System 350™
S350P Proportional Plus Integral Temperature Stage Module

The S350P is used in conjunction with the A350 Temperature Control to add proportional or proportional plus integral staging capability. The S350P is an electronic control with analog 0 to 10 VDC and 0 to 20 mA outputs.

As with all System 350 products, the S350P is housed in a NEMA 1, high-impact plastic enclosure. The modular design provides easy, plug-in connections for quick installation and future expandability.

Figure 1: S350P Electronic Proportional Plus Integral Temperature Stage Module

Features and Benefits

❑ **Plug-in Connectors and 35 mm DIN Rail Mountability**	Eliminates wiring between modules and reduces installation costs
❑ **Proportional or Proportional Plus Integral Output**	Adds proportional or proportional plus integral staging capability to all A350 Temperature Controls
❑ **Minimum Output Adjustable from 0 to 60%**	Tailors the output to the requirements of the controlled device; can also be used to set minimum valve or damper position
❑ **Adjustable Throttling Range of 2 to 30F° (1 to 17C°)**	Enables the user to tune the system for optimum performance
❑ **Field-selectable Reverse or Direct Acting Mode**	Works in heating or cooling applications
❑ **Three User-selectable Integration Constants**	Provides selection of the integration constant for applications requiring proportional and integral control
❑ **Light-Emitting Diode (LED) Bar Graph Display of Output**	Aids in adjustment, tuning, and troubleshooting

Part No. 24-7664-1202, Rev. —
Code No. LIT-930086

Application Overview

The S350P Proportional Stage Module must be used in conjunction with an A350 Temperature Control. The S350P receives its power, setpoint, and sensor inputs from the A350. The S350P adds a proportional or proportional plus integral output to the A350 control.

The maximum number of stages that can be used in a system varies with the type of control module (on-off, proportional, or reset), type of stage module (on-off, slave, or proportional), and type of power supply (external transformer or Y350R). Use the following table to determine the maximum number of stages that may be used with each control module.

Table 1: Maximum S350 Stage Modules per Control Module

Control	Maximum S350A or S350C Stage Modules	Maximum S350A or S350C (with 1 S350P)	Maximum S350A or S350C (with 2 S350P)
A350A, A350B, A350E, A350R, A350S (using Y350R)	9	6	4
A350P (using Y350R)	4	2	N/A
Any A350 (using external 40 VA transformer)	9	8	7

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.

The S350P is powered by the A350, and provides two simultaneous analog outputs: 0 to 10 VDC and 0 to 20 milliamperes (mA). A cover-mounted, ten segment LED bar graph indicates the percentage of output currently in use. S350P features include:

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

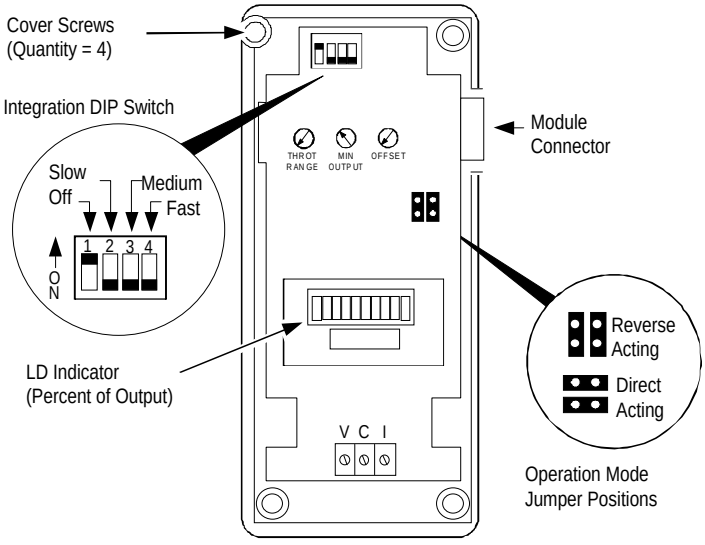

Figure 2: Interior View Illustrating S350P Features

Offset

The offset can be adjusted from 0 to 30F° (0 to 17C°). The offset adjustment determines the amount of offset between the A350's setpoint and where the S350P's throttling range begins (refer to Figure 5). This adjustment is made using the potentiometer marked OFFSET located at the upper portion of the circuit board (refer to Figure 2).

Mode of Operation (Direct Acting or Reverse Acting)

When configured for Reverse Acting (RA) operation, the analog output increases as the temperature drops below the value of the A350's setpoint minus the S350P's offset (refer to Figure 3).

When configured for Direct Acting (DA) operation, the analog output increases as the temperature rises above the value of the A350's setpoint plus the S350P's offset (refer to Figure 3).

Select the RA/DA mode by positioning the operation mode jumpers either vertically or horizontally (refer to Figure 2). Position the operation mode jumpers vertically for Reverse Action (RA) or horizontally for Direct Action (DA).

As shipped from the factory, the RA/DA operation mode jumpers are installed in the RA mode.

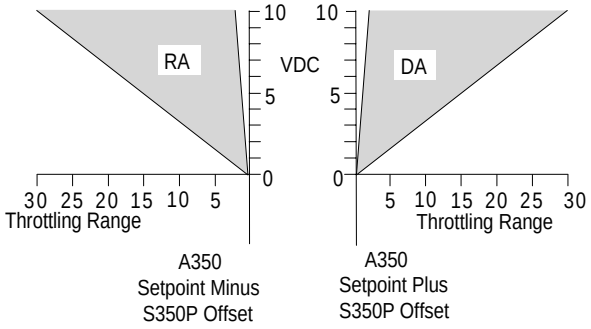

Figure 3: Direct or Reverse Acting Proportional Bands Shown in "Proportional Only" Mode (Shaded Area Shows Throttling Range Possibilities from Minimum to Maximum)

Throttling Range (Proportional Band)

The throttling range can be adjusted from 2 to 30F° (1 to 17C°). Make the adjustment at the throttling range potentiometer marked THROT RANGE (refer to Figure 2).

Included with the S350P is a Celsius scale throttling range decal. If the Celsius scale is desired:

1. Use a small screwdriver to pry underneath the existing decal and remove it along with the throttling range, minimum output, and offset potentiometer knobs.
2. Apply the Celsius scale decal where the original decal was located.
3. Rotate all knob stems completely counterclockwise.
4. Reinstall the potentiometer knobs so the arrows are at the furthest counterclockwise scale position (refer to Figure 2).

Minimum Output Adjustment

The minimum output adjustment sets the minimum voltage or milliampere output provided by the S350P. 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 to 20 mA output would require the minimum output to be adjusted to 20% or 4 mA (refer to Figure 4). The minimum output adjustment may also be used to set valves or dampers to minimum position.

Make the adjustment at the minimum output potentiometer marked as MIN OUTPUT (Figure 2). For each 10% increase in range, one bar on the LED indicator appears.

Note: Before setting the minimum output potentiometer, be sure the control is not generating an analog output signal.

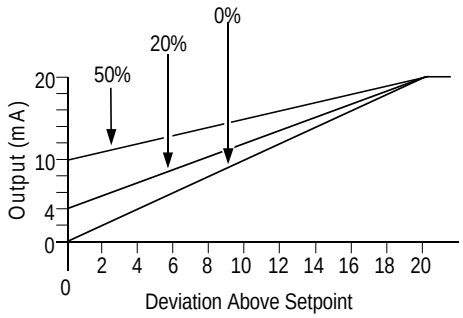

Figure 4: Output vs. Deviation from Setpoint for: Minimum Output = 0, 20, and 50%, Throttling Range = 20°F Direct Acting

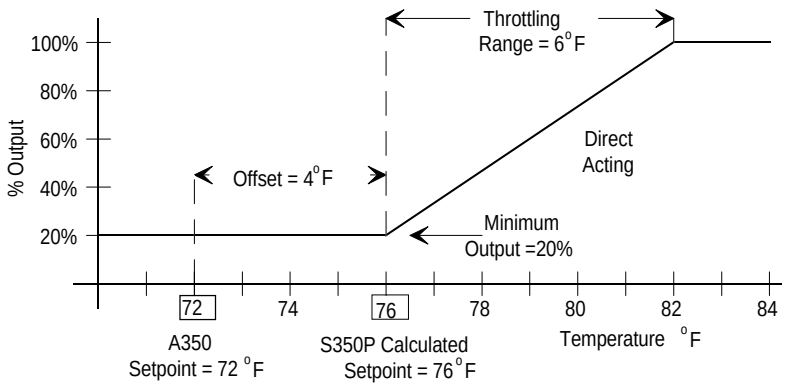

Figure 5: Example of S350P Adjustments

Integration Constant

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 causes the control point to be offset from the setpoint. The greater the load on the system, the further the control point offsets from the setpoint (this is commonly referred to as proportional offset) and under maximum load this error approaches the throttling range.

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

The S350P has an integration feature that forces the control point to match the S350P calculated setpoint. Over time, the S350P controls the heating/cooling equipment to balance the system load at the calculated setpoint (refer to Figure 6).

On traditional proportional plus integral controls, the amount of correction becomes 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 S350P avoids integral windup with a patented circuit that puts a dynamic ceiling on the integrator. This circuit resets the integration error when the sensor goes just above the calculated setpoint plus the throttling range (in DA mode) or just below the calculated 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 S350P has three field-selectable integration constants and an off position. The integration DIP switch selects the integration constant. (Refer to Figure 2 for location.) The field-selectable integration constants include:

- **Off (Switch 1 to On position, all others Off)** Provides proportional only operation.
- **Slow (C3) (Switch 2 to On position, all others Off)** This is the slowest integration constant (equal to 26 minutes) 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 to On position, all others Off)** This is the fastest integration constant (equal to 6.5 minutes). Use the fast setting only in instances where the rate of change at the sensor is extremely rapid and system capacity can compensate for that rapid change.

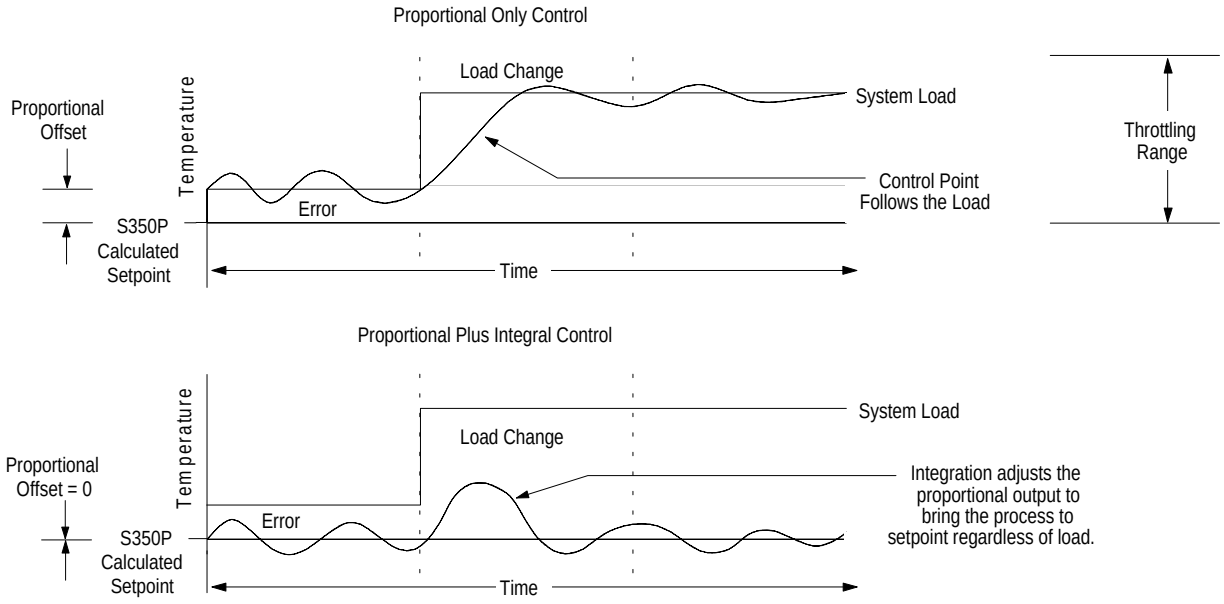

Figure 6: Operation of Proportional Only vs. Proportional Plus Integral Control

Dimensions

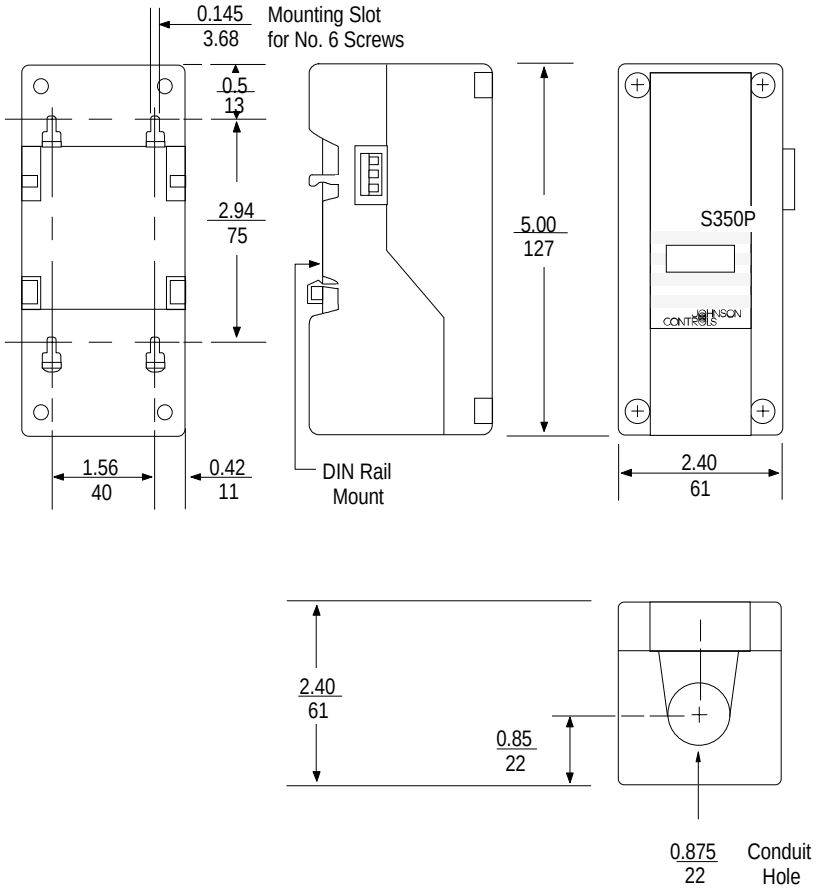

Figure 7: S350P Dimensions, in./mm

Installation and Wiring

The S350P Temperature Control is housed in a compact NEMA 1 plastic enclosure designed for standard 35 mm DIN rail mounting. The S350P is not position sensitive but should be mounted for convenient wiring and adjustment. Four key-slot mounting holes on the back of the control case are provided should surface mounting be required.

Note: When mounting the S350P (or any System 350 module) to rigid conduit, attach the hub to the conduit before securing the hub to the control enclosure.

> WARNING: **Shock hazard.** Disconnect power supply before wiring connections are made to avoid possible electrical shock or damage to equipment.

- 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. Only use copper conductors.
- The S350P can produce a variable signal from 0 to 10 VDC or 0 to 20 mA. (Both outputs can be used simultaneously.) Connections are made to the terminal block located in the wiring compartment at the bottom of the case.
- Connections can be made to both the voltage and milliampere outputs, allowing the S350P to drive two outputs off the same RA or DA ramp simultaneously. This feature can be used to drive motor actuators of several different types in a single application.

Table 2: Terminal Designations

Terminal Designation	Terminal Description
V	0 to 10 VDC output
COM	Common
I	0 to 20 mA output

Adjustments

Follow these procedures to set up the S350P for the types of operation desired.

1. Remove S350P cover by loosening the four cover screws (Figure 2).
2. Set the RA/DA operation mode jumpers to the desired mode of operation. Position the operation mode jumpers vertically for RA (Reverse Acting) or horizontally for DA (Direct Acting) (Figure 2).
3. Adjust the offset potentiometer to the number of degrees from the A350 control's setpoint that the S350P begins throttling. Clockwise rotation increases offset.
4. Adjust the throttling range potentiometer to desired setting. Rotate clockwise to increase the throttling range.

   Note: Included with the S350P is a Celsius scale throttling range decal. Refer to the *Throttling Range (Proportional Band)* section of this bulletin for decal installation instructions.

   If the S350P is to be used in proportional plus integral mode, 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.
5. If minimum output is required, set the minimum output potentiometer (labeled MIN OUT) to the desired position (Figure 2). Output can be read with a voltmeter or can be adjusted using the ten segment, front panel LED.

   Note: Before setting the minimum output potentiometer, be sure the control is not generating an analog output signal.

   For each 10% increase in range, one bar lights on the LED bar graph. In a milliampere application, each bar equals 2 mA. In a voltage application, each bar equals 1V. (Refer to Figure 4 for an example.)

   Example: To set the S350P for a minimum output of 4 mA, turn the minimum output potentiometer clockwise until the second LED segment lights. Slowly rotate the potentiometer counterclockwise just until the second segment disappears.

6. Make sure the system is stable in the proportional mode before selecting integration. Refer to *Checkout Procedure.*

7. Reinstall the cover and secure in place with the four cover screws.

Checkout Procedure

Follow this procedure to ensure the S350P is connected and functioning properly.

1. Before applying power, make sure that the installation and wiring connections comply with job specifications.

2. Set the system for the proportional mode and tune it for stable operation.

3. After making adjustments and electrical connections, put the system into operation and observe at least three complete operating cycles to determine that the system is stable.

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 Constant* section of this bulletin.)

5. Observe operation and make additional adjustments as necessary to obtain stable control.

Troubleshooting

If the control system does not function properly, verify the proper operation mode is selected on each module (e.g., RA/DA) and perform the following:

1. Check for proper voltage applied to the A350 control.

a. Connect a Digital Voltmeter (DVM) between the 24V (+) and C (-) terminals located on the A350's left side terminal block.

- If an external transformer is used, select AC volts on the DVM and verify that the voltage is between 20 and 30 VAC.
- If a Y350R Power Module is used, select DC volts on the DVM and verify that the voltage is between 16 and 38 VDC.
- If an external DC power supply is used, select DC volts on the DVM and verify that the voltage is between 22 and 29 VDC.

b. If the DVM voltage is within the indicated voltage range, proceed to Step 2.

c. If the DVM voltage is **not** within the indicated voltage range, check wiring, and then replace the Y350R or the external transformer.

2. Check temperature sensor for proper resistance.

a. Take an independent temperature reading at the sensor location (T_S). Allow the thermometer to stabilize before taking the reading.

b. Disconnect the sensor from the control. Using an ohmmeter, measure the resistance across the two sensor leads. Consult the Temperature vs. Resistance Chart (Figure 8) to verify sensor conformity.

c. Replace the sensor if its actual performance deviates substantially from that represented on the chart.

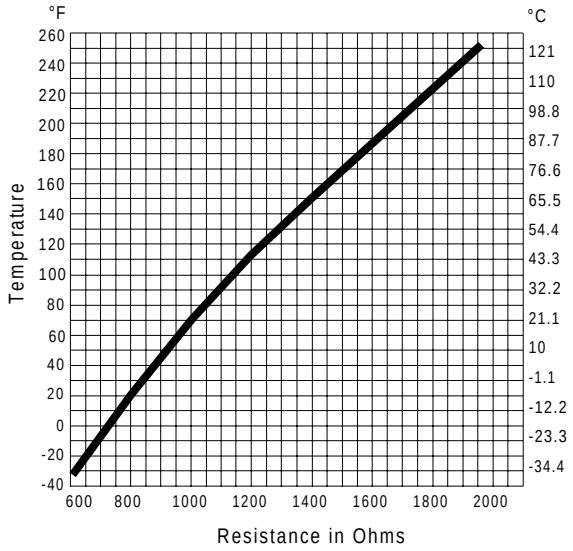

Figure 8: Temperature vs. Resistance Chart for the SET189A Series Sensor

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.

3. Check the S350P for proper operation.

Note: Steps 1 and 2 must be performed first.

a. Reconnect the sensor to the A350 and re-apply power.

b. Turn the A350's setpoint to minimum.

c. On the S350P, turn the throttling range and the minimum output to the minimum position by turning both potentiometers counterclockwise. Switch the integration off and select the RA mode.

d. Adjust the minimum output to the maximum position by turning the potentiometer clockwise. As the potentiometer is turned clockwise, the LEDs in the bar graph should turn on from left to right until the fifth or sixth bar is on. If they do not, replace the S350P.

e. Adjust the minimum output to zero again and select the DA mode. The "V" output voltage should be greater than or equal to 10 VDC, the "I" current output should be greater than or equal to 20 mA, and the rightmost LED should be on. If not, replace the S350P.

f. Slowly increase the setpoint on the A350. The LEDs should turn off from the right side to the left side of the bar graph, until all are off (indicating that the A350 setpoint dial has reached a value equal to the sensor temperature minus the S350P's offset). If they do not, then replace the S350P.

Note: Although unlikely, it is possible that a defect in one S350 could cause defective symptoms in all modules. Plug each stage module into the A350 and individually check its performance as outlined in Steps 3a to 3f.

Repairs and Replacement

Do not make field repairs or perform calibration. SET189A Temperature Sensors and replacement controls are available through local Johnson Controls representatives.

Ordering Information

Table 3: Ordering information

Product Code Number	Description
S350PQ-1C	Electronic Proportional Plus Integral Temperature Stage Module

Notes

Specifications

Product	S350P Proportional Plus Integral Temperature Stage Module
Input Voltage	5 VDC Reference Provided by the A350; 24V Power Supply
Ambient Temperatures	Operating: -30 to 150°F (-34 to 66°C) Shipping: -40 to 185°F (-40 to 85°C)
Humidity	0 to 95% RH Non-condensing; Maximum Dew Point: 85°F (29°C)
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.
Mode of Operation	Direct or reverse action is jumper selectable.
Offset Range	0 to 30F° (0 to 17C°)
Throttling Range	2 to 30F° (1 to 17C°)
Integration Constant	Four Selectable Rates: Fast, Medium, Slow, and Off
Material	Case, Cover: NEMA 1 High-impact Thermoplastic
Agency Listing	UL Guide No. XAPX and cUL Guide No. XAPX7, File E27734

The performance specifications are nominal and conform to acceptable industry standards. For application at conditions beyond these specifications, consult the local Johnson Controls office. Johnson Controls, Inc. shall not be liable for damages resulting from misapplication or misuse of its products.

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