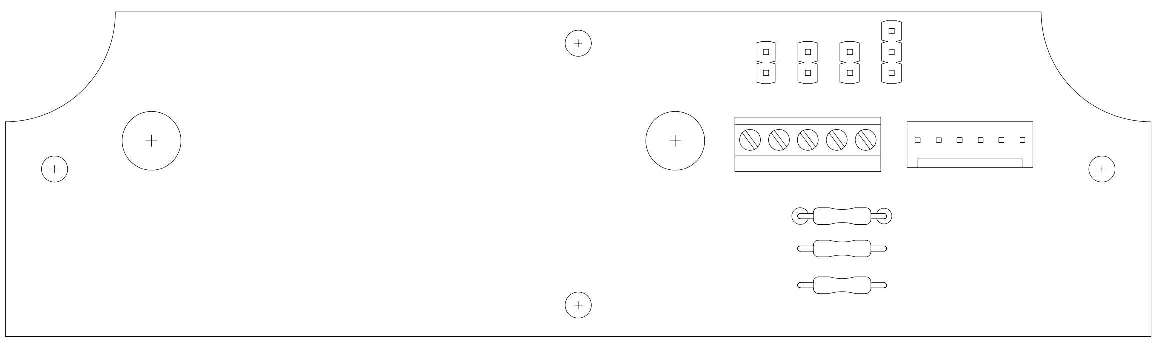
Installation Guide

Metretek
RS-485 Adaptor Board



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Introduction:

Most persons that work with computers and/or communications equipment are at least somewhat familiar with the terms RS-232, USB, Fire-wire, and LAN to name a few. RS-485 is less commonly known however, but serves well in applications where high data rates, excellent noise immunity, and long cable runs are necessary. As is often the case, there are both advantages and downsides to RS-485 when compared against other systems. It is the purpose of this manual to help develop a basic understanding of the RS-485 data transfer system, as well as providing specific details related to installation of the Metretek RS-485 adaptor board.

Overview of RS-232:

RS-232 (also known as V.24) is a relatively aged serial data transfer topology (1969), but still finds wide acceptance due to the large installed base, simplicity, and proven performance. Initially introduced with a 25-pin D-Sub style connector, the 9-pin variety is far more common at the present. Serial data is transferred over TXD and RXD lines with respect to a signal common. Transition levels are specified at a maximum of +15 volts to a minimum of -15 volts, although in practice it is more common to find swings in the range of approximately +8 to -8 volt levels. Data is transferred as a series of high and low signal levels, using a serial data transfer protocol with start bits, data bits, stop bits, and parity. A typical setting might be 1 start bit, 8 data bits, 1 stop bit, and no parity to transfer a single byte (8-bits) of useful information.
Maximum practical data transfer rate is 19.2k bits per second (bps), with cable lengths at 50 feet, and several times faster with shorter cable runs. It is only possible to have a single pair of devices connected; multi-drop capability does not exist. Immunity to electrical noise is rather poor when operating in harsh environments such as factory floor sites, traffic light controllers, refineries, etc.

Overview of RS-485:

As previously alluded to, RS-232 has some definite limitations for applications requiring longer cable runs and higher data transfer rates. RS-485 (EIA-485 standard) uses balanced transmission lines (differential signaling) to transfer serial data bytes. This method has inherently higher noise immunity, thereby permitting high data rates and long cable runs. Theoretical data transfer rates are on the order of 10M bps and 1200m (approx. 4000 ft) cable length, although it is often necessary to scale back the speed at such extreme lengths.

In the case of the RS-485 adaptor board coupled with the CNI, the limiting factor is the CNI board itself, which only supports data transfers up to 38,400 bps. Taking into consideration the intended applications for the CNI product, higher data transfer rates are not relevant, and it is the potential long cable runs that are beneficial.

RS-485 specifications state that 'multi-drops' are supported for additional transmitters and receivers sharing the same cable. Receiver impedance is specified to be 12k ohms for a single unit load. Given this impedance, up to 32 unit loads can be supported on the bus.

Receivers with a higher input impedance will have a fractional unit load value assigned, since the circuit loading effect is correspondingly less.

To obtain optimal performance with long cable runs and high data rates, it is necessary to carefully select the cable type that is to be used. A typical cable will have twisted pairs of 24awg. wires, be fully shielded, and have a nominal impedance of 120 ohms. Alpha Wire Company type 5473C, or equivalent is suitable for most applications. Additional recommendations for wiring practices are detailed in a later section of this document.

While it is beyond the scope of this document to elaborate on transmission line theory, it is not beyond the scope of the field installed device to demand proper termination of the signal line. Long cable runs and high data rates will require that a 120 ohm termination resistor is at the end of the cable, near the last receiver. This prevents reflections from occurring at the end of the cable, resulting in signal distortion. Referring again to the Metretek CNI product, leisurely data transfer rates of 38.4k bps (or slower) do not require as much concern about termination resistors. As a matter of practice, it is still a good idea however, and the Metretek RS-485 board can have the 120 ohm termination added by simply placing a jumper on JP1.

RS-485 differential signaling levels are specified to not exceed a ±6 volt swing for an unloaded transmitter, and the receiver sensitivity must be at least ±0.200 volts. Since it is possible to have multiple transmitters on a bus, the data transmission protocol must ensure that 'line contention' events do not take place. Specifics of signaling protocols and data transmission are not defined within the framework of the EIA-485 standard however; only the physical interface is detailed.

If the preceding description appears to suggest that the installer must possess an Engineering degree to understand and setup a system, then it must be admitted that this feeling is at least partially justified. If the goal was to operate at maximum transfer rates with lengthy cable runs, and numerous nodes, then it is true that the installation is likely to be a bit of a challenge. Fortunately enough, most applications for the Metretek CNI / RS-485 combination are relatively straightforward, and the following guidelines are intended to make the process as simple as possible.

Metretek RS-485 Board Installation:

If the RS-485 adaptor board is not already installed into the enclosure, then Figures 1 & 2 should be referenced for assembly. Two small #4 size self-threading type screws and a cable assembly will have been included with each kit.

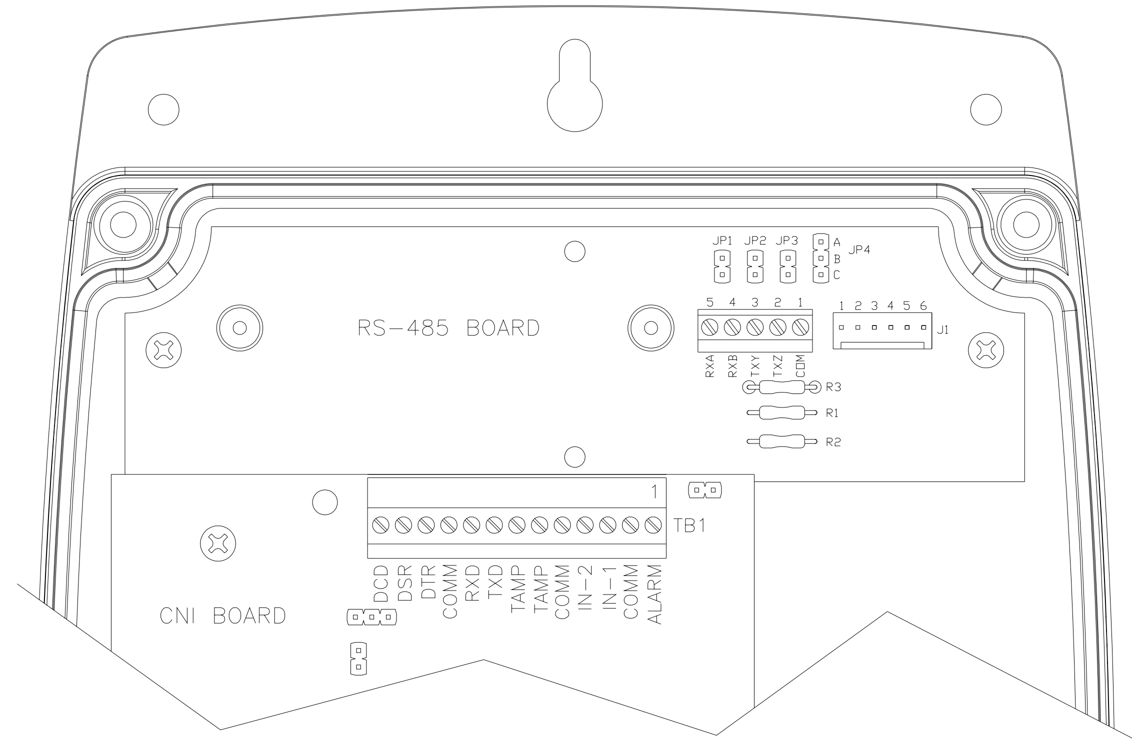

Figure-1
RS-485 Board Mounting Position

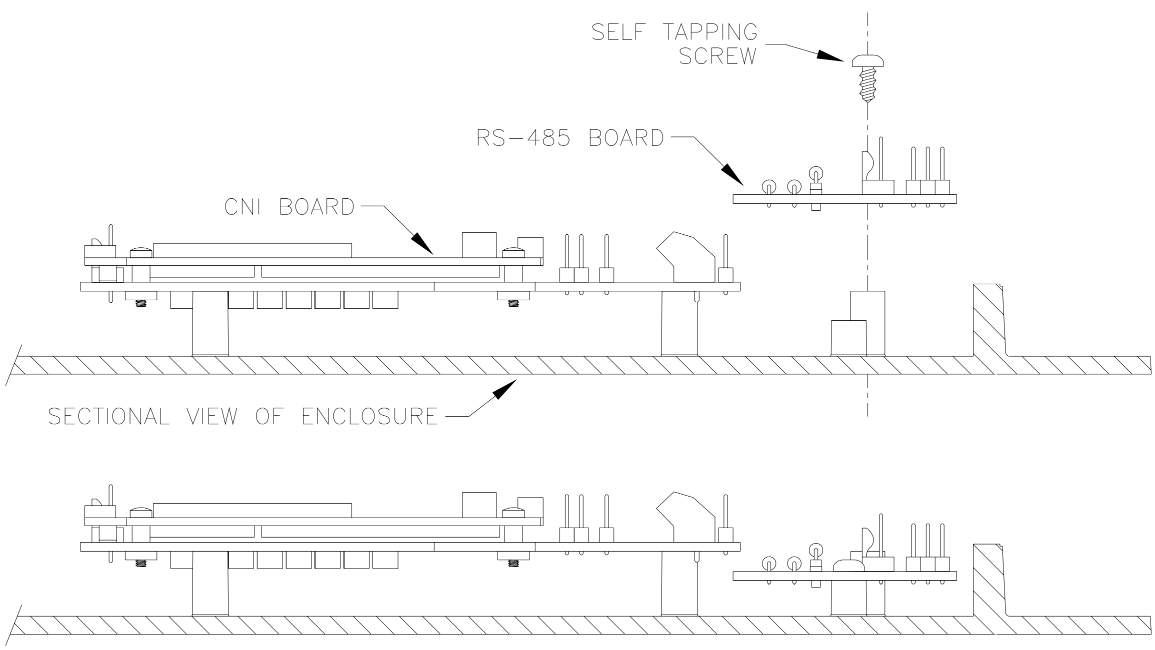

Figure-2
Securing the RS-485 Board

In some cases it may be desirable to install a serial port multiplexer board (Mux) into the system as well. Detailed information regarding the CNI and Mux board can be found in the relevant owners manual for these items. It should be mentioned however that it may be necessary to trim-off the header pins from the Mux board, if this was not previously done. Access to the header pins is not required, and in fact would pose a mechanical assembly conflict if left intact as seen in Figure-3.

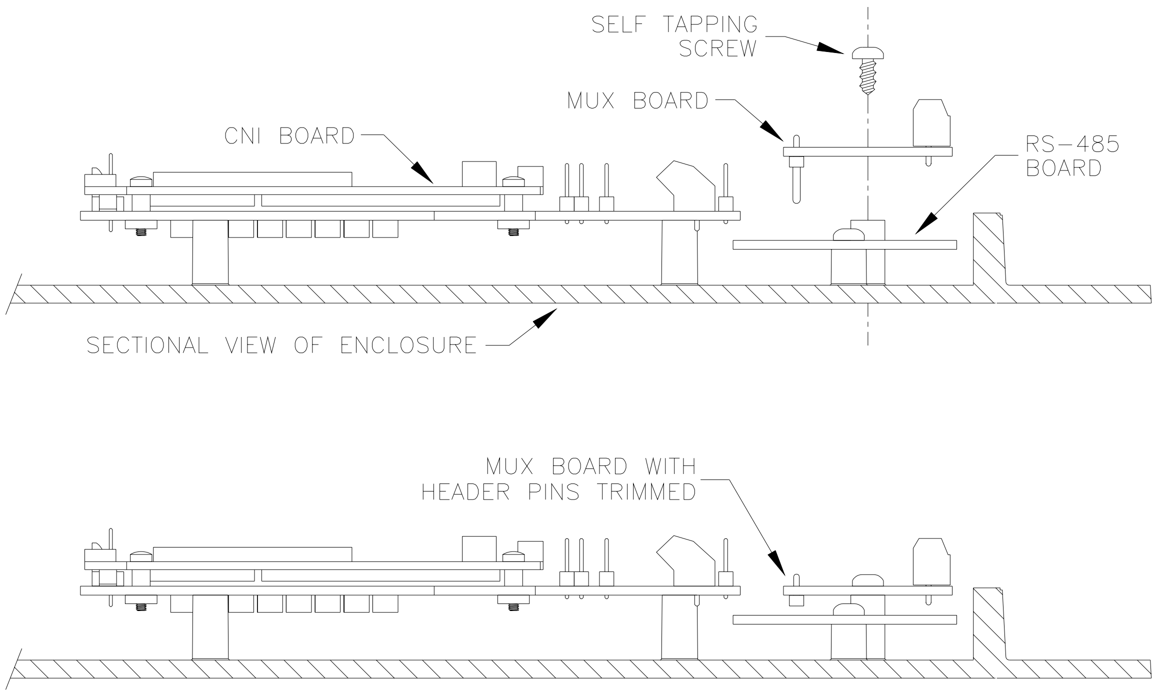

Figure-3
Optional RS-232 Multiplexer Board

Electrical connections to the CNI board are of course required, and a cable has been provided for this purpose as illustrated in Figure-4. The six position connector shown at the left of Figure-4 attaches to J1 of the RS-485 board. The rectangular power connector (R.H. side of drawing) connects to J3 on the CNI board. Remaining are the four individual wires that must be attached to the CNI terminal block. Terminal block positions are indicated for reference.

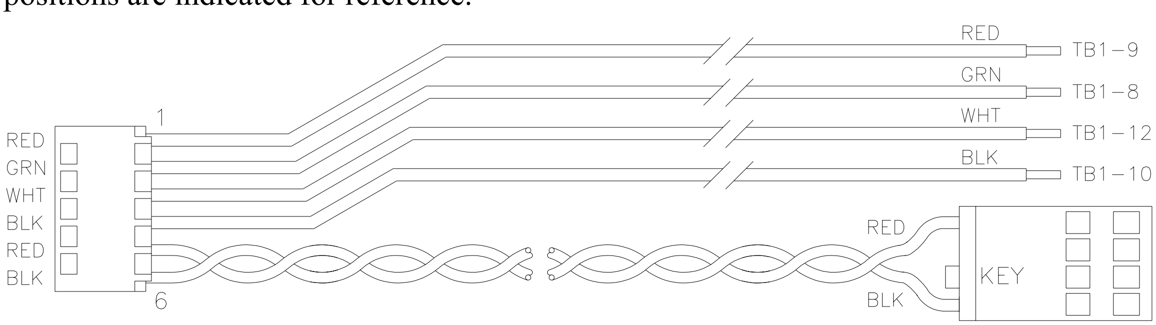

Figure-4
Cable Assembly, RS-485 Board to CNI Board

Metretek RS-485 Board Jumper Settings:

A number of jumpers are accessible on the RS-485 board to permit flexibility when attaching to varied product types in the field. The table below lists the default jumper settings that will work for most applications. Figure-5 illustrates where these jumpers are located on the board.

Jumper	Default	Function
JP 1	In	Enables termination resistor for receiver (RX-A, RX-B), 120 ohms.
JP 2	Out	Enables termination resistor for transmitter (TX-Y TX-Z), 120 ohms.
JP 3	Out	If in, reduces rise & fall times (bandwidth) for data bit transfer.
JP 4	A + B	Selects whether transmitter is always enabled (B+C) or controlled by the DSR signal of the CNI. (A+B)

Table-1
Jumper Assignments

Jumper JP1: When installed, this adds a simple 120 ohm resistive load across the receiver end of the RS-485 adaptor board. For most applications, this load resistor will remain installed.

Jumper JP2: When installed, this jumper adds a 120 ohm termination resistor across the transmitter output. Not often used, the option has been included to address the rare circumstance where at least two transmitters share the same line, and the length of the transmission cable ends here. This being the case, it is desirable to terminate the end of the cable to prevent reflections while the distant transmitter is sending bit streams.

Jumper JP3: When installed, the rise and fall times for each signal transition (slew rate) are reduced. This might be done for a system having signal integrity problems due to far end cable reflections, or the need to reduce EMI noise generation. The tradeoff is, of course, a slower data transfer capability. Default position is not installed.

Jumper JP4: This jumper controls whether the transmitter is continuously enabled, or if it is only periodically enabled by the CNI microprocessor for transmission bursts. If the overall system is wired for full-duplex and only the single transmitter element exists, then it is possible to set the jumper for B+C. If the system is wired for multi-drop with two transmitters on the same cable, or if it has been wired for half-duplex, then the setting A+B is mandatory (to prevent line contention).

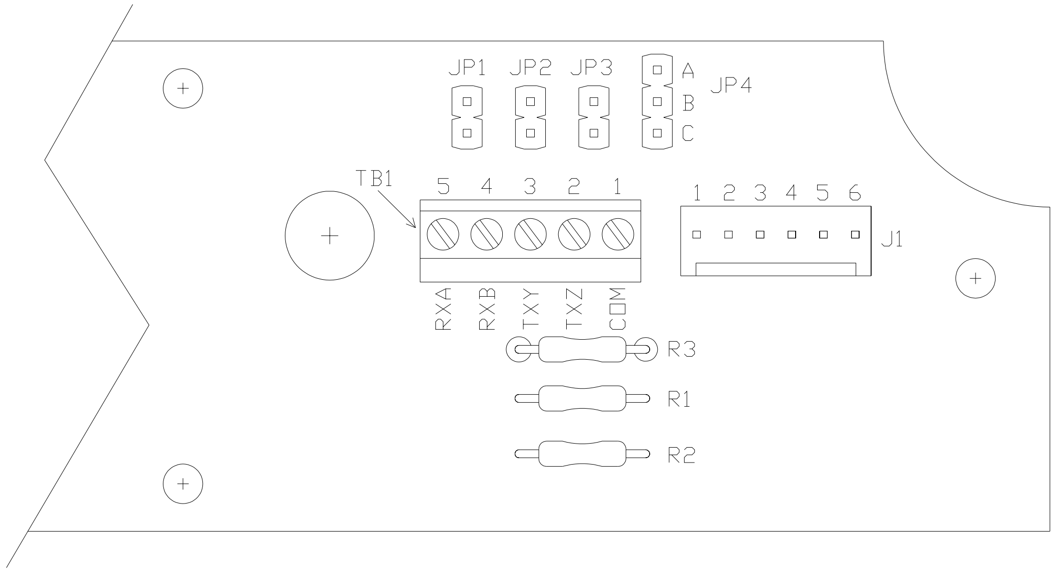

Figure-5
RS-485 Board Connectors & Jumpers

Full Duplex Wiring Configuration:

A full-duplex system, as illustrated in Figure-6, is the most straightforward configuration, and offers the highest potential for data transfers as there is no latency in enabling and disabling of transmitters. The downside here is the extra cost and larger cable size associated with full-duplex wiring. Cabling is specified as two sets of twisted pair wire, a common conductor, and a shield. In the marketplace it is easier to obtain a cable having 3 sets of twisted pairs, as opposed to a more specialized cable with 2 twisted pairs and a common conductor. Therefore, it is more practical to simply use an entire twisted pair set to serve as the signal common.

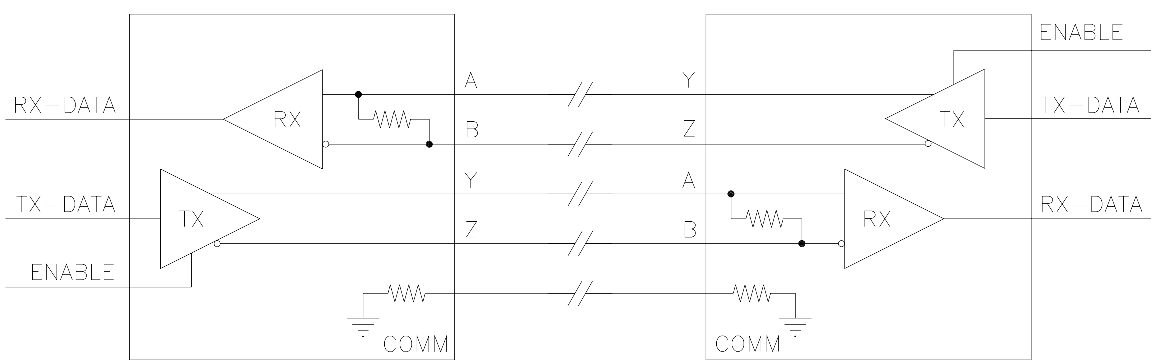

Figure-6
Point-to-Point Full Duplex Wiring

Note that Figure-6 is drawn to show the transmitter output TX-Y feeding into the receiver input RX-A, and the TX-Z going into RX-B. Correct polarity of the cable connections is mandatory for proper data transfers. Individual wires in a cable bundle are marked with colored stripes to make the task easier. The "A, B, Y, Z" notation shown here is more prevalent in the industry, and the Metretek RS-485 adaptor board conforms with this practice. Some manufacturers of RS-485 devices may deviate however, and in such cases triangular symbols for the transmitters and receivers should be referenced for guidance.

Figure-7 goes a bit further to illustrate a typical full-duplex system as it would be wired in the field for the Metretek RS-485 end. Note that the cable has three twisted pairs, and a shield connection. The drain wire from the shield connection must only be attached to earth ground at a single point to avoid potential ground loops.

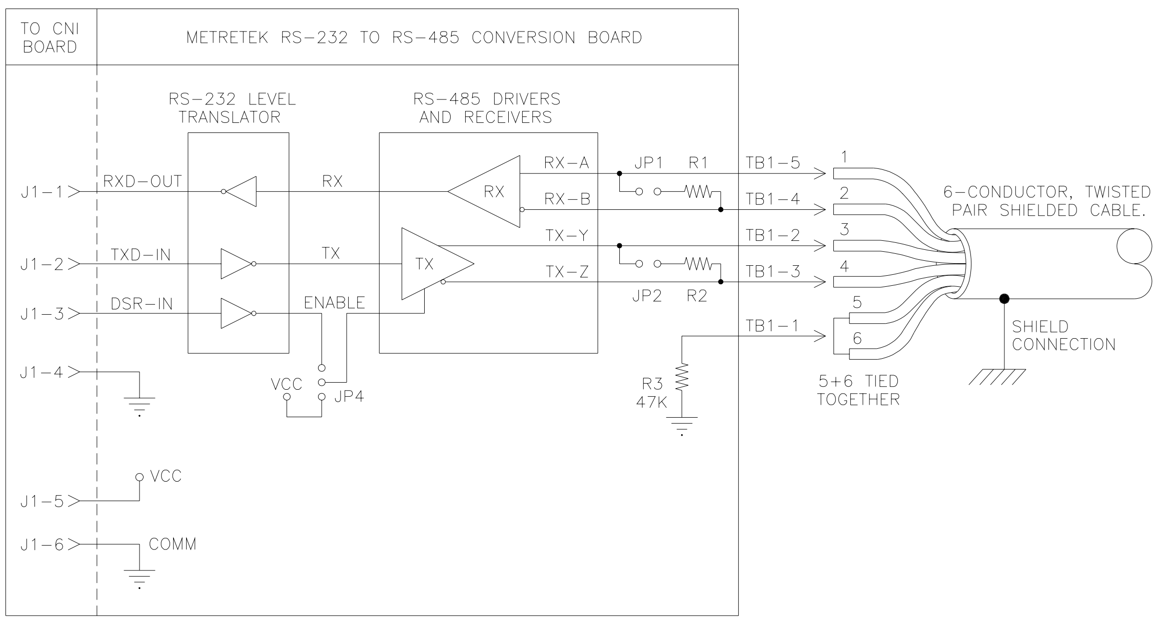

Figure-7
Shielded Cable Attachment

Figure-8 illustrates full-duplex connections for the user end point device. Naturally, this connection scheme appears essentially the same as that shown in Figure-7.

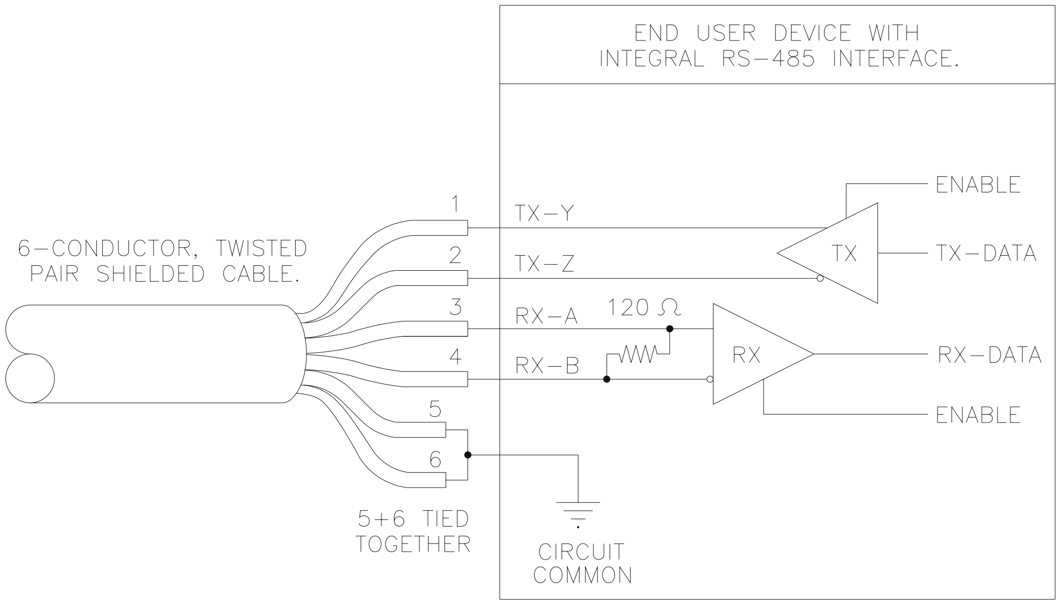

Figure-8
Wiring to Field Device

Half Duplex Wiring Configuration:

Justification for a half-duplex wiring configuration is, of course, the reduced number of conductors necessary for interconnection. The economic factors become obvious when considering cable runs of half a mile distance or more. With this configuration, it becomes necessary for the controlling electronics to enable and disable the relevant transmitters at appropriate times based upon the software system protocol. Otherwise, there is a possibility that line contentions might occur with two or more transmitters attempting to 'talk' at the same time.

Another possibility is to have an arrangement where one end only has a transmitter attached, and the opposite end only has a receiver attached (not shown). Implementation and utility of this type of unidirectional system will depend on the user application.

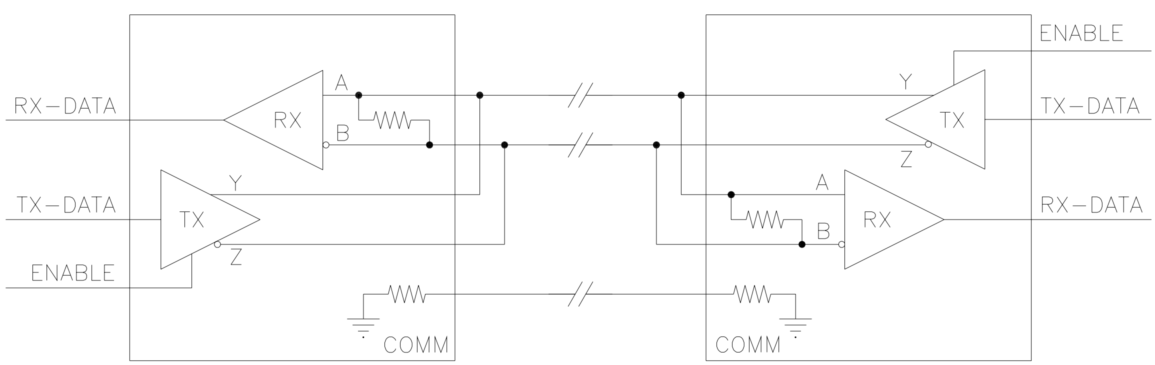

Figure-9
Point-to-Point Half Duplex Wiring

When setting-up a system for half-duplex operation, it is necessary to add two jumper wires as shown in Figure-10. As previously mentioned, maintaining the correct wire polarity is required for proper operation.

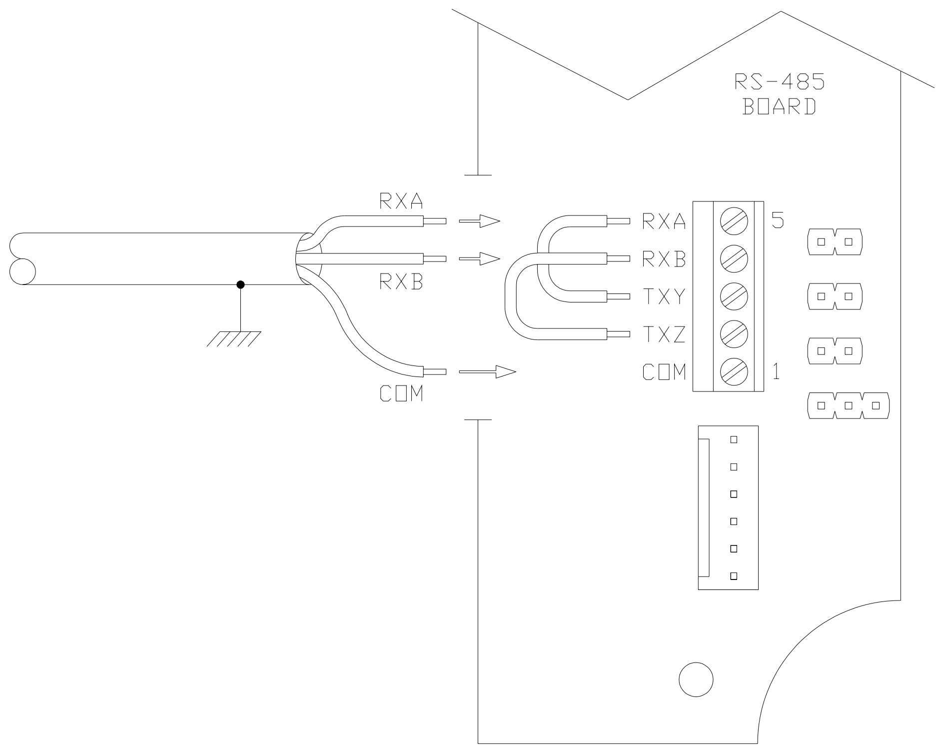

Figure-10
Half Duplex Configuration

Multi-Drop Configuration:

A hypothetical multi-drop system is illustrated in Figure-11, consisting of three transceivers and a single receiver node. As shown, two transceivers are attached at the far ends of the cable, while nodes 1 & 2 can be attached anywhere in-between. Notice that the nodes do not have termination resistors attached, and it is for this reason that the cable length for the stubs should be kept as short as practical to avoid signal distortion. The total number of node attachments is only limited by the unit loading of each receiver, with the bus supporting 32 unit loads maximum.

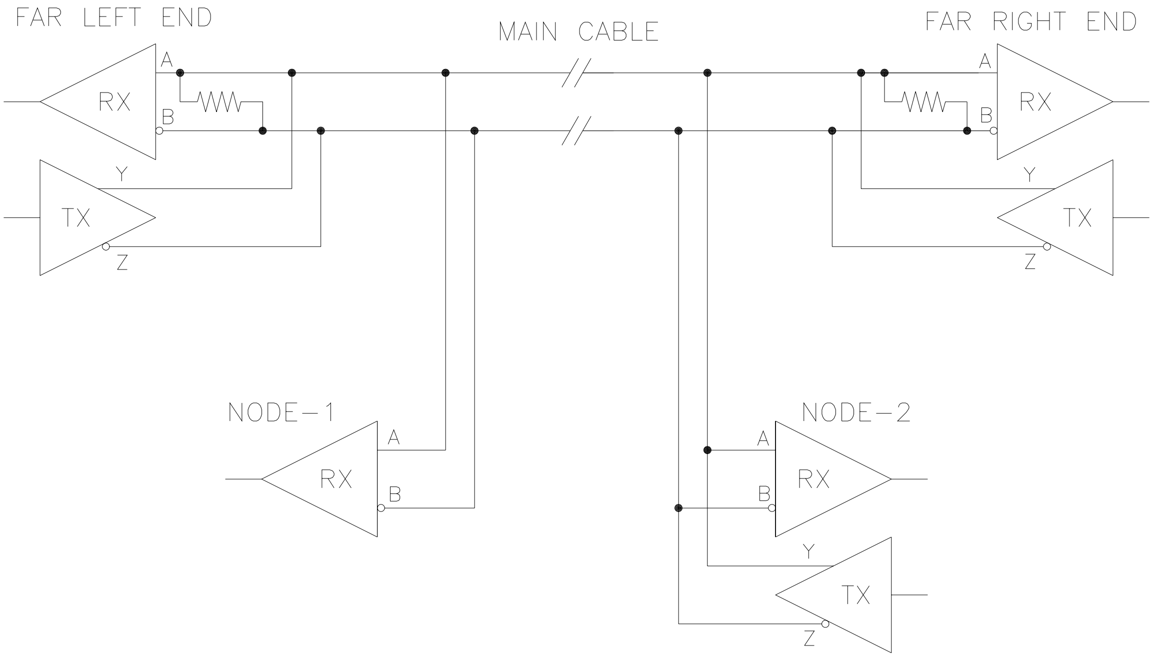

Figure-11
Multi-Drop System

Shield Grounding & Signal Common:

Of particular importance for system integrity and optimal performance is the attachment of the cable shield to an earth ground connection. As mentioned earlier in this text, only one end of the cable should be attached to earth to prevent ground loops. The shield connection wire becomes accessible upon removing a portion of the cable jacket from the end. This will be a simple non-insulated wire that runs the length of the cable. An earth conductor wire will need to be attached, and the wire gauge is not critical here.

Making reference to the earlier illustrations 6 & 7, it can be seen that a connection between the 'signal commons' is established, albeit through series resistors. The term 'signal common' here refers to the common ground system present in the electrical device, and is not to be confused with earth grounding. It is desirable to maintain some equilibrium between the signal commons of all the communications devices so as to prevent them from 'floating away' in terms of electrical potential.

At the same time, ground loop currents could potentially develop when units are separated over extended distances. Ground currents can be minimized however by use of a simple resistor in the circuit path. Resistor R3 on the RS-485 adaptor board provides this current limit function. Additionally, the resistor is mounted in miniature sockets so that the value can be easily changed if necessary. The default value for R3 is 47k ohms, and can be "stiffened" if necessary to perhaps 1k or 100 ohms. Circumstances specific to each field installation will ultimately determine if the R3 value should be adjusted or not.

Summary:

When examining the RS-485 standard, it becomes quite apparent this approach offers the potential for high performance over long distances. With this comes a price, and the price here is increased complexity in system setup. Many variables exist that must be properly selected by the user when customizing the system to his/her requirements. In contrast, the recently developed USB connection scheme offers fast data transfer, multiple node attachments, and consumer level simplicity, but with very limited cable lengths.

From a practical point of view, application of the Metretek CNI product with RS-485 adaptor board is likely to be straightforward in most circumstances. Data transfer rates are inherently limited by the CNI itself, at 38.4k bps maximum. Multi-drop attachments are likely to be a rare occurrence. Even most cable runs will be relatively short at most field sites; certainly less than 4000 feet. Taken together, what this means is that if the installer neglects to add a termination resistor, or doesn't use quite the ideal cabling, in all likelihood the system will still function just fine. The following points are recommended to help speed the installation process:

- Prepare the equipment for installation to the fullest extent possible while still at the office. Attaching miniature wires and updating the CNI configuration memory can test a persons patience when the outdoor temperature is 40 degrees and blowing rain.
- When possible, short cables runs should be configured for full-duplex operation. This reduces the possibility that two transmitters will ever "bang heads". In addition, trouble-shooting of problems becomes easier since it is well defined which twisted wire set is the 'talker', and which is the 'listener'.
- Observe proper wire polarities at each end. A reversed connection will not result in any circuit damage, but the communications link will of course fail to operate.
- Begin the field site installation using the default jumper settings JP1=In, JP2=Out, JP3=Out, and JP4=A+B. A full-duplex system with only a single transmitter per twisted wire pair can optionally have JP4 set at B+C to leave it continuously enabled.
- Bring along a spare CNI unit that is known to be in good working condition. Having this available can be of great assistance when trying to isolate problems in a non-functional system.

Appendix - A

Glossary of Terms:

Bit Rate:
This describes the number of transitions from low-to-high or high-to-low that take place over a period of time (measured as bits per second) on a given communications system. While the communications system can vary from satellite uplinks, fiber optic cable, etc., in this context the transmission medium is RS-485 with twisted wire cable.

Cable Impedance:
Characteristic impedance that a cable of infinite length (theoretical) will present to a high frequency signal propagating down the path. This is not something that can be measured with a simple ohmmeter across the leads. Placing a termination resistor of equal value (with reference to the cable impedance) at the far end serves to effectively absorb high frequency incoming signals, thereby preventing reflections.

CNI:
Metretek designation for their product line known as the "Cellular Network Interface".

Differential Signaling:
A communications method where a pair of wires are used to transfer information without reference to a signal common. In the case of RS-485, if a person was to place an oscilloscope across the two wires of the transmitter output while a 120 ohm load was being driven, it would be found that the signal toggles between +4 volts polarity and -4 volts polarity. Due to the fact that a signal common is not used as the return path, any injected noise will be common to both wires, and therefore tend to cancel out.

Isolation:
In this context, isolation refers to a design method where the RS-485 circuit signaling and power are coupled via capacitors and transformer to the other electrical circuits. In general, products having this type of construction are more resistant to electrical spikes and surges since the isolated circuit can 'float' to as high as 1000-2500 volts depending on the design. One trade-off for this robustness is a reduced data transfer rate, since it is not possible to exchange data at 10M bps over the isolation channel. The Metretek RS-485 adaptor board incorporates isolation to maximize survivability in the field.

Line Contention:
A condition where two or more transmitters attempt to 'talk' on a shared cable at the same time. For obvious reasons, this is to be avoided, although no permanent damage to the transmitters will occur. Software protocol is responsible for collision avoidance as there are no 'handshaking' control lines.

Multi-Drop:
The most basic RS-485 configuration will typically have two transceivers separated by a length of cable. When additional receivers, transmitters, (or both) are added at intermediate points along the main cable run, then the system is known as 'multi-drop'.

Node:
Refers to a receiver, transmitter (or transceiver) that has been attached somewhere along the path of the main RS-485 cable.

RS-422:
A predecessor to RS-485; some degree of compatibility between the two does exist. Companies such as Texas Instruments, Linear Technology, and others have application notes available at no cost that address the topic of compatibility in great detail.

RS Prefix:
An obsolete prefix that still finds common usage, the letters stand for 'Radio Sector'. References to RS-232 and RS-485 are used throughout this text.

Termination Resistor:
A resistor placed at the far end of a far end of a transmission cable, intended to absorb energy from incoming signals. Due to the high impedance of the receivers used within the RS-485 system, a termination resistor is often necessary to prevent undesirable reflections from the cable end.

Unit Load:
EIA-485 defines a single unit load to be 12k ohms for a receiver element, with each transmitter having the capability of driving 32 unit loads. If a receiver has a higher impedance than 12k (as is often the case), then the unit load value assigned to that receiver will be a smaller number. If all the unit loads were all 0.5 for example, then the transmitting element would be able to support 64 receiver nodes.

Appendix - B

RS-485 Adaptor Board Electrical Specifications:

Input Voltage Requirements:
5.00 volts ±0.50 at J1-5 (+) and J1-6 (-).

Current Requirements:
A source capacity of 200mA is recommended. Typical current draw for the board is 68mA with the transmitter driving a 120 ohm load, and 26mA with the load removed.

Isolation Voltage:
1250 Vrms isolation exists between the J1 connector and the TB1 connector. The limiting element here is the transformer T1 that is hipot rated at 1250 volts.

Maximum Data Transfer Rate:
Limited to 400k bps due to the isolation barrier architecture within the RS-485 conversion IC. The CNI board design further limits the serial data exchange rate at 38.4k bps maximum.

Transmitter Drive Levels:
Typical measured values are 6.20 volts with no load, and 4.02 volts when driving a 120 ohm load.

Receiver Sensitivity:
200mV sensitivity minimum.

Receiver Input Impedance:
68k ohms typical, representing approximately 1/4 unit load.