User's Guide

SLAU680–May 2018

MSP430FR2355 LaunchPad™ Development Kit (MSP-EXP430FR2355)

The MSP-EXP430FR2355 LaunchPad™ Development Kit is an easy-to-use Evaluation Module (EVM) for the MSP430FR2355 microcontroller (MCU). The kit contains everything needed to start developing on the ultra-low-power MSP430FRx FRAM microcontroller platform, including onboard debug probe for programming, debugging, and energy measurements. The board also features onboard buttons and LEDs for quick integration of a simple user interface, an onboard Grove connector for external Grove sensors, as well as an ambient light sensor to showcase the integrated analog peripherals.

Figure 1 shows the MSP-EXP430FR2355 LaunchPad development kit.

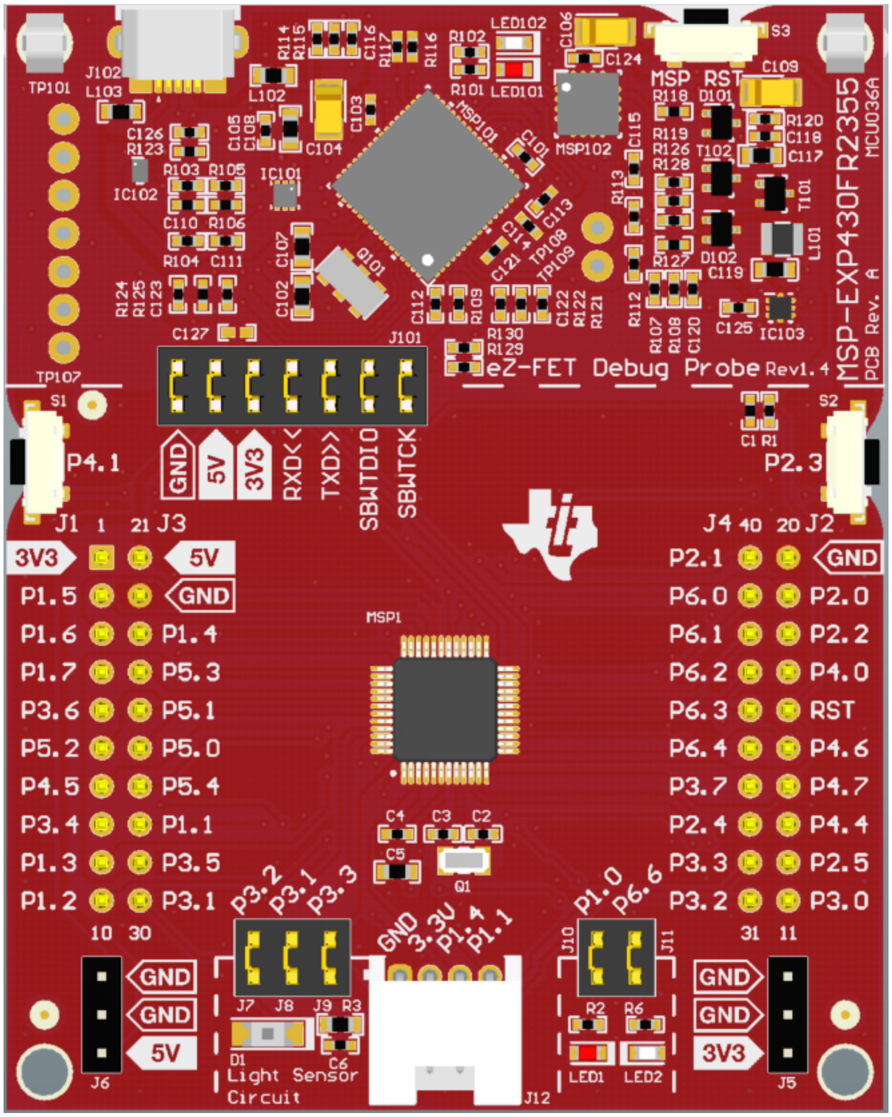

Figure 1. MSP-EXP430FR2355 LaunchPad Development Kit

Contents

List of Figures

List of Tables

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1 Getting Started

1.1 Introduction

The 24-MHz MSP430FR2355 device features 32KB of embedded FRAM (ferroelectric random access memory), a nonvolatile memory known for its ultra-low power, high endurance, and high speed write access. Combined with 4KB of on-chip RAM, users have access to 32KB of memory to split between their program and data as required. For example, a data logging application may require a large data memory with relatively small program memory, so the memory may be allocated as required between program and data memory.

Rapid prototyping is simplified by the 40-pin BoosterPack™ plug-in module headers, which support a wide range of available BoosterPack plug-in modules. You can quickly add features like wireless connectivity, graphical displays, environmental sensing, and much more. Design your own BoosterPack plug-in module or choose among many already available from TI and third-party developers.

Free software development tools are also available, such as TI's Eclipse-based Code Composer Studio™ IDE (CCS) and IAR Embedded Workbench® IDE. Both of these IDEs support EnergyTrace™ technology for real-time power profiling and debugging when paired with the MSP430FR2355 LaunchPad development kit.

1.2 Key Features

- MSP ULP FRAM technology based MSP430FR2355 16-bit MCU
- EnergyTrace technology available for ultra-low-power debugging
- 40-pin LaunchPad development kit standard leveraging the BoosterPack plug-in module ecosystem
- Onboard eZ-FET debug probe
- 2 buttons and 2 LEDs for user interaction
- Ambient light sensor for the Out-of-Box Experience demo
- Grove connector for external Grove sensors

1.3 What's Included

1.3.1 Kit Contents

- 1 MSP-EXP430FR2355 LaunchPad Development Kit
- 1 Micro USB cable
- 1 Quick Start Guide

1.3.2 Software Examples

- Out-of-Box Software

1.4 First Steps: Out-of-Box Experience

An easy way to get started with the EVM is by using its preprogrammed out-of-box code. It demonstrates some key features of the EVM.

1.4.1 Connecting to the Computer

Connect the LaunchPad development kit using the included USB cable to a computer. A green power LED should illuminate. For proper operation, drivers are needed. TI recommends that you get the drivers by installing an IDE such as TI's CCS or IAR EW430. Drivers are also available at www.ti.com/MSPdrivers.

1.4.2 Running the Out-of-Box Experience

The Out-of-Box Experience (OOBE) of the MSP-EXP430FR2355 LaunchPad development kit demonstrates how to set up multiple integrated Smart Analog Combo (SAC) peripherals of the MSP430FR2355 MCU and how to use the interconnections between SAC pairs in various demo scenarios. The OOBE includes two modes, a Light Sensor mode and a Function Generator mode. In the Function Generator mode, the LaunchPad development kit transmits digital data to the PC and can be visualized using the accompanying cloud GUI (visit MSP-EXP430FR2355 OOB GUI).

By default after power up, the MSP-EXP430FR2355 LaunchPad development kit enters the Light Sensor mode, in which LED1 or LED2 brightens or dims based on the amount of ambient light sensed by the photodiode, D1. A default brightness threshold is set at approximately half of the full brightness detection range of D1 at which both LED1 and LED2 are off. Shine a light source such as a flashlight or cover up D1 using your hand, and notice the green LED2 gets brighter as more light reaches D1, while the red LED1 gets brighter as less light reaches D1. Press button S1 in the Light Sensor mode to set the new brightness threshold at the current ambient light level.

Next, try pressing S2 to enter Function Generator mode. By default, the LaunchPad development kit starts to generate a 1-Hz inverted sine wave at 0.8-V amplitude on pin P1.5. This signal is a result of using one of the SAC 12-bit DACs to generate a sine wave and feeding it into a second SAC, which is configured as an inverting programmable gain amplifier (PGA). The resulting waveform on pin P1.5 is also captured by the MSP430FR2355 internal ADC, and the live data are transmitted to the PC. An accompanying cloud GUI (visit MSP-EXP430FR2355 OOB GUI) is available to visualize the ADC measurements of the generated waveform. This GUI also provides various controls for changing the signal type (sinusoidal, square, or sawtooth), frequency, and amplitude of the DAC waveform generation and for configuring the PGA mode (inverting or noninverting) and gain. See Section 3.1 for more details on the OOBE and how to use its accompanying cloud GUI.

This GUI is created with GUI Composer 2.0 with the source available for customization, imported from the TI Cloud Gallery. The serial communication port on the PC must be configured with 115200 bps, one stop bit, and no flow control.

NOTE: The OOB cloud GUI is only supported in the latest versions of Chrome, Firefox, and Safari browsers. An installer for the offline standalone GUI can also be downloaded from the TI Cloud Gallery.

1.5 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 and start editing the code examples. See Section 4 for available IDEs and where to download them.

The quickest way to get started using the LaunchPad development kit is to use TI’s Cloud Development Tools. The cloud-based Resource Explorer provides access to all of the examples and resources in MSPWare. Code Composer Studio Cloud is a simple Cloud-based IDE that enables developing and running applications on the LaunchPad development kit.

The out-of-box source code and more code examples are provided and available on the download page. Code is licensed under BSD, and TI encourages reuse and modifications to fit specific needs.

Section 3 describes all functions in detail and provides a project structure to help familiarize you with the code.

With the onboard eZ-FET debug probe, debugging and downloading new code is simple. A USB connection between the EVM and a PC through the provided USB cable is all that is needed.

2 Hardware

Figure 2 shows an overview of the MSP-EXP430FR2355 hardware.

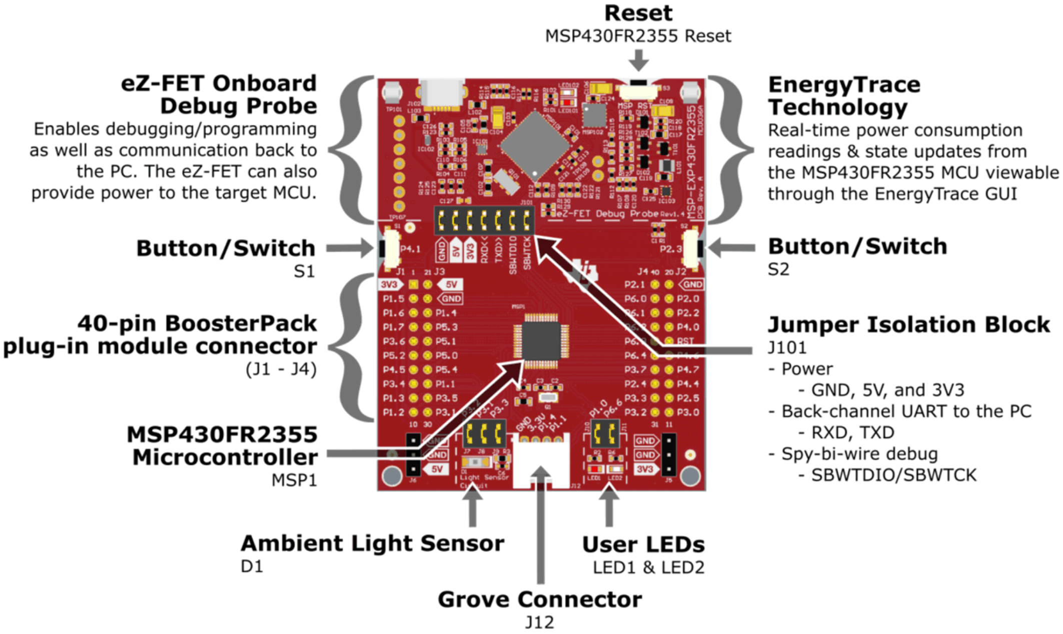

Reset
MSP430FR2355 Reset
eZ-FET Onboard Debug Probe
Enables debugging/programming as well as communication back to the PC. The eZ-FET can also provide power to the target MCU.
EnergyTrace Technology
Real-time power consumption readings & state updates from the MSP430FR2355 MCU viewable through the EnergyTrace GUI
Button/Switch
S1
Button/Switch
S2
40-pin BoosterPack plug-in module connector
(J1 - J4)
Jumper Isolation Block
J101
- Power
- GND, 5V, and 3V3
- Back-channel UART to the PC
- RXD, TXD
- Spy-bi-wire debug
- SBWTDIO/SBWTCK
MSP430FR2355 Microcontroller
MSP1
Ambient Light Sensor
D1
User LEDs
LED1 & LED2
Grove Connector
J12

Figure 2. MSP-EXP430FR2355 Overview

2.1 Block Diagram

Figure 3 shows the block diagram.

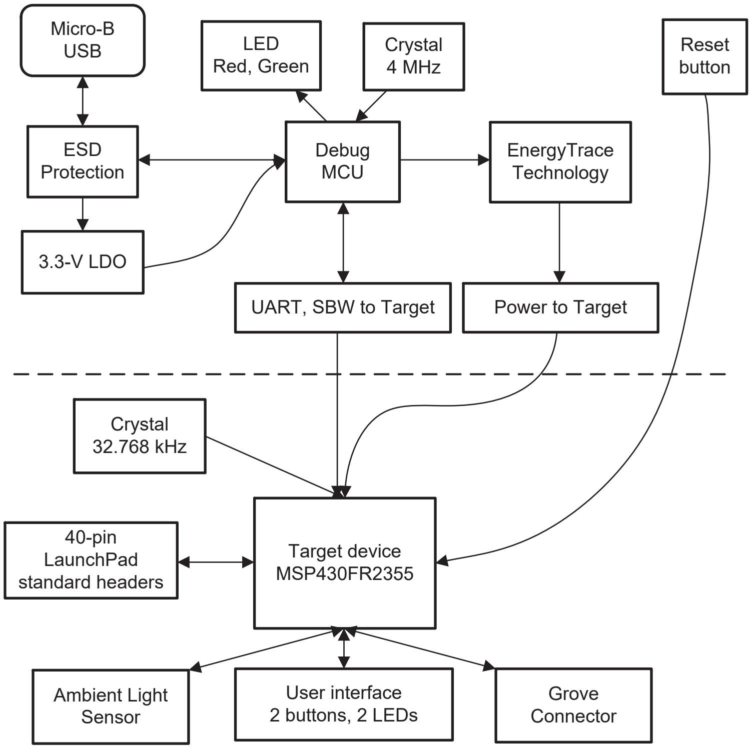


Figure 3. MSP-EXP430FR2355 Block Diagram

2.2 Hardware Features

2.2.1 MSP430FR2355 MCU

The MSP430FR2355 is an ultra-low-power MSP430FRx FRAM-based microcontroller (MCU), which offer extended data logging and security capabilities. The MSP430FR2355 offers the small LQFP package (7 mm × 7 mm) in the FRAM microcontroller portfolio, combined with a variety of integrated peripherals and ultra-low power consumption. FRAM is a cutting edge memory technology, combining the best features of flash and RAM into one nonvolatile memory. More information on FRAM can be found at www.ti.com/fram.

Device features include:

- 1.8-V to 3.6-V operation
- 16-Bit RISC architecture up to 24-MHz system clock and 8-MHz FRAM access
- 32KB of Program FRAM, 512 bytes of Information FRAM, and 4KB of RAM
- 12-channel 12-bit ADC
- Two enhanced comparator with integrated 6-bit DAC as reference voltage
- Four Smart Analog Combo (SAC-L3)
- Three 16-bit timers with three capture/compare registers (Timer_B3)
- One 16-bit timer with seven capture/compare registers (Timer_B7)
- 32-bit hardware multiplier (MPY)
- 44 GPIOs

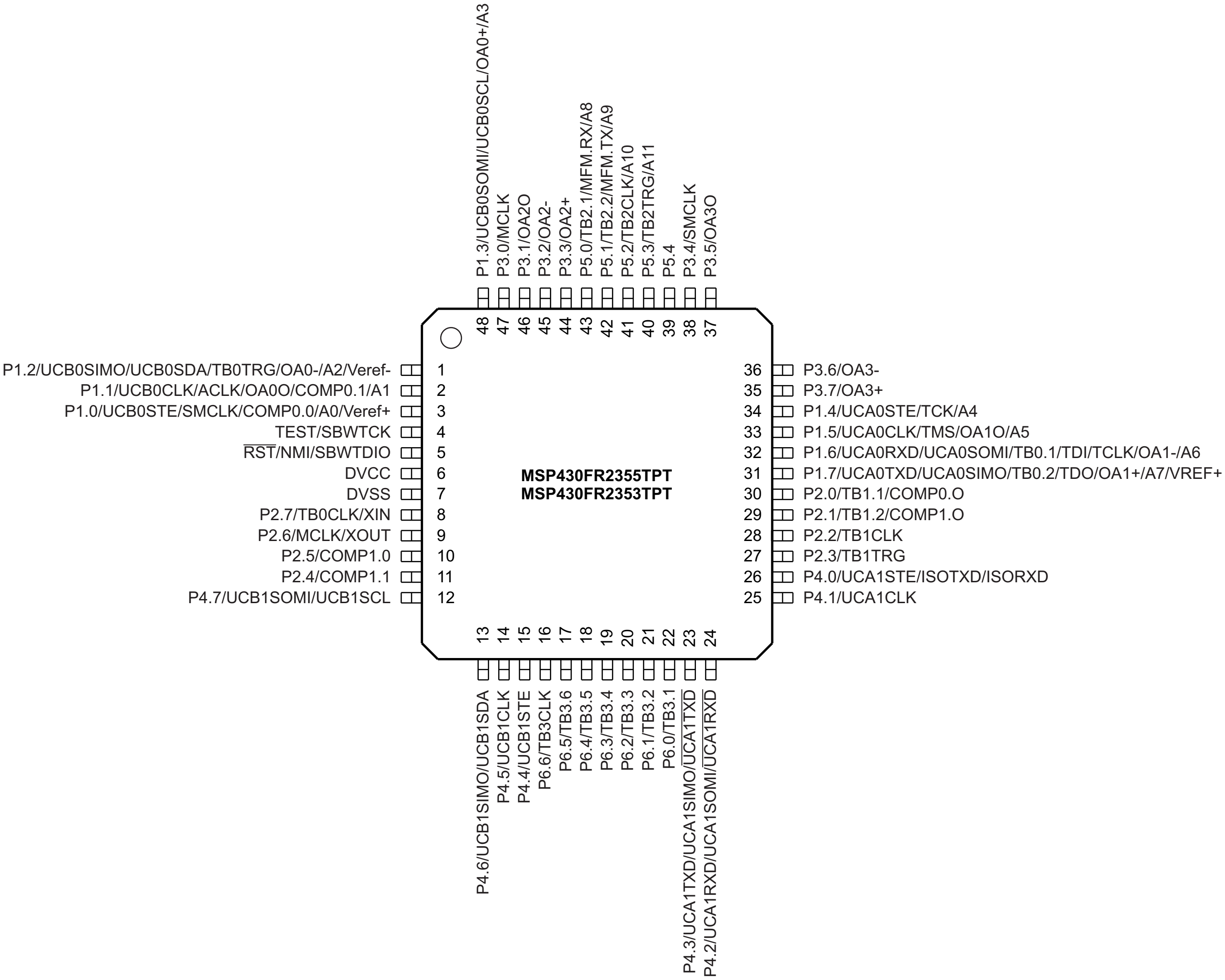


Figure 4. MSP430FR2355 Pinout

2.2.2 eZ-FET Onboard Debug Probe With EnergyTrace™ Technology

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-EXP430FR2355 has the eZ-FET debug probe (see Figure 5), which is a simple and low-cost debugger that supports all MSP430™ device derivatives.

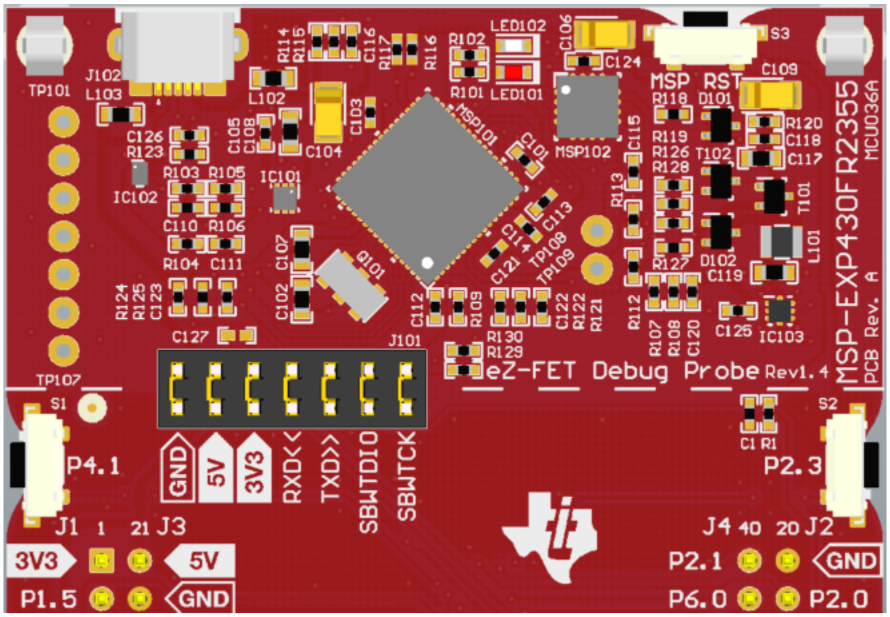


Figure 5. eZ-FET Debug Probe

The MSP-EXP430FR2355 LaunchPad development kit features EnergyTrace technology but does not have support for EnergyTrace++ technology. The EnergyTrace technology functionality varies across the MSP portfolio.

Table 1. EnergyTrace Technology

Features	EnergyTrace Technology	EnergyTrace++ Technology
Current Monitoring	✓	✓
CPU State		✓
Peripheral and System State		✓
Devices Supported	All MSP430 MCUs	MSP430FR59xx and MSP430FR69xx MCUs
Development Tool Required	MSP-FET or eZ-FET	MSP-FET or eZ-FET

The dotted line through J101 shown in Figure 5 divides the eZ-FET debug probe from the target area. The signals that cross this line can be disconnected by jumpers on J101, the isolation jumper block. More details on the isolation jumper block are in Section 2.2.3.

The eZ-FET also provides a "backchannel" UART-over-USB connection with the host, which can be very useful during debugging and for easy communication with a PC. More details can be found in Section 2.2.4.

The eZ-FET hardware can be found in the schematics in Section 6 and in the hardware design files download page. The software and more information about the debugger can be found on the eZ-FET wiki.

2.2.3 Debug Probe Connection: Isolation Jumper Block

The isolation jumper block at jumper J101 allows the user to connect or disconnect signals that cross from the eZ-FET domain into the MSP430FR2355 target domain. This includes eZ-FET Spy-Bi-Wire signals, application UART signals, and 3.3-V and 5-V power.

Reasons to open these connections:

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

Table 2. Isolation Block Connections

Jumper	Description
GND	Ground
5V	5-V VBUS from USB
3V3	3.3-V rail, derived from VBUS in the eZ-FET domain
RXD <<	Backchannel UART: The target FR2355 receives data through this signal. The arrows indicate the direction of the signal.
TXD >>	Backchannel UART: The target FR2355 sends data through this signal. The arrows indicate the direction of the signal.
SBW $\overline{\text{RST}}$	Spy-Bi-Wire debug: SBWTDIO data signal. This pin also functions as the $\overline{\text{RST}}$ signal (active low).
SBW TST	Spy-Bi-Wire debug: SBWTCK clock signal. This pin also functions as the TST signal.

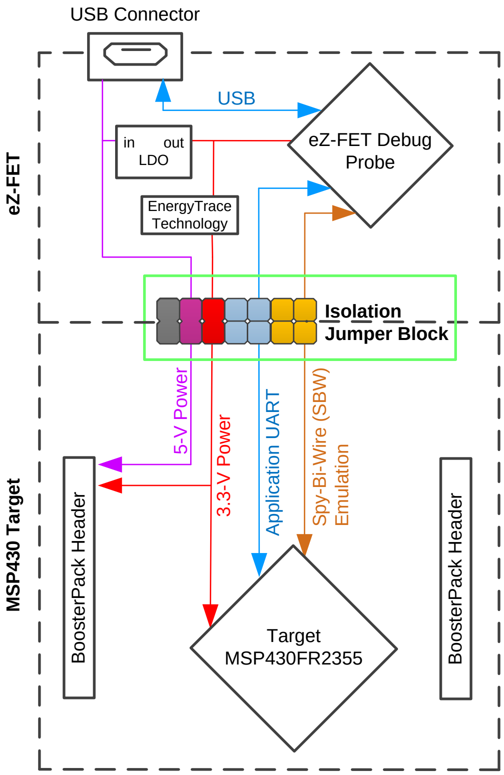


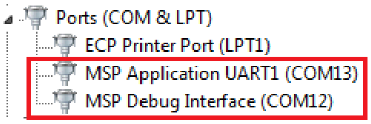
Figure 6. eZ-FET Isolation Jumper Block Diagram

2.2.4 Application (or "Backchannel") UART

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 graphical user interfaces (GUIs) and other programs on the PC that communicate with the LaunchPad development kit.

Figure 6 shows the pathway of the backchannel UART. The backchannel UART is the UART on eUSCI_A1.

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.



Ports (COM & LPT)
ECP Printer Port (LPT1)
MSP Application UART1 (COM13)
MSP Debug Interface (COM12)

Figure 7. Application Backchannel UART in Device Manager

The backchannel UART is the "MSP Application UART1" port. In this case, Figure 7 shows COM13, 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.

On the target MSP430FR2355 side, the backchannel is connected to the eUSCI_A1 module. The eZ-FET 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_A1.

2.2.5 Special Features

2.2.5.1 Smart Analog Combo (SAC)

The MSP430FR2355 MCU LaunchPad development kit features pins to access the SAC on the device. These pins are accessed on jumpers J7, J8 and J9 where the SAC operational amplifier is connected to the onboard photodiode circuit. These pins are also connected to the BoosterPack plug-in module header pins. For applications that use the SAC and a connected BoosterPack plug-in module, be sure to check for any pin conflicts. The photodiode circuit can be disconnected from the SAC using jumpers J7, J8 and J9. The user can connect an external analog sensor circuit to the SAC by removing jumpers J7, J8 and J9 and connecting their circuit to the appropriate header pins through the BoosterPack plug-in module headers or the jumpers near the light sensor circuit. To adjust the sensitivity of the light sensor circuit, the user can adjust either the software or the hardware. By changing the values of R3 and C6, the user can change the operational amplifier low-pass filter and sensitivity to the current of the photodiode. The user can also adjust the calculations performed in the software to adjust the sensitivity of the circuit to their desired level.

2.2.5.2 Grove Connector

The MSP430FR2355 MCU LaunchPad development kit features an onboard Grove connector for Analog and Digital Grove modules from Seeed Studio. The Grove connector consists of 4 pins that are routed to 3.3 V, GND, P1.1, and P1.4. Users can take advantage of this connector and begin prototyping with different Grove sensors and actuators without the need to interface the LaunchPad development kit with a Grove Base BoosterPack plug-in module.

2.3 Power

The board accommodates various powering methods, including through the onboard eZ-FET as well as external or BoosterPack plug-in module power (see Figure 8).

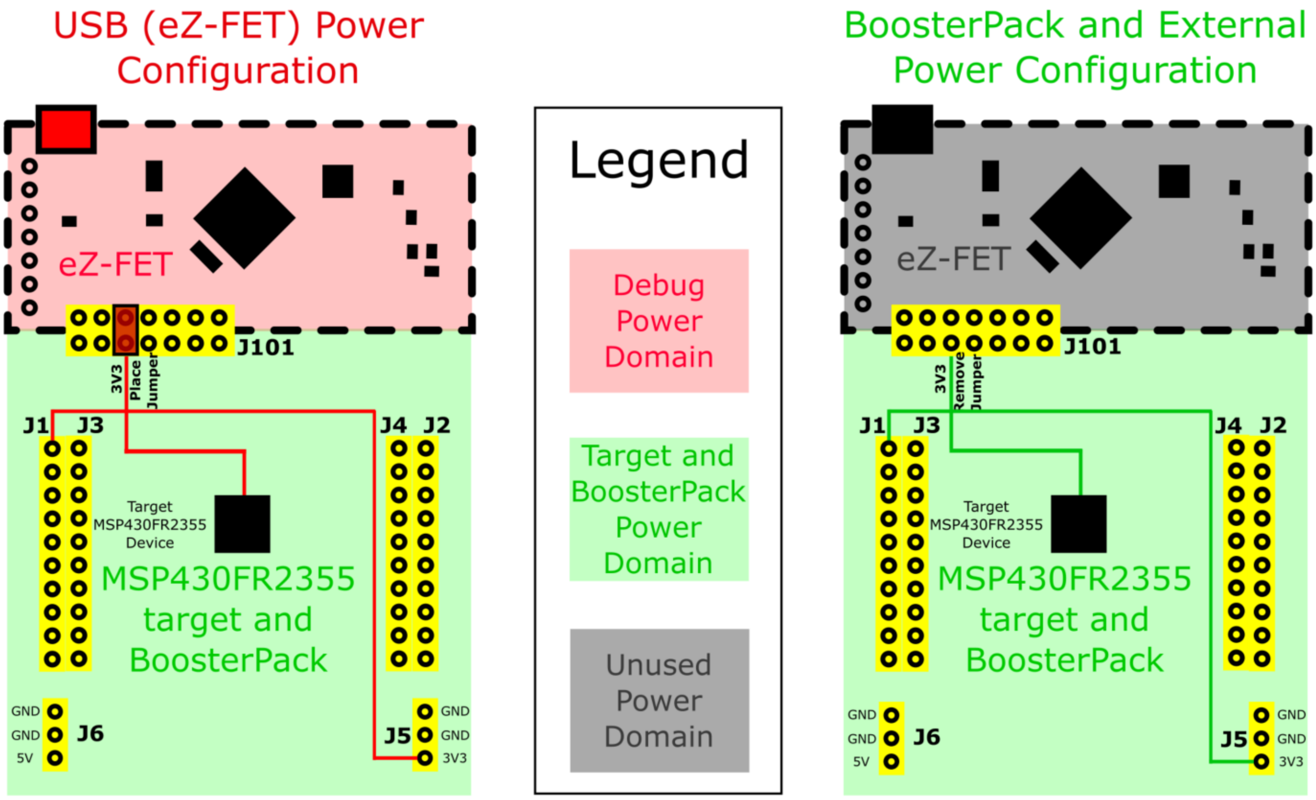

USB (eZ-FET) Power Configuration
eZ-FET
J101
3V3
Place Jumper
J1
J3
J4
J2
Target MSP430FR2355 Device
MSP430FR2355 target and BoosterPack
GND
GND
5V
J6
J5
GND
GND
3V3
Legend
Debug Power Domain
Target and BoosterPack Power Domain
Unused Power Domain
BoosterPack and External Power Configuration
eZ-FET
J101
3V3
Remove Jumper
J1
J3
J4
J2
Target MSP430FR2355 Device
MSP430FR2355 target and BoosterPack
GND
GND
5V
J6
J5
GND
GND
3V3

Figure 8. MSP-EXP430FR2355 Power Block Diagram

2.3.1 eZ-FET USB Power

The most common power-supply scenario is from USB through the eZ-FET debugger. This provides 5-V power from the USB and also regulates this power rail to 3.3 V for eZ-FET operation and 3.3 V to the target side of the LaunchPad development kit. Power from the eZ-FET is controlled by jumper J101. For 3.3 V, make sure that a jumper is connected across the J101 3V3 terminal.

2.3.2 BoosterPack Plug-in Module and External Power Supply

Header J5 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 MSP430FR2355 has an operating range of 1.8 V to 3.6 V. More information can be found in the MSP430FR2355 Mixed-Signal Microcontroller data sheet.

2.4 Measure Current Draw of the MSP430 MCU

To measure the current draw of the MSP430FR2355 MCU using a multimeter, use the 3V3 jumper on the J101 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:

- Remove the 3V3 jumper in the J101 isolation block, and attach an ammeter across this jumper.
- Consider the effect that the backchannel UART and any circuitry attached to the MSP430FR2355 may have on current draw. Consider disconnecting these at the isolation jumper block, or at least consider their current sinking and sourcing capability in the final measurement.

- Make sure there are no floating inputs/outputs (I/Os) on the MSP430FR2355. 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.
- Begin target execution.
- 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.

EnergyTrace technology can also be used to compare various current profiles and better optimize your energy performance!

2.5 Clocking

The MSP-EXP430FR2355 provides an external clock in addition to the internal clocks in the device.

- Q1: 32.768-kHz 12.5-pF crystal

The 32.768-kHz crystal allows for lower LPM sleep currents than do the other low-frequency clock sources. Therefore, the presence of the crystal allows the full range of low-power modes to be used.

The internal clocks in the device default to the following configuration:

- MCLK: DCO at 1 MHz
- SMCLK: DCO at 1 MHz
- ACLK: REFO at 32.768 kHz

For more information about configuring internal clocks and using the external oscillators, see the MSP430FR4xx and MSP430FR2xx Family User's Guide.

2.6 Using the eZ-FET Debug Probe with a Different Target

The eZ-FET debug probe on the LaunchPad development kit can interface to most MSP430 derivative devices, not just the onboard MSP430FR2355 target device.

To do this, disconnect every jumper in the isolation jumper block. This is necessary, because the debug probe cannot connect to more than one target at a time over the Spy-Bi-Wire (SBW) connection.

Next, make sure the target board has proper connections for SBW. Note that to be compatible with SBW, the capacitor on $\overline{\text{RST}}$/SBWTDIO cannot be greater than 2.2 nF. The documentation for designing MSP430 JTAG interface circuitry is the MSP430 Hardware Tools User's Guide.

Finally, wire together these signals from the debug probe side of the isolation jumper block to the target hardware:

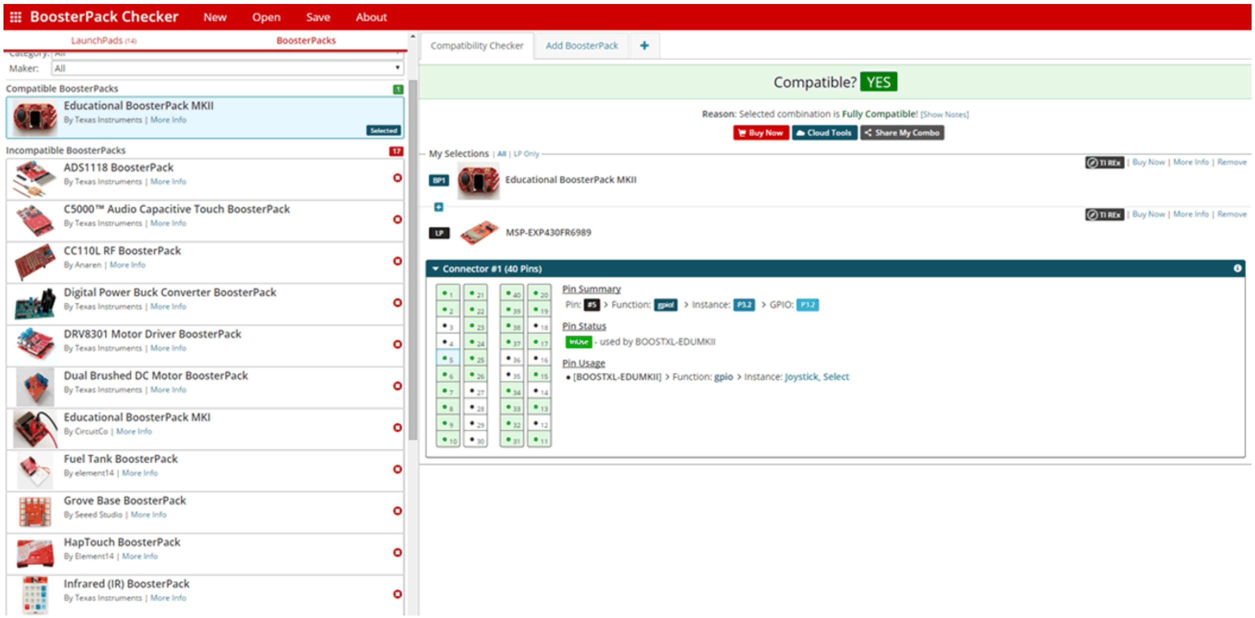
- 5 V (if 5 V is needed)
- 3.3 V
- GND
- SBWTDIO
- SBWTCK
- TXD (if the UART backchannel is to be used)
- RXD (if the UART backchannel is to be used)

This wiring can be done either with jumper wires or by designing the board with a connector that plugs into the isolation jumper block.

2.7 BoosterPack Plug-in Module Pinout

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

While most BoosterPack plug-in modules are compliant with the standard, some are not. The MSP-EXP430FR2355 LaunchPad development kit is compatible with all 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-EXP430FR2355 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 MSP430FR2355 device pin function configuration in software.



Category: All

Maker: All

Compatible BoosterPacks

- Educational BoosterPack MKII — By Texas Instruments | More Info

Incompatible BoosterPacks

- ADS1118 BoosterPack — By Texas Instruments | More Info
- C5000™ Audio Capacitive Touch BoosterPack — By Texas Instruments | More Info
- CC110L RF BoosterPack — By Anaren | More Info
- Digital Power Buck Converter BoosterPack — By Texas Instruments | More Info
- DRV8301 Motor Driver BoosterPack — By Texas Instruments | More Info
- Dual Brushed DC Motor BoosterPack — By Texas Instruments | More Info
- Educational BoosterPack MKI — By CircuitCo | More Info
- Fuel Tank BoosterPack — By element14 | More Info
- Grove Base BoosterPack — By Seeed Studio | More Info
- HapTouch BoosterPack — By Element14 | More Info
- Infrared (IR) BoosterPack — By Texas Instruments | More Info

Compatible? YES

Reason: Selected combination is Fully Compatible! [Show Notes]

My Selections | All | LP Only

BP1 Educational BoosterPack MKII

LP MSP-EXP430FR6989

Connector #1 (40 Pins)

Pin Summary
Pin: #5 > Function: gpio! > Instance: P3.2 > GPIO: P3.2

Pin Status
InUse - used by BOOSTXL-EDUMKII

Pin Usage
- [BOOSTXL-EDUMKII] > Function: gpio > Instance: Joystick, Select

Figure 9. BoosterPack Checker Tool

To check the compatibility of a BoosterPack plug-in module with the LaunchPad development kit of your choice, use the BoosterPack Checker tool. This allows you to select any LaunchPad development kit we offer and determine its compatibility with any number of BoosterPack plug-in modules that we offer. You can also add your own BoosterPack plug-in module to check its compatibility as you prototype that next design.

Figure 10 shows the 40-pin pinout of the MSP430FR2355 LaunchPad development kit.

Note that software's configuration of the pin functions plays a role in compatibility. The LaunchPad development kit side of the dashed line shows only the applicable function for conforming to the standard. However, each pin has other functionality that can be configured by the software. See the MSP430FR2355 device data sheet for more details on individual pin functions.

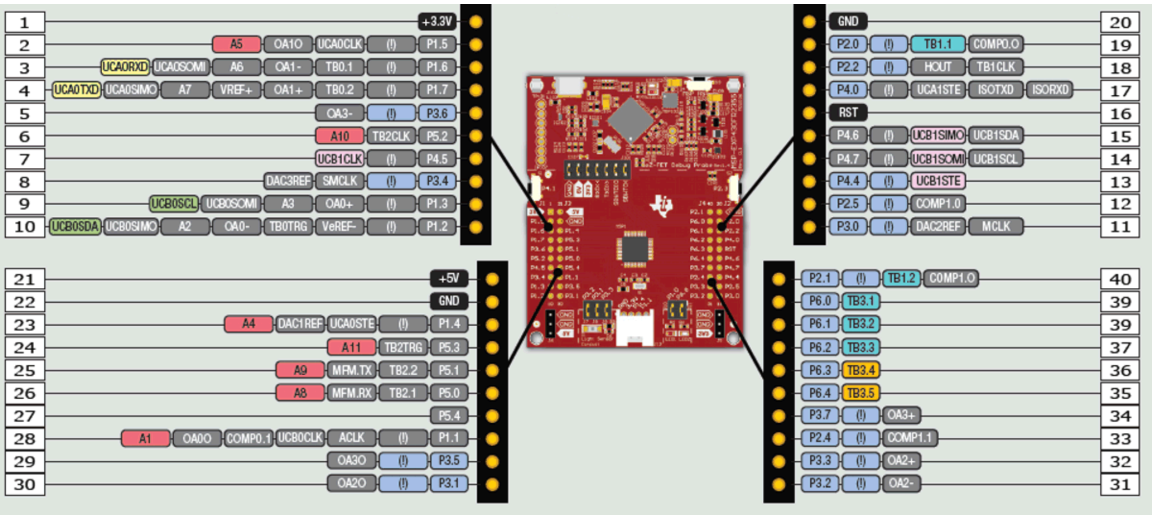


Figure 10. LaunchPad Development Kit to BoosterPack Plug-in Module Connector Pinout

2.8 Design Files

2.8.1 Hardware

Schematics can be found in Section 6. All design files including schematics, layout, bill of materials (BOM), Gerber files, and documentation are available on the MSP-EXP430FR2355 Design File download page.

2.8.2 Software

All design files including TI-TXT object-code firmware images, software example projects, and documentation are available on the MSP-EXP430FR2355 Design File download page.

2.9 Hardware Change Log

Table 3 lists the hardware revision history.

Table 3. Hardware Change Log

PCB Revision	Description
Rev A	Initial release

3 Software Examples

Two software examples are included with the MSP430FR2355 LaunchPad development kit (see Table 4), which can be found in the MSP430FR2355 LaunchPad development kit download page and are also available inside MSPWare.

Table 4. Software Examples

Demo Name	BoosterPack Plug-in Module Required	Description	More Details
OutofBox_MSP-EXP430FR2355	None	The out-of-box demo preprogrammed on the LaunchPad development kit from the factory. Demonstrates features of MSP430FR2355 device	Section 3.1
BlinkLED_MSP-EXP430FR2355	None	Blinks an LED on the LaunchPad development kit at a fixed interval	Section 3.2

To use any of the software examples with the LaunchPad development kit, you must have an integrated development environment (IDE) that supports the MSP430FR2355 device (see Table 5).

Table 5. IDE Minimum Requirements for MSP-EXP430FR2355

Code Composer Studio IDE	IAR Embedded Workbench for Texas Instruments MSP430 IDE
v8.0 or later	v7.12.1 or later

For more details on how to get started quickly and where to download the latest CCS and IAR 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 in the EVM.

The Out-of-Box Experience (OOBE) of the MSP-EXP430FR2355 LaunchPad development kit demonstrates how to set up the integrated SAC and use it to condition an analog output so that it can be properly sampled by the ADC converter on the MCU.

3.1.1 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	Out-of-Box demo main function
lightsensor.c	Contains functions for the Light Sensor mode
functiongenerator.c	Contains functions for the Function Generator mode
Library: driverlib	Device driver library
Library: jsmn	Minimalistic third-party library for parsing JSON formatted strings

3.1.2 Overview

Upon powering up the Out-of-Box demo, the board enters the Light Sensor mode where LED1 or LED2 brightens/dims based on the intensity of the ambient light hitting the on-board photodiode. By pressing button S2, the board enters the Function Generator mode where an input signal (sourced internally or externally) is fed into a SAC configured in PGA mode, and the final output waveform is captured with the internal ADC. At any time, press S2 to switch between the Light Sensor mode and Function Generator mode.

When the demo is in Function Generator mode, an online cloud GUI (MSP-EXP430FR2355 OOB GUI) can be used with the development kit to control the input signal source and visualize the real-time ADC measurement. In addition to S2, the GUI provides buttons that can also be used to switch between modes.

NOTE: The MSP430FR2355 microcontroller is equipped with four on-chip Smart Analog Combos (SAC), which come in pairs of two, SAC0 with SAC2 and SAC1 with SAC3. Each pair of SACs is interconnected, where the output of one SAC can be fed into the input of its paired SAC. The Out-of-Box demonstrates these interconnections and uses one SAC pair in the Light Sensor mode and the second SAC pair in the Function Generator mode.

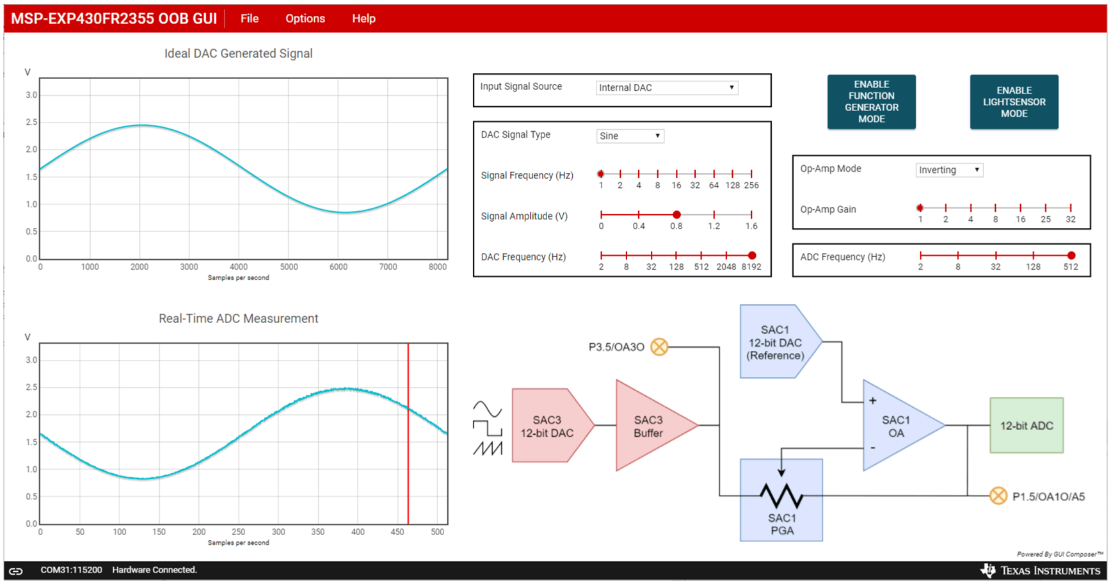
3.1.3 Light Sensor Mode

The Light Sensor mode uses the SAC0 and SAC2 pair, two Timer_B modules, and the ADC of the MSP430FR2355 MCU, combined with the on-board photodiode and LEDs of the LaunchPad development kit, to implement a simple light sensing application. It configures SAC2 as a generic op-amp and, together with R3 and C6, implements a transimpedance amplifier to convert the photodiode current to a voltage. To measure this voltage with the device's ADC, the output voltage of SAC2 is then fed through SAC0 (configured as a buffer), whose output is connected internally to the ADC.

When the Out-of-Box demo is first programmed onto the LaunchPad development kit, a default ADC threshold is set to approximately half of the full brightness detection range of D1. If the ADC measurement is below this brightness threshold, the red LED1 illuminates, and if the ADC measurement is above the default threshold, the green LED2 illuminates corresponding to the intensity of the ambient light. To recalibrate the threshold to the ADC value measured from the ambient light, press S1. The user can influence the amount of light reaching the photodiode by using a flashlight or covering the photodiode observing the changes in the LED brightness.

3.1.4 Function Generator Mode

In the Function Generator mode, an input signal (sourced internally or externally) is fed into the SAC1 configured in the Programmable Gain Amplifier (PGA) mode to be manipulated and captured with the internal ADC. The LaunchPad kit repeatedly measures and transfers this data to the PC through UART. When the Out-of-Box demo is first programmed onto the LaunchPad development kit, the Function Generator mode is initially configured to generate a 1-Hz sine wave at 0.8-V amplitude using the SAC3 DAC, and the sine wave is fed into SAC1 configured in the inverting PGA mode with a gain of 1. When visualized in the OOB GUI, you should see an inverted sine wave as shown in Figure 11.



MSP-EXP430FR2355 OOB GUI

Input Signal Source: Internal DAC

DAC Signal Type: Sine

Op-Amp Mode: Inverting

COM31:115200 Hardware Connected.

Figure 11. Default Waveform of the Function Generator Mode

Using the GUI, the input signal source can be selected between the internal 12-bit DAC (SAC3) and an external signal source. When the "Internal DAC" is selected as the input signal source, the GUI can be used to generate different types of signals (sinusoidal, square, or sawtooth) of various frequencies and amplitudes. The SAC1 PGA inverting or noninverting gain can be used to manipulate the generated signal of the SAC3 DAC, and the output waveform is captured with the internal ADC connection and displayed on the cloud GUI.

NOTE: When SAC1 is configured in the Inverting PGA mode, the SAC3 DAC generates sine, square, or sawtooth waveforms with a DC bias of +1.65 V, and the SAC1 DAC is used to generate a +1.65-V DC bias for the SAC1 PGA.

When SAC1 is configured in the Noninverting PGA mode, the SAC1 DAC is not available to generate a DC bias for its PGA and is based to 0 V by default. Therefore, the SAC3 DAC generates sine, square, or sawtooth waveforms with minimum peaks at 0 V.

Alternatively, an external signal source can be directly fed into the inverting input of the SAC1 PGA by selecting "P1.6 OA1- Inverting PGA IN" or the noninverting input of the SAC1 PGA by selecting "P1.7 OA1+ Non-inverting PGA IN" as the input signal source using the GUI. In these two input signal source configurations, the SAC1 PGA inverting or noninverting gain can be used to manipulate the external input signal on P1.6 or P1.7, and the output waveform is captured with the internal ADC connection and displayed on the cloud GUI.

Finally, SAC3 and SAC1 can be completely bypassed by selecting "P1.5 ADC Direct IN" as the input signal source. In this case, an external signal can be connected to P1.5 and measured directly by the internal ADC of the MCU, acting as a primitive oscilloscope.

3.2 Blink LED Example

This simple software example shows how to software toggle a GPIO to blink an LED on the LaunchPad development kit.

3.2.1 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
main.c	The Blink LED main function
Library: Driverlib	Device driver library

The main code uses the MSP430 Driver Library to halt the watchdog timer and to configure and toggle the P1.0 GPIO pin connected to the LED inside a software loop.

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 IDE (CCS) or IAR Embedded Workbench IDE.

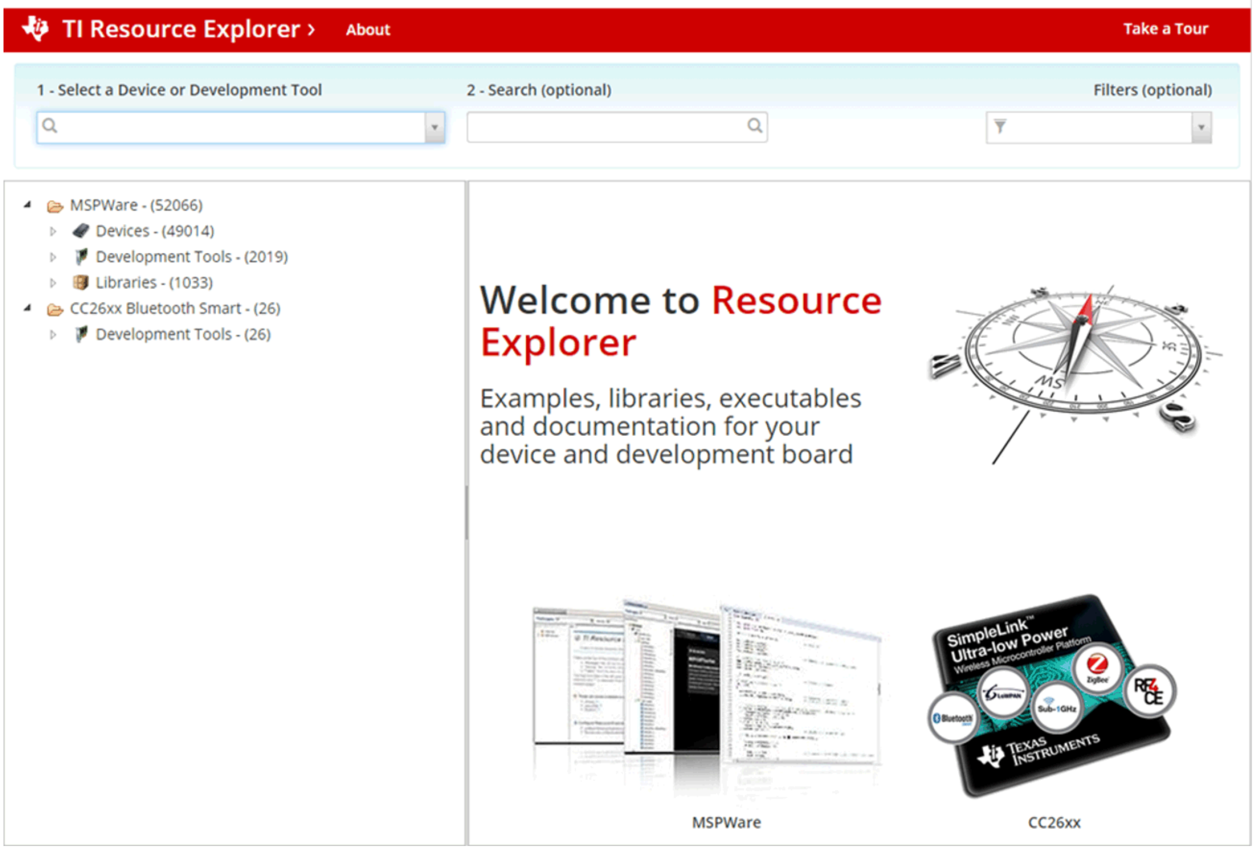
4.1.1 TI Cloud Development Tools

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.



TI Resource Explorer ›
About
Take a Tour
1 - Select a Device or Development Tool
2 - Search (optional)
Filters (optional)
MSPWare - (52066)
Devices - (49014)
Development Tools - (2019)
Libraries - (1033)
CC26xx Bluetooth Smart - (26)
Development Tools - (26)
Welcome to Resource Explorer
Examples, libraries, executables and documentation for your device and development board
MSPWare
SimpleLink™ Ultra-low Power Wireless Microcontroller Platform
CC26xx

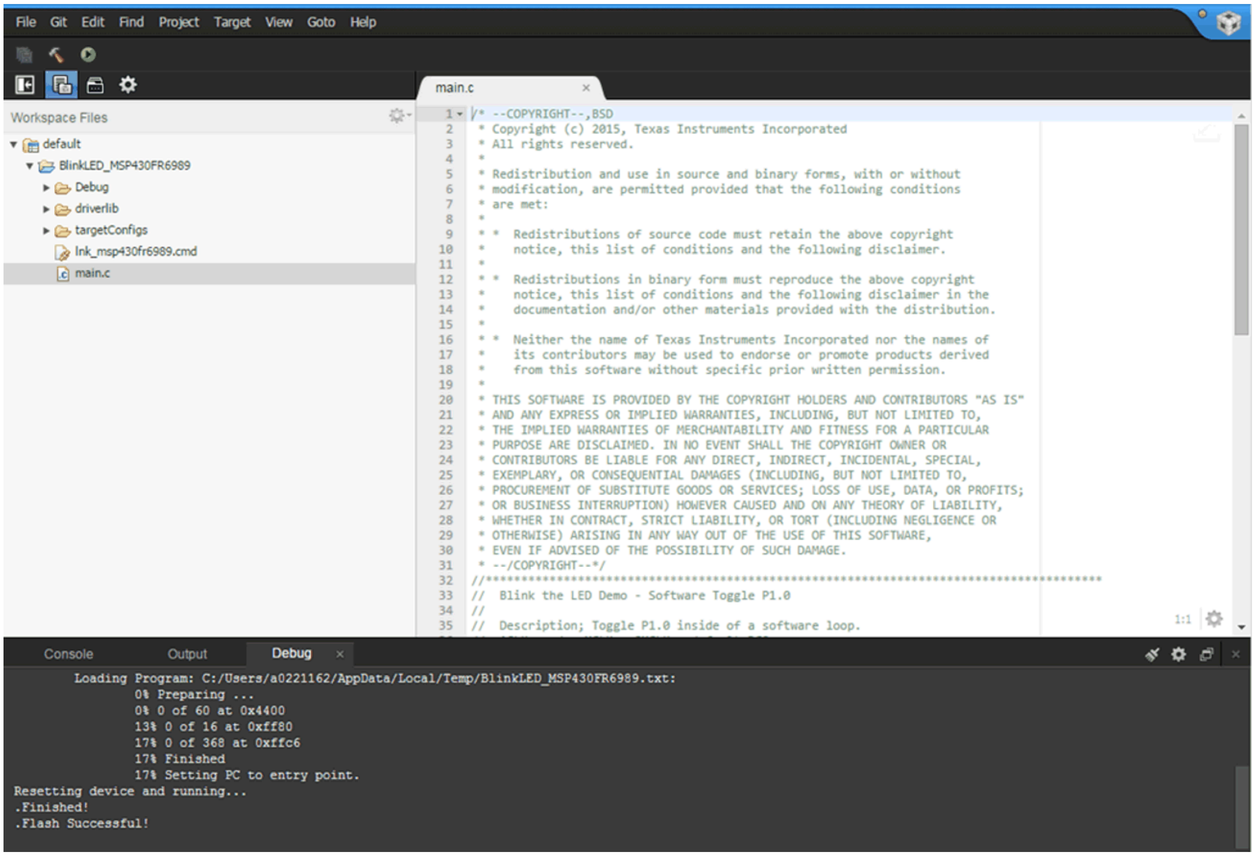
Figure 12. TI Resource Explorer Cloud

4.1.1.2 *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 supports debug features such as execution control, breakpoints and viewing variables.

For more information, see the full comparison between CCS Cloud and CCS Desktop.

Go check out Code Composer Studio Cloud now at dev.ti.com.



```
/* --COPYRIGHT--,BSD
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 *
 * Redistribution and use in source and binary forms, with or without
 * modification, are permitted provided that the following conditions
 * are met:
 *
 * *  Redistributions of source code must retain the above copyright
 *    notice, this list of conditions and the following disclaimer.
 *
 * *  Redistributions in binary form must reproduce the above copyright
 *    notice, this list of conditions and the following disclaimer in the
 *    documentation and/or other materials provided with the distribution.
 *
 * *  Neither the name of Texas Instruments Incorporated nor the names of
 *    its contributors may be used to endorse or promote products derived
 *    from this software without specific prior written permission.
 *
 * THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS"
 * AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO,
 * THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR
 * PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT OWNER OR
 * CONTRIBUTORS BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL,
 * EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO,
 * PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS;
 * OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY,
 * WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR
 * OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE,
 * EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
 * --/COPYRIGHT--*/
//******************************************************************************
//  Blink the LED Demo - Software Toggle P1.0
//
//  Description; Toggle P1.0 inside of a software loop.
```

```
        Loading Program: C:/Users/a0221162/AppData/Local/Temp/BlinkLED_MSP430FR6989.txt:
                0% Preparing ...
                0% 0 of 60 at 0x4400
                13% 0 of 16 at 0xff80
                17% 0 of 368 at 0xffc6
                17% Finished
                17% Setting PC to entry point.
Resetting device and running...
.Finished!
.Flash Successful!
```

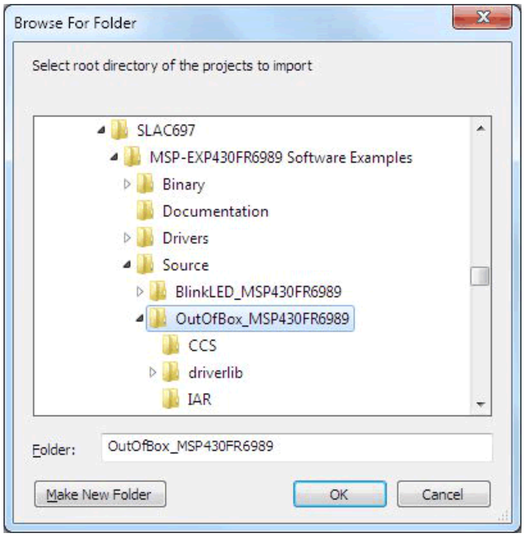
Figure 13. CCS Cloud

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.

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

CCS v8.0 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.



Browse For Folder

Select root directory of the projects to import

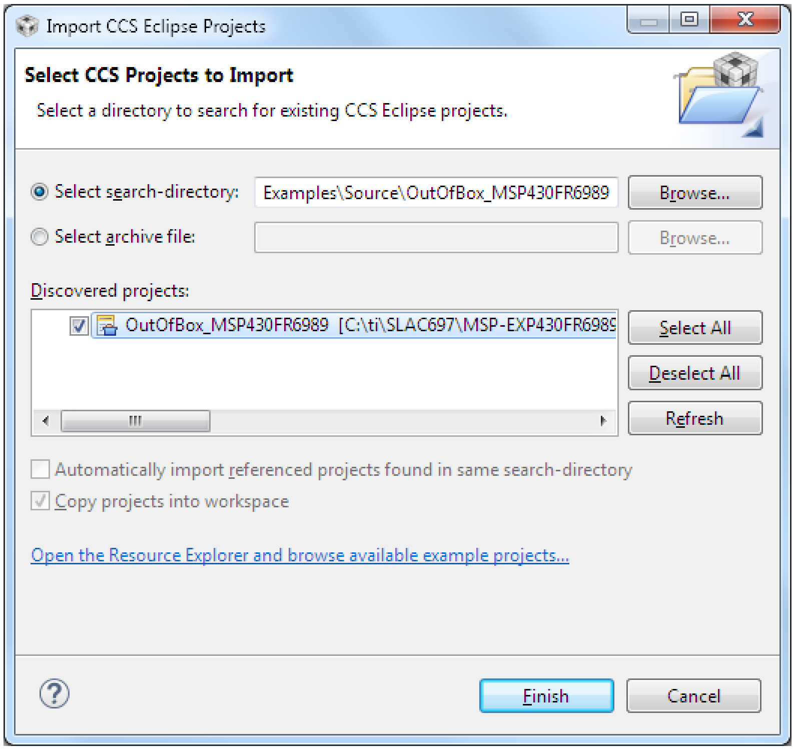
- SLAC697
  - MSP-EXP430FR6989 Software Examples
    - Binary
    - Documentation
    - Drivers
    - Source
      - BlinkLED_MSP430FR6989
      - OutOfBox_MSP430FR6989
        - CCS
        - driverlib
        - IAR

Folder: OutOfBox_MSP430FR6989

Figure 14. 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 Figure 15, and it has a checkmark to the left of it.



Import CCS Eclipse Projects

Select CCS Projects to Import

Select a directory to search for existing CCS Eclipse projects.

● Select search-directory: Examples\Source\OutOfBox_MSP430FR6989

○ Select archive file:

Discovered projects:

☑ OutOfBox_MSP430FR6989 [C:\ti\SLAC697\MSP-EXP430FR6989

□ Automatically import referenced projects found in same search-directory

☑ Copy projects into workspace

Open the Resource Explorer and browse available example projects...

Figure 15. When CCS Has Found the Project

Sometimes CCS 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 workspace, be sure to check the workspace directory on the file system.)

4.1.3 IAR Embedded Workbench for Texas Instruments 430 IDE

IAR Embedded Workbench for MSP430 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.

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

IAR v7.12.1 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, which contains MSP430 libraries and the TI Resource Explorer. These are already included in a CCS installation (unless the user selected otherwise).

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-EXP430FR2355 tool folder: resources specific to this particular LaunchPad development kit
- TI's LaunchPad development kit portal: information about all LaunchPad development kits from TI

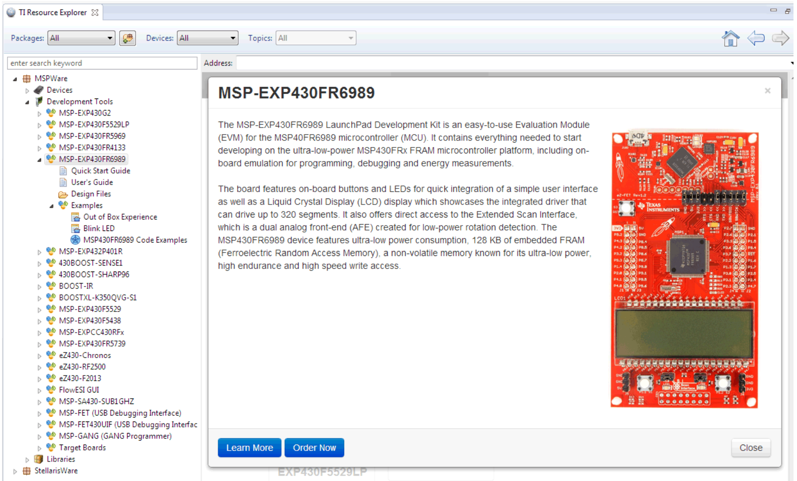
4.3 MSPWare and TI Resource Explorer

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 talk to MSP hardware. More information can be found at http://www.ti.com/tool/mspware.



MSP-EXP430FR6989

The MSP-EXP430FR6989 LaunchPad Development Kit is an easy-to-use Evaluation Module (EVM) for the MSP40FR6989 microcontroller (MCU). It contains everything needed to start developing on the ultra-low-power MSP430FRx FRAM microcontroller platform, including on-board emulation for programming, debugging and energy measurements.

The board features on-board buttons and LEDs for quick integration of a simple user interface as well as a Liquid Crystal Display (LCD) display which showcases the integrated driver that can drive up to 320 segments. It also offers direct access to the Extended Scan Interface, which is a dual analog front-end (AFE) created for low-power rotation detection. The MSP430FR6989 device features ultra-low power consumption, 128 KB of embedded FRAM (Ferroelectric Random Access Memory), a non-volatile memory known for its ultra-low power, high endurance and high speed write access.

Figure 16. Using TI Resource Explorer to Browse MSP-EXP430FR2355 in MSPWare

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

4.4 FRAM Utilities

The Texas Instruments FRAM Utilities is a collection of embedded software utilities that leverage the ultra-low-power and virtually unlimited write endurance of FRAM. The utilities are available for MSP430FRxx FRAM microcontrollers and provide example code to help start application development.

4.4.1 Compute Through Power Loss

Compute Through Power Loss is a utility API set that enables ease of use with LPMx.5 low-power modes and a powerful shutdown mode that allows an application to save and restore critical system components when a power loss is detected.

4.4.2 Nonvolatile Storage (NVS)

The nonvolatile storage (NVS) library makes handling of nonvolatile data easy and robust against intermittent power loss or asynchronous device resets. To keep data storage constant, the nonvolatile storage library contains functions that store data in a way that is guaranteed to recover the last valid entry without data corruption.

4.5 MSP430FR2355 MCU

4.5.1 Device Documentation

At some point, you will probably want more information about the MSP430FR2355 device. For every MSP device, the documentation is organized as shown in Table 8.

Table 8. How MSP Device Documentation is Organized

Document	For MSP430FR2355	Description
Device family user's guide	*MSP430FR4xx and MSP430FR2xx Family User's Guide*	Architectural information about the device, including all modules and peripherals such as clocks, timers, ADC, and so on
Device-specific data sheet	*MSP430FR2355 Mixed-Signal Microcontroller data sheet*	Device-specific information and all parametric information for this device

4.5.2 MSP430FR2355 Code Examples

MSP430FR243x, MSP430FR253x, MSP430FR263x Code Examples is a set of simple C examples that demonstrate how to use the entire set of peripherals on the MSP430FR2533 MCU, including serial communication, ADC10, Timer, and others, through direct register access. 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.

4.5.3 MSP430 Application Notes and TI Designs

Many application notes can be found at www.ti.com/msp430. Also see TI Designs for practical design examples and topics.

4.6 Community Resources

4.6.1 TI E2E™ Community

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

4.6.2 Community at Large

Many online communities focus on the LaunchPad development kit – for example, www.43oh.com. You can find additional tools, resources, and support from these communities.

5 FAQ

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

A: Check the following:

- Do the baud rate in the host 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 don’t see data, it might be a problem on the host side.
- Probe on TXD while sending data from the MSP. If you don’t 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).

Q: The MSP430G2 LaunchPad development kit had a socket, allowing me change the target device. Why doesn’t this LaunchPad development kit use one?

A: The target device on this LaunchPad development kit does not come in the dual in-line package. Sockets for the available device package are too expensive for this kit’s target price.

6 Schematics

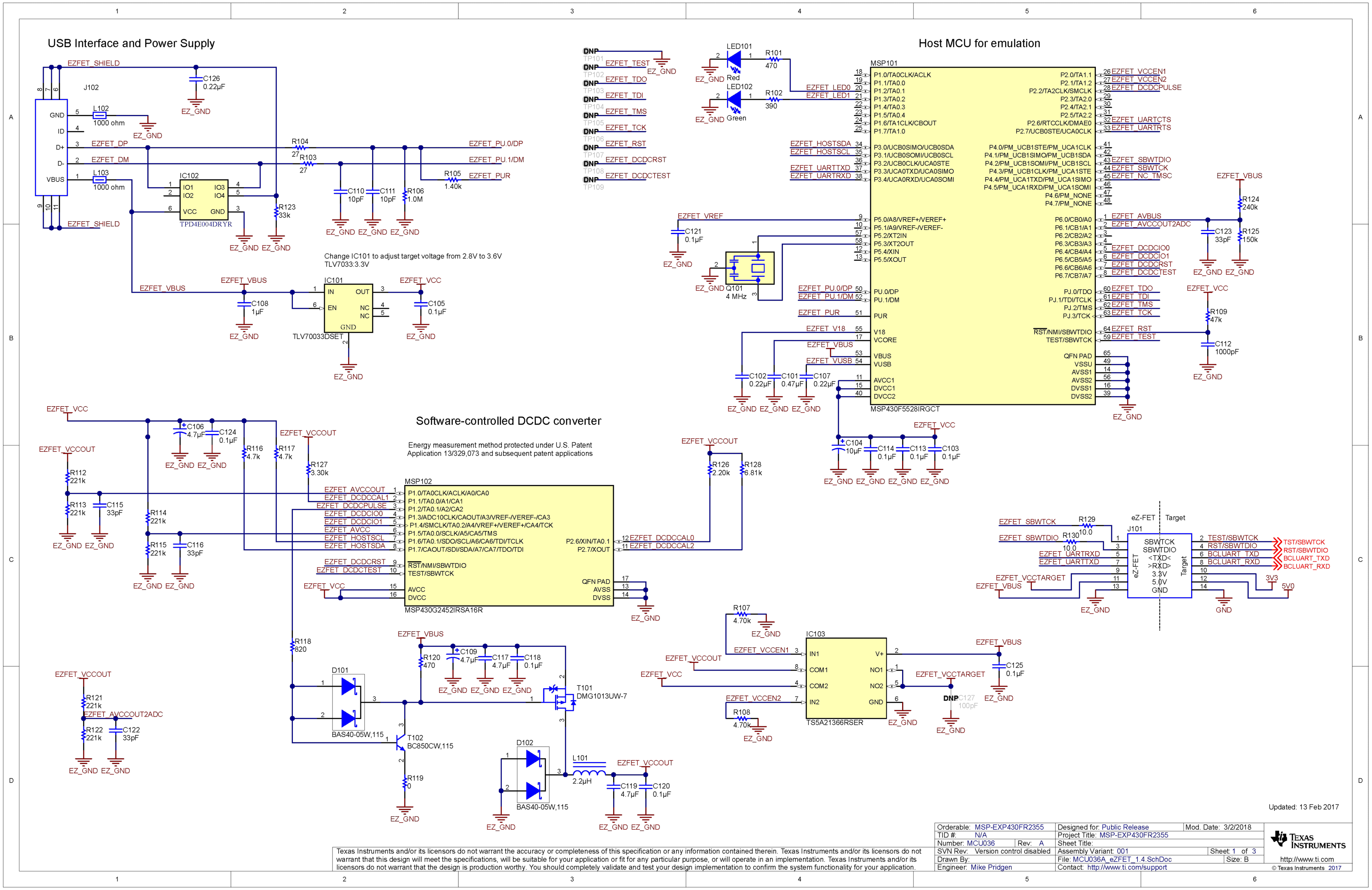
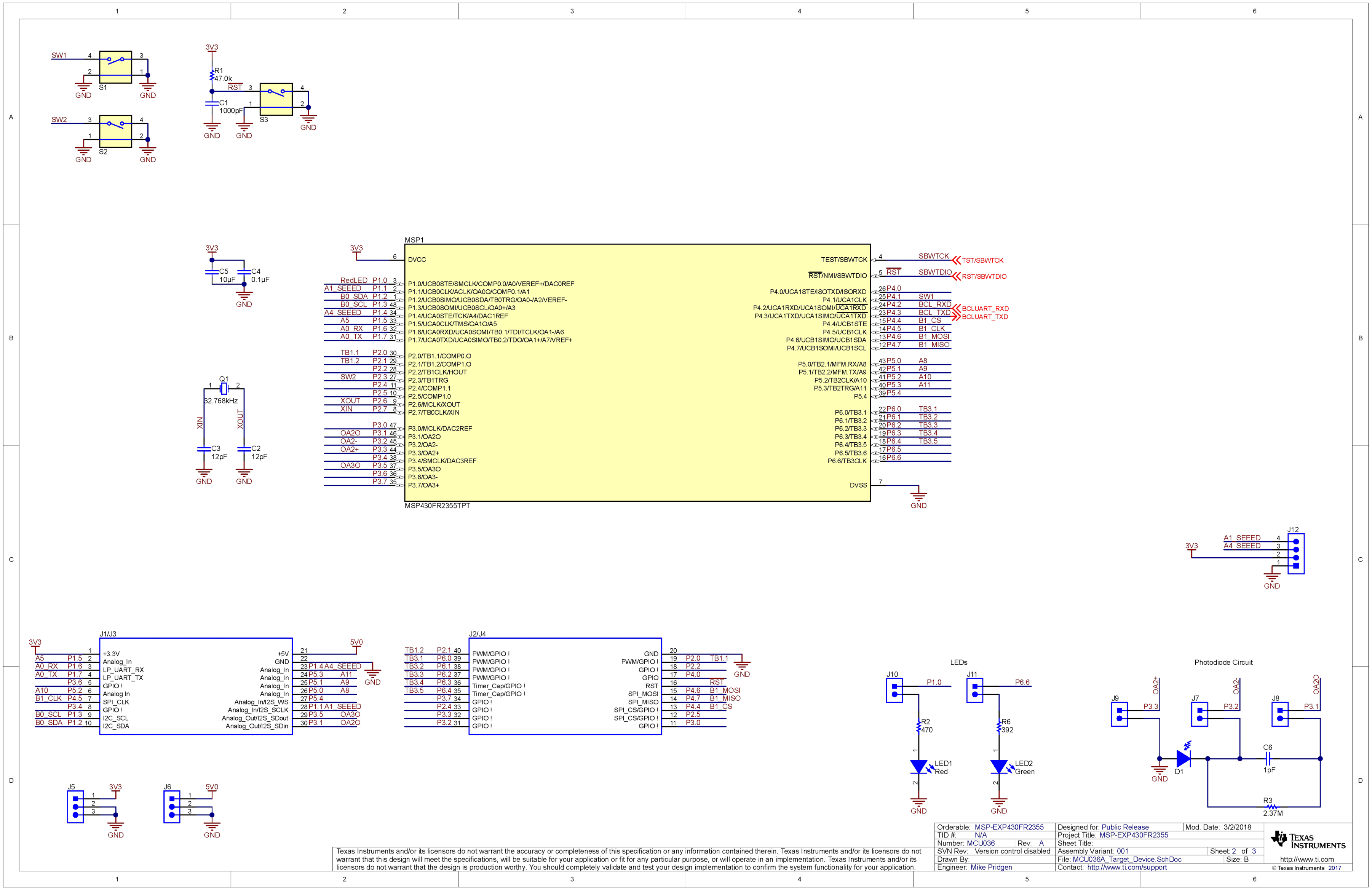


Figure 17. Schematics (1 of 2)



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Orderable: MSP-EXP430FR2355	Designed for: Public Release	Mod. Date: 3/2/2018
TID #: N/A	Project Title: MSP-EXP430FR2355	
Number: MCU036 Rev: A	Sheet Title:	
SVN Rev: Version control disabled	Assembly Variant: 001	Sheet: 2 of 3
Drawn By:	File: MCU036A_Target_Device.SchDoc	Size: B
Engineer: Mike Pridgen	Contact: http://www.ti.com/support	

TEXAS INSTRUMENTS
http://www.ti.com
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Figure 18. Schematics (2 of 2)

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