LM317

Adjustable 3-Terminal Regulator for Low-Cost Battery Charging Systems

Literature Number: SNVA581
Adjustable 3-Terminal Regulator for Low-Cost Battery Charging Systems

With the introduction of the LM317, a 3-terminal adjustable regulator, it becomes relatively easy to design high-performance, low-cost battery charging systems. Even single battery cells can be charged on this new regulator, which is adjustable down to 1.2V. The internal protection circuitry can be used to limit charging current as well as to protect against overloads. The output voltage is easily adjusted so multiple voltage chargers can be made.

The ability to accurately adjust the output voltage of the LM317 makes it especially attractive for constant voltage battery charging applications. Batteries are most quickly charged by “constant-voltage” charging circuits; however, close control of the charging voltage is necessary to prevent overcharging, especially with nickel cadmium cells. The internal protection circuitry of the LM317 is helpful in protecting against accidental overload conditions commonly occurring in charging systems.

Internal Current Limit

The peak charging current or output current is controlled by the internal current limit of the LM317. This current limit will work even if a battery is connected backwards to the output of the charger. Should a fault condition exist for an extended period of time, the thermal limiting circuitry will decrease the output current, protecting the regulator as well as the transformer. A constant voltage charger circuit is shown in Figure 1. The output voltage is set with resistors R2 and R3 and given by

\[ V_{OUT} = 1.25 \left(1 + \frac{R_3}{R_2}\right) \]

Since, in low cost applications, no filter capacitors are used on the output of the rectifier, the battery is only charged on the peaks of the sine wave. This requires the peak output voltage from the transformer to be at least 50% greater than the battery voltage plus 3V. However, little cost premium should result since the average current from the transformer is lower than capacitive input filter circuits. Optional resistors R1 and R2 are used to further control the charging characteristics. Resistor R1 controls the output impedance of the charger allowing a “taper-charge” characteristic to be generated. The LM317 can also be used to limit the peak charging current to a partially charged battery at a value other than the regulator current limit. With R1 in the circuit, the output impedance is:

\[ Z_{OUT} = R_1 \left(1 + \frac{R_3}{R_2}\right) \]

Including R1 in the feedback loop decreases the value of resistor needed for a particular output impedance reducing cost and power dissipation.

For example, with a 6V gelled electrolyte battery the regulator can be set to give a 6.9V output. Nominally, the battery is discharged to about 5V, making R1 0.4Ω output impedance and limiting the charging current to 0.5A at the start of charging rather than the internal current limit of the regulator. With a fully discharged battery or under short circuit conditions, the peak output current is still 2A for the LM317K with the resistor dissipating 1.6A as opposed to 8W if a 2Ω resistor were used directly in series with the battery. Resistor R4 can be included to provide a low “topping-up” current for a charged battery.

This regulator configuration provides some other important features to the charger. If input power is removed and a fully charged battery is connected to the charger output, there is no damage. Under these conditions about 5 mA of current will be drawn by divider R2, R3. Since there is no ground connection to the LM317 regulator, very little current flows through the LM317. In this respect, the LM317 differs from other 3-terminal regulators, which can be damaged by applying power to the output terminal with the input open-circuited. If the battery is connected backwards, the LM317 will current limit and thermal limit normally, protecting the charger.

Decreasing Current Limit

Adding a single NPN transistor can be used to decrease the current limit of the charge as shown in Figure 2.
Decreasing Current Limit (Continued)

Resistor R1 senses the output current and turns on Q1 when $I_{\text{OUT}}$ equals about 0.6V. Transistor Q1 pulls the adjustment terminal negatively decreasing the output voltage and controlling the output current. A limitation of this circuit is that it does not work for direct short circuits. The output voltage must be above about 0.6V for the external current limiting to be active. The internal current limit of the LM317, of course, is still operative. This is not usually a problem since batteries charge to above 0.6V very quickly. Resistors R4, R5 and R6 protect the regulator and transistor for both direct short circuits or reverse battery connections.

As illustrated in Figure 3, in float or standby applications, it is desirable to remove all loading from the battery when input power is “OFF.” When power is “ON,” Q1 is saturated, grounding the voltage setting divider R2, R3 and the circuit works in a similar manner to the charger circuit in Figure 1. When power is “OFF,” Q1 is open, eliminating any loading on the battery. A separate pair of low current diodes D1, D2 are necessary to bias Q1, rather than the power bridge rectifier. If R1 was tied to the output of the bridge, reverse current flow through the LM317 would keep Q1 “ON” and loading the battery.

A simple constant current charger for any type of battery is shown in Figure 4. A resistor R1 between the adjustment terminal and the output of the regulator sets the output current at:

$$I_{\text{OUT}} = \frac{1.25}{R_1}$$

Current can be set at anywhere between 10 mA and 1.5A by appropriate resistor choice. Current regulation is very tight at any current level since only 50 µA flows out of the adjustment terminal. This circuit is also immune to damage from shorts or reverse battery connections. The input voltage for regulation should also be about 1.5 times the battery voltage plus 3V.

**Uniquely Suited**

The ability to adjust the output of the LM317 3-terminal regulator makes it uniquely suited for battery charging systems. Little has been included about charging specific types of batteries, since the characteristics of the charger should be matched to the battery. These charger circuits, although very simple, perform well. They are easily modified for voltage, current or even temperature coefficient by making the divider string temperature sensitive. More complex chargers can be made since the output of the LM317 is easily controlled by driving the adjustment terminal. Finally, the chargers are inherently protected against overloads and fault conditions.
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.

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 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 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 and regulatory requirements concerning their products and applications. 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 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:

<table>
<thead>
<tr>
<th>Products</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Audio</td>
<td>Communications and Telecom</td>
</tr>
<tr>
<td>Amplifiers</td>
<td>Computers and Peripherals</td>
</tr>
<tr>
<td>Data Converters</td>
<td>Consumer Electronics</td>
</tr>
<tr>
<td>DLP® Products</td>
<td>Energy and Lighting</td>
</tr>
<tr>
<td>DSP</td>
<td>Industrial</td>
</tr>
<tr>
<td>Clocks and Timers</td>
<td>Medical</td>
</tr>
<tr>
<td>Interface</td>
<td>Security</td>
</tr>
<tr>
<td>Logic</td>
<td>Space, Avionics and Defense</td>
</tr>
<tr>
<td>Power Mgmt</td>
<td>Transportation and Automotive</td>
</tr>
<tr>
<td>Microcontrollers</td>
<td>Video and Imaging</td>
</tr>
<tr>
<td>RFID</td>
<td></td>
</tr>
<tr>
<td>OMAP Mobile Processors</td>
<td></td>
</tr>
<tr>
<td>Wireless Connectivity</td>
<td></td>
</tr>
</tbody>
</table>

TI E2E Community Home Page | e2e.ti.com

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