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BatteryCheck 2
Functional Specification

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Author: SETEC

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Designed by Wolfgang Reisch	2019-04-01	R&D
Released by Ralf.Rosenbaum@setec.com.au	2019-08-29	R&D
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	Document key	Pages 1 of 59

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1 History

Revision	Date	Author	Reason
0.1	01.04.2019	Wolfgang Reisch	Bring in line with direction received from Campbell James on 29.03.2019
1.0	28.05.2019	Wolfgang Reisch	First Version after integrating the SoC and SoH estimations into the BC2 firmware.
1.1	31.05.2019	Wolfagng Reisch	More Peukert exponents made available, but no history records anymore to free up processor memory. Min/Mid/Max point sampling parameters changed to allow better configuration.
1.2	04.06.2019	Wolfgang Reisch	Two days of history records retained for testing only, default parameters for battery added. Sw: 1V10
1.3	21.06.2019	Wolfgang Reisch	Voltage based SoC only to be applied at power up and after receiving new battery parameters. Byte (offset) in BC2 Battery Configuration Parameters starts at 0. Diagnostic information for testing added. Sw: 1V11
1.4	18.07.2019	Wolfgang Reisch	Nominal transmission intervals for BLE advertising messages included. Note inserted: There is no range check on battery configuration parameters. Definition of current polarity added.
1.5	26.07.2019	Wolfgang Reisch	Table of diagnostic console commands inserted into the appendix. Battery capacity estimation moved from max-point to mid- and min-points. Changed rated capacity from 90% to 100% of value received from App. Improved mid-point sampling, mid-point recording when voltage falls to or 100mV below threshold.

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1.6	06.08.2019	Wolfgang Reisch	Changed transition criteria for Empty to LT50 and LT50 to GT50 from voltage based to SoC based. Added state diagram for min-, mid- and max-point sampling.
1.7	23.08.2019	Wolfgang Reisch	1. Min/Max algorithm parameters for all battery types entered. 2. LED status indications included. 3. Add description how newly received App Settings are handled.

1.1 Acronyms

Acronym	Description
BC2	Battery Check 2 (100A or 300A) device
BC2H	Battery Check 2 300A
SoC	State of charge
SoH	State of health
C-Rate	The C-rate (Charge Rate) is a measure of the rate at which a battery is being charged or discharged. It is defined as the current through the battery divided by the theoretical current draw under which the battery would deliver its nominal rated capacity in one hour. It has the unit 1/h. For example the current of a C-Rate = 0.05 C of a 100Ah battery is 5A.
Coulomb	One Coulomb is the charge (symbol: Q) transported by a constant current of one ampere in one second: =1A * 1sec. The symbol for this physical unit is also C, but should not be mistaken for the Charge Rate (C-Rate).
IOS, Android	Smart Phone or Tablet operating system
BLE	Bluetooth Low Energy
ULP	Ultra Low Power sleep mode of the processor

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Acronym	Description
TBD	To Be Defined

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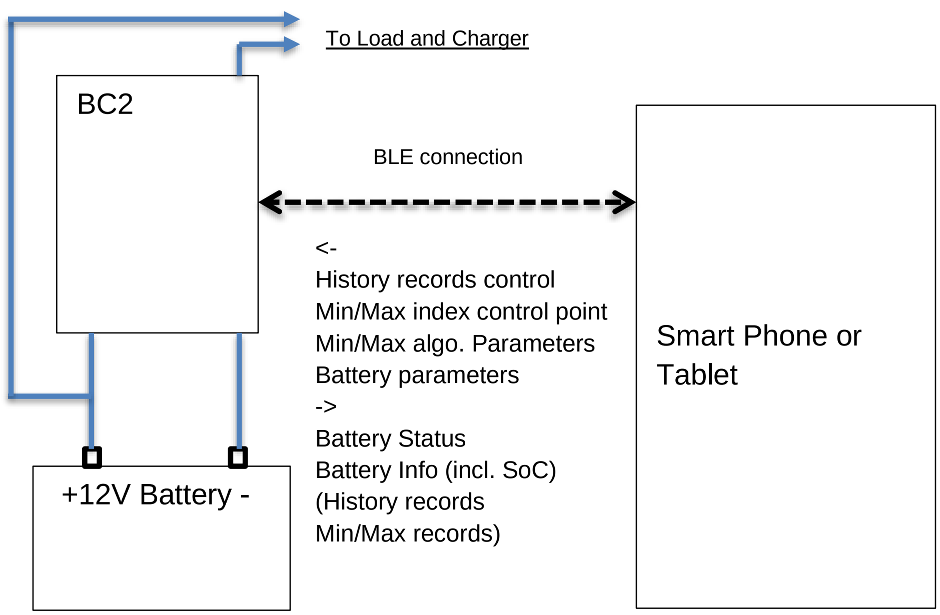
2 Introduction

This document describes the functionality of the “BatteryCheck 2” (BC2) consisting of the BC2 hardware with firmware and an Application program (App) for a smart phone or tablet. The BC2 hardware features a high current shunt-resistor with an attached microcontroller circuit measuring battery voltage, current and temperature. The measurement data together with the estimated Battery Capacity, State of Charge, “Time Remaining” and “State of Health” are transmitted to the smart phone via a Blue tooth Low Energy interface.

2.1 Blockdiagram



Definition of current polarity:
The current value is negative, when the battery is being discharged.

2.2 Variants

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The following BC2 variants exist:

BC2 variant commercial name	Complete local name	Firmware Variant
BatteryCheck100	'BC100 A0123456789'	BC100_MODEL
BatteryCheckPRO	'BCPRO A0123456789'	BCPRO_MODEL
BC300 (BC2H)	'BC300 A0123456789'	BC300_MODEL

2.3 Smart Phone or Tablet (Android or IOS) App functionality

Function	Inputs	Outputs
Battery Status	Battery Status.Current in mA updated in 500msec intervals	Display: CHARGING if I<-0.3A IDLE if -0.3<=I<=0.3A DISCHARGING if I>0.3A or DISCONNECTED
Battery Name/ Serial Number	Battery Name UUID: ffffff53-4554-4543-2043-414e20424c49	Display: String, example: A1745120032
VOLTS	Battery Status.Voltage in mV updated in 500msec intervals	Display: VOLTS and value in the format nn.dV, example: 12.9V
AMPS	Battery Status.Current in mA updated in 500msec intervals	Display: AMPS and value in the format snnn.dA, example: -0.6A
TEMP		Display: TEMP and value in the format nnºC, example: 27ºC
SoC	Battery Info Estimated State of Battery Charge (SoC) in 0.5%/256	Display: SoC in % shown inside the battery icon.
Time remaining	Battery Info Estimated Time Remaining in minutes	Display: HHh MMm
SoH	Battery Info	Display:

Function	Inputs	Outputs
	Estimated State of Battery Health with 0.5% resolution.	As text and symbol .
Low and high battery voltage warning	SoC	Display and Sound warning
Low battery alarm	SoC	Display and Sound alarm
Set-up screen	Default values	Battery chemistry from menu, rated battery capacity (Ah) and to be able to name the battery, low battery alarm threshold.as well as the Peukert parameter with a default value provided depending on the battery type. These parameters and also the V2SoC table should be transferred to the BC2, depending on battery type. Other apps will read and assume this data on connection.

3 State of Charge (SoC) algorithm

The State of Charge of a battery is the remaining capacity as a fraction of the battery's total capacity. For example a SoC value of 75% means the battery is three-quarter full or 25% discharged. Lead acid batteries should not be discharged below 50%. There are two methods used to estimate the State of Charge:

1. The SoC is estimated based on the actual battery voltage, for example with a Voltage to SOC lookup table.

2. The battery current (in or out) of the battery is integrated over time to derive the charge taken from (discharge) or charged into the battery. The value is set to 100% (synchronised), when the battery has been fully charged.

The BC2 calculates the State of Charge based on both methods depending on conditions..

3.1 SoC Estimation based on Voltage

The Voltage2SoC lookup table is used to estimate the state of charge based on measured battery voltage. The values in the table are in mV. Different battery types have different voltage levels and therefore these voltage levels need to be written to the BC2 by the App upon initialisation.

The low- and high-level warning rows are unrelated to the v2SoC but are used to determine the battery type-specific warnings in the App.

Voltage2SoC table (mV)

SoC	AGM	GEL	WET	CALCIUM	$LiFPO_4$ (LFP)
Low level alarm	10800	10800	10800	10800	12500
0% Low level alarm	11800	11800	11800	11800	12500
10% Low level alarm	11900	11900	11900	11900	13000
25% Low level warning	12000	12000	12000	12000	13197
50%	12300	12350	12200	12300	13340
75%	12600	12650	12450	12600	13483
90%	12700	12750	12600	12700	13595
100%	12800	12850	12700	12800	14400
High level warning	14700	14700	15000	15000	15000

The implementation in the BC2 uses linear interpolation between the two rows.

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3.2 SoC Estimation based on Current

BatteryCheck2 has sensors to measure the voltage across the battery, the current flowing in/out of it, and the temperature of the battery and the load shunt. It counts the amount of charge flowing in and out (inferred by integrating the average current over time), and records the SoC based on this. The charge counter is also called a Coulomb counter referring to the physical unit of the electrical charge.

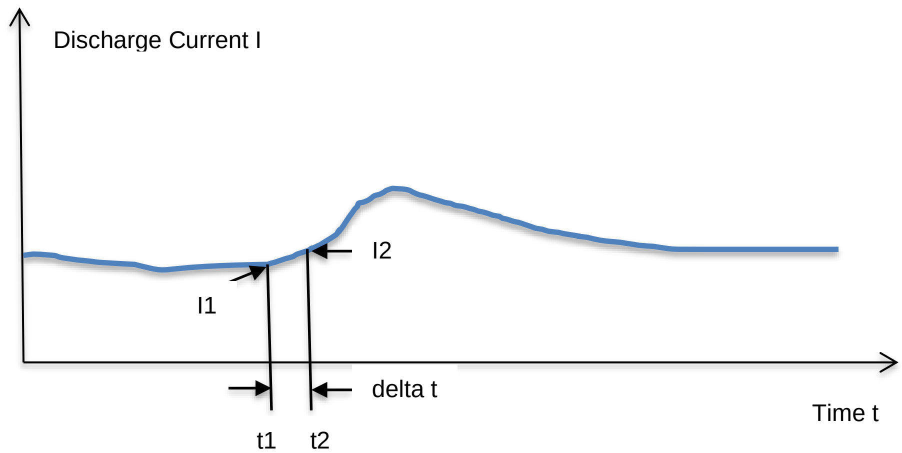
3.3 Synchonisiation of SoC

The charge current decreases to small values when a battery approaches full charge. This can be detected. When the battery voltage has reached 13.5V or more and at the same time the charge current has become less than 0.03 C (e;g; 3A for a 100Ah battery), then a lead acid battery would be considered fully charged. Different thresholds apply to Li-Ion batteries.

Therefore when it has been found that the battery is fully charged, the SoC value should be set to 100% to synchronise the SoC-value with the actual state of the battery.

In a situation where the battery will be charged, but does not reach full charge, the charge going into the battery needs to be accumulated and the SoC-value updated by integrating the current over time. Energy losses in the battery during charging will be considered by a charging efficiency factor, say 90%.

3.4 Discharging and the Peukert Effect



Sampling Interval: delta t = t2 – t1

Charge drawn during the Sampling Interval: delta Q = delta t * fp * (I2+I1)/2

Current Compensation Factor based on Peukert Law: fp = f(I)

The Peukert Law reflects the fact that the available battery capacity depends on the value of the discharge current. The nominal battery capacity is normally given for a 20hour discharge time from full to empty (100% to 0%) and constant load current. For shorter discharge times (higher currents) the available battery capacity is reduced.

The discharge time according to Peukert is: t = H*(C/I*H)^k

With
H = Rated Discharge time, normally 20h
C = rated Battery Capacity in Ah
I = Discharge Current in A
k = Peukert Exponent

The Peukert Exponent depends on the battery type and is >=1.

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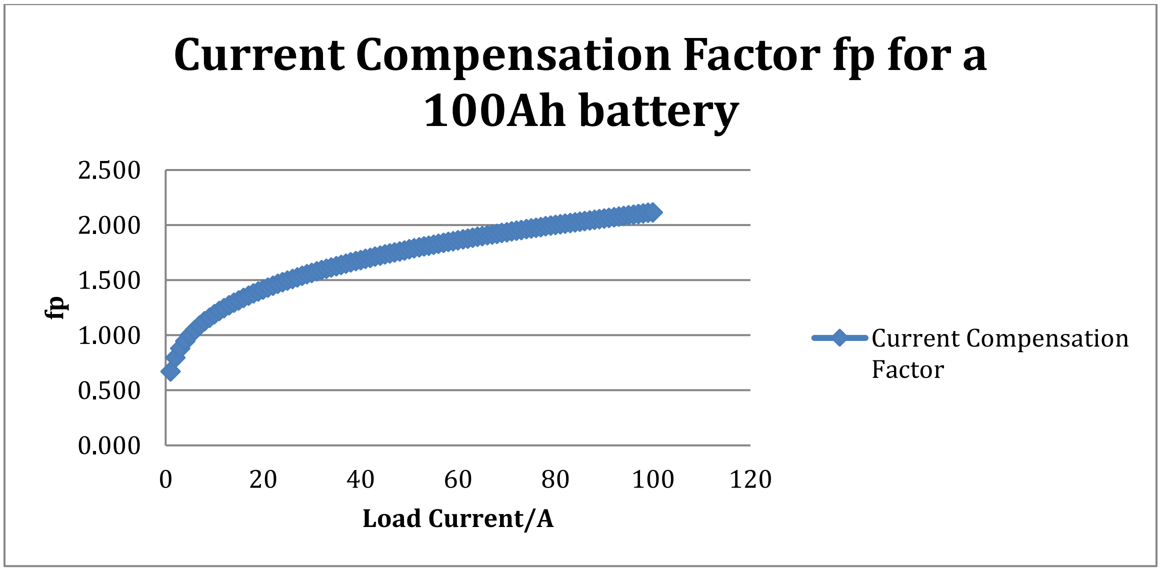
3.4.1 Peukert Constants:

Battery Type	AGM	Gel	Wet cell	Calcium	LiFP
Peukert k	1.25	1.25	1.25	1.25	1.05

To correct the calculated charge taken out of the battery for the Peukert effect the measured current value will be multiplied by the Current Compensation Factor fp, which is a function of the discharge current itself, the Peukert exponent and the rated battery capacity. The graph below shows an example of the Current Compensation Factor fp for a 100Ah lead acid battery assuming a Peukert Exponent of 1.25.



SoC(t2) [%] = SoC(t1) [%] + deltaSoC [%]

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3.4.2 Discharging:

When the battery is discharging the SoC is reduced by deltaSoC for every measuring interval.

deltaSoC [%] = -100 * delta Q [Ah] / estimated Capacity [Ah]

deltaSoC [%] = -(100 * delta t[h] * fp * (I2+I1)[A]/2) / estimated Capacity [Ah]

3.5 Charging:

deltaSoC [%] = 100 * delta Q [Ah] / estimated Capacity [Ah]
deltaSoC [%] = (100 * delta t[h] * fc * (I2+I1)[A]/2) / estimated Capacity [Ah]

fc = charging efficiency factor, say 0.9

Note: Symbols in [] show the physical unit of the variables, if the measurement values received from the BC2 have different physical units, then they need to be converted.

3.6 Combing voltage based and charge based SoC estimation

The Voltage based SoC is only applied at power up and after new battery parameters have been received from the App.

Background: Lithium ion batteries (e.g. LiFePO4) have a relative flat voltage/ SoC characteristic over a large part of the SoC range, therefore ongoing SoC adjustment based on voltage would introduce relatively large errors.

Note: This voltage to SoC conversion is done independent of the actual current and may therefore result in lower SoC estimations, if a significant current is drawn from the battery. A higher SoC estimation will result, if the battery is being charged by a significant current.

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4 Calculate estimated Capacity and State of Health (SoH)

The battery capacity changes with age and treatment of the battery. In the beginning a battery might not have reached its rated capacity and needs some charge and discharge cycles to increase the capacity. Then as the battery gets older the available capacity decreases. It is therefore interesting to the user what the actual capacity of the battery is. The BC2 attempts to

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estimate the capacity based on the SoC and charge removed at two points after a discharge phase.

Lead acid batteries age quickly, when the battery is discharged to a low SoC, so for a long battery life the user will try to avoid deep cycles. On the other hand will the accuracy of the capacity estimation be better the deeper the battery has been discharged.

The BC2 firmware applies the following strategy to provide a solution:

1. The Estimated Capacity is set equal to the Rated Capacity whenever it is entered during setup and when first powered. The Estimated Capacity is limited to no less than 30% and not more than 120% of the Rated Capacity.
2. After the battery voltage has increased above the “Tail voltage (Battery Configuration Parameter) and the charge rate has fallen below the “Tail current” the battery is considered fully charged. The max-point will be recorded then and the charge will be set to the estimated capacity value.

   Note: If the BC2 will be connected to a partially charged battery and then the battery will be discharged, no capacity estimation will be performed at mid- or min-point to avoid inaccurate capacity estimations.

3. When the battery discharges the voltage is monitored and when it falls to or 100mV below an Intermediate threshold, the battery status is recorded as the mid-point, if the battery current has been within configured limits for the configured time (see Min/Max algorithm parameters: stable current and stable time). Now the battery capacity can be estimated based on the recorded mid- and max-points (see 5 and 6 below). If the current was too high while the voltage was in the mid-point sampling range, then no mid-point will be recorded. Also if the voltage has fallen below the mid-point sampling and then the SoC increases by 5%, for example due to recharging, then the max-point will be marked as invalid. This is to prevent multiple capacity estimations at mid-points using the same max-point resulting in inaccurate capacity values.

4. If the battery will be further discharged and the voltage reaches the Min/Max algorithm parameter “Discharging voltage”, then under “stable current” conditions the battery status will be recorded as the min-point and an estimation of the battery capacity based on min- and max-points can be performed.

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5. The measured capacity is calculated:

   Measured Capacity = delta Charge / delta Soc
   Measured Capacity = (maxCharge - minCharge) / (maxSoC - minSoc)

   If a mid-point could be recorded, then the mid-point values will be used in the equation above instead of the min-point values. The Charge values applied here are “Peukert” compensated.

6. The new Estimated Capacity value becomes:

   Estimated Capacity = (1 - X) * Old Estimated Capacity + X * Measured Capacity

   Where X is the confidence factor (0<=X<=1) with X=0.2 if the mid-point was used and X=0.5 in case of the min-point.

7. Sampling of min-, mid- and max-points is performed every second.

The SoH can then be calculated:

Estimated State of Battery Health in % with 0.5% resolution
SoH = 200 * Estimated Capacity / Rated Capacity

The BC2 initialises the Rated Capacity to 100% of rated_capacity received from the app the first time the app is run and this battery is setup. A battery reserve will be maintained from the App rather than the BC2.

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5 Time remaining calculation

The time remaining shall provide an estimation of the remaining time until the battery is empty assuming an average current, which is Peukert corrected. The time remaining shall reach 0, when the low battery alarm will be triggered. To provide a last reserve, the low battery alarm threshold should be set so that 10% of the battery capacity remains.

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Time remaining [h] = Estimated Capacity[Ah] * (SoC[%] – SoC_Alarm[%])/ (100 * average current[A])

Time remaining [min] = (SoC[0.5%] – SoC_Alarm[0.5%]) * 60 * Estimated Capacity [mAh] / (200 * average current [mA])

Using internal normalisations and variable sizes:
u16Time2Go_min = (u16Ch2SoC/256 - SoC_n8LowBatAlarmSoC) * 3 * u32EstCapacity_mAh / (160 * u16IPT1_16mA)

A 16bit PT1-Filter dampens the average current, so that the Time remaining value does not appear too dynamic.

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6 BLE interface

The BC2 supports CAN and BLE Communications Protocol Specifications Protocol Version 2. Please see this document for more details.

6.1 Advertising

During advertising the BC2 transmits three packets providing information about the battery without the need of a connection.

Packet	Message type	Nominal interval / msec	Measured interval / msec
Introduction	0x00	1000	942 to 3024 (Median 947)
Battery Status	0x01	167	372 to 2080 (Median 567)
Battery Info	0x04	1000	941 to 4148 (Median 1135)

Measured intervals have been logged with the nrf-connect App running on an Android tablet. The sample size was 100 packets.

6.1.1 Introduction packet

Byte Offset	Variable	Description
11	=00	Message type = Introduction / Advertisement message
12	setec_ble_product_id	Setec product ID = BC2, BC2H
13	hwv.version	Hardware version major
14	hwv.revision	Hardware version minor
15	hwv.modification	Hardware version modification
16	VERSION_SOFTWARE_VERSION	High nibble – Software version major Low nibble – Software version minor
17	ID/SN0	ID Serial Number
18	ID/SN	
19	ID/SN	
20	ID/SN	
21	ID/SN	
22	ID/SN	
23	ID/SN10	

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Byte Offset	Variable	Description
24	uptime (lowest byte)	uptime (seconds, 32bit unsigned)
25	uptime	
26	uptime	
27	uptime (highest byte)	
28	discovery_on	Flags field: Bit 0: Discovery on – ready to be learned or learn (pairing)

6.1.2 Battery status packet

Byte Offset	Variable	Description
11	=01	Message type = Battery status
12	battery_status.voltage	Battery voltage (mV, 16bit signed)
13		
14	battery_status.current	Battery current (mA, 32bit signed), negative values when charging.
15		
16		
17		
18	battery_status.charge	Charge (mAh, 32bit signed)
19		
20		
21		
22	battery_status.temperature_shunt	Shunt Temperature (ºC, 8bit signed)
23	battery_status.temperature_battery	Battery Temperature (ºC, 8bit signed)
24	uptime (lowest byte)	uptime (seconds, 32bit unsigned)
25	uptime	
26	uptime	
27	uptime (highest byte)	
28	= 00	Error Flags, not used.

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The Battery Info packet is transmitted alternating with introduction message about every second and interleaved with Battery Status packet during advertising.

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6.1.3 Battery Info packet

Byte Offset	Variable	Description	Coding
11	u8MessageType	Message Type = Battery Info	= 0x04
12	u16Time2Go	Estimated Time Remaining in minutes	uint16_t (little Endian) Range 0 to 64000 min (1066hours) u16Time2Go = 0xFFFF indicates that no value has been calculated. u16Time2Go = Time Remaining
14	u16EstCapacity	Estimated Battery Capacity in Ah	uint16_t (little Endian) u16EstCapacity = 4 * Estimated Battery Capacity [Ah] u16EstCapacity - Range 0 to 3200 (0 to 800Ah)
16	u8SoC	Estimated State of Battery Charge in %.	uint8_t SoC in %, resolution 0.5% Range 0 to 125.0% u8SoC = 2 * SoC
17	u8SoH	Estimated State of Battery Health in %	uint8_t SoH in %, resolution 0.5% Range 0 to 125.0% u8SoH = 2 * SoH
18	u8Reserved	Reserved set to 0.	uint8_t
19 to		**Used for monitoring internal**	

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Byte Offset	Variable	Description	Coding
28		**values, see below.**	
19	u16V2SoC	Voltage based SoC in 0.5%	uint8_t SoC in %, resolution 0.5% Range 0 to 125.0% u16V2SoC = 2 * SoC
20	u16ChargeRate	(Dis)Charge Rate in C/SOC_nChargeRateFact	uint16_t u16ChargeRate
22	u16Ch2SoC_Factor	Ch2SoC Contribution Factor	uint16_t (high byte always 0) u16Ch2SoC_Factor 0 ... 1 corresponding to 0 ... 256
24	u32deltaT_500msec	Time between samples with 500msec resolution	uint8_t (only low byte) u32deltaT_500msec
25	u32IAvg_mA	Average Peukert corrected discharge current in mA	uint16_t Limited to 16bit
27	u16IPT1_16mA	PT1-Filtered Peukert corrected discharge current with 16mA resolution	uint16_t (only valid for discharge)

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6.2 BC2 Data logging

This section describes the characteristics offered over BLE to retrieve historical data from the BC2 for development or monitoring, but not supported by the App.

6.2.1 Description

The BC2 logs 2 types of data:

1) Historical records.
2) The most recent Minimum/Max point pair used to estimate battery capacity.

6.2.2 History Records

The history records are stored in the BC2 in an array in RAM. If the BC2 loses power the historical data is lost (this should be infrequent). A record will be taken every 20 minutes and will be added to the history array. The array will hold up to 3 days worth of records. If the array is full the latest record added will override the oldest record in the array.

The BC2 records the following signals:

1. Time
2. Charge
3. Voltage
4. State of Charge
5. Battery Temp. (average)
6. Shunt Temp. (average)
7. Current (average)

The time field in each record holds the time when the averaging began for voltage, battery temperature, shunt temperature and current fields, this averaging stops at the next record's time field.
The history data is accessed using two characteristics the History Record(s) characteristic and the History Record(s) Control Point characteristic. The History Record(s) characteristic will hold zero or more records depending on the MTU size negotiated during the Bluetooth connection and how many records are available (for the 20 minutes after the BC2 powers up no records are available). The History Record(s) Control Point characteristic selects which history record or records are placed in the History Record(s) characteristic.
The History Record(s) Control Point characteristic requires a 4 byte unsigned integer to be written to it. This integer represents the time in seconds of the first record's time field to load into the History Record(s) characteristic. If the time value written does not match a history record's time value then the history record loaded will be the time truncated/rounded down to the nearest time interval. If the time value written is too far in the future, i.e. beyond the set of history records then the History Record(s) characteristic will be loaded with nothing, i.e. it will be

zero length. If the time value written is too far in the past, it will round up the time value to the time field of the oldest record available.
If notifications are enabled for the History Record(s) characteristic above then a write into the History Record(s) Control Point characteristic will cause a succession of notifications to occur from the history record matching the time written to this characteristic to the most recently recorded history record. On first connecting to a BC2 a convenient way to get all available history records is to enable notifications and the write time=0x00000000 into the History Record(s) Control Point characteristic. For reference our testing of this interface would transfer 7 days of worth of records (when 3 records have been stored per hour) in ~9s.

6.2.3 When to read history data

History data should be request/read after more than 40 minutes has passed since the last received history record uptime field. Note history record with uptime 0 is the average of data in the range [0, 20 minutes) and is available at uptime = 20 minutes.

6.3 Min/Mid/Max-points sampling

The BC2 records a Min- or Mid-point, only if the current remained within limits (Stable current parameter) for a minimum time (Stable time parameter). These points are recorded to enable an estimation of the available battery capacity.

Min-point:
The Min-point is recorded, if the voltage has fallen below the “Discharging voltage” parameter (discharging_voltage_mv).

Mid-point:
The BC2 tries to save a Mid-point, when the battery is being discharged and the voltage falls to or 100mV below the Mid-point voltage (midpoint_voltage_mv) of the Min/Max algorithm parameters.

Max-point:
The Max-point is saved, when the voltage rises above the “Tail voltage” parameter while the current is below the “Tail current”.

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The following parameters are updateable via BLE characteristic:

Minimum/Max records sampling parameters
Stable current - `stable_current_ma`.
Mid-point voltage - `midpoint_voltage_mv`.
Discharging voltage - `discharging_voltage_mv`.
Stable time - `stable_time_sec`.

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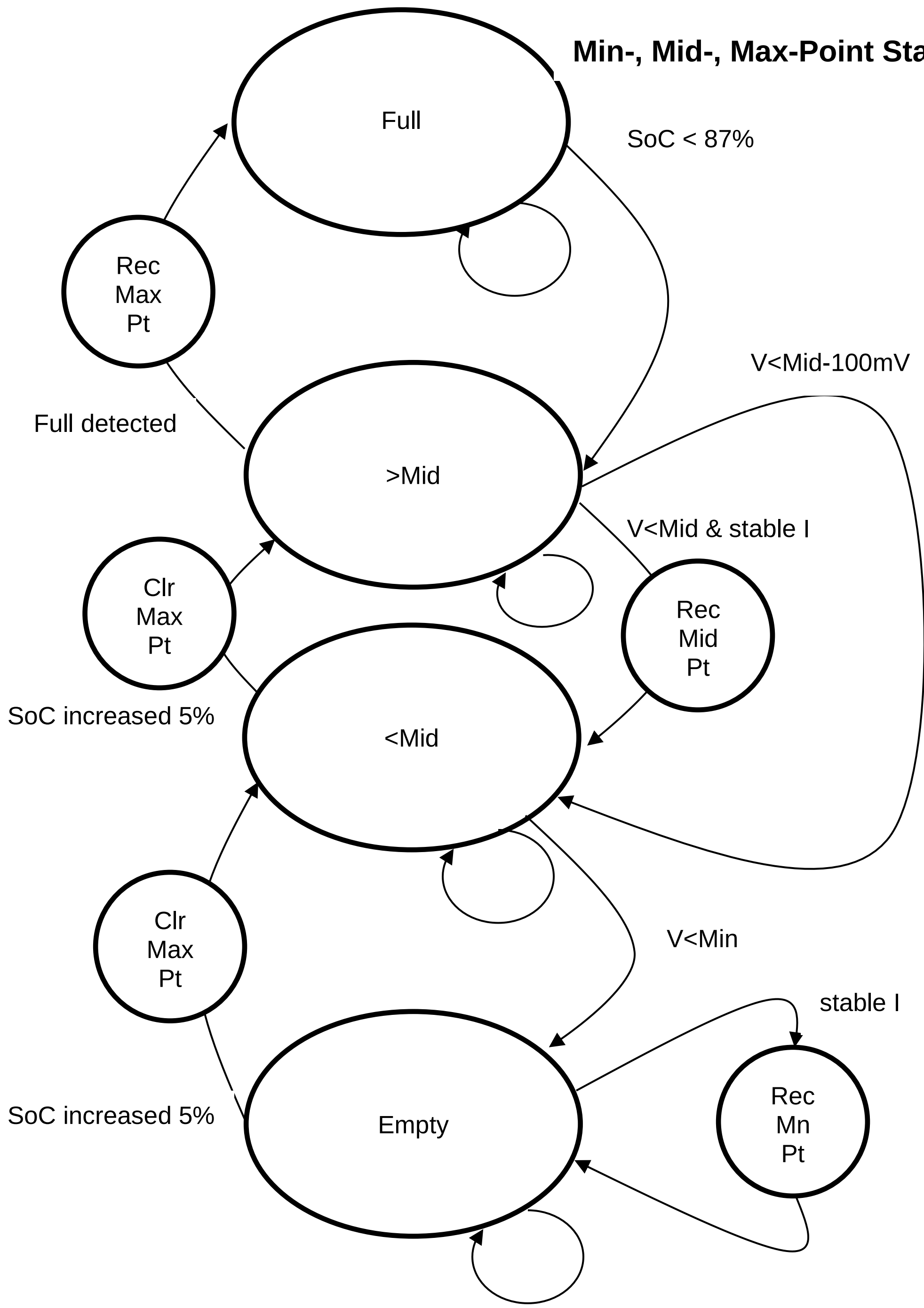
Min-, Mid-, Max-Point State Diagram



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State Transition Table

Transition	Condition	Action
Full to >Mid	SoC < 87%	None
>Mid to <Mid	Voltage smaller than Intermediate level and current smaller than Stable current for Stable time.	Record Mid-point and perform battery capacity estimation, if Max-Point valid.
>Mid to <Mid	Voltage less than Intermediate level minus 100mV.	None
<Mid to Empty	Voltage less than Discharging voltage level.	None
Empty to Empty via Rec Min Pt	Current smaller than Stable current for Stable time.	Record Min-point and perform battery capacity estimation, if Max-Point valid.
Empty to <Mid	SoC has increased by 5% since entering the Empty state.	Clear Max-point to prevent another capacity estimation at Mid- or Min-point before the battery is fully charged again.
<Mid to >Mid	SoC has increased by 5%.since entering the <Mid state.	Clear Max-point to prevent another capacity estimation at Mid- or Min-point before the battery is fully charged again.
>Mid to Full	Voltage greater than Tail voltage and charge rate less than Tail current for Tail delay time.	Record Max-point and clear any Min- or Mid-point.

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6.4 How to update reference records

The BC2 keeps track of two reference records, one for the instantaneous readings from the battery (reference) and one for the historical graph (historicalReference).

The reference record is intended to be the battery status record (V, I, C, TB, TS) before the current became large.

The historicalReference record is intended to be the battery history record (V, I, C, TB, TS) before the current became large. It is the latest reference record that is earlier than the most recent history record.

6.5 Accessible BC2 Characteristics

A list of accessible characteristics. These characteristics are in the BC2 Service UUID ffffffff-ffff-ff53-4554-454320424333.

6.5.1 History record(s)

UUID: ffffff53-4554-4543-2043-414e20424c46
R/W: Read / Notify
Field values:

Name	Time	Charge*	Voltage average	State of Charge	Battery Temp. (average)	Shunt Temp. (average)	Current (average)
Byte (offset)	0 - 3	4 - 7	8	9	10	11	12 - 15
Units	Seconds (after BC2 power	mAminute	100mV	0.5%	°C	°C	mA

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Name	Time	Charge*	Voltage average	State of Charge	Battery Temp. (average)	Shunt Temp. (average)	Current (average)
	up)						
C type	uint32_t	int32_t	uint8_t	uint8_t	int8_t	int8_t	int32_t

This characteristic holds between zero to 31 history records. The number of records placed in the characteristic will depend on the MTU negotiated after the Bluetooth LE connection is made and the number of records available in increasing time after the selected history record. Use the History Record(s) Control Point characteristic to select the 1st history record, see below:

Description	Record[n] selected by writing the time to the History Record(s) Control Point	Record[n+1]	...	Record[n+30]
Byte (offset)	0 - 15	16 - 31		480 - 495

* Note that (possibly relevant for graphing) the Charge field is recorded at the end of the averaging period for voltage, temperatures and current. On BC2 power up the charge is initialised as 0.

The time_delta between records is 1200 seconds (20 minutes). Note this could change depending on space constraints in the BC2.

Also note that this charge field is likely to roll over for a BC2 installed on a large battery for a long period of time (a year or more) and should be handled within the app.

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6.5.2 History record(s) control

UUID: ffffff53-4554-4543-2043-414e20424c47
R/W: Read / Write / Write without response
Field values:

Name	Time
Byte (offset)	0 - 3
Units	Seconds (after BC2 power up)
C type	uint32_t

This characteristic is used to control the History Record(s) characteristic above. Note that a write to this characteristic must always be 4 bytes in length.

6.5.3 Battery Status

UUID: ffffff53-4554-4543-2043-414e20424c48
R/W: Read / Notify
Field values:

Name	Time	Voltage	Battery Temp.	Shunt Temp.	Current
Bytes (offset)	0 - 3	4 - 5	6	7	8 - 11
Units	Seconds (after BC2 power up)	mV	°C	°C	mA
C type	uint32_t	uint16_t	int8_t	int8_t	int32_t

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Name	Estimated Time Remaining	Est. Battery Capacity	State of Charge	State of Health	Reserve set to 0x00	Reserve set to 0x00
Bytes (offset)	12 - 13	14 - 15	16	17	18	19
Units	minutes	250mAh	0.5%	0.5%		
C type	uint16_t	uint16_t	uint8_t	uint8_t	uint8_t	uint8_t

This characteristic holds the most recent battery status data sampled. If notifications are enabled for this characteristic then a notification will be sent for each new battery status update. An update happens about every half second. Note that this will mean you will receive two notifications with the same time field and other fields changing. Also note that current and charge are the only fields that updated at every half second.

** Note that the Charge units are not the same as those used for the History Record(s) characteristic Charge field.

6.5.4 Min/Max max record

UUID: ffffff53-4554-4543-2043-414e20424c4b
R/W: Read
Field values:

Name	Time	Charge	Voltage	Battery Temperature	Shunt Temperature	Current
Byte (offset)	0 - 3	4 - 7	8 - 9	10	11	12 - 15
Units	seconds	mAh	mV	°C	°C	mA
Type	uint32_t	int32_t	int16_t	int8_t	int8_t	int32_t

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Reads the max record of the min/max record pair set by the index written to the Min/Max control point described below.

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6.5.6 Min/Max min record

UUID: ffffff53-4554-4543-2043-414e20424c4c
R/W: Read
Field values:

Name	Time	Charge	Voltage	Battery Temperature	Shunt Temperature	Current
Byte (offset)	0 - 3	4 - 7	8 - 9	10	11	12 - 15
Units	seconds	mAh	mV	°C	°C	mA
Type	uint32_t	int32_t	int16_t	int8_t	int8_t	int32_t

Reads the min record of the min/max record pair set by the index written to the Min/Max control point described below.

6.5.7 Min/Max index control point

UUID: ffffff53-4554-4543-2043-414e20424c4d
R/W: Read / Write
Units: None
Sets/gets the record index for the min/max record pair to load into the Min/Max max and min characteristics above. If no records exist for the index written to this characteristic then the max and min record characteristics will have zero length when read. The length of this characteristic is 1 byte. Only one Min/Max record is supported, which is the latest pair recorded.

Note that a device reset function has been added to this characteristic. This is activated if 0xFF is written to the characteristic. The intention is if the app detects the BatteryCheck is behaving incorrectly then the app has the option to reset the BatteryCheck.

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6.5.8 Min/Max algorithm parameters

UUID: ffffff53-4554-4543-2043-414e20424c4e
R/W: Read / Write
Field values:

Name	Transition minimum sec	Mid-point voltage mV	Stable current mA	Discharging voltage mV	Stable time sec
Byte (offset)	0-1	2-3	4-5	6-7	8-9
Units	seconds	mV	mA	mV	seconds
C type	uint16_t	uint16_t	uint16_t	uint16_t	uint16_t
Default	30s	12,300mV	2,000mA	12,000mV	120s
AGM	30s	12,300mV	2,000mA	12,000mV	120s
GEL	30s	12,350mV	2,000mA	12,000mV	120s
WET	30s	12,200mV	2,000mA	12,000mV	120s
CALCIUM	30s	12,300mV	2,000mA	12,000mV	120s
LiFePO4	30s	13,197mV	2,000mA	13,000mV	120s

Sets/gets the min/mid sampling parameters. **These battery parameters must be written by the App at first battery connection together with the BC2 Battery Configuration Parameters.** The specified default values are applied, if no valid data has been received from the App.

Mid-point voltage - The voltage must fall below this to record a mid-point.
Note: The Mid-point voltage parameter must be larger than the Discharging voltage parameter.

Discharging voltage - The battery voltage must have dropped below this value before a min-record will be stored.

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Stable current - The absolute current must be less than this value before a max or min record is stored.

Stable time - The minimum seconds required before the battery state is considered stable (current equal or less than Stable current) before storing a min, mid or max record.
A value of 0xFFFF disables the min/mid and max point sampling and also the battery capacity estimation so that the battery capacity used in the calculations will always remain the rated capacity.

Transition minimum - The minimum time that has to pass between recording a minimum record and then recording a maximum record and vice versa. This parameter is not used.

6.5.9 App settings - BC2 Battery Configuration Parameters

UUID: ffffff53-4554-4543-2043-414e20424c4A
R/W: Read, Write

These are characteristic battery configuration parameters of the BC2's non-volatile memory. A read will always return 20 bytes and a write to the characteristic must be 20 bytes long. By default this characteristic will be all zeros and the battery parameters must be written by the App at first battery connection.

When the BC2 receives new App Settings (BC2 Battery Configuration Parameters) from the smart phone or tablet, these parameters will be directly applied and a new SoC estimation from voltage will be triggered. The Estimated Capacity will be updated to the newly received Rated Capacity.

Note: The update process described above is independent of the values received being different or identical to the previous parameter values.

BC2 Battery Configuration Parameters
Stored in "App settings" **UUID:** ffffff53-4554-4543-2043-414e20424c4A ???

Parameter	Description	Coding	Byte (offset)

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Parameter	Description	Coding	Byte (offset)
u8BatteryType	Selects the battery type inside the BC2 for example: AGM	uint8_t 0 = Not initialised 1 = AGM 2 = Calcium 3 = Wet cell 4 = LiFePo4 5 = Gel >5 = Reserved Default: 1	0
u8PeukertPara	Peukert Exponent Range 1.0 to 2.5.	uint8_t u8PeukertPara = k * 100 k = Peukert Exponent u8PeukertPara-Range: Values only 100, 105, 110, 115, 120 and 125 allowed! Example: k=1.25 -> u8PeukertPara = 125 Default: 125 :	1
u16RatedCapacity	This is the rated battery capacity of the new battery.	uint16_t (little Endian) u16RatedCapacity = 4 * Battery Capacity [Ah] u16RatedCapacity-Range 0 to 3200 (0 to 800Ah) Default: 35Ah	2, 3
u16TailCurrentLimit_C	Tail Current Limit expressed in Charge Rate C	uint16_t (little Endian) u16TailCurrentLimit_C=	4, 5

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Parameter	Description	Coding	Byte (offset)
		4096 * Charge Rate 0.03C would be 3A for a 100Ah battery -> 4096 * 0.03 = 122.88 Default: 123	
u16TailVoltageLimit	Tail Voltage in mV	uint16_t (little Endian) Default: 13500	6, 7
u8ChargeEff	Charging efficiency factor	uint8_t u8ChargeEff = 256 * Charge Efficiency Range 0 to 255 corresponding to 0 to 0.996 Default: 243 (95%)	8
au8V2SoCmap[7]	Voltage map values for 0, 10, 25, 50, 75, 90 and 100% SoC used when current is low.	uint8_t[7] au8V2SoCmap[n] = Battery Voltage [mV] / 100. au8V2SoCmap-Range 0 to 250 Default: 11800, 11900, 12000, 12300, 12600, 12700, 12800	9, 10, 11, 12, 13, 14, 15
u8LowBatAlarmSoC	State of Battery Charge in % when the battery is considered empty. This is the base value for the remaining time estimation.	uint8_t SoC in %, resolution 0.5% Range 0 to 125.0% u8LowBatAlarmSoC = 2 * SoC	16

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Parameter	Description	Coding	Byte (offset)
		Default: TBA Proposal: 100 (50%)	
u8TailDelay	Time the voltage must be above the Tail voltage and the current below the Tail current before the battery can be considered to be full.	uint8_t Time value with 4sec resolution. Range 0 to 250 -> 0 to 1000sec. Default: 300sec -> 75	17
	Reserved set to 0.		18, 19

Note: There is no range check on battery configuration parameters in the BC2 firmware, the App has to ensure valid data.

6.5.10 Battery Name

UUID: ffffff53-4554-4543-2043-414e20424c49
R/W: Read, Write
This characteristic can be used to store a Battery Name to the BC2's non-volatile memory. A read will always return 20 bytes and a write to the characteristic should always be 20 bytes long. Unused bytes in the Battery Name should be '\0'. By default this characteristic will be all zeros.

6.5.10.1 Complete local name

The complete local name advertisement data type is accessible in the scan response data provided by the BC2 firmware. The complete local name is the concatenation of a shortened commercial name and the device's assigned Setec serial number.

BC2 variant commercial name	Complete local name
BatteryCheck100	'BC100 A0123456789'

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BatteryCheckPRO	'BCPRO A0123456789'
BC300	'BC300 A0123456789'

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7 Thresholds and mapping

7.1 State of Charge to colour

When the battery is discharging or idle, the colour shown to the user in the battery meter should depend on the battery type (AGM, Li…): **TBD**

SoC	Colour
<30%	Red
30%≤s<60%	Orange
≥60%	Green

7.2 State of Health to colour

When the battery is discharging or idle, the colour shown to the user in the battery meter should be:

SoH	Colour
<30%	Red
30%≤s<70%	Orange
≥70%	Green

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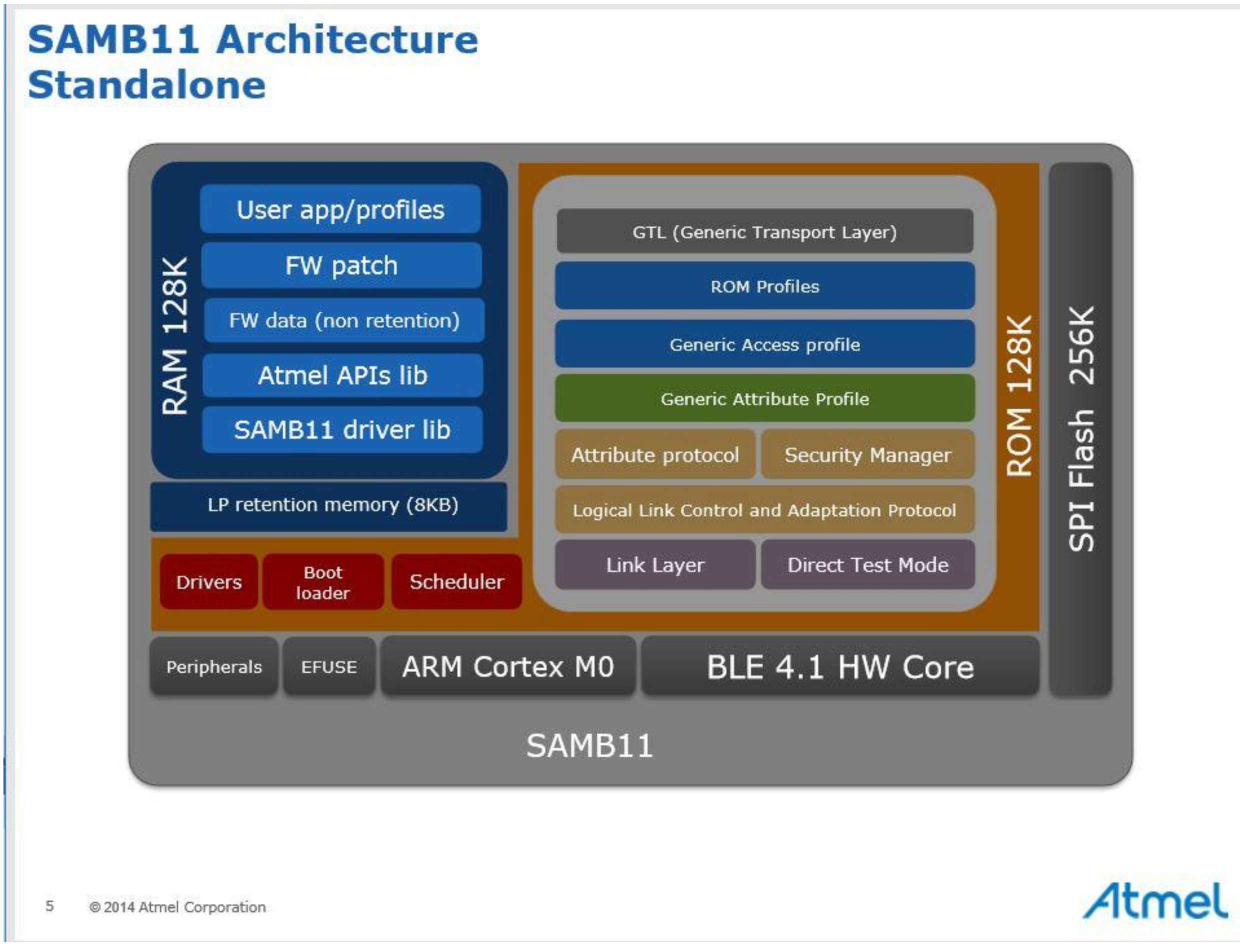
8 Appendix

8.1 Processor SAMB11 Software Architecture



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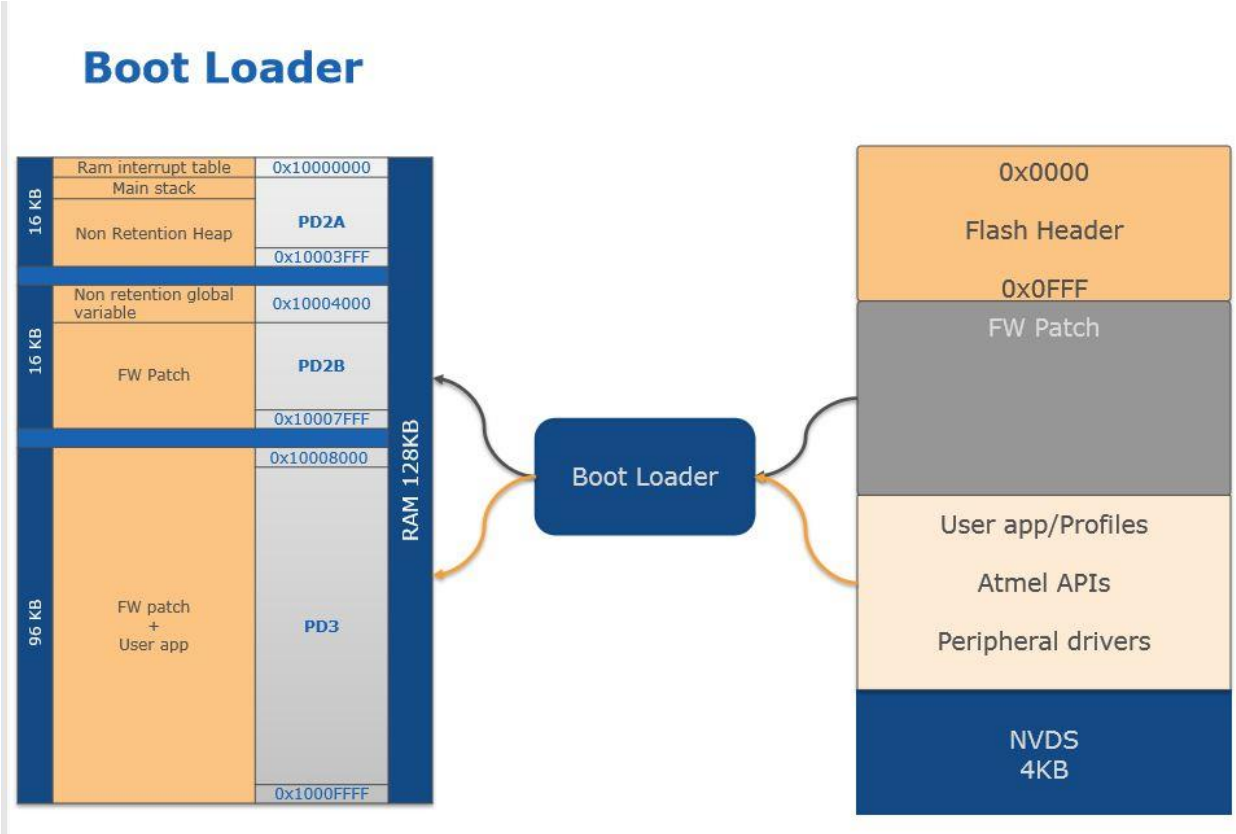
The following shows the unusual boot loader process of the SAMB11 and its associated memory structure. The Application Code in Flash memory is transferred via SPI into the processor's RAM after reset. This is the reason why it takes seconds for the boot process to finish. The code is then executed inside the RAM.
The Application area starts from address 0x10008000, but includes FW patch data. Application and FW patch data are limited to 96kBytes. The first Application memory address is at 0x10009000 leaving only about 90kByte for the application. Application end address is 1001F7FF.



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8.2 Firmware

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ATSAMB11 Tasks

ATSAMB11 supports the following tasks:
• Idle Task
– idle task is responsible for ULP (Ultra Low Power) sleep feature of ATSAMB11. It is the lowest priority task.

• Idle task is the first task created in the system.
• Initializes real-time environment, semaphores and MQ.
• Creates FW task.
• Context will be switched immediately to FW task.
• BLE related initializations will be executed.
• FW task will be blocked after initialization done.
• Context will be switched back to idle task.
• Create SAMB11 application task.
• Context will be switched to SAMB11 app task.
• SAMB11 app task will be executed, then blocked.
• Context will be switched back to idle task.
• Idle task puts the system in ULP or WFI mode based on the system status.

• FW Task
– firmware task responsible for BLE functionality. It is the highest priority task.

• Initializes different layers of BLE stack, core, Link Layer, RF, etc...
• Loop forever for any pending events.
• If there is nothing to be handled then BLE core is turned off.
• FW task will be blocked.
• Context will be switched to either SAMB11 app or Idle task.

• Application Task
– application task.
Applications developed for ATSAMB11 run as an application task. Its priority is higher than idle task but lower than the FW task.

On boot-up the firmware task is initialized, started, and then waits for any event to happen. If any application is loaded onto the platform, it will start the application task followed by the user

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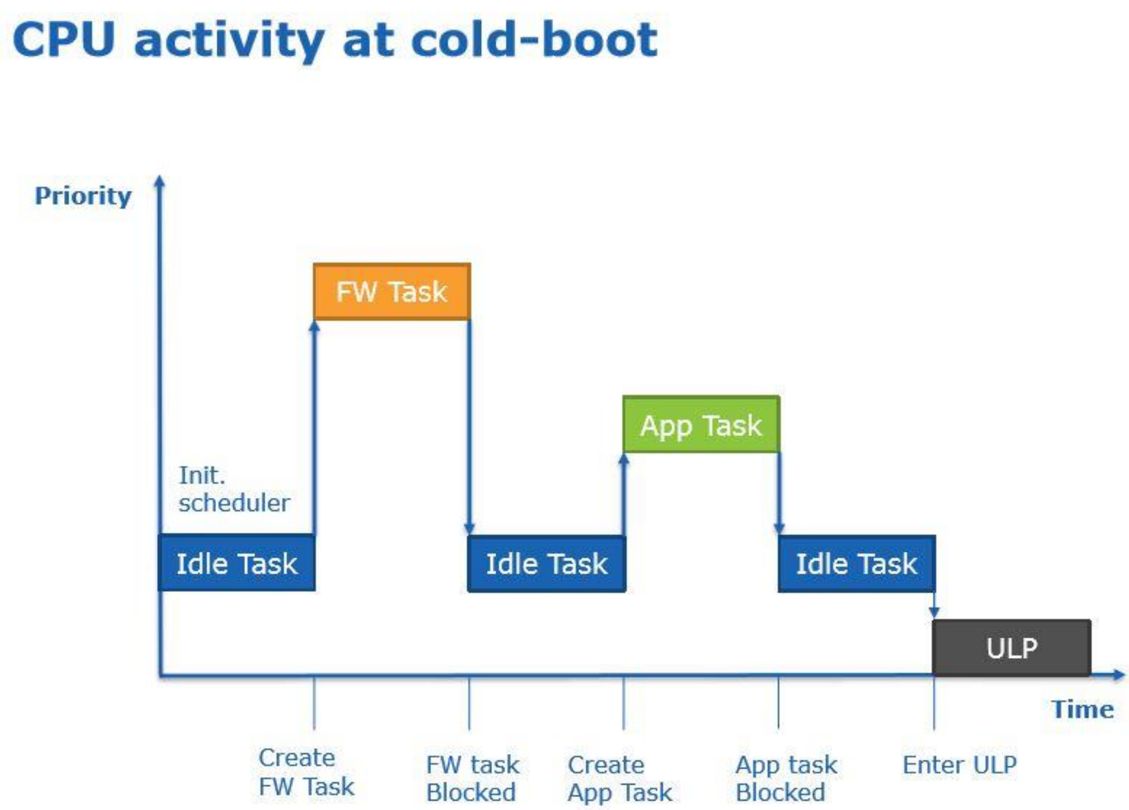
developed application. When both tasks are waiting for event/interrupt, the system goes to idle task where it will try to put the entire system into ULP Sleep state.



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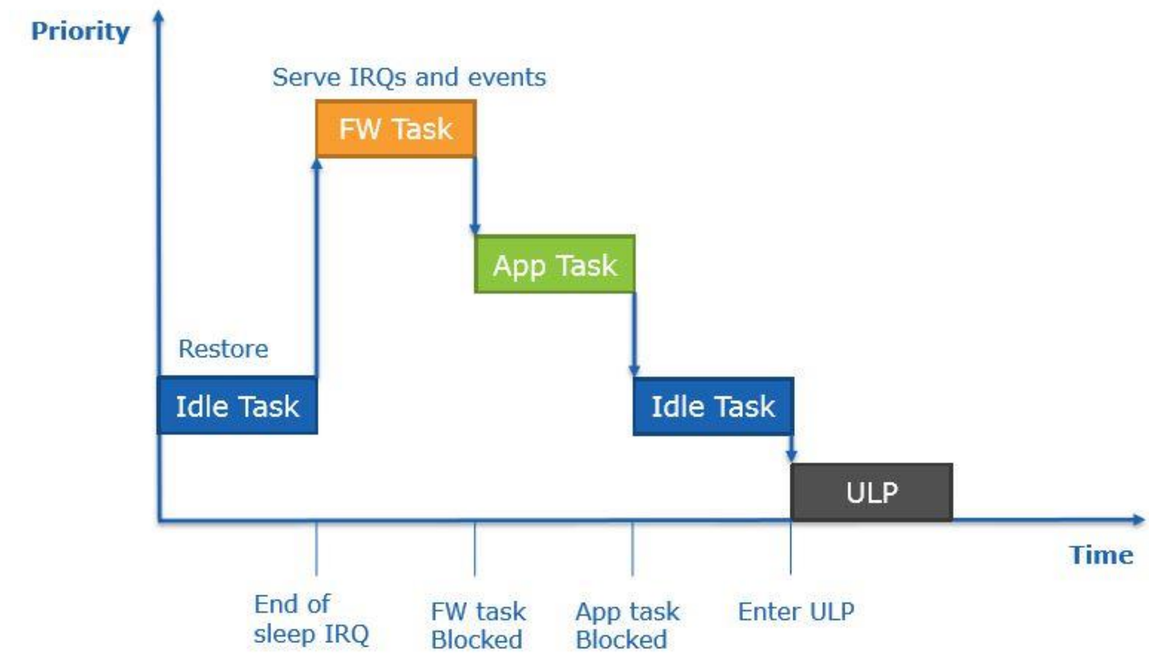
CPU activity at wake-up



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BLE Stack

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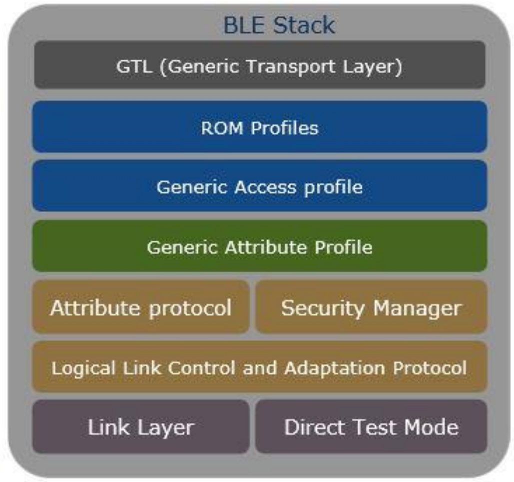
BLE Stack

- BLE stack.
  - ROM profiles (more details in next slides)
  - GAP (Generic Access Profile)
    - Control path for BLE responsible for advertising, scanning and connection.
  - GATT, ATT:
    - Data path for BLE, responsible for service creation and discovery.
  - L2CAP
    - Packet segmentation and reassembly.
  - SMP (Security Manager Protocol)
    - Pairing, bonding and encryption.
  - Link Layer
    - Low level operation for discovery, connection creation and maintenance, power save, and point to multi-point data transfer.
  - Direct Test mode
    - Four standard commands for RF testing.
    - Start Rx, Start Tx, Stop, and Reset,



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8.2.1 Timing

The three different clock sources 26 MHz XO, 26 MHz internal RC and 2 MHz internal RC can be used as input to ARM processor and other peripheral interfaces. The firmware uses the 26 MHz crystal oscillator integrated into the processor (SAMB11) to provide the precision clock for the BLE operations.

1. System Clock = CLOCK_FREQ_26_MHZ = 26000000 set in main_sam_b.c

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samb11_timer_system_clock_ticks_per_ms returns 26000

samb11_timer_get_raw returns 64bit timer value with 1/26000000 sec resolution based on the TIMER1 of the Dual Timer. TIMER1 is a 32bit down counter with interrupts on counter underflow. This timer interrupt is enabled.

timer_get_timestamp_msec returns samb11_timer_get_raw / 26000

The timer rolls over every 165sec = 2min 45sec.

2. Module event.c, h
Simple framework for scheduling events and determining delay to soonest event.

Event	**Init Status**	**Time / msec**	**Handler Function**
LED on/off	EVENT_ASAP	e.g. 50	leds_blink_update
Read Monitor IC	**EVENT_INACTIVE**	**167**	**app_stc3100_rd_data_handler**
Read Shunt Temp	*(not found in source)*	(50) or 1000	ntc_event_handler
Send advertising intro	EVENT_INACTIVE	50	bc2_seq_adv_update
Sets SWD as inputs	EVENT_INACTIVE	60000 at boot	gpio_swd_set_safe
Disconnect timeout	EVENT_INACTIVE	e.g. 60000	ble_mgr_idle_timeout

Function app_stc3100_rd_data_handler calls stc3100_t stc3100_rd_data(void) which has the following states (stc3100_rd_state):

1. STC3100_EOC
   Reads the STC3100 control register and if the EOC flag is set the function returns STC3100_RD_DATA_NOT_STABLE and transitions to state STC3100_CHECK after 167msec, else STC3100_RD_DATA_NOT_AVAILABLE will be returned.
2. STC3100_CHECK
   Reads the STC3100 data into a buffer, if unsuccessful STC3100_RD_I2C_FAILURE is returned and the state will be reset to STC3100_EOC. Unused bits are checked and if not as expected STC3100_RD_CORRUPTION is returned and the state will be reset to STC3100_EOC. If the data appears to be good, it is copied into the structure stc3100_data and stc3100_data_callback, which is normally set to stc3100_data_cb, is called. The state will be changed back to STC3100_EOC and the function returns STC3100_RD_SUCCESS.

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stc3100_rd_data returns the following:
STC3100_RD_SUCCESS = 0
STC3100_RD_FAILURE,
STC3100_RD_CALLBACK_NOT_SET,
STC3100_RD_DATA_NOT_AVAILABLE,
STC3100_RD_DATA_NOT_STABLE,
STC3100_RD_I2C_FAILURE,
STC3100_RD_CORRUPTION,

app_stc3100_rd_data_handler feeds the watchdog, only if stc3100_rd_data returned STC3100_RD_SUCCESS.

Function void bc2_seq_adv_update(void)

The function handles the advertising of the BC2 (beacon), it is scheduled 50msec after the sending of the Battery_status, every second.

This function has four cases:
1. BC2_ADV_SEQ_BAT_STATUS: Battery Status advertising.
Do nothing here, battery status beacons happen in STC3100 data callback.

2. BC2_ADV_SEQ_INTRODUCTION: Advertises introduction-message and changes the bc2_adv_seq_state to BC2_ADV_SEQ_BAT_STATUS.

3. BC2_ADV_SEQ_SoC: Advertises the SoC message and changes the bc2_adv_seq_state to BC2_ADV_SEQ_BAT_STATUS.

4. BC2_ADV_SEQ_WAIT: Does nothing during a connection.
Note: When the BC2 has a BLE connection, it pauses the advertising (bc2_adv_seq_state = BC2_ADV_SEQ_WAIT).
Function app_stc3100_rd_data_handler

Sets app_stc3100_rd_event_control delay to 167msec and calls stc3100_t stc3100_rd_data(void).

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Function static void stc3100_data_cb(stc3100_data_t *stc3100_data)
Is a callback function, which processes the STC3100 data received, among others it applies the hfilter. It also sends the battery status message and triggers sending the Introduction message or battery info message 50msec later every second.

8.2.2 LED Status indications

The BC2 hardware features a three color (RGB) LED, which is under firmware control.

The function leds_set_pattern_cb reassess the LED indications depending on different conditions. Normally most are disabled in the source code and only the normal blinking in blue or green is active. This function returns LEDS_BLINK_NORMAL in this case.

Function leds_blink_update calls leds_set_pattern_cb, if leds_blink_reassess is true and activates one of the following LED indications.

Indication Name	Action	Next action
LEDS_BLINK_OFF = 0	LED off	leds_blink_reassess
LEDS_BLINK_NORMAL	If BLE connected Blue, else Green for 50msec.	LEDS_BLINK_NORMAL_OFF
LEDS_BLINK_NORMAL_OFF	LED off for 4950msec	leds_blink_reassess
LEDS_BLINK_LEARN	Blue for 50msec	LEDS_BLINK_LEARN_OFF
LEDS_BLINK_LEARN_OFF	LED off for 950msec	leds_blink_reassess
LEDS_BLINK_OTAU_IDLE	White for 50msec	LEDS_BLINK_OTAU_IDLE_OFF
LEDS_BLINK_OTAU_IDLE_OFF	LED off for 950msec	leds_blink_reassess
LEDS_BLINK_OTAU_IN_PROGRESS	White for 1000msec	LEDS_BLINK_OTAU_IN_PROGRESS and leds_blink_reassess
LEDS_BLINK_ERROR	Red for 50msec	LEDS_BLINK_ERROR_OFF
LEDS_BLINK_ERROR_OFF	LED off for 950msec	leds_blink_reassess
LEDS_BLINK_TEST	Red, Green or Blue depending	LEDS_BLINK_TEST_OFF

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Indication Name	Action	Next action
	on variable leds_blink_test for 100msec.	
LEDS_BLINK_TEST_OFF	LED off for 400msec	leds_blink_reassess
LEDS_OVERRIDE	chip reset	N/A

8.3 Diagnostic information for functional testing

The serial interface of a terminal or PC with terminal software can be connected the edge connector pins CONSOLE_TX and CONSOLE_RX using a level converter from 3.3V to RS232 levels.

Communication Parameters are:

- Full duplex
- 115200 baud
- 8 data bits
- 1 start bit
- 1 stop bit
- no parity
- no software or hardware handshake

8.3.1 Monitor the SoC estimation

With the x-register command “1 20 X!” the following variable values will be sent by the BC2 every second:

Position	Variable	Unit	Comment
1	battery uptime	min	Time after BC2 power up (unsigned 32bit)
2	battery voltage	mV	(signed 16bit)

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Position	Variable	Unit	Comment
3	battery current	mA	Negative when charging (signed 32bit)
4	SoC	0.5%	(unsigned 8bit)
5	Time2Go_min	min	Estimated Time Remaining (unsigned 16bit)
6	EstCapacity_mAh	mAh	Estimated Capacity (unsigned 32bit)
7	V2SoC	0.5%	Voltage based SoC (unsigned 8bit)
8	IPT1_16mA	16mA	PT1-Filtered Peukert corrected discharge current (Unsigned 16bit)
9	IAvg_mA	mA	Average Peukert corrected discharge current (unsigned 32bit)
10	current_stable_sec	sec	Current within limits time for min/mid-point sampling (unsigned 16bit)
11	SoC.enChState		State of the min/mid/max-point state machine

8.3.2 App Settings

To read back app settings enter at the console prompt:
app-settings?

Only 1 byte of the app settings can be written at a time, the command spec is

[BYTE to write] [BYTE Index] set-app-settings

An example of modifying the last byte of app settings:

```
> app-settings?
01 7D 00 64 00 52 00 87 F2 76 77 78 7A 7E 7F 80 64 4B 00 00 (hex)

> $AA 19 set-app-settings

> app-settings?
01 7D 00 64 00 52 00 87 F2 76 77 78 7A 7E 7F 80 64 4B 00 AA (hex)
```

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8.3.3 Min/Max algorithm parameters

To read Min/Max algorithm parameters enter at the console prompt:
min-max-params?

30
12300
2000
12000
120

Displayed values are in the following order:
Transition minimum sec
Mid-point voltage mV
Stable current mA
Discharging voltage mV
Stable time sec

To write min-max-params the values must be entered in **reverse order** and the **mid-point voltage must be in the range from 8000 to 16000mV**.
> 120 12000 2000 12300 30 set-min-max-params

8.3.4 List of implemented console commands

X-registers are predefined variables or parameters, which can be read by name and / or index and in some cases they can be written with new values depending on the actual x-register. The values written remain only in RAM and will be lost when a power cycle is applied. To save values in NV memory a NV-Write command must be issued.

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Console command	Description
[index] x?	Prints the indexed x-register value. Example: 2 x?

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Console command	Description
	590 (x-register[2] = 590)
[value] [index] x!	Sets the indexed x-register to value. Example: 2 BC2_Model xn!
[value] [“string] xn!	Sets the x-register value with the name entered as string. Note: It may not make sense to write to some x-registers, because the value will be overwritten by the application.
[“string] xn?	Prints the value of the x-register with name given by the string entered. Example: "BC2_Model xn? 1 Please refer to [1] BC2 SERIES Production Notes for a list of x-registers.
[start index] [end index} xnvdump	Same as xdump
[start index] [end index} xdump	Prints the x-registers from start index to end index-1 in the following format: Value in hex, value in decimal, index, x-register name. Example: 0 10 xdump Prints x-registers 0 to 9.
ble-mac?	Prints the BLE MAC in hex-format. Example: BLE-MAC? F8F005E56A3C
ble-info?	Prints BLE info. Example: ble-info? Connected: 0 0x0 MAC 00:00:00:00:00:00, type 0 Handle 0 Bond 65535

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Console command	Description
	MTU 0
ble-disconnect	Disconnects BLE and returns status. Example: ble-disconnect status:226 Note: status 226=0xE2 -> Generic Failure, because BC2 was already disconnected.
sw-version?	Prints the software version. Example: sw-version? 1.14.0.2109 debug Software version 1.14 revision 0, build 2109, debug version.
product-revision?	Same as hw-version?
hw-version?	Prints the hardware version, hardware revision and hardware modification. Example: hw-version? 1.2X hardware version = 1 hardware revision = 2 hardware modification = X
build?	Prints the build date and time. Example: build? 19/07/2019 13:46:11
serial-id?	Prints the serial ID. Example: serial-id? A1745120032
[0 or 1] logm	Starts or stops the log message.

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Console command	Description
	Example: 1 logm Starts the output of the log message to the console. 0 logm Stops the output, it can be entered even while the console prints the log message. The log message periodically (every second) prints out the SoC variables.
logm?	Prints the status of XREG_LOGMESSAGE_TO_CONSOLE followed by XREG_LOGMESSAGE_TO_CONSOLE_APP_DEBUG_MASK Example: logm? $00000000 $00000004 app debug
restart	Triggers a platform_chip_reset.
[“SERIAL_ID] set-serial-id	Sets the serial ID, which is an 11 character ASCII string. Example: "A1745120032 set-serial-id Notice that the serial ID must be entered as a string preceded by “.
[hardware version] [hardware revision] [“hardware modification] set-product-revision	Sets the product revision, same as set-hw-ver.
[hardware version] [hardware revision] [“hardware modification] set-hw-ver	Sets the hardware version. Example: 1 2 "X set-hw-ver Notice that the hardware modification must be entered as a string preceded by “. Hardware version and revision

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Console command	Description
	must be entered as a decimal number.
nv-default	Restore default values (no NV-FACTORY-WIPE). Doesn't clear serial number, sw version, and eco revision number
nv-write	Writes NV values from RAM into Flash memory. Must be done after changing NV values to preserve them through power cycles.
uptime	Prints the "up-time" in seconds. Example: uptime 2504 seconds Notice there is no question mark required!
who?	Prints the VERSION_PROJECT_NAME. Example: who? BC2
[number] ["string] cal	Calibration command, please see [1] BC2 SERIES Production Notes.
cal?	Displays the calibration parameter values. Example: cal? STC3100_CURRENT_OFFSET: -1 SHUNT_R_NOHMS: 100575 Current offset is the current ADC offset (+/- 3) and shunt resistance is in Nano Ohm!
["string] set-battery-name	Sets the battery name. Example: "Bat1 set-battery-name
battery-name?	Prints the battery name. Example: battery-name? Bat1
[BYTE to write] [BYTE Index] set-app-settings	Sets the app-settings one indexed byte at a time. The app-settings has 20bytes, therefore the index is from 0 to 19. The byte value can be in hex and must then be preceded

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Console command	Description
	by a $. Example: $AA 19 set-app-settings Sets the last byte of the app-settings to 0xAA. See also description in section above this table.
app-settings?	Prints the app-settings. Example: app-settings? 01 7D 8C 00 78 00 BC 34 F2 76 77 78 7B 7E 7F 80 64 4B 00 00 (hex)
[“string] set-passkey	Sets the 6digit passkey. Example: "412850 SET-PASSKEY
passkey?	Prints the passkey. Example: passkey? 412850
[uint16] [uint16] [uint16] [uint16] [uint16] set-min-max-params	To write min-max-params the values must be entered in reverse order and the mid-point voltage must be in the range from 8000 to 16000mV. See section above this table for more details. Example: 120 12000 2000 12300 30 set-min-max-params
min-max-params?	Prints the min-max-params. Example: min-max-params? 30 12300 2000 12000 120
bonded-info?	Prints the bond information. Example:

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Console command	Description
	bonded-info? Bond 0 MAC 00:00:00:00:00:00, type 0 use indicator: 0 Bond 1 MAC 00:00:00:00:00:00, type 0 use indicator: 0 Bond 2 MAC 00:00:00:00:00:00, type 0 use indicator: 0 Bond 3 MAC 00:00:00:00:00:00, type 0 use indicator: 0 Bond 4 MAC 00:00:00:00:00:00, type 0 use indicator: 0
history?	Prints the history records. Example: history? s,mV,mA,mAm,tb,ts 0,130,32,648,20,25 1200,130,35,1346,21,25 2400,130,31,1968,21,26 3600,130,35,2660,21,26 1st column: Uptime in sec. 2nd column: Voltage in 100mV 3rd column: Current in mA 4th coulum: Charge in mAminutes 5th column: Battery temperature in deg. C. 6th column:

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Console command	Description
	Shunt temperature in deg. C.
min-max?	Prints the min-max points, if any have been recorded.
ext-wdt-test	The external watch dog timer will cause the system to reset. The reset will take between 10s to 39s to occur due to the long timeout time.

8.4 References

Reference Document	Version or Release Date
[1] BC2 SERIES Production Notes	Issue C, 15 May 2018
[2] 030589 BC2 Series ASSY BRD Main Sch - 5A.pdf	13 June 2017
[3] CAN and BLE Communications Protocol Specifications	Protocol Version 2