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Programmable Logic Controller (PLC) I/O Module Front-End Controller with Tiva C Series ARM® Cortex™-M4 MCU

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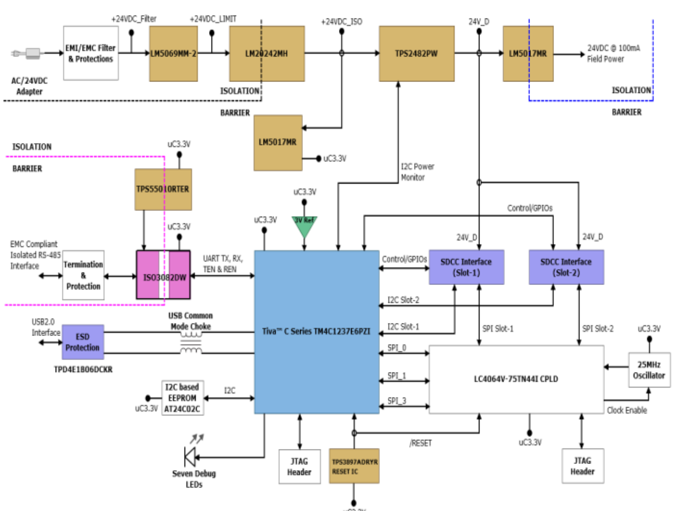
Design Resources

TIDA-00123	IO Module Controller Folder
TIDA-00118	Analog Input Card Folder
TIDA-00119	Analog Output Card Folder
TIDA-00017	Digital Input Card Folder
TM4C1237E6PZI	Product Folder
TPS3897ADRYR	Product Folder
TPS55010RTER	Product Folder
ISO3082DW	Product Folder
TPD4E1B06DCKR	Product Folder
LM5069MM-2/NOPB	Product Folder
LM5017MR/NOPB	Product Folder
LM20242MH/NOPB	Product Folder
TPS2482PW	Product Folder
CSD18501Q5A	Product Folder

Block Diagram



Design Features

- Designed around Tiva™ C Series 32-Bit MCU, 80MHz high-performance ARM® Cortex™- M4
- Used for SmartIO module performance evaluation
- Modular plug-in design: Two identical interface for pluggable PLC SmartIO modules
- Field bus interface: EMC compliant isolated RS-485 interface
- PC interface: EMC compliant USB 2.0 interface
- DC Input Supply: 18V to 32V power supply with In-rush current limit protection
- On-board Isolated 24VDC/100mA power supply for field sensors
- I2C based precision power monitoring of IO modules & field sensors
- Fast signal chain response time: Using high speed SPI & DMA
- Seven on-board LEDs for Debugging/ Indication
- LabView™ based GUI for IO module performance evaluation

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- Industrial Process Control and Automation
- PLC/PAC/DCS
- Test and measurement

IO Module Controller & two IO Cards

Table of Contents

1. **SYSTEM DESCRIPTION** 3
2. **DESIGN SPECIFICATIONS** 3
3. **BLOCK DIAGRAM** 4
4. **THEORY OF OPERATION** 4

4.1. MCU 4
4.1.1 Development Interface 7
4.1.2 SmartIO Interface (Slot#1 & Slot#2) 7
4.1.3 Field Bus Connectivity 9
4.1.4 PC Interface 9
4.1.5 RESET Circuitry 10
4.2. POWER SUPPLY 10
4.2.1 Power Supply Front-end 11
4.2.2 DC Input Isolation 13
4.2.3 MCU Supply 15
4.2.4 Field Sensor Power Supply 16

5. **TEST SETUP** 17
6. **SOFTWARE DESCRIPTION** 17
7. **CONNECTORS & OTHER FEATURES** 18
8. **PC BASED GUI SOFTWARE & TESTING** 19
9. **DESIGN FILES** 25

9.1 SCHEMATIC 25
9.2 BOM 34
9.3 PCB LAYOUT 38
9.4 PCB LAYERS 39
9.5 GERBER FILES 46
9.6 IO CONTROLLER SOFTWARE 46
9.7 PC BASED GUI SOFTWARE 46

1. System Description

Tiva™ C Series MCU based IO Controller for Programmable Logic Controllers (PLC) is a reference design to demonstrate Tiva™ C Series MCU's embedded processing capabilities, easy-to-use highly integrated peripherals and it's suitability as IO controller for end-equipment like PLC/PAC/DCS & Test and measurement.

This reference design showcases Tiva™ C Series MCU that can be used to evaluate different PLC I/O modules for the industrial market and demonstrates other TI parts that can be used in the entire PLC signal chain. Additionally, isolated and non-isolated power solutions and hot swap & in-rush current limit controller are the key takeaways from this reference design. The easy-to-use GUI accelerates the I/O modules performance evaluation process and decrease time-to-market.

The design files include Schematics, BOM, Layer plots, Altium files, Gerber and executable for easy-to-use Graphical User Interface (GUI).

2. Design Specifications

Following are the design specifications of the IO Controller:

- 32-Bit, 80MHz high-performance ARM® Cortex™- M4
- Modular plug-in design: Two identical interface for pluggable PLC SmartIO modules
- EMC compliant isolated RS485 interface for field bus connectivity
- EMC compliant USB 2.0 interface for PC connectivity
- DC input supply: 18V to 32V
- DC Power galvanic isolation using flybuck topology
- Power supply protections against:
  - Reverse polarity
  - Transient/Surge
  - In-rush current limit
- On-board Isolated 24VDC/100mA for field sensor power supply
- Power monitoring of SmartIO modules & field sensors
- Fast signal chain response time
- LEDs for Debugging/Indication purpose
- On-board EEPROM

3. Block Diagram

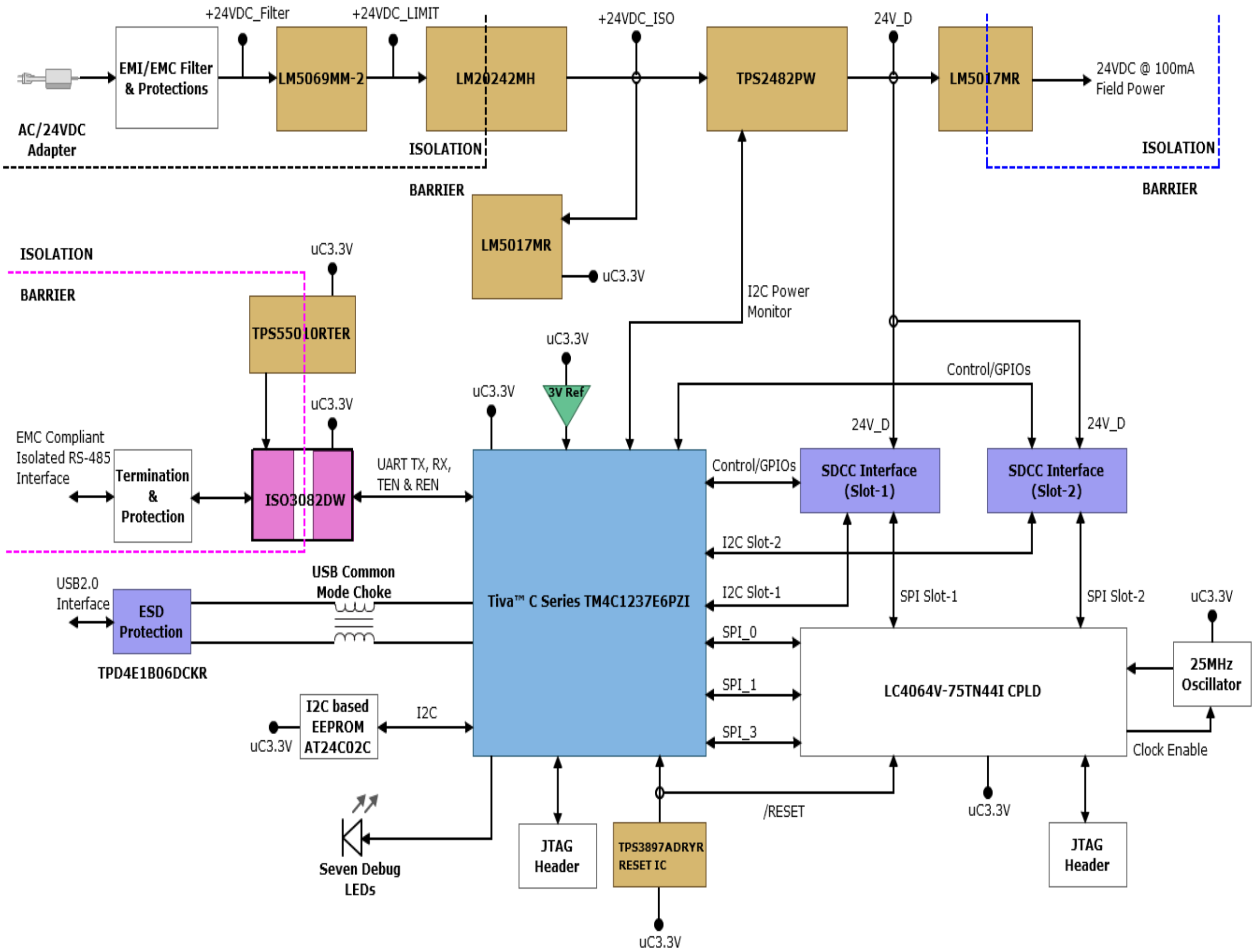


Figure 1: IO Controller Block Diagram

4. Theory of Operation

Tiva™ C Series MCU based IO Controller for PLC provides a convenient platform to test and evaluate SmartIO modules targeted for PLC system. IO Controller allows functional and parametric signal chain performance evaluation. IO Controller consists of the MCU, a power supply unit and SmartIO module interface. The IO Controller performs the main functions like scanning data, running control sequences and communication activities. IO Controller has on-board power supply unit that converts the DC input power supply to the required multiple output voltages. The power supply unit generates 3.3V required by MCU, isolated 24VDC required by SmartIO modules and isolated 24VDC/100mA to power-up field sensors. IO Controller has two identical 50-pin interfaces where various SmartIO modules can be plugged. Each interface has dedicated SPI and I2C to communicate with devices on the SmartIO modules. These pluggable I/O modules are used to measure data from field sensors and to control actuators. The SmartIO modules along with the IO Controller form a control loop. In addition, IO Controller has been equipped with increasing levels of processing power at reduced power consumption and connectivity like USB and RS-485.

4.1. MCU

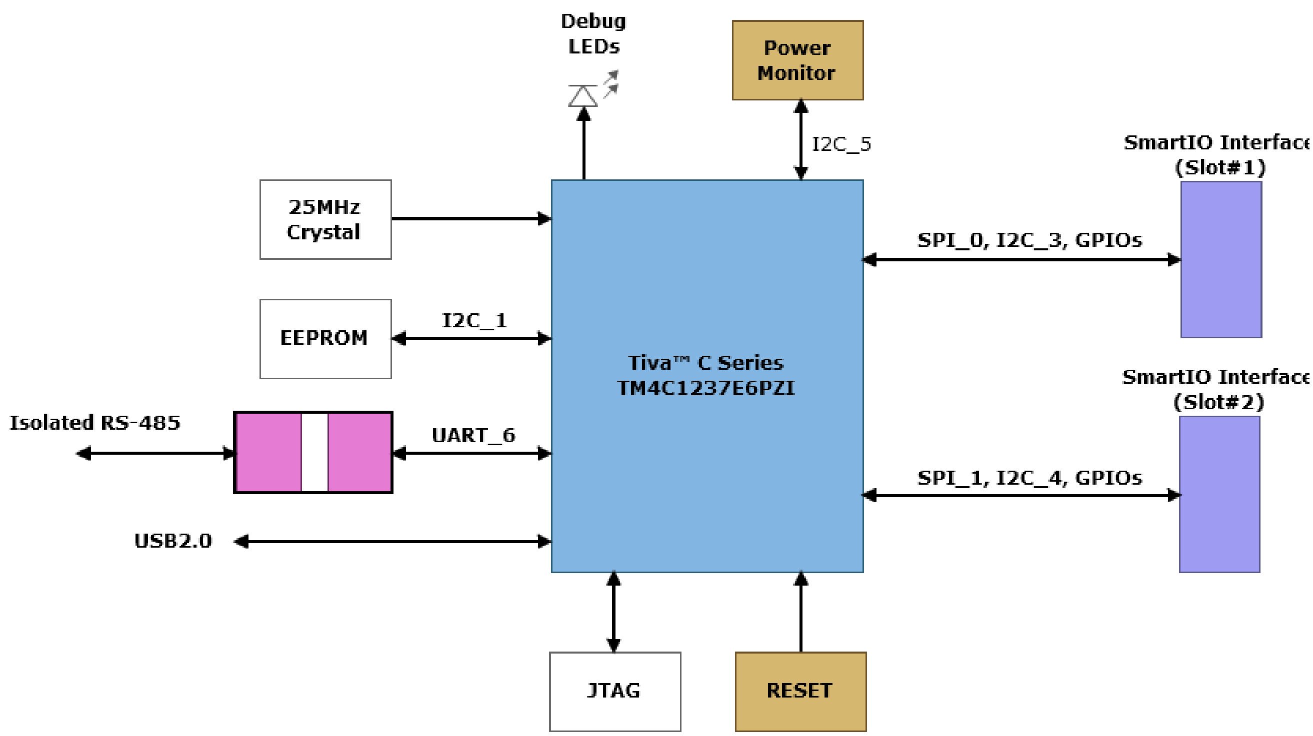


Figure 2: MCU Interface Diagram

The heart of this evaluation platform is Tiva™ C Series TM4C1237E6PZI MCU. Tiva™ C Series TM4C1237E6PZI MCU provides designers a high-performance ARM® Cortex™- M4F based architecture. TM4C1237E6PZI MCU also offers the advantages of ARM's widely available development tools and comprehensive software library supports. Targeting performance and flexibility, the Tiva™ C Series architecture offers 80 MHz Cortex-M with FPU, a variety of integrated memories, peripherals and multiple programmable GPIO, which minimize board costs and design-cycle time. Finally, the TM4C1237E6PZI microcontroller is code-compatible to all members of the extensive Tiva™ C Series that enables easy migration.

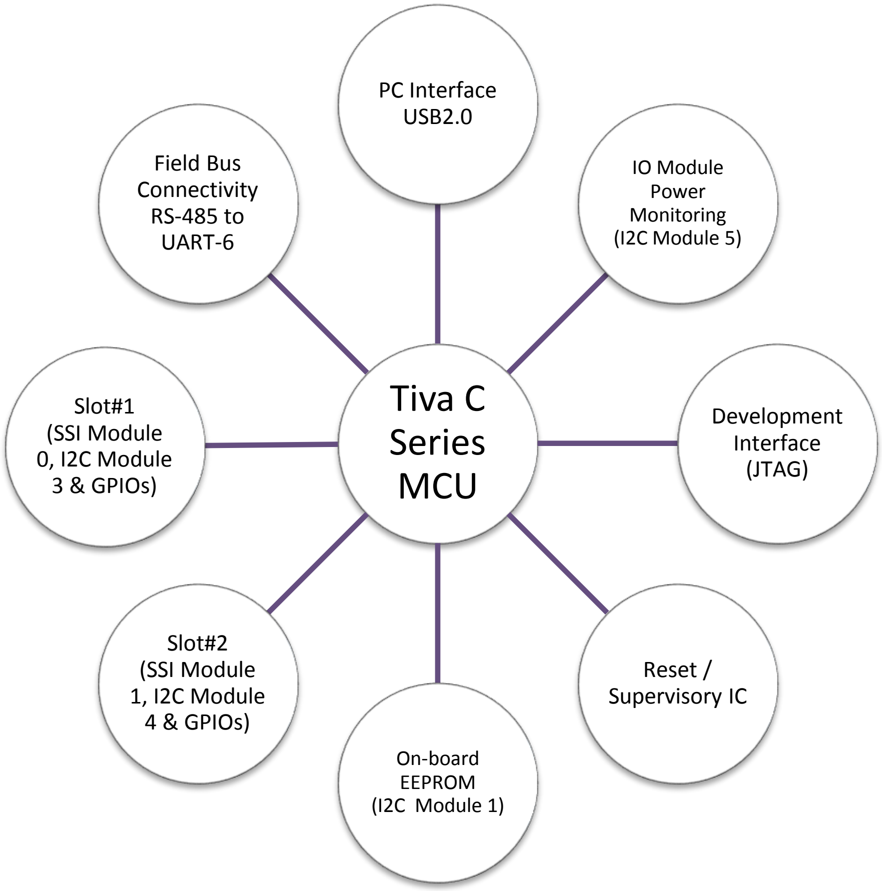


Figure 3: Tiva™ C Series MCU Interfacing

MCU Resource	Used for
PA2 – PA5 (SSI module 0)	Slot #1 SPI bus for SmartIO module interface
PA6 – PA7 (I2C module 1)	On-board EEPROM
PC0 – PC3 (JTAG Signals)	Development interface (Debugging/Programming MCU)
PG0 – PG1 (I2C module 3)	Slot #1 I2C bus for SmartIO module interface
PG2 – PG3 (I2C module 4)	Slot #2 I2C bus for SmartIO module interface
PJ0 – PJ1, PB0, PB1 (USBDM, USBDP, USBID, USBVBUS)	USB2.0 interface for PC interface
PG6 – PG7 (I2C module 5)	Power monitor for I/O modules & field sensors
PK0 – PK3 (SSI module 3)	SPI bus interfaced with CPLD (Currently not in use)
PF0 – PF6 (GPIOs)	Seven LEDs for debug/indication
PD4 – PD7, PE7 (UART module 6, GPIO)	RS-485 interface for field bus connectivity
PD0 – PD3 (SSI module 1)	Slot #2 SPI bus for SmartIO module interface

Refer to Tiva™ TM4C1237E6PZ MCU datasheet & System Design Guidelines for Tiva™ C Series MCU to follow the recommendations for creating a schematic and designing a circuit board.

4.1.1 Development Interface

The development interface available on the Tiva™ C Series MCU is 10-pin JTAG, which is used for debugging and programming purpose during the board bring-up and software development. Tiva™ C Series MCU have default internal pull-up resistors on TCK, TMS, TDI, and TDO signals. External pull-up resistors may not be required if these connections are kept short. If the JTAG signals are greater than 2 inches or routed near an area where they could pick up noise, TCK should be externally pulled-up with a 10K or stronger resistor to prevent any transitions that could unexpectedly execute a JTAG instruction.

4.1.2 SmartIO Interface (Slot#1 & Slot#2)

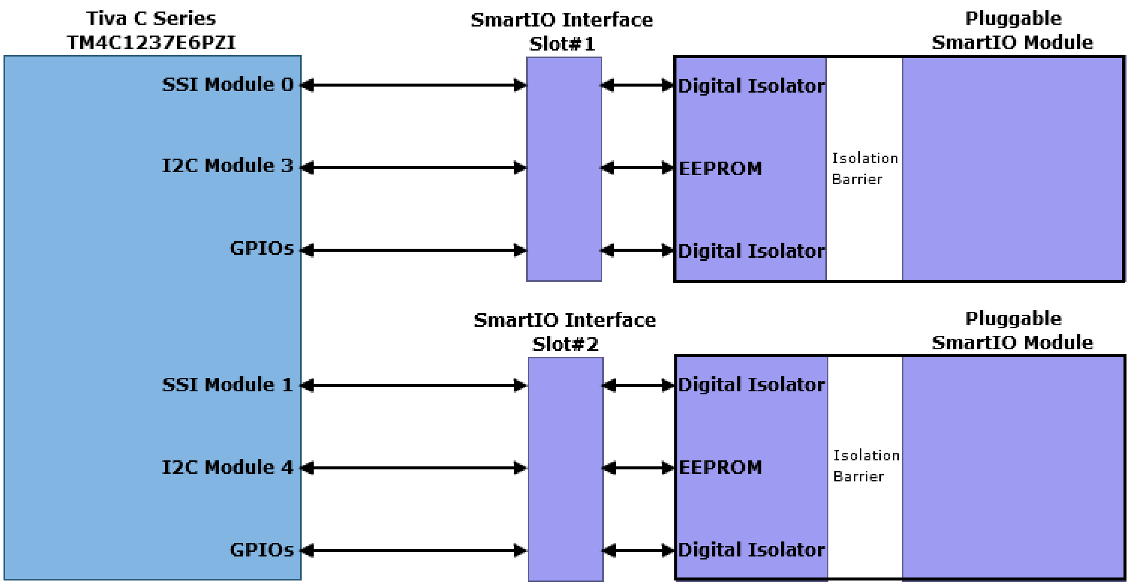


Figure 4: SmatIO Interface with Tiva™ C Series MCU Peripherals

TI also provides the reference design for SmartIO modules pluggable to Slot#1 and Slot#2.

TIDU192: 12-Bit Analog Input Module for Programmable Logic Controllers

TIDU189: 16-Bit Analog Output Module for Programmable Logic Controllers

Note: Other pluggable SmartIO modules reference designs are in pipeline.

The TM4C1237E6PZ MCU includes four Synchronous Serial Interface (SSI) modules. Each module can be configured either as mater or slave interface. SSI module supports operation for Freescale SPI, MICROWIRE, or Texas Instruments SSI. SSI module has separate transmit and receive FIFOs, each 16 bits wide and 8 locations deep. It also has separate transmit and receive µDMA channels for fast and efficient data transfer.

SSI module 0 and SSI module 1 have been used for two SmartIO interfaces (Slot#1 & Slot#2) to exchange data. Galvanic isolation for two SmartIO communication signals has not been provided on the IO Controller. The SSI includes a programmable bit rate clock divider and prescaler to generate the serial output clock. For master mode, the system clock must be at least two times faster than the SSI clock, with the restriction that SSI clock cannot be faster than 25 MHz. The system clock of 80 MHz is being used as the source for the SSI clock.

In SPI protocol, Master and Slave put the data on the bus on one clock edge and read the data on the next/opposite clock edge. In this way, SPI communication works fine without bit shift as long as the total round trip propagation delay is less than half of the clock period, because the data must come back to the master before the next clock edge. Implementing the digital isolation, adds substantial amount of propagation delay to the SPI timings. The minimum time required for the data from slave device to reach at the master is twice the maximum propagation delay. So, maximum SPI half clock period would be greater than twice of propagation delay. Isolator's propagation delay reduces the data throughput by imposing a limit on SPI clock speed.

Isolated SPI would work fine as long as:

$$\frac{T_{SPI}}{2} = \frac{1}{2 * F_{SPI}} = 2 * T_{pd} + T_{res}$$

In isolated SPI, SPI clock and MOSI data are always synchronous irrespective of SPI clock speed because both are travelling in same direction. But at higher SPI clock rates, MISO data and clock are no more synchronous, which means master will latch the data from slave at wrong instances and receive erroneous data.

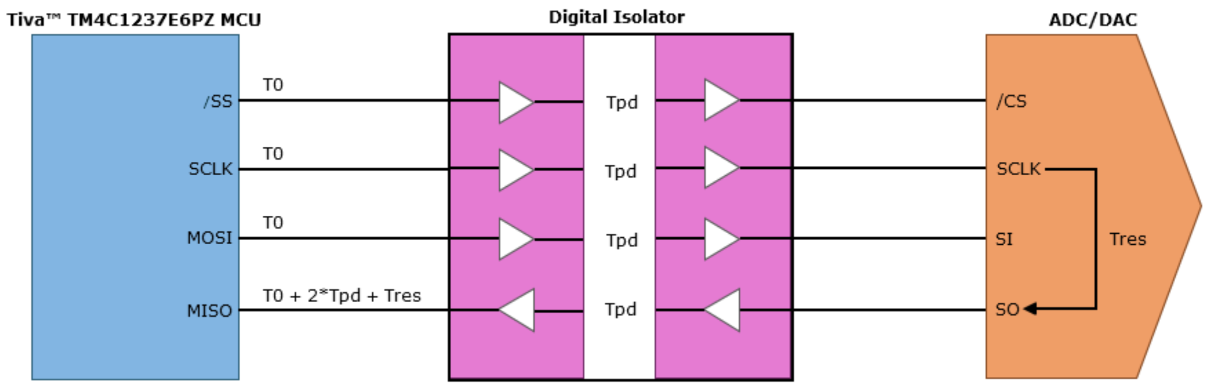


Figure 5: Isolated SPI using Digital Isolators

To achieve higher SPI speed with isolators, CPLD has been introduced between MCU's SSI signals and SmartIO interface.

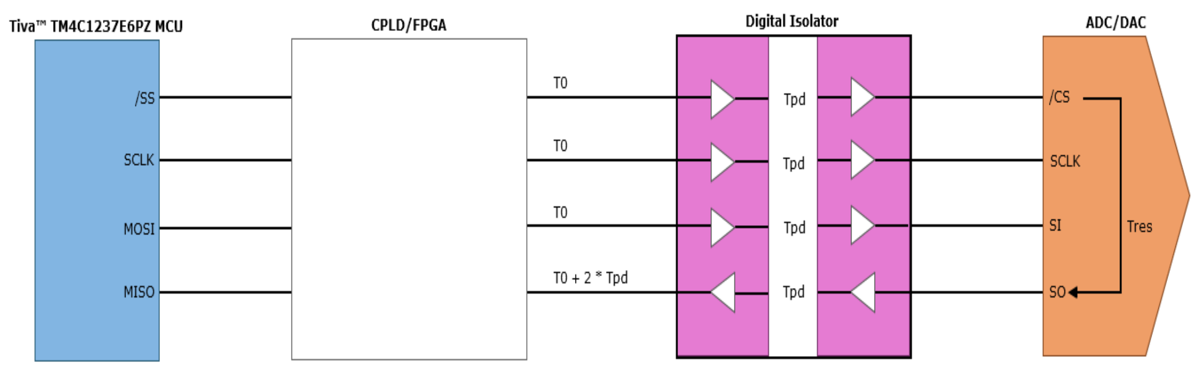


Figure 6: High Speed Isolated SPI with CPLD

The TM4C1237E6PZ MCU includes six Inter-Integrated Circuit (I2C) modules to communicate with other I2C based devices. Four out of six I2C modules are being used on the IO Controller and configured as I2C masters. It supports four transmission speeds: Standard (100 Kbps), Fast-mode (400 Kbps), Fast-mode plus (1 Mbps) and High-speed mode (3.33 Mbps). I2C module 3 and I2C module 4 buses are available on SmartIO interfaces Slot#1 and Slot#2, respectively. I2C module 3 and I2C module 4 buses communicate with slave EEPROMs installed on SmartIO modules to read the configuration (Type of I/O module plugged-in, number of input or output available, manufacturer's ID and etc.) and calibration data. IO Controller has a provision in hardware where I2C based EEPROM (slave address hardwired to 000) can be populated, which is interfaced with I2C module 1 of TM4C1237E6PZ MCU, but the current software doesn't support this. I2C module 5 has been interfaced with TPS2482PW device for current/power monitoring for SmartIO modules and field sensors.

Both SDA and SCL signals must be connected to a positive supply voltage (3.3V) using a pull-up resistor. Size of the pull-ups need to be determined carefully for proper operation, which depends upon supply voltage (VDD), total bus capacitance (C_{BUS}) and total high-level input current (I_{IH}). The value of pull-ups used in the design is 1.5KΩ.

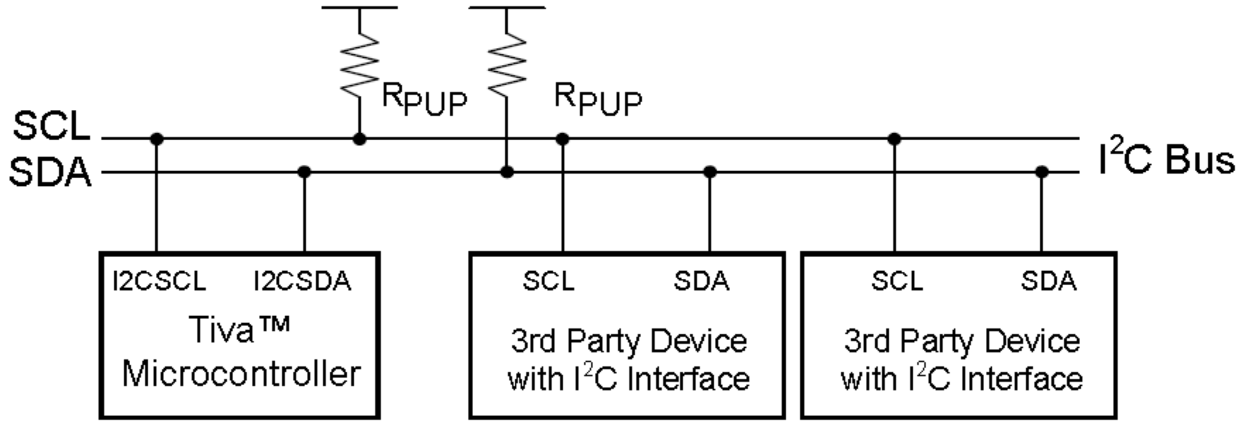


Figure 7: I2C Bus Interface & External Pull-ups

4.1.3 Field Bus Connectivity

IO Controller provides an EMC compliant isolated 1-Mbps, 3.3V to 5V RS-485 interface for field bus connectivity using ISO1176 transceiver and the TPS55010. This board achieves signal and power isolation with reduced board space and power consumption. TPS55010 has higher efficiency and better regulation accuracy since the Flybuck™ topology uses primary side feedback that provides excellent regulation over line and load compared to an open loop push pull converter without an opto-coupler. TPS55010 provides 3.3V to 5V and isolation levels using off-the-shelf flyback transformers. The transformer chosen here for the design has 475µH primary inductance and dielectric strength of 2500VAC for one minute between primary and secondary. The ISO1176 transceiver is an ideal device for long transmission lines since the ground loop is broken to provide for operation with a much larger common mode voltage range. The symmetrical isolation barrier provides 2500 VRMS of isolation between the line transceiver and the logic level interface. RS-485 bus is available on J1 and J20 screw type terminals/connectors.

An external fail safe biasing is provided on RS-485 bus that uses external resistor biasing to ensure failsafe operation during an idle bus. If none of the drivers connected to the bus are active, the differential voltage (V_{AB}) approaches zero or in between ±250mV, thus allowing the receivers to assume random output states. To force the receiver outputs into a defined state, failsafe biasing resistors, R53 = R62 = R_{FS}, are introduced with the terminating resistors, R53 = 120Ω, such that it must provide sufficient differential voltage to exceed the input-voltage threshold of the receiver. The RS-485 bus is also protected against EFT, ESD and surges with the help of transient voltage suppressor diodes (SMCJ15CA, 1500W series).

Note; The Fly-Buck Design Calculator Tool assists designers with routine calculations for the 2W TPS55010 isolated DC/DC Converter. Available at http://www.ti.com/tool/flybuck-designer

4.1.4 PC Interface

IO Controller also provides an EMC compliant USB2.0 interface to communicate with GUI based application running in PC. USB2.0 interface is available on USB2.0 OTG mini AB, receptacle J5. The TM4C1237E6PZ USB controller supports as a full-speed (12 Mbps) or low-speed (1.5 Mbps) operation with integrated PHY. Some USB controller signals are alternate functions for some GPIO signals and default to be GPIO signals at reset. EMI filtering has been provided by stuffing a common mode choke for the elimination of common mode noise in high speed USB data lines (USBDP & USBDM). The TPD4E1B06 device has quad channel ultra-low cap used for ESD protection. Its 1.0pF line capacitance makes it suitable for a USB2.0 interface. This device is placed on the

USB lines between the common mode choke and the USB connector pins. This provides the shortest current path to ground, minimizing the possibility of damage elsewhere on the PCB.

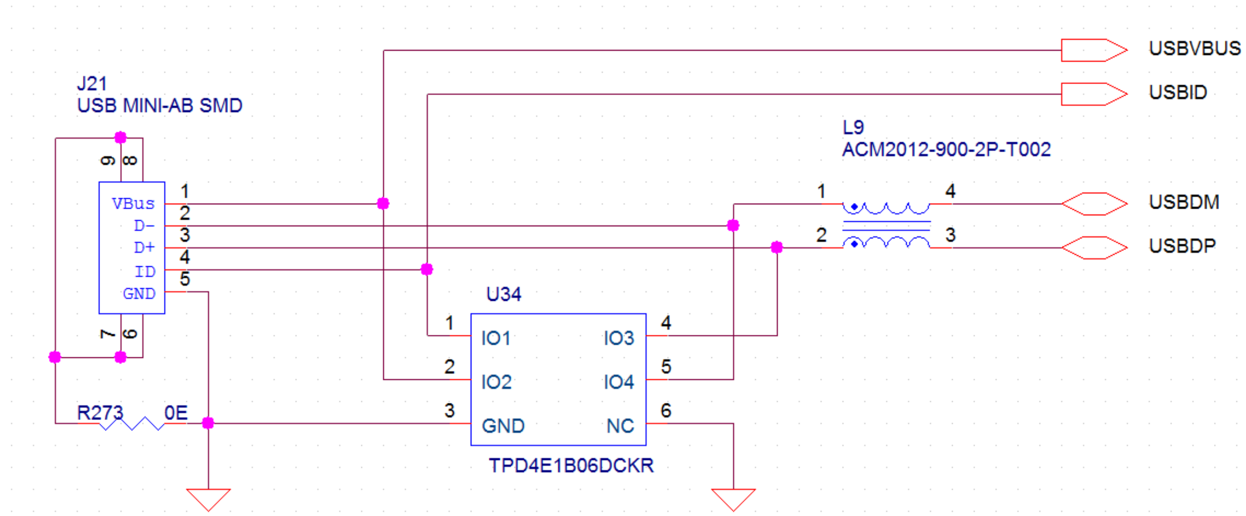


Figure 8: ESD Device Placement

4.1.5 RESET Circuitry

The external reset pin (/RST) input requires a minimum pulse width in order for the reset pulse to be recognized. The /RST pin resets the MCU including the core and all the on-chip peripherals. The external reset sequence is as follows:

- The external reset pin (RST) is asserted for the duration specified by T_{MIN} = 250 nsec and then de-asserted.
- The internal reset is released and the core loads from memory the initial stack pointer, the initial program counter, and the first instruction designated by the program counter, and then begins execution.

To program a user-defined, adjustable delay time, an external capacitor must be connected between the CT pin and GND. If the CT pin is left open, there will be a delay of 40 µsec. The adjustable delay time can be calculated as given below:

$T_{pd(r)} = [C_{CT}(\mu F) X\ 4] + 40\mu sec = [0.1\ X\ 4] + 40\mu sec$ = 40.4 µsec, which is greater than T_{MIN} and ensure guaranteed reset to the MCU and its peripherals.

4.2. Power Supply

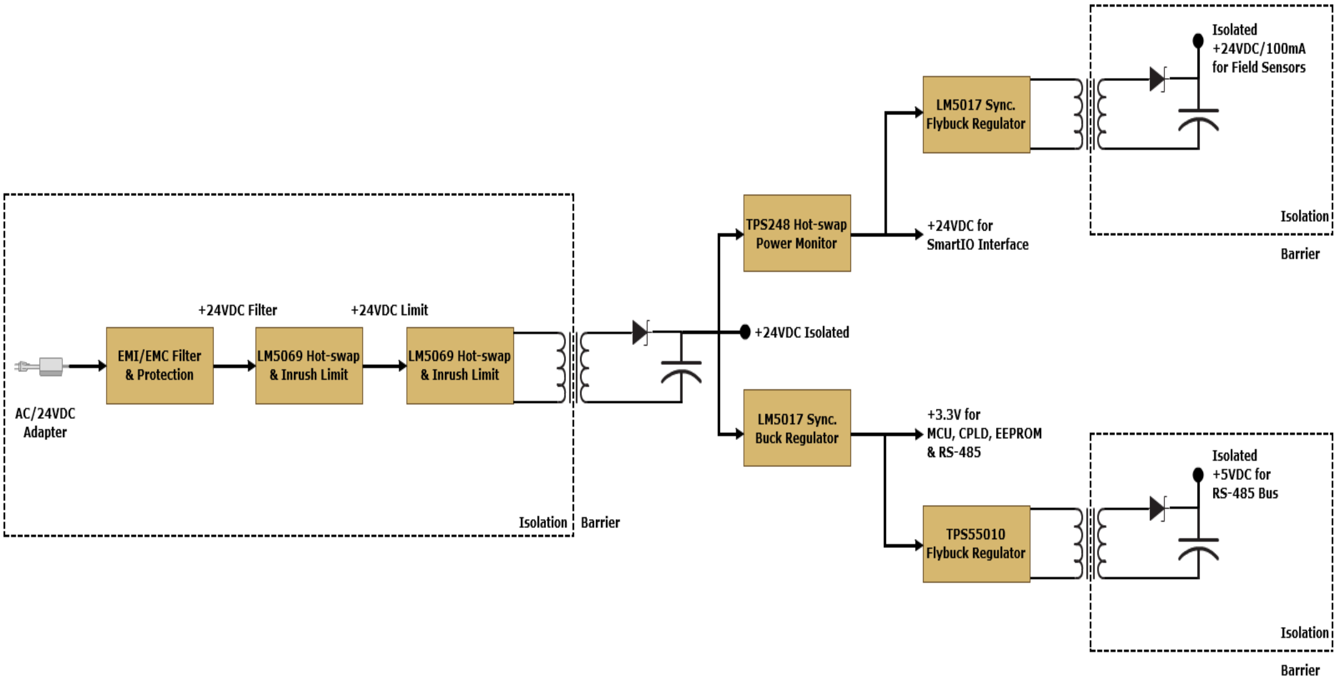


Figure 9: Power Supply Tree Diagram of IO Controller

Input +24VDC gets converted to isolated +24VDC, which is then down converted to regulated +3.3VDC required by MCU for its operation. The isolated +24VDC goes to the two 50-pin interface connector required to power-up SmartIO modules. The isolated +24VDC has also been used to generate another isolated +24VDC @ 100mA power supply for the field sensors.

4.2.1 Power Supply Front-end

The DC input is protected for EMI/EMC, transient/surge, reverse polarity, hot-swap / in-rush current limit and isolated to comply with harsh industrial environment. The reverse polarity protection has been provided using schottky diode D15 having rating of 200V and 4A. Whereas, MOV D16 and TVS diode D17 (SMBJ45CA, 600Watts series bi-directional TVS) serves for protection against transients and surges. R125 is a 2 ohm automotive AEC-Q200 Qualified, Pulse Withstanding / anti-surge resistor and used to limit the current in the event of transient/surge strikes.

The LM5069 positive hot swap controller provides intelligent control of the power supply connections during insertion and removal of circuit cards from a live system backplane or other "hot" power sources. The LM5069 provides in-rush current control to limit system voltage droop and transients. The current limit and power dissipation in the external series pass N Channel MOSFET are programmable, ensuring operation within the Safe Operating Area (SOA). The POWER GOOD output indicates when the output voltage is within 1.25V of the input voltage. The input under-voltage and over-voltage lockout levels and hysteresis are programmable, as well as the initial insertion delay time and fault detection time.

The POWER GOOD output signal may be connected to ENABLE / UVLO pin of the next stage regulator i.e. LM20242MH through R271 for power supply sequencing.

Current Limit:

Desired Current Limit Threshold (I_{LIMIT}) = $\frac{55mV}{R94\ (in\ m\Omega)} = \frac{55mV}{15m\Omega}$ = 3.67A

For proper operation of device, R94 must be smaller than 100mΩ.

Note: Current sense resistor (R94) must be placed near to LM5069 and connected using kelvin connection.

Power Limit:

Maximum Power Dissipation in M1 during Turn-on (P_{LIMIT}) = $\frac{R104}{1.25\ X\ 10^5\ X\ R94} = \frac{56K}{1.25\ X\ 10^5\ X\ 15m\Omega}$ = 30 Watts

Each time M1 is subjected to the maximum power limit conditions it is internally stressed for a few milliseconds. For this reason, the power limit threshold must be set lower than the limit indicated by the FET's SOA chart.

Insertion Time:

The insertion time starts when the input voltage at VIN reaches 7.6V, and its duration is equal to

$t_{INSERTION}$ = C68 x 7.24 x 10^5 = 340ms

During the insertion time, M1 is held off regardless of the voltage at VIN. This delay allows ringing and transients at VIN subside before the input voltage is applied to the load via M1.

Fault Timeout Period & Restart:

The fault timeout period and the restart timing are determined by the TIMER capacitor according to the following equations:

t_{FAULT} = C8 x 4.7 x 10^4 = 22ms

Note: The fault timeout period must be longer than the circuit's turn-on time; otherwise device may not come out of repeated restart sequence. Circuit's turn-on time should also be verified experimentally.

$t_{RESTART}$ = C8 x 9.4 x 10^6 = 4.42 seconds

UVLO & OVLO:

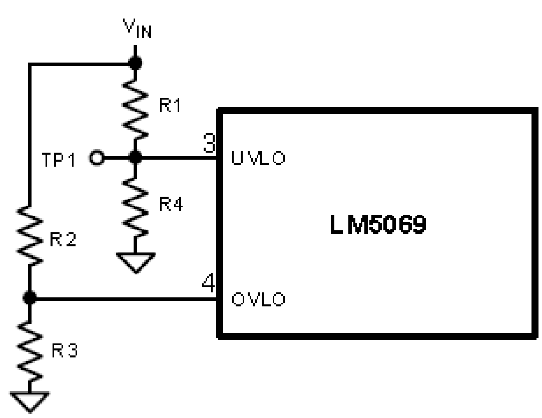


Figure 10: UVLO & OVLO using External Resistors

Choose the upper and lower UVLO thresholds:

R1 = $\frac{\text{VUVH} - \text{VUVL}}{21\mu A} = \frac{1.5\text{V}}{21\mu A} =$ 71.5K

R4 = $\frac{2.5V\ X\ R1}{\text{VUVL}-2.5\text{V}} = \frac{2.5V\ X\ 71.5K}{14.66\text{V}-2.5\text{V}}$ = 14.7K

Therefore, V_{UVH} = 16.1V & V_{UVL} = 14.66V with hysteresis of 1.5V that keeps the device from responding to power-on glitches during start up.

Choose the upper and lower OVLO thresholds:

R2 = $\frac{\text{VOVH} - \text{VOVL}}{21\mu A} = \frac{2\text{V}}{21\mu A}$ = 95.3K

R3 = $\frac{2.5V\ X\ R2}{\text{VOVL}-2.5\text{V}} = \frac{2.5V\ X\ 95.3K}{34.27\text{V}-2.5\text{V}}$ = 7.5K

Therefore, V_{OVH} = 34.27V & V_{OVL} = 31.77V with hysteresis of 2V.

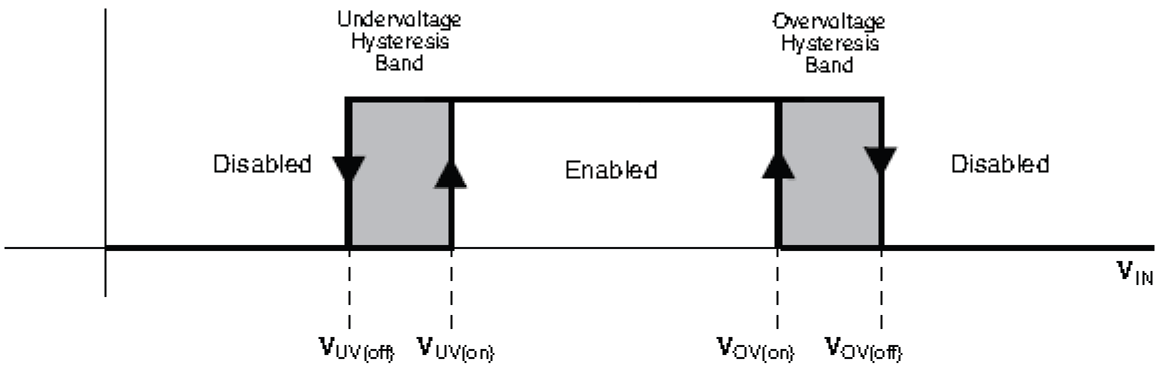


Figure 11: UVLO & OVLO Hysteresis

Refer to LM5069 datasheet and LM5069EVAL evaluation board for device operation, design procedure and recommended PCB layout guidelines.

4.2.2 DC Input Isolation

An isolated 24V to 24V DC-DC converter has been designed using LM20242 in flybuck topology. LM20242 is a synchronous buck regulator capable of delivering up to 2A of load current based on Current Mode Control. The circuit has been optimized to give an isolated 24V output with 500mA current. The input voltage ranges from 14.66V to 34.27V. LM20242 is operating at switching frequency of 800 KHz. The required power line isolation is provides small off-the-shelf flyback transformer. The transformer chosen here for the design has 66µH primary inductance and dielectric strength of 1500VAC for one minute between primary and secondary. Primary (1-8) to secondary (3-6) turns ratio is 1:2.

The first equation to calculate for any buck converter is duty-cycle. Ignoring conduction losses associated with the MOSFET's and parasitic, it can be approximated by:

Duty Cycle (D) = $\frac{V_{OUT}}{V_{In}}$

ADJUSTING THE OPERATING FREQUENCY (R_{RT}):

The operating frequency of the LM20242 can be adjusted by connecting a resistor from the R_{RT} pin to ground. Use the equation given below to calculate the value of R_{RT} for a given operating frequency. Where, f_{SW} is the switching frequency in kHz, and R_{RT} is the frequency adjust resistor in kΩ.

$$R_{RT} = \left(\frac{82000}{f_{SW}}\right) - 56$$

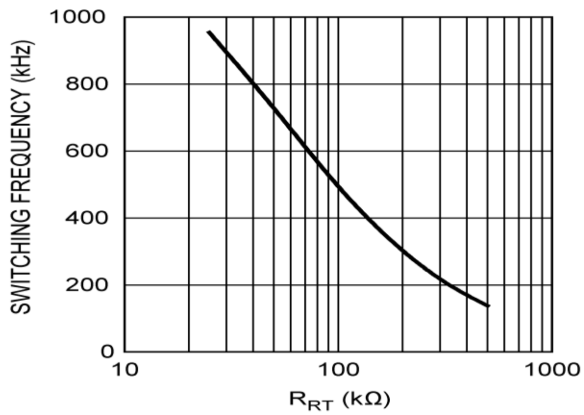


Figure 12: Switching Frequency Vs R_{RT}

Note: If the R_{RT} resistor is omitted the device will not operate.

Enable:

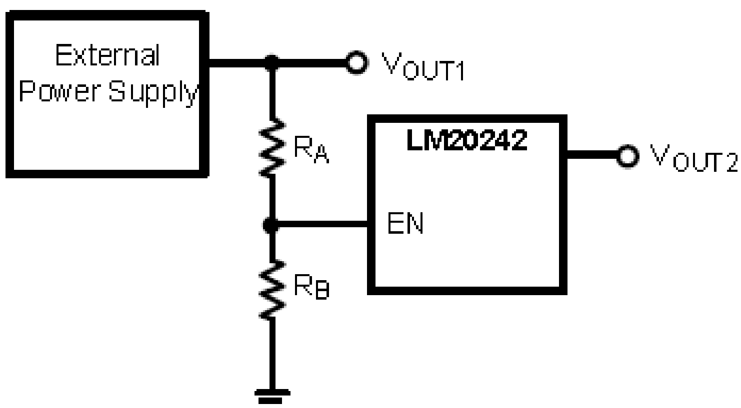


Figure 13: Enable Voltage using External Resistor Divider

The value for resistor R_B can be selected by the user to control the current through the divider. Typically, this resistor will be selected to be between 10kΩ and 1MΩ. Once the value for R_B is chosen the resistor R_A can be solved using equation given below to set the desired turn-on voltage.

$$R_A = \left(\frac{V_{TO}}{1.25} - 1\right) * R_B$$

If R_B is 10KΩ & V_{TO} is 15.625V, then R_A will be 115KΩ.

SETTING THE OUTPUT VOLTAGE (R_{FB1}, R_{FB2}):

The resistors R_{FB1} and R_{FB2} are selected to set the primary side non-isolated regulated output voltage for the device. Later, primary side voltage is doubled (24VDC_ISO) and rectified using a diode (D1) and a capacitor (C_{OUT2}).on the secondary of the flyback transformer and provides the galvanic isolation between primary and secondary winding. Flyback transformer must comply with the isolation requirement for the design. R_{FB2} should be selected to be between 4.99KΩ to 49.9KΩ and R_{FB1} can be calculated using equation given below:

$$R_{FB1} = \left(\frac{V_{OUT}}{0.8} - 1\right) * R_{FB2}$$

Where, V_{OUT} = 12V & R_{FB2} = 11KΩ, then R_{FB1} comes out to be 154 KΩ.

The secondary output voltage can be given as:

$$V_{SEC} = \frac{V_S}{V_P} * V_{PRI} - V_F$$

Where, V_F is the forward voltage drop of the secondary rectifier diode, and N_P, N_S are the number of turns in the primary and secondary windings, respectively. The secondary output (V_{SEC}) closely tracks the primary output voltage (V_{PRI}) without the need for additional transformer winding or an opto-coupler for feedback across the isolation boundary.

Refer to LM20242 datasheet and AN–1694 LM20242 evaluation board for device operation, design procedure and recommended PCB layout guidelines.

4.2.3 MCU Supply

LM5017 device has been used to generate 3.3V Volts from 24VDC_ISO required for Tiva™ C Series TM4C1237E6PZI MCU, CPLD, EEPROM and primary side power supply for RS485.

When the circuit is in regulation, the buck switch is turned on each cycle for a time determined by R97 and V_{IN} according to equation given below.

$$T_{ON} = \left(\frac{10^{-10}\ X\ R97}{VIN}\right) = \left(\frac{10^{-10}\ X\ 53.6K}{24V}\right) = 223.33\text{nsec}$$

The on-time varies inversely with input voltage. At the end of each on-time, the buck switch is off for at least 144ns. In normal operation, the off-time is much longer. During the off-time, the load current is supplied by the output capacitor (C290). When the output voltage falls sufficiently that the voltage at FB is below 1.225 V, the regulation comparator initiates a new on-time period. For stable, fixed frequency operation, a minimum of 25 mV of ripple is required at FB to switch the regulation comparator.

Note: R_{ON} should be selected for a minimum on-time (at maximum V_{IN}) greater than 100ns, for proper operation. This requirement limits the maximum switching frequency for high V_{IN}.

The operating frequency can be calculated as follows:

$$F_{SW} = \frac{V_{OUT}}{10^{-10} X\ R97} = \frac{3.3V}{10^{-10} X\ 53.6K} = 615.67\ \text{KHz}$$

The output voltage (V_{OUT}) is set by two external resistors (R101, R106). The regulated output voltage is calculated as follows:

$$V_{OUT} = 1.225 \text{ x } \left(\frac{R101}{R106} + 1\right) = 1.225 \text{ X } \left(\frac{8.2K}{5K} + 1\right) = 3.234V$$

UVLO:

The UVLO resistors R100 and R105 set the UVLO threshold and hysteresis according to the following relationship:

R100 = $\frac{UVLO\_HYSTERESIS}{20\mu A} = \frac{2.4V}{20\mu A}$ = 120KΩ

UVLO rising threshold = 1.225 x $\left(\frac{R100}{R105} + 1\right)$ = 1.225 X $\left(\frac{120K}{10K} + 1\right)$ = 15.925V

The board has been supplied with minimum ripple configuration (Type 3). Type 3 ripple method uses R_r and C_r and the switch node (SW) voltage to generate a triangular ramp. This triangular ramp is ac coupled using C_{ac} to the feedback node (FB). Since this circuit does not use the output voltage ripple, it is ideally suited for this applications as low output voltage ripple is required.

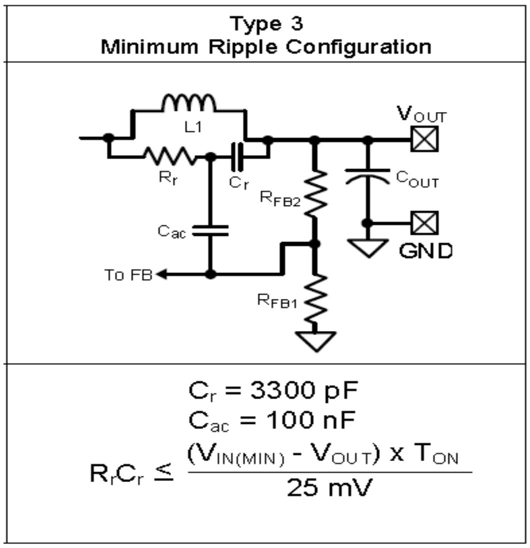


Figure 14: Type 3 Minimum Ripple Configuration

Refer to LM5017 datasheet, AN-2200 LM5017 evaluation board for device operation, design procedure and recommended PCB layout guidelines.

4.2.4 Field Sensor Power Supply

To protect against transients and ground loops, the field side which interfaces to sensors is electrically isolated from the control side. LM5017 device has been used to generate an isolated +24V_ISO_FIELD from 24VDC_ISO required to power up the field sensors.

An isolated buck converter (flybuck) uses a synchronous buck converter with coupled inductor windings to create isolated outputs. Isolated converters utilizing flybuck topology use a smaller transformer for an equivalent power transfer as the transformer primary and secondary turns ratios are better matched. There is no need for an opto-coupler or auxiliary winding as the secondary output closely tracks the primary output voltage, resulting in smaller solution size and cost.

When the circuit is in regulation, the buck switch is turned on each cycle for a time determined by R117 and V_{IN} according to equation given below.

T_{ON} = $\left(\frac{10^{-10}\ X\ R117}{VIN}\right) = \left(\frac{10^{-10}\ X\ 249K}{24V}\right)$ = 1.0375µsec

The operating frequency can be calculated as follows:

$$F_{SW} = \frac{V_{OUT}}{10^{-10} X\ R117} = \frac{12V}{10^{-10} X\ 249K} = 482\ KHz$$

The output voltage (V_{OUT1}) is set by two external resistors (R122, R124). The regulated output voltage is calculated as follows:

$$V_{OUT1} = 1.225 \times \left(\frac{R122}{R124} + 1\right) = 1.225\ X \left(\frac{110K}{12.4K} + 1\right) = 12.1V$$

Selection of rectifier diode D13:

The reverse bias voltage across D13 when the high side buck switch is on:

$$V_{D13} = \frac{Ns}{Np} V_{IN} = 2\ X\ 24 = 48V$$

So, the PIV for the selected diode must be greater than the 48V.

D14 is an optional diode connected between VOUT1 and VCC regulator output. When VOUT1 is > VCC the VCC supplied from VOUT1. This results in reduced losses in VCC regulator inside the IC.

Refer to LM5017 datasheet, AN-2292 Designing an Isolated Buck (Flybuck) Converter for device operation, design procedure and recommended PCB layout guidelines.

5. Test Setup

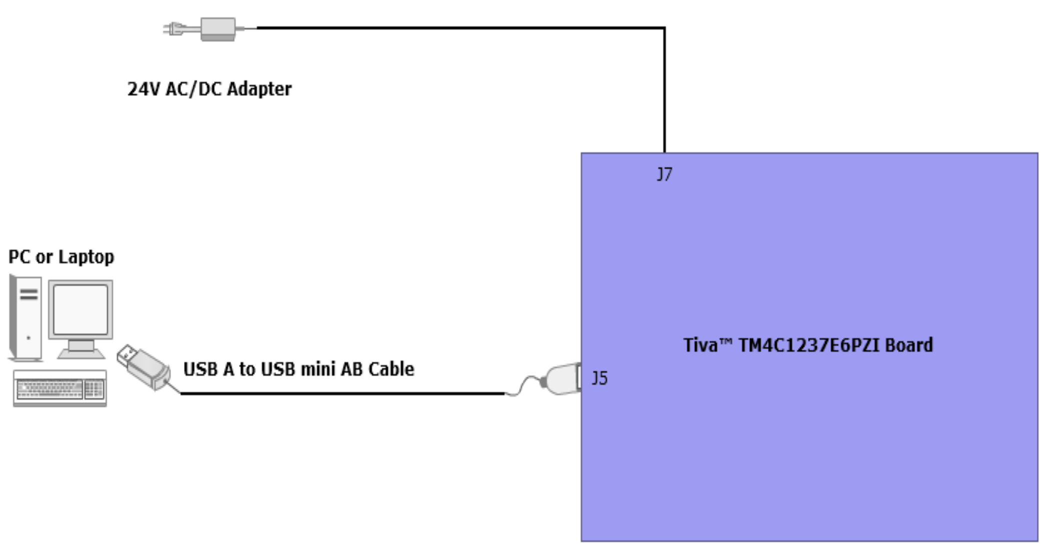


Figure 15: Setup Diagram for Test & Evaluation

6. Software Description

Tiva™ TM4C1237E6PZ MCU has got internal memories like ROM and RAM to store and run the main application program. During each operating cycle the controller examines the status of all input devices and communication interfaces, executes the logic and changes the appropriate output accordingly. The completion of one cycle in this sequence is called one scan. The total program execution time (or cycle time) depends on the length of the control program.

On power-up, program running inside Tiva™ C Series MCU will automatically detect the type of the I/O module plugged into slots by reading the configuration data stored in I/O module's EEPROM through I2C interface and configure itself accordingly. IO Controller can be connected to the GUI based application running on a desktop PC through USB interface and used evaluate the performance of the I/O modules by selecting the options in the GUI.

For evaluating the performance, Smart analog input module in one of the slot and Smart analog output module in another slot. Connect the any one channel of analog output module to voltage input analog input module using a small loopback cable. Now, with the help of GUI, user may generate voltage ramp and sinusoidal waveforms. Analog input module acquires the generated waveform. The acquired data is sent back to the GUI through USB, where it is analyzed and waveforms are plotted in the GUI from the acquired data and performance related parameters like linearity error, SNR, ENOB, Signal Power are calculated. Here, all the control and communication activities like receiving commands from GUI through USB, detecting type of SmartIO modules plugged-in, controlling analog input and output modules, sending the acquired data packets on USB, error reporting and all decision making totally supervised by Tiva™ TM4C1237E6PZ MCU.

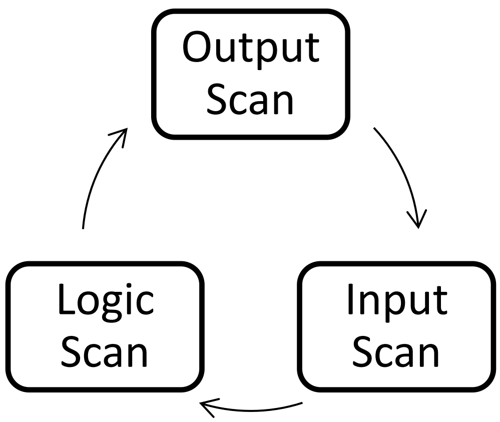


Figure 16: PLC Program Execution Sequence

7. Connectors & Other Features

J1 & J20	EMC compliant isolated RS-485 interface; Screwed terminal type connectors
J5	EMC compliant USB2.0 interface; USB 2.0 OTG mini AB, receptacle, surface mount, right angle, horizontal connector
J8	24VDC line power supply input; 2-Pin male header, shrouded (2 side) connector
J18	Chassis or Protective earth ground; 2-Pin male header, shrouded (2 side) connector
J7	24VDC @ 100mA output power supply for field sensors; 2-Pin male header, shrouded (2 side) connector
U10 & U11	SDCC interface to plug-in I/O modules; 50-Pin rugged high speed receptacle
J9	JATG header for programming/debugging Tiva™ TM4C1237E6PZ MCU; 2X5 male pin 2.54mm pitch header unshrouded connector
J2	Header to set address for Tiva™ TM4C1237E6PZ MCU in case of multiple MCU present in the network; 2X5 male pin 2.54mm pitch header unshrouded
J6	JATG header for programming CPLD; 2X5 male pin 2.54mm pitch header unshrouded connector
D1, D2, D3, D4, D53, D54, D55	Seven LEDs for debugging or indication purpose

SW2	Master manual RESET button; Top Actuated SPST-NO

8. PC Based GUI Software & Testing

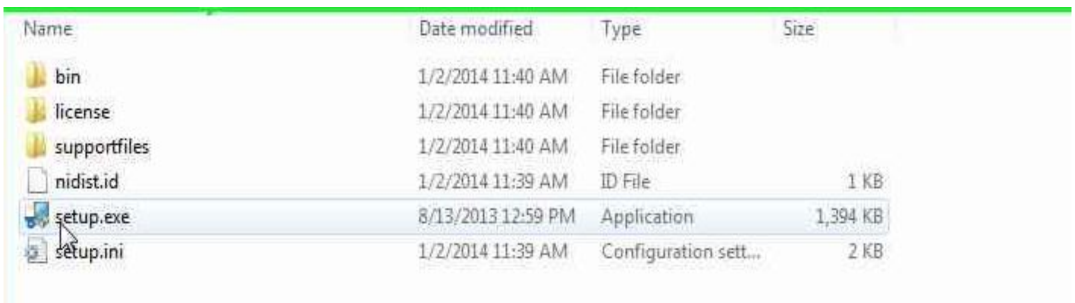
Follow the following steps to install the Smart IO GUI based utility in your PC, which is used to evaluate the performance of the SmartIO modules.

Note: IF PC doesn't have LabVIEW already installed in it, Step 1 and Step 2 are mandatory.

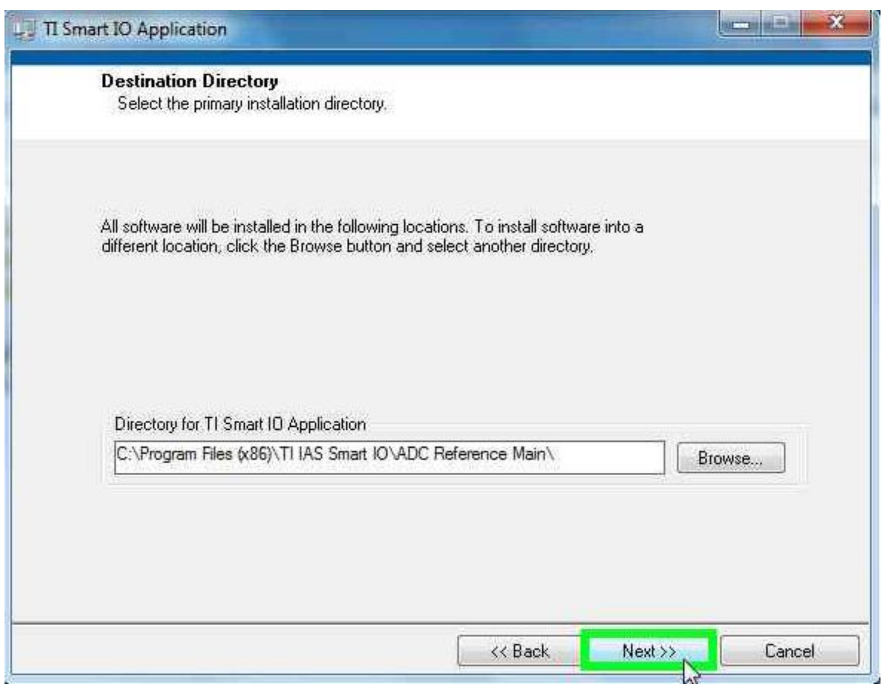
Step 1: Please click on the link given below to download and install the LabVIEW Run-Time Engine.
http://www.ni.com/download/labview-run-time-engine-2010-sp1/2292/en/

Step 2: Please click on the link given below to download and install the NI-VISA Run-Time Engine.
http://www.ni.com/download/labview-run-time-engine-2010-sp1/2292/en/

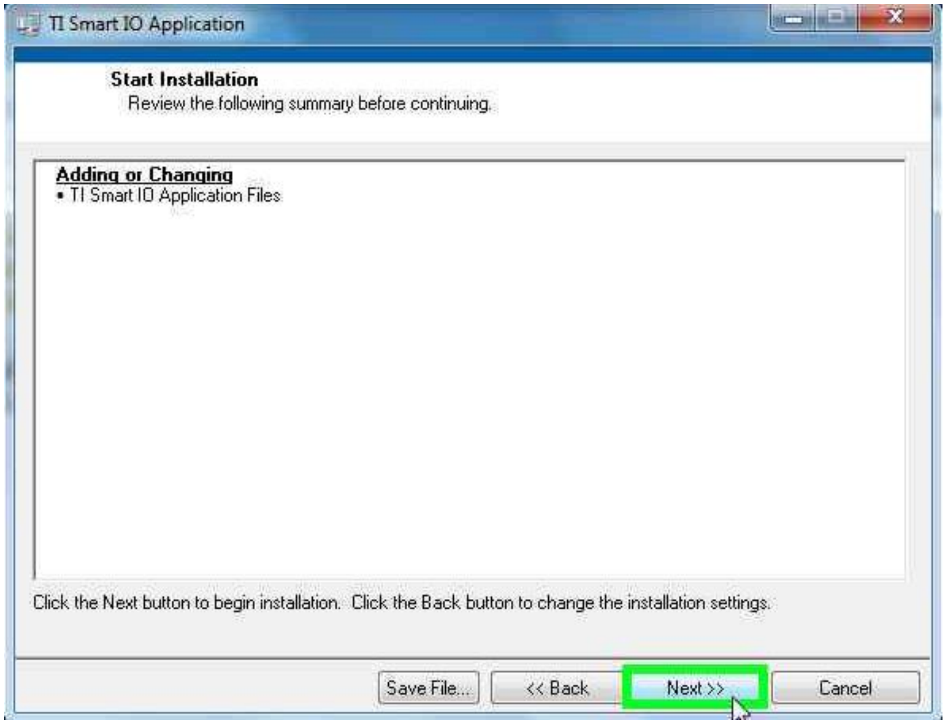
Step 3: GUI Installation: Run Setup.exe from the installer folder.



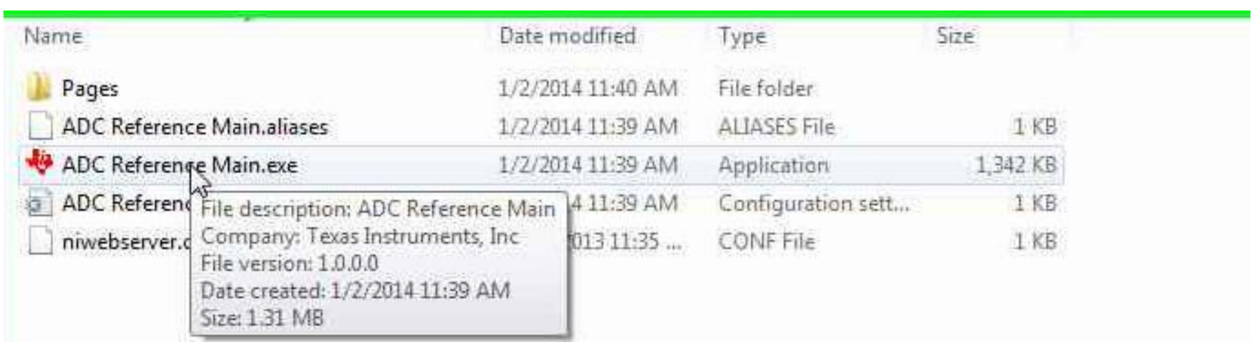
Step 4: Select the installation directory and press "Next" button.



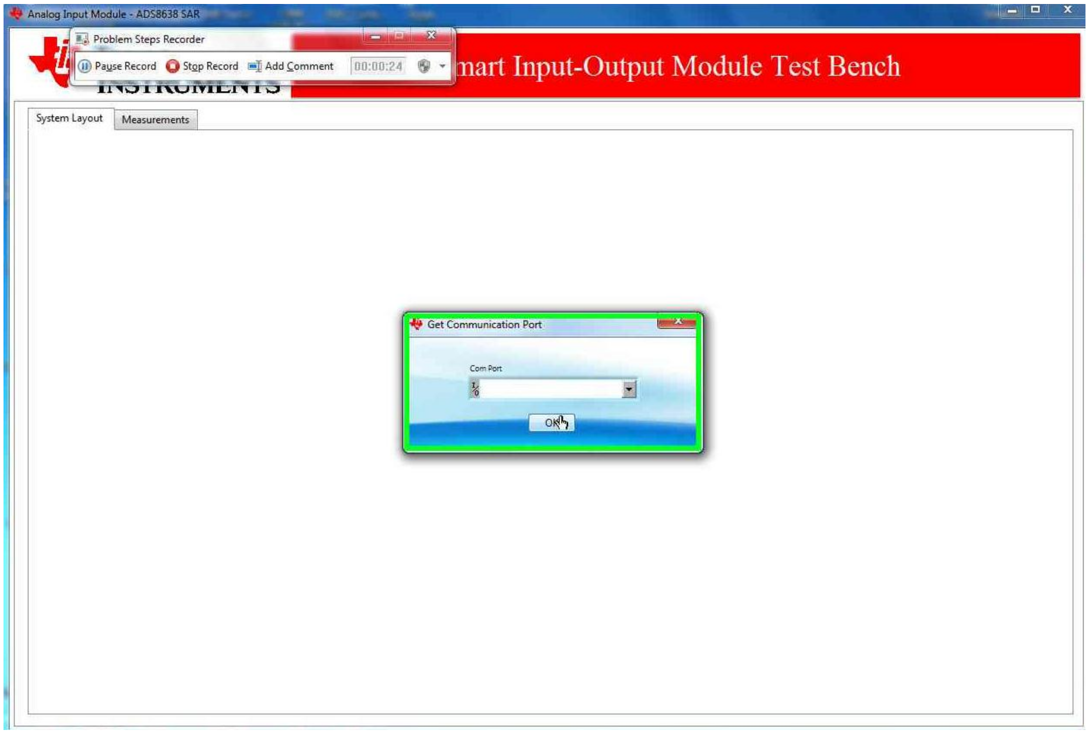
Step 5: Click on "Next" button to Install.



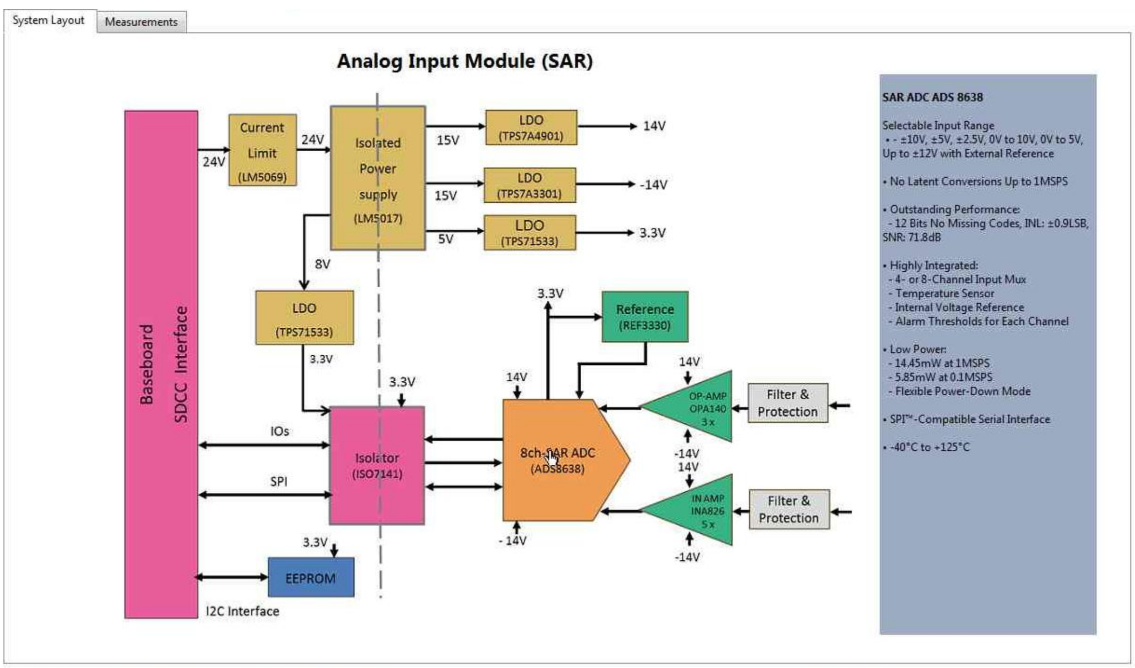
Step 6: Go to the installed location to find “ADC Reference Main.exe”. Double Click to run the executable.



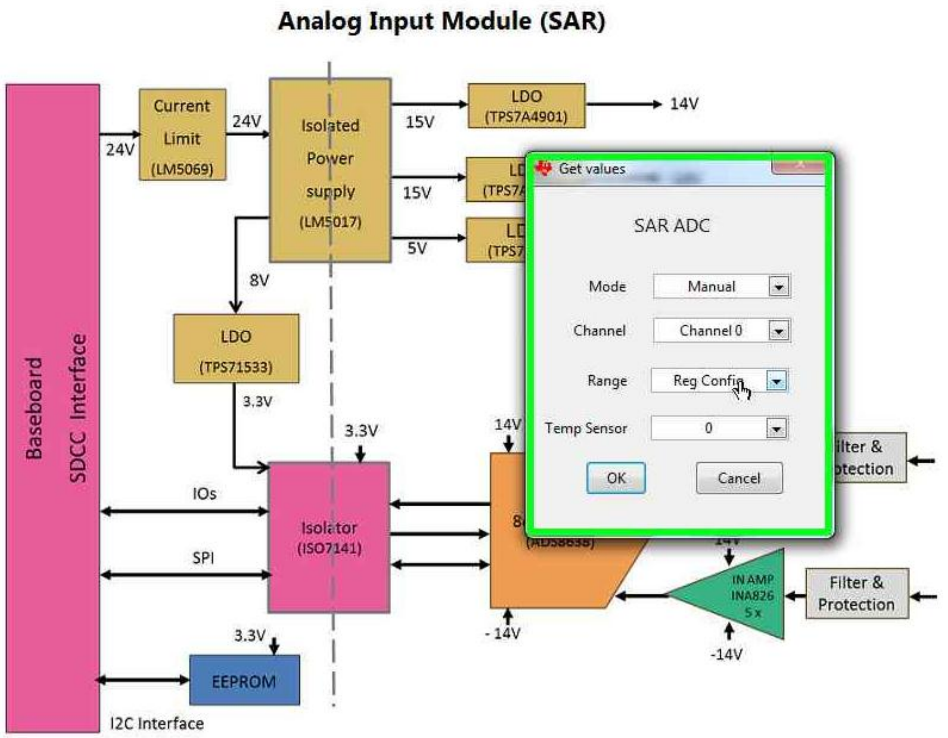
Step 7: Select the appropriate communication port and press “Ok” button to establish communication with the hardware.



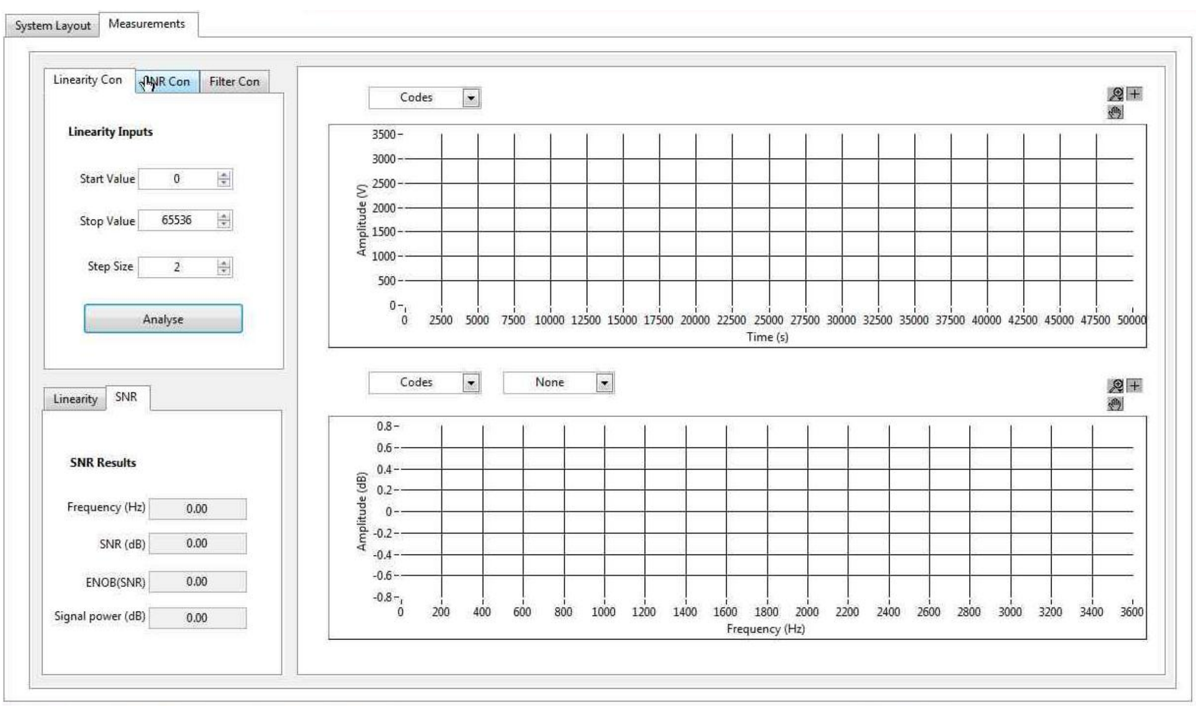
Step 8: System Layout Page: Block Diagram of the ADC reference design. Hover over blocks to see a brief description about the selected device.



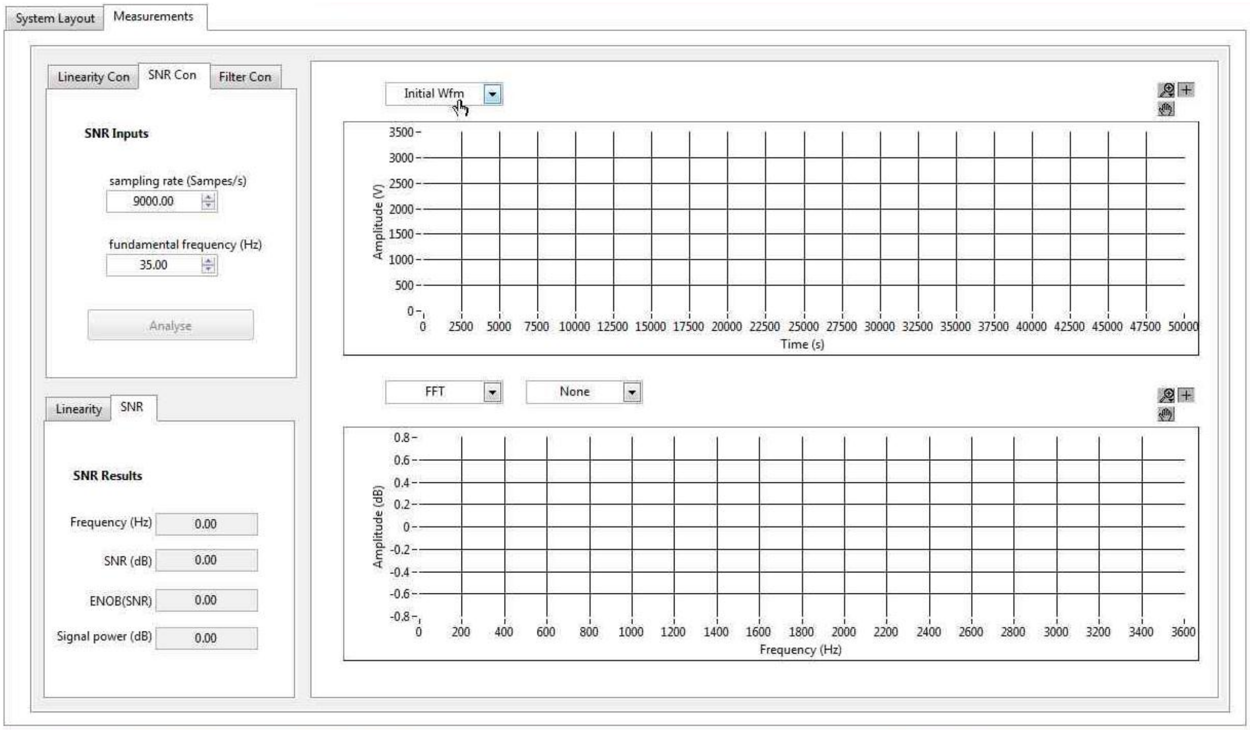
Step 9: System layout Page: Click on a block to configure various parameters associated with it.
Example: SAR-ADC Configuration.



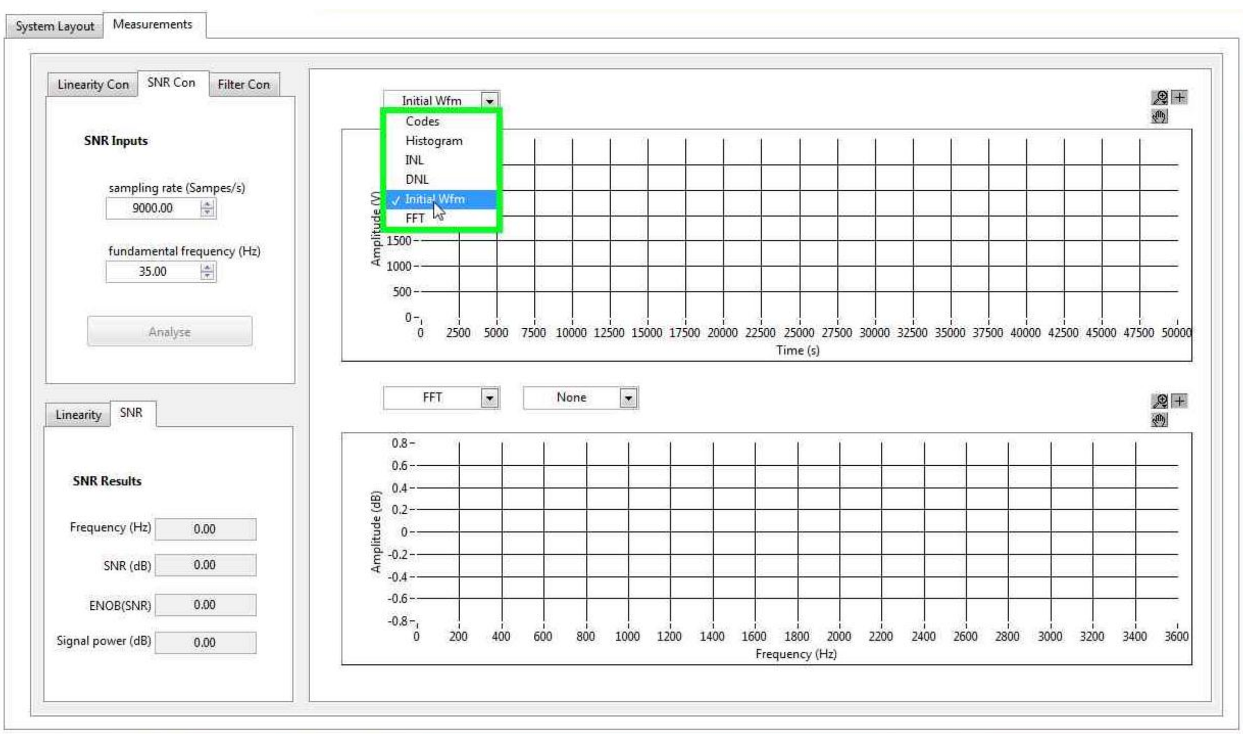
Step 10: Measurements Page: "Measurements", page gives you a series of measurements that you can perform on the connected reference design. Configure the input parameters accordingly and press "Analyze" to perform measurements.
Example: ADC design has Linearity and SNR Measurements.



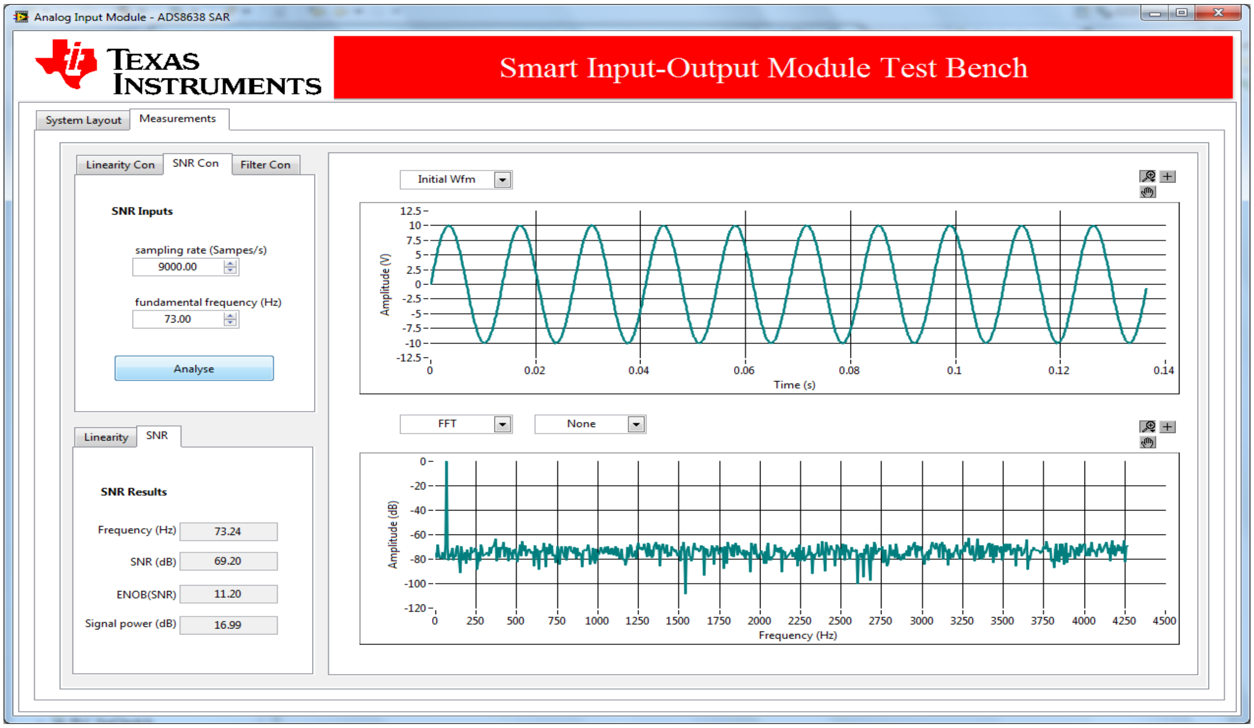
Step 11: Once the measurement is done results of the measurements will be displayed in the highlighted area.



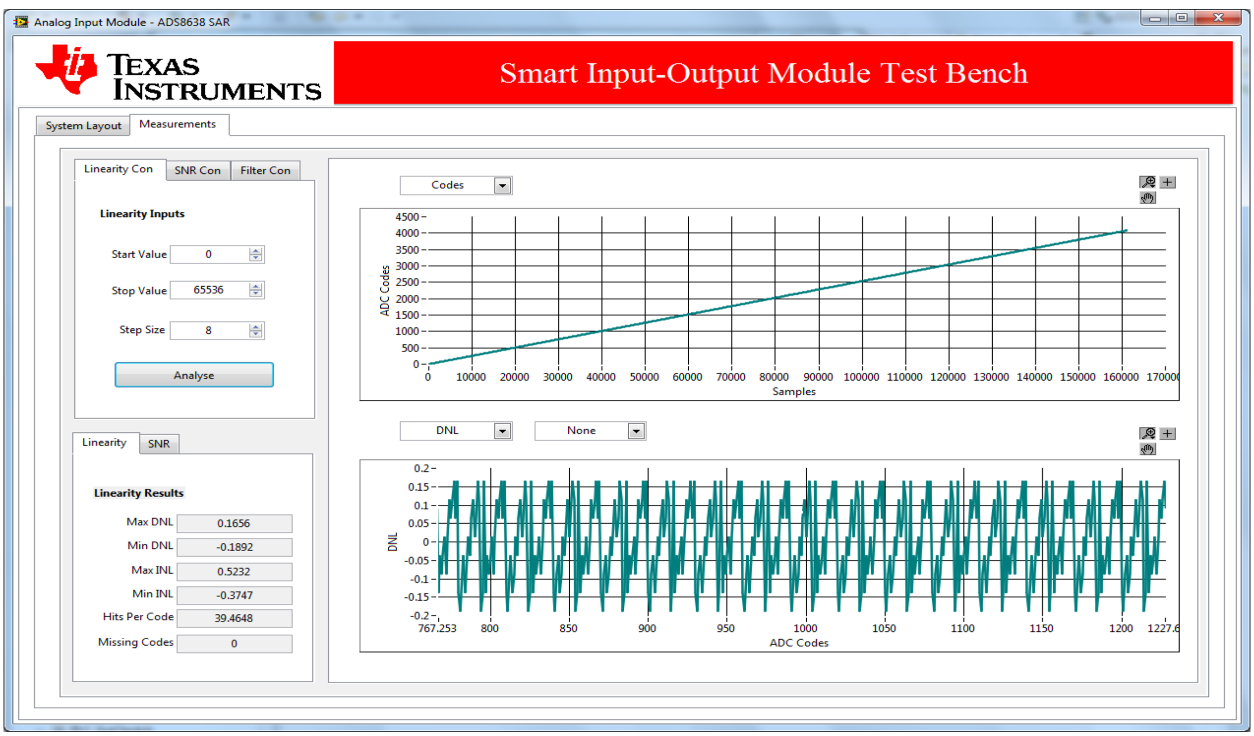
Step 12: There are two plots available which can be used to plot different data points as selected in the drop down menu.



Step 13: The below diagram shows an example data and plot for SNR measurements.



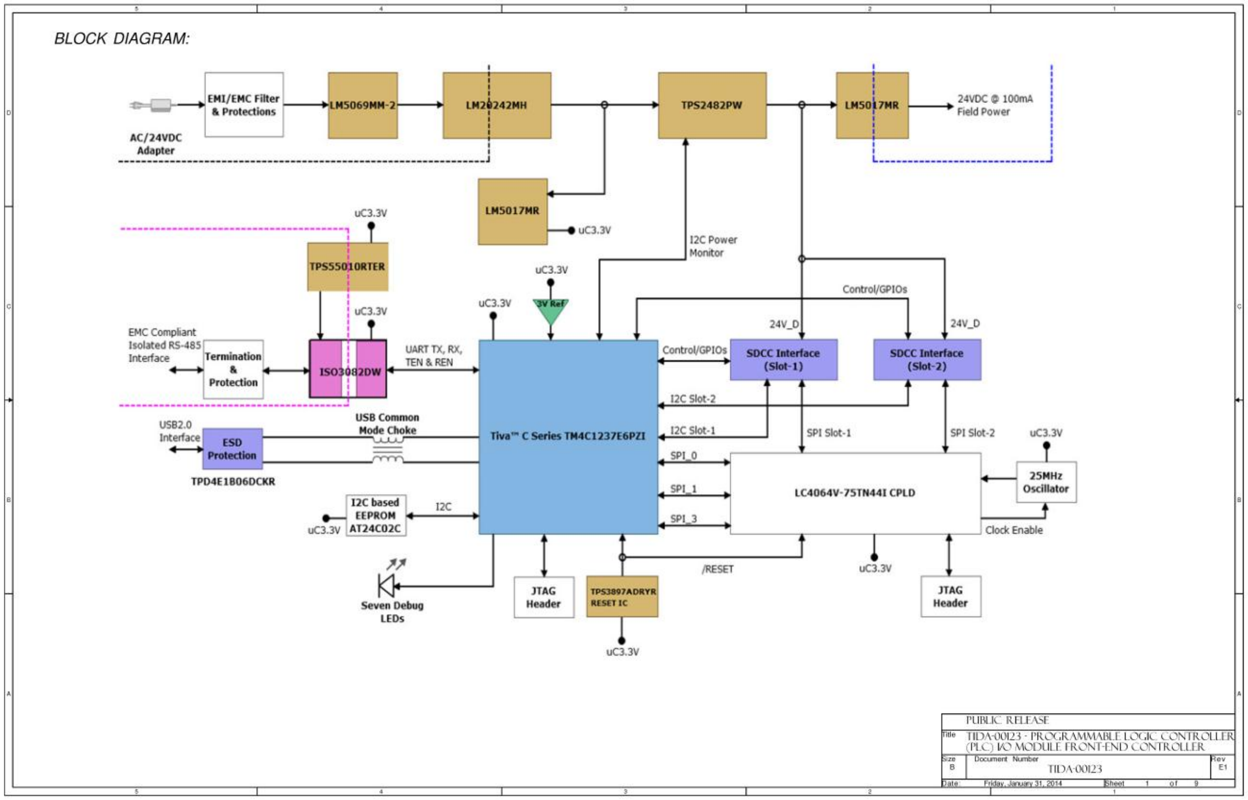
Step 14: The below diagram shows an example data and plot for Linearity measurements.

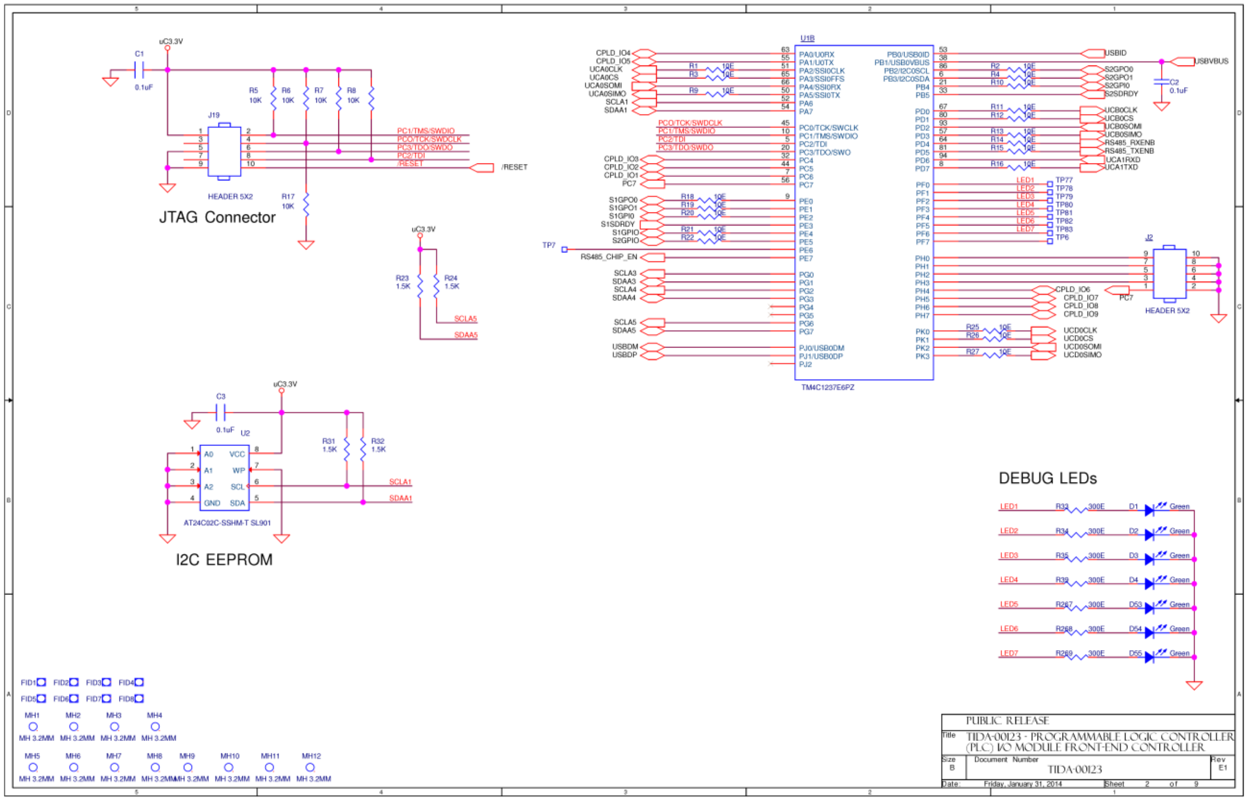


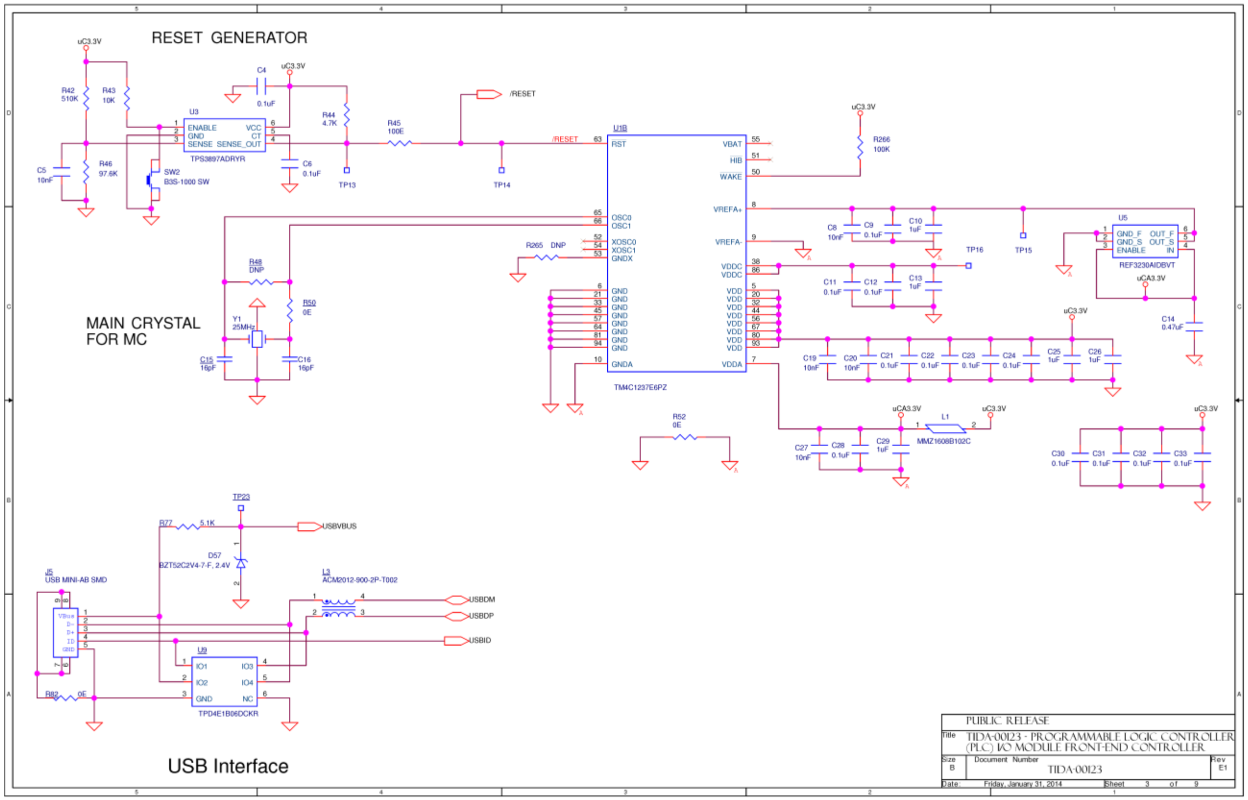
9. Design Files

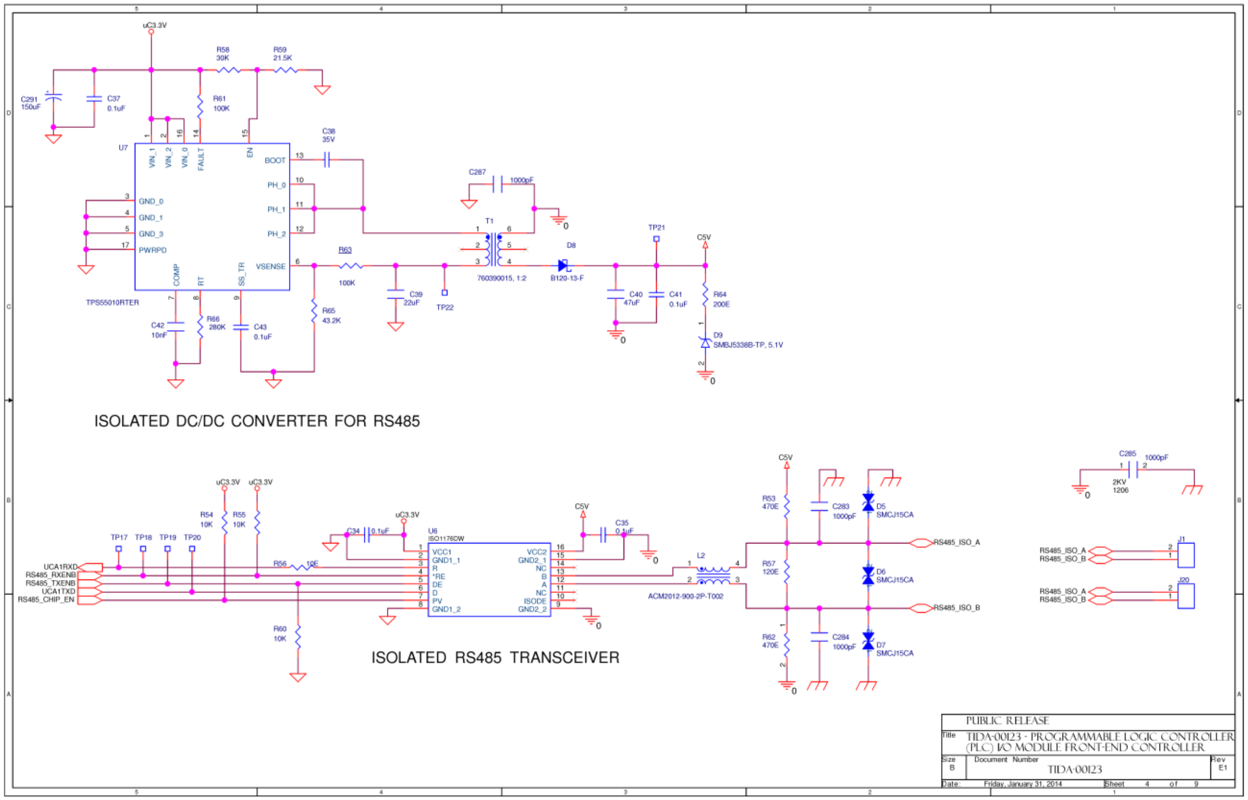
9.1 Schematic

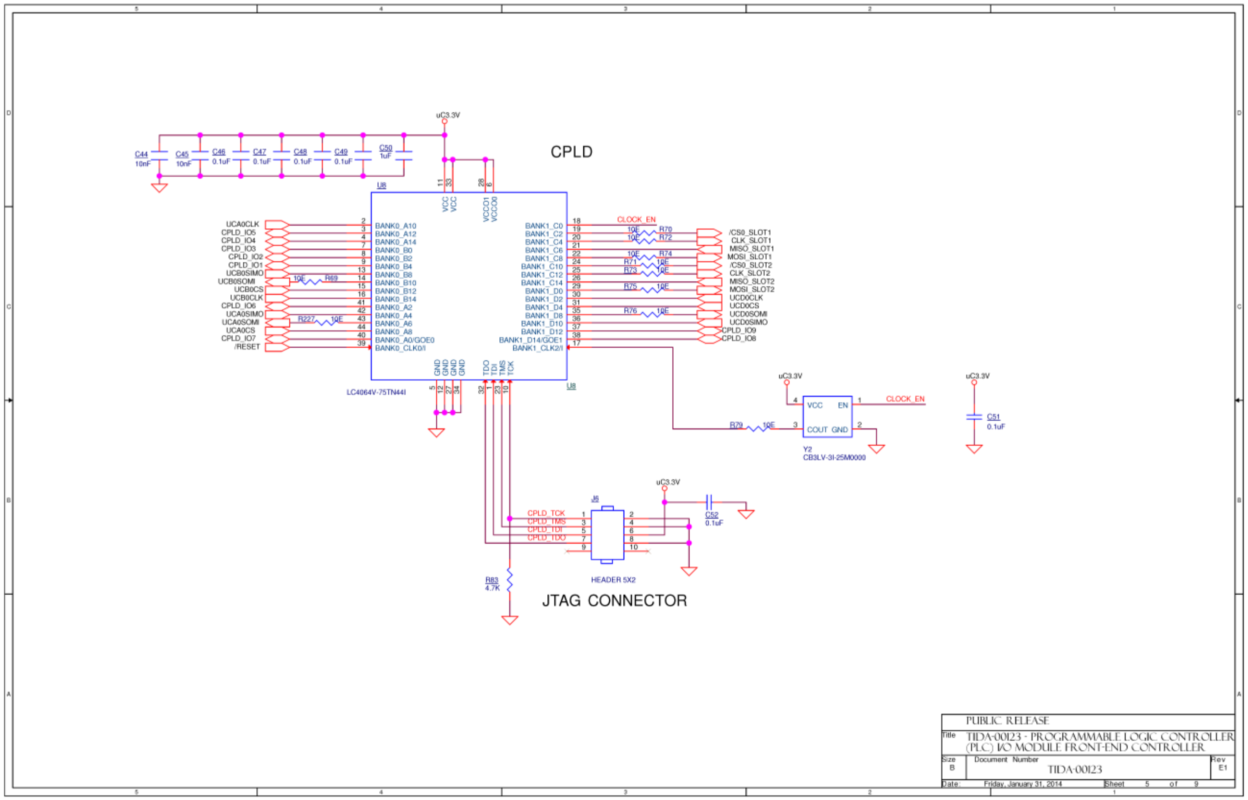
To download the Schematic files for the board, see the design files at: www.ti.com/tool/TIDA-00123

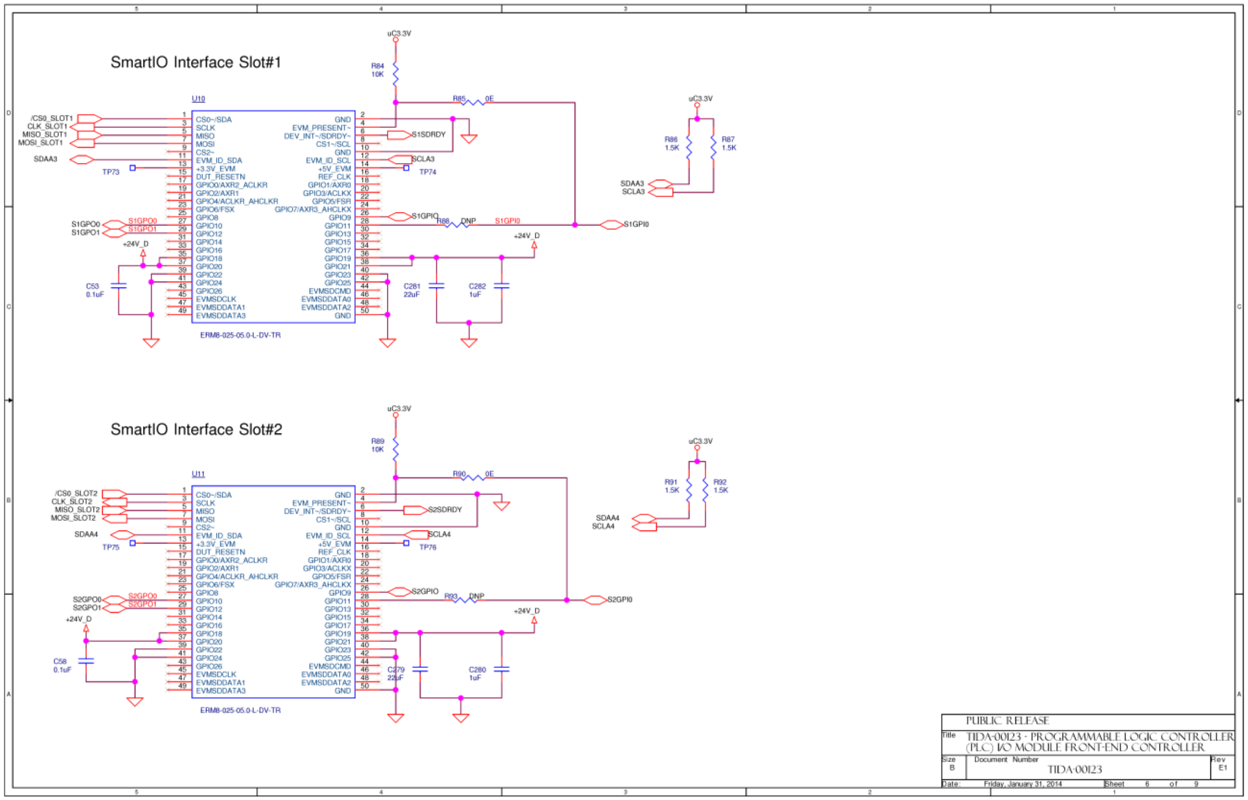


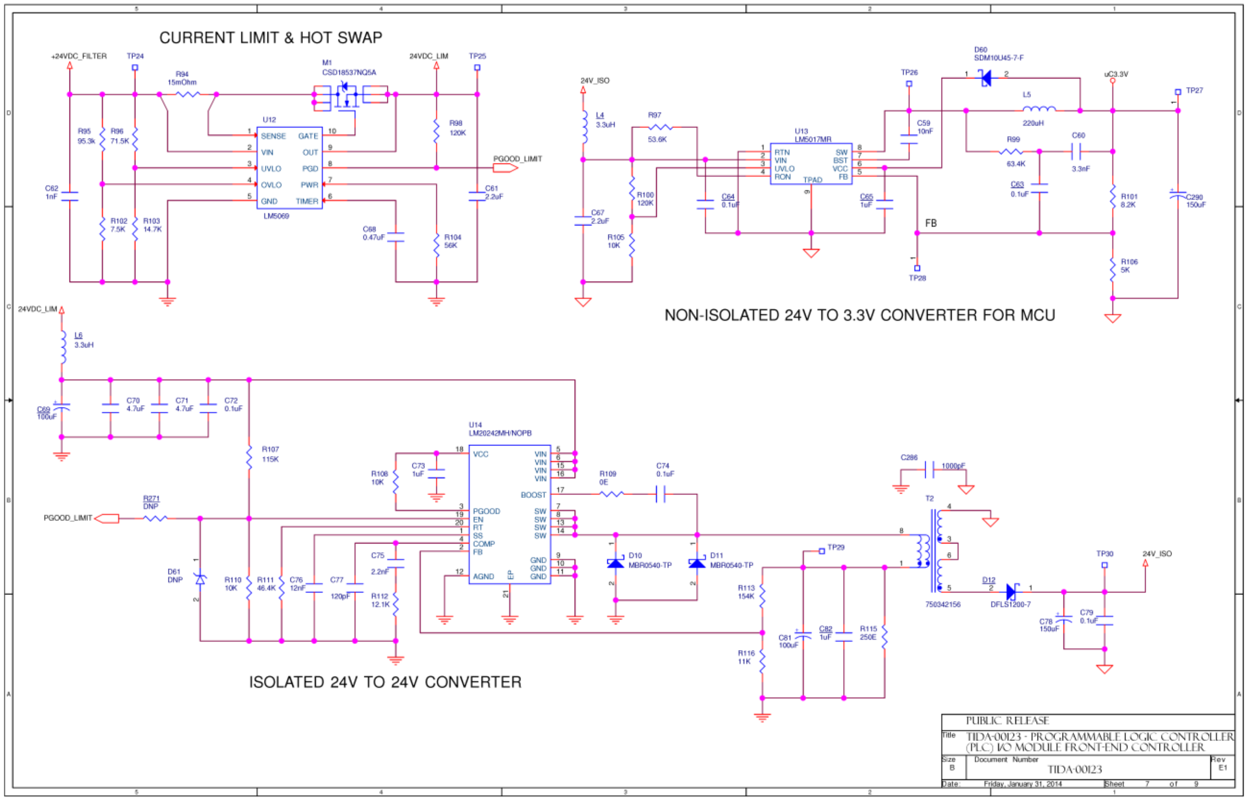

JTAG Connector
HEADER 5X2
I2C EEPROM
AT24C02C-SSHM-T SL901
DEBUG LEDs
TM4C1237E6PZ
HEADER 5X2
PUBLIC RELEASE
TIDA-00123 - PROGRAMMABLE LOGIC CONTROLLER (PLC) I/O MODULE FRONT-END CONTROLLER
TIDA-00123
Friday, January 31, 2014

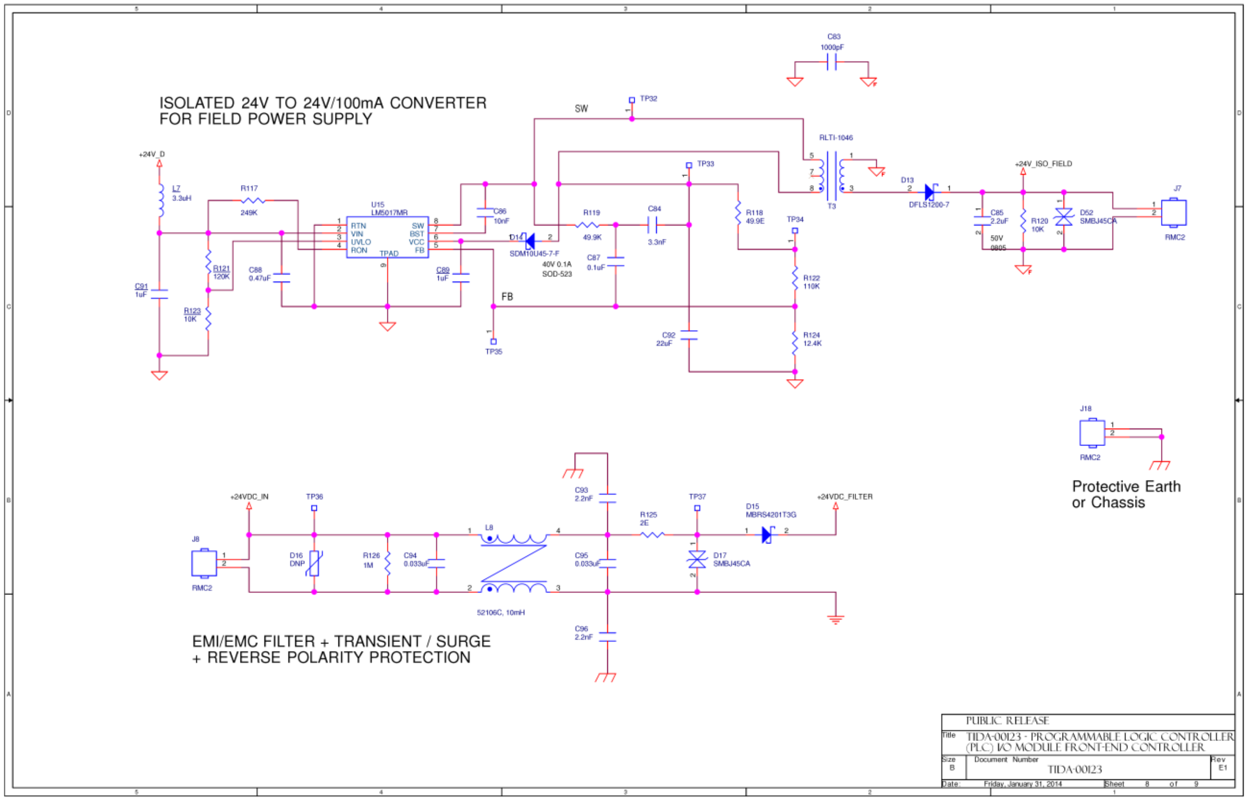

RESET GENERATOR
MAIN CRYSTAL FOR MC
USB Interface
TM4C1237E6PZ
TPS3897ADRYR
REF3230AIDBVT
TPD4E1B06DCKR
PUBLIC RELEASE
TIDA-00123 - PROGRAMMABLE LOGIC CONTROLLER (PLC) I/O MODULE FRONT-END CONTROLLER
TIDA-00123

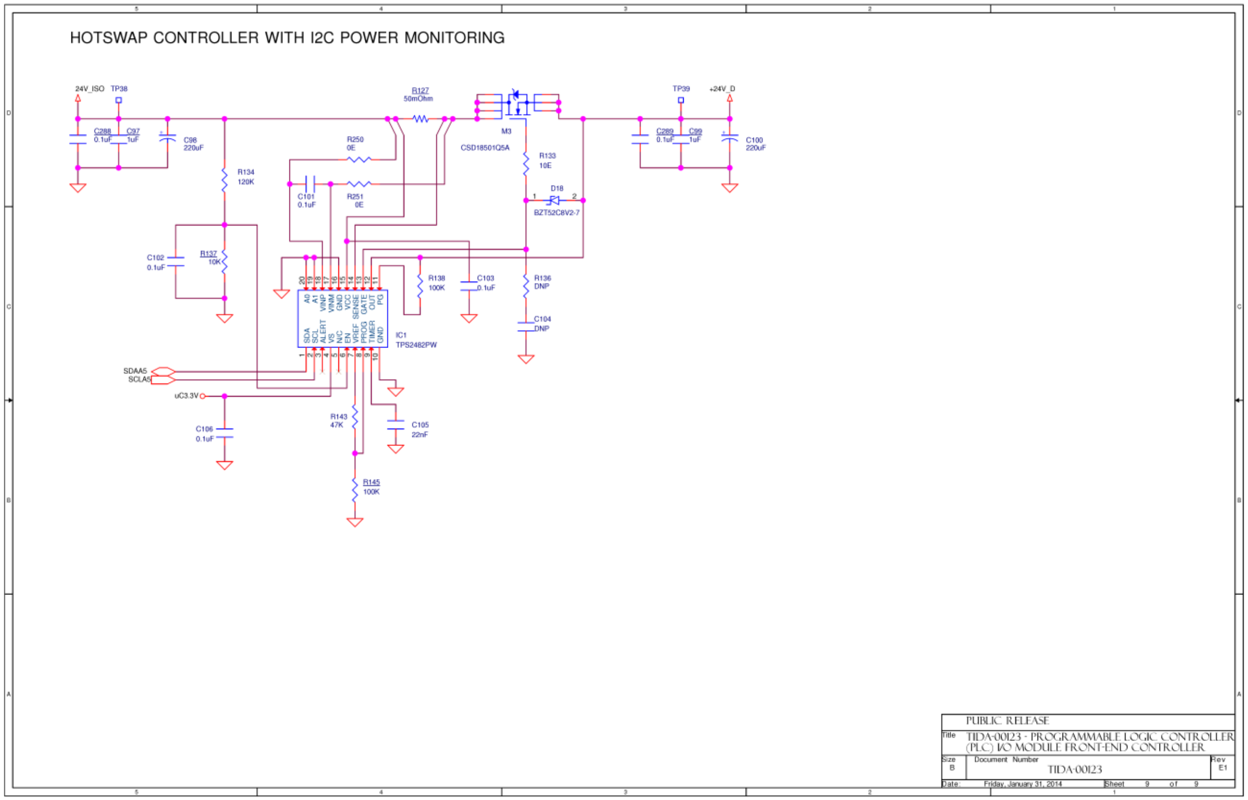

ISOLATED DC/DC CONVERTER FOR RS485
ISOLATED RS485 TRANSCEIVER
TPS55010RTER
ISO1176DW
ACM2012-900-2P-T002
760390015, 1:2
B120-13-F
SMBJ5338B-TP, 5.1V
SMCJ15CA
RS485_ISO_A
RS485_ISO_B
UCA1RXD
RS485_RXENB
RS485_TXENB
UCA1TXD
RS485_CHIP_EN
PUBLIC RELEASE
TIDA-00123 - PROGRAMMABLE LOGIC CONTROLLER (PLC) I/O MODULE FRONT-END CONTROLLER
TIDA-00123
Friday, January 31, 2014


CPLD
JTAG CONNECTOR
PUBLIC RELEASE
TIDA-00123 - PROGRAMMABLE LOGIC CONTROLLER (PLC) I/O MODULE FRONT-END CONTROLLER
TIDA-00123


SmartIO Interface Slot#1
SmartIO Interface Slot#2
PUBLIC RELEASE
TIDA-00123 - PROGRAMMABLE LOGIC CONTROLLER (PLC) I/O MODULE FRONT-END CONTROLLER
TIDA-00123


CURRENT LIMIT & HOT SWAP
NON-ISOLATED 24V TO 3.3V CONVERTER FOR MCU
ISOLATED 24V TO 24V CONVERTER
PUBLIC RELEASE
TIDA-00123 - PROGRAMMABLE LOGIC CONTROLLER (PLC) I/O MODULE FRONT-END CONTROLLER
TIDA-00123


ISOLATED 24V TO 24V/100mA CONVERTER
FOR FIELD POWER SUPPLY
EMI/EMC FILTER + TRANSIENT / SURGE
+ REVERSE POLARITY PROTECTION
Protective Earth
or Chassis
PUBLIC RELEASE
TIDA-00123 - PROGRAMMABLE LOGIC CONTROLLER
(PLC) I/O MODULE FRONT-END CONTROLLER
TIDA-00123
Friday, January 31, 2014


HOTSWAP CONTROLLER WITH I2C POWER MONITORING
24V_ISO
TP38
C288 0.1uF
C97 1uF
C98 220uF
R134 120K
R127 50mOhm
R250 0E
R251 0E
C101 0.1uF
M3
CSD18501Q5A
R133 10E
D18
BZT52C6V2-7
TP39
+24V_D
C289 0.1uF
C99 1uF
C100 220uF
C102 0.1uF
R137 10K
R138 100K
C103 0.1uF
R136 DNP
C104 DNP
IC1
TPS2482PW
SDAA5
SCLA5
uC3.3V
C106 0.1uF
R143 47K
C105 22nF
R145 100K
PUBLIC RELEASE
TIDA-00123 - PROGRAMMABLE LOGIC CONTROLLER (PLC) I/O MODULE FRONT-END CONTROLLER
TIDA-00123
Friday, January 31, 2014

9.2 BOM

Item	Reference	Qty.	Description	Manufacturer	Part Number	Assembly Status
1	C1, C2, C3, C4, C6, C9 , C11, C12, C21, C22, C23, C24, C28, C30, C31, C32, C33, C34, C35, C37, C38, C41, C43, C46, C47, C48, C49, C51, C52, C53, C58, C63, C87, C101, C102, C103, C106	37	CAP CER 0.1UF 35V 10% X5R 0603	Taiyo Yuden	GMK107BJ104KAHT	Assembled
2	C104	0	CAP CER 0.1UF 35V 10% X5R 0603	Taiyo Yuden	GMK107BJ104KAHT	DNP
3	C5, C8, C19, C20, C27, C42, C44, C45, C59, C86	10	CAP CER 10000PF 50V 20% X5R 0603	TDK Corporation	CGA3E2X5R1H103M080AA	Assembled
4	C10, C13, C25, C26, C29, C50, C65, C73, C82, C89, C91, C97, C99, C280, C282	15	CAP CER 1UF 50V 10% X5R 0603	TDK Corporation	C1608X5R1H105K080AB	Assembled
5	C14, C68, C88	3	CAP CER 0.47UF 50V 10% X5R 0603	Taiyo Yuden	UMK107ABJ474KA-T	Assembled
6	C15, C16	2	CAP CER 16PF 50V 5% NP0 0402	Murata Electronics North America	GRM1555C1H160JA01D	Assembled
7	C39, C92, C279, C281	4	CAP CER 22UF 35V 20% X5R 1206	TDK Corporation	C3216X5R1V226M160AC	Assembled
8	C40	1	CAP CER 47UF 25V 20% X5R 1206	TDK Corporation	C3216X5R1E476M160AC	Assembled
9	C60, C84	2	CAP CER 3300PF 50V 20% X5R 0603	TDK Corporation	CGA3E2X5R1H332M080AA	Assembled
10	C61, C67, C85	3	CAP CER 2.2UF 50V 10% X5R 0805	Samsung Electro-Mechanics America, Inc	CL21A225KB9LNNC	Assembled
11	C62	1	CAP CER 1000PF 100V 20% X5R 0603	TDK Corporation	C1608X5R2A102M080AA	Assembled
12	C64, C72, C74, C79, C288, C289	6	CAP CER 0.1UF 50V 10% X5R 0603	TDK Corporation	C1608X5R1H104K080AA	Assembled
13	C69, C81	2	CAP ALUM 100UF 50V 20% SMD	Panasonic Electronic Components	EEE-FTH101XAP	Assembled
14	C70, C71	2	CAP CER 4.7UF 50V 10% X5R 1206	Samsung Electro-Mechanics America, Inc	CL31A475KB9LNNC	Assembled
15	C75	1	CAP CER 2200PF 50V 10% X7R 0603	Kemet	C0603C222K5RACTU	Assembled
16	C76	1	CAP CER 0.012UF 50V 5% X7R 0603	Kemet	C0603C123J5RACTU	Assembled
17	C77	1	CAP CER 120PF 50V 10% X7R 0603	Samsung Electro-Mechanics America, Inc	CL10B121KB8NNNC	Assembled
18	C78, C290, C291	3	AP ALUM 150UF 50V 20% SMD	Panasonic Electronic Components	EEE-FK1H151P	Assembled
19	C83, C283, C284, C285, C286, C287	6	CAP CER 1000PF 2KV 10% X7R 1206	Johanson Dielectrics Inc	202R18W102KV4E	Assembled
20	C93, C96	2	CAP CER 2200PF 3KV 10% X7R 1812	AVX Corporation	1812HC222KAT1A	Assembled
21	C94, C95	2	CAP CER 0.033UF 250VAC X7R 2220	Murata Electronics North America	GA355ER7GB333KW01L	Assembled
22	C98,C100	2	CAP ALUM 220UF 50V 20% SMD	Panasonic Electronic Components	EEE-1HA221P	Assembled
23	C105	1	CAP CER 0.022UF 50V 10% X5R 0603	TDK Corporation	CGA3E2X5R1H223K080AA	Assembled
24	D1, D2, D3, D4, D53, D54, D55	7	LED SMARTLED GREEN 570NM 0603	OSRAM Opto Semiconductors Inc	LG L29K-G2J1-24-Z	Assembled
25	D5, D6, D7	3	DIODE TVS 15V 1500W BI 5% SMD	Bourns Inc.	SMCJ15CA	Assembled

26	D8	1	DIODE SCHOTTKY 20V 1A SMA	Diodes Inc	B120-13-F	Assembled
27	D9	1	DIODE ZENER 5.1V 5W DO214AA	Micro Commercial Co		Assembled
28	D10, D11	2	IODE SCHOTTKY 40V 0.5A SOD123	Micro Commercial Co	MBR0540-TP	Assembled
29	D12, D13	2	DIODE SCHOTKY 200V 1A POWERDI123	Diodes Inc.	DFLS1200-7	Assembled
30	D14, D60	2	DIODE SCHOTTKY 40V 0.1A SOD523	Diodes Inc.	SDM10U45-7-F	Assembled
31	D15	1	DIODE SCHOTTKY 200V 4A SMC	ON Semiconductor	MBRS4201T3G	Assembled
32	D16	0	Varistors 30Vrms 38VDC 8KA 11000pF 20mm Disc	Littelfuse Inc	V20E30P	DNP
33	D17, D52	2	DIODE TVS 45V 600W BIDIR 5% SMB	Littelfuse Inc	SMBJ45CA	Assembled
34	D18	1	Diode, Zener, Planar Power, 500mW, 8.2V	Diodes Inc	BZT52C8V2-7-F	Assembled
35	D57	1	DIODE ZENER 2.4V 500MW SOD123	Diodes Inc	BZT52C2V4-7-F	Assembled
36	D61	0	DIODE ZENER 2.4V 500MW SOD123	Diodes Inc	BZT52C2V4-7-F	DNP
37	IC1	1	IC, 36-V Hot swap Controller with Digital Power Monitoring	TI	TPS2482PW	Assembled
38	J1, J20	2	CONN TERM BLOCK 2.54MM 2POS PCB	On Shore Technology Inc	OSTVN02A150	Assembled
39	J2, J19	2	CONN HEADER 10POS .100 STR TIN	FCI	67997-410HLF	Assembled
40	J5	1	CONN RECEPT USB 5POS RT ANG SMD	Molex Inc	678038020	Assembled
41	J6	1	CONN HEADER 10POS DL PIN 2.54MM	Wurth Electronics Inc	61301021121	Assembled
42	J7, J8, J18	3	TERM BLOCK HDR 2POS VERT 5.08MM	TE Connectivity	282825-2	Assembled
43	L1	1	FERRITE CHIP 1000 OHM 300mA 0603	TDK Corporation	MMZ1608B102C	Assembled
44	L2, L3	2	CHOKE COMM MODE 90 OHM .4A SMD	TDK Corporation	ACM2012-900-2P-T002	Assembled
45	L5	1	Shielded SMD Power Inductor 220uH	BOURNS	SRR7032-221M	Assembled
46	L4, L6, L7	3	POWER INDUCTOR 3.3UH 1.1A SMD	Wurth Electronics Inc	74438333033	Assembled
47	L8	1	CHOKE COMMON MODE 10mH 1.7A T/H	Murata Power Solutions Inc	52106C	Assembled
48	M1	1	MOSF N CH 60V 11A (TA) 8SON	TI	CSD18537NQ5A	Assembled
49	M3	1	MOSFET, N-Chan, 40V, 25 A, 3.3 mOhm	TI	CSD18501Q5A	Assembled
50	R1, R2, R3, R4, R9, R10, R11, R12, R13, R14, R15, R16, R18, R19, R20, R21, R22, R25, R26, R27, R56, R69, R70, R71, R72, R73, R74, R75, R76, R79, R133, R227	32	RES 10.0 OHM 1/10W 1% 0603 SMD	Vishay Dale	CRCW060310R0FKEA	Assembled
51	R5, R6, R7, R8, R17, R43, R54, R55, R60, R84, R89, R105, R108, R110, R123, R137	16	RES 10K OHM 1/10W 1% 0603 SMD	Panasonic Electronic Components	ERJ-3EKF1002V	Assembled
52	R23, R24, R31, R32, R86, R87, R91, R92	8	RES 1.5K OHM 1/10W 1% 0402 SMD	Panasonic	ERJ-2RKF1501X	Assembled
53	R33, R34, R35, R39, R267, R268, R269	7	RES 300 OHM 1/10W 5% 0603 SMD	Panasonic Electronic Components	ERJ-3GEYJ301V	Assembled
54	R42	1	RES 510K OHM 1/16W 0.1% 0603	TE Connectivity	1-1879417-2	Assembled

55	R44, R83	2	ES 4.70K OHM .25W 1% 0603 SMD	Vishay Dale	CRCW06034K70FKEAHP	Assembled
56	R45	1	RES 100 OHM 1/10W 1% 0603 SMD	Panasonic Electronic Components	ERJ-3EKF1000V	Assembled
57	R46	1	RES 97.6K OHM 1/10W .1% 0603 SMD	Panasonic Electronic Components	ERA-3AEB9762V	Assembled
58	R52, R82, R85, R90, R109, R250, R251	7	RES 0.0 OHM 1/10W JUMP 0603 SMD	Panasonic Electronic Components	ERJ-3GEY0R00V	Assembled
59	R265, R271	0	RES 0.0 OHM 1/10W JUMP 0603 SMD	Panasonic Electronic Components	ERJ-3GEY0R00V	DNP
60	R50	1	RES 0.0 OHM 1/10W JUMP 0402 SMD	Panasonic Electronic Components	ERJ-2GE0R00X	Assembled
61	R48	0	RES 0.0 OHM 1/10W JUMP 0402 SMD	Panasonic Electronic Components	ERJ-2GE0R00X	DNP
62	R88, R93	0	RES 0.0 OHM 1/10W JUMP 0603 SMD	Panasonic Electronic Components	ERJ-3GEY0R00V	DNP
63	R53, R62	2	RES 470 OHM 1/8W 1% 0805 SMD	Rohm Semiconductor	ESR10EZPJ471	Assembled
64	R57	1	RES 120 OHM .4W 1% 0805 SMD	Rohm Semiconductor	ESR10EZPF1200	Assembled
65	R58	1	RES 30K OHM 1/10W 1% 0603 SMD	Panasonic Electronic Components	ERJ-3EKF3002V	Assembled
66	R59	1	RES 21.5K OHM 1/10W 1% 0603 SMD	Panasonic Electronic Components	ERJ-3EKF2152V	Assembled
67	R61, R63, R138, R145, R266	5	RES 100K OHM 1/4W 1% 0603 SMD	Rohm Semiconductor	ESR03EZPF1003	Assembled
68	R64	1	RES 200 OHM 1/4W 1% 0603 SMD	Rohm Semiconductor	ESR03EZPF2000	Assembled
69	R65	1	RES 43.2K OHM 1/10W .1% 0603 SMD	Panasonic Electronic Components	ERA-3AEB4322V	Assembled
70	R66	1	RES 280K OHM 1/10W 1% 0603 SMD	Panasonic Electronic Components	ERJ-3EKF2803V	Assembled
71	R77	1	RES 5.1K OHM 1/10W 1% 0603 SMD	Panasonic Electronic Components	ERJ-3EKF5101V	Assembled
72	R94	1	RES 0.015 OHM 3W 1% 2512 WIDE	Yageo	KRL6432E-M-R015-F-T1	Assembled
73	R95	1	RES 95.3K OHM 1/10W 1% 0603 SMD	Yageo	RC0603FR-0795K3L	Assembled
74	R96	1	RES 71.5K OHM 1/10W 1% 0603 SMD	Yageo	RC0603FR-0771K5L	Assembled
75	R97	1	RES 53.6K OHM 1/10W 1% 0603 SMD	Panasonic Electronic Components	ERJ-3EKF5362V	Assembled
76	R98, R100, R121, R134	4	RES 120K OHM 1/10W 1% 0603 SMD	Panasonic Electronic Components	ERJ-3EKF1203V	Assembled
77	R99	1	Thick Film Resistors - SMD 0603 63.4Kohms 0.2W 1% Tol	Panasonic Electronic Components	ERJ-P03F6342V	Assembled
78	R101	1	RES 8.2K OHM 1/10W .1% 0603 SMD	Panasonic Electronic Components	ERA-3AEB822V	Assembled
79	R102	1	RES 7.50K OHM 1/10W 1% 0603 SMD	Yageo	RC0603FR-077K5L	Assembled
80	R103	1	RES 14.7K OHM 1/10W 1% 0603 SMD	Yageo	RC0603FR-0714K7L	Assembled
81	R104	1	RES 56K OHM 1/10W 1% 0603 SMD	Yageo	RC0603FR-0756KL	Assembled
82	R106	1	RES 5.0K OHM .15W 0.1% 0603 SMD	Vishay Thin Film	PNM0603E5001BST5	Assembled
83	R107	1	RES 115K OHM 1/10W 1% 0603 SMD	Yageo	RC0603FR-07115KL	Assembled

84	R111	1	RES 46.4K OHM 1/10W 1% 0603 SMD	Panasonic Electronic Components	ERJ-3EKF4642V	Assembled
85	R112	1	RES 12.1K OHM 1/10W 1% 0603 SMD	Yageo	RC0603FR-0712K1L	Assembled
86	R113	1	RES 154K OHM 1/10W .1% 0603 SMD	Panasonic Electronic Components	ERA-3AEB1543V	Assembled
87	R115	1	ES 250 OHM 2W 1% 4124	Stackpole Electronics Inc	SM4124FT250R	Assembled
88	R116	1	RES 11K OHM 1/10W .1% 0603 SMD	Panasonic Electronic Components	ERA-3AEB113V	Assembled
89	R117	1	RES 249K OHM 1/10W 1% 0603 SMD	Panasonic Electronic Components	ERJ-3EKF2493V	Assembled
90	R118	1	RES 49.9 OHM 1/10W 1% 0603 SMD	Panasonic Electronic Components	ERJ-3EKF49R9V	Assembled
91	R119	1	RES 49.9K OHM 1/10W 1% 0603 SMD	Panasonic Electronic Components	ERJ-3EKF4992V	Assembled
92	R120	1	RES 10K OHM .4W 1% 0805 SMD	Rohm Semiconductor	ESR10EZPF1002	Assembled
93	R122	1	RES 110K OHM 1/10W .1% 0603 SMD	Panasonic Electronic Components	ERA-3AEB114V	Assembled
94	R124	1	RES 12.4K OHM 1/10W .1% 0603 SMD	Panasonic Electronic Components	ERA-3AEB1242V	Assembled
95	R125	1	RES 2.00 OHM 1.5W 1% 1218 SMD	Vishay Dale	CRCW12182R00FKEKHP	Assembled
96	R126	1	RES 1M OHM 2W 1% 2512	Stackpole Electronics Inc	HVCB2512FKC1M00	Assembled
97	R127	1	RES 0.05 OHM 2W 1% 2512	Stackpole Electronics Inc	CSRN2512FK50L0	Assembled
98	R143	1	RES 47K OHM 1/10W 1% 0603 SMD	Panasonic Electronic Components	ERJ-3EKF4702V	Assembled
99	R136	0	RES 1K OHM 1/4W 1% 0603 SMD	Rohm Semiconductor	ERJ-3EKF1002V	DNP
100	SW2	1	SWITCH TACTILE SPST-NO 0.05A 24V	Omron Electronics Inc-EMC Div	B3S-1000P	Assembled
101	T1	1	TRANSFORMER 475UH SMD	Wurth Electronics Midcom	760390015	Assembled
102	T2	1	Flyback Regulator Transformer 50uH	Wurth Elektronik	750342156	Assembled
103	T3	1	150uH Flyback Regulator Transformer	RENCO	RLTI-1046	Assembled
104	U1	1	Tiva C Series Microcontroller	TI	TM4C1237E6PZ	Assembled
105	U2	1	IC EEPROM 2KBIT 1MHZ 8SOIC	ATMEL	AT24C02C-SSHM-T SL901	Assembled
106	U3	1	IC SUPERVISOR MPU ADJ 6SON	TI	TPS3897ADRYR	Assembled
107	U5	1	IC VREF SERIES PREC 3V SOT-23-6	TI	REF3230AIDBVT	Assembled
108	U6	1	IC HALF-DUPLEX RS485 TXRX 16SOIC	TI	ISO3082DW	Assembled
109	U7	1	IC REG MULTI CONFIG SYNC 16WQFN	TI	TPS55010RTER	Assembled
110	U8	1	IC CPLD 64MACROCELLS 44TQFP	Lattice Semiconductor Corporation	LC4064V-75TN44I	Assembled
111	U9	1	IC ESD-PROT ARRAY 4CH SC70-6	TI	TPD4E1B06DCKR	Assembled
112	U10, U11	2	Rugged High Speed Header	Samtec	ERM8-025-05.0-L-DV-TR	Assembled
113	U12	1	IC CTRLR HOT SWAP 48V 10-MSOP	TI	LM5069MM-2/NOPB	Assembled
114	U13, U15	2	IC REG BUCK SYNC ADJ 0 .6A 8SO	TI	LM5017MR/NOPB	Assembled
115	U14	1	IC REG BUCK SYNC ADJ 2A 20TSSOP	TI	LM20242MH/NOPB	Assembled
116	Y1	1	CRYSTAL 25MHZ 10PF SMD	Abracon Corporation	ABM10-25.000MHZ-D30-T3	Assembled

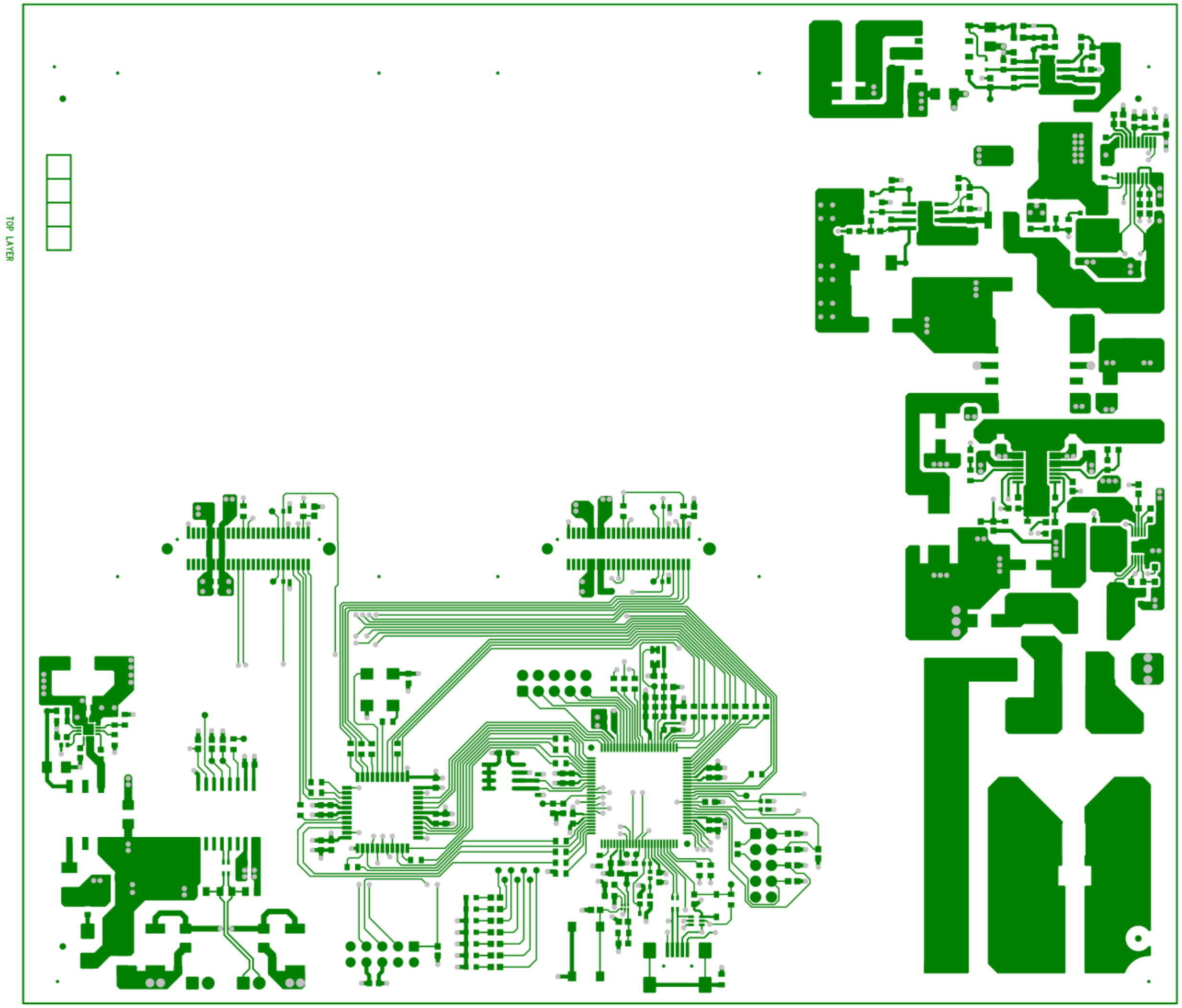
117	Y2	1	OSCILLATOR XO 25MHZ 3.3V SMD	CTS-Frequency Controls	CB3LV-3I-25M0000	Assembled

9.3 PCB Layout

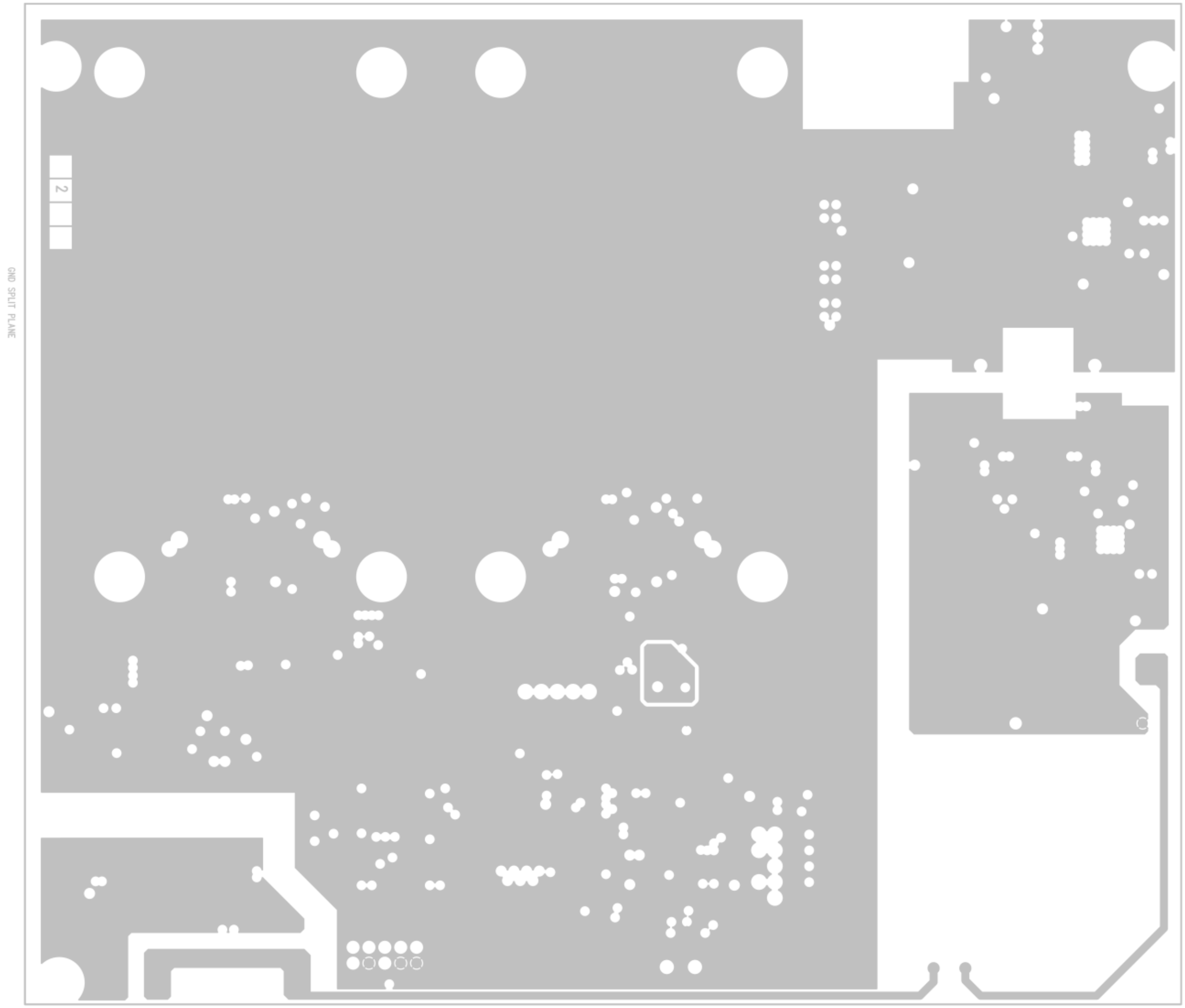
To download the PCB layout files for the board, see the design files at: www.ti.com/tool/TIDA-00123

9.4 PCB Layers

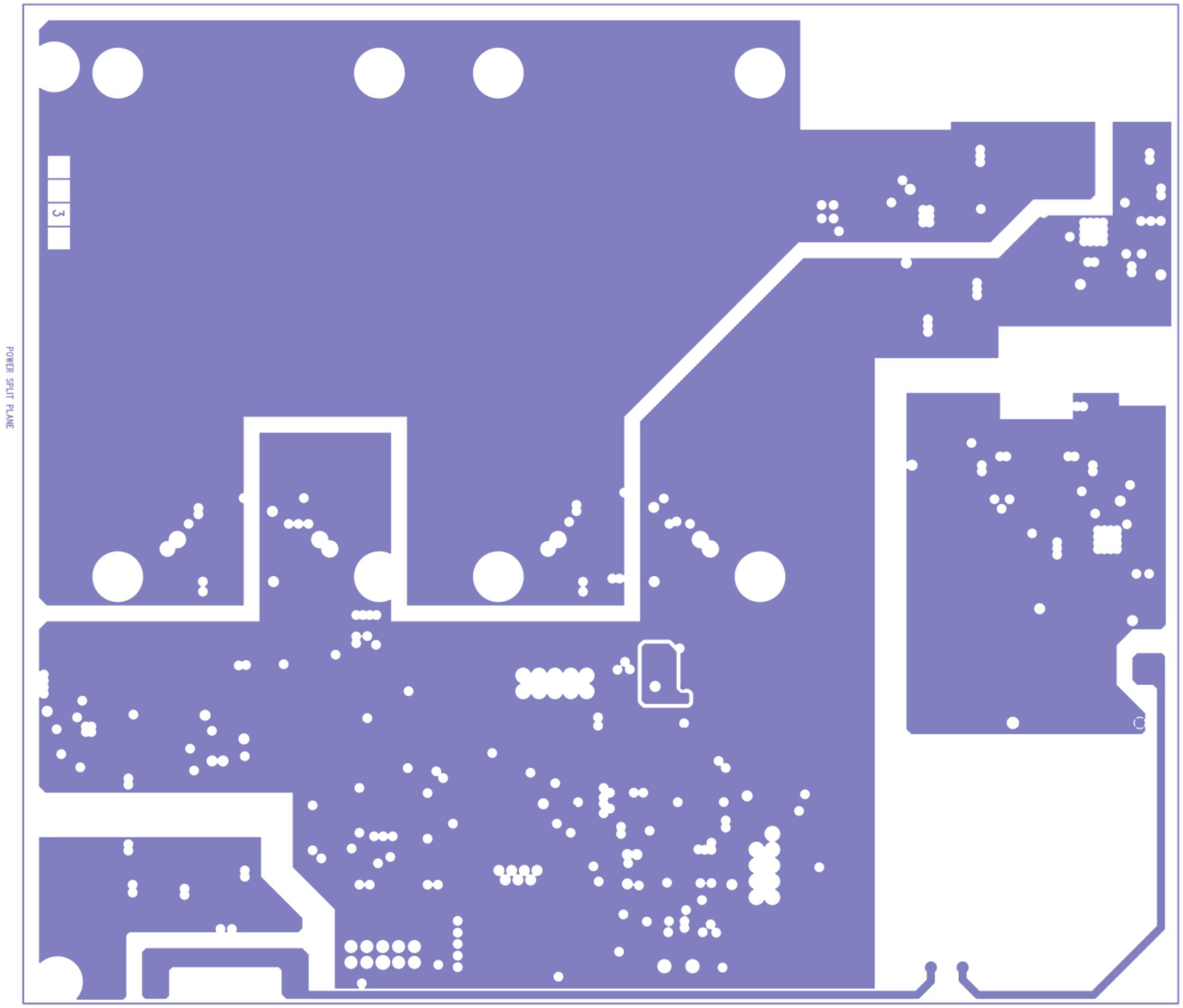
Top Layer:



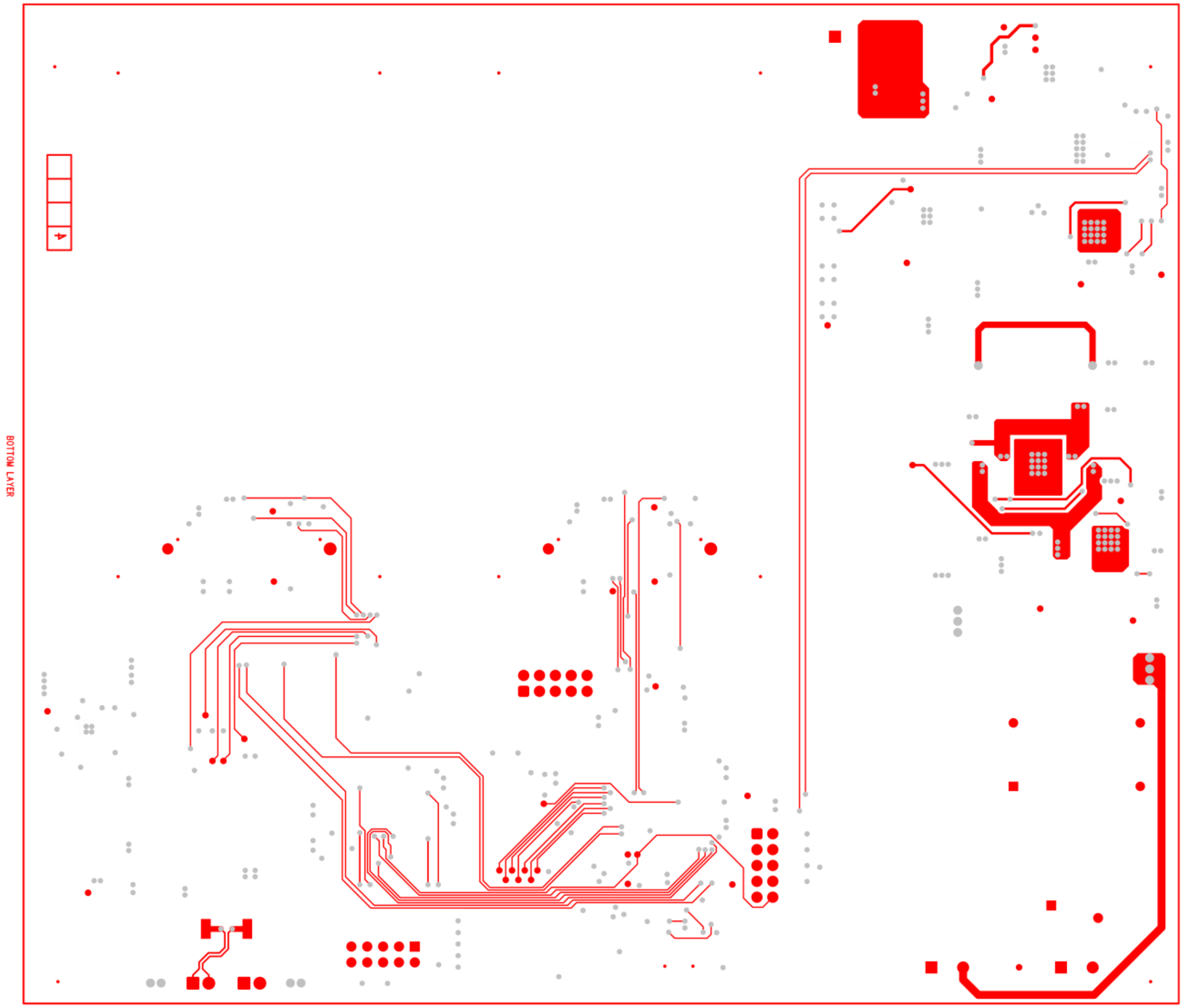
Inner Layer-1: ***Split Ground Plane***



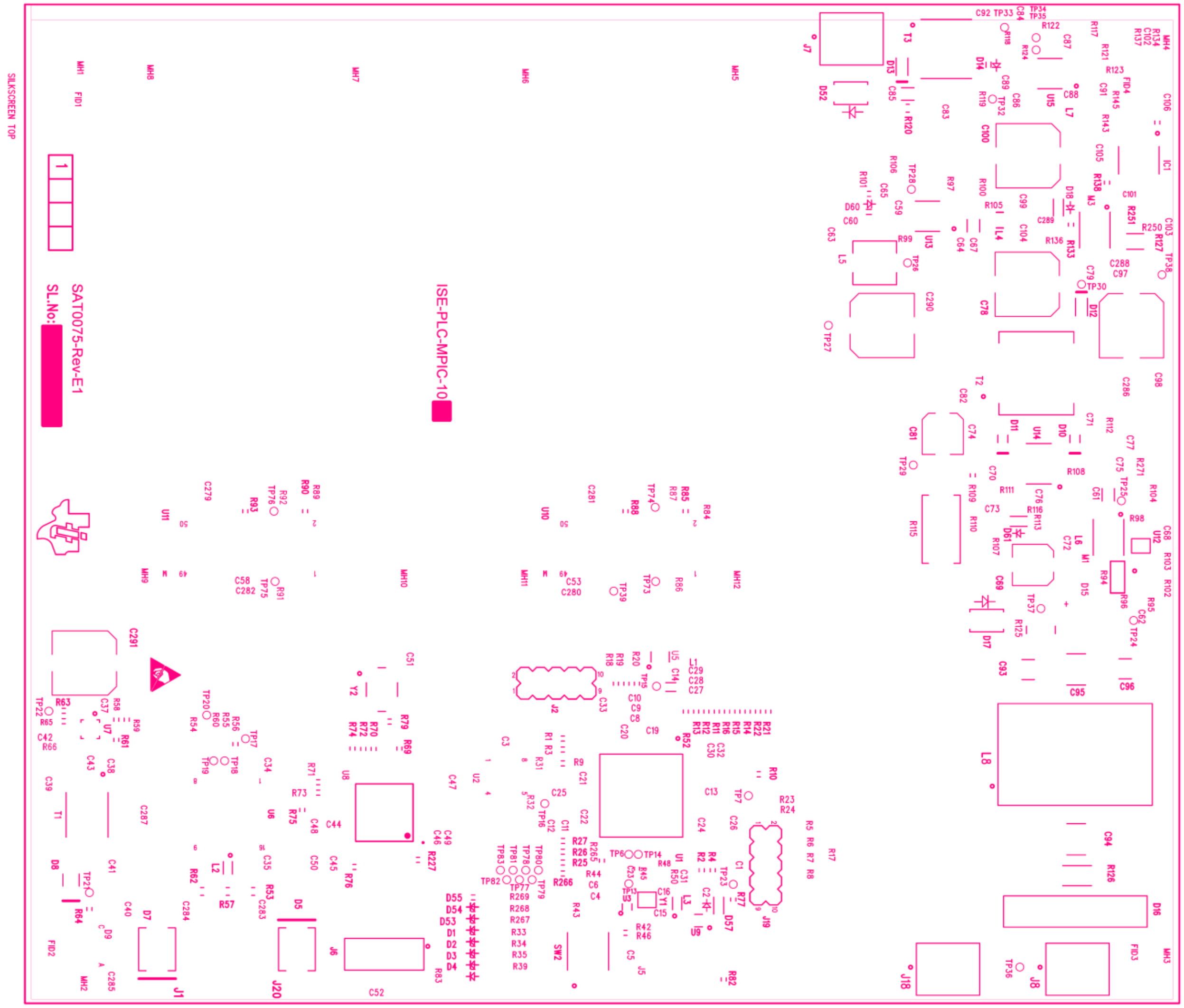
Inner Layer-2: Split Power Plane



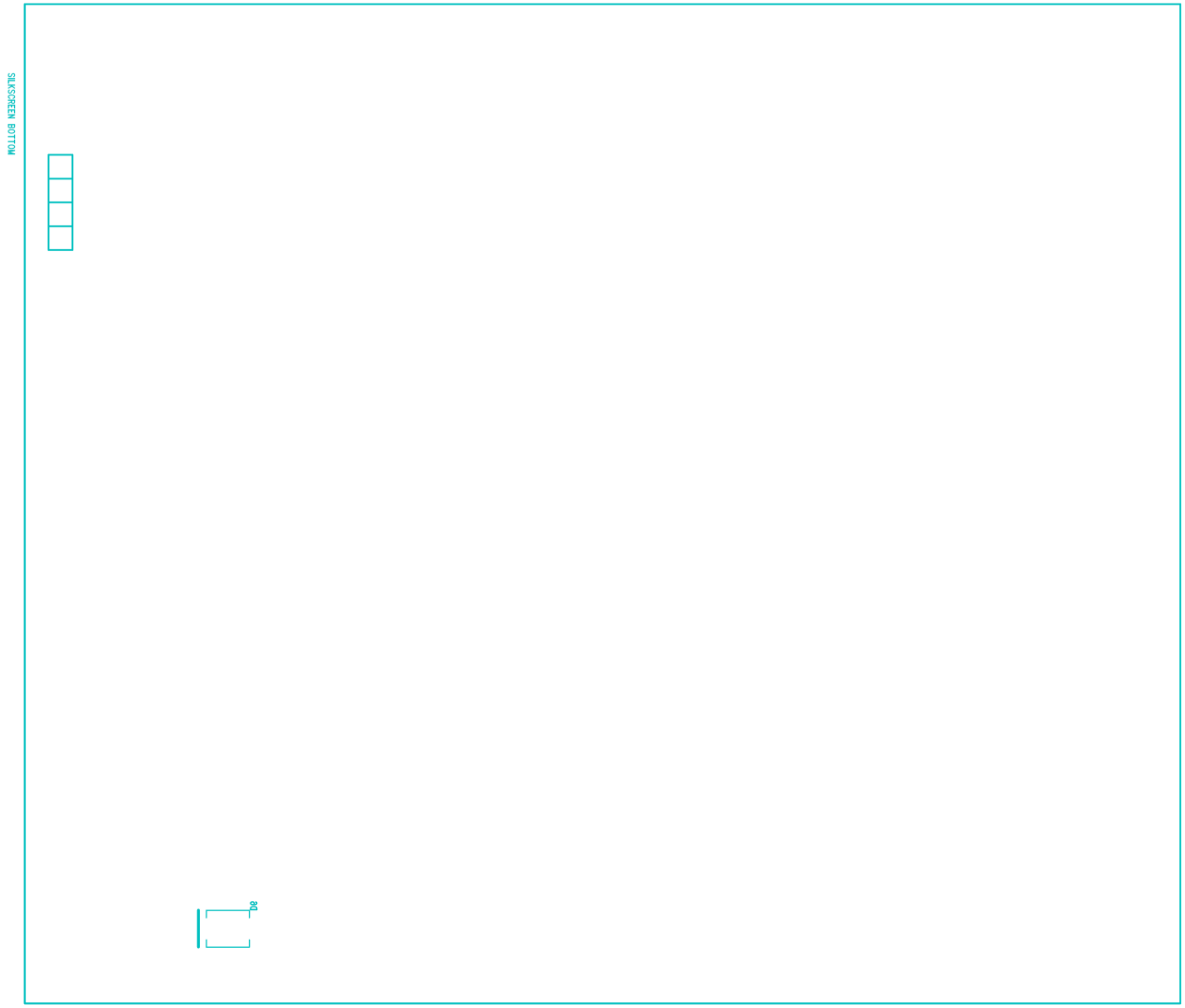
Bottom Layer:



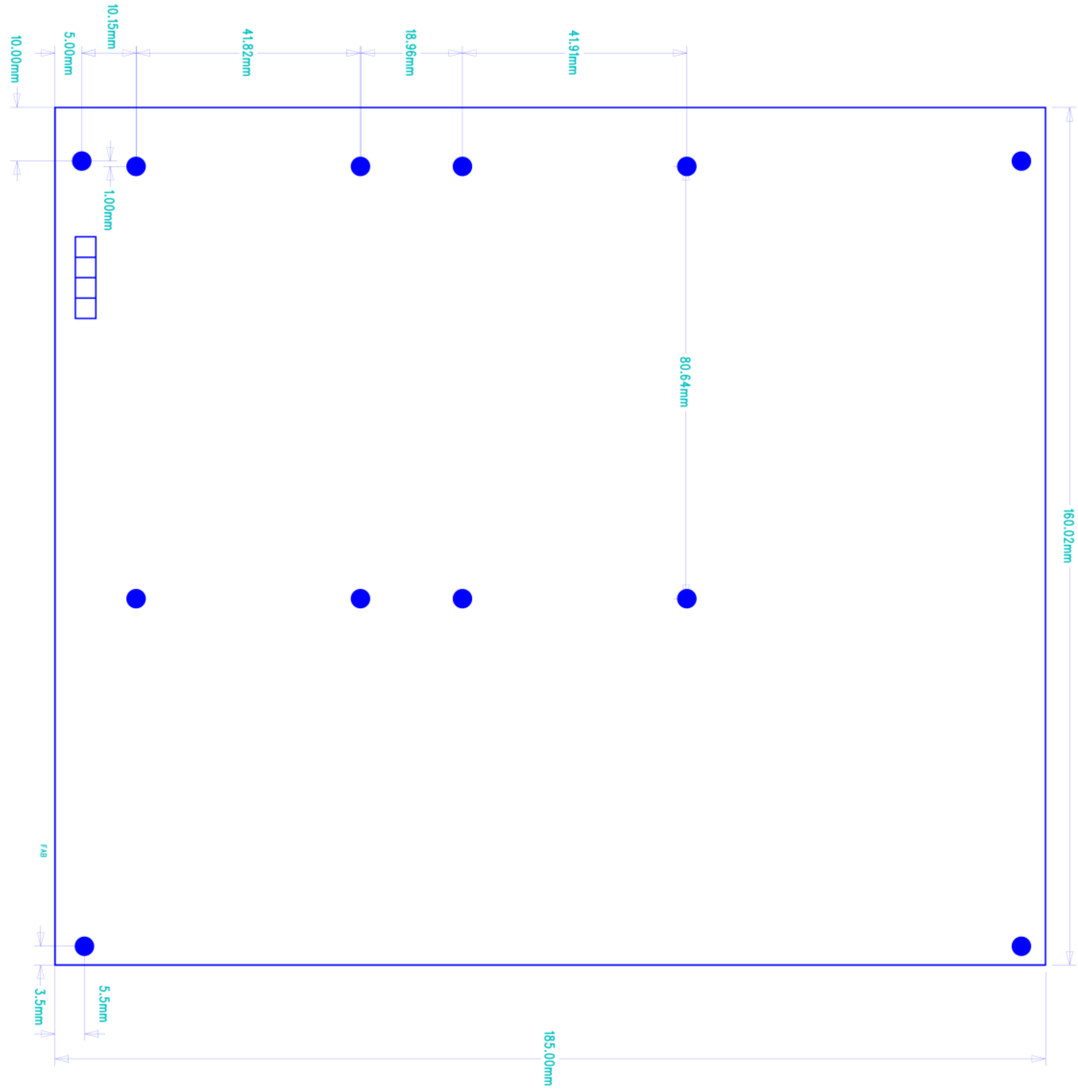
Top Silk Screen:



Bottom Silk Screen:



Board Outline & Dimensions:



9.5 Gerber Files

To download the Gerber files for the board, see the design files at: www.ti.com/tool/TIDA-00123

9.6 IO Controller Software

To download the IO Controller Software files for the board, see the design files at: www.ti.com/tool/TIDA-00123

9.7 PC Based GUI Software

To download the GUI Software files for the board, see the design files at: www.ti.com/tool/TIDA-00123

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