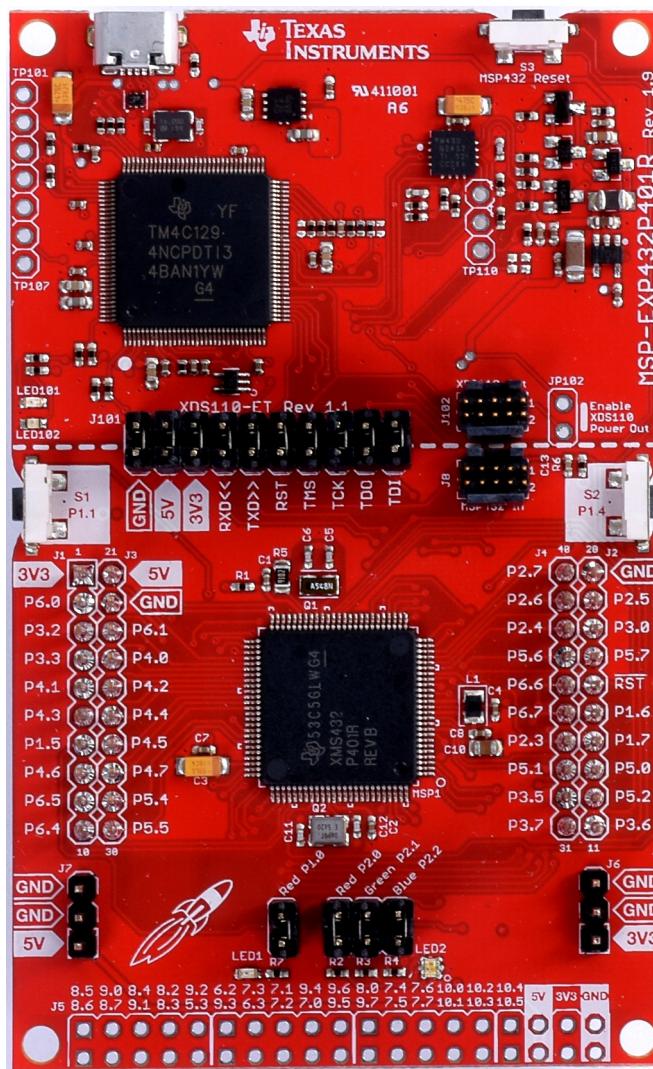


## **MSP432P401R LaunchPad™ Development Kit (MSP-EXP432P401R)**

The [MSP-EXP432P401R](#) LaunchPad™ development kit is an easy-to-use evaluation module for the [MSP432P401R](#) microcontroller. It contains everything needed to start developing on the MSP432™ Low-Power + Performance ARM® 32-bit Cortex®-M4F microcontroller (MCU), including onboard debug probe for programming, debugging, and energy measurements. The MSP432P401R device supports low-power applications requiring increased CPU speed, memory, analog, and 32-bit performance.



**Figure 1. MSP-EXP432P401R LaunchPad™ Development Kit**

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## 1 Getting Started

### 1.1 Introduction

The MSP-EXP432P401R LaunchPad development kit is an easy-to-use evaluation module for the [MSP432P401R microcontroller](#). It contains everything needed to start developing on the MSP432 Low-Power + Performance ARM 32-bit Cortex-M4F microcontroller (MCU), including onboard debug probe for programming, debugging, and energy measurements. The [MSP432P401R device](#) supports low-power applications that require increased CPU speed, memory, analog, and 32-bit performance.

Rapid prototyping is simplified by access to the 40-pin headers and a wide variety of BoosterPack™ plug-in modules that enable technologies such as wireless connectivity, graphical displays, environmental sensing, and many more. Free software development tools are also available such as TI's Eclipse-based [Code Composer Studio™](#) (CCS) IDE, [IAR Embedded Workbench™](#) IDE, and [Keil® µVision®](#) IDE. Code Composer (CCS) supports [EnergyTrace™ technology](#) when paired with the MSP432P401R LaunchPad development kit. More information about the LaunchPad development kit, the supported BoosterPack plug-in modules, and the available resources can be found at [TI's LaunchPad portal](#). To get started quickly, and find available resources in MSPWare, visit the [TI Cloud Development Environment](#).

### 1.2 Key Features

- Low-power ARM Cortex-M4F MSP432P401R
- 40-pin LaunchPad development kit standard that leverages the BoosterPack plug-in module ecosystem
- XDS110-ET, an open-source onboard debug probe featuring EnergyTrace+ technology and application UART
- Two buttons and two LEDs for user interaction
- Backchannel UART through USB to PC

## 1.3 What's Included

### 1.3.1 Kit Contents

- One MSP-EXP432P401R LaunchPad development kit
- One Micro USB cable
- One Quick Start Guide

### 1.3.2 Software Examples ([Section 3](#))

- Out-of-Box Software Example
- CC3100BOOST MQTT-Twitter LED Control Example
- BOOSTXL-K350QVG-S1 Graphics Library Example
- 430BOOST-SHARP96 Graphics Library Example
- BOOSTXL-BATPAKMKII Fuel Gauge Example
- BOOSTXL-SENSORS Sensor GUI Example
- BOOSTXL-SENSORS Sensor GUI with TI-RTOS Example

## 1.4 First Steps: Out-of-Box Experience

An easy way to get familiar with the EVM is by using its preprogrammed out-of-box code. It demonstrates some key features of the LaunchPad development kit from a user level, showing how to use the pushbutton switches together with onboard LEDs and basic serial communication with a computer.

A more detailed explanation of the out-of-box demo can be found in [Section 3](#).

## 1.5 Next Steps: Looking Into the Provided Code

It is now time to start exploring more features of the EVM!

[www.ti.com/beginMSP432launchpad](http://www.ti.com/beginMSP432launchpad)

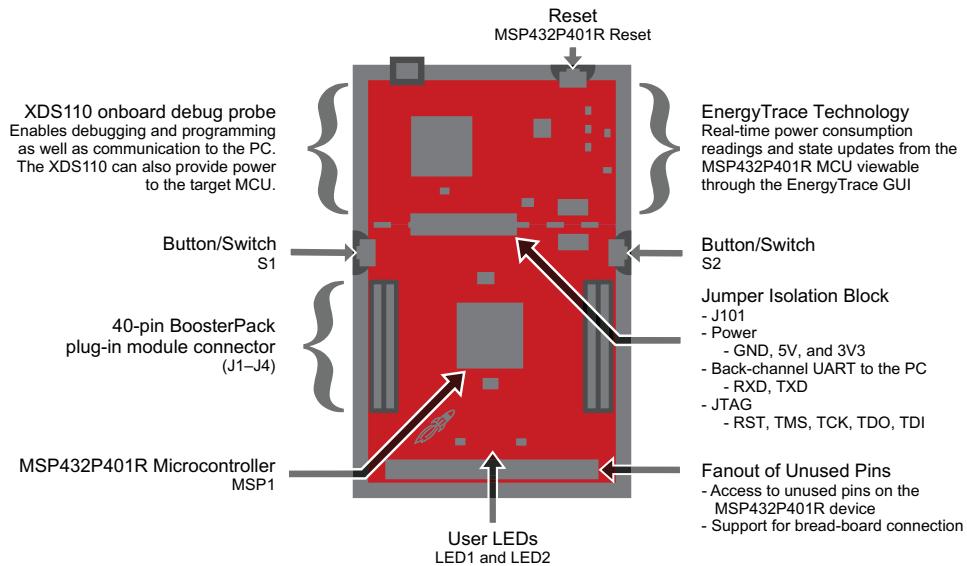
To get started, you will need an integrated development environment (IDE) to explore and start editing the code examples. Refer to [Section 4](#) for more information on IDEs and where to download them.

Continuing in the footsteps of the widely successful MSP430™ 16-bit ultra-low-power microcontroller platform, Texas Instruments expands its MSP product line with the MSP432 microcontroller platform. If you are used to developing with MSP430 devices, see [MSP432 Platform Porting](#) to help start your MSP432 application with ease.

The out-of-box source code and more code examples can be downloaded from the [MSP-EXP432P401R tool folder](#). Find what code examples are available and more details about each example in [Section 3](#). All code is licensed under BSD, and TI encourages reuse and modifications to fit specific needs.

## 2 Hardware

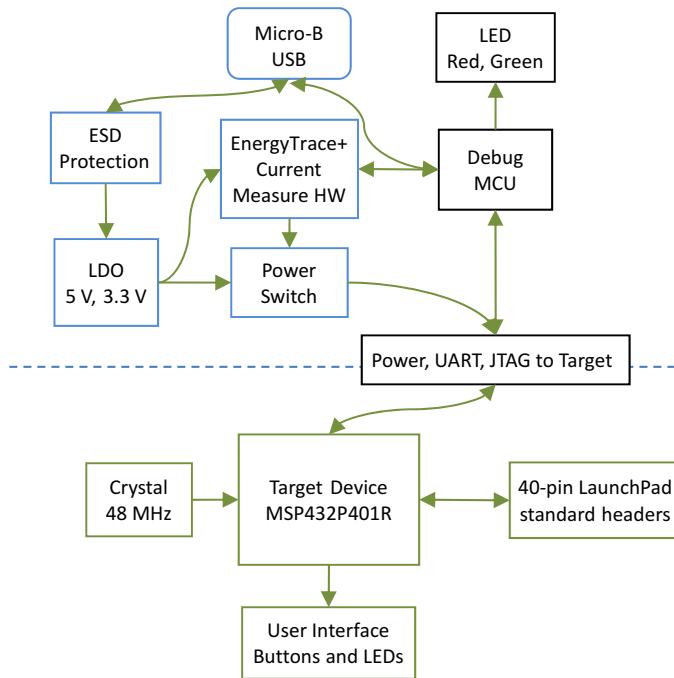
[Figure 2](#) shows an overview of the EVM hardware.



**Figure 2. MSP-EXP432P401R Overview**

### 2.1 Block Diagram

[Figure 3](#) shows the block diagram.



**Figure 3. Block Diagram**

## 2.2 MSP432P401R

The MSP432P401R is the first MSP432 family device featuring low-power performance with an ARM Cortex-M4F core. Device features include:

- Low-power ARM Cortex-M4F MSP432P401R
- Up to 48-MHz system clock
- 256KB flash memory, 64KB SRAM, and 32KB ROM with MSPWare libraries
- Four 16-bit timers with capture/compare/PWM, two 32-bit timers, and RTC
- Up to eight serial communication channels (I<sup>2</sup>C, SPI, UART, and IrDA)
- Analog: 14-bit SAR ADC, capacitive touch, comparator
- Digital: AES256, CRC, uDMA

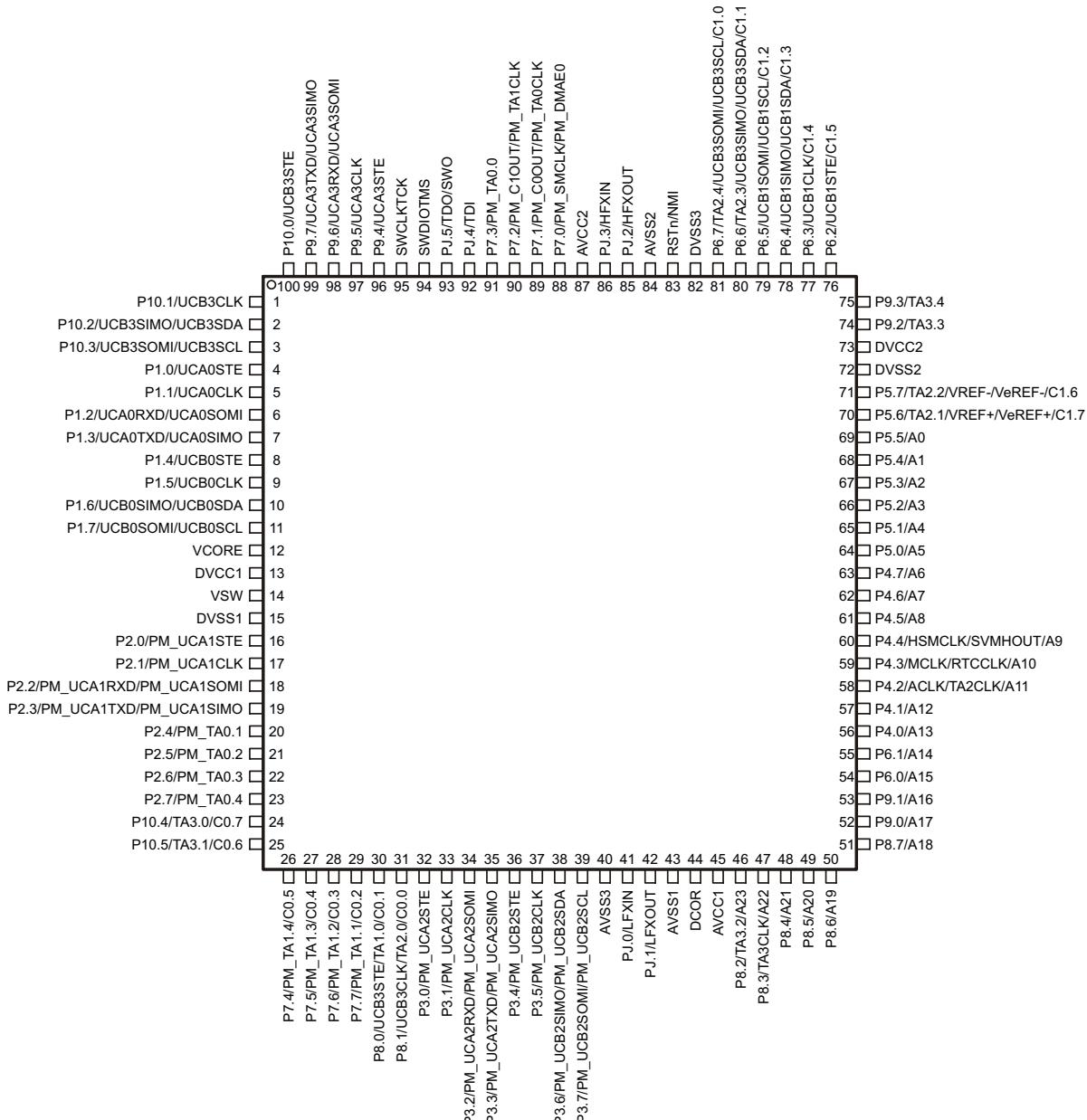
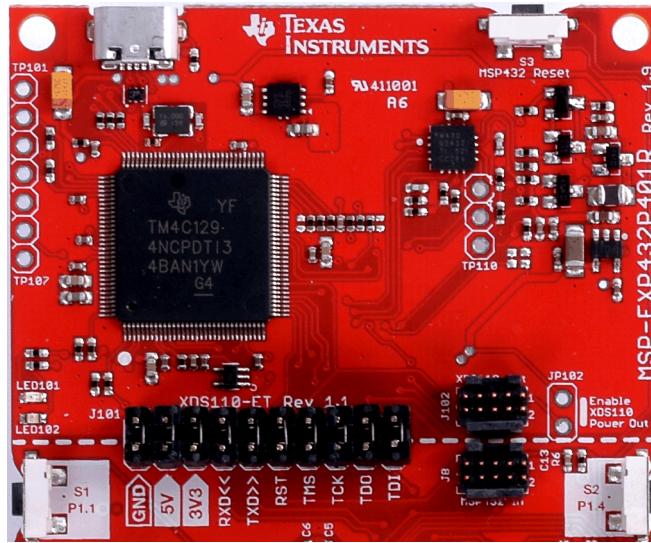


Figure 4. MSP432P401RIPZ Pinout

## 2.3 XDS110-ET Onboard Debug Probe

To keep development easy and cost effective, TI's LaunchPad development kits integrate an onboard debug probe, which eliminates the need for expensive programmers. The MSP-EXP432P401R has the XDS110-ET debug probe, which is a simple low-cost debug probe that supports nearly all TI ARM device derivatives.



**Figure 5. XDS110-ET Debug Probe**

The XDS110-ET hardware can be found in the schematics in [Section 6](#) and in the [MSP-EXP432P401R Hardware Design Files](#).

### 2.3.1 XDS110-ET Isolation Block J101

The J101 isolation block is composed of J101 jumpers shown in [Table 1](#). The J101 isolation block allows the user to connect or disconnect signals that cross from the XDS110-ET domain into the MSP432P401R target domain. This crossing is shown by the silkscreen dotted line across the LaunchPad development kit through J101. No other signals cross the domain, so the XDS110-ET can be completely decoupled from the MSP432P401R target side. This includes XDS110-ET power and GND signals, UART, and JTAG signals.

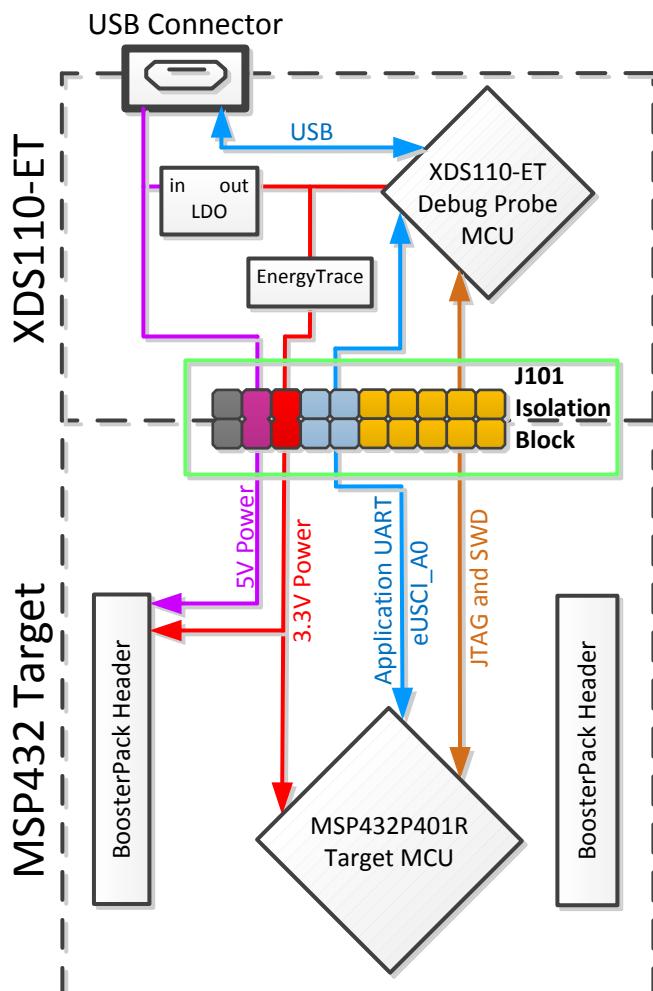
[Table 1](#) lists the signals that are controlled at the isolation block.

**Table 1. Isolation Block Connections**

Signal	Description
GND	GND power connection between XDS110 and MSP432 target GND planes. The GND jumper is populated to connect the separate GND planes. This connection is required for proper operation with 3V3, 5V, UART, and JTAG.
5V	5-V power rail, VBUS from USB
3V3	3.3-V power rail, derived from VBUS by an LDO in the XDS110-ET domain
RXD <<	Backchannel UART: The target MCU receives data through this signal. The arrows indicate the direction of the signal.
TXD >>	Backchannel UART: The target MCU sends data through this signal. The arrows indicate the direction of the signal.
RST	MCU RST signal (active low)
TCK_SWCLK	Serial wire clock input (SWCLK) / JTAG clock input (TCK)
TMS_SWDIO	Serial wire data input/output (SWDIO) / JTAG test mode select (TMS)
TDO_SWO	Serial wire trace output (SWO) / JTAG trace output (TWO) (Also PJ.5)
TDI	JTAG test data input (Also PJ.4)

Reasons to open these connections:

- To remove any and all influence from the XDS110-ET debug probe for high accuracy target power measurements
- To control 3-V and 5-V power flow between the XDS110-ET and target domains
- To expose the target MCU pins for other use than onboard debugging and application UART communication
- To expose the UART interface of the XDS110-ET so that it can be used for devices other than the onboard MCU.



**Figure 6. XDS110-ET Isolation Block**

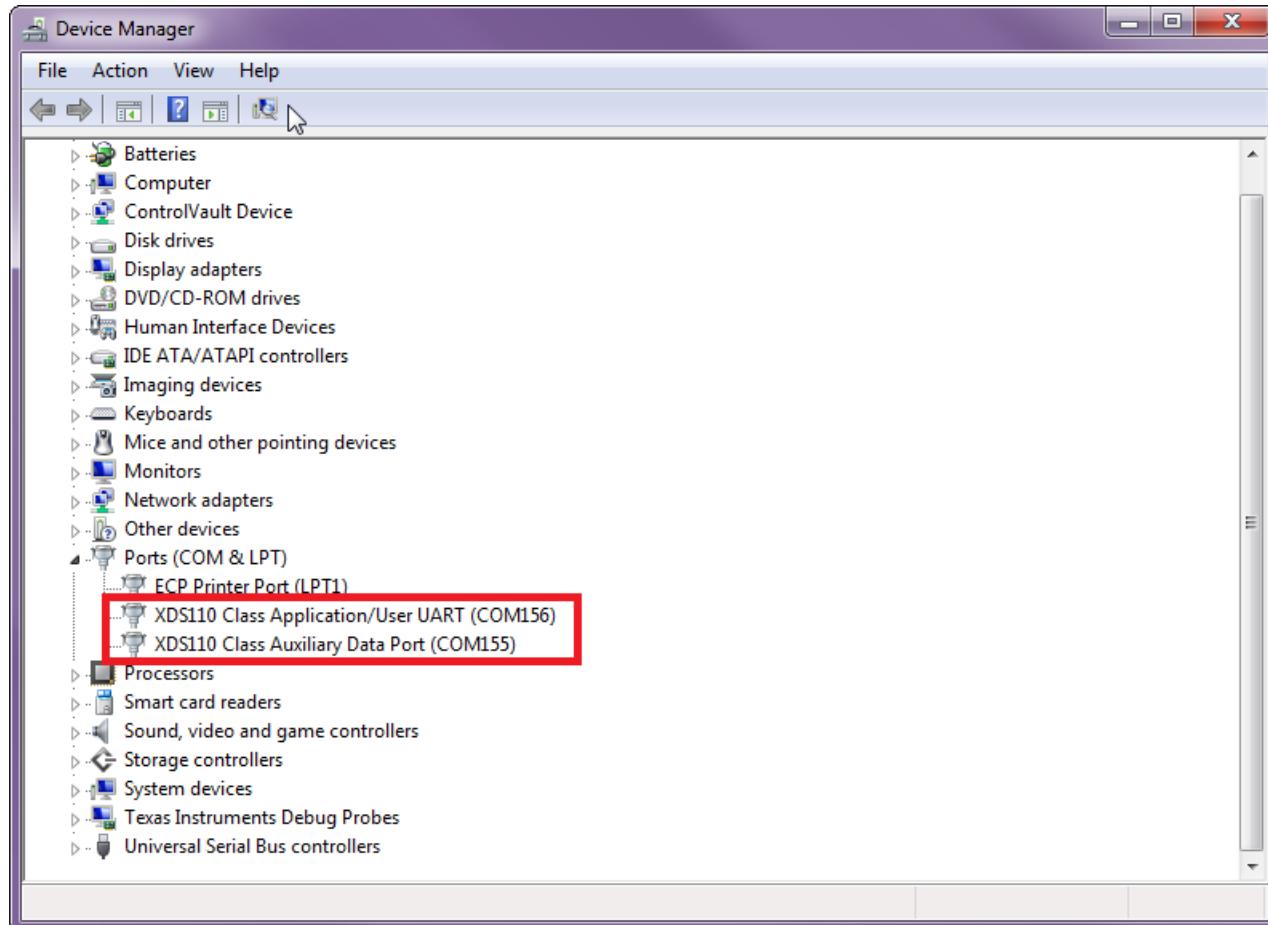
### 2.3.2 Application (or "Backchannel") UART

The XDS110-ET provides a "backchannel" UART-over-USB connection with the host, which can be very useful during debugging and for easy communication with a PC.

The backchannel UART allows communication with the USB host that is not part of the target application's main functionality. This is very useful during development, and also provides a communication channel to the PC host side. This can be used to create GUIs and other programs on the PC that communicate with the LaunchPad development kit.

The pathway of the backchannel UART is shown in [Figure 7](#). The backchannel UART eUSCI\_A0 is independent of the UART on the 40-pin BoosterPack plug-in module connector eUSCI\_A2.

On the host side, a virtual COM port for the application backchannel UART is generated when the LaunchPad development kit enumerates on the host. You can use any PC application that interfaces with COM ports, including terminal applications like Hyperterminal or Docklight, to open this port and communicate with the target application. You need to identify the COM port for the backchannel. On Windows PCs, Device Manager can assist.



**Figure 7. Application Backchannel UART in Device Manager**

The backchannel UART is the XDS110 Class Application/User UART port. In this case, [Figure 7](#) shows COM156, but this port can vary from one host PC to the next. After you identify the correct COM port, configure it in your host application according to its documentation. You can then open the port and begin communication to it from the host.

The XDS110-ET has a configurable baud rate; therefore, it is important that the PC application configures the baud rate to be the same as what is configured on the eUSCI\_A0 backchannel UART.

### 2.3.3 Using an External Debug Probe Instead of the Onboard XDS110-ET

Many users have a specific external debug probe that they prefer to use, and may wish to bypass the XDS110-ET debug probe to program the MSP432 target MCU. This is enabled by jumpers on isolation block J101, and the connector J8. Using an external debug probe is simple, and full JTAG access is provided through J8.

1. Remove jumpers on the JTAG signals on the J101 isolation block, including RST, TMS, TCK, TDO, and TDI.
2. Plug any ARM debug probe into J8.
  - (a) J8 follows the ARM Cortex Debug Connector standard outlined in [Cortex-M Debug Connectors](#).
3. Plug USB power into the LaunchPad development kit, or power it externally.
  - (a) Ensure that the jumpers across 3V3 and GND are connected if using USB power.
  - (b) External debug probes do not provide power, the VCC pin is a power sense pin.
  - (c) More details on powering the LaunchPad development kit can be found in [Section 2.4](#).

### 2.3.4 Using the XDS110-ET Debug Probe With a Different Target

The XDS110-ET debug probe on the LaunchPad can interface to most ARM Cortex-M devices, not just the onboard target MSP432P410R device. This functionality is enabled by the J102 [10-pin Cortex-M JTAG](#) connector. The 10-pin cable can be purchased from [DigiKey Electronics](#) (sold separately from the LaunchPad development kit).

Header J102 follows the Cortex-M ARM standard; however, pin 1 is not a voltage sense pin. The XDS110-ET outputs only 3.3-V JTAG signals. If another voltage level is needed, the user must provide level shifters to translate the JTAG signal voltages. Additionally, 3.3 V of output power can be sourced from the XDS110-ET when jumper JP102 is connected. This allows the XDS110-ET to power the external target at 3.3 V through pin 1. By default JP102 is not populated as it does not explicitly follow the standard.

1. Remove jumpers on the JTAG signals on the J101 isolation block, including RST, TMS, TCK, TDO, and TDI.
2. Plug the [10-pin cable](#) into J102, and connect to an external target a. J102 follows the ARM Cortex Debug Connector standard outlined in [Cortex-M Debug Connectors](#).
3. Plug USB power into the LaunchPad, or power it externally
  - (a) JTAG levels are 3.3 V ONLY.
  - (b) 3.3-V power can be sourced through J102 by shorting the JP102 jumper.

### 2.3.5 EnergyTrace+ Technology

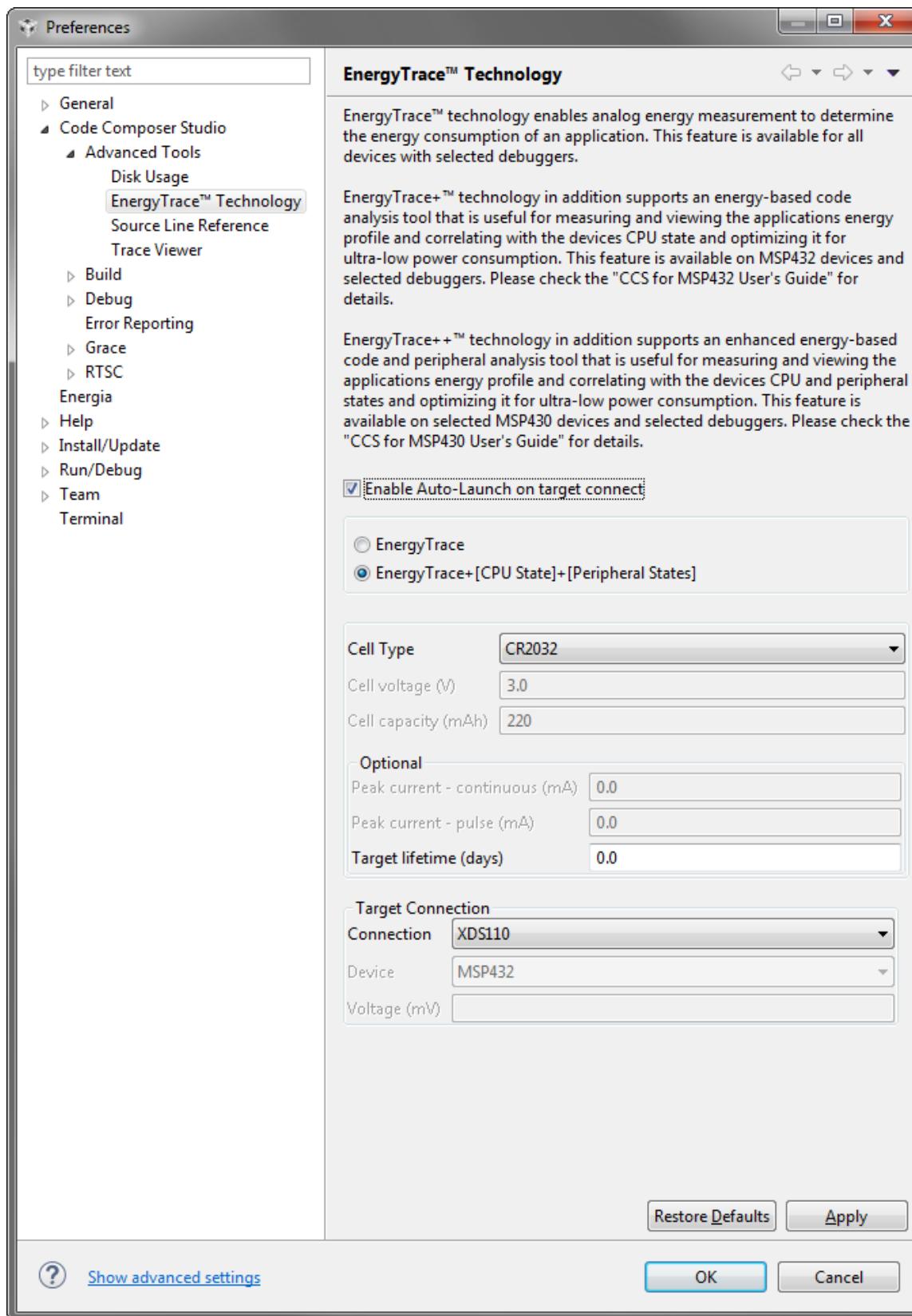
EnergyTrace™ technology is an energy-based code analysis tool that measures and displays the application's energy profile and helps to optimize it for ultra-low power consumption.

MSP432 devices with built-in EnergyTrace+[CPU State] (or in short EnergyTrace+) technology allow real-time monitoring of internal device states while user program code executes.

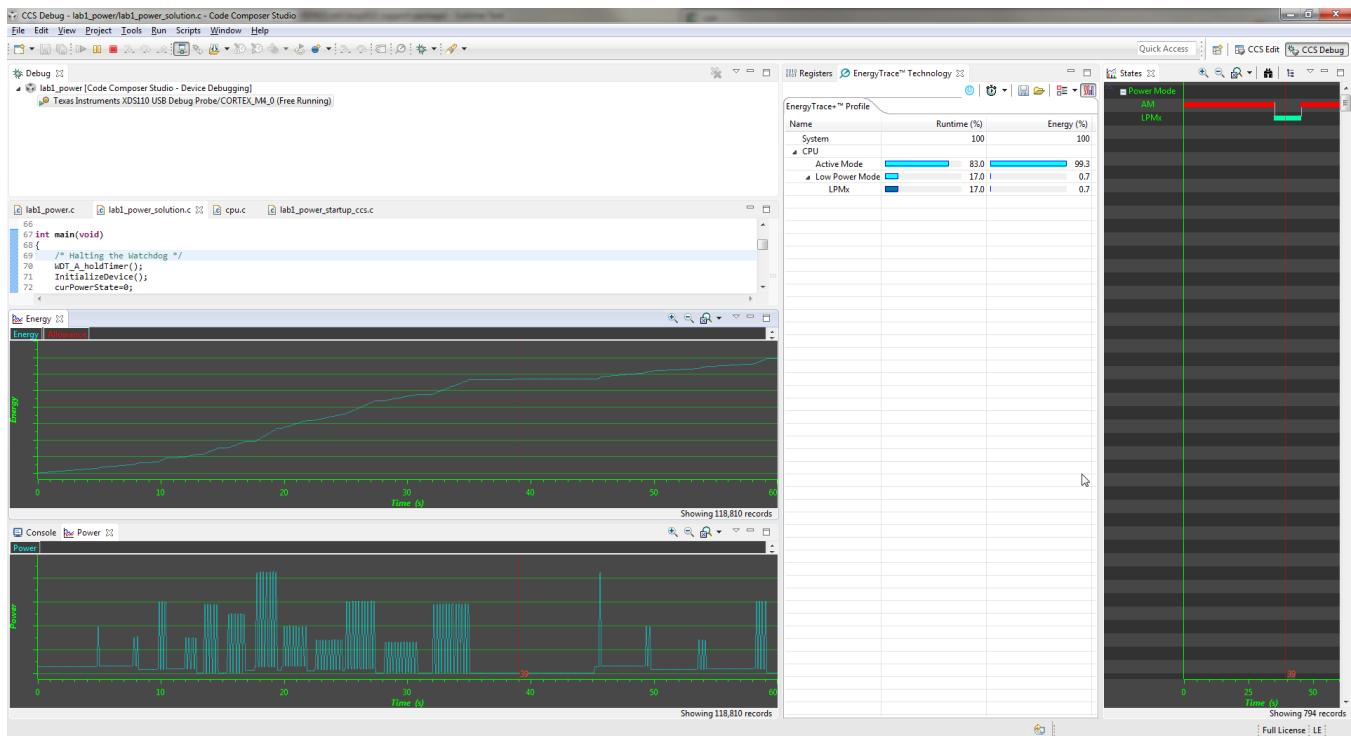
EnergyTrace+ technology is supported on the LaunchPad development kit MSP432P401R device + XDS110-ET debug probe. EnergyTrace technology is available as part of TI's Code Composer Studio IDE. During application debug, additional windows are available for EnergyTrace technology.

To enable EnergyTrace technology, go to:

- Window > Preferences > Code Composer Studio > Advanced Tools > EnergyTrace™ Technology
- Check the Enable Auto-Launch on target connect box


**Figure 8. EnergyTrace™ Technology Preferences**

Starting a debug session will now open EnergyTrace technology windows. These windows show energy, power, profile, and states to give the user a full view of the energy profile of their application.



**Figure 9. EnergyTrace™ Windows**

This data allows the user to see exactly where and how energy is consumed in their application. Optimizations for energy can be quickly made for the lowest power application possible.

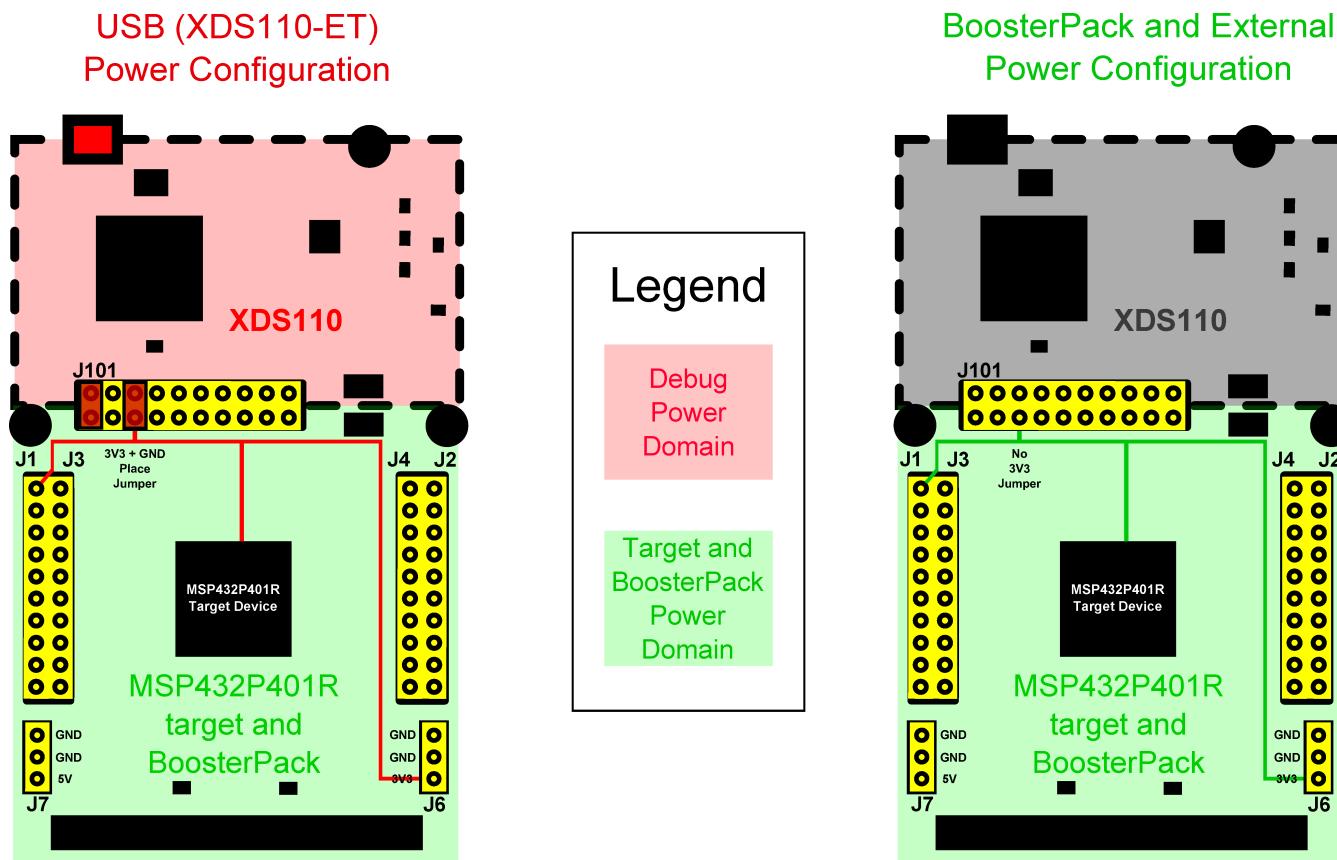
On the LaunchPad development kit, EnergyTrace technology measures the current that enters the target side of the LaunchPad development kit. This includes all BoosterPack plug-in modules plugged in, and anything else connected to the 3V3 power rail. For more information about powering the LaunchPad development kit, see [Section 2.4](#).

For more information about EnergyTrace technology, see <http://www.ti.com/tool/energytrace>.

For more details and questions about setting up and using EnergyTrace technology with the MSP432P401R, see the [Code Composer Studio 6 User's Guide for MSP432](#).

## 2.4 Power

The board was designed to accommodate various powering methods, including through the onboard XDS110-ET and from an external source or BoosterPack plug-in module.



**Figure 10. MSP-EXP432P401R Power Block Diagram**

### 2.4.1 XDS110-ET USB Power

The most common power-supply scenario is from USB through the XDS110-ET debug probe. This provides 5-V power from the USB and also regulates this power rail to 3.3 V for XDS110-ET operation and 3.3 V to the target side of the LaunchPad development kit. Power from the XDS110-ET is controlled by the isolation block 3V3 jumper, ensure this jumper is connected for power to be provided to the target MCU side.

Under normal operation, the LDO on the XDS110-ET can supply up to 500 mA of current to the target side including any BoosterPack plug-in modules plugged in. However, when debugging and using the EnergyTrace technology tool, this current is limited to 75 mA total. Be aware of this current limitation when using EnergyTrace technology.

### 2.4.2 BoosterPack Plug-in Module and External Power Supply

Header J6 is present on the board to supply external power directly. It is important to comply with the device voltage operation specifications when supplying external power. The MSP432P401R has an operating range of 1.62 V to 3.7 V. More information can be found in the [MSP432P401xx Mixed-Signal Microcontroller data sheet](#).

## 2.5 Measure MSP432 Current Draw

To measure the current draw of the MSP432P401R, use the 3V3 jumper on the jumper isolation block. The current measured includes the target device and any current drawn through the BoosterPack plug-in module headers.

To measure ultra-low power, follow these steps:

1. Remove the 3V3 jumper in the isolation block, and attach an ammeter across this jumper.
2. Consider the effect that the backchannel UART and any circuitry attached to the MSP432P401R may have on current draw. Disconnect these at the isolation block if possible, or at least consider their current sinking and sourcing capability in the final measurement.
3. Make sure there are no floating input I/Os. These cause unnecessary extra current draw. Every I/O should either be driven out or, if it is an input, should be pulled or driven to a high or low level.
4. Begin target execution.
5. Measure the current. Keep in mind that if the current levels are fluctuating, it may be difficult to get a stable measurement. It is easier to measure quiescent states.

For a better look at the power consumed in the application, use EnergyTrace+ Technology. EnergyTrace+ Technology allows the user to see energy consumed as the application progresses. More details about EnergyTrace+ Technology can be found in [Section 2.3.5](#).

## 2.6 Clocking

The MSP-EXP432P401R provides external clocks in addition to the internal clocks in the device.

- Q1: 32-kHz crystal (LFXTCLK)
- Q2: 48-MHz crystal (HFXTCLK)

The 32-kHz crystal allows for lower LPM3 sleep currents, and higher precision clock source than the default internal 32 kHz REFOCLK. Therefore, the presence of the crystal allows the full range of low-power modes to be used.

The 48-MHz crystal allows the device to run at its maximum operating speed for MCLK and HSMCLK.

The MSP432P401R device has several internal clocks that can be sourced from many clock sources. Most peripherals on the device can select which of the internal clocks to use to operate at the desired speed.

The internal clocks in the device default to the configuration listed in [Table 2](#).

**Table 2. Default Clock Operation**

Clock	Default Clock Source	Default Clock Frequency	Description
MCLK	DCO	3 MHz	Master Clock Sources CPU and peripherals
HSMCLK	DCO	3 MHz	Subsystem Master Clock Sources peripherals
SMCLK	DCO	3 MHz	Low-speed subsystem master clock Sources peripherals
ACLK	LFXT (or REFO if no crystal present)	32.768 kHz	Auxiliary clock Sources peripherals
BCLK	LFXT (or REFO if no crystal present)	32.768 kHz	Low-speed backup domain clock Sources LPM peripherals

For more information about configuring internal clocks and using the external oscillators, see the [MSP432P4xx Family Technical Reference Manual](#).

## 2.7 BoosterPack Plug-in Module Pinout

The MSP-EXP432P401R LaunchPad development kit adheres to the 40-pin LaunchPad development kit pinout standard. A standard was created to aid compatibility between LaunchPad development kit and BoosterPack plug-in module tools across the TI ecosystem.

The 40-pin standard is compatible with the 20-pin standard that is used by other LaunchPad development kits like the [MSP-EXP430FR4133](#). This allows some subset of functionality of 40-pin BoosterPack plug-in modules to be used with 20-pin LaunchPad development kits.

While most BoosterPack plug-in modules are compliant with the standard, some are not. The MSP-EXP432P401R LaunchPad development kit is compatible with all 20-pin and 40-pin BoosterPack plug-in modules that are compliant with the standard. If the reseller or owner of the BoosterPack plug-in module does not explicitly indicate compatibility with the MSP-EXP432P401R LaunchPad development kit, compare the schematic of the candidate BoosterPack plug-in module with the LaunchPad development kit to ensure compatibility. Keep in mind that sometimes conflicts can be resolved by changing the MSP432P401R device pin function configuration in software. More information about compatibility can also be found at <http://www.ti.com/launchpad>.

[Figure 11](#) shows the 40-pin pinout of the MSP-EXP432P401R LaunchPad development kit.

Note that software configuration of the pin functions plays a role in compatibility. The MSP-EXP432P401R LaunchPad development kit side of the dashed line in [Figure 11](#) shows all of the functions for which the MSP432P401R device's pins can be configured. This can also be seen in the MSP432P401R data sheet. The BoosterPack plug-in module side of the dashed line shows the standard. The MSP432P401R function whose color matches the BoosterPack plug-in module function shows the specific software-configurable function by which the MSP-EXP432P401R LaunchPad development kit adheres to the standard.

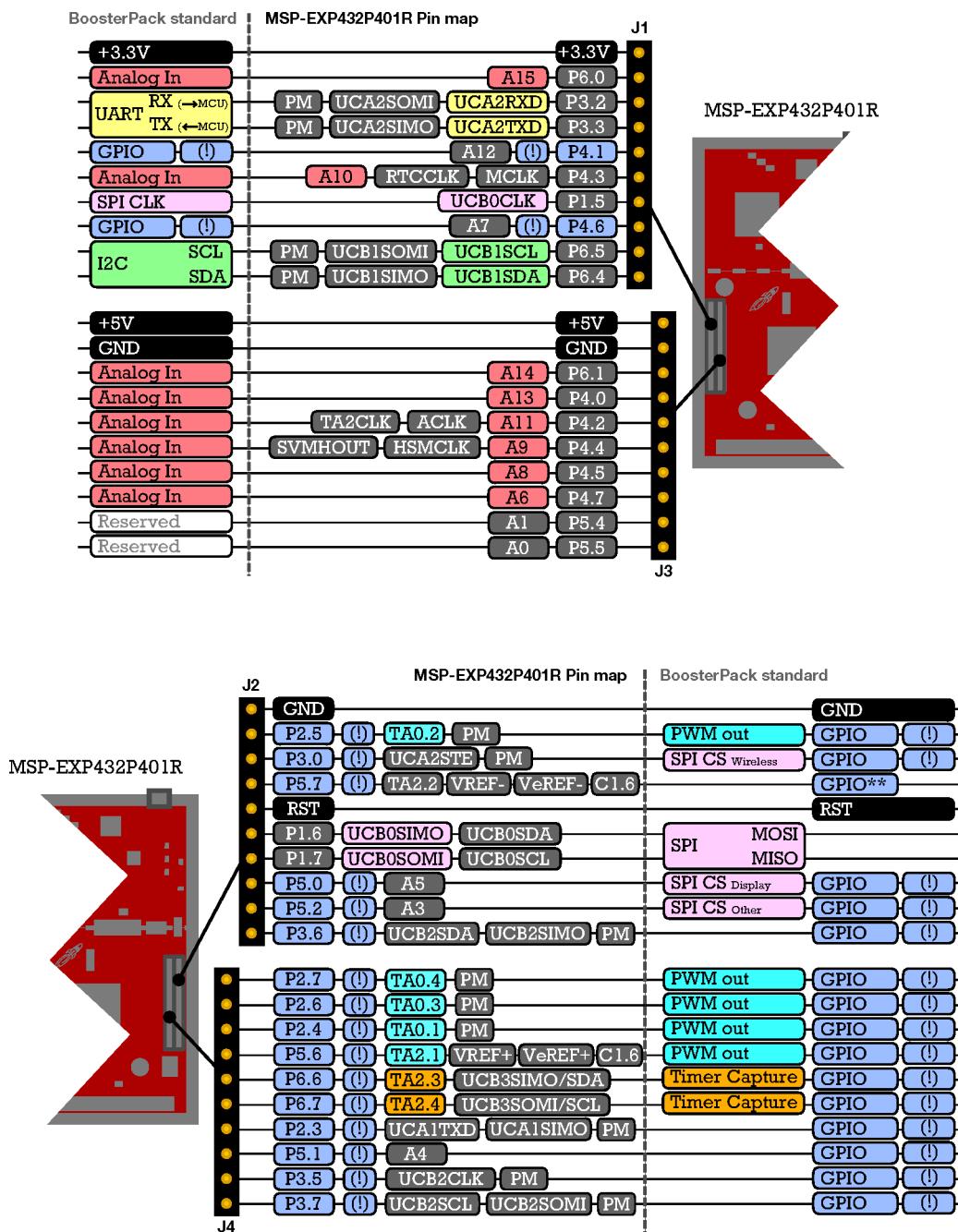


Figure 11. LaunchPad™ Development Kit to BoosterPack™ Plug-in Module Connector Pinout

## 2.8 Design Files

### 2.8.1 Hardware Design Files

Schematics can be found in Section 6. All design files including schematics, layout, bill of materials (BOM), Gerber files, and documentation are available in the [MSP-EXP432P401R Hardware Design Files](#).

Do you have an older version of the LaunchPad development kit? The differences in the hardware are outlined in [Section 2.9](#). The hardware design files for older versions of the LaunchPad are available at the link above – navigate to previous release versions according to [Table 3](#).

## 2.8.2 Software Examples

All design files including TI-TXT object-code firmware images, software example projects, and documentation are available in the [MSP-EXP432P401R Software Examples](#).

Do you have an older version of the LaunchPad development kit? The differences in the hardware are outlined in [Section 2.9](#). In addition to the hardware being different, the device revision also changes with the LaunchPad development kit revisions. Because of this, you must download a software package that matches your exact hardware. The software example files for older versions of the LaunchPad development kit are available at the link above – navigate to previous release versions according to [Table 3](#).

## 2.9 Hardware Change Log

[Table 3](#) lists the hardware revisions.

**Table 3. Hardware Change Log**

PCB Revision	Date	Description	MSP432P401R Device Revision	MSP-EXP432P401R Hardware and Software Download Version (for downloading zip packages online only)
Rev 1.0	March 2015	Initial Release	XMS432P401R Rev B	2_00_00_03
Rev 2.0	June 2016	RTM Silicon Release	XMS432P401R Rev C or MSP432P401R Rev C (check device markings to determine your version)	3_00_00_03

### 2.9.1 MSP-EXP432P401R Rev 1.0 (Black) LaunchPad Development Kit

As shown in [Table 3](#), this was the initially released LaunchPad development kit, with XMS432P401R Rev B silicon. Connecting any debugger to the old version of the MSP432 MCU will generate a warning telling the user to update their silicon. TI will continue to support this board for the foreseeable future. However, upgrading to the latest LaunchPad development kit gets you all the silicon upgrades and the final production version of Driver Library in ROM.

### 2.9.2 MSP-EXP432P401R Rev 2.0 (Red) LaunchPad Development Kit

As shown in [Table 3](#), this is the updated LaunchPad development kit for the silicon RTM, with XMS432P401R Rev C or MSP432P401R Rev C silicon. In addition to the latest silicon, several updates were made to the LaunchPad development kit hardware to enhance the user experience.

#### 2.9.2.1 MSP-EXP432P401R Updates

From the perspective of the board, all of the changes are aesthetic or make the kit easier to use (see [Figure 12](#)). For example, moving the user buttons to the side of the board makes them easier to reach when you have a BoosterPack plug-in module plugged into the top of the LaunchPad development kit. The button placement has changed, but the physical button connections are the same. The biggest change comes from the addition of an extra 10-pin ARM JTAG connector. This connector lets you use the LaunchPad development kit as a stand-alone XDS110 debug probe.

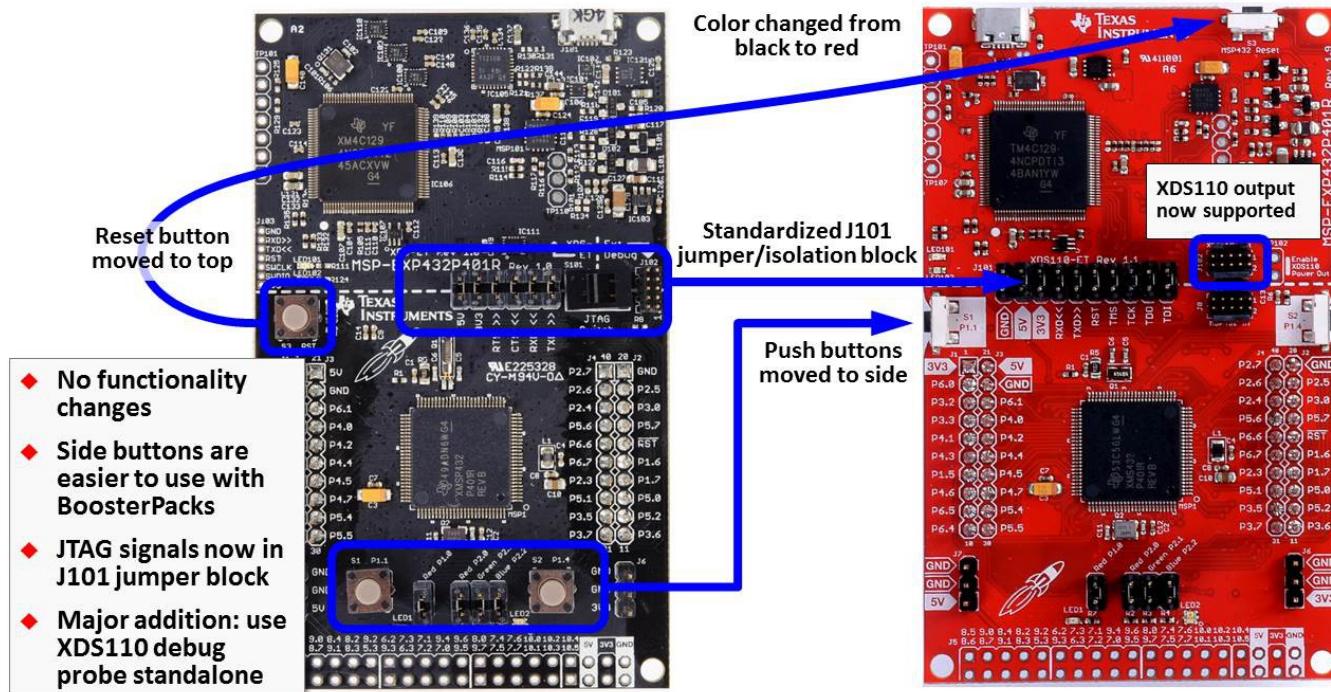


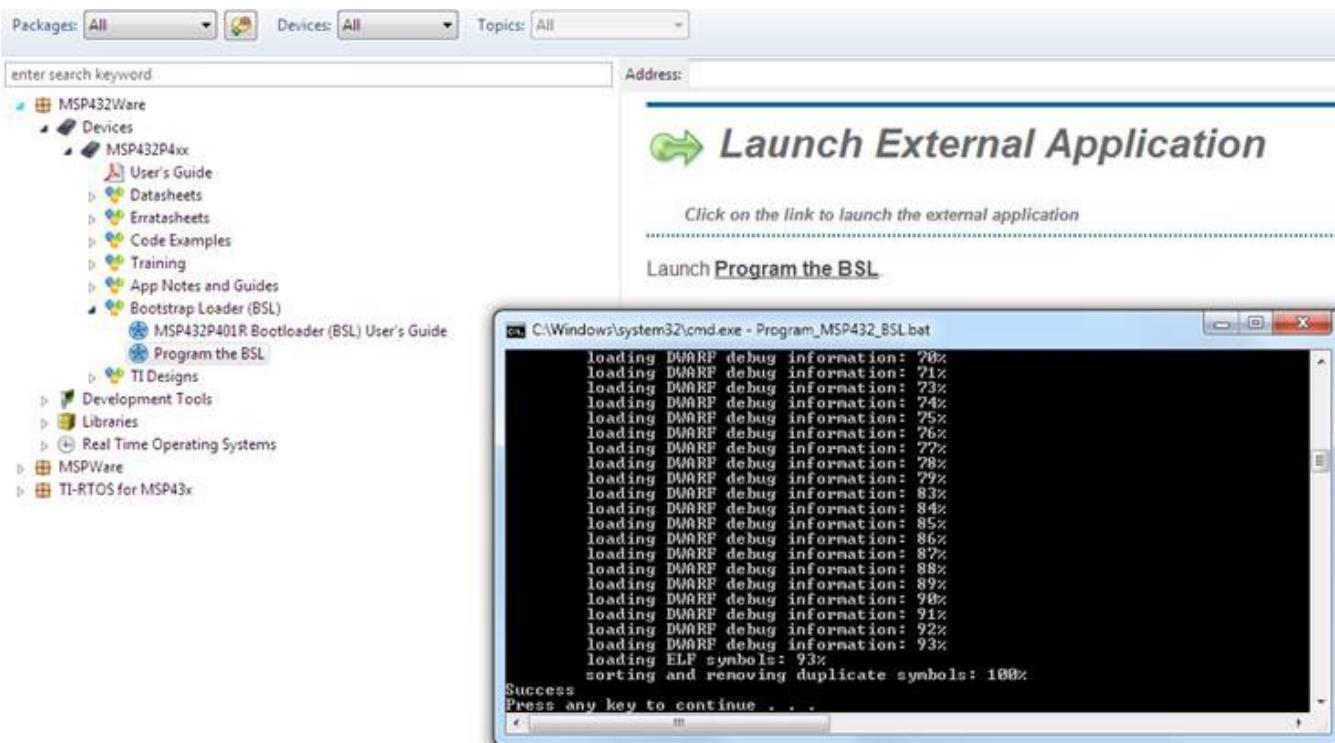
Figure 12. Differences Between Rev 1.0 (Black) and Rev 2.0 (Red)

### 2.9.2.2 MSP432P401R Device Revision Differences

The primary MSP432P401R silicon differences are the differences between Rev. B and Rev. C devices. For details of the differences, see [Moving From Evaluation to Production With MSP432P401x MCUs](#).

The first shipments of Rev 2.0 (Red) LaunchPad development kit have XMS432P401R Rev C. preproduction silicon before the final production version of MSP432P401R Rev C. silicon is released. Which device is on a particular LaunchPad development kit can be determined by looking at the markings on the MSP432P401R device. The XMS version have a marking of "XMS" instead of "MSP". For details on the differences between the preproduction and production silicon, see [XMS432P401x Rev. C Preproduction Advisories](#).

To work around Advisory 1 in the document above, and as a general way to update to the latest device BSL, TI provides a utility to download the latest BSL. This utility is available inside of TI Resource Explorer (see [Figure 13](#)). Alternatively, the BSL can be updated by running Program\_MSP432\_BSL.bat in the source files for [MSP432P401R BSL update](#).



**Figure 13. BSL Update Utility in TI Resource Explorer**

### 3 Software Examples

There are four software examples included with the MSP-EXP432P401R LaunchPad development kit (see [Table 4](#)), which can be found in the [MSP-EXP432P401R Software Examples](#).

**Table 4. Software Examples**

Demo Name	BoosterPack Required	Description	More Details
Out-of-Box Software Example	N/A	The out-of-box demo programmed on the LaunchPad development kit from the factory.	<a href="#">Section 3.1</a>
CC3100BOOST MQTT-Twitter LED Control Example	CC3100BOOST	An IoT application demonstrating controlling an RGB LED using Twitter through Wi-Fi	<a href="#">Section 3.2</a>
BOOSTXL-K350QVG-S1 Graphics Library Example	BOOSTXL-K350SVG-S1	A simple example showing how to use MSP Graphics Library (grlib) to display graphics primitives and images and implement touchscreen functionality	<a href="#">Section 3.3</a>
430BOOST-SHARP96 Graphics Library Example	430BOOST-SHARP96	A simple example showing how to use MSP Graphics Library (grlib) to display graphics primitives and images	<a href="#">Section 3.4</a>
BOOSTXL-BATPAKMKII_FuelGauge_MSP432P401R	BOOSTXL-BATPAKMKII	Demonstrates how to initialize bq27441-G1 fuel gauge configurations and how to control and read data registers	<a href="#">Section 3.5</a>
BOOSTXL-SENSORS_SensorGUI_MSP432P401R	BOOSTXL-SENSORS	Demonstrates how to sample data from the five onboard digital sensors and communicate that over UART in a JSON payload	<a href="#">Section 3.6</a>
BOOSTXL-SENSORS_TI-RTOS_SensorGUI_MSP432P401R	BOOSTXL-SENSORS	Demonstrates how to sample data from the five onboard digital sensors and communicate that over UART in a JSON payload using TI-RTOS	<a href="#">Section 3.7</a>

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 5](#)).

**Table 5. 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 7.10 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 Out-of-Box Software Example

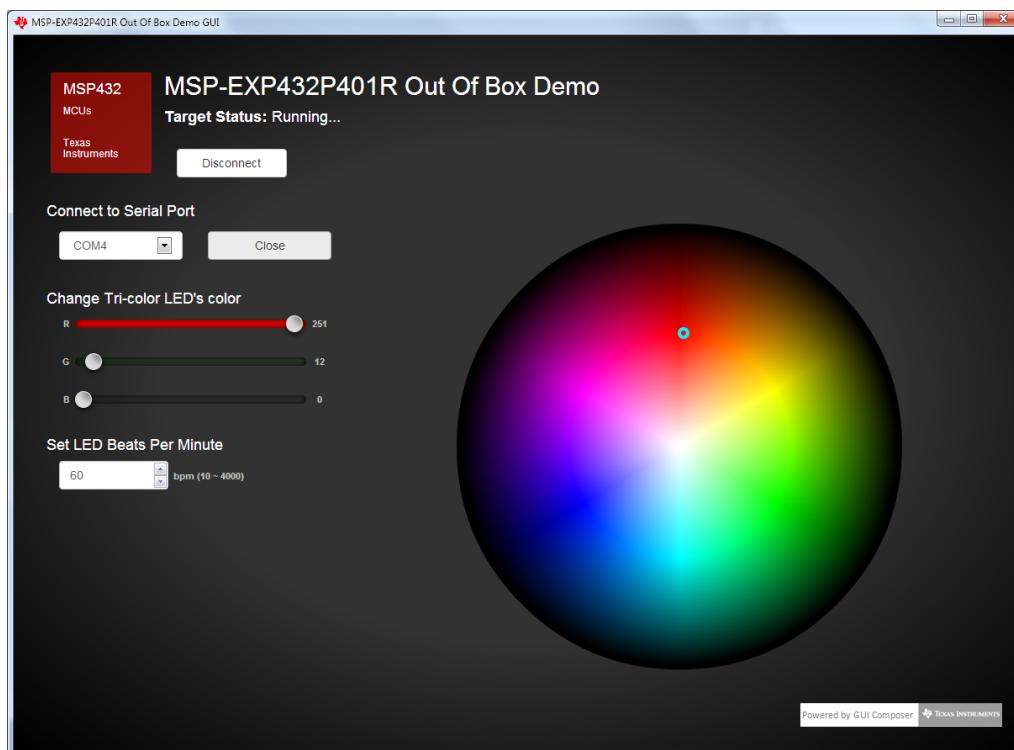
This section describes the functionality and structure of the out-of-box software that is preloaded on the EVM. The source code can be found in the [MSP-EXP432P401R Software Examples](#) download, or more easily accessible through MSPWare (see [Section 4.3](#)).

The out-of-box software extends a basic blink LED example to allow users to control the blink rate and color of an RGB LED on the MSP432 LaunchPad development kit.

#### 3.1.1 Operation

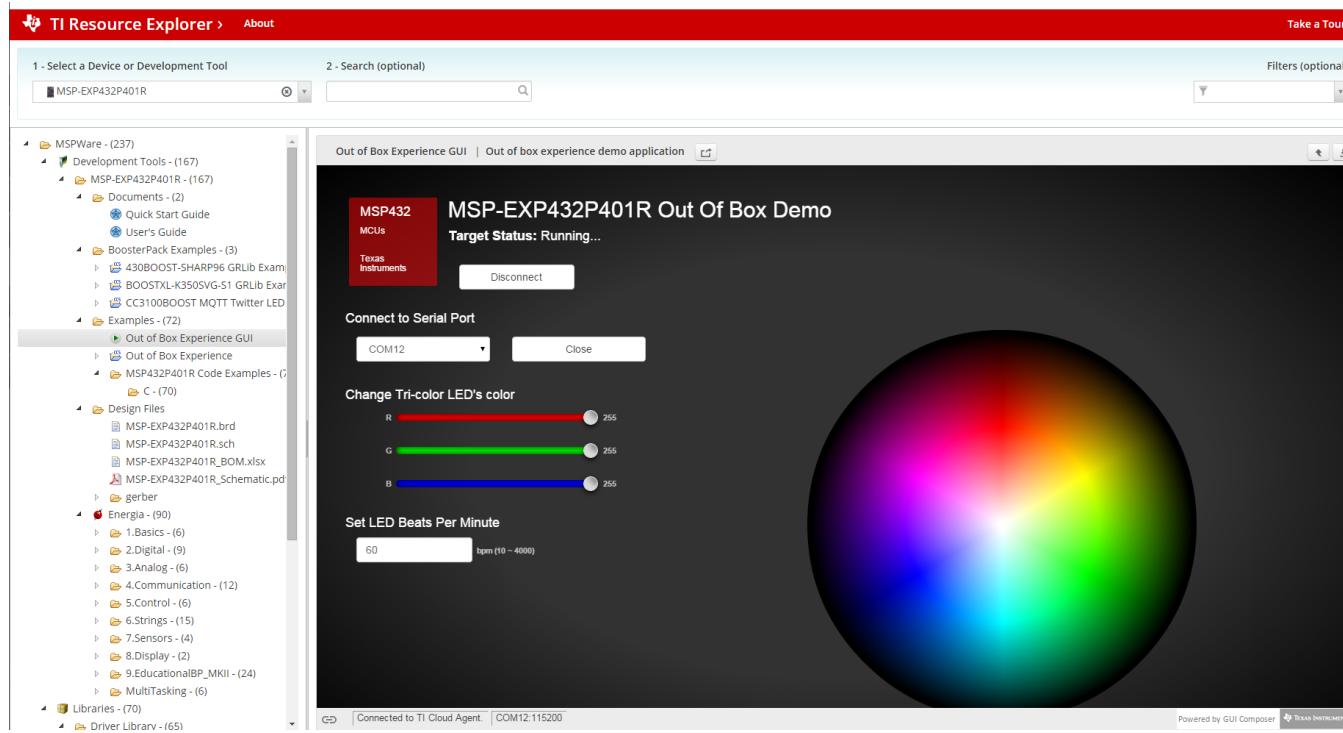
Upon powering up the out-of-box demo, the RGB LED2 blinks red at 1 Hz. Switch S1 can be tapped repeatedly at a constant rate to set the blink frequency of LED2. Switch S2 cycles LED2 through four different color settings: Red, Green, Blue, and random RGB color. Each color setting retains its own blink frequency.

A PC GUI accompanies the out-of-box demo to allow user to set the color and blink rate of the RGB LED. If not already, connect the LaunchPad development kit using the included USB cable to a computer. The out-of-box GUI can be opened from within CCS using the TI Resource Explorer: MSPWare > Development Tools > MSP-EXP432P401R > Examples > Out of Box Experience GUI. A copy can also be found in the [MSP-EXP432P401R Software Examples](#).



**Figure 14. Out-of-Box GUI Running Locally**

The GUI can also run directly from the TI Cloud Tools (see [Section 4.1.1](#)).



**Figure 15. Out-of-Box GUI Running From TI Cloud Tools**

Click on the Connect button to connect to the LaunchPad development kit then open the serial COM port. Once the connection has been established and the GUI indicates, "Target Status: Running...", you can use the color wheel or the Red, Green, and Blue color sliders to set the color of the LaunchPad development kit RGB LED. Changing the LED Beats Per Minute input box sets the RGB LED blink rate.

## 3.2 CC3100BOOST MQTT-Twitter LED Control Example

This section describes the functionality and structure of the CC3100BOOST MQTT-Twitter LED Control demo that is included in the [MSP-EXP432P401R Software Examples](#) download, or more easily accessible through MSPWare (see [Section 4.3](#)).

---

**NOTE:** This CC3100BOOST MQTT-Twitter LED Control demo requires the [CC3100BOOST](#) BoosterPack plug-in module to function properly.

---

This demo uses the MQTT connectivity protocol to realize a simple Internet-of-Things application that allows user to control MSP432 LaunchPad development kit RGB LED wirelessly using Twitter tweets.

### 3.2.1 Source File Structure

The project is split into multiple files (see [Table 6](#)). This makes it easier to navigate and reuse parts of it for other projects.

**Table 6. Source File and Folders**

Name	Description
main.c	The demo's main function, shared ISRs, and so on
sl_common.h	Common SimpleLink™ technology definitions
Driver: board	Board specific driver including basic initializations
Driver: cli_uart	Command line interface for backchannel UART communication
Driver: spi_cc3100	MSP432 SPI driver to interface CC3100
Driver: uart_cc3100	MSP432 UART driver to interface CC3100
Library: mqtt	MQTT protocol library
Library: simplelink	Simplelink library containing Wi-Fi APIs
Library: driverlib	Device driver library (MSP432DRIVERLIB)

### 3.2.2 Running the Demo

In order to connect the CC3100BOOST to a wireless access point, start by modifying *SSID\_NAME* and *PASSKEY* in the #define section of main.c with your wireless access point's information. You may also need to change *SEC\_TYPE* depending on your access point's setting.

Next, using [TI Cloud tools](#) or offline IDEs, build and download the project to the MSP432 LaunchPad development kit. If not already, plug the CC3100BOOST BoosterPack plug-in module onto the LaunchPad development kit, and connect the LaunchPad development kit to your computer. The CC3100 should automatically try to connect to the access point with the provided credentials. The LaunchPad development kit outputs status messages through its Application/User UART COM port, which can be viewed by opening it using terminal applications (see [Section 2.3.2](#)).

Once the CC3100 has established internet connection and successfully subscribed to the public MQTT broker server, the LaunchPad development kit RGB LED is ready to be controlled with Twitter. Any **public** tweets in the following format will change the RGB LED color on **all** MSP-EXP432P401R LaunchPad development kit running this demo:

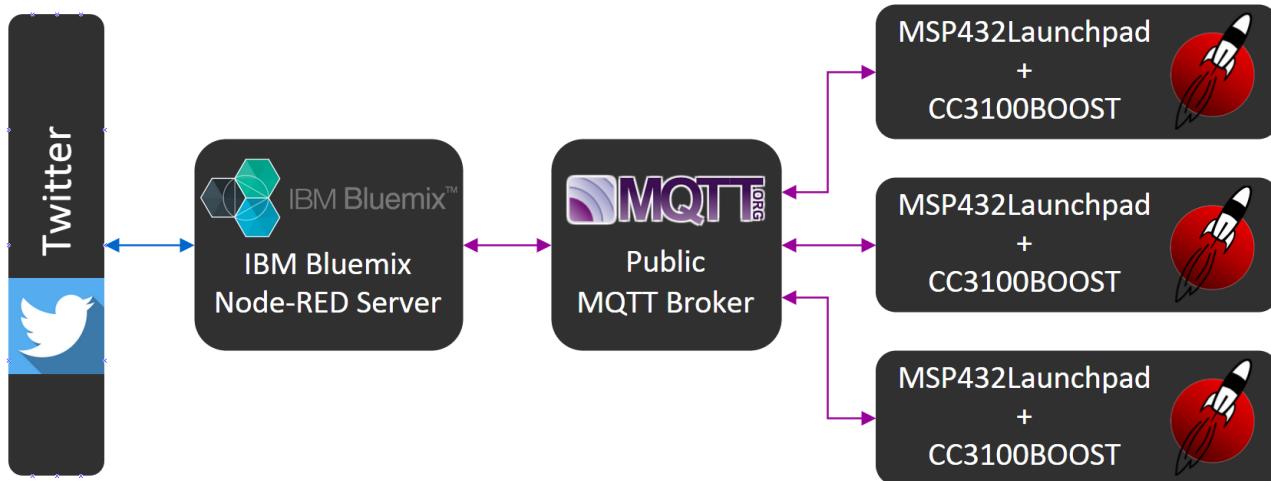
`RGB(red_value, green_value, blue_value) #MSP432LaunchPad`

The color parameters can be integers ranging from 0 to 255.

Pressing the left push button S1 on the LaunchPad development kit publishes a 32-bit unique ID from the LaunchPad development kit to the MQTT broker, which then gets tweeted by the twitter account, [@MSPLaunchPad](#). You may then use this 32-bit Unique ID in your tweet message to control the RGB LED on the specific LaunchPad development kit and CC3100BOOST combination tied to that unique ID:

`<32-bit unique ID> RGB(red_value, green_value, blue_value) #MSP432LaunchPad`

### 3.2.3 Overview of Backend Servers



**Figure 16. Backend Block Diagram of CC3100BOOST MQTT-Twitter LED Control Demo**

As shown in the above [Figure 16](#), inputs from either the MSP432 LaunchPad development kit or Twitter travel through a couple of intermediary servers before reaching the output on the opposite end. Instead of interacting with Twitter server directly through the more resource intensive HTTP, the MSP432 LaunchPad development kit communicates with the cloud solely through MQTT protocol. [MQTT](#) is a publish-subscribe messaging protocol designed for lightweight M2M communications. Multiple clients sends message to one another through a server known as a broker, and each client can publish messages to different topics and subscribe to multiple topics. While a dedicated MQTT broker can be setup for an application, this demo uses one of the several MQTT brokers that are freely available to the public, <http://iot.eclipse.org/sandbox.html>.

Every LaunchPad development kit running the CC3100BOOST MQTT-Twitter LED Control demo subscribes to the MQTT topic, "/msp/cc3100/demo". This is why any RGB data published to this topic will change the LED color on all LaunchPad development kits running this demo. However, each LaunchPad development kit also subscribes to an "<uniqueID>" topic that can be used to control LaunchPad development kits individually.

A cloud server is also setup/maintained by the MSP Team using the [IBM Bluemix](#) cloud platform service. This server runs a couple of [Node-RED](#) applications that interface with Twitter directly through HTTP. After processing public tweets containing #MSP432LaunchPad, the Node-RED server also act as a MQTT client, publishing color information to either the "/msp/cc3100/demo" or "<uniqueID>" topic, which then gets received on subscribed LaunchPad development kits. Conversely, unique id data published by the LaunchPad development kits to the "/msp/cc3100/demo/fromLP" topic gets received by the Node-RED server, which then tweets a time stamped message on the Twitter account [@MSPLaunchPad](#).

Check out [IBM Bluemix](#) to see how you can also build your own cloud application.

### 3.2.4 Developing With CC3100BOOST BoosterPack Plug-in Module

A SimpleLink Wi-Fi CC3100 Software Development Kit (SDK) can be downloaded at <http://www.ti.com/tool/cc3100sdk>. It contains drivers, many sample applications for Wi-Fi features and internet, and documentation needed to use the CC3100 Internet-on-a-chip™ solution.

The CC3100BOOST MQTT-Twitter LED Control Demo was developed on CC3100SDK\_1.0.0. Service pack update may be required on the CC3100BOOST with newer SDK release. Refer to the [CC3100 SimpleLink Wi-Fi and IoT Solution Getting Started Guide](#) for more information.

### 3.3 BOOSTXL-K350QVG-S1 Graphics Library Example

This software is available in the [MSP-EXP432P401R Software Examples](#), or more easily accessible through MSPWare (see [Section 4.3](#)).

The demo shows how to use the *MSP Graphics Library* <http://www.ti.com/tool/msp-grlib> or "grlib," in a project with the Kentec display. This demo shows the user how to enable the touch screen, create buttons, and use graphics primitives including colors and images.

The program begins by calibrating the touch screen. There is a routine that detects the four corner coordinates to determine if an eligible rectangle boundary is formed. If the calibration was incorrect, a message will display on the screen indicating the calibration failed. When successful, the calibration provides a reference for all button presses throughout the rest of the program.

The next step is to select the mode of the program- display primitives or images. Each mode simply cycles through without user interaction to show off features of the display. In the graphics primitives mode, the following primitives are shown:

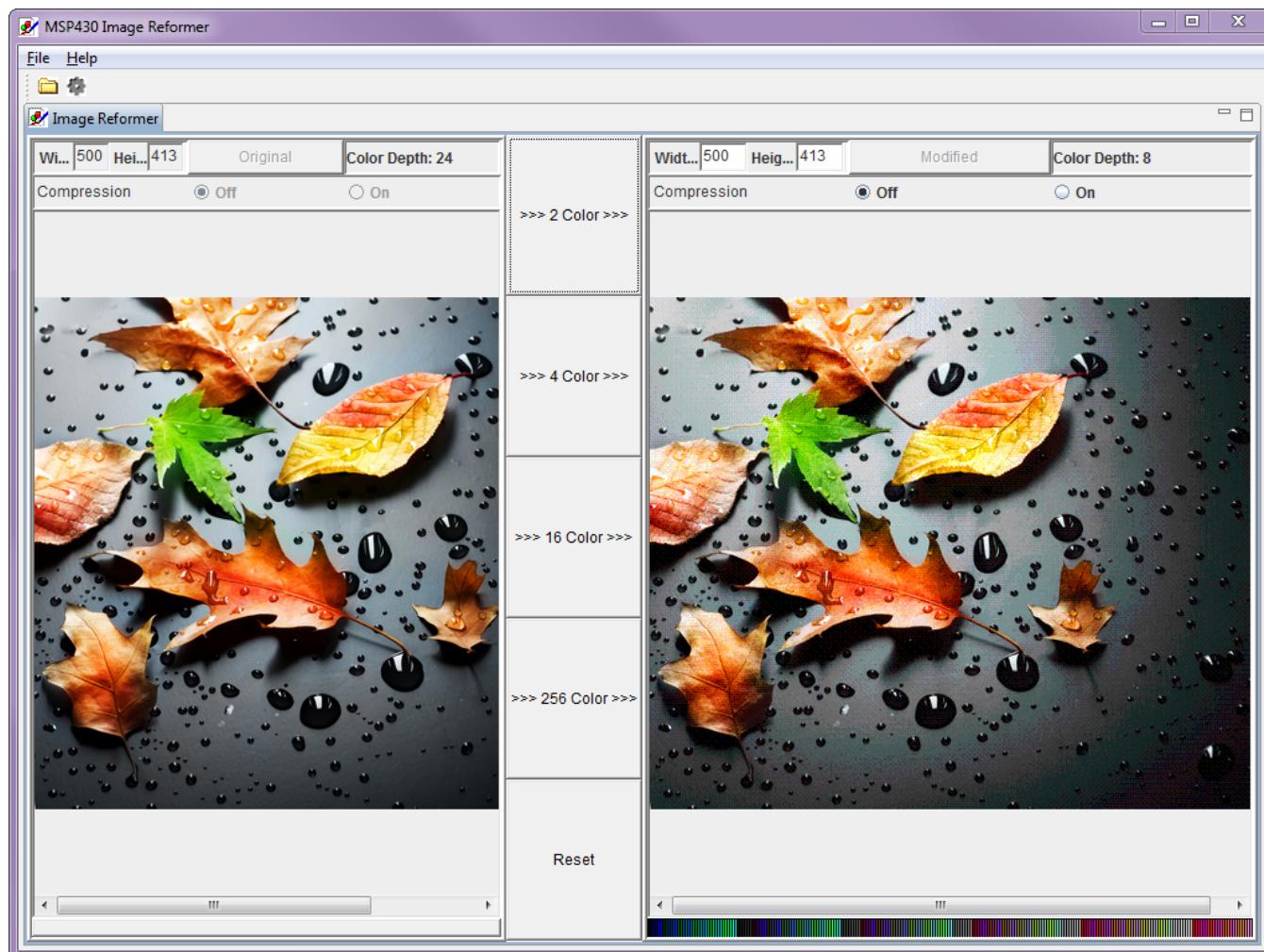
- Pixels
- Lines
- Circles
- Rectangles
- Text

The application is heavily commented to ensure it is very clear how to use the grlib APIs. The above primitives are shown as well as the underlying concepts of grlib including background and foreground colors, context, fonts, opacity, and more.

The images mode shows the drawing of a few different images both compressed and uncompressed. Image compression can have a big impact to drawing speeds for simple images. To draw images with the MSP Graphics Library, they must first be converted into the right file format. These files can be generated by the Image Reformer tool that comes packaged with grlib. Launch this tool from the grlib folder or direct from TI Resource Explorer.

- File Path: <grlib root>\utils\image-reformer\imagereformer.exe
- TI Resource Explorer > MSPWare > Libraries > Graphics Library > MSP430 Image Reformer

The Image Reformer tool allows you to import images and output into grlib specific files to add to your grlib project. Image Reformer does not manipulate any images (such as color modifications, rotation, or cropping), any image manipulation must be done before importing into the Image Reformer tool. More information about MSP grlib and the Image Reformer tool can be found in [Design Considerations When Using the MSP430 Graphics Library](#).



**Figure 17. Importing and Converting an Image With MSP Image Reformer**

### 3.4 430BOOST-SHARP96 Graphics Library Example

This software example is similar to the BOOSTXL-K350QVG-S1 Graphics library example. It shows how to use the *MSP Graphics Library* <http://www.ti.com/tool/msp-grlib> or "grlib," in a project with the Sharp 96x96 display. The Sharp 96x96 display BoosterPack plug-in module does not support touch or color, it is a simple monochrome LCD. It is a great LCD for ultra-low power display applications and has a unique mirrored pixel display.

This demo cycles screens without user interaction to show simple graphics primitives.

- Pixels
- Lines
- Circles
- Rectangles
- Text
- Images

This demo introduces the functions to configure grlib such as initialization, color inversion, and using foreground and background colors properly.

### 3.5 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 4.3](#)).

#### 3.5.1 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 ( <a href="#">MSP432DRIVERLIB</a> )
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

#### 3.5.2 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 18. 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 19](#) and [Figure 20](#)).

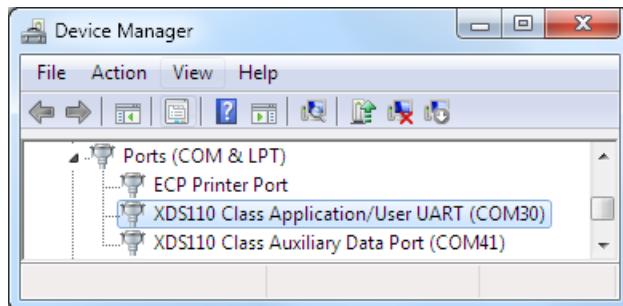


Figure 19. Determine COM Port Number Using Device Manager on Windows

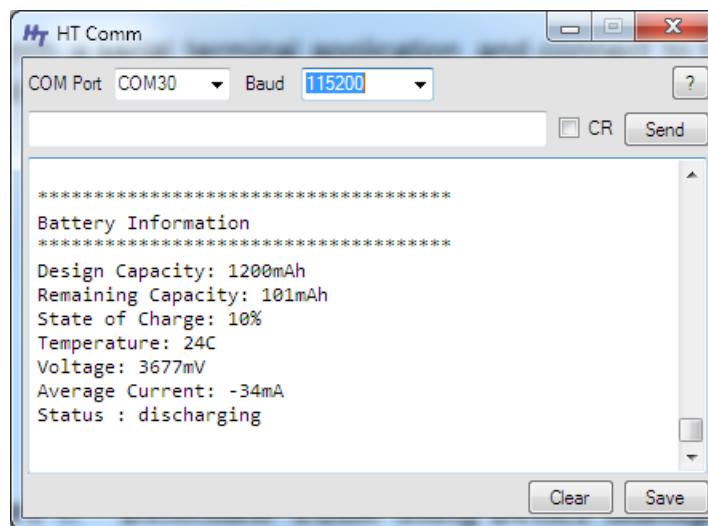
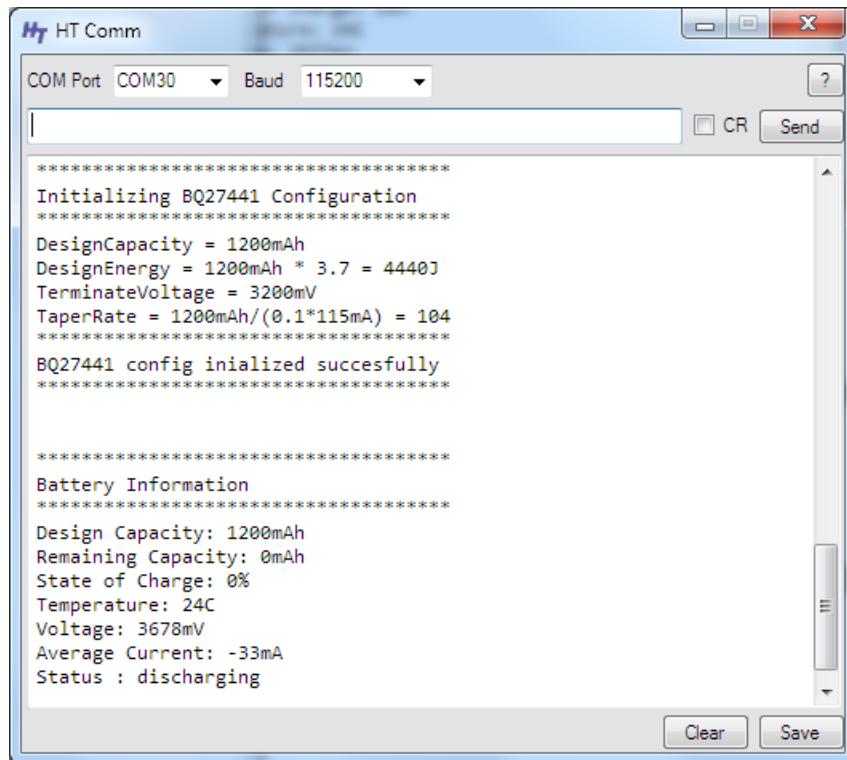


Figure 20. Example Serial Terminal Configuration

5. Press the reset button on the MSP-EXP432P401R LaunchPad development kit.
6. Observe serial data displaying Fuel Gauge configuration and Battery Information.



**Figure 21. Snapshot of Serial Terminal Connected to Running Fuel Gauge Demo**

### 3.5.3 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 (Battery 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.

## 3.6 BOOSTXL-SENSORS\_SensorGUI\_MSP432P401R

This section describes the functionality and structure of the BOOSTXL-SENSORS\_SensorGUI\_MSP432P401R demo that is included in the [MSP-EXP432P401R Software Examples](#) download, or more easily accessible through MSPWare (see [Section 4.3](#)).

### 3.6.1 Source File Structure

The project is split into multiple files (see [Table 8](#)). This makes it easier to navigate and reuse parts of it for other projects.

**Table 8. Source File and Folders**

Name	Description
msp432_startup_ccs.c	MSP432™ MCU family interrupt vector table for CGT
Library: driverlib	Device driver library ( <a href="#">MSP432DRIVERLIB</a> )
src/bme280.c	Driver for communicating with the environmental sensor
src/bme280_support.c	Support driver for communicating with the environmental sensor
src/bmi160.c	Driver for communicating with the IMU and magnetometer sensors
src/bmi160_support.c	Support driver for communicating with the IMU and magnetometer sensors
src/demo_sysctl.c	Delay function for MSP432 MCU
src/i2c_driver.c	Driver for I2C communication with the sensors
src/main.c	The demo's main function, interrupt service routines, global variables, etc
src/opt3001.c	Driver for communicating with the ambient light sensor
src/tmp007.c	Driver for communicating with the infrared temperature sensor
src/uart_driver.c	Driver for UART communication with the PC GUI

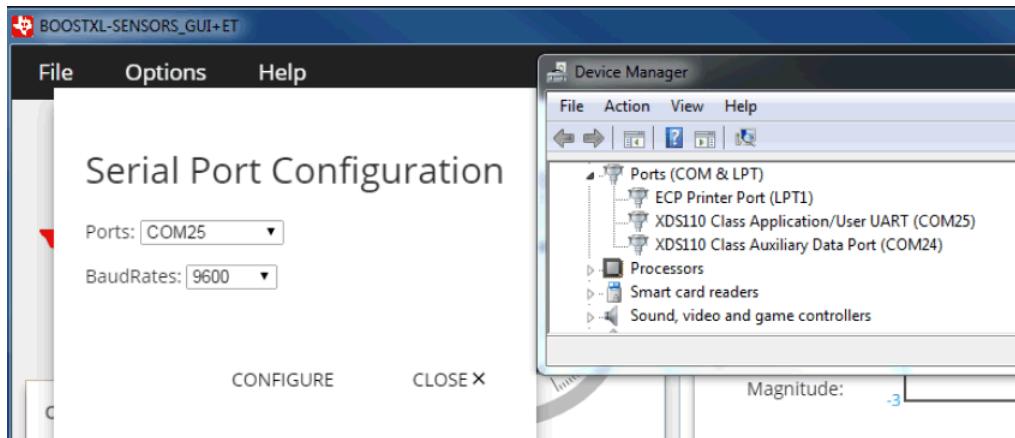
### 3.6.2 Working With the GUI

The Sensor GUI allows for quick visualizations of the sensors data and testing of applications.

#### 3.6.2.1 Getting Started

1. Download the BOOSTXL-SENSORS\_GUI+ET.zip, and extract its contents.
2. Launch BOOSTXL-SENSORS\_GUI+ET.
3. Plug in your MSP432P401R LaunchPad development kit with Sensors BoosterPack into a USB port. And click the  icon in the lower left corner of the GUI.
  - If needed, go to "Options" and select the proper COM Port for the Application UART and the baud rate as 115200 (see [Figure 22](#)).

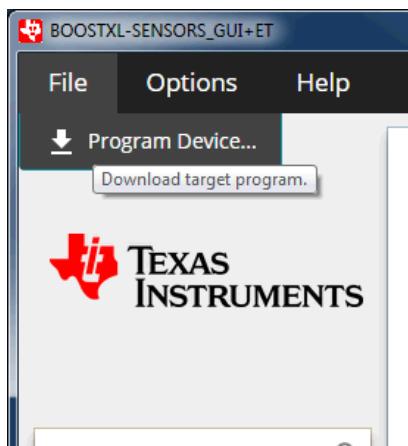
**NOTE:** For Windows, you can find the port number by opening Device Manager and looking for "XDS110 Class Application/User UART" under "Ports (COM & LPT)". It will be listed as COM $nn$ , where  $nn$  is the number of the port.



**Figure 22. Setting up COM Port Configuration for the LaunchPad™ Development Kit**

4. Click "File" and click "Program Device". The Firmware should download to the LaunchPad

development kit (see Figure 23).

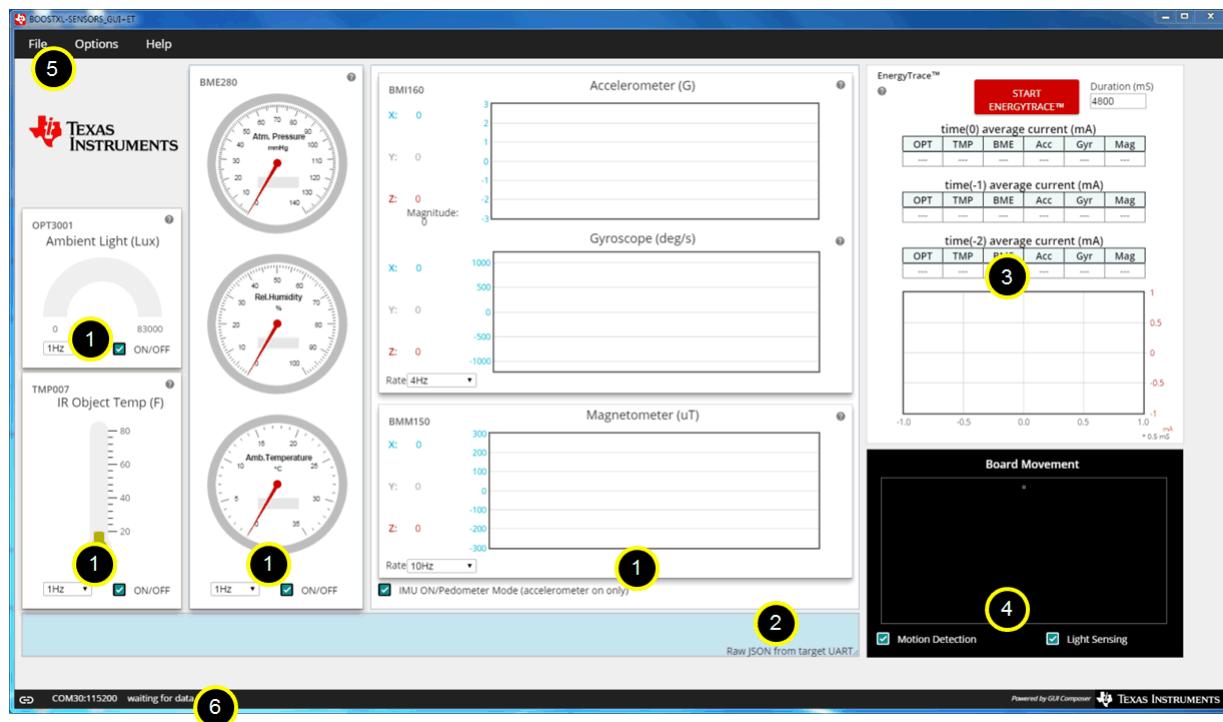


**Figure 23. Programming Sensor Software With the GUI**

5. You should now be seeing live sensor data from the LaunchPad + BoosterPack.

### 3.6.2.2 Understanding the GUI

Figure 24 shows the layout of the sensor GUI.



**Figure 24. Sensor GUI Layout**

The GUI contains six main elements:

1. Four sensor tiles
2. A serial monitor
3. The EnergyTrace™ software section
4. The board movement detection window
5. A menu bar
6. A status bar

The Serial Monitor lets you see the JSON <sup>(1)</sup> that is being reported back by the MCU.

The menu bar serves two functions:

- To change the serial port settings, click **Options** and then click **Serial Port...**. In the dialog, select a port number and the baud rate, which should be 115200. To apply the settings, click "Configure".
- To program the GUI firmware to the MSP432 MCU LaunchPad development kit, click "File" and then click "Program Device...".

The status bar indicates if the LaunchPad is connected to the PC, the port that is used, and the baud rate.

The following example indicates a connection to COM22 at 115000 baud:

 COM22:115200 Hardware Connected. Click  to disconnect the GUI:  Hardware Not Connected.

The following example indicates a busy port on COM22:

 COM22 could not be opened : Error: Opening \\COM22: Access denied. To connect the LaunchPad development kit to this COM port, close any programs that are using that port, disconnect the GUI by clicking  , disconnect and reconnect (or restart) the LaunchPad development kit, and reconnect the GUI.

### 3.6.2.3 Sensor Tiles

Four sensor tiles are available in the Sensor GUI for the **BOOSTXL-SENSORS** BoosterPack plug-in module (see [Figure 25](#)). Each tile represents the data output for a sensor or set of integrated sensors. The following is a brief description of each sensor tile:

The **OPT3001 Ambient Light Sensor** tile responds to ambient light, and displays the brightness of the light in lux. Casting a shadow over this sensor causes the reading to decrease, and shining a light on the sensor cause the reading to increase.

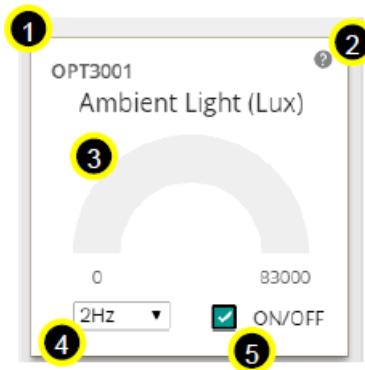
The **TMP007 IR Temperature Sensor** tile responds to infrared energy emitted by objects in its field of view, displaying this in degrees Celsius. Holding a warm or cold object over the sensor causes a response, even over short distances.

The **BME280 Ambient Temperature, Relative Humidity, and Atmospheric Pressure Sensor** tile responds to atmospheric pressure in millimeters of mercury (which can be stimulated using a pressure chamber or by lightly pressing on the sensor), relative humidity as a percentage, and ambient temperature in degrees Celsius (both of which can be stimulated by breathing on the sensor).

The **IMU** tile is made up of two subtiles:

- The **BMI160 Accelerometer and Gyroscope** tile responds to acceleration in g (which can be stimulated by changing the orientation of the board with respect to Earth's gravity, by shaking, or by changing speed along an axis) and rotation in degrees per second (which can be stimulated by rotating the board about its axes).
- The **BMM150 Magnetometer** tile responds to magnetic field in microtesla. This sensor can be stimulated by changing the sensor orientation with respect to Earth's geomagnetic field or by passing a magnet over it.

<sup>(1)</sup> JSON = JavaScript Object Notation. This is the data format in which the information is sent. For more information, go to [www.json.org](http://www.json.org).



**Figure 25. GUI Sensor Tile**

The sensor tiles all share a common set of features. With a special case being the IMU (which consists of the BMM150 and BMI160).

1. The sensor part number
2. A hint button. Click  for an animated demonstration on how to stimulate the sensors. Click again to hide the hint.
3. A graphical and numerical read out of the sensor values.
4. A sample rate selection drop-down menu. Click  to select another frequency. This is the frequency at which the sensor is checked, which also affects the rate at which the MCU wakes from LPM0.
5. A button to toggle the sensor on and off. Click  **ON/OFF** to toggle the sensor on or off. The current draw of each sensor's "ON" and "OFF" states can be seen in the table described in [Section 3.6.2.4](#), or in the [EnergyTrace](#) software hint.

The IMU tile is different from the other tiles in the following ways:

- It is made up of two parts, the BMI160 and the BMM150, each in its own box.
- Each box consists of graphs and numerical data, which are color coded to correspond to one another.
- Each part has its own sample rate selector.
- It has a hint button for each type of sensor; the accelerometer, gyroscope, and magnetometer.

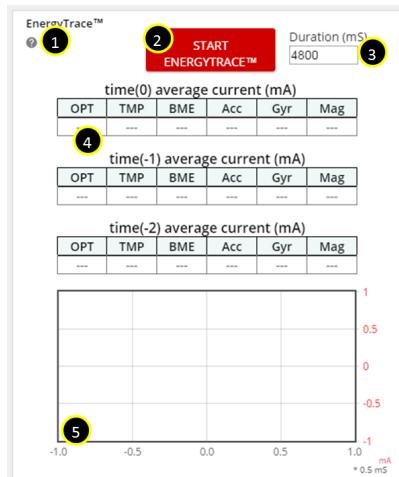
Magnitude:

The accelerometer has a display for the acceleration vector magnitude. 

The ON/OFF toggle button puts the BMM150 into hibernate and the BMI160 into pedometer mode, and only the accelerometer remains active.

### 3.6.2.4 EnergyTrace Software Function

Figure 26 shows the interface to EnergyTrace functions.



**Figure 26. GUI Integrated EnergyTrace™ Measurements**

This section provides monitoring of system current using TI's EnergyTrace technology. It consists of:

1. A hint button. Explains EnergyTrace software measurements and displays a table of expected sensor currents.
2. A start button. Press this to shift any previous data down to the next time frame, clear the graph, and begin the next measurement for the selected duration.

3. An input box. To set the duration in milliseconds, click the arrows or type a value:  ms
4. The past three sensor settings and current measurements, with the most recent on top.
5. A graph showing the actual current draw over time. The X-axis corresponds to 0.5-ms ticks, the Y-axis to the current in millamps. Each peak is a good indicator of when the MCU is in active mode, and the valleys indicate when the MCU is in LPM0.

This implementation is an abbreviated form of EnergyTrace software. The full version can track power consumption, power mode, and more. EnergyTrace software can be used on any application through Code Composer Studio™ IDE v6 or IAR Embedded Workbench™ IDE. For more information, visit <http://www.ti.com/tool/energytrace>

### 3.6.2.5 Board Movement Window

Figure 27 shows the board movement section. When the "motion detection" toggle box is checked, it responds to 10 motions (see Figure 28 through Figure 34):

- Translation along the X, Y, or Z axis
- Positive or negative rotation around the X, Y, or Z axis
- No movement

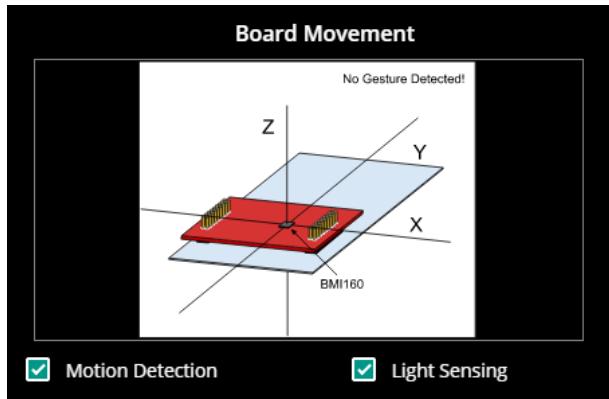


Figure 27. Board Movement Window

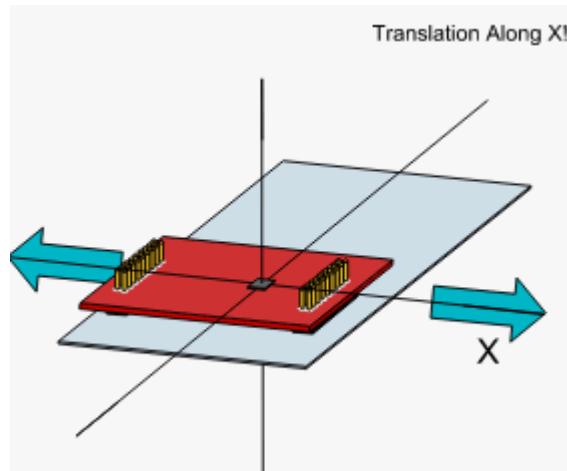


Figure 28. Translation Along the X Axis

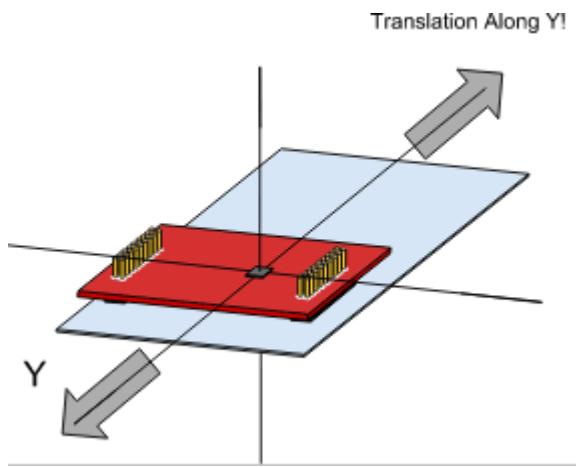


Figure 29. Translation Along the Y Axis

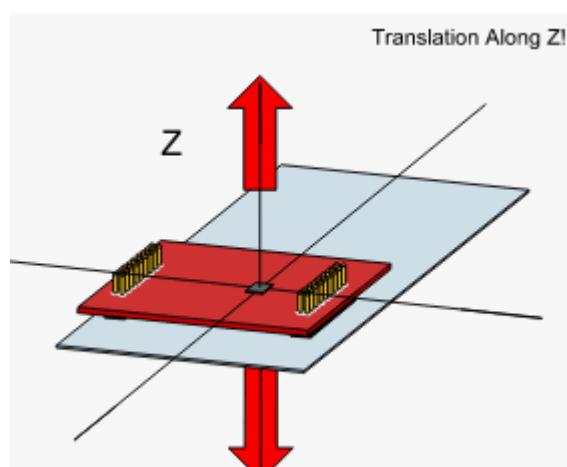


Figure 30. Translation Along the Z Axis

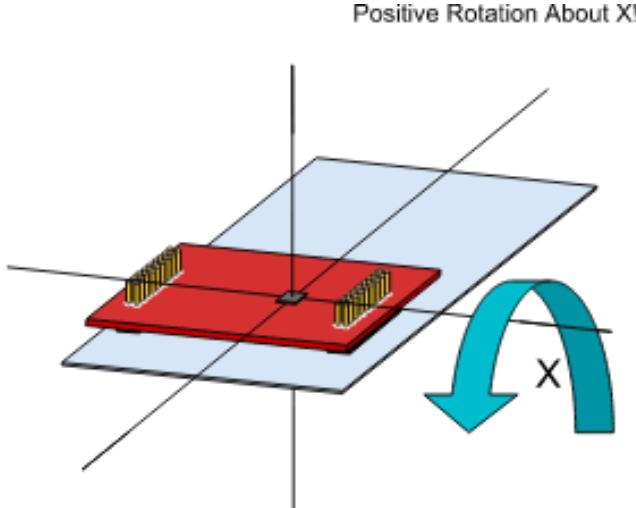
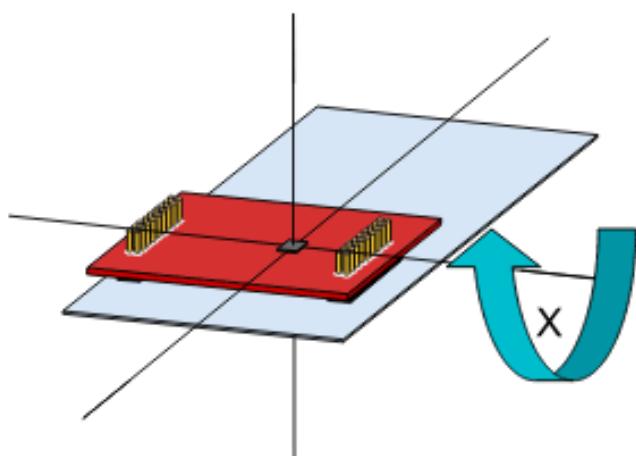
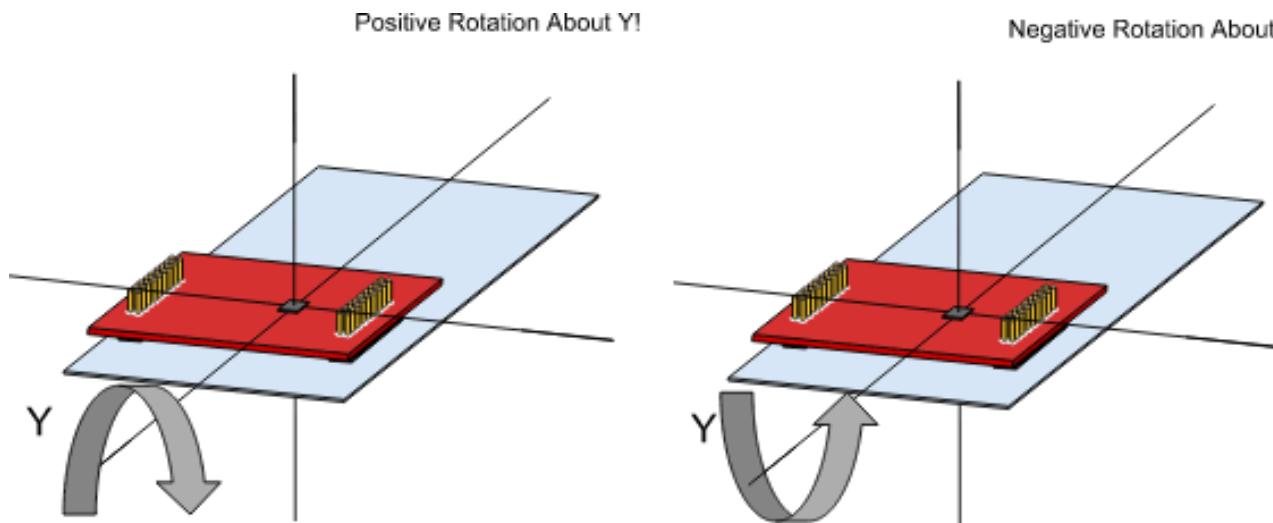
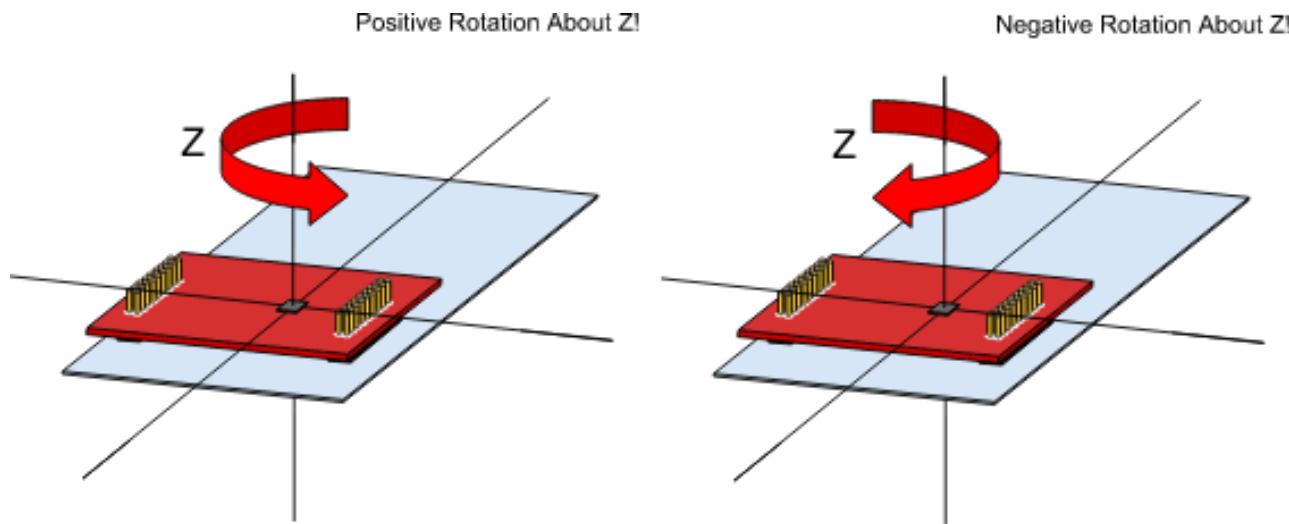


Figure 31. Rotation Around the X Axis

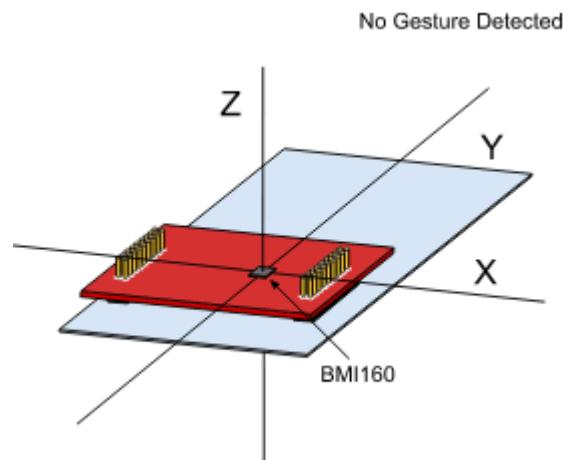




**Figure 32. Rotation Around the Y Axis**

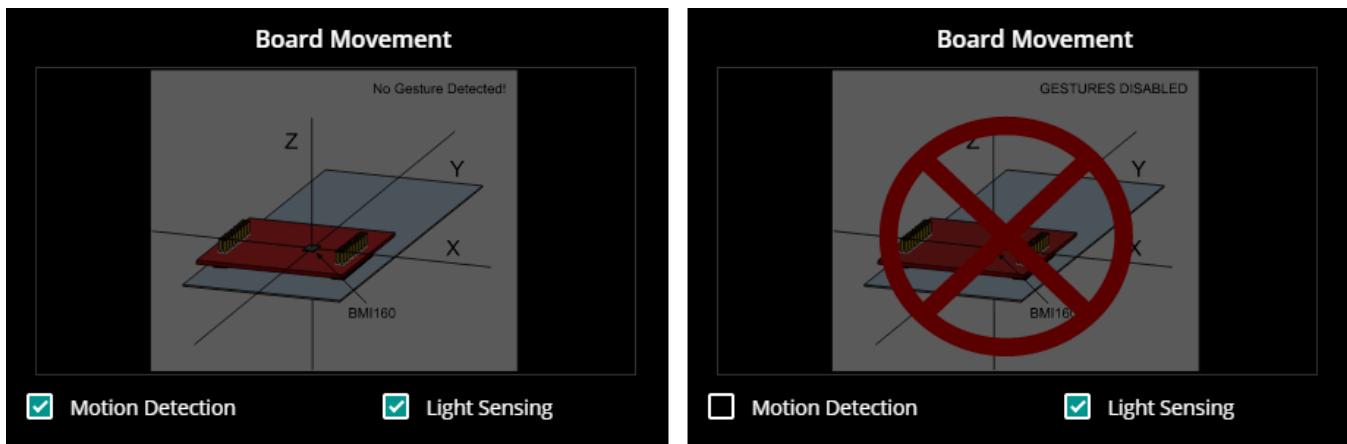


**Figure 33. Rotation Around the Z Axis**



**Figure 34. No Movement**

With both the OPT3001 tile on and the Light Sensing toggle box checked, the image darkens, whether or not gesture recognition is enabled (see [Figure 35](#)).



**Figure 35. Light Sensing in the Gesture Recognition Window**

Board movement data is updated whenever the BMI160 is sampled; that is, it follows the same frequency as the BMI160 drop-down selection box. If motion detection is not enabled, no related calculations are done on the microcontroller and hence no update occurs.

Similarly, light sensing data is updated whenever the OPT3001 is sampled.

### 3.7 BOOSTXL-SENSORS\_TI-RTOS\_SensorGUI\_MSP432P401R

This section describes the functionality structure of the BOOSTXL-SENSORS\_TI-RTOS\_SensorGUI\_MSP432P401R demo that is included in the MSP-EXP432P401R Software Examples download, or more easily accessible through MSPWare (see [Section 4.3](#)).

This example requires TI-RTOS MSP43x version 2\_16\_01\_14 to be installed in CCS.

More information on the use of TI-RTOS can be found within the TI-RTOS User's Guide.

#### 3.7.1 Source File Structure

[Table 9](#) lists the source files and folders.

**Table 9. Source Files and Folders**

Name	Description
OS: TI-RTOS	Real-Time Operating System using TI-RTOS Kernel
Library: driverlib	Device driver library (MSP432DRIVERLIB)
bme280.c	Driver for communicating with the environmental sensor
bme280_support.c	Support driver for communicating with the environmental sensor
bmi160.c	Driver for communicating with the IMU and magnetometer sensors
bmi160_support.c	Support driver for communicating with the IMU and magnetometer sensors
MSP_EXP432P401R.c	Driver for setting up board specific items (for example, I2C and UART)
main.c	The demo's main function, tasks, semaphores, global variables, and others
opt3001.c	Driver for communicating with the ambient light sensor
tmp007.c	Driver for communicating with the infrared temperature sensor

### 3.7.2 Working With the GUI

Collaboration with the Sensor GUI is identical to [Section 3.6.2](#), except for programming the device directly from the GUI. The .out file located within the GUI is specific to the BOOSTXL-SENSORS\_SensorGUI\_MSP432P401R example project. To download the program, you must use a separate IDE, such as CCS or IAR, and the BOOSTXL-SENSORS\_TI\_RTOS\_SensorGUI\_MSP432P401R source code found within MSP-EXP432P401R Software Examples.

## 4 Resources

### 4.1 Integrated Development Environments

Although the source files can be viewed with any text editor, more can be done with the projects if they're opened with a [development environment](#) like Code Composer Studio™ (CCS), Keil™ µVision®, IAR Embedded Workbench®, or Energia.

#### 4.1.1 TI Cloud Development Tools

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

##### 4.1.1.1 TI Resource Explorer Cloud

TI Resource Explorer Cloud provides a web interface for browsing examples, libraries and documentation found in MSPWare without having to download files to your local drive.

Go check out TI Resource Explorer Cloud now at [dev.ti.com](http://dev.ti.com).

##### 4.1.1.2 Code Composer Studio™ Cloud

Code Composer Studio Cloud is a web-based IDE that allows code edit, compile and download to devices right from your web browser. It also integrates seamlessly with TI Resource Explorer Cloud with the ability to import projects directly on the cloud.

A full comparison between CCS Cloud and CCS Desktop is available [here](#).

See Code Composer Studio Cloud now at [dev.ti.com](http://dev.ti.com).

#### 4.1.2 Code Composer Studio™ IDE

Code Composer Studio Desktop is a professional integrated development environment that supports TI's Microcontroller and Embedded Processors portfolio. Code Composer Studio 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.

**Note:** MSP432 LaunchPad development kit requires CCS Version 6.1.0 or later. Refer to the [Code Composer Studio 6.1 for MSP432 User's Guide](#) for detailed instructions of using the IDE with MSP432.

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

#### 4.1.3 Keil® µVision®

The µVision IDE is an embedded project development environment included in Keil's Microcontroller Development Kit Version 5, that provides an source code editor, project manager, and make utility tool. µVision supports all the Keil tools including C/C++ Compiler, Macro Assembler, Linker, Library Manager, and Object-HEX Converter.

**Note:** MSP432 LaunchPad development kit requires µVision IDE/MDK Version 5 or later. Refer to the [ARM Keil MDK 5 IDE for MSP432 User's Guide](#) for detailed instructions of using the IDE with MSP432.

Learn more about Keil µVision and download it at <http://www.keil.com/arm/mdk.asp>.

#### 4.1.4 IAR Embedded Workbench® for ARM

IAR Embedded Workbench for ARM 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.

---

**NOTE:** The MSP432 LaunchPad development kit requires the IAR Embedded Workbench for ARM IDE Version 7.10 or later. Refer to the [IAR Embedded Workbench for ARM 7.40.2 for MSP432 User's Guide](#) for detailed instructions of using the IDE with MSP432.

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Learn more about IAR Embedded Workbench and download it at <https://www.iar.com/iar-embedded-workbench/arm>.

#### 4.1.5 Energia

Energia is a simple open-source 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 CCS, Keil, or IAR. However, Energia is great for anyone who wants to get started very quickly or who does not have significant coding experience.

Learn more about Energia and download it at [www.energia.nu](http://www.energia.nu).

### 4.2 LaunchPad Development Kit Websites

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

- [MSP-EXP432P401R tool folder](#): Resources specific to this particular LaunchPad development kit
- [TI's LaunchPad portal](#): Information about all LaunchPad development kits from TI

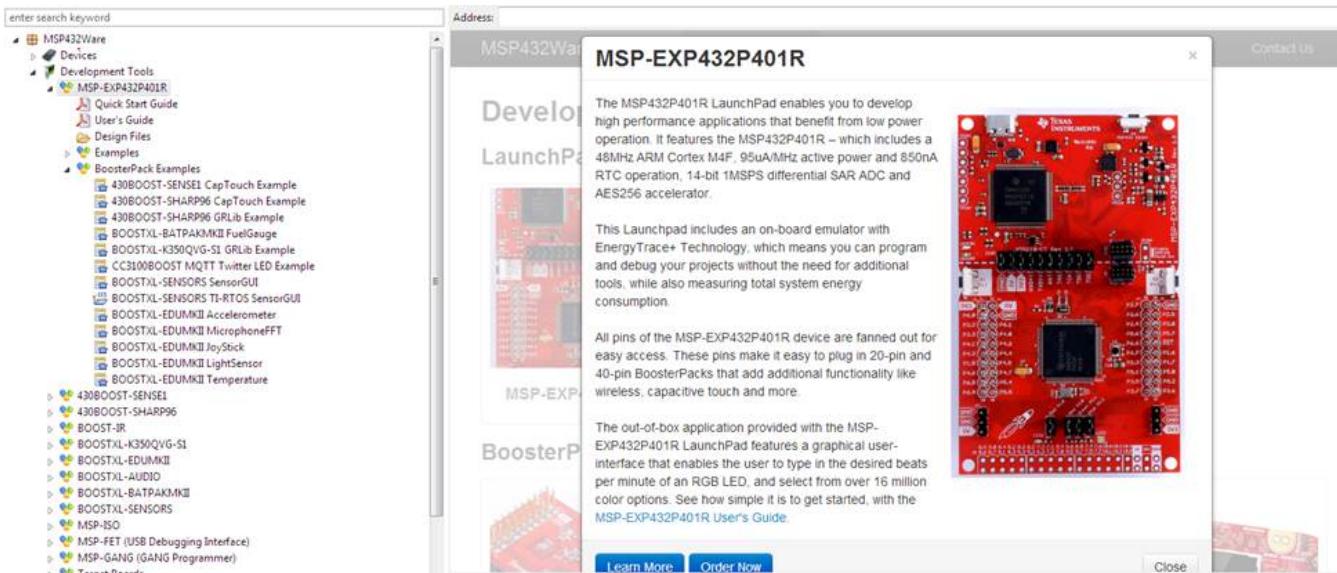
### 4.3 MSPWare and TI Resource Explorer

TI Resource Explorer is a tool integrated into CCS that allows you to browse through available design resources. TI Resource Explorer will help you quickly find what you need inside packages including MSPWare, ControlSuite, TivaWare and more. TI Resource Explorer is well organized to find everything that you need quickly, and you can import software projects into your workspace in one click!

TI Resource Explorer Cloud is one of the TI Cloud Development tools, and is tightly integrated with CCS Cloud. See [Section 4.1.1](#) for more information.

MSPWare is a collection of code examples, software libraries, data sheets, and other design resources for all MSP devices delivered in a convenient package – essentially everything developers need to become MSP experts!

In addition to providing a complete collection of existing MSP design resources, MSPWare also includes a high-level API called MSP Driver Library. This library makes it easy to program MSP hardware. More information can be found at <http://www.ti.com/tool/mspware>.



**Figure 36. Using TI Resource Explorer to Browse MSP-EXP432P401R in MSPWare**

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

## 4.4 MSP432P401R

### 4.4.1 Device Documentation

At some point, you will probably want more information about the MSP432P401R device. For every MSP device, the documentation is organized as shown in [Table 10](#).

**Table 10. How MSP Device Documentation is Organized**

Document	For MSP432P401R	Description
Device family user's guide	<a href="#">MSP432P4xx Family Technical Reference Manual</a>	Architectural information about the device, including all modules and peripherals such as clocks, timers, ADC, and so on.
Device-specific data sheet	<a href="#">MSP432P401xx Mixed-Signal Microcontroller data sheet</a>	Device-specific information and all parametric information for this device

### 4.4.2 MSP432P401R Code Examples

This is a set of very simple [MSP432P401xx code examples](#) that demonstrate how to use the entire set of MSP432 peripherals: serial communication, ADC14, Timer\_A, Timer\_B, and so on. These examples show both the direct register access and driver library methods.

Every MSP derivative has a set of these code examples. When starting a new project or adding a new peripheral, these examples serve as a great starting point.

### 4.4.3 MSP432 Application Notes and TI Designs

There are many application notes that can be found at [www.ti.com/msp432](#), as well as [TI Designs](#) with practical design examples and topics.

## 4.5 Community Resources

### 4.5.1 TI E2E™ Community

Search the E2E forums at [e2e.ti.com](http://e2e.ti.com). If you cannot find your answer, post your question to the community!

### 4.5.2 Community at Large

Many online communities focus on the LaunchPad development kit; for example, <http://www.43oh.com>. You can find additional tools, resources, and support from these communities.

## 5 FAQ

*Q: I can't program my LaunchPad development kit; the IDE can't connect to target. What's wrong?*

A: Check the following:

- Are the JTAG jumpers on J101 populated (GND, RST, TMS, TCK, TDO, TDI)
- Check for power to the target
  - Are the 3V3 and GND jumpers on J101 populated and USB cable plugged in?
  - If using an external debug probe, is USB power provided as shown above? Otherwise is external power provided to the target?
- Check the debug probe settings: change to Serial Wire Debug (SWD) without SWO
  - Under targetconfigs, double-click the \*.ccxml file
  - Click the Advanced tab at the bottom
  - Click on Texas Instruments XDS110 USB Debug Probe
  - Under Connection Properties, change SWD Mode Settings to Use SWD Mode with SWO Trace Disabled

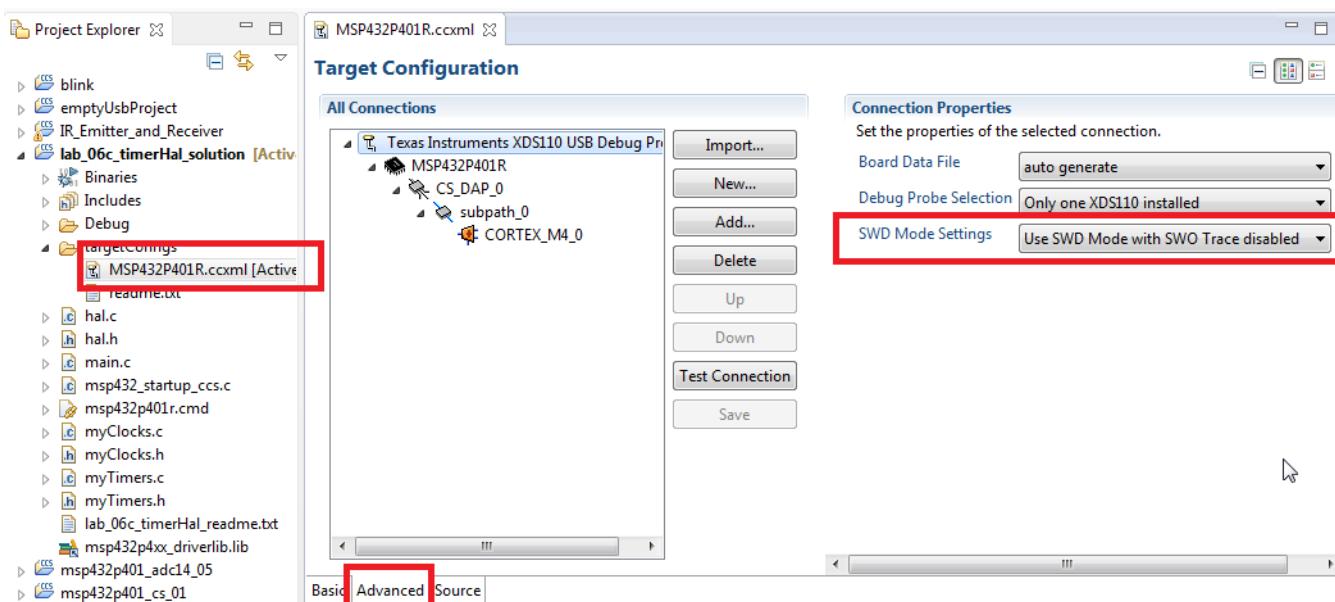
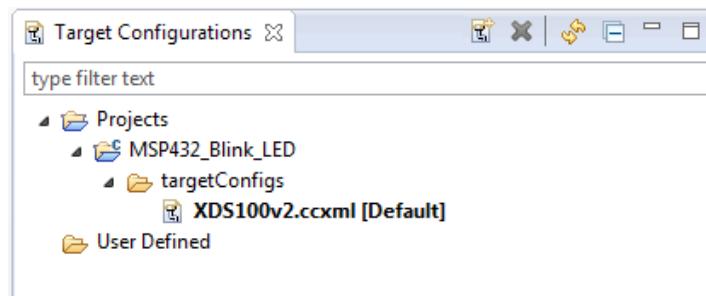


Figure 37. SWD Mode Settings

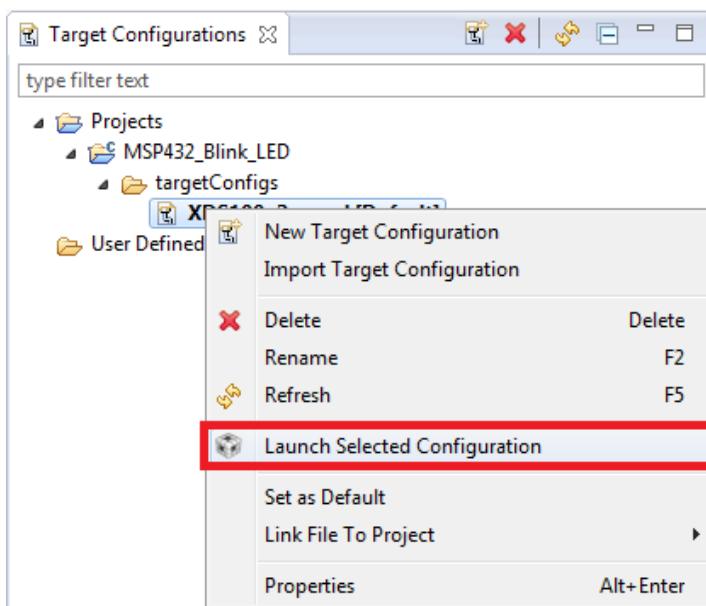
- When the settings of Port J (PJSEL0 and PJSEL1 bits) are changed, full JTAG access is prevented on these pins. Changing to use SWD allows access through the dedicated debug pins only.
- If even this cannot connect, reset the device to factory settings
  - Click **View → Target Configurations**. CCS shows the target configuration.



**Figure 38. Target Configurations**

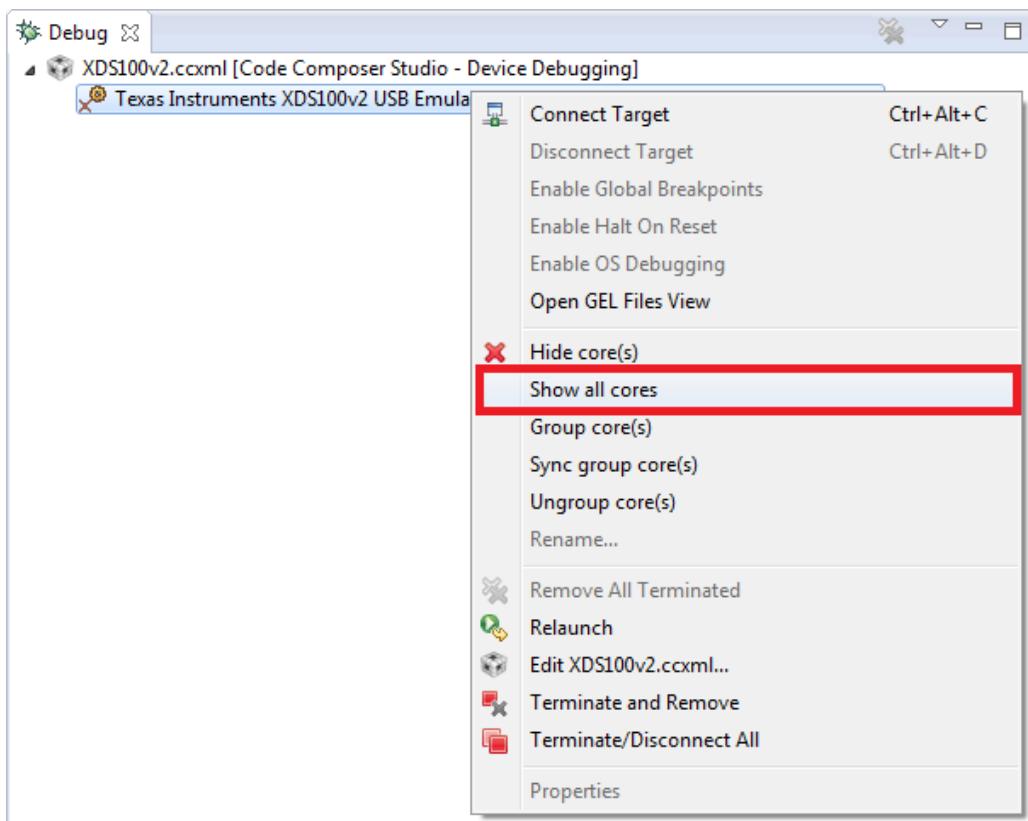
If using the onboard debug probe, XDS110-ET is shown.

- Right click **Launch Selected Configuration**.



**Figure 39. Launch Selected Configuration**

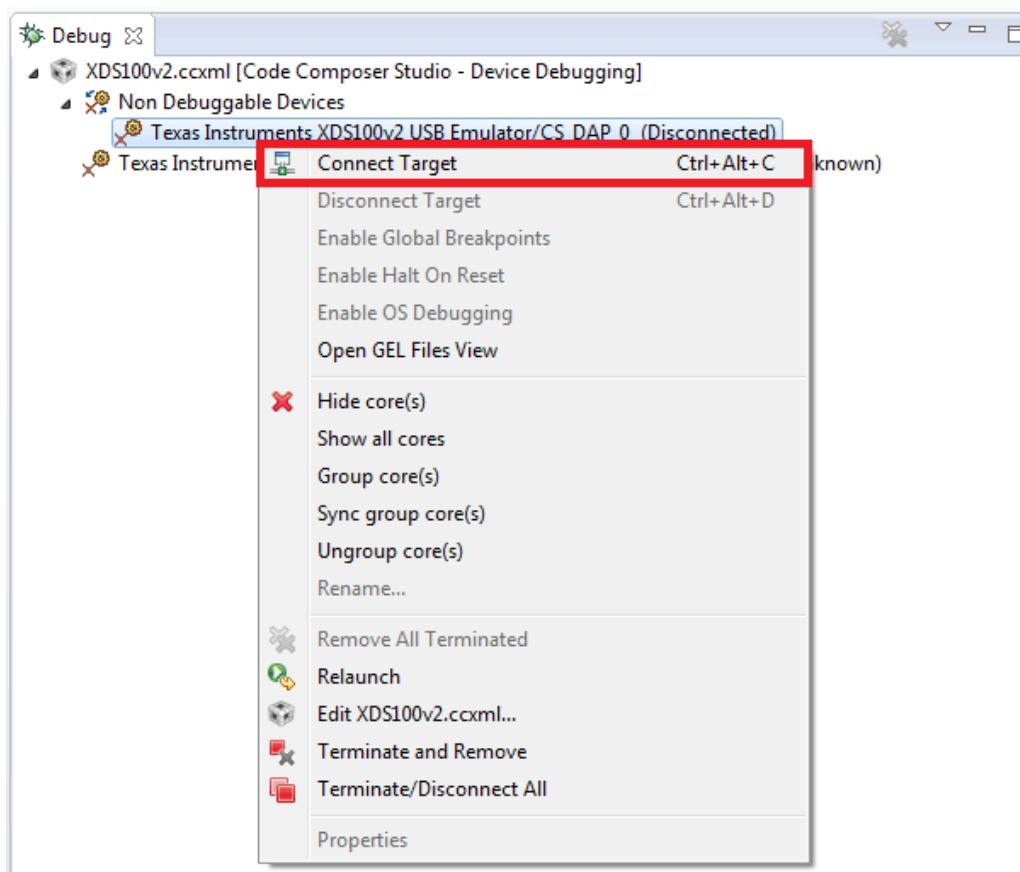
- The debug probe now connects to the device (which is still possible) but does not try to halt the CPU, write to registers, or even download code (which would not be possible). The Debug view that is spawned shows the CPU core but marks it as disconnected.
- Right click **Show all cores**.



**Figure 40. Show All Cores**

The MSP432 Debug Access Port, or DAP, is shown under **Non Debuggable Devices**.

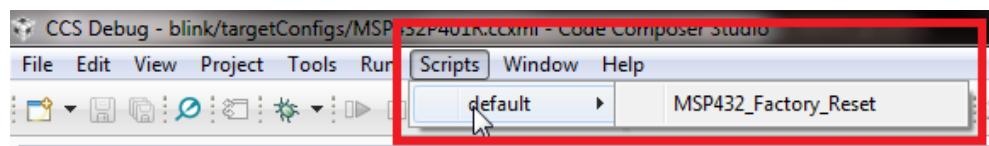
- Right click **Connect Target**



**Figure 41. Connect Target**

Now run a script to return the device back to factory settings:

Scripts > default > MSP432\_Factory\_Reset



**Figure 42. MSP432\_Factory\_Reset Script**

- These instructions are generally the same for all IDEs, but the exact steps may vary slightly by IDE. See the following MSP432 IDE user's guides for additional details:
  - Code Composer Studio 6 for MSP432 User's Guide
  - Keil µVision IDE Version 5 for MSP432 User's Guide
  - IAR Embedded Workbench for ARM 7.10 for MSP432 User's Guide

**Q:** How do I use the LaunchPad development kit and my Segger J-Link to debug the target externally? It won't connect to the onboard connector.

**A:** The Segger J-Link is the only major ARM debug probe that does not come with an adapter for the 10-pin small-pitch ARM connector. The adapter cable is found [here](#) and can be purchased [from Digi-Key](#).

*Q: Problems plugging the MSP432 LaunchPad development kit into a USB3.0 port.*

A: It has been observed that when the MSP432 LaunchPad development kit is connected to USB3.0 ports provided by a certain combination of USB3.0 host controller hardware and associated device drivers that the IDE is unable to establish a debug session with the LaunchPad development kit, resulting in an error message like "CS\_DAP\_0: Error connecting to the target: (Error -260 @ 0x0) An attempt to connect to the XDS110 failed." in the case of Code Composer Studio IDE. In this case the CCS-provided low-level command line utility 'xdsdfu' will also not be able to establish a connection with the LaunchPad development kit.

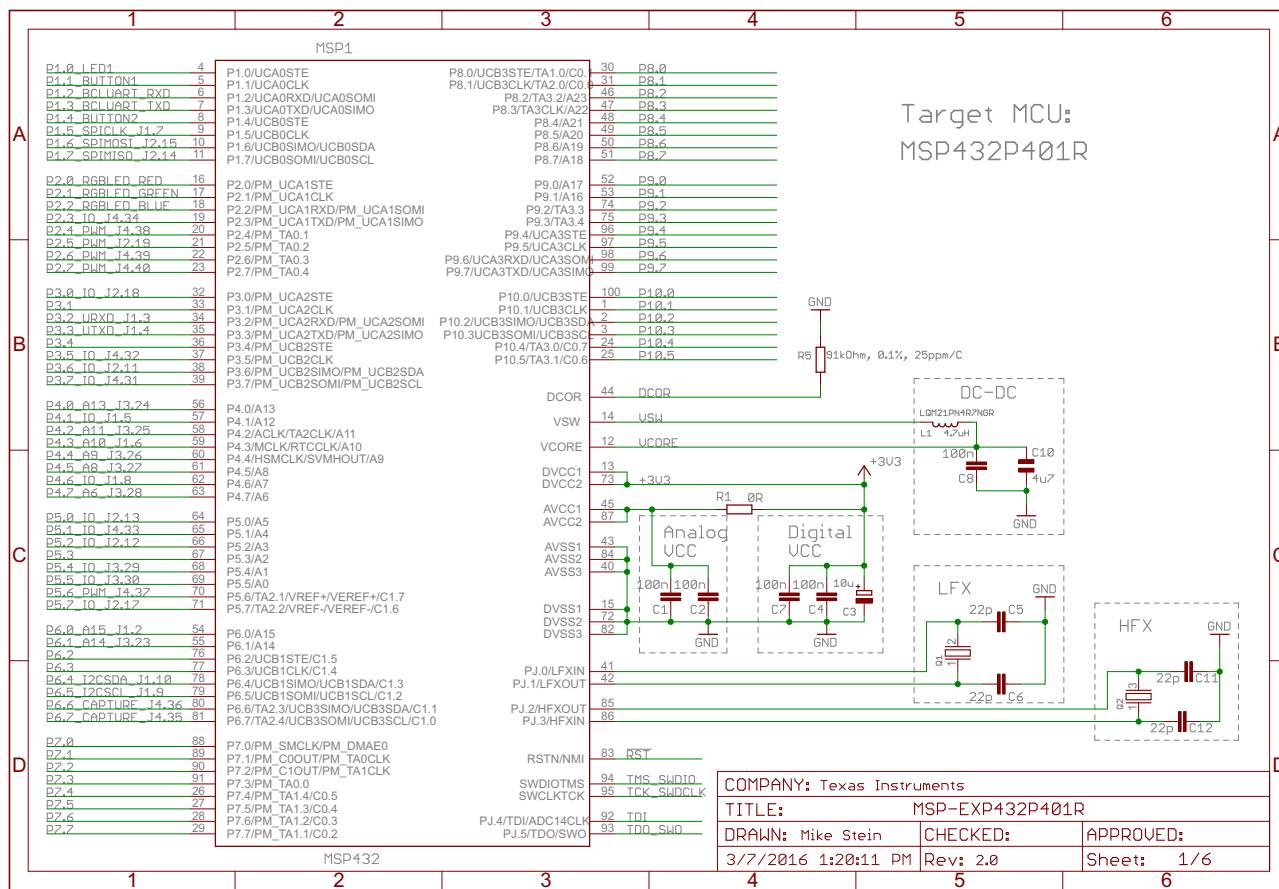
Specifically, this issue was observed on PCs running Windows 7 that show the "Renesas Electronics USB 3.0 Host Controller" and the associated "Renesas Electronics USB 3.0 Root Hub" in the device manager. After updating the associated Windows USB drivers to more recent versions obtained from the hardware vendor the issue went away. There might be other USB3.0 hardware and device driver combinations that will lead to the same issue. If you think you might be affected try contacting your PC vendor or try locating and installing more recent versions of the USB3.0 device drivers. Alternatively, connect the LaunchPad development kit to an USB2.0 port on your PC if one is available.

*Q: I can't get the backchannel UART to connect. What's wrong?*

A: Check the following:

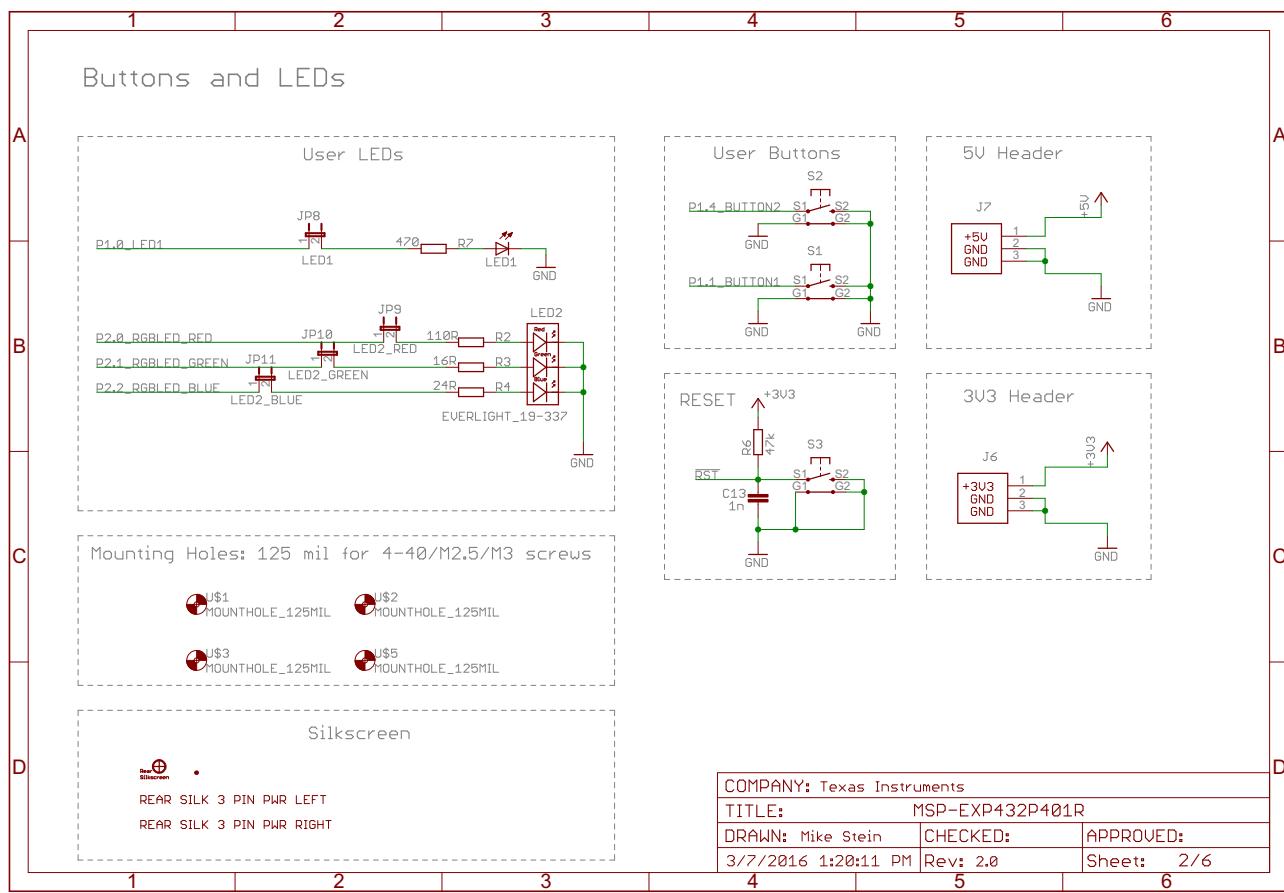
- Do the baud rate in the host's terminal application and the eUSCI settings match?
- Are the appropriate jumpers in place on the isolation jumper block?
- Probe on RXD and send data from the host. If you do not see data, it might be a problem on the host side.
- Probe on TXD while sending data from the MSP432. If you do not see data, it might be a configuration problem with the eUSCI module.
- Consider the use of the hardware flow control lines (especially for higher baud rates).

## 6 Schematics



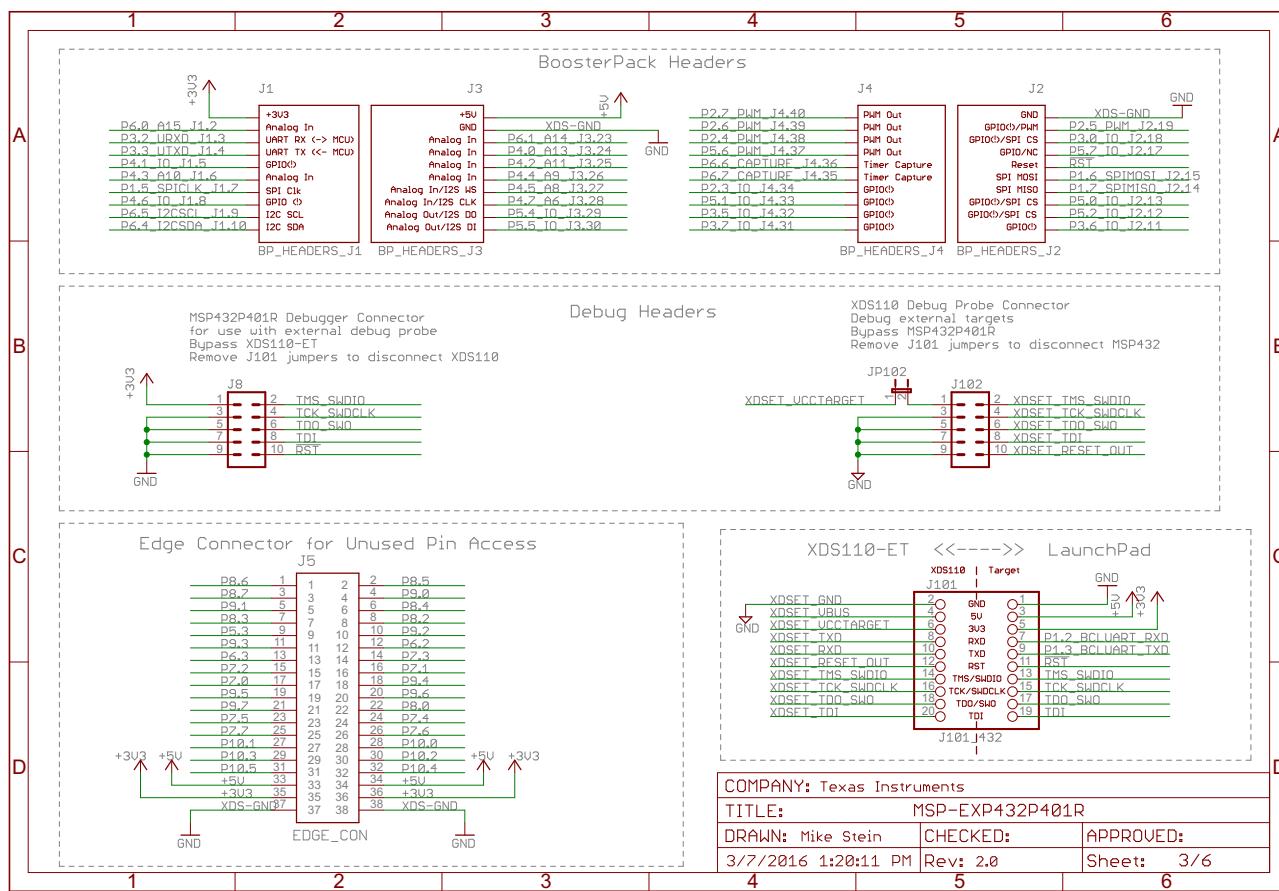
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**Figure 43. Schematics (1 of 6)**



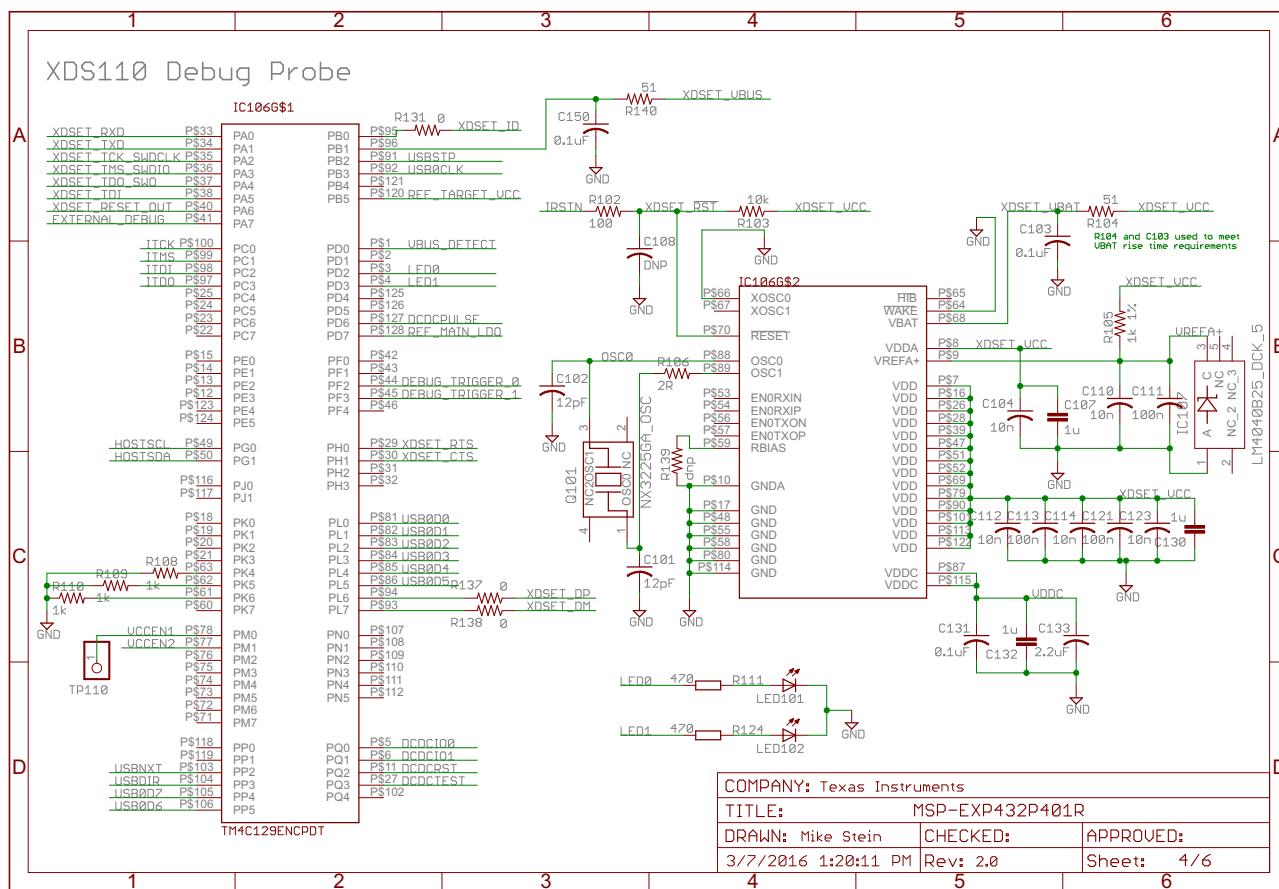
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**Figure 44. Schematics (2 of 6)**



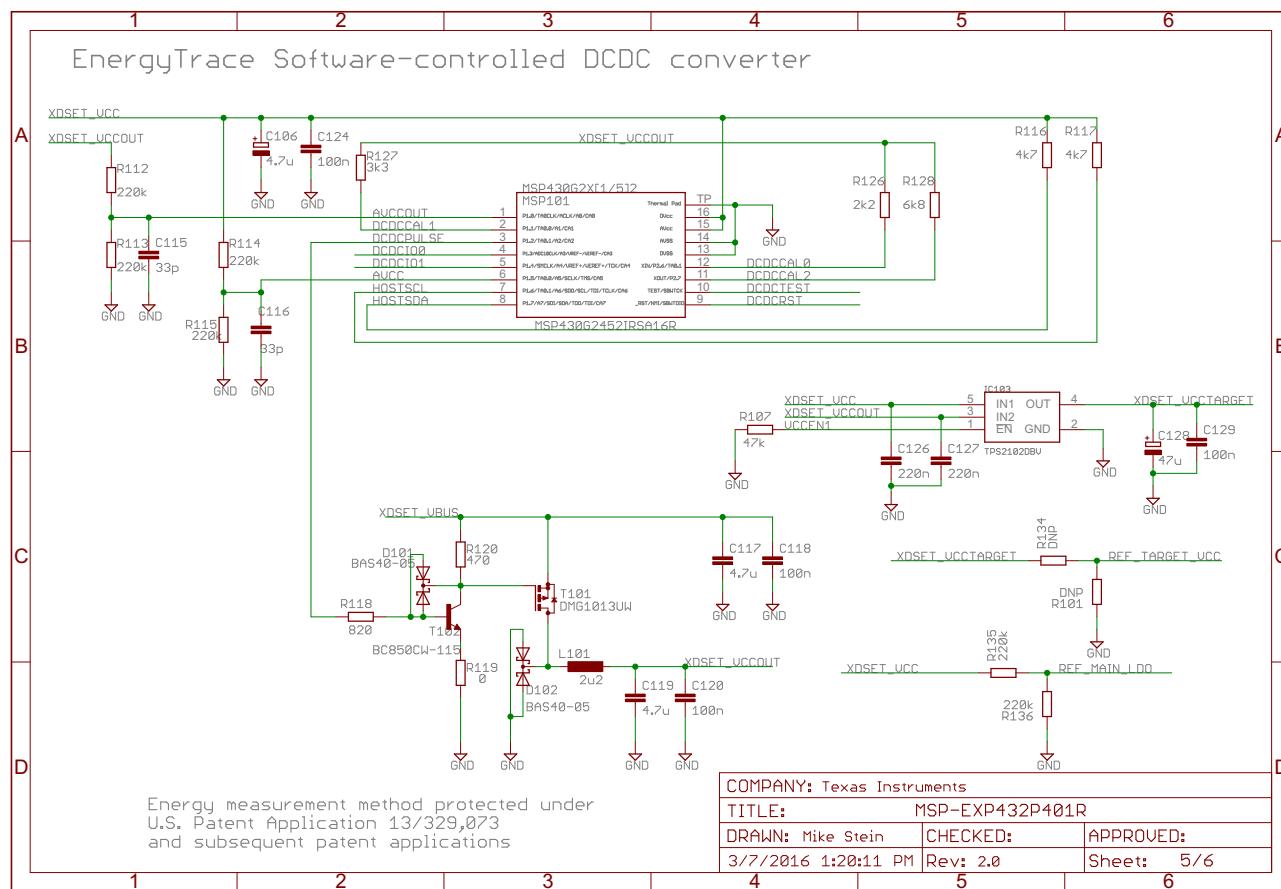
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**Figure 45. Schematics (3 of 6)**



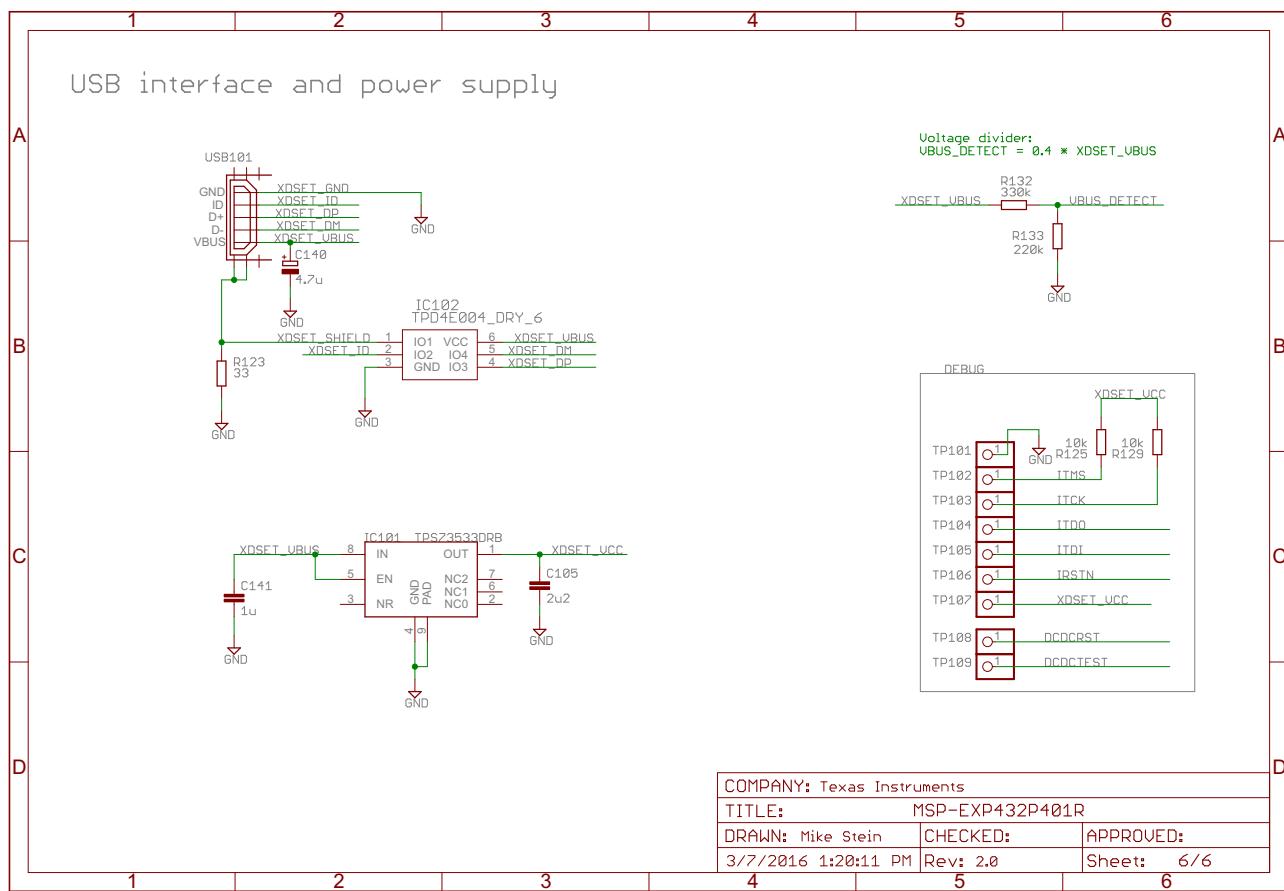
Copyright © 2016, Texas Instruments Incorporated

**Figure 46. Schematics (4 of 6)**



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**Figure 47. Schematics (5 of 6)**



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**Figure 48. Schematics (6 of 6)**

## **Revision History**

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

<b>Changes from July 21, 2015 to July 12, 2016</b>	<b>Page</b>
• Changed <a href="#">Figure 1</a> , <i>MSP-EXP432P401R LaunchPad™ Development Kit</i> .....	1
• Added last three list items in <a href="#">Section 1.3.2, Software Examples</a> .....	4
• Changed <a href="#">Figure 5</a> , <i>XDS110-ET Debug Probe</i> .....	7
• Changed first paragraph in <a href="#">Section 2.3.1, XDS110-ET Isolation Block J101</a> .....	7
• In <a href="#">Table 1, Isolation Block Connections</a> : removed Isolation Type column, removed RTS and CTS rows, removed notes, added GND row .....	7
• Changed <a href="#">Figure 6, XDS110-ET Isolation Block</a> .....	8
• Removed the sentence that started "The provided UART supports hardware flow control..." from the first paragraph of <a href="#">Section 2.3.2, Application (or "Backchannel") UART</a> .....	8
• Removed the paragraph that started "The XDS110-ET also supports hardware flow control..." in <a href="#">Section 2.3.2, Application (or "Backchannel") UART</a> .....	9
• Changed the first paragraph and all steps in <a href="#">Section 2.3.3, Using an External Debug Probe Instead of the Onboard XDS110-ET</a> .....	10
• Updated all contents of <a href="#">Section 2.3.4, Using the XDS110-ET Emulator With a Different Target</a> .....	10
• Changed <a href="#">Figure 10, MSP-EXP432P401R Power Block Diagram</a> .....	13
• Changed <a href="#">Figure 11, LaunchPad™ Development Kit to BoosterPack™ Plug-in Module Connector Pinout</a> .....	16
• Added the paragraph that starts "Do you have an older version..." in <a href="#">Section 2.8.1, Hardware Design Files</a> .....	16
• Added the paragraph that starts "Do you have an older version..." in <a href="#">Section 2.8.2, Software Examples</a> .....	17
• Added row for "Rev 2.0" and added two columns on right to <a href="#">Table 3, Hardware Change Log</a> .....	17
• Added <a href="#">Section 2.9.1, MSP-EXP432P401R Rev 1.0 (Black) LaunchPad Development Kit</a> .....	17
• Added <a href="#">Section 2.9.2, MSP-EXP432P401R Rev 2.0 (Red) LaunchPad Development Kit</a> .....	17
• Added the last three rows to <a href="#">Table 4, Software Examples</a> .....	19
• Added <a href="#">Section 3.5, BOOSTXL-BATPAKMKII Fuel Gauge Example</a> .....	26
• Added <a href="#">Section 3.6, BOOSTXL-SENSORS Sensor GUI Example</a> .....	28
• Added <a href="#">Section 3.7, BOOSTXL-SENSORS Sensor GUI With TI-RTOS Example</a> .....	36
• Changed <a href="#">Figure 36, Using TI Resource Explorer to Browse MSP-EXP432P401R in MSPWare</a> .....	39
• Changed the first two list items in the answer to the FAQ that starts "I can't program my LaunchPad development kit..." in <a href="#">Section 5, FAQ</a> .....	40
• Removed the FAQ that started "Q: Why doesn't the back-channel UART ..."	43
• Changed all figures in <a href="#">Section 6, Schematics</a> .....	45

## STANDARD TERMS AND CONDITIONS FOR EVALUATION MODULES

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- 3 *Regulatory Notices:*

- 3.1 *United States*

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

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

###### **Concerning EVMs Including Radio Transmitters:**

This device complies with Industry Canada license-exempt RSS standard(s). 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](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](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 by Radio Law of Japan to follow the instructions below with respect to EVMs:

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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#### 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.
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