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

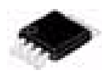
Applications

- 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.

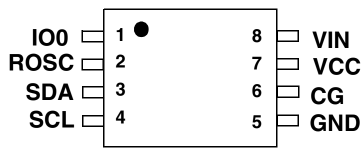
The device is programmable through the I2C interface.



MiniSO-8
(Plastic micropackage)

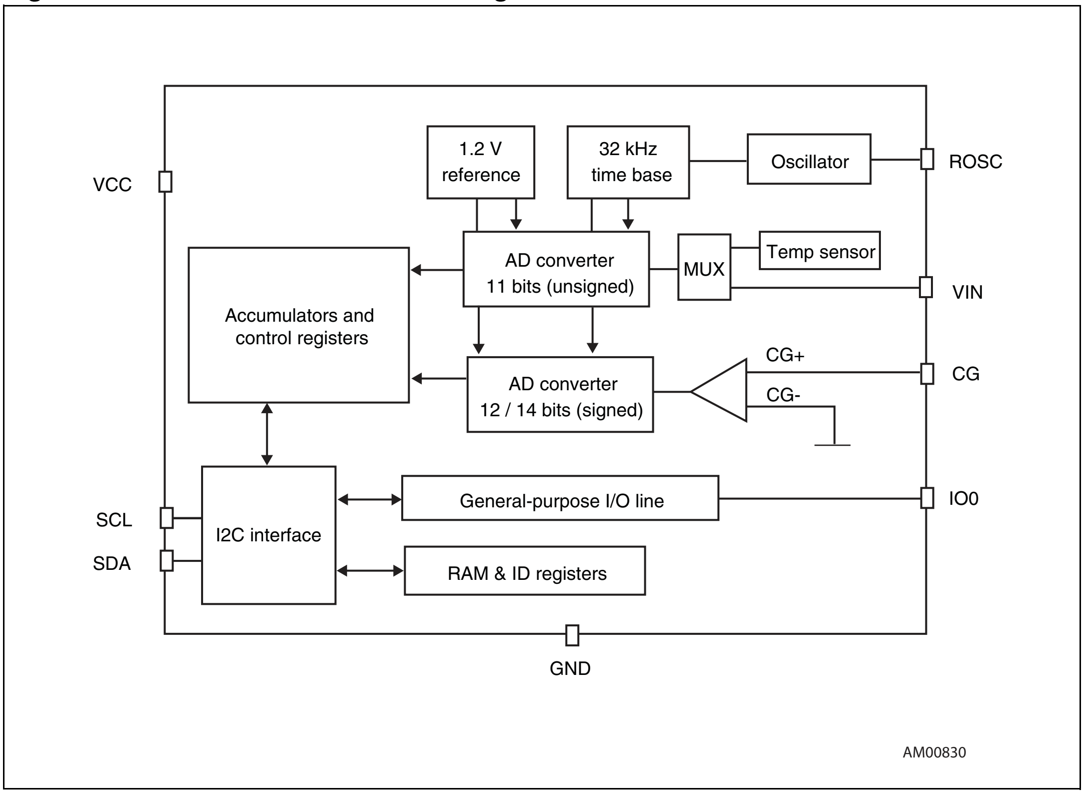
DFN8 3x3
(Plastic micropackage)

Pin connections
(top view)



1 Block diagram

Figure 1. STC3100 internal block diagram



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

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

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 13 bits 14 bits		47.08 23.54 11.77		uV uV uV
ADC_offset	AD converter offset	CG = 0V 12 bits 13 bits 14 bits	 -2 -2 -3		 2 2 3	 LSB LSB LSB
ADC_time	AD conversion time (32768Hz clock)	12 bits 13 bits 14 bits		125 250 500		ms ms ms
ADC_acc	AD converter gain accuracy at full scale	25° C over temperature range			0.5 1	% %
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 over temperature and voltage ranges			2 2.5	% %
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 Using external time base			3.5 1	% %

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 Temperature measurement		2.44 0.125		mV °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

5 Typical performance curves

Figure 2. Standby current vs. temperature

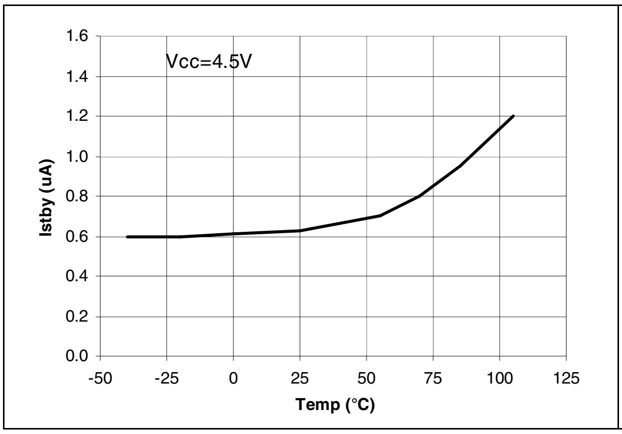


Figure 3. Current measurement accuracy vs. temperature

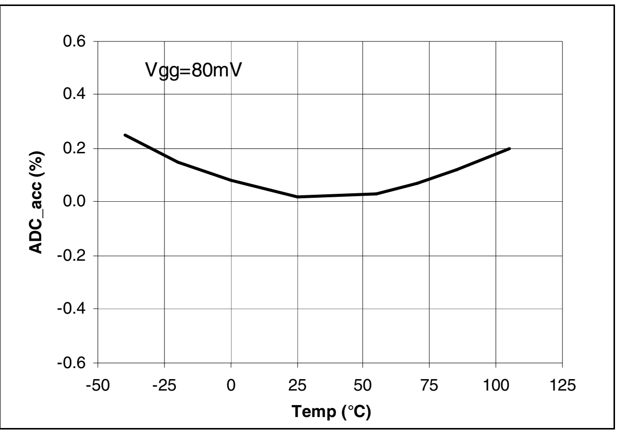


Figure 4. Oscillator frequency accuracy vs. temperature

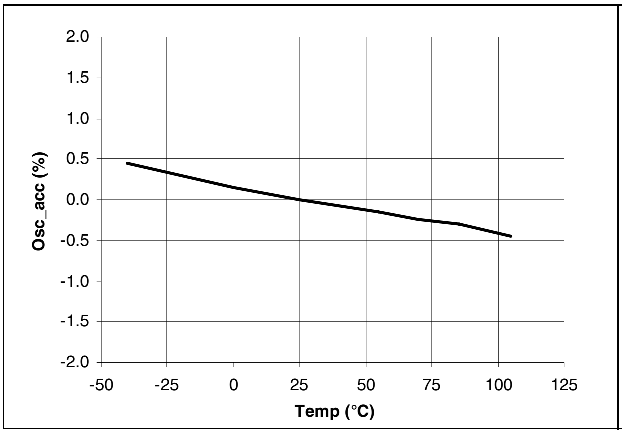
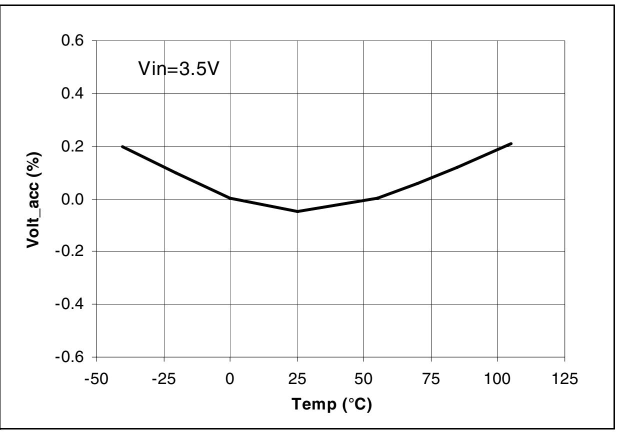


Figure 5. Voltage measurement accuracy vs. temperature



6 Application information

Figure 6. Example of an application schematic using the STC3100

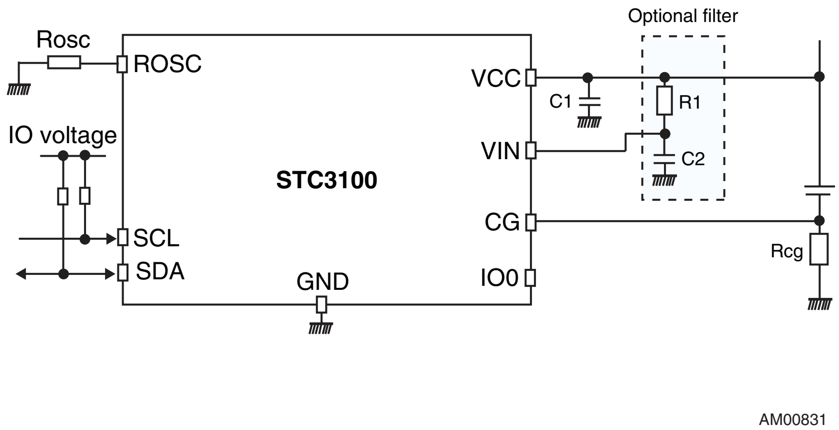


Table 5. External components list

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)

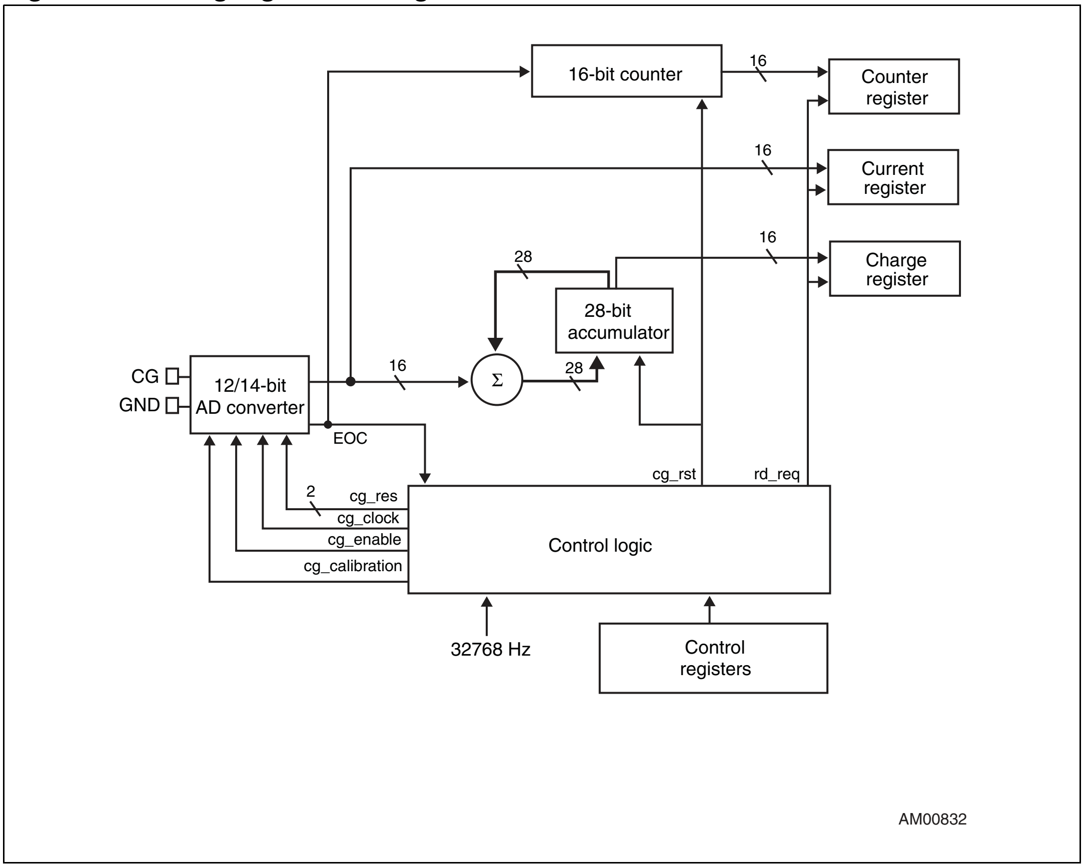
7 Functional description

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.

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.

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.

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

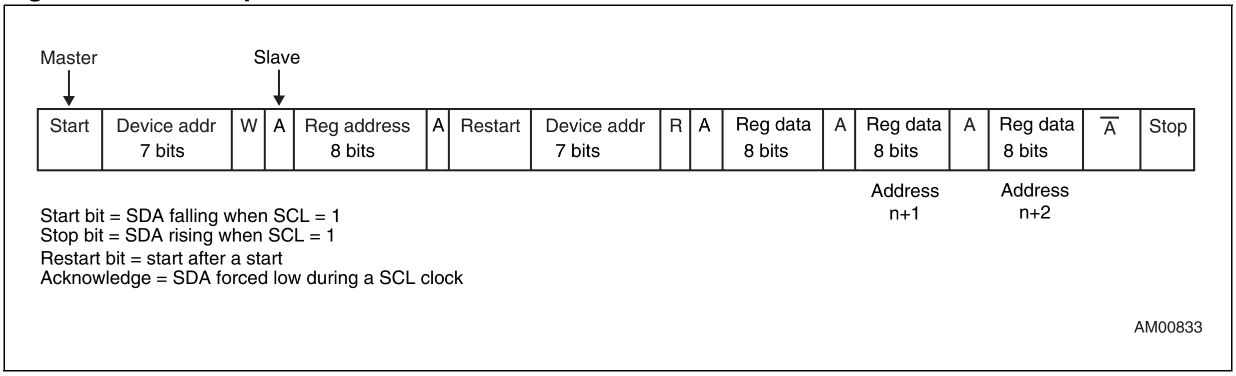


Figure 8. Read operation

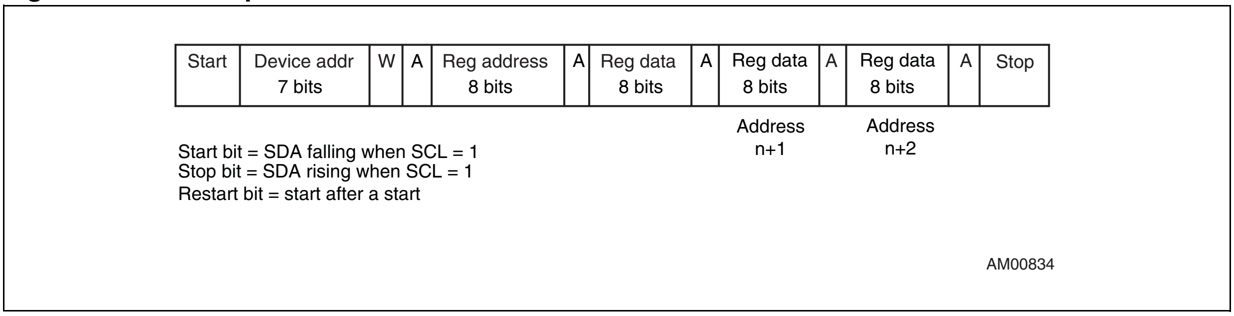


Figure 9. Write operation

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

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: 0: auto-detect, 1: external clock
GG_RES	[2,1]	R/W	00	Gas gauge ADC resolution: 00:14 bits, 01:13 bits, 10:12 bits
GG_CAL	3	R/W	0	0: no effect 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. 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: 0 = IO0 input is low, 1 = IO0 input is high
		W	1	Port IO0 data output drive: 0 = IO0 output is driven low,1 = IO0 output is open
GG_RST	1	W	0	0: no effect 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: 0 = no POR event occurred, 1 = POR event occurred
		W	0	Soft reset: 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

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.

9.1 MiniSO-8 package information

Figure 10. MiniSO-8 package mechanical drawing

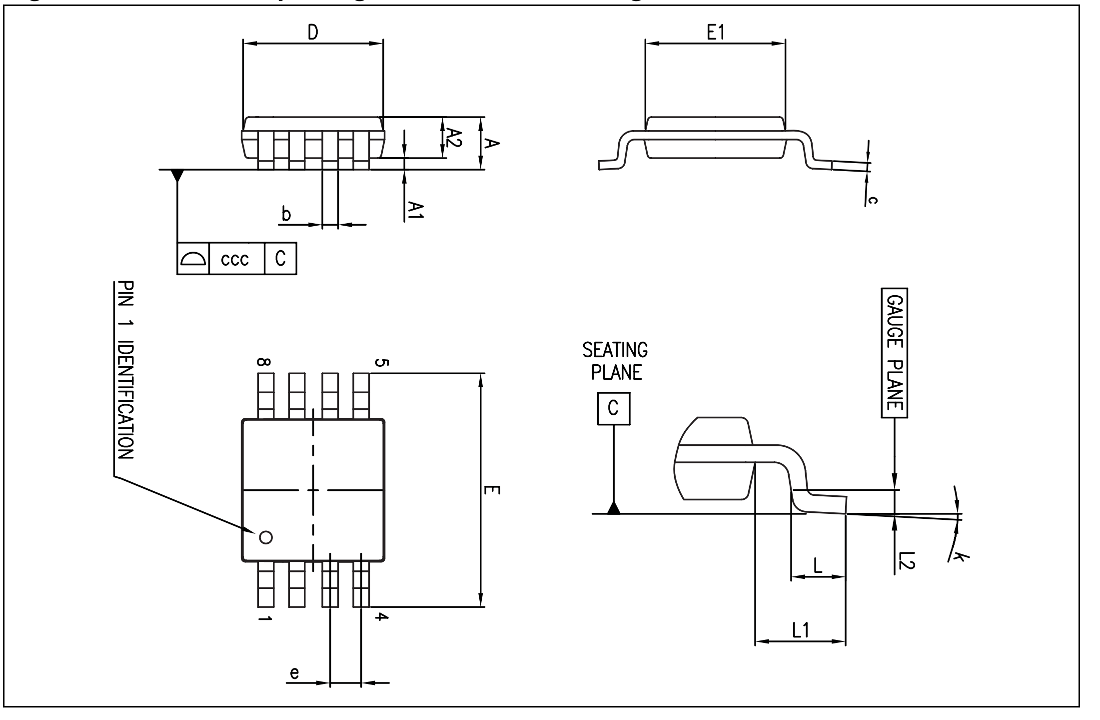


Table 12. Miniso-8 package mechanical data

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

9.2 DFN8 package information

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

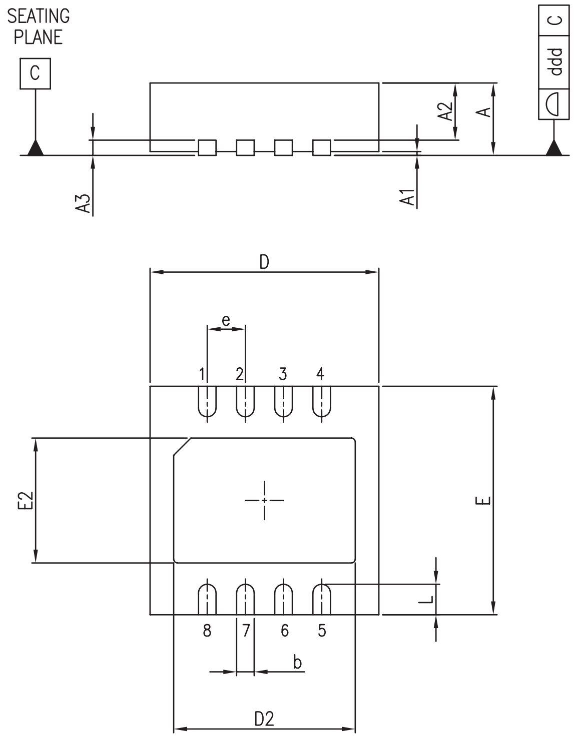


Table 13. DFN8 3x3x1.0 mm package mechanical data (pitch 0.5 mm)

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

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		

11 Revision history

Table 15. Document revision history

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