BP30
Battery Charger Specification

Edition 2006

Published by Neonseven s.r.l.,
Viale Stazione di Prosecco, 15

34010 Sgonico (Trieste) Italy

Table of Contents

1 Document Mission/Scope

1.1 Mission

This document describes how the GLOBE boards provide battery recharging environment.

1.2 Scope

The aim of this document is to introduce basic concepts used from battery charger driver, implemented in GLOBEx board. It is intended to describe to technical designers, engineers and programmers, the way charger driver uses to provide battery charging, power management and voltage measurements. The source code really implemented is not described here. Only fundamental concepts regarding above features.
The system described in this document is intended to provide very low cost solution, so indeed less accurate in respect to other architecture.

2 List of Acronyms

Abbreviation / Term	Explanation / Definition
HW	Hardware
SW	Software

3 Introduction

The E-GOLDlite/E-POWERlite (or S/M-POWER) platform offers a versatile hardware platform for battery charging. Facilities are provided for voltage and temperature measurements and charge current detection, as well as charge voltage control. Together with timing information this forms the platform for the battery charger SW.

4 System requirements

The whole system is designed to work on GLOBE boards, equipped with EGOLDradio an EPOWERlite chip, provided from Infineon. So this solution works with this platform, but may be easy to adapt also to other boards based on such chipset equipment.

5 Charger Environment

The charger control diagram gives an overview of the process of controlling the battery. A number of modules are employed in order to give a convenient partitioning of the software. The control diagram is to be taken as an implementation example, which has proven useful in practical experience, but of course other ways of implementing this software are possible.

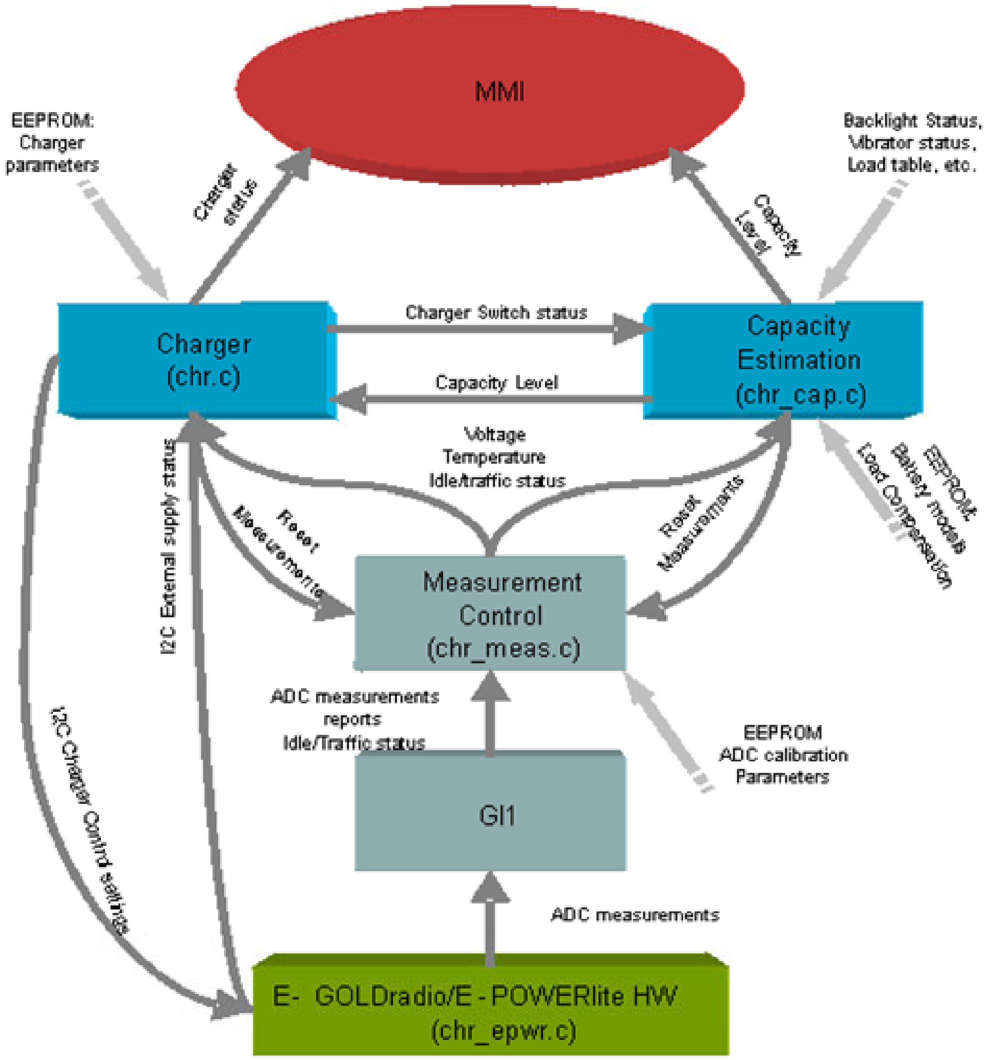


Figure 5-1

In order for the charge process to function correctly, some prerequisites have to be fulfilled. The HW platform for the charger has been developed with low cost and high flexibility in mind.

Supported battery technologies: NiMH, Li-Ion, Li-Polymer
External power supply, DC specification: Voltage: 5.0V +/- 0.3V

5.1 Measurement processing

The measurements of battery voltage and battery temperature are done using the ADC in the E-Gold. In order to establish the end of charge detection, accurately tracking of the characteristic features of the voltage and temperature during charging is necessary. To achieve that averaging of the measurements is necessary to filter out noise. In the following, it is assumed that a set of ADC measurements are received from GL1 at (relatively) regular intervals, depending on the general load on GL1. The measurements are the “raw” ADC values without compensation for tolerances. The measurement results can be obtained using the following macros:

BATT_MEAS_STM_BATT_STRESS_VOLT_VALUE:	VBAT ADC value in TX burst
BATT_MEAS_STM_BATT_VOLT_VALUE:	VBAT ADC value in idle frame

BATT_MEAS_STM_BATT_TEMP_VALUE:	TBAT ADC value
BATT_MEAS_STM_ENV_TEMP_VALUE:	TENV ADC value
BATT_MEAS_STM_BATT_TECH_VALUE:	BTEC ADC value
BATT_MEAS_STM_VCO_TEMP_VALUE:	TVCO ADC value
BATT_MEAS_STM_TX_ACTIVE	Traffic or idle

Table 5-1

The Measurement Control module translates these ADC into a complete general hardware status report. The contents of the status report can be requested by other SW modules.

Parameter	Description	Format	Unit	Range
CHR_rf_mean_voltage	Battery voltage measured on VBAT input during IDLE frame	u_int16	mV	0 - 32767
CHR_rf_peak_voltage	Battery voltage measured on VBAT input during TX burst	u_int16	mV	0 - 32767
CHR_battery_mean_temperature	Measured on BTEC input	s_char	°C	-128 – 127
adc_meas.eq_status.eq_detect_state	By measuring microphone bias voltage on TBAT input. **NB: Not supported in GLOBE**	u_char		0,1,2,3,ff
CHR_rf_mean_temperature	Temp output from Smarti+, measured on TENV input	s_char	°C	-128 - +127
		u_int16	mV	0 – 32767
adc_meas.tx_active	Traffic or idle status	s_char		0,1

Table 5-2

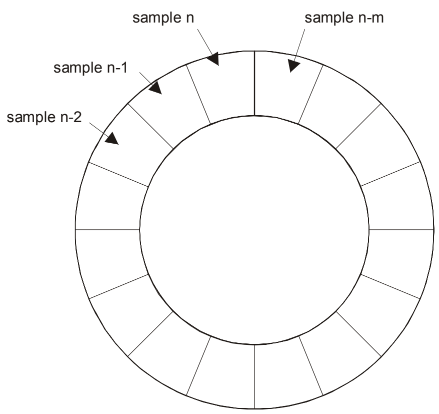
MC must support a reset command, which re-initiates all samples in the circular buffers, and immediately generates a new average value (valid for the battery voltage measurement).

For detailed specification of the interface to GL1, please refer to relevant specifications.

5.2 Battery Voltage

The Measurement Control module (MC) compensates the VBAT ADC samples for offset/gain errors according to 1.3.1, and stores the results in a circular buffer. MC maintains CHR_rf_mean_voltage and CHR_rf_peak_voltage, which are the average values contained in two circular circular buffers, one containing voltage samples sampled during idle frames, and one contains samples from TX bursts

CHR_rf_mean_voltage is used in the capacity estimation algorithm, while CHR_rf_peak_voltage is used for compensation of the PA output power at low battery voltages.



$$v\_bat\_mean(n) = \frac{\sum_{n-m}^{n} sample(n)}{m}$$

m = length of circular buffer

Inputs: BATT_MEAS_STM_BATT_STRESS_VOLT_VALUE
BATT_MEAS_STM_BATT_VOLT_VALUE
EEP_static.chr_adjcomp.vbat_gain
EEP_static.chr_adjcomp.vbat_offset

Outputs: CHR_rf_mean_voltage
CHR_rf_peak_voltage

Battery temperature

Input: BATT_MEAS_STM_BATT_TECH_VALUE
EEP_static.chr_adjcomp.btec_gain
EEP_static.chr_adjcomp.btec_offset
Output: CHR_battery_mean_temperature

The BTEC ADC input is used both to identify the battery type, and to measure battery temperature (*2). This is accomplished by first establishing under which ID voltage range the battery is, and next if the battery is identified as type0, to translate the measured voltage into a corresponding temperature.

Battery Type	Battery ID resistor [kOhm]	BTEC input voltage range [mV] *1
0	< 100	0 – 2000
1	150	2001 – 2300
error	-	> 2301

Table 5-3

Temperature [°C]	Battery NTC resistor [kOhm]	BTEC input voltage [mV] *1

-20	96.61	2002
-10	54.58	1770
0	32.15	1497
10	19.66	1216
20	12.43	959
30	8.10	745
40	5.43	578
50	3.73	454
60	2.62	363
70	1.88	298
80	1.37	251

Table 5-4

*1: Note: The internal reference current generator on the BTEC ADC input in E-Gold+ must be turned off during measurements.
*2: Note: Exact use of this ADC input depends on product. Necessary modifications to be done in chr_meas.c

5.3 VMIC voltage

The VMIC voltage can be measured and used to determine the type and status of the equipment connected to the system connector jack by applying the measured voltage to a lookup table. Since the valid range for a given state is quite large, there is no need for averaging of the measurements. Since the bias current of the built-in microphone has a certain tolerance, a measurement of the bias voltage is done during test and calibration, and the result vmic_ref is stored in NV memory and used as reference. This analog measurement approach introduces a latency of up to 2 sec on headset detection and hook key press.

- NB: The microphone supply voltage must be set in order to obtain valid measurements (VON = 1 in analog part control register)
- NB: For description of all digital solution, please refer to 2.2

Input: **BATT_MEAS_STM_BATT_TEMP_VALUE**
EEP_static.chr_adjcomp.tbat_gain
EEP_static.chr_adjcomp.tbat_offset
Output: **adc_meas.eq_status.eq_detect_state**

Equipment status	VMIC threshold voltage [mV]
VMIC not activated, detection not possible	< 500
Headset connected, hook key pressed	Vmic_ref – 300
Headset connected, hook key released	Vmic_ref – 150
No external	vmic_ref

equipment connected	
Error	Vmic_ref + 300

Table 5-5

5.4 RF temperature

The RF temperature is obtained by measuring the value of a NTC resistor placed close to the 26MHz XTAL with the TENV ADC input. The calibrated values are input in a circular buffer of same length m as the buffer used for VBAT, see above. The average voltage is calculated the same way, and used as input in the temperature formula.

Inputs: BATT_MEAS_STM_ENV_TEMP_VALUE
EEP_static.chr_adjcomp.tenv_gain
EEP_static.chr_adjcomp.tenv_offset

output: rf_mean_temperature

Temperature [°C]	NTC resistor [kOhm]	TENV input voltage [mV]
-20	738	2137
-10	409	2051
0	235	1923
10	140	1749
20	85.90	1535
30	54.20	1297
40	35.00	1057
50	23.20	840
60	15.67	654
70	10.80	506
80	7.57	392

Table 5-6

5.5 E-POWERlite interface

The charging concept uses some of the features contained in the E-POWERlite power management IC. This section contains a brief description of used functions. For further details on E-POWERlite, please refer to the datasheets. The control and status information is exchanged between E-GOLDlite and E-POWERlite via the I2C interface.

5.5.1 Charger HW status

Two status bits in E-Power are used to detect the presence of an external charger, and to detect the charging current:

Name	Bit	Register address	Description
CHV	7	82h	0: No charger connected

			1: External charger connected
CCAL	5	82h	0: Icharge > limit set by RVM[0:2] 1: Icharge < limit set by RVM[0:2]
CMD	6	82h	Not used

Table 5-7

5.5.2 Charger HW control

To provide correct current and voltage value to the battery, two control registers are used. In GLOBE boards, the driver of charger does not use all E-POWERlite capabilities. So only continuous charging mode is provided, while pulse charge is not implemented.
Driver can control a lot of parameter for battery recharging: charging voltage, current limit and threshold detection

Name	Bit	Register address	Description
ON	7	04h	0: Charge control MOSFET is off 1: Charge control MOSFET is on
PCH	6	04h	Not used
VMAX[0:1]	5:4	04h	00: Charge voltage = 4.1V 01: Charge voltage = 4.2V 10: Reserved 11: Charge voltage = 5.15V NOTE: typical values
VL	3	04h	Not used
PL[0:2]	2:0	04h	Not used
RVM[0:2]	7:5	08h	Reference Voltage Multiplier Level for charging current measurement 000: 0mA 001: Charge current detection threshold = 100mA 010: Charge current detection threshold = 200mA 011: Charge current detection threshold = 300mA 100: Charge current detection threshold = 400mA 101: Charge current detection threshold = 500mA 110: Charge current detection threshold = 600mA 111: Charge current detection threshold = 700mA
PREOFF	4	08h	0: 20 mA precharge is on 1: precharge is off
CHCLIM	2:0	08h	Battery Charge current limit 000: 400mA 001: 500mA 010: 600mA 011: 700mA 100: 800mA 101: 900mA 110: 1000mA 111: 1100mA

Table 5-8

6 Charger algorithm

The implementation of the charger allows for a very flexible concept, where various battery sizes can be handled correctly only by proper choice of the controlling parameters. Thus NiMH, Li-Ion and Li-Polymer of various capacities can be used without alterations of the software.

The state diagram for the charger is shown in Figure 6-1. Below a brief description of the various states are given.

1. Waiting For Supply

This is the default state, which is entered during initialisation, and, after a delay, whenever the external power supply is removed.

2. Wait For Recharge Response

This state is entered upon connection of an external power supply from the Waiting For Supply state. The purpose is to evaluate if the battery needs recharging, or if it is already fully charged.

capacity < battery[x]_recharge_capacity
OR
charger_last_state[x] = 1 (*1) => Fast Charge

Elapsed time(Wait For Recharge Response) > charger_t_initial_check => Trickle Charge

(*1) Please refer to Table 6-3 for explanation of parameters

3. Fast Charge

If the result of the Wait For Recharge Response state is that the battery needs recharging, this state is entered. During this state, the battery receives electrical energy from the external power supply until it is fully charged. Full charge is detected when one or more characteristic parameters exceeds their respective reference thresholds. During this state, the charger switch is ON, thus current from the external power supply will be charged to the battery. The bits VMAX[0:1] in the E-Power CHCTRL1 register will be set according to battery[x]_v_charge as follows:

battery[x]_v_charge	VMAX
4100mV	00h
4200mV	01h
5150mV	11h

Table 6-1

Charge current < battery[x]_i_eoc (*2)
OR
(Elapsed time(Fast Charge) > battery[x]_t_max_fast_charge AND capacity > battery[x]_recharge_capacity)
OR
(DT/dt > battery[x]_dt_eoc AND capacity > battery[x]_recharge_capacity)
OR
(-dV > battery[x]_dv_eoc AND capacity > battery[x]_recharge_capacity) => Top Charge

Temperature < battery[x]_temp_low_min
OR
Temperature > battery[x]_temp_hi_max => Fast Charge Paused

v_bat_mean > battery[x] v_max_fast
OR
(Elapsed time(Fast Charge) > battery[x]_t_max_fast_charge
AND Capacity < battery[x]_recharge_capacity) => Charge error!

(*2) CCAL bit in E-power set at RVM value specified by battery[x]_i_eoc:

battery[x]_i_eoc	EOC

(E-Power RVM value)	current
000	0mA
001	100 mA
010	200 mA
011	300 mA
100	400 mA
101	500 mA
110	600 mA
111	700 mA

Table 6-2

4. Fast paused

This state is entered if the environment temperature during fast charge exceeds either the maximum limit or the minimum limit specified for the battery. To allow for a limited temperature rise originating from the battery during Fast Charge, hysteresis is employed to avoid oscillation between the two states.

Temperature > battery[x]_temp_low_min

AND

Temperature < battery[x]_temp_hi_max – battery[x]_temp_hi_hysteresis

AND

DT/dt < battery[x]_dt_eoc => Fast Charge

5. Top Charge

The Top Charge state is entered upon an EOC in the Fast Charge State. The purpose of the Top Charge state is to evaluate if the EOC condition encountered in the Fast Charge state is valid. (Due to changing environmental conditions, ie. temperature rises, false EOC's can be triggered)
The secondary purpose of the top charge state is to top-off the capacity of the battery by supplying additional charge current to the battery after the primary end-of-charge criteria is met.

Elapsed time(Top Charge) > battery[x]_t_max_top_charge => Trickle Charge

DT/dt > battery[x]_dt_eoc => Fast paused

6. Trickle Charge

The Trickle Charge state is a maintenance state, where the battery is maintained at full charge, as long as the external power supply is connected. This is accomplished by turning off the charger switch for a fixed amount of time, and then turn the switch on again until the EOC criteria is met again. This way the capacity is maintained very close to full.

7. Supply Removed

This state is entered from all other states except Trickle Charging upon removal of the external power supply. The purpose of this state is to ensure a reliable charge, and that the battery is not overcharged due to repeated insertion/removal of the external power supply. As long as this state is sustained, the fast charge timer is not reset, hence the total charge time will never exceed the limit set in battery[x]_t_max_fast_charge.

Elapsed time(Supply Removed) > charger_t_reset_no_supply => Waiting For Supply

8. Fully Charged No Supply

If the external power supply is removed during trickle charge, this state is entered. The purpose is to avoid charging on a battery which is already fully charged. The state is sustained until the capacity (estimated by the Capacity Estimation module) is sufficiently low to allow recharging.

capacity < charger_recharge_capacity => Waiting For Supply

9. Pseudo Charge

This state is entered if the external power supply is connected while the charger is in the Fully Charged No Supply state; ie. the battery is fully charged and no further charge is allowed, this state is entered. The purpose is to signal to the MMI (the user) the recognition of the external power supply and to avoid the misinterpretation that the handset is not working correctly.

10. Charger Suspended

When the handset makes a call the current consumption rises significantly. Since the consumption varies the state of the CCAL bit in the E-Power becomes unreliable. Due to this, the check for EOC will be suspended during a call, however the charge switch will still be on to ensure sufficient supply current even if the battery is fully drained.

6.1 Charger state diagram

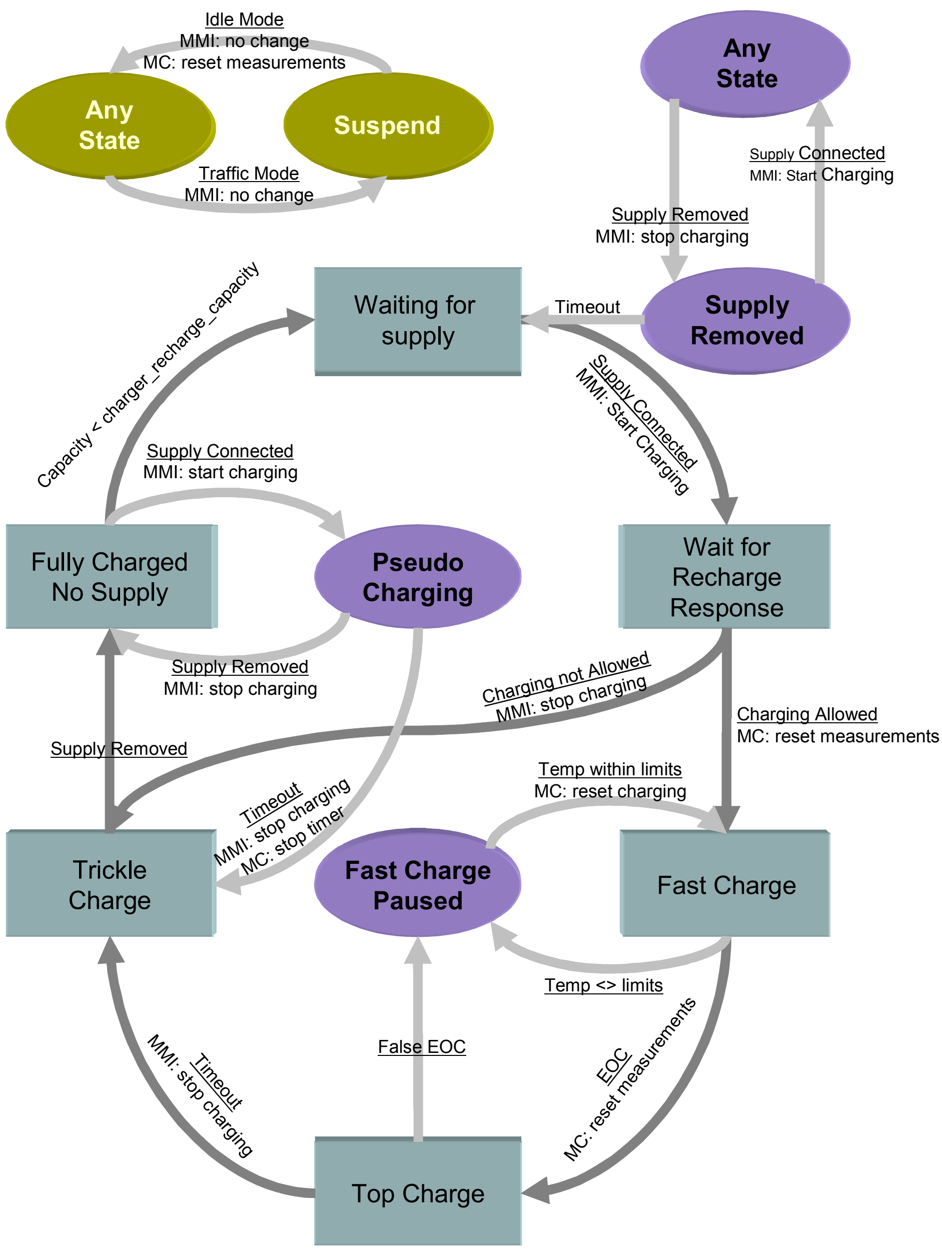


Figure 6-1

6.2 Charger EEPROM parameters

Parameter Name	Description	Format	Unit	Default value
Common Charger Parameters				
charger_t_reset_no_supply	Specifies max. amount of time to be spent in Supply Removed state.	u_char	min	10

charger_t_pseudo_charge	Specifies max. amount of time to be spent in Pseudo Charge state.	u_char	sec	10
charger_t_initial_check	Specifies max. amount of time to be spent in Wait For Recharge Response state.	u_char	min	5
charger_max_voltage	Specifies upper limit for charger voltage, if measured charger is above this limit, a Charge Error is generated.	u_int16	mV	6000
charger_last _state[7:0]	Each bit corresponds to one battery type: bit0: battery type 0 status bit1: battery type 1 status etc.. The bit is set when the Fast Charge state is entered. The bit is cleared when the Trickle Charge state is entered. When entering the Wait For recharge Response, the bit is tested. If set, a transition to the Fast Charge state is forced.	bitfield	n/a	Ffh
Battery Specific Parameters				
Battery Type 0 (NiMH 600mAh)				
Battery[0]_recharge_capacity	Specifies below which battery capacity level recharging is allowed.	u_char	%	90
battery[0]_t_max_fast_charge	Specifies max. amount of time after which an EOC will be forced in the Fast Charge state.	u_char	min	180
battery[0]_t_max_top_charge	Specifies time to be spent in the Top Charge state	u_char	min	20
battery[0]_temp_hi_max	Specifies max. temperature limit for Fast Charging	s_char	°C	50
battery[0]_temp_hi_hysteresis	Specifies how much the battery temperature must drop below battery[1]_temp_hi_max, before Fast Charge is resumed.	s_char	°C	5
battery[0]_temp_low_min	Specifies min. temperature limit for Fast Charge	s_char	°C	0
battery[0]_v_max_fast	Specifies the max. limit for the battery voltage during Fast Charge. If this voltage is exceeded, a Charge Error is generated.	u_int16	mV	5000
battery[0]_v_charge	Specifies the nominal charge voltage. The VMAX bits in the E-Power is set according to this value.	u_int16	mV	4700
battery[0]_i_eoc	Specifies below which charge current level an EOC is forced in the Fast Charge state.	u_char	mA x100	1
battery[0]_dt_eoc	Specifies temperature gradient above which an EOC is forced in fast charge mode.	u_char	°C *100/min	100
Battery Type 1 (Li-Ion 700mAh)				
Battery[1]_recharge_capacity	Specifies below which battery capacity level recharging is allowed.	u_char	%	95
battery[1]_t_max_fast_charge	Specifies max. amount of time after which an EOC will be forced in the Fast Charge state.	u_char	min	180
battery[1]_t_max_top_charge	Specifies time to be spent in the Top Charge state	u_char	min	20
battery[1]_temp_hi_max	Specifies max. temperature limit for Fast Charging	s_char	°C	50
battery[1]_temp_hi_hysteresis	Specifies how much the battery temperature must drop below battery[1]_temp_hi_max, before Fast Charge is resumed.	s_char	°C	5

battery[1]_temp_low_min	Specifies min. temperature limit for Fast Charge	s_char	°C	0
battery[1]_v_max_fast	Specifies the max. limit for the battery voltage during Fast Charge. If this voltage is exceeded, a Charge Error is generated.	u_int16	mV	4300
battery[1]_v_charge	Specifies the nominal charge voltage. The VMAX bits in the E-Power is set according to this value.	u_int16	mV	4200
battery[1]_i_eoc	Specifies below which charge current level an EOC is forced in the Fast Charge state.	u_char	mA x100	1
battery[1]_dt_eoc	Specifies temperature gradient above which an EOC is forced in fast charge mode.	u_char	°C *100/min	255
HW adjustment parameters				
vbat_gain (*1)	adjustment parameter. See chapt. 1.	s_int16	N/A	5275
vbat_offset (*1)	adjustment parameter. See chapt. 1.	s_int16	N/A	-8924
tbat_gain	adjustment parameter. See chapt. 1.	s_int16	N/A	13817
tbat_offset	adjustment parameter. See chapt. 1.	s_int16	N/A	-17923
tenv_gain (*1)	adjustment parameter. See chapt. 1.	s_int16	N/A	13929
tenv_offset (*1)	adjustment parameter. See chapt. 1.	s_int16	N/A	-15158
btec_gain	adjustment parameter. See chapt. 1.	s_int16	N/A	9643
btec_offset	adjustment parameter. See chapt. 1.	s_int16	N/A	-21644
tvco_gain	adjustment parameter. See chapt. 1.	s_int16	N/A	9643
tvco_offset	adjustment parameter. See chapt. 1.	s_int16	N/A	-21644
Other parameters				
window_length	Size of circular buffer used for averaging. Equal to m in figure 2.	u_char	N/A	20
*1: These parameters are found after test on a representative population of early prototypes. Other default HW adjustment parameters are calculated after datasheet specifications.				

Table 6-3

7 References

7.1 External

N.A.

7.2 Internal

Title	Doc ID

8 Document change report

	Change Reference		Record of changes made to previous released version	
Rev	**Date**	**CR**	**Section**	**Comment**
1.0	05/01/2006	N.A.		Document Created

9 Approval

Revision	Approver(s)	Date	Source/signature
1.0	Valter Jelicic	05/01/2006	Document stored on server