System-Side Impedance Track™ Fuel Gauge

Check for Samples: bq27505

1 INTRODUCTION

1.1 FEATURES

- **Battery Fuel Gauge for 1-Series Li-Ion Applications**
- **Resides on System Main Board**
  - **Works With Embedded or Removable Battery Packs**
- **Uses *PACK+*, *PACK–*, and *T* Battery Terminals**
- **Microcontroller Peripheral Provides:**
  - **Accurate Battery Fuel Gauging**
  - **Internal Temperature Sensor for Battery Temperature Reporting**
  - ***Battery Low* Interrupt Warning**
  - ***Battery Insertion* Indicator**
  - ***Configurable Level of State of Charge (SOC) Interrupts***
  - ***State of Health Indicator***
  - **96 Bytes of Non-Volatile Scratch-Pad FLASH**
- **Battery Fuel Gauge Based on Patented Impedance Track™ Technology**
  - **Models the 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 (10 mΩ or Less)**
- **400KHz I²C™ Interface for Connection to System Microcontroller Port**
- **In a 12-Pin NanoFree™ (CSP) Packaging**

1.2 APPLICATIONS

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

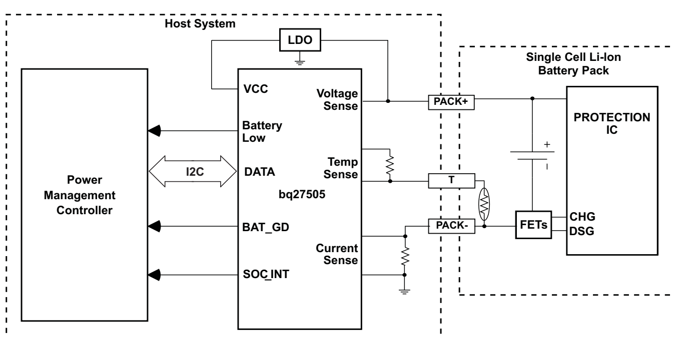
1.3 DESCRIPTION

The Texas Instruments bq27505 system-side 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. The bq27505 resides on the system's main board and manages an embedded battery (non-removable) or a removable battery pack.

The bq27505 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), temperature (°C) and state of health (%).

Battery fuel gauging with the bq27505 requires only PACK+ (P+), PACK– (P–), and Thermistor (T) connections to a removable battery pack or embedded battery circuit. The CSP option is a 12-ball package in the dimensions of 2,43 mm × 1,96 mm with 0,5 mm lead pitch. It is ideal for space constrained applications.

TYPICAL APPLICATION



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

2 DEVICE INFORMATION

2.1 AVAILABLE OPTIONS

PART NUMBER	FIRMWARE VERSION	PACKAGE(1)	T_A	COMMUNICATION FORMAT	TAPE and REEL QUANTITY
bq27505s1Tj ET BT /F2 7 Tf 100 Tz 0 g f 557.7 647.2 0.3 12.2 re53 78 2 7 Tf 100 Tz 0 g flZGR-J1Tz 0 g f 557.7 647.2 0.3 12.2 re53 4 T3 20.Tf 100 T3000Tz 0 g f 557.7 647.2 0					

FEA2i ET B 4858S FDABOVT

FE T40.21 0 6S FE T40.21 0 6S

FEIZGz 0 0 0 rg 4678S

FEA2i ET BT /F2 7 Tf8S 4.78SFO.ET B 4678S

2.3 PIN ASSIGNMENT

Table 2-1. PIN FUNCTIONS

TERMINAL		TYPE (1)	DESCRIPTION
NAME	NO.		
SRP	A1	IA	Analog input pin connected to the internal coulomb counter where SRP is nearest the PACK– connection. Connect to 5-mΩ to 20-mΩ sense resistor.
SRN	B1	IA	Analog input pin connected to the internal coulomb counter where SRN is nearest the Vss connection. Connect to 5-mΩ to 20-mΩ sense resistor.
BAT_LOW	C1	O	Battery Low output indicator. Active *high* by default, though polarity can be configured through the [BATL_POL] bit of ***Operation Configuration***. Push-pull output.
Vss	D1	P	Device ground
BAT_GD	A2	O	Battery-good indicator. Active-*low* by default, though polarity can be configured through the [BATG_POL] bit of ***Operation Configuration***. Push-pull output.
SOC_INT	B2	I/O	SOC state interrupts output. Generate a pulse under the conditions specified by Table 5-5. Open drain output.
BAT	C2	I	Cell-voltage measurement input. ADC input. Recommend 4.8V maximum for conversion accuracy.
Vcc	D2	P	Processor power input. Decouple with minimum 0.1μF ceramic capacitor.
SDA	A3	I/O	Slave I^2C serial communications data line for communication with system (Master). Open-drain I/O. Use with 10kΩ pull-up resistor (typical).
SCL	B3	I	Slave I^2C serial communications clock input line for communication with system (Master). Use with 10kΩ pull-up resistor (typical).
BI/TOUT	C3	I/O	Battery-insertion detection input. Power pin for pack thermistor network. Thermistor-multiplexer control pin. Use with pull-up resistor >1MΩ (1.8 MΩ typical).
TS	D3	IA	Pack thermistor voltage sense (use 103AT-type thermistor). ADC input

(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_{CC}	Supply voltage range	–0.3 to 2.75	V
V_{IOD}	Open-drain I/O pins (SDA, SCL, SOC_INT)	[illegible]	V
V_{BAT}	BAT input pin	–0.3 to 6	
V_I	Input voltage range to all other pins (BI/TOUT, TS, SRP, SRN, BAT_GD)	–0.3 to V_{CC} + 0.3	V
ESD	Human-body model (HBM), BAT pin	1.5	kV
	Human-body model (HBM), all other pins	2	
T_A	Operating free-air temperature range	–40 to 85	°C
T_F	Functional 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 = -40°C to 85°C; 2.4 V < V_{CC} < 2.6 V; Typical values at T_A = 25°C and V_{CC} = 2.5 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{CC}	Supply voltage		2.4	2.5	2.6	V
I_{CC}	Normal operating-mode current(1)	Fuel gauge in NORMAL mode.		114		μA
I_{SLP+}	Sleep+ operating mode current	Fuel gauge in SLEEP+ mode.				

3.8 ADC (TEMPERATURE AND CELL MEASUREMENT) CHARACTERISTICS

T_A = –40°C to 85°C, 2.4 V < V_{CC} < 2.6 V; typical values at T_A = 25°C and V_{CC} = 2.5 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{IN(ADC)}$	Input voltage range		–0.2		1	V
t_{ADC_CONV}	Conversion time				125	ms
	Resolution		14		15	bits
$V_{OS(ADC)}$	Input offset			1		mV
Z_{ADC1}	Effective input resistance (TS)(1)		8			MΩ
Z_{ADC2}	Effective input resistance (BAT)(1)	bq27505 not measuring cell voltage	8			MΩ
		bq27505 measuring cell voltage		100		kΩ
$I_{lkg(ADC)}$	Input leakage current(1)				0.3	μA

(1) Specified by design. Not tested in production.

3.9 DATA FLASH MEMORY CHARACTERISTICS

T_A = –40°C to 85°C, 2.4 V < V_{CC} < 2.6 V; typical values at T_A = 25°C and V_{CC} = 2.5 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
$t_{DFERASE}$	Data flash master erase time(1)		200			ms
$t_{IFERASE}$	Instruction flash master erase time(1)		200			ms
$t_{PGERASE}$	Flash page erase time(1)		20			ms

(1) Specified by design. Not production tested

3.10 I²C-COMPATIBLE INTERFACE COMMUNICATION TIMING CHARACTERISTICS

T_A = –40°C to 85°C, 2.4 V < V_{CC} < 2.6 V; typical values at T_A = 25°C and V_{CC} = 2.5 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_r	SCL/SDA rise time				300	ns
t_f	SCL/SDA fall time				300	ns
$t_{w(H)}$	SCL pulse duration (high)		600			ns
$t_{w(L)}$	SCL pulse duration (low)		1.3			μs
$t_{su(STA)}$	Setup for repeated start		600			ns
$t_{d(STA)}$	Start to first falling edge of SCL		600			ns
$t_{su(DAT)}$	Data setup time		100			ns
$t_{h(DAT)}$	Data hold time		0			ns
$t_{su(STOP)}$	Setup time for stop		600			ns
$t_{(BUF)}$	Bus free time between stop and start		66			μs
f_{SCL}	Clock frequency				400	kHz

UDG–041

Figure 3-1. I²C-Compatible Interface Timing Diagrams

4 GENERAL DESCRIPTION

The bq27505 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 time-to-empty (TTE), time-to-full (TTF) and state-of-charge (SOC) as well as SOC interrupt signal to the host.

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 bq27505 control and status registers, as well as its data flash locations. Commands are sent from system to gauge using the bq27505's I^2C serial communications engine, and can be executed during application development, pack manufacture, or end-equipment operation.

Cell information is stored in the bq27505 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 bq27505'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 bq27505 provides two 32-byte user-programmable data flash memory blocks: ***Manufacturer Info Block A*** and ***Manufacturer Info Block B***. This data space is accessed through a data flash interface. For specifics on accessing the data flash, MANUFACTURER INFORMATION BLOCKS.

The key to the bq27505's high-accuracy gas gauging prediction is Texas Instrument's proprietary Impedance Track™ 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 bq27505 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 bq27505, cell impedance is computed, based on cell current, cell open-circuit voltage (OCV), and cell voltage under loading conditions.

The bq27505 external temperature sensing is optimized with the use of a high accuracy negative temperature coefficient (NTC) thermistor with R_{25} = 10.0kΩ ±1%. B25/85 = 3435K ± 1% (such as Semitec NTC 103AT). The bq27505 can also be configured to use its internal temperature sensor. When an external themistor is used, a 18.2k pull up resistor between BT/TOUT and TS pins is also required. The bq27505 uses temperature to monitor the battery-pack environment, which is used for fuel gauging and cell protection functionality.

To minimize power consumption, the bq27505 has different power modes: NORMAL, SLEEP, SLEEP+, HIBERNATE, and BAT INSERT CHECK. The bq27505 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 POWER MODES.

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 STANDAa/F1 11igns

STANDAa/F1 11igns

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 bq27505 during normal operation and additional features when the bq27505 is in different access modes, as described in Table 4-2.

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 (eg: bq27505)
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
Write_Temperature	0x0006	Yes	Write temperature to the gauge when the *[WRTEMP]* is 1
PREV_MACWRITE	0x0007	Yes	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
OCV_CMD	0x000c	Yes	Request the gauge to take a OCV measurement
BAT_INSERT	0x000d	Yes	Forces the BAT_DET bit set when the *[BIE]* bit is 0
BAT_REMOV	0x000e	Yes	Forces the BAT_DET bit clear when the *[BIE]* bit is 0
SET_HIBERNATE	0x0011	Yes	Forces CONTROL_STATUS *[HIBERNATE]* to 1
CLEAR_HIBERNATE	0x0012	Yes	Forces CONTROL_STATUS *[HIBERNATE]* to 0
SET_SLEEP+	0x0013	Yes	Forces CONTROL_STATUS *[SNOOZE]* to 1
CLEAR_SLEEP+	0x0014	Yes	Forces CONTROL_STATUS *[SNOOZE]* to 0
SEALED	0x0020	No	Places the bq27505 in SEALED access mode
IT_ENABLE	0x0021	No	Enables the Impedance Track™ algorithm
IT_DISABLE	0x0023	No	Disables the Impedance Track™ algorithm
CAL_MODE	0x0040	No	Places the bq27505 in calibration mode
RESET	0x0041	ces	[illegible]

4.1.1.1.1 CONTROL_STATUS: 0x0000

Instructs the fuel gauge to return status information to control addresses 0x00/0x01. The status word includes the following information.

Table 4-3. CONTROL_STATUS Bit Definitions

	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0
High byte	–	FAS	SS	CSV	CCA	BCA	OCVCMDCOMP	OCVFAIL
Low byte	INITCOMP	HIBERNATE	SNOOZE	SLEEP	LDMD	RUP_DIS	VOK	QEN

FAS = Status bit indicating the bq27505 is in FULL ACCESS SEALED state. Active when set.
SS = Status bit indicating the bq27505 is in SEALED state. Active when set.
CSV = Status bit indicating a valid data flash checksum has been generated. Active when set.
CCA = Status bit indicating the bq27505 Coulomb Counter Calibration routine is active. The CCA routine will take place approximately 1 minute after the initialization. Active when set.
BCA = Status bit indicating the bq27505 board calibration routine is active. Active when set.
OCVCMDCOMP = Status bit indicating the bq27505 has executed the OCV command. This bit can only be set with battery's presence. True when set.
OCVFAIL = Status bit indicating bq27505 OCV reading is failed due to the current. This bit can only be set with battery's presence. True when set.
INITCOMP = Initialization completion bit indicating the initialization completed. This bit can only be set with battery's presence. True when set.
HIBERNATE = Status bit indicating a request for entry into HIBERNATE from SLEEP mode. True when set. Default is 0.
SNOOZE = Status bit indicating the bq27505 SLEEP+ mode is enabled. True when set.
SLEEP = Status bit indicating the bq27505 is in SLEEP mode. True when set.
LDMD = Status bit indicating the bq27505 Impedance Track™ algorithm is using constant-power mode. True when set. Default is 0 (constant-current mode).
RUP_DIS = Status bit indicating the bq27505 Ra table updates are disabled. Updates disabled when set.
VOK = Status bit indicating the bq27505 voltages are okay for Qmax. True when set.
QEN = Status bit indicating the bq27505 Qmax updates enabled. True when set.

4.1.1.1.2 DEVICE_TYPE: 0x0001

Instructs the fuel gauge to return the device type to addresses 0x00/0x01.

4.1.1.1.3 FW_VERSION: 0x0002

Instructs the fuel gauge to return the firmware version to addresses 0x00/0x01.

4.1.1.1.4 HW_VERSION: 0x0003

Instructs the fuel gauge to return the hardware version to addresses 0x00/0x01.

4.1.1.1.5 DF_CHECKSUM: 0x0004

Instructs the fuel gauge to compute the checksum of the data flash memory. The checksum value is written and returned to addresses 0x00/0x01 (UNSEALED mode only). The checksum will not be calculated in SEALED mode; however, the checksum value can still be read.

4.1.1.1.6 WRITE_TEMPERATURE: 0X0006

Instructs the gauge to write the temperature. The temperature should be in the hexadecimal format with the unit of 0.1K.

4.1.1.1.7 PREV_MACWRITE: 0x0007

Instructs the fuel gauge to return the previous command written to addresses 0x00/0x01.

4.1.1.1.8 CHEM_ID: 0x0008

Instructs the fuel gauge to return the chemical identifier for the Impedance Track™ configuration to addresses 0x00/0x01.

4.1.1.1.9 BOARD_OFFSET: 0X0009

Instructs the fuel gauge to compute the coulomb counter offset with internal short and then without internal short applied across the sensing resistor (SR) inputs. The difference between the two measurements is the board offset. After a delay of approximately 32 seconds, this offset value is returned to addresses 0x00/0x01 and written to data flash. The CONROL STATUS *[BCA]* is also set. The user must prevent any charge or discharge current from flowing during the process. This function is only available when the fuel gauge is UNSEALED. When SEALED, this command only reads back the board-offset value stored in data flash.

4.1.1.1.10 CC_INT_OFFSET: 0X000A

Control data of 0x000a instructs the fuel gauge to compute the coulomb counter offset with internal short applied across the SR inputs. The offset value is returned to addresses 0x00/0x01, after a delay of approximately 16 seconds. This function is only available when the fuel gauge is UNSEALED. When SEALED, this command only reads back the CC_INT_OFFSET value stored in data flash.

4.1.1.1.11 WRITE_OFFSET: 0X000B

Control data of 0x000b causes the fuel gauge to write the coulomb counter offset to data flash.

4.1.1.1.12 OCV CMD: 0X000C

This command is to request the gauge to take a OCV reading. This command can only be issued after the *[INICOMP]* has been set, indicating the initialization has been completed. The OCV measurement take place at the beginning of the next repeated 1s firmware synchronization clock. The measurement takes about 183ms. During the same time period, the SOC_INT will be negated. The host should use this signal to reduce the load current below the C/20 in 8ms for a valid OCV reading. The OCV command *[OCVFAIL]* bit will be set if the OCV_CMD is issued when *[CHG_INH]* is set.

4.1.1.1.13 BAT_INSERT: 0X000D

This command is to force the BAT_DET bit to be set when the battery insertion detection is disabled. When the BIE is set to 0, the battery insertion detection is disabled. The gauge relies on the host to inform the battery insertion with this command to set the BAT_DET bit.

4.1.1.1.14 BAT_REMOVE: 0X000E

This command is to force the BAT_DET bit to be clear when the battery insertion detection is disabled. When the BIE is set to 0, the battery insertion detection is disabled. The gauge relies on the host to inform the battery insertion with this command to set the BAT_DET bit.

4.1.1.1.15 SET_HIBERNATE: 0x0011

Instructs the fuel gauge to force the CONTROL_STATUS *[HIBERNATE]* bit to 1. This will allow the gauge to enter the HIBERNATE power mode after the transition to SLEEP power state is detected. The *[HIBERNATE]* bit is automatically cleared upon exiting from HIBERNATE mode.

4.1.1.1.16 CLEAR_HIBERNATE: 0x0012

Instructs the fuel gauge to force the CONTROL_STATUS *[HIBERNATE]* bit to 0. This prevents the gauge from entering the HIBERNATE power mode after the transition to the SLEEP power state is detected. It can also be used to force the gauge out of HIBERNATE mode.

4.1.1.1.17 ENABLE SLEEP+ MODE: 0X0013

Instructs [illegible]
mode. The gauge will enter SLEEP+ power mode after the transition conditions are meet.

4.1.1.1.18Tj 25.23 1.1.1.18Tj 25.23 1.1.1.18Tj 2 Td (Instru/F3 10 .6ter)nIS

4.1.1.1.19 SEALED: 0x0020

Instructs the fuel gauge to transition from the UNSEALED state to the SEALED state. The fuel gauge must always be set to the SEALED state for use in end equipment.

4.1.1.1.20 IT_ENABLE: 0x0021

This command forces the fuel gauge to begin the Impedance Track™ algorithm, sets the ***IT Enable*** to 0x01 and causes the *[VOK]* and *[QEN]* flags to be set in the CONTROL_STATUS register. *[VOK]* is cleared if the voltages are not suitable for a Qmax update. This command is only available when the fuel gauge is UNSEALED.

4.1.1.1.21 IT_DISABLE: 0x0023

This command disables the fuel gauge the Impedance Track™ algorithm, clears the ***IT Enable*** to 0x00 and causes the *[QEN]* flags to be cleared in the CONTROL_STATUS register. This command is only available when the fuel gauge is UNSEALED.

4.1.1.1.22 CAL_MODE: 0X0040

This command instructs the fuel gauge to enter calibration mode. This command is only available when the fuel gauge is UNSEALED.

4.1.1.1.23 RESET: 0x0041

This command instructs the fuel gauge to perform a full reset. This command is only available when the fuel gauge is UNSEALED.

4.1.1.2 *AtRate( )*: 0x02/0x03

The *AtRate( )* read-/write-word function is the first half of a two-function command set used to set the AtRate value used in calculations made by the *AtRateTimeToEmpty( )* function. The *AtRate( )* units are in mA.

The *AtRate( )* value is a signed integer, with negative values interpreted as a discharge current value. The *AtRateTimeToEmpty( )* function returns the predicted operating time at the AtRate value of discharge. The default value for *AtRate( )* is zero and forces *AtRateTimeToEmpty( )* to return 65,535. Both the *AtRate( )* and *AtRateTimeToEmpty( )* commands must only be used in NORMAL mode.

4.1.1.3 *AtRateTimeToEmpty( )*: 0x04/0x05

This read-word function returns an unsigned integer value of the predicted remaining operating time if the battery is discharged at the *AtRate( )* value in minutes with a range of 0 to 65,534. A value of 65,535 indicates *AtRate( )* = 0. The fuel gauge updates *AtRateTimeToEmpty( )* within 1 s after the system sets the *AtRate( )* value. The fuel gauge automatically updates *AtRateTimeToEmpty( )* based on the *AtRate( )* value every 1 s. Both the *AtRate( )* and *AtRateTimeToEmpty( )* commands must only be used in NORMAL mode.

4.1.1.4 *Temperature( )*: 0x06/0x07

This read-word function returns an unsigned integer value of the temperature in units of 0.1 K measured by the fuel gauge.

4.1.1.5 *Voltage( )*: 0x08/0x09

This read-word function returns an unsigned integer value of the measured cell-pack voltage in mV with a range of 0 to 6000 mV.

4.1.1.6 *Flags( )*: 0x0a/0x0b

This read-word function returns the contents of the fuel-gauge status register, depicting the current operating status.

Table 4-4. Flags Bit Definitions

	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0
High byte	OTC	OTD	–	–	CHG_INH	XCHG	FC	CHG
Low byte	–	–	OCV_GD	WAIT_ID	BAT_DET	SOC1	SYSDOWN	DSG

OTC = Overtemperature in charge condition is detected. True when set.
OTD = Overtemperature in discharge condition is detected. True when set.
CHG_INH = Charge inhibit: unable to begin charging (temperature outside the range ***[Charge Inhibit Temp Low, Charge Inhibit Temp High]***). True when set.
XCHG = Charge suspend alert (temperature outside the range ***[Suspend Temperature Low, Suspend Temperature High]***). True when set.
FC = Full-charged condition reached. Set when charge termination condition is met. (RMFCC=1; Set FC_Set % = -1% when RMFCC = 0). True when set
CHG = (Fast) charging allowed. True when set.
OCV_GD = Good OCV measurement taken. True when set.
WAIT_ID = Waiting to identify inserted battery. True when set.
BAT_DET = Battery detected. True when set.
SOC1 = State-of-charge threshold 1 (***SOC1 Set***) reached. True when set.
SysDown = SystemDown bit indicating the system shut down. True when set
DSG = Discharging detected. True when set.

4.1.1.7 *NominalAvailableCapacity( )*: 0x0c/0x0d

This read-only command pair returns the uncompensated (less than C/20 load) battery capacity remaining. Units are mAh.

4.1.1.8 *FullAvailableCapacity( )*: 0x0e/0x0f

This read-only command pair returns the uncompensated (less than C/20 load) capacity of the battery ing

4.1.1.14 *StandbyCurrent( )*: 0x1a/0x1b

This read-only function returns a signed integer value of the measured standby current through the sense resistor. The *StandbyCurrent( )* is an adaptive measurement. Initially it reports the standby current programmed in ***Initial Standby***, and after spending several seconds in standby, reports the measured standby current.

The register value is updated every 1 second when the measured current is above the ***Deadband*** and is less than or equal to 2 × ***Initial Standby***. The first and last values that meet this criteria are not averaged in, since they may not be stable values. To approximate a 1 minute time constant, each new *StandbyCurrent( )* value is computed by taking approximate 93% weight of the last standby current and approximate 7% of the current measured average current.

4.1.1.15 *StandbyTimeToEmpty( )*: 0x1c/0x1d

This read-only function returns an unsigned integer value of the predicted remaining battery life at the standby rate of discharge, in minutes 0Td(value)Tjery

4.1.1.21 StateofHealth( ): 0x28/0x29

0x28 SOH percentage: this read-only fu[redacted] percentage of the ration of predicted *FCC(25* [redacted] *SOH LoadI)* is the calculated full charge capa[redacted] data flash. The range of the returned SOH[redacted] correspondingly.

0x29 SOH Status: this read-only function retur[redacted] SOH percentage. The meanings of the returned[redacted]

- 0x00: SOH not valid (initialization)
- 0x01: Instant SOH value ready
- 0x02: Initial SOH value ready
  - Calculation based on uncompensated Qmax
  - Updated at first grid point update after cell insertion
- 0x03: SOH value ready
  - Utilize the updated Qmax update
  - Calculation based on compensated Qmax
  - Updated after complete charge and relax is complete
- 0x04-0xFF: Reserved

4.1.1.22 *StateOfCharge( )*: 0x2c/0x2d

This read-only function returns an unsigned integer value of the predicted remaining battery cap[redacted] expressed as a percentage of *FullChargeCapacity( )*, with a range of 0 to 100%.

4.1.1.23 NormalizedImpedanceCal( ): 0x2e/0x2f

This read-only function returns an unsigned integer value of the calculated normalized impedance to 0°C at the current Depth of Discharge, with the unit of mΩ.

4.1.1.24 InstaneousCurrent Reading( ) 0x30/0x31

This read-only function returns a signed integer value that is the instantaneous current flow through the sense resistor. The conversion time is 125ms. It is updated every 1 second. Units are mA.

4.1.2 E)Tj 38.alue(initi Td (Read9 0 Td (Ÿ)Tj /F3)ommTd smeaniner

Table 4-5. Extended Data Commands (continued)

NAME		COMMAND CODE	UNITS	SEALED ACCESS(1) (2)	UNSEALED ACCESS(1) (2)
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

4.1.2.1 *DesignCapacity( )*: 0x3c/0x3d

SEALED and UNSEALED Access: This command returns the value is stored in ***Design Capacity*** and is expressed in mAh. This is intended to be the theoretical or nominal capacity of a new pack, but has no bearing on the operation of the fuel gauge functionality.

4.1.2.2 *DataFlashClass( )*: 0x3e

UNSEALED Access: This command sets the data flash class to be accessed. The class to be accessed must be entered in hexadecimal.

SEALED Access: This command is not available in SEALED mode.

4.1.2.3 *DataFlashBlock( )*: 0x3f

UNSEALED Access: This command sets the data flash block to be accessed. When 0x00 is written to *BlockDataControl( )*, *DataFlashBlock( )* holds the block number of the data flash to be read or written. Example: writing a 0x00 to *DataFlashBlock( )* specifies access to the first 32-byte block, a 0x01 specifies access to the second 32-byte block, and so on.

SEALED Access: This command directs which data flash block is accessed by the *BlockData( )* command. Writing a 0x00 to *DataFlashBlock( )* specifies that the *BlockData( )* command transfers authentication data. Issuing a 0x01 or 0x02 instructs the *BlockData( )* command to transfer ***Manufacturer Info Block A*** or ***B***, respectively.

4.1.2.4 *BlockData( )*: 0x40…0x5f

UNSEALED Access: This data block is the remainder of the 32 byte data block when accessing data flash.

SEALED Access: This data block is the remainder of the 32 byte data block when accessing ***Manufacturer Block Info A or B***.

4.1.2.5 *BlockDataChecksum( )*: 0x60

UNSEALED Access: This byte contains the checksum on the 32 bytes of block data read or written to data flash. The least-significant byte of the sum of the data bytes written must be complemented ([255 – *x*], for *x* the least-significant byte) before being written to 0x60.

SEALED Access: This byte contains the checksum for the 32 bytes of block data written to ***Manufacturer Info Block A or B***. The least-significant byte of the sum of the data bytes written must be complemented ([255 – *x*], for *x* the least-significant byte) before being written to 0x60.

4.1.2.6 *BlockDataControl( )*: 0x61

UNSEALED Access: This command is used to control data flash access mode. Writing 0x00 to this command enables *BlockData( )* to access general data flash. Writing a 0x01 to this command enables SEALED mode operation of *DataFlashBlock( )*.

SEALED Access: This command is not available in SEALED mode.

4.1.2.7 *DeviceNameLength( )*: 0x62

UNSEALED and SEALED Access:

4.3 MANUFACTURER INFORMATION BLOCKS

The bq27505 contains 96 bytes of user programmable data flash storage: ***Manufacturer Info Block A***, and ***Manufacturer Info Block B***. The method for accessing these memory locations is slightly different, depending on whether the device is in UNSEALED or SEALED modes.

When in UNSEALED mode and when and 0x00 has been written to *BlockDataControl( )*, accessing the manufacturer information blocks is identical to accessing general data flash locations. First, a *DataFlashClass( )* command is used to set the subclass, then a *DataFlashBlock( )* command sets the offset for the first data flash address within the subclass. The *BlockData( )* command codes contain the referenced data flash data. When writing the data flash, a checksum is expected to be received by *BlockDataChecksum( )*. Only when the checksum is received and verified is the data actually written to data flash.

As an [illegible] 58 and an Offset = 32 through 63 (32 byte block). The specification of Class = System Data is no(is[illegible]

4.4 ACCESS MODES

The bq27505 provides three security modes (FULL ACCESS, UNSEALED, and SEALED) that control data flash access permissions, according to Table 4

[redacted]

with SOC and the Qmax value, to determine *FullChargeCapacity( )* and *StateOfCharge( )*, speciffCspeciffC

Table 5-2. Constant-Power Model Used When *Load Mode = 1*

LoadSelect Value	**Power Model Used**
0	Average discharge power from previous cycle: There is an internal register that records the average discharge power through each entire discharge cycle. The previous average is stored in this register.
1(default)	Present average discharge power: This is the average discharge power from the beginning of this discharge cycle until present time.
2	Average current × voltage: based off the ***AverageCurrent( )*** and ***Voltage( )***.
3	Current × voltage: based off of a low-pass-filtered version of ***AverageCurrent( )*** *(τ=14 s)* and ***Voltage( )***
4	Design energy / 5: C Rate based off of Design Energy /5 or a C/5 rate in mA.
5	AtRate (10 mW): Use whatever value is in ***AtRate( )***.
6	User_Rate-10mW: Use the value in *User_Rate-10mW*. This mode provides a completely user-configurable method.

5.2.3 Reserve Cap-mAh

Reserve Cap-mAh determines how much actual remaining capacity exists after reaching 0 ***RemainingCapacity( )***, before ***Terminate Voltage*** is reached. A no-load rate of compensation is applied to this reserve.

5.2.4 Reserve Cap-mWh

Reserve Cap-mWh determines how much actual remaining capacity exists after reaching 0 ***AvailableEnergy( )***, before ***Terminate Voltage*** is reached. A no-load rate of compensation is applied to this reserve capacity.

5.2.5 Dsg Current Threshold

This register is used as a threshold by many functions in the bq27505 to determine if actual discharge current is flowing into or out of the cell. The default for this register is in Table 4-7, which should be sufficient for most applications. This threshold should be set low enough to be below any normal application load current but high enough to prevent noise or drift from affecting the measurement.

5.2.6 Chg Current Threshold

This register is used as a threshold by many functions in the bq27505 to determine if actual charge current is flowing into or out of the cell. The default for this register is in Table 4-7, which should be sufficient for most applications. This threshold should be set low enough to be below any normal charge current but high enough to prevent noise or drift from affecting the measurement.

5.2.7 Quit Current, DSG Relax Time, CHG Relax Time, and Quit Relax Time

The ***Quit Current*** is used as part of the Impedance Track™ algorithm to determine when the bq27505 enters relaxation mode from a current-flowing mode in either the charge direction or the discharge direction. The value of *Quit Current* is set to a default value in Table 4-7 and should be above the standby current of the system.

Either of the following criteria must be met to enter relaxation mode:

- |1 0™Td a(4-7)Tj 5 02s algorithm A0 t112 0 Td this (ox4j 45.2s6 0 Td (A0 Td (This)Tj 2405Td (.)i40.5.2s6

5.2.8 Qmax 0 and Qmax 1

Generically called *Qmax*

Table 5-3. Operation Configuration Bit Definition

	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0
High byte	RESCAP	BATG_OVR	INT_BREM	PFC_CFG1	PFC_CFG0	IWAKE	RSNS1	RSNS0
Low byte	INT_FOCV	IDSELEN	SLEEP	RMFCC	SOCI_POL	BATG_POL	BATL_POL	TEMPS

RESCAP = No-load rate of compensation is applied to the reserve capacity calculation. True when set. Default is 0.
BATG_OVR = BAT_GD override bit. If the gauge enters Hibernate only due to the cell voltage, the BAT_GD will not negate. True when set. Default is 0.
INT_BERM = Battery removal interrupt bit. The SOC_INT negates 1ms when the battery removal interrupt is enabled. True when set. The default is 0.
PFC_CFG1/PFC_CFG0 = Pin function code (PFC) mode selection: PFC 0, 1, or 2 selected by 0/0, 0/1, or 1/0, respectively. Default is PFC 1 (0/1).
IWAKE/RSNS1/RSNS0 = These bits configure the current wake function (see Table 5-6). Default is 0/0/1.
INT_FOCV = Indication of the measurement of the OCV during the initialization. The SOC_INT will negate during the first measurement if this bit is set. True when set. Default is 0.
IDSELEN = Enables cell profile selection feature. True when set. Default is 1.
SLEEP = The fuel gauge can enter sleep, if operating conditions allow. True when set. Default is 1.
RMFCC = RM is updated with the value from FCC, on valid charge termination. True when set. Default is 1.
SOCI_POL = SOC interrupt polarity is active-low. True when cleared. Default is 0.
BATG_POL = BAT_GD pin is active-low. True when cleared. Default is 0.
BATL_POL = BAT_LOW pin is active-high. True when set. Default is 1.
TEMPS = Selects external thermistor for *Temperature( )* measurements. True when set. Default is 1.

Some bq27505 pins are configured via the ***Operation Configuration B*** data flash register, as indicated in Table 5-4. This register is programmed/read via the methods described in Section 4.2.1: Accessing the Data Flash. The register is located at subclass = 64, offset = 9.

Table 5-4. Operation Configuration B Bit Definition

bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0
WRTEMP	BIE	BL_INT	GNDSEL	BattGdInit	–	–	–

WRTEMP = Enables the temperature write. The temperature could be written by the host. True when set. Default is 0.
BIE = Battery insertion detection enable. When the battery insertion detection is disabled, the gauge relies on the host command to set the BAT_DET bit. True when set. Default is 1.
BL_INT = Battery low interrupt enable. True when set. Default is 0.
GNDSEL = The ADC ground select control. The Vss (Pin D1) is selected as ground reference when the bit is clear. Pin A1 is selected when the bit is set. Default is 1.
BattGdInit = BAT_GD will be asserted during the initialization. It is for application that needs the system be powered up ASAP. True when set. Default is 0.

5.3.2 Pin Function Code Descriptions

The bq27505 has three possible pin-function variations that can be selected in accordance with the circuit architecture of the end application. Each variation has been assigned a pin function code, or PFC.

When the PFC is set to 0, only the bq27505 measures battery temperature under discharge and relaxation conditions. The charger does not receive any information from the bq27505 about the temperature readings, and therefore operates open-loop with respect to battery temperature.

A PFC of 1 is like a PFC of 0, except temperature is also monitored during battery charging. If charging temperature falls outside of the preset range defined in data flash, a ch[illegible]

5.3.4 Power Path Control With the BAT_GD Pin

The bq27505 must operate in conjunction with other electronics in a system appliance, such as chargers or other ICs and application circuits that draw appreciable power. After a battery is inserted into the system, there should be no charging current or a discharging current higher than C/20, so that an accurate OCV can be read. The OCV is used for helping determine which battery profile to use, as it constitutes part of the battery impedance measurement

When a battery is inserted into a system, the Impedance Track™ algorithm requires that no charging of the battery takes place and that any discharge is limited to less than C/20—these conditions are sufficient for the fuel gauge to take an accurate OCV reading. To disable these functions, the BAT_GD pin is merely negated from the default setting. Once an OCV reading has be made, the BAT_GD pin is asserted, thereby enabling battery charging and regular discharge of the battery. The ***Operation Configuration [BATG_POL]*** bit can be used to set the polarity of the battery good signal, should the default configuration need to be changed.

Figure 5-1. Power Mode Diagram

Figure 5-1 details how the BAT_GD pin functions in the context of battery insertion and removal, as well as NORMAL vs. SLEEP modes.

In PFC 1, the BAT_GD pin is also used to disable battery charging when the bq27505 reads battery temperatures outside the range defined by ***[Charge Inhibit Temp Low, Charge Inhibit Temp High]***. The BAT_GD line is asserted once temperature falls within the range ***[Charge Inhibit Temp Low + Temp Hys, Charge Inhibit Temp High – Temp Hys]***.

5.3.5 Battery Detection Using the BI/TOUT Pin

During power-up or hibernate activities, or any other activity where the bq27505 needs to determine whether a battery is connected or not, the fuel gauge applies a test for battery presence. First, the BI/TOUT pin is put into high-Z status. The weak 1.8MΩ pull-up resistor will keep the pin high while no battery is present. When a battery is inserted (or is already inserted) into the system device, the BI/TOUT pin will be pulled low. This state is detected by the fuel gauge, which polls this pin every second when the gauge has power. A *battery-disconnected* status is assumed when the bq27505 reads a thermistor voltage that is near 2.5V.

5.3.6 SOC_INT pin

The SOC_INT pin generates a pulse with different pulse width under various conditions. Some features needs to be enabled by setting the Operation Config.

Table 5-5. SOC_INT Pulse Condition and Width

	Enable Condition	Pulse Width	Comment
SOC_Delta Point	SOC_Delta ≠ 0	1 ms	During charge, when the SOC reaches (≥) the points, 1% + n × SOC_Delta and 100%; During discharge, when the SOC is less than (<) the points 1% + n × SOC_Delta and 0%; where n is an integer starting from 0 and the number generating SOC no greater than 100%
SOC1 Set	Always	1 ms	When RSOC reached the SOC1 Set or Clear threshold set in the Data Flash and BL_INT bit in ***Operation Configuration B*** is set.
SOC1 Clear	Always	1 ms	
SysDown Set	Always	1 ms	When the Battery Voltage reached the SysDown Set or Clear threshold set in the Data Flash
SysDown Clear	Always	1 ms	
State Change	SOC_Delta ≠ 0	1 ms	When there is a state change including charging, discharging and relaxation -
Battery Removal	*INT_BREM* bit is set in OpConfig	1ms	
OCV Command Fail	When CHG_INH is set	1ms	The OCV Command is failed when CHG_INT is set. The *OCV_FAIL* bit is also set.
OCV Command	After Initialization	Same as the OCV command execution time period	SOC_INT pulses for the OCV command after the initialization
OCV Command	*INT_FOCV* bit is set in OpConfig	Same as the OCV command execution time period	This command is to generate the SOC_INT pulse during the initialization

5.4 TEMPERATURE MEASUREMENT

The bq27505 measures battery temperature via its TS input, in order to supply battery temperature status information to the fuel gauging algorithm and charger-control sections of the gauge. Alternatively, it can also measure internal temperature via its on-chip temperature sensor, but only if the ***[TEMPS]*** bit of the ***Operation Configuration*** register is cleared. The ***[GNDSEL]*** bit of Operation Configuration B register selects the ground reference of the ADC converter for temperature measurement.

Regardless of which sensor is used for measurement, a system processor can request the current battery temperature by calling the *Temperature( )* function (see Section 4.1.1, *Standard Data Commands*, for specific information).

The thermistor circuit requires the use of an external NTC 103AT-type thermistor. Additional circuit information for connecting this thermistor to the bq27505 is shown in Section 8, *Reference Schematic*.

5.5 OVERTEMPERATURE INDICATION

5.5.1 Overtemperature: Charge

If during charging, *Temperature( )* reaches the threshold of ***OT Chg*** for a period of ***OT Chg Time*** and *AverageCurrent( )* > ***Chg Current Threshold***, then the *[OTC]* bit of *Flags( )* is set. When *Temperature( )* falls to ***OT Chg Recovery***, the *[OTC]* of *Flags( )* is reset.

If ***OT Chg Time*** = 0, then the feature is completely disabled.

5.5.2 Overtemperature: Discharge

If during discharging, *Temperature( )* reaches the threshold of ***OT Dsg*** for a period of ***OT Dsg Time***, and *AverageCurrent( )* ≤ ***–Dsg Current Threshold***, then the *[OTD]* bit of *Flags( )* is set. When *Temperature( )* falls to ***OT Dsg Recovery***, the *[OTD]* bit of *Flags( )* is reset.

If ***OT Dsg Time*** = 0, then feature is completely disabled.

5.6 CHARGING AND CHARGE-TERMINATION INDICATION

5.6.1 Detecting Charge Termination

For proper bq27505 operation, the cell charging voltage must be specified by the

5.7 POWER MODES

The bq27505 has different power modes: BAT INSERT CHECK, NORMAL, SLEEP, SLEEP+ and HIBERNATE. In NORMAL mode, the bq27505 is fully powered and can execute any allowable task. In SLEEP+ mode, both low frequency and high frequency oscillators are active. Although the SLEEP+ has higher current consumption than the SLEEP mode, it is also a reduced power mode. In SLEEP mode, the fuel gauge turns off the high frequency oscillator and exists in a reduced-power state, periodically taking measurements and performing calculations. In HIBERNATE mode, the fuel gauge is in a very low power state, but can be woken up by communication or certain I/O activity. Finally, the BAT INSERT CHECK mode is a powered-up, but low-power halted, state, where the bq27505 resides when no battery is inserted into the system.

The relationship between these modes is shown in Figure 5-1.

5.7.1 BAT INSERT CHECK Mode

This mode is a halted-CPU state that occurs when an adapter, or other power source, is present to power the bq27505 (and system), yet no battery has been detected. When battery insertion is detected, a series of initialization activities begin, which include: OCV measurement, setting the BAT_GD pin, and selecting the appropriate battery profiles.

Some commands, issued by a system processor, can be processed while the bq27505 is halted in this mode. The gauge will wake up to process the command, then return to the halted state awaiting battery insertion.

5.7.2 NORMAL MODE

The fuel gauge is in NORMAL mode when not in any other power mode. During this mode, *AverageCurrent( )*, *Voltage( )* and *Temperature( )* measurements are taken, and the interface data set is updated. Decisions to change states are also made. This mode is exited by activating a different power mode.

Because the gauge consumes the most power in NORMAL mode, the Impedance Track™ algorithm minimizes the time the fuel gauge remains in this mode.

5.7.3 SLEEP MODE

SLEEP mode is entered automatically if the feature is enabled (***Operation Configuration [SLEEP]*** = 1) and *AverageCurrent( )* is below

5.7.4 SLEEP+ MODE

Compared to the SLEEP mode, SLEEP+ mode has the high frequency oscillator in operation. The communication delay could be eliminated. The SLEEP+ is entered automatically if the feature is enabled (***CONTROL STATUS [SNOOZE]*** = 1) and *AverageCurrent( )* is below the programmable level ***Sleep Current***.

During SLEEP+ mode, the bq27505 periodically takes data measurements and updates its data set. However, a majority of its time is spent in an idle condition.

The bq27505 exits SLEEP+ if any entry condition is broken, specifically when (1) any communication activity with the gauge, or (2) *AverageCurrent( )* rises above ***Sleep Current***, or (3) a current in excess of I_{WAKE} through R_{SENSE} is detected.

5.7.5 HIBERNATE MODE

HIBERNATE mode should be used when the system equipment needs to enter a low-power state, and minimal gauge power consumption is required. This mode is ideal when a system equipment is set to its own HIBERNATE, SHUTDOWN, or OFF modes.

Before the fuel gauge can enter HIBERNATE mode, the system must set the *[HIBERNATE]* bit of the CONTROL_STATUS register. The gauge waits to enter HIBERNATE mode until it has taken a valid OCV measurement and the magnitude of the average cell current has fallen below ***Hibernate Current***. The gauge can also enter HIBERNATE mode if the cell voltage falls below ***Hibernate Voltage*** and a valid OCV measurement has been taken. The gauge will remain in HIBERNATE mode until the system issues a direct I^2C command to the gauge or a POR occurs. I^2C Communication that is not directed to the gauge will not wake the gauge.

It is important that BAT_GD be set to *disable* status (no battery charging/discharging). This prevents a charger application from inadvertently charging the battery before an OCV reading can be taken. It is the system's responsibility to wake the bq27505 after it has gone into HIBERNATE mode. After waking, the gauge can proceed with the initialization of the battery information (OCV, profile selection, etc.)

5.8 POWER CONTROL

5.8.1 WAKE-UP COMPARATOR

The wake up comparator is used to indicate a change in cell current while the bq27505 is in either SLEEP or HIBERNATE mode. ***Operation Configuration*** uses bits ***[RSNS1–RSNS0]*** to set the sense resistor selection. ***Operation Configuration*** also uses the ***[IWAKE]*** bit to select one of two possible voltage threshold ranges for the given sense resistor selection. An internal interrupt is generated when the threshold is breached in either the charge or discharge direction. Setting both ***[RSNS1]*** and ***[RSNS0]*** to 0 disables this feature.

Table 5-6. I_{WAKE} Threshold Settings[(1)]

RSNS1	RSNS0	IWAKE	Vth(SRP–SRN)
0	0	0	Disabled
0	0	1	Disabled
0	1	0	1.25 mV or –1.25 mV
0	1	1	2.5 mV or –2.5 mV
1	0	0	2.5 mV or –2.5 mV
1	0	1	5 mV or –5 mV
1	1	0	5 mV or –5 mV
1	1	1	10 mV or –10 mV

(1) The actual resistance value vs the setting of the sense resistor is n.4 62 0(1)BT /F80 Tf 8 ...

res25652 01f 0 Td (remV}52 0 Td5j 11.3 0 Td (mr)T09Td (is){tempera ure2.4 60)Tj ET BT changeBT /36)vibra 1on52 0Td (0)Tj Ej 29.12 0 Td (5-6.)Tj 81235 Td (actiTj 25.972

vibra 1on52 0/F7jj 29.148 76)

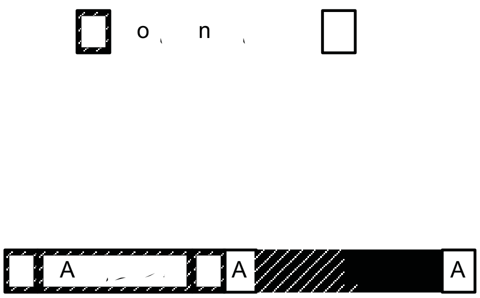
resduration 30 0 79.3 114 57FlashBT /F7 measurementd (164 2g 114 57accuracy.BT / ((1))Tjj 29.12 0 Td (5-6.)Tj 81240 TTd0 TzAutoc(vibra 1on52 06f 4j 11.3 0 fj 231Td6 0 Td (of)Tj 9.0

1) ET BT condi 10ns52 009.7.75 -2 Tchange.30.80 0 V

7 COMMUNICATIONS

7.1 I²C INTERFACE

The 27505 supports the standard I²C read, incremental read, quick read, one byte write, and incremental write functions. The 7 bit device address (ADDR) is the most significant 7 bits of the hex address and is fixed as 1010101. The 8-bit device address will; therefore, be 0xAA or 0xAB for write or read, respectively.

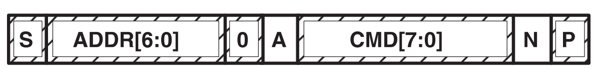


The "quick read" returns data at the address indicated by the address pointer. The address pointer, a register internal to the I²C communication engine, will increment whenever data is acknowledged by the bq27505 or the I²C master. "Quick writes" function in the same manner and are a convenient means of sending multiple bytes to consecutive command locations (such as two-byte commands that require two bytes of data)

The following command sequences are not supported:

Attempt to write a read-only address (NACK after data sent by master):

Attempt to read an address above 0x6B (NACK command):



7.2 I²C Time Out

The I²C engine will release both SDA and SCL if the I2C bus is held low for about 2 seconds. If the bq27505 was holding the lines, releasing them will free for the master to drive the lines. If an external condition is holding either of the lines low, the I²C engine will enter the low power sleep mode.

7.3 I²C Command Waiting time

To make sure the correct results of a command with the 400KHz I²C operation, a proper waiting time should be added between issuing command and reading results. For subcommands, the following diagram shows the waiting time required between issuing the control command the reading the status with the exception of checksum and OCV commands. A 100ms waiting time is required between the checksum command and reading result, and a 1.2 second waiting time is required between the OCV command and result. For read-write standard command, a minimum of 2 seconds is required to get the result updated. For read-only standard commands, there is no waiting time required, but the host should not iss[illegible] (ro

8 REFERENCE SCHEMATICS

8.1 SCHEMATIC

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/ Ball Finish	MSL Peak Temp (3)	Samples (Requires Login)
BQ27505YZGR-J1	NRND	DSBGA	YZG	12	3000	Green (RoHS & no Sb/Br)	SNAGCU	Level-1-260C-UNLIM	
BQ27505YZGT-J1	NRND	DSBGA	YZG	12	250	Green (RoHS & no Sb/Br)	SNAGCU	Level-1-260C-UNLIM	

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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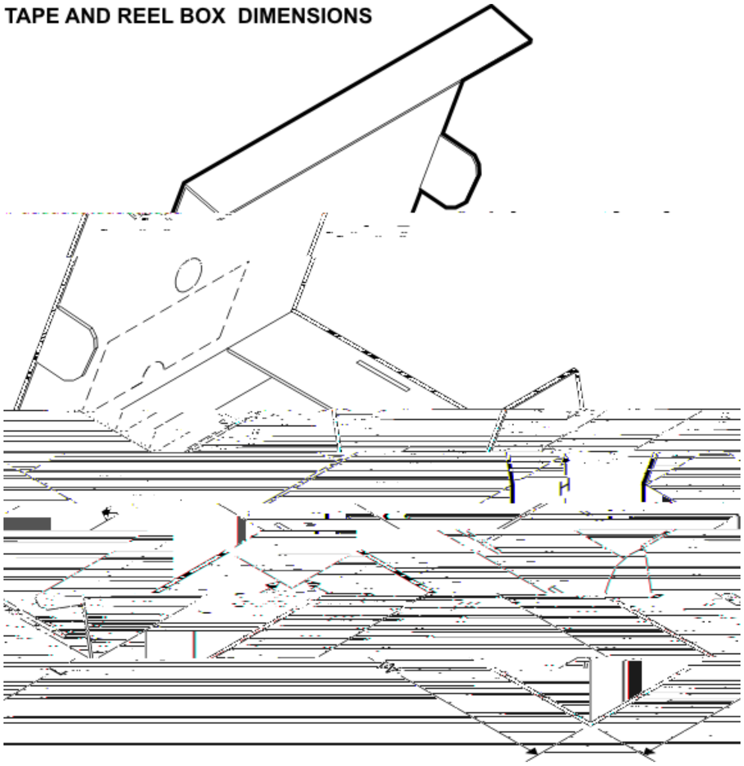
TAPE AND REEL INFORMATION

REEL DIMENSIONS TAPE DIMENSIONS

*All dimensions are nominal

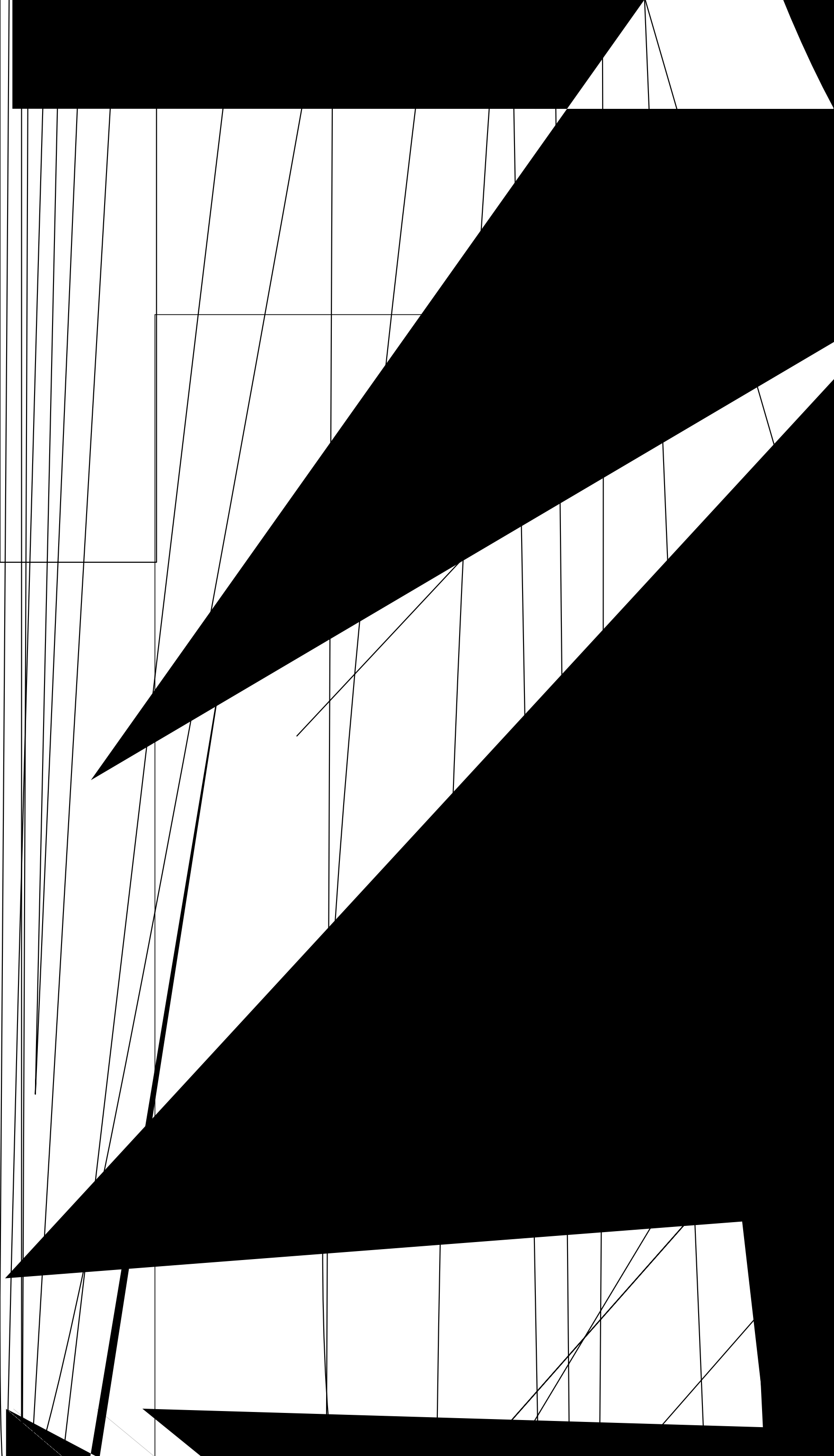
Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
BQ27505YZGT-J1	DSBGA	YZG	12	250	180.0	8.4	2.1	2.57	0.81	4.0	8.0	Q1

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
BQ27505YZGT-J1	DSBGA	YZG	12	250	220.0	220.0	34.0



NOTES:

IMPORTANT NOTICE