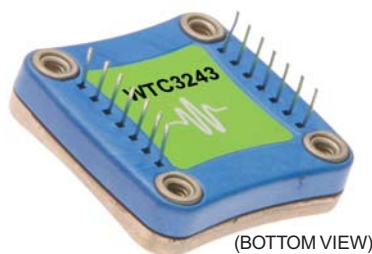




WTC3243

Ultrastable Thermoelectric Controller



(BOTTOM VIEW)

GENERAL DESCRIPTION:

The WTC3243 is a powerful, compact analog PI (Proportional, Integral) control loop circuit optimized for use in ultrastable thermoelectric temperature control applications.

The WTC3243 maintains precision temperature regulation using an adjustable sensor bias current and error amplifier circuit that operates directly with thermistors, RTDs, AD590 type, and LM335 type temperature sensors.

Supply up to 2 Amps of heat and cool current to your thermoelectric from a single +5 Volt power supply. Operate resistive heaters by disabling the cooling current output. Adjust temperature at the voltage setpoint input pin. Independently configure the adjustable PI control loop using simple resistors.

An evaluation board is available to quickly integrate the WTC3243 in your system.

FEATURES:

- Low Cost
- Ultrastable PI Control
- High ± 2 Amps Output Current
- Control Above and Below Ambient
- Small Package Size (1.30" X 1.26" X 0.313")
- Voltage Controlled Setpoint
- Adjustable Sensor Bias Current Source
- Adjustable Sensor Gain
- Independent Heat and Cool Current Limits

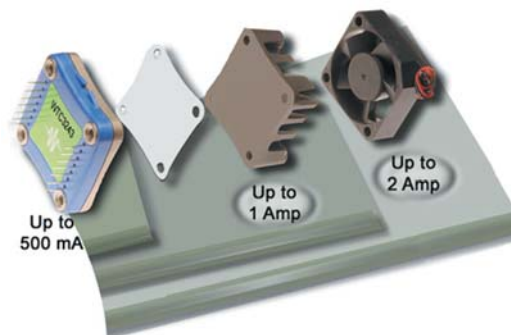
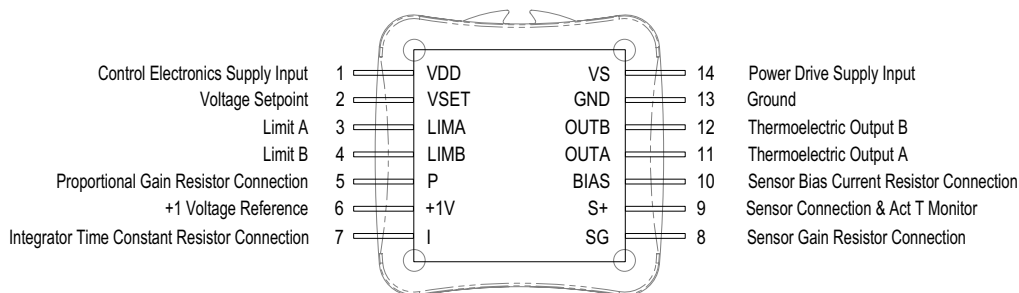


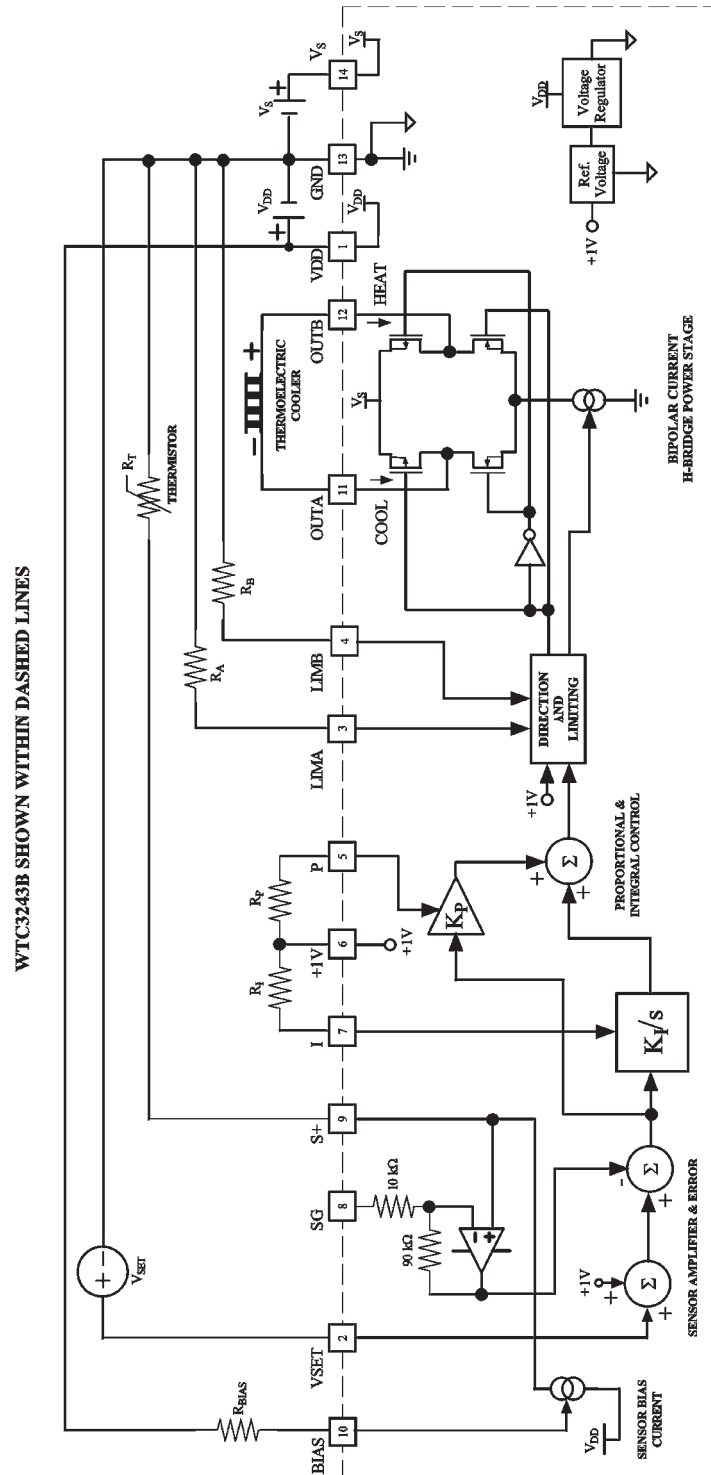
Figure 1
Top View Pin Layout
and Descriptions

TOP VIEW



IF YOU ARE UPGRADING FROM THE WHY5640: The position of Pin 1 on the WHY5640 is reversed (or mirrored) relative to the position of Pin 1 on the WTC3243.

Figure 2
External Connections
Using Thermistor Temperature Sensors



ELECTRICAL AND OPERATING SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS RATING

	SYMBOL	VALUE	UNIT
Supply Voltage 1 (Voltage on Pin 1)	V _{DD}	+4.5 to +30	Volts DC
Supply Voltage 2 (Voltage on Pin 14)	V _S	+4.5 to +30	Volts DC
Output Current (See SOA Chart)	I _{OUT}	±2.5	Amperes
Power Dissipation, T _{AMBIENT} = +25°C (See SOA Chart) (with fan and heat sink)	P _{MAX}	9	Watts
Operating Temperature, case	T _{OPR}	-40 to +85	°C
Storage Temperature	T _{STG}	-65 to +150	°C

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
TEMPERATURE CONTROL					
Short Term Stability, 1 hour	TSET = 25°C using 10 kΩ thermistor	0.001	0.005	0.010	°C
Long Term Stability, 24 hour	TSET = 25°C using 10 kΩ thermistor	0.003	0.008	0.010	°C
Control Loop		P	PI		
P (Proportional Gain)		1		100	A/V
I (Integrator Time Constant)		0.75		4.5	Sec.
Setpoint vs. Actual T Accuracy	TSET = 25°C using 10 kΩ thermistor		<1% (Rev A) <0.2% (Rev B)		
OUTPUT					
Current, peak, see SOA Chart		±2.0	±2.2	± 2.5	Amps
Compliance Voltage, Pin 11 to Pin 12	Full Temp. Range, I _{OUT} = 100 mA	V _S - 0.7	V _S - 0.5		Volts
Compliance Voltage, Pin 11 to Pin 12	Full Temp. Range, I _{OUT} = 1 Amp	V _S - 1.2	V _S - 1.0		Volts
Compliance Voltage, Pin 11 to Pin 12	Full Temp. Range, I _{OUT} = 1.5 Amps	V _S - 1.6	V _S - 1.4		Volts
Compliance Voltage, Pin 11 to Pin 12	Full Temp. Range, I _{OUT} = 2.0 Amps	V _S - 1.8	V _S - 1.6		Volts
Compliance Voltage, Resistive Heater	Full Temp. Range, I _{OUT} = 2.0 Amps	V _S - 1.7	V _S - 1.6		
POWER SUPPLY					
Voltage, VDD		4.5		28	Volts
Current, VDD supply, quiescent			55	105	mA
Voltage, V _S		4.5		28	Volts
Current, V _S supply, quiescent		20	50	100	mA

ELECTRICAL AND OPERATING SPECIFICATIONS

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
INPUT					
Offset Voltage, initial	Pins 2 and 9		1	2	mV
Bias Current	Pins 2 and 9, $T_{\text{AMBIENT}} = 25^{\circ}\text{C}$		20	50	nA
Offset Current	Pins 2 and 9, $T_{\text{AMBIENT}} = 25^{\circ}\text{C}$		2	10	nA
Common Mode Range	Pins 2 and 9, Full Temp. Range	0		$V_{\text{DD}} - 2^1$	V
Common Mode Rejection	Full Temperature Range	60	85		dB
Power Supply Rejection	Full Temperature Range	60	80		dB
Input Impedence			500		k Ω
Input voltage range		GND		$V_{\text{DD}} - 2^1$	Volts
THERMAL					
Heatspreader Temperature Rise	$T_{\text{AMBIENT}} = 25^{\circ}\text{C}$	28	30	33	$^{\circ}\text{C/W}$
Heatspreader Temperature Rise	With WHS302 Heatsink, WTW002 Thermal Washer	18	21.5	25	$^{\circ}\text{C/W}$
Heatspreader Temperature Rise	With WHS302 Heatsink, WTW002 Thermal Washer, and 3.5 CFM Fan	3.1	3.4	3.9	$^{\circ}\text{C/W}$

¹The bias source has a compliance up to $V_{\text{DD}} - 2.0\text{ V}$. In normal operation this limits the sensor voltage range from 0.0V to $V_{\text{DD}} - 2.0\text{ V}$. While voltages up to $\pm 5\text{ V}$ outside this range on the Vset pin will not damage the unit, it will not provide proper control under these conditions.

PIN DESCRIPTIONS

PIN NO.	PIN	NAME	FUNCTION
1	VDD	Control Electronics Power Supply Input	Connect a +4.5V to +30V power supply to Pin 1 (VDD) and Pin 13 (GND).
2	VSET	Voltage Setpoint [Transfer functions are noted on operating diagrams with a "**"]	Connect a voltage source between Pin 2 (VSET) and Pin 13 (GND) to control the temperature setting.
3	LIMA	Limit A	A resistor connected between Pin 3 (LIMA) and Pin 13 (GND) limits the output current drawn off the Pin 14 (VS) supply input to the Pin 11 (OUTA).
4	LIMB	Limit B	A resistor connected between Pin 4 (LIMB) and Pin 13 (GND) limits the output current drawn off the Pin 14 (VS) supply input to the Pin 12 (OUTB).
5	P	Proportional Gain Resistor Connection	Connect a resistor between Pin 5 (P) and Pin 6 (+1V) to configure the Proportional Gain setting.
6	+1V	+1 Volt	+1 Volt Reference
7	I	Integrator Time Constant Resistor Connection	Connect a resistor between Pin 7 (I) and Pin 6 (+1V) to configure the Integrator Time Constant setting.
8	SG	Sensor Gain Resistor Connection	Connect a resistor between Pin 8 (SG) and Pin 13 (GND) to adjust the Sensor Gain setting.
9	S+	Sensor Connection	Connect resistive and LM335 type temperature sensors across Pin 9 (S+) and Pin 13 (GND). Connect a 10 k Ω resistor across Pin 9 (S+) and Pin 13 (GND) when using AD590 type temperature sensors. The negative terminal of the AD590 sensor connects to Pin 9 (S+) and the positive terminal to Pin 1 (VDD). AD590 operation requires that VDD be +8 Volts or greater for proper operation.
10	BIAS	Sensor Bias Current Resistor Connection	Connect a resistor between Pin 10 (BIAS) and Pin 1 (VDD) to configure the sensor bias current.

IF YOU ARE UPGRADING FROM THE WHY5640: The position of Pin 1 on the WHY5640 is reversed (or mirrored) relative to the position of Pin 1 on the WTC3243.

PIN DESCRIPTIONS

PIN NO.	PIN	NAME	FUNCTION
11	OUTA	Thermoelectric Output A	Connect Pin 11 (OUTA) to the negative terminal on your thermoelectric when controlling temperature with Negative Temperature Coefficient thermistors. Connect Pin 11 (OUTA) to the positive thermoelectric terminal when using Positive Temperature Coefficient RTDs, LM335 type, and AD590 type temperature sensors.
12	OUTB	Thermoelectric Output B	Connect Pin 12 (OUTB) to the positive terminal on your thermoelectric when controlling temperature with Negative Temperature Coefficient thermistors. Connect Pin 12 (OUTB) to the negative thermoelectric terminal when using Positive Temperature Coefficient RTDs, LM335 type, and AD590 type temperature sensors.
13	GND	Ground	Connect the power supply ground connections to Pin 13 (GND). All ground connections to this pin shall be wired separately.
14	VS	Power Drive Supply Input	Provides power to the WTC3243 H-Bridge power stage. Supply range input for this pin is +3 to +30 Volts DC. The maximum current drain on this terminal should not exceed 2.5 Amps. CAUTION: Care should be taken to observe the maximum power dissipation limits when operating with supply voltages greater than +12V.

IF YOU ARE UPGRADING FROM THE WHY5640: The position of Pin 1 on the WHY5640 is reversed (or mirrored) relative to the position of Pin 1 on the WTC3243.

TYPICAL PERFORMANCE GRAPHS

Caution:

Do not exceed the Safe Operating Area (SOA). Exceeding the SOA voids the warranty.

To determine if the operating parameters fall within the SOA of the device, the maximum voltage drop across the controller and the maximum current must be plotted on the SOA curves.

These values are used for the example SOA determination:

$V_s = 12$ volts

$V_{load} = 5$ volts

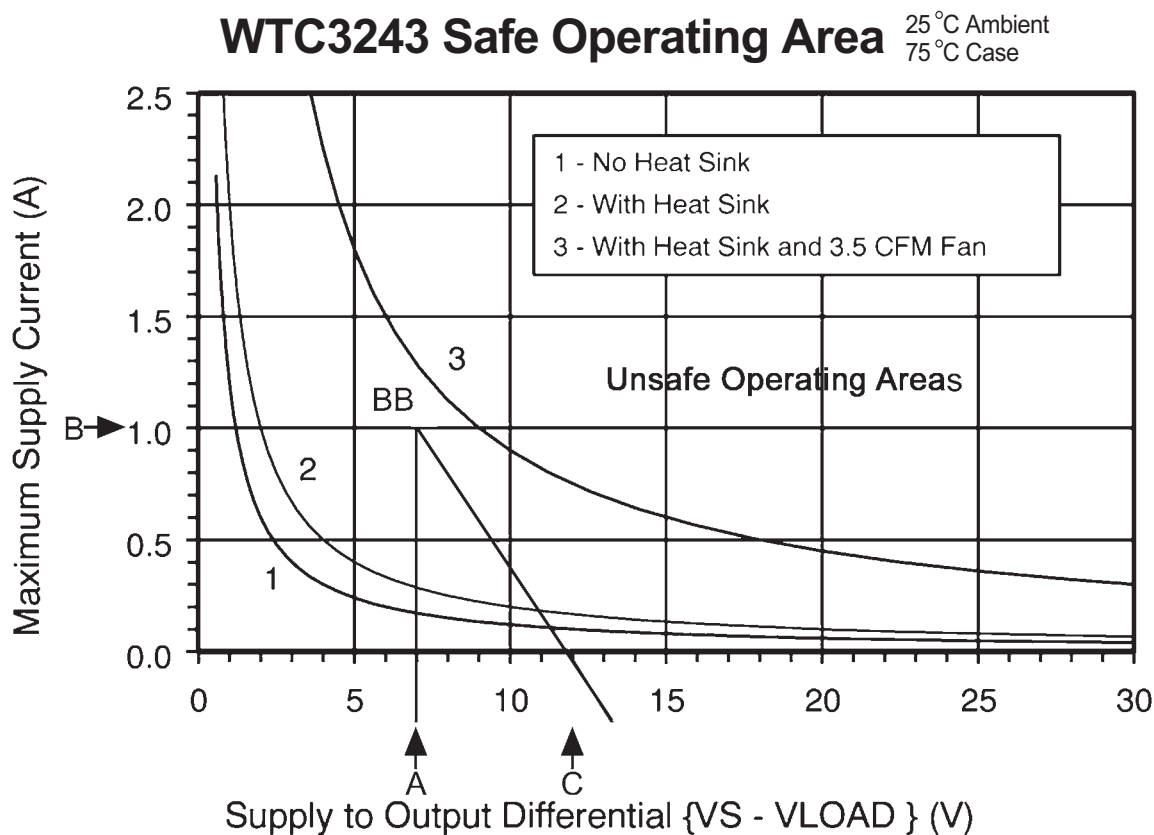
$I_{load} = 1$ amp

} These values are determined from the specifications of the TEC or resistive heater

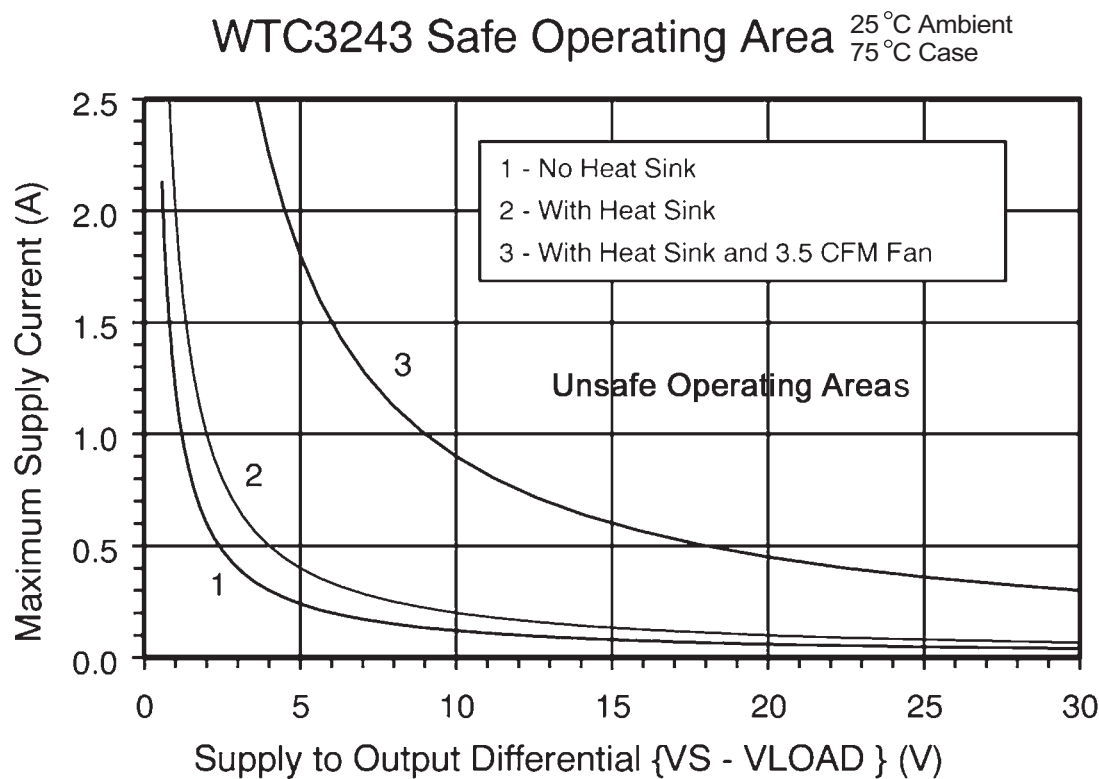
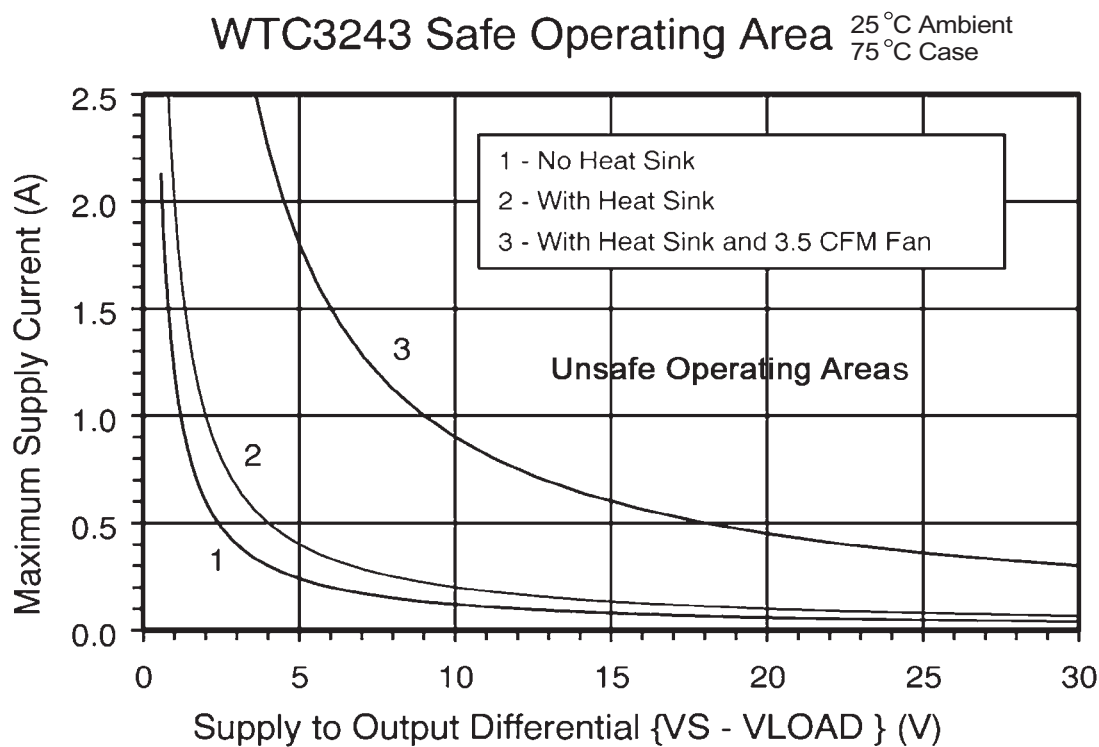
Follow these steps:

1. Determine the maximum voltage drop across the controller, $V_s - V_{load}$, and mark on the X axis. (12volts - 5 volts = 7 volts, Point A)
2. Determine the maximum current, I_{load} , through the controller and mark on the Y axis: (1 amp, Point B)
3. Draw a horizontal line through Point B across the chart. (Line BB)
4. Draw a vertical line from Point A to the maximum current line indicated by Line BB.
5. Mark V_s on the X axis. (Point C)
6. Draw the Load Line from where the vertical line from point A intersects Line BB down to Point C.

Refer to the chart shown below and note that the Load Line is in the Unsafe Operating Areas for use with no heatsink (1) or the heatsink alone (2), but is outside of the Unsafe Operating Area for use with heatsink and Fan (3).



SOA Charts for Customer Use:



OPERATION

1. CONFIGURING HEATING AND COOLING CURRENT LIMITS

Refer to Table 1 to select appropriate resistor values for R_A and R_B .

Setting Current Limits Independently Using Trimpots

The 5k Ω trimpots shown in Figure 4 adjust the maximum output currents from 0 to 2.3 Amps.

Heat and Cool Current Limits

APPROXIMATE VALUE OF CURRENT LIMIT RESISTOR R_C vs MAXIMUM OUTPUT CURRENT

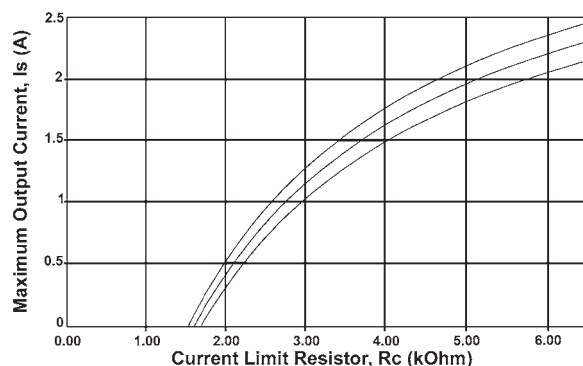


Figure 3
Fixed Heat and Cool Current Limits

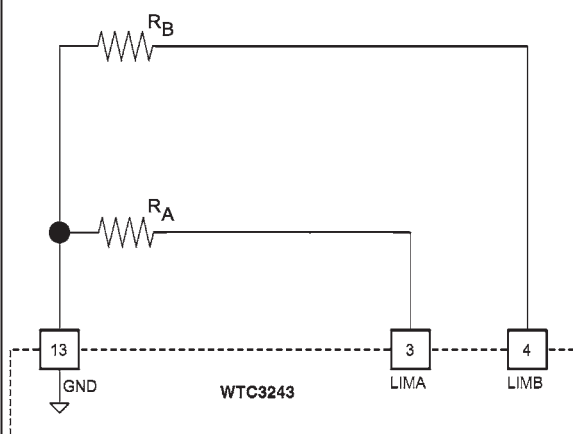
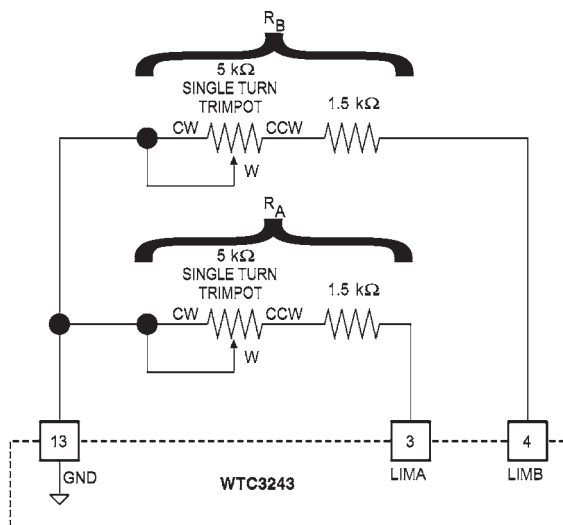


Table 1

Current Limit Set Resistor vs Maximum Output Current

Maximum Output Currents (Amps)	Current Limit Set Resistor, (k Ω) R_A, R_B	Maximum Output Current (Amps)	Current Limit Set Resistor, (k Ω) R_A, R_B
0.0	1.60	1.2	3.05
0.1	1.69	1.3	3.23
0.2	1.78	1.4	3.43
0.3	1.87	1.5	3.65
0.4	1.97	1.6	3.88
0.5	2.08	1.7	4.13
0.6	2.19	1.8	4.42
0.7	2.31	1.9	4.72
0.8	2.44	2.0	5.07
0.9	2.58	2.1	5.45
1.0	2.72	2.2	5.88
1.1	2.88	2.3	6.36

Figure 4
Independently Adjustable Heat and Cool Current Limits



OPERATION

2. RESISTIVE HEATER TEMPERATURE CONTROL

The WTC3243 can operate resistive heaters by disabling the cooling output current. When using Resistive Heaters with NTC thermistors, connect Pin 3 (LIMA) to Pin 13 (GND) with a 1.5 kΩ resistor.

Connect Pin 4 (LIMB) to Pin 13 (GND) with a 1.5 kΩ resistor when using RTDs, LM335 type, and AD590 type temperature sensors with a resistive heater.

3. DISABLING THE OUTPUT CURRENT

The output current can be enabled and disabled, as shown in Figure 5, using a DPDT (Double Pole–Double Throw) switch.

4. ADJUSTING THE SENSOR BIAS CURRENT AND SENSOR GAIN FOR RESISTIVE TEMPERATURE SENSORS

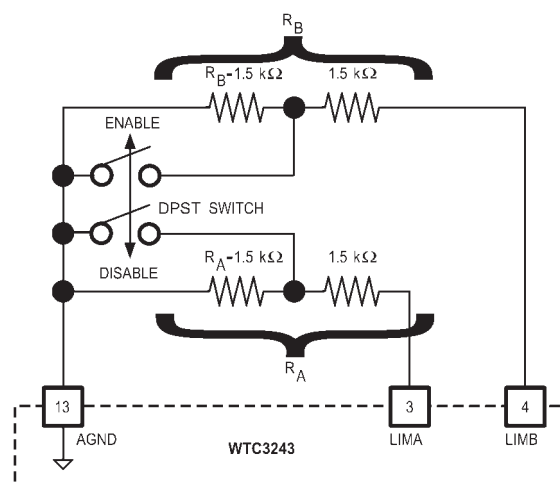
Connect a resistor R_{BIAS} between Pin 10 (BIAS) and Pin 1 (VDD) to adjust the sensor bias current. Table 2 lists the suggested resistor values for R_{BIAS} versus the range of resistances of the resistive temperature sensor. Equation 1 demonstrates how to calculate a value of R_{BIAS} given a desired sensor bias current, I_{BIAS} .

The sensor signal applied to Pin 9 (S+) can be amplified up to a factor of 10 by inserting a resistor, R_S , between Pin 8 (SG) and Pin 13 (GND). Connect Pin 8 (SG) directly to Pin 13 (GND) for a sensor gain of 10. The lower the value of R_S , the more gain applied to the sensor signal.

Equation 2 demonstrates how to calculate a value for R_S given a desired sensor gain.

Table 2 lists the suggested resistor values for R_S versus the range of resistances of the resistive temperature sensor.

Figure 5
Disabling the Output Current



Equation 1

Calculating R_{BIAS}

$$R_{BIAS} = \frac{2}{I_{BIAS}} [\Omega]$$

Equation 2

Calculating R_S

$$R_S = \left(\frac{90,000}{(G_{sensor} - 1)} - 10,000 \right) [\Omega]$$

Table 2

Sensor Gain Resistor R_S vs Resistance Temperature Sensor

Sensor Resistance Range	Sensor Bias Resistor, R_{BIAS}	Sensor Bias Current	Sensor Gain Resistor, R_S	Sensor Gain
35Ω to 350Ω	2 kΩ	1mA	SHORT	10
350Ω to 3.5kΩ	2 kΩ	1mA	OPEN	1
3.5kΩ to 35kΩ	20 kΩ	100μA	OPEN	1
35kΩ to 350kΩ	200 kΩ	10μA	OPEN	1

OPERATION

5. ADJUSTING THE CONTROL LOOP PROPORTIONAL GAIN

The control loop proportional gain can be adjusted by inserting a resistor, R_P , between Pin 5 (P) and Pin 6 (+1V) to set I from 1 to 100.

Equation 3 demonstrates how to calculate a value for R_P given a desired proportional gain.

Equation 4 demonstrates how to calculate the Proportional gain, P , given a value for R_P .

Table 3 lists the suggested resistor values for R_P versus sensor type and the thermal loads ability to change temperature rapidly.

6. ADJUSTING THE CONTROL LOOP INTEGRATOR TIME CONSTANT

The control loop integrator time constant can be adjusted by inserting a resistor, R_I , between Pin 6 (+1V) and Pin 7 (I) to set I_{TC} from 0.75 to 4.5 seconds.

Equation 5 demonstrates how to calculate a value for R_I given a desired integrator time constant. The integrator time constant, I_{TC} , is measured in seconds.

Equation 6 demonstrates how to calculate the integrator time constant, I_{TC} , given a value for R_I .

Table 4 lists the suggested resistor values for R_I versus sensor type and the thermal loads ability to change temperature rapidly.

Equation 3

Calculating R_P from P

$$R_P = \frac{100,000}{\frac{100}{P} - 1} [\Omega]$$

Equation 4

Calculating P From R_P

$$P = \frac{100}{\frac{100,000}{R_P} + 1} [\text{Amps} / \text{Volts}]$$

Equation 5

Calculating R_I from I_{TC}

$$R_I = \frac{100,000}{\frac{4}{3} I_{TC} - 1} [\Omega]$$

Equation 6

Calculating I_{TC} from R_I

$$I_{TC} = \frac{3}{4} \left[\frac{100,000}{R_I} + 1 \right] [\text{Seconds}]$$

Table 3

Proportional Gain Resistor R_P vs Sensor Type and Thermal Load Speed

Proportional Gain Resistor, R_P	Proportional Gain, [Amps/Volt]	Sensor Type/ Thermal Load Speed
4.99 k Ω	5	Thermistor/Fast
24.9 k Ω	20	Thermistor/Slow
100 k Ω	50	RTD/Fast
Open	100	RTD/Slow
24.9 k Ω	20	AD590 or LM335/ Fast
100 k Ω	50	AD590 or LM335/ Slow

Table 4

Integrator Time Constant vs Sensor Type and Thermal Load Speed

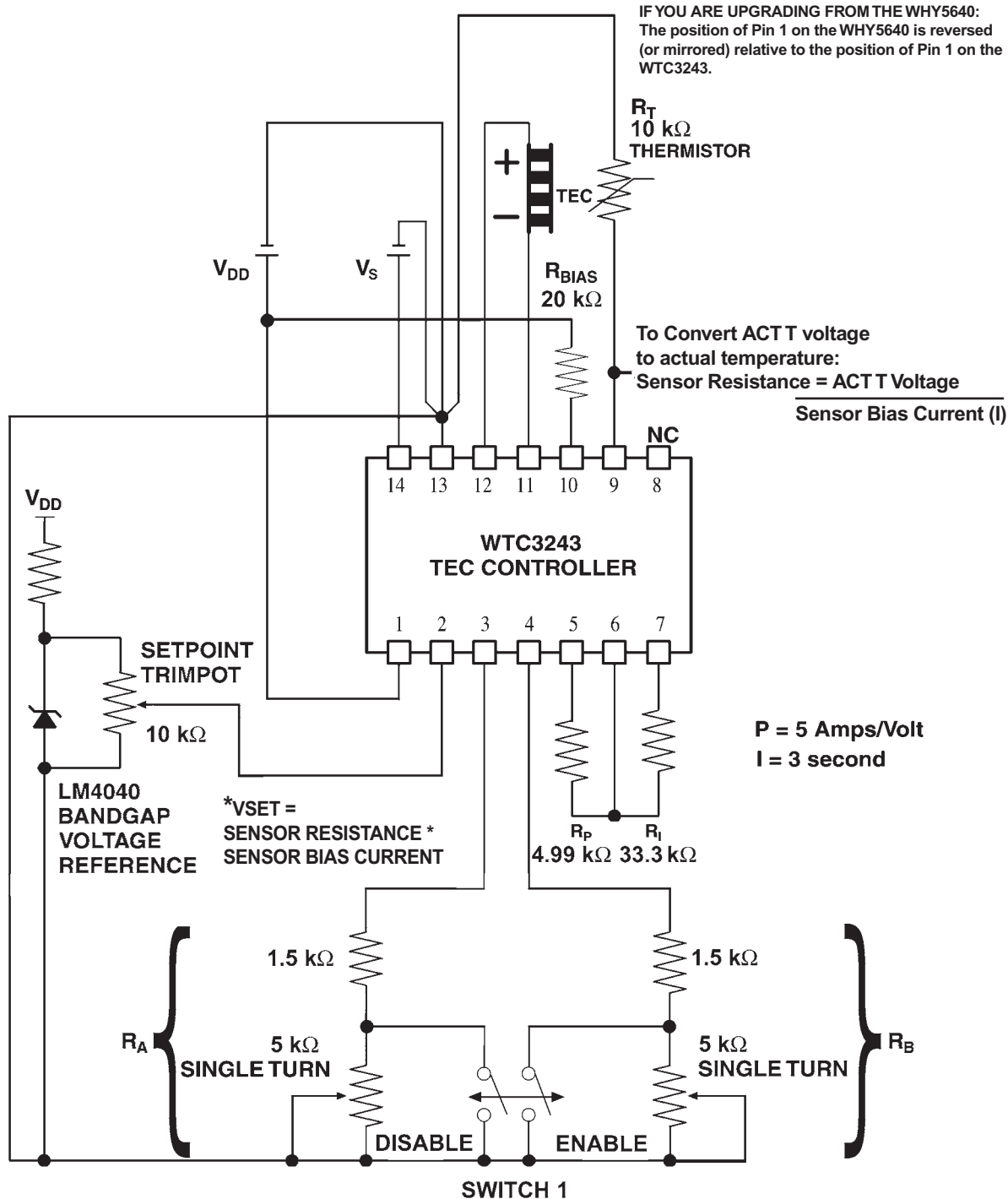
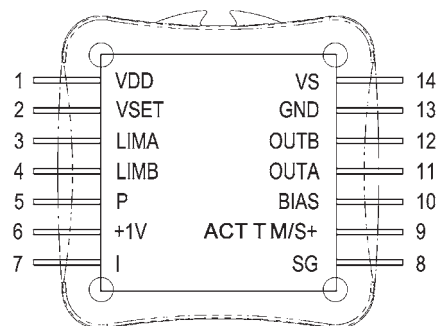
Integrator Resistor, R_I	Integrator Time Constant, [Seconds]	Sensor Type/ Thermal Load Speed
33.3 k Ω	3	Thermistor/Fast
20 k Ω	4.5	Thermistor/Slow
Open	0.75	RTD/Fast
300 k Ω	1	RTD/Slow
300 k Ω	1	AD590 or LM335/ Fast
20 k Ω	4.5	AD590 or LM335/ Slow

TOP VIEW

Figure 6 demonstrates how to configure the WTC3243 for operation with a 10 k Ω thermistor temperature sensor.

FIGURE 6

Configuring the WTC3243 to operate with Thermistors

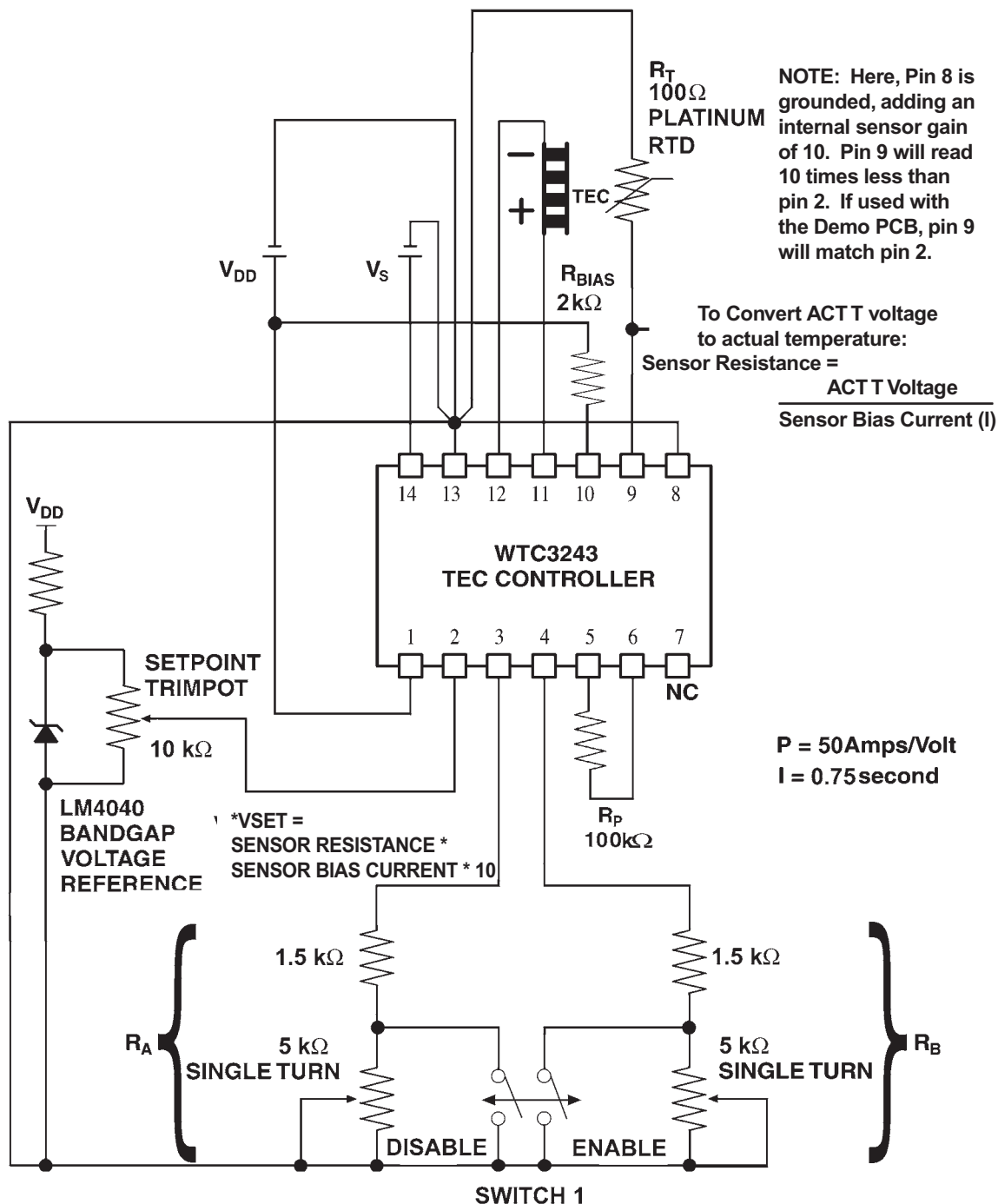
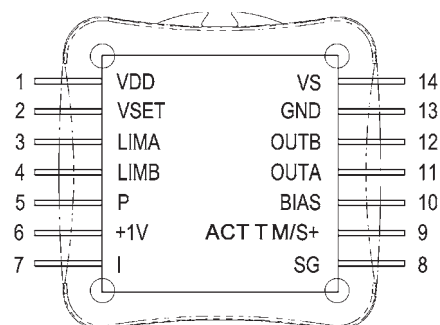


TOP VIEW

Figure 7 demonstrates how to configure the WTC3243 for operation with a 100 Ω Platinum RTD temperature sensor.

FIGURE 7

Configuring the WTC3243 to operate with RTDs



OPERATION

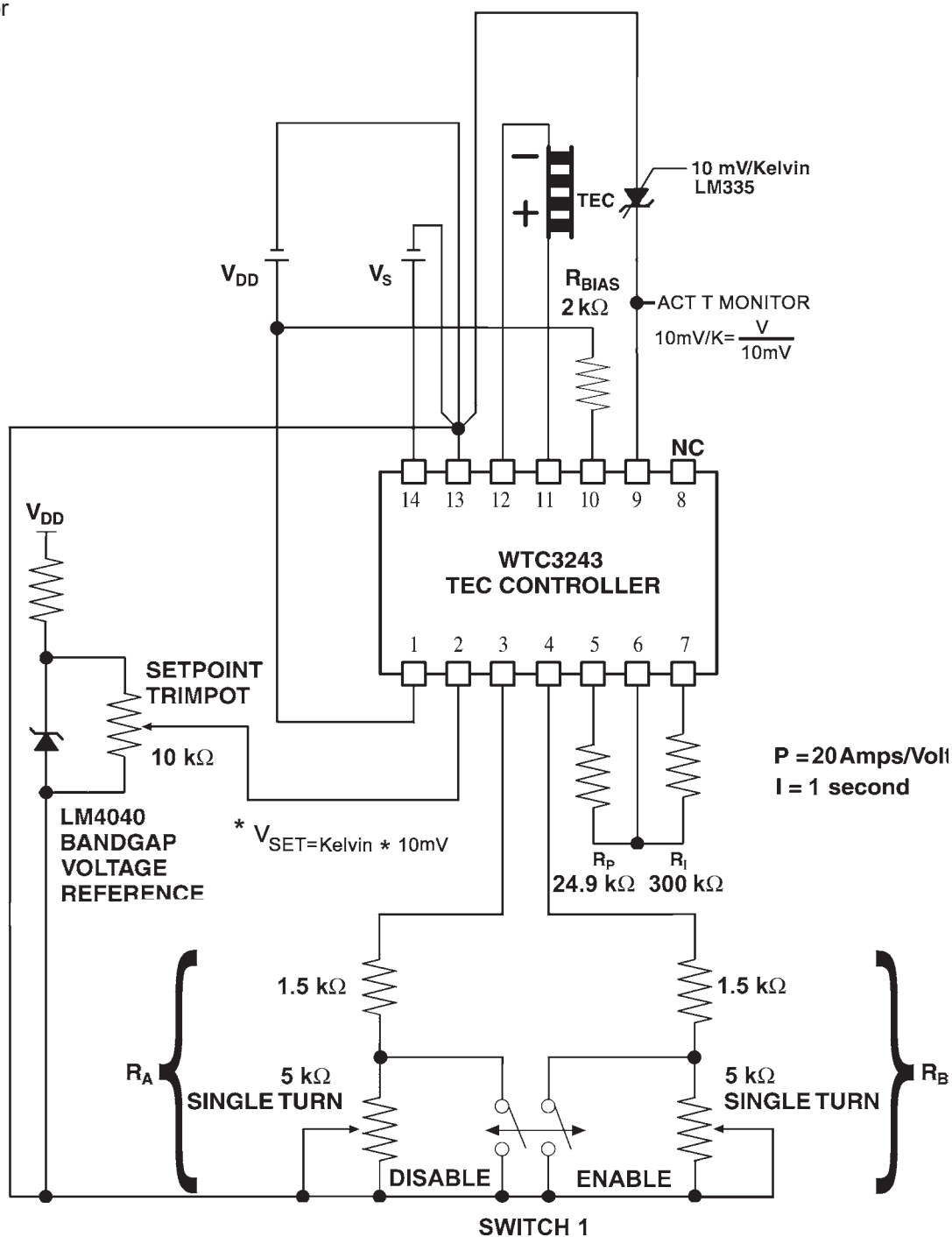
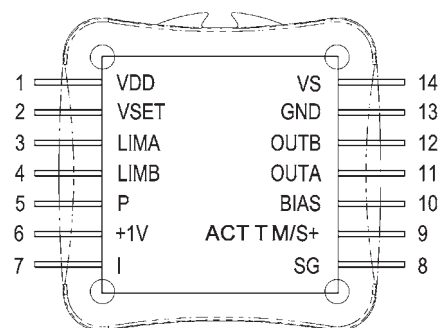
TOP VIEW

9. OPERATING WITH LM335 TYPE TEMPERATURE SENSORS

Figure 8 demonstrates how to configure the WTC3243 for operation with a National Semiconductor LM335 temperature sensor.

FIGURE 8

Configuring the WTC3243 to operate with a National Semiconductor LM335 Temperature Sensor



OPERATION

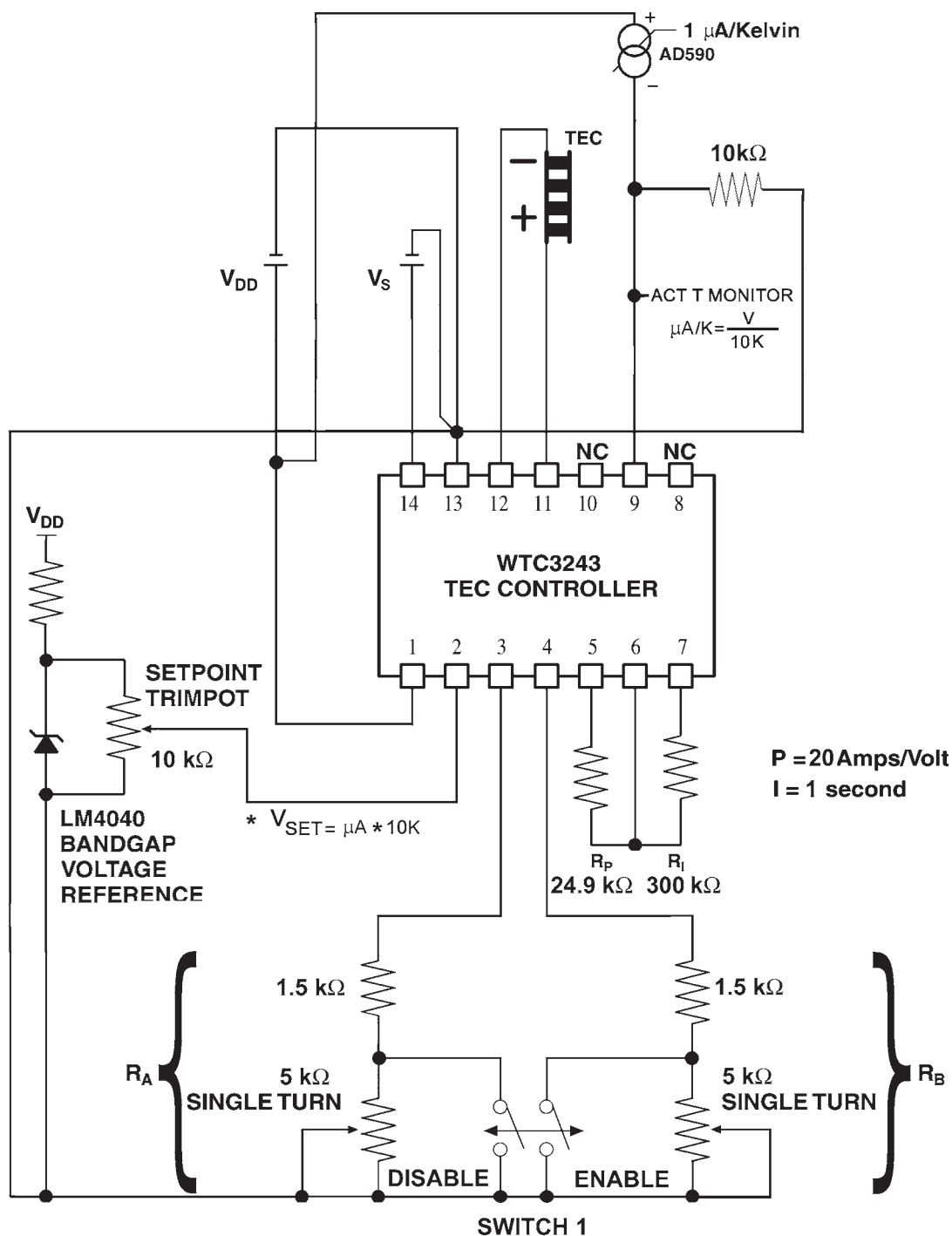
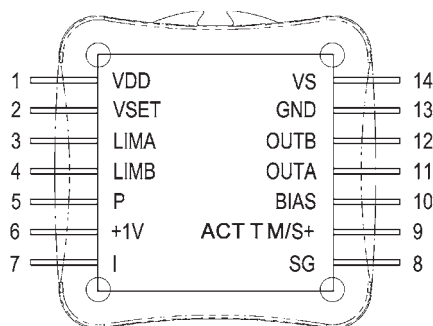
10. OPERATING WITH AD590 TYPE TEMPERATURE SENSORS

Figure 9 demonstrates how to configure the WTC3243 for operation with an Analog Devices AD590 Temperature Sensor.

FIGURE 9

Configuring the WTC3243 to operate with an Analog Devices AD590 Temperature Sensor

TOP VIEW



11. OPERATING THE WTC3243 WITH RESISTIVE HEATERS

The WTC3243 can efficiently control a wide range of resistive heaters. Since resistive heaters do not require bipolar current drive, one side of a resistive heater can be directly connected to V_s , which bypasses part of the H₁ drive circuitry inside the WTC3243. This reduces internal power dissipation and increases the output power capacity of the WTC3243.

Safe operation considerations:

1. Resistive heater applications are still subject to the SOA limitations of the WTC3243 and should be plotted on the SOA charts on page 8.
2. The resistive heater must connect to the appropriate output pins according to the sensor type. For thermistors, connect the heater between V_s and Pin12 (OUTB). For all other sensor types, connect the heater between V_s and Pin11 (OUTA).

EXAMPLE:

Heater resistance: 10 ohms

Desired Output Power: 15 watts

Calculate output current required for 15 watts of output power:

$$P = I^2 * R \rightarrow 15 = I^2 * 10 \rightarrow I = 1.2 \text{ amps}$$

This current will require a voltage across the heater of:

$$V = I * R \rightarrow V = 1.2 * 10 \rightarrow V = 12.2 \text{ volts}$$

The supply voltage required is the sum of the heater voltage and the internal voltage drop (from page 3) of the WTC3243:

$$V_s = 12.2 + 1.5 \rightarrow V_s = 13.7 \text{ volts.}$$

A 15 volt, 1.5 amp power supply could be chosen for this application.

These values are plotted on the SOA chart shown as shown below.

•Point A:

$$V_s - V_{load} \rightarrow 15 - 12.2V = 2.8 \text{ volts}$$

•Point B, Line BB:

$$\text{Max current} = 1.2 \text{ amps}$$

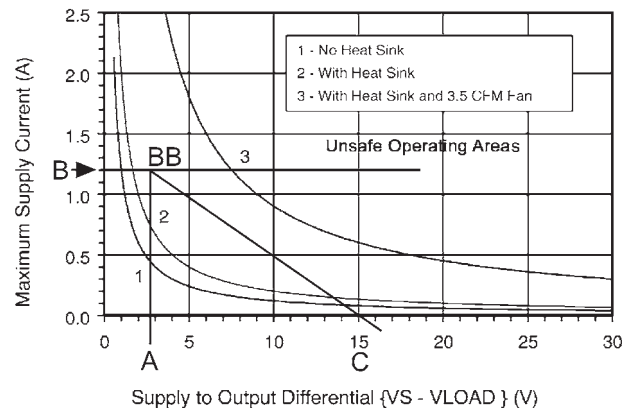
•Point C, $V_s = 15 \text{ Volts}$

•Load Line:

From Intersection of vertical line from Point A to Line BB down to Point C

The position of the load line shows that the WTC3243 can only be used safely with a heatsink and fan.

WTC3243 Safe Operating Area



Contact Wavelength Electronics technical support at (406) 587-4910 for assistance with plotting SOA charts or for information on high resistance applications.

OPERATION

13. HELPFUL HINTS

Selecting a Temperature Sensor

Select a temperature sensor that is responsive around the desired operating temperature. The temperature sensor should produce a large sensor output for small changes in temperature. Sensor selection should maximize the voltage change per °C for best stability.

Table 6 compares temperature sensors versus their ability to maintain stable load temperatures with the WTC3243.

Mounting the Temperature Sensor

The temperature sensor should be in good thermal contact with the device being temperature controlled. This requires that the temperature sensor be mounted using thermal epoxy or some form of mechanical mounting and thermal grease.

Hint: Resistive temperature sensors and LM335 type temperature sensors should connect their negative termination directly to Pin 13 (GND) to avoid parasitic resistances and voltages effecting temperature stability and accuracy.

Avoid placing the temperature sensor physically far from the thermoelectric. This is typically the cause for long thermal lag and creates a sluggish thermal response that produces considerable temperature overshoot once at the desired operating temperature.

Mounting the Thermoelectric

The thermoelectric should be in good thermal contact with its heatsink and load. Contact your thermoelectric manufacturer for their recommended mounting methods.

Heatsink Notes

If your device stabilizes at temperature but then drifts away from the setpoint temperature towards ambient, you are experiencing a condition known as thermal runaway. This is caused by insufficient heat removal from the thermoelectric's hot plate and is most commonly caused by an undersized thermoelectric heatsink.

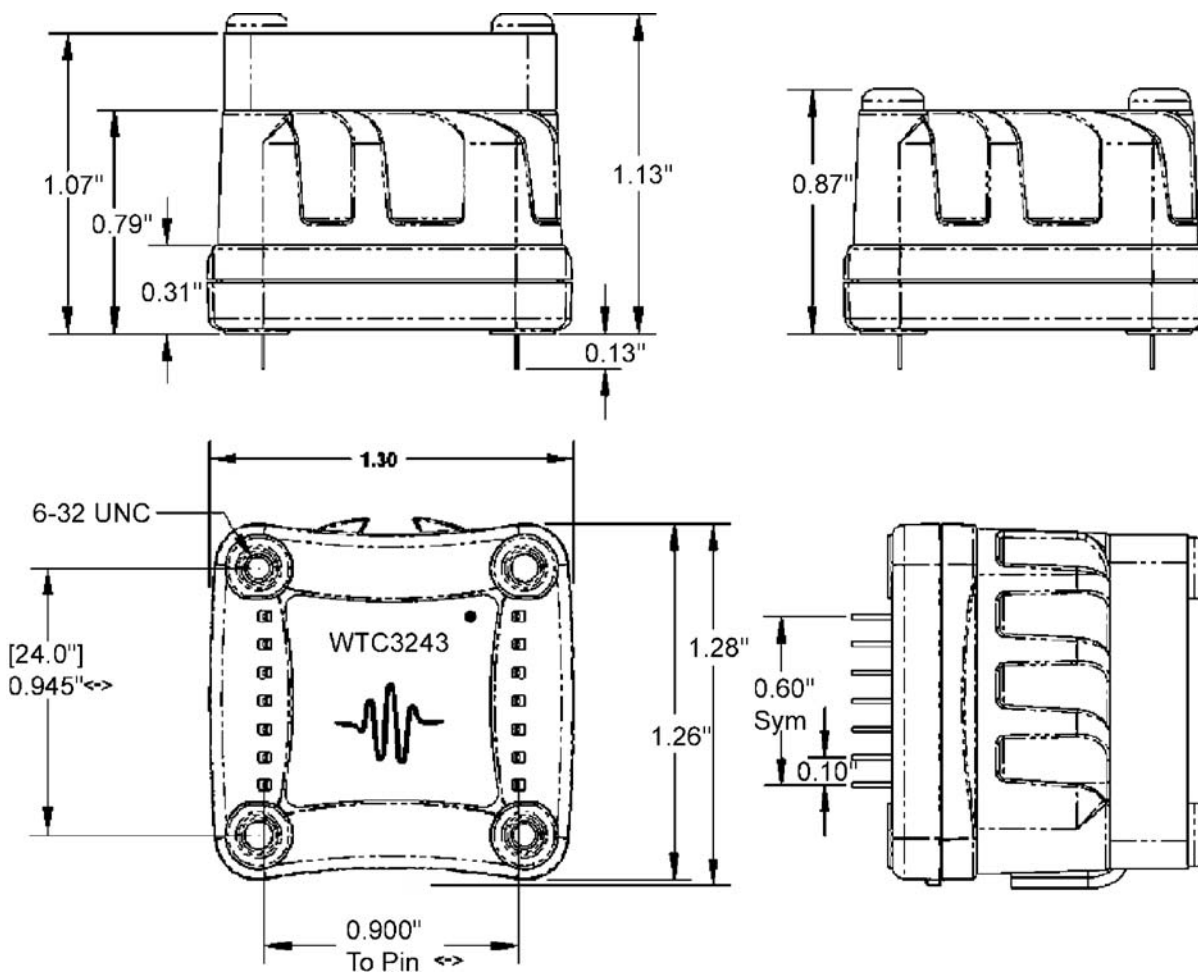
Ambient temperature disturbances can pass through the heatsink and thermoelectric and affect the device temperature stability. Choosing a heatsink with a larger mass will improve temperature stability.

Table 5

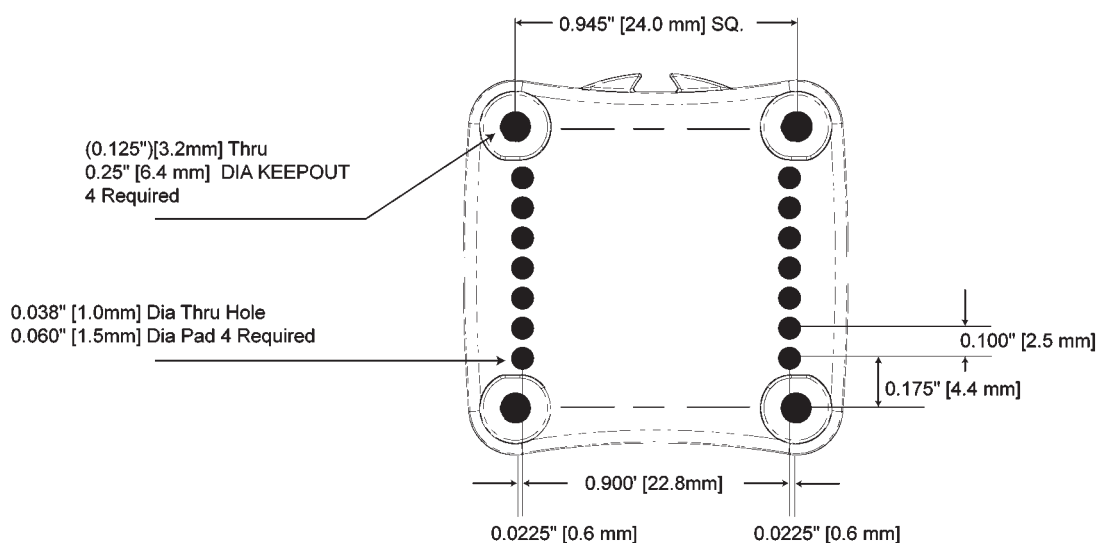
Temperature Sensor Comparison

SENSOR	Thermistor	RTD	AD590	LM335
RATING	Best	Poor	Good	Good

MECHANICAL SPECIFICATIONS



PCB FOOTPRINT



CERTIFICATION AND WARRANTY

CERTIFICATION:

Wavelength Electronics (WEI) certifies that this product met its published specifications at the time of shipment. Wavelength further certifies that its calibration measurements are traceable to the United States National Institute of Standard and Technology, to the extent allowed by that organization's calibration facilities, and to the calibration facilities of other International Standards Organization members.

WARRANTY:

This Wavelength product is warranted against defects in materials and workmanship for a period of one year from date of shipment. During the warranty period, Wavelength, will, at its option, either repair or replace products which prove to be defective.

WARRANTY SERVICE:

For warranty service or repair, this product must be returned to the factory. For products returned to Wavelength for warranty service, the Buyer shall prepay shipping charges to Wavelength and Wavelength shall pay shipping charges to return the product to the Buyer. However, the Buyer shall pay all shipping charges, duties, and taxes for products returned to Wavelength from another country.

LIMITATIONS OF WARRANTY:

The warranty shall not apply to defects resulting from improper use or misuse of the instrument outside published specifications.

No other warranty is expressed or implied. Wavelength specifically disclaims the implied warranties of merchantability and fitness for a particular purpose.

EXCLUSIVE REMEDIES:

The remedies provided herein are the Buyer's sole and exclusive remedies. Wavelength shall not be liable for any direct, indirect, special, incidental, or consequential damages, whether based on contract, tort, or any other legal theory.

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SAFETY:

There are no user serviceability parts inside this product. Return the product to Wavelength Electronics for service and repair to assure that safety features are maintained.

LIFE SUPPORT POLICY:

As a general policy, Wavelength Electronics, Inc. does not recommend the use of any of its products in life support applications where the failure or malfunction of the Wavelength Electronics, Inc. product can be reasonably expected to cause failure of the life support device or to significantly affect its safety or effectiveness. Wavelength Electronics, Inc. will not knowingly sell its products for use in such applications unless it receives written assurances satisfactory to Wavelength Electronics, Inc. that the risks of injury or damage have been minimized, the customer assumes all such risks, and there is no product liability for Wavelength Electronics, Inc. Examples or devices considered to be life support devices are neonatal oxygen analyzers, nerve stimulators (for any use), auto transfusion devices, blood pumps, defibrillators, arrhythmia detectors and alarms, pacemakers, hemodialysis systems, peritoneal dialysis systems, ventilators of all types, and infusion pumps as well as other devices designated as "critical" by the FDA. The above are representative examples only and are not intended to be conclusive or exclusive of any other life support device.

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