BATTERY CHARGING PROCESS

Specification Document and User Guide

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1 Introduction

With the increasing of the integration scale, applications need more and more polyvalent components to achieve several different jobs in one unic chip.

One of the most wanted feature for very high integrated applications is the Battery Charging.

Following the trend Wavecom includes this functionality for its WISMO™ modules.

This document aims to present this feature and its way of functioning for the WISMO™ modules.

2 Coverage and limitations

The Battery Charging Process (BCP) exposed here is only applicable for Li-Ion batteries.

The battery must be a 3.6V to 5V maximum voltage capacity (Vbatt) and must accept pulsed charging mode.

3 General principal

3.1 What is a typical battery charging process ?

One typical BCP is exposed here after.
It splits into two different phases:
- First phase, so called the "continuous mode" aims to reduce the charging time of the battery.
- The second one, so called the "pulsed mode" aims to bring the battery autonomy to the very maximum.

3.1.1 Two phases, why ?

The continuous mode allows to charge the battery very quickly but it makes the battery warming a lot.

Due to a too high temperature, the battery could explode, burn, melt down or whatever else. Thus a temperature sensor is obviously always feated on the battery. To be sure the battery will not be damaged in the continues mode, the charging process permanently survey the values given by this very important security sensor. When the maximum allowed temperature threshold is reached the BCP immediately stops the continues mode.

The temperature is however not the only event that stops the charging. The maximum voltage threshold is the main determining event to stop the battery charging during the continuous mode.

But at this stage the maximum autonomy is not available. The BCP must continue the charge to obtain this maximum autonomy. To avoid any damage, this is then realised using a safer mode (for the battery) which is the pulsed mode.

The Pulsed mode allows to near the voltage limit without overriding it.

3.1.2 Continuous mode

In the continuous mode, the BCP permanently feeds the battery with its nominal charging Voltage.

It only stops on the happening of three possible events which are:
- when the battery delivery voltage – so called Vbatt - reaches its maximum;
- when the security timer as expired (continuous mode duration);
- when the battery temperature is too high.

3.1.3 Pulsed mode

During the pulsed mode, the BCP also feeds the battery with its nominal charging voltage but this time, in a pulsed manner.

The pulse width is constant, but the pulsing frequency decreases. Let us call P the pulse duration (pulse width) and T the period.

Straight before each pulse, the delivery voltage – so called Vbatt – is read by the BCP and compared with the maximum capacity. This means that the Vbatt value is checked every T seconds.
If this value is higher than the previous one, then T is increased.
If this value is the same as the previous one, then T stays the same.
If this value is lower then the previous one, then T is decreased.

When the period (T) is increased, no pulse is generated, the BCP waits again for this new T and re-check the delivery voltage (Vbatt).

When T is at its maximum and the last read Vbatt value was either higher or the same as the previous one, the BCP stops the charging of the battery. It is then commonly considered that the battery is efficiently charged to obtain the best autonomy.

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The following picture shows a generic battery charging process detailing the autonomy with regards to charging type/time.
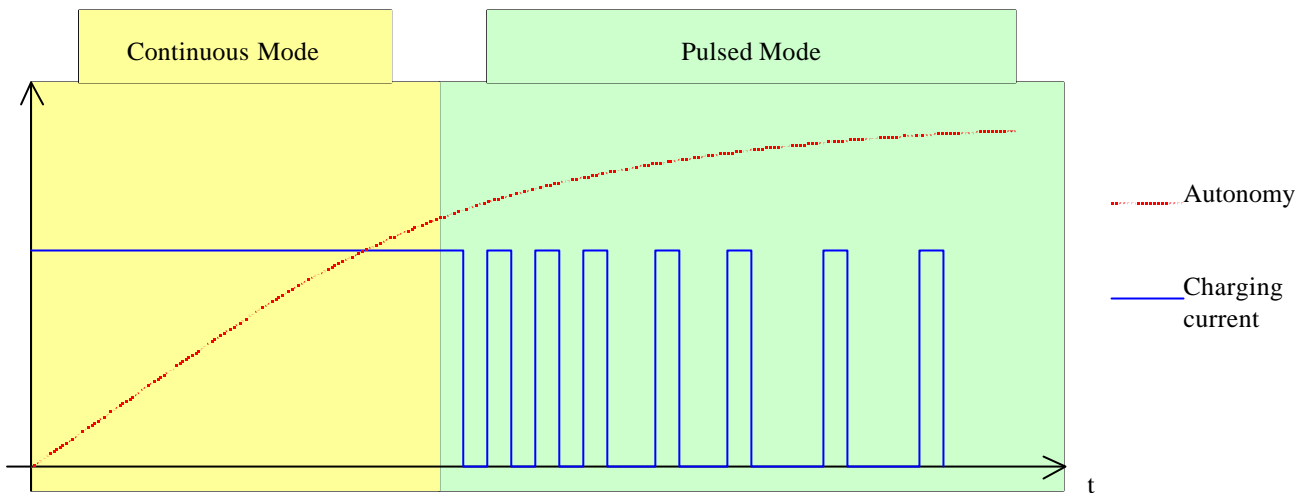

Figure 1 : Autonomy and charging modes

4 Wavecom Battery charging

The Wavecom's BCP only implements one charging mode.

4.1 Only one mode, why ?

As a very important matter, the global security aspect of the Battery Charging leaded Wavecom to only implements the Pulsed mode charging. Indeed, the BCP must efficiently charge the battery but shall not increase the risk to damage the battery nor the components around the battery itself even less your application.

4.2 Pulsed mode

The Pulsed mode for the Wavecom's BCP is quiet the same as the standard one.

During the pulsed mode, the BCP feeds the battery with its nominal charging voltage but in a pulsed manner.

The pulse width and the frequency are constant.
Let us call P the pulse duration (pulse width) and T the period.

Straight before each pulse, the delivery voltage – so called Vbatt – is read by the BCP and compared with the maximum capacity configured by the AT-command +WBCM. This means that the Vbatt value is checked every T seconds.
If this value is higher or the same as the previous one, then charging process is stopped.
If this value is lower then the previous one, then the charging follows on.

The difference is in the fact that the frequency is fixed. There is no automatic period enlargement to reach the best autonomy. Therefore the BCP immediately stops charging as soon as the delivery voltage reaches (and stays at) the first time its nominal value.
This does not mean that the best autonomy can not be reached, but only that the process is no more driven by the module itself but rather by your application (see chapter 6 User guide page 10). Thus your application can completely control the battery charging to reach the suitable level and/or to interrupt the charging or to start it (again).

Meaning that it is still possible to charge a battery to obtain the maximum autonomy but that the controlling unit is no more the BCP from WISMO™ Modules but your application.
Your application decides either or not it continues the charging of your battery.

Please consider and take into account all safety rules regarding the use and charging of batteries or battery pack. You should always try to hold the risks at the minimum level by respecting the battery manufacturer's integration specifications and guide lines.

Also as a reminder read in appendices a non exhaustive summary for security rules, constraints and specification to be observed for a proper safe battery use in your application.

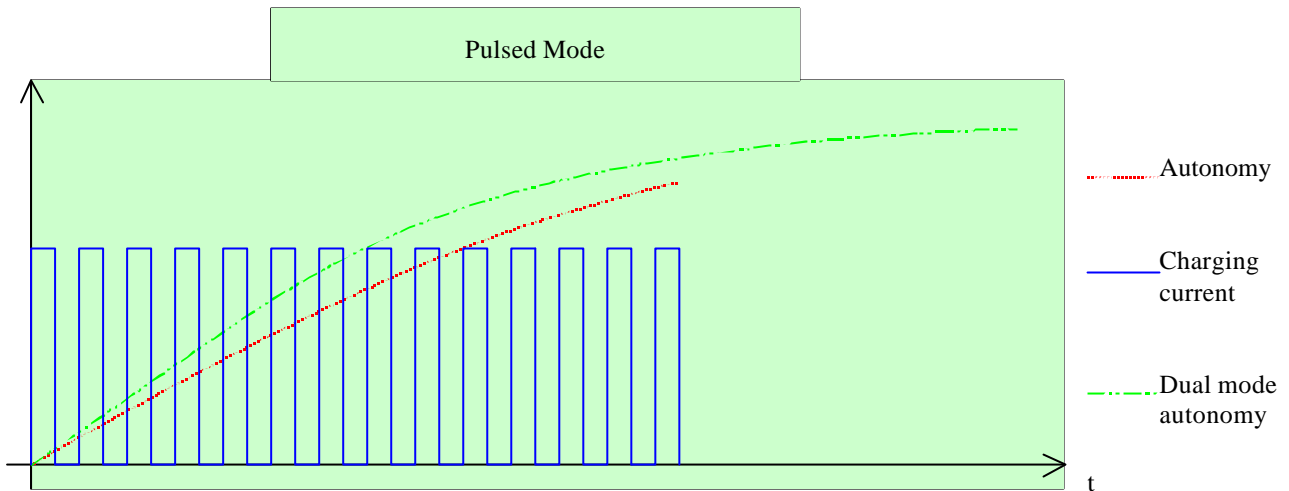The following picture shows a Pulsed mode only BCP detailing the autonomy with regards to charging time.

Figure 2 : Autonomy and Pulsed mode

As you can see on the above picture, using this Pulsed mode BCP and stopping at the first stable level reached, the battery doesn't reach its maximum autonomy.

In chapter 6 "User guide" page 10, the way to reach the best autonomy is explained and shown with help of an AT-commands sequence example.

5 Why this difference ?

5.1 Security

There is no temperature sensor feated on the Wismo™ modules. And as explain above (see paragraph 3.1.1 "Two phases, why ?" page 5) this sensor is mandatory to insure a safe continuous mode charging process.

Nevertheless, some batteries are directly provided with a temperature sensor. But, and this is critical, each battery (battery pack) has its own sensor with its own characteristics and they are all different from one to the other. The BCP, for security reason should be able to work with all sensors. It becomes impossible to have a BCP capable of managing each and every temperature sensor !

For these two reasons strongly bundled to security aspects, Wavecom only offers a Pulsed mode charging process for the WISMO™ modules.

5.2 Genericity

WISMO™ which means WIreless Standard MOdule, is an OEM, ready to use product. It is designed to fulfil the most integration constraints for vertical applications and highly integrated products such as PDAs.

A generic interface gives you the possibility to choose any suitable battery[*] or battery pack[*] without having to take into consideration any battery charging controller aspect. Indeed an easy to use dedicated AT commands set allows you to configure the BCP to handle the battery of your choice without any supplementary external components.

This facilitates your integration process and let you save place on your PCB for other relevant components for your application.

5.3 Vbatt Add-On

As a matter of fact, battery charging is not enough to efficiently insure the correct powering of an application, it is also very important to implement several mechanisms that allow the customer application to be informed about the battery state.

For that reason the unsolicited indication +WBCI has been implemented in the AT-commands set related to the battery management.

This unsolicited indication feature gives your application information about the battery state in order to properly react on battery events.

Among others, this unsolicited message informs the application about two important battery events:
- that the battery is at its lowest level and that the WISMO™ module will be stopped;
- that the battery is charged respecting the +WBCM settings.

The aim of the +WBCI indication is also to indicate the current battery voltage. This information can be used to be directly displayed or, combined with the consumption of all constituting components, to calculate the global application functioning autonomy which can then be shown on a display.

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[*] Li-Ion Battery or Li-Ion battery Pack

6 User guide

Wavecom developed a specific proprietary AT command set to handle battery charging.

These BCP AT commands are detailed in the AT Documentation related to the WISMO™ products. An extract of the BCP AT commands is included in this document in appendices.

The short user guide presented here aims to give you some hints and examples to properly configure the BCP to charge your battery in the most efficient and safe way.

In order to reach the maximum available autonomy it is worth that your application uses a so called "driven pulsed mode".

6.1 Driven Pulsed Mode

Here are some figures for informative purposes.

These figures show the impact in term of autonomy and charging time between both charging modes. They are given for a 4.2V Li-Ion Battery only for comparison purposes.

The original battery voltage at test start is the same for both cases. The stop condition for the complete mode is when the battery voltage stays at 4.2V during 10s. The stop condition for the pulsed mode is when the 4.2V level is reached the first time.

First case: Complete mode "Continuous + Pulsed mode".

> 1h25 charge time with 1h45 autonomy (in constant communication at maximum power level; TxPwer = 5).

Second case: Pulsed mode.

> 1h10 charge time with 1h30 autonomy (in constant communication at maximum power level; TxPwer = 5).

Considering the worst cases, we have then a difference of 14% for the autonomy.

To be sure that you reach the maximum autonomy, it is then recommended that the application "drives" the BCP. That is to say that the application restart the BCP with a larger Period each time it is needed until the maximum Period (10s) is reached.

Applying this so called "Driven Pulsed mode" the customer application can achieve to completely charge the battery obtaining the best autonomy.
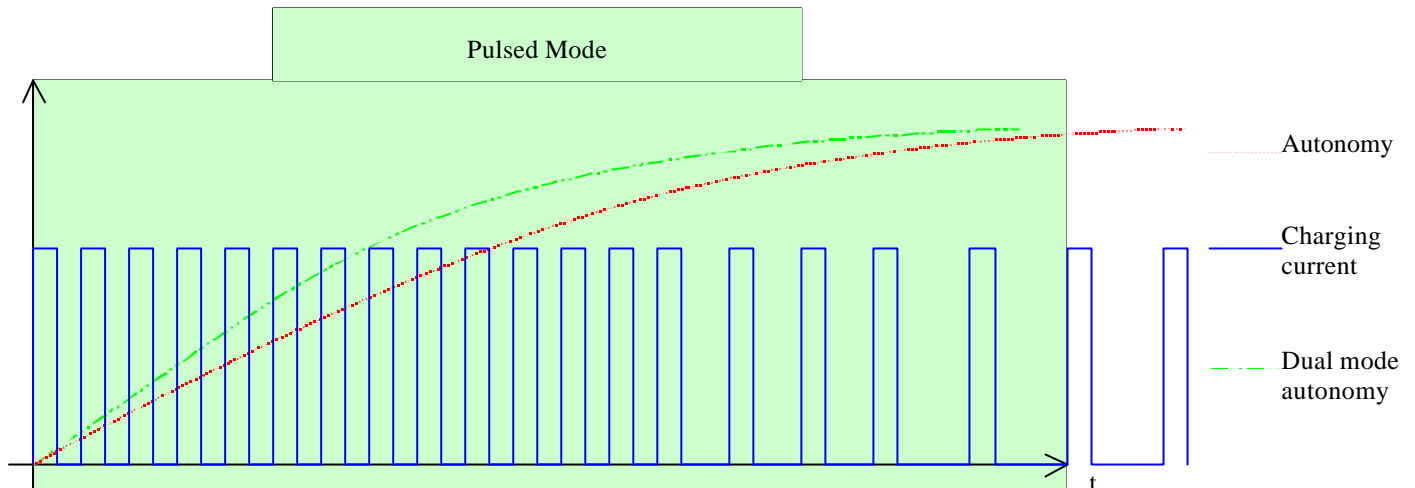
Figure 3 : Driven pulsed mode

6.2 Hint

We recommend to use the first one for portable applications and the second one for fix application.

Indeed, a portable application will run using batteries "unplugged" and is from time to time replaced on its host to be recharged. Thus it is better to insure for these kind of applications that the autonomy always reaches its maximum.
Example a POS (Point Of Sale).

Whereas for fix application (always plugged to an energy source which is not always available), there is no need to systematically obtain the best autonomy. Indeed obtaining the necessary autonomy to insure the functioning during the time that the energy source is no more available is sufficient.
Example any application powered by Solar cells and featured with batteries for the night service.

6.3 Programming example

Please find hereafter an example to drive the BCP in "Driven Pulsed mode" in order to reach the maximum battery autonomy in the shortest time.

This example is provided "as is" without warranty of any kind, express or implied. Wavecom specifically disclaims all warranties that it is operating properly as well as any warranty of fitness for a particular purpose. The use of this example and its implementation in your application is made at your own risk. Wavecom will not be responsible for any damage caused directly or indirectly by the use of this programming sequence.

Be aware also that this sequence was established only for informative purposes and using a 4.2V Li-Ion Battery.

Comments are added and begin with the header // (as for C++).

The example bellow configure the module to begin the charge with 100ms period in charge and an unsolicited battery level report every 10s.

```
//First of all check the actual status
AT+WBCM?
+WBCM: 0, 0, 4200, 3300, 100, 5000, 0
OK
//Here the BCP is disabled (leading 0)

//Then configure the BCP with unsolicited
//charge indications
AT+WBCM=3,1,4200,3200,100,10000,0
OK


//Now activate the BCP
AT+WBCM=1
OK


//As the BCP begins charging and the unsolicited
//indications were activated, also reporting begins.
//We assume here that the battery has already 3,2 V voltage.
//(as an example)
+WBCI: 2, 3200

+WBCI: 2, 3200


//All traces are not given as they are not relevant


+WBCI: 2, 4200

+WBCI: 1
//Indication that the battery has reached a first charge level
//and that the charging process is stopped.

//Restart with a larger period (REMAINDER : the pulse width is the same).
//We replace the 100 value through a 500
AT+WBCM=3,1,4200,3200,500,10000,0
OK

//Now activate the BCP again
AT+WBCM=1
OK

//As the BCP restarts charging, also reporting restarts.
//We assume the battery has already 4,0 V voltage.
//(as an example)
+WBCI: 2, 4000

+WBCI: 2, 4000


//All traces are not given as they are not relevant


+WBCI: 2, 4200
```

```
+WBCI: 1
//Indication that the battery has reached the next charge level

//Restart with a larger period (REMAINDER : the pulse width is the same).
//We replace the 500 value through a 1000
AT+WBCM=3,1,4200,3200,1000,10000,0
OK

//Now activate the BCP
AT+WBCM=1
OK

//As the BCP begins charging, also reporting begin.
//We assume here that the battery has already 4,1 V voltage.
//(as an example)
+WBCI: 2, 4100

+WBCI: 2, 4100


//All traces are not given as they are not relevant


+WBCI: 2, 4200

+WBCI: 1
//Indication that the battery has reached the next charge level

//Restart with a larger period (REMAINDER : the pulse width is the same).
//We replace the 1000 value through a 2000
```

and so on, after 2000, the value could be 4000 and then to terminate, 10000.

The end of the BCP looks then like following:

```
//Restart with the largest period (REMAINDER : the pulse width is the same).
//We replace the 4000 value through a 10000
AT+WBCM=3,1,4200,3200,10000,10000,0
OK


//Now activate the BCP
AT+WBCM=1
OK


//As the BCP begins charging, also reporting begin.
//We assume here that the battery has already 4,152 V voltage.
//(as an example)
+WBCI: 2, 4152


+WBCI: 2, 4152



//All traces are not given as they are not relevant


+WBCI: 2, 4200

+WBCI: 1
//Indication that the battery has reached the last charge level
//Which obviously means: Maximum Autonomy
```

That's all folks !

Now you can activate the reporting of the Battery charge level. Here after is an additional example:

```
//Activate the report
AT+WBCM=2
OK

//Let's suppose here some hours have passed
+WBCI: 3, 3700
```

7 Appendices

7.1 Unsolicited result : Wavecom Battery Charge Indication +WBCI

7.1.1 Description

This unsolicited result (USR) reports information about the battery charge (max. level reached, current battery voltage, etc). It is activated by the +WBCM command. Refer to this command for more details regarding the activation.

7.1.2 Syntax

+WBCI: <Status>[,<BattLevel>]

7.1.3 Defined values

<Status>   **0**   Min. battery level reached, and the battery is considered as discharged. The module is turned off (as for the **+CPOF** command behaviour) after this indication.

1   Max. battery level reached, and the battery is considered as charged. The battery charge is stopped.

2   Battery currently in charge.

3   Battery currently out of charge.

*Note : <Status> 2 and 3 are solicited through syntax **+WBCM=2**, or unsolicited when <ChargeInd> parameter of **+WBCM** command is set to 1. With these <Status> values, <BattLevel> parameter is also present.*

<BattLevel>   Current battery voltage (Vbatt) during or out of the charge. The allowed range is **[2800 ; 5000]**. (mV unit)

7.2 Wavecom Battery Charge Management +WBCM

7.2.1 Description

This **specific** command allows to manage the battery charge (start and stop the charge, enable or disable unsolicited Battery Charge Indications "**+WBCI**", and set the battery charge parameters).

Command syntax

AT+WBCM =   <Mode> [, [<ChargeInd>] [, [<BattLevelMax>], [<BattLevelMin>], [<TPulseInCharge>], [<TPulseOutCharge>], [<BattIntRes>]]]

Command	Possible responses
AT+WBCM=0 *Stop the battery charge.*	OK *Note: Command valid*
AT+WBCM=1,1 *Start the battery charge with indications of charge.*	OK *Note: Command valid*
	+WBCI: 2, 4060 *Unsolicited indication of charge: the current battery voltage is 4,06V. Cf. **+WBCI** description.*
AT+WBCM=1,0 *Start the battery charge without indications of charge.*	OK *Note: Command valid*
AT+WBCM=2 *Get the battery voltage during the charge.*	+WBCI: 2, 4110 OK *See the description of **+WBCI** unsolicited response. the current battery voltage is 4,11V.*
	+WBCI: 1 *The battery voltage has reached the max. level. The battery is considered as charged, and the charge is stopped.*
AT+WBCM?	+WBCM: 0,0,4200,3300,100,5000,0 OK *Current values*
AT+WBCM=0,1 *Enables the battery charge unsolicited indications out of charge.*	OK *Note: Command valid.*
	+WBCI: 3,4195 *The current battery voltage is 4,195V.*
AT+WBCM=3,0,3800,3000,500,3000,0 *Configure the battery charging parameters.*	OK *Note: Command valid.*

AT+WBCM=? *Get the parameters range.*	+WBCM: (0-3), (0-1), (4000-5000), (2800-3800), (100-10000), (100-10000), (0-255) OK
	+WBCI: 0 *The battery voltage has reached the min. level. The battery is considered as discharged, and the module is turned off, as for the +CPOF command behaviour.*

7.2.3 Defined values:

<Mode>	**0**	Stop the battery charge (**default**).
	1	Start the battery charge.
	2	Get the current battery voltage.
	3	Set the battery charge parameters.

Note: with <Mode>s 0 and 1, only <ChargeInd> parameter is allowed;
<Mode> 2 does not allow any supplementary parameter;
<Mode> 3 allows all parameters.

<ChargeInd>	**0**	Disables the battery charge unsolicited indications (**default**)
	1	Enables the battery charge unsolicited indications (cf. **+WBCI** description)

<BattLevelMax>   Level max. for the battery voltage. When it is reached, the battery is considered as charged.
The allowed range is **[4000; 5000]**.
(mV unit, **default value: 4200**)

<BattLevelMin>   Level min. for the battery voltage. When it is reached, the battery is considered as discharged, and the module is turned off (as for **+CPOF** command behaviour).
The allowed range is **[2800; 3800]**.
(mV unit, **default value: 3300**).

Note: <BattLevelMax> and <BattLevelMin> parameters can not be modified during the battery charge (when <Mode> = 1).

| <TPulseInCharge> | Time between pulses for the pulsed charge. The pulse time is one second. When the battery charge is started with unsolicited charging indications (<ChargeInd> = 1), **+WBCI** responses are returned by the ME with a "<pulse time>(=1s) + <TPulseInCharge>" period. The allowed range is **[100; 10000]**. (ms unit, **default value: 100**). |

<TPulseOutCharge>   Time between +WBCI unsolicited responses when the battery charge is stopped with charging indications requested (<ChargeInd> = 1).
The allowed range is **[100; 10000]**.
(ms unit, **default value: 5000**).

<BattIntRes>   Battery Internal Resistor. It must be set to have good reading values with **+WBCI** unsolicited results.
The allowed range is **[0; 255]**.
(Ω (ohm) unit, **default value: 0**)

Note: When the <BattIntRes> parameter is changed, the module must be reset to take in account the modification.