BQ27Z846 Dynamic Z-Track™ Gauge with Integrated Protection and Authentication for 1 Cell Battery Packs

1 Features

- Fully integrated battery gas gauge, protector, and authenticator
- Battery chemistries supported include Li-ion with LCO, NMC, or LFP cathodes and with graphite or silicon anodes
- Battery fuel gauging based on patented Dynamic Z-Track™ technology
  - Models battery impedance for accurate time-to-empty predictions for static and dynamic loads
  - Automatically adjusts for aging, temperature, and rate-induced effects on the battery
- High-accuracy analog front end with two independent ADCs:
  - 18-bit low offset, high resolution delta-sigma ADC for coulomb counting with ±100mV input range
  - 16-bit delta-sigma ADC for cell voltage and internal and external temperature sensors
- High-side or low-side current sensing for system flexibility
- Programmable safety and protection:
  - Hardware-level OVP, UVP, OCC, OCD, SCD protections
  - Firmware-level OVP, UVP, OCC, OCD, UT, OT, FETF, CTO, PCHGC, and more...
- Integrated high efficiency high-side NMOS protection FET drivers
- Up to 1MHz I^2C bus communications interface with 1.2V- and 1.8V-level support
- ECC ECDSA and SHA-256 authentication support with secure memory
- Wake from push-button or charger detect
- True zero-volt charging to support dead battery charging
- Ultra-compact, 15-ball DSBGA package (YAH)

2 Applications

- Any end equipment with 1-series rechargeable batteries:
  - Smartphones
  - Tablets
  - VR headsets
  - Personal electronics
  - Hearables
  - Portable wearables/medical

3 Description

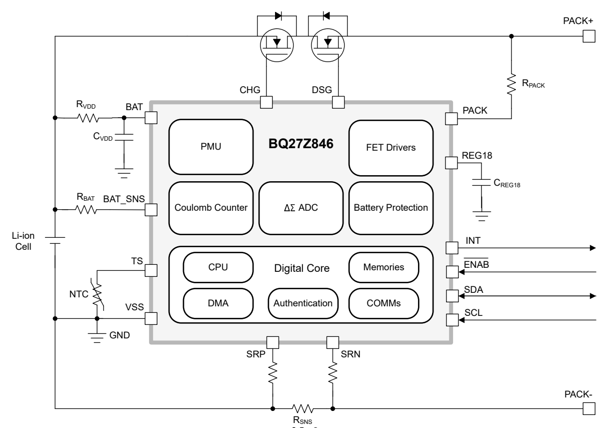
The Texas Instruments BQ27Z846 Dynamic Z-Track™ gas gauge device is a fully integrated and accurate,1-series cell gas gauge, protection, and authentication option.

The BQ27Z846 gas gauge communicates through an I^2C compatible interface and combines an ultra-low power RISC processor, high accuracy analog measurement capabilities, integrated flash memory, high-side NMOS FET drivers, and ECC ECDSA and SHA-2 authentication to provide a complete, high-performance battery management option.

Package Information

PART NUMBER	PACKAGE(1)	PACKAGE SIZE(2)
BQ27Z846	DSBGA (YAH, 15)	1.51mm × 2.55mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.
(2) The package size (length × width) is a nominal value and includes pins, where applicable.



BQ27Z846 Simplified Schematic

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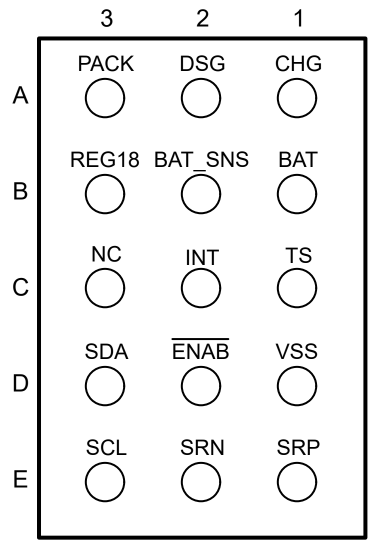
4 Pin Configurations and Functions

Bottom View



Top View

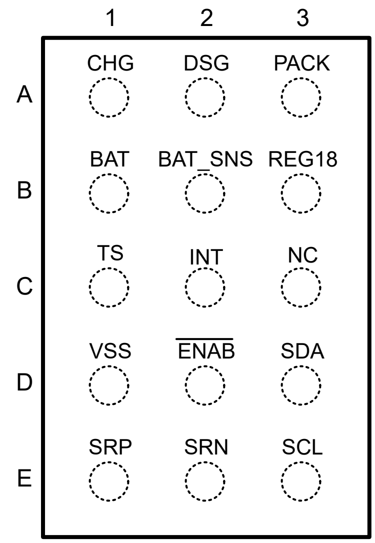


Table 4-1. Pin Functions

PIN			DESCRIPTION
NAME	NO.	TYPE[(1)]	
CHG	A1	AO	High-side NMOS charge FET driver output
DSG	A2	AO	High-side NMOS discharge FET driver output
PACK	A3	AI	Pack input voltage sensing pin and path for zero-volt charge (ZVCHG) current to flow within the device from PACK to BAT. Connect a series 1kΩ typical resistor (R_{PACK}) between the PACK pin and PACK+ battery pack terminal.
BAT	B1	P	LDO regulator input. Connect a capacitor (C_{BAT}) with the recommended typical capacitance of 1µF between BAT and VSS. Place the capacitor close to the gauge.
BAT_SNS	B2	AI	Battery voltage measurement sense input
REG18	B3	P	Internal regulator output. Requires a capacitor (C_{REG18}) with the recommended typical capacitance of 1.5µF connected between REG18 and VSS. Place the capacitor close to the gauge.
TS	C1	AI	Thermistor input to VADC with internal 18kΩ pull-up resistor. If not used, connect directly to VSS or leave floating and configure data flash accordingly.
INT	C2	I/O	Programmable output interrupt to host. Can also be configured as a programmable push-pull GPIO via device firmware. If not used, leave floating and configure data flash accordingly.
NC	C3	-	No Connect. Can be left floating or connected to VSS.
VSS	D1	P	Device ground
$\overline{\text{ENAB}}$	D2	I	Active low digital input with weak internal pull-up to BAT. Driving this signal to the PACK- battery pack terminal while the device is in a SHELF or SHUTDOWN mode will enable the device to wake up.
SDA	D3	I/O	Digital input, open drain output for I^2C serial data
SRP	E1	AI	Analog input pin connected to the internal Coulomb counter for integrating a small voltage between SRP and SRN, where SRP is the top of the sense resistor. A charging current generates a positive voltage at SRP relative to SRN.
SRN	E2	AI	Analog input pin connected to the internal Coulomb counter for integrating a small voltage between SRP and SRN, where SRN is the bottom of the sense resistor. A charging current generates a positive voltage at SRP relative to SRN.
SCL	E3	I/O	Digital input, open drain output for I^2C serial clock

(1) I/O = Digital Input/Output, AI = Analog Input, AO= Analog Output, P = Power

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5 Specifications

5.1 Absolute Maximum Ratings

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

		MIN	MAX	UNIT
Supply voltage range, V_{CC}	BAT	-0.3	6	V
Input voltage range, V_{IN}	BAT	-0.3	6	V
	BAT_SNS	-0.3	6	
	PACK (no R_{PACK})	-0.3	7	
	PACK+ external battery pack input terminal with 1kΩ resistor in series to device PACK input pin	-0.3	24	
	$\overline{ENAB}$	-0.3	6	
	SDA, SCL	-0.3	6	
	INT, TS	-0.3	6	
	SRP, SRN	-0.3	V_{BAT} + 0.3	
Output voltage range, V_{OUT}	CHG, DSG	-0.3	8.5	V
Output voltage range, V_{REG18}	REG18	-0.3	2	V
Junction temperature, T_J			105	°C
Storage temperature, T_{stg}		-65	150	°C

(1) Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under Recommended Operating Conditions. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

5.2 ESD Ratings

			VALUE	UNIT
V_{ESD}	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001(1)	±1500	V
		Charged device model (CDM), per ANSI/ESDA/JEDEC JS-002(2)	±500	

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

5.3 Recommended Operating Conditions

Typical values stated where T_A = 25℃ and V_{BAT} = 3.8V, MIN/MAX values stated where T_A = -40℃ to 85℃ and V_{BAT} = 2.0V to 5.0V (unless otherwise noted)

		TEST CONDITIONS	MIN	NOM	MAX	UNIT
V_{CC}	Supply voltage range	BAT	2.0		5.5	V
V_{IN}	Input voltage range	BAT_SNS	1.5		5.5	V
		PACK (with 1kΩ R_{PACK} current limit)	0		6	
		PACK (no R_{PACK} current limit)	0		5.5	
		$\overline{ENAB}$	-0.3		BAT	
		SDA, SCL	-0.2		3.6	
		TS	V_{SS}		V_{REG18}	
		SRP, SRN	V_{CCADC_CM} - 0.1		V_{CCADC_CM} + 0.1	

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Typical values stated where T_A = 25°C and V_{BAT} = 3.8V, MIN/MAX values stated where T_A = -40°C to 85°C and V_{BAT} = 2.0V to 5.0V (unless otherwise noted)

		TEST CONDITIONS	MIN	NOM	MAX	UNIT
V_{OUT}	Output voltage range	INT	0		V_{REG18}	V
		CHG, DSG	V_{SS}		$V_{FET\_ON(MAX)}$	
C_{BAT} (1)	External decoupling capacitor on BAT pin	Derated capacitance	0.5	1		µF
C_{REG18} (1)	External decoupling capacitor on REG18 pin	Derated capacitance	1	1.5		µF
C_{TS} (1)	External decoupling capacitor on TS pin	Derated capacitance			0.01	µF
R_{PACK} (1)	External resistor from PACK+ terminal to device PACK pin	Nominal resistance, ±5% tolerance	1			kΩ
R_{SENSE} (1)	External sense resistor from SRN to SRP pins		0.5			mΩ
T_A	Operating temperature	Operating ambient temperature	-40		85	°C

(1) Specified by Design. Not production tested.

5.4 Supply Current

Typical values stated where T_A = 25°C and V_{BAT} = 3.8V, MIN/MAX values stated where T_A = -40°C to 85°C and V_{BAT} = 2.0V to 5.0V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_{ACTIVE} (1) (2)	ACTIVE mode	V_{BAT} = 4V, CHG ON, DSG ON, No I^2C communication		36		µA
I_{SLEEP} (1) (2)	SLEEP mode	Measured Current ≤ ***Sleep Current*** (3), V_{BAT} = 4V, CHG ON, DSG ON, No I^2C communication		17		µA
I_{DEEP_SLEEP} (1) (2)	DEEP SLEEP mode	Measured Current ≤ ***Deep Sleep Current*** (3), V_{BAT} = 4V, CHG ON, DSG ON, No I^2C communication		10		µA
I_{SHELF1} (1) (2)	SHELF1 mode	SHELF1 mode enabled, V_{BAT} = 4V, CHG OFF, DSG OFF		4		µA
I_{SHELF2} (1) (2)	SHELF2 mode	SHELF2 mode enabled, V_{BAT} = 4V, CHG OFF, DSG OFF, LFO ON for timekeeping, Wakeup via PACK detection and $\overline{ENAB}$ pin enabled		2		µA
$I_{SHUTDOWN}$ (1)	SHUTDOWN mode	SHUTDOWN mode enabled or V_{BAT} < ***Shutdown Voltage*** (3), Wakeup via PACK detection and $\overline{ENAB}$ pin enabled		0.2		µA

(1) Specified by Bench Evaluation with device firmware. Not production tested.
(2) Average current over 60s with default firmware settings. Device power consumption dependent on firmware configuration and version.
(3) Firmware-based parameter. The data flash configuration value can be changed in FULL ACCESS mode and is locked in SEALED mode. Refer to the BQ27Z846 Technical Reference Manual.

5.5 1.8V LDO Regulator (REG18)

Typical values stated where T_A = 25°C and V_{BAT} = 3.8V, MIN/MAX values stated where T_A = -40°C to 85°C and V_{BAT} = 2.0V to 5.0V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{REG18}	Regulator output voltage	During device power-up	1.6	1.8	2.0	V
		After device power-up	1.74	1.8	1.86	
$\Delta V_{REG18TEMP}$ (2)	Regulator output change with temperature, $\Delta V_{REG18}/V_{REG18}$	I_{REG18} = 1mA	-1.7		1.1	%

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Typical values stated where T_A = 25°C and V_{BAT} = 3.8V, MIN/MAX values stated where T_A = -40°C to 85°C and V_{BAT} = 2.0V to 5.0V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$\Delta V_{REG18LINE}$	Line regulation, $\Delta V_{REG18}/\Delta V_{BAT}$	I_{REG18} = 1mA	-0.25		0.25	%
I_{REG18_SHORT}	Short circuit current limit	V_{REG18} = 0V	16		65	mA
V_{POR_TH}	POR threshold	Rising threshold	1.55	1.75	1.90	V
V_{POR_HYS}	Falling POR hysteresis	After trim is loaded		90		mV
V_{ENAB} (1)	$\overline{ENAB}$ pin voltage for device wake-up from SHELF1, SHELF2, or SHUTDOWN mode	Active low falling threshold			0.65	V
R_{ENAB} (1)	$\overline{ENAB}$ pin pull-up resistance			1		MΩ
V_{WAKEUP} (1)	Minimum PACK pin voltage for device wake-up from SHELF1, SHELF2, or SHUTDOWN mode			2.0		V

(1) Specified by Design. Not production tested.
(2) Specified by Characterization. Not production tested.

5.6 Low Frequency Oscillator (LFO)

Typical values stated where T_A = 25°C and V_{BAT} = 3.8V, MIN/MAX values stated where T_A = -40°C to 85°C and V_{BAT} = 2.0V to 5.0V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
F_{LFO}	Operating frequency			65.536		kHz
F_{LFO_DRIFT} (1) (2)	Frequency drift		-2.5		2.5	%

(1) Specified by Characterization. Not production tested.
(2) The frequency drift is included and measured from the trimmed frequency at T_A = 25°C, with the minimum and maximum based on Characterization, actual value stored in OTP

5.7 High Frequency Oscillator (HFO)

Typical values stated where T_A = 25°C and V_{BAT} = 3.8V, MIN/MAX values stated where T_A = -40°C to 85°C and V_{BAT} = 2.0V to 5.0V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
F_{HFO}	Operating frequency			16.384		MHz
F_{HFO_DRIFT} (1) (2)	Frequency drift	T_A = -25°C to 65°C	-2		2	%
		T_A = -40°C to 85°C	-3.5		3.5	

(1) Specified by Characterization. Not production tested.
(2) The frequency drift is included and measured from the trimmed frequency at T_A = 25°C, with the minimum and maximum based on Characterization, actual value stored in OTP

5.8 PACK Clamp (PACK_CLAMP)

Typical values stated where T_A = 25°C and V_{BAT} = 3.8V, MIN/MAX values stated where T_A = -40°C to 85°C and V_{BAT} = 2.0V to 5.0V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{PACK_CLAMP}	Rising voltage on PACK when clamp is active	I_{PACK_CLAMP} < 1mA, R_{PACK} = 1kΩ	5.5		7	V
$I_{PACK\_CLAMP\_PEAK}$ (2)	Peak clamp current when clamp fully active	For a time < 2.5ms, R_{PACK} = 1kΩ			22	mA
$I_{PACK\_CLAMP\_ON}$ (1)	Clamp current when clamp fully active	R_{PACK} = 1kΩ		18	19	mA

(1) Specified by Characterization. Not production tested.

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(2) Specified by Bench Evaluation. Not production tested.

5.9 Analog-to-Digital Converter (VADC)

Typical values stated where T_A = 25℃ and V_{BAT} = 3.8V, MIN/MAX values stated where T_A = -40℃ to 85℃ and V_{BAT} = 2.0V to 5.0V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{BAT_FS}	Battery voltage measurement full scale range	V_{IN} = V_{BAT}	-0.2		5.5	V
V_{BAT_ERR}	Battery voltage measurement error	V_{IN} = V_{BAT}, T_A = 25℃, V_{BAT} = 2.5 to 5.0V, Post-Calibration	-4	±2	4	mV
V_{TS_FS}	External thermistor voltage measurement full scale range	V_{IN} = V_{TS}	-0.2		V_{REG18}	V
t_{ADC_CONV} [3]	Conversion time	Single conversion		11.72		ms
B_{ADC_ER} [1] [2]	Effective resolution	Single conversion	14	15		bits

(1) Specified by Characterization. Not production tested.
(2) Effective Resolution is defined as the resolution such that the data exhibits 1-sigma variation within ±1 LSB.
(3) Timing accuracy is relative to F_{LFO} accuracy

5.10 Coulomb Counter (CCADC)

Typical values stated where T_A = 25℃ and V_{BAT} = 3.8V, MIN/MAX values stated where T_A = -40℃ to 85℃ and V_{BAT} = 2.0V to 5.0V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{CCADC_IN} [3]	Input voltage range		-100		100	mV
V_{CCADC_CM}	Common mode voltage range	V_{SS} = 0V, 2V ≤ V_{BAT} ≤ 5V	V_{SS}		V_{BAT}	V
V_{CCADC_IN}	Input voltage range with common mode voltage range		V_{CCADC_CM} - 0.1		V_{CCADC_CM} + 0.1	V
V_{CCADC_OFF} [2]	Offset error	18-bit, T_A = 25℃, Post-Calibration	-2		2	LSB[3]
R_{CCADC_IN} [1]	Effective input resistance			1.5		MΩ

(1) Specified by Design. Not production tested.
(2) Specified by Characterization. Not production tested.
(3) The LSB size for an 18-bit, 1000ms CCADC result is 923nV

5.11 Coulomb Counter Digital Filter (CC1)

Typical values stated where T_A = 25℃ and V_{BAT} = 3.8V, MIN/MAX values stated where T_A = -40℃ to 85℃ and V_{BAT} = 2.0V to 5.0V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_{CC1_CONV} [4]	Conversion time	Single conversion		1000		ms
B_{CC1_ER} [1] [2] [3]	Effective resolution	Single conversion		18		bits

(1) Specified by Characterization. Not production tested
(2) Effective Resolution is defined as the resolution such that the data exhibits 1-sigma variation within ±1-LSB.
(3) Input signal DC = ±1mV, Harmonic Free Full Scale
(4) Timing accuracy is relative to F_{LFO} accuracy

5.12 Current Measurement Digital Filter (CC2)

Typical values stated where T_A = 25℃ and V_{BAT} = 3.8V, MIN/MAX values stated where T_A = -40℃ to 85℃ and V_{BAT} = 2.0V to 5.0V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_{CC2_CONV} [4]	Conversion time	Single conversion		11.72		ms

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Typical values stated where T_A = 25°C and V_{BAT} = 3.8V, MIN/MAX values stated where T_A = -40°C to 85°C and V_{BAT} = 2.0V to 5.0V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
B_{CC2_ER} (1) (2) (3)	Effective resolution	Single conversion	14	15		bits

(1) Specified by Characterization. Not production tested
(2) Effective Resolution is defined as the resolution such that the data exhibits 1-sigma variation within ±1-LSB.
(3) Input signal DC = ±1mV, Harmonic Free Full Scale
(4) Timing accuracy is relative to F_{LFO} accuracy

5.13 Wake-up Comparator (I-WAKE)

Typical values stated where T_A = 25°C and V_{BAT} = 3.8V, MIN/MAX values stated where T_A = -40°C to 85°C and V_{BAT} = 2.0V to 5.0V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{WAKE_THR} (1) (3)	Wake-up voltage threshold range	Nominal settings, threshold based on $V_{SRP} – V_{SRN}$, 0.5mV steps, typical value is default threshold	-7.5	±4.5	7.5	mV
$V_{WAKE\_THR\_ERR}$ (2)	Wake-up voltage threshold error	All V_{WAKE_THR} settings, $V_{WAKE} = V_{SRP} – V_{SRN}$	–250		250	µV

(1) Specified by Design. Not production tested.
(2) Specified by Characterization. Not production tested.
(3) Specified typical value is the factory default setting. The setting in data flash can be changed in FULL ACCESS mode and is locked in SEALED mode. Refer to the BQ27Z846 Technical Reference Manual.

5.14 Internal Temperature Sensor (INT_TEMP)

Typical values stated where T_A = 25°C and V_{BAT} = 3.8V, MIN/MAX values stated where T_A = -40°C to 85°C and V_{BAT} = 2.0V to 5.0V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{INT_TEMP} (1)	Internal temperature sensor voltage drift	V_{INT_TEMP}	-1.88	-1.83	-1.74	mV/°C

(1) Specified by Characterization. Not production tested.

5.15 Thermistor Measurement Support

Typical values stated where T_A = 25°C and V_{BAT} = 3.8V, MIN/MAX values stated where T_A = -40°C to 85°C and V_{BAT} = 2.0V to 5.0V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
R_{TS_PU}	Internal pull-up resistance	Setting for nominal 18kΩ	14.4	18	21.6	kΩ
$R_{TS\_PU\_DRIFT}$ (1)	Resistance drift over temperature	Change over –40°C to +85°C vs value at 25°C for nominal 18kΩ	-200		200	Ω

(1) Specified by Characterization. Not production tested.

5.16 Hardware-based Protection (SCOMP) Thresholds (OVP, UVP, OCC, OCD, SCD)

Typical values stated where T_A = 25°C and V_{BAT} = 3.8V, MIN/MAX values stated where T_A = -40°C to 85°C and V_{BAT} = 2.0V to 5.0V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{OVP} (1) (4)	Hardware overvoltage protection (OVP) detection range	$V_{IN} = V_{BAT}$, threshold range, 50mV steps, typical value is default	3500	4300	5000	mV
V_{OVP_ACC} (2) (3)	Hardware OVP detection accuracy	$V_{IN} = V_{BAT}$, T_A = 0ºC to 60ºC, C_{LOAD} at CHG/DSG < 1µA	–25		25	mV
		$V_{IN} = V_{BAT}$, T_A = -40ºC to 85ºC, C_{LOAD} at CHG/DSG < 1µA	–53		53	

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Typical values stated where T_A = 25℃ and V_{BAT} = 3.8V, MIN/MAX values stated where T_A = -40℃ to 85℃ and V_{BAT} = 2.0V to 5.0V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{UVP} (1) (4)	Hardware undervoltage protection (UVP) detection range	V_{IN} = V_{BAT}, threshold range, 50mV steps, typical value is default	2000	2300	4000	mV
V_{UVP_ACC} (2) (3)	Hardware UVP detection accuracy	V_{IN} = V_{BAT}, T_A = 0ºC to 60ºC, C_{LOAD} at CHG/DSG < 1µA	-30		30	mV
		V_{IN} = V_{BAT}, T_A = -40ºC to 85ºC, C_{LOAD} at CHG/DSG < 1µA	-50		50	
$R_{PACK-VSS}$	Resistance between PACK and VSS	SHELF2 and SHUTDOWN modes only	100	300	550	kΩ
V_{OCC} (1) (4)	Hardware overcurrent in charge (OCC) detection range	V_{IN} = V_{SRP} - V_{SRN}, threshold range, 1mV steps, typical value is default	4	14	100	mV
V_{OCD} (1) (4)	Hardware overcurrent in discharge (OCD) detection range	V_{IN} = V_{SRP} - V_{SRN}, threshold range, 1mV steps, typical value is default	–4	-16	–100	mV
V_{SCD} (1) (4)	Hardware short circuit current in discharge (SCD) detection range	V_{IN} = V_{SRP} - V_{SRN}, threshold range, 1mV steps, typical value is default	–5	-20	–120	mV
V_{OCx_ACC} (2)	Overcurrent (OCC, OCD, SCD) detection accuracy	V_{IN} = V_{SRP} - V_{SRN}, |Setting| < 20mV, T_A = -25ºC to 65ºC	-2.1		2.1	mV
		V_{IN} = V_{SRP} - V_{SRN}, |Setting| < 20mV	-2.1		2.1	
		V_{IN} = V_{SRP} - V_{SRN}, |Setting| = 20 to 55mV	-3		3	
		V_{IN} = V_{SRP} - V_{SRN}, |Setting| = 56 to 100mV	-5		5	
		V_{IN} = V_{SRP} - V_{SRN}, |Setting| >100mV	-12		12	

(1) Specified by Design. Not production tested.
(2) Specified by Characterization. Not production tested.
(3) Accuracy defined by specified default threshold.
(4) Specified typical value is the factory default setting. The setting in data flash can be changed in FULL ACCESS mode and is locked in SEALED mode. Refer to the BQ27Z846 Technical Reference Manual.

5.17 Hardware-based Protections (SCOMP) Timing (OVP, UVP, OCC, OCD, SCD)

Typical values stated where T_A = 25℃ and V_{BAT} = 3.8V, MIN/MAX values stated where T_A = -40℃ to 85℃ and V_{BAT} = 2.0V to 5.0V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_{OVP} (1) (2) (3)	OVP detection delay options	Configurable with 8191 delay steps. To calculate expected delay time = 1.708 + DelayStep# * 0.854 . Factory default = 1171 counts = 1.708 + 1171 * 0.854 = 1001ms	2.56	1001	6996	ms
t_{UVP} (1) (2) (3)	UVP detection delay options	Configurable with 255 delay steps. To calculate expected delay time = 1.708 + DelayStep# * 0.854 . Factory default = 117 counts = 1.708 + 117 * 0.854 = 101ms	2.56	101	219	ms
t_{OCC} (1) (2) (3)	OCC detection delay options	Configurable with 127 delay steps. To calculate expected delay time = 1.708 + DelayStep# * 0.854 . Factory default = 10 counts = 1.708 + 10 * 0.854 = 10.2ms	2.56	10.2	110	ms
t_{OCD} (1) (2) (3)	OCD detection delay options	Configurable with 127 delay steps. To calculate expected delay time = 1.708 + DelayStep# * 0.854 . Factory default = 18 counts = 1.708 + 18 * 0.854 = 17ms	2.56	17	110	ms

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Typical values stated where T_A = 25℃ and V_{BAT} = 3.8V, MIN/MAX values stated where T_A = -40℃ to 85℃ and V_{BAT} = 2.0V to 5.0V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_{SCD} (1) (2) (3)	SCD detection delay options	Configurable with 7 delay options. To calculate expected delay time = DelayStep# * 0.122 + 0.2745 Factory default = 1 count = 1 * 0.122 + 0.2745	396	396	1128	μs
t_{WAKE_CC} (1) (2) (3)	Current wake in charge detection delay options	Configurable with 31 delay steps. To calculate expected delay time = 1.708 + (14 + DelayStep# - 2) * 0.854 . Factory default = 7 counts = 1.708 (14 + 7 - 2) * 0.854 = 17.93ms	12.81	17.93	38.43	ms
t_{WAKE_CD} (1) (2) (3)	Current wake in discharge detection delay options	Configurable with 31 delay steps. To calculate expected delay time = 1.708 + (14 + DelayStep# - 2) * 0.854 . Factory default = 7 counts = 1.708 (14 + 7 - 2) * 0.854 = 17.93ms	12.81	17.93	38.43	ms

(1) Specified by Bench Evaluation. Not production tested.
(2) Specified typical value is the factory default setting. The setting in data flash can be changed in FULL ACCESS mode and is locked in SEALED mode. Refer to the BQ27Z846 Technical Reference Manual.
(3) Not including LFO Frequency Error

5.18 CHG, DSG NFET Drivers

Typical values stated where T_A = 25℃ and V_{BAT} = 3.8V, MIN/MAX values stated where T_A = -40℃ to 85℃ and V_{BAT} = 2.0V to 5.0V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{DSG_ON}	DSG FET driver ON output voltage	C_{LOAD} = 10nF, V_{BAT} ≥ 4V	7.9	8.0	8.3	V
		C_{LOAD} = 10nF, V_{BAT} < 4V	1.95 × V_{BAT}	2 × V_{BAT}	2.1 × V_{BAT}	
V_{CHG_ON}	CHG FET driver ON output voltage	C_{LOAD} = 10nF, V_{BAT} ≥ 4V	7.9	8.0	8.3	V
		C_{LOAD} = 10nF, V_{BAT} < 4V	1.95 × V_{BAT}	2 × V_{BAT}	2.1 × V_{BAT}	
V_{DSG_OFF}	DSG FET driver OFF output voltage	C_{LOAD} = 10nF, V_{DSG_OFF} = V_{DSG} - V_{SS}			0.1	V
V_{CHG_OFF}	CHG FET driver OFF output voltage	C_{LOAD} = 10nF, V_{CHG_OFF} = V_{CHG} - V_{SS}			0.1	V
t_{DSG_RISE} (1)	DSG FET driver rise time	C_{LOAD} = 10nF, V_{DSG_ON} changes from 10% to 90% of V_{BAT} to $V_{DSG\_ON(TYP)}$		400	800	μs
t_{CHG_RISE} (1)	CHG FET driver rise time	C_{LOAD} = 10nF, V_{CHG_ON} changes from 10% to 90% of V_{BAT} to $V_{CHG\_ON(TYP)}$		400	800	μs
t_{FET_FALL} (1)	DSG and CHG FET driver fall time	C_{LOAD} = 10nF, V_{FET} changes from $V_{FET\_ON(TYP)}$ to V_{FET_OFF}		50	200	μs

(1) Specified by Bench Evaluation. Not production tested.

5.19 Zero-volt Charging (ZVCHG)

Typical values stated where T_A = 25℃ and V_{BAT} = 3.8V, MIN/MAX values stated where T_A = -40℃ to 85℃ and V_{BAT} = 2.0V to 5.0V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_{ZVCHG}	Zero-volt charging current	V_{PACK+} = 5V, V_{BAT} = 0V, R_{PACK} = 1kΩ			5	mA

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5.20 General Purpose Input-Outputs (INT)

Typical values stated where T_A = 25℃ and V_{BAT} = 3.8V, MIN/MAX values stated where T_A = -40℃ to 85℃ and V_{BAT} = 2.0V to 5.0V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{IH}	High-level input voltage	INT	0.7 × V_{REG18}			V
V_{IL}	Low-level input voltage	INT			0.3 × V_{REG18}	V
V_{OH}	Output voltage high	INT, I_{OH} = -450μA	0.85 × V_{REG18}			V
V_{OL}	Output voltage low	INT, I_{OL} = 1mA			0.35	V
R_{PD}	Internal pull-down resistance	INT	80	100	120	kΩ
R_{PU}	Internal pull-up resistance	INT	80	100	120	kΩ
C_{IN} (1)	Input capacitance	INT		1.5		pF
I_{LKG} (1)	Input leakage current	INT		1		μA

(1) Specified by Design. Not production tested.

5.21 I²C Interface I/O (SDA, SCL)

Typical values stated where T_A = 25℃ and V_{BAT} = 3.8V, MIN/MAX values stated where T_A = -40℃ to 85℃ and V_{BAT} = 2.0V to 5.0V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{IN}	Input Voltage range		-0.2		3.6	V
V_{IH}	Input voltage high	SDA, SCL	0.84			V
V_{IL}	Input voltage low	SDA, SCL			0.36	V
V_{OL}	Output low voltage	SDA, SCL, I_{OL} = –3mA			0.4	V
C_{IN} (1)	Input capacitance	SDA, SCL			10	pF
I_{LKG} (1)	Input leakage current	SDA, SCL		0.5		μA

(1) Specified by Design. Not production tested.

5.22 I²C Interface Timing

Typical values stated where T_A = 25℃ and V_{BAT} = 3.8V, MIN/MAX values stated where T_A = -40℃ to 85℃ and V_{BAT} = 2.0V to 5.0V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	NOM	MAX	UNIT
I²C 100kHz						
f_{SCL} (1)	Clock frequency				100	kHz
$t_{HD:STA}$ (1)	START condition hold time		4			μs
t_{LOW} (1)	Low period of SCL clock		4.7			μs
t_{HIGH} (1)	High period of SCL clock		4			μs
$t_{SU:STA}$ (1)	Setup time for repeated START		4.7			μs
$t_{HD:DAT}$ (1)	Data in hold time		0			μs
$t_{SU:DAT}$ (1)	Data in setup time		250			ns
	Data out setup time		250			ns
t_r (1) (2)	SDA and SCL rise time	30% to 70% of V_{DDIO}			1000	ns
t_F (1) (2)	SDA and SCL fall time	30% to 70% of V_{DDIO}			300	ns
$t_{SU:STO}$ (1)	STOP condition setup time		4			μs
t_{BUF} (1)	Bus free time between STOP and START		4.7			μs

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Typical values stated where T_A = 25℃ and V_{BAT} = 3.8V, MIN/MAX values stated where T_A = -40℃ to 85℃ and V_{BAT} = 2.0V to 5.0V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	NOM	MAX	UNIT
C_D	Capacitive load for each bus line				400	pF
I^2C 400kHz						
f_{SCL} [1]	Clock frequency				400	kHz
$t_{HD:STA}$ [1]	START condition hold time		0.6			µs
t_{LOW} [1]	Low period of SCL clock		1.3			µs
t_{HIGH} [1]	High period of SCL clock		0.6			µs
$t_{SU:STA}$ [1]	Setup time for repeated START		0.6			µs
$t_{HD:DAT}$ [1]	Data in hold time		0			µs
$t_{SU:DAT}$ [1]	Data in setup time		100			ns
	Data out setup time		100			ns
t_r [1] [2]	SDA and SCL rise time	30% to 70% of V_{DDIO}	20		300	ns
t_F [1] [2]	SDA and SCL fall time	30% to 70% of V_{DDIO}	20 × (V_{DDIO}/ 5.5)		300	ns
$t_{SU:STO}$ [1]	STOP condition setup time		0.6			µs
t_{BUF} [1]	Bus free time between STOP and START		1.3			µs
C_D	Capacitive load for each bus line				400	pF
I^2C 1MHz						
f_{SCL} [1]	Clock frequency				1000	kHz
$t_{HD:STA}$ [1]	START condition hold time		0.26			µs
t_{LOW} [1]	Low period of SCL clock		0.5			µs
t_{HIGH} [1]	High period of SCL clock		0.26			µs
$t_{SU:STA}$ [1]	Setup time for repeated START		0.26			µs
$t_{HD:DAT}$ [1]	Data in hold time		0			µs
$t_{SU:DAT}$ [1]	Data in setup time		50			ns
	Data out setup time		50			ns
t_r [1] [2]	SDA and SCL rise time	30% to 70% of V_{DDIO}			120	ns
t_F [1] [2]	SDA and SCL fall time	30% to 70% of V_{DDIO}	20 × (V_{DDIO}/ 5.5)		120	ns
$t_{SU:STO}$ [1]	STOP condition setup time		0.26			µs
t_{BUF} [1]	Bus free time between STOP and START		0.5			µs
C_D	Capacitive load for each bus line				100	pF

(1) Specified by Characterization. Not production tested.
(2) V_{DDIO} = 1.2V

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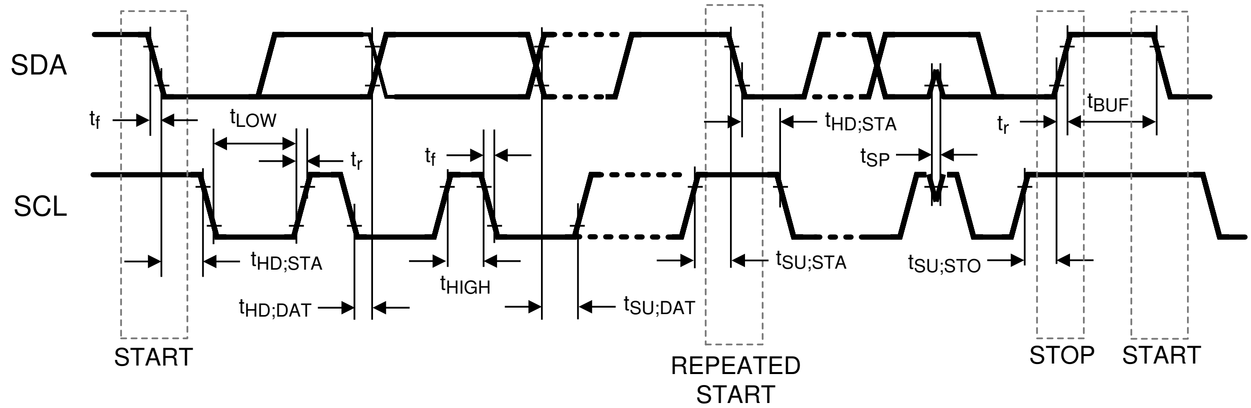

Figure 5-1. I²C Timing Diagram

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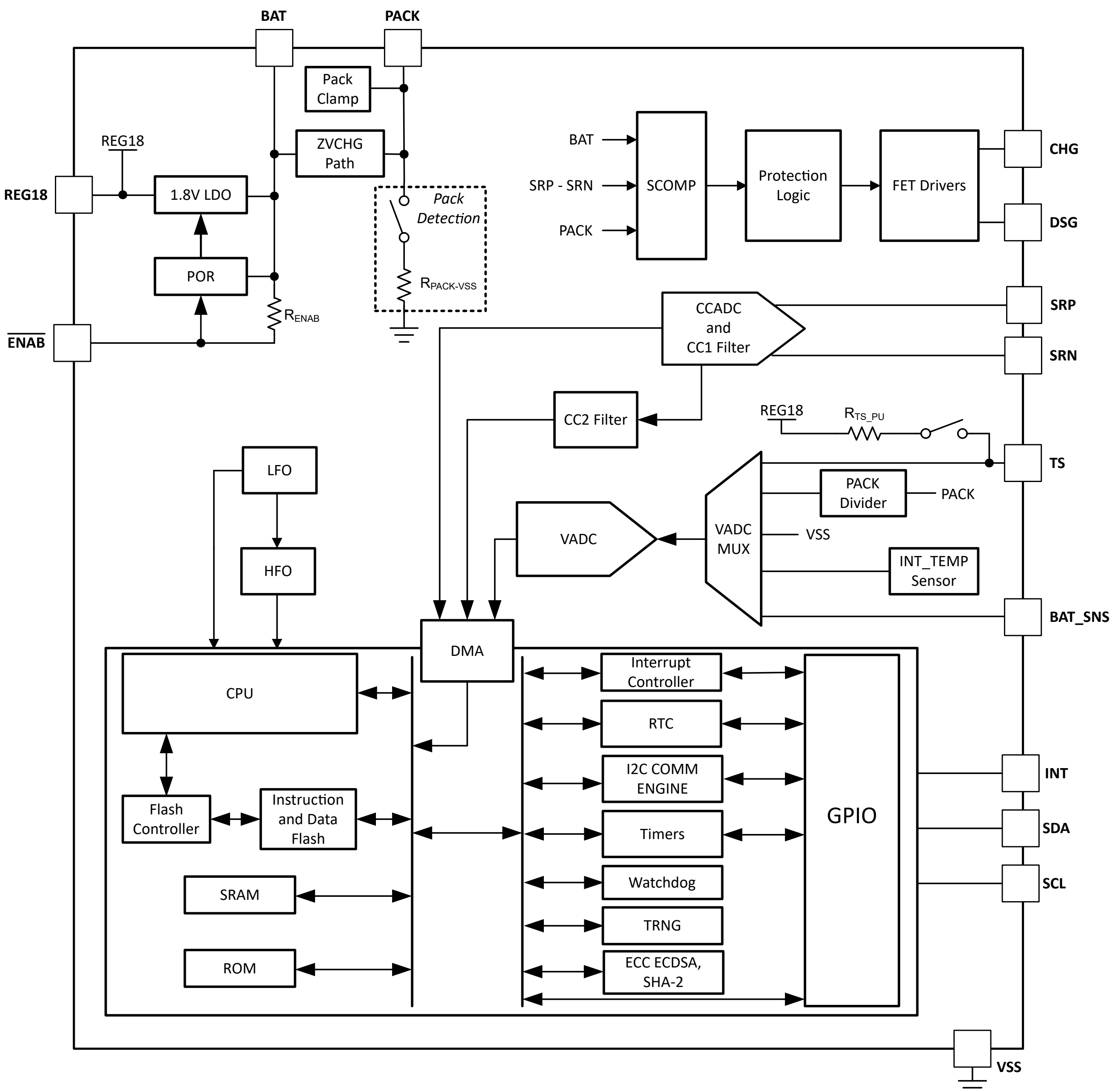
6 Detailed Description

6.1 Overview

The BQ27Z846 Single Cell Battery Fuel Gauge is a fully integrated battery management option that employs integrated flash-based firmware, hardware- and firmware-based protections, and ECC ECDSA and SHA-2 authentication to provide a complete solution for single-cell battery architectures. The BQ27Z846 interfaces with a host system via an I^2C interface and processes instructions and data using a state-of-the-art, ultra-low-power 32-bit RISC processor. High-performance, integrated analog peripherals allow support for a sense resistor down to 0.5mΩ and simultaneous current and voltage data conversion for instant power calculations. The following sections detail the overall block diagram and major component blocks included as part of the BQ27Z846 Single Cell Battery Fuel Gauge.

6.2 Functional Block Diagram



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6.3 Feature Description

6.3.1 BQ27Z855 Processor

The BQ27Z846 processor incorporates a 32-bit RISC Arm M0+ processor, a single-cycle 32-bit multiplier, 24-bit SysTick timer, and a nested vector interrupt controller (NVIC). All are all integrated in the processor.

6.3.2 Battery Parameter Measurements

The BQ27Z846 device measures cell voltage and current simultaneously using two independent ADCs and also measures temperature to calculate the information related to remaining capacity, full charge capacity, state-of-health, and other gauging parameters.

6.3.2.1 Analog-to-Digital Converter (VADC)

The first ADC is a 16-bit delta-sigma converter designed for general-purpose voltage measurements. The VADC automatically scales the input voltage range during sampling based on channel selection. The converter resolution is a function of its full scale range and number of bits yielding a 38µV resolution.

6.3.2.2 VADC Multiplexer

The VADC multiplexer provides selectable connections to the device's external BAT_SNS, PACK, and TS pins as well as the device's internal temperature sensor (INT_TEMP). In addition, the multiplexer can independently enable the TS input connection to the internal biasing circuitry for an external thermistor and enables the user to short the multiplexer inputs for test and calibration purposes.

6.3.2.3 Coulomb Counter (CCADC) and Digital Filter (CC1)

The second ADC is an integrating analog-to-digital converter designed specifically for tracking charge and discharge activity, or coulomb counting, of a rechargeable battery. It features a single-channel differential input that converts the voltage difference across a sense resistor between the SRP and SRN terminals with a resolution of 923nV. The differential input common mode voltage range is from V_{SS} to V_{BAT} and supports a 1-series cell high-side or low-side sensing option with a ±100mV input range.

The CC1 digital filter generates an 18-bit conversion value from the delta-sigma CCADC front-end. New conversions are available every 1s.

6.3.2.4 Internal Temperature Sensor (INT_TEMP)

An internal temperature sensor is available on the BQ27Z846 device to reduce the cost, power, and size of the external components necessary to measure temperature. It is measured by the VADC using the multiplexer and is ideal for quickly determining pack temperature under a variety of operating conditions.

The internal temperature sensor reports the measured temperature in terms of voltage and device firmware converts this voltage to temperature in units of °C to be reported for gauging and protection tasks. As an example, a difference in 0.05mV/°C between the $V_{INT\_TEMP(TYP)}$ value as stated in the Internal Temperature Sensor (INT_TEMP) Specifications table and the actual voltage drift value reported by the internal temperature sensor approximately equates to a temperature error of ±1°C.

6.3.2.5 External Temperature Sensor Support

The TS input is enabled with an internal 18kΩ (TYP) linearization pull-up resistor to support the use of a 10kΩ (25°C) NTC external thermistor, such as the Semitec 103AT-2. The NTC thermistor should be connected between VSS and the individual TS pin. The analog measurement is then taken by the VADC through its input multiplexer.

If a different thermistor type is required, then changes to configurations in the device firmware may be required.

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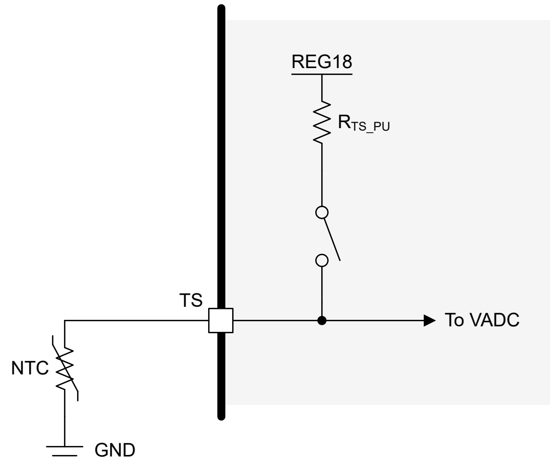

Figure 6-1. External Thermistor Biasing

6.3.3 Power Supply Control

The BQ27Z846 device uses the BAT pin as its power source. BAT powers the internal voltage sources and 1.8V LDO that supply references for the device.

The BAT_SNS pin is a non-current carrying path and used as a Kelvin sense connection to the battery cell.

6.3.4 $\overline{\text{ENAB}}$ Pin

The BQ27Z846 device can use the active low digital input $\overline{\text{ENAB}}$ pin to exit the device's SHELF1, SHELF2, and SHUTDOWN power modes. The digital input is connected to a weak internal pull-up to BAT. A push-button can be connected to the $\overline{\text{ENAB}}$ pin to drive the pin to a low state for the device to exit SHELF1, SHELF2, or SHUTDOWN mode.

If the $\overline{\text{ENAB}}$ pin is connected directly to the device's GND reference (VSS), the BQ27Z846 device will not be able to enter SHELF1, SHELF2, or SHUTDOWN mode.

The $\overline{\text{ENAB}}$ pin can be left floating if using a push-button to exit SHELF1, SHELF2, or SHUTDOWN mode is not needed. The $\overline{\text{ENAB}}$ pin can also be left floating if the device needs the capability to enter SHELF1, SHELF2, or SHUTDOWN mode.

6.3.5 I^2C Bus Communication Interface

The BQ27Z846 device has an I^2C bus communication interface capable of supporting as low as 1.2V-level logic and up to a 1MHz I^2C clock frequency.

6.3.6 Low Frequency Oscillator (LFO)

The BQ27Z846 device includes a low frequency oscillator (LFO) running at 65.536kHz.

6.3.7 High Frequency Oscillator (HFO)

The BQ27Z846 includes a high frequency oscillator (HFO) running at 16.384MHz.

The HFO is frequency locked to the LFO output.

6.3.8 Real Time Clock (RTC)

The BQ27Z846 includes a real time clock (RTC) that can provide the following information:

- Calendar
  - 4-digit year with automatic leap-year adjustment
  - Month
  - Day of the month
  - Day of the week
- Time of Day

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- Hours (24-hour format with optional daylight savings adjustment)
- Minutes
- Seconds

The RTC is sourced from the integrated LFO and can be enabled in all power modes except SHUTDOWN.

6.3.9 1.8V Low Dropout Regulator (REG18)

The BQ27Z846 device contains an integrated 1.8V LDO (REG18) that provides regulated supply voltage for the internal circuitry of the device.

This LDO requires a capacitor (C_{REG18}) with the recommended typical capacitance of 1.5µF connected between the device's REG18 and VSS pins. The capacitor must be placed as close as possible to the device.

6.3.10 FET Drivers (CHG, DSG)

The BQ27Z846 gas gauge includes two high-side NMOS FET drivers for charge (CHG) and discharge (DSG) control to disconnect the cell from the system and to control the flow of charge and discharge current. The device controls the two external N-channel MOSFETs in a back-to-back configuration for battery protection. The CHG and DSG FETs are automatically disabled if a protection fault is detected and can re-enabled if the recovery conditions programmed in the device firmware are met.

6.3.10.1 Charge (CHG) FET Driver

The device's charge (CHG) FET driver allows for independent control of the CHG FET. The CHG FET is disabled automatically if a charge-related protection fault is detected, such as battery overvoltage (OVP) and overcurrent in charge (OCC). The CHG FET can be re-enabled if the recovery conditions programmed in the device firmware are met.

6.3.10.2 Discharge (DSG) FET Driver

The device's discharge (DSG) FET driver allows for independent control of the DSG FET. The DSG FET is disabled automatically if a discharge-related protection fault is detected, such as battery undervoltage (UVP), overcurrent in discharge (OCD), and short circuit in discharge (SCD). The DSG FET can be re-enabled if the recovery conditions programmed in the device firmware are met.

6.3.11 Zero-volt Charging (ZVCHG)

ZVCHG (0V charging) is a special function that allows charging a severely depleted battery. The BQ27Z846 device has ZVCHG enabled with no inhibit. This means a severely depleted battery with a voltage as low as 0V can be charged.

With a voltage applied at the PACK+ terminal of the battery pack, the BQ27Z846 device conducts ZVCHG current within the device via an internal path from the PACK pin to the BAT pin. The resistor between the PACK+ terminal of the battery pack and the PACK pin of the device current limits the ZVCHG current (I_{ZVCHG}) through the device effectively setting what ZVCHG current the battery charges at or is used to wake a secondary protector. I_{ZVCHG} is limited to $I_{ZVCHG(MAX)}$ as stated in the Zero-volt Charging Specifications table.

If V_{BAT} is below the entry threshold set by device firmware to qualify the battery as being in a ZVCHG state, the BQ27Z846 device disables both the CHG and DSG FET and can start zero-volt charging once a voltage is applied at the PACK+ terminal of the battery pack. Once the battery is charged enough and V_{BAT} reaches the exit threshold programmed in device firmware, the device stops conducting zero-volt charging and assesses if the FETs can be turned ON.

Both the CHG and DSG FETs are disabled while the device is in a ZVCHG state.

The ZVCHG path through the device is enabled when V_{BAT} is below the device POR threshold (V_{POR_TH} - V_{POR_HYS}) or the device is in SHUTDOWN mode.

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CAUTION

Some battery providers do not recommend charging a depleted (self-discharged) battery. Consult the battery supplier to determine whether to have the ZVCHG battery charger function.

For safety purposes, the BQ27Z846 is specifically designed to be used in battery systems with at least 1 additional protector unit with an inhibited zero-volt charging feature. This prevents unwanted battery self-discharge to severely low voltage levels or initiating charging at very low battery voltages that can cause irreversible damage to the battery.

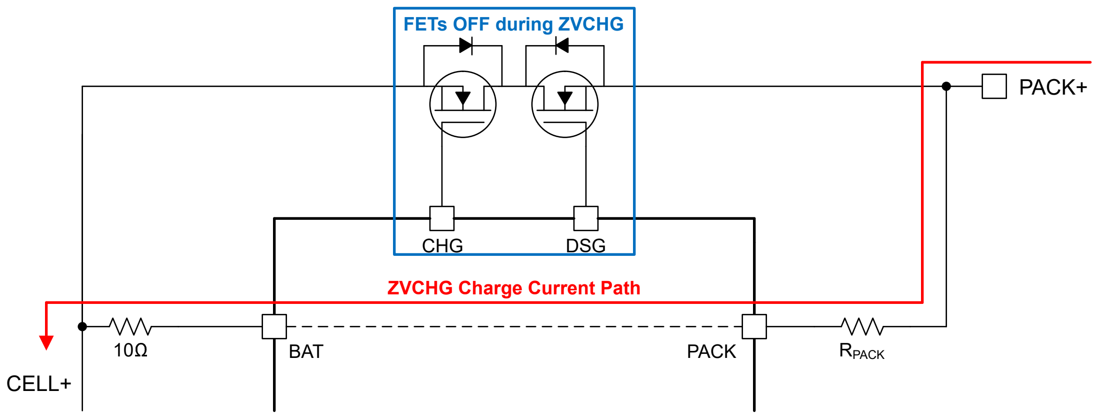

Figure 6-2. Zero-volt Charging Path

6.3.12 Integrated Protections

The BQ27Z846 gas gauge supports a wide range of hardware- and firmware-based protections for battery and system protection that can be easily configured using device firmware.

6.3.12.1 Hardware-based Protections

The BQ27Z846 device includes a module for hardware fault detection using a shared comparator (SCOMP) utilized for multiple voltage and current condition detections and can turn the CHG or DSG FET OFF if an abnormal voltage or current condition is detected. These detections include:

- Overvoltage Protection
- Undervoltage Protection
- Overcurrent in Charge Protection
- Overcurrent in Discharge Protection
- Short Circuit Current in Discharge Protection

6.3.12.1.1 Overvoltage Protection (OVP)

The overvoltage (OVP or HCOV) function detects abnormally high battery voltage. The OVP threshold and delay time are configurable through the device firmware. The detection circuit incorporates the delay setting before disabling the CHG FET. Recovery is handled purely in the firmware for all protection events.

6.3.12.1.2 Undervoltage Protection (UVP)

The undervoltage (UVP or HCUV) function detects abnormally low battery voltage. The UVP threshold and delay time are configurable through the device firmware. The detection circuit incorporates the delay setting before disabling the DSG FET. Recovery is handled purely in the firmware for all protection events.

6.3.12.1.3 Overcurrent in Charge Protection (OCC)

The overcurrent in charge (OCC or HOCC) function detects abnormally high current in the charge direction. The OCC threshold and delay time are configurable through the device firmware. The detection circuit incorporates the delay setting before disabling the CHG FET. Recovery is handled purely in the firmware for all protection events.

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6.3.12.1.4 Overcurrent in Discharge Protection (OCD)

The overcurrent in discharge (OCD or HOCD) function detects abnormally high current in the discharge direction. The OCD threshold and delay time are configurable through the device firmware. The detection circuit incorporates the delay setting before disabling the DSG FET. Recovery is handled purely in the firmware for all protection events.

6.3.12.1.5 Short Circuit Current in Discharge Protection (SCD)

The short circuit current in discharge (SCD or HSCD) function detects catastrophic current conditions in the discharge direction. The SCD thresholds and delay times are configurable through the device firmware. The detection circuit incorporates the delay setting before disabling the DSG FET. Recovery is handled purely in the firmware for all protection events.

6.3.12.1.6 Wake-up Comparator (I-WAKE)

The BQ27Z846 device has the ability to wake from SLEEP and DEEP SLEEP mode if substantial charge or discharge current is detected flowing across the external sense resistor. The device has two independent current wake thresholds for detecting charge current (WAKE_CC) and discharge current (WAKE_CD) that are configurable through device firmware.

6.3.12.2 Firmware-based Protections

In addition to hardware-based protections, the BQ27Z846 device includes a large suite of firmware-based protections to detect multiple voltage and current conditions and turn the CHG or DSG FET OFF if an abnormal voltage or current condition is detected. These firmware-based protections are divided into primary and permanent failure protections.

6.3.12.2.1 Primary Level Protection Features

Primary level protections are protection features that can disable the CHG or DSG FET when an abnormal voltage or current condition is detected and the device can recover from to turn the appropriate FET back ON when the abnormal condition is removed.

The BQ27Z846 gas gauge supports the following primary level protection features for battery and system protection, which can be configured using device firmware:

- Cell Undervoltage Protection (CUV)
- Cell Overvoltage Protection (COV)
- Overcurrent in CHARGE (OCC)
- Overcurrent in DISCHARGE (OCD)
- Overtemperature in CHARGE (OTC)
- Overtemperature in DISCHARGE (OTD)
- Undertemperature in CHARGE (UTC)
- Undertemperature in DISCHARGE (UTD)
- Precharge Timeout (PTO)
- Fast Charge Timeout (CTO)
- OverPrecharging Current Protection (OPCHG)
- Host Watchdog Protection (HWD)

6.3.12.2.2 Permanent Failure Protection Features

Permanent failure protections are protection features that can be used to indicate more serious faults and permanently disable the use of the battery pack.

The BQ27Z846 gas gauge supports the following permanent failure protection features for battery and system protection, which can be configured using device firmware:

- Safety Cell Undervoltage (SUV)
- Safety Cell Overvoltage (SOV)
- Safety Overcurrent in Charge (SOCC)
- Safety Overcurrent in Discharge (SOCD)
- Safety Overtemperature Cell (SOTD)

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- Safety Overtemperature FET (SOTF)
- Capacity Degradation Failure (CD)
- CHG FET Failure (CFETF)
- DSG FET Failure (DFETF)
- Battery Swelling Failure (BSD)
- Data Flash Failure (DF)
- Cell Overvoltage Latch (COVL)
- Internal Short Indication (ISI)

6.3.13 Gas Gauging

The BQ27Z846 uses the Dynamic Z-Track™ algorithm to measure and calculate the available capacity in battery cells. The BQ27Z846 accumulates a measure of charge and discharge currents and compensates the charge current measurement for the temperature, state-of-charge, and relaxation time constants of the battery. The BQ27Z846 estimates self-discharge of the battery and also adjusts the self-discharge estimation based on temperature.

For more information on the theory and implementation of the Dynamic Z-Track™ algorithm, refer to the following Application Note on Dynamic Z-Track™: *Dynamic Z-Track™ Technology: An Advanced Battery Gauging Algorithm for Dynamic Load Applications*.

6.3.14 Advanced Battery Algorithms

In addition to gas gauging via the Dynamic Z-Track™ algorithm, the BQ27Z846 device includes a suite of advanced battery algorithms to support Li-ion cell chemistries with Si-anodes and to provide an extra layer of battery monitoring and additional information to the system host device.

For more details on each individual algorithm, refer to their respective sections in the BQ27Z846 Technical Reference Manual.

6.3.14.1 Si-anode Chemistry Support

Li-ion batteries with silicon-based anodes offer unique advantages compared to Li-ion batteries with graphite-based anodes. The primary advantage is that Li-ion cells with Si-anodes tend to have a higher energy density than Li-ion cells with graphite anodes. However, the silicon degrades faster than graphite in the anode of Li-ion cells causing the Si-anode cell's open circuit voltage (OCV) curve to shift over time with cell aging. This OCV curve shift is especially prevalent in batteries containing a small amount of silicon (up to 20%).

Through device firmware, the BQ27Z846 device enables support for gauging Si-anode cells accurately on both small and dominant silicon type batteries by tracking the OCV curve shift using the predictive modeling of the Dynamic Z-Track™ technology.

6.3.14.2 Internal Short Indication (ISI)

Li-ion cells typically have a very low level of self-discharge or leakage current indicating the cell is healthy. However, abnormally high leakage current, typically due to a build-up of copper dendrites in Li-ion cells, can indicate serious safety concerns with the cell.

The BQ27Z846 device can be enabled via firmware to determine if a battery has an internal short via measuring the leakage current of the battery cell and alert the system host if the leakage current exceeds a programmed threshold for the host to intervene and take any appropriate action.

6.3.14.3 Battery Swelling Detection (BSD)

Over the lifetime use of a Li-ion cell, particularly pouch cells, a battery can grow or inflate typically due to gas buildup in the cell during use. This battery swelling is correlated to the change in battery impedance.

The BQ27Z846 can be enabled via firmware to track the impedance of the battery and alert the system host if the tracked change in battery impedance indicates potential battery swelling. The host can then intervene and take any appropriate action.

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6.3.15 Charge Control Features

The BQ27Z846 device supports charge control features such as:

- Reports charging voltage and charging current based on the active temperature range—JEITA temperature ranges T1, T2, T3, T4, T5, and T6
- Provides more complex charging profiles, including sub-ranges within a standard temperature range
- Reports the appropriate charging current and charging voltage needed for constant current – constant voltage (CC–CV) charging profile to a smart charger using the I^2C bus communication interface
- Provides pre-charging and zero-volt charging
- Employs charge inhibit and charge suspend if battery pack temperature is out of programmed range
- Activates charge and discharge alarms to report charging faults and to indicate charge status
- Request reduced charging current and charging voltage from a smart charger to account for cell aging

Refer to the Advanced Charge Algorithm chapter of the BQ27Z846 Technical Reference Manual for more information on the device's charge control features.

6.3.16 Lifetime Data Logging Features

The device supports data logging of several key parameters for warranty and analysis:

- Maximum and Minimum Cell Voltages
- Maximum Charge Current
- Maximum Discharge Current
- Maximum Average Discharge Current
- Maximum Average Discharge Power
- Maximum and Minimum Cell Temperature
- Maximum and Minimum Internal Temperature Sensor Temperature
- Number of Safety Events Occurrences and the Last Cycle of the Occurrence
- Number of Valid Charge Termination and the Last Cycle of the Valid Charge Termination
- Number of Qmax and Ra Updates and the Last Cycle of the Qmax and Ra Updates
- Number of Shutdown Events
- Total FW Runtime and Time Spent in Each Temperature Range (This data is updated every 2 hours if a difference is detected.)

Refer to the Lifetime Data Collection chapter of the BQ27Z846 Technical Reference Manual for more information on the device's lifetime data logging features.

6.3.17 Authentication

The BQ27Z846 device supports authentication by the host using Elliptic Curve Cryptography (ECC) or SHA-256.

6.3.17.1 ECC ECDSA Authentication

The BQ27Z846 device supports authentication by the host using ECC, which uses a 256-bit key system for the authentication process. The BQ27Z846 device employs the ECDSA variant of ECC authentication. Additionally, the ECC private key is required to be stored only in the battery pack, which makes ECC-based key management more simple and secure. The signing time would be less than 200ms and the overall hardware and firmware architecture to support this response time enables an additional level of protection.

For additional information on ECC authentication on the TI gas gauges, refer to the following Application Note: *Implementation of Elliptic Curve Cryptography Authentication on TI Battery Fuel Gauges*.

6.3.17.2 SHA-256 Authentication

The device supports authentication by the host using SHA-256.

The gas gauge can be configured to require SHA-256 authentication before the device can be unsealed or allow full access.

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6.3.18 Over the Air (OTA) Field Updater

The BQ27Z846 device incorporates the ability to update device firmware remotely in the field using over the air (OTA) updates. These OTA updates to device firmware can be made to update device firmware version, upgrade firmware-based features and algorithms, and modify ChemID parameters.

All hardware-based protections are still enabled while OTA updates occur. It is not recommended to change the threshold and delay settings of the hardware-based protections when the device is operating in the field.

Device firmware is updated in small portions allowing corrupt portions to be re-written.

For more details on OTA updates on the BQ27Z846 device, refer to the BQ27Z846 Technical Reference Manual.

6.3.19 Configuration

The device supports accurate data measurements and data logging of several key parameters.

6.3.19.1 Cell Voltage Measurements

The BQ27Z846 gas gauge measures the cell voltage at 1s intervals using the VADC. This measured value is internally scaled for the VADC and is calibrated to reduce any errors due to offsets. This data is also used for calculating the impedance of the cell for Dynamic Z-Track™ gas gauging.

6.3.19.2 Coulomb Counting

The device uses an integrating delta-sigma analog-to-digital converter (CCADC) for current measurement. The CCADC measures charge and discharge flow of the battery by measuring the voltage drop across a very small external sense resistor. The CCADC measures a bipolar signal from a range of –100mV to 100mV where a positive value of $V_{SRP} – V_{SRN}$ indicates charge current and a negative value indicates discharge current.

The external sense resistor can be as low as 0.5mΩ and the polarity of the differential voltage determines if the cell is in the CHARGE or DISCHARGE mode.

6.3.19.3 Temperature Measurements

The BQ27Z846 device has an internal temperature sensor (INT_TEMP) for on-die temperature measurements and the ability to support an external temperature measurement using an external NTC connected to the TS pin. These two measurements can be individually enabled and configured via device firmware.

6.4 Device Functional Modes

The BQ27Z846 device supports multiple power modes to accommodate different modes the battery pack can be in and reduce device power consumption:

- In ACTIVE mode, the BQ27Z846 performs measurements, calculations, protection decisions, and data updates in 1s intervals. Between these intervals, the BQ27Z846 is in a reduced power stage to minimize device power consumption. Battery protections are continuously monitored in this mode.
- In SLEEP mode, the BQ27Z846 performs measurements, calculations, protection decisions, and data updates in adjustable time intervals. Between these intervals, the BQ27Z846 is in a reduced power stage. While in SLEEP mode, the device's Coulomb counter is continuously integrating. Battery protections are continuously monitored in this mode. The BQ27Z846 has a wake function that enables exit from SLEEP mode when current flow, a battery protection event, or a failure is detected.
- In DEEP SLEEP mode, the BQ27Z846 performs measurements, calculations, protection decisions, and data updates in adjustable time intervals. Between these intervals, the BQ27Z846 is in a further reduced power stage. While in DEEP SLEEP mode, the device's Coulomb counter turns ON at adjustable time intervals to read current and is OFF in between these measurements. Battery protections are continuously monitored in this mode. The BQ27Z846 has a wake function that enables exit from DEEP SLEEP mode when current flow, a battery protection event, or a failure is detected.
- In SHELF1 mode, the BQ27Z846 is placed in a very low power state for shipping or shelf life purposes. The device measures voltage and temperature very infrequently and at shorter ADC conversion times, and current is not measured or Coulomb counted. Additionally, the CHG and DSG FETs and all hardware-based protections are OFF. Due to this, no external power is available to the system when the gauge is in SHELF1 mode. Current is assumed to be and reported as 0mA. Therefore, the device tracks the battery's state-of-

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charge from cell voltage or OCV measurements. The measurements performed each interval are cell voltage, temperature, and PACK voltage (every fourth interval). Processing is minimized by reducing the number of calculations. Some calculations are performed less frequently and only after voltage and temperature are measured. These less frequent calculations include updating firmware-based protections, lifetime data, and the voltage and temperature ranges of the Advanced Charge Algorithm. Other calculations, such as updating *RemainingCapacity()* and *FullChargeCapacity()*, are not performed at all with the assumption the system is OFF and cannot communicate with the gauge.

- In SHELF2 mode, the BQ27Z846 is placed in an even lower power state than SHELF1 mode for shipping or shelf life purposes. The device wakes up at an adjustable time interval to perform measurements, calculations, and, if needed, data updates then immediately enters a SHUTDOWN-like state to be in during these intervals where only the minimum number of blocks are ON. The device uses the LFO for timekeeping to determine when the next wake interval is reached and how long the device has been in SHELF2 mode. Current is assumed to be and reported as 0mA. Therefore, the device tracks the battery's state-of-charge from cell voltage or OCV measurements. Gauging calculations, such as updating *RemainingCapacity()* and *FullChargeCapacity()*, are not performed at all with the assumption the system is OFF and cannot communicate with the gauge.
- In SHUTDOWN mode, the BQ27Z846 is completely disabled.

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7 Application and Implementation

Note

Information in the following applications sections 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.

7.1 Application Information

The BQ27Z846 can be used with a 1-series Li-ion or Li-polymer battery pack. To implement and design a comprehensive set of parameters for a specific battery pack, the user needs Battery Management Studio (BQStudio), which is a graphical user-interface tool installed on a PC during development, and a USB-based PC interface board such as the EV2500 or EV2400 to program and communicate with the gauge. The firmware installed in the product has default values, which are summarized in the associated BQ27Z846 Technical Reference Manual. Using the BQStudio tool, these default values can be changed to cater to specific application requirements during development once the system parameters, such as enable or disable certain features for operation, cell configuration, chemistry that best matches the cell used, and more. The final flash image, which is extracted once configuration and testing are complete, is used for mass production and is referred to as the "golden image."

7.2 Typical Application Schematics

The following are example BQ27Z846 application schematics for a single-cell battery pack.

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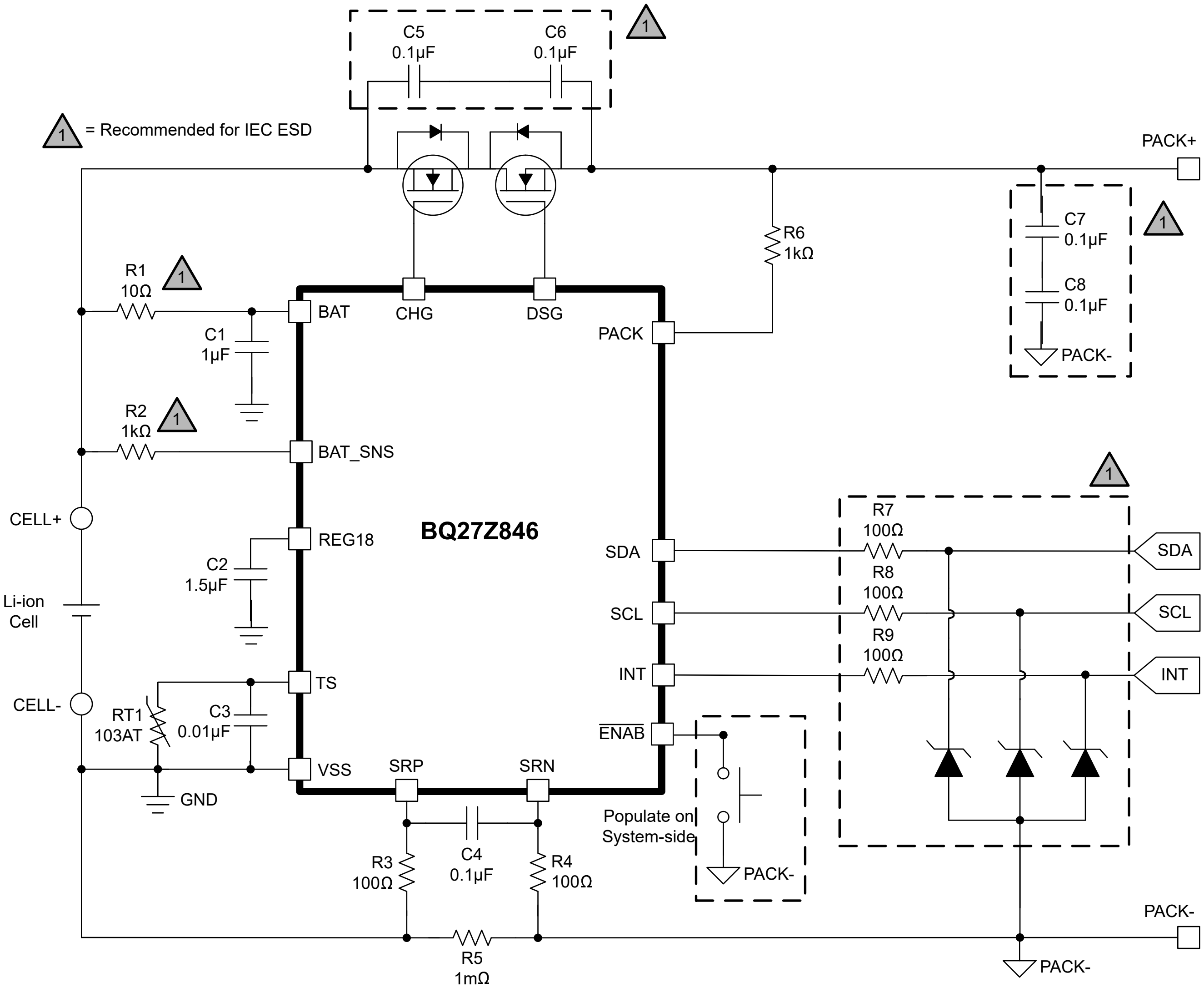

Figure 7-1. BQ27Z846 Typical Application Schematic with Low-side Current Sensing

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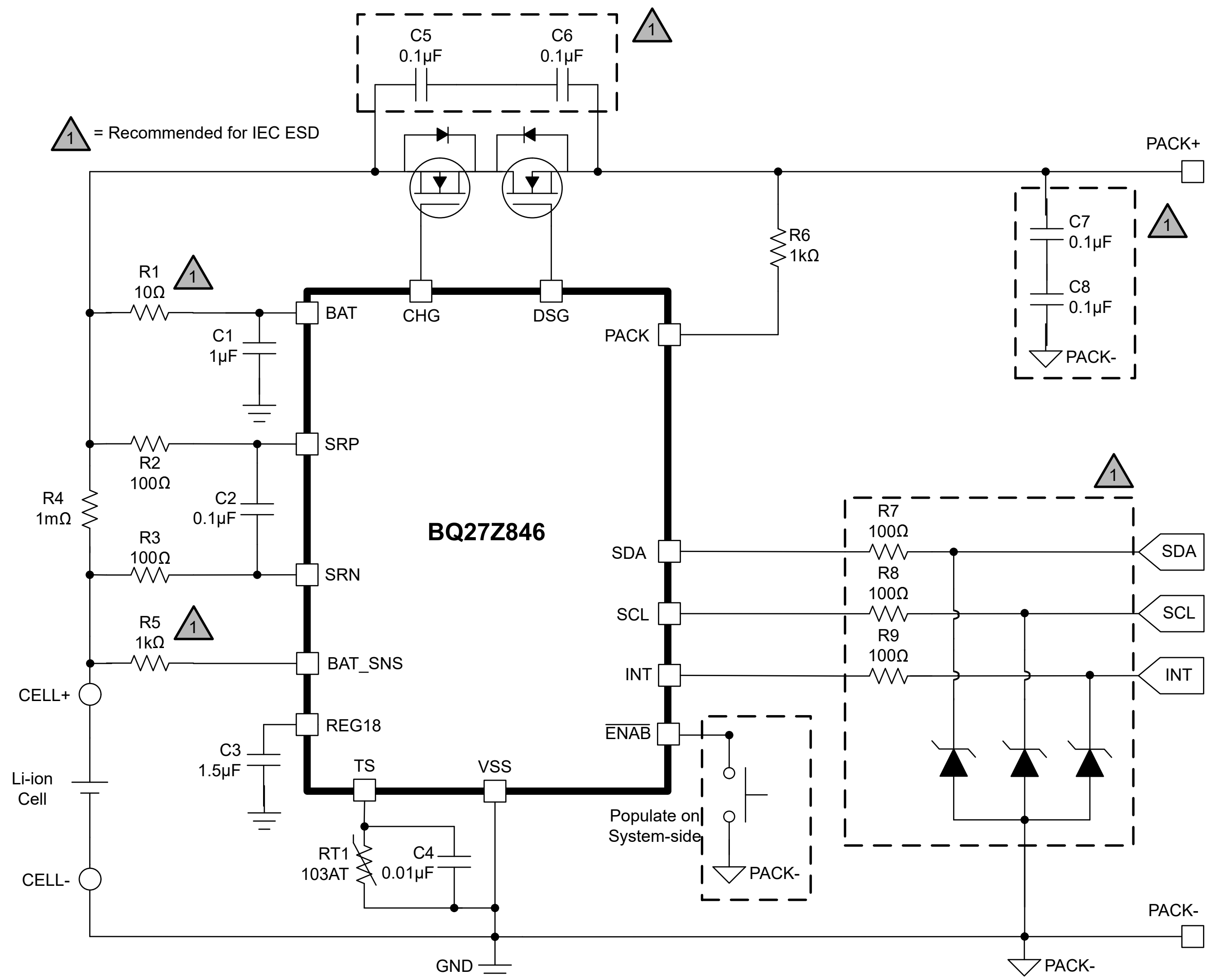

Figure 7-2. BQ27Z846 Typical Application Schematic with High-side Current Sensing

7.2.1 Design Requirements

Example Design Parameters shows the default settings for the main parameters. Use the BQStudio tool to update the settings to meet the specific application or battery pack configuration requirements.

The device should be calibrated before any gauging test. Follow the BQStudio **Calibration** page to calibrate the device, and use the BQStudio **Chemistry** page to update the chemistry profile on the device.

Table 7-1. Example Design Parameters

Design Parameter	Example
Cell Configuration	1S1P: 1 series with 1 parallel
Device Chemistry	Li-ion
Design Capacity	4500mAh
Charging Voltage	4400mV
Termination Voltage	3000mV
Design Voltage	3700mV
Dsg Current Threshold	100mA
Chg Current Threshold	50mA

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Table 7-1. Example Design Parameters (continued)

Design Parameter	Example
Quit Current Threshold	10mA
Charge Termination Taper Current	450mA
Cell Undervoltage	2500mV
Cell Overvoltage at Standard Temperature	4500mV
Shutdown Voltage	2300mV
Overcurrent in CHARGE Threshold	6000mA
Overcurrent in DISCHARGE Threshold	-6000mA
Short Circuit in DISCHARGE Threshold	-8000mA
Internal and External Temperature Sensor	Only External Temperature Sensor used
Undertemperature in CHARGE Threshold	0°C
Undertemperature in DISCHARGE Threshold	0°C
BROADCAST Mode	Disabled

The design parameters needed to fit the design requirements can be adjusted in the device firmware. For more information on particular design parameters, refer to the BQ27Z846 Technical Reference Manual.

7.2.2 Detailed Design Procedure

7.2.2.1 High-Current Path

The high-current path begins at the PACK+ terminal of the battery pack. As charge current travels from the PACK+ terminal, it finds its way through protection FETs, the battery cell and cell connections, the sense resistor, and then returns to the PACK– terminal. In addition, some components are placed across the PACK+ and PACK– terminals to reduce effects from electrostatic discharge.

7.2.2.1.1 Protection FETs

The BQ27Z846 device is supports driving external N-channel protection FETs using integrated NFET Drivers. Select the N-channel charge and discharge FETs for a given application.

The gates of the CHG and DSG protection FETs are pulled to the device GND reference (VSS) to ensure the FETs are turned off if the gate drive is open.

Capacitors C5 and C6 help protect the FETs during an ESD event. Using two devices ensures normal operation if one capacitor becomes shorted. To have good ESD protection, the copper trace inductance of the capacitor leads must be designed to be as short and wide as possible. Ensure that the voltage rating of both C5 and C6 are adequate to hold off the applied voltage if one of the capacitors becomes shorted.

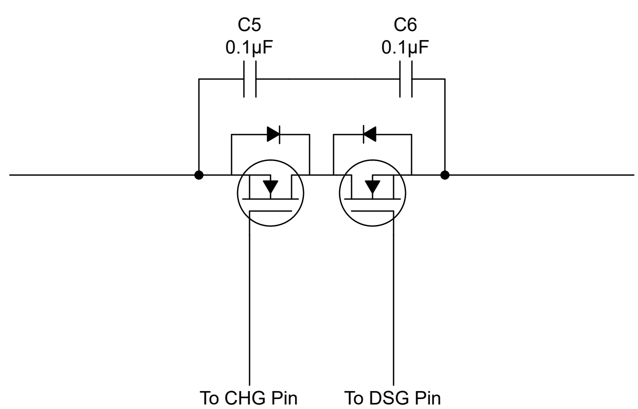

Figure 7-3. Protection FETs

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7.2.2.1.2 Battery Cell Connections

The high current flows through the top and bottom connections of the battery cell. Therefore, the voltage sense leads at these points must be made with a Kelvin connection to avoid any errors due to a voltage drop caused by the copper trace. The location marked 1P in Figure 7-4 indicates the Kelvin connection at the positive terminal of the cell. The single-point connection at 1N to the low-current ground is needed to avoid an undesired voltage drop through long traces while the gas gauge is measuring the cell voltage.

Additionally, the device's BAT pin is recommended to be Kelvin connected to reduce trace resistance between the connection point and the input power supply of the device. The Kelvin connection can be made to the postive terminal of the battery, the location marked 1P in Figure 7-4, or to the top or SRP node of the sense resistor depending on if the device is configured for low-side or high-side current sensing.

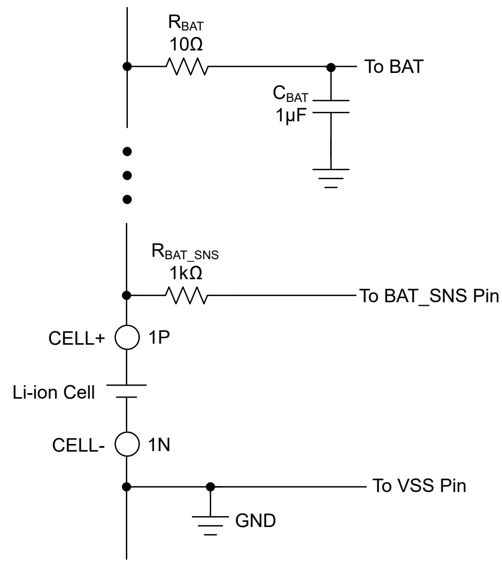

Figure 7-4. Battery Cell Connections

7.2.2.1.3 Sense Resistor

As with the cell connections, the quality of the Kelvin connections at the sense resistor is critical. The sense resistor must have a temperature coefficient no greater than 50ppm in order to minimize current measurement drift with temperature. Choose the value of the sense resistor to correspond to the available overcurrent and short circuit protection ranges and desired protection threshold setting of the BQ27Z846. It is recommended to select the smallest value possible for a given application to minimize the negative voltage generated on the BQ27Z846 V_{SS} node during a short circuit in discharge event. This pin has an absolute minimum of –0.3V.

Parallel resistors can be used as long as good Kelvin sensing is ensured. The device is designed to support a minimum sense resistor value of 0.5mΩ.

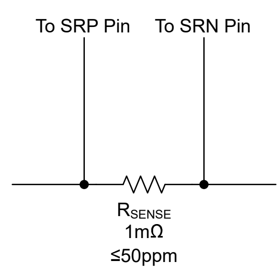

Figure 7-5. Sense Resistor

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7.2.2.1.4 ESD Mitigation

A pair of series 0.1µF ceramic capacitors (C7 and C8) is placed across the PACK+ and PACK– terminals to help in the mitigation of external system-level electrostatic discharges. The two devices in series maintain continued operation of the battery pack if one of the capacitors becomes shorted.

7.2.2.2 Gas Gauge Circuit

The gas gauge circuit includes the BQ27Z846 and its peripheral components. These components are divided into the following groups:

- Cell voltage measurement interface
- Coulomb counter interface
- Temperature measurement
- 1.8V LDO (REG18)
- I^2C communication
- Interrupt to host interface via the INT pin

7.2.2.2.1 Cell Voltage Measurement Interface

The BQ27Z846 device uses the BAT_SNS pin to measure the cell voltage. A 1kΩ resistor (R_{BAT_SNS}) can be placed in between the connection to the positive terminal of the battery (CELL+) and the device's BAT_SNS pin to provide ESD protection during cell connect and device operation.

As described in Section 7.2.2.1.2, the top node of the cell must be sensed at the battery connections with a Kelvin connection to prevent voltage sensing errors caused by a voltage drop from the PCB copper trace.

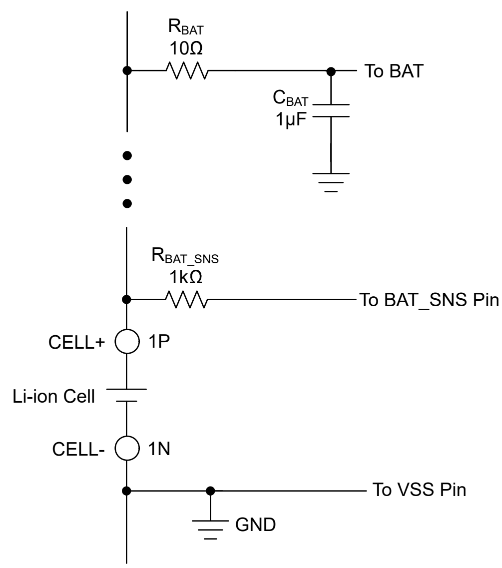

Figure 7-6. Cell Voltage Measurement Input

7.2.2.2.2 Coulomb Counter Interface

The BQ27Z846 uses an integrating delta-sigma ADC, or Coulomb counter, for current measurements. For more robust noise immunity, a differential low-pass filter can be added between the sense resistor connections to the device's SRP and SRN pins. Add 100Ω resistors (R_{CCADC} resistors) from the sense resistor to the SRP and SRN inputs of the device. Place a 0.1µF (C_{CCADC}) filter capacitor across the SRP and SRN inputs.

One key item to consider when choosing a sense resistor (R_{SENSE}) value is the tradeoff between the sense resistor value and the current resolution the device's Coulomb counter will report for gauging calculations. A higher sense resistor value yields a lower current resolution and can be more appropriate for applications using lower battery capacities and/or lower currents. A lower sense resistor value yields a higher current resolution and can be more appropriate for applications using higher battery capacities and/or higher currents.

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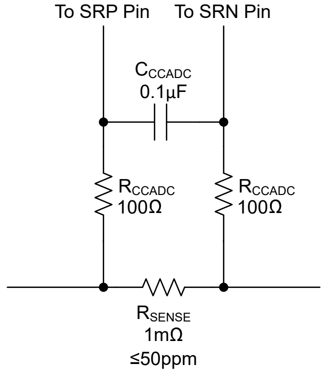

Figure 7-7. Coulomb Counter Differential Filter

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7.2.2.2.3 Temperature Measurement

For the BQ27Z846 device, the TS pin provides an internal thermistor bias network under firmware control in order to measure cell temperature using an external NTC thermistor. The TS pin can be enabled with an integrated 18kΩ (TYP) linearization pull-up resistor to support the use of a 10kΩ at 25°C NTC external thermistor such as a Semitec 103AT-2. The BQ27Z846 device supports one external thermistor.

Optionally, a small 0.01µF capacitor (C_{TS}) can be connected in parallel to the external NTC thermistor for more robust noise immunity during temperature measurement and ESD performance.

The BQ27Z846 device also includes an internal temperature sensor that can be used in place of or in addition to an external thermistor. This internal temperature sensor can be enabled and disabled via device firmware.

Temperature-based protection settings can be configured via device firmware. Refer to the BQ27Z846 Technical Reference Manual for more details.

If the TS pin is unused, connect the pin directly to VSS or leave it floating and configure data flash accordingly to disable measuring temperature on the unused TS pin. If the internal temperature sensor is unused, configure data flash accordingly to disable the sensor.

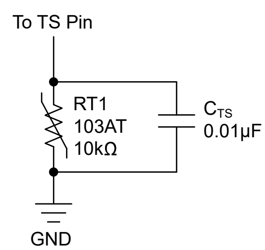

Figure 7-8. External NTC Thermistor Support

7.2.2.2.4 1.8V Low Dropout Regulator (REG18)

The BQ27Z846 includes a 1.8V low dropout regulator to support the device and provide regulated supply voltage for the device CPU and internal digital logic.

A capacitor (C_{REG18}) with the recommended typical capacitance of 1.5µF is required to be connected as close to the REG18 pin as possible for optimal operation.

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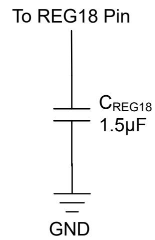

Figure 7-9. REG18 External Capacitor

7.2.2.2.5 I²C Communication (SDA, SCL)

The device's I²C clock and data pins have an absolute maximum voltage rating of 6V and have integrated high-voltage ESD protection circuits. However, adding a Zener diode or ESD TVS diode and 100Ω series resistors can provide more robust ESD performance.

The SDA and SCL pins have internal pull-down resistors. When the gas gauge senses that both lines are low (such as during removal of the battery pack), the device goes into SLEEP mode to conserve power.

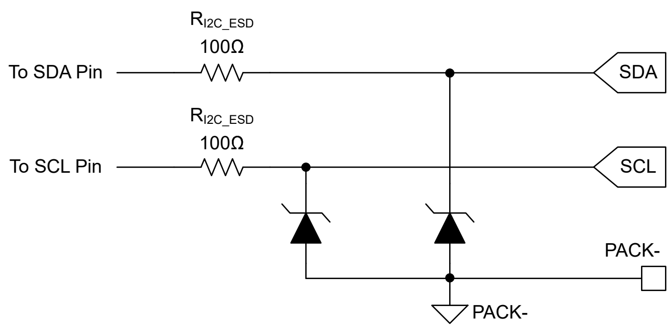

Figure 7-10. ESD Protection for I²C Communication

7.2.2.2.6 Interrupt to Host Interface (INT)

The device's INT pin also has an absolute maximum voltage rating of 6V and integrated high-voltage ESD protection circuits. Similar to the I²C pins, a Zener diode or ESD TVS diode and a 100Ω series resistor can be added for more robust ESD performance.

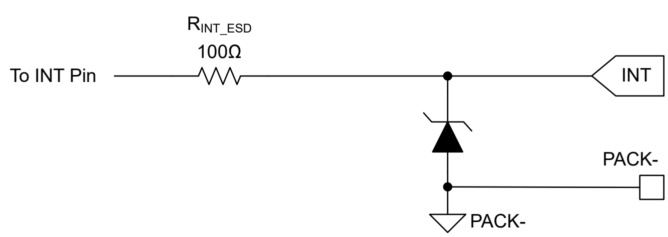

Figure 7-11. ESD Protection for INT Output to System-side Host

7.2.2.3 Co-design with BQ27Z746 and BQ27Z758

The BQ27Z846 device is footprint compatibility with the TI BQ27Z746 and BQ27Z758 family of 1S Battery Gas Gauge and Protection devices and can be used in designs that require components to be interchangeable.

The following sections outline key information and differences between the BQ27Z846 device and BQ27Z7xx family of devices for designs that necessitate the gas gauge to be interchangeable.

7.2.2.3.1 Footprint Compatibility and Equivalent Pins

The BQ27Z846 is footprint compatible with the BQ27Z7xx family of TI gas gauge devices because both devices are 3x5 ball grid array devices and can be placed on the same land pattern on a PCB.

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The BQ27Z846 is not exactly pin-to-pin with the BQ27Z746 and BQ27Z758 devices. However, most of the BQ27Z846 device's pins are in the same locations as on the BQ27Z746 and BQ27Z758 devices to more easily accommodate designs where the gas gauge component is interchangeable.

The pins on the BQ27Z7xx family of devices that are equivalent to the pins on BQ27Z846 is shown in BQ27Z7xx v. BQ27Z846 Pinouts and BQ27Z7xx v. BQ27Z846 Equivalent Pin Map below.

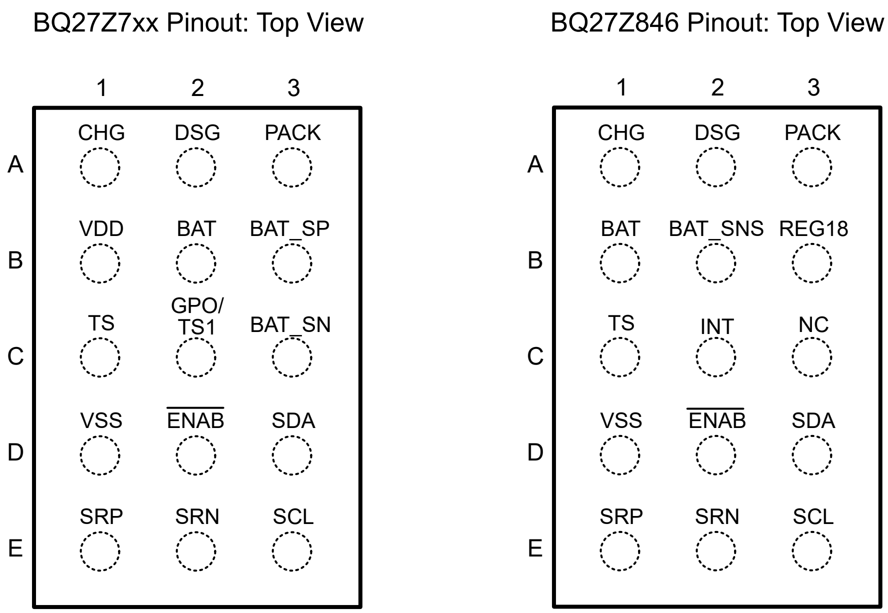

Figure 7-12. BQ27Z7xx v. BQ27Z846 Pinouts

Table 7-2. BQ27Z7xx v. BQ27Z846 Equivalent Pin Map

PIN NO.	BQ27Z7xx Pin	Equivalent Pin on BQ27Z846
A1	CHG	CHG
A2	DSG	DSG
A3	PACK	PACK
B1	VDD	BAT
B2	BAT	BAT_SNS
B3	BAT_SP	N/A
C1	TS	TS
C2	GPO/TS1	INT: No extra TS1 function
C3	BAT_SN	N/A
D1	VSS	VSS
D2	$\overline{\text{ENAB}}$	$\overline{\text{ENAB}}$
D3	SDA	SDA
E1	SRP	SRP
E2	SRN	SRN
E3	SCL	SCL

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7.2.2.3.2 Co-layout Example

BQ27Z846 and BQ27Z7xx Co-layout Example illustrates an example co-layout between the BQ27Z846 device and the BQ27Z7xx family of TI gas gauge devices that can accommodate both devices so one device can be a drop-in replacement for the other. This example co-layout uses the pinout of the BQ27Z846 and low-side current sensing configuration as a reference.

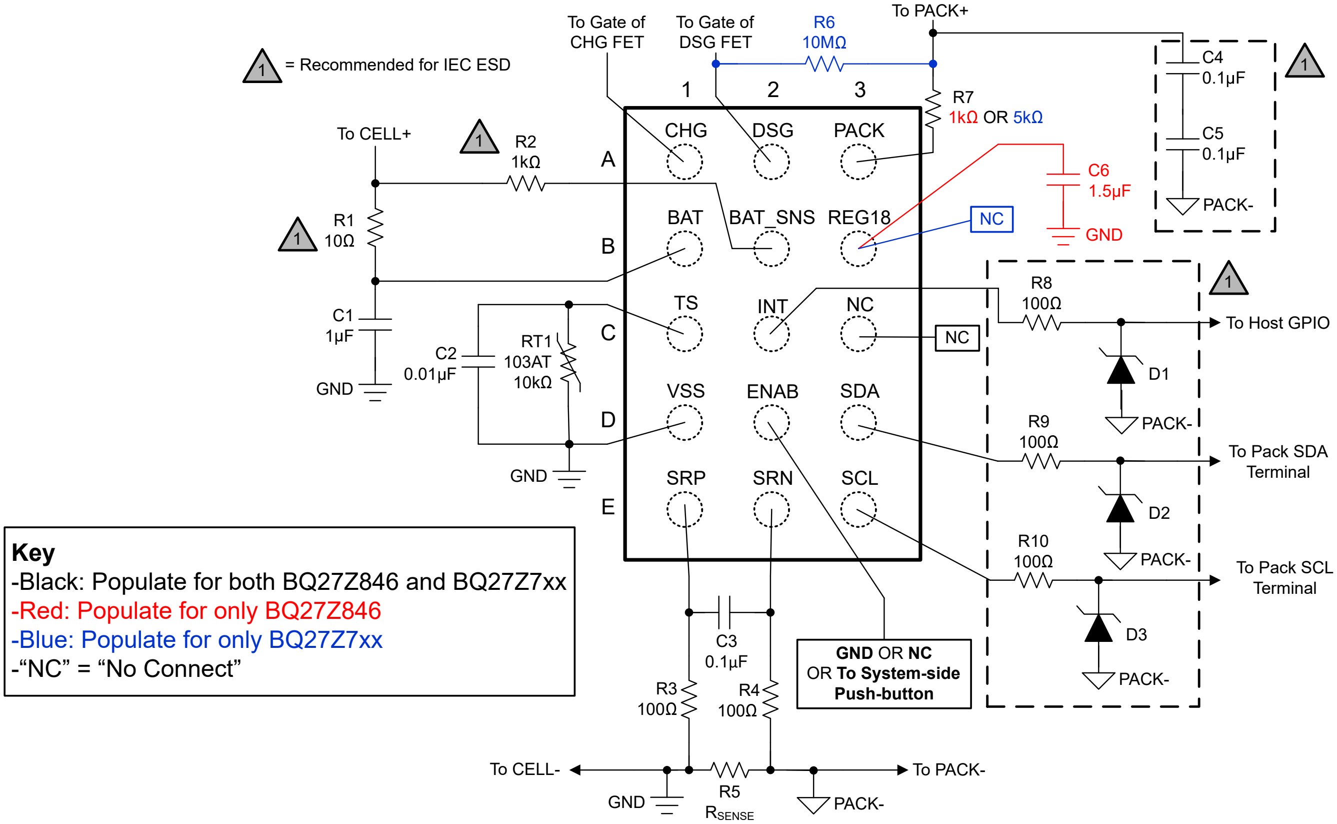

Figure 7-13. BQ27Z846 and BQ27Z7xx Co-layout Example

BQ27Z846 v. BQ27Z7xx External Components details the differences in external components between the BQ27Z846 device and the BQ27Z7xx family of devices.

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Table 7-3. BQ27Z846 v. BQ27Z7xx External Components

Component	TYP Value for BQ27Z846	TYP Value for BQ27Z7xx
R1(1)	10Ω	10Ω
R2(1)	1kΩ	1kΩ
R3	100Ω	100Ω
R4	100Ω	100Ω
R5	R_{SENSE}	R_{SENSE}
R6	DNP	10MΩ
R7	1kΩ	5kΩ
R8(1)	100Ω	100Ω
R9(1)	100Ω	100Ω
R10(1)	100Ω	100Ω
C1	1µF	1µF
C2	0.01µF	0.01µF
C3	0.1µF	0.1µF
C4(1)	0.1µF	0.1µF
C5(1)	0.1µF	0.1µF
C6	1.5µF	DNP
RT1	10kΩ	10kΩ
D1(1)	-	-
D2(1)	-	-
D3(1)	-	-

(1) Recommended for IEC ESD

7.3 Power Supply Recommendations

The BQ27Z846 device uses the BAT pin as its power source. The BAT pin powers the internal voltage sources and 1.8V LDO that supply references for the device.

A capacitor (C_{BAT}) with the recommended typical capacitance of 1µF connected between the BAT pin and VSS is recommended and must be placed as close to the BAT pin as possible.

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8 Layout

8.1 Layout Guidelines

- The quality of the Kelvin connections at the sense resistor is critical. The sense resistor must have a temperature coefficient no greater than 50ppm to minimize current measurement drift with temperature. Choose the value of the sense resistor to correspond to the available overcurrent and short circuit protection ranges and desired protection threshold setting of the BQ27Z846. Select the smallest sense resistor value possible to minimize thermal dissipation and still maintain required measurement accuracy. The value of the sense resistor impacts the differential voltage generated across the BQ27Z846 SRP and SRN nodes during a short circuit. These pins have a differential voltage and should not exceed V_{CCADC_IN} of ±100mV for normal operation. Parallel sense resistors can be used as long as good Kelvin sensing is maintained. The device is designed to support a minimum sense resistor value of 0.5mΩ.
- BAT_SNS should be tied directly to the positive connection of the battery with a series 1kΩ resistor. It should not share a path with the BAT pin and its 10Ω series resistor. The quality of the Kelvin connection to the battery cell is critical. The Kelvin connection at the positive terminal of the cell avoids any errors due to a voltage drop caused by the copper trace.
- The device's BAT pin is recommended to be Kelvin connected to reduce trace resistance between the connection point and the input power supply of the device. The Kelvin connection can be made to the postive terminal of the battery (CELL+) or to the top or SRP node of the sense resistor depending on if the device is configured for low-side or high-side current sensing.
- In reference to the gas gauge circuit, the following features require attention for component placement and layout:
  - **BAT decoupling capacitor:** Place a capacitor (C_{BAT}) with the recommended typical capacitance of 1μF connected between the BAT pin and VSS as close to the BAT pin as possible.
  - **Coulomb counter interface at the SRP and SRN pins:** The BQ27Z846 gas gauge uses an integrating delta-sigma ADC for current measurements. Add 100Ω resistors from the sense resistor to the SRP and SRN inputs of the device. Place a 0.1μF filter capacitor across the SRP and SRN inputs. Place all filter components as close as possible to the device. Route the traces from the sense resistor as differential pairs to the filter circuit. Adding a ground plane around the filter network can provide additional noise immunity
  - **REG18 decoupling capacitor:** The device's internal 1.8V LDO requires an external decoupling capacitor to support proper device operation. Place a capacitor (C_{REG18}) with the recommended typical capacitance of 1.5μF connected between the REG18 pin and VSS as close to the REG18 pin as possible.
  - **I^2C communication and INT pin ESD external protection:** The I^2C clock and data pins and INT pin have integrated high-voltage ESD protection circuits. However, adding a Zener diode and series resistor provides more robust ESD performance. The I2C clock and data lines have internal pull-down resistors. When the gas gauge senses that both lines are low (such as during removal of the pack), the device goes into SLEEP mode to conserve power.

ADVANCE INFORMATION

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9 Device and Documentation Support

9.1 Third-Party Products Disclaimer

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9.2 Documentation Support

9.2.1 Related Documentation

For related documentation, see the following:

- Texas Instruments, *BQ27Z846 Technical Reference Manual*
- Texas Instruments, *Dynamic Z-Track™ Technology: An Advanced Battery Gauging Algorithm for Dynamic Load Applications*
- Texas Instruments, *Implementation of Elliptic Curve Cryptography Authentication on TI Battery Fuel Gauges*
- Texas Instruments, *IC Package Thermal Metrics*

9.3 Trademarks

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9.4 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.

9.5 Glossary

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

10 Revision History

DATE	REVISION	NOTES
April 2026	*	Initial Release

11 Mechanical, Packaging, and Orderable Information

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

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PACKAGE OPTION ADDENDUM

PACKAGING INFORMATION

Orderable part number	Status	Material type	Package | Pins	Package qty | Carrier	RoHS	Lead finish/Ball material	MSL rating/Peak reflow	Op temp (°C)	Part marking
BQ27Z846YAHR	Active	Preproduction	DSBGA (YAH) | 15	3000 | LARGE T&R	Y	SAC396	Level-1-260C-UNLIM	-40 to 85	BQ27Z846

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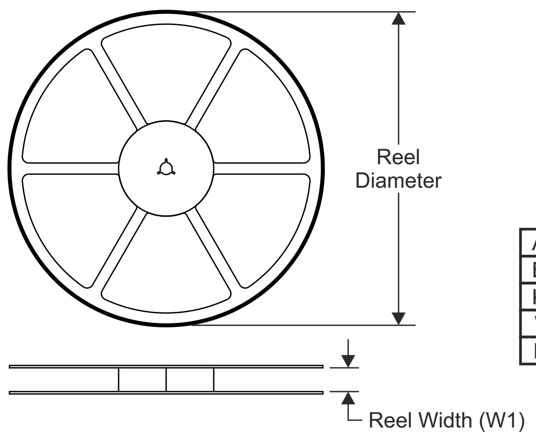
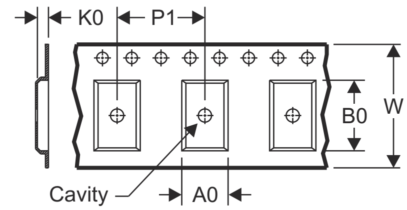
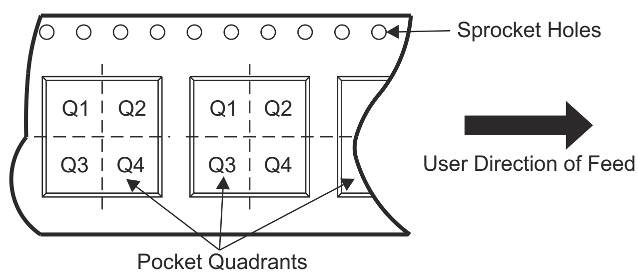
ADVANCE INFORMATION

11.1 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



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
BQ27Z846YAHR	DSBGA	YAH	15	3000	180.0	12.4	1.88	2.76	0.55	4.0	12.0	Q1

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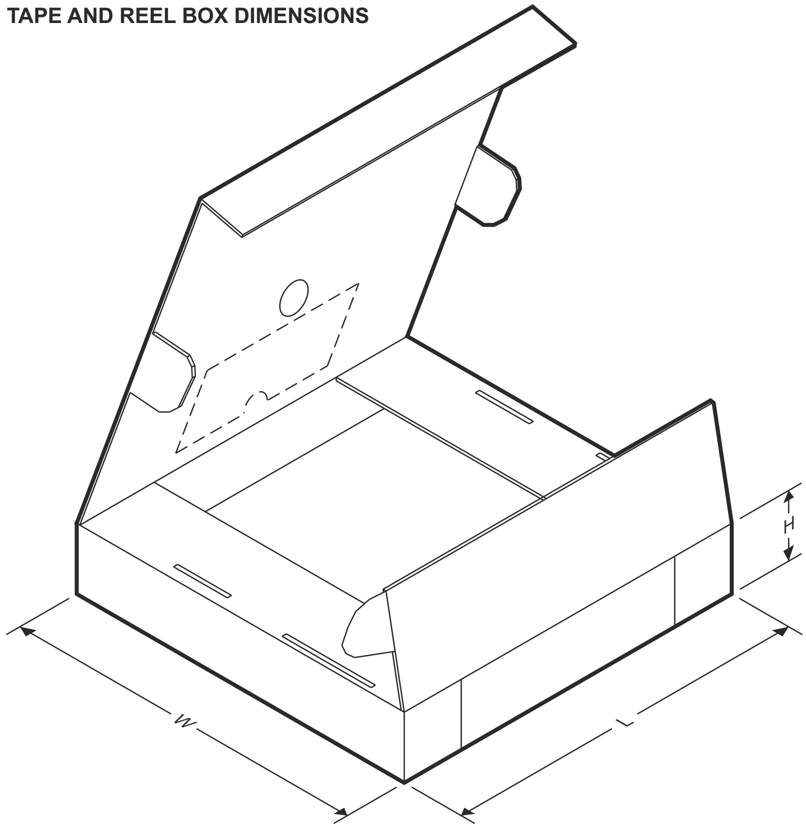
TAPE AND REEL BOX DIMENSIONS



Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
BQ27Z846YAHR	DSBGA	YAH	15	3000	182.0	182.0	20.0

ADVANCE INFORMATION

ADVANCE INFORMATION

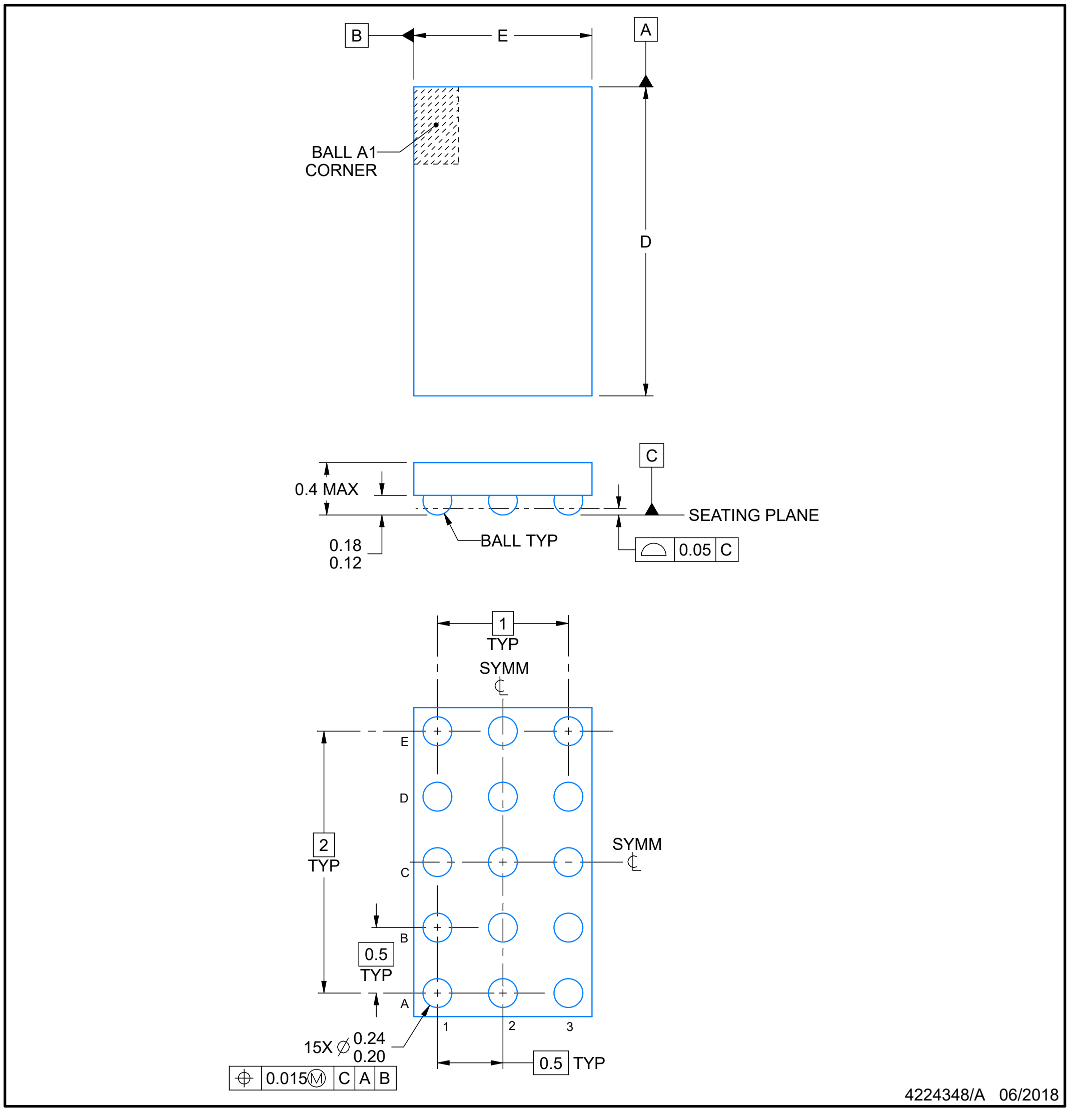
11.2 Mechanical Data

YAH0015

PACKAGE OUTLINE

DSBGA - 0.4 mm max height

DIE SIZE BALL GRID ARRAY



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.

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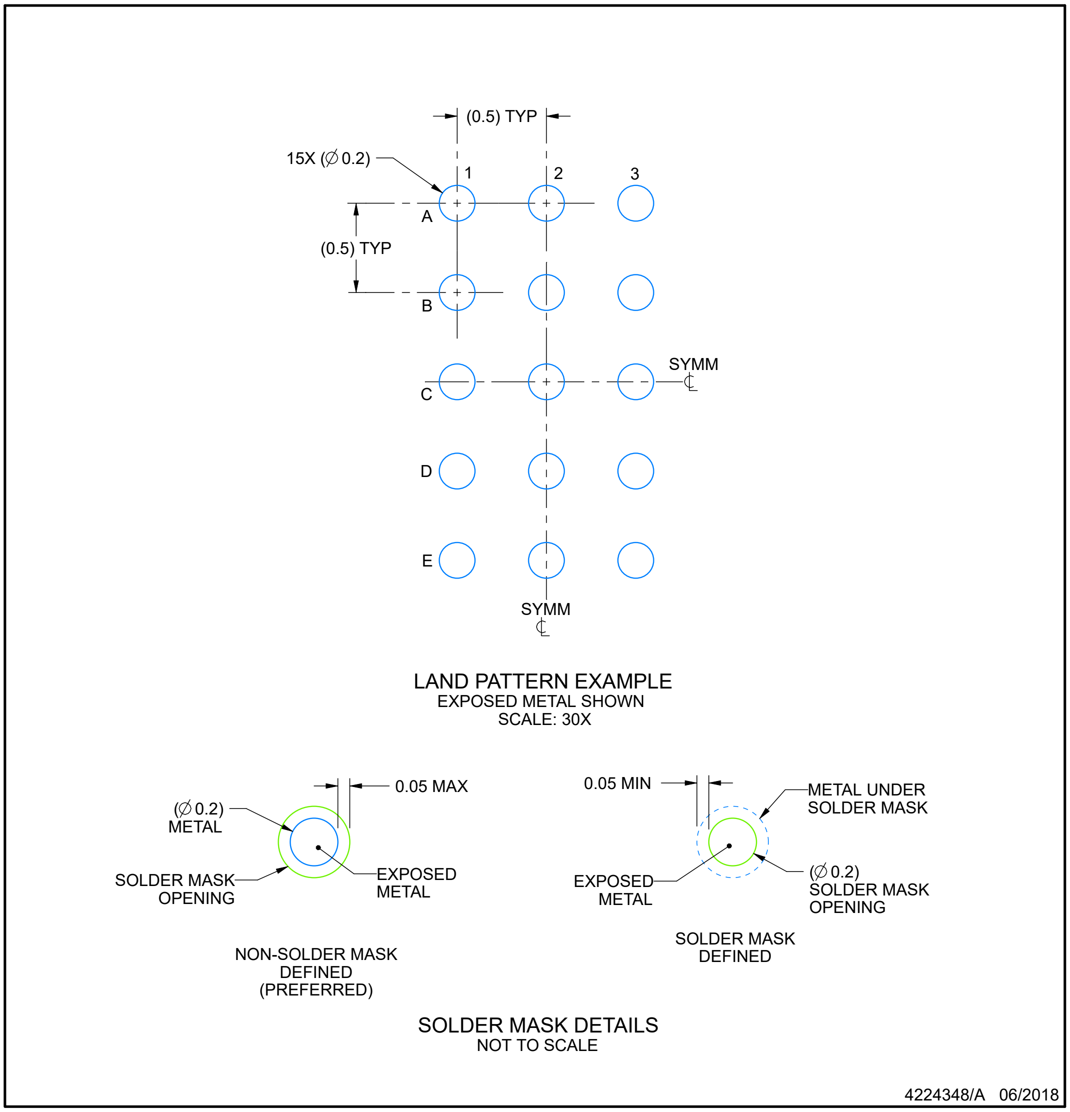
EXAMPLE BOARD LAYOUT

YAH0015 DSBGA - 0.4 mm max height

DIE SIZE BALL GRID ARRAY



NOTES: (continued)

3. Final dimensions may vary due to manufacturing tolerance considerations and also routing constraints. See Texas Instruments Literature No. SNVA009 (www.ti.com/lit/snva009).

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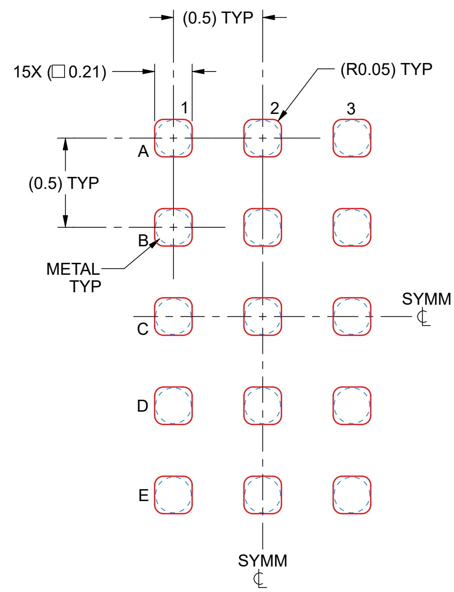
EXAMPLE STENCIL DESIGN

YAH0015

DSBGA - 0.4 mm max height

DIE SIZE BALL GRID ARRAY



SOLDER PASTE EXAMPLE
BASED ON 0.075 mm THICK STENCIL
SCALE: 30X

4224348/A 06/2018

NOTES: (continued)

4. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release.

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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)
PQ27Z846YAHR	Active	Preproduction	DSBGA (YAH) | 15	3000 | LARGE T&R	-	Call TI	Call TI	-40 to 85	

(1) **Status:** For more details on status, see our product life cycle.

(2) **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.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.

(4) **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.

(5) **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.

(6) **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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