

## bq20z65EVM-001 SBS 1.1 Impedance Track<sup>™</sup> Technology Enabled Battery Management Solution Evaluation Module

This evaluation module (EVM) is a complete evaluation system for the bq20z65/bq29412 battery management system. The EVM includes one bq20z65/bq29412 circuit module and a link to Windows<sup>™</sup>-based PC software. The circuit module includes one bq20z65 integrated circuit (IC), one bq29412 IC, and all other onboard components necessary to monitor and predict capacity, perform cell balancing, monitor critical parameters, protect the cells from overcharge, over-discharge, short-circuit, and overcurrent in 2-, 3- or 4-series cell Li-ion or Li-polymer battery packs. The circuit module connects directly across the cells in a battery. With the EV2300 interface board and software, the user can read the bq20z65 data registers, program the chipset for different pack configurations, log cycling data for further evaluation, and evaluate the overall functionality of the bq20z65/bq29412 solution under different charge and discharge conditions.

#### Contents

1	Features	2
2	bq20z65-Based Circuit Module	2
3	bq20z65 Circuit Module Schematic	3
4	Circuit Module Physical Layouts and Bill of Materials	3
5	EVM Hardware and Software Setup	8
6	Troubleshooting Unexpected Dialog Boxes	8
7	Hardware Connection	8
8	Operation	9
9	Calibration Screen	12
10	Pro (Advanced) Screen	13
11	Related Documentation from Texas Instruments	14

#### List of Figures

1	bq20z65EVM-001 Layout – Silk Screen	4
2	Top Assembly	4
3	Top Layer	
4	Bottom Layer	5
5	Bottom Assembly	5
6	Schematic	7
7	bq20z65 Circuit Module Connection to Cells and System Load/Charger	9
8	SBS Data Screen	10
9	Data Flash Screen, 1st Level Safety Class	11
10	Calibration Screen	13
11	Pro (Advanced) Screen	14

#### List of Tables

1	Ordering Information	2
2	Components and Flash-Memory Settings for Different Precharge Modes	3
3	Bill of Materials	5
4	Performance Specification Summary	8
5	Circuit Module to EV2300 Connections	9

#### 1 Features

- Complete evaluation system for the bq20z65 SBS 1.1-compliant advanced gas gauge with Impedance Track<sup>™</sup> technology and bq29412 independent overvoltage protection IC
- Populated circuit module for quick setup
- Software that allows data logging for system analysis

## 1.1 Kit Contents

- bq20z65/bq29412 circuit module
- Set of support documentation

## 1.2 Ordering Information

#### Table 1. Ordering Information

EVM PART NUMBER	CHEMISTRY	CONFIGURATION	CAPACITY
bq20z65EVM-001	Li-ion	2, 3, or 4 cell	Any

## 2 bq20z65-Based Circuit Module

The bq20z65/bq29412-based circuit module is a complete and compact example solution of a bq20z65 circuit for battery management and protection of Li-ion or Li-polymer packs. The circuit module incorporates a bq20z65 battery monitor IC, bq29412 independent overvoltage protection IC, and all other components necessary to accurately predict the capacity of 2-, 3-, or 4-series cells.

## 2.1 Circuit Module Connections

Contacts on the circuit module provide the following connections:

- Direct connection to the cells: 1N (BAT-), 1P, 2P, 3P, 4P (BAT+)
- To the serial communications port (SMBC, SMBD)
- The system load and charger connect across PACK+ and PACK-
- To the system-present pin (SYS PRES)

## 2.2 Pin Descriptions

•	
PIN NAME	DESCRIPTION
1N	-ve connection of first (bottom) cell
1P	+ve connection of first (bottom) cell
2P	+ve connection of second cell
3P	+ve connection of third cell
4P	+ve connection of fourth (top) cell
SMBC	Serial communication port clock
SMBD	Serial communication data port
SYS PRES	System present pin (if low, system is present)
PACK-	Pack negative terminal
VSS	Pack negative terminal
PACK+	Pack positive terminal

Impedance Track, bqEasy are trademarks of Texas Instruments. Windows is a trademark of Microsoft Corporation.



#### 3 bq20z65 Circuit Module Schematic

This section contains information for modifying and choosing a precharge mode for bq20z65/bq29412 implementation.

## 3.1 Schematic

The schematic follows the bill of materials in this user's guide.

#### 3.2 Modifications for Choosing Particular Precharge Mode

In order to charge, the charge FET (CHG-FET) must be turned on to create a current path. When the  $V_{(BAT)}$  is 0 V and CHG-FET = ON, the  $V_{(PACK)}$  is as low as the battery voltage. In this case, the supply voltage for the device is too low to operate. This function has three possible configurations, and the IC can be easily configured according to the application needs. The three modes are 0-V Charge FET mode, Common FET mode, and Precharge FET mode.

- 1. 0-V Charge FET mode Dedicates a precharge current path using an additional FET (ZVCHG-FET) to sustain the PACK+ voltage level.
- 2. Common FET mode Does not use a dedicated precharge FET. The charge FET (CHG-FET) is set to ON state as default.
- 3. Precharge FET mode Dedicates a precharge current path using an additional open-drain (OD) pin drive FET (PCHG-FET) to sustain the PACK+ voltage level.

To use a particular mode of charging with the EVM, add or remove some elements shown in Table 2, and use the given settings of DF.Configuration, ZVCHG1, 0.

		Wodes		
MODE	RESISTORS	PRECHG FET	ZVCHG1	ZVCHG0
1. 0-V Chg (default)	R21, R28	Q3	0	0
2. Common FET	R24	Q2	0	1
3. Precharge	R23, R28	Q3	1	0

# Table 2. Components and Flash-Memory Settings for Different Precharge Modes

For more details about precharge operation and mode choices, see the bq20z65 data sheet (SLUS878).

#### 3.3 Testing Fuse-Blowing Circuit

To prevent the loss of board functionality during the fuse-blowing test, the actual chemical fuse is not provided in the circuit. FET Q1 drives TP3 low if a fuse-blow condition occurs; so, monitoring TP3 can be used to test this condition. Fuse placement on the application board is shown in the bq20z65 data sheet reference-board schematic.

#### 4 Circuit Module Physical Layouts and Bill of Materials

This section contains the printed-circuit board (PCB) layout, bill of materials, and assembly drawings for the bq20z65/bq29412 circuit module.

#### 4.1 Board Layout

This section shows the dimensions, PCB layers (Figure 1 through Figure 5), and assembly drawing for the bq20z65 module.

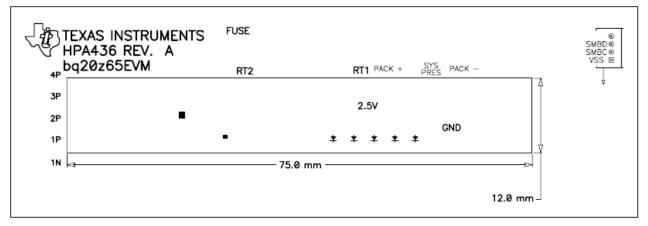
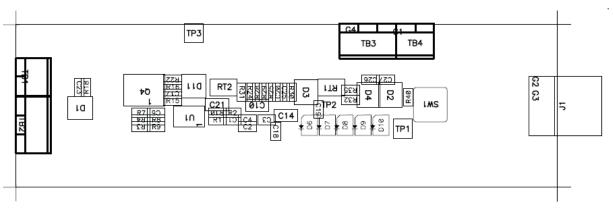


Figure 1. bq20z65EVM-001 Layout - Silk Screen



## Figure 2. Top Assembly

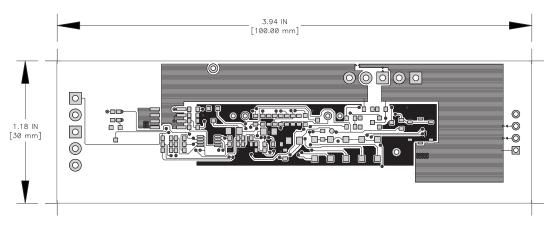
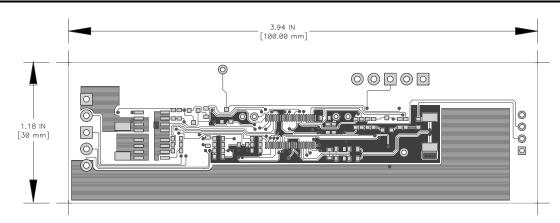


Figure 3. Top Layer







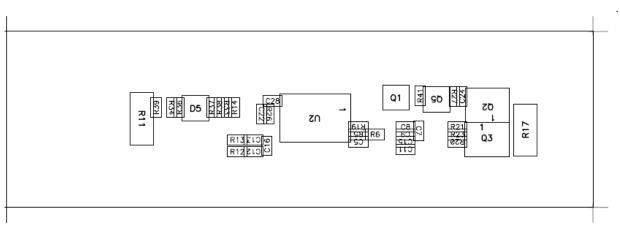


Figure 5. Bottom Assembly

## 4.2 Bill of Materials and Schematic

#### Table 3. Bill of Materials

Count	RefDes	Description	Size	Mfr	Part Number
21	C1–C9, C12, C13, C15–C18, C23, C24, C26–C28	Capacitor, Ceramic, 0.1µF, 50 V, X7R, 20%	0603	Any	STD
1	C11	Capacitor, Ceramic, 0.22µF, 50 V, X7R, 20%	0603	Any	STD
1	C19	Capacitor, Ceramic, 4.7µF, 10 V, X7R, 20%	0603	Any	STD
1	C20	Capacitor, Ceramic, 47nF, 50 V, X7R, 20%	0603	Any	STD
2	C22, C25	Capacitor, Ceramic, 0.47µF, 16 V, X7R, 20%	0603	Any	STD
3	C10, C14, C21	Capacitor, Ceramic, 1.0µF, 25 V, X7R, 20%	0805	Any	STD
4	D1–D3, D11	Diode, Switching, 150-mA, 75-V, 350mW	SOT23	Vishay-Liteon	BAS16
2	D4, D5	Diode, Dual, Zener, 5.6V, 300mW	SOT23	Vishay- Telefunken	AZ23C5V6
5	D6-D10	Diode, LED, Green, Gullwing, GW Type, 20ma, 7.5 mcd typ.	0.120 × 0.087 inches	Panasonic	LN1361C
1	J1	Header, Friction Lock Ass'y, 4-pin Right Angle,	0.400  imes 0.500	Molex	22-05-3041
1	Q1	MOSFET, N-ch, 20-V, 1.3A, 0.16-Ω	SOT23	Fairchild	NDS331N
2	Q2, Q4	MOSFET, N-ch Logic Level, Power Trench, 30V, 11A, 12.5 m $\Omega$	SO8	Fairchild	FDS6690A



Count	RefDes	Description	Size	Mfr	Part Number
1	Q3	MOSFET, P-ch, 30-V, 8.0-A, 20-mΩ	SO8	Siliconix	Si4435DY
1	Q6	MOSFET, Nch, 50V, 0.22A, 6 Ω	SOT23	Fairchild	BSS138
12	R1–R5, R12, R13, R32–R34, R38, R39	Resistor, Chip, 100-Ω, 1/16-W, 5%	0603	Std	Std
1	R11	Resistor, Chip, 0.010 Ω, 1-W, xx%	2512	Vishay	WSL-2512-010 1% R86
3	R15, R16, R40	Resistor, Chip, 220 kΩ, 1/16-W, 5%	0603	Std	Std
1	R17	Resistor, Chip, 300-Ω, 1-W, 10%	2512		WSL-2512-300 1% R86
2	R18, R27	Resistor, Chip, 3.01MΩ, 1/16-W, 5%	0603	Std	Std
5	R14, R19, R21–R23	Resistor, Chip, 5.1kΩ, 1/16-W, 5%	0603	Std	Std
4	R20, R36, R37, R41	Resistor, Chip, 1MΩ, 1/16-W, 5%	0603	Std	Std
2	R24, R28	Resistor, Chip, 100kΩ, 1/16-W, 5%	0603	Std	Std
2	R25, R29	Resistor, Chip, 8.45kΩ, 1/16-W, 1%	0603	Std	Std
2	R26, R30	Resistor, Chip, 61.9kΩ, 1/16-W, 1%	0603	Std	Std
7	R6–R10, R31, R35	Resistor, Chip, 1kΩ, 1/16-W, 5%	0603	Std	Std
2	RT1, RT2	Thermistor, $10k\Omega$	0.095 × 0.150	Semitec	NTC103AT
1	SW1	Switch, Push button, Momentary, N.O. Low Profile	$5 \text{ mm} \times 5 \text{ mm}$	Panasonic	EVQPLCxxxx
2	TB1, TB4	Terminal Block, 2-pin, 6-A, 3,5mm	0.27 × 0.25	OST	ED1514
2	TB2, TB3	Terminal Block, 3-pin, 6-A, 3,5mm	0.41 × 0.25	OST	ED1515
1	TP1	Test Point, Black, Thru Hole Color Keyed	$0.100 \times 0.100$ inch	Keystone	5001
1	TP3	Test Point, White, Thru Hole Color Keyed	$0.100 \times 0.100$ inch	Keystone	5002
1	U1	IC, Voltage Protection for 2, 3, 4 Cell Lion , 2nd Protection, 4.45 V OVP	SSOP-08	ТІ	BQ29412DCT
1	U2	IC, Cool-GG Programmable Battery Management	TSSOP30	ТІ	bq20z65DBT

#### Table 3. Bill of Materials (continued)





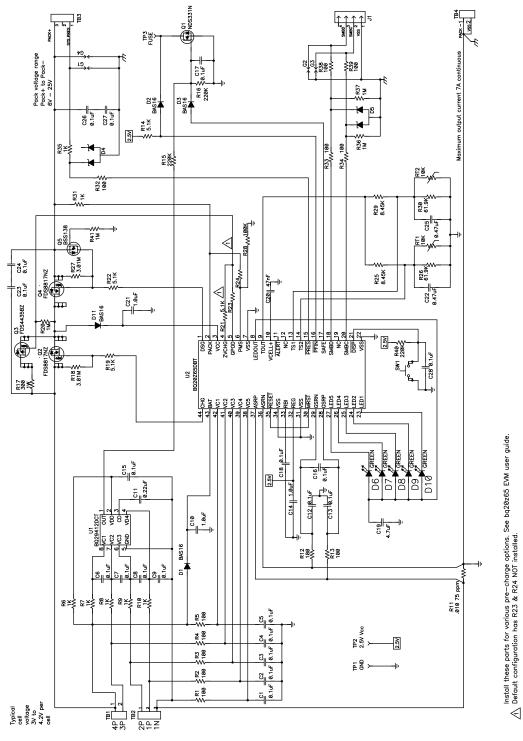


Figure 6. Schematic

## 4.3 bq20z65/bq29412 Circuit Module Performance Specification Summary

This section summarizes the performance specifications of the bq20z65/bq29412 circuit module.



		inal y		
Specification	Minimum	Typical	Maximum	Units
Input voltage Pack+ to Pack-	6	15	25	V
Charge and discharge current	0	2	7	А

#### Table 4. Performance Specification Summary

#### 5 EVM Hardware and Software Setup

This section describes how to install the bq20z65 PC software and how to connect the different components of the EVM.

#### 5.1 System Requirements

The bq20z65EVSW software requires Windows™ 2000 or Windows XP.

#### 5.2 Software Installation

Find the latest software version in the bq20z65 tool folder on <u>power.ti.com</u>. Use the following steps to install the bq20z65EVSW software:

- Copy the files from the Ti Web site into a temporary directory you select, double-click on bqEV-EASYSetup00.09.xx.exe, where xx indicates the version, and follow the installer instructions to complete the bq20z60 EVSW installation.
- If the EV2300 was not previously installed, after bq20z60 EVSW installation, a TI USB DRIVER INSTALLER pops up. Click Yes for the agreement message and follow its instructions. Two drivers are associated with the EV2300. Follow the instructions to install both. Do not reboot the computer, even if asked to do so.
- 3. Plug the EV2300 into a USB port. The Windows system may show a prompt that new hardware has been found. When asked, "Can Windows connect to Windows Update to search for software?", select "No, not this time" and click on NEXT. In the next dialog window, it indicates "This wizard helps you install software for: TI USB Firmware Updater", select "Install the software automatically (Recommended)" and click NEXT. It is common for the next screen to be the Confirm File Replace screen. Click No to continue. If this screen does not appear, then go to the next step. After Windows indicates that the installation was finished, a similar dialog window pops up to install the second driver; proceed with the same installation preference as the first one. The second driver is TI USB bq80xx Driver.

#### 6 Troubleshooting Unexpected Dialog Boxes

The following actions can help the user to avoid unexpected dialog boxes.

- Ensure that the files were extracted from the zip file using the Preserve Folder names option.
- Ensure that all the files were extracted from the zip file.
- The user that is downloading the files must be logged in as the administrator.
- The driver is not signed, so the administrator must allow installation of unsigned drivers in the operating system policy.

#### 7 Hardware Connection

The bq20z65EVM-001 comprises three hardware components: the bq20z65/bq29412 circuit module, the EV2300 PC interface board, and the PC.

#### 7.1 Connecting bq20z65/bq29412 Circuit Module to Battery Pack

Figure 7 shows how to connect the bq20z65/bq29412 circuit module to the cells and system load/charger.

The cells must be connected in the following order:



- 1. 4-Cell Pack: 1N (BAT–), 1P, 2P, 3P, and 4P (see Section 2.1 for definitions).
- 2. 3-Cell Pack: 1N (BAT–), 1P, 2P, and then connect 4P and 3P together.
- 3. 2-Cell Pack: 1N (BAT-), 1P, and then connect 4P, 3P, and 2P together

To start charge or discharge test, connect PRES pin to PACK- pin to set SYS PRES state. To test sleep mode, disconnect the SYS PRES pin.

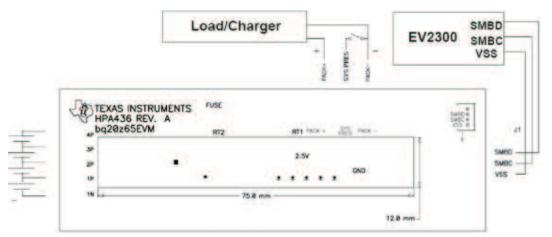


Figure 7. bq20z65 Circuit Module Connection to Cells and System Load/Charger

## 7.2 PC Interface Connection

The following steps configure the hardware for interface to the PC:

1. Connect the bq20z65-based smart battery to the EV2300 using wire leads as shown in Table 5.

bq20z65-Based Battery	EV2300
SMBD	SMBD
SMBC	SMBC
VSS	GND

#### Table 5. Circuit Module to EV2300 Connections

2. Connect the PC USB cable to the EV2300 and the PC USB port.

The bq20z65EVM-001 is now set up for operation.

## 8 Operation

This section details the operation of the bq20z65 EVSW software.

#### 8.1 Starting the Program

Run bq Evaluation Software from the Start | Programs | Texas Instruments | bq20z65 EVSW menu sequence. The SBS Data screen (Figure 8) appears. Data begins to appear once the <Refresh> (single time scan) button is clicked, or when the <Keep Scanning> check box is checked. To disable the scan feature, deselect <Keep Scanning>.

The continuous scanning period can be set via the | Options | and | Set Scan Interval | menu selections. The range for this interval is 0 ms to 65535 ms. Only items that are selected for scanning are scanned within this period.



Operation

The bq Evaluation Software provides a logging function which logs the values that were last scanned by EVSW. To enable this function, select the *Start Logging* button; this causes the *Keep Scanning* button to be selected. When logging is *Stopped*, the keep scanning button is still selected and has to be manually unchecked.

The logging intervals are specified under the | Options | menu with the maximum value of 65535 ms. The *Log* interval cannot be smaller than the scan interval because this results in the same value being logged at least twice.

150	<u>A</u> utoCycle <u>V</u> iew <u>W</u> indow	ATTAN)			A C 616	A COLUMN TO A COLUMN	56.050	COLUMN T	No.		100-000	Distance.	101000	2.10
	🤣 TEXAS INSTRUME	NTS			REA	L W D	RLD	SIGN	I A L	- P	RO	C E Ş	5 I N	
	Refresh Logging		Keep canning	6	Write 2 Comma									
	Name	Value	Unit	Log	Scan	Name		Value	Unit	Log	Scan	1		
	Manufacturer Access	0000	hex	V		Average Tim	e to Empty	65535	min	V	V			
	Remaining Cap. Alarm	300	mAh	7		Average Tim		65535	min	V	1			
SRS	Remaining Time Alarm	10	min	-	~	Charging Cur		4000	mA	-	V			
	Battery Mode	6081	hex	V		Charging Vol		16800	mV	1	1			
	At Rate	0	mA	-		Battery State		0000	hex	~	1			
	At Rate Time To Full	65535	min	V	V	Cycle Count		0	-	V	V			
SBS Data Flash Pro Calibrate bqCHEM	At Rate Time To Empty	65535	min	V		Cell Voltage -	4	4033	mV	V	V			
Flash	At Rate OK	1		V		Cell Voltage		3990	mV	V	V			
lash	Temperature	24.75	degC	V		Cell Voltage :		3986	mV	V	V			
	Voltage	15989	mV	7		Cell Voltage		3979	mV	V	7			
	Current	0	mA	-		FET Control		0006	hex	V	V			
	Average Current	0	mA	V		PF Status		0000	hex	V	V			
Pro	Max Error	100	%	-	1	PF Status2		0000	hex	V	V			
	Relative State of Charge	84	%	-	7	Safety Statu	15	0000	hex	V	V			
	Absolute State of Charge	77	%	-		Safety Statu		0000	hex	V	V			
	Remaining Capacity	3386	mAh	V	V	Operation St		8043	hex	V	V			
brate	Full charge Capacity	4048	mAh	V		Charging Sta		0400	hex	V	V			
	Run time To Empty	65535		7	~	Temperature		0004	hex	V	1			
			1000 B 100 B	8 N C		Alter Maria and and								
HEM	Flags / Status Bits													
	Battery Status - SCANN	ING					Operatio	n Status -	5CANN	IING				
	OCA TCA RSVD	OTA	TDA	RS	D RCA	RTA	PRES			CSV	RSVD	LDMD	RSVD	RSVD
	INIT DSG FC	FD	EC3	EC	2 EC1	EC0	WAKE	DSG X	DSG X	DSGI	DSGIN	R_DIS	VOK	QEN
	Charging Status - SCAN	NING					PF Status	- SCANN	ING					
	XCHG CHSUSP PCHG				HG ST2CH		RSVD			RSVD		SOCC	AFE_P	AFE_C
	RSVD CB RSVD	RSVD	RSVD	RS	D OC	RSVD	DFF	DFETF CF	ETFC	IM_R	SOT1D	SOTIC	SOV	PFIN
	PF Status2 - SCANNING			-	31-12			Node - SCA	_	_			-	
	RSVD RSVD RSVD		RSVD	RSI			CapM			RSVD	RSVD	RSVD	PB	CC
	RSVD RSVD RSVD	RSVD	RSVD	SOT	2D SOT2	C CIM_A	CF			RSVD	RSVD	RSVD	PBS	ICC
	FET Control - SCANNIN	0.43	-			-	A CONTRACT OF A	ure Range		A CONTRACTOR OF	201			
100%	RSVD RSVD RSVD RSVD RSVD RSVD		RSVD	RS\ CH		RSVD	the second se			TR4	RSVD TR3	RSVD TR2a	RSVD TR2	RSVD TR1
	the second state of the second state	alexan "	ZUCHO		0 000	KOOD	and the second second	and the Train	and the second s	-censer	1160	INZU	ING	INA
	Safety Status - SCANN	ENG OCC	RSVD	RSI	D RSVD	RSVD	Satety S RSVD	tatus2 - So RSVD R		NG RSVD	RSVD	RSVD	RSVD	RSVD
	CUV COV PF	RSVD	WDF	AO		SCD	RSVD			RSVD	RSVD	RSVD	OT2D	OT2C
							[	No. I N						
	i.	Shor	. Flags							Shou	v Static	Data		
I Gauge	L	21101		-			<u> </u>			Gridy	, ordine	Ford		

Figure 8. SBS Data Screen

This screen (Figure 8) shows the SBS data set along with additional ManufacturersAccess() command information such as individual cell measurements. Additional Flag and Static data can be viewed by selecting the appropriate tab at the bottom of the SBS screen.

Data such as SBS.ManufacturerName() is static and does not change. This data is viewed separately using the *Static Data* tab available at the bottom of the screen.

Dragging the splitter bar (line that separates the Flags/Static data from SBS values) changes the height of the Flags/Static Data display. Selecting | View |, then | Auto Arrange | returns the splitter bar to its original location.



## 8.2 Setting Programmable bq20z65 Options

The bq20z65 data flash comes configured per the default settings detailed in the bq20z65 data sheet. Ensure that the settings are correctly changed to match the pack and application for the bq20z65 solution being evaluated.

**IMPORTANT:** The correct setting of these options is essential to get the best performance.

The settings can be configured using the Data Flash screen (Figure 9).

Bead All       Write All       Write All, Preserve       "Right click on constant name for more information         PF Status       Calibration       Power       Gas Gauging       Ra Table         Ist Level Safety       2nd Level Safety       Charge Control       SBS Configuration       System Data         Name       Value       Unit       Name       Value       Unit         It CoV Threshold       4300       mV       AFE SC Dsg Cfg       77       -         It CoV Threshold       4500       mV       Name       Value       Unit         AFE SC OW Recovery       4100       mV       OT1 Chg Threshold       55.0       degC         St COV Threshold       4200       mV       OT1 Chg Recovery       50.0       degC         OT1 Chg Recovery       3000       mV       OT2 Chg Threshold       55.0       degC         OT2 Chy Recovery       3000       mV       OT2 Chg Recovery       50.0       degC         OC (List Tier) Chg       6000       mA       OT2 Dsg Threshold       60.0       degC         OT1 Dsg Recovery       55.0       degC       OT2 Dsg Threshold       60.0       degC         OT2 Dsg Time       2       5       OT2 Dsg Threshold       60.0	V TEXAS INSTRU		- 1997 1997	EALWO				
ConfigurationLED SupportPowerGas GaugingRa TableTet Level Safety2nd Level SafetyCharge ControlSBS ConfigurationSystem DataB5NameValueUnitNameValueUnitVoltageAFE SC Dsg Cfg77-LT COV Threshold4300mVOT1 Chg Threshold55.0degCST COV Threshold4500mVOT1 Chg Threshold55.0degCST COV Threshold4500mVOT1 Chg Threshold55.0degCST COV Recovery4300mVOT1 Chg Recovery50.0degCHT COV Threshold4200mVOT2 Chg Threshold55.0degCHT COV Threshold2200mVOT2 Chg Threshold55.0degCCUV Threshold2200mVOT2 Chg Recovery50.0degCCUV Recovery3000mVOT1 Dsg Threshold60.0degCCUV Recovery3000mAOT1 Dsg Threshold60.0degCCUV Recovery3000mAOT1 Dsg Time2sOC (1st Tier) Chg6000mAOT1 Dsg Recovery55.0degCOC (1st Tier) Dsg6000mAOT2 Dsg Threshold60.0degCOC (1st Tier) Dsg6000mAOT2 Dsg Threshold60.0degCOC (1st Tier) Dsg12OT2 Dsg Recovery55.0degCAFE OC Dsg12-OT2 Dsg Recovery55.0degCA	<u>Bead All</u> Writ	e All Write All,	Preserve	*Right click o	on constant nam	e for more in	formation	
Ist Level Safety       2nd Level Safety       Charge Control       SBS Configuration       System Data         Name       Value       Unit       Name       Value       Unit         Voltage       -       -       AFE SC Dsg Cfg       77       -         LT COV Threshold       4300       mV       Temperature       -       -         LT COV Threshold       4500       mV       OT1 Chg Threshold       55.0       degC         ST COV Threshold       4500       mV       OT1 Chg Recovery       50.0       degC         ST COV Recovery       4300       mV       OT1 Chg Recovery       50.0       degC         HT COV Threshold       4200       mV       OT2 Chg Threshold       55.0       degC         HT COV Threshold       2200       mV       OT2 Chg Threshold       50.0       degC         CUV Threshold       2200       mV       OT2 Chg Recovery       50.0       degC         CUV Threshold       2200       mV       OT2 Chg Recovery       50.0       degC         CUV Recovery       3000       mV       OT1 bg Time       2       s         OC (1st Tier) Chg       6000       mA       OT2 bg Threshold       60.0       degC <th>PF Status</th> <th>Calibration</th> <th>1</th> <th></th> <th>_</th> <th></th> <th></th> <th></th>	PF Status	Calibration	1		_			
NameValueUnitVoltageLT COV Threshold4300mVLT COV Threshold4300mVLT COV Recovery4100mVST COV Threshold4500mVST COV Threshold4500mVST COV Recovery4300mVOT1 Chg Time2sST COV Recovery4300mVOT1 Chg Recovery50.0degCHT COV Threshold4200mVOT2 Chg Threshold55.0degCHT COV Threshold2200mVOT2 Chg Threshold55.0degCCUV Threshold2200mVOT2 Chg Threshold60.0degCCUV Threshold2000mVOT1 bg Time2sCUV Recovery3000mVOT1 bg Time2sOC (1st Tier) Chg6000mAOT1 bg Time2sOC (1st Tier) Dsg6000mAOT2 bg Threshold60.0degC0C (1st Tier) Dsg6000MAOT2 bg Time2AFE OC Dsg12-AFE OC Dsg Time0F-Hi bg Start Temp60.0degC	Configuration	LED Support	Y	Power	Gas Ga	uging )	Ra Table	
Voltage       -       -         LT COV Threshold       4300       mV         LT COV Threshold       4300       mV         LT COV Recovery       4100       mV         ST COV Threshold       4500       mV         ST COV Threshold       4500       mV         ST COV Threshold       4500       mV         HT COV Threshold       4500       mV         HT COV Threshold       4200       mV         OT1 Chg Time       2       s         CUV Threshold       4200       mV       OT2 Chg Threshold       55.0       degC         HT COV Threshold       2200       mV       OT2 Chg Threshold       55.0       degC         CUV Threshold       2200       mV       OT2 Chg Recovery       50.0       degC         CUV Recovery       3000       mV       OT1 Dsg Threshold       60.0       degC         CUV Recovery       3000       mV       OT1 Dsg Threshold       60.0       degC         CUV Recovery       3000       mA       OT1 Dsg Threshold       60.0       degC         CUV Recovery       3000       mA       OT1 Dsg Threshold       60.0       degC         OC (1st Tier) Chg       600	1st Level Safety	2nd Level Safety	ľ	Charge Control	SBS Configu	ration	System Data	
VoltageAFE SC bsg Cfg77-LT COV Threshold4300mVTemperatureLT COV Recovery4100mVOT1 chg Threshold55.0degCST COV Threshold4500mVOT1 chg Threshold55.0degCST COV Recovery4300mVOT1 chg Time2sST COV Recovery4300mVOT1 chg Recovery50.0degCHT COV Threshold4200mVOT2 chg Threshold55.0degCHT COV Recovery4000mVOT2 chg Time2sCUV Threshold2200mVOT2 chg Recovery50.0degCCUV Threshold2000mVOT1 bsg Threshold60.0degCCUV Recovery3000mVOT1 bsg Threshold60.0degCCUV Recovery3000mAOT1 bsg Time2sOC (1st Tier) Chg6000mAOT1 bsg Recovery55.0degCOC (1st Tier) Dsg6000mAOT2 bsg Threshold60.0degCOC (1st Tier) Dsg6000mAOT2 bsg Threshold60.0degCCurrentOT2 bsg Recovery55.0degCAFE OC bsg12-OT2 bsg Recovery55.0degCAFE OC bsg Time0F-Hi bsg Start Temp60.0degC	S Name	Value	Unit	Name		Value	Unit	
LT COV Recovery       4100       mV       OT1 Chg Threshold       55.0       degC         ST COV Threshold       4500       mV       OT1 Chg Threshold       55.0       degC         ST COV Recovery       4300       mV       OT1 Chg Threshold       55.0       degC         HT COV Threshold       4200       mV       OT2 Chg Threshold       55.0       degC         HT COV Threshold       4200       mV       OT2 Chg Threshold       55.0       degC         CUV Threshold       2200       mV       OT2 Chg Threshold       55.0       degC         CUV Threshold       2200       mV       OT2 Chg Recovery       50.0       degC         CUV Threshold       2000       mV       OT2 Chg Recovery       50.0       degC         CUV Recovery       3000       mV       OT1 bg Threshold       60.0       degC         CUV Recovery       3000       mV       OT1 bg Threshold       60.0       degC         Current       -       -       OT1 bg Threshold       60.0       degC         OC (1st Tier) Chg       6000       mA       OT2 bg Threshold       60.0       degC         Current Recovery Time       8       s       OT2 bg Recovery       55.0 </td <td></td> <td></td> <td>100</td> <td>AFE SC Dsg</td> <td>Cfg</td> <td>77</td> <td>-</td> <td></td>			100	AFE SC Dsg	Cfg	77	-	
std ash       ST COV Threshold       4500       mV       OT1 Chg Time       2       s         std ash       ST COV Recovery       4300       mV       OT1 Chg Time       2       s         ro       HT COV Threshold       4200       mV       OT2 Chg Threshold       55.0       degC         ro       CUV Threshold       2200       mV       OT2 Chg Time       2       s         cUV Threshold       2000       mV       OT2 Chg Recovery       50.0       degC         cUV Threshold       2000       mV       OT2 Chg Recovery       50.0       degC         cUV Recovery       3000       mV       OT1 Dsg Threshold       60.0       degC         current       -       -       OT1 Dsg Threshold       60.0       degC         oC (1st Tier) Chg       6000       mA       OT1 Dsg Recovery       55.0       degC         oC (1st Tier) Dsg       6000       mA       OT2 Dsg Threshold       60.0       degC         current Recovery Time       8       s       OT2 Dsg Recovery       55.0       degC         AFE OC Dsg       12       -       OT2 Dsg Recovery       55.0       degC         AFE OC Dsg Time       0F       -	LT COV Threshold	4300	mV	Temperature	£			
ST COV Recovery       4300       mV       OT1 Chg Recovery       50.0       degC         ash       HT COV Threshold       4200       mV       OT2 Chg Threshold       55.0       degC         HT COV Recovery       4000       mV       OT2 Chg Threshold       55.0       degC         CUV Threshold       2200       mV       OT2 Chg Recovery       50.0       degC         CUV Threshold       2200       mV       OT2 Chg Recovery       50.0       degC         CUV Recovery       3000       mV       OT2 Chg Recovery       50.0       degC         CUV Recovery       3000       mV       OT1 Dsg Threshold       60.0       degC         Current       -       -       OT1 Dsg Threshold       60.0       degC         OC (1st Tier) Chg       6000       mA       OT2 Dsg Threshold       60.0       degC         OC (1st Tier) Dsg       6000       mA       OT2 Dsg Threshold       60.0       degC         Current Recovery Time       8       s       OT2 Dsg Recovery       55.0       degC         AFE OC Dsg       12       -       OT2 Dsg Recovery       55.0       degC         AFE OC Dsg Time       0F       -       Hi Dsg Start Temp	LT COV Recovery	4100	mV	OTI Chg Thr	eshold	55.0	degC	
ST COV Recovery         4300         mV         OT1 Chg Recovery         50.0         degc           HT COV Threshold         4200         mV         OT2 Chg Threshold         55.0         degc           HT COV Recovery         4000         mV         OT2 Chg Threshold         55.0         degc           CUV Threshold         2200         mV         OT2 Chg Time         2         s           CUV Threshold         2000         mV         OT2 Chg Recovery         50.0         degc           CUV Threshold         2000         mV         OT2 Chg Recovery         50.0         degc           CUV Recovery         3000         mV         OT1 bsg Threshold         60.0         degc           Current         -         -         OT1 bsg Time         2         s           OC (1st Tier) Chg         6000         mA         OT2 bsg Threshold         60.0         degc           OC (1st Tier) Dsg         6000         mA         OT2 bsg Threshold         60.0         degc           Current Recovery Time         8         s         OT2 bsg Recovery         55.0         degc           AFE OC bsg         12         -         OT2 bsg Recovery         55.0         degc	ST COV Threshold	4500	mV	OT1 Chg Tim	e	2	s	
HT COV Threshold       4200       mV       OT2 Chg Threshold       55.0       degC         HT COV Recovery       4000       mV       OT2 Chg Time       2       s         CUV Threshold       2200       mV       OT2 Chg Recovery       50.0       degC         CUV Recovery       3000       mV       OT2 Chg Recovery       50.0       degC         CUV Recovery       3000       mV       OT1 bsg Threshold       60.0       degC         Current       -       -       OT1 bsg Time       2       s         OC (1st Tier) Chg       6000       mA       OT1 bsg Recovery       55.0       degC         OC (1st Tier) Dsg       6000       mA       OT2 bsg Threshold       60.0       degC         Current Recovery Time       8       s       OT2 bsg Time       2       s         AFE OC bsg       12       -       OT2 bsg Recovery       55.0       degC         AFE OC bsg Time       0F       -       Hi bsg Start Temp       60.0       degC	CT COULD a service of	4300	mV	OT1 Chg Rec	overy	50.0	degC	
CUV Threshold         2200         mV         OT2 Chg Recovery         50.0         degC           CUV Recovery         3000         mV         OT1 bg Threshold         60.0         degC           Current         -         -         OT1 bg Threshold         60.0         degC           OC (1st Tier) Chg         6000         mA         OT1 bg Recovery         55.0         degC           OC (1st Tier) Dsg         6000         mA         OT2 bg Recovery         55.0         degC           OC (1st Tier) Dsg         6000         mA         OT2 bg Recovery         55.0         degC           Current Recovery Time         8         s         OT2 bg Recovery         55.0         degC           AFE OC bsg         12         -         OT2 bg Recovery         55.0         degC           AFE OC bsg Time         0F         -         Hi bg Start Temp         60.0         degC	HT COV Threshold	4200	mV	OT2 Chg Thr	reshold	55.0	degC	
CUV Recovery         3000         mV         OT1 big Threshold         60.0         degC           Current         -         -         -         OT1 big Threshold         60.0         degC           OC (1st Tier) Chg         6000         mA         OT1 big Time         2         s           OC (1st Tier) Dsg         6000         mA         OT2 big Threshold         60.0         degC           OC (1st Tier) Dsg         6000         mA         OT2 big Threshold         60.0         degC           Current Recovery Time         8         s         OT2 big Time         2         s           AFE OC big         12         -         OT2 big Recovery         55.0         degC           AFE OC big Time         0F         -         Hi big Start Temp         60.0         degC	HT COV Recovery	4000	mV	OT2 Chg Tim	ne	2	S	
Current         -         -         OT1 bg Time         2         s           OC (1st Tier) Chg         6000         mA         OT1 bg Recovery         55.0         degC           OC (1st Tier) Dsg         6000         mA         OT2 bg Threshold         60.0         degC           OC (1st Tier) Dsg         6000         mA         OT2 bg Threshold         60.0         degC           Current Recovery Time         8         s         OT2 bg Time         2         s           AFE OC bsg         12         -         OT2 bg Recovery         55.0         degC           AFE OC bsg Time         0F         -         Hi bg Start Temp         60.0         degC	CUV Threshold	2200	mV	OT2 Chg Red	overy	50.0	degC	
Current         -         -         OT1 bsg Time         2         s           OC (1st Tier) Chg         6000         mA         OT1 bsg Recovery         55.0         degC           OC (1st Tier) Dsg         6000         mA         OT2 bsg Threshold         60.0         degC           OC (1st Tier) Dsg         6000         mA         OT2 bsg Threshold         60.0         degC           Current Recovery Time         8         s         OT2 bsg Time         2         s           AFE OC bsg         12         -         OT2 bsg Recovery         55.0         degC           AFE OC bsg Time         0F         -         Hi bsg Start Temp         60.0         degC	CUV Recovery	3000	mV	OT1 Dsg Thr	eshold	60.0	degC	
OC (1st Tier) Dsg     6000     mA     OT2 Dsg Threshold     60.0     degC       Current Recovery Time     8     s     OT2 Dsg Time     2     s       AFE OC Dsg     12     -     OT2 Dsg Recovery     55.0     degC       AFE OC Dsg Time     0F     -     Hi Dsg Start Temp     60.0     degC	Current		100	OT1 Dsg Tim	e	2	s	
Current Recovery Time         8         s         OT2 Dsg Time         2         s           AFE OC Dsg         12         -         OT2 Dsg Recovery         55.0         degC           AFE OC Dsg Time         OF         -         Hi Dsg Start Temp         60.0         degC	OC (1st Tier) Chg	6000	mA	OT1 Dsg Rec	overy	55.0	degC	
AFE OC bsg         12         -         OT2 bsg Recovery         55.0         degC           AFE OC bsg Time         0F         -         Hi bsg Start Temp         60.0         degC	OC (1st Tier) Dsg	6000	mA	OT2 Dsg Thr	reshold	60.0	degC	
AFE OC bsg         12         -         OT2 bsg Recovery         55.0         degC           AFE OC bsg Time         0F         -         Hi bsg Start Temp         60.0         degC	Current Recovery Tir	ne 8	s	OT2 Dsg Tim	ne	2	S	
	AFE OC Dsg	12		OT2 Dsg Red	overy	55.0	degC	
AFE SC Chg Cfg 77 -	AFE OC Dsg Time	OF	14	Hi Dsg Start	Temp	60.0	degC	
	AFE SC Chg Cfg	77	(e) ;					
	And the provide state of the second state of t		-	Hi Dsg Start	Temp	60.0	degC	

Figure 9. Data Flash Screen, 1st Level Safety Class

To read all the data from the bq20z65 data flash, click on menu option | Data Flash | Read All |.

To write to a data flash location, click on the desired location, enter the data and press <Enter>, which writes the entire tab of flash data, or select menu option | Data Flash | Write All |. The data flash must be read before any writes are performed to avoid any incorrect data being written to the device.

The | File | Special Export | menu option allows the data flash to be exported, but it configures the exported data flash to a learned state ready for mass production use.

The data flash configuration can be saved to a file by selecting | File | Export | and entering a file name. A data flash file also can be retrieved in this way, imported, and written to the bq20z65 using the | Write All | button.

The configuration information of the bq29z95 and module calibration data also is held in the bq20z65 data flash.



The bq20z65 allows for an automatic data flash export function, similar to the SBS Data logging function. This feature, when selected via | Options | Auto Export |, exports Data Flash to a sequential series of files named as *FilenameNNNN.gg* where N = a decimal number from 0 to 9.

The AutoExport interval is set under the | Options menu | with a minimum value of 15 s. The AutoExport filename also is set under the | Options menu |.

When a check mark is next to | AutoExport |, the AutoExport is in progress. The same menu selection is used to turn on/off AutoExport.

If the data flash screen is blank, then the bq20z65 that is being used may not be supported by the bqEVSW version that is being used. An upgrade may be required.

#### 9 Calibration Screen

#### 9.1 How to Calibrate

The bq20z65 must be calibrated using power supplies or a power supply and cell simulation resistors (200  $\Omega$  to 1000  $\Omega$  each) before cells are attached. Before the bq20z65 is calibrated:

- Connect and measure a 2-A current source from 1N (-) and Pack- (+) to calibrate without using the FETs. (Calibration using the FETs is not recommended.)
- Measure the pack voltage from Batt+ to Batt- (total of cell voltages).
- Measure the temperature of the pack.
- These steps may not be required, depending on the type of calibration being performed.

## 9.2 To Calibrate the bq20z65

Perform the following steps.

- 1. Select the types of calibration to be performed (see Figure 10).
- 2. Enter the measured values for the types selected (except for CC Offset Calibration).
- 3. If Voltage Calibration is selected, then enter the number of cells on the pack.
- 4. If *Temperature Calibration* is selected, then select the sensor that is to be calibrated.
- 5. If the current source is connected between 1N and Pack-, then select the Off (bypassed) check box in the FET Control section.
- 6. Press the *Calibrate Part* button.

#### 9.3 Board Offset Calibration

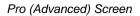
The following steps perform the offset calibration for the current offset of the board.

- 1. Remove load/external voltage and short Pack- to Batt-.
- 2. Press the CC Board Offset Calibration button.

#### 9.4 Pack Voltage Calibration

The following steps calibrate the voltage at the AFE Pack pin.

- 1. Ensure that *Voltage Calibration* has been performed for the pack. Ensure that a stable charger voltage higher than 8-V is present at Pack+.
- 2. Press the *Pack Voltage* button to calibrate.





e <u>W</u> indo							-	
12	🐺 Texas Inst	REA	REAL WORLD SIGNAL PROCES					
	This screen supports bq20z80 version 0.13 and newer. Please ensure that scanning/communication is off on all other open windows.							
H.		d CC Board Offset	Calibration	Street and	for 2 sec	7		
•	Pack <u>V</u> oltage Calibration			<u>S</u> oft Offse	ware Board et Calibration			
B5	Calibrate Part as indicated below			<mark>⊮ K</mark>	eep refreshing <u>m</u> easi	ured values of V,T & I shown	n below	
ata Iash	CC Offset Calibration							
Pro	☐ Voltage Calibration	Measured voltage 15990 <sub>mV</sub>	Enter actual voltage 0 mV	Cell Count	FET Control	Ensure voltage reference stable. Calibration with ce connected is not recomm unless cells are in a state	lls ended	
brate	☐ Temperature Calibration	Measured temperature 24.7 +C	Enter actual temperature	☐ [nt. Se ☑ Ext. Se ☐ Ext. Se				
•	Pack Current	Measured current 0 mA	Enter actual FET Control current © On (External Load) -2000 mA © Diff (Bypassed) Apply a 2 Ampere discharge load. Discharge current is a negative value.					
Gauge								

Figure 10. Calibration Screen

## 10 Pro (Advanced) Screen

## 10.1 SMB Communication

The set of read/write operations over SMBus are not specific to any gas gauge. These are provided as general-purpose communication tools (Figure 11).

## 10.2 Hexadecimal/Decimal Converter

These two boxes convert between hexadecimal and decimal as soon as values are typed into the boxes. Invalid values may cause erroneous results.

When scaling converted hexadecimal values to a higher number of bytes, follow these rules:

- When unsigned is selected, the left pad contains zeroes.
- When signed is selected, the left pad contains zeroes for a positive number, or the left pad contains *F* for negative numbers.



Related Documentation from Texas Instruments

www.ti.com

## 10.3 Programming

This screen allows device reprogramming from unencrypted and encrypted files.

and the second se	uments bq Gas Gauge Evaluation Software - bq20z65 v0.01 - [Pro (Advanced) Screen]
	TEXAS INSTRUMENTS REAL WORLD SIGNAL PROCES
-	This screen is only for advanced users. Some commands may cause permanent damage to the hardware. Please use caution. All Values are in Hexadecimal without the 0x prefix. Target Address 17 Send SMB Command
•	SMB Command DE Send
5B5	Read SMB Word
	SMB Command OD Result (hex) None.
	Write SMB Word
Data Flash	SMB Command 00 Word (hex) 0F00 Wite 1
	Read SMB Block
	SMB Command 78 Read: Result (hex) None.
Pro	Result (ASCII)
	Write SMB Block
Calibrate	SMB Command 78 Block Data 0102 0304 05 06 Write Write
· · · · · · · · · · · · · · · · · · ·	Hexadecimal to Decimal converter and vice versa
•	Hexadecimal value 00 = Signed C Decimal value 00
100%	Srec programming 🔽 Sate Erace
	Erogram :
0% Fuel Gauge 84%	
Communication DK	SBS Task Progress: 100% Task Completed. 02:34:27 PM

Figure 11. Pro (Advanced) Screen

#### 11 Related Documentation from Texas Instruments

- bq20z95, SBS 1.1-Compliant Gas Gauge Enabled and Protection Enabled With Impedance Track<sup>™</sup> data sheet (<u>SLUS757</u>)
- 2. bq20z90-V1.50 + bq29330, bq20z95 Technical Reference manual (SLUU264)
- 3. bq20z70 and bq20z90 Application Book (SLUA404)
- 4. Quick-Start Guide for bq20zxx Family Gas Gauge application report (SLUA421)
- 5. bqEasy<sup>™</sup> User's Guide (SLUU278)

#### **EVALUATION BOARD/KIT IMPORTANT NOTICE**

Texas Instruments (TI) provides the enclosed product(s) under the following conditions:

This evaluation board/kit is intended for use for ENGINEERING DEVELOPMENT, DEMONSTRATION, OR EVALUATION PURPOSES ONLY and is not considered by TI to be a finished end-product fit for general consumer use. Persons handling the product(s) must have electronics training and observe good engineering practice standards. As such, the goods being provided are not intended to be complete in terms of required design-, marketing-, and/or manufacturing-related protective considerations, including product safety and environmental measures typically found in end products that incorporate such semiconductor components or circuit boards. This evaluation board/kit does not fall within the scope of the European Union directives regarding electromagnetic compatibility, restricted substances (RoHS), recycling (WEEE), FCC, CE or UL, and therefore may not meet the technical requirements of these directives or other related directives.

Should this evaluation board/kit not meet the specifications indicated in the User's Guide, the board/kit may be returned within 30 days from the date of delivery for a full refund. THE FOREGOING WARRANTY IS THE EXCLUSIVE WARRANTY MADE BY SELLER TO BUYER AND IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED, IMPLIED, OR STATUTORY, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE.

The user assumes all responsibility and liability for proper and safe handling of the goods. Further, the user indemnifies TI from all claims arising from the handling or use of the goods. Due to the open construction of the product, it is the user's responsibility to take any and all appropriate precautions with regard to electrostatic discharge.

EXCEPT TO THE EXTENT OF THE INDEMNITY SET FORTH ABOVE, NEITHER PARTY SHALL BE LIABLE TO THE OTHER FOR ANY INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES.

TI currently deals with a variety of customers for products, and therefore our arrangement with the user is not exclusive.

# TI assumes no liability for applications assistance, customer product design, software performance, or infringement of patents or services described herein.

Please read the User's Guide and, specifically, the Warnings and Restrictions notice in the User's Guide prior to handling the product. This notice contains important safety information about temperatures and voltages. For additional information on TI's environmental and/or safety programs, please contact the TI application engineer or visit <a href="http://www.ti.com/esh">www.ti.com/esh</a>.

No license is granted under any patent right or other intellectual property right of TI covering or relating to any machine, process, or combination in which such TI products or services might be or are used.

#### **FCC Warning**

This evaluation board/kit is intended for use for **ENGINEERING DEVELOPMENT, DEMONSTRATION, OR EVALUATION PURPOSES ONLY** and is not considered by TI to be a finished end-product fit for general consumer use. It generates, uses, and can radiate radio frequency energy and has not been tested for compliance with the limits of computing devices pursuant to part 15 of FCC rules, which are designed to provide reasonable protection against radio frequency interference. Operation of this equipment in other environments may cause interference with radio communications, in which case the user at his own expense will be required to take whatever measures may be required to correct this interference.

#### **EVM WARNINGS AND RESTRICTIONS**

It is important to operate this EVM within the input voltage range of 6 V to 25 V and the output voltage range of 0 V to 16.4 V.

Exceeding the specified input range may cause unexpected operation and/or irreversible damage to the EVM. If there are questions concerning the input range, please contact a TI field representative prior to connecting the input power.

Applying loads outside of the specified output range may result in unintended operation and/or possible permanent damage to the EVM. Please consult the EVM User's Guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative.

During normal operation, some circuit components may have case temperatures greater than 60°C. The EVM is designed to operate properly with certain components above 60°C as long as the input and output ranges are maintained. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors. These types of devices can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during operation, please be aware that these devices may be very warm to the touch.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265 Copyright © 2009, Texas Instruments Incorporated

## IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to TI's Terms of Sale or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265 Copyright © 2021, Texas Instruments Incorporated