

RS-485: Passive Failsafe for an Idle Bus

Despite the integrated failsafe features of modern RS-485 transceivers many applications use legacy parts lacking these features. Knowing how to provide failsafe operation, and in particular during an idle-bus condition, ranks therefore at the top of the list of customer inquiries to interface application groups worldwide. This article shows how to apply failsafe biasing for idle-buses externally and also suggests low-cost solutions that integrate this feature.

Failsafe Operation

RS-485 specifies the receiver output state to be logic high for differential input voltages of $V_{AB} \geq +200\text{mV}$, and logic low for $V_{AB} \leq -200\text{mV}$. For input voltages in between these limits a receiver's output state is not defined and can randomly assume high or low.

Removing the uncertainty of random output states modern transceiver designs include internal biasing circuits which put the receiver output into a defined state (typically high) in the absence of a valid input signal.

There are three possible scenarios that can cause the loss of an input signal.

- an open-circuit caused by a wire break or the unintentional disconnection of a transceiver from the bus,
- a short-circuit due to an insulation fault, connecting both conductors of a differential pair to one another,
- an idle-bus when none of the bus transceivers is active. This particular condition is not a fault but occurs regularly when bus control is handed over from one driver to another avoiding bus contention.

While modern transceiver designs provide failsafe operation for all three categories, legacy designs don't. For these components it is necessary to provide external resistor biasing to ensure failsafe operation during an idle-bus.

External Idle-Bus Failsafe Biasing

Figure 1 shows an RS-485 bus with its distributed network nodes. If none of the drivers connected to the bus is active the differential voltage, V_{AB} , approaches zero, thus allowing the receivers to assume random output states.

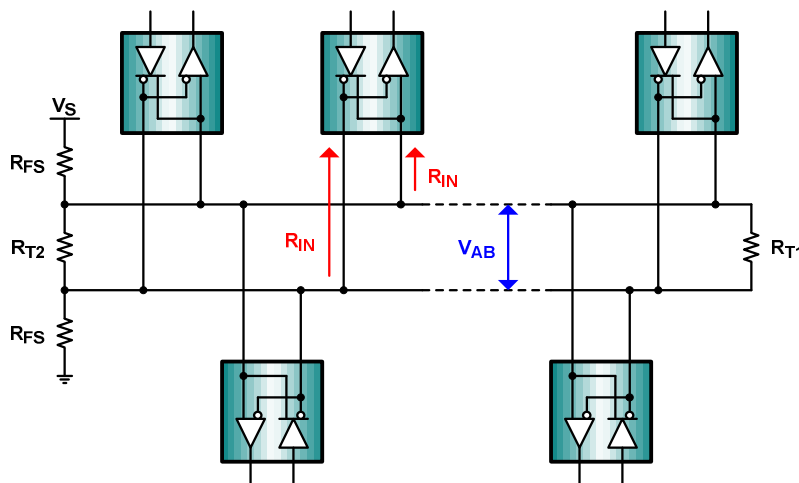


Figure 1. RS-485 Network with Failsafe Bias Resistors

To force the receiver outputs into a defined state, failsafe biasing resistors, R_{FS} , are introduced that, through voltage-divider action with the terminating resistors R_{T2} and R_{T1} must provide sufficient differential voltage to exceed the input voltage threshold, V_{IT} , of the receiver.

For clarity Figure 2 shows the lumped equivalent circuit of the RS-485 bus with the failsafe bias resistors, R_{FS} , the terminating resistors R_{T1} and R_{T2} , and the equivalent input resistance, R_{INEQ} , representing the common-mode input resistance of all transceivers connected to the bus.

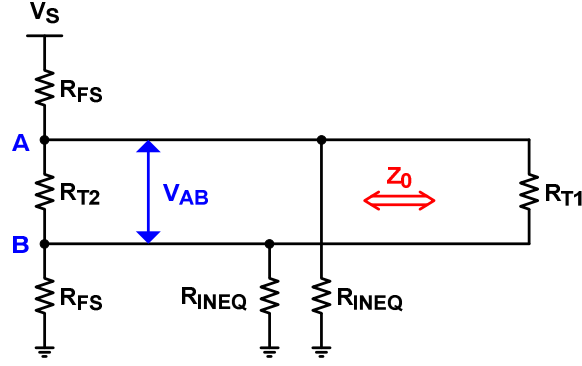


Figure 2. Lumped Equivalent Circuit

To find an equation that allows us to calculate the R_{FS} values, we determine the node-currents in A and B and solve for the respective line voltages V_A and V_B :

$$\text{node A: } \frac{V_S - V_A}{R_{FS}} = \frac{V_A - V_B}{R_{T2}} + \frac{V_A - V_B}{R_{T1}} + \frac{V_A}{R_{INEQ}} \rightarrow V_A = R_{INEQ} \cdot \left[\frac{V_S - V_A}{R_{FS}} - (V_A - V_B) \cdot \left(\frac{1}{R_{T1}} + \frac{1}{R_{T2}} \right) \right]$$

$$\text{node B: } \frac{V_A - V_B}{R_{T2}} + \frac{V_A - V_B}{R_{T1}} = \frac{V_B}{R_{FS}} + \frac{V_B}{R_{INEQ}} \rightarrow V_B = R_{INEQ} \cdot \left[(V_A - V_B) \cdot \left(\frac{1}{R_{T1}} + \frac{1}{R_{T2}} \right) - \frac{V_B}{R_{INEQ}} \right]$$

Establishing the difference between both line voltages yields the differential input voltage, V_{AB} :

$$V_{AB} = \frac{V_S}{R_{FS}} \cdot \frac{1}{\frac{1}{R_{INEQ}} + \frac{1}{R_{FS}} + 2 \left(\frac{1}{R_{T1}} + \frac{1}{R_{T2}} \right)} \quad 1).$$

The value of R_{FS} is subject to a number of system and standard constraints.

1. The RS-485 standard specifies a maximum common-mode loading, (or minimum common-mode resistance), of $R_{CM} = 375\Omega$. Because the failsafe bias resistors present common-loads to both, A and B wires, the parallel combination of R_{FS} and R_{INEQ} must be greater than or equal to 375Ω , which is expressed through the following equation:

$$R_{FS} \parallel R_{INEQ} = R_{CM} \quad \text{or} \quad \frac{1}{R_{INEQ}} + \frac{1}{R_{FS}} = \frac{1}{375\Omega} \quad 2).$$

2. The cable end without the biasing network is usually terminated with the resistor, R_{T1} , whose value matches the line impedance; for RS-485 this is:

$$R_{T1} = 120\Omega \quad \text{or} \quad \frac{1}{R_{T1}} = \frac{1}{120\Omega} \quad 3).$$

3. During normal operation, a driver output sees the series of both failsafe bias resistors in parallel to the terminating resistor R_{T2} . Thus, for line impedance matching the parallel circuit of R_{T2} and $2R_{FS}$ should equal Z_0 :

$$R_{T2} \parallel 2R_{FS} = Z_0 \quad \text{or} \quad \frac{1}{R_{T2}} = \frac{1}{120\Omega} - \frac{1}{2R_{FS}} \quad 4)$$

Inserting Equations 2, 3, and 4 into Equation 1 simplifies the expression for V_{AB} to:

$$V_{AB} = \frac{V_S}{0.036 \cdot R_{FS} - 1} \quad 5),$$

and solving for R_{FS} yields:

$$R_{FS} = \left(\frac{V_S}{V_{AB}} + 1 \right) \cdot 27.8\Omega \quad 6).$$

Note that Equation 6 is a generic form for calculating the bias resistor value, with the constant of 27.8 Ω representing the common-mode loading and line matching constraints of an RS-485 system.

Because idle-bus failsafe must work under worst case conditions, the values of the bias resistors must be calculated for minimum supply voltage at maximum noise. While for a standard 5V supply with + 5% tolerance, $V_{S-min} = 4.75V$, the maximum noise is usually subject to measurement. For a well balanced system however, we can assume a differential noise of less than 50mV, so that the sum of receiver input threshold and noise yields a differential input voltage of:

$$V_{AB} = V_{IT} + V_{Noise} = 200mV + 50mV = 250mV.$$

Calculating R_{FS} under these conditions provides a theoretical value of:

$$R_{FS} = \left(\frac{4.75V}{0.25V} + 1 \right) \cdot 27.8\Omega = 556\Omega$$

Choosing the next lower value of 549 Ω from the E-96 series allows for a slightly higher voltage drop across R_{T2} .

With R_{FS} in place we can now determine R_{T2} using the reciprocal of Equation 4 and the actual value of $R_{FS} = 549\Omega$ and receive:

$$R_{T2} = \frac{1}{\frac{1}{120\Omega} - \frac{1}{2R_{FS}}} = \frac{1}{\frac{1}{120\Omega} - \frac{1}{2 \cdot 549\Omega}} = 134\Omega$$

Choosing the closest E-96 value makes $R_{T2} = 133\Omega$ and the differential impedance of $R_{T1} \parallel R_{T2} \parallel 2R_{FS} = 59.7\Omega$.

As mentioned earlier, failsafe biasing presents additional common-mode load to the A and B wires. To stay below the specified common-mode load of 375 Ω it is necessary to determine the maximum numbers of transceivers that can be connected to the bus. For this purpose we solve Equation 2 for R_{INEQ} and receive:

$$R_{INEQ} = \frac{1}{\frac{1}{R_{CM}} - \frac{1}{R_{FS}}} = \frac{1}{\frac{1}{375\Omega} - \frac{1}{549\Omega}} = 1.183 \text{ k}\Omega$$

The maximum number of transceiver, n_{max} , is determined by dividing a standard Unit-Load (UL) through the value of R_{INEQ} :

$$n_{max} = \frac{UL}{R_{INEQ}} = \frac{12k\Omega}{1.183k\Omega} = 10.14$$

This result indicates a maximum of 10 standard unit-load transceivers, (10 x ULs), can be connected to the bus, which is equivalent to 20 x 1/2 ULs, 40 x 1/4 ULs, or 80x 1/8 ULs.

The final circuit with the actual resistor values is shown in Figure 3.

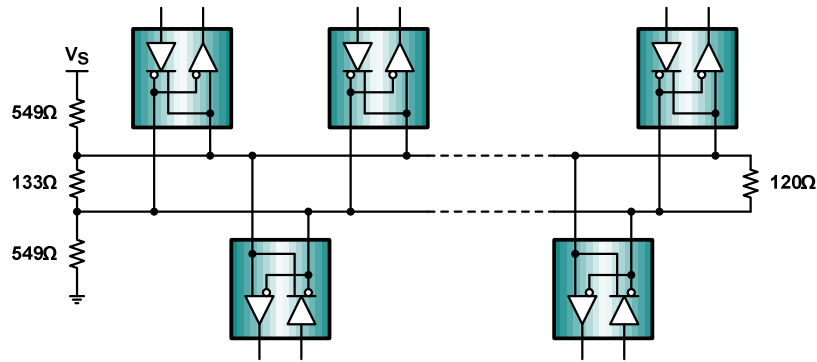


Figure 3. Final RS-485 Network with actual Resistor Values

Conclusion

While the calculation of a failsafe bias network for legacy transceivers is straight forward, using Equations 6 and 4, the use of modern RS-485 transceivers, such as the SN65HVD308x family from Texas Instruments, eliminate external failsafe biasing. These low-cost devices provide integrated failsafe biasing for open-circuit, short-circuit, and idle-bus as well as 1/8 unit loading, thus increasing the number of possible transceivers connected to a bus to 256.

References

- Interface Circuits for TIA/EIA-485 (RS-485), (slla036C), March 2007