TI Designs
Compact CAN-to-Ethernet Converter Using 32-Bit ARM® Cortex™-M4F MCU

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Design Resources

TM4C129XNCZAD	Tool Folder Containing Design Files
TPD4E1U06	Product Folder
SN65HVD256D	Product Folder
TPS62177	Product Folder
SN65HVD72DR	Product Folder
INA196AIDBVR	Product Folder

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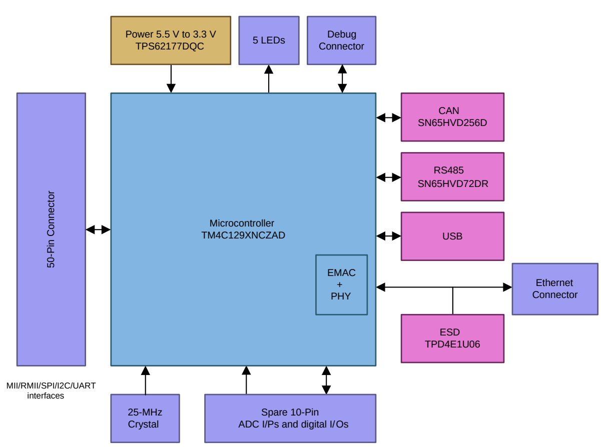
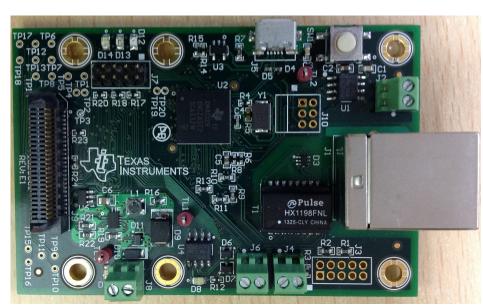
Featured Applications

- Industrial Motor Drives and Industrial Automation
- Circuit Breakers, Protection Relays, and Panel Mount Multi-Function Power and Energy Meters
- Substation Automation Products: Remote Terminal Unit (RTU), Protection Relay, Intelligent Electronic Devices (IEDs), Converters, and Gateways
- Industrial Remote Monitoring: Remote I/O and Data Loggers

Design Features

- TM4C129XNCZAD 32-Bit Advanced RISC Machines (ARM) Cortex-M4F Microcontroller (MCU) Based
- Integrated 10/100 Ethernet Media Access Control (MAC) and Physical Interface Device (PHY)
- 10/100 Ethernet MAC With Advanced IEEE 1588 Precision Time Protocol (PTP) Hardware and Both Media Independent Interface (MII) and Reduced MII (RMII) Support
- Provision to Connect to External Boards for Isolated Communication Interface and Power Over Ethernet (POE)
- On-Board Non-Isolated Controller Area Network (CAN) and RS-485 PHY
- 50-Pin Connector for External Interface With MII and RMII Ethernet PHY
- Expansion Connectors for Access to Communication, Analog-to-Digital Converter (ADC), and General Purpose Input and Output (GPIO) Interfaces
- 1024-KB Flash Memory and 256-KB Single-Cycle System SRAM





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1 System Description

A simple and effective design makes Ethernet the most popular networking solution at the physical and data link levels of the Open Systems Interconnection (OSI) model. With high speed options and a variety of media types to choose from, Ethernet is efficient and flexible. In addition, the low cost of Ethernet hardware makes Ethernet an attractive option for industrial networking applications. The opportunity to use open protocols such as TCP/IP over Ethernet networks offers a high level of standardization and interoperability. The result has been an ongoing shift to the use of Ethernet for industrial control and automation applications. Ethernet is increasingly replacing proprietary communications.

The CAN-Ethernet Converter is useful in the field of industrial drives monitoring and control as well as supervisory control and data acquisition (SCADA) systems. The same hardware can be used either as a CAN-Ethernet gateway or as a CAN-Ethernet bridge with the changes in the firmware. The CAN-Ethernet gateway is useful for monitoring remote CAN networks over Ethernet or local area network (LAN). The CAN-Ethernet bridge is useful for the transparent coupling of CAN networks through the internet or LAN.

The reference design platform demonstrates capabilities of the TM4C129XNCZAD 32-bit ARM Cortex-M4F MCU. The design supports 10/100 Base-T and is compliant with the IEEE 802.3 standard. The reference design operates from a single power supply (5.5-V input with an on-board regulator of 3.3 V).

CAN standard:

The CAN bus was developed by BOSCH as a multi-master, message broadcast system that specifies a maximum signaling rate of 1 Mbps. Unlike a traditional network, such as USB or Ethernet, CAN does not send large blocks of data point-to-point between the nodes under the supervision of a central bus master. In a CAN network, many short messages are broadcast to the entire network, which provides data consistency in every node of the system. Although CAN was originally designed for the automotive industry, CAN has become a popular bus in industrial applications as well.

CAN bus cable and termination:

The High-Speed ISO 11898 standard specifications are given for a maximum signaling rate of 1 Mbps with a bus length of 40 meters and a maximum of 30 nodes. The standard also recommends a maximum un-terminated stub length of 0.3 m. The cable is specified to be a shielded or unshielded twisted-pair with a 120-Ω characteristic impedance (Z_O). The standard defines a single line of twisted-pair cable with the network topology as shown in Figure 1. The cable is terminated at both ends with 120-Ω resistors, which match the characteristic impedance of the line to prevent signal reflections. According to ISO 11898, avoid placing R_L on a node because the bus lines lose termination if the node is disconnected from the bus.

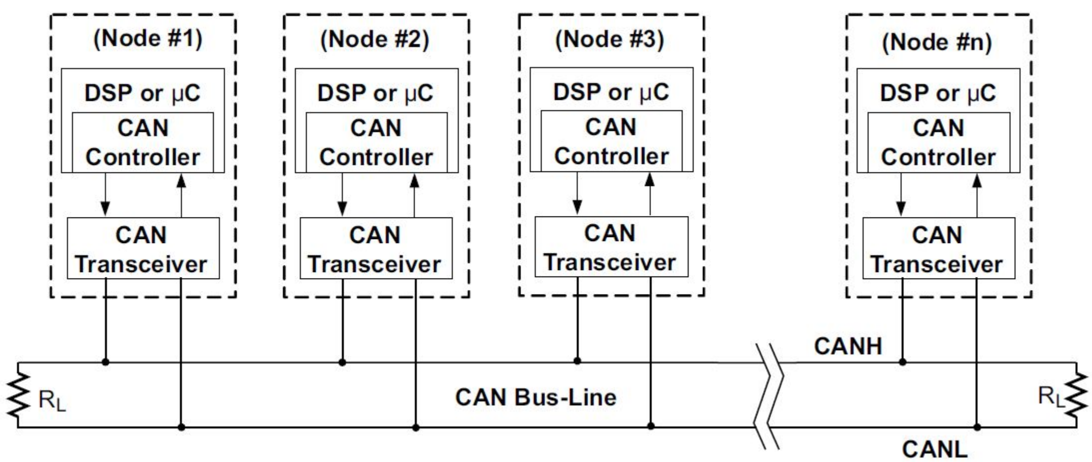

Figure 1. Details of a Typical CAN Node

2 Design Features

ITEM	DESCRIPTION
MCU	TM4C129XNCZAD 32-bit ARM Cortex
Ethernet	• Built-in 10/100 Ethernet MAC and PHY • Option for interfacing external 10/100 Ethernet PHY
Ethernet LEDs	Activity, link, and speed
CAN	SN65HVD256 Turbo-CAN transceiver for high data rates and larger networks (meets ISO 11898-2 requirements)
RS485	Half duplex transceiver up to 250 kbps
Power supply	Single supply - 3.3 V, 0.5-A output
External interface	MII interface connector: 50-pin with an option for power input

3 Block Diagram

The system block diagram of the design is shown in Figure 2.

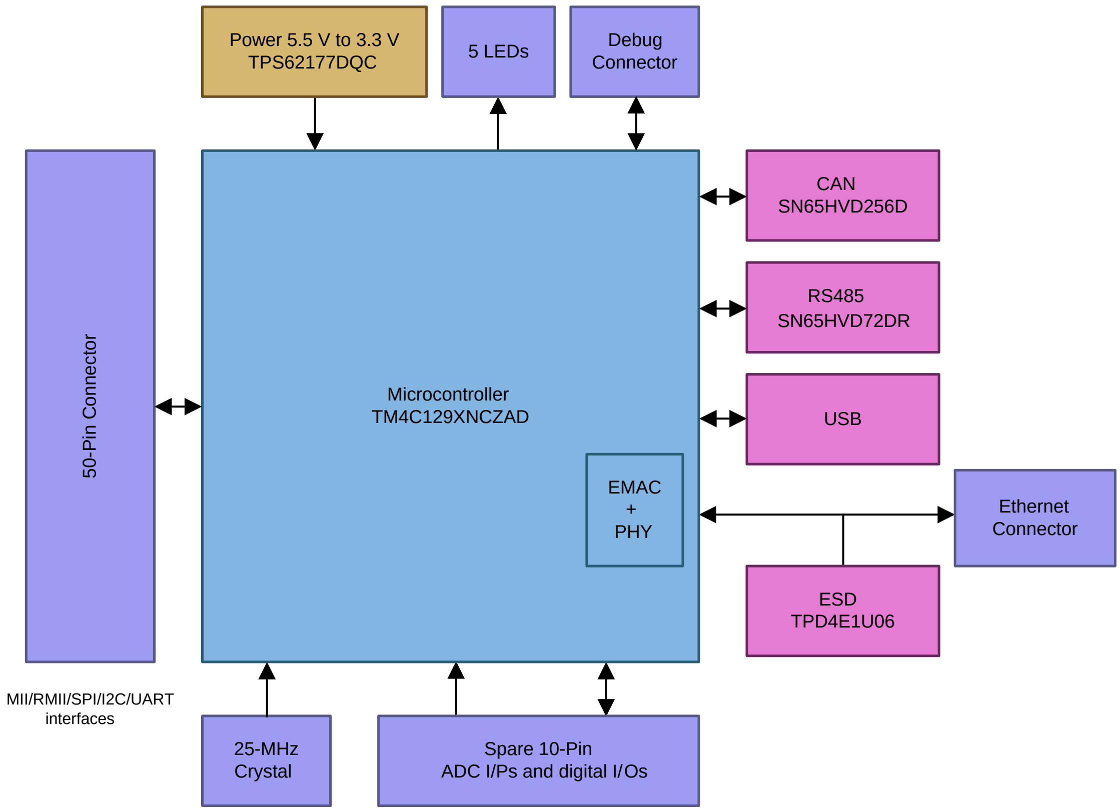

Figure 2. System Block Diagram

3.1 MCU

The Tiva TM4C129XNCZAD is an ARM Cortex-M4-based microcontroller with a 1024-KB flash program memory, 256-KB SRAM, and 120-MHz operation; USB host, device, and on-the-go (OTG); Ethernet controller, integrated Ethernet PHY, and hibernation module; and a wide range of other peripherals. See the TM4C129XNCZAD microcontroller data sheet for complete device details. This device offers 140 GPIOs and the internal multiplexer allows different peripheral functions to be assigned to these GPIO pads. The Tiva PinMux Utility can be used to quickly develop pin assignments and the code required to configure them.

3.2 Ethernet

The TM4C129XNCZAD device supports the following Ethernet interfaces:

1. 10/100 Ethernet interface with internal MAC and PHY
2. Optional 10/100 Ethernet interface with internal MAC and external PHY—the external PHY is interfaced with the MII/RMII interface

3.3 Power Supply

The board is powered from an external, single 5.5-V power supply. The TPS62177 (28-V, 0.5-A step-down converter) is used in this design to derive 3.3 V from the external input.

3.4 Non-Isolated RS485 Interface

This design uses the SN65HVD72DR device as the RS-485 transceiver. These type of devices are half-duplex transceivers designed for RS-485 data bus networks. Powered by a 3.3-V supply, the transceivers are fully compliant with the TIA/EIA-485A standard. This device features a wide common-mode voltage range making the device suitable for multi-point applications over long cable runs. SN65HVD72DR devices are optimized for signaling rates up to 250 kbps.

3.5 Non-Isolated CAN Interface

The SN65HVD256 Turbo-CAN transceiver is used for high data rates and large networks (the device meets the requirements of ISO 11898-2).

3.6 Expansion Connectors

Expansion outputs have been provided for further use as required.

3.7 PCB Dimensions and PCB Physical Layout

This reference design has been designed in a small-form factor, four-layer PCB with a dedicated ground and power plane.

3.8 Programming

Tiva microcontrollers support the Joint Test Action Group (JTAG) interface for debugging and programming. The designer can place headers on the board and connect them to the JTAG pins on the chip (see the datasheet for pin out information). The use of an external JTAG programmer is required to connect the PC to the board. The Tiva LaunchPad can also be used as an external programmer.

4 Featured Applications

The Tiva C Series ARM Cortex-M4 microcontrollers provide top performance and advanced integration. The product family is positioned for cost-effective applications requiring significant control processing and connectivity capabilities such as:

- Network appliances, gateways, and adapters
- Remote connectivity and monitoring
- Security and access systems
- Human-machine interface (HMI) control panels
- Factory automation control
- Motion control and power inversion
- Electronic point-of-sale (POS) displays
- Smart energy and smart grid solutions
- Intelligent lighting control

The provided CAN interface can be used for the following applications:

- Motor control
- Power inverters
- Industrial automation
- Building automation networks
- Automotive applications

5 Circuit Design and Component Selection

The CAN-Ethernet converter is based on the TM4C129XNCZAD device, a 32-bit ARM Cortex-M4F core-based microcontroller. The program that runs on this microcontroller uses lwIP (lightweight IP) stack. LwIP is a widely used, open-source TCP/IP stack designed for embedded systems. LwIP was originally developed by Adam Dunkels at the Swedish Institute of Computer Science and is now developed and maintained by a worldwide network of developers.

5.1 MCU

Tiva C Series microcontrollers integrate a large variety of rich communication features to enable a new class of highly connected designs with the ability to allow critical, real-time control between performance and power. The microcontrollers feature integrated communication peripherals along with other high-performance analog and digital functions to offer a strong foundation for many different target uses, spanning from HMI to networked system management controllers.

In addition, Tiva C Series microcontrollers offer the advantages of ARM's widely available development tools, System-on-Chip (SoC) infrastructure, and a large user community. Additionally, these microcontrollers use ARM's Thumb®-compatible Thumb-2 instruction set to reduce memory requirements and cost. Finally, the TM4C129XNCZAD microcontroller is code-compatible to all members of the extensive Tiva C Series, providing flexibility to fit precise needs.

Some important features of the MCU are as follows:

- Performance
  - ARM Cortex-M4F processor core, 120-MHz operation; 150-Dhrystone million instructions per second (DMIPS) performance, 1024-KB flash memory
  - 256-KB single-cycle system SRAM, 6KB of electrically erasable programmable read-only memory (EEPROM)
- Communication interfaces
  - Eight universal asynchronous receivers and transmitters (UARTs); four quad synchronous serial interface (QSSI) modules with bi-, quad-, and advanced synchronous serial interface (SSI) support; ten Inter-Integrated Circuit (I2C) modules with four transmission speeds, including high-speed mode; CAN 2.0 A male to B male (A/B) controllers; 10/100 Ethernet MAC and Ethernet PHY with IEEE 1588 PTP hardware support; and a USB 2.0 with host, device, and OTG compatibility with a low-pin interface (ULPI) option and link power management (LPM) support
- Analog support
  - Two 12-bit ADC modules, each with a maximum sample rate of one million samples per second
- One JTAG module with an integrated ARM serial wire debug (SWD)
- 212-Ball grid array (BGA) package
- Operating range (ambient)
  - Industrial (–40°C to 85°C) temperature range
  - Extended (–40°C to 105°C) temperature range

5.2 Ethernet

The TM4C129X supports 10/100 Mbps Ethernet connections. The board is designed to connect directly to an Ethernet network using RJ45 style connectors. The microcontroller contains a fully integrated Ethernet MAC and PHY. This integration creates a simple, elegant, and cost-saving Ethernet circuit design. Example code is available for both the unmanaged internet protocol (uIP) and lwIP TCP/IP protocol stacks. The embedded Ethernet on this device can be programmed to act as an HTTP server, client, or both. The design and integration of the circuit and microcontroller also enable users to synchronize events over the network using the IEEE1588 precision time protocol.

5.2.1 LEDs

The PHY controls three LEDs as shown in Table 1.

Table 1. PHY-LED Control

Pin	Function
PK4	EN0LED0 – Link
PK6	EN0LED1 – Activity
PF1	EN0LED2 – Speed

5.2.2 RJ45 and Isolation Transformer

Magnetics are used in Figure 3 with the choke on the side of the PHY.

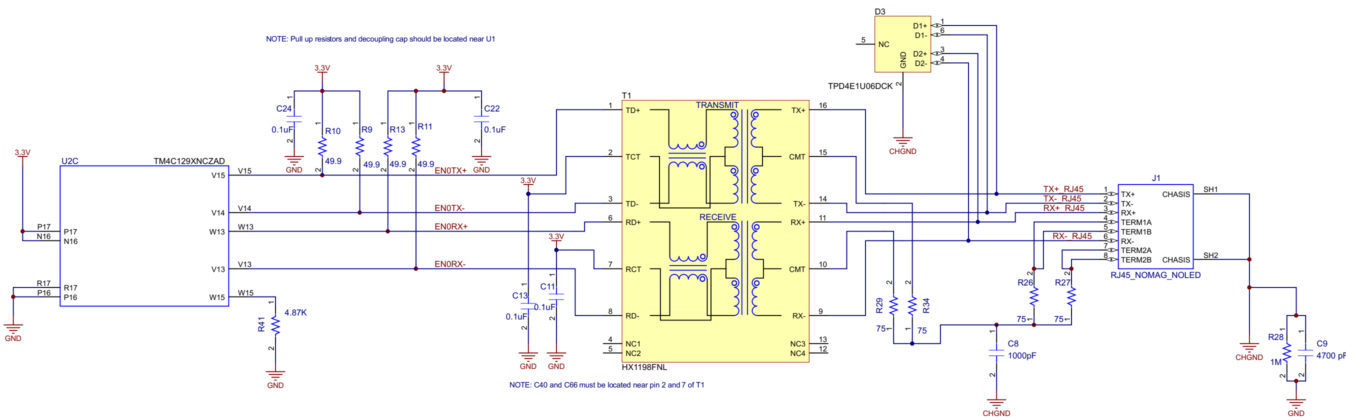

Figure 3. Magnetics for Ethernet Section

5.3 *Power Supply*

As Figure 4 shows, the TPS62177 is programmed to a fixed output voltage of 3.3 V. For the fixed output voltage version, the FB pin is pulled low internally by a 400-kΩ resistor. TI recommends connecting the FB pin to AGND to improve thermal resistance.

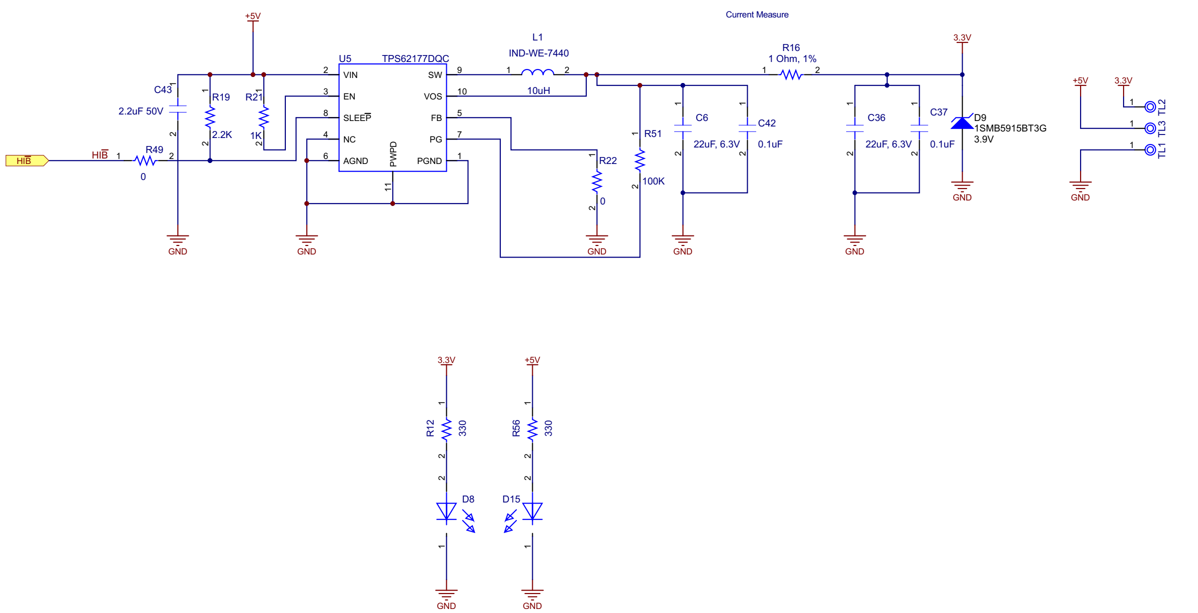

Figure 4. Power Supply Section

5.3.1 External Component Selection for the Power Supply

The external components must fulfill the needs of the application, but also the stability criteria of the control loop of the device. The TPS62175/7 is optimized to work within a wide range of external components. The inductance and capacitance of the LC output filter must be considered together, creating a double pole that is responsible for the corner frequency of the converter.

5.3.2 Layout Considerations for the Power Supply

The input capacitor must be placed as close as possible to the IC pins (VIN and PGND). The inductor must be placed close to the SW pin and connect directly to the output capacitor—minimizing the loop area between the SW pin, inductor, output capacitor, and PGND pin. The sensitive nodes like FB and VOS must be connected with short wires instead of nearby high dv/dt signals (for example, the SW pin). The feedback resistors must be placed close to the IC and connect directly to the AGND and FB pins.

5.3.3 Thermal Data for the Power Supply

The TPS62175/7 device is designed for a maximum operating junction temperature (T_j) of 125°C. Therefore the maximum output power is limited by the power losses. As the thermal resistance of the package is given, the size of the surrounding copper area and a proper thermal connection of the IC can reduce the thermal resistance.

5.4 Non-Isolated CAN Interface

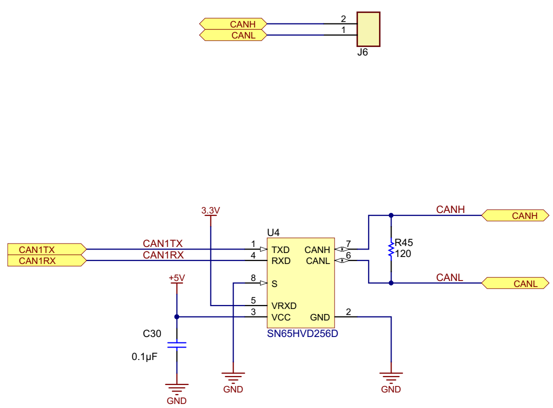

Figure 5. CAN Interface

As Figure 5 shows, the CAN transceiver SN65HVD256 is used to provide the differential transmit and differential receive capabilities to the CAN controller of the MCU. This CAN transceiver meets the ISO1189-2 High Speed CAN Physical Layer standard. The transceiver is designed for data rates in excess of 1 Mbps for CAN in short networks, and enhanced timing margin and higher data rates in long and highly-loaded networks. The device provides many protection features to enhance device and CAN network robustness.

5.5 Expansion Connectors

In the design, peripherals that are not currently used, such as SPI, UART, and I2C signals, are terminated on the 50-pin SDCC connector as Figure 6 shows.

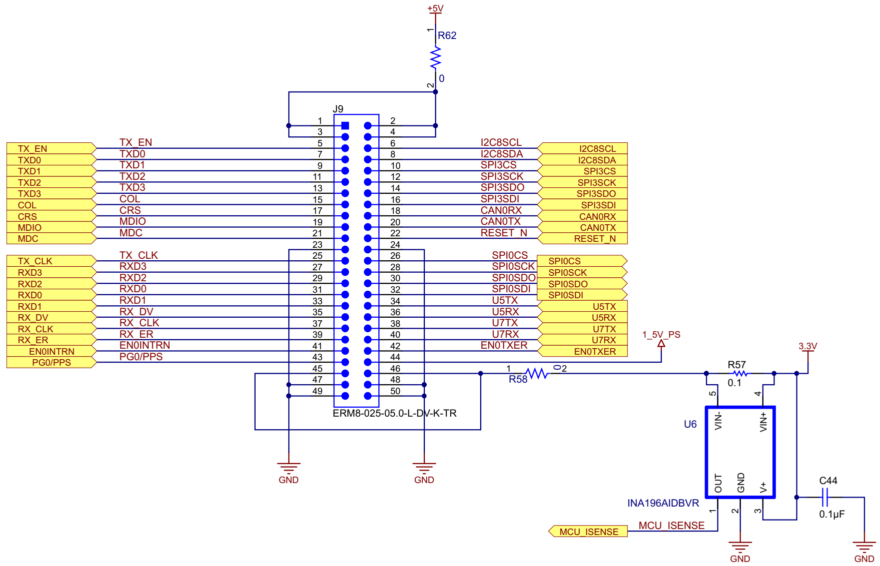

Figure 6. 50-Pin SDCC Connector

An option to measure the consumption of 3.3 V supplied to the external PHY interface has been provided. The same 50-pin has CAN, UART, SPI, and I2C signals.

5.5.1 Interface for Isolated UART and CAN:

Figure 7 shows the connector that can be used to interface with the high-efficiency isolated CAN and Process Field Bus (PROFIBUS) interface.

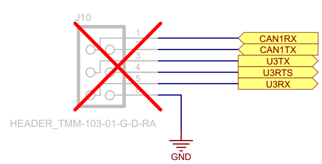

Figure 7. Interface for Isolated UART and CAN

5.5.2 Optional Interface for USB

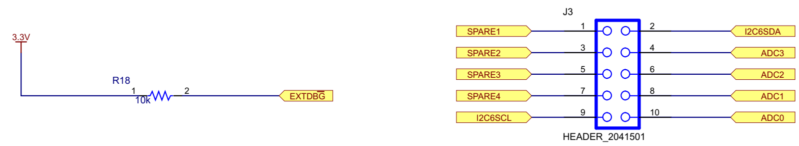

Figure 8. Interface for ADC and Spare I/Os

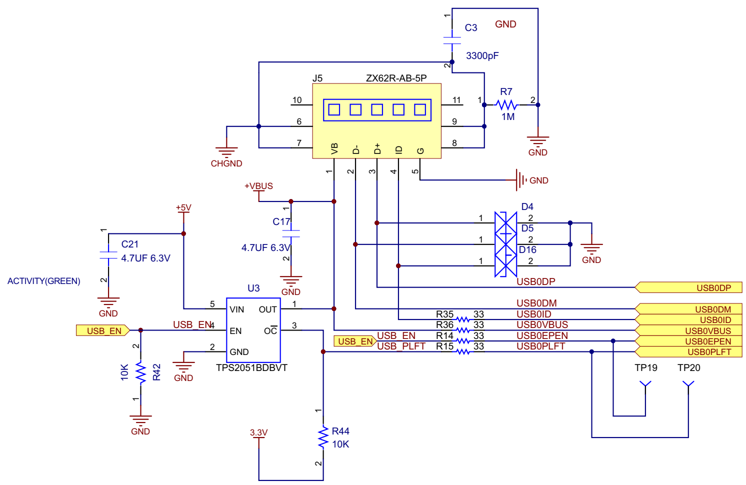

Figure 9. Interface for USB

5.5.3 Programming Connector:

The JTAG interface has been provided for programming as shown in Figure 10.

PIN	FUNCTION
TCK - JTAG	JTAG test clock signal. This pin is also the SWCLK signal for TCK serial wire debug (SWD) connections.
TMS - JTAG	JTAG test mode select. This pin is also the SWDIO signal for TMS SWD connections.
TDO - JTAG	JTAG test data out. This pin is also the SWO signal for SWD connections.
TDI	JTAG test data in.
EXT-DBG	Pull this pin low to tri-state the on-board ICDI drive signals. This action prevents the ICDI from interfering with an external debug-in connection.
RESET	Target reset pin.
GND	Ground pin of MCU. Connect this pin to the external JTAG programmer ground pin. In situations where the LaunchPad is used as a programmer, this pin must be connected to the ground pin of the LaunchPad.

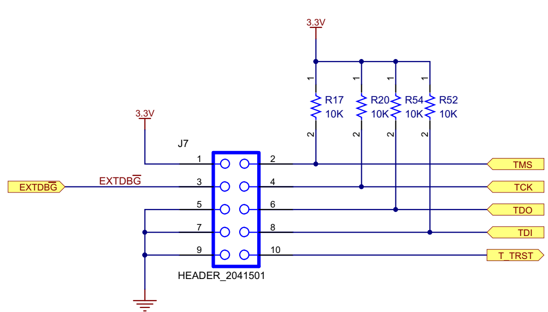

Figure 10. Programming Connector

6 Software Description

The software provided for the CAN-Ethernet converter performs the CAN-Ethernet gateway operation. Using a PC and the CAN-Ethernet converter, the user can send and receive messages through the Telnet interface (using a free terminal emulator application such as Tera Term). Telnet is a client-server protocol based on a reliable connection-oriented transport. Typically, this protocol is used to establish a connection to TCP port number 23, where a Telnet server application (telnetd) is listening. Tera Term is an open-source, free, software-implemented terminal emulator program. The example software provides testing of the hardware by simple character transfers via telnet to the CAN bus and vice versa. The software is tested at different CAN baud rates of 10 kbps, 500 kbps, and 1 Mbps.

7 Test Results

7.1 Functional Testing

Table 2. Functional Testing Values

Clock	25 MHz
V_{CC} (3 to 3.6 V)	3.31 V
Internal 1.55 V	1.55 V
MII interface	OK
Link and activity LED	OK

7.2 CAN-Ethernet Gateway Testing

7.2.1 Test Setup

Figure 11 shows the test setup.

- A 5.5-V DC power supply powers the CAN-Ethernet converter.
- This board must be programmed with the CAN to Ethernet software provided. (Note: To program the TM4C microcontrollers, the user can use the ARM JTAG debugger or the TM4C LaunchPad as a JTAG programmer. For programming, the user can use LM Flash Programmer GUI or Code Composer Studio (CCS) available on www.ti.com).
- Use a standard RJ45 cable to connect the CAN-Ethernet converter to the PC.
- Use the DK-TM4C123G evaluation board available from TI and program the board with the CAN example software provided in the TivaWare software installation. (Note: TivaWare is available for free download on the TI website. When installing in the C:\ drive of the PC, the CAN example software can be found in the folder *C:\ti\TivaWare_C_Series-2.1.0.12573\examples\boards\dk-tm4c123g\can*). This sample program enables sending and receiving of characters via the UART to the CAN bus. This board must be connected to the USB port of the PC. If TivaWare has been previously installed on the PC, the necessary drivers will automatically install and update upon connecting the board to the PC.
- Connect a 120-Ω resistor across the CANH and CANL terminals of the DK-TM4C123G board.
- Connect the CAN outputs of the CAN-Ethernet converter and the DK-TM4C123G evaluation board using a twisted-pair cable.
- Download and install the free Tera Term software to use as a terminal emulator for the testing.
- Download and install the free Wireshark network analyzer. For installation, right-click on the downloaded .exe file and click *Run as administrator*.

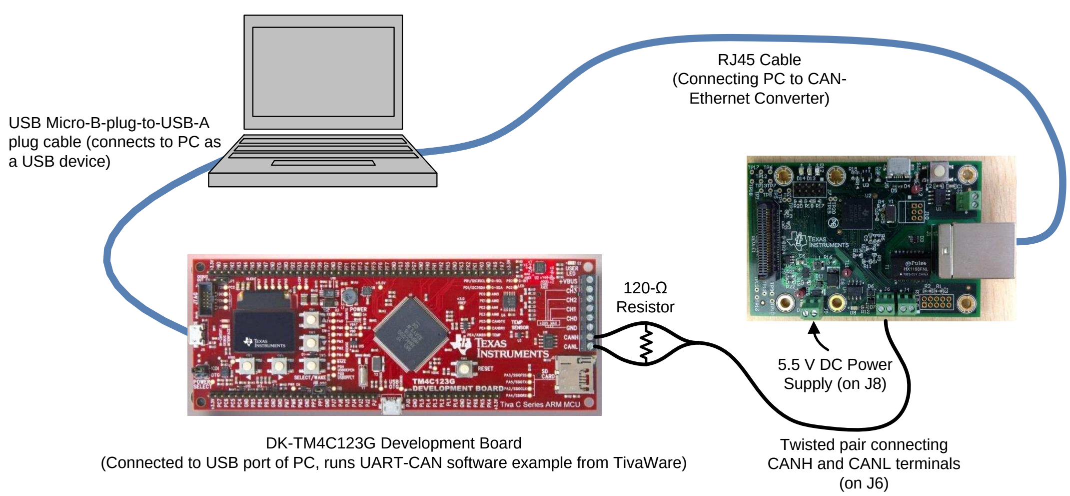

Figure 11. Test Setup for Testing CAN-Ethernet Converter

7.2.2 Test Procedure

- Assigning the IP address to PC Ethernet port (Figure 12):
  - The user must manually assign an IP address to the PC, as the gateway is directly connected to the PC. Click on the *Windows Start* button and type *view network connections* in the Search programs and files box. Click on *View network connections* under the Control Panel heading.
  - Find the correct Local Area Connection for the Ethernet port and right-click on it. Select *Properties*.
  - Click on *Internet Protocol Version 4* and then click the *Properties* button.
  - Click on *Use the following IP address*. Select and assign a compatible address to the port. The address could be 169.254.31.001. The *Subnet mask* automatically defaults to 255.255.0.0.
  - Click *OK*.
  - If using a laptop, be sure to disable the wireless LAN connection.

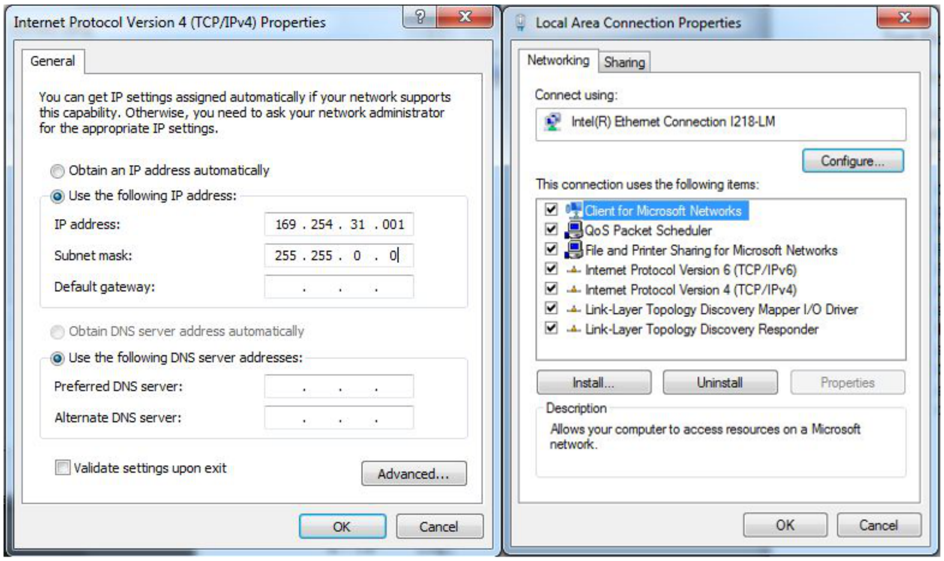

Figure 12. Assigning the IP Address

- Starting the test:
  - Power up the CAN-Ethernet converter with the Ethernet connected to the PC and run the Wireshark program.
  - The CAN-Ethernet software uses auto IP, so the PC automatically assigns an IP to the CAN-Ethernet converter.
  - As the Wireshark screen capture from Figure 13 shows, the CAN-Ethernet converter requests the allocation of an IP address.
  - The PC allocates the IP address within five seconds. The same allocated address can be seen from the Wireshark screen capture. For example, in Figure 13 the IP address allocated to the CAN-Ethernet board is 169.254.254.255.

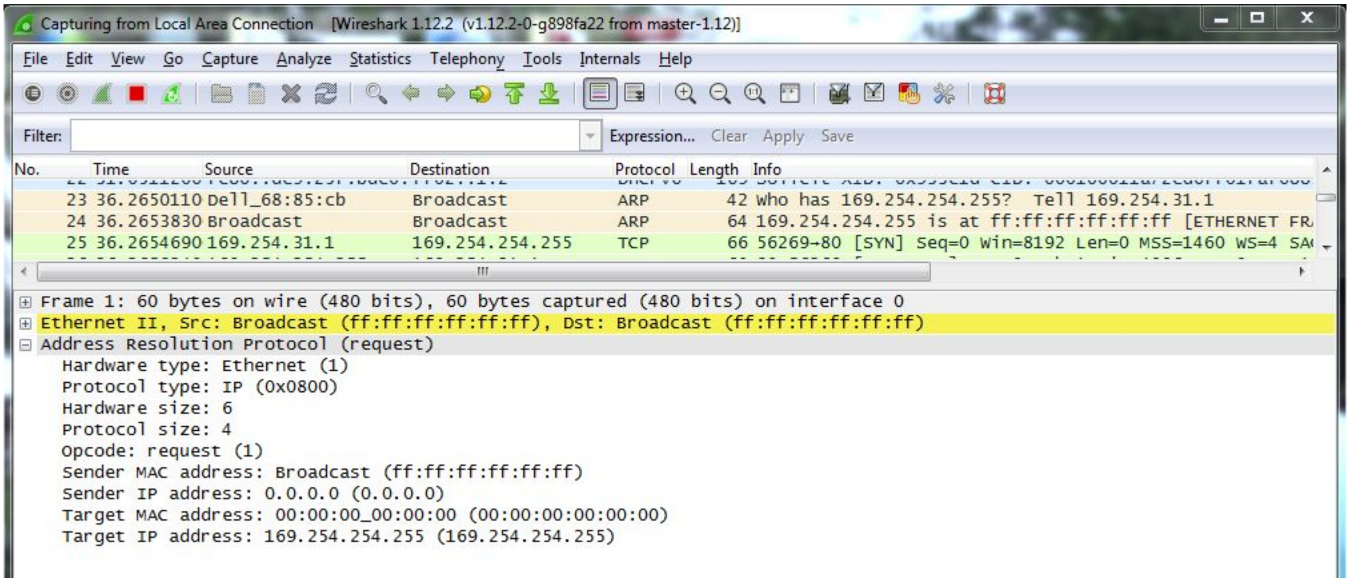

Figure 13. Wireshark Capture

- Power up the DK-TM4C123G device by connecting to the USB of the PC.
- Open the Tera Term program for creating a new connection, as Figure 14 shows. Select *TCP/IP* and *Telnet*. Type in the IP address allocated to the CAN-Ethernet converter in the *Host* field. For example, if the IP address allocated is 169.254.254.255, enter that as the address.

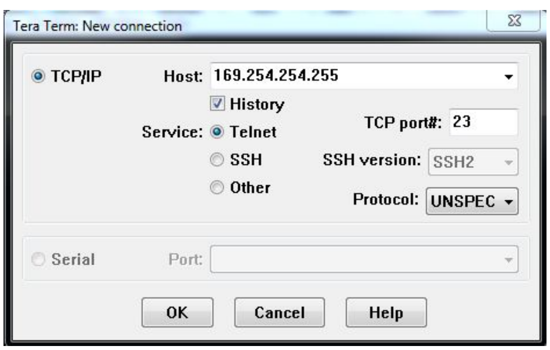

Figure 14. Tera Term Telnet Connection

- Open the Tera Term again for creating a new connection. Now select *Serial* and select the port on which the USB-COM driver of the DK-TM4C123G device is mounted. The port number becomes visible in the *Serial* selection box. As Figure 15 shows, set the *Baud rate* field to "115200" , the *Data* field to "8 bit", the *Parity* field to "none", the *Stop* field to "1 bit", and the *Flow control* field to "none".

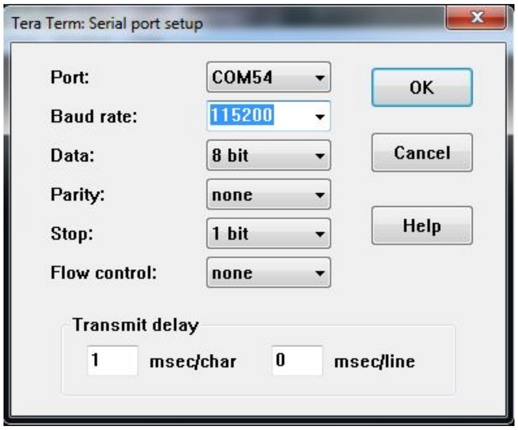

Figure 15. Serial Communication Settings

- The user can now type in either the Telnet Tera Term connection or the Serial COM Tera Term connection and observe the characters transmitting to the other terminal. Basically, through the Serial COM Tera Term window, the DK-TM4C123G board receives the data from UART and sends the data to the CAN bus. The CAN-Ethernet board receives the data from the CAN bus and sends the data to Ethernet. Similarly, the data can flow the other direction, as well.

NOTE: **On modifying the (CAN-Ethernet Gateway) software:** The example software is tested with Code Composer Studio V6. If the user wants to open, modify, or recompile the project, installing the CCS installation is required. The example software also uses the resources from TivaWare—the compiled project refers to the TivaWare installation at the default installation path *C:\ti\TivaWare_C_Series-2.1.0.12573*. The options and settings of the project require updating if the TivaWare version number or the installation path is different.

7.3 Electromagnetic Interference-Radiated Emission

The test distance for radiated emission from the equipment under test to antenna is 10 m. The test was performed in a semi-anechoic chamber, which conforms to the Volumetric Normalized Site Attenuation (VNSA) for ten-meter measurements.

Table 3. Specifications for Radiated Emissions

FREQUENCY RANGE	CLASS A LIMITS QUASI-PEAK	CLASS B LIMITS QUASI-PEAK
30 MHz to 230 MHz and 230 MHz to 1 GHz	40 and 47 dB µV/m	30 and 37 dB µV/m

Table 4. Observation for Radiated Emissions

REQUIREMENTS	FREQUENCY	RESULT
EN 55011: 2009 + A1: 2010, Class A	30 MHz to 1000 MHz	Pass

7.3.1 Test Result Graphs

The test is done with the TM4C129XNCZAD 32-bit ARM Cortex-M4F MCU with the internal MAC and PHY enabled. Figure 16 and Figure 17 show the graphs for horizontal and vertical polarization, respectively.

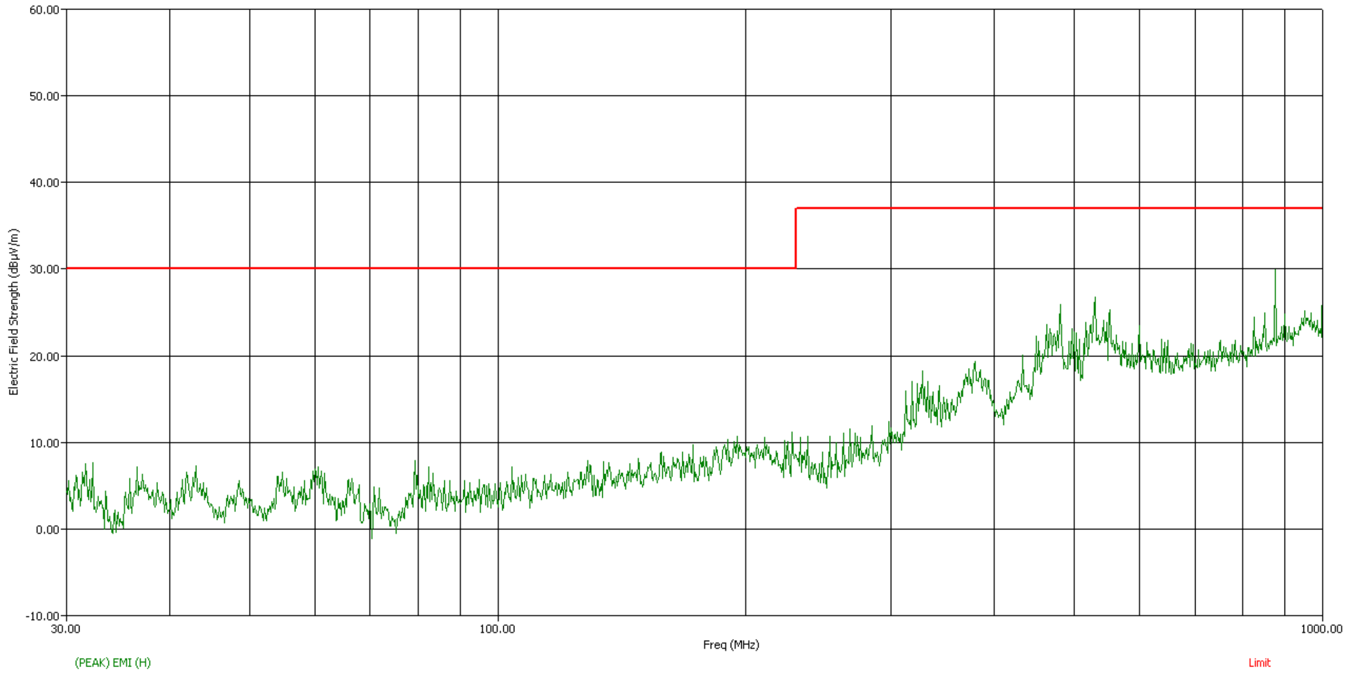

Figure 16. Horizontal Polarization

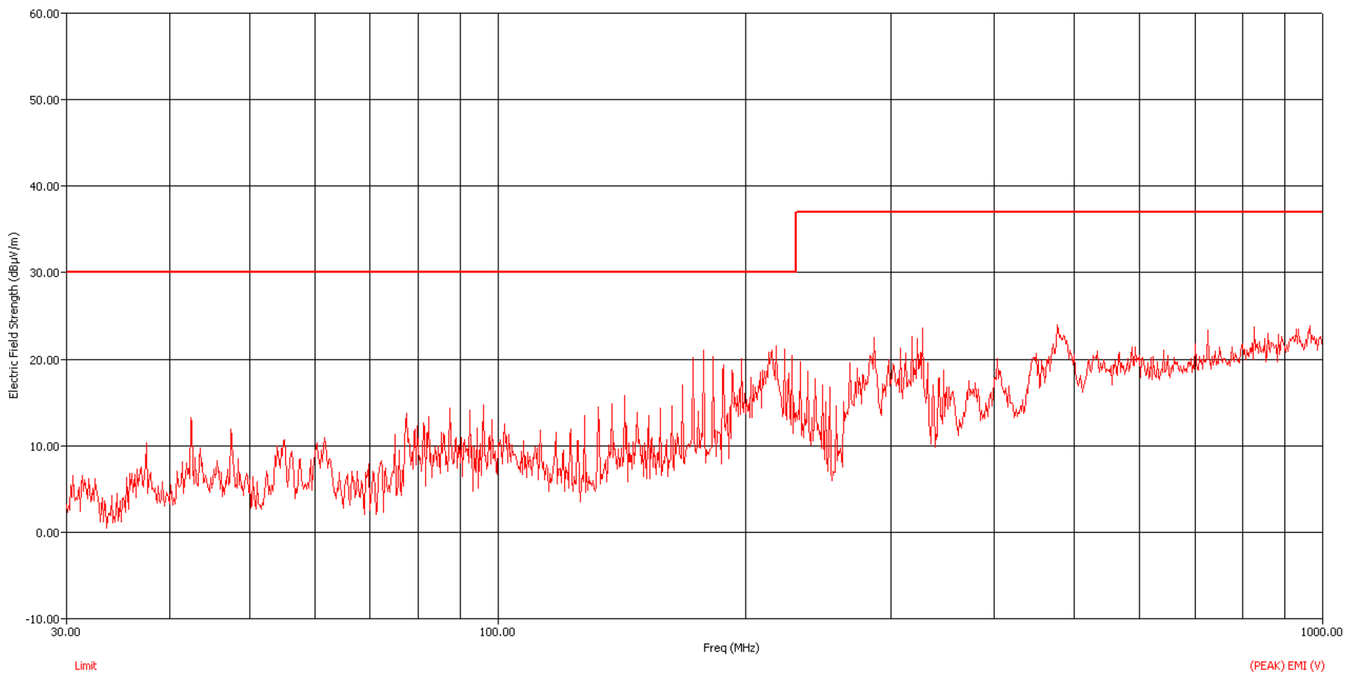

Figure 17. Vertical Polarization

7.4 Electro Static Discharge (ESD), Electromagnetic Interference (EMI), and Electromagnetic Compatibility (EMC) Recommendations and Design Guidelines

The following list provides recommendations to improve EMI performance:

1. Use a guard ring for the crystal.
2. Use a metal-shielded RJ-45 connector to connect the shield to chassis ground.
3. Use magnetics with integrated, common-mode choking devices with the choke on the side of the PHY (for example, the Pulse HX1198FNL).
4. Do not overlap the circuit and chassis ground planes, keep them isolated. Connect the chassis ground and system ground together using one capacitor with 4700 pF, 2 kV, 10% tolerance, and an X7R type.

8 Design Files

8.1 Schematics

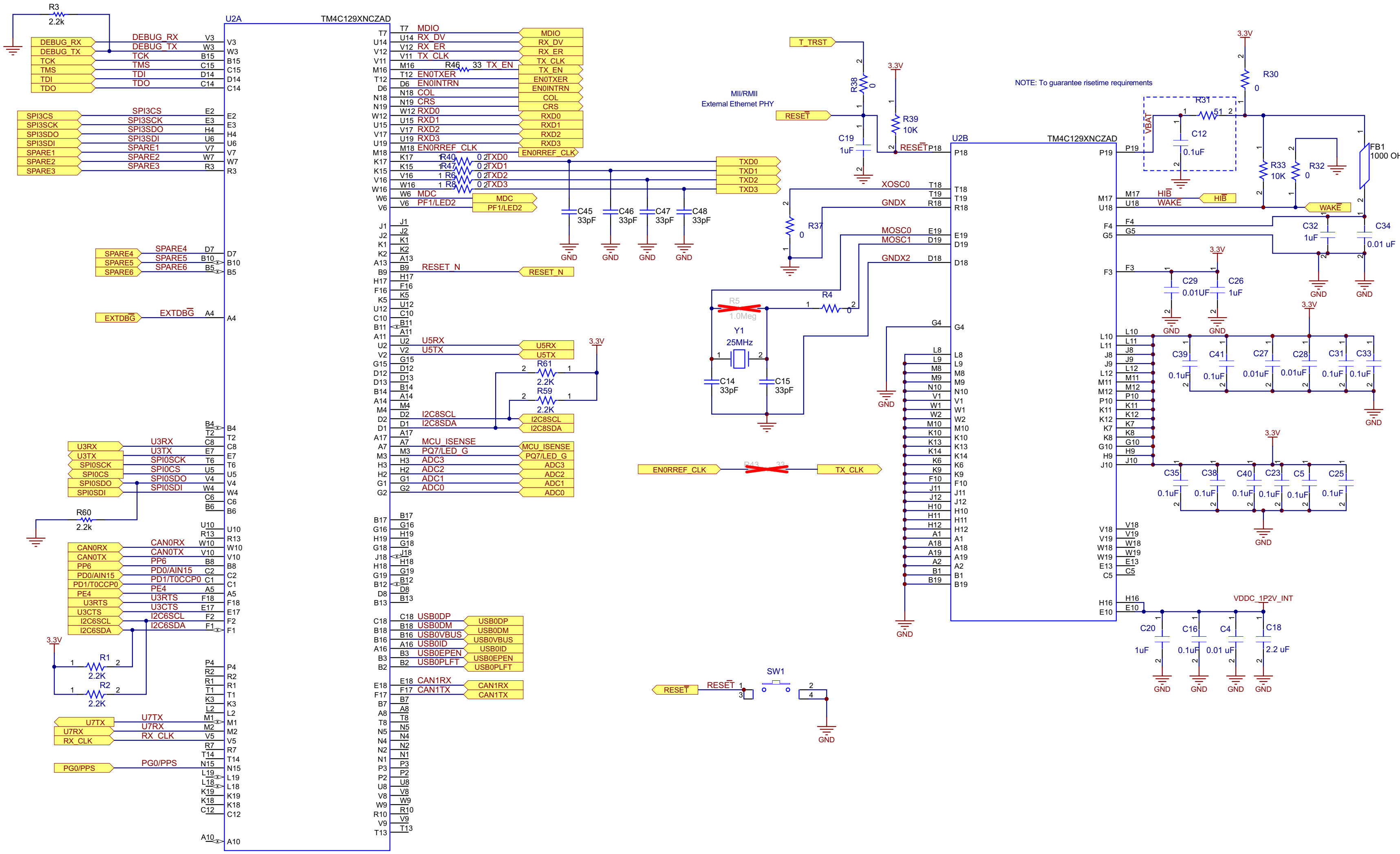

Figure 18. Microcontroller Schematic

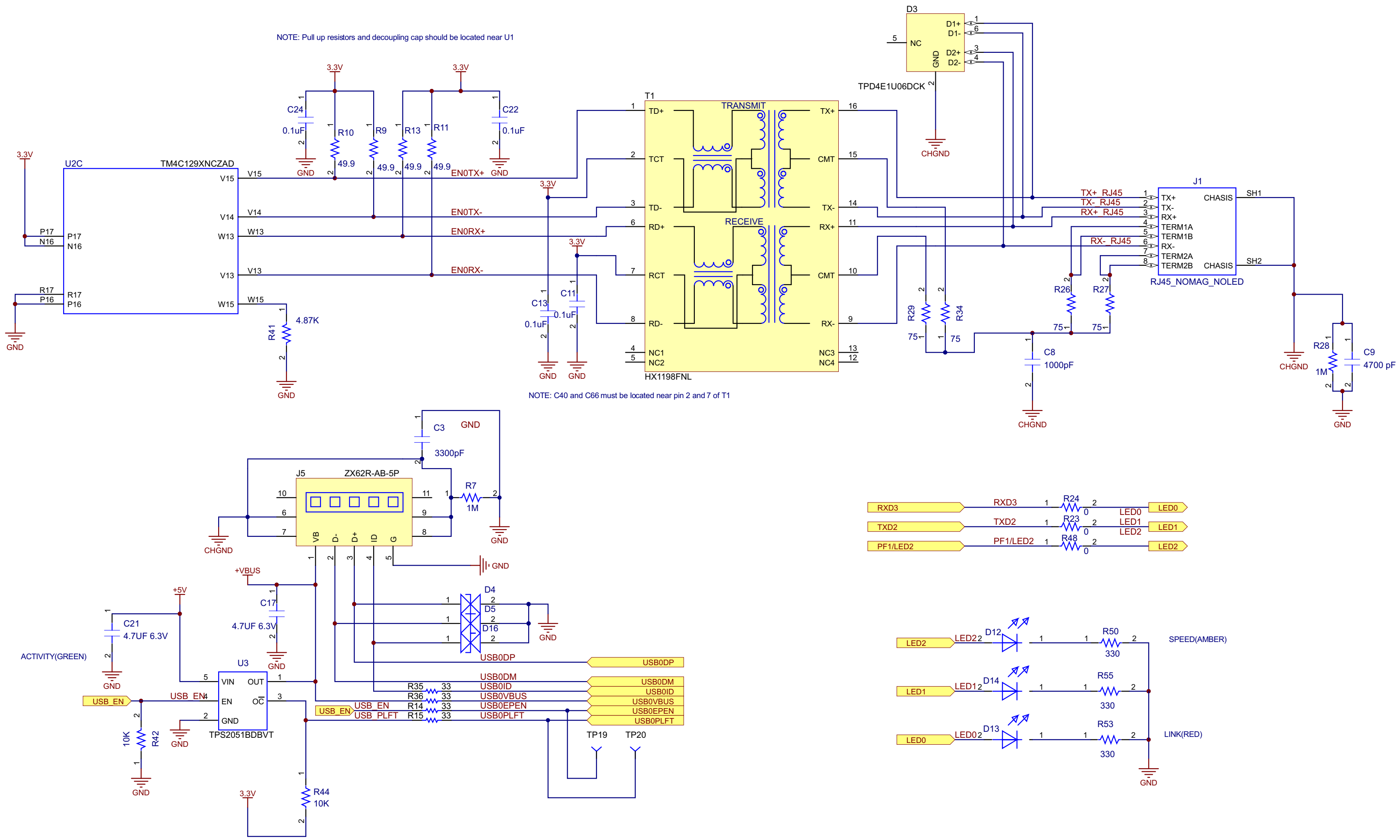

Figure 19. 10/100 Ethernet USB Schematic

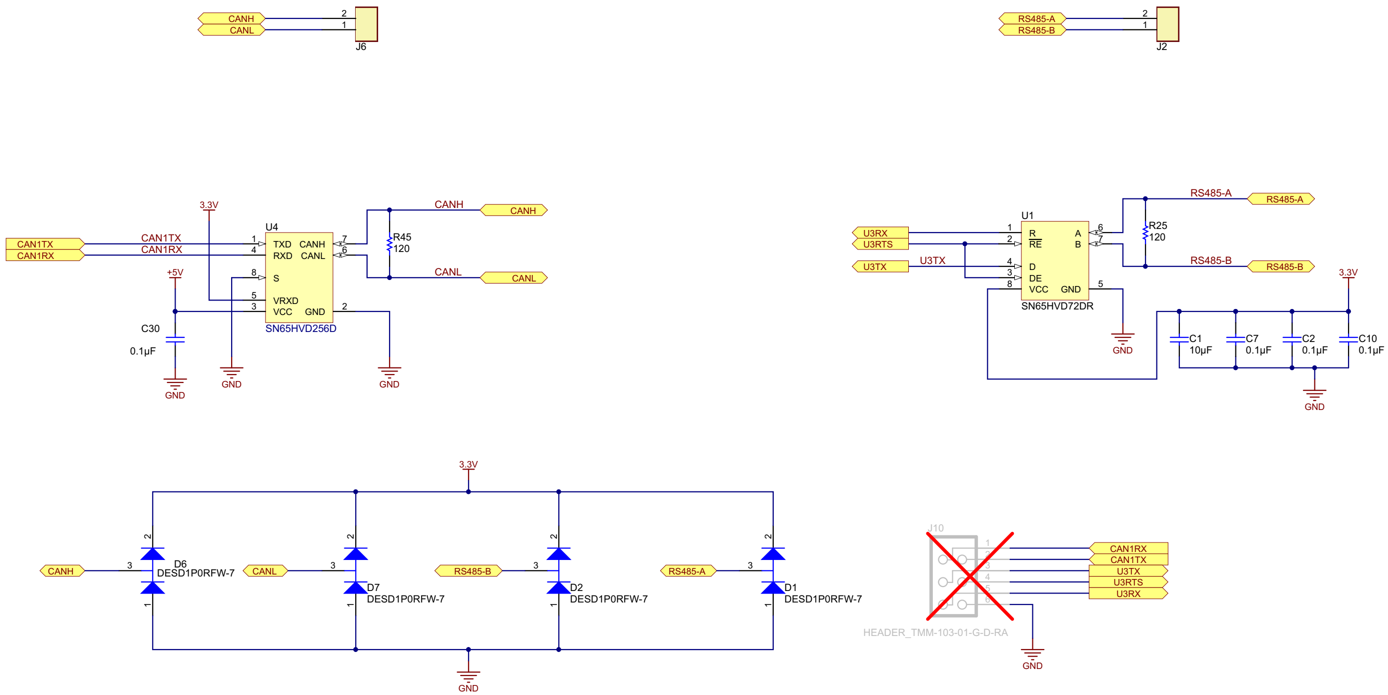

Figure 20. CAN, RS485 Schematic

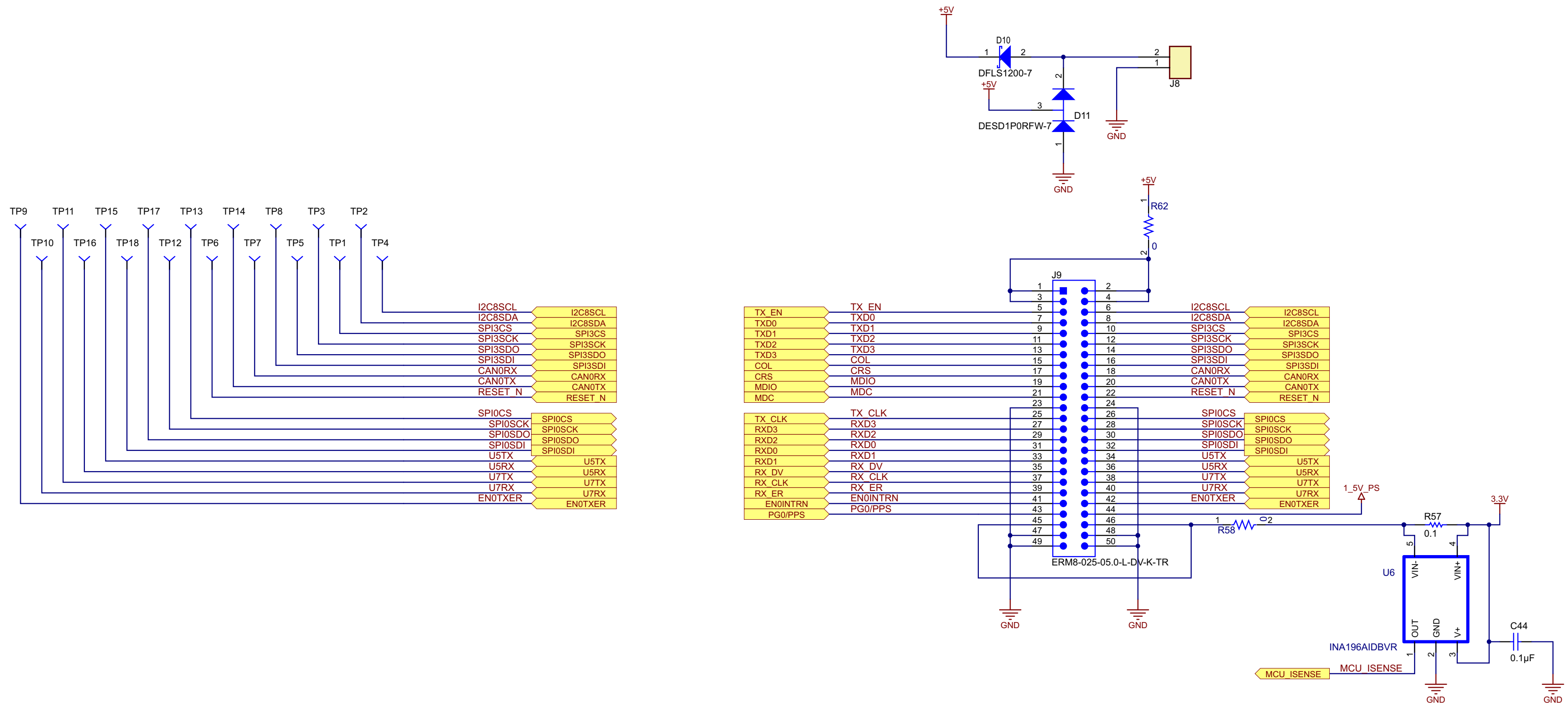

Figure 21. MII and RMII Interface Schematic

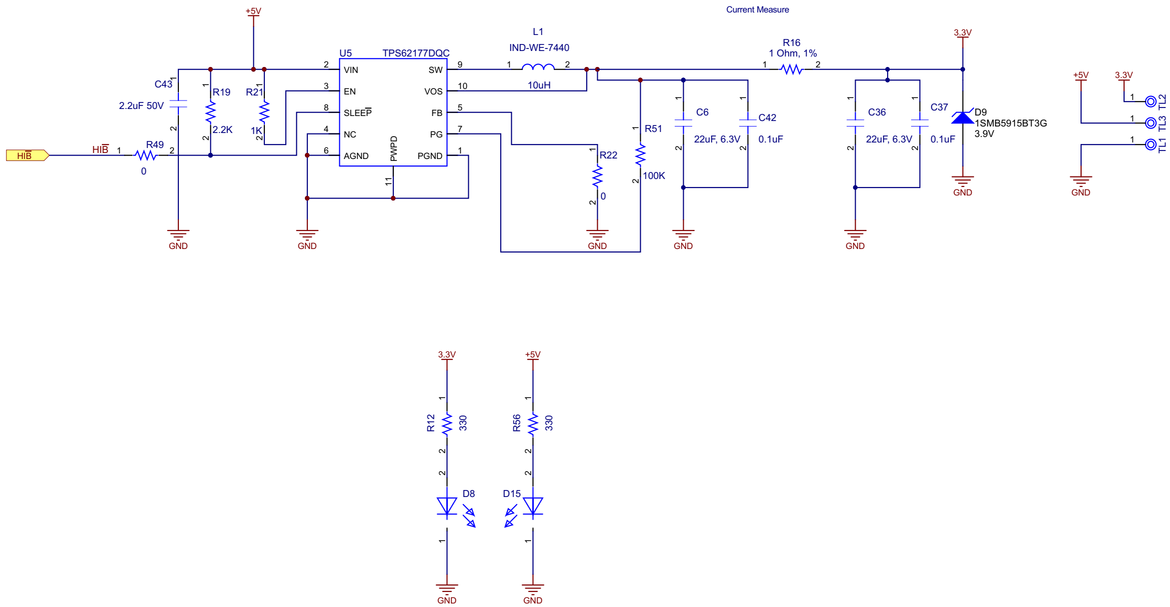

Figure 22. Power Supply Schematic

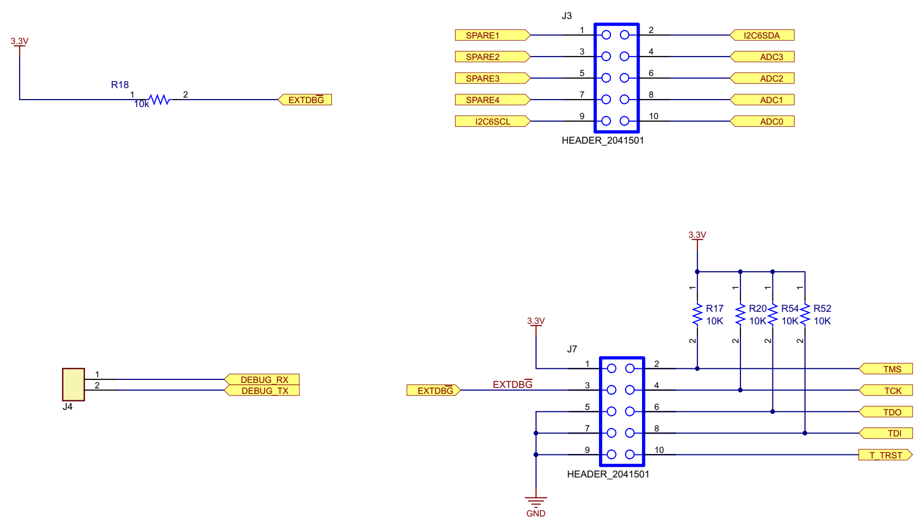

Figure 23. Spare and Debug Schematic

8.2 Bill of Materials

To download the bill of materials (BOM), see the design files at TIDA-00203.

Table 5. BOM

FITTED	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER	MANUFACTURER PART #
Fitted	1	C1	CAP, CERM, 10uF, 6.3V, +/-20%, X5R, 0603	Kemet	C0603C106M9PACTU
Fitted	3	C2, C7, C10	CAP, CERM, 0.1uF, 16V, +/-10%, X5R, 0603	MuRata	GRM188R61C104KA01D
Fitted	1	C3	Capacitor, 3300pF, 50V, 10%, X7R, 0603	TDK Corporation	C1608X7R1H332K
Fitted	4	C4, C27, C28, C34	Capacitor, 0.01uF 25V, 10% 0402 X7R	Taiyo Yuden	TMK105B7103KV-F
Fitted	16	C5, C11, C12, C13, C16, C22, C23, C24, C25, C35, C37, C38, C39, C40, C41, C42	Capacitor, 0.1uF 50V, 20% 0603 X7R	TDK Corporation	C1608X7R1H104M
Fitted	1	C6	Capacitor, 22uF 6.3V 20% X5R 0805	TDK Corporation	C2012X5R0J226M
Fitted	1	C8	CAP CER 1000PF 2KV 20% X7R 1210	KEMET	C1210C102MGRACTU
Fitted	1	C9	Capacitor, 4700pF, 2kV, 10%, X7R, 1812	AVX	1812GC472KAT1A
Fitted	6	C14, C15, C45, C46, C47, C48	CAP, CERM, 33pF, 50V, +/-5%, C0G/NP0, 0402	MuRata	GRM1555C1H330JA01D
Fitted	2	C17, C21	Capacitor, 4.7uF, 6.3V, 10% 0805, X5R	Taiyo Yuden	JMK212BJ475KG-T
Fitted	1	C18	Capacitor, 2.2uF, 16V, 10%, 0603, X5R	Murata	GRM188R61C225KE15D
Fitted	4	C19, C20, C26, C32	Capacitor, 1uF , X5R, 10V, 0402	TDK Corporation	C1005X5R1A105M050BB
Fitted	3	C29, C31, C33	Capacitor, 0.1uF 16V, 10% 0402 X7R	Taiyo Yuden	EMK105B7104KV-F
Fitted	2	C30, C44	CAP, CERM, 0.1uF, 25V, +/-5%, X7R, 0603	AVX	06033C104JAT2A
Fitted	1	C36	Capacitor, 22uF 6.3V 20% X5R 0805	TDK Corporation	C2012X5R0J226M/1.25
Fitted	1	C43	Capacitor, 2.2uF 50V 10% X5R 0805	TDK Corporation	C2012X5R1H225K
Fitted	5	D1, D2, D6, D7, D11	Diode, P-N, 70V, 0.2A, SOT-323	Diodes Inc	DESD1P0RFW-7
Fitted	1	D3	Quad Channel High Speed ESD Protection Device, DCK0006A	Texas Instruments	TPD4E1U06DCK
Fitted	3	D4, D5, D16	Diode, 5.6V ESD Suppressor 0402	Epcos	B72590D0050H160
Fitted	2	D8, D14	LED, Green 565nm, Clear 0805 SMD	Lite on	LTST-C171GKT
Fitted	1	D9	Diode, Zener, 3.9V, 550mW, SMB	ON Semiconductor	1SMB5915BT3G
Fitted	1	D10	Diode, Schottky, 200V, 1A, PowerDI123	Diodes Inc.	DFLS1200-7
Fitted	2	D12, D15	LED AMBER CLEAR 0805 SMD	Lite on	LTST-C170AKT
Fitted	1	D13	LED, Red 630nm, Clear 0805 SMD	Lite on	LTST-C171EKT
Fitted	1	FB1	FERRITE CHIP 1000 OHM 300MA 0603	TDK Corporation	MMZ1608B102C
Fitted	6	FID1, FID2, FID3, FID4, FID5, FID6	Fiducial mark. There is nothing to buy or mount.	N/A	N/A
Fitted	6	H1, H2, H3, H4, H5, H6	Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead	B&F Fastener Supply	NY PMS 440 0025 PH
Fitted	1	J1	Connector, RJ45 NO MAG, shielded THRU HOLE	TE conncetivity	6116526-1
Fitted	4	J2, J4, J6, J8	Terminal Block, 4x1, 2.54mm, TH	On Shore Technology Inc	OSTVN02A150

Table 5. BOM (continued)

FITTED	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER	MANUFACTURER PART #
Fitted	2	J3, J7	Header, 2X5 2mm spacing	Harwin Inc	M22-2020505
Fitted	1	J5	Connector, USB micro AB Receptacle Reversed SMD	HIROSE ELECTRIC CO. LTD.	ZX62R-AB-5P
Fitted	1	J9	CONN MICRO HS TERM STRP HDR 50 POS	Samtec	ERM8-025-05.0-L-DV-K-TR
Not Fitted	0	J10	Header, 2mm, Low Profile 2x3	Samtec	TMM-103-01-G-D-RA
Fitted	1	L1	Inductor 10uH, SMD 2.8x2.8mm, 0.5A, 0.47 Ohm	Wurth Electronics Inc	744029100
Not Fitted	0	LBL1	Thermal Transfer Printable Labels, 0.650 W x 0.200" H - 10	000 per roll"	Brady
Fitted	5	R1, R2, R19, R59, R61	Resistor, 2.2K OHM 1/10W 5% 0603 SMD	Vishay-Dale	CRCW06032K20JNEA
Fitted	2	R3, R60	RES, 2.2k ohm, 5%, 0.063W, 0402	Vishay-Dale	CRCW04022K20JNED
Fitted	12	R4, R6, R8, R23, R24, R30, R32, R37, R38, R40, R47, R48	Resistor, 0 ohm, 1/10W, 5%, 0402	Panasonic Electronic Components	ERJ-2GE0R00X
Not Fitted	0	R5	RES, 1.0Meg ohm, 5%, 0.063W, 0402	Vishay-Dale	CRCW04021M00JNED
Fitted	1	R7	Resistor, 1M OHM 1/10W 5% 0603 SMD	Panasonic Electronic Components	ERJ-3GEYJ105V
Fitted	4	R9, R10, R11, R13	Resistor, 49.9 OHM 1/10W 1% 0603 Thick	Panasonic Electronic Components	ERJ-3EKF49R9V
Fitted	2	R12, R56	Resistor, 330 ohm, 1/10W, 5%, 0402	Panasonic Electronic Components	RC0402FR-07330RL
Fitted	5	R14, R15, R35, R36, R46	RES, 33 ohm, 5%, 0.063W, 0402	Vishay-Dale	CRCW040233R0JNED
Fitted	1	R16	Resistor, 1 OHM 1/10W 1% 0603, Thick	Panasonic Electronic Components	ERJ-3RQF1R0V
Fitted	8	R17, R18, R20, R33, R39, R44, R52, R54	Resistor, 10k ohm, 1/10W, 5%, 0402 Thick Film	Yageo America	RC0402FR-0710KL
Fitted	1	R21	Resistor, 1K Ohm, 1/10W, 5%, SMD, Thick	Panasonic Electronic Components	ERJ-3GEYJ102V
Fitted	4	R22, R49, R58, R62	Resistor, 0 OHM 1/10W 0603 SMD	Panasonic Electronic Components	ERJ-3GEY0R00V
Fitted	2	R25, R45	RES, 120 ohm, 1%, 0.25W, 1206	Yageo America	RC1206FR-07120RL
Fitted	4	R26, R27, R29, R34	Resistor, 75 Ohm, 1/10W, 1%, SMD, Thick	Panasonic Electronic Components	ERJ-3EKF75R0V
Fitted	1	R28	RES 1M OHM 5% 1206 TF	Panasonic Electronic Components	ERJ-8GEYJ105V
Fitted	1	R31	Resistor, 51 ohm, 1/10W, 5%, 0402	Panasonic Electronic Components	ERJ-2GEJ510X
Fitted	1	R41	Resistor, 4.87K Ohm, 1/10W, 1%, SMD, Thick	Panasonic Electronic Components	ERJ-3EKF4871V

Table 5. BOM (continued)

FITTED	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER	MANUFACTURER PART #
Fitted	1	R42	Resistor, 10K OHM 1/10W 5% 0603 SMD	Panasonic Electronic Components	ERJ-3GEYJ103V
Not Fitted	0	R43	RES, 33 ohm, 5%, 0.063W, 0402	Vishay-Dale	CRCW040233R0JNED
Fitted	3	R50, R53, R55	Resistor, 330 OHM 1/10W 5% 0603 SMD	Panasonic Electronic Components	ERJ-3GEYJ331V
Fitted	1	R51	Resistor, 100K OHM 1/10W 5% 0603 Thick	Panasonic Electronic Components	ERJ-3GEYJ104V
Fitted	1	R57	RES, 0.1 ohm, 1%, 0.1W, 0603	Panasonic	ERJ-3RSFR10V
Fitted	1	SW1	Switch, Tact 6mm SMT, 160gf	Omron Electronics Inc-EMC Div	B3S-1000
Fitted	1	T1	TRANSFORMER, MDL, XFMR SGL ETHR LAN, SOIC-16	PULSE ELECTRONICS	HX1198FNL
Fitted	1	U1	IC, RS485 TRANSCEIVER LP, 8-SOIC	Texas Instruments	SN65HVD72DR
Fitted	1	U2	Stellaris MCU TM4C129XNCZAD 212 BGA	Texas Instruments	TM4C129XNCZAD
Fitted	1	U3	Load Switch, 5.5V, SOT23-5, TPS2051BDBV	Texas Instruments	TPS2051BDBVT
Fitted	1	U4	CAN Transceiver with Fast Loop Times for Highly Loaded Networks, 85 mA, 5 V, -40 to 125 degC, 8-pin SOIC (D), Green (RoHS & no Sb/Br)	Texas Instruments	SN65HVD256D
Fitted	1	U5	Regulator, Step Down 3.3V, 0.5A	Texas Instruments	TPS62177DQC
Fitted	1	U6	IC, Current Shunt Monitor, -16V to 80V Common-Mode Range	Texas Instruments	INA196AIDBVR
Fitted	1	Y1	Crystal, 25.00MHz 5.0x3.2mm SMT	CTS-Frequency Controls	445I23D25M00000

8.3 PCB Layout

The complete board is designed in a 2 × 3 inch form-factor PCB. To download the layer plots, see the design files at TIDA-00203.

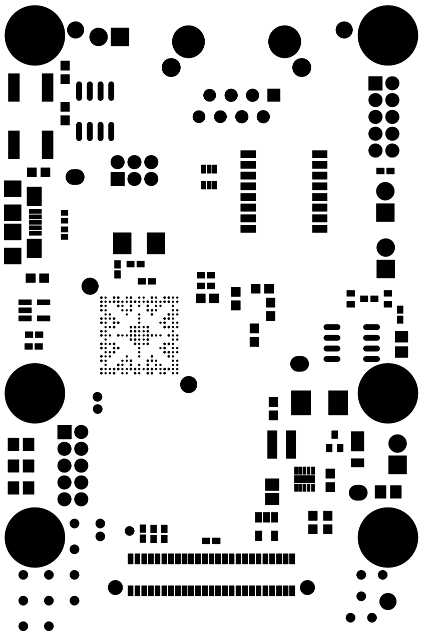

Figure 24. Top Soldermask

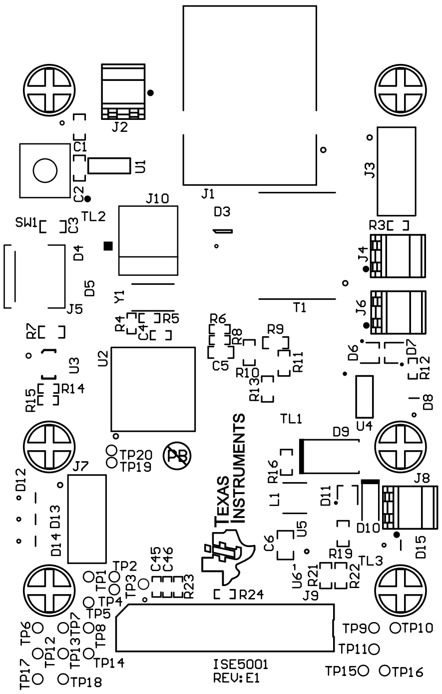

Figure 25. Top Overlay

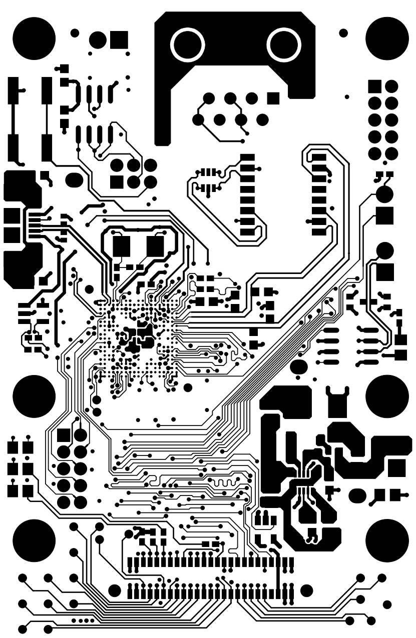

Figure 26. Top Layer

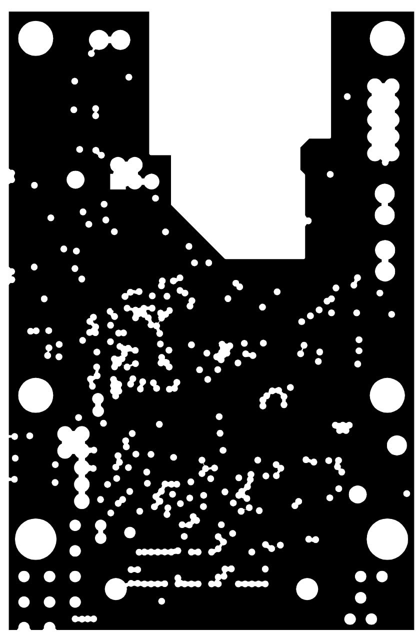

Figure 27. L2 GND Plane

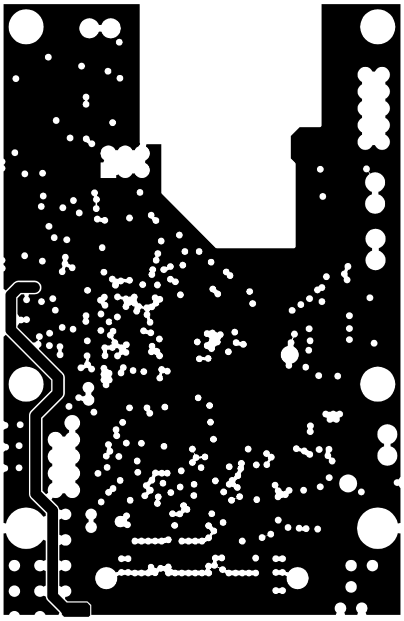

Figure 28. L3 PWR Plane

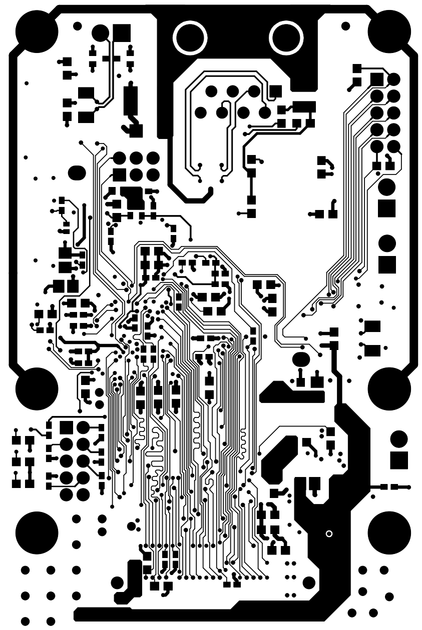

Figure 29. Bottom Layer

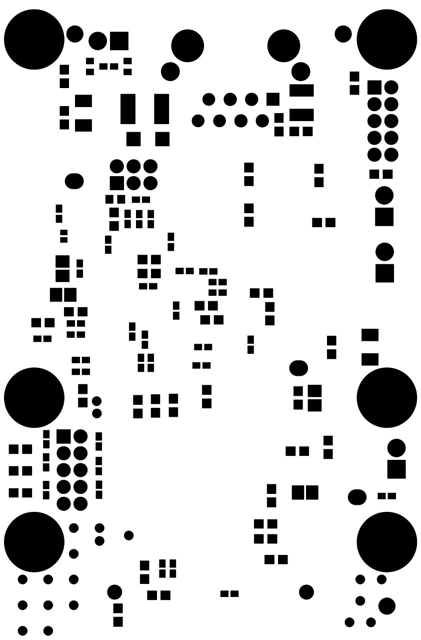

Figure 30. Bottom Soldermask

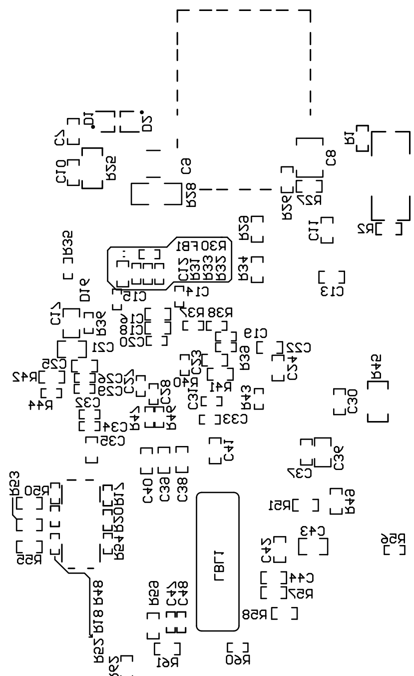

Figure 31. Bottom Overlay

8.4 Altium Project

To download the Altium project files, see the design files at TIDA-00203.

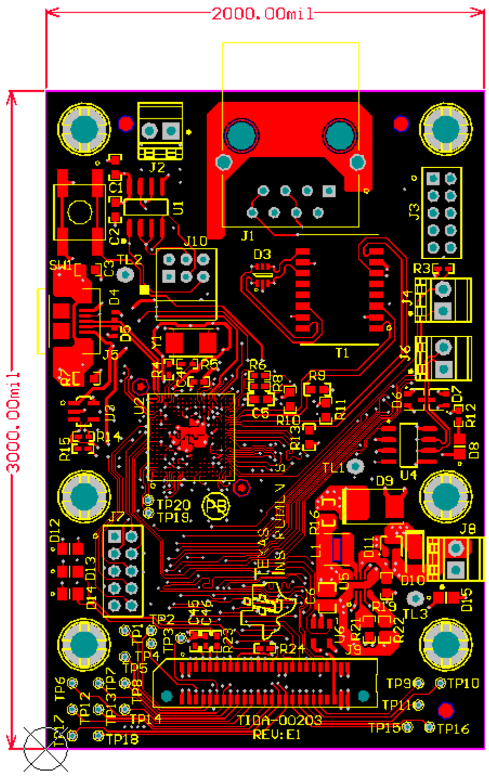

Figure 32. Altium Top Layer

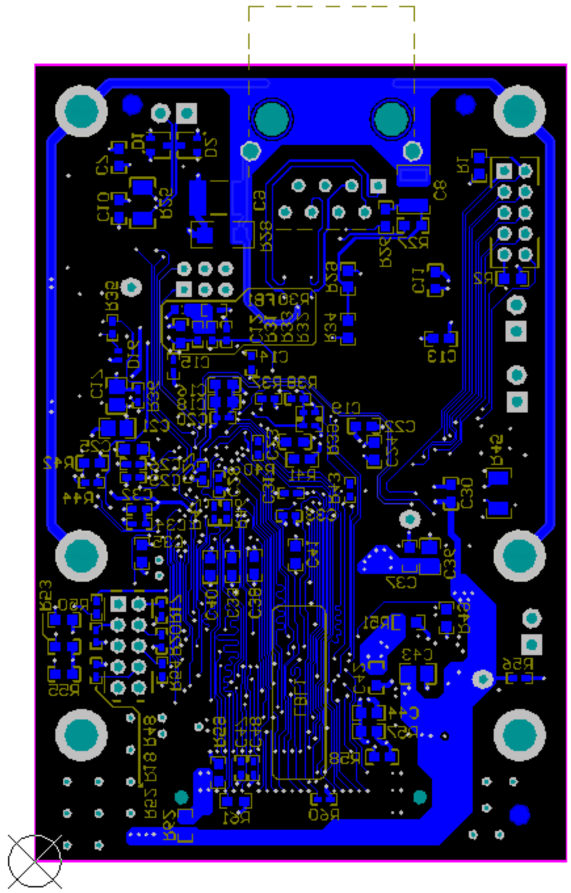

Figure 33. Altium Bottom Layer

8.5 Gerber Files

To download the Gerber files, see the design files at TIDA-00203.

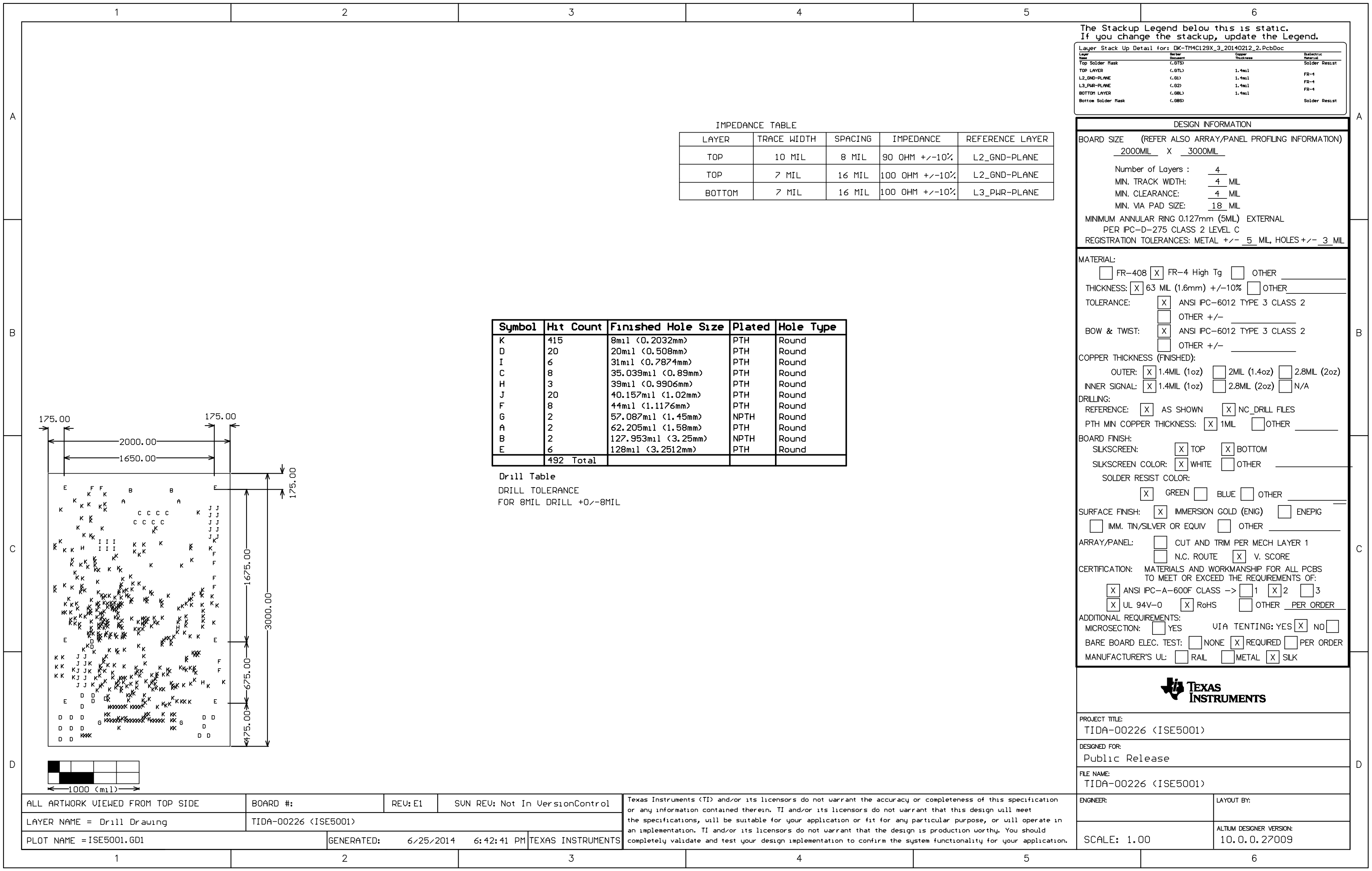

Figure 34. Fabrication Drawing

8.6 Assembly Drawings

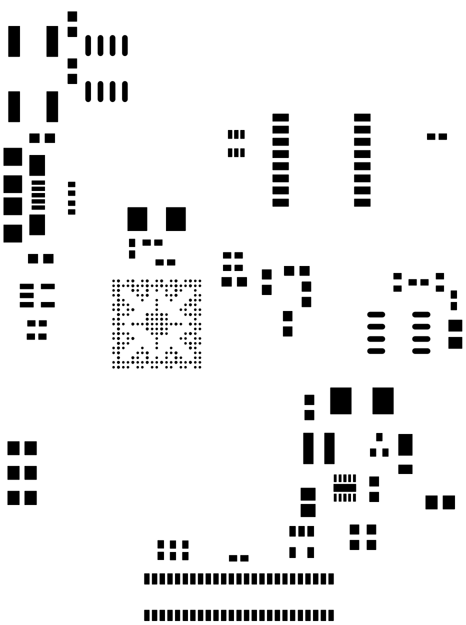

Figure 35. Top Paste Assembly

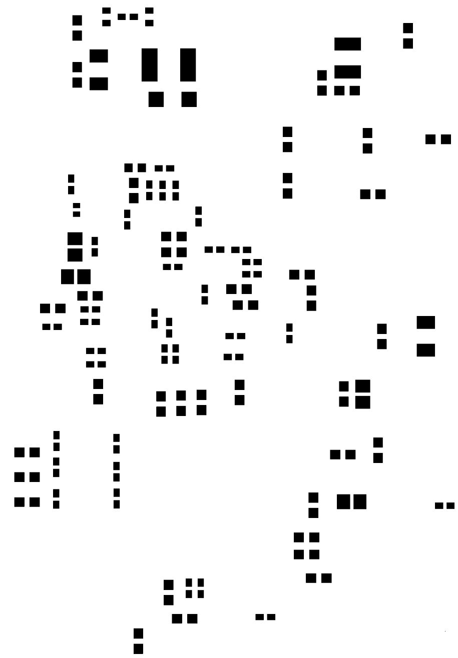

Figure 36. Bottom Paste Assembly

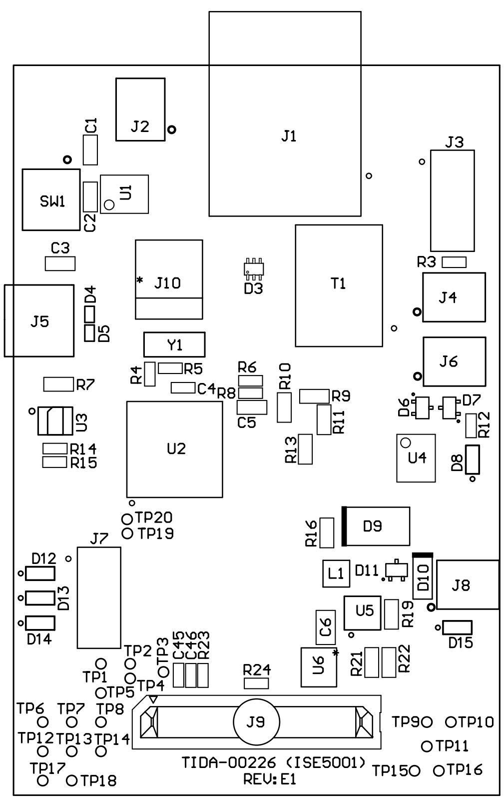

Figure 37. Top Assembly

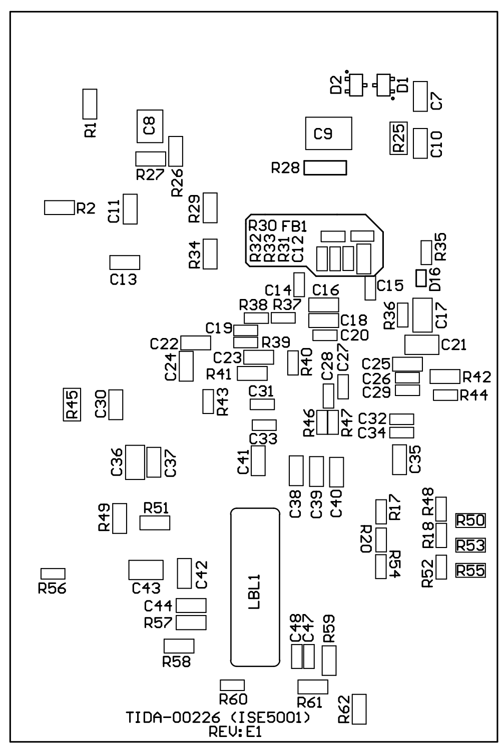

Figure 38. Bottom Assembly

8.7 Software Files

To download the software files, see the design files at TIDA-00203.

9 References

1. Texas Instruments, *System Design Guidelines for the TM4C129x Family of Tiva™ C Series Microcontrollers*, Application Report (SPMA056).
2. Texas Instruments, *Tiva ™ TM4C12 9X Development Board*, User's Guide (SPMU360).
3. Texas Instruments, *Tiva™ TM4C1292NCZAD Microcontroller*, Data Sheet (SPMS444).
4. Texas Instruments, *Tiva ™ C Series TM4C1294 Connected LaunchPad Evaluation Kit*, User's Guide (SPMU365).
5. Texas Instruments, *Introduction to the Controller Area Network (CAN)*, Application Report (SLOA101).
6. Texas Instruments, *Controller Area Network Physical Layer Requirements*, Application Report (SLLA270).

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