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Battery Management System Protection

- EV Infrastructure
- Renewable Energy
- Energy Storage

Users must independently evaluate the suitability of, and test each product selected for their own specific applications. It is the user's sole responsibility to determine fitness or use of a particular system based on their own performance criteria, conditions, specific application, compatibility with other parts, and environmental conditions. Users must independently provide appropriate design and operating safeguards to minimize any risks associated with their applications and products. Littelfuse products are not designed for, and may not be used in, all applications. Read complete Disclaimer Notice at littelfuse.com/disclaimer-electronics.

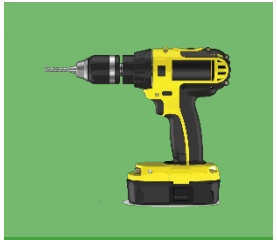
REV0725

Battery system classification by power/voltage

Small APL

- Personal care **>3.7 V**
- IoT **<10 V**
- Mobile device **<3.7 V**
- Wearables **<3.7 V**

<3 Wh
<10 V



Power tool, Industrial Power Tool

- Power tool **12–36 V**
- Industrial power tool **36–96 V**
- eBike **36–48 V**

>3.6 kWh
12–96 V

Two-/Three-Wheeler

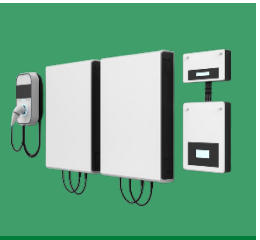
- Two-wheeler **36–96 V**
- Three-wheeler **48–96 V**
- ATV/golf cart **24–72 V**

3–10 kWh
24–96 V

Transportation, eMobility

- Passenger car **400–800 V**
- Truck & bus **400–1,000 V**
- Off-highway **200–800 V**
- Material handling **24–80 V**

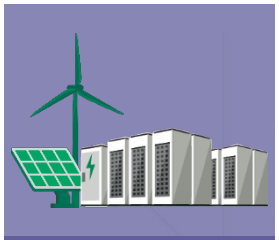
50–1,000 kWh
Up to 800 V



Behind Meter

- UPS **48 V**
- Residential **48–400 V**
- Stationary commercial & industrial **120–400 V (1,000 V)**

5–15 kWh
48–400 V



Utility Grid

- Integrated renewable storage **>400 V**
- Megawatt charging buffer **>400 V**
- Demand response **>400 V**

>20 kWh
400–1200 V

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Battery Management Systems (BMS) market statistics and drivers

Market trends and drivers

Consumer Electronics: The demand for efficient battery management in devices like smartphones, laptops, tablets, and wearable technology is significant due to the need for longer battery life and better performance.

Home Appliances: Certain home appliances, especially those that are battery-operated, benefit from BMS to enhance battery performance and longevity.

Two-/Three-Wheelers: The global electric two- and three-wheeler Li-ion battery pack market is growing at a CAGR of ~34%; shift the focus from lead acid batteries to Li-ion batteries. Most battery packs are 48 V; higher-end models (>20 kW) also come with 60−96 V battery packs.

Electric Vehicles: The growth of the BMS industry can be attributed to the increasing adoption of EVs and Hybrid Electric Vehicles (HEVs) across the globe, owing to stringent policies, such as the Kyoto Protocol, implemented to curb Greenhouse Gas (GHG) emissions.

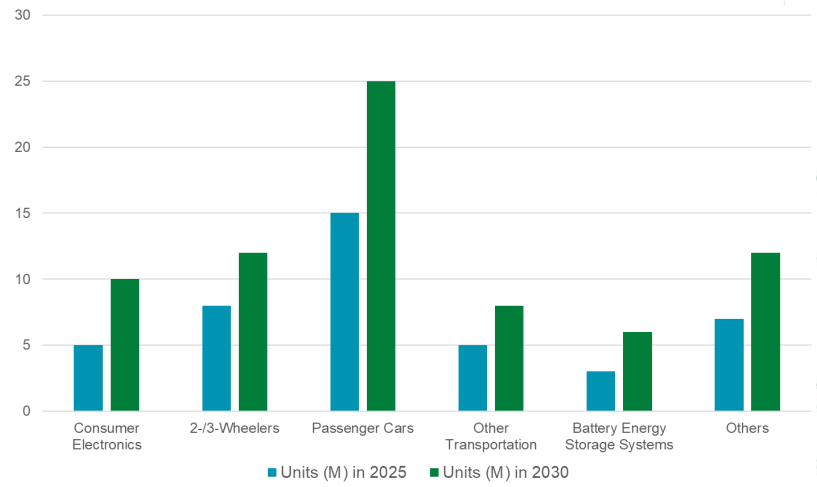
Battery Energy Storage Systems: Growing demand for renewable energy sources, such as solar and wind power, also fuels demand BMS to manage the batteries used in consumer electronics, automotive, energy storage, and defense systems.

Industrial Machinery: BMS are used in various industrial applications to ensure the efficient operation of machinery and equipment that rely on rechargeable batteries.

Telecommunications: Telecom infrastructure, including backup power systems for cell towers and data centers, utilizes BMS to maintain reliable power supply and manage battery health.

Portable Medical Equipment: Medical devices such as portable diagnostic tools and patient monitoring systems require BMS to ensure safe and reliable operation.

Global BMS Market Analysis and Forecast (2025–2030)



Sources:

1. *Littelfuse estimates*
2. *Grandviewresearch*
3. *Grandviewresearch for Global BESS Market*
4. *Vynzresearch*

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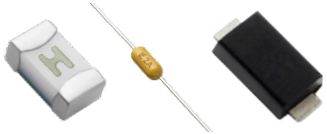
Battery Management System (BMS) protection

Main disconnect Fuse
High Voltage Fuse

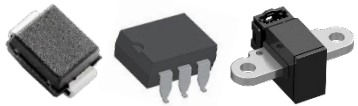
Analog front end & cell balancing
SMD or In-Line Fuse, TVS Diode



Temperature control
TTape™ Platform

Module BMS
Diode Array, TVS Diode

Isolation monitoring & current sensing
TVS Diode, Solid State Relay, Current Sensor



Main BMS
Fuse, Gate Driver, Diode Array, TVS Diode Array

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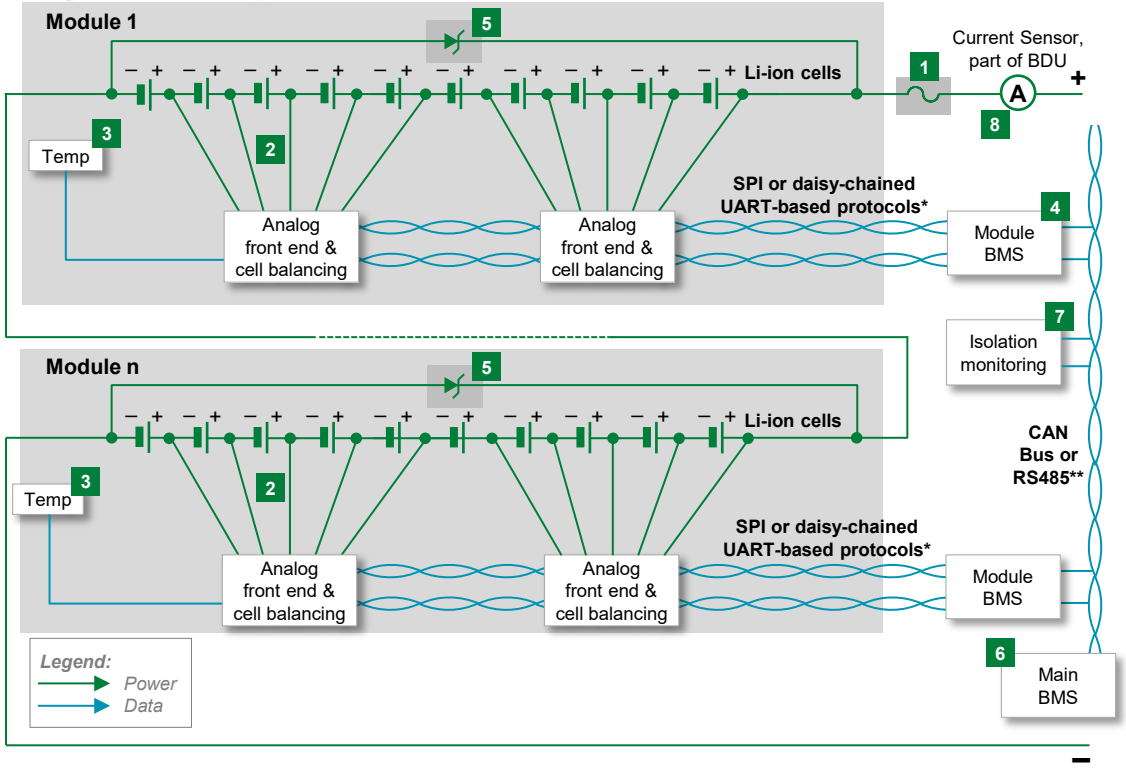
Basic Battery Management System



	Technology	Product Series
1	Main Fuse	30EV1K, 25EV1K, Midi, Maxi, Mega
2	SMD Fuse	437A, 438A, 451*, 453*, 483A
	OR	
	In-Line Fuse	521
	TVS Diode	SZSMF5.0AT1G-X, TPSMA6L, SD05
3	TTape™ Platform	TTP
4	Diode Array	AQ05C/AQ1205/AQ12C
5	TVS Diode	TPSMB-L, TPSMB, TPSMC, TPSMD, TP5.0SM DJ
6	Gate Driver	IXD_6xxSI, IX4340NE
	Diode Array	AQ24COM-02, AQ24COM-01
	Fuse	885
	TVS Diode	TPSMB, TPSMC
7	TVS Diode	TPSMB
	Solid State Relay	PLA171*, PLA172*
8	Current Sensor	CH1B02xM, CH1P01xM
	OR	
	Current Sensing Resistor	SSA, WPA/WPB/WPC*, WSTM*

* *For non-automotive qualified applications*

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Potential Littelfuse products for high-voltage battery system

Click the product series in the table below for more info

	Technology	Function in application	Product series	Benefits	Features
1	High-Voltage Fuse	Main fuse design to protect BMS from short circuit, wiring failure, etc.	30EV1K, 25EV1K, Midi, Maxi, Mega	Provides safety protection in high-voltage environments; full range fuse	Bolt-down form factor; high breaking capacity; ISO 8820 qualified
2	SMD Fuse ***OR*** In-Line Fuse	Protects cells and BMS components from overcurrent	437A, 438A, 451*, 453*, 483A 521 (In-Line Fuse)	Excellent temperature stability and performance reliability; ceramic substrate ensures compatibility with high-temperature environment	Tested to new AEC-Q specification; fast response to fault current; surface mount device
	TVS Diode	Cell monitor IC sense line input overvoltage protection	SZSMF5.0AT1G-X, TPSMA6L, SD05	Excellent clamping capability; meets automotive industry standards; fast response time; low reverse leakage current (I_R)	AEC-Q101 qualified; meets IEC standards for ESD protection and ISO standards for in-vehicle transient surges
3	TTape™ Platform	Overtemperature monitoring of many cells or large area with single MCU input	TTP	Helps the MCU wake from sleep mode at overtemperature events; <1 s response for temperature monitoring; extremely thin device suitable for conformal installation	Simple integration with existing BMS solutions complementing NTCs; no calibration or temperature look-up tables needed; pressure-sensitive adhesive for simple, quick installation
4	Diode Array	Transient voltage suppression	AQ05C/AQ1205/ AQ12C	Excellent clamping capability; meets automotive industry standards; fast response time	AEC-Q101 qualified; meets IEC standards for ESD protection and ISO standards for in-vehicle transient surges
5	TVS Diode	Protects battery from fast, high-voltage transients	TPSMB-L, TPSMB, TPSMC, TPSMD, TP5.0SM DJ	Low clamping voltage; meets automotive industry standards; fast response time	AEC-Q101 qualified; meets IEC standards for ESD protection and ISO standards for in-vehicle transient surges

* *For non-automotive qualified applications*

Potential Littelfuse products for high-voltage battery system

Click the product series in the table below for more info

	Technology	Function in application	Product series	Benefits	Features
6	Gate Driver	Controls the switching MOSFETs	IXD_6xxSI, IX4340NE	Dual outputs provide space-efficient design; high immunity to latch-up; rise/fall times lower than 10 ns	Tight tolerance; small form factor; fast thermal response
	Diode Array	Protects CAN bus from ESD, EFT, and voltage transient	AQ24COM-02, AQ24COM-01	Ensures reliability of the equipment without performance degradation	AEC-Q101 qualified; meets ESD protection levels specified under IEC 61000-4-2 and ISO 10605; low-leakage current and clamping voltage
	Fuse	Protects cells and BMS components from overcurrent	885	High-voltage SMD form-factor enables compact design; ceramic body ensures compatibility with high-temperature environment	Tested to new AEC-Q specification; fast response to fault current; surface mount device
	TVS Diode	Transient voltage suppression	TPSMB, TPSMC	Excellent clamping capability; meets automotive industry standards; fast response time	AEC-Q101 qualified; meets IEC standards for ESD protection and ISO standards for in-vehicle transient surges
7	TVS Diode	Protects Solid State Relays from voltage transients	TPSMB	Excellent clamping capability; meets automotive industry standards; fast response time	AEC-Q101 qualified; meets IEC standards for ESD protection and ISO standards for in-vehicle transient surges
	Solid State Relay	Isolation monitoring	PLA171*, PLA172*	Ideal solid state replacement for larger reed and electromechanical relays; board space savings	Low drive current; high reliability; no EMI or RFI generation; small package size
8	Current Sensor ***OR*** Current Sensing Resistor	Measures current on each phase of the inverter/motor and/or the DC link current	CH1B02xM, CH1P01xM	High sensing accuracy; low thermal offset drift; low thermal sensitivity drift	Up to 2000 A with analog or CAN output; functional safety ratings from ASIL QM to ASIL C available
		Measures the overall output current	SSA, WPA/WPB/WPC*, WSTM*	High sensing accuracy; low thermal offset drift; low thermal sensitivity drift	Isolated from HV network; no additional power loss due to shunt resistor

* *For non-automotive qualified application*

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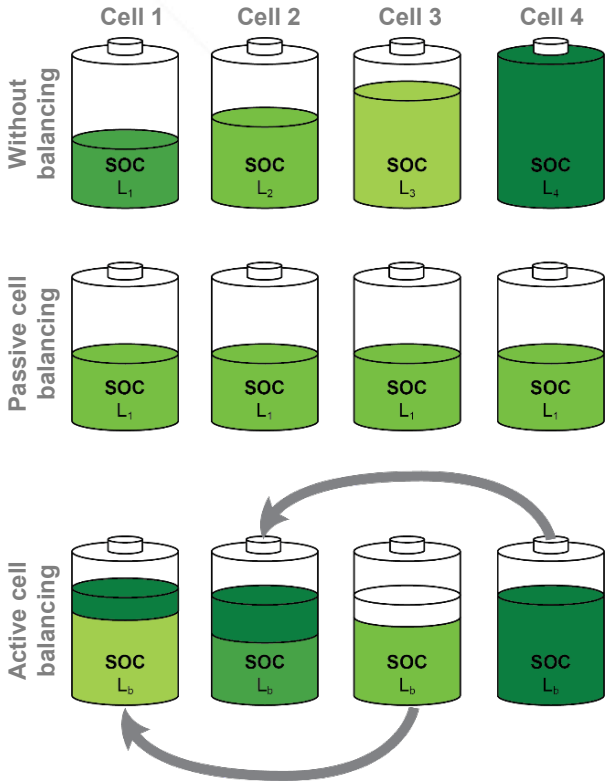
Focus Topic: active/passive cell balancing

Minimizing performance degradation and safety risks



- **Example:** Battery pack with 4 cells (cell 1…4)
  - SOC/voltage levels: 40%, 60%, 80%, 100%
- **Passive Balancing:**
  - Dissipates energy from higher SOC cells
  - Aligns all cells to lowest SOC level (40%)
- **Active Balancing:**
  - Transfers energy between cells to equalize SOC
- **Benefits:**
  - Enhanced efficiency
  - Improved safety
  - Prolonged battery lifespan
- **Drawbacks:**
  - Energy loss (passive balancing)
  - Complexity and cost (active balancing)
  - Heat generation
  - Maintenance requirements

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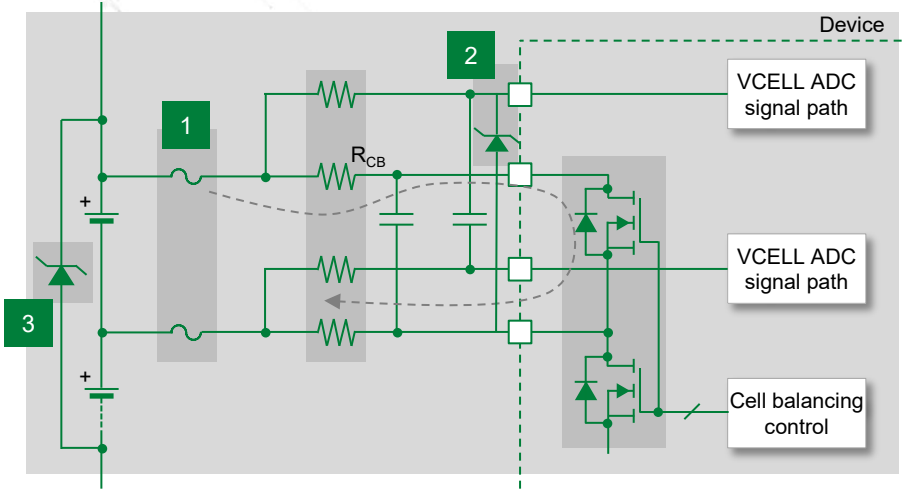
Passive balancing using switching shunt resistors

Protecting the balancing IC, flexPCB, balancing resistor, etc. with SMD Fuses



- Charge from “full” cells is dissipated at charge–balancing resistors R_{CB} during the charge cycle (balancing currents: ~50 mA to ~250 mA).
- Cell-to-cell shorts: Higher currents (A–kA) can occur that might damage the flex PCB, electrical components, the AFE, or the Module BMS.
- PCB traces should NOT be used to protect against these events.
  - Over-currents can be too low to reliably open the traces.
  - Undefined failure that can cause severe damage to the battery system.

1 **Balancing line/sense line fuse to protect from shorting:**

- Depending on the battery system, there can be dozens or hundreds of balancing lines/sense lines per system,
- Shorting can happen between random balancing/sense lines depending on failure modes: assembly issues, accidents, leakage of liquids that can build conductive deposits.
  - SMD fuses with a low resistance and a fast opening (<1s)
  - Fuses on the flex PCB and/or the AFE/Module BMS
  - Recommended products: 437A, 438A, 451, 453, 483A

2 **IC Sense line/power line input overvoltage protection:**

- Protects low-voltage (5 V) input terminals of cell monitor from transients.
- Hot plug transients occur during assembly and maintenance of battery pack; other transients can be induced from the surrounding system either via conduction or inductive coupling from adjacent cabling.
  - TVS Diodes (SZSMF5.0AT1G-X, TPSMA6L/SD05)

3 **Overvoltage protection for battery cells:**

- TVS Diodes (TPSMB-L, TPSMB, TPSMC, TPSMD, TP5.0SM DJ)

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TPSMB-L series TVS Diode with low V_{CLAMP}

For 800 V platforms with 16-cell/18-cell AFE protection

Part Number (Uni)	Marking	Reverse Stand Off Voltage V_P (Volts)	Breakdown Voltage V^{BR} (Volts) @I^T		Test Current I^T (mA)	Maximum Clamping Voltage V_C@I_{PP} (10/1000µs) (V)	Maximum Peak Pulse Current I_{PP} (10/1000µs) (A)	Maximum Clamping Voltage V_C@I_{PP}=10 A (8/20µs) (V)	Maximum Clamping Voltage V_C@I_{PP} (8/20µs) (V)	Maximum Peak Pulse Current I_{PP} (8/20µs) (A)	Maximum Reverse Leackage @VR (µA)	Agency Approval
			Min	Max								
TPSMB75A-L	75AAL	64.10	71.30	78.80	1	96.0	5.9	83.0	95.0	29.5	1	X
TPSMB82A-L	82AAL	70.10	77.90	86.10	1	100.0	5.4	90.0	100.0	27.0	1	X
TPSMB91A-L	91AAL	77.80	86.50	95.50	1	114.0	4.9	100.0	109.0	24.5	1	X

AFE	Pin	Voltage
Tx BQ79818	Cell 13–18	108 V
	Cell 7–12	85 V
	Cell 1–6	40 V
Tx BQ79718	Cell 13–18	100 V
	Cell 7–12	85 V
	Cell 1–6	40 V
Axx BMS6832/ 6833	Cell 0–14/V_{CC}	85 V
	Cell 15	95 V
	Cell 16	105 V
	Cell 18	110 V

Suitable for battery packs with up to 18 Li-ion/NMC cells

- AFE protection on V_{BAT} level
- 16/18 cells: 100 V clamping voltage @ 77.8 V reverse standoff voltage
- Not available from any competitor product

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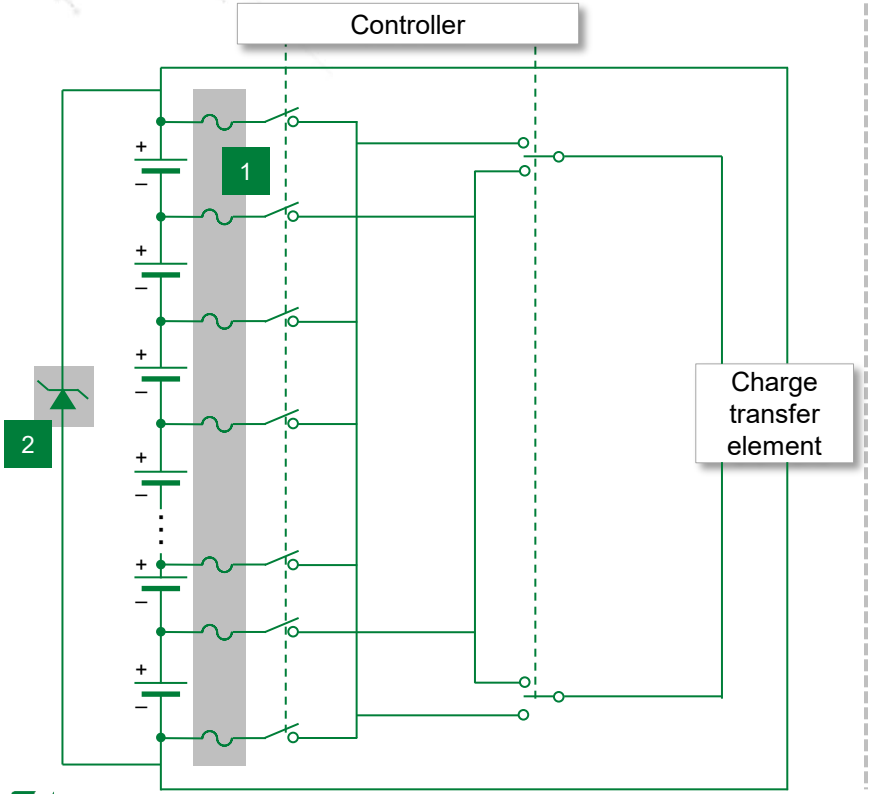
Active balancing using a charge transfer element

Protecting the balancing IC, flexPCB,… with SMD fuses



- Capacitors, inductors, and converters can be used as **charge transfer elements** to transfer charge/energy from one cell to another through a switch matrix.
- Active balancing solutions come with **higher complexity, higher cost, and larger size** than passive balancing approaches.

1 Balancing line/sense line fuse to protect from shorting:

- Depending on the battery system, there can be dozens or hundreds of sense lines/power lines per system.
- Shorting can happen between random sense/balancing lines depending on failure modes: assembly issues, accidents, leakage of liquids that can build conductive deposits.
  - SMD fuses with a low resistance and a fast opening (<1s)
  - Fuses on the flex PCB and/or the AFE/module BMS
  - Recommended products: 437A, 438A, 451, 453, 483A

2 Overvoltage protection for battery cells

- TVS Diodes
  - Recommanded products: TPSMB-L/TPSMB, TPSMC, TPSMD, TP5.0SM DJ

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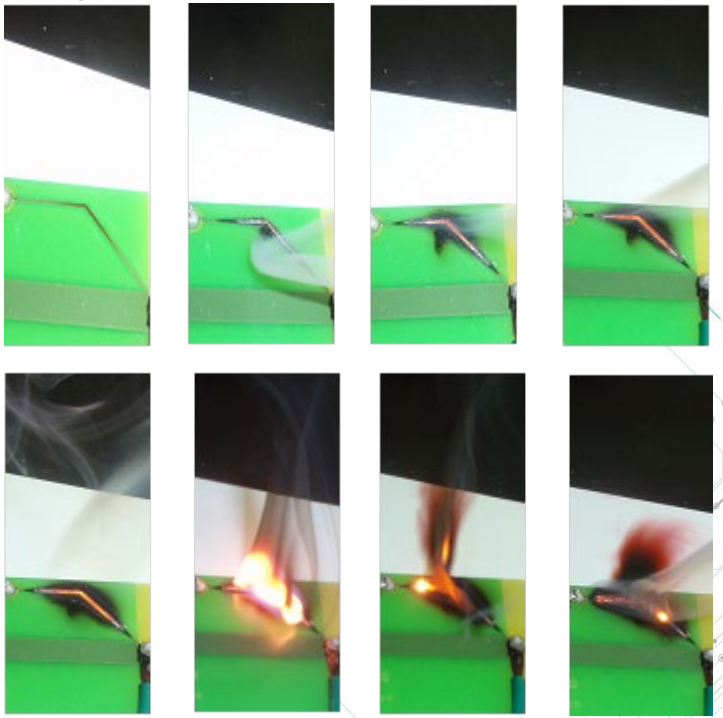
Littelfuse SMD Fuses vs. Fusible PCB Traces

	SMD Fuse	PCB Trace
Reliable fusing	mA–kA* (arcing enclosed in fuse packaging)	~kA* (open arcing possible)
Trigger time window	Well defined opening time	Unpredictable opening time and behavior (Cu, epoxy, dendrites, etc.)
Open state	Defined open state → fail-safe, no contamination (enclosed fuse element)	Undefined open state, contamination of PCB
Cascaded fusing	Cascaded fusing possible (e.g., fuse on flexPCB → fuse on BMS PCB)	Not possible due to unpredictable opening
Risk @ low overload condition	None	Fire hazard (e.g., FR4: high carbon content)
Qualification/ agency approvals	AEC-Q qualified	No

* *Short circuit current can be in mA–kA range depending on pack architecture (R_i), nature of the short (R_{short}), and voltage drop (voltage difference between cells, charge source).*

Example:



Recommendation: Use SMD fuses to minimize risk of severe damage & fire

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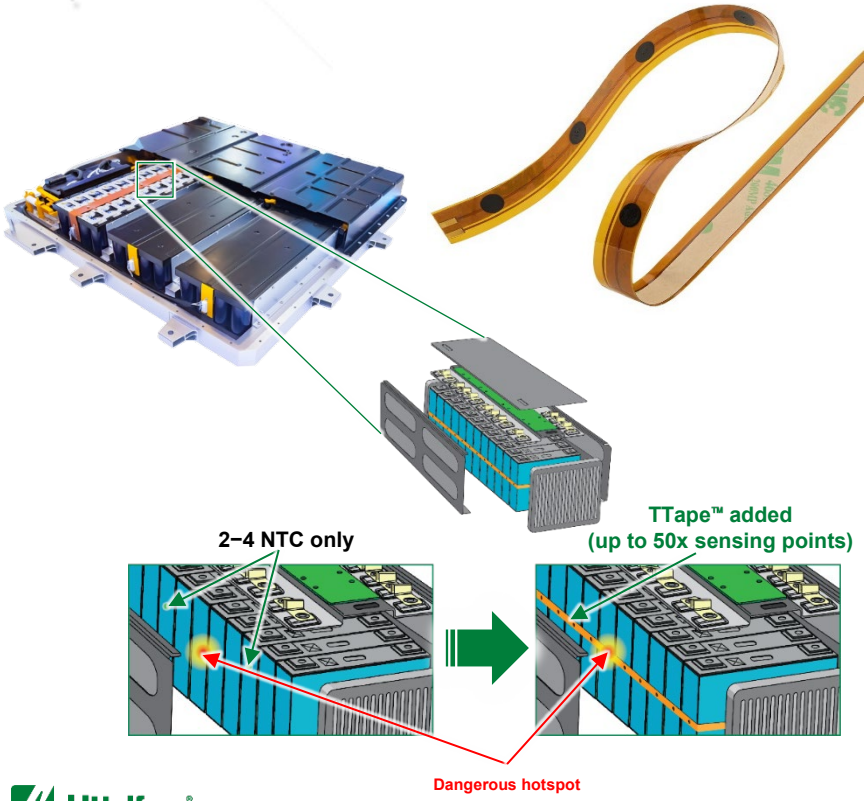
CSA Certification in Canada is equivalent to UL listing in the United States. Recognized under the Component Program of Underwriters Laboratories.

TTape™ Platform for overtemperature detection at each cell



Value proposition

- Suitable for cylindrical, prismatic, and pouch cells
- Geometry and number of monitoring points fully customized for perfect fit
- 1-port connection for up to 50 monitoring points
- One quasi-digital signal per device if T_{trip} is exceeded at any of the monitoring points
- Signal can be used as MCU wake-up trigger
- Automatic installation option
- AEC-Q200 qualified

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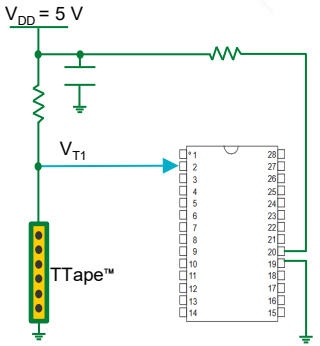
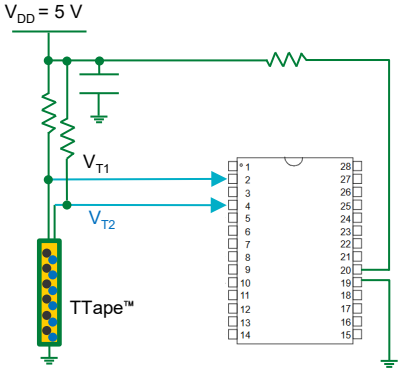
Simple connection & system implementation

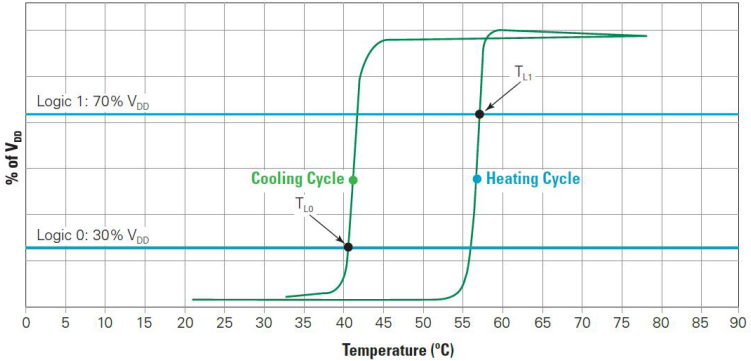
One-trip temperature circuit



Two-trip temperature circuit



V_T output to MCU, 58 ºC device



TTape™–distributed temperature monitoring; with various activation temperatures for different applications

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Additional information can be found at Littelfuse.com

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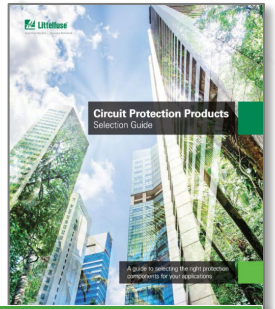
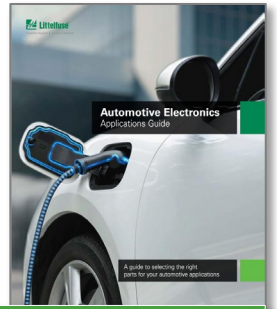
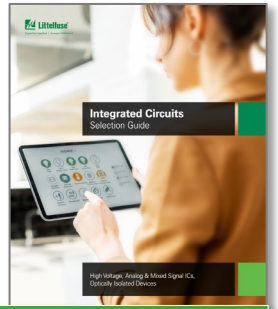


Circuit Protection Selection Guide

Power Semiconductor Product Catalog



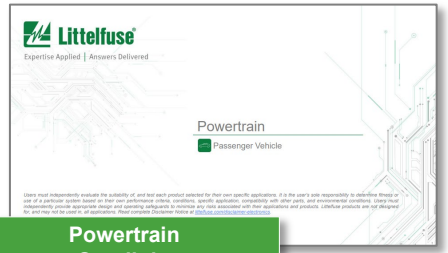
Automotive Electronics Application Guide



Integrated Circuit Selection Guide

C&K Switches Selection Guide

Click the images for more information



Powertrain Spotlight

Automotive Circuit Protection With TVS

AEC-Q200 Specification Spotlight

Scan the code to learn more!

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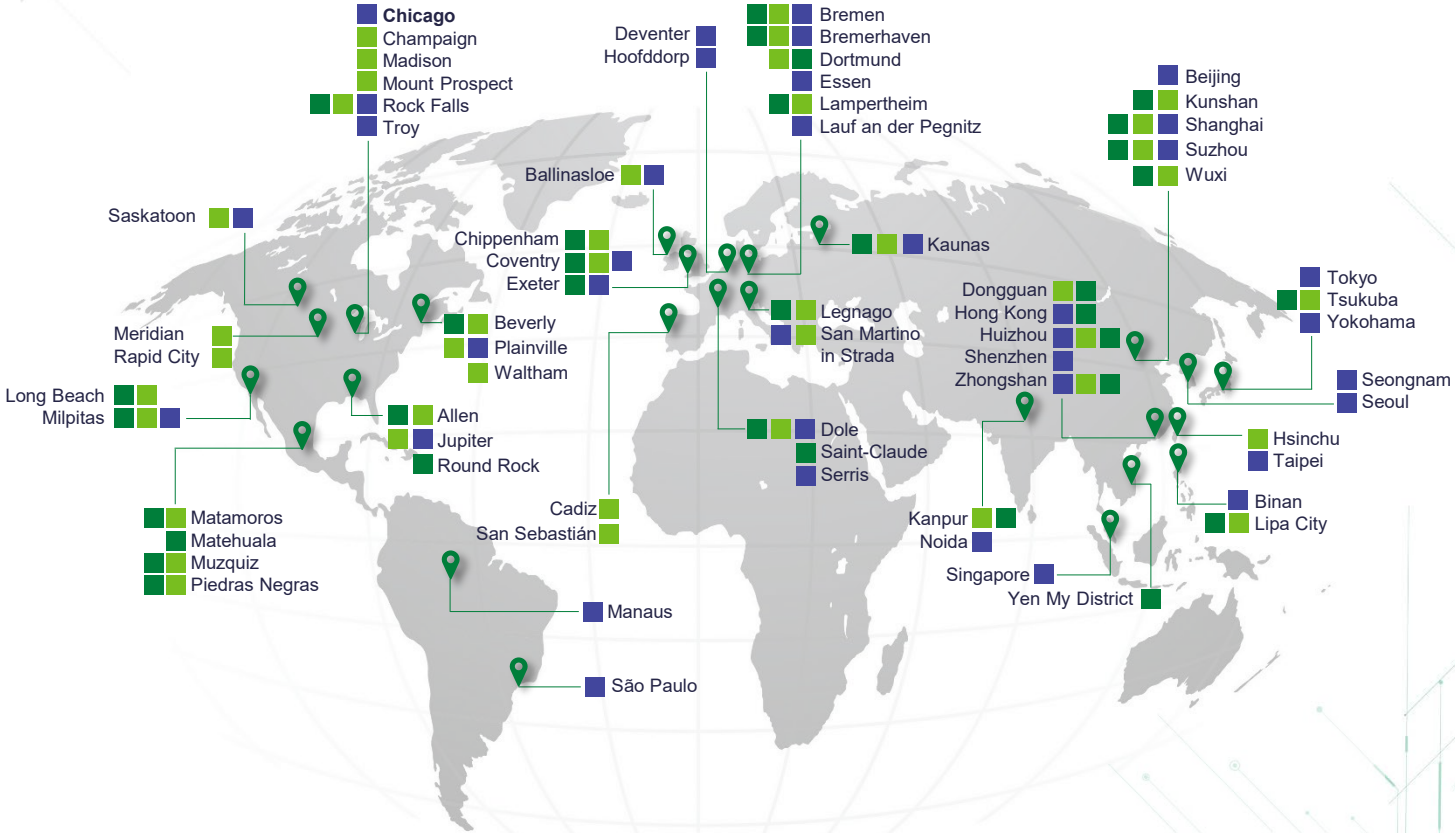
Local resources supporting our global customers



Legend

- ***Sales***
- ***R&D***
- ***Manufacturing***

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Partner for tomorrow’s electronic systems

Broad Product Portfolio

We are an industrial technology manufacturing company empowering a sustainable, connected, and safer world.

Testing Capabilities

We help customers get products to market faster, and we offer certification testing per global regulatory standards.

Application Expertise

Our engineers partner directly with customers to help speed up product design and meet their unique needs.

Compliance and Regulatory

We help customers in the design process to account for requirements set by global regulatory authorities.

Global Customer Service

Our global customer service team is with you to anticipate your needs and ensure a seamless experience.

Global Manufacturing

Our high-volume manufacturing is committed to the highest quality standards.

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