1 INTRODUCTION

1.1 FEATURES

- Battery Fuel Gauge for 1-Series Li-Ion Applications
- Microcontroller Peripheral Provides:
  - Accurate Battery Fuel Gauging
  - Internal Temperature Sensor for System Temperature Reporting
  - SHA-1/HMAC Authentication
  - 96 bytes of Non-Volatile Scratch Pad FLASH
- Battery Fuel Gauging Based on Patented Impedance Track™ Technology
  - Models Battery Discharge Curve for Accurate Time-To-Empty predictions
  - Automatically Adjusts for Battery Aging, Battery Self-Discharge, and Temperature/Rate Inefficiencies
  - Low-Value Sense Resistor (10mΩ or less)
- SDQ, HDQ, and I²C™ Interface Formats for Communication with Host System
- Small 12-pin 2,5mm x 4mm SON Package

1.2 APPLICATIONS

- Smartphones
- PDAs
- Digital Still and Video Cameras
- Handheld Terminals
- MP3 or Multimedia Players

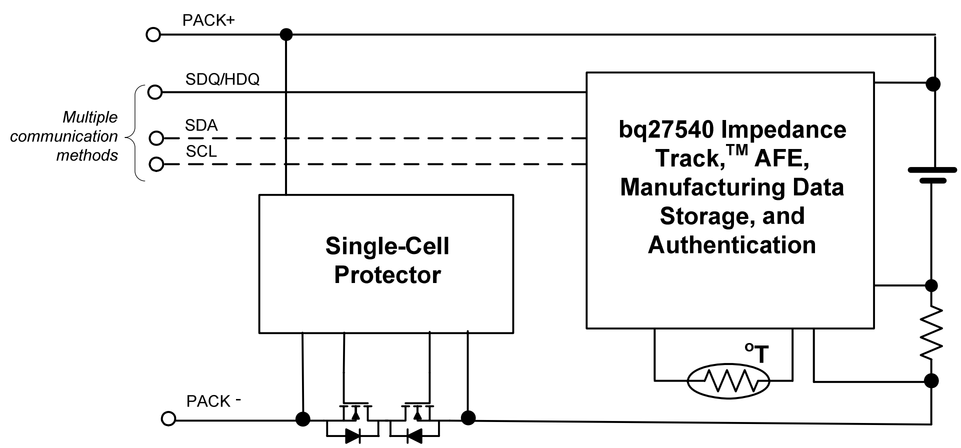
1.3 DESCRIPTION

The Texas Instruments bq27540 Li-Ion battery fuel gauge is a microcontroller peripheral that provides fuel gauging for single-cell Li-Ion battery packs. The device requires little system microcontroller firmware development for accurate battery fuel gauging. The bq27540 resides within the battery pack or on the system's main-board with an embedded battery (non-removable).

The bq27540 uses the patented Impedance Track™ algorithm for fuel gauging, and provides information such as remaining battery capacity (mAh), state-of-charge (%), run-time to empty (min.), battery voltage (mV), and temperature (°C).

The bq27540 also features integrated support for secure battery pack authentication, using the SHA-1/HMAC authentication algorithm.

TYPICAL APPLICATION



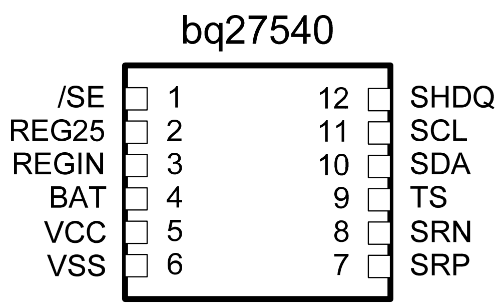
2 DEVICE INFORMATION

2.1 AVAILABLE OPTIONS

PART NUMBER	PACKAGE	T_A	COMMUNICATION FORMAT	TAPE and REEL QUANTITY
bq27540DRZR	12-pin, 2,5-mm x 4-mm SON	-40°C to +85°C	I2C, SDQ, HDQ(1)	3000
bq27540DRZT				250

(1): bq27540 is shipped in I2C mode.

2.2 PIN DIAGRAMS



2.3 TERMINAL FUNCTIONS

NAME	bq27540 PIN NO.	TYPE(1)	DESCRIPTION
BAT	4	I	Cell-voltage measurement input. ADC input.
SHDQ	12	I/O	SDQ and HDQ serial communications line (Slave). Open-drain.
REG25	2	P	Regulator output (2.5V)
REGIN	3	P	Regulator input.
SCL	11	I	Slave I^2C serial communications clock input line for communication with system (Slave). Use with 10kΩ pull-up resistor (typical).
SDA	10	I/O	Slave I^2C serial communications data line for communication with system (Slave). Open-drain I/O. Use with 10kΩ pull-up resistor (typical).
/SE	1	O	Shutdown Enable output. Open-drain.
SRN	8	IA	Analog input pin connected to the internal coulomb counter where SRN is nearest the PACK- connection. Connect to 5-mΩ to 20-mΩ sense resistor.
SRP	7	IA	Analog input pin connected to the internal coulomb counter where SRP is nearest the CELL- connection. Connect to 5-mΩ to 20-mΩ sense resistor.
TS	9	IA	Pack thermistor voltage sense (use 103AT-type thermistor). ADC input
Vcc	5	P	Processor power input. Decouple with 0.1uF, minimum.
Vss	6	P	Device ground

(1) I/O = Digital input/output, IA = Analog input", P = Power connection

3 ELECTRICAL SPECIFICATIONS

3.1 ABSOLUTE MAXIMUM RATINGS

Over operating free-air temperature range (unless otherwise noted) (1)

PARAMETER		VALUE	UNIT
V_{REGIN}	Regulator input (3)	-0.3 to +24	V
V_{BAT}	BAT input pin	-0.3 to +12	V
V_{CC}	Supply voltage range	-0.3 to +2.75	V
V_{REG25}	Regulator output (2)	-0.3 to +16.5	V
V_{IOD}	Open-drain I/O pins (10, 11, and 12)	-0.3 to +6	V
V_I	Input voltage range to all other pins (1, 7, 8, 9)	-0.3 to V_{CC} + 0.3	V
ESD	Human Body Model (HBM), all pins	2	kV
T_A	Operating free-air temperature range	-40 to +100	°C
T_{STG}	Storage temperature range	-65 to +150	°C

(1) Stresses beyond those listed under absolute maximum ratings may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under recommended operating conditions is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

3.2 RECOMMENDED OPERATING CONDITIONS

T_A = 25°C and V_{REGIN} = V_{BAT} = 3.6 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{REGIN}	Supply voltage		2.45	4.2	5.5	V
I_{CC}	Normal operating mode current	Fuel gauge in NORMAL mode. I_{LOAD} > ***Sleep Current***		103		µA
I_{SLP}	Low-power operating mode current	Fuel gauge in SLEEP mode. I_{LOAD} < ***Sleep Current***		18		µA
I_{HIB}	Hibernate operating mode current	Fuel gauge in HIBERNATE mode. I_{LOAD} < ***Hibernate Current***		4		µA
V_{OL}	Output voltage low (HDQ, SDQ, SDA, SCL, /SE)	I_{OL} = 0.5 mA			0.4	V
V_{OH}	Output high voltage (HDQ, SDQ, SDA, SCL, /SE)	External pull-up resistor connected to Vcc	V_{CC}-0.5			V
V_{IL}	Input voltage low (HDQ, SDQ, SDA, SCL, /SE)		-0.3		0.6	V
V_{IH}	Input voltage high (HDQ, SDQ, SDA, SCL, /SE)		1.2		6	V
V_{A1}	Input voltage range (TS)		V_{SS}-0.125		2	V
V_{A2}	Input voltage range (BAT)		V_{SS}-0.125		5	V
V_{A3}	Input voltage range (SRP, SRN)		V_{SS}-0.125		0.125	V
t_{PUCD}	Power-up communication delay			250		ms

3.3 DISSIPATION RATINGS

PACKAGE	$T_A \leq 40°C$ POWER RATING	DERATING FACTOR $T_A \leq 40°C$	$R_{\theta JA}$
12-pin DRZ[(1)]	482mW	5.67mW/°C	176 °C/W

(1) This data is based on using a 4-layer JEDEC high-K board with the exposed die pad connected to a Cu pad on the board. The board pad is connected to the ground plane by a 2- x 2-via matrix.

3.4 POWER-ON RESET

T_A = –40°C to 85°C, C_{REG} = 0.47μF, 2.45 V < V_{REGIN} = V_{BAT} < 5.5 V; typical values at T_A = 25°C and V_{REGIN} = V_{BAT} = 3.6 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{IT+}	Positive-going battery voltage input at V_{CC}		2.05	2.20	2.31	V
V_{HYS}	Power-on reset hysteresis		45	115	185	mV

3.5 2.5V LDO REGULATOR

T_A = –40°C to 85°C, C_{REG} = 0.47μF, 2.45 V < V_{REGIN} = V_{BAT} < 5.5 V; typical values at T_A = 25°C and V_{REGIN} = V_{BAT} = 3.6 V (unless otherwise noted)

PARAMETER		TEST CONDITION		MIN	NOM	MAX	UNIT
V_{REG25}	Regulator output voltage	2.7V ≤ V_{REGIN} ≤ 5.5V, I_{OUT} ≤ 16mA	T_A=-40°C to 85°C	2.42	2.48	2.57	V
		2.45V ≤ V_{REGIN} < 2.7V (low battery), I_{OUT} ≤ 3mA	T_A=-40°C to 85°C	2.40			V
V_{DO}	Regulator dropout voltage	2.7V, I_{OUT} ≤ 16mA	T_A=-40°C to 85°C			280	mV
		2.45V, I_{OUT} ≤ 3mA	T_A=-40°C to 85°C			50	
$\Delta V_{REGTEMP}$	Regulator output change with temperature	V_{REGIN} = 3.6V, I_{OUT} = 16mA	T_A=-40°C to 85°C		0.3		%
$\Delta V_{REGLINE}$	Line regulation	2.7V ≤ V_{REGIN} ≤ 5.5V, I_{OUT} = 16mA			11	25	mV
$\Delta V_{REGLOAD}$	Load regulation	0.2mA ≤ I_{OUT} ≤ 3mA, V_{REGIN} = 2.45 V			34	40	mV
		3mA ≤ I_{OUT} ≤ 16mA, V_{REGIN} = 2.7 V			31		mV
I_{SHORT}[(2)]	Short Circuit Current Limit	V_{REG25} = 0V ,T_A=-40°C to 85°C				250	mA

(1) LDO output current, IOUT, is the sum of internal and external load currents.
(2) Guaranteed by design. Not production tested.

3.6 INTERNAL TEMPERATURE SENSOR CHARACTERISTICS

T_A = –40°C to 85°C, C_{REG} = 0.47μF, 2.45 V < V_{REGIN} = V_{BAT} < 5.5 V; typical values at T_A = 25°C and V_{REGIN} = V_{BAT} = 3.6 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
G_{TEMP}	Temperature sensor voltage gain			-2		mV/°C

3.7 HIGH FREQUENCY OSCILLATOR

T_A = –40°C to 85°C, C_{REG} = 0.47μF, 2.45 V < V_{REGIN} = V_{BAT} < 5.5 V; typical values at T_A = 25°C and V_{REGIN} = V_{BAT} = 3.6 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
f_{OSC}	Operating frequency			2.097		MHz
f_{EIO}	Frequency error (1), (2)	T_A = 0°C to 60°C	–2.0	0.38	2.0	%
		T_A = -20°C to 70°C	–3.0	0.38	3.0	%
		T_A = -40°C to 85°C	-4.5	0.38	4.5	%
t_{SXO}	Start-up time (3)			2.5	5	ms

(1) The frequency error is measured from 2.097 MHz.
(2) The frequency drift is included and measured from the trimmed frequency at V_{CC} = 2.5V, T_A = 25°C.
(3) The startup time is defined as the time it takes for the oscillator output frequency to be ±3% of typical oscillator frequency.

3.8 LOW FREQUENCY OSCILLATOR

T_A = –40°C to 85°C, C_{REG} = 0.47μF, 2.45 V < V_{REGIN} = V_{BAT} < 5.5 V; typical values at T_A = 25°C and V_{REGIN} = V_{BAT} = 3.6 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
f_{LOSC}	Operating frequency			32.768		kHz
f_{LEIO}	Frequency error (1), (2)	T_A = 0°C to 60°C	–1.5	0.25	1.5	%
		T_A = -20°C to 70°C	–2.5	0.25	2.5	%
		T_A = -40°C to 85°C	-4.0	0.25	4.0	%
t_{LSXO}	Start-up time (3)				500	μs

(1) The frequency drift is included and measured from the trimmed frequency at V_{CC} = 2.5V, T_A = 25°C.
(2) The frequency error is measured from 32.768kHz.
(3) The startup time is defined as the time it takes for the oscillator output frequency to be ±3% of typical oscillator frequency.

3.9 INTEGRATING ADC (COULOMB COUNTER) CHARACTERISTICS

T_A = –40°C to 85°C, C_{REG} = 0.47μF, 2.45 V < V_{REGIN} = V_{BAT} < 5.5 V; typical values at T_A = 25°C and V_{REGIN} = V_{BAT} = 3.6 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{SR_IN}	Input voltage range, $V_{(SRN)}$ and $V_{(SRP)}$	$V_{SR} = V_{(SRN)} – V_{(SRP)}$	–0.125		0.125	V
t_{SR_CONV}	Conversion time	Single conversion		1		s
	Resolution		14		15	bits
V_{SR_OS}	Input offset			10		μV
INL	Integral nonlinearity error			±0.007	±0.034	% FSR
Z_{SR_IN}	Effective input resistance(1)		2.5			MΩ
I_{SR_LKG}	Input Leakage Current(1)				0.3	uA

(1) Assured by design. Not production tested

3.10 ADC (TEMPERATURE AND CELL MEASUREMENT) CHARACTERISTICS

T_A = –40°C to 85°C, C_{REG} = 0.47μF, 2.45 V < V_{REGIN} = V_{BAT} < 5.5 V; typical values at T_A = 25°C and V_{REGIN} = V_{BAT} = 3.6 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{ADC_IN}	Input voltage range		–0.2		1	V
t_{ADC_CONV}	Conversion time				125	ms
	Resolution		14		15	bits
V_{ADC_OS}	Input offset			1		mV
Z_{ADC1}	Effective input resistance (TS) (1)		8			MΩ
Z_{ADC2}	Effective input resistance (BAT) (1)	bq27540 not measuring cell voltage	8			MΩ
		bq27540 measuring cell voltage		100		kΩ
I_{ADC_LKG}	Input Leakage Current(1)				0.3	uA

(1) Assured by design. Not production tested

3.11 DATA FLASH MEMORY CHARACTERISTICS

T_A = –40°C to 85°C, C_{REG} = 0.47μF, 2.45 V < V_{REGIN} = V_{BAT} < 5.5 V; typical values at T_A = 25°C and V_{REGIN} = V_{BAT} = 3.6 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_{DR}	Data retention(1)		10			Years
	Flash programming write-cycles (1)		20,000			Cycles
$t_{WORDPROG)}$	Word programming time (1)				2	ms
$I_{CCPROG)}$	Flash-write supply current (1)			5	10	mA

(1) Assured by design. Not production tested

3.12 SDQ COMMUNICATION TIMING CHARACTERISTICS

T_A = –40°C to 85°C, C_{REG} = 0.47µF, 2.45 V < V_{REGIN} = V_{BAT} < 5.5 V; typical values at T_A = 25°C and V_{REGIN} = V_{BAT} = 3.6 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_{RSTL}	Reset time – low		480			
t_{RSTH}	Reset time – high		480			
t_{PDL}	Presence detect – low		60		240	
t_{PDH}	Presence detect – high		15		60	
t_{REC}	Recovery time		1			
t_{SLOT}	Host bit window		60		120	
t_{LOW1}	Host sends 1		1		13	µs
t_{LOW0}	Host sends 0		60		120	
t_{LOWR}	Host read bit start		1		13	
t_{SLOT}	DEVICE bit window		60		120	
t_{SU}	DEVICE data setup				1	
t_{RDV}	DEVICE data valid			exactly 15		
$t_{RELEASE}$	DEVICE data release		0	15	45	

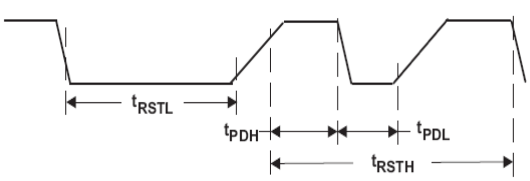


Figure 3-3: Reset and Presence Timing

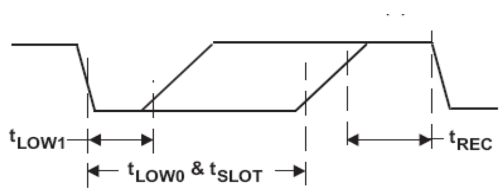


Figure 3-3: Host transmitted bit timing

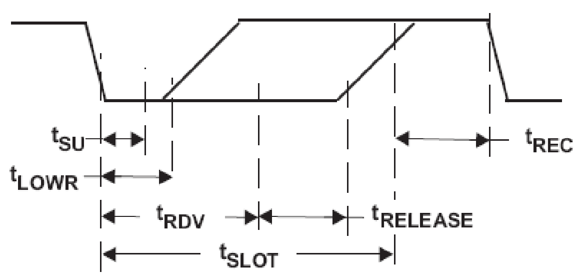


Figure 3-3: DEVICE transmitted bit timing

3.13 HDQ COMMUNICATION TIMING CHARACTERISTICS

T_A = –40°C to 85°C, C_{REG} = 0.47µF, 2.45 V < V_{REGIN} = V_{BAT} < 5.5 V; typical values at T_A = 25°C and V_{REGIN} = V_{BAT} = 3.6 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{(CYCH)}$	Cycle time, host to bq27540 (write)		190			µs
$t_{(CYCD)}$	Cycle time, bq27540 to host (read)		190	205	250	µs
$t_{(HW1)}$	Start hold time, host to bq27540 (write)		0.5		1	µs
$t_{(DW1)}$	Start hold time, host to bq27540 (read)		32		50	µs
$t_{(HW0)}$	Stop setup time		86		145	µs
$t_{(DW0)}$	Stop setup time		80		145	µs
$t_{(RSPS)}$	Response time, bq27540 to host		190		320	µs
$t_{(B)}$	Break time		190			µs
$t_{(BR)}$	Break recovery time		40			µs
$t_{(BUSERR)}$	Bus error timeout			16		s
$t_{(BUSERR\_ACC)}$	Bus error timeout accuracy		-20		20	%

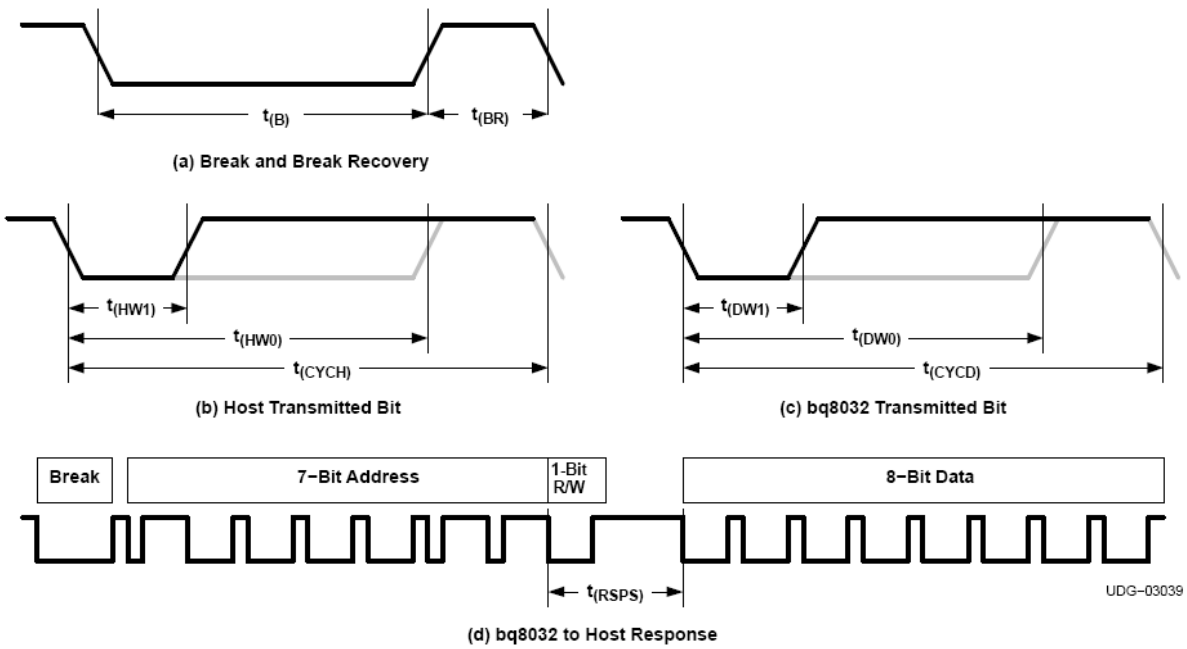


Figure 3-4: Timing diagrams for HDQ Breaking (a), HDQ Host to bq27540 communication (b), bq27540 to Host communication (c), and bq27540 to Host response format (d).

3.14 I²C-COMPATIBLE INTERFACE COMMUNICATION TIMING CHARACTERISTICS

T_A = –40°C to 85°C, C_{REG} = 0.47μF, 2.45 V < V_{REGIN} = V_{BAT} < 5.5 V; typical values at T_A = 25°C and V_{REGIN} = V_{BAT} = 3.6 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_r	SCL/SDA rise time				1	µs
t_f	SCL/SDA fall time				300	ns
$t_{w(H)}$	SCL pulse width (high)		4			µs
$t_{w(L)}$	SCL pulse width (low)		4.7			µs
$t_{su(STA)}$	Setup for repeated start		4.7			µs
$t_{d(STA)}$	Start to first falling edge of SCL		4			µs
$t_{su(DAT)}$	Data setup time		250			ns
$t_{h(DAT)}$	Data hold time	Receive mode	0			ns
		Transmit mode	300			
$t_{su(STOP)}$	Setup time for stop		4			µs
t_{BUF}	Bus free time between stop and start		4.7			µs
f_{SCL}	Clock frequency		10		100	kHz
t_{BUSERR}	Bus error timeout		17.3		21.2	s

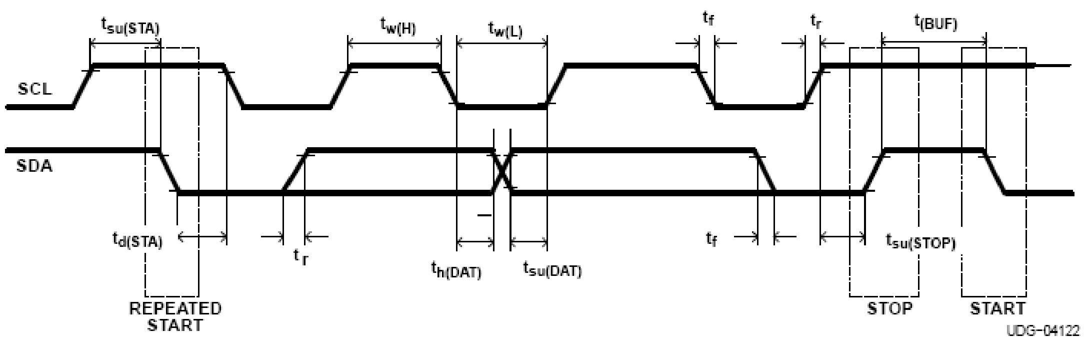


Figure 3-5: I²C-Compatible Interface Timing Diagrams

4 GENERAL DESCRIPTION

The bq27540 accurately predicts the battery capacity and other operational characteristics of a single Li-based rechargeable cell. It can be interrogated by a system processor to provide cell information, such as state-of-charge (SOC), time-to-empty (TTE) and time-to-full (TTF).

Information is accessed through a series of commands, called *Standard Commands*. Further capabilities are provided by the additional *Extended Commands* set. Both sets of commands, indicated by the general format *Command( )*, are used to read and write information contained within the bq27540 control and status registers, as well as its data flash locations. Commands are sent from system to gauge using the bq27540's serial communications engine, and can be executed during application development, pack manufacture, or end-equipment operation.

Cell information is stored in the bq27540 in non-volatile flash memory. Many of these data flash locations are accessible during application development. They cannot, generally, be accessed directly during end-equipment operation. Access to these locations is achieved by either use of the bq27540's companion evaluation software, through individual commands, or through a sequence of data-flash-access commands. To access a desired data flash location, the correct data flash subclass and offset must be known.

The bq27540 provides 96 bytes of user-programmable data flash memory, partitioned into 3 32-byte blocks: ***Manufacturer Info Block A*****,** ***Manufacturer Info Block B***, and ***Manufacturer Info Block C***. This data space is accessed through a data flash interface. For specifics on accessing the data flash, Section **Error! Reference source not found.**, ***Error! Reference source not found.***.***Error! Reference source not found.***The key to the bq27540's high-accuracy gas gauging prediction is Texas Instrument's proprietary Impedance Track^{TM} algorithm. This algorithm uses cell measurements, characteristics, and properties to create state-of-charge predictions that can achieve less than 1% error across a wide variety of operating conditions and over the lifetime of the battery.

The bq27540 measures charge/discharge activity by monitoring the voltage across a small-value series sense resistor (5 mΩ to 20 mΩ typ.) located between the system's Vss and the battery's PACK- terminal. When a cell is attached to the bq27540, cell impedance is computed, based on cell current, cell open-circuit Voltage (OCV), and cell voltage under loading conditions.

The bq27540 can use an NTC thermistor (default is Semitec 103AT) for temperature measurement, or can also be configured to use its internal temperature sensor. The bq27540 uses temperature to monitor the battery-pack environment, which is used for fuel gauging and cell protection functionality.

To minimize power consumption, the bq27540 has several power modes: NORMAL, SLEEP, HIBERNATE, and PRESHUTDOWN. The bq27540 passes automatically between these modes, depending upon the occurrence of specific events, though a system processor can initiate some of these modes directly. More details can be found in Section **Error! Reference source not found.**, ***Error! Reference source not found.***.

NOTE

FORMATTING CONVENTIONS IN THIS DOCUMENT:

Commands: *italics* with parentheses and no breaking spaces, *e.g. RemainingCapacity( )*.

Data Flash: *italics,* **bold***,* and *breaking spaces, e.g.* ***Design Capacity***.

Register bits and flags: brackets and *italics*, *e.g. [TDA]*

Data flash bits: brackets, *italics* and **bold**, *e.g:* ***[LED1]***

Modes and states: ALL CAPITALS, *e.g.* UNSEALED mode.

4.1 DATA COMMANDS

4.1.1 Standard Data Commands

The bq27540 uses a series of 2-byte standard commands to enable system reading and writing of battery information. Each standard command has an associated command-code pair, as indicated in Table 4-1. Because each command consists of two bytes of data, two consecutive I^2C transmissions must be executed both to initiate the command function, and to read or write the corresponding two bytes of data. Additional options for transferring data, such as spooling, are described in Section **Error! Reference source not found.**. Standard commands are accessible in NORMAL operation. Read/Write permissions depend on the active access mode, SEALED or UNSEALED (for details on the SEALED and UNSEALED states, refer to Section **Error! Reference source not found.**, ***Error! Reference source not found.***.)

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Table 4-1: Standard Commands

NAME		COMMAND CODE	UNITS	SEALED ACCESS	UNSEALED ACCESS
Control( )	CNTL	0x00 / 0x01	N/A	R/W	R/W
AtRate( )	AR	0x02 / 0x03	mA	R/W	R/W
AtRateTimeToEmpty( )	ARTTE	0x04 / 0x05	Minutes	R	R
Temperature( )	TEMP	0x06 / 0x07	0.1K	R	R
Voltage( )	VOLT	0x08 / 0x09	mV	R	R
Flags( )	FLAGS	0x0a / 0x0b	N/A	R	R
NominalAvailableCapacity( )	NAC	0x0c / 0x0d	mAh	R	R
FullAvailableCapacity( )	FAC	0x0e / 0x0f	mAh	R	R
RemainingCapacity( )	RM	0x10 / 0x11	mAh	R	R
FullChargeCapacity( )	FCC	0x12 / 0x13	mAh	R	R
AverageCurrent( )	AI	0x14 / 0x15	mA	R	R
TimeToEmpty( )	TTE	0x16 / 0x17	Minutes	R	R
TimeToFull( )	TTF	0x18 / 0x19	Minutes	R	R
StandbyCurrent( )	SI	0x1a / 0x1b	mA	R	R
StandbyTimeToEmpty( )	STTE	0x1c / 0x1d	Minutes	R	R
MaxLoadCurrent( )	MLI	0x1e / 0x1f	mA	R	R
MaxLoadTimeToEmpty( )	MLTTE	0x20 / 0x21	Minutes	R	R
AvailableEnergy( )	AE	0x22 / 0x23	10 mWhr	R	R
AveragePower( )	AP	0x24 / 0x25	10 mW	R	R
TTEatConstantPower( )	TTECP	0x26 / 0x27	Minutes	R	R
Reserved	RSVD	0x28 / 0x29	N/A	R	R
CycleCount( )	CC	0x2a / 0x2b	Counts	R	R
StateOfCharge( )	SOC	0x2c / 0x2d	%	R	R

4.1.1.1 Control( ): 0x00/0x01

Issuing a *Control( )* command requires a subsequent 2-byte subcommand. These additional bytes specify the particular control function desired. The *Control( )* command allows the system to control specific features of the bq27540 during normal operation and additional features when the bq27540 is in different access modes, as described in

Table 4-2: *Control( )* Subcommands

CNTL FUNCTION	CNTL DATA	SEALED ACCESS	DESCRIPTION
CONTROL_STATUS	0x0000	Yes	Reports the status of DF Checksum, Hibernate, IT, etc.
DEVICE_TYPE	0x0001	Yes	Reports the device type of 0x0540 (indicating ”bq27540”)
FW_VERSION	0x0002	Yes	Reports the firmware version on the device type
HW_VERSION	0x0003	Yes	Reports the hardware version of the device type
DF_CHECKSUM	0x0004	No	Enables a data flash checksum to be generated and reports on a read
RESET_DATA	0x0005	No	Returns reset data
Reserved	0x0006	No	Not to be used
PREV_MACWRITE	0x0007	No	Returns previous MAC command code
CHEM_ID	0x0008	Yes	Reports the chemical identifier of the Impedance Track™ configuration
BOARD_OFFSET	0x0009	No	Forces the device to measure and store the board offset
CC_INT_OFFSET	0x000a	No	Forces the device to measure the internal CC offset
WRITE_CC_OFFSET	0x000b	No	Forces the device to store the internal CC offset
SET_HIBERNATE	0x0011	Yes	Forces CONTROL_STATUS *[HIBERNATE]* to 1
CLEAR_HIBERNATE	0x0012	Yes	Forces CONTROL_STATUS *[HIBERNATE]* to 0
SET_SHUTDOWN	0x0013	No	Enables the /SE pin to change state
CLEAR_SHUTDOWN	0x0014	No	Disables the /SE pin from changing state
SEALED	0x0020	No	Places the bq27540 is SEALED access mode
IT_ENABLE	0x0021	No	Enables the Impedance Track™ algorithm
IF_CHECKSUM	0x0022	No	Reports the instruction flash checksum
CAL_MODE	0x0040	No	Places the bq27540 in calibration mode
RESET	0x0041	No	Forces a full reset of the bq27540

4.1.2 Extended Data Commands

Extended commands offer additional functionality beyond the standard set of commands. They are used in the same manner; however unlike standard commands, extended commands are not limited to 2-byte words. The number of commands bytes for a given extended command ranges in size from single to multiple bytes, as specified in Table 4-3. For details on the SEALED and UNSEALED states, see Section **Error! Reference source not found.**, ***Error! Reference source not found.***.

Table 4-3: Extended Commands

NAME		COMMAND CODE	UNITS	SEALED ACCESS (1), (2)	UNSEALED ACCESS (1), (2)
Reserved	RSVD	0x34…0x3b	N/A	R	R
DesignCapacity( )	DCAP	0x3c / 0x3d	mAh	R	R
DataFlashClass( ) (2)	DFCLS	0x3e	N/A	N/A	R/W
DataFlashBlock( ) (2)	DFBLK	0x3f	N/A	R/W	R/W
Authenticate( )/BlockData( )	A/DF	0x40…0x53	N/A	R/W	R/W
AuthenticateCheckSum( )/BlockData( )	ACKS/DFD	0x54	N/A	R/W	R/W
BlockData( )	DFD	0x55…0x5f	N/A	R	R/W
BlockDataCheckSum( )	DFDCKS	0x60	N/A	R/W	R/W
BlockDataControl( )	DFDCNTL	0x61	N/A	N/A	R/W
DeviceNameLength( )	DNAMELEN	0x62	N/A	R	R
DeviceName( )	DNAME	0x63...0x69	N/A	R	R
ApplicationStatus( )	APPSTAT	0x6a	N/A	R	R
Reserved	RSVD	0x6b...0x7f	N/A	R	R

Note: 1: SEALED and UNSEALED states are entered via commands to ***Control( )*** 0x00/0x01
2: In sealed mode, data flash CANNOT be accessed through commands 0x3e and 0x3f.

4.2 DATA FLASH SUMMARY

Table 4-4 summarizes the data flash locations available to the user, including their default, minimum, and maximum values.

Table 4-4: Data Flash Summary

Class	Subclass ID	Subclass	Offset	Name	Data Type	Min Value	Max Value	Default Value	Units
Configuration	2	Safety	0	OT Chg	I2	0	1200	400	0.1°C
Configuration	2	Safety	2	OT Chg Time	U1	0	60	2	s
Configuration	2	Safety	3	OT Chg Recovery	I2	0	1200	350	0.1°C
Configuration	2	Safety	5	OT Dsg	I2	0	1200	400	0.1°C
Configuration	2	Safety	7	OT Dsg Time	U1	0	60	2	s
Configuration	2	Safety	8	OT Dsg Recovery	I2	0	1200	350	0.1°C
Configuration	32	Charge Inhibit Config	0	Charge Inhibit Temp Low	I2	-400	1200	0	0.1°C
Configuration	32	Charge Inhibit Config	2	Charge Inhibit Temp High	I2	-400	1200	450	0.1°C
Configuration	32	Charge Inhibit Config	4	Temp Hys	I2	0	100	50	0.1°C
Configuration	34	Charge	2	Charging Voltage	I2	0	20,000	4200	mV
Configuration	34	Charge	4	Delta Temperature	I2	0	500	50	0.1°C
Configuration	34	Charge	6	Suspend Temperature Low	I2	-400	1200	5	0.1°C
Configuration	34	Charge	8	Suspend Temperature High	I2	-400	1200	400	0.1°C
Configuration	36	Charge Termination	2	Taper Current	I2	0	1000	100	mA
Configuration	36	Charge Termination	4	Minimum Taper Charge	I2	0	1000	0.25	mAh
Configuration	36	Charge Termination	6	Taper Voltage	I2	0	1000	100	mV
Configuration	36	Charge Termination	8	Current Taper Window	U1	0	60	40	s
Configuration	48	Data	4	Initial Standby Current	I1	-128	0	-10	mA
Configuration	48	Data	5	Initial Max Load Current	I2	-32,767	0	-500	mA
Configuration	48	Data	7	CC Threshold	I2	100	32,767	900	mAh
Configuration	48	Data	10	Design Capacity	I2	0	65,535	1000	mAh
Configuration	48	Data	12	Device Name	S8	x	x	bq27540	-
Configuration	49	Discharge	0	SOC1 Set Threshold	U1	0	255	150	mAh
		Discharge	1	SOC1 Clear Threshold	U1	0	255	175	mAh
Configuration	49	Discharge	2	SOCF Set Threshold	U1	0	255	75	mAh
Configuration	49	Discharge	3	SOCF Clear Threshold	U1	0	255	100	mAh

System Data	58	Manufacturer Info	0 - 31	Block A [0 - 31]	H1	0x00	0xff	0x00	-
System Data	58	Manufacturer Info	32 - 63	Block B [0 – 31]	H1	0x00	0xff	0x00	-
System Data	58	Manufacturer Info	64 - 95	Block C [0 – 31]	H1	0x00	0xff	0x00	-
Configuration	64	Registers	0	Operation Configuration	H2	0x0000	0xffff	TBD	
Configuration	68	Power	0	Flash Update OK Voltage	I2	0	4200	2800	mV
Configuration	68	Power	7	Sleep Current	I2	0	100	10	mA
Configuration	68	Power	16	Hibernate Current	U2	0	700	8	mA
Configuration	68	Power	18	Hibernate Voltage	U2	2400	3000	2550	mV
Gas Gauging	80	IT Cfg	0	Load Select	U1	0	255	1	-
Gas Gauging	80	IT Cfg	1	Load Mode	U1	0	255	0	-
Gas Gauging	80	IT Cfg	48	Terminate Voltage	I2	-32,768	32,767	3000	mV
Gas Gauging	80	IT Cfg	53	User Rate-mA	I2	0	9000	0	mA
Gas Gauging	80	IT Cfg	55	User Rate-mW	I2	0	14,000	0	10mW
Gas Gauging	80	IT Cfg	57	Reserve Cap-mAh	I2	0	9000	0	mAh
Gas Gauging	80	IT Cfg	59	Reserve Cap-mWh	I2	0	14,000	0	10mWh
Gas Gauging	81	Current Thresholds	0	Dsg Current Threshold	I2	0	2000	60	mA
Gas Gauging	81	Current Thresholds	2	Chg Current Threshold	I2	0	2000	75	mA
Gas Gauging	81	Current Thresholds	4	Quit Current	I2	0	1000	40	mA
Gas Gauging	81	Current Thresholds	6	Dsg Relax Time	U2	0	8191	1800	s
Gas Gauging	81	Current Thresholds	8	Chg Relax Time	U1	0	255	60	s
Gas Gauging	81	Current Thresholds	9	Quit Relax Time	U1	0	63	1	s
Gas Gauging	82	State	0	IT Enable	H1	0x00	0xff	0x00	
Gas Gauging	82	State	2	Qmax	I2	0	32,767	1000	mAh
Gas Gauging	82	State	4	Cycle Count	U2	0	65,535	0	-
Gas Gauging	82	State	6	Update Status	H1	0x00	0x03	0x00	-
Gas Gauging	82	State	16	Avg I Last Run	I2	-32,768	32,767	300	mA
Gas Gauging	82	State	18	Avg P Last Run	I2	-32,768	32,767	1200	mAh
Default Ra Tables	87	Def Ra	0-18	See Note (1)					
Ra Tables	91	Pack Ra	0-18	See Note (1)					
Ra Tables	93	Pack Rax	0-18						
Calibration	104	Data	0	CC Gain	F4	0.1	4	0.47095	-
Calibration	104	Data	4	CC Delta	F4	2,9826	1,193,046	559,538.8	-
Calibration	104	Data	8	CC Offset	I2	-32768	32767	-1667	mV
Calibration	104	Data	10	Board Offset	I1	-128	127	0	mV
Calibration	104	Data	11	Int Temp Offset	I1	-128	127	0	0.1°C
Calibration	104	Data	12	Ext Temp Offset	I1	-128	127	0	0.1°C
Calibration	104	Data	13	Pack V Offset	I1	-128	127	0	mV

Calibration	107	Current	1	Deadband	U1	0	255	3	mA
Security	112	Codes	0	Unseal Key 0	H2	0x0000	0xffff	0x3672	-
Security	112	Codes	2	Unseal Key 1	H2	0x0000	0xffff	0x0414	-
Security	112	Codes	4	Full-Access Key 0	H2	0x0000	0xffff	0xffff	-
Security	112	Codes	6	Full-Access Key 1	H2	0x0000	0xffff	0xffff	-
Security	TBD	Codes	x to x+16	Authentication Key	H4	0x0000	0xffff	0x01234567 89ABCDEF FEDCBA98 76543210	-

(1) Encoded battery profile information created by bqEasy software.

5 FUNCTIONAL DESCRIPTION

5.1 FUEL GAUGING

The bq27540 measures the cell voltage, temperature, and current to determine battery SOC. The bq27540 monitors charge and discharge activity by sensing the voltage across a small-value resistor (5 mΩ to 20 mΩ typ.) between the SRP and SRN pins and in series with the cell. By integrating charge passing through the battery, the battery's SOC is adjusted during battery charge or discharge.

The total battery capacity is found by comparing states of charge before and after applying the load with the amount of charge passed. When an application load is applied, the impedance of the cell is measured by comparing the OCV obtained from a predefined function for present SOC with the measured voltage under load. Measurements of OCV and charge integration determine chemical state of charge and chemical capacity (Qmax). The initial Qmax values are taken from a cell manufacturers' data sheet multiplied by the number of parallel cells. It is also used for the value in ***Design Capacity***. The bq27540 acquires and updates the battery-impedance profile during normal battery usage. It uses this profile, along with SOC and the Qmax value, to determine *FullChargeCapacity( )* and *StateOfCharge( ),* specifically for the present load and temperature. *FullChargeCapacity( )* is reported as capacity available from a fully charged battery under the present load and temperature until *Voltage( )* reaches the ***Term Voltage***. *NominalAvailableCapacity( )* and *FullAvailableCapacity( )* are the uncompensated (no or light load) versions of *RemainingCapacity( )* and *FullChargeCapacity( )* respectively.

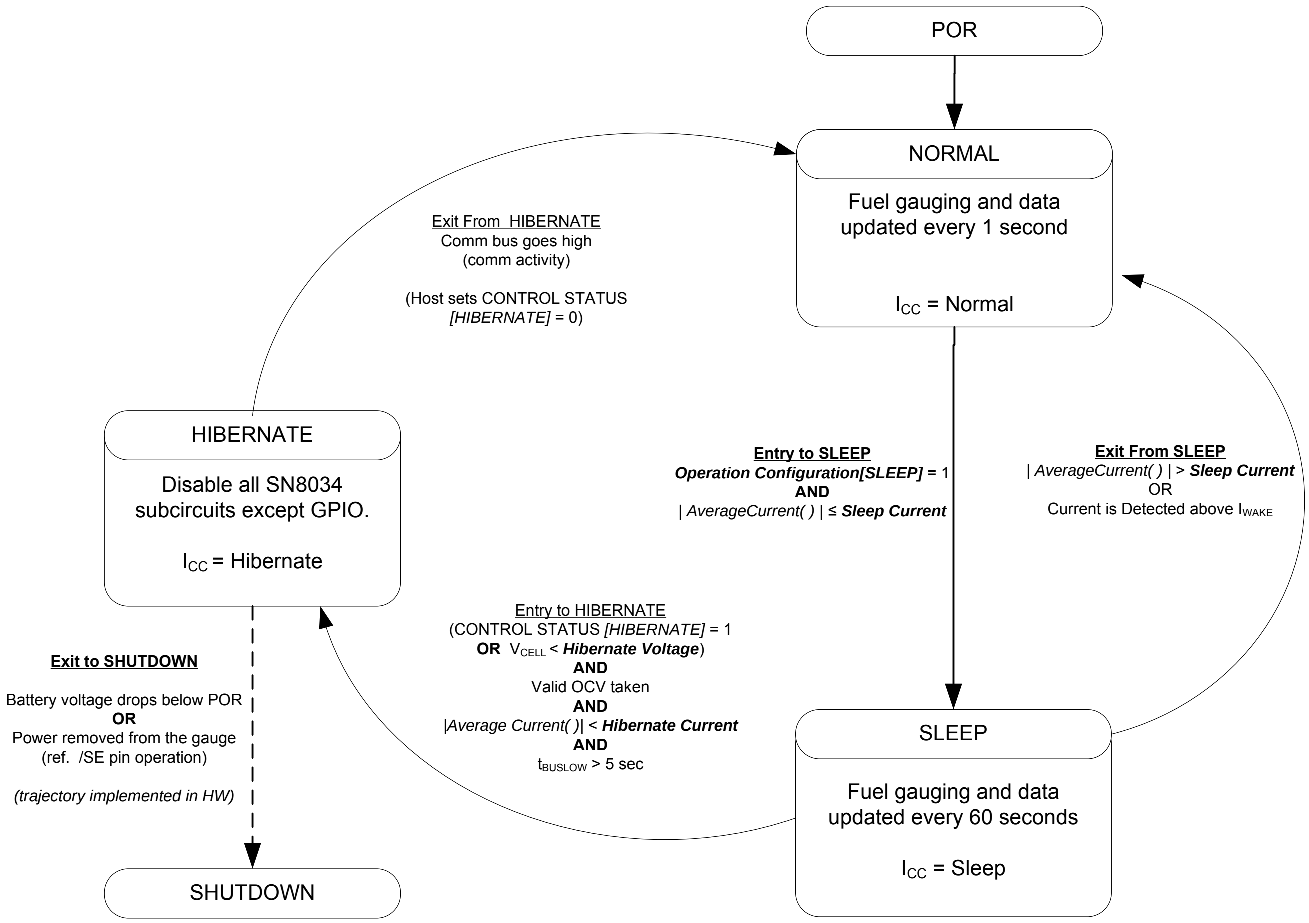
The bq27540 has two flags accessed by the *Flags( )* function that warns when the battery's SOC has fallen to critical levels. When *RemainingCapacity( )* falls below the first capacity threshold, specified in ***SOC1 Set Threshold***, the *[SOC1]* (*State of Charge Initial*) flag is set. The flag is cleared once *RemainingCapacity( )* rises above ***SOC1 Set Threshold****.* All units are in mAh.

When *RemainingCapacity( )* falls below the second capacity threshold, ***SOCF Set Threshold****,* the *[SOCF]* (*State of Charge Final*) flag is set, serving as a final discharge warning. If ***SOCF Set Threshold*** = -1, the flag is inoperative during discharge. Similarly, when *RemainingCapacity( )* rises above ***SOCF Clear Threshold*** and the *[SOCF]* flag has already been set, the *[SOCF]* flag is cleared. All units are in mAh.

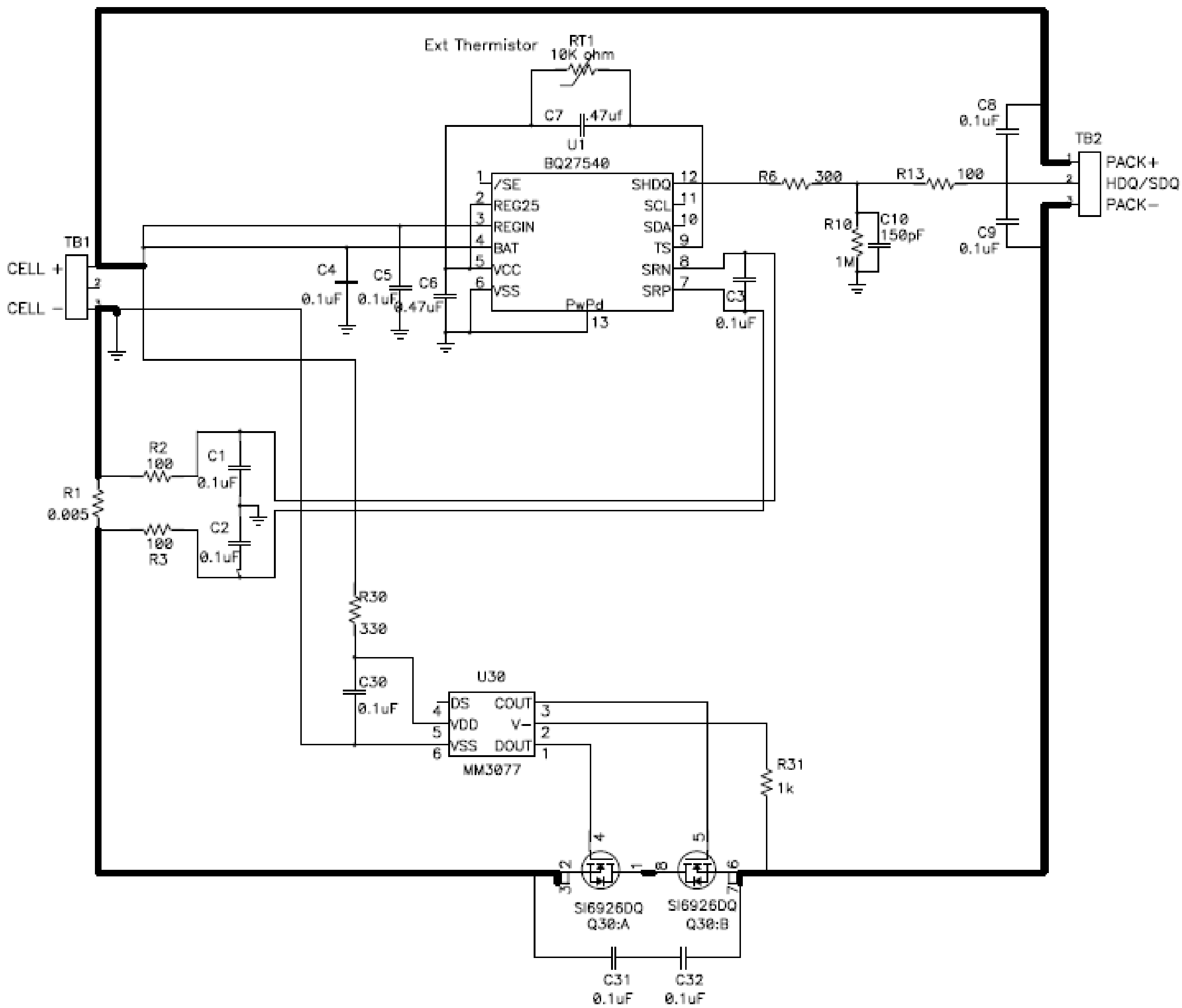
5.2 AUTHENTICATION

The bq27540 can act as a SHA-1/HMAC authentication slave by using its internal engine. Sending a 160-bit SHA-1 challenge message to the bq27540 will cause the gauge to return a 160-bit digest, based upon the challenge message and a hidden, 128-bit plain-text authentication key. If this digest matches an identical one generated by a host or dedicated authentication master, and when operating on the same challenge message and using the same plain text keys, the authentication process is successful.

Figure 5-1: Power Mode Diagram

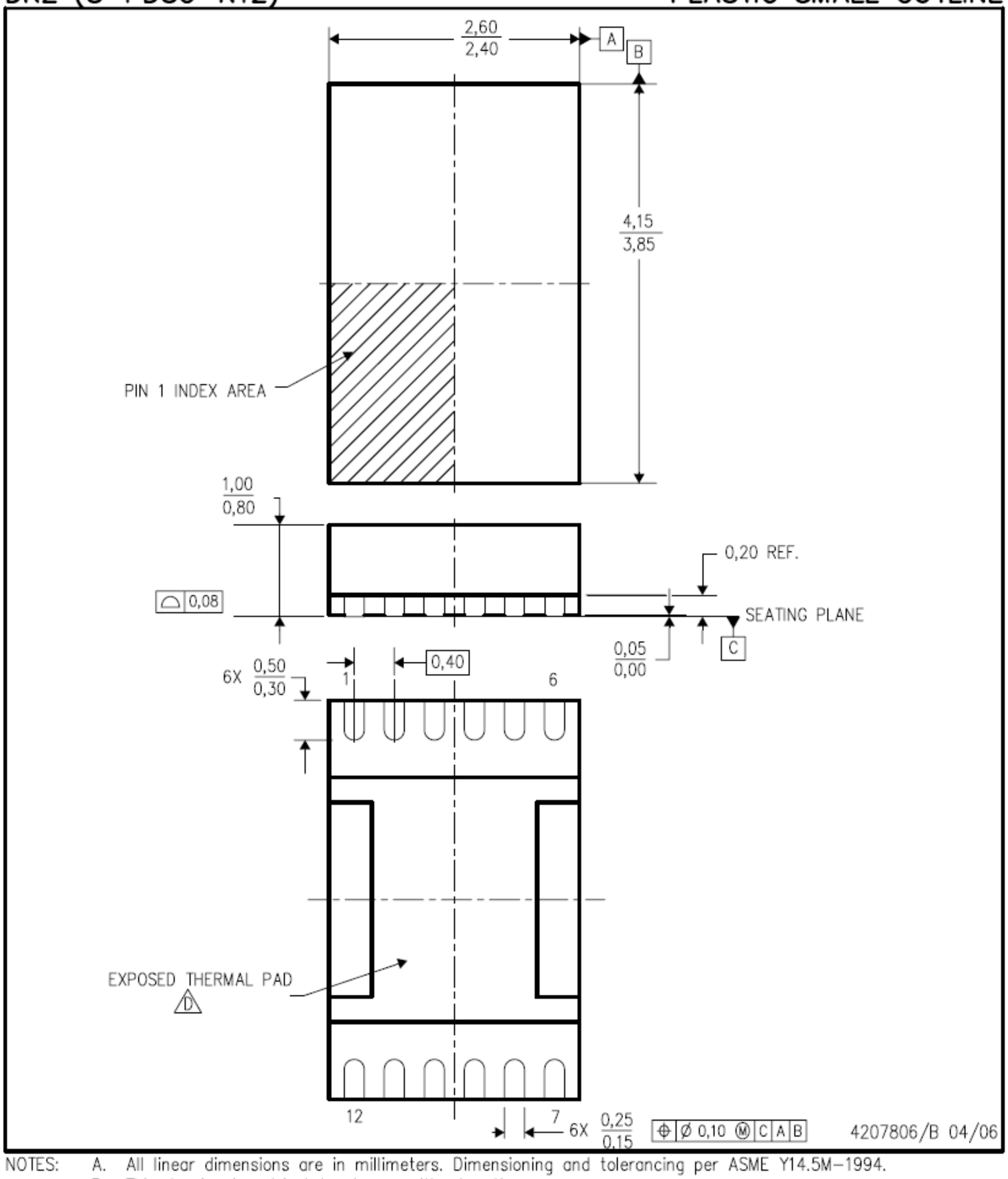


6 REFERENCE SCHEMATIC



7 MECHANICAL DATA

DRZ (S–PDSO–N12) PLASTIC SMALL OUTLINE



NOTES:
A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M–1994.
B. This drawing is subject to change without notice.
C. Small Outline No–Lead (SON) package configuration.
D. The package thermal pad must be soldered to the board for thermal and mechanical performance. See the Product Data Sheet for details regarding the exposed thermal pad dimensions.
E. This package is lead–free.

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