User's Guide

SLAU618A–June 2016–Revised June 2018

Fuel Tank MKII Battery BoosterPack™ Plug-in Module (BOOSTXL-BATPAKMKII)

The Fuel Tank MKII BoosterPack™ plug-in module is the next generation design of the original Fuel Tank BoosterPack plug-in module. The Fuel Tank MKII BoosterPack plug-in module includes next-generation TI battery monitoring ICs and other new features to make it easier to use. The Fuel Tank MKII BoosterPack plug-in module allows TI LaunchPad™ development kits to be powered from the included rechargeable lithium polymer battery, further enabling mobile application development and evaluation.

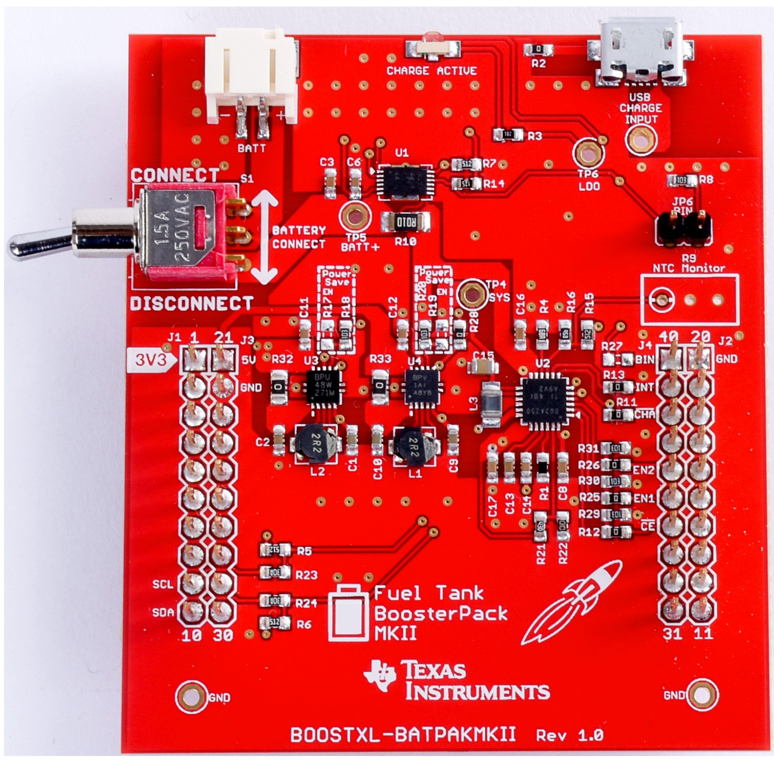

Figure 1. BOOSTXL-BATPAKMKII Fuel Tank MKII Battery BoosterPack Plug-in Module

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1 Getting Started

1.1 Introduction

The Fuel Tank MKII BoosterPack plug-in module is the next generation design of the original Fuel Tank BoosterPack plug-in module. This BoosterPack plug-in module includes next-generation TI battery monitoring ICs and other new features to make it easier to use. The Fuel Tank MKII BoosterPack plug-in module module allows TI LaunchPad™ development kits to be powered from the included rechargeable lithium polymer battery, further enabling mobile application development and evaluation.

The Fuel Tank MKII BoosterPack plug-in module includes an onboard lithium polymer battery charger and gas gauge that provide critical parameters of the battery, including temperature, charging state, capacity, and more. The BoosterPack plug-in module module comes with a lithium polymer battery cell, which can be disconnected by a switch and charged through an onboard micro USB connector.

1.2 Key Features

- 3.7-V 1200-mAh lithium polymer battery
- Onboard bq27441 fuel (gas) gauge
- Onboard bq24250 lithium polymer charger
- USB charging with indicator LED
- Works with TI LaunchPad development kits

1.3 What's Included

1.3.1 Kit Contents

- 1 x BOOSTXL-BATPAKMKII BoosterPack plug-in module
- 1 x AE503759P6HA Li-Polymer rechargeable battery
- 1 x Quick Start Guide

1.3.2 Software Examples

- MSP-EXP432P401R + BOOSTXL-BATPAKMKII demo (see Section 3)

1.4 Next Steps: Looking Into the Provided Code

After the EVM features have been explored, the fun can begin. It's time to open an integrated development environment (IDE) and start looking at the code examples. Section 3 describes the example projects available to make it easy to understand the provided software.

2 Hardware

Figure 2 shows an overview of the BOOSTXL-BATPAKMKII.

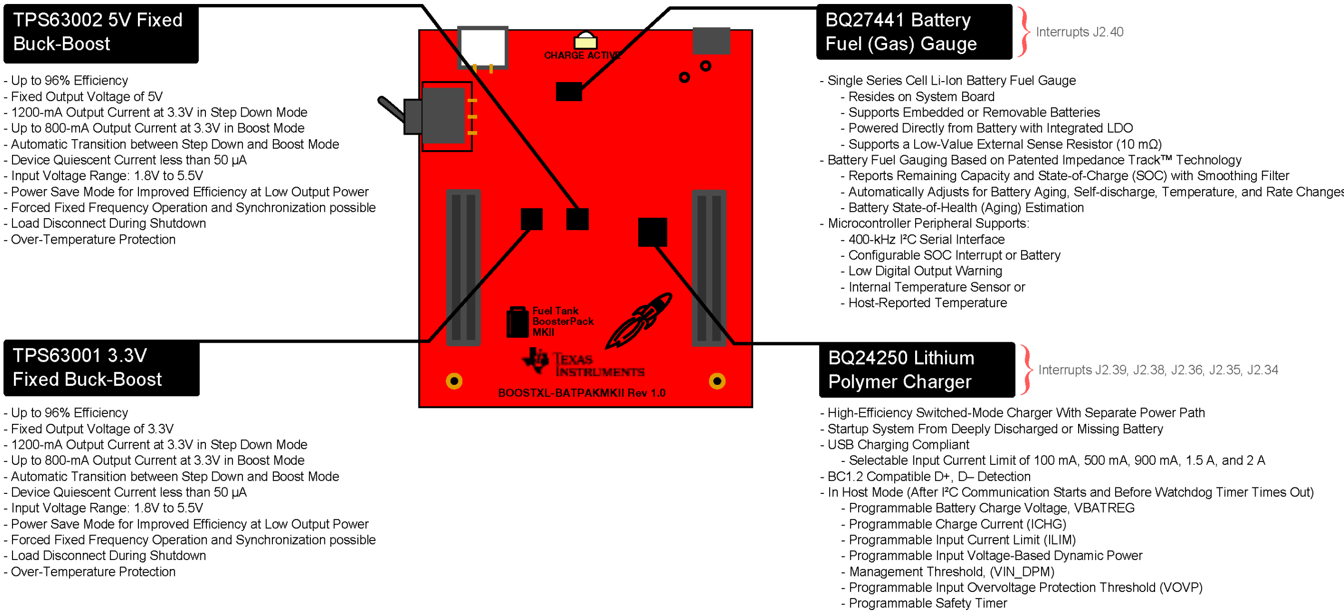

Figure 2. BOOSTXL-BATPAKMKII Overview

2.1 Hardware Features

2.1.1 BoosterPack Plug-in Module Pinout

Figure 3 shows the pinout of the BOOSTXL-BATPAKMKII.

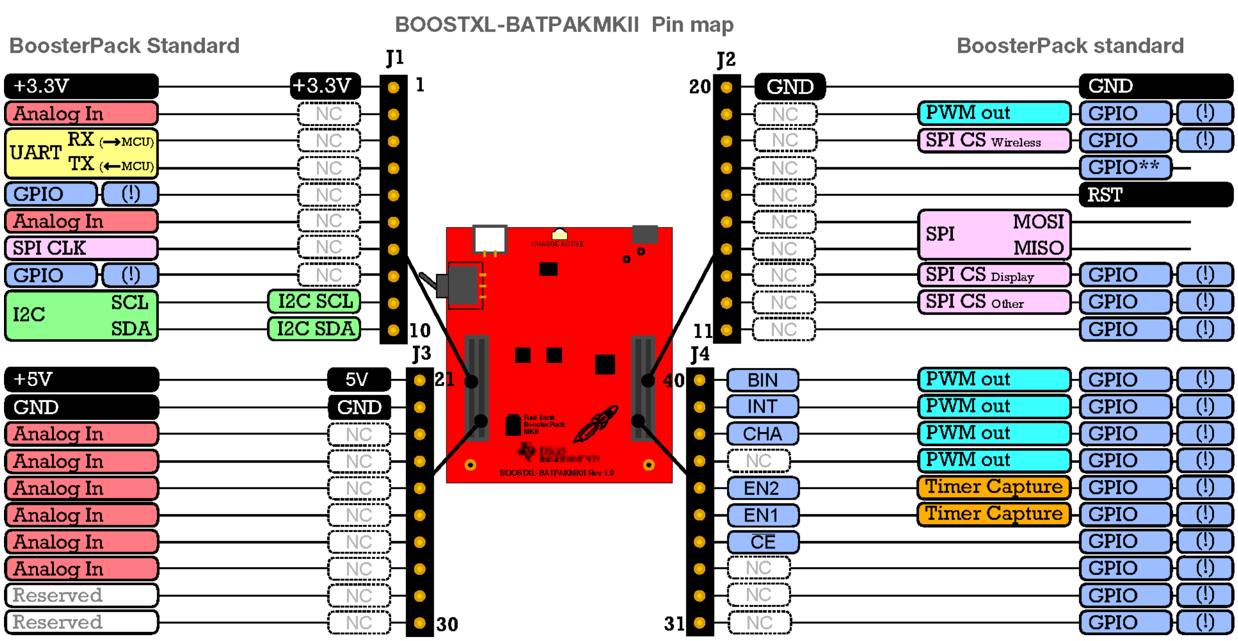

Figure 3. BoosterPack Plug-in Module Pinout

The Fuel Tank MKII BoosterPack plug-in module adheres to the 40-pin LaunchPad development kit and BoosterPack plug-in module pinout standard. This standard was created to aid compatibility between LaunchPad development kits and BoosterPack plug-in modules across the TI ecosystem.

The 40-pin standard followed by the BOOSTXL-BATPAKMKII is compatible with the 20-pin standard that is used by other LaunchPad development kits like the MSP-EXP430G2 LaunchPad development kit. This allows for 40-pin BoosterPack plug-in modules to be used with 20-pin LaunchPad development kits.

The BOOSTXL-BATPAKMKII BoosterPack plug-in module has male and female headers to support stacking on top or bottom.

More information about compatibility can also be found at http://www.ti.com/launchpad.

2.1.2 TI BQ27441-G1 Fuel Gauge (Gas Gauge)

The bq27441-G1 fuel gauge is a microcontroller peripheral that provides system-side fuel gauging for single-cell Li-Ion batteries. The device requires minimal user configuration and system microcontroller firmware development.

The bq27441-G1 battery fuel gauge uses the patented Impedance Track™ technology for fuel gauging and provides information such as remaining battery capacity (mAh), state of charge (%), and battery voltage (mV).

The digital output is reported over an I^2C 2-wire serial interface. The reference designator for the bq27441-G1 is U1, with I^2C 8-bit addresses 0xAA and 0xAB for write and read, respectively (0x55, 7-bit address).

More information on the bq27441-G1 fuel gauge can be found at http://www.ti.com/product/bq27441-g1 and in the bq27441-G1 technical reference manual. Table 1 lists the pin connections for the bq27441-G1.

Table 1. BQ27441-G1 Pinout

BoosterPack Plug-in Module Header Connection	Pin Function
J1.9 (1)	I^2C SCL
J1.10 (1)	I^2C SDA
J4.40	BIN

(1) Pin is multiplexed with the I^2C communication lines of the bq27441-G1 and bq24250

The BIN pin detects when a battery is present. A jumper JP6 is available to simulate battery connect or disconnect with the BoosterPack plug-in module hardware (J6 shorted = battery inserted; J6 open = battery removed). Additionally, switch S1 can be used to fully disconnect the battery. The MCU device on the LaunchPad development kit can monitor the BIN pin through the BoosterPack plug-in module header when using hardware to control this pin. To enable BIN detection or control on the BoosterPack plug-in module header, resistor R27 must be populated with 0 Ω (shorted).

The BIN hardware signal can be bypassed by the MCU software by using the BIE (Batter Insert Enable) bit in the fuel gauge operation configuration register. When BIE is cleared, the battery detection relies on the host to issue a BAT_INSERT subcommand to indicate battery presence, bypassing the J6 BIN jumper.

2.1.3 TI BQ24250 Lithium-Ion Battery Charger

The bq24250 is a highly integrated single-cell Li-Ion battery chargers and system power-path management devices targeted for space-limited portable applications with high-capacity batteries. The single-cell charger has a single input that operates from either a USB port or an AC wall adapter for a versatile solution.

The digital output is reported over an I^2C two-wire serial interface. The reference designator for the bq24250 is U2, with I^2C address 0x6A (7-bit address).

More information on the bq24250 charger can be found at http://www.ti.com/product/bq24250. Table 2 lists the pin connections for the bq24250.

Table 2. BQ24250 Pinout

BoosterPack Plug-in Module Header Connection	Pin Function
J1.9 (1)	I^2C SCL
J1.10 (1)	I^2C SDA
J4.39	INT
J4.38	Charge
J4.36	EN2
J4.35	EN1
J4.34	CE

(1) Pin is multiplexed with the I^2C communication lines of the bq27441-G1 and bq24250

The CHG pin represents charge status as indicated by the LED. The LED is great for checking visually that the battery is charging, but the CHG pin is also brought to the BoosterPack plug-in module header for the MCU to check in a battery application. CHG pin is high impedance (LED off) when the battery is not charging, and low (LED on) when the battery is charging. The CHG pin does not indicate recharge cycles.

The INT pin is similar to the CHG pin, but there are a few differences. INT represents the charging status and fault interrupts. It is recommended to connect INT through an internal MCU pullup to properly read the signal. When charging, INT is pulled low. When charging is complete (or charger disabled), INT will change to high impedance. When used with a pullup resistor this can be read as high. INT delivers an interrupt pulse when a fault is detected, and it also does indicate recharge cycles.

The CE pin is active-low charge enable. When CE is low the charger is enabled. Setting this pin high with the MCU disables the charger.

The EN1 and EN2 pins set the input current limitations of the charger. By default they are set to input current limit = 1 A and V_{IN_DPM} = 4.36 V. These can be changed (along with other corresponding hardware) to set the desired limits for these pins. See the device data sheet for more information.

2.1.4 3.7-V 1200-mAh Lithium-Polymer Battery

The battery featured on the Fuel Tank MKII BoosterPack plug-in module is AEenergy, type 503759, part number AE503759P6HA. It is a Li-Polymer rechargeable battery rated at 3.7 V and 1200 mAh. Table 3 is an overview of the battery specifications.

Table 3. Battery Specifications

Description	Specification
Nominal Capacity	1200 mAh (typical)
Nominal Voltage	3.7 V
Charging Voltage	4.20 ±0.05 V
Max Charging Current	1100 mA
Max Continuous Discharge Current	2200 mA
Discharge Cutoff Voltage	2.75 V
Battery Dimensions	37 mm × 60 mm × 5 mm
Battery Weight	24 ±2.0 g

2.1.5 Switch S1

Switch S1 is a mechanical switch that fully disconnects the battery from the onboard circuitry. The original Fuel Tank BoosterPack plug-in module had no switch and required the user to disconnect the battery from the connector on the BoosterPack plug-in module to prevent the battery from draining.

The Fuel Tank MKII BoosterPack plug-in module features this switch as an easy way to fully disconnect the battery to prevent discharge when not in use, or to power off the system during use.

2.2 Power

The Fuel Tank BoosterPack plug-in module MKII was designed to power TI LaunchPad development kits for applications that cannot be connected to USB power. More details on the power system behavior are below.

2.2.1 LaunchPad Development Kit 3V3 and 5V rails

The 3V3 (J1.1) and 5V (J3.21) rails to power the LaunchPad development kit are derived from two buck-boost converters on the BOOSTXL-BATPAKMKII.

2.2.1.1 TI TPS63001 3.3-V Buck-Boost DC-DC Converter

The TPS63001 provides a regulated 3.3-V power rail (J1.1) on the LaunchPad development kit. This 3V3 rail has a maximum current output limit of 1200 mA.

The input to the TPS63001 is the PAK+_OUT signal directly from the battery. Because of the direct battery connection, configuration of the fuel gauge and Li-Ion charger are irrelevant to this voltage output. The buck-boost converter is able to provide the regulated 3.3 V across the full range of the battery from 4.2 V down to 2.8 V. The buck-boost converters are disabled when the BAT_LOW signal is asserted by the fuel gauge. This BAT_LOW signal is directly tied to the EN pin of the buck-boost converter to disable any voltage output when the battery is critically low.

The TPS63001 has a power save mode of operation that uses less quiescent current, but provides a slightly less stable voltage rail. To enable this feature, the PS pin needs to be pulled low. This can be done by removing R18 and populating R17.

2.2.1.2 TI TPS63002 5-V Buck-Boost DC-DC Converter

The TPS63002 provides a regulated 5-V power rail (J3.21) on the LaunchPad development kit. This 5V rail has a maximum current output limit of 800 mA.

The input to the TPS63002 is the PAK+_OUT signal directly from the battery. Because of the direct battery connection, configuration of the fuel gauge and Li-Ion charger are irrelevant to this voltage output. The buck-boost converter is able to provide the regulated 5V across the full range of the battery from 4.2 V down to 2.8 V. The buck-boost converters are disabled when the BAT_LOW signal is asserted by the fuel gauge. This BAT_LOW signal is directly tied to the EN pin of the buck-boost converter to disable any voltage output when the battery is critically low.

The TPS63002 has a power save mode of operation that uses less quiescent current, but provides a slightly less stable voltage rail. To enable this feature, the PS pin needs to be pulled low. This can be done by removing R20 and populating R19.

2.2.1.3 BQ24250 DC-DC SYS Output

The bq24250 Li-Ion battery charger provides its own regulated DC-DC output on the SYS pin. In many applications this output is used to provide system power. On the Fuel Tank MKII BoosterPack plug-in module, this output is placed onto a test point for access (TP4), but not explicitly used to power the connected LaunchPad development kit.

2.2.2 Charging the Battery

The battery is charged by the USB connector on the Fuel Tank MKII BoosterPack plug-in module. 5V through the USB connection on the Fuel Tank MKII BoosterPack plug-in module or connected to TP1 is the only way to charge the battery.

NOTE: Connecting USB directly to a LaunchPad development kit that is plugged into the Fuel Tank MKII BoosterPack plug-in module does not charge the battery.

The charging LED (LED2) indicates if a charge is active or not. This provides a quick visual check that the battery is charging, and also alerts the user when the battery has finished charging.

NOTE: The tolerance of the resistors populated at R15 and R16 can cause the voltage on the TS pin to go above the V_{COLD} threshold, which disables charging. If the battery is not charging as expected and R9 is not populated, decrease the resistance of R16 to 5.1 kΩ or populate R9 with a 10-kΩ resistor to put the TS voltage between the V_{COOL} and V_{WARM} thresholds.

2.2.3 Using the Fuel Tank MKII BoosterPack Plug-in Module and LaunchPad Development Kit PC Connection

In certain situations, users may wish to connect the Fuel Tank MKII BoosterPack plug-in module to the LaunchPad development kit, while the LaunchPad development kit communicates with a PC. The MSP-EXP432P401R software example is a good example of this use case.

When this setup is needed, it is important to disconnect the power rails on the LaunchPad development kit from its own USB connection, so that there is not a power rail conflict with the on-LaunchPad development kit voltage and the Fuel Tank MKII BoosterPack plug-in module. To do this, the 3V3 and 5V jumpers that connect the LaunchPad development kit target side to the debugger must be removed. The debugger still receives power from the USB connection, and the target side will receive power from the Fuel Tank MKII BoosterPack plug-in module. Figure 4 shows an example on the MSP-EXP432P401R LaunchPad development kit.

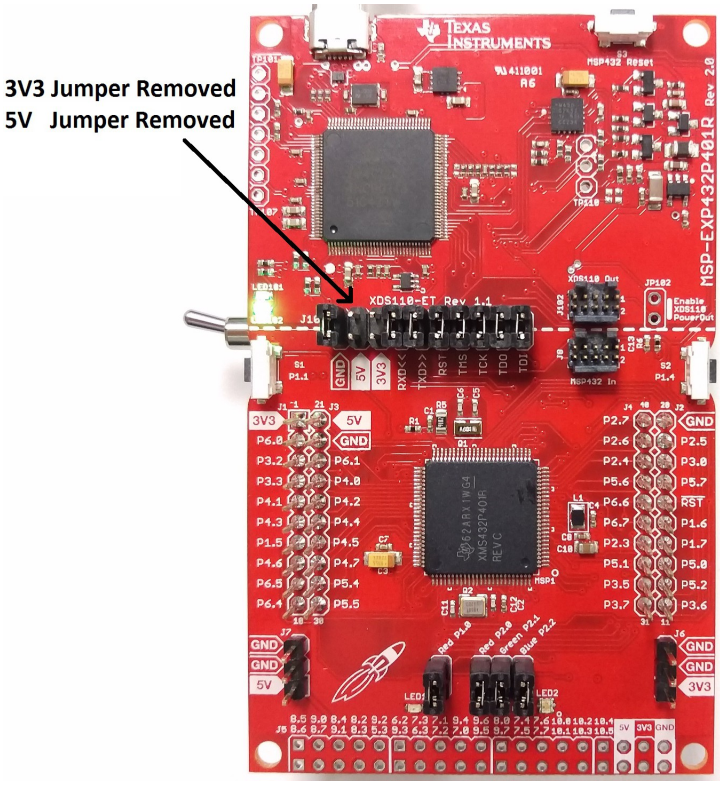

Figure 4. LaunchPad Development Kit Jumper Removal With USB Connection

2.3 Design Files

2.3.1 Hardware

Section 5 shows the schematics. All design files including schematics, layout, bill of materials (BOM), Gerber files, and documentation are available on the BOOSTXL-BATPAKMKII Hardware Design Files on the download page.

2.3.2 Software

All design files including TI-TXT object-code firmware images, software example projects, and documentation are available in the LaunchPad development kit specific software folders. To see which LaunchPad development kits feature BOOSTXL-BATPAKMKII examples, visit the download page.

2.3.3 Quick Start Guide

A Quick Start Guide is also available.

2.4 Hardware Change log

Table 4 lists the revision history of the BOOSTXL-BATPAKMKII hardware.

Table 4. Hardware Change Log

PCB Revision	Description
Rev 1.0	Initial release
Rev 1.1	CE EMC compliance and updates to Charger TS pin circuit

3 Software Examples

One software example is included with the MSP-EXP432P401R LaunchPad development kit for the Battery BoosterPack plug-in module (see Table 5). This example can be found in the MSP-EXP432P401R Software Examples zip folder.

Table 5. Software Examples

Demo name	LaunchPad / BoosterPack Required	Description	More Details
BOOSTXL-BATPAKMKII_ FuelGauge_MSP432P401R	MSP-EXP432P401R / BOOSTXL-BATPAKMKII	Demonstrates how to initialize bq27441-G1 fuel gauge configurations and how to control and read data registers	Section 3.1

To use any of the software examples with the LaunchPad development kit, you must have an integrated development environment (IDE) that supports the MSP432P401R device (see Table 6).

Table 6. IDE Minimum Requirements for MSP-EXP432P401R

Code Composer Studio™ IDE	IAR Embedded Workbench® IDE	Keil® µVision® IDE
CCS v6.1 or later	IAR Embedded Workbench for ARM 7.40 or later	Keil µVision MDK-ARM v5 or later

For more details on how to get started quickly, and where to download the latest CCS, IAR, and Keil IDEs, see Section 4.

3.1 BOOSTXL-BATPAKMKII_FuelGauge_MSP432P401R

This section describes the functionality and structure of the BOOSTXL-BATPAKMKII_FuelGauge_MSP432P401R demo that is included in the MSP-EXP432P401R Software Examples download, or more easily accessible through MSPWare (see Section 4.2).

3.1.1 Source File Structure

The project is split into multiple files (see Table 7). This makes it easier to navigate and reuse parts of it for other projects.

Table 7. Source File and Folders

Name	Description
Library: driverlib	Device driver library (MSP432DRIVERLIB)
startup_msp432p401r.c	MSP432™ MCU family interrupt vector table for CGT
HAL_BQ27441.c	Driver for communicating with the bq27441-G1 fuel gauge
HAL_I2C.c	Board specific support driver for I2C communication
HAL_UART.c	Board specific driver for UART communication through Application/User UART
main.c	The main function of the demo, global variables, and more

3.1.2 Running the Fuel Gauge Example

After the compiling/loading the BOOSTXL-BATPAKMKII_FuelGauge_MSP432P401R project or downloading the pre-built firmware binary onto the MSP-EXP432P401R LaunchPad development kit, included in the MSP-EXP432P401R Software Examples, follow the steps below to run the demo firmware.

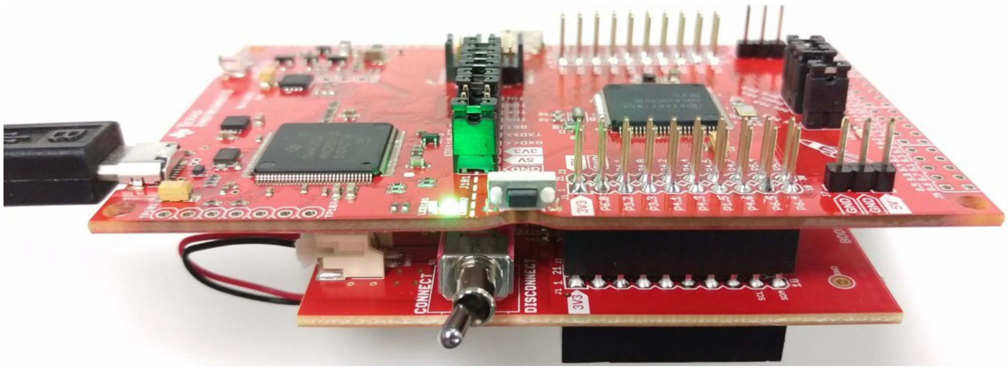

Figure 5. Hardware Setup and Connections

1. Attach the BOOSTXL-BATPAKMKII Battery BoosterPack plug-in module to the LaunchPad development kit.
2. Flip the switch to the "ON" position on the side of the BOOSTXL-BATPAKMKII Battery BoosterPack plug-in module.
3. Connect the MSP-EXP432P401R LaunchPad development kit to a computer via micro-USB cable.
4. Launch a serial terminal application and connect to the COM port for "XDS110 Class Application/User UART" at 115200 baud rate (see Figure 6 and Figure 7).

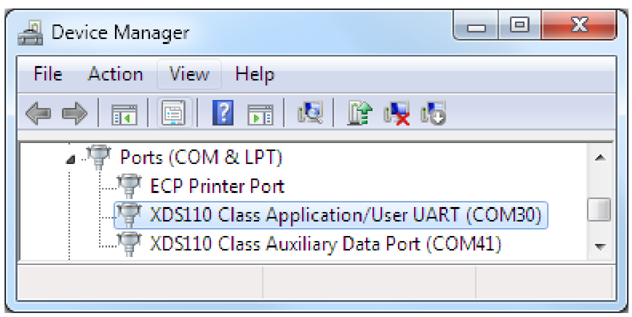

Figure 6. Determine COM Port Number Using Device Manager on Windows

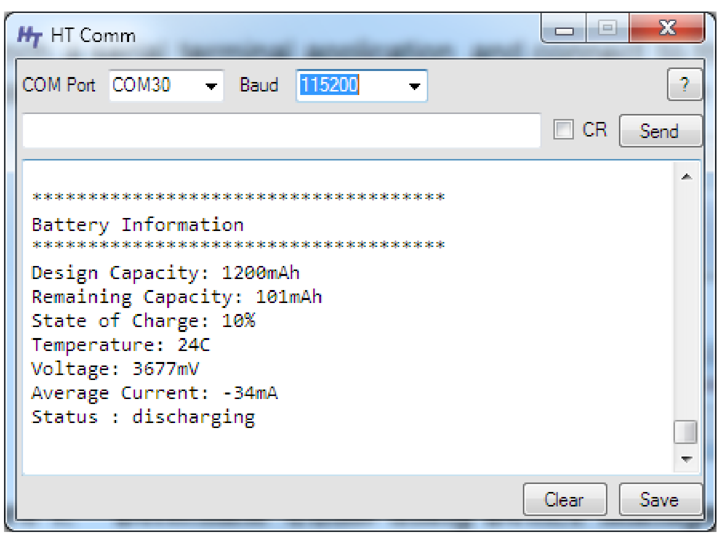

Figure 7. Example Serial Terminal Configuration

5. Press the reset button on the MSP-EXP432P401R LaunchPad development kit.

6. Observe serial data displaying Fuel Gauge configuration and Battery Information.

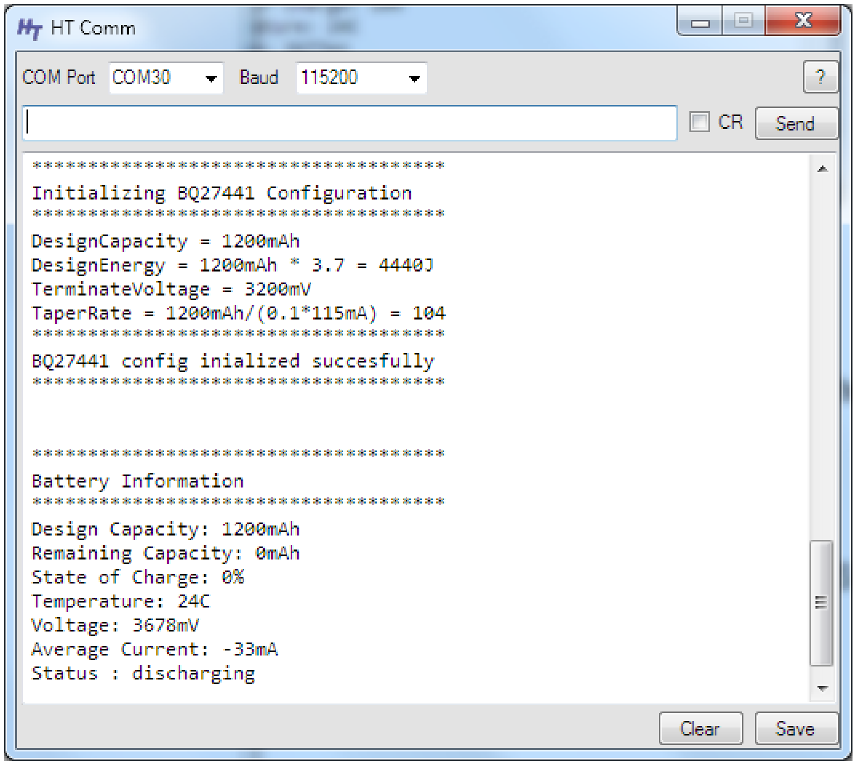

Figure 8. Snapshot of Serial Terminal Connected to Running Fuel Gauge Demo

3.1.3 Firmware Overview

Refer to Quick Start Guide for bq27441-G1 and bq27441-G1 Technical Reference Manual for detailed description of the Battery Fuel Gauge usage.

The demo program begins by initializing a number of configuration parameters in the bq27441-G1 to match the target battery. Four important parameters are Design Capacity, Design Energy, Terminate Voltage, and Taper Rate. Values are determined based on the target battery properties and bq27441-G1 documentations.

Next, the host MSP432P401R MCU clears the BIE (Batter Insert Enable) bit in the fuel gauge operation configuration register. When BIE is cleared, the battery detection will rely on the host to issue a BAT_INSERT subcommand to indicate battery presence, bypassing the J6 BIN jumper on the BOOSTXL-BATPAKMKII BoosterPack plug-in module that the fuel gauge relies on for battery detection by default when BIE is set (J6 shorted = Battery Inserted; J6 open = Battery Removed). This is done to ensure the demo application works regardless if J6 is connected or not.

In end user applications, a switch or the host MCU would more likely be used control the BIN state of the fuel gauge depending on battery connection. However, this is not implemented on the BoosterPack plug-in module and a jumper is used to manually toggle between battery insertion and removal.

Once the bq27441-G1 has been configured properly, the main loop repeatedly reads back DESIGN_CAPACITY, REMAINING_CAPACITY, STATE_OF_CHARGE, TEMPERATURE, VOLTAGE, and AVERAGE_CURRENT from the fuel gauge. Results are formatted and transmitted through Application/User UART.

4 Additional Resources

4.1 TI LaunchPad™ Development Kit Portal

More information about LaunchPad development kits, supported BoosterPack plug-in modules, and available resources can be found at:

- TI's LaunchPad portal: information about all LaunchPad development kits from TI, for all microcontrollers

4.2 TI Cloud Development Tools

TI's Cloud-based software development tools provide instant access to MSPWare software content and a web-based IDE.

4.2.1 TI Resource Explorer Cloud

TI Resource Explorer Cloud provides a web interface for browsing examples, libraries and documentation found in the MSPWare software without having to download files to your local drive (see Figure 9).

Learn more about TI Resource Explorer Cloud now at https://dev.ti.com/.

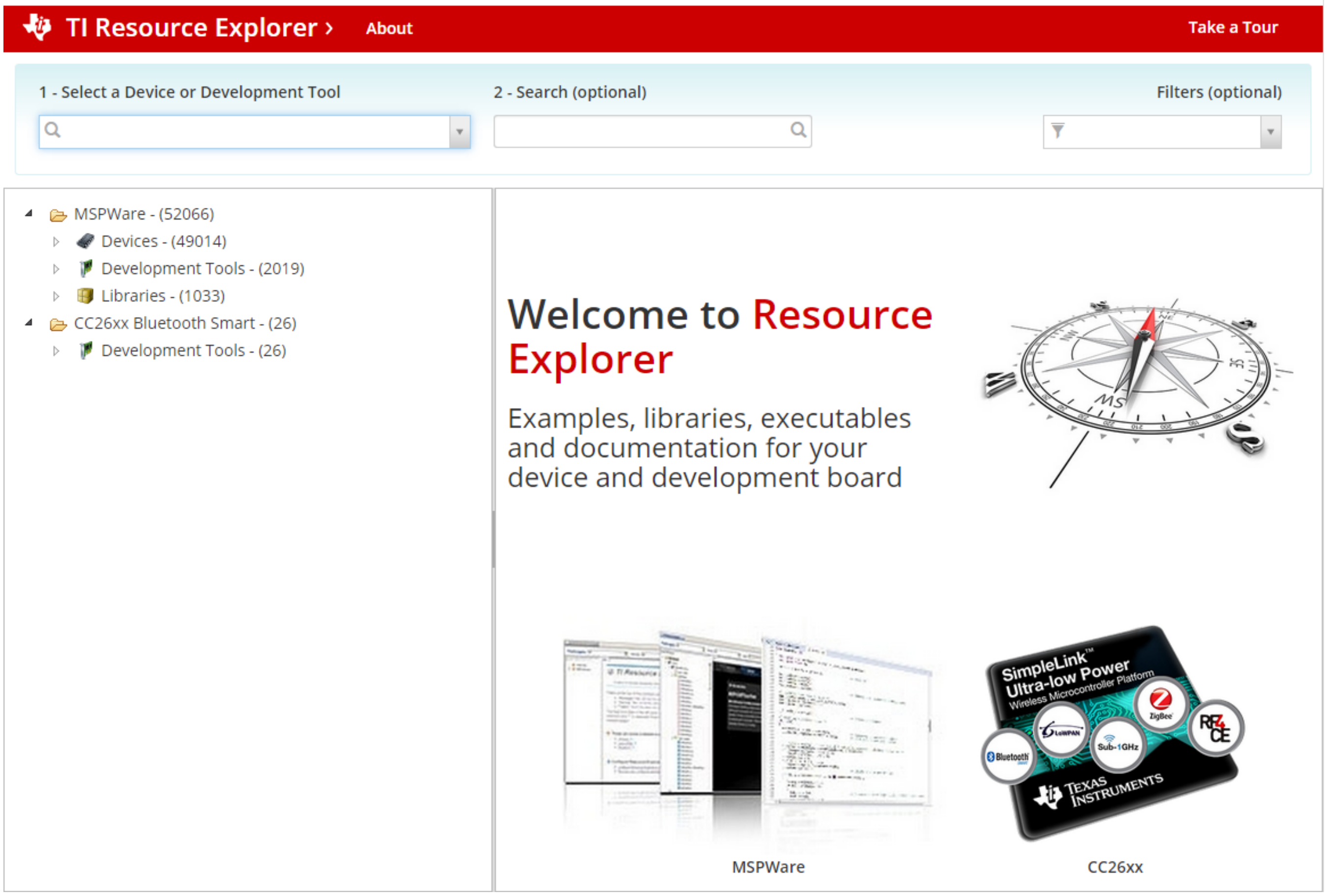

Figure 9. TI Resource Explorer Cloud

4.2.2 Code Composer Studio™ Cloud

Code Composer Studio™ Cloud (CCS Cloud) is a web-based IDE that enables you to quickly create, edit, build and debug applications for your LaunchPad development kit. No need to download and install large software packages, simply connect your LaunchPad development kit and begin. You can choose to select from a large variety of examples in MSPWare software and Energia or develop your own application. CCS Cloud IDE supports debug features such as execution control, breakpoints and viewing variables.

A full comparison between CCS IDE Cloud and CCS Desktop is available here.

Learn more about Code Composer Studio Cloud IDE now at https://dev.ti.com/.

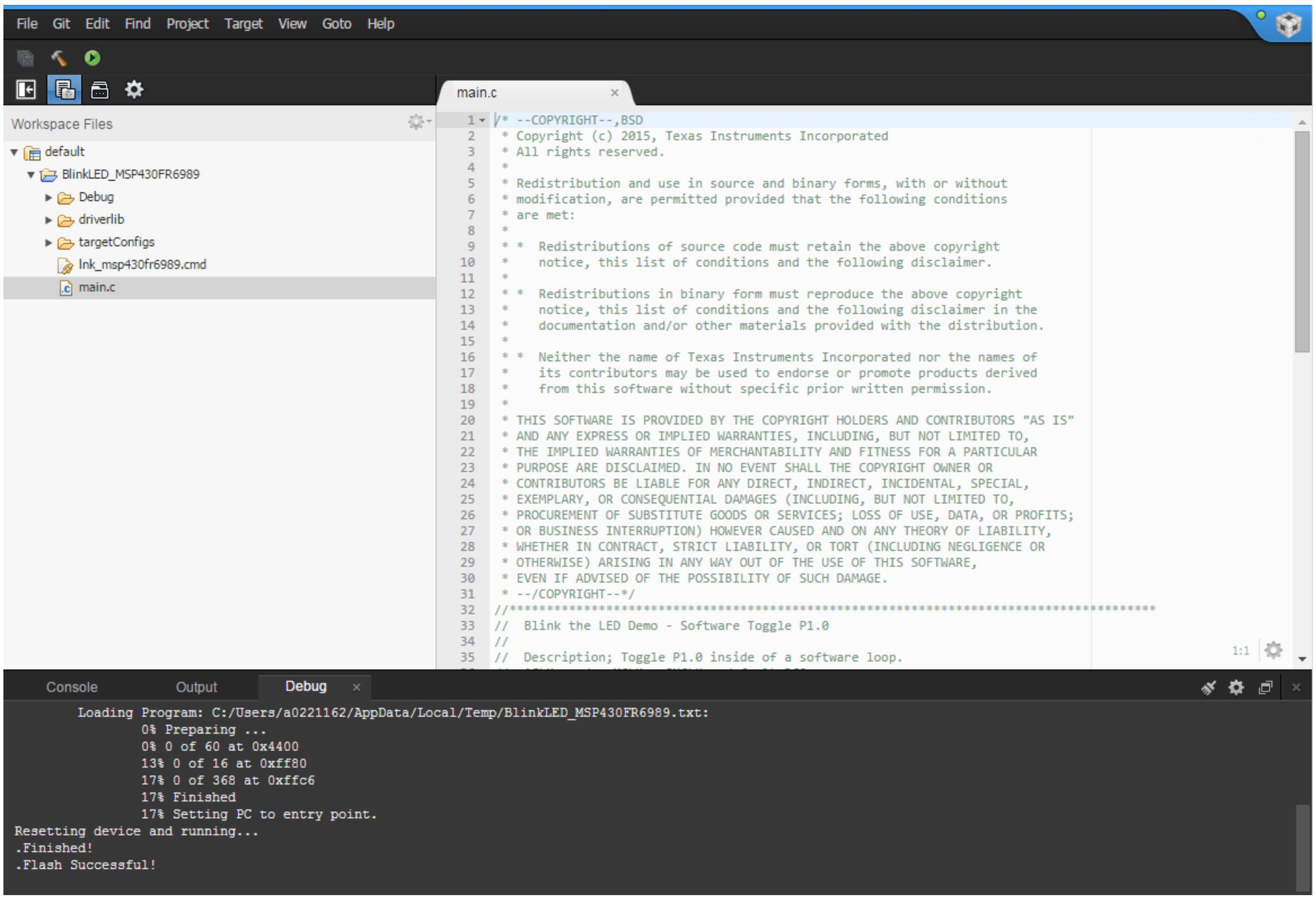

Figure 10. CCS Cloud

4.3 Code Composer Studio™ IDE

Code Composer Studio (CCS) IDE Desktop is a professional integrated development environment that supports TI's microcontroller and Embedded Processors portfolio. Code Composer Studio IDE comprises a suite of tools used to develop and debug embedded applications. It includes an optimizing C/C++ compiler, source code editor, project build environment, debugger, profiler, and many other features.

Learn more about CCS IDE and download it at http://www.ti.com/tool/ccstudio.

CCS IDE v6.1 or higher is required. When CCS has been launched, and a workspace directory chosen, use Project → Import Existing CCS Eclipse Project. Direct it to the desired demo project directory that contains main.c.

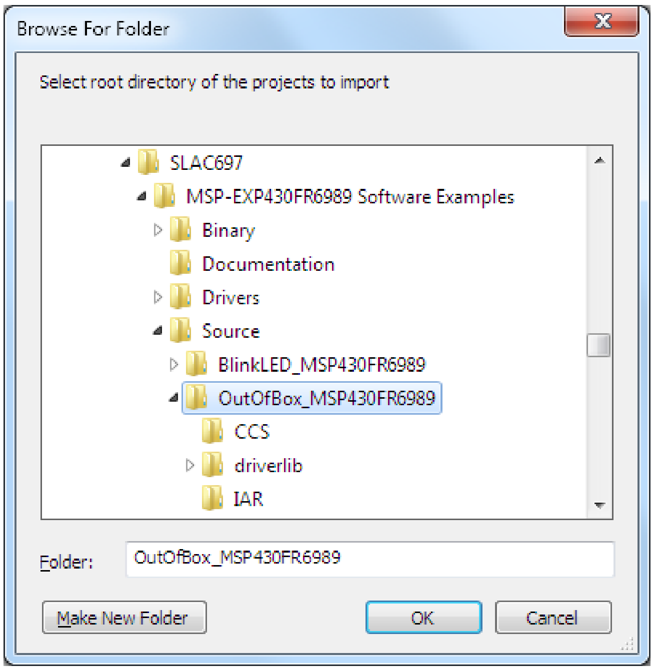

Figure 11. Directing the Project → Import Function to the Demo Project

Selecting the \CCS subdirectory also works. The CCS-specific files are located there.

When you click OK, CCS should recognize the project and allow you to import it. The indication that CCS has found it is that the project appears in the box shown in 12, and it has a checkmark to the left of it (see Figure 12).

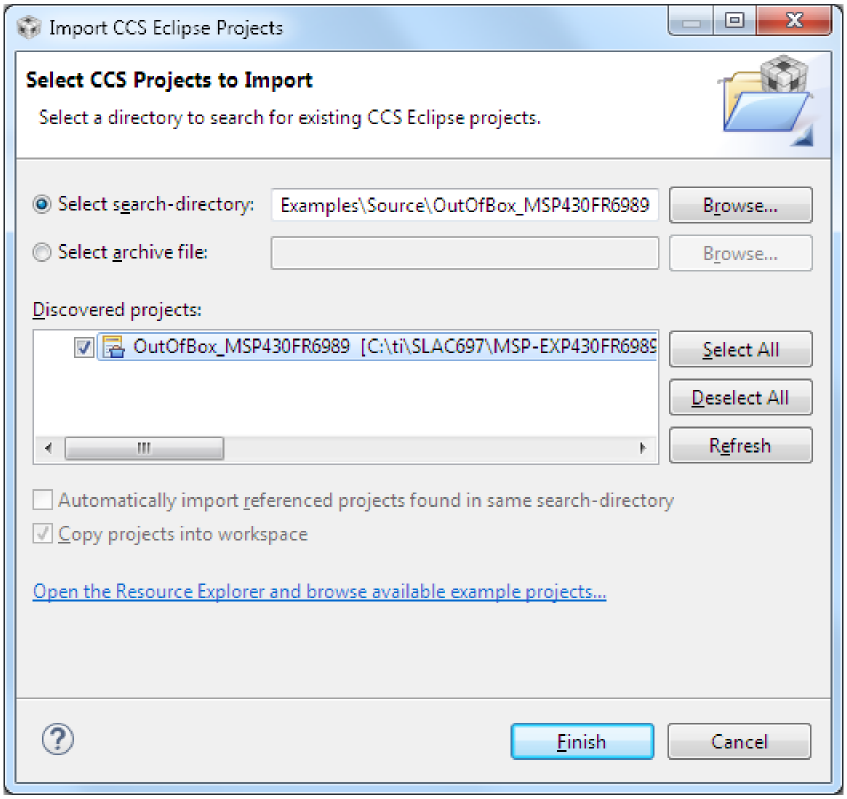

Figure 12. When CCS Has Found the Project

Sometimes CCS IDE finds the project but does not show a checkmark; this might mean that your workspace already has a project by that name. You can resolve this by renaming or deleting that project. (Even if you do not see it in the CCS IDE workspace, be sure to check the workspace directory on the file system.)

4.4 IAR Embedded Workbench® for Texas Instruments MSP430 MCUs

IAR Embedded Workbench for MSP430 MCUs is another very powerful integrated development environment that allows you to develop and manage complete embedded application projects. It integrates the IAR C/C++ Compiler, IAR Assembler, IAR ILINK Linker, editor, project manager, command line build utility, and IAR C-SPY® Debugger.

You can learn more about IAR Embedded Workbench for MSP430 and download it at http://supp.iar.com/Download/SW/?item=EW430-EVAL.

IAR 6.10 or higher is required. To open the demo in IAR, click File → Open → Workspace…, and browse to the *.eww workspace file inside the \IAR subdirectory of the desired demo. All workspace information is contained within this file.

The subdirectory also has an *.ewp project file. This file can be opened into an existing workspace by clicking Project → Add-Existing-Project.….

Although the software examples have all of the code required to run them, IAR users may download and install MSPWare software, which contains MSP430 MCU libraries and the TI Resource Explorer. These are already included in a Code Composer Studio installation (unless the user selected otherwise).

4.5 Energia

Energia is a simple, open-source, and community-driven code editor that is based on the Wiring and Arduino framework. Energia provides unmatched ease of use through very high-level APIs that can be used across hardware platforms. Energia is a light-weight IDE that does not have the full feature set of Code Composer Studio IDE or IAR. However, Energia is great for anyone who wants to get started very quickly or who does not have significant coding experience.

You can learn more about Energia and download it at www.energia.nu.

4.6 MSPWare Software and TI Resource Explorer

MSPWare software is a complete collection of libraries and tools. It includes a driver library (driverlib), graphics library (grlib), and many other software tools. MSPWare software is optionally included in a Code Composer Studio installation or can be downloaded separately. IAR users must download it separately.

MSPWare software includes the TI Resource Explorer, for easily browsing tools (see Figure 13). For example, all the software examples are shown in the tree.

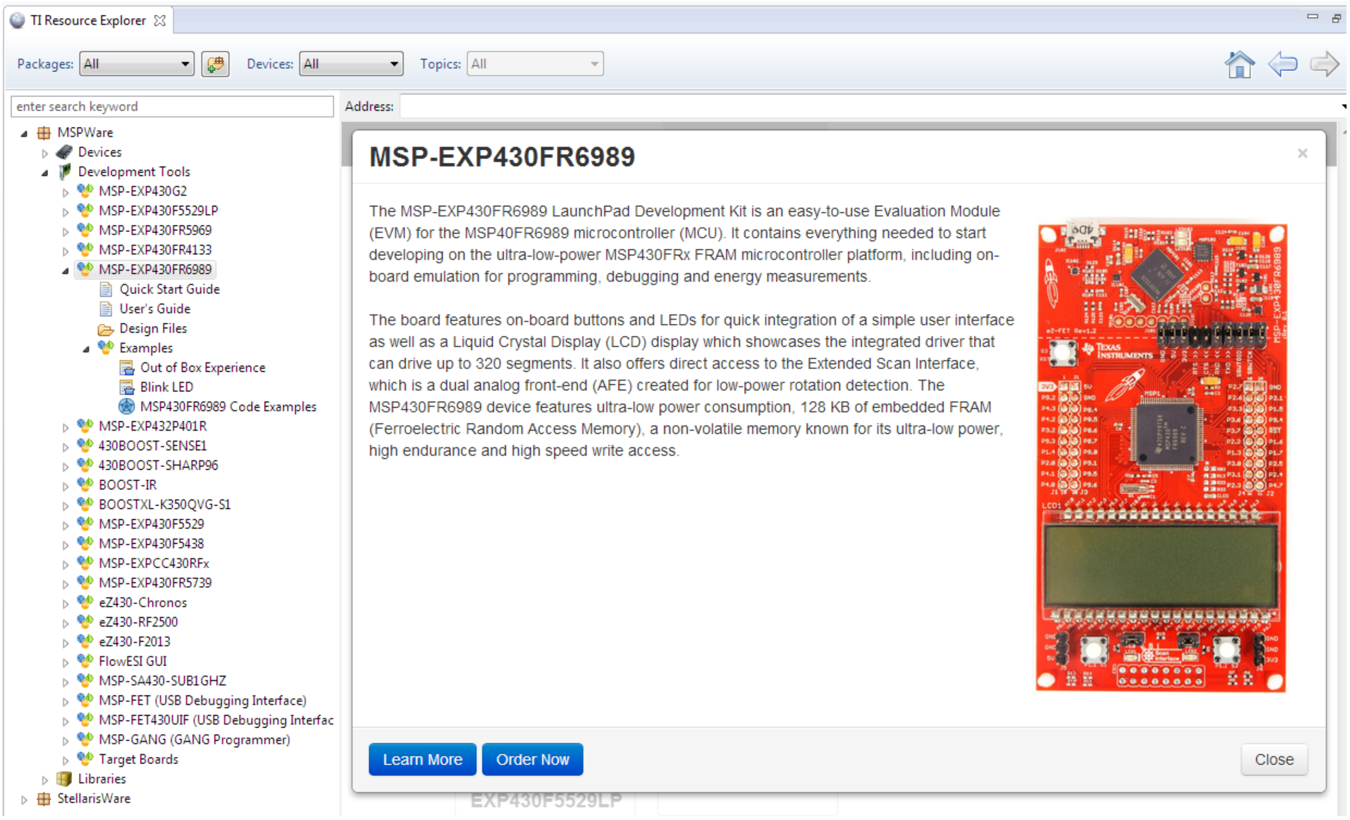

Figure 13. Software Examples in TI Resource Explorer

Inside TI Resource Explorer, these examples and many more can be found, and easily imported into Code Composer Studio IDE with one click.

4.7 The Community

4.7.1 TI E2E™ Online Community

Search the forums at http://e2e.ti.com. If you cannot find your answer, post your question to the community.

4.7.2 Community at Large

Many online communities focus on the LaunchPad development kit and BoosterPack plug-in module ecosystem; for example, http://www.43oh.com. You can find additional tools, resources, and support from these communities.

5 Schematics

Hardware design files can be found at BOOSTXL-BATPAKMKII Hardware Design Files.

Figure 14 shows the schematic.

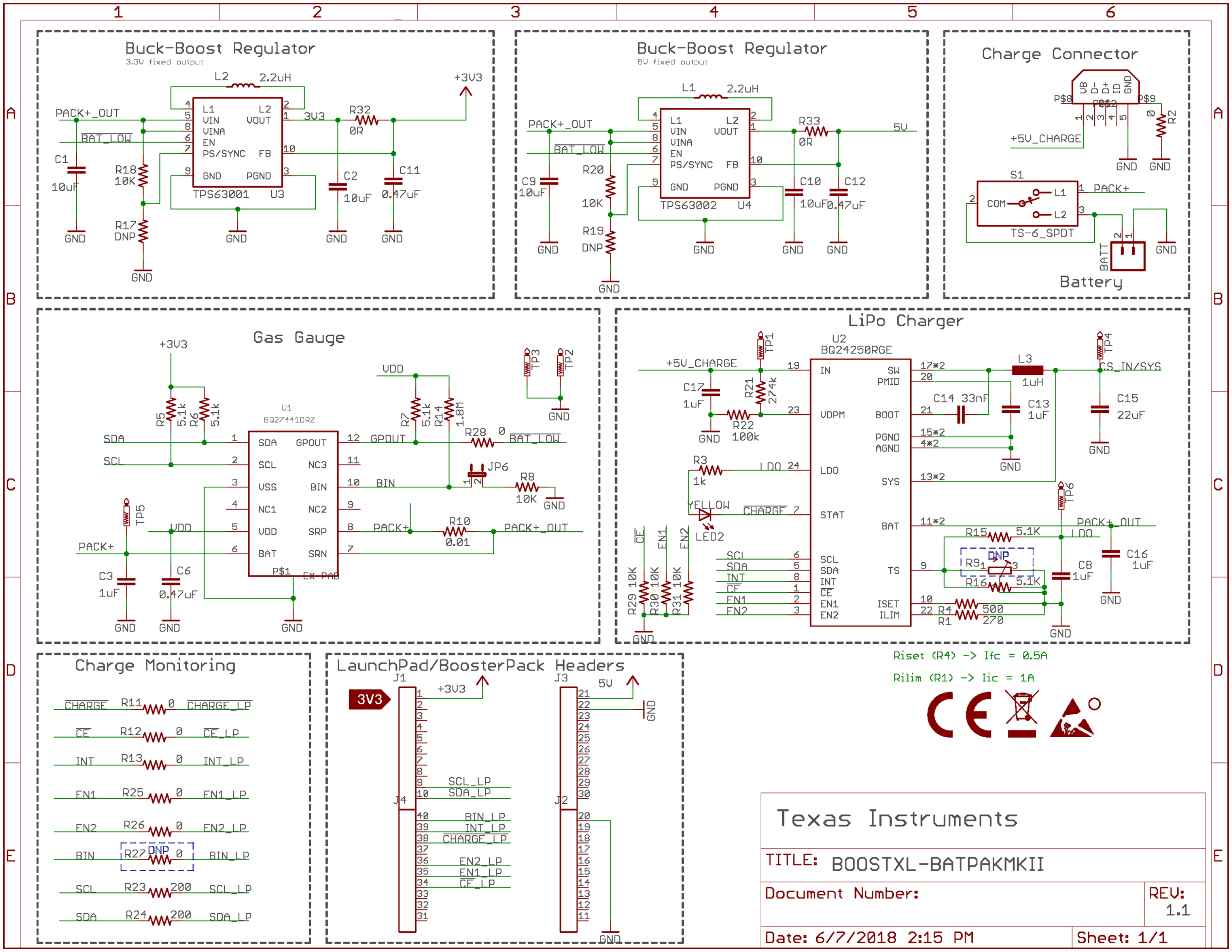

Figure 14. Schematics

Revision History

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

Changes from June 28, 2016 to June 8, 2018 **Page**

- Added the note that begins "The tolerance of the resistors populated at R15 and R16..." in Section 2.2.2, *Charging the Battery* ... 8
- Added Rev 1.1 to Table 4, *Hardware Change Log* ... 9
- Changed Figure 14, *Schematics*, for board rev 1.1 ... 19

STANDARD TERMS FOR EVALUATION MODULES

1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, and/or documentation which may be provided together or separately (collectively, an "EVM" or "EVMs") to the User ("User") in accordance with the terms set forth herein. User's acceptance of the EVM is expressly subject to the following terms.

   1.1 EVMs are intended solely for product or software developers for use in a research and development setting to facilitate feasibility evaluation, experimentation, or scientific analysis of TI semiconductors products. EVMs have no direct function and are not finished products. EVMs shall not be directly or indirectly assembled as a part or subassembly in any finished product. For clarification, any software or software tools provided with the EVM ("Software") shall not be subject to the terms and conditions set forth herein but rather shall be subject to the applicable terms that accompany such Software

   1.2 EVMs are not intended for consumer or household use. EVMs may not be sold, sublicensed, leased, rented, loaned, assigned, or otherwise distributed for commercial purposes by Users, in whole or in part, or used in any finished product or production system.

2 *Limited Warranty and Related Remedies/Disclaimers*:

   2.1 These terms do not apply to Software. The warranty, if any, for Software is covered in the applicable Software License Agreement.

   2.2 TI warrants that the TI EVM will conform to TI's published specifications for ninety (90) days after the date TI delivers such EVM to User. Notwithstanding the foregoing, TI shall not be liable for a nonconforming EVM if (a) the nonconformity was caused by neglect, misuse or mistreatment by an entity other than TI, including improper installation or testing, or for any EVMs that have been altered or modified in any way by an entity other than TI, (b) the nonconformity resulted from User's design, specifications or instructions for such EVMs or improper system design, or (c) User has not paid on time. Testing and other quality control techniques are used to the extent TI deems necessary. TI does not test all parameters of each EVM. User's claims against TI under this Section 2 are void if User fails to notify TI of any apparent defects in the EVMs within ten (10) business days after delivery, or of any hidden defects with ten (10) business days after the defect has been detected.

   2.3 TI's sole liability shall be at its option to repair or replace EVMs that fail to conform to the warranty set forth above, or credit User's account for such EVM. TI's liability under this warranty shall be limited to EVMs that are returned during the warranty period to the address designated by TI and that are determined by TI not to conform to such warranty. If TI elects to repair or replace such EVM, TI shall have a reasonable time to repair such EVM or provide replacements. Repaired EVMs shall be warranted for the remainder of the original warranty period. Replaced EVMs shall be warranted for a new full ninety (90) day warranty period.

3 *Regulatory Notices:*

   3.1 *United States*

   3.1.1 *Notice applicable to EVMs not FCC-Approved:*

   FCC NOTICE: This kit is designed to allow product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and software developers to write software applications for use with the end product. This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.

   3.1.2 *For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant:*

   CAUTION

   This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

   Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

   FCC Interference Statement for Class A EVM devices

   NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

FCC Interference Statement for Class B EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- *Reorient or relocate the receiving antenna.*
- *Increase the separation between the equipment and receiver.*
- *Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.*
- *Consult the dealer or an experienced radio/TV technician for help.*

3.2 *Canada*

3.2.1 *For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210 or RSS-247*

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSSs. Operation is subject to the following two conditions:

(1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concernant les EVMs avec appareils radio:

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Concerning EVMs Including Detachable Antennas:

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d’usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur

3.3 *Japan*

3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page 日本国内に輸入される評価用キット、ボードについては、次のところをご覧ください。
http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page

3.3.2 *Notice for Users of EVMs Considered “Radio Frequency Products” in Japan:* EVMs entering Japan may not be certified by TI as conforming to Technical Regulations of Radio Law of Japan.

If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required to follow the instructions set forth by Radio Law of Japan, which includes, but is not limited to, the instructions below with respect to EVMs (which for the avoidance of doubt are stated strictly for convenience and should be verified by User):

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry’s Rule for Enforcement of Radio Law of Japan,
2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

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1. 電波法施行規則第6条第1項第1号に基づく平成18年3月28日総務省告示第173号で定められた電波暗室等の試験設備でご使用いただく。
2. 実験局の免許を取得後ご使用いただく。
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なお、本製品は、上記の「ご使用にあたっての注意」を譲渡先、移転先に通知しない限り、譲渡、移転できないものとします。

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3.4 *European Union*

3.4.1 *For EVMs subject to EU Directive 2014/30/EU (Electromagnetic Compatibility Directive)*:

This is a class A product intended for use in environments other than domestic environments that are connected to a low-voltage power-supply network that supplies buildings used for domestic purposes. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

4 *EVM Use Restrictions and Warnings:*

4.1 EVMS ARE NOT FOR USE IN FUNCTIONAL SAFETY AND/OR SAFETY CRITICAL EVALUATIONS, INCLUDING BUT NOT LIMITED TO EVALUATIONS OF LIFE SUPPORT APPLICATIONS.

4.2 User must read and apply the user guide and other available documentation provided by TI regarding the EVM prior to handling or using the EVM, including without limitation any warning or restriction notices. The notices contain important safety information related to, for example, temperatures and voltages.

4.3 *Safety-Related Warnings and Restrictions:*

4.3.1 User shall operate the EVM within TI's recommended specifications and environmental considerations stated in the user guide, other available documentation provided by TI, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the EVM may cause personal injury or death, or property damage. If there are questions concerning performance ratings and specifications, User should contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may also result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM user 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, even with the inputs and outputs kept within the specified allowable ranges, some circuit components may have elevated case temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, current sense resistors, and heat sinks, which can be identified using the information in the associated documentation. When working with the EVM, please be aware that the EVM may become very warm.

4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.

4.4 User assumes all responsibility and liability to determine whether the EVM is subject to any applicable international, federal, state, or local laws and regulations related to User's handling and use of the EVM and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the EVM consistent with all applicable international, federal, state, and local requirements.

5. *Accuracy of Information:* To the extent TI provides information on the availability and function of EVMs, TI attempts to be as accurate as possible. However, TI does not warrant the accuracy of EVM descriptions, EVM availability or other information on its websites as accurate, complete, reliable, current, or error-free.

6. *Disclaimers:*

   6.1 EXCEPT AS SET FORTH ABOVE, EVMS AND ANY MATERIALS PROVIDED WITH THE EVM (INCLUDING, BUT NOT LIMITED TO, REFERENCE DESIGNS AND THE DESIGN OF THE EVM ITSELF) ARE PROVIDED "AS IS" AND "WITH ALL FAULTS." TI DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, REGARDING SUCH ITEMS, INCLUDING BUT NOT LIMITED TO ANY EPIDEMIC FAILURE WARRANTY OR IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF ANY THIRD PARTY PATENTS, COPYRIGHTS, TRADE SECRETS OR OTHER INTELLECTUAL PROPERTY RIGHTS.

   6.2 EXCEPT FOR THE LIMITED RIGHT TO USE THE EVM SET FORTH HEREIN, NOTHING IN THESE TERMS SHALL BE CONSTRUED AS GRANTING OR CONFERRING ANY RIGHTS BY LICENSE, PATENT, OR ANY OTHER INDUSTRIAL OR INTELLECTUAL PROPERTY RIGHT OF TI, ITS SUPPLIERS/LICENSORS OR ANY OTHER THIRD PARTY, TO USE THE EVM IN ANY FINISHED END-USER OR READY-TO-USE FINAL PRODUCT, OR FOR ANY INVENTION, DISCOVERY OR IMPROVEMENT, REGARDLESS OF WHEN MADE, CONCEIVED OR ACQUIRED.

7. *USER'S INDEMNITY OBLIGATIONS AND REPRESENTATIONS.* USER WILL DEFEND, INDEMNIFY AND HOLD TI, ITS LICENSORS AND THEIR REPRESENTATIVES HARMLESS FROM AND AGAINST ANY AND ALL CLAIMS, DAMAGES, LOSSES, EXPENSES, COSTS AND LIABILITIES (COLLECTIVELY, "CLAIMS") ARISING OUT OF OR IN CONNECTION WITH ANY HANDLING OR USE OF THE EVM THAT IS NOT IN ACCORDANCE WITH THESE TERMS. THIS OBLIGATION SHALL APPLY WHETHER CLAIMS ARISE UNDER STATUTE, REGULATION, OR THE LAW OF TORT, CONTRACT OR ANY OTHER LEGAL THEORY, AND EVEN IF THE EVM FAILS TO PERFORM AS DESCRIBED OR EXPECTED.

8. *Limitations on Damages and Liability:*

   8.1 *General Limitations*. IN NO EVENT SHALL TI BE LIABLE FOR ANY SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL, OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF THESE TERMS OR THE USE OF THE EVMS , REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. EXCLUDED DAMAGES INCLUDE, BUT ARE NOT LIMITED TO, COST OF REMOVAL OR REINSTALLATION, ANCILLARY COSTS TO THE PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES, RETESTING, OUTSIDE COMPUTER TIME, LABOR COSTS, LOSS OF GOODWILL, LOSS OF PROFITS, LOSS OF SAVINGS, LOSS OF USE, LOSS OF DATA, OR BUSINESS INTERRUPTION. NO CLAIM, SUIT OR ACTION SHALL BE BROUGHT AGAINST TI MORE THAN TWELVE (12) MONTHS AFTER THE EVENT THAT GAVE RISE TO THE CAUSE OF ACTION HAS OCCURRED.

   8.2 *Specific Limitations.* IN NO EVENT SHALL TI'S AGGREGATE LIABILITY FROM ANY USE OF AN EVM PROVIDED HEREUNDER, INCLUDING FROM ANY WARRANTY, INDEMITY OR OTHER OBLIGATION ARISING OUT OF OR IN CONNECTION WITH THESE TERMS, , EXCEED THE TOTAL AMOUNT PAID TO TI BY USER FOR THE PARTICULAR EVM(S) AT ISSUE DURING THE PRIOR TWELVE (12) MONTHS WITH RESPECT TO WHICH LOSSES OR DAMAGES ARE CLAIMED. THE EXISTENCE OF MORE THAN ONE CLAIM SHALL NOT ENLARGE OR EXTEND THIS LIMIT.

9. *Return Policy.* Except as otherwise provided, TI does not offer any refunds, returns, or exchanges. Furthermore, no return of EVM(s) will be accepted if the package has been opened and no return of the EVM(s) will be accepted if they are damaged or otherwise not in a resalable condition. If User feels it has been incorrectly charged for the EVM(s) it ordered or that delivery violates the applicable order, User should contact TI. All refunds will be made in full within thirty (30) working days from the return of the components(s), excluding any postage or packaging costs.

10. *Governing Law:* These terms and conditions shall be governed by and interpreted in accordance with the laws of the State of Texas, without reference to conflict-of-laws principles. User agrees that non-exclusive jurisdiction for any dispute arising out of or relating to these terms and conditions lies within courts located in the State of Texas and consents to venue in Dallas County, Texas. Notwithstanding the foregoing, any judgment may be enforced in any United States or foreign court, and TI may seek injunctive relief in any United States or foreign court.

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