TIER Solar Charge Controller

27 January 2010

1 Specifications

- 100 W for a 12 V system
- 160 W for a 24 V system
- Panel voltage up to 60V
- MPPT
- Optimized battery charging
- LVDC
- Voltage and current reporting
- Temperature sense and reporting
- Serial interface
- Load disconnect on serial receive
- Grid powered source connections

2 Power Rating

The controller can handle any combination of panels up to an open circuit voltage of 60 Volts. Output power to the battery and load are dependent on the battery voltage selected. For a 12 Volt system, the controller can handle up to 100 W. For a 24 Volt system, output power is 160 W. The difference in power handling is primarily due to the power ratings of the devices used. The power conversion circuit can safely handle higher voltages. Output current is limited to 10 A.

A switch mode converter centered around the LT3800 high-voltage step down converter chip couples the solar panel to the battery and the load. The converter can handle input voltages up to 60 Volts. The converter output base voltage is selectable between 12 V or 24 V. Incremental voltage adjustments from the base voltage are also provided to enable maximum power point tracking either for the 12 V or 24 V system. The converter is designed for output currents of up to 10 A.

3 MPPT

The controller continuously adjusts the voltage conversion to achieve maximum power from the solar panels, and maximize the charge current to the battery. The controller searches for the best power point setting every minute by incrementally adjusting the voltage conversion until the setting which gives maximum power is found.

A PIC16F88 microntroller is used to control the MPPT. The PIC samples the voltages of the panel, battery and load through a voltage divider network. The currents are read through LT6101/4 current sense circuits. The sampled voltages and currents allow the PIC to calculate power values within the system. The PIC is also responsible for adjusting the voltage conversion between the panel and battery. The PIC accomplishes this by forcing the reference voltage of the switch mode power converter higher or lower depending on the search algorithm for maximum power.

4 Battery Charging

The controller is programmed for optimized battery charging. Battery constants are programmed into the PIC microntroller and can be change by the user depending on the battery charateristics. Depending on the state of the battery, charging is either in bulk, absorption or trickle mode. With MPPT, bulk charging can send as much current that is available from the solar panel to the battery to maximize battery charging. Trickle mode maintains the battery in near fully charge state without damaging the battery.

Battery charging is directly controlled by the PIC microcontroller. The PIC samples battery voltage every second to determine if bulk charging is required. In bulk charging mode, the PIC microntroller adjusts the voltage converter to maximum power point to get as much charge into the battery as is available. However, if the charge current at maximum power is above the absolute converter limit or the preset maximum battery current, the PIC switches the converter to the appropriate limit. If the battery voltage during charging is near the absorption threshold, then the PIC microcontroller reduces the battery charge current to near zero and then determines if whether absorption mode or trickle charge is appropriate. If battery voltage is at or above float voltage, then battery charging mode is switched to trickle charge. If voltage is below the float voltage, then absorption mode is enabled.

5 Low Voltage Load Disconnect

A low voltage load disconnect is implemented to avoid draining the battery below a preset threshold. A 0.5 V hysterisis window is provided to prevent unnecessary load on-off sequences when the battery voltage is at the disconnect threshold. In addtion, the controller also tracks and reports the number of consecutive load connect and disconnect sequences. This information can be used to indicate if the battery is already near or is at the end of its useful life. This feature could also be configured to prevent the controller from reconnecting and disconnecting the load too often, which may sometimes lead to damaging the load.

6 System Monitoring Through the Serial Interface

A 19.2 kbps, RS-232 compatible three pin serial interface is provided for system monitoring. The system outputs the status through the serial interface every second. The following information are reported.

- solar panel voltage and current
- battery voltage, current and charging mode

- load voltage and current
- number of consecutive disconnect and reconnect sequences
- temperature
- voltage conversion mode

When searching for the maximum power point, the controller reports the above information every half second. This enables the user to monitor how the controller determines the maximum power point setting. Similarly, when the battery voltage is near float voltage, reports are shown every half second to show how float voltage is determined and when trickle charge is enabled.

The controller monitors the serial interface for incoming commands. When the controller receives a character through the serial interface, the load is disconnected for a preset amount of time. This feature is helpful in performing a hard reboot of the load or for saving energy when the load is not required to be powered.

The serial interface is implemented using the internal UART of the PIC with a MAX232 serial line driver. The temperature is acquired by the PIC using a DS18S20 temperature sensor.

The solar charge controller reports the system status using the following format.

[ISUN] [ILOAD] [IBAT] [VSUN] [VLOAD] [VBAT] [DB0] [DB1] [TEMP] [DB2] [DB3]

Each entry above is a 4 digit hexadecimal number which translates to the actual values using the conversion below.

- solar panel current = 4.6239e-04 x [ISUN]
- load current = 4.6239e-04 x [ILOAD]
- battery current = 9.5369e-04 x [IBAT - 0x9000]
- solar panel voltage = 7.6295e-04 x [VSUN]
- load voltage = 7.6295e-04 x [VLOAD]
- battery voltage = 7.6295e-04 x [VBAT]
- temperature = 0.0019531 x [TEMP]

The other values reported through serial (DB[0:3]) are used for debugging. A sample output reported is shown below.

0E80 0C80 A0C0 95C0 3DCF 3E00 9880 0000 3200 EDFF BBFF

The above sample output translates to

- solar panel current = 1.17 A
- load current = 1.48 A
- battery current = 4.09 A

- solar panel voltage = 29.25 V
- load voltage = 12.07 V
- battery voltage = 12.11 V
- temperature = 25 C

Figure 1 shows the location of the pins for the serial interface.

7 Grid Powered Connection

The controller board provides an additional connection for grid supplied power through an appropriate DC apadpter. This connection accepts an input voltage of up to 60 V and is monitored similar to the solar panel connection. The controller allows both solar panel and grid powered sources to be connected simultaneously. Power will be drawn from the source supplying the higher voltage. Figure 1 shows the terminals (GRID+ and GRID-) provided for connecting DC adapters powered from the grid.

8 In Circuit Programming

The behavior of the charge controller is modified through the in-circuit programming terminals. A low cost PIC programmer can be hooked up to the board to update the PIC firmware. Figure 1 shows terminals where the PIC programmer can be connected. Under normal operations, a jumper is connected between pins 5 and 6 of the PIC programming terminals. When programming, the jumper is removed and the PIC programmer is connected to pins 1 to 5.

9 Connection Layout

The connections to the solar controller are shown in Figure 1.

- Grid supplied power connection (GRID+ and GRID-) need to be made directly to the PCB. This connection is envisioned to take in power from a DC adapter with an output voltage 20V to 60V. If the supply will exclusively come from the grid power, then the solar panel connections (SOLAR+ and SOLAR-) may be used instead of the connections for the grid supplied power.

- The connections for the solar panel are made through SOLAR+ and SOLAR-. The panel should have a maximum open circuit voltage of 60V.

- The battery is connected to BAT+ and BAT- terminals. The board by default is programmed for a 12V battery system. Programming the PIC (through the programming terminals) with a modified firmware allows for a 24V battery system operation.

- The load is connected to the LOAD+ and LOAD- terminals. To protect the battery, the load is disconnected when battery voltage falls below a threshold (11.3V for a 12V system). Load is automatically reconnected when voltage is sufficiently above the threshold voltage.

- Serial connection is made through three pins (GND, TX and RX). The board is configured for 19.2 kbps, 8N1 serial communication.
- PIC firmware programming is achieve through 5 pins. These pins a typical pins provided for by PIC programmers.

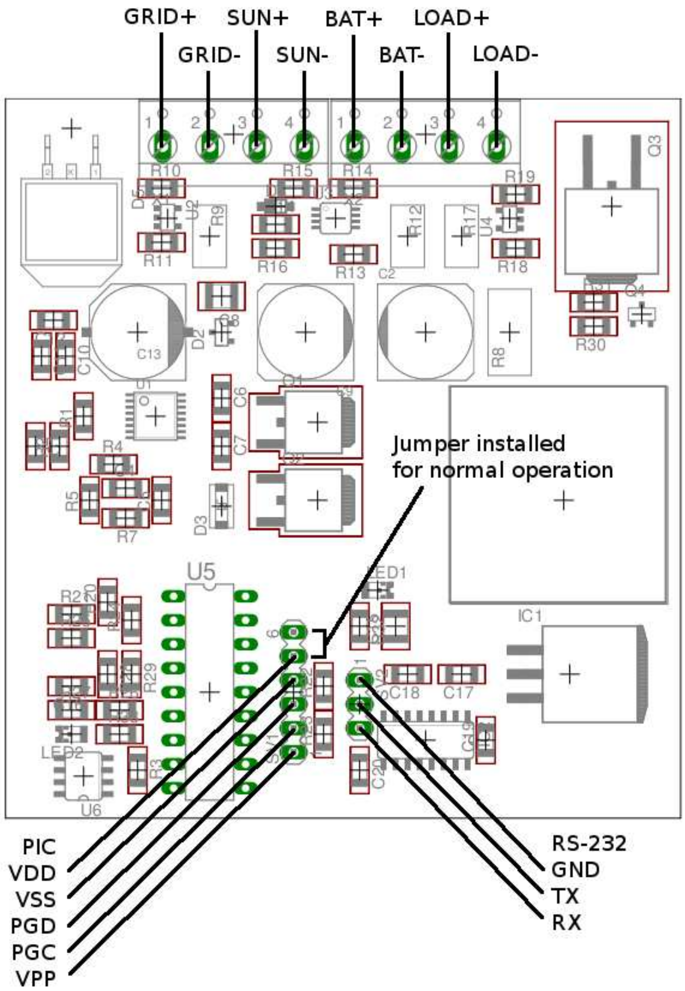

Figure 1: Board Connections