Using Thermistors to Enhance Thermal Protection for Battery Management Systems

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TEXAS INSTRUMENTS

Introduction

A Battery Management System (BMS) is widely used in automotive, industrial, and personal electronics sectors for battery cell management. Typically, a BMS is used to monitor battery cells by relaying information to the microcontroller (MCU) or microprocessor (MPU) to optimize system performance and increase longevity of the cells. In some instances, the BMS can take actions locally and doesn't need communication with the MCU/MPU to execute tasks.

A BMS is widely used to protect the batteries from functioning outside their temperature, voltage, and current operating range. Furthermore, it monitors the state of charge (SOC), state of health (SOH), and state of power (SOP). Depending on these conditions, a BMS can take action to protect the system by shutting down, implementing cell balancing, or feeding into the cooling control system.

Battery chemistry is temperature-dependent, and operation outside its thermal range could lead to a reduction in battery life and performance over its life. Different battery technologies have unique charging and discharging characteristics that are affected by temperature, shown in Table 1. The discharge temperature range is typically wider than the charge temperature range. Charging the cells too quickly may lead to a reduced life and venting. Furthermore, long exposure to high temperatures could lead to cell degradation and can result in thermal runway and explosion. On the other hand, low temperatures increase the resistance of the battery causing the charge capacity to drop significantly.

Table 1. Common Charge and Discharge Temperature Limits for Various Batteries

BATTERY TYPE	CHARGE TEMPERATURE	DISCHARGE TEMPERATURE
Lead Acid	–20°C to 50°C	–20°C to 50°C
NiCd, NiMH	0°C to 45°C	–20°C to 65°C
Li-ion	0°C to 45°C	–20°C to 60°C

Thermistor Overview

Thermal monitoring allows the BMS to make informed decisions and take the proper action to protect the battery cells. In this tech note, a silicon-based positive temperature coefficient (PTC) thermistor is compared to a negative temperature coefficient (NTC) thermistor.

Thermistors are passive components that respond to a change in temperature by changing their resistance. NTCs are made from ceramic while PTCs can be made from silicon, metal, polymer, or ceramic.

Thermistors have been widely used in BMS due to their versatility, low cost, and straightforward implementation. A voltage divider is commonly used to bias the thermistor. The voltage read across the thermistor is then converted to a temperature reading by the MCU/MPU to actively monitor the battery cells. It can also be used as a switch to turn on a cooling system or shut down the system.

Thermistor Comparison for BMS

When designing a thermistor-monitoring circuit for a BMS, the designer must account for thermistor linearity and tolerance, bias resistor temperature drift, and Analog to Digital Converter (ADC) resolution errors. These errors can greatly influence the thermistor output and compromise the safety of the system.

NTC thermistors are inherently nonlinear, as shown in Figure 1, which makes it difficult to achieve high accuracy over the whole temperature range.

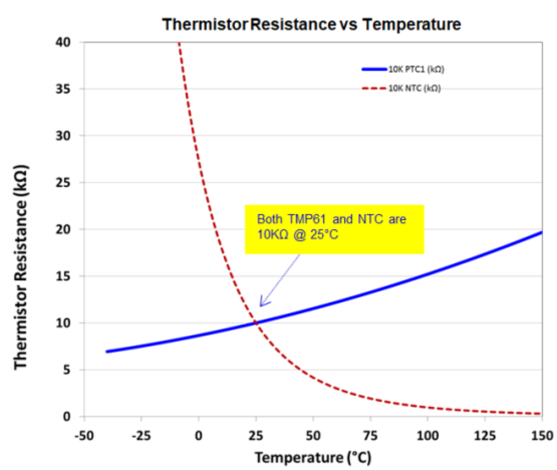

Figure 1. Resistance vs Temperature of PTC vs NTC

At high temperatures, the ratio of volts per degree diminishes, and the resolution is coarse due to noise and errors. Such effects of non-linearity are often managed through the use of hardware and software-based linearization methods.

Software calibration will increase power consumption and the required processing power of MCU/MPU. Hardware calibration can affect the sensitivity of the voltage reading and add to the system cost. Unlike NTCs, PTCs have a positive linear shift in resistance with an increase in temperature.

If an NTC is disconnected from the system due to poor layout or other mechanical stresses, the microcontroller (MCU) or microprocessor (MPU) will read a low temperature due to the open circuit (high resistance). On the other hand, if a PTC is disconnected from the system, the MCU/MPU will read a high temperature and take the necessary actions for protection, increasing the overall reliability and safety of the module. Furthermore, software calibration for NTCs requires an extensive lookup table (LUT) or a high order Polyfit to accurately convert the system ADC output values to a temperature reading.

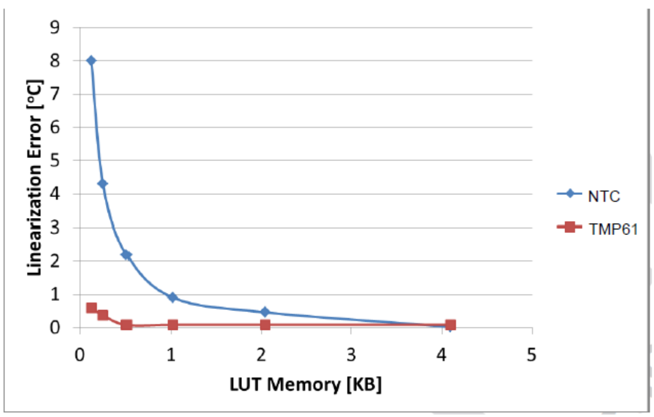

Figure 2. LUT Comparison Between PTC vs NTC

In contrast, silicon-based PTCs have a much smaller lookup table and save memory resources used for the MCU/MPU. Figure 2 shows the trade-off between linearization error, due to the resolution of the ADC, and LUT memory. By using a PTC, calibration errors and the overall system cost are minimized.

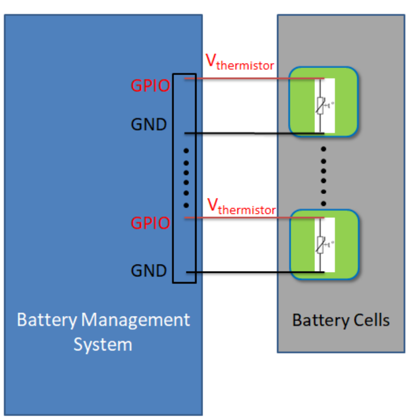

Figure 3. BMS Overview

Figure 3 shows a system level implementation of using the TMP61 to monitor the temperature of battery cells in a BMS.

Thermistor Circuit Design Considerations

In some instances, both thermal monitoring and protection are required. The specific implementation of the thermal monitoring circuit depends on application requirements, such as accuracy, size (footprint), power, and cost.

A typical thermistor-conditioning circuit is shown in Figure 4. Thermal management can be achieved by actively monitoring the battery cells using an ADC, or by using the output of the thermistor to compare it to a reference voltage for overtemperature (OT) or undertemperature (UT) protection.

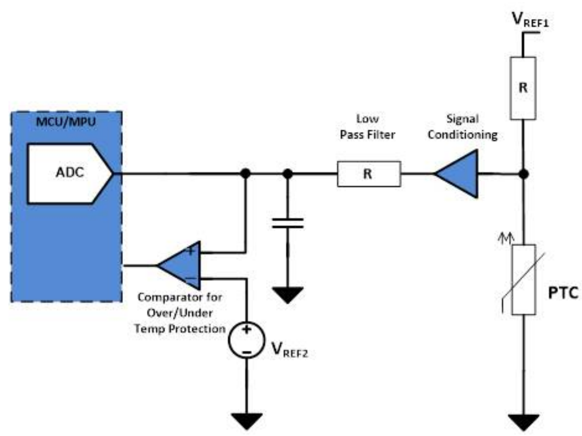

Figure 4. Example Discrete Implementation of a Temperature Monitor and Switch

Device Recommendations

The TMP61 is a silicon-based PTC thermistor designed for temperature measurement, protection, compensation, and control systems. The TMP61 has a tolerance of ±1% between –0°C to 70°C, and a wide operating range of –65°C to 150°C. Compared to traditional NTCs, the TMP61 offers enhanced linearity and consistent sensitivity across the full temperature range. To learn more about the TMP61, batteries, and temperature protection, refer to the reference material in Table 2.

Table 2. Related Documentation

COLLATERAL	DESCRIPTION
Data Sheet	*TMP61 Silicon-Based Linear Thermistors*
Application Report	*Methods to Reduce Thermistor Linearization Error, Memory, and Power Requirements Over Wide operating Temperature Ranges*
Tech Note	*How to Protect Battery Power Management Systems From Thermal Damage*
Tech Note	*Methods to Calibrate Temperature Monitoring Systems*
Web Link	*BU-410: Charging at High and Low Temperatures*