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RS-485: A Primer

Serial communication between electronic devices faces three challenges: speed, distance and the ability to operate in an electrically noisy environment. The ability for multiple devices to share the same communication channel is also a desirable feature. As the requirements and the capabilities of the electronics industry have evolved, the new standards have been introduced to meet them.

Initially serial data communication was handled by a 20mA current loop (not to be confused with the industrial analog 4-20mA current loop). It was slow, but was inherently immune to noise and could be transmitted over long distances. RS-232 was developed as a means of interfacing a computer with a modem as a means of transmitting data over longer distance and at higher speeds. Over time RS-232 became the dominant interface standard in the office communications market despite the fact that modems were not necessarily involved. RS-232 is prone to disturbance by noise and is not intended to support communications over long distances. Changes in technology have allowed communications from the original 20Kbit/sec to 230Kbit/sec.

RS-485 goes a long way (pun intended) to satisfy the three challenges. In addition it also allows multipoint communication. This primer will attempt to describe how it addresses these issues.

The Specification

While RS-232 does not place any requirements on the format of the serial message (number of bits, protocol etc.), it does cover the connector type, pinout and the handshake across the interface. It also covers the electrical characteristics of the signals. In contrast, RS-485 is limited to the description of electrical signal characteristics. As a result RS-485 may be used as the transmission technique for protocols as complex as LON or ARCNET as well as proprietary protocols.

Differential Signals

RS-485 employs differential signal techniques (translation: two wires for every signal). The RS-485 driver has two outputs generally termed A and B. When the input to the driver is in the "mark" state (a logical one) output A is high and output B is low. When the input to the driver changes to the "space" state, the outputs reverse with the output A going low and output B going high. At the receiver, when A is greater than B the output is a mark, and when B is greater than A the output is a space. Differential signals exhibit a high degree of noise immunity. Since the signals change in opposition to each other, when the same signal appears on both lines (called common mode signal) the receiver will reject it. Ambient electrical noise appears as common mode signal on the communication lines so RS-485 is suitable for use in environments with high electrical noise, typically industrial applications.

The RS-485 circuitry can withstand common mode voltages of -7VDC to +12VDC and continue to operate correctly. RS-485 works nominally at 5VDC and the receiver will change state when one input exceeds the other by 200mVDC.

Multiport Operation

RS-485 was designed to allow multiple electronic units to be connected to a single communications channel. To this end RS-485 transmitters can be placed in a high impedance state and only enabled onto the channel when data must be transmitted. The process of how this is done is beyond the scope of the RS-485 specification. It should be noted that simultaneous transmissions will result in the message being lost, and possibly the destruction of the drivers.

A channel can be configured for “full duplex” or “half duplex” operation. In full duplex the transmitting device can support data reception at the same time as transmission. To achieve this, RS-485 requires 2 data wire pairs, one for transmission and the other for reception. In half duplex operation the transmitter first sends its data, disables its driver and waits for the reply. This allows the use of a single data pair for bidirectional communication.

The RS-485 specification also allows for up to 32 unit loads to be placed on a channel. This is also known as “multidrop” configuration. This normally requires some method of “addressing” each module, but once again that level of protocol is outside the scope of RS-485. A “unit load” is somewhat akin to the telephone standard load. It places a limit on the number of devices that can communicate on the channel. If a device loads the channel by more than a single unit load the number of “drops” is reduced. There are devices that present one quarter of a unit load allowing up to 128 drops. Of course there is a tradeoff in that the maximum communication speed is reduced.

Speed vs. Distance

The RS-485 specification calls for the circuitry to be capable of communicating at 10 Mbit/s for 40 feet (12 metres). At 4000 feet (1200 metres) maximum cable length the data rate is reduced to 100 Kbit/s. There are other factors involved including the network configuration, wire characteristics, the device used, biassing resistors and termination resistors (see later) that can influence the data rate. One of the most frequently asked questions and one of the most difficult to answer is the speed/distance/number of drops tradeoff.

Different studies in the industry have given some of the following (often conflicting) results, however Table 1 provides a conservative estimate based on the assumption of a daisy chain topology with no stubs.

Table 1.

Data Rate (Kbps)	Distance (feet)	Distance (metres)
<100	4000	1200
200	2000	600
300	1000	300
400	800	240
500	700	210
600	600	180
700	500	150
800	450	135
900	425	125
1000	400	120
2000	105	32
3000	95	28
4000	70	21
5000	50	15
10000	40	12

Termination

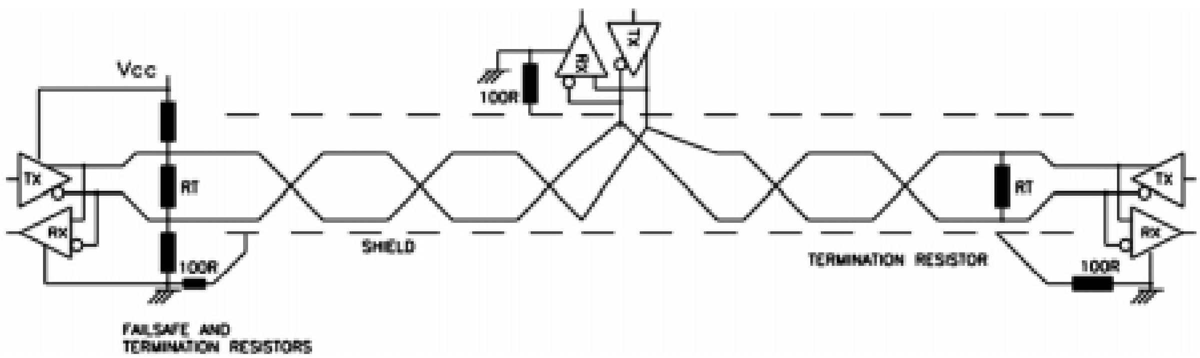

Figure 1

Although normally required at higher transmission frequencies, it is good practice to terminate the cable runs with a resistor equal to the characteristic impedance of the cable. This reduces the reflection of a signal when it reaches the end of the cable. For half duplex operation there should be a termination resistor at each end of the cable run. For full duplex operation there should be a termination resistor at the receiver at the furthest end away from the transmitter and one at the receiving end on the return line. Avoid adding a termination resistor at other locations as this can overload the driver and reduce the reliability of the data transfer. Refer to Figure 1. The distance can be increased by the use of repeaters.

Topology

It is possible to interconnect the drops on the network in a number of methods. The principle arrangement can be either a “star” or a “daisy chain” arrangement. In the star arrangement the drops all connect to a central node using individual cable runs (see figure 2(a)). In the daisy chain arrangement the cable goes from drop to drop (see figure 2(c)). A variation of both is achieved by using connections that “piggy back” onto one of the cable runs. These are known as stubs (see figure 2(b)). In the star topology reflections can be generated from each “arm” of the configuration reducing the effectiveness of the network. Termination resistors can overload the driver. This configuration should be avoided. Stubs are rather like an additional star network and subject to the same problems. If they are used, they should be kept to a very short length to reduce the potential for problems. Refer to Figure 2.

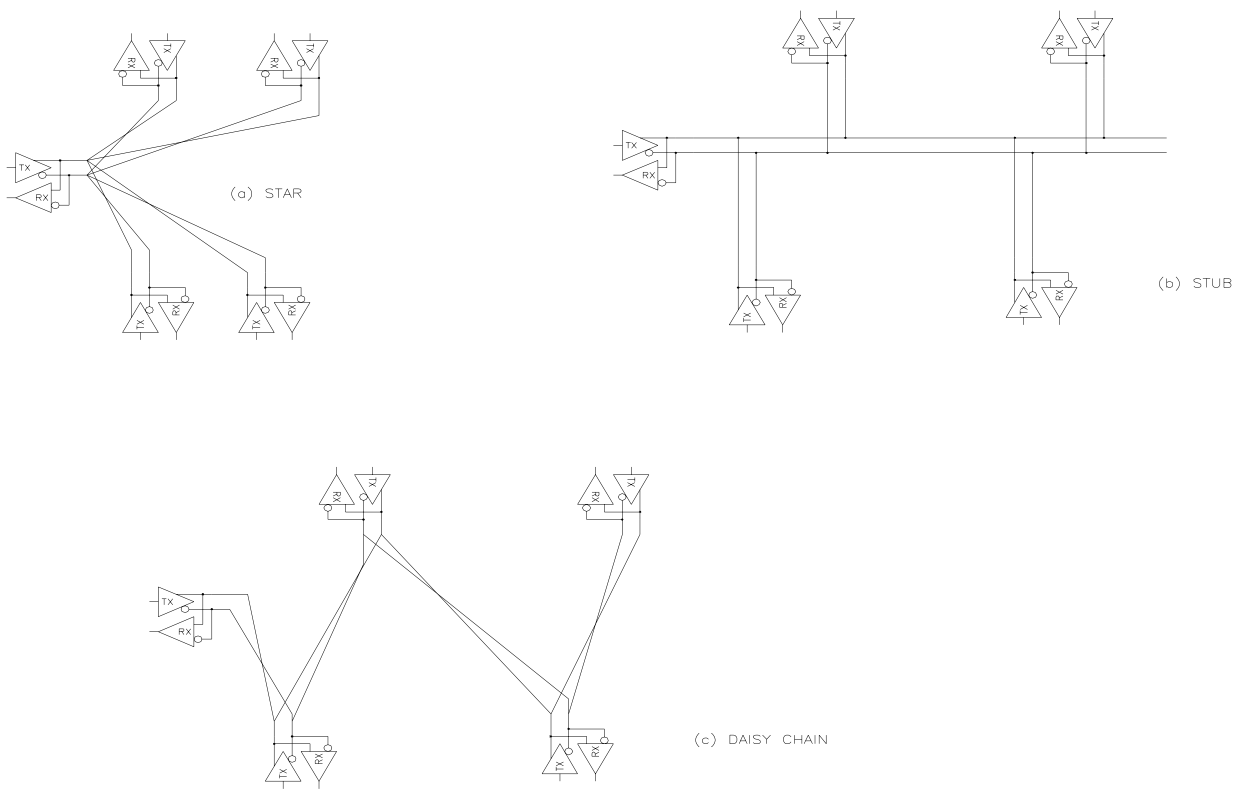

Figure 2

Common Mode Problems

As discussed earlier the common mode voltage can vary between -7V and 12V. Aside from the induced noise there is another problem associated with this requirement. If only the two signal wires are used to connect the nodes then the commons of the electronic devices may be floating in relation to each other. If the relative voltage exceeds the common mode specifications, then not only may communications be disrupted, but permanent damage to the integrated circuits may also occur. At its most frustrating, communications may be intermittent.

There must be a method of assuring that the commons of each node are interconnected in some fashion. One method is to use the earth, but this should be tested as “earth” may differ form location to location by tens of volts. Another technique is to use the shield of the twisted pair (if it exists). This has the added benefit of reducing the induced electromagnetic noise on the data lines, but may induce current loops since the commons may not be at the same potential. A technique to reduce this involves connecting a series resistance of 100 ohms between the common of the circuitry and the shield. A further alternative is to use devices that include some form of isolation between the input and the output. To use this in all 32 nodes may prove expensive, but a combination of isolation and non isolation could be used depending on the circumstances (see Figure 1).

Failsafe Operation

In a multidrop configuration there may be periods when the line is inactive with no driver active to keep the line at a defined state. This floating condition could lead to false triggering of a unit's input connected to the network. This affect may be aggravated by reflections on the line. Using a pull up and a pull down resistor at the input solves this problem . These resistors constitute a resistive divider (with the line termination resistors) and should be chosen for an input value of greater than 200mV. Newer devices may include failsafe protection to prevent false triggering.

The output should be protected against electrical failure when driving into a short. Conversely, if an input should fail it should not fail as a short circuit and as a result inhibit communications on the line.

Electromagnetic Immunity

All equipment intended for use in Europe requires the CE mark. The CE mark implies that the unit will meet all the relevant standards applicable to the product. One of those standards is IEC1000. Not withstanding the European requirements, it is good practice to ensure that the equipment meets IEC1000. This is broken into a number of subcategories: immunity to static discharge, immunity to induced electromagnetic noise and surges, immunity to Radio Frequency (RF) transmissions and RF radiation. There are several techniques to address the first two categories, normally employing surge suppressors and possibly resistors. It is important the unit meet these requirements or it may suffer permanent damage in an industrial environment.

RF immunity and general noise immunity is achieved by differential signal transmission (enough said) and possibly additional filtering and shielding the cable. RF transmissions in the proximity of the system may disrupt communications during the period of the transmission.

RF radiation is possibly a bigger problem since the cable acts as an antenna for the data signal being carried. Not only is the data frequency being transmitted, but the sharp transitions between logic levels can generate harmonics at much higher frequencies. A perfect differential signal tends to cancel out these harmonics, but the imperfections of the real world lead to a phenomenon known as "skew" where one of the signal pairs goes high at a slightly different rate than the other goes low. In summary, low skew devices generate less RF emissions. A shield on the cable also reduces RF radiation. RF radiation may disrupt the operation of other devices in the vicinity of the network.

Surge and electrostatic immunity is required to protect electronic devices from undesirable electrical signals that could permanently destroy the device. These signals could be generated by electrostatic discharge from a human touching the system, or an induced current surge where the signal wire is in close proximity to a device using high currents (e.g. an arc welder) or many other sources.

RS-422 versus RS-485

Another common question relates to the differences between RS-422 and RS-485. They can be summarized as follows:
RS-422 can only drive 10 unit loads, RS-485 can drive 32 unit loads.
RS-422 can only operate in simplex, i.e. it can only handle a fully duplex connection. RS-485 allows for half duplex operation allowing the same pair of wires to be used for transmission and reception. The upshot is that there can only be 1 "master" with a maximum of 10 "slaves" in the case of RS422.

Rules of Thumb

1. Check the data sheet of the devices that will be used, to determine their maximum data rates.
2. Ensure that the correct termination resistors are used. Use only one termination resistor for the transmission and one for the reception at the ends of the data path.
3. Biassing resistors can degrade system performance, but are desirable if the unit does not have a failsafe input.
4. Choose shielded twisted pair cable of known impedance (100 ohm or 120 ohm are good choices).
5. Choose a simple daisy chain configuration with very short stubs.
6. Ensure that the commons of the nodes are within the common mode range of the standard by connecting the commons of the RS-485 transceivers.
7. Allow for flexibility (easily adjustable data rates) and try system out for optimal data rates once the system has been established.
8. Be conservative to allow for changes due to temperature variation and other environmental changes.
9. Allow for system expansion.
10. Ensure the unit meets IEC1000 (to provide damage protection from electromagnetic and electrostatic signals).

References

1. Standard Microsystems Corporation, Technical Note 7-5, RS-485 Cabling Guidelines for the COM20020 Universal Local Area Network Controller (ULANC) and Experimental Procedure For Verification of RS-485 Cabling Guidlines, by Shaun Knoll, Systems Engineer and Stephanie Colo, Project Engineer.
2. National Semiconductor AN-216, AN-409
3. Linear Technology, DN39, Low Power CMOS RS-485 Transceiver by Robert Reay
4. Texas Instruments, 1991/1993 Linear Design Seminar, Data Transmission
5. Maxim, 1993 Applications And Product Highlights, Interface Products
6. AMD, Use of the Am26LS29, 30,31 and 32 Quad Driver Receiver in EIA RS-422 and 423 Applications by David A. Laws and Roy J. Levy.
7. EDN magazine August 1, 1996, Ten ways to bulletproof RS-485 interfaces, John Goldie, National Semiconductor
8. Texas Instruments DSP/Analog Technologies, 1998 Seminar Series