

System 350™ A350P Electronic Proportional Plus Integral Temperature Control

The A350P is an electronic, proportional plus integral temperature control with analog 0 to 10 VDC and 0 to 20 mA outputs. The control is equipped with three user-selectable time integration constants and an adjustable throttling range of 2 to 30F° (1 to 17C°). Two models cover a setpoint range of -30 to 130°F (-35 to 55°C) and 90 to 250°F (32 to 121°C).

As are all System 350™ products, the A350P control is housed in a NEMA 1, high-impact plastic enclosure. The modular design provides easy, plug-together connections for quick installation and future expandability.



Figure 1: A350P Electronic Proportional Plus Integral Temperature Control

Features and Benefits	
<input type="checkbox"/> Modular Design	Enables stage, display, and power modules to be purchased and installed as needed
<input type="checkbox"/> Plug-Together Connectors and 35 mm DIN Rail Mounting	Eliminates wiring between modules, which reduces installation costs
<input type="checkbox"/> Two Models Cover a Wide Setpoint Range of -30 to 250°F (-35 to 121°C)	Reduces inventory by encompassing temperature ranges required to support the majority of Heating, Ventilation, Air Conditioning, and Refrigeration (HVAC/R) applications
<input type="checkbox"/> Minimum Output Adjustable from 0 to 60%	Tailors the output to the requirements of the controlled device; can be used to set minimum valve or damper position
<input type="checkbox"/> Adjustable Throttling Range of 2 to 30F° (1 to 17C°)	Enables the user to tune the system for optimum stable performance
<input type="checkbox"/> Field-selectable Reverse or Direct Acting Mode	Works in heating or cooling applications
<input type="checkbox"/> Three User-Selectable Integration Time Constants	Provides selection of the integration constant for applications requiring proportional plus integral control
<input type="checkbox"/> Interchangeable Temperature Sensors	Increase versatility and serviceability

Application

The A350P Temperature Control can be used as a standalone device or in conjunction with plug-together accessory modules. The addition of S350 Stage Modules allows for the control of multiple stage HVAC/R applications. Typical application for the A350P includes:

- proportional heating control with staged direct expansion cooling
- simple temperature control for air handling units
- modulating damper actuators for mixed air control
- simple proportional mixed air control

A typical System 350 Temperature Control setup includes the following:

- A350P Temperature Control
- A99B Series Temperature Sensor
- Y350R Power Module (or 24 VAC Class 2 transformer)
- S350 Stage Modules
- D350 Digital Temperature Display Module

Operation

The A350P control operates on 24 VAC/VDC and provides two simultaneous analog outputs: 0 to 10 VDC and 0 to 20 mA. A cover-mounted, 10-segment Light-Emitting Diode (LED) bar graph indicates percentage of output.

Features include:

- adjustable setpoint
- adjustable minimum output
- adjustable throttling range (proportional band)
- selectable integration time constant
- selectable Reverse Acting (RA) or Direct Acting (DA) mode of operation

IMPORTANT: All System 350 controls are designed for use **only** as operating controls. Where an operating control failure would result in personal injury and/or loss of property, it is the responsibility of the installer to add devices (safety, limit controls) or systems (alarm, supervisory systems) that protect against, or warn of, control failure.

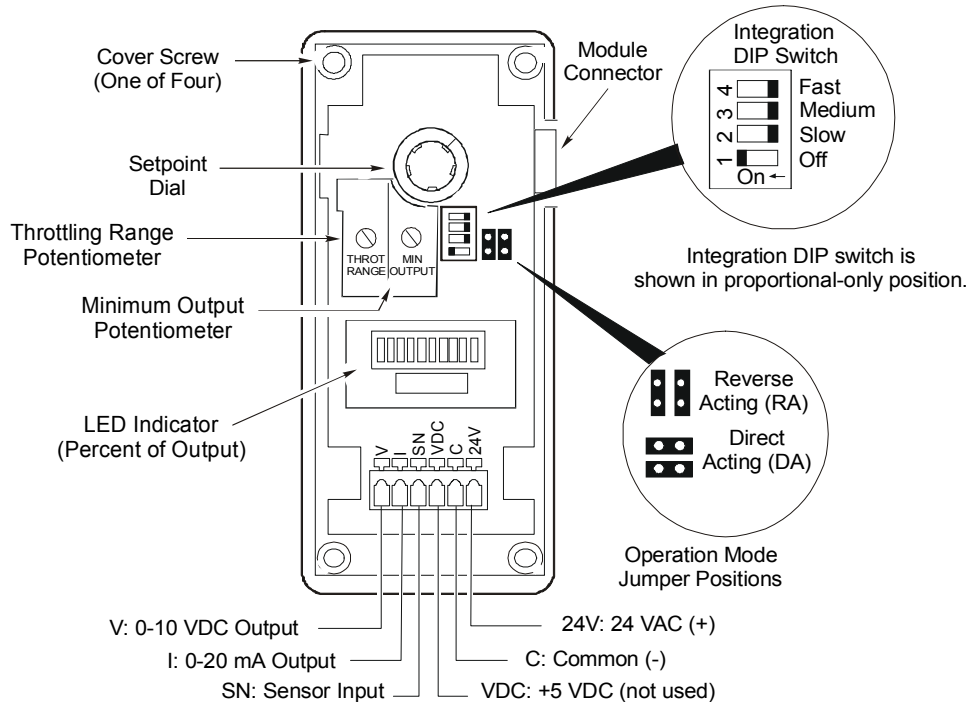


Figure 2: Interior View Showing A350P Control's Features

Minimum Output Adjustment

The minimum output adjustment sets the minimum voltage or milliampere output provided by the A350P control. It can be adjusted from 0 to 60% (0 to 6 VDC or 0 to 12 mA) of the output range.

Example:

A controlled device responding to a 4-20 mA output would require the minimum output to be adjusted to 20% or 4 mA. (See Figure 3.) The minimum output adjustment may also be used to set valves or dampers to minimum positions.

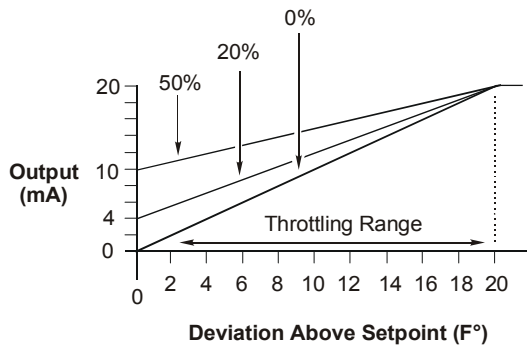


Figure 3: Output vs. Deviation from Setpoint for: Minimum Output = 0, 20, and 50%, Throttling Range = 20°F (DA)

Make the adjustment at the minimum output potentiometer marked as MIN OUTPUT. (See Figure 2.) For each 10% increase in output, the **next** bar on the LED indicator will light (only one bar is lit at any time).

Note: Before setting the minimum output potentiometer, verify that the control reads zero output (that is, no LEDs are lit).

Throttling Range (Proportional Band)

The throttling range is the range over which a control is active. Throttling range for the A350P control can be adjusted from 2 to 30F° (1 to 17C°). Make the adjustment at the throttling range potentiometer marked THROT RANGE (see Figure 2).

Integration Function

Proportional-only controls cannot hold a process at the exact setpoint. A proportional offset is always present because the control output is 0% at setpoint. Any load on the system will cause the control point to be offset from the setpoint. The greater the load on the system, the further the control point will be offset from the setpoint. (This is commonly referred to as proportional offset, and under maximum load this error will approach the throttling range.)

Some proportional-only controls are designed with their setpoint located midway through the proportional band to help compensate for this offset. This results in a plus/minus error from the setpoint rather than a single-ended error. Refer to Figure 4.

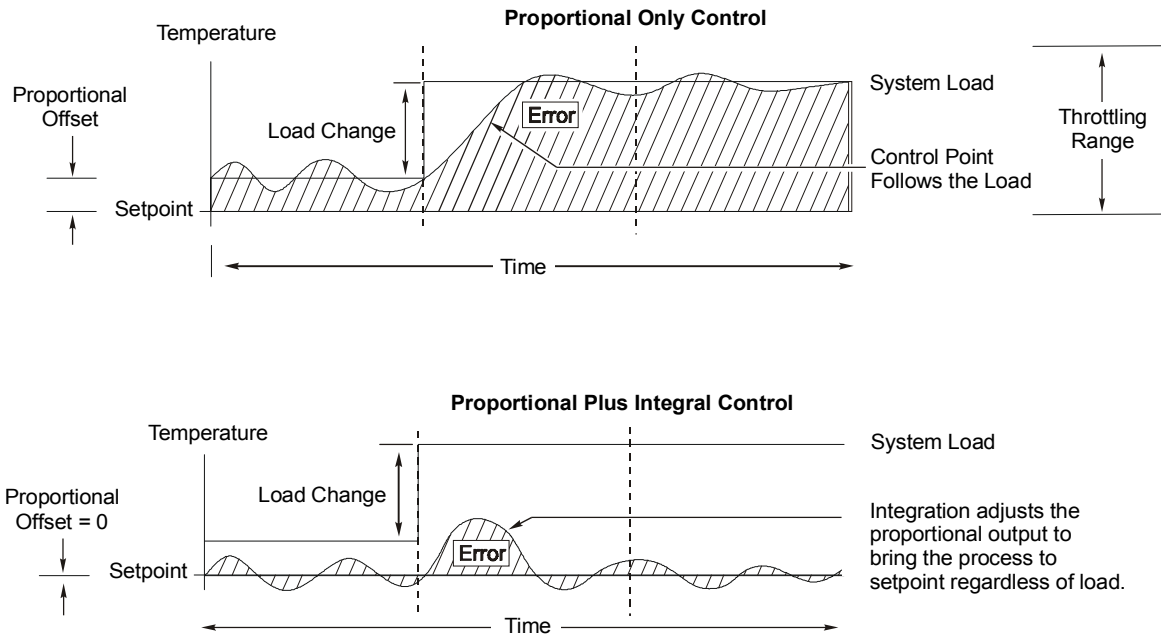


Figure 4: Comparison Between Proportional Only and Proportional Plus Integral Control

The A350P control has an integration feature that forces the control point to match the setpoint. Over time, the A350P will control the heating/cooling equipment to balance the system load at the control setpoint. (See Figure 4.)

On traditional proportional plus integral controls, the amount of correction will become too large if the system load exceeds the capacity of the equipment. When the actuated device (valve or damper) is fully open or closed and the setpoint still cannot be reached, the integration error continues to grow. The result is called *integral windup*.

The A350P control avoids *integral windup* with a patented circuit that puts a dynamic ceiling on the integrator. This resets the integration error when the sensor goes just above the setpoint plus the throttling range (in DA mode) or just below the setpoint minus the throttling range (in RA mode). This allows the process to recover from an out-of-range condition without a large overshoot.

The A350P control has three field-selectable integration constants and an off position. The integration DIP switch selects the integration constant. (See Figure 2 for location.)

The field-selectable integration constants include:

- **OFF: Switch 1 to On position, all others Off** provides proportional-only operation.

Note: In open-loop (without feedback) applications, select OFF (proportional-only) operation.

- **Slow (C3): Switch 2 to On position, all others Off** is the slowest integration constant (26 minute), and is suitable for most proportional plus integral applications. Slow is the recommended initial setting.
- **Medium (C2): Switch 3 to On position, all others Off** selects a 13-minute integration constant. If the rate of system recovery to setpoint is sluggish with the control set to slow, and if the system has enough capacity to drive the process to setpoint at a faster rate, the medium setting may be used.
- **Fast (C1): Switch 4 in On position, all others Off** is the fastest integration constant (6.5 minutes). Use fast only in instances where the rate of change at the sensor is extremely rapid and system capacity can compensate for that rapid change.

Reverse or Direct Acting Operation

With the operation jumpers in the Reverse Acting (RA) position, the analog output increases as the temperature drops below setpoint. (See Figure 5.)

With the operation jumpers in the Direct Acting (DA) position, the analog output will increase as the temperature rises above the setpoint.

Select the RA/DA mode by positioning the operation jumpers vertically or horizontally. (See Figure 2.) Position the operation jumpers vertically for RA and horizontally for DA.

The RA/DA operation jumpers are installed in the RA mode at the factory.

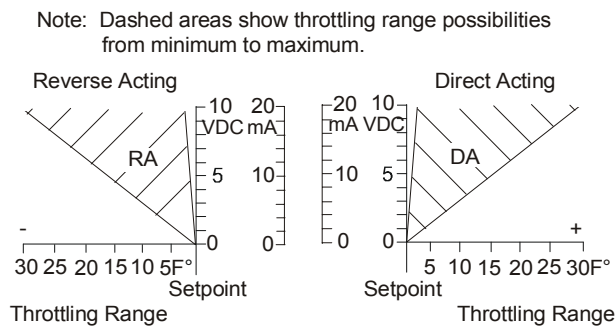


Figure 5: RA and DA Proportional Bands Shown in Proportional-Only Mode

Add-on Modules

The maximum number of add-on modules is listed in Table 1.

Table 1: Maximum Number of S350 Stage Modules per A350P

Power Source	Number of S350A or S350C Stage Modules Allowed	Number of S350A or S350C Modules (with One S350P) Allowed	Number of S350A or S350C Modules (with Two S350Ps) Allowed
Y350R	4	2	0
External Class 2 Transformer	9	8	7

S350A On-Off Stage Modules

S350A On-Off stage modules receive power, setpoint, and sensor input from the A350P control. S350A stage modules perform switching functions based on the control's setpoint and sensor information, as well as the offset and differential selected at the S350A stage module.

For more information on these modules, refer to the *System 350™ S350 Temperature, S351 Humidity, and S352 Pressure On/Off Stage Modules Product/Technical Bulletin (LIT-930080)*.

S350C Slave Stage Module

S350C slave stage modules receive power and sensor input from the A350P control. S350C slave stage modules perform switching functions based upon the control's sensor information, as well as the setpoint and differential selected at the S350C stage module.

For more information on these modules, refer to the *System 350™ S350C Temperature Slave Stage Module Product/Technical Bulletin (LIT-930084)*.

S350P Proportional Stage Modules

S350P proportional stage modules receive power, setpoint, and sensor input from the A350P control. The S350P stage module responds with an analog 0 to 10 VDC and 0 to 20 mA output signal. This is based upon the control's setpoint and sensor information, as well as the offset, throttling range, and minimum output selected at the S350P stage module.

For more information on these modules, refer to the *System 350™ S350P Proportional Plus Integral Temperature Stage Module Product/Technical Bulletin (LIT-930086)*.

Dimensions

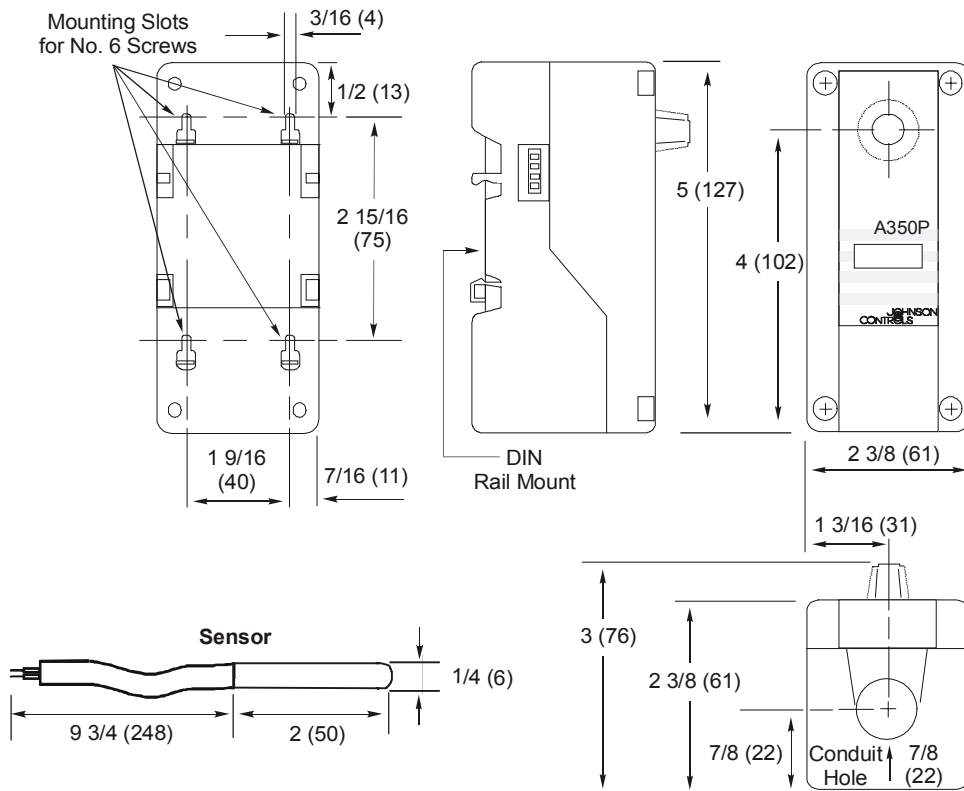


Figure 6: A350P Control and Sensor Dimensions, in. (mm)

Installation and Wiring


Celsius Scale Conversion

A Celsius scale throttling range decal is included with the A350P control. If the Celsius scale is desired:

1. Locate the throttling range and minimum output potentiometers on the main PC board. (See Figure 2.) Carefully remove the knobs and the existing decal.
2. Apply the Celsius scale decal in the same place as the original decal.
3. Rotate both knob stems completely counterclockwise (CCW).
4. Reinstall the potentiometer knobs so the arrows point to the minimum values.

The A350P Temperature Control is housed in a compact NEMA 1 plastic enclosure designed for standard 35 mm DIN rail mounting. Four key-slot mounting holes on the back of the control case are provided should surface mounting be required. If a Y350R is used, it should be mounted immediately to the right of the control. Any S350 modules would follow on the right, with the D350 being the last module mounted, also on the right.

Note: When mounting any System 350 module to rigid conduit, attach the hub to the conduit before securing the hub to the control enclosure.

 **WARNING: Risk of Electrical Shock.**
Disconnect power supply before making electrical connections to avoid possible electrical shock or equipment damage.

Wiring Terminals

Install all wiring to conform to the National Electrical Code and local regulations. For maximum electrical rating of control, refer to the label inside the control cover. Terminals will accept 12 to 26 AWG wire. Use only copper conductors.

1. Use a 1/8 in. (3 mm) flat-blade screwdriver to push the clamp arm down.
2. Insert the appropriate wire into the opening. Refer to Table 2 for terminal designations.
3. Release the clamp arm to secure the wire. See Figure 7.

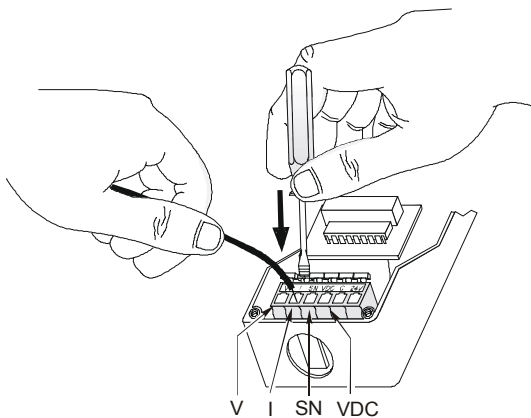


Figure 7: Cage Clamp Terminal Block

Table 2: Terminal Designations

Terminal	Description
V	0 to 10 VDC output
I	0 to 20 mA output
SN	Temperature sensor input
VDC	5 VDC power supply (not used)
C	Common for power supply, temperature sensor, and outputs
24V	24 Volts AC

Note: Output signals from the A350P control vary from 0 to 10 VDC and 0 to 20 mA. (Both outputs can be used simultaneously.) Connections can be made to both the V and I terminals, allowing the control to drive two outputs from the same RA or DA ramp simultaneously. This feature can be used to drive motor actuators of different types in a single application.

Sensor Connection

Shielded cable is not generally required for sensor wiring on runs of less than 50 feet. When using shielded cable, isolate and tape the shield at the sensor. Connect the shield to Terminal C on the A350P control.

Refer to Table 3 for the maximum recommended cable lengths for particular sizes of wire.

Table 3: Maximum Recommended Sensor Cable Lengths

Wire Gauge	Shielded Cable Length	
	Feet	Meters
14 AWG	800	244
16 AWG	500	152
18 AWG	310	94
20 AWG	200	61
22 AWG	124	38

- Various A99B Series Temperature Sensors and mounting hardware are available for use with A350P Series controls.

The sensor must be connected to Terminals SN and C. (See Figure 2.) The sensors are not polarity sensitive.

- The sensor must be mounted so that it can accurately sense the temperature of the controlled medium.

Table 4: A350P Controls And Sensors

Control	Sensor Included Sensor Lead Length is 9-3/4 in. (0.25 m)
A350PS-1C	A99BB-25C; Range: -40 to 212°F (-40 to 100°C)
A350PS-1CM	A99BB-25C; Range: -40 to 212°F (-40 to 100°C)
A350PS-2C	A99BC-25; Range: -40 to 248°F (-40 to 120°C)
A350PS-2CM	A99BC-25; Range: -40 to 248°F (-40 to 120°C)
A350PT-1C	No Sensor Included
A350BA-2C	A99BC-25; Range: -40 to 248°F (-40 to 120°C)

- For more information regarding sensor options and installation, refer to the *A99B Series Temperature Sensors Product/Technical Bulletin (LIT-125186)*.

Adjustments

Follow this procedure to set up the A350P control for the types of operation desired.

1. Remove its cover by loosening the four captive cover screws. (See Figure 2.)
2. Set the RA/DA operation jumpers to the desired mode of operation. Position the operation jumpers vertically for RA (Reverse Acting) or horizontally for DA (Direct Acting). (See Figure 2.)
3. Adjust the throttling range potentiometer to desired setting. Rotate Clockwise (CW) to increase the throttling range.

Notes: Included with the control is a Celsius scale throttling range decal. If the Celsius scale is desired, refer to the *Celsius Scale Conversion* section for decal installation instructions.

If the A350P is to be used in proportional plus integral control, the initial throttling range adjustment is seldom set below 6F° (3C°). A narrow proportional band used in conjunction with the integration may result in unstable control.

4. If minimum output is required, set the minimum output potentiometer (see Figure 2) to the desired position. The 10-segment front LED panel or a voltmeter can be used to read the minimum output. (The minimum setting for the **control** is designated by the 0 on the decal.)

Notes: Before adjusting the minimum output potentiometer, verify that the control reads zero output (that is, no LEDs are lit).

For each 10% increase in output, the **next** bar will light on the LED bar graph (only one bar is lit at anytime). In a milliampere application, each bar equals 2 mA. In a voltage application, each bar equals 1 VDC. (Refer to Figure 3.)

Example:

To set the control for a minimum output of 4 mA, turn the minimum output potentiometer clockwise until the second LED segment just lights.

5. Make sure the system is stable in the proportional mode before selecting integration. Refer to the *Checkout Procedure* section.
6. Reinstall the cover and secure in place with the four captive cover screws.
7. Adjust the setpoint dial to the desired setpoint.

If using the D350 Display Module, press and hold the setpoint button on the D350 while rotating the setpoint dial.

Note: The control's setpoint is factory calibrated at midscale to a tolerance of $\pm 1F^\circ$ (0.6C°). The setpoint tolerance at the extreme ends of the setpoint scale may be $\pm 4F^\circ$ (2.2C°). The D350 Display Module is unaffected by this tolerance shift. Use the D350 for the most accurate setpoint selection.

Checkout Procedure

Follow this procedure to verify the A350P control is connected and functioning properly.

1. Before applying power, make sure that the installation and wiring connections are according to job specifications.
2. Set up the system for proportional mode (Integration = OFF), and make any necessary adjustments to the setpoint, throttling range, and minimum output. Then select Reverse or Direct Acting mode.
3. After making adjustments and electrical connections, apply power to the system, and observe it for stable operation.
4. If integration is required, select the fast (C1), medium (C2), or slow (C3) integration constant. Slow is the recommended initial setting. (Refer to the *Integration Function* section.)
5. Put the system back into operation. If instability occurs, consider increasing the throttling range.

Troubleshooting

If the control system does not function properly, verify that the proper operation mode is selected on each module (DA or RA), and perform the following procedures to determine the cause of the problem:

1. Check for proper voltages on the A350P control.
 - a. Connect a digital voltmeter (DVM) between Terminals 24V (+) and C (-) located on the A350P's terminal block. (See Figure 2.)

If an external transformer is used, select AC volts on the DVM. Verify that the voltage is between 20 and 30 VAC.

If a Y350R Power Module is used, select DC volts on the DVM. Verify that the voltage is between 16 and 38 VDC.

If an external DC power supply is used, select DC volts on the DVM. Verify that the voltage is between 22 and 29 VDC.
 - b. If the DVM reading is within the indicated voltage range, select DC volts on the DVM (DVM must be accurate to +/-0.01 VDC), and connect the (+) lead to Terminal VDC and the (-) lead to Terminal C.

If the DVM voltage is between 4.9 and 5.1 VDC, proceed to Step 2.

If the DVM voltage is above 5.1 VDC, replace the A350P.
 - c. If the DVM voltage is below 4.9 VDC, check the control using the following procedure.

Disconnect all loads from the A350P control. (If in Direct Acting mode with power on, the system will go to full output when the sensor is disconnected. Thus, ensure that any loads are disconnected *before* disconnecting the temperature sensor.)

Disconnect the temperature sensor completely, and recheck the DVM voltage.

If the DVM voltage rises to a value between 4.9 and 5.1 VDC, replace the sensor.

If the DVM voltage is still below 4.9 VDC, replace the A350P control.

2. Check sensor for proper resistance at a given temperature. (The resistance across the sensor changes with the temperature of the sensor.)
 - a. Disconnect power from the A350P control.
 - b. Disconnect the sensor from the control and measure the resistance across sensor leads.
 - c. When measuring the sensor's resistance, use an accurate thermometer to measure the temperature at the sensor.
 - d. Refer to Figure 8 to determine the optimal resistance for the measured temperature.
 - e. If the measured resistance varies substantially from the optimal resistance for that temperature, the sensor or wiring must be replaced.
 - f. If the sensor's resistance conforms to the chart in Figure 8, reconnect the sensor to the control.
 - g. Reconnect power to the control.

Note: The sensor reading indicated by the D350 may differ somewhat from thermometer readings due to sensor tolerances, time constants, thermometer accuracy, and other factors.

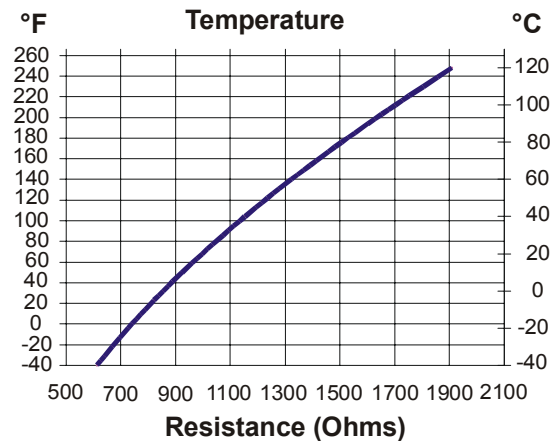


Figure 8: Temperature vs. Resistance Chart for the A99B Series Sensor

3. Check the A350P control for proper operation.

Note: Perform Steps 1 and 2 first.

- a. Reconnect the sensor to the control and re-apply power.
- b. Turn the throttling range and the minimum output to minimum by turning both potentiometers counterclockwise.
- c. Switch off the integration.
- d. Select the RA mode.
- e. Connect the DVM (+) lead to the A350P control's Terminal SN and the (-) lead to Terminal C.

If the sensor voltage is less than 1.8 VDC on model A350PS-1C or less than 2.3 VDC on model A350PS-2C, go to Step 3g.

- f. If the voltage is greater than 1.8 VDC on model A350PS 1C or greater than 2.3 VDC on model A350PS-2C, adjust the setpoint to 120°F (49°C) on model A350PS-1C or 240°F (116°C) on model A350PS-2C.

The output Terminal V should be less than 0.1 VDC, and all LEDs in the bar graph display should be off. If not, replace the A350P.

1. Adjust the minimum output to the maximum by turning the potentiometer CW. As the potentiometer is turned CW, the LEDs in the bar graph should turn on from left to right until the fifth or sixth bar is on. If not, replace the A350P control.
2. Adjust the minimum output to zero again, and select the DA mode.
3. If the right most LED in the bar graph is on (Terminal V = 10 VDC, Terminal I = 20 mA), go to Step 3h. If the LED is not on, replace the A350P.

- g. If the sensor voltage is above 1.1 VDC on A350PS-1C or above 1.6 VDC on A350PS-2C, adjust the setpoint to match the actual temperature (T_S). The output Terminal V should be less than 0.1 VDC, and all LEDs in the bar graph should be off.

Note: Some tolerance error is present between the setpoint scale and the setpoint knob pointer. Refer to the *Adjustments* section.

1. Make sure the A350P control is in RA mode.
 2. Increase the setpoint in increments of 2F° (1C°).
 3. As the setpoint is increased, the control's Terminal V output voltage should go from 0 to 10 VDC, the Terminal I output current should go from 0 to 20 mA, and the LEDs should turn on, one at a time from left to right.
 4. If the LEDs do not turn on and if the outputs of terminals V and I do not change as described above, replace the control.
- h. Readjust the A350P control to the desired control settings.

Repairs and Replacement

Do not make field repairs or perform calibration. A99B Temperature Sensors and replacement controls are available through the nearest Johnson Controls representative. (See Tables 5 and 6 for ordering information.)

Ordering Information

Table 5: System 350 Products

Item	Product Code Number	Description
A350P Proportional Plus Integral Temperature Controls	A350PS-1C	Range: -30 to 130°F (-35 to 55°C) Throttling Range: 2 to 30 F° (1 to 17C°) (Includes the A99BC-25C Temperature Sensor)
	A350PS-2C	Range: 90 to 250°F (30 to 120°C) Throttling Range: 2 to 30 F° (1 to 17C°) (Includes the A99BC-25C Temperature Sensor)
	A350PT-1C	Range: -30 to 130°F (-35 to 55°C) Throttling Range: 2 to 30F° (1 to 17C°) (Sensor not included)
Display Modules	D350AA-1C	Digital Temperature Display Module (Fahrenheit Scale)
	D350BA-1C	Digital Temperature Display Module (Celsius Scale)
On/Off Stage Modules	S350AA-1C	Fahrenheit Scale
	S350AB-1C	Celsius Scale
Slave Stage Module	S350CC-1C	Dual Scale (°F and °C)
Proportional Stage Module	S350PQ-1C	Dual Scale (°F and °C)
Power Module	Y350R-1C	120 or 240 VAC, 50/60 Hz Input, Rectified Class 2, 24 VAC Output

Table 6: System 350 Accessories

Item	Product Code Number	Description
Wall Mount Plate	TE-6001-4	Includes sensor mounting clip
Cover	T-4000-2644	For wall mount plate
Mounting Clip	A99-CLP-1	Surface mounting clip for the A99B Temperature Sensor
Duct Mounting	TE-6001-1	Duct-mounting hardware with handy box
Duct Mounting	TE-6001-11	Duct-mounting hardware without handy box
Conduit Adaptor	ADP11A-600R	1/2 in. snap-fit EMT conduit adaptor (box of 10)
Immersion Well	WEL11A-601R	For liquid sensing applications
Sun Shield	SHL10A-603R	For use with outside sensors in sunny locations
DIN Rail Sections	BKT287-1R	12 in. (0.3 m) long
	BKT287-2R	39-1/3 in. (1.0 m) long
DIN Rail End Clamp	PLT344-1R	Consists of two end clamps
Cables for Remote Mounting of D350 Display Module	WHA29A-600R*	3 ft (0.9 m)
	WHA29A-603R	25 ft (7.6 m)
	WHA29A-604R	50 ft (15.2 m)

*WHA29A-600R may be used to daisy chain S350 modules together.

Specifications

Product	A350P Proportional Plus Time Integral Temperature Control	
Supply Voltage	Y350R Power Module:	Input: 120/240 VAC 50/60 Hz Output: 24 VDC, unfiltered, 10 VA
	External Source:	24 VAC, 50/60 Hz, Class 2 (20-30 VAC)
	Note: Only one supply voltage source may be used.	
Power Consumption	3.2 VA maximum	
Ambient Temperature	Operating:	-30 to 150°F (-34 to 66°C)
	Shipping:	-40 to 185°F (-40 to 85°C)
Humidity (all modules)	0 to 95% RH non-condensing; maximum dew point 85°F (29°C)	
Setpoint Adjustment Range	A350PS-1C:	-30 to 130°F (-35 to 55°C)
	A350PS-2C:	90 to 250°F (30 to 120°C)
	A350PT-1C:	-30 to 130°F (-35 to 55°C)
Throttling Adjustment Range	2 to 30F° (1 to 17C°)	
Analog Outputs	0 to 10 VDC (550 ohm load minimum) and 0 to 20 mA (600 ohm load maximum)	
Minimum Output	Adjustable from 0 to 60% of the output	
Output Indication	A ten segment LED bar graph indicates percentage of output.	
Control Action	Direct or reverse action is jumper selectable.	
Integration Constant	Four selectable rates: fast, medium, slow, and off	
Sensor	Replaceable positive temperature coefficient sensor Reference resistance 1035 ohms at 77°F (25°C)	
Material	Case and cover:	NEMA 1 high-impact thermoplastic
Agency Listing	UL Listed, CCN XAPX, File E27734 UL Listed for Canada, CCN XAPX7, File E27734	

The performance specifications are nominal and conform to acceptable industry standards. For application at conditions beyond these specifications, consult Johnson Controls Application Engineering at (414) 274-5535. Johnson Controls, Inc. shall not be liable for damages resulting from misapplication or misuse of its products.



Controls Group
507 E. Michigan Street
P.O. Box 423
Milwaukee, WI 53201

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