BOOST-IR Infrared (IR) BoosterPack™ Plug-in Module

The BOOST-IR BoosterPack™ Plug-in Module can be plugged into a LaunchPad™ Development Kit for simple integration of infrared (IR) transceiver functionality. LaunchPad developers can use this BoosterPack to start developing remote control applications using the on-board keypad, IR LED transmitter, and IR receiver + demodulator.

Infrared modulation can be simplified by using on-chip IR Modulation Logic, which can be found on select MSP430 ultra-low-power microcontrollers within the MSP430FRxx MCU series.

Explore IR communication using the MSP430FR4xx and MSP430FR2xx microcontrollers

TI Designs are also available to help accelerate development using IR transceiver capabilities. These designs contain documentation, design files, and test data to minimize design overhead.

Download a full reference design leveraging the MSP-EXP430FR4133 LaunchPad and BOOST-IR BoosterPack

Figure 1. BOOST-IR BoosterPack

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1 Getting Started

1.1 Introduction

The BOOST-IR BoosterPack™ Plug-in Module can be plugged into a LaunchPad™ Development Kit for simple integration of infrared (IR) transceiver functionality. LaunchPad developers can use this BoosterPack to start developing remote control applications using the on-board keypad, IR LED transmitter, and IR receiver + demodulator.

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Download a full reference design leveraging the MSP-EXP430FR4133 LaunchPad and BOOST-IR BoosterPack

1.2 Key Features

- IR LED transmitter
- IR receiver and demodulator
- 4x4 membrane keypad
- 20-pin BoosterPack standard for use with any LaunchPad
- Compatibility with different IR signal-generation methods

1.3 What's Included

1.3.1 Kit Contents

- 1 x BOOST-IR BoosterPack Plug-in module
- 1 x Quick Start Guide

1.3.2 Software Examples

- MSP-EXP430FR4133 LaunchPad and BOOST-IR demos (see Section 3)
  - IR Emitter and Receiver
  - IR Learning Mode

1.4 Next Steps: Looking Into the Provided Code

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

2 Hardware

Figure 2 shows an overview of the BOOST-IR module.

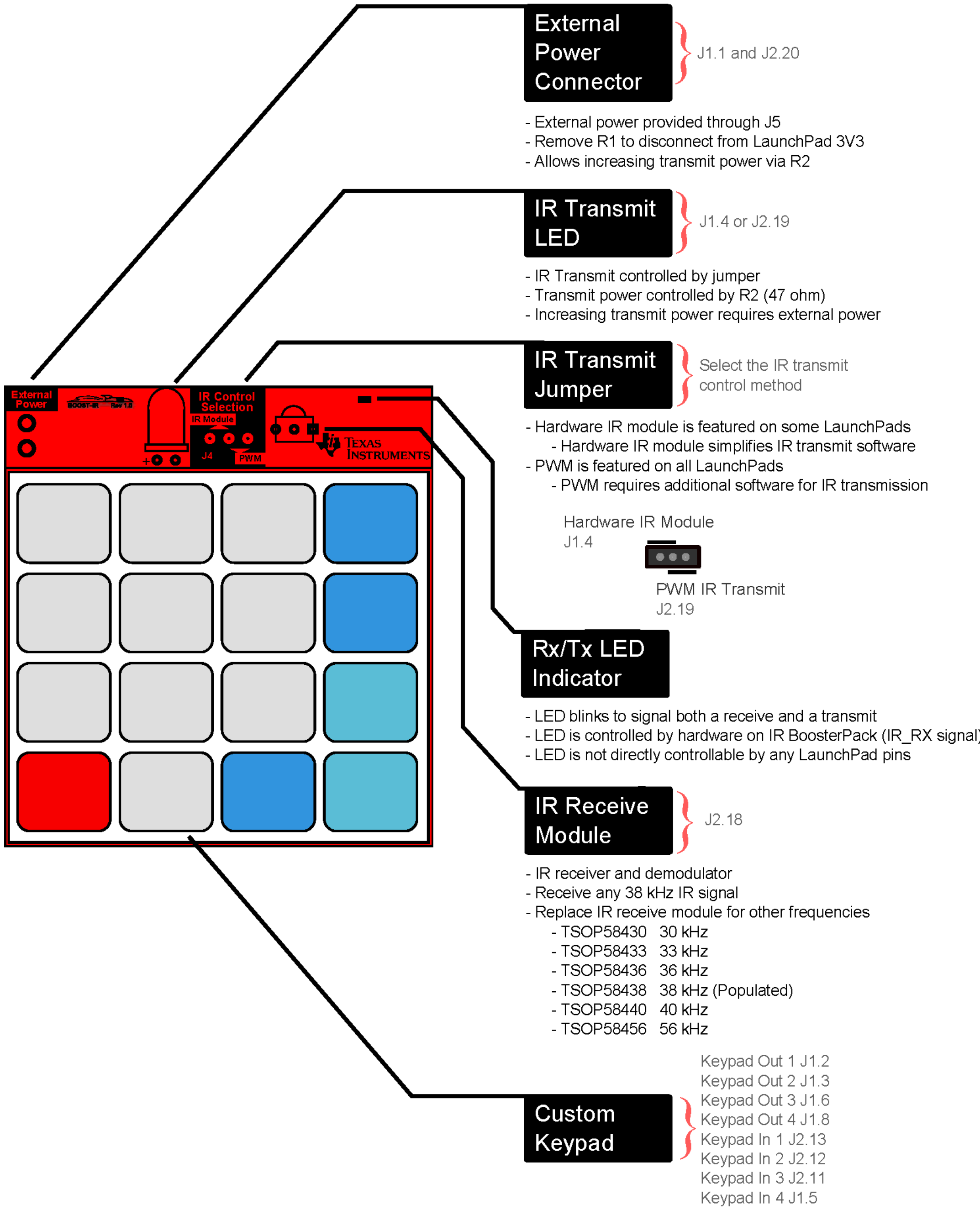


Figure 2. BOOST-IR Overview

2.1 Hardware Features

2.1.1 BoosterPack Pinout

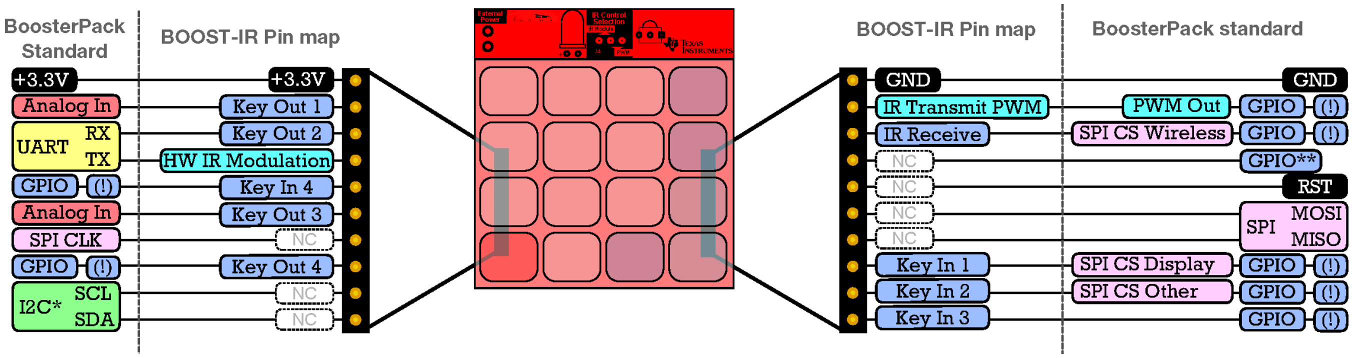


Figure 3. BoosterPack Pinout

The IR BoosterPack adheres to the 20-pin LaunchPad and BoosterPack pinout standard (see Figure 3). This standard was created to aid compatibility between LaunchPad and BoosterPack tools across the TI ecosystem.

The 20-pin standard is compatible with the 40-pin standard that is used by other LaunchPad kits like the MSP-EXP430F5529LP. This allows for 20-pin BoosterPacks to be used with 40-pin LaunchPads.

The BOOST-IR intentionally does not use the I^2C and SPI pins to allow other BoosterPacks that use these pins to be stacked together with the IR BoosterPack. This BoosterPack does not have both male and female headers to support stacking on top. This is because the keypad is too large, and in most applications this keypad would be on the top. To stack other BoosterPacks along with BOOST-IR, use them lower in the "stack" with BOOST-IR on top.

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

2.1.2 Membrane Keypad

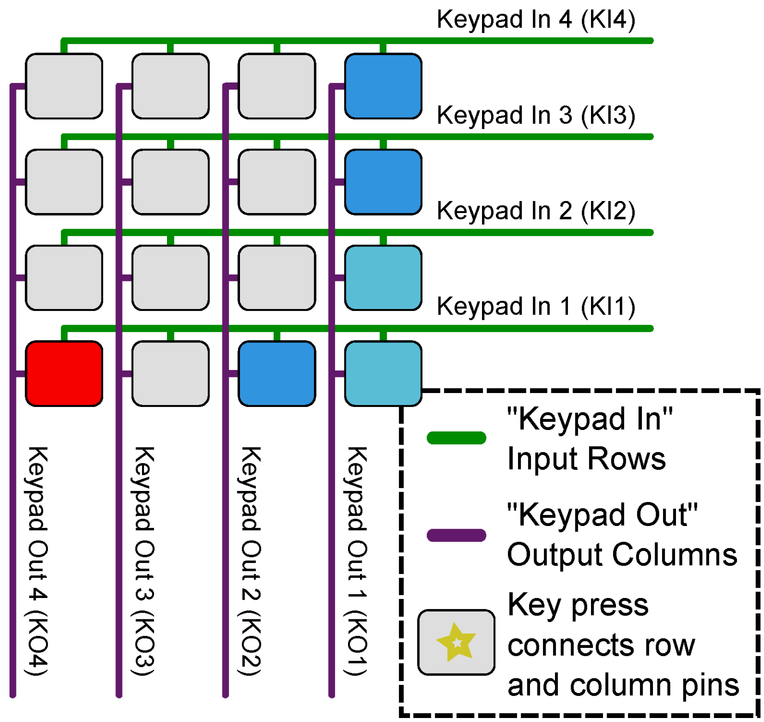


Figure 4. Membrane Keypad Connections

The membrane keypad is a 4x4 matrix keypad, controlled by 4 *Keypad Out* pins (columns), and 4 *Keypad In* pins (rows). Without any buttons pressed, the columns and rows are not connected to each other. When a button is pressed, it connects its corresponding column pin with its corresponding row pin.

To detect any key presses, the connection of the row pin to the column pin must be detected. This is accomplished by configuring the *Keypad Out* pins as outputs, and *Keypad In* pins as inputs. The Keypad Out pins are toggled high one at a time, while the *Keypad In* pins are read for any changes. This allows the exact key to be determined in the 4x4 matrix.

As an example, refer to the Figure 4 keypad layout. If the bottom left button is pressed, the *Keypad Out 4* pin is now connected to the *Keypad In 1* pin. The host MCU starts reading the keypad matrix by toggling *Keypad Out 1* high (while keeping all other *Keypad Out* pins low), and reads all *Keypad In* pins low. This is because *Keypad Out 1* is still not connected to any *Keypad In* pins by a button press. The host MCU then toggles *Keypad Out 2* high, and reads all *Keypad In* pins still low. Eventually, the MCU toggles *Keypad Out 4* high, and reads that *Keypad In 1* has now transitioned to high. Recall that the bottom left button connects *Keypad Out 4* with *Keypad In 1*, forcing the input row to read high. The MCU maps out this connection and knows that the bottom left button was pushed, because that is the intersection point of *Keypad Out 4* and *Keypad In 1*. The MCU can now perform the action that corresponds to the key press.

It may seem like a key press can be missed with this procedure, but it is happening many times per second, allowing for any key press to be detected. It is possible for keys to go undetected due to key "ghosting" in a matrix keypad, but that is outside the scope of this brief overview. This only occurs when multiple buttons are pressed at the same time, and there are ghost key detection algorithms to prevent any misinterpretations.

NOTE: The *Keypad Out 2* (J1.3) pin is connected to the UART receive pin on the BoosterPack standard. On most 20-pin LaunchPads (MSP-EXP430G2, MSP-EXP430FR5969, MSP-EXP430FR4133), the *Keypad Out 2* pin is also connected to the LaunchPad backchannel UART pin. For proper operation of the Keypad, disconnect the UART RX jumper on the LaunchPad isolation block.

2.1.3 IR Transmit

Figure 5 shows the schematic of the IR transmit circuit.

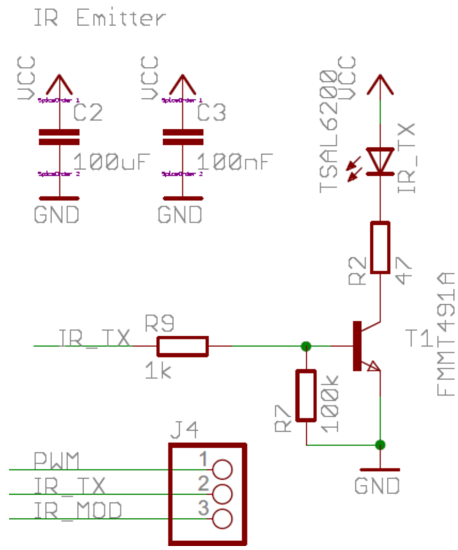


Figure 5. IR Transmit Circuit

2.1.3.1 IR Transmit Overview

To transmit an IR signal, an infrared (IR) LED is toggled to blink the LED. Using IR protocols, messages can be read such as commands from remote controls. More information on IR protocol can be found in *Infrared Remote Control Implementation With MSP430FR4xx* (SLAA644) and also in Section 3.1.1.

Because the IR LED requires high currents to transmit longer distances, this LED is not controlled directly with a general purpose IO pin from the MCU. Instead a switching circuit that allows current to flow directly from the main power source is used. See Section 2.2 for more information on power and Section 6 for the schematics.

2.1.3.2 Setting IR Transmit Power

To set the current of the IR LED, resistor R2 (47 Ω) is used. This resistor can be adjusted to change the IR LED transmit power. Decreasing R2 increases the power through the IR LED, which increases the range of the remote.

NOTE: Increasing the IR transmit power may draw more current than supported from the LaunchPad. Check the specific LaunchPad user's guide to make sure that enough power can be provided, or use external power (see Section 2.2.2).

2.1.3.3 IR Transmit Selection

IR transmit can be controlled by two different pins, selectable by jumper J4 (see Figure 2).

Setting the J4 jumper to the left side selects the hardware IR module (J1.4), which is only featured on some LaunchPads, such as the MSP-EXP430FR4133. The hardware IR module simplifies the software needed for IR transmission, because the hardware handles the protocol.

NOTE: When using the hardware IR module (J1.4), this pin is connected to the UART transmit pin on the BoosterPack standard. On some LaunchPads, such as the MSP-EXP430FR4133, the hardware IR module pin is also connected to the LaunchPad backchannel UART pin. For proper operation of the hardware IR module, it is recommended to disconnect the UART TX jumper on the LaunchPad isolation block.

Setting jumper J4 to the right selects PWM control (J2.19), which can be used on any LaunchPad. The PWM method requires additional software to control the PWM pin according to the IR protocol.

2.1.4 IR Receive

Figure 6 shows the schematic of the IR receive circuit.

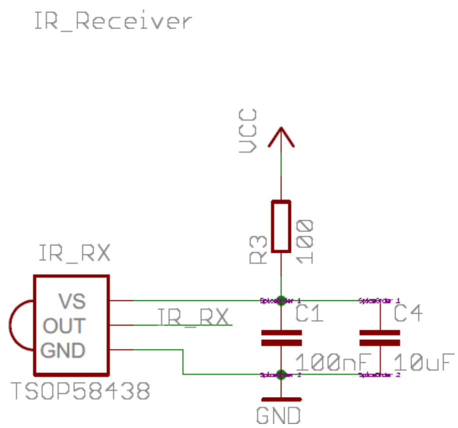


Figure 6. IR Receive Circuit

The IR receive module receives and demodulates the incoming signal. The default IR receiver supports IR transmission at 38 kHz. This is the most commonly used IR frequency for use in remote controls. If another frequency is needed, the IR receive module can be replaced with a drop-in replacement that supports another frequency (see Table 1). More information on IR protocol can be found in *Infrared Remote Control Implementation With MSP430FR4xx* (SLAA644) and also in Section 3.1.1.2.

Table 1. IR Receiver Replacement Options

Part Number	Receive Frequency
TSOP58430	30 kHz
TSOP58433	33 kHz
TSOP58436	36 kHz
TSOP58438	38 kHz (Populated)
TSOP58440	40 kHz
TSOP58456	56 kHz

The IR receive module is very sensitive and receives almost all of the IR transmissions from its own IR LED. This is mostly unavoidable without physically altering the BoosterPack. Make sure that your firmware compensates for receiving its own transmissions by ignoring them or verifying that the proper output was sent.

2.2 Power

The board was designed to be powered either by the attached LaunchPad or by an external source through the external power connector.

2.2.1 LaunchPad Power

This is the default power configuration for the BOOST-IR. In this configuration, power is provided through the 3V3 (J1.1) pin on the BoosterPack headers. The 3V3 pin powers everything on the IR BoosterPack, including IR transmit and receive.

2.2.2 External Power

There are a few reasons why you may want to provide external power, including higher IR transmit power, changing to a different voltage, or using a battery to go "wireless." To provide external power, use the following procedure.

1. Disconnect BOOST-IR power from the LaunchPad power source
   - (a) Option 1: Remove the 3V3 jumper on the LaunchPad isolation block

     In this case, the MCU is also powered by the external source; make sure that the voltage is within the MCU device voltage operation specification.
   - (b) Option 2: Remove R1 on the BOOST-IR to completely disconnect LaunchPad and BoosterPack power
     - (i) In this case, the LaunchPad must provide power to its own MCU.
     - (ii) If the LaunchPad and BoosterPack have different operating voltages, IR communication may not function properly.
2. Connect the external power supply.

After these steps are complete, you should be able to operate the IR BoosterPack with an external voltage.

2.3 Design Files

2.3.1 Hardware

Schematics can be found in Section 6. All design files including schematics, layout, bill of materials (BOM), Gerber files, and documentation are available in a zip folder (SLAR104).

2.3.2 Software

All design files including TI-TXT object-code firmware images, software example projects, and documentation are available in the LaunchPad specific software folders. To see which LaunchPads feature BOOST-IR examples, refer to the "What's Included" section on the BOOST-IR tool folder.

2.3.3 Quick Start Guide

The *BOOST-IR Quick Start Guide* is SLAU614.

2.4 Hardware Change Log

Table 2. Hardware Change Log

PCB Revision	Description
Rev 1.0	Initial Release

3 TI Design and Software Examples

3.1 TI Design: BOOST-IR + MSP-EXP430FR4133 IR Remote Control

TI Designs

TI Designs provide the foundation that you need including methodology, testing, and design files to quickly evaluate and customize the system. TI Designs help *you* accelerate your time to market.

System Description

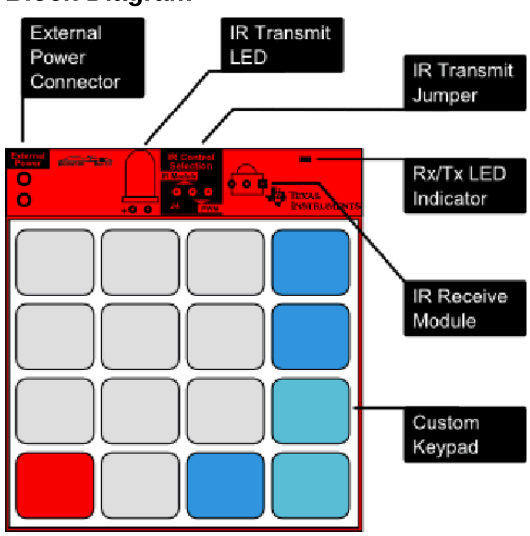
The BOOST-IR BoosterPack is an easy-to-use plug-in module for adding Infrared (IR) communications to your Launchpad design. It contains everything that you need to start developing IR communication with your Launchpad, including a keypad, IR LED transmitter, and IR receiver + demodulator.

Design Resources

TIDM-BOOST-IR-REMOTE	Design Folder
MSP-EXP430FR4133	Product Folder
BOOST-IR	Product Folder
MSP430FR4133	Product Folder

TI E2E™ Community — Find an answer: MSP430 E2E Support Forum

Block Diagram



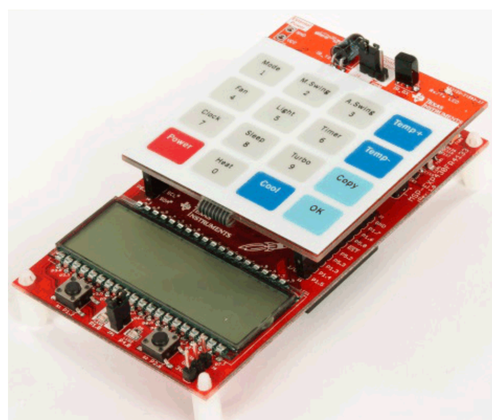
Design Features

- Implements ASK IR modulation
- 38-kHz onboard demodulator
- 4x4 membrane keypad
- Jumper to configure IR generation method - support for most LaunchPad kits
- IR Emitter and Receiver examples
- IR Learning Mode example

Featured Applications

- TV Remote Control
- Air Conditioner Remote Control

Design Photo



3.1.1 System Design Theory

The following sections discuss the IR modulation and demodulation schemes used in this design. For additional information about IR remote control theory and implementing IR protocols on FR4xx devices, see the application note Infrared Remote Control Implementation with MSP430FR4xx (SLAA644).

3.1.1.1 ASK Modulation

The MSP-EXP430FR4133 + BOOST-IR Remote Control sends and receives ASK modulated IR signals with a 38-kHz carrier frequency. 38 kHz is one of the most common IR carrier frequencies for remote control applications and is used by many TV and air conditioner manufacturers.

In ASK modulation, two signals (the higher-frequency carrier, and the envelope) are combined to form the modulated signal. The envelope contains the data to be sent, under one of many different standard encoding schemes (for example, pulse position, pulse distance, pulse width, or Manchester encoding). The carrier is simply a high frequency signal. When the two signals are combined, the carrier frequency is output whenever the envelope is high, and the signal is held low when the envelope is low. Figure 7 shows an example of an IR modulated signal using Pulse Position encoding.

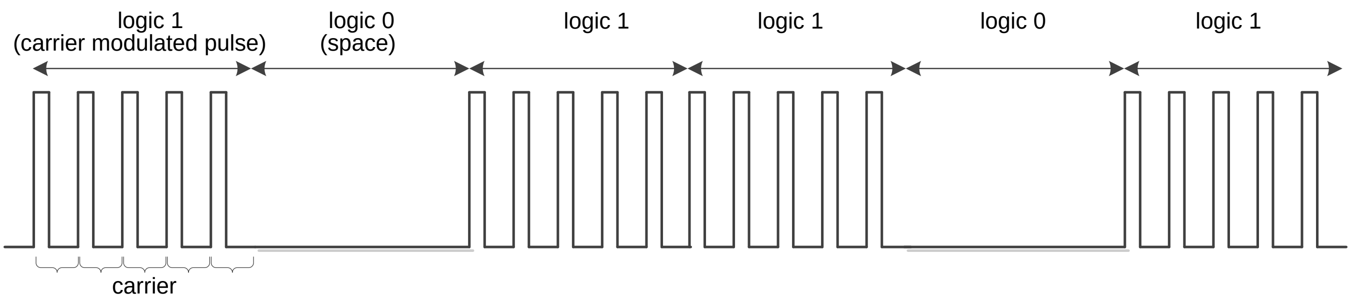


Figure 7. Pulse Position Encoding (ASK)

3.1.1.2 IR Modulation Logic on MSP430FR4133

The MSP430FR4133 device includes some logic to help enable IR modulation, inside of the SYS module. This logic block allows the outputs signals from some timer modules in the device (producing the carrier frequency) to be combined with an envelope generated by another timer module, the output of the USCI_A0 module, or with a software controlled IRDATA line. In addition, the Timers can optionally be cascaded. TA1 can select to use TA0 as the clock source so that TA1 is essentially counting ticks of the TA0 PWM output signal. This arrangement allows for flexible and configurable generation of all different kinds of ASK and FSK modulation schemes. Figure 8 shows an overview of the modules involved in internal IR signal generation on the FR4133.

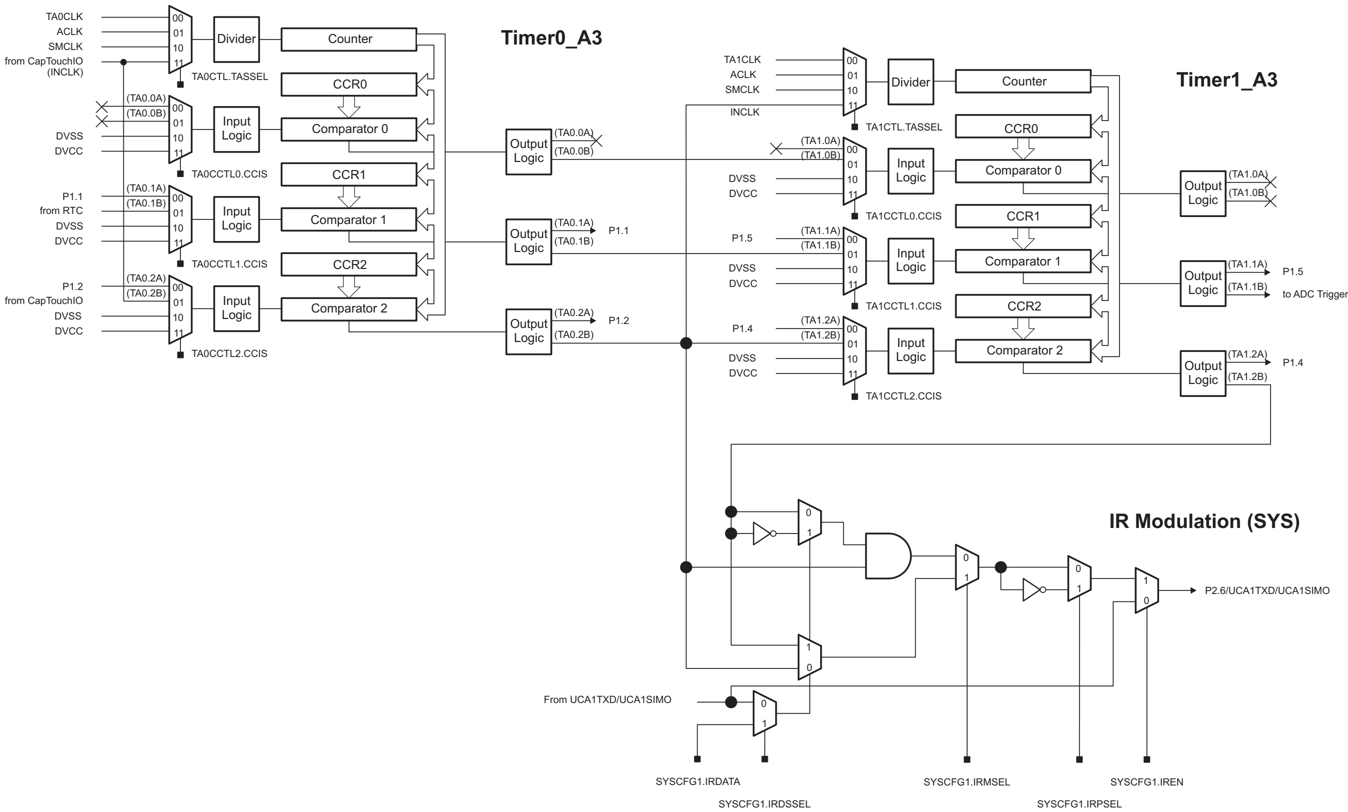


Figure 8. IR Modulation Logic Blocks in MSP430FR4133

Figure 9 shows the ASK IR Modulation signal generation used in the example software for this TI Design, found in the MSP-EXP430FR4133 Software Examples. TA0CCR2 output is used as the carrier frequency, and is ANDed with TA1CCR2 which is generating the envelope, before the final resulting signal is brought out on the output pin.

Therefore to generate the signal, TA0CCR0 and TA0CCR2 are set once at the beginning of the code to generate a 38-kHz PWM for the carrier signal. For each bit to be sent, the TA1CCR0 and TA1CCR2 values are updated to generate a PWM with the correct envelope timing for sending a 0 or 1 using Pulse Distance Encoding.

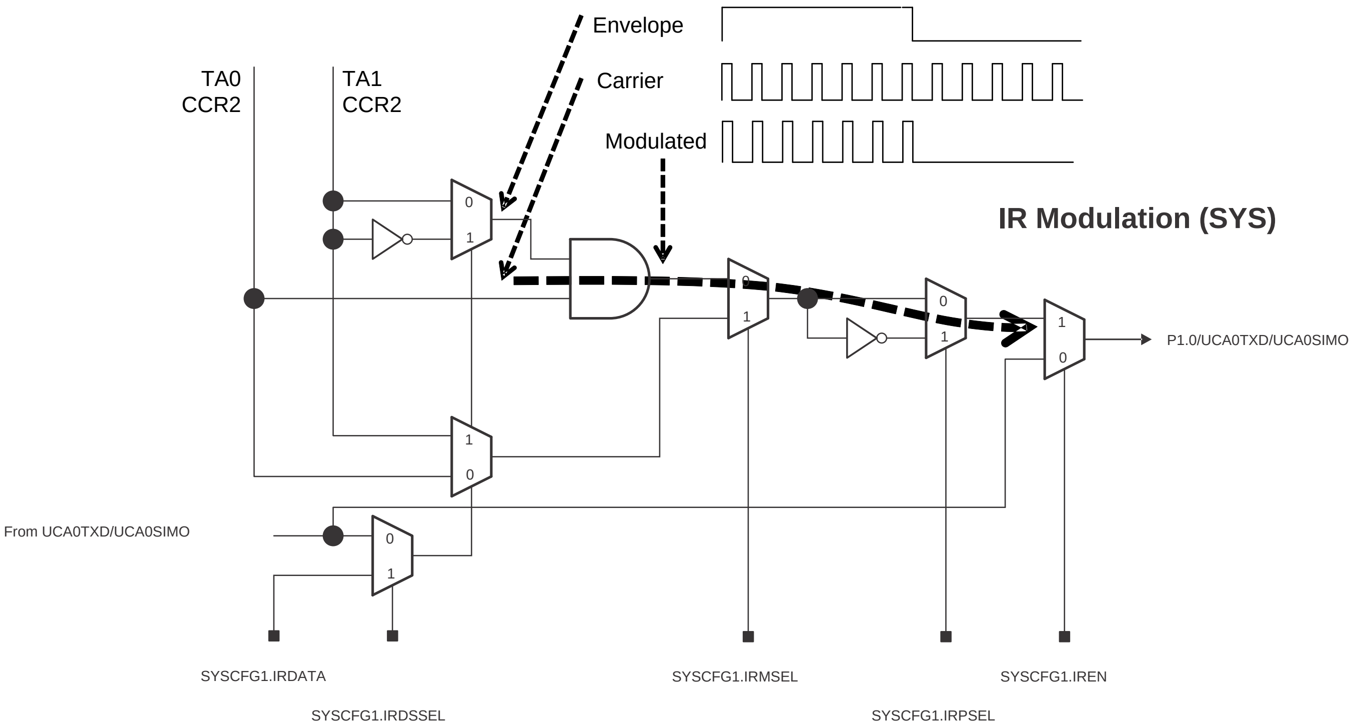


Figure 9. ASK IR Generation on MSP430FR4133

3.1.1.3 ASK Demodulation

The receiver uses a photodiode to convert the IR light to current. A transimpedance amplifier is frequently used to convert the current into voltage, which passes through a gain amplifier and filter before demodulation, which removes the carrier signal. Then the demodulated signal, which is essentially just the envelope signal now that the carrier has been removed, can be connected directly the MCU for decoding (see Figure 10).

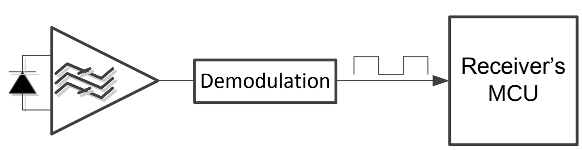


Figure 10. IR Demodulation

The BOOST-IR BoosterPack features a Vishay TSOP59348 IR Receiver device. This device performs all of the steps above, stripping off the carrier signal, and then provides the envelope directly to the FR4133 TA0.2 input. The Timer A0 module is then used in capture mode to record the edges of the signal. The pulse length is calculated from these capture values to determine if a 0 or 1 was received using pulse distance encoding.

3.1.1.4 Pulse Distance Encoding and Protocol

The software IR emitter and receiver examples included with this TI Design use a Pulse Distance protocol for communication between two LaunchPads + BoosterPacks. This protocol is similar to that used on many commercially available remote control devices. In Pulse Distance Encoding, each bit is a carrier modulated pulse and a space – the carrier modulated pulse width is constant, while the width of the space varies to indicate a logic 0 or logic 1.

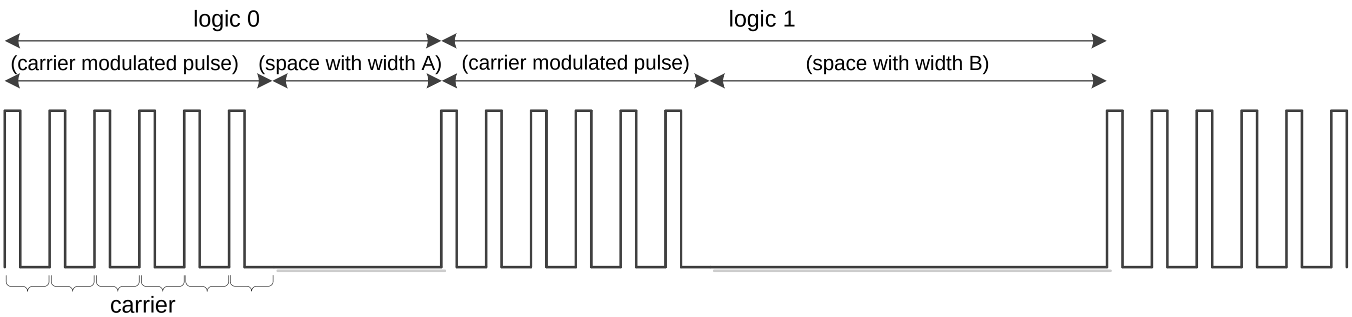


Figure 11. Pulse Distance Encoding

The provided IR Emitter and Receiver code uses a standard timing for remote controls using pulse distance protocol. Logic 1 is defined as a 560-µs carrier modulated period followed by a 1690-µs space period. Logic 0 is defined as a 560-µs carrier modulated period followed by a 560-µs space period. The data frame starts with a Leading Code of 9-ms modulated period followed by a 4.5-ms space period.

After the Leading Code, the data payload begins. The payload consists of 4 bytes:

1. 1 address byte
2. The same address byte inverted
3. 1 command byte
4. The same command byte inverted

The address byte is used to identify the device so that receivers can ignore signals from other IR remotes that are intended for other devices. The example code has arbitrarily chosen 0x55 for the address byte. The command byte is the actual data that you want to send – in this example it is a byte that corresponds to the number of the key that was pressed. The protocol follows the address byte with an inverted version of itself, and the command byte with an inverted version of itself. This is to help catch any errors in the communication to increase robustness, and is a standard feature of the pulse distance protocol used by many remote controls.

After the payload is transmitted, the Data Frame ends with a tail pulse to indicate the end of the packet. This tail is a 560 us carrier modulated pulse.

Figure 12 shows the full Data Frame Format.

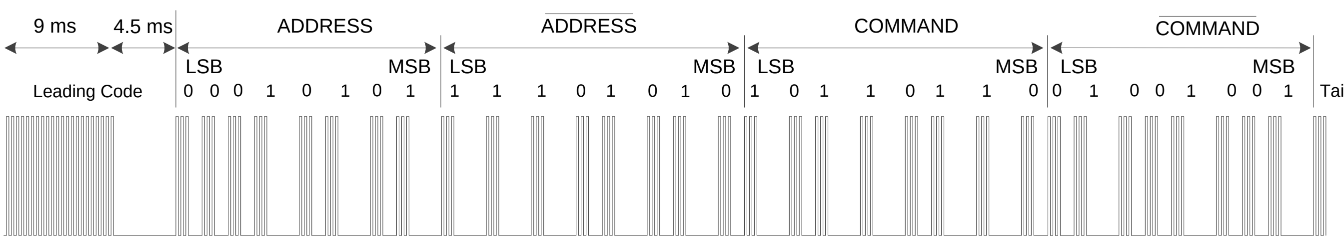


Figure 12. Pulse Distance Protocol, Data Frame Format

3.1.1.5 *IR Learning Mode*

For some applications like universal TV remotes, it is useful to have a device that can learn different IR codes. To do this, the device needs to be able to receive an IR signal from another device, record it, and then later be able to reproduce it on command. The MSP430FR4133 is an FRAM device, allowing for a large amount of nonvolatile storage that can be quickly and easily accessed with no extra steps needed (like is needed for writing Flash) . FRAM can be written just like RAM at speeds up to 8 MHz – perfect for logging data. The FRAM also has near-infinite write cycles, so the IR codes can be reprogrammed frequently without risk of wearing out the memory. Because of this, the device is a great candidate for implementing IR applications that require "learning" IR codes. The example software for this TI Design includes a Learning Mode example.

The learning mode example code provided uses a Timer A capture input to receive an IR signal stripped of its 38-kHz carrier, and records the edge timing of the signal. This timing information is stored in FRAM for later use. Later, when the code should reproduce the same signal for TX, it simply reads the timing information from FRAM and uses this to set the envelope Timer values for the transmission until the transmission is complete.

In this type of application, the device does not need to decode or understand any protocol – it simply needs to be able to reproduce the signal on command. This code therefore supports all different ASK encoding and protocols, allowing it to be able to copy and repeat IR commands from a wide variety of sources like consumer television remotes.

The only limits are:

- 38-kHz carrier

  This is due to the frequency of the Vishay demodulator present on the BoosterPack. This part can be replaced and the code modified if other carrier frequencies are needed.
- Quantity of FRAM available on the device compared to the length and number of codes to store

  The code timing information is stored in FRAM, so the amount of available FRAM in your code determines how many different codes, and the length of the codes, that can be learned.

3.1.2 Hardware

The MSP430FR4133 device has built-in IR modulation capabilities. The internal IR modulation is configurable and flexible. It supports both ASK and FSK modulation, which allows implementation of a variety of IR protocols. For more information on the IR modulation capabilities of the FR4133 device, see the *MSP430FR4xx and MSP430FR2xx Family User's Guide* (SLAU445). For more information on how to implement different remote control IR protocols using the FR4133 IR features, see the application report *Infrared Remote Control Implementation With MSP430FR4xx* (SLAA644).

3.1.2.1 MSP-EXP430FR4133 LaunchPad

The MSP430FR4133 device is the first device in TI’s FRAM technology platform to combine an LCD driver and infrared modulation functions with FRAM. 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
- Up to 16-MHz system clock and 8-MHz FRAM access
- 15.5KB of FRAM and 2KB of SRAM
- Ultra-low-power operation
- Low-power liquid crystal display (LCD) with LPM3.5 support
- Two timer blocks and two serial interfaces (SPI, UART, or I^2C)
- RTC counter (real-time counter module) with LPM3.5 support
- Analog: 10-channel 10-bit ADC with window comparator
- Capacitive Touch I/Os on all GPIO pins (60) to enable touch applications
- Digital: CRC16

For more information on the hardware and capabilities of the MSP-EXP430FR4133 LaunchPad, see the *MSP430FR4133 LaunchPad Development Kit (MSP-EXP430FR4133) User's Guide* (SLAU595).

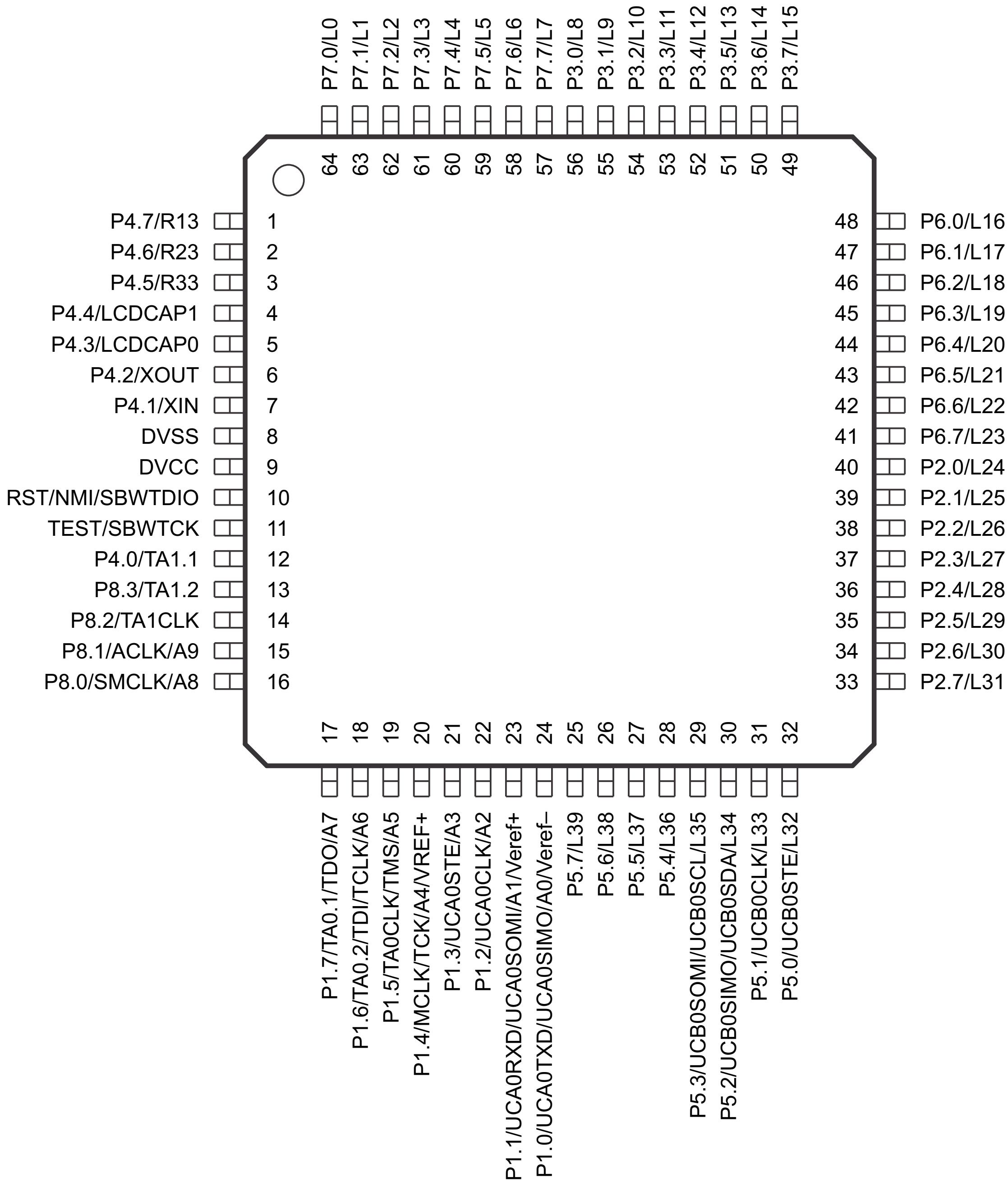


Figure 13. MSP430FR4133 Pinout

3.1.3 Software Examples

There are two BOOST-IR software examples included with the MSP-EXP430FR4133 LaunchPad (see Table 3), which can be found in the MSP-EXP430FR4133 Software Examples.

Table 3. Software Examples

Demo Name	LaunchPad Required	Description	More Details
IR Emitter and Receiver	MSP-EXP430FR4133	This example uses **two** MSP-EXP430FR4133 LaunchPad kits and BOOST-IR BoosterPack modules to communicate. One LaunchPad is programmed with the Emitter code, and the other is programmed with the Receiver code.	Section 3.1.5
IR Learning Mode	MSP-EXP430FR4133	This example uses **one** MSP-EXP430FR4133 LaunchPad with the BOOST-IR BoosterPack to copy and repeat IR sequences from some other IR emitter (for example, a TV remote control)	Section 3.1.6

3.1.4 Development Environment Requirements

To use any of the software examples with the LaunchPad, you must have an integrated development environment (IDE) that supports the MSP430FR4133 device.

Table 4. IDE Minimum Requirements for MSP430FR4133

Code Composer Studio™ IDE	IAR Embedded Workbench™ IDE
CCS v 6.1 or later	IAR EW430 v7.0 or later

For more details on where to download the latest IDE, see Section 4.2.

3.1.4.1 CCS

CCS 6.1 or higher is required. When CCS has been launched and a workspace directory chosen, use Project > Import Existing CCS Eclipse Project (see Figure 14). Browse to the desired demo project directory that contains main.c. This is IR_Emitter_and_Receiver or IR_Learning_Mode.

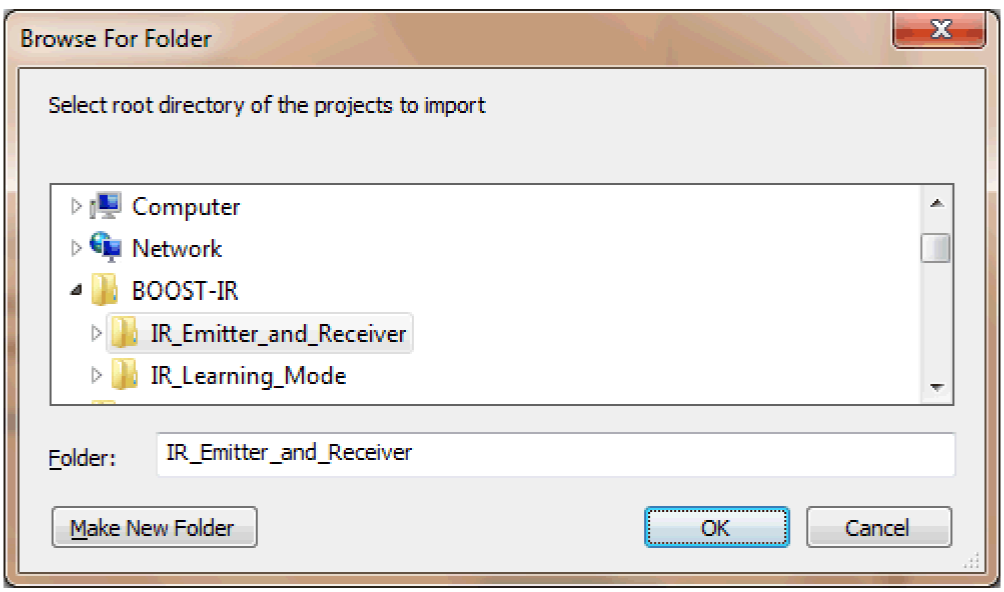


Figure 14. Directing the Project>Import Function to the Demo Project

Selecting the \CCS folder 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 the project is that its name is shown in the Import CCS Eclipse Projects window with a check mark to the left of it, as shown in Figure 15.

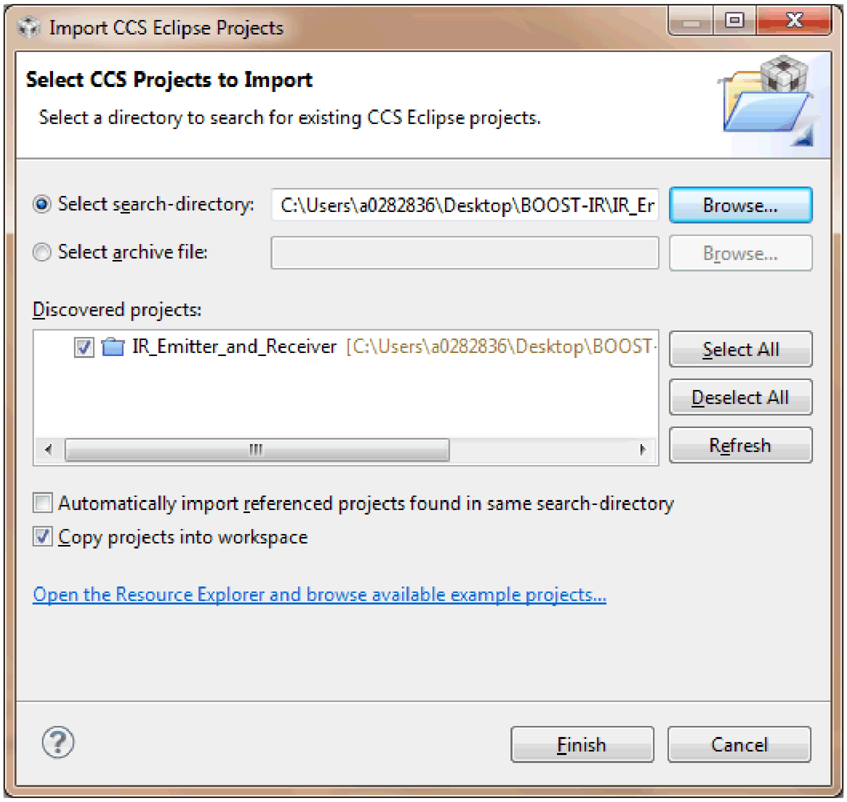


Figure 15. When CCS Has Found the Project

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's directory on the file system.)

Make sure to check Copy projects into workspace, then click Finish to complete the import process. For the IR Emitter and Receiver project, note that the project contains two separate pieces of code – one for programming the device for transmit and one for programming the device to receive. This is handled within one project by using build configurations. To change between Emitter and Receiver, right-click on the CCS project and go to Build Configurations > Set Active and then select either IR Emitter or IR Receiver.

3.1.4.2 IAR

IAR 6.10.2 or higher is required. To open the demo in IAR, click File>Open>Workspace…, and browse to the *.eww workspace file inside the \IAR folder of the desired demo. All workspace information is contained within this file.

The \IAR folder 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 MSP430Ware, which contains MSP430™ libraries and the TI Resource Explorer. These are already included in a CCS installation (unless the user selected otherwise).

3.1.5 IR Emitter and Receiver Software Example

This code shows how to send and receive IR signals using the BOOST-IR BoosterPack. The example requires two sets of MSP-EXP430FR4133 LaunchPad kits and BOOST-IR BoosterPack modules to communicate with each other.

3.1.5.1 Source File Structure

This project is organized in multiple files. This makes it easier to navigate and reuse parts of it for other projects. Table 5 describes each file in the project.

Table 5. Source Files and Folders

Name	Description
FR4133_IR_BP_RX.c	IR receiver main function, IR setup and processing, and other functions
FR4133_IR_BP_TX.c	IR emitter main function, IR setup and processing, and other functions
HAL_FR4133LP_Board.c	Board initialization functions, keypad scanning functions
HAL_FR4133LP_LCD.c	LCD initialization functions, LCD display functions

3.1.5.2 IR Emitter Example

The IR Emitter code sends messages to the other board. Whenever a button is pressed on the BoosterPack, a command corresponding to the key pressed is sent to the other board. You can tell that the IR emitter code is loaded into the BoosterPack because the LCD radio symbol and TX are displayed. An LED is lit when the transmission is happening. The button that is pressed is also displayed on the LCD.

This example makes use of the IR features of the MSP430FR4133 device for generating an ASK modulated signal. TA1CCR2 generates the envelope for the data to be sent, and TA0CCR2 generates the carrier frequency. The timers are connected internally and using the SYSCFG settings are combined to generate the IR signal output on a pin, which goes to the IR emitter LED on the BoosterPack. For more details on the IR generation using the IR modulation features of the MSP430FR4133, and information on how data is encoded in the examples, see Section 3.1.1.

3.1.5.3 IR Receiver Example

The IR Receiver code receives messages from the emitter board. Whenever a signal is received from the other board (i.e. when a button on the keypad is pressed on the other BoosterPack), and the Receiver BoosterPack receives the signal, the name of the button pressed is displayed on the LaunchPad LCD. For example, if the button POWER is pressed on the emitter BoosterPack, and the signal is received by the receiver BoosterPack, "POWER" is displayed on the receiver LaunchPad LCD and the LED on P4.0 blinks.

This example uses the IR receiver and demodulator on the BoosterPack to strip the carrier off of the received signal. This means that the signal into the MSP430 is just the envelope signal. The timer capture registers are used to measure the high and low pulses to decode the data. For more details on the IR demodulation and decode using the BoosterPack hardware and the timers of the MSP430FR4133, and for information on how data is encoded in the examples, see Section 3.1.1.

3.1.6 IR Learning Mode Software Example

The Learning Mode example can receive IR sequences from a remote control or other device and store them in memory associated with different buttons on the BoosterPack keypad. Then the sequences can be transmitted from the BoosterPack by pushing the keypad buttons, and used to control IR devices.

3.1.6.1 Source File Structure

This project is organized in multiple files. This makes it easier to navigate and reuse parts of it for other projects. Table 6 describes each file in the project.

Table 6. Source Files and Folders

Name	Description
FR4133_IR_BP_Learn.c	IR Learning mode main function, IR setup and processing, and other functions
HAL_FR4133LP_Learn_Board.c	Board initialization functions, keypad scanning functions
HAL_FR4133LP_LCD.c	LCD initialization functions, LCD display functions

3.1.6.2 IR Learning Mode Example

When the COPY button is pressed, the firmware enters learning mode. Push the button on the keypad that you want to train, and then transmit the signal to be learned from a device like a TV remote. Continue this until all desired buttons are assigned, and then press OK to return to normal transmit mode. Now, when a button is pressed, the stored signal is transmitted.

While receiving signals in learning mode, the MSP430FR4133 device uses the timer capture function to record the time between signal edges for the high and low pulses. The sequence of pulse lengths is stored in FRAM for later use to generate the same signal when the button is pressed. For more details about how the learning mode software works, see Section 3.1.1.5.

Note that the IR receiver and demodulator on the BoosterPack is tuned for 38-kHz carrier frequency. This is one of the most common carrier frequencies used by many remote control manufacturers for a number of devices. If communication needs to be with a device that uses a different carrier (for example, 40 kHz), this component can be replaced with a different receiver and demodulator device.

3.1.7 Testing

3.1.7.1 Test Environment

For current measurements

Test instrument: Fluke 87, set to µA measurement

Voltage supply at 3.3 V applied to MSP-EXP430FR4133 3V3 and GND pins on J6 of LaunchPad. All jumpers on LaunchPad J101 removed to exclude the eZ-FET from the measurement. JP1 for LED is also removed to remove the indicator LED (not transmission LED) from the measurement as well.

For range measurements

Measured with two MSP-EXP430FR4133 + BOOST-IR, one programmed as Emitter, and one programmed as Receiver. Environment was a normal home/office environment with normal ambient overhead white fluorescent lighting and with no obstructions between the LaunchPads. Distance was increased until the Receiver LaunchPad no longer received correct codes from Transmitter LaunchPad.

Range was tested with two different resistor values to show the impact of the resistor size on IR signal strength. Changing this resistor is described in Section 2.1.3.2.

3.1.7.2 Test Data

Table 7 shows current measurements both with and without the BOOST-IR module connected to the board. This is to show the contribution of just the MSP430 versus the consumption of the whole system.

Table 7. Current Consumption

Software	Idle Current With BOOST-IR (No Buttons Pressed)	Idle Current (MSP-EXP430FR4133 Only)
IR Emitter	830 µA	4.0 µA
IR Receiver	1059 µA	238 µA

Current consumption when the BOOST-IR module is present is much higher due to the consumption of the IR demodulator TSOP58238 module. The TSOP58238 module on its own consumes approximately 800 µA, so it makes up the bulk of the current consumption of the system. For product designs where IR RX function is not needed, only TX, this device could be eliminated and a lower current consumption in idle mode more like the MSP-EXP430FR4133 current for IR Emitter shown above could be achieved. Note that while sending a transmission by pressing a button, the current peaks – this peak current depends on the R value that you have selected for R2 (which also affects range as detailed below).

The current consumption for IR Receiver mode of just the MSP-EXP430FR4133 was measured at approximately 238 µA. This is higher than the IR Emitter code, because while the IR Emitter code can remain in LPM3 until a button is pressed, the IR Receiver must have the timer capture set up with the timer module sourced from the high-frequency SMCLK to have a high enough timer resolution to decode the signals. To keep SMCLK enabled while idle, IR Emitter code can only enter LPM0, because this is the lowest power mode in which SMCLK is on. See the MSP430FR4133 data sheet (SLAS865) for more details about low-power modes (LPMs) and current consumption.

Table 8. Range Testing

Resistor Used for R2 (Ω)	Range (meters)
47	8 m
4.7	20 m

By default, the BOOST-IR module comes with a 47-Ω resistor for R2. R2 controls the TX current for the IR LED. This has a direct effect on the brightness of the IR LED and therefore the range of transmission that is possible. When testing with the TX and RX code examples, the maximum range for transmitting from one BOOST-IR to the other was 8 meters with the default 47-Ω R2 – at longer distances, transmission and reception became unreliable. When the value of R2 was changed to 4.7 Ω, the LED is driven with more current and able to transmit much farther. In our test, we achieved a 20-meter transmission distance with this resistor. Using a smaller R2 allows for longer transmission distances at the expense of increased current consumption. For transmission power this high, external power must be provided, because the MSP-EXP430FR4133 and other LaunchPads are unable to provide this much power directly. In a production design, experimentation should be used to help determine the best resistor value to achieve the desired transmission range while still fitting within the design's power budget.

3.1.8 Design Files

For software files, see the MSP-EXP430FR4133 Software Examples

For hardware files, see:

- BOOST-IR Hardware Design Files and Section 2 and Section 6.
- MSP-EXP430FR4133 Hardware Design Files

4 Additional Resources

4.1 TI LaunchPad Portal

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

- TI's LaunchPad portal: information about all LaunchPad kits from TI for all MCUs

4.2 Download CCS, IAR, or Energia

Although the 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), IAR, or Energia.

4.3 MSP430Ware and TI Resource Explorer

MSP430Ware is a complete collection of libraries and tools. It includes a driver library (driverlib), graphics library (grlib), and many other software tools. MSP430Ware is optionally included in a CCS installation or can be downloaded separately. IAR users must download it separately.

MSP430Ware includes the TI Resource Explorer, for easily browsing tools. For example, Figure 16 shows all the software examples in the tree. Inside TI Resource Explorer, these examples and many more can be found and easily imported into CCS with one click.

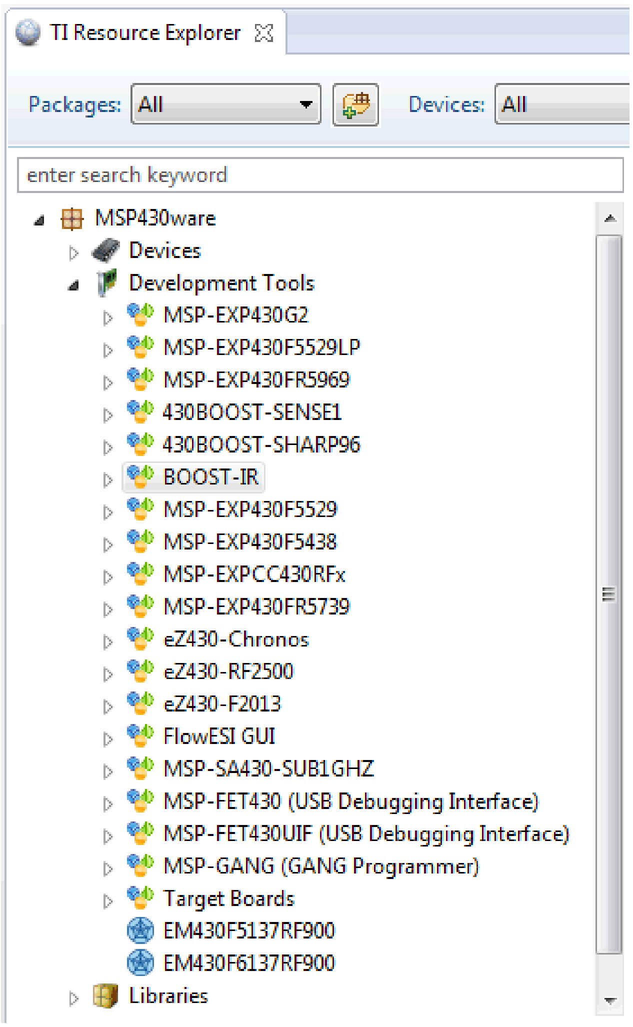


Figure 16. BOOST-IR Software Examples in TI Resource Explorer

4.4 The Community

4.4.1 TI E2E™ Community

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

4.4.2 Community at Large

Many online communities are dedicated to the LaunchPad and BoosterPack ecosystem – for example, http://www.43oh.com. You can find additional tools, resources, and support from these communities.

5 FAQs

Q: Why does one column on my keypad not work?

A: On some LaunchPads, one of the column pins is connected to the UART RX pin through the backchannel UART. Disconnect the UART RX jumper on the LaunchPad isolation block.

Q: Why do I receive everything that I transmit?

A: The receiver module is sensitive, and receives almost every transmission sent by the IR LED. Make sure that your firmware ignores the messages that you send.

6 Schematics

Hardware design files can be downloaded from www.ti.com/lit/zip/slar104.

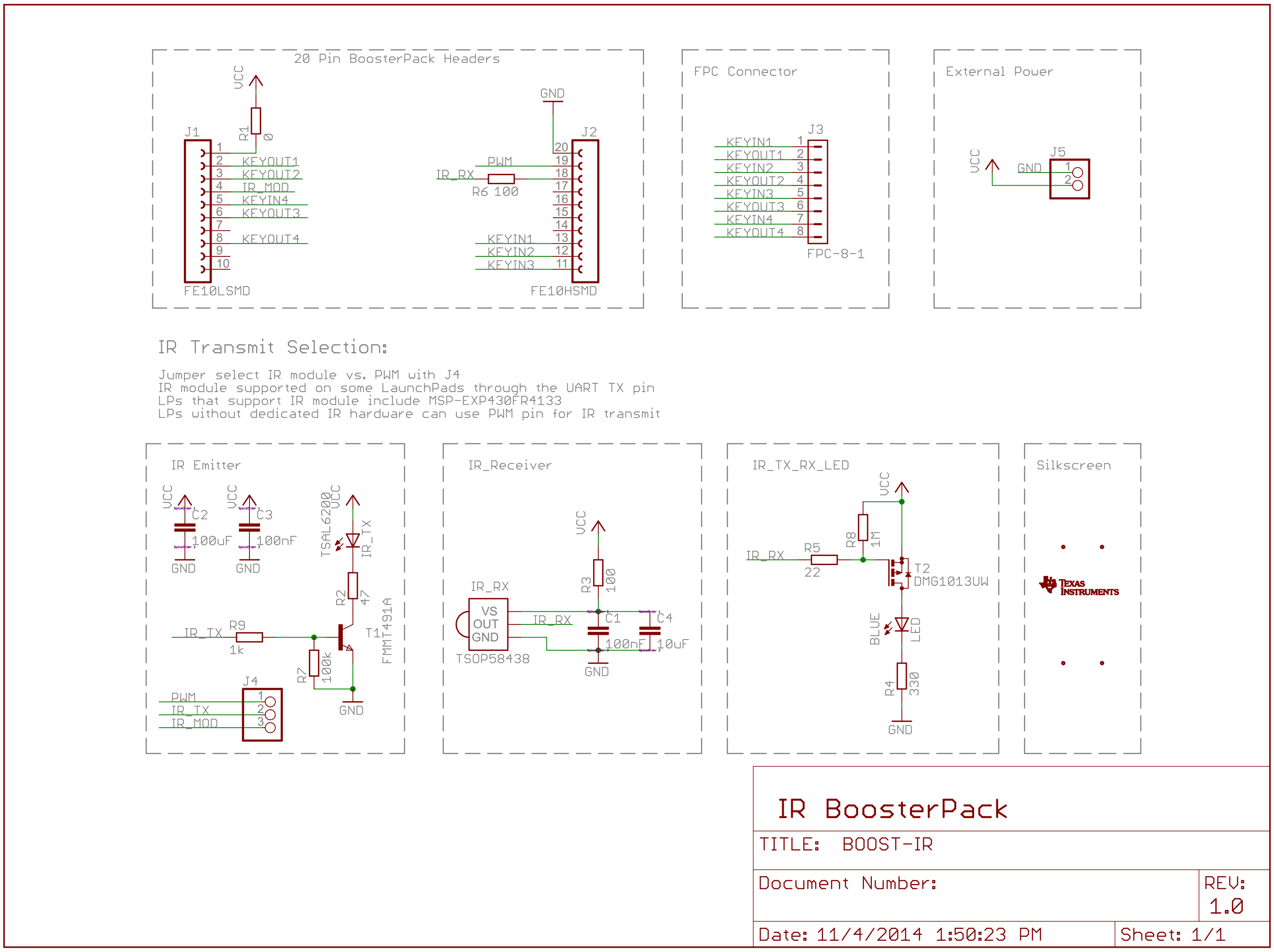


Figure 17. Schematics

Revision History

Changes from December 5, 2014 to July 20, 2015 **Page**

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

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