bq27411-G1 Single Cell Li-Ion Battery Fuel Gauge for Battery Pack Integration

1 Features

- Single-Series Cell Li-Ion Battery Fuel Gauge
  - Resides in Battery Pack
  - Low-Value External Sense Resistor (10 mΩ Typical)
  - One Time Programmable (OTP) Configuration Non-Volatile Memory (NVM)
  - Powered Directly from Battery with Integrated LDO
  - 400-kHz I^2C Serial Interface
  - Internal Temperature Sensor or Host-reported Temperature
- Battery Fuel Gauging Based on Patented Impedance Track™ Technology
  - Reports Remaining Capacity and State of Charge (SOC) with Smoothing Filter
  - Automatically Adjusts for Battery Aging, Self-discharge, Temperature, and Rate Changes
  - Battery State of Health (Aging) Estimation

2 Applications

- Smartphones, Feature Phones, and Tablets
- Digital Still and Video Cameras
- Handheld Terminals
- MP3 or Multimedia Players

3 Description

The Texas Instruments bq27411-G1 device is a battery fuel gauging solution for single-series cell Li-Ion battery packs. The device requires minimal configuration and uses One Time Programmable (OTP) Non-Volatile Memory (NVM) to avoid an initialization download by the system processor.

The fuel gauge uses the patented Impedance Track™ algorithm for fuel gauging, and provides information such as remaining battery capacity (mAh), state-of-charge (%), and battery voltage (mV).

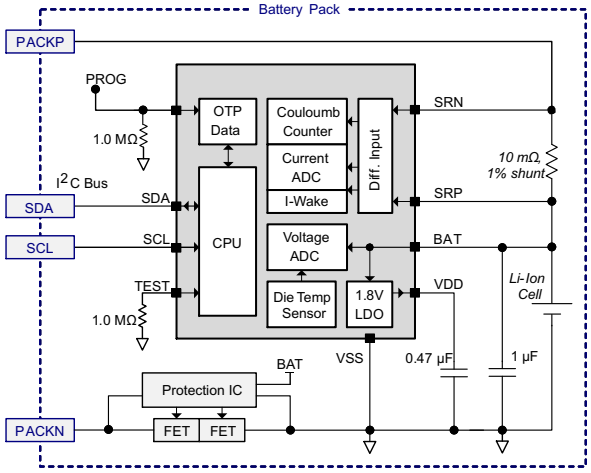
The small, 12-pin, 2.50 mm × 4.00 mm, Small Outline No-Lead (SON) package is ideal for space-constrained applications.

Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
bq27411-G1	VSON (12)	2.50 mm x 4.00 mm

(1) For all available packages, see the orderable addendum at the end of the datasheet.

4 Simplified Schematic



An IMPORTANT NOTICE at the end of this data sheet addresses availability, warranty, changes, use in safety-critical applications, intellectual property matters and other important disclaimers. PRODUCTION DATA.

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5 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision B (December 2014) to Revision C — **Page**

- Changed Figure 5 ... 13
- Added *Community Resources* ... 18

Changes from Revision A (October 2014) to Revision B — **Page**

- Changed schematic by adding a 1-µF capacitor ... 1
- Added description for connecting 1-µF capacitor ... 3
- Changed Handling Ratings to ESD Ratings ... 4
- Changed by adding a 1-µF capacitor ... 8
- Changed connection description for BAT pin ... 16
- Changed recommend to required ... 17
- Added C_{BAT} capacitor ... 17

Changes from Original (January 2014) to Revision A — **Page**

- Added *Handling Ratings* table, *Feature Description* section, *Device Functional Modes*, *Application and Implementation* section, *Power Supply Recommendations* section, *Layout* section, *Device and Documentation Support* section, and *Mechanical, Packaging, and Orderable Information* section ... 1

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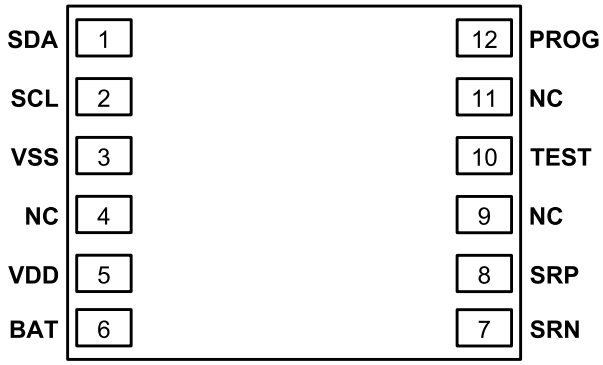
6 Device Comparison Table

PART NUMBER	BATTERY TYPE	CHEM_ID(1)	DM_CODE(2)	FIRMWARE VERSION(3)
bq27411DRZR-G1A	$LiCoO_2$ (4.2 V maximum charge)	0x0128	0x80	1.09 (0x0109)
bq27411DRZT-G1A				
bq27411DRZR-G1B	$LiCoO_2$ (4.3 V maximum charge)	0x0312	0x90	
bq27411DRZT-G1B				
bq27411DRZR-G1C	$LiCoO_2$ (4.35 V maximum charge)	0x0354	0xA0	
bq27411DRZT-G1C				

(1) Refer to the *CHEM_ID* subcommand to confirm the battery chemistry type.
(2) Refer to the *DM_CODE* subcommand to confirm the Data Memory code.
(3) Refer to the *FW_VERSION* subcommand to confirm the firmware version.

7 Pin Configuration and Functions

(TOP VIEW)



Pin Functions

PIN		TYPE(1)	DESCRIPTION
NAME	NUMBER		
BAT	6	PI, AI	LDO regulator input, battery voltage input, and coulomb counter input typically connected to the PACK+ terminal. Connect a capacitor (1 µF) between BAT to V_{SS}. Place the capacitor close to gauge.
NC	4, 8, 11	—	No internal connection. May be left floating or tied to V_{SS}.
PROG	12	DO	Programming voltage input for the One Time Programmable (OTP) memory to be used during customer factory configuration. To avoid a floating input condition, recommend terminating with a 1.0-MΩ (typical) pulldown resistor to V_{SS} for reduced power consumption.
SCL	2	DIO	Slave I^2C serial bus for communication with system (Master). Open-drain pins. Use with external 5- to 10-kΩ pullup resistors (typical) for each pin. If the external pullup resistors will be disconnected from these pins during normal operation, recommend using external 1.0-MΩ pulldown resistors to V_{SS} at each pin to avoid floating inputs.
SDA	1	DIO	
SRN	7	AI	Coulomb counter differential inputs expecting an external 10-mΩ, 1% sense resistor. Connect SRP to BAT (CELLP) and connect SRN to PACKP. Low-side current sensing can be enabled by connecting SRN to BATN and SRP to PACKN. Refer to the typical application diagrams in *Typical Applications*.
SRP	8	AI	
TEST	10	DI	This digital factory TEST pin must be pulled low for proper operation in customer's application. Recommend terminating with a 1.0-MΩ (typical) pulldown resistor to V_{SS} for reduced power consumption.
V_{DD}	5	PO	1.8-V Regulator Output. Decouple with 0.47-µF ceramic capacitor to V_{SS}. This pin is not intended to provide power for other devices in the system.
V_{SS}	3	PI	Ground pin

(1) DIO = Digital input-output, AI = Analog input, P = Power connection

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8 Specifications

8.1 Absolute Maximum Ratings

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

		MIN	MAX	UNIT
V_{BAT}	BAT pin input voltage range	–0.3	6	V
V_{SR}	SRP and SRN pins input voltage range	–0.3	V_{BAT} + 0.3	V
	Differential voltage across SRP and SRN. ABS(SRP – SRN)		2	V
V_{DD}	V_{DD} pin supply voltage range (LDO output)	–0.3	2	V
V_{IOD}	Open-drain IO pins (SDA, SCL)	–0.3	6	V
V_{PROG}	PROG (pin 12)	–0.3	7.8	V
V_{IOPP}	Push-pull IO pins (TEST, pin 10)	–0.3	V_{DD} + 0.3	V
T_A	Operating free-air temperature range	–40	85	°C
T_{stg}	Storage temperature	–65	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.

8.2 ESD Ratings

		VALUE	UNIT
$V_{(ESD)}$ Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001(1)	±1500	V
	Charged-device model (CDM), per JEDEC specification JESD22-C101(2)	±250	

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

8.3 Recommended Operating Conditions

T_A = 30°C and V_{REGIN} = V_{BAT} = 3.6 V (unless otherwise noted)

			MIN	NOM	MAX	UNIT
C_{BAT}(1)	External input capacitor for internal LDO between BAT and V_{SS}	Nominal capacitor values specified. Recommend a 5% ceramic X5R type capacitor located close to the device.		0.1		µF
C_{LDO18}(1)	External output capacitor for internal LDO between V_{DD} and V_{SS}			0.47		µF
V_{PU}(1)	External pull-up voltage for open-drain pins (SDA, SCL, PROG)		1.62		3.6	V
V_{PV}	PROG Programming Voltage [RA0]	T_A = 15°C to 35°C. OTP Programming mode only.	7.3	7.4	7.5	V
I_{PV}	PROG Programming Current [RA0]			4	5	mA

(1) Specified by design. Not production tested.

8.4 Thermal Information

over operating free-air temperature range (unless otherwise noted)

THERMAL METRIC(1)		bq27411-G1	UNIT
		DRZ (12 PINS)	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	64.1	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	59.8	
$R_{\theta JB}$	Junction-to-board thermal resistance	52.7	
ψ_{JT}	Junction-to-top characterization parameter	0.3	
ψ_{JB}	Junction-to-board characterization parameter	28.3	
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	2.4	

(1) For more information about traditional and new thermal metrics, see the IC Package Thermal Metrics application report, SPRA953.

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8.5 Supply Current

T_A = 30°C and V_{REGIN} = V_{BAT} = 3.6 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_{CC} (1)	NORMAL mode current	I_{LOAD} > ***Sleep Current*** (2)		93		µA
I_{SLP} (1)	SLEEP mode current	I_{LOAD} < ***Sleep Current*** (2)		21		µA
I_{HIB} (1)	HIBERNATE mode current	I_{LOAD} < ***Hibernate Current*** (2)		9		µA
I_{SD} (1)	SHUTDOWN mode current	Fuel gauge in host-commanded SHUTDOWN mode. (LDO regulator output disabled)		0.6		µA

(1) Specified by design. Not production tested.
(2) Wake Comparator Disabled

8.6 Digital Input and Output DC Characteristics

T_A = –40°C to 85°C, typical values at T_A = 30°C and V_{REGIN} = 3.6 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{IH(OD)}$	Input voltage, high (2)	External pullup resistor to V_{PU}	V_{PU} × 0.7			V
$V_{IH(PP)}$	Input voltage, high (3)		1.4			V
V_{IL}	Input voltage, low (2) (3)				0.6	V
V_{OL}	Output voltage, low (2)				0.6	V
I_{OH}	Output source current, high (2)				0.5	mA
$I_{OL(OD)}$	Output sink current, low (2)				–3	mA
C_{IN} (1)	Input capacitance (2) (3)				5	pF
I_{lkg}	Input leakage current (2) (3)	SCL, SDA, and TEST pins			0.1	µA
		PROG pin			1.0	

(1) Specified by design. Not production tested.
(2) Open Drain pins: (SCL, SDA, PROG)
(3) Push-pull pin: (TEST)

8.7 LDO Regulator, Wake-Up, and Auto-Shutdown DC Characteristics

T_A = –40°C to 85°C, typical values at T_A = 30°C and V_{REGIN} = 3.6 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{BAT}	BAT pin regulator input		2.45		4.5	V
V_{DD}	Regulator output voltage			1.8		V
$UVLO_{IT+}$	V_{BAT} Undervoltage lockout LDO Wake-up rising threshold			2		V
$UVLO_{IT-}$	V_{BAT} Undervoltage lockout LDO Auto-shutdown falling threshold			1.95		V

(1) Specified by design. Not production tested.

8.8 ADC (Temperature and Cell Measurement) Characteristics

T_A = –40°C to 85°C; typical values at T_A = 30°C and V_{REGIN} = 3.6 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{IN(BAT)}$	BAT pin voltage measurement range	Voltage divider enabled	2.45		4.5	V
t_{ADC_CONV}	Conversion time			125		ms
	Effective Resolution			15		bits

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

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8.9 Integrating ADC (Coulomb Counter) Characteristics

T_A = –40°C to 85°C; typical values at T_A = 30°C and V_{REGIN} = 3.6 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{SR}	Input voltage range from BAT to SRX pins		BAT ± 25			mV
t_{SR_CONV}	Conversion time	Single conversion		1		s
	Effective Resolution	Single conversion		16		bits

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

8.10 I²C-Compatible Interface Communication Timing Characteristics

T_A = –40°C to 85°C; typical values at T_A = 30°C and V_{REGIN} = 3.6 V (unless otherwise noted)

			MIN	TYP	MAX	UNIT
Standard Mode (100 kHz)						
$t_{d(STA)}$	Start to first falling edge of SCL		4			µs
$t_{w(L)}$	SCL pulse duration (low)		4.7			µs
$t_{w(H)}$	SCL pulse duration (high)		4			µs
$t_{su(STA)}$	Setup for repeated start		4.7			µs
$t_{su(DAT)}$	Data setup time	Host drives SDA	250			ns
$t_{h(DAT)}$	Data hold time	Host drives SDA	0			ns
$t_{su(STOP)}$	Setup time for stop		4			µs
$t_{(BUF)}$	Bus free time between stop and start	Includes command waiting time	66			µs
t_f	SCL or SDA fall time (1)				300	ns
t_r	SCL or SDA rise time (1)				300	ns
f_{SCL}	Clock frequency (2)				100	kHz
Fast Mode (400 kHz)						
$t_{d(STA)}$	Start to first falling edge of SCL		600			ns
$t_{w(L)}$	SCL pulse duration (low)		1300			ns
$t_{w(H)}$	SCL pulse duration (high)		600			ns
$t_{su(STA)}$	Setup for repeated start		600			ns
$t_{su(DAT)}$	Data setup time	Host drives SDA	100			ns
$t_{h(DAT)}$	Data hold time	Host drives SDA	0			ns
$t_{su(STOP)}$	Setup time for stop		600			ns
$t_{(BUF)}$	Bus free time between stop and start	Includes command waiting time	66			µs
t_f	SCL or SDA fall time (1)				300	ns
t_r	SCL or SDA rise time (1)				300	ns
f_{SCL}	Clock frequency (2)				400	kHz

(1) Specified by design. Not production tested.
(2) If the clock frequency (f_{SCL}) is > 100 kHz, use 1-byte write commands for proper operation. All other transactions types are supported at 400 kHz. (See *I²C Interface* and *I²C Command Waiting Time*.)

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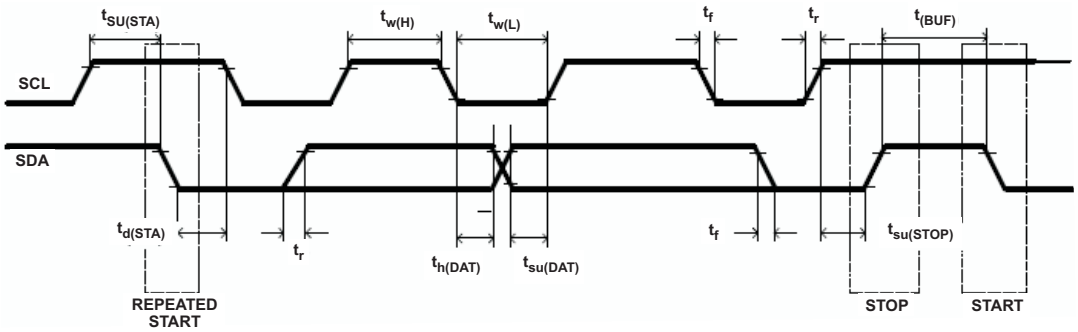


Figure 1. I²C-Compatible Interface Timing Diagrams

8.11 Typical Characteristics

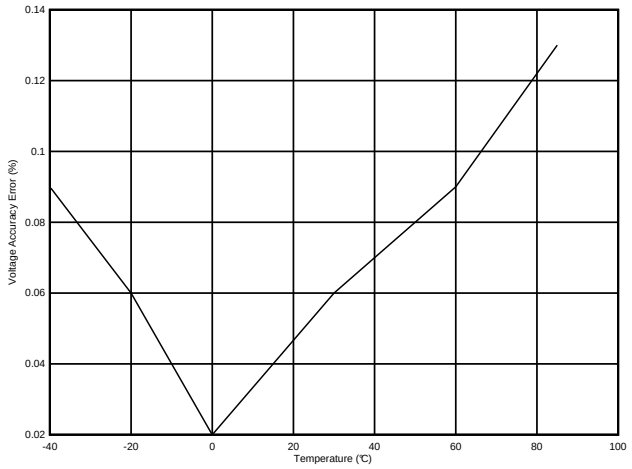


Figure 2. Voltage Accuracy

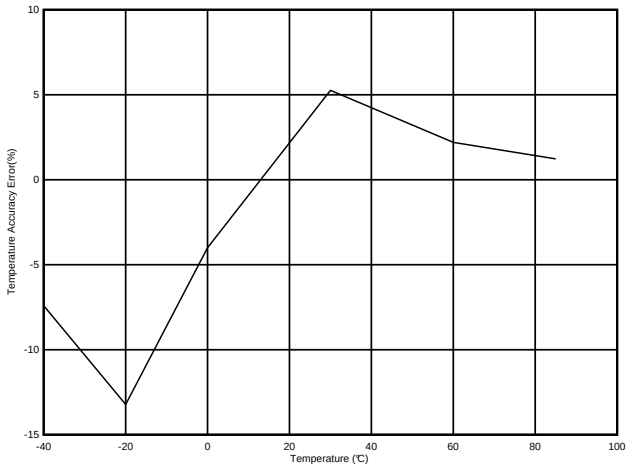


Figure 3. Temperature Accuracy

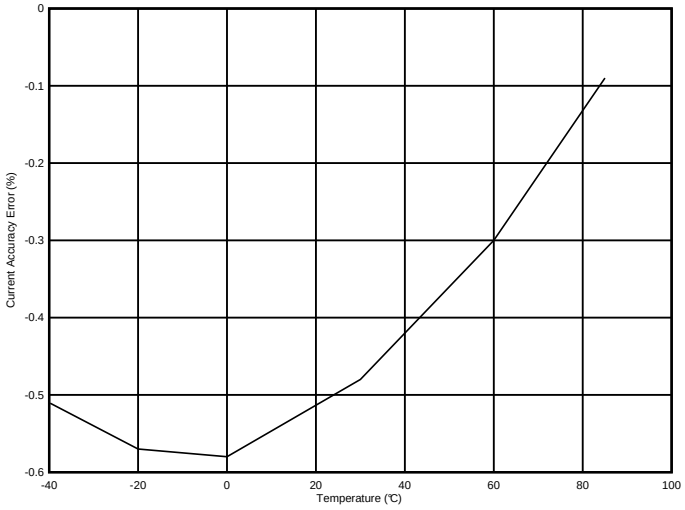


Figure 4. Current Accuracy

9 Detailed Description

9.1 Overview

The bq27411-G1 fuel gauge 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). The fuel gauge is available in several options optimized for different battery cell chemistries (see *Device Comparison Table*). Configuration parameters unique to the customer's application are programmed in OTP memory at the customer's factory using a 7.4-V typical voltage applied to the PROG pin and a set of I^2C programming commands. More details are available in the *SmartFlash OTP Programming* (SLUA703) document.

NOTE

Formatting Conventions used in this Document:

Commands: *italics* with parentheses() and no breaking spaces, for example, *Control().*

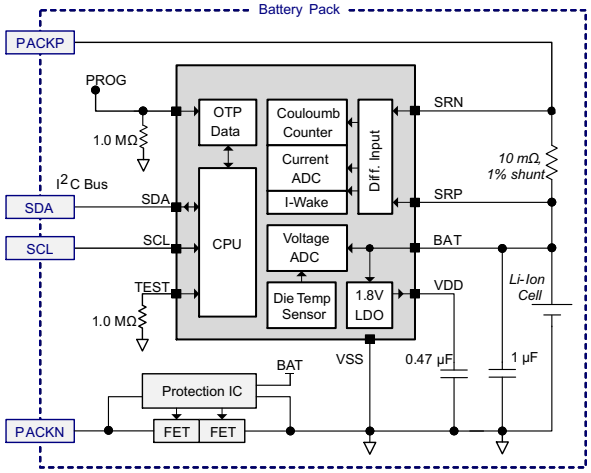
Data Flash: *italics*, **bold**, and breaking spaces, for example, ***Design Capacity***.

Register bits and flags: *italics* with brackets [ ], for example, *[TDA]*

Data flash bits: *italics*, **bold**, and brackets [ ], for example, ***[LED1]***

Modes and states: ALL CAPITALS, for example, UNSEALED mode.

9.2 Functional Block Diagram



9.3 Feature Description

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 control and status registers, as well as its data locations.

The key to the high-accuracy gas gauging prediction is Texas Instruments proprietary Impedance Track algorithm. This algorithm uses cell measurements, characteristics, and properties to create state-of-charge predictions that can achieve high accuracy across a wide variety of operating conditions and over the lifetime of the battery.

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Feature Description (continued)

The fuel gauge measures the charging or discharging of the battery by monitoring the voltage across a small-value sense resistor. When a cell is attached to the fuel gauge, cell impedance is computed, based on cell current, cell open-circuit voltage (OCV), and cell voltage under loading conditions.

The fuel gauge uses an integrated temperature sensor for estimating cell temperature. Alternatively, the host processor can provide temperature data for the fuel gauge.

For more details, see the *bq27411-G1 Technical Reference Manual* (SLUUAS7).

9.4 Device Functional Modes

To minimize power consumption, the fuel gauge has several power modes: INITIALIZATION, NORMAL, SLEEP, and HIBERNATE. The fuel gauge passes automatically between these modes, depending upon the occurrence of specific events, though a system processor can initiate some of these modes directly.

For more details, see the *bq27411-G1 Technical Reference Manual* (SLUUAS7).

9.5 Programming

9.5.1 Standard Data Commands

The bq27411-G1 fuel gauge 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 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. For more details, see the *bq27411-G1 Technical Reference Manual* (SLUUAS7).

Table 1. Standard Commands

NAME		COMMAND CODE	UNIT	SEALED ACCESS
Control()	CNTL	0x00 and 0x01	NA	R/W
Temperature()	TEMP	0x02 and 0x03	0.1°K	R/W
Voltage()	VOLT	0x04 and 0x05	mV	R
Flags()	FLAGS	0x06 and 0x07	NA	R
NominalAvailableCapacity()		0x08 and 0x09	mAh	R
FullAvailableCapacity()		0x0A and 0x0B	mAh	R
RemainingCapacity()	RM	0x0C and 0x0D	mAh	R
FullChargeCapacity()	FCC	0x0E and 0x0F	mAh	R
AverageCurrent()		0x10 and 0x11	mA	R
StandbyCurrent()		0x12 and 0x13	mA	R
MaxLoadCurrent()		0x14 and 0x15	mA	R
AveragePower()		0x18 and 0x19	mW	R
StateOfCharge()	SOC	0x1C and 0x1D	%	R
InternalTemperature()		0x1E and 0x1F	0.1°K	R
StateOfHealth()	SOH	0x20 and 0x21	num / %	R
RemainingCapacityUnfiltered()		0x28 and 0x29	mAh	R
RemainingCapacityFiltered()		0x2A and 0x2B	mAh	R
FullChargeCapacityUnfiltered()		0x2C and 0x2D	mAh	R
FullChargeCapacityFlitered()		0x2E and 0x2F	mAh	R
StateOfChargeUnfiltered()		0x30 and 0x31	%	R

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9.5.2 *Control()*: 0x00 and 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 fuel gauge during normal operation and additional features when the device is in different access modes, as described in Table 2. For additional details, see the *bq27411-G1 Technical Reference Manual* (SLUUAS7).

Table 2. *Control()* Subcommands

CONTROL FUNCTION	CONTROL DATA	SEALED ACCESS	DESCRIPTION
CONTROL_STATUS	0x0000	Yes	Reports the status of device
DEVICE_TYPE	0x0001	Yes	Reports the device type (0x0421)
FW_VERSION	0x0002	Yes	Reports the firmware version of the device
DM_CODE	0x0004	Yes	Reports the Data Memory Code number stored in OTP memory
PREV_MACWRITE	0x0007	Yes	Returns previous MAC command code
CHEM_ID	0x0008	Yes	Reports the chemical identifier of the battery profile currently used by the Impedance Track configuration
SET_HIBERNATE	0x0011	Yes	Forces CONTROL_STATUS [*HIBERNATE*] to 1.
CLEAR_HIBERNATE	0x0012	Yes	Forces CONTROL_STATUS [*HIBERNATE*] to 0.
SET_CFGUPDATE	0x0013	No	Force CONTROL_STATUS [*CFGUPMODE*] to 1 and gauge enters CONFIG UPDATE mode.
SEALED	0x0020	No	Places the device in SEALED access mode.
RESET	0x0041	No	Performs a full device reset.
SOFT_RESET	0x0042	No	Gauge exits CONFIG UPDATE mode.

9.5.3 Extended Data Commands

Extended data 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 command bytes for a given extended command ranges in size from single to multiple bytes, as specified in Table 3.

Table 3. Extended Commands

Name	Command Code	Unit	SEALED Access (1) (2)	UNSEALED Access (1) (2)
OpConfig()	0x3A and 0x3B	NA	R	R
DesignCapacity()	0x3C and 0x3D	mAh	R	R
DataClass() (2)	0x3E	NA	NA	RW
DataBlock() (2)	0x3F	NA	RW	RW
BlockData()	0x40 through 0x5F	NA	R	RW
BlockDataCheckSum()	0x60	NA	RW	RW
BlockDataControl()	0x61	NA	NA	RW
Reserved	0x62 through 0x7F	NA	R	R

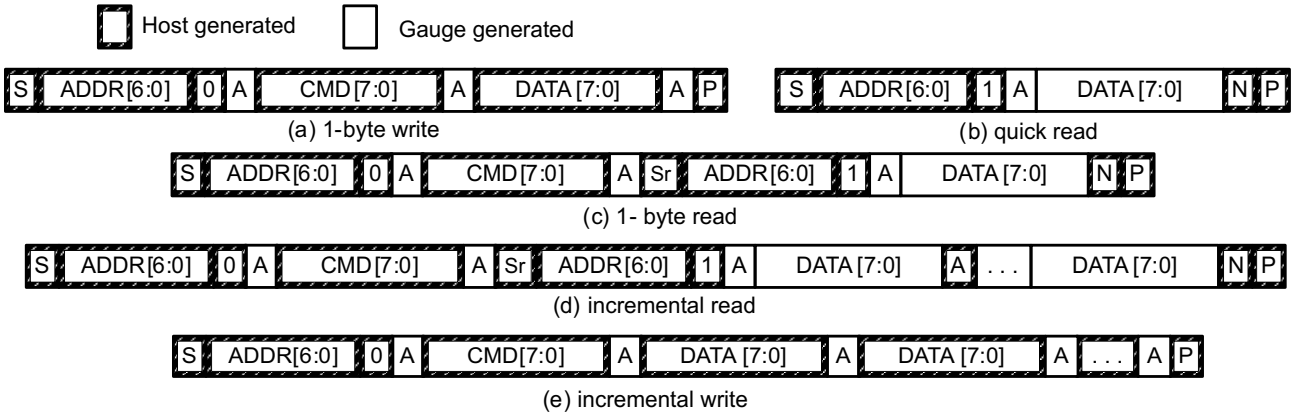
(1) SEALED and UNSEALED states are entered via commands to *Control()* 0x00 and 0x01
(2) In SEALED mode, data cannot be accessed through commands 0x3E and 0x3F.

9.5.4 Communications

9.5.4.1 I^2C Interface

The bq27411-G1 fuel gauge supports the standard I^2C 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 first 8 bits of the I^2C protocol are, therefore, 0xAA or 0xAB for write or read, respectively.

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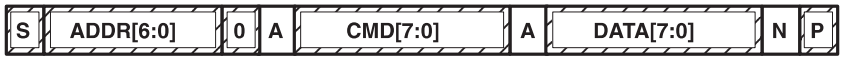


(S = Start, Sr = Repeated Start, A = Acknowledge, N = No Acknowledge, and P = Stop).

The quick read returns data at the address indicated by the address pointer. The address pointer, a register internal to the I^2C communication engine, increments whenever data is acknowledged by the fuel gauge or the I^2C 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):



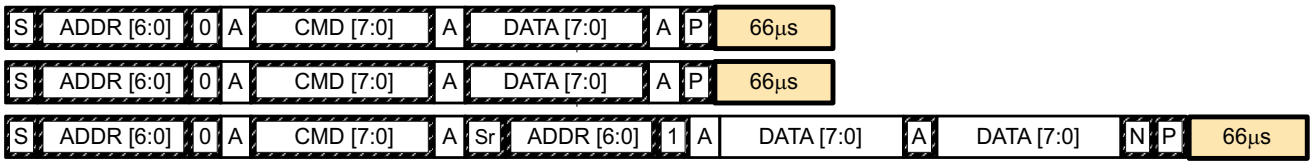
9.5.4.2 I^2C Time Out

The I^2C engine releases both SDA and SCL if the I^2C bus is held low for 2 seconds. If the fuel gauge is holding the lines, releasing them frees them for the master to drive the lines. If an external condition is holding either of the lines low, the I^2C engine enters the low-power SLEEP mode.

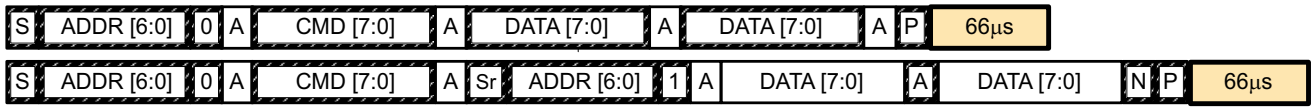
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9.5.4.3 I²C Command Waiting Time

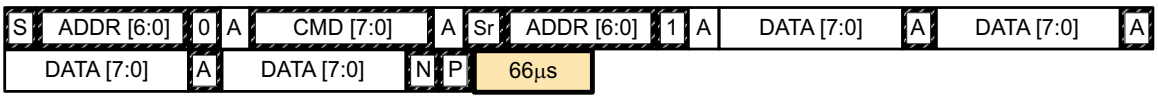
To ensure proper operation at 400 kHz, a $t_{(BUF)}$ ≥ 66-µs bus-free waiting time must be inserted between all packets addressed to the fuel gauge. In addition, if the SCL clock frequency (f_{SCL}) is > 100 kHz, use individual 1-byte write commands for proper data flow control. The following diagram shows the standard waiting time required between issuing the control subcommand the reading the status 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 must not issue any standard command more than two times per second. Otherwise, the gauge could result in a reset issue due to the expiration of the watchdog timer.



Waiting time inserted between two 1-byte write packets for a subcommand and reading results
(required for 100 kHz < f_{SCL} ≤ 400 kHz)



Waiting time inserted between incremental 2-byte write packet for a subcommand and reading results
(acceptable for f_{SCL} ≤ 100 kHz)



Waiting time inserted after incremental read

9.5.4.4 I²C Clock Stretching

A clock stretch of up to 4 ms can occur during all modes of fuel gauge operation. In SLEEP and HIBERNATE modes, a short ≤ 100-µs clock stretch occurs on all I²C traffic as the device must wake-up to process the packet. In the other modes (INITIALIZATION, NORMAL) a ≤ 4-ms clock stretching period may occur within packets addressed for the fuel gauge. The majority of clock stretch periods are small while the I²C interface performs normal data flow control.

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10 Applications and Implementation

NOTE

Information in the following application section is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

10.1 Application Information

The bq27411-G1 device is a fuel gauging solution for single-series cell Li-Ion battery packs. The device requires minimal configuration and uses One Time Programmable (OTP) Non-Volatile Memory (NVM) to avoid an initialization download by the system processor. To allow for optimal performance in the end application, special considerations must be taken to ensure minimization of measurement error through proper printed circuit board (PCB) board layout. Such requirements are detailed in *Design Requirements*.

10.2 Typical Applications

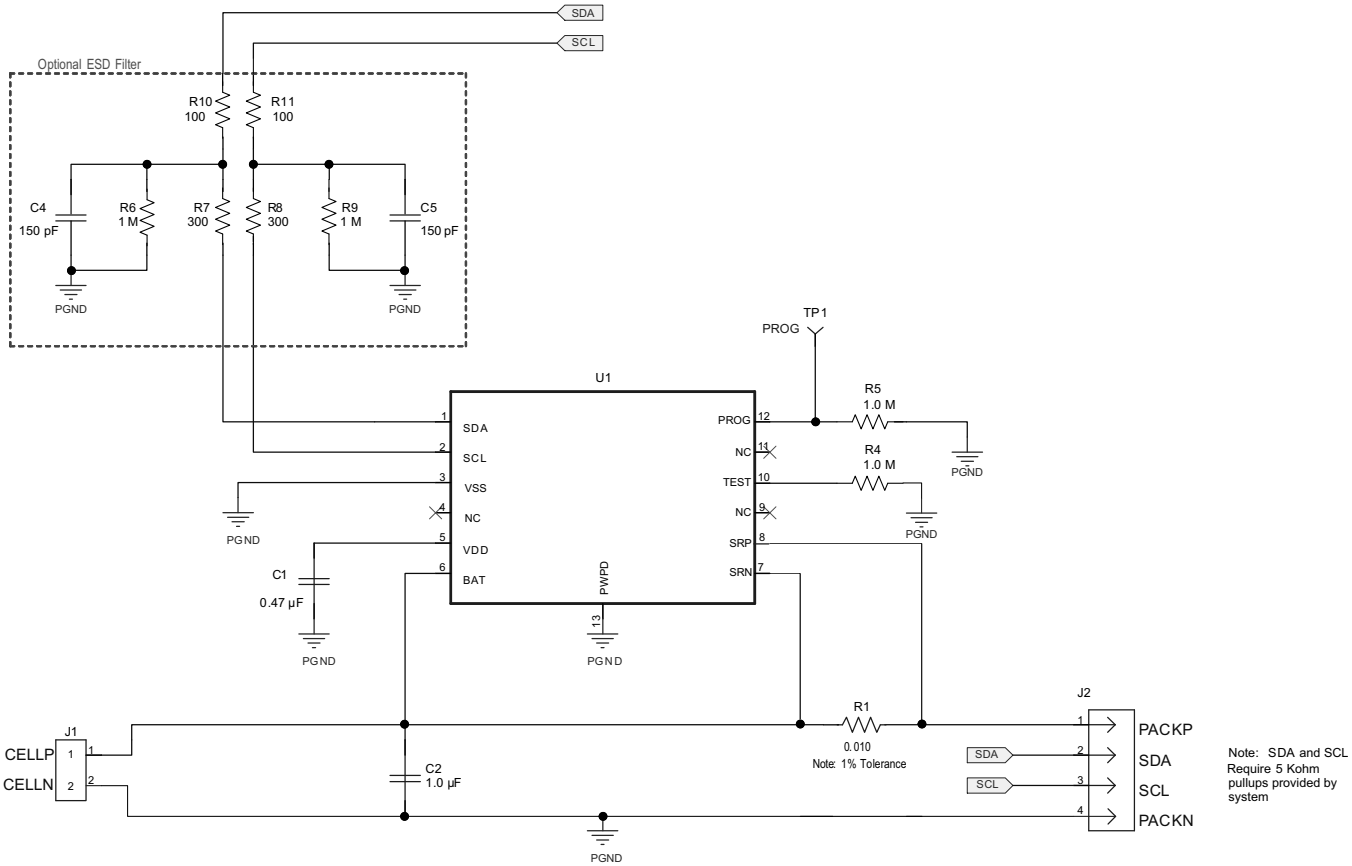


Figure 5. Typical Application with High-Side Current Sense Resistor

Typical Applications (continued)

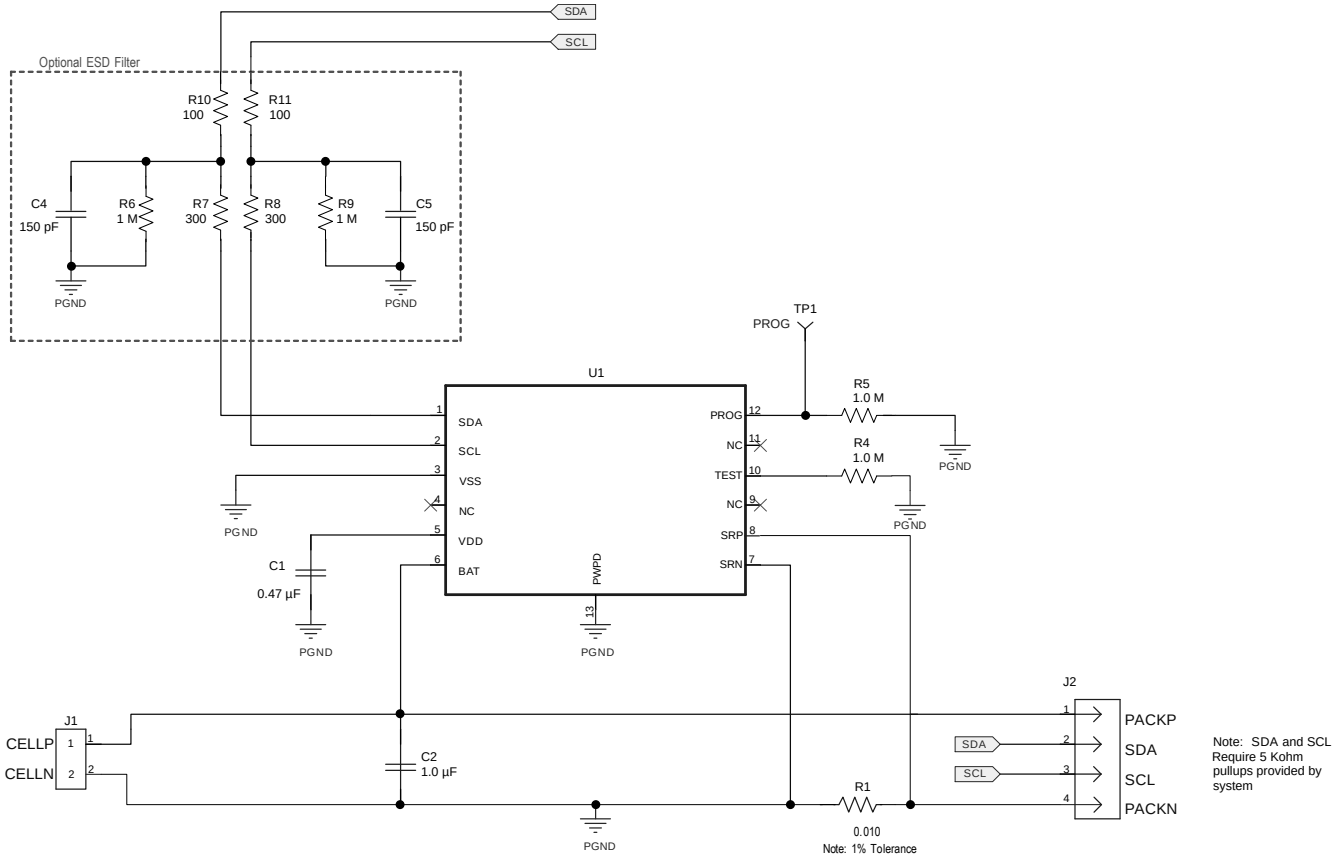


Figure 6. Typical Application with Low-Side Current Sense Resistor

10.2.1 Design Requirements

As shipped from the Texas Instruments factory, many bq27411-G1 parameters in OTP NVM are left in the unprogrammed state (zero) while some parameters directly associated with the CHEMID are preprogrammed. This partially programmed configuration facilitates customization for each end application. Upon device reset, the contents of OTP are copied to associated volatile RAM-based Data Memory blocks. For proper operation, all parameters in RAM-based Data Memory require initialization—either by updating Data Memory parameters in a lab/evaluation situation or by programming the OTP for customer production. Chapter 5 in the *bq27411-G1 Technical Reference Manual* (SLUUAS7) shows the default value and a typically expected value appropriate for most applications.

10.2.2 Detailed Design Procedure

10.2.2.1 High-Side or Low-Side Sense Resistor

The bq27411-G1 device can be used with a high-side current resistor as shown in Figure 5 or a low-side current resistor as shown in Figure 6.

10.2.2.2 BAT Voltage Sense Input

A ceramic capacitor at the input to the BAT pin is used to bypass AC voltage ripple to ground, greatly reducing its influence on battery voltage measurements. It proves most effective in applications with load profiles that exhibit high-frequency current pulses (that is, cell phones) but is recommended for use in all applications to reduce noise on this sensitive high-impedance measurement node.

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Typical Applications (continued)

10.2.2.3 Sense Resistor Selection

Any variation encountered in the resistance present between the SRP and SRN pins of the fuel gauge will affect the resulting differential voltage, and derived current, it senses. As such, it is recommended to select a sense resistor with minimal tolerance and temperature coefficient of resistance (TCR) characteristics. The standard recommendation based on best compromise between performance and price is a 1% tolerance, 50-ppm drift sense resistor with a 1-W power rating.

10.2.2.4 Communication Interface Lines

A protection network composed of resistors and capacitors is recommended on each of the serial communication inputs to protect the fuel gauge from dangerous ESD transients.

10.2.3 Application Curves

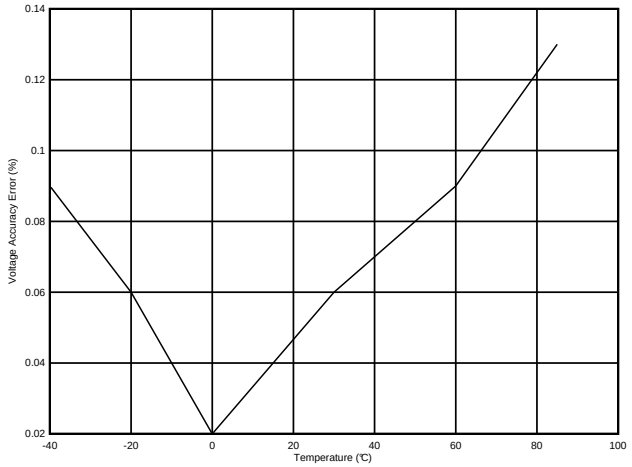


Figure 7. Voltage Accuracy

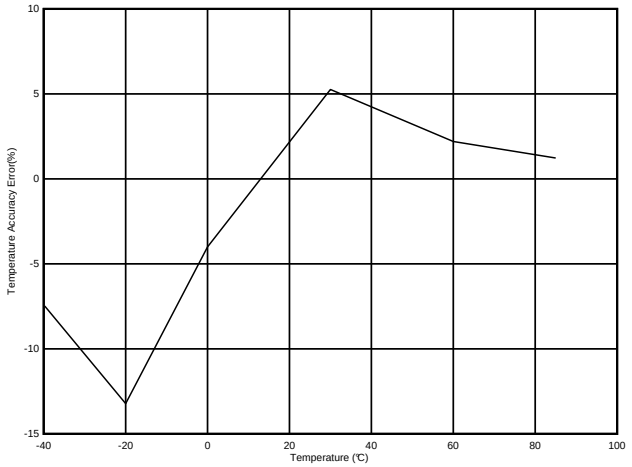


Figure 8. Temperature Accuracy

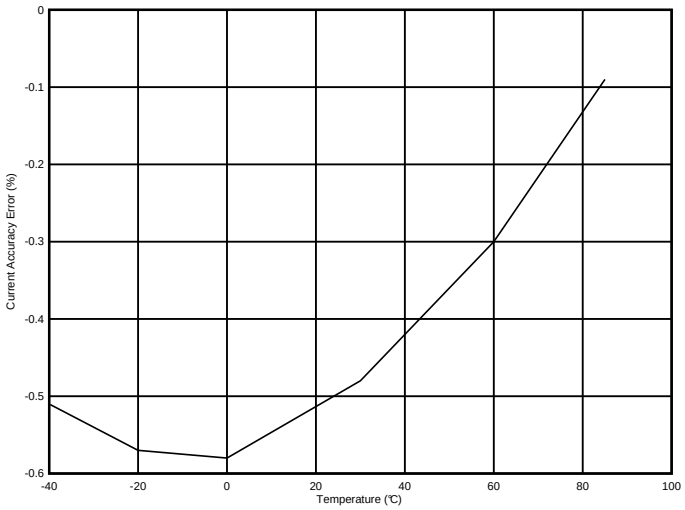


Figure 9. Current Accuracy

11 Power Supply Recommendation

11.1 Power Supply Decoupling

The battery connection on the BAT pin is used for two purposes:

- To supply power to the fuel gauge
- As an input for voltage measurement of the battery

A capacitor of value of at least 1 µF should be connected between BAT and V_{SS}. The capacitor should be placed close to the gauge IC and have short traces to both the V_{DD} pin and V_{SS}.

The fuel gauge has an integrated LDO with an output on the V_{DD} pin of approximately 1.8 V. A capacitor of value at least 0.47 µF should be connected between the BAT pin and V_{SS}. The capacitor should be placed close to the gauge IC and have short traces to both the V_{DD} pin and V_{SS}.

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12 Layout

12.1 Layout Guidelines

- A capacitor, of value at least 0.47 µF, is connected between the V_{DD} pin and V_{SS}. The capacitor should be placed close to the gauge IC and have short traces to both the V_{DD} pin and V_{SS}.
- It is required to have a capacitor, at least 1.0 µF, connect between the BAT pin and V_{SS} if the connection between the battery pack and the gauge BAT pin has the potential to pick up noise. The capacitor should be placed close to the gauge IC and have short traces to both the V_{DD} pin and V_{SS}.
- If the external pullup resistors on the SCL and SDA lines will be disconnected from the host during low-power operation, it is recommend to use external 1-MΩ pulldown resistors to V_{SS} to avoid floating inputs to the I^2C engine.
- The value of the SCL and SDA pullup resistors should take into consideration the pullup voltage and the bus capacitance. Some recommended values, assuming a bus capacitance of 10 pF, can be seen in Table 4.

Table 4. Recommended Values for SCL and SDA Pullup Resistors

VPU	1.8 V		3.3 V	
R_{PU}	Range	Typical	Range	Typical
	400 Ω ≤ R_{PU} ≤ 37.6 kΩ	10 kΩ	900 Ω ≤ R_{PU} ≤ 29.2 kΩ	5.1 kΩ

- If the GPOUT pin is not used by the host, the pin should still be pulled up to V_{DD} with a 4.7-kΩ or 10-kΩ resistor.
- If the battery pack thermistor is not connected to the BIN pin, the BIN pin should be pulled down to V_{SS} with a 10-kΩ resistor.
- The BIN pin should not be shorted directly to V_{DD} or V_{SS}.
- The actual device ground is the center pin (B2). The C1 pin is floating internally and can be used as a bridge to connect the board ground plane to the device ground (B2).

12.2 Layout Example

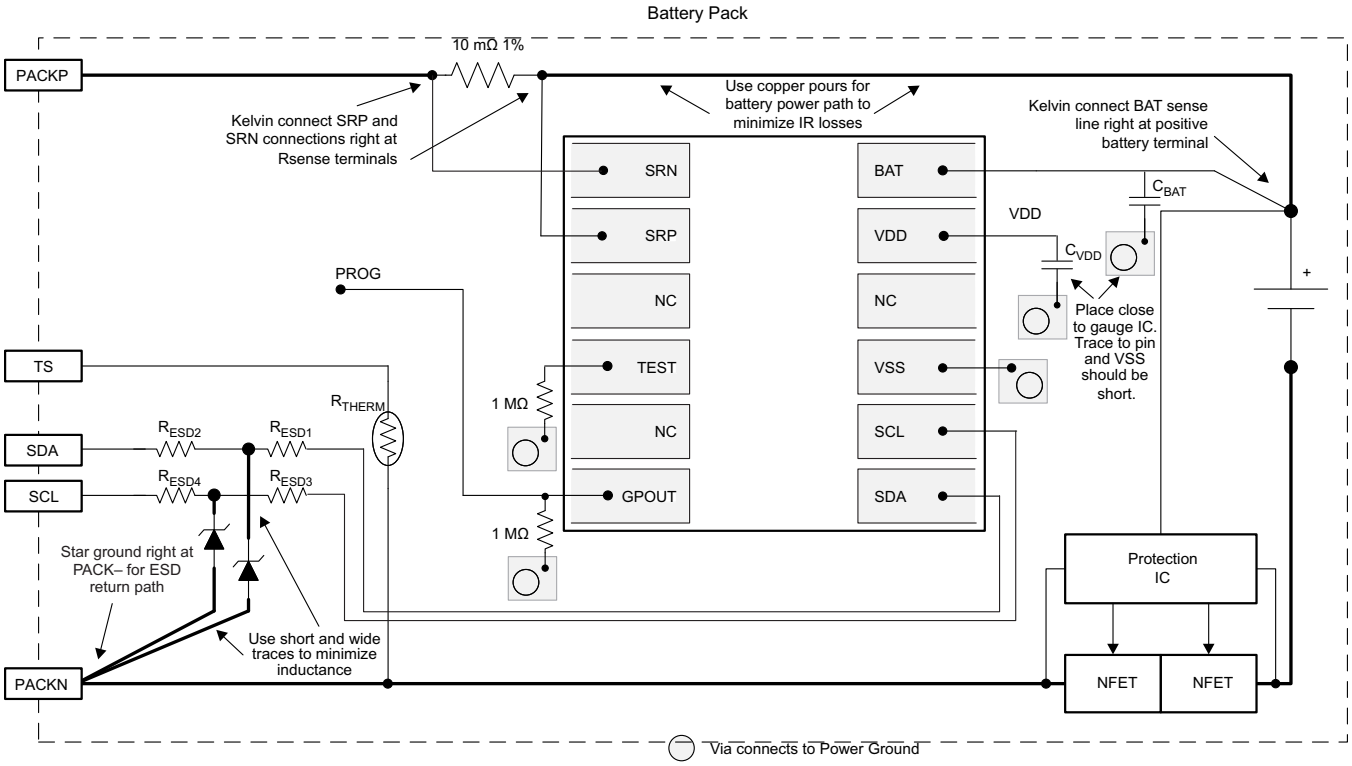


Figure 10. bq27411-G1 Board Layout

13 Device and Documentation Support

13.1 Documentation Support

13.1.1 Related Documentation

- *bq27411-G1 Technical Reference Manual* (SLUUAS7)
- *bq27411 EVM: Single-Cell Technology User's Guide* (SLUUAP3)
- *Quickstart Guide for bq27411-G1* (SLUUAP6)
- *Single Cell Gas Gauge Circuit Design* (SLUA456)
- *Key Design Considerations for the bq27500 and bq27501* (SLUA439)
- *Single Cell Impedance Track Printed-Circuit Board Layout Guide* (SLUA457)
- *ESD and RF Mitigation in Handheld Battery Electronics* (SLUA460)

13.1.2 Community Resources

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

TI E2E™ Online Community ***TI's Engineer-to-Engineer (E2E) Community.*** Created to foster collaboration among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

Design Support ***TI's Design Support*** Quickly find helpful E2E forums along with design support tools and contact information for technical support.

13.2 Trademarks

Impedance Track, E2E are trademarks of Texas Instruments.
All other trademarks are the property of their respective owners.

13.3 Electrostatic Discharge Caution

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

13.4 Glossary

SLYZ022 — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

14 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

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PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
BQ27411DRZ-G1A	PREVIEW	SON	DRZ	12		TBD	Call TI	Call TI	-40 to 85		
BQ27411DRZ-G1C	PREVIEW	SON	DRZ	12		TBD	Call TI	Call TI	-40 to 85		
BQ27411DRZR-G1A	ACTIVE	SON	DRZ	12	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	BQ27 411A	Samples
BQ27411DRZR-G1C	ACTIVE	SON	DRZ	12	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	BQ27 411C	Samples
BQ27411DRZT-G1A	ACTIVE	SON	DRZ	12	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	BQ27 411A	Samples
BQ27411DRZT-G1C	ACTIVE	SON	DRZ	12	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	BQ27 411C	Samples

(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.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

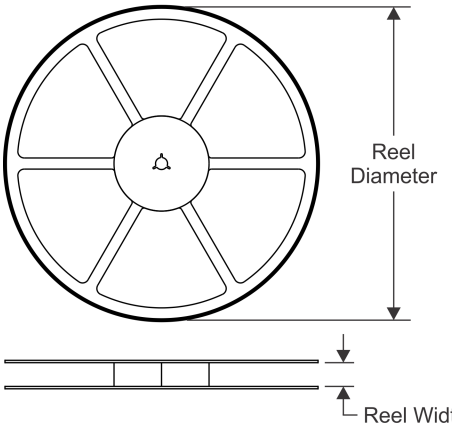
(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

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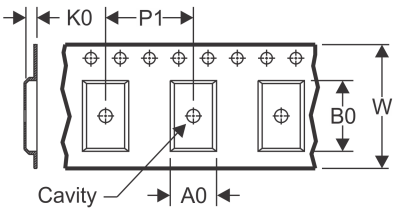
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TAPE AND REEL INFORMATION

REEL DIMENSIONS

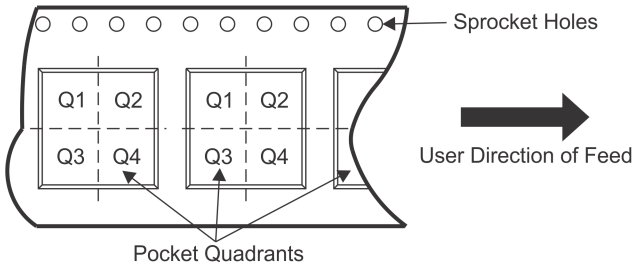


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

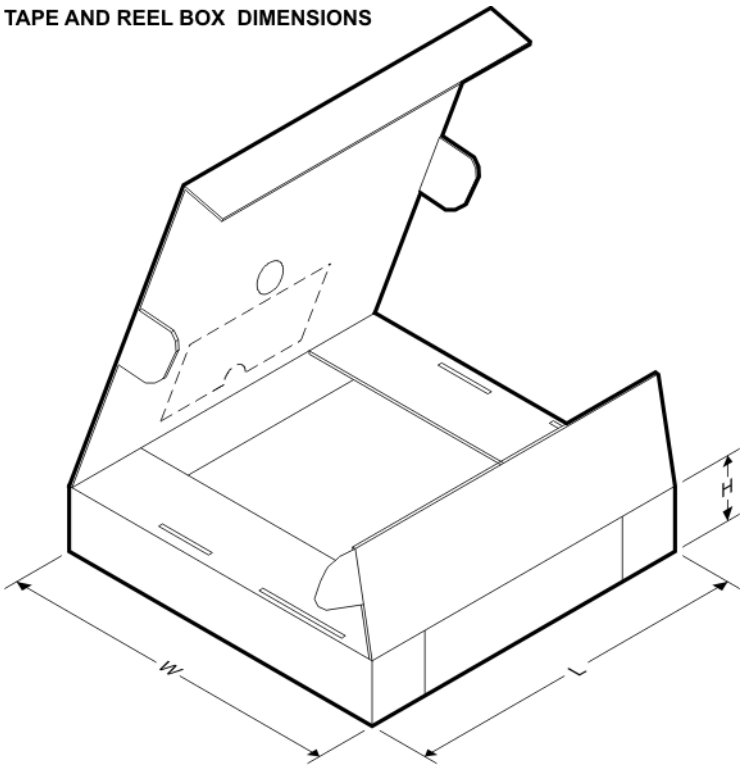
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
BQ27411DRZR-G1A	SON	DRZ	12	3000	330.0	12.4	2.8	4.3	1.2	4.0	12.0	Q2
BQ27411DRZR-G1C	SON	DRZ	12	3000	330.0	12.4	2.8	4.3	1.2	4.0	12.0	Q2
BQ27411DRZT-G1A	SON	DRZ	12	250	180.0	12.4	2.8	4.3	1.2	4.0	12.0	Q2
BQ27411DRZT-G1C	SON	DRZ	12	250	180.0	12.4	2.8	4.3	1.2	4.0	12.0	Q2

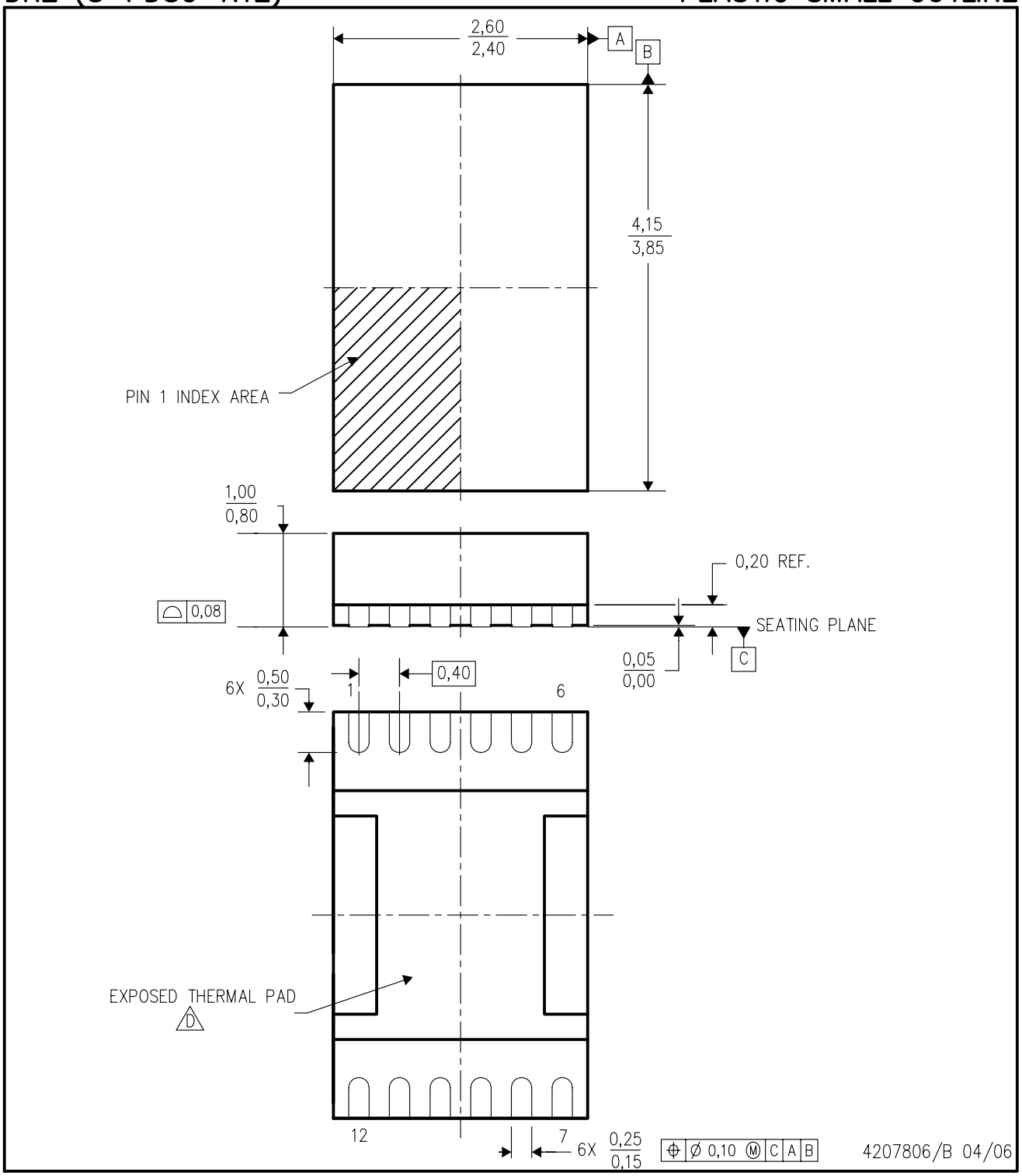
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
BQ27411DRZR-G1A	SON	DRZ	12	3000	367.0	367.0	35.0
BQ27411DRZR-G1C	SON	DRZ	12	3000	367.0	367.0	35.0
BQ27411DRZT-G1A	SON	DRZ	12	250	210.0	185.0	35.0
BQ27411DRZT-G1C	SON	DRZ	12	250	210.0	185.0	35.0

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.

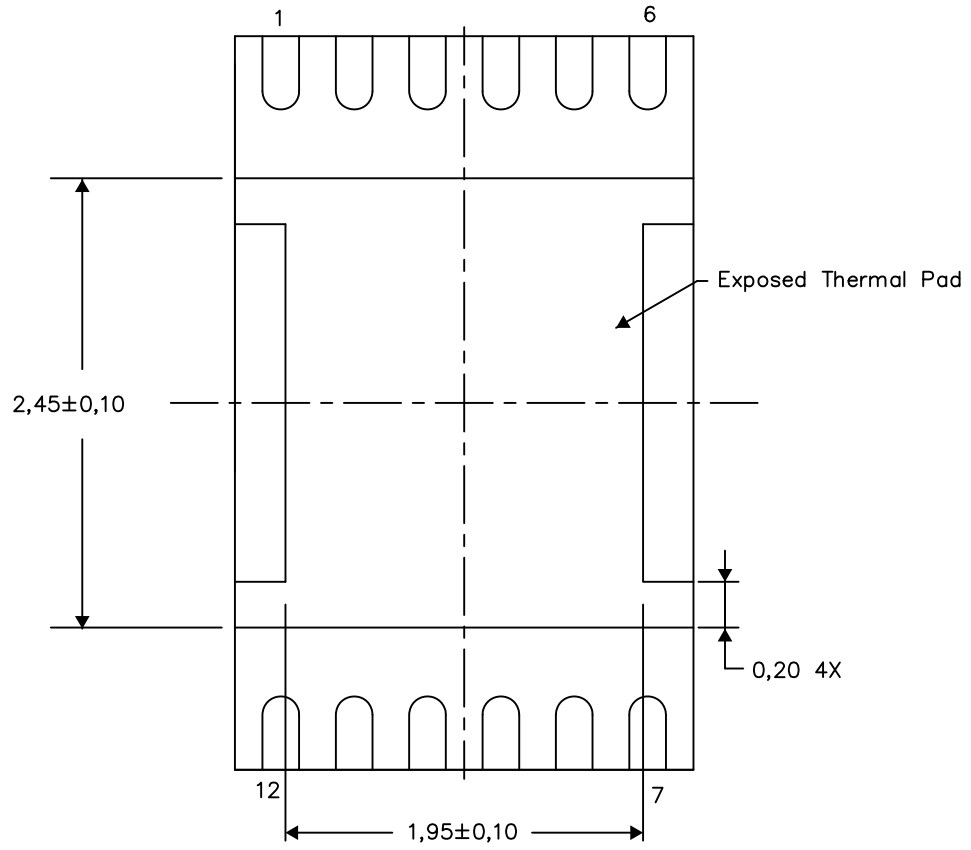
DRZ (R–PDSO–N12) PLASTIC SMALL OUTLINE NO–LEAD

THERMAL INFORMATION

This package incorporates an exposed thermal pad that is designed to be attached directly to an external heatsink. The thermal pad must be soldered directly to the printed circuit board (PCB). After soldering, the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane shown in the electrical schematic for the device, or alternatively, can be attached to a special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).

For information on the Quad Flatpack No–Lead (QFN) package and its advantages, refer to Application Report, QFN/SON PCB Attachment, Texas Instruments Literature No. SLUA271. This document is available at www.ti.com.

The exposed thermal pad dimensions for this package are shown in the following illustration.



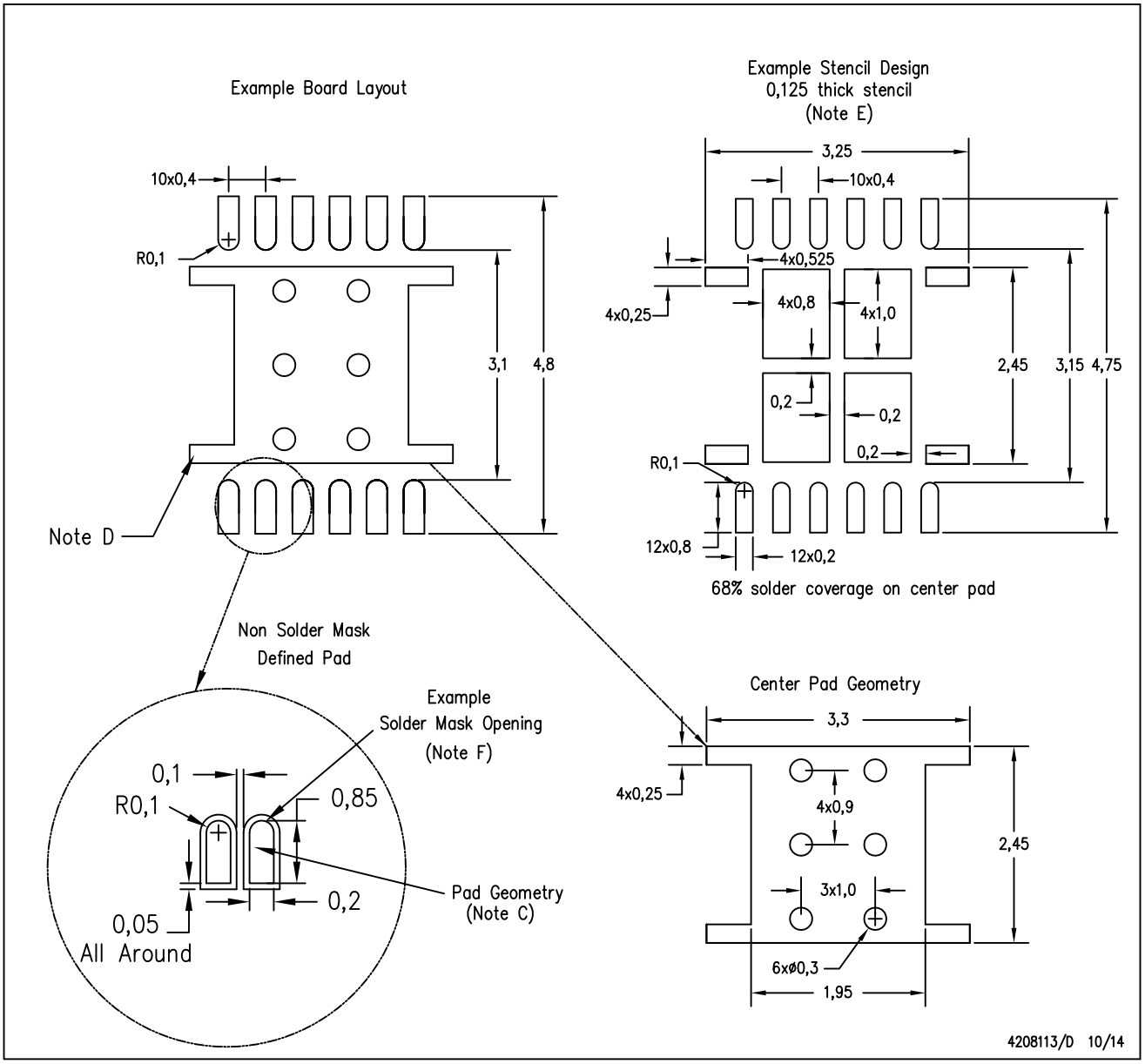
Bottom View

Exposed Thermal Pad Dimensions

4208114/F 10/14

NOTE: All linear dimensions are in millimeters

DRZ (S–PDSO–N12) PLASTIC SMALL OUTLINE NO–LEAD



NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Publication IPC–7351 is recommended for alternate designs.
D. This package is designed to be soldered to a thermal pad on the board. Refer to Application Note, Quad Flat–Pack Packages, Texas Instruments Literature No. SCBA017, SLUA271, and also the Product Data Sheets for specific thermal information, via requirements, and recommended board layout. These documents are available at www.ti.com <http://www.ti.com>.
E. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC 7525 for stencil design considerations.
F. Customers should contact their board fabrication site for minimum solder mask web tolerances between signal pads.

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