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# STC3100

## Battery monitor IC with Coulomb counter/gas gauge

### Features

- Battery voltage monitoring
- Internal temperature sensor
- Coulomb counter with 12/14-bit AD converter, +/- 80 mV input voltage range
- Internal or external 32768 Hz time base
- I2C interface for gas gauge monitoring and device control
- 32-RAM bytes
- 8-byte unique device ID
- One general-purpose I/O

### Applications

- Cellular phones, PDA, MP3 players, cordless phones
- Digital cameras, USB appliances, Bluetooth devices

### Description

The STC3100 monitors the critical parameters of a single-cell Li-Ion battery (voltage, temperature and current) and includes hardware functions to implement a gas gauge for battery charge monitoring, based on a programmable 12- to 14-bit A/D converter. With a typical 30 milliOhms external sense resistor, the battery current can be up to 2.5 A and the accumulator system provides a capacity up to +/-7000 mAh with a resolution of 0.2 mAh.

The device is programmable through the I2C interface.

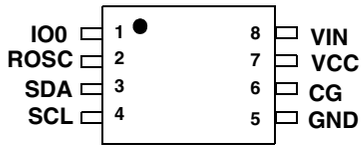


**MiniSO-8**
(Plastic micropackage)



**DFN8 3x3**
(Plastic micropackage)

Pin connections
(top view)

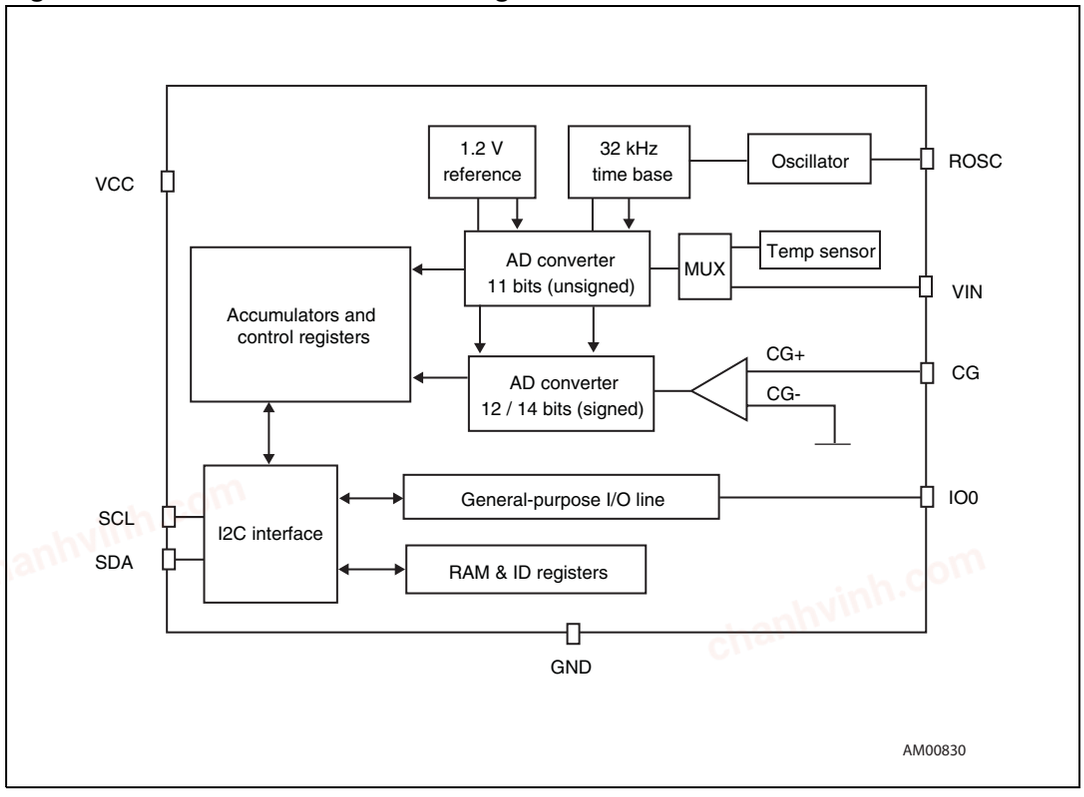


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# 1 Block diagram

**Figure 1. STC3100 internal block diagram**



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# 2 Pin assignment

**Table 1. STC3100 pin description**

| Pin # | Pin name | Type | Function |
|---|---|---|---|
| 1 | IO0 | I/OD | General-purpose I/O |
| 2 | ROSC | I_AD | Oscillator bias resistor or external 32 kHz clock for gas gauge |
| 3 | SDA | I/OD | I2C serial data |
| 4 | SCL | I_D | I2C serial clock |
| 5 | GND | Ground | Analog and digital ground |
| 6 | CG | I_A | Gas gauge current sense input |
| 7 | VCC | Supply | Power supply |
| 8 | VIN | I_A | Battery voltage sense input |

*Note:* *I: input*
*O: output*
*OD: open drain*
*A: analog*
*D: digital*

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# 3 Absolute maximum ratings and operating conditions

**Table 2. Absolute maximum ratings**

| Symbol | Parameter | Value | Unit |
|---|---|---|---|
| Vmax | Maximum voltage on any pin | 7 | V |
| Vio | Voltage on I/O pins | -0.3 to 7 | V |
| Tstg | Storage temperature | -55 to 150 | °C |
| Tj | Maximum junction temperature | 150 | °C |
| ESD | Electrostatic discharge (HBM human body model) | 2 | kV |

**Table 3. Operating conditions**

| Symbol | Parameter | Value | Unit |
|---|---|---|---|
| Vcc | Operating supply voltage on $V_{CC}$ | 2.7 to 5.5 | V |
| Vin | Input voltage on Vin | 0 to Vcc | V |
| Vmin | Minimum voltage on $V_{CC}$ for RAM content retention | 2.0 | V |
| Toper | Operating free air temperature range | -40 to 85 | °C |

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# 4 Electrical characteristics

**Table 4. Electrical characteristics (2.7 V < $V_{CC}$ < 4.5 V, -20° C to 70° C)**

| Symbol | Parameter | Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| **Supply** | | | | | | |
| $I_{CC}$ | Operating current consumption | Average value over 4s | | | 100 | uA |
| Istby | Current consumption in standby | standby mode, inputs=0V | | | 2 | uA |
| Ipdn | Current consumption in power down | $V_{CC}$ < UVLOth, inputs=0V | | | 1 | uA |
| UVLOth | Undervoltage threshold | ($V_{CC}$ decreasing) | 2.5 | 2.6 | 2.7 | V |
| UVLOhyst | Undervoltage threshold hysteresis | | | 100 | | mV |
| POR | Power-on reset threshold | ($V_{CC}$ decreasing) | | 2.0 | | V |
| **Gas gauge A/D converter** | | | | | | |
| Vin_gg | Input voltage range | | -80 | | +80 | mV |
| Iin | Input current for CG pin | | | | 500 | nA |
| ADC_res | AD converter granularity | 12 bits<br>13 bits<br>14 bits | | 47.08<br>23.54<br>11.77 | | uV<br>uV<br>uV |
| ADC_offset | AD converter offset | CG = 0V<br>12 bits<br>13 bits<br>14 bits | <br>-2<br>-2<br>-3 | | <br>2<br>2<br>3 | <br>LSB<br>LSB<br>LSB |
| ADC_time | AD conversion time (32768Hz clock) | 12 bits<br>13 bits<br>14 bits | | 125<br>250<br>500 | | ms<br>ms<br>ms |
| ADC_acc | AD converter gain accuracy at full scale | 25° C<br>over temperature range | | | 0.5<br>1 | %<br>% |
| Fosc | Internal time base frequency | Rosc = 200 kΩ 0.1% | | 32768 | | Hz |
| Osc_acc | Internal time base accuracy | 25° C, $V_{CC}$ = 3.6 V<br>over temperature and voltage ranges | | | 2<br>2.5 | %<br>% |
| Fosc_ext | External time base frequency range | | 30 | | 70 | kHz |
| Cur_res | Current register LSB value | | | 11.77 | | uV |
| Chg_res | Charge register LSB value (32,768 Hz clock) | =Cur_res*2^12*0.5/3600 | | 6.70 | | uV.h |
| Global_ CG_acc | Gas gauge accuracy (not including the external sense resistor tolerance) | Using internal time base<br>Using external time base | | | 3.5<br>1 | %<br>% |

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**Table 4. Electrical characteristics (2.7 V < $V_{CC}$ < 4.5 V, -20° C to 70° C) (continued)**

| Symbol | Parameter | Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| **Battery voltage and temperature a/d converter** | | | | | | |
| Vin_adc | Input voltage range | Vcc = 5 V | 0 | | 5 | V |
| LSB | LSB value | Voltage measurement<br>Temperature measurement | | 2.44<br>0.125 | | mV<br>°C |
| ADC_time | AD conversion time (32,768 Hz clock) | | | 250 | | ms |
| Volt_acc | Battery voltage measurement accuracy | 2.7 V<Vin<4.5 V, $V_{CC}$=Vin | -0.5 | | +0.5 | % |
| Temp_acc | Internal temperature sensor accuracy | | -3 | | +3 | °C |
| **Digital I/O pins (SCL, SDA, IO0)** | | | | | | |
| Vih | Input logic high | | 1.2 | | | V |
| Vil | Input logic low | | | | 0.35 | V |
| Vol | Output logic low (SDA, IO0) | Iol = 4 mA | | | 0.4 | V |

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# 5 Typical performance curves

**Figure 2. Standby current vs. temperature**

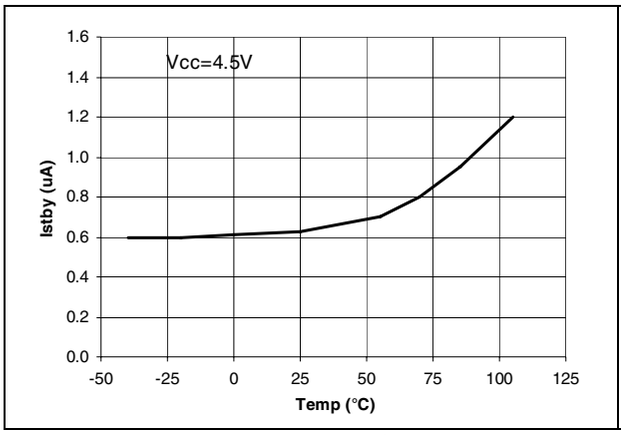



**Figure 3. Current measurement accuracy vs. temperature**

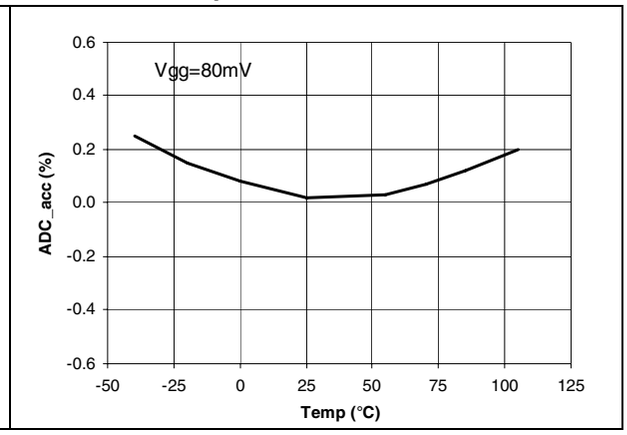



**Figure 4. Oscillator frequency accuracy vs. temperature**

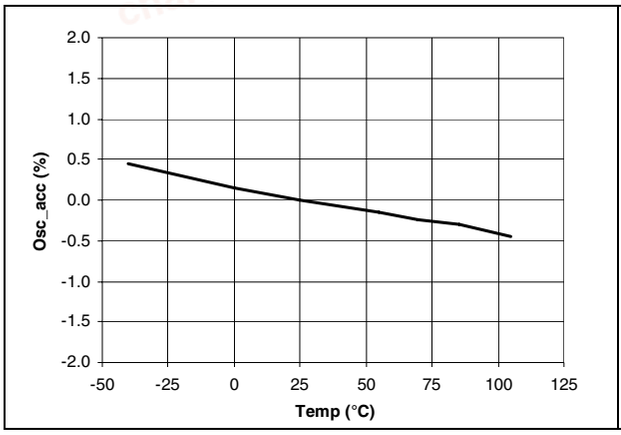
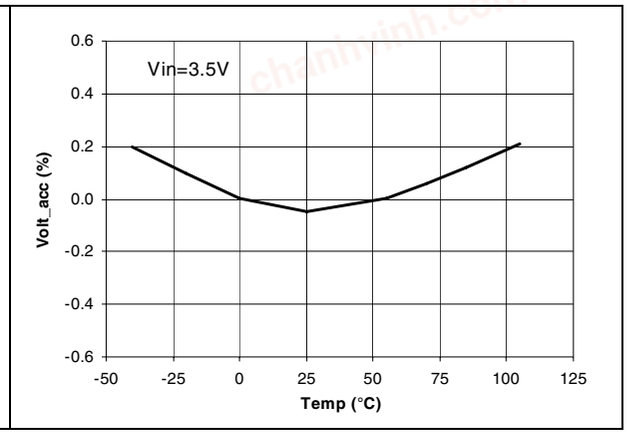



**Figure 5. Voltage measurement accuracy vs. temperature**



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# 6 Application information

**Figure 6. Example of an application schematic using the STC3100**

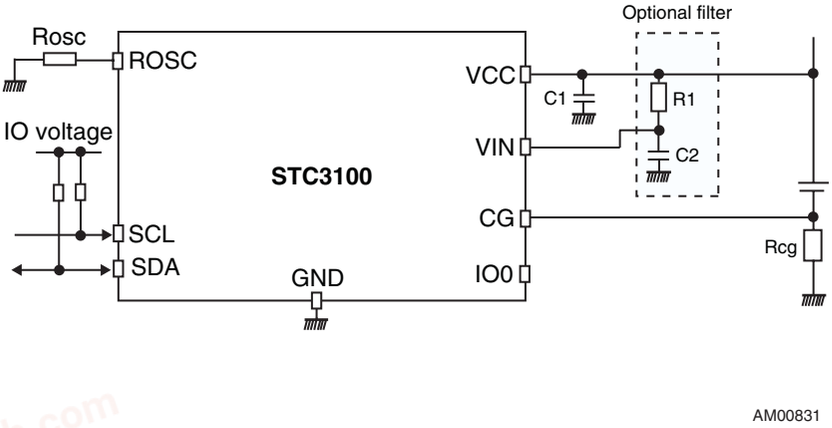



**Table 5. External components list**

| Name | Value | Tolerance | Comments |
|---|---|---|---|
| Rcg | 10 to 50 mΩ | 1% | Gas gauge sense resistor |
| Rosc | 200 kΩ | 0.1% | Internal oscillator bias resistor |
| C1 | 1 µF | | Supply decoupling capacitor |
| C2 | 220 nF | | Battery voltage input filter (optional) |
| R1 | 1 kΩ | | Battery voltage input filter (optional) |

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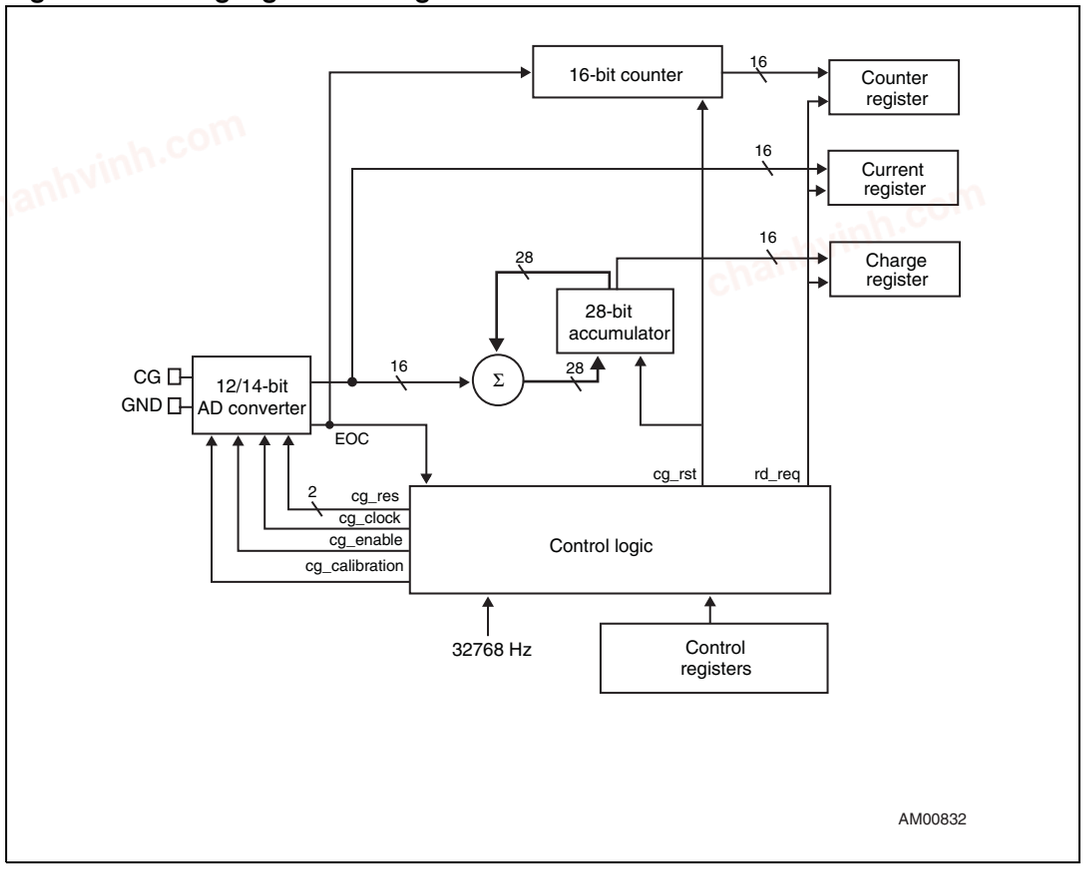
# 7 Functional description

## 7.1 Gas gauge

The gas gauge is used to monitor the available battery capacity. The voltage drop across the external sense resistor is integrated during a conversion period and input to a 12- to 14-bit AD converter. The output conversion is accumulated into a 28-bit accumulator. The system controller can control the gas gauge and read the data (upper 16 bits of the accumulator) through the I2C control registers.

The AD converter output is in two's complement format. When a conversion cycle is completed, the result is added to the charge accumulator and the number of conversions is incremented in a 16-bit counter.

**Figure 7. Gas gauge block diagram**




The controller can read the value of the most recent conversion in two's complement format by reading the REG_CURRENT registers. These registers are updated at the end of each conversion.

The differential inputs are scaled to the full range of the AD converter, introducing a small offset error. A high value written to the CG_CAL bit of the control register connects the inputs of the AD converter together, allowing the controller to measure the digital offset error. Using this measurement, one can calibrate the gas gauge and reduce errors due to the internal offset error.

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The conversion cycle for n bit resolution is $2^n$ clock cycles. Using the 32,768 Hz internal clock, the conversion cycle time is 125 to 500 ms for a 12- to 14-bit resolution. The LSB value is set by the internal gain and internal reference and is 11.77 uV at maximum resolutions. When using an external 30 milliOhms sense resistor, the 28-bit accumulator results in a capacity of approximately +/- 7300 mA.h. The upper 16 bits of the accumulator can be read from the I2C interface, giving a resolution of 0.2 mA.h.

When the battery voltage falls below the under voltage lockout threshold at 2.7 V, the gas gauge system is stopped and the STC3100 stays in standby mode with minimum quiescent current. All registers are maintained down to 2.0 V. Below 2.0 V, the registers are reset to their default power-on value.

The gas gauge system needs an accurate 32,768 Hz timebase to compute the level of charge flowing from/to the battery. The STC3100 can operate from an internal oscillator, or use an external RTC signal for highest accuracy.

## 7.2 Battery voltage and temperature monitoring

The battery voltage and chip temperature (close to the battery temperature) are measured by means of an A/D converter and a multiplexer. This function takes place concurrently to the gas gauge function with a dedicated A/D converter, which means that it does not affect the performance of the gas gauge. To reduce the power consumption, a conversion takes place only every two seconds, alternatively for battery voltage and temperature (so each value is refreshed every four seconds).
The conversion cycle takes $2^{13}$ = 8192 clock cycles. Using the 32,768 Hz internal clock, the conversion cycle time is 250 ms. The resolution is 2.44 mV for the battery voltage and 0.125° C for the temperature.

## 7.3 General-purpose input/output

A general-purpose I/O line is available. The output is an open drain, and an external pull-up resistor may be needed in the application. Writing the IO0DATA bit to 0 forces the IO0 output low; writing the IO0DATA bit to 1 leaves the IO0 output in a high impedance state. Reading the IO0DATA bit gives the state of the IO0 pin.
In standby (CG_RUN=0), reset (PORDET set to 1) and power-down (Vcc<UVLOth) states, the IO0 output is open and the input is read as zero whatever is the actual state of the IO0 pin.

## 7.4 RAM registers

The STC3100 provides 32 RAM registers to store any information regarding battery status, charge cycles, battery aging, proprietary informations, etc...
The register content is maintained during standby and low voltage states, down to the power-on reset level of approximately 2.0 V. Below this level, the content is not preserved. This usually means that the Li-Ion cell was very deeply discharged and has been damaged.

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## 7.5 Unique device ID

The STC3100 provides a means to identify the battery pack or the subsystem. Each device has its own unique 8-byte ID made of an 8-bit part ID (value = 10h for the STC3100), a 48-bit random unique ID and an 8-bit CRC.

The CRC-8 is calculated according to bytes REG_ID0 to REG_ID6 using the "x8 + x2 + x + 1" polynomial with a zero initial value.

Since the device ID is downloaded from the ROM at power-up and is subsequently kept in read-only RAM locations together with the general-purpose RAM registers, the device ID can also be used as an indicator of the RAM integrity.

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# 8 I2C interface

## 8.1 Read and write operations

The interface is used to control and read the current accumulator and registers. It is compatible with the Philips I2C registered trademark (version 2.1). It is a slave serial interface with a serial data line (SDA) and a serial clock line (SCL).

- SCL: input clock used to shift data.
- SDA: input/output bidirectional data transfers.

A filter rejects the potential spikes on the bus data line to preserve data integrity.

The bidirectional data line supports transfers up to 400 kbit/s (fast mode). The data is shifted to and from the chip on the SDA line, MSB first.

The first bit must be high (START) followed by the device address and read/write bit control. Bits DevADDR0 to DevADDR2 are factory-programmable, the default device address value being 70h (AddrID0 = AddrID1 = AddrID2 = 0). The STC3100 then sends an acknowledge at the end of an 8-bit long sequence. The next 8 bits correspond to the register address followed by another acknowledge.

The data field is the last 8-bit long sequence sent, followed by a last acknowledge.

**Table 6. Device address format**

| b7 | b6 | b5 | b4 | b3 | b2 | b1 | b0 |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 0 | DevADDR2 | DevADDR1 | DevADDR0 | R/W |

**Table 7. Register address format**

| b7 | b6 | b5 | b4 | b3 | b2 | b1 | b0 |
|---|---|---|---|---|---|---|---|
| RegADDR7 | RegADDR6 | RegADDR5 | RegADDR4 | RegADDR3 | RegADDR2 | RegADDR1 | RegADDR0 |

**Table 8. Register data format**

| b7 | b6 | b5 | b4 | b3 | b2 | b1 | b0 |
|---|---|---|---|---|---|---|---|
| DATA7 | DATA6 | DATA5 | DATA4 | DATA3 | DATA2 | DATA1 | DATA0 |

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**Figure 8. Read operation**

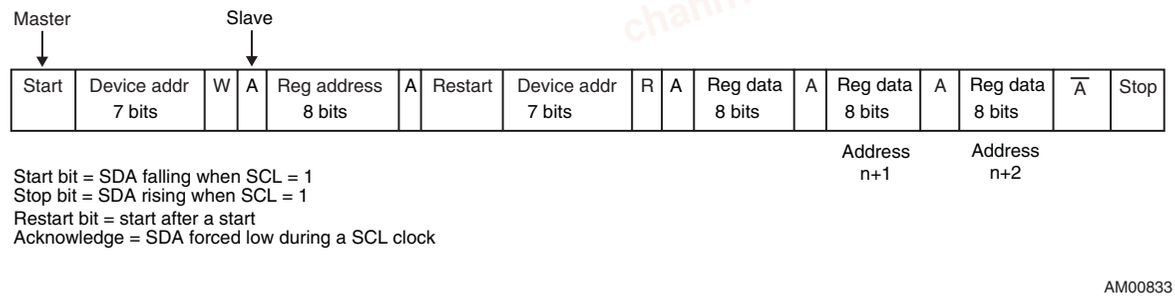
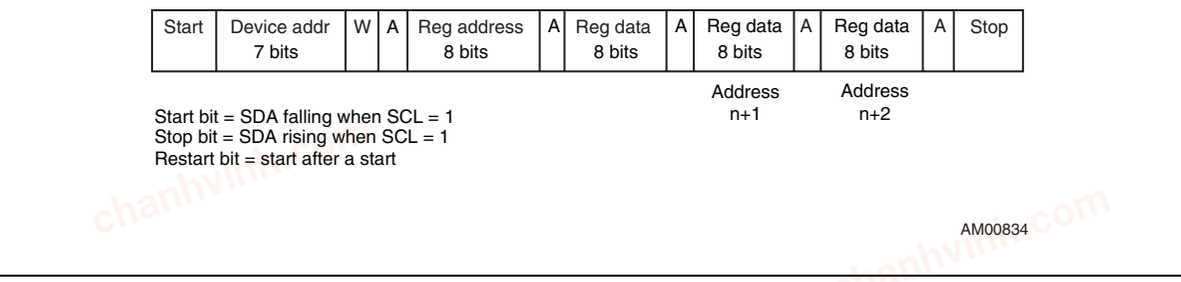



**Figure 9. Write operation**



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## 8.2 Register map

The register space provides 12 control registers, 8 read-only (factory OTP) registers for unique device ID and 32 read/write general-purpose RAM registers. Mapping of all registers is shown in *Table 9*. Detailed descriptions of registers 0 (REG_MODE) and 1 (REG_CTRL) are shown in *Table 10* and *Table 11*. All registers are reset to default values at power-on or reset, and the PORDET bit in register REG_CTRL is used to indicate the occurrence of a power-on reset.

**Table 9. Register map**

| Name | Address (decimal) | Type | Description |
|---|---|---|---|
| **Control registers** | 0 to 23 | | |
| REG_MODE | 0 | R/W | Mode register |
| REG_CTRL | 1 | R/W | Control and status register |
| REG_CHARGE_LOW | 2 | R | Gas gauge charge data, bits 0-7 |
| REG_CHARGE_HIGH | 3 | R | Gas gauge charge data, bits 8-15 |
| REG_COUNTER_LOW | 4 | R | Number of conversions, bits 0-7 |
| REG_COUNTER_HIGH | 5 | R | Number of conversions, bits 8-15 |
| REG_CURRENT_LOW | 6 | R | Battery current value, bits 0-7 |
| REG_CURRENT_HIGH | 7 | R | Battery current value, bits 8-15 |
| REG_VOLTAGE_LOW | 8 | R | Battery voltage value, bits 0-7 |
| REG_VOLTAGE_HIGH | 9 | R | Battery voltage value, bits 8-15 |
| REG_TEMPERATURE_LOW | 10 | R | Temperature value, bits 0-7 |
| REG_TEMPERATURE_HIGH | 11 | R | Temperature value, bits 8-15 |
| **Device ID registers** | 24 to 31 | | |
| REG_ID0 | 24 | R | Part type ID = 10h |
| REG_ID1 | 25 | R | Unique part ID, bits 0-7 |
| REG_ID2 | 26 | R | Unique part ID, bits 8-15 |
| REG_ID3 | 27 | R | Unique part ID, bits 16-23 |
| REG_ID4 | 28 | R | Unique part ID, bits 24-31 |
| REG_ID5 | 29 | R | Unique part ID, bits 32-39 |
| REG_ID6 | 30 | R | Unique part ID, bits 40-47 |
| REG_ID7 | 31 | R | Device ID CRC |
| **RAM registers** | 32 to 63 | | |
| REG_RAM0 | 32 | R/W | General-purpose RAM register 0 |
| ... | ... | | ... |
| REG_RAM31 | 63 | R/W | General-purpose RAM register 31 |

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Values held in consecutive registers (such as the charge value in the REG_CHARGE_LOW and REG_CHARGE_HIGH registers) must be read with a single I2C access to ensure data integrity. It is possible to read multiple values in one I2C access, all values will be consistent.

The charge data is coded in 2's complement format, and the LSB value is 6.70 uV.h.
The battery current is coded in 2's complement format, and the LSB value is 11.77 uV. In 13-bit resolution mode, the 0 bit is always set to zero. In 12-bit resolution, bits 0 and 1 are always set to zero.
The battery voltage is coded in binary format, and the LSB value is 2.44 mV.
The temperature value is coded in 2's complement format, and the LSB value is 0.125° C.
The temperature of 0° C corresponds to code 0.

**Table 10. REG_MODE - address 0**

| Name | Pos. | Type | Def. | Description |
|---|---|---|---|---|
| SEL_EXT_CLK | 0 | R/W | 0 | 32,768 Hz clock source:<br>0: auto-detect, 1: external clock |
| GG_RES | [2,1] | R/W | 00 | Gas gauge ADC resolution:<br>00:14 bits, 01:13 bits, 10:12 bits |
| GG_CAL | 3 | R/W | 0 | 0: no effect<br>1: used to calibrate the AD converters |
| GG_RUN | 4 | R/W | 0 | 0: standby mode. Accumulator and counter registers are frozen, gas gauge and battery monitor functions are in standby.<br>1: operating mode. |
| | [7..5] | | | Unused |

**Table 11. REG_CTRL - address 1**

| Name | Pos. | Type | Def. | Description |
|---|---|---|---|---|
| IO0DATA | 0 | R | X | Port IO0 data status:<br>0 = IO0 input is low, 1 = IO0 input is high |
| | | W | 1 | Port IO0 data output drive:<br>0 = IO0 output is driven low,1 = IO0 output is open |
| GG_RST | 1 | W | 0 | 0: no effect<br>1: resets the charge accumulator and conversion counter. GG_RST is a self-clearing bit. |
| GG_EOC | 2 | R | 1 | Set at the end of a battery current conversion cycle. Clears upon reading. |
| VTM_EOC | 3 | R | 1 | Set at the end of a battery voltage or temperature conversion cycle. Clears upon reading. |
| PORDET | 4 | R | 1 | Power on reset (POR) detection bit:<br>0 = no POR event occurred,<br>1 = POR event occurred |
| | | W | 0 | Soft reset:<br>0 = release the soft-reset and clear the POR detection bit, 1 = assert the soft-reset and set the POR detection bit. |
| | [7..5] | | | Unused |

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# 9 Package information

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK® packages, depending on their level of environmental compliance. ECOPACK® specifications, grade definitions and product status are available at: www.st.com. ECOPACK® is an ST trademark.

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## 9.1 MiniSO-8 package information

**Figure 10. MiniSO-8 package mechanical drawing**

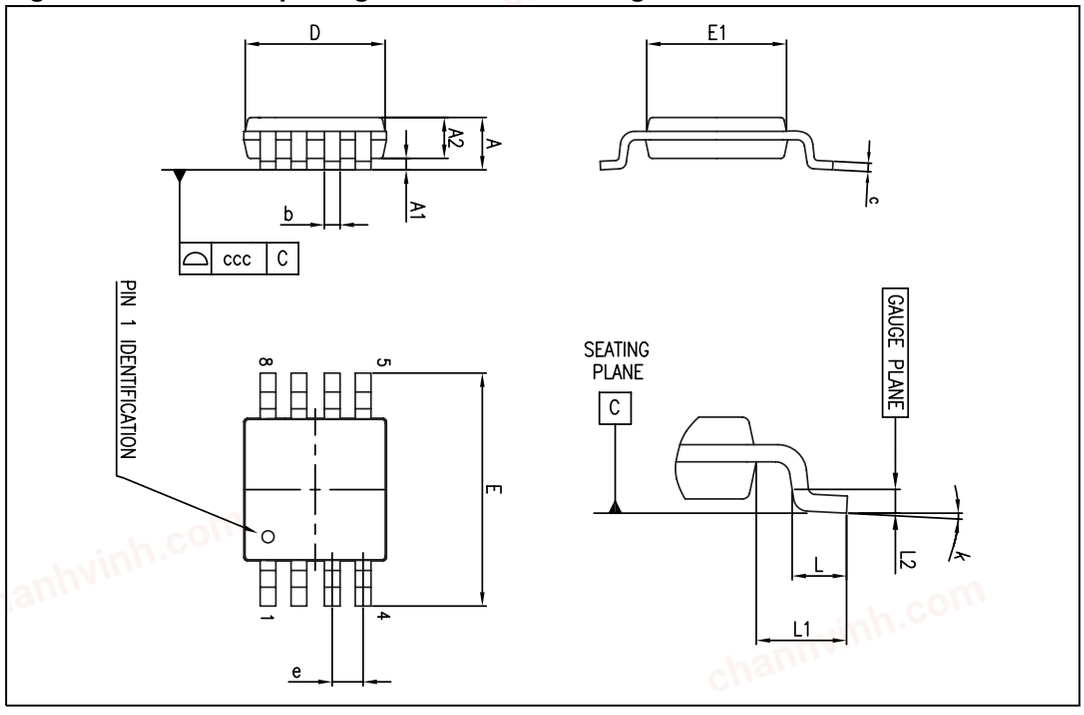



**Table 12. Miniso-8 package mechanical data**

| Ref. | Dimensions | | | | | |
|---|---|---|---|---|---|---|
| | Millimeters | | | Inches | | |
| | Min. | Typ. | Max. | Min. | Typ. | Max. |
| A | | | 1.10 | | | 0.043 |
| A1 | | | 0.15 | | | 0.006 |
| A2 | 0.75 | 0.85 | 0.95 | 0.030 | 0.033 | 0.037 |
| b | 0.22 | | 0.40 | 0.009 | | 0.016 |
| c | 0.08 | | 0.23 | 0.003 | | 0.009 |
| D | 2.80 | 3.00 | 3.20 | 0.110 | 0.118 | 0.126 |
| E | 4.65 | 4.90 | 5.15 | 0.183 | 0.193 | 0.203 |
| E1 | 2.80 | 3.00 | 3.10 | 0.110 | 0.118 | 0.122 |
| e | | 0.65 | | | 0.026 | |
| L | 0.40 | 0.60 | 0.80 | 0.016 | 0.024 | 0.031 |
| L1 | | 0.95 | | | 0.037 | |
| L2 | | 0.25 | | | 0.010 | |
| k | 0 | | 8 | | | |
| ccc | | | 0.10 | | | 0.004 |

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## 9.2 DFN8 package information

**Figure 11. DFN8 3x3x1.0 mm package mechanical drawing (pitch 0.5 mm)**

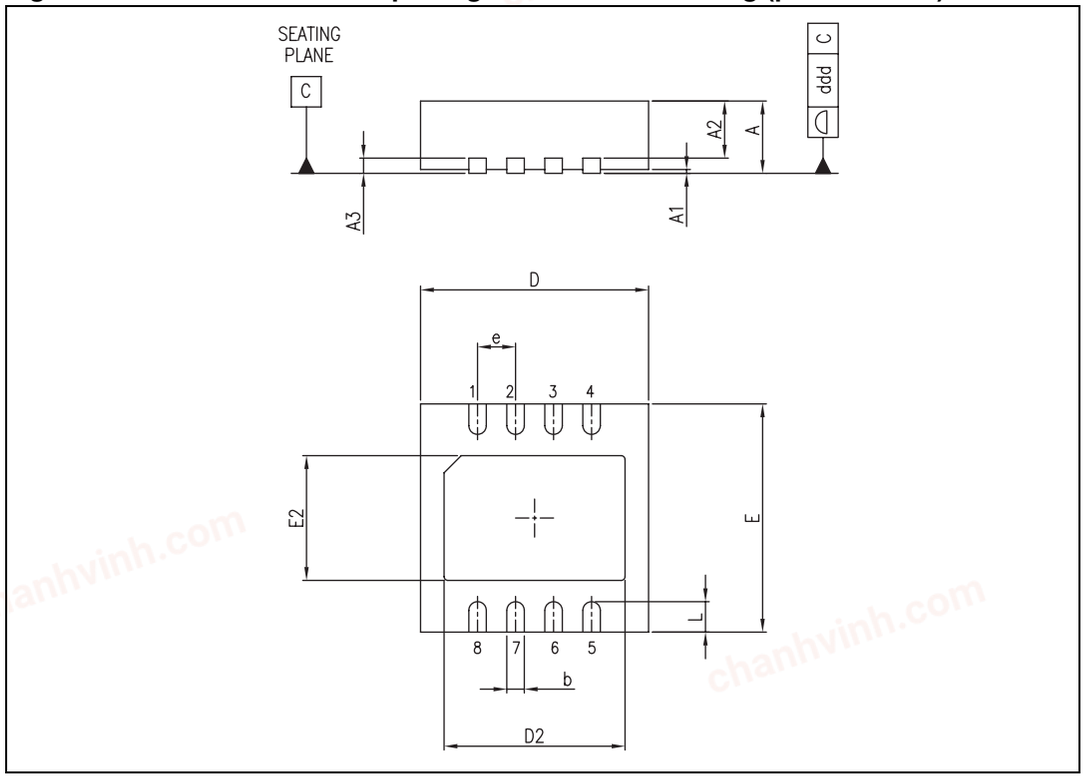



**Table 13. DFN8 3x3x1.0 mm package mechanical data (pitch 0.5 mm)**

| Ref. | Dimensions | | | | | |
|---|---|---|---|---|---|---|
| | Millimeters | | | Inches | | |
| | Min. | Typ. | Max. | Min. | Typ. | Max. |
| A | 0.80 | 0.90 | 1.00 | 0.031 | 0.035 | 0.039 |
| A1 | | 0.02 | 0.05 | | 0.0008 | 0.0019 |
| A2 | 0.55 | 0.65 | 0.80 | 0.021 | 0.025 | 0.031 |
| A3 | | 0.20 | | | 0.008 | |
| b | 0.18 | 0.25 | 0.30 | 0.007 | 0.010 | 0.012 |
| D | 2.85 | 3.00 | 3.15 | 0.112 | 0.118 | 0.124 |
| D2 | 2.20 | | 2.70 | 0.087 | | 0.106 |
| E | 2.85 | 3.00 | 3.15 | 0.112 | 0.118 | 0.124 |
| E2 | 1.40 | | 1.75 | 0.055 | | 0.069 |
| e | | 0.50 | | | 0.020 | |
| L | 0.30 | 0.40 | 0.50 | 0.012 | 0.016 | 0.020 |
| ddd | | | 0.08 | | | 0.003 |

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# 10 Ordering information

**Table 14. Order codes**

| Part number | Temperature range | Package | Packing | Marking |
|---|---|---|---|---|
| STC3100IST | -40°C, +85°C | MiniSO-8 | Tape & reel | O201 |
| STC3100IQT | | DFN8 3 x 3 | | |

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# 11 Revision history

Table 15. Document revision history

| Date | Revision | Changes |
|---|---|---|
| 27-Jan-2009 | 1 | Initial release. |

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