Why design with MSP430FR2355?

Mitch Ridgeway

MSP430 Industrial Sensing

Why design with MSP430FR2355?

MSP430FR2355 device overview

Solving customer challenges

Analog Integration

Customers need more analog features for their applications
Provide flexibility within system design and save system BOM with integrated analog peripherals including 12-bit ADC, SACs (OA/PGA/12-bit DAC) and Comparators

Extended Temp Range

Extended temp range is required for more applications
1st 105C FRAM MCU provides customers with a solution to meet requirements of broader industrial applications and to benefit from FRAM data logging capabilities at higher temperatures

Extension of VL Portfolio

32 KB

Customers need more memory and faster CPU speeds
32KB memory option with up to 24MHz CPU speed to the FRAM portfolio
Developers can meet the needs of industrial applications with larger memory size and higher performance processing speed

MSP430™ FR235x devices

MSP430FR235x

| Temperatures | -40°C to 105°C |

MSP430FR2355
16-bit
Up to 24 MHz

Features/benefits

- **FRAM: Ultra-low power, universal memory** – Nearly infinite (10^{15}) write cycles, >100x faster than Flash (2MB/s), 250x less power in writes, flexible as data or program memory

- **High-performance analog** – Smart Analog Combo (SAC) integrated OpAmp, PGA, and 12-bit DAC cooperated with 12-bit ADC make the analog signal chain for small signal amplification and processing. Comparator with integrated 6-bit DAC can support full rail to rail voltage monitor

- **Abundant peripherals** – Offers 4x serial interfaces, 4x timers and up to 44 GPIOs

- **Designed for industrial applications** – Offers 105C temp

Tools & references

MSP430FR2355 LaunchPad ™ Development Kit
Target Development Board for MSP430FR2355 MCU - 48-pin
4- to 20-mA Loop-Powered RTD Temperature Transmitter Reference Design
MSP430 Value Line MCUs

Software

- MSP430FR235x, MSP430FR215x Code Examples
- MSP430Ware for MSP Microcontrollers
- Bootloader (BSL) for MSP low-power microcontrollers
- Fixed Point Math Library for MSP

Peripherals
- CRC16
- 32 x 32 Multiplier
- IR Modulation Logic
- Interrupt Compare Controller

Serial Interface
- 2 × eUSCI_A (UART/IrDA/SPI)
- 2 × eUSCI_B (SPI/I^{2}C)

Analog
- 2 x Comp with 6-bit DAC
- 12ch × 12-bit ADC
- 4 × SAC – L3 (Configurable OpAmp, PGA, 12-bit DAC combo)

Memory
- Up to 32KB FRAM (with segment protections for code/data)
- Up to 4KB SRAM

Debug
- Embedded Emulation
- Real-Time JTAG/SBW
- Bootstrap Loader

Timers
- Watchdog Timer
- 3 x 16-bit TB w/ 3CC regs
- 1 × 16-bit TB w/ 7CC regs
- Real-Time Clock Counter

Power & Clocking
- PMM with BOR, POR, PUC and SVS
- HF/LFXT
- DCO
- FLL
- REFO
- MODOSC
- VLO

Connectivity
- Up to 44 GPIOs

Packages
- 48 LQFP
- 40 VQFN
- 38 TSSOP

Target applications

- **Mid/High-End smoke detector**
- **Gas or PM2.5 sensor**
- **Current-loop transmitter**
- **Circuit breaker**
- **Audio**
- **Blood glucose meter or oximeter**

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Why design with MSP430FR2355?

Analog signal chain peripherals

SAR ADC block diagram

ADC Voltage Range
- **Internal 1.5V, 2.0V, 2.5V Reference**
- **Device Power (VCC)**
- **External Reference Options**
    - **200 ksps Max Sample Rate**
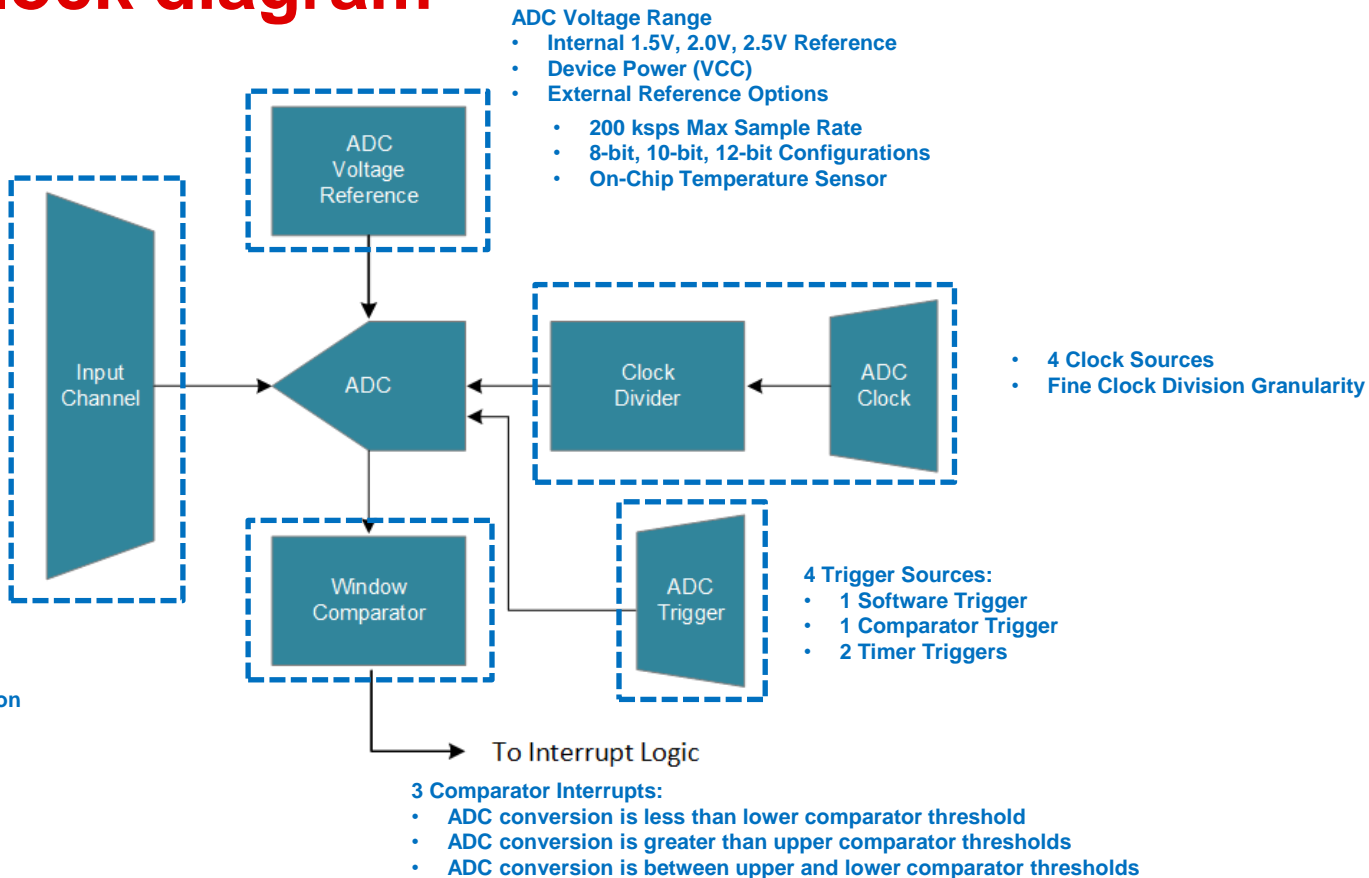   - **8-bit, 10-bit, 12-bit Configurations**
    - **On-Chip Temperature Sensor**

Sample modes:
- **Extended Sample Mode**
    - **Sample & Hold Input Signal directly controls length of sample period**
- **Pulse Sample Mode**
    - **Sample & Hold Input Signal triggers the sampling timer**

- **12 External Channels**
- **4 Internal Channels**

4 Clock Sources
Fine Clock Division Granularity

4 Trigger Sources:
- **1 Software Trigger**
- **1 Comparator Trigger**
- **2 Timer Triggers**

Conversion modes:
- **Single-channel single-conversion**
- **Sequence-of-channels**
- **Repeat-single-channel**
- **Repeat-sequence-of-channels**

ADC Voltage Reference

Input Channel

ADC

Clock Divider

ADC Clock

Window Comparator

ADC Trigger

To Interrupt Logic

3 Comparator Interrupts:
- **ADC conversion is less than lower comparator threshold**
- **ADC conversion is greater than upper comparator thresholds**
- **ADC conversion is between upper and lower comparator thresholds**

Enhanced comparator block diagram

- **External Inputs**
- **Internal Inputs from SAC**
- **1 DAC Output to Both Terminals**
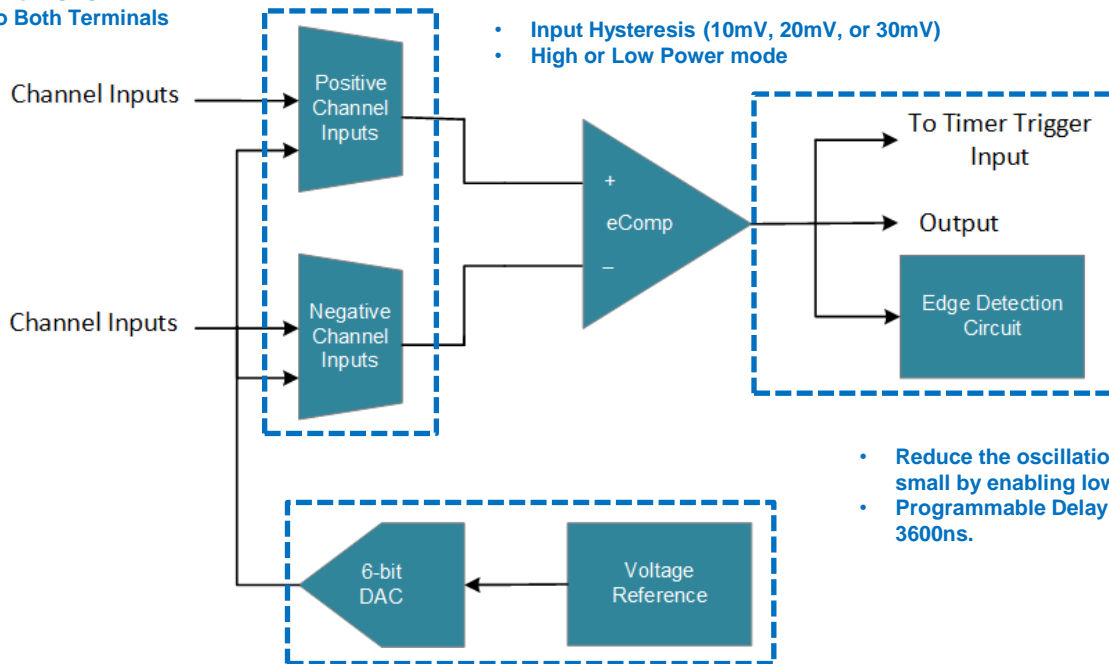
- **Input Hysteresis (10mV, 20mV, or 30mV)**
- **High or Low Power mode**

Output:
- **To External Pin**
- **To Timer Capture**
- **Edge Detection Circuit**

Interrupt Sources
- **Non Inverted Edge**
- **Inverted Edge**

- **Reduce the oscillation when voltage difference is small by enabling low-pass filter**
- **Programmable Delay: 450ns, 900ns, 1800ns, 3600ns.**

6-bit DAC:
- **Voltage reference from DVCC or on-chip VREF (1.5V, 2.0V, or 2.5V).**
- **Dual buffer can be set by the eCOMP output or the CPDACSW bit**

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Smart Analog Combo (SAC) operation
Interconnection with other peripherals
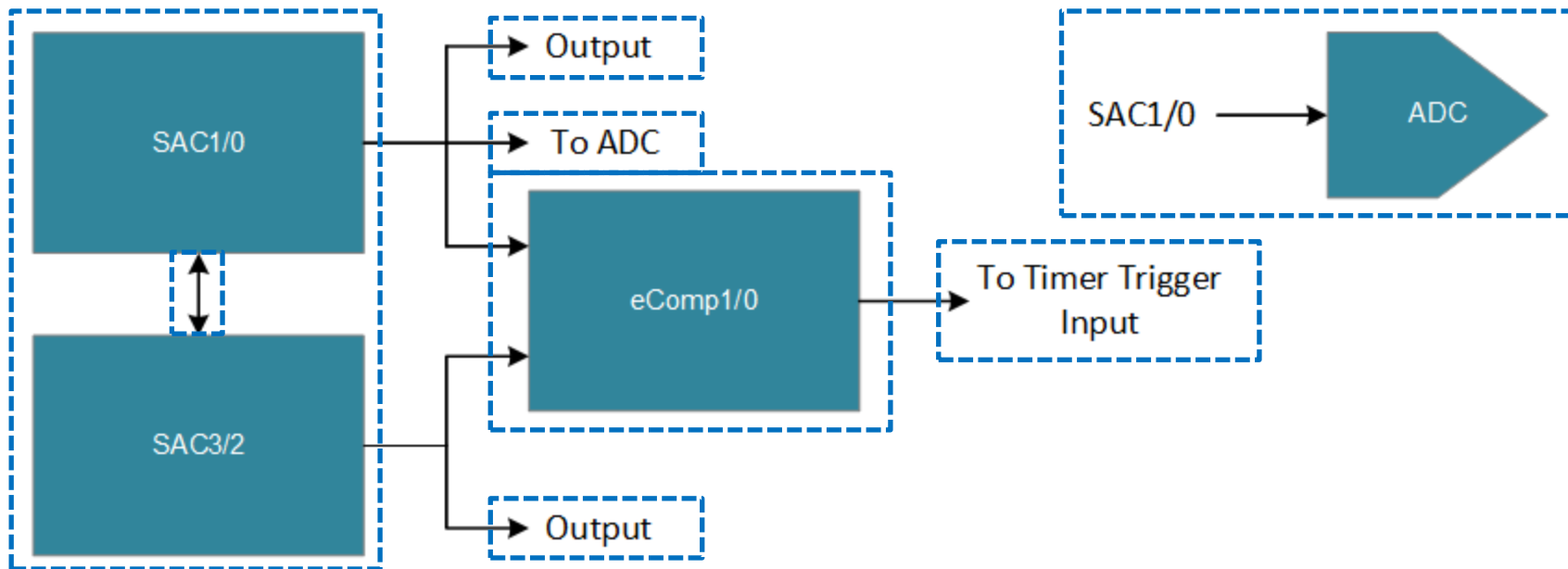
Why design with MSP430FR2355?

ROM libraries

ROM libraries

- **Driver Lib**
  - Provides user-friendly API for developing applications on MSP devices
  - Easy to use function calls keeps you above the bits and bytes of the MSP hardware
  - Complete projects with minimal overhead

- **FFT Library**
  - Allows users to perform fixed-point FFT transformations (real & complex)
  - Increased performance
  - Subset of DSPLib Transform functions
  - The following DSPLib APIs are included in ROM:
    - msp_cmplx_fft_auto_q15
    - msp_cmplx_fft_fixed_q15
    - msp_fft_auto_q15
    - msp_fft_fixed_q15
    - msp_cmplx_fft_iq31
    - msp_fft_iq31
  - 2048-point complex twiddle table also included

Driver Lib

```
//Turn LED1 off
MAP_GPIO_setOutputLowOnPin(
        GPIO_PORT_LED1,
        GPIO_PIN_LED1
        );

//Set LED1 as an output pin.
//NOTE: Using MAP_ will execute from ROM if available, FRAM if not available
MAP_GPIO_setAsOutputPin(
        GPIO_PORT_LED1,
        GPIO_PIN_LED1);
```

```
//Initialize the ADC Module
/*
 * Base Address for the ADC Module
 * Use internal ADC bit as sample/hold signal to start conversion
 * USE MODOSC 5MHZ Digital Oscillator as clock source
 * Use default clock divider of 1
 */
MAP_ADC_init(ADC_BASE,
        ADC_SAMPLEHOLDSOURCE_SC,
        ADC_CLOCKSOURCE_ADCOSC,
        ADC_CLOCKDIVIDER_1);

MAP_ADC_enable(ADC_BASE);

/*
 * Base Address for the ADC Module
 * Sample/hold for 16 clock cycles
 * Do not enable Multiple Sampling
 */
MAP_ADC_setupSamplingTimer(ADC_BASE,
        ADC_CYCLEHOLD_16_CYCLES,
        ADC_MULTIPLESAMPLESDISABLE);
```

```
//Configure Memory Buffer
/*
 * Base Address for the ADC Module
 * Use input A7
 * Use positive reference of AVcc
 * Use negative reference of AVss
 */
MAP_ADC_configureMemory(ADC_BASE,
        ADC_INPUT_A7,
        ADC_VREFPOS_AVCC,
        ADC_VREFNEG_AVSS);

MAP_ADC_clearInterrupt(ADC_BASE,
        ADC_COMPLETED_INTERRUPT);

//Enable Memory Buffer interrupt
MAP_ADC_enableInterrupt(ADC_BASE,
        ADC_COMPLETED_INTERRUPT);
```
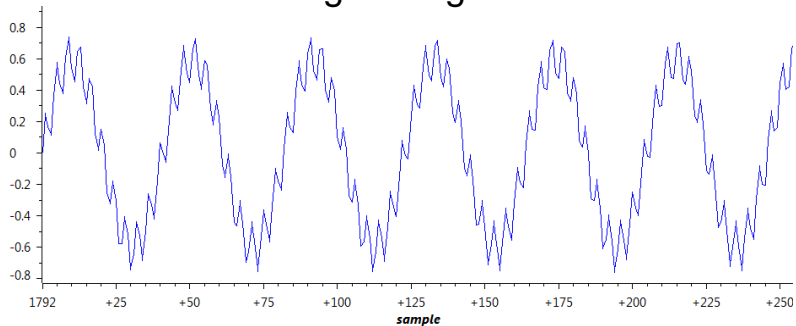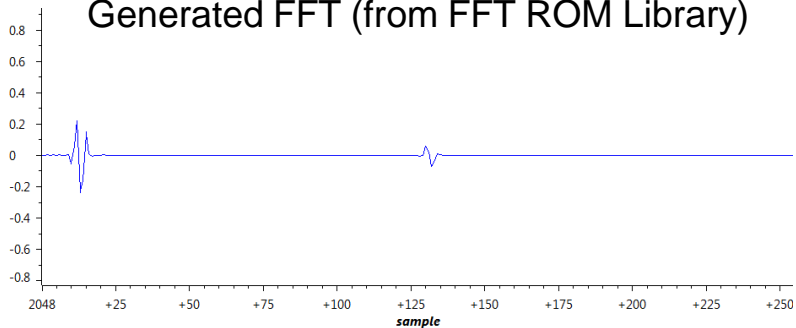
```
//Enable and Start the conversion
//in Single-Channel, Single Conversion Mode
MAP_ADC_startConversion(ADC_BASE,
        ADC_SINGLECHANNEL);
```

ROM FFT function - MSP_FFT_FIXED_Q15
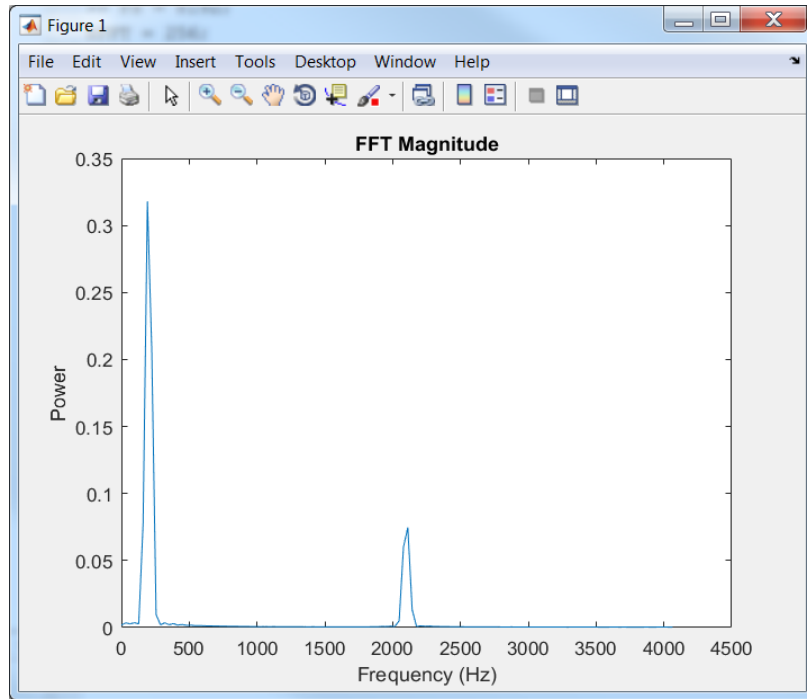
Original Signal

Magnitude of Generated FFT

Generated FFT (from FFT ROM Library)

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ROM libraries

- **FR235x/215x devices in MSP430FR4xx/2xx family have MSP430 Driver library and FFT library in ROM.**

- Compatible with both CCS and IAR compilers

- Code execution is faster out of ROM than FRAM
  - Code execution at clock speeds that exceed 8MHz is faster from ROM than from FRAM because the code avoids FRAM wait states (except FRAM controller cache hits).

- Save 20KB of nonvolatile storage (FRAM) in your device for application code rather than software libraries

DriverLib Link

DSPLib Link

# Why design with MSP430FR2355?

Ecosystem

Hardware tools
MSP430FR2355 LaunchPad™ Development Kit and target board

- ## Launchpad Development Kit
  - Integrated eZ-FET Debugger with EnergyTrace™
  - 40-pin BoosterPack Headers
  - 2 User Push Buttons
  - 2 User LEDs (Red & Green)
  - Ambient Light Sensor
  - Grove Connector for external Grove sensors

- ## Target socket board
  - Socket board to program and debug the 48-pin QFP package
  - 4-wire and 2-wire JTAG
  - I2C and UART BSL
  - Access to all device pins
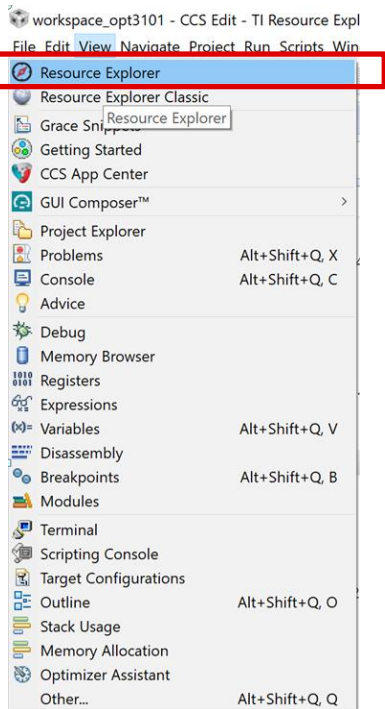 - Indicator LEDs and user switches
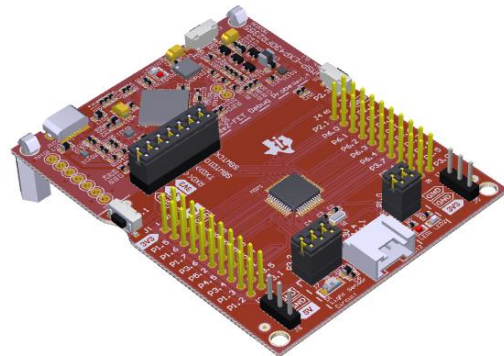
MSP-EXP430FR2355 LaunchPad
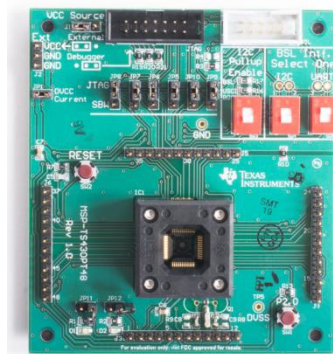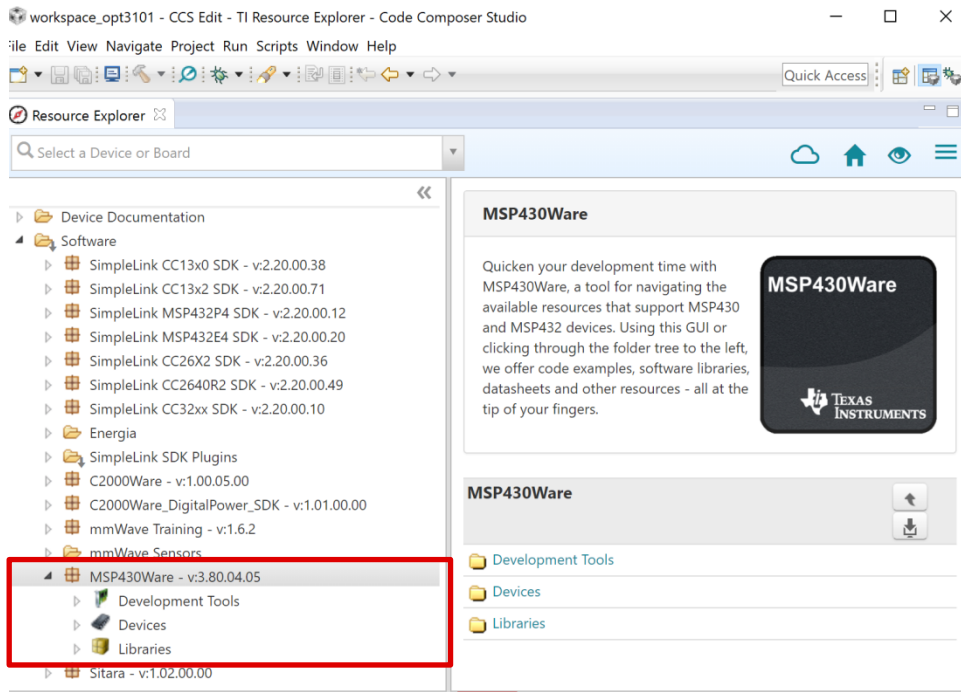

MSP-TS430PT48 Target Board

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Code Composer Studio
Code examples

Step1: Open Resource Explorer in CCS by clicking View > Resource Explorer

Step 2: Find code examples by clicking Software > MSP430Ware

EnergyTrace ™ technology

- Provides a complete ecosystem for real-time power debugging and quickens time to market. Spends less time debugging and more time developing.

- Graphical User Interface in TI's Code Composer Studio integrated development environment (IDE) and IAR Systems' Embedded provides energy profiles of your application

  – Current measurement can be tracked over time
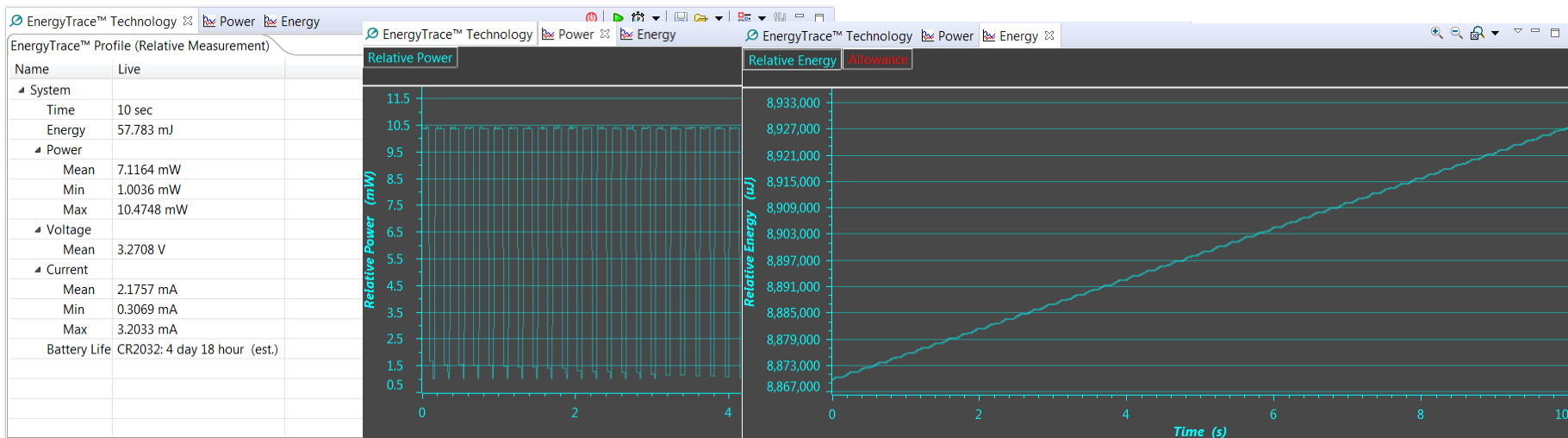
Software tools
MSP-EXP430FR2355 out of box demo with GUI

- This GUI allows interaction with an MSP-EXP430FR2355 LaunchPad running its out-of-box demo software.
- The LaunchPad implements a light sensor (using SAC0 & SAC2) and a function generator (using SAC1 & SAC3).
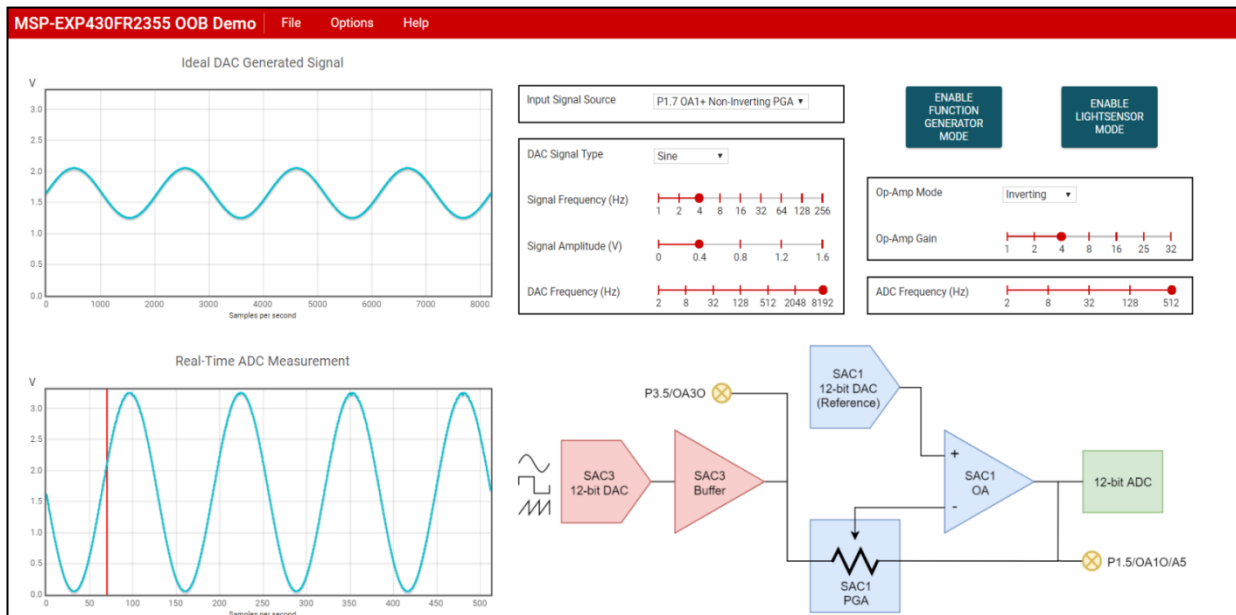
MSP-EXP430FR2355 Out of Box Demo with GUI

Resources:
- Training video: Smart Analog Combo GUI in the LaunchPad out of box demo video
- E2E blog: Configure your MSP430 MCU's analog signal chain using the Smart Analog Combo GUI

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Why design with MSP430FR2355?

- Enhanced MCU performance
  - Extended temperature range (105C)
  - Faster clock (24MHz)
  - More memory (32KB FRAM)

- Integrated analog signal chain
  - Smart Analog Combo peripheral (SAC)
  - Flexible configuration options with SAC, ADC, eComp, & Timers

- Integrated ROM libraries
  - Driver Lib
  - FFT library

- Easy-to-use ecosystem