TI Designs

Small Form Factor, Digital Isolator-Based Half-Duplex RS-485 Interface Module Reference Design

TI Designs

The RS-485 bus standard is one of the most widely used physical layer bus interface in protection, control, and monitoring applications. The RS-485 interface could be half duplex of full duplex. The RS-485 communication interface could be non-isolated or isolated. This TI Design provides half-duplex RS-485 interface solution for grid applications. A wide selection of transceivers is available for signaling rates, number of nodes, ESD withstand capability, and fault protection. This TI Design also provides a solution for an isolated interface with a digital isolator or isolated transceiver. The required isolated power is generated on board. The design also provides indication for data transmit and data receive. The required device can be used based on the cost and functionality.

Design Resources

TIDA-00308	Design Folder
SN6501	Product Folder
ISO3088	Product Folder
ISO7221A	Product Folder
SN65HVD3082E	Product Folder
TPS7A6533-Q1	Product Folder
TLV70450	Product Folder
ISO7321C	Product Folder

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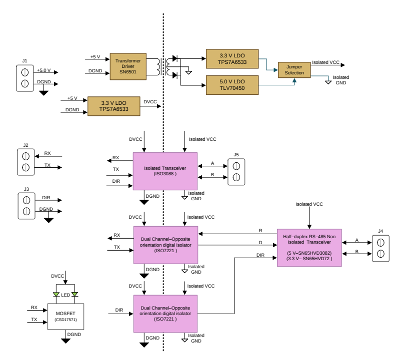
Design Features

- Demonstrates Half-Duplex Communication With These Types of Transceivers:
  - Interface to RS-485 Transceiver Through Digital Isolator
  - Digital Isolator Can be Bypassed for Non-Isolated Communication
  - Interface to Isolated RS-485 Transceiver
  - Isolator Interface Compatible to ISO7321 or ISO7221
  - For Non-Isolated interface, Compatible to Most 8-Pin Transceiver Devices Including SN65HVD888 With Polarity Correction Feature
- SN6501 Transformer Driver-Based Isolated power Supply
- Operates With Single 5-V Input
- External EMC Protection Provided as Part of Design
- LED Indication for TTL RS-232 Communication—Transmit and Receive Status
- LDOs to Generate Isolated and Non-Isolated Power Supplies

Featured Applications

- Smart Grid Automation Applications
- Protection Relays
- Circuit Breakers
- Remote IO or RTD Modules
- Panel Meters and Power Quality Meters
- MODBUS Protocol Converter



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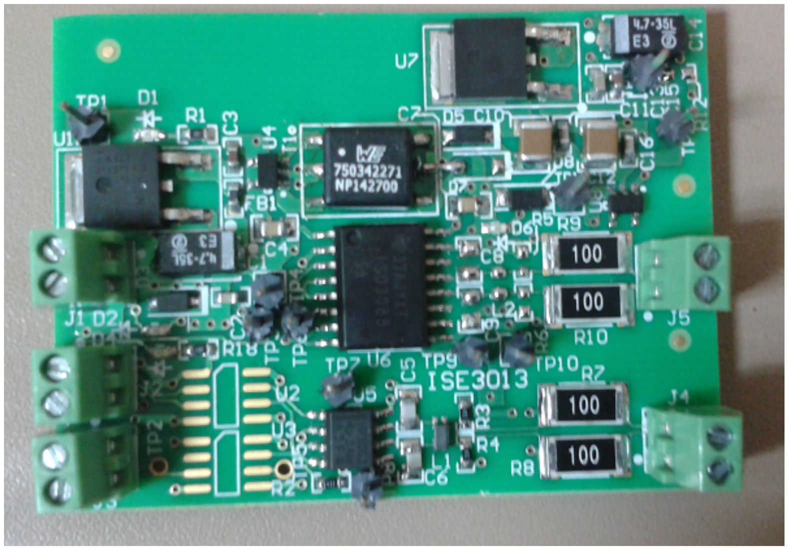
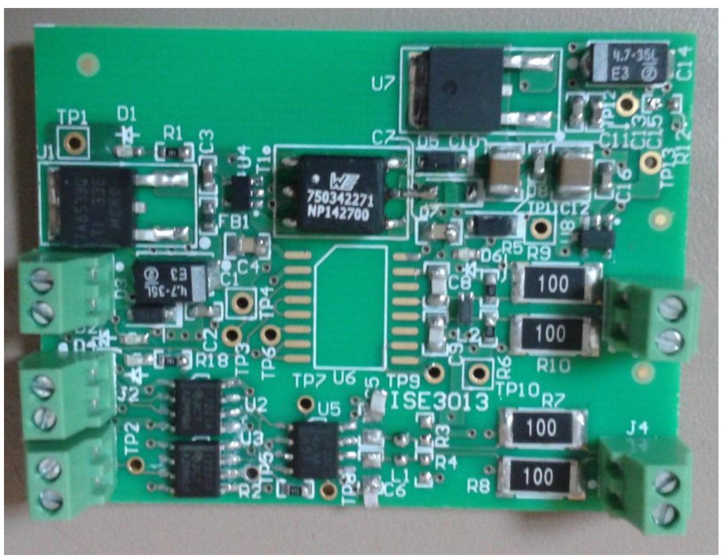


Isolated Transceiver



Digital Isolator-Based Communication

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1 System Description

1.1 Communication in Smart Grid

An electricity grid without adequate communications is simply a power broadcaster. It is through the addition of two-way communications that the power grid is made “smart.” Communications enables utilities to achieve three key objectives: intelligent monitoring, security and load balancing.

Using two-way communications, data can be collected from sensors and meters located throughout the grid and transmitted directly to the grid operator’s control room. This added communications capability provides enough bandwidth for the control room operator to actively manage the grid.

The communications must be reliable, secure, and low cost. The sheer scale of the electrical grid network makes cost a critical consideration when implementing a communications technology. Selecting a solution that minimizes the number of modems and concentrators needed to cover the entire system can dramatically reduce infrastructure costs. At the same time, the selected technology must have enough bandwidth to handle all data traffic being sent in both directions over the grid network.

1.2 Serial communications – RS-485

Industrial and instrumentation applications (I & I) require transmission of data between multiple systems often over very long distances. The RS-485 bus standard is one of the most widely used physical layer bus designs in I & I applications. The key features of RS-485 that make it ideal for use in I & I communications applications are:

- Long distance links of up to 4000 feet
- Bidirectional communications possible over a single pair of twisted cables
- Differential transmission increases noise immunity and decreases noise emissions
- Multiple drivers and receivers can be connected on the same bus
- Wide common-mode range allows for differences in ground potential between the driver and receiver
- TIA/EIA-485-A allow for data rates of up to 10 Mbps. Devices meeting the TIA/EIA-485-A specifications do not have to operate over the entire range and are not limited to 10 Mbps.

Achieve long cable runs in noisy environments

In harsh and noisy environments such as multi-unit residential buildings or industrial settings, an RS-485 bus architecture can be used to implement a low-cost, yet robust communications network. The differential nature of RS-485 signaling makes it less susceptible to external interference. Moreover, the RS-485 specification supports multidrop configurations, thus allowing the connection of multiple meters to a single bus. For instance, RS-485 can be used in an apartment building to transmit data from meters in each apartment to a central unit that aggregates the data from the individual meters, which can then be read through a wireless or PLC link. A similar approach can be used in industrial systems that require multiple cost centers to be metered.

1.2.1 RS-485 functionality

RS-485 is an electrical-only standard. In contrast to complete interface standards, which define the functional, mechanical, and electrical specifications, RS-485 only defines the electrical characteristics of drivers and receivers that could be used to implement a balanced multipoint transmission line. This standard, however, is intended to be referenced by higher level standards, such as DL/T645 for example, which defines the communication protocol for electronic energy-meters in China, specifying RS-485 as the physical layer standard.

Key features of RS-485 are:

- Balanced interface
- Multipoint operation from a single 5 V supply
- –7 V to +12 V bus common-mode range
- Up to 32 unit loads
- 10 Mbps maximum data rate (at 40 feet)
- 4000-foot maximum cable length (at 100 kbps)

RS-485 is well suited for long-distance networking in noisy environments. One reason for this is that RS-485 drivers provide a differential output of a minimum 1.5 V across a 54-Ω load, whereas receivers detect a differential input down to 200 mV. This provides sufficient margin for a reliable data transmission even under severe signal degradation across the cable and connectors.

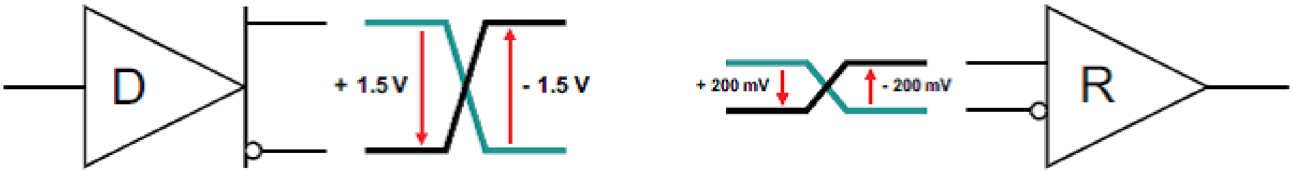


Figure 1. RS-485 Specified Minimum Bus Signal Levels

Differential signaling over twisted-pair cable also benefits RS-485 applications, because noise from external sources couples equally into both signal lines as common-mode noise, which is rejected by the differential receiver input.

The RS-485 standard suggests that its nodes be networked in a daisy-chain, also known as party line or bus topology (see Figure 2). In this topology, the participating drivers, receivers, and transceivers connect to a main cable trunk by way of short network stubs. The interface bus can be designed for full-duplex or Half-Duplex transmission (see Figure 3).

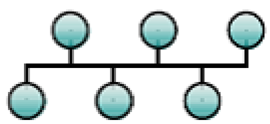


Figure 2. RS-485 Bus Structure

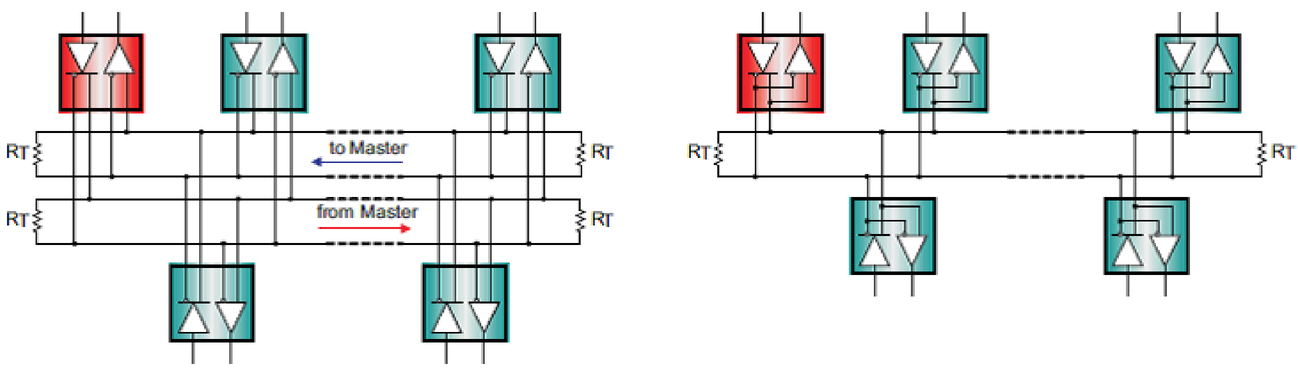


Figure 3. Full-duplex and Half-Duplex Bus Structures in RS-485

Data transmission lines should always be terminated and stubs should be as short as possible to avoid signal reflections on the line. Proper termination requires the matching of the terminating resistors, RT, to the characteristic impedance, Z0, of the transmission cable. Because the RS-485 standard recommends cables with Z0 = 120 Ω, the cable trunk is commonly terminated with 120-Ω resistors, one at each cable end. The maximum bus length is limited by the transmission line losses and the signal jitter at a given data rate.

1.2.2 How does RS-485 function in practice?

By default, all the senders on the RS-485 bus are in tri-state with high impedance. In higher level protocols, one of the nodes is defined as a master that sends queries or commands over the RS-485 bus. All other nodes receive this data. Depending on the information in the sent data, zero or more nodes on the line respond to the master. In this situation, almost 100% bandwidth can be used. There are other implementations of RS-485 networks in which every node can start a data session on its own. This is comparable with the way ethernet networks function. Because there is a chance of data collision with this implementation, theory indicates that in this case only 37% of the bandwidth will be effectively used. With such an implementation of a RS-485 network, error detection must be implemented in the higher level protocol to detect the data corruption and resend the information at a later time.

RS-485 drivers automatically return to their high impedance tri-state within a few microseconds after the data has been sent. Therefore it is not needed to have delays between the data packets on the RS-485 bus. RS-485 is used as the electrical layer for many well-known interface standards, including Modbus.

1.3 Characteristics of RS-485 compared to RS-232, RS-422

Table 1. Comparison Table

	RS-232	RS-422	RS-485
Differential	no	yes	yes
Modes of operation	Half-duplex Full-duplex	Half-Duplex	Half-Duplex
Network topology	point-to-point	Multi drop	multipoint
Max distance (acc. standard)	15 m	1200 m	1200 m
Max speed at 12 m Max speed at 1200 m	20 kbs (1 kbs)	10 Mbs 100 kbs	35 Mbs 100 kbs
Receiver input resistance	3...7 kΩ	≧ 4 kΩ	≧ 12 kΩ
Receiver input sensitivity	±3 V	±200 mV	±200 mV

1.4 RS-485 Features

1.4.1 RS-485 and the Unit Load Concept

The input impedance of the RS-485 receiver is specified as larger than or equal to 12 kΩ. This impedance is defined as having one unit load (UL). The RS-485 specification specifies the capability to sustain up to 32 ULs.

Some RS-485 receivers are specified as having ¼ UL or ⅛ UL. A receiver specified to have ¼ UL means that the receiver only loads the bus by ¼ of the standard UL and, therefore, 4 times as many of these receivers can be connected to the bus (4 × 32 = 128 nodes).

Similarly, if an RS-485 receiver is specified to have ⅛ UL, the receiver only loads the bus by ⅛ of the standard UL, and therefore 8 times as many of these receivers can be connected to the bus (8 × 32 = 256 nodes). See Table 2 for UL and receiver input impedance details.

Table 2. UL Receiver Input Impedance

Unit Load	No. of Loads	Min. Receiver Input impedance
1	32	12 K Ω
1/2	64	24 K Ω
1/4	128	48 K Ω
1/8	256	96 K Ω

1.4.2 Data Rates and Slew-Rate Limiting

At some time during the design of an RS-485 system, a maximum data rate appropriate for that system is determined. It then becomes necessary to choose the physical RS-485 devices capable of running at this speed. Devices are selected that are rated for speeds equal to or greater than the required data rate. Knowing this, there are disadvantages in choosing the fastest devices available, as they might be overkill.

Although fast devices can be used for both high data rates and low data rates, there are drawbacks in using devices that are faster than necessary, including higher radiated emissions and greater susceptibility to improper terminations.

Radiated emissions occur because the wiring used in RS-485 acts as an antenna. RS-485 tries to minimize radiated emissions by using twisted-pair cabling and balanced transmitters. The idea behind this is that the balanced transmitter generates two equal but opposite signals that are sent down the two wires in a twisted pair. Because the wires are virtually on top of each other, they tend to radiate the exact opposite signal that the other wire is transmitting. This has the effect of canceling each other out, and ideally results in no net radiated emissions. This tends to work fairly well, but is not perfect. Inevitably, some radiated emissions will leak out. As a general rule, the higher the frequency components in the signal and the longer the cable, the worse the situation.

The same applies to cable terminations. Because of the distances of the cabling and the data rates, careful attention must be paid to transmission-line effects. Both ends of an RS-485 cable should be properly terminated in the characteristic impedance of the cable to prevent reflections. Resistor and cable tolerances, among other things, can result in mismatches between these two impedances. This will result in reflections that reduce the noise margins and can ultimately cause loss of data. Similar to radiated emissions, the higher the frequency components sent down the cable and the longer the cable, the more likely it is that reflections will affect the system.

1.4.3 Fail-Safe

Fail-safe is ability of the Rx to assume a determined output state in the absence of an input signal. Deciding whether a termination resistor is necessary is only part of the problem in implementing an RS-485 system. Normally, an RS-485 receiver output is 1 if A > B by +200 mV or more, and 0 if B > A by 200 mV or more. In a Half-Duplex RS-485 network, the master transceiver tri-states the bus after transmitting a message to the slaves. Then, with no signal driving the bus, the output state of the receiver is undefined, as the difference between A and B tends towards 0 V. If the receiver output, RO, is 0, the slaves interpret it as a new start bit and attempt to read the following byte. The result is a framing error because the stop bit never occurs. The bus goes unclaimed, and the network stalls.

The four common faults that an RS-485 system can experience are as follows:

1. All transmitters in a system are in shutdown
2. The receiver is not connected to the cable
3. The cable has an open
4. The cable has a short

RS-485 specifies that the input threshold of a receiver be between ±200 mV differential, meaning that if the differential voltage on a receiver is 0 V, the output state is indeterminate. Unfortunately, unless designed otherwise, this is exactly what happens in each of the faults listed above. Worse, if a receiver has a threshold very close to 0 V, any noise coupled into it may be enough to trip the threshold and cause the output to chatter. This chatter can appear as a signal and confuse the system.

1.5 Selecting an RS-485 transceiver

To maintain signal quality over long cable lengths through noisy environments, designers should look for transceivers with the following features.

- **ESD protection** to prevent damage from handling and connection of the transceivers.
- **Fail-safe circuitry** to protect the design from open- and short-circuit conditions.
- **Slew-rate limiting** to reduce radiated emissions and data errors.
- **Hot-swap capability** to eliminate false transitions on the bus during power-up or live insertion of the transceiver.
- **Isolation** to protect against voltage spikes, ground loops, electrical storms, and so forth.
- **Auto-Direction** control to save an opto-coupler by eliminating the need for an isolated control channel.

1.6 Isolated Communication

1.6.1 System Isolation Overview

Computer and industrial serial interfacing are areas where noise can seriously affect the integrity of data transfer. A tested method of improving noise performance for any interface circuit is galvanic isolation. Isolation in data communication systems is achieved without direct galvanic connection (wires) between drivers and receivers. Magnetic linkage from transformers provides the power for the system, and TI's capacitively-coupled digital isolators provide the data connection. Galvanic isolation removes ground-loop currents, and the resulting noise voltage that corrupts data is eliminated. Also, common-mode noise effects and many forms of radiated noise can be reduced to negligible limits using this technique.

Unwanted currents and voltages on a cable bus connecting multiple systems could potentially cause severe problems. High voltages and currents can destroy components connected to the bus. These unwanted voltages and currents come primarily from two sources: ground loops and electrical line surges.

Ground loops occur when a bus or system utilizes multiple ground paths. It cannot be assumed that two system grounds connected to the bus and separated by hundreds or thousands of meters will be at the same potential. Because these grounds are unlikely to be at the same potential, current will flow between these points. This unintended current flow can damage or destroy components.

Electrical surges can be caused by many sources, the result of currents coupled onto cable lines through induction. Long cable lines in industrial environments are especially susceptible to this phenomena. The operation of electric motors, in particular, causes rapid changes in the ground potential. These changes can generate a current flow through any nearby lines to equalize the ground potential. Other induction surge sources include electrostatic discharge (ESD) and lightning strikes. These induced surges can result in hundreds, or even thousands of volts of potential on the line, and manifest themselves as transient current and voltage surges.

Thus, a remote node may receive a 5 V switching signal superimposed on a high voltage level with respect to the local ground. These uncontrolled voltages and currents can corrupt the signal and be catastrophic to the device and system, causing damage or destruction of the components connected to the bus and resulting in system failure. RS-485 systems that run over long distances and connect multiple systems are especially susceptible to these events.

To protect against this potentially destructive energy, all devices on the bus and systems connected to the bus must be referenced to only one ground. Isolating the RS-485 system devices from each of the systems connected to the bus prevents ground loops and electrical surges from destroying circuits. Isolation prevents ground loops, as each system connected to RS-485 cable bus, and each RS-485 circuit, has a separate and isolated ground. By referencing each RS-485 circuit only to one ground, ground loops are eliminated.

Isolation also allows the RS-485 circuit reference voltage levels to rise and fall with any surges that appear on the cable line. Allowing the circuit voltage reference to move with surges, rather than being clamped to a fixed ground, prevents devices from being damaged or destroyed. To accomplish system isolation, both the RS-485 signal lines and power supplies must be isolated. Power isolation is obtained through the use of an isolated DC to DC power supply. Signal isolation is typically accomplished with opto-couplers, or with TI Digital Isolators.

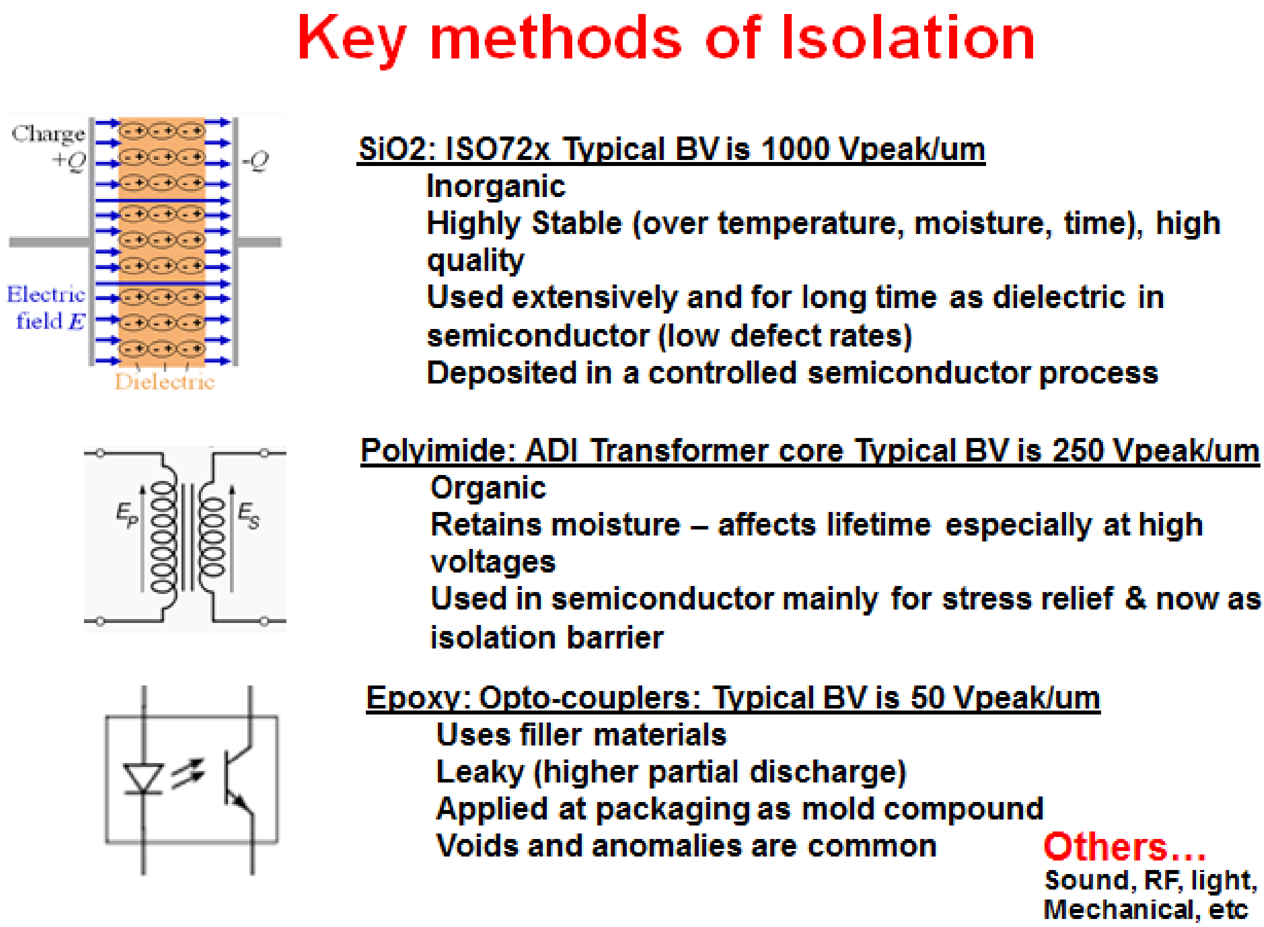


Figure 4. Key Isolation Methods

How reliable are they?

	Opto	Magnetic	Capacitive
Signaling Rate (Mbps)	50	150	150
Propagation Delay Time (ns)	20	32	12
Pulse Width Distortion (ns)	2	2	1.5
Channel-to-Channel skew (ns)	16	2.0	1.6
Part-to-Part Skew (ns)	20	10	2
ESD on all Pins (kV)	± 2	± 2	± 4
CM Transient Immunity (kV/us)	20	25	25
Temperature (°C)	-45..125	-40..125	-55..125
MTTF @ 125°C, 90% Confidence (yrs)	8	1746	2255
FIT@ 125°C, 90% Confidence	14391	65	50
Magnetic Immunity @ 1 kHz (Wb/m^2)	-	10^2	10^8
Radiated Electromagnetic-Field Immunity			
IEC61000-4-3 (80MHz-1000MHz)	-	Fails	Complies
MIL-STD 461E RS103 (30MHz-1000MHz)	-	Fails	Complies
High-Voltage Lifetime Expectancy (yrs)	<5	< 10	> 28

Figure 5. Isolation Solutions Reliability

1.6.2 Isolation Implementation

RS-485 system signal path isolation is accomplished by designing isolators into the digital signal path between the RS-485 driver and receiver, and the local system. The isolator contains input and output circuits electrically isolated from one another. To complete the isolation of the RS-485 circuits from the local system, a DC-to-DC isolated power converter is required. The isolated power supply supplies power to the local RS-485 driver, receiver, and RS-485 side of the isolator. The isolated power supply is typically supplied from the local system.

The combination of digital isolators and an isolated DC-to-DC power supply creates an effective protection against surge damage and eliminates ground loops.

1.6.3 Isolation Device Selection

System performance requirements have the most impact on the selection of an isolation device. Other considerations include space constraints and cost.

1.6.4 Data Rate Requirements

System data rate requirements are often the single most important parameter for device selection. If a system uses high data rates, such as the high speed PROFIBUS protocol, the minimum data rate speed requirement of 9.6 Mbps will narrow the device selection to the high performance products available. Conversely, if the RS-485 network runs at much lower data rate speeds, there are more possible device selection options.

Device costs typically rise in proportion to data rate performance. Therefore, a designer should take care not to specify a device with more performance than is required. However, low performance device selection can make future system performance upgrades more costly and involved, as all devices incompatible with upgraded system data speeds will require replacement.

1.6.5 Space Requirements

Space constraints are a second area of concern that can limit a designer’s choices. Maximum dimension requirements are a concern for virtually all applications. Some implementations can be severely space-limited. Fortunately, there are solutions for these situations.

1.6.6 Cost Requirements

Cost constraints and concerns are a reality in virtually all system design work. Cost considerations can have an effect on the design choices for a system. As noted above, isolator device cost rises in proportion with data rate performance. Specifying a device with only the system performance required can reduce costs. Other cost issues include a consideration of the number of devices used.

Additional cost benefits of integrating as many channels into one device include reduction in board space and assembly costs. A lower device count results in smaller boards. Also, lower device count typically results in a less complex board layout. The combination of smaller boards and less complex layout reduces board costs. In addition, circuit board assembly costs typically decrease proportionally as the number of devices required for the board assembly process decreases. Therefore, designing with fewer devices results in lower manufacturing costs.

1.7 EMC Transient Overvoltage Stress Protection

In industrial applications, lightning strikes, power source fluctuations, inductive switching, and electrostatic discharge can cause damage to RS-485 transceivers by generating large transient voltages. The following ESD protection, EFT protection, and surge protection specifications are relevant to RS-485 applications:

- IEC 61000-4-2 ESD protection
- IEC 61000-4-5 surge protection

The level of protection can be further enhanced when using external clamping devices, such as TVS diodes. TVS diodes are normally used to protect silicon devices, such as RS-485 transceivers, from transients. The protection is accomplished by clamping the voltage spike to a limit, by the low impedance avalanche breakdown of a PN junction. TVS diodes are ideally open-circuit devices. A TVS diode can be modeled as a large resistance in parallel with some capacitance while working below its breakdown voltage. When a transient is generated and the surge voltage is larger than the breakdown voltage of the TVS, the resistance of the TVS decreases to keep the clamping voltage constant. The TVS clamps the pulse to a level that does not damage the device that it is protecting. The transients are clamped instantaneously (< ns) and the damaging current is diverted away from the protected device.

The function of a TVS in RS-485 applications is to clamp the voltage on the bus to the common-mode voltage range of the RS-485 transceiver (−7 V to +12 V). Some TVS devices are specifically-designed for RS-485 applications. For higher power transients, protection can be increased by adding Resistors RS (between 10 Ω and 20 Ω) between the protected device and the input pin.

1.8 TI solutions for RS-485 and Current Design Solution Advantage

TI has a wide range of RS-485 transceivers.

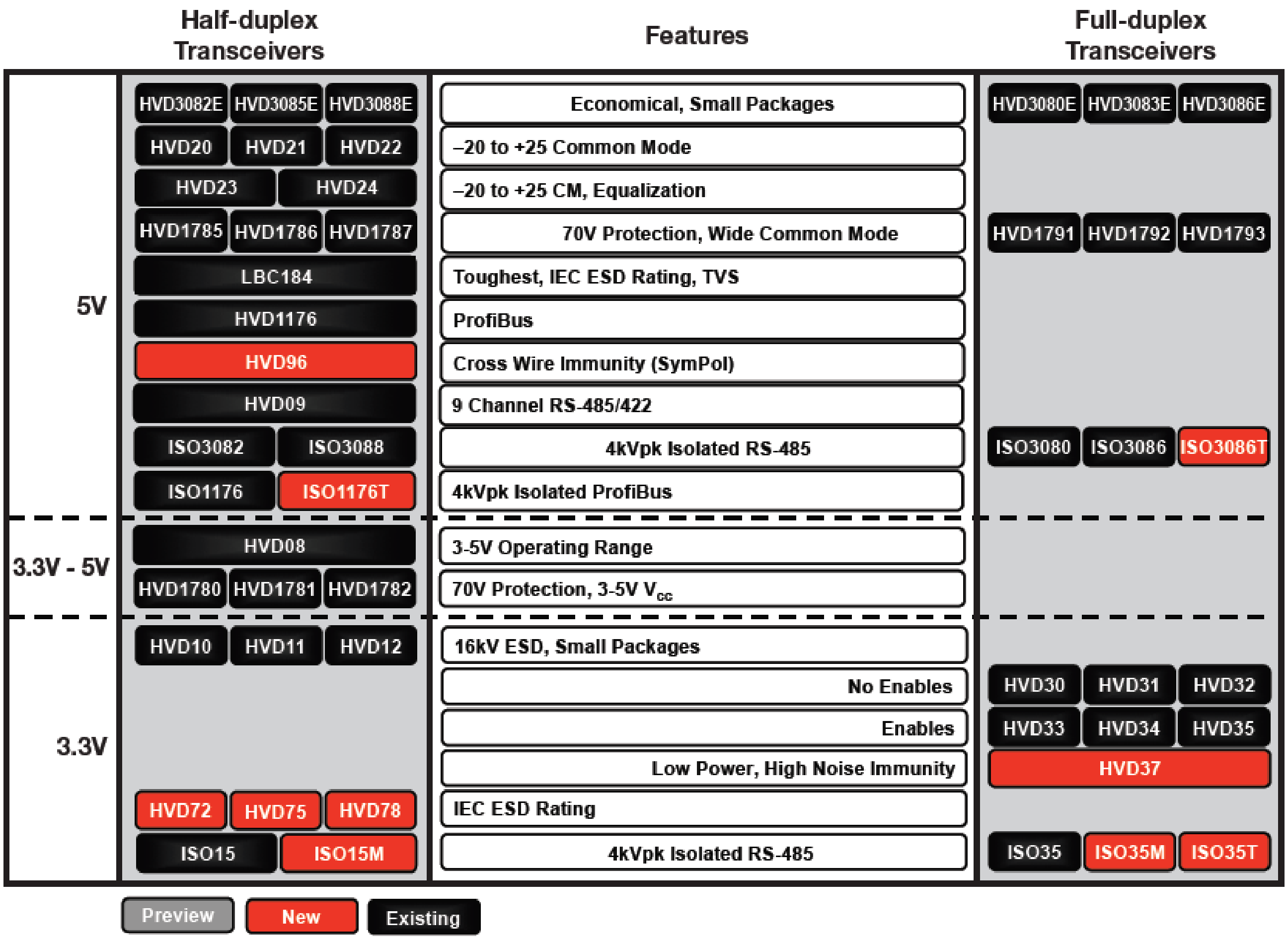


Figure 6. RS-485 Half-Duplex Portfolio

1.8.1 Overview of Isolated Transceivers

ISO3088 isolated RS-485 transceivers have a logic input and output buffer separated by a silicon oxide (SiO2) insulation barrier. Used in conjunction with isolated power supplies, these devices block high voltage, isolate grounds, and prevent noise currents on a data bus or other circuits from entering the local ground and interfering with or damaging sensitive circuitry.

These devices are ideal for long transmission lines, as the ground loop is broken to allow for a much larger common-mode voltage range. The symmetrical isolation barrier of the device is tested to provide 2500 Vrms of isolation for 60s between the bus-line transceiver and the logic-level interface. Any cabled I/O can be subjected to electrical noise transients from various sources. These noise transients can cause damage to the transceiver and/or near-by sensitive circuitry if they are of sufficient magnitude and duration. These isolated devices can significantly increase protection and reduce the risk of damage to expensive control circuits. The pin-outs of the isolated RS-485 transceivers are displayed below. The EVM comes with the ISO3082 Half-Duplex transceiver installed, however a user may reconfigure the EVM for use with any of the devices or may contact TI for a factory installation of any of the other devices.

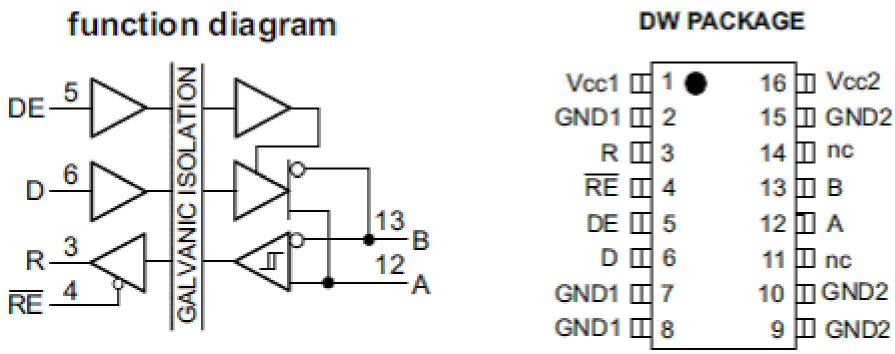


Figure 7. The ISO15, ISO3082, and ISO3088 Half-Duplex Function Diagram and Pinout

1.8.2 TI RS-485 Half-Duplex

TI RS-485 Half-Duplex devices in the 8-pin SOIC package have robust drivers and receivers in a small package, for demanding industrial applications. The bus pins are robust to ESD events, with high levels of protection to Human-Body Model and IEC Contact Discharge specifications. These devices each combine a differential driver and a differential receiver, which operate from a single power supply. The driver differential outputs and the receiver differential inputs are connected internally to form a bus port suitable for Half-Duplex (two-wire bus) communication, and all feature a wide common-mode voltage range making the devices suitable for multi-point applications over long cable runs. TI's RS-485 devices are characterized for industrial applications.

1.8.3 ISO72x Family of High-Speed Digital Isolators

The Texas Instruments ISO72x family of isolators use capacitive coupling. The capacitive coupling solution uses proven and cost-effective manufacturing processes and provides an inherent immunity to magnetic fields.

To provide transfer of steady-state information, the ISO72x uses both a high-signaling rate and low-signaling rate channel to communicate as shown in Figure 8. The high-signaling rate channel is not encoded and it transmits data transitions across the barrier after a single-ended-to-differential conversion. The low-signaling rate channel encodes the data in a pulse-width modulated format and transmits the data across the barrier differentially, ensuring the accurate communication of steady-state conditions (a long string of 1s or 0s).

Differential transfer of the single-ended logic signal across the isolation barrier allows low-level signals and small coupling capacitance. This appears high impedance to common-mode noise and, with the common-mode noise rejection of the receiver, gives excellent transient immunity, the primary concern in capacitive coupling of signals.

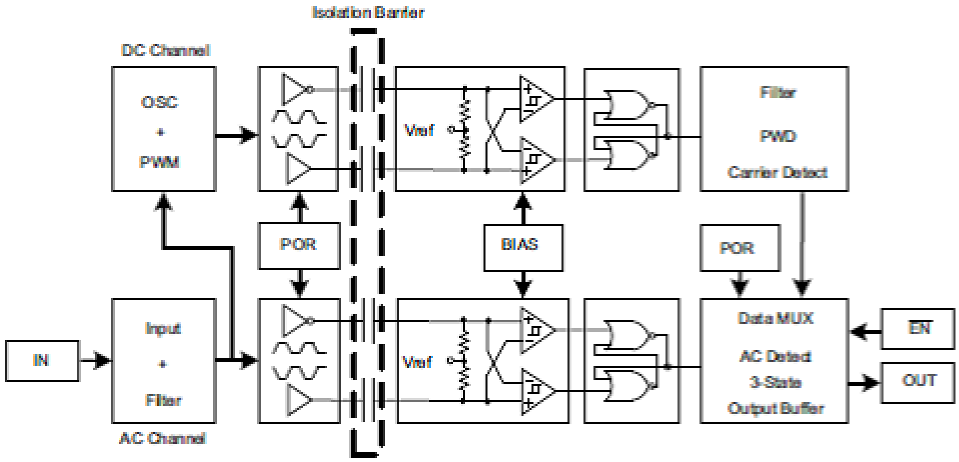


Figure 8. : ISO72x Isolator Internal Diagram

1.8.3.1 Power Consumption

Beyond the efficiency of the signal transfer across the barrier, the design of the input and output conditioning circuitry has the most to do with power consumption. As shown in Figure 9, the optocouplers use more power than the inductive or capacitive examples.

Table 3. Quiescent Power-Supply Current

Part	Coupling Technology	Vcc1 and Vcc2 (V)	Icc1 (mA)	Icc2 (mA)	Power (mW)
ISO721	Capacitive	5	1	11	60
		3.3	0.5	6	21.5
ADuM1100	Magnetic	5	0.8	0.06	4.3
		3.3	0.3	0.04	1.2
HCPL-0900	Magnetic	5	0.018	6	30
		3.3	0.01	4	13.2
HCPL-0721	Optical	5 Only	10 (1)	9	95
HCPL-0723	Optical	5 Only	10 (1)	17.5 (2)	137.5

(1) 10 mA is for the logic-low input state. When the logic input state is high, then the current consumption drops to 3 mA.
(2) 17.5 mA is for the logic-low input state. When the logic input state is high, then the current consumption drops to 16.5 mA.

Figure 9. Quicent Power Supply Current Table

1.8.3.2 Reliability

Mean time to failure (MTTF) is a standard measure for reliability of semiconductor devices. For digital isolators, this measure represents the reliability of both the integrated circuit and the isolation mechanism. Figure 10 shows the MTTF of an optical, inductive, and capacitive digital isolator. The ISO721 is very reliable when compared to inductive and optical solutions.

Table 4. MTTF Reliability Measurements

			Typical, 60% Confidence		Typical, 90% Confidence	
Part	Coupling Technology	Ambient Temperature (°C)	MTTF (Hr/Fail.)	FITs (Fail./10^9 Hr)	MTTF (Hr/Fail.)	FITs (Fail./10^9 Hr)
ISO721	Capacitive	125	1,246,889	802	504,408	1983
HCPL-0900	Inductive	125	288,118	3471	114,654	8722
HCPL-0721	Optical	125	174,617	5727	69,487	14,391

Figure 10. MTTF Reliability Measurement

1.8.4 Current TI Design Advantage

This TI design demonstrates the following:

- TI Half-Duplex isolated transceivers
- TI capacitive isolator connected to Half-Duplex transducer transceiver
- TI RS-485 transceiver – Half-Duplex
- Isolated power supply with transformer driver
- 3.3 V and 5 V LDOs

With this TI design, customers can design Half-Duplex communication modules for the following requirements:

- No isolated power supply available in the current product
- Isolated power supply is available in the current product
- Isolated communication required in the current product
- Non isolated communication is required in the current product
- If the current product design does not have RS-485 communication and has to be added as a sub-system outside the board (add-on module or design changes)

2 Design Features

Table 3. Design Features

Requirements	Specifications /Features
Isolated Transceiver for Half-Duplex communication	ISO3088DW
Isolators for Half-Duplex communication	ISO7221AD or ISO7320C
Non Isolated Hal-Duplex Transceiver	SN65HVD3082ED
Isolated DC-DC Converter Driver	SN6501
Power Supply	Non-Isolated 3.3 V - TPS7A6533QKVURQ1
	Isolated 3.3 V (TPS7A6533QKVURQ1) – Optional 5 V TLV70450DBV
Communication Indications	Two LEDs with MOSFET driver to indicate TTL data transmit and receive
Power Indications	Two LEDs to Indicate 5 V and 3.3 V status
Interface	Screw type connectors
ESD Immunity	IEC 61000-4-2 , 4KV contact discharge
Surge Transient Immunity	IEC 61000-4-5: ±1.0 kV
Transmission rate	Min. 4800 baud

3 Block Diagram

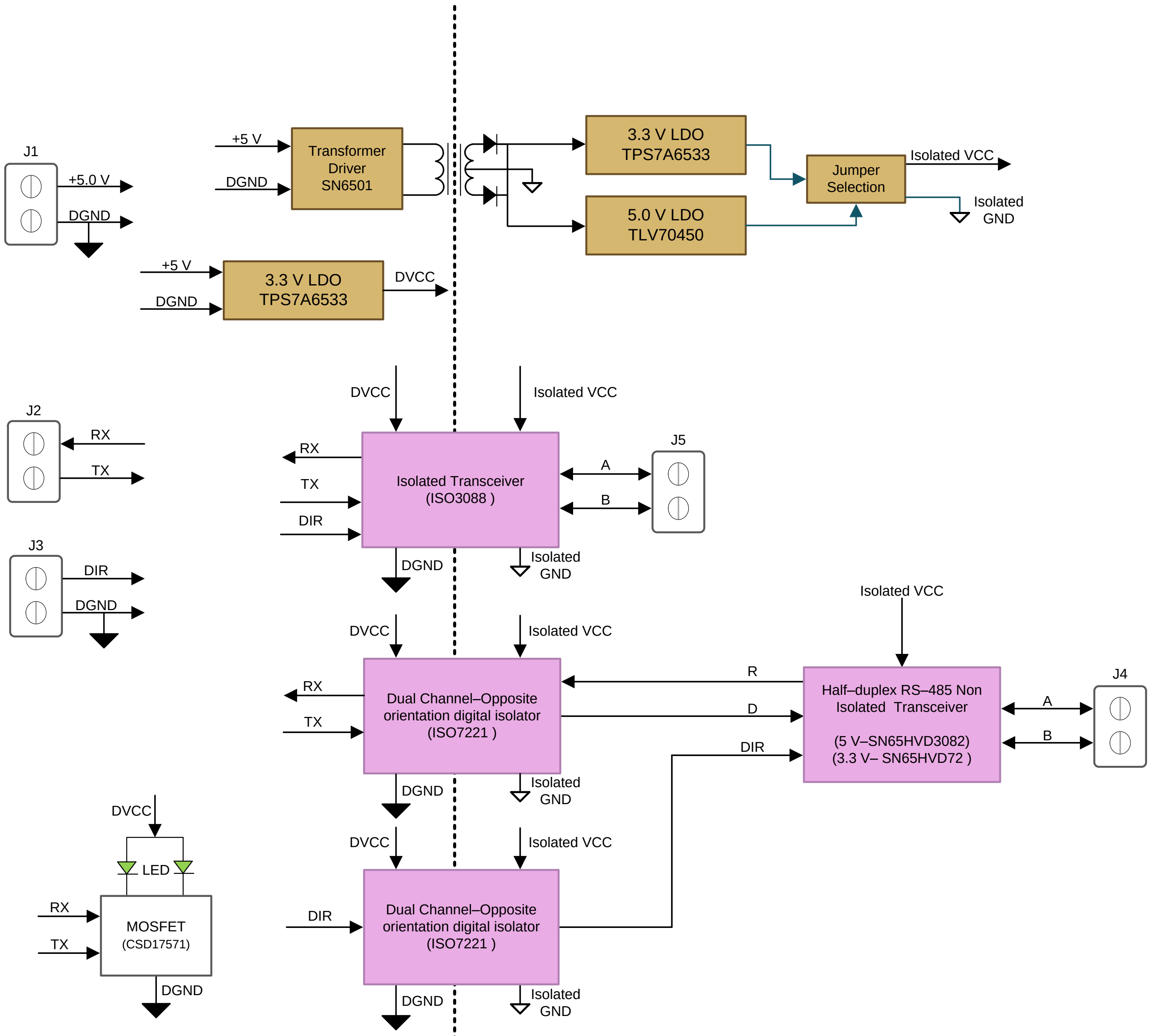


Figure 11. RS-485 Interface Module Block Diagram

3.1 *Isolated Transceiver*

ISO3088 is an isolated Half-Duplex differential line transceiver, used for isolating the RS-485 signals.

3.2 *Digital Isolator*

ISO7221A is a Dual Channel Opposite Polarity, 1/1, 1 Mbps Digital Isolator used for providing isolation to the RS-485 signals when the board is configured for the isolator based RS-485 interface .

3.3 *RS-485 Half-Duplex Transceiver*

Provision to mount 8-pin Half-Duplex transceiver has been provided in this design. The following Half-Duplex devices have been used in this TI design:

- SN65HVD3082E is a low-power Half-Duplex RS-485 transceiver for 5 V
- SN65HVD72 is a low-power Half-Duplex RS-485 transceiver for 3.3 V (Pin compatible - not tested)

3.4 Transformer Drive for Isolated Power

SN6501 Transformer Driver is used for generating isolated power. The SN6501 is a monolithic oscillator/power-driver, specifically designed for small form factor, isolated power supplies in isolated interface applications.

3.5 Power Supply

The following LDOs are used in this design

- TPS7A6533-Q1 300-mA 40-V Low-Dropout Regulator with Ultra-Low Quiescent Current to generate 3.3 V for isolated or non-isolated power supply.
- TLV70450 150 mA, Ultra-Low IQ, High Vin low-dropout regulator to generate isolated 5 V power supply.

Table 4. Transceivers and Digital Isolator Current

Device	Non Isolated Side – Current	Isolated Side - Current
ISO3088	Icc1 Logic-side supply current, 10 mA	Icc2 Bus-side supply current, 15 mA
ISO7221A	Icc1, 18 mA	Icc2, 18 mA
SN65HVD3082E	Max ~ 10 mA	

3.6 LEDs

Two LEDs are provided to indicate transmission and reception of the host data.The LEDs are driven by MOSFET to minimize loading of the host signals. LEDs are provided for transmit and receive. 30 V N-channel NexFET Power MOSFETs, CSD17571Q2 drives the LEDs .

4 Circuit Design and Component Selection

4.1 Isolated Transceiver

The ISO3088 is an isolated Half-Duplex differential line transceiver for TIA/EIA 485/422 applications. These devices are ideal for long transmission lines, as the ground loop is broken to allow for a much larger common-mode voltage range. The symmetrical isolation barrier of the device is tested to provide 2500 Vrms of isolation for 60s between the bus-line transceiver and the logic-level interface. Any cabled I/O can be subjected to electrical noise transients from various sources. These noise transients can cause damage to the transceiver or near-by sensitive circuitry if they are of sufficient magnitude and duration. These isolated devices can significantly increase protection and reduce the risk of damage to expensive control circuits.

The ISO3088 is qualified for use from –40°C to 85°C.

4.1.1 Features

- 4000-V_{PEAK} Isolation, 560-V_{peak} V_{IORM}
  - UL 1577, IEC 60747-5-2 (VDE 0884, Rev. 2), IEC 61010-1, IEC 60950-1 and CSA Approved
- Bus-Pin ESD Protection
  - 12 kV HBM Between Bus Pins and GND2
  - 6 kV HBM Between Bus Pins and GND1
- 1/8 Unit Load – Up to 256 Nodes on a Bus
- Meets or Exceeds TIA/EIA RS-485 Requirements
- Signaling Rates up to 20 Mbps
- Thermal Shutdown Protection
- Low Bus Capacitance – 16 pF (Typ)
- 50 kV/µs Typical Transient Immunity
- Fail-safe Receiver for Bus Open, Short, Idle
- 3.3-V Inputs are 5-V Tolerant

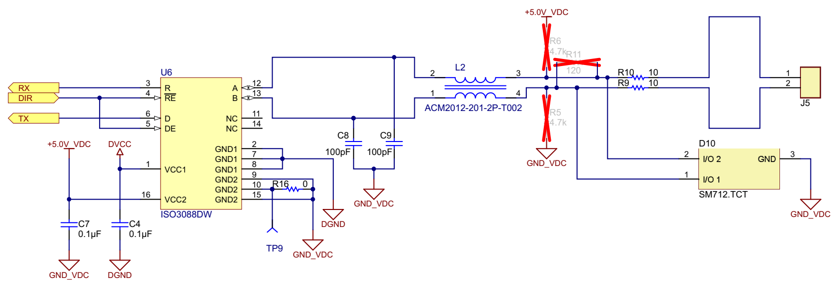


Figure 12. Isolated Transceiver

4.2 Digital Isolator

The ISO7221 is a dual-channel digital isolator. To facilitate PCB layout, the channels are oriented in opposite directions in the ISO7221. These devices have a logic input and output buffer separated by TI's silicon-dioxide (SiO_2) isolation barrier, providing galvanic isolation of up to 4000 VPK. Used in conjunction with isolated power supplies, these devices block high voltage, isolate grounds, and prevent noise currents on a data bus or other circuits from entering the local ground and interfering with or damaging sensitive circuitry.

A binary input signal is conditioned, translated to a balanced signal, then differentiated by the capacitive isolation barrier. Across the isolation barrier, a differential comparator receives the logic transition information, then sets or resets a flip-flop and the output circuit accordingly. A periodic update pulse is sent across the barrier to ensure the proper DC level of the output. If this DC-refresh pulse is not received every 4 µs, the input is assumed to be unpowered or not being actively driven, and the fail-safe circuit drives the output to a logic high state.

These devices require two supply voltages of 2.8 V (C-Grade), 3.3 V, 5 V, or any combination. All inputs are 5 V tolerant when supplied from a 3.3 V supply, and all outputs are 4 mA CMOS.

These devices are characterized for operation over the ambient temperature range of –40°C to 125°C.

4.2.1 Features

- 1, 5, 25 Signaling Rate Options
  - Low Channel-to-Channel Output Skew; 1 ns max
  - Low Pulse-Width Distortion (PWD); 1 ns max
  - Low Jitter Content
- Typical 25-Year Life at Rated Voltage (see app. note SLLA197)
- 4000 VPK VIOTM, 560 VPK VIORM per IEC 60747-5-2 (VDE 0884, Rev2)
- UL 1577, IEC 61010-1, IEC 60950-1 and CSA Approved
- 50 kV/µs Typical Transient Immunity
- Operates with 2.8-V (C-Grade), 3.3-V or 5-V Supplies
- 4 kV ESD Protection
- High Electromagnetic Immunity
- –40°C to 125°C Operating Range
- Applications:
  - Industrial Fieldbus
    - Modbus
    - Profibus™
    - DeviceNet Data Buses
  - Computer Peripheral Interface
  - Servo Control Interface
  - Data Acquisition

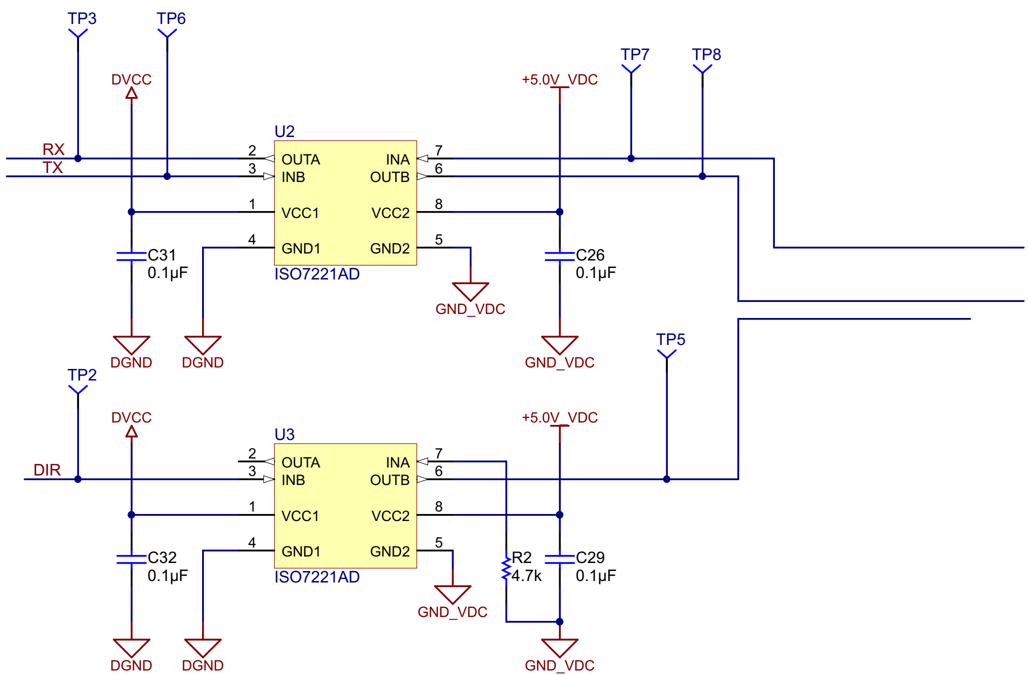


Figure 13. Digital Isolator

4.3 RS-485 Half-Duplex Transceiver

4.3.1 Option 1 – 5V Supply

These devices are Half-Duplex transceivers designed for RS-485 data bus networks. Powered by a 5 V supply, they are fully compliant with the TIA/EIA-485A standard. With controlled transition times, these devices are suitable for transmitting data over long twisted-pair cables. SN65HVD3082E and SN75HVD3082E devices are optimized for signaling rates up to 200 kbps. These devices are designed to operate with very low supply current, typically 0.3 mA, exclusive of the load. When in the inactive shutdown mode, the supply current drops to a few nanoamps, making these devices ideal for power-sensitive applications.

The wide common-mode range and high ESD protection levels of these devices make them suitable for demanding applications such as energy meter networks, electrical inverters, status/command signals across telecom racks, cabled chassis interconnects, and industrial automation networks where noise tolerance is essential. These devices match the industry-standard footprint of SN75176. Power-on reset circuits keep the outputs in a high impedance state until the supply voltage has stabilized. A thermal shutdown function protects the device from damage due to system fault conditions. The SN75HVD3082E is characterized for operation from 0°C to 70°C, and SN65HVD308xE are characterized for operation from -40°C to 85°C air temperature.

4.3.1.1 Features

- Available in a Small MSOP-8 Package
- Meets or exceeds the requirements of the TIA/EIA\x92485A Standard
- Low Quiescent Power
  - 0.3 mA Active Mode
  - 1 nA Shutdown Mode
- 1/8 Unit Load-up to 256 Nodes on a Bus
- Bus-Pin ESD Protection up to 15 kV
- Industry-Standard SN75176 Footprint
- Failsafe Receiver (Bus Open, Bus Shorted, Bus Idle)
- Glitch-Free Power-Up/Down Bus Inputs and Outputs

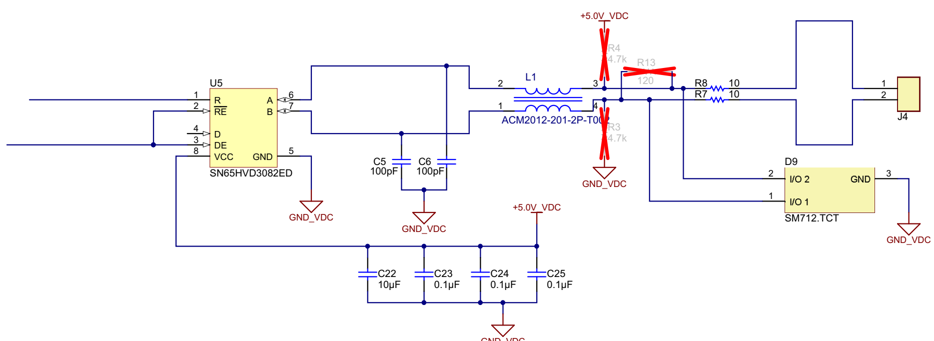


Figure 14. Half-Duplex Transceiver

4.3.2 Option 2 – 3.3 V Supply (Not Tested)

These devices have robust 3.3 V drivers and receivers in a small package for demanding industrial applications. The bus pins are robust to ESD events, with high levels of protection to Human-Body Model and IEC Contact Discharge specifications.

These devices each combine a differential driver and a differential receiver, which operate from a single 3.3 V power supply. The driver differential outputs and the receiver differential inputs are internally connected to form a bus port suitable for Half-Duplex (two-wire bus) communication. These devices feature a wide common-mode voltage range, making the devices suitable for multi-point applications over long cable runs. These devices are characterized from –40°C to 125°C.

4.3.2.1 Features

- Small-size MSOP Packages Save Board Space, or SOIC for Drop-in Compatibility
- Bus I/O Protection
  - > ±15kV HBM protection
  - > ±12kV IEC61000-4-2 Contact Discharge
- Extended Industrial Temperature Range –40°C to 125°C
- Large Receiver Hysteresis (80 mV) for Noise Rejection
- Low Unit-loading allows over 200 connected nodes
- Low Power Consumption
  - Low Standby Supply Current: < 2 µA
  - I_{CC} < 1 mA Quiescent During Operation
- 5V-Tolerant Logic Inputs Compatible With 3.3 V or 5 V Controllers
- Signaling Rate Options Optimized for: 250 kbps and 20 Mbps

4.4 Transformer Drive for Isolated Power

The SN6501 is a monolithic oscillator/power-driver, specifically designed for small form factor, isolated power supplies in isolated interface applications. It drives a low-profile, center-tapped transformer primary from a 3.3 V or 5 V DC power supply. The secondary can be wound to provide any isolated voltage based on transformer turns ratio.

The SN6501 consists of an oscillator followed by a gate drive circuit that provides the complementary output signals to drive the ground-referenced, N-channel power switches. The internal logic ensures break-before-make action between the two switches.

The SN6501 is available in a small SOT23-5 package, and is specified for operation at temperatures from –40°C to 125°C.

4.4.1 Features

- Push-Pull Driver for Small Transformers
- Single 3.3 V or 5 V Supply
- High Primary-side Current Drive:
  - 5 V Supply: 350 mA (max)
  - 3.3 V Supply: 150 mA (max)
- Low Ripple on Rectified Output Permits Small Output Capacitors
- Small 5-pin SOT23 Package

NOTE: For a higher output current requirement, consider the SN6505A.

4.5 Power Supply

4.5.1 3.3 V Power Supply

The TPS7A65xx-Q1 is a family of low-dropout linear voltage regulators designed for low power consumption and quiescent current less than 25 µA in light-load applications. These devices feature integrated overcurrent protection and a design to achieve stable operation even with low-ESR ceramic output capacitors. A low-voltage tracking feature allows for a smaller input capacitor, and can possibly eliminate the need of using a boost converter during cold crank conditions. Because of these features, these devices are well-suited in power supplies for various automotive applications.

4.5.1.1 Features

- Low Dropout Voltage
  - 300 mV at I_{OUT} = 150 mA
- 4 V to 40 V Wide Input Voltage Range with up to 45-V Transients
- 300 mA Maximum Output Current
- 25 µA (Typ) Ultralow Quiescent Current at Light Loads
- 3.3 V and 5 V Fixed Output Voltage with ±2% Tolerance
- Low-ESR Ceramic Output Stability Capacitor
- Integrated Fault Protection
  - Short-Circuit and Overcurrent Protection
  - Thermal Shutdown
- Low Input-Voltage Tracking

4.5.2 5 V Power Supply

The TLV704xx series of low dropout (LDO) regulators are ultralow quiescent current devices designed for extremely power-sensitive applications. Quiescent current is virtually constant over the complete load current and ambient temperature range. These devices are an ideal power management attachment to low-power microcontrollers, such as the MSP430.

The TLV704xx operate over a wide operating input voltage of 2.5 V to 24 V, making it an excellent choice for both battery-powered systems, as well as industrial applications that see large line transients. The TLV704xx is available in a 3 mm × 3 mm SOT23-5 package, which is ideal for cost-effective board manufacturing.

4.5.2.1 Features

- Wide Input Voltage Range: 2.5 V to 24 V
- Low 3.2 µA Quiescent Current
- Ground Pin Current: 3.4 µA at 100 mA I_{OUT}
- Stable with Any Capacitor (> 0.47 µF)
- Operating Junction Temperature: –40°C to +125°C
- Available in SOT23-5 Package

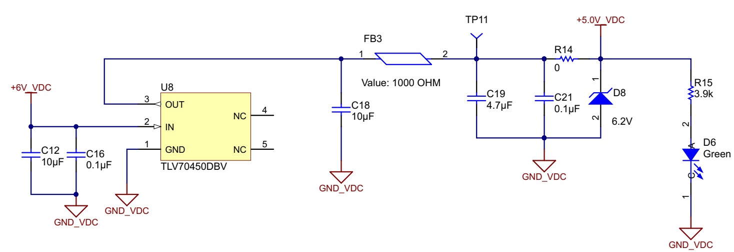


Figure 15. 5V Regulator

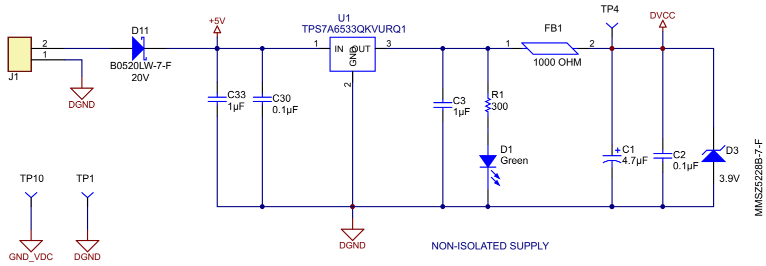


Figure 16. 3.3V Regulator

4.6 LEDs

The Mosfet used is a 30 V, 20 mΩ, Son2x2 NexFET power MOSFET designed to minimize losses in power conversion and load management applications, while offering excellent thermal performance for the size of the package.

4.6.1 Features

- Low Q_g and Q_{gd}
- Low Thermal Resistance
- Avalanche Rated
- Pb-Free Terminal Plating
- RoHS Compliant

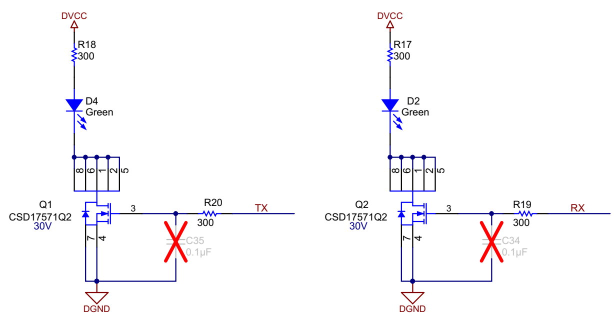


Figure 17. Communication Indication LEDs

4.7 Tiva C Series LaunchPad interface

The Tiva™ C Series LaunchPad (EK-TM4C123GXL) is a low-cost evaluation platform for ARM® Cortex™-M4F-based microcontrollers. The Tiva C Series LaunchPad design highlights the TM4C123GH6PMI microcontroller USB 2.0 device interface, hibernation module, and motion control pulse-width modulator (MC PWM) module. The Tiva C Series LaunchPad also features programmable user buttons and an RGB LED for custom applications. The stackable headers of the Tiva C Series LaunchPad BoosterPack XL interface demonstrate how easy it is to expand the functionality of the Tiva C Series LaunchPad when interfacing to other peripherals on many existing BoosterPack add-on boards as well as future products. Figure 18 shows a photo of the Tiva C Series LaunchPad.

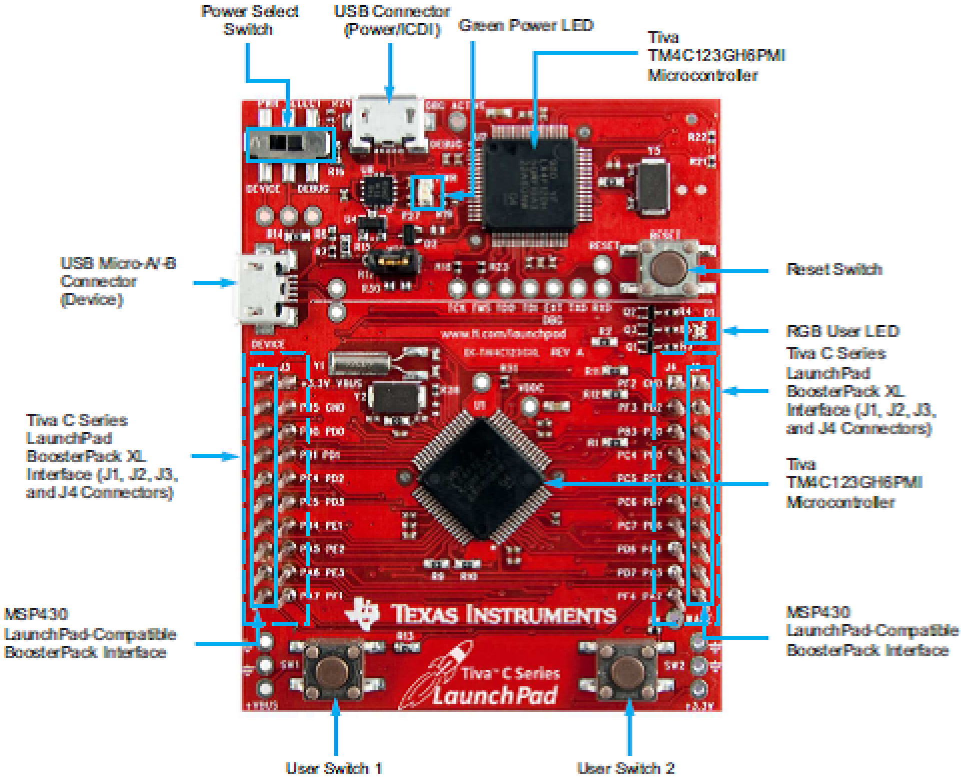


Figure 18. Tiva C Series TM4C123G LaunchPad Evaluation Board

4.8 PCB Design – General Guidelines

- Creepage and clearance requirements should be applied according to the specific application isolation standards. Care should be taken to maintain these distances on the board design to ensure that the mounting pads for the isolator do not reduce this distance. Creepage and clearance on the printed-circuit board become equal in certain cases. Techniques such as inserting grooves and/or ribs on the printed circuit board are used to help increase these specifications.
- An SMD ceramic bypass capacitor of approximately 0.1 µF in value is recommended. If leaded components are necessary, leads should be kept as short as possible to minimize lead inductance.
- A continuous ground plane is ideal for providing a low-impedance signal return path, as well as generating the lowest EMI signature by reducing phenomena such as unintended current loops.
- Should a continuous ground plane not be possible, minimize the length of the trace connecting VCC and ground.
- Isolated communication may often have to meet specified creepage and clearance criteria. Creepage and clearance requirements are determined by the end-use device specifications.
- PCB material - Standard FR-4 epoxy-glass as printed-circuit board (PCB) material is preferred for industrial applications wirh speed <100 Mhz l. FR-4 (Flame Retardant 4) meets the requirements of Underwriters Laboratories UL94-V0 and is preferred over cheaper alternatives due to its lower dielectric losses at high frequencies, less moisture absorption, greater strength and stiffness, and its self-extinguishing, flammability characteristics.
- Trace Routing - Use 45° bends (chamfered corners), instead of right-angle (90°) bends. Right-angle bends increase the effective trace width, and thus the trace impedance. This creates additional impedance mismatch, which may lead to higher reflections.

4.9 Board Configuration for Communication Testing

Table 5. RS-485 Communication with Isolated Transceiver

IC	Mounting Option
ISO7221A	Not Mounted
ISO3088D	Mounted
SN65HVD3082	Not Mounted
Isolated 3.3 V LDO	Not Mounted
Isolated 5 V LDO	Mounted

Table 6. RS-485 with Digital Isolator

IC	Mounting Option
ISO7221A	Mounted
ISO3088D	Not Mounted
SN65HVD3082	Mounted
Isolated 3.3 V LDO	Not Mounted
Isolated 5 V LDO	Mounted

Table 7. RS-485 without Isolation – For 5 V Transceivers

IC	Mounting Option
ISO7221A	Not Mounted
ISO3088D	Not Mounted, shorted through jumpers
SN65HVD3082	Mounted
Isolated 3.3 V LDO	Not Mounted
Isolated 5 V LDO	Mounted

4.10 Enhancements or Device Selection

Table 8 provides some of the devices that can be considered for RS-485 interface modules. The device selection can be based on the application requirement.

Table 8. TI Product Selection for RS-485 Interface Module

Product	Device Part Number	Description
Transceiver	ISO3082	2.5-kV_{RMS} Isolated 5-V Half-Duplex RS-485 Transceiver
Transceiver	SN65HVD3088E	Low-power Half-duplex RS-485 Transceiver
Transceiver	SN65HVD08	3.3- or 5-V RS-485 Transceiver
Digital Isolator	ISO7421E	Low-Power Dual Channel Digital Isolators
Digital Isolator	ISO7321C	Robust EMC, Low Power, Dual-Channel 1/1 Digital Isolator, Fail-safe High
Transformer Drive	SN6505A	Low-Noise 1-A Transformer Driver for Isolated Power Supplies, Internal Clock-160 kHz

Visit this page for more device options and selections: http://www.ti.com/lsds/ti/interface/rs-485-products.page#.

4.11 Application—Serial-to-Ethernet Converter

This TI Design can be interfaced with the TIDA-00226 for designing an isolated serial-to-Ethernet converter. This design can be used in applications that connect a Modbus RS-485 interface to the Ethernet for remote monitoring.

See the following link for details: http://www.ti.com/tool/TIDA-00226.

5 Test Results

5.1 Functional Testing

Table 9. Measurements

Parameters	Specification	Measurement
Isolated Supply – LDO output	3.3 V	3.28
	5 V	5.01
Non-isolated Supply – LDO output	3.3 V	3.29
LED indication for Power Supply	2 LEDs ON	OK
LED Indication for Communication	Transmit and Receive LEDs toggle	OK
Digital Isolator Data Output	Error free communication	OK
Digital Isolator Data Direction Control Output	Error free communication	OK

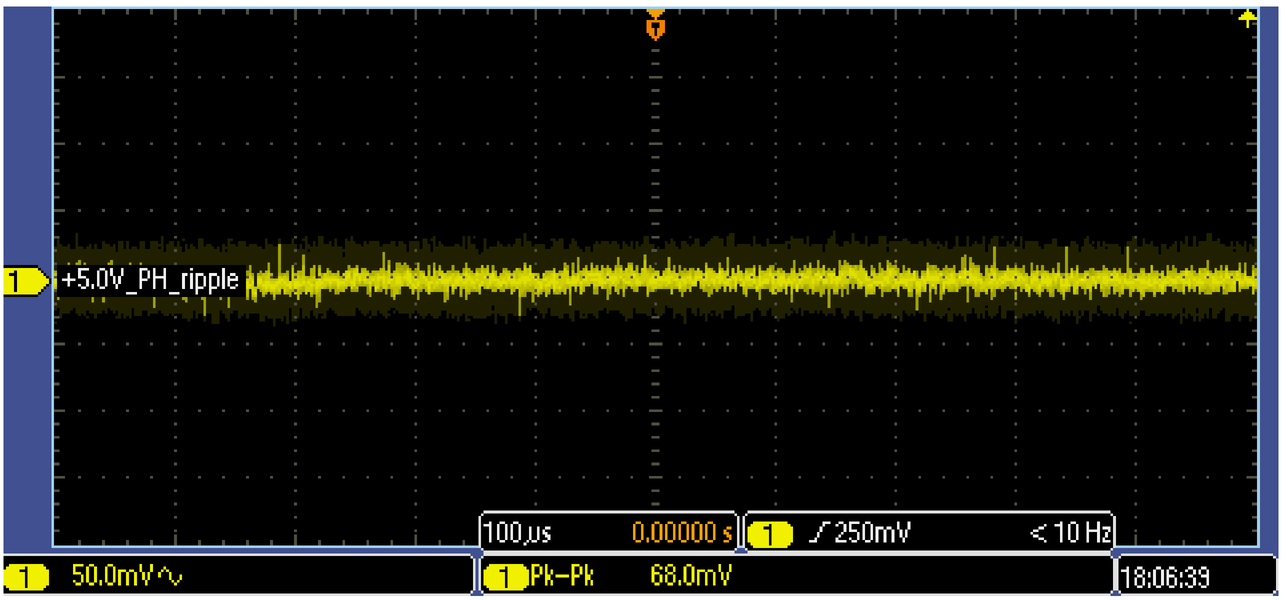


Figure 19. Ripple on +5.0V_VDC

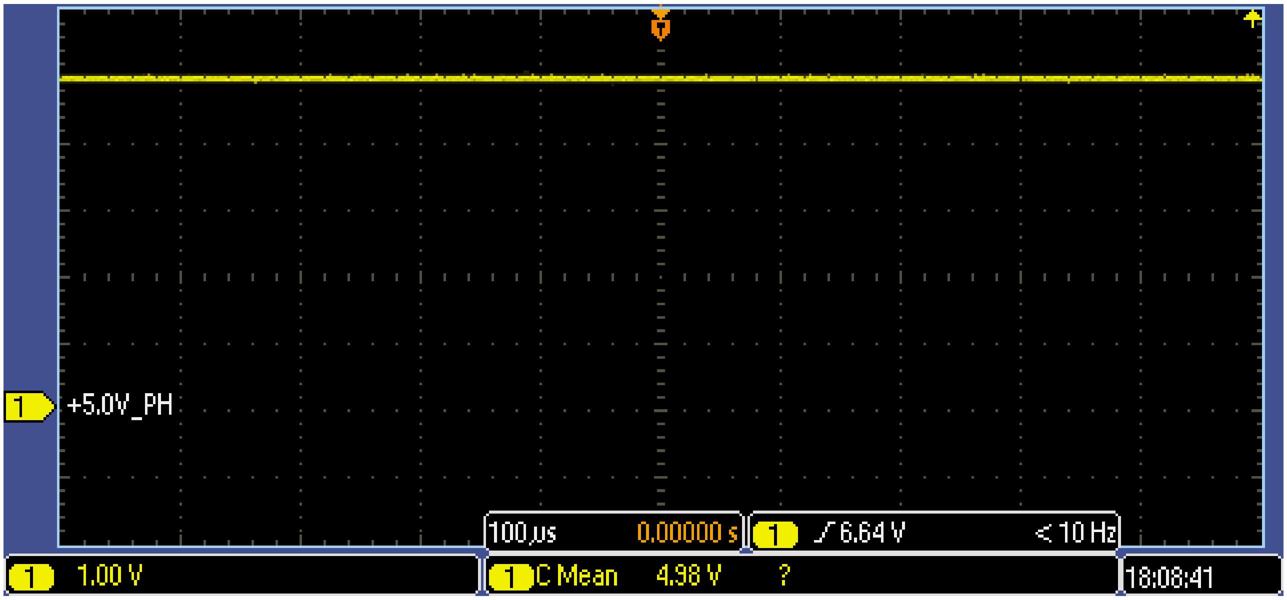


Figure 20. +5.0V_VDC Output

5.2 Communication Testing for RS-485 Board

Table 10. Communication Testing for RS-485 Board with Isolated Transceivers

Baud Rates	Data Communication Result
2400	OK , No failure observed for > 100 transfer cycles
4800	OK , No failure observed for > 100 transfer cycles
9600	OK , No failure observed for > 100 transfer cycles
19200	OK , No failure observed for > 100 transfer cycles
115k	OK , No failure observed for > 100 transfer cycles

Table 11. Communication Testing for RS-485 Board with Digital Isolator and Half-Duplex Transceivers

Baud Rates	Data Communication Result
2400	OK , No failure observed for > 100 transfer cycles
4800	OK , No failure observed for > 100 transfer cycles
9600	OK , No failure observed for > 100 transfer cycles
19200	OK , No failure observed for > 100 transfer cycles
115k	OK , No failure observed for > 100 transfer cycles

NOTE: Sample programs provided by the Tiva™ C Series LaunchPad (EK-TM4C123GXL) were used to test communication for the conditions as stated above.

5.2.1 Test Setup and Procedure

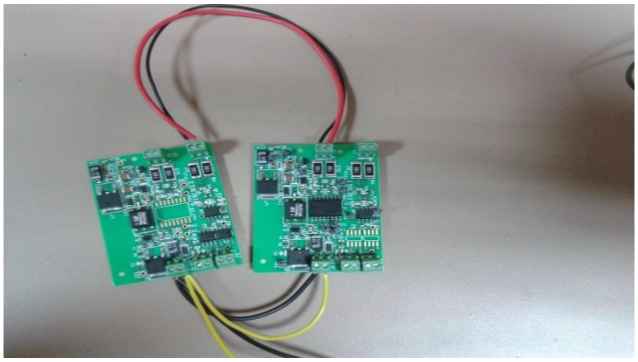


Figure 21. Two RS-485 Boards Daisy-Chained

5.2.1.1 Method

1. Use two small form factor Half-Duplex RS-485 interface boards.
2. Daisy-chain the RS-485 outputs.
3. Configure one card as transmitter on the RS-232 TTL side.
4. Configure the second card as receiver on the RS-232 TTL side.
5. Transmit string “Enter Text\n” and receive the transmitted string.
6. Validate if the transmitted and received strings match.
7. The data transmitter and receiver is monitored on the CCS GUI.
8. Use Tiva™ C Series LaunchPad (EK-TM4C123GXL) for communication testing.

5.3 IEC Pre-Compliance testing

The following EMC tests were performed:

Table 12. EMC Tests

Tests	Standards
Electro Static Discharge	IEC61000-4-2
Surge	IEC61000-4-5

Table 13. Performance Criteria

Criteria	Performance (Pass) Criteria
A	The Analog Output Module continues to operate as intended. No loss of function or performance during the test.
B	Temporary degradation of performance is accepted. After the test, the Analog Output Module continues to operate as intended without manual intervention.
C	During the test loss of functions accepted, but no destruction of hardware or software. After the test, the Analog Output Module continues to operate as intended automatically, after manual restart or power off/power on.

5.3.1 IEC61000-4-2 ESD Test

The IEC610004-2 electrostatic discharge (ESD) test simulates the electrostatic discharge of an operator directly onto an adjacent electronic component. Electrostatic charge usually develops in low relative humidity, on low-conductivity carpets, or on vinyl garments. To simulate a discharge event, an ESD generator applies ESD pulses to the equipment-under-test (EUT), which happens through direct contact with the EUT (contact discharge), or through an air-gap (air-discharge). This is applied across signal inputs only. A series of 10 negative and positive pulses are applied directly on the RS-485 bus terminal block screws during the test (contact discharge). After the test, the RS-485 board is attached to the TM4C123GXL Launch-Pad to verify functionality. The test results show the EUT is able to withstand the required discharge. The EUT was not permanently damaged.

Table 14. ESD Test Steps

Test No.	Test Mode	Observation
1	Contact +1 kV	Pass
2	Contact -1 kV	Pass
3	Contact +2 kV	Pass
4	Contact -2 kV	Pass
5	Contact +4 kV	Pass
6	Contact -4 kV	Pass

Table 15. ESD Test Observations

Immunity Test	Standard	Port	Target Voltage	Result
ESD	IEC 61000-4-2, contact	Signal Lines	±4 kV	Pass, Criteria B (After the test the module continued to operate as intended)

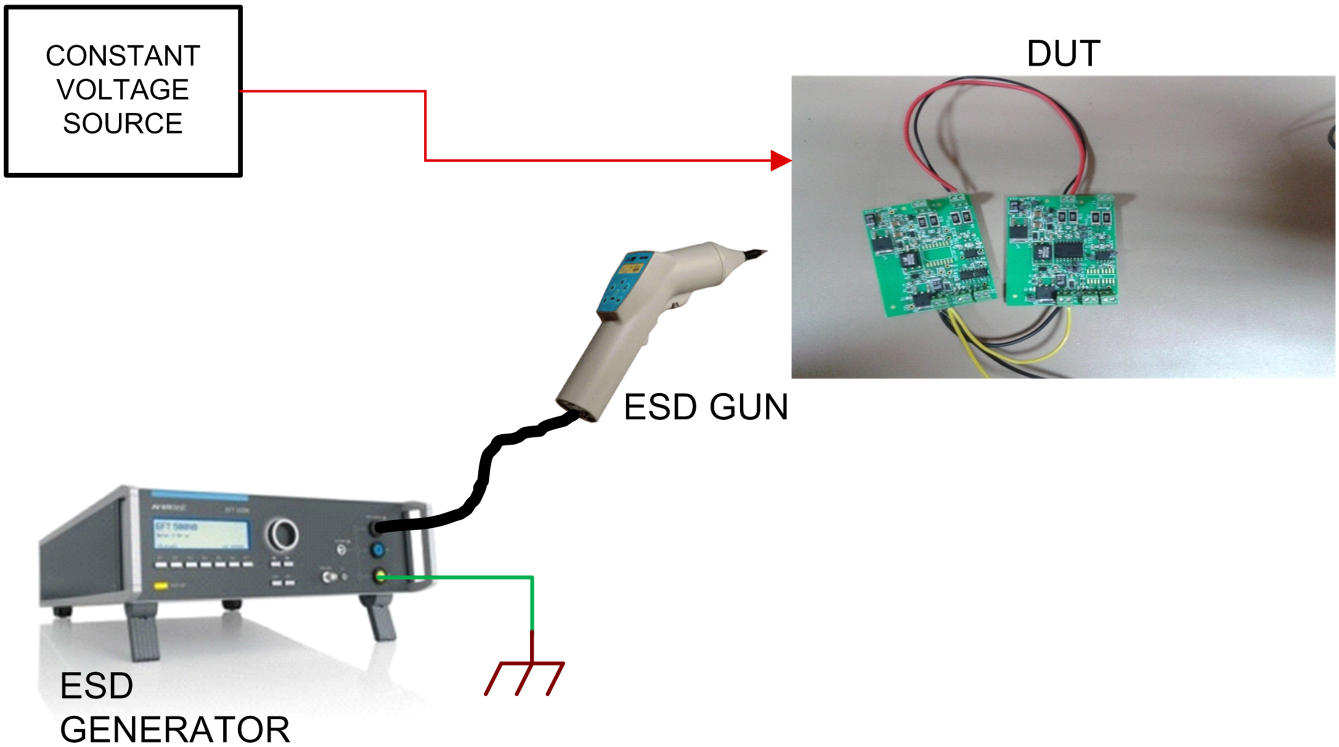


Figure 22. ESD Setup for RS-485 Communication Board

5.3.2 IEC61000-4-5 Surge Test

The IEC61000-4-5 surge test simulates switching transients caused by lightning strikes or the switching of power systems, including load changes and short circuits. The test requires 5 positive and 5 negative surge pulses with a time interval between successive pulses of 1 minute or less. The unshielded symmetrical data line setup as defined by the IEC61000-4-5 specification is used for this test. The test generator is configured for 1.2/50 µs surges, and diode clamps are used for line-to-ground coupling. A series of 5 negative and positive pulses, with 10 seconds spacing between each pulse, are applied during the test. After the test, the RS-485 board is attached to the TM4C123GXL LaunchPads to verify functionality. The test results show the EUT is able to withstand up to ±500 V bursts. The EUT is able to perform normally after each test. Because functionality could not be verified during the test, the result is noted as passing with Class B.

Table 16. Surge Test Observations

Immunity Test	Standard	Port	Target Voltage	Result
Surge	IEC 61000-4-5: (1.2 / 50 µs–8 / 20 µs), 42 Ω–0.5 µF	Signal Lines	± 1 kV	Pass, Criteria B (After the test the module continued to operate as intended)

Table 17. Surge Test Steps

Test No.	Test Mode	Observation
1	+ 0.5 kV	Pass
2	- 0.5 kV	Pass
3	+ 1 kV	Pass
4	- 1 kV	Pass

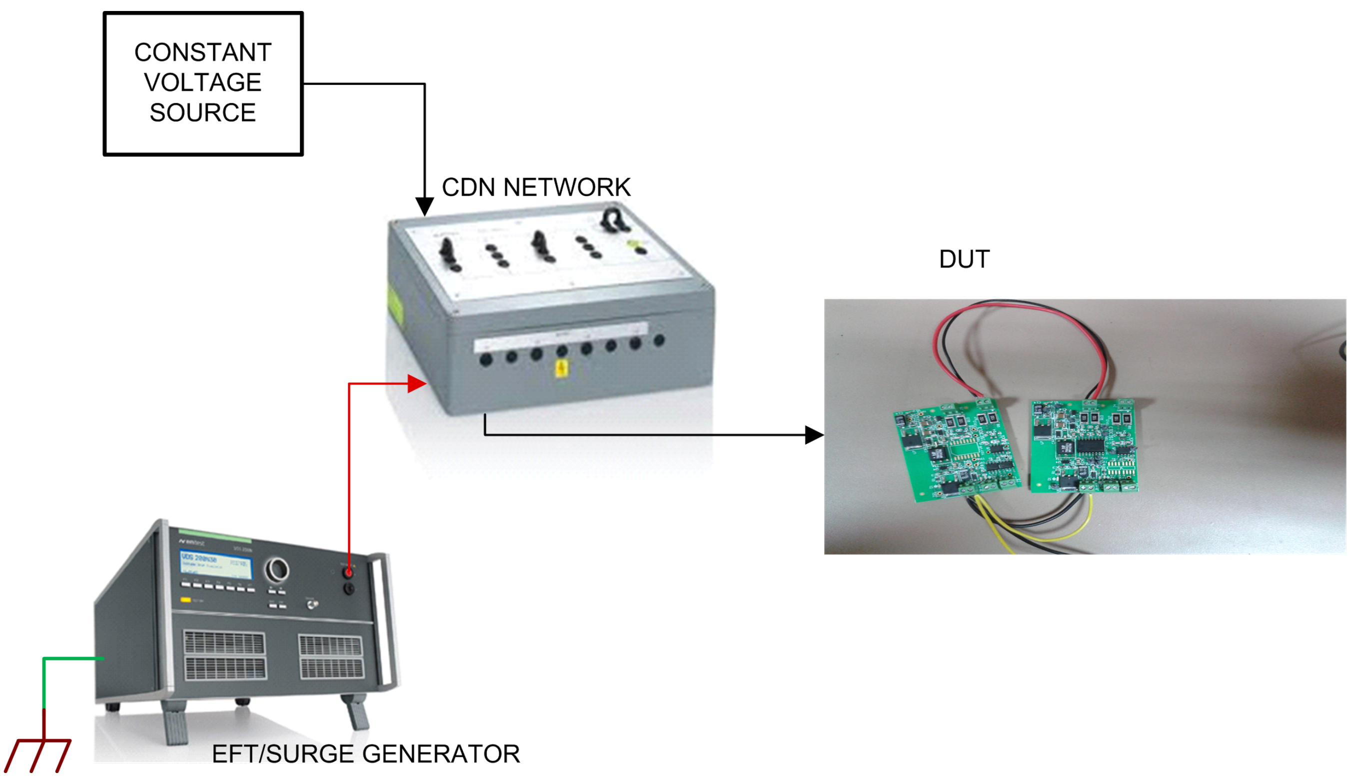


Figure 23. Surge Setup for RS-485 Communication Board

5.4 Test Results Summary

Table 18. Test Results Summary

Isolated power output with SN6501 transformer driver	OK
LDO output for isolated and non-isolated power supplies	OK
Communication testing with isolated transceiver	No errors during communication up to 115K
Communication testing with digital isolator and Half-Duplex transceiver	No errors during communication up to 115K
EMC tests	Complies

6 Design Files

6.1 Schematics

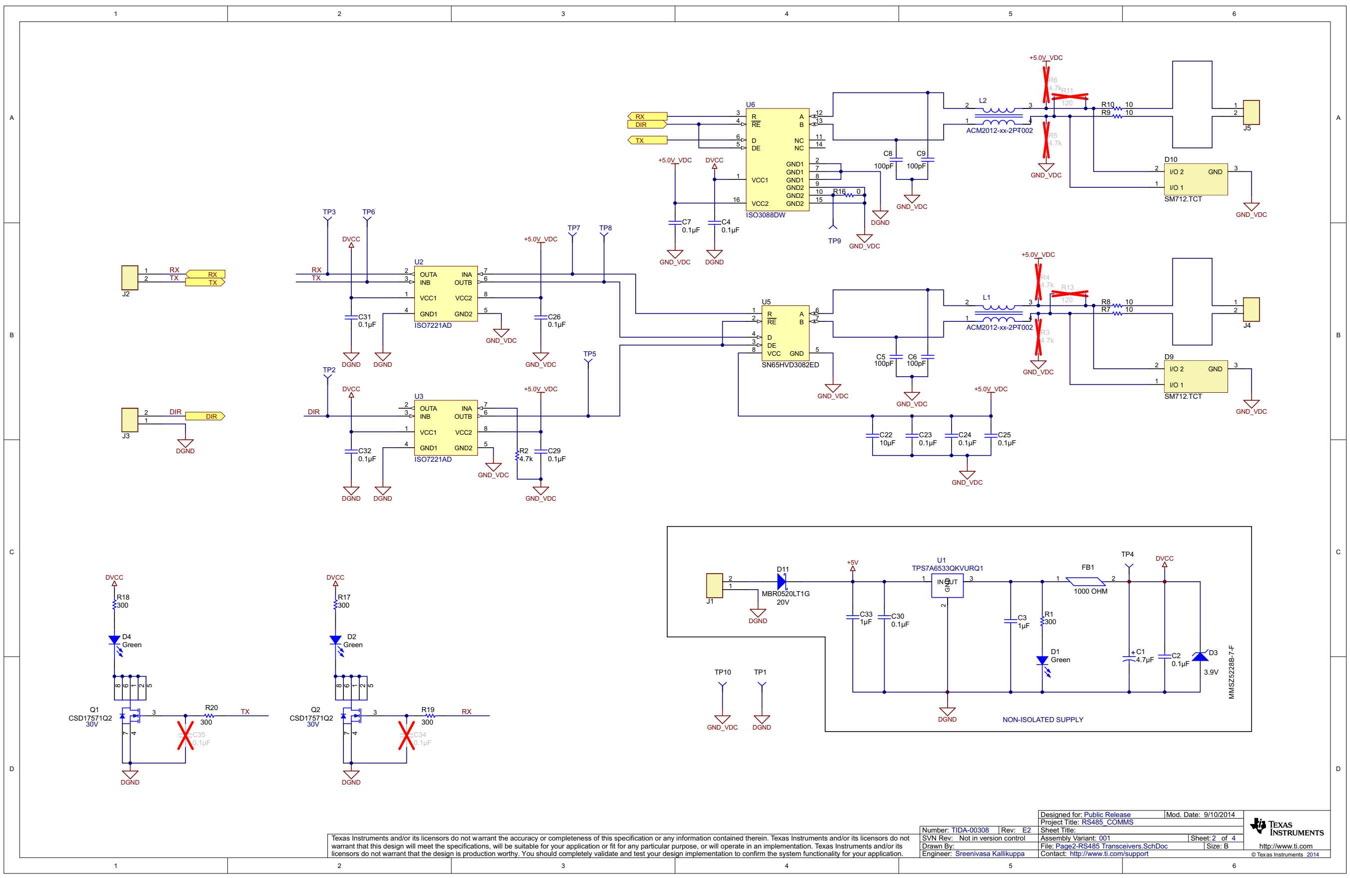


Figure 24. RS-485 Transceiver, Non-Isolated Power Supply

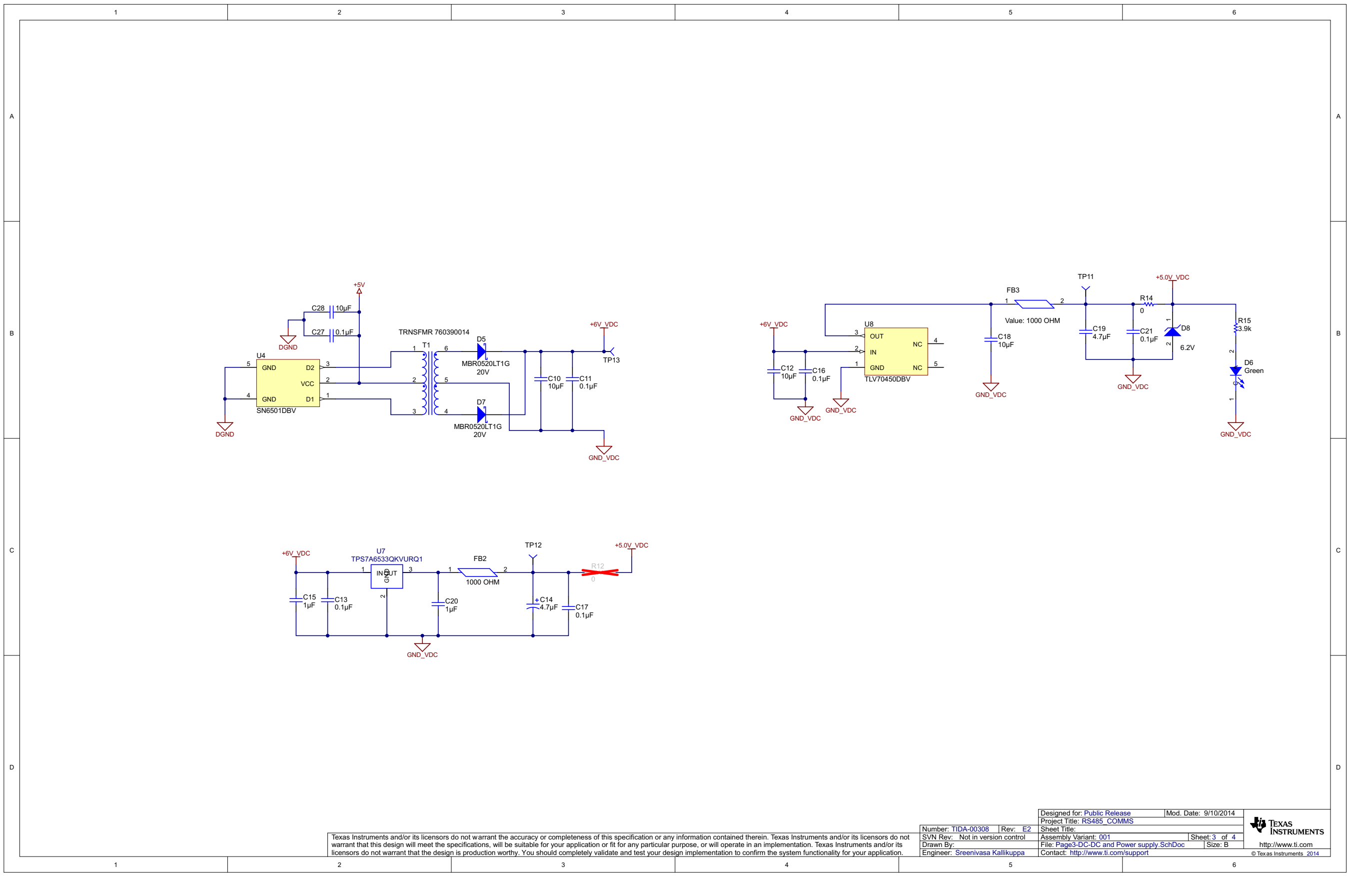


Figure 25. Isolated Power Supply

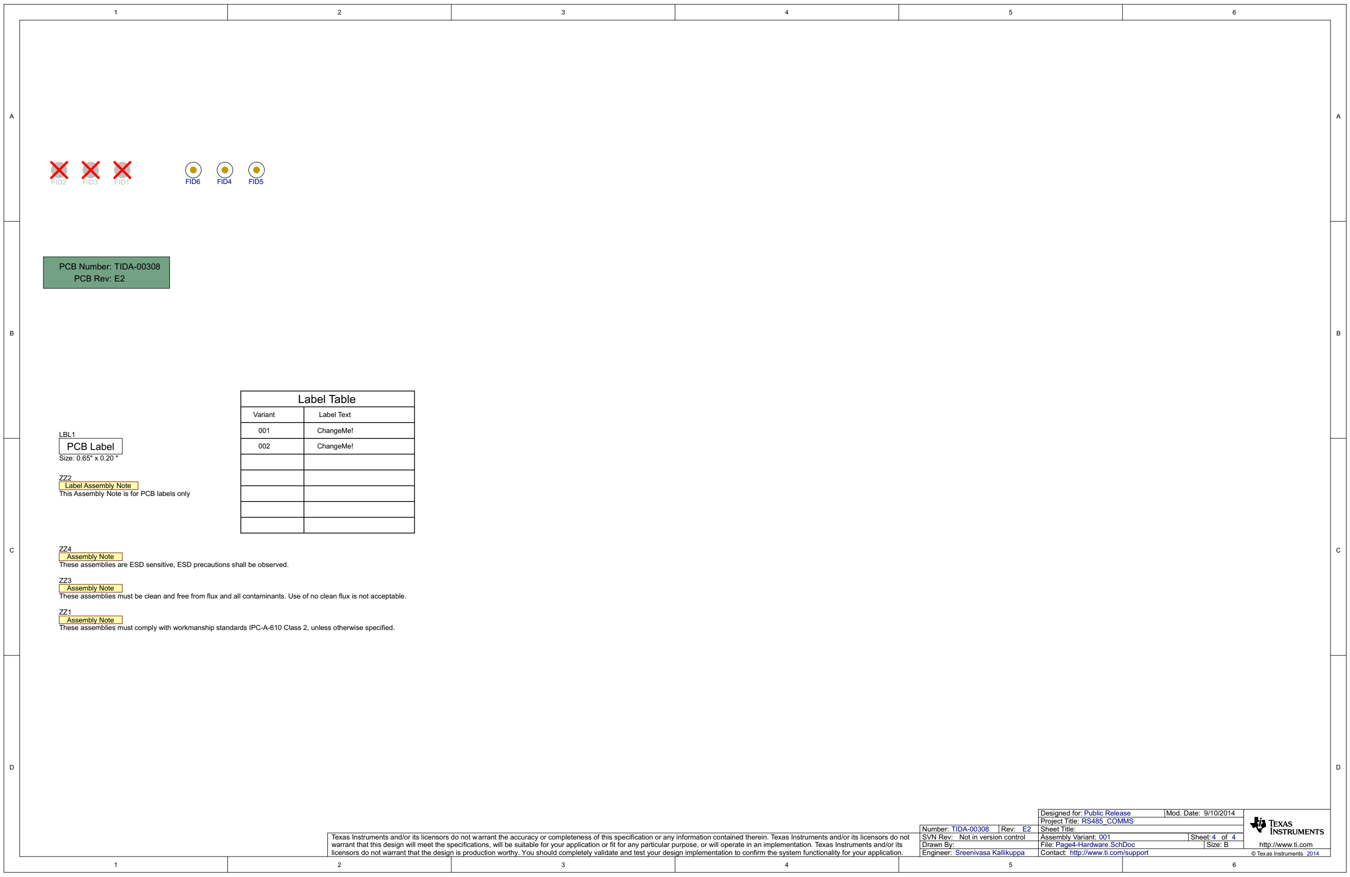


Figure 26. Schematics Page 3

6.2 Bill of Materials

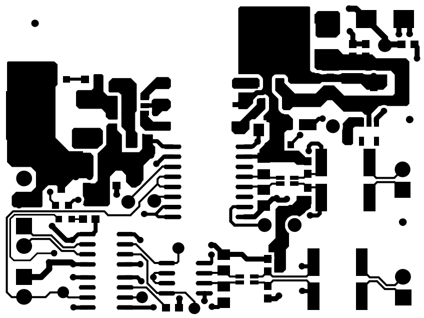
Table 19. BOM

Fitted	Designator	Description	Manufacturer	Part Number	Quantity	Supplier 1	Supplier Part Number 1	Footprint
Fitted	C1, C14	CAP, TA, 4.7 uF, 35 V, +/-10%, 1.9 ohm, SMD	Vishay-Sprague	293D475X9035C2TE3	2	Digi-Key	718-1083-1-ND	6032-28
Fitted	C2, C11, C13, C16, C17, C21, C27, C30	CAP, CERM, 0.1 uF, 50 V, +/-10%, X7R, 0603	Kemet	C0603C104K5RACTU	8	Digi-Key	399-5089-1-ND	0603
Fitted	C3, C15, C20, C33	CAP, CERM, 1 uF, 16 V, +/-10%, X7R, 0603	TDK	C1608X7R1C105K	4	Digi-Key	445-1604-1-ND	0603
Fitted	C4, C7, C26, C29, C31, C32	CAP, CERM, 0.1 uF, 50 V, +/-10%, X7R, 0805	AVX	08055C104KAT2A	6	Digi-Key	478-1395-1-ND	0805_HV
Fitted	C5, C6, C8, C9	CAP, CERM, 100 pF, 50 V, +/-5%, C0G/NP0, 0805	AVX	08055A101JAT2A	4	Digi-Key	478-1316-1-ND	0805_HV
Fitted	C10, C12, C18, C28	CAP, CERM, 10 uF, 35 V, +/-20%, X7R, 1210	Taiyo Yuden	GMK325AB7106MM-T	4	Digi-Key	587-2779-1-ND	1210
Fitted	C19	CAP, CERM, 4.7 uF, 50 V, +/-10%, X5R, 0805	TDK	C2012X5R1H475K125AB	1	Digi-Key	445-5980-1-ND	0805_HV
Fitted	C22	CAP, CERM, 10 uF, 6.3 V, +/-20%, X5R, 0603	Kemet	C0603C106M9PACTU	1	Digi-Key	399-5504-1-ND	0603
Fitted	C23, C24, C25	CAP CER 0.1uF 25 V 5% X7R 0603	AVX	06033C104JAT2A	3	Digi-Key	478-3713-1-ND	0603
Not Fitted	C34, C35	CAP, CERM, 0.1 uF, 25 V, +/-5%, X7R, 0603	AVX	06033C104JAT2A	2	Digi-Key	478-3713-1-ND	0603
Fitted	D1, D2, D4, D6	LED SmartLED Green 570NM	OSRAM	LG L29K-G2J1-24-Z	4	Digi-Key	475-2709-1-ND, 475-2709-2-ND	LED0603AA
Fitted	D3	DIODE ZENER 3.9 V 500 MW SOD123	Diodes Inc	MMSZ5228B-7-F	1	Digi-Key	MMSZ5228B-FDICT-ND	sod-123

Table 19. BOM (continued)

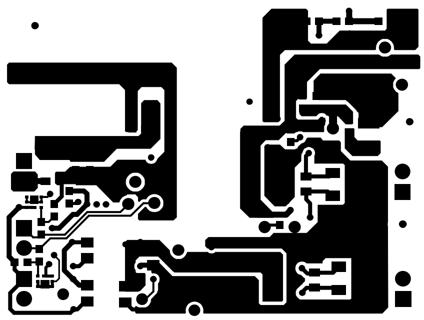
Fitted	Designator	Description	Manufacturer	Part Number	Quantity	Supplier 1	Supplier Part Number 1	Footprint
Fitted	D5, D7, D11	DIODE SCHOTTKY 20 V 0.5 A SOD123	Diodes Inc	B0520LW-7-F	3	Digi-Key	B0520LW-FDICT-ND	sod-123
Fitted	D8	Diode, Zener, 6.2 V, 1 W, PowerDI123	Diodes Inc	DFLZ6V2-7	1	Digi-Key	DFLZ6V2DICT-ND	powerDI123
Fitted	D9, D10	IC TVS ASYMM RS485V 7/12 V SOT23	Semtech	SM712.TCT	2	Digi-Key	SM712CT-ND	SM712.TCT
Fitted	FB1, FB2, FB3	FERRITE CHIP 1000 OHM 300 MA 0603	TDK	MMZ1608B102C	3	Digi-Key	445-8672-1-ND, 445-8672-2-ND	0603, FB0603
Fitted	J1, J2, J3, J4, J5	CONN TERM BLOCK 2.54 MM 2POS PCB, Terminal Block, 4x1, 2.54 mm, TH	On Shore Technology Inc	OSTVN02A150	5	Digi-Key	ED10561-ND	CN2_MTB_P100_PD80_D1.1_S5.54X6.5_STACK
Fitted	L1, L2	CHOKE COMM MODE 200 OHM .35 A SMD	TDK	ACM2012-201-2P-T002	2	Digi-Key	445-2209-1-ND	IND_0805-4P
Fitted	Q1, Q2	MOSFET, N-CH, 30 V, 22 A, SON 2X2 MM	Texas Instruments	CSD17571Q2	2			SON_CSD17571Q2
Fitted	R1, R17, R18, R19, R20	RES, 300 ohm, 5%, 0.1 W, 0603	Vishay-Dale	CRCW0603300RJNEA	5	Digi-Key	541-300GCT-ND	0603
Fitted	R2	RES, 4.7k ohm, 5%, 0.1 W, 0603	Vishay-Dale	CRCW06034K70JNEA	1	Mouser	71-CRCW0603J-4.7K-E3	0603
Not Fitted	R3, R4, R5, R6	RES, 4.7k ohm, 5%, 0.1 W, 0603	Vishay-Dale	CRCW06034K70JNEA	4	Mouser	71-CRCW0603J-4.7K-E3	0603
Fitted	R7, R8, R9, R10	RES, 10 ohm, 5%, 1 W, 2512	Panasonic	ERJ-1TYJ100U	4	Digi-Key	PT10XCT-ND	2512M
Not Fitted	R11, R13	RES, 120 ohm, 1%, 0.25 W, 1206	Yageo America	RC1206FR-07120RL	2	Digi-Key	311-120FRCT-ND	1206
Not Fitted	R12	RES, 0 ohm, 5%, 0.1 W, 0603	Vishay-Dale	CRCW06030000Z0EA	1	Digi-Key	541-0.0GCT-ND	0603
Fitted	R14, R16	RES, 0 ohm, 5%, 0.1 W, 0603	Vishay-Dale	CRCW06030000Z0EA	2	Digi-Key	541-0.0GCT-ND	0603
Fitted	R15	RES, 3.9k ohm, 5%, 0.1 W, 0603	Vishay-Dale	CRCW06033K90JNEA	1	Digi-Key	541-3.9KGCT-ND	0603
Fitted	T1	Transformer 475 uH SMD	Wurth Electronics Midcom	760390014	1	Digi-Key	732-4458-1-ND	760390015
Fitted	U1, U7	IC, 300 mA 40 V LOW-DROPOUT REGULATOR WITH 25 uA QUIESCENT CURRENT	Texas Instruments	TPS7A6533QKVURQ1	2			KVU_1
Fitted	U2, U3	1 Mbps Dual Channels, 1 / 1, Digital Isolator, 3.3 V / 5 V, -40 to +125 degC, 8-pin SOIC (D), Green (RoHS & no Sb/Br)	Texas Instruments	ISO7221AD	2	Digi-Key	296-26077-5-ND	D0008A_N
Fitted	U4	Transformer Driver for Isolated Power Supplies, DBV0005A	Texas Instruments	SN6501DBV	1			DBV0005A_N
Fitted	U5	IC, RS485 TRANSCEIVER LP, 8-SOIC	Texas Instruments	SN65HVD3082ED	1			D0008A_N
Fitted	U6	Isolated RS485 Transceiver, 20 Mbps, 5 V, Half Duplex, -40 to 85 degC, 16-pin SOIC (DW)	Texas Instruments	ISO3088DW	1	Digi-Key	296-23490-5-ND	DW0016A_N
Fitted	U8	Regulator, LDO, 5 V, 0.15 A, SOT23-5	Texas Instruments	TLV70450DBV	1			DBV0005A_N

6.3 Gerber Plots



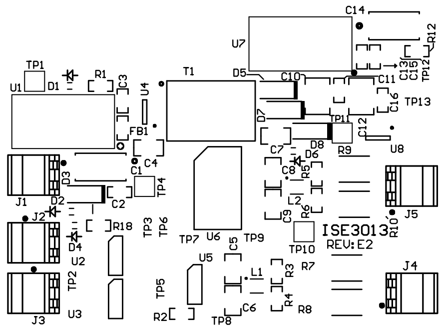
ALL ARTWORK VIEWED FROM TOP SIDE	BOARD #: TIDA-00308	REV: E2	SVN REV: Not In VersionControl
LAYER NAME = Top Layer	ISE3013		
PLOT NAME = RS485_ADAPTOR_E2.GTL	GENERATED : 9/9/2014 1:30:01 PM		TEXAS INSTRUMENTS

Figure 27. Top Layer



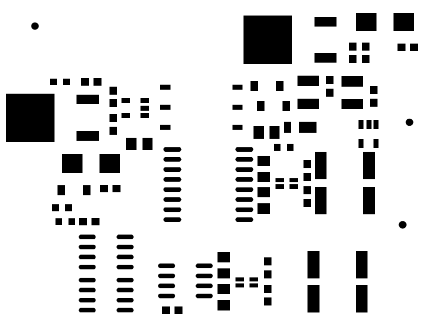
ALL ARTWORK VIEWED FROM TOP SIDE	BOARD #: TIDA-00308	REV: E2	SVN REV: Not In VersionControl
LAYER NAME = Bottom Layer	ISE3013		
PLOT NAME = RS485_ADAPTOR_E2.GBL	GENERATED : 9/9/2014 1:30:01 PM		TEXAS INSTRUMENTS

Figure 28. Bottom Layer



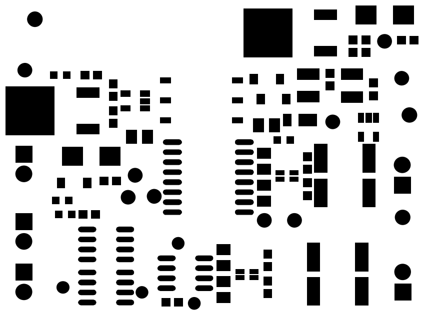
ALL ARTWORK VIEWED FROM TOP SIDE	BOARD #: TIDA-00308	REV: E2	SVN REV: Not In VersionControl
LAYER NAME = Top Overlay	ISE3013		
PLOT NAME = RS485_ADAPTOR_E2.GTO	GENERATED : 9/9/2014 1:30:01 PM		TEXAS INSTRUMENTS

Figure 29. Top Overlay



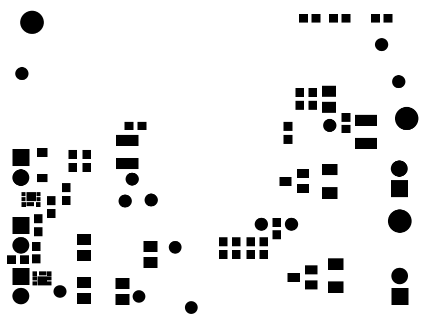
ALL ARTWORK VIEWED FROM TOP SIDE	BOARD #: TIDA-00308	REV: E2	SVN REV: Not In VersionControl
LAYER NAME = Top Paste	ISE3013		
PLOT NAME = RS485_ADAPTOR_E2.GTP	GENERATED : 9/9/2014 1:30:01 PM		TEXAS INSTRUMENTS

Figure 30. Top Paste



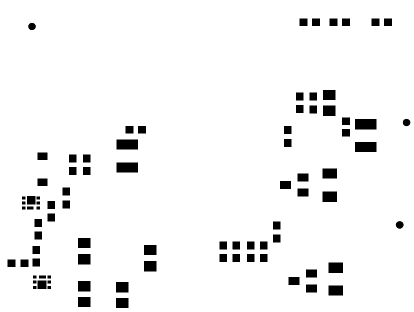
ALL ARTWORK VIEWED FROM TOP SIDE	BOARD #: TIDA-00308	REV: E2	SVN REV: Not In VersionControl
LAYER NAME = Top Solder	ISE3013		
PLOT NAME = RS485_ADAPTOR_E2.GTS	GENERATED : 9/9/2014 1:30:01 PM		TEXAS INSTRUMENTS

Figure 31. Top Solder



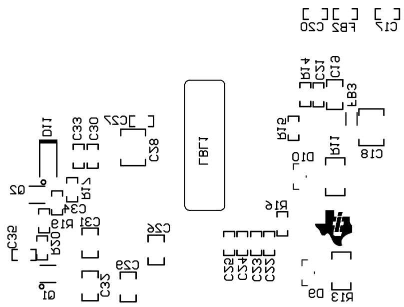
ALL ARTWORK VIEWED FROM TOP SIDE	BOARD #: TIDA-00308	REV: E2	SVN REV: Not In VersionControl
LAYER NAME = Bottom Solder	ISE3013		
PLOT NAME = RS485_ADAPTOR_E2.GBS	GENERATED : 9/9/2014 1:30:01 PM		TEXAS INSTRUMENTS

Figure 32. Bottom Solder



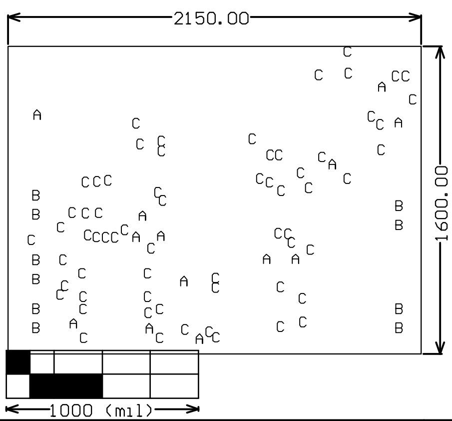
ALL ARTWORK VIEWED FROM TOP SIDE	BOARD #: TIDA-00308	REV: E2	SVN REV: Not In VersionControl
LAYER NAME = Bottom Paste	ISE3013		
PLOT NAME = RS485_ADAPTOR_E2.GBP	GENERATED : 9/9/2014 1:30:02 PM		TEXAS INSTRUMENTS

Figure 33. Bottom Paste



ALL ARTWORK VIEWED FROM TOP SIDE	BOARD #: TIDA-00308	REV: E2	SVN REV: Not In VersionControl
LAYER NAME = Bottom Overlay	ISE3013		
PLOT NAME = RS485_ADAPTOR_E2.GBO	GENERATED : 9/9/2014 1:30:02 PM		TEXAS INSTRUMENTS

Figure 34. Bottom Overlay



Symbol	Hit Count	Finished Hole Size	Plated	Hole Type
C	64	16mil (0.4064mm)	PTH	Round
A	13	40mil (1.016mm)	PTH	Round
B	10	44mil (1.1176mm)	PTH	Round
	87 Total			

Drill Table

DRILL TOLERANCES: FOR PTH +/-3MILS
FOR NPTH +/-2MILS

ALL ARTWORK VIEWED FROM TOP SIDE	BOARD #: TIDA-00308	REV: E2	SVN REV: Not In VersionControl
LAYER NAME = Drill Drawing	ISE3013		
PLOT NAME = RS485_ADAPTOR_E2.GD1	GENERATED : 9/9/2014 1:28:00 PM		TEXAS INSTRUMENTS

Figure 35. Drill Layer

6.4 PCB Assembly Files

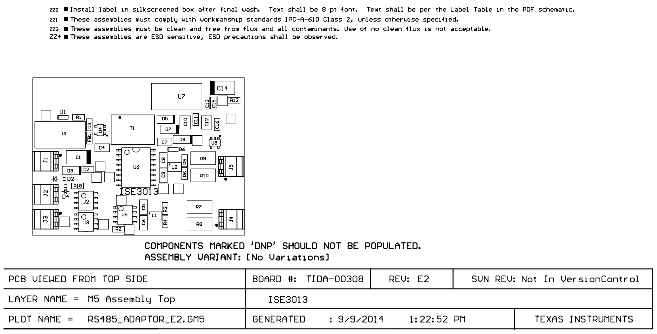


Figure 36. M5 Assembly Top

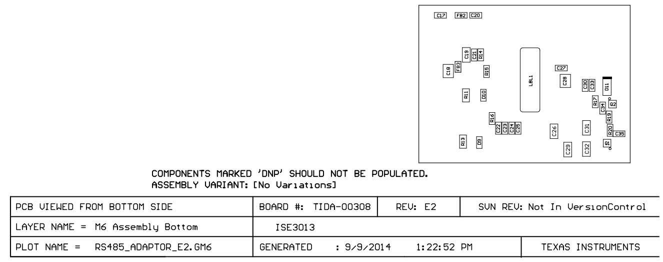


Figure 37. M6 Assembly Bottom

6.5 PCB Plots

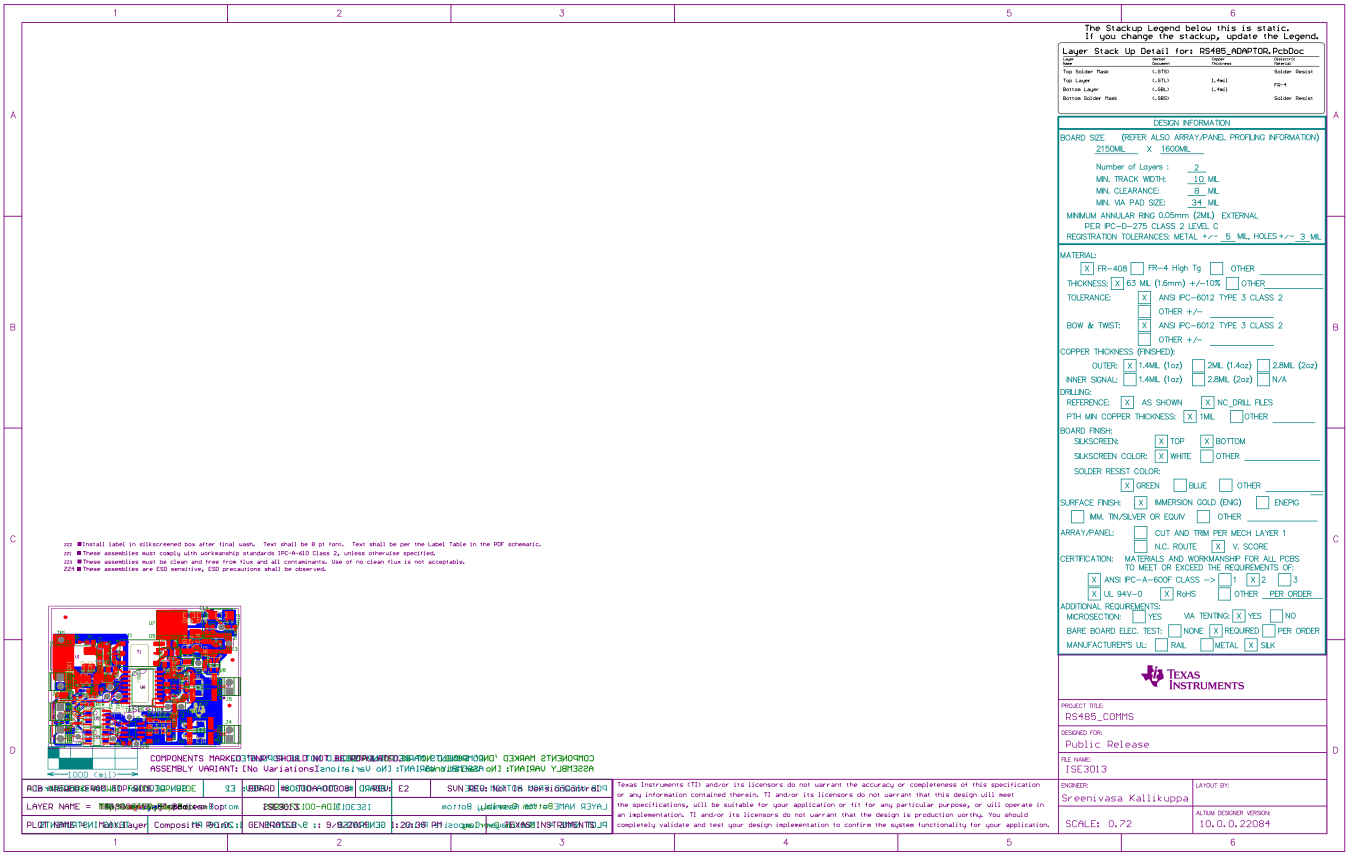


Figure 38. Combined PCB Plots

7 References

Application Note SLLA284, *Digital Isolator Design Guide*.

8 Appendix - Terminologies

External Clearance	The shortest distance through air, between conductive input and output leads, measured in mm.
Comparative Tracking Index (CTI)	Outer molding material characterization in the presence of aqueous contaminants. The higher the CTI value, the more resistant the material is to electrical arc tracking. CTI is often used with creepage by safety agencies to determine working voltage.
External Creepage	The shortest distance along the outside surface, between input and output leads, measured in mm.
Dielectric Insulation Voltage Withstand Rating	The ability to withstand, without breakdown, a 60 second application of a defined dielectric insulation voltage between input and output leads.
Installation Class	I Equipment in closed systems (such as telecom) protected against overvoltage with devices such as diverters, filters, capacitors, and so forth. II Energy consuming equipment (such as appliances) supplied through a fixed installation. III Primarily equipment in fixed installations (such as fixed industrial equipment). IV Primary supply level for industrial factories
Insulation	Operational - required for correct equipment operation but not as a protection against electric shock. Basic - protects against electric shock. Supplementary – independently applied to basic insulation to protect against shock in the event of failure. Double - composed of both basic and supplementary. Reinforced - A single insulation system composed of several layers (for example, single and supplementary).
Material Group (see Comparative Tracking Index)	I 600 < CTI II 400 < CTI < 600 IIIa 175 < CTI < 400 IIIb 100 < CTI < 175
Partial Discharge	Electric discharge that partially bridges the insulation between two electrodes. Agilent supports partial discharge measurements per VDE0884, a technique developed to evaluate the integrity of insulating materials.
Pollution Degree	1 - Nonconductive pollution only. 2 - Only occasional, temporary conductivity due to condensation. 3 - Frequent conductive pollution due to condensation. 4 - Persistent conductive pollution due to dust, rain or snow.
Rated Mains Voltage	Primary power voltage declared by manufacturer. Used to categorize optocoupler maximum allowable working voltage.
Commonmode Transient Rejection (CMTR)	CMTR describes the maximum tolerable rate-of-rise (or fall) of a common-mode voltage (given in volts per microsecond). The specification for CMTR also includes the amplitude of the common-mode voltage (VCM) that can be tolerated. Common-mode interference that exceeds the maximum specification might result in abnormal voltage transitions or excessive noise on the output signal.

9 About the Author

KALLIKUPPA MUNIYAPPA SREENIVASA is a systems architect at Texas Instruments where he is responsible for developing reference design solutions for the industrial segment. Sreenivasa brings to this role his experience in high-speed digital and analog systems design. Sreenivasa earned his Bachelor of Electronics (BE) in electronics and communication engineering (BE-E and C) from VTU, Mysore, India.

Revision A History

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

Changes from Original (September 2014) to A Revision	Page
• Changed title from "Small Form Factor Half-Duplex RS485 Interface"	1
• Added design description to front page	1
• Added ISO7321C to Design Resources	1
• Changed "Expansion Modules" to "Remote IO or RTD Modules" in Featured Applications	1
• Changed "E-Meters" to "Panel Meters" in Featured Applications	1
• Changed "Protocol Converters and Serial Servers" to "MODBUS Protocol Converter" in Featured Applications	1
• Added "or ISO7320C" to isolators for half-duplex communication in Table 3	15
• Deleted "max. 115200 baud" from transmission rate in Table 3	15
• Added note in Section 4.4.1	21
• Added Section 4.10	25
• Added Section 4.11	26

IMPORTANT NOTICE FOR TI REFERENCE DESIGNS