

# LM3641

## *LM3641 Application Information Guide*



Literature Number: SNOA813

## LM3641 Application Information Guide

National Semiconductor  
Application Note 1067  
Greg J Smith  
Luc Van de Perre  
March 2004



### INTRODUCTION

The LM3641 Lithium Protection Integrated Circuit resides inside a 3.6V Lithium-Ion battery pack consisting of a single cell or multiple parallel cells. The IC controls the ON/OFF state of a pair of low threshold N-channel power MOSFETs placed in series with the battery cell(s). The purpose of this MOSFET pair is to protect the cell(s) from inadvertent electrical over-stress. The IC compares the cell voltage against internally programmed minimum and maximum limits.

The IC also monitors the bi-directional current flow in the battery pack by measuring the voltage across a robust 4 mΩ current sensing resistor internal to the protection IC package. The IC turns OFF the MOSFET pair whenever any fault limit is exceeded. The limits for overcharge and overdischarge voltage, as well as independent limits for each direction of overcurrent are factory adjusted employing EEPROM. A Control pin allows external ON/OFF control of the MOSFET pair and resets the IC after the MOSFET pair is turned off and the pack is safe to operate again.

In this application note, there will be a description of the Low Cell Charge Enable (LCCE) feature and the Active Rectification (AR) feature.

### LOW CELL CHARGE ENABLE FEATURE

Low Cell Charge Enable (LCCE) is a passive method of enabling the cell to be charged when the cell voltage is too low to keep the active IC circuitry operational. The circuit in *Figure 1* illustrates the effective signal path to the GATE pin of the IC resulting from a connection of a charger to the pack. The base of the PNP is pulled low with bias current from the charger through R1 and the NPN. The collector of the PNP is high on the GATE pin. When the cell voltage is high enough to power up the rest of the IC, the logic will short the base-emitter of the PNP with switch, S1. This occurs at about 1.4V. The logic is able to determine at this time if a charger is applied to the pack and turn on the normal switches that activate GATE = V<sub>DD</sub> drive with switch S2.

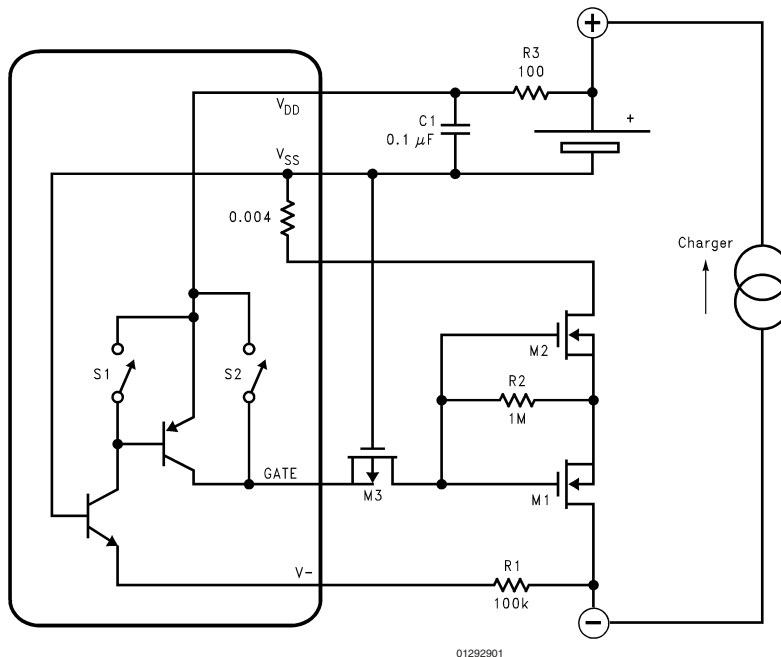


FIGURE 1. Low Cell Charge Enable Circuit

The various PCB voltages related to LCCE operation are shown in *Figure 2*. This plot illustrates the relative value of terminal voltages versus cell voltages that ranges from 0V to greater than V<sub>MAX</sub>. The GATE pin of the IC tracks the cell voltage as it increases from 0V, except for a narrow flat

region. This flat region occurs between the point that the M3 cascode can conduct and the logic of the IC powers up. The reason for the flat region will be explained. First, notice the gate voltage of the power MOSFETs M1 and M2. These FETs do not turn on until the initial conduction of M3 and also

## LOW CELL CHARGE ENABLE FEATURE (Continued)

exhibit the flat region of operation. The power FETs' gate voltage equals the cell voltage beyond this region and below  $V_{MAX}$ . Next, the IC's V- pin voltage is seen as being slightly below 0V ( $V_{SS}$ ) whenever  $V_{CELL}$  is less than approximately 1.4V. This is because the power FETs have not turned on, or fully turned on, the V- pin is pulled below 0V. The V- pin voltage is determined by the  $V_{BE}$  of the NPN for the bias

current allowed by R1. The V- terminal of the pack follows the same track as the V- pin of the IC except during the flat region. This is because during the flat region, the pack's V- terminal is set by the  $V_{GS}$  of the power FET's necessary to conduct the charger's compliance current. The pack's components operate in a feedback loop in the flat region. The PNP drive to the GATE pin can not pull any higher without also pulling the IC's V- pin higher, which would deprive base current to the PNP.

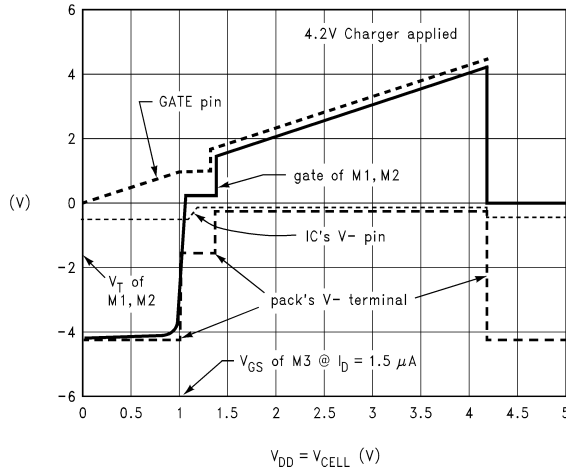


FIGURE 2. FET Drive vs CELL Voltage (Charging)

The cell voltage that allows the power FETs to initially conduct is determined by the threshold voltage of M3. When  $V_{CELL} = M3's V_{GS(ON)}$  for  $I_D = V_{T(M1)}/1 \text{ m}\Omega$ , then the M1 and M2 are able to start conducting. This is also the start of the flat region. In the flat region loop that maintains the PNP in the active region keeps the power FETs on. Finally at  $\approx 1.4V$ , the IC's logic will now pull the GATE pin high in open loop mode.

If at any time the charger is removed and the cell voltage is below  $V_{MIN}$ , then the GATE pin will turn off and the power FETs will not conduct.

## ACTIVE RECTIFICATION FEATURE

**Notes**

AN-1067

## Notes

### LIFE SUPPORT POLICY

NATIONAL'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF THE PRESIDENT AND GENERAL COUNSEL OF NATIONAL SEMICONDUCTOR CORPORATION. As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury to the user.
2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

### BANNED SUBSTANCE COMPLIANCE

National Semiconductor certifies that the products and packing materials meet the provisions of the Customer Products Stewardship Specification (CSP-9-111C2) and the Banned Substances and Materials of Interest Specification (CSP-9-111S2) and contain no "Banned Substances" as defined in CSP-9-111S2.



**National Semiconductor  
Americas Customer  
Support Center**  
Email: [new.feedback@nsc.com](mailto:new.feedback@nsc.com)  
Tel: 1-800-272-9959

[www.national.com](http://www.national.com)

**National Semiconductor  
Europe Customer Support Center**  
Fax: +49 (0) 180-530 85 86  
Email: [europe.support@nsc.com](mailto:europe.support@nsc.com)  
Deutsch Tel: +49 (0) 69 9508 6208  
English Tel: +44 (0) 870 24 0 2171  
Français Tel: +33 (0) 1 41 91 8790

**National Semiconductor  
Asia Pacific Customer  
Support Center**  
Email: [ap.support@nsc.com](mailto:ap.support@nsc.com)

**National Semiconductor  
Japan Customer Support Center**  
Fax: 81-3-5639-7507  
Email: [jpn.feedback@nsc.com](mailto:jpn.feedback@nsc.com)  
Tel: 81-3-5639-7560

National does not assume any responsibility for use of any circuitry described, no circuit patent licenses are implied and National reserves the right at any time without notice to change said circuitry and specifications.

## IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

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

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

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI 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 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. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

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

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

### Products

Audio	<a href="http://www.ti.com/audio">www.ti.com/audio</a>
Amplifiers	<a href="http://amplifier.ti.com">amplifier.ti.com</a>
Data Converters	<a href="http://dataconverter.ti.com">dataconverter.ti.com</a>
DLP® Products	<a href="http://www.dlp.com">www.dlp.com</a>
DSP	<a href="http://dsp.ti.com">dsp.ti.com</a>
Clocks and Timers	<a href="http://www.ti.com/clocks">www.ti.com/clocks</a>
Interface	<a href="http://interface.ti.com">interface.ti.com</a>
Logic	<a href="http://logic.ti.com">logic.ti.com</a>
Power Mgmt	<a href="http://power.ti.com">power.ti.com</a>
Microcontrollers	<a href="http://microcontroller.ti.com">microcontroller.ti.com</a>
RFID	<a href="http://www.ti-rfid.com">www.ti-rfid.com</a>
OMAP Mobile Processors	<a href="http://www.ti.com/omap">www.ti.com/omap</a>
Wireless Connectivity	<a href="http://www.ti.com/wirelessconnectivity">www.ti.com/wirelessconnectivity</a>

### Applications

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

TI E2E Community Home Page

[e2e.ti.com](http://e2e.ti.com)

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265  
Copyright © 2011, Texas Instruments Incorporated