AN5954

Application note

Low consumption with STC311x gas gauge family

Introduction

This application note describes a system part supplied by a lithium cobalt oxide (LCO) type battery and which uses a gas gauge from STMicroelectronics to monitor the Li-ion battery. In recent applications requiring low consumption for sustainability, the goal is to use different existing products inside low power systems.

The ST311x gas gauge family was designed for low power consumption applications, but recent constraints in IoT systems to satisfy ultra-low power have elicited creative solutions to further reduce the standby current of these kinds of systems.

To maintain accuracy in the state of charge (SOC), the gas gauge stays switched on. But, to reduce consumption by I^2C, the gas gauge can be switched off and the current and voltage are no longer measured, and thus the SOC loses its accuracy.

The system described hereinafter uses a trick to reduce the consumption and to maintain the SOC's accuracy.

The battery is disconnected from the system in standby thanks to a MOSFET, the system is no longer supplied, and only a simple analog product is connected to the battery, which allows the full application to wake up. The consumption is linked to one device only, and thus, is minimized.

As an example, the STC3117 can consume a maximum of 40 µA in standby. Generally, users have a low consumption budget of around 10 to 20 µA maximum.

Adding a controlled MOSFET through a Smart Reset™, which was designed to provide this feature, the consumption of the board can be decreased (only the MOSFET leakage + the consumption of the STM6620 (a maximum 5 µA (Cf product datasheet)) should be considered).

Thanks to the STMicroelectronics device STM6620, the system can be set to ON through a push-button or any device (providing the correct information, the pin should be set to low voltage during a predefined time) or, the system can be woken up through a VBUS voltage up to 30 V dc (when the USB Type-C® is plugged, for example).

Moreover, the Smart Reset™ device can be used to perform the reset of the system.

1 Why monitor a battery?

All systems running on a battery should inform the end-user that the battery is at a certain discharge level. This information allows the end-user to choose when to recharge the battery.

SOC information is now easily accessible to end-users because this information is present on all products supplied by a battery (smartphones are ubiquitous now).

Different algorithms are used to estimate the SOC, which is provided generally as a percentage (%) of the remaining capacity of the battery. The SOC is based on the measurement of the current and/or the voltage. The temperature can also be considered in the algorithms.

Battery monitoring is generally performed by a dedicated device called a “gas gauge” or “fuel gauge.” This is the proposal made in this part of the system. The ST device gas gauge accurately monitors the SOC of the LCO battery whatever the current and voltage.

In standby, the gas gauge is disconnected to reduce the battery current consumption. The SOC information is no longer available.

During the next power up sequence, the gas gauge measures the battery voltage. Then, from the internal Open Curve Voltage (OCV) and the battery voltage measured at the power up, the gas gauge recovers the previous SOC state.

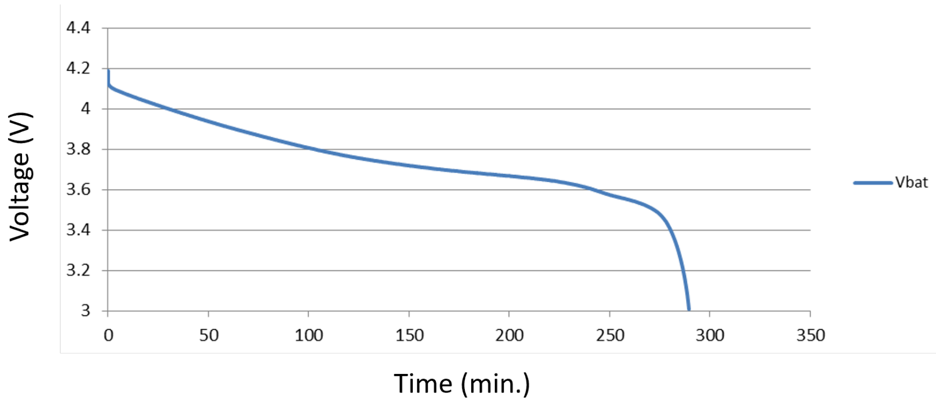
2 Battery information

The system is designed to use a Li-ion battery. There are different battery technologies, and the STC311x family has been designed for one of them: LCO and LCO-like batteries.

Within Li-ion battery technology there are some subcategories:

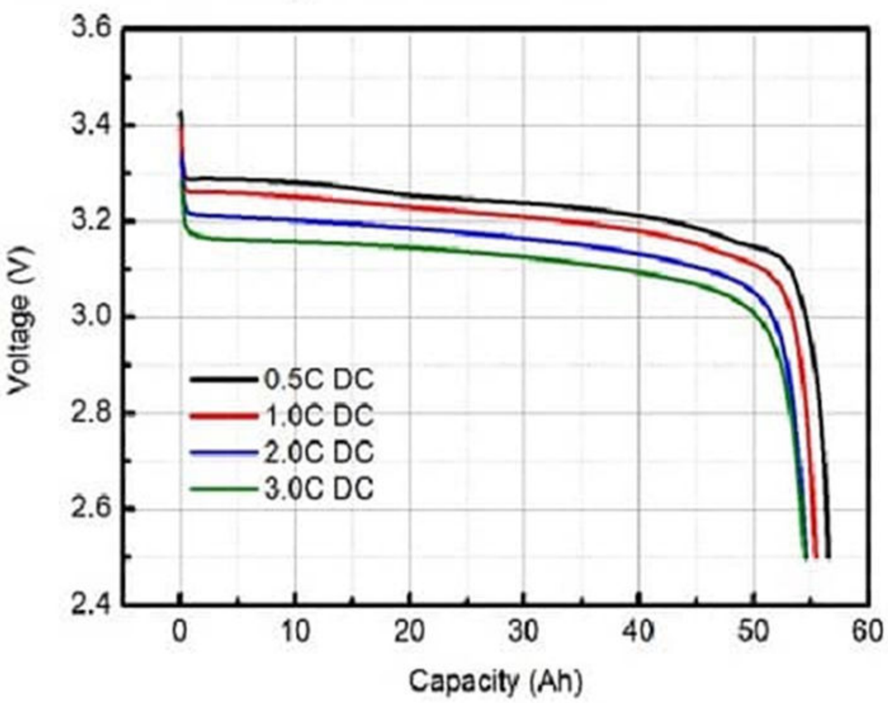
- LCO ($LiCO_2$ = lithium cobalt oxide), which is a battery found in smartphones. The main characteristic is its very powerful energy, which is stored in a minimum of weight and size for a secondary battery.
  Furthermore, these batteries have a nice discharge with a slope that allows the voltage to get to the SOC using only a small 12-bit ADC.
  These batteries have a maximum float voltage of 4.2 V or 4.35 V (a more common voltage in today's applications).
  Figure 1 shows a typical discharge of this LCO kind of battery. The curve shows the slope, and the relaxation of these kinds of batteries goes back to the open circuit voltage. This propriety can be used to determine the SOC after some time the battery is in rest.

Figure 1. LCO typical battery discharge (GNB application lab)



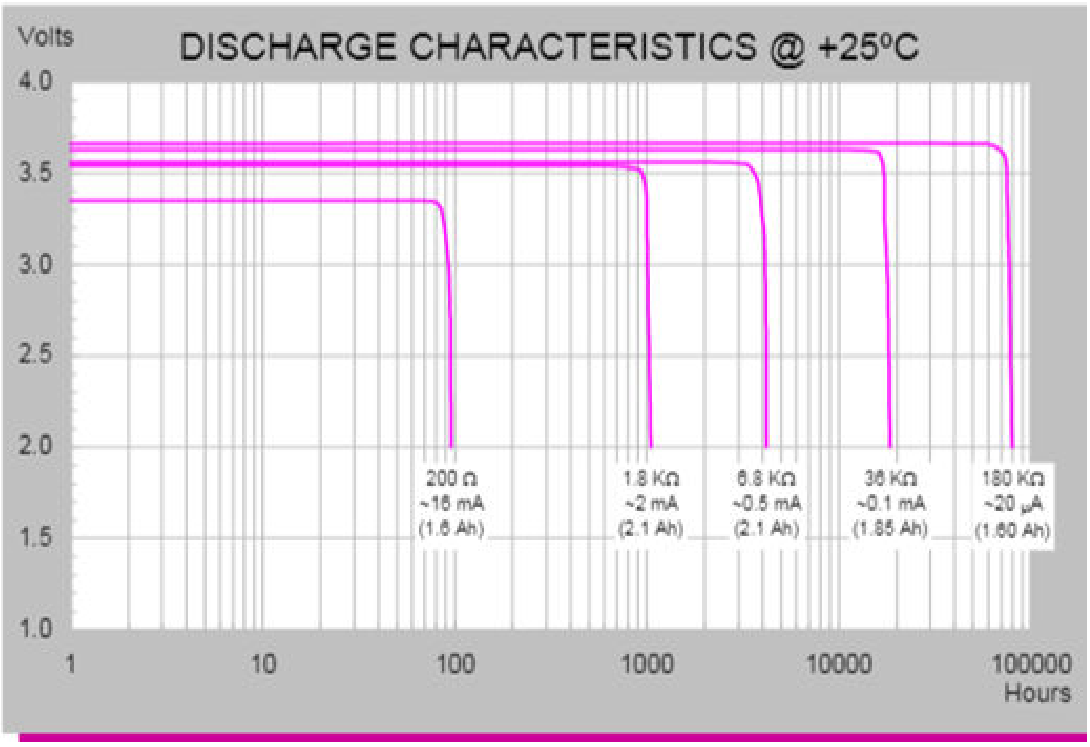
- In the same family is NCA, a lithium battery with nickel, cobalt, and aluminum. This battery behaves similarly to the LCO one with a bigger slope in general.
  LFP (LiFePO4 = lithium iron phosphate or lithium ferro-phosphate) is another kind of battery that can only be monitored by current. The plateau is very flat, and it is difficult to get the voltage accurately linked to the SOC (especially with a 12-bit ADC). Furthermore, relaxation is not directly linked to the voltage that is really close to the maximum float voltage.

Figure 2. **LFP typical battery discharge at 25 °C**



- $Li\text{-}SoCl_2$ = lithium thionyl chloride is the third type of battery that is often used in the industrial market for metering applications. Once again, the STC311x family can be used but these gas gauges have not been designed for these two last kinds of batteries (LFP and LISoCL2).

Figure 3. **LiSoCL2 typical battery discharge (from Tadiran documentation)**



So, in using a dedicated gas gauge component, the battery technology must conform to the battery type for which the device has been designed. This is why in the case presented here, the consumption limitation works fine with LCO technology.

The SOC is generally provided as a percentage (%), and is calculated from the current with a coulomb counting or by measuring the voltage using a simple voltage mode gas gauge.

To use the voltage, some constraints should be respected by the battery and the LCO (LiCoO2) has a perfect discharge shape. As seen in Figure 1, the LCO battery presents a slope discharge shape that easily determines the OCV for each SOC. Furthermore, when the battery is relaxed, the final relaxed voltage is unique and can determine the SOC.

3 System overview

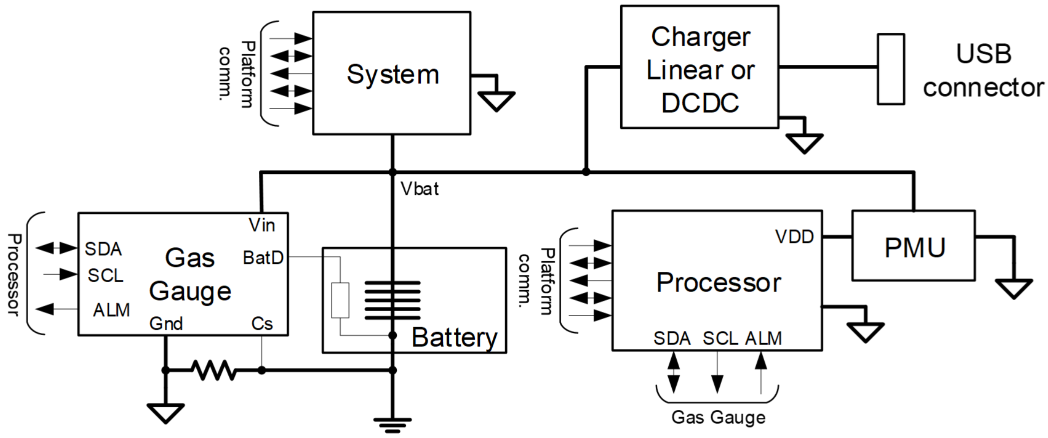
The system is a classical application using a battery that can be charged by an external power source such as a USB connection through a battery charger, or discharged when providing power to a load.

The system battery is monitored by a gas gauge from STMicroelectronics, and the main products are STC3115 and STC3117. The following description can run with both. The STC3117 (the most recent product) is used in the following example.

Figure 4 shows a system running on a battery, with the possibility to be charged through a charger and an external source (a USB here) and discharged by powering a load. The monitoring is done by a gas gauge.

The system can run and consume a large amount of current coming from the battery. But, when the product is only supplied by the battery, the product can be in standby for a while and the user's demand is the minimum consumption at that time.

Figure 4. Classical system supplied by a battery



As the STC311x gas gauge family devices were designed for large batteries used in smartphones some years ago, the consumption is in line with recent smartphone demand, around 40 µA. But for some systems in IoT, such as smart cigarettes or other products, this consumption might be above the total budget of the system (around 15 µA).

To use this STMicroelectronics component in such systems, a solution must be found (via the introduction of a Smart Reset™ device) and used to limit the gas gauge current consumption in standby.

4 How to use the STC3117 to get the SOC

STMicroelectronics has designed different gas gauges. The first one is STC3100, which is an analog front-end (AFE) providing only current, voltage, and temperature. The real gas gauge was developed a bit later with the STC3115, that calculates the SOC, and the last product of the family was the STC3117 gas gauge.

The differences between STC3115 and STC3117 are mainly: the package, the way the open circuit curve (OCV) is implemented inside the device, and some other features (like charger deactivation, current averaging, etc.).

This last product, the STC3117, is interesting because it is smaller than the STC3115. With optimized features, the STC3117 can continue to provide measured current, voltage, temperature, and calculate the SOC.

Furthermore, this last product is perfectly adapted to add a software code to a microcontroller to calculate a more accurate SOC or to let the customer implement the state of health.

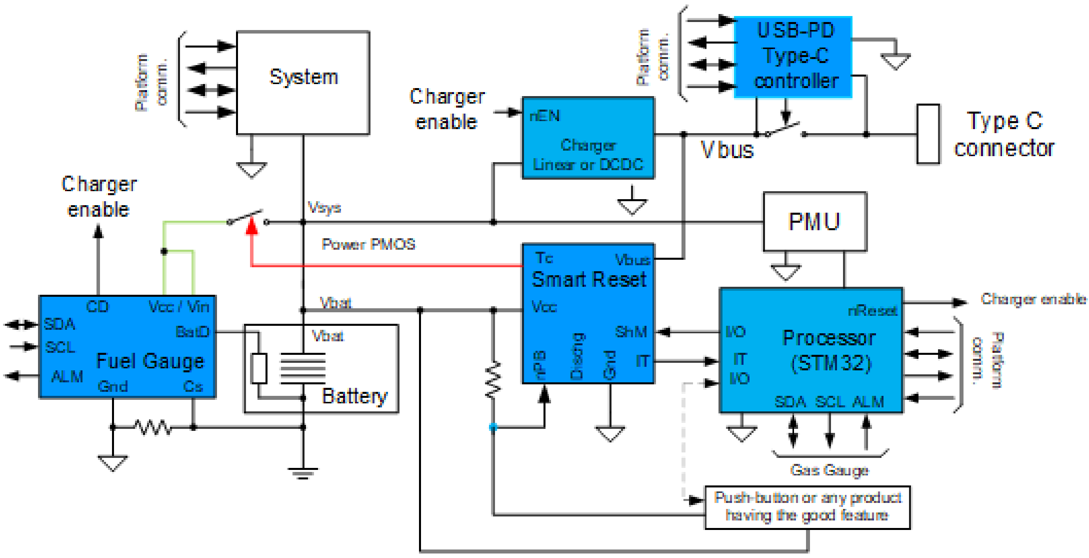
The STC3115 and STC3117 have been designed to consume low current but for some applications in IoT, for example, the consumption can be still too high on a low-capacity single cell.

The STMicroelectronics gas gauges have the possibility to measure the voltage when the device is supplied for the first time. So, when the battery is connected the first time, the device can provide a voltage and finally report an accurate SOC to the relaxed battery voltage measured. This is a very important point for the next steps in the system demonstration. The idea is to cut the power supply coming from the battery. This disconnection of the gas gauge to the battery can be done easily, and the gas gauge starts again with an accurate voltage measurement of the relaxed battery and finally can provide the SOC thanks to an internal calculation done using the battery discharge characteristics of the OCV curve.

5 Demonstration target: low consumption

Figure 5 presents a low consumption board that stops the gauging and stops supplying the load and the microcontroller using ST devices. This feature is done in an analog way only.

Figure 5. Current consumption limited board (using ST devices)

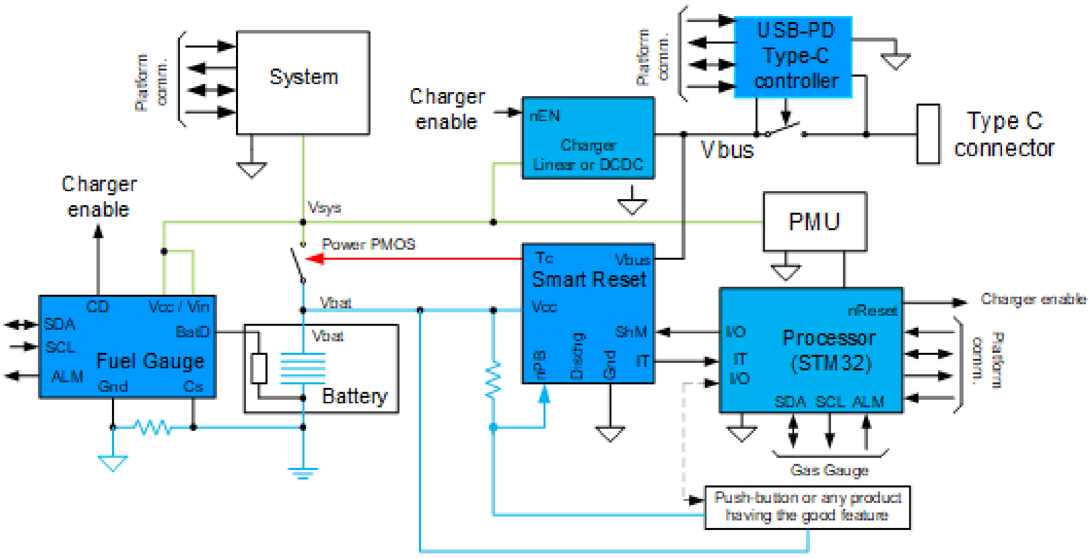


As said in the introduction, the system must consume the minimum current in standby. The system is composed of:

- A battery providing energy. This battery must be from a specific technology, such as lithium cobalt oxide or similar technology (addition of metal oxide). These batteries present a specific slope during the discharge and the STC3117 used inside the demonstrator was designed for these kinds of batteries.
- A gas gauge from ST Microelectronics company. The gas gauge is issued by the STC31xx family and the component used is the STC3117 in WLSCP package (refer to the datasheet to get more information). This device has a unique way to start: when a battery is connected the first time, the product takes a measurement of the voltage, current, and temperature. These measurements allow the initial SOC percentage to be managed. So, to reduce the consumption, this device can be on a particular power line and disconnected (as other devices). When the power line is connected again to the battery, the SOC is automatically adapted to the battery rest voltage.
- A Smart Reset™ product that can control an external MOSFET and that can have the possibility to restart by a push-button (or equivalent sensor delivering a low voltage for a while (debouncing period)) or by the connection of a USB voltage. A resistor is connected to the VBUS power line, and this power line can be 5 V or up to 30 V. This last voltage is above the new USB Power Delivery voltage of 20 V. This product is well-suited for this kind of application.
- The Smart Reset™ controls a power MOSFET when a ship mode is requested. To enter in this mode a five pulse signal is requested on a particular input of the device. In the demonstrator, a NE555 (or ST555) is used to generate this pulse with a push-button but a microcontroller can also do this action.
- This mode is normally used in a factory setting to let the battery charge for a long time before the system is bought by an end-user, but in this case this mode is used each time the system goes in standby. The MOSFET is opened after a predefined time and it can be used to put different parts of the system in standby (if necessary). When the MOSFET is activated, and the power line is no longer supplied by the battery, the consumption falls to the minimum, and only the Smart Reset™ is connected to the battery. In standby, the Smart Reset™ consumes only 5 µA maximum, and this consumption can be the total consumption of the system.
- The demonstration board is composed of a USB Type-C® controller STUBS4500L, and a linear charger from the company STSN01. The first device is used to restart the system when a connector providing 5 V or more is connected to the board, and this power line VBUS is connected to the battery charger that can recharge the battery.

Figure 6 shows the block diagram of the system. On this board the choice has been made to cut the power line supplying the entire system. The yellow line, the VBAT power line, supplies only the Smart Reset™. By running the application in this mode, the processor is off in standby and the only device on the battery at that time (standby) is the Smart Reset™.

Figure 6. Low consumption system using the existing product



6 The demonstration board

Figure 7 shows the board developed in the Grenoble application laboratory. A second version has been developed to eliminate some components that are not mandatory, that were present in the first version to do tests, and also to correct some minor errors.

Figure 7. Low consumption system board block diagram

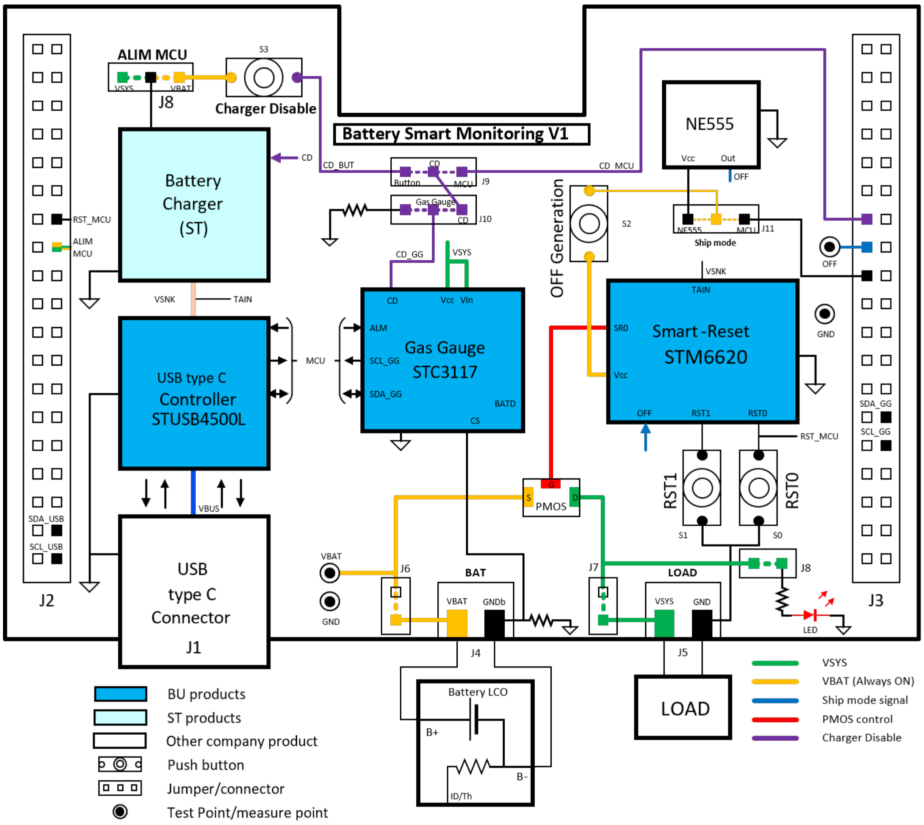
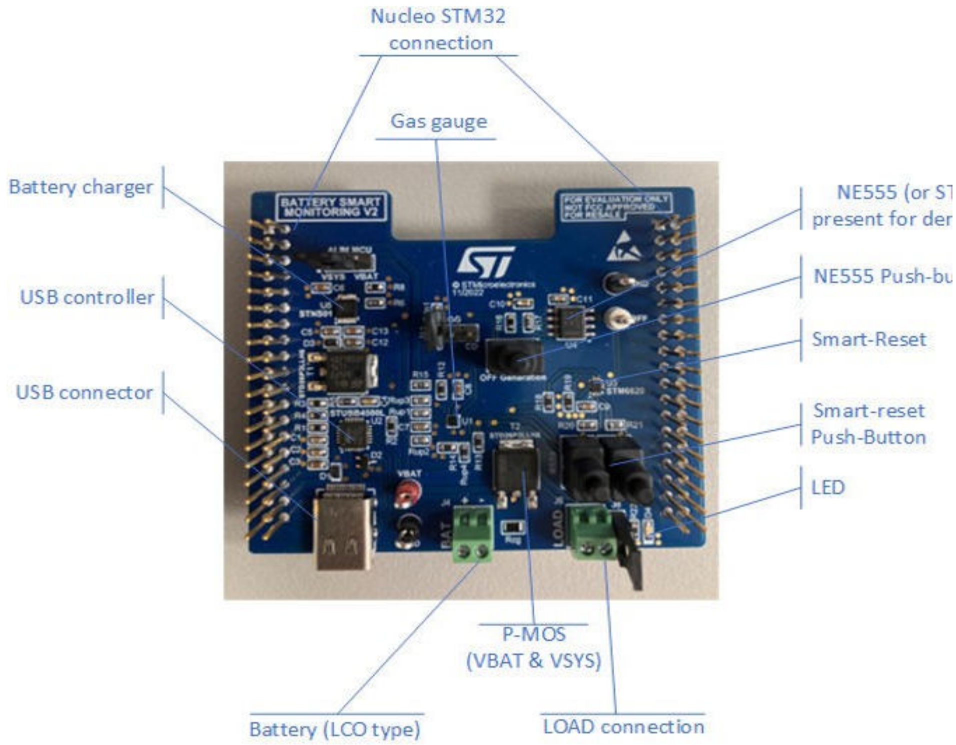


Figure 8 describes the different components used to make the BMS board. All components are from ST.

Figure 8. Low consumption system board module description



The board is organized so as to run on a battery (LCO type) and with all the products needed to charge, monitor the battery, and stop and start the system. This board is relatively autonomous because it is an analog way to manage power. The low consumption feature is managed by the buttons on the right. A USB Type-C® connector is on the left, following this connector the controller is present, and the MOSFET opening the power path to the battery charger and the rest of the application is set. A battery charger is present, and in the middle a gas gauge device is used to monitor the battery. This device runs only when the Smart Reset™ control is ON the P-MOSFET, otherwise the battery is disconnected supplying only the Smart Reset™ present on the middle right of the board.

This board uses the concept that a large P-MOSFET is used to separate the power path into two branches: VBAT and VSYS.

The VBAT is the battery power path that comes from the battery. This path is used to discharge and charge the battery. VBAT is directly connected to the Smart Reset™ device that is always on with a limited consumption. The maximum current used by the device is 5 µA.

VSYS is the power path used to supply the rest of the system, and in particular, the load. The microcontroller can be on this power path, and in that case, the microcontroller is stopped to reset itself properly and the other peripheral devices like the gas gauge. VSYS has its consumption falling to null when the Smart Reset™ pilots OFF the power P-MOSFET.

The gas gauge from ST is a very interesting device because it first takes a battery measurement when the battery is plugged. So, the SOC is always accurate because the SOC is recalculated after each stop.

Remark: "On this board, the consumption is higher than 5 µA because the NE555 has a resistor connected to the VBAT. The resistor maintains the NE555 at the correct frequency, while increasing the current in standby. If this resistor is removed (which is true in a real application), the consumption is effectively 5 µA maximum (a measurement from a production sample shows 1.3 µA consumption)."

7 Visual results

The results presented in this document have been obtained on the board alone because the microcontroller is only used to report the SOC calculated by the gas gauge. All the systems are purely analog and can run autonomously.

Figure 9 proposes a full system able to provide the SOC on a PC via the USB bus and a HyperTerminal.

Figure 9. BSM board plugged with a Nucleo (STM32)

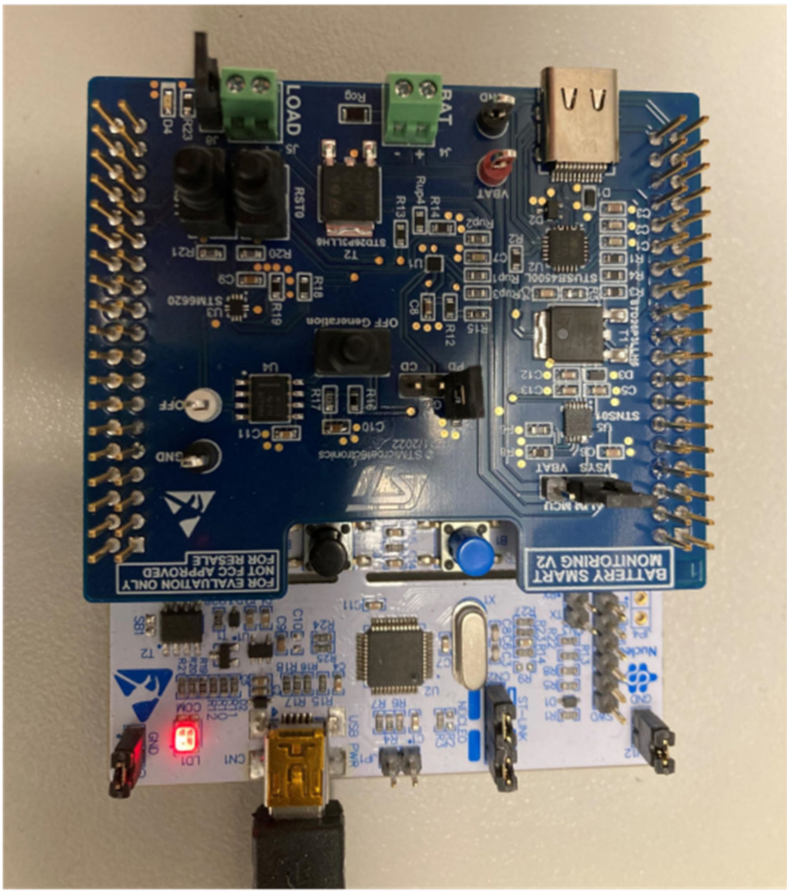
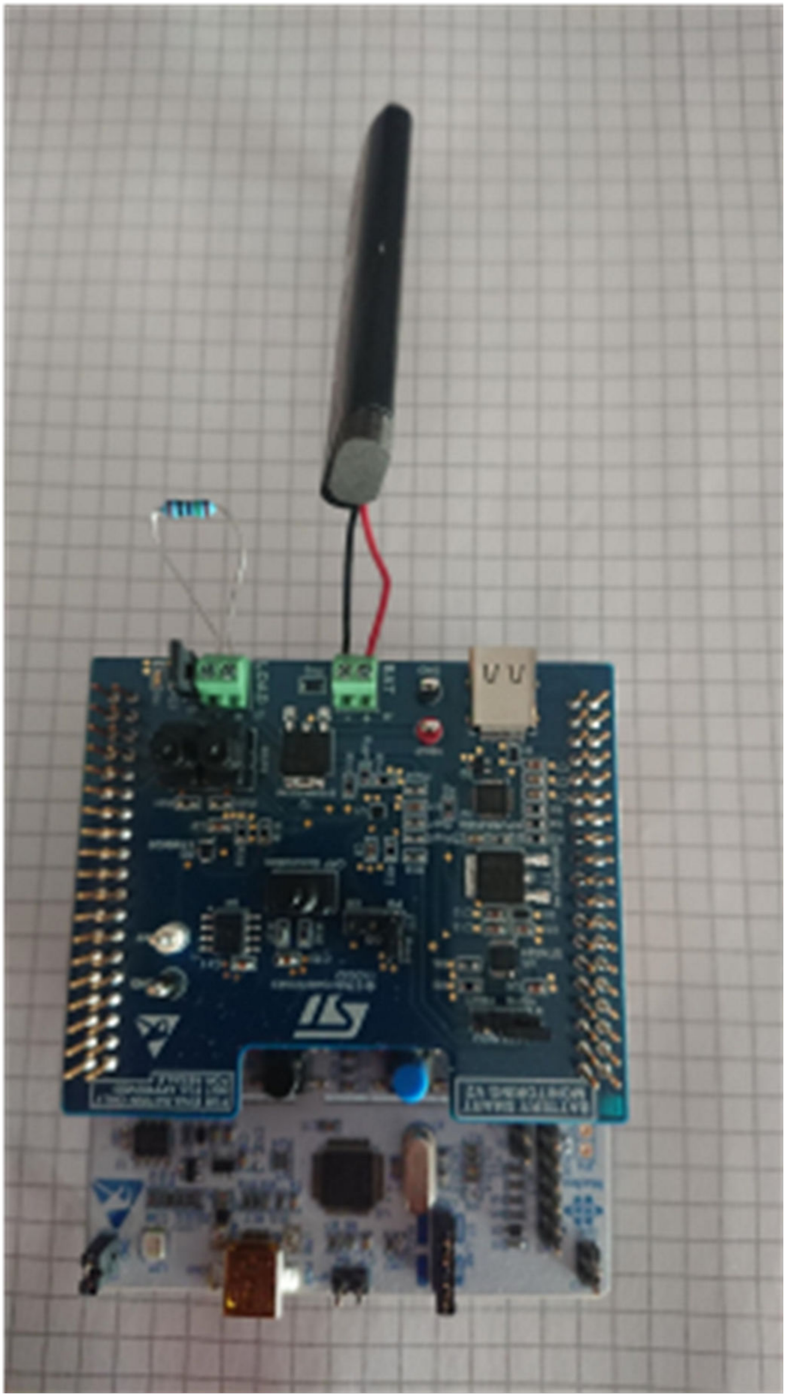


Figure 10 shows the place of the load represented by a resistor and the battery (typical batteries are an LCO type).

Figure 10. **BSM + Nucleo boards with load and battery**



So, the system is fully analog and can run autonomously as previously noted. An LED is put on the BSM board when the system is supplied by the battery and when the load receives current. When the system is shut down or in standby, the LEDs are not highlighted on the BSM board nor on the Nucleo board.

Figure 11 presents the BSM supplying the load. The LED on the BSM board is highlighted (the current goes through this LED as it goes through the resistor set as a load). The BSM runs with a current flowing through the load because the Smart Reset^{TM} is set on a running mode that controls the P-MOS thanks to the input push-button or thanks to the presence of the USB Type-C® source connected to the BSM board.

Figure 12 shows the same BSM board when the MOSFET is opened. The LED is switched off because there is no more current flowing through it and through the resistance set as a load. The battery is only supplying the Smart Reset™. This state is obtained thanks to the Smart Reset™ that detects five pulses on the input OFF. After around 12 s the device controls the P-MOS to cut the VBAT separating the VBAT and the VSYS. The VSYS is no longer supplied (on this board the five pulses are generated by the NE555 that is supplied thanks to a push-button).

Figure 11. When all devices are supplied by the battery (MOSFET is closed)

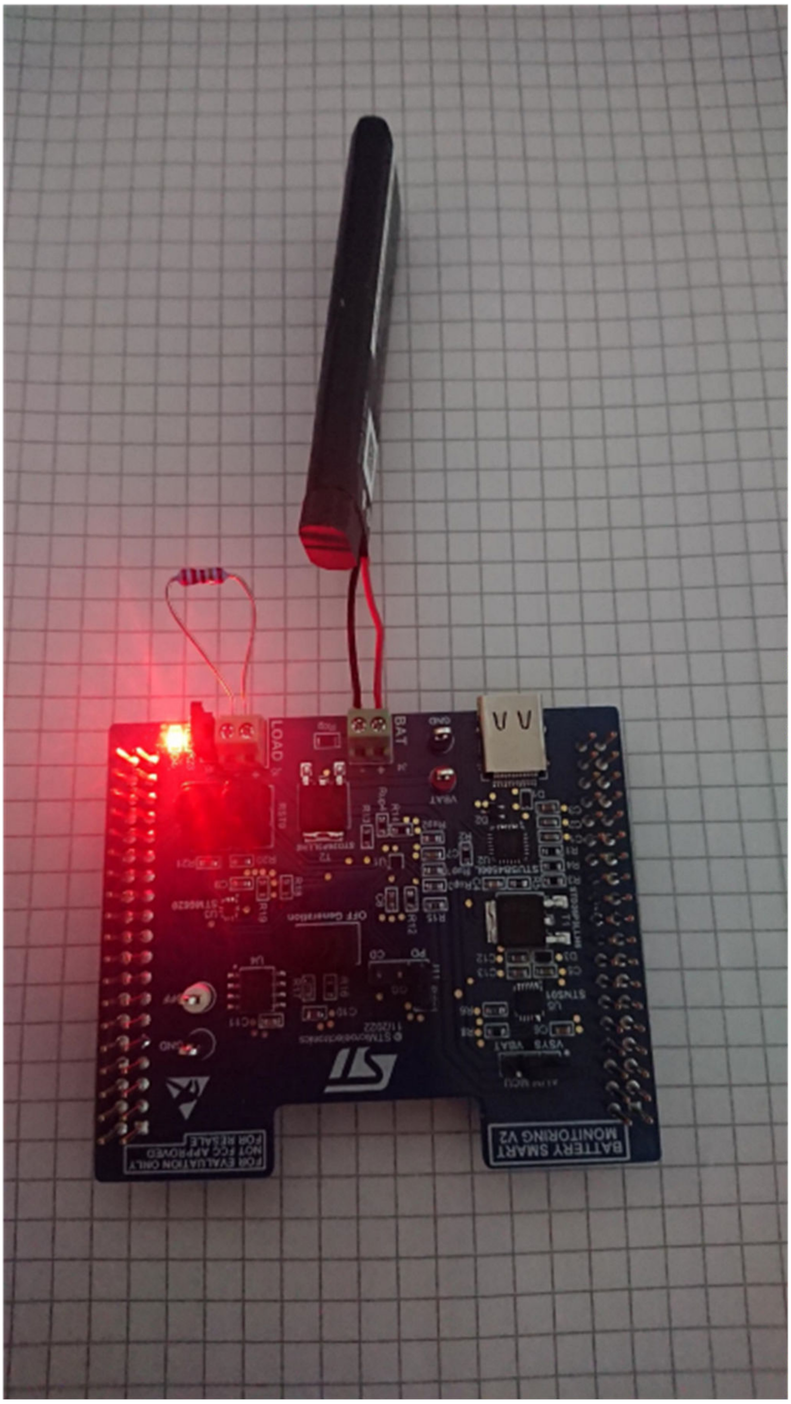
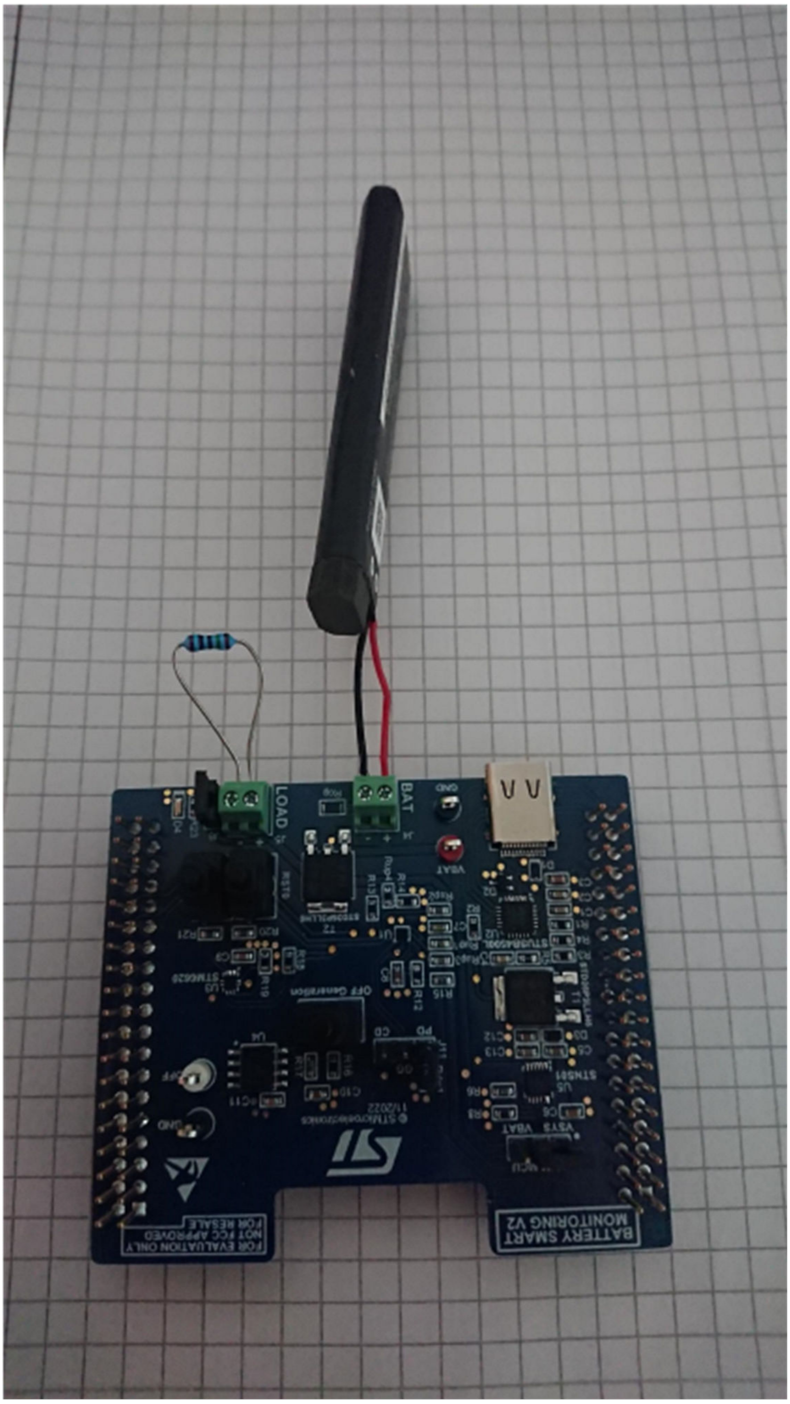


Figure 12. When all devices are switched off by the MOSFET (MOSFET is opened)



Revision history

Table 1. **Document revision history**

Date	Version	Changes
12-Mar-2024	1	Initial release.

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