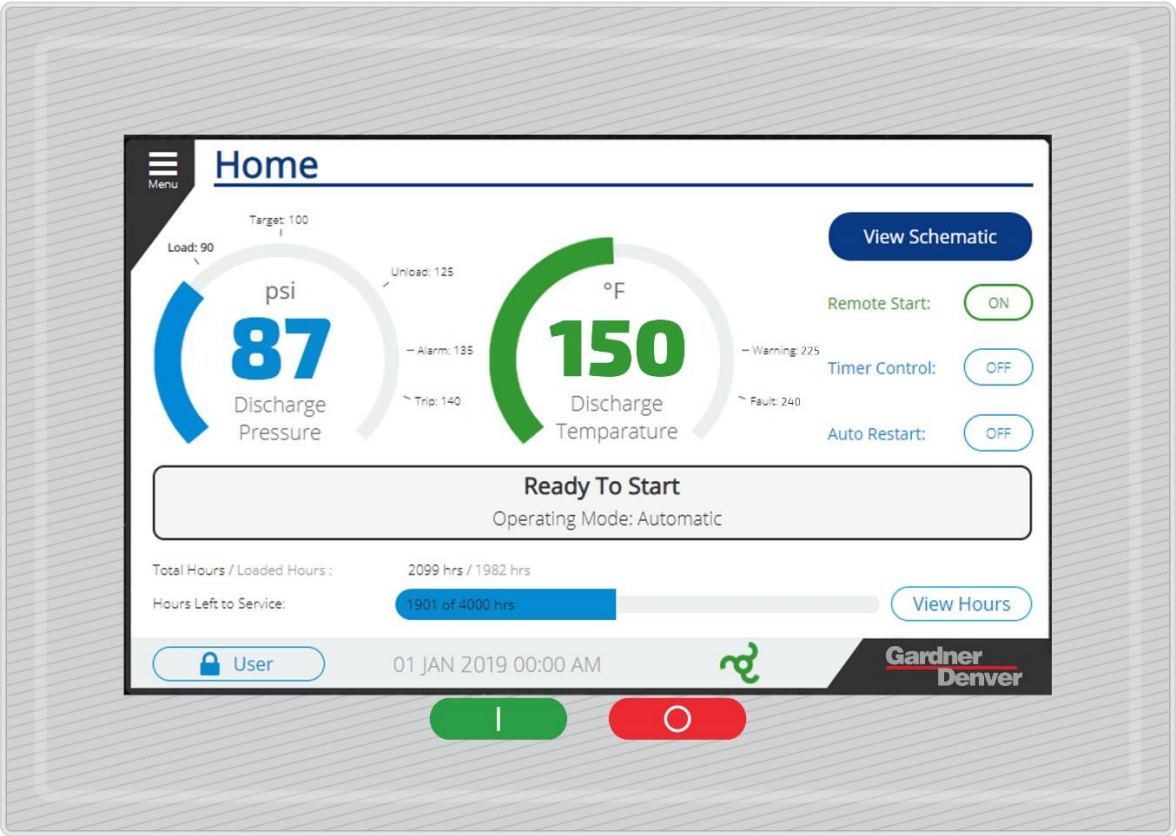
Gardner Denver

13-17-625
Version: 00
July 15, 2020

Governor™ Controller



MULTI-MACHINE SEQUENCING MANUAL

7” | 4.3” Governor Compressor Applications

WARNING – PROHIBITION – MANDATORY LABEL INFORMATION

Gardner Denver compressors are the result of advanced engineering and skilled manufacturing. To be assured of receiving maximum service from this machine, the owner must exercise care in its operation and maintenance. This book is written to give the operator and maintenance department essential information for day-to-day operation, maintenance and adjustment. Careful adherence to these instructions will result in economical operation and minimum downtime.

Boxed text formats are used, within this manual, to alert users of the following conditions:

Safety Labels are used, within this manual and affixed to the appropriate areas of the compressor package, to alert users of the following conditions:

⚠ DANGER

Indicates a hazard with a high level of risk, which if not avoided, <u>WILL</u> result in death or serious injury.

Equipment Starts Automatically

Health Hazard – Explosive Release of Pressure

Cutting of Finger or Hand Hazard – Rotating Impeller Blade

High Voltage – Hazard of Shock, Burn, or Death Present until Electrical Power is Removed

Cutting of Finger or Hand Hazard – Rotating Fan Blade

Entanglement of Fingers or Hand/Rotating Shaft

⚠WARNING

Indicates a hazard with a medium level of risk which, if not avoided, <u>COULD</u> result in death or serious injury.

Asphyxiation Hazard – Poisonous Fumes or Toxic Gases in Compressed Air

⚠CAUTION

Indicates a hazard with a low level of risk which, if not avoided, <u>MAY</u> result in a minor or moderate injury.

Burn Hazard – Hot surface

PROHIBITION/MANDATORY ACTION REQUIREMENTS

Do not Operate Compressor with Guard Removed

Lockout Electrical Equipment in De-Energized State

Do Not Lift Equipment with Hook – No Lift Point

Loud Noise Hazard – Wear Ear Protection

Handle Package at Forklift Points Only

Read the Operator's Manual Before Proceeding with Task

SAFETY PRECAUTIONS

The following text presents common safety issues of which the user should be aware. Though the list below includes unit and supporting equipment dangers present, the user must also be vigilant to other hazards introduced in an industrial environment, and ensure they have received the necessary safety training.

Failure to observe these notices will result in injury to or death of personnel.

- **Keep fingers and clothing away from rotating fan, drive coupling/belting, etc.**
- **Disconnect the compressor unit from its power source, lockout and tagout before working on the unit – this machine is automatically controlled and may start at any time.**
- **Do not loosen or remove the enclosure or belt covers, or break any connections, etc., in the compressor air system until the unit is shut down and the air pressure has been relieved.**
- **Electrical shock can and may be fatal.**
- **Perform all wiring in accordance with the National Electrical Code (NFPA-70) and any applicable local electrical codes. Wiring and electrical service must be performed only by qualified electricians.**
- **Open main disconnect switch, lockout and tagout and check for voltage before working on the control.**

Failure to observe these notices could result in damage to equipment.

- **Stop the unit if any repairs or adjustments on or around the compressor are required.**
- **Do not use the air discharge from this unit for breathing – not suitable for human consumption.**
- **An Excess Flow Valve should be on all compressed air supply hoses exceeding 1/2 inch inside diameter (OSHA Regulation, Section 1926.302).**
- **Do not exceed the rated maximum pressure values shown on the nameplate.**
- **Do not operate unit if safety devices are not operating properly. Check periodically. Never bypass safety devices.**

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1. General Information

Compressor sequencing refers to the intelligent control of system consisting of multiple compressors to provide a single compressed air supply. This is done to optimize energy efficiency, pressure control, and maintenance schedules of the system.

The Gardner Denver Governor™ controller is capable of communicating with several different generations of Gardner Denver controls to allow multi-machine sequencing of new and existing Gardner Denver equipment. Depending on the protocol selected, up to 4 or 8 machines may be sequenced on a single installation without the use of a master controller.

This manual describes the requirements, configuration / installation, and operation of compressors under sequencing control with the Gardner Denver Governor™ controller. Note: All Governor Controller screenshots in this manual are for the 7" screen, however the 4.3" screens and settings are very similar and are located in the same location in the menus.

The following requirements must be met to ensure proper operation of the system.

1.1 System Design

In order for the system to be sequenced reliably, all compressors must be connected to an air storage system with minimal pressure differential between machines and adequate storage for the system. The machines must also be selected to work in a coordinated manner based on the demand profile. If these requirements are not met, the system may not be able to adequately meet the customer's requirements.

A proper sequencing installation requires two or more Gardner Denver rotary air compressors with supported controllers, piped into a common air system, interconnected as described above. Connect the units directly to a common header and receiver, without any intervening dryers, filters, or other restrictions. There should be no check valves or other devices which isolate a member from the air system. During operation, be sure that any unit is taken out of the sequence mode before closing its service valve.

The receiver should also be sized to prevent excessive drops or rapid rises in pressures during the operation as described below. Note that "receiver" really applies to the entire storage volume of a physical receiver and the volume of the air distribution throughout the plant. Modulating systems work best when the receiver is at least one gallon for the rated CFM of a member compressor in the system (the largest if they differ). Note that when demand exceeds the capacity of the running unit(s), there will be a delay until the next unit starts and delivers additional air. The stored air serves the plant during this period. With a properly sized receiver, pressure changes on a receiver gauge should be very slow and gradual.

All standard practices common to sound air compressor installations such as proper sizing of piping, proper electrical supply and conductor sizing, and grounding are to be observed. It is recommended that the compressors are run in Automatic mode for at least one week to evaluate system performance before activating sequencing.

1.2 Hardware

All of the supported sequencing protocols use an RS485 serial network for communications. RS485 is an industrial communications network that is suitable for robust communications in industrial networks, but proper installation is still important to ensure reliability.

Gardner Denver provides kit number **317AUX6028** which includes all hardware required to add a machine to a new or existing sequencing network. This includes cable glands, cable, and components to add a system pressure sensor to the machine (utilized for the AirSmart protocol). If the Gardner Denver-supplied kit is not used, it is important that the communications cable is 3-wire

shielded cable suitable for industrial environments. The parts list for **317AUX6028** is shown in Table 1.

Table 1: 317AUX6028 Sequencing Kit

Part Number	Description	Quantity
24CA2865	FITTING-ELECTRICAL .125-.25 1/2"CONDUIT	2
64EB368	COUPLING-PIPE 1/4FPT 3/J-16 COUPLING	1
88H369	TRANSDUCER-PRESSURE 15BAR 4-20mA, 1/4NPT	1
64AC2	PLUG 1/4" NPT HEX SOCKET HEAD PRESSURE	1
97J93	CABLE,3 COND,FOIL/SHIELD W/ 22 AWG TWIST	100 ft
VP1033693	HARNESS-WIRING	1
24A77	LOCKNUT-CONDUIT	2
24A383	O-RING SEALING 1/2"	2

1.3 Software

It is recommended that all machines in the sequenced network have the most up-to-date software available installed. The most up to date software ensures that the machines have all of the latest features and operate as intended. Check GD Inside for any available software updates.

1.4 System Connections

The system connections for sequencing configurations are shown below. The air and pressure connections for the system is shown in *Figure 1*. Note that the system pressure feedback is only required for AirSmart protocols. The “AirSmart Controller” in the figure would be replaced by either Delcos or ES+ when configuring those systems.

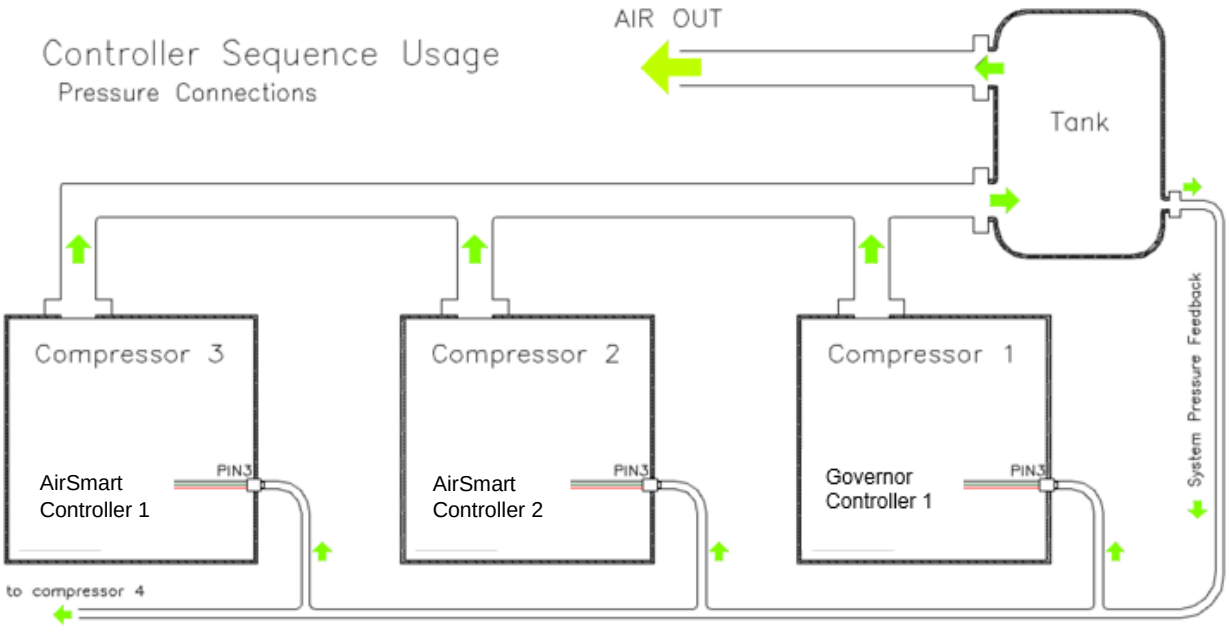

Figure 1: Sequencing Pressure Connections

Figure 2 shows an example of a sequenced set of machines where there is a single master and three slave machines, or a group of 4 sequenced peer machines.

- For the AirSmart and ES+ protocols, any machine in the sequenced network can automatically take on the role of master or slave depending on the system configuration and the machines running.
- When using the Delcos protocol, the master machine is dedicated and selected through the controller configuration. For any Delcos network using a Governor controller, a machine with a Governor controller must be configured as the master of the network.

Figure 2: Example - Master with three Slave Machines

Figure 3 shows example RS485 wiring connections from the master machine to each of the slave machines in the sequenced system of machines. The communications interface must form a bus structure so that all compressors are connected in series.

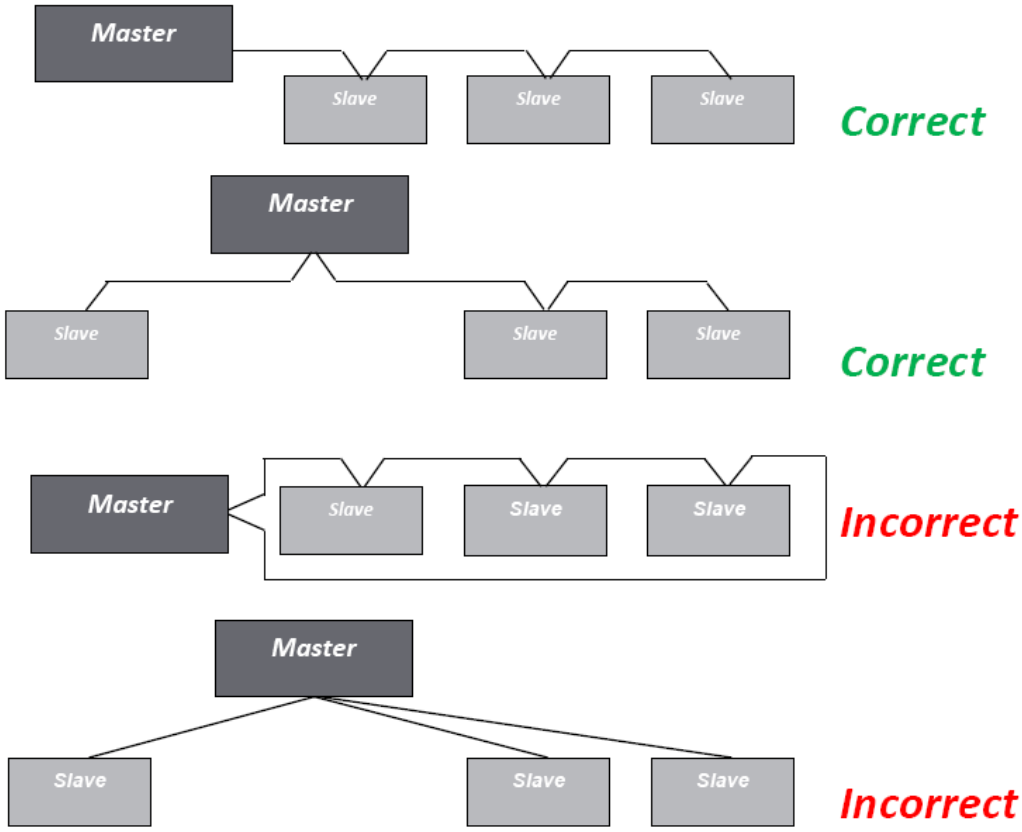

Figure 3: Example RS485 configurations of the Master/Slave controls for communications

2. Supported Protocols

The Governor™ controller will communicate with several different Gardner Denver sequencing protocols. For new installations, any mode may be used and selected based on the features of the installation. This section provides some basic information on each protocol to help you determine the best option for your system. Once you have selected the best protocol for your application, refer to the detailed instructions in the following sections specific to that protocol.

2.1 AirSmart Protocol

The AirSmart protocol is the native protocol for fixed and variable speed compressors using the AirSmart or AirSmart G2 controller. If you are connecting to other Gardner Denver compressors with these controllers, the AirSmart protocol should be used to allow for direct and optimal sequencing control. The AirSmart protocol is uniquely designed to handle sequencing and load sharing of variable speed compressors or a mix of up to 8 variable speed and fixed speed machines. It also features the ability to use a dedicated system pressure input to sample a true network delivery pressure.

The system will automatically determine the master of the network based on machine size and total hours. In addition, all variable speed machines will be run at the same load percentage based on the master's command to optimize system pressure and equalize load across all running units. If the set maximum load percentage for the network is met and more machines are required to meet demand, machines will be started in a controlled manner before allowing the system to run all machines at 100% capacity. Likewise, if all running machines are operating at the set minimum

percent load for the network and pressure exceeds the unload pressure setting, machines will be removed from operation, preventing the entire network from running at a low capacity when not required.

2.3 Delcos Protocol

The Delcos protocol is the native protocol for Gardner Denver machines using the GD Pilot, GD Pilot TS, GD Pilot XTC, Delcos Pro, Delcos XL, and Delcos XXL controllers. If you are connecting to other Gardner Denver compressors with one of these controllers, this is the protocol that should be used. It is also the protocol to select if you are using a Gardner Denver Connect 12™ system controller.

The Delcos protocol can sequence up to 4 compressors. One of the compressors must be configured as the master, with up to 3 slaves connected, as shown above in *Figure 2.*

While using Delcos protocol, all the slave machines run off the master machine's delivery pressure sensor. The master machine can be either fixed speed or variable speed, but all slave machines must be the same type for the system to function properly.

2.4 ES+ Protocol

The ES+ protocol is the native protocol for Gardner Denver machines using the Auto Sentry ES+ Controllers. Only fixed speed machines may be sequenced using the ES+ protocol.

The ES+ protocol was designed to optimize systems of machines with turn valve and inlet valve modulation so that air requirements are met and machines are not run when they are not required. In ES+ mode, the system will automatically rotate the lead of the system, and will vary the amount of modulation across the machines in the system to save energy.

The ES+ protocol is the best choice if you are installing into a system of existing machines with ES+ controllers. The protocol will function most efficiently if all machines in the network are relatively similar in flow capacity.

3. Sequencing Using the AirSmart™ Protocol

This section describes how to connect and configure machines using the AirSmart™ protocol.

3.1 Wiring Connections

Example machine wiring connections for the AirSmart sequencing protocol are detailed below. A System Pressure feedback input is required for AirSmart sequencing. However, if desired, the Delivery Pressure of the compressor may also be configured for sequencing in some cases and is explained in more detail below this section. The pressure transducer wiring to the Governor controller IO Module can be found in Figure 4 using the cable provided in the sequencing kit. The compressor network may be comprised of any combination of Governor, AirSmart, and AirSmart G2 controlled machines, as well as ES+ machines equipped with a PCM module.

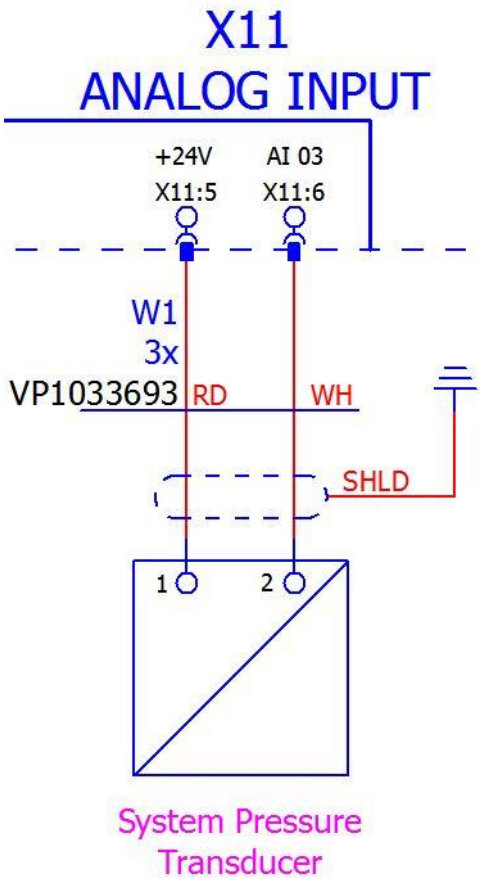

Figure 4: System Pressure Transducer Wiring on IO Module using cable VP1033693

Daisy chain the RS485 connections from the master machine to the first slave machine then second slave machine, etc. for each machine in the sequenced group. The AirSmart RS485 connections are located on the IO Module at X02 in the control cabinet. The wiring diagram is shown in Figure 5. RS485-2 at X03 on the IO module can also be used if present on the machine. Setup and configuration for RS485-2 is identical to RS485-1.

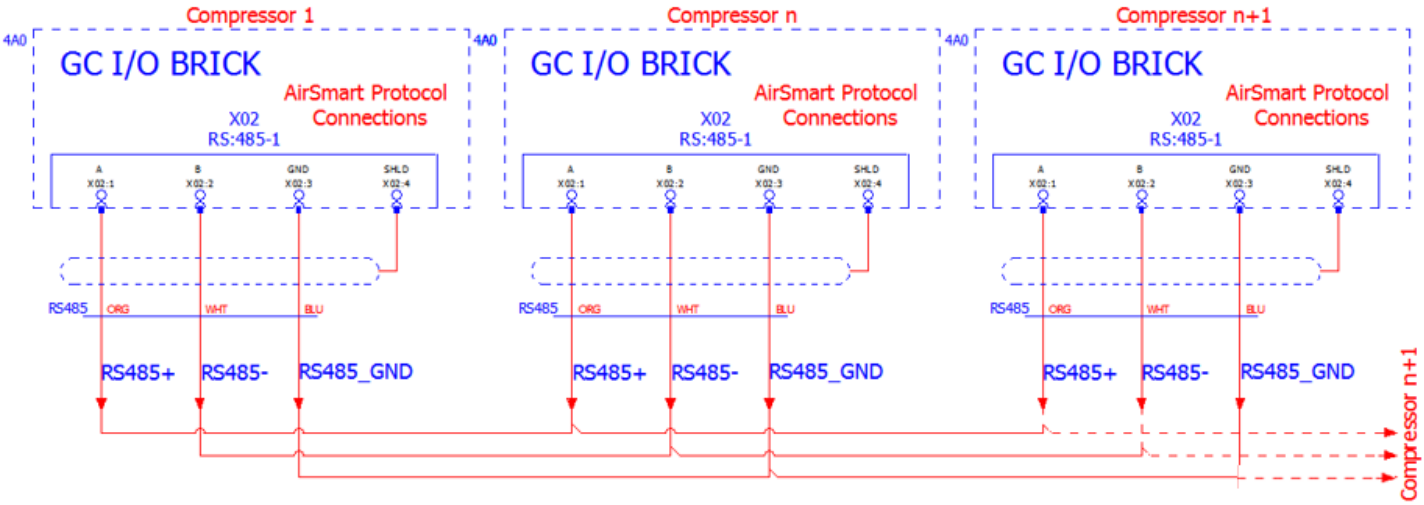

Figure 5: AirSmart RS485 Communication Wiring Schematic

Figure 6 is the hardware Interface for the RS485 Connections on the IO Module shown in the wiring diagram in Figure 5. Make sure that the machines at the end of the sequencing network have the RS485 terminating resistor DIP switch in the 'ON' position. The location of the terminating resistor selection for X02 is highlighted below in Figure 6.

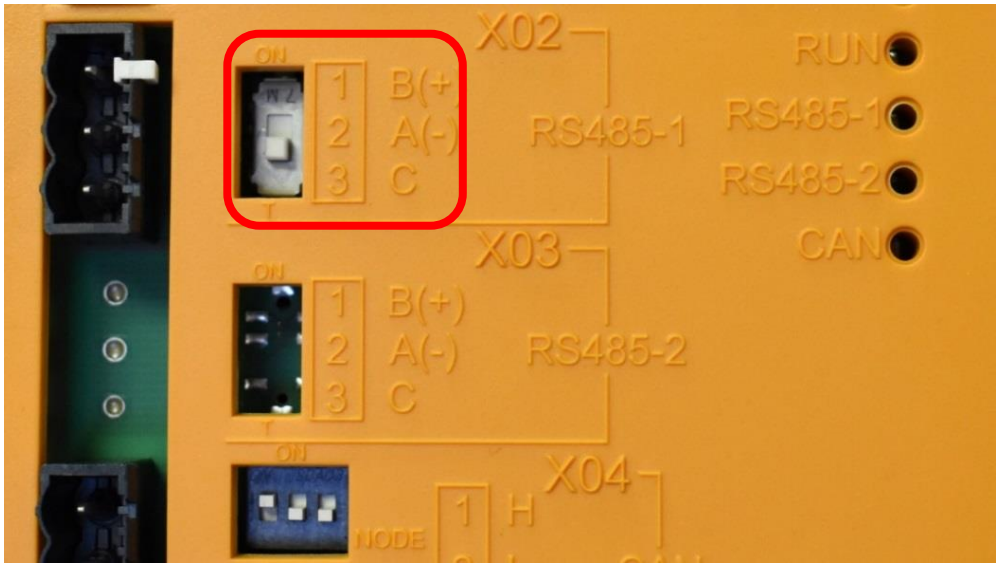

Figure 6: IO Module DIP Switch Settings at RS485-1 Port

Figure 7 shows the RJ-45 adapter (PN: 24CA7402) used on existing AirSmart G2 control systems which use an RJ45 connector for the sequencing network. This part is included in the AirSmart G2 sequencing kit, and should be utilized if connecting to an existing network of AirSmart G2-controlled machines. Using the cable supplied in the sequencing kit, the terminations on the connector are as follows: GND or C on terminal 8, RS485 + on terminal 2, and RS485 - on terminal 1. With the RS-45 pins facing upwards as shown below, the topmost terminal is referred to as terminal 1.

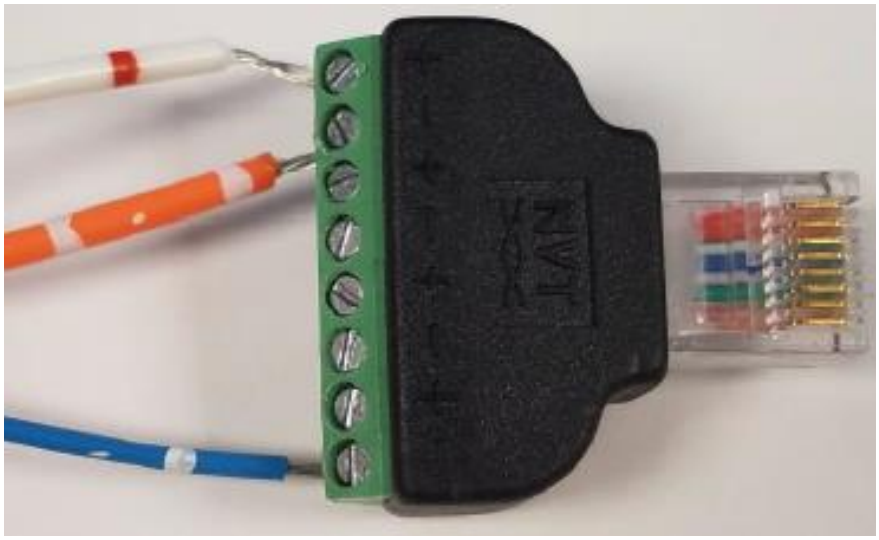

Figure 7: Blue is RS485 GND, Orange is RS485+, White is RS485-

Figure 8 shows the serial connection on the communications module on AirSmart machines using the cable supplied in the sequencing kit. The communications module may be used on machines in the field using AirSmart control systems. The RS485 serial port for sequencing is located at P19.

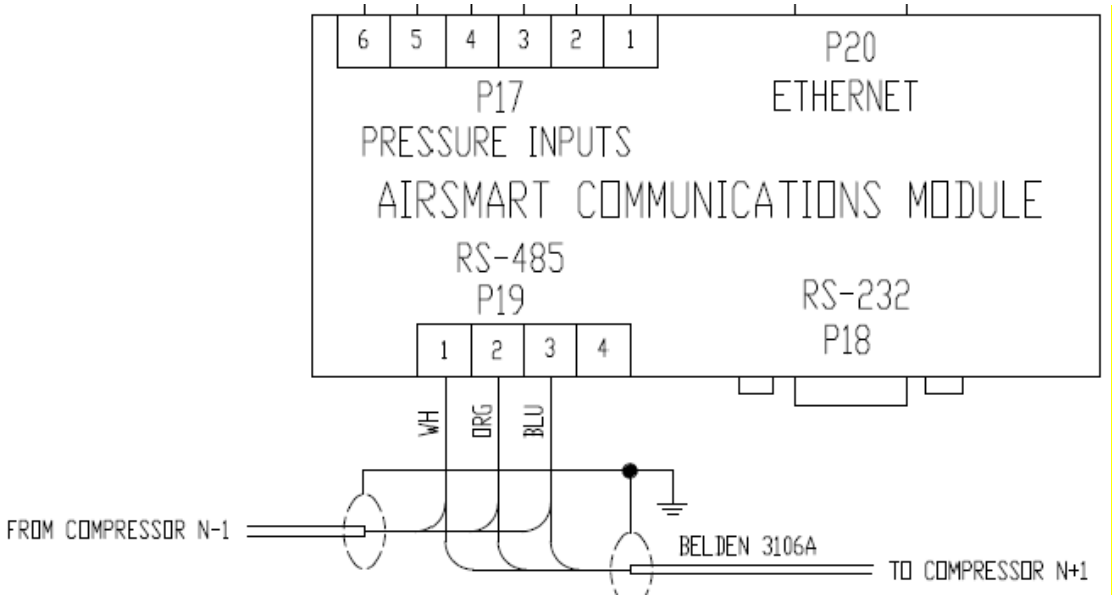

Figure 8: Blue is RS485 GND, Orange is RS485+, White is RS485-

3.2 Communication Configuration

In order to set up communication between the machines, the RS485 communications will need to be configured on the controller. AirSmart sequencing requires a baud rate of 19200, which will be set automatically after selecting the sequence mode.

Navigate to the communication settings by selecting Menu, Settings, Configuration, and then Communication, shown in Figure 9. Select the RS485-1 tab then change the mode to *Sequence – AirSmart.* Machines which have RS485-2 at X03 populated will show an additional tab called

"*RS485-2*" in the menu with the same settings available. Use the port that corresponds to the physical location of the wiring connections on the machine.

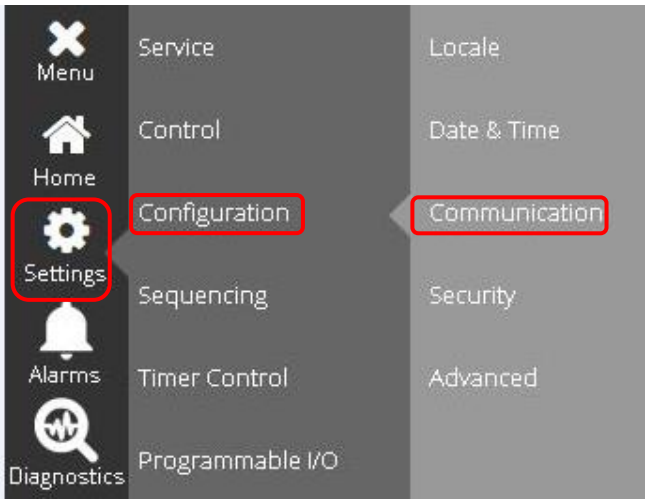

Figure 9: Menu navigation to communications screen

Please note that the controller may prompt the user to reboot following the mode change of the communication parameters. Select OK and allow the controller to reboot before continuing with the additional settings.

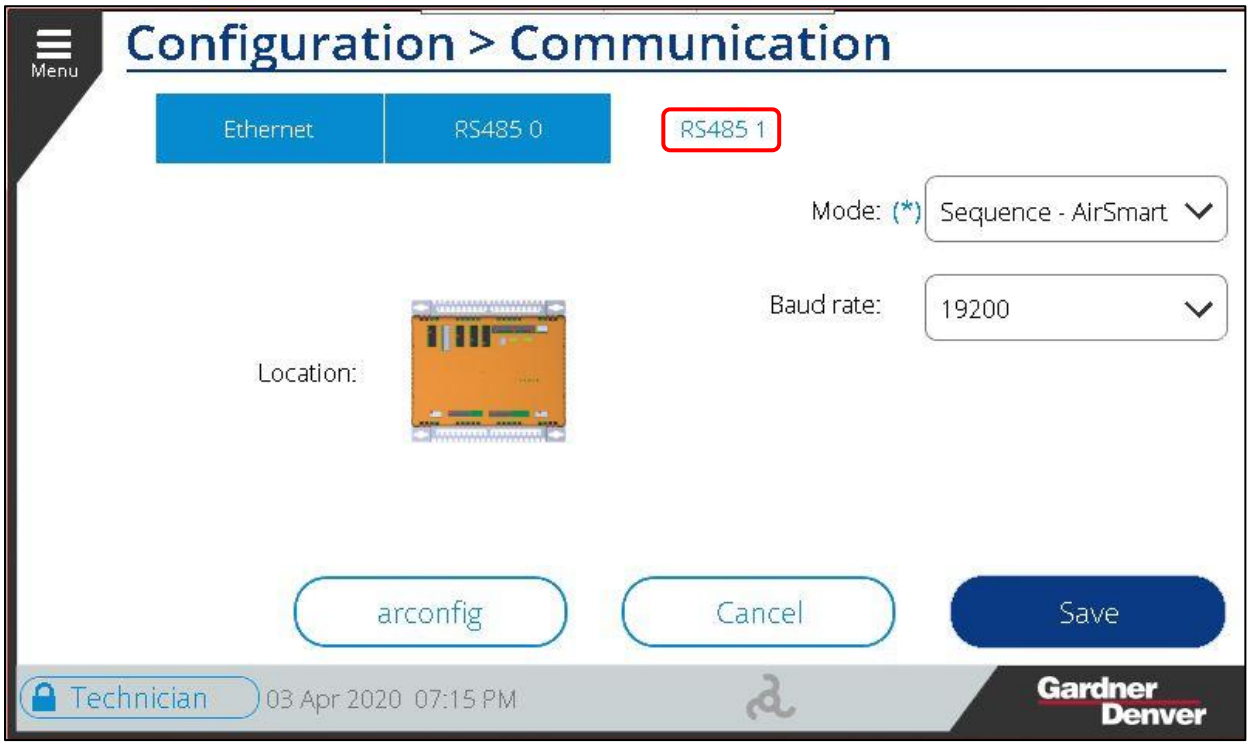

Figure 10: AirSmart Communications Configuration Screen

3.3 Operating Mode Setting

Next, the operating mode for machine control needs to be configured. Navigate to the control settings menu following Figure 11 by selecting Menu, Settings, and then Control. Change the operating mode to *Sequencing*, shown in Figure 12.

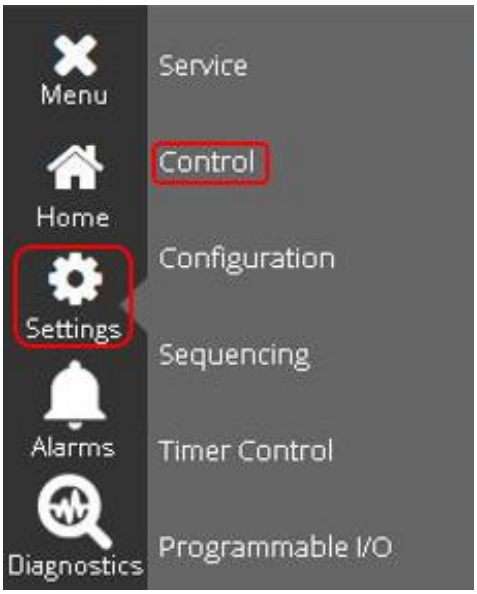

Figure 11: Menu Navigation to Control Settings

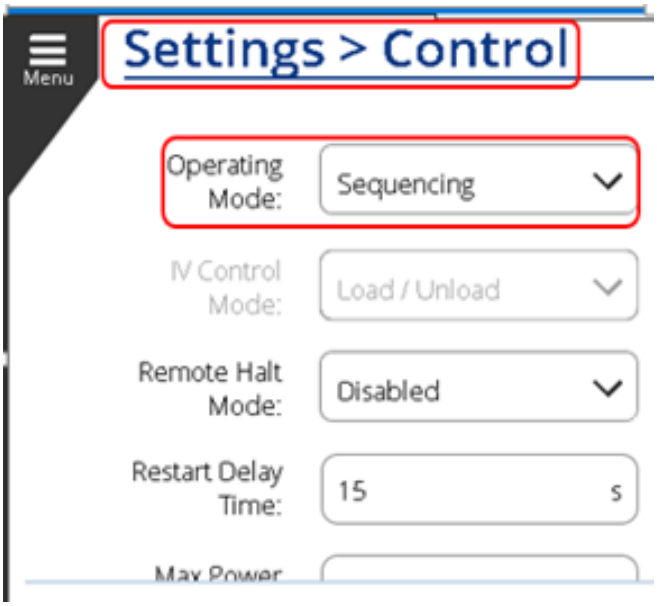

Figure 12: Operating Mode Setting in Control Settings Menu

3.4 Sequencing Settings

Next, navigate to the sequencing settings menu as shown in Figure 13. Figure 14 shows the sequencing settings screen and all of the different settings that can be configured. Table 2 at the end of this section outlines the settings associated with the AirSmart sequencing protocol in more detail and shows the default parameters that are set in the controller. The parameter settings are different depending on the sequence mode selected while configuring the RS485 communication settings. The Capacity settings will vary depending on the machine size, while other default values

will be constant. For AirSmart mode the master/slave designation can change based on the capacity and total machine run hours for priority of master control.

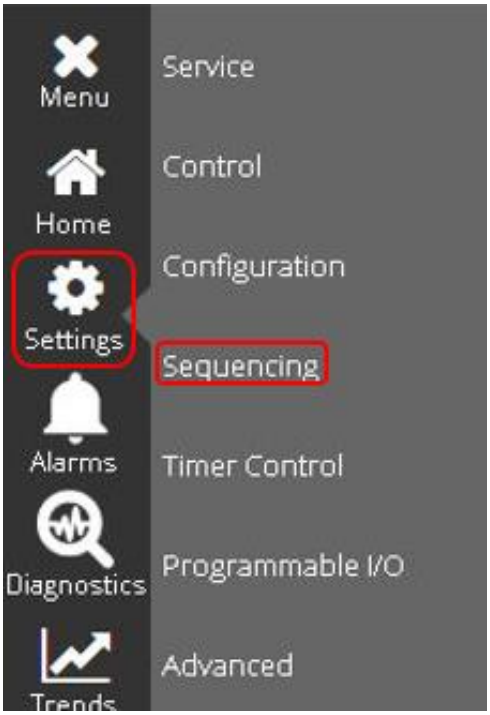

Figure 13: Menu navigation to sequencing screen

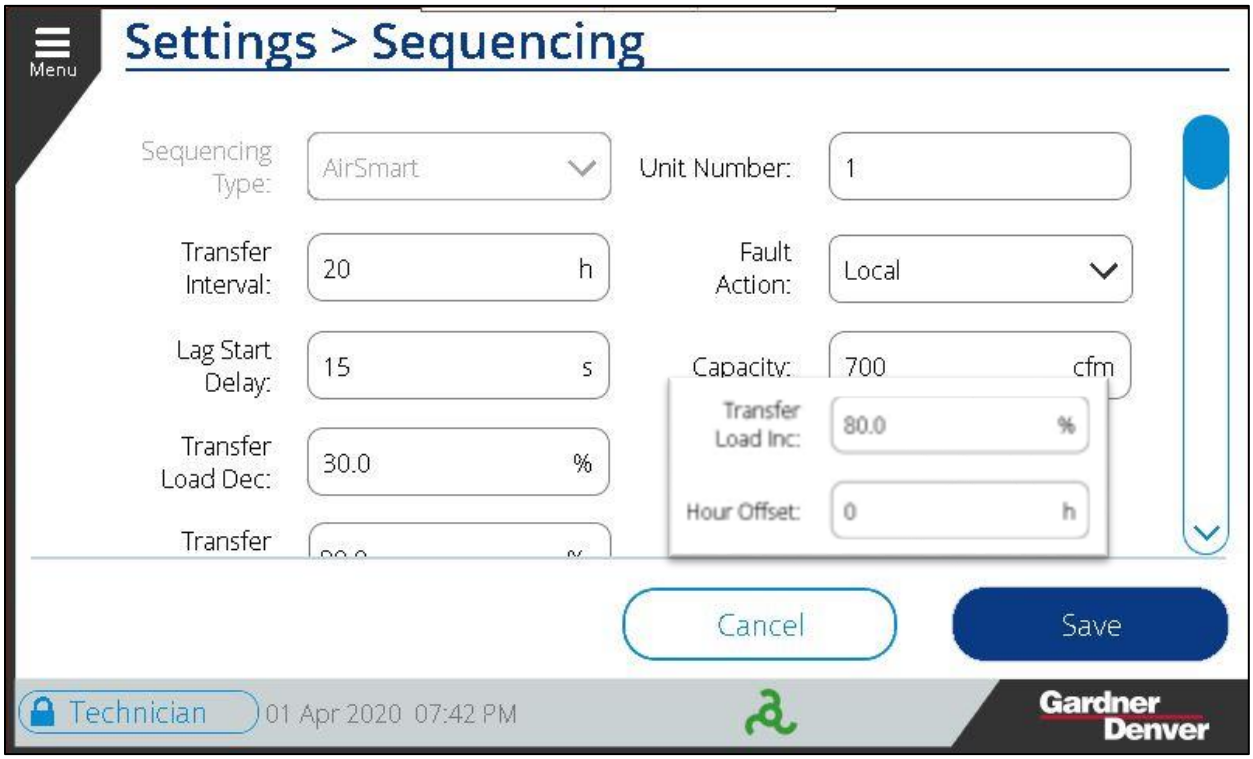

Figure 14: Sequencing Settings Screen

Table 2: AirSmart Multi-Machine Sequencing Settings

Settings	Default Values	Description
Unit Number	1	A number between one and eight assigned to each machine in sequence. No two machines can share a unit number.
Transfer Interval	4 hours	Controls how frequent the Leader role is transferred. The leader role will be transferred to another capable master of the same capacity when the difference between the run hours of the two machines is equal to the Transfer Interval.
Fault Action	Local	This value may be set to Local or Wait. Indicates what a slave compressor (one that cannot become master because no system pressure transducer is assigned) should do when it no longer receives data from a master compressor. Local: modulate the pressure based on the compressor's own delivery pressure sensor and use the compressor's own set points. Wait: blowdown and stop compressor until communication with a valid master compressor is reestablished. Note that the AirSmart controller does not have this setting and will utilize the Wait behavior described above.
Lag Start Delay	15 seconds	The Lag Start Delay is a value in seconds that sets amount of time the Master will wait between commands to other machines in the system. This ensures that machines are not brought on or offline too quickly. In most cases the default value of 15 seconds should be used.
Capacity	700 CFM	Capacity value in CFM used to decide which machine is the Master in the sequence. The largest machine capable of running as a master will always be the master in the sequence, so Capacity values must be set to the same value for all machines that you wish to rotate as the master of the system.
Transfer Load Decrement	35%	Transfer Load Decrement sets the minimum percent load the network will run before unloading one of the slave compressors due to pressure exceeding the unload setpoint.
Transfer Load Increment	80%	Transfer Load Increment sets the maximum percent load the network will run before loading another slave to meet demand.
Hour Offset	0 hours	The Hour Offset can be used to equalize maintenance hours of master machines on the network. For example, if machine A has 100 hours and machine B has 25000 hours, the Hour Offset on machine A could be set to 24900 hours so that the transfer interval calculation would consider that the machines had equal run time.

3.5 Programmable IO Configuration

Next, the System Pressure input needs to be assigned on the Programmable IO settings page. The AirSmart protocol requires a pressure sensor input representing the system pressure that is measured at the system storage in order for a machine to be considered capable of being a master on the network. An additional system pressure transducer connected to an open analog input on the IO module at X11 is typically used for this and will need to be properly addressed. The system pressure transducer shown in the diagram above in Figure 4 is connected to Analog Input 3 on the IO module. The mapping of this location would correspond to Channel 3 for the Sequence System Pressure, as shown below in Figure 15.

Machine delivery pressure may also be used in place of the system pressure transducer, if desired. This is only recommended for small installations where there is little differential between the delivery pressure and the system pressure, as well as between the delivery pressure of the machines in the sequencing network. In this case, the channel that is assigned to Delivery Pressure may be assigned to System Pressure on the Programmable IO configuration and the controller will use this pressure signal for both purposes. On many machines, delivery pressure is on Analog Input 2, but refer to the wiring diagram for your machine to verify this value.

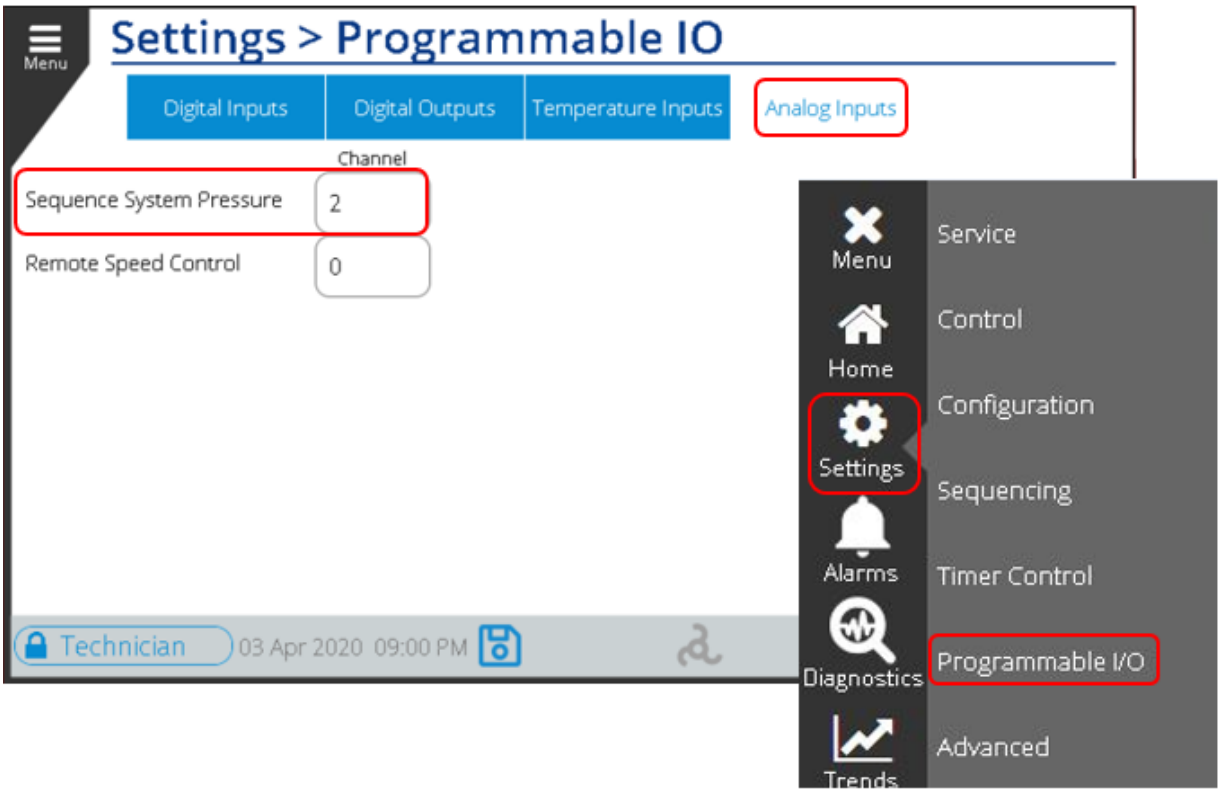

Figure 15: Programmable IO Settings Screen

3.6 AirSmart System Operation

This section provides information on the operation of the AirSmart sequencing protocol. Note that only the main features of the system are discussed and this should not be considered a full description of the behavior.

When the system is first started, it will determine the master of the system. Any machine that is enabled and has a system pressure transducer assigned is capable of being a master. The machine with the largest capacity that is master-capable will always become the master of the system. If multiple master-capable machines have the same Capacity setting, the one with the lowest Unit Number will become the master. Once the master has been decided, it will be automatically rotated to other machines based on the following conditions:

1. A new master-capable machine with larger capacity comes online.
2. The run hours of the master machine exceeds the run hours of a slave machine of equal capacity by more than the Transfer Interval setting. (Note that the Hours Offset setting is also taken into account.)

The master machine will begin running and producing air when the system pressure falls below the Load Pressure setpoint. After loading, it will accelerate to try to maintain the system pressure at the target pressure. Other machines will be brought on and off load according to the rules below:

1. If there are slaves available to run that are not loaded, the master will keep the system running at or below the Transfer Load Increment percent load. All of the variable speed machines will run off of the master's speed command. If the system falls below the Load Pressure setpoint, the master will command the next slave unit to load. If needed, more machines will be asked to load, waiting Transfer Interval seconds between each machine. If

all slaves are loaded, the master will allow the system to run up to 100% load to maintain the target pressure.

2. If the master and one or more slaves are running, the master will keep the system running at or above the Transfer Load Decrement percent load. If the system pressure rises above the Unload Pressure setpoint, the master will command one slave to unload. If needed, more machines will be commanded to unload, waiting Transfer Interval seconds between each command. If all slaves are unloaded (only the master is running), the master will run down to its minimum speed to attempt to maintain the target pressure. If the master is running at minimum speed and the system pressure rises above the unload pressure, the master will unload.

Note that only variable speed machines can accept a speed command from the master. Also, a fixed speed master cannot send a speed command other than 100% to slave machines. If there are any variable speed machines on the network, the system will operate most efficiently if the largest variable speed machine is the master of the group.

3.7 AirSmart Sequencing Diagnostics

The Sequencing Diagnostics page can be found by going to Menu, then selecting Diagnostics, then Sequencing as shown in Figure 16 below. This page shows the status of the network and each individual compressor.

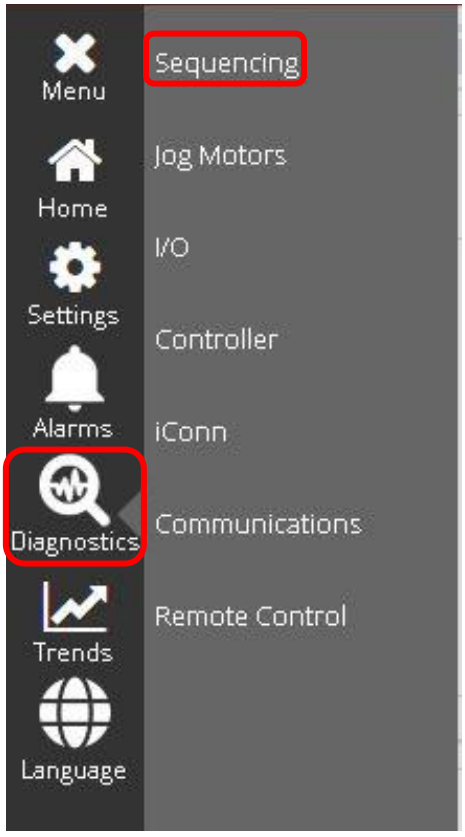

Figure 16: AirSmart Sequencing Diagnostics Menu Navigation

The information on the Sequencing Diagnostics page for AirSmart mode is shown in Figure 17 below. This page gives an overview of the sequencing operation for the network. The compressor name, run hours, capacity, and operating pressure is also shown at the top of this page. As more

compressors are added to the sequenced network, the white space fills with additional compressor information. Only two compressors are shown in the example below.

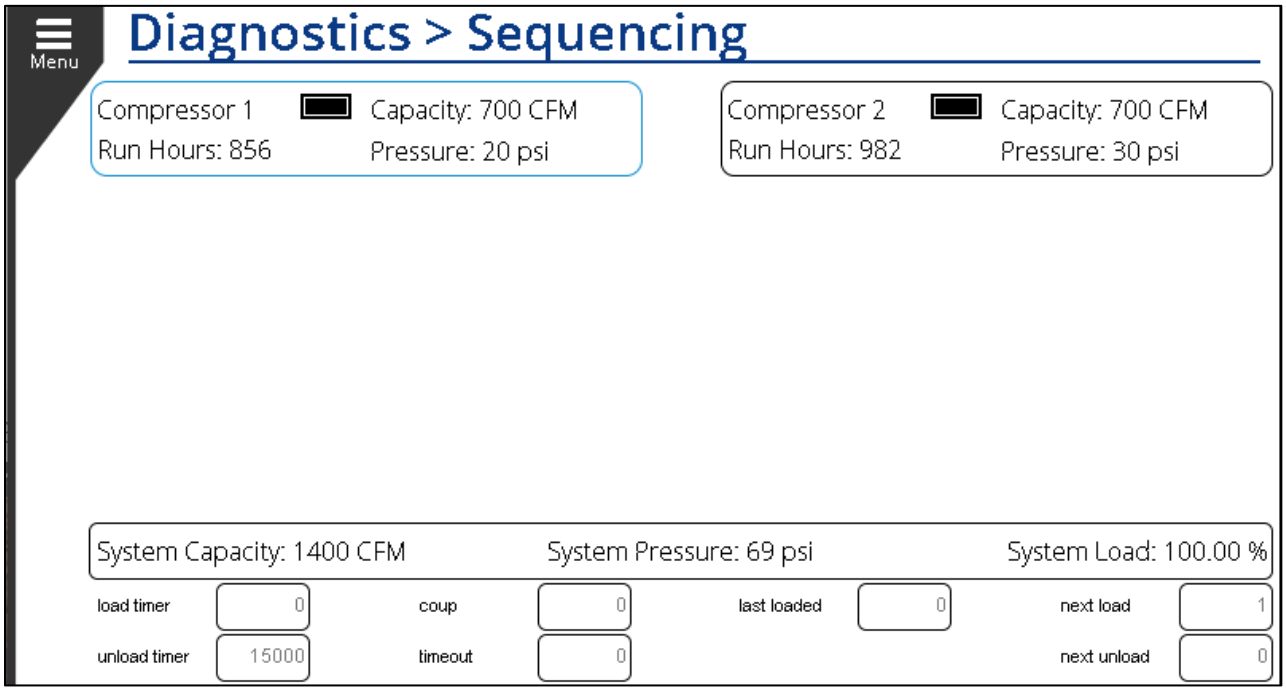

Figure 17: AirSmart Sequencing Diagnostics Page

The machine shown with the blue border around its information is the current master of the network. Each compressor detected will have a status icon on the tile according to the legend in Table 3 below:

Table 3: Sequencing Diagnostic Symbols

Symbol	Meaning
	The compressor is not loaded. The motor may or may not be running.
	The compressor is loaded and producing air.
	The compressor is switched off or faulted.

4. Sequencing Using the Delcos Protocol

This section describes how to connect and configure machines for sequencing using the Delcos protocol. This protocol is also used for machines connected to a Connect 12 system controller.

4.1 Wiring Connections

Wiring connections for the Delcos sequencing protocol are shown in Figure 18 below. Daisy chain the RS485 connections from the master machine to the first slave machine then second slave machine, etc. for each machine in the sequenced group. The Delcos RS485 connections are located on the IO Module at X02 in the control cabinet. Depending on the machine configuration, RS485-2 at X03 on the IO module can also be used, if populated. Setup and configuration for RS485-2 is identical to RS485-1.

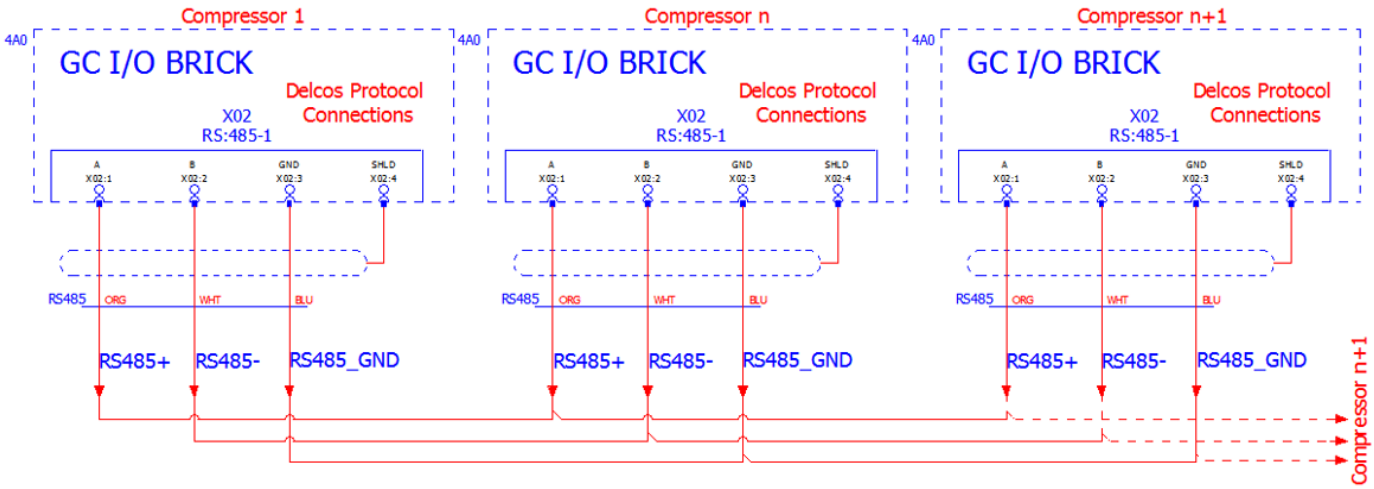

Figure 18: Delcos RS485 Communication Wiring Schematic

Figure 19 shows the hardware Interface for the RS485 Connections on the IO Module as shown in the wiring diagram in Figure 18. Make sure that the machines at the end of the sequencing network have the RS485 terminating resistor DIP switch in the ‘ON’ position. The location of the DIP switch is highlighted below in Figure 19.

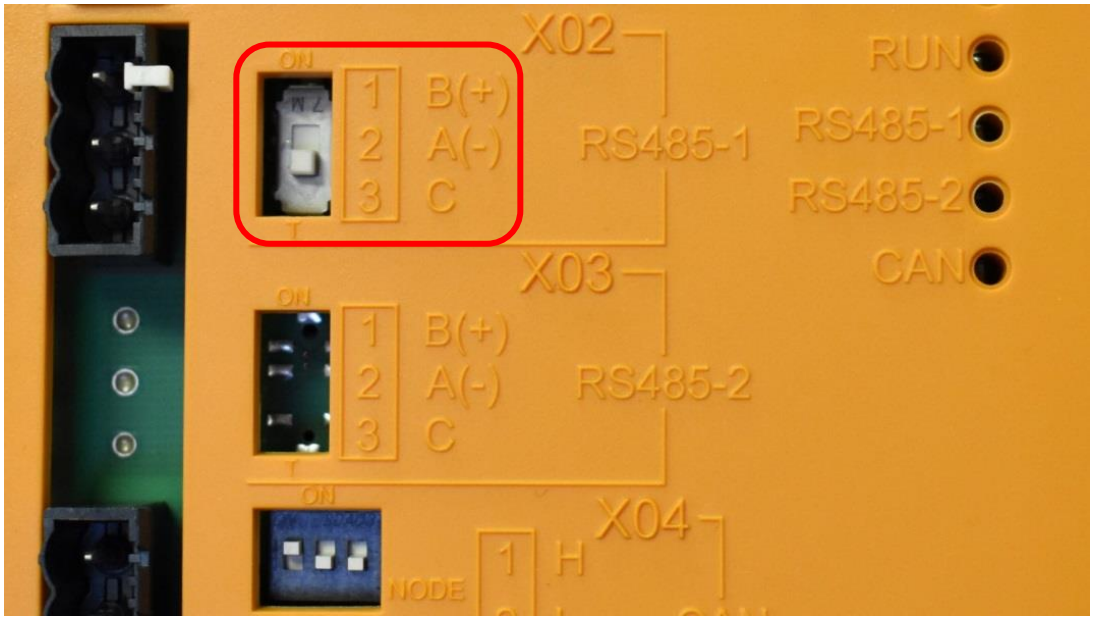

Figure 19: IO Module DIP Switch Settings at RS485-1 Port

4.2 Communication Configuration

The RS485 communications will need to be configured in the settings and the sequence mode will need to be selected. Delcos sequencing requires a baud rate of 9600, which will be set automatically once the protocol has been selected. Navigate to the communication settings by selecting Menu, Settings, Configuration, and then Communication, shown in Figure 20. Select the RS485-1 tab, and then change the mode to *Sequence – Delcos.* Machines which have RS485-2 at X03 populated will show an additional tab called "*RS485-2*" in the menu with the same settings available. Use the port that corresponds to the physical location of the wiring connections on the machine.

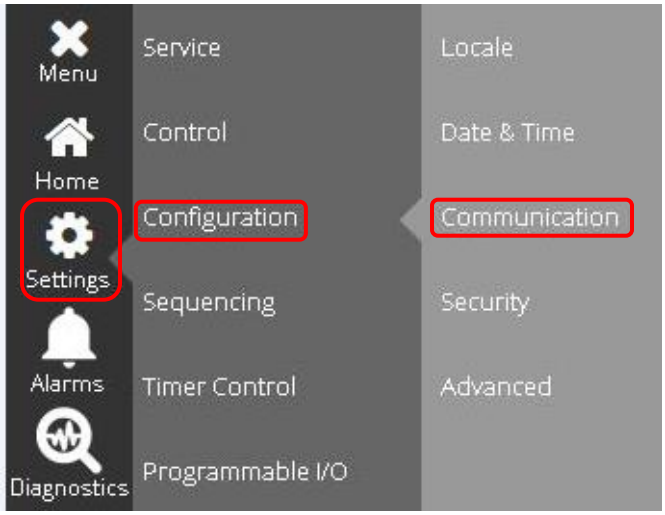

Figure 20: Menu Navigation to Communications Screen

Please note that the controller may prompt the user to reboot following the mode change of the communication parameters. Select OK and allow the controller to reboot before continuing with the additional settings.

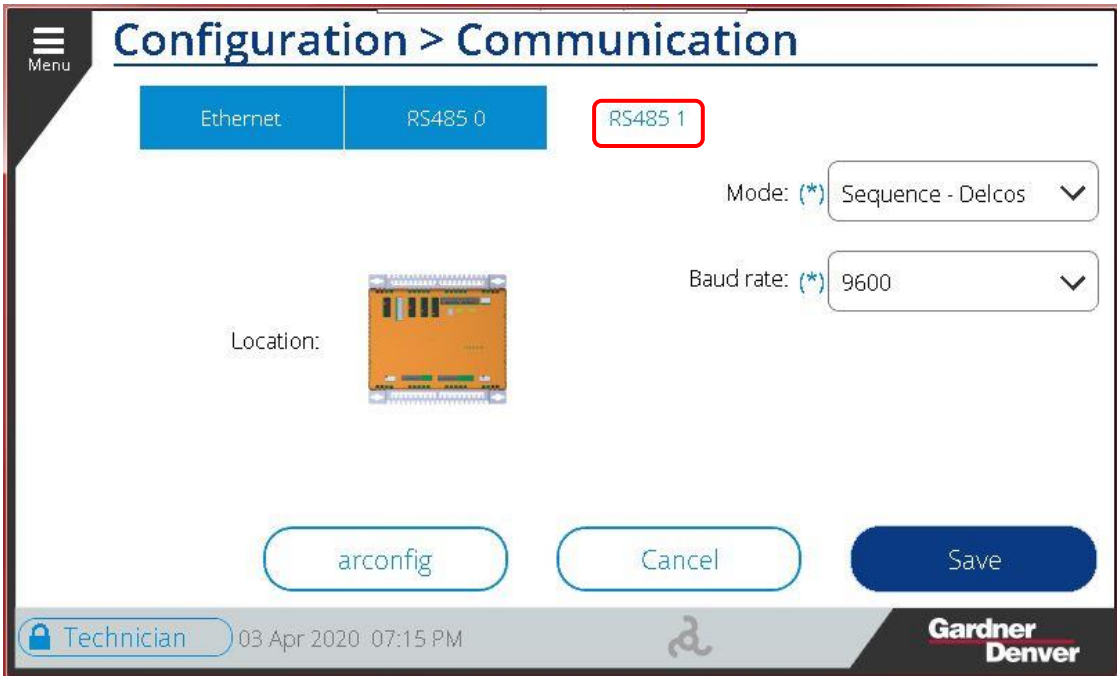

Figure 21: Delco's Communication Configuration Screen

4.3 Operating Mode Setting

Next, the operating mode for machine control needs to be configured. Navigate to the control settings menu following Figure 22 by selecting menu, settings, and then control. Change the operating mode to *Sequencing*, shown in Figure 23.

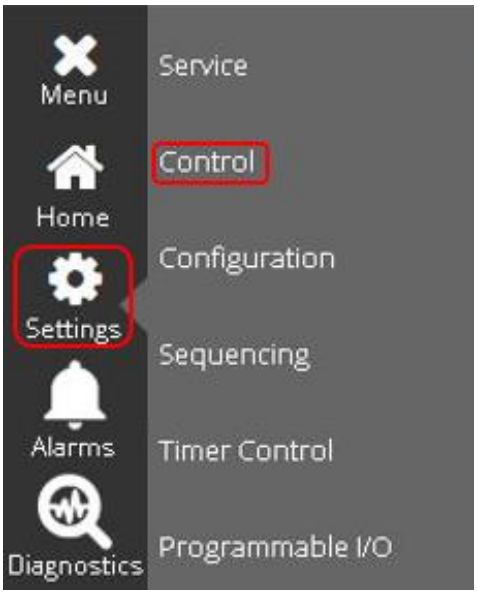

Figure 22: Menu Navigation to Control Settings

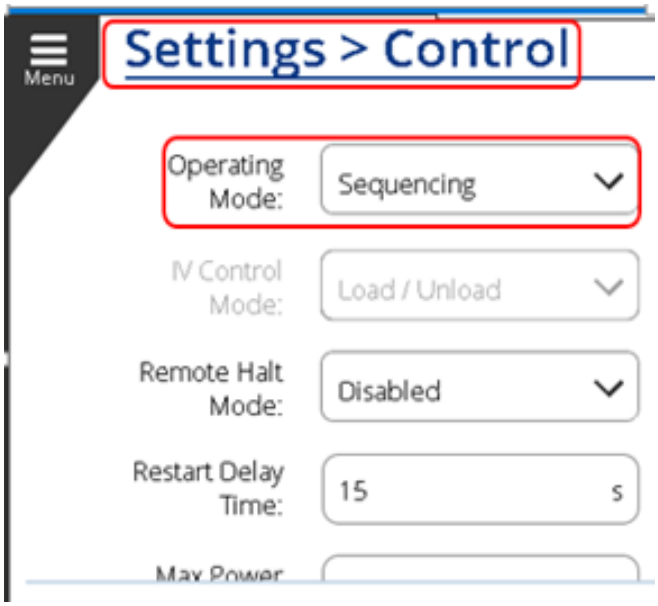

Figure 23: Operating Mode Setting in Control Settings Menu

4.4 Sequencing Settings

Next, navigate to the sequencing settings menu as shown in Figure 24. Figure 25 shows the sequencing settings screen and all of the different settings that can be configured. Table 4 at the end of this section outlines the settings associated with the Delcos sequencing protocol in more detail and lists all default parameters that are set in the controller. The parameter settings are different depending on the sequence mode selected while configuring the RS485 communication settings.

For Delcos systems, the Governor controller can be integrated into any existing control system as long as a Governor controller is the master-enabled machine and all other machines are configured as Slaves.

Figure 24: Menu Navigation to Sequencing Screen

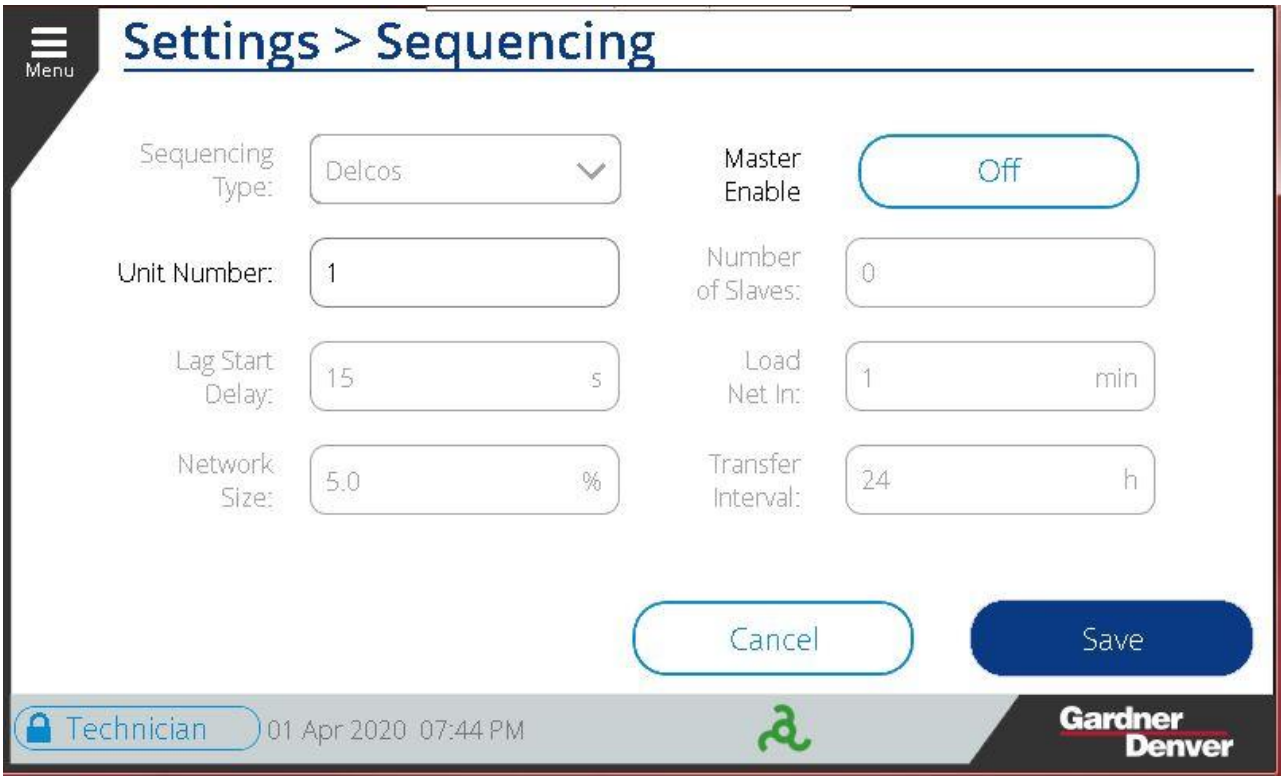

Figure 25: Delcos Sequencing Settings Screen

Table 4 below outlines each of the Delcos protocol settings in detail and their corresponding default values.

Table 4: Delcos Multi-Machine Sequencing Settings

Settings	Default Values	Description
Master Enable	Off	Designates which machine in the sequenced network is the Master. Only a single machine in the network can have Mater Enable turned on. Master Enable must also set to Off for sequencing with a Connect 12.
Unit Number	1	Number between one and four assigned to each machine in sequence. No two machines can share a unit number.
Number of Slaves	0	Number of machines in the sequenced group behind the Master.
Lag Start Delay	15 seconds	The Lag Start delay sets the amount of time Master will wait before asking another machine to come online.
Load Net In	15 minutes	This value sets the amount of time to increase network pressure to target pressure from when sequencing is activated. Shorter values will switch on more compressors at startup. When sequencing is activated, the compressed air network is filled in the time set and only the number of compressors required to fill the compressed air network in this time are switched on.
Network Size	5%	Network Size is used to calculate how many compressors to switch on or off to meet changes in demand. This value should only be changed if there are significant fluctuations in compressed air requirements. Formula to calculate: a = (100 x b) / c where a = network size (%), b = network volume size (size of closest receiving tank, ignore size of pipework and other air tanks), c = total delivery volume of network.
Transfer Interval	24 hours	The Transfer Interval controls how frequently the sequence is redefined based on the hours run (BLS) setting of the compressor.

4.5 Delcos Sequencing System Operation

Delcos sequencing systems use a dedicated master running in the Sequencing operating mode. Up to three slaves can be connected to the master via a serial connection and should be of the same type of machine (either all fixed speed or all variable speed) and relatively the same capacity.

Delcos sequencing has the following two functions: (1) a central high-level controller is used to control a group of compressors in order to maintain the system pressure within a narrow pressure band, and (2) the master controller regularly changes the priority of the compressors in the group so that the load is distributed among the compressors.

As long as the machine's operating mode is not set to Sequencing, the slaves run independently of the master and use their local set points. When the sequencing mode is activated, the network is pressurized within a defined period of time according to the Load Net In setting. To do so, only the required number of compressors are switched on in order to pressurize the network within this time period. After a power loss, this function is not activated, because in this case it is important to pressurize the network as fast as possible.

In case of a Pressure sensor fault on the master controller, the master can no longer control the group and therefore switches sequencing off until the fault is cleared and reset. If the master compressor switches itself off because a different fault than the Pressure sensor fault has occurred, or if it is manually stopped, the master continues to control the sequencing network using the remaining slaves.

As soon as the pressure is above the Unload Pressure setting, the compressor to the far right in the sequence is switched off. When the Unload Pressure is exceeded, additional compressors are switched off in sequence at short time intervals. If the system pressure drops below the Load

Pressure, the next available compressor is started immediately, followed by additional compressors in a defined sequence if the system pressure remains low.

Variable Speed Master – Fixed Speed Slaves: The line pressure is controlled precisely between the minimum and maximum line pressure by the speed-controlled compressor, within the available speed range. If the limits of the pressure band have been reached, then compressors are switched on or off as described above.

Variable Speed Master – Variable Speed Slaves: The speed-controlled compressors run at approximately the same speed and load if they are approximately the same size. After a compressor is restarted manually (e.g., after Service), the speed may not be synchronous for a brief period, until the compressor reaches its minimum or maximum speed limit for the first time.

Defining a new sequence based on Hours Run (BLS) When the Transfer Interval has expired, the master defines a new sequence based on the Hours Run (BLS) of the compressors. The compressor with the least Hours Run (BLS) is placed first in the sequence, etc. The next section for sequencing diagnostics shows how to change the BLS Run Hours. On variable speed compressors with fixed speed slaves, the variable speed compressor will always remain in the first place of the sequence, while the position of the slaves is changed periodically.

To use the Governor™ controller with a Connect 12 system, the sequencing mode will need to be configured as a slave machine with the master enable turned off. All machines are configured this way and the Connect 12 acts as the Master Control. To use the Governor with a Connect 4 system, an iPCB module is required.

4.6 Delcos Sequencing Diagnostics

The sequencing diagnostics page can be found by going to menu, then selecting Diagnostics, then Sequencing as shown in the Figure 26 below.

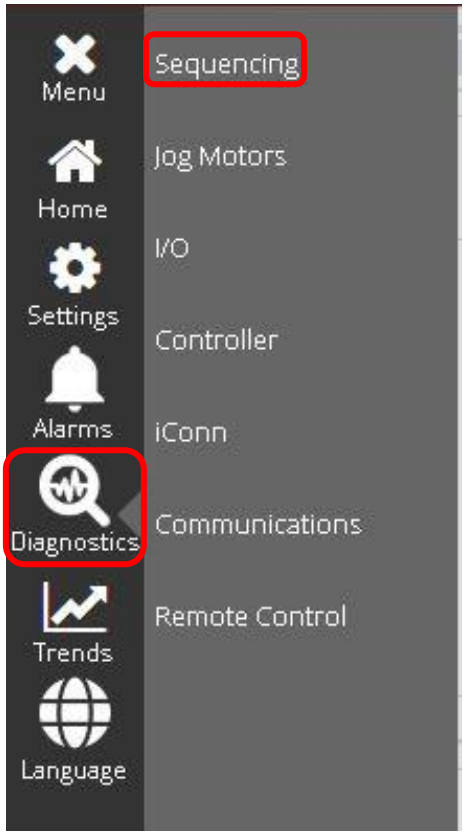

Figure 26: Delcos Sequencing Diagnostics Meu Navigations

The information on the sequencing diagnostics page is shown in Figure 27 below for a master enabled machine. This page gives an overview of the sequencing settings for the machine. The compressor name, run hours, BLS run hours, operating pressure, and pressure bands is also shown on this page for machines that are configured as a master. Slave machines will only have the name of the compressor, network pressure, and pressure band for the machine shown, as in Figure 28.

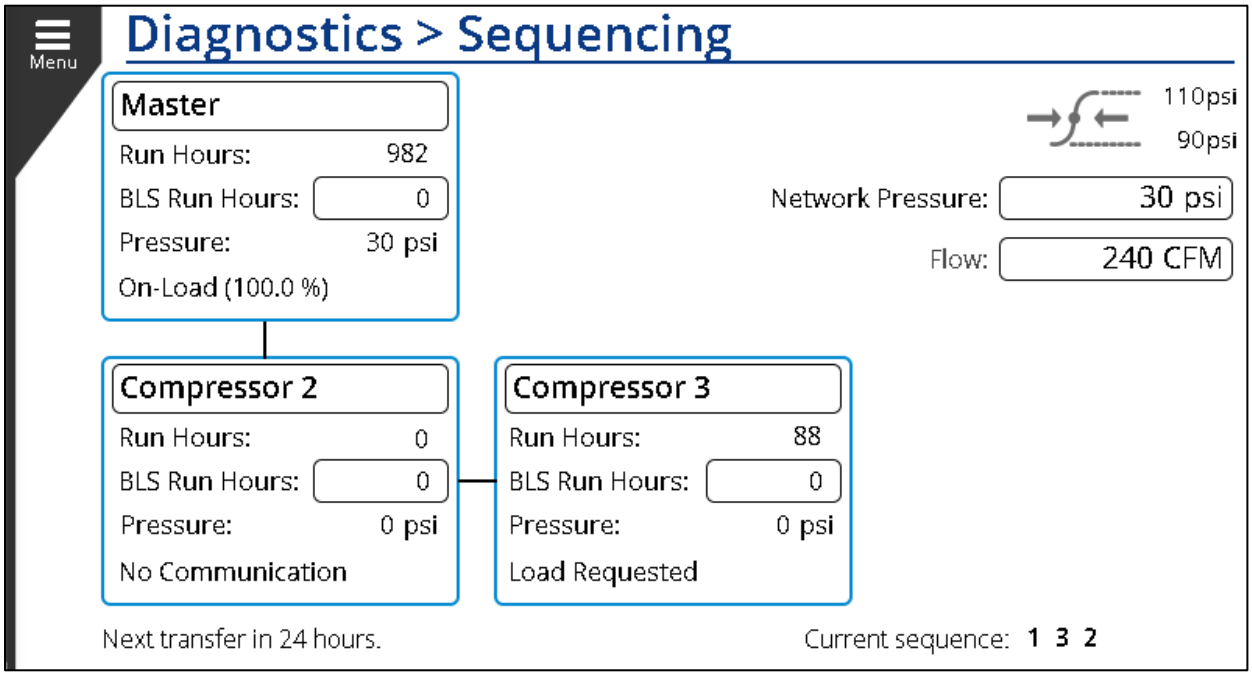

Figure 27: Delcos Dequencing Diagnostics Page for a Master

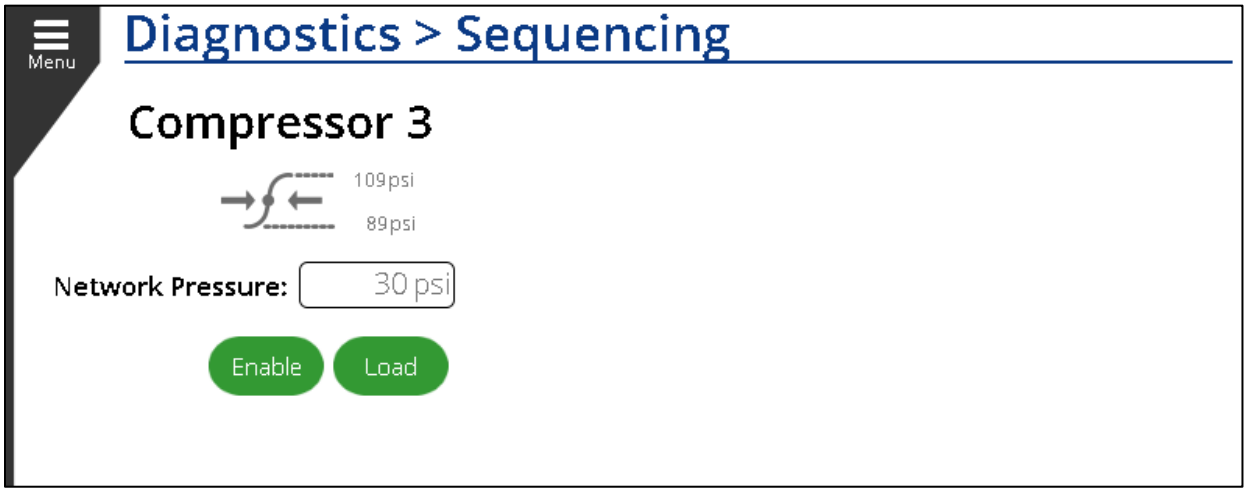

Figure 28: Delcos Sequencing Diagnostics Page for a Slave

To change the name of the compressor or the BLS Run Hours for a master machine the user will need to be signed in as a technician and click on the box shown in Figure 29 that says ‘Master” or ‘0’ for BLS Run Hours on the sequencing diagnostics screen. The keyboard in Figure 29 will come up on the screen when changing the name of the machine and the number pad in Figure 30 when changing the BLS Run Hours.

Figure 29: Delcos Keyboard to Change Name of Master Machine

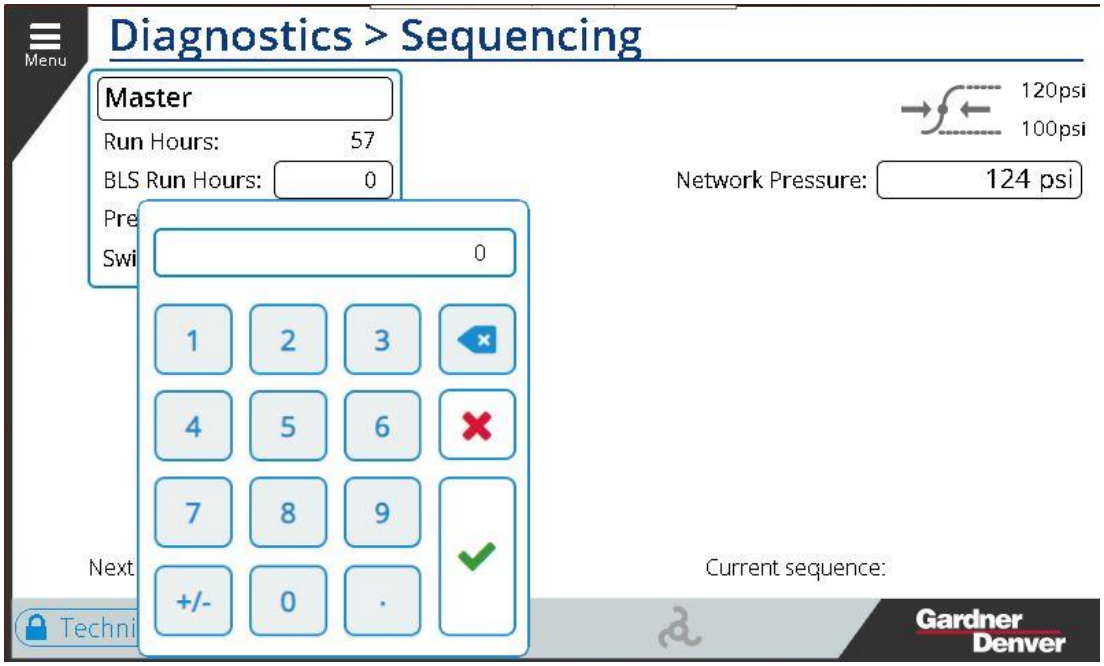

Figure 30: Delcos Change BLS Run Hours

5. ES+

This section provides details on configuration and operation of the system in ES+ sequencing.

5.1 Wiring Connections

Figure 31 below shows the wiring connections for the ES+ sequencing protocol. Note that ES+ sequencing can only be configured for fixed speed machines.

Daisy chain the RS485 connections from the master machine to the first slave machine then second slave machine, etc. for each machine in the sequenced group. Unlike AirSmart and Delcos protocol, the ES+ RS485 connections are located on the Governor display at ***RS485 IF5*** in the control cabinet, as shown in Figure 32.

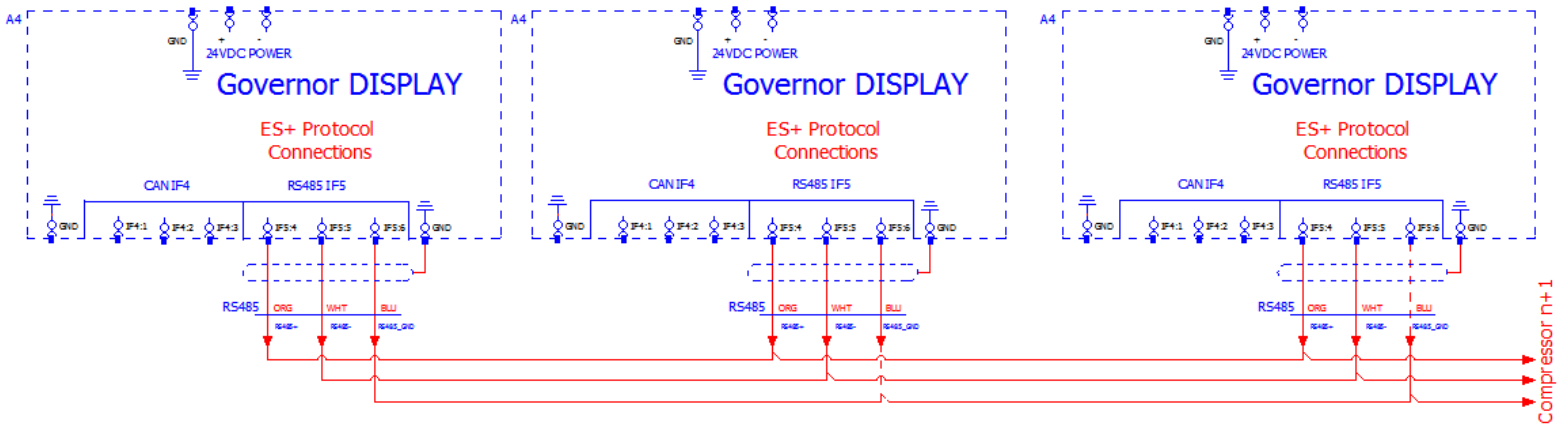

Figure 31: ES+ RS485 Communication Wiring Schematic

Figure 32 below shows how to connect a legacy ES+ machine to the Governor controller using the 6-conductor telecommunications cable that may already be included on existing ES+-controlled machines for communications (GD PN: 97J49 for reference). The cable connects to the Governor display at the IF5 interface using the 6-pin connector on the display with two conductors per pin as shown. The black/yellow pair connects to terminal 4, white/blue pair connect to terminal 5, and green/red pair connect to terminal 6. You will need to carefully strip and terminate the cable and conductors to make the connection to the controller.

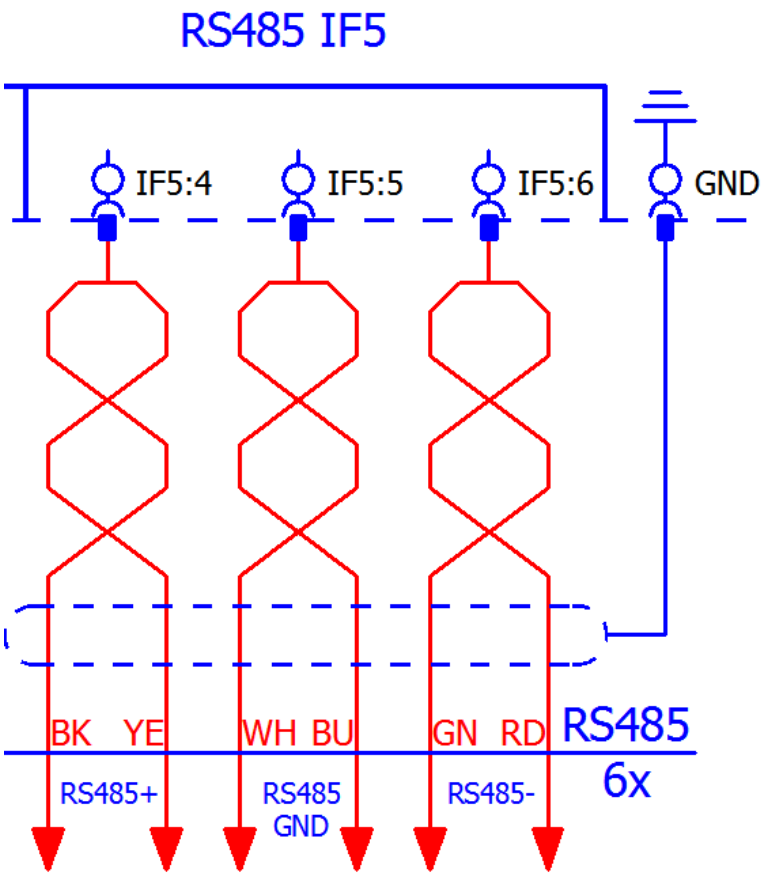

Figure 32: Legacy ES+ RS485 Communication Wiring to Governor Display

Alternatively, the 6-conductor cable can be used to connect the ES+ to the Governor display using the RJ-12 connector shown below in GD Kit ***324AUX6028*** in Table 5. Connect the cable between the RJ-12 terminal breakout and Governor Display at the IF5 interface as shown in Figure 32 above. The terminal breakout has a total of six terminals to wire into corresponding to the six wires on the telecommunications cable connected to the ES+ controller. The signal pinout for this board will be as follows: Pin 1: RS485 GND, Pin 2: RS485 +, Pin 3: RS485 -. Use a communications cable such as 97J93 to wire from these terminals to the Governor controller on IF5. Connect a 6-wire telecommunications cable between the ES+ controller on one of two RJ-12 jacks and the RJ-12 connector on the terminal breakout. Mount the terminal breakout board on the DIN rail in the ES+ compressor control box.

For installations with more than two units, the pigtail plug in one of the ES+ RJ-12 ports must be disconnected on all controllers except the two at each end of the communications line. The order of interconnection has no effect on the operation.

Figure 33: RJ-12 to Terminal Breakout Connector (GD PN: TEN023981)

Gardner Denver provides a kit **324AUX6028** that includes all hardware required to add a machine to a new or existing ES+ sequencing network. The parts list for **324AUX6028** is listed in Table 5*.*

Table 5: 324AUX6028 Sequencing Kit

Part Number	Description	Quantity
24CA3403	PLUG-MODULAR SPC TA-30-6	2
97J49	WIRE #24-6/C FLAT SPC TXW6205-WF	10 FT
TEN023981	Breakout Terminal Block, DIN Rail Mounted, 2 Amp, 120 Volt	1
24CA3404	CRIMPING-TOOL	1

5.2 Communication Configuration

Next, configure the RS485 communications under the Communications Configuration page. ES+ sequencing requires a specific baud rate for communications, which will be set automatically after selecting the sequence mode. ES+ sequencing can operate on both 9600 and 1200 baud as long as all devices on the network are set to the same baud rate. Navigate to the communication settings by selecting Menu, Settings, Configuration, and then Communication, as shown in Figure 34. Select the RS485-0 tab then change the mode to *Sequence – ES+.* The location of the ES+ communications is on the display.

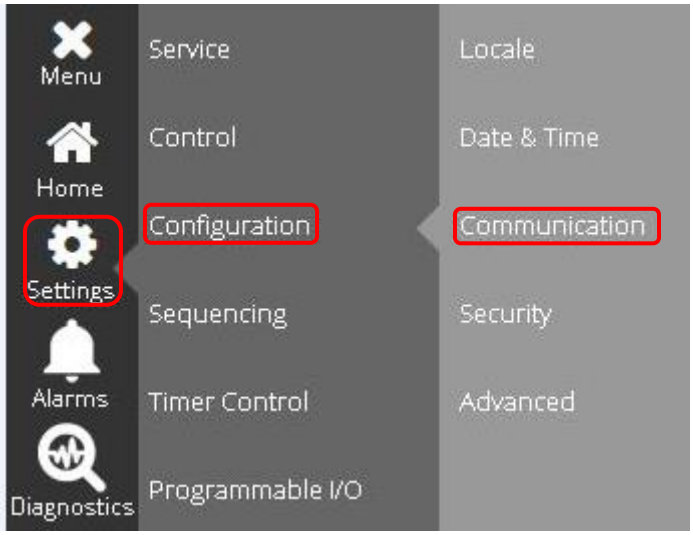

Figure 34: Menu navigation to communications screen

Please note that the controller may prompt the user to reboot following the mode change of the communication parameters. Select OK and allow the controller to reboot before continuing with the additional settings.

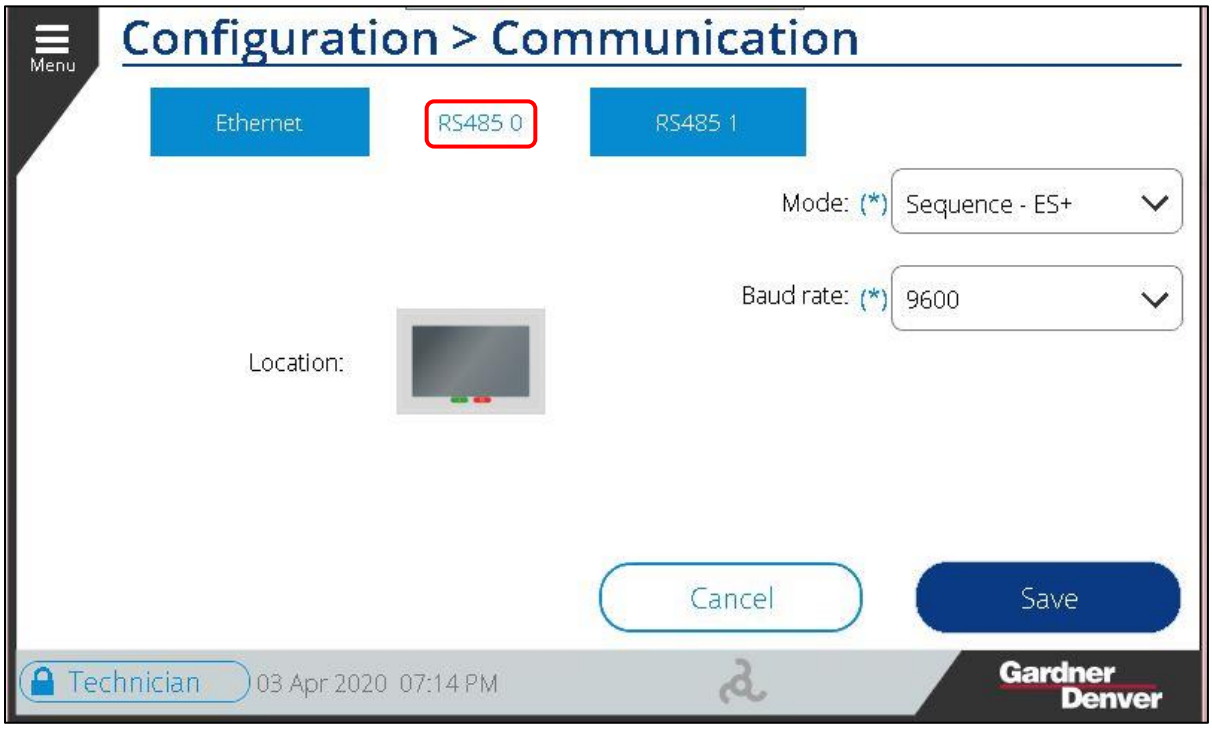

Figure 35: ES+ Communications Configuration Screen

5.3 Operating Mode Setting

Next, the operating mode for machine control needs to be configured. Navigate to the control settings menu following Figure 36 by selecting menu, settings, and then control. Change the operating mode to *Sequencing*, shown in Figure 37.

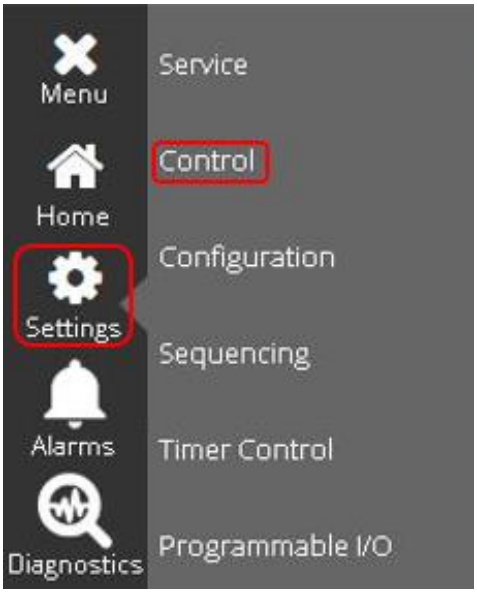

Figure 36: Menu Navigation to Control Settings

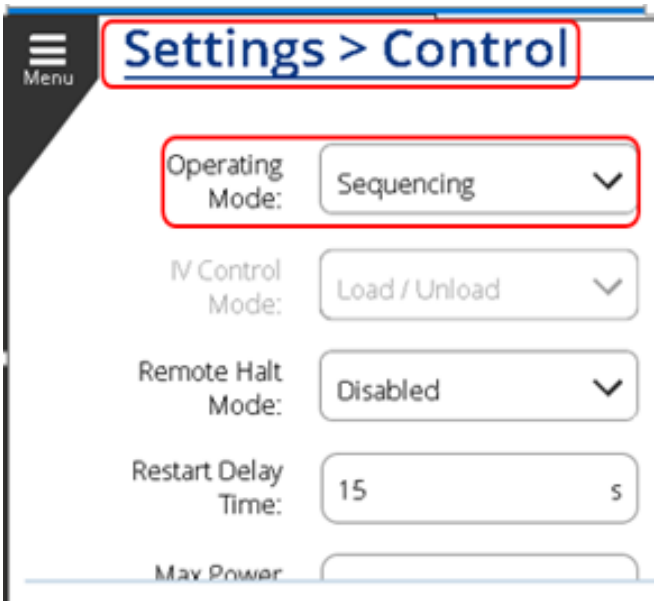

Figure 37: Operating Mode Setting in Control Settings Menu

5.4 Sequencing Configuration

Next, set the sequencing configuration for each controller on the network. Following Figure 38, navigate to the sequencing settings menu. Figure 39Figure 38 shows the sequencing settings screen and all of the different settings that can be configured. Table 6 at the end of this section outlines the settings associated with the ES+ sequencing protocol in more detail and lists all default parameters that are set in the controller. The parameter settings are different depending on the sequence mode selected while configuring the RS485 communication settings.

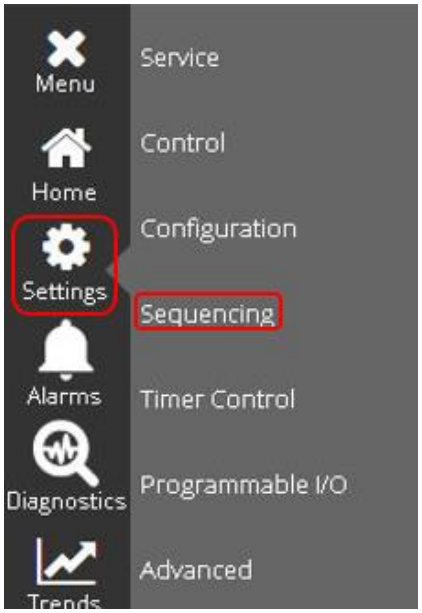

Figure 38: Menu Navigation to Sequencing Screen

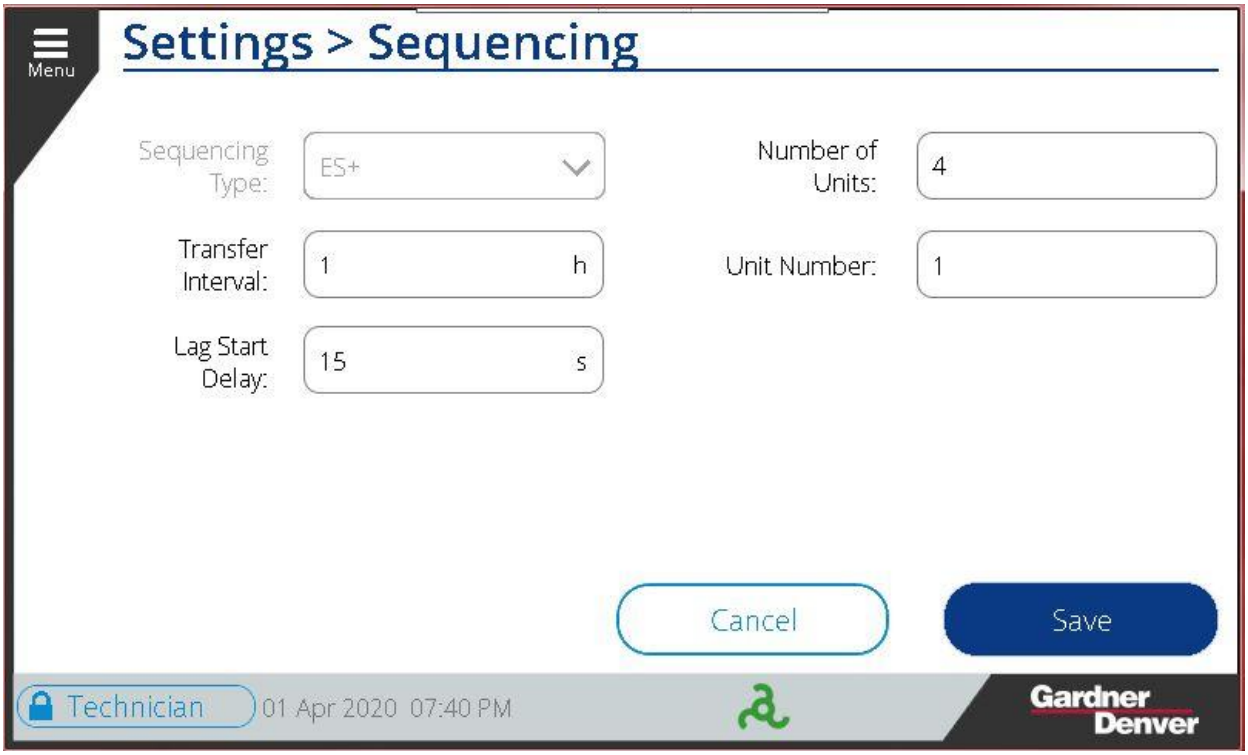

Figure 39: ES+ Sequencing Settings Screen

The below table outlines each of the ES+ protocol settings in detail and their corresponding default values.

Table 6: ES+ Multi-Machine Sequencing

ES+ Protocol			
Settings	**Default Values**	**Description**	***FIXED SPEED MACHINES ONLY***
Number of Units	1	Number of machines in the sequenced group. Maximum 8.	
Transfer Interval	24 hours	The Transfer Interval controls how frequently the Lead role is transferred. A machine will run this many hours before releasing Leader control and becoming a Lag machine in the sequence. The next machine in the rotation will automatically assume the lead role.	
Unit Number	1	Number between one and eight assigned to each machine in sequence. No two machines can share a unit number.	
Lag Start Delay	30 seconds	Lag Start delay sets amount of time between a compressor in the rotation coming online before the next machine in the rotation will load.	

5.4 ES+ System Operation

The ES+ sequencing system is a master-less system that rotates the lead and lag compressors between all of the available machines. The compressors will operate very similarly to Automatic operation, except that the set points will be controlled by the sequencing network. By varying the set points across the machines in the network, the load is spread across the network so that the pressure band is maintained while running only the number of machines required to meet the demand. Most machines in the network will run fully loaded and modulation will be handled almost completely by the last compressor in the rotation.

5.4.1 Establishing the Initial Sequence

Once the system has been configured, press the Start button on each of the compressors to start operation of the sequenced system. Since the sequencing algorithm includes provisions for automatic replacement of a failed master or 'lead' compressor, it is important for the operator to be aware of the hierarchy of events when starting the system.

The first compressor placed into sequence mode will become the Lead. However, since any compressor first placed into sequence has no way of knowing whether a Lead exists, it will first assume the highest rotation number available. For example, if the number of units to be sequenced is programmed at four, any compressor will start out in position four when placed in sequence mode. It will then listen for communications on the bus. If no communication is received, it will assume position three and again wait for communications. If a compressor with a lower rotation number is not detected it assumes position two. Subsequently, it assumes position one, which makes it the Lead compressor.

Before a master is established, the system is not deprived of air. This is due to one of the outstanding features of the ES+ sequencing system: pressure control is always executed locally at each compressor. The effective setpoint for compressor control is the programmed setpoint minus 3 *(rotation number - 1). So, while a compressor is counting down towards establishing a master, it is also capable of delivering air at a pressure determined by the above formula.

To dictate the complete initial sequence manually, wait until the previous machine decrements one position and then place the next desired compressor in operation by pressing the Start button on each in sequence. Otherwise, simply press start on all compressors and the initial sequence will be determined automatically.

Rotation numbers are displayed on the home screen in the Status Bar, as well as on the sequencing diagnostics page.

5.4.2 How the ES+ Controls Pressure While Sequencing

Each compressor operates exactly the same as if it were in Automatic mode with one exception: it has a dynamic setpoint. The initial setpoint is determined by the equation shown above. A compressor starts when the system pressure drops below its programmed reset point, after waiting for [Lag Start Interval * (rotation number - 1)] seconds. This prevents all lag compressors from starting at once. Note that a compressor's timer is not reset to zero until that compressor is started or until another unit in the system stops. This means that the time for the next lag compressor to come on may be somewhat less than the programmed Lag Start Interval setting.

For example, consider a three compressor sequence system with the following settings, Target Pressure = 100 PSI; Load Pressure = 90 PSI; Lag Start Interval = 15 seconds. The lead compressor is running alone, maintaining 100 PSI by modulation when an air tool comes on line and causes the air demand to exceed the capacity of the lead compressor. When the pressure drops to 90 PSI, the #2 unit times out its 15 second timer and starts. It takes 5 additional seconds for the pressure to rise above 90 PSI. The #3 unit whose timer was initially set at 30 seconds (15 x [3 - 1]), has counted down 20 seconds (the total time that system pressure was below 90 PSI). If air demand increases again, the pressure will have to fall below 90 PSI for only 10 seconds more to start unit #3.

A lag compressor's target setpoint is [Target Pressure - 3(rotation number - 1)]. So, in the above example the first lag compressor (rotation #2) has a Target Pressure of 97 PSI; the second lag, 94 PSI, and so on. But look what happens in an eight compressor installation: The eighth compressor will have an initial setpoint of [100 - 3(8 - 1)], or 79 PSI. However, this does this not mean that an eight compressor installation must operate 21 PSI below the desired operating point when all compressors are running. This is where the dynamic setpoint control takes over. Whenever the system pressure is below the programmed Load Pressure, the Target Setpoint of each lag compressor is incremented at a pre-determined rate. After a short interval (about five minutes in this example), the Target Setpoint of the last sequenced compressor will climb until either it equals the Load Pressure, or a decrease in demand causes the actual system pressure to rise above the Load Pressure. The system will maintain delivery pressure between the Load and Target set points.

Dynamic setpoint control will also work in reverse of the operation described above. Obviously, incrementing set points will cause overlap of the compressors' modulation ranges. While this enables us to maintain a higher pressure, overlap is undesirable as demand decreases, because a system could end up with several compressors running partially loaded instead of running the minimum number of fully loaded compressors. To overcome this, as pressure rises through the range between Load Pressure and Target Pressure, the lag compressors' Target Pressures are now decremented. This reverses the effect described above during periods of high demand.

5.4.3 Automatic Sequence Change

A controller will be the Lead compressor for the time programmed as Transfer Interval. Then, it assigns itself the highest available rotation number. The lag compressors detect this and decrement their rotation numbers. Number 2 becomes number 1, the new lead; number 3 becomes number 2, etc.

Whenever a missing rotation number is detected, such as when a compressor is turned off that was previously in the rotation, it will automatically 'close the gap' by decrementing the rotation numbers of all compressors whose rotation numbers were greater than the missing number. Likewise, if for whatever reason the lead compressor fails to carry out its role, all lag compressors begin decrementing their rotation number until a new lead is established. Regardless of the scenario, the result will always be that the compressors that remain in rotation will end up with the lowest possible rotation numbers.

5.4.4 Other Features

Any air system will exhibit pressure differences from one point to the next. Even a well-designed multi-compressor installation will show 'minor' pressure variations between one compressor's discharge point and another compressor's discharge. These points will also vary from the central system (normally the air storage receiver). The ES+ sequencing system is designed to tolerate minor variations.

Since these pressure variations are not constant (they will vary due to demand changes, compressor load percentage changes, and number of compressors running), any scheme to compensate for the pressure variations must be dynamic. The compressors on the network continually receive system pressure values from every machine in the sequence rotation. The values are averaged and all compressors, lead and lag, then compare their local pressure reading to the average and adjust their Target by the amount of error. The effect is that all compressors are controlling to a single pressure reading, a reading that is not one that is picked up somewhere removed from the compressor, but an average of actual delivery pressures.

This pressure is displayed on the Sequencing Diagnostics page.

5.5 Sequencing Diagnostics

The sequencing diagnostics page can be found by going to menu, then selecting Diagnostics, then Sequencing as shown in Figure 40 below.

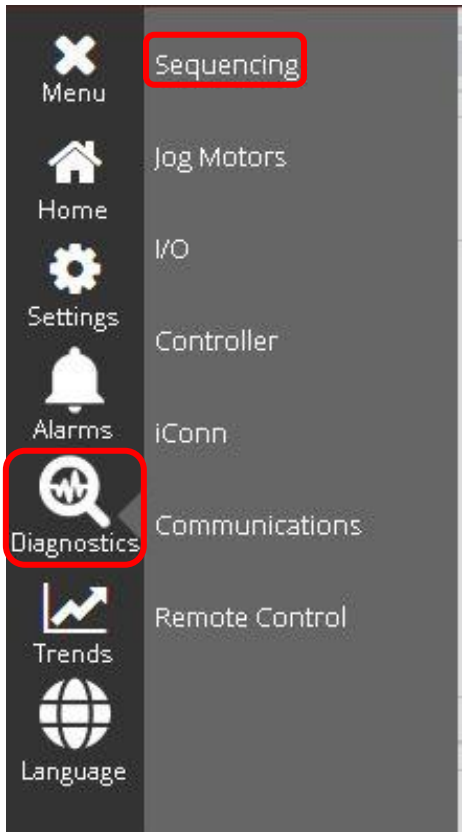

Figure 40: ES+ Sequencing Diagnostics Menu Navigation

The information on the ES+ Sequencing Diagnostics page is shown in Figure 41 below. This page is the same for all machines in the sequencing network regardless of rotation number, and gives an overview of the each of the sequenced machines in the network and information on each, such as

the name of the machine, run hours, load hours, operation mode, and the sequence number (unit number).

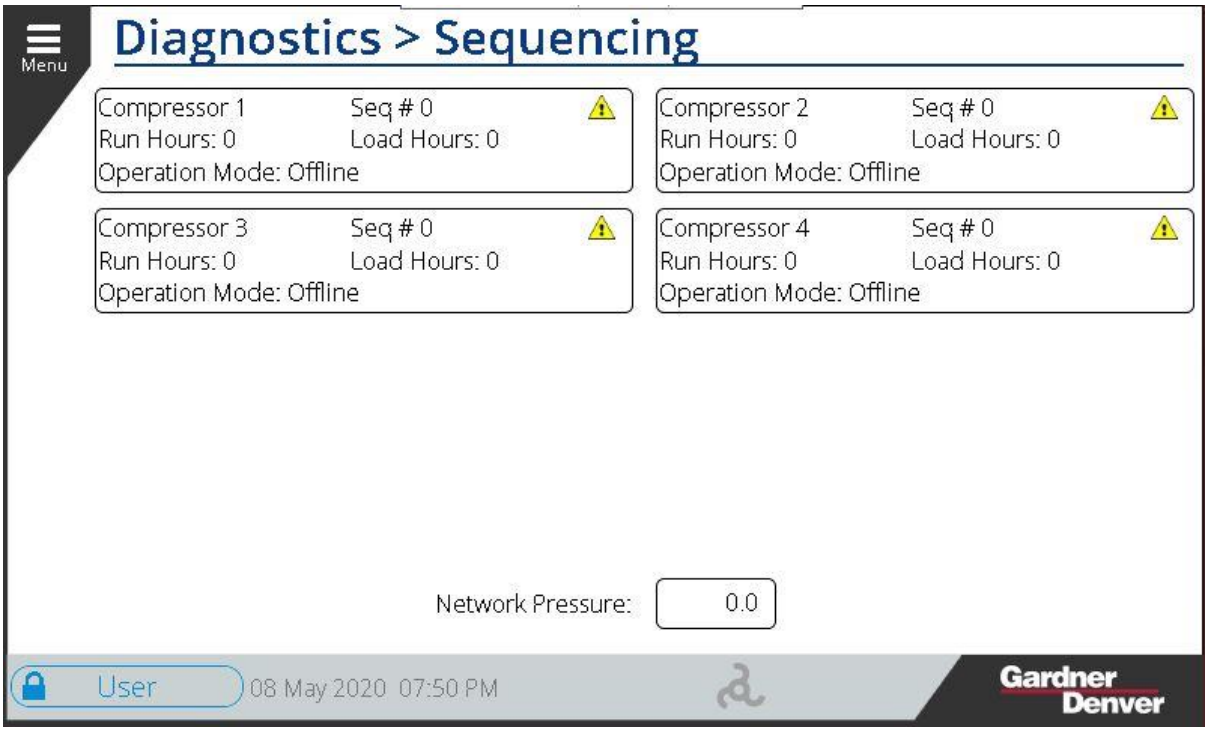

Figure 41: ES+ Sequencing Diagnostics Page for a Master/Slave

NOTES:

NOTES:

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www.contactgd.com/compressors

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