How to Configure the ICF-1150's Pull High/Low Resistors

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Moxa's new ICF-1150 media converter provides users with a valuable tool for tuning the converter's pull high/low resistors. The two rotary switches located on the converter's front panel can be adjusted independently to one of ten resistance values to ensure that data is transmitted without error through an RS-485 multi-drop network. Refer to the following table to get an idea of the degree of versatility the converter provides.

Position	0	1	2	3	4	5	6	7	8	9
Ohms	150K	10K	4.7K	3.3K	1K	909	822	770	500	485

Tuning the pull high/low resistors will inevitably involve a certain amount of trial-and-error. The brute force approach is to start with the lowest value on the dial, test the integrity of the network, and then work your way up the dial if you find that your data is not transmitted properly. A more intelligent approach is to use basic electronics principles to derive a reasonable starting value for the pull high/low resistance values. In this tech note we give users a straightforward method of determining such a value.

RS-485 communication uses balanced line drivers and differential transmission over 2 wires to transmit data between nodes. The precise amount of power needed by the interface transceiver driver at each node of an RS-485 network is influenced by the number of nodes, which can range from just a few all the way up to 256. As more nodes are added, the equivalent internal load impedance of the network as a whole will increase proportionately. For example, if a device can handle 32 nodes on the bus then the equivalent internal load impedance of the network as a whole is generally 12 KΩ. Since the impedance increases proportionately to the number of nodes, if the device can handle 64 nodes then the equivalent internal load impedance would be 24 KΩ, and if it can handle 256 nodes then the equivalent internal load impedance would be 96 KΩ. Since on RS-485 networks most devices are connected in parallel, a larger resistance will have a smaller effect on the total impedance.

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About Moxa

Moxa manufactures a wide array of device networking products for industrial automation. Information about all Moxa products, which include embedded computers, Ethernet switches, wireless solutions, serial device servers, multiport serial boards, media converters, USB-to-serial converters, embedded device servers, video networking products, and industrial I/O solutions is available on Moxa's website. Our products are key components of many networking applications, including industrial automation, manufacturing, POS, and medical treatment facilities.

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The voltage difference across the two signal lines of a balanced line receiver is used to indicate the value of a bit. If the voltage difference is between 200 mV and 6 V, then the bit value is 1. If the voltage difference is between -200 mV and -6 V, then the bit value is 0. Voltage differences between -200 mV and 200 mV are interpreted as unknown. In addition, a voltage difference greater than 200 mV or less than -200 mV is used to indicate an idle state (also called tri-state), which means that all drivers connected the network are inactive.

In order to maintain a proper idle voltage state, bias resistors must be applied to force the data lines to the idle condition. The most typical bias resistors are pull high and pull low resistors. The locations of pull high and pull low resistors for a particular node are shown in Figure 1.

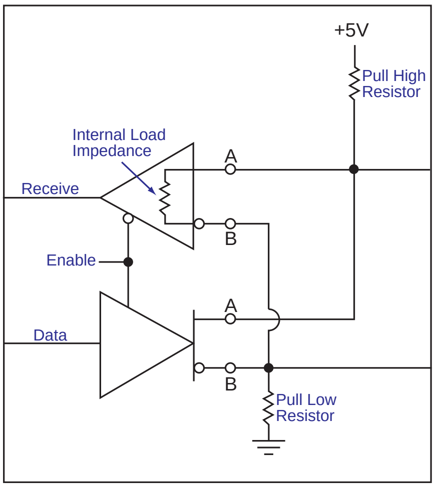

Figure 1: Locations of Pull High and Pull Low Resistors for a Particular Node

Note that in an RS-485 4-wire configuration, the bias resistors should be placed on the receiver lines. The pull high and pull low resistors are used to guarantee that enough DC bias current will be generated on the network to maintain a minimum voltage of 200 mV between the A and B lines when the RS-485 node is in idle mode (also called listen mode). We can illustrate the pull high and pull low resistors more simply as in Figure 2.

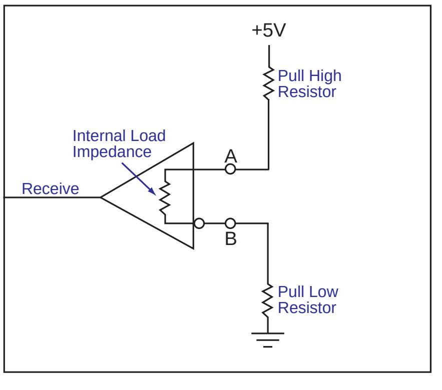

Fig. 2: Simpler Illustration of Pull High Pull Low Resistor Locations

On an RS-485 network, it is quite common to add termination resistors to the network to reduce signal reflection due to the mismatch between node impedance and transmission line impedance. The termination resistors used by Moxa are connected in parallel and have a resistance of 120 Ω. The location of the termination resistors is shown in figure 3.

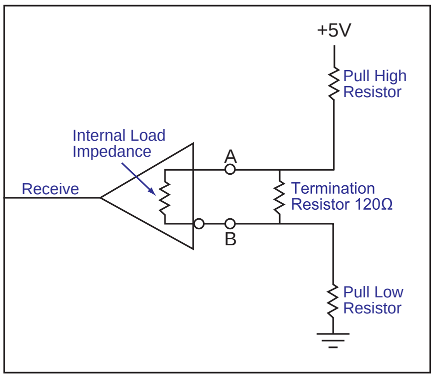

Fig. 3: Location of Termination Resistors

When we use fiber converters to increase the transmission distance of an RS-485 network or to avoid inference, the network is cut into two independent segments. In this case, the impedance of the two segments should be measured separately. The ICF-1150 is equipped with two important tools to help the engineer keep the network running as smoothly as when a fiber converter is not used. The first tool is being able to enable and disable the 120 Ω termination resistors, and the second tool is being able to configure the resistance of the pull high/low resistors.

Before we select the pull high/low resistance value, we should first calculate the total load impedance of the line (see Figure 3). Assume that the internal load impedance of all RS-485 nodes is the same, and then check how many nodes can be added to the network without violating this assumption. Let's call the load impedance R(i). For example, if there are 20 nodes and the load impedance of each node is 12 KΩ then

$$R(i) = 12\ K\Omega / 20 = 12{,}000\ \Omega / 20 = 600\ \Omega.$$

If the RS-485 network is using termination resistors, then let R(t) represent the effective resistance of all termination resistors combined. For example, if there are 2 terminators and each one is 120 Ω, then R(t) = 120 Ω / 2 = 60 Ω.

Next, let R(h) and R(l) represent the effective resistance of all the pull high and pull low resistors, respectively. Since we generally use the same resistance for the pull high and pull low resistors, let's assume that R(h) = R(l).

With reference to Figure 3, keep in mind that the magnitude of the voltage across signal lines A and B must be greater than 200 mV. We will use the fundamental equation 1/R(s) = 1/R(i)+1/R(t) to derive two inequalities—one inequality for networks that use termination resistors and one for networks that don't.

If the network is using termination resistors, then we calculate the total effect that resistors R(i) and R(t) have on R(s) as follows:

$$5\ V \times R(s) / (R(h) + R(l) + R(s)) > 0.2\ V$$

On the other hand, if the network is not using termination resistors, then:

$$5\ V \times R(i) / (R(h) + R(l) + R(i)) > 0.2\ V$$

Example: RS-485 multidrop network with 20 nodes and two 120 Ω termination resistors on each side.

In this case:

$$R(i) = 12\ K\Omega / 20 = 600\ \Omega$$

$$R(t) = 120\ \Omega / 2 = 60\ \Omega$$

$$R(s) = 600 \times 60 / (600+60)\ \Omega = 55\ \Omega$$

And then:

$$5\ V \times 55\ \Omega / (R(h) + R(l) + 55\ \Omega) > 0.2\ V$$

$$R(h) + R(l) > 1320\ \Omega$$

Conclusion

This last inequality gives us a reference number for setting the pull high and pull low resistors. Note that R(h) and R(l) together represent the total effect of all pull high and pull low resistors on the network. However, since for most devices you won't know how many pull high/low resistors the devices have internally, we will assume that none of the devices have pull high or pull low resistors, and just set the ICF-1150's pull high and pull low resistor resistors to fit in the formula.

The equations in this document are designed to provide you with a straightforward procedure to find the best pull high/low resistance values for your system. Even though there are many variations of RS-485, the formulas in this paper give us a logical starting point for determining the pull high/low resistance values, allowing you to get your network up and running as quickly as possible.