Simplify Small Solar Systems* with Hysteretic Controller

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Battery-based solar power systems in the 10W–100W range often use a switching regulator to control battery charge. These have the advantage of high efficiency and facilitate peak power point tracking, but only at the cost of an inductor, circuit complexity and noise. As a simpler alternative to a switching regulator, linear control is feasible in applications up to about 20W. While simple and quiet, linear charge controllers generate heat, which must be shed by means of a heat sink. The bulk, cost and assembly complexity of a heat sink somewhat nullify a linear charge controller's perceived advantages over a switching regulator approach.

A hysteretic controller that simply connects or disconnects the solar panel as needed to limit the battery's state of charge provides an excellent anodyne, one devoid of inductors, complexity, noise and heat sinking.

Both series and shunt hysteretic switch topologies are possible. A series configuration opens the connection to the solar panel when the battery has reached its maximum charging voltage, then reconnects when the battery voltage falls to a lower threshold. The chief difficulty with a series configuration is driving the high side switch, which requires either a charge pump for an n-channel implementation or a high voltage, high side gate drive circuit for a p-channel MOSFET.

The preferable shunt arrangement is shown in Figure 1. In this case the switch (S1) turns off when the battery voltage falls below a certain threshold, allowing the solar panel current to charge the battery. When the battery voltage exceeds a second, higher threshold, the switch turns on to divert solar panel current to ground. Diode D1 isolates the battery when S1 shorts the solar panel. The switch is easily implemented with an n-channel MOSFET, directly driven by the output of a ground-referred comparator.

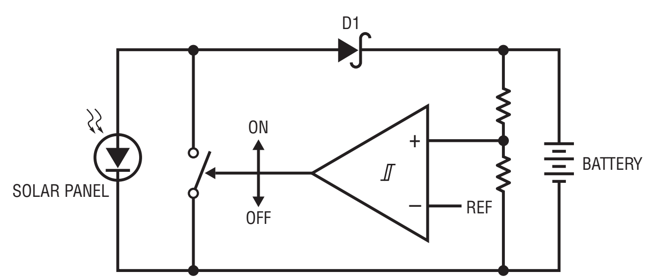

Figure 1. Shunt mode hysteretic switch regulates battery charge in small solar system

Figure 2 shows a complete shunt charge controller for a 12V lead-acid battery using an LTC2965 100V micropower voltage monitor as the controlling element. While it is not monitoring 100V in this application, the LTC2965's 3.5V to 100V operating range generously encompasses the normal voltage range of a 12V battery, with plenty of margin.

The LTC2965 contains a ~78M, 10:1 divider which monitors the battery voltage at the V_{IN} pin. Thresholds are generated from a precision 2.412V reference by a separate, external divider, and compared against the attenuated version of V_{IN}. This arrangement eliminates the need for precise, high value resistors in the main divider.

Hysteresis is developed by switching the comparator's inverting input back and forth between high and low thresholds as set at the INH and INL pins. These trip points determine the voltages at which battery charging commences and terminates.

Other important features include the LTC2965's low power operation (40µA total supply current including Q1's gate drive), built-in 0.5% accurate reference, and hysteretic operation with independent threshold adjustment.

Operation is as follows. Initially, with a battery voltage of less than 13.7V the comparator output is low and Q1 is off, allowing all available solar panel current

* Pun intended.

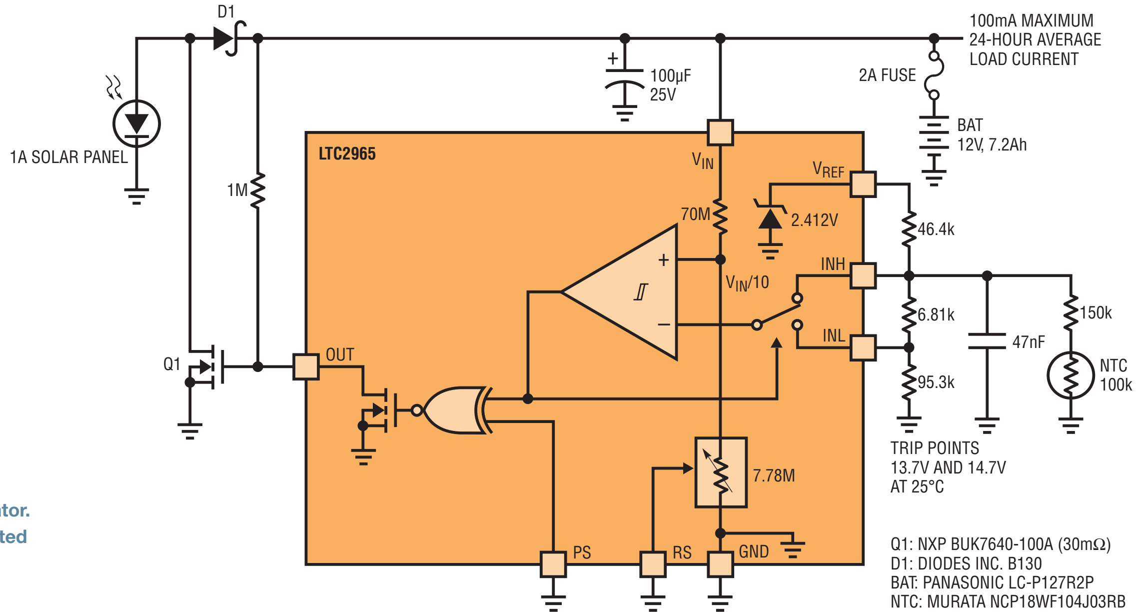

Figure 2. Shunt mode hysteretic regulator. Trip points are temperature compensated from 0°C to 50°C

to pass through D1 to the battery and load. As the battery charges, its voltage rises and upon reaching an upper charging limit of 14.7V, Q1 turns on, shorting the solar panel to ground. D1 isolates the battery from the shunt path. With Q1 on, the battery voltage falls at a rate dependent on the state of charge and the magnitude of the load current. When the battery voltage reaches a lower float limit of 13.7V, Q1 turns off and the panel current is, once again, applied to the battery and load.

This charging scheme shares certain attributes of cycle charging and trickle charging. Initial charging proceeds until the battery voltage reaches 14.7V, whereupon the circuit begins pulse charging to complete the process.

It is important to correctly size the battery and the solar panel for a specific application. As a general rule, choose a maximum or "peak" panel current equal to 10× the load current averaged over a 24-hour period, and a battery ampere-hour capacity equal to 100× this same averaged figure. Peak current of a 36-cell panel is estimated by dividing the panel's claimed "marketing" watts by 15. A 15W panel can be expected to produce ~1A maximum output current under favorable conditions, but this should be verified by actual measurement of the panel under consideration.

These relationships were derived for Milpitas, California to give 4 days' run time on unassisted battery power, with the panel oriented for maximum winter insolation. In the case of Figure 2, the circuit was designed for a continuous 100mA load (2.4Ah/day), dictating the use of a 1A panel and 10Ah battery. The somewhat smaller battery specified in Figure 2 is undersized for about 3 days' operating time, deprived of any solar input.

The charging thresholds are temperature compensated by an NTC thermistor over a 0°C to 50°C range. If operated in a controlled environment, temperature compensation is unnecessary and the thermistor and 150k resistor can be replaced by a fixed, 249k unit. For readers who wish to trim out errors introduced by the 1% resistors, Figure 3 shows a simple scheme for adjusting the charging threshold ±250mV.

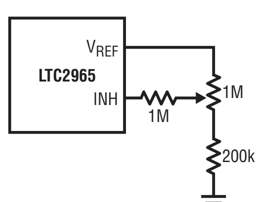

Figure 3. ±250mV trim scheme. Add to V_{REF} and INH pins in Figure 2.

While solar panels are normally directed to collect maximum total energy per annum, a standalone system must be optimized for operation under conditions of minimum seasonal insolation, with allowance made for coincidental weather patterns. The primary concern is solar panel orientation, which is a science unto itself. Calculation of a theoretically ideal, fixed orientation is relatively straightforward; nevertheless a host of non-idealities including atmospheric scattering, fog, clouds, shading, horizon angles and other factors make this science inexact, at best. An excellent overview of this subject may be found at www.solarpaneltilt.com. ■