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## FAQs: RS-485 Transceivers

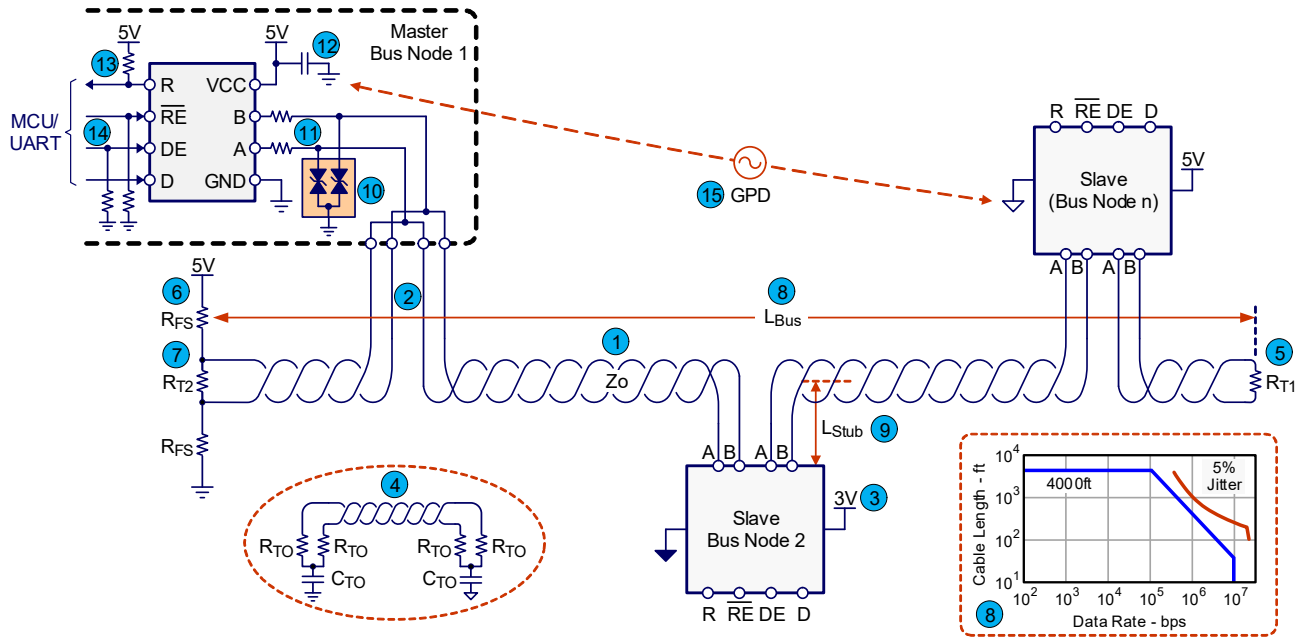
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This application note addresses some frequently asked questions about the RS-485 Transceivers.

### Contents

1. RS-485 Design Check List .....	2
2. Can I interface a 5V transceiver with a 3V controller? .....	3
3. Can I mix 3.3V and 5V transceivers on the same bus? .....	3
4. Can I use a 5Mbps transceiver in a product operating at <200kbps? .....	4
5. What is the maximum stub length between backbone cable and transceiver? .....	5
6. How do I wire a differential receiver Input to accept single-ended levels? .....	5
7. How do I route a bus cable to avoid long stubs? .....	6
8. When do I need to terminate a Bus? .....	8
9. What are the benefits of the ISL315xE transceivers? .....	9
10. Why do RS-485 transceivers require high EFT immunity? .....	10
11. How can I protect my RS-485 transceiver against surge transients? .....	10
12. Do you have more RS-485 application collateral? .....	11
13. Revision History .....	11

# 1. RS-485 Design Check List



- 1) Use twisted pair cable with:  
 $Z_0 = 120\Omega$  or  $100\Omega$
- 2) Connect bus nodes using:  
Daisy-Chain
- 3) You can mix 3V and 5V transceivers on a bus
- 4) Terminate unused conductors with:  
 $R_{T0} = Z_0/2$  and  $C_{T0} = 1\mu F$
- 5) Terminate one cable end with:  
 $R_{T1} = Z_0$
- 6) Apply fail-safe biasing to the other end with:  
 $R_{FS} = K \times (1 + V_{CC(min)} / V_{FS})$   
 $K = 27.8\Omega$  for  $Z_0 = 120\Omega$   
 $K = 23.4\Omega$  for  $Z_0 = 100\Omega$
- 7) Terminate this end with:  
 $R_{T2} = \frac{2R_{FS} \times Z_0}{2R_{FS} - Z_0}$
- 8) Determine maximum cable length with:  
Chart in bottom right corner
- 9) Make stub length no longer than:  
 $L_{Stub} = 3 \times 10^4 \times t_r \times v$   
 $L_{Stub} = \text{Stub length (m)}$   
 $t_r = \text{Driver rise time (ns)}$   
 $v = \text{Cable velocity (\%)}$
- 10) For transient protection (ESD, EFT, Surge) use:  
SM712 or read app notes AN1976 to AN1979.
- 11) Limit transceiver input current during TVS clamping with  $20\Omega$  carbon-composite or MELF resistors.
- 12) Apply a capacitor of at least  $0.1\mu F$  close to supply to ensure sufficient supply current during transceiver switching
- 13) Pull RO up with a  $1k\Omega$  to  $10k\Omega$  resistor to ensure RO is high when the receiver is disabled
- 14) Pull enable pins down with  $1k\Omega$  to  $10k\Omega$  resistors to ensure receiver is enabled and the driver is disabled during power-up.
- 15) For  $\pm 7V$  GPDs use ISL315xE or RAA78815x  
For  $\pm 25V$  GPDs use ISL3245xE or ISL3249xE  
For higher GPDs isolate ISL315xE with optocouplers

## 2. Can I interface a 5V transceiver with a 3V controller?

Yes. Because the output voltage levels of 3V MCUs are sufficiently high to properly drive the TTL input levels of 5V transceivers, controller outputs can be directly connected to transceiver inputs.

In the opposite direction however, the receiver output level at RO exceeds the MCU maximum input rating and level shifting is required. Figure 1 shows a simple solution using a small signal Schottky diode ( $D_1$ ) and a pull-up resistor ( $R_{PU}$ ) connected to the 3.3V controller supply. The other 10k $\Omega$  pull-up connected to the 5V transceiver supply is always needed to ensure RO is high when the receiver is disabled.

Then, when RO is high or high-impedance, the diode is reverse-biased and blocks current flow. In this case, the RxD input of the controller receives a logic high of 3.3V via  $R_{PU}$ . If RO is low, the diode is forward-biased and conducts, thus pulling RxD low.

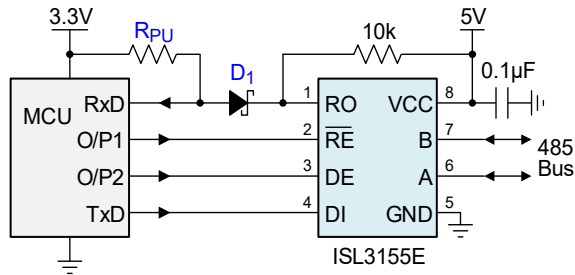


Figure 1. Level Shifting with Schottky Diode and Pull-Up Resistor

For a low RxD input capacitance of 5pF, the combination of a BAS70 Schottky diode ( $D_1$ ) and a 10k $\Omega$  pull-up resistor ( $R_{PU}$ ) provides crisp level-shifting up to about 1Mbps.

## 3. Can I mix 3.3V and 5V transceivers on the same bus?

Yes. The differential driver of an RS-485 transceiver produces a differential output voltage ( $V_{OD}$ ) that swings around a common-mode level of  $V_{CC}/2$ . The differential receiver of an RS-485 transceiver, however, rejects any common-mode voltage and only detects differential signals. Therefore, eliminating the impact of the supply dependent common-mode level at the driver output.

It is therefore possible to have a 5V driver communicating with a 3V receiver, or a 3V driver communicating with a 5V receiver (Figure 2).

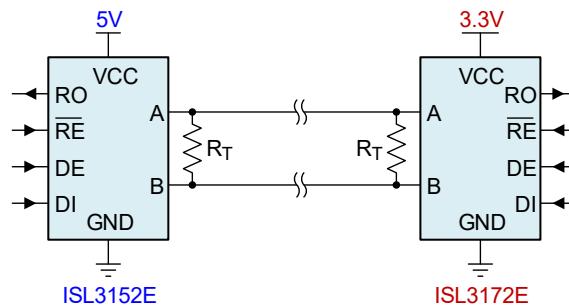


Figure 2. Interfacing 3V and 5V Transceivers on the Same Bus

## 4. Can I use a 5Mbps transceiver in a product operating at <200kbps?

It depends on the EMI requirements of the application the product will be used for.

The outputs of RS-485 transceivers with data rates below 1Mbps are slew-rate limited to minimize signal overshoot and therefore, outgoing electromagnetic interference (EMI) to the environment.

High-speed transceivers are not slew-rate limited, which can increase EMI significantly, especially in long cable runs because of the higher cable inductance.

A good tool for deciding what transceiver data rate to apply for a given cable length, is the cable-length-versus data-rate characteristics provided in the Telecommunications Systems Bulletin, TSB-89-A (Figure 1).

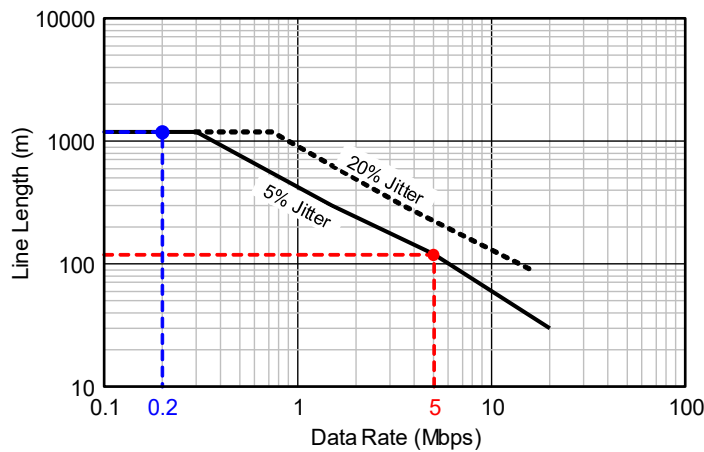


Figure 3. Maximum Line Length vs Data Rate

A simple measurement of the signal rise time out of a length of cable yields an estimation for the maximum length at a specific data-signaling rate using Equation 1 where  $t_{r,f}$  is the 10%-to-90% transition (rise or fall) time of the signal at the end of the interconnection and  $T_{Bit}$  is the minimum bit width.

$$(EQ. 1) \quad t_{r,f} \leq \frac{T_{Bit}}{2}$$

Obviously, a 200kbps transceiver, such as ISL81487L, easily clears a 1200m distance, while a 5Mbps transceiver, such as ISL81487E, only supports 1/10th of that distance, 120m.

Certainly, a 5Mbps transceiver can be operated at 200kbps, but a product manufacturer would have to specify its limitation in cable length.

## 5. What is the maximum stub length between backbone cable and transceiver?

A stub is the distance between the transceiver interconnection on a bus node circuit board and the main cable trunk. As stubs must not be terminated to avoid overloading the bus, a stub must be kept short to avoid turning into a transmission line. The stub length is calculated using [Equation 2](#):

$$(EQ. 2) \quad L_{Stub} \leq \frac{t_r}{4} \times v \times c$$

with

- $L_{Stub}$  = maximum stub length (m)
- $t_r$  = driver rise time (ns)
- $v$  = signal velocity of the cable as a factor of  $c$
- $c$  = Speed of light ( $3 \times 10^8$  m/s)

[Table 1](#) lists the stub length for a variety of RS-485 Transceivers and their corresponding driver rise times.

**Table 1. Stub Length vs Driver Rise Times**

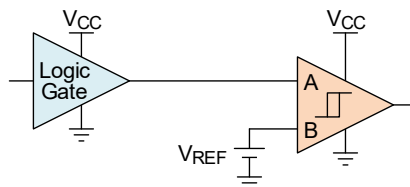
Part Number	Data Rate (Mbps)	Rise Time (ns)	Stub Length	
			(m)	(ft)
ISL3152E	0.115	700	31.5	103
ISL8487E	0.25	250	11.25	37
ISL3155E	1	150	6.75	22
ISL81487E	5	3	0.14	0.4
ISL3158E	20	2	0.09	0.3
ISL3159E	40			
ISL3259E	100			

## 6. How do I wire a differential receiver input to accept single-ended levels?

Interfacing a logic gate to a differential receiver is simply accomplished by feeding the non-inverting receiver input with the gate output, while biasing the inverting input with a low-impedance reference voltage,  $V_{REF}$ . Do not rely on the receiver internal, high-impedance biasing, which might be sensitive to noise coupling, therefore, making it easy to shift.  $V_{REF}$  should lie between the lowest  $V_{OH\_MIN}$  and the highest  $V_{OL\_MAX}$  level:

$$(EQ. 3) \quad V_{REF} = \frac{V_{OH\_MIN} + V_{OL\_MAX}}{2}$$

For a modern 1/8 unit-load receiver, you can produce  $V_{REF}$  with a voltage divider, or a low-cost linear voltage regulator.



**Figure 4. Wiring a Differential Input to Accept Single-Ended Levels**

## 7. How do I route a bus cable to avoid long stubs?

The most reliable method of routing an RS-485 network is by daisy-chaining its bus transceivers. Daisy-chaining means, running the bus cable as close as possible to an equipment (bus node), tapping off a short connection to the actual transceiver (stub), and continuing the cable run to the next bus node (Figure 5). This method requires the first and last bus node in the network to be terminated with a termination resistor (T), whose value matches the characteristic impedance of the RS-485 cable. Daisy-chaining ensures the shortest stubs, while allowing for long cable runs of several thousands of feet.

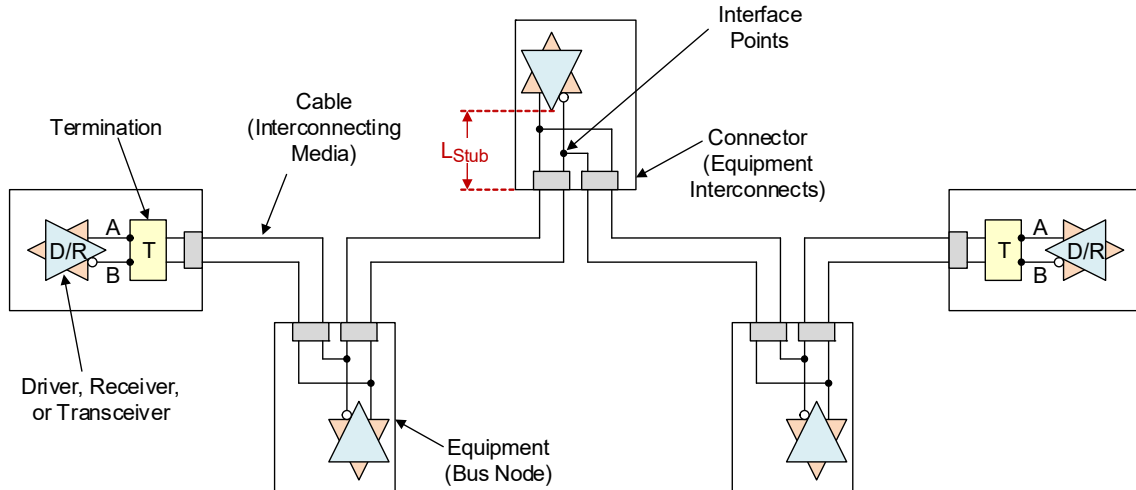


Figure 5. RS-485 Daisy-Chain Configuration Aiming for Shortest Possible Stubs

Other network configurations are acceptable, such as tapping off transceiver connections from a backbone cable by using junction boxes (Figure 6). This configuration method, however, requires the entire length from the backbone to the transceiver to be included in the stub length calculation.

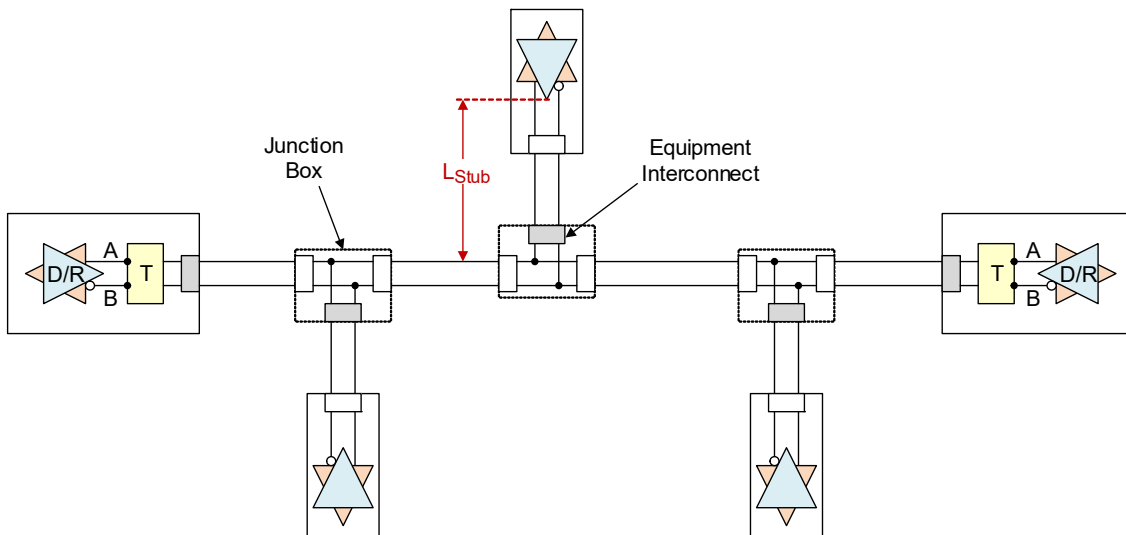
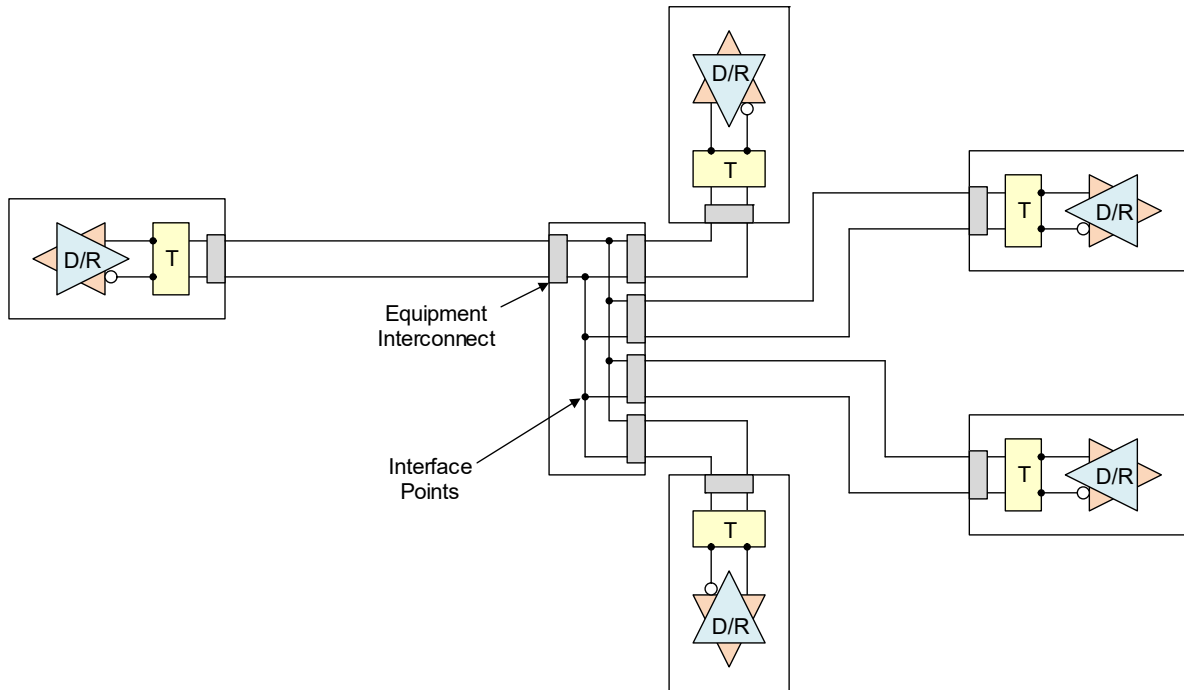


Figure 6. RS-485 Bus with Stub Cables Off a Main Backbone Cable

Configuring transceivers in a star configuration (Figure 7) is not recommended, as it requires the termination of each branch. Multiple terminations will electrically overload the output of a standard transceiver. However, Renesas' ISL315xE transceivers have been specifically designed for this type of application and can drive up to eight termination loads.



**Figure 7. Star Configuration with  $L_{Stub} \gg L_{Stub(max)}$  (Not Recommended for Standard Transceiver, but Possible with ISL315xE Transceivers, which can Drive Up to 8 Terminations)**

## 8. When do I need to terminate a Bus?

A general guideline is to terminate transmission lines to minimize signal reflections on the line. A cable turns becomes a transmission line when its two-way propagation delay approaches the transition time of the signal source (driver rise/fall time). Practical measurements, however, lead to a rule-of-thumb, stating that termination should be applied if the two-way propagation time equals 50% of the driver rise time, which is equivalent to the single-way propagation being equal to 25% or ¼ of the driver rise time.

**Note:** This is the same equation used to calculate the maximum stub length, with the exception that the equation sign changes from  $\leq$  to  $>$ . In other words, terminate the line if its electrical length is:

$$\text{(EQ. 4)} \quad L_{\text{Line}} > \frac{t_r}{4} \times v \times c$$

with

- $L_{\text{Line}}$  = Line length (m)
- $t_r$  = Driver rise time (ns)
- $v$  = Signal velocity of the cable as a factor of  $c$
- $c$  = speed of light ( $3 \times 10^8 \text{m/s}$ )

Another question arising from the above discussion could be: ***When would I not need termination?***

If your application can tolerate a reflections for a limited time and you drive the bus at low data rate, so that the bit width is about ten times the two-way prop-delay, you can operate a bus without termination. In this case, line reflections would only occur in the first half of the bit width and settling for the remaining duration of a bit.



Figure 8. Line Reflections during the First Half of a Bit



## 9. What are the benefits of the ISL315xE transceivers?

The ISL315xE transceivers have high output drives, about 60% higher than that of standard transceivers, 3.1V versus 1.9V across a differential load of 54Ω (Figure 1).

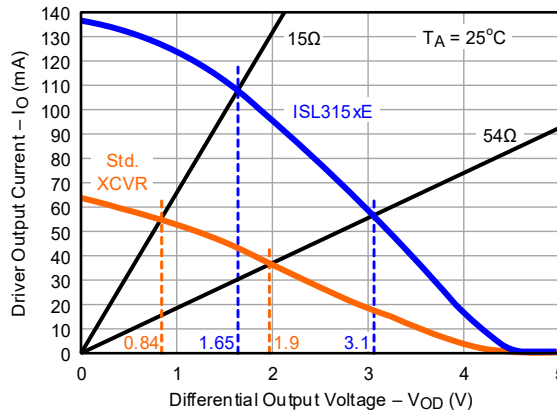


Figure 9. Output Drive Comparison: ISL315xE vs Standard Transceivers

This high driver capability allows them to drive

- up to 2600m (twice the maximum cable length suggested in TSB-89-A)
- or twice the number of 1/8 unit-load transceivers (512 versus 256)
- or even be configured in a star configuration (eight versus two terminations, see Figure 10)

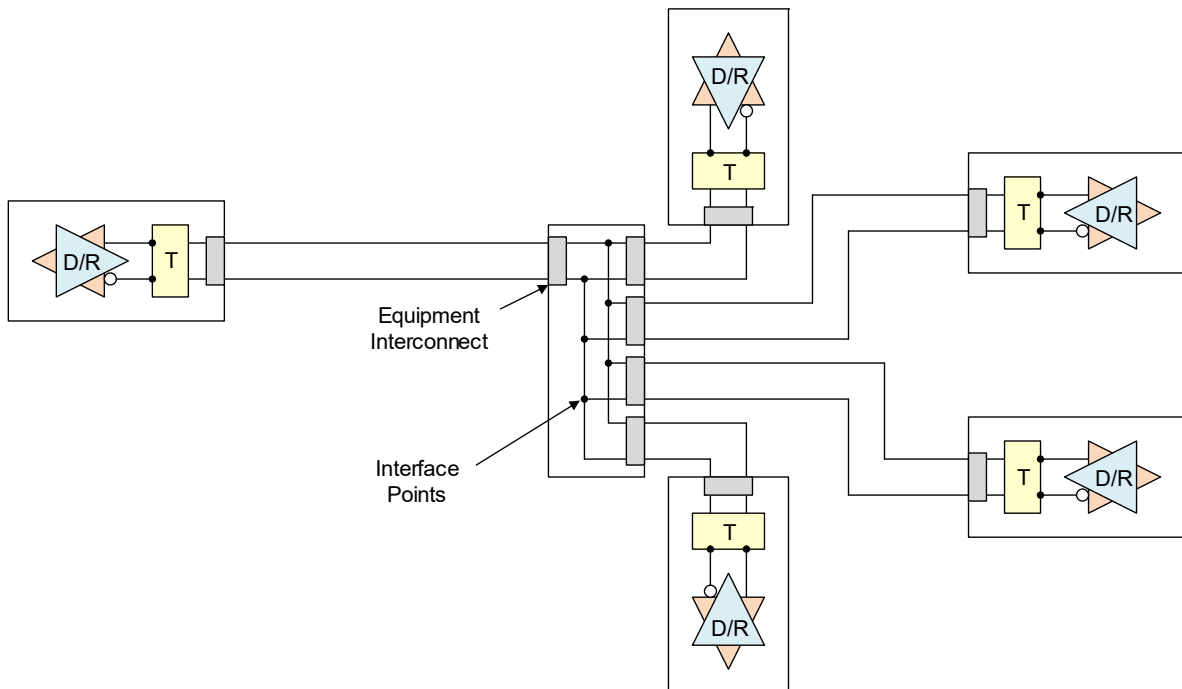


Figure 10. Star Configuration with  $L_{Stub} \gg L_{Stub(max)}$  (Not Recommended for Standard Transceiver, but Possible with ISL315xE Transceivers, which can Drive up to 8 Terminations)

For more detailed information, consult the *ISL315xE datasheet*.

## 10. Why do RS-485 transceivers require high EFT immunity?

Industrial RS-485 networks often are subject to electrical fast transient (EFT) bombardment on a daily base. These transients originate when inductive loads, such as relays, switch contactors, or heavy-duty motors, are de-energized. They can corrupt the data traffic bus nodes and even damage transceivers, resulting in network downtime.

To withstand these transient without the need for external transient suppressors, the RAA78815x family of RS-485 transceivers was developed.

The RAA78815x transceivers were exposed to 5kV EFT transients and subsequently tested for parametric performance. None of the devices showed any parametric shift, thus making them the transceiver family with the industry's highest EFT immunity.

For detailed information consult application note R15AN0006EU0100 EFT, *Immunity of the RAA78815x Family of 5V RS-485/RS-422 Transceivers*.

## 11. How can I protect my RS-485 transceiver against surge transients?

Surge transients result from lightning strikes (direct strike or induced voltages and currents due to an indirect strike), and the switching of power systems, including load changes and short circuits switching.

Their energy content is about 100 times that of an EFT pulse train and more than 8-million times that of an ESD pulse, which makes them the most lethal form of overvoltage transients.

To protect against lethal surge transients, external transient suppressor devices (TVS) are recommended. For standard transceivers, whose internal ESD structures have lower trigger voltages in the range of 10V to 15V, series resistors with values of 10Ω to 50Ω are required to prevent interaction between the internal ESD diodes and the external TVS devices (Figure 11).

Overvoltage protected transceivers with ESD trigger levels of more than 60V, do not require these resistors. Instead, they can operate with more powerful TVS devices to achieve protection levels of up to several thousands of volts (Figure 12).

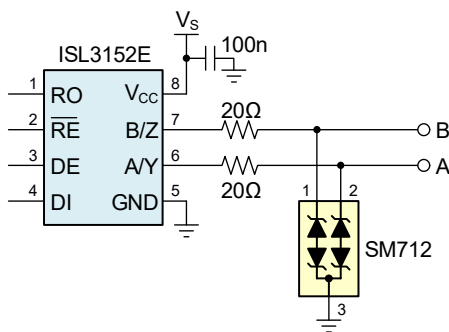


Figure 11. 500V Surge Protection for a Standard Transceiver

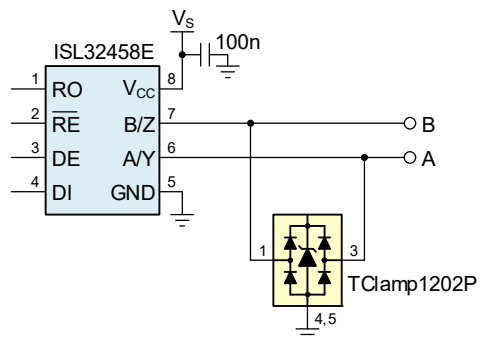


Figure 12. 3kV Surge Protection for an Overvoltage Protected Transceiver

For more in-depth information on the various transient immunity tests, types of transient suppressors, and protection schemes for standard and overvoltage protected transceivers, consult the following application notes:

- AN1976: *Important Transient Immunity Tests for RS-485 Networks*
- AN1977: *Transient Voltage Suppressors: Operation and Features*
- AN1978: *Surge Protection for Renesas' Standard RS-485 Transceivers*
- AN1979: *Surge Protection simplified with Renesas' Overvoltage Protected (OVP) Transceivers*

## 12. Do you have more RS-485 application collateral?

**Table 2. List of Application Notes**

File Number	Title
AN1593	<i>Add a Loss-of-Signal (LOS) Indicator to your RS-485 Transceiver</i>
AN1976	<i>Important Transient Immunity Tests for RS-485 Networks</i>
AN1977	<i>Transient Voltage Suppressors: Operation and Features</i>
AN1978	<i>Surge Protection for Renesas' Standard RS-485 Transceivers</i>
AN1979	<i>Surge Protection simplified with Renesas' Overvoltage Protected (OVP) Transceivers</i>
AN1980	<i>Ground Potential Differences: Origin and Remedies</i>
AN1986	<i>External Failsafe Biasing of RS-485 Networks</i>
AN1988	<i>Isolated RS-485 Repeaters, the Backbone of Industrial Long Haul Networks</i>
AN1991	<i>Isolating RS-485 Interfaces with High-Speed Digital Optocouplers</i>
R15AN0002	<i>RS-485 Transient Protection in Industrial DC-Supply Buses</i>

**Table 3. List of Technical Briefs**

File Number	Title
TB505	<i>Understanding the Difference between HBM and IEC61000-4-2 ESD Immunity</i>
TB506	<i>Functional Principles of RS-485 Drivers and Receivers</i>
TB507	<i>Dual-Protocol Transceivers simplify Interface Designs</i>
TB508	<i>Dual-Protocol Applications: Programmable versus Standard Transceivers</i>
TB509	<i>Detecting Bus Signals correctly with Failsafe biased RS-485 Receivers</i>
TB510	<i>Transmitting Full-Duplex Data over Single Twisted-Pair cable</i>
TB511	<i>The Unit Load Concept</i>

**Table 4. List of White Papers**

<i>How to simplify Industrial PC Interfaces</i>
<i>Dual Protocol Transceivers ease the Design of Industrial Interfaces</i>
<i>Overvoltage Protection for RS-485 Bus Nodes</i>
<i>Design Considerations for High-Speed RS-485 Data Links</i>
<i>RS-485 Transceiver Tutorial</i>
<i>How to simplify Industrial PC Interfaces</i>

## 13. Revision History

Revision	Date	Description
1.00	May 17, 2022	Initial release.

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(Rev.1.0 Mar 2020)

### Corporate Headquarters

TOYOSU FORESIA, 3-2-24 Toyosu,  
Koto-ku, Tokyo 135-0061, Japan  
[www.renesas.com](http://www.renesas.com)

### Contact Information

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