

# Stellaris® LM4F232 Evaluation Board

## User's Manual



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## Board Overview

**Figure 1-1. Stellaris® LM4F232 Evaluation Board**



- Stellaris EK-LM4F232 evaluation board
- On-board Stellaris® In-Circuit Debug Interface (ICDI)
- Cables
  - USB Mini-B to USB-A plug cable (for debug)
  - USB Micro-A plug to USB-A receptacle cable
  - USB Micro-B plug to USB-A plug cable
- USB Flash drive

- 3 V CR2032 lithium coin cell battery
- CD containing:
  - StellarisWare® Peripheral Driver Library and example source code
  - Stellaris® Firmware Development Package with example source code
  - Quickstart application with source code
    - Windows companion application for quickstart application
  - Complete documentation
  - A supported version of one of the following:
    - Keil™ RealView® Microcontroller Development Kit (MDK-ARM)
    - IAR Embedded Workbench® development tools
    - Sourcery CodeBench development tools
    - Code Red Technologies development tools
    - Texas Instruments' Code Composer Studio™ IDE

## Using the EK-LM4F232

The recommended steps for using the EK-LM4F232 evaluation kit are:

1. **Follow the README First document included in the kit.** The README First document will help get the EK-LM4F232 evaluation board up and running in minutes.
2. **Use your preferred ARM tool-chain and the Stellaris Peripheral Driver Library to develop an application.** Software applications are loaded using the on-board Stellaris® In-Circuit Debug Interface (ICDI). See Chapter 3, “Software Development” on page 20, for the programming procedure. The *StellarisWare Peripheral Driver Library Software Reference Manual* contains specific information on software structure and function.
3. **Customize and integrate the hardware to suit an end application.** This user's manual is an important reference for understanding circuit operation and completing hardware modification.

## Features

The EK-LM4F232 evaluation kit includes the following features:

- Stellaris® LM4F232H5QD microcontroller
- Data logger demo application
  - 6 screw terminals
    - 4 analog inputs (0-20 V)
    - Power
    - Ground
  - 3-axis analog accelerometer
  - 2 Analog temperature sensors
    - External TMP20 temperature sensor
    - Internal microcontroller temperature sensor
  - Microcontroller current shunt amplifier

- 96 x 64 color OLED display
- USB Micro-AB connector for Host/Device/OTG
- microSD card slot
- 5 user/navigation switches
- User LED
- Precision 3.0 V reference
- Available I/O brought out to headers on 0.1" grid
- Debug
  - Stellaris® In-Circuit Debug Interface (ICDI)
  - Standard 10-pin JTAG header
- Shunt resistors to measure current on V<sub>BAT</sub> and V<sub>DD</sub>
- Coin cell backup battery for Hibernate mode
- Reset button

## Specifications

Table 1-1 shows the specifications for the EK-LM4F232 evaluation board.

**Table 1-1. EK-LM4F232 Specifications**

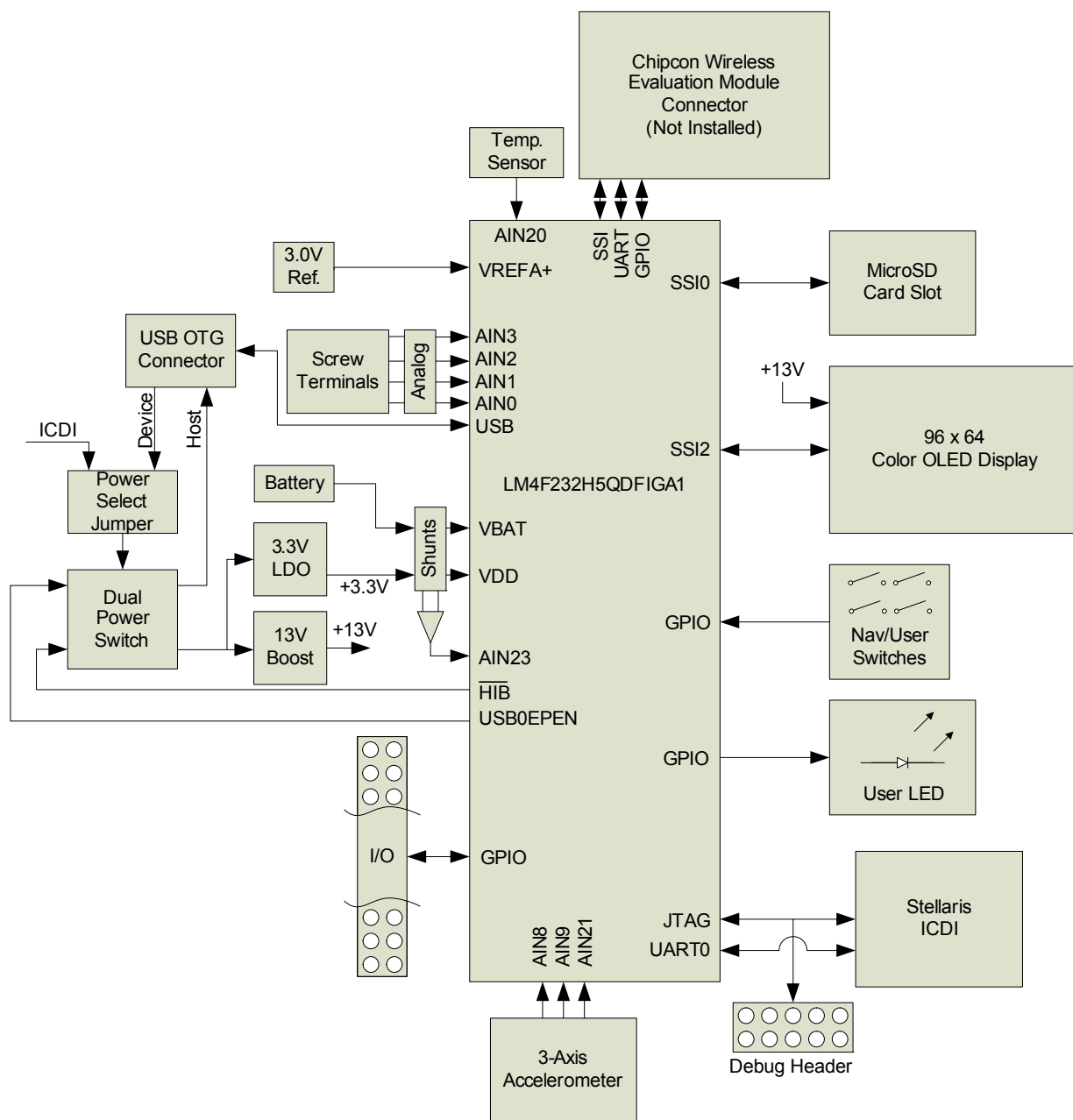
| Parameter            | Value                        |
|----------------------|------------------------------|
| Board supply voltage | 4.75–5.25 V                  |
| Dimensions           | 6.0" x 2.25" x 0.84" (LxWxH) |
| RoHS status          | Compliant                    |

# CHAPTER 2

## Hardware Description

The EK-LM4F232 evaluation board includes a Stellaris LM4F232H5QD microcontroller and an integrated Stellaris® In-Circuit Debug Interface (ICDI) as well as a range of useful peripheral features (see the block diagram in Figure 2-1). This chapter describes how these peripherals operate and interface to the microcontroller.

Figure 2-1. EK-LM4F232 Evaluation Board Block Diagram



## Functional Description

### Microcontroller, USB OTG, User/Navigation Switches, User LED, and GPIO Headers (Schematic page 1)

#### Microcontroller

The Stellaris LM4F232H5QD is an ARM® Cortex™-M4F-based microcontroller with 256-KB Flash memory, 32-KB SRAM, 80-MHz operation, USB Host/Device/OTG, Hibernation module, and a wide range of other peripherals. See the LM4F232H5QD microcontroller data sheet (order number DS-LM4F232H5QD) for complete device details.

Most of the microcontroller signals are routed to 0.1" pitch break-out pads and labeled with their GPIO reference. An internal multiplexer allows different peripheral functions to be assigned to each of these GPIO pads. When adding external circuitry, consideration should be given to the additional load on the evaluation board's power rails.

The LM4F232H5QD microcontroller is factory-programmed with a quickstart demo program. The quickstart program resides in on-chip Flash memory and runs each time power is applied, unless the quickstart application has been replaced with a user program.

#### USB Host/Device/OTG

The EK-LM4F232 includes a USB Micro-AB (OTG) connector to allow for USB Host, Device, and OTG operation. The following signals are used for USB OTG.

**Table 2-1. USB Host/Device/OTG Signals**

| GPIO Pin | Pin Function | USB OTG                     |
|----------|--------------|-----------------------------|
| PL6      | USB0DP       | D+                          |
| PL7      | USB0DM       | D-                          |
| PB0      | USB0ID       | ID                          |
| PB1      | USB0VBUS     | USB VBUS                    |
| GPIO Pin | Pin Function | Load Switch                 |
| PG4      | USB0EPEN     | USB VBUS Power Enable (EN2) |
| PG5      | USB0PFLTn    | Power Fault (OC2n)          |

In USB Host mode, the evaluation board can provide power to the OTG connector. The USB0EPEN signal controls the Channel 2 Enable (EN2) of a Texas Instruments' TPS2052B Load Switch (U7) which enables power to the connector's V<sub>BUS</sub> pin. The POWER SELECT jumper must be in the "ICDI" position.

In Device mode, the evaluation board can be powered from either the Stellaris® ICDI or the OTG connectors. The user can select the power source by moving the POWER SELECT jumper to the appropriate position.

In OTG mode, the POWER SELECT jumper's position needs special consideration depending on the system and code configuration.

## User Switches and User LED

Five switches on the board provide navigation and selection for the preloaded quickstart application. These switches can be used for other purposes in the user's custom applications.

The evaluation board also has a green user LED.

Table 2-2 shows how these features are connected to the pins on the microcontroller.

**Table 2-2. User Switches and User LED Signals**

| GPIO Pin | Pin Function | Feature           |
|----------|--------------|-------------------|
| PM0      | GPIO         | SW1 (Up)          |
| PM1      | GPIO         | SW2 (Down)        |
| PM2      | GPIO         | SW3 (Left)        |
| PM3      | GPIO         | SW4 (Right)       |
| PM4      | GPIO         | SW5 (Select/Wake) |
| PG2      | GPIO         | User LED          |

## GPIO Headers

All unused pins on the microcontroller are routed out to 0.1" headers along the edges of the board and are conveniently labeled with their port and pin names.

The remaining pins are broken out to headers located near the hardware feature that uses them. These are also on a 0.1" grid. All of these headers are labeled with the port and pin name, and, where possible, labeled with their function. See "Schematics" on page 22 for detailed information on these signals.

## Data Logger, Accelerometer, Temperature Sensor, OLED, and SD Card (Schematic page 2)

### Data Logger

The EK-LM4F232 comes with a quickstart application loaded into the Flash memory. This application implements a multi-channel data logger which can measure up to four analog channels (0-20 V), a three-axis analog accelerometer, two analog temperature sensors, and the microcontroller running current.

A Windows quickstart companion application is also provided on the evaluation kit CD and serves as a secondary display for the Data Logger application. See the "Software Description" on page 20 for more information.

### 4-Channel Analog Measurement

A 6-position screw terminal block is included on the evaluation board to make easy connections to external signals. Table 2-3 shows how the screw terminals and channels are arranged.

Table 2-3. 4-Channel Analog Measurement Signals

| GPIO Pin | Pin Function | Terminal |
|----------|--------------|----------|
| -        | -            | +VBUS    |
| PE0      | AIN3         | CH3      |
| PE1      | AIN2         | CH2      |
| PE2      | AIN1         | CH1      |
| PE3      | AIN0         | CH0      |
| -        | -            | GND      |

Each of the 4 channels can measure 0-20 V with an approximate 0.01 V resolution. A voltage divider on each channel scales the 0-20 V range on the terminal to the 0-3 V range of the 12-bit Analog-to-Digital Converter (ADC) of the LM4F232H5QD microcontroller. Each scaled-down signal passes through a unity-gain amplifier to provide a low-impedance source for the microcontroller's ADC. Below are some useful equations to keep on hand when using the four data logger channels.

$$V_{\text{TERMINAL}} = \frac{V_{\text{ADC}}}{\left(\frac{R_2}{R_1 + R_2}\right)} = \frac{V_{\text{ADC}}}{\left(\frac{18000}{105000 + 18000}\right)} \approx \frac{V_{\text{ADC}}}{0.146}$$

$$V_{\text{ADC}} = \frac{V_{\text{REFA+}}}{2^{12} - 1} \times \text{ADCCODE} = \frac{3.0\text{V}}{4095} \times \text{ADCCODE} \approx 0.7326\text{mV} \times \text{ADCCODE}$$

For example, if the code read from the ADC is 2048, the voltage measured by the ADC is:

$$V_{\text{ADC}} = 0.7326\text{mV} \times 2048 = 1.5\text{V}$$

Therefore, the voltage being measured at the screw terminal is:

$$V_{\text{TERMINAL}} = \frac{V_{\text{ADC}}}{0.146} = \frac{1.5\text{V}}{0.146} = 10.27\text{V}$$

**Caution** – Exceeding the input range on either the screw terminal or the ADC pins directly can damage the analog circuitry.

### 3-Axis Analog Accelerometer

The evaluation board includes a Bosch BMA140 3-axis analog accelerometer. The accelerometer is powered by a Texas Instruments' REF5030 Precision 3.0 V Reference (U9) and outputs an analog signal centered on half the 3.0 V source; therefore, 0 g translates to 1.5 V on the output. The sensor can measure accelerations up to  $\pm 4$  g.

Each axis has its own analog signal;  $A_X$ ,  $A_Y$ , and  $A_Z$ . The sensor outputs are passed through a unity-gain amplifier to provide a low-impedance source for the microcontroller's ADC. Table 2-4 shows which microcontroller pins are used for the accelerometer,

**Table 2-4. 3-Axis Analog Accelerometer Signals**

| GPIO Pin | Pin Function | Accelerometer |
|----------|--------------|---------------|
| PE5      | AIN8         | $A_X$         |
| PE4      | AIN9         | $A_Y$         |
| PE6      | AIN21        | $A_Z$         |

The following equations from the *Bosch Sensortec Triaxial, Analog Acceleration Sensor Data Sheet (BMA140)* define the sensor output  $A_X$ ,  $A_Y$ , and  $A_Z$  in volts based on the acceleration vector in each direction ( $a_X$ ,  $a_Y$ , and  $a_Z$ ) in g's and the sensor sensitivity ( $S$ ) in V/g. All three axes share the same relation, therefore, only the equation for the X axis is shown.

$$S = \frac{V_{DD}}{10} = 0.3V$$

$$A_X = \left( \frac{V_{DD}}{2} + S \times a_X \right) = 1.5V + 0.3V \times a_X$$

Given the code read from the ADC, the acceleration vector can be calculated as follows:

$$A_X = V_{ADC} = \frac{V_{REFA+}}{2^{12} - 1} \times ADCCODE = \frac{3.0V}{4095} \times ADCCODE \approx 0.7326mV \times ADCCODE$$

$$a_x = \frac{A_X - 1.5V}{0.3V} = \frac{(0.7326mV \times ADCCODE) - 1.5V}{0.3V} = (0.002442 \times ADCCODE) - 5$$

For example, if the code read from the ADC on  $A_X$  is 2457, the acceleration measured is:

$$a_x = (0.002442 \times ADCCODE) - 5 = (0.002442 \times 2457) - 5 = 1g$$

See the *Bosch Sensortec Triaxial, Analog Acceleration Sensor Data Sheet (BMA140)* for more information about the accelerometer.

### Temperature Sensors

Temperature can be measured by the Texas Instruments' TMP20 Analog Temperature Sensor (U3) and/or the internal microcontroller temperature sensor.

#### External TMP20 Temperature Sensor

The output of the sensor is passed through a unity-gain amplifier to provide a low-impedance source for the microcontroller's ADC. Table 2-5 shows the signal used by the temperature sensor.

**Table 2-5. Temperature Sensor GPIO**

| GPIO Pin | Pin Function | Temp. Sensor |
|----------|--------------|--------------|
| PE7      | AIN20        | $V_{OUT}$    |

The sensor's analog output over the -55°C to +130°C temperature range corresponds to the parabolic transfer function (taken from the TMP20 data sheet):

$$V_{OUT} = (-3.88 \times 10^{-6} \times T^2) + (-1.15 \times 10^{-2} \times T) + 1.8639V$$

Where the temperature T is in °C. Solving for temperature results in the following equation:

$$T = -1481.96 + \sqrt{\frac{2.19262 \times 10^6 + (1.8639 - V_{OUT})}{3.88 \times 10^{-6}}}$$

When only concerned with a narrow temperature range, a linear transfer function can be calculated. See the  $\pm 2.5^\circ\text{C}$  Low-Power, Analog Out Temperature Sensor Data Sheet (TMP20) for these calculations. Table 2-6 shows the linear transfer functions for a common selection of temperature ranges.

**Table 2-6. Linear Transfer Functions for Common Temperature Ranges**

| Temperature Range     |                       | Linear Equation (V)                                          | Maximum Deviation from Parabolic Equation (°C) |
|-----------------------|-----------------------|--------------------------------------------------------------|------------------------------------------------|
| T <sub>MIN</sub> (°C) | T <sub>MAX</sub> (°C) |                                                              |                                                |
| -55                   | 130                   | $V_{OUT} = -11.79\text{mV}/^\circ\text{C} \times T + 1.8528$ | $\pm 1.41$                                     |
| -40                   | 110                   | $V_{OUT} = -11.77\text{mV}/^\circ\text{C} \times T + 1.8577$ | $\pm 0.93$                                     |
| -30                   | 100                   | $V_{OUT} = -11.77\text{mV}/^\circ\text{C} \times T + 1.8605$ | $\pm 0.70$                                     |
| -40                   | 85                    | $V_{OUT} = -11.67\text{mV}/^\circ\text{C} \times T + 1.8583$ | $\pm 0.65$                                     |
| -10                   | 65                    | $V_{OUT} = -11.71\text{mV}/^\circ\text{C} \times T + 1.8641$ | $\pm 0.23$                                     |
| 35                    | 45                    | $V_{OUT} = -11.81\text{mV}/^\circ\text{C} \times T + 1.8701$ | $\pm 0.004$                                    |
| 20                    | 30                    | $V_{OUT} = -11.69\text{mV}/^\circ\text{C} \times T + 1.8663$ | $\pm 0.004$                                    |

#### **Internal Microcontroller Temperature Sensor**

The LM4F232H5QD microcontroller has an internal temperature sensor that can be used to notify the system that the internal temperature is too high or low for reliable operation. The temperature sensor can be sampled internally by the ADC. Given the ADC reading, the internal temperature, T in °C, can be calculated as follows (taken from the LM4F232H5QD data sheet):

$$T = 147.5 - \frac{225 \times ADCCODE}{4095}$$

See the LM4F232H5QD data sheet for more information on the internal microcontroller temperature sensor.

#### **Microcontroller Running Current**

The microcontroller running current I<sub>DD</sub> can be measured by the microcontroller itself. The output of a Texas Instruments' INA198 Current Shunt Amplifier (U15) is connected to the ADC on the microcontroller. This amplifier increases the voltage drop on a 0.1-Ohm current shunt resistor in

line with the  $V_{DD}$  source for the microcontroller. Table 2-7 shows the signal used to measure the amplifier output.

**Table 2-7. Microcontroller Running Current Signals**

| GPIO Pin | Pin Function | Amplifier |
|----------|--------------|-----------|
| PP0      | AIN23        | OUT       |

See “Current Shunt Resistors” on page 16 for more details on calculating the running current from the ADC readings.

## OLED Display

The evaluation board includes a 96 x 64 color Organic LED (OLED) display. The OLED display is powered from the on-board 13 V regulator which has to be enabled before using the display.

Data is written to the display using the SSI2 peripheral. Table 2-8 shows the signals used by the display.

**Table 2-8. OLED Display Signals**

| GPIO Pin | Pin Function | OLED Function |
|----------|--------------|---------------|
| PH7      | SSI2TX       | SDIN          |
| PH5      | SSI2FSS      | CSn           |
| PH4      | SSI2CLK      | SCLK          |
| PH6      | GPIO         | D/Cn          |
| PG1      | GPIO         | RSTn          |
| PG0      | GPIO         | +13VEN        |

## SD Card

The EK-LM4F232 features a microSD card slot. Table 2-9 shows the signals used with the SD card.

**Table 2-9. SD Card Signals**

| GPIO Pin | Pin Function | SD Card Function |
|----------|--------------|------------------|
| PA5      | SSI0TX       | DI               |
| PA4      | SSI0RX       | DO               |
| PA3      | SSI0FSS      | CSn              |
| PA2      | SSI0CLK      | CLK              |

## Hibernate, Current Shunts, Power Supplies, Reset, and Crystals

### (Schematic page 3)

#### Hibernate

The EK-LM4F232 provides a 32.768 kHz crystal (Y1) as the clock source for the LM4F232H5QD's Hibernation module clock source. It also provides a separate 3.0-V CR2032 lithium coin-cell backup battery connected to  $V_{BAT}$  that provides power to the Hibernation module when the microcontroller is in Hibernate mode. The current draw while in Hibernate mode can be measured indirectly by measuring the voltage across the 1-k $\Omega$  current shunt resistor. See the section, "Current Shunt Resistors" on page 16 for more details.

Several conditions can generate a wake signal to the Hibernate module; waking on a Real-time Clock (RTC) match, waking on low battery, and/or waking on assertion of the  $\overline{WAKE}$  pin. The SELECT/WAKE switch is connected to the  $\overline{WAKE}$  pin on the microcontroller. When the microcontroller is configured to wake on  $\overline{WAKE}$  assertion, the switch can be used to wake the part from Hibernate mode. The SELECT/WAKE switch is also connected to PM4 by way of a diode to prevent PM4 from asserting  $\overline{WAKE}$  when the part enters Hibernate mode. See Appendix A, "Schematics" on page 22 for details.

To achieve the lowest power consumption while in Hibernate mode, the  $\overline{HIB}$  signal is connected to the Channel 1 Enable (EN1) signal of the Texas Instruments' TPS2052B load switch (U7). In Hibernate mode, the  $\overline{HIB}$  signal is asserted and the load switch cuts main power to the entire board. The Hibernation mode is powered solely by the back-up battery.

The EK-LM4F232 has additional circuitry that allows the evaluation board to be turned on even when a battery is not present or when the battery voltage is too low. A Texas Instruments' TPS3803-01 Voltage Detector (U12) monitors  $V_{BAT}$  and produces a  $V_{BAT\_GOOD}$  signal when the battery voltage is above 2.1 V. Using standard logic gates and the state of  $V_{BAT}$  and  $V_{DD}$ , the  $\overline{HIB}$  signal can be forced high when  $V_{BAT}$  is not valid and the microcontroller is not already powered. With this circuit, a USB-powered board can turn itself on when the back-up battery is either missing or fully discharged. See Appendix A, "Schematics" on page 22 for more details.

This additional circuitry may not be needed in all applications. For example, a device powered by one main battery that doubles as the back-up battery does not need this circuit. Or, when using the Hibernate module in VDD3ON mode, power is cut to the microcontroller internally which eliminates the need to use  $\overline{HIB}$  to turn off an external supply.

There are many different ways that Hibernate mode can be implemented in an embedded system. Each implementation requires its own special design considerations.

#### Current Shunt Resistors

The evaluation board provides two current shunt resistors to measure the microcontroller running current,  $I_{DD}$ , and the Hibernation mode battery current,  $I_{BAT}$ .  $I_{DD}$  can be measured by the microcontroller through a Texas Instruments' INA198 Current Shunt Amplifier (U15). See "Microcontroller Running Current  $I_{DD}$ " on page 16.  $I_{BAT}$  must be measured externally.

##### Microcontroller Running Current $I_{DD}$

The shunt resistor for  $I_{DD}$ ,  $R_{VDDSHUNT}$ , is 0.1 Ohms and the INA198 amplifier gain is 100 V/V.

Therefore:

$$I_{DD} = \frac{V_{VDDSHUNT}}{R_{VDDSHUNT}} = \frac{V_{VDDSHUNT}}{0.1}$$

$$V_{ADC} = V_{VDDSHUNT} \times Gain = V_{VDDSHUNT} \times 100$$

Given the ADC measurement, you can calculate  $I_{DD}$ :

$$I_{DD} = \frac{V_{VDDSHUNT}}{R_{VDDSHUNT}} = \frac{\left(\frac{V_{ADC}}{100}\right)}{0.1} = \frac{V_{ADC}}{10}$$

Or simply, 10 mV per mA.

#### **Hibernation Mode Battery Current $I_{BAT}$**

The shunt resistor for  $I_{BAT}$ ,  $R_{VBATSHUNT}$ , is 1 kOhm.

$$I_{BAT} = \frac{V_{VBATSHUNT}}{R_{VBATSHUNT}} = \frac{V_{VBATSHUNT}}{1000}$$

Or simply, 1 mV per  $\mu$ A.

## **Clocking**

The EK-LM4F232 uses a 16.0-MHz crystal (Y2) to complete the LM4F232H5QD microcontroller's main internal clock circuit. An internal PLL, configured in software, multiplies this clock to higher frequencies for core and peripheral timing.

The Hibernation module is clocked from an external 32.768 kHz crystal (Y1).

## **Reset**

The  $\overline{RESET}$  signal into the LM4F232H5QD microcontroller connects to the RESET switch and to the Stellaris® ICDI circuit for a debugger-controlled reset.

External reset is asserted (active low) under any one of these conditions:

- Power-on reset
- RESET switch held down
- By the Stellaris® ICDI circuit when instructed by the debugger (this capability is optional, and may not be supported by all debuggers)

The OLED display has special reset timing requirements requiring a dedicated control line from the microcontroller.

## **Power Supplies and Jumper**

The EK-LM4F232 can be powered from one of two power sources:

- Stellaris® ICDI USB cable (default)
- USB OTG cable

A moveable jumper shunt on the POWER SELECT headers is used to select one of the two power sources. Only one source should be selected at a time.

See “USB Host/Device/OTG” on page 10 for the recommended jumper positions for the specific USB modes.

The evaluation board is designed to provide power to a limited amount of external circuitry. Table 2-10 shows the board's power requirements and Table 2-11 shows the board's breakout requirements.

**Table 2-10. Power Requirements**

| Board Supply   | Min  | Typical | Max  | Unit |
|----------------|------|---------|------|------|
| ICDI USB Cable | 4.75 | 5.0     | 5.25 | V    |
| USB OTG Cable  |      |         |      |      |

**Table 2-11. Breakout Requirements**

| Breakout              | Condition                 | Max | Unit |
|-----------------------|---------------------------|-----|------|
| +3.3 V                | —                         | 260 | mA   |
| +5.0 V <sup>a,b</sup> | +3.3 V @ 260 mA, OLED on  | 350 | mA   |
|                       | +3.3 V @ 260 mA, OLED off | 380 | mA   |

a. This represents the +5.0 V breakout and the +V<sub>BUS</sub> breakout. Total current = I<sub>5V</sub> + I<sub>VBUS</sub>.

b. +5.0 V is switched by the load switch (U7); however, +V<sub>BUS</sub> is always connected.

## Debug and Virtual COM Port (Schematic Page 4)

### Stellaris® In-Circuit Debug Interface (ICDI) and Virtual COM Port

The EK-LM4F232 evaluation board comes with an on-board Stellaris® In-Circuit Debug Interface (ICDI). The Stellaris® ICDI allows for the programming and debug of the LM4F232H5QD using LM Flash Programmer and/or any of the supported tool chains. Both JTAG and Serial Wire Debug (SWD) are supported.

An external debugger can be connected to the evaluation board through a 2 x 5 fine pitch (0.05”) ARM JTAG header. When connecting an external debugger, pin 3 of the JTAG header must be tied to ground in order for the Stellaris® ICDI to release control of the JTAG signals. The ARM standard pinout specifies pin 3 as ground, therefore, any standard third-party debugger should work.

Table 2-12 shows the pins used for JTAG and SWD.

**Table 2-12. Stellaris® In-Circuit Debug Interface (ICDI) Signals**

| GPIO Pin | Pin Function | JTAG Header Pin |
|----------|--------------|-----------------|
| PC0      | TCK/SWCLK    | 4               |
| PC1      | TMS/SWDIO    | 2               |
| PC2      | TDI          | 8               |
| PC3      | TDO/SWO      | 6               |

**Table 2-12. Stellaris® In-Circuit Debug Interface (ICDI) Signals (Continued)**

| GPIO Pin                | Pin Function               | JTAG Header Pin |
|-------------------------|----------------------------|-----------------|
| $\overline{\text{RST}}$ | $\overline{\text{RST}}$    | 10              |
| GPIO Pin                | Pin Function               | ICDI Function   |
| —                       | $\overline{\text{EXTDBG}}$ | 3               |

See Appendix A, “Schematics” on page 22 for the full header pinout.

## Virtual COM Port

When plugged in to a PC, the device enumerates as a debugger and a virtual COM port. Table 2-13 shows the connections for the COM port to the pins on the microcontroller.

**Table 2-13. Virtual COM Port Signals**

| GPIO Pin | Pin Function | Virtual COM Port |
|----------|--------------|------------------|
| PA0      | U0RX         | TXD              |
| PA1      | U0TX         | RXD              |

## Chipcon Wireless Evaluation Module Connector (Schematic Page 5)

These features are not populated on the board. The pads have been laid out on the board for customers who want to solder the headers to connect a Texas Instruments' wireless evaluation module. See Appendix C, “Bill of Materials (BOM)” on page 29 for the orderable part numbers that can be populated on the pads (J9, J10, Y4, C66, and C67).

Although no wireless software support is provided out of the box, customers and third parties are encouraged to port existing wireless projects to the EK-LM4F232 evaluation board through the use of this interface. See the Chipcon Wireless Evaluation Module Connector schematic on page 27 for information on what peripherals are connected to the wireless headers.

## Software Development

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

### Software Description

The software provided with the EK-LM4F232 provides access to all of the peripheral devices supplied in the design. The StellarisWare® Peripheral Driver Library is used to operate the on-chip peripherals.

The software includes a set of example applications that use the StellarisWare® Peripheral Driver Library. These applications demonstrate the capabilities of the LM4F232H5QD microcontroller, as well as provide a starting point for the development of the final application for use on the EK-LM4F232 evaluation board.

The EK-LM4F232 Evaluation Kit CD also contains a Windows quickstart companion for the Data Logger quickstart application. The companion application provides a strip-chart display for up to 10 channels of data from the EK-LM4F232 evaluation board. You can enable or disable the display for each channel and log the data to a comma-separated values (CSV) file.

### Source Code

The complete source code is included on the EK-LM4F232 CD including the source code for the Windows quickstart companion application. See the README First document for a detailed description of hardware setup and how to install the source code. The source code and binary files are installed in the DriverLib tree.

### Tool Options

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

- Keil ARM RealView® Microcontroller Development System
- IAR Embedded Workbench for ARM
- Sourcery CodeBench
- Code Red Technology Red Suite
- Generic Gnu C compiler
- Texas Instruments' Code Composer Studio™ IDE

Download evaluation versions of these tools from [www.ti.com/stellaris](http://www.ti.com/stellaris). 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.

Instructions on installing and using each of the evaluation tools can be found in the Quickstart guides (for example, Quickstart-Keil, Quickstart-IAR) which are available for download from the evaluation kit section of our web site at [www.ti.com/stellaris](http://www.ti.com/stellaris).

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

## Programming the EK-LM4F232 Board

The EK-LM4F232 software package includes pre-built binaries for each of the example applications. If you installed DriverLib to the default installation path of C:/DriverLib, you can find the example applications in "C:/DriverLib/boards/ek-lm4f232". The on-board Stellaris ICD1 is used with the Stellaris LM Flash Programmer tool to program applications on the EK-LM4F232 board.

Follow these steps to program example applications into the EK-LM4F232 evaluation board using the Stellaris® ICD1:

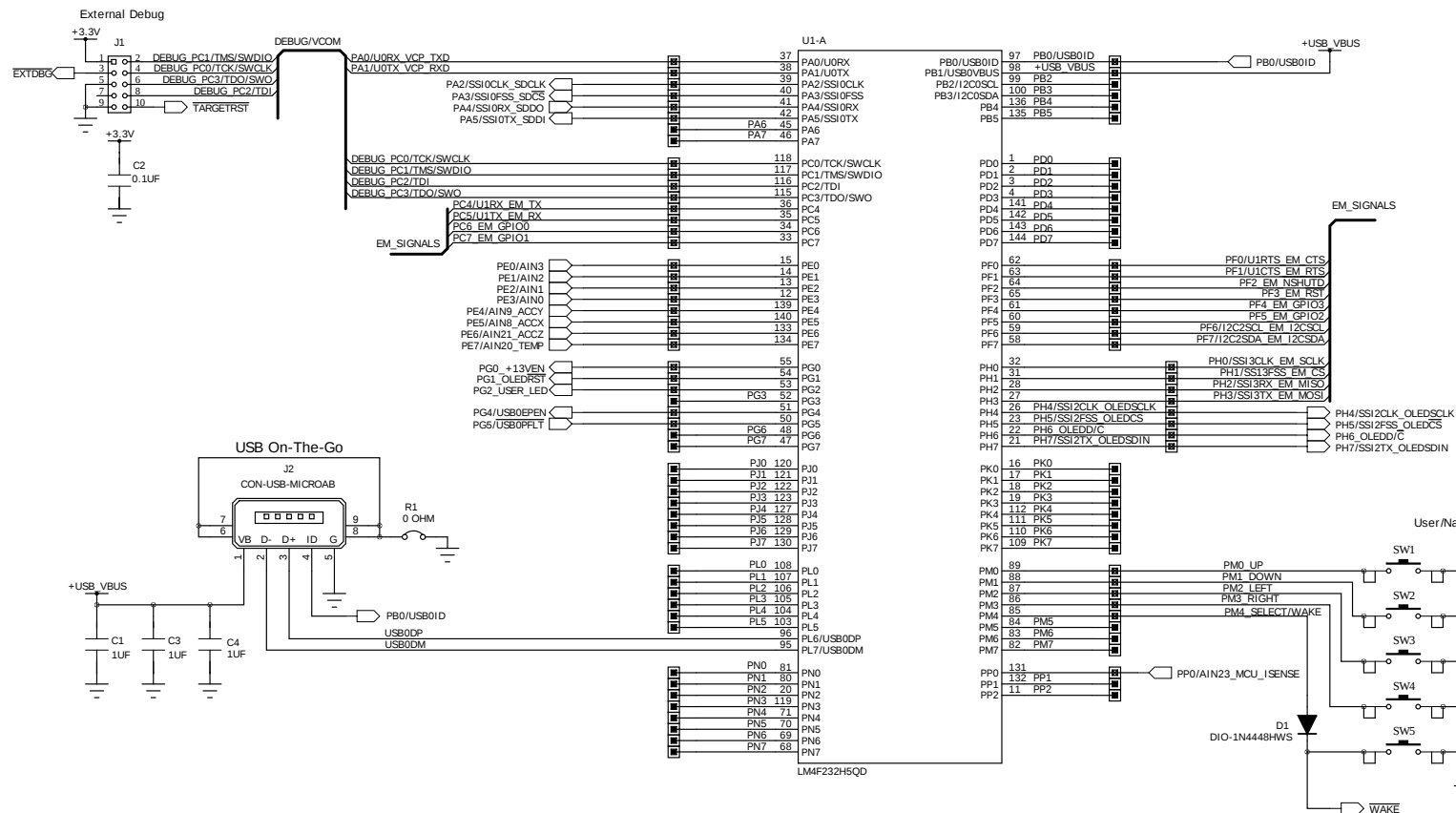
1. Install LM Flash Programmer on a Windows PC.
2. Connect the USB-A cable plug to an available port on the PC and the Mini-B plug to the board.
3. Verify that the POWER LED D4 on the board is lit.
4. Run LM Flash Programmer.
5. In the Configuration tab, use the Quick Set control to select the EK-LM4F232 evaluation board.
6. Move to the Program tab and click the Browse button. Navigate to the example applications directory (the default location is "C:/DriverLib/boards/ek-lm4f232/").
7. Each example application has its own directory. Navigate to the example directory that you want to load and then into the directory which contains the binary (\*.bin) files. Select the binary file and click Open.
8. Set the "Erase Method" to "Erase Necessary Pages," check the "Verify After Program" box, and check "Reset MCU After Program".
9. Click the Program button to start the Erase, Download, and Verify process. The DEBUG ACTIVE LED (D5) on the board turns on at this time.

Program execution starts once the Verify process is complete.

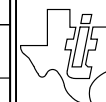
## Schematics

This section contains the schematics for the EK-LM4F232 board.

- Microcontroller, USB OTG, User Switches, and LED on page 23
- Logger, Temp Sensor, OLED, SD Card on page 24
- Power on page 25
- Stellaris In-Circuit Debug Interface (ICDI) on page 26
- Chipcon Wireless Evaluation Module Connector on page 27



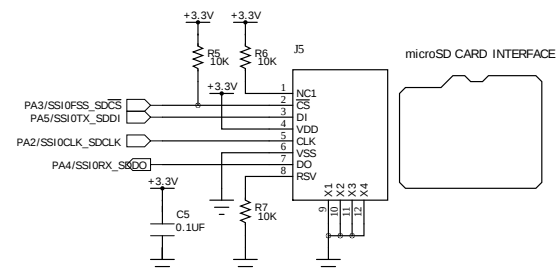
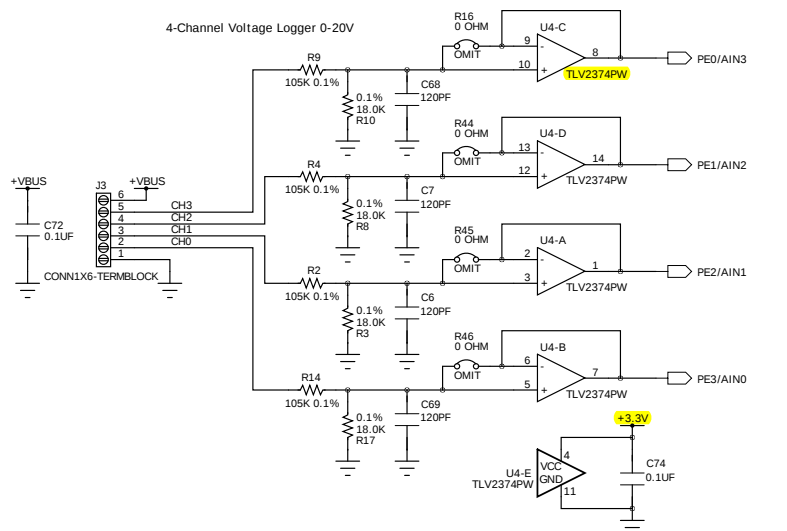
|                                                                   |               |                  |
|-------------------------------------------------------------------|---------------|------------------|
| DESIGNER<br>DAY                                                   | REVISION<br>A | DATE<br>9/7/2011 |
| PROJECT<br>LM4F232H5QD Evaluation Kit                             |               |                  |
| DESCRIPTION<br>Microcontroller, USB OTG,<br>User Switches and LED |               |                  |
| FILENAME<br>Armadillo Rev A.sch                                   |               |                  |



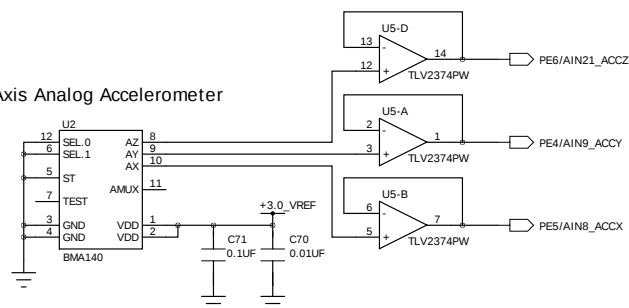
**TEXAS INSTRUMENTS**  
**STELLARIS® MICROCONTROLLERS**  
 108 WILD BASIN ROAD, SUITE 350  
 AUSTIN TX, 78746  
[www.ti.com/stellaris](http://www.ti.com/stellaris)

PART NO. EK-LM4F232

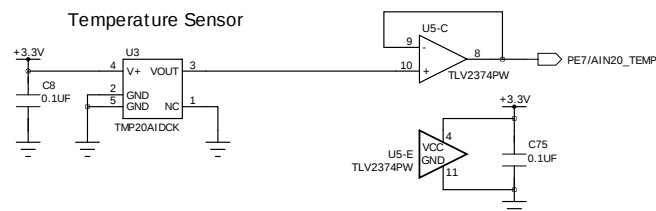
SHEET 1 OF 5



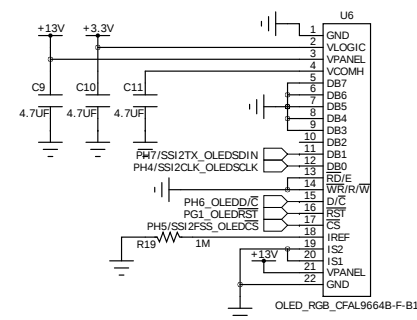
### 3-Axis Analog Accelerometer



### Temperature Sensor

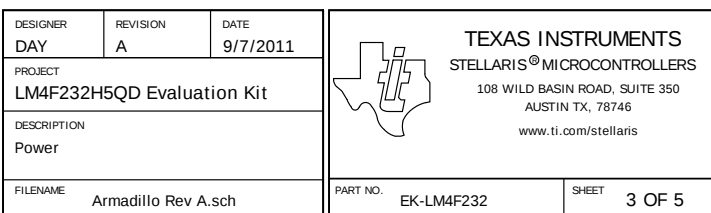
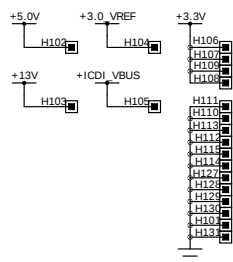
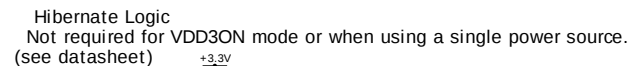
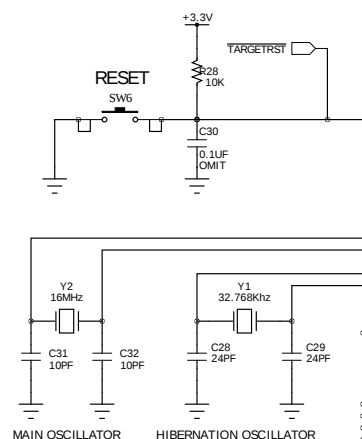


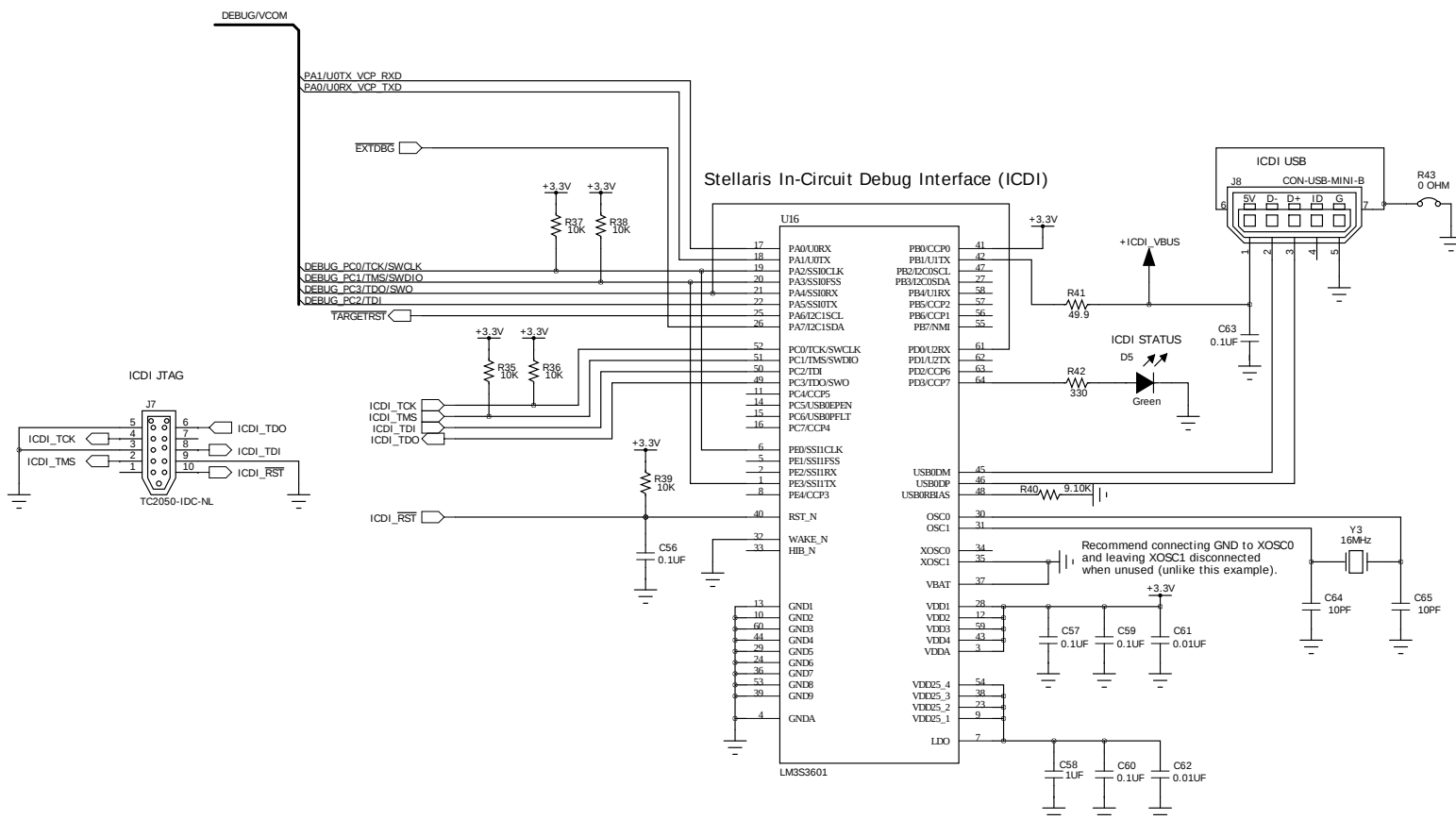
### 96X64 RGB OLED Display



|                                                   |               |                  |
|---------------------------------------------------|---------------|------------------|
| DESIGNER<br>DAY                                   | REVISION<br>A | DATE<br>9/7/2011 |
| PROJECT<br>LM4F232H5QD Evaluation Kit             |               |                  |
| DESCRIPTION<br>Logger, Temp Sensor, OLED, SD Card |               |                  |
| FILENAME<br>Armadillo Rev A.sch                   |               |                  |

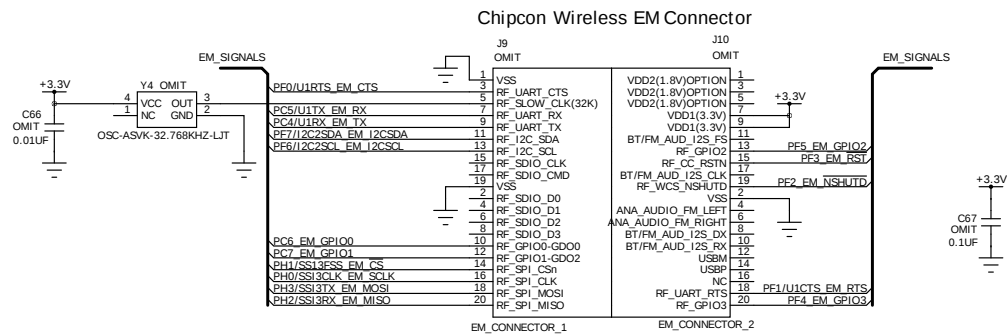
|                                                                                                                                                                                                                                                                       |                 |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|
|  <b>TEXAS INSTRUMENTS</b><br>STELLARIS® MICROCONTROLLERS<br>108 WILD BASIN ROAD, SUITE 350<br>AUSTIN TX, 78746<br><a href="http://www.ti.com/stellaris">www.ti.com/stellaris</a> |                 |
| PART NO.<br>EK-LM4F232                                                                                                                                                                                                                                                | SHEET<br>2 OF 5 |





|                                                     |               |                  |
|-----------------------------------------------------|---------------|------------------|
| DESIGNER<br>DAY                                     | REVISION<br>A | DATE<br>9/7/2011 |
| PROJECT<br>LM4F232H5QD Evaluation Kit               |               |                  |
| DESCRIPTION<br>Stellaris In Circuit Debug Interface |               |                  |
| FILENAME<br>Armadillo Rev A.sch                     |               |                  |

|                                                                                                                                                                                                                                                                       |                 |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|
|  <b>TEXAS INSTRUMENTS</b><br>STELLARIS® MICROCONTROLLERS<br>108 WILD BASIN ROAD, SUITE 350<br>AUSTIN TX, 78746<br><a href="http://www.ti.com/stellaris">www.ti.com/stellaris</a> |                 |
| PART NO.<br>EK-LM4F232                                                                                                                                                                                                                                                | SHEET<br>4 OF 5 |



|                                                                 |               |                  |
|-----------------------------------------------------------------|---------------|------------------|
| DESIGNER<br>DAY                                                 | REVISION<br>A | DATE<br>9/7/2011 |
| PROJECT<br>LM4F232H5QD Evaluation Kit                           |               |                  |
| DESCRIPTION<br>Chipcon Wireless EM Connector<br>(Not Installed) |               |                  |
| FILENAME<br>Armadillo Rev A.sch                                 |               |                  |

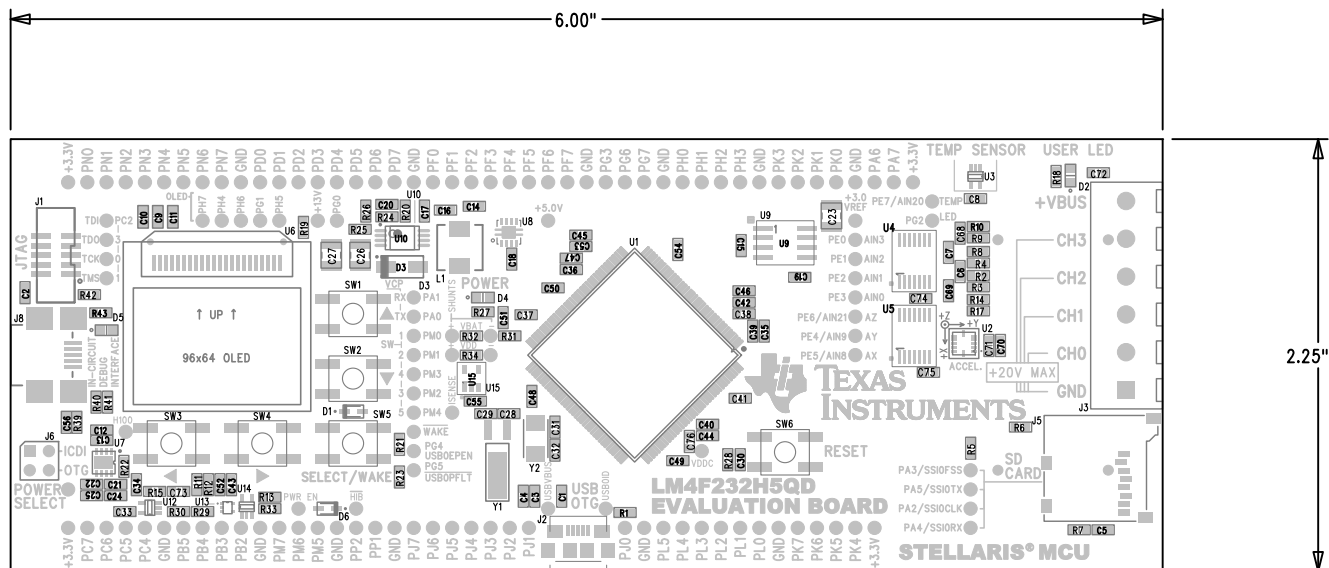
|                                                                                                                                                                                                                                        |  |                        |  |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|------------------------|--|
|  <p><b>TEXAS INSTRUMENTS</b><br/>STELLARIS® MICROCONTROLLERS<br/>108 WILD BASIN ROAD, SUITE 350<br/>AUSTIN TX, 78746<br/>www.ti.com/stellaris</p> |  | SHEET<br>5 OF 5        |  |
|                                                                                                                                                                                                                                        |  | PART NO.<br>EK-LM4F232 |  |

# APPENDIX B

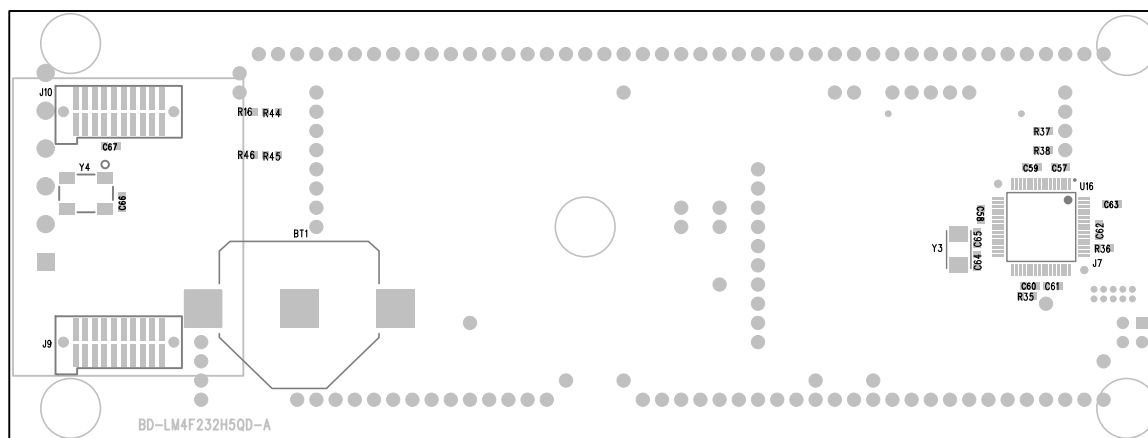
## Component Locations

Plots of the top-side and bottom-side component locations are shown in Figure B-1 and Figure B-2.

**Figure B-1. EK-LM4F232 Component Locations (Top View)**



**Figure B-2. EK-LM4F232 Component Locations (Bottom View)**



# A P P E N D I X C

## Bill of Materials (BOM)

Table C-1 shows the Bill of Materials for the EK-LM4F232 evaluation board.

**Table C-1. EK-LM4F232 Bill of Materials (BOM)**

| Item | Reference                                                                              | Qty | Description                                    | Mfg        | Part Number            |
|------|----------------------------------------------------------------------------------------|-----|------------------------------------------------|------------|------------------------|
| 1    | BT1                                                                                    | 1   | Battery Holder, CR2032, SMT                    | Keystone   | 3002TR                 |
|      |                                                                                        |     |                                                | Keystone   | 3002TR                 |
| 2    | C2 C5 C8 C12 C17<br>C34-36 C40 C42-43<br>C45 C48-50 C52<br>C55-57 C59-60 C63<br>C71-75 | 27  | Capacitor, 0.1uF 50V, 10% 0603 X7R             | Murata     | GRM188R71H104<br>KA93D |
| 3    | C20                                                                                    | 1   | Capacitor, 820pF, 50V, 5%, 0603,<br>COG        | TDK        | C1608C0G1H821J         |
| 4    | C23 C26-27                                                                             | 3   | Capacitor, 10uF, 50V, -20% +80%,<br>1210, Y5V  | Murata     | GRM32DF51H106<br>ZA01L |
| 5    | C29 C28                                                                                | 2   | Capacitor, 24pF, 50V, 5%, 0603,<br>COG         | TDK        | C1608C0G1H240J         |
| 6    | C31-32 C64-65                                                                          | 4   | Capacitor, 10pF 50V 5% Ceramic<br>NPO/COG 0603 | Kemet      | C0603C100J5GAC<br>TU   |
|      |                                                                                        |     |                                                | Kemet      | C0603C100J5RAC<br>TU   |
| 7    | C33                                                                                    | 1   | Capacitor, 200pF, 50V, 5%, 0603,<br>COG        | TDK        | C1608C0G1H201J         |
| 8    | C41 C37-39 C70<br>C18 C61-62                                                           | 8   | Capacitor, 0.01uF 50V 5% 0603 X7R              | Kemet      | C0603C103J5RAC<br>TU   |
| 9    | C58 C1 C3-4 C13-16<br>C19 C21-22 C24-25<br>C44 C46-47 C53-54<br>C76                    | 19  | Capacitor, 1.0uF 25V 10% X5R 0603              | TDK        | C1608X5R1E105K         |
|      |                                                                                        |     |                                                | TDK        | C1608X5R1E105K         |
| 10   | C6-7 C68-69                                                                            | 4   | Capacitor, 120pF, 50V, 5%, 0603,<br>COG        | TDK        | C1608C0G1H121J         |
| 11   | C9-11                                                                                  | 3   | Capacitor, 4.7uF 25V 10% 0805 X5R              | Murata     | GRM21BR61E475<br>KA12L |
| 12   | D1 D6                                                                                  | 2   | Diode, Fast Switching, 80V, 250mA,<br>SOD-323  | Diodes Inc | 1N4448HWS-7-F          |

Table C-1. EK-LM4F232 Bill of Materials (BOM) (Continued)

| Item | Reference         | Qty | Description                                                 | Mfg                    | Part Number       |
|------|-------------------|-----|-------------------------------------------------------------|------------------------|-------------------|
| 13   | D2 D4-5           | 3   | LED, Green 565nm, Clear 0805 SMD                            | Lite-On                | LTST-C171GKT      |
|      |                   |     |                                                             | Lite-On                | LTST-C171GKT      |
| 14   | D3                | 1   | Diode, Schottky, 20V, 1A                                    | Taiwan Semiconductor   | SS12              |
| 15   | J1                | 1   | Header 2x5, 0.050, SM, Vertical Shrouded                    | Samtec                 | SHF-105-01-S-D-SM |
|      |                   |     |                                                             | Don Connex Electronics | C44-10BSA1-G      |
| 16   | J2                | 1   | Connector, USB micro AB Receptacle SMD                      | Hirose                 | ZX62-AB-5PA       |
| 17   | J3                | 1   | Terminal, Screw, 5mm, 6 Pos                                 | Molex                  | 0395430006        |
|      |                   |     |                                                             | Molex                  | 0395430006        |
| 18   | J5                | 1   | Connector, Micro SD card, push-push SMT                     | 3M                     | 2908-05WB-MG      |
| 19   | J6                | 1   | Header, 2x2, 0.100, T-Hole, Vertical Unshrouded, 0.230 Mate | FCI                    | 67997-104HLF      |
|      |                   |     |                                                             | 4UCON                  | 00998             |
| 20   | J8                | 1   | Connector, USB Mini-B SMT 5pin                              | Molex                  | 54819-0572        |
| 21   | L1                | 1   | Inductor, 3.3uH, SMD, 6mm x 6mm, 1.7A, 0.044 Ohm            | Panasonic              | ELL-6PG3R3N       |
| 22   | R1 R43            | 2   | Resistor, 0 OHM 1/10W 0603 SMD                              | Panasonic              | ERJ-3GEY0R00V     |
| 23   | R12               | 1   | Resistor, 20K OHM 1/10W 5% 0603 Thick                       | Yageo                  | RC0603JR-0720KL   |
| 24   | R13 R19           | 2   | Resistor, 1M OHM 1/10W 5% 0603 SMD                          | Panasonic              | ERJ-3GEYJ105V     |
| 25   | R2 R4 R9 R14      | 4   | Resistor, 105.0K Ohm, 1/10W, 0.1%, 0603, Thin               | Susumu                 | RG1608P-1053-B-T5 |
| 26   | R24               | 1   | Resistor, 36.5K Ohm, 1/10W, 1%, 0603, Thick                 | Yageo                  | RC0603FR-0736K5L  |
| 27   | R25               | 1   | Resistor, 174K Ohm, 1/10W, 1%, 0603, Thick                  | Yageo                  | RC0603FR-07174KL  |
| 28   | R26 R10 R8 R3 R17 | 5   | Resistor, 18.00K Ohm, 1/10W, 0.1%, 0603, Thin               | Panasonic              | ERA-3AEB183V      |
| 29   | R27 R18 R42       | 3   | Resistor, 330 OHM 1/10W 5% 0603 SMD                         | Panasonic              | ERJ-3GEYJ331V     |
| 30   | R29               | 1   | Resistor, 9.53M Ohm, 1/10W, 1%, 0603, Thick                 | Vishay                 | CRCW06039M53FKEA  |

**Table C-1. EK-LM4F232 Bill of Materials (BOM) (Continued)**

| Item | Reference                         | Qty | Description                                                       | Mfg               | Part Number       |
|------|-----------------------------------|-----|-------------------------------------------------------------------|-------------------|-------------------|
| 31   | R30                               | 1   | Resistor, 6.8M Ohm, 1/10W, 5%, 0603, Thick                        | Yageo             | RC0603JR-076M8L   |
| 32   | R31                               | 1   | Resistor, 220K Ohm, 1/10W, 1%, SMD, Thick                         | Panasonic         | ERJ-3EKF2203V     |
| 33   | R32-33                            | 2   | Resistor, 1K OHM 1/10W 1% 0603 Thick                              | Panasonic         | ERJ-3EKF1001V     |
| 34   | R34                               | 1   | Resistor, 0.1 Ohm, 1/10W, 1%, 0603, Thick                         | Panasonic         | ERJ-3RSFR10V      |
| 35   | R40                               | 1   | Resistor, 9.1K OHM 1/10W 1% 0603 Thick                            | Panasonic         | ERJ-3EKF9101V     |
| 36   | R41                               | 1   | Resistor, 49.9 OHM 1/10W 1% 0603 Thick                            | Panasonic         | ERJ-3EKF49R9V     |
| 37   | R5-7 R11 R15<br>R20-23 R28 R35-39 | 15  | Resistor, 10K OHM 1/10W 5% 0603 SMD                               | Panasonic         | ERJ-3GEYJ103V     |
| 38   | SW1-6                             | 6   | Switch, Tact 6mm SMT, 160gf                                       | Omron             | B3S-1000          |
| 39   | U1                                | 1   | Stellaris, LM4F232H5QDFIGA1                                       | Texas Instruments | LM4F232H5QDFIG A1 |
| 40   | U10                               | 1   | Regulator, 2.3V - 6V in, 18.5Vout max, 2.0A                       | Texas Instruments | TPS61085PW        |
| 41   | U12                               | 1   | IC, Single Voltage Detector, Adjustable, 5-SC70(DCK)              | Texas Instruments | TPS3803-01DCKR    |
| 42   | U13                               | 1   | IC, Single 2-input OR-Gate, 5SOT(DRL)                             | Texas Instruments | SN74AHCT1G32D RLR |
| 43   | U14                               | 1   | IC, Single Tri-state Buffer, SC70-5 (DCK)                         | Texas Instruments | SN74AHC1G125D CKR |
| 44   | U15                               | 1   | Current Shunt Monitor, INA198, 100V/V Gain, 5SOP(DBV)             | Texas Instruments | INA198AIDBVR      |
| 45   | U16                               | 1   | Stellaris MCU, LM3S3601                                           | Texas Instruments | LM3S3601-IQR50    |
| 46   | U2                                | 1   | IC, 3 Axis Analog Accelerometer, +/- 4g                           | Bosch Sensortec   | BMA140            |
| 47   | U3                                | 1   | IC, Analog Temperature Sensor -55C to +130C, +/-2.5C, 5-SC70(DCK) | Texas Instruments | TMP20AIDCKR       |
| 48   | U4-5                              | 2   | Op Amp, 3 MHz, Quad, Rail-to-Rail, 14TSSOP                        | Texas Instruments | TLV2374IPWR       |
| 49   | U6                                | 1   | OLED Display, 96x64, RGB                                          | Crystalfontz      | CFAL9664B-F-B1    |
| 50   | U7                                | 1   | Fault protected power switch, dual channel, 8-SON                 | Texas Instruments | TPS2052BDRBR      |

Table C-1. EK-LM4F232 Bill of Materials (BOM) (Continued)

| Item                                                         | Reference   | Qty | Description                                          | Mfg               | Part Number           |
|--------------------------------------------------------------|-------------|-----|------------------------------------------------------|-------------------|-----------------------|
| 51                                                           | U8          | 1   | Regulator, 3.3V, 400mA, LDO                          | Texas Instruments | TPS73633DRBT          |
| 52                                                           | U9          | 1   | Precision 3.0V reference SOIC-8                      | Texas Instruments | REF5030AID            |
| 53                                                           | Y1          | 1   | Crystal, 32.768KHz Radial Can                        | Abracon           | AB26TRB-32.768KHZ-T   |
| 54                                                           | Y2-3        | 2   | Crystal, 16.00MHz 5.0x3.2mm SMT                      | NDK               | NX5032GA-16.000000MHZ |
|                                                              |             |     |                                                      | Abracon           | ABM3-16.000MHZ-B2-T   |
| 55                                                           | PCB1        | 1   | PCB for EK-LM4F232H5QD FR-4 6-layer ENIG Rev A       |                   |                       |
| <b>PCB Do Not Populate List (Shown for information only)</b> |             |     |                                                      |                   |                       |
| 56                                                           | C30 C51 C67 | 3   | Capacitor, 0.1uF 50V, 10% 0603 X7R                   | Murata            | GRM188R71H104KA93D    |
| 57                                                           | C66         | 1   | Capacitor, 0.01uF 50V 5% 0603 X7R                    | Kemet             | C0603C103J5RAC TU     |
| 58                                                           | J9, J10     | 2   | Header, 2x10, 0.050, SMT, Vertical, Shrouded, Socket | Samtec            | TFM-110-02-S-D-K-A    |
| 59                                                           | R16 R44-46  | 4   | Resistor, 0 OHM 1/10W 0603 SMD                       | Panasonic         | ERJ-3GEY0R00V         |
| 60                                                           | Y4          | 1   | Oscillator, 32.768 kHz, SMT                          | Abracon           | ASVK-32.768KHZ-LJT    |
|                                                              |             |     |                                                      |                   |                       |
| <b>Final Assembly Bill Of Materials</b>                      |             |     |                                                      |                   |                       |
| 61                                                           | Z1          | 1   | Battery, Lithium, CR2032, Non-Rechargeable           | Panasonic         | CR2032                |
| 62                                                           | Z2          | 1   | Jumper, 0.100, Gold, Black, Closed                   | Sullins           | SPC02SYAN             |
| 63                                                           | Z3-7        | 5   | Rubber Feet, Adhesive, Round, 0.312 x 0.200          | 3M                | SJ-61A1               |

## References

In addition to this document, the following references are included on the Stellaris LM4F232H5QD Evaluation Kit CD and are also available for download at [www.ti.com](http://www.ti.com).

- *Stellaris LM4F232H5QD Microcontroller Data Sheet*, publication DS-LM4F232H5QD
- StellarisWare Driver Library
- *StellarisWare Driver Library User's Manual*, publication SW-DRL-UG

Additional references include:

- *±2.5°C Low-Power, Analog Out Temperature Sensor Data Sheet (TMP20)*
- *Voltage Output High-Side Measurement Current Shunt Monitor Data Sheet (INA198)*
- *Low Noise, Very Low Drift, Precision Voltage Reference Data Sheet (REF5030)*
- *Current-Limited, Power-Distribution Switches Data Sheet (TPS2052B)*
- *Single Voltage Detector Data Sheet (TPS3803-01)*

The following data sheet can be obtained from the manufacturer:

- *Bosch Sensortec Triaxial, Analog Acceleration Sensor Data Sheet (BMA140)*

Information on development tool being used:

- RealView MDK web site, [www.keil.com/arm/rvmdkkit.asp](http://www.keil.com/arm/rvmdkkit.asp)
- IAR Embedded Workbench web site, [www.iar.com](http://www.iar.com)
- Sourcery CodeBench development tools web site, [www.codesourcery.com/gnu\\_toolchains/arm](http://www.codesourcery.com/gnu_toolchains/arm)
- Code Red Technologies development tools web site, [www.code-red-tech.com](http://www.code-red-tech.com)
- Texas Instruments' Code Composer Studio™ IDE web site, [www.ti.com/ccs](http://www.ti.com/ccs)

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Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

### Products

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| DLP® Products          | <a href="http://www.dlp.com">www.dlp.com</a>                                         |
| DSP                    | <a href="http://dsp.ti.com">dsp.ti.com</a>                                           |
| Clocks and Timers      | <a href="http://www.ti.com/clocks">www.ti.com/clocks</a>                             |
| Interface              | <a href="http://interface.ti.com">interface.ti.com</a>                               |
| Logic                  | <a href="http://logic.ti.com">logic.ti.com</a>                                       |
| Power Mgmt             | <a href="http://power.ti.com">power.ti.com</a>                                       |
| Microcontrollers       | <a href="http://microcontroller.ti.com">microcontroller.ti.com</a>                   |
| RFID                   | <a href="http://www.ti-rfid.com">www.ti-rfid.com</a>                                 |
| OMAP Mobile Processors | <a href="http://www.ti.com/omap">www.ti.com/omap</a>                                 |
| Wireless Connectivity  | <a href="http://www.ti.com/wirelessconnectivity">www.ti.com/wirelessconnectivity</a> |

### Applications

|                               |                                                                                          |
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| Computers and Peripherals     | <a href="http://www.ti.com/computers">www.ti.com/computers</a>                           |
| Consumer Electronics          | <a href="http://www.ti.com/consumer-apps">www.ti.com/consumer-apps</a>                   |
| Energy and Lighting           | <a href="http://www.ti.com/energy">www.ti.com/energy</a>                                 |
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