

1/4 DIN Controller Combines Fuzzy and PID Control For Fast Response to Process Disturbances

- Advanced PID control provides optimal response during start-up and steady-state operation
- Fuzzy and PID control work together to correct a process upset quickly, with minimal overshoot
- Fuzzy parameters can be changed to adjust fuzzy control's impact on the process
- Accuracy to  $\pm 0.3\%$  of set value
- Field-selectable temperature ranges, °F/°C scaling, and sensor input types
- Plug-in outputs for field interchangeability
- Communications function and heater burnout alarm models available
- 3-year warranty



## Ordering Information

### ■ TEMPERATURE CONTROLLERS

Order one control output separately below. For example, **E5AF-A02-F** with **E53-S** SSR output unit. For heater burnout models, be sure to order a current transformer. To order models marked for degrees Celsius, omit the "F" at the end of the part number.

Communications type	Standard	Heater burnout type*
None	<b>E5AF-A-F</b>	<b>E5AF-AH-F</b>
RS-232C	<b>E5AF-A01-F</b>	<b>E5AF-AH01-F</b>
RS-422	<b>E5AF-A02-F</b>	<b>E5AF-AH02-F</b>
RS-485	<b>E5AF-A03-F</b>	<b>E5AF-AH03-F</b>
BCD	<b>E5AF-A20-F</b>	<b>E5AF-AH20-F</b>
Transmission output (4-20 mA)	<b>E5AF-AF-F</b>	<b>E5AF-AHF-F</b>

\* Current Output E53-C may not be used with heater burnout type controllers.

### ■ CONTROL OUTPUT UNITS

Output type	Relay output*	SSR output	Voltage output (for driving SSR)			Current output
			12 VDC (NPN)	24 VDC (NPN)	24 VDC (PNP)	
<b>Part number</b>	<b>E53-R</b>	<b>E53-S</b>	<b>E53-Q</b>	<b>E53-Q3</b>	<b>E53-Q4</b>	<b>E53-C</b>

\*Note: If control period is less than 5 seconds, use solid state relay or voltage relay.

### ■ CURRENT TRANSFORMERS FOR HEATER-BURNOUT CONTROLLERS

Hole diameter	5.8 mm (0.23 in)	12.0 mm (0.47 in)
<b>Part number</b>	<b>E54-CT1</b>	<b>E54-CT3</b>

### ■ TEMPERATURE RANGES

Input type (switch selectable)	Thermocouple						Platinum RTD	
	Type K	Type J/L	Type T/U	Type E	Type R	Type S	100Ω	
Temperature range	°C	-200 to 1,300	-100 to 850	-200 to 400	0 to 600	0 to 1,700	0 to 1,700	-99.9 to 450.0
	°F	0399 to 2,300	-100 to 1,500	-300 to 700	0 to 1,100	0 to 3,000	0 to 3,000	-99.9 to 800.0
Unit of measure	1° C or F, main setting and alarm						0.1° C or F, main setting and alarm	

# Advanced PID Control Improved with Fuzzy Control

Omron's E5AF temperature controllers combine advanced PID control with fuzzy logic control to improve responsiveness to external process disturbances, events that cause a clear offset between the process and set temperatures.

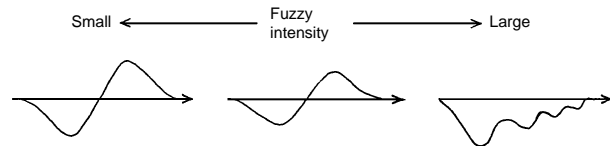
Omron's feed-forward (FF) advanced PID control and fuzzy logic control operate in parallel. The PID control operates during normal conditions, while the fuzzy logic control operates only when there has been an external disturbance to the

process. The start-up and stable state operation is identical to Omron's conventional PID controllers. The output of the E5AF is the sum total of the output of the PID and fuzzy control functions. Both PID and fuzzy scale parameters can be set automatically by auto-tuning, or may be manually set.

There are three fuzzy parameters users can set, and the illustrations show the impact of each one:

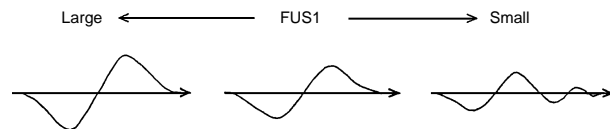
## ■ FUZZY INTENSITY

**Fuzzy intensity (FU1)** determines the impact of the fuzzy logic section of the control algorithm, on the final control output percentage. This parameter is the nominal value which can be set from 0 to 99%. Default setting is 50%. When set to 0%, fuzzy control will have no influence, and the unit will function as a PID controller (like Omron's E5AX). As this value is increased, the corrective actions taken by the controller will become larger. The FU1 value should be increased in applications where quicker neutralization of a process disturbance is required, and/or overshoot on the recover from the disturbance needs to be further minimized.



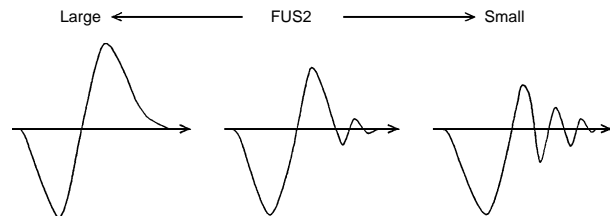
## ■ FUZZY SCALE 1

**Fuzzy Scale 1 (FUS1)** controls the magnitude of error "membership function". This value corresponds to what the controller should consider to be a "large" error and can be set in a range of 0.2° to 999.9° (C or F). Default setting is 40°. For every sample the controller compares the present error to FUS1 value in order to make a subjective decision about the size of the error. Decreasing this value makes the controller more sensitive to error, and will decrease the response time for returning the process back to set value.

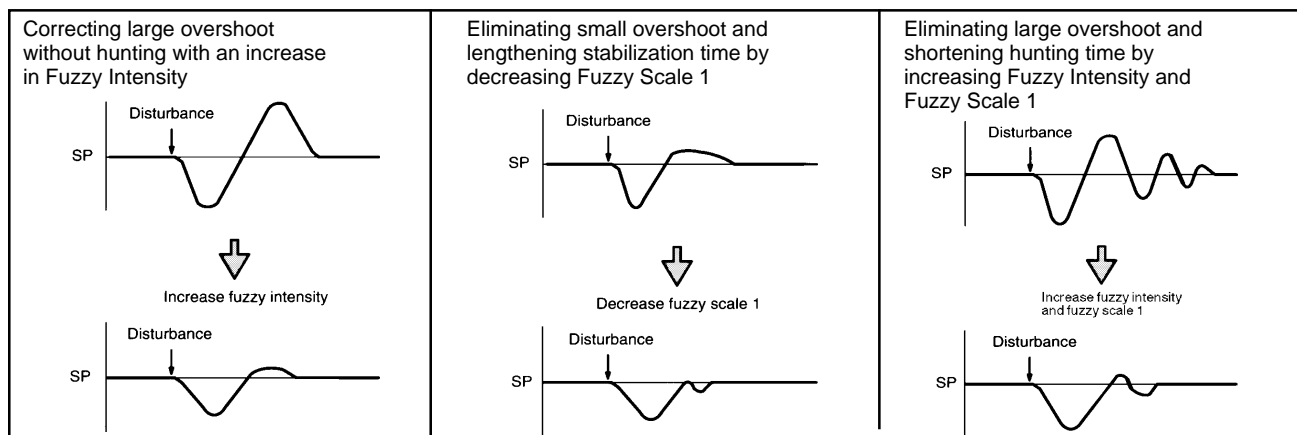


## ■ FUZZY SCALE 2

**Fuzzy Scale 2 (FUS2)** controls the rate-of-change "membership function". This value corresponds to what the controller should consider a "large" rate of change, and can be set in a range from 0.20° to 99.9° (C or F) per second. For every sample the controller compares the present rate-of-change to the FUS2 value in order to make a subjective decision about the size of the change. Decreasing this value will make the controller more sensitive to change. Because small changes in this value can cause a large increase in oscillations, best results can usually be achieved by manually setting FU1 and FUS1 and leaving FUS2 at the auto-tuned value.



## ■ COMBINED EFFECTS OF FUZZY ADJUSTMENTS



# Specifications

Supply voltage		100 to 240 VAC, 50/60 Hz	
Operating voltage		85 to 110% of rated supply voltage	
Power consumption		Approx. 10 VA at 100 VAC to 15 VA at 240 VAC	
Control output	Number	One output unit, ordered separately; mounts in internal socket of Standard E5AF-A and heater burnout E5AF-AH types	
	Type	Relay*	SPDT, 5 A, 250 VAC (resistive load) using E53-R output unit
		SSR	SPST-NO, 1 A, 75 to 250 VAC using E53-S output unit
	Voltage	40 mA, 12 VDC, NPN, using E53-Q output unit with short-circuit protection 20 mA, 24 VDC, NPN, using E53-Q3 output unit with short-circuit protection 20 mA, 24 VDC, PNP, using E53-Q4 output unit with short-circuit protection	
	Current	4 to 20 mA DC, 600 $\Omega$ max. load, 8-bit resolution using E53-C output unit. Current output unit cannot be used with heater burnout type E5AF-AH	
	Isolation	All output units are optically isolated from the internal circuits	
	Hysteresis	0.0 to 999.9 $^{\circ}\text{C}/^{\circ}\text{F}$ in units of 0.1 (during ON/OFF control action)	
	Update time	Output	500 ms for pulse output
		Display	500 ms
	Service life	100,000 electrical operations minimum for relay output unit E53-R 10 million mechanical operations minimum for relay output unit E53-R	
Alarm output	Number	Two SPST-NO relays, 3 A, 250 VAC for E5AF-A; one SPST-NO relay for E5AF-AH	
	Setting range	Thermocouple: -999 to 9,999 $^{\circ}\text{C}/^{\circ}\text{F}$ Platinum RTD: -99.9 to 999.9 $^{\circ}\text{C}/^{\circ}\text{F}$	
Heater burnout output E5AF-H only	Type	SPST-NO relay, 1 A, 250 VAC	
	Setting range	0.1 to 49.9 A in units of 0.1 A 0.0 setting disables the output 50.0 setting turns output ON continuously	
	Minimum detectable ON time	200 ms; heater current is not measured when the control output is ON less than 200 ms	
Indication accuracy	General	$\pm 0.3\%$ of set value or $\pm 1^{\circ}$ , whichever is greater, $\pm 1$ digit maximum	
	Exceptions	Accuracy of types T and U thermocouples is $\pm 2^{\circ}\text{C}$ ( $3.6^{\circ}\text{F}$ ) from $-150^{\circ}$ to $400^{\circ}\text{C}$ ( $-240$ to $700^{\circ}\text{F}$ ), $\pm 1$ digit. Accuracy is not guaranteed below $-150^{\circ}\text{C}$ ( $-240^{\circ}\text{F}$ ). Accuracy of types R and S thermocouples is $\pm 3^{\circ}\text{C}$ ( $\pm 5.4^{\circ}\text{F}$ ) from $0^{\circ}$ to $200^{\circ}\text{C}$ ( $32^{\circ}$ to $400^{\circ}\text{F}$ ), $\pm 1$ digit.	
	Heater burnout	$\pm 5\%$ of full scale, $\pm 1$ digit maximum of heater current	
	Display Range	-9999 to 9999 (limited by input type)	
Setting accuracy		Set value coincides with the indicated value, since no relative error exists between both values	
Control modes	Type	ON/OFF or auto-tuning PID with fuzzy control to prevent overshoot	
	Proportional band	P = 0.0 to 999.9 $^{\circ}\text{C}/^{\circ}\text{F}$ in units of 0.1 $^{\circ}$	
	Reset time	I = 0 to 3,999 seconds in units of 1 second	
	Rate time	D = 0 to 3,999 seconds in units of 1 second	
	Control period	Pulse output: 1 to 99 seconds in units of 1 second	
	Sampling period	500 ms	
	Fuzzy intensity	FU = 0 to 99% in units of 1%; factory set to 50% for general-purpose control applications	
	Fuzzy scale 1	FUS1 = 0.2 to 999.9 $^{\circ}\text{C}$ or $^{\circ}\text{F}$ in units of 0.1 $^{\circ}$ ; factory set to 40.0 $^{\circ}\text{C}$	
Fuzzy scale 2	FUS2 = 0.20 to 99.99 $^{\circ}\text{C}$ or $^{\circ}\text{F}/\text{sec}^2$ in units of 0.01 $^{\circ}\text{F}$ or $^{\circ}\text{C}/\text{sec}^2$ ; factory set to 0.47 $^{\circ}\text{C}/\text{sec}^2$		
Memory protection		Non-volatile memory (EEPROM)	
Other functions	Shift set input E5AF-A only	Sets a second set point. Requires no-voltage contact signal with input impedance of 100 $\Omega$ max. Thermocouple range: -999 to 9,999 $^{\circ}\text{C}/^{\circ}\text{F}$ Platinum RTD range: -99.9 to 999.9 $^{\circ}\text{C}/^{\circ}\text{F}$	
	Input shift, all models	Offsets input value and display value to accommodate a sensor input that deviates by a known value. Thermocouple range: -999 to 9,999 $^{\circ}\text{C}/^{\circ}\text{F}$ Platinum RTD range: -99.9 to 999.9 $^{\circ}\text{C}/^{\circ}\text{F}$	
	Miscellaneous	Upper and lower set value limits, setting key disable, $^{\circ}\text{C}/^{\circ}\text{F}$ selectable internally, input shift, shift set (not on heater burnout models) Normal and Reverse output selection, Watchdog function to detect CPU failure and restore CPU to normal operation.	
Indicators		Present Value (green LED), 15 mm H (0.59 in); Set Value (red LED), 11 mm H (0.43 in); LED indicators for all functions	

\*Note: If control period is less than 5 seconds, use solid state relay or voltage relay.

## SPECIFICATIONS (continued)

Materials		Plastic case
Mounting		Fits 1/4 DIN panel cutouts; includes two panel mounting brackets
Connections		Plated steel screw terminals mounted on rear of unit
Weight		Approx. 480 g (17 oz.), with communications 530 g (18.7 oz.)
Enclosure ratings	Front panel	IEC IP50, NEMA 4 with optional cover Y92A-96N
	Rear panel	IEC IP20
	Terminals	IEC IP00
Approvals	UL	Recognized, File Number E68481 (all models)
	CSA	Certified, File Number LR59623 (all models)
Ambient temperature	Operating	-10° to 55°C (14° to 131°F)
	Storage	-25° to 65°C (-13° to 149°F)
Humidity		35 to 85% RH
Insulation resistance		20 MΩ minimum at 500 VDC, measured with an output unit installed
Dielectric strength		2,000 VAC, 50/60 Hz for 1 minute between terminals of different polarity, measured with an output unit installed
Vibration	Mechanical durability	10 to 55 Hz, 0.75 mm (0.03 in) in X, Y, and Z directions for 2 hours each
	Malfunction durability	2 to 5 Hz, 2 G, in X, Y, and Z directions for 10 minutes each
Shock	Mechanical durability	300 m/s <sup>2</sup> in 6 directions, 3 times each
	Malfunction durability	200 m/s <sup>2</sup> in 6 directions, 3 times each

## ■ COMMUNICATIONS FEATURES

Output type	RS-232C	RS-422	RS-485	BCD	Transmission output
Transmission method	4-wire half duplex	4-wire half duplex	2-wire half-duplex	Data select code	4 to 20 mA DC, 600 Ω max. load Resolution 1/3200
Maximum cable length	15 m (49.2 ft)	500 m (1,640 ft)	500 m (1,640 ft)	–	–
Synchronization method	Start-stop	Start-stop	Start-stop	–	–
Transmission rate	150/300/600/1,200/2,400/4,800/9,600 bps			–	–
Transmission code	ASCII (7 bits)			–	–
Write to controller functions	Set temperature, alarm value, proportional band, integral time, rate time, auto-tuning start/stop, fuzzy intensity, fuzzy scales 1 and 2, heater burnout alarm set value (E5AF-H)			Set temperature, alarm value	Write disabled
Read from controller functions	Set temperature, alarm value, proportional band, reset time, rate time, output variable, process value, fuzzy intensity, fuzzy scales 1 and 2, heater burnout current and current transformer input value (E5AF-H)			Set temperature, alarm value, process value, error codes, etc.	Process value within the set limits, output variable
System limits	Peer-to-peer	A maximum of 32 temperature controllers can be connected to one host computer in serial communication		–	–

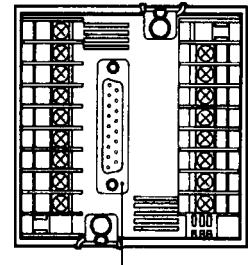
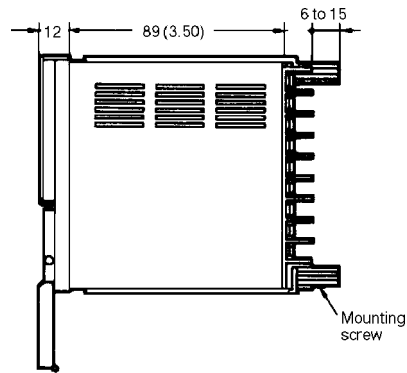
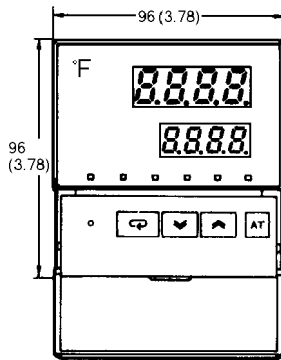
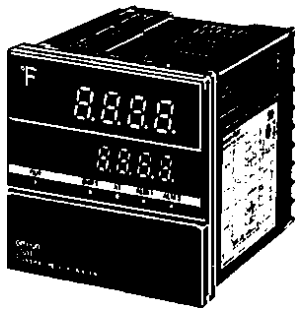
## ■ CURRENT TRANSFORMERS (for E5AF-H)

Heater current	Maximum 50 A continuous service, single-phase
Weight	Approx. 11.5 g (0.41 oz.) for E54-CT1; approx. 50 g (1.8 oz.) for E54-CT3
Dielectric strength	1,000 VAC
Vibration	50 Hz (approx. 10 G)

# Dimensions

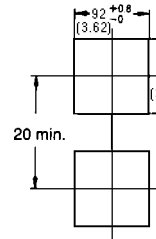
Unit: mm (inch)

## ■ TEMPERATURE CONTROLLER

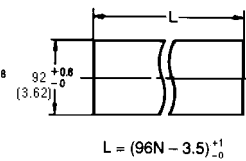


Communications port connector (RS-232 and BCD type shown)

### Panel cutout



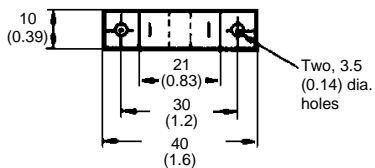
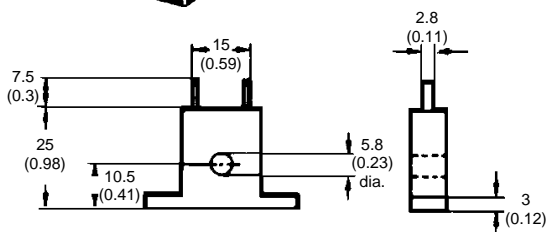
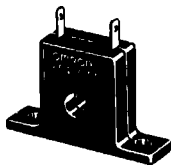
### Side-by-side mounting of several controllers



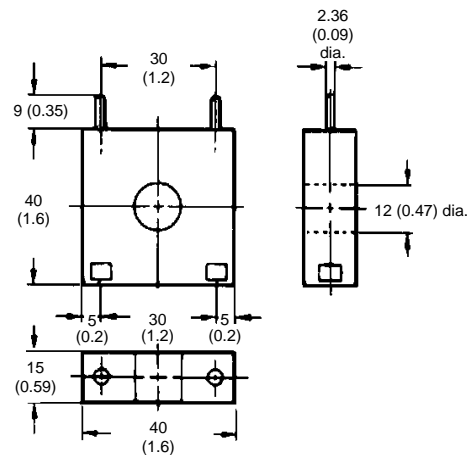
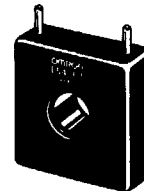
For side-by-side mounting:  
 $L = 96 \text{ mm} \times \text{Number of units} - 3.5 \text{ mm}$   
 $= (3.78 \text{ in} \times \text{Number of units} - 0.14 \text{ in})$

## ■ CURRENT TRANSFORMERS (for E5AF-H)

### E54-CT1

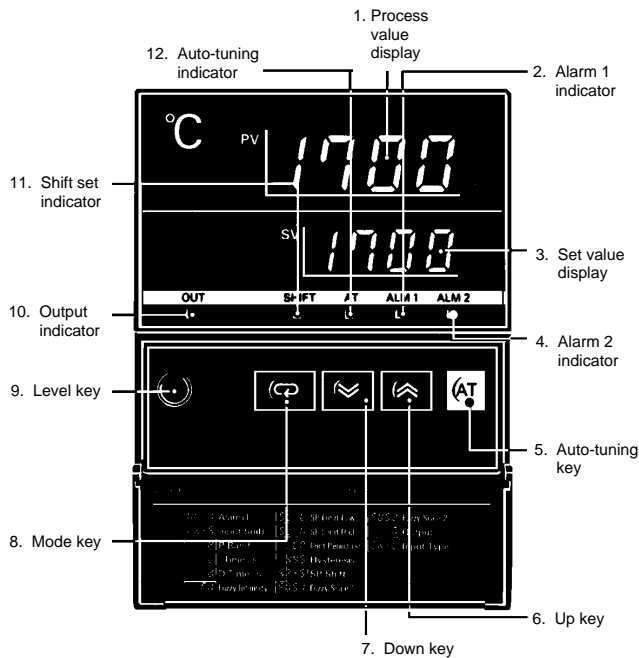


### E54-CT3

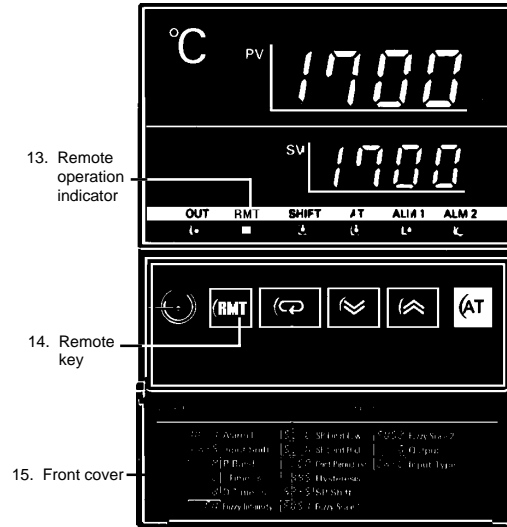


# Nomenclature

## ■ E5AF controller without communications

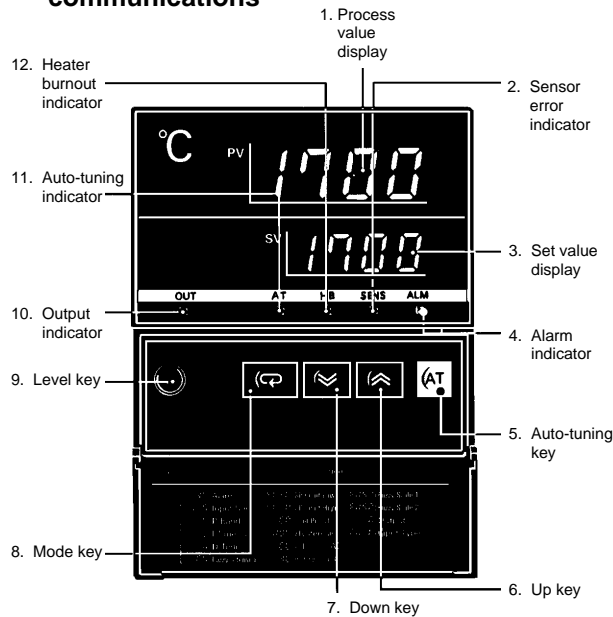


## ■ E5AF controllers with communications

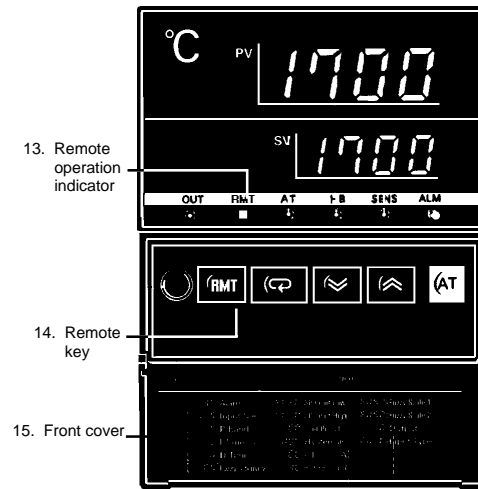


Key	Description	Key	Description
1.	Process value display shows process temperature and various messages, including the parameter being displayed and error codes for troubleshooting.	8.	Mode key changes the display mode within the display levels.
2.	Alarm 1 indicator lights when alarm 1 output is ON.	9.	Level key changes the display level when pressed for at least 2 seconds.
3.	Set value display shows the set temperature and other parameters.	10.	Output indicator lights when the control output is ON (except when using a current output unit).
4.	Alarm 2 indicator lights when alarm 2 output is ON.	11.	Shift set indicator lights when the shift set input has been activated by an external contact closure.
5.	Auto-tuning key, pressed for at least 1 second, starts the automatic tuning of PID and fuzzy scale parameters. Press for more than 1 second during auto-tuning to stop auto-tuning.	12.	Auto-tuning indicator flashes at intervals of 1 second when auto-tuning of PID and fuzzy parameters is in progress.
6.	Up key increases the temperature settings and other parameters by one. Pressed for 1 second or more, the display increments at 50 units in 1 second until the upper-limit value has been reached.	13.	Remote operation indicator lights when the controller is in remote (on-line) communication mode.
7.	Down key decreases the temperature settings and other parameters by one. Pressed for 1 second or more, the display decrements at 50 units in 1 second until the lower-limit value has been reached.	14.	Remote key, on models with communications boards only, selects remote (on-line) mode to enable communications or local mode to allow manual changes of settings.
		15.	Front cover shows display codes inside.

### ■ E5AF-H Heater burnout controller without communications



### ■ E5AF-H Heater burnout controllers with communications

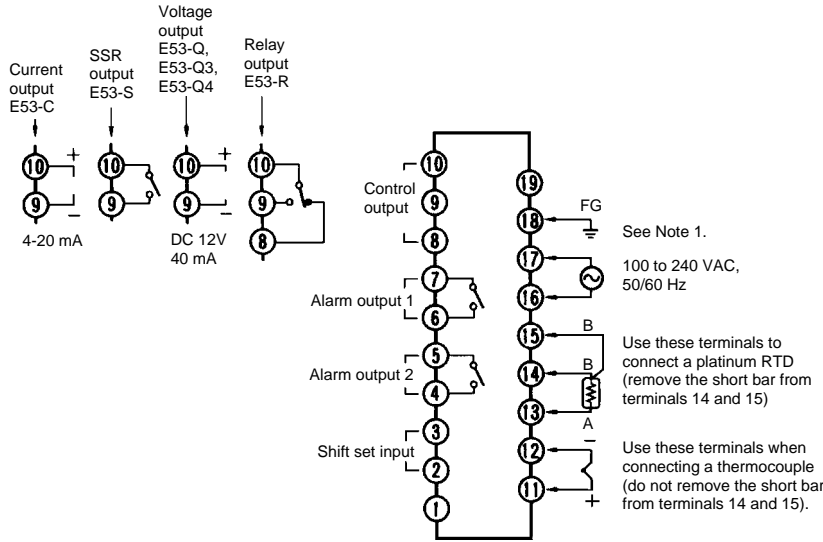


Key	Description	Key	Description
1.	Process value display shows process temperature and various messages, including the parameter being displayed and error codes for troubleshooting.	8.	Mode key changes the display mode within the display levels.
2.	Sensor error indicator lights when a sensor fails or an error is detected..	9.	Level key changes the display level when pressed for at least 2 seconds.
3.	Set value display shows the set temperature and other parameters.	10.	Output indicator lights when the control output is ON (except when using a current output unit).
4.	Alarm indicator lights when alarm output is ON.	11.	Auto-tuning indicator flashes at intervals of 1 second when auto-tuning of PID and fuzzy parameters is in progress.
5.	Auto-tuning key, pressed for at least 1 second, starts the automatic tuning of PID and fuzzy scale parameters. Press for more than 1 second during auto-tuning to stop auto-tuning.	12.	Heater burnout indicator lights when a heater burnout is detected and stays lit until reset. Provided on the Heater Burnout models only.
6.	Up key increases the temperature settings and other parameters by one. Pressed for 1 second or more, the display increments at 50 units in 1 second until the upper-limit value has been reached.	13.	Remote operation indicator lights when the controller is in remote (on-line) communication mode.
7.	Down key decreases the temperature settings and other parameters by one. Pressed for 1 second or more, the display decrements at 50 units in 1 second until the lower-limit value has been reached.	14.	Remote key, on models with communications boards only, selects remote (on-line) mode to enable communications or local mode to allow manual changes of settings.
		15.	Front cover shows display codes inside.

# Connections

## ■ E5AF

### Controllers without Heater Burnout Alarm

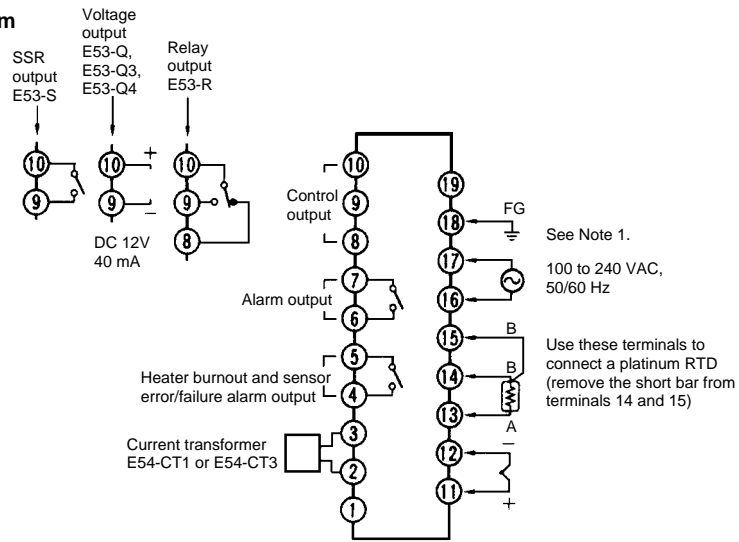


Note:

1. The field ground (FG) terminal 18 does not usually have to be grounded. Ground it through a resistance of less than 100 Ω only when the temperature controller is placed in an electrically noisy environment.
2. Do not use the vacant terminals.

## ■ E5AF-H

### Controllers with Heater Burnout Alarm

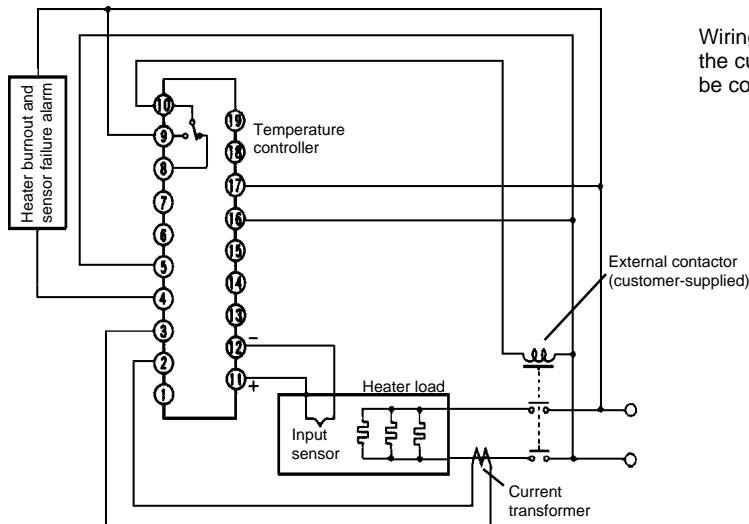


See Note 1.

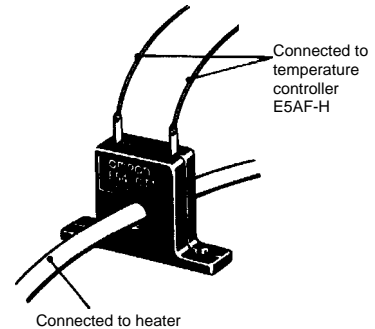
100 to 240 VAC,  
50/60 Hz

Use these terminals to connect a platinum RTD (remove the short bar from terminals 14 and 15)

### Overall System



Wiring for the heaters must pass through the hole of the current transformer. The current transformer can be connected to the controller in any polarity.





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