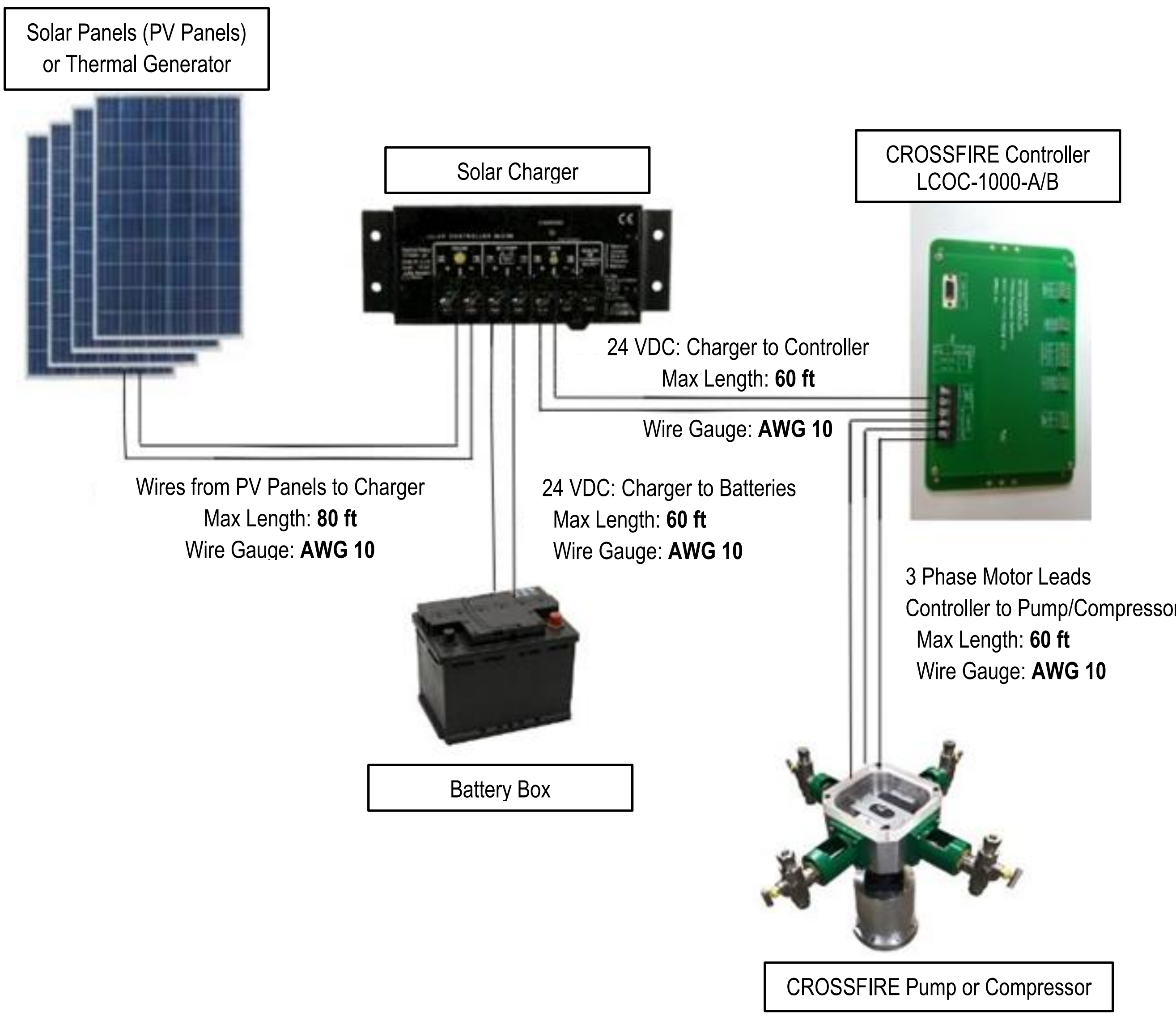
Critical Installation Requirements and Common Errors

LCO Technologies' smart controller (LCOC-1000-A and LCOC-1000-B) can be used for both the *CROSSFIRE* Chemical Injection Pump and Instrument Air Compressor. In order to guarantee a successful installation, critical requirements such as wire length, wire size, cable resistance, and equipment location must be followed. If the installation does not adhere to these critical guidelines, the *CROSSFIRE* may not work as anticipated, may have a higher than average current consumption, and may not function at all. Improper wiring may lead to damage of the controller and may result in repair charges. Please contact LCO directly for any additional assistance to ensure successful installation.

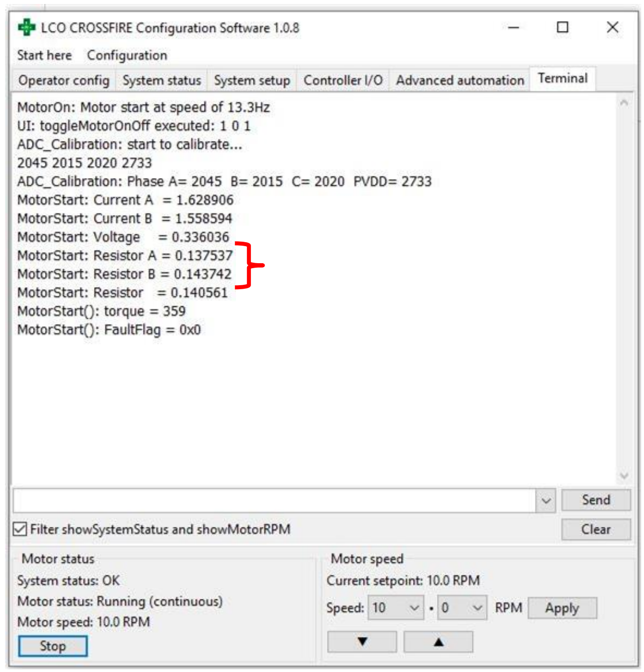
Conductor Wire Length, Wire Gauge and Installation Requirements:



It is critical to reduce power loss on cable runs so there is enough voltage and current to power the motor. In addition, it is important to recognize that the LCO controller is a Variable Frequency Driver (VFD) which can be sensitive to the transient voltage spikes induced by the inductance of long cable runs. Components of the power system must be properly placed at site to **minimize** the length of cables throughout the entire system in order to minimize cable inductance and resistance.

Note: The maximum wire lengths in the above diagram are based on the AWG guide for wire resistance (See Attachment 1). *If the cables used do not conform to the AWG guidelines, the maximum length must be reduced proportionally relative to the deviation from the AWG guide. For example, if the cable has three times the resistance stated in the AWG guide, the maximum wire length is reduced to 20 ft, AWG 10. In addition to wire size, quality and length, all control conductor wires must be stranded copper conductors (AWG 20-24) terminated with proper end ferrule conductors.*

Long cable runs and poor electrical contacts at terminals will increase the overall resistance and will affect performance. These resistance valves can be confirmed in the LCO Technologies configuration software under the "*terminal*" tab when the motor is started; refer to the figure to the right which shows "*Resistor A*" and "*Resistor B*". Ensure neither resistance values exceed 0.3 Ohm. If the maximum resistance is greater than 0.3 Ohm, check all power wire connections are tightened down sufficiently, re-arrange locations of equipment or shorten cable length until Resistor A and B both read 0.3 Ohm or less.



Note: If the specified wire lengths are not achievable on your well site, please consult LCO Technologies directly for additional options available

Open Circuit Voltage: Requirement for Voltage Suppression in Installations

When installing a CROSSFIRE product, open circuit voltage may be a condition that requires special installation instructions and parts depending on the site and power conditions. When connected to solar power, the open circuit voltage generated from a PV panel is significantly higher than the charging voltage of the batteries. As a result, a transient voltage spike will be generated at the instance the charger turns on to route current to the batteries and the CROSSFIRE controller. Such voltage spike can damage the CROSSFIRE controller if it exceeds 40 volts at the controller's terminals even though the duration is generally very short (<1ms) as the transient voltage spike propagates from the PV panel to the charger, and through to the CROSSFIRE controller. In order to protect the CROSSFIRE controller, this voltage spike must be absorbed by the batteries which can be controlled by the ratio of cable length. The magnitude of a spike at the controller is proportional to ratio of the cable length from PV panels to charger, and charger to batteries.

Example:

If three PV panels are installed in series and each has open circuit voltage of 22V then the total open circuit voltage is 66V (22V X 3). The charging voltage of the batteries is 28V. Therefore, the transient voltage spike at PV panels when the charger turns on the switch is 38V.

$$38V_{spike}+28V_{battery} = 66V_{OC}.$$

The transient voltage spike will decrease proportionally as it propagates toward the controller. Therefore, the spike must be less than 12V at the controller terminals in order not to exceed 40V ($12V_{spike}+28V_{battery}$). A quick calculation below shows that the length of the cable run from the charger to the batteries (L2) must be less than 1/2 of the cable length from PV panels to the charger (L1).

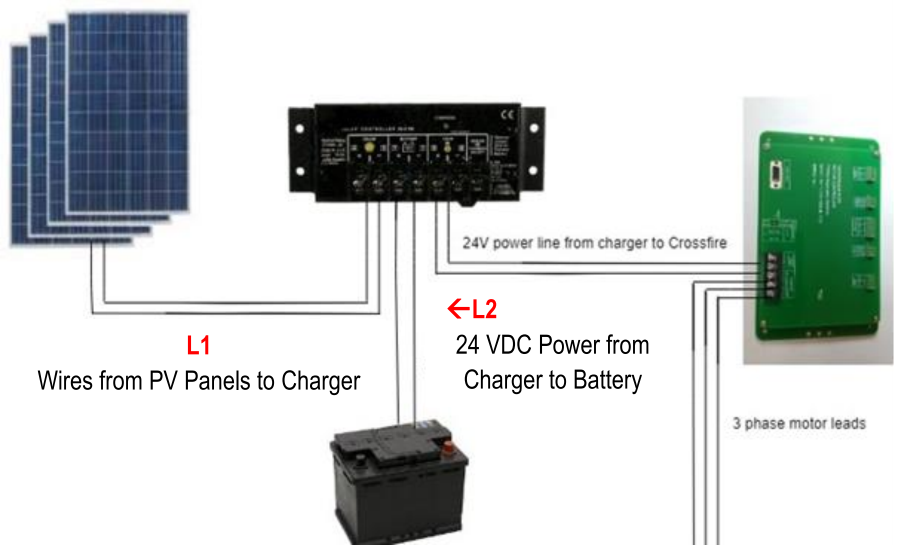
Recommendation: Have the length of L2 as short as possible.

<u>Formula:</u>

L1 = Cable length from PV panels to charger
L2 = Cable length from charger to batteries
Voc = open circuit voltage at PV panels
Vc = maximum voltage that Crossfire Controller can withstand = 40V
Vb = battery charging voltage = 28V

Maximum L2 = (Vc – Vb) / (Voc – Vc) * L1
= (40 – 28) / (Voc – 40) * L1

Maximum Ratio: L2 / L1 = (40 – 28) / (Voc – 40)



If the installation adheres to these standards and cable lengths, the risk of transient voltage spikes can be considered mitigated and no surge protection devices are required. However, if the installation is nearing the maximum cable length calculated, the calculation for the specific site not completed, or the resistance of the cables is anything greater than the published AWG standard, a surge protector device must be installed.

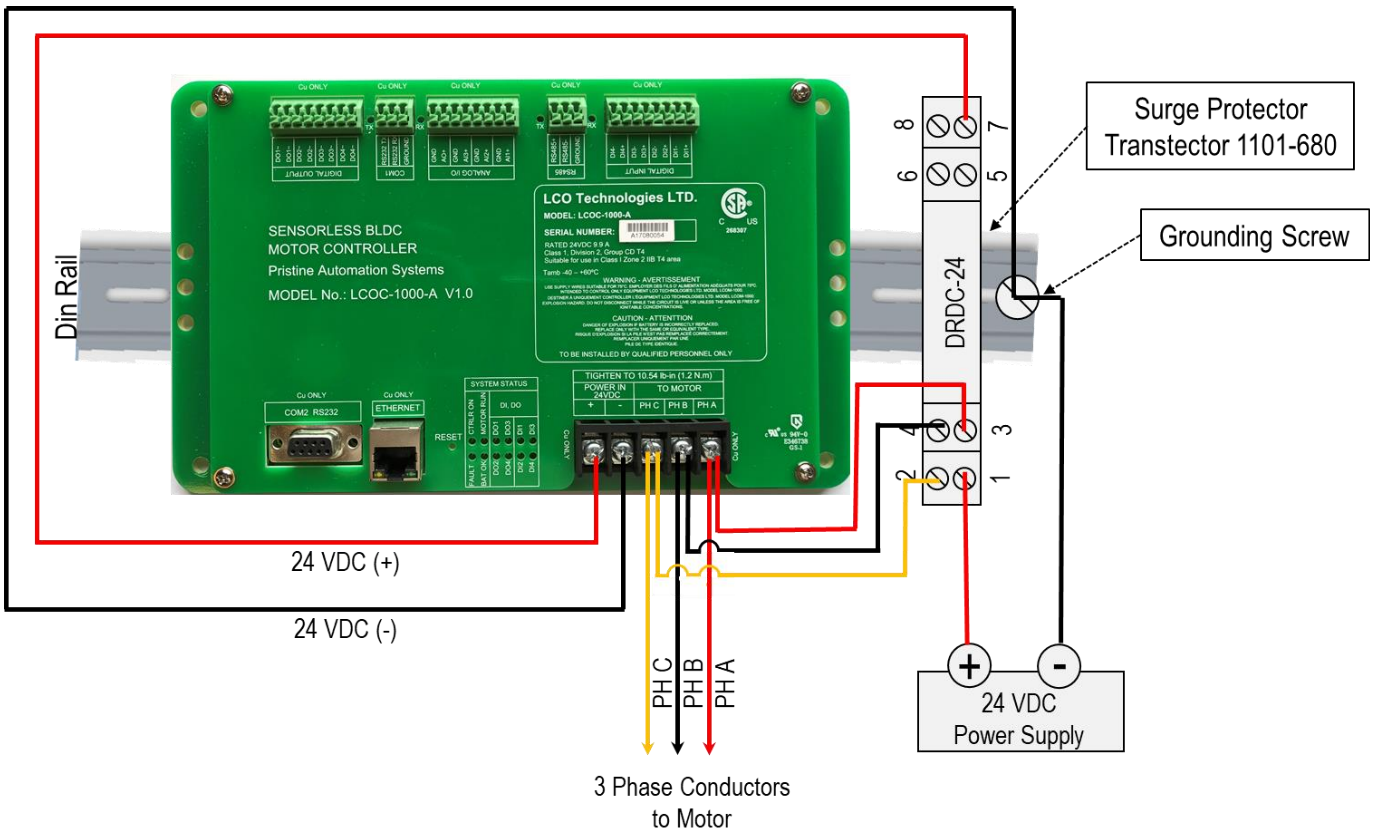
Recommended Surge Protector Devices:

- Non-hazardous area: Low cost bi-directional surge suppression diode (TVS 5KP33CA)
  - Install a bi-directional diode across the 24 VDC line on the CROSSFIRE controller
  - Ensure the diode is installed after a 10A fuse (one lead of the TVS diode should be connected to the low side of the fuse terminal, while the other lead is connected to ground).

  - Please note that the recommended TVS diode is highly effective but is not CSA certified for hazardous locations
- Class 1 Div. 2 hazardous area: Transtector 1101-680 surge protector
  - Install the surge protector as per the wiring diagram listed on page 4
  - Please note that the recommended Transtector surge protector is din rail mountable and CSA certified for installations within a class 1 div 2 hazardous area

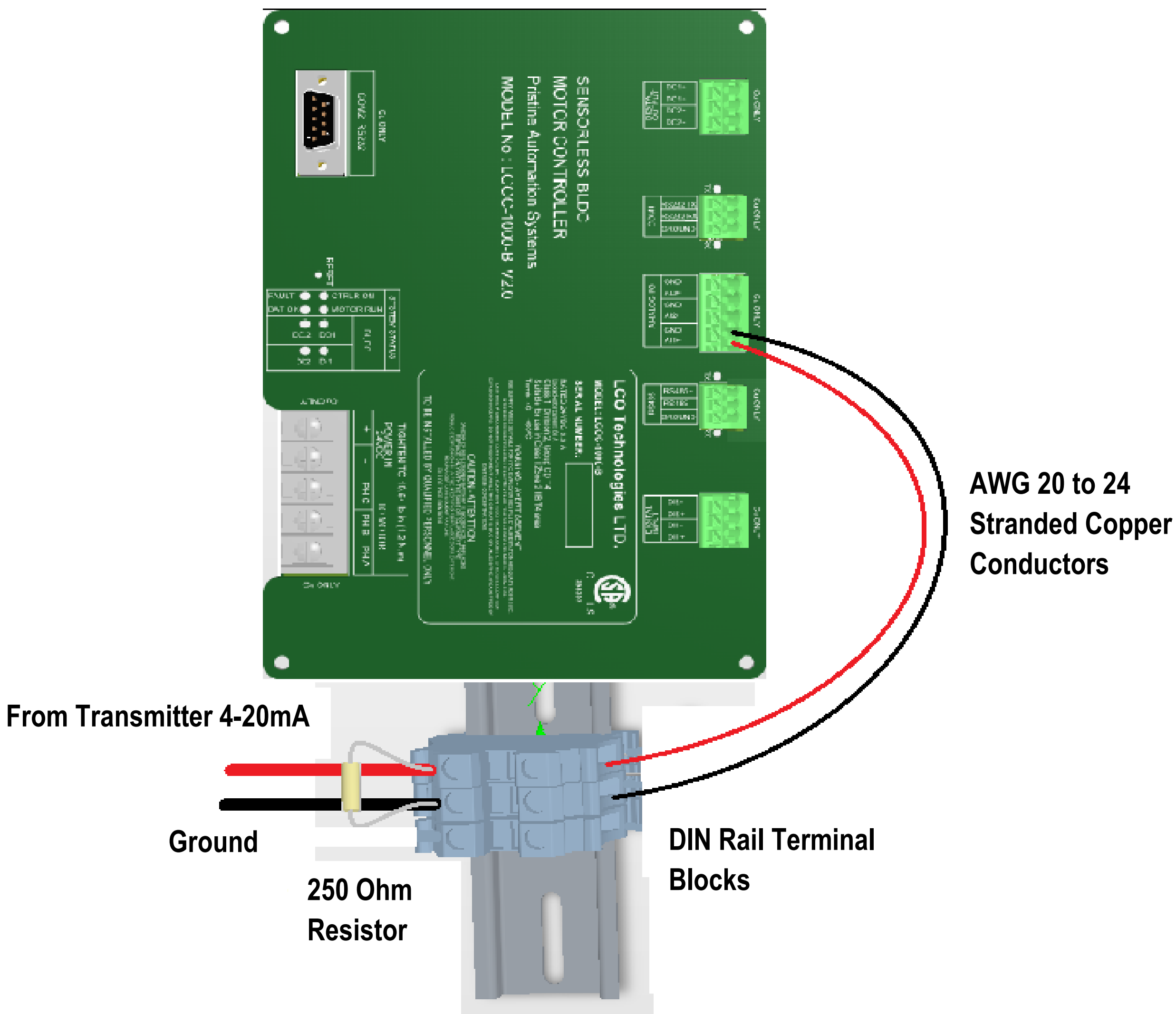
Transtector 1101-680 Surge Protector

Wiring Diagram for Installation of Transtector Surge Protector (Model # 1101-680)

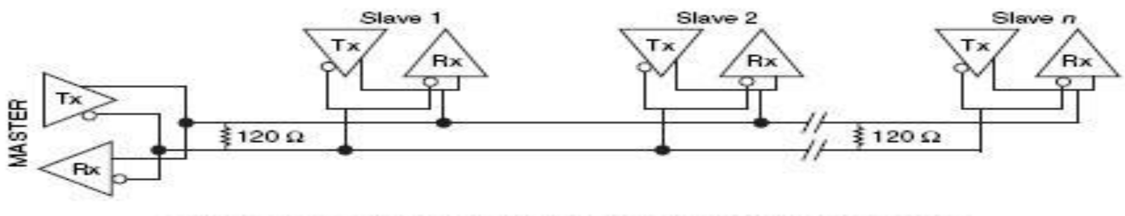


Resistor Wiring Requirements:

When installing a CROSSFIRE instrument air compressor, a 250 Ohm resistor for the 4-20mA signal loop for reverse proportional pressure control is required. The resistor must be installed on the terminal blocks inside the control or instrument panel. It cannot be installed directly on the CROSSFIRE Controller AI1 terminals as these terminals are to small to accommodate both the conductor wires and resistors. Installing the resistor directly on the CROSSFIRE controller may lead to damage of the terminal and may void warranty or result in repair charges. See diagram below:

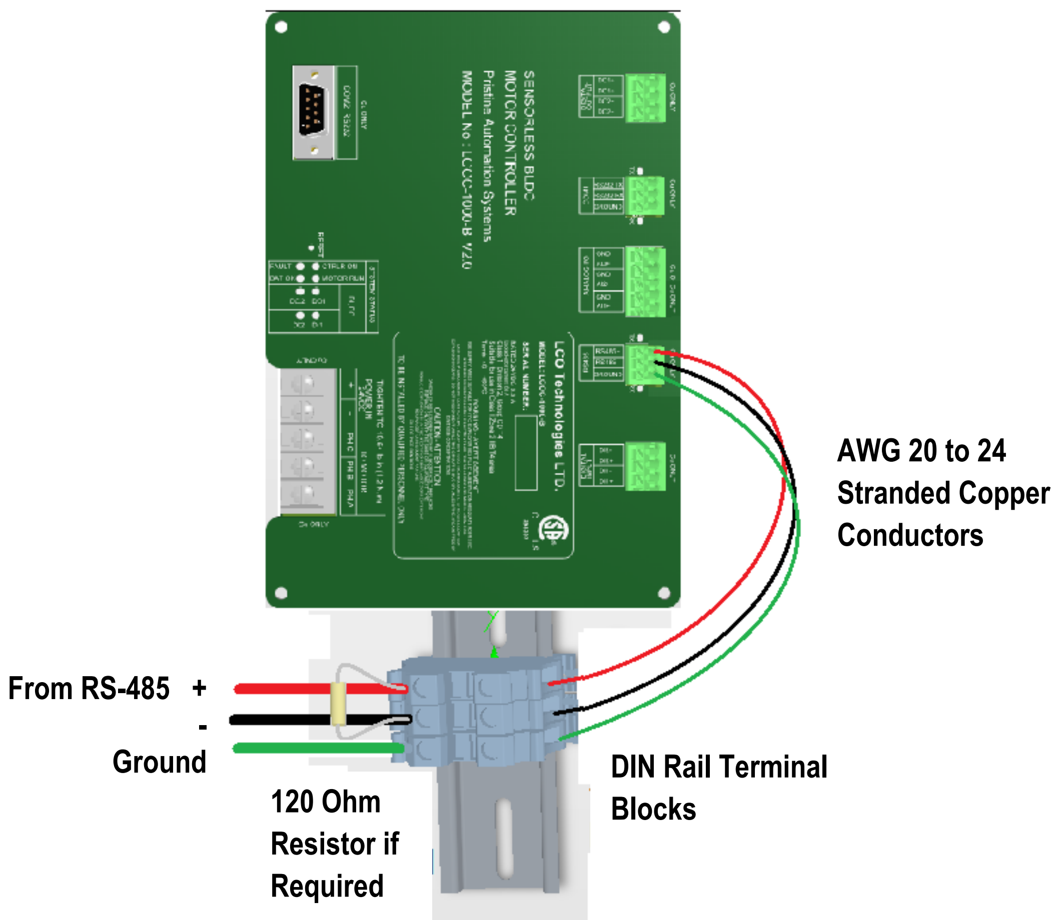


In addition, for both the CROSSFIRE chemical injection pump and instrument air compressor, a RS-485 bus can used for Modbus communication, which is a multidrop network allowing a single master to poll multiple slaves. Both ends of RS-485 trunk must be terminated with a 120 Ohm resistor. The slaves in the middle do not require termination.



2-Wire Multidrop Network Using Terminating Resistors

If the CROSSFIRE controller is installed at the end of a RS-485 bus, please refer to the below diagram for wiring instructions. Please note that the GROUND terminal in the RS-485 port is a signal ground reference. It is only to be connected to the RTU's RS-485 port GND, not to be connected to the chassis/safety ground at all. Please note that this signal GROUND connection may not be necessary if proper termination as described is completed.



Attachment 1: AWG Guide

AWG gauge	Conductor Diameter Inches	Conductor Diameter mm	Conductor cross section in mm^2	Ohms per 1000 ft.	Ohms per km	Maximum amps for chassis wiring	Maximum amps for power transmission	Maximum frequency for 100% skin depth for solid conductor copper
0000	0.46	11.684	107	0.049	0.16072	380	302	125 Hz
000	0.4096	10.40384	84.9	0.0618	0.202704	328	239	160 Hz
00	0.3648	9.26592	67.4	0.0779	0.255512	283	190	200 Hz
0	0.3249	8.25246	53.5	0.0983	0.322424	245	150	250 Hz
1	0.2893	7.34822	42.4	0.1239	0.406392	211	119	325 Hz
2	0.2576	6.54304	33.6	0.1563	0.512664	181	94	410 Hz
3	0.2294	5.82676	26.7	0.197	0.64616	158	75	500 Hz
4	0.2043	5.18922	21.1	0.2485	0.81508	135	60	650 Hz
5	0.1819	4.62026	16.8	0.3133	1.027624	118	47	810 Hz
6	0.162	4.1148	13.3	0.3951	1.295928	101	37	1100 Hz
7	0.1443	3.66522	10.6	0.4982	1.634096	89	30	1300 Hz
8	0.1285	3.2639	8.37	0.6282	2.060496	73	24	1650 Hz
9	0.1144	2.90576	6.63	0.7921	2.598088	64	19	2050 Hz
10	0.1019	2.58826	5.26	0.9989	3.276392	55	15	2600 Hz
11	0.0907	2.30378	4.17	1.26	4.1328	47	12	3200 Hz
12	0.0808	2.05232	3.31	1.588	5.20864	41	9.3	4150 Hz
13	0.072	1.8288	2.63	2.003	6.56984	35	7.4	5300 Hz
14	0.0641	1.62814	2.08	2.525	8.282	32	5.9	6700 Hz
15	0.0571	1.45034	1.65	3.184	10.44352	28	4.7	8250 Hz
16	0.0508	1.29032	1.31	4.016	13.17248	22	3.7	11 k Hz
17	0.0453	1.15062	1.04	5.064	16.60992	19	2.9	13 k Hz
18	0.0403	1.02362	0.823	6.385	20.9428	16	2.3	17 kHz
19	0.0359	0.91186	0.653	8.051	26.40728	14	1.8	21 kHz
20	0.032	0.8128	0.519	10.15	33.292	11	1.5	27 kHz
21	0.0285	0.7239	0.412	12.8	41.984	9	1.2	33 kHz
22	0.0253	0.64516	0.327	16.14	52.9392	7	0.92	42 kHz
23	0.0226	0.57404	0.259	20.36	66.7808	4.7	0.729	53 kHz
24	0.0201	0.51054	0.205	25.67	84.1976	3.5	0.577	68 kHz
25	0.0179	0.45466	0.162	32.37	106.1736	2.7	0.457	85 kHz
26	0.0159	0.40386	0.128	40.81	133.8568	2.2	0.361	107 kHz
27	0.0142	0.36068	0.102	51.47	168.8216	1.7	0.288	130 kHz
28	0.0126	0.32004	0.080	64.9	212.872	1.4	0.226	170 kHz
29	0.0113	0.28702	0.0647	81.83	268.4024	1.2	0.182	210 kHz
30	0.01	0.254	0.0507	103.2	338.496	0.86	0.142	270 kHz
31	0.0089	0.22606	0.0401	130.1	426.728	0.7	0.113	340 kHz
32	0.008	0.2032	0.0324	164.1	538.248	0.53	0.091	430 kHz
Metric 2.0	0.00787	0.200	0.0314	169.39	555.61	0.51	0.088	440 kHz
33	0.0071	0.18034	0.0255	206.9	678.632	0.43	0.072	540 kHz
Metric 1.8	0.00709	0.180	0.0254	207.5	680.55	0.43	0.072	540 kHz
34	0.0063	0.16002	0.0201	260.9	855.752	0.33	0.056	690 kHz
Metric 1.6	0.0063	0.16002	0.0201	260.9	855.752	0.33	0.056	690 kHz
35	0.0056	0.14224	0.0159	329	1079.12	0.27	0.044	870 kHz
Metric 1.4	.00551	.140	0.0154	339	1114	0.26	0.043	900 kHz
36	0.005	0.127	0.0127	414.8	1360	0.21	0.035	1100 kHz
Metric 1.25	.00492	0.125	0.0123	428.2	1404	0.20	0.034	1150 kHz
37	0.0045	0.1143	0.0103	523.1	1715	0.17	0.0289	1350 kHz
Metric 1.12	.00441	0.112	0.00985	533.8	1750	0.163	0.0277	1400 kHz
38	0.004	0.1016	0.00811	659.6	2163	0.13	0.0228	1750 kHz
Metric 1	.00394	0.1000	0.00785	670.2	2198	0.126	0.0225	1750 kHz
39	0.0035	0.0889	0.00621	831.8	2728	0.11	0.0175	2250 kHz
40	0.0031	0.07874	0.00487	1049	3440	0.09	0.0137	2900 kHz