

## Using PolySwitch PPTC Devices for LPS Compliance in Li-ion and LiP Cell Battery Applications



### Introduction

Batteries, especially Lithium-Ion (Li-ion) and Lithium Polymer (LiP) cells, are sensitive to faults such as external shorts, runaway charging or abusive over-charging that can lead to overcurrent and overtemperature conditions. When over-charge, deep discharge or short circuit conditions create heat and oxygen in battery applications, the cell being used in the product has the potential to swell, rupture or even ignite. Because Li-ion and LiP cells are commonly used in tablets, smart phones, ultra-thin laptops and other portable electronics, safety is a primary consideration for the manufacturers of these products.

In May 1997, Underwriters Laboratories (UL) published the UL 2054 safety standard for “Household and Commercial Batteries” to help reduce safety risks when batteries or battery packs are used in consumer products. Drawing upon IEC/UL UL60950 Limited Power Source (LPS) Clause 2-5 table 2B, the UL 2054 standard states the requirements of a Limited Power Source, or LPS, test.

This application note explains the nuances of the LPS clause of the UL2054 standard – which can sometimes be difficult to interpret – as it relates to the various circuit techniques that can be employed to meet the LPS requirements for systems not exceeding  $20V_{DC}$ . It also provides examples of how resettable PolySwitch PPTC (polymeric positive thermal coefficient) devices can help designers achieve LPS compliance while also enabling a space-saving design well suited for ultra-slim portables.

### Advantages of LPS Compliance

Battery packs marked “LPS” are safe for consumers to replace and access, negating the need for specialized electrical technicians to perform basic battery maintenance procedures. Conversely, if the source is not a Limited Power Source, the live voltage on that circuit must be contained in an environment where a tool is needed to access a secured panel. The benefit of an LPS circuit is that connectors and cables connected to the active circuit may require fewer tests and eliminate the need for certification.

In the first UL edition, battery packs were required to limit current flow to below 8A, or to use the highest current that would not cause a recognized overcurrent protection device to operate for 60 seconds. Also, it had to be able to avoid igniting the cheesecloth draped over a load constructed of an appropriate-length, 20-gauge nichrome wire. Although this first edition eliminated most cases of battery-caused catastrophic events, it was found that in cases where the user repeatedly reset the device and reapplied power multiple times without allowing a cooling off or equilibration period, certain loads could staircase in temperature. This sometimes led to inadvertent hazards, such as exceeding touch temperature ratings on surfaces or, even worse, accidental combustion of the material or rupturing of the cell.

Over the years, several adjustments have been made to the UL definitions and test requirements to take into account outlying conditions that were discovered over time. This evolution of the Limited Power Source subsection has continued to help support the safe proliferation of high-energy density rechargeable batteries.

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Two of the revisions in the most recent 2011 edition of UL 2054 (UL 2054 Limited Power Source Test Clause 13 table 13-1(13-2)), address the LPS requirement and the measurement methods for limits for inherently Limited Power Sources. According to these revisions, certain end-product devices require that the power output of a battery be limited to reduce the risk a device failure that may lead to fire or injury. The LPS test described in Section 13 of UL2054 Second Edition is used to determine whether a cell or battery is suitable in such applications where hazards may otherwise exist.

### Four Approaches for LPS Compliance

UL 2054 Section 13A describes four different approaches that can be followed to meet LPS requirements for batteries, as shown in Table 1. The subsequent sections of this paper cover each approach and give examples of circuits that can help provide solutions for meeting the LPS requirements, which are described in the LPS section for test cases “a,” “b,” “c” and “d.”

UL 2054 LPS Requirement		
Paragraph	Requirement	Notes
13.2 A a)	Battery limited inherently	For example, a 1.4 A-Hr battery can deliver 8A for over 600 seconds
13.2 A b)	Battery limited by impedance	A linear impedance would dissipate too much energy
13.2 A c)	Battery limited by regulator network or IC	Allows 8A for 5s, 60s allowed when used with limiting impedance
13.2 A d)	Battery limited by fuse or circuit breaker	Overcurrent protection devices are bypassed to increase current stress to worst case

Table 1. The four approaches for meeting the UL 2054 LPS requirements.

A key step in meeting LPS requirements is by testing at the maximum power point load. The value of this load is determined prior to commencement of the tests. To pass the LPS test, the source should be tested under the normal load, at the maximum current load fault condition and at the maximum power load fault condition. For example, the maximum current load used in the following test examples for test cases a, b, and c is an 8.01A electronic load; 8.01A is selected to ensure that the current is at 8A per the requirement of the test.

Figure 1 shows “Table 13.1” taken from the UL standard, which lists compliance requirements for cases a, b and c.

Table 13.1  
Limits for power sources without an overcurrent protective device  
(Revised Table 13.1 effective November 11, 2011)

Output Voltage $U_{OC}$ , $V_{DC}$ <sup>a</sup>	Output Current $I_{SC}$ , amperes <sup>b,d</sup>	Apparent Power $S$ , VA <sup>c,d</sup>
$U_{OC} \leq 30$ $30 \leq U_{OC} \leq 60$	$\leq 8.0$ $\leq 150/U_{OC}$	$\leq 100$ $\leq 100$

<sup>a</sup>  $U_{OC}$  — Open circuit battery voltage with all load circuits disconnected.  
<sup>b</sup>  $I_{SC}$  — Maximum output current with any non-capacitive load, including a short circuit.  
<sup>c</sup>  $S(VA)$  — Maximum output VA with any non-capacitive load, including short circuit.  
<sup>d</sup> — Measurement of  $I_{SC}$  and  $S$  are made 5s after application of the load if protection is by an electronic circuit or a positive temperature coefficient device, and 60s in other cases. If multiple protections are provided, such as combination of electronic circuit and positive temperature coefficient device,  $I_{SC}$  and  $S$  are measured 60s after the application of the load with or without single fault condition applied.

Figure 1. UL’s Table 13.1 for LPS compliance using an overcurrent protection device. (Courtesy of UL.)

Cases a, b, and c require that currents be under 8A, and that apparent power be less than 100W after a specified amount of time has elapsed. The green highlighted area in Figure 2 illustrates the acceptable values of current and voltage.

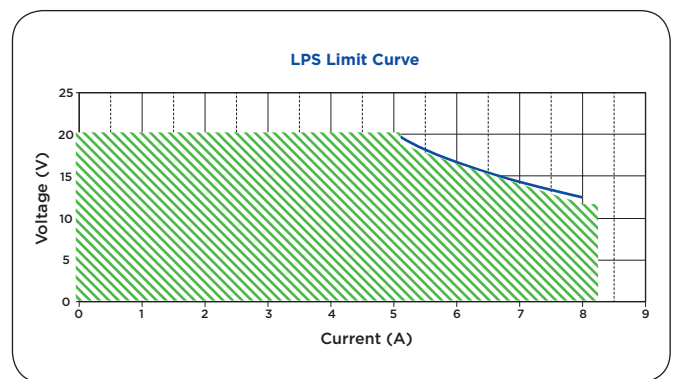


Figure 2. Limiting voltage and current curve for LPS requirements. (Courtesy of UL.)

## Using PolySwitch PPTC Devices for LPS Compliance in Li-ion and LiP Cell Battery Applications

Figure 3 shows the UL's "Table 13.2" for case d.

Table 13.2  
Limits for battery sources (with overcurrent protective device)  
(Table 13.2 revised September 14, 2011)

Output Voltage $U_{OC}$ , $V_{DC}^a$	Output Current $I_{SC}$ , amperes <sup>b,d</sup>	Apparent Power $S$ , VA <sup>c,d</sup>	Current Rating of Overcurrent Protective Device, amperes <sup>e</sup>
$< 20$ $20 < U_{OC} \leq 30$ $30 < U_{OC} \leq 60$	$\leq 1000/U_{OC}$	$\leq 250$	$\leq 5$ $\leq 100/U_{OC}$ $\leq 100/U_{OC}$

<sup>a</sup>  $U_{OC}$  — Open circuit battery voltage with all load circuits disconnected.

<sup>b</sup>  $I_{SC}$  — Maximum output current with any non-capacitive load, including a short circuit, measured 60s after application of the load.

<sup>c</sup>  $S(VA)$  — Maximum output VA after 60s of operation with any non-capacitive load, including short circuit.

<sup>d</sup> — Current limiting impedances remain in the circuit during measurement, but overcurrent protective devices are bypassed.

<sup>e</sup> — The current ratings of overcurrent protective devices are based on fuses and circuit breakers that break the circuit within 120s with a current equal to 210% of the current rating specified in the table.

Note — The reason for making measurements with overcurrent protective devices bypassed is to determine the amount of energy that is available to cause possible overheating during the operating time of the overcurrent protective devices.

Figure 3. UL's Table 13.2 shows case "d" — limiting batter sources with overcurrent protection devices. (Courtesy of UL.)

### Test Examples

The following sections show examples of circuits that can help meet the UL 2054 LPS requirements for cases a, b, c and d.

Examples for cases b and c illustrate how PolySwitch PPTC devices, offered by Littelfuse, can be used to help meet the UL's LPS requirements recommending PTC thermistors on the circuit. As polymeric positive thermal coefficient, or PPTC, devices, PolySwitch devices are resettable. Unlike traditional single-blow fuses, PolySwitch PPTC devices can reset after a fault is cleared; whereas, when using a fuse, the battery pack becomes disabled if a fuse activates. Additionally, PolySwitch PPTC devices are available in a broad array of current ratings and form factors to help designers' target specific applications.

### 13.2 Case "a" — Inherently Limited

A battery that complies with Table 13.2 A for the case "a" (Inherently Limited) requirement must not deliver power that exceeds the limits of Table 13.1 in UL 2054 (shown in Figure 1). In this example there are no protection devices in the circuit. To determine if the battery is inherently limited, fully charged cells are connected to each of the three loads (normal, maximum power, maximum current), as shown in the schematic in Figure 4. In each case, the voltage and current are measured and recorded at  $t = 60s$ . If the resulting current and voltage measurement results fall within the green portion of the chart in Figure 2, the source is inherently limited.

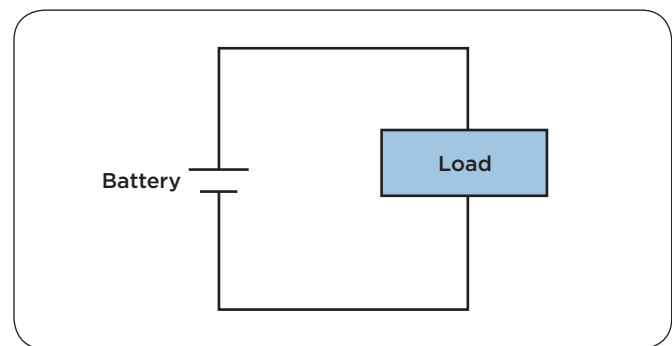


Figure 4. Case "a": inherently limited source — without the use of circuit protection devices.

## Using PolySwitch PPTC Devices for LPS Compliance in Li-ion and LiP Cell Battery Applications

### 13.2 Case “b” — PolySwitch PPTC Device

To verify case “b,” the battery is connected with a PolySwitch PPTC device, as shown in Figure 5. As shown in this example, the load should be set to 8.01A in CC mode and the current, voltage and apparent power should be measured at five seconds. It should then be verified that the results fall in the green portion of the curve shown in Figure 2. With fully charged cells, the test should be run once with the normal load and once with the maximum power load; and, again, all the results should be confirmed to fall into the green area of the chart in Figure 2.

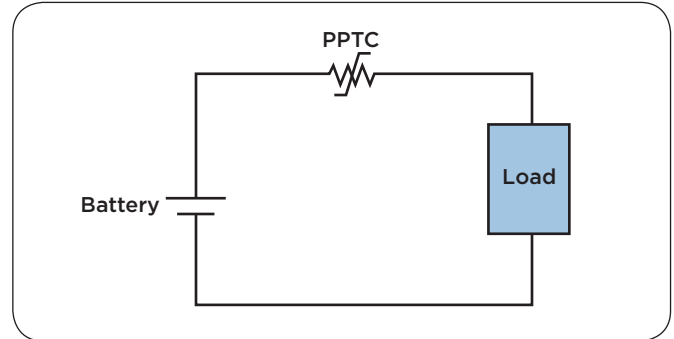


Figure 5. Case “b”: UL 1434-recognized PolySwitch PPTC device.

### 13.2 Case “c” — PolySwitch PPTC Device and Electronic Switch

To verify case “c,” the designer can connect the circuit as shown in Figure 6 using a PolySwitch PPTC device and an electronic switch. The load is set to 8.01A in CC mode and the current, voltage and apparent power is measured at 60 seconds. As with the previous tests, it should be verified that the results fall in the green portion of the curve in Figure 2. With fully charged cells, the test should be run once with the normal load and once with the maximum power load. Finally, all results should be verified that they fall in the green area on the chart in Figure 2.

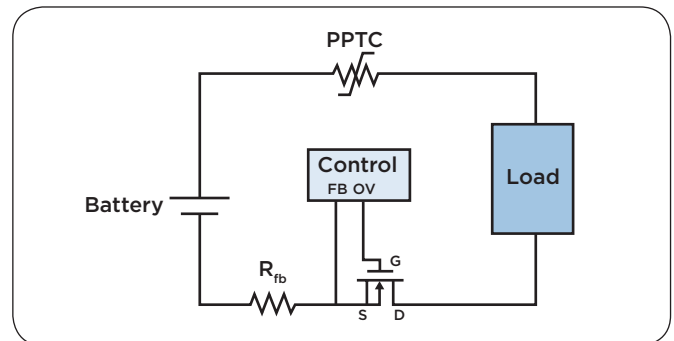


Figure 6. Case “c”: UL 1434-recognized PolySwitch PPTC device and electronic switch.

### 13.2 Case “d” — Power Source Limited with Protective Fuse

To verify case “d,” the circuit is connected with a protective fuse, as shown in Figure 7. The load is set to maximum current (at 210% or 2.10 x fuse current rating) in CC mode and the current, voltage and apparent power is measured at 60 seconds with the fuse bypassed. The results should be verified to fall in the green portion of the curve in Figure 2. Using fully charged cells the test should be run once with the normal load and once with the maximum power load. All results should fall within the parameters specified in Table 13.2 (Figure 3).

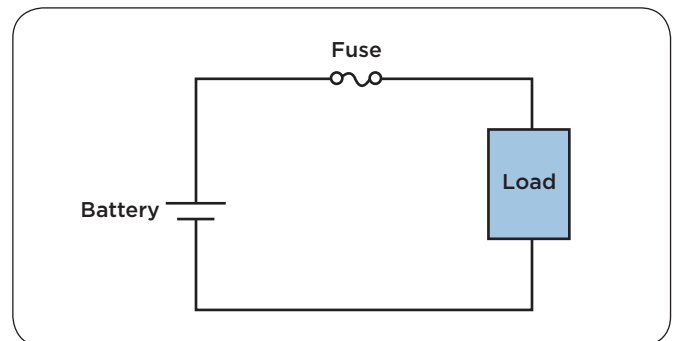


Figure 7. Case “d”: power source limited with protective fuse.

## Using PolySwitch PPTC Devices for LPS Compliance in Li-ion and LiP Cell Battery Applications

### Device Selection

Electronic products that use LiP or Li-ion cells in batteries or battery packs can be adversely affected by fault conditions. To meet the UL's LPS requirement for battery safety in consumer products, designers can use the PolySwitch PPTC resettable overcurrent devices for two of the four circuit protection approaches shown in the test examples described in this paper.

The PolySwitch product family includes surface-mount miniSMDC, microSMD, nanoSMDC, picoSMD and femtoSMD devices, as well as strap devices and a reflowable/weldable device. This wide range of products offers designers flexibility and space-savings advantages in today's low-profile, ultra-slim portable applications.

Table 2 below lists UL 1434-recognized PolySwitch PPTC devices suitable for helping to meet LPS compliance. The numbers at the end of each product model name indicates performance characteristic for that model. \*

mini SMD			micro SMD	nano SMD	
miniSMDC020F	miniSMDC110F/16	miniSMDC260F/16	microSMD005F	nanoSMDC012F	nanoSMDC150F
miniSMDC075F	miniSMDC110F/24	miniSMDC300F	microSMD010F	nanoSMDC016F	nanoSMDC200
miniSMDC010F	miniSMDC125F		microSMD035F	nanoSMDC035F	
miniSMDC014F	miniSMDC150F		microSMD050F	nanoSMDC050F/13.2	
miniSMDC020F	miniSMDC150F/12		microSMD075F	nanoSMDC075F	
miniSMDC030F	miniSMDC150F/24		microSMD110F	nanoSMDC110F	
miniSMDC050F	miniSMDC150F/16		microSMD150F		
miniSMDC075F	miniSMDC160F				
miniSMDC075F/24	miniSMDC200F				
miniSMDC075F/33	miniSMDC200F/16				
miniSMDC100F	miniSMDC260F				
miniSMDC110F	miniSMDC260F/13.2				
pico SMD		femto SMD	Straps Devices		Reflowable and Weldable
	picoSMDC010S	femtoSMDC005F	VLP120UF	MXP180	MGP450
	picoSMDC012S	femtoSMDC010F	VLP175UAF	MXP190BB	MGP500
	picoSMDC020S	femtoSMDC012F	VTP110F	MXP270ZL	
	picoSMDC035S	femtoSMDC016F			
	picoSMDC075S	femtoSMDC020F			
	picoSMDC110S	femtoSMDC035F			

Table 2. Littelfuse's recommended PolySwitch product for LPS applications.

\* Selection of the appropriate circuit protection device depends on the end use application, in addition to the relevant tests and electrical specifications. If devices with specific performance characteristics requirements are not listed here, please contact Littelfuse to request information.

### Notice:

Information furnished is believed to be accurate and reliable. However, users should independently evaluate the suitability of and test each product selected for their own applications. Littelfuse products are not designed for, and shall not be used for, any purpose (including, without limitation, military, aerospace, medical, life-saving, life-sustaining or nuclear facility applications, devices intended for surgical implant into the body, or any other application in which the failure or lack of desired operation of the product may result in personal injury, death, or property damage) other than those expressly set forth in applicable Littelfuse product documentation. Warranties granted by Littelfuse shall be deemed void for products used for any purpose not expressly set forth in applicable Littelfuse documentation. Littelfuse shall not be liable for any claims or damages arising out of products used in applications not expressly intended by Littelfuse as set forth in applicable Littelfuse documentation. The sale and use of Littelfuse products is subject to Littelfuse Terms and Conditions of Sale, unless otherwise agreed by Littelfuse.