ battery, needs 3.6 V instead of a 4.2-V charge voltage. A Zener diode solution is unsuitable because the voltage regulation variation is much higher than the 4.1-V case. As a result, the operational amplifier solution is used. The voltage regulation needs to be changed to 3.6 V at normal temperature by connecting R1 directly to ground. Figure 3 shows the circuit implementation to change the charge voltage to 3.6 V.

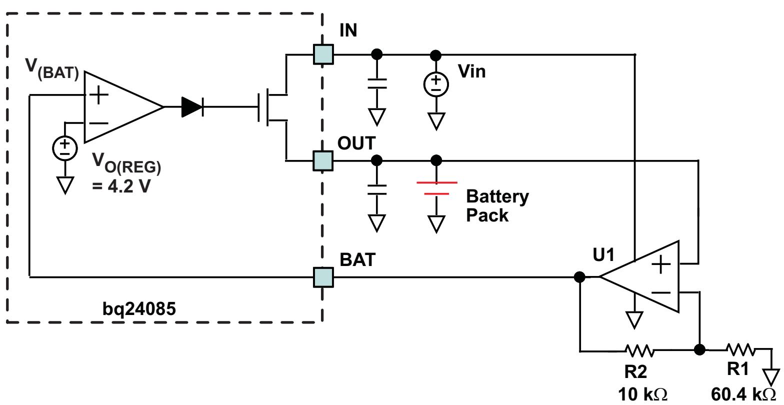

Figure 3. Circuit Implementation to Change Charge Voltage to 3.6 V by Using an Operational Amplifier

The output voltage regulation changes according to the following equation:

$$V_{OUT} = V_{O(REG)} \times \frac{R_1}{R_1 + R_2}$$

Where $V_{O(REG)}$ = 4.2 V, V_{OUT} = 3.6 V

Solving the equation gives the following result.

$$R_1 = \frac{V_{OUT}}{V_{O(REG)} - V_{OUT}} \times R_2 = \frac{3.6}{4.2 - 3.6} \times R_2 = 6R_2$$

Select R1 = 10 kΩ, then R2 is 60 kΩ. Select the standard 60.4 kΩ. Table 3 summarizes the test result. When the input is changed from 4.5 V to 6.5 V, the output voltage only changes 3 mV.

Table 3. Test Result of Operational Amplifier Circuit for 3.6-V Output

Vin (V)	Vo (V)
4.5	3.604
5	3.605
5.5	3.606
6	3.606
6.5	3.607

The two modification circuits both have a drawback. When a battery is removed, the output follows input, and Charge Done status is indicated. However, it is acceptable for those applications where the battery pack is unremovable.

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