Sporlan Kelvin II Controller

Installation and Operation Instructions

SD-324M/122011 Controller v. E

The Sporlan Kelvin II is a standalone superheat controller. The Kelvin II controller may also be connected with a Modbus® master for remote access to pressure and temperature readings in addition to viewing and editing the controller's setpoints. A remote display unit is optional.

Features:

- Superheat control
- Optional room temperature control
- 4-digit LED display and input knob
- OEM version available without display
- Optional remote display unit
- Optional display networking for 2-valve control
- Optional controller networking for remote access
- Four temperature inputs (Sporlan surface or air sensors)
- One pressure input (Sporlan transducer)
- One digital input (for external switch or relay)

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Kelvin IIsd	p/n 952567	Controller with a display	
Kelvin IIs	p/n 952569	Controller without a display	
Kelvin IId	p/n 952568	Remote display unit	

1. INSTALLATION

Refer to *Appendix H - Wiring Diagram* and *Appendix I - Sensor Installation*

Tools required:

- Small flat screwdriver for terminal connections
- Phillips and flat screwdrivers
- Cordless screwdriver
- Needle-nose pliers
- Wire cutters
- Scotch-Brite™ pad
- Two #8 x ½" self-tapping screws to mount DIN rail

1. Mount the controller in a rain-tight, protected location using the supplied DIN Rail. To leave enough working space, the suggested mounting area is 10 inches high and 5 inches wide. The minimum depth is 3 inches. See Figures 1 and 2.
2. Connect the suction temperature sensor wires to terminals 31 and 32. The sensor is not polarized.
3. Connect the pressure transducer wires to terminals 33, 34, and 35. Sporlan has used transducer cables with two wire color combinations; see Table 1. **Maximum torque on screw terminals is 3.5 in-lbs.**
4. Connect the optional room temperature sensor wires to terminals 29 and 30. The sensor is not polarized.
5. Connect terminals 27 and 28 to a digital input. A short or a closed contact from an external relay will close the valve for pump down. *See Section 4 - System Operation.*
6. Connect the Sporlan EEV wires to terminals 5, 6, 7, and 8.
7. Connect power wires to terminals 1 and 2. Power requirements are 24 volts AC at 40 VA, Class II transformer.
8. Remove the protective clear film from the front of the Kelvin II controller.

NOTE: Sensor leads may be extended to 100 ft. (30.5 m) with 18 awg wires and Scotchlok™ UR connectors for long- term integrity.

WARNING: Route and secure cables away from hot surfaces, high voltage lines, and moving components.

NOTE: The Sporlan Kelvin II refrigeration controller should be installed only by a qualified professional. All other system components (valves and sensors) should be supplied by Sporlan to ensure compatibility and proper operation. There are no user-serviceable components inside the Kelvin II Controller. Opening the case will void the warranty.

WARNING: Use caution when working around high voltage components. Safety covers should be used for personal safety on high voltage panels.

Figure 1 - Recommended Mounting Clearance

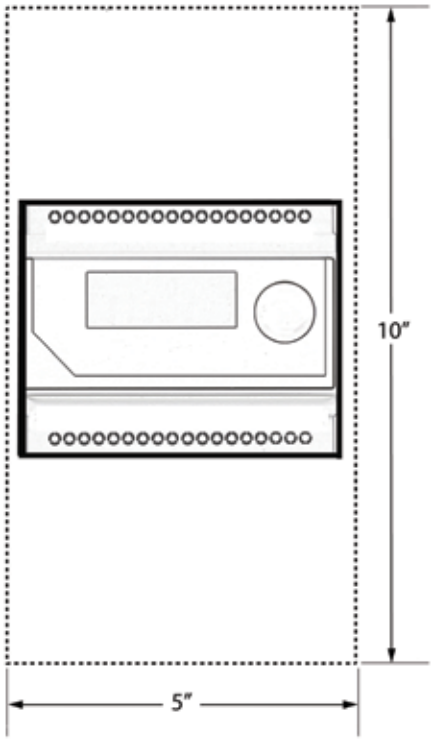


Figure 2 - DIN Rail Detail

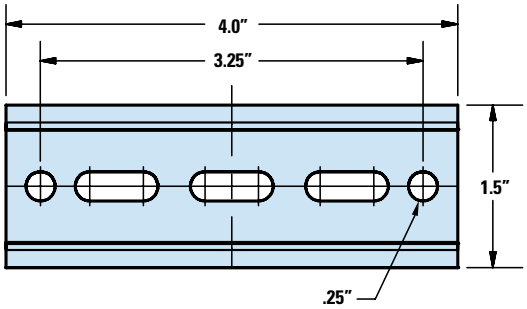


Table 1 - Pressure Transducer Wire Colors

	CONTROLLER TERMINAL	OLD PIGTAIL LEADS	NEW HERMETIC CABLE
+5VDC	35	Red	Black
Signal	33	Green	White
Ground	34	Black	Green

2. SETUP

Kelvin II with Display

The Kelvin II controller has preset setpoints for most system parameters. Basic system parameters will be verified through the setup menu. If additional parameter setpoints need to be changed, follow the steps in this section and in *Section 3 - Setpoint Menu Operation*.

Enter values for six system variables following the steps below. Refer to *Appendix A - Setup Menu*. The EEV is closed upon power-up and the system will not operate until completing setup. The controller will display the firmware versions for the display and the controller. It will then display the first variable to set.

1. Set StEP, Step Motor Stroke. Press and then turn the SELECT knob to select the correct number of steps for the EEV being used. See Table 2 for a list of Sporlan EEVs. Default is 2500. Press the SELECT knob again to save the value. The next variable is displayed.
2. Set rEFr, Refrigerant. Select the actual refrigerant used in the system, following the steps above. Default is R-404A.

NOTE: Verify the actual refrigerant used in the system.

3. Set tt4P, Temperature Sensor Type. Select 2K or 3K; see pictures below. Default is 2K.

2K sensor

3K sensor

4. Set Pt4P, Pressure Sensor Type. Select Absolute or Gauge (sealed), following the steps above. Default is Gauge.
5. Set Un_t, Temperature Units. Select Fahrenheit or Celsius. Default is Fahrenheit.
6. Set Un_P, Pressure Units. Select PSI or Bar. Default is PSI.

Setup is now complete. The Kelvin II will begin controlling superheat, and will display SuPH. The controller is now in the Process Values Menu (Appendix B). Rotate the SELECT knob to view the values.

NOTE: Not all refrigeration systems are designed alike. See *Section 7 - PID Tuning* to adjust the settings according to the specific needs of the system.

Kelvin II without Display

To set up a Kelvin II*s* (controller without an LED display) that is connected to either a Kelvin II*d* (remote display unit) or a Kelvin II*sd* (controller with a display), first go to *Section 5 - Display Networking* to establish a network connection. Then follow the directions in this section and in *Section 3 - Setpoint Menu Operation*.

3. SETPOINT MENU OPERATION

See *Appendix C - Setpoint Parameters*. All setpoints must be verified prior to system startup for proper system operation. It may be necessary to adjust these parameters for a specific system. Details on advanced features can be reviewed in *Section 4 - System Operation*.

1. Enter the Setpoint Menu: Press the SELECT knob for 5 seconds. Enter the password " 111 " and press the SELECT knob again.
2. To view a parameter, rotate the SELECT knob to the desired parameter and press the knob. The default value will display.
3. Turn the SELECT knob to change the value and then press the SELECT knob to enter the value and return to the Setpoint Menu.
4. After all desired parameters are set, turn the SELECT knob to "ESC" and press the knob to save and implement all changes. Observe the system for proper operation.

NOTE: The Setpoint Menu times out after 60 seconds of inactivity and you will lose all changes entered.

The Kelvin II is now operational and displaying the Process Values Menu (Appendix B). To view system parameters while in operation, turn the SELECT knob and scroll through the menu. Select the desired parameter. For example, to view system superheat, turn the SELECT knob to SuPH. After a few seconds, the actual system superheat will be displayed. See *Appendix B – Process Values* for a description of each variable.

Pressing the SELECT knob at any time will display the Controller Display Address CAdr.

Table 2 - Electric Expansion Valves

SPORLAN MODEL NUMBERS	STEPS
SEI-.5, SEI-1, SER-1.5, SEI-2, SEI-3.5 SEI-6, SER-6, SEI-11, SER-11, SER-20	1596
SER-B, C, D, G, J, K, L	2500
SEI-30	3193
SEI-50, SEH-100, SEH-175	6386
ESX	400

4. SYSTEM OPERATION

The Sporlan Kelvin II controller can be configured as a standalone superheat controller or a refrigerated space temperature controller. The controller can be used in refrigeration systems, chillers, or air conditioning systems. The Kelvin II should not be used inside of a conditioned space that exceeds product specifications (See *Appendix E - Technical Specifications*).

The controller, by default, is designed to control superheat in refrigerated spaces that use evaporator pressure regulators (EPRs). In all applications, use a normally closed solenoid valve upstream of the electronic expansion valve to ensure positive shutoff of refrigerant flow during power loss.

Refrigeration

Superheat control on cases with EEPR (preferred method):
The Kelvin II will regulate the refrigerant flow entering the evaporator to achieve the superheat set point. The EEPR is typically controlled by a system level controller and provides consistent evaporator temperatures based on the discharge air set point (set through the system controller). This combination provides greater stability in control, increased efficiency of the evaporator coil, and accurate case temperatures.

Superheat control on cases with liquid line solenoid or suction stop solenoid valves:
Some applications in refrigeration that typically use mechanical expansion valves also use a solenoid valve upstream (liquid line) or downstream (suction stop) of the TEV to control case temperature. The system controller closes and opens the solenoid valve to meet cut-in and cut-out temperatures. If the Kelvin II controller is used on these systems in conjunction with an EEV, a digital input must be connected to the Auxiliary Temperature Sensor terminals (27 and 28 in *Appendix H – Wiring Diagram*). Since refrigerant flow is a critical part of the Kelvin II control scheme, the controller must be tied into the liquid line solenoid or suction stop solenoid when flow is stopped. This input allows the controller to respond to major flow variations upstream or downstream of the EEV.

Case temperature control using cut-in / cut-out:
The Kelvin II can be used as a thermostat by connecting a room sensor to T2 (terminals 29 and 30) and setting C_ in and Cout to the desired cut-in and cut-out temperatures respectively. For optimum control, the room sensor must be located inside the case as specified by the case manufacturer. Connect a normally closed solenoid valve (upstream of the EEV) to terminals 19 and 20. The controller will maximize the efficiency of the evaporator coil by regulating the EEV to control superheat until the cut-out temperature is reached. The solenoid valve and EEV will then close until the temperature rises to the cut-in temperature. During defrosts, a digital input must be connected to the T3 Temperature Sensor terminals (27 and 28 in *Appendix H – Wiring Diagram*) so the controller will close the EEV. A standard dry contact relay can be used.

Minimum relay on and off time:
This feature is used to prevent compressor short cycling when the Kelvin II is used as a thermostat using the C_ in and Cout with the room sensor attached to T2 (terminals 29 and 30) in a

standalone system. These settings should be set according to the compressor manufactuer recommendations. When the Kelvin II receives a pump down or defrost call at the T3 temperature sensor terminals (27 and 28) the system will not execute the procedure to pump down until the minimum relay on time has expired.

Minimum Relay On Time, ront - The amount of time (minutes) the output of the relay (terminals 19 and 20) must remain on after it is energized.

Minimum Relay Off Time, roFt - The amount of time (minutes) the output of the relay (terminals 19 and 20) must remain off after it is de-energized.

WARNING: The default setting for the Minimum Relay On and Off time is 0 minutes. For a standalone system you must set the values for this feature to be utilized and prevent compressor short cycling.

NOTE: Use caution. An oversized compressor can cause low product temperatures during minimum relay on time cycle.

CHILLERS AND AIR CONDITIONERS

Superheat control - Single evaporator:

The Kelvin II controller may be used on single evaporator chillers or air conditioners. The default control scheme is optimized for quick pull down (coil temperature) and stable holding loads. If the controller is used on systems with major transient conditions (impulse heat loads) it may be necessary to adjust the PID control scheme parameters. See *Section 7 - PID Tuning*.

Superheat control - Dual evaporator:

On some systems, it may be necessary to control two independent evaporator coils. This setup will consist of a Kelvin II with display and a Kelvin II without display. A network must be established between the two controllers; see *Section 6 – Controller Networking*. The display can be used to set up both controllers and to review parameters from each evaporator coil.

ADVANCED FEATURES

Pumpdown

Closing or shorting terminals 27 and 28 (T3) places the controller in pumpdown mode and closes the EEV. A standard dry contact relay can be used. During pumpdown signal, the Kelvin II will open terminals 19 and 20 (relay), which can be used to pilot a solenoid valve or compressor. During this time, the controller will shut down the control scheme and prepare for restart. This ensures maximum control efficiency and system stability.

Bleed System Equalization

Use of an electric expansion valve (EEV) can dramatically improve the efficiency of a cooling system. By accurately controlling the system's superheat, the EEV achieves full utilization of the evaporator coil surface area. A drawback to the use of EEVs with some compressors is the need for off-cycle pressure equalization. Specifically, when the system is off the compressor is not cycling refrigerant and the EEV is closed, keeping refrigerant from flowing through the system. This condition can cause high backpressure on the discharge side of the compressor, and hence a hard starting condition. Setting a Bleed Step Position, b_St, allows a small amount of liquid refrigerant to pass through the EEV. Normal industry practice is to set a bleed to equalize the system in 3-5 minutes. The Kelvin II also allows the delay of the bleed process by setting the parameter b_dL.

Manual Valve Positioning

The Kelvin II can be used to manually control the EEV via local or remote displays. Access the Setpoint menu and change SPoS to the desired valve position, between 0 and 100% of full stroke. The system will time out after 60 minutes of inactivity while in manual control. To end manual control of the EEV, press the SELECT knob to go back to SPoS.

The EEV can also be manually controlled via Modbus by writing a 1 to the "Manual Valve Enabled" coil (see *Appendix J - Modbus Memory Map)*.

NOTE: To avoid floodback, start with the valve in the low position. Never leave the sysem unattended while in manual mode.

ADDITIONAL HELPFUL SYSTEM PARAMETERS

Delay On, d_on - The amount of time the EEV will be placed in the specified "Delay Percent Open" position before the internal relay (terminals 19 and 20) is activated. Range is 0 to 60 seconds. Time starts when the valve reaches the "Delay Percent Open" setting. This feature can be used on small single compressor systems to position the valve prior to starting the system. Terminals 19 and 20 can be used to pilot a compressor relay.

Delay Off, doFF - The amount of time the system waits to de-energize terminals 19 and 20. If called to shut off the system, it closes the EEV and waits for system pumpdown by the specified Delay Off time, then deenergize the relay (terminals 19 and 20). Delay Off time starts when EEV is at 0%.

Delay Percent Open, d_St - The position the valve will be placed in prior to starting. Used in conjunction "Delay On".

Low Operating Pressure, L_oP - This setting can be used in smaller systems for startup. If the EEV is not open enough (superheat above set point and pressure below LOP) the Kelvin II will open the EEV 100% to equalize system pressure to maintain mass flow to keep the system running. It will go back to controlling superheat when suction pressure rises above LOP setpoint. Superheat control takes priority as a safeguard.

Maximum Operation Pressure, H_oP - Used in various systems to control maximum suction pressure. The Kelvin II limits the amount of high pressure / high temperature gas going to the compressor by closing the EEV when pressure is within 3 psi of the Maximum Operating Pressure setpoint.

Max Valve Capacity, H iCP - The maximum opening position of the valve. Can be used to compensate for an improper, oversized EEV. If set too low, system superheat may become too high.

Dead Band, dbnd - Provides a smoother operational range around superheat set point. For tighter superheat control, the deadband may be decreased. Options are in degrees superheat around set point, 1 (+/- 1 degree) or 2 (+/- 2 degrees).

Supermarket Mode, SuPS - Supermarket Mode uses a PID control scheme that is designed for refrigerated cases that use evaporator pressure regulators. This default mode provides quick

case temperature pull down after defrost and refrigeration off time. Once the system reaches steady state control, the controller will adjust the electronic valve movement to minimize superheat oscillation. The PID settings under this mode will only adjust the steady state condition. See PID section for further information on adjustments.

5. DISPLAY NETWORKING

A Kelvin II remote display unit can be connected to another Kelvin II controller in order to set up that controller, view that controller's process values, and change setpoints.

To network a Kelvin II*s* (controller without an LED display) with a Kelvin II*d* (remote display unit):

1. Connect the two controllers with a Cat-5 Ethernet cable.
2. The remote display unit will access the Kelvin II*s*.
3. Set up the Kelvin II*s* controller (*Section 2 - Setup*).

To network a Kelvin II*s* (controller without an LED display) with a Kelvin II*sd* (controller with a display):

1. Connect the 2 controllers with a Cat-5 Ethernet cable.
2. The Kelvin II*sd* must have its CAdr parameter (Display Address) set to 1-99 to enable display networking. Navigate to "End" in the process variables display of the Kelvin II*sd* and press the SELECT knob to select a different controller on the display network. (Controller should display "LocL")
   Note: "End" is not available if "CAdr" is 0.
3. Turn the SELECT knob to find the Kelvin II*s* (2 is default for the Kelvin II*s*), and press the knob to connect.
4. After a connection is established the display should switch from "----" to the firmware version of the Kelvin II*s* controller followed by the setup screen (if the controller has not been set up as described in Section 2).

The local controller is listed as LocL. To view a different controller on the display network, rotate the SELECT knob to CAdr and then press and release the knob. Rotate the knob to select the address of a controller. Once the address is selected it will take a moment to boot up. Setpoints on any controller can be changed as described in *Section 3 - Setpoint Menu Operation*.

The CAdr of a Kelvin II*s* controller can also be set through Modbus.

Multiple Controllers

The CAdr of a Kelvin II*s* controller, display address 3-99, must be set individually using a Kelvin II*d* or through Modbus.

Three or more controllers can be networked through the use of a special junction box that is easily fabricated. The controllers are wired to the junction box using the RJ-45 jacks and Cat 5 Ethernet cable (see *Figure 3 - Display Networking*). Kelvin II controllers can connect to any junction box ports. Unpowered remote display units (Kelvin II*d*) should be connected to specially wired ports designated for the remote display, shown in red in Figure 4.

Junction Box Fabrication

Category 5E junction boxes can be sourced from L-com.

- Model SMM45-6W can connect 6 controllers (1 remote display and 5 Kelvin II controllers with or without displays).
- Model SMM45-12W can connect 12 controllers.

Kelvin II*d* remote displays, being unpowered, must be connected to an energized port (red jacks in Figure 3), with a powered controller plugged into the other red jack. If all the networked controllers are powered models, no special wiring (red jacks) is necessary.

To wire a junction box, punch down all blue and blue/white wires. To wire a pair of energized (red) jacks, punch down brown and brown/white wires between 2 jacks. See Figure 4.

Figure 3 - Display Networking

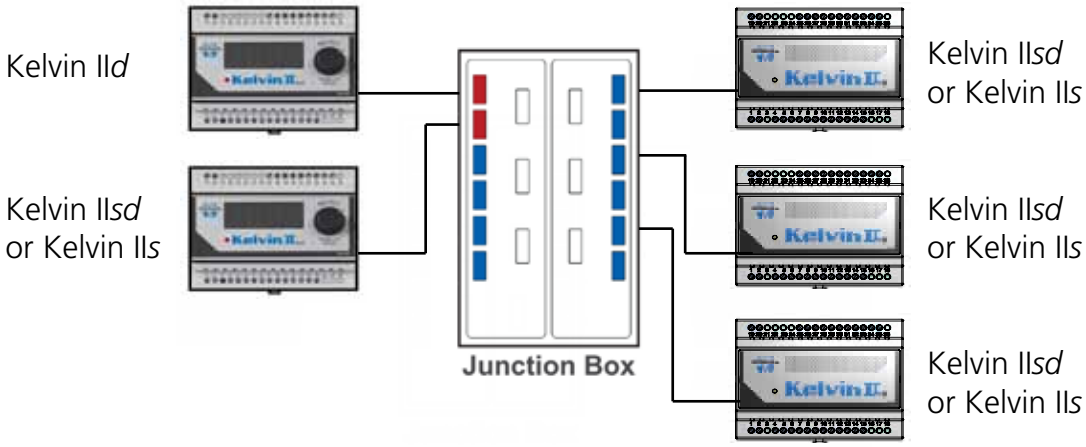
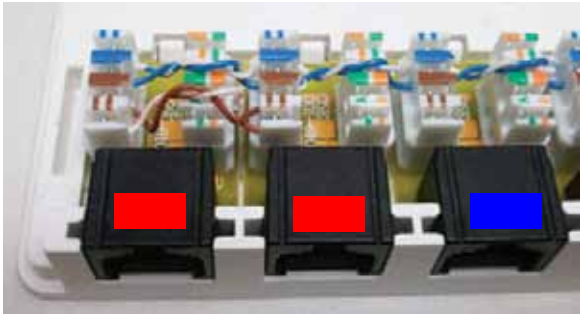


Figure 4 - Wiring the powered (red) jacks



6. CONTROLLER NETWORKING

The Sporlan Kelvin II can communicate with a Modbus communication master via RS485 to transfer process values and setpoints. See *Appendix J - Modbus Memory Map*.

The Kelvin II supports only the RTU transmission mode. The serial settings are:

- 9600 baud (default), 19200 baud, 38400 baud
- 8 data bits
- 1 stop bit
- Even parity (default), odd parity, no parity

Scaling

For better precision, scaling is used for Bar or Celsius units. PSI and Fahrenheit are whole numbers and have no scaling.

Celsius values transferred via Modbus are 10X. For example, a value of 45 will be transferred for the superheat when the actual superheat temperature is 4.5°C. Remember this when changing a setpoint.

Bar values transferred via Modbus are 100X. For example a value of 1034 will be transferred for the Maximum Operating Pressure when the actual pressure is 10.34 Bar. Remember this when changing a setpoint.

Setup

The Sporlan Kelvin II controllers can be networked to communicate process variables back to a master controller. This information can be used for verifying system performance or updating individual setpoints via RS-485 and PC interface. Data can be accessed remotely through the master controller. For further information on remote monitoring, see the documentation for the master controller.

Prior to connecting the network, each controller must be assigned a separate address on the Modbus network, Addr. Refer to *Section 3 – Setpoint Menu Operation* to enter the Setpoint menu. Once in the Setpoint menu, scroll to Addr and assign each controller on the network an individual address. Note that no two controllers can have the same address. Default address for each controller is '1'.

NOTE: Addr is the Modbus address, CAdr is the controller display address.

Modbus Connection Requirements

See *Figure 5 - Modbus Wiring*.

Wire Type: 18 AWG Universal Twisted Pair

Maximum Number of Network Nodes: 100

Maximum Run Length: 4000 ft

Recommended Network Configuration: Daisy Chain, a single continuous transmission line from one end to the other. Other configurations involving triple-lug connections, such as star, are not recommended. See Figure 6.

Noise Reduction: Termination resistance (R_T in Figure 5) is recommended to reduce reflections and noise on the data transmission lines. Place the resistance at the extreme ends of the cable, with the resistance value matching the characteristic impedance of the transmission line (typically 120 ohms for twisted pair cables).

Shielding prevents noise from EMI sources. If the cable is shielded, connect the shield to earth ground at one end only. NOTE: Do not connect shield to RS485 GND.

Keep RS485 wiring away from high voltage AC lines to reduce noise and data errors on the communication lines. RS485 communication cable should be placed perpendicular to AC lines at any intersection.

Grounding: Connect a third conductor to RS485 GND (terminal 13) to prevent ground potentials between nodes. This conductor should be included in the shield of the twisted pair cable to prevent noise. NOTE: Do not connect RS485 GND to earth ground.

Third Party Controllers: To avoid nuisance "network errors", the use of third-party controllers on the same RS485 network with Sporlan controllers is not recommended.

See *Appendix J - Modbus Memory Map*. Also, refer to the documentation supplied with the communication master for additional RS485 network requirements.

Figure 6 - Daisy Chain Network Configuration

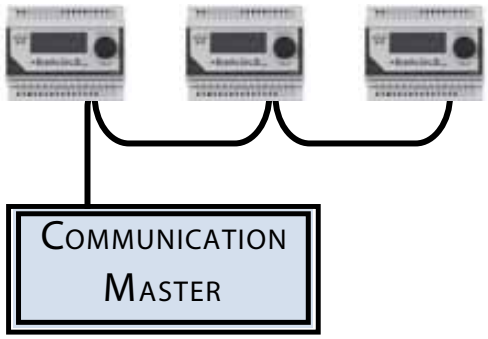
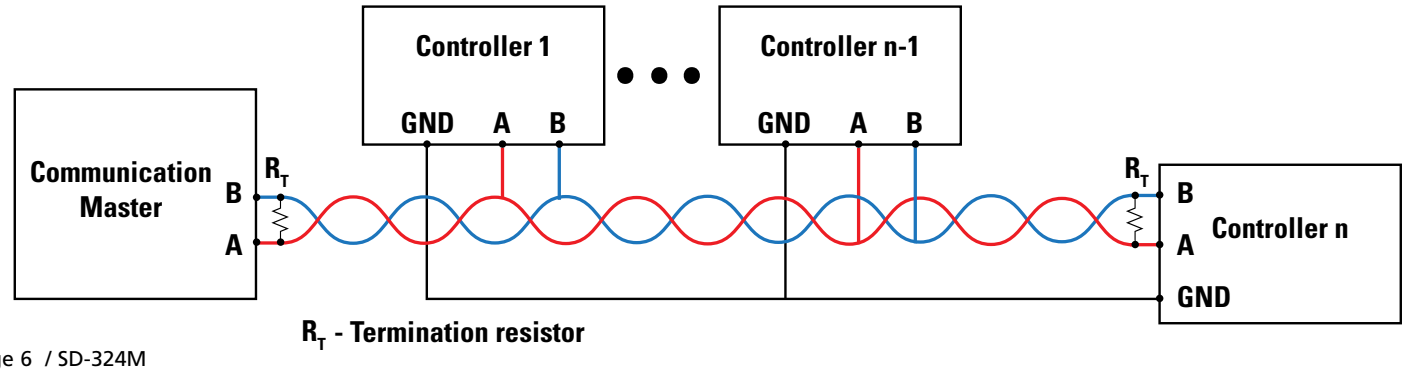


Figure 5 - Modbus Wiring



7. PID TUNING

If temperature pull down is satisfactory, then the default control scheme (supermarket mode) should be used. The PID values may be adjusted if superheat is not stable. If superheat is oscillating around setpoint at steady state conditions, reduce PID settings to half of existing values. If pull down is not satisfactory, then the Kelvin II can be configured into a standard PID scheme that can be fully adjustable. This feature can be accessed by entering the Setpoint Parameters Menu as described in Section 3. Go to parameter SuPS, supermarket mode, and change its value to OFF.

NOTE: Only experienced professionals should access this feature. System stability and performance may be improved by adjusting PID.

The Kelvin II is factory programmed with default Proportional–Integral–Derivative (PID) settings that will provide efficient control. It may be necessary, however, to fine tune the PID settings in applications where systems experience rapid transient conditions (such as frequent "impulse" changes in loading or mass flow rates).

In most instances, adjustments to the PI setpoints are adequate. If tuning is needed, see *Section 3 - Setpoint Menu Operation* to enter the PID setpoint menu. The following guidelines should be followed:

- -P- (Proportional Coefficient) - Increase value to increase valve response to superheat.
- -I- (Integral Coefficient) - Increase value to increase valve response to superheat over a given time period.
- -d- (Derivative Coefficient) - Increase value to increase valve response to rate of change in superheat.

When PID adjustments are made, allow adequate time for the system to respond to the changes.

When the superheat is oscillating to extremes, the Proportional and/or the Integral value may be too high. If superheat is slow to react to a transient system change, then the Proportional and/or the Integral value may be too low in value.

NOTE: Not all refrigeration systems are designed alike. Use caution when tuning PID setpoints.

8. TROUBLESHOOTING

SYMPTOM	CHECK
Will not power up	Wiring terminals for power at transformer and controller
	Supply voltage (see Appendix E - Technical Specifications)
Superheat below setpoint	Pressure Transducer Range (correct transducer set up in controller; 0-300, etc)
	Pressure Transducer Type (correct transducer set up in controller; gauge/sealed vs absolute)
	Temperature Sensor Type (correct sensor set up in controller; 2K or 3K (see Appendix I - Sensor Installation)
	Temperature Sensor wiring (ensure sensor locations are not mismatched)
	Foam insulation on piping and sensors
Superheat above setpoint	Liquid condition entering expansion valve
	Pressure Transducer Range (correct transducer set up in controller; 0-300, etc)
	Temperature Sensor Type (correct sensor set up in controller; 2K or 3K, see Appendix I - Sensor Installation)
	EEV (correct valve set up in controller; 1596, 2500 steps, etc)
	EEV sizing (if EEV position in controller is at 100% when symptom exists, EEV may be undersized)
	Heat exchanger sizing
	Proper system refrigerant charge
	Oil return (oil logging in heat exchanger)
	Liquid line filter (clogging or excessive pressure drop)
No Superheat	Wiring terminals (power) at transformer and controller
	Proper system refrigerant charge
	Pressure Transducer Range (correct transducer set up in controller; 0-300, etc)
	Pressure Transducer Type (correct transducer set up in controller; gauge/sealed vs absolute)
	Temperature Sensor Type (correct sensor set up in controller; 2K or 3K (see Appendix I - Sensor Installation)
	Temperature Sensor wiring (ensure sensor locations are not mismatched)
	Foam insulation on piping and sensors
Superheat unstable	Wiring terminals (power) at transformer and controller
	Wiring terminals (sensors) at controller
	Sensor locations
	Sensor operation (See additional information under Section 8 - Troubleshooting)
	Proper heat exchanger flow direction
	Stability of head pressure control valves (upstream of EEV)
	Stability of suction pressure control valves (downstream of EEV)
	Stability of rack controller (verify compressors are not short cycling)
	Controller PID setting (See Section 7 - PID Tuning)
No Communication	Wiring at controller and master communication board
	Addresses of controllers (see Section 6 - Controller Networking)
Communication errors	Wiring terminals at controller and master communication board
	Network wiring from controller to master communication board (see Section 5 - Controller Networking)
	Proper network wire grounding (see Section 6 - Controller Networking)
	Termination resistors (see Section 6 - Controller Networking)
	Network parameters in controller and master communication board (baud rate, parity, etc; see Section 5)
	Third-party controllers on Control network
Setpoints not saved	ESC must be set within 60 seconds of changes being made

Troubleshooting Recommendations

As with any refrigeration component troubleshooting, actual system conditions should be verified with a gauge set and a calibrated temperature sensor (i.e verify actual superheat and refrigerant condition). This system information is valuable in determining whether it is component related or system related.

For systems or applications that experience light loads on the Kelvin II circuit, it is important that the heat exchanger and refrigerant lines are sized correctly. This will ensure proper oil return and will minimize the effects of oil logging in the heat exchanger. Many heat exchanger manufacturers recommend a hot gas bypass for loads below 50%.

Sensors

Failed sensors will trigger an alarm. An alarm code will show which sensor is mis-wired, disconnected, or faulty. The alarm will persist until the problem is corrected.

Failed temperature sensors may read extremely low or infinite resistance when tested with an ohmmeter. Readings should be taken with the sensor disconnected from the Kelvin II. A missing or disconnected temperature sensor will read -60 on the controller.

Temperature sensor output can be checked by measuring the DC voltage across the sensor wires and consulting the tables in Appendix K and Appendix L.

2K and 3K sensors have approximately 1.9KΩ and 2.8KΩ, respectively, at 80˚F measured across sensor wires.

Pressure transducers must be installed tight enough to depress the valve stem in the fitting. Failure to do so will result in erroneous pressure readings and possibly leaks.

Pressure transducers should be tested while connected to the controller and powered. Test at the controller terminals. Voltage between terminals 34 and 35 should be 4.8 - 5.2 volts DC. Voltage between 33 and 34 should be between 0.5 and 4.5 volts DC. See *Table 1 - Pressure Transducer Wire Colors*.

To test the accuracy of the transducer, use a gauge set to obtain the actual system pressure. For volts-to-pressure conversion, measure the voltage between terminals 33 and 34. Identify the pressure transducer used and find the correct range Prn9 in *Table 3*. Substitute the measured voltage (v) into the formula in the PSI column. The result should be within 3 psi of the actual system pressure shown on the gauge set. If not, check the transducer for proper installation, correct Schrader valve, and verify the pressure range identified on the transducer.

To test the transducer cable, disconnect the cable from the transducer and check for 4.8 - 5.2 volts between terminals **+** and **–** . See *Figure 7 - Pressure Sensor Cable*.

Figure 7 - Pressure Sensor Cable

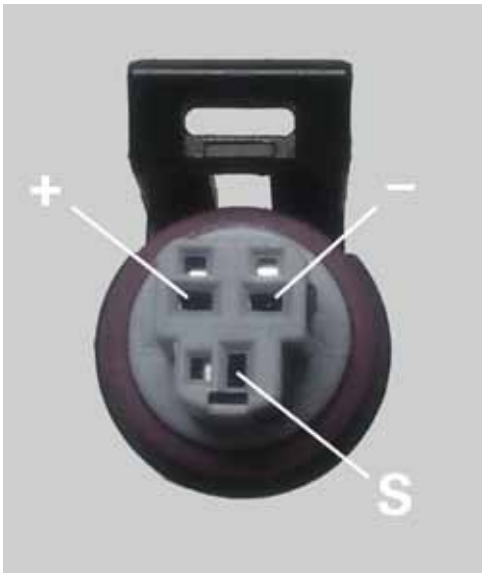


Table 3 - Pressure Transducer Specifications

LABEL COLOR	Prn9	PSI
Green	150	(v-.5) x 37.5
None / Silver	300	(v-.5) x 75
Yellow	500	(v-.5) x 125

ALARMS

If the superheat is 2 degrees below setpoint for 30 seconds, the controller will display the alarm LSHA.

Alarms will persist until the problem is corrected.

Table 4 - Alarm Actions

ALARM	DESCRIPTION	ACTION
PSAL	Pressure Sensor Failure	Pumpdown (open terminals 19 & 20) and close EEV
tSAL	Suction Temp Sensor Failure	Pumpdown (open terminals 19 & 20) and close EEV
LSHA	Low Superheat	If superheat is 2 degrees or less, EEV will close more aggressively
HSHA	High Superheat	No system response

APPENDIX A - Setup Menu

DISPLAY	DESCRIPTION	OPTIONS
StEP	Valve Type	**Display Readout** / **Description** 1596 — 1596 Step Bipolar Valve 3193 — 3193 Step Bipolar Valve **2500** — **2500 Step Bipolar Valve** 6386 — 6386 Step Bipolar Valve 400 — 400 Step Unipolar Valve
rEFr	Refrigerant Type NOTE: Select the **actual** refrigerant used in the system.	**Display Readout** / **Description** r22 — R-22 134A — R-134a 402A — R-402A **404A** — **R-404A** 407A — R-407A 407C — R-407C 410A — R-410A 417A — R-417A 422A — R-422A 422d — R-422D r507 — R-507A r744 — R-744 245F — R-245FA r-E5 — R-E5 438A — R-438A 401b — R-401B 408A — R-408A 508A — R-508A 508b — R-508B
tYP	Temperature Sensor Type	**Readout** / **Description** tYP3 — 3K Thermistor **tYP2** — **2K Thermistor**
PtYP	Pressure Sensor Type	**Display Readout** / **Description** AbSL — Absolute Pressure Type **GAUG** — **Gauge (Sealed) Pressure Type**
Un_t	Temperature Units	**Display Readout** / **Description** **FAHr** — **Fahrenheit** CELS — Celsius
Un_P	Pressure Units	**Display Readout** / **Description** **PSI** — **Pounds per square inch** bAr — Bar units

Counterclockwise

Clockwise

Default values are highlighted.

APPENDIX B - Process Values

<table>
<tr><th>PROCESS</th><th>DESCRIPTION</th><th>RANGE</th></tr>
<tr><td>End</td><td>End display session with controller</td><td>Controller display address CAdr must be reset *</td></tr>
<tr><td>SuPH</td><td>Superheat (t_{out}-t_{sat})</td><td>0 to 165°F (0 to 91.6°C)</td></tr>
<tr><td>SucP</td><td>Suction Pressure</td><td>Depends on pressure sensor range and type
-14.7 to 500 PSI (-1.01 to 34.47 Bar) Max. range</td></tr>
<tr><td>tSAt</td><td>Saturation Temperature</td><td>-60 to 150°F (-51.1 to 65.6°C)</td></tr>
<tr><td>tout</td><td>Suction Temperature</td><td>-60 to 150°F (-51.1 to 65.6°C)</td></tr>
<tr><td>CtP</td><td>Case / Room Temperature</td><td>-60 to 150°F (-51.1 to 65.6°C)</td></tr>
<tr><td>PoSn</td><td>EEV Position (% of max stroke)</td><td>0 to 100% Open</td></tr>
<tr><td>S-3</td><td>Auxiliary Temperature 1
or Pumpdown State</td><td>-60 to 150°F (-51.1 to 65.6°C) if input is within range for a valid temperature reading
Otherwise:
<table>
<tr><th>Display</th><th>Description</th></tr>
<tr><td>CooL</td><td>Cool Mode - High Resistance or open on T3</td></tr>
<tr><td>Pdn</td><td>Pumpdown Mode - Low Resistance or short on T3</td></tr>
</table></td></tr>
<tr><td>S-4</td><td>Auxiliary Temperature 2</td><td>-60 to 150°F (-51.1 to 65.6°C)</td></tr>
<tr><td>rELA</td><td>Relay Status</td><td>
<table>
<tr><th>Display</th><th>Description</th></tr>
<tr><td>dEnG</td><td>Relay is de-energized (open)</td></tr>
<tr><td>EnG</td><td>Relay is energized (open)</td></tr>
</table></td></tr>
<tr><td>StAt</td><td>System State</td><td>
<table>
<tr><th>Display</th><th>Description</th></tr>
<tr><td>SEtU</td><td>Setup Mode</td></tr>
<tr><td>OFF</td><td>Off Mode</td></tr>
<tr><td>COOL</td><td>Cool Mode</td></tr>
<tr><td>Pdn</td><td>Pumpdown Mode</td></tr>
<tr><td>StPO</td><td>Manual Valve Override Mode</td></tr>
</table></td></tr>
<tr><td>ALS</td><td>Controller Alarms</td><td>
<table>
<tr><th>Display</th><th>Description</th></tr>
<tr><td>nonE</td><td>No Active Alarms</td></tr>
<tr><td>PSAL</td><td>Pressure Sensor Failure</td></tr>
<tr><td>tSAL</td><td>Suction Temp Sensor Failure</td></tr>
<tr><td>LSHA</td><td>Low Superheat Alarm</td></tr>
<tr><td>HSHA</td><td>High Superheat Alarm</td></tr>
</table></td></tr>
</table>

NOTE: The controller's default menu is the Process Values Menu.

*If the controller display is alternating between CtrL, and either a number 1-99 or LocL, then scroll to LocL and press the SELECT knob to view the local controller attached to this display. Press and hold the SELECT knob for approximately 5 seconds and enter password 111 when prompted. Scroll to CAdr (Controller address) and set it to 0. Exit the setpoint menu.

APPENDIX C - Setpoint Parameters

PARAMETERS			
ESC	Escape and save settings	-	
SHSP	Superheat Setpoint Change to desired Superheat Setpoint	5 to 45°F (2.7 to 25°C) Default is 10°F (5.5°C)	
rEFr Chosen at Setup	Refrigerant Type Change to desired Refrigerant Type	r22	R-22
		134A	R-134A
		402A	R-402A
		404A	R-404A
		407A	R-407A
		407C	R-407C
		410A	R-410A
		417A	R-417A
		422A	R-422A
		422d	R-422D
		r507	R-507A
		r744	R-744
		245F	R-245FA
		r-E5	R-E5
		438A	R-438A
		401b	R-401B
		408A	R-408A
		508A	R-508A
		508b	R-508B
d_on	Delay On	0 to 60 seconds Default is 0	
doFF	Delay Off	0 to 60 seconds Default is 0	
d_St	Delay Step Position Open of Valve	0 to 100% Default is 0%	
b_St	Bleed Step Position of Valve %	0 to 15.0% Default is 0.0%	
b_dL	Bleed Delay Time	0 to 9999 seconds Default is 0	
L_oP	Low Operating Pressure	Values depend on pressure sensor range & type -14.7 to 485 psi (-1.03 to 9.30 Bar) max. range	
H_oP	Maximum Operating Pressure	Values depend on pressure sensor range & type 5 to 485 psi (1.37 to 34.47 Bar) max. range	
C_in	Cut-in Temperature	-59 to 125°F (-50.5 to 51.6°C) Default is -59 (-50.5 C)	
Cout	Cut-out Temperature	-60 to 125°F (-51.1 to 51.0°C) Default is -60 (-51.1 C)	
ront	Minimum Relay On Time	0 to 10 (default is 0)	
roFt	Minimum Relay Off Time	0 to 10 (default is 0)	
H iCP	Max Valve Capacity	0 to 100% Default is 100	
SUPS	Supermarket Mode	ON or OFF	
dbnd	Superheat Control Deadband	1 (+/-1°F) or 2 (+/-2°F) Default is 2	
		SUPS ON	***SUPS OFF***
-P-	Proportional Coefficient	0 to 18 Default is 6	0 to 50 Default is 6
-I-	Integral Coefficient	0 to 24 Default is 12	0 to 100 Default is 12
-d-	Derivative Coefficient	0 to 4 Default is 1	0 to 50 Default is 1

Counterclockwise

Clockwise

Default values are highlighted.

APPENDIX C - Setpoint Parameters (continued)

PARAMETERS			
StEP Chosen at Setup	Valve Type	1596	1596 Step Bipolar Valve
		3 193	3193 Step Bipolar Valve
		2500	2500 Step Bipolar Valve
		6386	6386 Step Bipolar Valve
		400	400 Step Unipolar Valve
SPoS	Manual Valve Position	0 to 100% Open Default is current valve position	
nEt	Network Type	nbUS (Modbus) or ProP (Network Master)	
Addr	Modbus Network Address	1 to 255 Default is 1	
bAud	Modbus Baud Rate	96	9600
		192	19200
		384	38400
nPAr	Modbus Network Parity	nonE	No Parity
		EvEn	Even Parity
		odd	Odd Parity
Un_P	Pressure Units	PSi	Pounds Force Per Square Inch
		bAr	Bars
Un_t	Temperature Units	FAHr	Fahrenheit
		CELS	Celsius
ttyP Chosen at Setup	Temperature Sensor Type	**Readout**	**Description**
		tYP3	3k thermistor
		tYP2	2k thermistor
PtyP Chosen at Setup	Pressure Sensor Type	AbSL	Absolute Pressure Type
		GAUG	Gauge (Sealed) Pressure Type
PrnG	Pressure Sensor Range	Auto	Based on Refrigerant
		150	0-150 psi
		300	0-300 psi
		500	0-500 psi
CALP	Pressure Sensor Calibration Offset	-5 to 5 psi (-.34 to .34 Bar) Default is 0 psi (0.00 Bar)	
CLt1	Suction Temperature Calibration Offset	-5 to 5°F (-2.7 to 2.7°C) Default is 0	
CLt2	T2 / Room Temperature Calibration Offset	-5 to 5°F (-2.7 to 2.7°C) Default is 0	
CLt3	T3 Temperature Calibration Offset	-5 to 5°F (-2.7 to 2.7°C) Default is 0	
CLt4	T4 Temperature Calibration Offset	-5 to 5°F (-2.7 to 2.7°C) Default is 0	
CAdr	Controller Display Address	0 to 99 Default is 0 for sd, 2 for s	

Counterclockwise

Clockwise

Default values are highlighted.

APPENDIX D - Accessories

DESCRIPTION	ITEM	NOTES
Kelvin II Refrigeration Control		
Kelvin II sd	952567	Standalone Controller with display
Kelvin II s	952569	Standalone Controller, no display
Kelvin II d	952568	Remote display unit
Parker Sporlan Temperature Probes		
2K Sensor - Nickel plated brass	952662	Used with well. Can be used without well.
3K Sensor - Brass	952551	Not used with well.
Parker Sporlan Pressure Transducers (Select one per controller based on refrigerant)		
PSPT0500SVSP-S	952576	0-500 psis transducer (R744)
PSPT0300SVSP-S	952574	0-300 psis transducer (R410A)
PSPT0150SVSP-S	952572	0-150 psis transducer (all other refrigerants)
Transducer Cables		
PSPT000000CP50	953100	5 meter cable
PSPT000000CP20	953192	2 meter cable
Troubleshooting Accessories		
SMA-12	953276	Handheld digital instrument for testing EEV performance.

APPENDIX E - Technical Specifications

ELECTRICAL

Supply Voltage	20-26VAC 50/60Hz or 22-26.6VDC; Class II input.
Digital Inputs	0-5VDC Max Range, Interface to dry contact or open collector
Analog Inputs	4 Temperature Sensors 2Kohm (3Kohm optional)
	1 Pressure Transducer .5 - 4.5VR
Relay Outputs	100-240VAC, 3A ind/250V
	22-28VDC, 250mA digital output w/ground (Not currently used)
Digital Display	LED - Red, 7 segment, 4 digit
Indicators	LED - Red, Power
User Interface	Optical Encoder (SELECT knob)
Data Interface	RS 485, Modbus

MECHANICAL

Operating Temperature	-40°F to 158°F (-40°C to 70°C)
Humidity	0-95%RH (Non-Condensing)
Enclosure	PC - Light Gray
Wiring	Screw terminal
Mounting	DIN Rail - EN 50 022

COMPLIANCE

Environmental	RoHS
	WEEE
Electrical	CE
	UL/CUL (Recognized per 873)
	FCC (Class A, part 15)
	C-tick

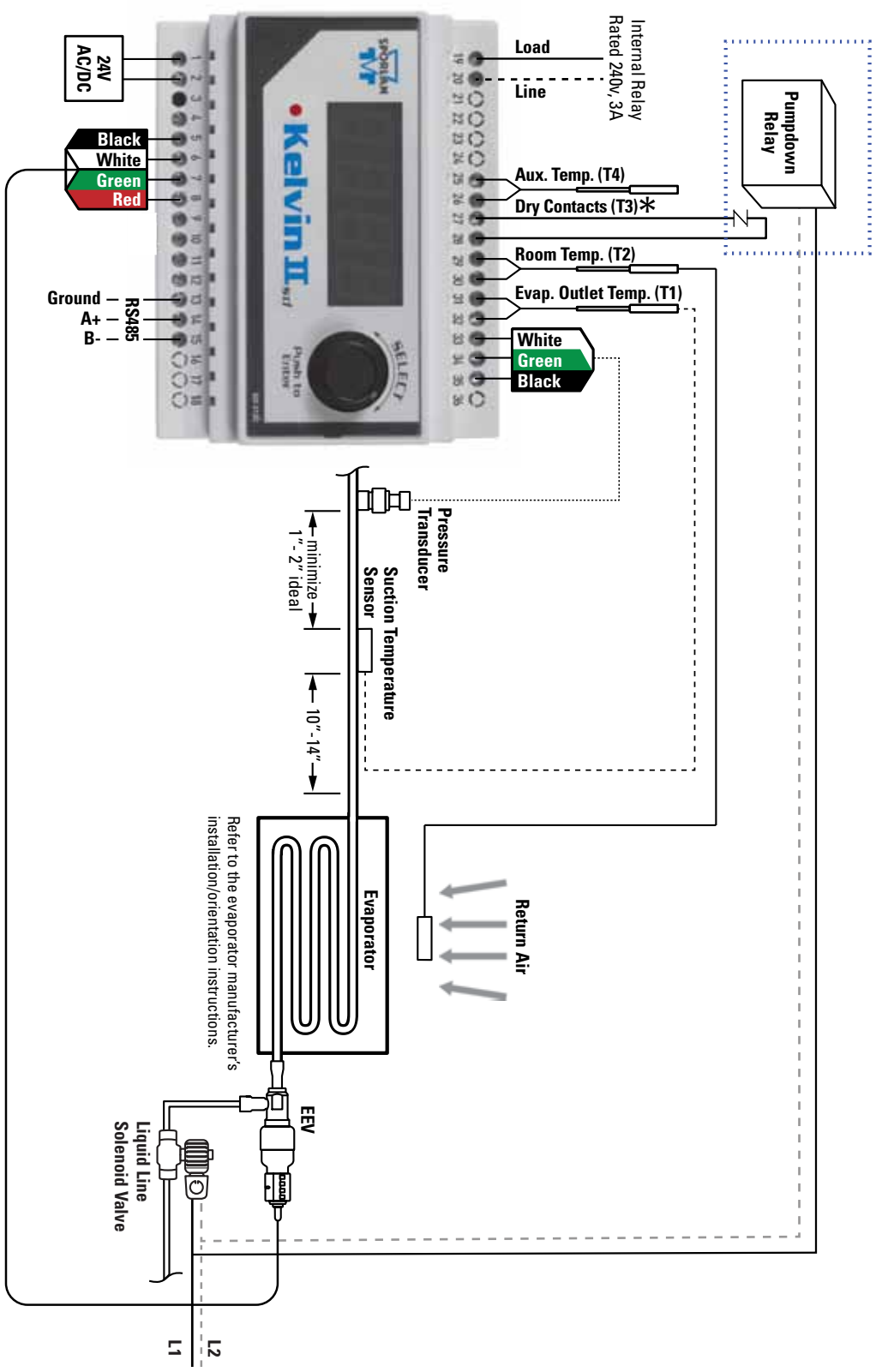
APPENDIX F - Controller Status

DISPLAY	DESCRIPTION
CooL	Compressor running
Pdn	Kelvin II Off (Pumpdown)
OFF	Compressor not running

APPENDIX G - Miscellaneous Displays

DISPLAY	DESCRIPTION
End	Press SELECT knob to exit menu
bAd	The wrong password has been entered
LocL	Shows that readings refer to current controller
CtrL	Shows which controller is displayed

APPENDIX H - Wiring Diagram



*T3 can be used as an Auxillary Temperature Input ***or*** a Pumpdown Input signal.
Note: Piping and sensor insulation is not shown.

For 400 Step Sporlan Unipolar Valve
4 -> Gray Wire
5 -> Orange Wire
6 -> Yellow Wire
7 -> Red Wire
8 -> Black Wire

NOTE: Use caution when working around high voltage components.

APPENDIX I - Sensor Installation

Refer to *Appendix H - Wiring Diagram* for sensor locations.

Mount the Pressure Transducer

1. Locate or install a ¼" SAE access fitting on the suction line near the outlet of the evaporator. Mount it at 12 o'clock on a free-draining horizontal line to decrease the possibility of oil trapping.

WARNING: Remove pressurized refrigerant from the line before installing the fitting.

2. Install the transducer, tighten it to 8 ft-lbs, and check for leaks. Do not use a gasket or a washer.

WARNING: For safety, ensure that the correct Schrader core is installed in the access fitting and use caution when removing Schrader cap/installing transducer to avoid contacting escaping refrigerant.

3. Connect the pressure transducer cable to the transducer.
4. Route and secure transducer cable away from hot surfaces and high power A/C voltage lines.
5. Connect transducer wires to the Kelvin II controller.
6. Ensure pressure range and type (gauge or absolute) are configured properly in the Kelvin II, See *Section 2 - SETUP.*
7. After startup, use a gauge set to verify proper pressure reading through the controller. An improperly installed Schrader core can cause erroneous pressure readings.
8. Check for leaks after system is in operation.

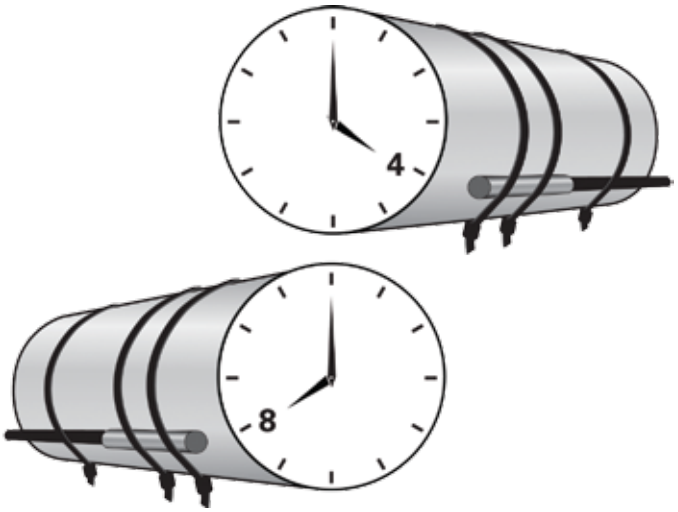
Mount the Suction Outlet Temperature Sensor

1. Per *Appendix H - Wiring Diagram*, the temperature sensor should be installed 10-14 inches from the heat exchanger, on a free-draining horizontal line. Minimize the distance from the pressure transducer.
2. Use Scotch-Brite™ to clean the copper line at the installation location. Remove oxides and dirt to increase sensor accuracy.
3. Fasten the suction temperature sensor as oriented in *Figure 8*. Mount the sensor on the suction line after the heat exchanger, near the pressure transducer.
4. Route the cable away from hot surfaces and high power A/C voltage lines.
5. Connect sensor wires to the Kelvin II controller.
6. Verify that the Kelvin II is configured properly for the temperature sensor used (2K or 3K sensor), See *Section 2 - SETUP*.
7. Wrap temperature sensor and copper tube with foam insulation to minimize ambient temperature effects (Figure 9).

Mount the Optional Room Temperature Sensor

1. Mount the Room or Box temperature sensor in the area to be controlled. Ensure that it is at least 4 inches from the surface of the evaporator coil.
2. Connect sensor wires to terminals 29 and 30 on the Kelvin II controller as shown in *Appendix H - Wiring Diagram*. The sensor leads are not polarized.
3. Ensure that the Kelvin II is configured properly for the temperature sensor used (2K or 3K sensor), See *Section 2 - SETUP*.

Figure 8 - Temperature Sensor Positioning



Temperature sensor should be mounted at either 4 or 8 o'clock, on a free-draining horizontal line.

Figure 9 - Cutaway of Pipe Insulation

2K sensor shown

NOTE: Sensors may be extended to 100 ft. (30.5 m) using 18 gauge shielded twisted pair cable. Splice connections should be use Scotchlok™ UR connectors for long-term integrity.

WARNING: Route and secure sensor cables away from hot surfaces, high voltage lines, and moving components.

APPENDIX J - Modbus Memory Map

	REGISTER ADDRESS/DESCRIPTION	RANGE	
Read Coils (0x01)	0. Manual Valve Enabled Flag	0 = Disabled 1 = Enabled	
	1. Manual Valve Duration Enabled Flag	0 = Disabled 1 = Enabled	
Read Holding Register (0x03)	0. Superheat Setpoint	5 to 45°F (2.7 to 25.0°C)	
	1. Refrigerant Type	0 = R-22 1 = R-134A 2 = R-402A 3 = R-404A 4 = R-407A 5 = R-407C 6 = R-410A 7 = R-417A 8 = R-422A 9 = R-422D	10 = R-507A 11 = R-744 12 = R-245FA 13 = R-E5 14 = R-438A 15 = R-401B 16 = R-408A 17 = R-508A 18 = R-508B
	2. Delay On Relay	0 to 60 seconds	
	3. Delay Off Relay	0 to 60 seconds	
	4. Delay Steps	0 to 100% open	
	5. Low Operating Pressure	0 to 150 psi (0 to 13.34 Bar)	
	6. Maximum Operating Pressure	0 to 150 psi (0 to 13.34 Bar)	
	7. Temperature Cut-in	-60 to 125°F (-51 to 51.7°C)	
	8. Temperature Cut-out	-60 to 125°F (-51 to 51.7°C)	
	9. Valve Maximum	0 to 100%	
	10. Supermarket Mode	1=On, 0=Off	
	8. Proportional Coefficient	0 to 18 if Supermarket Mode is On 0 to 50 if Supermarket Mode is Off	
	9. Integral Coefficient	0 to 24 if Supermarket Mode is On 0 to 100 if Supermarket Mode is Off	
	13. Derivative Coefficient	0 to 4 if Supermarket Mode is On 0 to 50 if Supermarket Mode is Off	
	14. Valve Type	0 = 1596 1 = 3193 2 = 2500 3 = 6386 4 = 400	
	15. Manual Valve Position	0 to 100.0% Open	
	16. Modbus Network Address	1 to 255	
	17. Pressure Units	0 = PSI 1 = BAR	
	18. Temperature Units	0 = FAHR 1 = CELS	
	19. Pressure Sensor Type	0 = ABSL 1 = GauG	

APPENDIX J - Modbus Memory Map (continued)

	REGISTER ADDRESS/DESCRIPTION	RANGE
Read Holding Register (0x03)	20. Pressure Calibration Offset	-5 to 5 PSI (-0.34 to 0.34 Bar)
	21. Suction Temperature Calibration Offset	-5 to 5°F (-2.8 to 2.8°C)
	22. Room Temperature Calibration Offset	-5 to 5°F (-2.8 to 2.8°C)
	23. Auxiliary Temperature 1 Calibration Offset	-5 to 5°F (-2.8 to 2.8°C)
	24. Pressure Range	0 = Auto (based of refrigerant) 1 = 150 PSI 2 = 300 PSI 3 = 500 PSI
	25. Bleed Port Percent Open of Valve	0 to 150 (0 to 15 percent)
	26. Bleed Delay Time	0 to 9999 seconds
	27. Controller Display Address	0 to 99
	28. Temperature Sensor Type	0 = 3K thermistor 1 = 2K thermistor
	29. Auxillary Temp 2 Calibration Offset	-5 to 5°F (-2.8 to 2.8°C)
	30. Superheat Control Deadband	1 or 2 deg F (.6 or 1.1°C)
	31. Minimum Relay On Time	0 to 10 minutes
	32. Minimum Relay Off Time	0 to 10 minutes
Read Input Registers (0x04)	0. Superheat	0 to 165°F (0 to 91.6°C)
	1. Suction Pressure	Depends on Pressure Sensor Range and Type -15 to 500 PSI (-1.01 to 34.47 Bar) Maximum Range
	2. Saturation Temperature	-60 to 150°F (-51.1 to 65.6°C)
	3. Suction Temperature	-60 to 150°F (-51.1 to 65.6°C)
	4. Room Temperature	-60 to 150°F (-51.1 to 65.6°C)
	5. Valve Position (% of Max. Stroke)	0 to 100.0% Open
	6. Auxiliary Temperature 1	-60 to 150°F (-51.1 to 65.6°C)
	7. Relay Status	0 = de-energized, 1 = energized
	8. Alarm Status	If Bit set then alarm is active: Bit 0 = Pressure Sensor Failure Alarm Bit 1 = Suction Temperature Sensor Failure Alarm Bit 2 = Low Superheat Alarm Bit 3 = High Superheat Alarm
	9. System State	If Bit set then mode is active: Bit 1 = Setup Mode Bit 2 = Off Cycle Bit 3 = Cooling Cycle Bit 4 = Pump-down Cycle Bit 5 = Manual Valve Override Mode
	10. Firmware Revision	Controller Firmware revision
	11. Auxiliary Temperature 2	-60 to 150°F (-51.1 to 65.6°C)
Write Single Coil (0x05)	0. Manual Valve Enabled Flag	0 = Disabled, 1 = Enabled Other coils are read-only
Write Single Register (0x06)	Same as above.	The max number of registers written at a time is 1. The limits are listed under 'Read Holding Register'.

APPENDIX K - 2k Temperature Sensor Specs

°C	°F	RANGE VDC
-51.1	-60	4.375 - 4.555
-50.6	-59	4.361 - 4.539
-50.0	-58	4.345 - 4.524
-49.4	-57	4.330 - 4.508
-48.9	-56	4.314 - 4.492
-48.3	-55	4.299 - 4.475
-47.8	-54	4.282 - 4.458
-47.2	-53	4.266 - 4.441
-46.7	-52	4.249 - 4.423
-46.1	-51	4.232 - 4.406
-45.6	-50	4.214 - 4.387
-45.0	-49	4.196 - 4.369
-44.4	-48	4.178 - 4.350
-43.9	-47	4.160 - 4.331
-43.3	-46	4.141 - 4.311
-42.8	-45	4.122 - 4.291
-42.2	-44	4.102 - 4.271
-41.7	-43	4.083 - 4.251
-41.1	-42	4.063 - 4.230
-40.6	-41	4.042 - 4.209
-40.0	-40	4.022 - 4.187
-39.4	-39	4.001 - 4.165
-38.9	-38	3.979 - 4.143
-38.3	-37	3.958 - 4.121
-37.8	-36	3.936 - 4.098
-37.2	-35	3.914 - 4.075
-36.7	-34	3.891 - 4.052
-36.1	-33	3.868 - 4.028
-35.6	-32	3.845 - 4.004
-35.0	-31	3.822 - 3.980
-34.4	-30	3.798 - 3.955
-33.9	-29	3.774 - 3.930
-33.3	-28	3.750 - 3.905
-32.8	-27	3.726 - 3.880
-32.2	-26	3.701 - 3.854
-31.7	-25	3.676 - 3.828
-31.1	-24	3.651 - 3.802
-30.6	-23	3.625 - 3.775
-30.0	-22	3.600 - 3.749
-29.4	-21	3.574 - 3.722
-28.9	-20	3.548 - 3.694
-28.3	-19	3.521 - 3.667
-27.8	-18	3.495 - 3.639
-27.2	-17	3.468 - 3.611
-26.7	-16	3.441 - 3.583
-26.1	-15	3.414 - 3.555
-25.6	-14	3.386 - 3.527
-25.0	-13	3.359 - 3.498
-24.4	-12	3.331 - 3.469
-23.9	-11	3.303 - 3.440
-23.3	-10	3.275 - 3.411
-22.8	-9	3.247 - 3.381
-22.2	-8	3.218 - 3.352
-21.7	-7	3.190 - 3.322
-21.1	-6	3.161 - 3.293
-20.6	-5	3.133 - 3.263
-20.0	-4	3.104 - 3.233
-19.4	-3	3.075 - 3.203
-18.9	-2	3.046 - 3.173
-18.3	-1	3.017 - 3.142
-17.8	0	2.988 - 3.112
-17.2	1	2.958 - 3.082
-16.7	2	2.929 - 3.051
-16.1	3	2.900 - 3.021
-15.6	4	2.871 - 2.990
-15.0	5	2.841 - 2.960
-14.4	6	2.812 - 2.929
-13.9	7	2.782 - 2.899
-13.3	8	2.753 - 2.868
-12.8	9	2.724 - 2.837
-12.2	10	2.694 - 2.807
-11.7	11	2.665 - 2.776
-11.1	12	2.636 - 2.746
-10.6	13	2.607 - 2.716
-10.0	14	2.577 - 2.685
-9.4	15	2.548 - 2.655
-8.9	16	2.519 - 2.625
-8.3	17	2.490 - 2.595
-7.8	18	2.462 - 2.565
-7.2	19	2.433 - 2.535
-6.7	20	2.404 - 2.505
-6.1	21	2.376 - 2.475
-5.6	22	2.347 - 2.446
-5.0	23	2.319 - 2.416
-4.4	24	2.291 - 2.387
-3.9	25	2.263 - 2.358
-3.3	26	2.235 - 2.329
-2.8	27	2.207 - 2.300
-2.2	28	2.179 - 2.271
-1.7	29	2.152 - 2.242
-1.1	30	2.125 - 2.214
-0.6	31	2.098 - 2.186
0.0	32	2.071 - 2.158
0.6	33	2.044 - 2.130
1.1	34	2.017 - 2.102
1.7	35	1.991 - 2.075
2.2	36	1.965 - 2.048
2.8	37	1.939 - 2.021
3.3	38	1.913 - 1.994
3.9	39	1.888 - 1.967
4.4	40	1.862 - 1.941
5.0	41	1.837 - 1.915
5.6	42	1.812 - 1.889
6.1	43	1.788 - 1.863
6.7	44	1.763 - 1.837
7.2	45	1.739 - 1.812
7.8	46	1.715 - 1.787
8.3	47	1.691 - 1.763
8.9	48	1.668 - 1.738
9.4	49	1.644 - 1.714
10.0	50	1.621 - 1.690
10.6	51	1.598 - 1.666
11.1	52	1.576 - 1.642
11.7	53	1.554 - 1.619
12.2	54	1.531 - 1.596
12.8	55	1.510 - 1.573
13.3	56	1.488 - 1.551
13.9	57	1.467 - 1.529
14.4	58	1.446 - 1.507
15.0	59	1.425 - 1.485
15.6	60	1.404 - 1.463
16.1	61	1.384 - 1.442
16.7	62	1.363 - 1.421

APPENDIX K - 2k Temperature Sensor Specs (continued)

°C	°F	RANGE VDC
17.2	63	1.344 - 1.400
17.8	64	1.324 - 1.380
18.3	65	1.305 - 1.360
18.9	66	1.285 - 1.340
19.4	67	1.266 - 1.320
20.0	68	1.248 - 1.301
20.6	69	1.229 - 1.281
21.1	70	1.211 - 1.262
21.7	71	1.193 - 1.244
22.2	72	1.175 - 1.225
22.8	73	1.158 - 1.207
23.3	74	1.141 - 1.189
23.9	75	1.124 - 1.171
24.4	76	1.107 - 1.154
25.0	77	1.090 - 1.137
25.6	78	1.074 - 1.120
26.1	79	1.058 - 1.103
26.7	80	1.042 - 1.086
27.2	81	1.026 - 1.070
27.8	82	1.011 - 1.054
28.3	83	0.996 - 1.038
28.9	84	0.981 - 1.022
29.4	85	0.966 - 1.007
30.0	86	0.951 - 0.992
30.6	87	0.937 - 0.977
31.1	88	0.923 - 0.962
31.7	89	0.909 - 0.948
32.2	90	0.895 - 0.933
32.8	91	0.882 - 0.919
33.3	92	0.868 - 0.905
33.9	93	0.855 - 0.892
34.4	94	0.842 - 0.878
35.0	95	0.830 - 0.865
35.6	96	0.817 - 0.852
36.1	97	0.805 - 0.839
36.7	98	0.792 - 0.826
37.2	99	0.780 - 0.814
37.8	100	0.769 - 0.801
38.3	101	0.757 - 0.789
38.9	102	0.746 - 0.777
39.4	103	0.734 - 0.766
40.0	104	0.723 - 0.754
40.6	105	0.712 - 0.743
41.1	106	0.702 - 0.731
41.7	107	0.691 - 0.720
42.2	108	0.681 - 0.710
42.8	109	0.670 - 0.699
43.3	110	0.660 - 0.688
43.9	111	0.650 - 0.678
44.4	112	0.641 - 0.668
45.0	113	0.631 - 0.658
45.6	114	0.621 - 0.648
46.1	115	0.612 - 0.638
46.7	116	0.603 - 0.629
47.2	117	0.594 - 0.619
47.8	118	0.585 - 0.610
48.3	119	0.576 - 0.601
48.9	120	0.568 - 0.592
49.4	121	0.559 - 0.583
50.0	122	0.551 - 0.574
50.6	123	0.543 - 0.566
51.1	124	0.535 - 0.557
51.7	125	0.527 - 0.549
52.2	126	0.519 - 0.541
52.8	127	0.511 - 0.533
53.3	128	0.504 - 0.525
53.9	129	0.496 - 0.517
54.4	130	0.489 - 0.510
55.0	131	0.482 - 0.502
55.6	132	0.475 - 0.495
56.1	133	0.468 - 0.488
56.7	134	0.461 - 0.480
57.2	135	0.454 - 0.473
57.8	136	0.447 - 0.466
58.3	137	0.441 - 0.460
58.9	138	0.434 - 0.453
59.4	139	0.428 - 0.446
60.0	140	0.422 - 0.440
60.6	141	0.416 - 0.433
61.1	142	0.410 - 0.427
61.7	143	0.404 - 0.421
62.2	144	0.398 - 0.415
62.8	145	0.392 - 0.409
63.3	146	0.386 - 0.403
63.9	147	0.381 - 0.397
64.4	148	0.375 - 0.391
65.0	149	0.370 - 0.386
65.6	150	0.365 - 0.380

APPENDIX L - 3k Temperature Sensor Specs

°C	°F	RANGE VDC
-51.1	-60	4.747 - 4.941
-50.6	-59	4.741 - 4.935
-50.0	-58	4.735 - 4.928
-49.4	-57	4.728 - 4.921
-48.9	-56	4.722 - 4.915
-48.3	-55	4.715 - 4.907
-47.8	-54	4.708 - 4.900
-47.2	-53	4.700 - 4.893
-46.7	-52	4.693 - 4.885
-46.1	-51	4.685 - 4.877
-45.6	-50	4.677 - 4.868
-45.0	-49	4.669 - 4.860
-44.4	-48	4.660 - 4.851
-43.9	-47	4.651 - 4.842
-43.3	-46	4.642 - 4.832
-42.8	-45	4.633 - 4.823
-42.2	-44	4.623 - 4.813
-41.7	-43	4.613 - 4.802
-41.1	-42	4.603 - 4.792
-40.6	-41	4.593 - 4.781
-40.0	-40	4.582 - 4.769
-39.4	-39	4.571 - 4.758
-38.9	-38	4.559 - 4.746
-38.3	-37	4.547 - 4.734
-37.8	-36	4.535 - 4.721
-37.2	-35	4.523 - 4.708
-36.7	-34	4.510 - 4.695
-36.1	-33	4.497 - 4.681
-35.6	-32	4.484 - 4.667
-35.0	-31	4.470 - 4.653
-34.4	-30	4.456 - 4.638
-33.9	-29	4.441 - 4.623
-33.3	-28	4.426 - 4.608
-32.8	-27	4.411 - 4.592
-32.2	-26	4.395 - 4.576
-31.7	-25	4.379 - 4.559
-31.1	-24	4.363 - 4.542
-30.6	-23	4.346 - 4.525
-30.0	-22	4.329 - 4.507
-29.4	-21	4.312 - 4.489
-28.9	-20	4.294 - 4.470
-28.3	-19	4.275 - 4.451
-27.8	-18	4.256 - 4.431
-27.2	-17	4.237 - 4.411
-26.7	-16	4.218 - 4.391
-26.1	-15	4.198 - 4.370
-25.6	-14	4.177 - 4.349
-25.0	-13	4.157 - 4.327
-24.4	-12	4.135 - 4.305
-23.9	-11	4.114 - 4.283
-23.3	-10	4.092 - 4.260
-22.8	-9	4.069 - 4.237
-22.2	-8	4.046 - 4.213
-21.7	-7	4.023 - 4.189
-21.1	-6	3.999 - 4.164
-20.6	-5	3.975 - 4.139
-20.0	-4	3.951 - 4.114
-19.4	-3	3.926 - 4.088
-18.9	-2	3.901 - 4.062
-18.3	-1	3.875 - 4.035
-17.8	0	3.849 - 4.008
-17.2	1	3.823 - 3.981
-16.7	2	3.796 - 3.953
-16.1	3	3.769 - 3.924
-15.6	4	3.741 - 3.896
-15.0	5	3.713 - 3.867
-14.4	6	3.685 - 3.837
-13.9	7	3.657 - 3.808
-13.3	8	3.628 - 3.778
-12.8	9	3.598 - 3.747
-12.2	10	3.569 - 3.717
-11.7	11	3.539 - 3.686
-11.1	12	3.509 - 3.654
-10.6	13	3.478 - 3.623
-10.0	14	3.448 - 3.591
-9.4	15	3.417 - 3.558
-8.9	16	3.385 - 3.526
-8.3	17	3.354 - 3.493
-7.8	18	3.322 - 3.460
-7.2	19	3.290 - 3.427
-6.7	20	3.258 - 3.393
-6.1	21	3.226 - 3.360
-5.6	22	3.193 - 3.326
-5.0	23	3.160 - 3.292
-4.4	24	3.127 - 3.257
-3.9	25	3.094 - 3.223
-3.3	26	3.061 - 3.189
-2.8	27	3.028 - 3.154
-2.2	28	2.994 - 3.119
-1.7	29	2.961 - 3.084
-1.1	30	2.927 - 3.049
-0.6	31	2.894 - 3.014
0.0	32	2.860 - 2.979
0.6	33	2.826 - 2.944
1.1	34	2.792 - 2.909
1.7	35	2.758 - 2.874
2.2	36	2.725 - 2.838
2.8	37	2.691 - 2.803
3.3	38	2.657 - 2.768
3.9	39	2.623 - 2.733
4.4	40	2.590 - 2.698
5.0	41	2.556 - 2.663
5.6	42	2.522 - 2.628
6.1	43	2.489 - 2.593
6.7	44	2.455 - 2.558
7.2	45	2.422 - 2.524
7.8	46	2.389 - 2.489
8.3	47	2.356 - 2.455
8.9	48	2.323 - 2.421
9.4	49	2.290 - 2.386
10.0	50	2.258 - 2.353
10.6	51	2.226 - 2.319
11.1	52	2.193 - 2.285
11.7	53	2.161 - 2.252
12.2	54	2.130 - 2.219
12.8	55	2.098 - 2.186
13.3	56	2.067 - 2.154
13.9	57	2.036 - 2.121
14.4	58	2.005 - 2.089
15.0	59	1.974 - 2.057
15.6	60	1.944 - 2.026
16.1	61	1.914 - 1.994
16.7	62	1.884 - 1.963

APPENDIX L - 3k Temperature Sensor Specs (continued)

°C	°F	RANGE VDC
17.2	63	1.854 - 1.932
17.8	64	1.825 - 1.902
18.3	65	1.796 - 1.872
18.9	66	1.767 - 1.842
19.4	67	1.739 - 1.812
20.0	68	1.711 - 1.783
20.6	69	1.683 - 1.754
21.1	70	1.656 - 1.725
21.7	71	1.628 - 1.697
22.2	72	1.602 - 1.669
22.8	73	1.575 - 1.641
23.3	74	1.549 - 1.614
23.9	75	1.523 - 1.587
24.4	76	1.497 - 1.561
25.0	77	1.472 - 1.534
25.6	78	1.447 - 1.508
26.1	79	1.422 - 1.483
26.7	80	1.398 - 1.457
27.2	81	1.374 - 1.432
27.8	82	1.351 - 1.408
28.3	83	1.327 - 1.383
28.9	84	1.304 - 1.360
29.4	85	1.282 - 1.336
30.0	86	1.259 - 1.313
30.6	87	1.237 - 1.290
31.1	88	1.216 - 1.267
31.7	89	1.194 - 1.245
32.2	90	1.173 - 1.223
32.8	91	1.153 - 1.202
33.3	92	1.132 - 1.180

°C	°F	RANGE VDC
33.9	93	1.112 - 1.159
34.4	94	1.093 - 1.139
35.0	95	1.073 - 1.119
35.6	96	1.054 - 1.099
36.1	97	1.035 - 1.079
36.7	98	1.017 - 1.060
37.2	99	0.998 - 1.041
37.8	100	0.981 - 1.022
38.3	101	0.963 - 1.004
38.9	102	0.946 - 0.986
39.4	103	0.929 - 0.968
40.0	104	0.912 - 0.951
40.6	105	0.895 - 0.934
41.1	106	0.879 - 0.917
41.7	107	0.863 - 0.900
42.2	108	0.848 - 0.884
42.8	109	0.832 - 0.868
43.3	110	0.817 - 0.852
43.9	111	0.803 - 0.837
44.4	112	0.788 - 0.822
45.0	113	0.774 - 0.807
45.6	114	0.760 - 0.792
46.1	115	0.746 - 0.778
46.7	116	0.732 - 0.764
47.2	117	0.719 - 0.750
47.8	118	0.706 - 0.736
48.3	119	0.693 - 0.723
48.9	120	0.681 - 0.710
49.4	121	0.668 - 0.697
50.0	122	0.656 - 0.684

°C	°F	RANGE VDC
50.6	123	0.644 - 0.672
51.1	124	0.633 - 0.660
51.7	125	0.621 - 0.648
52.2	126	0.610 - 0.636
52.8	127	0.599 - 0.624
53.3	128	0.588 - 0.613
53.9	129	0.577 - 0.602
54.4	130	0.567 - 0.591
55.0	131	0.557 - 0.580
55.6	132	0.547 - 0.570
56.1	133	0.537 - 0.560
56.7	134	0.527 - 0.550
57.2	135	0.518 - 0.540
57.8	136	0.508 - 0.530
58.3	137	0.499 - 0.520
58.9	138	0.490 - 0.511
59.4	139	0.481 - 0.502
60.0	140	0.473 - 0.493
60.6	141	0.464 - 0.484
61.1	142	0.456 - 0.475
61.7	143	0.448 - 0.467
62.2	144	0.440 - 0.459
62.8	145	0.432 - 0.450
63.3	146	0.424 - 0.442
63.9	147	0.417 - 0.435
64.4	148	0.409 - 0.427
65.0	149	0.402 - 0.419
65.6	150	0.395 - 0.412

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122011 / SD-324M

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