USING RS-232 to RS-485 CONVERTERS
(With RS-232, RS-422 and RS-485 devices)

INTRODUCTION

This application note provides information about using ICSDataCom's RS-232 to RS-485 Converters in some typical applications. This note also provides basic connection information and reviews RS-485 data communication. For information on the theory of serial communication, refer to Application Bulletin AN-1, Serial Backgrounder. Also refer to your converter's manual for detailed instructions on its use and on how to set its internal jumpers.

RS-422 AND RS-485 SIGNAL CHARACTERISTICS

RS-422 and RS-485 systems are electrically very similar. Both use two-wire differential signals to transmit a single signal. Differential signals provide greater noise immunity and can drive longer cables at higher speeds than can single line RS-232 or RS-423 signals. The RS-422/RS-485 receiver looks for the difference between the two signals to determine the bit value vs looking for an absolute signal level. The same noise is picked up by both lines so it is cancelled out. Differential signals only have to swing one or two volts to produce a good readable signal at the receiver. It is these improvements that provide faster baud rates, drive longer distances and let users route the serial line through high noise areas such as factory floors or by fluorescent lights.

RS-422 receivers are specified to have a ± 0.2 V sensitivity, 4 kohm minimum input impedance and be capable of withstanding a maximum input of ± 10 V. An RS-422 transmitter can drive up to seven RS-422 loads.

RS-485 devices are similar to RS-422 devices except their transmitters are capable of driving up to 32 receivers and cable lengths up to 10,000 meters. Both types of devices can be mixed on the same system as long as the RS-422 loading limits are not exceeded. Cable terminators and transmitter wave shaping may be required to minimize cross talk and hold the line in the 'mark' condition when idle.

RS-485 terminals are typically labeled A and B or '+' and '-'. The differential transmitter output terminal that is negative with respect to the other terminal for the logic '1' data signal is designated the A terminal. The positive terminal is designated the B terminal. All voltage measurements are made by connecting a voltmeter between the A and B terminals. Signal logic levels are listed in Table 1.

Table 1 RS-422/RS-485 Logic Levels

Diff. Voltage	+2 to +6 V	-2 to -6 V
Data A/B Control A/B	0 1 (On)	1 0 (Off)

On some RS-232 to RS-485 Converters, the negative or 'A' signal is labeled with a bar over the signal name. When the RS-232 input is in a mark condition (-6 to -25 Vdc), the TX output is + 4 Vdc with respect to the $\overline{\text{TX}}$ terminal.

FULL-DUPLEX vs HALF-DUPLEX OPERATION

The transmission path between two or more devices can be designed for full-duplex or half-duplex operation. Full-duplex simply means that both devices can send and receive data simultaneously. Full-duplex is similar to two trains passing each other on two adjacent tracks. Half-duplex means that only one device can send data while the other one listens and waits its turn to send data. This is analogous to two trains waiting to use a single track tunnel, only one can go at a time and the train from the opposite direction must wait until the first train has passed through the tunnel before entering the tunnel. For true full-duplex data communication, all parts of the data transmission path have to be capable of simultaneously sending and receiving data. This includes the computers, the modems, the data transmission circuits and the software.

A full-duplex RS-422 or RS-485 system is implemented with two pairs of wires, one pair for each direction. A half-full-duplex system is implemented with just a single pair of wires

Most test systems operate in a half-duplex fashion. This is because we send a command or query to a device and wait for its response. We do not expect the device to be sending us a data before it has received the query.

Many people confuse the RS-422 and RS-485 Standards with full and half-duplex circuits. This confusion arises since most RS-485 devices are two-wire, half-duplex devices. The EIA RS-422 and RS-485 Standards only defined voltage levels and not transmission circuits. Both types of devices can be used with 4-wire full-duplex and 2-wire half-duplex circuits.

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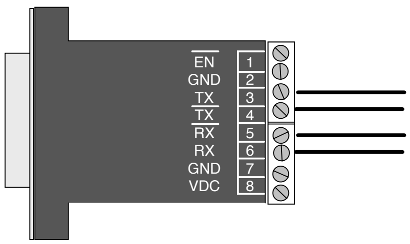
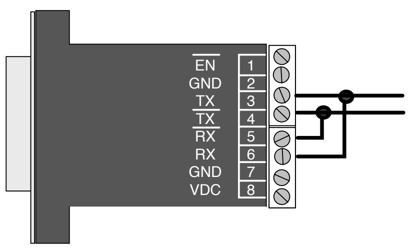
RS-422/RS-485 CONNECTIONS

Figure 1a shows the RS-485 side of the RS-232 to RS-485 Converters. All of the RS-485 (RS-422) signals and power connections are made on an eight screw terminal strip that plugs into the converter. There are two terminals for the RS-485 transmitter, (TX and TX-), and two terminals for the RS-485 receiver, (RX and RX-). An external AC adapter (not shown) supplies 9 Vdc power for the VDC and GND terminals. Figure 1(a) shows the full duplex serial connection with separate wires for the transmit and receive paths. Figure 1(b) shows the TX and RX terminals jumpered together to make a half-duplex serial connection.



(a) Full-Duplex Connection



(b) Half-Duplex Connection

Figure 1 Full and Half-Duplex Signal Connections

EXTENDING AN RS-232 DATA LINK

Figure 2 shows two RS-232 to RS-485 Converters connected in a back-to-back fashion to extend an RS-232 signal beyond its 50 foot limit. In Figure 2, the TX and RX signal pairs from two converters crossed in a typical null-modem fashion (The TX signals of one converter connect to the other converter's RX signal inputs). The converters could plug into two PCs or into a PC and an RS-232 device.

The basic RS-232 signal extension in Figure 2 is a full-duplex data path. The extension circuit is full-duplex but the system may still operate in a half-duplex or full-duplex fashion. The extension path shown in Figure 2 does not limit the system's operation.

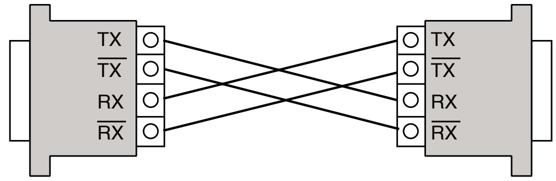


Figure 2 Basic RS-232 Signal Extension

The RS-232 link extension does not require any special software in to control the converters. Because the connection between the two converters is a four wire connection, the RS-485 transmitters in the converters can be left on at all times. Termination networks are not required because the transmitters are always on.

If you need to isolate the two devices, use the 485Fi or 485F9i Converters. These converters eliminate ground loops and provide the RS-232 equipment with protection against electrical transients.

CONNECTING TO A RS-422 DEVICE

Full-duplex connections can also be used when connecting a RS-232 system to a four wire RS-422 or RS-485 device. These are the easiest type of an RS-422 or RS-485 device to connect to they do not require any type of transmitter control or terminating networks. Figure 3 shows the cable connections. Connect the device's 'A' or '-' pins to the TX- or RX- pins on ICS's converters. Treat a two-wire RS-422 device as described below for a two-wire RS-485 device.

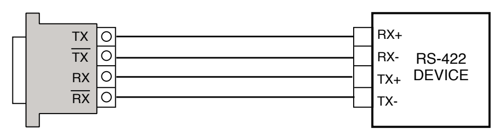


Figure 3 Connection to a Full-Duplex RS-422 or RS-485 Device

CONNECTING TO RS-485 DEVICES

Devices with RS-485 interfaces can have either a two wire or a four wire connection. Note that people commonly misuse the term 'RS-485' to mean a two wire, half-duplex connection. The four wire connection is the same as the full-duplex connection shown above in Figure 3 for a RS-422 device.

The two wire connection is a half-duplex connection. With the RS-232 to RS-485 Converters, the half-duplex connection is made by jumpering the TX and RX terminals together on the converter's terminal strip as shown earlier in Figure 1(b). The complete half-duplex connection is shown in Figure 5. Check the RS-485 device's manual for its signal polarity and advice on making connections to it. In general, connect the 'A' or '-' signal to the TX- terminal on the 485 series converters.

Half-duplex systems work because only one device on the network transmits at a time. The transmitter in the other device is disabled and the device only receives until it is its turn to transmit. The transmitter in the RS-485 device is only turned on when transmitting.

Older RS-232 to RS-485 Converters used the RTS (Request-to-send) signal in the PC's COM port to control the transmitter. The user's software had to control the RTS signal so it is turned on to enable the transmitter when sending a message and left off the rest of the time. Some converters also had an external Enable input that could be used to control the transmitter. (See the EN terminal in Figures 1a and 1b)

Newer RS-232 to RS-485 Converters like ICSDataCom's Magic series have a start bit detection circuit that automatically enables the transmitter. The transmitter is automatically turned off after the last character is transmitted. This reduces the burden on the user's software and makes the RS-232 to RS-485 conversion completely transparent.

Devices with RS-485 half-duplex interfaces normally operate in a disciplined fashion. That is they wait until they are sent a query before responding. They are often designed to return an acknowledgment each time they are sent a command. They should not be designed to periodically transmit data as that makes them undisciplined and their transmissions could collide with data transmissions from other devices. Undisciplined devices that transmit asynchronous messages should not be placed on the same network with other devices.

Because there are periods of time when nothing is being transmitted, the undriven transmission lines float and may appear as noise inputs to the receivers. To keep the lines from floating, a three resistor termination network is placed on each end of the transmission lines to bias the lines as a logic '1' when they are idle. Figure 4 shows a typical RS-485 termination network. The pullup and pulldown resistors are typically 1 to 2 kohms. The load resistor can be any value from 100 to 200 ohms and is often picked to match the line impedance.

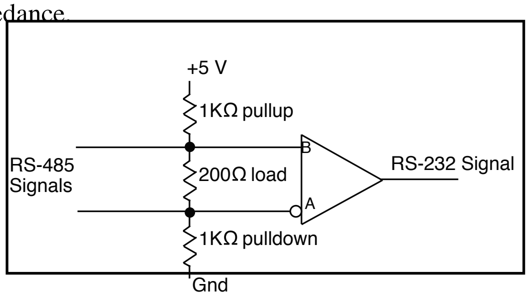


Figure 4 A typical RS-485 Termination Network

The complete half-duplex connection is shown in Figure 5. The pair of lines is shown as two wires for illustration purposes. In actual practice, they should be a twisted shielded pair of wires. If the transmission lines are short (less than 200 feet) and the data rates are low (under 20,000 baud) the user will be able to get by with unshielded lines and only one termination network in the system.

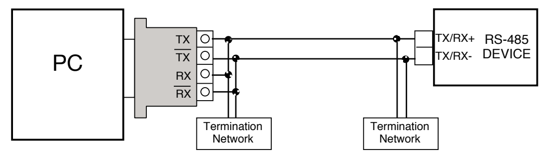


Figure 5 Connection to a Half-Duplex RS-485 Device

CONNECTING TO MULTIPLE RS-422 OR RS-485 DEVICES

Multiple devices with RS-422 or RS-485 interfaces can be connected together to form a multi-device network. Before connecting additional devices to the system, check their manual to be sure that they can operate in a multi-device network. Devices on a multi-device network must have an address setting function so that they can recognize messages set to them.

Four Wire Network

In a four-wire network, each device's receiver is connected to the computer's TX outputs. The device's transmitters are all connected to the computer's RX inputs. The controlling computer transmits messages on the TX lines that is received by all of the devices. Only the addressed device responds by transmitting on the computer's RX lines. The computer can leave its transmitter on when it is not transmitting since it operates in a broadcast mode and doesn't conflict with any of the other devices' transmitters. Since there is no requirement to disable the computer's transmitter, the four-wire network can be implemented with the less expensive basic RS-232 to RS-485 Converters. Figure 6 shows a four wire network for RS-422 or RS-485 devices.

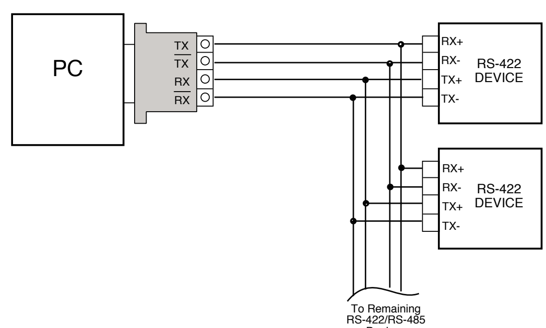


Figure 6 Four Wire Connection to Multiple RS-422 or RS-485 Devices

The devices on the network only enable their transmitters when sending a message to the host computer. The computer's receive signal line must be terminated to prevent the computer from receiving noise when the line is idle.

Two Wire Network

Figure 7 shows a similar network for a two-wire devices. In the two-wire network, all of the transmitters and receivers are connected to the same pair of wires. All transmitters must be tristated when not transmitting. Two-wire networks can be a star configuration or daisy chained. The connection depends upon the physical location of each device relative to the other devices on the network. In a star layout, it is best to place the termination network at the center of the star. In daisy chained systems, the termination network is typically placed at the end of the cable.

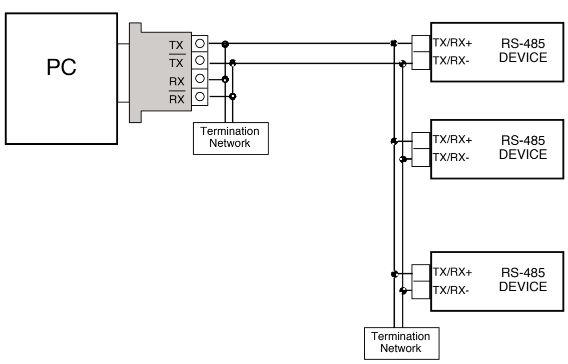


Figure 7 Two-wire Connection to Multiple RS-485 Devices

LOAD RESISTORS

For proper operation of an RS-422 or RS-485 lines, the line should be terminated at the receiver end with a load resistor to minimize signal reflections. In point-to-point systems as shown in Figures 2 and 3, the termination should be at the receiver at each end of the line. Typical termination resistor values are 120 to 220 ohms and are selected to match the transmission line's characteristic impedance. This value can be found in the cable supplier's catalog. At low frequencies this value is not critical but it becomes important at higher frequencies (>40 kHz). ICSDataCom's converters have internal 120 ohm resistors which matches the . Refer to the converter manual for instructions on connecting or disconnecting the termination resistor from the input terminals.

In half-duplex or multi-drop systems with multiple receivers, the termination resistor should be at the last receiver on each end of the shared line. In Figures 5, 6 and 7, only the two end receivers should have termination resistors. No more than two termination resistors should be put on a RS-422 or RS-485 line. Short systems with less that 200 feet of cable and slower baud rates (less than 20,000 baud) can get away with just one load resistor.

TERMINATION NETWORKS

With half-duplex or multi-drop networks, there are times when all of the transmitters are disabled and the transmission line floats. If the quiet time is long enough, the lines voltages become equal and the receivers input noise or random characters. The random characters could show up as corrupted messages when the received string is read by the computer. To avoid this problem, the user should install a termination network at each end of the transmission line.

Figure 4 shows a typical termination network with a pullup, termination load and pull down resistors. The pullup and pulldown resistor values are not critical. Typical resistor values with a + 5 pullup voltage are 1 to 2 kohms. A current level of 2 to 3 mA through the divider works fine. These values keep the midpoint of the divider string at 2.5 volts. The load resistance can be 220 to 120 ohms. Adjust the resistors accordingly for other pullup voltages.

Figure 8 shows a way the pullup and pulldown resistors can be added to the terminals on ICSDataCom's RS-232 to RS-485 Converters. The converts have an internal load resistor so the user only has to add the pullup and pulldown resistors. The user should check the voltage at the Vdc terminal and select the pullup resistor according to the following equation so the transmission line is biased close to 2.5 Vdc. Verify that the voltage between the two lines is at least 0.3 Vdc.

pullup = (Vdc / 5) x Rpulldown

If Vdc = 9 volts then

Rpullup = (9/5) 1 kohm = 1.8 kohm

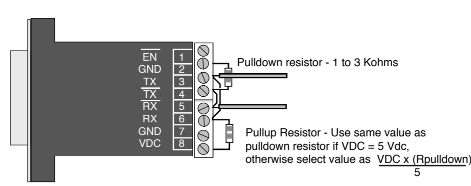


Figure 8 Adding Pullup and Pulldown Resistors to 485 Converters

Other devices with RS-485 interfaces may also have terminals or good mounting points for attaching terminating networks to the device. For instance, Watlow F4 Temperature Controllers have screw terminal strips with ground, TX/RX+, TX/RX- and + 5 Vdc. Mounting the terminating network to the Watlow F4 Controller is similar to adding it to ICSDataCom's RS-232 to RS-485 Converters.

DATA FLOW CONTROL ON RS-485 NETWORKS

In serial data communication systems, data flow control is used to prevent the transmitter from overrunning the capacity of the receiver to input and store data. This condition usually only occurs when the parties are transmitting long messages such as files between computers or output files to printers or plotters. Long is relative and is determined by the amount of buffering available in the receiving device(s).

Four-wire, full-duplex systems can use the X-ON/X-OFF protocol. X-ON/X-OFF protocol works by placing unused control characters into the data stream. The receiving device strips off the flow control characters before the data is printed or passed to the application. When X-ON/X-OFF flow control is used, both devices normally power up in the X-ON mode. The user should check the other device's manual in case it requires a initial X-ON character. When the receive buffer in either device becomes nearly full, the receiving device sends an X-OFF character (13 HEX) to the transmitting device. When there is again room in the receive buffer, the receiving device sends the X-ON character (11 HEX) to restart the data transmission. The X-ON/X-OFF protocol should not be used with binary data.

Half-duplex two-wire systems and four-wire multi-drop systems with instrumentation products are normally disciplined systems where the remote devices only transmit in response to query or command from the system controller. The messages in this kind of system are typically short (10 to 100 characters) so there is little likelihood of overrunning the computer's receiver or the device's RX buffer. Flow control is normally not required in these kinds of systems.

Flow control can be accomplished on a half-duplex system by implementing a file transfer protocol. File transfer protocols such as XMODEM, KERMIT etc. have block transfer handshaking and flow control as part of their data transfer protocol. They are readily available as part of the terminal or communications package on most computers and are recommended for file transfers. You can implement a simple protocol by breaking the file data into manageable size blocks and then only transmitting a block when the receiving device has signaled that it is ready.

ADDRESSING MULTIPLE DEVICES

Multiple serial devices are addressed by prefixing an identification or address sequence to the device's commands. In general, the address sequence consists of a starting character followed by the device's address number. The starting character is generally one that is not expected in the normal message. In ICS Electronics' 236x series serial interfaces, the address sequence is a STX character (HEX 02) plus the address number. i.e. <STX> 1. Other companies use a '/' or a N to start the address sequence and add a one or two digit address number. i.e.

Computer sends
    <STX>4*idn?<LF>
Device responds with
    ICS Electronics, 2361, S/N 121212, Revision 3.4 <LF>

RS-485 SERIAL INTERFACE PROBLEMS

The following are the most common RS-485 connection problems:

Correct signal polarity - Each RS-422 and RS-485 manufacturer seems to identify the transmit and receive signals differently. When good information is not available, use a DVM to find the positive and negative transmit pins by measuring between the two signals. If the transmitter is enabled, the pin with the negative voltage is the 'A' or '-' lead. The DVM should read >1.2 volts for a loaded transmitter or > 2 volts for an open circuit. Follow the instructions supplied by the manufacturer on connecting his unit to the other 485 devices.

Needed Transmit Control Signal - Two wire systems need to inhibit the transmitters that are not being used. When using simple 485 Converters, the suggested method is to set them so the PC's RTS signal enables the transmitter. The user's program can wait and then turn RTS off after the last character has been transmitted.

Receiving bad data between messages - In half duplex RS-422/RS-485 systems, there are times when the lines are not driven and the signal lines float. Some receivers may see the floating lines as noise inputs. Add a termination network to hold the undriven lines in the mark state. Refer to the Termination Networks section of this application note for directions.

Receiving ones own messages - Caused by the receiver in the 485 Converter listening to the transmit message. Change the program to discard the transmitted message. Model 485F9 converters can be set to disable the receiver when the transmitter is enabled.

Missing the first character(s) - In half-duplex systems, this is most likely caused by the last transmitter staying enabled longer that it takes for the responding device to start transmitting. Either increase the time before the device transmits or disable the transmitter sooner after the last bit has been transmitted.

Receiving garbage characters or bad first character of a message - In half-duplex systems, this is most likely caused by the lack of a termination network with the correct pullup and pulldown resistors or the resistors are not connected to a good power source. Refer to the paragraph on Termination Networks in this application note. If the line is > 100 feet, add a network at both ends of the line. Use a voltmeter to verify that the quiet line differential voltage is > 0.3 volts. If not, adjust the resistors as needed.