Single Cell Li-Ion Battery Fuel Gauge with Integrated Protection

Check for Samples: bq27741-G1

FEATURES

- **Battery Fuel Gauge and Protector for 1-Series Li-Ion Applications**
- **Microcontroller Peripheral Provides:**
  - **Accurate Battery Fuel Gauging Supports up to 32 Ahr**
  - **External and Internal Temperature Sensors for Battery Temperature Reporting**
  - **Precision 16-bit High-Side Coulomb Counter with High-Side Low-Value Sense Resistor (5 mΩ to 20 mΩ)**
  - **Lifetime and Current Data Logging**
  - **64 Bytes of Non-Volatile Scratch Pad Flash**
  - **SHA-1/HMAC Authentication**
- **Battery Fuel Gauging Based on Patented Impedance Track™ Technology**
  - **Models Battery Discharge Curve for Accurate Time-To-Empty Predictions**
  - **Automatically Adjusts for Aging, Self-Discharge, and Temperature- and Rate-Induced Effects on Battery**
- **Advanced Fuel Gauging Features**
  - **Internal Short Detection**
  - **Tab Disconnection Detection**
- **Safety and Protection:**
  - **Over- and Undervoltage Protection with Brown-out Low-Power Mode**
  - **Overcharging and Discharging Current Protection**
  - **Overtemperature Protection**
  - **Short-Circuit Protection**
  - **Low-Voltage Notification**
  - **Voltage Doubler to Support High-side NFET Protection**
- **HDQ and I^2C™ Interface Formats for Communication With Host System**
- **Small 15-ball NanoFree™ (CSP) Packaging**

APPLICATIONS

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

DESCRIPTION

The Texas Instruments bq27741-G1 Li-Ion battery fuel gauge is a microcontroller peripheral that provides fuel gauging for single-cell Li-Ion battery packs. The device requires little system microcontroller firmware development for accurate battery fuel gauging. The fuel gauge resides within the battery pack or on the system's main board with an embedded battery (non-removable). The fuel gauge provides hardware-based over- and undervoltage, overcurrent in charge or discharge, and short-circuit protections.

The fuel gauge 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 (minimum), battery voltage (mV), and temperature (°C), as well as recording vital parameters throughout the lifetime of the battery.

The CSP is a 15-ball package (2.776 mm x 1.96 mm) that is ideal for space-constrained applications.

DEVICE INFORMATION

bq27741 PIN DIAGRAM
(TOP VIEW)

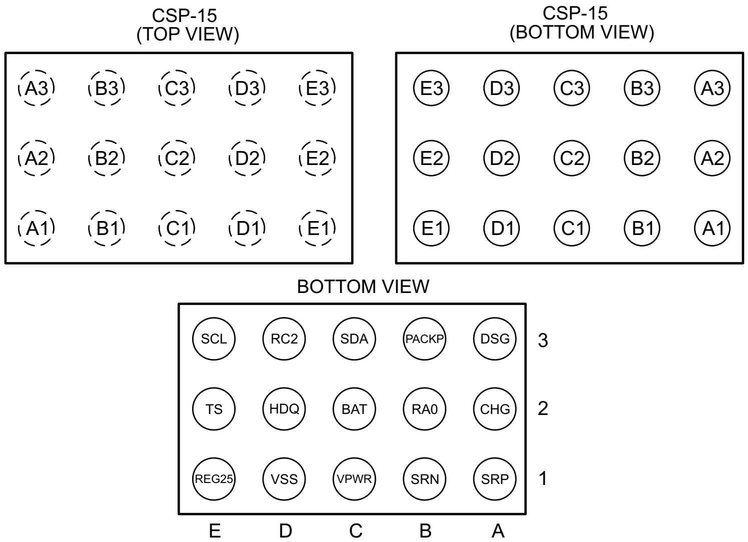


Table 1. Terminal Functions

TERMINAL		TYPE(1)	DESCRIPTION
PIN	NAME		
A1	SRP	IA	Analog input pin connected to the internal coulomb counter where SRP is nearest the PACK+ connection. Connect to sense resistor.
A2	CHG	O	External high side N-channel charge FET driver.
A3	DSG	O	External high side N-channel discharge FET driver.
B1	SRN	IA	Analog input pin connected to the internal coulomb counter where SRN is nearest the CELL+ connection. Connect to sense resistor.
B2	RA0	IO	General Purpose IO. Open-drain I/O.
B3	PACKP	IA	Pack voltage measurement input for protector operation.
C1	VPWR	P	Power input. Decouple with 0.1-µF ceramic capacitor to V_{SS}.
C2	BAT	IA	Cell-voltage measurement input. ADC input.
C3	SDA	IO	Slave I^2C serial communications data line for communication with system. Open-drain I/O. Use with 10-kΩ pullup resistor (typical).
D1	VSS	P	Device ground.
D2	HDQ	IO	HDQ serial communications line. Open-drain.
D3	RC2	IO	General purpose IO. Push-pull output.
E1	REG25	P	Regulator output and bq27741-G1 processor power. Decouple with 1.0-µF ceramic capacitor to V_{SS}.
E2	TS	IA	Pack thermistor voltage sense (use 103AT-type thermistor). ADC input.
E3	SCL	IO	Slave I^2C serial communications clock input line for communication with system. Use with 10-kΩ pullup resistor (typical).

(1) IO = Digital input-output, IA = Analog input, P = Power connection, O = Output

Table 2. Default Configuration

OVERVOLTAGE PROTECTION (V_{OVP})	UNDERVOLTAGE PROTECTION (V_{UVP})	OVERCURRENT IN DISCHARGE (V_{OCD})	OVERCURRENT IN CHARGE (V_{OCC})	SHORT CIRCUIT IN DISCHARGE (V_{scd})
4.390 V	2.407 V	34.4 mV	20 mV	74.6 mV

OVERVOLTAGE PROTECTION DELAY (t_{OVP})	UNDERVOLTAGE PROTECTION DELAY (t_{UVP})	OVERCURRENT IN DISCHARGE DELAY (t_{OCD})	OVERCURRENT IN CHARGE DELAY (t_{OCC})	SHORT CIRCUIT IN DISCHARGE DELAY (t_{scd})
1 s	31.25 ms	31.25 ms	7.8125 ms	312.5 µs

THERMAL INFORMATION

THERMAL METRIC(1)		bq27741-G1 YZF (15 PINS)	UNIT
θ_{JA}	Junction-to-ambient thermal resistance	70	°C/W
θ_{JCtop}	Junction-to-case (top) thermal resistance	17	
θ_{JB}	Junction-to-board thermal resistance	20	
ψ_{JT}	Junction-to-top characterization parameter	1	
ψ_{JB}	Junction-to-board characterization parameter	18	
θ_{JCbot}	Junction-to-case (bottom) thermal resistance	NA	

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

ELECTRICAL SPECIFICATIONS

Absolute Maximum Ratings

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

PARAMETER		MIN	MAX	UNIT
V_{VPWR}	Power input range	–0.3	5.5	V
V_{REG25}	Supply voltage range	–0.3	2.75	V
V_{PACKP}	PACKP input pin	–0.3	5.5	V
	PACK+ input when external 2-kΩ resistor is in series with PACKP input pin (see Reference Schematics)	–0.3	28	V
V_{OUT}	Voltage output pins (DSG, CHG)	–0.3	10	V
V_{IOD1}	Push-pull IO pins (RC2)	–0.3	2.75	V
V_{IOD2}	Open-drain IO pins (SDA, SCL, HDQ, RA0)	–0.3	5.5	V
V_{BAT}	BAT input pin	–0.3	5.5	V
V_I	Input voltage range to all other pins (SRP, SRN)	–0.3	5.5	V
V_{TS}	Input voltage range for TS	–0.3	2.75	V
ESD	Human Body Model (HBM), all pins	2		kV
T_A	Operating free-air temperature range	–40	85	°C
T_F	Functional temperature range	–40	100	°C
T_{STG}	Storage temperature range	–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.

Recommended Operating Conditions

T_A = 25°C, C_{REG25} = 1.0 µF, and V_{VPWR} = 3.6 V (unless otherwise noted)

PARAMETER		TEST CONDITION	MIN	NOM	MAX	UNIT
V_{VPWR}	Supply voltage	No operating restrictions	2.8		5.0	V
		No FLASH writes	2.45		2.8	
C_{VPWR}	External input capacitor for internal LDO between VPWR and V_{SS}	Nominal capacitor values specified. Recommend a 5% ceramic X5R type capacitor located close to the device.		0.1		µF
C_{REG25}	External output capacitor for internal LDO between REG25 and V_{SS}		0.47	1.0		µF
I_{CC}	Normal operating mode current[(1)(2)] (VPWR)	Fuel gauge in NORMAL mode. I_{LOAD} > ***Sleep Current*** with charge pumps on (FETs on)		167		µA
I_{SLP}	SLEEP mode current[(1)(2)] (VPWR)	Fuel gauge in SLEEP+ mode. I_{LOAD} < ***Sleep Current*** with charge pumps on (FETs on)		88		µA
$I_{FULLSLP}$	FULLSLEEP mode current[(1)(2)] (VPWR)	Fuel gauge in SLEEP mode. I_{LOAD} < ***Sleep Current*** with charge pumps on (FETs on)		40		µA
$I_{SHUTDOWN}$	Shutdown mode current[(1)(2)] (VPWR)	Fuel gauge in SHUTDOWN mode. UVP tripped with fuel gauge and protector turned off (FETs off) V_{VPWR} = 2.5 V T_A = 25°C		0.1	0.2	µA
		T_A = –40°C to 85°C			0.5	µA
V_{OL}	Output voltage low (SCL, SDA, HDQ, RA0, RC2)	I_{OL} = 1 mA			0.4	V
$V_{OH(OD)}$	Output voltage high (SDA, SCL, HDQ, RA0, RC2)	External pullup resistor connected to V_{REG25}	V_{REG25} – 0.5			V
V_{IL}	Input voltage low (SDA, SCL, HDQ, RA0)		–0.3		0.6	V
$V_{IH(OD)}$	Input voltage high (SDA, SCL, HDQ, RA0)		1.2		5.5	V
V_{A1}	Input voltage range (TS)		V_{SS} – 0.125		2	V
V_{A2}	Input voltage range (BAT)		V_{SS} – 0.125		5	V
V_{A3}	Input voltage range (SRP, SRN)		V_{VPWR} – 0.125		V_{VPWR} + 0.125	V
I_{lkg}	Input leakage current (I/O pins)				0.3	µA
t_{PUCD}	Power-up communication delay			250		ms

(1) All currents are specified as charge pump on (FETs on).
(2) All currents are continuous average over 5-second period.

Power-On Reset

T_A = 25°C, C_{REG25} = 1.0 µF, and V_{VPWR} = 3.6 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{IT+}	Increasing battery voltage input at V_{REG25}		2.09	2.20	2.31	V
V_{HYS}	Power-on reset hysteresis		45	115	185	mV

2.5-V LDO Regulator(1)

T_A = 25°C, C_{REG25} = 1.0 µF, and V_{VPWR} = 3.6 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_{REG25}	Regulator output voltage	2.8 V ≤ V_{VPWR} ≤ 4.5 V, I_{OUT}(1) ≤ 16 mA	T_A = –40°C to 85°C	2.3	2.5	2.6	V
		2.45 V ≤ V_{VPWR} < 2.8 V (low battery), I_{OUT}(1) ≤ 3 mA		2.3			V
I_{SHORT} (2)	Short-circuit current limit	V_{REG25} = 0 V	T_A = –40°C to 85°C			250	mA

(1) LDO output current, I_{OUT}, is the sum of internal and external load currents.
(2) Assured by characterization. Not production tested.

Charger Attachment and Removal Detection

T_A = 25°C, C_{REG25} = 1.0 µF, and V_{VPWR} = 3.6 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{CHGATT}	Voltage threshold for charger attachment detection			2.7	3.0	V
V_{CHGREM}	Voltage threshold for charger removal detection		0.5	1.0		V

Voltage Doubler

T_A = 25°C, C_{REG25} = 1.0 µF, and V_{VPWR} = 3.6 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{FETON}	CHG and DSG FETs on	I_L = 1 µA T_A = –40°C to 85°C	2 × V_{VPWR} – 0.4	2 × V_{VPWR} – 0.2	2 × V_{VPWR}	V
V_{FETOFF}	CHG and DSG FETs off	T_A = –40°C to 85°C			0.2	V
$V_{FETRIPPLE}$(1)	CHG and DSG FETs on	I_L = 1 µA T_A = –40°C to 85°C			0.1	V_{PP}
t_{FETON}	FET gate rise time (10% to 90%)	C_L = 4 nF T_A = –40°C to 85°C No series resistance	67	140	218	µs
t_{FETOFF}	FET gate fall time (90% to 10%)	C_L = 4 nF T_A = –40°C to 85°C No series resistance	10	30	60	µs

(1) Assured by characterization. Not production tested.

Overvoltage Protection (OVP)

T_A = 25°C and C_{REG25} = 1.0 µF (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{OVP}	OVP detection voltage threshold	T_A = 25°C	V_{OVP} – 0.006	V_{OVP}	V_{OVP} + 0.006	V
		T_A = 0°C to 25°C	V_{OVP} – 0.023	V_{OVP}	V_{OVP} + 0.020	
		T_A = 25°C to 50°C	V_{OVP} – 0.018	V_{OVP}	V_{OVP} + 0.014	
		T_A = –40°C to 85°C	V_{OVP} – 0.053	V_{OVP}	V_{OVP} + 0.035	
V_{OVPREL}	OVP release voltage	T_A = 25°C	V_{OVPREL} – 0.012	V_{OVP} – 0.215	V_{OVPREL} + 0.012	V
		T_A = 0°C to 25°C	V_{OVPREL} – 0.023	V_{OVP} – 0.215	V_{OVPREL} + 0.020	
		T_A = 25°C to 50°C	V_{OVPREL} – 0.018	V_{OVP} – 0.215	V_{OVPREL} + 0.014	
		T_A = –40°C to 85°C	V_{OVPREL} – 0.053	V_{OVP} – 0.215	V_{OVPREL} + 0.035	
t_{OVP}	OVP delay time	T_A = –40°C to 85°C	t_{OVP} – 5%	t_{OVP}	t_{OVP} + 5%	s

Undervoltage Protection (UVP)

T_A = 25°C and C_{REG25} = 1.0 µF (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{UVP}	UVP detection voltage threshold	T_A = 25°C	V_{UVP} – 0.012	V_{UVP}	V_{UVP} + 0.012	V
		T_A = –5°C to 50°C	V_{UVP} – 0.020	V_{UVP}	V_{UVP} + 0.020	
		T_A = –40°C to 85°C	V_{UVP} – 0.040	V_{UVP}	V_{UVP} + 0.040	
V_{UVPREL}	UVP release voltage	T_A = 25°C	V_{UVPREL} – 0.012	V_{UVP} + 0.105	V_{UVPREL} + 0.012	V
		T_A = –5°C to 50°C	V_{UVPREL} – 0.020	V_{UVP} + 0.105	V_{UVPREL} + 0.020	
		T_A = –40°C to 85°C	V_{UVPREL} – 0.040	V_{UVP} + 0.105	V_{UVPREL} + 0.040	
t_{UVP}	UVP delay time	T_A = –40°C to 85°C	t_{UVP} – 5%	t_{UVP}	t_{UVP} + 5%	ms

Overcurrent in Discharge (OCD)

T_A = 25°C, C_{REG25} = 1.0 µF, and V_{VPWR} = 3.6 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{OCD}	OCD detection voltage threshold	T_A = 25°C V_{SRN} – V_{SRP}	V_{OCD} – 3	V_{OCD}	V_{OCD} + 3	mV
		T_A = –20°C to 60°C V_{SRN} – V_{SRP}	V_{OCD} – 3.785	V_{OCD}	V_{OCD} + 3.785	
		T_A = –40°C to 85°C V_{SRN} – V_{SRP}	V_{OCD} – 4.16	V_{OCD}	V_{OCD} + 4.16	
t_{OCD}	OCD delay time	T_A = –40°C to 85°C	t_{OCD} – 5%	t_{OCD}	t_{OCD} + 5%	ms

Overcurrent in Charge (OCC)

T_A = 25°C, C_{REG25} = 1.0 µF, and V_{VPWR} = 3.6 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{OCC}	OCC detection voltage threshold	T_A = 25°C V_{SRP} – V_{SRN}	V_{OCC} – 3	V_{OCC}	V_{OCC} + 3	mV
		T_A = –20°C to 60°C V_{SRP} – V_{SRN}	V_{OCC} – 3.49	V_{OCC}	V_{OCC} + 3.49	
		T_A = –40°C to 85°C V_{SRP} – V_{SRN}	V_{OCC} – 3.86	V_{OCC}	V_{OCC} + 3.86	
t_{OCC}	OCC delay time	T_A = –40°C to 85°C	t_{OCC} – 5%	t_{OCC}	t_{OCC} + 5%	ms

Short-Circuit in Discharge (SCD)

T_A = 25°C, C_{REG25} = 1.0 µF, and V_{VPWR} = 3.6 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{SCD}	SCD detection voltage threshold	T_A = 25°C $V_{SRN} – V_{SRP}$	V_{SCD} – 3	V_{SCD}	V_{SCD} + 3	mV
		T_A = –20°C to 60°C $V_{SRN} – V_{SRP}$	V_{SCD} – 4.5	V_{SCD}	V_{SCD} + 4.5	
		T_A = –40°C to 85°C $V_{SRN} – V_{SRP}$	V_{SCD} – 4.9	V_{SCD}	V_{SCD} + 4.9	
t_{SCD}	SCD delay time	T_A = –40°C to 85°C	t_{SCD} – 10%	t_{SCD}	t_{SCD} + 10%	µs

Low Voltage Charging

T_A = 25°C, C_{REG25} = 1.0 µF, and V_{VPWR} = 3.6 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{LVDET}	Voltage threshold for low-voltage charging detection	T_A = –40°C to 85°C	1.4	1.55	1.7	V

Internal Temperature Sensor Characteristics

T_A = –40°C to 85°C, 2.4 V < V_{REG25} < 2.6 V

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

High-Frequency Oscillator

2.4 V < V_{REG25} < 2.6 V; typical values at T_A = 25°C and V_{REG25} = 2.5 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
f_{OSC}	Operating frequency			8.389		MHz
f_{EIO}	Frequency error[(1)] [(2)]	T_A = 0°C to 60°C	–2.0%	0.38%	2.0%	
		T_A = –20°C to 70°C	–3.0%	0.38%	3.0%	
		T_A = –40°C to 85°C	-4.5%	0.38%	4.5%	
t_{SXO}	Start-up time[(3)]	T_A = –40°C to 85°C		2.5	5	ms

(1) The frequency error is measured from 2.097 MHz.
(2) The frequency drift is included and measured from the trimmed frequency at V_{REG25} = 2.5 V, T_A = 25°C.
(3) The startup time is defined as the time it takes for the oscillator output frequency to be ±3% of the typical oscillator frequency.

Low-Frequency Oscillator

2.4 V < V_{REG25} < 2.6 V; typical values at T_A = 25°C and V_{REG25} = 2.5 V (unless otherwise noted)

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

(1) The frequency drift is included and measured from the trimmed frequency at V_{REG25} = 2.5 V, T_A = 25°C.
(2) The frequency error is measured from 32.768 kHz.
(3) The startup time is defined as the time it takes for the oscillator output frequency to be ±3% of the typical oscillator frequency.

Integrating ADC (Coulomb Counter) Characteristics

T_A = –40°C to 85°C, 2.4 V < V_{REG25} < 2.6 V; typical values at T_A = 25°C and V_{REG25} = 2.5 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{SR_IN}	Input voltage range, V_{SRN} and V_{SRP}	$V_{SR} = V_{SRN} - V_{SRP}$	V_{VPWR} – 0.125		V_{VPWR} + 0.125	V
t_{SR_CONV}	Conversion time	Single conversion		1		s
	Resolution		14		15	bits
V_{SR_OS}	Input offset			10		μV
INL	Integral nonlinearity error			±0.007	±0.034	%FSR
Z_{SR_IN}	Effective input resistance (1)		7			MΩ
I_{SR_LKG}	Input leakage current (1)				0.3	μA

(1) Assured by design. Not production tested.

ADC (Temperature and Cell Voltage) Characteristics

T_A = –40°C to 85°C, 2.4 V < V_{REG25} < 2.6 V; typical values at T_A = 25°C and V_{REG25} = 2.5 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{ADC_IN}	Input voltage range (VBAT channel)		V_{SS} – 0.125		5	V
	Input voltage range (other channels)		V_{SS} – 0.125		1	V
t_{ADC_CONV}	Conversion time				125	ms
	Resolution		14		15	bits
V_{ADC_OS}	Input offset			1		mV
Z_{ADC1}	Effective input resistance (TS) (1)		55			MΩ
Z_{ADC2}	Effective input resistance (BAT) (1)	Not measuring cell voltage	55			MΩ
		Measuring cell voltage		100		kΩ
I_{ADC_LKG}	Input leakage current (1)				0.3	μA

(1) Assured by design. Not production tested.

Data Flash Memory Characteristics

T_A = –40°C to 85°C, 2.4 V < V_{REG25} < 2.6 V; typical values at T_A = 25°C and V_{REG25} = 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

(1) Assured by design. Not production tested.

I²C-Compatible Interface Timing Characteristics

T_A = –40°C to 85°C, 2.4 V < V_{REG25} < 2.6 V; typical values at T_A = 25°C and V_{REG25} = 2.5 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_R	SCL or SDA rise time				300	ns
t_F	SCL or SDA fall time				300	ns
$t_{w(H)}$	SCL pulse width (high)		600			ns
$t_{w(L)}$	SCL pulse width (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

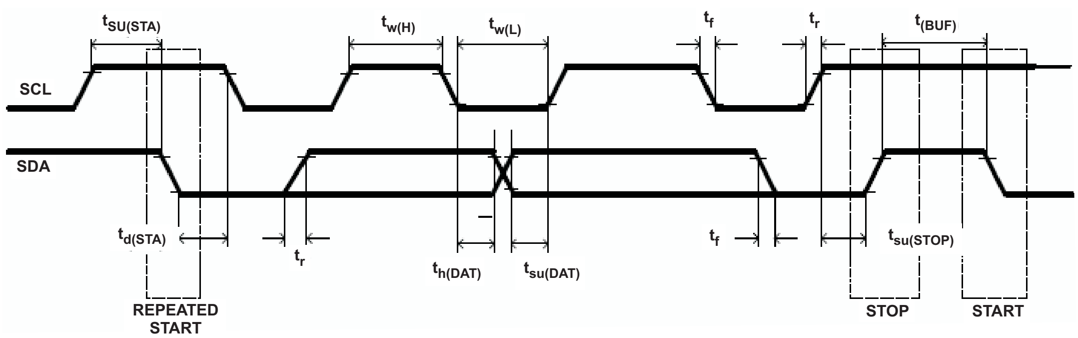


Figure 1. I²C-Compatible Interface Timing Diagrams

HDQ Communication Timing Characteristics

T_A = –40°C to 85°C, 2.4 V < V_{REG25} < 2.6 V; typical values at T_A = 25°C and V_{REG25} = 2.5 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{(CYCH)}$	Cycle time, host to fuel gauge		190			µs
$t_{(CYCD)}$	Cycle time, fuel gauge to host		190	205	250	µs
$t_{(HW1)}$	Host sends 1 to fuel gauge		0.5		50	µs
$t_{(DW1)}$	Fuel gauge sends 1 to host		32		50	µs
$t_{(HW0)}$	Host sends 0 to fuel gauge		86		145	µs
$t_{(DW0)}$	Fuel gauge sends 0 to host		80		145	µs
$t_{(RSPS)}$	Response time, fuel gauge to host		190		950	µs
$t_{(B)}$	Break time		190			µs
$t_{(BR)}$	Break recovery time		40			µs
$t_{(RST)}$	HDQ reset		1.8		2.2	s
$t_{(RISE)}$	HDQ line rise time to logic 1 (1.2 V)				950	ns

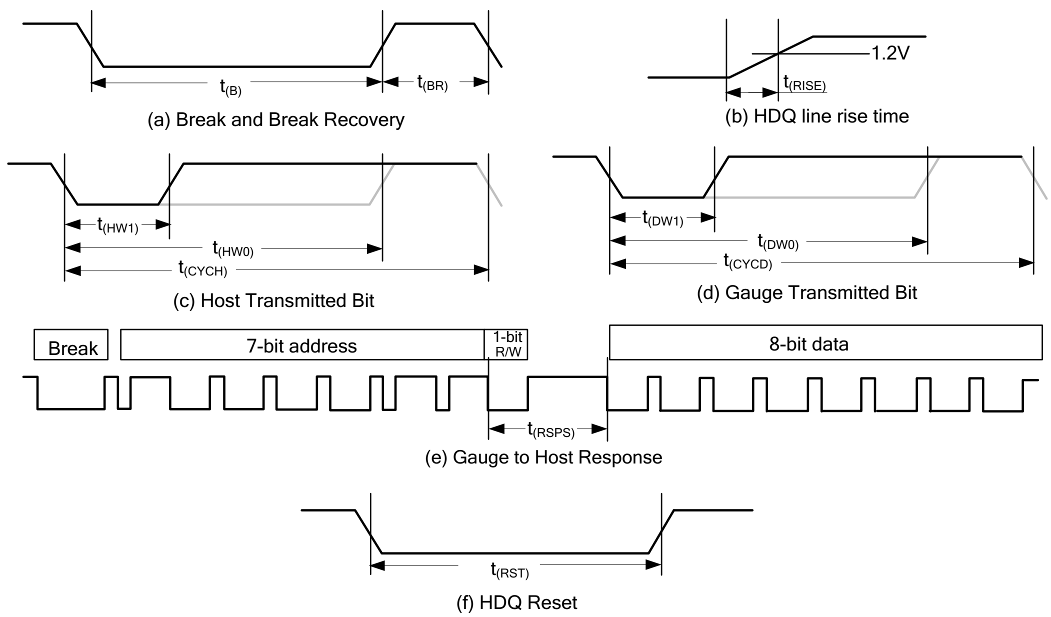


Figure 2. Timing Diagrams

(a) HDQ Breaking
(b) Rise time of HDQ line
(c) HDQ Host to fuel gauge communication
(d) Fuel gauge to Host communication
(e) Fuel gauge to Host response format
(f) HDQ Host to fuel gauge reset

FEATURE SET

The bq27741-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), time-to-empty (TTE), and time-to-full (TTF).

Configuration

Cell information is stored in the fuel gauge 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 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 fuel gauge provides 96 bytes of user-programmable data flash memory, partitioned into three 32-byte blocks: ***Manufacturer Info Block A*** and ***Manufacturer Info Block B***. This data space is accessed through a data flash interface.

Fuel Gauging

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 less than 1% error across a wide variety of operating conditions and over the lifetime of the battery.

See application note SLUA364B, *Theory and Implementation of Impedance Track Battery Fuel-Gauging Algorithm*, for further details.

Power Modes

To minimize power consumption, the fuel gauge has different power modes: NORMAL, SLEEP, and FULLSLEEP. 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.

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

SLEEP Mode

SLEEP mode performs *AverageCurrent()*, *Voltage()*, and *Temperature()* less frequently which results in reduced power consumption. SLEEP mode is entered automatically if the feature is enabled (***Pack Configuration [SLEEP]*** = 1) and *AverageCurrent( )* is below the programmable level ***Sleep Current***. Once entry into SLEEP mode has been qualified, but prior to entering it, the fuel gauge performs an ADC autocalibration to minimize offset.

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

The fuel gauge exits SLEEP if any entry condition is broken, specifically when either:

- *AverageCurrent( )* rises above ***Sleep Current***, or
- A current in excess of I_{WAKE} through R_{SENSE} is detected.

FULLSLEEP Mode

FULLSLEEP mode turns off the high-frequency oscillator and performs *AverageCurrent()*, *Voltage()*, and *Temperature()* less frequently which results in power consumption that is lower than that of the SLEEP mode.

FULLSLEEP mode can be enabled by two methods:

- Setting the ***[FULLSLEEP]*** bit in the Control Status register using the FULL_SLEEP subcommand and ***Full Sleep Wait Time (FS Wait)*** in data flash is set as 0.
- Setting the ***Full Sleep Wait Time (FS Wait)*** in data flash to a number larger than 0. This method is disabled when the ***FS Wait*** is set as 0.

FULLSLEEP mode is entered automatically when it is enabled by one of the methods above. When the first method is used, the gauge enters the FULLSLEEP mode when the fuel gauge is in SLEEP mode. When the second method is used, the FULLSLEEP mode is entered when the fuel gauge is in SLEEP mode and the timer counts down to 0.

The fuel gauge exits the FULLSLEEP mode when there is any communication activity. Therefore, the execution of SET_FULLSLEEP sets the ***[FULLSLEEP]*** bit. The FULLSLEEP mode can be verified by measuring the current consumption of the gauge.

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

The fuel gauge exits SLEEP if any entry condition is broken, specifically when either:

- *AverageCurrent( )* rises above ***Sleep Current***, or
- A current in excess of I_{WAKE} through R_{SENSE} is detected.

While in FULLSLEEP mode, the fuel gauge can suspend serial communications by as much as 4 ms by holding the comm line(s) low. This delay is necessary to correctly process host communication, because the fuel gauge processor is mostly halted in SLEEP mode.

Battery Protector Description

The battery protector controls two external high-side N-channel FETs in a back-to-back configuration for battery protection. The protector uses two voltage doublers to drive the CHG and DSG FETs on.

High-Side NFET Charge and Discharge FET Drive

The CHG or DSG FET is turned on by pulling the FET gate input up to V_{FETON}. The FETs are turned off by pulling the FET gate input down to V_{SS}. These FETs are automatically turned off by the protector based on the detected protection faults, or when commanded to turn off via the *FETTest*(0x74/0x75) extended command. Once the protection fault(s) is cleared, the FETs may be turned on again.

Operating Modes

The battery protector has several operating modes:

- Virtual shutdown mode
  - Analog shutdown
  - Low voltage charging
- UVP fault (POR state)
- Normal mode
- Shutdown wait
- OCD or SCD fault mode
- OCC fault mode
- OVP fault mode

The relationships among these modes are shown in Figure 3.

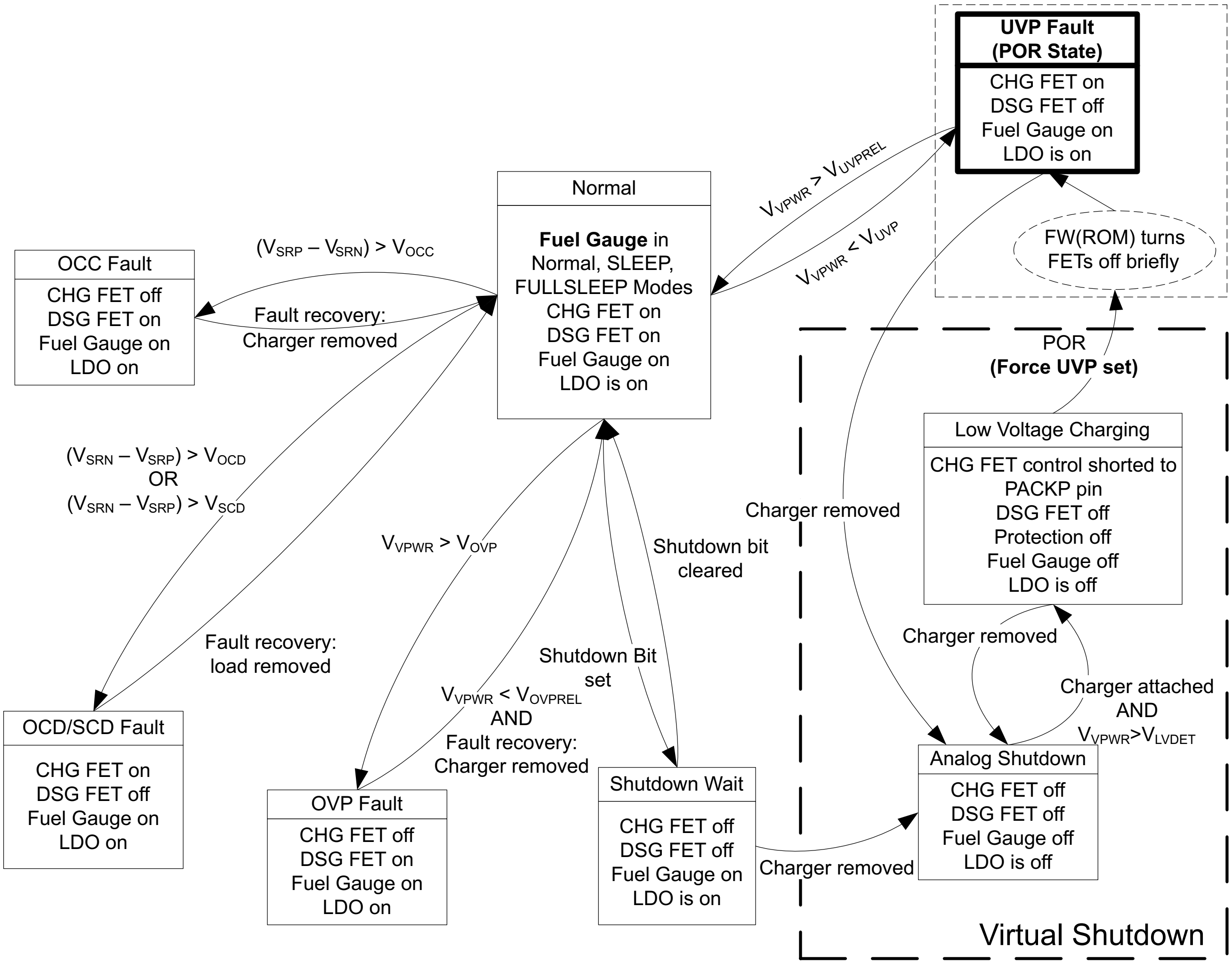


Figure 3. Operating Modes

Virtual Shutdown Mode

In this mode, the fuel gauge is not functional and only certain portions of analog circuitry are running to allow device wakeup from shutdown and low voltage charging.

Analog Shutdown Mode

In this mode, the fuel gauge is not functional. Once the charger is connected, the fuel gauge determines if low voltage charging is allowed and then transitions to low voltage charging.

Low Voltage Charging Mode

In this mode, the fuel gauge closes CHG FET by shorting the gate to PACKP pin. Low voltage charging continues until the cell voltage (V_{VPWR}) rises above the POR threshold.

Undervoltage Fault Mode

In this mode, the voltage on VPWR pin is below V_{UVP} and the charger is connected. As soon as the charger disconnects, the fuel gauge transitions into Analog Shutdown Mode to save power.

The fuel gauge can enter this mode from Low Voltage Charging Mode when the battery pack is being charged from a deeply discharged state or from Normal Mode when the battery pack is being discharged below the allowed voltage.

When the battery pack is charged above V_{UVPREL}, the fuel gauge transitions to Normal Mode.

Normal Mode

In this mode, the protector is fully powered and operational. Both CHG and DSG FETs are closed, while further operation is determined by the firmware. Protector is continuously checking for all faults.

The CHG or DSG FET may be commanded to be opened via the protector register by the firmware, but it does not affect protector operation nor changes the mode of operation.

Firmware can also command the fuel gauge to go into shutdown mode based on the command from the host. In this case, firmware sets the Shutdown bit to indicate intent to go into shutdown mode. The fuel gauge then transitions to Shutdown Wait Mode.

Shutdown Wait Mode

In this mode, the shutdown bit was set by the firmware and the fuel gauge initiated the shutdown sequence.

The shutdown sequence:

1. Open both CHG and DSG FETs
2. Determine if any faults are set. If any faults are set, then go back to Normal Mode.
3. Wait for charger removal. Once the charger is removed, turn off the LDO, which puts the fuel gauge into Analog Shutdown Mode.

Overcurrent Discharge (OCD) and Short-Circuit Discharge (SCD) Fault Mode

In this mode, a short-circuit discharge (SCD) or overcurrent discharge (OCD) protection fault is detected when the voltage across the sense resistor continuously exceeds the configured V_{OCD} or V_{SCD} thresholds for longer than the configured delay.

The fuel gauge enables the fault removal detection circuitry, which monitors load removal. A special high resistance load is switched in to monitor load presence. The OCD/SCD fault is cleared when the load is removed, which causes the fuel gauge to transition into Normal Mode.

Overcurrent Charge (OCC) Fault Mode

In this mode, an overcurrent charge (OCC) protection fault is detected when the voltage across the sense resistor continuously exceeds the configured V_{OCC} for longer than the configured delay.

The fuel gauge enables the fault removal detection circuitry, which monitors the charger removal. The OCC fault is cleared once the charger voltage drops below the cell voltage by more than 300 mV, which causes the fuel gauge to transition to Normal Mode.

Overvoltage Protection (OVP) Fault Mode

In this mode, an overvoltage protection (OVP) fault mode is entered when the voltage on VPWR pin continuously exceeds the configured V_{OVP} threshold for longer than the configured delay.

The fuel gauge enables the fault removal detection circuitry, which monitors the charger removal. The OVP fault is cleared once the charger voltage drops below the cell voltage by more than 300 mV and the cell voltage drops below V_{OVPREL}, which causes the fuel gauge to transition to Normal Mode.

Firmware Control of Protector

The firmware has control to open the CHG FET or DSG FET independently by overriding hardware control. However, it has no control to close the CHG FET or DSG FET and can only disable the FET override.

Overtemperature Fault Mode

Overtemperature protection is implemented in firmware. Gauging firmware monitors temperature every second and will open both CHG and DSG FETs if Temperature() > *OT Prot Threshold* for *OT Prot Delay*. CHG and DSG FETs override will be released when Temperature() < *OT Prot Recover*.

Wake-Up Comparator

The wake-up comparator indicates a change in cell current while the fuel gauge is in SLEEP mode. Wake comparator threshold can be configured in firmware and set to the thresholds in Table 3. An internal event is generated when the threshold is breached in either charge or discharge directions.

Table 3. I_{WAKE} Threshold Settings(1)

RSNS1	RSNS0	IWAKE	Vth(SRP-SRN)
0	0	0	Disabled
0	0	1	Disabled
0	1	0	1.0 mV or –1.0 mV
0	1	1	2.2 mV or –2.2 mV
1	0	0	2.2 mV or –2.2 mV
1	0	1	4.6 mV or –4.6 mV
1	1	0	4.6 mV or –4.6 mV
1	1	1	9.8 mV or –9.8 mV

(1) The actual resistance value versus the setting of the sense resistor is not important just the actual voltage threshold when calculating the configuration. The voltage thresholds are typical values under room temperature.

Battery Parameter Measurements

Charge and Discharge Counting

The integrating delta-sigma ADC measures the charge or discharge flow of the battery by measuring the voltage drop across a small-value sense resistor between the SRP and SRN pins. The integrating ADC measures bipolar signals and detects charge activity when $V_{SR} = V_{SRP} – V_{SRN}$ is positive and discharge activity when $V_{SR} = V_{SRP} – V_{SRN}$ is negative. The fuel gauge continuously integrates the signal over time using an internal counter.

Voltage

The fuel gauge updates cell voltages at 1-second intervals when in NORMAL mode. The internal ADC of the fuel gauge measures the voltage, and scales and calibrates it appropriately. Voltage measurement is automatically compensated based on temperature. This data is also used to calculate the impedance of the cell for Impedance Track™ fuel gauging.

Current

The fuel gauge uses the SRP and SRN inputs to measure and calculate the battery charge and discharge current using a 5-mΩ to 20-mΩ typical sense resistor.

Auto-Calibration

The fuel gauge provides an auto-calibration feature to cancel the voltage offset error across SRN and SRP for maximum charge measurement accuracy. The fuel gauge performs auto-calibration before entering the SLEEP mode.

Temperature

The fuel gauge external temperature sensing is optimized with the use of a high-accuracy negative temperature coefficient (NTC) thermistor with R25 = 10 kΩ ± 1% and B25/85 = 3435 kΩ ± 1% (such as Semitec 103AT for measurement). The fuel gauge can also be configured to use its internal temperature sensor. The fuel gauge uses temperature to monitor the battery-pack environment, which is used for fuel gauging and cell protection functionality.

NOTE

Formatting Conventions in This Document:

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

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

Register Bits and Flags: brackets only, for example, [TDA]

Data Flash Bits: *italic* and **bold**, for example, ***[XYZ1]***

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

Communications

HDQ Single-Pin Serial Interface

The HDQ interface is an asynchronous return-to-one protocol where a processor sends the command code to the fuel gauge. With HDQ, the least significant bit (LSB) of a data byte (command) or word (data) is transmitted first. The DATA signal on pin 12 is open-drain and requires an external pullup resistor. The 8-bit command code consists of two fields: the 7-bit HDQ command code (bits 0 through 6) and the 1-bit RW field (MSB bit 7). The RW field directs the fuel gauge either to:

- Store the next 8 bits of data to a specified register, or
- Output 8 bits of data from the specified register

The HDQ peripheral can transmit and receive data as either an HDQ master or slave.

HDQ serial communication is normally initiated by the host processor sending a break command to the fuel gauge. A break is detected when the DATA pin is driven to a logic low state for a time $t_{(B)}$ or greater. The DATA pin then is returned to its normal ready logic high state for a time $t_{(BR)}$. The fuel gauge is now ready to receive information from the host processor.

The fuel gauge is shipped in the I^2C mode. TI provides tools to enable the HDQ peripheral.

HDQ Host Interruption

The default fuel gauge behaves as an HDQ slave-only device. If the HDQ interrupt function is enabled, the fuel gauge is capable of mastering and also communicating to a HDQ device. There is no mechanism for negotiating which is to function as the HDQ master and care must be taken to avoid message collisions. The interrupt is signaled to the host processor with the fuel gauge mastering an HDQ message. This message is a fixed message that signals the interrupt condition. The message itself is 0x80 (slave write to register 0x00) with no data byte being sent as the command is not intended to convey any status of the interrupt condition. The HDQ interrupt function is not public and needs to be enabled by command.

When the SET_HDQINTEN subcommand is received, the fuel gauge detects any of the interrupt conditions and asserts the interrupt at one-second intervals until either:

- The *CLEAR_HDQINTEN* subcommand is received, or
- The number of tries for interrupting the host has exceeded a predetermined limit. After the interrupt event, interrupts are automatically disabled. To re-enable interrupts, SET_HDQINTEN needs to be sent.

Low Battery Capacity

This feature works identically to SOC1. It uses the same data flash entries as SOC1 and triggers interrupts as long as SOC1 = 1 and HDQIntEN = 1.

Temperature

This feature triggers an interrupt based on the OTC (Overtemperature in Charge) or OTD (Overtemperature in Discharge) condition being met. It uses the same data flash entries as OTC or OTD and triggers interrupts as long as either the OTD or OTC condition is met and HDQIntEN = 1. (See detail in HDQ Host Interruption.)

I²C Interface

The fuel gauge supports the standard I²C read, incremental read, one-byte write quick read, and 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 is therefore 0xAA or 0xAB for write or read, respectively.

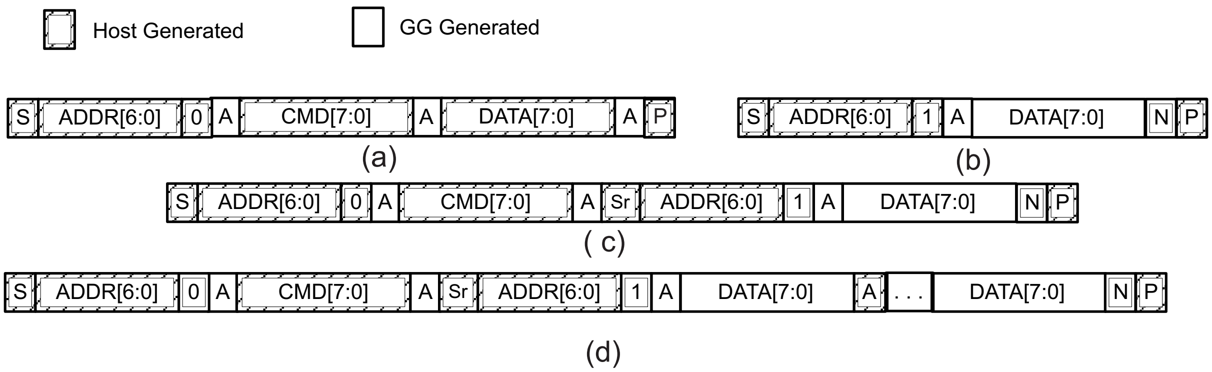
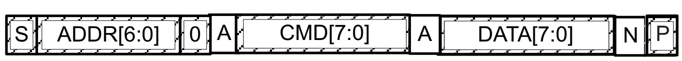


Figure 4. Supported I²C Formats

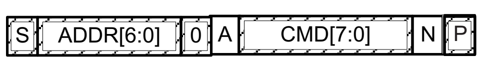
(a) 1-byte write
(b) Quick read
(c) 1-byte read
(d) Incremental read (S = Start, Sr = Repeated Start, A = Acknowledge, N = No Acknowledge, and P = Stop).

The quick read returns data at the address indicated by the address pointer. The address pointer, a register internal to the I²C communication engine, increments whenever data is acknowledged by the fuel gauge 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).

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

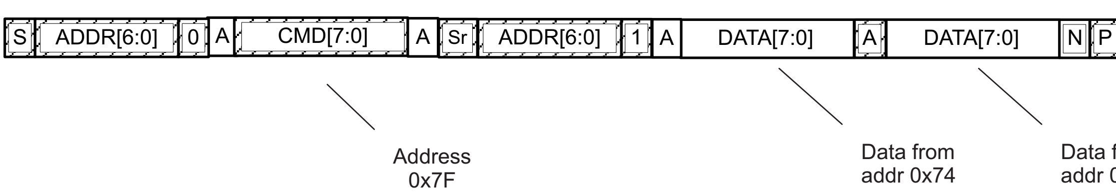


Attempt to read an address above 0x7F (NACK command):



Attempt at incremental writes (NACK all extra data bytes sent):

Incremental read at the maximum allowed read address:



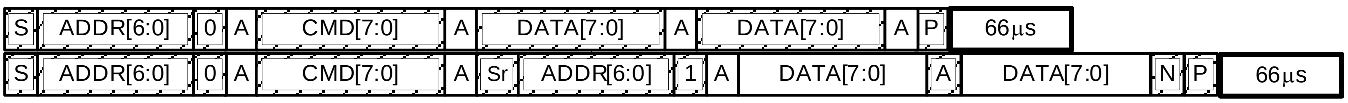
The I²C engine releases both SDA and SCL if the I²C bus is held low for $t_{(BUSERR)}$. If the fuel gauge was holding the lines, releasing them frees the master to drive the lines. If an external condition is holding either of the lines low, the I²C engine enters the low-power sleep mode.

I²C Time Out

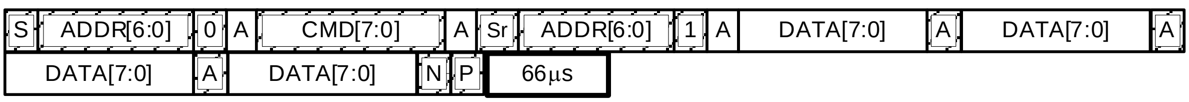
The I²C engine releases both SDA and SCL lines if the I²C bus is held low for about 2 seconds. If the fuel gauge was holding the lines, releasing them frees the master to drive the lines.

I²C Command Waiting Time

To ensure the correct results of a command with the 400-kHz I²C operation, a proper waiting time must be added between issuing a command and reading the results. For subcommands, the following diagram shows the waiting time required between issuing the control command and reading the status with the exception of the checksum command. A 100-ms waiting time is required between the checksum command and reading the result. For read-write standard commands, 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 between control subcommand and reading results



Waiting time between continuous reading results

The I²C clock stretch could happen in a typical application. A maximum 80-ms clock stretch could be observed during the flash updates. There is up to a 270-ms clock stretch after the OCV command is issued.

DATA COMMANDS

Standard Data Commands

The 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 4. Each protocol has specific means to access the data at each Command Code. Data RAM is updated and read by the gauge only once per second. Standard commands are accessible in NORMAL operation mode.

Table 4. Standard Commands

NAME		COMMAND CODE	UNIT	SEALED ACCESS
Control( )	CNTL	0x00 and 0x01	NA	RW
AtRate( )	AR	0x02 and 0x03	mA	RW
UnfilteredSOC()	UFSOC	0x04 and 0x05	%	R
Temperature( )	TEMP	0x06 and 0x07	0.1°K	R
Voltage( )	VOLT	0x08 and 0x09	mV	R
Flags( )	FLAGS	0x0A and 0x0B	NA	R
NomAvailableCapacity( )	NAC	0x0C and 0x0D	mAh	R
FullAvailableCapacity( )	FAC	0x0E and 0x0F	mAh	R
RemainingCapacity( )	RM	0x10 and 0x11	mAh	R
FullChargeCapacity( )	FCC	0x12 and 0x13	mAh	R
AverageCurrent( )	AI	0x14 and 0x15	mA	R
TimeToEmpty( )	TTE	0x16 and 0x17	minutes	R
FilteredFCC()	FFCC	0x18 and 0x19	mAh	R
StandbyCurrent( )	SI	0x1A and 0x1B	mA	R
UnfilteredFCC()	UFFCC	0x1C and 0x1D	mAh	R
MaxLoadCurrent( )	MLI	0x1E and 0x1F	mA	R
UnfilteredRM()	UFRM	0x20 and 0x21	mAh	R
FilteredRM()	FRM	0x22 and 0x23	mAh	R
AveragePower( )	AP	0x24 and 0x25	mW or cW	R
InternalTemperature( )	INTTEMP	0x28 and 0x29	0.1°K	R
CycleCount( )	CC	0x2A and 0x2B	Counts	R
StateOfCharge( )	SOC	0x2C and 0x2D	%	R
StateOfHealth( )	SOH	0x2E and 0x2F	% / num	R
PassedCharge( )	PCHG	0x34 and 0x35	mAh	R
DOD0( )	DOD0	0x36 and 0x37	hex#	R
SelfDischargeCurrent()	SDSG	0x38 and 0x39	mA	R

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 fuel gauge is in different access modes, as described in Table 5.

Table 5. *Control( )* Subcommands

CNTL FUNCTION	CNTL DATA	SEALED ACCESS	DESCRIPTION
CONTROL_STATUS	0x0000	Yes	Reports the status of DF Checksum, Impedance Track™, etc.
DEVICE_TYPE	0x0001	Yes	Reports the device type of 0x0741 (indicating bq27741-G1)
FW_VERSION	0x0002	Yes	Reports the firmware version on the device type
HW_VERSION	0x0003	Yes	Reports the hardware version of the device type
PROTECTOR_VERSION	0x0004	Yes	Reports the hardware version of the protector portion of the device
RESET_DATA	0x0005	Yes	Returns reset data
Reserved	0x0006	No	Not to be used
PREV_MACWRITE	0x0007	Yes	Returns previous *Control( )* subcommand 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_OFFSET	0x000A	No	Forces the device to measure internal CC offset
CC_OFFSET_SAVE	0x000B	No	Forces the device to store the internal CC offset
DF_VERSION	0x000C	Yes	Reports the data flash version on the device
SET_FULLSLEEP	0x0010	Yes	Sets the *CONTROL_STATUS [FULLSLEEP]* bit to 1
SET_SHUTDOWN	0x0013	Yes	Sets the *CONTROL_STATUS [SHUTDN_EN]* bit to 1
CLEAR_SHUTDOWN	0x0014	Yes	Clears the *CONTROL_STATUS [SHUTDN_EN]* bit to 0
SET_HDQINTEN	0x0015	Yes	Forces the *CONTROL_STATUS [HDQIntEn]* bit to 1
CLEAR_HDQINTEN	0x0016	Yes	Forces the *CONTROL_STATUS [HDQIntEn]* bit to 0
STATIC_CHEM_CHKSUM	0x0017	Yes	Calculates chemistry checksum
ALL_DF_CHKSUM	0x0018	Yes	Reports checksum for all data flash excluding device specific variables
STATIC_DF_CHKSUM	0x0019	Yes	Reports checksum for static data flash excluding device specific variables
SEALED	0x0020	No	Places the fuel gauge in SEALED access mode
IT_ENABLE	0x0021	No	Enables the Impedance Track™ algorithm
START_FET_TEST	0x0024	No	Starts FET Test based on data entered in FET Test register. Sets and clears the *[FETTST]* bit in *CONTROL_STATUS* register
CAL_ENABLE	0x002D	No	Toggle calibration mode
RESET	0x0041	No	Forces a full reset of the fuel gauge
EXIT_CAL	0x0080	No	Exit calibration mode
ENTER_CAL	0x0081	No	Enter calibration mode
OFFSET_CAL	0x0082	No	Reports internal CC offset in calibration mode

Extended Data Commands

Extended commands offer additional functionality beyond the standard set of commands. They are used in the same manner; however unlike standard commands, extended commands are not limited to 2-byte words. The number of command bytes for a given extended command ranges in size from single to multiple bytes, as specified in Table 6. For details on the SEALED and UNSEALED states, see the *Access Modes* section in the TRM, SLUUAA3.

Table 6. Extended Commands

NAME		COMMAND CODE	UNIT	SEALED ACCESS(1) (2)	UNSEALED ACCESS(1) (2)
PackConfig( )	PCR	0x3A and 0x3B	hex#	R	R
DesignCapacity( )	DCAP	0x3C and 0x3D	mAh	R	R
DataFlashClass( ) (2)	DFCLS	0x3E	NA	NA	RW
DataFlashBlock( ) (2)	DFBLK	0x3F	NA	RW	RW
BlockData( ) / Authenticate( ) (3)	A/DF	0x40 to 0x53	NA	RW	RW
BlockData( ) / AuthenticateCheckSum( ) (3)	ACKS/DFD	0x54	NA	RW	RW
BlockData( )	DFD	0x55 to 0x5F	NA	R	RW
BlockDataCheckSum( )	DFDCKS	0x60	NA	RW	RW
BlockDataControl( )	DFDCNTL	0x61	NA	NA	RW
DeviceNameLength( )	DNAMELEN	0x62	NA	R	R
DeviceName( )	DNAME	0x63 to 0x6C	NA	R	R
Protector Status	AFESTAT1	0x6D	hex	R	R
Reserved	RSVD	0x6E and 0x6F	NA	R	R
Simultaneous Current		0x70 and 0x71	NA	R	R
Reserved	RSVD	0x72 and 0x73	NA	R	R
FETTest( )		0x74 and 0x75	NA	NA	RW
Reserved	RSVD	0x76 and 0x77	NA	R	R
Protector State	AFESTATE	0x78	hex	R	R
Reserved (4)	RSVD	0x79	NA	R	R
DODatEOC( ) (4)		0x7A and 0x7B	NA	R	R
QStart( ) (4)		0x7C and 0x7D	mA	R	R
FastQmax( ) (4)		0x7E and 0x7F	mAh	R	R
AN_COUNTER (5)		0x79			
AN_CURRENT_LSB (5)		0x7A			
AN_CURRENT_MSB (5)		0x7B			
AN_VCELL_LSB (5)		0x7C			
AN_VCELL_MSB (5)		0x7D			
AN_TEMP_LSB (5)		0x7E			
AN_TEMP_MSB (5)		0x7F			

(1) SEALED and UNSEALED states are entered via commands to *Control( )* 0x00 and 0x01
(2) In SEALED mode, data flash cannot be accessed through commands 0x3E and 0x3F.
(3) The *BlockData( )* command area shares functionality for accessing general data flash and for using Authentication. See *Authentication* in the bq27741-G1 TRM (SLUUAA3) for more details.
(4) If *CONTROL_STATUS [CALMODE]* bit = 0, then this address or command is valid.
(5) If *CONTROL_STATUS [CALMODE]* bit = 1, then this address or command is valid.

DATA FLASH SUMMARY

Table 7 through Table 13 summarize the data flash locations available to the user, including their default, minimum, and maximum values.

Table 7. Data Flash Summary—Configuration Class

SUBCLASS ID	SUBCLASS	NAME	OFFSET	DATA TYPE	VALUE			UNIT
					MIN	MAX	DEFAULT	
2	Safety	OT Chg	0	I2	0	1200	550	0.1°C
		OT Chg Time	2	U1	0	60	5	s
		OT Chg Recovery	3	I2	0	1200	500	0.1°C
		OT Dsg	5	I2	0	1200	600	0.1°C
		OT Dsg Time	7	U1	0	60	5	s
		OT Dsg Recovery	8	I2	0	1200	550	0.1°C
		OT Prot Threshold	10	I2	0	1200	600	0.1°C
		OT Prot Delay	12	U1	0	60	3	s
		OT Prot Recovery	13	I2	0	1200	550	0.1°C
34	Charge	Charge Voltage	0	I2	0	4600	4200	mV
36	Charge Termination	Taper Current	0	I2	0	1000	100	mA
		Min Taper Capacity	2	I2	0	1000	25	mAh
		Taper Voltage	4	I2	0	1000	100	mV
		Current Taper Window	6	U1	0	60	40	s
		TCA Set %	7	I1	–1%	100%	99%	
		TCA Clear %	8	I1	–1%	100%	95%	
		FC Set %	9	I1	–1%	100%	–1%	
		FC Clear %	10	I1	–1%	100%	98%	
		DODatEOC Delta T	11	I2	0	1000	50	0.1°C
48	Data	Initial Standby	8	I1	–256	0	–10	mA
		Initial MaxLoad	9	I2	–32767	0	–500	mA
		Cycle Count	17	U2	0	65535	0	Count
		CC Threshold	19	I2	100	32767	900	mAh
		Design Capacity	23	I2	0	32767	1000	mAh
		Design Energy	25	I2	0	32767	5400	mWh
		SOH Load I	27	I2	–32767	0	-400	mA
		TDD SOH Percent	29	I1	0%	100%	80%	
		ISD Current	40	I2	0	32767	10	Hour Rate
		ISD I Filter	42	U1	0	255	127	Count
		Min ISD Time	43	U1	0	255	7	Hour
		Design Energy Scale	44	U1	1	10	1	number
		Device Name	45	S11	x	x	bq27741-G1	

Table 7. Data Flash Summary—Configuration Class (continued)

SUBCLASS ID	SUBCLASS	NAME	OFFSET	DATA TYPE	VALUE			UNIT
					MIN	MAX	DEFAULT	
49	Discharge	SOC1 Set Threshold	0	U2	0	65535	150	mAh
		SOC1 Clear Threshold	2	U2	0	65535	175	mAh
		SOCF Set Threshold	4	U2	0	65535	75	mAh
		SOCF Clear Threshold	6	U2	0	65535	100	mAh
		BL Set Volt Threshold	9	I2	0	16800	2500	mV
		BL Set Volt Time	11	U1	0	60	2	s
		BL Clear Volt Threshold	12	I2	0	16800	2600	mV
		BH Set Volt Threshold	14	I2	0	16800	4500	mV
		BH Volt Time	16	U1	0	60	2	s
		BH Clear Volt Threshold	17	I2	0	16800	4400	mV
56	Manufacturer Data	Pack Lot Code	0	H2	0x0000	0xFFFF	0x0000	hex
		PCB Lot Code	2	H2	0x0000	0xFFFF	0x0000	hex
		Firmware Version	4	H2	0x0000	0xFFFF	0x0000	hex
		Hardware Revision	6	H2	0x0000	0xFFFF	0x0000	hex
		Cell Revision	8	H2	0x0000	0xFFFF	0x0000	hex
		DFI Config Version	10	H2	0x0000	0xFFFF	0x0000	hex
57	Integrity Data	All DF Checksum	6	H2	0x0000	0x7FFF	0x0000	hex
		Static Chem DF Checksum	8	H2	0x0000	0x7FFF	0x0000	hex
		Static DF Checksum	10	H2	0x0000	0x7FFF	0x0000	hex
59	Lifetime Data	Lifetime Max Temp	0	I2	0	1400	0	0.1°C
		Lifetime Min Temp	2	I2	–600	1400	500	0.1°C
		Lifetime Max Pack Voltage	4	I2	0	32767	2800	mV
		Lifetime Min Pack Voltage	6	I2	0	32767	4200	mV
		Lifetime Max Chg Current	8	I2	–32767	32767	0	mA
		Lifetime Max Dsg Current	10	I2	–32767	32767	0	mA
60	Lifetime Temp Samples	LT Flash Cnt	0	I2	0	32767	0	Count
		LT AFE Status	2	H1	0x00	0xFF	0x00	hex
64	Registers	Pack Configuration	0	H2	0x0000	0xFFFF	0x1171	flags
		Pack Configuration B	2	H1	0x00	0xFF	0xA7	flags
		Pack Configuration C	3	H1	0x00	0xFF	0x1C	flags
66	Lifetime Resolution	LT Temp Res	0	U1	0	255	10	°C
		LT V Res	1	U1	0	255	25	mV
		LT Cur Res	2	U1	0	255	100	mA
		LT Update Time	3	U2	0	65535	60	s
68	Power	Flash Update OK Voltage	0	I2	0	4200	2800	mV
		Sleep Current	2	I2	0	100	10	mA
		Shutdown V	11	I2	0	2600	0	mV
		FS Wait	13	U1	0	255	0	s

Table 8. Data Flash Summary—System Data Class

SUBCLASS ID	SUBCLASS	NAME	OFFSET	DATA TYPE	VALUE			UNIT
					MIN	MAX	DEFAULT	
58	Manufacturer Info	Block A [0 through 31]	0 through 31	H1	0x00	0xFF	0x00	hex
		Block B [0 through 31]	32 through 63	H1	0x00	0xFF	0x00	hex

Table 9. Data Flash Summary—Gas Gauging Class

SUBCLASS ID	SUBCLASS	NAME	OFFSET	DATA TYPE	VALUE			UNIT
					MIN	MAX	DEFAULT	
80	IT Cfg	Load Select	0	U1	0	255	1	number
		Load Mode	1	U1	0	255	0	number
		Max Res Factor	21	U1	0	255	15	number
		Min Res Factor	22	U1	0	255	5	number
		Ra Filter	25	U2	0	1000	800	number
		Fast Qmax Start DOD %	42	U1	0%	255%	92%	
		Fast Qmax End DOD %	43	U1	0%	255%	96%	
		Fast Qmax Start Volt Delta	44	I2	0	4200	200	mV
		Fast Qmax Current Threshold	46	I2	0	1000	4	C/rate
		Qmax Capacity Err	64	U1	0	100	15	0.10%
		Max Qmax Change	65	U1	0%	255%	30%	
		Terminate Voltage	67	I2	2800	3700	3000	mV
		Term V Delta	69	I2	0	4200	200	mV
		ResRelax Time	72	U2	0	65534	500	s
		User Rate-Pwr	78	I2	3000	14000	0	cW
		Reserve Cap-mAh	80	I2	0	9000	0	mAh
		Reserve Energy	82	I2	0	14000	0	cWh
		Max DeltaV	87	U2	0	65535	200	mV
		Min DeltaV	89	U2	0	65535	0	mV
		Max Sim Rate	91	U1	0	255	1	C/rate
		Min Sim Rate	92	U1	0	255	20	C/rate
		Ra Max Delta	93	U2	0	65535	43	mΩ
		Qmax Max Delta %	95	U1	0%	100%	5%	
		Qmax Bound %	96	U1	0%	255%	130%	
		DeltaV Max Delta	97	U2	0	65535	10	mV
		Max Res Scale	99	U2	0	32767	5000	number
		Min Res Scale	101	U2	0	32767	200	number
		Fast Scale Start SOC	103	U1	0%	100%	10%	
		Charge Hys V Shift	104	I2	0	2000	40	mV
81	Current Thresholds	Dsg Detection Threshold	0	I2	0	2000	60	mA
		Chg Detection Threshold	2	I2	0	2000	75	mA
		Quit Current	4	I2	0	1000	40	mA
		Dsg Relax Time	6	U2	0	8191	60	s
		Chg Relax Time	8	U1	0	255	60	s
		Quit Relax Time	9	U1	0	63	1	s
		Max IR Correct	10	U2	0	1000	400	mV

Table 9. Data Flash Summary—Gas Gauging Class (continued)

SUBCLASS ID	SUBCLASS	NAME	OFFSET	DATA TYPE	VALUE			UNIT
					MIN	MAX	DEFAULT	
82	State	Qmax Cell 0	0	I2	0	32767	1000	mAh
		Update Status	2	H1	0x0	0x6	0x0	hex
		V at Chg Term	3	I2	0	5000	4200	mV
		Avg I Last Run	5	I2	–32768	32767	–299	mA
		Avg P Last Run	7	I2	–32768	32767	–1131	Power (mA)
		Delta Voltage	9	I2	–32768	32767	2	mV
		T Rise	13	I2	0	32767	20	number
		T Time Constant	15	I2	0	32767	1000	number

Table 10. Data Flash Summary—OCV Table Class

SUBCLASS ID	SUBCLASS	NAME	OFFSET	DATA TYPE	VALUE			UNIT
					MIN	MAX	DEFAULT	
83	OCVa Table	Chem ID	0	H2	0x0000	0xFFFF	0x128	flags

Table 11. Data Flash Summary—Ra Table Class

SUBCLASS ID	SUBCLASS	NAME	OFFSET	DATA TYPE	VALUE			UNIT
					MIN	MAX	DEFAULT	
88	R_a0	Cell0 R_a flag	0	H2	0x0000	0x0000	0xFF55	hex
		Cell0 R_a 0	2	I2	183	183	407	2^{-10} Ω
		Cell0 R_a 1	4	I2	181	181	407	2^{-10} Ω
		Cell0 R_a 2	6	I2	198	198	396	2^{-10} Ω
		Cell0 R_a 3	8	I2	244	244	429	2^{-10} Ω
		Cell0 R_a 4	10	I2	254	254	287	2^{-10} Ω
		Cell0 R_a 5	12	I2	261	261	236	2^{-10} Ω
		Cell0 R_a 6	14	I2	333	333	249	2^{-10} Ω
		Cell0 R_a 7	16	I2	338	338	252	2^{-10} Ω
		Cell0 R_a 8	18	I2	345	345	211	2^{-10} Ω
		Cell0 R_a 9	20	I2	350	350	189	2^{-10} Ω
		Cell0 R_a 10	22	I2	382	382	238	2^{-10} Ω
		Cell0 R_a 11	24	I2	429	429	281	2^{-10} Ω
		Cell0 R_a 12	26	I2	502	502	560	2^{-10} Ω
		Cell0 R_a 13	28	I2	545	545	1475	2^{-10} Ω
		Cell0 R_a 14	30	I2	366	366	2350	2^{-10} Ω

Table 11. Data Flash Summary—Ra Table Class (continued)

SUBCLASS ID	SUBCLASS	NAME	OFFSET	DATA TYPE	VALUE			UNIT
					MIN	MAX	DEFAULT	
89	R_a0x	xCell0 R_a flag	0	H2	0xFFFF	0xFFFF	0xFFFF	hex
		xCell0 R_a 0	2	I2	183	183	407	2^{-10} Ω
		xCell0 R_a 1	4	I2	181	181	407	2^{-10} Ω
		xCell0 R_a 2	6	I2	198	198	396	2^{-10} Ω
		xCell0 R_a 3	8	I2	244	244	429	2^{-10} Ω
		xCell0 R_a 4	10	I2	254	254	287	2^{-10} Ω
		xCell0 R_a 5	12	I2	261	261	236	2^{-10} Ω
		xCell0 R_a 6	14	I2	333	333	249	2^{-10} Ω
		xCell0 R_a 7	16	I2	338	338	252	2^{-10} Ω
		xCell0 R_a 8	18	I2	345	345	211	2^{-10} Ω
		xCell0 R_a 9	20	I2	350	350	189	2^{-10} Ω
		xCell0 R_a 10	22	I2	382	382	238	2^{-10} Ω
		xCell0 R_a 11	24	I2	429	429	281	2^{-10} Ω
		xCell0 R_a 12	26	I2	502	502	560	2^{-10} Ω
		xCell0 R_a 13	28	I2	545	545	1475	2^{-10} Ω
		xCell0 R_a 14	30	I2	366	366	2350	2^{-10} Ω

Table 12. Data Flash Summary—Calibration

SUBCLASS ID	SUBCLASS	NAME	OFFSET	DATA TYPE	VALUE			UNIT
					MIN	MAX	DEFAULT	
104	Data	CC Gain	0	F4	0.100	40.00	0.9536	mΩ
		CC Delta	4	F4	29800	1190000	1119000	mΩ
		CC Offset	8	I2	–32768	32767	–1500	mA
		Board Offset	10	I1	–128	127	0	µA
		Int Temp Offset	11	I1	–128	127	0	°C
		Ext Temp Offset	12	I1	–128	127	0	°C
		Pack V Offset	13	I1	–128	127	0	mV
		ADC I Offset	14	I1	–128	127	0	mA
107	Current	Filter	0	U1	0	255	239	number
		Deadband	1	U1	0	255	5	mA

Table 13. Data Flash Summary—Security

SUBCLASS ID	SUBCLASS	NAME	OFFSET	DATA TYPE	VALUE			UNIT
					MIN	MAX	DEFAULT	
112	Codes	Sealed to Unsealed	0	H4	0x0000 0000	0xFFFF FFFF	0x3672 0414	hex
		Unsealed to Full	4	H4	0x0000 0000	0xFFFF FFFF	0xFFFF FFFF	hex
		Authen Key3	8	H4	0x0000 0000	0xFFFF FFFF	0x0123 4567	hex
		Authen Key2	12	H4	0x0000 0000	0xFFFF FFFF	0x89AB CDEF	hex
		Authen Key1	16	H4	0x0000 0000	0xFFFF FFFF	0xFEDC BA98	hex
		Authen Key0	20	H4	0x0000 0000	0xFFFF FFFF	0x7654 3210	hex

Table 14. Data Flash to EVSW Conversion

Class	SubClass ID	SubClass	Offset	Name	Data Type	Data Flash Default	Data Flash Unit	EVSW Default	EVSW Unit	Data Flash to EVSW Conversion
Gas Gauging	80	IT Cfg	78	User Rate-Pwr	I2	0	cW/10W	0	mW/cW	DF × 10
			82	Reserve Energy	I2	0	cWh/10cWh	0	mWh/cW	DF × 10
Calibration	104	Data	0	CC Gain	F4	0.47095	number	10.124	mΩ	4.768/DF
			4	CC Delta	F4	5.595e5	number	10.147	mΩ	5677445/DF
			8	CC Offset	I2	–1200	number	–0.576	mV	DF × 0.0048
			10	Board Offset	I1	0	number	0	µV	DF × 0.0075

Table 15. ORDERING INFORMATION

PRODUCTION PART NO.(1)	FIRMWARE VERSION	PACKAGE(2)	T_A	COMMUNICATION FORMAT	TAPE and REEL QUANTITY
bq27741YZFR-G1	1.08	CSP-15	–40°C to 85°C	I^2C, HDQ(1)	3000
bq27741YZFT-G1					250

(1) bq27741-G1 is shipped in the I^2C mode.
(2) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI website at www.ti.com.

APPLICATION INFORMATION

Reference Schematics

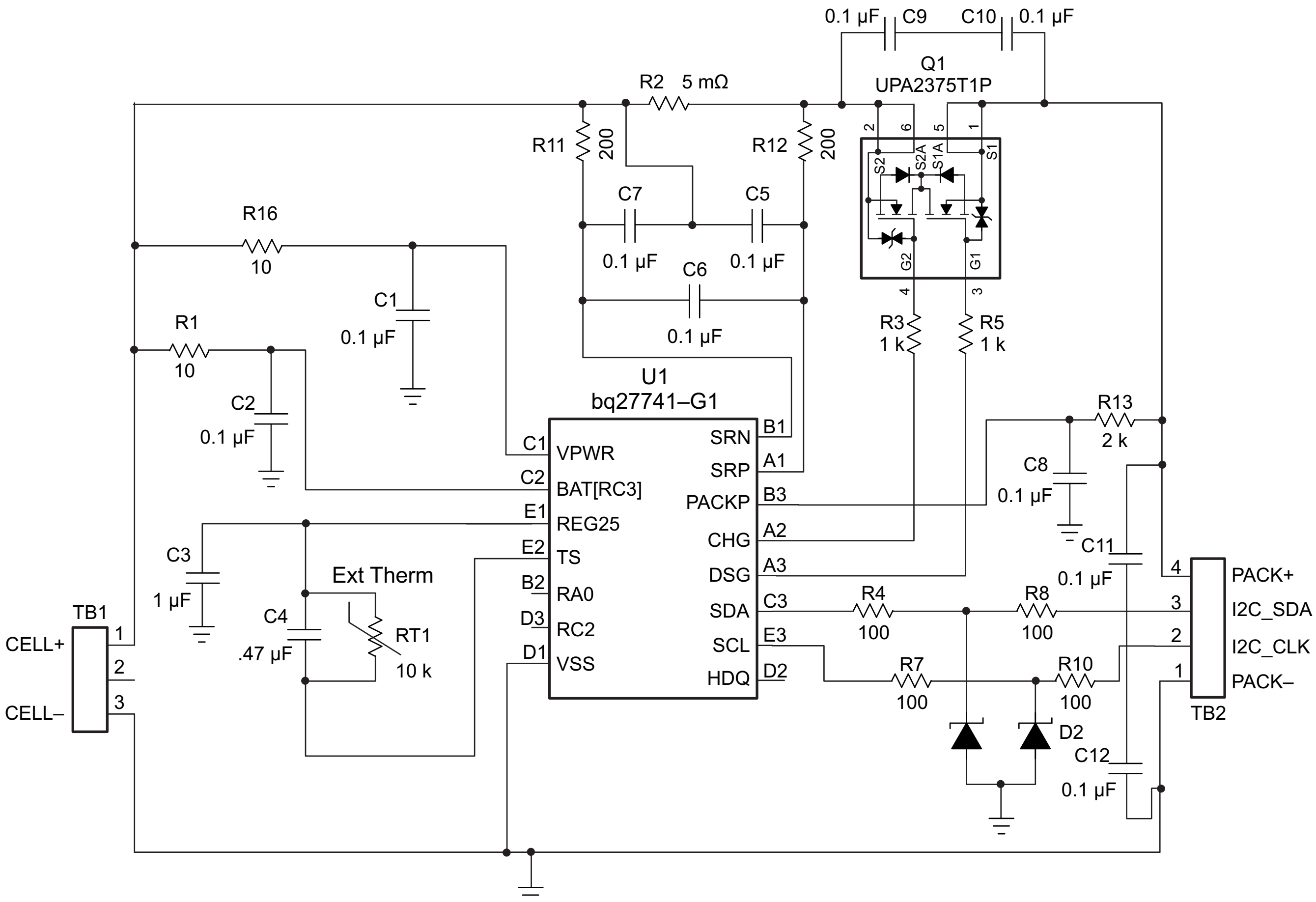


Figure 5. I²C Mode

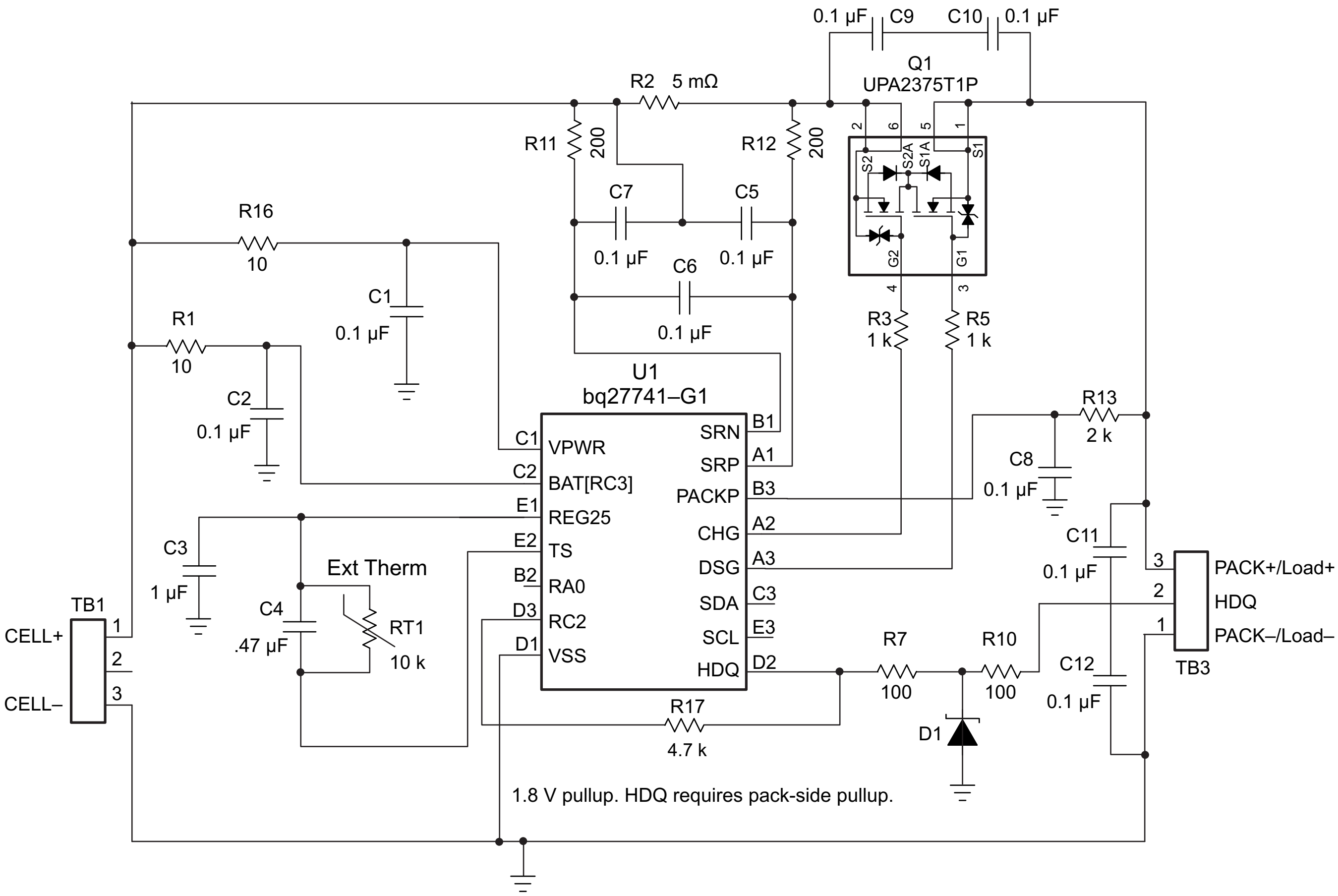
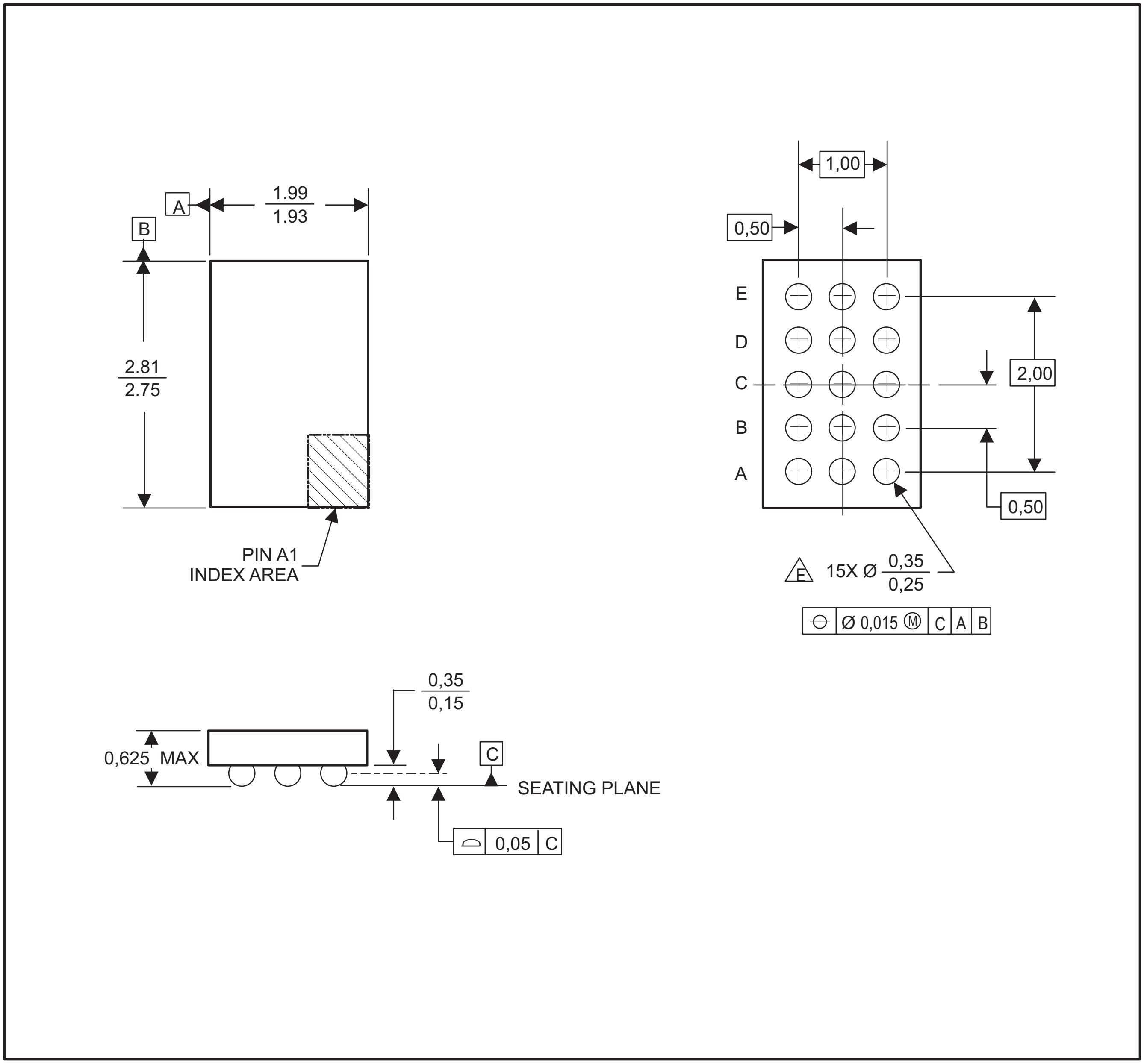


Figure 6. HDQ Mode

MECHANICAL DATA

Package Information

YZF (R–XBGA–N15) DIE–SIZE BALL GRID ARRAY



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. NanoFree™ package configuration.

Figure 7. Mechanical Package

Package Dimensions

The dimensions for the YZF package are shown in Table 16.

Table 16. YZF Package Dimension

PACKAGED DEVICES	D	E
BQ27741YZFR-G1	2.776 ± 0.030 mm	1.956 ± 0.030 mm

Related Documentation from Texas Instruments

To obtain a copy of any of the following TI documents, call the Texas Instruments Literature Response Center at (800) 477-8924 or the Product Information Center (PIC) at (972) 644-5580. When ordering, identify this document by its title and literature number. Updated documents also can be obtained through the TI Web site at www.ti.com.

1. *bq27741-G1, Pack-Side Impedance Track™ Battery Fuel Gauge With Integrated Protector and LDO* User's Guide (SLUUAA3)
2. *bq27741EVM Single Cell Impedance Track™ Technology Evaluation Module* User's Guide (SLUUAH1)

REVISION HISTORY

Changes from Original (July 2013) to Revision A **Page**

- Changed the FIRMWARE VERSION From 1.07 To 1.08 in Table 15 28

GLOSSARY

ACK	Acknowledge character
ADC	Analog-to-digital converter
BCA	Board calibration
CC	Coulomb counter
CCA	Coulomb counter calibration
CE	Chip enable
cWh	Centiwatt-hour
DF	Data flash
DOD	Depth of discharge in percent as related to Qmax. 100% corresponds to empty battery.
DOD0	Depth of discharge that was looked up in the DOD (OCV) table based on OCV measurement in relaxed state.
EOC	End of charge
FC	Fully charged
FCC	Full charge capacity. Total capacity of the battery compensated for present load current, temperature, and aging effects (reduction in chemical capacity and increase in internal impedance).
FIFO	First in, first out
FVCA	Fast voltage and current acquisition
GPIO	General-purpose input output
HDQ	High-speed data queue
IC	Integrated circuit
ID	Identification
IO	Input or output
IT	Impedance Track™
I^2C	Inter-integrated circuit
LDO	Low dropout
LSB	Least significant bit
LT	Lifetime
MAC	Manufacturer access command or control command
mAh	Milliamp-hour
MSB	Most significant bit
mWh	Milliwatt-hour
NACK	Negative acknowledge character
NTC	Negative temperature coefficient
OCV	Open-circuit voltage. Voltage measured on fully-relaxed battery with no load applied.
OTC	Overtemperature in charge
OTD	Overtemperature in discharge
Qmax	Maximum chemical capacity
RM	Remaining capacity
RW	Read or write
SCL	Serial clock: programmable serial clock used in the I^2C interface
SDA	Serial data: serial data bus in the I^2C interface
SE	Shutdown enable
SOC	State-of-charge in percent related to FCC
SOC1	State-of-charge initial
SOCF	State-of-charge final
TCA	Terminate charge alarm
TS	Temperature status
TTE	Time-to-empty
TTF	Time-to-full

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
BQ27741YZFR-G1	ACTIVE	DSBGA	YZF	15	3000	Green (RoHS & no Sb/Br)	SNAGCU	Level-1-260C-UNLIM	-40 to 85	BQ27741-G1	Samples
BQ27741YZFT-G1	ACTIVE	DSBGA	YZF	15	250	Green (RoHS & no Sb/Br)	SNAGCU	Level-1-260C-UNLIM	-40 to 85	BQ27741-G1	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.

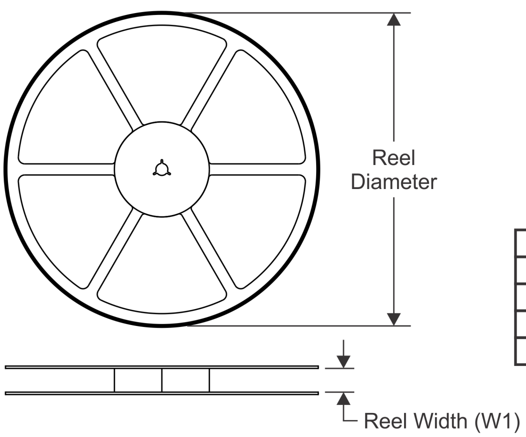
(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

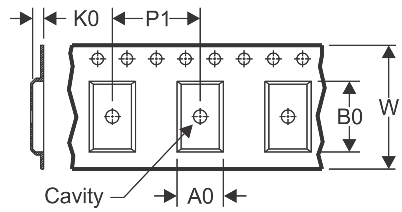
(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

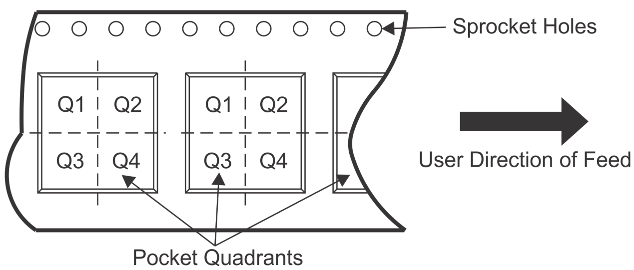
TAPE AND REEL INFORMATION





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

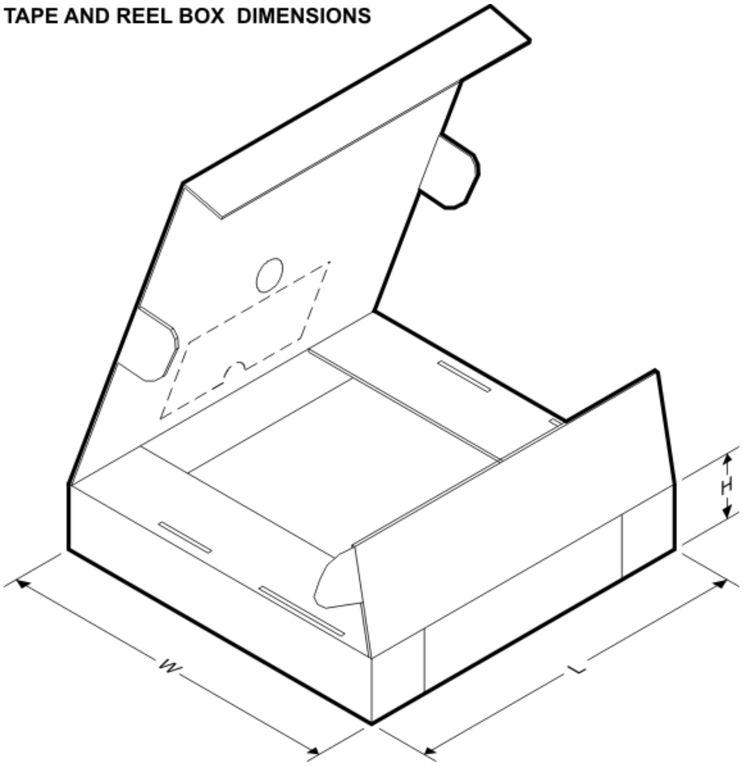
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
BQ27741YZFR-G1	DSBGA	YZF	15	3000	180.0	8.4	2.06	2.88	0.69	4.0	8.0	Q1

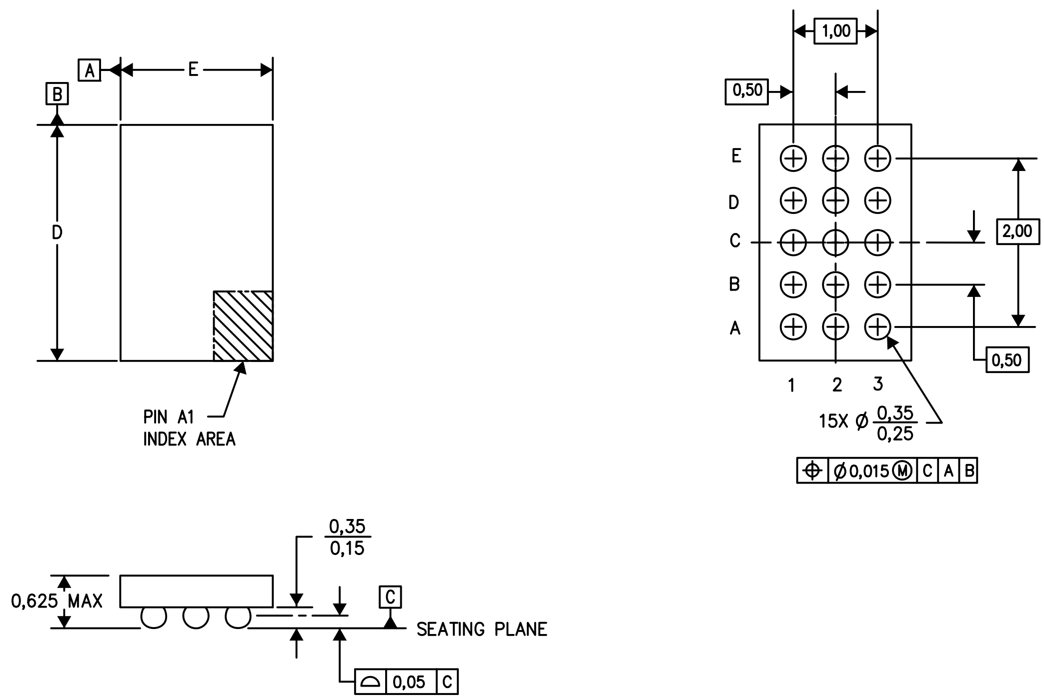
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
BQ27741YZFR-G1	DSBGA	YZF	15	3000	182.0	182.0	17.0

YZF (R-XBGA-N15) DIE-SIZE BALL GRID ARRAY



4205058-5/P 07/13

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. NanoFree™ package configuration.

NanoFree is a trademark of Texas Instruments.

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as “components”) are sold subject to TI’s terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI’s terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers’ products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers’ products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI’s goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or “enhanced plastic” are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have ***not*** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

Products		**Applications**	
Audio	www.ti.com/audio	Automotive and Transportation	www.ti.com/automotive
Amplifiers	amplifier.ti.com	Communications and Telecom	www.ti.com/communications
Data Converters	dataconverter.ti.com	Computers and Peripherals	www.ti.com/computers
DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps
DSP	dsp.ti.com	Energy and Lighting	www.ti.com/energy
Clocks and Timers	www.ti.com/clocks	Industrial	www.ti.com/industrial
Interface	interface.ti.com	Medical	www.ti.com/medical
Logic	logic.ti.com	Security	www.ti.com/security
Power Mgmt	power.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Applications Processors	www.ti.com/omap	**TI E2E Community**	e2e.ti.com
Wireless Connectivity	www.ti.com/wirelessconnectivity		

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265