

TI Designs: TIDA-050013

Ultra-Small RGB LED Animation Solution for Battery-Powered Applications Reference Design



Description

This reference design is a 2-cm x 2-cm RGB LED animation solution for battery-powered applications using the LP5523 and MSP430FR2111 devices. The LP5523 device is an LED driver with a programmable control engine in a DSBGA package. The LP5523 enables vivid lighting patterns for applications that must fit within a very small PCB. This design demonstrates full functionality while using limited MCU resources.

Resources

TIDA-050013	Design Folder
LP5523	Product Folder
MSP430FR2111	Product Folder



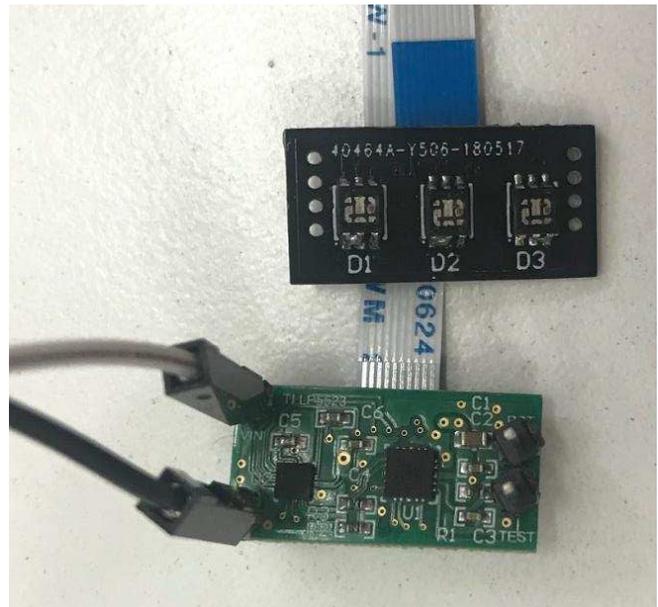
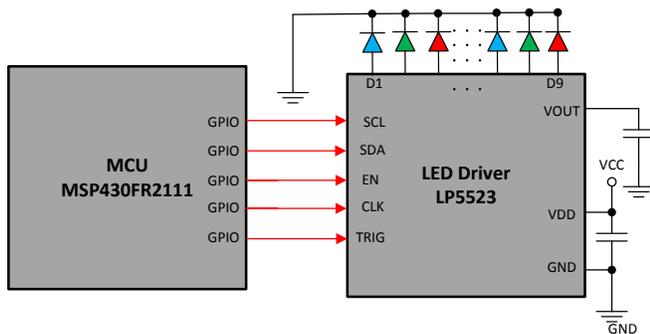
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Features

- Minimum MCU Loading When Running Preset Lighting Pattern
- Lower System Current Consumption Through LP5523 Engine Control
- Low Quiescent Current During Standby Mode
- Full Diagnostics and Protection
- 2-cm² Small PCB Size Design

Applications

- [E-cigarettes](#)
- [Smart Watches](#)
- [Virtual- and Augmented-Reality Headsets and Glasses](#)
- [Wearable Cameras](#)
- [Smart ID Tags](#)
- [Mouse](#)
- [Mobile Phones](#)



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1 System Description

Mobile phones, smart watches, smart ID tags, and e-cigarettes are compact-sized products that benefit from vivid LED animation to catch the consumer's eye. This reference design is an ultra-small RGB LED animation solution for battery-powered applications that makes vivid lighting patterns on a 2-cm² PCB board. The design uses a minimal MCU resource to keep the target design within the limited PCB size. The LP5523 device, a 9-channel RGB or white-LED driver with internal program memory and integrated charge pump, is used to drive 3 RGB LED modules with constant-current control and to run the various lighting patterns autonomously. In this reference design the MSP430FR2111 device loads the engine code to the LP5523 device after power on.

1.1 Key System Specifications

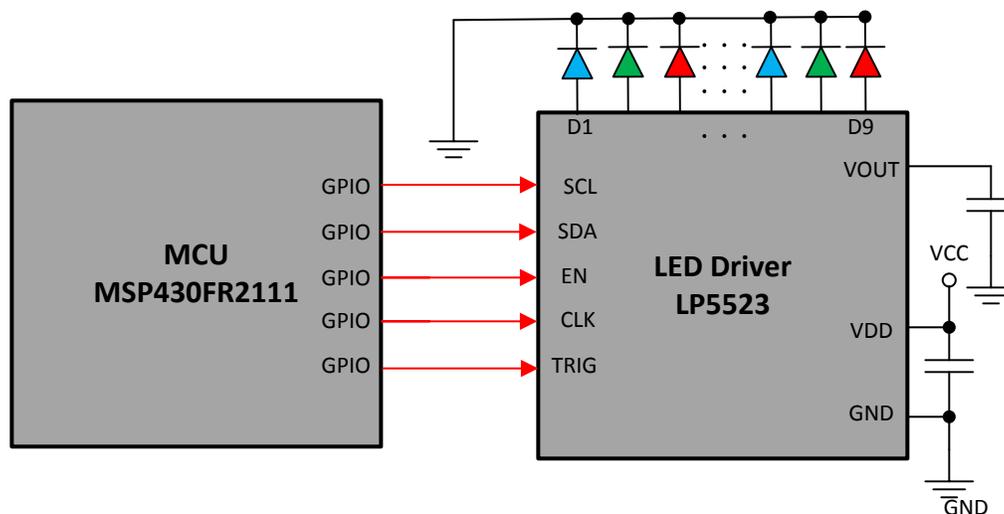
Table 1. Key System Specifications

PARAMETER	SPECIFICATIONS
Input voltage range	2.7 V to 5.5 V
Output current	17.5 mA/channel
LED number	3 RGB modules
LED type	ASMT-YTC2-0AA02
Lighting pattern style	3

2 System Overview

2.1 Block Diagram

Figure 1. TIDA-050013 Block Diagram



2.2 Design Considerations

In this reference design, the MSP430FR2111 device loads the engine code to LP5523 device after power on. The LP5523 device, a 9-channel RGB or white-LED driver with internal program memory and integrated charge pump, is used to drive 3 RGB LED modules with constant-current control and to run the various lighting patterns autonomously. The MSP430FR2111 MCU communicates with the LP5523 device through the I²C protocol which is simulated by 2 GPIOs. The LP5523 device only needs a minimum number of components. The SCL and SDA lines must each have a pullup resistor placed somewhere on the line. In typical applications, values of 1.8 k Ω to 4.7 k Ω , with 4.7 k Ω used here. Other values can be used, depending on the bus capacitance, I/O voltage, and the desired communication speed. For the VOUT and VDD capacitors, see [AN-2227 LP5523 Evaluation Kit](#) for the process of obtaining the selected value, which is 1 μ F.

2.3 Highlighted Products

The following highlighted products are used in this reference design. The key features for selecting the devices for this reference design are outlined in the following subsections. For the complete details of the highlighted devices, see their respective product data sheets.

2.3.1 LP5523 Nine-Channel RGB- and White-LED Driver With Internal Program Memory and Integrated Charge Pump – DSBGA Package

The LP5523 device is a 9-channel LED driver designed to produce lighting effects for mobile devices. A high-efficiency charge pump enables LED driving over the full Lithium-ion battery voltage range. The device is equipped with an internal program memory, which allows operation without processor control.

The LP5523 device maintains excellent efficiency over a wide operating range by autonomously selecting the best charge-pump gain based on LED forward voltage requirements. The LP5523 device is able to automatically enter power-save mode when LED outputs are not active, thus lowering idle current consumption down to 10 μ A (typical).

The LP5523 device has an I²C-compatible control interface with four pin-selectable addresses. The device has a flexible general-purpose output (GPO), which can be used as a digital control pin for other devices. The INT pin can be used to notify the processor when a lighting sequence has ended (interrupt function). Also, the device has a trigger input interface, which allows synchronization, for example, between multiple LP5523 devices.

The device requires only four small, low-cost ceramic capacitors. The LP5523 device is available in a tiny 25-pin DSBGA package (0.4-mm pitch).

2.3.2 MSP430FR2111 16-MHz Ultra-low-Power Microcontroller With 4 KB FRAM, 1 KB SRAM, 12 IOs, and 8-Ch 10-Bit ADC

The MSP430FR2000 and MSP430FR21xx devices are part of the MSP430™ microcontroller (MCU) value-line sensing portfolio. This ultra-low-power, low-cost MCU family offers memory sizes from 0.5 KB to 4 KB of FRAM unified memory with several package options including a small 3-mm x 3-mm VQFN package. The architecture, FRAM, and integrated peripherals, combined with extensive low-power modes, are optimized to achieve extended battery life in portable, battery-powered sensing applications. The MSP430FR2000 and MSP430FR21xx devices offer a migration path for 8-bit designs to gain additional features and functionality from peripheral integration and the data-logging and low-power benefits of FRAM.

Additionally, existing designs using MSP430G2x MCUs can migrate to the MSP430FR2000 and MSP430FR21xx family to increase performance and get the benefits of FRAM. The MSP430FR2000 and MSP430FR21xx MCUs feature a powerful 16-bit RISC CPU, 16-bit registers, and a constant generator that contribute to maximum code efficiency. The digitally controlled oscillator (DCO) also allows the device to wake up from low-power modes to active mode typically in less than 10 μ s. The feature set of this MCU can meet the needs of many applications ranging from appliance battery packs and battery monitoring to smoke detectors and fitness accessories.

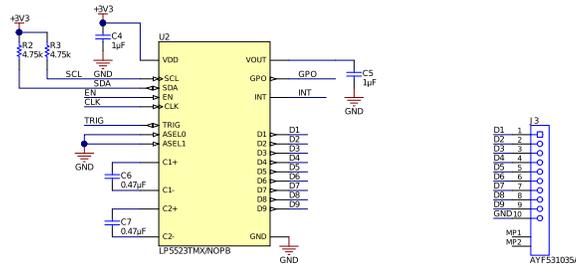
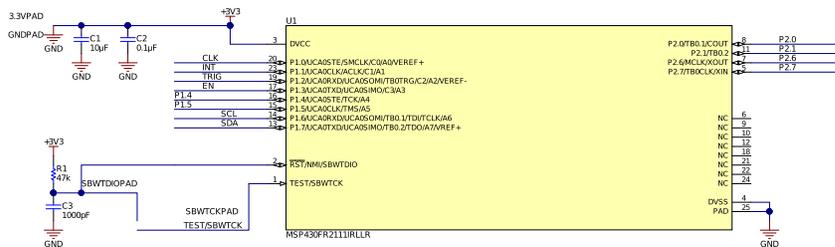
2.4 System Design Theory

One LP5523 device is used to drive 3 RGB LED modules with constant-current control. The MSP430FR2111 device loads the engine code to the LP5523 device after power on and enters the power-save mode. Then the LP5523 device runs the various lighting patterns autonomously.

2.4.1 System Schematics

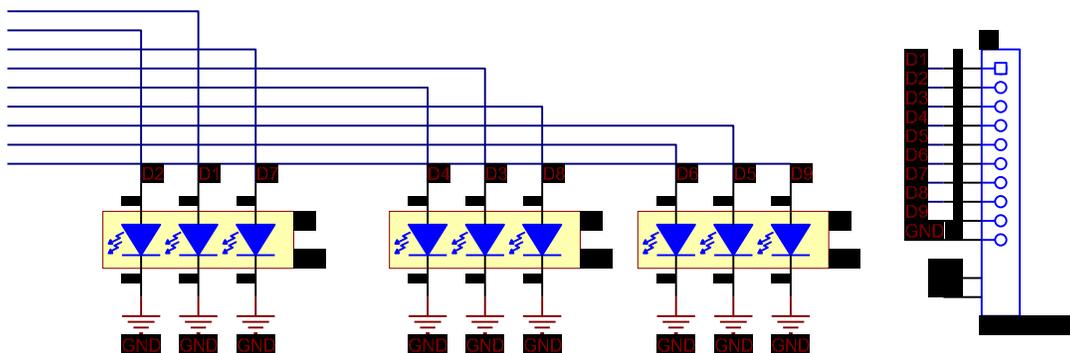
Figure 2 and Figure 3 show the schematics for the LED driver board and LED load board, respectively.

Figure 2. LED Driver Board Schematic



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Figure 3. LED Load Board Schematic



2.4.2 Detailed Design Procedure

To begin the design process, one must decide on a few parameters. The designer must know the following:

- Current of each LED
- LED board layout map
- Lighting pattern

2.4.2.1 LED Current

The maximum current of each LED is 25.5 mA.

2.4.2.2 LED Board Layout Map

Three RGB LED modules are placed in a straight line on the PCB board.

2.4.2.3 Lighting Pattern Design

Firstly, define the LED mapping in the beginning of the engine coding as shown below.

```
; This is a demo for the multicolor breathing. ; This demo to displays a slow ramp of ; all 3
colors for each tri-
color LED ENG1: dw 0000000100010001b ; ENG2: dw 0000000010001100b ; ENG3: dw 0000000001100010b ;
row1: dw 0000000001001001b ;Map B LED = D1,D4,D7 on the eval. board. row2: dw 0000000010010010b
;Map G LED = D2,D5,D8 on the eval. board. row3: dw 0000000100100100b ;Map R LED = D3,D6,D9 on the
eval. board. row4: dw 0000000011011011b ;Map B LED = D1,D2 on the eval. board. row5: dw
0000000110110110b ;Map G LED = D2,D3 on the eval. board. row6: dw 0000000101101101b ;Map R LED =
D1,D3 on the eval. board. row7: dw 0000000111111111b ;Map all LEDs on the eval. board.
```

2.4.2.3.1 Breathing

During the breathing pattern, all LEDs fade in and out as the same color at the same rate. The sample code is as follows:

```
.segment program1 mux_map_addr row7 set_pwm 0 loop1_0: mux_map_start row1 ;Map the first LED.
mux_ld_end row7 ;End address of the mapping data table. loop1: ramp 2, 200 ;Increase PWM 0-
>PWM200 in 2 second. ramp 2, -255 ;Decrease PWM 200-
>0% in 2 seconds. wait 0.4 ;Wait for 0.4 seconds. ramp 2, 200 ;Increase PWM 0-
>PWM200 in 2 second. ramp 2, -255 ;Decrease PWM 200-
>0% in 2 seconds. wait 0.4 ;Wait for 0.4 seconds. mux_map_next ;Set the next row active in the
mapping table. branch 6,loop1 ;Loop 6 time mux_map_addr row1 ramp 1.5, 200 ;Increase PWM 0-
>PWM200 in 1.5 second. wait 0.4 ;Wait for 0.4 seconds. wait 0.4 ;Wait for 0.4 seconds.
mux_map_addr row2 ramp 3, 200 ;Increase PWM 0->PWM200 in 3 second. ramp 3, -255 ;Decrease PWM 200-
>0% in 3 seconds. ramp 3, 200 ;Increase PWM 0->PWM200 in 3 second. ramp 3, -255 ;Decrease PWM 200-
>0% in 3 seconds. mux_map_addr row1 ramp 1.5, -255 ;Decrease PWM 100->0% in 1.5 seconds. mux_clr
```

2.4.2.3.2 Mixer

This is sample code to display a slow ramp of all 3 colors for each tri-color LED.

```
trigger s{2|3} loop2: mux_map_addr ENG1 ramp 2, 255 ramp 2, -255 ramp 2, -
255 branch 6, loop2 rst .segment program2 trigger w{1} loop3: mux_map_addr ENG2 ramp 2, -
255 ramp 2, 255 ramp 2, -
255 branch 6, loop3 rst .segment program3 trigger w{1} loop4: mux_map_addr ENG3 ramp 2, -
255 ramp 2, -255 ramp 2, 255 branch 6, loop4 rst
```

2.4.2.3.3 Other

For instructions on how to design your own custom lighting pattern, see [LP5523 Nine-Channel RGB- and White-LED Driver With Internal Program Memory and Integrated Charge Pump – DSBGA Package](#).

3 Hardware, Software, Testing Requirements, and Test Results

3.1 Required Hardware and Software

The hardware boards include one LED driver board and one LED load board, and the two boards are connected with the flexible flat cable.

3.1.1 Hardware

The following hardware is required for the testing.

- A personal computer with Windows® OS
- A 3.3-V dc power supply
- An MSP430RF2311 LaunchPad™

After downloading the firmware from the [TIDA-0510013 product folder](#), connect a 3.3-V dc supply to the LED board input connector (VIN pad). Then use the USB port to load the firmware to the MSP430RF2111 device with the MSP430RF2311 LaunchPad development kit through the Code Composer Studio™ integrated development environment (IDE). Then the LED driver and LED load boards can run the pattern.

3.1.2 Software

Install the [Code Composer Studio \(IDE\)](#) in the PC.

3.2 Testing and Results

3.2.1 Test Setup

Download the sample code at [TIDA-050013](#). Open the project in the Code Composer Studio IDE and download to the MSP430RF2111 device.

Connect the MSP430RF2311 LaunchPad development kit with the LED driver board as shown in [Figure 4](#) and [Figure 5](#). Connect RST (MSP430RF2111 pin 2 on the LED driver board) with red wire to SRWTDI0 (MSP430RF2311 LaunchPad development kit). Connect TEST (MSP430RF2111 pin 1 on the LED driver board) with orange wire to SRWTCK (MSP430RF2311 LaunchPad development kit). Connect the two board GNDs together with blue wire and connect the two board VCCs (3.3 V) together with black wire.

Figure 4. Wire Connections on The LED Driver Board

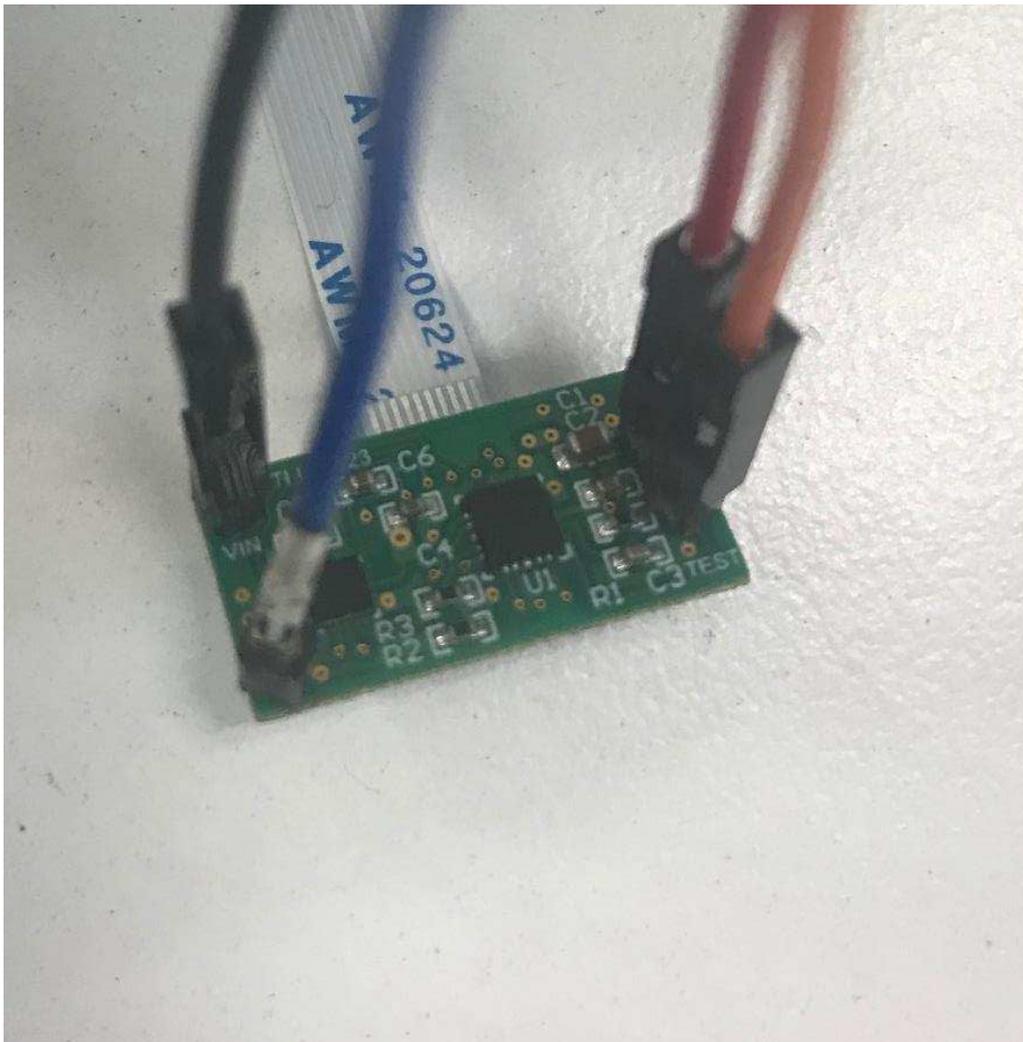
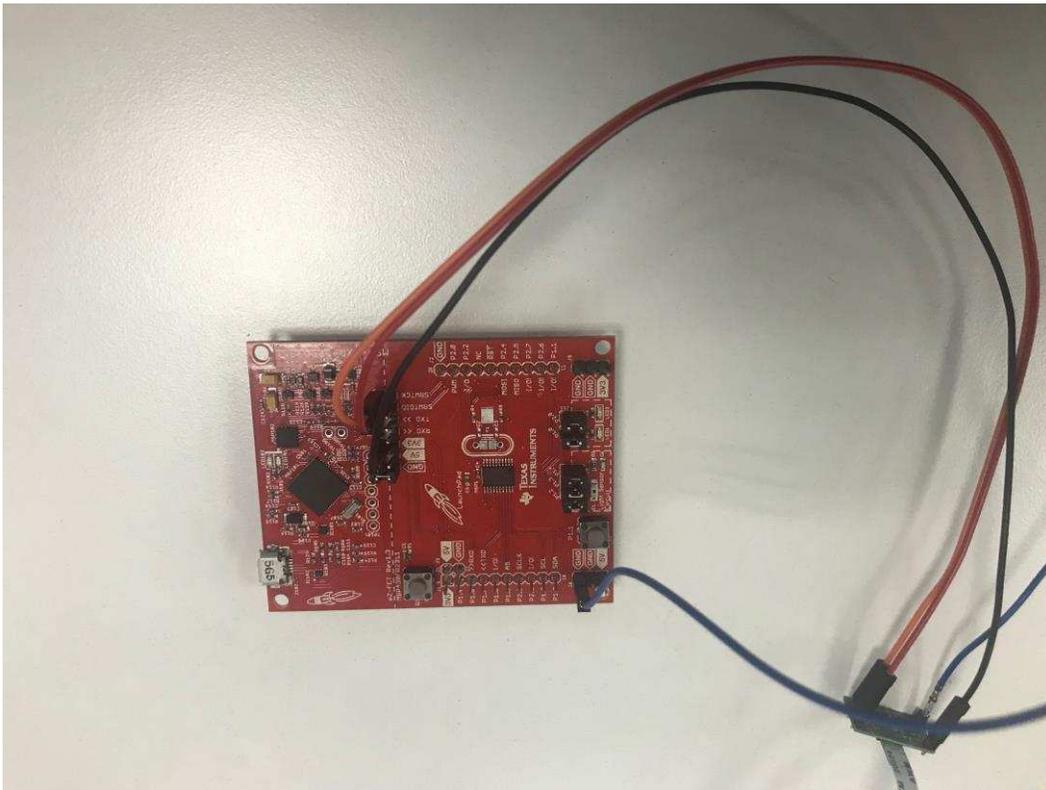


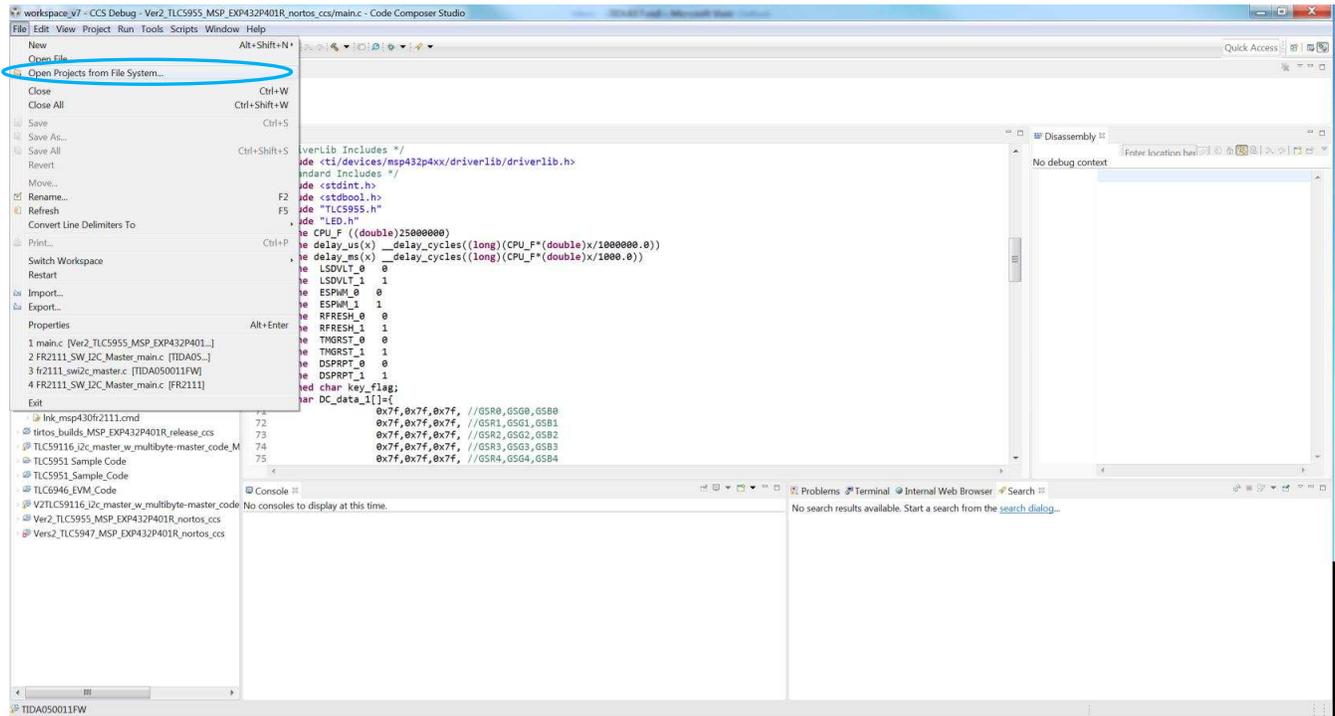
Figure 5. Wire Connections on The MSP430RF2311 LaunchPad Development Kit



After opening the Code Composer Studio integrated development environment (IDE), load the sample code to the MSP430FR2111. The code then runs in the MSP430FR2111.

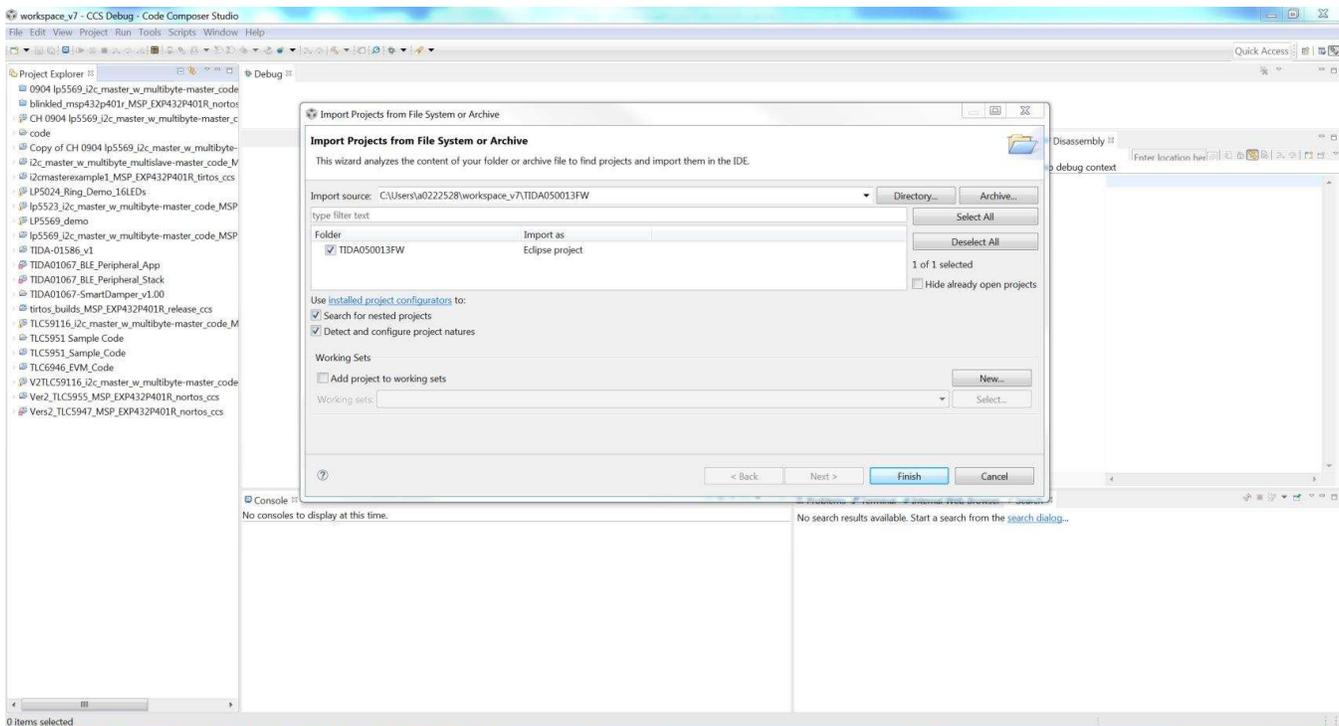
Open the project through the *Open Projects from File System* drop-down menu under *File*.

Figure 6. Open The Project Menu



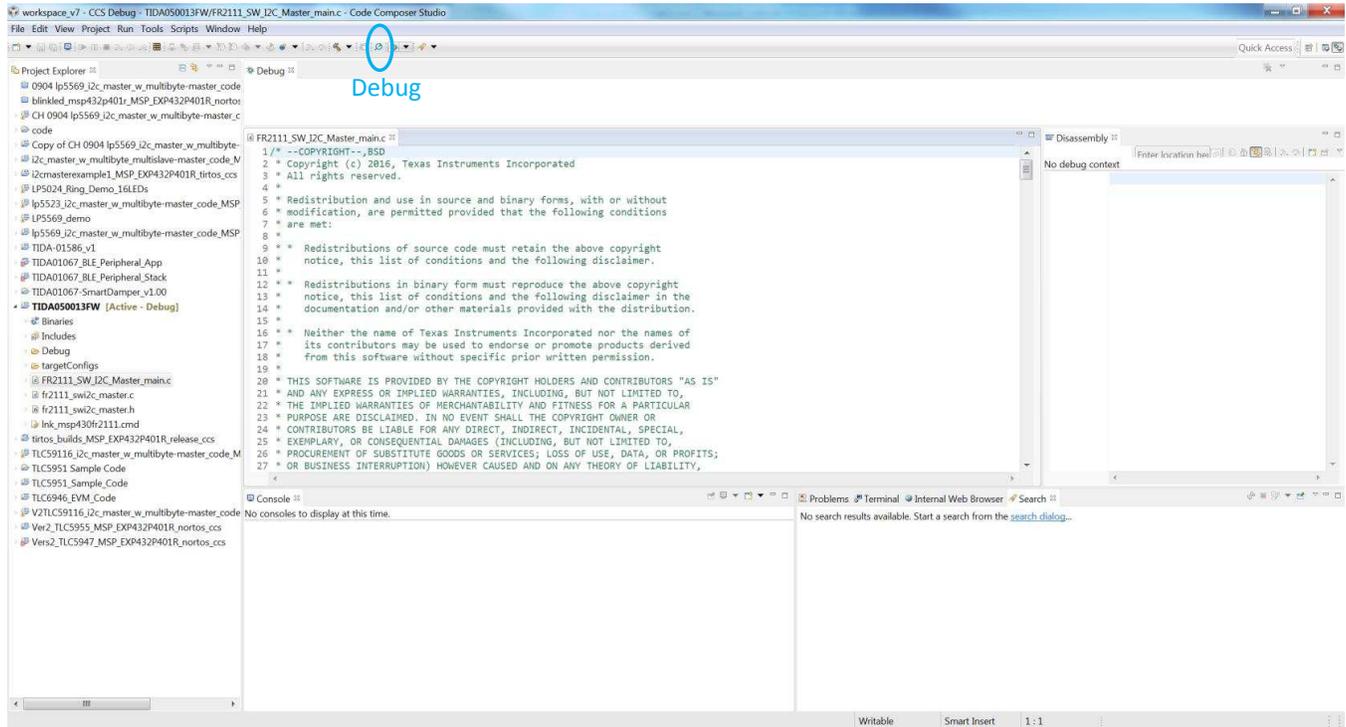
Open the TIDA050013FW folder.

Figure 7. Open Firmware Project



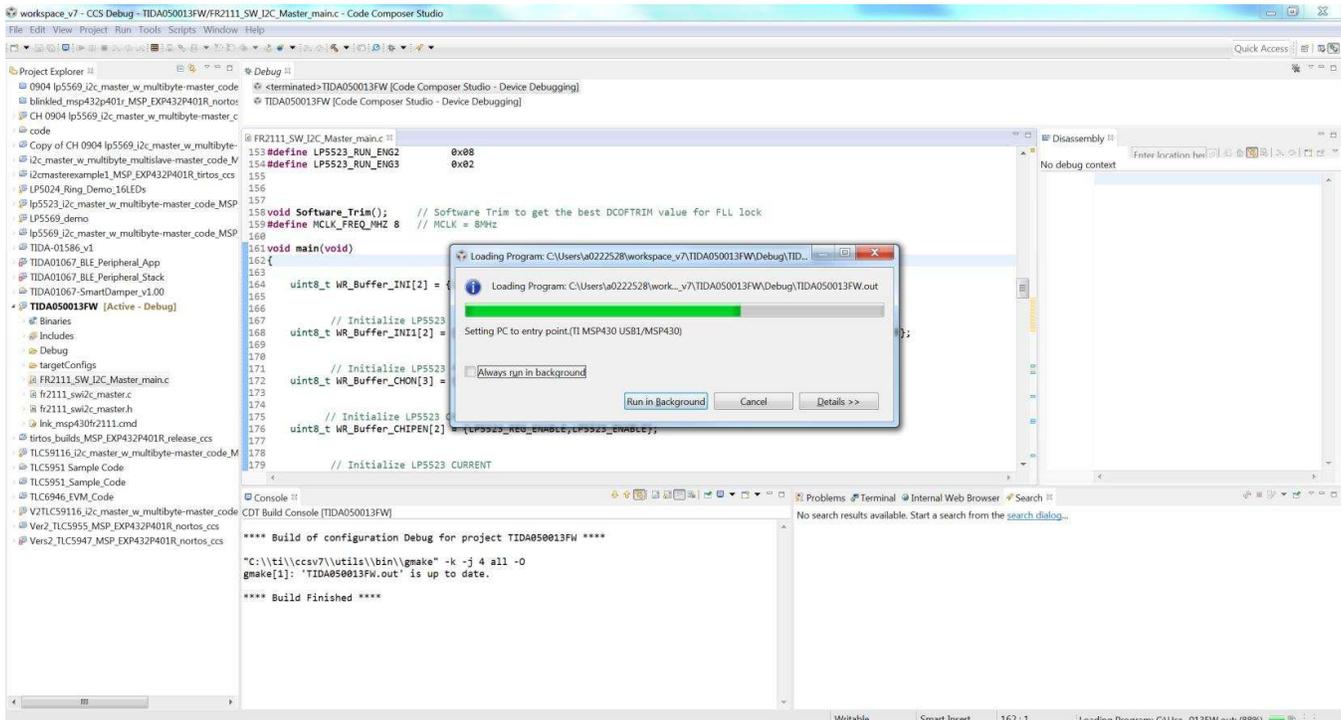
Click the Debug button to load the firmware to the MSP430FR2111 device.

Figure 8. Using Debug to Load The Program



The firmware loading is completed.

Figure 9. Finishing The Program Loading



3.2.2 Test Results

All the effects appear as shown in the video on the [product folder](#).

4 Design Files

4.1 Schematics

To download the schematics, see the design files at [TIDA-050013](#).

4.2 Bill of Materials

To download the bill of materials (BOM), see the design files at [TIDA-050013](#).

4.3 PCB Layout Recommendations

Place capacitors as close as possible to the LP5523 device to minimize the current loops. External components for the MSP430FR2111 device that are shown in the schematic must be placed as close as possible to the respective device pins to avoid long traces, because they add additional parasitic capacitance, inductance, and resistance on the signal. Avoid routing analog input signals close to a high-frequency pin (for example, a high-frequency PWM), because the high-frequency switching can be coupled into the analog signal.

4.3.1 Layout Prints

To download the layout prints, see the design files at [TIDA-050013](#).

4.4 Altium Project

To download the Altium Designer® project files, see the design files at [TIDA-050013](#).

4.5 Gerber Files

To download the Gerber files, see the design files at [TIDA-050013](#).

4.6 Assembly Drawings

To download the assembly drawings, see the design files at [TIDA-050013](#).

5 Software Files

To download the software files, see the design files at [TIDA-050013](#).

6 Related Documentation

1. [LP5523 Nine-Channel RGB- and White-LED Driver With Internal Program Memory and Integrated Charge Pump – DSBGA Package](#)
2. [AN-2227 LP5523 Evaluation Kit](#)
3. [MSP430FR21xx, MSP430FR2000 Mixed-Signal Microcontrollers](#)

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7 About the Author

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