How to protect battery power management systems from thermal damage

Introduction

With a growing demand for portable personal electronics, battery power management systems are becoming increasingly important for stringent design, reliability, and safety requirements. Nowadays, customers expect their personal electronics to have a longer battery life, a shorter charge time, and a smaller form factor. The increased charge and discharge currents, as well as the smaller form factor, make the battery packs vulnerable to thermal damage. In addition, different battery technologies have different charging and discharging requirements that are sensitive to temperature as shown in Table 1. Typically, batteries can be discharged over a wider temperature range, but the charge temperature is limited. Note: fast charging can be done safely if the cell temperature is kept between 10°C and 40°C. These temperature limits are tied to the battery cell chemistry due to its temperature dependent chemical reaction. If charged too quickly, the cell pressure can build up and may lead to venting and reduced battery life. If the operating temperature is too high, cell degradation can occur and may result in thermal runaway and explosion. On the other hand, if the temperature is too low, irreversible cell chemical reactions can occur and shorten battery life. Thus, battery temperature monitoring is very critical for battery management systems.

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

Thermal Protection Solutions

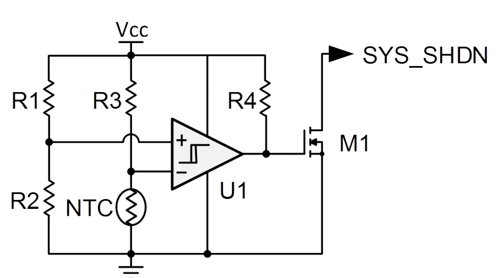

Figure 1. Example Discrete Implementation of a Temperature Switch

To protect battery management systems (BMS) from thermal damage, either discrete or integrated temperature-sensing solutions are used. A discrete solution consists of a thermistor, a comparator, and a voltage reference as shown in Figure 1. This approach provides real-time thermal protection without interrupting the control processing system. Since battery applications require protection at both hot and cold temperatures, a temperature window comparator is better solution. An example of this output is displayed in Figure 2. In this example, the trip points are set to 60°C and 0°C with a 10°C hysteresis. Note that the Set Output High (SOH) is a system diagnostic test feature that allows the user to force the output high independent of the temperature. The specific implementation depends on the application requirements:

- Features
- Cost
- Footprint
- Power
- Accuracy

Some of the key features that customers typically look for are hysteresis, trip point programmability, trip test, qualifications (like automotive and UL, for example), output type, channel count, and supply voltage range.

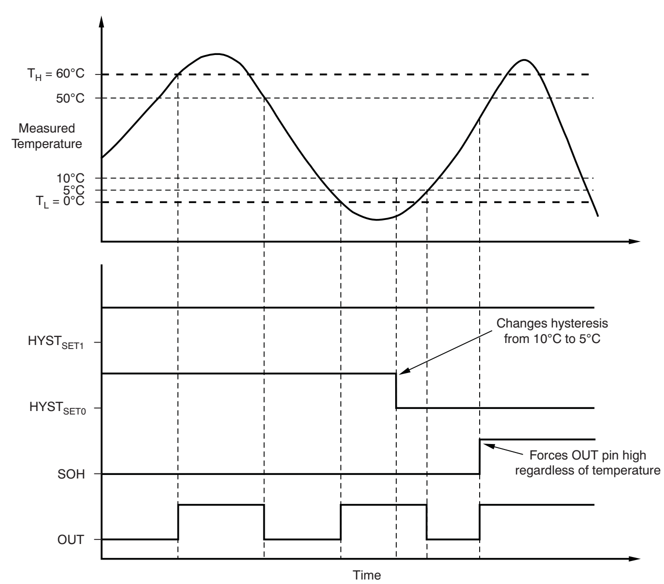

Figure 2. Example Temperature Window Comparator Output Behavior

Discrete Solutions

It is quite common to see discrete implementations of a temperature switch using a Negative Temperature Coefficient (NTC) thermistor since the use of these devices are well established. Furthermore, thermistor solutions are often considered low-cost. However, due to the demanding requirements of thermal protection like guaranteed performance, discrete solutions often prove to be challenging and costly. Some of the key challenges when designing a discrete thermal protection solution are accuracy, reliability, and efficiency.

Due to the non-linear nature of NTC thermistors, maintaining an accurate trip point at high or low temperatures is difficult without using precision components that can increase system cost. Calibration is also not practical in these hardware-based switching applications. In addition, discrete implementations require multiple components to work together, which can decrease system reliability. Lastly, NTC discrete solutions dissipate a significant amount of power at hot temperatures because the NTC resistance decreases significantly.

IC Solutions: Temperature Switch/Thermostats

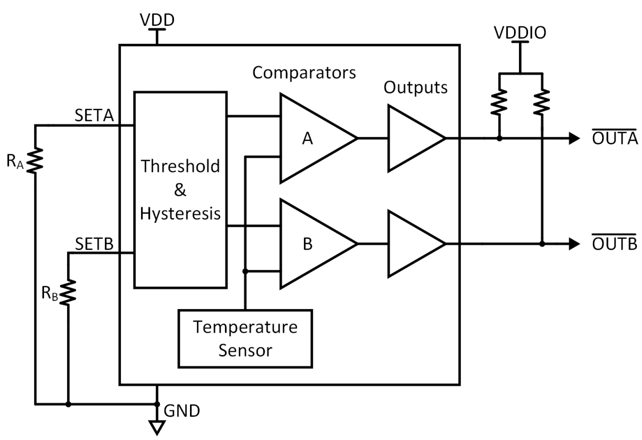

Figure 3. TMP390 Block Diagram

Integrated temperature switches, like the TMP303 and TMP390, are becoming more popular with battery power management systems. These devices typically have a temperature sensor, comparator, and voltage reference fully integrated in a single chip. These reduce design complexity by autonomously making decisions providing real-time thermal protection without interrupting the control processing system. The key advantages of these sensors are as follows:

- Autonomously enable thermal protection independent of control unit
- Zero software
- Guaranteed temperature accuracy for trip point with hysteresis
- Simple & cost effective over / under temperature detection
- Various threshold programming options (resistor, pin programmable, factory preset)
- Some parts also offer analog output

The highly integrated sensor lowers the solution cost, which enables redundancy in safety applications.

TI provides a broad portfolio of temperature switch/thermostats like the TMP303 and TMP390. The TMP303 uses a window comparator and offers design flexibility through an extra small footprint (SOT-563), low power (5 μA maximum) and low supply voltage capability (as low as 1.4 V). No additional components are required for operation and can function independent of microprocessors or microcontrollers. Seven trip points are available through different device options which can be programmed at the factory to any desired temperature. For applications that require different values, contact your local TI representative.

The TMP390, as shown in Figure 3, is a resistor-programmable dual-output temperature switch with two internal comparators and two outputs. The TMP390 is offered in the same small package, has ultra-low power (1 μA maximum) and low supply voltage capability (1.62 V). Both the hot and cold trip points can be configured at any desired temperature window with hysteresis options between 5°C and 30°C, using just two resistors. The separate hot and cold trip outputs generate independent warning signals to be interpreted by the microprocessor.

For alternative device recommendations, refer to Table 2. To learn more about batteries, PCB guidelines, and protection, refer to the reference material in Table 3.

Table 2. Alternative Device Recommendations

Device	Optimized Parameters	Performance Trade-Off
TMP708	Resistor Programmable	Reduced Accuracy
TMP302	Pin-programmable temperature switch	Increased power consumption
LM56	Two internal comparators. Two overtemp outputs and one analog output	Increased power consumption

Table 3. Related Documentation

Literature Number	Title
Web Link	BU-410: Charging at High and Low Temperatures
SNOA967	Temperature Sensors: PCB Guidelines for Surface Mount Devices
SNOA996	Protecting Control Systems From Thermal Damage