Implementation of microprocessor-controlled, wide-input-voltage, SMBus smart battery charger

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With the increasing popularity of lithium-ion chemistries in all types of electronics designs, innovative solutions for charging these batteries are becoming essential. For the utmost in system flexibility, a microprocessor can be used to control all aspects of battery charging, including unique charging algorithms to increase the charging rate and lifetime of the cells. This method also allows for higher-voltage battery-pack implementations.

This article describes using a microprocessor to control the power-stage board of a wide-input-voltage DC/DC controller. This solution can support an input voltage of up to 55 V; a battery-charging voltage ranging from 5 to 51 V; and up to 10 A of output current in most cases. Both the hardware and software discussed in this article have been developed and tested by Texas Instruments (TI) applications staff to allow customers to quickly prototype the solution.

For ease of development, the battery charger is split into two separate boards: the microprocessor controller board and the DC/DC-converter power-stage board (see Figure 1). The positive and negative battery terminals are connected to the power-stage board, while the system-management bus (SMBus) communication lines are connected to the microprocessor board. The smart battery sends the desired charging voltage and current information to the microprocessor, which then sends two pulse-width-modulated (PWM) signals to the DC/DC-converter power-stage board to set the actual output voltage and current.

To permit the use of a standard wide-input-voltage DC/DC converter, the power-stage board is designed with a special feedback circuit (see Figure 2) to properly control the charging of the battery. The charging sequence that the microprocessor follows is to first limit the charge current until the battery voltage approaches its specified maximum voltage. When the maximum voltage is reached, the charge voltage is held constant, allowing the charge current to taper down until the battery is deemed fully charged. At this point the PWM output signals are shut off.

The initial current-limiting charge rate could have two current levels. When a battery has been overly discharged, a fractional charge rate is used until the battery voltage is at a safe enough level to accept the normal charge rate.

In the feedback circuit shown in Figure 2, U3:B compares the PWM-current reference voltage (I_PWM1) to the measured current (ISNS1) being delivered to the battery. If the PWM reference voltage is higher than the measured current, the output of the amplifier is high. If the reference voltage is lower, the output of the amplifier is low.

A resistor divider (R30 and R34) is used to measure the output voltage at the VBATT1 input to U3:A. This voltage is compared to the PWM-output reference voltage (V_PWM1). If this reference voltage is higher, the output of the amplifier is high. If the reference voltage is lower, the output of the amplifier is low. The maximum output voltage is dictated by

$$V_{OUT(max)} = \frac{\mathrm{VBATT1}}{\mathrm{R34} \times (\mathrm{R34} + \mathrm{R30})}.$$

Figure 1. High-level system block diagram of wide-input-voltage smart battery charger

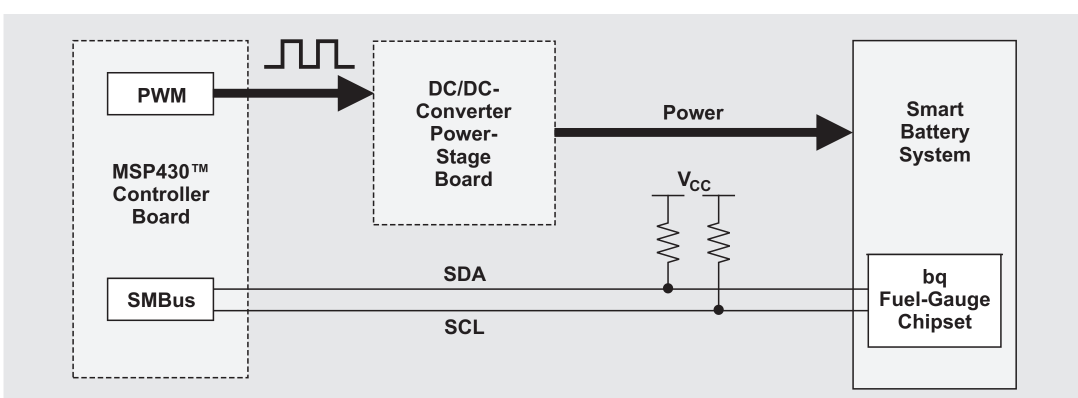


Figure 2. Constant-current/voltage-feedback circuitry to properly charge a battery

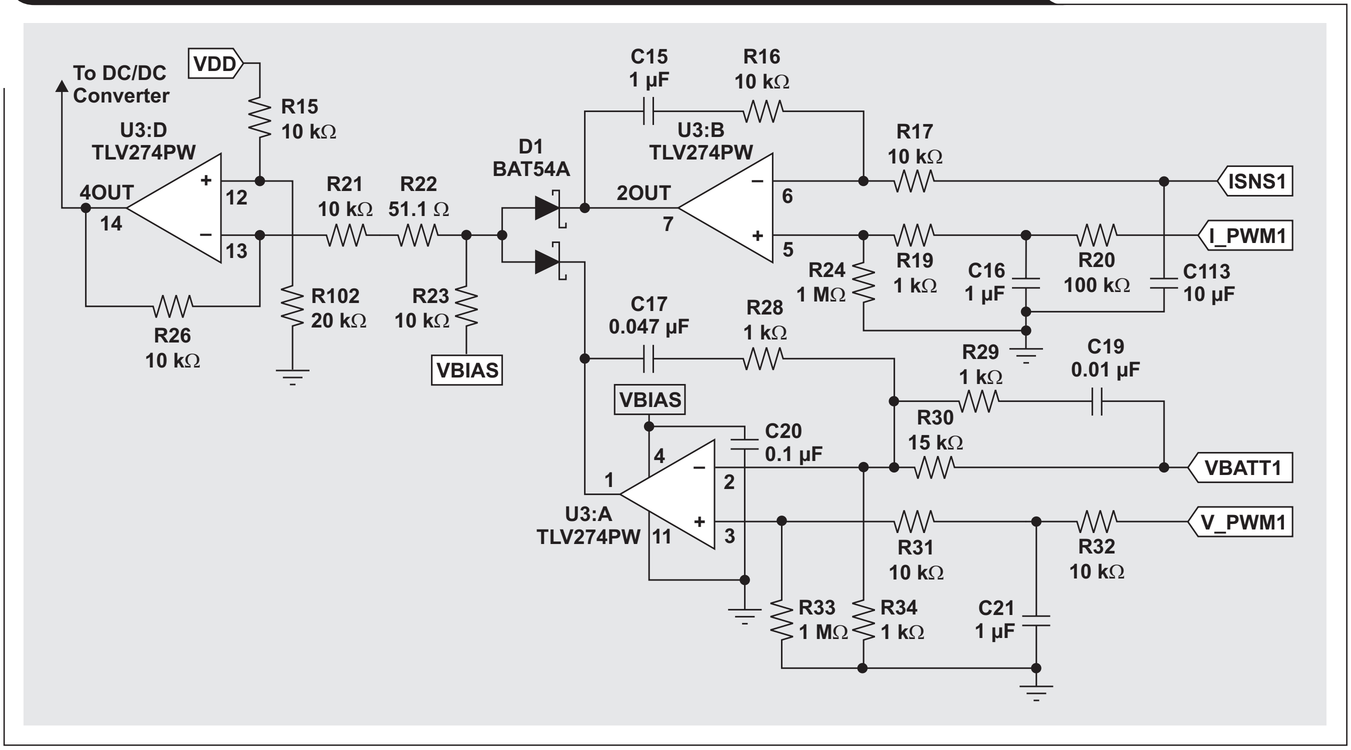
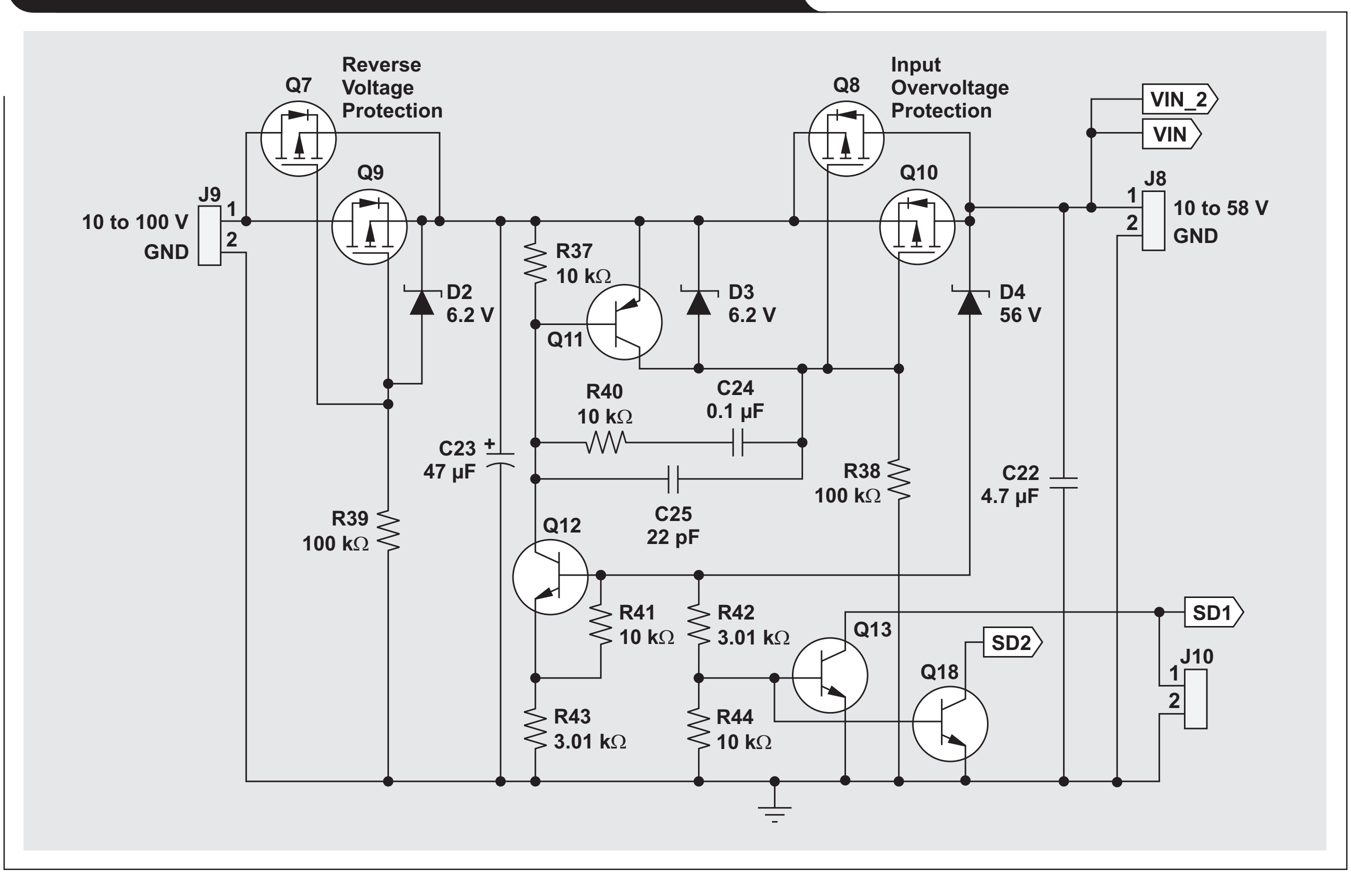


Figure 3. Overvoltage and reverse-polarity protection circuitry

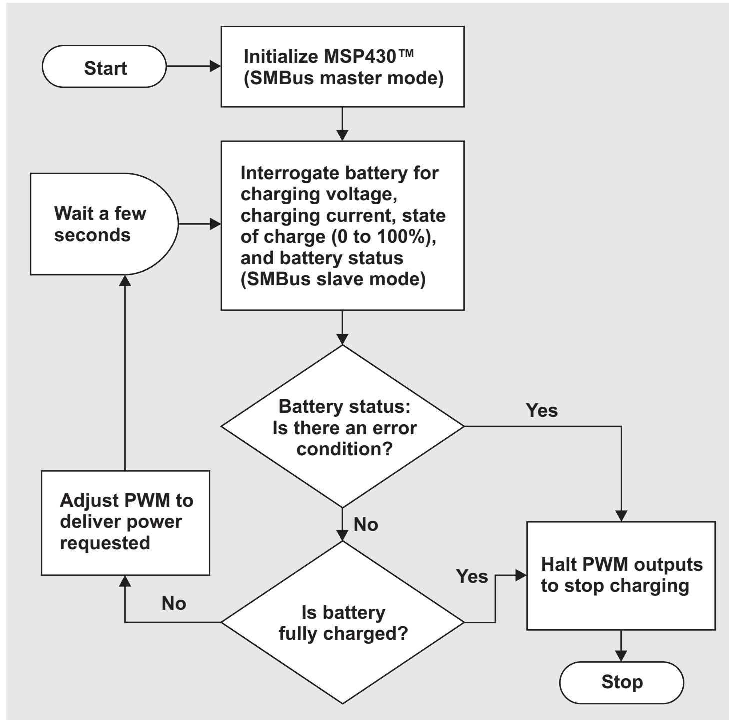


The D1 diodes combine the outputs of the two amplifiers with a logical OR. The voltage that is lowest is fed into an inverting amplifier (U3:D) that makes the error signal's polarity correct for the DC/DC controller (in this case TI's TPS40170). The basic operation is that the controller tries to send a set current; and, if the load can accept this current, the controller regulates to that current level. If the load cannot accept the full amount of current, the voltage begins to rise and eventually reaches $V_{OUT(max)}$. When this happens, the voltage loop takes over and regulates the output voltage.

To enhance the safety of the solution, also included on the power-stage board is protection circuitry both for overvoltage conditions (up to 100 V) and for reverse-voltage connections (where the positive and negative leads are swapped). This circuitry is shown in Figure 3.

Reverse-voltage protection is provided by MOSFETs Q7 and Q9 along with D2 in case the input voltage is connected backwards. This does not allow a negative voltage to be applied to the system. Input-overvoltage protection is provided by MOSFETs Q8 and Q10. Zener diode D4 sets the voltage that the circuit starts to clamp. Once the Zener voltage is exceeded, the gate-to-source voltage of the FETs starts to drop. This causes the FETs to operate in the linear region and allows the microprocessor to continue to be powered. At the same time, the DC/DC converters are turned off, with signals SD1 and SD2 being pulled to ground.

Figure 4. Abbreviated overview of software flowchart



The software implementation is equally as important as the hardware. The abbreviated software flowchart is shown in Figure 4. The microprocessor interrogates the battery via SMBus for its desired charging voltage and current. After confirming the values, it sets two PWM outputs accordingly to regulate the output voltage and current going to the battery. If at any time the battery issues a charging alarm, the PWM outputs will shut off. Additionally, the PWM outputs will shut off as soon as the battery's state of charge reaches 100% or the fully charged bit is set.

Safety is of utmost concern during battery charging. Any solution should allow for several levels of protection. The first level of protection is the smart battery itself with its internal protection MOSFETs. During charging, the microprocessor should communicate with the battery on a regular basis (every 2 seconds is good) and monitor for any safety flags in the "Battery Status" register. The flag bits that require action are the overcharge alarm (OCA), terminate-charge alarm (TCA), overtemperature alarm (OTA), and fully charged (FC) condition. The microprocessor's onboard analog-to-digital converter can be used as a secondary check for an overvoltage or overcurrent event.

Conclusion

A fully programmable, wide-input-voltage battery charger can be designed by using a microprocessor in conjunction with a wide-input-voltage DC/DC controller. This article has presented a solution that uses TI's low-power MSP430F5510 microprocessor together with the TPS40170 DC/DC controller, a configuration that can support an input voltage of up to 55 V. The special feedback network developed by TI applications staff for proper battery charging has been described. Additionally, a novel solution was shown for overvoltage protection, and reverse-voltage protection was discussed. The software required to communicate to a smart battery via SMBus communications protocol can be downloaded from a link in Reference 1, which is an application report. Detailed information on the SMBus smart battery charger is also available in Reference 1.

Reference

For more information related to this article, you can download an Acrobat® Reader® file at www.ti.com/lit/*litnumber* and replace "*litnumber*" with the **TI Lit. #** for the materials listed below.

Document Title **TI Lit. #**

1. Abhishek A. Joshi and Keith J. Keller, "Wide-Vin battery charger using SMBus communication interface between MSP430™ MCUs and bq fuel gauges," Application Report. slaa476

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