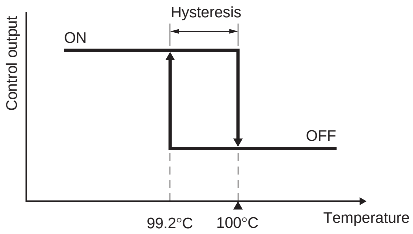
Temperature Controller Glossary

■ Glossary of Control Terminology

Hysteresis

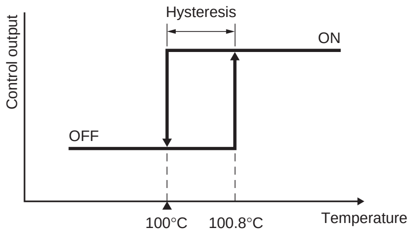
ON/OFF control action turns the output ON or OFF based on the set point. The output frequently changes according to minute temperature changes as a result, and this shortens the life of the output relay or unfavorably affects some devices connected to the Temperature Controller. To prevent this from happening, a temperature band called hysteresis is created between the ON and OFF operations.

Hysteresis (Reverse Operation)



Example: Hysteresis indicates 0.8°C.

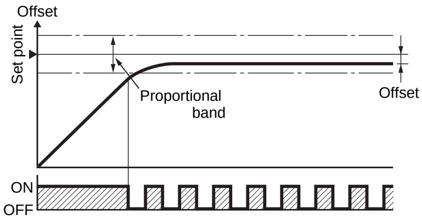
Hysteresis (Forward Operation)



Example: Hysteresis indicates 0.8°C.

Offset

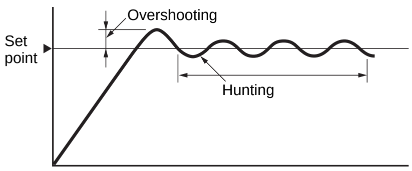
Proportional control action causes an error in the process value due to the heat capacity of the controlled object and the capacity of the heater. The result is a small discrepancy between the process value and the set point in stable operation. This error is called offset. Offset is the difference in temperature between the set point and the actual process temperature. It may exist above or below the set point.



Hunting and Overshooting

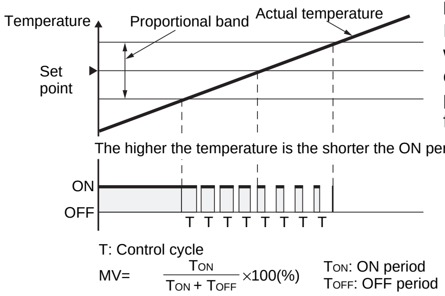
ON/OFF control action often involves the waveform shown in the following diagram. A temperature rise that exceeds the set point after temperature control starts is called overshooting. Temperature oscillation near the set point is called hunting. Improved temperature control is to be expected if the degree of overshooting and hunting are low.

Hunting and Overshooting in ON/OFF Control Action



Control Cycle and Time-Proportioning Control Action

The control output will be turned ON intermittently according to a preset cycle if P action is used with a relay or SSR. This preset cycle is called the control cycle and this method of control is called time-proportioning control action.



Example:
If the control cycle is 10 s with an 80% control output, the ON and OFF periods will be as follows.

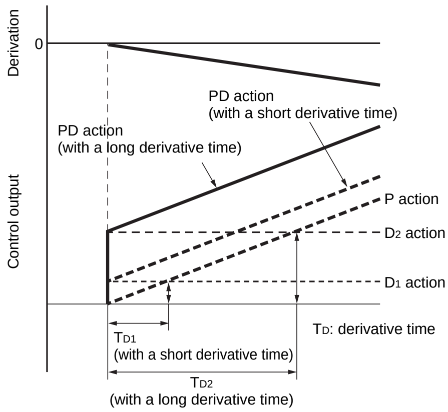
T_{ON}: 8 s

T_{OFF}: 2 s

Derivative Time

Derivative time is the period required for a ramp-type deviation in derivative control (e.g., the deviation shown in the following graph) that coincides with the control output in proportional control action. The longer the derivative time is the stronger the derivative control action will be.

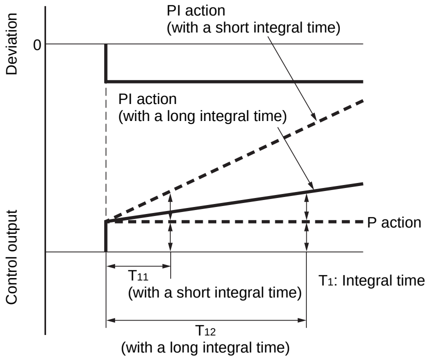
PD Action and Derivative Time



Integral Time

Integral time is the period required for a step-type deviation in integral control (e.g., the deviation shown in the following graph) to coincide with the control output in proportional control action. The shorter the integral time is the stronger the integral action will be. If the integral time is too short, however, hunting may result.

PI Action and Integral Time



Constant Value Control

For constant value control, control is preformed at specific temperatures.

Program Control

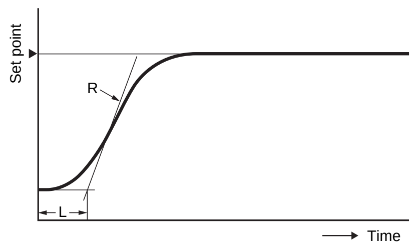
Program control is used to control temperature for a target value that changes at predetermined time intervals.

Auto-tuning

The PID constant values and combinations that are used for temperature control depend on the characteristics of the controlled object. A variety of conventional methods that are used to obtain these PID constants have been suggested and implemented based on actual control temperature waveforms. Auto-tuning methods make it possible to obtain PID constants suitable to a variety of controlling objects. The most common types of auto-tuning are the step response, marginal sensitivity, and limit cycle methods.

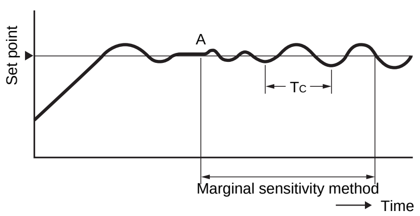
Step Response Method

The value most frequently used must be the set point in this method. Calculate the maximum temperature ramp R and the dead time L from a 100% step-type control output. Then obtain the PID constants from R and L.



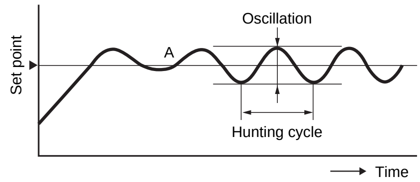
Marginal Sensitivity Method

Proportional control action begins from start point A in this method. Narrow the width of the proportional band until the temperature starts to oscillate. Then obtain the PID constants from the value of the proportional band and the oscillation cycle time T at that time.



Limit Cycle Method

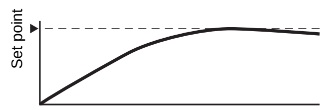
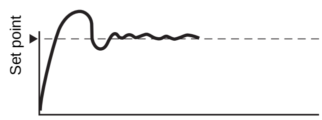
ON/OFF control begins from start point A in this method. Then obtain the PID constants from the hunting cycle T and oscillation D.



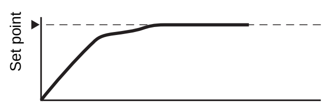
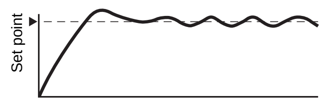
Readjusting PID Constants

PID constants calculated in auto-tuning operation normally do not cause problems <u>except for some particular applications</u>. In those cases, refer to the following diagrams to readjust the constants.

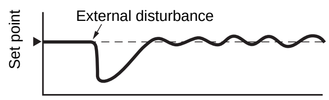
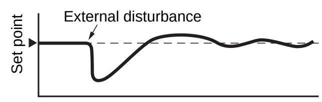
Response to Change in the Proportional Band

Wider		It is possible to suppress overshooting although a comparatively long startup time and set time will be required.
Narrower		The process value reaches the set point within a comparatively short time and keeps the temperature stable although overshooting and hunting will result until the temperature becomes stable.

Response to Change in Integral Time

Wider		The set point takes longer to reach. It is possible to reduce hunting, overshooting, and undershooting although a comparatively long startup time and set time will be required.
Narrower		The process temperature reaches the set point within a comparatively short time although overshooting, undershooting, and hunting will result.

Response to Change in Derivative Time

Wider		The process value reaches the set point within a comparatively short time with comparatively small amounts of overshooting and undershooting. Fine-cycle hunting will result due to the change in process value.
Narrower		The process value will take a relatively long time to reach the set point with heavy overshooting and undershooting.

Fuzzy Self-tuning

PID constants must be determined according to the characteristics of the controlled object for proper temperature control. The conventional Temperature Controller incorporates an auto-tuning function to calculate PID constants. In that case, it is necessary to give instructions to the Temperature Controller to trigger the auto-tuning function. Furthermore, temperature disturbances may result if the limit cycle is adopted. The Temperature Controller in fuzzy self-tuning operation determines the start of tuning and ensures smooth tuning without disturbing temperature control. In other words, the fuzzy self-tuning function makes it possible to adjust PID constants according to the characteristics of the controlled object.

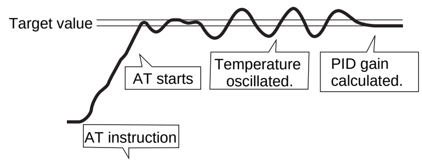
Fuzzy Self-tuning in 3 Modes

- PID constants are calculated by tuning when the set point changes.
- When an external disturbance affects the process value, the PID constants will be adjusted and kept in a specified range.
- If hunting results, the PID constants will be adjusted to suppress hunting.

Auto-tuning with a Conventional Temperature Controller

Auto-tuning (AT) Function: A function that automatically calculates optimum PID constants for controlled objects.

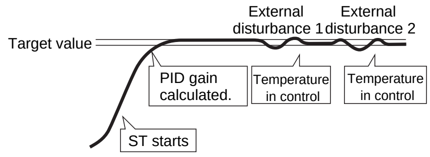
Features: (1) Tuning will be performed when the AT instruction is given.
(2) The limit cycle signal is generated to oscillate the temperature before tuning.



Self-tuning

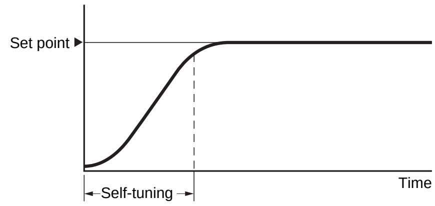
Self-tuning (ST) Function: A function that automatically calculates optimum PID constants for controlled objects.

Features: (1) Whether to perform tuning or not is determined by the Temperature Controller.
(2) No signal that disturbs the process value is generated.



Self-tuning

Self-tuning is supported by the E5☐S. Trends in temperature changes are used to automatically calculate and set a suitable proportional band.



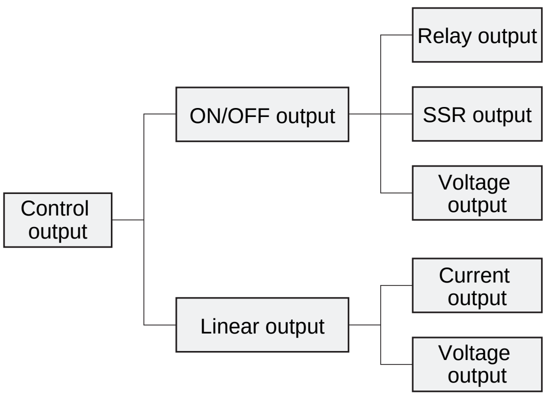
PID Control and Tuning Methods for Temperature Controllers

Model / Type of PID	PID	Two PID	Two PID + Fuzzy
E5☐N (See note.)		AT, ST**	
E5☐S	ST*		
E5ZN		AT	
E5ZD		AT	AT
C200H-TC		AT	
C200H-TV		AT	
C200H-PID		AT	
CQM1-TC		AT	

ST: Fuzzy self-tuning, ST*: Self-tuning, ST**: Executed only for SP changes, AT: Autotuning

Note: Not including the E5ZN

Control Outputs



Relay output: Contact relay output used for control methods with comparatively low switching frequencies.

SSR output: Non-contact solid-state relay output for switching 1 A maximum.

Voltage output (ON/OFF): ON/OFF pulse output at 5, 12, or 24 VDC externally connected to a high-capacity SSR. ON/OFF action is ideal for high switching frequency and PID action is ideal for time-proportioning control action.

Current output: Continuous 4- to 20-mA or 0- to 20-mA DC output used for driving power controllers and electromagnetic valves. Ideal for high-precision control. A preset linear output is produced if the load resistance falls below allowable levels.

Voltage output (linear): Continuous 0 to 5 or 0 to 10 VDC output used for driving pressure controllers. Ideal for high-precision control.

■ Glossary of Alarm Terminology

Alarm Operation

The Temperature Controller compares the process value and the preset alarm value, turns the alarm signal ON, and displays the type of alarm in the preset operation mode.

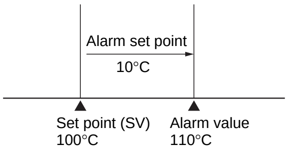
Deviation Alarm

The deviation alarm turns ON according to the deviation from the set point in the Temperature Controller.

Setting Example

Alarm temperature is set to 110º.

The alarm set point is set to 10°C.



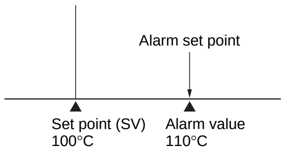
Absolute-value Alarm

The absolute-value alarm turns ON according to the alarm temperature regardless of the set point in the Temperature Controller.

Setting Example

Alarm temperature is set to 110°C.

The alarm set point is set to 110°C.

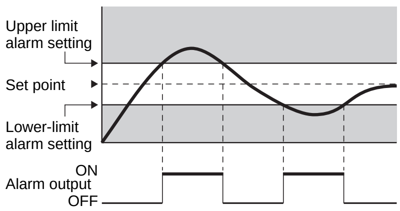


Standby Sequence Alarm

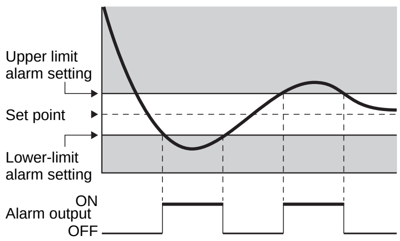
It may be difficult to keep the process value outside the specified alarm range in some cases (e.g., when starting up the Temperature Controller), and the alarm turns ON abruptly as a result. This can be prevented with the standby sequential function of the Temperature Controller. This function makes it possible to ignore the process value right after the Temperature Controller is turned ON or right after the Temperature Controller starts temperature control. In this case, the alarm will turn ON if the process value enters the alarm range after the process value has been once stabilized.

Example of Alarm Output with Standby Sequence Set

Temperature rise



Temperature Drop



SSR Failure Alarm

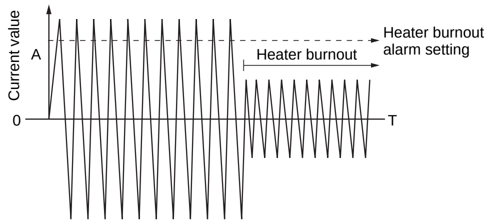
(Applicable models: E5CN)

The SSR Failure Alarm is output when an SSR short-circuit failure is detected. A CT (Current Transformer) is used by the Temperature Controller to detect heater current and it outputs an alarm when a short circuit occurs.

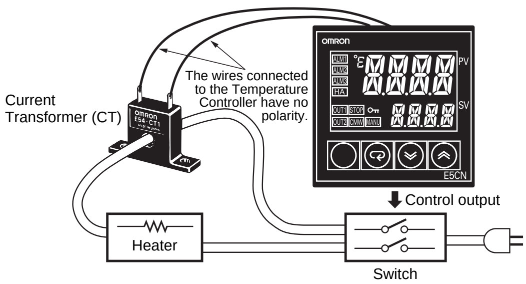
Heater Burnout Alarm

(Three phase (E5CN, E5AN, and E5EN only) and single phase)

Many types of heaters are used to raise the temperature of the controlled object. The CT (Current Transformer) is used by the Temperature Controller to detect the heater current. If the heater's power consumption drops, the Temperature Controller will detect heater burnout from the CT and will output the heater burnout alarm.

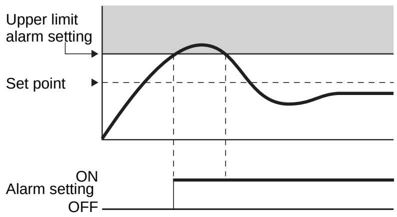


Heater current waveform (CT waveform)



Alarm Latch

The alarm will turn OFF if the process value falls outside alarm operation range. This can be prevented if the process value enters the alarm range and an alarm is output by holding the alarm output until the power supply turns OFF.



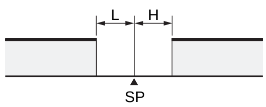
LBA

(Applicable models: E5CN, E5AN, and E5EN)

The LBA (loop break alarm) is a function that turns the alarm signal ON by assuming the occurrence of control loop failure if there is no input change with the deviation above a certain level. Therefore, this function can be used to detect control loop errors.

Configurable Upper and Lower Limit Alarm Settings

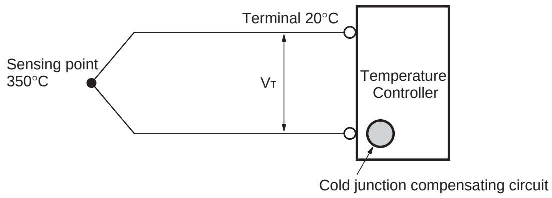
(Applicable models: E5☐N and E5☐R)



■ Glossary of Temperature Sensor Terminology

Cold Junction Compensation

The thermo-electromotive force of the thermocouple is generated due to the temperature difference between the hot and cold junctions.
Therefore, if the cold junction temperature fluctuates, the thermo-electromotive force will change even if the hot junction temperature remains stable.
To negate this effect, a separate sensor is built into the Temperature Controller at a location with essentially the same temperature as the cold junction to monitor any changes in the temperature. A voltage that is equivalent to the resulting thermo-electromotive force is added to compensate for (i.e., cancel) changes that occur in the thermo-electromotive force.
Compensation for fluctuations by adding a voltage is called cold junction compensation.



In the above diagram, the thermo-electromotive force (1) V_T that is measured at the input terminal of the Temperature Controller is equal to V (350, 20). Here, V (A, B) gives the thermo-electromotive force when the cold junction is A °C and the cold junction is B °C. Based on the law of intermediate temperatures, a basic behavior of thermocouples, (2) V (A, B) = V (A, C) - V(B, C).

When the ambient (terminal section) temperature is 20°C, the temperature sensor inside the Temperature Controller detects 20°C. If we add the voltage V(20, 0) that corresponds to 20°C in the standard electromotive force table to the right side, we get the following:

V(350, 20) + V(20, 0)

V(350, 20) ↓ Thermo-electromotive force from thermocouple

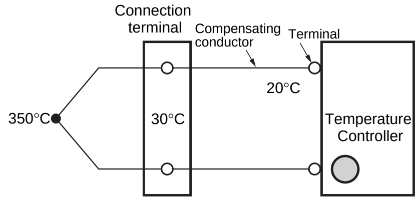
V(20, 0) ↓ Electromotive force generated by the cold junction compensation circuit

If we expand the first part of formula (2) with A = 350, B = 20, and C = 0, we get the following:
= V{(350, 0) − V(20, 0)} + V(20, 0) = V(350, 0).

V(350, 0) is the thermo-electromotive force for a cold junction temperature of 0°C. This is the value that is defined as the standard thermo-electromotive force by JIS, so if we check the voltage, we can find the temperature of the hot junction (here, 350°C).

Compensating conductor

An actual application may have a sensing point that is located far away from the Temperature Controller.
If normal copper wires are used because the wiring length is limited for a sensor that uses thermocouple wires or because conductors are too expensive, a large error will occur in the temperature.
Compensating conductors are used instead of plain wires to extend the thermocouple wires.
If compensating conductors are used within a limit temperature range (often near room temperature), a thermo-electromotive force that is essentially the same as the original thermocouple is generated, so they are used to extend the thermocouple wires.
However, if compensating conductors that are suitable for the type of thermocouple are not used, the measured temperature will not be correct.



V (350, 30) + V (30, 20) + V (20, 0)

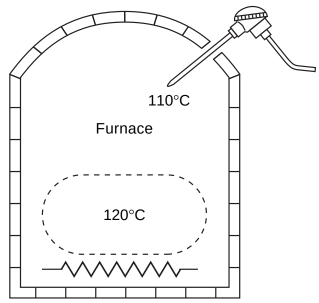
- V (350, 30): Thermo-electromotive force from thermocouple
- V (30, 20): Thermo-electromotive force from compensating conductors
- V (20, 0): Voltage from cold junction compensation

= {V (350, 30) - V (30, 0)} + {V(30, 0) - V (20, 0)} + V (20, 0)
= V (350, 0)

Example of Compensating Conductor Use

Input Shift

A preset point is added to or subtracted from the temperature detected by the Temperature Sensor of the Temperature Controller to display the process value. The difference between the detected temperature and the displayed temperature is set as an input compensation value.

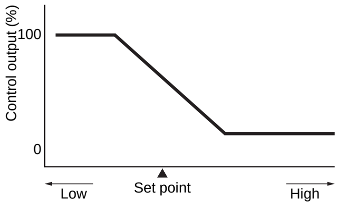


Input compensation value: 10°C (Displayed value is 120°C.)
(120 – 110 = 10)

■ Glossary of Output Terminology

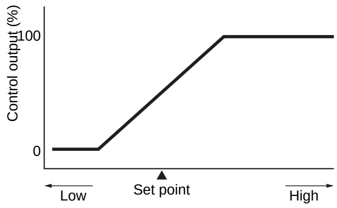
Reverse Operation (Heating)

The Temperature Controller in reverse operation will increase control output if the process value is lower than the set point (i.e., if the Temperature Controller has a negative deviation).



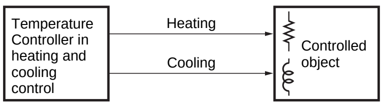
Direct Operation (Cooling)

The Temperature Controller in normal operation will increase control output if the process value is higher than the set point (i.e., if the Temperature Controller has a positive deviation).

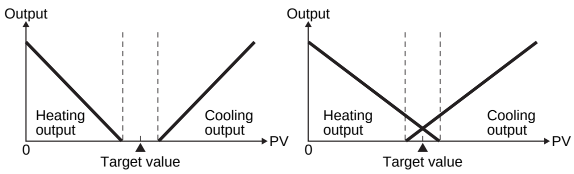


Heating and Cooling Control

Temperature control over a controlled object would be difficult if heating was the only type of control available, so cooling control was also added. Two control outputs (one for heating and one for cooling) can be provided by one Temperature Controller.

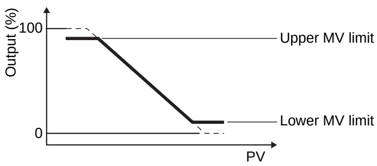


Heating and Cooling Outputs

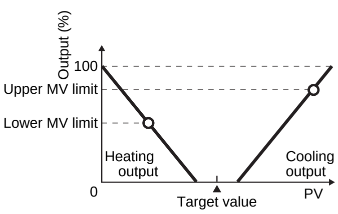


MV (Manipulated Variable) Limiter

The upper and lower limits for the MV limiter are set by the upper MV and lower MV settings. When the MV calculated by the Temperature Controller falls outside the MV limiter range, the actual output will be either the upper or lower MV limit.

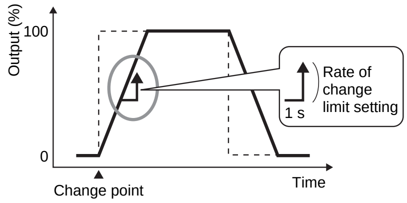


With heating and cooling control, the cooling MV is treated as a negative value. Generally speaking then, the upper limit (positive value) is set to the heating output and the lower limit (negative value) is set to the cooling output as shown in the following diagram.



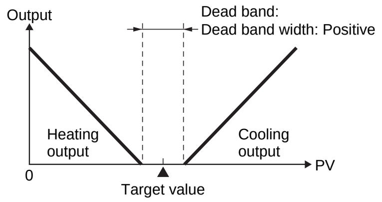
Rate of Change Limit

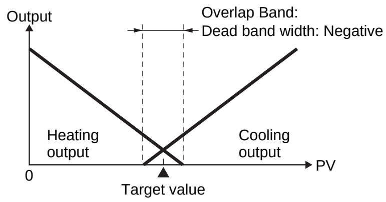
The rate of change limit for the MV sets the amount of change that occurs per second in the MV. If the MV calculated by the Temperature Controller changes significantly, the actual output follows the rate of change limiter setting for MV until it approaches the calculated value.



Dead Band

The overlap band and dead band are set for the cooling output. A negative value here produces an overlap band and a positive value produces a dead band.





Cooling Coefficient

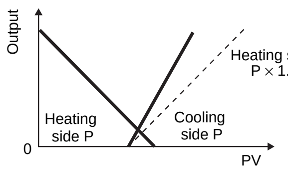
When adequate control characteristics cannot be obtained using the same PID constants, such as when the heating and cooling characteristics of the controlled object vary significantly, adjust the proportional band on the cooling side (cooling side P) using the cooling coefficient until heating and cooling side control are balanced. P on the heating and cooling control sides is calculated from the following formula.

Heating side P = P

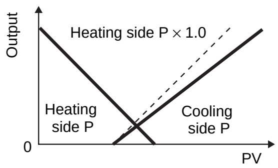
Cooling side P = Heating side P x cooling coefficient

For cooling side P control when heating side characteristics are different, multiply the heating side P by the cooling coefficient.

Heating Side P × 0.8

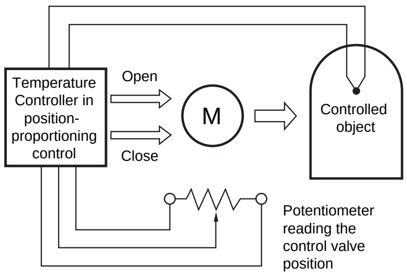


Heating Side P × 1.5



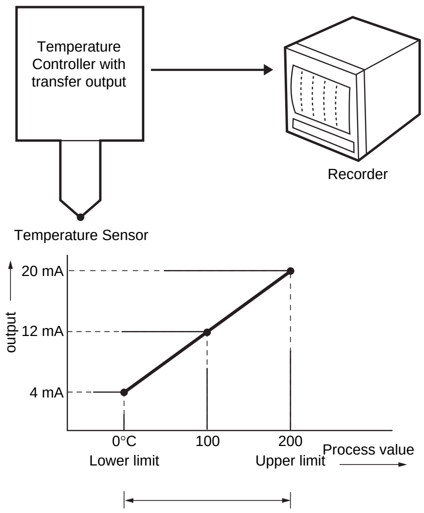
Positioning-Proportioning Control

This is also called ON/OFF servo control. When a Control Motor or Modutrol Motor with a valve is used in this control system, a potentiometer for open/close control reads the degree of opening (position) of the control valve, outputs an open and close signal, and transmits the control output to Temperature Controller. The Temperature Controller outputs two signals: an open and close signal. OMRON uses floating control. This means that the potentiometer does not feed back the control valve position and temperature can be controlled with or without a potentiometer.



Transfer Output

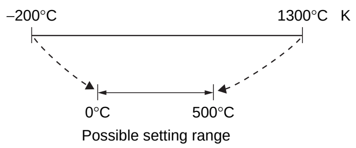
A Temperature Controller with current output independent from control output is available. The process value or set point within the available temperature range of the Temperature Controller is converted into 4- to 20-mA linear output that can be input into recorders to keep the results of temperature control on record.



■ Glossary of Setting Terminology

Set Limit

The set point range depends on the Temperature Sensor and the set limit is used to restrict the set point range. This restriction affects the transfer output of the Temperature Controller.

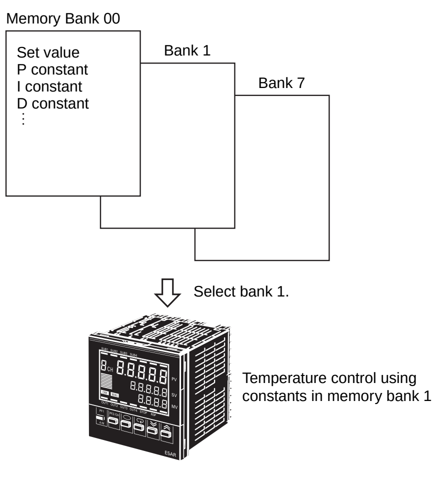


Multiple Set Points

Two or more set points independent from each other can be set in the Temperature Controller in control operation.

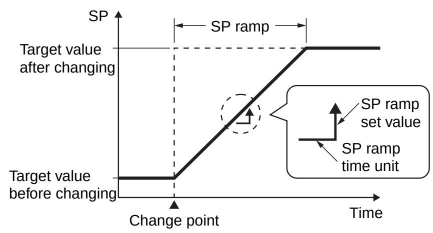
Setting Memory Banks

The Temperature Controller stores a maximum of eight groups of data (e.g., set value and PID constant data) in built-in memory banks for temperature control. The Temperature Controller selects one of these banks in actual control operation.



Set Point (SP) Ramp

The SP ramp function controls the target value change rate with the variation factor. Therefore, when the SP ramp function is enabled, some range of the target value will be controlled if the change rate exceeds the variation factor as shown on the right.



Remote Set Point (SP) Input

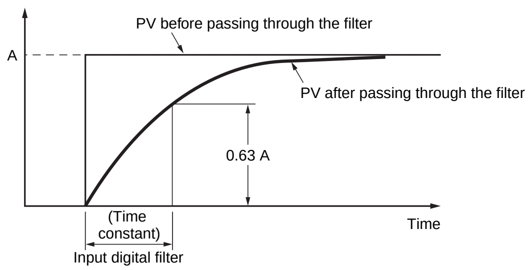
For a remote set point input, the Temperature Controller uses an external input ranging from 4- to 20-mA for the target temperature. When the remote SP function is enabled, the 4- to 20-mA input becomes the remote set point.

Event Input

An event input is an external signal that can be used to control various actions, such as target value switching, equipment or process RUN/STOP, and pattern selection.

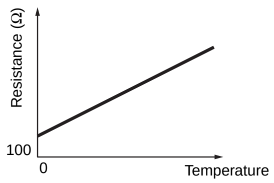
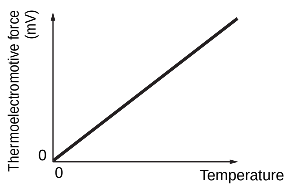
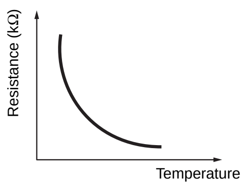
Input Digital Filter

The input digital filter parameter is used to set the time constant of the digital filter. Data that has passed through the digital filter appears as shown in the following diagram.



Temperature Sensor Glossary

■ Temperature Sensor Types and Features

<table>
<tr><th>Type</th><th>Principle and characteristics</th><th>Advantages</th><th>Disadvantages</th><th>Element type</th><th>Class</th></tr>
<tr>
<td>Platinum resistance thermometer</td>
<td>The electrical resistance of the metal used by platinum resistance thermometers has a fixed relationship to the temperature. Therefore, a platinum wire with extremely high purity is used for the resistor.
Temperature Characteristics

</td>
<td>• High precision</td>
<td>• Expensive
• Easily influenced by lead wire resistance (OMRON minimizes influence by using a 3-conductor system.)
• Slow thermal response
• Low resistance to shock and vibration</td>
<td>JPt100
Pt100</td>
<td>JIS Standard
<table>
<tr><th>Class</th><th>Tolerance</th></tr>
<tr><td>Class A</td><td>± (0.15+0.002│ t │) °C</td></tr>
<tr><td>Class B</td><td>± (0.3+0.005│ t │) °C</td></tr>
</table>
Note: │ t │ represents the absolute value of the temperature range.</td>
</tr>
<tr>
<td>Thermocouple</td>
<td>Thermocouple temperature sensors are constructed using two dissimilar metals that are joined together. The junctions are called the measuring junction and the reference junction (output terminal side). A thermoelectromotive force is generated between the junctions with a fixed correlation to the temperature providing the difference in temperature. Therefore, the temperature at the measuring junction can be determined from the thermoelectromotive force when a fixed temperature is maintained at the reference junction. Thermocouple temperature sensors are capable of measuring the highest temperatures among contact temperature sensors by using this measurement method.
Standard Thermoelectromotive Force

</td>
<td>• Broad temperature range
• High-temperature measurement
• High resistance to shock and vibration
• Fast thermal response</td>
<td>• Compensating conductors are required when extending the lead wires</td>
<td>K (CA)
J (IC)
R (PR)</td>
<td>JIS Standard for Thermocouples
<table>
<tr><th>Material code</th><th>Model name</th><th>Temperature range</th><th>Class</th><th>Tolerance (See note.)</th></tr>
<tr><td>R</td><td>PR</td><td>0°C to 1,600°C</td><td>Class 2 (0.25)</td><td>±1.5°C or ±0.25% of measured temperature</td></tr>
<tr><td>K</td><td>CA</td><td>0°C to 1,200°C</td><td>Class 2 (0.75)</td><td>±2.5°C or ±0.75% of measured temperature</td></tr>
<tr><td>J</td><td>IC</td><td>0°C to 750°C</td><td>Class 2 (0.75)</td><td>±2.5°C or ±0.75% of measured temperature</td></tr>
</table>
Note: The tolerance is either the value in °C or %, whichever is larger.</td>
</tr>
<tr>
<td>Thermistor</td>
<td>Temperature Characteristics

</td>
<td>• Fast thermal response
• Small error due to lead wire resistance</td>
<td>• Limited temperature range
• Low resistance to shock</td>
<td>Thermistor</td>
<td>JIS Standard Class 1
<table>
<tr><th>Measured temperature</th><th>Tolerance</th></tr>
<tr><td>–50 to 100°C</td><td>±1°C max.</td></tr>
<tr><td>100 to 350°C</td><td>±1% max. of measured temperature</td></tr>
</table></td>
</tr>
</table>

■ Pt100 and JPt100

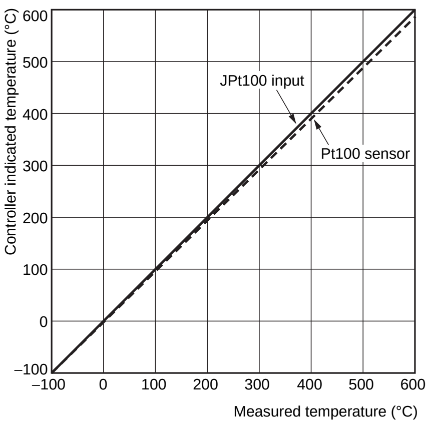
In January 1, 1989, the JIS standard for platinum resistance thermometers (Pt100) was revised to incorporate the IEC (International Electrotechnical Commission) standard. The new JIS standard was established on April 1, 1989. Platinum resistance thermometers prior to the JIS standard revision are distinguished as JPt100. Therefore, make sure that the correct platinum resistance thermometer is being used.

• The following table shows the differences in appearance of the Pt100 and JPt100.

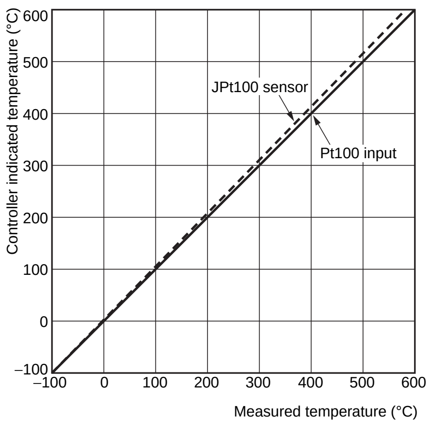
	Classification by model
Pt100 **(New JIS standard)**	E52-P15AY Pt100 is indicated as P.
JPt100 **(Previous JIS standard)**	E52-PT15A JPt100 is indicated as PT.

Note: OMRON discontinued production of JPt100 Sensors in March of 2003.

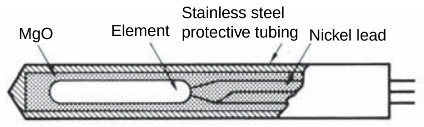
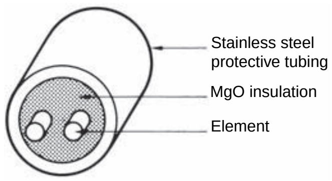
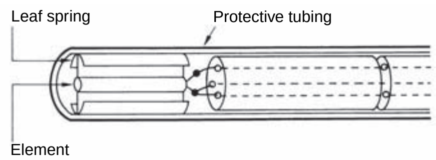
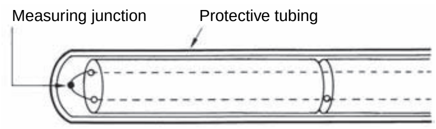
● Indicated Temperature when Connecting Pt100 Sensor to JPt100 Input



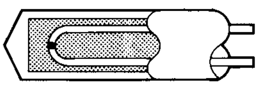
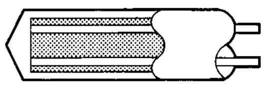
● Indicated Temperature when Connecting JPt100 Sensor to Pt100 Input



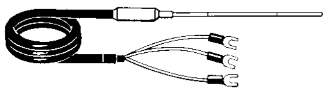
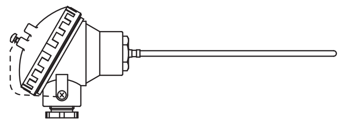
■ Temperature Sensor Construction

	Sheathed	Standard
Features	• Compared with standard models, these sensors have high resistance to vibration and shock. • The finished outer diameter is extremely slim enabling easy insertion in small sensing objects, and low heat capacity enables fast response to changes in temperature. • The sheathed tubing is flexible, enabling insertion and measurement within complex machinery. • The airtight construction provides high sensitivity and prevents oxidation, for superior heat resistance and durability.	• Compared with the sheathed models, the thick tubing diameter provides strength and durability. • Slow response speed.
Internal structure	Sheathed platinum resistance thermometer  Sheathed thermocouple 	Standard platinum resistance thermometer  Standard thermocouple 

■ Thermocouple Measuring Junction Construction

	Non-grounded models	Grounded models
Features	• Fully isolated measuring junction and protective tubing • Response is inferior to grounded models, but noise resistance is high. • Widely used for general-purpose applications.	• Soldered ends of measuring junction protective tubing. • Fast response but noise resistance is low. • High productivity at a low cost.
Internal con-struction	 **Non-grounded model** The protective tubing and thermocouple are insulated.	 **Grounded model** There is no insulation between the protective tubing and thermocouple.

■ Terminal Block Appearance

	Exposed lead wires	Exposed terminals	Enclosed terminals
Features	Lead wires directly extend from protective tubing, enabling low-cost manufacturing without requiring more space. ➜ For building into machines	Construction uses exposed terminal screws for easy maintenance. ➜ For general-purpose indoor use	Construction with enclosed terminal screws enables broad range of applications. ➜ For indoor industrial equipment
Appearance			
Permissible temperature in dry air	• Sleeve Standard: 0 to +70°C Heat Resistive: 0 to +100°C • Lead wire (platinum resistance thermometer) Standard (vinyl-covered): –20 to +70°C Heat resistive (glass-wool-covered with stainless-steel external shield): 0 to 180°C • Lead wire (compensating conductor) Standard (vinyl-covered): –20 to +70°C Heat resistive (glass-wool-covered with stainless-steel external shield): 0 to 150°C	Permissible temperature in dry air for terminal box: 0 to +100°C	Permissible temperature in dry air for terminal box: 0 to +90°C

■ Temperature Sensor Thermal Response

A temperature sensor has a thermal capacity. That means that time is required from when the temperature sensor touches the sensing object until the temperature sensor and sensing object reach the same temperature.
For a thermocouple, the response time is the time required for the temperature sensor to reach 63.2% of temperature of the sensing object. For a resistance thermometer, the response time is the time to reach 50% of temperature of the sensing object.

● Thermal Response of Sheathed Temperature Sensors (Reference Value)

Protective tubing: ASTM316L

Test conditions	Static water, room temperature to 100 °C									
Protective tubing dia. (mm)	1.0 dia.	1.6 dia.	3.2 dia.		4.8 dia.		6.4 dia.		8 dia.
Indicated value	Thermocouple	Thermocouple	Thermocouple	Platinum resistance thermometer	Thermocouple	Platinum resistance thermometer	Thermocouple	Platinum resistance thermometer	Platinum resistance thermometer
Response time	1 s max.	1 s max.	1 s	2.5 s	1.8 s	4.2 s	4 s	9.9 s	12.9 s

● Standard Temperature Sensors

Thermal Response of Standard Thermocouple (Reference Value)

Protective tubing: SUS316

Test conditions	Static water		Dry air, room temperature to 100°C		
Protective tubing dia. (mm)	12 dia. (thermocouple element dia: 1.6 mm)				
Indicated value	Room temperature to 100°C	100°C to room temperature	Static air	Fed air: 1.5 m/s	Fed air: 3 m/s
Response time	55 s	56 s	6 min. 50 s	2 min. 2 s	1 min. 43 s

Thermal Response of Platinum Resistance Thermometer (Reference Value)

Protective tubing: SUS316

Test conditions	Static water, room temperature to 100°C
Protective tubing dia. (mm)	10 dia.
Indicated value	
Response time	23.6 s

■ Vibration and Shock Resistance

The testing standards for temperature sensors specified by JIS are provided in the tables on the right. Refer to these standards and provide sufficient margins for the application conditions.

● Vibration Resistance

Thermocouple (Conforms to JIS C1602-1995)

Test item	Frequency (Hz)	Double amplitude (mm)	Testing tim (min)		Vibration direction
			Sweeps	Destruction	
Resonance test	30 to 100	0.05	2	---	Two axis directions including length direction
Fixed frequency durability test	100	0.02	---	60	

Note: This test is not performed for Sensors with non-metal protective tubing.
Fixed frequency durability tests are conducted at 70 Hz when the resonance point is 100 Hz.

Platinum Resistance Thermometer (Conforms to JIS C1604-1997)

Frequency (Hz)	Acceleration (m/s^2)	Sweeps per minute	No. of sweeps
10 to 150	10 to 20	2	10

Note: This test is not performed for Sensors with non-metal protective tubing.

● Shock Resistance

Holding the test product on its side, the product is then dropped from a height of 250 mm onto a steel plate 6 mm thick placed on a hard floor. This process is repeated 10 times, after which the product is checked for electrical faults in the measuring junctions and terminal contacts. This test is not performed, however, on products with non-metal protective tubing (conforms to JIS C1602-1995 and JIS C1604-1997).

■ Permissible Temperature in Dry Air

The permissible temperature is the temperature limit for continuous usage in air.
For thermocouples with protective tubes, the permissible temperature is determined collectively by the type of thermocouple, the element diameters, the insulating tube material, protective tube materials, heat resistance, and other factors. The permissible temperature is also called the usage limit.
Generally speaking, lowering the usage temperature will increase the life of a thermocouple. Allow sufficient leeway in the permissible temperature.

● Sheathed

Thermocouple Permissible Temperature in Dry Air

M: Protective tubing material
D: Protective tubing diameter (mm)

Element M / D	K (CA) ASTM316L	J (IC) ASTM316L
1 dia.	650°C	450°C
1.6 dia.	650°C	450°C
3.2 dia.	750°C	650°C
4.8 dia.	800°C	750°C
6.4 dia.	800°C	750°C
8.0 dia.	900°C	750°C

● Standard

Thermocouple Permissible Temperature in Dry Air

M: Protective tubing material
D: Protective tubing diameter (mm)

Element M / D	K (CA) SUS310S	K (CA) SUS316	J (IC) SUS316
10 dia.	750°C	750°C	450°C
12 dia.	850°C	850°C	500°C
15 dia.	900°C	850°C	550°C
22 dia.	1,000°C	900°C	600°C

Permissible Temperature in Dry Air

Element M / D	R PT0	R PT1
15 dia.	1,400°C	

JIS symbol	Type
PT0	Protective tubing: Special ceramic
PT1	Protective tubing: Ceramic Cat. 1

Reference Material for Temperature Sensors

■ Thermocouple Standard Potential Difference

Thermocouples generate voltage according to the temperature difference. The potential difference is prescribed by Japanese Industrial Standards (JIS).
The following chart gives the potential difference for R, S, K, and J thermocouples when the temperature of the reference junction is 0°C.

(Standards Published in 1995) JIS C 1602-1995 (Unit: µV)

Category	Temperature (°C)	0	10	20	30	40	50	60	70	80	90
R standard potential difference	**0**	0	54	111	171	232	296	363	431	501	573
	100	647	723	800	879	959	1,041	1,124	1,208	1,294	1,381
	200	1,469	1,558	1,648	1,739	1,831	1,923	2,017	2,112	2,207	2,304
	300	2,401	2,498	2,597	2,696	2,796	2,896	2,997	3,099	3,201	3,304
	400	3,408	3,512	3,616	3,721	3,827	3,933	4,040	4,147	4,255	4,363
	500	4,471	4,580	4,690	4,800	4,910	5,021	5,133	5,245	5,357	5,470
	600	5,583	5,697	5,812	5,926	6,041	6,157	6,273	6,390	6,507	6,625
	700	6,743	6,861	6,980	7,100	7,220	7,340	7,461	7,583	7,705	7,827
	800	7,950	8,073	8,197	8,321	8,446	8,571	8,697	8,823	8,950	9,077
	900	9,205	9,333	9,461	9,590	9,720	9,850	9,980	10,111	10,242	10,374
	1,000	10,506	10,638	10,771	10,905	11,039	11,173	11,307	11,442	11,578	11,714
	1,100	11,850	11,986	12,123	12,260	12,397	12,535	12,673	12,812	12,950	13,089
	1,200	13,228	13,367	13,507	13,646	13,786	13,926	14,066	14,207	14,347	14,488
	1,300	14,629	14,770	14,911	15,052	15,193	15,334	15,475	15,616	15,758	15,899
	1,400	16,040	16,181	16,323	16,464	16,605	16,746	16,887	17,028	17,169	17,310
	1,500	17,451	17,591	17,732	17,872	18,012	18,152	18,292	18,431	18,571	18,710
	1,600	18,849	18,988	19,126	19,264	19,402	19,540	19,677	19,814	19,951	20,087
	1,700	20,222	20,356	20,488	20,620	20,749	20,877	21,003	---	---	---
S standard potential difference	**0**	0	55	113	173	235	299	365	433	502	573
	100	646	720	795	872	950	1,029	1,110	1,191	1,273	1,357
	200	1,441	1,526	1,612	1,698	1,786	1,874	1,962	2,052	2,141	2,232
	300	2,323	2,415	2,507	2,599	2,692	2,786	2,880	2,974	3,069	3,164
	400	3,259	3,355	3,451	3,548	3,645	3,742	3,840	3,938	4,036	4,134
	500	4,233	4,332	4,432	4,532	4,632	4,732	4,833	4,934	5,035	5,137
	600	5,239	5,341	5,443	5,546	5,649	5,753	5,857	5,961	6,065	6,170
	700	6,275	6,381	6,486	6,593	6,699	6,806	6,913	7,020	7,128	7,236
	800	7,345	7,454	7,563	7,673	7,783	7,893	8,003	8,114	8,226	8,337
	900	8,449	8,562	8,674	8,787	8,900	9,014	9,128	9,242	9,357	9,472
	1,000	9,587	9,703	9,819	9,935	10,051	10,168	10,285	10,403	10,520	10,638
	1,100	10,757	10,875	10,994	11,113	11,232	11,351	11,471	11,590	11,710	11,830
	1,200	11,951	12,071	12,191	12,312	12,433	12,554	12,675	12,796	12,917	13,038
	1,300	13,159	13,280	13,402	13,523	13,644	13,766	13,887	14,009	14,130	14,251
	1,400	14,373	14,494	14,615	14,736	14,857	14,978	15,099	15,220	15,341	15,461
	1,500	15,582	15,702	15,822	15,942	16,062	16,182	16,301	16,420	16,539	16,658
	1,600	16,777	16,895	17,013	17,131	17,249	17,366	17,483	17,600	17,717	17,832
	1,700	17,947	18,061	18,174	18,285	18,395	18,503	18,609	---	---	---
K standard potential difference	**0**	0	397	798	1,203	1,612	2,023	2,436	2,851	3,267	3,682
	100	4,096	4,509	4,920	5,328	5,735	6,138	6,540	6,941	7,340	7,739
	200	8,138	8,539	8,940	9,343	9,747	10,153	10,561	10,971	11,382	11,795
	300	12,209	12,624	13,040	13,457	13,874	14,293	14,713	15,133	15,554	15,975
	400	16,397	16,820	17,243	17,667	18,091	18,516	18,941	19,366	19,792	20,218
	500	20,644	21,071	21,497	21,924	22,350	22,776	23,203	23,629	24,055	24,480
	600	24,905	25,330	25,755	26,179	26,602	27,025	27,447	27,869	28,289	28,710
	700	29,129	29,548	29,965	30,382	30,798	31,213	31,628	32,041	32,453	32,865
	800	33,275	33,685	34,093	34,501	34,908	35,313	35,718	36,121	36,524	36,925
	900	37,326	37,725	38,124	38,522	38,918	39,314	39,708	40,101	40,494	40,885
	1,000	41,276	41,665	42,053	42,440	42,826	43,211	43,595	43,978	44,359	44,740
	1,100	45,119	45,497	45,873	46,249	46,623	46,995	47,367	47,737	48,105	48,473
	1,200	48,838	49,202	49,565	49,926	50,286	50,644	51,000	51,355	51,708	52,060
	1,300	52,410	52,759	53,106	53,451	53,795	54,138	54,479	54,819	---	---
J standard potential difference	**0**	0	507	1,019	1,537	2,059	2,585	3,116	3,650	4,187	4,726
	100	5,269	5,814	6,360	6,909	7,459	8,010	8,562	9,115	9,669	10,224
	200	10,779	11,334	11,889	12,445	13,000	13,555	14,110	14,665	15,219	15,773
	300	16,327	16,881	17,434	17,986	18,538	19,090	19,642	20,194	20,745	21,297
	400	21,848	22,400	22,952	23,504	24,057	24,610	25,164	25,720	26,276	26,834
	500	27,393	27,953	28,516	29,080	29,647	30,216	30,788	31,362	31,939	32,519
	600	33,102	33,689	34,279	34,873	35,470	36,071	36,675	37,284	37,896	38,512
	700	39,132	39,755	40,382	41,012	41,645	42,281	42,919	43,559	44,203	44,848
	800	45,494	46,141	46,786	47,431	48,074	48,715	49,353	49,989	50,622	51,251
	900	51,877	52,500	53,119	53,735	54,347	54,956	55,561	56,164	56,763	57,360
	1,000	57,953	58,545	59,134	59,721	60,307	60,890	61,473	62,054	62,634	63,214
	1,100	63,792	64,370	64,948	65,525	66,102	66,679	67,255	67,831	68,406	68,980
	1,200	69,553	---	---	---	---	---	---	---	---	---

■ Reference Temperature Characteristics for Platinum Resistance Thermometers (Ω)

Pt100

JIS C 1604-1997

Temperature (°C)	–100	–0	Temperature (°C)	0	100	200	300	400	500	600	700	800
0	60.26	100.00	0	100.00	138.51	175.86	212.05	247.09	280.98	313.71	345.28	375.70
–10	56.19	96.09	10	103.90	142.29	179.53	215.61	250.53	284.30	316.92	348.38	378.68
–20	52.11	92.16	20	107.79	146.07	183.19	219.15	253.96	287.62	320.12	351.46	381.65
–30	48.00	88.22	30	111.67	149.83	186.84	222.68	257.38	290.92	323.30	354.53	384.60
–40	43.88	84.27	40	115.54	153.58	190.47	226.21	260.78	294.21	326.48	357.59	387.55
–50	39.72	80.31	50	119.40	157.33	194.10	229.72	264.18	297.49	329.64	360.64	390.48
–60	35.54	76.33	60	123.24	161.05	197.71	233.21	267.56	300.75	332.79	363.67	---
–70	31.34	72.33	70	127.08	164.77	201.31	236.70	270.93	304.01	335.93	366.70	---
–80	27.10	68.33	80	130.90	168.48	204.90	240.18	274.29	307.25	339.06	369.71	---
–90	22.83	64.30	90	134.71	172.17	208.48	243.64	277.64	310.49	342.18	372.71	---
–100	18.52	60.26	100	138.51	175.86	212.05	247.09	280.98	313.71	345.28	375.70	---

JPt100

JIS C 1604-1997

Temperature (°C)	–100	–0	Temperature (°C)	0	100	200	300	400	500
0	59.57	100.00	0	100.00	139.16	177.13	213.93	249.56	284.02
–10	55.44	96.02	10	103.97	143.01	180.86	217.54	253.06	---
–20	51.29	92.02	20	107.93	146.85	184.58	221.15	256.55	---
–30	47.11	88.01	30	111.88	150.67	188.29	224.74	260.02	---
–40	42.91	83.99	40	115.81	154.49	191.99	228.32	263.49	---
–50	38.68	79.96	50	119.73	158.29	195.67	231.89	266.94	---
–60	34.42	75.91	60	123.64	162.08	199.35	235.45	270.38	---
–70	30.12	71.85	70	127.54	165.86	203.01	238.99	273.80	---
–80	25.80	67.77	80	131.42	169.63	206.66	242.53	277.22	---
–90	21.46	63.68	90	135.30	173.38	210.30	246.05	280.63	---
–100	17.14	59.57	100	139.16	177.13	213.93	249.56	284.02	---

■ Standard Temperature Characteristics for Element-interchangeable Thermistors

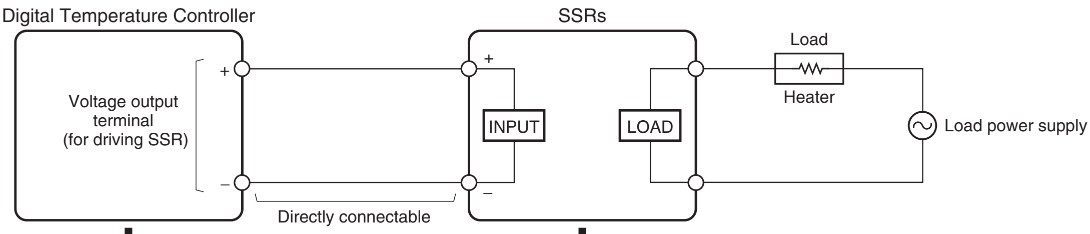
The following chart gives the temperature characteristics for low-cost thermistors used in the E5C2, E5L, and E5CS. JIS C 1611-1975

Nominal resistance	6 kΩ (0°C)		30 kΩ (0°C)		3 kΩ (100°C)		0.55 kΩ (200°C)		4 kΩ (200°C)		8 kΩ (200°C)	
Ambient operating temperature	–50 to 100°C		0 to 150°C		50 to 200°C		100 to 250°C		250 to 300°C		200 to 350°C	
Temper-ature (°C) / Deviation in characteristics and resistance	Resistance	Resistance deviation	Resistance	Resistance deviation	Resistance	Resistance deviation	Resistance	Resistance deviation	Resistance	Resistance deviation	Resistance	Resistance deviation
–50	75.36 kΩ	±4.28 kΩ										
–40	42.90	±2.28										
–30	25.23	±1.26										
–20	15.21	±0.72	77.07 kΩ									
–10	9.414	±0.422	47.41									
0	6.000	±0.261	30.00	±1.35 kΩ								
10	3.934	±0.158	19.49	±0.80								
20	2.637	±0.100	12.97	±0.50								
30	1.812	±0.065	8.828	±0.323	28.05 kΩ							
40	1.266	±0.043	6.140	±0.212	19.31							
50	904.2 Ω	±29.0 Ω	4.356	±0.144	13.57	±0.47 kΩ						
60	657.7	±20.0	3.147	±0.098	9.717	±0.310						
70	487.0	±14.0	2.317	±0.068	7.081	±0.214						
80	365.7	±10.0	1.734	±0.048	5.243	±0.151	12.66 kΩ					
90	278.9	±7.2	1.318	±0.035	3.939	±0.108	8.626					
100	215.6	±5.5	1.017	±0.026	3.000	±0.080	6.281	±0.194 kΩ				
110	168.4		794.0 Ω	±18.9 Ω	2.314	±9.058	4.649	±0.134				
120	133.3		627.7	±14.2	1.805	±0.043	3.495	±0.096				
130			501.7	±10.8	1.424	±0.033	2.664	±0.069	23.06 kΩ			
140			405.2	±8.3	1.134	±0.025	2.056	±0.051	17.44			
150			330.5	±5.6	912.1 Ω	±19.5 Ω	1.610	±0.039	13.33	±0.35 kΩ		
160			272.0		734.9	±15.4	1.273	±0.029	10.29	±0.26		
170			225.8		596.1	±12.1	1.017	±0.022	8.027	±0.194		
180					486.7	±9.6	823.6 Ω	±17.0 Ω	6.312	±0.147	13.39 kΩ	
190					400.0	±7.7	669.3	±13.2	5.006	±0.113	10.29	
200					330.6	±6.2	550.0	±10.5	4.000	±0.087	8.000	±0.190 kΩ
210							455.4	±8.3	3.221	±0.068	6.305	±0.146
220							380.6	±6.7	2.611	±0.053	5.015	±0.111
230							319.2	±5.4	2.131	±0.042	4.014	±0.086
240							269.9	±4.4	1.751	±0.034	3.240	±0.076
250							230.0	±3.5	1.445	±0.027	2.634	±0.054
260							196.8		1.202	±0.022	2.156	±0.042
270							169.5		1.004	±0.018	1.779	±0.033
280									842.5 Ω	±14.4 Ω	1.474	±0.027
290									710.8	±11.8	1.228	±0.022
300									602.4	±9.7	1.030	±0.018
310									512.8		868.1 Ω	±14.3 Ω
320									438.3		738.2	±11.7
330											631.0	±9.6
340											542.2	±7.9
350											468.0	±6.8
Thermistor constant B	3,390 K		3,450 K		3,894 K		4,300 K		5,133 K		5,559 K	

Note: Amount of change in resistance per degree C in the resistance deviation and specified temperature.

Connection Examples between Digital Temperature Controllers and SSRs

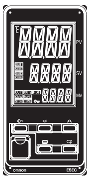
CSM_Connecting_TS_SSR_CG_E_3_1



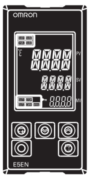
Number of Connectable SSRs in parallel

Digital Temperature Controllers with voltage output of 40 mA at 12 VDC

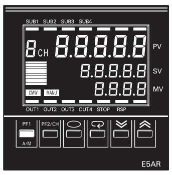
E5EC/E5AC
E5EC-T/E5AC-T



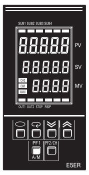
E5AN-H/E5EN-H



E5AR/E5AR-T

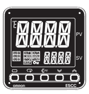


E5ER/E5ER-T



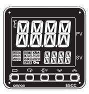
Digital Temperature Controllers with voltage output of 21 mA at 12 VDC

E5CC/-T

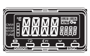


E5CN-H

E5CC-U



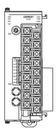
E5GC



E5CB

E5CS Series

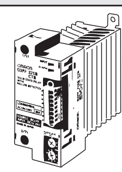
EJ1



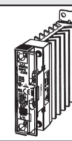
SSRs

SSR	Number of connectable SSRs (40 mA controllers)	Number of connectable SSRs (21 mA controllers)	Rating	Rated input voltage	Features
G3PF (SSR with built-in Current Transformer)	8	4	25 A or 35 A at 240/480 VAC	12 to 24 VDC	With built-in CT. Detects heater burnout and SSR short-circuit failures.
G3PE (Single-phase)	5 *1	3 *2	15 A, 25 A, 35 A, or 45 A at 240/480 VAC	12 to 24 VDC	Extremely thin Relays integrated with heat sinks.
G3PE (Three-phase)	4	2	15 A, 25 A, 35 A, or 45 A at 240/480 VAC	12 to 24 VDC	Slim design with 3-phase output and built-in heat sinks.
G3PA	5 *3	3 *4	10 A, 20 A, 40 A, or 60 A at 240 VAC 20 A, 30 A, or 50 A at 480 VAC	5 to 24 VDC or 12 to 24 VDC	Thin Relays integrated with heat sinks.
G3NA	5 *5	3 *6	5 A, 10 A, 20 A, 40 A, 75 A, or 90 A at 240 VAC 10 A, 20 A, 40 A, 75 A, or 90 A at 480 VAC	5 to 24 VDC	Standard model with screw terminals.
G3NE	2	1	5 A, 10 A, or 20 A at 240 VAC	12 VDC	Compact, low-cost model with faston terminals.
G3PH	8	4	75 A or 150 A at 240/480 VAC	5 to 24 VDC	For high-power heater control.

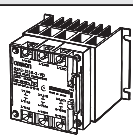
G3PF



G3PE (Single-phase)

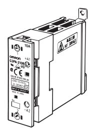


G3PE (Three-phase)

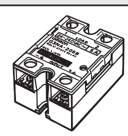


Note: Refer to your OMRON website for details.

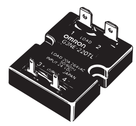
G3PA



G3NA



G3NE



G3PH

● Calculating the Number of Connectable SSRs in Parallel

(A): The maximum load current for the voltage output (for driving SSR) of each Temperature Controller.

(B): SSR input current

(A) ÷ (B) = Number of connectable SSRs

*1. Two G3PE-BL SSRs can be connected.
*2. One G3PE-BL SSR can be connected.
*3. Two G3PA-BL SSRs can be connected.
*4. One G3PA-BL SSR can be connected.
*5. Two of the -UTU models of the G3NA SSRs can be connected.
*6. One of the -UTU model of the G3NA SSRs can be connected. Four of the 480-VAC models of the G3NA SSRs can be connected.