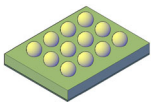
Battery Fuel Gauge [Smart LiB Gauge] for 1-Cell Lithium-ion/ Polymer (Li+) with Low Power 2 μA Operation

LC709209F



WLCSP12 1.48x1.91x0.51
CASE 567XE

MARKING DIAGRAM



209** = 20901 (LC709209FXE−01TBG)
A = Assembly Site
WL = Wafer Lot Number
YW = Assembly Start Week

ORDERING INFORMATION

See detailed ordering and shipping information on page 22 of this data sheet.

Overview

LC709209F is a Fuel Gauge (in other words, Fuel Gauge IC, Gas Gauge, Battery Monitor or Battery Gauge) for 1−Cell Lithium−ion/Polymer batteries. 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−CVR2**. The **HG−CVR2** algorithm 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. The Fuel Gauge feature of the **HG−CVR2** algorithm makes it highly applicable in various applications. The device can immediately start battery measurement by setting a few parameters after battery insertion, without the need for long learning cycles that can complicate the application development process.

The device also supports battery safety by alarm functions and SOH (State of Health) reporting to the application processor. The operating consumption current of 2 μA is very low, making it suitable for applications such as wearables and 1series N parallel batteries.

Features

- **HG−CVR2** Algorithm Technology
  - Small Footprint: No Need for Current Sensing Resistor
  - Accurate RSOC of Aging Battery
  - Stable Gauging by Automatic Convergence of Error
  - Immediate Accurate Gauging after Battery Insertion
  - Eliminates Learning Cycle
- Low Power Consumption
  - 2 μA Operational Mode Current
- Start Gauging Immediately Stand−Alone
  - Store the Initial Setting Values Required for Gauging in the Built−in Non Volatile Memory
  - Continue Gauging Even After Sudden Power Down
- Improvement of the Battery Safety by Alarm Function
  RSOC / Voltage / Temperature
- Battery Lifetime Measurement
  SOH / Cycle Count / Operating Time
- Remaining Time Estimation
  Time to Full / Time to Empty
- Two Temperature Inputs
  - Input to Sense an NTC Thermistor
  - Via I^2C
- I^2C Interface (Supported up to 400 kHz)
- These Devices are Pb−Free, Halogen Free/BFR Free and are RoHS Compliant

Applications

- Battery Packs
- Wearables / IoT Devices
- Smartphones/PDA Devices
- Digital Cameras
- Portable Game Players
- USB-related Devices

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Application Circuit Example

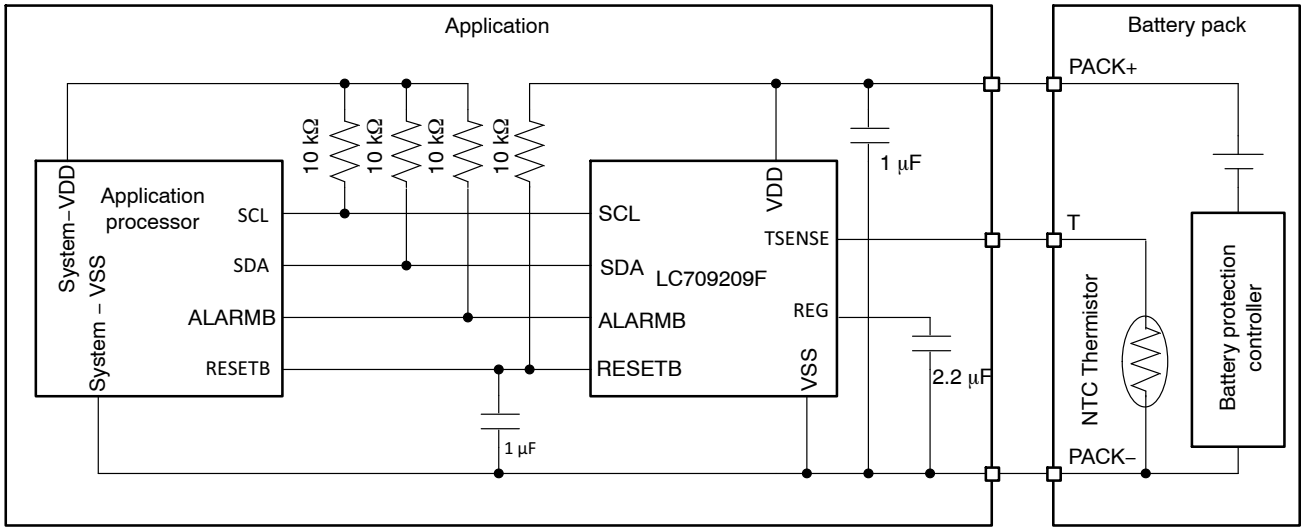


Figure 1. Example of an Application Schematic Using LC709209F (The Temperature is Measured Using TSENSE pin.)

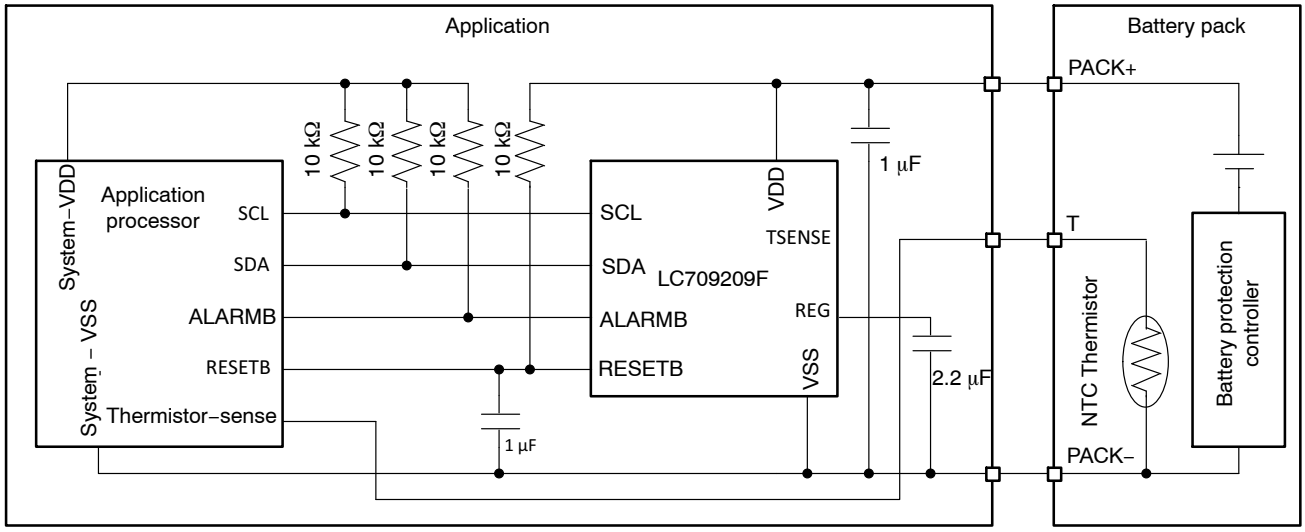


Figure 2. Example of an Application Schematic Using LC709209F (The Temperature is Sent via I^2C.)

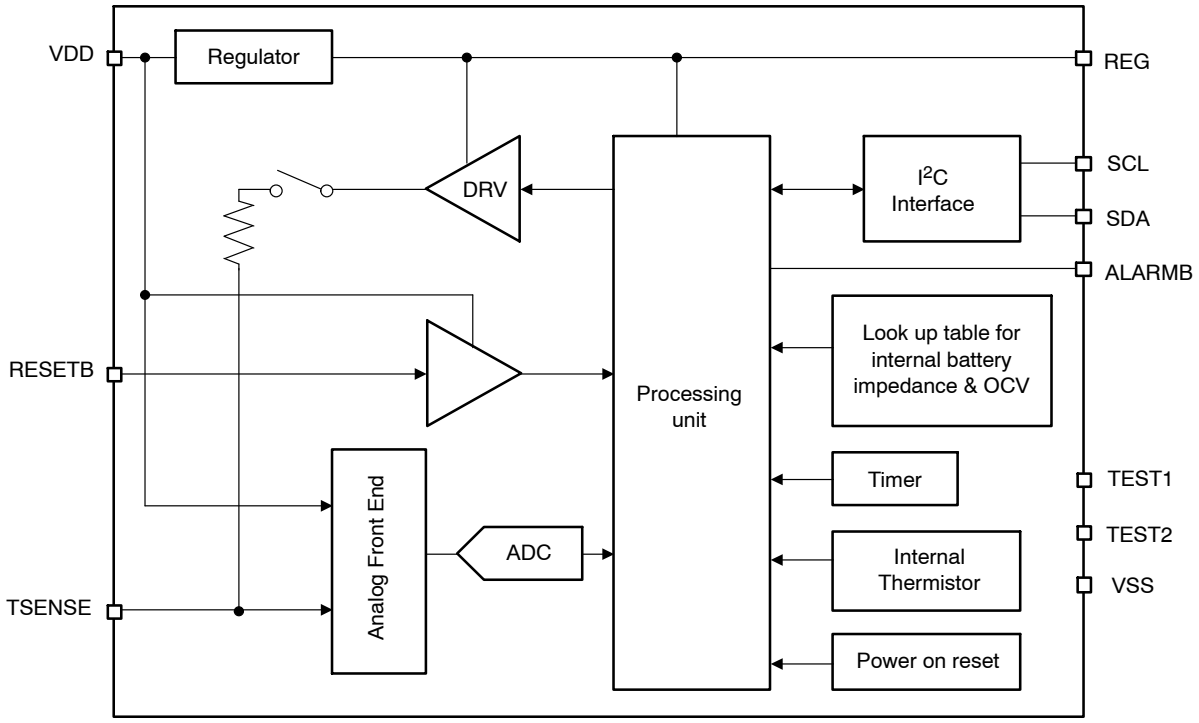
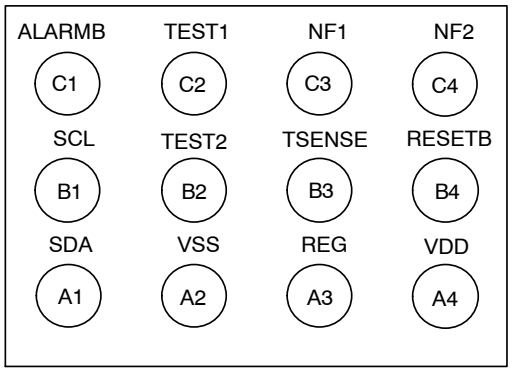


Figure 3. Block Diagram



(Bottom View)

Figure 4. Pin Assignment

Table 1. PIN FUNCTION

WLCSP12	Name	I/O	Description
A1	SDA	I/O	I²C Data pin (open drain). Pull−up must be done externally.
B1	SCL	I/O	I²C Clock pin (open drain). Pull−up must be done externally.
C1	ALARMB	O	This pin indicates an alarm by a low output (open drain). Pull−up must be done externally. Keep this pin OPEN when not in use.
A2	V_{SS}	−	Connect this pin to the battery's negative (−) pin.
B2	TEST2	I	Connect this pin to the battery's negative (−) pin.
C2	TEST1	I	Connect this pin to the battery's negative (−) pin.
A3	REG	O	Regulator output. Connect this pin to the capacitor.
B3	TSENSE	I/O	Sense input and power supply for a thermistor. Connect 10 kΩ NTC thermistor to measure "Cell temperature (0x80)". Keep this pin OPEN when not in use.
C3	NF1	−	No function pin. Keep this pin OPEN. Short−pin with TSENSE is permitted to pull it out.
A4	VDD	−	Connect this pin to the battery's positive (+) pin.
B4	RESETB	I	System reset input. The device is reset when this pin is low. Connect 1.0 μF capacitor and 10 kΩ pull−up resistor to this pin. The pull−up resistor must be connected between this pin and VDD.
C4	NF2	−	No function pin. Keep this pin OPEN.

Table 2. ABSOLUTE MAXIMUM RATINGS (T_A = 25°C, V_{SS} = 0 V)

Parameter	Symbol	Pin/Remarks	Conditions	V_{DD} (V)	Specification			Unit
					Min	Typ	Max	
Maximum Supply Voltage	V_{DD} max	VDD		−	−0.3	−	+6.5	V
Input Voltage	V_I (1)	ALARMB, SDA, SCL, ESETB, NF1, NF2		−	−0.3	−	+6.5	
Output Voltage	V_o (1)	REG, TSENSE		−	−0.3	−	+4.6	
Allowable Power Dissipation	$P_{d\ max}$		T_A = −40 to +85°C	−	−	−	150	mW
Operating Ambient Temperature	T_{aopr}			−	−40	−	+85	°C
Storage Ambient Temperature	T_{stg}			−	−40	−	+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 (T_A = −40 to +85°C, V_{SS} = 0 V)

Parameter	Symbol	Pin/Remarks	Conditions	V_{DD} (V)	Specification			Unit
					Min	Typ	Max	
Operating Supply Voltage	V_{DD} (1)	VDD		−	2.5	−	5.0	V
Operating Supply Voltage	V_{DD} (2)	VDD	T_A = 10°C to +50°C Write to NVM	−	3.0	−	5.0	V

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.

Table 4. ELECTRICAL CHARACTERISTICS (T_A = −40 to +85°C, V_{SS} = 0 V, Typ: 4 V, T_A = 25°C)

Parameter	Symbol	Pin/ Remarks	Conditions		Specification			Unit
				V_{DD} [V]	Min	Typ	Max	
LDO								
LDO Output Voltage	V_{REG}	REG		2.5 to 5.0	2.3	2.7	3.0	V
CONSUMPTION CURRENT								
Operational Mode	I_{DD} (1)	VDD	T_A = −20°C to +70°C Average current with 0.01C Constant discharge.	2.5 to 5.0	–	2	–	μA
Sleep Mode	I_{DD} (2)		T_A = −20°C to +70°C	2.5 to 5.0	–	1.3	–	
INPUT / OUTPUT								
High Level Input Voltage	V_{IH} (1)	ALARMB, SDA, SCL		2.5 to 5.0	1.4	–	5.5	V
	V_{IH} (2)	RESETB		2.5 to 5.0	0.7 V_{DD}	–	V_{DD}	V
Low Level Input Voltage	V_{IL} (1)	ALARMB, SDA, SCL		2.5 to 5.0	–	–	0.5	V
	V_{IL} (2)	RESETB		2.5 to 5.0	V_{SS}		0.3 V_{DD}	V
High Level Input Current	I_{IH}	ALARMB SDA, SCL, RESETB, NF1,NF2	V_{IN} = V_{DD} (including output transistor off leakage current)	2.5 to 5.0	–	–	1	μA
Low Level Input Current	I_{IL}	ALARMB, SDA, SCL, RESETB, NF1,NF2	V_{IN} = V_{SS} (including output transistor off leakage current)	2.5 to 5.0	−1	–	–	
Low Level Output Voltage	V_{OL} (1)	ALARMB, SDA, SCL	I_{OL} = 3.0 mA	3.3 to 5.0	–	–	0.4	V
	V_{OL} (2)		I_{OL} = 1.3 mA	2.5 to 5.0	–	–	0.4	
Hysteresis Voltage	VHYS	ALARMB, SDA, SCL		2.5 to 5.0	–	0.2	–	
Pull−up Resistor Resistance	Rpu	TSENSE		2.5 to 5.0	–	10	–	kΩ
Pull−up Resistor Temperature Coefficient	Rpuc	TSENSE	T_A = −20°C to +70°C	2.5 to 5.0	−0.05	–	+0.05	%/°C
POWER ON RESET								
Reset Release Voltage	V_{RR}	VDD		–	–	–	2.4	V
Initialization Time after Reset Release	T_{INIT}			2.4 to 5.0	–	–	100	ms
RESETB Pulse Width	T_{RESB}	T_{RESETB}			0.1	–	–	ms
TIMER								
Time Measurement Accuracy	T_{ME}		T_A = 25°C	2.5 to 5.0	−1	–	+1	%
BATTERY VOLTAGE								
Voltage Measurement Accuracy	V_{ME} (1)	VDD	T_A = +25°C	4	−7.5	–	+7.5	mV/cell
	V_{ME} (2)		T_A = −20°C to +70°C	2.5 to 5.0	−20	–	+20	

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.

Table 5. I²C SLAVE CHARACTERISTICS (T_A = −40 to +85°C, V_{SS} = 0 V)

Parameter	Symbol	Pin/Remarks	Conditions	V_{DD} (V)	Specification		Unit
					Min	Max	
Clock Frequency	T_{SCL}	SCL		2.5 to 5.0	–	400	kHz
Bus Free Time between STOP Condition and START Condition	T_{BUF}	SCL, SDA	(See Figure 5)		1.3	–	μs
Hold Time (Repeated) START Condition	$T_{HD:STA}$	SCL, SDA	(See Figure 5)		0.6	–	μs
Repeated START Condition Setup Time	$T_{SU:STA}$	SCL, SDA	(See Figure 5)		0.6	–	μs
STOP Condition Setup Time	$T_{SU:STO}$	SCL, SDA	(See Figure 5)		0.6	–	μs
Data Hold Time	$T_{HD:DAT}$	SCL, SDA	(See Figure 5)		0	–	μs
Data Setup Time	$T_{SU:DAT}$	SCL, SDA	(See Figure 5)		100	–	ns
Clock Low Period	T_{LOW}	SCL	(See Figure 5)		1.3	–	μs
Clock High Period	T_{HIGH}	SCL	(See Figure 5)		0.6	–	μs
Time-out Interval (Notes 1, 2)	T_{TMO}	SCL, SDA	(See Figure 6)		12	14	s
Clock Stretch Time during Reading CRC32	$T_{CS:CRC}$	SCL	(See Figure 21)		–	0.5	ms

1. This device resets I²C communication if the communication takes more than T_{TMO}. It initializes an internal timer to measure the interval when it detects the ninth clock pulse. It can receive a new START condition after the reset.
2. This device may lose I²C communication at this reset operation. Then if a master can't receive a response it must restart the transaction from the START condition.

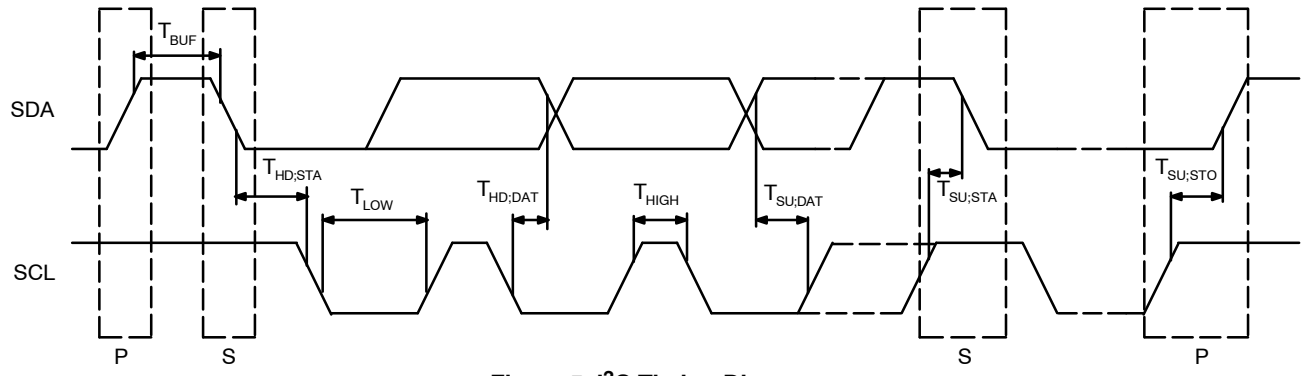


Figure 5. I²C Timing Diagram

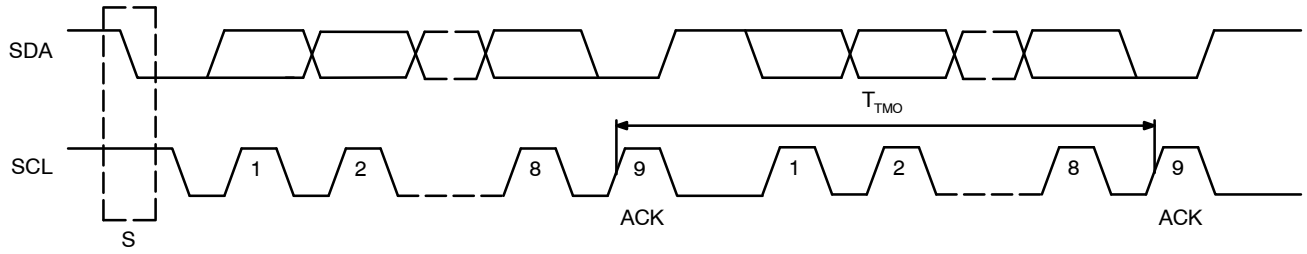


Figure 6. I²C Time-out Interval

I²C Communication Protocol

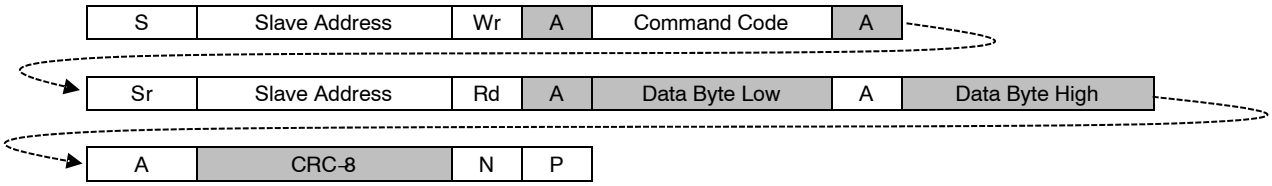
Communication protocol type: I²C

Frequency: Supported up to 400 kHz

Slave Address: 0001011 (The first 8−bits after the Strat Condition is 0x16 (WRITE) or 0x17 (READ).)
The device will stretch the clock.

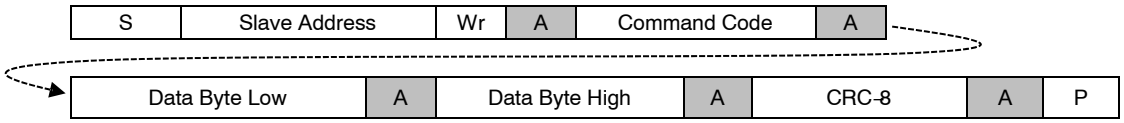
Bus Protocols

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.3778 mV : 0x16, 0x09, 0x17, 0xC2, 0x0E → 0x86)
	:	Master-to-Slave
	:	Slave-to-Master
…	:	Continuation of protocol



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

Figure 7. Read 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

Figure 8. Write Word Protocol

Table 6. FUNCTION OF REGISTERS

Command Code	Register Name	R/W	Range	Unit	Description	Initial Value
BATTERY PROFILE−RELATED REGISTERS						
0x12	Change of the Parameter	R/W	0x0000 to 0x0004	Selects a battery profile.		0x0000 (Note 3)
0x1A	Number of the Parameter	R	0x0000 to 0xFFFF	Displays the battery profile code.		−
0x0B	APA	R/W	0x0000 to 0xFFFF	Sets an adjustment parameter.		− (Note 3)
0x1C	Termination Current Rate	R/W	0x0002 to 0x001E: Threshold (0.02C to 0.3C)	0.01C	Sets termination current rate.	0x0002 (Note 3)
0x1D	Empty Cell Voltage	R/W	0x0000: Disable 0x09C4 to 0x1388: Threshold (2.5 V to 5V)	mV	Sets empty cell voltage.	0x0000 (Note 3)
0x1E	ITE Offset	R/W	0x0000 to 0x03E8 (0.0% to 100.0%)	0.1%	Sets ITE corresponding to 0% RSOC.	0x0000 (Note 3)
THERMISTOR−RELATED REGISTERS						
0x16	Status Bit	R/W	0x0000: I²C mode 0x0001: Thermistor mode	Selects I²C or Thermistor mode.		0x0000 (Note 3)
0x06	TSENSE Thermistor B	R/W	0x0000 to 0xFFFF	K	Sets B−constant of the TSENSE thermistor.	0x0D34 (3380 K) (Note 3)
0x0C	APT	R/W	0x0000 to 0xFFFF	Delays temperature measurement timing.		0x001E (Note 3)
0x08	Cell Temperature (TSENSE)	R	0x0980 to 0x0DCC (−30°C to +80°C)	0.1K (0.0°C = 0x0AAC)	Displays Cell Temperature.	0x0BA6 (25°C)
		W			Sets Cell Temperature in I²C mode.	
CONTROL REGISTERS						
0x15	IC Power Mode	R/W	0x0001: Operational mode 0x0002: Sleep mode	Selects Operational or Sleep mode.		0x0002 (Note 3)
0x0A	Current Direction	R/W	0x0000: Auto mode 0x0001: Charge mode 0xFFFF: Discharge mode	Selects Auto, Charge or Discharge mode.		0x0000
0x04	Before RSOC	W	0xAA55: 1st sampling 0xAA56: 2nd sampling 0xAA57: 3rd sampling 0xAA58: 4th sampling	Optional Command, especially for obtaining the voltage with intentional timing after power on reset.		−
0x07	Initial RSOC	W	0xAA55: Initialize RSOC	Initializes RSOC with current voltage when 0xAA55 is set.		−
REPORTING REGISTERS						
0x09	Cell Voltage	R	0x09C4 to 0x1388 (2.5V to 5V)	mV	Displays cell voltage.	−
0x0D	RSOC	R/W	0x0000 to 0x0064 (0% to 100%)	%	Displays RSOC value based on a 0 to 100 scale.	−
0x0F	ITE (Indicator to Empty)	R	0x0000 to 0x03E8 (0.0% to 100.0%)	0.1%	Displays RSOC value based on a 0 to 1000 scale.	−
0x03	Time To Empty	R	0x0000 to 0xFFFF	minutes	Displays estimated time to empty.	0xFFFF
0x05	Time To Full	R	0x0000 to 0xFFFF	minutes	Displays estimated time to full.	0xFFFF
SOH−RELATED REGISTERS						
0x32	State of Health	R	0x000A to 0x0064 (10% to 100%)	%	Displays current SOH of the battery.	0x0064 (100%)

Table 6. FUNCTION OF REGISTERS (continued)

Command Code	Register Name	R/W	Range	Unit	Description	Initial Value
LOG REGISTERS						
0x17	Cycle Count	R	0x0000 to 0xFFFF	count	Displays cycle count.	0x0000
0x25,0x24	Total Runtime	R/W	0x00000000 to 0x00FFFFFF 0x24: Lower 16−bit 0x25: Higher 8−bit	minutes	Displays operating time.	0x0000
0x27,0x26	Accumulated Temperature	R/W	0x00000000 to 0xFFFFFFFF 0x26: Lower 16−bit 0x27: Higher 16−bit	2K × minutes	Displays accumulated temperature.	0x0000
0x29,0x28	Accumulated RSOC	R/W	0x00000000 to 0xFFFFFFFF 0x28: Lower 16−bit 0x29: Higher 16−bit	% × minutes	Displays accumulated RSOC.	0x0000
0x2A	Maximum Cell Voltage	R/W	0x09C4 to 0x1388 (2.5 V to 5 V)	mV	Displays the maximum historical Cell Voltage.	0x0000
0x2B	Minimum Cell Voltage	R/W	0x09C4 to 0x1388 (2.5 V to 5 V)	mV	Displays the minimum historical Cell Voltage.	0x1388 (5 V)
0x2C	Maximum Cell Temperature (TSENSE)	R/W	0x0980 to 0x0DCC (−30°C to +80°C)	0.1K (0.0°C = 0x0AAC)	Displays the historical maximum temperature of TSENSE.	0x0980 (−30°C)
0x2D	Minimum Cell Temperature (TSENSE)	R/W	0x0980 to 0x0DCC (−30°C to +80°C)	0.1K (0.0°C = 0x0AAC)	Displays the historical minimum temperature of TSENSE.	0x0DCC (80°C)
ALARM THRESHOLD AND STATUS REGISTERS						
0x19	Battery Status	R/W	0x0000 to 0xFFFF	Displays alarms that occurred and estimated state of the battery.		0x00C0
0x1F	Alarm High Cell Voltage	R/W	0x0000: Disable 0x09C4 to 0x1388: Threshold (2.5 V to 5 V)	mV	Sets the threshold for high cell voltage alarm.	0x0000 (Note 3)
0x21	Alarm High Temperature	R/W	0x0000: Disable 0x0980 to 0x0DCC: Threshold (−30°C to +80°C)	0.1K (0.0°C = 0x0AAC)	Sets the threshold for high temperature alarm.	0x0000 (Note 3)
0x14	Alarm Low Cell Voltage	R/W	0x0000: Disable 0x09C4 to 0x1388: Threshold (2.5 V to 5 V)	mV	Sets the threshold for low cell voltage alarm.	0x0000 (Note 3)
0x13	Alarm Low RSOC	R/W	0x0000: Disable 0x0001 to 0x0064: Threshold (1% to 100%)	%	Sets the threshold for low RSOC alarm.	0x0000 (Note 3)
0x20	Alarm Low Temperature	R/W	0x0000: Disable 0x0980 to 0x0DCC: Threshold (−30°C to +80°C)	0.1K (0.0°C = 0x0AAC)	Sets the threshold for low temperature alarm.	0x0000 (Note 3)
OTHER REGISTERS						
0x11	IC Version	R	0x0000 to 0xFFFF	Displays the internal management code.		−
0x37,0x36	User ID	R	0x00000000 to 0xFFFFFFFF 0x36: Lower 16−bit 0x37: Higher 16−bit	Displays 32−bit user ID.		(Note 3)
0x39,0x38	CRC32	R	0x00000000 to 0xFFFFFFFF 0x38: Lower 16−bit 0x39: Higher 16−bit	Displays CRC32 result.		−
Except above commands	No Function	−	−	Registers that is access prohibited.		−

0xXXXX = Hexadecimal notation

3. The initial values are set on the device using the specified writing protocol for the built−in NVM. Please refer to the application note about how to program it.

Table 7. BATTERY PROFILE VS REGISTER

IC Type	Battery Type	Nominal / Rated Voltage	Charging Voltage	Number of the Parameter (0x1A)	Change of the Parameter (0x12)
LC709209FXE−01TBG	01	3.7 V	4.2 V	0x1001	0x00
	04	UR18650ZY (Panasonic)			0x01
	05	ICR18650−26H (SAMSUNG)			0x02
	06	3.8 V	4.35 V		0x03
	07	3.85 V	4.4 V		0x04

Battery Profile−related Registers

Change of the Parameter (0x12)

The device contains five types of battery profiles. This register is used to select a target battery profile from them. See Table 7 for the details on battery types and the corresponding values for this register. You should check your battery nominal voltage and charging voltage against the table and select the battery type where either of them matches.

Alternatively, you can also select the suitable battery profile by using the Smart LiB Gauge Automatic Support Tool. Please refer to the user guides in the Strata Developer Studio™ for the details. In addition to the profile selection, writing into this register also executes the RSOC initialization. For the initialization it uses the selected battery profile and the first sampled voltage after battery insertion. Refer to “Before RSOC (0x04)” section for the details on the initialization.

Number of the Parameter (0x1A)

This register contains identity of installed battery profiles.

Adjustment Pack Application (0x0B)

APA values are parameter to fit a pre−installed battery profile into target battery characteristics. They are set in the APA register (0x0B). Appropriate APA values for the target battery will improve RSOC accuracy. You can select either of the two following approaches to obtain the APA value.

- Design capacity to typical APA conversion table
- Smart LiB Gauge Automatic Support Tool

If you will obtain the typical APA from the design capacity, refer to Table 8. Typical APA values can be taken from the design capacity of the cell in the table. If some batteries are connected in parallel, use the design capacity per 1−cell in the table. Calculate APA values using linear supplement if your required design capacity is not shown in the table. See eq. 1 for how to calculate the APA value manually. An example for a 1500 mAh battery with corresponding DEC value for their HEX is also shown.

$$\text{APAvalue} = \text{Lower_APA} + (\text{Upper_APA} - \text{Lower_APA}) \times \frac{\text{Capacity} - \text{Lower_Cap.}}{\text{Upper_Cap.} - \text{Lower_Cap.}} \quad \text{(eq. 1)}$$

Calculation example in case 1500 mAh battery Type−01:

$$\text{APAvalue} = 45{:}0x2D + (50{:}0x3A - 45{:}0x2D) \times \frac{1500 - 1000}{2000 - 1000} = 52{:}0x34$$

The upper 8 bits and the lower 8 bits of the APA register correspond to the charging and discharging adjustment parameters respectively. See Table 9 for the bit configuration. Table 8 shows the case where both the upper and lower bits have the same value. For example, set the value in the APA register to 0x0D0D for an APA value of 0x0D.

Table 8. DESIGN CAPACITY TO TYPICAL APA CONVERSION TABLE

Design Capacity / Cell (Note 4)	APA[15:8], APA[7:0]		
	Type−01	Type−06	Type−07
50 mAh	0x13, 0x13	0x0C, 0x0C	0x03, 0x03
100 mAh	0x15, 0x15	0x0E, 0x0E	0x05, 0x05
200 mAh	0x18, 0x18	0x11, 0x11	0x07, 0x07
500 mAh	0x21, 0x21	0x17, 0x17	0x0D, 0x0D
1000 mAh	0x2D, 0x2D	0x1E, 0x1E	0x13, 0x13
2000 mAh	0x3A, 0x3A	0x28, 0x28	0x19, 0x19
3000 mAh	0x3F, 0x3F	0x30, 0x30	0x1C, 0x1C
4000 mAh	0x42, 0x42	0x34, 0x34	−
5000 mAh	0x44, 0x44	0x36, 0x36	−
6000 mAh	0x45, 0x45	0x37, 0x37	−
Design Capacity / Cell (Note 4)	**APA[15:8], APA[7:0]**		
	Type−04		**Type−05**
2600 mAh	0x10, 0x10		0x06, 0x06

4. Use capacity per 1−cell if some batteries are connected in parallel.

Table 9. DESIGN CAPACITY TO TYPICAL APA CONVERSION TABLE

BITS	Register Name
APA[15:8]	APA value for charging adjustment
APA[7:0]	APA value for discharging adjustment

The Smart LiB Gauge Automatic Support Tool automatically evaluates the optimum APA by measuring the target battery. The evaluated APA will improve the RSOC accuracy more than the APA from the conversion table. For the evaluation, the tool discharges a target battery using the on−board programmable load and measures the cell voltage and temperature. The tool works in the Strata Developer Studio. Please refer to the documents in the Strata Developer Studio for further details about the tool.

Termination Current Rate (0x1C)

This register contains the termination current rate in 0.01C. (i.e. the set value is 0x02 for 3000 mAh design capacity and 60 mA termination current.) This termination current rate is used to adjust RSOC repot so that 100% is reported at the end of the charging period, or even before the charger finishes charging.

When this value is the default 0.02C, there is no offset at full charge state (RSOC (0x0D) is 100%) between ITE (0x0F) and RSOC (0x0D). When the value exceeds 0x02, there will be an offset between them, as shown in Figure 9. This corresponds to a decrease in the full charged capacity as an increase in the termination current. As the result, the RSOC will reach 100% faster. This offset value is calculated automatically according to the battery profile and this register value.

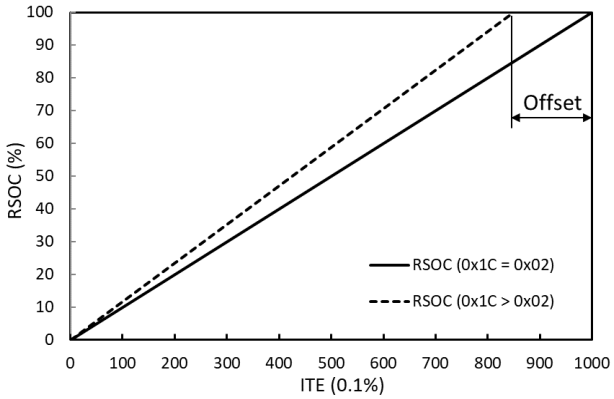


Figure 9. Rescaled RSOC with Termination Current Rate

ITE Offset (0x1E)

This register contains is an offset between ITE (0x0F) and RSOC (0x0D) at empty state in 0.1% unit. When this value is the default zero, there is no offset between them at the empty state (RSOC (0x0D) is 0%). If the value exceeds zero, there will be an offset between them, as shown in Figure 10. As the result, the RSOC will reach 0% faster.

This register can also be automatically updated with the detected empty cell voltage. Refer to the following Empty Cell Voltage section about it.

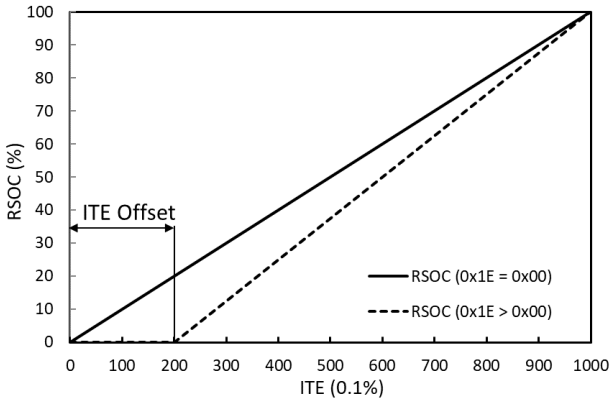


Figure 10. Rescaled RSOC with ITE Offset

Empty Cell Voltage (0x1D)

Set the empty cell voltage in mV for 0% RSOC. In most cases, the set voltage is the lowest cell voltage that your application can tolerate. The device adjusts the RSOC report so that it can report 0% RSOC at this voltage. For this adjustment the device automatically writes the current value of the ITE register (0x0F) into the ITE offset register (0x1E), when all three of the following conditions are met.

Cell Voltage (0x09) < Empty Cell Voltage (0x1D) (eq. 2)

ITE (0x0F) > ITE Offset (0x1E) (eq. 3)

Cell Temperature (0x08) > 0x0AAC(0°C) (eq. 4)

As the result, the device will report 0% RSOC at the empty cell voltage, as shown in Figure 10 and 11. However, if non−rescaled RSOC reaches 0% when the cell voltage is higher than the empty cell voltage, the ITE offset is never written automatically. Set this register to 0 not to update ITE offset automatically.

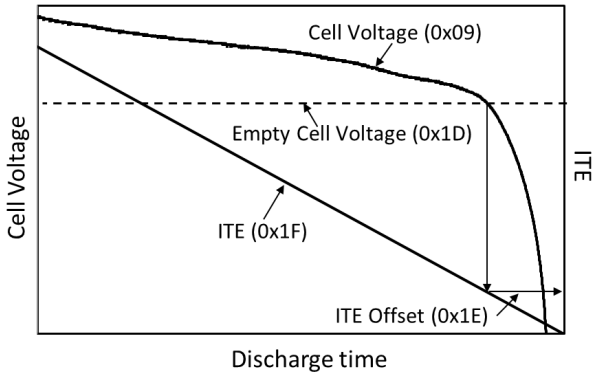


Figure 11. Rescaled RSOC with ITE Offset

THERMISTOR−RELATED REGISTERS

Status Bit (0x16)

This register controls the cell temperature measurement. The bit selection details is shown in Table 10. Set the bit0 to 1 to measure the temperature using a thermistor connected to the TSENSE pin. If the thermistor is not connected to the device, set the bit0 to 0. Refer to Cell Temperature (0x08) section to see the details on using the I^2C mode.

Table 10. STATUS BIT

Register Name	Status BIT	Set Value in Status Bit	
		0	1
Cell Temperature	BIT0	I2C mode	Thermistor mode

NOTE: Thermistor mode: The device measures thermistors directly. I^2C mode: The device receives temperature information via I^2C.

TSENSE Thermistor B (0x06)

Sets B−constant value of the thermistor connected to the TSENSE pin in K. Refer to the specification sheet of the thermistor for the B−constant value.

Adjustment Pack Thermistor (0x0C)

The device periodically charges the thermistors connected to the TSENSE pin to measure the cell temperature, as shown in Figure 12. This register controls the delay time from the start of charging to the temperature measurement. The delay time is calculated using this register value and following formula.

$$\text{Delay} = 0.167\ \mu s \times (200 + \text{APT}) \quad \text{(eq. 5)}$$

The default APT (0x001E) will meet most of thermistors or battery packs. However, if a capacitor is connected in parallel with the thermistor as shown in Figure 13, this register should be used to delay the temperature measurement in order to wait for the TSENSE voltage to stabilize.

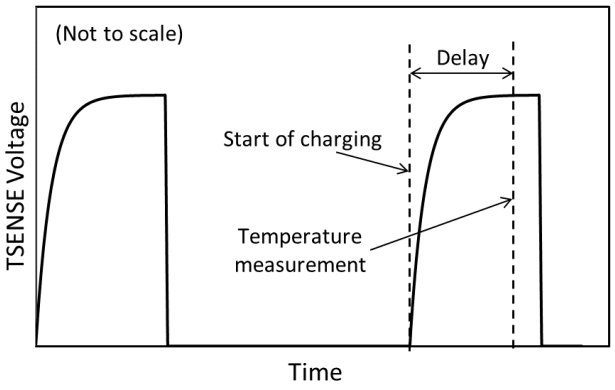


Figure 12. TSENSE Voltage at Temperature Measurement

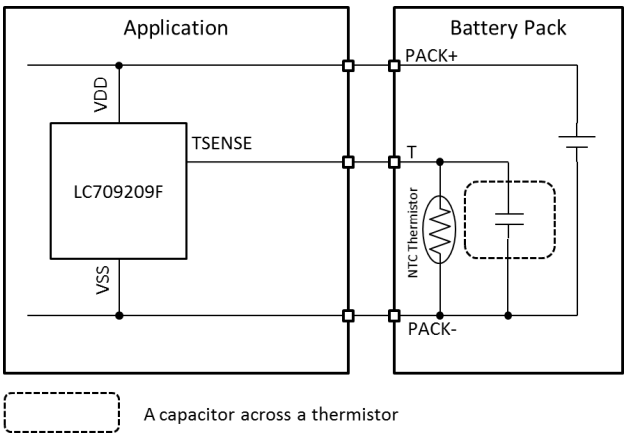


Figure 13. An Example of a Capacitor across the Thermistor

Cell Temperature (0x08)

This register contains the cell temperature from −30°C (0x0980) to +80°C (0x0DCC) measured in 0.1°C units. When the "Thermistor mode" is set in Status Bit (0x16), the device measures the thermistor connected to the TSENSE pin and loads the temperature into this register. Temperature measurement timing is controlled by the device, and the power to the thermistor is supplied only at the time of measurement.

When the "I^2C mode" is set in Status Bit (0x16), the device will not update this register. In that case, an application processor must write the measured cell temperature by the other device to this register. Because it is an essential parameter for the RSOC measurement. For the high precision RSOC measurement, it is recommended to update this register every time when the temperature changes by more than 1°C. The updating is not required in Sleep mode.

CONTROL REGISTERS

IC Power Mode (0x15)

This register selects the power mode. Operational mode (0x15 = 01) or Sleep mode (0x15 = 02). In the Operational mode all functions operate with full calculation and tracking of RSOC during charge and discharge. In the Sleep mode all functions except for I^2C communication are stopped. Therefore RSOC and all the other registers are not updated and ALARMB pin is released from low. After the device returns to the Operational mode, it starts calculation and tracking based on the data stored in the previous Operational mode.

Current Direction (0x0A)

This register can constrain the increase or decrease of RSOC register (0x0D). When this register is set in the Auto mode, the value of the RSOC register increases or decreases according to the RSOC gauging result. However, in the

Charge or Discharge mode, the decrease or increase is prohibited, as shown in Figure 14 and 15.

Generally, RSOC may increase slightly without charging due to the difference in usable battery capacity at each cell temperature. However, if an application cannot allow such an RSOC increase without charging, you can use the Discharge mode to prevent the increase. Note that if the Discharge mode is set during charging, the RSOC register value will deviate significantly from the actual RSOC.

Table 11. CURRENT DIRECTION

Data	Mode	Description
0x0000	Auto mode	RSOC is not restricted.
0x0001	Charge mode	Decrease of RSOC is restricted.
0xFFFF	Discharge mode	Increase of RSOC is restricted.

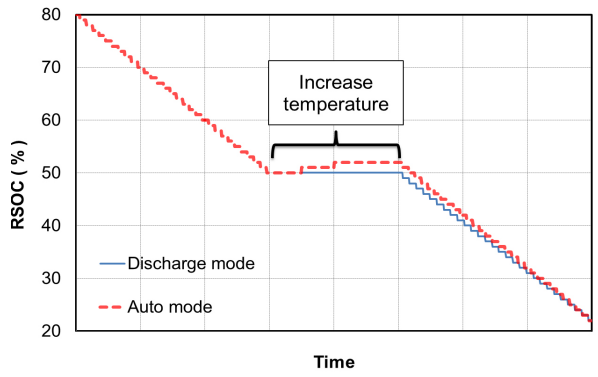


Figure 14. Discharge Mode
(An example with increasing in temperature. A warm cell has more capacity than a cold cell. Therefore RSOC increases without charging in Auto mode).

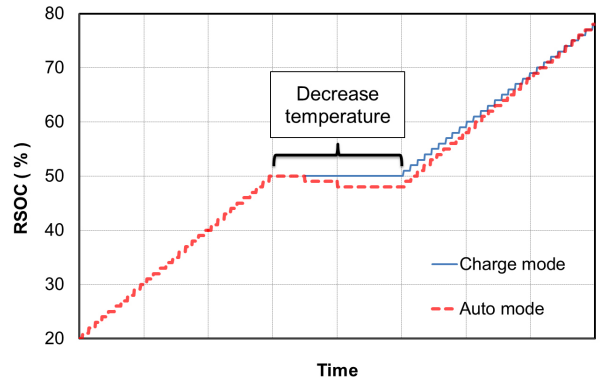


Figure 15. Charge Mode
(An example with decreasing in temperature. A cold cell has less capacity than a warm cell. Therefore RSOC decreases without discharging in Auto mode).

Before RSOC (0x04)

This register is used to execute "Before RSOC" command. This command obtains the initial RSOC using one of the automatically measured cell voltages after battery insertion as shown in Figure 16. These cell voltages are measured four times every 10 ms after the battery insertion. This is an optional command, because the device obtains the initial RSOC automatically using the first sampling cell voltage. However, if the first RSOC does not satisfy the requirements for the target battery, this command can initialize the RSOC again using the second, the third or the forth sampling cell voltage.

The cell voltage is used as Open Circuit Voltage (OCV) to obtain the initial RSOC. Therefore, in order to obtain the RSOC accurately, it is desirable that the battery current at the voltage measurement is smaller. It is recommended that the current is less than 0.025C. (i.e. less than 75 mA for 3000 mAh design capacity battery.) If the battery is not charged, "Before RSOC" command to give the maximum RSOC with the maximum cell voltage is estimated to be suitable for more accurate initial RSOC.

To execute this command, write one of the data shown in Table 12 into this register. The data selects a sampling cell voltage to initial RSOC.

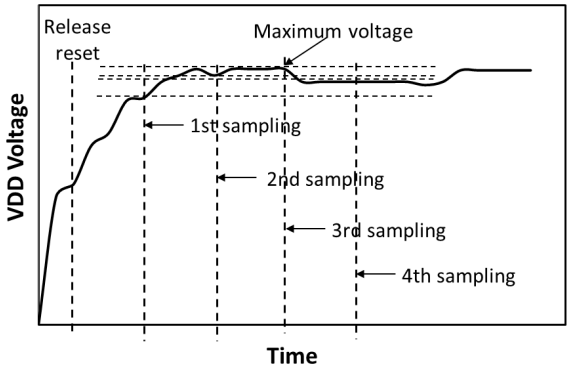


Figure 16. Sampling Order for Before RSOC Command

Table 12. BEFORE RSOC COMMAND

Command Code	DATA	Sampling order of battery voltage for RSOC initialization
0x04	0xAA55	1st sampling
	0xAA56	2nd sampling
	0xAA57	3rd sampling
	0xAA58	4th sampling

Initial RSOC (0x07)

This register is used to execute "Initial RSOC" command. The command obtains the initial RSOC using the cell voltage at which it is executed, as shown in Figure 17. When this command is executed, it is desirable for battery current to be less than 0.025C like "Before RSOC" command. However, an application processor and other devices may be operating and consuming the battery current at this time. Therefore it is generally recommended to use the RSOC that

was automatically obtained after the battery insertion without using this command.

To execute this command, mode 0xAA55 data into this register.

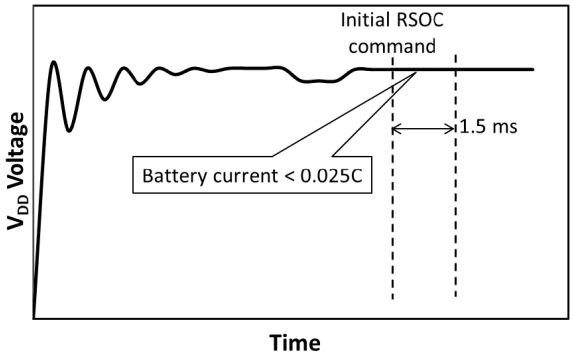


Figure 17. Initial RSOC Command

REPORTING REGISTERS

Cell Voltage (0x09)

This register contains the V_{DD} voltage in mV.

RSOC (0x0D)

This register contains RSOC of a battery in 1% unit. The RSOC is updated automatically as a result of battery gauging in Operational mode. The RSOC is the same as ITE (0x0F) when Termination current rate (0x1C) and Empty Cell Voltage (0x1D) are default values.

Although this register is writable, it is not recommended for general use. If a value which differs from the actual battery RSOC is written, it will gradually converge itself to an actual battery RSOC in Operational mode. Refer to Automatic Convergence of the Error section about the convergence.

Indicator to Empty (0x0F)

This register contains RSOC in 0.1% increments. It is updated automatically throughout the battery gauging process.

TimeToEmpty (0x03)

This register contains estimated time to empty in minutes. The empty condition is defined as the state that RSOC (0x0D) is 0%.

TimeToFull (0x05)

This register contains estimated time to full in minutes. The full condition is defined as the state that RSOC (0x0D) is 100%.

SOH– RELATED REGISTERS

State of Health (0x32)

This register contains SOH of a battery in 1% unit. The SOH is updated automatically according to battery aging. The initial value after reset or power on is 100% (0x0064).

LOG REGISTERS

Cycle Count (0x17)

This register contains the number of charging and discharging cycles of a battery. The cycle is counted as “1” when the total “Decrement of RSOC” reaches 100%. The count is started with 0 after battery insertion. Figure 18 shows an example where the Cycle Count is set to 1 when one full discharge cycle is completed.

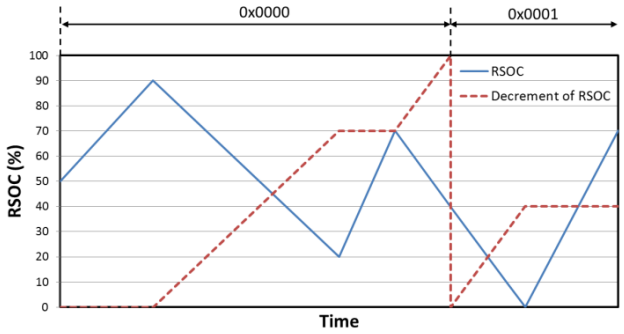


Figure 18. CycleCount

Total Runtime (0x24, 0x25)

This register contains an elapsed time of Operational mode after battery insertion in minutes. The device stops the counting when it reaches 0xFFFFFF. When this register is written it starts counting from the written value. It doesn’t count in Sleep mode.

Accumulated Temperature (0x26, 0x27)

In Operational mode this register accumulates Cell Temperature (0x08) value per a minute shown in eq. 6.

$$\text{AccumulatedTemperature} = \text{AccumulatedTemperature} + \frac{\text{CellTemperature}}{20} \quad \text{(eq. 6)}$$

You can calculate averaged cell temperature using this register and TotalRuntime register. The initial value after power on reset is 0. When this register reaches 0xFFFFFFFF or the device is in Sleep mode, it will stop accumulating. If this register is written it will start accumulating from the written value.

Accumulated RSOC (0x28, 0x29)

In Operational mode this register accumulates RSOC (0x0D) value per minute shown in eq. 7.

You can calculate averaged RSOC using this register and TotalRuntime register. The initial value after power on reset is 0.

$$\text{AccumulatedRSOC} = \text{AccumulatedRSOC} + \text{RSOC} \quad \text{(eq. 7)}$$

When this register reaches 0xFFFFFFFF or the device is in Sleep mode, it will stop accumulating. If this register is written it will start accumulating from the written value.

Maximum Cell Voltage (0x2A)

The maximum Cell Voltage (0x09) is stored. This register will be updated whenever the higher voltage is detected. If the lower voltage is written it can detect the higher voltage than the written voltage again.

Minimum Cell Voltage (0x2B)

The minimum Cell Voltage (0x09) is stored. This register will be updated whenever the lower voltage is detected. If the higher voltage is written it can detect the lower voltage than the written voltage again.

Maximum Cell Temperature (TSENSE) (0x2C)

The maximum Cell Temperature (0x08) is stored. This register will be updated whenever the higher temperature is detected. If the lower temperature is written it can detect the higher temperature than the written temperature again.

Minimum Cell Temperature (TSENSE) (0x2D)

The minimum Cell Temperature (0x08) is stored. This register will be updated whenever the lower temperature is detected. If the higher temperature is written it can detect the lower temperature than the written temperature again.

ALARM THRESHOLD AND STATUS REGISTERS

Battery Status (0x19)

This register contains different alarms and estimated states of the battery. See Table 13. Each alarm bit is set to 1 when its alarm condition is reached. The bits which are set to 1 will remain at 1 even if their corresponding alarm conditions are resolved. Set the alarm bits to 0 manually after having confirmed the cause of the alarm.

Status bit 6, Discharging, reports on the current state of the battery. When it is 1, it means that the battery is discharged; and when it is 0, the battery is charged.

Status bit 7, INITIALIZED, helps an application processor to detect the power−on reset of the device. The bit is automatically set to 1 after power−on reset.

Table 13. BATTERY STATUS

	BIT	Function	ALARMB control	Initial value
ALARM	15	High Cell Voltage	✓	0
	14	Reserved	–	0
	13	Reserved	–	0
	12	High Temperature	✓	0
	11	Low Cell Voltage	✓	0
	10	Reserved	–	0
	9	Low RSOC	✓	0
ALARM	8	Low Temperature	✓	0
STATUS	7	INITIALIZED	–	1
	6	Discharging	–	1
	5	Reserved	–	0
	4	Reserved	–	0
	3	Reserved	–	0
	2	Reserved	–	0
	1	Reserved	–	0
	0	Reserved	–	0

Alarm Low Cell Voltage (0x14)

This register contains the threshold in mV of the alarm low cell voltage. When Cell Voltage (0x09) falls below this value, ALARMB pin outputs low level and bit 11 of the Battery Status register (0x19) is set to 1. When the Cell Voltage rises above this value, ALARMB is released. Set this register to 0 to disable this function. See Figure 19.

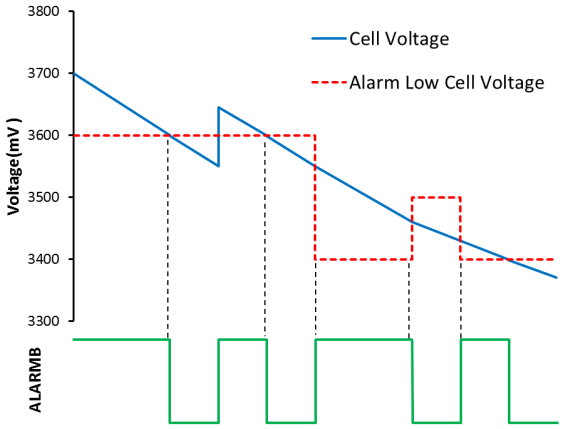


Figure 19. Alarm Low Cell Voltage

Alarm High Cell Voltage (0x1F)

This register contains the threshold in mV of the alarm high cell voltage. When Cell Voltage (0x09) rises above this value, ALARMB pin outputs low level and the bit 15 of Battery Status register (0x19) is set to 1. When the Cell Voltage falls below this value, ALARMB is released. Set this register to 0 to disable this function.

Alarm Low RSOC (0x13)

This register contains the threshold in % of the alarm low RSOC. When RSOC (0x0D) falls below this value, ALARMB pin outputs low level and bit 9 of the Battery Status register (0x19) is set to 1. When the RSOC rises above this value, ALARMB is released. Set this register to 0 to disable this function. See Figure 20.

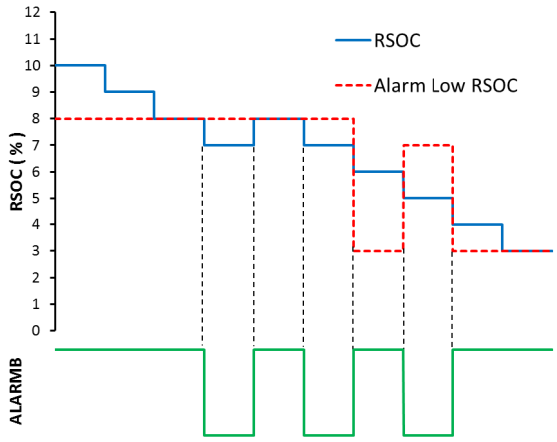


Figure 20. Alarm Low RSOC

Alarm Low Temperature (0x20)

This register contains the threshold in 0.1K of the alarm low cell temperature. When Cell Temperature (0x18) falls below this value, ALARMB pin outputs low level and bit 8 of the Battery Status register (0x19) is set to 1. When the Cell Temperature rises above this value, ALARMB is released. Set this register to 0 or I^2C mode to disable this function.

Alarm High Temperature (0x21)

This register contains the threshold in 0.1K of the alarm high cell temperature. When Cell Temperature (0x18) rises above this value, ALARMB pin outputs low level and bit 12 of the Battery Status register (0x19) is set to 1. When the Cell Temperature falls below this value, ALARMB is released. Set this register to 0 or I^2C mode to disable this function.

OTHER REGISTERS

CRC32 (0x38, 0x39)

This register contains CRC−32 result calculated from the registers shown in Table 13.The CRC−32 specifications are defined by the following Polynomial, Normal and Bit Reverse values.

Polynomial :
x ^ 32 + x ^ 26 + x ^ 23 + x ^ 22 + x ^ 16 + x ^ 12
+ x ^ 11 + x ^ 10 + x ^ 8 + x ^ 7 + x ^ 5 + x ^ 4
+ x ^ 2 + x ^ 1
Normal : 0x4C11DB7
BitReverse : 0xEDB88320

The register data in Table 14 is converted to CRC−32 input data in the order shown in Table 15. The device will start CRC−32 calculation using the converted data if an application processor reads either 0x39 or 0x38 from the CRC32 register. As shown in Figure 21, the clock stretch to calculate the CRC−32 is inserted between Acknowledge and Data Byte Low.

Table 14. INPUT REGISTERS INTO CRC−32

No.	Command Code	Register Name
1	0x06	TSENSE Thermistor B
2	0x0B	APA
3	0x0C	APT
4	0x12	Change Of The Parameter
5	0x13	Alarm Low RSOC
6	0x14	Alarm Low Cell Voltage
7	0x15	IC Power Mode
8	0x16	Status Bit
9	0x1C	Termination current rate
10	0x1D	Empty Cell Voltage
11	0x1F	Alarm High Cell Voltage
12	0x20	Alarm Low Temperature
13	0x21	Alarm High Temperature

NOTE: The device never update these registers automatically.

Table 15. INPUT DATA ORDER INTO CRC−32

CRC−32 Input	MSB			LSB
Register No.	No. 1 LSB … MSB	No. 2 LSB … MSB	…	No. 13 LSB … MSB

User ID (0x36, 0x37)

This register contains 32−bit data written in built−in NVM. It is usable for various purposes. Refer to the application note about how to write the NVM.

IC Version (0x11)

This register contains an internal management code. The value is not published.

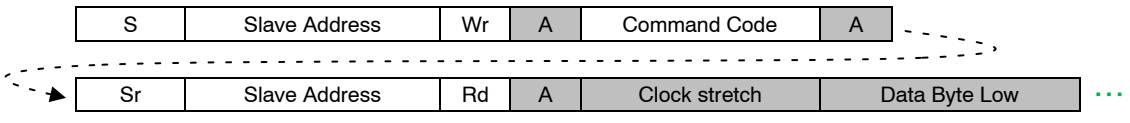


Figure 21. Clock Stretch during Reading CRC32 Register

HG−CVR2

Hybrid Gauging by Current-Voltage Tracking with Internal Resistance

HG−CVR2 is **onsemi**'s unique method which is used to calculate accurate RSOC. **HG−CVR2** first measures battery voltage and temperature. Precise reference voltage is essential for accurate voltage measurement. LC709209F 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.

$$V(VARIED) = V(MEASURED) - OCV \quad \text{(eq. 8)}$$

$$I = \frac{V(VARIED)}{R(INTERNAL)} \quad \text{(eq. 9)}$$

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. The device has built−in look up tables for such variable conditions **HG−CVR2** 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 and charge cycles, 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).

$$RSOC = \frac{RM}{FCC} \times 100\% \quad \text{(eq. 10)}$$

Then the decreased FCC must be preliminarily measured with learning cycle. But **HG−CVR2** can measure the RSOC of deteriorated battery without the learning cycle. The internal battery impedance that **HG−CVR2** uses to calculate the current correlates highly with FCC. The correlation is based on battery chemistry. The RSOC that the device reports using the correlation is not affected by aging.

Automatic Convergence of the Error

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

The device with **HG−CVR2** has the feature that the error of RSOC converges automatically, and doesn't require any calibration. The error constantly converges in the value estimated from the Open Circuit Voltage. Figure 22 shows the convergent characteristic example from the initialize error.

Also, one of the drawbacks of the counting method is that it cannot detect accurate residual change because the amount of the current from self−discharge is too small but **HG−CVR2** is capable of dealing with such issues by using the voltage information.

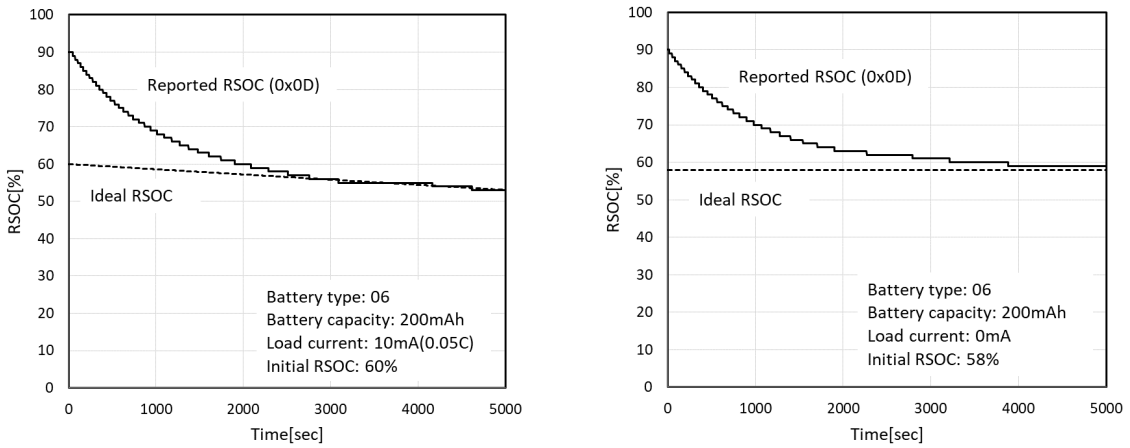
Simple and Quick Setup

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 the LC709209F device is that only a very small number of parameters need to be set up. Such simple and quick start−up is made possible by the integration of data for multiple battery profiles into the device to support various types of lithium−ion/polymer batteries. Please contact your local sales office to learn more about how to measure a battery whose parameters do not match the already−prepared battery profile data given in Table 7.

Low Power Consumption

Low power consumption of 2 μA is realized in the Operation mode. The device monitors the charge/discharge condition of a battery and changes the sampling rate according to the change in battery current. Power consumption reduction without deteriorating the RSOC accuracy was enabled by utilizing this sampling method.

TYPICAL CHARACTERISTICS



NOTE: This Graph is the example for starting point 90% (includes 30% to 32% RSOC error).

Figure 22. Convergent Characteristic from the Initialize Error

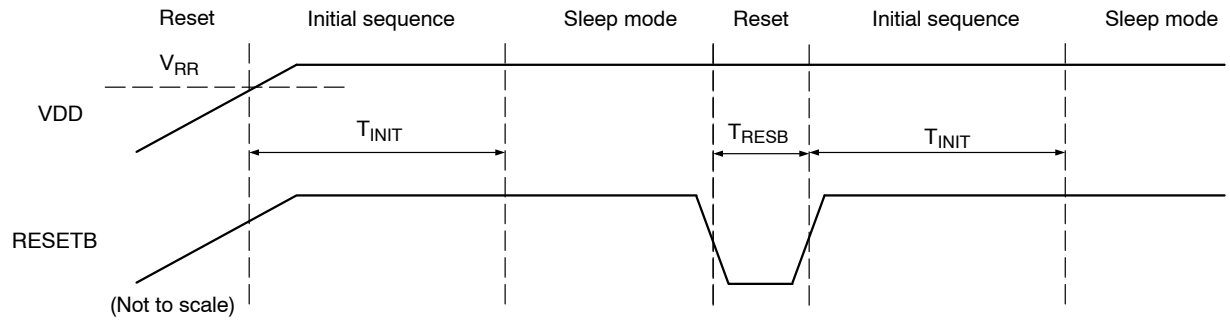


Figure 23. Power On and RESETB Timing Diagram

Power on Reset and Battery Insertion Detection

If the device detects battery insertion, it will be reset automatically. And when the battery voltage exceeds VRR, the device will be released from the reset status. After the reset is released, the device's initial sequence will complete in TINIT as shown in Figure 23, and the device goes into Sleep mode. Then I^2C communication can be started. All registers are initialized during the initial sequence. The initial values for the registers shown in Table 16 are loaded from the built−in NVM. Those for the other registers are fixed.

RESETB

The device can be also reset by a low level input to the RESETB pin. After the low level release, the device will complete the initial sequence, as the same timing as the battery insertion shown in Figure 23.

Stand−alone Initial Setting for Gauging

The device requires to set the registers indicated as "Mandatory" in Table 16 to start the battery gauging. These registers provide basic information for the battery gauging such as battery profile, power mode and temperature measurement conditions. On the other hand, the registers indicated as "Optional" in the table can be set if the user's application requires the related functions.

All the initial values of the registers in the table can be programmed into the built−in NVM. If the required initial values have been programmed once into the built−in NVM, they are loaded automatically during every initial sequence after the reset or power on. As a result, the device can start gauging directly even if an application processor sends no I^2C command. Refer to the application note about how to write into the built−in NVM.

Table 16. REGISTERS FOR INITIAL SETTING

Command Code	Register Name	Mandatory or Optional	Initial Value is Stored in NVM
0x06	TSENSE Thermistor B	Mandatory (Thermistor Mode)	✓
0x0B	APA	Mandatory	✓
0x0C	APT	Optional	✓
0x12	Change of the Parameter	Mandatory	✓
0x13	Alarm Low RSOC	Optional	✓
0x14	Alarm Low Cell Voltage	Optional	✓
0x15	IC Power Mode	Mandatory	✓
0x16	Status Bit	Mandatory (Thermistor Mode)	✓
0x1C	Termination Current Rate	Optional	✓
0x1D	Empty Cell Voltage	Optional	✓
0x1E	ITE Offset	Optional	✓
0x1F	Alarm High Cell Voltage	Optional	✓
0x20	Alarm Low Temperature	Optional	✓
0x21	Alarm High Temperature	Optional	✓

Initial Setting with I²C Communication

If the required initial values of the registers in Table 16 is not programmed in the built−in NVM preliminarily, an application processor must write them with I²C communication after every reset or power on. The starting flows for the initial setting are shown in Figure 24 and 25. If the device is used in thermistor mode, refer to Figure 24. If the device is used in I²C mode, refer to Figure 25.

At the end of the flow, it is recommended to set the INITIALIZED bit of BatteryStatus (0x19) to 0. By reading the bit, an application processor can detect whether the device was reinitialized. For example, if the device was turned−off by the battery protection controller, the bit is reset to 1. In that case, repeat the starting flow again.

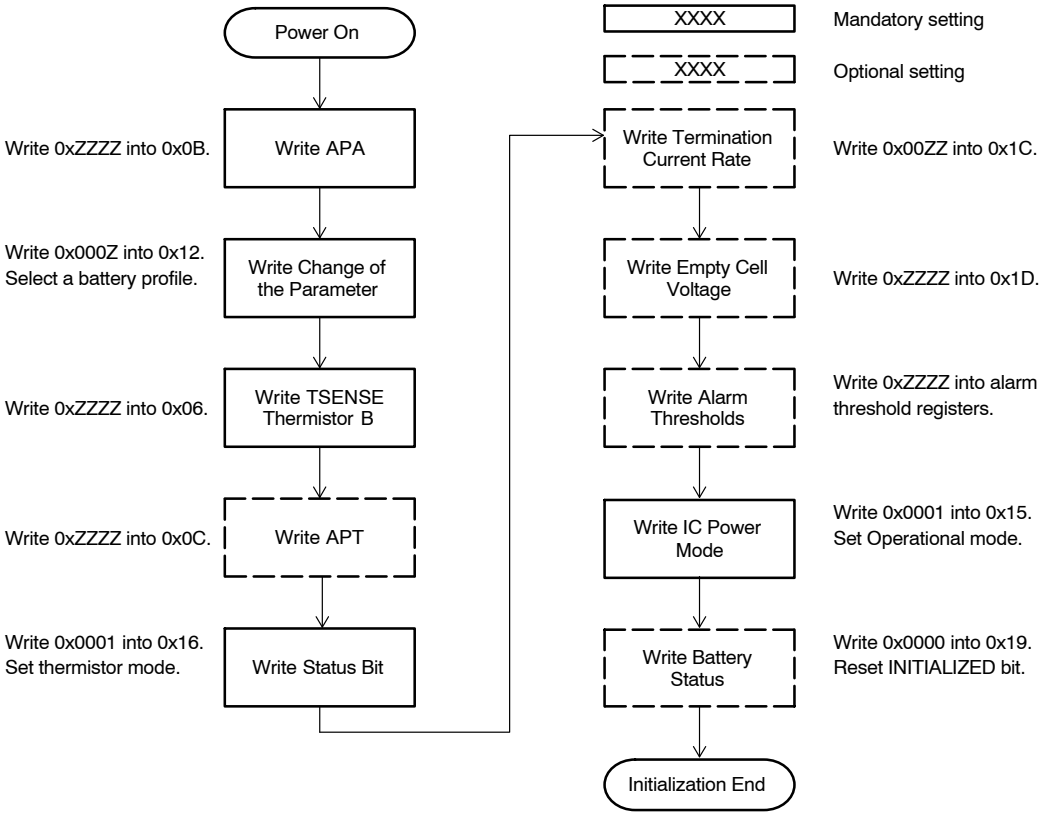


Figure 24. Starting Flow at Thermistor Mode

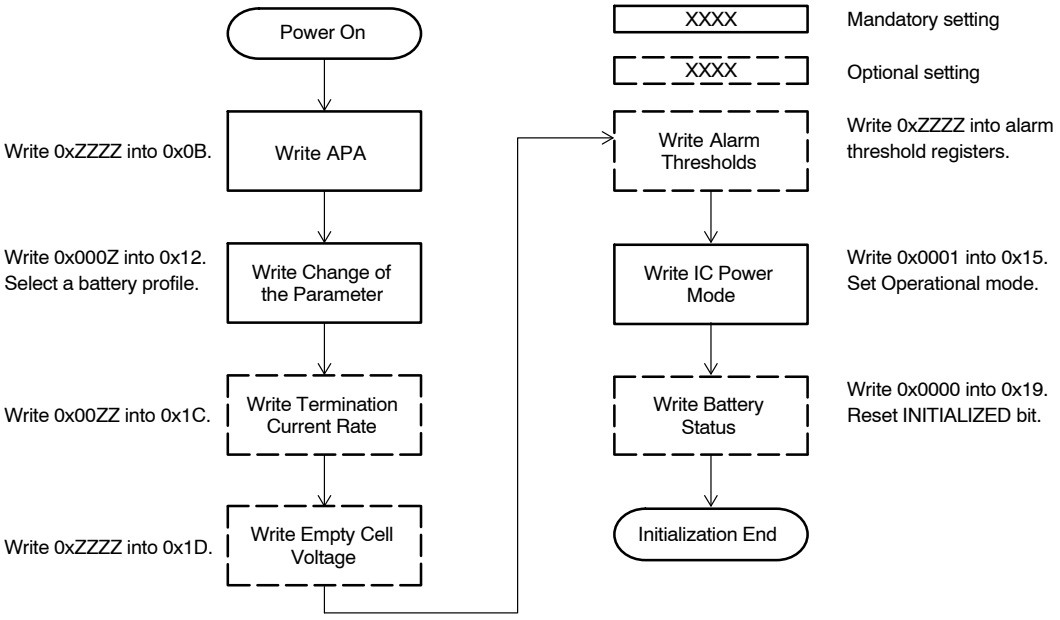


Figure 25. Starting Flow at I^2C Mode

Layout Guide

Figure 26 shows the recommended layout pattern around LC709209F. Place CVDD and CREG capacitor near the device. It is permissible to pull the TSENSE pin out of the device over the NF1 pin. Figure 27 shows the position to place the device on the power paths. The resistance of the power paths between the battery or the battery pack and the device affects the gauging.

Place the device to minimize the resistance from PACK+ and PACK−. But it is not necessary to minimize the resistance of the low power paths that is connected only to VDD and VSS of the device.

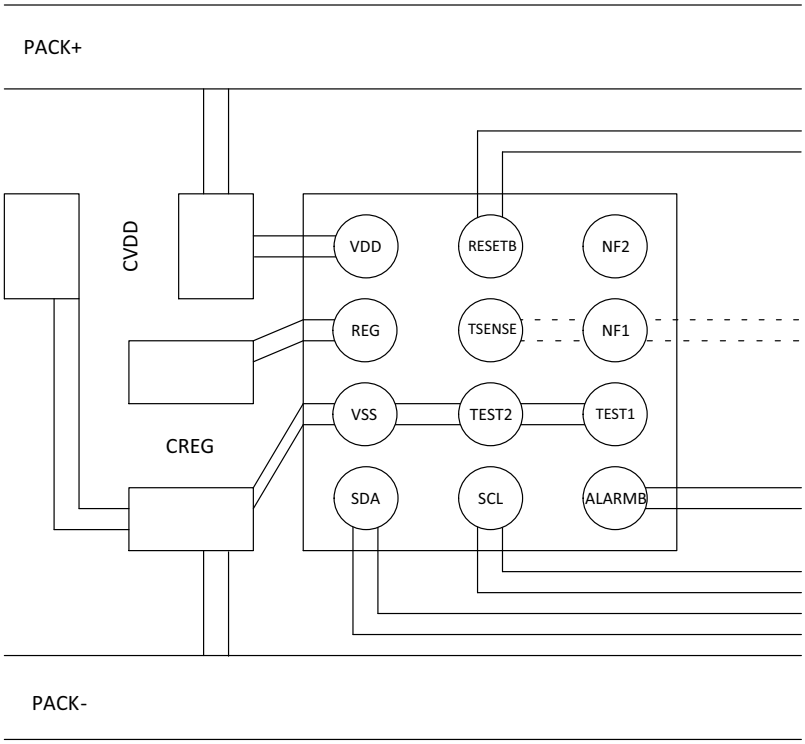


Figure 26. Layout Pattern Example Around LC709209F (Top View)

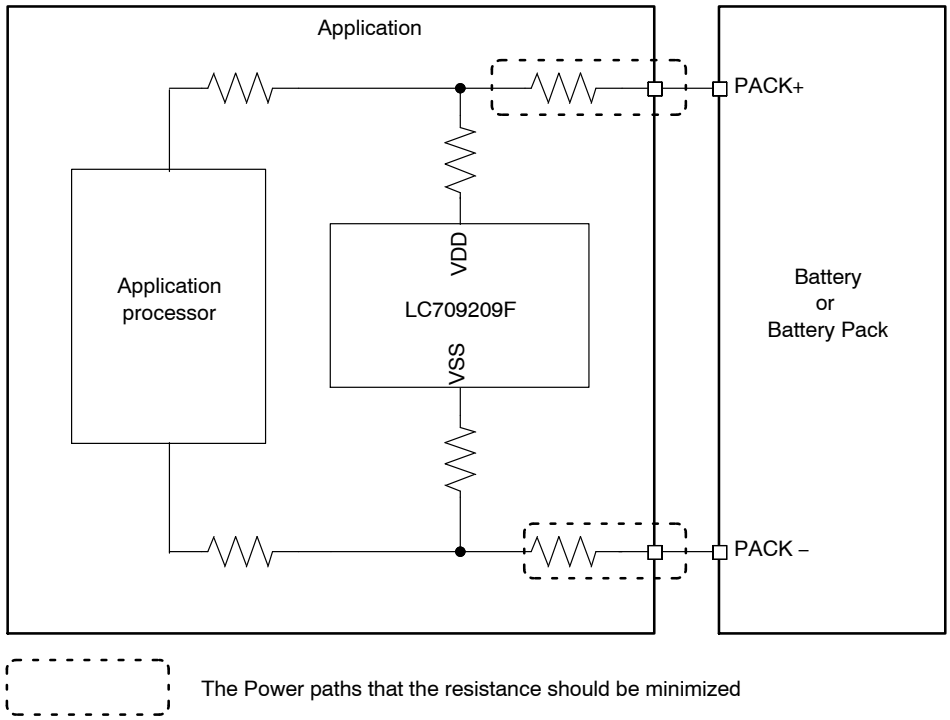


Figure 27. Position to Connect LC709209F on Power Supply Lines

Table 17. ORDERING INFORMATION

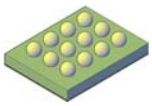
Device	Package	Shipping†
LC709209FXE−01TBG	WLCSP12, 1.48x1.91x0.51 (Pb-Free / Halogen Free)	5 000 / Tape & Reel

†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.

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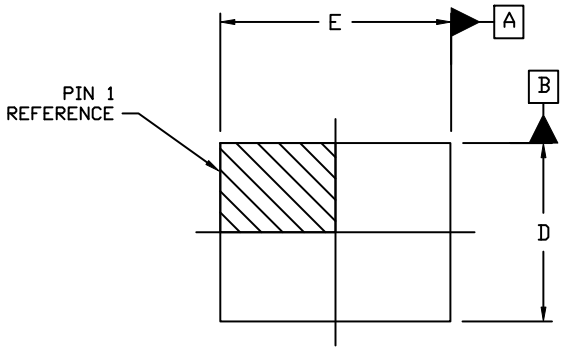
MECHANICAL CASE OUTLINE
PACKAGE DIMENSIONS

ON Semiconductor®

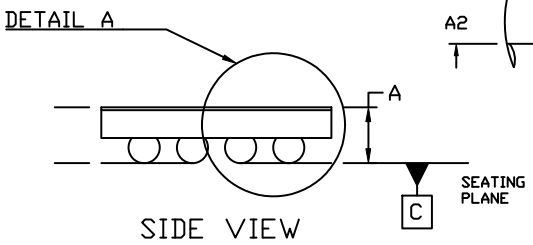


WLCSP12, 1.48x1.91x0.51
CASE 567XE
ISSUE A

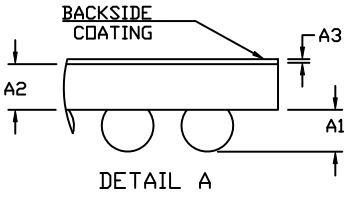
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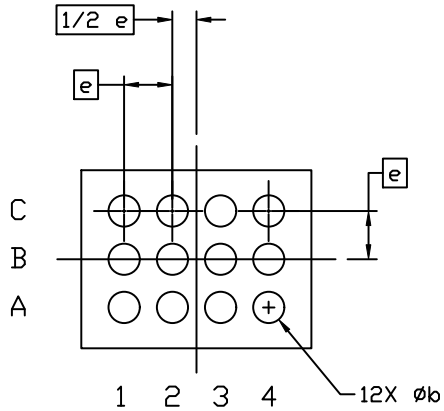
TOP VIEW



SIDE VIEW



DETAIL A

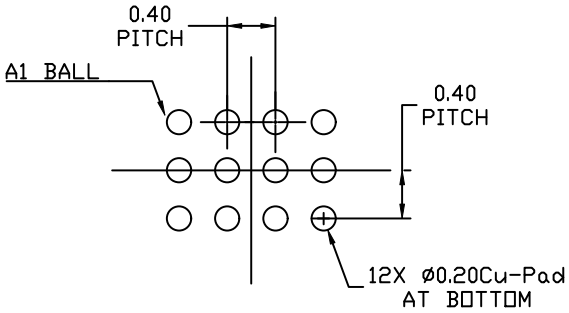


BOTTOM VIEW

NOTES:

1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 2009.
2. CONTROLLING DIMENSION: MILLIMETERS
3. DATUM C, THE SEATING PLANE, IS DEFINED BY THE SPERICAL CROWNS OF THE CONTACT BALLS.
4. COPLANARITY APPLIES TO THE SPHERICAL CROWNS OF THE CONTACT BALLS.
5. DIMENSION b IS MEASURED AT THE MAXIMUM CONTACT BALL DIAMETER PARALLEL TO DATUM C.

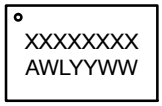
DIM	MILLIMETERS		
	MIN.	NOM.	MAX.
A	---	---	0.510
A1	0.18	0.21	0.24
A2	0.245 REF		
A3	0.025 REF		
b	0.21	0.26	0.31
D	1.43	1.48	1.53
E	1.86	1.91	1.96
e	0.40 BSC		



RECOMMENDED
MOUNTING FOOTPRINT*
(NSMD PAD TYPE)

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

GENERIC MARKING DIAGRAM*



XXXX = Specific Device Code
A = Assembly Location
WL = Wafer Lot
YY = Year
WW = Work Week

*This information is generic. Please refer to device data sheet for actual part marking. Pb−Free indicator, “G” or microdot “▪”, may or may not be present. Some products may not follow the Generic Marking.

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