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CONSIDERATIONS FOR EFFECTIVE RS-485 NETWORK DESIGN

INTRODUCTION

This publication provides suggestions for applying circuits complying with TIA/EIA-485-A standard, to form a balanced multipoint data bus. Basic design considerations for the physical layer of a RS-485 network will be discussed; more specifically, bus termination and idle-state biasing.

ELECTRICAL CHARACTERISTICS

Transmitter

Per Standard ANSI/TIA/EIA-485-A-1998, the steady-state load on an active transmitter shall be defined in terms of unit loads. The system load caused by each receiver shall be specified by portions of unit loads present. One transceiver must be able to support a total of 32 unit loads and an effective total termination resistance of as low as $60\,\Omega$ while providing the minimum differential voltage of $V_t = 1.5\,V$, where $1.5\,V \leq V_t \leq 6.0\,V$.

Receiver

The allowable range of common-mode input voltages (V_A & V_B with respect to receiver common 'C') appearing at the receiver's input terminals shall be between $-7\,V$ and $+12\,V$. For any combination of receiver input voltages within this range, the receiver shall assume an intended logic state with an applied differential voltage of $\pm 0.2\,V$ or more. A logic '1' occurs when the A terminal of the receiver is negative with respect to the B terminal. A logic '0' occurs when the A terminal of the receiver is positive with respect to the B terminal. Figure 1 shows the logic levels for transceivers used in Basler Electric devices per TIA/EIA-485-A.

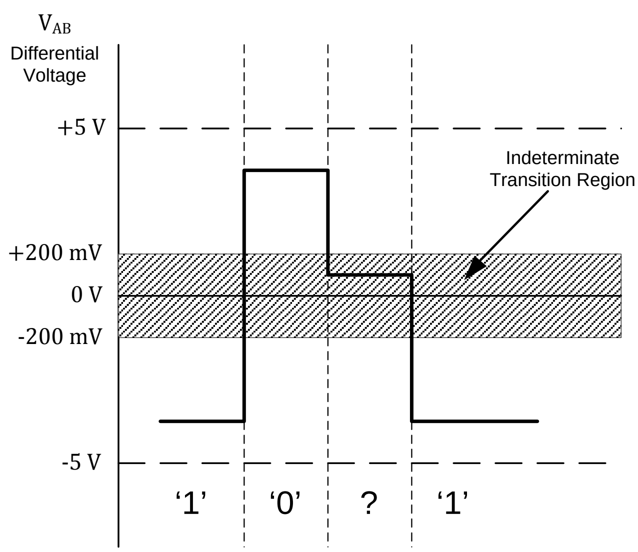

Figure 1: Receiver Logic

The transition threshold for the logic switch lies between $-200\,mV$ and $+200\,mV$. Differential voltages (V_{AB}) lying within this range are indeterminate and can take either logic state depending on the individual receiver's threshold.

Grounding/Shielding

Although RS-485 communication relies on the differential voltage between two data bus conductors (A & B) to determine the signal, the bus needs a ground (C) to provide a return path for induced common-mode noise and currents such as the receiver's input current. Standard EIA-485 states that generators and receivers require a return path between circuit grounds at each end of the connection. This return can be an actual wire run with the data conductors, or using earth as the return at each device on the bus. Exercise caution for long network spans and multiple bus drops, since differing earth potentials could cause damage to device transceivers.

Failure to provide a current return path can cause damage to a device's transceiver or signal distortion from increased emissions. If a third wire is used, the standard requires that the connection between logic ground and the return wire must have a limiting resistance with a minimum of $100\ \Omega$. This resistance is provided internally by Basler Electric devices. If shielded wire is used, the shield can be substituted for the third wire acting as the return path.

NETWORK TERMINATION

Depending on the length and signal rate of the network, termination may be required to mitigate transmission line effects such as reflections. The disadvantage to using terminating resistors is increased power consumption during steady-state conditions. In the absence of an active driver on the bus termination resistors, it will pull the differential voltage to near zero volts, which places the bus in an indeterminate state to an active receiver. In this case, biasing is required to maintain correct signal levels. For shorter and slower links, power and components can be saved by not using terminating components. On a short line, the reflections die out long before the receiver is ready to read the signal.

The maximum network cable length from end to end is $4000\ ft$, and it is it is assumed that reflections from a signal transition will dampen out after three round trips through the network. This dampening should occur before the bit is sampled by any device on the network. Usually, the bit is determined within half of a bit's time, given by the reciprocal of the baud rate. Conduction speed through copper is approximately $0.66\ ft/ns$. As an example, for a network operating at 9600 baud, the maximum un-terminated cable length can be found by:

$$\text{Half Bit Time} = \frac{1\ sec}{9600\ bits} \times 0.5 = 52{,}083\ ns$$

$$\text{Half Bit Distance Travelled} = 52{,}083\ ns \times 0.66\ ft/ns = 34{,}375 ft$$

Since three round trips are assumed for the signal to dampen completely, the half bit distance is divided by six to obtain the maximum un-terminated cable length.

$$\text{Max. Cable Length (Not Terminated)} = \frac{34{,}375\ ft}{6} = 5729\ ft$$

Because the maximum allowed distance is $4000\ ft$, networks operating at 9600 baud do not require termination. It is possible to add termination for shorter spans, but provisions should be made for the increased load on the bus (biasing). For all networks longer than the recommended lengths in Table 1, symmetrical terminating resistors on each end of the bus matching the cable characteristic impedance (usually $120\ \Omega$) are recommended. This example is extended to other common baud rates in Table 1.

Table 1: Termination Requirements

Baud Rate	Maximum Un-terminated Cable Length (feet)	Termination Requirements
1200	4000	None
2400	4000	None
4800	4000	None
9600	4000	None
19200	2865	Beyond $2865\ ft$, $120\ \Omega$ each end
38400	1432	Beyond $1432\ ft$, $120\ \Omega$ each end
57600	955	Beyond $955\ ft$, $120\ \Omega$ each end
115200	477	Beyond $477\ ft$, $120\ \Omega$ each end

BIASING

Idle-State Biasing

During communication over a RS-485 network, periods exist where no devices are driving the bus (idle state). Referring to Figure 1, if the differential voltage on the bus is less than $0.2\ V$, the receiver's output state is not defined. Therefore, the transceiver IC can interpret the bus condition as either high or low depending on the threshold of the individual IC. The threshold of some transceivers may trigger at +190mV while others may trigger at -190mV. Hence, some devices are more susceptible to falling into an undesired logic state than others.

Loading the RS-485 communication lines, either through termination resistors or many devices tapped onto the bus, can reduce the reliability due to the reduction of the differential voltage (A-B) during idle state to less than $0.2\ V$. If the idle state of the bus is interpreted incorrectly the start bit from the master request is missed, causing a framing error. In this case, the slave unit will receive an incomplete packet, and reject the data. The symptom of this failure is the slave not responding to a register request. Noise induced during the idle state can also cause improper logic transitions which disrupt the device's synchronization timing, resulting in framing errors. Biasing is often recommended for heavily loaded networks or for networks in high noise environments to address these concerns. Figure 2 shows a typical biasing circuit for a RS-485 network.

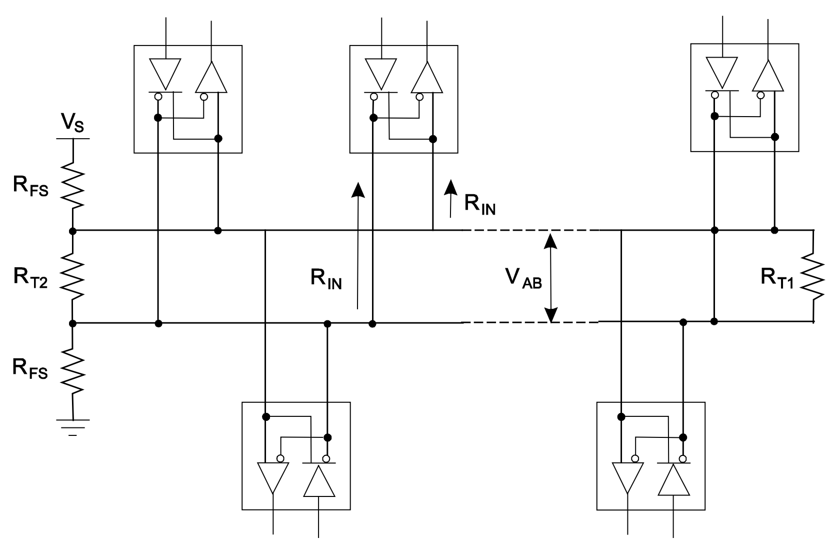

Figure 2: Biasing Circuit for Idle-State Conditions

To avoid indeterminate states and to provide enough margin for noise immunity, it is desired during idle conditions to hold the differential voltage to $250\,mV$ or greater. Assuming a $5\,V \pm 5\%$ supply voltage is used with a fully loaded bus at $54\,\Omega$ load, and a maximum of $50\,mV$ noise transient, the bias resistors R_{FS} can be calculated by:

$$I_{RT} = \frac{250\,mV}{54\,\Omega} = 4.6\,mA$$

$$R_{FS} = \frac{4.75\,V/4.6\,mA - 54\,\Omega}{2} = 489\,\Omega\,(\text{max.})$$

$470\,\Omega$ resistors can be readily obtained for this application. Installation of these components ensures correct bus state during idle periods.

OTHER CONSIDERATIONS

Topology

The recommended network configuration for RS-485 is a daisy-chain connection (Figure 3) from node 1 to node 2 on up to node n. The bus should form a single continuous path, and it is recommended the nodes in the middle of the bus not be at the ends of long branches or stubs. The star configuration shown in Figure 4 should be avoided. This layout could result in any transmitter driving into many terminated loads resulting in possible damage to components and unreliable communications. Other configurations can be employed by using well-placed network repeaters.

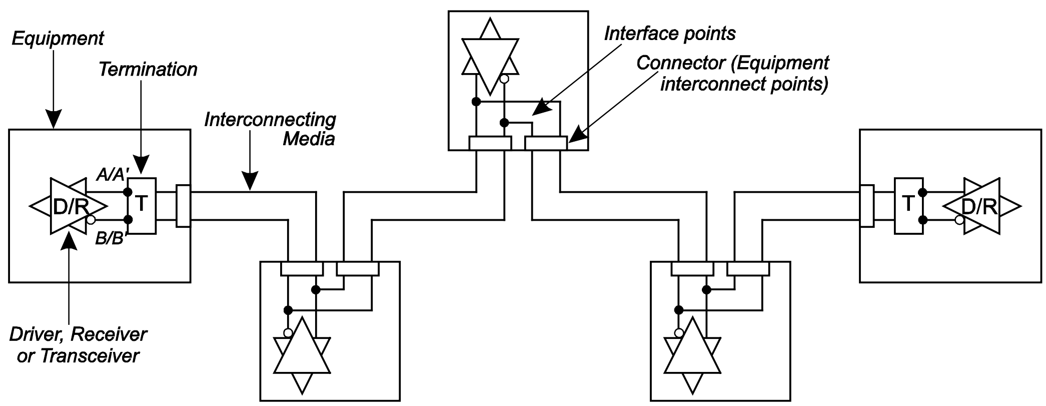

Figure 3: Daisy-Chain Configuration (Recommended)

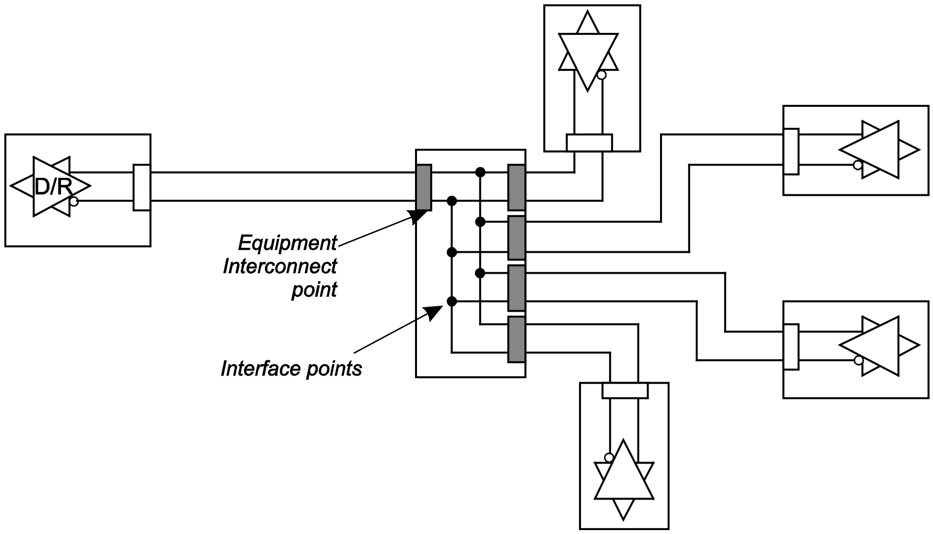

Figure 4: Star Configuration (Not Recommended)

CONCLUSION

There are many factors that need to be considered when designing a RS-485 network. Simply connecting a device that supports RS-485 communications to a bus does not ensure signal integrity for the device or any other devices on the network. If the device is provided correct RS-485 signals per the TIA/EIA-485-A standard, it will reliably provide slave responses to a master poll. During the design of a RS-485 network, it is recommended that the designer take steps to ensure fail-safe communication and prevent data loss.

This document is intended for informational use only and does not represent the sole approach or method for effective network design. The final network should be designed and installed by competent, knowledgeable individuals.

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