Application Note ANI-22

Enhanced Receiver Failsafe Implementation In Dual Protocol SP339 and XR34350 Serial Transceivers

Introduction

The standard receiver failsafe feature is used to keep the data bus in a known state when there are no active signals on the bus. The receivers of Exar's RS-485/RS-422 transceiver typically fall into two different failsafe types: standard RS-485/RS-422 failsafe (or traditional failsafe) and RS-485/RS-422 enhanced failsafe mode. This application note discusses how the enhanced receiver failsafe features of the SP339 and XR34350 Serial Transceivers can help customers with failsafe problems in their network.

Standard Receiver Failsafe Feature

A typical standard RS-485/422 transceiver with the failsafe feature such as the Exar's SP491 only offers a standard receiver failsafe mode. The receiver provides a logic high at the receiver output when the receiver inputs are open circuit or un-driven. For example, when the data cable is disconnected from the network, the receiver output will keep the output RO at a logic high. The standard receiver failsafe device has an internal weak biasing network that will force the open inputs to voltage greater than 200mV, which results in a logic high at the RO receiver output. Figure 1 shows the receiver configuration for the failsafe logic high output.

The standard failsafe receiver only supports one condition:

1. Open Input

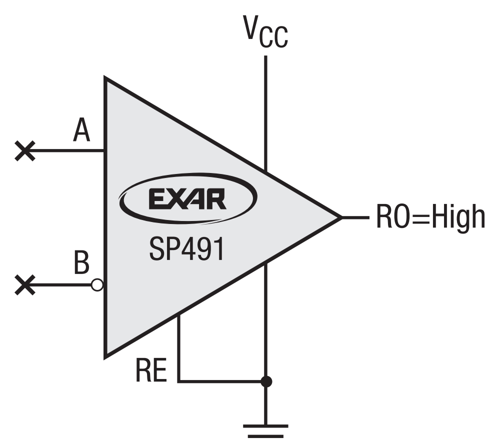

Figure 1: Standard Failsafe with Open Input

In some applications, the network is operating at high speeds with termination resistors at both end of the bus to prevent signal reflections. These termination resistors are used to match the characteristic impedance of the data cable. In most applications, the bus termination resistor (R_{TERM}) is typically 120Ω. When a termination resistor is connected between receiver inputs A and B (see Figure 2), the standard receiver failsafe feature will not operate properly.

This is a very common problem with standard failsafe receiver devices. The termination resistor (R_{TERM}) causes potential difference between input A and input B to be close to 0V, so the internal biasing circuitry inside the device is not strong enough to override the termination load. It will put the device into the "Indeterminate Region" (see the standard sensitivity

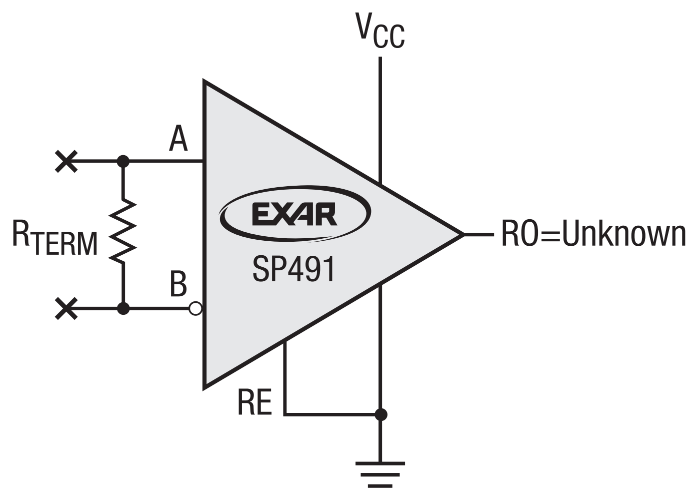

Figure 2: Standard Failsafe with Termination Resistor (R_{TERM})

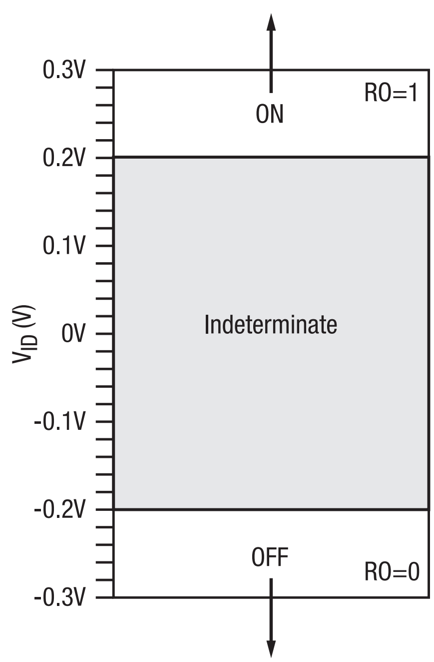

Figure 3: Standard Failsafe Receiver Sensitivity Range

range in Figure 3) which could result in the receiver output (RO) to be unknown (could be at logic high or logic low).

The standard failsafe receiver has a wide input sensitivity of +/-200mV. This means that any potential difference between input A and input B within +/- 200mV will put the receiver output into the indeterminate range and an unknown state. Under this condition, the user may find the receiver output state on some devices at logic high while others devices are at logic low. In some customer installations with enough noise present on the network, an oscillating clock pulse at output RO could be produced.

One solution to solve this problem is to include an external biasing network that will provide a potential difference much larger than 200mV across the receiver inputs A and B. This external biasing network is a simple pull-up resistor from input A to Vcc and a pull-down resistor from input B to GND (as seen in Figure 4). The values of the pull-up and pull-down resistors

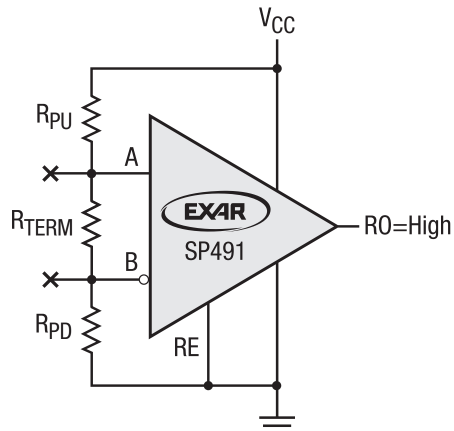

Figure 4: Standard Failsafe with Termination Resistor (R_{TERM})

are selected to provide at least 200mV across the A and B inputs.

Example:

A common 549/60/549Ω resistor network is commonly use to bias the standard failsafe receiver

Given: Vcc=5V, R_{TERM} = 60Ω, R_{PU} = 549Ω, R_{PD} = 549Ω

V_{AB} = Vcc * (R_{TERM} / (R_{PU} + R_{TERM} + R_{PD})) = 5 V * (60Ω / (549Ω + 60Ω + 549Ω))

V_{AB} = 5 * (60 / 1158) V

V_{AB} = 0.25907V = 259mV (which is greater than +200mV and in the region where RO = 1).

In this case, the receiver output RO is a high.

SP339 and XR34350 Enhanced Receiver Failsafe Feature

The RS-485/RS-422 mode transceiver of the SP339 and XR34350 has an enhanced receiver failsafe feature, where the receiver supports three conditions:

1. Open input
2. Shorted input
3. Un-driven terminated lines

The enhanced failsafe feature of the SP339 and XR34350 guarantees a logic high receiver output when the receiver inputs are open, shorted, or terminated but un-driven/idle. The resulting SP339 and XR34350 interpret 0V differential voltage at the receiver input produces a logic high at receiver output. No further external biasing resistors are required. There is still an

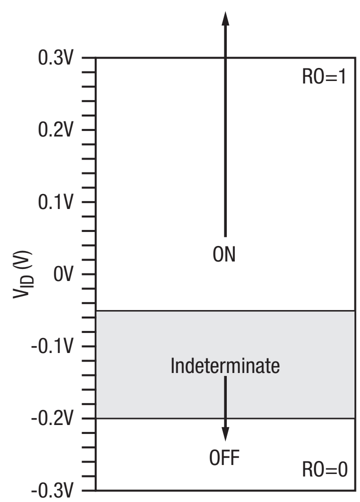

Figure 5: Enhanced Failsafe Receiver Sensitivity Range

indeterminate range from -200mV to -50mV where the output of receiver is unknown.

The enhanced failsafe receiver sensitivity range is shown in Figure 5.

When the connected driver is disabled while the receiver input is open, shorted, or terminated the potential difference at

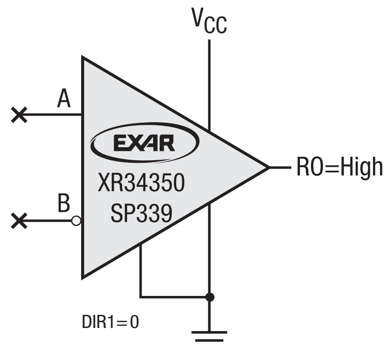

Figure 6: Enhance Failsafe SP339 and XR34350 with Open Input

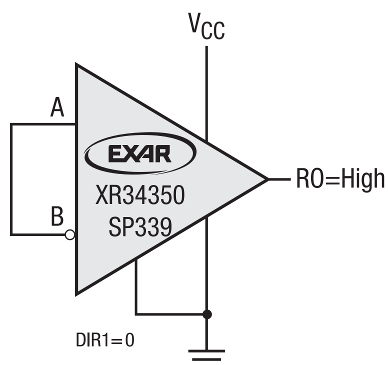

Figure 7: Enhanced Failsafe with Shorted Input

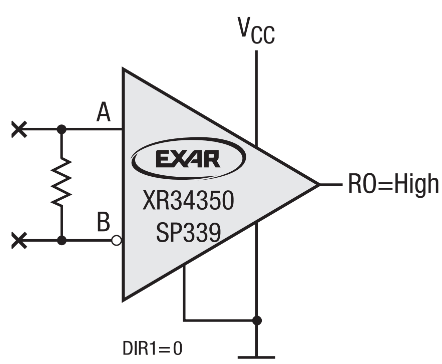

Figure 8: Enhanced Failsafe SP339 and XR34350 with Un-driven Terminated Lines

receiver input will be very close to 0V. Since the enhanced receiver failsafe device has a built in negative threshold, the output is still a logic high when the differential voltage is 0V. Figures 6, 7 and 8 show the three different conditions for the enhanced receiver failsafe mode with a high output.

The receiver of the SP339 and XR34350 must provide reliable operations in demanding operating environments. The enhanced failsafe feature on the SP339 and XR34350 receivers will ensure that it will default to a known output state even if there is no differential signal on the bus, the bus is shorted together, or the bus is terminated but un-driven.

In most customer applications, the standard technique for improving differential failsafe is to bias differential lines on the SP339 and XR34350 receivers to a known state. Placing a pull-up resistor (R_{PU}) with a jumper option JP1 to a Vcc on one

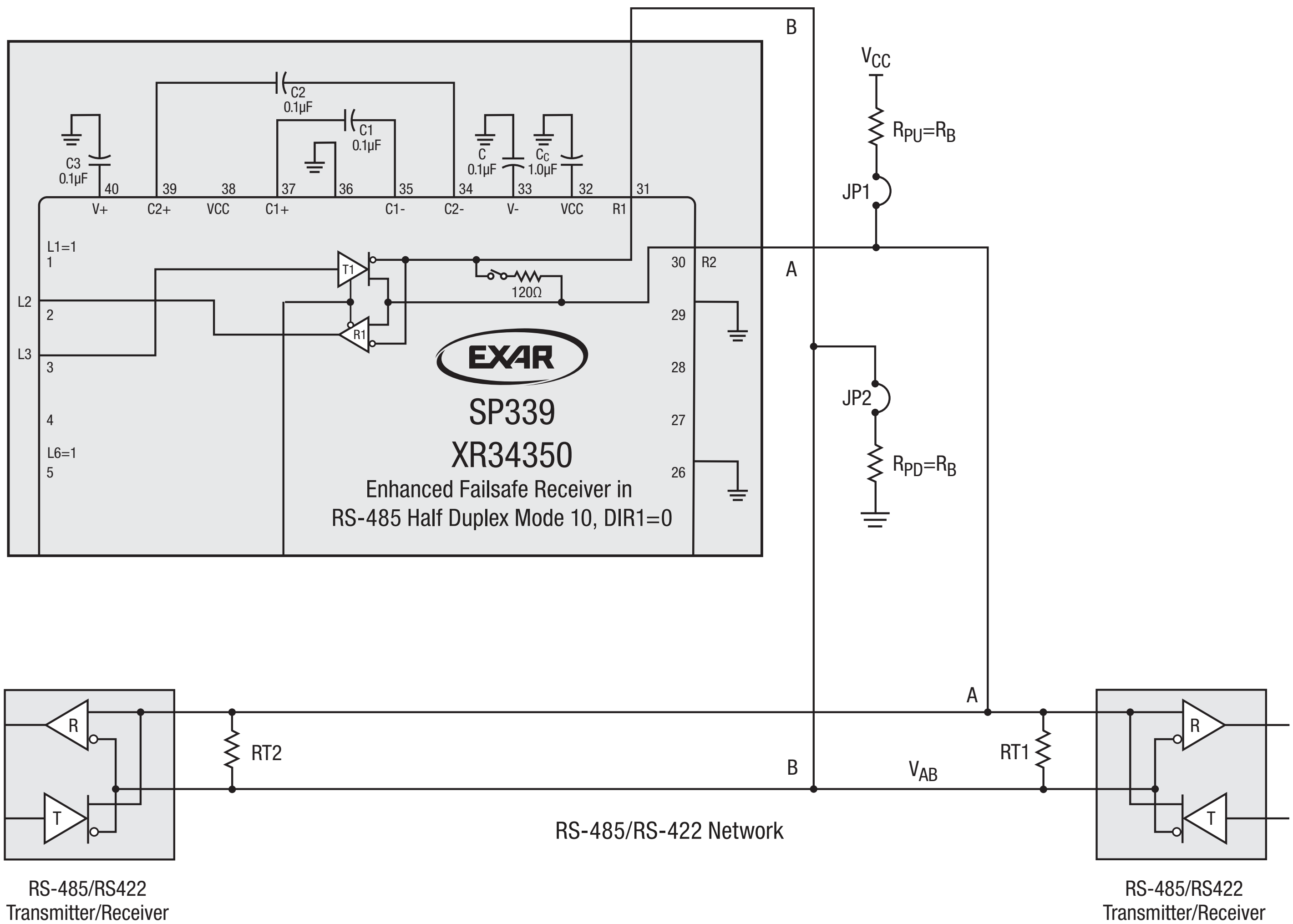

Figure 9: SP339 and XR34350 in RS-485 or RS-422 Mode with JP1 and JP2 Installed

line and a pull-down (R_{PD}) resistor with a jumper option JP2 to a ground on the other line of SP339 and XR34350 receiver inputs ensures that the others receivers will always see a differential voltage (much greater than 200mV) even if there is no driver activity on the bus. Figure 9 is an example of SP339 and XR34350 configuration when the RS485/RS-422 receiver is used (DIR1 = 0, Mode 10).

How are the R_{PU} and R_{PD} calculated for the RS-485/RS-422 network with multiple standard failsafe receivers? For simplicity,

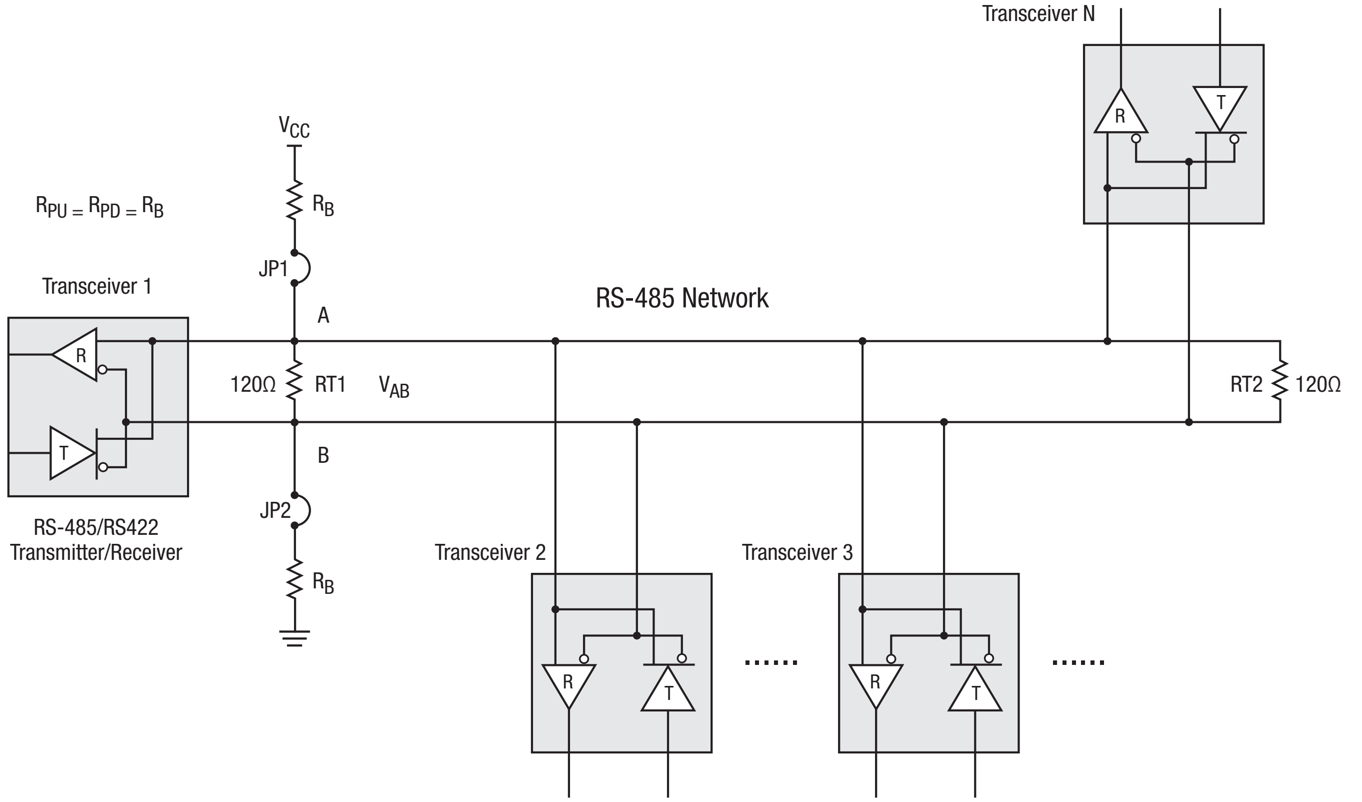

Figure 10: SP339 and XR34350 in RS-485 Mode with Other Transceivers

let's call $R_{PU} = R_{PD} = R_B$, where R is a biasing resistor in our network.

Figure 10 shows an equivalent RS-485 distributed network with multiple standard failsafe transceivers. In order to force

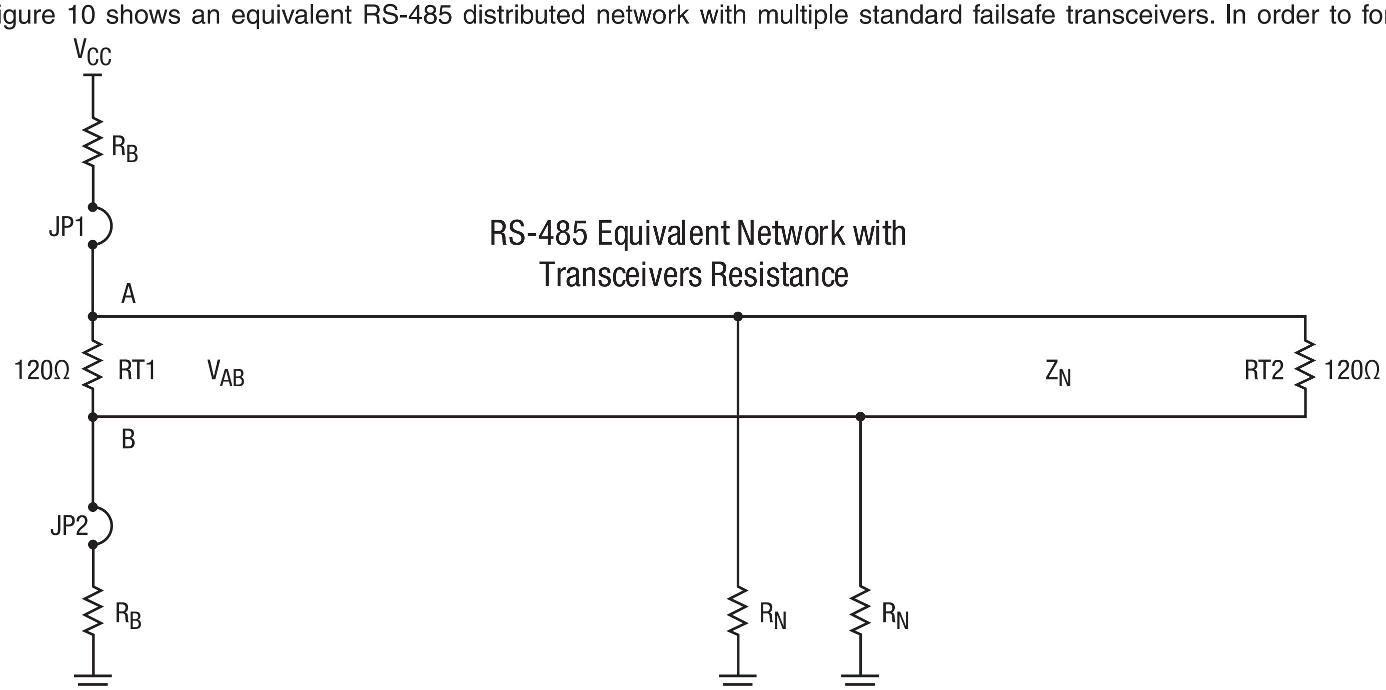

Figure 11: Equivalent Network with Transceivers Resistance

receiver outputs into a defined state, failsafe biasing resistors Rb are introduced. They provide a voltage V_{AB} across the input A and input B receivers when the RS-485 bus is in idle mode.

$$\frac{V_{CC}-V_A}{R_B} = \frac{V_A-V_B}{RT1} + \frac{V_A}{R_N} + \frac{V_A-V_B}{RT2}$$

$$\frac{V_{CC}-V_A}{R_B} = (V_A-V_B) * \left(\frac{1}{RT1} + \frac{1}{RT2}\right) + \frac{V_A}{R_N}$$

$$\frac{V_A}{R_N} = \frac{V_{CC}-V_A}{R_B} - (V_A-V_B) * \left(\frac{1}{RT1} + \frac{1}{RT2}\right) \qquad \text{Equation (1)}$$

If R_N is used to represent the net resistance of all others transceivers on the network, the RS-485 equivalent network model is shown below:

$$\frac{V_B}{R_B} + \frac{V_B}{R_N} = \frac{V_A-V_B}{RT1} + \frac{V_A-V_B}{RT2}$$

$$\frac{V_B}{R_N} = (V_A-V_B) * \left(\frac{1}{RT1} + \frac{1}{RT2}\right) - \frac{V_B}{R_B} \qquad \text{Equation (2)}$$

Using Kirchoff's current law at node A:

$$\frac{V_A}{R_N} - \frac{V_B}{R_N} = \frac{V_{CC}-V_A}{R_B} - (V_A-V_B) * \left(\frac{1}{RT1} + \frac{1}{RT2}\right) - (V_A-V_B) * \left(\frac{1}{RT1} + \frac{1}{RT2}\right) + \frac{V_B}{R_B}$$

$$\frac{V_A}{R_N} - \frac{V_B}{R_N} = \frac{V_{CC}}{R_B} - \frac{V_A-V_B}{R_B} - 2(V_A-V_B) * \left(\frac{1}{RT1} + \frac{1}{RT2}\right)$$

$$\frac{V_{CC}}{R_B} = \frac{V_A-V_B}{R_N} + \frac{V_A-V_B}{R_B} + 2(V_A-V_B) * \left(\frac{1}{RT1} + \frac{1}{RT2}\right)$$

$$\frac{V_{CC}}{R_B} = (V_A-V_B) * \left(\frac{1}{R_N} + \frac{1}{R_B} + 2\left(\frac{1}{RT1} + \frac{1}{RT2}\right)\right)$$

And at node B input:

$$\frac{1}{R_N} + \frac{1}{R_B} \geq \frac{1}{375} \qquad \text{Equation (3)}$$

The voltage $V_{AB} = V_A - V_B$ is found by subtracting Equation (2) from Equation (1):

$$R_B = \frac{\dfrac{V_{CC}}{(V_A-V_B)}}{\left(\dfrac{1}{R_N} + \dfrac{1}{R_B} + 2\left(\dfrac{1}{RT1} + \dfrac{1}{RT2}\right)\right)} \qquad \text{Equation (4)}$$

The RS-485/RS-422 standard specifies the minimum common mode resistance RCM= 375Ω looking into the input A/B. The parallel combination of R_N and R_B must be equal to or greater than 375Ω.

$$R_B = \frac{5}{0.25} \Big/ \left(\frac{1}{375} + \frac{4}{120}\right) = \frac{5}{0.25} * 27.78 = 555.56\Omega$$

The bias-resistor R_B is equal to:

Given V_{CC} = 5V, RT1 = RT2 = 120Ω, $V_A - V_B = V_{AB}$ = 250 mV (50mV above the required minimum +200mV for receiver output RO=high):

$$\frac{1}{R_N} + \frac{1}{R_B} \geq \frac{1}{375}$$

$$\frac{1}{R_N} \geq \frac{1}{375} - \frac{1}{549}$$

$$R_N \leq 1184.2\Omega$$

With tolerance of 1% resistor, the next closest bias-resistor is 549Ω.

$$N_{MAX} \leq \frac{12000}{1184.2}$$

$$N_{MAX} \leq 10.13$$

$$N_{MAX} = 10 \text{ transceivers on the bus}$$

As observed from Figure 10, failsafe biasing is adding additional load to the RS-485 network. The maximum number of devices on the network can be calculated from Equation (3).

The maximum number of transceivers N_{MAX} is then equal to the unit load resistance divided by the value of R_N:

Transceivers Type	Maximum Number of Transceivers N_{MAX}
UL	10
1/2 UL	20
1/4 UL	40
1/8 UL	80

Table 1: Transceiver Type and Maximum Number of Transceivers

Given the standard unit load input resistance is specified at 12kΩ, the maximum number of transceivers on the bus is calculated to be about ten transceivers. Table 1 calculates the maximum numbers of transceivers on the bus for one unit load (UL), 1/2 UL, 1/4 UL and 1/8 UL transceiver.

A common misconception is that an individual biasing network for each transceiver is needed, although it can be accomplished

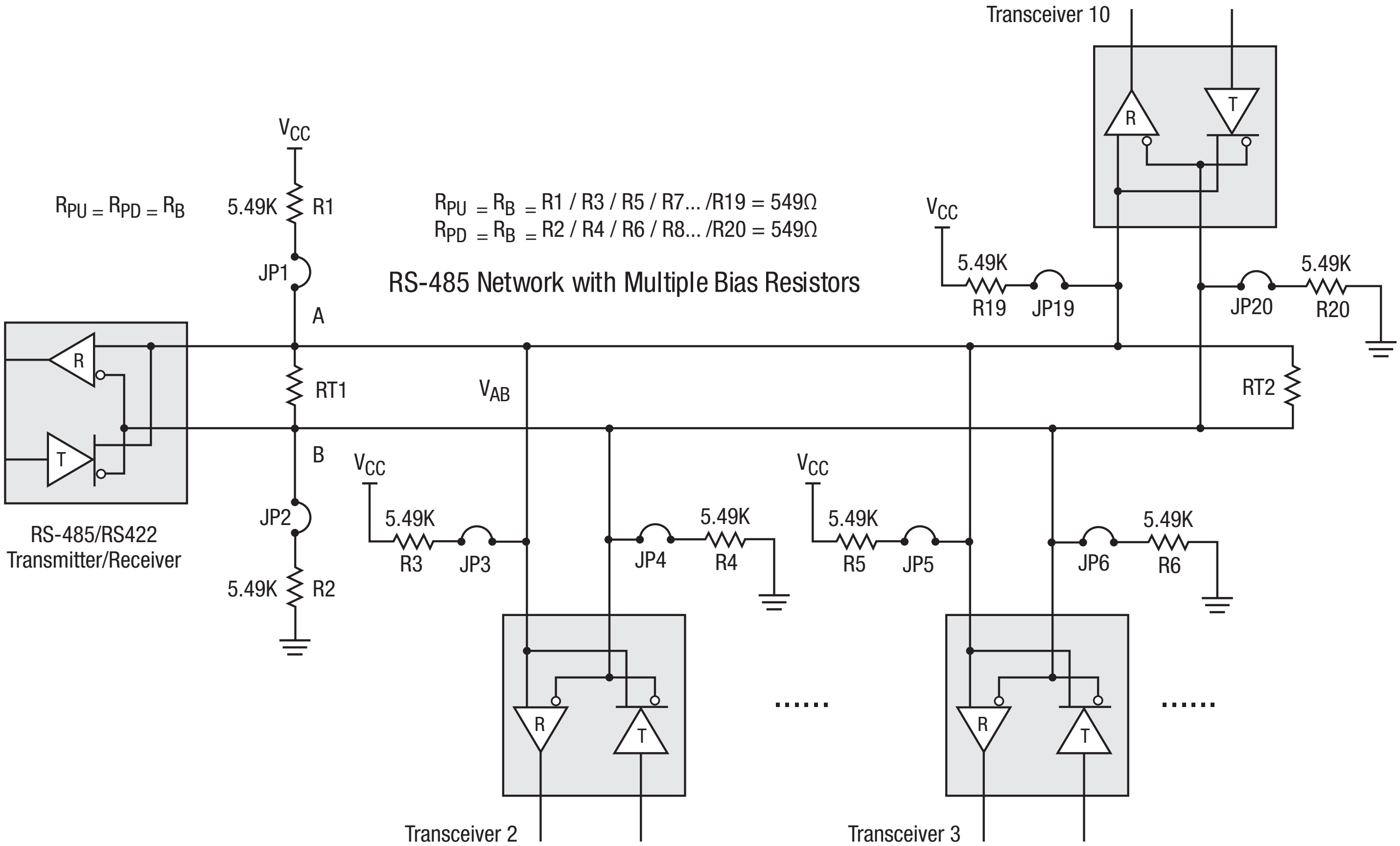

Figure 12: Network with Multiples Pull-up and Pull-down Bias Resistors

by dividing the bias resistor R_B into the number of transceivers on the network. For example, in our previous network with 10 devices on the bus, the pull-up/pull-down resistors are 5.49kΩ. When all 10 resistors are combined in parallel, the bias resistor R_B is 549Ω as required for failsafe biasing.

As observed in Figure 12, it is rather complicated to implement the network with multiple pull-up/pull-down resistors. The best method is to have one bias resistors network as shown previously in Figure 10 (with only JP1 and JP2 installed, R_B = 549Ω, and RT1 = RT2 = 120Ω, all others jumpers and resistors should be removed).

Considerations for using biasing resistors in a mixed RS-232/RS-485 application is one of the most complex challenges

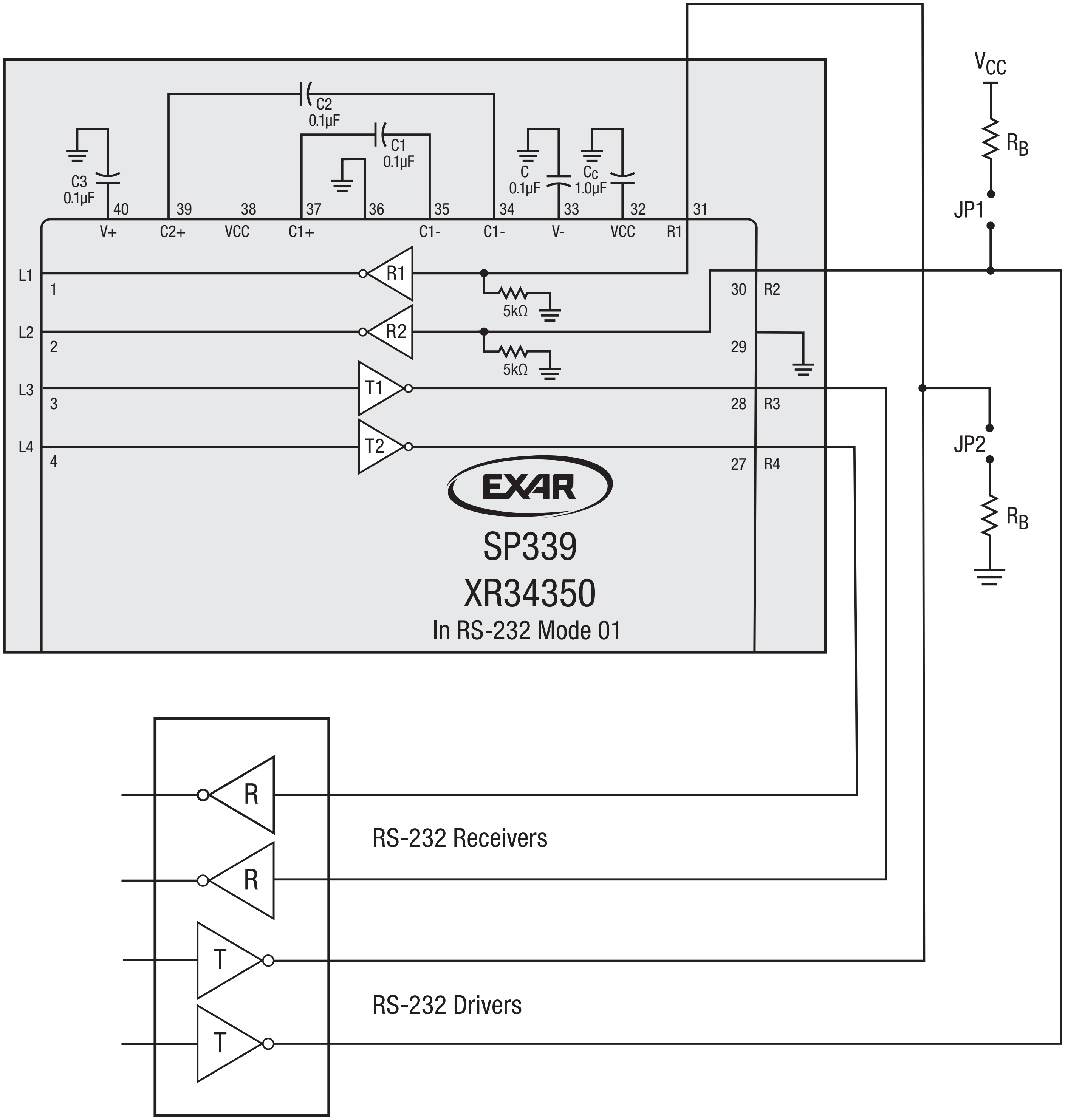

Figure 13: SP339 and XR34350 in RS-232 Mode with JP1 and JP2 Removed

system designers have to face when sharing the RS-485/RS-422 bus lines across multiple serial devices. Pull-up/pull-down R_B resistors may be necessary for reliable RS-485/RS-422 communication, but they must be removed when the SP339 and XR34350 are operating in a RS-232 network installation as shown in Figure 13.

When switching the SP339 and XR34350 to the RS-232 mode (Mode 01) and leaving the pull-up and pull-down resistors connected to the RS-232 input/output, additional resistance is introduced into the RS-232 signal path. The extra resistance could add unexpected delays and skew into the RS-232 signals. In order to resolve this issue, many customers have to remove the jumpers JP1 and JP2 from the system circuitry when the SP339 and XR34350 are operating in RS-232 mode. Removing the JP1 and JP2 jumpers removes the pull-up/pull-down resistors from the RS-232 connections and ensures the signal integrity of the RS-232 signals.

Conclusion

While the biasing network for the standard failsafe receiver is very straightforward, the use of enhanced failsafe receiver such as the SP339 and XR34350 eliminates external failsafe biasing for open input, shorted, and terminated un-driven busses. Under extremely noisy RS-485/RS-422 bus environments, external pull-up/pull-down resistors are recommended to prevent the differential voltage to fall into the indeterminate range. However in RS-232 mode, the SP339 and XR34350 already have internal build in termination, so the external pull-up/pull-down resistors are not recommended. The use of jumpers for the pull-up/pull-down resistors make configuration between RS-232 mode and RS-485/RS-422 mode easier.

For Further Assistance:

Email: CustomerSupport@exar.com or uartTechSupport@exar.com

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Exar Corporation Headquarters and Sales Offices
48720 Kato Road Tel.: +1 (510) 668-7000
Fremont, CA 94538 - USA Fax: +1 (510) 668-7001