AN4324
Application note

STC3115 system integration

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Introduction

Mobile application users demand accurate battery capacity monitoring. In particular, they are interested to know if the battery state of charge (SOC) in stressful conditions is logical and accurate. To this end, STMicroelectronics has developed a device (STC3115) which uses its internal algorithm to provide the user with accurate and reliable information about the battery's SOC. This tiny chip can be used in any handheld electronic mobile phone or tablet. The purpose of this application note is to provide the basics of how to build an accurate fuel gauge system using the STC3115.

A complete fuel gauge system is a combination of hardware and software functions. The STC3115 has been designed to convert the physical nonlinear measurements of lithium-ion battery models to stable and compensated information, which can easily be reported to the final user of a mobile application. Chipset manages the real-time aspects of the battery gauging. It combines the voltage method and coulomb counter to provide the best accuracy in every application state. The application software is concerned with the reporting and calculation of application-dependent information.

Contents

1 Architectural overview 4
2 STC3115 selection guide 5
2.1 STC3115 version selection 5
2.2 STC3115 version detection 6
3 Battery parameters 7
3.1 Battery internal impedance identification 8
3.2 Battery open circuit voltage (OCV) curve measurement and calculation 9
4 Schematic guidelines 10
4.1 Sense resistor selection 10
4.1.1 Sense resistor impedance value 10
4.1.2 Sense resistance impedance accuracy 10
4.1.3 Sense resistance power dissipation capability 10
4.1.4 Sense resistor deviation over temperature range (TCR) 11
4.1.5 Sense resistor selection proposal 11
4.2 BatD pin system integration 11
4.3 RSTIO pin system integration 14
5 Place and route guidelines 16
5.1 Vin pin connection 16
5.2 External sense resistor 17
5.3 Temperature considerations 18
5.4 STMicroelectronics PCB design recommendations 19
6 Software 20
6.1 STC3115 RAM memory organization proposal 21
6.2 Chip initialization 22
6.3 STC3115 running configuration 27
6.4 Periodic device access 27
6.4.1 First STC3115 access after initialization 27
6.5 STC3115 task procedure 28
6.5.1 How often the STC3115 has to be called in run mode 28
6.6 STOP procedure 28
6.7 Power saving mode software management 29

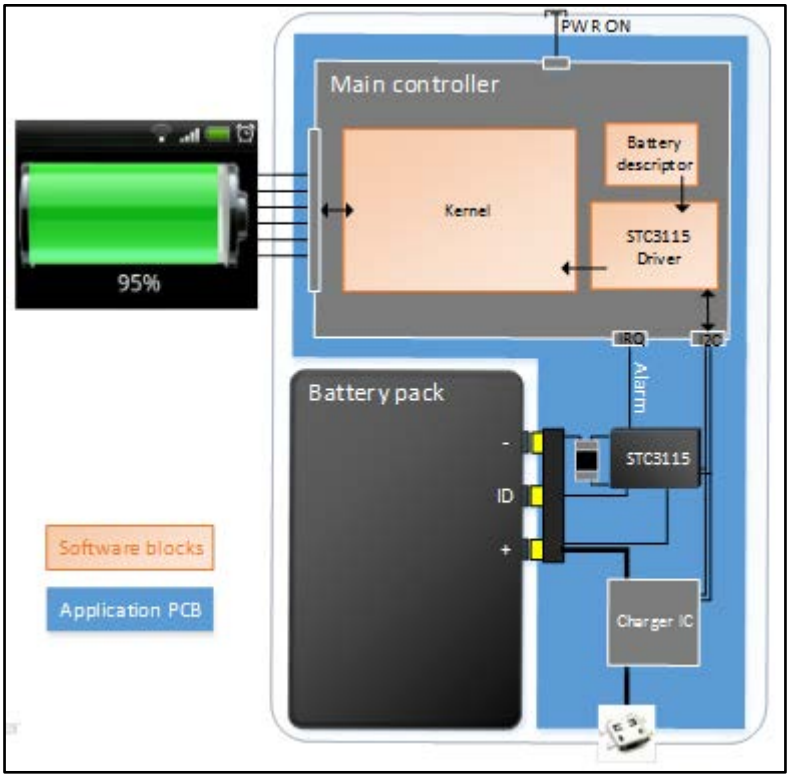
7 Revision history 30

1 Architectural overview

The system architecture has been separated into two main parts in order to facilitate the most flexible integration. The STC3115 takes physical measurements and reports the battery state of charge (SOC) through I²C interface while the software layer is concerned with battery parameter initialization and compensation using all the dedicated features of the chipset.

Depending on the targeted accuracy of the application environment, the STC3115 can be used alone without software compensation. In this configuration, the application software uses only the STC3115 register information to display the battery SOC to the user. If the temperature and aging effects need to be compensated, the software layer uses the STC3115 dedicated features.

Figure 1: System architecture overview



2 STC3115 selection guide

Two versions, in two different packages, of the STC3115 device currently exist. They are:

1. STC3115AIJT / STC3115AIQT
2. STC3115IJT / STC3115IQT

Either version can be selected to plug onto the application.

2.1 STC3115 version selection

The STC3115 can lend its functionalities to different battery types with different voltage ranges. Depending on the battery voltage, either the STC3115AIJT / STC3115AIQT or the STC3115IJT / STC3115IQT can be selected.

Table 1: STC3115 version selection

STC3115 version	Battery voltage (typ)	Battery voltage (max)
STC3115AIJT / STC3115AIQT	3.7 V	4.2 V
STC3115IJT / STC3115IQT	3.8 V	4.35 V

The STC3115 behavior is the same with the different versions but the device uses a different initial internal open circuit voltage (OCV) curve to track the battery state of charge. The table below describes the internal OCV curve of each STC3115 version.

Table 2: STC3115 internal OCV curve references

State of charge (%)	STC3115AIJT / STC3115AIQT	STC3115IJT / STC3115IQT
100	4.176	4.313
90	4.076	4.197
80	3.991	4.088
70	3.929	3.990
65	3.899	3.953
60	3.863	3.914
50	3.802	3.825
40	3.778	3.790
30	3.761	3.770
25	3.747	3.761
20	3.721	3.743
15	3.695	3.710
10	3.658	3.675
6	3.618	3.651
3	3.541	3.571
0	3.300	3.300

If the battery to be tracked is not exactly in line with the voltages described in the tables above, the closest STC3115 version should be selected. Then, by software, the internal OCV curve is adjusted using the REG_OCVTAB registers (see STC3115 datasheet). The internal curve can be fine-tuned to better fit with battery behavior, using the OCV offset e.g. chip initialization (see *Section 3.2: "Battery open circuit voltage (OCV) curve measurement and calculation"*).

2.2 STC3115 version detection

This section describes how to detect which version of the STC3115 is plugged onto the application. If the STC3115AIJT / STC3115AIQT version of the device is power supplied, a 4.2 V power supply provides 100 % state of charge information. If the STC3115IJT / STC3115IQT version is power supplied, a 4.2 V power supply provides 90 % state of charge information into the STC3115 REG_SOC.

3 Battery parameters

This section describes how to calculate the parameters of the application.

To operate properly, the STC3115 uses typical values of the battery to track the state of charge (SOC) in the application at a given time.

The parameters can be calculated using the formulae below. This parameter set is commonly called the "battery model". This model is an image of battery behavior against the STC3115 principle. The parameters and their calculation are also described in the STC3115 datasheet.

- REG_CC_CNF: (Rsense x Nominal battery capacity) / 49.556
- REG_VM_CNF: (Internal battery impedance x Nominal battery capacity) / 977.78
- REG_ALARM_SOC has to be set according to the application needs (e.g. 10 % as a typical value)
- REG_ALARM_VOLTAGE has to be set according to the application needs (e.g. 3600 mV as a typical value)
- REG_CURRENT_THRES: (Battery capacity / 10), up to 200 mA

3.1 Battery internal impedance identification

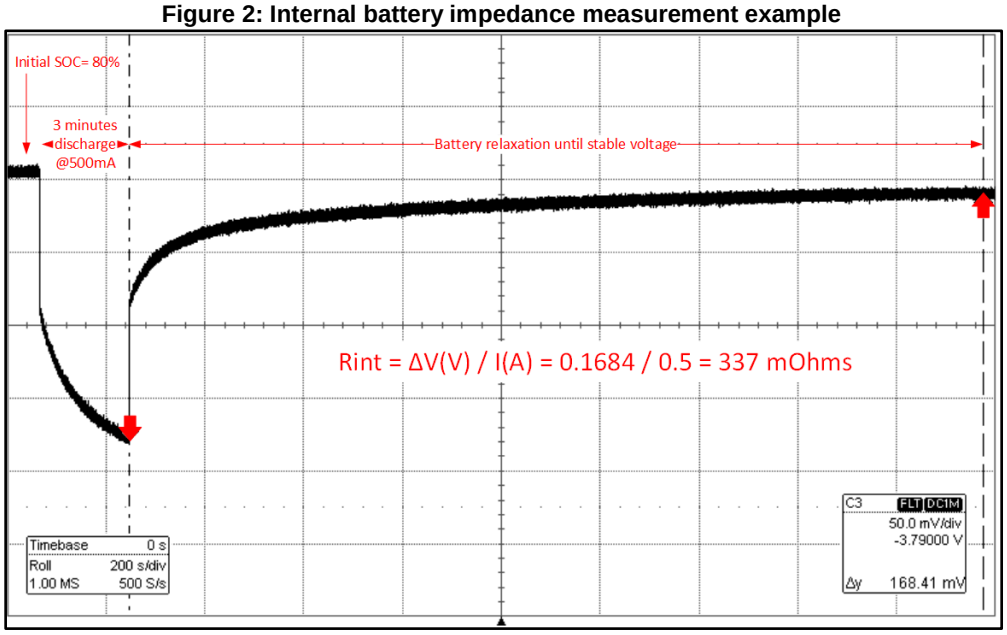
Thanks to its internal OptimGauge algorithm, the STC3115 does not depend on the variation of the internal battery impedance over the state of charge (SOC) range. In other words, only one internal battery impedance value is necessary to represent internal battery impedance behavior at a given temperature.

The internal impedance factor can be measured using several solutions which are described in the literature. One solution is to:

- measure the battery voltage at the end of several minutes discharge (with a fixed current value)
- measure the battery voltage again after 30 minutes of relaxation
- calculate the voltage difference
- use the discharge current value to find the internal battery impedance

To use this method successfully, a value of around 80 % SOC allows the VM_CNF parameter (see datasheet) to be calculated with enough accuracy to track the battery SOC correctly.

Figure 2: Internal battery impedance measurement example



3.2 Battery open circuit voltage (OCV) curve measurement and calculation

The default OCV curve selected by the STC3115 version can be adjusted to fit the battery REG_OCVTAB model. The TAB registers can be filled to define the OCV curve as in the equation: OCV[x] = OCVinit[x] + OCVTAB[x].

The battery OCV curve can be characterized and evaluated by measuring the relaxed voltage of the battery at a given state of charge (SOC). In the table below, column 2, "Battery OCV (V)", should be measured using the relaxed voltages of the corresponding "SOC (%)" values in column 1. These measured points can then be used to define the REG_OCVTAB(0.55mV) "Value" in column 6 using the equation: REG_OCVTAB[x] = ($Batt_{ocv}$[x] - OCV_{init}[x]) / 0.55.

Table 3: OCV offset calculation table

SOC (%)	Battery OCV in volts (battery measurement data)	OCV-init(V)		REG_OCVTAB(0.55mV)	
		STC3115AIJT / STC3115AIQT	STC3115IJT / STC3115IQT	Address	Value
100		4.176	4.313	0x3F	
90		4.076	4.197	0x3E	
80		3.991	4.088	0x3D	
70		3.929	3.990	0x3C	
65		3.899	3.953	0x3B	
60		3.863	3.914	0x3A	
50		3.802	3.825	0x39	
40		3.778	3.790	0x38	
30		3.761	3.770	0x37	
25		3.747	3.761	0x36	
20		3.721	3.743	0x35	
15		3.695	3.710	0x34	
10		3.658	3.675	0x33	
6		3.618	3.651	0x32	
3		3.541	3.571	0x31	
0		3.300	3.300	0x30	

4 Schematic guidelines

The STC3115 is designed to limit the external component amount versus accuracy of the reported information. To provide the best accuracy versus flexibility, an external sense resistor has to be selected. The STC3115 provides standard application signal interfaces that are used to give the best accuracy in specific application-use cases.

4.1 Sense resistor selection

To use the STC3115 enhanced mixed mode, a sense resistor must be placed between the battery minus pin and the application ground. The sense resistor should be capable of measuring current accurately so, it is imperative not to connect any signal on the battery minus pin except the sense resistor.

The external sense resistor measures the current which is used internally by the device and integrated over time to provide a coulomb counter feature which tracks the battery state of charge (SOC). The choice of sense resistor is extremely important and has a direct impact on battery monitoring accuracy. The following points concerning the sense resistor value and reference must be considered:

1. Sense resistor impedance value
2. Sense resistor impedance accuracy
3. Sense resistor power dissipation capability
4. Sense resistor deviation over temperature range (TCR)
5. Sense resistor selection proposal

4.1.1 Sense resistor impedance value

The sense resistor impedance depends on the application maximum current and the STC3115 Vin_gg input voltage range (see datasheet).

$Vin_gg = Rcg \times I_{Max}$

Where Rcg = sense resistor value in mΩ and I_{Max} = application peak current in A

Vin_gg must be below 40 mV for I_{Max} charging and above -40 mV for I_{Max} discharging.

4.1.2 Sense resistance impedance accuracy

The precision of the sense resistor depends on the targeted accuracy of the application. An accuracy of 1 % allows the STC3115 to attain its best accuracy.

4.1.3 Sense resistance power dissipation capability

To limit self-heating of the sense resistor due to current flow into it, the power dissipation capability of the chosen sense reference has to be in line with the application current consumption. Assuming a voltage drop of 40 mV on the sense resistor and in the case of a 10 mΩ resistor, the sense resistor power dissipation capability has to be at least 160 mW.

4.1.4 Sense resistor deviation over temperature range (TCR)

The sense resistor impedance value depends on ambient temperature. The generated error from temperature deviation has to be limited in order to ensure that the impact of temperature on current measurement accuracy is minimized. A 0.3 % impedance value deviation at maximum temperature deviation is acceptable as it does not impact the current measurement accuracy over the temperature range too much.

Example for a 75 ppm TCR sense of 10 mΩ, with a 40 °C maximum temperature deviation from typical temperature:

MaxError: ((TCR x Rsense x d) / Rsense) x 100 = ((0.000075 x 0.01 x 40) / 0.01) x 100 = 0.3 %

Where d = temperature in ˚C.

4.1.5 Sense resistor selection proposal

Table 4: Proposed sense resistor references

Product reference	Manufacturer	Impedance	Accuracy	Power dissipation	Sense resistor deviation over temperature range (TCR)	Package
ERJM03NF10MV	PANASONIC	10 mΩ	±1 %	250 mW	±100 ppm/°C	0603
WSL0603R0100FEA	VISHAY DALE		±1 %	100 mW	±75 ppm/°C	

4.2 BatD pin system integration

The BatD pin detects battery removal events: either the third battery pin is an ID pin or a thermal information pin. The following three situations describe several application cases where the battery is removed and how the STC3115 detects such an event:

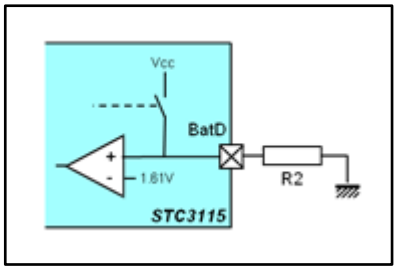
1. **Battery is removed during a low consumption stage:** At this time, the application consumption is low and the Vbat voltage can take time to decrease (application capacitor discharging period). At the same time, the third battery pin is disconnected and the BatD pin voltage is fixed by the pull-up voltage value. Battery removal is detected rapidly by the BatD feature.
2. **Battery is removed during a high consumption stage:** At this time the application consumption is high and the Vbat voltage decreases rapidly. The STC3115 detects battery removal and in this case the BatD pin is not used.
3. **Battery is removed if the charger is already connected:** At this time, Vbat voltage maintains the same value or increases slightly. The BatD pin is used to detect battery removal as the battery voltage information cannot be used.

During battery removal, the BatD pull-up voltage should be ON and higher than 1.61 V internal threshold.

For most applications, the pull-up voltage should always be available and above the threshold. The best voltage to use is the Vbat voltage itself.

The following configurations can be used. In each one, the R2 resistor is mandatory. If the STC3115 BatD pin is pulled down to ground, the BatD feature is disabled. Battery removal and swap events are only detected using the battery voltage reference.

Figure 3: STC3115 BatD schematic if the BatD feature is disabled or not used

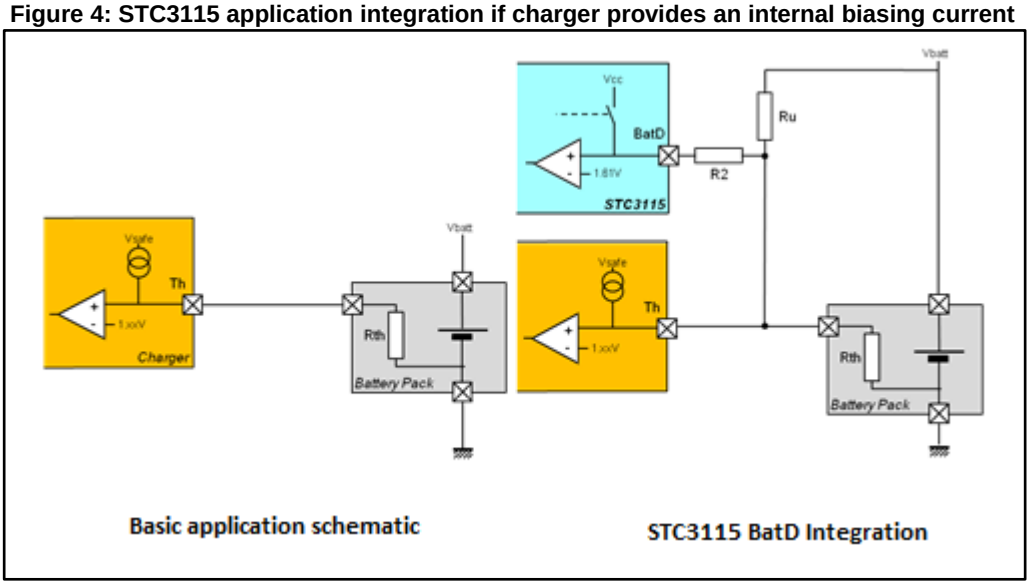


1. Typical R2 value = 1 kΩ

If the third battery pin is used by the charger thermal protection signal, the STC3115 BatD pin has to be connected to this signal to prevent an open circuit voltage (OCV) measurement error due to a charging current at application start-up.

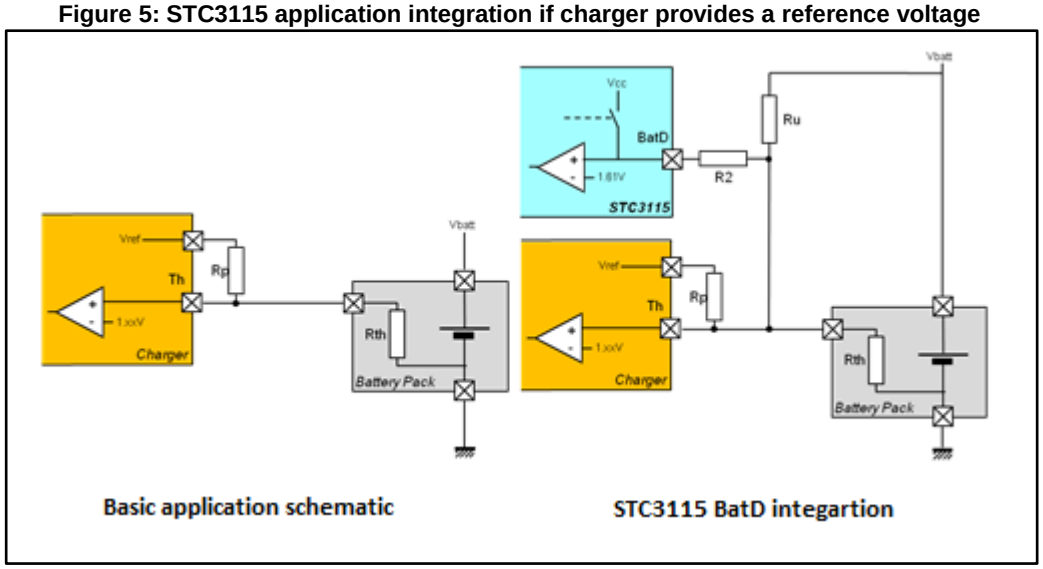
This protection mechanism forces the battery protection pin to disable the charger because it indicates that the battery cannot be charged. This state is maintained during the first OCV measurement period. The measurement is made only after battery insertion and each time a battery insertion is detected.

Figure 4: STC3115 application integration if charger provides an internal biasing current



1. Typical R2 value = 1 kΩ, Ru = 1 MΩ

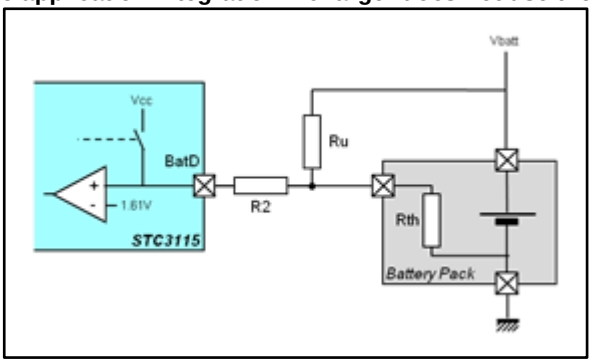
Figure 5: STC3115 application integration if charger provides a reference voltage



1. Typical R2 value = 1 kΩ, Ru = 1 MΩ

The application can be connected to the STC3115 BatD pin even if it has no charger or the application charger does not manage the battery security pin. In this configuration, the BatD feature improves battery presence detection.

Figure 6: STC3115 application integration if charger does not use the third battery pin



1. Typical R2 value = 1 kΩ, Ru = 1 MΩ

4.3 RSTIO pin system integration

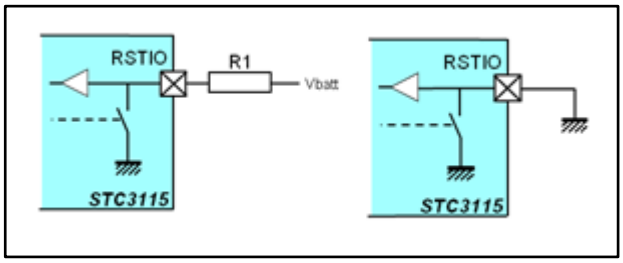
The STC3115 RSTIO is an open drain pin which, to operate, must always be pulled-up to a V_{CC}.

The STC3115 RSTIO feature maintains the accuracy of the first open circuit voltage (OCV) measurement in all application start-up sequences. This feature prevents the first OCV measurement from a fast application start-up. If the main application reset signal is detected as low before the beginning of the first OCV measurement, it is forced low by the RSTIO pin until the end of the measurement to guarantee measurement accuracy. In this reset state, the application consumption is low and no battery voltage drop is implied. This operation takes a maximum of 500 ms.

Several typical application implementations are described below.

The Vbatt voltage used to pull-up the RSTIO signal can be another system voltage such as an IO voltage (see *Figure 7: "STC3115 RSTIO schematic if the RSTIO feature is disabled"*). If the RSTIO pin is pulled-up to a fixed positive voltage or if it is grounded, this feature is disabled.

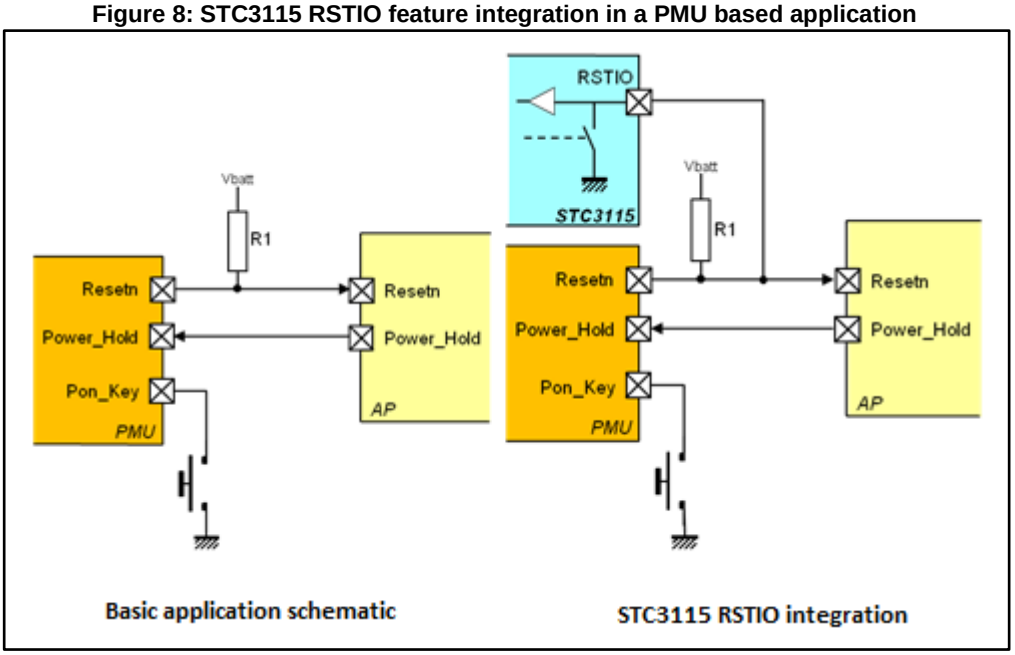
Figure 7: STC3115 RSTIO schematic if the RSTIO feature is disabled



1. Typical R1 value = 1 kΩ

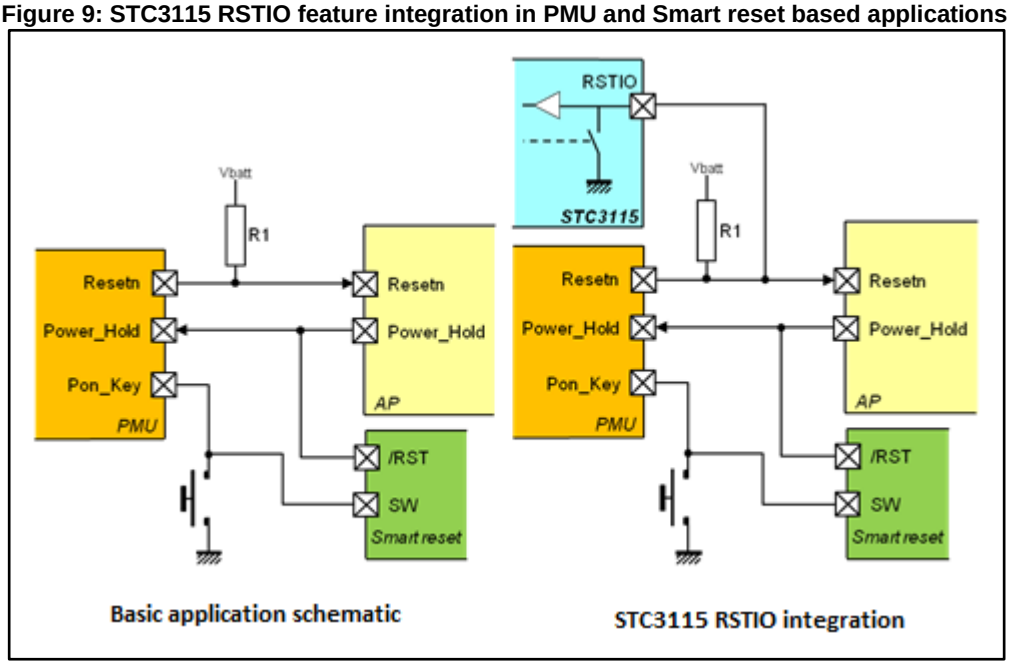
In the architecture of *Figure 8: "STC3115 RSTIO feature integration in a PMU based application"*, it is assumed that the application processor (AP) consumes the most power. Once the PMU is ready to provide the voltage and clock to the AP, the RESETN signal is relaxed by the PMU (which informs the AP that the PMU is ready). The STC3115 RSTIO pin relaxes this signal at the end of the first OCV measurement.

Figure 8: STC3115 RSTIO feature integration in a PMU based application



1. Typical R1 value = 1 kΩ

Figure 9: STC3115 RSTIO feature integration in PMU and Smart reset based applications



5 Place and route guidelines

The four layout "rules" listed below should be followed to achieve the best STC3115 accuracy in an application.

1. Connect the Vin signal to the battery connector with a specific track and not directly through a Vbatt+ plan.
2. Connect an external sense resistor if the STC3115 is used in mixed mode.
3. Consider the temperature with regard to the placement of the battery, the STC3115, and the components of the application.
4. Use the STMicroelectronics PCB design recommendations.

5.1 Vin pin connection

The Vin pin should be connected to the battery connector with a specific track and not directly through a Vbatt+ plan. This is to improve the voltage measurement accuracy during the first open circuit voltage (OCV) and during the life of the application.

The voltage drop coming from track impedance and current amount is not negligible compared to the targeted accuracy of the voltage measurement. This rule aims to minimize the current impact on the voltage measurement by minimizing the voltage drop due to track impedance combined with current level.

In low power mode as well as in mixed mode, the STC3115 voltage algorithm is used. In both configurations and in every application state (sleep, normal, fast) the voltage measurement accuracy is critical. The lower the current flowing in the Vin track is, the more accurate the measurement is.

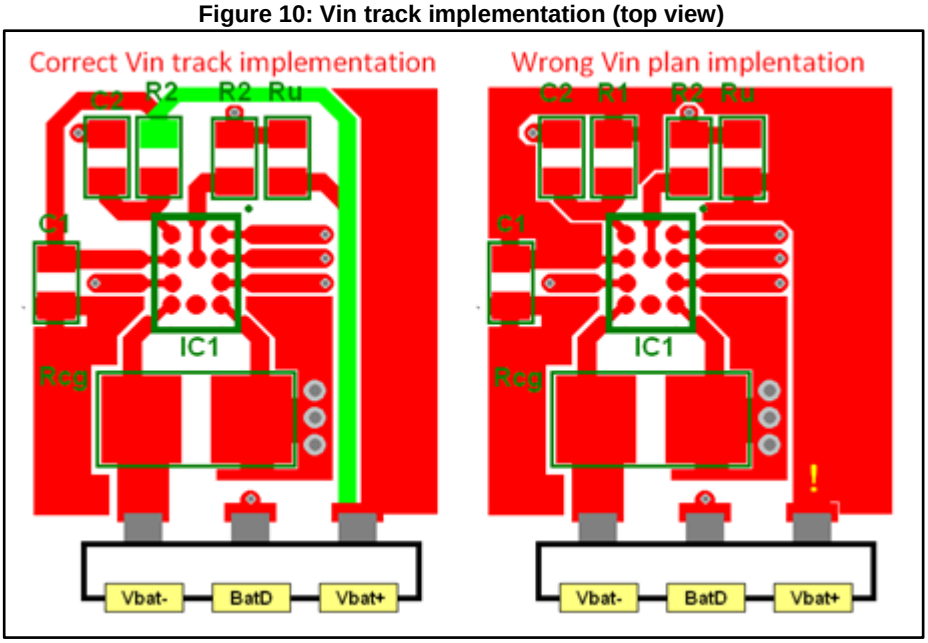
Rule description:

1. Minimize the track and connector impedances
2. Minimize the current to take into account for the voltage drop calculation

This is a priority 2 rule and is not mandatory (priority 1 indicates a mandatory rule). If low power mode is used to track the battery state, this rule becomes a priority 1.

In the diagram below, the image on the left is the correct implementation since the single Vin track involves a very low current level in the voltage measurement track. The maximum value of this current is equal to the STC3115 consumption when the V_{cc} is also powered by this track. This involves a quasi-null voltage drop and guarantees the best voltage measurement accuracy in every application consumption condition. To achieve even greater efficiency, this track should be separated from the other system power supply tracks that come directly from the battery connector.

Figure 10: Vin track implementation (top view)



5.2 External sense resistor

If the STC3115 is used in mixed mode, an external sense resistor has to be connected between the CG+ and the GND pin. The aim of this rule is to sense the battery flowing current properly by connecting the STC3115 dedicated pins to the system through the sense resistor. The protocol for doing this is as follows (priority 1 indicates a mandatory rule):

1. Place the sense resistor close to the battery connector with the minimum track length to minimize the equivalent impedance. In the same logic, ensure the track wideness is in line with the application power consumption (priority 2).
2. Connect the STC3115 CG pin directly to the sense resistor without any connection with the track coming from the battery (VBat-). The CG pin connection with BATD- pin is performed through the sense resistor pad (see *Figure 11: "CG track implementation (top view)"*) (priority 1).
3. Connect the STC3115 GND pin directly to the sense resistor with a track. The sense resistor has to be independently connected to the ground to avoid any voltage reference issue. The GND pin connection with application ground plane is performed through the sense resistor pad (see *Figure 12: "GND plan implementation (top view)"*) (priority 1).
4. Connect the sense resistor to the ground plane with the minimum equivalent impedance to minimize the sense resistor effect on the application behavior (priority 1).
5. If there are multiple PCB layers with GND plane or if there is a Vbat track on a layer other than Reg, the STC3115 CG and GND pins must be connected to the RCG pads directly on the RCG layer.

Figure 11: CG track implementation (top view)

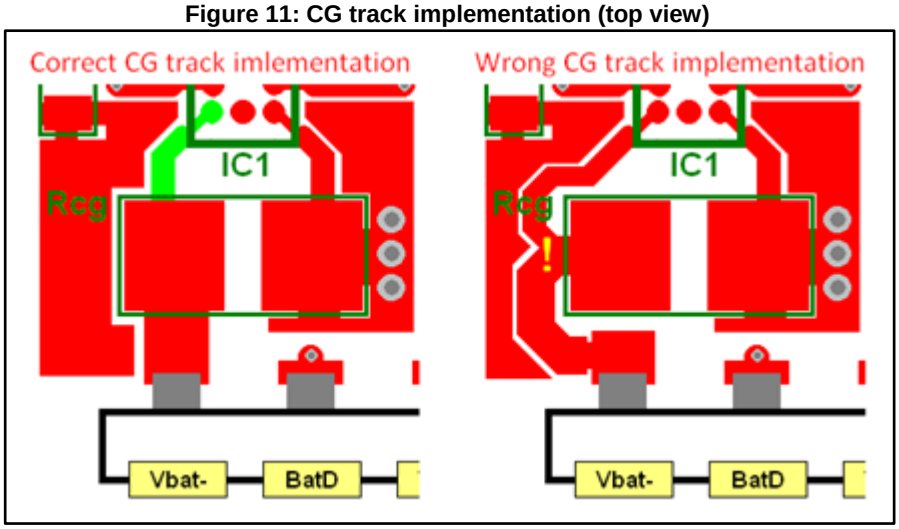
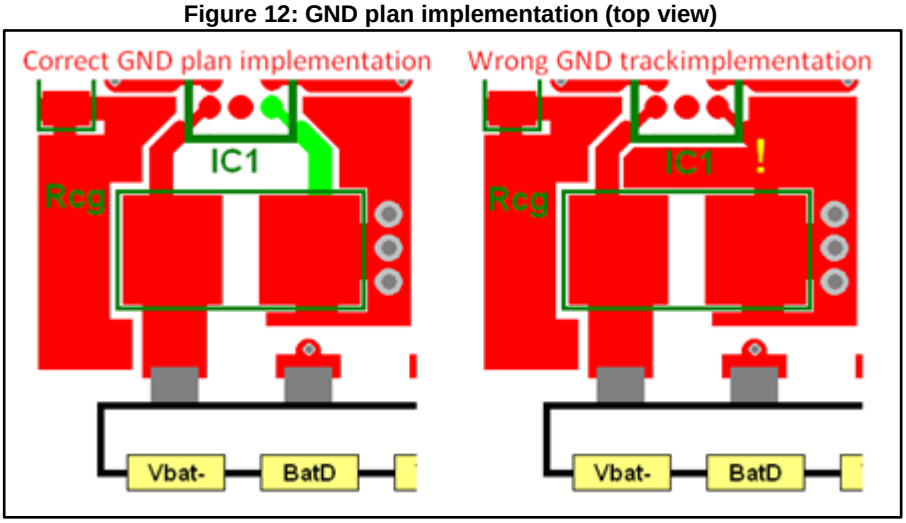


Figure 12: GND plan implementation (top view)



5.3 Temperature considerations

The STC3115 provides an accurate temperature sensor feature. If this internal temperature sensor is used for battery temperature compensation, the position of the STC3115 with respect to the battery position impacts slightly the accuracy of the temperature measurement. The closer the STC3115 is to the battery, the more accurate the temperature measurement and compensation is.

The other heating components of the application should be placed as far from the STC3115 as possible to avoid big temperature measurement errors. For example, during application charging mode, the IC charger temperature can be increased by several degrees.

5.4 STMicroelectronics PCB design recommendations

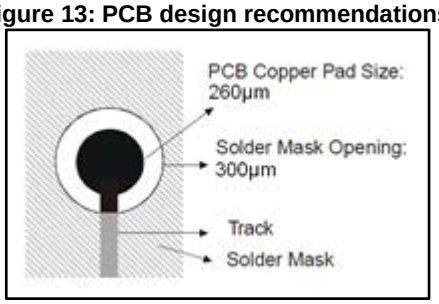
For optimum electrical performance and highly reliable solder joints, STMicroelectronics recommends the PCB design guidelines listed below.

Table 5: PCB design recommendations with "solder mask defined"

PCB pad design	Non solder mask defined, micro via under bump allowed
PCB pad size	Ø = 260 µm max (circular) – 220 µm recommended
Solder mask opening	Ø = 300 µm min (for 260 µm diameter pad)
	Ø = 260 µm min (for 220 µm diameter pad)
PCB pad finishing	Cu – Ni (2-6 µm) – Au (0.2 µm max)

To optimize the natural self-centering effect of Flip-Chips on the PCB, the PCB pad positioning and size have to be properly designed (see *Figure 13: "PCB design recommendations"*).

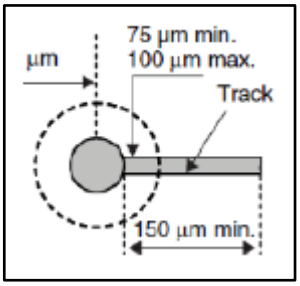
Figure 13: PCB design recommendations



A thick gold layer finishing on the PCB pad is not recommended (low joint reliability).

The PCB tracks close to the CSP footprint have to be designed to ensure a correct mechanical assembly (see *Figure 14: "PCB track recommendations"*).

Figure 14: PCB track recommendations



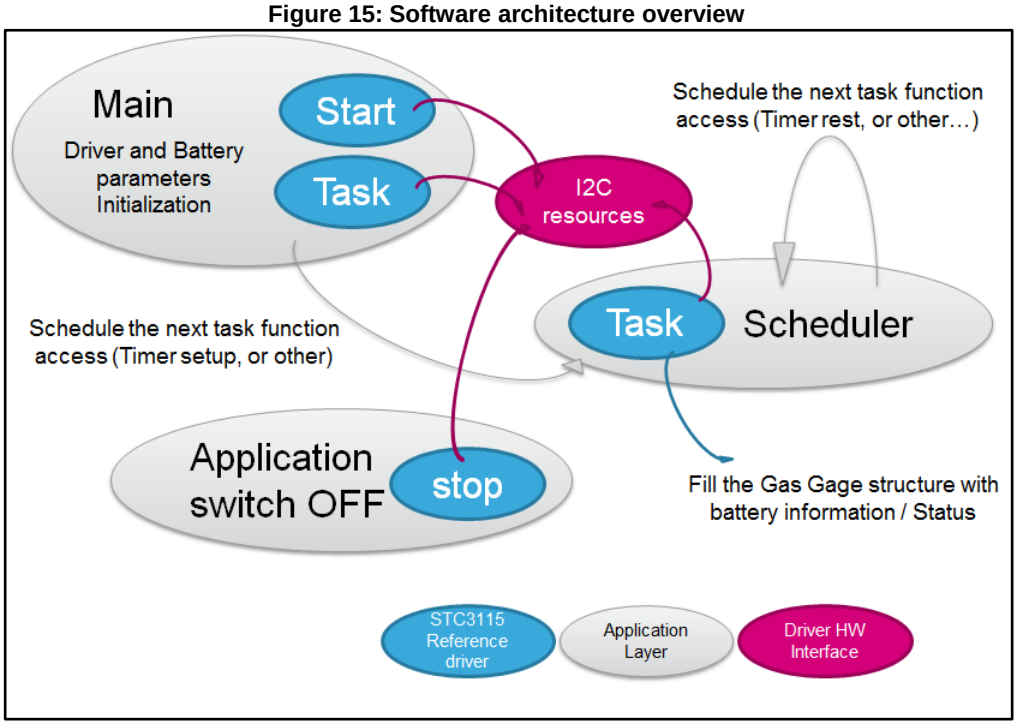
6 Software

The STC3115 hardware architecture can autonomously track the battery status. From battery plug-in to battery plug out, a simple initialization is enough to provide an accurate battery state of charge (SOC). From this initial point, the system can access when the SOC has to be refreshed and displayed to the user without any real time constraints.

An additional software layer can also be used to compensate the temperature and aging effects. This layer uses the STC3115 hardware features for accuracy and to be independent from the host system.

The software architecture can be separated into several blocks (e.g. start, task, and API) which are described below.

Figure 15: Software architecture overview



The STC3115 start block initializes and configures the STC3115. Effectively, this block updates the register reset values so that the values are in line with the battery that has to be tracked.

The STC3115 periodic task is the software block which periodically reads the STC3115 register to update the system with the new battery status. This block can be enriched to compensate temperature and aging effects.

The STC3115 software API is the software block between the main application software and the driver itself. This block allows communication between each layer.

6.1 STC3115 RAM memory organization proposal

The STC3115 device embeds a 16-byte RAM memory area.The registers of this area can be used to periodically save the battery status. This allows battery information to be recovered when the application is stopped but the battery is not unplugged.

The STC3115 registers can be initialized with memorized data (see *Section 6.2*) which is called "restoration". The choice of whether to use a default initialization or a restoration is based on the STC3115 CTRL_REG and on the RAM memory content.

A RAM organisation is proposed in *Table 6* below. The RAM test word is a fixed word but, the cyclic redundancy check (CRC) word has to be calculated after each RAM write operation. The CRC calculation can be made using any standard algorithm.

Before checking if the STC3115 can be restored or not, chcek to see if the RAM data can be used to initialize the STC3115 registers or not i.e. check if the test and CRC words located in the RAM memory are used to secure and check the validity of the RAM content.

Table 6: STC3115 RAM stack example, 16 bytes @0x20

RAM register	Content proposal
REG_RAM0	RAM test word
REG_RAM1	Battery SOC_LOW
REG_RAM2	Battery SOC_HIGH
REG_RAM3	Battery CC_CNF_LOW
REG_RAM4	Battery CC_CNF_HIGH
REG_RAM5	Battery VM_CNF_LOW
REG_RAM6	Battery VM_CNF_HIGH
...	...
REG_RAM15	CRC



16 RAM bytes can be used to save other information/events

6.2 Chip initialization

The STC3115 has to be initialized from a specific value. The initialization process is different depending on the history of the application before startup. We can identify two main situations:

1. New battery plug-in. Full battery initialization has to be performed starting from the default software point and using the initial battery model. The initial open circuit voltage (OCV) measurement and state of charge (SOC) have to be used as the initial battery state. This information can be retrieved from the STC3115 registers.
2. The battery has not been removed. When the battery has not been removed since the last application switch off, the last recorded data can be recovered and stored in the STC3115 using the data saved in the RAM memory.

At every application startup, the following steps are recommended to correctly configure the STC3115 registers:

1. Read the chip ID in the REG_ID at address 0x18
2. Check the RAM memory status (test and CRC words)
3. If the RAM content is incorrect, initialize the RAM and the chip with default parameters
4. If the RAM content is correct, check the PORDET and BATFAIL bits
5. If BATFAIL = 1, the battery voltage was previously decreased below 2.6 V (UVLO threshold), the Batd pin detected a battery removal/switch event, and the chip has to be fully initialized. If PORDET = 1, the battery voltage was previously decreased below 2 V (POR threshold), the battery was removed/switched, and the chip has to be fully initialized. The STC3115 cannot be restored and full STC3115 initialization is required (i.e. STC3115 initialization steps).
6. If the BATFAIL/PORDET = 0, the battery has not been removed and chipset configuration can be recovered from the RAM data information (e.g. from the RAM memory content description). STC3115 restoration is possible; the saved RAM data can be used to restart the STC3115 from a previous application status (i.e. STC3115 restoration steps).

Once the validity of the STC3115 RAM memory and the status of the REG_CTRL register has been checked, the STC3115 can then be initialized with default parameters or with restored parameters (see *Section 6.1* for RAM content clarification).

STC3115 initialization steps

This is the standard STC3115 initialization flow: all registers have to be initialized using default values and the first open circuit voltage (OCV) measurement. Carry out the following three steps when no data can be retreived from the last STC3115 running mode.

1. Read the OCV register. The first OCV measurement reflects the initial battery state of charge (SOC). Read it and save it into a temporary variable.
2. Set the STC3115 parameters (ensuring first that the GG_RUN bit is set to 0). The REG_OCVTAB registers have to be filled with their previously calculated values as well as the values of the REG_CC_CNF and REG_VM_CNF registers. Then configure the application parameters by setting the REG_ALARM_SOC, REG_ALARM_VOLTAGE, REG_CURRENT_THRES, REG_RELAX_MAX, REG_ALARM_SOC, and REG_ALARM_VOLTAGE registers as required by the application to provide an HW interruption signal on the ALM pin when one of the measurements is detected as being below the defined threshold. The REG_CURRENT_THRES and REG_RELAX_MAX registers are used to configure the internal behavior of the STC3115. Default values are enough to provide good accuracy.

3. From this point, the battery model characteristics and application threshold are initialized and battery tracking can start. To define the battery starting point, write back the OCV value into the REG_OCV register (16 bits) using the variable content. From this operation, the first battery SOC is available in the REG_SOC register 100 ms later. At this point, the provided SOC is based on the fine-tuned OCV curve defined in *Table 3* plus the initial OCV curve described in *Table 2*.

STC3115 restoration steps

In this case, some registers can be initialized with the recorded RAM data using the improved battery model from the last running period. Other registers have to be initialized with default values.

1. Read the RAM memory. In this case, the last recorded state-of-charge (SOC) reflects the initial battery SOC. Read it and save it as a temporary variable.
2. Set the STC3115 parameters (ensuring first that the GG_RUN bit is set to 0). The REG_OCVTAB registers have to be filled with their previously calculated values. The REG_CC_CNF and REG_VM_CNF registers have to be initialized using RAM information that can be different and more accurate regarding battery aging. Then, configure the application parameters by setting the REG_ALARM_SOC, REG_ALARM_VOLTAGE, REG_CURRENT_THRES, REG_RELAX_MAX, REG_ALARM_SOC, and REG_ALARM_VOLTAGE registers as required by the application to provide an HW interruption signal on the ALM pin when one of the measurements is detected as being below the defined threshold. The REG_CURRENT_THRES and REG_RELAX_MAX registers are used to configure the internal behavior of the STC3115. Default values are enough to provide good accuracy.
3. Write the REG_SOC register. From this point, the battery model characteristics and application threshold are initialized and battery tracking can start. To define the battery starting point, write back the SOC value (read previously in the RAM) into the REG_SOC register (16 bits). From this operation, the first battery SOC is available in the REG_SOC register without delay. To start battery monitoring, set the GG_RUN bit, as well as the VMODE bit if the power saving mode is selected (refer to *Section 6.3*).

Figure 16 summarizes the initialization steps and *Figure 17* summarizes the initialization and restoration flowcharts.

Figure 16: STC3115 initialization type selection flowchart

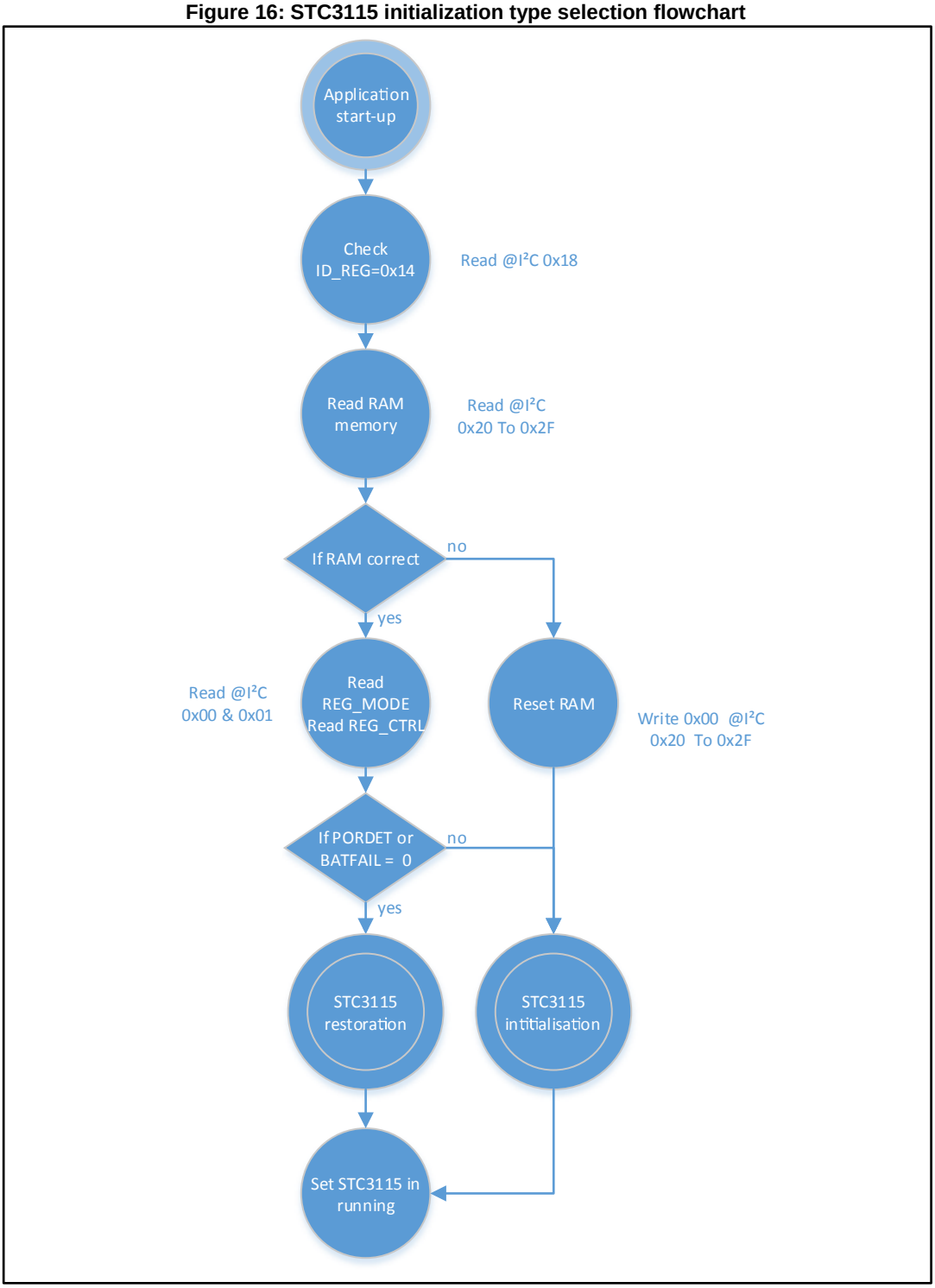


Figure 17: STC3115 initialization and restoration flowcharts

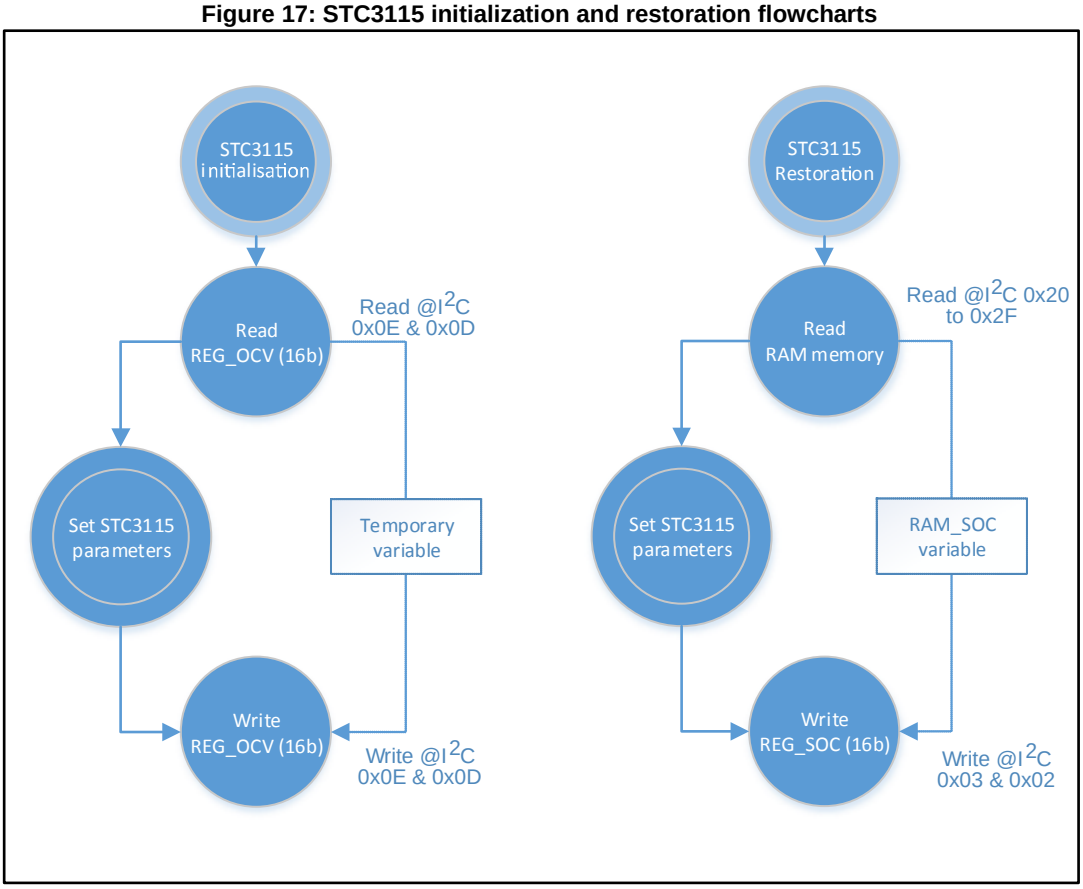
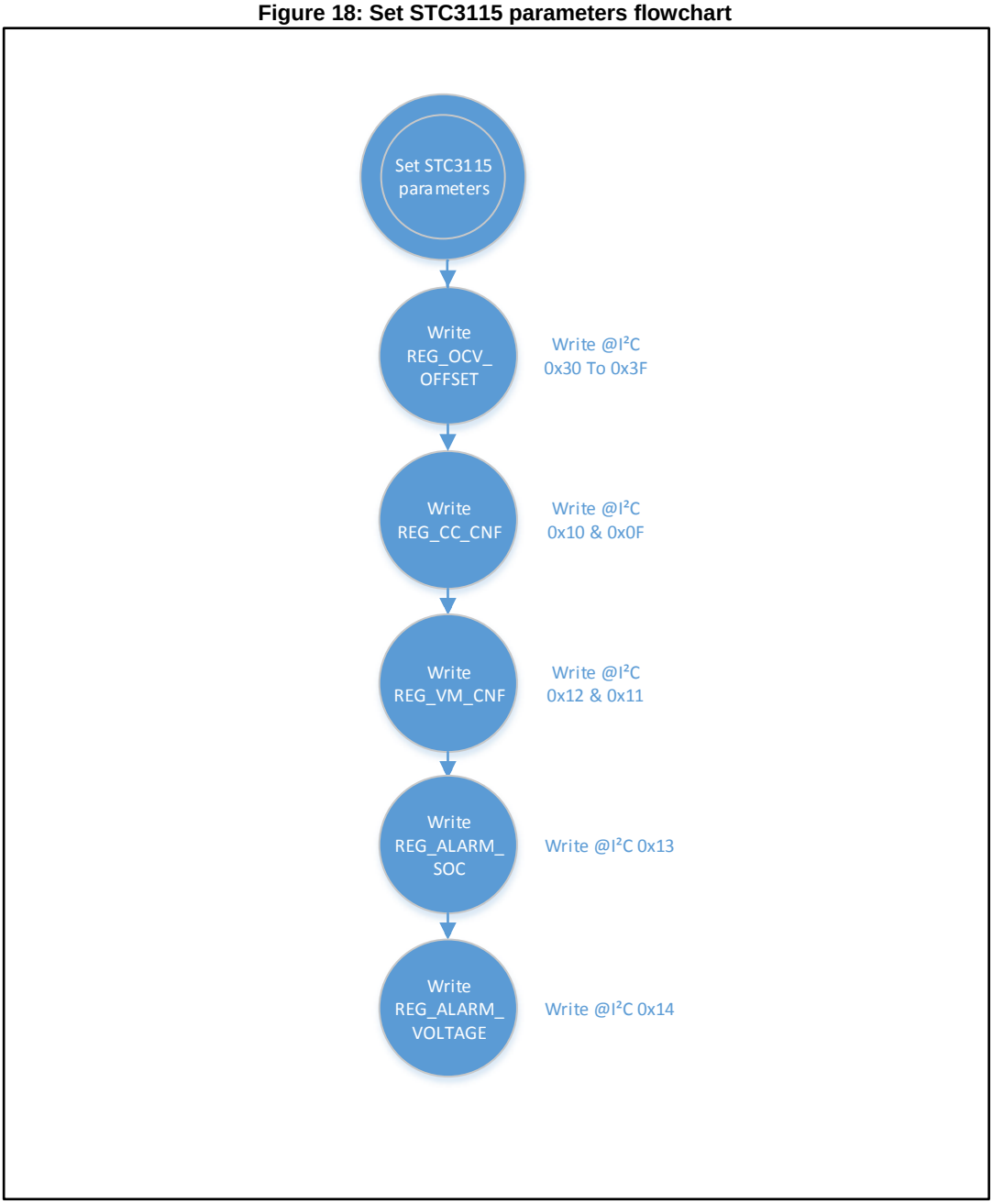


Figure 18: Set STC3115 parameters flowchart



6.3 STC3115 running configuration

During initialization, the STC3115 is in standby mode after initialization. It has to be configured in run mode to track the battery state of charge (SOC). The GG_RUN bit in REG_MODE register must be set to one. At same time, STC3115 run mode has to be selected, by setting the VMODE bit in the REG_MODE register.

- If VMODE is set to 1, the STC3115 is in power saving mode and it uses only the voltage measurement to track the battery state. This mode is recommended for low power applications or during a low power application state.
- If VMODE is set to 0, the STC3115 is set to mixed mode using the internal OptimGauge algorithm to provide the battery SOC status using voltage and current measurements simultaneously. This mode is recommended to provide the best accuracy whatever the application consumption.



The IODATA bit has to be written to 1 to enable the ALM pin report using previously initialized parameters.

After GG_RUN = 1 configuration, the REG_COUNTER register is increased every 0.5 s and the REG_SOC, REG_VOLTAGE, REG_CURRENT, and REG_TEMPERATURE registers are updated at the same frequency.



The REG_COUNTER register is not increased if the BatD signal is above 1.61 V.

6.4 Periodic device access

To refresh the battery state that is reported to the application, the STC3115 needs to be accessed. The period duration and frequency accuracy do not impact the accuracy of the report.

6.4.1 First STC3115 access after initialization

Depending on whether the STC3115 was fully initialized or restored, the state of charge (SOC) availability can be delayed:

1. After full initialization, the REG_SOC register is updated 100 ms after the end of the REG_OCV write operation.
2. After restoration, the REG_SOC register is directly available, and even the temporary variable content can be reported to the user.

Note that a simple way to manage the SOC delay is to use the STC3115 conversion counter information available in the REG_COUNTER register. This conversion counter is increased by 1 every 500 ms (after setting the GG_RUN bit to 1). To ensure availability of the first SOC, the software can wait to read a counter higher than 2.

6.5 STC3115 task procedure

The task software block reports the battery state. From a simple system status check to a full battery report, the STC3115 task software block is called periodically at any frequency to be in line with the system power consumption.

6.5.1 How often the STC3115 has to be called in run mode

A delay between two STC3115 accesses does not change the report accuracy. For example, when the state of charge (SOC) is moving faster, an access delay can be scaled by the application consumption to update more frequently the SOC reported to the user. This can be achieved by using the REG_CURENT value. The STC3115 access delay can also be decreased accordingly to the SOC level. The lower the SOC is, the lower the access delay is.

Alternatively, the STC3115 can be accessed with a fixed period. A fixed period has to be in line with application consumption and battery capacity. For example, the period could be equal to a minimum delay of 1 % discharge:

(Battery capacity (mAh) / application maximum current (mA)) x 0.01 = STC3115 access period (h).

By default, a delay of 30 seconds to 1 minute between two STC3115 accesses is considered adequate for most standard applications.

During the periodic access to the STC3115, several simple checks have to be performed to verify system stability. Consequently, the task function needs to read the STC3115 to report the information to the system.

The application checks verify if any battery swaps or removal events have occurred since checking the BATFAIL and PORDET bits. The RAM memory integrity can also be checked to ensure chipset stability and reliability between two driver accesses. From these bits and the RAM status, the driver can either report the updated battery status or it can restart and reset the data in the exchange structure.

At the end of the task procedure, the exchange data structure has to be updated to report the last battery status to the system. At this time, the RAM memory registers have also to be updated to save their status for the next driver access.

An additional feature of this procedure is to track the application state. Based on current and voltage measured values, charging, end of charging, idle, discharging, and low battery status can also be reported to the system.

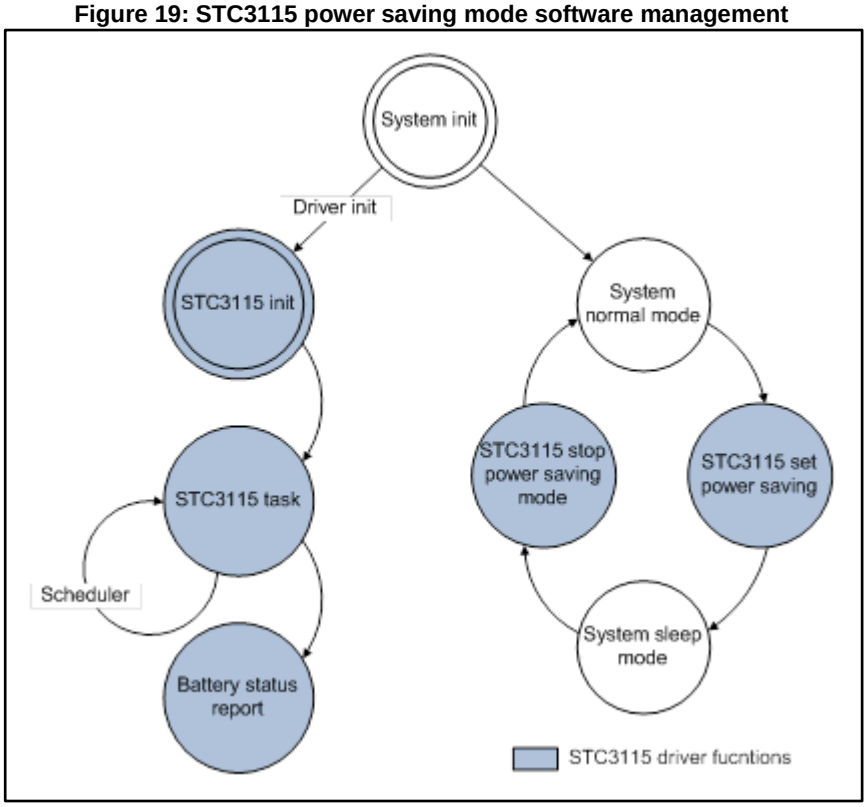
6.6 STOP procedure

To stop the device correctly if the application switches off, the GG_Run bit has to be cleared. The RAM can also be updated with the last updated battery state. This information can be used during the START procedure if the battery has not been removed.

6.7 Power saving mode software management

The power saving mode of the STC3115 can be set dynamically during normal application running. To maintain the best accuracy from the device, the driver should be called to use power saving integrated functions (see *Figure 19: "STC3115 power saving mode software management"*). Power saving management can be done in parallel with the normal application workflow.

Figure 19: STC3115 power saving mode software management



The global behavior of the driver remains the same irrespective of the STC3115 power mode: it reports the battery state information to the system after each scheduled task.

From the application software point of view, the STC3115 VMODE bit has to set to 1 to enter power saving mode and has to be set to 0 to go back to normal mode. The VMODE bit can be set to power saving mode or mixed mode according to the system mode as shown in *Figure 19: "STC3115 power saving mode software management"*.

Even if the STC3115 power saving mode is ON by default and used as the main mode for reporting the battery state over the application life, the STC3115 mixed mode remains more accurate. Mixed mode allows the user to get the best performance from the STC3115. Mixed mode must not be set if no sense resistor is connected to the CG pin.

7 Revision history

Table 7: Document revision history

Date	Revision	Changes
30-Oct-2013	1	Initial release
12-Nov-2014	2	Added order codes STC3115AIQT and STC3115IQT Replaced "REG_OCV_OFFSET" register with "REG_OCVTAB" register *Section 3.1*: updated text and added *Figure 2* *Section 3.2*: updated register names *Section 4.1*: The five points concerning the sense resistor value and reference "must" be considered (and not "should" be considered). *Section 4.1.3*: replaced 10 mW with 160 mW *Section 4.2*: updated internal threshold of BatD pull-up voltage from1.6 V to 1.61 V; updated title of *Figure 3* *Section 4.3:*replaced "voltage platform" with "system voltage" *Figure 10*: added "top view" to title *Section 5.2*: added fifth point to the protocol on how to add an external resistor *Figure 11* and *Figure 12*: added "top view" to titles *Table 5*: added option "Ø = 260 µm min (for 220 µm diameter pad)" Added *Section 6.1* *Section 6.2* deleted the two subsections related to this section and added them into the main section, updated text, updated *Figure 16* and *Figure 17*, added *Figure 18*. Updated *Section 6.3* *Section 6.4*: modified section title *Section 6.5.1*: modified section title *Section 6.7*: updated text explaining *Figure 19*

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