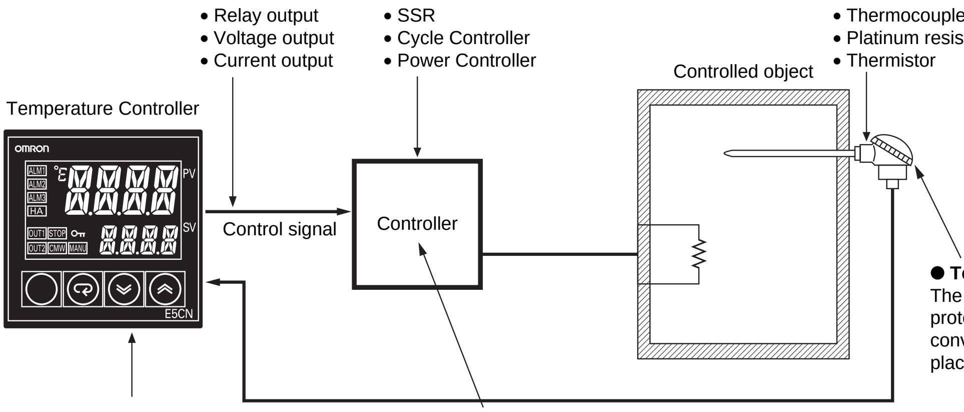
Over View of Temperature Controllers

■ Temperature Control Configuration Example

The following example describes the basic configuration for temperature control.



● **Temperature Sensor**
The Temperature Sensor consists of an element protected by a pipe. Locate the element, which converts temperatures into electrical signals, in places where temperature control is required.

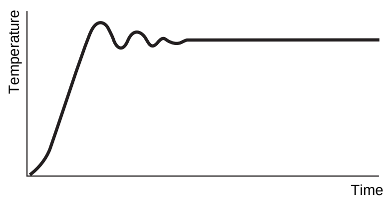
● **Temperature Controller**
A Temperature Controller receives electrical signals input from the Temperature Sensor, compares the electrical signal input to the set point, and outputs adjustment signals to the Controller.

● **Controller**
A Controller is used to heat or cool furnaces and tanks using devices such as a solenoid that cuts off electric current to a heater or a fuel valve that shuts off the fuel supply.

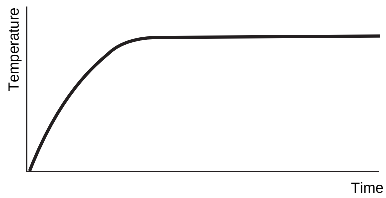
■ Temperature Control

The set point is input to operate the Temperature Controller. The time required for stable temperature control varies with the controlled object. Attempting to shorten the response time will usually result in overshooting or hunting the temperature. The response time must not be shortened to reduce overshooting or hunting the temperature. There are applications that require prompt, stable control in the waveform shown in (1) despite overshooting. There are other applications that require the suppression of overshooting in the waveform shown in (3) despite the long time required to stabilize the temperature. In other words, the type of temperature control varies with the application and purpose. The waveform shown in (2) is usually considered to be a proper one for standard applications.

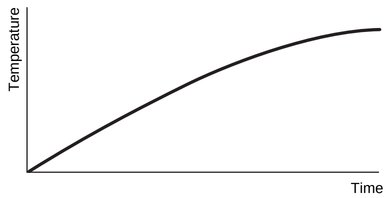
1. The temperature stabilizes after overshooting several times.



2. Proper response



3. The response is slow in reaching the set point.



■ Characteristics of the Controlled Object

Before selecting a Temperature Controller or Temperature Sensor, it is necessary to understand the thermal characteristics of the controlled object for proper temperature control.

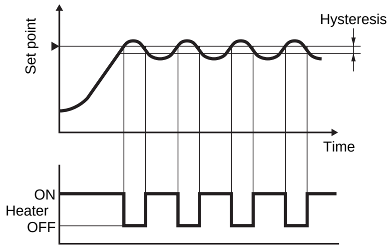
Characteristics of the controlled object

- Heat capacity ·······Heat capacity, which indicates the ease of heating, varies with the capacity of the furnace.
- Static characteristics ·······Static characteristics, which indicate heating capability, vary with the capacity of the heater.
- Dynamic characteristics ·······Dynamic characteristics, which indicate the startup characteristics (i.e. excessive response) of heating, vary with heater and furnace capacity that can affect each other in a complex way.
- External disturbances ·······External disturbances cause temperature changes. For example, the opening or closing of a door on a constant temperature tank can cause external disturbances that generate temperature changes.

ON/OFF Control Action

As shown in the graph below, if the process value is lower than the set point, the output will be turned ON and power will be supplied to the heater. If the process value is higher than the set point, the output will be turned OFF and power to the heater will be shut off. This control method, in which the output is turned ON and OFF based on the set point in order to keep the temperature constant, is called ON/OFF control action. With this action, the temperature is controlled using two values (i.e., 0% and 100% of the set point). Therefore, the operation is also called two-position control action.

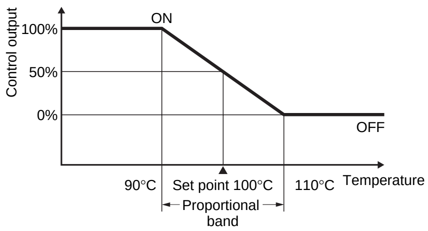
Characteristics of ON/OFF control action



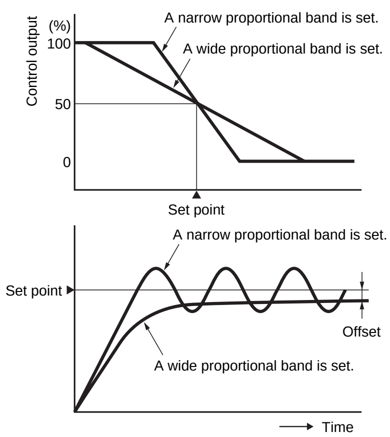
P Action

P action (or proportional control action) is used to obtain an output in proportion to the input. The Temperature Controller in P action has a proportional band with the set point in the proportional band. The control output varies in proportion to deviation in the proportional band. In normal operation, a 100% control output will be ON if the process value is lower than the proportional band. The control output will be decreased gradually in proportion to the deviation if the process value is within the proportional band, and a 50% control output will be ON if the set point coincides with the process value. (i.e., there is no deviation). This means P action ensures smoother control with minimal hunting compared with the ON/OFF control action.

Proportional control action



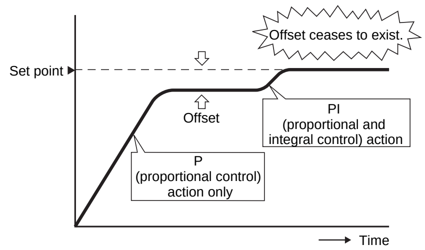
Example: If a Temperature Controller with a temperature range of 0°C to 400°C has a 5% proportional band, the width of the proportional band will be converted into a temperature range of 20°C. In this case, a full output is kept turned ON until the process value reaches 90°C, and the output is OFF periodically when the process value exceeds 90°C, provided the set point is 100°C. When the process value is 100°C, there will be no difference in time between the ON period and the OFF period (i.e. the output is turned ON and OFF 50% of the time.)

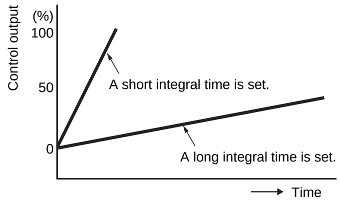


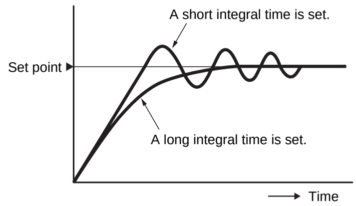
I Action

I action (integral control action) is used to obtain an output in proportion to the time integral value of the input.

P action causes an offset. Therefore if proportional control action and integral control action are used in combination, the offset will be reduced over time until the control temperature eventually will coincide with the set point and the offset will cease to exist.



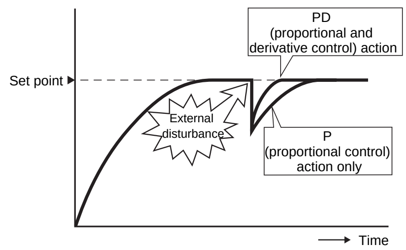


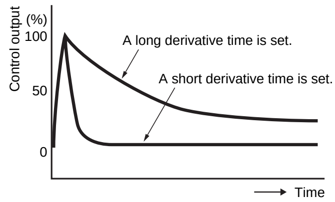


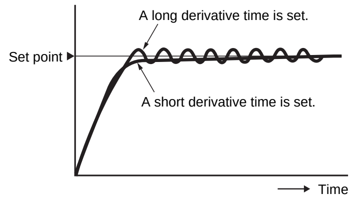
D Action

D action (derivative control action) is used to obtain an output in proportion to the time derivative value of the input.

Proportional control action corrects the control results as does integral control action. Therefore, proportional control action and integral control action respond slowly to temperature change. This is why derivative control is required. Derivative control action corrects control results by adding the control output in proportion to the slope of temperature change. A large control output is applied to radical external disturbances to get the temperature quickly back under control.

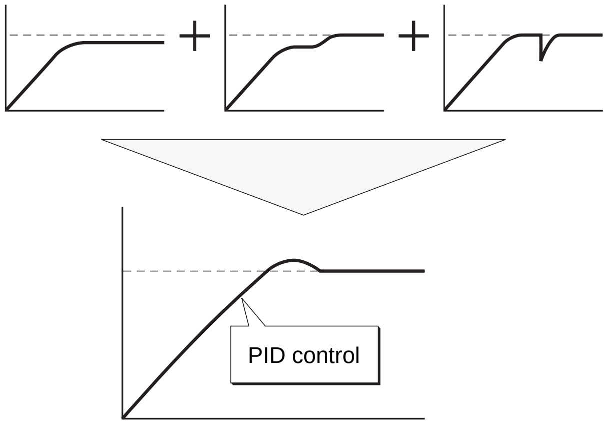






PID Control

PID control is a combination of proportional, integral, and derivative control actions. The temperature is controlled smoothly here by proportional control action without hunting, automatic offset adjustment is made by integral control action, and quick response to an external disturbance is made possible by derivative control action.



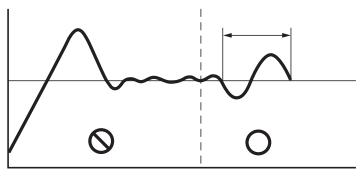
Two PID Control

Conventional PID control uses a single control block to control the responses of the Temperature Controller to a target value and to external disturbances. Therefore, the response to the target value will oscillate due to overshooting if importance is placed on responding to external disturbances with the P and I parameters set to small values and the D parameter set to a large value in the control block. On the other hand, the Temperature Controller will not be able to respond to external disturbances quickly if importance is placed on responding to the target value (i.e., the P and I parameters are set to large values). This makes it impossible to satisfy both the types of response in this case.

Two PID control eliminates this drawback while maintaining the strengths of PID control. This makes it possible to improve both types of responses.

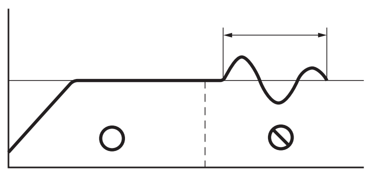
PID Control

(1)



Response to the target value will be slow if response to the external disturbance is improved.

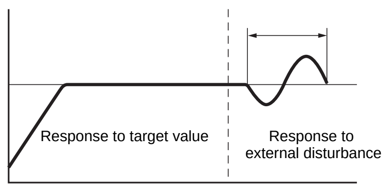
(2)



Response to the external disturbance will be slow if response to the target value is improved.

Two PID Control

(3)



Controls both the target value and the external disturbance response.

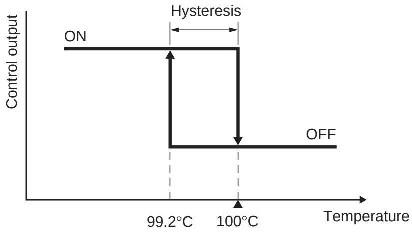
Temperature Controller Glossary

■ Glossary of Control Terminology

Hysteresis

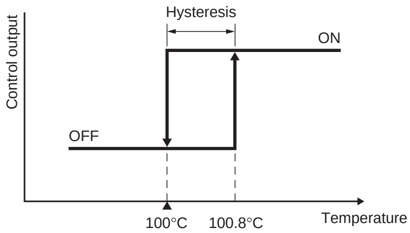
ON/OFF control action turns the output ON or OFF based on the set point. The output frequently changes according to minute temperature changes as a result, and this shortens the life of the output relay or unfavorably affects some devices connected to the Temperature Controller. To prevent this from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

Hysteresis (Reverse Operation)



Example: Hysteresis indicates 0.8°C.

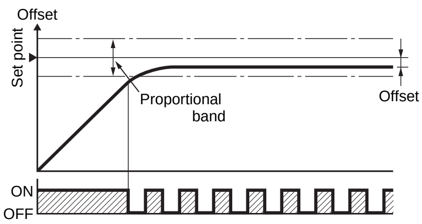
Hysteresis (Forward Operation)



Example: Hysteresis indicates 0.8°C.

Offset

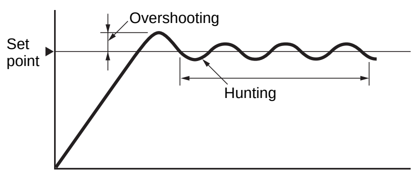
Proportional control action causes an error in the process value due to the heat capacity of the controlled object and the capacity of the heater. The result is a small discrepancy between the process value and the set point in stable operation. This error is called offset. Offset is the difference in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



Hunting and Overshooting

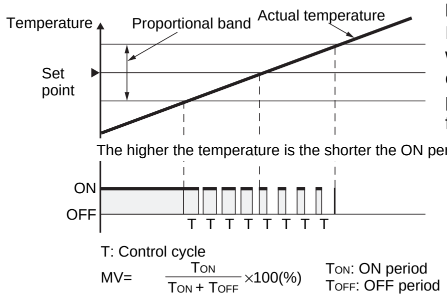
ON/OFF control action often involves the waveform shown in the following diagram. A temperature rise that exceeds the set point after temperature control starts is called overshooting. Temperature oscillation near the set point is called hunting. Improved temperature control is to be expected if the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

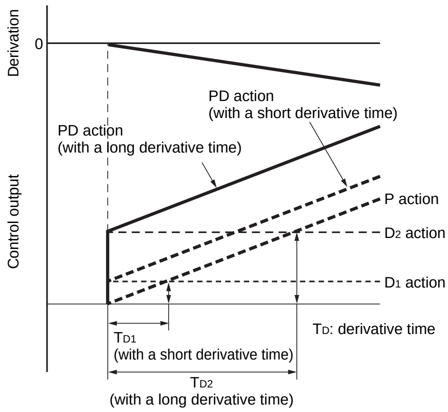
T_{ON}: 8 s

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.

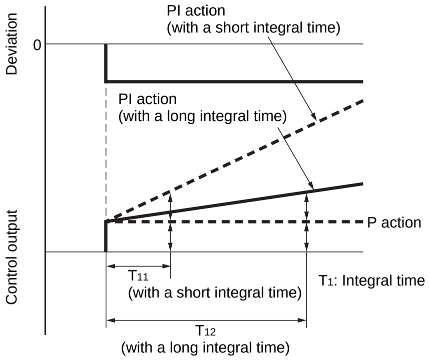
PD Action and Derivative Time



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

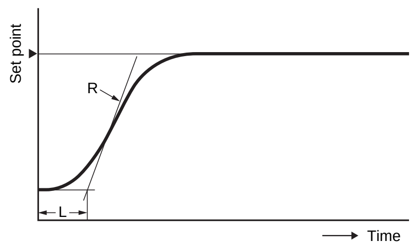
Program control is used to control temperature for a target value that changes at predetermined time intervals.

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.

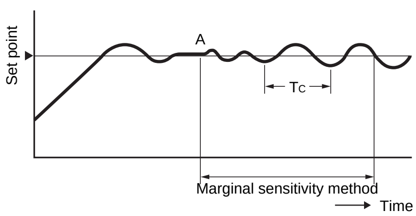
Step Response Method

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.



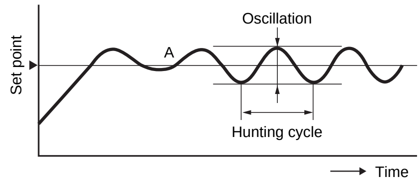
Marginal Sensitivity Method

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

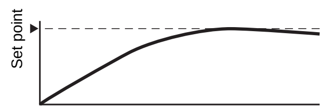
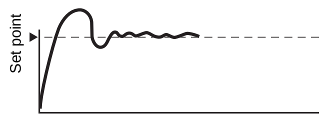
ON/OFF control begins from start point A in this method. Then obtain the PID constants from the hunting cycle T and oscillation D.



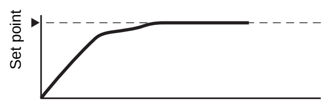
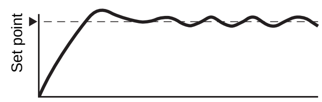
Readjusting PID Constants

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

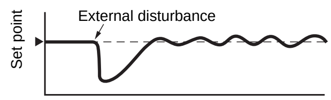
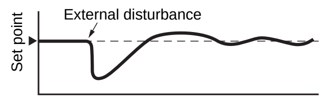
Response to Change in the Proportional Band

Wider		It is possible to suppress overshooting although a comparatively long startup time and set time will be required.
Nar-rower		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.
Nar-rower		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.
Nar-rower		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.

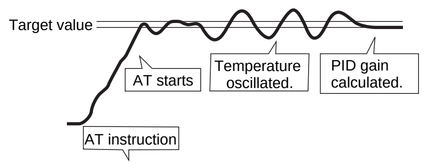
Fuzzy Self-tuning in 3 Modes

- 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.

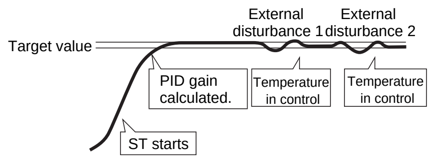
Features: (1) Tuning will be performed when the AT instruction is given.
(2) The limit cycle signal is generated to oscillate the temperature before tuning.



Self-tuning

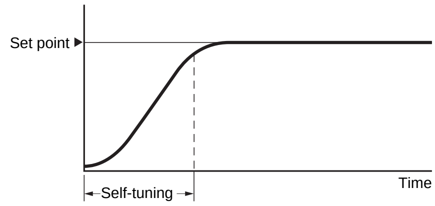
Self-tuning (ST) Function: A function that automatically calculates optimum PID constants for controlled objects.

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.



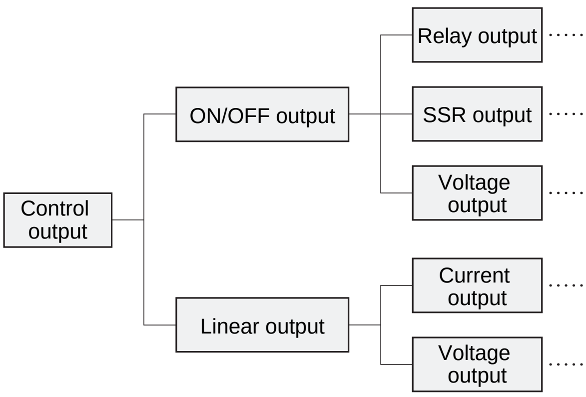
PID Control and Tuning Methods for Temperature Controllers

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 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: 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.

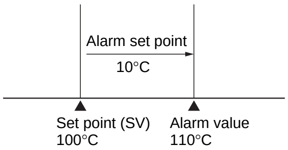
Deviation Alarm

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.



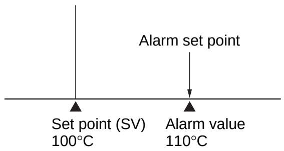
Absolute-value Alarm

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.

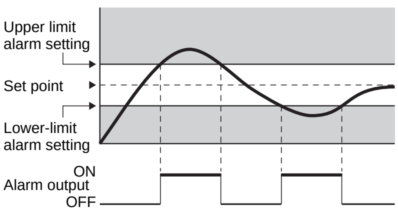


Standby Sequence Alarm

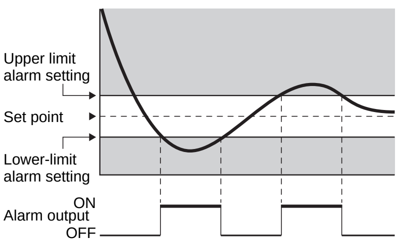
It may be difficult to keep the process value outside the specified alarm range in some cases (e.g., when starting up the Temperature Controller), and the alarm turns ON abruptly as a result. This can be prevented with the standby sequential function of the Temperature Controller. This function makes 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

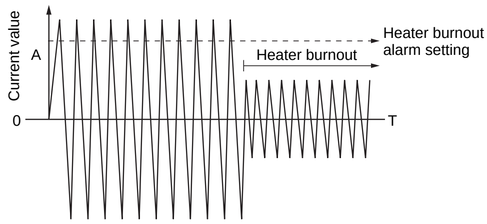
(Applicable models: E5CN)

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.

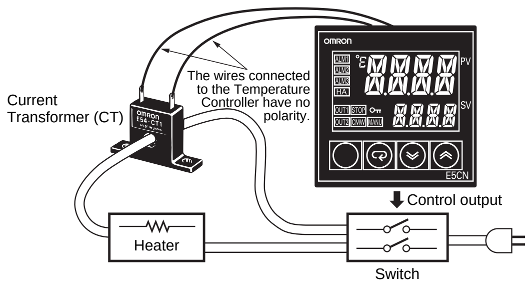
Heater Burnout Alarm

(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.

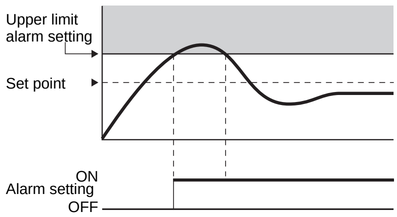


Heater current waveform (CT waveform)



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.



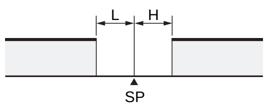
LBA

(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

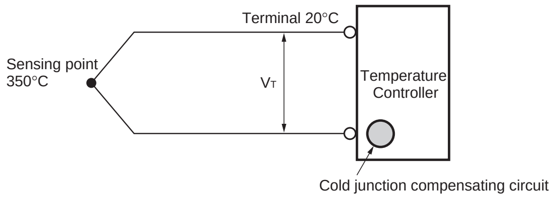
(Applicable models: E5☐N and E5☐R)



■ 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:

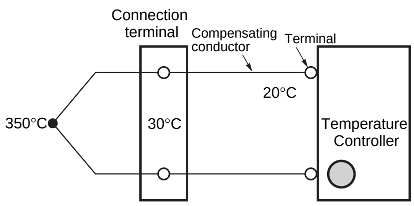
$$\underbrace{V(350, 20)}_{\text{Thermo-electromotive force from thermocouple}} + \underbrace{V(20, 0)}_{\text{Electromotive force generated by the cold junction compensation circuit}}$$

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.



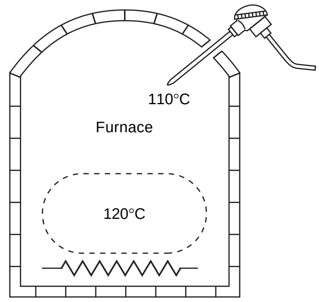
$$\underbrace{V\ (350, 30)}_{\text{Thermo-electromotive force from thermocouple}} + \underbrace{V\ (30, 20)}_{\text{Thermo-electromotive force from compensating conductors}} + \underbrace{V\ (20, 0)}_{\text{Voltage from cold junction compensation}}$$

= {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.

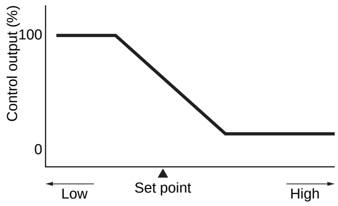


Input compensation value: 10°C (Displayed value is 120°C.)
(120 – 110 = 10)

■ Glossary of Output Terminology

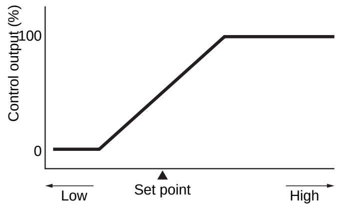
Reverse Operation (Heating)

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).



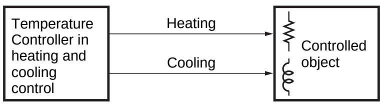
Direct Operation (Cooling)

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).

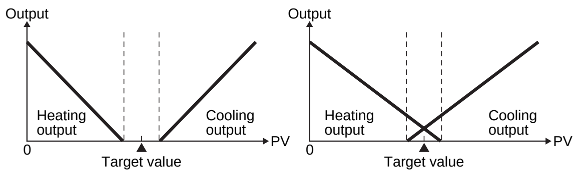


Heating and Cooling Control

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.

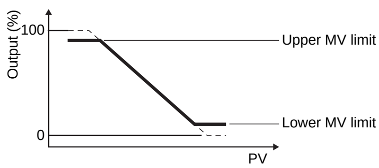


Heating and Cooling Outputs

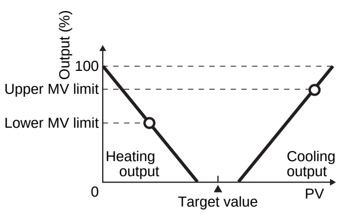


MV (Manipulated Variable) Limiter

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.

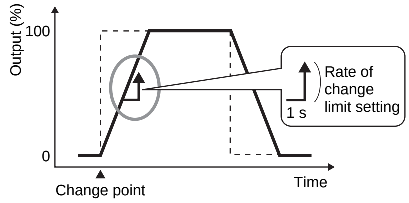


With heating and cooling control, the cooling MV is treated as a negative value. Generally speaking then, the upper limit (positive value) is set to the heating output and the lower limit (negative value) is set to the cooling output as shown in the following diagram.



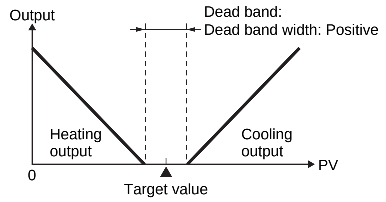
Rate of Change Limit

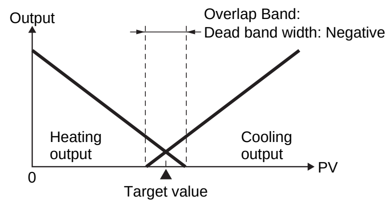
The rate of change limit for the MV sets the amount of change that occurs per second in the MV. If the MV calculated by the Temperature Controller changes significantly, the actual output follows the rate of change limiter setting for MV until it approaches the calculated value.



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

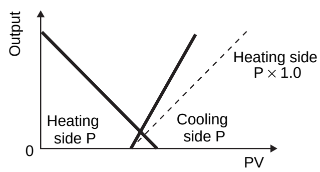
When adequate control characteristics cannot be obtained using the same PID constants, such as when the heating and cooling characteristics of the controlled object vary significantly, adjust the proportional band on the cooling side (cooling side P) using the cooling coefficient until heating and cooling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

Heating side P = P

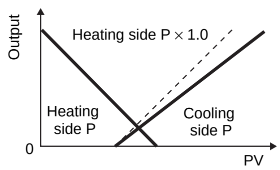
Cooling side P = Heating side P x cooling coefficient

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

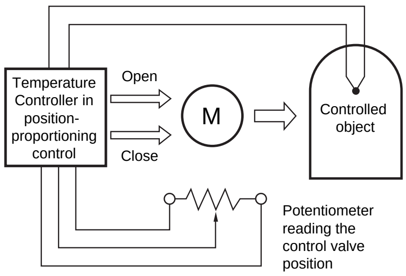


Heating Side P × 1.5



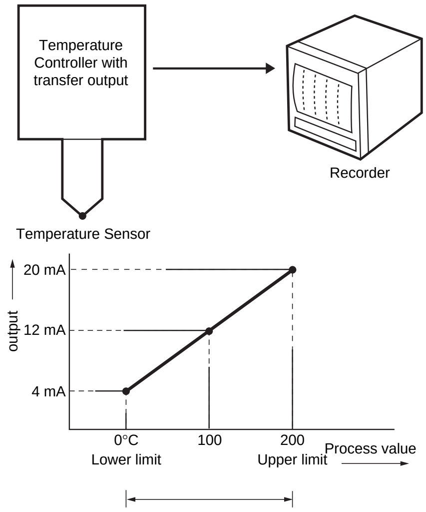
Positioning-Proportioning Control

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

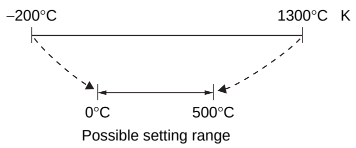
A Temperature Controller with current output independent from control output is available. The process value or set point within the available temperature range of the Temperature Controller is converted into 4- to 20-mA linear output that can be input into recorders to keep the results of temperature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

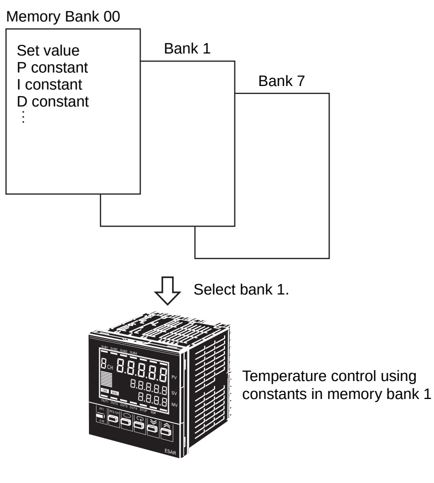


Multiple Set Points

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

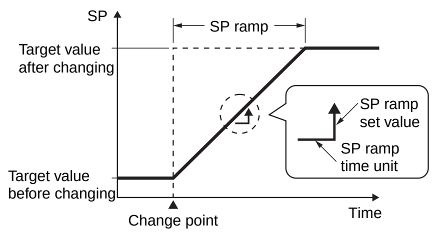
Setting Memory Banks

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

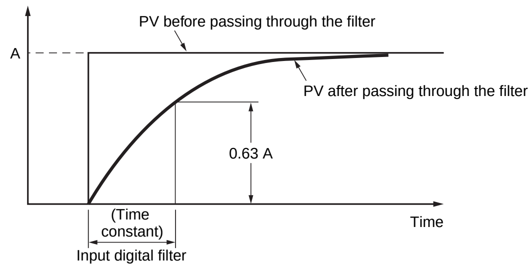
For a remote set point input, the Temperature Controller uses an external input ranging from 4- to 20-mA for the target temperature. When the remote SP function is enabled, the 4- to 20-mA input becomes the remote set point.

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.



Precautions for Correct Use of Temperature Controllers

For the precautions for individual products, refer to the *Safety Precautions* for that product.

■ Correct Use

Service Life

Use each product within the range of specifications for that product.

When the Temperature Controller is incorporated in a control panel, make sure that the Controller's ambient temperature and not the ambient temperature of the control panel does not exceed the specified temperature range.

The service life of the Temperature Controller and other electronic devices is determined not only by the number of times the relays are switched, but also by the service life of internal electronic components. Component service life is affected by the ambient temperature: the higher the temperature, the shorter the service life, and the lower the temperature, the longer the service life. Therefore, the service life can be extended by lowering the temperature of the Temperature Controller.

Mounting two or more Temperature Controllers side by side, or mounting Temperature Controllers one above another may cause heat to build up inside the Temperature Controllers, which will shorten their service life. If the Temperature Controllers are mounted one above another or side by side, use forced cooling by fans or other means of air ventilation to cool the Temperature Controllers. Be sure not to cool only the terminals. Otherwise, measurement errors may occur.

Ensuring Measurement Accuracy

When extending or connecting the thermocouple lead wires, be sure to use compensating wires that match the thermocouple type.

When extending or connecting the lead wire of the platinum resistance thermometer, be sure to use wires that have low resistance and keep the resistance of the three lead wires the same.

Make sure that the temperature sensor type and the input type of the Temperature Controller are the same.

There are two types of platinum resistance thermometer: Pt and JPt. Correct measurement will not be possible if the input type of the Temperature Controller is incorrect.

Mount the Temperature Controller so that it is horizontally level.
If the measurement accuracy is low, check that to see if the input shift has been set correctly.

Waterproofing

Models for which the degree of protection is not specified and models with IP□0 degree of protection do not have waterproof specifications.

EN/IEC Standards

If the Temperature Controller is to conform to EN/IEC standards, it is recommended to install the following fuse in the power supply terminal section.

Recommended fuse: T2A, 250-VAC, time-lag fuse with low breaking capacity

Operating Precautions

1. It takes up to 5 s for the outputs to turn ON after the power supply is turned ON. Take this time into consideration when the Temperature Controller is incorporated in a sequence circuit.
2. When using the self-tuning function of the E5□N, turn ON the Temperature Controller and load (e.g., heater) simultaneously or turn ON the load before the Temperature Controller. If the load is turned ON after the Temperature Controller, correct self-tuning and optimum control will not be possible. When starting operation after the Temperature Controller has warmed up, turn OFF the power supply and then turn it ON again at the same time as turning ON the power supply for the load. (Instead of turning the Temperature Controller OFF and ON again, switching from STOP mode to RUN mode can also be used.)
3. Using the Temperature Controller near radios, televisions, or wireless devices may cause reception interference.

ALL DIMENSIONS SHOWN ARE IN MILLIMETERS.
To convert millimeters into inches, multiply by 0.03937. To convert grams into ounces, multiply by 0.03527.