RS-485

External Fail-Safe Biasing for Isolated Long Haul Buses

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Abstract

Fail-safe biasing is a method of generating a minimum differential bus voltage, V_{AB}, during periods of time when the bus is not actively driven. In this case, V_{AB} must be larger than the sum of the receiver input switching threshold for rising edges, V_{TH+}, and the expected differential peak noise voltage V_N. This ensures that all receivers connected to the bus output logic are high during bus idling.

Though modern *full fail-safe* transceivers can detect zero bus voltage conditions by having V_{TH+} offset to slightly negative values, the small offset is no match for the large noise pick-up encountered in harsh industrial environments, particularly in long haul buses.

While there is plenty of literature available on external fail-safe biasing, most of it concerns short-distance, non-isolated bus systems neglecting the cable DC resistance.

This application note, however, explains fail-safe biasing for isolated long haul buses and thus, takes the cable resistance into consideration. With the help of a symmetrical, dual fail-safe biasing model, this application note derives the equations for calculating the resistor values of these networks.

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1. Introduction

Long haul RS-485 networks use isolated transceiver circuits to free the bus from the large ground potential differences that exist between the local Earth grounds of remote located bus nodes. Unlike non-isolated networks, where the transceiver input impedances present Common-Mode (CM) loads to a bus, isolated networks do not suffer from CM loading. Since all bus node grounds are galvanically isolated from one another, only differential currents flow, making the transceiver input impedances appear as purely differential loads. Figure 1 shows a typical isolated bus with only differential current flow.

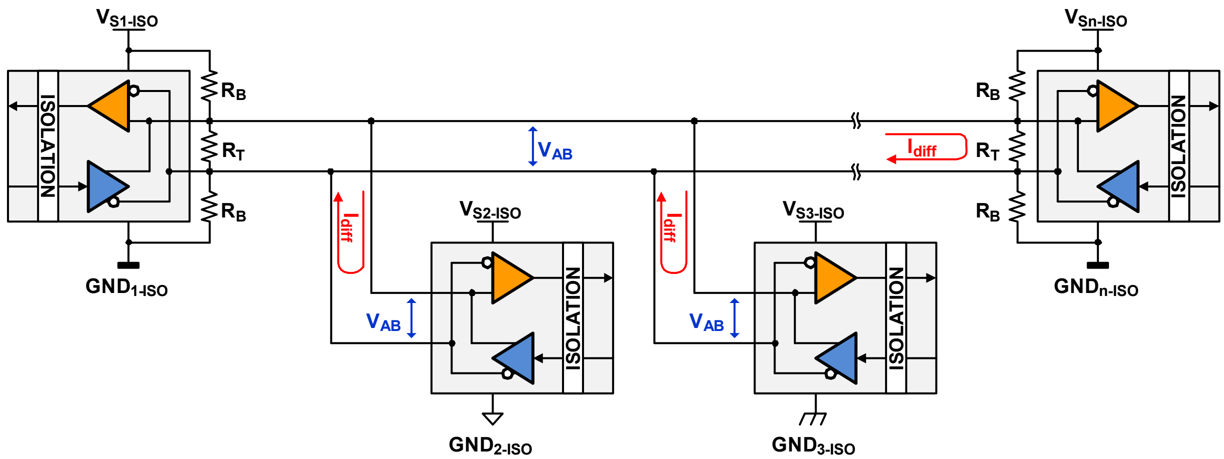

Figure 1. Isolated RS-485 Bus with Transceiver Input Impedances Being Purely Differential

2. Idle-Bus Model

Long distance buses use two fail-safe biasing networks, one at each cable end to maintain a relative constant V_{AB} across the bus. Figure 2 shows a lumped equivalent model of the circuit in Figure 1 on page 2 for an idle bus condition. Here, R_B and R_T are the biasing and termination resistors respectively, and R_{INEQ} is the equivalent input resistance of all bus transceivers.

To ensure maximum loading to each biasing network, R_{INEQ} is placed in the middle of the bus. Due to circuit symmetry, both biasing networks drive the same amount of current through R_{INEQ}. By converting R_{INEQ} into the parallel combination of two resistors with twice the value ($R_{INEQ} = 2R_{INEQ} \parallel 2R_{INEQ}$), we can split the left circuit into two identical voltage dividers, one of which we will be using as the calculation model.

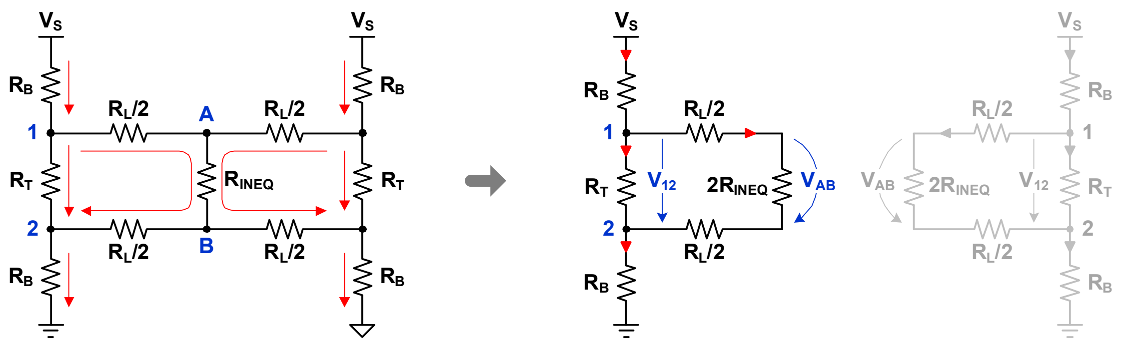

Figure 2. Lumped Equivalent Model and its Reduction to a Simple Voltage Divider

Prior to deriving the equations for calculating the resistor values, we establish the conditions that must be satisfied for line termination and differential loading.

For line impedance matching during normal operation, the series combination of the two biasing resistors in parallel with the termination resistor, R_T, must match the characteristic cable impedance: $Z_0 = 2R_B \| R_T$. Thus, for a given value of R_B, R_T becomes:

$$R_T = \frac{2R_B \cdot Z_0}{2R_B - Z_0} = \frac{2R_B \cdot 120\Omega}{2R_B - 120\Omega} \quad \text{(EQ. 1)}$$

RS-485 specifies the maximum differential load for a standard compliant transceiver with $R_D = 54\Omega$, which includes the parallel combination of the two line terminations of $Z_0/2 = 60\Omega$. The minimum value of R_{INEQ} is therefore limited to:

$$R_{INEQ} = \frac{Z_0/2 \cdot R_D}{Z_0/2 - R_D} = \frac{60\Omega \cdot 54\Omega}{60\Omega - 54\Omega} = 540\Omega \quad \text{(EQ. 2)}$$

The total cable resistance, R_L, is a function of the bus length, L, and the cable specific DC resistance DCR:

$$R_L = L \cdot DCR \quad \text{(EQ. 3)}$$

For a typical RS-485 cable, such as the Belden 3105A, DCR is in the range of 0.05Ω/m. To receive R_L in ohms (Ω), L must be applied in meters (m).

To find the equation for calculating R_B, we determine the differential bus voltages at the biasing network and at the middle of the bus:

$$V_{12} = V_S \cdot \frac{R_T \| (R_L + 2R_{INEQ})}{2R_B + R_T \| (R_L + 2R_{INEQ})} \quad \text{(EQ. 4)}$$

$$V_{AB} = V_{12} \cdot \frac{2R_{INEQ}}{R_L + 2R_{INEQ}} \quad \text{(EQ. 5)}$$

Inserting Equations 1 through 4 into Equation 5 provides the final DC-bus idle voltage:

$$V_{AB} = \frac{V_S}{R_B \cdot \left(\frac{L \cdot DCR}{Z_0 R_{INEQ}} + \frac{1}{R_D} \right)} \tag{EQ. 6}$$

Solving for R_B yields the minimum required bias resistor value:

$$R_B = \frac{V_S / V_{AB}}{\frac{L \cdot DCR}{Z_0 R_{INEQ}} + \frac{1}{R_D}} \tag{EQ. 7}$$

Inserting the actual values of DCR = 0.05Ω/m, Z_0 = 120Ω, R_{INEQ} = 540Ω, and R_D = 54Ω, provides the minimum R_B value for maximum loading. Eliminating all decimal powers presents R_B in kΩ:

$$R_B(k\Omega) = \frac{V_S / V_{AB}}{L/1296 + 18.52} \tag{EQ. 8}$$

3. Calculation Example for Maximum Differential Loading

Assuming a bus segment length of L = 1600m (1 mile) with maximum differential loading of R_{INEQ} = 540Ω, while assuring a minimum fail-safe voltage of V_{AB} = 200mV, at a minimum supply of V_S = 4.5V, requires a minimum R_B value of:

$$R_B = \frac{V_S / V_{AB}}{L/1296 + 18.52} = \frac{4.5/0.2}{1600/1296 + 18.52} = 1.14k\Omega$$

The termination resistor required to match the line impedance is calculated with (EQ. 2):

$$R_T = \frac{2R_B \cdot Z_0}{2R_B - Z_0} = \frac{2 \cdot 1.14k\Omega \cdot 120\Omega}{2 \cdot 1.14k\Omega - 120\Omega} = 127\Omega$$

The maximum number of bus transceivers is calculated by dividing the single transceiver input impedance through the equivalent input impedance:

$$n_{XCVR} = \frac{R_{IN}}{R_{INEQ}} \qquad \text{(EQ. 9)}$$

R_{IN}, however, depends on the transceiver's Unit Load (UL) rating. A 1UL transceiver has a nominal common-mode input resistance of 12kΩ, measured between the bus input and ground. Its differential input resistance (measured between inputs), is therefore twice as high, 24kΩ. In contrast, a 1/8UL transceiver has 1/8 the input current and hence an 8-times higher input resistance of 192kΩ.

Using (EQ. 9), the maximum transceiver numbers for 1UL and 1/8UL transceivers are:

$n_{1UL} = \frac{24k\Omega}{540\Omega} = 44$ and $n_{1/8UL} = \frac{192k\Omega}{540\Omega} = 355$, respectively.

4. Conclusion

External fail-safe biasing networks ensure stable network node operation during bus idle times. For maximum noise margin use full fail-safe transceivers whose positive input threshold is below 0V V_{AB}. Any DC bias level above that is pure noise margin and helps to maintain high R_B values. An excellent transceiver family designed for high noise environments is Intersil's ISL315x family of half- and full-duplex transceivers with high output drive capability, full-fail-safe features, and small (≤1/8) UL rating.

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