OMRON®

Fuzzy Temperature Controllers	E5AF

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 ±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	**E5AF-A-F**	**E5AF-AH-F**
RS-232C	**E5AF-A01-F**	**E5AF-AH01-F**
RS-422	**E5AF-A02-F**	**E5AF-AH02-F**
RS-485	**E5AF-A03-F**	**E5AF-AH03-F**
BCD	**E5AF-A20-F**	**E5AF-AH20-F**
Transmission output (4-20 mA)	**E5AF-AF-F**	**E5AF-AHF-F**

* 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)	
Part number	**E53-R**	**E53-S**	**E53-Q**	**E53-Q3**	**E53-Q4**	**E53-C**

*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)
Part number	**E54-CT1**	**E54-CT3**

■ 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.
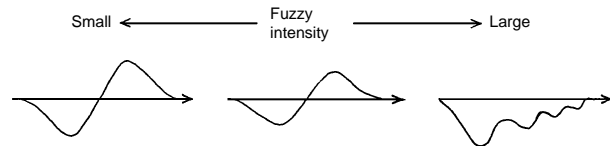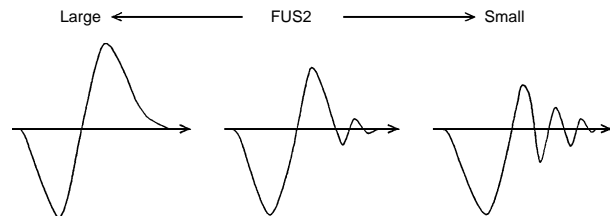

■ FUZZY SCALE 1

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.
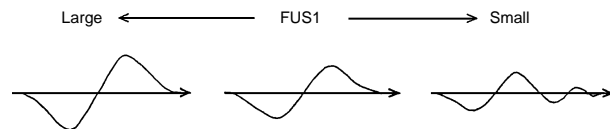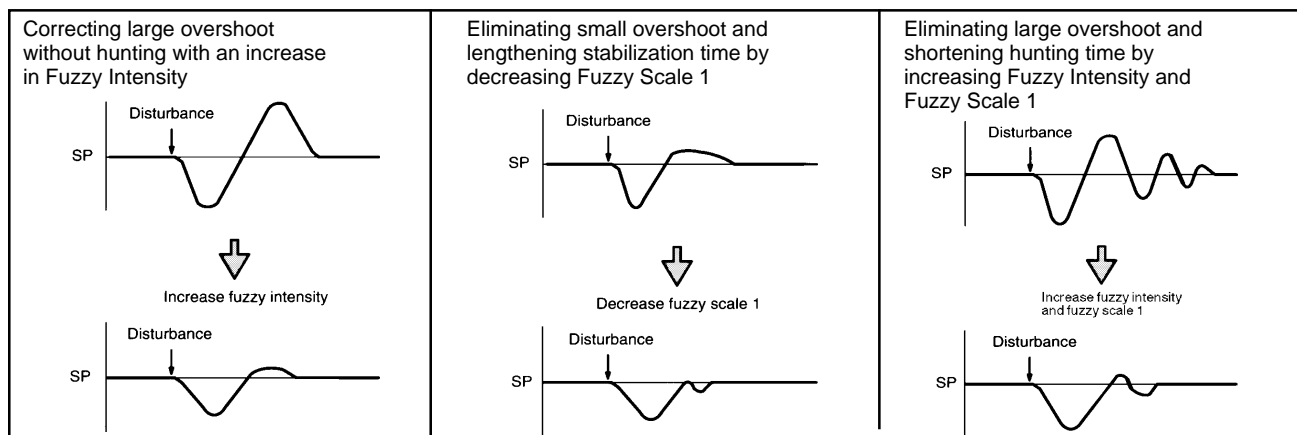

■ FUZZY SCALE 2

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

Correcting large overshoot without hunting with an increase in Fuzzy Intensity

Eliminating small overshoot and lengthening stabilization time by decreasing Fuzzy Scale 1

Eliminating large overshoot and shortening hunting time by increasing Fuzzy Intensity and Fuzzy Scale 1

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 Ω 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 °C/°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 °C/°F Platinum RTD: -99.9 to 999.9 °C/°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		±0.3% of set value or ±1°, whichever is greater, ±1 digit maximum
	Exceptions		Accuracy of types T and U thermocouples is ±2°C (3.6°F) from -150° to 400°C (-240 to 700°F), ±1 digit. Accuracy is not guaranteed below -150°C (-240°F). Accuracy of types R and S thermocouples is ±3°C (±5.4°F) from 0° to 200°C (32° to 400°F), ±1 digit.
	Heater burnout		±5% of full scale, ±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 °C/°F in units of 0.1°
	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 °C or °F in units of 0.1°; factory set to 40.0°C
	Fuzzy scale 2		FUS2 = 0.20 to 99.99 °C or °F/sec^2 in units of 0.01 °F or °C/sec^2; factory set to 0.47°C/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 Ω max.
			Thermocouple range: -999 to 9,999 °C/°F Platinum RTD range: -99.9 to 999.9 °C/°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 °C/°F Platinum RTD range: -99.9 to 999.9 °C/°F
	Miscellaneous		Upper and lower set value limits, setting key disable, °C/°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 Rear panel Terminals	IEC IP50, NEMA 4 with optional cover Y92A-96N IEC IP20 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^2 in 6 directions, 3 times each
	Malfunction durability	200 m/s^2 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)

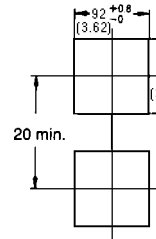| Heater current	Maximum 50 A continuous service, single-phase
Weight	Approx. 11.5 g (0.41 oz.) for E54-CT1; approx. 50 g (1.8 oz.) for E54-CT3
Dielectric strength	1,000 VAC
Vibration	50 Hz (approx. 10 G)

Dimensions

Unit: mm (inch)

■ TEMPERATURE CONTROLLER
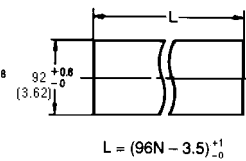

96 (3.78)

96 (3.78)

12

89 (3.50)

6 to 15

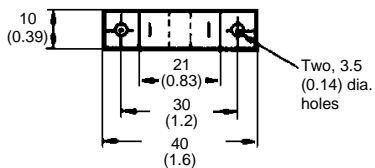Mounting screw
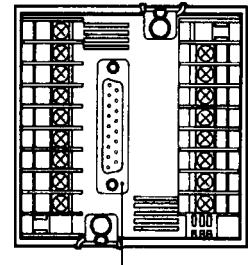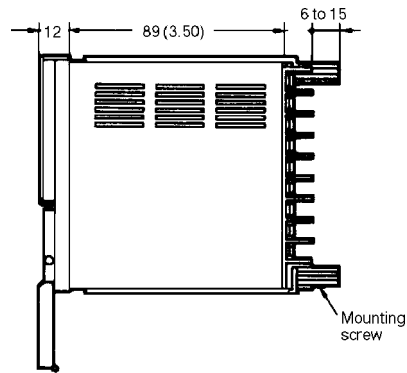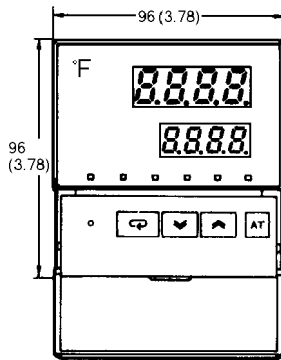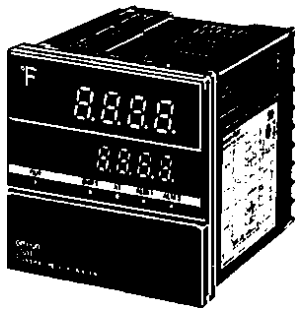
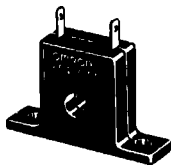Communications port connector (RS-232 and BCD type shown)
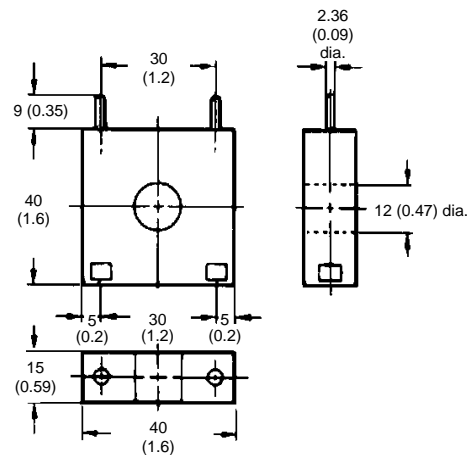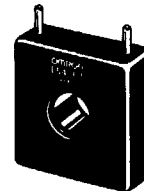
Panel cutout   **Side-by-side mounting of several controllers**

$92^{+0.8}_{-0}$ (3.62)

$92^{+0.8}_{-0}$ (3.62)

$92^{+0.8}_{-0}$ (3.62)

L

20 min.

$L = (96N - 3.5)^{+1}_{-0}$

For side-by-side mounting:
L = 96 mm x Number of units - 3.5 mm
= (3.78 in x Number of units - 0.14 in)

■ CURRENT TRANSFORMERS (for E5AF-H)

E54-CT1

15 (0.59)

2.8 (0.11)

7.5 (0.3)

25 (0.98)

10.5 (0.41)

5.8 (0.23) dia.

3 (0.12)

10 (0.39)

21 (0.83)

30 (1.2)

40 (1.6)

Two, 3.5 (0.14) dia. holes

E54-CT3

30 (1.2)

2.36 (0.09) dia.

9 (0.35)

40 (1.6)

12 (0.47) dia.
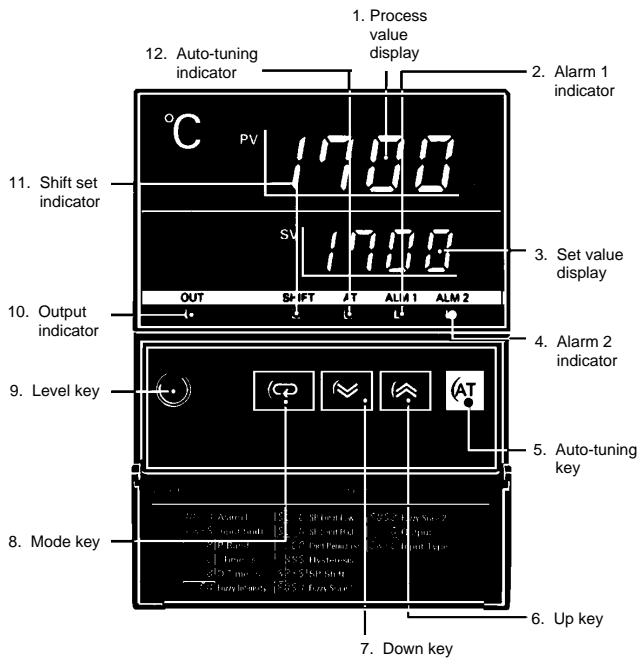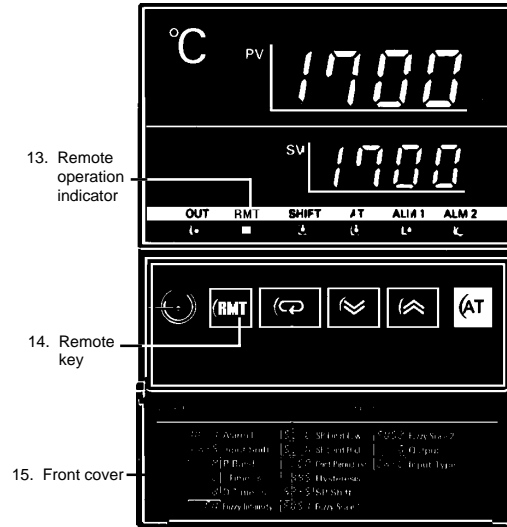
5 (0.2)

30 (1.2)

5 (0.2)

15 (0.59)

40 (1.6)

5
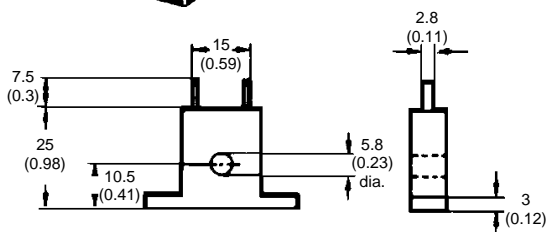
Nomenclature

■ **E5AF controller without communications**

■ **E5AF controllers with communications**

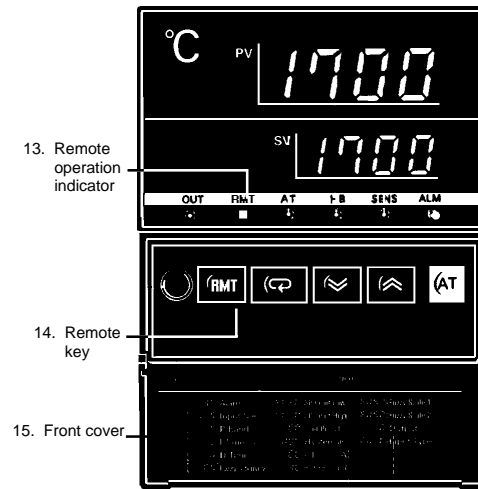| Key	Description		Key	Description
1.	Process value display shows process temperature and various messages, including the parameter being displayed and error codes for troubleshooting.		8.	Mode key changes the display mode within the display levels.
2.	Alarm 1 indicator lights when alarm 1 output is 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**

1. Process value display
2. Sensor error indicator
3. Set value display
4. Alarm indicator
5. Auto-tuning key
6. Up key
7. Down key
8. Mode key
9. Level key
10. Output indicator
11. Auto-tuning indicator
12. Heater burnout indicator

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

13. Remote operation indicator
14. Remote key
15. Front cover

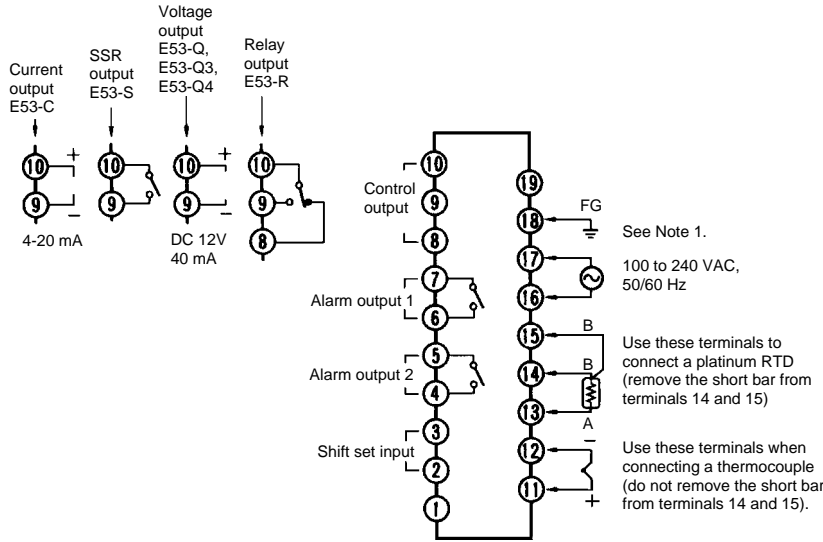| Key	Description
1.	Process value display shows process temperature and various messages, including the parameter being displayed and error codes for troubleshooting.
2.	Sensor error indicator lights when a sensor fails or an error is detected..
3.	Set value display shows the set temperature and other parameters.
4.	Alarm indicator lights when alarm output is ON.
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.
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.
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.

Key	Description
8.	Mode key changes the display mode within the display levels.
9.	Level key changes the display level when pressed for at least 2 seconds.
10.	Output indicator lights when the control output is ON (except when using a current output unit).
11.	Auto-tuning indicator flashes at intervals of 1 second when auto-tuning of PID and fuzzy parameters is in progress.
12.	Heater burnout indicator lights when a heater burnout is detected and stays lit until reset. Provided on the Heater Burnout models only.
13.	Remote operation indicator lights when the controller is in remote (on-line) communication mode.
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

Current output E53-C — 4-20 mA
SSR output E53-S
Voltage output E53-Q, E53-Q3, E53-Q4 — DC 12V 40 mA
Relay output E53-R

Control output
Alarm output 1
Alarm output 2
Shift set input

FG — See Note 1.
100 to 240 VAC, 50/60 Hz
B / B — Use these terminals to connect a platinum RTD (remove the short bar from terminals 14 and 15)
A / − / + — Use these terminals when connecting a thermocouple (do not remove the short bar from terminals 14 and 15).
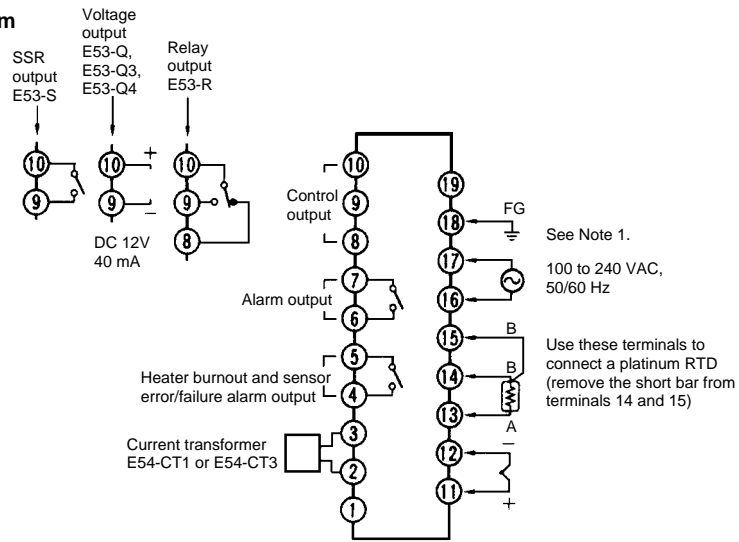
Note:
1. The field ground (FG) terminal 18 does not usually have to be grounded. Ground it through a resistance of less than 100 Ω only when the temperature controller is placed in an electrically noisy environment.
2. Do not use the vacant terminals.

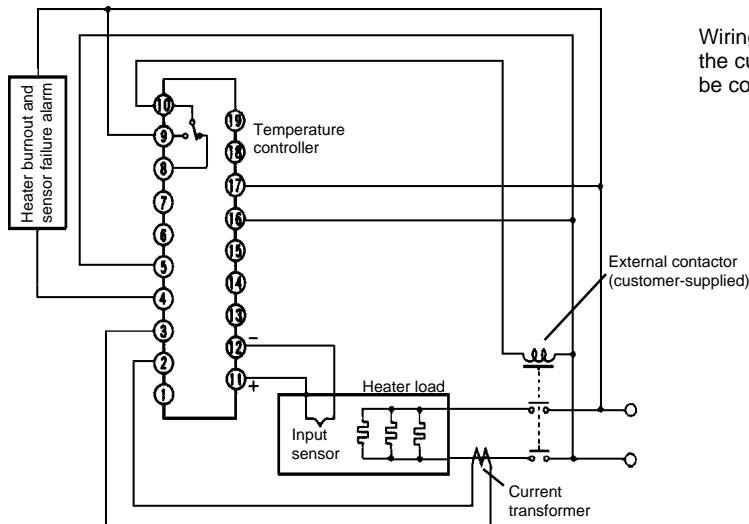## ■ E5AF-H

Controllers with Heater Burnout Alarm

SSR output E53-S
Voltage output E53-Q, E53-Q3, E53-Q4 — DC 12V 40 mA
Relay output E53-R

Control output
Alarm output
Heater burnout and sensor error/failure alarm output
Current transformer E54-CT1 or E54-CT3

FG — See Note 1.
100 to 240 VAC, 50/60 Hz
B / B — Use these terminals to connect a platinum RTD (remove the short bar from terminals 14 and 15)
A / − / +

Overall System

Heater burnout and sensor failure alarm
Temperature controller
External contactor (customer-supplied)
Heater load
Input sensor
Current transformer

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.

Connected to temperature controller E5AF-H
Connected to heater
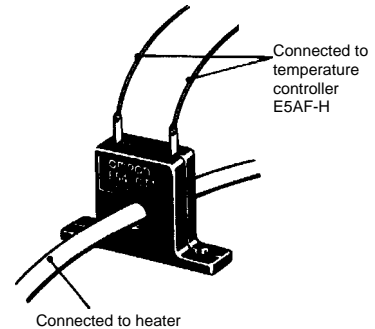
OMRON

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