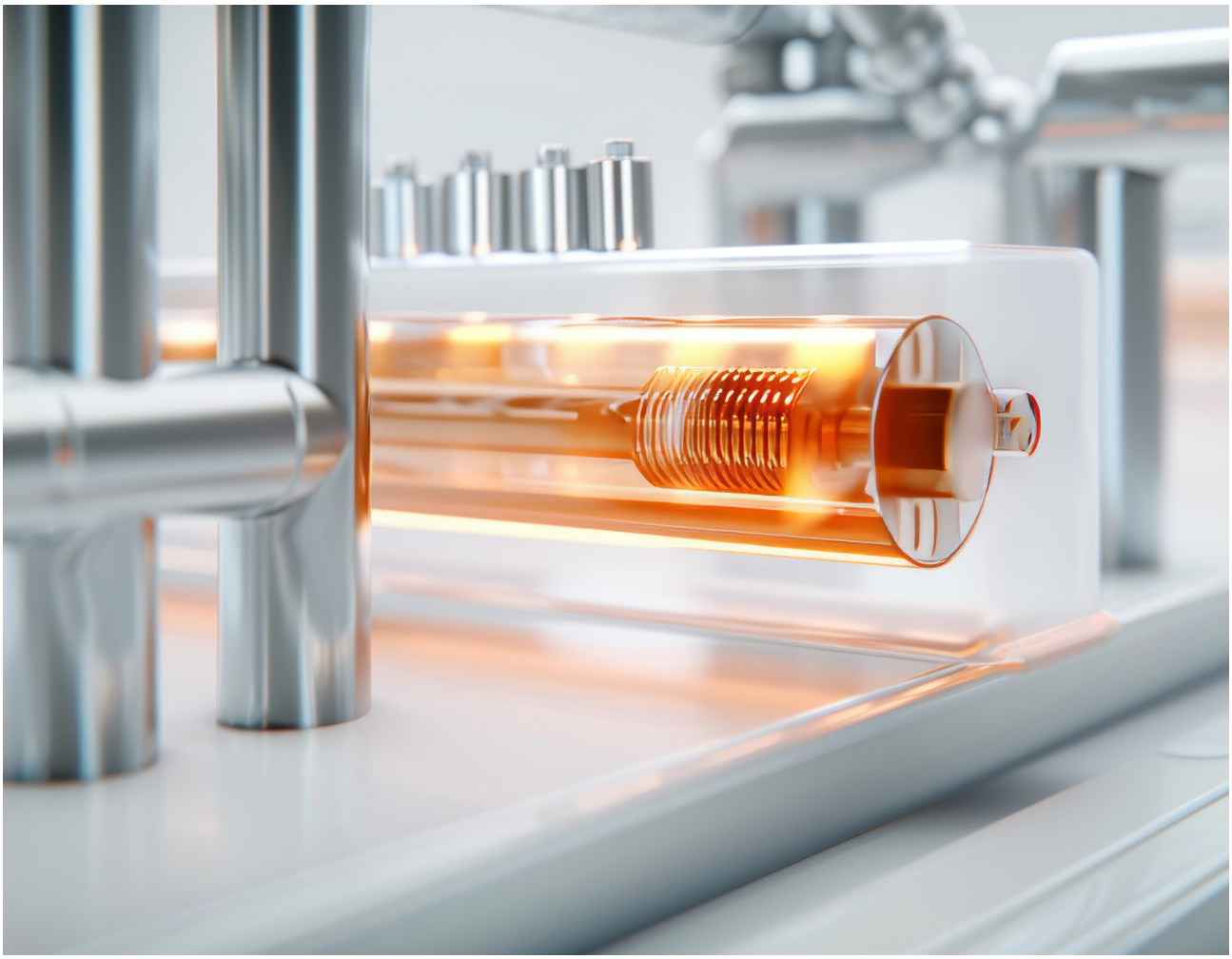
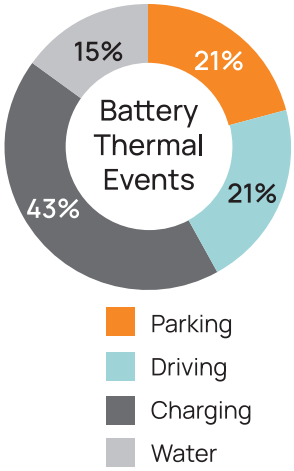
Churod Electronics

Thermal Runaway Sensor Advances Improve Regulatory Compliance

A new generation of pressure sensor technology brings new features to EV battery protection and emerging requirements.



As electric vehicles become more commonplace, they have proven to have an extremely safe track record despite their relative newness. This is something the general public may not understand due to that newness, and the media reports that accompany every fire involving an EV. In reality, however, traditional petrol-powered cars are at least 20 times more likely to catch fire, as IEEE Spectrum has documented, even when parked. When EVs do catch fire, Lithium-ion battery (LiB) batteries are the primary culprit, and thermal runaway is the leading cause.

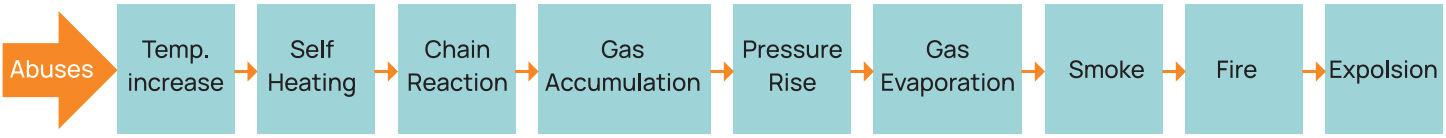


This discussion will explore thermal runaway detection requirements and review sensor technologies for effective detection. After reviewing the pros and cons of these technologies, we'll provide details about a new-generation pressure sensor solution we believe is the ideal choice for performance, safety, and compliance.

Thermal runaway occurs when a battery cell generates more heat than it dissipates and enters a state of uncontrollable self-heating. Causes include three categories of abuses:

- **Mechanical:** crushing, penetration, such as in a traffic accident
- **Thermal:** Overheating due to operation in extremely hot or cold environments.
- **Electrical:** internal short circuit in the cell, overcharging above safe voltage, multiple, excessive over-discharge, external short circuit

The greatest danger of a single-cell runaway is that it can propagate rapidly across the entire pack, resulting in smoke, fire, explosion, and harm to people and surroundings. As rare as it is, thermal runaway is a relatively new challenge and a critical concern for the public, manufacturers, and regulators.



The role of sensors in early-warning regulations

The United Nations has been a clearinghouse for EV safety standards via its Global Technical Regulation on the Electric Vehicle Safety (EVS GTR, also known as UN GTR No.20). This was first passed in 2018 and has been updated since. A particular passage places BMS and sensor solutions front and center:

> "Vehicle manufacturers shall make available documentation demonstrating the vehicle's ability to minimize the risk associated with single-cell thermal runaway caused by an internal short circuit. Moreover, the vehicle shall provide an advance warning indication to allow occupant egress or five minutes prior to hazardous conditions inside the passenger compartment."

In 2020, China became the first country to adopt regulations based on this work, including the five-minute warning. The country's Ministry of Industry and Information Technology (MIIT) has reported that its subsequent standards are geared to the UN EV safety standard "and some requirements are stricter than international regulations." Europe and the US are on similar paths. Overall, the industry is actively pursuing these standards and is actively involved in certification efforts with organizations such as TUV and UL.

Comparison of sensor technologies

Many methods can be used for thermal management and communication with the BMS. For example, the BMS continuously monitors voltage and temperature for thermal monitoring and control of battery air-cooling vents or active liquid cooling systems. These systems help improve battery performance but may be insufficient for specifically monitoring thermal runaway in cells or meeting the emerging five-minute warning requirement. TABLE 1 Technologies for Thermal Runaway Detection & Warnings, provides a general comparison of commercially used measurement alternatives. Each has benefits and limitations.

Table 1: Technologies for Thermal Runaway Detection & Warnings

Sensing Solutions	Sensing Object	Signal Clarity	Response Speed	Sensor Reliability	Diagnostics	Power Consumption	System Cost
Pressure Sensor	Air Pressure Inside Pack	Good	Immediately at Cell Venting	High	High (Capable for FuSa)	Low to Medium	Low
Gas Sensor	H2, CO, CH, etc.	Good but just qualitative	Sometimes earlier before cell venting	Low, no automotive grade product	Neutral	High	High
Pressure switch	Air pressure inside pack	Good but just qualitative	Immediately at cell venting	Medium, especially for low range	Poor	Low	Low
Add-on T sensor	Temperature inside pack	Good	Uncertain depends on location and heat transfer	High	Neutral	Depend on Quantity	Medium to high due to multi T sensors needed
Software solution w/o add-on sensor	Existing V, T, etc.	Neutral, no function in parking	Uncertain	High	Good	High	Gas Sensor

Gas sensors typically detect hydrogen and/or other gases released by cells during thermal runaway. They are higher in power consumption than most alternatives. They're relatively inexpensive, but this depends on how many sensors are needed for fast, reliable measurement. Reliability remains a judgment call due to deterioration risks reported beyond a safe service life of 10 years.

Temperature sensors are reliable depending on their location and the number used. A runaway cell located further from the sensor will be detected more slowly. While every cell should ideally have a temperature sensor, their cost typically leads manufacturers to greatly reduce the number they use, which can compromise this type of sensor's effectiveness.

Software solutions using add-on sensor(s) can calculate measurements based on existing sensors such as temperature and voltage, which are monitored continuously. This would appear to be low-cost, however, there are numerous variables to account for in order to derive a predictable response.

Pressure switches are typically based on a spring diaphragm or metal disc. They can open or close a circuit to trip an alarm above a set pressure threshold, but that threshold is limited in input range, especially as the ambient environment changes. A case in point: Measurements are susceptible to false-positive readings owning to changes in atmospheric pressure such as when, for example, driving at changing elevations or tunnels.

Pressure sensors based on micro-electromechanical system (MEMS) technology can measure absolute pressure as well as quantify the rate of pressure change. This provides greater flexibility for diagnostics and safety features, allowing for customizable warning thresholds. Only one sensor is required, and it can be mounted anywhere inside the pack because the shockwave generated by a single cell changes internal pack pressure instantaneously, at the speed of sound. These sensors, in some cases, include onboard programming to compensate for atmospheric pressure — and even during times the BMS' thermal management activates passive cooling via a venting system.

New trends in battery development in China are leading packs to be developed using a separate exhaust compartment in an effort to localize thermal runaway to single cells within the pack. With only minor physical adjustments to the inlet port of the pressure sensor, it can be adapted to be used in these new designs. Endurance testing has demonstrated this solution to be advantageous and more easily implemented than other competing technologies. (See Figure 1.)

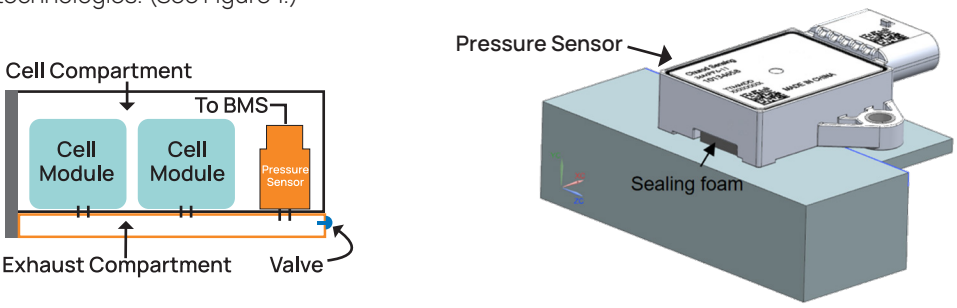


Figure 1: Isolating thermal venting into a separate exhaust chamber is a coming trend in battery pack design that is ideally suited for measuring changes in pressure.

Full-time 24/7 functionality is important for another critical situation: waking the BMS from sleep in unexpected, dangerous conditions. For example, a battery's temperature can rise above safe conditions when parked on a hot summer day.

The ability of a sensor technology to wake the BMS when the car is parked is as critical as when driving. Not all sensor solutions can accomplish this. There is one major caveat in claiming pressure sensors can do this — and many other features we have claimed they do. In fact, we have been using the example of a new kind of pressure sensor, which we'll discuss below. (See Figure 1, Battery Thermal Events.)

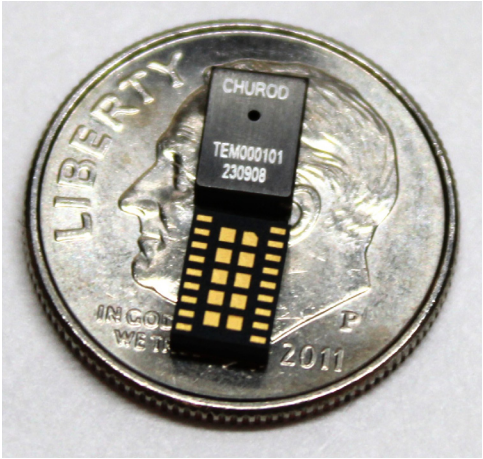
A new kind of pressure sensor

Our discussion of pressure sensors has focused on a new generation of pressure sensor from Churod Americas: Smart BPS. We've already highlighted some of its attributes including onboard programming and customizable configuration. These also relate to benefits regarding power consumption and the management of sensor states.

The Smart BPS solution is powered directly by the vehicle's lead-acid battery and includes three modes: A **high-power mode** is the normal mode for driving and charging. The sensor continuously sends pressure measurement signals to the BMS at a rate of 10 times per second, consuming 7 mA (vs. the 35 mA of prior-generation sensors). A **low power or sleep mode**, when the car is parked or off, switches battery consumption to 0.06 mA (vs. 0.2 mA for prior-gen offerings) with scan times configurable up to two seconds. This mode features a wake-up feature that sends a warning signal to BMS if detected pressure exceeds a set threshold, enabling BMS action and warnings. Finally, a **deep sleep** mode provides no pressure monitoring and no communication with the BMS for cases when the vehicle will be safely parked or stored for extended periods to preserve lead-acid battery life. Thresholds for each mode are preconfigured but can be custom configured at the factory or in software provided to the battery manufacturer.

Flexible software configuration is also offered for alerts and warning thresholds. Communications between sensor and BMS are handled by a high-speed digital network, or more accurately, a selection of standard digital network protocols (CAN and other network protocols) to suit both the battery manufacturer and the EV-maker's specifications.

This new-generation sensor takes full advantage of modern miniaturization via MEMS technology. Custom-designed for battery pressure sensing in every detail, it includes the microprocessor and the sensor's mechanical and electronic components in a sealed, smart sensor package measuring 4mm x 5.5mm. This is orders of magnitude smaller than marketplace alternatives and offers additional benefits.



A new, miniaturized version of the Churod Smart BPS sensor is orders of magnitude smaller and offers additional benefits.

In summary, the Smart BPS provides a highly effective solution and offers additional features to offer unique value to the industry:

- Elimination of false warnings for thermal runaway with high reliability
- Extremely low power consumption in sleep and deep-sleep modes
- Offer digital communication with BMU wakeup function
- Automotive Grade Design
- Easy mounting on the BMS, eliminating connectors
- Single-unit simplicity with no position requirement
- Quick response and warning to single-cell thermal runaway
- Self-diagnostics to ensure and protect safety-related function
- Suitable for new pack designs using thermal electric separation scheme

Milliseconds matter when it comes to thermal runaway detection. Now is the best time to evaluate the Smart BPS. For details, visit the Churod Sensing Technologies (Suzhou) on the web.

About Churod Americas

Churod Americas is a subsidiary of Dongguan Churod Electronics Co., a leading relay solution provider and manufacturer based in China. Since its founding in 2006, the company has expanded from relays to high-voltage DC contactors, semiconductor products, and sensors. The company maintains five manufacturing campuses in China along with offices and sales support around the world. Our mission is to provide customers across the globe with a full range of cutting-edge products and value-added services. Visit us on the web at www.ChurodAmericas.com or email CAsales@ChurodAmericas.com.

At Churod, everything we do is for our customers' advantage.