TI Designs: Verified Design
Isolated Auto-Polarity RS-485 Transceiver

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Design Resources

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SN65HVD888	Product Folder
ISO7641FM	Product Folder
SN6501	Product Folder
TPS76350	Product Folder

Circuit Description

This reference design demonstrates an isolated RS-485 bus node with automatic correction of a reversed bus signal polarity caused by cross-wire faults. The design provides transient protection protecting the signal path against ESD, EFT, and surge transients specified in the IEC 61000 family of transient immunity standards.

An isolated DC-DC converter provides power supply across the isolation barrier utilizing the push-pull converter principle.

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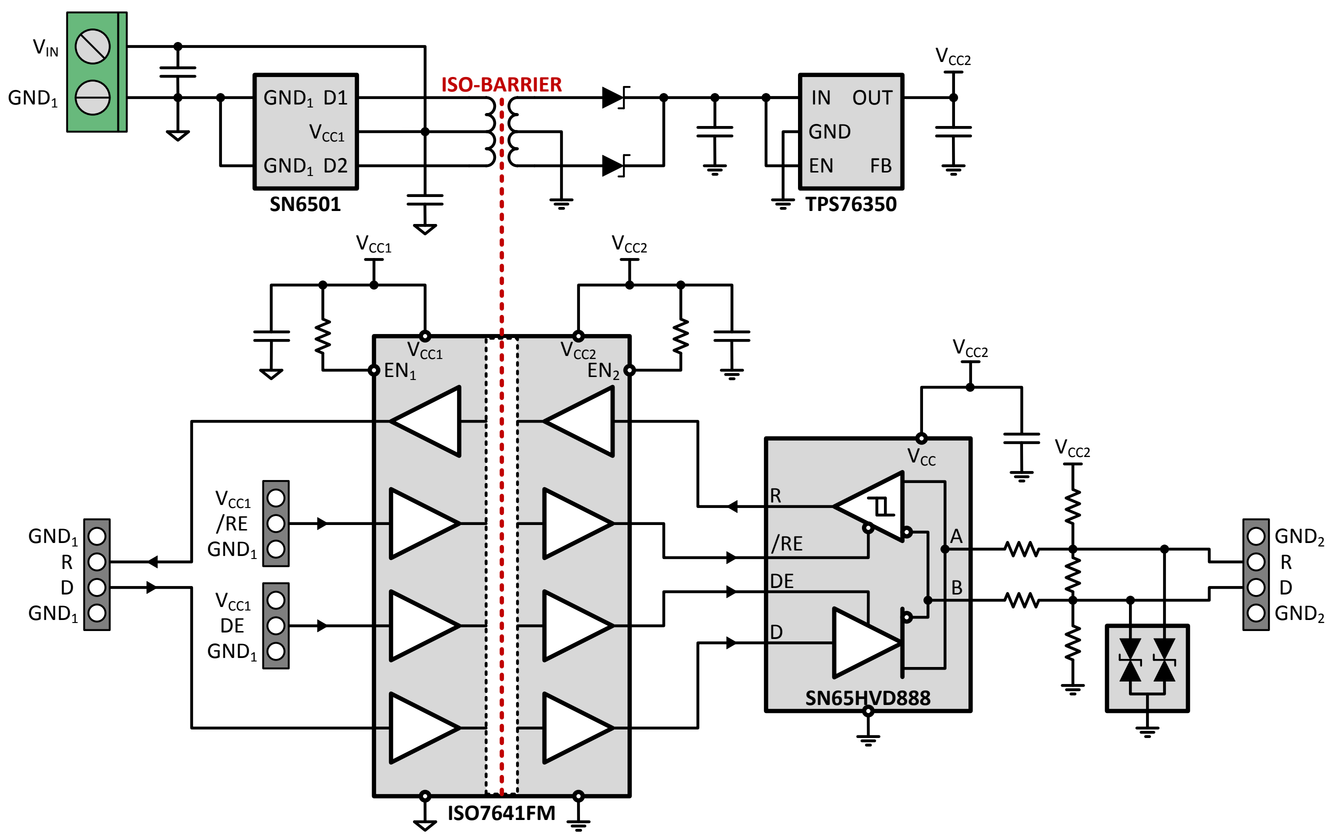

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1 Design Summary

The RS-485 transceiver node is designed to meet the following specifications:

- 6kV peak isolation
- IEC 61000-4-2 up to 16kV
- IEC 61000-4-4 up to 4kV
- IEC 61000-4-5 up to 1kV
- Data rate up to 250kbps

2 Design Considerations

2.1 RS-485 Transceiver

The SN65HVD888 is a low-power RS-485 transceiver with bus-polarity correction and transient protection. Upon hot plug-in the device detects and corrects the bus polarity within the first 76ms of bus idling. On-chip transient protection protects the device against IEC 61000 ESD and EFT transients.

The device automatically corrects a wrong bus signal polarity caused by a cross-wire fault. In order to detect the bus polarity, all three of the following conditions must be met:

- A failsafe biasing network (commonly at the master node) that defines the signal polarity of the bus,
- A slave node must have its receiver enabled and its driver disabled (/RE = DE = low),
- The bus must be idling for the failsafe time, $t_{FS\text{-}max}$.

After the failsafe time has passed, the polarity correction is complete and applied to both receive and transmit data. The status of the bus polarity is latched within the transceiver and maintained for all following data transmissions. That is, switching between drive and receive mode will not reset the bus polarity status.

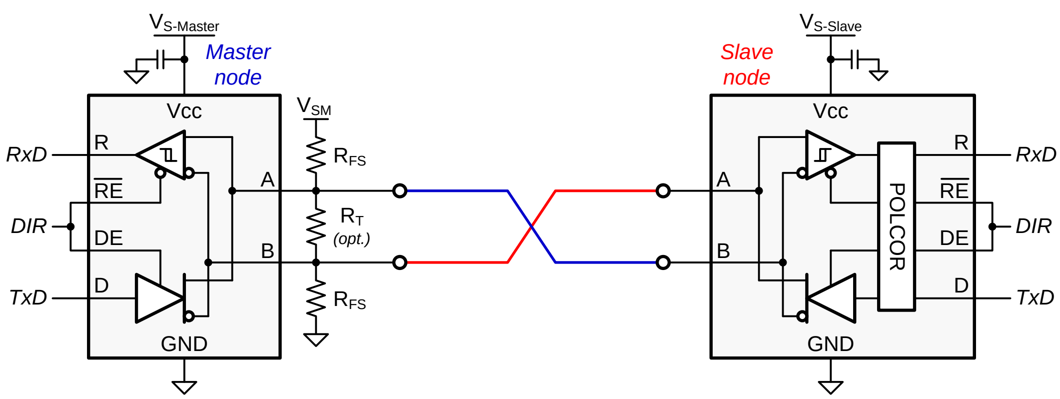

Figure 1: Point-to-point data link with cross-wire fault

Figure 1 shows a simple point-to-point data link between a master and a slave node. Because the failsafe biasing network at the master node determines the signal polarity on the bus, a standard RS-485 transceiver without polarity correction, such as the SN65HVD82, may be used as a master. All slave nodes, however, require the SN65HVD888 transceiver with polarity correction.

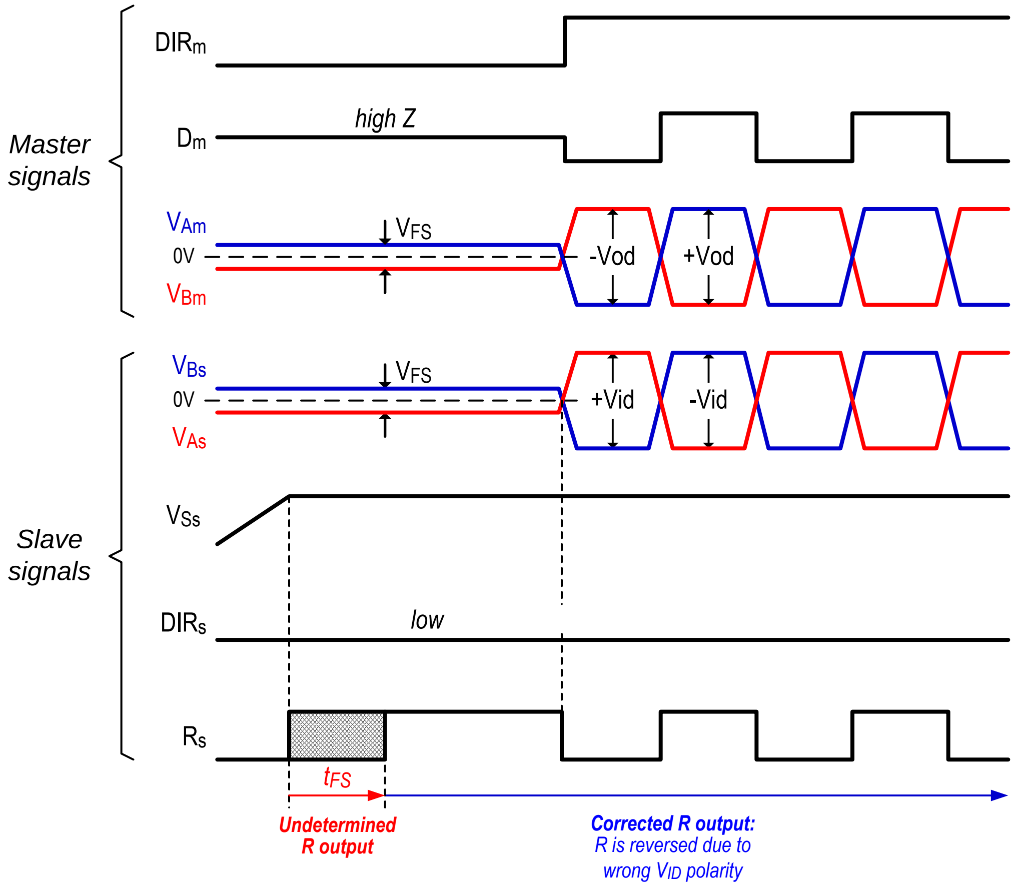

Figure 2: Polarity correcting timing prior to data transmission

Figure 2 shows the timing diagram for the transceiver control and bus terminals during polarity correction. During power-up a slave node with polarity correction can assume correct or incorrect bus polarity. Following power-up, a bus-idle period of 76ms must pass in order for the slave to detect the correct polarity status.

During bus-idling, the slave receiver detects the reversed polarity of the bus failsafe voltage and, after the maximum correction time of $t_{FS\text{-}max}$ = 76ms, turns R_S high.

From this point on all incoming bus data with reversed polarity are reversed within the transceiver. Because polarity correction is also applied to the transmit path, the data sent by the slave MCU are reversed by the POLCOR logic and then fed into the driver.

The reversed data from the slave node are reversed again by the cross-wiring fault in the bus, and the correct bus signal polarity is reestablished at the master end.

Long strings of ones and zeros exceeding the minimum polarity correction time of 44ms can also trigger a polarity correction. In order to prevent such incidents, it is recommended to include encoding /decoding schemes to the data stream. Typical coding schemes are clock-encoded, such as Manchester coding, or simply add/subtract fixed data patterns to and from the transmit data.

If a slave node is plugged in during an ongoing data transmission, the polarity status is undetermined, and the receiver output may provide correct or incorrect data. In order to allow for hot plug-in, a bus-idle period of 76ms between transmissions is advised.

2.2 Digital Isolator

The control side of the SN65HVD888 is isolated from the node controller via a four-channel, digital isolator, ISO7641FM, providing up to 6kV peak isolation. This isolator utilizes capacitive isolation with silicon dioxide (SiO_2) as dielectric. Digital capacitive isolators are industry's most reliable and most precise, low-power isolators.

2.3 Transient Protection

The SM712 transient voltage suppressor (TVS) provides ESD, EFT, and Surge protection for data ports meeting IEC 61000-4-2 (ESD), IEC 61000-4-4 (EFT), and IEC 61000-4-5 (Surge) requirements. The device comprises two bidirectional TVS diodes rated for 400W peak power at an 8/20 µs peak pulse current of 17A.

Its high clamping voltage of 26V, however, can trigger the internal ESD diode structure of the transceiver. When this happens, the internal ESD structure shunts the external TVS and absorbs the entire transient energy. This can lead to latch-up and transceiver damage. To prevent this from happening, 10Ω, pulse-proof, thick-film resistors are inserted between the TVS diodes and the transceiver A and B bus terminals. These resistors provide sufficient voltage drop during a transient event to maintain the external TVS turned on.

A high-voltage capacitor (C8) provides an AC connection between ISO-ground and Protective-Earth (PE). Implemented here as a banana jack, this allows for the connection of a low-inductance cable between the surge generator and ground.

The high-impedance resistor (R10) parallel to C8 functions as a bleeder resistor to prevent the build-up of electrostatic charges on the bus lines.

2.4 Power Supply

The isolated DC-DC power supply converter utilizes the push-pull converter principle. The transformer driver SN6501 drives an isolated transformer with center-tap. The transformer output is rectified by two Schottky diodes (D1, D2) and capacitor (C3). The subsequent low dropout regulator, TPS76350, provides a regulated 5V output for up to 250mA output current. For best stability and lowest ripple, a low-ESR, 4.7µF ceramic capacitor (C4) buffers the regulator output.

3 Measurement

3.1 Data Transmission

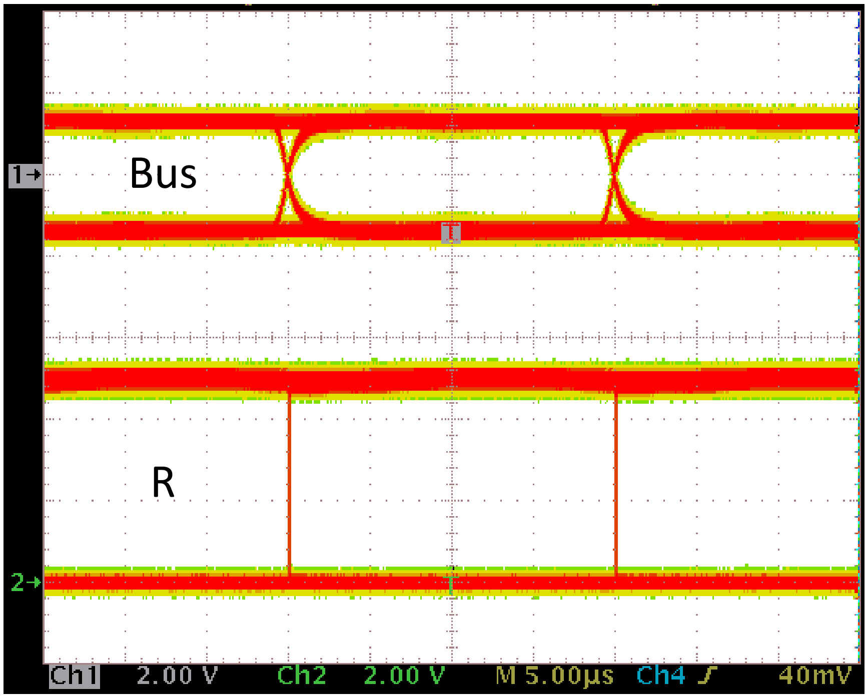

Figure 3: Eye diagram - 50kbps at 1000m

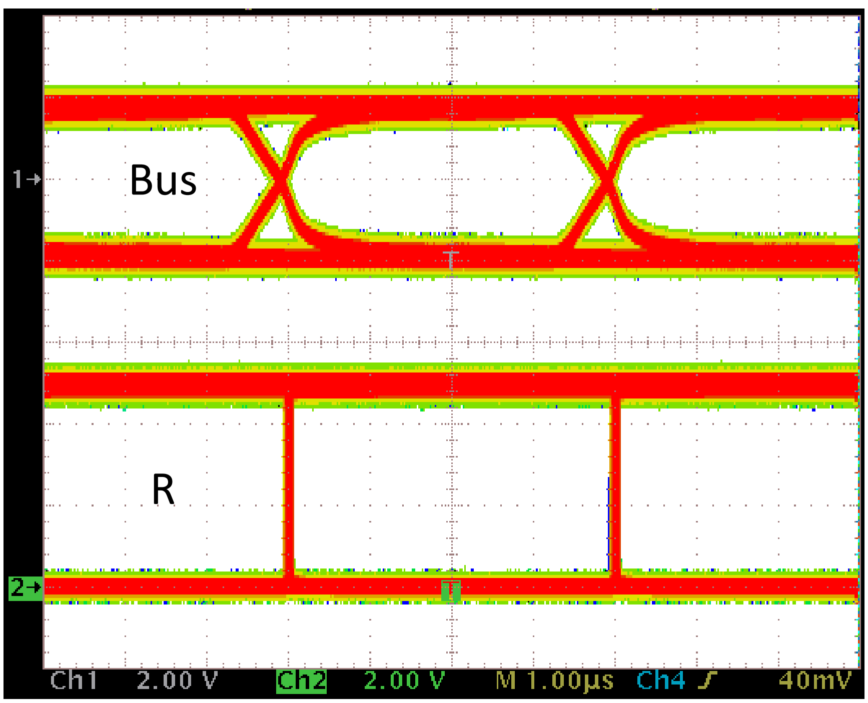

Figure 4: Eye diagram - 250kbps at 300m

3.2 Polarity Correction

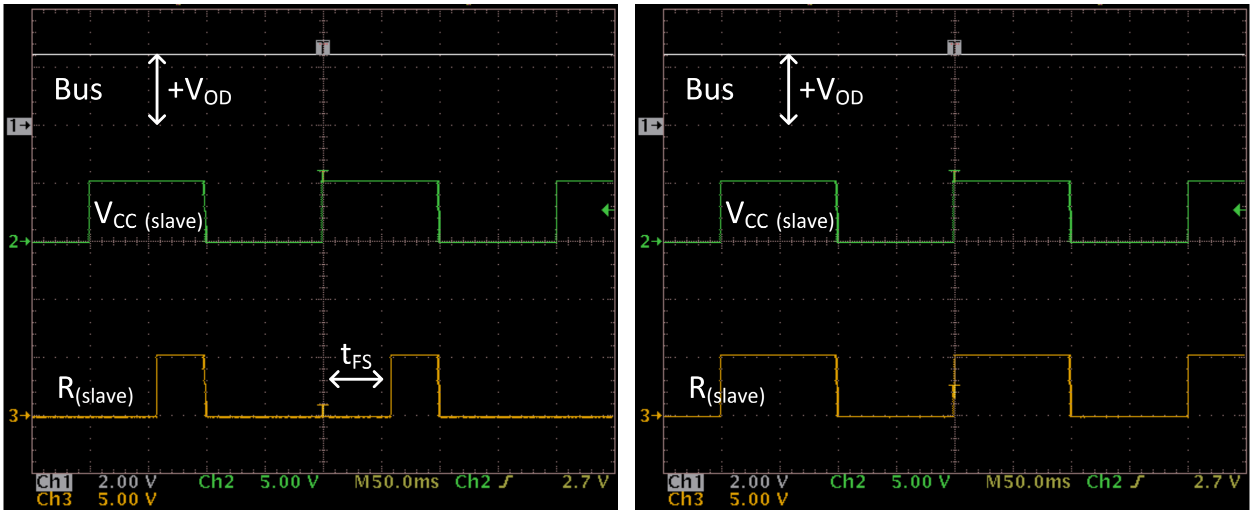

Figure 5: Polarity correction with (left) and without (right) cross-wire fault

4 PCB Design

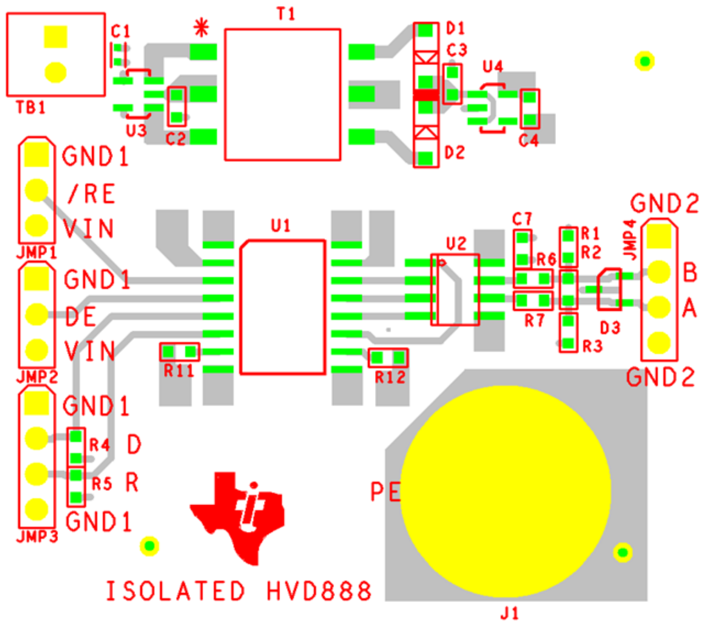

Figure 6: PCB layout top

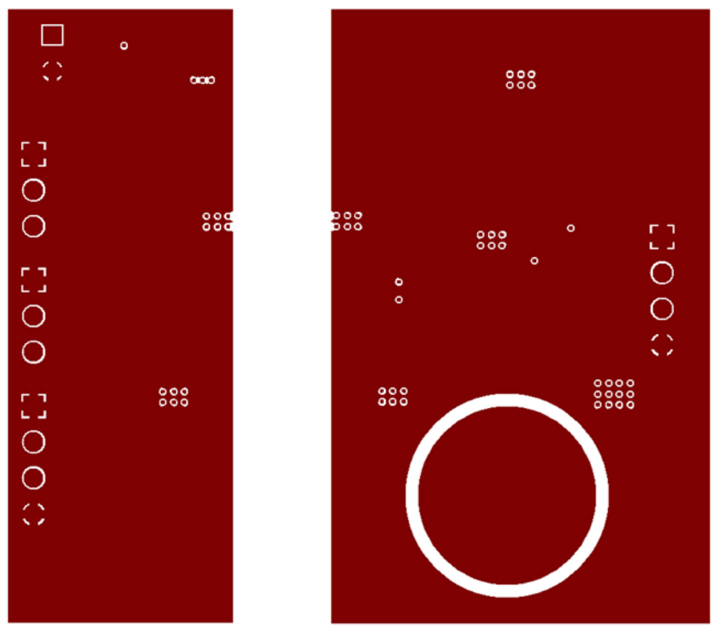

Figure 7: PCB layout ground

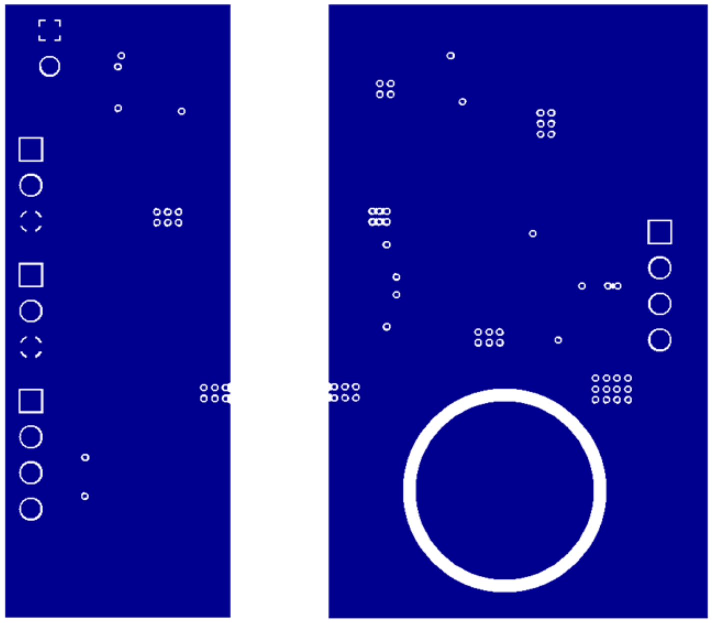

Figure 8: PCB layout power

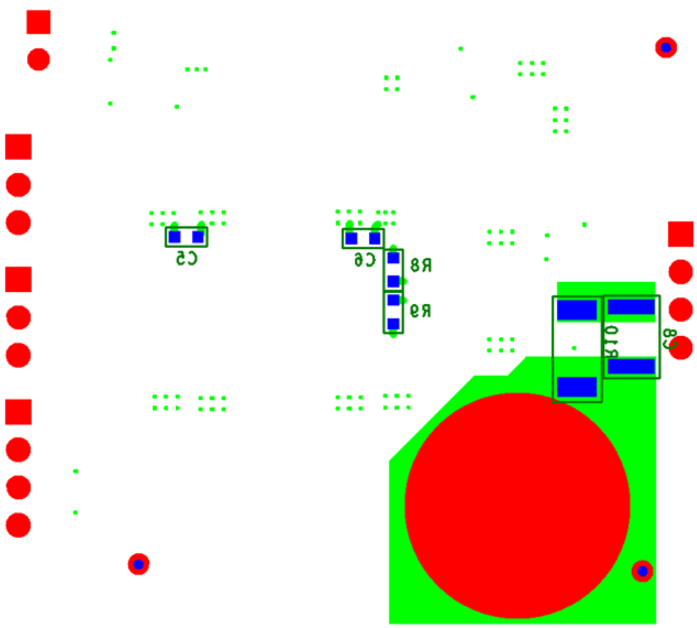

Figure 9: PCB layout bottom

5 References

1. *The RS-485 Design Guide*, Kugelstadt 2008, SLLA272B

6 Appendix

6.1 Schematic

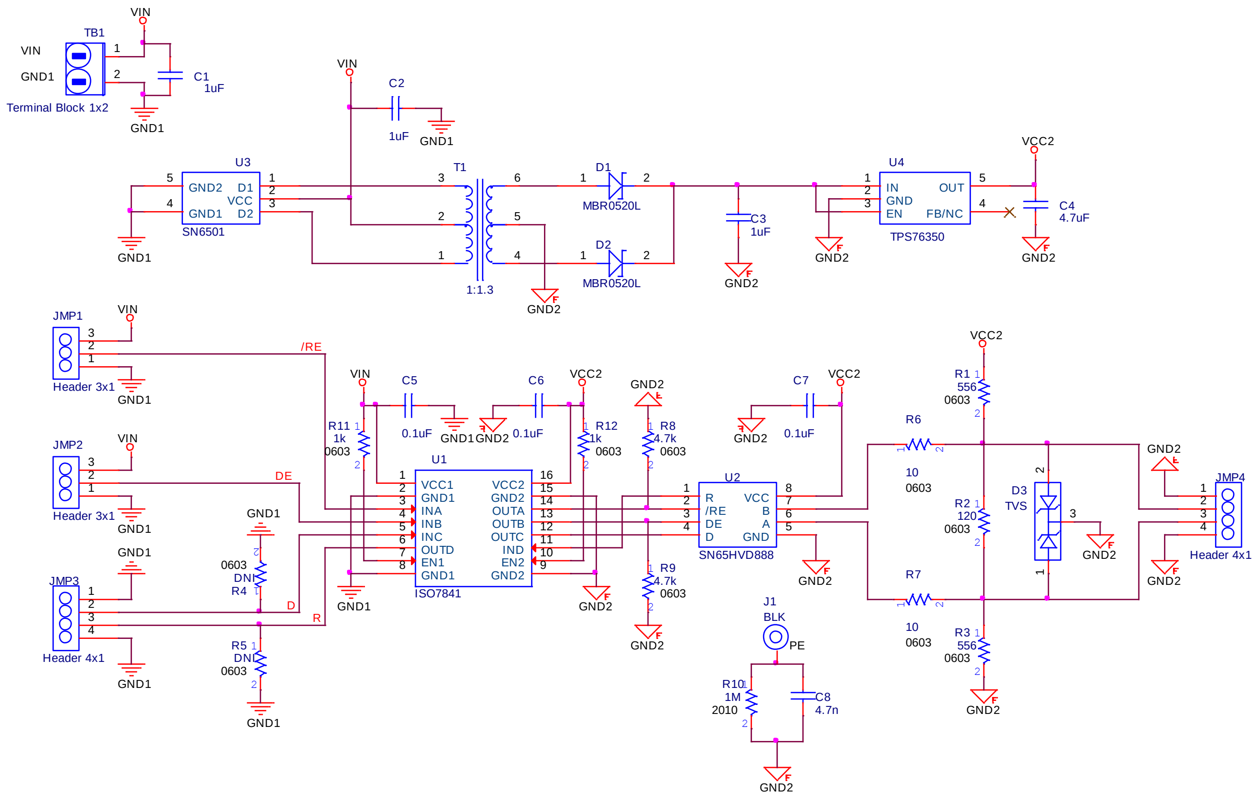

Figure 10: Isolated auto-polarity RS-485 transceiver schematic

6.2 Bill of Materials

Table 1: Isolated auto-polarity RS-485 transceiver Bill of Materials

Item	Quantity	Reference	Part	Footprint	Manufacturer	Manufacturer Part Number
1	1	C1	1.0µF	0402	Taiyo Yuden	LMK105BJ105KV-F
2	1	C2	1.0µF	0603	TDK Corporation	C1608X7R1C105K
3	1	C3	1.0µF	0603	TDK Corporation	C1608X7R1C105K
4	1	C4	4.7µF	0603	TDK Corporation	C1608X5R0J475K/0.80
5	3	C5, C6, C7	0.1µF	0603	Murata Electronics North America	GRM188R71H104KA93D
6	1	C8	4700pF	1812	Novacap	1812B472K202NT
7	2	D1, D2	MBR0520LT1G	SOD-123	ON Semiconductor	MBR0520LT1G
8	1	D3	CDSOD323-T24C-DSL	SOT-23-3	Bourns Inc	CDSOT23-SM712
9	6	JMP1, JMP2	HTSW-150-07-G-S	0.1"	Samtec Inc	HTSW-150-07-G-S
10	8	JMP3, JMP4	HTSW-150-07-G-S	0.1"	Samtec Inc	HTSW-150-07-G-S
11	1	J1	Banana Jack BLACK	4 MM	Alectron	ST-351B BLACK
12	2	R1, R3	560	0603	Venkel	CR0603-10W-5600FT
13	1	R2	120	0603	Panasonic Electronic Components	ERJ-3EKF1200V
14	2	R4, R5	DNI	DNI	DNI	DNI
15	2	R6, R7	10	0603	Vishay Dale	CRCW060310R0FKEAHP
16	2	R8, R9	4.70K	0603	Rohm Semiconductor	MCR03ERTF4701
17	1	R10	1.00M	2010	Vishay Dale	CRCW20101M00FKEF
18	2	R11, R12	1.00K	0603	Yageo	RC0603FR-071KL
19	1	TB1	2 Pin Female R/A	2.54mm	TE Connectivity	282834-2
20	1	T1	1:1.3	SMT	Wurth Electronics	750313638
21	1	U1	ISO7641FMDW	16-SOIC	Texas Instruments	ISO7641FMDW
22	1	U2	SN65HVD888	8-SOIC	Texas Instruments	SN65HVD888
23	1	U3	SN6501DBV	SOT-23-5	Texas Instruments	SN6501DBV
24	1	U4	TPS76350DBVR	SOT-23-5	Texas Instruments	TPS76350DBVR