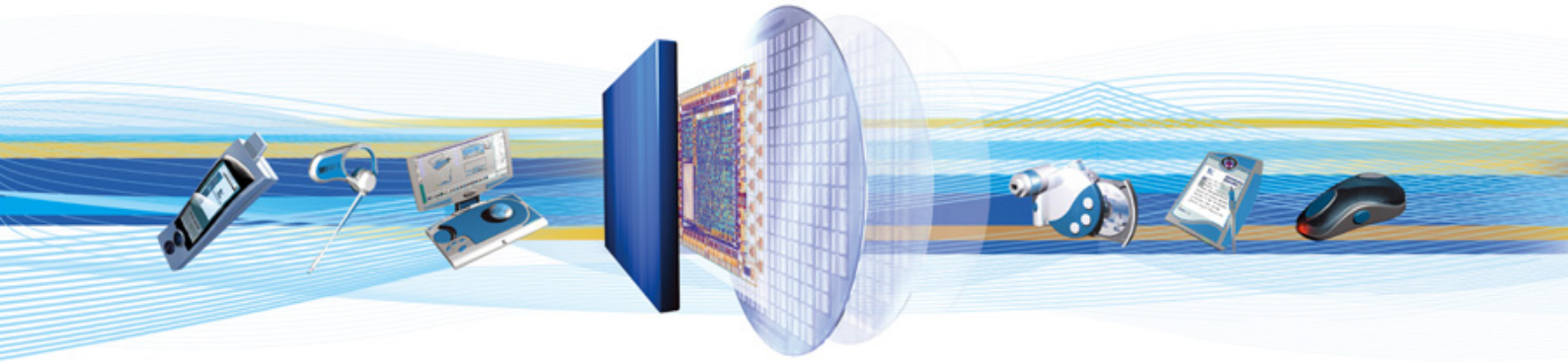
BlueCore™

BlueCore4-Headset ROM Charger Description and Calibration

Application Note

February 2006



CSR

Cambridge Science Park
Milton Road
Cambridge CB4 0WH
United Kingdom

Registered in England 4187346

Tel: +44 (0)1223 692000
Fax: +44 (0)1223 692001
www.csr.com

Contents

List of Figures

1 Introduction

The **BlueCore4™-Headset ROM** device contains a battery charger designed for use with lithium-ion batteries.

The battery charger is controlled by a set of comparators that operate with a state machine to set the charger current.

It is very important not to overcharge the battery for safety reasons, but turning off the charger too early can very significantly reduce the effective capacity of the battery. To get the required close tolerance the battery charger needs to be calibrated on the production line as part of the product test and configuration activity.

This document describes the operation of the battery charger, and the steps needed to calibrate a design using the BlueCore4-Headset ROM battery charger.

2 Technical Details

2.1 Battery Charger Operation

Figure 2.1 describes the BlueCore4-Headset ROM battery charger operation in a flow diagram. The battery charger operation is configured by the PS Keys:

- CHARGER_CURRENT
- CHARGER_TRIM
- CHARGER_SET_TRIM_VOLTAGE
- CHARGER_CEASE_CHARGE_VOLTAGE

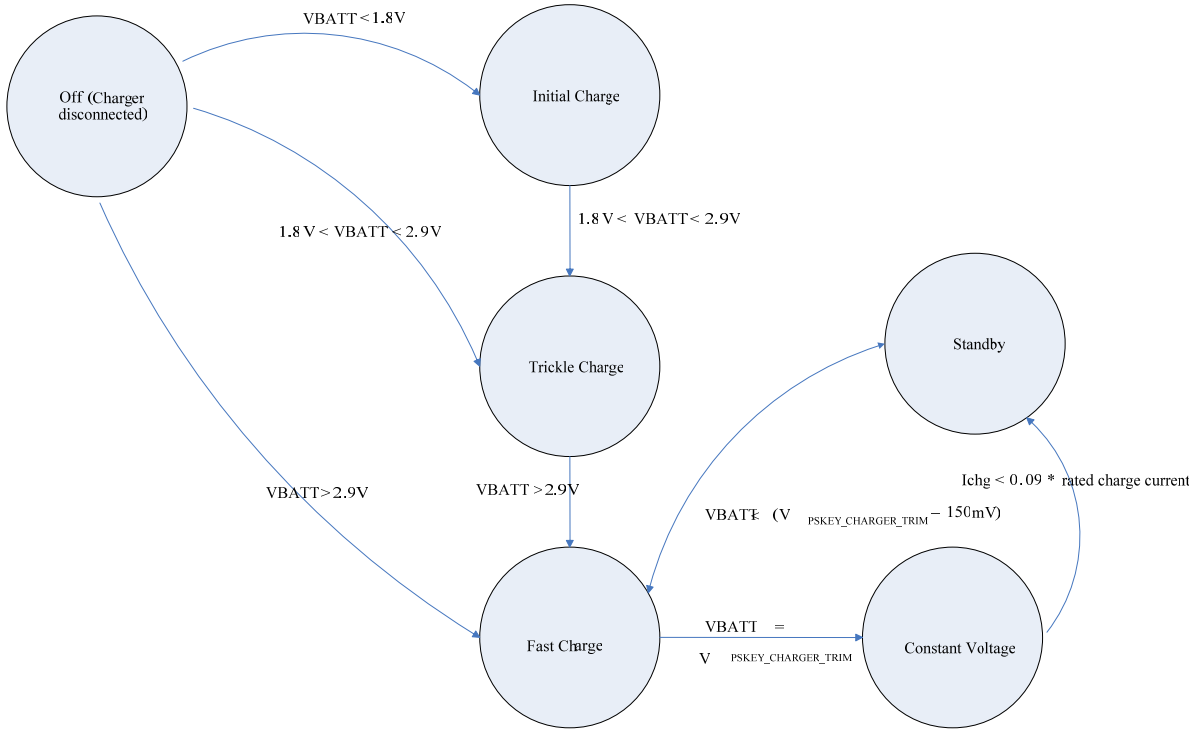


Figure 2.1: Battery Charger Flow Diagram

The flow states are:

- Initial Charge
- Trickle Charge
- Fast Charge
- Constant Voltage
- Standby

The *Initial Charge* state occurs when the charger is connected and the battery voltage is less than 1.8V. This very low current charge is for a deeply discharged battery, and the charge current is limited to approximately 1mA. The BlueCore4 core is not powered in this state. The battery charger transitions to the *Trickle Charge* state when the battery voltage reaches approximately 1.8V.

The *Trickle Charge* state limits the battery charger to a low current charge (2.5mA) to prepare the battery cell for *Fast Charge.* The BlueCore4 core is not powered in this state. The battery charger transitions to the Fast Charge state when the battery voltage reaches approximately 2.9V.

The BlueCore4 core powers up after the charger has entered *Fast Charge*. The core, when it is not in power save operation, requires more current than is supplied by *Initial Charge* or *Trickle Charge*. If the core powers up before *Fast Charge*, the battery could discharge, and the charger would not get to *Fast Charge*. To avoid this, the core is not powered up until *Fast Charge*. In many designs, the BlueCore4 Headset ROM is reset by external circuitry when the charger is connected. This reset turns off the power to the BlueCore4 core, and the core remains powered down until the charger has entered *Fast Charge*.

The *Fast Charge* state is the high current charge. When the battery charger first enters *Fast Charge*, the current output is increased to 25mA. Then the BlueCore4 Core is powered, and the PS Keys are read by the core. The PS Keys are all applied after they are read, except for PS Key CHARGER_TRIM, which is applied when the battery voltage is the same as that specified in PS Key CHARGER_SET_TRIM_VOLTAGE. The battery charger current increases, if needed, to the value specified in PSKey CHARGER_CURRENT. The battery charger monitors the battery voltage, and when the voltage reaches the value indicated by PSKey CHARGER_TRIM, then the charger goes to the *Constant Voltage* state.

The voltage at which the charger switches from *Fast Charge* to *Constant Voltage* is extremely critical, and depends on the battery specification. This is normally in the region of 4.2V. It is very important not to overcharge the battery for safety reasons, but turning off the charger too early can significantly reduce the effective capacity of the battery. The voltage level is controlled by PS Key CHARGER_TRIM. This defaults to a safe level of around 3.8V to completely avoid the possibility of overcharge.

To get the required close tolerance this should be calibrated on the production line as part of the product test and configuration activity, and the PS Key set to the appropriate value. This calibration process is described in Section 2.2.

In the *Constant Voltage* state, the current is reduced to maintain the battery voltage of PS Key CHARGER_TRIM. When the charger current is less than 10% of the value of PS Key CHARGER_CURRENT, the charger then goes into *Standby*.

PS Key CHARGER_CEASE_CHARGE_VOLTAGE is read by BlueCore4, and is used to turn off the charge LED before the battery reaches full charge, as specified by PS Key CHARGER_TRIM. It is not required to set this PS Key unless the design needs the charge LED to turn off before the charger goes into *Standby*. PS Key CHARGER_CEASE_CHARGE_VOLTAGE is the LED turn off voltage in mV. If not set, this PS Key defaults to a value of 0, and the charge LED turns off after the charger goes into *Standby*.

When the charger is in *Standby*, the battery charger does not supply any current to the battery. The battery voltage is monitored, and when the battery voltage drops by 150mV, the charger transitions from *Standby* to the *Fast Charge* state.

From any state it is possible to transition directly to *Off* by disconnecting the charger.

Key Name	Key Number	Type	Default Setting
CHARGER_CEASE_CHARGE_VOLTAGE	0x038e	uint16	0x0
For certain hardware designs it may not be desirable to wait for the battery to reach its final charge voltage before turning off the charger LED. This PS Key specifies a battery voltage in mV at which the charger will stop lighting the charge LED. For example, if the LED should be turned off at 3.8v, then CHARGER_CEASE_CHARGE_VOLTAGE would have a value of 3800			
CHARGER_SET_TRIM_VOLTAGE	0x038f	uint16	3500
This PS Key specifies a battery voltage in mV at which the charger trim value specified by PS Key CHARGER_TRIM will be written to the chip. This permits the battery to be charged to a configurable voltage before setting the charger trim.			
CHARGER_CURRENT	0x039b	uint16	0x0
The BlueCore4-Headset ROM allows a number of different currents to be used in the battery charger hardware. Values written to this key in the range 0..15 specify the charger current from 25..100mA in 5mA steps. Values outside the valid 0..15 range result in no change to the charging current. The default charging current is 25mA.			
CHARGER_TRIM	0x03b7	uint16	0x0
This PS key supplies a value for the charger trim. Values written to this key in the range 0..15 specify the voltage that will be maintained in *Constant Voltage* operation. The PS Key CHARGER_TRIM adjusts this voltage in steps of 50mV, over a range of 0.75 V (typically between 3.8 and 4.55V). This PS key allows the constant voltage level to be set within the tolerance required by a typical battery, compensating for variations in the BlueCore device. The procedure for determining the correct value for charger trim is described in Section 2.2 Values outside the valid 0..15 range will result in no change to the PS Key CHARGER_TRIM voltage. By default the PS Key CHARGER_TRIM voltage is set to the lowest voltage, typically 3.8V.			

2.2 Charger Calibration

2.2.1 Test Configuration

Figure 2.2 shows a typical test setup.

A PC controls the test equipment (in this case a PSU used in place of the standard charger) and a battery simulator over a control interface, in this case General Purpose Interface Bus (GPIB). The PSU voltage and the battery simulator voltage can be set via the GPIB. Also, the charge current can be read from the battery simulator.

The PC also directly controls the Device Under Test (DUT) via the CSR TrueTest libraries, over a UART (or SPI) connection.

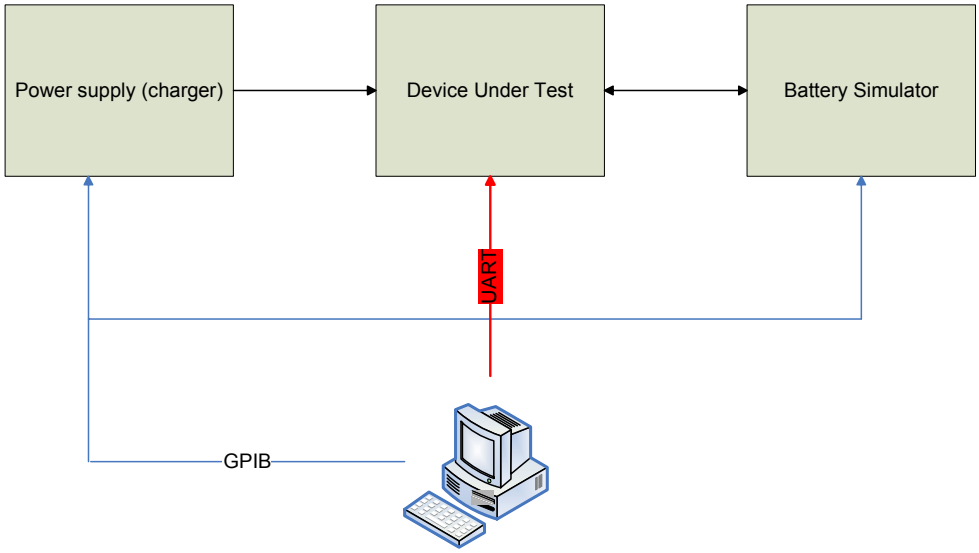


Figure 2.2: Test Configuration for Charger Calibration

2.2.2 Calibration Procedure

The calibration procedure is controlled by a test program running on the PC.

The TrueTest libraries should be used to control the DUT in response to function calls made by the test application. TrueTest supports the use of Visual Basic, C, C++ and LabView for the test application. The charger calibration may be combined with other test and configuration operations, depending on the number of test stations being used.

The calibration algorithm below ensures that the voltage at which BlueCore transitions from *Charging* to *Standby* is set correctly. It operates by setting the PSU trim register in BlueCore4-Headset ROM to its maximum setting while applying the required charger off voltage to the battery connector. The PSU trim register is then reduced progressively until the charger turns off, and the final value is recorded in PS Key `CHARGER_TRIM`.

When implementing the calibration, the TrueTest function call `bccmdSetPsuTrim` sets the PSU trim register. See the TrueTest help files for details of using this call.

The final value is written to PS Key CHARGER_TRIM (# 0x3b7). This is used by the BlueCore4-Headset ROM firmware to control the charger during normal operation. It is important that when this has been set for a given unit, it is not overwritten during software upgrades, etc.

Calibration Algorithm

1. Turn off charger voltage.
2. Set Battery Simulator to the same voltage as a fully charged battery; this value is battery dependent and must be obtained from the battery data sheet.
3. Set PSU trim register to 15 (maximum value).
4. Turn on charger voltage.
5. Set PS Key CHARGER_CURRENT to the required value.
6. Measure current into battery.
7. Decrement PSU trim register.
8. If current into battery ≤ 9% of value measured in step 6,
   write PSU trim register value into PS Key CHARGER_TRIM
   stop – successful calibration
9. If PSU trim register equals zero
   stop – device failed
   else
   go to step 6

Terms and Definitions

BlueCore™	Group term for CSR's range of Bluetooth wireless technology chips
Bluetooth®	Set of technologies providing audio and data transfer over short-range radio connections
CSR	Cambridge Silicon Radio
DUT	Device Under Test
GPIB	General Purpose Interface Bus
LED	Light Emitting Diode
PC	Personal Computer
PS Key	Persistent Store Key
PSU	Power Supply Unit
ROM	Read Only Memory
SPI	Serial Peripheral Interface
UART	Universal Asynchronous Receiver Transmitter

Document History

Revision	Date	Reason for Change
a	20 FEB 06	Original publication of this document (CSR reference: bcore-an-076Pa)

BlueCore™

BlueCore4-Headset ROM Charger Description and Calibration

Application Note

bcore-an-076Pa

February 2006