Solar Charge Controller

for Medium Power Applications

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This article is the companion for the low voltage disconnect circuit in *HP* #60. This circuit regulates the charging of the battery in a solar system by monitoring battery voltage and switching the solar or other power source off when the battery reaches a preset voltage. A charge controller circuit can increase battery life by preventing over-charging which can cause loss of electrolyte. The absence of a relay and its associated coil current makes this circuit efficient for small systems as well as for systems using larger current components.

This charge controller was designed for high efficiency, use of common parts, and operation with common ground circuitry. Some ideas used were inspired by an article in *QST* magazine, but this is a much simplified circuit. A circuit board is available with both the charge controller and low voltage disconnect circuits on one board. The charge controller circuit has been used with solar power input. It also functions well as a battery charger when used with any current limited DC power supply such as small "wall wart" transformers or a high current supply with a series resistor.

Specifications
Night time current drain: 0.6 mA
Operational current drain: 19 mA (less without LEDs)
Maximum solar panel current: 3-10 Amps (see text)
Voltage drop during charging: 0.5 Volts at 1 Amp

Theory
During charging, current flows from the solar panel through diode D1, MOSFET transistor Q1, fuse F1, and into the battery. Power MOSFET transistor Q1 is the main switching device in the charge controller circuit. It connects the solar panel to the battery when it is in need of charging and power is available from the solar panel. As with the LVD circuit, Q1 is set up in a "high side" switch arrangement which allows for a common ground circuit. This is helpful in automotive and other applications. Switching efficiency is very high due to the low "on" resistance of modern power MOSFETS, usually under 0.1Ω. Diode D1 is a Schottky device preventing back currents from flowing from the battery to the solar panel. A regular silicon diode may be used but a Schottky will have a lower forward voltage drop and resulting higher efficiency. Fuse F1 provides a safety limit on the current available from the battery in the event of a short.

Comparator U2 is used to control power to the rest of the charge controller circuit. When the solar panel voltage is lower than the battery voltage, the rest of the circuitry is disabled, reducing night time idle current to the few milliamps consumed by U2 and its associated input circuitry. When the solar panel voltage rises above the battery voltage, the output of U2 goes negative, switching on transistor Q2 which provides power to the rest of the circuit. Resistor networks R1/R13 and R2/R4 scale the battery and solar panel voltages to a range that is useful to U2. Capacitor C23 prevents oscillation in the comparator at start up. Voltage regulator U4 is used as a reference for the battery set points, the reference points are adjusted via resistor network R11, R12, and R3. Comparators U1A and U1B monitor the battery voltage and switch states when the battery is fully charged (U1B) or has dropped to a voltage where charging should resume (U1A). The comparators drive

Above: Charge controller circuit board in action.

a set-reset flip-flop circuit consisting of U3A and U3D. The comparator outputs are inverted logic, on is low and off is high. The output of the flip-flop is used to turn the oscillator consisting of U3B and U3C on and off. The flip-flop also drives the two LEDs used to indicate charging or battery full states. The oscillator generates a 10 kHz square wave that is stepped up to around 25 Volts DC by the voltage doubler circuit of D5, D6, D7, and C7, C8, C21. The gate voltage is higher than the battery's 13 Volts, and is used to turn Q1 on fully. Ferrite bead L2 is used to prevent oscillation in Q1. Resistor R9 discharges the voltage doubler when the oscillator is shut off. The technically picky may note that all of the ICs comparators are really common op-amps, not special purpose comparators. The op-amps are wired in a comparator configuration. The circuit is fairly dependent on the use of 741 and 1458 op-amp parts. Other op-amps may require changing the values of R1 and R2. An equalize switch is included to allow for occasional over-charging of the battery by raising the threshold of the high voltage sensing comparator, forcing the charge current on. Equalizing helps bring lower voltage cells in the battery up to a full charge.

Alignment

Alignment equipment consists of a multi-meter, a charged 12 Volt lead acid battery, and a 0-16 Volts DC variable voltage power supply with a 10Ω 25 watt resistor in series with the positive lead to limit the current. A word of caution is in order when dealing with circuits involving potentially high battery currents: the circuit should be placed on an insulating surface for testing and all wiring should be insulated to lessen the chance of creating a short circuit. Be sure not to reverse the polarity of the battery wires, doing so may damage the circuit. The voltages in this circuit present no shock hazard but the currents present a potential burn hazard.

The first step of the alignment is to set the charge controller turn-on voltage with R13. Start by turning R12 fully clockwise (toward positive) and turn R11 and R13 fully counter-clockwise (towards ground). Connect the charged 12 Volt battery to the battery terminals and connect the current limited variable power supply to the solar panel input on the charge controller. Connect the volt meter across the Schottky Diode D1 with the negative volt meter lead on the cathode (bar end) of the diode. Adjust the variable supply from zero up to around 13 Volts until the meter reads about 0.3 Volts across the diode. Slowly turn R13 clockwise until the red LED just turns off, now turn R13 counter-clockwise again until the red LED just turns on.

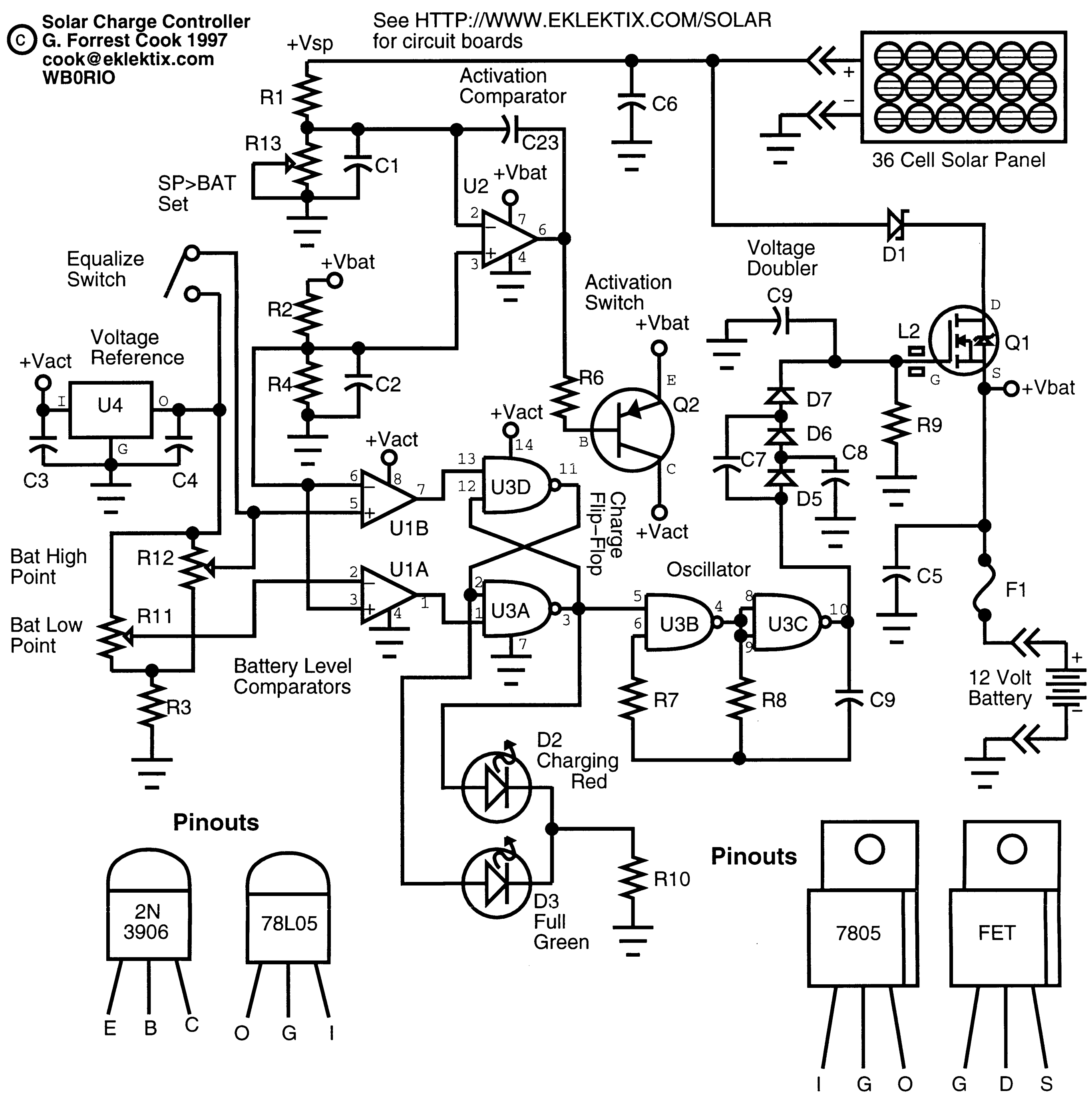
The second and third alignment steps involve setting the low and high points that the battery will alternate

Above: Prototype charge controller on perf board.

between when it is fully charged. Connect the volt meter across the battery for this step. Turn the variable voltage supply to 15 Volts. Adjust R12 counter-clockwise until the green LED turns on. Adjust R11 clockwise until the red LED turns on. At this point, the charge controller should be functioning and the LEDs should alternate. Adjust R12 until the battery voltage peaks at the desired high charge point. Richard Perez recommends setting the high charge point to 13.8 Volts for sealed gel-cells and to 14.5 Volts for flooded cell (wet) lead-acid batteries. Richard also notes that these values are for solar applications where the sun only shines for part of the day, the values should be lower for applications with continuous power sources. The battery low set point should be set to 0.5 to 1 Volts lower than the high set point, adjust R11 until the battery drops to the desired voltage before the charging cycle begins again. In a properly adjusted circuit, the two LEDs should alternate several times per minute. This varies with battery and solar panel capacities. If the battery voltage drops too slowly during the test, it may be helpful to connect a small 12 Volt lamp across the battery, this will cause the battery to discharge faster. It may also help to adjust the voltage of the variable supply, this will vary the charging current and duty cycle of the flip-flop.

Current Capacity

The current handling capacity of this circuit is determined by the MOSFET transistor Q1, diode D1, fuse F1, and the current carrying wires in the path between the solar panel and the battery. An IRFZ34 MOSFET is rated at 30 Amps max and should easily handle 10 Amp charging currents. A heat sink should be used on the MOSFET and diode D1 if you are running



currents higher than 2 or 3 Amps through the circuit. The peak current may be determined from the solar panel specs. Diode D1 can be an IR 80SQ045 when the max current is less than 8 Amps. higher current diodes such as the GI MBR1045GI rated at 10 Amps may also be used with a heat sink. For efficiency, it is important to use a Schottky barrier diode since it has a voltage drop of around 0.4 Volts under load while a regular silicon diode has a voltage drop of around 0.8 Volts under load. At 5 Amps, the silicon diode would waste 4 Watts while the Schottky diode wastes only 2 Watts. The circuit board version of this circuit can handle about 8 Amps maximum if the proper semiconductors are used. The fuse should be rated the same as the maximum current of the FET or diode D1, whichever is lower.

Construction

I built the prototype circuit on perforated circuit board using point to point wiring. Teflon insulation over tinned bare wire works well and does not melt under a soldering iron. Be careful not to overheat any of the

Parts List

U1	1458 dual op-amp
U2	741 op-amp
U3	4011 CMOS quad nand gate IC
U4	78L05 or 7805 voltage regulator IC
Q1	IRFZ34 power MOSFET, see text
Q2	2N3906 PNP silicon transistor
D1	80SQ045, or MBR1045GI Schottky diode, see text
D2	Red LED
D3	Green LED
D5-D7	1N4148 silicon switching diode
C1-C8,C21,C23	0.1µF ceramic disc capacitor
C9	0.001µF ceramic disc capacitor
C20	100µF 16V electrolytic capacitor
R1-R3,R7	100KΩ 1/4w resistor
R4	39KΩ 1/4w resistor
R6,R10	2.2KΩ 1/4w resistor
R8	47KΩ 1/4w resistor
R9	1MΩ 1/4w resistor
R11-R13	100KΩ 10 or 15 turn trimmer potentiometer
F1	DC fast blow fuse, see text
L2	ferrite bead or 3 turns #24 wire on a 22 Ω 1/4w resistor
Heat Sink	TO-220 finned heat sink on Q1 for greater than 3A capacity (don't ground the Q1 tab, it's hot)
Battery	12 Volt lead acid flooded or gel cell battery
Solar Panel	36 cell photovoltaic panel, see text about maximum current

semiconductors, especially the LEDs. IC sockets may save a lot of time and grief in circuit debugging. Wires between the solar panel, D1, Q1, F1, and the battery should be heavy gauge to handle the charging current. Be sure to use thick wires for the current carrying part of the circuit. In the prototype I built the circuit into a small plastic box and used banana plugs as connectors for the input and output terminals.

Use

Connect the solar panel to the solar panel terminals and the battery to the battery terminals and watch the battery charge up. When the LEDs alternately blink, the battery is charged. A load may be connected between ground and the fused C5-Q1 source junction if the load current is lower than the fuse rating. The circuit board has the companion LVD circuit connected in at this point. Be sure to use battery cables that can handle the load current. If the circuit is to be connected to a high current source such as an automobile cigarette plug or a high current capable power supply instead of a solar panel, it will be necessary to use a high wattage series resistor between the positive power source and the charge controller solar panel input. A 10Ω, 25 watt resistor would be a good value to start with.

Access

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Circuit Board: A blank 3 by 4.5 inch circuit board with this charge controller and the low voltage disconnect circuit shown in HP #60 is available from Eklektix, Inc. for $20. An 8 Amp circuit board and parts kit is available for $45. An 8 Amp assembled and tested circuit board is available for $60. US Postage is included, we are not set up to do foreign orders yet. Assembly instructions are included with bare boards and kits. Make a postal money order or check out to Eklektix, Inc.

Parts

Digi-Key • 1-800-DIGIKEY
Newark Electronics • 1-800-4NEWARK
Mouser Electronics • 1-800-346-6873

Article

The FET Charge Controller, by Michael Bryce • WB8VGE, *QST*, January 1992