# TM4C Series TM4C129E Crypto Connected LaunchPad Evaluation Kit

**EK-TM4C129EXL**

# User's Guide

![Texas Instruments logo]

![Texas Instruments logo]

# Contents

Contents 3

# List of Figures

# List of Tables

# Board Overview

The TM4C Series TM4C129E Crypto Connected LaunchPad™ Evaluation Board (EK-TM4C129EXL) is a low-cost evaluation platform for ARM® Cortex®-M4F-based microcontrollers. The Crypto Connected LaunchPad design highlights the TM4C129ENCPDT microcontroller with its on-chip crypto acceleration hardware, 10/100 Ethernet MAC and PHY, USB 2.0, hibernation module, motion control pulse-width modulation and a multitude of simultaneous serial connectivity. The Crypto Connected LaunchPad also features two user switches, four user LEDs, dedicated reset and wake switches, a breadboard expansion option and two independent BoosterPack XL expansion connectors. The pre-programmed out of the box demo on the Crypto Connected LaunchPad also enables remote monitoring and control of the evaluation board securely from an internet browser anywhere in the world. The web interface is provided by 3rd party, Exosite. Each Crypto Connected LaunchPad is enabled on the Exosite platform allowing users to create and customize their own secure Internet-of-Things (IoT) applications.

Figure 1-1 shows a photo of the Crypto Connected LaunchPad with key features highlighted.
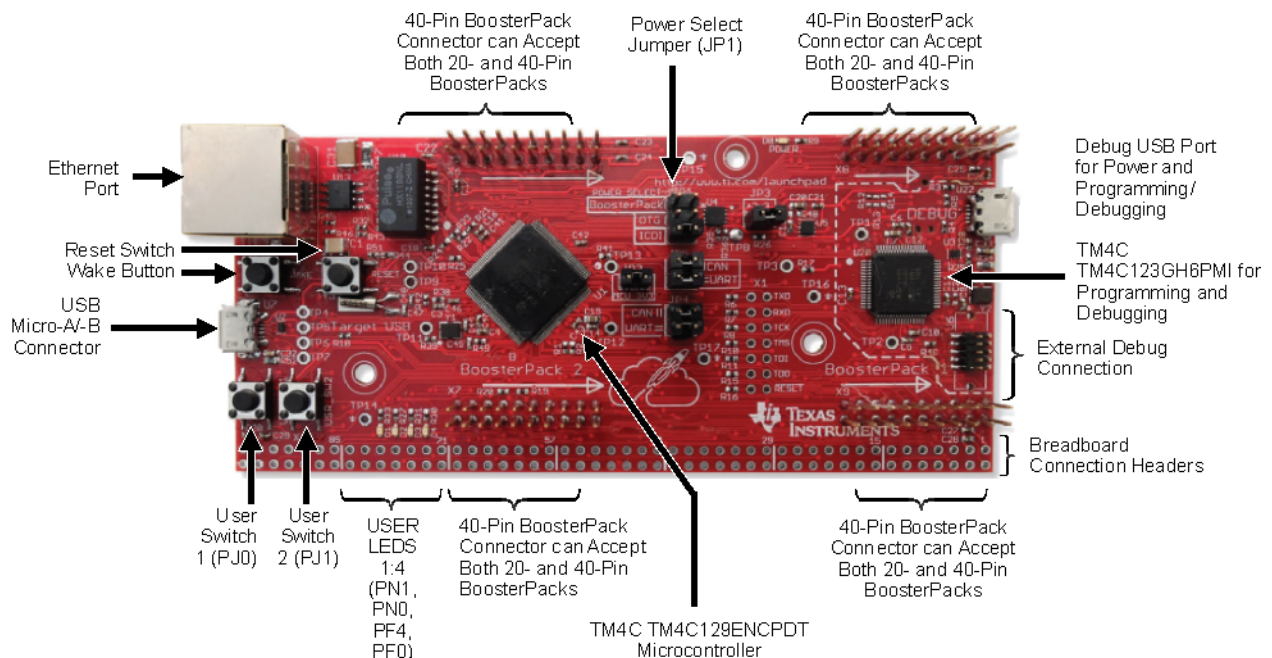


**Figure 1-1. TM4C Series Crypto Connected LaunchPad Evaluation Board**

## 1.1  Kit Contents

The Crypto Connected LaunchPad Evaluation Kit contains the following items:

- TM4C Series TM4C129E Evaluation Board (EK-TM4C129EXL)
- Retractable Ethernet cable
- USB Micro-B plug to USB-A plug cable
- 90° 49x2 breadboard header
- *Meet the TM4C Series TM4C129E Crypto LaunchPad Evaluation Kit* (SPMZ862)

## 1.2  Using the Crypto Connected LaunchPad

The recommended steps for using the Crypto Connected LaunchPad Evaluation Kit are:

1. **Follow the README First document included in the kit.** The README First helps you get the Crypto Connected LaunchPad up and running in minutes. Within just a few minutes you can be controlling and monitoring the Crypto Connected LaunchPad through the internet using Exosite and the pre-programmed out of the box demo.

2. **Experiment with BoosterPacks.** This evaluation kit conforms to the latest revision of the BoosterPack pinout standard. It has two independent BoosterPack connections to enable a multitude of expansion opportunities.

3. **Take the first step towards developing your own applications.** The Crypto Connected LaunchPad is supported by TivaWare™ for C Series. All the applications that work on TM4C series TM4C1294 Connected LaunchPad Evaluation Board (EK-TM4C1294XL) will work on the Crypto Connected LaunchPad. After installing TivaWare, look in the installation directory for *examples\boards\EK-TM4C1294XL*. You can find pre-configured example applications for the Connected LaunchPad board as well as for with selected BoosterPacks. These examples will work on the Crypto Connected LaunchPad board. Alternately, use Energīa for a wiring framework-based cross-platform, fast-prototyping environment that works with this and other TI LaunchPads. For more details about software development, see Chapter 3 of this document. TivaWare can be downloaded from the TI website at http://www.ti.com/tool/sw-tm4c. Energīa can be found at http://energia.nu.

4. **Customize and integrate the hardware to suit your end application.** This evaluation kit can be used as a reference for building your own custom circuits based on TM4C microcontrollers or as a foundation for expansion with your custom BoosterPack or other circuit. This manual can serve as a starting point for this endeavor.

5. **Get Trained.** You can also download hours of written and video training materials on this and related LaunchPads. For more information, visit the TM4C Series LaunchPad Workshop Wiki.

6. **More Resources.** For more information and the available BoosterPacks, see the TI MCU LaunchPad web page (http://www.ti.com/tiva-c-launchpad).

## 1.3  Features

Your Crypto Connected LaunchPad includes the following features:

- TM4C129ENCPDT microcontroller
- Ethernet connectivity with fully integrated 10/100 Ethernet MAC and PHY motion control pulse width modulation (PWM)
- Crypto acceleration hardware blocks
- USB 2.0 Micro A/B connector
- Four user LEDs
- Two user buttons
- One independent hibernate wake switch
- One independent microcontroller reset switch

- Jumper for selecting power source:
  - ICDI USB
  - USB Device
  - BoosterPack
- Preloaded secure access of Internet-of-Things product to Exosite application
- I/O brought to board edge for breadboard expansion
- Two independent BoosterPack XL standard connectors featuring stackable headers to maximize expansion through BoosterPack ecosystem
  - For a complete list of BoosterPacks, see the TI MCU LaunchPad web page: http://www.ti.com/launchpad

## 1.4 BoosterPacks

The Crypto Connected LaunchPad provides an easy and inexpensive way to develop applications with the TM4C129ENCPDT microcontroller. BoosterPacks are add-on boards that follow a pin-out standard created by Texas Instruments. The TI and third-party ecosystem of BoosterPacks greatly expands the peripherals and potential applications that you can easily explore with the Crypto Connected LaunchPad.

You can also build your own BoosterPack by following the design guidelines on TI's website. Texas Instruments even helps you promote your BoosterPack to other members of the community. TI offers a variety of avenues for you to reach potential customers with your solutions.

## 1.5 Energīa

Energīa is an open-source electronics prototyping platform started in January of 2012 with the goal of bringing the Wiring and Arduino framework to the TI LaunchPad community. Energīa includes an integrated development environment (IDE) that is based on Processing.

Together with Energīa, LaunchPads can be used to develop interactive objects, taking inputs from a variety of switches or sensors, and controlling a variety of lights, motors, and other physical outputs. LaunchPad projects can be stand-alone (only run on the target board, for example, your LaunchPad), or they can communicate with software running on your computer (Host PC). Energīa projects are highly portable between supported LaunchPad platforms.

More information is available at http://energia.nu.

## 1.6 Specifications

Table 1-1 summarizes the specifications for the Crypto Connected LaunchPad.

**Table 1-1. EK-TM4C129EXL Specifications**

| Parameter | Value |
|---|---|
| Board Supply Voltage | 4.75 $V_{DC}$ to 5.25 $V_{DC}$ from one of the following sources: See schematic symbol JP1 for power input selection. <br>• Debug USB U22 (ICDI) USB Micro-B cable connected to PC or other compatible power source.<br>• Target USB (U7) USB Micro-B cable connected to PC or other compatible power source.<br>• BoosterPack 1 (X8-4)<br>• BoosterPack 2 (X6-4)<br>• Breadboard expansion header (X11-2 or X11-97). |
| Dimensions | 4.9 in x 2.2 in x .425 in (12.45 cm x 5.59 cm x 10.8 mm) (L x W x H) |
| Break-out Power Output | • 5 $V_{DC}$ to BoosterPacks, current limited by TPS2052B. Nominal rating 1 Amp. Board input power supply limitations may also apply.<br>• 3.3 $V_{DC}$ to BoosterPacks, limited by output of TPS73733 LDO. This 3.3-V plane is shared with on-board components. Total output power limit of TPS73733 is 1 Amp. |
| RoHS Status | Compliant |

# Hardware Description

The Crypto Connected LaunchPad includes a TM4C129ENCPDT microcontroller with an integrated 10/100 Ethernet MAC and PHY and crypto acceleration blocks. This advanced ARM Cortex M4F MCU has a wide range of peripherals that are made available to users via the on-board accessories and the BoosterPack connectors. This chapter explains how those peripherals operate and interface to the microcontroller.

Figure 2-1 provides a high-level block diagram of the Crypto Connected LaunchPad.
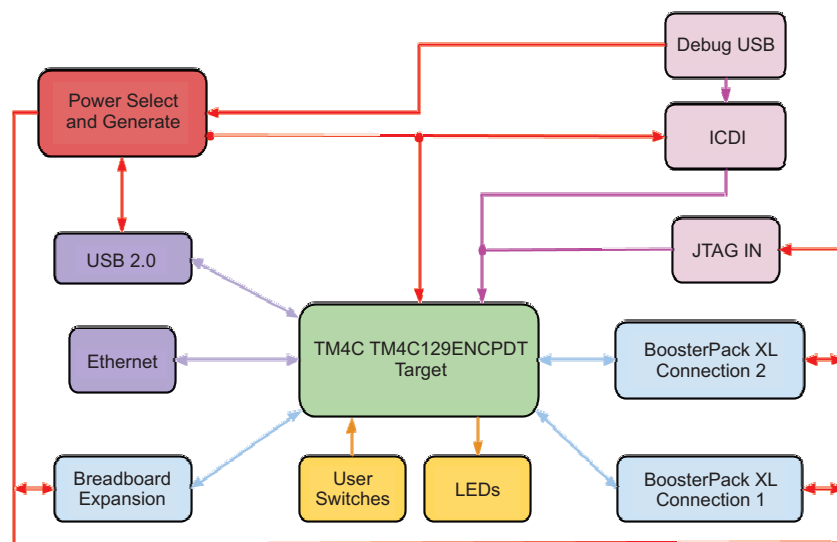


**Figure 2-1. TM4C Crypto Connected LaunchPad Evaluation Board Block Diagram**

## 2.1  Functional Description

### 2.1.1  Microcontroller

The TM4C129ENCPDT is a 32-bit ARM Cortex-M4F based microcontroller with 1024-kB Flash memory, 256-kB SRAM, 6-kB EEPROM, and 120 MHz operation; integrated 10/100 Ethernet MAC and PHY; integrated hardware crypto accelerators; integrated USB 2.0 connectivity with external high-speed USB 3.0 PHY capability; a hibernation module, a multitude of serial connectivity and motion control PWM; as well as a wide range of other peripherals. For more complete details, see the TM4C129ENCPDT microcontroller data sheet.

Most of the microcontroller's signals are routed to 0.1-in (2.54-mm) pitch headers or through-hole solder pads. An internal multiplexor allows different peripheral functions to be assigned to each of these general-purpose input/output (GPIO) pads. When adding external circuitry, consider the additional load on the evaluation board power rails.

The TM4C129ENCPDT microcontroller is factory-programmed with an out of the box demo program. The out of the box program resides in on-chip Flash memory and runs each time power is applied, unless the out of the box application has been replaced with a user program. The out of the box application automatically connects to https://ti.exosite.com when an internet connection is provided through the RJ45 Ethernet jack on the evaluation board.

### 2.1.2 Ethernet Connectivity

The Crypto Connected LaunchPad is designed to connect directly to an Ethernet network using RJ45 style connectors. The microcontroller contains a fully integrated Ethernet MAC and PHY. This integration creates a simple, elegant and cost-saving Ethernet circuit design. Example code is available for both the uIP and LwIP TCP/IP protocol stacks. The embedded Ethernet on this device can be programmed to act as an HTTP server, client or both. The design and integration of the circuit and microcontroller also enable users to synchronize events over the network using the IEEE1588 precision time protocol.

When configured for an Ethernet operation, it is recommended that the user configure LED D3 and D4 to be controlled by the Ethernet MAC to indicate connection and transmit/receive status.

### 2.1.3 Crypto Accelerators

The Crypto Connected LaunchPad features the hardware acceleration blocks such as Advanced Encryption Standard (AES), Data Encryption Standard (DES), and Secure Hash Algorithm/MD5 Message Digest Algorithm (SHA/MD5) that offload data encryption and decryption functions from CPU. These hardware cipher blocks support the µDMA operation and have improved performance over software cipher blocks.

The AES block is a symmetric cipher module that supports multiple encrypt and decrypt operations, feedback operating modes, authentication modes, key sizes (128 bit, 192 bit, or 256 bit) and key scheduling in hardware. The DES block is also a symmetric cipher module with DES/3DES encryption and decryption along with support for multiple feedback operating modes. The SHA/MD5 block is a hash module that can run functions like MD5, SHA-1, SHA224, SHA256 and Hash message authentication code (HMAC).

### 2.1.4 USB Connectivity

The Crypto Connected LaunchPad is designed to be USB 2.0 ready. A TPS2052B load switch is connected to and controlled by the microcontroller USB peripheral, which manages power to the USB micro A/B connector when functioning in a USB host. When functioning as a USB device, the entire Crypto Connected LaunchPad can be powered directly from the USB micro A/B connector. Use JP1 to select the desired power source.

USB 2.0 functionality is provided and supported directly out of the box with the target USB micro A/B connector. High-speed USB 3.0 functionality can be enabled by adding an external USB PHY. The USB external PHY control and data signals are provided on the breadboard expansion header X11.

### 2.1.5 Motion Control

The Crypto Connected LaunchPad includes the TM4C Series Motion Control PWM technology, featuring a PWM module capable of generating eight PWM outputs. The PWM module provides a great deal of flexibility and can generate simple PWM signals (for example, those signals required by a simple charge pump, as well as paired PWM signals with dead-band delays such as those required by a half-H bridge driver). Three generator blocks can also generate the full six channels of gate controls required by a 3-phase inverter bridge.

A quadrature encoder interface (QEI) is also available to provide motion control feedback.

For details about the availability of these signals on the BoosterPack interfaces, see the BoosterPacks and Headers of this document.

### 2.1.6  User Switches and LED's

Two user switches are provided for input and control of the TM4C129ENCPDT software. The switches are connected to GPIO pins PJ0 and PJ1.

A reset switch and a wake switch are also provided. The reset switch initiates a system reset of the microcontroller whenever it is pressed and released. Pressing the reset switch also asserts the reset signal to the BoosterPack and Breadboard headers. The wake switch is one way to bring the device out of hibernate mode.

Four user LEDs are provided on the board. D1 and D2 are connected to GPIOs PN1 and PN0. These LEDs are dedicated for use by the software application. D3 and D4 are connected to GPIOs PF4 and PF0, which can be controlled by user's software or the integrated Ethernet module of the microcontroller.

A power LED is also provided to indicate that 3.3 V power is present on the board.

### 2.1.7 BoosterPacks and Headers

#### 2.1.7.1 BoosterPack 1

The Crypto Connected LaunchPad features two fully independent BoosterPack XL connectors. BoosterPack 1, located around the ICDI portion of the board, is fully compliant with the BoosterPack standard with the single exception of GPIO pin PA6 (X8-16), which does not provide analog capability. PA6 is located near the bottom of the inner left BoosterPack XL header.

Inter-integrated circuit (I2C) is provided in both the original BoosterPack standard configuration as well as the updated standard location. Use of I2C on the bottom left of the BoosterPack connections per the updated standard is highly encouraged whenever possible.

Motion control advanced PWM connections are provided on the inner right connector for motion control applications.

Table 2-1 provides a complete listing of the BoosterPack pins and the GPIO alternate functions available on each pin. The TM4C129ENCPDT GPIO register GPIOPCTL values are shown for each configuration. The headers in this table are labeled from left to right in ten pin columns. 'A' and 'D' make up the outer BoosterPack standard pins, 'B' and 'C' make up the inner BoosterPack XL standard pins.

**Table 2-1. BoosterPack 1 GPIO and Signal Muxing**

| Header | Pin | Standard Function | GPIO | MCU Pin | Analog | Digital Function (GPIOPCTL Bit Encoding) | | | | | | | | | | |
|--------|-----|-------------------|------|---------|--------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| | | | | | | 1 | 2 | 3 | 5 | 6 | 7 | 8 | 11 | 13 | 14 | 15 |
| A1 | 1 | +3.3 V | | | | 3.3 V | | | | | | | | | | |
| A1 | 2 | Analog | PE4 | 123 | AIN9 | U1RI | - | - | - | - | - | - | - | - | - | SSI1XDAT0 |
| A1 | 3 | UART RX | PC4 | 25 | C1- | U7Rx | - | - | - | - | - | - | - | - | - | EPI0S7 |
| A1 | 4 | UART TX | PC5 | 24 | C1+ | U7Tx | - | - | - | RTCCLK | - | - | - | - | - | EPI0S6 |
| A1 | 5 | GPIO | PC6 | 23 | C0+ | U5Rx | - | - | - | - | - | - | - | - | - | EPI0S5 |
| A1 | 6 | Analog | PE5 | 124 | AIN8 | - | - | - | - | - | - | - | - | - | - | SSIXDAT1 |
| A1 | 7 | SPI CLK | PD3 | 4 | AIN12 | - | I2C8SDA | T1CCP1 | - | - | - | - | - | - | - | SSI2CLk |
| A1 | 8 | GPIO | PC7 | 22 | C0- | U5Tx | - | - | - | - | - | - | - | - | - | EPI0S4 |
| A1 | 9 | I2C SCL | PB2 | 91 | - | - | I2C0SCL | T5CCP0 | - | - | - | - | - | - | USB0STP | EPI0S27 |
| A1 | 10 | I2C SDA | PB3 | 92 | - | - | I2C0SDA | T5CCP1 | - | - | - | - | - | - | USB0CLK | EPI0S28 |
| B1 | 1 | +5 volts | | | | 5 V | | | | | | | | | | |
| B1 | 2 | Ground | | | | GND | | | | | | | | | | |
| B1 | 3 | Analog | PE0 | 15 | AIN3 | U1RTS | - | - | - | - | - | - | - | - | - | - |
| B1 | 4 | Analog | PE1 | 14 | AIN2 | U1DSR | - | - | - | - | - | - | - | - | - | - |
| B1 | 5 | Analog | PE2 | 13 | AIN1 | U1DCD | - | - | - | - | - | - | - | - | - | - |
| B1 | 6 | Analog | PE3 | 12 | AIN0 | U1DTR | - | - | - | - | - | - | - | - | - | - |
| B1 | 7 | Analog | PD7 | 128 | AIN4 | U2CTS | - | T4CCP1 | USB0PFLT | - | - | NMI | - | - | - | SSI2XDAT2 |
| B1 | 8 | Analog | PA6 | 40 | - | U2Rx | I2C6SCL | T3CCP0 | USB0EPEN | - | - | - | - | SSI0XDAT2 | - | EPI0S8 |
| B1 | 9 | A out | PM4 | 74 | TMPR3 | U0CTS | - | T4CCP0 | - | - | - | - | - | - | - | - |
| B1 | 10 | A out | PM5 | 73 | TMPR2 | U0DCD | - | T4CCP1 | - | - | - | - | - | - | - | - |

### Table 2-1. BoosterPack 1 GPIO and Signal Muxing (continued)

| Header | Pin | Standard Function | GPIO | MCU Pin | Analog | Digital Function (GPIOPCTL Bit Encoding) | | | | | | | | | | |
|--------|-----|-------------------|------|---------|--------|----|----|----|----|----|----|----|----|----|----|----|
| | | | | | | 1 | 2 | 3 | 5 | 6 | 7 | 8 | 11 | 13 | 14 | 15 |
| C1 | 1 | PWM | PF1 | 43 | - | - | - | - | EN0LED2 | M0PWM1 | - | - | - | - | SSI3XDAT0 | TRD1 |
| C1 | 2 | PWM | PF2 | 44 | - | - | - | - | - | M0PWM2 | - | - | - | - | SSI3Fss | TRD0 |
| C1 | 3 | PWM | PF3 | 45 | - | - | - | - | - | M0PWM3 | - | - | - | - | SSI3Clk | TRCLK |
| C1 | 4 | PWM | PG0 | 49 | - | - | I2C1SCL | - | EN0PPS | M0PWM4 | - | - | - | - | - | EPI0S11 |
| C1 | 5 | Capture | PL4 | 85 | - | - | - | T0CCP0 | - | - | - | - | - | - | USB0D4 | EPI0S26 |
| C1 | 6 | Capture | PL5 | 86 | - | - | - | T0CCP1 | - | - | - | - | - | - | USB0D5 | EPI0S33 |
| C1 | 7 | GPIO | PL0 | 81 | - | - | I2C2SDA | - | - | M0FAULT3 | - | - | - | - | USB0D0 | EPI0S16 |
| C1 | 8 | GPIO | PL1 | 82 | - | - | I2C2SCL | - | - | PhA0 | - | - | - | - | USB0D1 | EPI0S17 |
| C1 | 9 | GPIO | PL2 | 83 | - | - | - | - | C0o | PhB0 | - | - | - | - | USB0D2 | EPI0S18 |
| C1 | 10 | GPIO | PL3 | 84 | - | - | - | - | C1o | IDX0 | - | - | - | - | USB0D3 | EPI0S19 |
| D1 | 1 | Ground | GND | | | | | | | | | | | | | |
| D1 | 2 | PWM | PM3 | 75 | - | - | - | T3CCP1 | - | - | - | - | - | - | - | EPI0S12 |
| D1 | 3 | GPIO | PH2 | 31 | - | U0DCD | - | - | - | - | - | - | - | - | - | EPI0S2 |
| D1 | 4 | GPIO | PH3 | 32 | - | U0DSR | - | - | - | - | - | - | - | - | - | EPI0S3 |
| D1 | 5 | Reset | RESET | | | | | | | | | | | | | |
| D1 | 6 | SPI MOSI | PD1 | 2 | AIN14 | - | I2C7SDA | T0CCP1 | C1o | - | - | - | - | - | - | SSI2XDAT0 |
| D1 | 7 | SPI MISO | PD0 | 1 | AIN15 | - | I2C7SCL | T0CCP0 | C0o | - | - | - | - | - | - | SSI2XDAT1 |
| D1 | 8 | GPIO | PN2 | 109 | - | U1DCD | U2RTS | - | - | - | - | - | - | - | - | EPI0S29 |
| D1 | 9 | GPIO | PN3 | 110 | - | U1DSR | U2CTS | - | - | - | - | - | - | - | - | EPI0S30 |
| D1 | 10 | GPIO | PP2 | 103 | - | U0DTR | - | - | - | - | - | - | - | - | USB0NXT | EPI0S29 |

### 2.1.7.2   BoosterPack 2

The second BoosterPack XL interface is located near the middle of the board. This interface is fully compliant with the BoosterPack standard and adds features not covered by the BoosterPack standard that enable operation with additional BoosterPacks.

An additional analog signal is provided on the outer left header (X6-9). This signal can be used to monitor the touch panel on the popular Kentec EB-LM4F120-L35 BoosterPack.

Using the jumpers JP4 and JP5, Controller Area Network (CAN) digital receive and transmit signals can be optionally routed to the BoosterPack 2 interface. The location of these signals is consistent with the CAN interface on the TM4C Series TM4C123G LaunchPad and the Stellaris LM4F120 LaunchPad. In the default configuration, UART0 is used for the ICDI virtual UART and CAN is not present on the BoosterPack headers. In this configuration, the ROM serial bootloader can be used over the ICDI virtual UART. When the jumpers are configured for CAN on the BoosterPack, then UART2 must be used for the ICDI virtual UART.

To comply with both the original and the new BoosterPack standard, I2C is provided on both sides of the BoosterPack connection. Use of I2C on the bottom left of the BoosterPack connection is highly encouraged where possible, to be in compliance with the new BoosterPack standard. To provide I2C capability on the right side of the connector, per the original standard, two zero-ohm resistors (R19 and R20) are used to combine the SPI and I2C signals. These signals are not shared with any other pins on the LaunchPad and therefore removal of these zero-ohm resistors should not be required. Software should be certain that unused GPIO signals are configured as inputs.

Table 2-2 provides a complete listing of the BoosterPack pins and the GPIO alternate functions available at each pin. The TM4C129ENCPDT GPIO register GPIOPCTL values are shown for each configuration. The headers in this table are labeled from left to right in ten pin columns. 'A' and 'D' make up the outer BoosterPack standard pins, 'B' and 'C' make up the inner BoosterPack XL standard pins.

### Table 2-2. BoosterPack 2 GPIO and Signal Muxing

| Header | Pin | Standard Function | GPIO | MCU Pin | Analog | Digital Function (FPIOPCTL Bit Encoding) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 1 | 2 | 3 | 5 | 6 | 7 | 8 | 11 | 13 | 14 | 15 |
| A2 | 1 | | | | | 3.3 V | | | | | | | | | | |
| A2 | 2 | Analog | PD2 | 3 | AIN13 | - | I2C8SCL | T1CCP0 | C2o | - | - | - | - | - | - | SSI2Fss |
| A2 | 3 | UART RX | PP0 | 118 | C2+ | U6Rx | - | - | - | - | - | - | - | - | - | SSI3XDAT2 |
| A2 | 4 | UART TX | PP1 | 119 | C2- | U6Tx | - | - | - | - | - | - | - | - | - | SSI3XDAT3 |
| A2 | 5 | GPIO (See JP4) | PD4 | 125 | AIN7 | U2Rx | - | T3CCP0 | - | - | - | - | - | - | - | SSI1XDAT2 |
| | | | PA0 | 33 | - | U0Rx | I2C9SCL | T0CCP0 | - | - | CANORx | - | - | - | - | - |
| A2 | 6 | Analog (See JP5) | PD5 | 126 | AIN6 | U2Tx | - | T3CCP1 | - | - | - | - | - | - | - | SSI1XDAT3 |
| | | | PA1 | 34 | - | U0Tx | I2C9SDA | T0CCP1 | - | - | CAN0Tx | - | - | - | - | - |
| A2 | 7 | SPI CLK | PQ0 | 5 | - | - | - | - | - | - | - | - | - | - | SSI3Clk | EPI0S20 |
| A2 | 8 | GPIO | PP4 | 105 | - | U3RTS | U0DSR | - | - | - | - | - | - | - | USB0D7 | - |
| A2 | 9 | I2C SCL | PN5 | 112 | - | U1RI | U3CTS | I2C2SCL | - | - | - | - | - | - | - | EPIO0S35 |
| A2 | 10 | I2C SDA | PN4 | 111 | - | U1DTR | U3RTS | I2C2SDA | - | - | - | - | - | - | - | EPIO0S34 |
| B2 | 1 | | | | | 5 V | | | | | | | | | | |
| B2 | 2 | | | | | GND | | | | | | | | | | |
| B2 | 3 | Analog | PB4 | 121 | AIN10 | U0CTS | I2C5SCL | - | - | - | - | - | - | - | - | SSI1Fss |

## Table 2-2. BoosterPack 2 GPIO and Signal Muxing (continued)

| Header | Pin | Standard Function | GPIO | MCU Pin | Analog | 1 | 2 | 3 | 5 | 6 | 7 | 8 | 11 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Digital Function (FPIOPCTL Bit Encoding) | | | | | | | | | | |
| B2 | 4 | Analog | PB5 | 120 | AIN11 | U0RTS | I2C5SDA | - | - | - | - | - | - | - | - | SSI1Clk |
| B2 | 5 | Analog | PK0 | 18 | AIN16 | U4Rx | - | - | - | - | - | - | - | - | - | EPI0S0 |
| B2 | 6 | Analog | PK1 | 19 | AIN17 | U4Tx | - | - | - | - | - | - | - | - | - | EPI0S1 |
| B2 | 7 | Analog | PK2 | 20 | AIN18 | U4RTS | - | - | - | - | - | - | - | - | - | EPI0S2 |
| B2 | 8 | Analog | PK3 | 21 | AIN19 | u4CTS | - | - | - | - | - | - | - | - | - | EPI0S3 |
| B2 | 9 | A out | PA4 | 37 | - | U3Rx | I2C7SCL | T2CCP0 | - | - | - | - | - | - | - | SSI0XDAT0 |
| B2 | 10 | A out | PA5 | 38 | - | U3Tx | I2C7SDA | T2CCP1 | - | - | - | - | - | - | - | SSI0XDAT1 |
| C2 | 1 | PWM | PG1 | 50 | - | - | I2C1SDA | - | - | M0PWM5 | - | - | - | - | - | EPI0S10 |
| C2 | 2 | PWM | PK4 | 63 | - | - | I2C3SCL | - | EN0LED0 | M0PWM6 | - | - | - | - | - | EPI0S32 |
| C2 | 3 | PWM | PK5 | 62 | - | - | I2C3SDA | - | EN0LED2 | M0PWM7 | - | - | - | - | - | EPI0S31 |
| C2 | 4 | PWM | PM0 | 78 | - | - | - | T2CCP0 | - | - | - | - | - | - | - | EPI0S15 |
| C2 | 5 | Capture | PM1 | 77 | - | - | - | T2CCP1 | - | - | - | - | - | - | - | EPI0S14 |
| C2 | 6 | Capture | PM2 | 76 | - | - | - | T3CCP0 | - | - | - | - | - | - | - | EPI0S13 |
| C2 | 7 | GPIO | PH0 | 29 | - | U0RTS | - | - | - | - | - | - | - | - | - | EPI0S0 |
| C2 | 8 | GPIO | PH1 | 30 | - | U0CTS | - | - | - | - | - | - | - | - | - | EPI0S1 |
| C2 | 9 | GPIO | PK6 | 61 | - | - | I2C4SCL | - | EN0LED1 | M0FAULT1 | - | - | - | - | - | EPI0S25 |
| C2 | 10 | GPIO | PK7 | 60 | - | U0RI | I2C4SDA | - | RTCCLK | M0FAULT2 | - | - | - | - | - | EPI0S24 |
| D2 | 1 | | | | | GND | | | | | | | | | | |
| D2 | 2 | PWM | PM7 | 71 | TMPR0 | U0RI | - | T5CCP1 | - | - | - | - | - | - | - | - |
| D2 | 3 | GPIO | PP5 | 106 | - | U3CTS | I2C2SDL | - | - | - | - | - | - | - | USB0D6 | - |
| D2 | 4 | GPIO | PA7 | 41 | - | U2Tx | I2C6SDA | T3CCP1 | USB0PFLT | - | - | - | USB0EPEN | SSI0XDAT3 | - | EPI0S9 |
| D2 | 5 | | | | | RESET | | | | | | | | | | |
| D2 | 6 | SPI MOSI | PQ2 | 11 | - | - | - | - | - | - | - | - | - | - | SSI3XDAT0 | EPI0S22 |
| D2 | 6 | I2C | PA3 | 36 | - | U4Tx | I2C8SDA | T1CCP1 | - | - | - | - | - | - | - | SSI0Fss |
| D2 | 7 | SPI MISO | PQ3 | 27 | - | - | - | - | - | - | - | - | - | - | SSI3XDAT1 | EPI0S23 |
| D2 | 7 | I2C | PA2 | 35 | - | U4Rx | I2C8SCL | T1CCP0 | - | - | - | - | - | - | - | SSI0Clk |
| D2 | 8 | GPIO | PP3 | 104 | - | U1CTS | U0DCD | - | - | - | - | - | - | - | USB0DIR | EPI0S30 |
| D2 | 9 | GPIO | PQ1 | 6 | - | - | - | - | - | - | - | - | - | - | SSI3Fss | EPI0S21 |
| D2 | 10 | GPIO | PM6 | 72 | TMPR1 | U0DSR | - | T5CCP0 | - | - | - | - | - | - | - | - |

### 2.1.7.3 Breadboard Connection

The breadboard adapter section of the board is a set of 98 holes on a 0.1 inch grid. Properly combined with a pair of right angle headers, the entire Crypto Connected LaunchPad can be plugged directly into a standard 300 mil (0.3 inch) wide solder-less breadboard. The right angle headers and breadboard are not provided with this kit. Suggested part numbers are Samtec TSW-149-09-L-S-RE and TSW-149-08-L-S-RA right angle pin headers and Twin industries TW-E40-1020 solder-less breadboard. Samtec TSW-149-09-F-S-RE and TSW-149-09-F-S-RA may be substituted.

A detailed explanation of how to install the headers is available on the TI LaunchPad Wiki or at http://users.ece.utexas.edu/~valvano/EE345L/Labs/Fall2011/LM3S1968soldering.pdf.

Nearly all microcontroller signals are made available at the breadboard adapter holes (X11). These signals are grouped by function, where possible. For example, all EPI signals are grouped on one side of the connector. Many of the analog signals are grouped near VREF, and UART, SSI and I2C signals are grouped by peripheral to make expansion and customization simpler.

Table 2-3 and Table 2-4 show the GPIO pin and signal muxing for the X11 breadboard adapter pads.

### Table 2-3. X11 Breadboard Adapter Odd-Numbered Pad GPIO and Signal Muxing

| Pin | Port | MCU PIN | Analog | Digital Function (GPIOPCTL Bit Encoding) | | | | | | | | | | |
|-----|------|---------|--------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| | | | | 1 | 2 | 3 | 5 | 6 | 7 | 8 | 11 | 13 | 14 | 15 |
| 1 | | | | 3V3 | | | | | | | | | | |
| 3 | | | | GND | | | | | | | | | | |
| 5 | PB4 | 121 | AIN10 | U0CTS | I2C5SCL | - | - | - | - | - | - | - | - | SSI1Fss |
| 7 | PB5 | 120 | AIN11 | U0RTS | I2C5SDA | - | - | - | - | - | - | - | - | SSI1Clk |
| 9 | PH0 | 29 | - | U0RTS | - | - | - | - | - | - | - | - | - | EPI0S0 |
| 11 | PH1 | 30 | - | U0CTS | - | - | - | - | - | - | - | - | - | EPI0S1 |
| 13 | PH2 | 31 | - | U0DCD | - | - | - | - | - | - | - | - | - | EPI0S2 |
| 15 | PH3 | 32 | - | U0DSR | - | - | - | - | - | - | - | - | - | EPI0S3 |
| 17 | PC7 | 22 | C0- | U5Tx | - | - | - | - | - | - | - | - | - | EPI0S4 |
| 19 | PC6 | 23 | C0+ | U5Rx | - | - | - | - | - | - | - | - | - | EPI0S5 |
| 21 | PC5 | 24 | C1+ | U7Tx | - | - | - | - | RTCCLK | - | - | - | - | EPI0S6 |
| 23 | PC4 | 25 | C1- | U7Rx | - | - | - | - | - | - | - | - | - | EPI0S7 |
| 25 | PA6 | 40 | - | U2Rx | I2C6SCL | T3CCP0 | USB0EPEN | - | - | - | - | SSI0XDAT2 | - | EPI0S8 |
| 27 | PA7 | 41 | - | U2Tx | I2C6SDA | T3CCP1 | USB0PFLT | - | - | - | USB0EPEN | SSI0XDAT3 | - | EPI0S9 |
| 29 | PG1 | 50 | - | - | I2C1SDA | - | - | M0PWM5 | - | - | - | - | - | EPI0S10 |
| 31 | PG0 | 49 | - | - | I2C1SCL | - | EN0PPS | M0PWM4 | - | - | - | - | - | EPI0S11 |
| 33 | PM3 | 75 | - | - | - | T3CCP1 | - | - | - | - | - | - | - | EPI0S12 |
| 35 | | | | GND | | | | | | | | | | |
| 37 | PM2 | 76 | - | - | - | T3CCP0 | - | - | - | - | - | - | - | EPI0S13 |
| 39 | PM1 | 77 | - | - | - | T2CCP1 | - | - | - | - | - | - | - | EPI0S14 |

**Table 2-3. X11 Breadboard Adapter Odd-Numbered Pad GPIO and Signal Muxing (continued)**

| Pin | Port | MCU PIN | Analog | Digital Function (GPIOPCTL Bit Encoding) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 1 | 2 | 3 | 5 | 6 | 7 | 8 | 11 | 13 | 14 | 15 |
| 41 | PM0 | 78 | - | - | - | T2CCP0 | - | - | - | - | - | - | - | EPI0S15 |
| 43 | PL0 | 81 | - | - | I2C2SDA | - | - | M0FAULT3 | - | - | - | - | USB0D0 | EPI0S16 |
| 45 | PL1 | 82 | - | - | I2C2SCL | - | - | PhA0 | - | - | - | - | USB0D1 | EPI0S17 |
| 47 | PL2 | 83 | - | - | - | - | C0o | PhB0 | - | - | - | - | USB0D2 | EPI0S18 |
| 49 | PL3 | 84 | - | - | - | - | C1o | IDX0 | - | - | - | - | USB0D3 | EPI0S19 |
| 51 | PQ0 | 5 | - | - | - | - | - | - | - | - | - | - | SSI3Clk | EPI0S20 |
| 53 | PQ1 | 6 | - | - | - | - | - | - | - | - | - | - | SSI3Fss | EPI0S21 |
| 55 | PQ2 | 11 | - | - | - | - | - | - | - | - | - | - | SSI3XDAT0 | EPI0S22 |
| 57 | PQ3 | 27 | - | - | - | - | - | - | - | - | - | - | SSI3XDAT1 | EPI0S23 |
| 59 | PK7 | 60 | - | U0RI | I2C4SDA | - | | - | - | - | - | - | - | EPI0S24 |
| 61 | | | | | | | GND | | | | | | | |
| 63 | PK6 | 61 | - | - | I2C4SCL | - | EN0LED1 | M0FAULT1 | - | - | - | - | - | EPI0S25 |
| 65 | PL4 | 85 | - | - | - | T0CCP0 | - | - | - | - | - | - | USB0D4 | EPI0S26 |
| 67 | PB2 | 91 | - | - | I2C0SCL | T5CCP0 | - | - | - | - | - | - | USB0STP | EPI0S27 |
| 69 | PB3 | 92 | - | - | I2C0SDA | T5CCP1 | - | - | - | - | - | - | USB0CLK | EPI0S28 |
| 71 | PP2 | 103 | - | U0DTR | - | - | - | - | - | - | - | - | USB0NXT | EPI0S29 |
| 73 | PP3 | 104 | - | U1CTS | U0DCD | - | - | - | RTCCLK | - | - | - | USB0DIR | EPI0S30 |
| 75 | PK5 | 62 | - | - | I2C3SDA | - | EN0LED2 | M0PWM7 | - | - | - | - | - | EPI0S31 |
| 77 | PK4 | 63 | - | - | I2C3SCL | - | EN0LED0 | M0PWM6 | - | - | - | - | - | EPI0S32 |
| 79 | PL5 | 86 | - | - | - | T0CCP1 | - | - | - | - | - | - | USB0D5 | EPI0S33 |
| 81 | PN4 | 111 | - | U1DTR | U3RTS | I2C2SDA | - | - | - | - | - | - | - | EPI0S34 |
| 83 | PN5 | 112 | - | U1RI | U3CTS | I2C2SCL | - | - | - | - | - | - | - | EPI0S35 |
| 85 | PN0 | 107 | - | U1RTS | - | - | - | - | - | - | - | - | - | - |
| 87 | PN1 | 108 | - | U1CTS | - | - | - | - | - | - | - | - | - | - |
| 89 | PN2 | 109 | - | U1DCD | U2RTS | - | - | - | - | - | - | - | - | EPI0S29 |
| 91 | PN3 | 110 | - | U1DSR | U2CTS | - | - | - | - | - | - | - | - | EPI0S30 |
| 93 | PQ4 | 102 | - | U1Rx | - | - | - | - | - | DIVSCLK | - | - | - | - |
| 95 | | | | | | | WAKE | | | | | | | |
| 97 | | | | | | | 5 V | | | | | | | |

**Table 2-4. X11 Breadboard Adapter Even-Numbered Pad GPIO and Signal Muxing**

| Pin | Port | MCU PIN | Analog | Digital Function (GPIOPCTL Bit Encoding) | | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | | | | 1 | 2 | 3 | 5 | 6 | 7 | 8 | 11 | 13 | 14 | 15 |
| 2 | | | | 5 V | | | | | | | | | | |
| 4 | | | | GND | | | | | | | | | | |
| 6 | PA2 | 35 | - | U4Rx | I2C8SCL | T1CCP0 | - | - | - | - | - | - | - | SSI0Clk |
| 8 | PA3 | 36 | - | U4Tx | I2C8SDA | T1CCP1 | - | - | - | - | - | - | - | SSI0Fss |
| 10 | PA4 | 37 | - | U3Rx | I2C7SCL | T2CCP0 | - | - | - | - | - | - | - | SSI0XDAT0 |
| 12 | PA5 | 38 | - | U3Tx | I2C7SDA | T2CCP1 | - | - | - | - | - | - | - | SSI0XDAT1 |
| 14 | PE0 | 15 | AIN3 | U1RTS | - | - | - | - | - | - | - | - | - | - |
| 16 | PE1 | 14 | AIN2 | U1DSR | - | - | - | - | - | - | - | - | - | - |
| 18 | PE2 | 13 | AIN1 | U1DCD | - | - | - | - | - | - | - | - | - | - |
| 20 | PE3 | 12 | AIN0 | U1DTR | - | - | - | - | - | - | - | - | - | - |
| 22 | PE4 | 123 | AIN9 | U1RI | - | - | - | - | - | - | - | - | - | SSI1XDAT0 |
| 24 | PE5 | 124 | AIN8 | - | - | - | - | - | - | - | - | - | - | SSI1XDAT1 |
| 26 | PK0 | 18 | AIN16 | U4Rx | - | - | - | - | - | - | - | - | - | EPI0S0 |
| 28 | PK1 | 19 | AIN17 | U4Tx | - | - | - | - | - | - | - | - | - | EPI0S1 |
| 30 | PK2 | 20 | AIN18 | U4RTS | - | - | - | - | - | - | - | - | - | EPI0S2 |
| 32 | PK3 | 21 | AIN19 | U4CTS | - | - | - | - | - | - | - | - | - | EPI0S3 |
| 34 | | | | VREF | | | | | | | | | | |
| 36 | | | | GND | | | | | | | | | | |
| 38 | PD5 | 126 | AIN6 | U2Tx | - | T3CCP1 | - | - | - | - | - | - | - | SSI1XDAT3 |
| 40 | PD4 | 125 | AIN7 | U2Rx | - | T3CCP0 | - | - | - | - | - | - | - | SSI1XDAT2 |
| 42 | PD7 | 128 | AIN4 | U2CTS | - | T4CCP1 | USB0PFLT | - | - | NMI | - | - | - | SSI2XDAT2 |
| 44 | PD6 | 127 | AIN5 | U2RTS | - | T4CCP0 | USB0EPEN | - | - | - | - | - | - | SSI2XDAT3 |
| 46 | PD3 | 4 | AIN12 | - | I2C8SDA | T1CCP1 | - | - | - | - | - | - | - | SSI2Clk |
| 48 | PD1 | 2 | AIN14 | - | I2C7SDA | T0CCP1 | C1o | - | - | - | - | - | - | SSI2XDAT0 |
| 50 | PD0 | 1 | AIN15 | - | I2C7SCL | T0CCP0 | C0o | - | - | - | - | - | - | SSI2XDAT1 |
| 52 | PD2 | 3 | AIN13 | - | I2C8SCL | T1CCP0 | C2o | - | - | - | - | - | - | SSI2Fss |
| 54 | PP0 | 118 | C2+ | U6Rx | - | - | - | - | - | - | - | - | - | SSI3XDAT2 |
| 56 | PP1 | 119 | C2- | U6Tx | - | - | - | - | - | - | - | - | - | SSI3XDAT3 |
| 58 | PB0 | 95 | USB0ID | U1Rx | I2C5SCL | T4CCP0 | - | - | CAN1Rx | - | - | - | - | - |
| 60 | PB1 | 96 | USB0VBUS | U1Tx | I2C5SDA | T4CCP1 | - | - | CAN1Tx | - | - | - | - | - |
| 62 | | | | GND | | | | | | | | | | |
| 64 | PF4 | 46 | - | - | - | - | EN0LED1 | M0FAULT0 | - | - | - | - | SSI3XDAT2 | TRD3 |
| 66 | PF0 | 42 | - | - | - | - | EN0LED0 | M0PWM0 | - | - | - | - | SSI3XDAT1 | TRD2 |

**Table 2-4. X11 Breadboard Adapter Even-Numbered Pad GPIO and Signal Muxing (continued)**

| Pin | Port | MCU PIN | Analog | Digital Function (GPIOPCTL Bit Encoding) | | | | | | | | | | |
|-----|------|---------|--------|------|------|------|------|------|------|------|------|------|------|------|
| | | | | 1 | 2 | 3 | 5 | 6 | 7 | 8 | 11 | 13 | 14 | 15 |
| 68 | PF1 | 43 | - | - | - | - | EN0LED2 | M0PWM1 | - | - | - | - | SSI3XDAT0 | TRD1 |
| 70 | PF2 | 44 | - | - | - | - | - | M0PWM2 | - | - | - | - | SSI3Fss | TRD0 |
| 72 | PF3 | 45 | - | - | - | - | - | M0PWM3 | - | - | - | - | SSI3Clk | TRCLK |
| 74 | PA0 | 33 | - | U0Rx | I2C9SCL | T0CCP0 | - | - | CAN0Rx | - | - | - | - | - |
| 76 | PA1 | 34 | - | U0Tx | I2C9SDA | T0CCP1 | - | - | CAN0Tx | - | - | - | - | - |
| 78 | PP4 | 105 | - | U3RTS | U0DSR | - | - | - | - | - | - | - | USB0D7 | - |
| 80 | PP5 | 106 | - | U3CTS | I2C2SCL | - | - | - | - | - | - | - | USB0D6 | - |
| 82 | PJ0 | 116 | - | U3Rx | - | - | - | - | - | - | - | - | - | - |
| 84 | PJ1 | 117 | - | U3Tx | - | - | - | - | - | - | - | - | - | - |
| 86 | PM7 | 71 | TMPR0 | U0RI | - | T5CCP1 | - | - | - | - | - | - | - | - |
| 88 | PM6 | 72 | TMPR1 | U0DSR | - | T5CCP0 | - | - | - | - | - | - | - | - |
| 90 | PM5 | 73 | TMPR2 | U0DCD | - | T4CCP1 | - | - | - | - | - | - | - | - |
| 92 | PM4 | 74 | TMPR3 | U0CTS | - | T4CCP0 | - | - | - | - | - | - | - | - |
| 94 | RESET | | | | | | | | | | | | | |
| 96 | GND | | | | | | | | | | | | | |
| 98 | 3V3 | | | | | | | | | | | | | |

#### 2.1.7.4 Other Headers and Jumpers

JP1 is provided to select the power input source for the Crypto Connected LaunchPad. The top position is for BoosterPack power; this position also disconnects both USB voltages from the board's primary 5-V input. In the top position, the TPS2052B does not limit current so additional care should be exercised. The middle position draws power from the USB connector on the left side of the board near the Ethernet jack. The bottom position is the default, in which power is drawn from the ICDI (Debug) USB connection.

JP2 separates the MCU 3.3-V power domain from the rest of the 3.3-V power on the board allowing an ammeter to be used to obtain more accurate measurements of microcontroller power consumption.

JP3 isolates the output of the TPS73733 LDO from the board's 3.3-V power domain.

JP4 and JP5 are used to configure CAN signals to the BoosterPack 2 interface. In the default horizontal configuration, CAN is not present on the BoosterPack. UART2 goes to the BoosterPack and UART 0 goes to the ICDI virtual serial port to provide ROM serial bootloader capability. In the vertical CAN-enabled configuration, UART2 goes to the ICDI virtual serial port and CAN signals are available on the BoosterPack. The ROM serial bootloader is not available to the ICDI virtual serial port while the jumpers are in the CAN position.

Figure 2-2 shows the default configuration and relative location of the jumpers on the board.
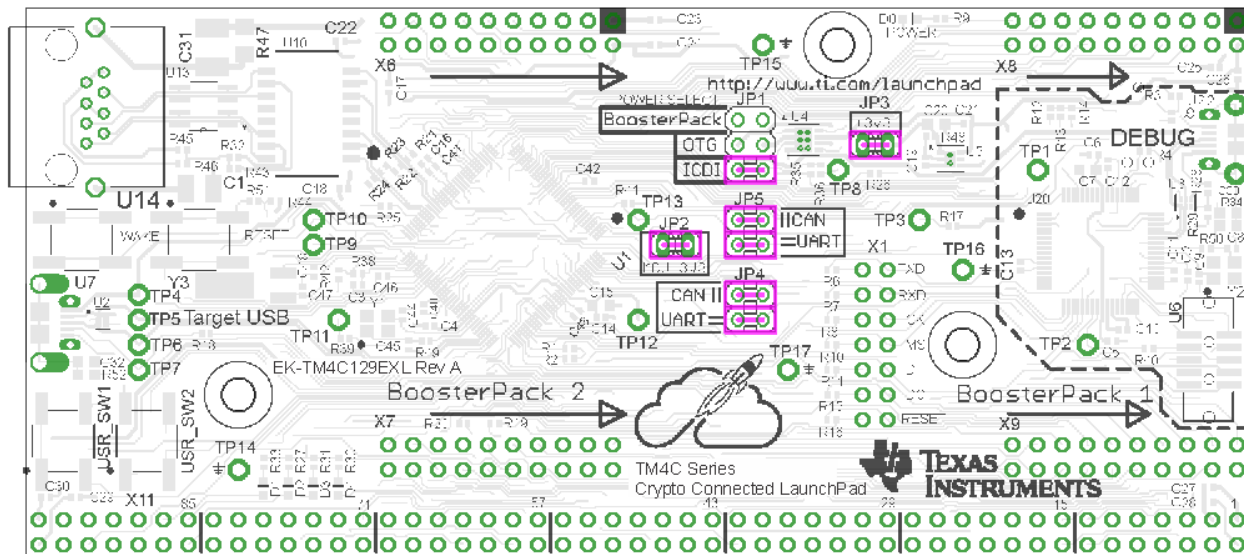


**Figure 2-2. Default Jumper Locations**

## 2.2 Power Management

### 2.2.1 Power Supplies

The Crypto Connected LaunchPad can be powered from three different input options:
- On-board ICDI USB cable (Debug, Default)
- Target USB cable
- BoosterPack or Breadboard adapter connection

The JP1 power-select jumper is used to select one of the power sources.

In addition, the JP3 power jumper can be used to isolate the 3.3-V output of the TPS73733 from the board's 3.3-V rail.

A TPS2052B load switch is used to regulate and control power to the Target USB connector when the microcontroller is acting in USB host mode. This load switch also limits current to the BoosterPack and Breadboard adapter headers when the JP1 jumper is in the ICDI position.

### 2.2.2  Low Power Modes

The Crypto Connected LaunchPad demonstrates several low power microcontroller modes. In run mode, the microcontroller can be clocked from several sources such as the internal precision oscillator or an external crystal oscillator. Either of these sources can then optionally drive an internal PLL to increase the effective frequency of the system up to 120 MHz. In this way, the run mode clock speed can be used to manage run mode current consumption.

The microcontroller also provides sleep and deep sleep modes and internal voltage adjustments to the flash and SRAM to further refine power consumption when the processor is not in use but peripherals must remain active. Each peripheral can be individually clock gated in these modes so that current consumption by unused peripherals is minimized. A wide variety of conditions from internal and external sources can trigger a return to run mode.

The lowest power setting of the microcontroller is hibernation, which requires a small amount of supporting external circuitry available on the Crypto Connected LaunchPad. The Crypto Connected LaunchPad can achieve microcontroller current consumption modes under 2 micro-Amps using hibernate VDD3ON mode. Hibernation with VDD3ON mode is not supported on this board. The Crypto Connected LaunchPad can be woken from hibernate by several triggers including the dedicated wake button, the reset button, an internal RTC timer and a subset of the device GPIO pins. The hibernation module provides a small area of internal SRAM that can preserve data through a hibernate cycle.

### 2.2.3  Clocking

The Crypto Connected LaunchPad uses a 25 MHz crystal (Y1) to drive the main TM4C129ENCPDT internal clock circuit. Most software examples use the internal PLL to multiply this clock to higher frequencies up to 120 MHz for core and peripheral timing. The 25-MHz crystal is required when using the integrated Ethernet MAC and PHY.

The Hibernation module is clocked from an external 32.768-KHz crystal (Y3).

### 2.2.4  Reset

The RESET signal to the TM4C129ENCPDT microcontroller connects to the RESET switch, BoosterPack connectors, Breadboard adapter and to the ICDI circuit for a debugger-controller reset.

External reset is asserted (active low) under the following conditions:

* Power-on reset (filtered by and R-C network)
* RESET switch is held down.
* By the ICDI circuit when instructed by the debugger (this capability is optional, and may not be supported by all debuggers)
* By an external circuit attached to the BoosterPack or Breadboard connectors.

## 2.3  Debug Interface

### 2.3.1  In-Circuit Debug Interface (ICDI)

The Crypto Connected LaunchPad comes with an on-board ICDI. The ICDI allows for the programming and debugging of the TM4C129ENCPDT using LM Flash Programmer and/or any of the supported tool chains. Note that ICDI only supports JTAG debugging at this time. It is possible to use other JTAG emulators instead of the on board ICDI, by connecting to U6. When the ICDI detects an external debug adapter connection on the JTAG connector U6 and disables the ICDI outputs to allow the external debug adapter to drive the debug circuit. For more information, see Section 2.3.2.

Debug out of the ICDI is possible by removing resistors R6, R7, R8, R10, R11, R15, R16 and R40 from the Crypto Connected LaunchPad and use the ICDI to drive JTAG signals out on U6 for the purpose of programming or debugging other boards. To restore the connection to the on-board TM4C129ENCPDT microcontroller, install jumpers from the odd to even pins of X1 or re-install the resistors. Removal of R40 disables the detection of an attached external debugger. R40 must be installed to use an external debug adapter to program or debug the Crypto Connected LaunchPad.

### 2.3.2 External Debugger

The connector U6 is provided for the attachment of an external debug adapter such as the IAR J-Link or Keil ULINK. This connector follows the ARM standard 10-pin JTAG pinout. This interface can use either JTAG or SWD if supported by the external debug adapter.

### 2.3.3 Virtual COM Port

When plugged into a USB host, the ICDI enumerates as both a debugger and a virtual COM port. JP4 and JP5 control the selection of which UART from the TM4C129ENCPDT is connected to the virtual COM port. In the default configuration, UART0 maps to the virtual COM port of the ICDI. In the CAN jumper configuration, UART2 maps to the virtual COM port of the ICDI.

# Software Development

This chapter provides general information on software development as well as instructions for flash memory programming.

## 3.1 Secure IoT Demo

### 3.1.1 Software Description

The out-of-box "Secure IoT" application demonstrates the use of Transport Layer Security/Secure Sockets Layer (TLS/SSL) protocol to connect an IoT product to a cloud server securely. This application runs on TI-RTOS and uses WolfSSL library for TLS/SSL support. The WolfSSL library uses the hardware encryption accelerators, available on the Crypto Connected LaunchPad board, which enables the development of connected applications with data encryption (for secure communication) at relatively higher performance. This application connects to Exosite's cloud server using HTTPS protocol.

The "Secure IoT" application records information about the Crypto Connected LaunchPad and user activity on this board, which is securely reported to Exosite cloud server. A command-line interface is provided to interact with the application. With the command-line interface one can control the eval board like changing the state of the LED or play a game of tic-tac-toe either locally or with a remote user.

For more details about example usage, see the "Readme.txt" file available with the "Secure IoT" application.

### 3.1.2 Source Code Download and Build Instructions

The source code and binary files for the "Secure IoT" application are provided as part of an installer at http://www.ti.com/lit/zip/spmc022.

Instructions for downloading and installing TI-RTOS and WolfSSL along with detailed instructions on building WolfSSL libraries for TI-RTOS are provided at http://processors.wiki.ti.com/index.php/Using_wolfSSL_with_TI-RTOS. This application works with TI-RTOS v2.14.00.10 or later and WolfSSL v3.6.6 or later.

After building the WolfSSL libraries for TI-RTOS with support for TM4C hardware ciphers, follow the instructions under "Build Details - Application" in the "Readme.txt" file available with the "Secure IoT" application's installation.

## 3.2 TivaWare for C Series Software

### 3.2.1 Software Description

The TivaWare software provides drivers for all of the peripheral devices supplied in the design. The TM4C Series Peripheral Driver Library is used to operate the on-chip peripherals as part of TivaWare.

TivaWare includes a set of example applications that use the TivaWare Peripheral Driver Library. These applications demonstrate the capabilities of the TM4C129ENCPDT microcontroller, as well as provide a starting point for the development of the final application for use on the Crypto Connected LaunchPad evaluation board. Example applications provided for the TM4C Series TM4C1294 Connected LaunchPad and examples paired with selected BoosterPacks will work with the Crypto Connected LaunchPad.

### 3.2.2   Source Code

The complete source code including the source code installation instructions are provided at
http://www.ti.com/tool/sw-tm4c. The source code and binary files are installed in the TivaWare software
tree.

### 3.2.3   Tool Options

The source code installation includes directories containing projects, makefiles, and binaries for the
following tool-chains:

- Keil ARM RealView® Microcontroller Development System
- IAR Embedded Workbench® for ARM
- Generic GNU C Compiler
- Texas Instruments' Code Composer Studio™ IDE

Download evaluation versions of these tools from the Tools & Software section of www.ti.com/tiva. Due to
code size restrictions, the evaluation tools may not build all example programs. A full license is necessary
to re-build or debug all examples.

For detailed information on using the tools, see the documentation included in the tool chain installation or
visit the website of the tools supplier.

## 3.3   Programming the Crypto Connected LaunchPad

The TivaWare software package includes pre-built binaries for each of the example applications. If you
installed the TivaWare software to the default installation path of *C:\ti\TivaWare_C_Series_<version>*, you
can find the example applications in *C:\ti\TivaWare_C_Series-<version>\examples\boards\ek-tm4c1294xl*.
The on-board ICDI is used with the LM Flash Programmer tool to program applications on the Crypto
Connected LaunchPad.

Follow these steps to program example applications into the Crypto Connected LaunchPad evaulation
board using the ICDI:

1.  Install LM Flash Programmer on a PC running Microsoft Windows.
2.  Place JP1 into the ICDI position on the Crypto Connected LaunchPad.
3.  Connect the USB-A cable plug in to an available USB port on the PC and plug the Micro-B plug to the
    Debug USB port (U22) on the Crypto Connected LaunchPad.
4.  Verify that LED D0 at the top of the board is illuminated.
5.  Install Windows ICDI and Virtual COM Port drivers if prompted. Installation instructions can be found in
    the *Stellaris® In-Circuit Debug Interface (ICDI) and Virtual COM Port Driver Installation Instructions*
    (SPMU287).
6.  Run the LM Flash Programmer application on the PC.
7.  In the Configuration tap, use the Quick Set control to select "TM4C1294XL LaunchPad".
8.  Move to the Program tab and click the Browse button. Navigate to the example applications directory
    (the default location is *C:\ti\TivaWare_C_Series_<version>\examples\boards\EK-TM4C1294XL\*).
9.  Each example application has its own directory. Navigate to the example directory that you want to
    load and then into the sub-directory for one of the supported tool chains that contains the binary (*.bin)
    file. Select the binary file and click Open.
10. Set the Erase Method to Erase Necessary Pages, check the Verify After Program box, and check
    Reset MCU After Program. The example program starts execution once the verify process is complete.

# References

## 4.1 References

In addition to this document the following references are available for download at www.ti.com.

- *TivaWare for C Series* (http://www.ti.com/tool/sw-tm4c)
- *TivaWare Peripheral Driver Library Users' Guide* (SPMU298)
- *Quick Start Guide: Crypto Connected LaunchPad Evaluation Kit (EK-TM4C129EXL)* (SPMZ862)
- *LM Flash Programmer Tool* (http://www.ti.com/lmflashprogrammer)
- *TPS73733 Low-Dropout Regulator with Reverse Current Protection* (http://www.ti.com/product/tps79733)
- *Texas Instruments Code Composer Studio website* (http://www.ti.com/ccs)
- *Tiva TM4C129ENCPDT Microcontroller Data Sheet* (SPMS441)
- *Build Your Own BoosterPack* information regarding the BoosterPack standard (http://www.ti.com/byob)
- *Stellaris® In-Circuit Debug Interface (ICDI) and Virtual COM Port Driver Installation Instructions* (SPMU287)
- TI-RTOS (http://www.ti.com/tool/TI-RTOS)

Additional Support:

- *Keil RealView MDK-ARM* (http://www.keil.com/arm/mdk.asp)
- *IAR Embedded Workbench* for ARM (http://iar.com/ewarm/)
- *Sourcery CodeBench* development tools (http://www.mentor.com/embedded-software/sourcery-tools/sourcery-codebench/overview)
- *Exosite* (http://ti.exosite.com)
- WolfSSL (http://wolfssl.com)

![Texas Instruments logo]

# *PCB Layout and Bill of Materials*

## A.1 Component Locations

Figure A-1 is a dimensioned drawing of the Crypto Connected LaunchPad that shows the location of selected features of the board, as well as the component locations.
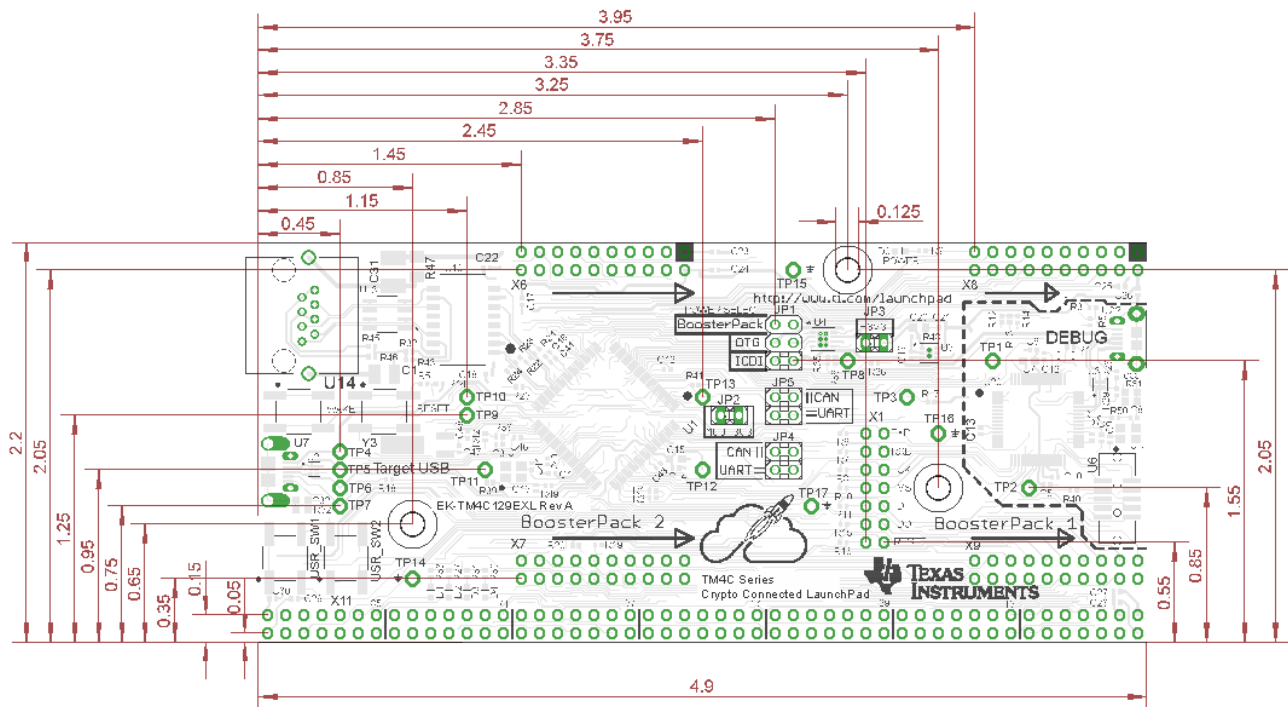


**Figure A-1. Crypto Connected LaunchPad Dimensions and Component Locations**

## A.2   Bill of Materials

Table A-1 is the Crypto Connected LaunchPad bill of materials list.

### Table A-1. Crypto Connected LaunchPad Bill of Materials

| Item | Ref | Qty | Description | Mfg | Part Number |
|---|---|---|---|---|---|
| 1 | C1 | 1 | Capacitor, 1000 pF, 2kV, 20%, X7R, 1210 | Kemet | C1210C102MGRACTU |
| 2 | C3, C4, C5, C10, C11, C12, C13, C16, C17, C18, C19, C21, C22, C23, C24, C25, C26, C27, C28, C29, C30, C40, C41, C42, C43, C46 | 26 | Capacitor, 0.1 µF 16 V, 10%, 0402 X7R | Taiyo Yuden | EMK105B7104KV-F |
| 3 | C31 | 1 | Capacitor, 4700 pF, 2kV, 10%, X7R, 1812 | AVX | 1812GC472KAT1A |
| 4 | C32, C33 | 2 | Capacitor, 3300 pF, 50 V, 10%, X7R, 0603 | TDK | C1608X7R1H332K |
| 5 | C6, C14 | 2 | Capacitor, 1 µF, X5R, 10 V, low ESR, 0402 | Johanson Dielectrics Inc | 100R07X105KV4T |
| 6 | C7, C15, C20 | 3 | Capacitor, 2.2 µF, 16 V, 10%, 0603, X5R | Murata | GRM188R61C225KE15D |
| 7 | C8, C9, C44, C45, C47, C48 | 6 | Capacitor, 12 pF, 50 V, 5%, 0402, COG | Murata | GRM1555C1H120JZ01D |
| 8 | D0, D1, D2, D3, D4 | 5 | Green LED 0603 | Everlight | 19-217/G7C-AL1M2B/3T |
| 9 | J1, J2, J3, J4, J5, J6, J7 | 7 | Jumper, 0.100, Gold, Black, Open | 3M | 969102-0000-DA |
|   |   |   |   | Kobiconn | 151-8000-E |
| 10 | JP1 | 1 | Header, 2x3, 0.100, T-hole, vertical unshrouded, 0.230 mate, gold | FCI | 67996-206HLF |
| 11 | JP2, JP3 | 2 | Header, 1x2, 0.100, T-hole, vertical unshrouded, 0.220 mate | 3M | 961102-6404-AR |
|   |   |   |   | FCI | 68001-102HLF |
|   |   |   |   | Anyone | 1x2-head |
| 12 | JP4, JP5 | 2 | Header, 2x2, 0.100, T-hole, vertical unshrouded, 0.230 mate | FCI | 67997-104HLF |
|   |   |   |   | 4UCON | 00998 |
| 13 | R1, R2, R3, R4, R5, R29, R35, R44 | 8 | Resistor, 10k Ω, 1/10W, 5%, 0402 thick film | Yageo | RC0402FR-0710KL |
| 14 | R17, R26, R36 | 3 | 100k 5% 0402 resistor SMD | Rohm | MCR01MRTJ104 |
| 15 | R18, R51 | 2 | Resistor 0402 100 Ω 5% | Rohm | MCR1MRTJ101 |
| 16 | R23, R21, R22, R24 | 4 | Resistor 49.9 Ω 0402. 1 % | Rohm | MCR01MRTF49R9 |
| 17 | R25 | 1 | Resistor 4.87k 1% 0402 SMD | Rohm | MCR01MRTF4871 |
| 18 | R28 | 1 | Resistor, 5.6k Ω, 1/10W, 5%, 0402 | Panasonic | ERJ-2GEJ562X |
| 19 | R32, R43, R45, R46 | 4 | Resistor 75 Ω 0402 5% | Rohm | MCR01MRTJ750 |
| 20 | R34, R52 | 2 | Resistor, 1M OH, 1/10W, 5% 0603 SMD | Panasonic | ERJ-3GEYJ105V |
| 21 | R38 | 1 | Resistor, 51 Ω, 1/10W, 5%, 0402 | Panasonic | ERJ-2GEJ510X |

### Table A-1. Crypto Connected LaunchPad Bill of Materials (continued)

| Item | Ref | Qty | Description | Mfg | Part Number |
|------|-----|-----|-------------|-----|-------------|
| 22 | R42 | 1 | Resistor, 1M Ω, 1/10W, 5%, 0402 | Rohm | MCR01MRTF1004 |
| 23 | R47 | 1 | RES 1M Ω 5% 1206 TF | Panasonic | ERJ-8GEYJ105V |
| 24 | R49, R50 | 2 | Resistor, 2.0k Ω, 1/10W, 5%, 0402 | Panasonic | ERJ-3GEYJ202V |
| 25 | R6, R7, R8, R10, R11, R15, R16, R19, R20, R39, R40, R41 | 12 | Resistor, 0 Ω, 1/10W, 5%, 0402 | Panasonic | ERJ-2GE0R00X |
| 26 | R9, R27, R30, R31, R33 | 5 | Resistor, 330 Ω, 1/10W, 5%, 0402 | Yageo | RC0402FR-07330RL |
| 27 | RESET, USR_SW1, USR_SW2, WAKE | 4 | Switch, Tact 6mm SMT, 160gf | Omron | B3S-1000 |
| 28 | U1 | 1 | TM4C, MCU TM4C129ENCPDT 128 QFP with cryptographic modules and Ethernet MAC + PHY | Texas Instruments | TM4C129ENCPDT |
| 29 | U10 | 1 | Transformer, Ethernet, 1 to 1. SOIC 16 | Pulse Electronics | HX1198FNL |
| 30 | U13 | 1 | Diode, 8 chan, ±15KV, ESD protection array, SO-8 | Semtech | SLVU2.8-4.TBT |
| 31 | U14 | 1 | Connector, RJ45 NO MAG, shielded THRU HOLE | TE Connectivity | 1-406541-5 |
| 32 | U2, U3 | 2 | IC 4CH ESD solution w/clamp 6SON | Texas Instruments | TPD4S012DRYR |
| 33 | U20 | 1 | Stellaris TM4C MCU TM4C123GH6PMI | Texas Instruments | TM4C123GH6PMI |
| 34 | U22 | 1 | USB Micro B receptacle right angle with guides | FCI | 10118194-0001LF |
| 35 | U4 | 1 | Fault protected power switch, dual channel, 8-SON | Texas Instruments | TPS2052BDRBR |
| 36 | U5 | 1 | 3.3 V LDO TI TPS73733DRV fixed out 5 V in | Texas Instruments | TPS73733DRV |
| 37 | U6 | 1 | Header 2x5, 0.050, SM, vertical shrouded | Samtec | SHF-105-01-S-D-SM |
| | | | | Don Connex Electronics | C44-10BSA1-G |
| 38 | U7 | 1 | USB Micro AB receptacle. Right angle with through guides | Hirose | ZX62D-AB-5P8 |
| 39 | X6, X7, X8, X9 | 4 | Header, 2x10, T-hole vertical unshrouded stacking | Samtec | SSW-110-23-S-D |
| | | | | Major League Electronics | SSHQ-110-D-08-F-LF |
| 40 | Y1 | 1 | Crystal 25 MHz 3.2 x 2.5 mm | NDK | nx3225ga-25.000m-std-crg-2 |
| 41 | Y2 | 1 | Crystal 16 MHz 3.2 x 2.5 mm 4 pin | NDK | NX3225GA-16.000M-STD-CRG-2 |
| 42 | Y3 | 1 | Crystal, 32.768 KHz radial CAN | Citizen Finetech Miyota | CMR200T-32.768KDZY-UT |

### Table A-1. Crypto Connected LaunchPad Bill of Materials (continued)

| Item | Ref | Qty | Description | Mfg | Part Number |
|---|---|---|---|---|---|
| **PCB Do Not Populate List (Shown for information only)** | | | | |
| 43 | C2 | 1 | Capacitor, 0.1 µF 16 V, 10%, 0402 X7R | Taiyo Yuden | EMK105B7104KV-F |
| 44 | H1, H4, H6 | 3 | Screw, #4 x 0.625" Pan head, sheet metal, Phillips/slotted (for fan) | McMaster | 90077A112 |
| 45 | R12, R13, R14 | 3 | Resistor, 5.6k Ω, 1/10W, 5%, 0402 | Panasonic | ERJ-2GEJ562X |
| 46 | R48 | 1 | Resistor 0402 1% 52.3k | Rohm | TRR01MZPF5232 |
| 47 | TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP8, TP9, TP10, TP11, TP12, TP13, TP14, TP15, TP16, TP17 | 17 | Terminal, test point miniature loop, red, T-hole | Keystone | 5000 |
| 48 | X1 | 1 | Header, 2x7, 0.100, T-hole, vertical, unshrouded, 0.230 mate | FCI | 67997-114HLF |
| 49 | X11A | 1 | Valvano style bread board connect. Right angle extended, 1 x 49 0.100 pitch. | Samtec | TSW-149-09-F-S-RE |
| 50 | X11B | 1 | Valvano style breadboard header | Samtec | TSW-149-08-F-S-RA |

# *Schematic*

This section contains the complete schematics for the TM4C Series TM4C129E Crypto Connected LaunchPad.

- Microcontroller, USB, Buttons, and LED's
- BoosterPack connectors
- Breadboard connector
- Ethernet and Ethernet LED's
- Power
- In-Circuit Debug Interface

## Revision History

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

**Changes from Original (September 2015) to A Revision** **Page**

* GLOBAL: Updated/Changed all instances of "UART4" to "UART2" .................................................................... 5

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        **FCC NOTICE:** This kit is designed to allow product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and software developers to write software applications for use with the end product. This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.

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        **CAUTION**

        This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

        Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

        **FCC Interference Statement for Class A EVM devices**

        *NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.*

**FCC Interference Statement for Class B EVM devices**

*NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:*

- *Reorient or relocate the receiving antenna.*
- *Increase the separation between the equipment and receiver.*
- *Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.*
- *Consult the dealer or an experienced radio/TV technician for help.*

## 3.2 Canada

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Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

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Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

**Concernant les EVMs avec antennes détachables**

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur

## 3.3 Japan

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2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or

3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

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