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LC709203F

Smart LiB Gauge Battery Fuel Gauge LSI for 1-Cell Lithium-ion (Li+)

Overview

LC709203F is a Fuel Gauge for a single lithium ion battery. It is part of our **Smart LiB Gauge** family of Fuel Gauges which measure the battery RSOC (Relative State Of Charge) using its unique algorithm called **HG-CVR**. The **HG-CVR** algorithm eliminates the use of a sense resistor and provides accurate RSOC information even under unstable conditions (e.g. changes of battery; temperature, loading, aging and self-discharge). An accurate RSOC contributes to the operating time of portable devices.

LC709203F is available in two small packages realizing the industries smallest PCB footprint for the complete solution. It has minimal parameters to be set by the user enabling simple, quick setup and operation.

Features

- **HG-CVR** algorithm technology
 - No external sense resistor
 - 2.8% accuracy of RSOC
 - Accurate RSOC of aging battery
 - Automatic convergence of error
 - Adjustment for the parasitic impedance around the battery
 - Simple and Quick Setup
- Low power consumption
 - 3 μ A Operational mode
- Precision Voltage measurement
 - ± 7.5 mV
- Precision Timer
 - $\pm 3.5\%$
- Alerts for Low RSOC and / or Low Voltage
- Temperature compensation
 - Sense Thermistor input
 - Via I^2C
- Detect Battery insertion
- I^2C Interface (up to 400 kHz supported)

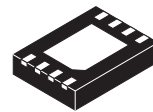
Applications

- Wireless Handsets
- Smartphones / PDA devices
- MP3 players
- Digital cameras
- Portable Game Players
- USB-related devices

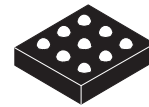


ON Semiconductor[®]

www.onsemi.com



WDFN8 3x4, 0.65P
Pb-Free, Halogen Free type



WLCSP9, 1.60x1.76
Pb-Free, Halogen Free type

ORDERING INFORMATION

See detailed ordering and shipping information on page 24 of this data sheet.

LC709203F

Application Circuit Example

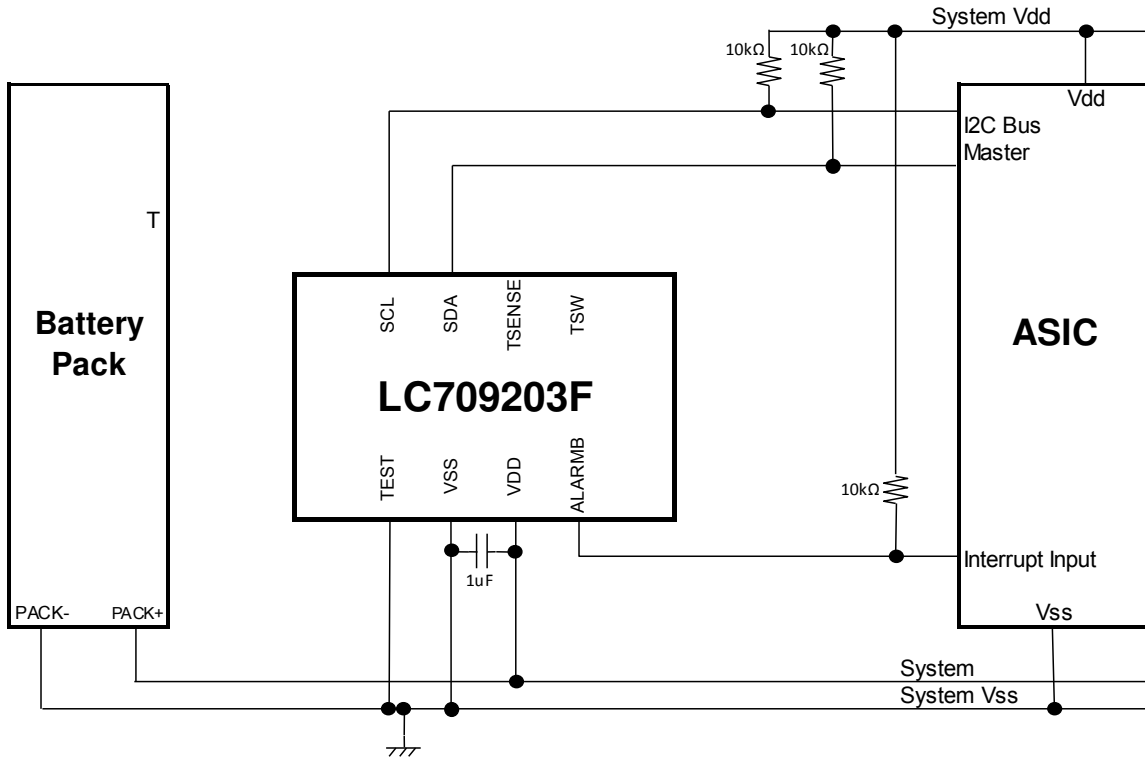


Figure 1. Example of an application schematic using LC709203F (Temperature input via I²C.)

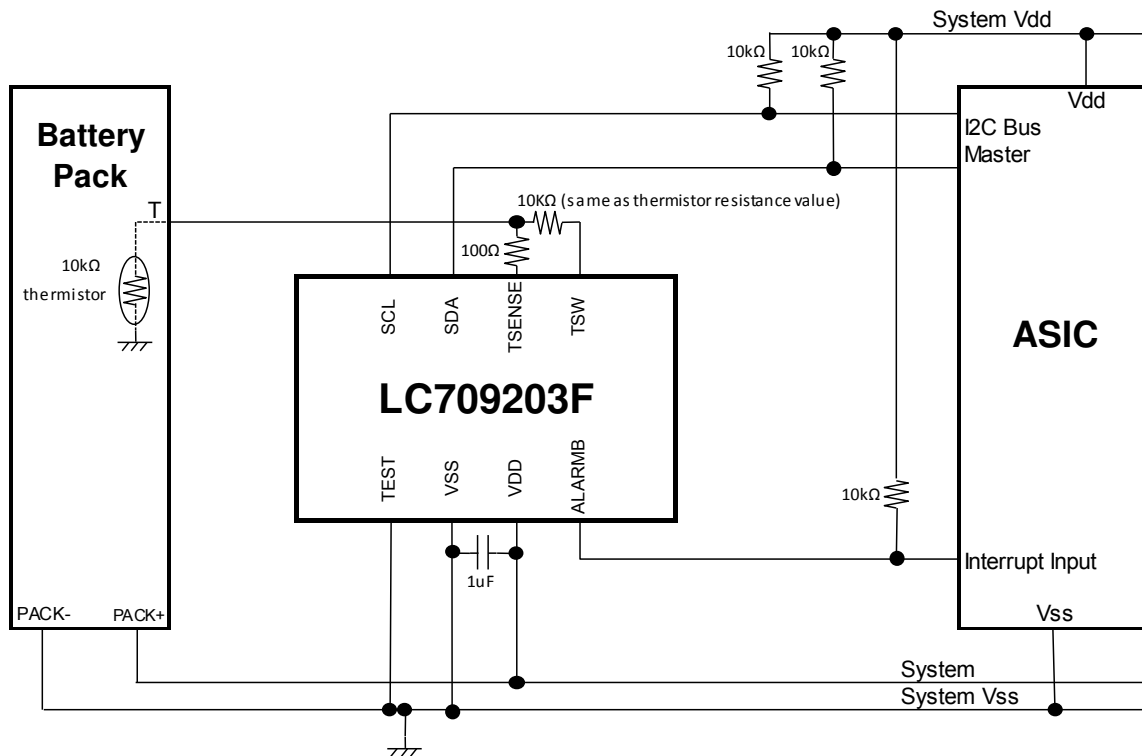


Figure 2. Example of an application schematic using LC709203F (The temperature is measured directly by a thermistor.)

LC709203F

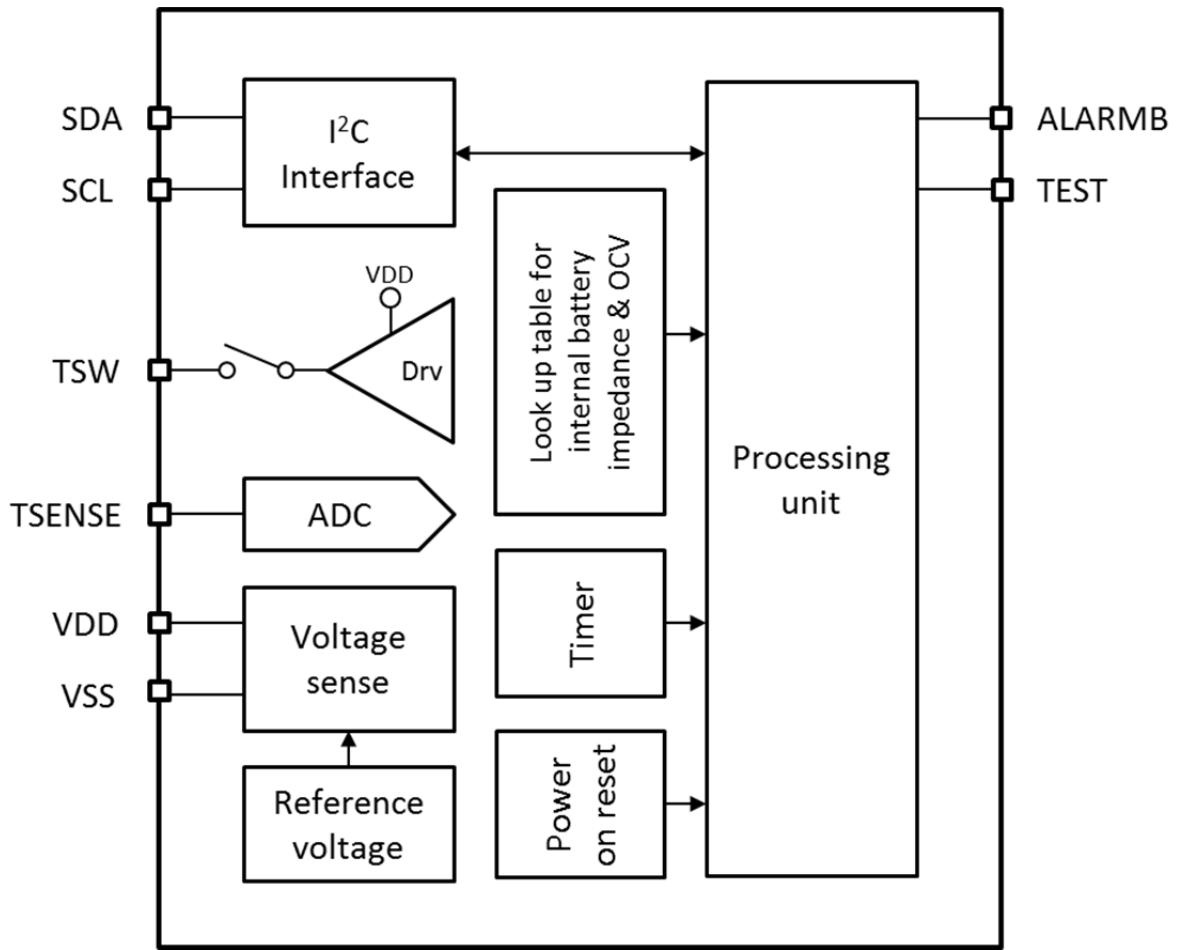
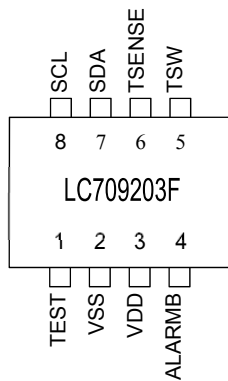


Figure 3. Simplified Block Diagram

WDFN8 3x4, 0.65P
 "Pb-Free, Halogen Free Type"

Top view



WLCSP9, 1.60x1.76
 "Pb-Free, Halogen Free Type"

Bottom view

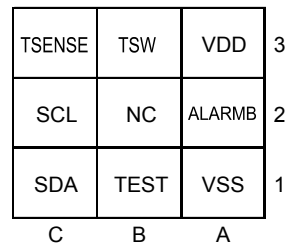


Figure 4. Pin Assignment

LC709203F

Table 1. Pin Function

| WDFN8 | WLP9 | Pin Name | I/O | Description |
|-------|------|-----------------|-----|---|
| 1 | 1B | TEST | I | Connect this pin to V _{SS} . |
| 2 | 1A | V _{SS} | – | Connect this pin to the battery's negative (–) pin. |
| 3 | 3A | V _{DD} | – | Connect this pin to the battery's positive (+) pin. |
| 4 | 2A | ALARMB | O | This pin indicates alarm by low output(open drain). Pull-up must be done externally. Alarm conditions are specified by registers (0x13 or 0x14). Connect this pin to V _{SS} when not in use. |
| 5 | 3B | TSW | O | Power supply output for thermistor. This pin goes HIGH during temperature read operation. Resistance value of TSW (for thermistor pull-up) must be the same value as the thermistor. (Note 1) |
| 6 | 3C | TSENSE | I | Thermistor sense input. If you connect this pin to thermistor, insert 100Ω resistance between them for ESD. (Note 1) |
| 7 | 1C | SDA | I/O | I ² C Data pin (open drain). Pull-up must be done externally. |
| 8 | 2C | SCL | I/O | I ² C Clock pin (open drain). Pull-up must be done externally. |
| – | 2B | NC | – | Don't care. |

Note 1 : TSW and TSENSE must be disconnected as figure 1 when not in use.

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Table 2. Absolute Maximum Ratings at $T_a = 25^\circ\text{C}$, $V_{SS} = 0\text{ V}$

| Parameter | Symbol | Pin/Remarks | Conditions | Specification | | | Unit | |
|-------------------------------|---------------------|-------------|---|---------------|------|-----|----------------|------------------|
| | | | | V_{DD} [V] | min | typ | | max |
| Maximum supply voltage | $V_{DD\text{ max}}$ | V_{DD} | | | -0.3 | | +6.5 | V |
| Input voltage | V_I (1) | TSENSE | | | -0.3 | | $V_{DD} + 0.3$ | |
| Output voltage | V_O (1) | TSW | | | -0.3 | | $V_{DD} + 0.3$ | |
| | V_O (2) | ALARMB | | | -0.3 | | | |
| Input/output voltage | V_{IO} (1) | SDA, SCL | | | -0.3 | | +5.5 | |
| Allowable power dissipation | $P_d\text{ max}$ | WDFN8 | $T_a = -40\text{ to }+85^\circ\text{C}$ | | | | 480 | mW |
| | | WLP9 | | | | | 210 | |
| Operating ambient temperature | T_{opr} | | | | -40 | | +85 | $^\circ\text{C}$ |
| Storage ambient temperature | T_{stg} | | | | -55 | | +125 | |

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

Table 3. Allowable Operating Conditions at $T_a = -40\text{ to }+85^\circ\text{C}$, $V_{SS} = 0\text{ V}$

| Parameter | Symbol | Pin/Remarks | Conditions | Specification | | | Unit | |
|--------------------------|--------------|------------------|------------|---------------|-------------|-----|--------------|-----|
| | | | | V_{DD} [V] | min | typ | | max |
| Operating supply voltage | V_{DD} (1) | V_{DD} | | | 2.5 | | 4.5 | V |
| High level input voltage | V_{IH} (1) | TSENSE | | 2.5 to 4.5 | $0.7V_{DD}$ | | V_{DD} | |
| | V_{IH} (2) | ALARMB, SDA, SCL | | 2.5 to 4.5 | 1.4 | | | |
| Low level input voltage | V_{IL} (1) | TSENSE | | 2.5 to 4.5 | V_{SS} | | $0.25V_{DD}$ | |
| | V_{IL} (2) | ALARMB, SDA, SCL | | 2.5 to 4.5 | | | 0.5 | |

Functional operation above the stresses listed in the Recommended Operating Ranges is not implied. Extended exposure to stresses beyond the Recommended Operating Ranges limits may affect device reliability.

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Table 4. Electrical Characteristics at Ta = -40 to +85°C, VSS = 0 V

| Parameter | Symbol | Pin/Remarks | Conditions | Specification | | | Unit | |
|---|----------------------|-----------------------------|--|---------------|----------------------|--------------------|------|---------|
| | | | | VDD [V] | min | typ | | max |
| High level input current | I _{IH} (1) | SDA, SCL | V _{IN} = V _{DD} (including output transistor off leakage current) | 2.5 to 4.5 | | | 1 | μA |
| Low level input current | I _{IL} (1) | SDA, SCL | V _{IN} = V _{SS} (including output transistor off leakage current) | 2.5 to 4.5 | -1 | | | |
| High level output voltage | V _{OH} (1) | TSW | I _{OH} = -0.4 mA | 3.0 to 4.5 | V _{DD} -0.4 | | | V |
| | V _{OH} (2) | | I _{OH} = -0.2 mA | 2.5 to 4.5 | V _{DD} -0.4 | | | |
| Low level output voltage | V _{OL} (1) | TSW, ALARMB, SDA, SCL | I _{OL} = 3.0 mA | 3.0 to 4.5 | | | 0.4 | |
| | V _{OL} (2) | | I _{OL} = 1.3 mA | 2.5 to 4.5 | | | 0.4 | |
| Hysteresis voltage | V _{HYS} (1) | SDA, SCL | | 2.5 to 4.5 | | 0.1V _{DD} | | |
| Pin capacitance | CP | All pins | Pins other than the pin under test V _{IN} = V _{SS} Ta = 25°C | 2.5 to 4.5 | | 10 | | pF |
| Reset Release Voltage(Note 2) | V _{RR} | V _{DD} | | | | | 2.4 | V |
| Initialization Time after Reset release(Note 2) | T _{INIT} | | | 2.4 to 4.5 | | | 90 | ms |
| Auto sleep set time | T _{ATS} | | | 2.4 to 4.5 | | 1 | 1.2 | s |
| Time measurement accuracy | T _{ME} | | Ta = -20°C to +70°C | 2.5 to 4.5 | -3.5 | | +3.5 | % |
| Consumption current (Note 3) | I _{DD} (1) | V _{DD} | Operational mode | 2.5 to 4.5 | | 3 | 4.5 | μA |
| | I _{DD} (2) | | Sleep mode | 2.5 to 4.5 | | 1 | 2 | |
| Voltage measurement accuracy | V _{ME} (1) | V _{DD} | Ta = +25°C | 3.6 | -7.5 | | +7.5 | mV/cell |
| | V _{ME} (2) | | Ta = -20°C to +70°C | 2.5 to 4.5 | -20 | | +20 | |

Note 2 : Once V_{DD} voltage exceeds over the V_{RR}, this LSI will release RESET status. And the LSI goes into Sleep mode T_{INIT} after it.

Note 3 : Consumption current is a value in the range of -20°C to +70°C.

Product parametric performance is indicated in the Electrical Characteristics for the listed test conditions, unless otherwise noted. Product performance may not be indicated by the Electrical Characteristics if operated under different conditions.

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Table 5. I²C Slave Characteristics at Ta = -40 to +85°C, V_{SS} = 0 V

| Parameter | Symbol | Pin/Remarks | Conditions | V _{DD} [V] | Specification | | unit |
|--|---------|-------------|-------------|---------------------|------------------------|-----|------|
| | | | | | min | Max | |
| Clock frequency | TSCL | SCL | | 2.5 to 4.5 | | 400 | kHz |
| Bus free time between STOP condition and START condition | TBUF | SCL, SDA | See Fig. 5. | | 1.3 | | μs |
| Hold time (repeated) START condition First clock pulse is generated after this interval | THD:STA | SCL, SDA | See Fig. 5. | | 0.6 | | μs |
| Repeated START condition setup time | TSU:STA | SCL, SDA | See Fig. 5. | | 0.6 | | μs |
| STOP condition setup time | TSU:STO | SCL, SDA | See Fig. 5. | | 0.6 | | μs |
| Data hold time | THD:DAT | SCL, SDA | See Fig. 5. | | 0 | 0.9 | μs |
| Data setup time | TSU:DAT | SCL, SDA | See Fig. 5. | | 100 | | ns |
| Clock low period | TLOW | SCL | See Fig. 5. | | 1.3 | | μs |
| Clock high period | THIGH | SCL | See Fig. 5. | | 0.6 | | μs |
| Clock/data fall time | TF | SCL, SDA | | | 20 + 0.1C _B | 300 | ns |
| Clock/data rise time | TR | SCL, SDA | | | 20 + 0.1C _B | 300 | ns |
| Wake up time from Sleep mode | TWU | SDA | See Fig. 6. | | | 400 | μs |
| SDA low pulse width to wake up | TSP | SDA | See Fig. 6. | | 0.6 | | μs |
| Wake up retention time from the falling edge of SDA | TWR1 | SDA | See Fig. 6. | | 500 | | ms |
| Wake up retention time from STOP condition | TWR2 | SCL, SDA | See Fig. 6. | | 500 | | ms |

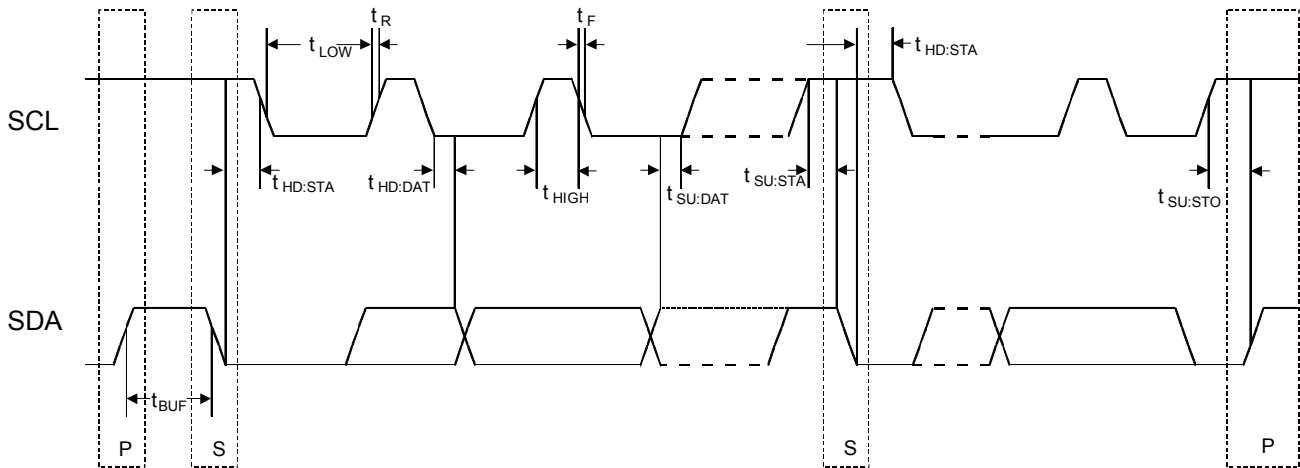


Figure 5. I²C Timing Diagram

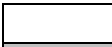

I²C Communication Protocol

Communication protocol type : I²C

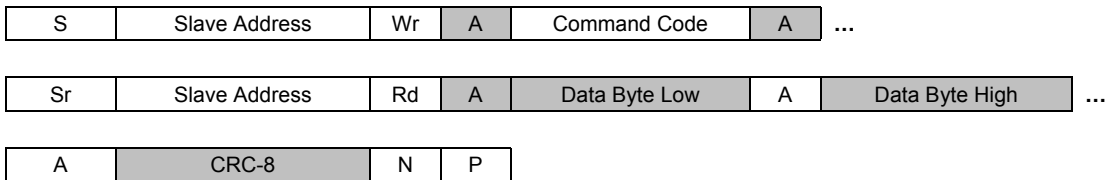
Frequency : Supported up to 400 kHz

IC address [Slave Address] : 0x16 (It becomes "0001011X" when you write a binary, because the slave address is 7 bits. [X]=Rd/Wr.)

Bus Protocols

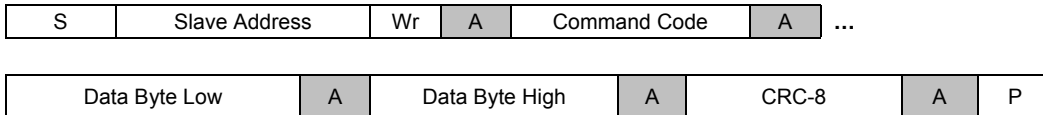
| | | |
|---|---|--|
| S | : | Start Condition |
| Sr | : | Repeated Start Condition |
| Rd | : | Read (bit value of 1) |
| Wr | : | Write (bit value of 0) |
| A | : | ACK (bit value of 0) |
| N | : | NACK (bit value of 1) |
| P | : | Stop Condition |
| CRC-8 | : | Slave Address to Last Data (CRC-8-ATM : ex.3778mV : 0x16, 0x09, 0x17, 0xC2, 0x0E → 0x86) |
|  | : | Master-to-Slave |
|  | : | Slave-to-Master |
| ... | : | Continuation of protocol |

Read Word Protocol



* When you do not read CRC-8, there is not the reliability of data. CRC-8-ATM ex : (5 bytes) 0x16, 0x09, 0x17, 0xC2, 0x0E → 0x86

Write Word Protocol



* When you do not add CRC-8, the Written data (Data byte Low/High) become invalid.

CRC-8-ATM ex : (4 bytes) 0x16, 0x09, 0x55, 0xAA → 0x3B

Wake up from Sleep mode

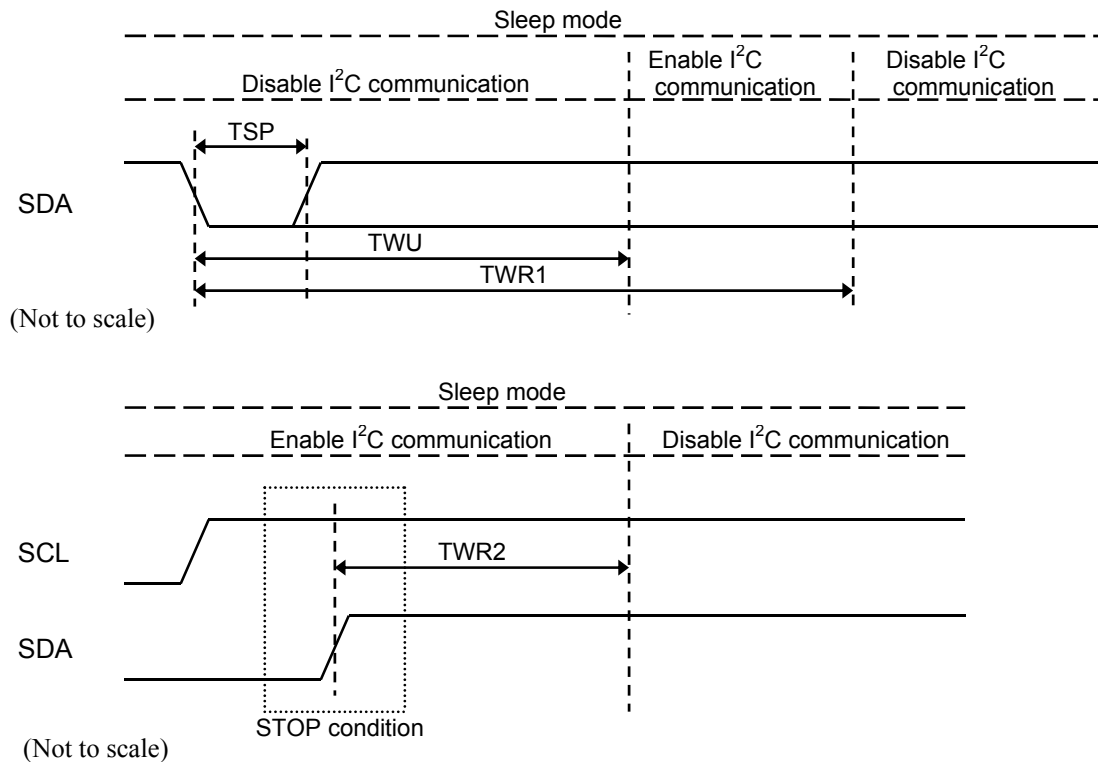


Figure 6. I²C Wake up Timing Diagram

To wake up from Sleep mode, and to start I²C communication, Host side must set SDA low prior to the I²C communication. The Fuel Gauge LSI enables I²C communication after the TWU time period which is measured from the falling edge of SDA, as above timing chart. This “Wake up condition” is invalid for the following two cases.

- 1) After TWR1 timing following the falling edge of SDA, the Fuel Gauge LSI “Wake up condition” goes into autonomous disable. Once I²C communication is started, the operation doesn’t go into disable until the TWR2 timing has elapsed after STOP condition (below case).
- 2) After TWR2 timing following I²C Bus STOP condition, the Fuel gauge LSI “Wake up condition” goes into autonomous disable.

If the “Wake up condition” goes into disable, set SDA low to once again wake up from the Sleep mode prior to the I²C communication. If Operational mode is set, it is possible to start I²C communication without this “Wake up operation”.

Notice for I²C communication shared with another device

When the I²C Bus (on which the Fuel Gauge LSI is connected) is shared with another device the Fuel Gauge LSI must be in its operation mode before the other Device starts I²C communication.

Table 6. Function of Registers

| Command Code | Register Name | R/W | Range | Unit | Description | Initial Value |
|--------------|--------------------------------------|------------|--|--------------------------|---|------------------|
| 0x04 | Before RSOC | W | 0xAA55: Initialize RSOC | | Executes RSOC initialization with sampled maximum voltage when 0xAA55 is set. | - |
| 0x06 | Thermistor B | R/W | 0x0000 to 0xFFFF | 1K | Sets B-constant of the thermistor to be measured. | 0x0D34 |
| 0x07 | Initial RSOC | W | 0xAA55: Initialize RSOC | | Executes RSOC initialization when 0xAA55 is set. | - |
| 0x08 | Cell Temperature | R | 0x0000 to 0xFFFF | 0.1K (0.0°C = 0x0AAC) | Displays Cell Temperature. Sets Cell Temperature in I ² C mode. | 0x0BA6 (25°C) |
| | | W | 0x09E4 to 0x0D04 (I ² C mode) | | | |
| 0x09 | Cell Voltage | R | 0x0000 to 0xFFFF | 1mV | Displays Cell Voltage. | - |
| 0x0A | Current Direction | R/W | 0x0000: Auto mode 0x0001: Charge mode 0xFFFF: Discharge mode | | Selects Auto/Charge/Discharge mode. | 0x0000 |
| 0x0B | APA (Adjustment Pack Application) | R/W | 0x0000 to 0x00FF | 1 mΩ | Sets Parasitic impedance. | - |
| 0x0C | APT (Adjustment Pack Thermistor) | R/W | 0x0000 to 0xFFFF | | Sets a value to adjust temperature measurement delay timing. | 0x001E |
| 0x0D | RSOC | R | 0x0000 to 0x0064 | 1% | Displays RSOC value based on a 0-100 scale | - |
| 0x0F | ITE (Indicator to Empty) | R | 0x0000 to 0x03E8 | 0.1% | Displays RSOC value based on a 0-1000 scale | - |
| 0x11 | IC Version | R | 0x0000 to 0xFFFF | | Displays an ID number of an IC. | - |
| 0x12 | Change Of The Parameter | R/W | 0x0000 or 0x0001 | | Selects a battery profile. | 0x0000 |
| 0x13 | Alarm Low RSOC | R/W | 0x0000: Disable 0x0001to0x0064: Threshold | 1% | Sets RSOC threshold to generate Alarm signal. | 0x0008 |
| 0x14 | Alarm Low Cell Voltage | R/W | 0x0000: Disable 0x0001to0xFFFF: Threshold | 1mV | Sets Voltage threshold to generate Alarm signal. | 0x0000 |
| 0x15 | IC Power Mode | R/W | 0x0001: Operational mode 0x0002: Sleep mode | | Selects Power mode. | (Note4) |
| 0x16 | Status Bit | R/W | 0x0000: I ² C mode 0x0001: Thermistor mode | | Selects Temperature obtaining method. | 0x0000 |
| 0x1A | Number of The Parameter | R | 0x0301 or 0x0504 | | Displays Battery profile code. | - |

0xXXXX = Hexadecimal notation

Note 4 : See “Power-on Reset / Battery Insertion Detection” and figure 16.

Before RSOC (0x04)

This LSI obtains Open Circuit Voltage (OCV) reading 10 ms after Power-on reset to initialize RSOC (See figure 7).

Or the LSI can be forced to initialize RSOC by sending the Before RSOC Command (0x04 = AA55) or the Initial RSOC Command (0x07 = AA55). The accuracy of the Initialization requires the OCV reading to be taken with minimal load or charge, under 0.025C, on the battery. (i.e. less than 75mA for 3000mAh design capacity battery.)

The LSI initializes RSOC by the maximum voltage between initialize after Power-on reset and setting the command when the Before RSOC command is written. (See figure 8).

Thermistor B (0x06)

Sets B-constant of the thermistor to be measured. Refer to the specification sheet of the thermistor for the set value to use.

Initial RSOC (0x07)

The LSI can be forced to initialize RSOC by sending the Before RSOC Command (0x04 = AA55) or the Initial RSOC Command (0x07 = AA55).

The LSI initializes RSOC by the measured voltage at that time when the Initial RSOC command is written. (See figure 9). The maximum time to initialize RSOC after the command is written is 1.5 ms.

Cell Temperature (0x08)

This register contains the cell temperature from -20°C (0x09E4) to +60°C (0x0D04) measured in 0.1°C units.

In the Thermistor mode (0x16 = 01) the LSI measures the attached thermistor and loads the temperature into the Cell Temperature register. In the Thermistor mode, the thermistor shall be connected to the LSI as shown in figure 2. The temperature is measured by having TSW pin to provide power into the thermistor and TSENSE pin to sense the output voltage from the thermistor. Temperature measurement timing is controlled by the LSI, and the power to the thermistor is not supplied for other reasons except to measure the temperature.

In the I²C mode (0x16 = 00) the temperature is provided by the host processor. During discharge/charge the register should be updates when the temperature changes more than 1°C

Cell Voltage (0x09)

This register contains the voltage on V_{DD} 1mV units.

Current Direction (0x0A)

This register is used to control the reporting of RSOC. In Auto mode the RSOC is reported as it increases or decreases. In Charge mode the RSOC is not permitted to decrease. In Discharge mode the RSOC is not permitted to increase.

With consideration of capacity influence by temperature, we recommend operating in Auto because RSOC is affected by the cell temperature. A warm cell has more capacity than a cold cell. Be sure not to charge in the Discharge mode and discharge in the Charge mode; it will create an error.

An example of RSOC reporting is shown in Figures 10 and 11.

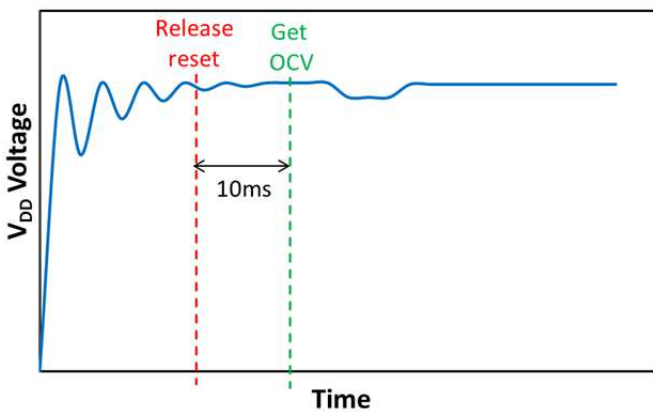


Figure 7. RSOC automatic initialization

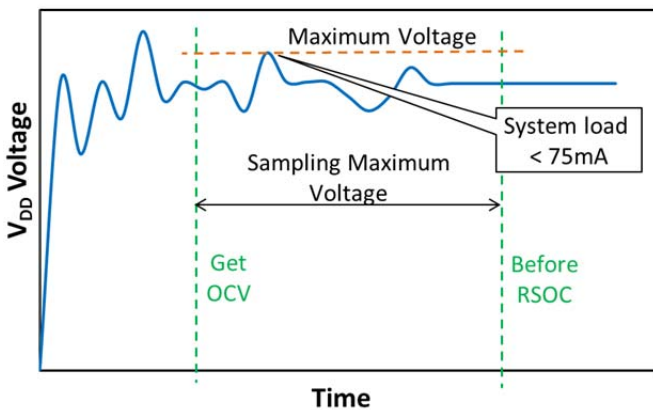


Figure 8. Before RSOC command

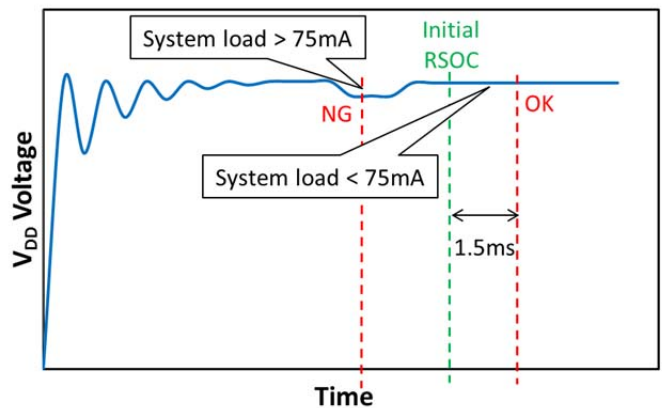


Figure 9. Initial RSOC command

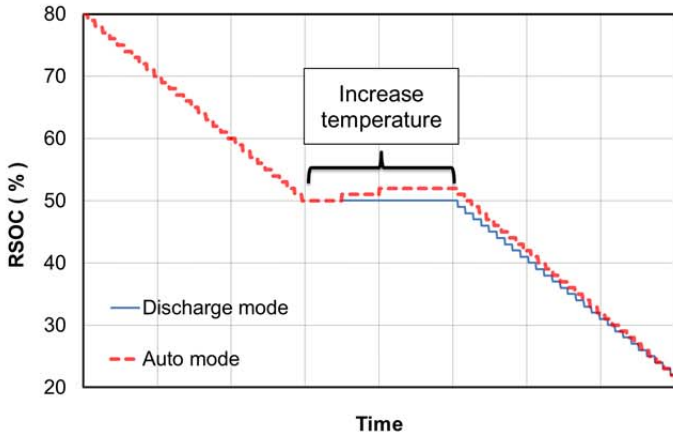


Figure 10. Discharge Mode

(An example with increasing in temperature. A warm cell has more capacity than a cold cell. Therefore RSOC increases without charging in Auto mode.)

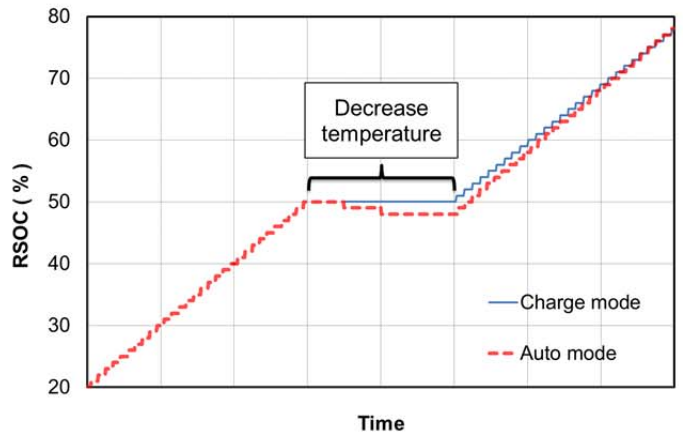


Figure 11. Charge mode

(An example with decreasing in temperature. A cold cell has less capacity than a warm cell. Therefore RSOC decreases without discharging in Auto mode.)

Adjustment Pack Application (0x0B)

This register contains the adjustment value for a battery type to improve the RSOC precision. Figure 12 and Table 7 show typical values of APA according to the design capacities per 1 cell and battery type. When some batteries are connected in parallel, the design capacity per 1 cell is applied to the table. The APA values of Type-04 and Type-05 are used for battery type that is specified in Table 8. Please contact ON Semiconductor if you don't satisfy the RSOC precision. The deeper adjustment of APA may improve the accuracy.

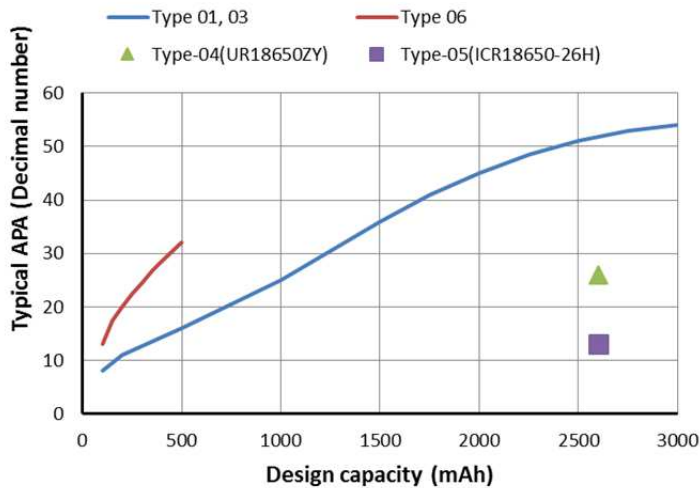


Figure 12. Typical APA

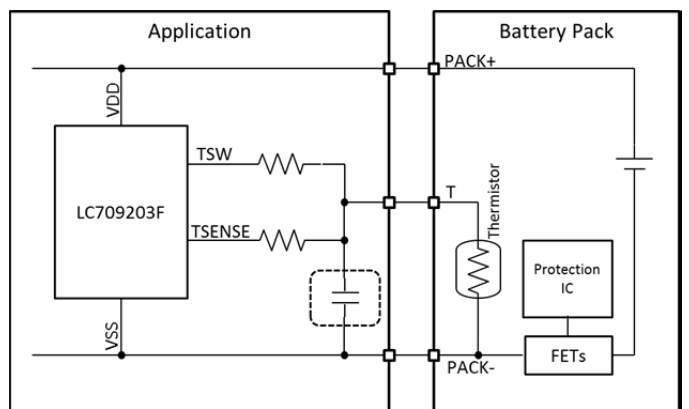
Adjustment Pack Thermistor (0x0C)

This is used to compensate for the delay of the thermistor measurement caused by a capacitor across the thermistor. The default value has been found to meet most of circuits where a capacitor like showing in figure13 is not put.

Please contact ON Semiconductor if you have an unusual circuit implementation.

Table 7. Typical APA

| Design capacity of battery | APA(0x0B) | | | |
|----------------------------|------------|---------|---------|---------|
| | Type-01,03 | Type-06 | Type-04 | Type-05 |
| 100mAh | 0x08 | 0x0D | - | - |
| 200mAh | 0x0B | 0x15 | - | - |
| 500mAh | 0x10 | 0x20 | - | - |
| 1000mAh | 0x19 | - | - | - |
| 2000mAh | 0x2D | - | - | - |
| 3000mAh | 0x36 | - | - | - |
| 2600mAh | - | - | 0x1A | 0x0D |



A capacitor across a thermistor

Figure 13. An example of a capacitor across the thermistor

RSOC (0x0D)

RSOC is reported in 1% units over the range 0% to 100%.

Indicator to Empty (0x0F)

This is the same as RSOC with a resolution of 0.1% over the range 0.0% to 100.0%.

IC Version (0x11)

This is an ID number of an LSI.

Change of the Parameter (0x12)

The LSI contains a data file comprised of two battery profiles. This register is used to select the battery profile to be used. See Table 8. Register Number of the Parameter (0x1A) contains identity of the data file.

The Data file is loaded during final test depending on the part number ordered.

Most of the time, battery nominal/rated voltage or charging voltage values are used to determine which profile data shall be used. Please contact ON Semi if you cannot identify which profile to select.

Alarm Low RSOC (0x13)

The ALARMB pin will be set low when the RSOC value falls below this value, will be released from low when RSOC value rises than this value. Set to Zero to disable. Figure 14.

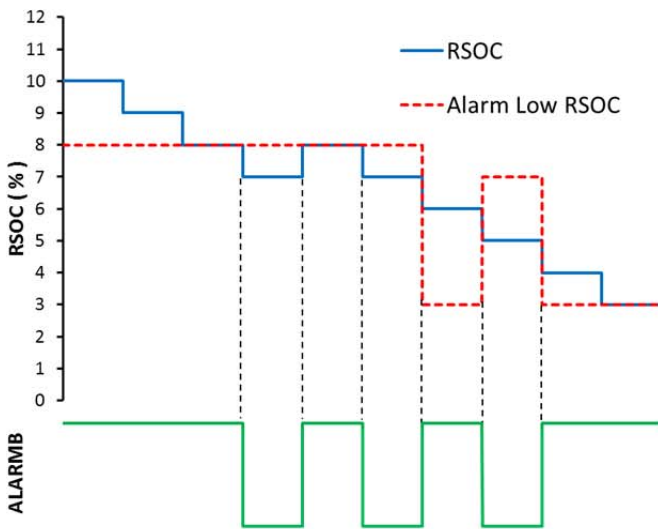


Figure 14. Alarm Low RSOC

Alarm Low Cell Voltage (0x14)

The ALARMB pin will be set low if VDD falls below this value, will be released from low if VDD rises than this value. Set to Zero to disable. Figure 15.

IC Power Mode (0x15)

The LSI has two power modes. Sleep (0x15 = 02) or Operational mode (0x15 = 01). In the Sleep mode only I²C communication functions. In the Operational mode all functions operate with full calculation and tracking of RSOC during charge and discharge.

If the battery is significantly charged or discharged during sleep mode, the RSOC will not be accurate. Moved charge is counted continuously to measure the RSOC in Operational mode. If battery is discharged or charged in the Sleep mode, the count breaks off.

When it is switched from Sleep mode to Operational mode, RSOC calculation is continued by using the data which was measured in the previous Operational mode.

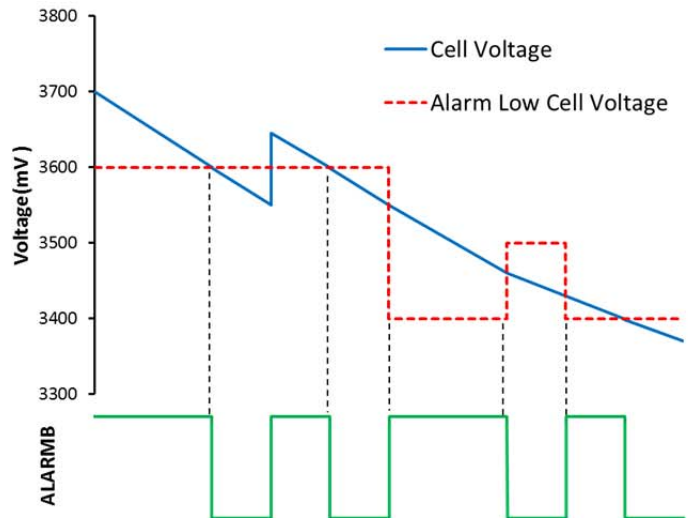


Figure 15. Alarm Low Cell Voltage

Status Bit (0x16)

This selects the Thermistor mode. Thermistor mode (0x16 = 01) the LSI measures the attached thermistor and loads the temperature into the Cell Temperature register. I²C mode (0x16 = 00) the temperature is provided by the host processor.

Number of the Parameter (0x1A)

The LSI contains a data file comprised of two battery profiles. This register contains identity of the data file. Please see register **Change of the Parameter (0x12)** to select the battery profile to be used. See Table 8.

The Data file is loaded during final test depending on the part number ordered. This file can be loaded in the field if required.

Please contact ON Semi if you cannot identify which profile to select.

LC709203F

Table 8. Battery profile vs register

| IC Type | Battery Type | Nominal / Rated Voltage | Charging Voltage | Design Capacity | Number of The Parameter (0x1A) | Change of The Parameter (0x12) |
|------------------|--------------|-------------------------|------------------|-----------------|--------------------------------|--------------------------------|
| LC709203Fxx-01xx | 03 | 3.8 V | 4.35 V | ≥ 500 mAh | 0x0301 | 0x0000 |
| | 01 | 3.7 V | 4.2 V | – | | 0x0001 |
| LC709203Fxx-03xx | 06 | 3.8 V | 4.35 V | < 500 mAh | 0x0601 | 0x0000 |
| | 01 | 3.7 V | 4.2 V | – | | 0x0001 |
| LC709203Fxx-04xx | 05 | ICR18650-26H (SAMSUNG) | | | 0x0504 | 0x0000 |
| | 04 | UR18650ZY (Panasonic) | | | | 0x0001 |

HG-CVR

Hybrid Gauging by Current-Voltage tracking with internal Resistance

HG-CVR is ON Semiconductor's unique method which is used to calculate accurate RSOC. **HG-CVR** first measures battery voltage and temperature. Precise reference voltage is essential for accurate voltage measurement. LC709203F has accurate internal reference voltage circuit with little temperature dependency.

It also uses the measured battery voltage and internal impedance and Open Circuit Voltage (OCV) of a battery for the current measurement. OCV is battery voltage without load current. The measured battery voltage is separated into OCV and varied voltage by load current. The varied voltage is the product of load current and internal impedance. Then the current is determined by the following formulas.

$$V(VARIED) = V(MEASURED) - OCV \quad (1)$$

$$I = \frac{V(VARIED)}{R(INTERNAL)} \quad (2)$$

Where $V(VARIED)$ is varied voltage by load current, $V(MEASURED)$ is measured voltage, $R(INTERNAL)$ is internal impedance of a battery. Detailed information about the internal impedance and OCV is installed in the LSI. The internal impedance is affected by remaining capacity, load-current, temperature, and more. Then the LSI has the information as look up table. **HG-CVR** accumulates battery coulomb using the information of the current and a steady period by a high accuracy internal timer. The remaining capacity of a battery is calculated with the accumulated coulomb.

How to identify Aging

By repeating discharge/charge, internal impedance of a battery will gradually increase, and the Full Charge Capacity (FCC) will decrease. In coulomb counting method RSOC is generally calculated using the FCC and the Remaining Capacity (RM).

$$RSOC = \frac{RM}{FCC} \times 100\% \quad (3)$$

Then the decreased FCC must be preliminarily measured with learning cycle. But **HG-CVR** can measure the RSOC of deteriorated battery without learning cycle. The internal battery impedance that **HG-CVR** uses to calculate the current correlates highly with FCC. The correlation is based on battery chemistry. The RSOC that this LSI reports using the correlation is not affected by aging.

Figure 23-25 show RSOC measurement result of a battery with decreased FCC due to its aging. The shown RSOC is based on the decreased FCC even with a battery with 80% FCC after executing 300 times of discharge/charge.

Automatic Convergence of the Error

A problem of coulomb counting method is the fact that the error is accumulated over time - This error must be corrected. The general gauges using coulomb counting method must find an opportunity to correct it.

This LSI with **HG-CVR** has the feature that the error of RSOC converges autonomously, and doesn't require calibration opportunities. The error constantly converges in the value estimated from the Open Circuit Voltage. Figure 26 shows the convergent characteristic example from the initialize error.

Also, coulomb counting method cannot detect accurate residual change because the amount of the current from self-discharge is too small but **HG-CVR** is capable to deal with such detection by using the voltage information.

Simple and Quick Setup

In general, it is necessary to obtain multiple parameters for a fuel gauge and it takes a lot of resource and additional development time of the users. One of the unique features of LC709203F is very small number of parameters to be prepared by the beginning of battery measurement - the minimum amount of parameter which users may make is one because Adjustment pack application register has to have one. Such simple and quick start-up is realized by having multiple profile data in the LSI to support various types of batteries. Please contact your local sales office to learn more information on how to measure a battery that cannot use already-prepared profile data.

Low Power Consumption

Low power consumption of 3 μ A is realized in the Operation mode. This LSI monitors charge/discharge condition of a battery and changes the sampling rate according to its change of current. Power consumption reduction without deteriorating its RSOC accuracy was enabled by utilizing this method.

Power-on Reset / Battery Insertion Detection

When this LSI detects battery insertion, it starts Power-on reset automatically. Once the battery voltage exceeds over the V_{RR} , it will release RESET status and will complete LSI initialization within T_{INIT} to enter into Operational mode. All registers are initialized after Power-on reset. Then I²C communication can be started.

LC709203FXE-0xMH sets itself into Sleep mode automatically after T_{ATS} from the end of initialization. Therefore set to operational mode manually after it enters into Sleep mode. LC709203FQH-0xTWG doesn't set itself into Sleep mode automatically. Figure 16.

This LSI will also execute system reset automatically if a battery voltage exceeds under the V_{RR} during operation. Furthermore after Change of the Parameter (0x12) command input it will execute LSI initialization like battery insertion. Figure 17.

Parasitic resistance

The LSI measures RSOC by using internal impedance of a battery. Therefore, the parasitic resistance which exists in VDD/VSS Lines between measured Battery or Battery Pack to the LSI can become an error factor. But the resistance of Lines which is not connected other than the LSI is not included. Figure 18.

The lower resistance may improve the RSOC precision. Please see LC709203F Application note for information about layout method of VDD/VSS Lines to reduce it.

Measurement Starting Flow

After Reset release, users can start battery measurement by writing appropriate value into the registers by following the flow shown in Figure 19-20. Please refer to Register function section for more information about each register.

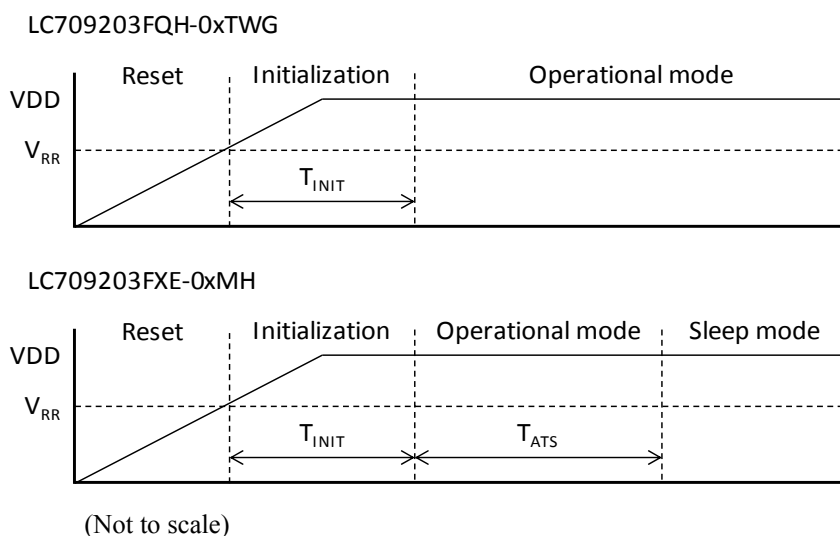


Figure 16. Power on Timing Diagram

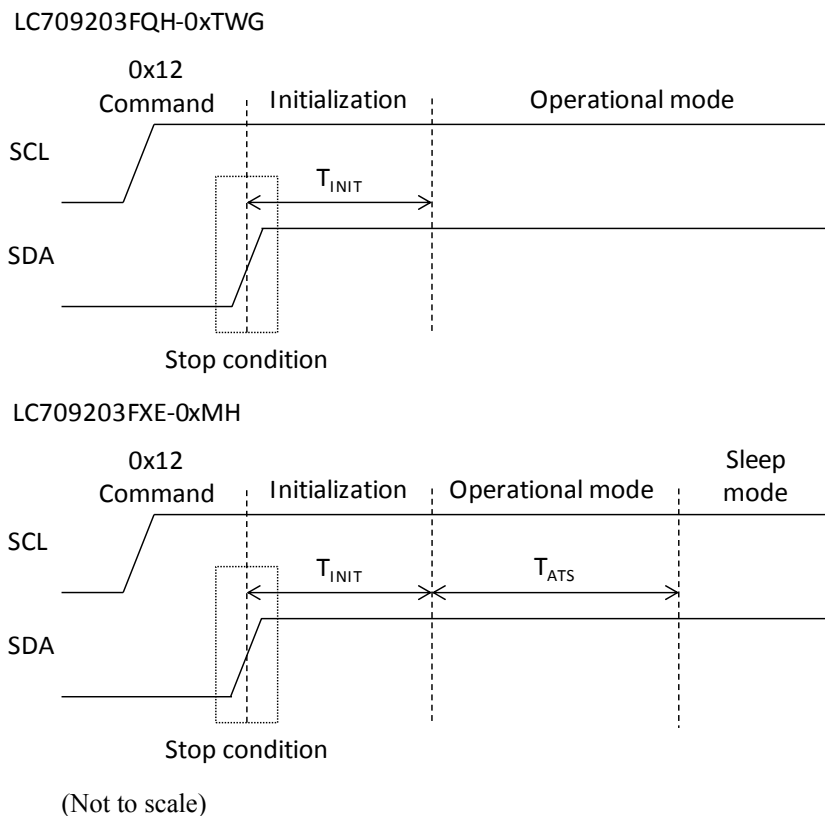


Figure 17. Timing Diagram after 0x12 command

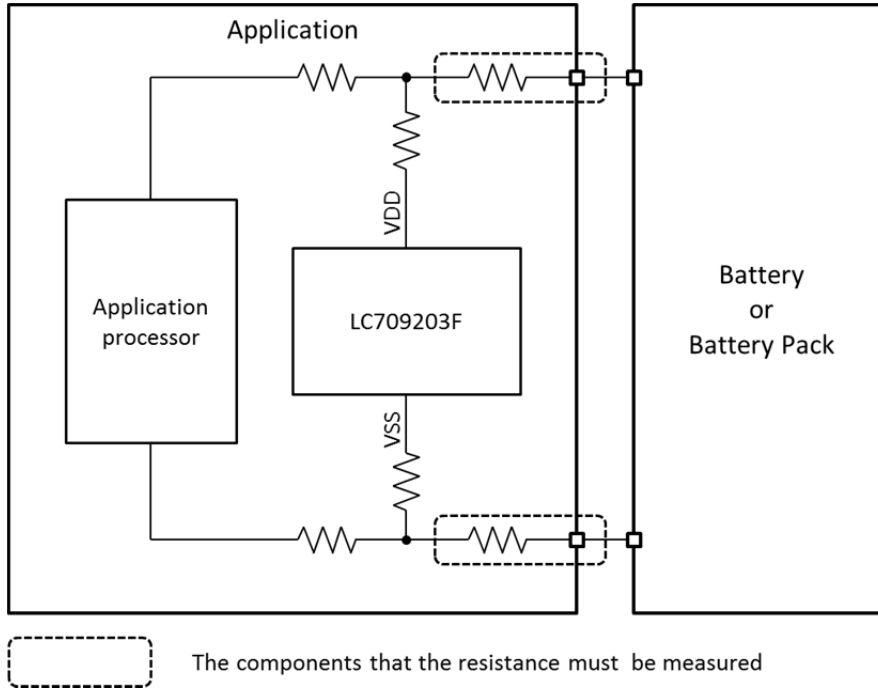


Figure 18. An example of parasitic resistance

Starting flow

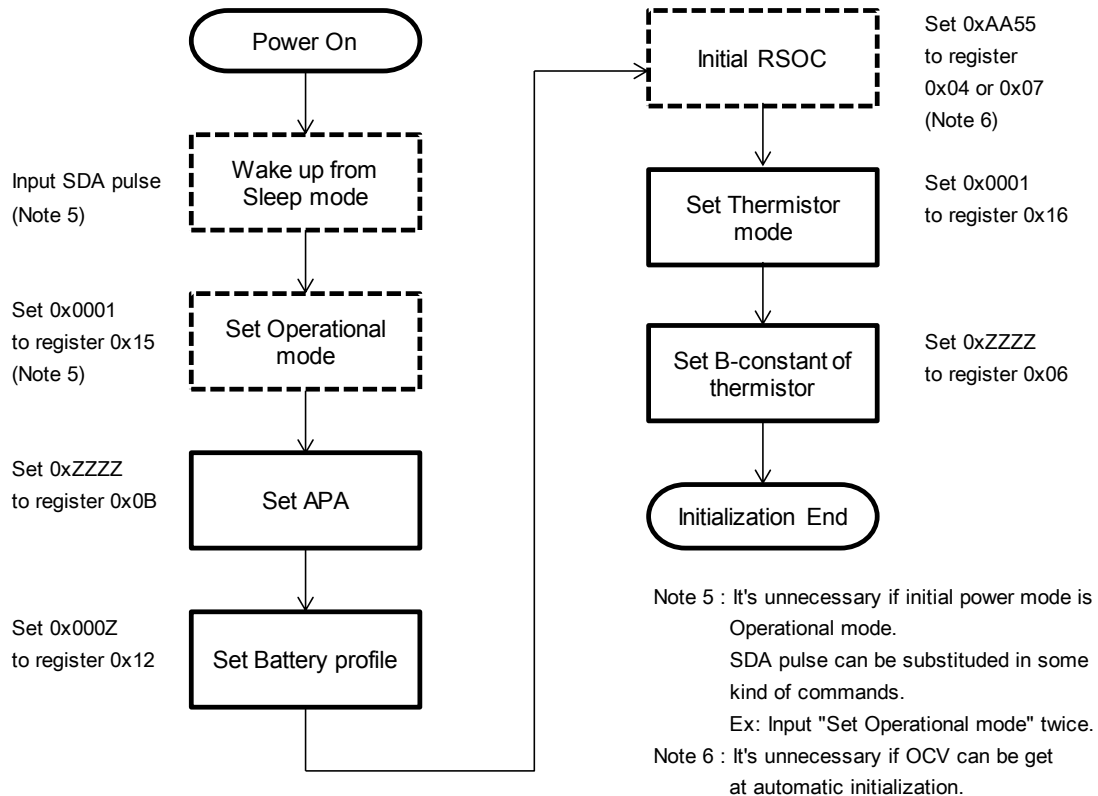


Figure 19. Starting flow at Thermistor mode

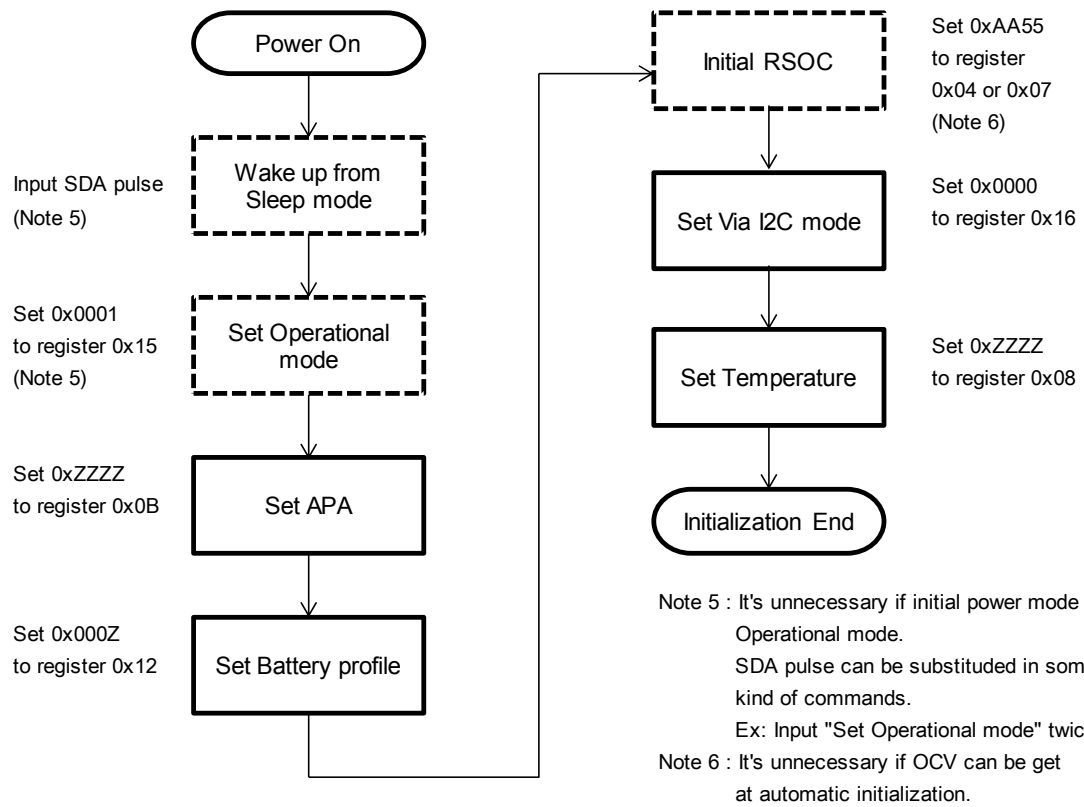


Figure 20. Starting flow at I²C mode

TYPICAL CHARACTERISTICS

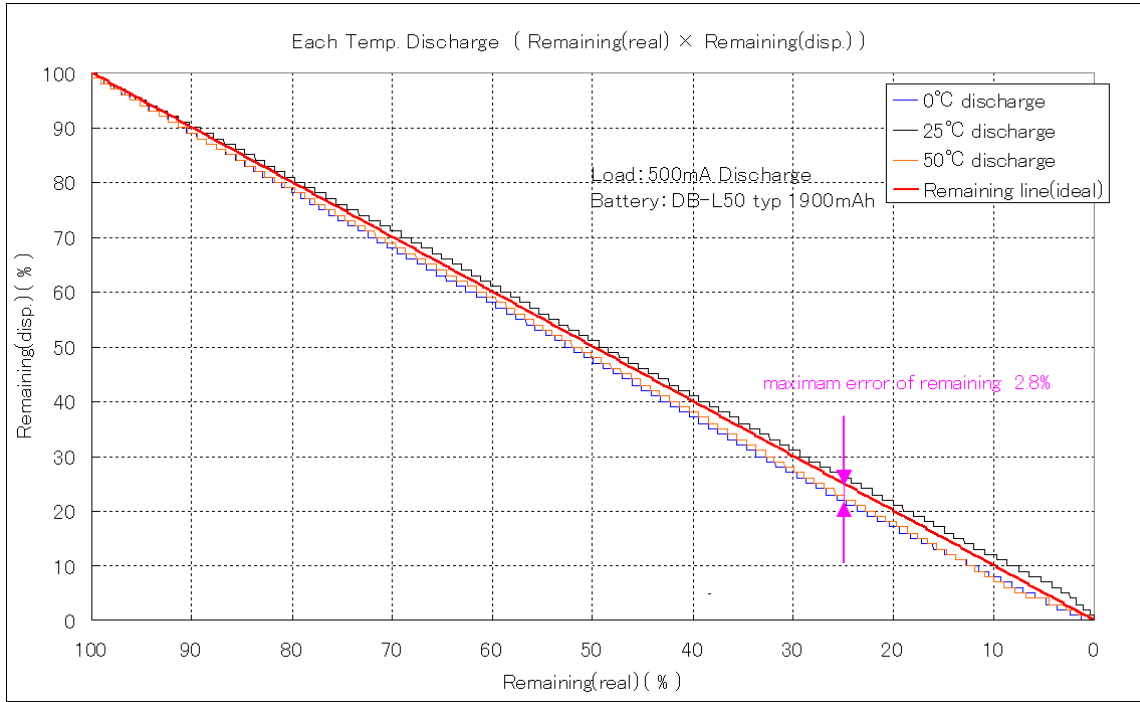


Figure 21 Discharge Characteristics by Temperature Change

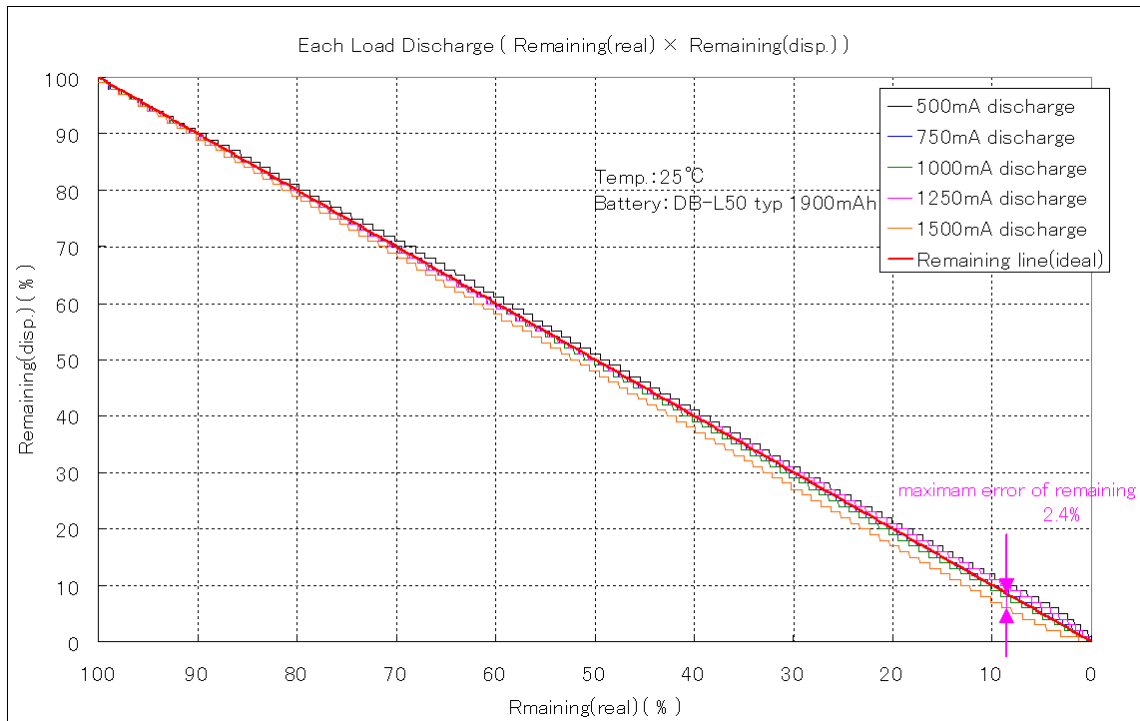


Figure 22 Discharge Characteristics by Load Change

TYPICAL CHARACTERISTICS

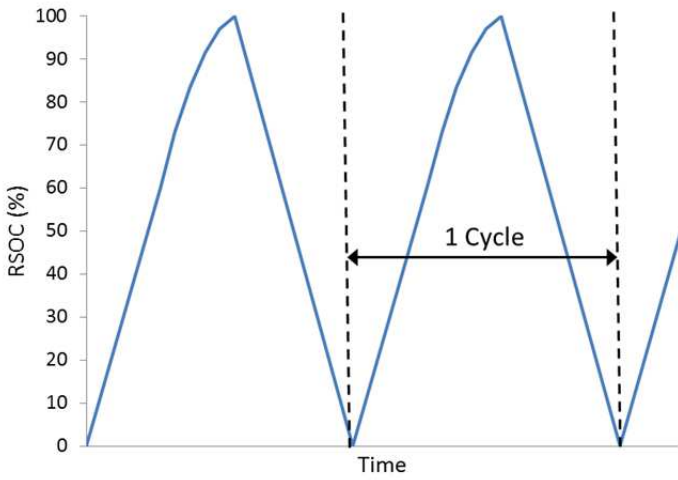


Figure 23 Discharge/Charge cycle

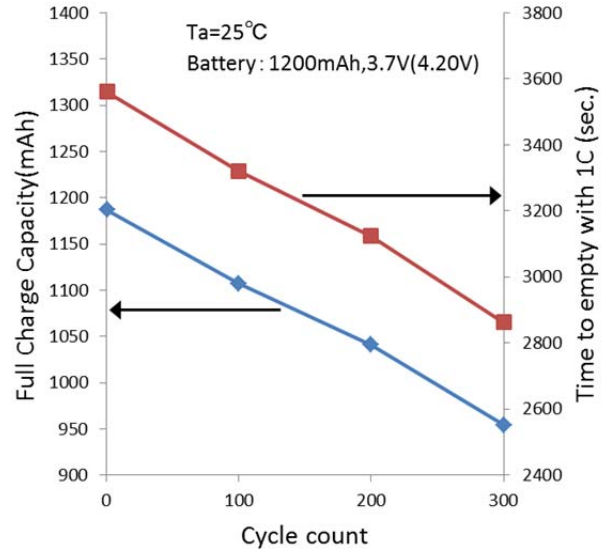


Figure 24 Battery capacity deterioration

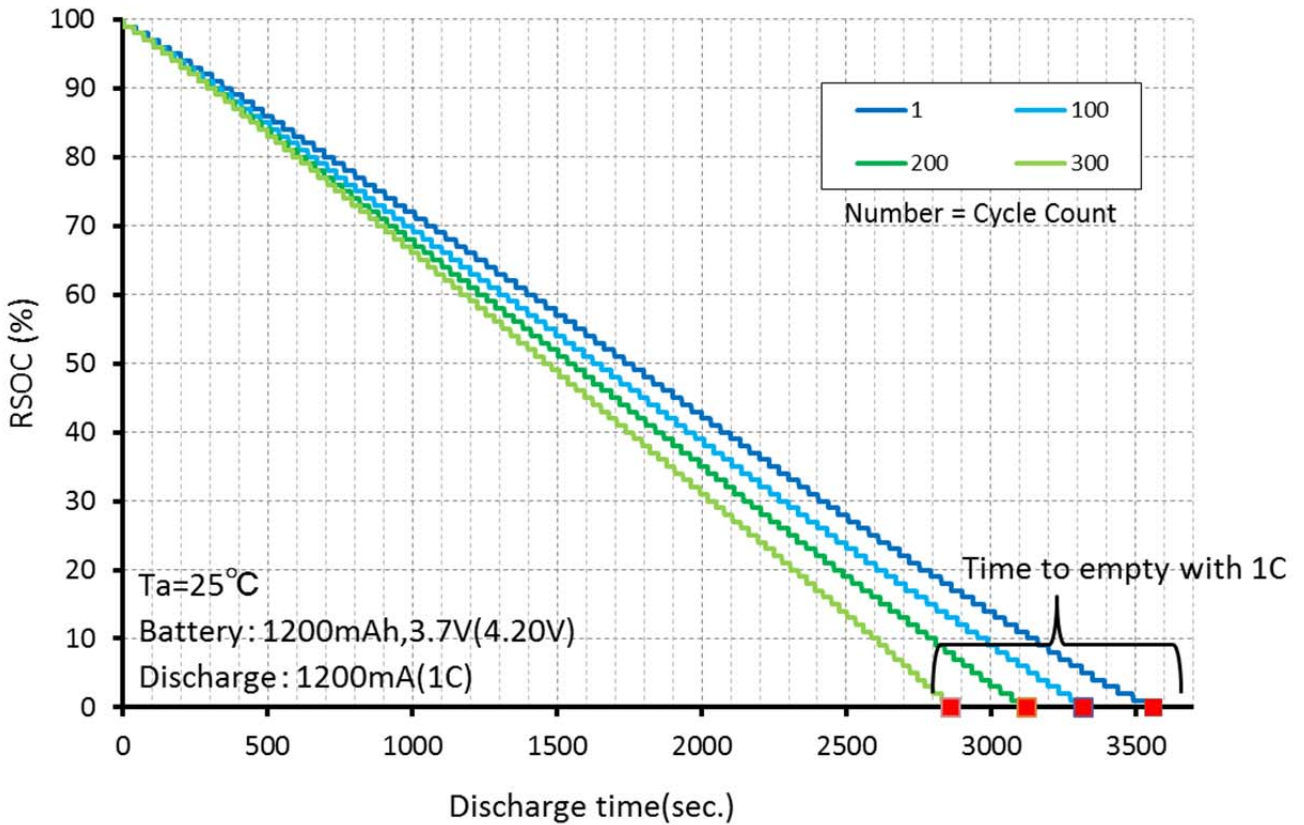


Figure 25 1 Discharge characteristics of deterioration battery

TYPICAL CHARACTERISTICS

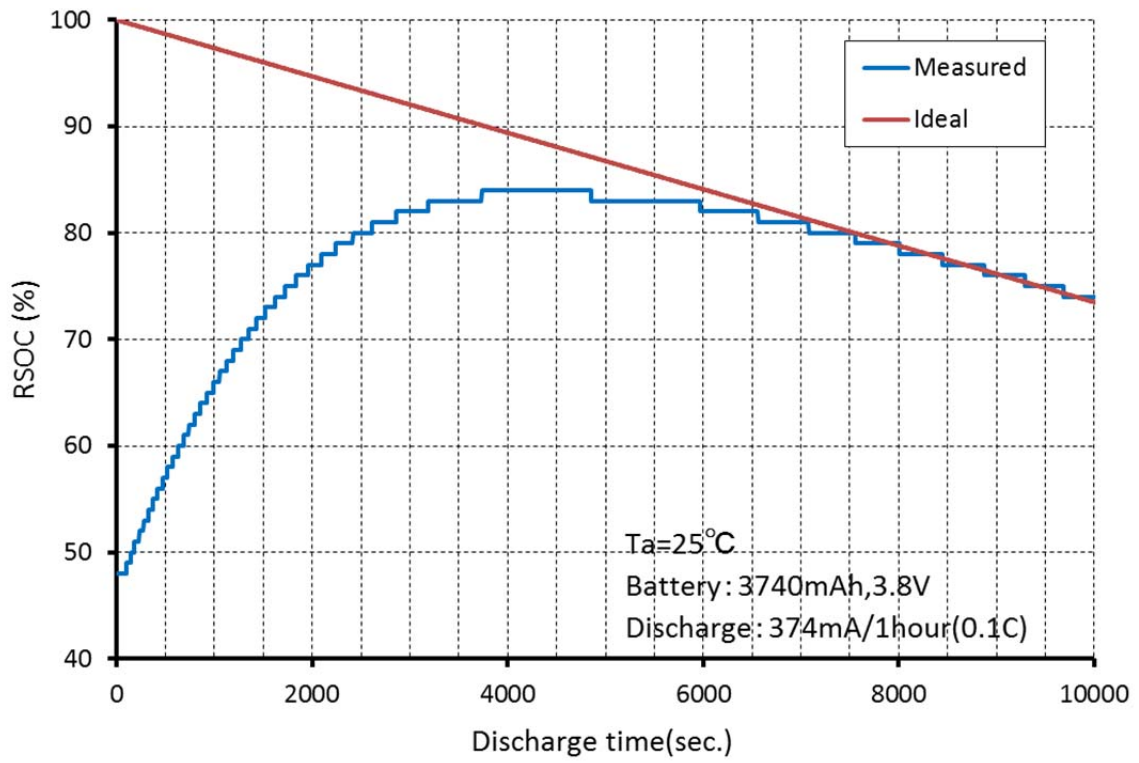


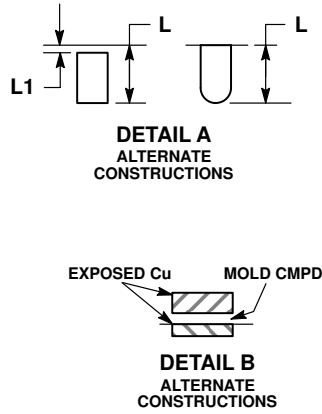
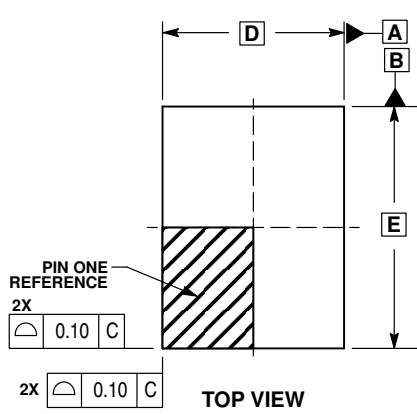
Figure 26 Convergent characteristic from the initialize error
 This Graph is the example for starting point 48% (includes 52% Error case) instead of 100% (No Error).

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PACKAGE DIMENSIONS

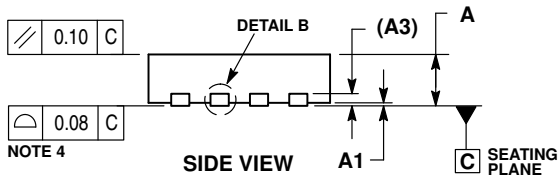
unit : mm

WDFN8 3x4, 0.65P
CASE 509AF
ISSUE C

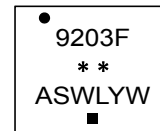


- NOTES:
1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
 2. CONTROLLING DIMENSION: MILLIMETERS.
 3. DIMENSION b APPLIES TO PLATED TERMINAL AND IS MEASURED BETWEEN 0.15 AND 0.30mm FROM THE TERMINAL TIP.
 4. PROFILE TOLERANCE APPLIES TO THE EXPOSED PAD AS WELL AS THE LEADS.

| DIM | MILLIMETERS | |
|-----|-------------|------|
| | MIN | MAX |
| A | --- | 0.80 |
| A1 | 0.00 | 0.05 |
| A3 | 0.20 | REF |
| b | 0.20 | 0.30 |
| D | 3.00 | BSC |
| D2 | 1.70 | 1.90 |
| E | 4.00 | BSC |
| E2 | 2.30 | 2.50 |
| e | 0.65 | BSC |
| L | 0.45 | 0.55 |
| L1 | --- | 0.10 |

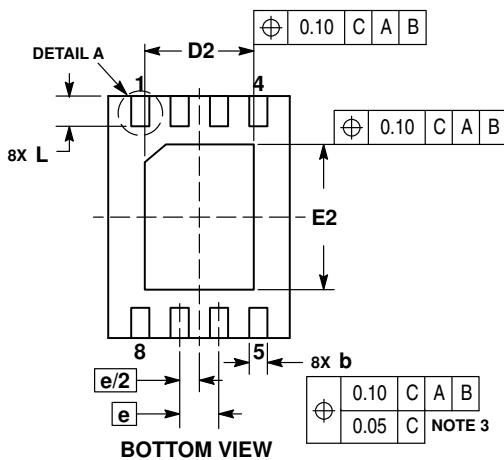


MARKING DIAGRAM

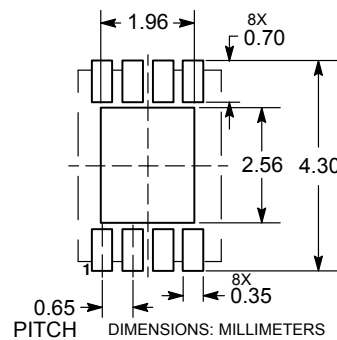


- AS = Assembly Location
 WL = Lot Number
 YW = Work Week
 ■ = Pb-Free

| ** | Device |
|----|-------------------|
| 01 | LC709203FQH-01TWG |
| 02 | LC709203FQH-02TWG |
| 03 | LC709203FQH-03TWG |
| 04 | LC709203FQH-04TWG |



RECOMMENDED SOLDERING FOOTPRINT*



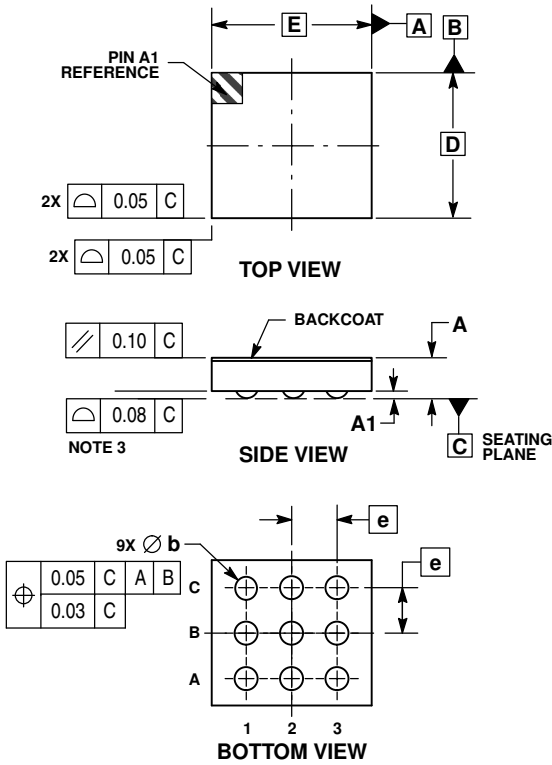
*For additional information on our Pb-Free strategy and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.

LC709203F

PACKAGE DIMENSIONS

unit : mm

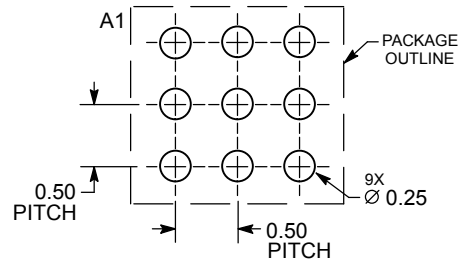
WLCSP9, 1.60x1.76
CASE 567JH
ISSUE B



- NOTES:
1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
 2. CONTROLLING DIMENSION: MILLIMETERS.
 3. COPLANARITY APPLIES TO THE SPHERICAL CROWNS OF THE SOLDER BALLS.

| MILLIMETERS | | |
|-------------|----------|------|
| DIM | MIN | MAX |
| A | --- | 0.51 |
| A1 | 0.09 | 0.19 |
| b | 0.20 | 0.30 |
| D | 1.60 BSC | |
| E | 1.76 BSC | |
| e | 0.50 BSC | |

RECOMMENDED SOLDERING FOOTPRINT*



DIMENSIONS: MILLIMETERS

*For additional information on our Pb-Free strategy and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.

MARKING DIAGRAM



Y = Year
M = Month Code
XXX = Lot Number

| ** | Device |
|----|------------------|
| 01 | LC709203FXE-01MH |
| 02 | LC709203FXE-02MH |
| 03 | LC709203FXE-03MH |
| 04 | LC709203FXE-04MH |

LC709203F

ORDERING INFORMATION

| Device | Package | Shipping (Qty / Packing) |
|-------------------|---|--------------------------|
| LC709203FQH-01TWG | WDFN8 3x4, 0.65P (Pb-Free / Halogen Free) | 2000 / Tape & Reel |
| LC709203FQH-02TWG | WDFN8 3x4, 0.65P (Pb-Free / Halogen Free) | 2000 / Tape & Reel |
| LC709203FQH-03TWG | WDFN8 3x4, 0.65P (Pb-Free / Halogen Free) | 2000 / Tape & Reel |
| LC709203FQH-04TWG | WDFN8 3x4, 0.65P (Pb-Free / Halogen Free) | 2000 / Tape & Reel |
| LC709203FXE-01MH | WLCSP9, 1.60x1.76 (Pb-Free / Halogen Free) | 5000 / Tape & Reel |
| LC709203FXE-02MH | WLCSP9, 1.60x1.76 (Pb-Free / Halogen Free) | 5000 / Tape & Reel |
| LC709203FXE-03MH | WLCSP9, 1.60x1.76 (Pb-Free / Halogen Free) | 5000 / Tape & Reel |
| LC709203FXE-04MH | WLCSP9, 1.60x1.76 (Pb-Free / Halogen Free) | 5000 / Tape & Reel |

† For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specifications Brochure, BRD8011/D. http://www.onsemi.com/pub_link/Collateral/BRD8011-D.PDF

(Note)

IC performance may vary depend on the types of battery to be in use. Contact your local sales office for assistance in choosing the correct model.

* I²C Bus is a trademark of Philips Corporation.

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