Reverse Battery Protection With the TPS27081A

Michael Schultis

ABSTRACT

In portable electronic equipment, there are many times throughout the lifetime of the device when the battery needs to be changed. Typically, there are indicators for the polarity of the battery, but if the battery is placed into the device incorrectly, it is possible that the electronic equipment could be permanently damaged. Adding protection circuitry can ensure that no damage occurs by disconnecting the battery from the circuit in the event of reverse polarity. The TPS27081A device is described as a 1.2-V to 8-V, 3A PFET High-Side Load Switch, which is typically used to disconnect high power consumption peripherals when not in use, but with slight schematic changes, it can be used to implement reverse battery protection. This application report describes how to implement this reverse battery protection and details the advantages, implementation, schematic, and layout.

Contents

1 TPS27081A Device ........................................................................................................ 2
2 Implementation ........................................................................................................... 3

List of Figures

1 TPS27081A Functional Block Diagram ................................................................................ 2
2 Correct Battery Polarity ................................................................................................. 3
3 Reverse Battery Polarity ............................................................................................... 3
4 AA Battery Tester With Incorrect Polarity ....................................................................... 3
5 AA Battery Tester With Correct Polarity ....................................................................... 3
6 Reverse Battery Protection Schematic ............................................................................ 4
7 Reverse Battery Protection Layout Example .................................................................... 4
1 TPS27081A Device

The TPS27081A device is a 1.2-V to 8-V load switch that integrates a Power PFET and Control NFET in a very small package as shown in Figure 1. The TPS27081A device has the following features:

- Low ON-Resistance, High-Current PFET
  - $R_{DS(on)} = 32 \, \text{m} \Omega$ at $V_{GS} = -4.5 \, \text{V}$
  - $R_{DS(on)} = 44 \, \text{m} \Omega$ at $V_{GS} = -3 \, \text{V}$
  - $R_{DS(on)} = 82 \, \text{m} \Omega$ at $V_{GS} = -1.8 \, \text{V}$
  - $R_{DS(on)} = 93 \, \text{m} \Omega$ at $V_{GS} = -1.5 \, \text{V}$
  - $R_{DS(on)} = 155 \, \text{m} \Omega$ at $V_{GS} = -1.2 \, \text{V}$
- Adjustable Turnon and Turnoff Slew Rate Control Through External R1, R2, and C1
- Supports a Wide Range of 1.2-V to 8-V Supply Inputs
- Integrated NMOS for PFET Control
- NMOS ON/OFF Supports a Wide Range of 1-V to 8-V Control Logic Interface
- Full ESD Protection (All Pins)
  - HBM 2 kV, CDM 500 V
- Ultra-Low Leakage Current in Standby (Typical 100 nA)
- Available in Tiny 6-Pin Package
  - 2.9 mm × 2.8 mm × 0.75 mm SOT (DDC)

The TPS27081A, outside of being used as a high-current load switch, can be used in a unique way. In any electronic device, if a battery is placed into the battery socket with an inverted polarity, there is potential for the onboard devices to see an inverted voltage that could cause permanent damage. In order to prevent damage to the electronics, there must be some form of reverse battery protection. The TPS27081A can be used for reverse battery protection, and has the following advantages for being used to protect against inverted voltage:

- PFET connected to power path without driver circuitry
- Low power dissipation in comparison to a comparable diode solution
- Capable of high constant current, up to 3 A
- Enabled with as low as 1.0 V, suitable for all battery voltages, including rechargeable
- Lower profile package compared to standard SOT23 package
- Better thermal dissipation as compared to SOT23 package
- Integrated ESD cells aid in system level ESD protection
2 Implementation

The high current PFET is connected in the power path to allow current flow when the battery is connected properly and prevent current flow when the battery polarity is inverted. With the battery inserted correctly, as shown in Figure 2, it ensures a negative $V_{GS}$ voltage, turning on the FET and allowing the supply to be connected to the load with minimal power consumption. With the battery polarity reversed, as shown in Figure 3, the $V_{GS}$ voltage is positive, ensuring that the battery is disconnected from the load. The VOUT pin normally acts as the drain for this device, but in this configuration VOUT acts as the source pin. Therefore the full battery voltage becomes the $V_{GS}$ to enable a low on-state resistance.

![Figure 2. Correct Battery Polarity](image1)

![Figure 3. Reverse Battery Polarity](image2)

2.1 TPS27081A in AA Battery Voltage Tester (TIDA-00670)

Additionally, one of the key considerations for using a PFET for reverse battery protection is the direction of the body diode. The body diode of the PFET should point in the direction of the load. If the body diode were not directed toward the load, then even though the FET would be off, the body diode could conduct, thereby completing the reverse polarity conduction path.

This reverse battery protection scheme was implemented in the Low-Cost, Flexible Voltage Supervisor and Battery Tester Reference Design (TIDA-00670). Figure 4 displays the battery tester without the correct orientation, and the TPS27081A is providing protection to the board circuitry. After the battery was placed into the socket incorrectly as shown in Figure 4, Figure 5 shows the battery tester with the correct polarity. The battery tester reads the voltage of the battery indicating that the circuitry was not damaged and is working appropriately.

![Figure 4. AA Battery Tester With Incorrect Polarity](image3)

![Figure 5. AA Battery Tester With Correct Polarity](image4)
### 2.2 Example Schematic

Figure 6 is an example of the schematic for using the TPS27081A.

**NOTE:** The pinout for this device is designed for a load switching application, so when using the device for reverse battery protection the VOUT is connected to the supply (battery) and VIN is connected to the load. The R1/C1 pin must be connected to the negative terminal of the battery. The R2 and ON/OFF pins may be left floating, but TI recommends that the pins connect to the negative terminal of the battery to improve thermal performance.

The VOUT pin normally acts as the drain for this device, but in this configuration acts as the source pin. Therefore the full battery voltage becomes the $V_{gs}$ to enable a low on-state resistance.

![Figure 6. Reverse Battery Protection Schematic](image)

### 2.3 Example Layout

Figure 7 is an example layout for using the TPS27081A as reverse battery protection. Use polygon pours on all pins to help with thermal dissipation when the load requires large supply current. Vias to the board ground are recommended for better thermal performance.

![Figure 7. Reverse Battery Protection Layout Example](image)
**IMPORTANT NOTICE**

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as “components”) are sold subject to TI’s terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI's terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers' products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers' products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI’s goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or “enhanced plastic” are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have not been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

### Products
- **Audio**: www.ti.com/audio
- **Amplifiers**: amplifier.ti.com
- **Data Converters**: dataconverter.ti.com
- **DLP® Products**: www.dlp.com
- **DSP**: dsp.ti.com
- **Clocks and Timers**: www.ti.com/clocks
- **Interface**: interface.ti.com
- **Logic**: logic.ti.com
- **Power Mgmt**: power.ti.com
- **Microcontrollers**: microcontroller.ti.com
- **RFID**: www.ti-rfid.com
- **OMAP Applications Processors**: www.ti.com/omap
- **Wireless Connectivity**: www.ti.com/wirelessconnectivity

### Applications
- **Automotive and Transportation**: www.ti.com/automotive
- **Communications and Telecom**: www.ti.com/communications
- **Computers and Peripherals**: www.ti.com/computers
- **Consumer Electronics**: www.ti.com/consumer-apps
- **Energy and Lighting**: www.ti.com/energy
- **Industrial**: www.ti.com/industrial
- **Medical**: www.ti.com/medical
- **Security**: www.ti.com/security
- **Space, Avionics and Defense**: www.ti.com/space-avionics-defense
- **Video and Imaging**: www.ti.com/video

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265  
Copyright © 2016, Texas Instruments Incorporated