Increasing RS-485 Robustness

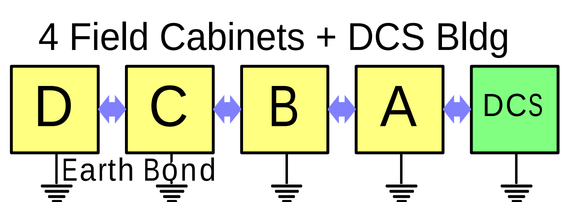
RobustDC Application Note #32

Quick Index:

See Also:

- RobustDC Application Note AN005 *Grounding and RS-422/485*
- RobustDC Application Note AN011 *Using Isolated RS-485 Repeaters*
- RobustDC Application Note AN018 *Surge Management 101 - A Simple Primer*

• Overview



A large petro-chemical plant had an RS-485 headache. An analyzer system with RS-485 multi-drop was frequently damaged and off-line – doubly painful since it was a 2-channel redundant design. Each channel was 4-wire RS-485 with a typical run connecting about 20 Modbus/RTU slaves in 4 out-buildings. The overall length was a modest 600 meters. Since every device was grounded to the earth-bonding system, they ran only 2-pair cable with no 5th ground wire. An unremarkably design like this with reasonable length and number of slaves should be working fine.

What were the symptoms? In 2 years they had burned out nearly 30 RS-485 Comm. Modules with a total installed base of 200 slaves. They complained that on some days it all worked, while on other days the farthest building or two would disappear. Damage to any one RS-485 slave usually brought down the whole network, which was bad for both operations and rapid trouble-shooting. Plus when they had identified the faulty slave, they couldn't always prove it was bad to the vendor because it often appeared to work when connected alone. Trouble-shooting suggestions are not repeated here - see Robust DataComm application notes # 006 "*Troubleshooting RS-485*". **Instead, this application note covers some of the factors that create robust RS-485 designs that need no trouble-shooting. RS-485 devies are not "consumables" – the**

notion that a few burn-outs a year is normal is wrong. With proper design, one can easily design an RS-485 network that runs a full decade without failure.

• What makes an RS-485 design more or less robust?

Unfortunately, there is no simple formula for robust RS-485 networks. Many factors affect the overall robustness of your design. These factors can be traded off to increase the robustness or to increase the tolerance for less than ideal constraints. For example, if you need to run your RS-485 1500 or 2000m, then you may need to use better cable and/or run at a slower baud rate and/or place fewer devices on your RS-485 segment and/or be careful of the electrical load of your surge devices.

	Factor	More Robust	Less Robust
1	**Number of Nodes per Segment**	Fewer (ex: 2)	More (ex: 32)
2	**Overall Length of Bus Segment**	Shorter (ex: 50m)	Longer (ex: 1000m)
3	**Quality of Your Cable**	Official RS-485 cable	Other cables
4	**Speed (baud rate) of Communications**	Slower (ex: 2400)	Faster (ex: 115kbps)
5	**Length of Drop (Taps) to Slaves**	Shorter (ex: 0m)	Longer (ex: 15m)
6	**Number of Screw Terminals Per Wire**	Fewer (ex: 4)	More (ex: 200)
7	**Surge Protection**	Sometime More	Sometimes Less
8	**Proper Termination & Bias**	N/A (do it right!)	N/A (do it right!)

1) **Number of Nodes**: an RS-485 network with 2 or 3 devices will be inherently more robust than one with 32. Electrically, RS-485 appears as 1 driver attempting to maintain a voltage difference between 2 wires in a pair, while the receivers (or loads) measure that difference by drawing a small amount of power. Thus a driver must expend more power to retain the same quality of signal as more receivers are added. More receivers also mean it is more likely that cable resistances and other passive loads prevent the driver from maintaining a good signal. Repeaters can be used to break a larger RS-485 network into many subnets, each with fewer nodes and better signal quality.

2) **Segment Length**: this affects the voltage drop of the signal, the noise characteristics, and the susceptibility to induced surges. There are many ways to break large RS-485 networks into shorter segments (see RobustDC app note #011). So two RS-485 segments of 800m each joined by a repeater will be more robust and have a better signal than as a single 1600m long RS-485 segment.

3) **Quality of Cable**: while this should seem obvious, true 120-ohm RS-485 cable is often hard to find in lengths longer than 1000ft or 330m. So for logistics and budget reasons, users often end up running RS-485 thru less than ideal twisted-pair cable instead. This is acceptable if you manage the robustness tradeoffs. Using analog loop cable for a 200m RS-485 with 3 nodes will likely work fine, while using it for a 2200m RS-485 with 27 nodes is downright stupid. When you bend the rules and use poor quality cable, make sure you have a fall-back plan. One fall-back is to wire for RS-485 4-wire instead of 2-wire, and a second is to accept dropping your speed if required. But if logistics or budget will prevent you

from using a good RS-485 cable, we recommend selecting a more common 100-ohm communication cable before using analog loop cable.

4) **Speed (baud rate)**: once in the field, varying speed is the easiest tradeoff to make. If you are having trouble communicating on a long RS-485 segment you can try dropping the speed a few notches - even to 1200 baud. If you still cannot get communications to work, then it isn't signal quality that is stopping you, but some physical problem or configuration error. In fact, we've found this a very useful bargaining chip with unrealistic users (or bosses). Some insist that using 1400 m of analog loop cable is fine and want us to confirm their decision. Just saying "no" won't always work, but saying "It should work, but you may have to drop your baud rate to 2400 or 1200 baud" seems to be a better deterrent to poor cable selection than just saying "no".

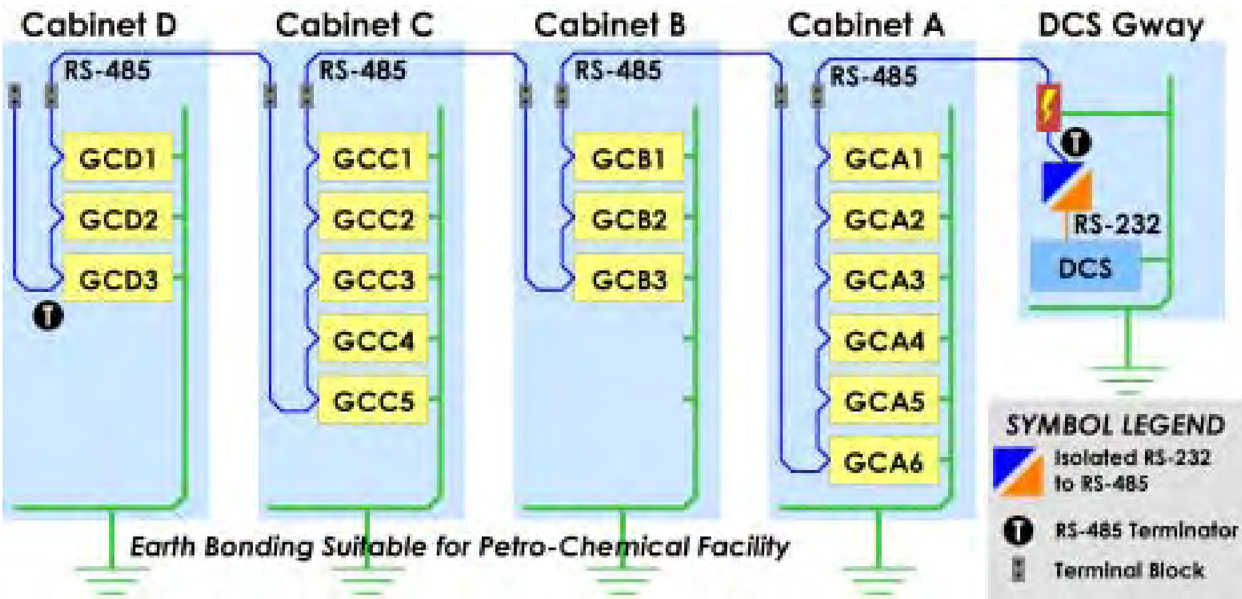
5) **Drop Length**: formally, EIA/RS-485 says the drop length between driver chip and RS-485 bus should be zero inches. Obviously this is impossible – most devices will have already a few inches of PCB trace between the driver chip and terminal block. So obviously, zero inches is not required. Since the EIA/RS-485 standard really just describes creating a chip, we look instead to the ISO-8482 standard that covers application of RS-485 in real-world terms. ISO-8482 allows multi-drop RS-485 to be used for up to 32 nodes with up to 15m drops between each node and the RS-485 bus. So zero drop may be the ideal, but up to 15m drops can be used if other tradeoff factors are improved.

6) **Number of Screw Terminals**: this is an important but often overlooked measure of robustness. Not only do screws slow down your installation and maintenance, but they represent a liability or potential for future failures. Screws can come loose or even not be tight to begin with. Wire strands can break off or short between adjacent screws. So designs with fewer wire segments and fewer screw terminals are more robust than designs with many of these physical points-of-failure.

7) **Surge Protection**: this is difficult to include as "robustness tradeoffs". Obviously, a robust design requires appropriate surge protection, and a design without surge protection can never be robust. However, there are a wide variety of surge devices. They add differing levels of impedance, capacitance, and inline resistance to your RS-485. So in general we say adding appropriate surge protection is critical, but it will likely negatively impact your signal quality. This means in some designs other robustness factors must need to be improved to compensate.

8) **Proper Termination and Bias**: this really should not be a tradeoff, as it is too easy to correctly. If you have 120-ohm cable, then use two 120-ohm termination resisters. Do not use 220 or 240-ohms since we are matching impedance here, NOT resistance! If you have 100-ohm cable, then use two 100-ohm termination resisters. This is not 100% ideal since the EIA/RS-485 chips will be optimized to drive 120-ohm cable, but it is a valid trade-off acknowledging the wider availability of good quality 100-ohm data communication cable. Also, all RS-485 designs should include proper bias resisters to hold the RS-485 wires idle when no driver is active. All RobustDC RS-485 products have jumpers to enable suitable pull-up and pull-down bias to "quiet" a floating RS-485 wire pair.

• The Existing "Problematic" Design



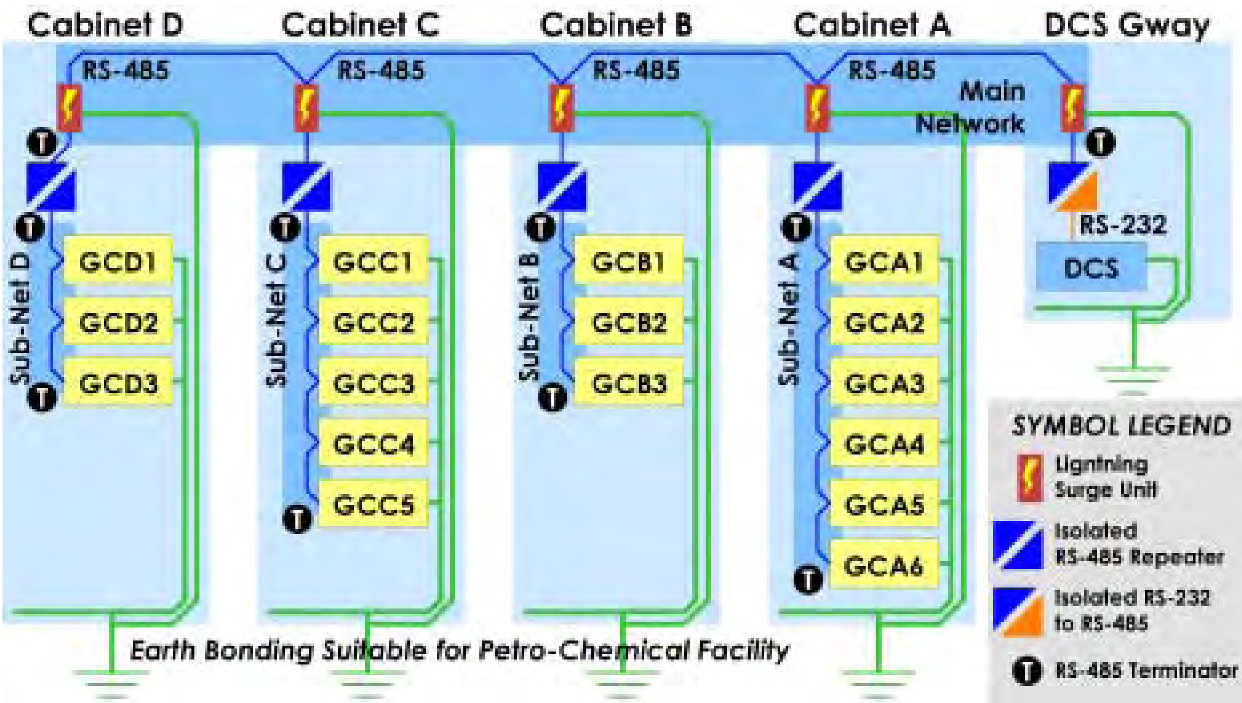
The original design has all of the devices on a single RS-485 network. Only the DCS gateway device is well designed with appropriate surge protection. The original design has no surge protection in the field cabinets. Below is a quick analysis of the "Robustness Factors" (**N/C means we don't plan to change or No-Change**). We have 18 devices on one 600m RS-485 bus. Every wire has about 72 points for mechanical failure – meaning the 4-wire RS-485 network has almost 300 screws to come loose.

	Factor	Main				
1	**Number of Nodes on Segment**	18				
2	**Overall Length of Bus Segment**	600m				
3	**Quality of Your Cable**	N/C				
4	**Speed (baud rate) of Communications**	N/C				
5	**Length of Drop (Taps) to Slaves**	N/C				
6	**Number of Screw Terminals Per Wire**	72				
7	**Surge Protection**	Poor				
8	**Proper Termination & Bias**	No bias				

• A word on Lightning Protection

This customer had just initiated a contract to swap the field terminal blocks with good 31vDC surge protectors. This caused 2 concerns for us: 1) RS-485's normal operating range is -7 to +12v and EIA-485 requires chips to survive +/- 25v surges. So we always recommend 15v to 18v surge protection and feel the 31v level is not appropriate. 2) Adding 7 more LPU with more inline resistance and capacitance risks weakening the existing RS-485 signal quality already stretched over 600m and 18 devices.

• The Final "Robust" Design



So here is our recommendation to the customer. We suggested the customer add 4 LPU (rdcLPU) and 4 isolated RS-485 repeaters (rdc485ir5). This totally removes the expensive Modbus/RTU slaves (gas analyzers) from the surge-prone main RS-485 back-bone. It creates 5 electrically distinct RS-485 sub-networks, each with terminating resisters and its own independent relation to earth ground. The analysis below shows that all 5 are significantly more robust than the original single RS-485 network (**N/C means No Change from original design**). This is especially true of the 4 new RS-485 sub-networks A to D isolated within the cabinets. They are now 100% contained within a single metal structure – they will now be virtually surge-proof. Only the Main RS-485 backplane is still exposed to surge and grounding problems, and it now has only 5 isolated RS-485 devices and heavy lightning protection.

	Factor	Main	SN # A	SN # B	SN # C	SN # D
1	**Number of Nodes on Segment**	5	7	4	6	4
2	**Overall Length of Bus Segment**	550m	5m	5m	5m	5m
3	**Quality of Your Cable**	N/C	N/C	N/C	N/C	N/C
4	**Speed (baud rate) of Communications**	N/C	N/C	N/C	N/C	N/C
5	**Length of Drop (Taps) to Slaves**	N/C	N/C	N/C	N/C	N/C
6	**Number of Screw Terminals Per Wire**	15	12	6	10	6
7	**Surge Protection**	Heavy	Spike	Spike	Spike	Spike
8	**Proper Termination & Bias**	+ Bias	+ Bias	+ Bias	+ Bias	+ Bias

A more detailed analysis follows:

1) **Number of Nodes**: while the original design had 18 devices on one RS-485 network, the new RS-485 networks have only between 4 to 7 devices, so each will be more robust.

2) **Segment Length**: while the original design had one long bus running between the 4 cabinets plus looping within each cabinet, the new RS-485 networks are all shorter. The main RS-485 is a few % shorter as it no longer loops within each cabinet. The isolated RS-485 networks within the 4 cabinets have now become near trivial RS-485 length of a few meters each.

3) **Quality of Cable**: we did not change the cable.

4) **Speed (baud rate)**: we did not change the speed - but perhaps it could even increase now!

5) **Drop Length**: we did not change the drop length, which in the original design was near zero.

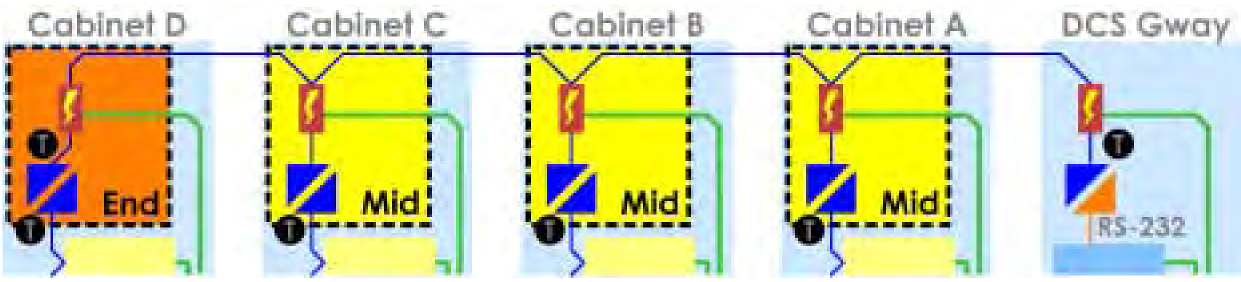
6) **Number of Screw Terminals**: while the original design had many physical points of failure (4 x 72 or nearly 300!), the 5 new RS-485 subnets have only 10% to 15% as many as the original.

7) **Surge Protection**: Only the Main RS-485 backplane is exposed to surge and grounding problems and now will have good 20,000Amp lightning protection. The 4 isolated RS-485 subnets internal to the cabinets are adequately protected from small induced noise spikes by the surge diodes included within the rdc485ir5 isolated repeaters.

8) **Proper Termination and Bias**: the original design didn't include any explicit line bias. Therefore the design robustness is improved since the rdc485ir5 isolated repeaters include proper pull-up and pull-down bias to "quiet" a floating RS-485 wire pair.

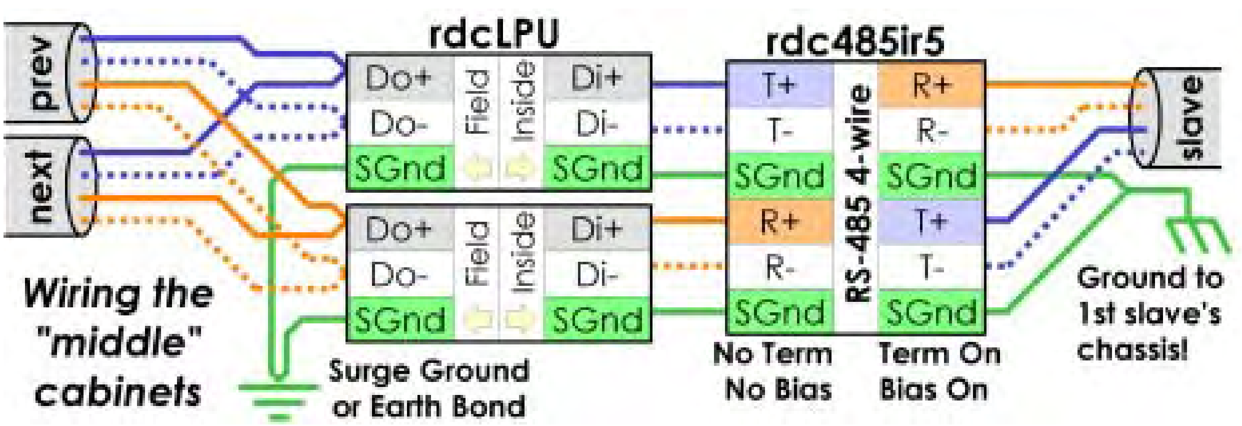
- **Detailed Wiring Diagrams**

The four added rdcLPU + rdc485ir5 should be wired in 2 different configurations: "end" & "mid" below. The DCS end of the main RS-485 need not change – although adding some line bias would be helpful.



- **Wiring the Three Middle ("Mid") Cabinets**

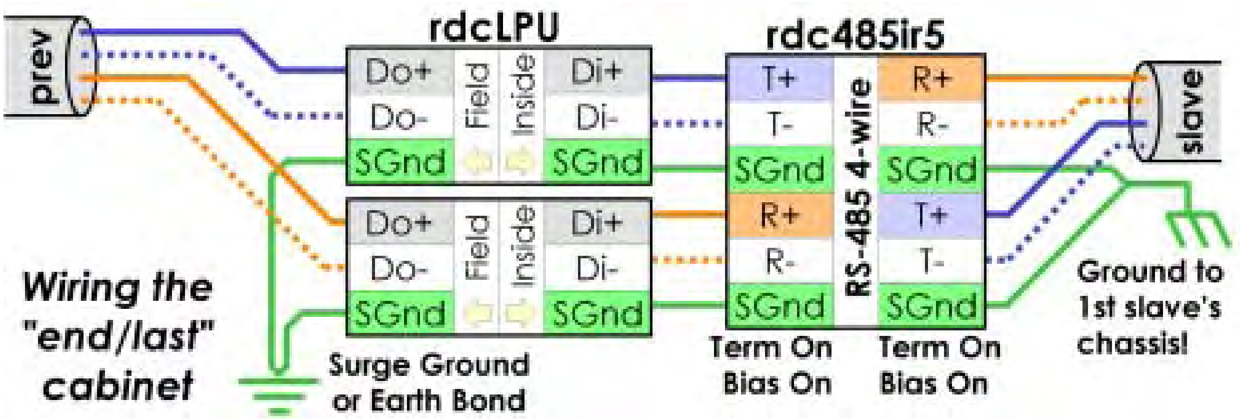
The field wires from the "previous" and "next" cabinets are joined at the rdcLPU to create a continuous RS-485 bus. The surge output of the rdcLPU must be run by 1.5mm wire as directly to the earth bond as possible. We recommend not treating the chassis as a surge earth "bus bar". The wiring between the rdcLPU and rdc485ir5 is direct and must include the signal ground wires to properly reference the field side of the floating isolator to earth bond. The rdc485ir5's internal jumpers on the field side are removed to disable the bias and terminating resisters.



The cabinet side of the rdc485ir5 must have the jumpers installed (factory default) to enable the bias and terminating resisters. The rdc485ir5 will not work if the bias resisters are NOT enabled here. Since the rdc485ir5 has floating grounds, the signal ground of the isolator must be connected to something. Since in this installation all of the RS-485 slaves reference their signal ground to the chassis, you must run a ground wire from the rdc485ir5's signal ground to the chassis ground of the first RS-485 slave. If the slaves have a physical signal ground terminal, that also can be used.

• Wiring the Last ("End") Cabinet

The field wires from the "previous" cabinets connect to the rdcLPU. The surge output of the rdcLPU must be run by 1.5mm wire as directly to the earth bond as possible. We recommend not treating the chassis as a surge earth "bus bar". The wiring between the rdcLPU and rdc485ir5 is direct and must include the signal ground wires to properly reference the field side of the floating isolator to earth bond. The rdc485ir5's internal jumpers on the field side are installed to enable the bias and terminating resisters. Note that the rdc485ir5 will not work properly if the bias resisters are NOT enabled on this side.



The cabinet side of the rdc485ir5 must have the jumpers installed (factory default) to enable the bias and terminating resisters. Note the rdc485ir5 will not work if the bias resisters are NOT enabled on this side. Since the rdc485ir5 has floating grounds, the signal ground on this side of the isolator must be connected to something. Since in this installation, all of the RS-485 slaves reference their signal ground to the chassis, you must run a ground wire from the rdc485ir5's signal ground to the chassis ground of the first RS-485 slave. If the slaves have a physical signal ground terminal, that also can be used.

• For More Information

Robust DataComm can truly make your data flow like water - safely, sanely, and silently.

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