DALLAS SEMICONDUCTOR

Application Note 54
Increasing Charging Current and Voltage for the DS1633 Battery Recharger

INTRODUCTION

The DS1633 Battery Recharger is designed to be a complete battery charging system for standard charge or trickle charge applications. The device is flexible enough to be used with a variety of battery chemistries and cell capacities. It provides timer termination of standard charge and automatically shifts into trickle charge. Battery voltage may be monitored and charging terminated if it exceeds a preset maximum as a safety feature. The output load line may be specified as the usual constant current recharge with a voltage limit or it may be configured to approximate any practical load line. All parameters, such as power supply range, charge current load line, trickle charge rate, and timer setting, are programmed into nonvolatile memory using the battery pin as a one–wire communication port. This functionality is provided in a small, 3–pin TO–220 package.

The DS1633's functionality is a result of its unique architecture. The device monitors the battery voltage and adjusts the values of the output impedance (R_{TH}) and the open circuit voltage (V_{OC}) it presents to the battery. These values may be adjusted at 32 user–definable points (breakpoints) that occur roughly every 37 mV. This allows the device to approximate a wide range of charging lines and is not limited to constant current or even monotonically decreasing functions.

Using only the DS1633, supply voltages of either 5V or 6V may be used, and battery voltages as high as 4.7V (3.7V for 5V supplies) are allowed. The DS1633 is available in preprogrammed versions, with charging currents up to 100 mA available. These provide for a simple component solution to several battery charging tasks, which users may stock and use when needed.

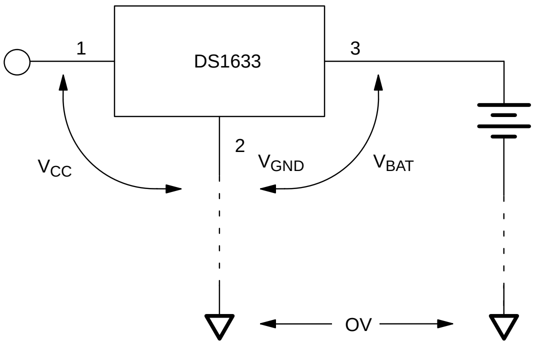
For typical NiCd batteries, the 4.7V limit on battery voltage limits the battery stack to three cells. Many battery packs today use five cells. In addition, with higher capacity battery packs available, there are situations which require charging currents higher than 100 mA. This application note examines some circuit alternatives that allow the DS1633 to be used with battery packs that have more than three cells, or in applications which require higher charging currents. Other circuit features are presented which show how easily the DS1633 can be made into a full–featured charging system.

DEFINITIONS

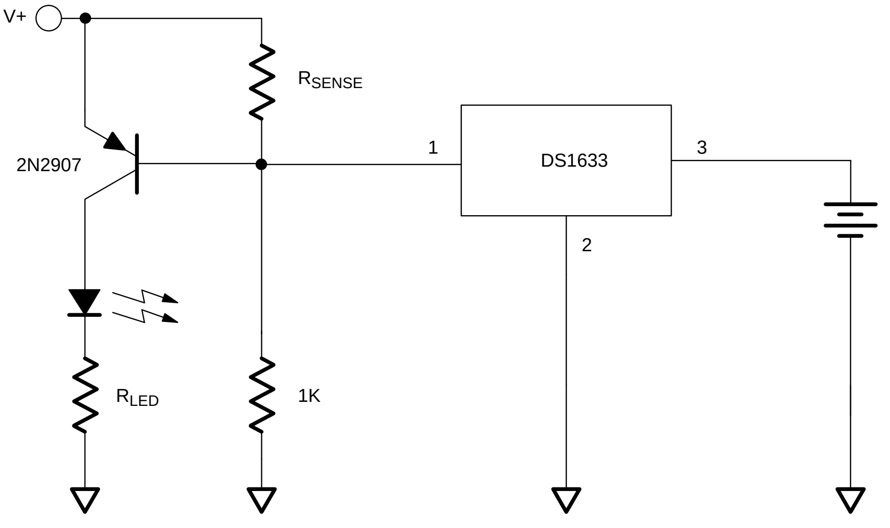
The DS1633 has only three pins, as shown in Figure 1. The voltages which will be referred to throughout this application note are defined in Figure 1 and in the table below.

VOLTAGE	DESCRIPTION	LIMITS
V_{CC}	DS1633 Supply Voltage	5V mode: $4.75V<V_{CC}<6.5V$ referred to V_{GND} 6V mode: $5.7V<V_{CC}<6.5V$ referred to V_{GND}
V_{BAT}	Battery Voltage	5V mode: $0<V_{BAT}<3.7V$ referred to V_{GND} 6V mode: $0<V_{BAT}<4.7V$ referred to V_{GND}
V_{GND}	Ground. All DS1633 voltages are referred to this potential.	None

DS1633 VOLTAGE DEFINITIONS Figure 1



ADDING A CHARGE INDICATION LED Figure 2



$$R_{SENSE} = \frac{0.7V}{I_{CHG}}$$

ADDING AN LED FOR CHARGING INDICATION

Typically, battery chargers have some visual indication that standard charging is taking place and may also indicate trickle charge mode. This feature is easy to add to a DS1633, using the circuit shown in Figure 2.

The DS1633 draws only 1 mA of quiescent current itself. The sense resistor, R_{SENSE}, is selected so that when the charging current begins to be drawn from the V+ supply, 0.7V is dropped across it. This forward–biases the transistor, allowing current to flow out of the transistor's collector to drive the LED. The LED current is limited by R_{LED}.

The values for R_{SENSE} and R_{LED} depend upon the charger application. To turn on the transistor, the voltage drop across R_{SENSE} must be greater than 0.7V. The value for R_{SENSE} may be found by where I_{CHG} is the magnitude of the charging current. The 1K resistor to ground is optional; it may be needed to set a proper operating point for the transistor to switch properly when the DS1633 is in trickle mode.

It is important to note that the voltage drop across R_{SENSE} must be accounted for in the overall charger design; the DS1633's V_{CC} limits must be observed. For example, with a DS1633 in 6V mode, and a charge current of 50 mA, R_{SENSE} would be 14 ohms; a 15 ohm resistor would do fine as the closest available 10% resistor value. This means that 0.75V would be dropped across R_{SENSE}; and so V+ must be in the range 6.45V<V+<6.5V, so that the DS1633's V_{CC} limits are met. The upper limit is not changed by the addition of the resistor, since when the DS1633 goes into trickle mode, the output current will at times drop to zero, so only the quiescent current of the DS1633 is flowing. This would cause the full input voltage to be seen at pin 1. A regulated V+ is therefore necessary.

The value for R_{LED} depends upon the type of LED used, and its desired brightness. Typically, LEDs drop approximately 2V across them, and require 20 mA of drive current for full brightness. Using this information, and assuming that the V_{CESAT} of the 2N2907 is negligible, R_{LED} may be found by

$$R_{LED} = \frac{(V+) - 2V}{20\ mA}$$

For example, using a V+ of 7V as found above, R_{LED} would be 250 ohms for full brightness; a 510 ohm resistor could be used for a slightly dimmer LED. Some LEDs can be driven with as little as 1 or 2 mA; use the lowest current possible to drive the LED in order to reduce the current drive requirements of the power supply for the charger.

One of the interesting aspects of this circuit is its operation in trickle mode. In standard charge mode, the LED will be on all the time. When the DS1633 moves into trickle mode, however, it does so by pulsing the standard charge current at some specified duty cycle. This means that trickle mode will be indicated by the LED blinking at a slow rate. When full charge is achieved, (i.e. the battery voltage limits have been met), current is turned off completely, and the LED will be extinguished. Thus, this indicator can show when the DS1633 is in standard charge mode, in trickle charge mode, and when charging is complete.

INCREASING OUTPUT CURRENT

While the DS1633 is capable of supplying up to 100 mA of charging current, there are situations where more charging current is desired. For example, an 800 mAh battery pack would require almost 13 hours of charging at 100 mA. If the charging current could be increased to 160 mA, this battery could be fully charged in 8 hours.

Preprogrammed DS1633's come in several different charge currents, all with 8 hour timer cutoff. The products that are available preprogrammed, requiring no further programming by the user, are shown in Table 1.

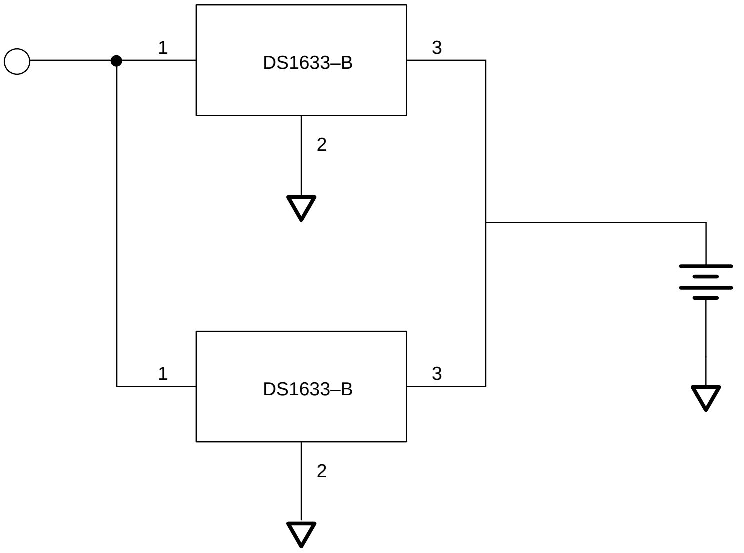
PRODUCT SELECTION GUIDE Table 1

PART NUMBER	I_{MAX} (mA)	V_{MAX} (V)	TIMER (Hours)
DS1633–A	100	4.65	8
DS1633–B	80	4.65	8
DS1633–C	60	4.65	8
DS1633–D	40	4.65	8
DS1633–E	20	4.65	8

Since the DS1633 is essentially a voltage source with an adjustable resistor, it is capable only of sourcing current; it cannot sink current. This fact makes it possible to place any number of DS1633's in parallel, with no need for any external components. It is generally wise, however, to keep the timer lengths of the paralleled parts the same to avoid one going into trickle much before its counterpart does.

Using this approach, the 800 mAh battery may be charged using a charger as shown in Figure 3.

PARALLEL DS1633's Figure 3



The charge indication circuit of Figure 2 may be used with this circuit to provide an indication of charging status.

INCREASING BATTERY VOLTAGE RANGE

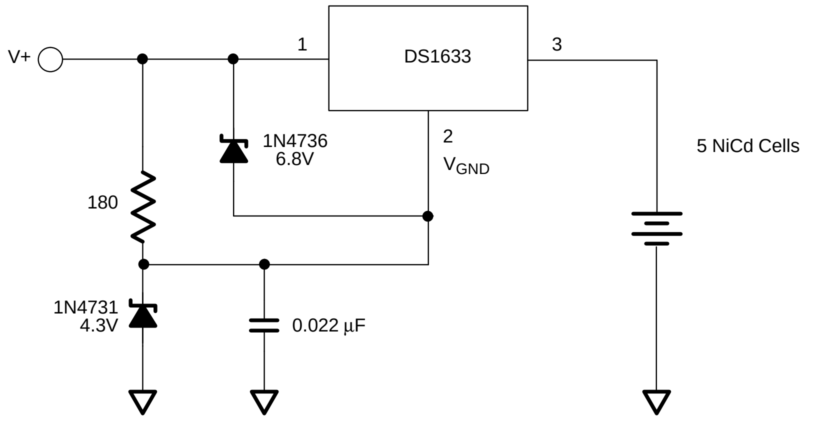
The battery voltage limits on the DS1633 are suitable for NiCd battery packs with up to three cells. With five cell battery packs increasing in usage, a method of charging these battery packs using the DS1633 is desirable.

Since the limit on the battery voltage is 4.7V referred to V_{GND}, it is possible to raise the potential of V_{GND} to keep V_{BAT} within limits. This method allows the DS1633 to charge any number of NiCd cells, with certain constraints.

The circuit of Figure 4 provides the DS1633 with the ability to charge a five cell NiCd battery pack. Typically, a NiCd cell will be considered fully discharged when the cell voltage goes to 0.9V. This means the total voltage across the battery pack at a minimum will be 4.5V. By offsetting the DS1633 GND pin to 4.3V using the zener diode shown, the V_{BAT} referred to ground will range from 0.2V (when the battery potential is 4.5V) to 3.7V (when the battery potential is 8V, in a fully charged condition).

Note that by offsetting the GND pin, the V+ voltage required for the DS1633 is now between 10V and 11.5V (these levels keep V_{CC} between 5.7V and 6.5V referred to V_{GND}).

INCREASING BATTERY VOLTAGE RANGE Figure 4



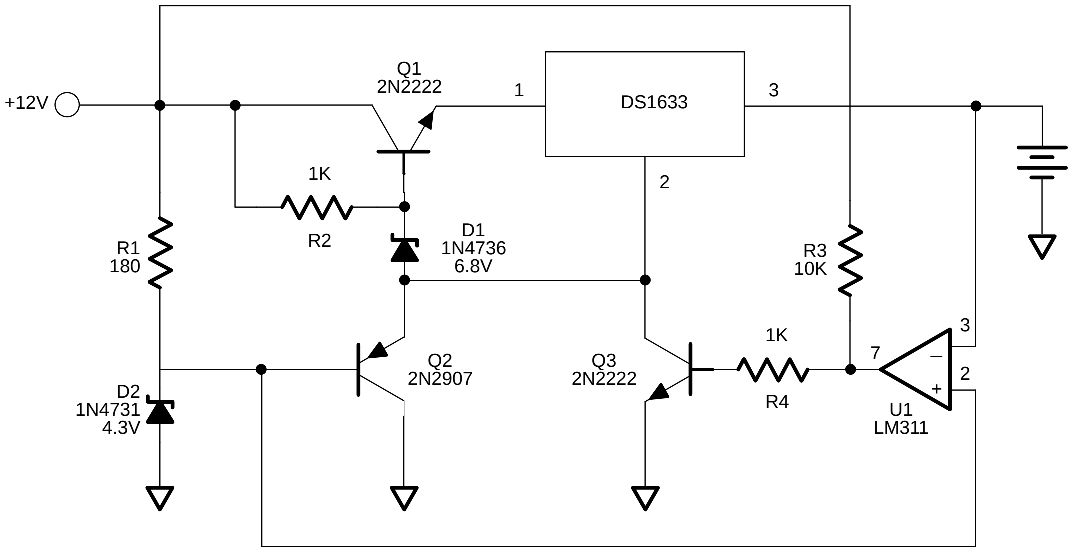
It is possible that the V+ potential may rise faster than the V_{GND} potential from the zener upon power up. If this should happen, the DS1633 may be damaged, or may be placed in a test/programming mode. The 6.8V zener from V_{CC} to V_{GND} assures that this will never happen.

The circuit of Figure 4 will work reliably as long as it is never connected to a battery pack which is discharged below 4.5V. Should the V_{BAT} potential ever fall below that of V_{GND}, substrate diodes will be forward biased and large currents will flow; these may damage the DS1633. Therefore, it is advised that this circuit be used with caution, and only if the battery potentials are well known and controlled.

A circuit which allows battery voltages to go below 4.5V and still will charge batteries with more than three cells is shown in Figure 5. This circuit has several features which will be discussed below.

The first feature of this circuit consists of Q1, R2, and D1; this simple pass voltage regulator supplies the DS1633 with V_{CC} of 6.2V referred to V_{GND} at all times. This serves two purposes, the first of which is to allow the V+ supply for the charger to be a convenient value, such as +12V, rather than requiring a precise 10V or 11V, as with the circuit in Figure 4. The second purpose will become clear in a moment.

BATTERY CHARGER FOR ONE TO FIVE CELLS Figure 5



R1 and D2 set up the offset ground reference voltage, as was done in the circuit of Figure 4. The reference voltage is connected to V_{GND} through Q2, which is configured as an emitter follower. Note that this will place V_{GND} at approximately 0.7V above the zener voltage of D2.

The reference voltage is also fed to a comparator, consisting of U1 and R3. The comparator compares the battery voltage with the reference supplied by R1 and D2.

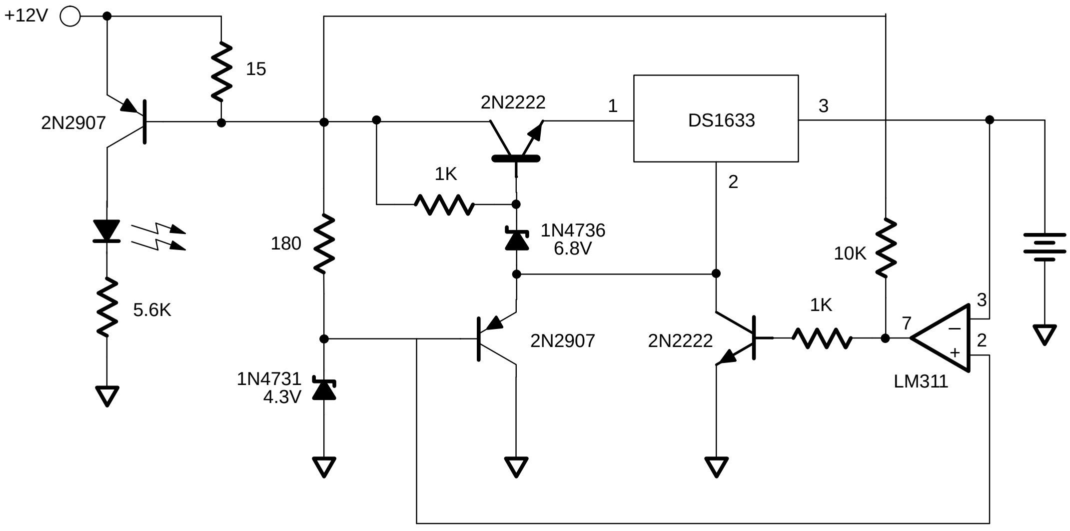
If the battery voltage is below 4.3V, the comparator's output will go high. This will turn on Q3, which will effectively pull V_{GND} down to within a few millivolts of the ground potential. This is good enough to make the DS1633 operate at battery voltages between 0V and 4.3V.

If the battery voltage is above 4.3V, Q3 is turned off, and V_{GND} goes to the reference voltage as supplied through Q2. The change in ground reference voltage is automatic, and will occur during charging if necessary.

It is this ability to dynamically shift the V_{GND} potential which requires the regulator circuit initially discussed. This regulator "floats" with the V_{GND} voltage, and will maintain the proper V_{CC} voltage for the charger for either V_{GND} potential available.

A full–featured charger which provides this automatic battery voltage sensing and charge indication is shown in Figure 6.

FULL FEATURED BATTERY CHARGER Figure 6



Another method of charging batteries with more than three cells is an alternative to the method presented above. Instead of offsetting the DS1633's V_{GND}, it is possible to change the battery's reference point.

This is accomplished by using a bipolar supply to drive the DS1633. The positive side drives the DS1633, while the negative supply is used as the battery reference, as shown in Figure 7.

As with the circuit of Figure 4, this approach works well provided that the battery voltage is greater than 5V at all times. Other negative potentials may be used to adjust the circuit to a specific application.

USING A BIPOLAR SUPPLY TO INCREASE BATTERY VOLTAGE RANGE Figure 7