Application Report
SLVA473–August 2011

# Reducing Precharge Phase Region for bq24650

*Tahar Allag* *Battery Power Applications*

**ABSTRACT**

The bq24650 is a battery charger operates in three phases: precharge phase, fast-charge current regulation, and fast-charge voltage regulation. In many applications, a long precharge region is not required when using bq24650 as a charger. Thus, the following application note describes a method of reducing the precharge region for this charger. In this method, a circuit is designed to force the voltage of the feed back pin above the lower threshold for fast charge. This keeps the charger in fast-charge mode regardless of the battery voltage.

## 1 bq24650 Description

The bq24650 is highly integrated switch-mode battery charger for solar panels. Its input voltage can vary from 5 V to 28 V. It charges batteries with adjustable voltage from 2.1 V to 26 V with feedback reference set internally to 2.1 V. This device charges batteries in three phases based on the state of charge of the battery at any given time as shown in Figure 1.

The first phase is the precharge current regulation phase. In this phase, the voltage on the feedback pin must be lower than the typical value of 1.55 V ($V_{Lowv}$ typical). The purpose of this phase is to revive the deeply discharged cells. The charger applies a precharge current, usually very small, that can be set using the SRP and SRN pins. In the fast-charge current regulation phase, the feedback voltage must be between 1.55 V and 2.1 V. The charging current is 10 times higher than the current of the precharge phase. As the battery charges with time, its terminal voltage increases. As it reaches the expected regulation voltage level, the fast-charge phase ends and the fast-charge voltage regulation starts.

In this phase, the voltage is kept constant, and the current drops as the battery charges until termination. During termination, the charger stops injecting current into the battery as shown in Figure 1.

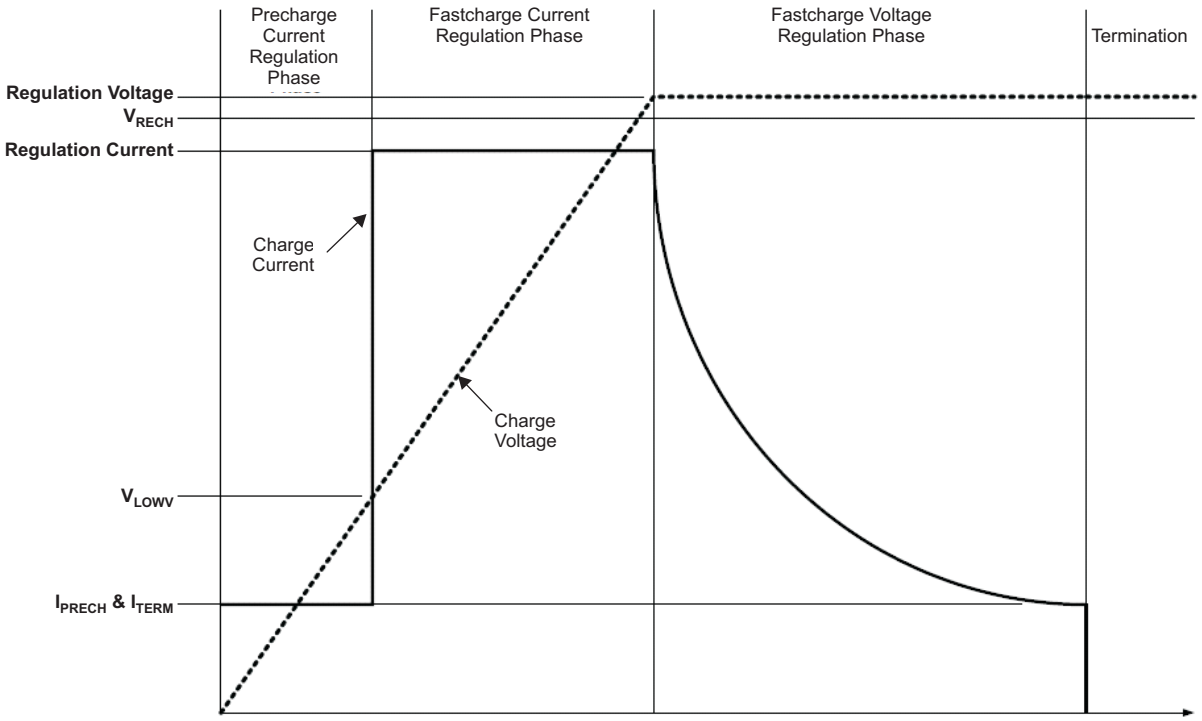


**Figure 1. Typical Charge Profile**

## 2 Circuit to Reduce the Precharge Region

As described in the previous section, if the battery voltage is below the $V_{LOWV}$, the charger enters the precharge phase. In some applications, the precharge region needs to be reduced. The following circuit partially disables the precharge region. The battery voltage can go down to about 2 V, and the charger is still working in the fast-charge region.

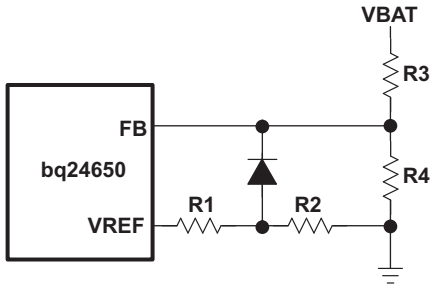


**Figure 2. Circuit to Partially Disable Precharge Mode**

The circuit in Figure 2 clamps the FB pin above the $V_{LOWV}$. $V_{REF}$ is always constant to 3.3 V and R1, R2, R3, and R4 are designed such that:

$$(V_{FB\ REG} + V_{LOWV}) / 2 = V_{REF}\ R2 / (R1+R2) - V_F$$

$$V_{FB\ REG} = V_{BAT(Full\ Charge)}\ R4 / (R3 + R4)$$

Where:

$V_{FB\ REG}$: Feedback regulation voltage
$V_{LOWV}$: Precharge to fast-charge threshold voltage
$V_{REF}$: Reference voltage
$V_{BAT\ (Full\ Charge)}$: Battery voltage at full charge
$V_F$: Forward diode voltage

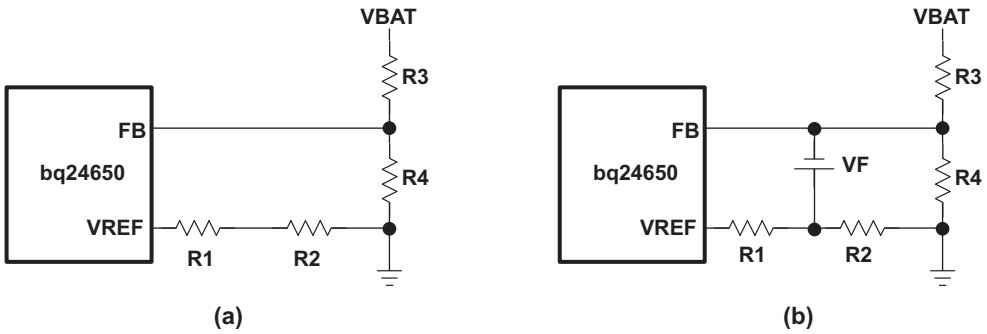


**Figure 3. Circuit to Partially Disable Precharge Mode During Precharge and Fast-Charge Battery Voltage Levels**

- If $V_{BAT}$ × R4 / (R3 +R4) > $V_{LOWV}$, the disable precharge mode circuit appears as in Figure 3 (a). During these conditions, the FB pin connected directly to the battery voltage through the resistor divider.
- If $V_{BAT}$ × R4 / (R3 +R4) < $V_{LOWV}$, the diode is automatically forward-biased as shown in Figure 3 (b). The clamp circuit forces the feedback pin voltage to approximately ($V_{FB\ REG}$ – $V_{LOWV}$)/2.

R2 must be at least 10 times smaller than R4 to make the clamper circuit dominant during the precharge phase. However, low resistance values on R1 and R2 can cause power loss from the reference pin to the ground. For that reason, A 1-10 kΩ range is preferred for R1 and R2. Also, the leakage current from the FB is about 100 nA. To have a good accuracy in the feedback pin reading, R3 and R4 must be in the range of 100 kΩ to 1000 kΩ. A design example is illustrated with results in the forthcoming sections.

## 3 Design Example

The bq24650 evaluation board is used to test the proposed circuitry. The feedback voltage regulation is given in the data sheet (SLUSA75) to be $V_{FB\ REG}$: 2.1 V and $V_{LOWV}$: 1.55 V. The reference voltage is $V_{REF}$: 3.3 V. In the EVM board, the R3 and R4 values have been given to be R3 = 499 kΩ and R4 = 100 kΩ. They are designed for $V_{BAT\ (Full\ Charge)}$: 12.57 V. The diode is chosen to have approximately 0.5-V forward voltage. Using Equation 1 of the bq24650 data sheet, R1 and R2 can be designed. Resistor R2 = 10 kΩ was chosen to be 10 times smaller than R4; solving Equation 1 for R1, the value was found to be 5 kΩ.

## 4 Test Result

First, the evaluation board is tested without the proposed circuitry, and the result is shown in Figure 4. The precharge phase is active for any battery voltage less than 9.3 V. However, in the second test, the proposed circuitry is used, and the result shown in Figure 5. The precharge region is reduced to a battery voltage of approximately 2 V. Any battery voltage above the 2-V level, the precharge phase is disabled.

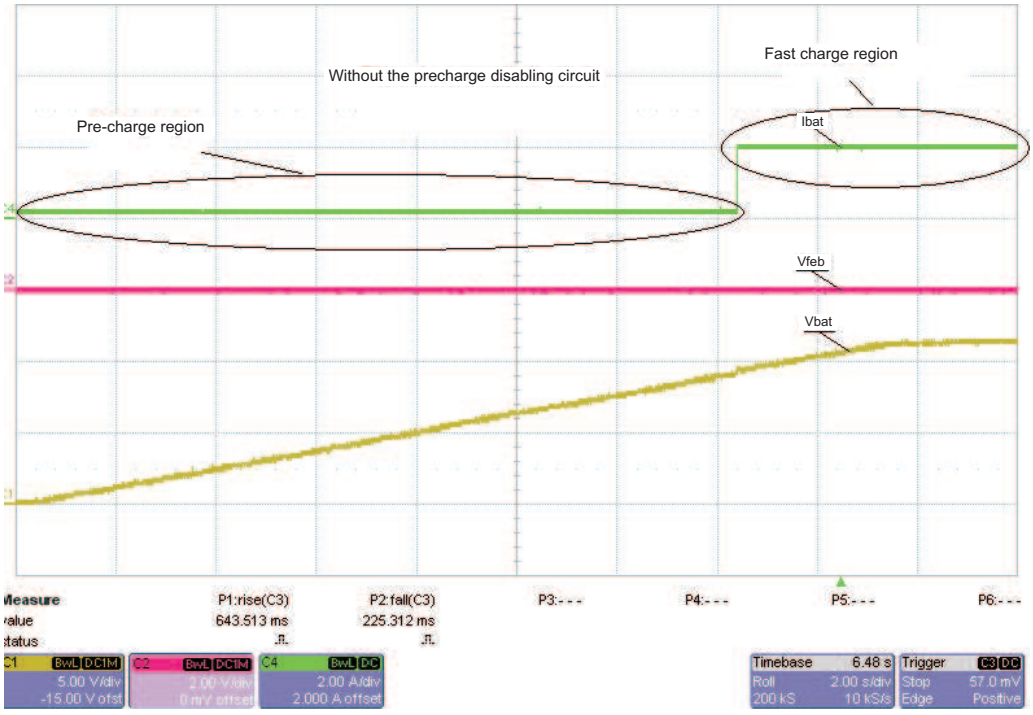


**Figure 4. Without Additional Circuit, Precharge Region Fully Active**

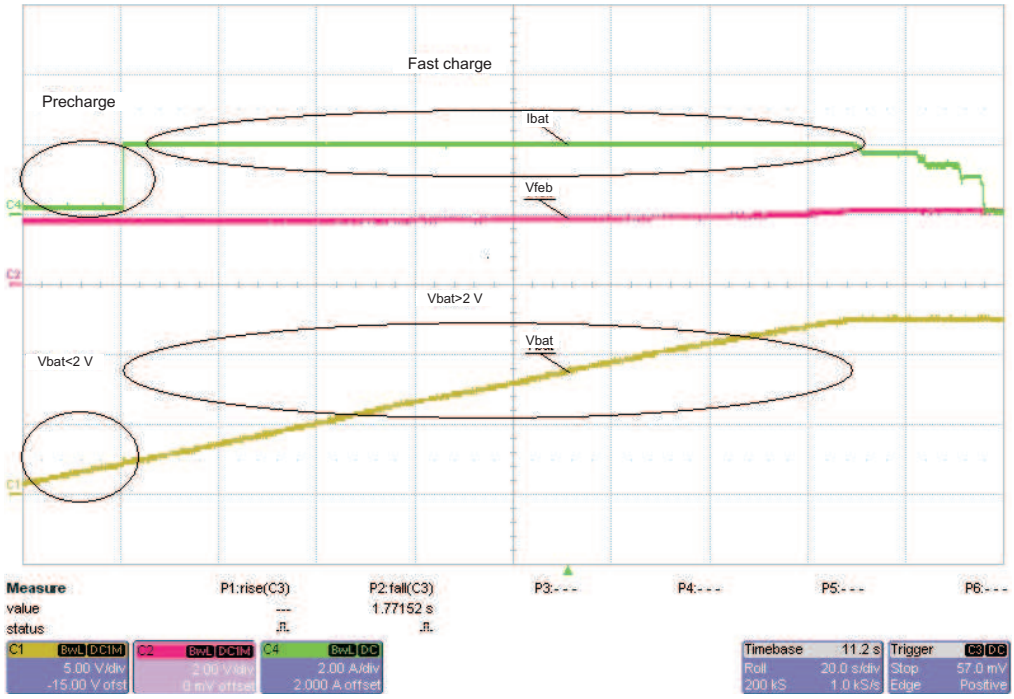


**Figure 5. With Precharge Circuit, Precharge Region Disabled Partially**

## 5 Conclusion

The precharge circuit described in this application report partially disables the precharge phase of the bq24650. It forces the feedback pin to regulation regardless of the battery voltage. However, the precharge phase cannot be fully disabled because of the SRP and SRN pins sensing the battery voltage. As the battery voltage drops below 2 V, the sensed feedback pin voltage is ignored, and the charger is forced to operate in the precharge mode.

## 6 References

1. *Using the bq24650 to Charge a Sealed, Lead-Acid Battery* application report (SLVA437)
2. *bq24650, Synchronous Switch-Mode Battery Charge Controller for Solar Power With Maximum Power Point Tracking* data sheet (SLUSA75)

## IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

| **Products** | | **Applications** | |
|---|---|---|---|
| Audio | www.ti.com/audio | Communications and Telecom | www.ti.com/communications |
| Amplifiers | amplifier.ti.com | Computers and Peripherals | www.ti.com/computers |
| Data Converters | dataconverter.ti.com | Consumer Electronics | www.ti.com/consumer-apps |
| DLP® Products | www.dlp.com | Energy and Lighting | www.ti.com/energy |
| DSP | dsp.ti.com | Industrial | www.ti.com/industrial |
| Clocks and Timers | www.ti.com/clocks | Medical | www.ti.com/medical |
| Interface | interface.ti.com | Security | www.ti.com/security |
| Logic | logic.ti.com | Space, Avionics and Defense | www.ti.com/space-avionics-defense |
| Power Mgmt | power.ti.com | Transportation and Automotive | www.ti.com/automotive |
| Microcontrollers | microcontroller.ti.com | Video and Imaging | www.ti.com/video |
| RFID | www.ti-rfid.com | | |
| OMAP Mobile Processors | www.ti.com/omap | | |
| Wireless Connctivity | www.ti.com/wirelessconnectivity | | |
| | **TI E2E Community Home Page** | | e2e.ti.com |

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265