Reverse Current/Battery Protection Circuits

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ABSTRACT

Users of battery powered equipment expect safeguards to prevent damage to the internal electronics in the event of reverse battery installation, accidental short circuiting, or other inappropriate operation. These safeguards can be either mechanical or electronic. An example of a mechanical safeguard is requiring the use of special connectors and instructional pictures and symbols. For example, a 9-V battery has different terminals, and its rechargeable battery packs are physically designed for one direction of insertion. Other battery types, like single-cell alkaline, are not so easily protected by mechanical safeguards. Therefore, battery powered equipment designers and manufacturers must ensure that any reverse current flow and reverse bias voltage is low enough to prevent damage to either the battery itself or the equipment's internal electronics. To provide these electronic safeguards, manufacturers typically chose either a diode or transistor for reverse battery protection.

Using a Diode

The simplest protection against reverse battery protection is a diode in series with the battery, as seen in Figure 1.

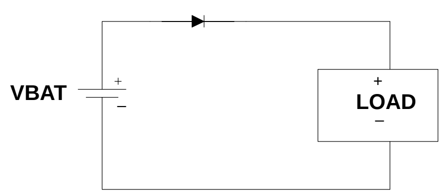

Figure 1. Diode in Series With Battery

In Figure 1, the diode becomes forward biased and the load's normal operating current flows through the diode. When the battery is installed backwards, the diode reverse–biases and no current flows. This approach is used for any battery type, from single-cell alkaline to multiple Li-Ion, but it has two major disadvantages. The forward voltage drop across the diode shortens the usable battery life, i.e., a dual alkaline battery pack capable of providing 1.8 V, is limited to 1.8 V – 0.6 V = 1.2 V. In addition, the efficiency of the power circuitry (e.g., a boost converter) following the battery suffers due to this drop. To minimize these disadvantages, many designers use a Schottky diode, since its forward drop is lower than that of a regular diode. However, the disadvantage of using a Schottky diode is that it is more expensive than a standard diode.

Using a FET

The most recent MOSFETs are very low on resistances, and therefore, are ideal for providing reverse current protection with minimal loss. Figure 2 shows a low-side NMOS FET in the ground return path and Figure 3 shows a high-side PMOS FET in the power path.

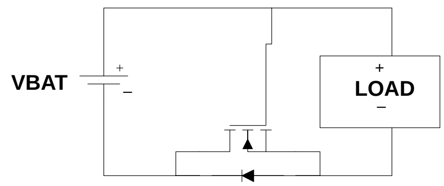

Figure 2. NMOS FET in the Ground Return Path

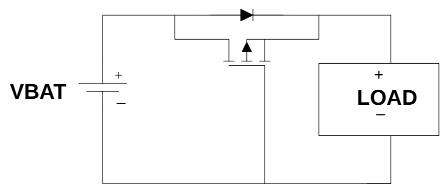

Figure 3. PMOS FET in the Power Path

In each circuit, the FET's body diode is oriented in the direction of normal current flow. When the battery is installed incorrectly, the NMOS (PMOS) FET's gate voltage is low (high), preventing it from turning on.

When the battery is installed properly and the portable equipment is powered, the NMOS (PMOS) FET's gate voltage is taken high (low) and its channel shorts out the diode

A voltage drop of $r_{DS(on)} \times I_{LOAD}$ is seen in the ground return path when using the NMOS FET and in the power path when using the PMOS FET. In the past, the primary disadvantage of these circuits has been the high cost of low $r_{DS(on)}$, low-threshold voltage FETs. However, advances in semiconductor processing have resulted in FETs that provide minimal drops in small packages. Some of the latest FET's threshold voltages and $r_{DS(on)}$'s are shown in Table 1.

Table 1. Small Packaged FETs With Low $r_{ds(on)}$

MANUFACTURER	PART NO	PACKAGE	$r_{DS(on)}$
NMOS			
IRF	ILRML2502	SOT–23	80 mΩ at 2.7 V
Vishay	Si2312	SOT–23	51 mΩ at 1.8 V
PMOS			
IRF	ILRML6401	SOT–23	85 mΩ at 2.7 V
Vishay	Si2323	SOT–23	68 mΩ at 1.8 V

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