Application Report
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Charging NiMH Battery Using bq24105-Q1 in Automotive Applications

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ABSTRACT

NiMH batteries are often used in automotive applications due to its stable chemical characteristics. This application report is mainly focused on charging topology for NiMH batteries in eCall application and using bq24105-Q1 to charge the battery following the charge profile.

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1 Introduction

NiMH battery is often used in automotive application such as eCall/telematics system as backup battery due to its stable chemistry characteristics. However, NiMH battery voltage changes with battery cell temperature. With same amount of capacity, the NiMH battery cell voltage can be much higher at 0°C comparing to at 25°C illustrated in Figure 1.

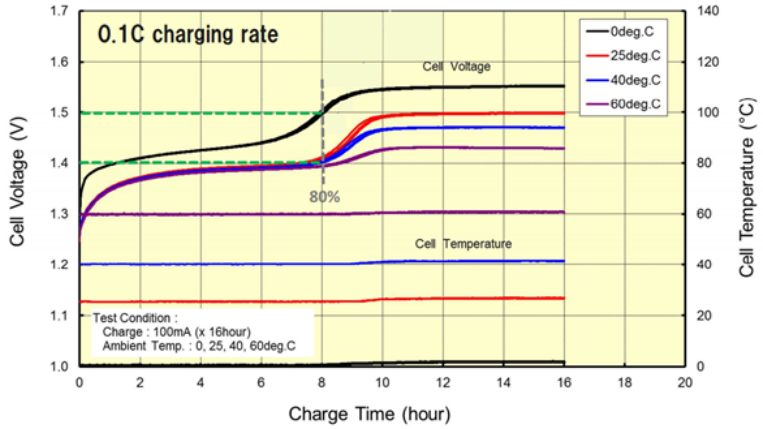

Figure 1. Charge Temperature Characteristics of HR-AAULT (1000 mAh) (Provided by FDK)

Thus environmental effect such as temperature plays an important role in automotive application. Thus environmental effect and the characteristics of NiMH battery should be take into consideration when designing eCall system. Using the termination method such as negative delta V, dv/dt, or dT/dt, has potential risk. For example, when the environment temperature is cold, heat generation from the engine can cause the temperature surround the battery raises fast and cell voltage would drop respectively. The rising of the environment temperature can potentially cause false termination by dT/dt or –ΔV and lead to under charge the battery. Therefore, it is recommended to use timer control for charging termination for in-vehicle application.

2 Charging Procedure for in Vehicle Application

Figure 2 is a charging procedure recommended by FDK for in-vehicle application. Basically, this charging method is intended to maintain the back-up battery fully charged. When the back-up battery is not fully charged, timer charge is performed; and when there is enough charge in the battery, maintenance charge is performed. The charge current is recommended to set below 0.1C of the battery. The timer is set based on 80% of the battery capacity. For 0.1C charge current, the safety timer can be set to 8 hours for charging termination; while for 0.05C rate, the safety timer can be set to 16 hours for charging termination. There are three different charging procedures based on cell voltage. The first case is when the battery open circuit voltage is below 1.24 V/cell, charge is enabled along with safety timer. Once safety timer is expired, the charging is terminated. Then battery open circuit voltage is checked again, if at this time the voltage is below 1.34 V/cell, then the charge is re-enabled and timer reset. If the battery voltage rise above 1.34 V/cell, charge current should be pulsed at rate of 1.2s off and 58.8s on. The second case is when battery open circuit voltage is between 1.24 V/cell and 1.34 V/cell. Charge is enabled along with safety timer. The only difference from the first case is that after timer expires, the pulse charging starts right away. The third case is when the battery open circuit voltage is greater than 1.34 V/cell, the NiMH battery should be pulse charging. Battery temperature should be monitored at any time. Once the battery temperature falls below 0˚C or rises above 60˚C, charging should be suspend.

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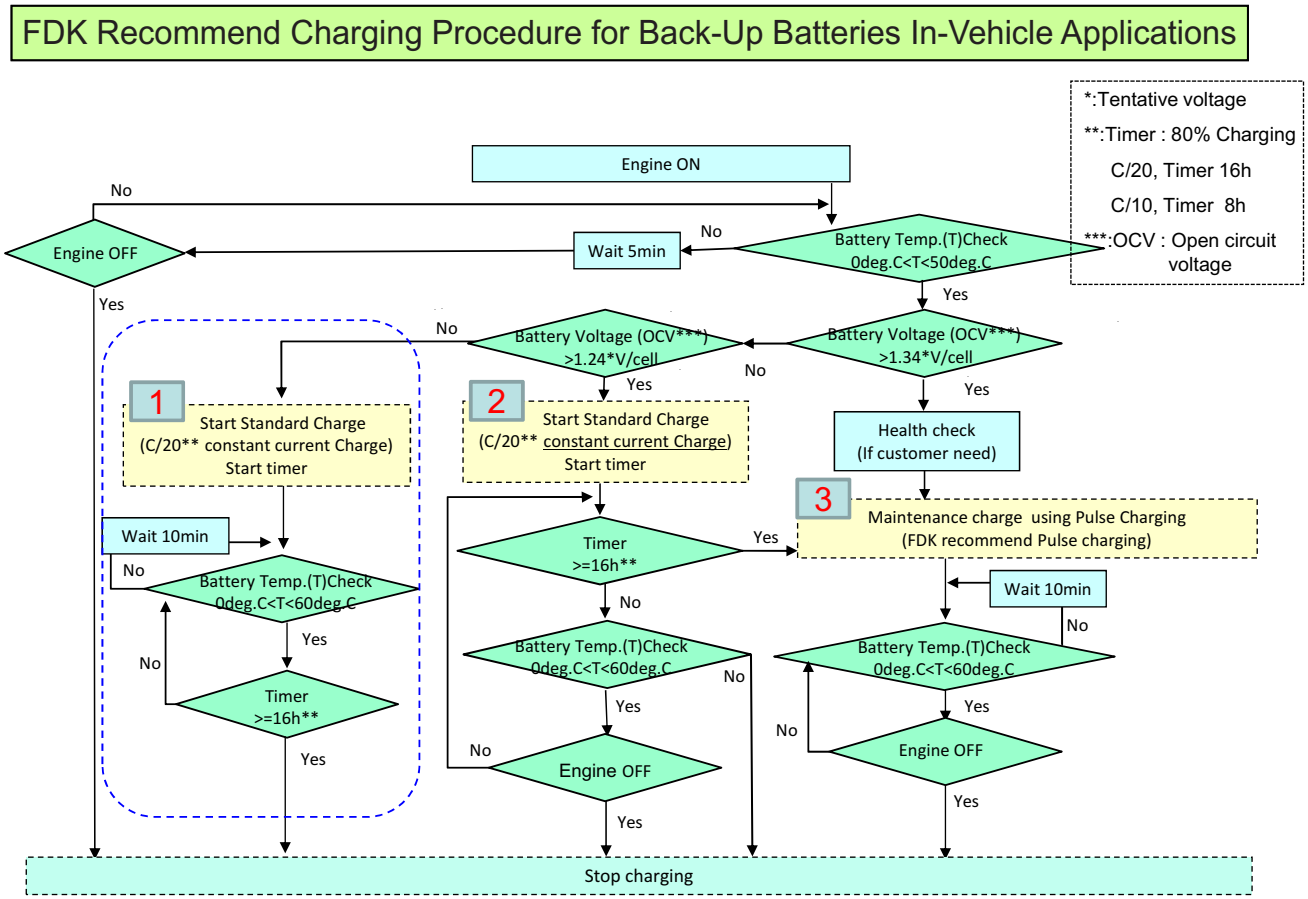

Figure 2. Recommended Charging Procedure for backup batteries for In-vehicle Applications (Provided by FDK)

3 Application Example Using bq24105-Q1

Even though the bq200x series can support this charging method, the operating ambient temperature rating for the bq200x is from –20°C to 70°C. Automotive applications typically require operating temperature rating from –40°C to 125°C. The bq24105-Q1 is an automotive qualified switch mode charger which has adjustable battery regulation voltage and safety timer. The device was original design for Li-ion based battery charging. However, with external MCU, the charging circuit can be modified such that the charging profile meets the FDK recommended procedure above.

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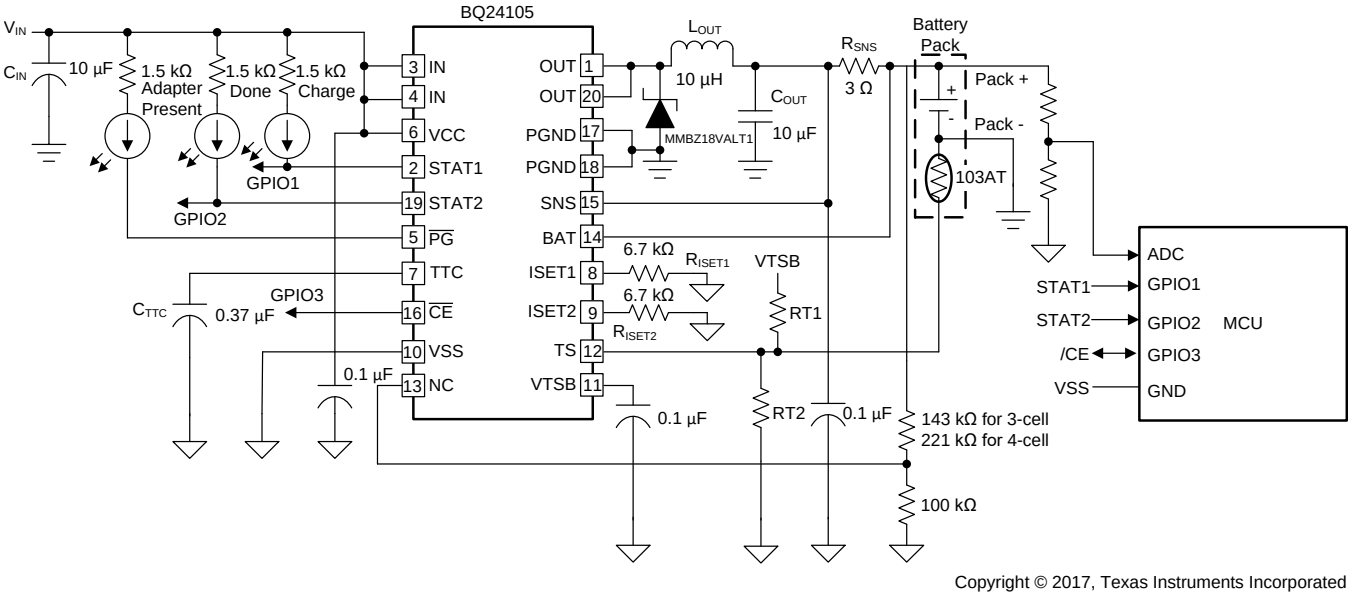

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Figure 3. Example Block Diagram Using bq24105-Q1 with MCU forNiMH Battery Charge

The block diagram above shows an example of the configuration to use bq24105-Q1 to charge NiMH batteries. Since the cell voltage of NiMH batteries varies with temperature with the same capacity, the regulation voltage should be set to higher than 1.34 V/cell. The battery regulation voltage can be set by resistor divider from BAT to FB and FB to VSS. The V_{OREG} can be set to 5.1 V and 6.8 V for a 3-cell pack and 4-cell pack respectively using Equation 1. V_{IBAT} is 2.1 V (typical), which can be found from the datasheet specification table.

$$V_{OREG} = \frac{(R1 + R2)}{R2} \text{ x } V_{IBAT} \quad (1)$$

In order to set the current, first choose R_{SNS} based on the regulation threshold V_{IREG} across this resistor. The best accuracy is achieved when the V_{IREG} is between 100 mV and 200 mV. If the result is not a standard sense resistor value, choose the next larger value. Using the selected standard value, solve for V_{IREG}. Once the sense resistor is selected, the I_{SET1} resistor can be calculated using Equation 3 where K_{ISET1} is 1000 V/A (typical), V_{ISET1} is 1 V (typical), and R_{SNS} is the charge current sense resistor.

$$R_{(SNS)} = \frac{V_{IREG}}{I_{OCHARGE}} \quad (2)$$

$$R_{ISET1} = \frac{K_{ISET1} \; x \; V_{ISET1}}{R_{SNS} \; x \; I_{CHARGE}} \quad (3)$$

The charge time is programmed by the value of a capacitor connected between the TTC pin and GND using Equation 4 where $K_{(TTC)}$ is 2.6 min/nF (typical). It is verified on the bench that the timer can be up to 20 hours. Note that the precharge timer is fixed at 30 minutes.

$$t_{CHARGE} = C_{(TTC)} \; x \; K_{(TTC)} \quad (4)$$

Temperature is monitored through TS function in the charger at all time. To initiate a charge cycle, the battery temperature must be within the $V_{(LTF)}$-to-$V_{(HTF)}$ thresholds. If battery temperature is outside of this range, the bqSWITCHER™ suspends charge and waits until the battery temperature is within the $V_{(LTF)}$-to-$V_{(HTF)}$ range. During the charge cycle (both precharge and fast charge), the battery temperature must be within the $V_{(LTF)}$-to-$V_{(TCO)}$ thresholds. If battery temperature is outside of this range, the bqSWITCHER™ suspends charge and waits until the battery temperature is within the $V_{(LTF)}$-to-$V_{(HTF)}$ range. The bqSWITCHER™ suspends charge by turning off the PWM and holding the timer value (that is, timers are not reset during a suspend condition). Note that the bias for the external resistor divider is provided from the V_{TSB} output. Applying a constant voltage between the $V_{(LTF)}$-to-$V_{(HTF)}$ thresholds to the TS pin disables the temperature-sensing feature.

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$$RT2 = \frac{V_{O(VTSB)} \; x \; RTH_{COLD} \; x \; RTH_{HOT} \; x \left[\frac{1}{V_{LTF}} - \frac{1}{V_{HTF}}\right]}{RTH_{HOT} \; x \left(\frac{V_{O(VTSB)}}{V_{HTF}} - 1\right) - RTH_{COLD} \; x \left(\frac{V_{O(VTSB)}}{V_{LTF}} - 1\right)} \quad (5)$$

$$RT1 = \frac{\frac{V_{O(VTSB)}}{V_{LTF}} - 1}{\frac{1}{RT2} + \frac{1}{RTH_{COLD}}} \quad (6)$$

Where:

- $V_{(LTF)} = V_{O(VTSB)}$ x % LTF-100 / 100
- $V_{(HTF)} = V_{O(VTSB)}$ x % LTF-100 / 100

3.1 Charging Flow Control Logic

Open circuit battery voltage should be measured after pulling $\overline{CE}$ pin high. The battery voltage is measured by the ADC in the MCU. the following is an example of the charging flow for MCU programming. Timing parameter can be adjusted accordingly.

- Case 1. Battery voltage < 1.24 V/cell

```
pull /CE pin low to initiate charge, let it charge until STAT1 and STAT2 turns high, high
then pull /CE high to measure the battery voltage
    if VBAT < 1.24V/cell, go back to case 1
    if 1.24V/cell < VBAT < 1.34V/cell, go to case 2
    if VBAT > 1.34V/cell, then go to case 3
```

- Case 2. 1.24V/cell < battery voltage < 1.34 V/cell

```
pull /CE pin low to initiate charge, let it charge until STAT1 and STAT2 turns high,
then pulse /CE pin at a rate of 2s LOW and 58s HIGH
check the battery voltage at the end of every 58s when /CE is high
    if VBAT < 1.24V/cell, go back to case 1
    if 1.24V/cell < VBAT < 1.34V/cell, go to case 2
    if VBAT > 1.34V/cell, then go to case 3
```

- Case 3. Battery voltage higher than > 1.34V/cell

```
pulse /CE pin at a rate of 2s LOW and 58s HIGH
check the battery voltage at the end of every 58s when /CE is high
    if VBAT < 1.24V/cell, go back to case 1
    if 1.24V/cell < VBAT < 1.34V/cell, go to case 2
```


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3.2 Test Result

The following is the result tested using bq24105EVM and MSP430 Launchpad (MSP-EXP430F5529LP) and FDK HR-AAULT battery in 3s configuration. The output regulation voltage on the bq24105-Q1 is set to 4.5 V, charge current is set to 100 mA, the charging timer is set to 8 hours. The limitation on using the bq24105 is the STAT1 and STAT2 pins only has three statuses. It does not have a unique status for timer fault. Once the STAT1 and STAT2 is OFF and OFF, the $\overline{CE}$ pin is toggled by the MCU according to the above flow. However, for overvoltage, sleep mode, and battery absent, charge will not resume until those faults are clear regardless of the status of $\overline{CE}$ pin

Table 1. STAT1 and STAT2 Status Indication

Charge State	STAT1	STAT2
Charge-in-progress	ON	OFF
Charge complete	OFF	ON
Charge suspend, timer fault, overvoltage, sleep mode, battery absent	OFF	OFF

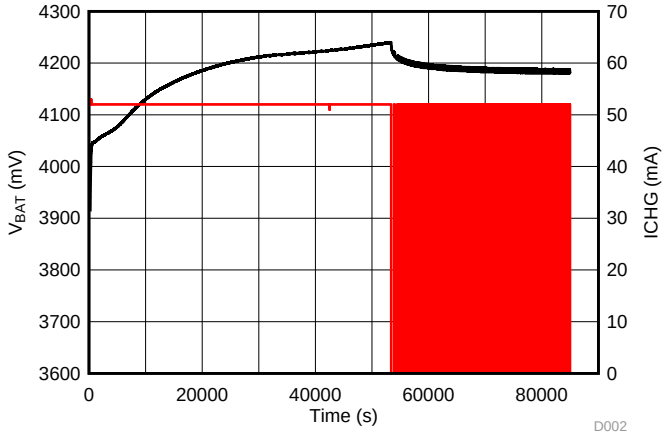

Figure 4. bq24105 Charge Cycle with FDK HR-AAULT at Room Temperature

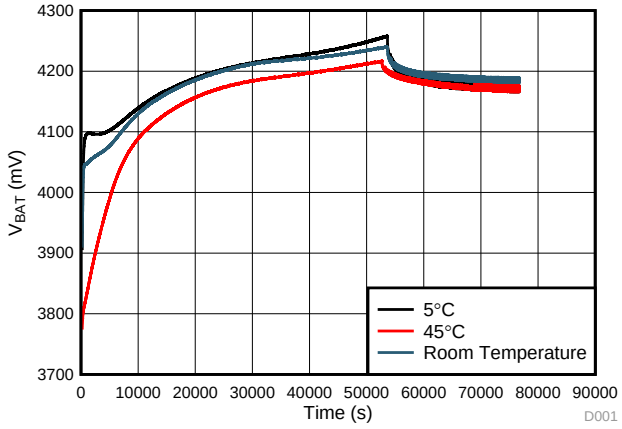

Figure 5. bq24105 Charge Cycle with FDK HR-AAULT VBAT at Different Temperatures

4 References

- Datasheet: *Synchronous Switch-Mode, Li-Ion, and Li-Pol Charge Management IC (bqSwitcher), SLUS953*

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