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RS-485 Advanced Fail-Safe Feature

Application Note

Revision History

Document No.	Release Date	Change Description
291ANR01	May 18, 2023	**Updated:** ■ “Devices with Standard or Advanced RS-485/RS-422 Fail-Safe Receivers” table. ■ "Standard Fail-Safe Receiver with Termination Resistors Network" figure.
291ANR00	December 17, 2021	Initial release.

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Introduction

The modern RS-485 devices have an advanced receiver that uses an advanced fail-safe feature. The advanced fail-safe receiver solves the problems encountered in the standard fail-safe receiver and also:

- Ensures that the receiver output is in the *known state* when the network is idle.
- Reduces the overall cost and other inefficiencies within the standard system.
- Supports open, shorted, and terminated inputs.

Note: The standard fail-safe feature only supports the *open inputs* condition.

This document describes the benefits of using the advanced fail-safe receiver in the RS-485 network.

1.0 Standard and Advanced RS-485 Fail-Safe Receivers

The common RS-485 receivers, such as SP485E, provide a standard fail-safe feature that produces an output with a logic *high* when the inputs A and B are left floating. Internal to the receiver, the non-inverting input A has a very low bias voltage, a difference of more than 200mV compared to the inverting input B. This causes the receiver output (RO) to be logic *high* when both inputs are left floating (or open inputs).

The following figure shows the SP485 standard fail-safe receiver with open inputs.

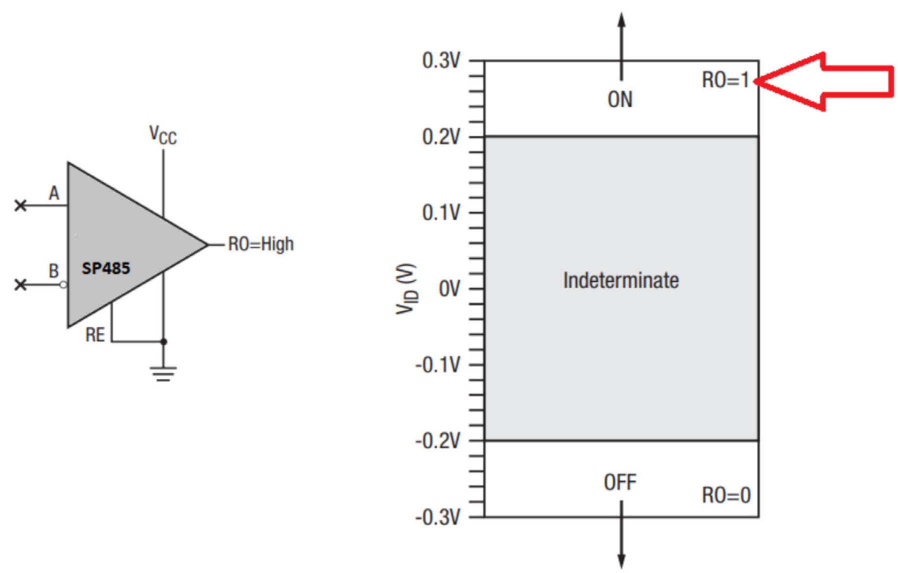

Figure 1: Standard Fail-Safe Receiver with Open Inputs

The previous arrangement works as expected for the standard fail-safe receiver with floating (or open) inputs of A and B, but problems can occur when there is a termination resistor or a short between the inputs A and B. The bias voltage of the input A is low, and not strong enough to create the necessary potential difference of 200mV between the inputs. The voltage difference between the inputs A and B collapses to approximately 0mV when the inputs are shorted or terminated. With this result, the SP485 standard fail-safe receiver is placed in the *indeterminate* region, where the result of the RO is in the *indeterminate* zone (either a *1* or a *0*). Figure 2 shows this situation. The output is unpredictable and therefore not desirable for use in the RS-485 network.

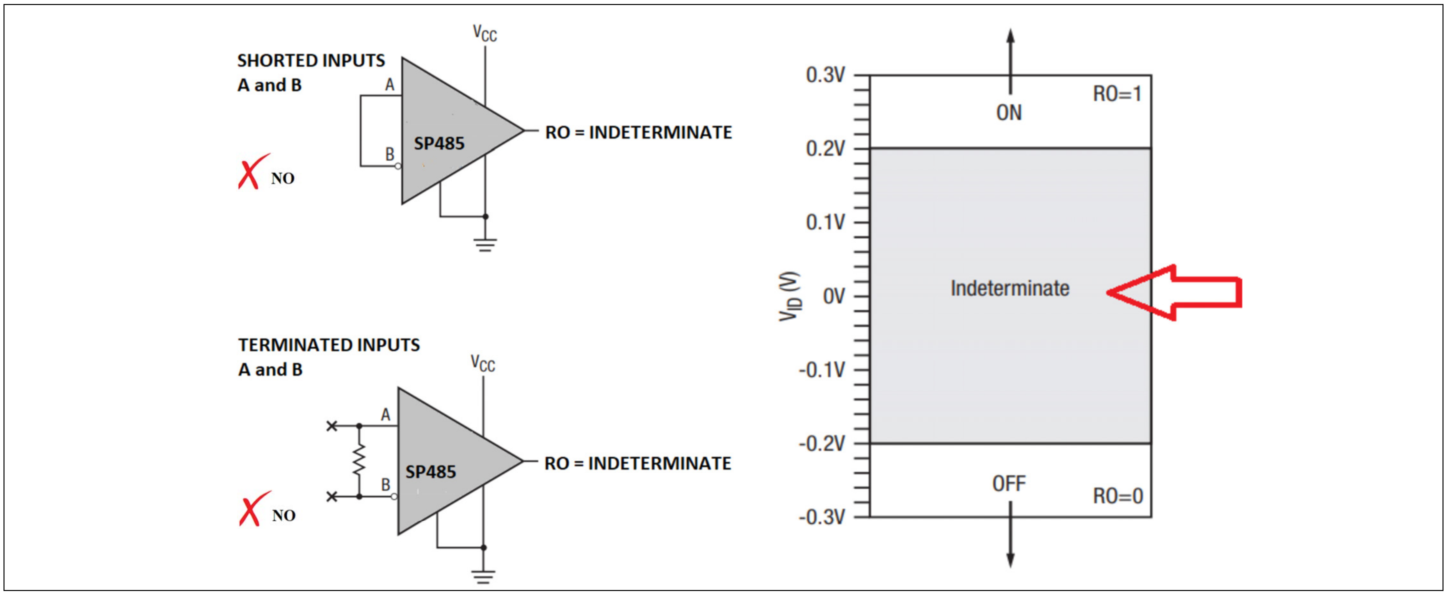

Figure 2: Standard Fail-Safe Receiver with Shorted and Terminated Inputs

To prevent the scenarios previously described from occurring in the RS-485 network when there is a termination resistor or a shorted between the inputs A and B, the standard fail-safe receivers must have additional resistors—pull-up (Rpu) and pull-down (Rpd) resistors—on the RS-485 bus. While the Rpu and Rpd resistors typically have a value of 4.7kΩ, the additional resistors ensure that the voltage difference between the inputs A and B, on the bus, is greater than 200mV. When the bus is idle (not driven), the node A is pulled to V_{CC} and the node B to 0V. The voltage difference between the node A and the node B is much greater than 200mV. This results in an RO of logic *1* (or V_{CC} as the output).

The following figure shows the bus in idle condition.

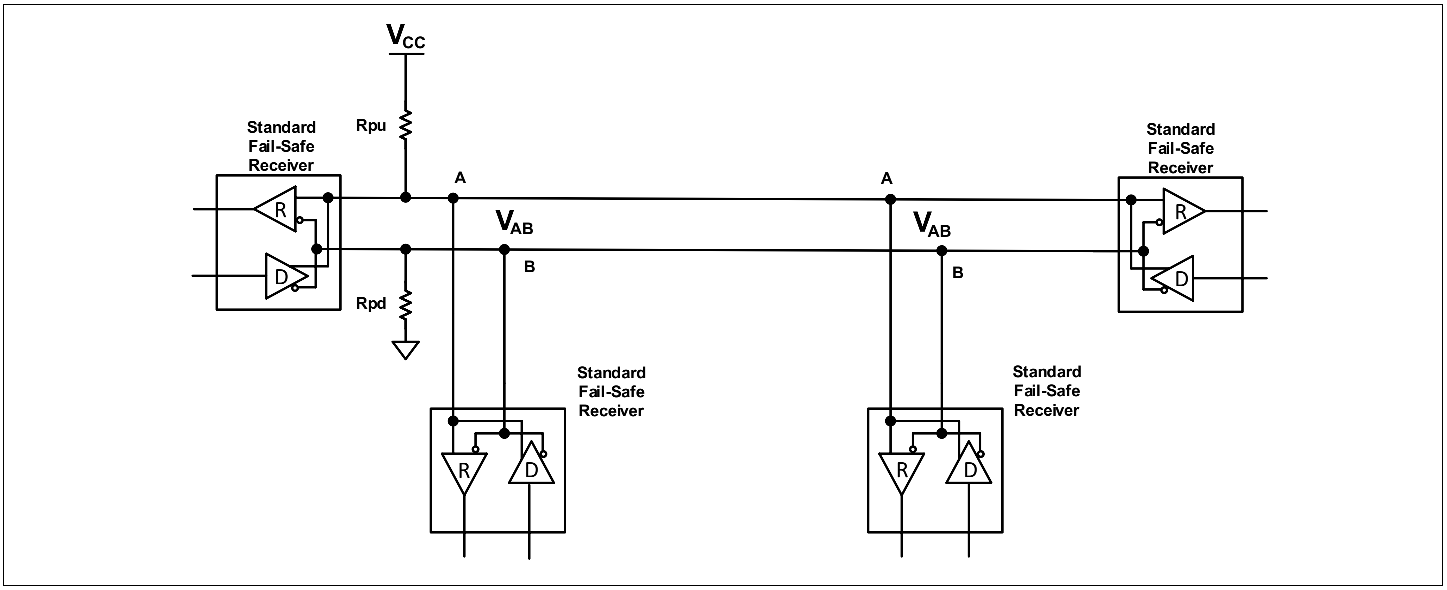

Figure 3: Bus in Idle Condition

The arrangement shown in Figure 3 works for all standard fail-safe receivers on the bus. It forces the output of all standard receivers on the bus to a logic *1* (or high) output.

When you add the termination resistor RT1 = 60Ω on the biasing network, the 4.7kΩ pull-up/pull-down resistors are ineffective because the voltage drops across the 60Ω resistor (or V_{AB}) and places all the standard fail-safe receiver inputs in the *indeterminate* region. To force the voltage difference between the nodes A and B to be greater than 200mV, an additional calculation must be done for the biasing network.

The following figure shows the standard fail-safe receiver and the termination resistors network.

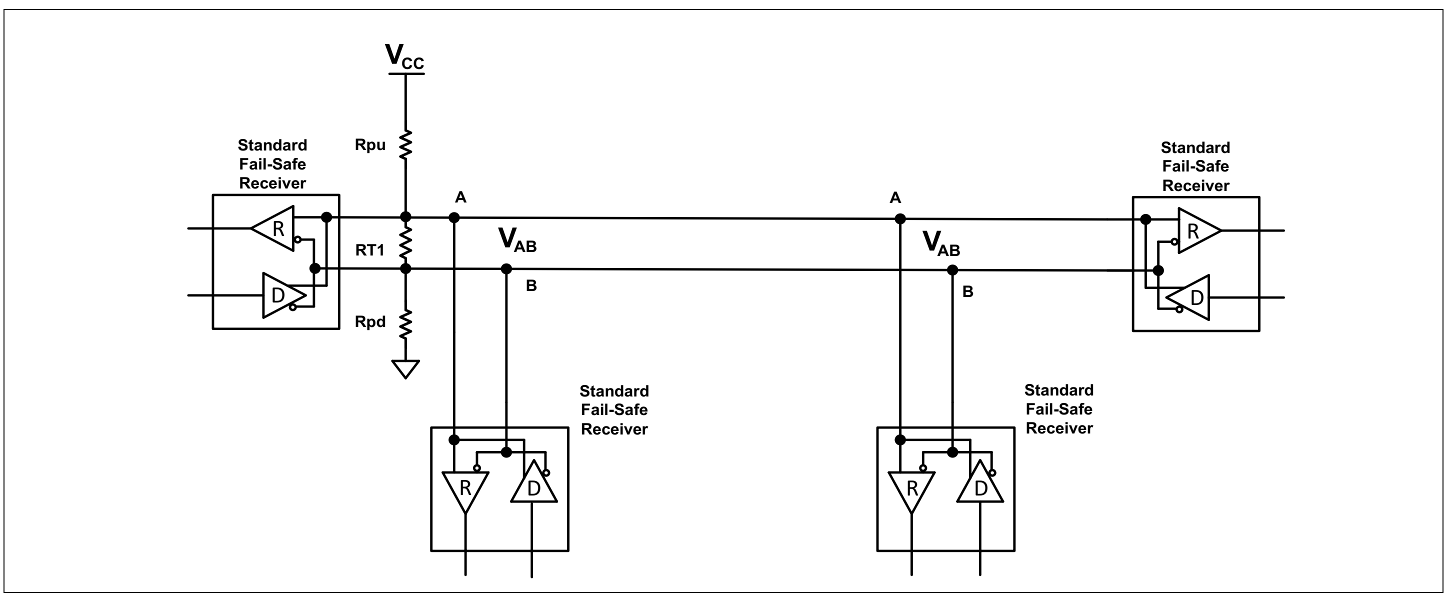

Figure 4: Standard Fail-Safe Receiver with Termination Resistors Network

For this calculation, the voltage difference between the node A and the node B is set to approximately 400mV, forcing the RO to equal a *1* output. The new calculation is as follows:

$RT1 = 60\Omega$ (equivalent resistor between the node A and the node B)

$Rpu = Rpd = Rs$ (the same pull-up and pull-down resistor)

With $V_{CC} = 5V$

$$V_{AB} = \frac{5 \times RT1}{(Rpu + Rpd + RT1)}$$

$$0.4 = \frac{5 \times 60}{(2 \times Rs + 60)}$$

$$2 \times Rs + 60 = \frac{5 \times 60}{0.4}$$

$$Rs = \frac{(750 - 60)}{2} = 345\Omega$$

With $V_{CC} = 3.3V$

$$V_{AB} = \frac{3.3 \times RT1}{(Rpu + Rpd + RT1)}$$

$$0.4 = \frac{3.3 \times 60}{(2 \times Rs + 60)}$$

$$2 \times Rs + 60 = \frac{3.3 \times 60}{0.4}$$

$$Rs = \frac{(495 - 60)}{2} = 217.5\Omega$$

The standard fail-safe receiver does not offer solutions for shorted or terminated inputs without additional biasing resistors on the bus. Therefore, a different solution is required to handle the shorted and terminated input conditions without the need for a complex termination circuit. An advanced fail-safe receiver provides the additional features required to manage open, shorted, and terminated inputs, as shown in the following figure.

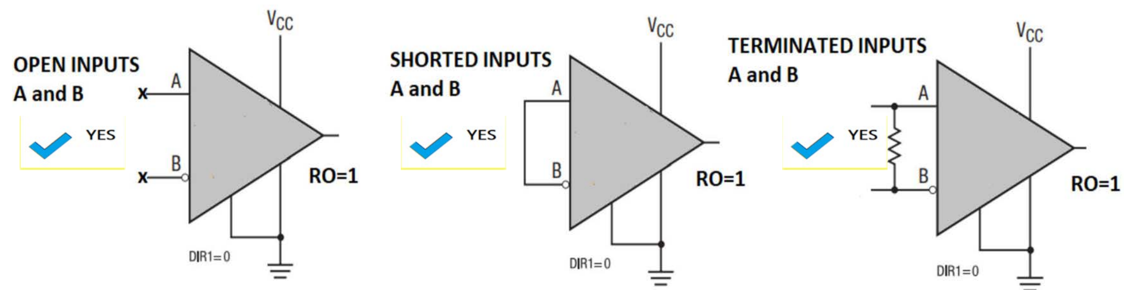

Figure 5: Advanced Fail-Safe Receiver Support of Open, Shorted, and Terminated Inputs

The advanced fail-safe receivers have different input sensitivity ranges compared to the standard fail-safe receivers. The following figure shows the input sensitivity range of an advanced fail-safe receiver.

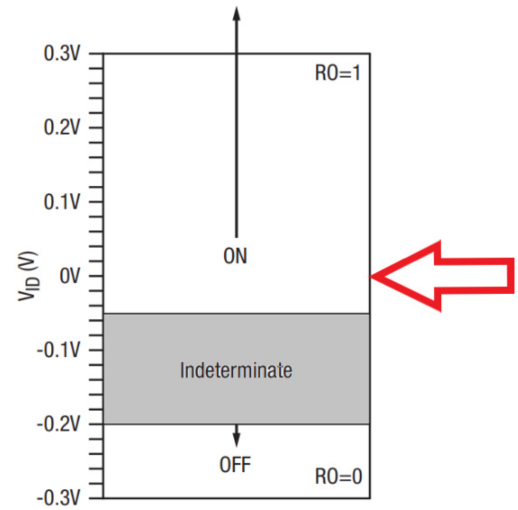

Figure 6: Advanced Fail-Safe Receiver Input Sensitivity Range

In Figure 6, there is still an *indeterminate* region from –50mV to –200mV, where the RO of the advanced fail-safe receiver is indeterminate.

The following figure shows the typical system connections for the advanced fail-safe receiver.

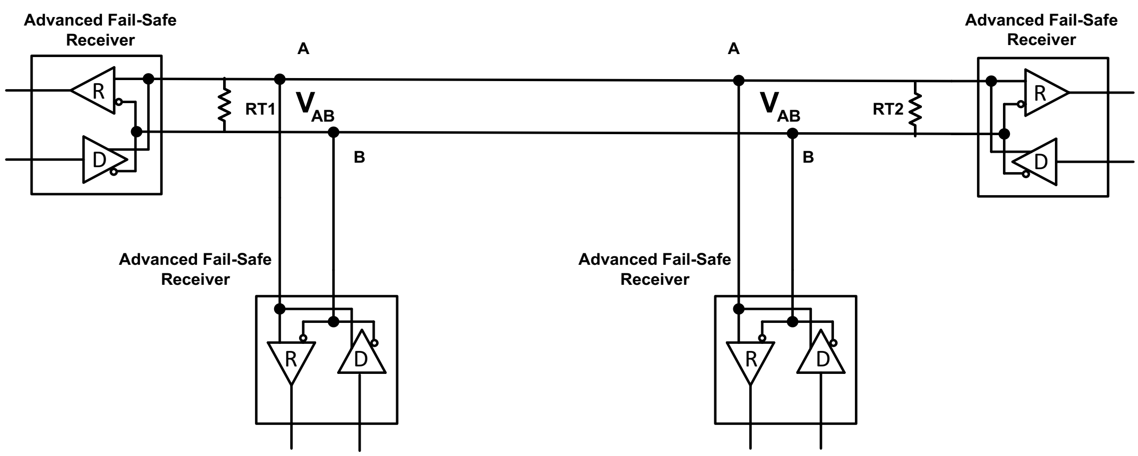

Figure 7: Advanced Fail-Safe Receiver Typical System Connections

Advanced Fail-Safe Receiver Advantages

The advanced fail-safe receiver provides features that ensure that the receiver output is in the *known state* when the network is not driven. The advanced fail-safe receiver also drives the receiver output to a logic *high* if the receiver input is open, terminated, or shorted, which was previously limited to a single open input in the standard fail-safe receiver. In addition, the advanced fail-safe receivers have the following advantages over the standard fail-safe receivers:

- They do not require an external fail-safe-bias resistors network on the system. There is a complicated calculation for the bias network if you choose the standard fail-safe receivers.
- They allow more advanced fail-safe receivers to connect to the bus. The advanced fail-safe receivers typically have an impedance of 96kΩ, which allows up to 256 receivers on the bus, while the standard fail-safe receivers typically have an impedance of 12kΩ, which allows approximately 32 receivers maximum on the bus.
- They are more robust against the ±15kV electrostatic discharge (ESD) protection and ±8kV ESD direct contact on bus pins.
- They have more packaging options, which can:
  - Produce a much smaller environmental footprint compared to the standard fail-safe transceivers.
  - Save PCB space, simplify layout constraints, and reduce system cost.
- They contain an additional handling provision for shorted and terminated inputs while the standard fail-safe receivers can only handle open input conditions.

The following table lists the devices that have the standard RS-485 or RS-422 fail-safe receiver and the devices with the advanced RS-485 or RS-422 fail-safe receiver.

Table 1: Devices with Standard or Advanced RS-485/RS-422 Fail-Safe Receivers

Product	
Advanced Fail-Safe RS-485/RS-422	**Standard Fail-Safe RS-485/RS-422**
XR33202	SP491E
XR33183	SP491
XR33181	SP490E
XR33180	SP490
XR33158	SP485R
XR33156	SP485E
XR33155	SP485
XR33152	SP483E
XR33058	SP483
XR33055	SP481E
XR33053	SP4082E
XR33052	SP3494
XR33038	SP3491
XR33035	SP3490
XR33032	SP3485
XR3088X	SP3483
XR3087X	SP26LV432
XR3085X	SP1485E
XR3082X	
XR3078X	
XR3072X	
SP3088E	
SP3085E	
SP3083E	
SP3082E	
SP3078E	
SP3077E	
SP3076E	
SP3075E	
SP3074E	
SP3073E	
SP3072E	
SP3071E	
SP3070E	
SP1486E	
MxL83101	
MxL83102	
MxL83111	
MxL83112	

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