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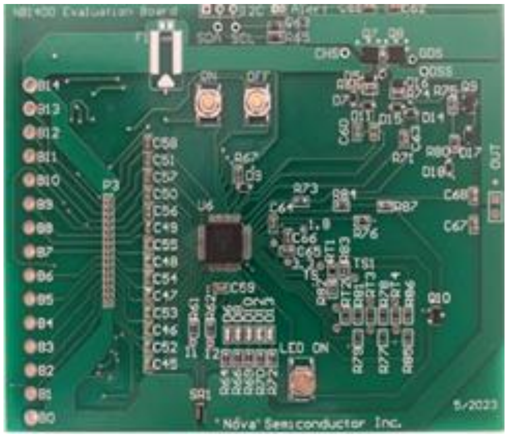
Li-Ion Battery Safety & Early Fault Detection

The vulnerabilities of Li-Ion batteries are no secret, especially when subjected to mishandling, which can potentially turn them into ticking time bombs. Such mistreatment typically falls into two main categories: mechanical and electrical. Mechanical issues, such as pressure, impact, or exposure to excessive heat, are crucial aspects related to the battery's design and packaging. This discussion, however, specifically delves into the electrical aspects and the potential risks associated with misuse due to electrical issues.

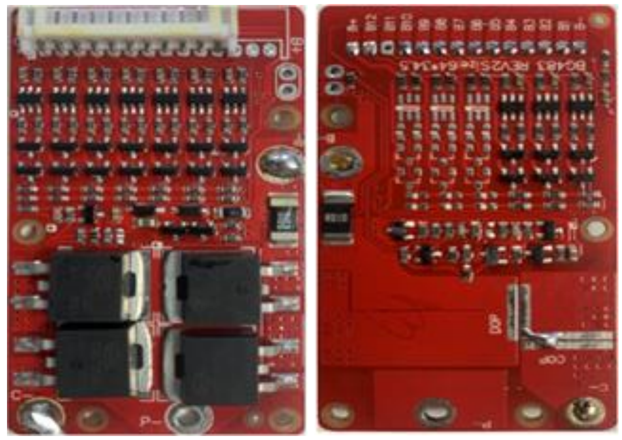
In the vibrant landscape of New York City, the increasing popularity of eBikes and Scooters has become a ubiquitous part of daily life. However, the period of 2022/3 witnessed a concerning trend – hundreds of recorded fires related to battery fires and explosions. Regrettably, these incidents are frequently violent and challenging to contain, attributed to the inherent characteristics of Li-Ion chemistries and their propensity to catch fire. While not all these incidents were solely electrical issues, a significant number can be traced back to improper Battery Management System (BMS) design and the absence of essential protection functions required in a robust BMS module.

Subsequently, both New York City and the New York State have implemented stringent legislations and mandates aimed at enforcing standard safety measures to mitigate the occurrence of such fires. Moreover, there are ongoing efforts at the national level to formulate legislations that will ensure the safety of such equipment throughout the country.

Safeguarding Li-Ion batteries from abuse involves maintaining safe operating limits, encompassing overvoltage, undervoltage, overtemperature, and overcurrent. BMS integrated circuits establish and enforce these limits, triggering switches to cease charge or discharge currents if surpassed. Despite the apparent simplicity, challenges emerge. BMS ICs must not only deliver exceptional measurement accuracy but also integrate self-check capabilities to identify and rectify internal faults, given that semiconductor failures may stem from defects, stress, or substandard design. Premium BMS systems feature secondary protection, an independent monitoring element for fault detection if the primary BMS falters. Conversely, cost-conscious BMS boards with straightforward discrete components often lack self-check mechanisms and secondary protection, heightening the risk of catastrophic failure, including explosions and fires.



- NB1400, with all the necessary features and measures for safety and self-check with best-in-class measurement accuracy, and simultaneous measurement of all cell voltages and current



- Typical discrete implementation used in many eBikes with minimal safety features, mainly focused on detecting overvoltage, and overcurrent, no self-check, no secondary protection, no balancing, no telemetry or SOH, many components with high potential for failure

While hard limits serve to avert catastrophic failures, advanced BMS functions incorporate state-of-health (SOH) detection and telemetry for early warning. Picture a scenario where your car abruptly loses power and comes to a halt during your journey—contrasted with a system that provides a warning of battery weakness long before such an event. The latter becomes achievable through robust and effective SOH monitoring, facilitating early detection.

The determination of the state-of-health (SOH) in batteries involves a comprehensive analysis that goes beyond simple hard limits. One crucial aspect of this analysis is monitoring and detecting changes in battery impedance, a fundamental parameter that serves as a key indicator of the battery's overall condition.

In essence, a healthy battery typically exhibits low nominal impedance when it is fresh and in optimal condition. However, as batteries age or experience misuse, this impedance begins to increase. The challenge lies not just in setting a threshold for impedance but in the nuanced task of identifying changes or sudden variations in impedance. This nuanced approach is essential because normal aging processes also contribute to a gradual increase in battery impedance.

Measuring battery impedance is far from a trivial task, particularly when dealing with batteries embedded within a larger pack. The complexity arises from the absence of a direct method for measuring this parameter. In the realm of embedded battery packs, the measurement of impedance is achieved by closely monitoring the voltage of the individual cells as the current undergoes changes.

This intricate process allows for a more nuanced understanding of the battery's health, going beyond the binary concept of "healthy" or "unhealthy." By focusing on impedance changes, it becomes possible to detect subtle variations that might signal the early stages of battery degradation or issues. In practical terms, envision a scenario where a vehicle's battery management system provides a warning of potential issues before a critical failure occurs. This proactive approach can significantly enhance safety, reliability, and longevity, offering users the opportunity to address battery concerns well in advance of critical failures.

In battery management systems, the accuracy of impedance measurements is paramount, and systems that lack the capability for simultaneous measurement of all cell voltages and current introduce significant uncertainties and errors into the determination of impedance. The crux of achieving precise measurements of cell impedance lies in the simultaneous measurement of all individual cell voltages and the overall current.

By ensuring that these measurements occur simultaneously, we mitigate the introduction of additional errors and inaccuracies, thereby maintaining the integrity of the impedance determination process. In addition to simultaneous measurements, it is also critical to develop and implement a robust and accurate algorithm tailored for this intricate measurement task.

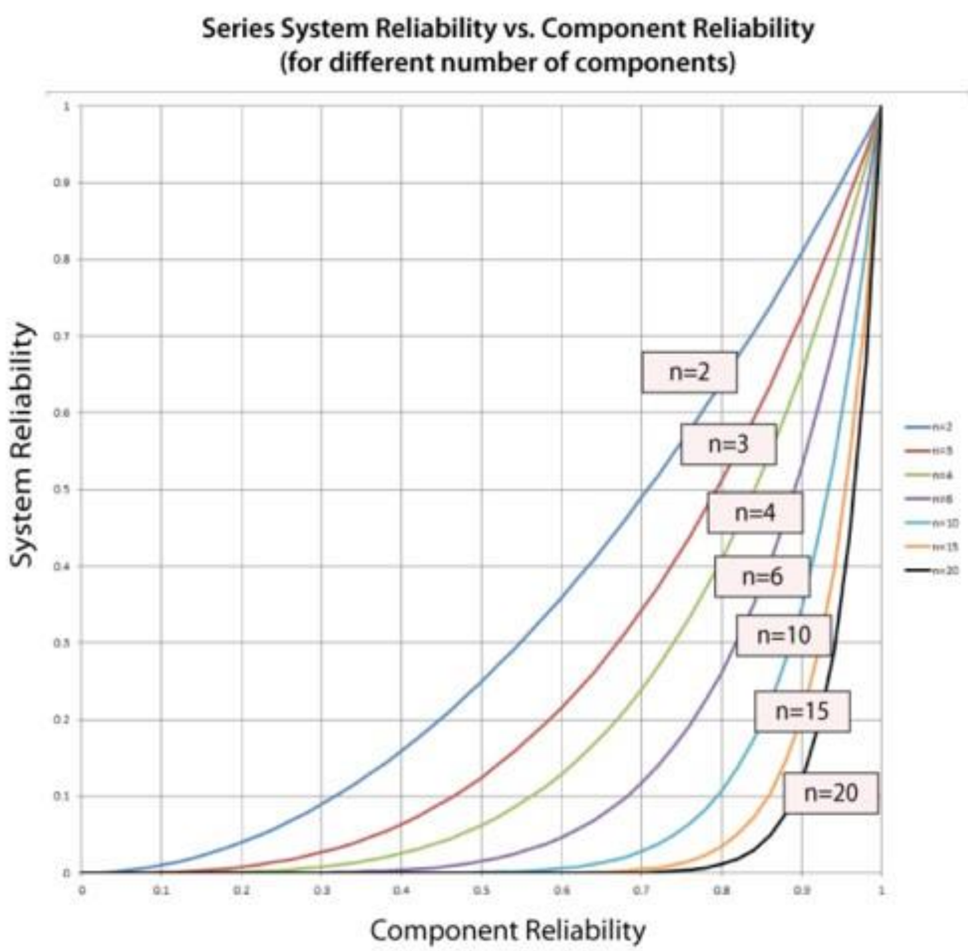
A key consideration in this context is the avoidance of pitfalls associated with time-multiplexed measurements. Time-multiplexed approaches, where measurements are taken sequentially rather than simultaneously, can introduce timing-related inaccuracies and compromise the precision of impedance determination. Therefore, a meticulous approach to measurement, which includes simultaneous monitoring of cell voltages and current, coupled with a sophisticated algorithm, is pivotal for obtaining reliable and meaningful impedance data. This commitment to precision is fundamental in navigating the complexities and sensitivities inherent in battery management systems, ensuring that impedance measurements serve as a trustworthy indicator of a battery's health and performance.

The notion of relying on precise measurements of each cell's temperature for State of Health (SOH) determination has been proposed. However, this approach, while conceptually reasonable, falls short compared to the precision achievable through impedance tracking and faces significant practical challenges.

One notable challenge is the issue of accuracy, attributed to the sensitivity of temperature measurements to ambient temperature changes. The ambient temperature directly influences cell temperature, effectively introducing a signal-to-noise ratio, akin to mixing the desired signal with environmental noise. Adding to this complexity is the uneven heat dissipation within battery pack designs. According to fundamental physics laws, the center of any heat-generating body is the hottest, while the edges, with efficient heat transfer mechanisms, remain cooler. This introduces another layer of noise into the signal.

Beyond these accuracy-related concerns, the practical implementation of measuring each cell's temperature presents challenges. Employing thermistors to touch each cell is necessary for accurate measurements. In a hypothetical scenario with a single integrated circuit (IC) managing 14 series cells and 4 parallel cells (14S4P), a staggering 56 sensors — one for each battery — would be required. Implementing this with wires would create a cluttered and impractical mesh, rendering it unacceptable. Alternatively, placing a single chip on each cell and devising a communication method to a central point introduces excessive costs and susceptibility to low reliability. Considering this setup as a series system, where the total reliability (Rs) is equal to the reliability of one component (R) raised to the power of the number of components (n), it becomes evident that the relationship between total reliability and "n" is a decaying exponential. This implies that a system with 56 sensors or sensing chips has substantially lower reliability compared to a single-chip system.

This reliability decay, coupled with the accuracy challenges mentioned earlier, renders the SOH assessment based on the temperature of each cell quite inadequate and cumbersome.



Notice the reliability exponential decay from n=2 to n=20. Imagine how much worse it gets at n=54!

Courtesy of Vskills

Given that the impedance shift of a single cell in parallel cells can be overshadowed by the presence of healthy cells, the accuracy of the measurement becomes crucial for effective detection. Nova's NB1400 stands out with unparalleled accuracy in measuring both cell voltage and current, making it well-suited for this type of detection even in scenarios involving numerous cells in parallel. The NB1400's capability for simultaneous measurement of all cells and current not only ensures best-in-class accuracy but also delivers unparalleled linearity and fidelity in the measurement process.

In essence, Nova's NB1400 emerges as the beacon of innovation and reliability in the realm of Battery Management Systems (BMS). As the industry grapples with the vulnerabilities of Li-Ion batteries, particularly in scenarios like the prevalent use of eBikes and Scooters in New York City and other metropolitan areas, the significance of a robust BMS cannot be overstated. Nova's NB1400 stands out as the epitome of cutting-edge design, offering unparalleled accuracy in measuring both cell voltage and current.

While legislative measures are being enforced to standardize safety across the nation, the NB1400 goes beyond compliance, setting a new standard for BMS excellence. Its simultaneous measurement of all cells and current not only ensures best-in-class accuracy but also delivers unparalleled linearity and fidelity. This capability makes the NB1400 the optimal solution for scenarios involving numerous cells in parallel, where accuracy is paramount for effective detection.

In the dynamic landscape of BMS technology, where the determination of State of Health (SOH) requires precision, Nova's NB1400 takes center stage. Its commitment to simultaneous monitoring, coupled with sophisticated algorithms, ensures reliable impedance data, setting it apart as the go-to solution for industry leaders and innovators.

As the industry seeks solutions that transcend traditional limits, Nova Semiconductor's NB1400 paves the way for a new era in battery management. Its reliability, accuracy, and advanced features position it as the catalyst for enhanced safety, reliability, and longevity in Li-Ion battery applications. In choosing the NB1400, industry players are not just adopting a BMS; they are embracing a paradigm shift towards excellence and innovation in Li-Ion battery management.

Saving our planet, one battery pack at a time!

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