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iCE40 Ultra Wearable Development Platform User Guide

EB100 Version 1.0, July 2015

Introduction

The iCE40 Ultra Wearable Development Platform is an easy-to-use platform which demonstrates how the iCE40 Ultra and MachXO2 FPGAs can be utilized in wearable and mobile applications. Along with the evaluation board and accessories, there are reference designs available to demonstrate the functionality of the boards and components.

The iCE40 Ultra Wearable Development Platform consists of two boards: the Main Board and the Sensor Board. The Main Board contains the iCE40 Ultra and MachXO2 FPGAs, which drive various components on the board. The iCE40 Ultra focuses on interfacing with peripheral components such as LEDs, sensors and BLE connectivity. The MachXO2 focuses on driving the MIPI DSI Display from a Quad SPI flash functioning as a frame buffer and storage device. The Sensor Board contains several sensors that are typically found in mobile and wearable devices. By separating the two boards, the interconnect headers can be used to directly interface with peripherals for testing (see the Headers section).

The contents of this user guide include a description of the board features, header connection descriptions and pinouts, instructions on loading demonstration bitstreams, a complete set of schematics, and the bill of materials.

Features

The iCE40 Ultra Wearable Development Platform includes:

- iCE40 Ultra Wearable Development Platform Main Board:
  - — iCE40 Ultra (iCE5LP-4K-SWG36) device in a 36-ball WLCSP package
  - — MachXO2 (LCMXO2-2000ZE-1UWG49) device in a 49-ball WLCSP package
  - — High-current IR, White, and RGB LEDs
  - — Stereo Microphones
  - — Connector and driver circuitry for MIPI DSI Display
  - — Headers for I2C, SPI, and UART
  - — Mini-USB programming connection
  - — Battery charger
  - — RoHS-compliant packaging and process
- iCE40 Ultra Wearable Development Platform Sensor Board:
  - – Bluetooth Low-Energy Module
  - – Heart-rate/SpO2 Sensor and Analog Front End
  - – Skin temperature sensor
  - – Pressure sensor
  - – Accelerometer/Gyroscope
  - – Pads for soldering on battery (charger accepts Li-Ion and Li-Po)
- Syma 652030 Battery – 3.7 V, 250 mAh Lithium-Polymer Battery provides power while the USB cable is disconnected
- LG LH154Q01 Display – 240x240 Single Lane MIPI DSI Display. Must be attached prior to power-up
- USB Connector Cable – A mini-USB port provides power and a programming interface for the board
- Watch Strap – A watch strap comes pre-attached to the Sensor Board

Note: Static electricity can severely shorten the lifespan of electrical components. Use care while handling the iCE40 Ultra Wearable Development Platform to avoid ESD damage.

Figure 1 through Figure 4 show the top and bottom sides of the Main and Sensor boards, with key features highlighted.

Figure 1. Main Board (Top Side)

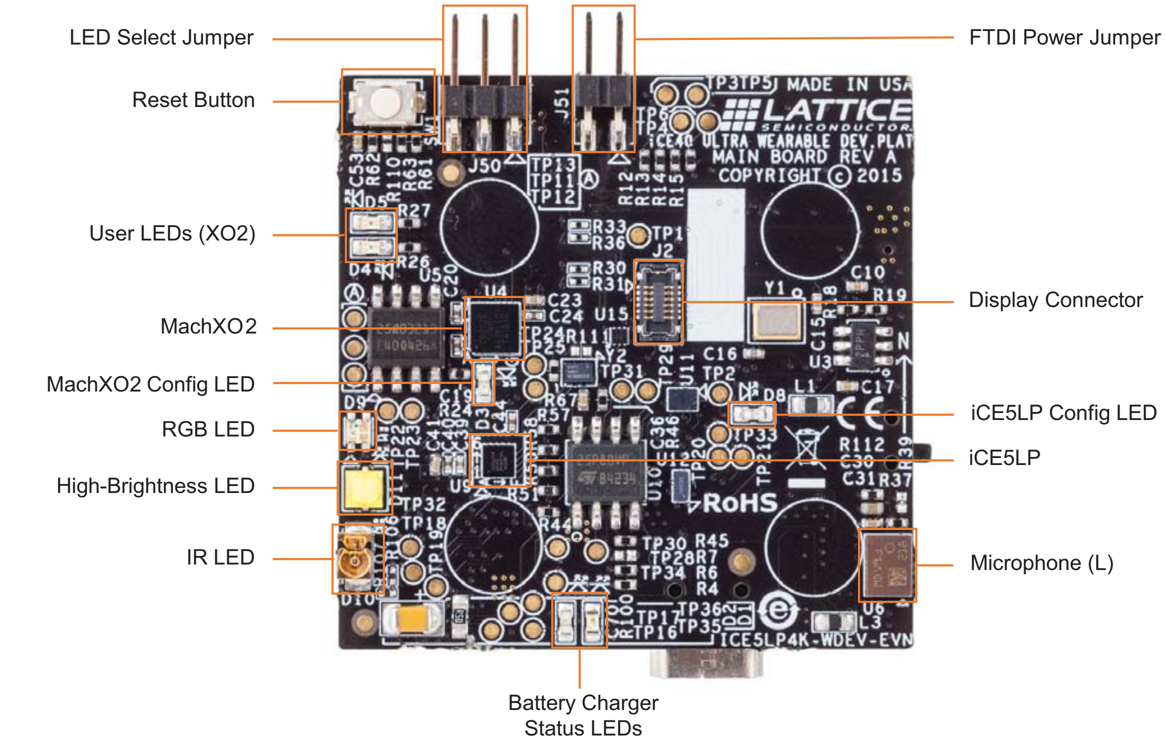


Figure 2. Main Board (Bottom Side)

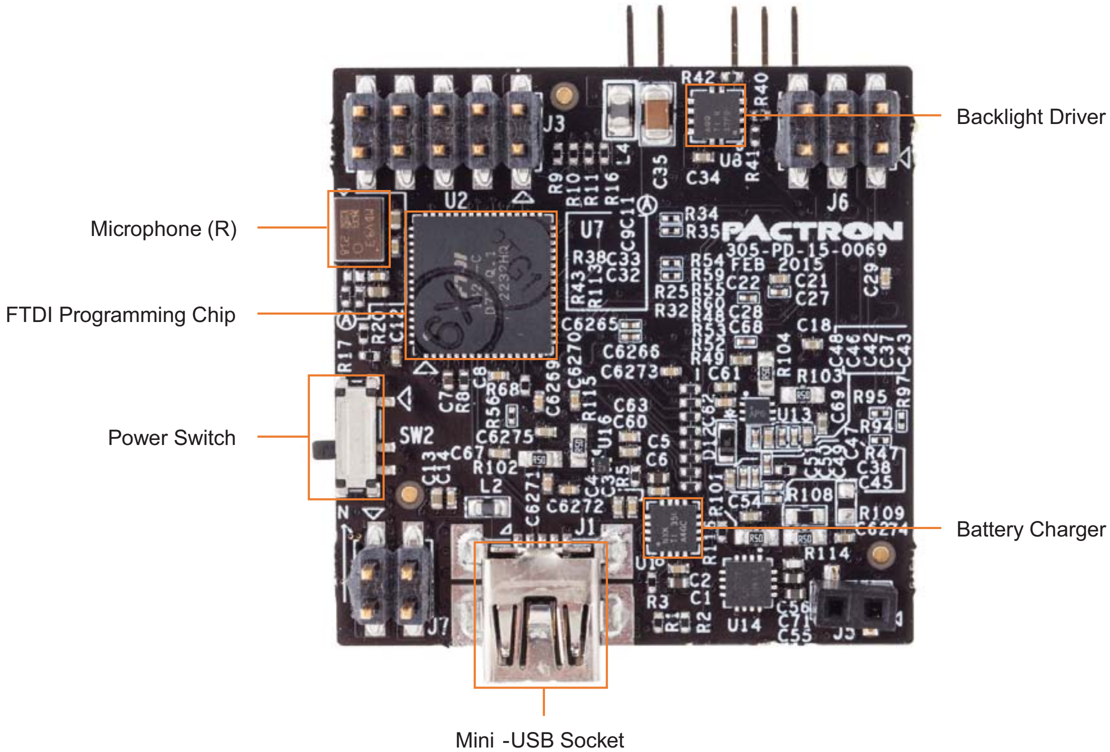


Figure 3. Sensor Board (Top Side)

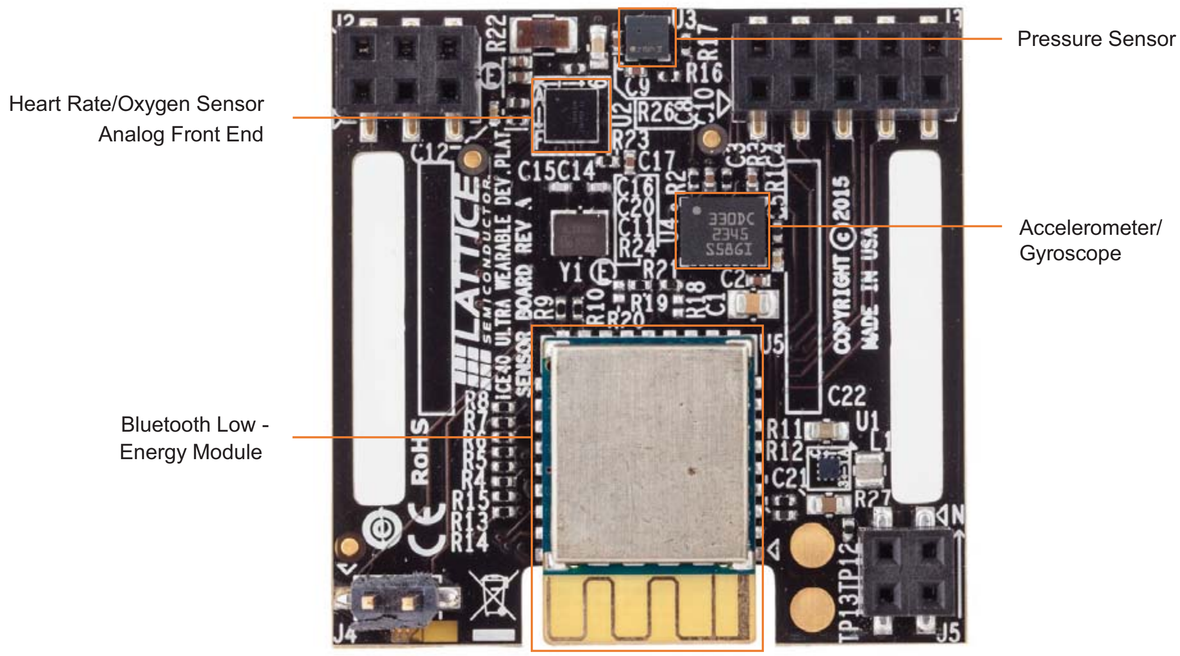
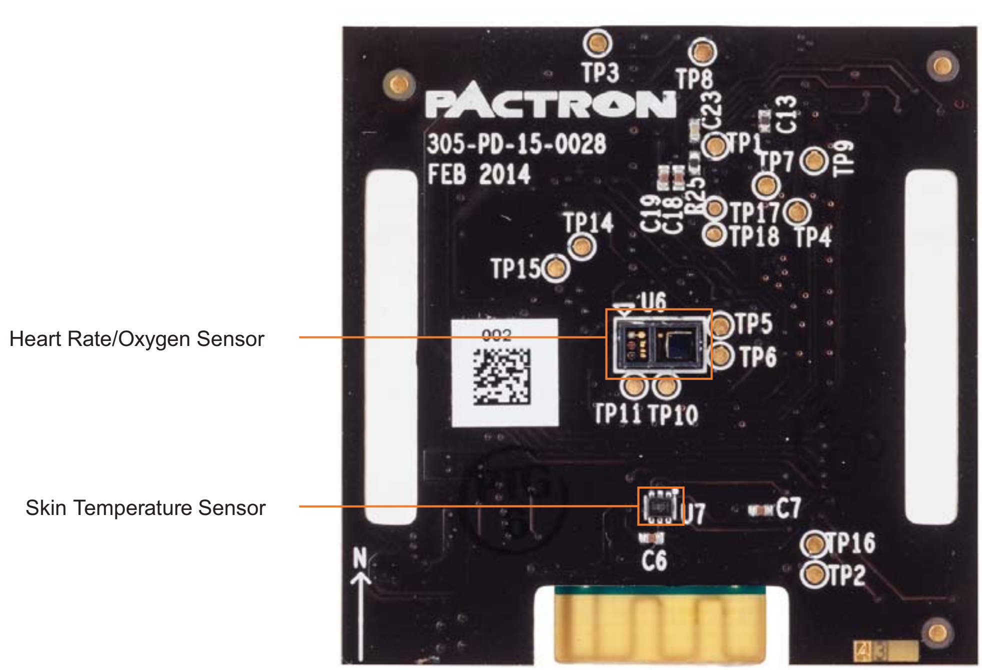


Figure 4. Sensor Board (Bottom Side)



Lattice Semiconductor Devices

The Main Board features an iCE5LP4K and a MachXO2-2000ZE FPGA.

The iCE5LP4K has a 1.2 V core supply and is packaged in a 36-ball WLCSP package. For a complete description of this device, see DS1048, iCE40 Ultra Family Data Sheet.

The MachXO2-2000ZE has a 1.2 V core supply and is packaged in a 49-ball WLCSP package. For a complete description of this device, see DS1035, MachXO2 Family Data Sheet.

Software Requirements

The following software must be installed before designs can be developed for this board:

- iCEcube2 2014-12 (or higher)
- Diamond® 3.4 (or higher)
- Diamond Programmer 3.4 (or higher)

This software is available at the Lattice website Design Software & IP page.

Board Power

The iCE40 Ultra Wearable Development Platform uses the USB connection as its primary source of power. It is also equipped with a battery and charger for use without a wired connection. A power switch (SW2) allows for the regulators to be disabled while allowing the battery to continue charging. Two status LEDs allow the battery charger to be monitored (see Table 12).

The battery charger and regulators are located on the Main Board. The battery attaches to the Sensor Board. Power is transferred between the two boards using the Power Connector header. See Table 2 for connections.

The VREG_ADJ I/O supply net for the iCE5LP is adjustable, but is an internal, reserved feature. Changing this net from 3.3 V (default) to 1.8 V will cause voltage-level mismatches that can permanently damage the iCE5LP.

To allow current measurements to be made for specific supplies, resistors with test points have been inserted into the circuit. Refer to Table 1 to see which test points correspond to which supplies.

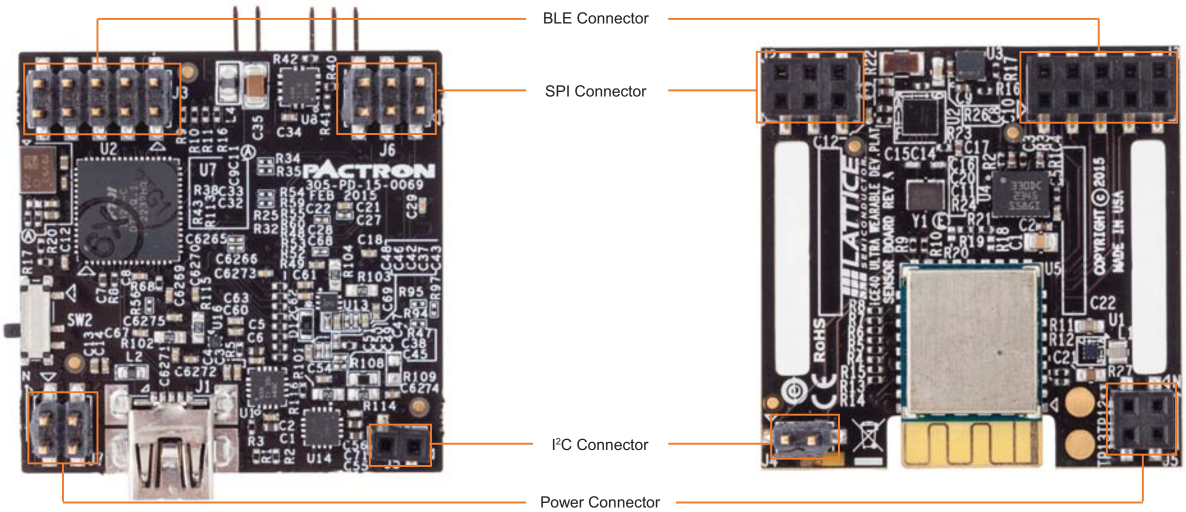
Table 1. Supply Current Test Points

Supply	TP+	TP-	Resistance
MachXO2 1.2 V	TP20	TP21	0.5 Ohms
MachXO2 3.3 V	TP18	TP19	0.5 Ohms
iCE5LP 1.2 V	TP20	TP33	0.5 Ohms
iCE5LP 3.3 V	TP18	TP32	0.5 Ohms
3.3 V Regulator	TP16	TP17	0.5 Ohms
Display 3 V	TP25	TP24	0.5 Ohms
Display 1.8 V	TP22	TP23	0.5 Ohms

Headers

Four headers are used to connect the Main Board and the Sensor Board. The signals and connections are shown in the tables below:

Figure 5. Headers



Power Connector (Main Board J7, Sensor Board J5): Power connection between the two boards

Table 2. Power Connector

Pin Number	Signal	Description
1	3V3	Regulated 3.3 V supply
2	BT_3V7	Unregulated ~3.7 V battery voltage
3	VREG_ADJ	Adjustable I/O Voltage (3.3 V default)
4	GND	Ground

I2C Connector (Main Board J5, Sensor Board): Interface for pressure sensor, temperature sensor, and accelerometer/gyroscope

Table 3. I2C Connector

Pin Number	Signal	iCE5LP Ball #
1	Sensor SCL	C1
2	Sensor SDA	E2

SPI Connector (Main Board J6, Sensor Board): Interface for the Analog Front-End of the Heart Beat/SpO2 sensor

Table 4. SPI Connector

Pin Number	Signal	iCE5LP Ball #
1	AFE SCLK	D6
2	AFE MISO	F6
3	AFE Ready	B5
4	AFE SS	D5
5	AFE MOSI	E6
6	GND	—

BLE Connector (Main Board J3, Sensor Board): Contains a UART connection to iCE5LP and a configuration SPI connection for the iCE5LP

Table 5. BLE Connector

Pin Number	Signal	Ball #
1	BLE Prog	MachXO2 G2
2	BLE SS	Config
3	BLE MISO	Config
4	BLE MOSI	Config
5	BLE SCLK	Config
6	CRSTb	—
7	CDONE	MachXO2 E3
8	UART Rx (out)	iCE5LP F5
9	UART Tx (in)	iCE5LP E5
10	GND	—

Jumpers

The following jumpers can be used for adjusting board functionality:

- High-current LED select (J50): Controls whether the IR LED (1+2) or High-current White LED (2+3) is driven by the iCE5LP device
- FTDI Power (J51): To minimize power consumption and increase battery life, the FTDI programming chip can have its power supply cut-off by removing the jumper from J51. J51 must be in place prior to powering up in order to program the devices on this board.

Test Points

Several test points have been included into the design to ease debug. Descriptions of these test points can be found below:

Table 6. Main Board Test Points

Test Point	Signal/Function
1	Configuration Signal: CResetn_FTDI
2	Configuration Signal: iCE_CDONE
3	Configuration Signal: FTDI_TCK (XO2)
4	Configuration Signal: FTDI_TDI (XO2)
5	Configuration Signal: FTDI_TDO (XO2)
6	Configuration Signal: FTDI_TMS (XO2)
11	Configuration Signal: JTAGEN (XO2)
12	Configuration Signal: PROGRAMN (XO2)
13	Configuration Signal: INITN (XO2)
16	Current Measurement (See Table 1)
17	Current Measurement (See Table 1)
18	Current Measurement (See Table 1)
19	Current Measurement (See Table 1)
20	Current Measurement (See Table 1)
21	Current Measurement (See Table 1)
22	Current Measurement (See Table 1)
23	Current Measurement (See Table 1)
24	Current Measurement (See Table 1)
25	Current Measurement (See Table 1)
28	Configuration Signal: FLASH_MISO (iCE)
29	Configuration Signal: FLASH_MOSI (iCE)
30	Configuration Signal: FLASH_CSB (iCE)
31	Configuration Signal: FLASH_SCLK (iCE)
32	Current Measurement (See Table 1)
33	Current Measurement (See Table 1)
34	3.3 V Regulator Output Control (See TPS7A7200)
35	3.3 V Regulator Output Control (See TPS7A7200)
36	3.3 V Regulator Output Control (See TPS7A7200)

Table 7. Sensor Board Testpoints

Test Point	Signal/Function
1	AFE4403: CLKOUT
2	BLE Config: SWCLK
3	LPS25H: INT1
4	AFE4403: TX3
5	AFE4403: INN
6	AFE4403: INP
7	AFE4403: ADC_RDY
8	AFE4403: LED_DRV_SUP
9	AFE4403: VCM
10	AFE4403: TXP
11	AFE4403: TXN
12	Battery Connector (+)
13	Battery Connector (-)
14	LSM330DLC: INT1_G
15	LSM330DLC: INT2_G
16	BLE Config: SWDIO
17	AFE4403: Manual Reset, short to TP18
18	AFE4403: Manual Reset, short to TP17

Device Interconnects

Six general purpose connections have been made between Lattice MachXO2 and iCE5LP devices for communication between FPGAs. Level translators have been implemented on these lines, which limit their operation frequency. Table 8 lists connection ports and maximum operation frequencies:

Table 8. MachXO2 and iCE5LP Interconnections

Net Number	MachXO2 Ball	iCE5LP Ball	Max Frequency
1	E6	C2	20 MHz
2	E5	B1	20 MHz
3	D5	D2	100 MHz
4	D4	B2	100 MHz
5	G4	B4	100 MHz
6	F4	F4	100 MHz

Display

The iCE40 Ultra Wearable Development Platform includes an LG LH154Q01 Display and necessary driving circuitry. MIPI DSI clock and data signals are driven by the Lattice MachXO2 device, through a resistor network for achieving proper voltage levels. This display also provides a frame-sync signal, B_Sync, which is routed to a MachXO2 pin. Display supplies and the backlight driver are controlled by outputs from the MachXO2.

Table 9. Display Signals

Signal	MachXO2 Ball	I/O Type
Clock HS+	C4	LVDS25
Clock HS-	D3 (Auto)	LVDS25 (Auto)
Clock LP+	C7	LVCMOS12
Clock LP-	C6	LVCMOS12
Data HS+	C1	LVDS25
Data HS-	D2 (Auto)	LVDS25 (Auto)
Data LP+	A7	LVCMOS12
Data LP-	B6	LVCMOS12
Reset	B2	LVCMOS33
B_Sync	A3	LVCMOS33
Backlight PWM	C3	LVCMOS33
3 V Enable	C2	LVCMOS33
1.8 V Enable	E2	LVCMOS33

Note: For the high-speed differential signals (Clock HS, Data HS) only the positive channel must be assigned, the negative channel will be automatically placed.

Clock Sources

The Main Board has a single 27 MHz clock source that connects to the Lattice MachXO2 device. To use this external clock with the iCE5LP device, the 27 MHz clock can be routed from the MachXO2 via one of the six general purpose interconnects. These connections can be found in Table 8.

Table 10. Clock Sources

Source	Frequency	XO2 Ball	iCE Ball
Oscillator	27 MHz	E4	—

Reset Button

A button (SW1) is included for performing resets of systems on board the iCE40 Ultra Wearable Development Platform. By default, this button will perform a configuration reset of the iCE5LP, MachXO2, and the Bluetooth module.

Table 11. Reset Resistors and Pins

Device	Resistor	FPGA Ball
MachXO2	R110	B3
iCE5LP	R62	—
Seeed BLE	R63	—

Note: If VREG_ADJ (see the Board Power section) is changed, these resistors must be removed to prevent voltage level mismatches.

LEDs

The Main Board has four system status LEDs, two user LEDs, an RGB LED, an IR LED, and a High-current White LED.

The iCE40 Ultra has I/O ports specially built for sinking current from high-power LEDs. The RGB LED ports (A6, B6, and C6) are able to sink 24 mA each, while the high-current LED port (A2) is able to sink up to 500 mA.

Please note that the IR LED is only rated for 100 mA and can be damaged by incorrectly configuring the port in custom designs. This is not a problem for the RGB LED and High-current White LED, since they are rated for more current than the ports can sink.

The LED functions and FPGA connections are detailed below:

Table 12. Main Board LEDs

LED Number	MachXO2 Ball	iCE40 Ball	Function
D1	—	—	Power Source Connected
D2	—	—	Battery Charging
D3	Config	—	MachXO2 CDONE
D4	E7	—	User LED
D5	F7	—	User LED
D8	—	Config	iCE40 CDONE
D9 (R)	—	C6	RGB LED (Red)
D9 (G)	—	B6	RGB LED (Green)
D9 (B)	—	A6	RGB LED (Blue)
D10	—	A2*	IR LED (see the Jumpers section)
D11	—	A2*	High-current White LED (see the Jumpers section)

Sensors and Peripherals

The iCE40 Ultra Wearable Development Platform utilizes several third-party devices. Links for more information can be found below:

Table 13. Main Board Sensors and Peripherals

Name	Reference Number	Interface	FPGA Connections	Part Number	Link
Microphone	U6, U7	I2S	iCE5LP: Clock (F3), Data (E3)	MP34DB01	http://www.st.com/web/en/catalog/sense_power/FM125/SC1564/PF250941

Table 14. Sensor Board Sensors and Peripherals

Name	Reference Number	Interface	FPGA Connections	Part Number	Link
Temperature Sensor	U7	I2C	See Table 3	TMP112	http://www.ti.com/product/tmp112
Pressure Sensor	U3	I2C	See Table 3	LPS25H	http://www.st.com/web/catalog/sense_power/FM89/SC1316/PF255230
Accelerometer/ Gyroscope	U4	I2C	See Table 3	LSM330DLC	http://www.st.com/web/en/catalog/sense_power/FM89/SC1448/PF252427
Heart Rate & Oxygen Sensor	U6	—	—	SFH7050	http://www.osram-os.com/osram_os/en/products/product-promotions/infrared-products/sensor-family/biomon-sensor-sfh-7050/index.jsp
Analog Front End	U2	SPI	See Table 4	AFE4403	http://www.ti.com/product/afe4403
BLE Module	U5	UART	See Table 5	Seeed 113050012	http://www.seeedstudio.com/wiki/BLE_Micro

Flash Memory Devices

The Lattice MachXO2 and iCE5LP are each equipped with an external SPI Flash memory device.

Table 15. Flash Devices

Master Device	Reference Number	Part Number
MachXO2	U5	Micron N25Q032A13ESC40G
iCE5LP	U10	Micron M25P80-VMN6TP

The iCE5LP external Flash memory is intended for holding configuration data, while the MachXO2 external Flash memory is intended for storing data, such as images for the included display. Because of the target application, the Flash device connected to the MachXO2 is capable of using the higher-bandwidth Quad-SPI protocol.

Table 16. Flash Connections

Master Device	Reference Number	Signal	FPGA Ball
MachXO2	U5	DQ0	G1
		DQ1	F5
		DQ2	F3
		DQ3	G3
		SCLK	F6
		CS	G7
iCE5LP	U10	MISO	F2
		MOSI	D1
		SCLK	E1
		CS	F1

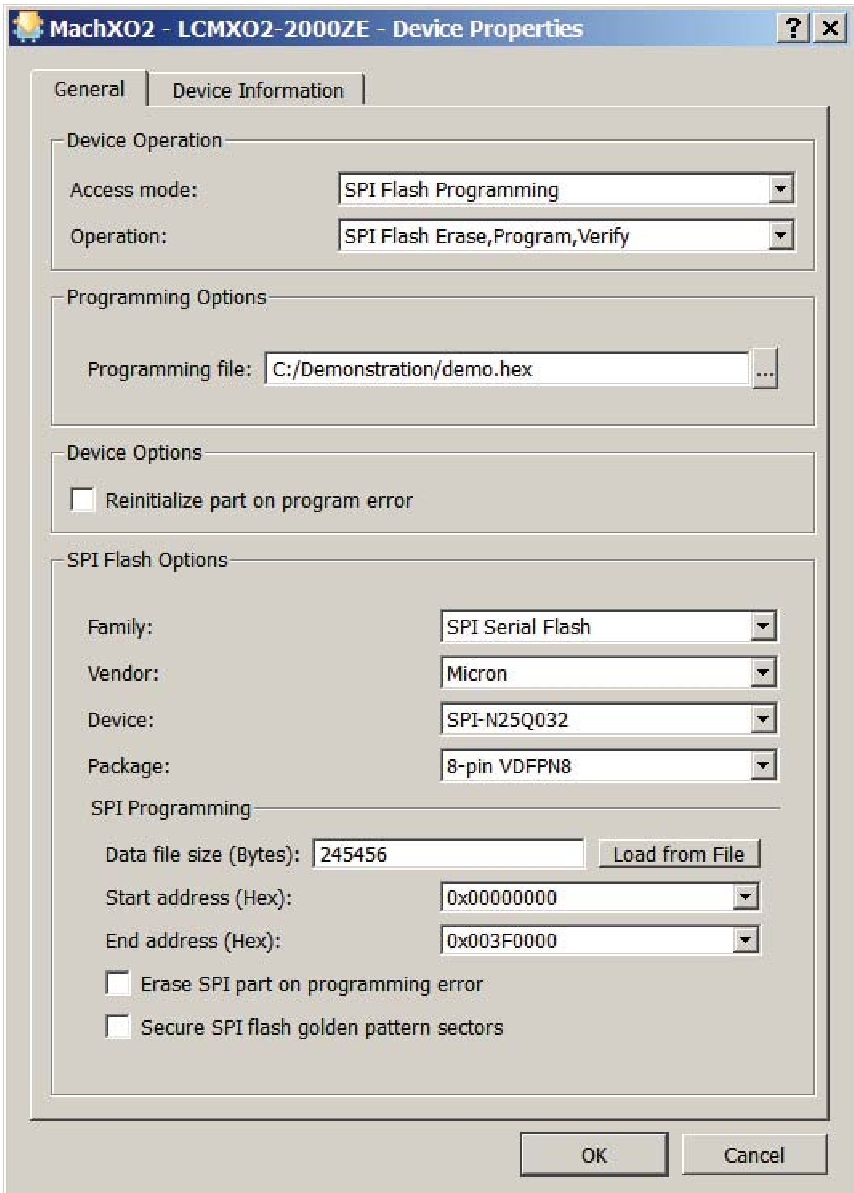
Board Configuration and Programming

Lattice MachXO2

The Lattice MachXO2 features internal configuration Flash. This allows configuration data to be stored internally while the external Flash memory device is used for auxiliary functions.

1. Ensure that header J51 is shunted and the power switch (SW2) is in the *on* position.
2. Plug in the mini-USB cable (J1).
3. Launch Diamond Programmer.
4. Select **Create a new project from a scan** and click **Detect Cable**.
5. Select the FTUSB-1 Port.
6. Select **MachXO2** and **LCMXO2-2000ZE** in the Device Family and Device columns.
7. Double click on the Operation column and select the appropriate operation.
    a. Internal Flash: Flash Programming Mode: SPI Flash Erase, Program, Verify
    b. External Flash: SPI Flash Programming: SPI Flash Erase, Program, Verify
8. If targeting the External Flash memory, copy the SPI Flash Options from Figure 6.
9. Select the programming bitstream in the “File Name” column.
10. Click the Program Icon or select Program from the Design dropdown menu.

Figure 6. MachXO2 External Flash



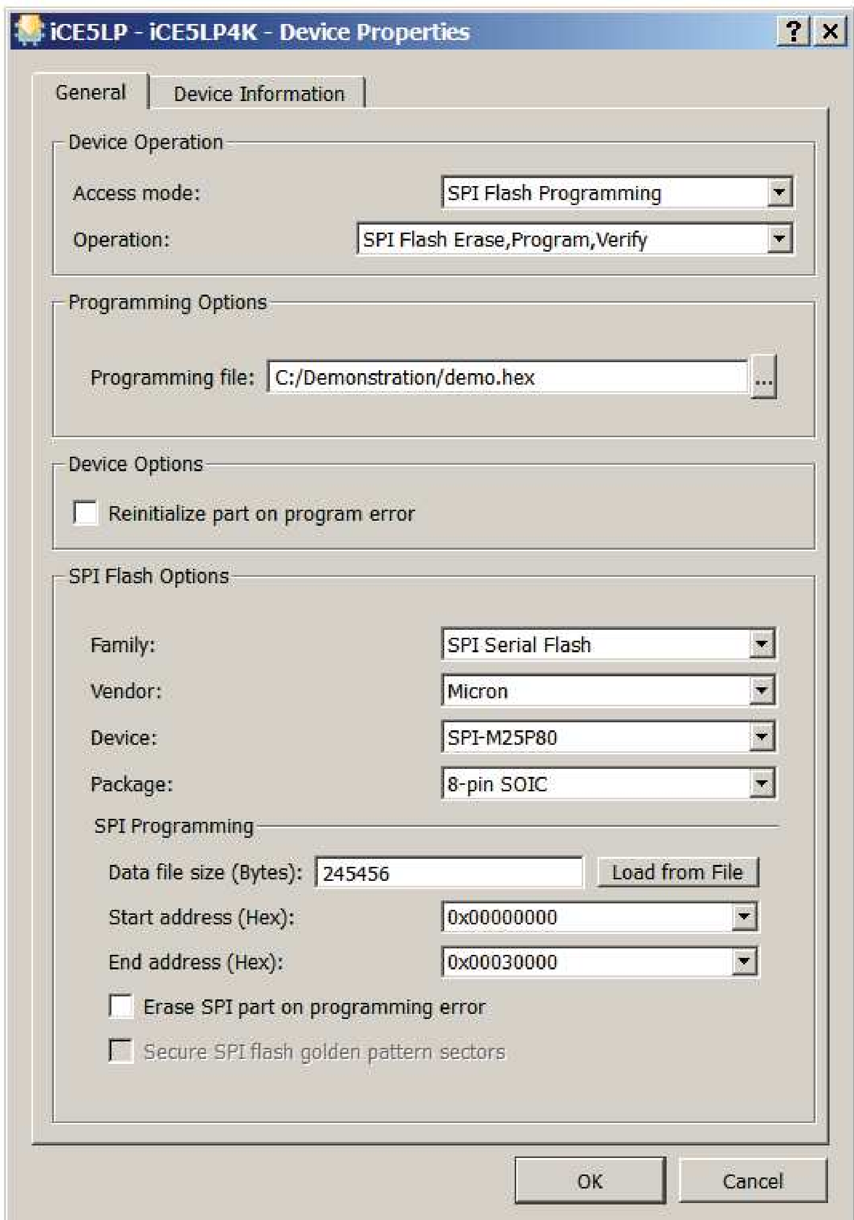
Lattice iCE5LP

The Lattice iCE5LP can be directly programmed, however, unless single-time programmable NVCM is used, the configuration data will be lost when the device is powered down.

1. Ensure that header J51 is shunted and the power switch (SW2) is in the *on* position.
2. Plug in the mini-USB cable (J1).
3. Launch Diamond Programmer.
4. Select **Create a new project from a scan** and click **Detect Cable**.
5. Select the FTUSB-0 Port.
6. Select **iCE5LP** and **iCE5LP4K** in the Device Family and Device columns.

7. Double click on the Operation column and select the appropriate operation
   a. Direct Program: CRAM Programming: Fast Program (Volatile)
   b. NVCM (Single-use): NVCM Programming Mode: NVCM Program, Verify, Secure
   c. External Flash: SPI Flash Programming: SPI Flash Erase, Program, Verify
8. If targeting the External Flash memory, copy the SPI Flash Options from Figure 7.
9. Select the programming bitstream in the File Name column
10. Click the Program Icon or select Program from the Design dropdown menu

Figure 7. iCE5LP External Flash

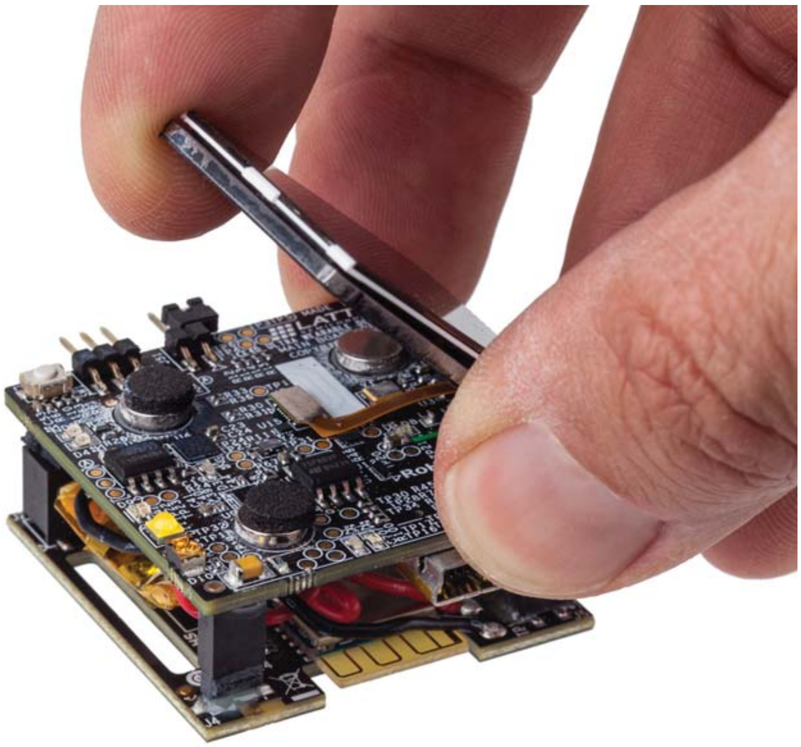


Pre-Loaded Demonstration Design

The iCE40 Ultra Wearable Development Platform comes pre-loaded with the Parallel-to-MIPI DSI demo. In order to run the demo, follow these steps:

1. Ensure that the display is attached in the proper orientation, with the connector ribbon extending toward the right edge of the device (see Figure 8).

Figure 8. Display Connector



2. Plug a mini-USB cable into the mini-USB port (J1) to supply power to the device.
3. Switch power switch to the *on* position.
4. The screen should alternate between two images, with the User LEDs (D4, D5) indicating the demo mode.

For more detailed operation instructions, please refer to the Quick Start User Guide included with the demo design.

This demo design can be reprogrammed onto the board by downloading the project (see the Additional Demonstration Designs section) and following the documented instructions. Please note that in this demo, the MachXO2 uses its internal Flash to store configuration data and the external Flash to store image data, so two programming procedures must be performed.

Additional Demonstration Designs

Several additional demonstration designs have been developed for the iCE40 Ultra Wearable Development Platform. These designs can be found under the Design File Tab of the Documentation section of the board web page here: http://www.latticesemi.com/ultrawearable.

Ordering Information

Description	Ordering Part Number	China RoHS Environment-Friendly Use Period (EFUP)
iCE40 Ultra Wearable Development Platform	ICE5LP4K-WDEV-EVN	

Technical Support Assistance

Submit a technical support case through www.latticesemi.com/techsupport.

Revision History

Date	Version	Change Summary
July 2015	1.0	Initial release.

Appendix A. Main Board Schematic Diagrams

Figure 9. Block Diagram

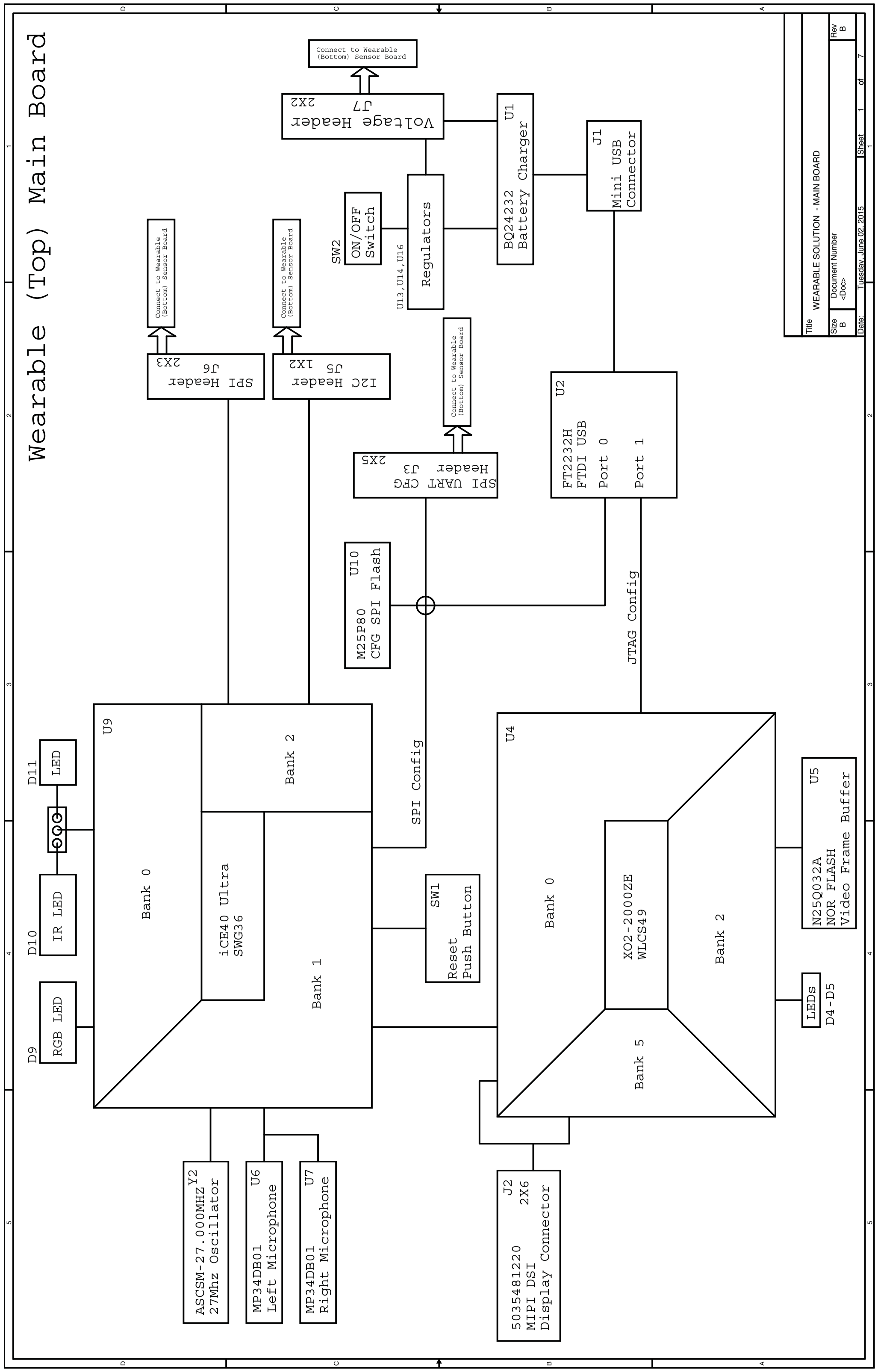


Figure 10. Mechanical Design

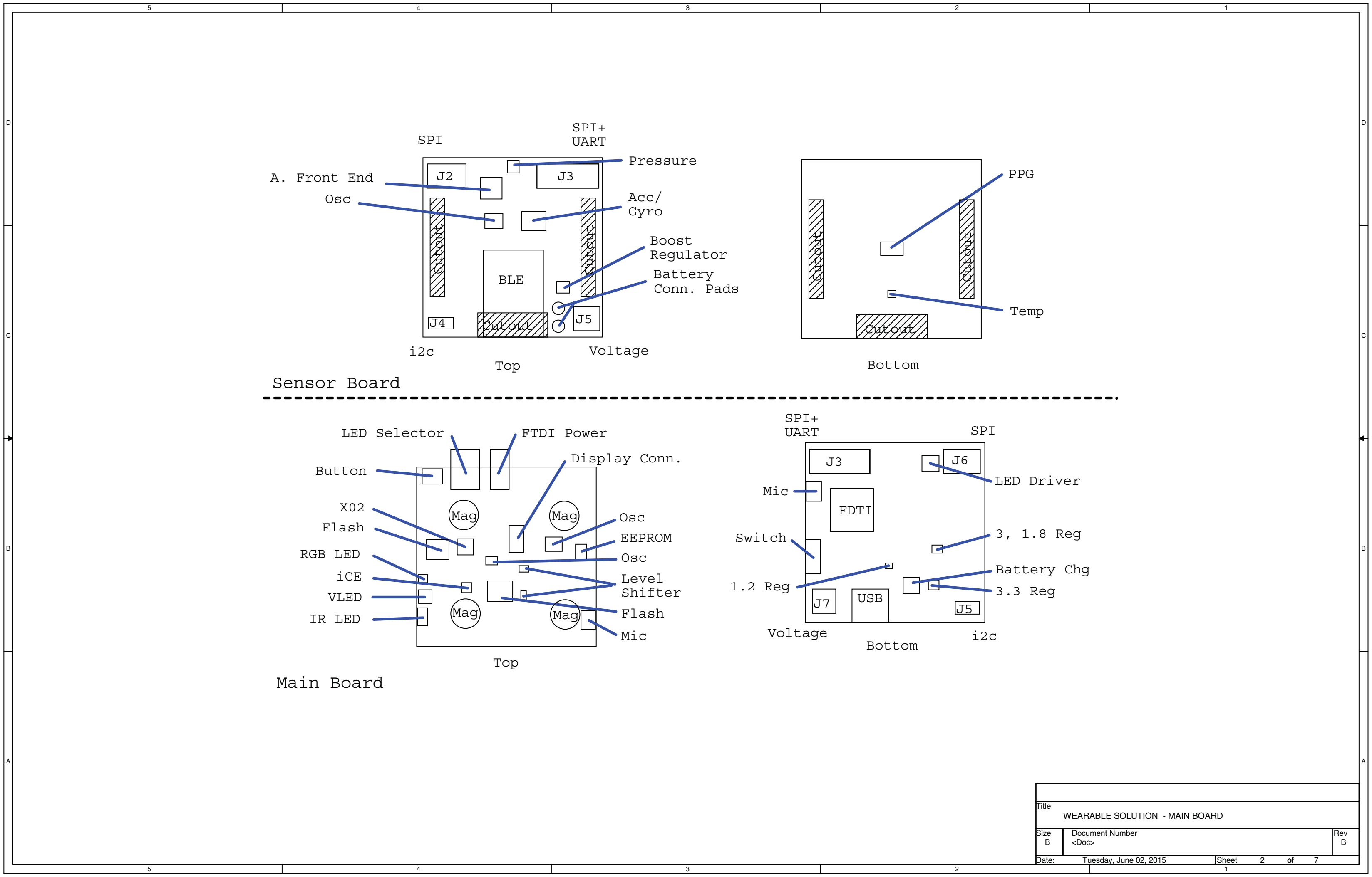
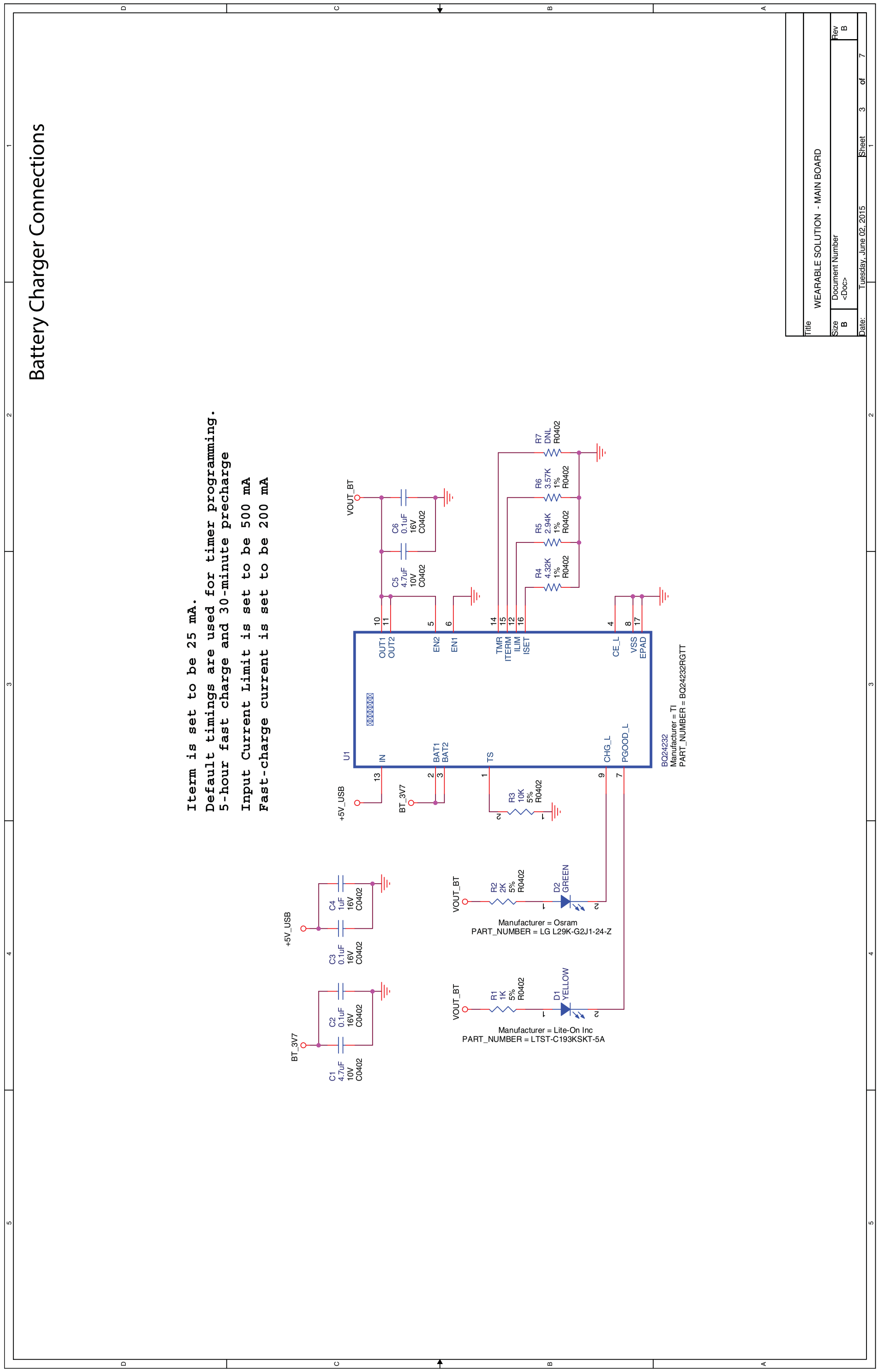


Figure 11. Battery Charger Connections



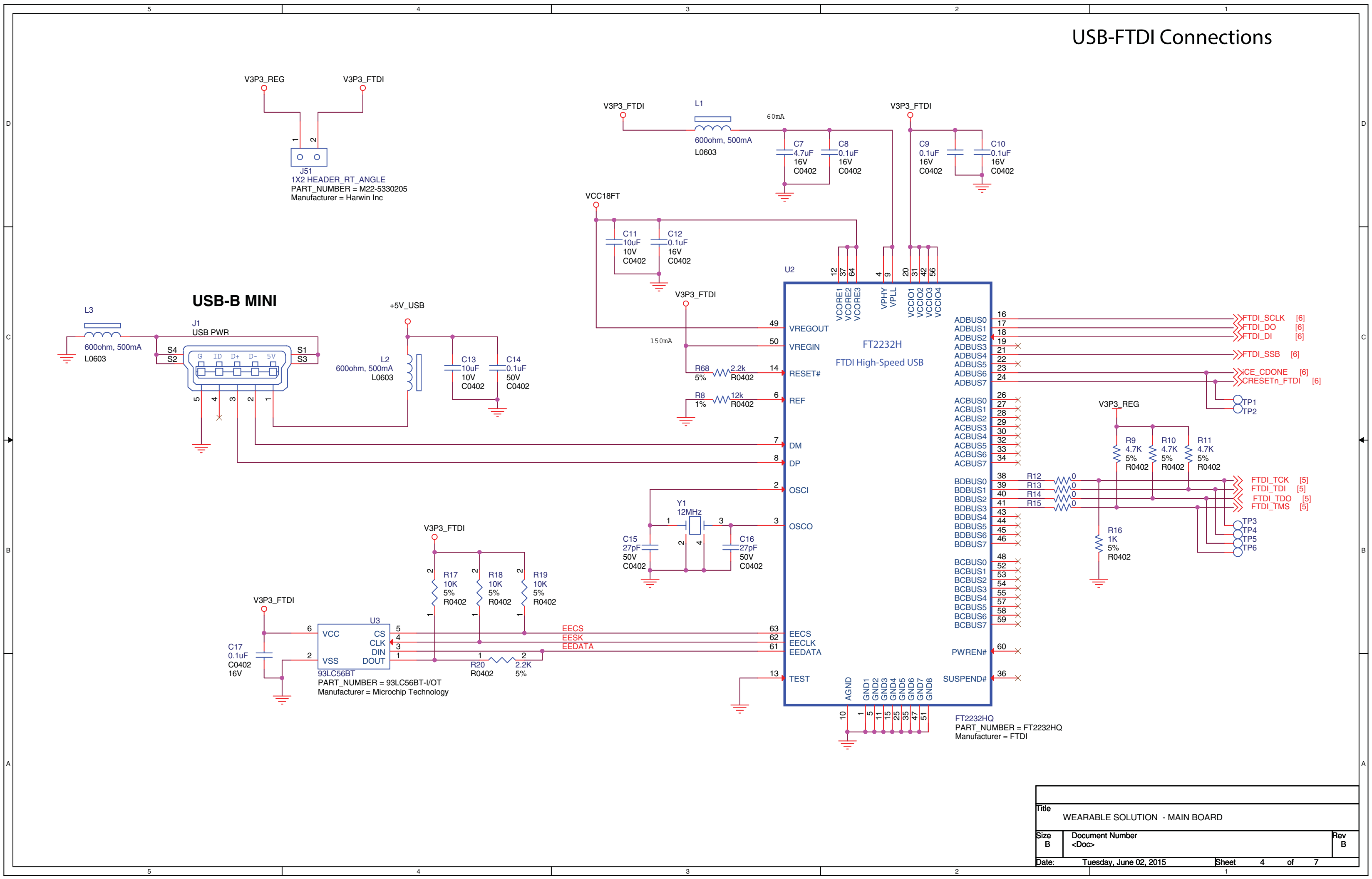


Figure 12. USB-FTDI Connections

Figure 13. MachXO2-2000ZE Connections

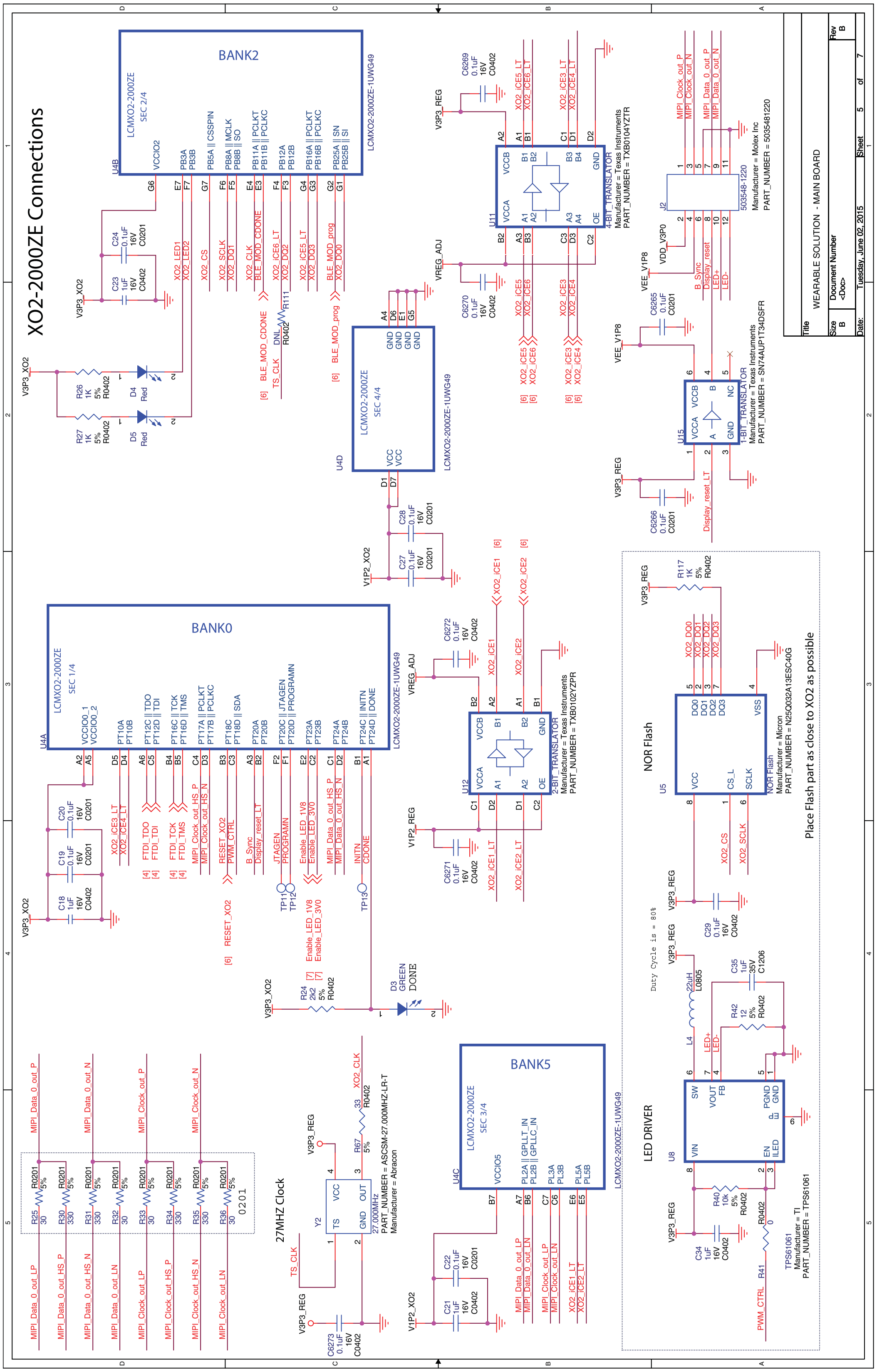
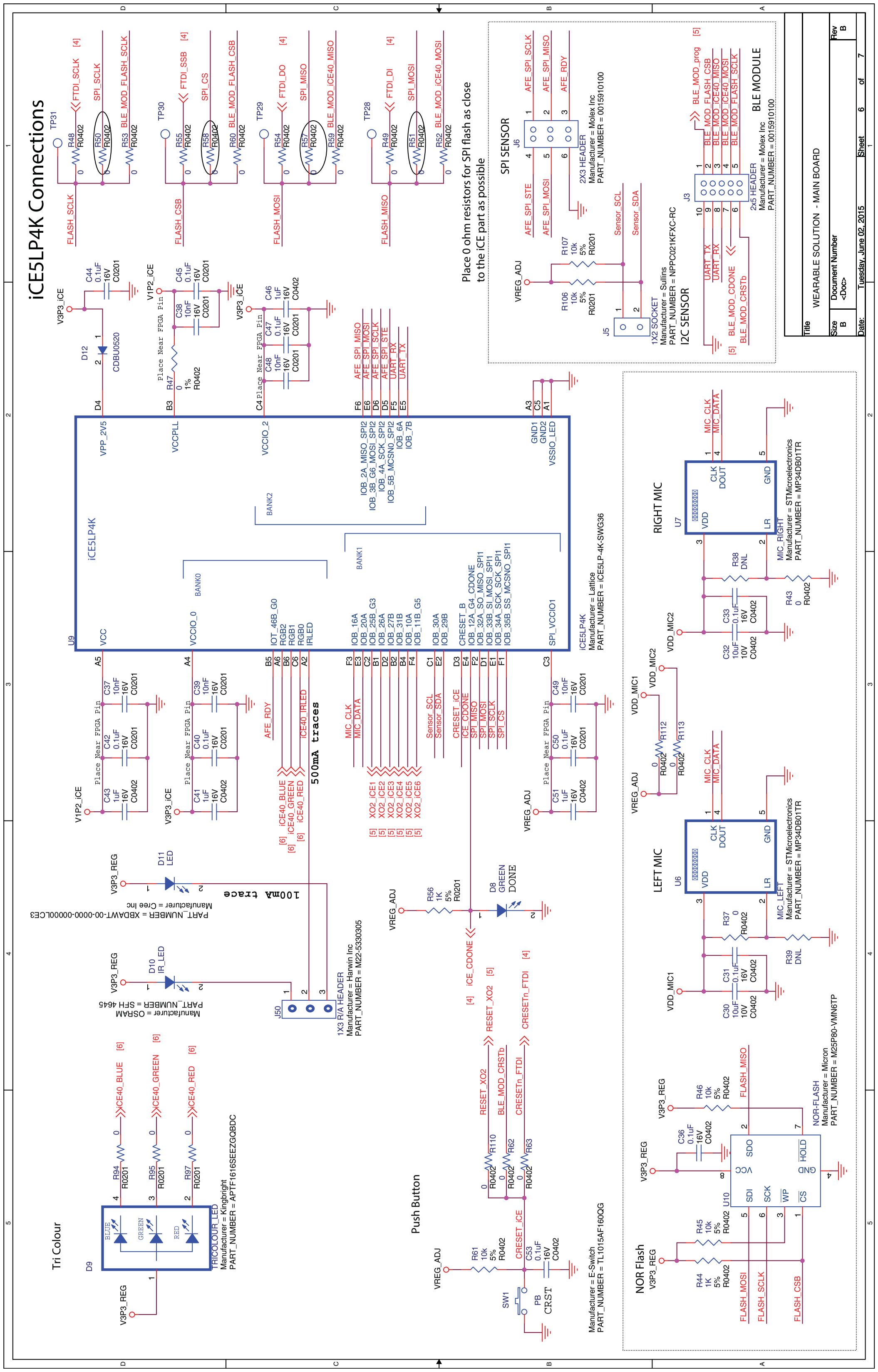


Figure 14. iCE5LP4K Connections



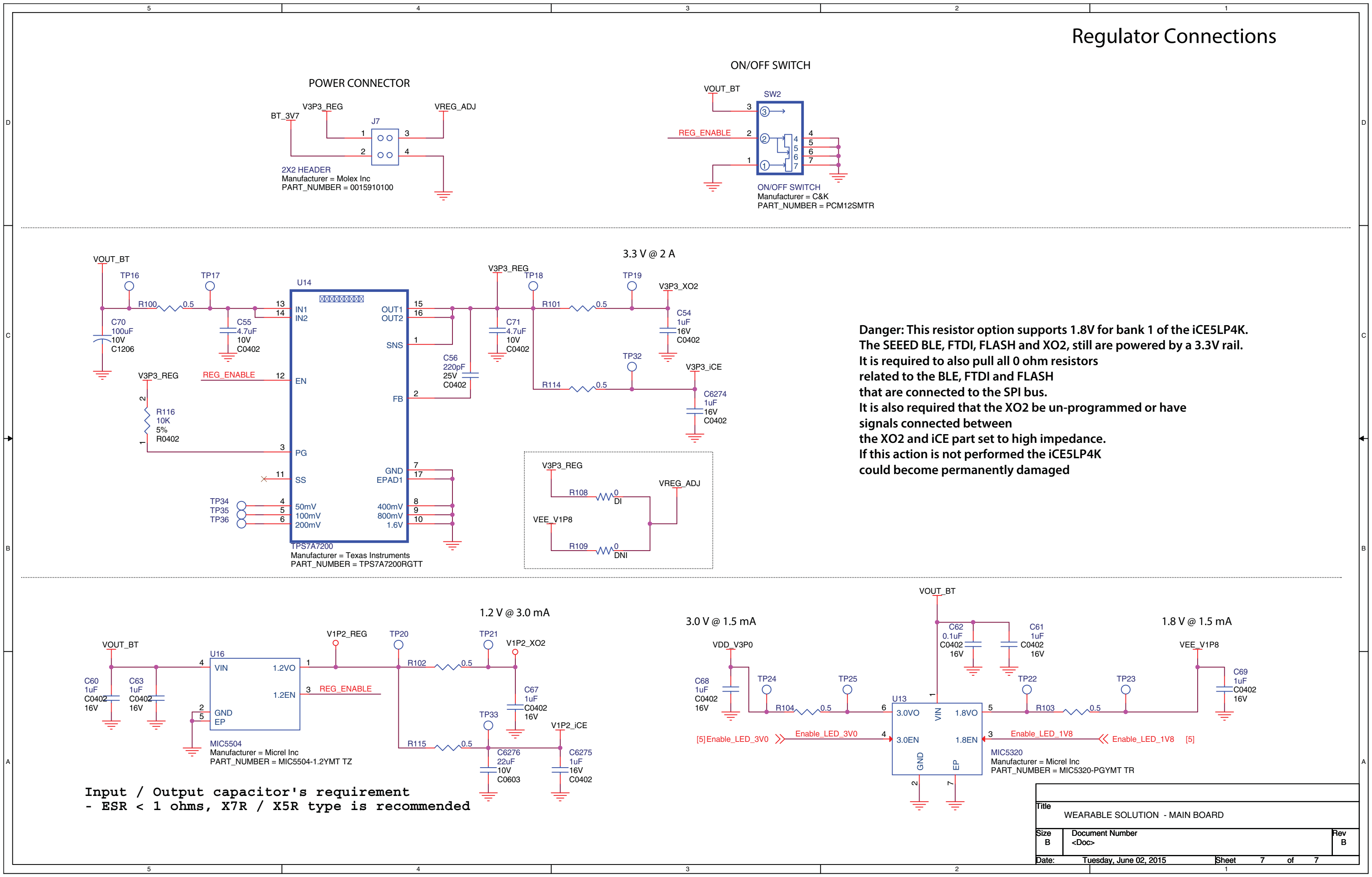


Figure 15. Regulator Connections

Appendix B. Sensor Board Schematic Diagrams

Figure 16. Block Diagram