Designing Effective Overtemperature Lithium Polymer Battery Cell Protection for Notebook PCs

BOURNS® MINI-BREAKERS WHITE PAPER


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AA Series


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INTRODUCTION

Notebook Personal Computers (PCs) continue to rapidly evolve and excite consumers with stunning new display technologies, ever-greater processing power, larger memories, and longer battery run times in smaller and slimmer chassis. This reduction in notebook thickness has helped captivate the market and yet the driver behind this evolution has gone largely unnoticed. Traditionally, notebook PCs used battery packs assembled from cylindrical lithium-ion batteries known as 18650 (similar to the ubiquitous AA battery cell). These cylindrical batteries helped dictate the size of the notebooks themselves. However, in recent years, the trend has been to move away from lithium-ion cylindrical cells to extremely thin lithium polymer pouch cells. Using these pouch-type battery cells eliminates many of the physical constraints caused by cylindrical cells and has, in turn, led to a new phase in battery designs.

This white paper will review the construction and operation of lithium polymer pouch cells. It will demonstrate the advantages of using miniature resettable Thermal Cutoff devices (TCOs) for overtemperature control in notebook PCs by showing how TCOs work and how they provide more effective battery pack protection.

LITHIUM POLYMER POUCH TYPE CELLS

Lithium-ion polymer batteries utilize a polymer electrolyte as well as a polymer separator that is encased in a flexible foil-based enclosure. These pouch-type cells are soft and malleable compared to the rigid metal cases of cylindrical cells. Pouch cells are typically lighter than their cylindrical equivalents making them very desirable for portable applications such as notebook PCs. The simple laminate structure of the lithium-ion polymer cells is inherently easier to produce in various shapes and sizes, enabling them to be designed to spread across the full shape of any notebook PC. However, in reality, notebook PCs use multiple cells in series and parallel to attain higher voltages and capacity. The most common is a six-cell lithium polymer that uses three cells in series with two cells positioned in parallel (3S2P).

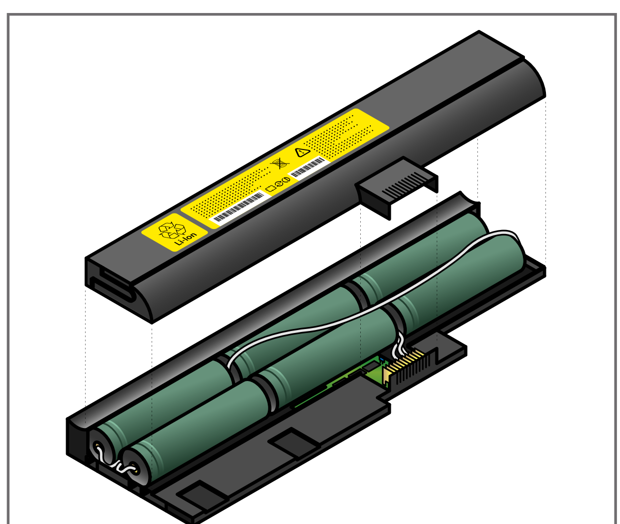

Figure 1. | *Traditional Six-cell (3S2P) Notebook PC Battery Pack Using Cylindrical Cells*

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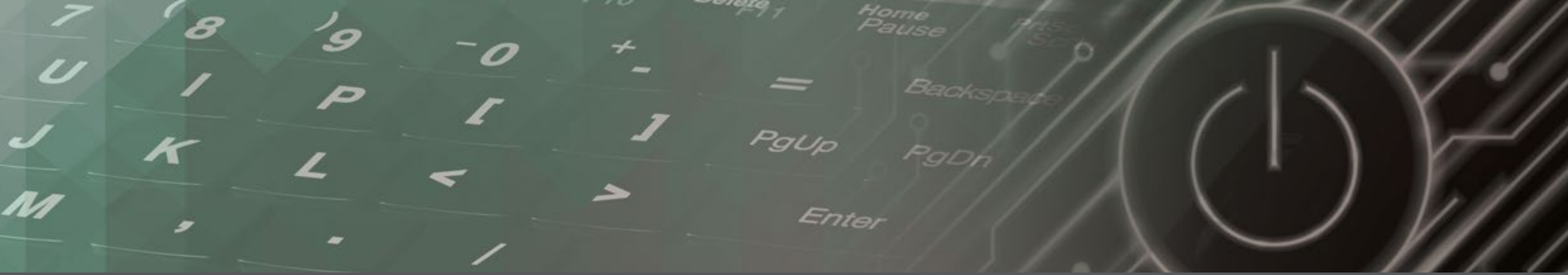

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LITHIUM POLYMER POUCH TYPE CELLS *(Continued)*

While lithium-ion polymer cells boast many desirable features such as low cost, ease of large scale manufacturing, lighter non-universal sizes and high-energy densities, the technology still has the same limitations as other types of lithium-ion cells. Protection circuits are required to maintain the voltage and current within safe limits, which is one of the primary limitations of a lithium-ion battery. The soft foil cell design also adds a further disadvantage as the cells visibly inflate during overcharge conditions because of internal delamination.

One of the latest approaches for providing a safety circuit to lithium-ion battery packs is the use of the miniature resettable thermal cutoff devices (TCOs). TCOs are designed to provide accurate and repeatable overcurrent and overtemperature protection.

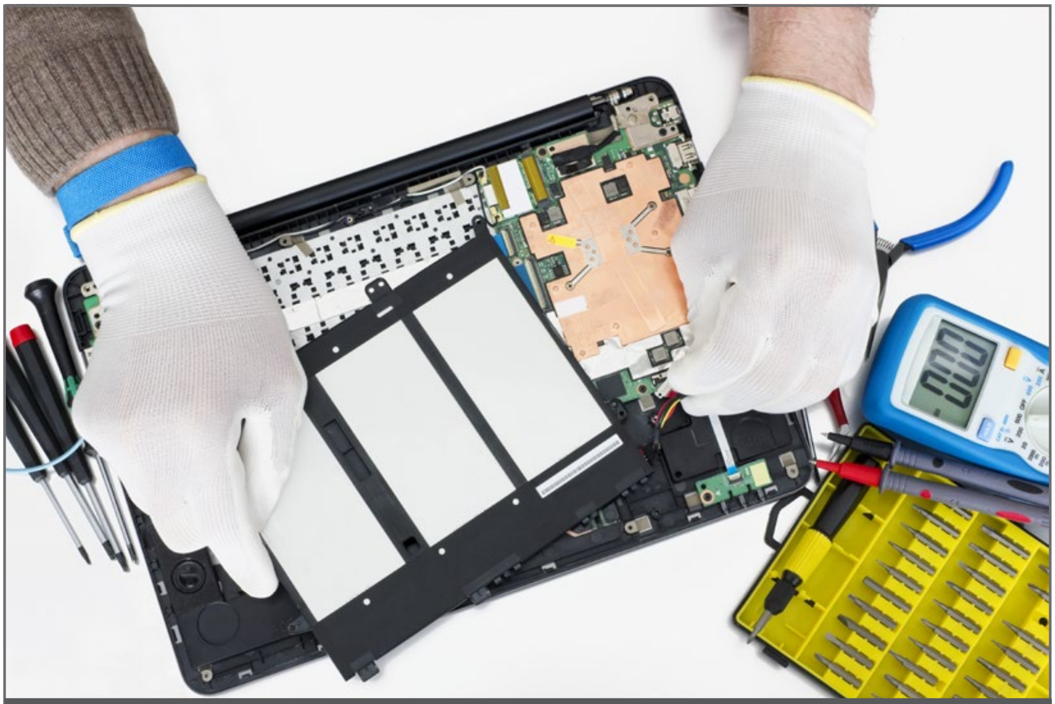
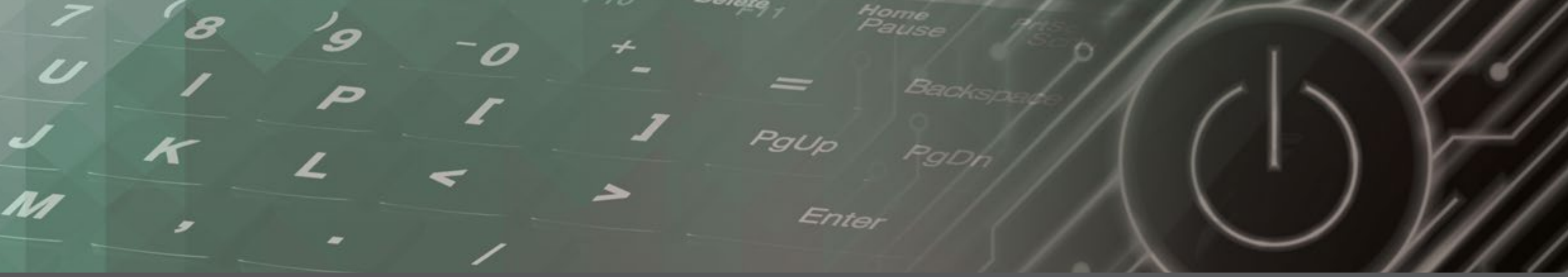


Figure 2. | New Multi-cell Notebook PC Battery Pack Using Lithium Polymer Pouch Cells



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EFFECTIVE BATTERY PROTECTION SOLUTIONS

Meeting the changing protection demands in next-generation lithium-ion battery packs has led to the evolution of TCO technology as well. Today's TCOs combine two common circuit protection technologies, a PTC and a bimetal switch. Bourns, as one the leading suppliers of miniature TCOs, has leveraged its extensive experience in precision metal stamping, plastic injection molding and high-end assembly, allowing the company to utilize these ubiquitous technologies to create innovative and effective circuit protection solutions.

Figure 3 below provides a simple schematic of the construction of a Bourns® miniature TCO. The two terminals (arm terminal and base terminal) are connected in a normally closed position to allow current to flow through the device. The contact point between both terminals serves a critical function in supporting high precision contact resistance, which can be as low as 2 milliohms max., in some model families. The importance of contact resistance will be discussed in more detail below.

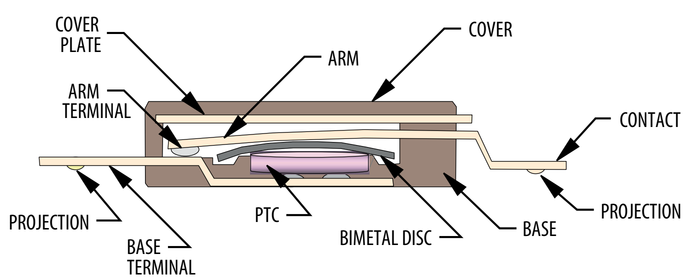
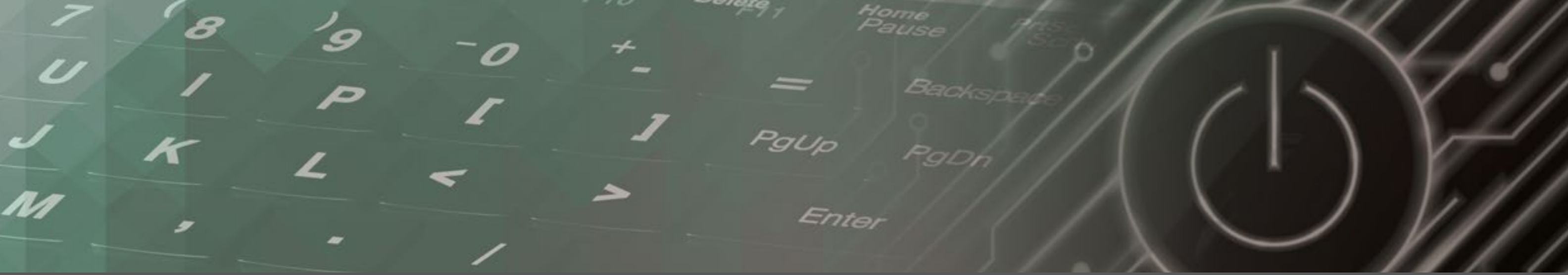


Figure 3. . Construction of Bourns® Mini-breaker TCO

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HOW TCOs WORK TO PROTECT A BATTERY CELL

Figures 4 and 5 illustrate how miniature TCOs mechanically provide protection to the circuit. Under normal conditions, current flows through the arm terminal, down through the very low resistance contact point and out through the base terminal. Key to any battery application is low resistance, hence, the need for the right contact resistance between the arm terminal and the base terminal.

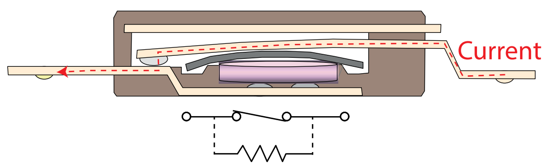


Figure 4. | *Miniature TCO in the Normally Closed Position*

The TCO can be triggered by either an increase in the environmental temperature or by excessive current flow. Once the trip temperature has been reached, the bimetal disc heats and flexes and this motion causes the arm to open (see figure 5). If the TCO used only a bimetal disc for its protection, the arm would quickly close as the temperature cooled. However, the benefit of the design of Bourns® miniature TCO is that the PTC operates in parallel with the arm terminal. When the bimetal disc causes the arm to open, current flows through the bimetal disc and into the PTC. This current causes the PTC to act like a current-limiting heater, which provides sufficient heat to keep the bimetal disc flexed and the arm open. The combination of the bimetal disc and the PTC prevents oscillating opening and closing of the TCO arm. Instead, this design allows the arm to remain open until a lower and safer temperature level is reached (between 40 °C and 10 °C below the lower specification limit of the TCO), at which point the arm will reset. As part of UL 60730 testing, the opening and closing mechanism of most Bourns® miniature TCO devices is tested up to 6000 cycles.

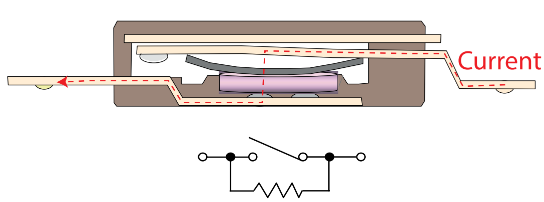
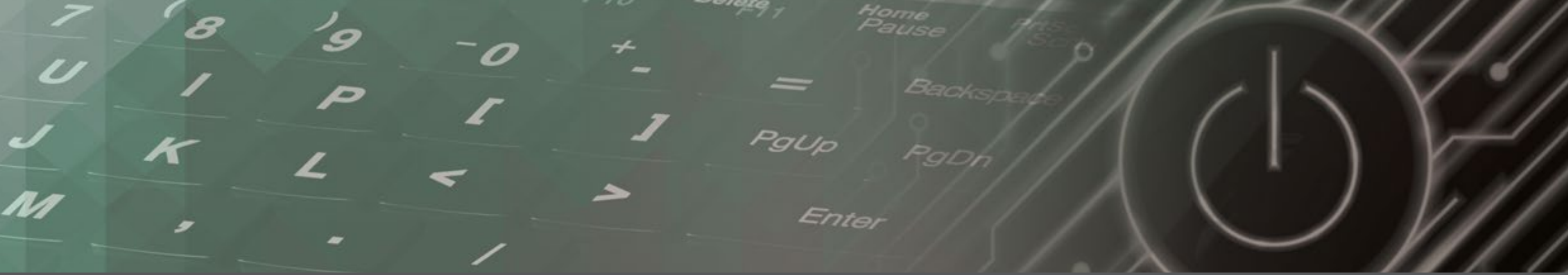


Figure 5. | *Mini-breaker Triggered Open*



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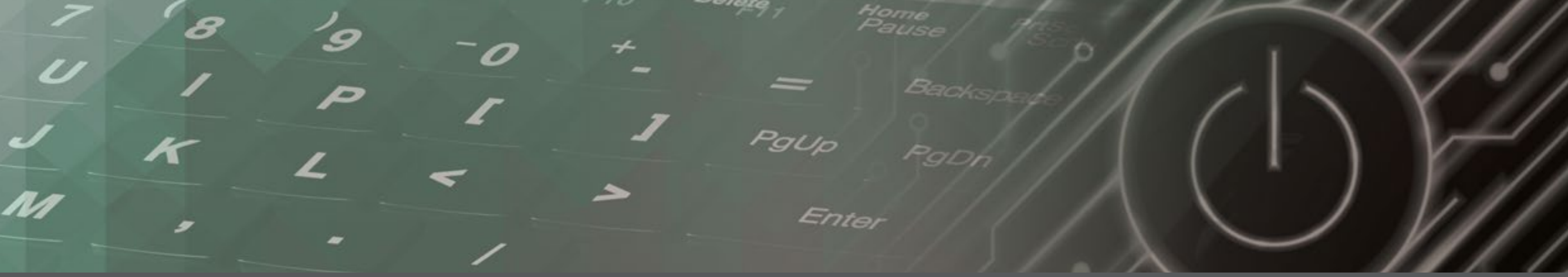
THE NEED FOR RELIABLE BATTERY PACK PROTECTION

Because lithium polymer cells are smaller and lighter now, it makes the cells more power dense. Improper use of the cells can lead to potential hazards such as chemical and electrical risks. Therefore, it is incumbent on the battery pack designer to mitigate against such risks. There are numerous standards that help govern battery pack safety such as IEC 62133 for secondary cells and batteries containing alkaline or other non-acid electrolytes and UL 2054 for household and commercial batteries. These standards have helped guide designers into taking a layered approach to battery protection with multiple levels of redundancy being built into a pack. An integral part of maximizing battery pack efficiency and safe operation is the Battery Management System (BMS) that uses various primary and secondary protection devices as well as software and hardware elements to manage the state of charge, current, voltage and ambient battery temperatures.

TCOs are key elements in the protection architecture that is being increasingly used in lithium polymer pouch cell arrangements. The traditional 18650 cylindrical cells used embedded overcurrent polymer PTCs and mechanical Circuit Interrupt Devices (CIDs), but the flat lithium polymer cells require protection to be attached to each cell because there is no space internally to embed the protection. TCOs are usually manufactured in an axial leaded format to allow the device to be welded to the positive terminals of the battery cells. The battery cell terminals are typically made from aluminum tabs so that the TCOs can be welded to nickel tabs before those nickel tabs are welded to the battery cell terminals. The advantage of the TCOs being welded so close to the battery tabs is that they can be situated in intimate contact with the individual battery cells enabling them to react quickly to any unusual rises in cell temperature. As each battery pack is customized to fit the limited space within the notebook PC, TCOs offer the ability to be welded to nickel tabs of various sizes and formats.

Figure 6. | Mini-breaker TCOs in Battery Cell Protection Circuit

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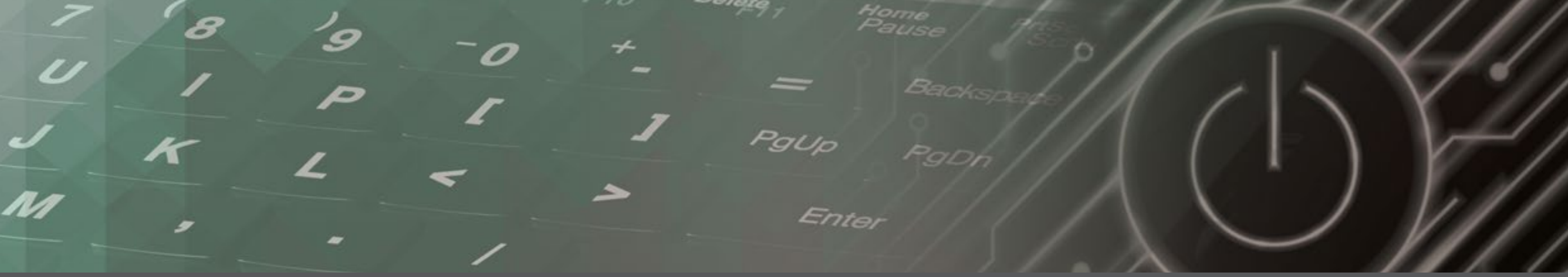
MINI-BREAKERS FOR NOTEBOOK PC BATTERY PACK PROTECTION *(Continued)*

Individual battery pack manufacturers will arrange the cells depending on their specific power requirements. Cells are normally arranged in a combination of series to add voltage and are positioned in parallel to increase capacity. A typical lithium polymer cell is 4.2 V fully charged and the nominal voltage is 3.7 V. Therefore, a 3S battery will be 12.6 V nominal voltage (4.2 V x 3) and charged voltage of 11.1 V (3.7 V x 3). If the pack is 3S2P with each cell capacity of 2600 mAh, then the capacity increases to 5200 mAh (2600 mAh x 2). As the lithium polymer batteries are used, their cells may discharge unevenly and become unbalanced.

> ***"TCOs can be used individually on each cell as a form of backup protection since each cell will perform slightly different to the other in the pack arrangement"***

Because overcharging above the charged voltage or over-discharging below the discharge voltage of the cells is potentially damaging, balancing the cells becomes a very important part of battery pack charging and discharging. Preventing damaging events is one of the key functions of the battery management ICs. Typically, battery management units integrate battery charging control output, gas gauging and protection for autonomous operations of multiple series lithium polymer battery packs. These ICs have integrated cell balancing drives to optimize the charging profile. However, TCOs can be used individually on each cell as a form of backup protection since each cell will perform slightly differently to the other cells in the pack arrangement. As a fault can occur individually in one cell, it is important that the TCO be connected to the positive electrode of the cell, and is designed to cut power before the cell can fail and cause a chain reaction amongst the other cells. Using a single TCO to protect the entire battery pack is not recommended as TCOs have optimal performance when they are in intimate contact with individual cells, and will lose thermal sensitively when located at a distance from the cells they are protecting.



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IMPORTANT TCO SPECIFICATIONS

To ensure battery safety, designers try to protect against cell thermal run-away, whereby the increase in cell temperature may cause fire or harmful gas exhaustion. Thermal run-away will occur above 150 °C. In multiple cells, the failure in one cell can quickly cause a chain reaction to the rest of the cells in the pack. Therefore, the trip temperature of a TCO is a key specification to battery pack manufacturers. Bourns has developed the ability to target specific trip temperature values in its miniature TCOs. The combination of the composite bimetal material and the precision forming of the bimetal disc allows Bourns® TCOs to target trip temperatures from 72 °C to 90 °C within a ±5 °C accuracy. When a Bourns® TCO trips, it immediately cuts the power to the cell and allows the cell to cool. Figure 7 demonstrates this function using a Bourns® Model NR72AB0 72 °C TCO.

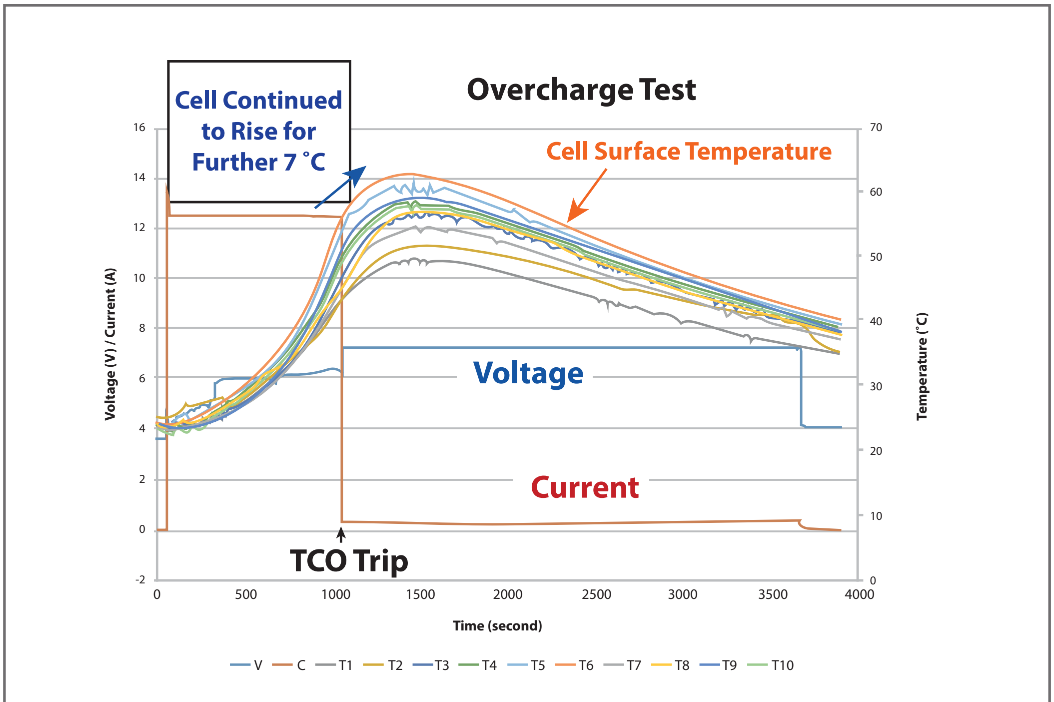
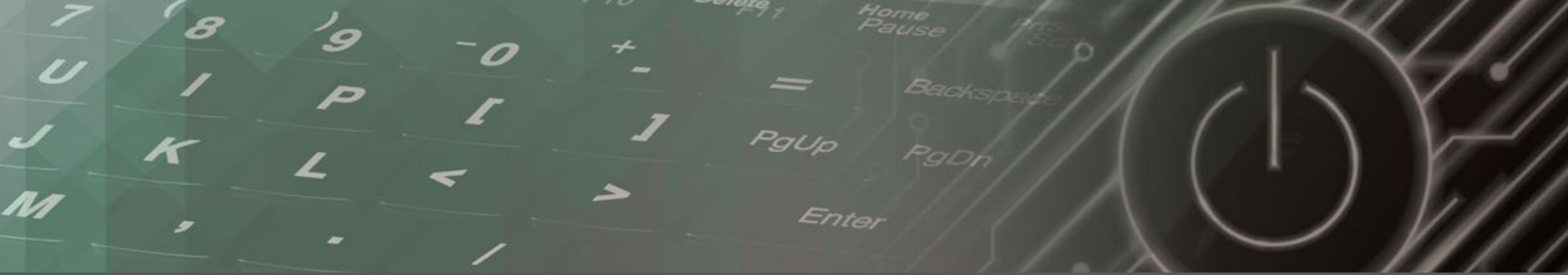


Figure 7. | *Mini-breaker TCOs in Battery Cell Protection Circuit*



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IMPORTANT TCO SPECIFICATIONS *(Continued)*

Notebook PC batteries use a combination of different battery capacities. For this reason, Bourns carries a range of low current (LC Series), high current (HC Series) and very high current (AA Series) miniature TCO models that can be tailored for each cell in the battery pack arrangement. TCOs trigger from a combination of temperature and current. The ambient temperature will rise from the I^2R Joule heating (or resistive heating) caused by the interactions of the electrons from the electric current and the atomic ions in the terminals. Consequently, TCOs at lower ambient temperatures can hold significantly higher currents than TCOs at higher ambient temperatures. The graph in figure 8 illustrates the ambient current impact of operating currents on various Bourns® TCO models – from low current to high current.

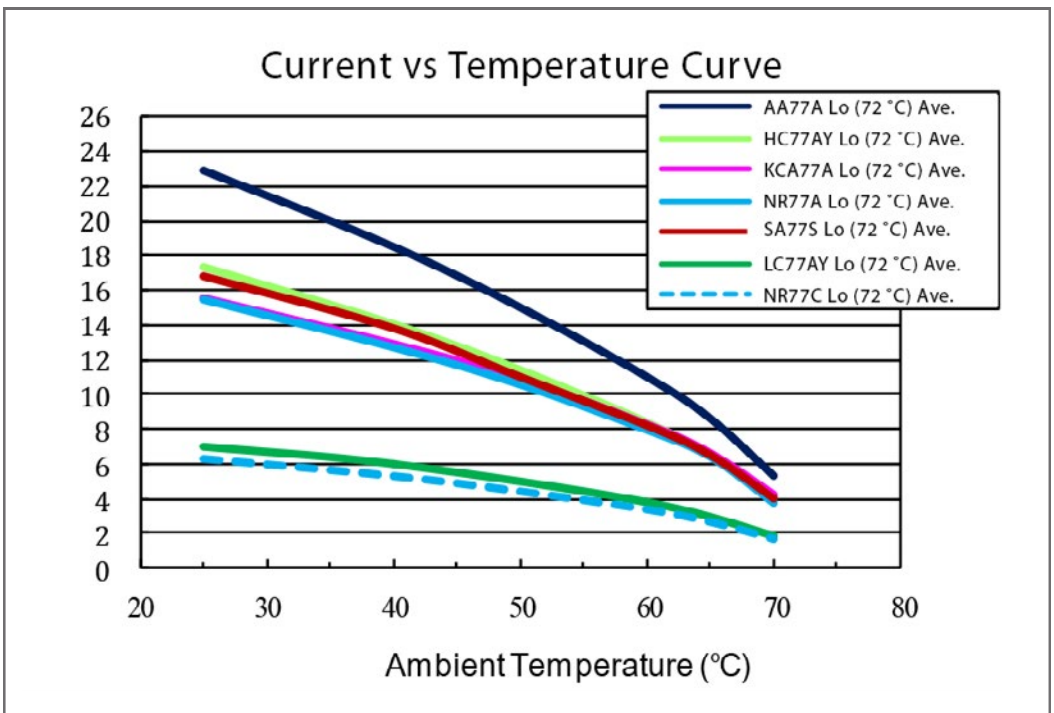
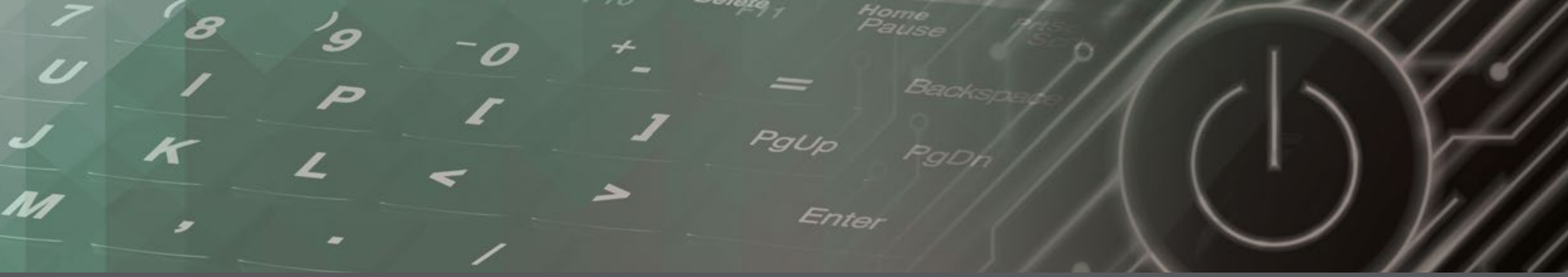


Figure 8. | *Ambient Temperature Impact on Bourns® TCO Operating Currents*



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CONCLUSION

As lithium polymer pouch battery packs continue to expand in use compared to the traditional cylindrical cell pack designs, it is critical that safety circuits match these demands. Bourns' broad line of mini-breaker TCO products provides recognized premium battery protection with more than 2.7 billion units sold. Bourns is committed to designing and manufacturing the highest level of quality proven miniature TCOs with its history of no field returns received. This level of performance and quality is the foundation that ensures Bourns' customers of continued innovation as the company prepares to meet the demand for higher currents, smaller sizes and surface mount formats.

ADDITIONAL RESOURCES

Please contact your local Bourns Application Engineer or
Bourns Sales Representative for additional information.
Visit Bourns online at:

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Americas: *Tel* +1-951 781-5500
Email americus@bourns.com

EMEA: *Tel* +36 88 520 390
Email eurocus@bourns.com

Asia-Pacific: *Tel* +886-2 256 241 17
Email asiacus@bourns.com