

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

## 1 Features

- Single-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<sup>2</sup>C™ 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-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).

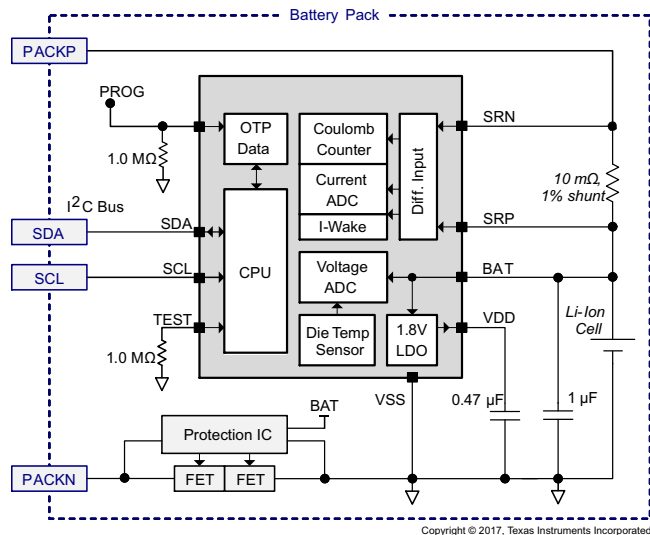
The small, 12-pin, 2.50 mm × 4.00 mm, Small Outline No-Lead (SON) package is ideal for space-constrained applications.

### Device Information<sup>(1)</sup>

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 data sheet.

### Simplified Schematic



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## 4 Revision History

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

Changes from Revision C (September 2015) to Revision D	Page
• Changed <a href="#">Simplified Schematic</a>	1
• Changed <a href="#">Pin Functions</a> PROG description	3
• Changed <a href="#">Figure 5</a>	13
• Changed <a href="#">Figure 6</a>	14
• Changed <a href="#">Power Supply Decoupling</a>	16
• Changed <a href="#">Layout Guidelines</a>	17
• Changed <a href="#">Figure 10</a>	18

## 5 Device Comparison Table

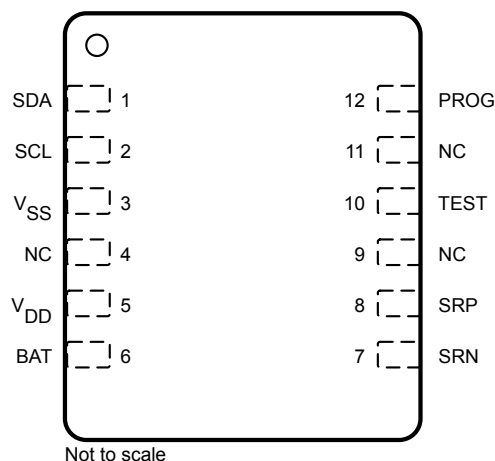
PART NUMBER	BATTERY TYPE	CHEM_ID <sup>(1)</sup>	DM_CODE <sup>(2)</sup>	FIRMWARE VERSION <sup>(3)</sup>
bq27411DRZR-G1A	LiCoO <sub>2</sub> (4.2-V maximum charge)	0x0128	0x80	1.09 (0x0109)
bq27411DRZT-G1A				
bq27411DRZR-G1B	LiCoO <sub>2</sub> (4.3-V maximum charge)	0x0312	0x90	
bq27411DRZT-G1B				
bq27411DRZR-G1C	LiCoO <sub>2</sub> (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.

## 6 Pin Configuration and Functions



### Pin Functions

NUMBER	NAME	TYPE <sup>(1)</sup>	DESCRIPTION
1	SDA	DIO	Slave I <sup>2</sup> C 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 <sub>SS</sub> at each pin to avoid floating inputs.
2	SCL	DIO	
3	V <sub>SS</sub>	PI	Ground pin
4	NC	—	No internal connection. May be left floating or tied to V <sub>SS</sub> .
5	V <sub>DD</sub>	PO	1.8-V Regulator Output. Decouple with 0.47-μF ceramic capacitor to V <sub>SS</sub> . This pin is not intended to provide power for other devices in the system.
6	BAT	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 <sub>SS</sub> . Place the capacitor close to gauge.
7	SRN	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 <a href="#">Typical Applications</a> .
8	SRP	AI	
9	NC	—	No internal connection. May be left floating or tied to V <sub>SS</sub> .
10	TEST	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 <sub>SS</sub> for reduced power consumption.
11	NC	—	No internal connection. May be left floating or tied to V <sub>SS</sub> .
12	PROG	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 <sub>SS</sub> for reduced power consumption. If the device is in SHUTDOWN mode, toggling PROG causes the gauge exit SHUTDOWN. It is recommended to connect PROG to the SDA line through a 470-KΩ resistor, so that in case of any inadvertent shutdown condition, the gauge can be commanded to come out of SHUTDOWN.

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

## 7 Specifications

### 7.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)<sup>(1)</sup>

		MIN	MAX	UNIT
V <sub>BAT</sub>	BAT pin input voltage range	−0.3	6	V
V <sub>SR</sub>	SRP and SRN pins input voltage range	−0.3	V <sub>BAT</sub> + 0.3	V
	Differential voltage across SRP and SRN. ABS(SRP−SRN)		2	V
V <sub>DD</sub>	V <sub>DD</sub> pin supply voltage range (LDO output)	−0.3	2	V
V <sub>IOD</sub>	Open-drain IO pins (SDA, SCL)	−0.3	6	V
V <sub>PROG</sub>	PROG (pin 12)	−0.3	7.8	V
V <sub>IOPP</sub>	Push-pull IO pins (TEST, pin 10)	−0.3	V <sub>DD</sub> + 0.3	V
T <sub>A</sub>	Operating free-air temperature range	−40	85	°C
T <sub>stg</sub>	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.

### 7.2 ESD Ratings

		VALUE	UNIT
V <sub>(ESD)</sub>	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup>	±1500
		Charged-device model (CDM), per JEDEC specification JESD22-C101 <sup>(2)</sup>	±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.

### 7.3 Recommended Operating Conditions

T<sub>A</sub> = 30°C and V<sub>REGIN</sub> = V<sub>BAT</sub> = 3.6 V (unless otherwise noted)

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

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

### 7.4 Thermal Information

THERMAL METRIC <sup>(1)</sup>		bq27411-G1	UNIT
		DRZ (12 PINS)	
R <sub>θJA</sub>	Junction-to-ambient thermal resistance	64.1	°C/W
R <sub>θJC(top)</sub>	Junction-to-case (top) thermal resistance	59.8	
R <sub>θJB</sub>	Junction-to-board thermal resistance	52.7	
ψ <sub>JT</sub>	Junction-to-top characterization parameter	0.3	
ψ <sub>JB</sub>	Junction-to-board characterization parameter	28.3	
R <sub>θJC(bot)</sub>	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](#).

## 7.5 Supply Current

 $T_A = 30^\circ\text{C}$  and  $V_{\text{REGIN}} = V_{\text{BAT}} = 3.6\text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$I_{\text{CC}}^{(1)}$	NORMAL mode current		93		$\mu\text{A}$
$I_{\text{SLP}}^{(1)}$	SLEEP mode current		21		$\mu\text{A}$
$I_{\text{HIB}}^{(1)}$	HIBERNATE mode current		9		$\mu\text{A}$
$I_{\text{SD}}^{(1)}$	SHUTDOWN mode current		0.6		$\mu\text{A}$
	Fuel gauge in host-commanded SHUTDOWN mode. (LDO regulator output disabled)				

(1) Specified by design. Not production tested.

(2) Wake Comparator Disabled

## 7.6 Digital Input and Output DC Characteristics

 $T_A = -40^\circ\text{C}$  to  $85^\circ\text{C}$ , typical values at  $T_A = 30^\circ\text{C}$  and  $V_{\text{REGIN}} = 3.6\text{ V}$  (unless otherwise noted)

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

(1) Specified by design. Not production tested.

(2) Open Drain pins: (SCL, SDA, PROG)

(3) Push-pull pin: (TEST)

## 7.7 LDO Regulator, Wake-Up, and Auto-Shutdown DC Characteristics

 $T_A = -40^\circ\text{C}$  to  $85^\circ\text{C}$ , typical values at  $T_A = 30^\circ\text{C}$  and  $V_{\text{REGIN}} = 3.6\text{ V}$  (unless otherwise noted)

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

(1) Specified by design. Not production tested.

## 7.8 ADC (Temperature and Cell Measurement) Characteristics

 $T_A = -40^\circ\text{C}$  to  $85^\circ\text{C}$ ; typical values at  $T_A = 30^\circ\text{C}$  and  $V_{\text{REGIN}} = 3.6\text{ V}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{\text{IN(BAT)}}$	BAT pin voltage measurement range	2.45		4.5	V
$t_{\text{ADC\_CONV}}$	Conversion time		125		ms
	Effective Resolution		15		bits

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

## 7.9 Integrating ADC (Coulomb Counter) Characteristics

 $T_A = -40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ ; typical values at  $T_A = 30^{\circ}\text{C}$  and  $V_{\text{REGIN}} = 3.6\text{ V}$  (unless otherwise noted)

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

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

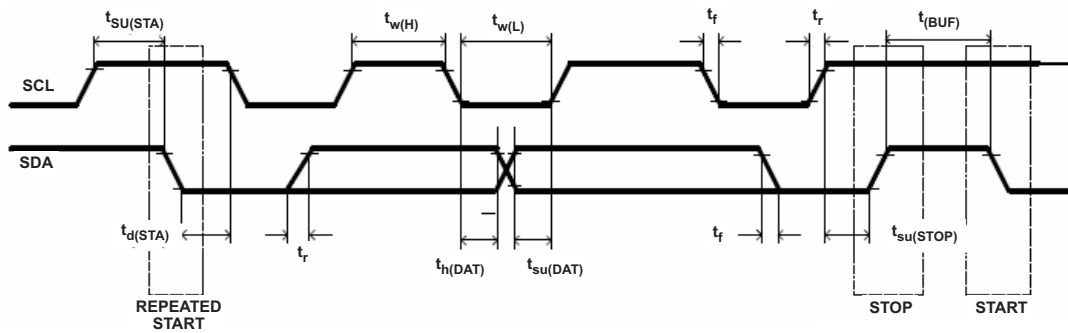
## 7.10 I<sup>2</sup>C-Compatible Interface Communication Timing Characteristics

 $T_A = -40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ ; typical values at  $T_A = 30^{\circ}\text{C}$  and  $V_{\text{REGIN}} = 3.6\text{ V}$  (unless otherwise noted)

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

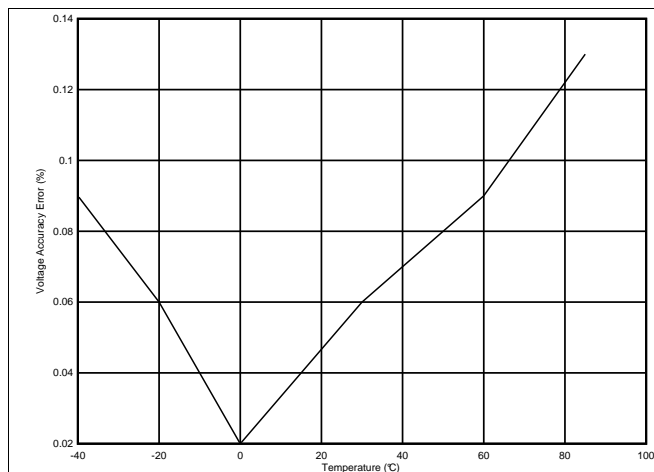
(1) Specified by design. Not production tested.

(2) If the clock frequency ( $f_{\text{SCL}}$ ) is  $> 100\text{ kHz}$ , use 1-byte write commands for proper operation. All other transactions types are supported at 400 kHz. (See [I<sup>2</sup>C Interface](#) and [I<sup>2</sup>C Command Waiting Time](#).)

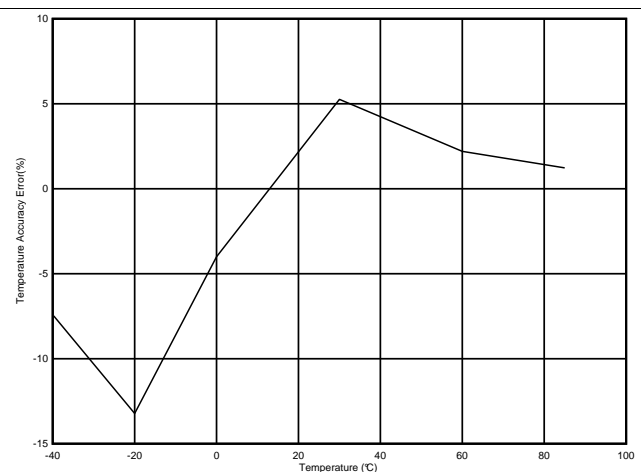


**Figure 1. I²C-Compatible Interface Timing Diagrams**

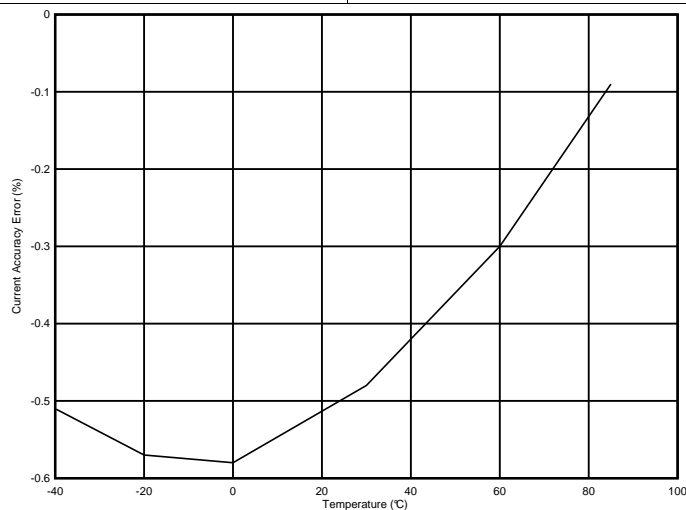
## 7.11 Typical Characteristics



**Figure 2. Voltage Accuracy**



**Figure 3. Temperature Accuracy**



**Figure 4. Current Accuracy**

## 8 Detailed Description

### 8.1 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<sup>2</sup>C programming commands. More details are available in the *SmartFlash OTP Programming Application Report* (SLUA703).

#### NOTE

**Formatting Conventions used in this Document:**

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

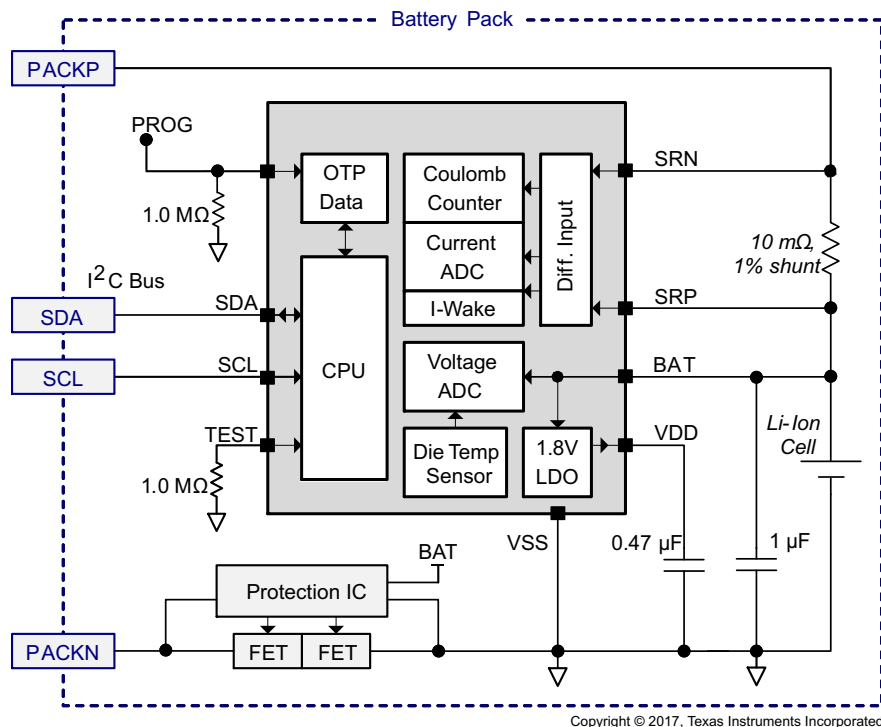
**Data Flash:** *italics*, **bold**, and breaking spaces; for example, ***Design Capacity***

**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

### 8.2 Functional Block Diagram



### 8.3 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.



## Feature Description (continued)

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.

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).

## 8.4 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).

## 8.5 Programming

### 8.5.1 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<sup>2</sup>C 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
<i>Control()</i>	CNTL	0x00 and 0x01	NA	R/W
<i>Temperature()</i>	TEMP	0x02 and 0x03	0.1°K	R/W
<i>Voltage()</i>	VOLT	0x04 and 0x05	mV	R
<i>Flags()</i>	FLAGS	0x06 and 0x07	NA	R
<i>NominalAvailableCapacity()</i>		0x08 and 0x09	mAh	R
<i>FullAvailableCapacity()</i>		0x0A and 0x0B	mAh	R
<i>RemainingCapacity()</i>	RM	0x0C and 0x0D	mAh	R
<i>FullChargeCapacity()</i>	FCC	0x0E and 0x0F	mAh	R
<i>AverageCurrent()</i>		0x10 and 0x11	mA	R
<i>StandbyCurrent()</i>		0x12 and 0x13	mA	R
<i>MaxLoadCurrent()</i>		0x14 and 0x15	mA	R
<i>AveragePower()</i>		0x18 and 0x19	mW	R
<i>StateOfCharge()</i>	SOC	0x1C and 0x1D	%	R
<i>InternalTemperature()</i>		0x1E and 0x1F	0.1°K	R
<i>StateOfHealth()</i>	SOH	0x20 and 0x21	num / %	R
<i>RemainingCapacityUnfiltered()</i>		0x28 and 0x29	mAh	R
<i>RemainingCapacityFiltered()</i>		0x2A and 0x2B	mAh	R
<i>FullChargeCapacityUnfiltered()</i>		0x2C and 0x2D	mAh	R
<i>FullChargeCapacityFiltered()</i>		0x2E and 0x2F	mAh	R
<i>StateOfChargeUnfiltered()</i>		0x30 and 0x31	%	R

### 8.5.2 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	Forces 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

### 8.5.3 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 <sup>(1) (2)</sup>	UNSEALED Access <sup>(1) (2)</sup>
<i>OpConfig()</i>	0x3A and 0x3B	NA	R	R
<i>DesignCapacity()</i>	0x3C and 0x3D	mAh	R	R
<i>DataClass()</i> <sup>(2)</sup>	0x3E	NA	NA	RW
<i>DataBlock()</i> <sup>(2)</sup>	0x3F	NA	RW	RW
<i>BlockData()</i>	0x40 through 0x5F	NA	R	RW
<i>BlockDataChecksum()</i>	0x60	NA	RW	RW
<i>BlockDataControl()</i>	0x61	NA	NA	RW
Reserved	0x62 through 0x7F	NA	R	R

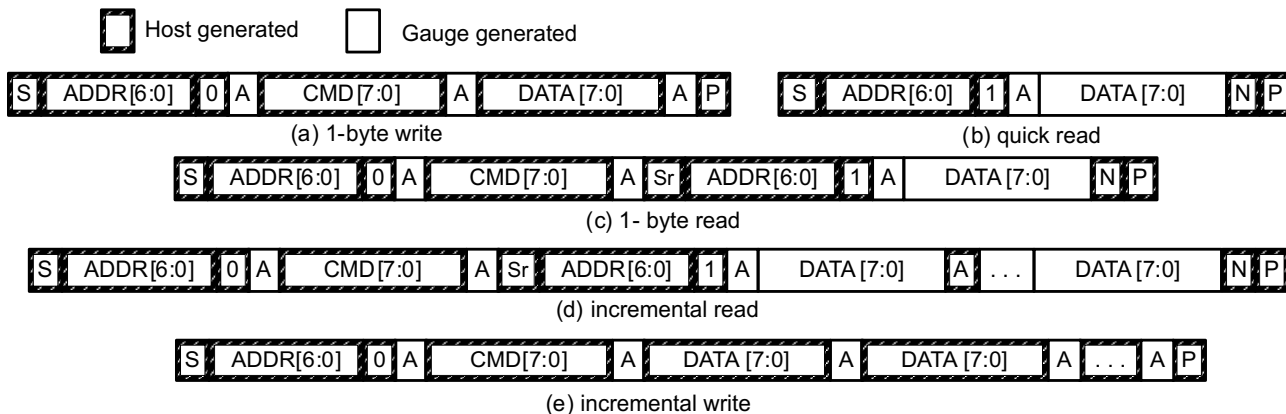
(1) SEALED and UNSEALED states are entered via commands to *Control()* 0x00 and 0x01

(2) In SEALED mode, data cannot be accessed through commands 0x3E and 0x3F.

### 8.5.4 Communications

#### 8.5.4.1 I<sup>2</sup>C Interface

The bq27411-G1 fuel gauge supports the standard I<sup>2</sup>C 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<sup>2</sup>C protocol are, therefore, 0xAA or 0xAB for write or read, respectively.

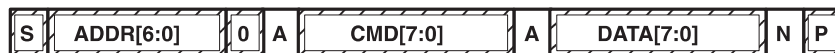


(S = Start, Sr = Repeated Start, A = Acknowledge, N = No Acknowledge, and P = Stop).

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

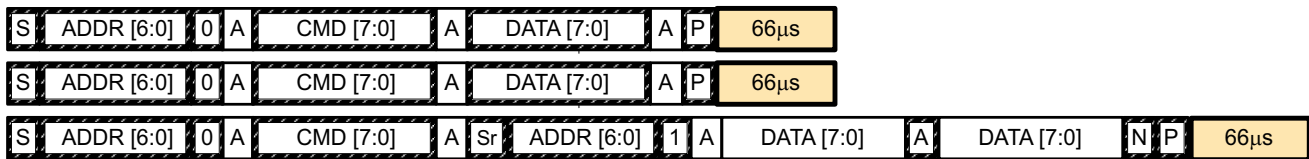


#### 8.5.4.2 I<sup>2</sup>C Time Out

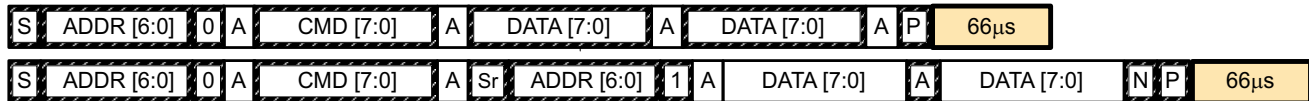
The I<sup>2</sup>C engine releases both SDA and SCL if the I<sup>2</sup>C bus is held low for 2 seconds. If the fuel gauge is holding the lines, releasing them frees them for the master to drive the lines. If an external condition is holding either of the lines low, the I<sup>2</sup>C engine enters the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

#### 8.5.4.3 I<sup>2</sup>C Command Waiting Time

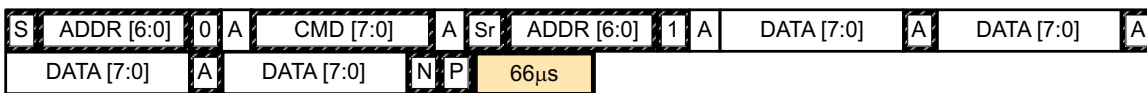
To ensure proper operation at 400 kHz, a  $t_{(BUF)} \geq 66\text{-}\mu\text{s}$  bus-free waiting time must be inserted between all packets addressed to the fuel gauge. In addition, if the SCL clock frequency ( $f_{SCL}$ ) is  $> 100\text{ kHz}$ , use individual 1-byte write commands for proper data 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  $100 \text{ kHz} < f_{\text{SCL}} \leq 400 \text{ kHz}$ )



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



Waiting time inserted after incremental read

#### 8.5.4.4 $I^2C$ 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  $\leq 100\text{-}\mu\text{s}$  clock stretch occurs on all  $I^2C$  traffic as the device must wake-up to process the packet. In the other modes (INITIALIZATION, NORMAL) a  $\leq 4\text{-ms}$  clock stretching period may occur within packets addressed for the fuel gauge. The majority of clock stretch periods are small while the  $I^2C$  interface performs normal data flow control.

## 9 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.

### 9.1 Application Information

The bq27411-G1 device is a fuel gauging solution for single-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](#).

### 9.2 Typical Applications

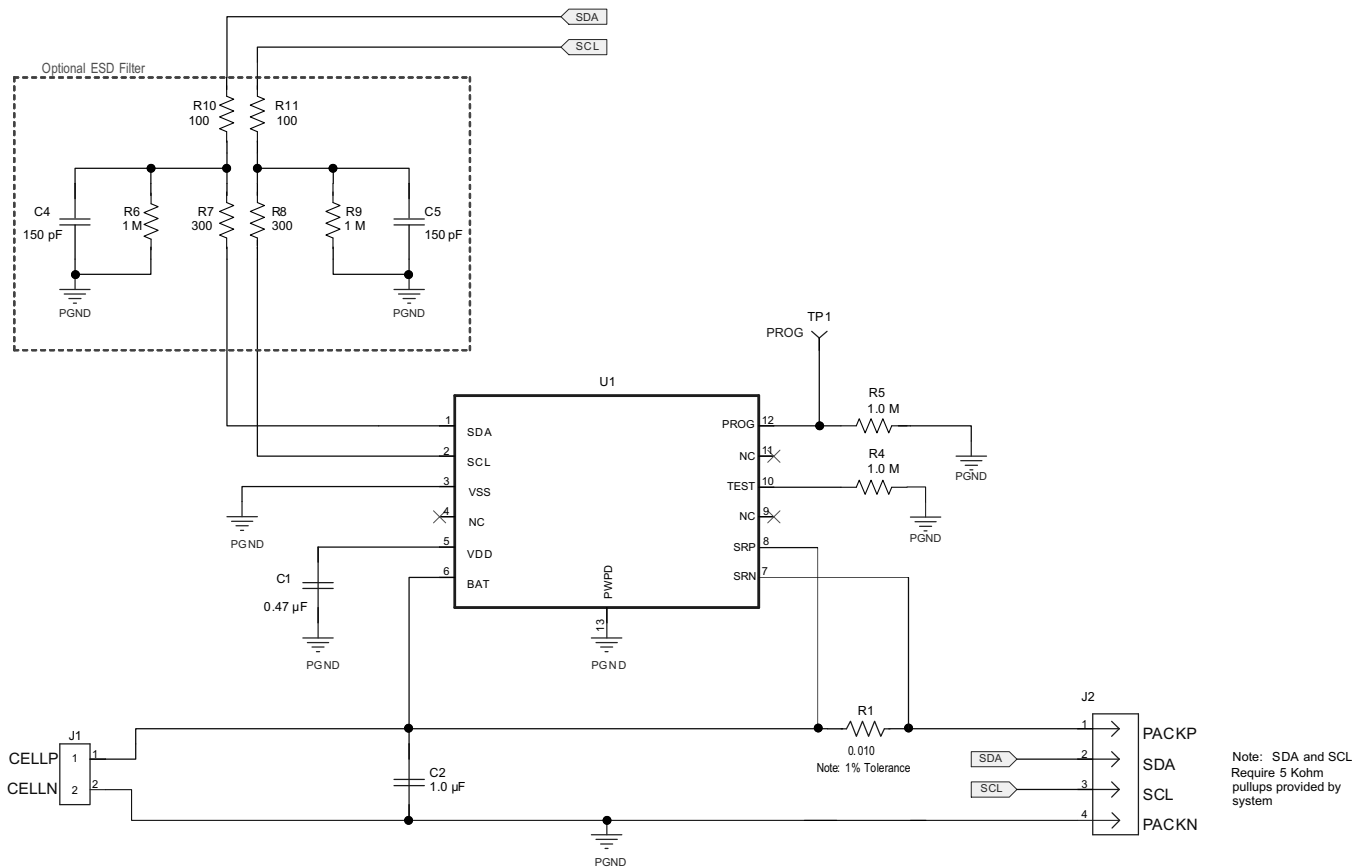
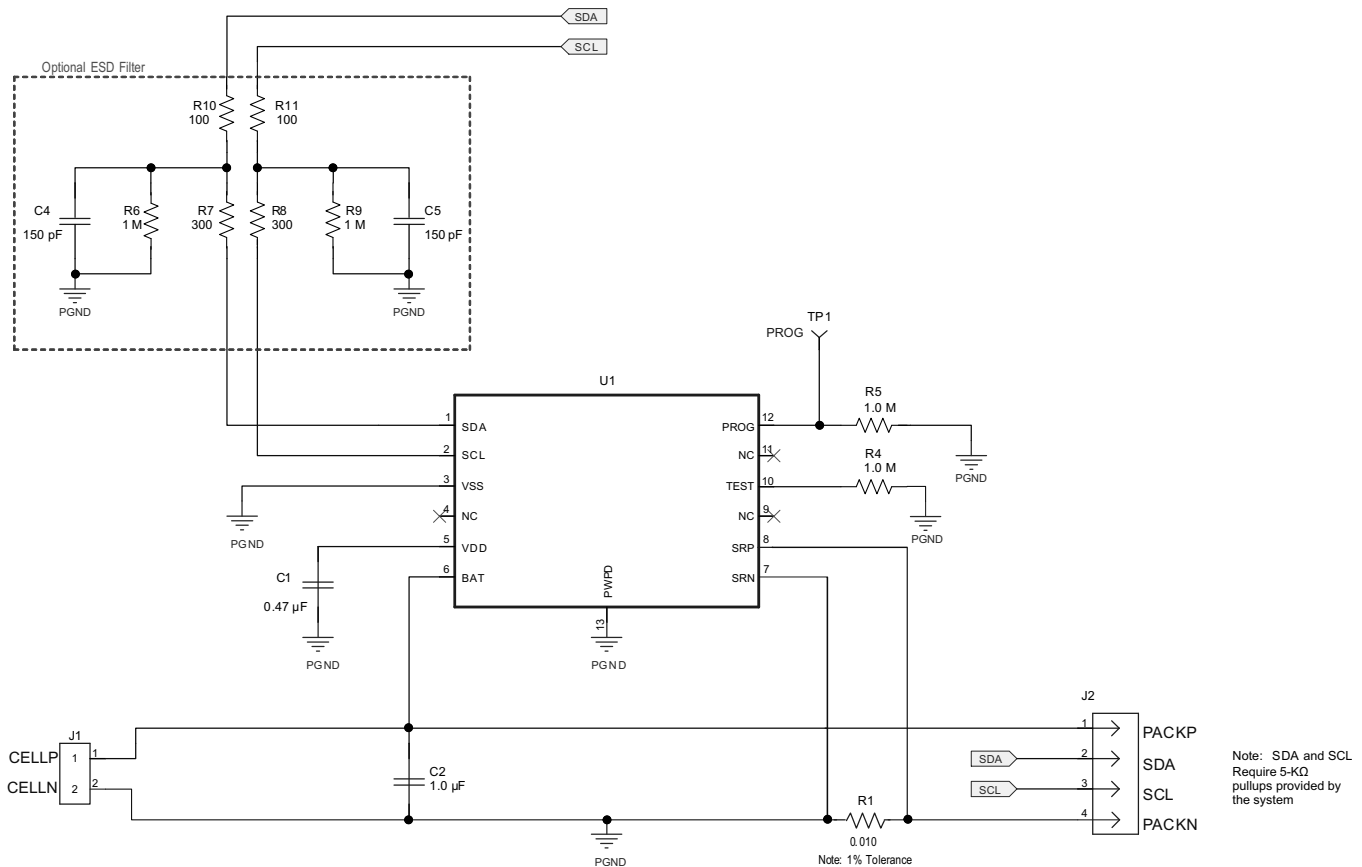


Figure 5. Typical Application with High-Side Current Sense Resistor

## Typical Applications (continued)



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

### 9.2.1 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.

### 9.2.2 Detailed Design Procedure

#### 9.2.2.1 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.

#### 9.2.2.2 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.

## Typical Applications (continued)

### 9.2.2.3 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.

### 9.2.2.4 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.

### 9.2.3 Application Curves

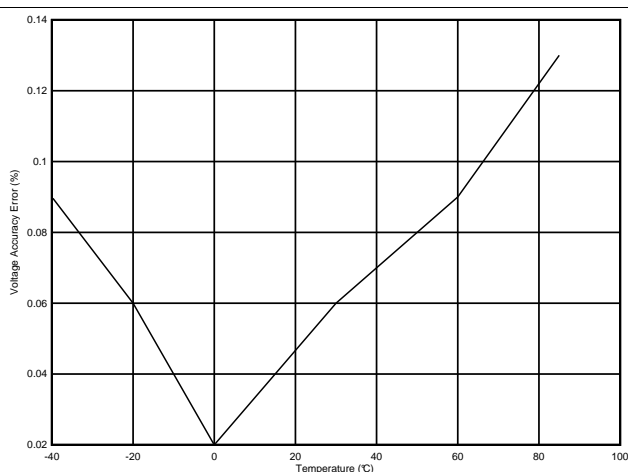


Figure 7. Voltage Accuracy

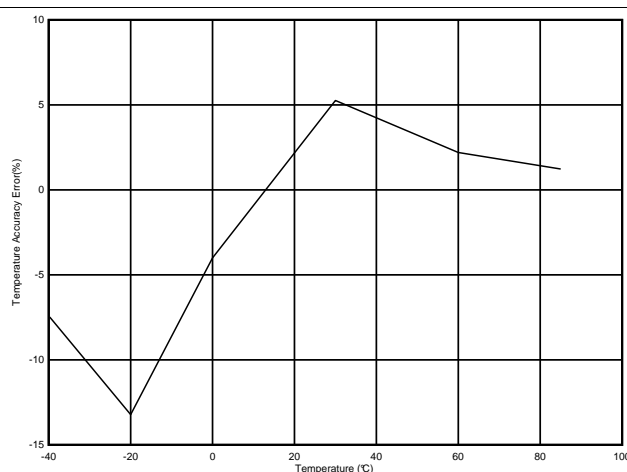


Figure 8. Temperature Accuracy

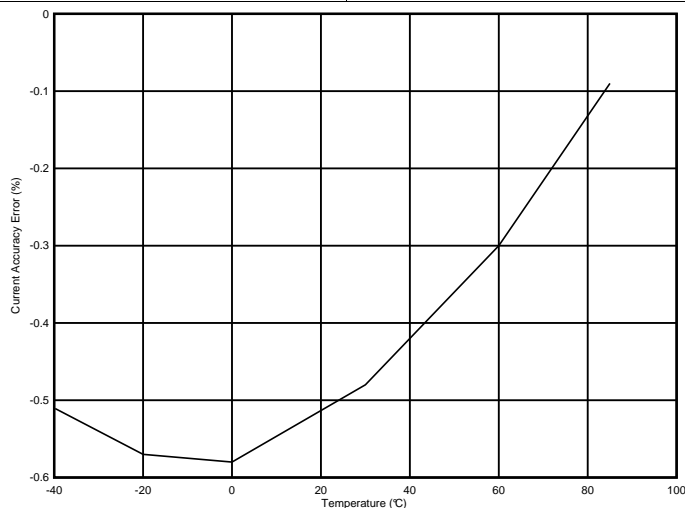


Figure 9. Current Accuracy

## 10 Power Supply Recommendation

### 10.1 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  $\mu\text{F}$  should be connected between BAT and  $V_{\text{SS}}$ . The capacitor should be placed close to the gauge IC and have short traces to both the  $V_{\text{DD}}$  pin and  $V_{\text{SS}}$ .

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



## 11 Layout

### 11.1 Layout Guidelines

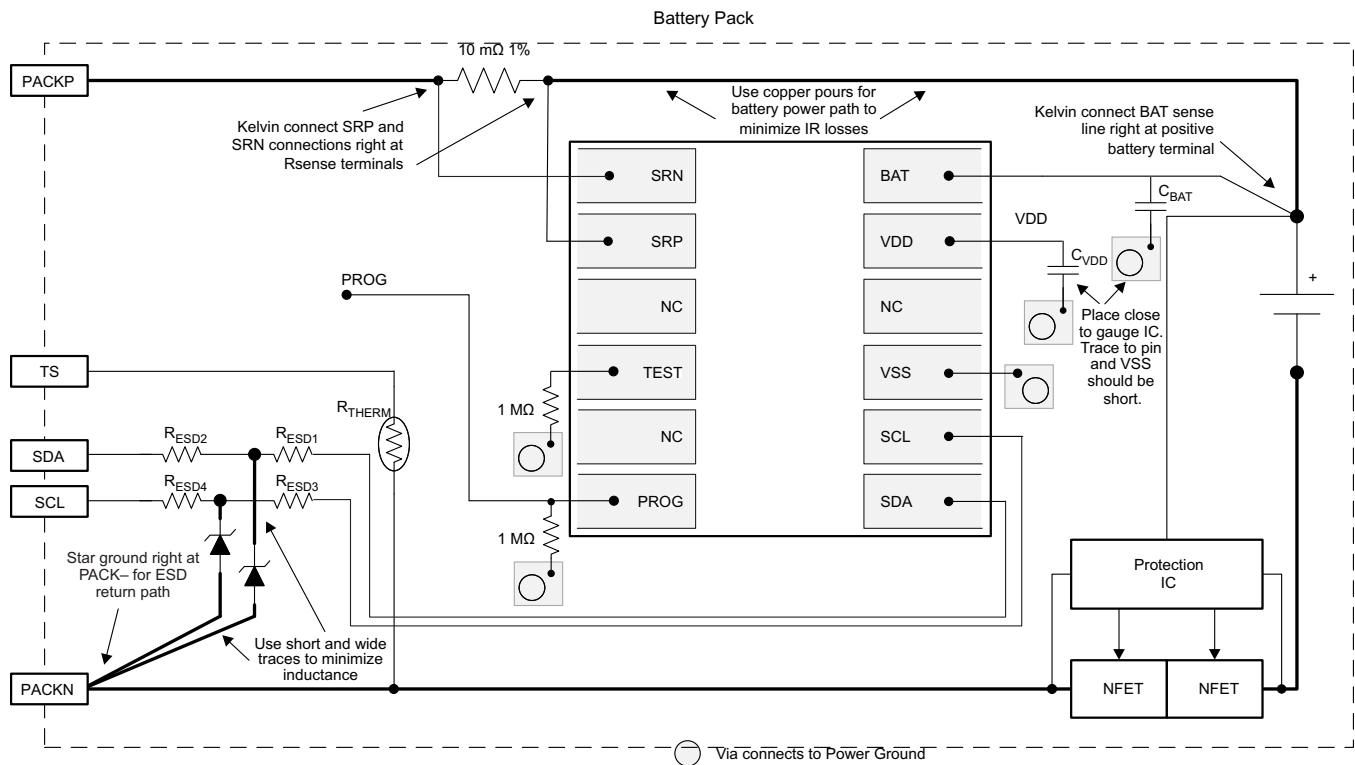
- A capacitor, of value at least 0.47  $\mu\text{F}$ , is connected between the  $V_{\text{DD}}$  pin and  $V_{\text{SS}}$ . The capacitor should be placed close to the gauge IC and have short traces to both the  $V_{\text{DD}}$  pin and  $V_{\text{SS}}$ .
- It is required to have a capacitor, at least 1.0  $\mu\text{F}$ , connect between the BAT pin and  $V_{\text{SS}}$  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  $V_{\text{DD}}$  pin and  $V_{\text{SS}}$ .
- If the external pullup resistors on the SCL and SDA lines will be disconnected from the host during low-power operation, it is recommended to use external 1-M $\Omega$  pulldown resistors to  $V_{\text{SS}}$  to avoid floating inputs to the I<sup>2</sup>C 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 <sub>PU</sub>	Range	Typical	Range	Typical
	400 $\Omega \leq R_{\text{PU}} \leq 37.6 \text{ k}\Omega$	10 k $\Omega$	900 $\Omega \leq R_{\text{PU}} \leq 29.2 \text{ k}\Omega$	5.1 k $\Omega$

- If the GPOUT pin is not used by the host, the pin should still be pulled up to  $V_{\text{DD}}$  with a 4.7-k $\Omega$  or 10-k $\Omega$  resistor. After the OTP has been programmed, it is recommended that PROG be connected to the SDA line with a 470-K $\Omega$  resistor so that in cases where the device is in SHUTDOWN, toggling PROG can wake the gauge up from the SHUTDOWN state.
- If the battery pack thermistor is not connected to the BIN pin, the BIN pin should be pulled down to  $V_{\text{SS}}$  with a 10-k $\Omega$  resistor.
- The BIN pin should not be shorted directly to  $V_{\text{DD}}$  or  $V_{\text{SS}}$ .
- 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).

## 11.2 Layout Example



**Figure 10. bq27411-G1 Board Layout**

## 12 Device and Documentation Support

### 12.1 Documentation Support

#### 12.1.1 Related Documentation

- *bq27411-G1 Technical Reference Manual* ([SLUUA57](#))
- *bq27411 EVM: Single-Cell Technology User's Guide* ([SLUUA3](#))
- *SmartFlash OTP Programming* (SLUA703)
- *Quickstart Guide for bq27411-G1* ([SLUUA6](#))
- *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](#))

#### 12.1.2 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](http://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.

### 12.2 Trademarks

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I<sup>2</sup>C is a trademark of NXP B.V. Corporation.  
All other trademarks are the property of their respective owners.

### 12.3 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.

### 12.4 Glossary

[SLYZ022](#) — *TI Glossary*.

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

## 13 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.

## PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package   Pins	Package qty   Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
<a href="#">BQ27411DRZR-G1A</a>	Active	Production	SON (DRZ)   12	3000   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	BQ27 411A
BQ27411DRZR-G1A.A	Active	Production	SON (DRZ)   12	3000   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	BQ27 411A
<a href="#">BQ27411DRZR-G1C</a>	Active	Production	SON (DRZ)   12	3000   LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	BQ27 411C
BQ27411DRZR-G1C.A	Active	Production	SON (DRZ)   12	3000   LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	BQ27 411C
<a href="#">BQ27411DRZT-G1A</a>	Active	Production	SON (DRZ)   12	250   SMALL T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	BQ27 411A
BQ27411DRZT-G1A.A	Active	Production	SON (DRZ)   12	250   SMALL T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	BQ27 411A
<a href="#">BQ27411DRZT-G1C</a>	Active	Production	SON (DRZ)   12	250   SMALL T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	BQ27 411C
BQ27411DRZT-G1C.A	Active	Production	SON (DRZ)   12	250   SMALL T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	BQ27 411C
BQ27411DRZT-G1CG4	Active	Production	SON (DRZ)   12	250   SMALL T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	BQ27 411C
BQ27411DRZT-G1CG4.A	Active	Production	SON (DRZ)   12	250   SMALL T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	BQ27 411C

<sup>(1)</sup> **Status:** For more details on status, see our [product life cycle](#).

<sup>(2)</sup> **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

<sup>(3)</sup> **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

<sup>(4)</sup> **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

<sup>(5)</sup> **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

<sup>(6)</sup> **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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## TAPE AND REEL INFORMATION



\*All dimensions are nominal

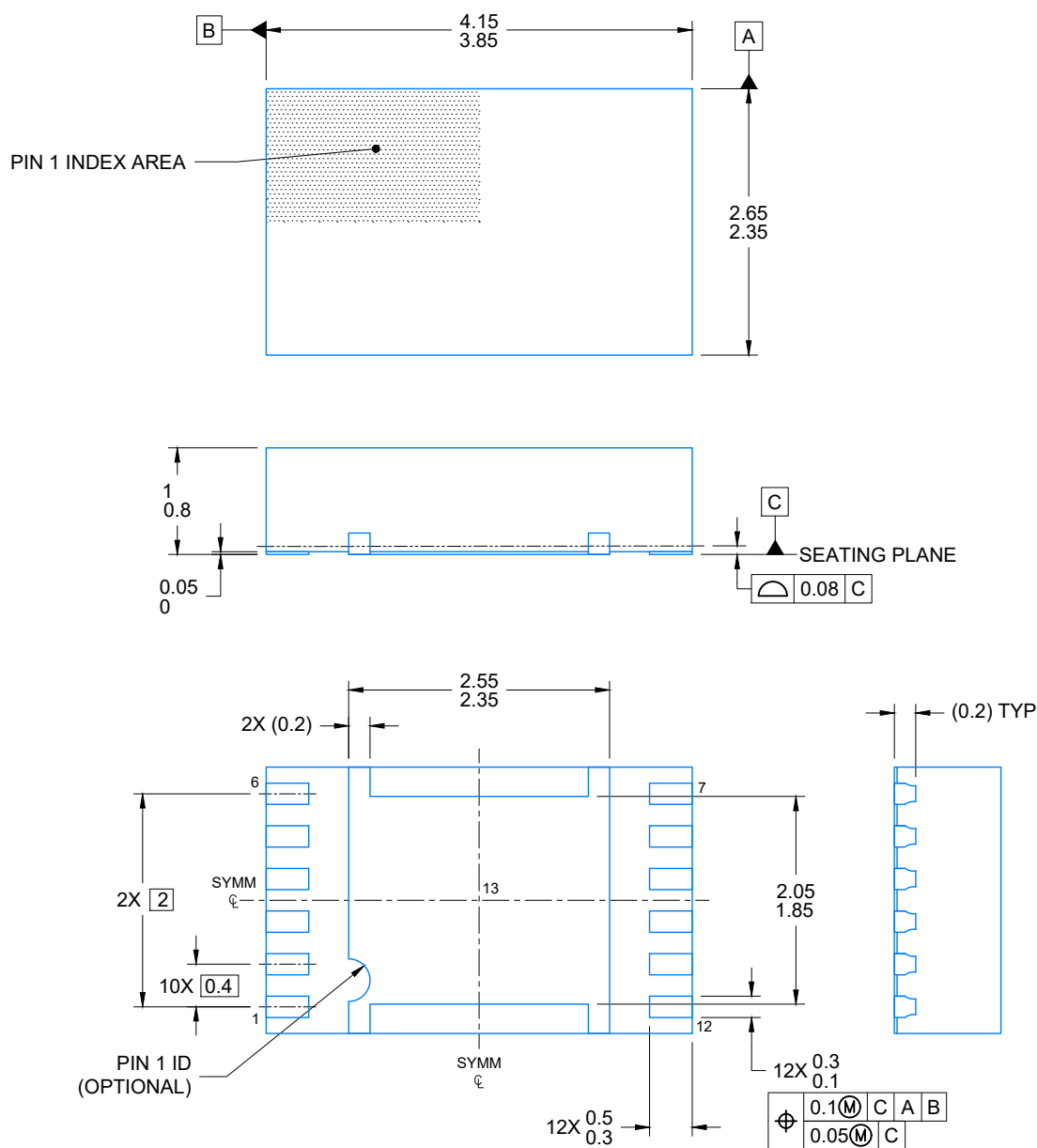
Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
BQ27411DRZR-G1A	SON	DRZ	12	3000	330.0	12.4	2.8	4.3	1.2	4.0	12.0	Q2
BQ27411DRZR-G1C	SON	DRZ	12	3000	330.0	12.4	2.8	4.3	1.2	4.0	12.0	Q2
BQ27411DRZT-G1A	SON	DRZ	12	250	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
BQ27411DRZT-G1CG4	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	346.0	346.0	33.0
BQ27411DRZR-G1C	SON	DRZ	12	3000	346.0	346.0	33.0
BQ27411DRZT-G1A	SON	DRZ	12	250	182.0	182.0	20.0
BQ27411DRZT-G1C	SON	DRZ	12	250	210.0	185.0	35.0
BQ27411DRZT-G1CG4	SON	DRZ	12	250	210.0	185.0	35.0

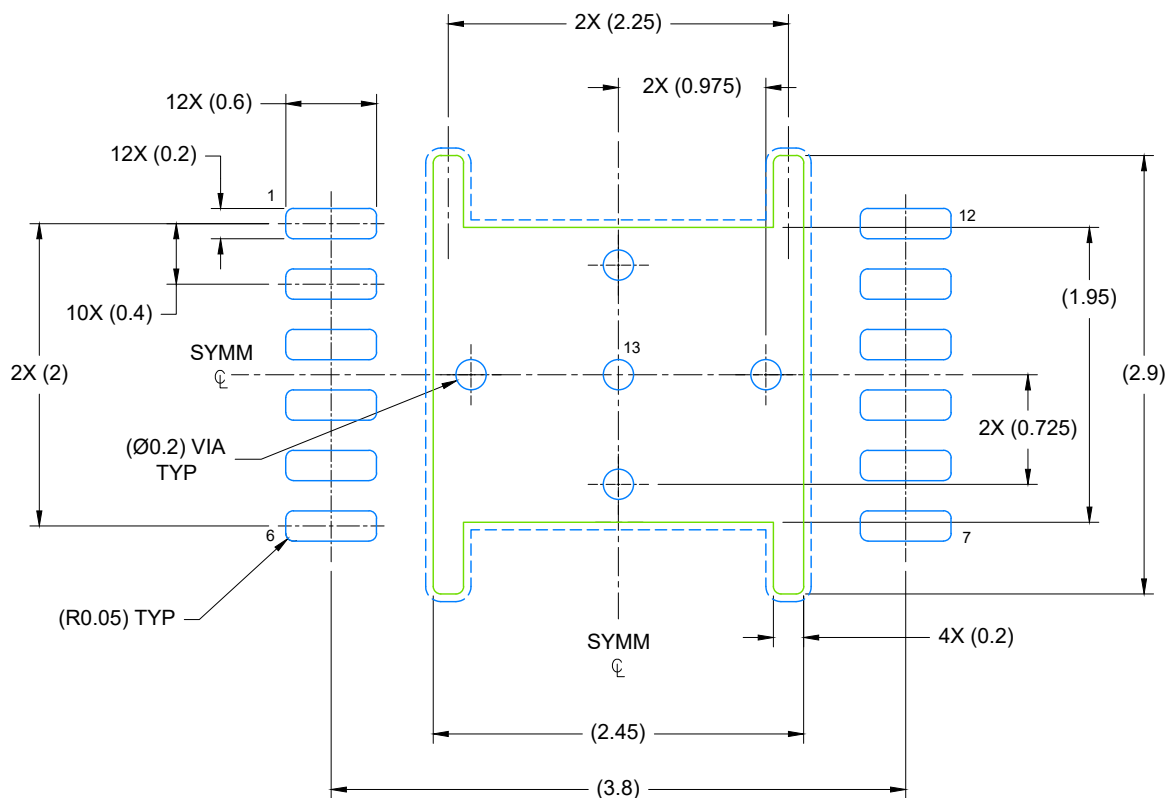


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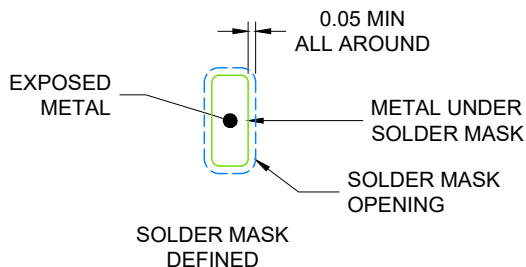
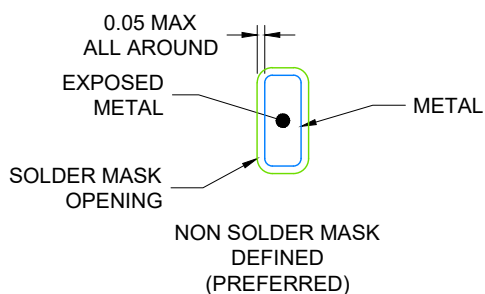
NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pad must be soldered to the printed circuit board for optimal thermal and mechanical performance.





LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE: 20X



SOLDER MASK DETAILS

4218895/B 03/2022

NOTES: (continued)

- This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 ([www.ti.com/lit/sluea271](http://www.ti.com/lit/sluea271)).
- Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.

**VSON - 1 mm max height**

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