

.M56 Dual Output Low Power Thermostat

5°C

## **Dual Output Low Power Thermostat**

## **General Description**

The LM56 is a precision low power thermostat. Two stable temperature trip points (V<sub>T1</sub> and V<sub>T2</sub>) are generated by dividing down the LM56 1.250V bandgap voltage reference using 3 external resistors. The LM56 has two digital outputs. OUT1 goes LOW when the temperature exceeds T1 and goes HIGH when the temperature goes below (T1–T<sub>HYST</sub>). Similarly, OUT2 goes LOW when the temperature exceeds T2 and goes HIGH when the temperature goes below (T2–T<sub>HYST</sub>). T<sub>HYST</sub> is an internally set 5°C typical hysteresis.

The LM56 is available in an 8-lead Mini-SO8 surface mount package and an 8-lead small outline package.

## **Applications**

- Microprocessor Thermal Management
- Appliances
- Portable Battery Powered 3.0V or 5V Systems
- Fan Control
- Industrial Process Control
- HVAC Systems
- Remote Temperature Sensing
- Electronic System Protection

## **Features**

- Digital outputs support TTL logic levels
- Internal temperature sensor
- 2 internal comparators with hysteresis
- Internal voltage reference
- Available in 8-pin SO and Mini-SO8 plastic packages

## **Key Specifications**

Power Supply Voltage	2.7V–10V
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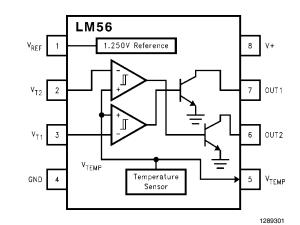
- Power Supply Current 230 µA (max)
- V<sub>BEF</sub> 1.250V ±1% (max)
- Hysteresis Temperature
- Internal Temperature Sensor Output Voltage:

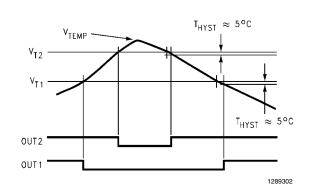
(+6.20 mV/°C x T) + 395 mV

Temperature Trip Point Accuracy:

	LM56BIM	LM56CIM
+25°C	±2°C (max)	±3°C (max)
+25°C to +85°C	±2°C (max)	±3°C (max)
–40°C to +125°C	±3°C (max)	±4°C (max)

## Simplified Block Diagram and Connection Diagram





Order Number	LM56BIM	LM56BIMX	LM56CIM	LM56CIMX	LM56BIMM	LM56BIMMX	LM56CIMM	LM56CIMMX
NS Package	M08A	M08A	M08A	M08A	MUA08A	MUA08A	MUA08A	MUA08A
Number	SOP-8	SOP-8	SOP-8	SOP-8	MSOP-8	MSOP-8	MSOP-8	MSOP-8
Transport		2500 Units		2500 Units	1000 Units	3500 Units	1000 Units	3500 Units
Media	Rail	Tape & Reel	Rail	Tape & Reel				
Package Marking	LM56BIM	LM56BIM	LM56CIM	LM56CIM	T02B	T02B	T02C	T02C

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## **Typical Application**

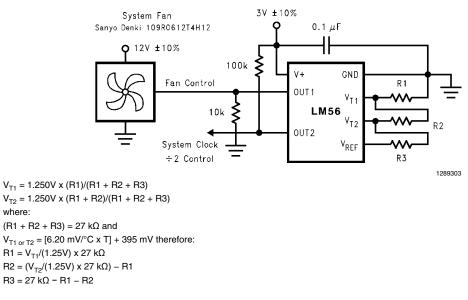


FIGURE 1. Microprocessor Thermal Management

## Absolute Maximum Ratings (Note 1)

Input Voltage	12V
Input Current at any pin (Note 2)	5 mA
Package Input Current(Note 2)	20 mA
Package Dissipation at T <sub>A</sub> = 25°C	
(Note 4)	900 mW
ESD Susceptibility (Note 5)	
Human Body Model - Pin 3 Only:	800V
All other pins	1000V

Machine Model Storage Temperature 125V -65°C to + 150°C

## Operating Ratings (Note 1)

Operating Temperature Range	$T_{MIN} \le T_A \le T_{MAX}$
LM56BIM, LM56CIM	–40°C ≤ T <sub>A</sub> ≤ +125°C
Positive Supply Voltage (V+)	+2.7V to +10V
Maximum $V_{\text{OUT1}}$ and $V_{\text{OUT2}}$	+10V

Soldering process must comply with National Semiconductor's Reflow Temperature Profile specifications. Refer to www.national.com/packaging.(Note 3)

## LM56 Electrical Characteristics

The following specifications apply for V<sup>+</sup> = 2.7 V<sub>DC</sub>, and V<sub>REF</sub> load current = 50  $\mu$ A unless otherwise specified. **Boldface limits apply for T<sub>A</sub> = T<sub>J</sub> = T<sub>MIN</sub> to T<sub>MAX</sub>;** all other limits T<sub>A</sub> = T<sub>J</sub> = 25°C unless otherwise specified.

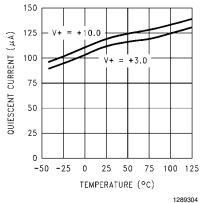
Symbol	Parameter	Conditions	Typical (Note 6)	LM56BIM Limits (Note 7)	LM56CIM Limits (Note 7)	Units (Limits)
Femperatu	re Sensor					
	Trip Point Accuracy (Includes			±2	±3	°C (max)
	V <sub>REF</sub> , Comparator Offset, and	+25°C ≤ T <sub>A</sub> ≤ +85°C		±2	±3	°C (max)
	Temperature Sensitivity errors)	–40°C ≤ T <sub>A</sub> ≤ +125°C		±3	±4	°C (max)
	Trip Point Hysteresis	$T_A = -40^{\circ}C$	4	3	3	°C (min)
				6	6	°C (max)
		T <sub>A</sub> = +25°C	5	3.5	3.5	°C (min)
				6.5	6.5	°C (max)
		T <sub>A</sub> = +85°C	6	4.5	4.5	°C (min)
				7.5	7.5	°C (max)
		T <sub>A</sub> = +125°C	6	4	4	°C (min)
				8	8	°C (max)
	Internal Temperature Sensitivity		+6.20			mV/°C
	Temperature Sensitivity Error			±2	±3	°C (max)
				±3	±4	°C (max)
	Output Impedance	−1 μA ≤ I <sub>L</sub> ≤ +40 μA		1500	1500	Ω (max)
	Line Regulation	$+3.0V \le V^+ \le +10V$ ,		-0.72/	-0.72/	mV/V (max
		+25 °C ≤ T <sub>A</sub> ≤ +85 °C		+0.36	+0.36	
		$+3.0V \le V^+ \le +10V$ ,		-1.14/	-1.14/	mV/V (max
		–40 °C ≤ T <sub>A</sub> <25 °C		+0.61	+0.61	
		+2.7V ≤ V+ ≤ +3.3V		±2.3	±2.3	mV (max)
$I_{T1}$ and $V_{T2}$	Analog Inputs					
BIAS	Analog Input Bias Current		150	300	300	nA (max)
/ <sub>IN</sub>	Analog Input Voltage Range		V+ – 1			V
			GND			V
/ <sub>os</sub>	Comparator Offset		2	8	8	mV (max)
/ <sub>REF</sub> Outpu	t					
/ <sub>REF</sub>	V <sub>REF</sub> Nominal		1.250V			V
	V <sub>REF</sub> Error			±1	±1	% (max)
				±12.5	±12.5	mV (max)
$\Delta V_{REF} / \Delta V^+$	Line Regulation	+3.0V ≤ V+ ≤ +10V	0.13	0.25	0.25	mV/V (max

$V_{REF}/\Delta I_L$ Load Regulation Sourcing $+2.7V \le V+ \le +3.3V$ 0.15       1.1       1.1       mV (max) $V_{REF}/\Delta I_L$ Load Regulation Sourcing $+30 \ \mu A \le I_L \le +50 \ \mu A$ 0.15       0.15       0.15       mV/ $\mu A$ (max)         Symbol       Parameter       Conditions       Typical (Note 6)       Limits (Note 7)       Units (Limits)         '+ Power Supply       Supply Current       V+ = +10V V+ = +2.7V       230 $\mu A$ (max)         Digital Outputs       Dut("1")       Logical "1" Output Leakage Current       V+ = +5.0V       1 $\mu A$ (max)         Model 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics. The guaranteed specifications apply only for the test conditions listed. Some performance characteristics may degrade when the device is not operated under the listed test conditions.         Note 2: When the input voltage (V <sub>1</sub> ) at any pin exceeds the power supply exceed the power supplies with an input current of 5 mA to four.         Note 3: Reflow temperature profiles are different for lead-free and non-lead-free packages.         Note 3: Reflow temperature profiles are different for lead-free and non-lead-free packages.         Note 3: Reflow temperature profiles are different for lead-free and non-lead-free packages.	$+2.7V \le V \le 4.3.3V$ $0.15$ $1.1$ $1.1$ $nV$ (max) $MV_{REF}/\Delta I_L$ Load Regulation Sourcing $+30 \ \mu A \le I_L \le +50 \ \mu A$ $0.15$ $0.15$ $nV/\mu A$ (max)         Symbol       Parameter       Conditions       Typical (Note 6)       Limits (Note 7)       Units (Limits)         /* Power Supply       Supply Current       V* = +10V V* = +2.7V       230 $\mu A$ (max)         Olifical Outputs       V* = +10V Current       V* = +5.0V       1 $\mu A$ (max)         OUT(*1)       Logical "1" Output Leakage Current       V* = +5.0V       1 $\mu A$ (max) $A_{OUT(*0)}$ Logical "0" Output Voltage $I_{OUT} = +50 \ \mu A$ 0.4       V (max)         Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is specifications apply only for the test conditions listed. Some performance characteristics may degrade when the device is not operated under the listed test conditions.       Note 2: When the input voltage (V) at any pin exceeds the power supplies with an input current of 5 mA to four.         Note 3: Reflow temperature profiles are different for lead-free and non-lead-free packages.       Note 3: Reflow temperature profiles are different for lead-free and non-lead-free packages.         Note 4: The maximum power dissipation must be derated at elevated temperatures and is dictated by T <sub>Jmax</sub> (m	Symbol Parameter		Conditions		Typical (Note 6)	LM56BIM Limits (Note 7)	LM56CIM Limits (Note 7)	Units (Limits)
Symbol       Parameter       Conditions       Typical (Note 6)       Limits (Note 7)       Units (Limits)         ** Power Supply       Supply Current       V* = +10V V* = +2.7V       230 $\mu$ A (max) $\mu$ A (max)         bigital Outputs       Dur(1')       Logical "1" Output Leakage       V* = +2.7V       230 $\mu$ A (max)         Outr(1')       Logical "1" Output Leakage       V* = +5.0V       1 $\mu$ A (max)         Current       Ur(1')       Logical "0" Output Voltage $I_{OUT}$ = +50 $\mu$ A       0.4       V (max)         Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics. The guaranteed specifications apply only for the test conditions listed. Some performance characteristics may degrade when the device is not operated under the listed test conditions, see the electrical Characteristics. The 20 mA maximum package input current rating limits the number of pins that can safely exceed the power supplies with an input current of 5 mA to four.         Note 3: The Ration temperature profiles are different for lead-free and noil-ad-free packages.         Note 3: The Ration temperature profiles are different for lead-free and noil-ad-free package.         Note 3: The flow temperature profiles are different for leader free ackages.         Note 3: The naximum and resistance ( $\theta_{JA}$ ) of the	Symbol       Parameter       Conditions       Typical (Note 6)       Limits (Note 7)       Units (Limits)         /* Power Supply       s       Supply Current       V* = +10V V* = +2.7V       230 $\mu$ A (max) $\mu$ A (max)         Digital Outputs       0017(1')       Logical "1" Output Leakage Current       V* = +5.0V       1 $\mu$ A (max)         /outr(0)       Logical "0" Output Voltage $V_{=}$ = +50 $\mu$ A       0.4       V (max)         Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics. The guaranteed specifications apply only for the test conditions listed. Some performance characteristics may degrade when the device is in to perated under the listed test conditions.         Note 2: When the input voltage (V) at any pin exceeds the power supplix (V, < GND or V <sub>1</sub> > V <sup>1</sup> ), the current at that pin should be limited to 5 mA. The 20 mA maximum package input current rating limits the number ed-free and non-lead-free paced the power supplies with an input current of 5 mA to four.       Note 3: The maximum power dissipation must be derated at elevated temperatures and is dictated by T <sub>imax</sub> (maximum junction temperature), $\theta_{A}$ (function to ambient themat resistance) edf <sub>A</sub> or the number given in the Absolute Maximum Ratings, whichever is lower. For this device, T <sub>imax</sub> = 125°C. For this device the typical thermal resistance ( $\theta_{A}$ ) of the different package types when board mounted follow:			+2.7V ≤ V+ ≤ +	-3.3V	0.15	1.1	. ,	mV (max)
Symbol       Parameter       Conditions       Typical (Note 6)       Limits (Note 7)       Units (Limits)         ** Power Supply       5       Supply Current       V* = +10V V* = +2.7V       230 $\mu A$ (max) $\mu A$ (max)         bigital Outputs       0       230 $\mu A$ (max)         DUT("1")       Logical "1" Output Leakage Current       V* = +5.0V       1 $\mu A$ (max)         'outr("0")       Logical "0" Output Voltage       I       I $\mu A$ (max)         'outr("0")       Logical "0" Output Voltage       I       I $\mu A$ (max)         'outr("0")       Logical "0" Output Voltage       I       I $\mu A$ (max)         Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions listed test conditions.       The test conditions listed cest is functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics. The guaranteed specifications apply only for the test conditions listed. Some performance characteristics may degrade when the device is not operated under the listed test conditional, but do not guarantee specific performance fries and selve exceed the power supplies with an input current at the limits the number of pins that can sately exceed the power supplies with an input current of 5 mA to four.         Note 3: Reflow temperature profiles are different for lead-free and non-lead-free packages.       Dut _max (maximum	Symbol       Parameter       Conditions       Typical (Note 6)       Limits (Note 7)       Units (Limits)         /* Power Supply       S       Supply Current       V* = +10V V* = +2.7V       230 $\mu$ A (max) $\mu$ A (max)         Digital Outputs       Out("1")       Logical "1" Output Leakage Current       V* = +5.0V       1 $\mu$ A (max)         /OUT("0")       Logical "0" Output Voltage       I_OUT = +50 $\mu$ A       0.4       V (max)         Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics. The guaranteed specifications apply only for the test conditions listed. Some performance characteristics may degrade when the device is not operated under the listed test conditions.         Note 2: When the input voltage (V) at any pin exceeds the power supplive with an input current of 5 mA. The 20 mA maximum package input current rating limits the number of pins that can safely exceed thes power supplies with an input current of 5 mA to four.         Note 3: Reflow temperature profiles are different for lead-free and non-lead-free packages.       Mo8A       110"C/W MuA08A       100"C/W MuA08A       100"C/W MUA08A       100"C/W MUA08A       10"C/W MUA08A       10"C/W MUA08A       250"C/W       10"A       10"A       10"A       10"A         Note 5: The human body model is a 100 pF cap	ΔV <sub>BEE</sub> /ΔI	Load Regulation Sourcing	+30 µA ≤ I <sub>1</sub> ≤ -	+50 μA		0.15	0.15	mV/µA (max
Image: constraint of the second s	Image: constraint of the second s							1	1
Supply Current       V+ = +10V       230 $\mu$ A (max)         Digital Outputs       230 $\mu$ A (max)         DUT("1")       Logical "1" Output Leakage       V+ = +5.0V       1 $\mu$ A (max)         Vour("1")       Logical "0" Output Voltage $I_{=} + 5.0V$ 1 $\mu$ A (max)         Vour("0")       Logical "0" Output Voltage $I_{=} + 5.0 \mu$ A       0.4       V (max)         Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics. The guaranteed specifications apply only for the test conditions listed. Some performance characteristics may degrade when the device is not operated under the listed test conditions.         Note 2: When the input voltage (V <sub>1</sub> ) at any pin exceeds the power supply (V <sub>1</sub> < GND or V <sub>1</sub> > V <sup>+</sup> ), the current at that pin should be limited to 5 mA. The 20 mA maximum package input current rating limits the number of pins that can sately exceed the power supplies with an input current of 5 mA to four.         Note 3: Reflow temperature profiles are different for lead-free and non-lead-free packages.       Note 4: fine maximum power dissipation must be derated at elevated temperatures and is dictated by $T_{imax}$ (maximum junction temperature). $\theta_{jA}$ (junction to ambient thermal resistance) and $T_{i}$ (ambient temperature). For this device, $T_{imax} = 125^\circ$ C. For this device the typical thermal resistance ( $\theta_{jA}$ ) of the different package types w	S       Supply Current       V+ = +10V       230 $\mu$ A (max)         Digital Outputs       230 $\mu$ A (max)         OUT("1")       Logical "1" Output Leakage       V+ = +5.0V       1 $\mu$ A (max) $M_{OUT("1")}$ Logical "0" Output Voltage $I_{OUT}$ = +50 $\mu$ A       0.4       V (max)         Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics. The guaranteed specifications apply only for the test conditions listed. Some performance characteristics may degrade when the device is not operated under the listed test conditions.         Note 2: When the input voltage (V <sub>1</sub> ) at any pin exceeds the power supply (V <sub>1</sub> < GND or V <sub>1</sub> > V <sup>+</sup> ), the current at that pin should be limited to 5 mA. The 20 mA maximum package input current rating limits the number of pins that can sately exceed the power supplies with an input current of 5 mA to four.         Note 3: Reflow temperature profiles are different for lead-free and non-lead-free packages.         Note 4: The maximum power dissipation must be derated at elevated temperatures and is dictated by $T_{max}$ (maximum junction temperature). $\theta_{j,k}$ (junction to ambient thermal resistance) and T <sub>k</sub> (ambient temperature). The maximum allowable power dissipation at any temperature is $\theta_{j,k}$ of the number given in the Absolute Maximum Ratings, whichever is lower. For this device, T <sub>j,max</sub> = 125°C. For this device the typical thermal resistance ( $\theta_{j,k}$ ) of the	Symbo	ol Parameter	Conc	litions				
S       μm (max)         V <sup>+</sup> = +2.7V       230       μA (max)         Digital Outputs       Logical "1" Output Leakage       V <sup>+</sup> = +5.0V       1       μA (max)         OUT("1)       Logical "0" Output Voltage       I <sub>OUT</sub> = +50 μA       0.4       V (max)         Mote 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics. The guaranteed specifications apply only for the test conditions for which the device is conditions.         Note 1: Absolute Maximum Ratings indicate limits. For guaranteed specifications and test conditions, see the Electrical Characteristics. The guaranteed specifications apply only for the test conditions listed. 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For this device the typical thermal resistance (θ <sub>jA</sub> ) of the different package types when board mounted follow: <td>S       μr ( ritid)         V<sup>+</sup> = +2.7V       230       μA (max)         Digital Outputs       Current       1       μA (max)         OUT("1")       Logical "1" Output Leakage       V<sup>+</sup> = +5.0V       1       μA (max)         OUT("1")       Logical "0" Output Voltage       I<sub>OUT</sub> = +50 μA       0.4       V (max)         Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics. The guaranteed specifications apply only for the test conditions for subtent be device in some performance characteristics may degrade when the device is not operated under the listed test conditions.         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For this device the typical thermal resistance (θ<sub>iA</sub>) of the differ</td> <td>/+ Power S</td> <td>upply</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>	S       μr ( ritid)         V <sup>+</sup> = +2.7V       230       μA (max)         Digital Outputs       Current       1       μA (max)         OUT("1")       Logical "1" Output Leakage       V <sup>+</sup> = +5.0V       1       μA (max)         OUT("1")       Logical "0" Output Voltage       I <sub>OUT</sub> = +50 μA       0.4       V (max)         Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics. 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The maximum allowable power dissipation at any temperature is P <sub>D</sub> = (T <sub>imax</sub> -T <sub>A</sub> )/θ <sub>iA</sub> or the number given in the Absolute Maximum Ratings, whichever is lower. For this device, T <sub>imax</sub> = 125°C. For this device the typical thermal resistance (θ <sub>iA</sub> ) of the differ	/+ Power S	upply						
Duplicital Outputs       Logical "1" Output Leakage       V+ = +5.0V       1       μA (max) $O_{OUT("1")}$ Logical "0" Output Voltage $I_{OUT}$ = +50 μA       0.4       V (max) $M_{OUT("0")}$ Logical "0" Output Voltage $I_{OUT}$ = +50 μA       0.4       V (max)         Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics. The guaranteed specifications apply only for the test conditions listed. Some performance characteristics may degrade when the device is not operated under the listed test conditions.         Note 2: When the input voltage (V <sub>1</sub> ) at any pin exceeds the power supply (V <sub>1</sub> < GND or V <sub>1</sub> > V <sup>1</sup> ), the current at that pin should be limited to 5 mA. The 20 mA maximum package input current rating limits the number of pins that can safely exceed the power supplies with an input current of 5 mA to four.         Note 3: Reflow temperature profiles are different for lead-free and non-lead-free packages.         Note 4: The maximum power dissipation must be derated at elevated temperatures and is dictated by T <sub>imax</sub> (maximum junction temperature). $\theta_{j,k}$ (junction to ambient thermal resistance) and T <sub>A</sub> (ambient temperature). The maximum allowable power dissipation at any temperature is P <sub>D</sub> = (T <sub>imax</sub> - T <sub>A</sub> )/ $\theta_{j,A}$ or the number given in the Absolute Maximum Ratings, whichever is lower. For this device, T <sub>imax</sub> = 125°C. For this device the typical thermal resistance ( $\theta_{j,A}$ ) of the different package types when board m	Digital Outputs       Image: Digital Outputs         OUT("1")       Logical "1" Output Leakage       V+ = +5.0V       1       µA (max)         OUT("1")       Logical "0" Output Voltage $I_{OUT}$ = +50 µA       0.4       V (max)         Mote 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics. The guaranteed specifications apply only for the test conditions listed. Some performance characteristics may degrade when the device is not operated under the listed test conditions.         Note 2: When the input voltage (V) at any pin exceeds the power supply (V <sub>1</sub> < GND or V <sub>1</sub> > V <sup>+</sup> ), the current at that pin should be limited to 5 mA. The 20 mA maximum package input current rating limits the number of pins that can safely exceed the power supplies with an input current of 5 mA to four.         Note 3: Reflow temperature profiles are different for lead-free and non-lead-free packages.         Note 4: The maximum power dissipation must be derated at elevated temperatures and is dictated by T <sub>imax</sub> (maximum junction temperature), θ <sub>inf</sub> (junction to ambient thermal resistance) and T <sub>A</sub> (ambient temperature). The maximum allowable power dissipation at any temperature is P <sub>D</sub> = (T <sub>imax</sub> T <sub>A</sub> )/θ <sub>inf</sub> or the number given in the Absolute Maximum Ratings, whichever is lower. For this device, T <sub>jmax</sub> = 125°C. For this device the typical thermal resistance (θ <sub>jA</sub> ) of the different package types when board mounted follow:         Wote 5: The human body model is a 100 pF capacitor discharge	S	Supply Current	V+ = +10V				230	µA (max)
Dut("1")       Logical "1" Output Leakage Current       V+ = +5.0V       1 $\mu A$ (max) $I_{OUT("0")}$ Logical "0" Output Voltage $I_{OUT}$ = +50 $\mu A$ 0.4       V (max)         Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics. The guaranteed specifications apply only for the test conditions listed. Some performance characteristics may degrade when the device is not operated under the listed test conditions.         Note 2: When the input voltage (V) at any pin exceeds the power supply (V <sub>1</sub> < GND or V <sub>1</sub> > V <sup>+</sup> ), the current at that pin should be limited to 5 mA. The 20 mA maximum package input current rating limits the number of pins that can safely exceed the power supplies with an input current of 5 mA to four.         Note 3: Reflow temperature profiles are different for lead-free and non-lead-free packages.         Note 4: The maximum power dissipation must be derated at elevated temperatures and is dictated by $T_{Jmax}$ (maximum junction temperature), $\theta_{JA}$ (gunction to ambient thermal resistance) and $T_A$ (ambient temperature). The maximum allowable power dissipation at any temperature is $P_D = (T_{Jmax} - T_A)/\theta_{JA}$ or the number given in the Absolute Maximum Ratings, whichever is lower. For this device, $T_{Jmax} = 125^{\circ}$ C. For this device the typical thermal resistance ( $\theta_{JA}$ ) of the different package types when board mounted follow:         Note 5: The human body model is a 100 pF capacitor discharge through a 1.5 k\Omega resistor into each pin.	Dur("1")       Logical "1" Output Leakage Current       V+ = +5.0V       1       μA (max) $I_{OUT("0")}$ Logical "0" Output Voltage $I_{OUT}$ = +50 μA       0.4       V (max)         Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics. The guaranteed specifications apply only for the test conditions listed. Some performance characteristics may degrade when the device is not operated under the listed test conditions.         Note 2: When the input voltage (V <sub>i</sub> ) at any pin exceeds the power supply (V <sub>i</sub> < GND or V <sub>i</sub> > V <sup>i</sup> ), the current at that pin should be limited to 5 mA. The 20 mA maximum package input current rating limits the number of pins that can safely exceed the power supplies with an input current of 5 mA to four.         Note 3: Reflow temperature profiles are different for lead-free and non-lead-free packages.         Note 4: The maximum power dissipation must be derated at elevated temperatures and is dictated by $T_{Jmax}$ (maximum junction temperature), $\theta_{JA}$ (junction to ambient thermal resistance) and $T_A$ (ambient temperature). The maximum allowable power dissipation at any temperature is $P_D = (T_{Jmax} - T_A)/\theta_{JA}$ of the different package types when board mounted follow:         Note 5: The human body model is a 100 pF capacitor discharge through a 1.5 kΩ resistor into each pin.       The machine model is a 200 pF capacitor discharged directly into each pin.         Note 6: Typicals are at $T_J = T_A = 25^{\circ}$ C and represent			V+ = +2.7V	/			230	µA (max)
Current       Logical "0" Output Voltage       I	Current       Logical "0" Output Voltage       I	Digital Outp	puts						
$V_{OUT("0")}$ Logical "0" Output VoltageIIOutputOutputV (max)Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is specifications apply only for the test conditions listed. Some performance characteristics may degrade when the device is not operated under the listed test conditions.Note 2: When the input voltage (V <sub>1</sub> ) at any pin exceeds the power supply (V <sub>1</sub> < GND or V <sub>1</sub> > V <sup>+</sup> ), the current at that pin should be limited to 5 mA. The 20 mA maximum package input current rating limits the number of pins that can safely exceed the power supplies with an input current of 5 mA to four.Note 3: Reflow temperature profiles are different for lead-free and non-lead-free packages.Note 4: The maximum power dissipation must be derated at elevated temperatures and is dictated by T amax (maximum junction temperature), θ J <sub>A</sub> (junction to ambient thermal resistance) and T A (abient temperature). The maximum allowable power dissipation at any temperature is P D = (T J max -T A)/θ J <sub>A</sub> or the number given in the Absolute Maximum Ratings, whichever is lower. For this device, T Jmax = 125°C. For this device the typical thermal resistance (θ JA) of the different package types when board mounted follow:Note 5: The human body model is a 100 pF capacitor discharge through a 1.5 kΩ resistor into each pin.The machine model is a 200 pF capacitor discharge discharged through a 1.5 kΩ resistor into each pin.Note 6: Typicals are at T J = T A = 25°C and represent most likely parametric norm.1.5 kΩ resistor into each pin.	$I_{OUT(*0^{\circ})}$ Logical "0" Output Voltage $I_{OUT} = +50 \ \mu A$ 0.4V (max)Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics. The guaranteed specifications apply only for the test conditions listed. Some performance characteristics may degrade when the device is not operated under the listed test conditions.Note 2: When the input voltage (V <sub>i</sub> ) at any pin exceeds the power supply (V <sub>i</sub> < GND or V <sub>i</sub> > V <sup>+</sup> ), the current at that pin should be limited to 5 mA. The 20 mA maximum package input current rating limits the number of pins that can safely exceed the power supplies with an input current of 5 mA to four.Note 3: Reflow temperature profiles are different for lead-free and non-lead-free packages.Note 4: The maximum power dissipation must be derated at elevated temperatures and is dictated by T <sub>Jmax</sub> (maximum junction temperature), θ <sub>JA</sub> (junction to ambient thermal resistance) and T <sub>A</sub> (ambient temperature). The maximum allowable power dissipation at any temperature is P <sub>D</sub> = (T <sub>Jmax</sub> -T <sub>A</sub> )/θ <sub>JA</sub> or the number given in the Absolute Maximum Ratings, whichever is lower. For this device, T <sub>Jmax</sub> = 125°C. For this device the typical thermal resistance ( $\theta_{JA}$ ) of the different package types $\theta_{JA}$ Note 5: The human body model is a 100 pF capacitor discharge through a 1.5 kΩ resistor into each pin.Note 6: The human body model is a 100 pF capacitor discharge through a 1.5 kΩ resistor into each pin.Note 6: The human body model is a 100 pF capacitor discharge through a 1.5 kΩ res	OUT("1")	Logical "1" Output Leakage	e V+ = +5.0V	/			1	µA (max)
Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics. The guaranteed specifications. Such as the Electrical Characteristics are performance characteristics may degrade when the device is not operated under the listed test conditions. Note 2: When the input voltage (V <sub>1</sub> ) at any pin exceeds the power supply (V <sub>1</sub> < GND or V <sub>1</sub> > V <sup>+</sup> ), the current at that pin should be limited to 5 mA. The 20 mA maximum package input current rating limits the number of pins that can safely exceed the power supplies with an input current of 5 mA to four. Note 3: Reflow temperature profiles are different for lead-free and non-lead-free packages. Note 4: The maximum power dissipation must be derated at elevated temperatures and is dictated by $T_{Jmax}$ (maximum junction temperature), $\theta_{JA}$ (junction to ambient thermal resistance) and $T_a$ (ambient there). The maximum allowable power dissipation at any temperature is $P_D = (T_{Jmax} - T_A)/\theta_J \alpha$ or the number given in the Absolute Maximum Ratings, whichever is lower. For this device, $T_{Jmax} = 125^{\circ}$ C. For this device the typical thermal resistance $(\theta_{JA})$ of the different package types $\theta_{JA}$ MO8A 110°C/W MUA08A 250°C/W Note 5: The human body model is a 100 pF capacitor discharge through a 1.5 kΩ resistor into each pin. The machine model is a 200 pF capacitor discharged directly into each pin. Note 6: Typicals are at $T_J = T_A = 25^{\circ}$ C and represent most likely parametric norm.	Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics. The guaranteed specifications apply only for the test conditions listed. Some performance characteristics may degrade when the device is not operated under the listed test conditions. Note 2: When the input voltage (V <sub>1</sub> ) at any pin exceeds the power supply (V <sub>1</sub> < GND or V <sub>1</sub> > V <sup>+</sup> ), the current at that pin should be limited to 5 mA. The 20 mA maximum package input current rating limits the number of pins that can safely exceed the power supplies with an input current of 5 mA to four. Note 3: Reflow temperature profiles are different for lead-free and non-lead-free packages. Note 4: The maximum power dissipation must be derated at elevated temperatures and is dictated by $T_{jmax}$ (maximum junction temperature), $\theta_{jA}$ (junction to ambient thermal resistance) and $T_{a}$ (ambient temperature). For maximum allowable power dissipation at any temperature is $P_{D} = (T_{jmax}-T_{A})/\theta_{JA}$ or the number given in the Absolute Maximum Ratings, whichever is lower. For this device, $T_{jmax} = 125^{\circ}$ C. For this device the typical thermal resistance ( $\theta_{jA}$ ) of the different package types $\theta_{JA}$ MO8A 110°C/W MUA08A 250°C/W Note 5: The human body model is a 100 pF capacitor discharge through a 1.5 k\Omega resistor into each pin. The machine model is a 200 pF capacitor discharged directly into each pin. Note 6: Typicals are at $T_J = T_A = 25^{\circ}$ C and represent most likely parametric norm.		Current						
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$\begin{tabular}{ c c c c c c c c c c c c c c c c c c c$	$\begin{tabular}{ c c c c c c c c c c c c c c c c c c c$	given in the	Absolute Maximum Ratings, whichever is	s lower. For this device, T	105°C Earth				
MUA08A $250^{\circ}$ C/WNote 5: The human body model is a 100 pF capacitor discharge through a 1.5 kΩ resistor into each pin. The machine model is a 200 pF capacitor discharged directly into each pin.Note 6: Typicals are at $T_J = T_A = 25^{\circ}$ C and represent most likely parametric norm.	MUA08A $250^{\circ}$ C/WNote 5: The human body model is a 100 pF capacitor discharge through a 1.5 kΩ resistor into each pin. The machine model is a 200 pF capacitor discharged directly into each pin.Note 6: Typicals are at $T_J = T_A = 25^{\circ}$ C and represent most likely parametric norm.	package typ			-1	his device the	typical thermal	resistance (θ <sub>JA</sub> )	of the different
<b>Note 5:</b> The human body model is a 100 pF capacitor discharge through a 1.5 k $\Omega$ resistor into each pin. The machine model is a 200 pF capacitor discharged directly into each pin. <b>Note 6:</b> Typicals are at T <sub>J</sub> = T <sub>A</sub> = 25°C and represent most likely parametric norm.	<b>Note 5:</b> The human body model is a 100 pF capacitor discharge through a 1.5 k $\Omega$ resistor into each pin. The machine model is a 200 pF capacitor discharged directly into each pin. <b>Note 6:</b> Typicals are at T <sub>J</sub> = T <sub>A</sub> = 25°C and represent most likely parametric norm.	package typ		Package Type	θ <sub>JA</sub>		typical thermal	resistance ( $\hat{\Theta}_{JA}$ )	of the different
			es when board mounted follow:	Package Type M08A MUA08A	θ <sub>JA</sub> 110°C/V 250°C/V	N N		resistance (θ <sub>JA</sub> )	
		Note 5: The directly into Note 6: Typ	es when board mounted follow: e human body model is a 100 pF capacito each pin. bicals are at T <sub>J</sub> = T <sub>A</sub> = 25°C and represent	Package Type         M08A         MUA08A         r discharge through a 1.5 kΩ         t most likely parametric norm	θ <sub>JA</sub> 110°C/V 250°C/V resistor into eac	N N		resistance (θ <sub>JA</sub> )	
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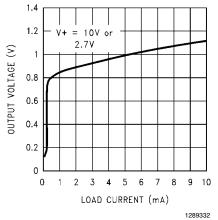
4

## **Typical Performance Characteristics**

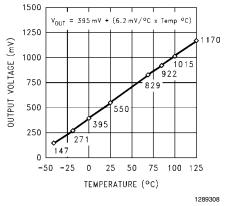
**Quiescent Current vs Temperature** 

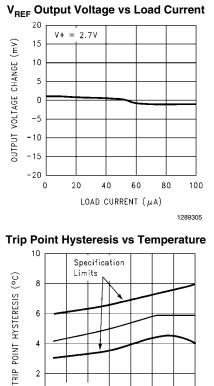


#### OUT1 and OUT2 Voltage Levels vs Load Current



#### **Temperature Sensor Output Voltage vs Temperature**





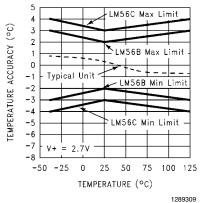
= 2.7 V-50 -25 0 25 50 75 100 125 TEMPERATURE (°C)

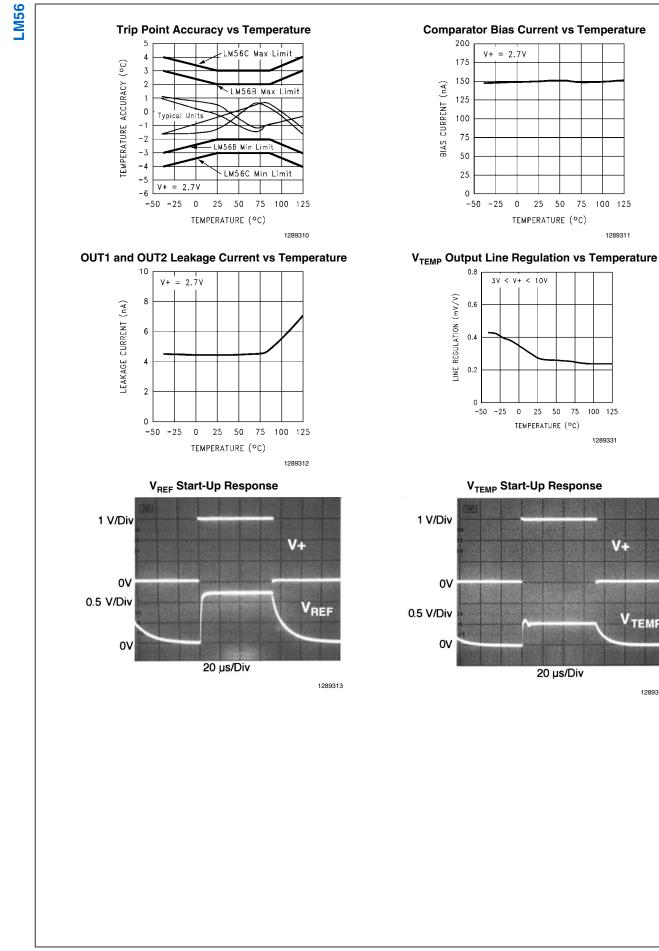
1289307

#### **Temperature Sensor Output Accuracy vs Temperature**

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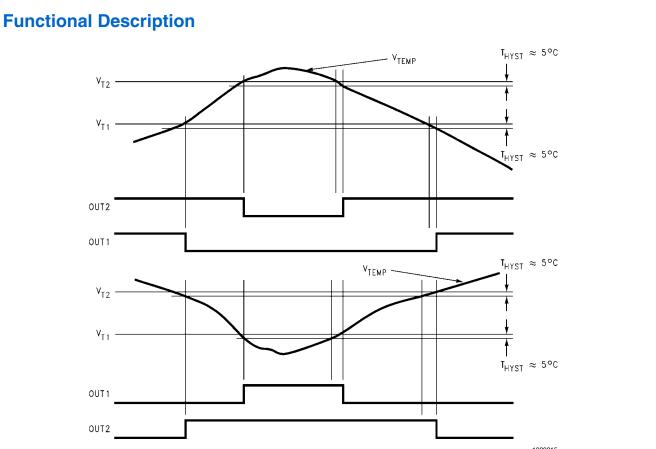
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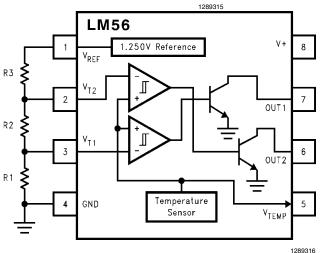
www.national.com

1289314



## **Pin Descriptions**

- $V^{+} \qquad \mbox{This is the positive supply voltage pin. This pin should} \\ \mbox{be bypassed with a 0.1 } \mu\mbox{F} \mbox{ capacitor to ground.} \\$
- GND This is the ground pin.
- $V_{\text{REF}} \quad \begin{array}{l} \text{This is the 1.250V bandgap voltage reference output} \\ \text{pin. In order to maintain trip point accuracy this pin} \\ \text{should source a 50 } \mu\text{A load.} \end{array}$
- $V_{\text{TEMP}}$  This is the temperature sensor output pin.
- OUT1 This is an open collector digital output. OUT1 is active LOW. It goes LOW when the temperature is greater than T<sub>1</sub> and goes HIGH when the temperature drops below T<sub>1</sub>– 5°C. This output is not intended to directly drive a fan motor.
- OUT2 This is an open collector digital output. OUT2 is active LOW. It goes LOW when the temperature is greater than the  $T_2$  set point and goes HIGH when the temperature is less than  $T_2$  5°C. This output is not intended to directly drive a fan motor.
- $V_{T1}$  This is the input pin for the temperature trip point voltage for OUT1.
- $V_{T2}$  This is the input pin for the low temperature trip point voltage for OUT2.



$$\begin{split} V_{T1} &= 1.250V \; x \; (R1)/(R1 + R2 + R3) \\ V_{T2} &= 1.250V \; x \; (R1 + R2)/(R1 + R2 + R3) \\ \text{where:} \\ (R1 + R2 + R3) &= 27 \; \text{k}\Omega \; \text{and} \end{split}$$

$$\begin{split} & (11 + 112 + 116) = 27 \text{ km and} \\ & V_{T1 \text{ or } T2} = [6.20 \text{ mV}/^{\circ}\text{C x T}] + 395 \text{ mV therefore:} \\ & \text{R1} = V_{T1}/(1.25\text{V}) \times 27 \text{ k}\Omega \\ & \text{R2} = (V_{T2}/(1.25\text{V}) \times 27 \text{ k})\Omega \text{--}\text{R1} \\ & \text{R3} = 27 \text{ k}\Omega \text{--}\text{R1} \text{--}\text{R2} \end{split}$$

LM56

## **Application Hints**

#### **1.0 LM56 TRIP POINT ACCURACY SPECIFICATION**

Trip Point Error Voltage =  $V_{TPE}$ , Comparator Offset Error for  $V_{T1E}$ Temperature Sensor Error =  $V_{TSE}$ Reference Output Error =  $V_{RE}$ 

For simplicity the following is an analysis of the trip point accuracy using the single output configuration show in *Figure* 2 with a set point of 82°C.

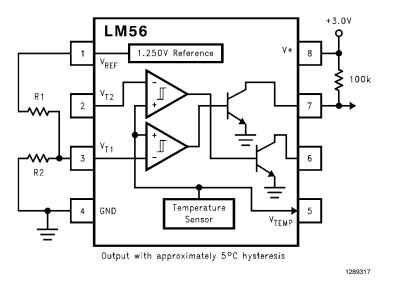


FIGURE 2. Single Output Configuration

1.  $V_{TPE} = \pm V_{T1E} - V_{TSE} + V_{RE}$ Where:

2.  $V_{T1E} = \pm 8 \text{ mV} \text{ (max)}$ 

2.  $V_{T1E} = \pm 0$  mV (max)

3.  $V_{TSE} = (6.20 \text{ mV/}^{\circ}\text{C}) \times (\pm 3^{\circ}\text{C}) = \pm 18.6 \text{ mV}$ 

4.  $V_{RE} = 1.250V \text{ x} (\pm 0.01) \text{ R2/(R1 + R2)}$ 

Using Equations from page 1 of the datasheet.

 $V_{T1}=1.25VxR2/(R1+R2)=(6.20 \text{ mV})^{\circ}C)(82^{\circ}C) +395 \text{ mV}$ Solving for R2/(R1 + R2) = 0.7227

then.

5. V<sub>RE</sub> = 1.250V x (±0.01) R2/(R1 + R2) = (0.0125) x (0.7227) = ±9.03 mV

The individual errors do not add algebraically because, the odds of all the errors being at their extremes are rare. This is proven by the fact the specification for the trip point accuracy stated in the Electrical Characteristic for the temperature range of  $-40^{\circ}$ C to  $+125^{\circ}$ C, for example, is specified at  $\pm 3^{\circ}$ C for the LM56BIM. Note this trip point error specification does not include any error introduced by the tolerance of the actual resistors used, nor any error introduced by power supply variation.

If the resistors have a  $\pm 0.5\%$  tolerance, an additional error of  $\pm 0.4^{\circ}$ C will be introduced. This error will increase to  $\pm 0.8^{\circ}$ C when both external resistors have a  $\pm 1\%$  tolerance.

#### 2.0 BIAS CURRENT EFFECT ON TRIP POINT ACCURACY

Bias current for the comparator inputs is 300 nA (max) each, over the specified temperature range and will not introduce considerable error if the sum of the resistor values are kept to about 27 k $\Omega$  as shown in the typical application of *Figure 1*. This bias current of one comparator input will not flow if the temperature is well below the trip point level. As the temperature approaches trip point level the bias current will start to

flow into the resistor network. When the temperature sensor output is equal to the trip point level the bias current will be 150 nA (max). Once the temperature is well above the trip point level the bias current will be 300 nA (max). Therefore, the first trip point will be affected by 150 nA of bias current. The leakage current is very small when the comparator input transistor of the different pair is off (see *Figure 3*).

The effect of the bias current on the first trip point can be defined by the following equations:

$$K1 = \frac{R1}{R1 + R2 + R3}$$
$$V_{T1} = K1 \times V_{REF} + K1 \times (R2 + R3) \times \frac{I_{B}}{2}$$

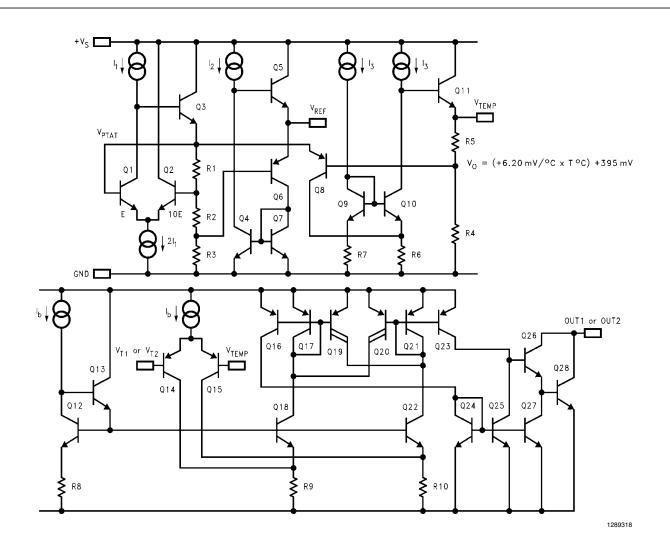
where  $I_{B} = 300$  nA (the maximum specified error).

The effect of the bias current on the second trip point can be defined by the following equations:

$$\begin{split} & \kappa 2 = \frac{R1 + R2}{R1 + R2 + R3} \\ & V_{T2} = K2 \, x \, V_{REF} + \left(K1 + \frac{K2}{2}\right) x \, R3 \, x \, I_B \end{split}$$

where  $I_B = 300$  nA (the maximum specified error).

The closer the two trip points are to each other the more significant the error is. Worst case would be when  $V_{T1} = V_{T2} = V_{REF}/2$ .



**FIGURE 3. Simplified Schematic** 

### 3.0 MOUNTING CONSIDERATIONS

The majority of the temperature that the LM56 is measuring is the temperature of its leads. Therefore, when the LM56 is placed on a printed circuit board, it is not sensing the temperature of the ambient air. It is actually sensing the temperature difference of the air and the lands and printed circuit board that the leads are attached to. The most accurate temperature sensing is obtained when the ambient temperature is equivalent to the LM56's lead temperature.

As with any IC, the LM56 and accompanying wiring and circuits must be kept insulated and dry, to avoid leakage and corrosion. This is especially true if the circuit operates at cold temperatures where condensation can occur. Printed-circuit coatings are often used to ensure that moisture cannot corrode the LM56 or its connections.

#### 4.0 V<sub>REF</sub> AND V<sub>TEMP</sub> CAPACITIVE LOADING

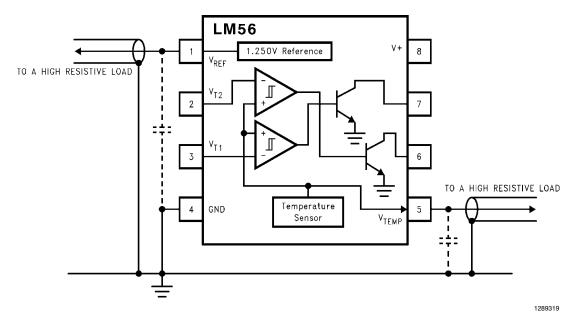


FIGURE 4. Loading of V<sub>REF</sub> and V<sub>TEMP</sub>

The LM56  $\mathrm{V}_{\mathrm{REF}}$  and  $\mathrm{V}_{\mathrm{TEMP}}$  outputs handle capacitive loading well. Without any special precautions, these outputs can drive any capacitive load as shown in Figure 4. **5.0 NOISY ENVIRONMENTS** 

Over the specified temperature range the LM56  $V_{TEMP}$  output has a maximum output impedance of  $1500\Omega$ . In an extremely noisy environment it may be necessary to add some filtering to minimize noise pickup. It is recommended that 0.1 µF be added from V<sup>+</sup> to GND to bypass the power supply voltage, as shown in Figure 4. In a noisy environment it may be necessary to add a capacitor from the  $V_{\text{TEMP}}$  output to ground. A 1  $\mu$ F output capacitor with the 1500 $\Omega$  output impedance will form a 106 Hz lowpass filter. Since the thermal time constant of the V<sub>TEMP</sub> output is much slower than the 9.4 ms time constant formed by the RC, the overall response time of the  $V_{\text{TEMP}}$  output will not be significantly affected. For much larger capacitors this additional time lag will increase the overall response time of the LM56.

#### **6.0 APPLICATIONS CIRCUITS**

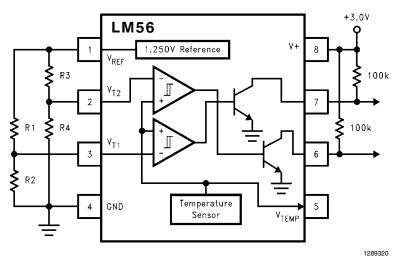


FIGURE 5. Reducing Errors Caused by Bias Current

The circuit shown in Figure 5 will reduce the effective bias current error for  $V^{}_{\rm T2}$  as discussed in Section 3.0 to be equivalent to the error term of  $V_{T1}$ . For this circuit the effect of the bias current on the first trip point can be defined by the following equations:

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$$K1 = \frac{R2}{R1 + R2}$$
  
 $V_{T1} = K1 \times V_{REF} + K1 \times (R1) \times \frac{I_B}{2}$ 

where  $I_B = 300$  nA (the maximum specified error). Similarly, bias current affect on  $V_{T2}$  can be defined by:

$$K2 = \frac{R4}{R3 + R4}$$
$$V_{T1} = K2 \times V_{REF} + K1 \times (R3) \times \frac{l_B}{2}$$

where  $I_B = 300 \text{ nA}$  (the maximum specified error).

The current shown in *Figure 6* is a simple overtemperature detector for power devices. In this example, an audio power amplifier IC is bolted to a heat sink and an LM56 Celsius temperature sensor is mounted on a PC board that is bolted to the heat sink near the power amplifier. To ensure that the sensing element is at the same temperature as the heat sink, the sensor's leads are mounted to pads that have feed throughs to the back side of the PC board. Since the LM56 is sensing the temperature of the actual PC board the back side of the PC board also has large ground plane to help conduct the heat to the device. The comparator's output goes low if the heat sink temperature rises above a threshold set by R1, R2, and the voltage reference. This fault detection output from the comparator now can be used to turn on a cooling fan. The circuit as shown in design to turn the fan on when heat sink temperature exceeds about 80°C, and to turn the fan off when the heat sink temperature falls below approximately 75°C.

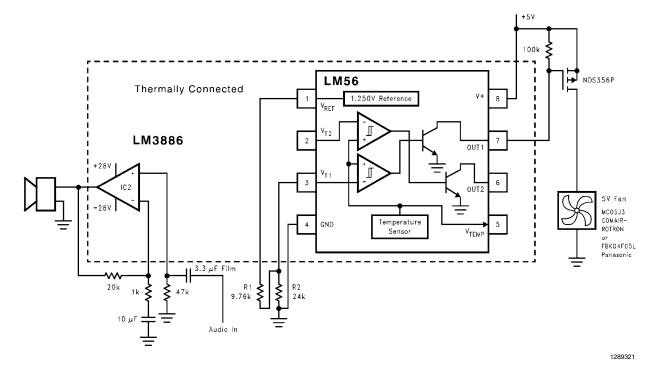
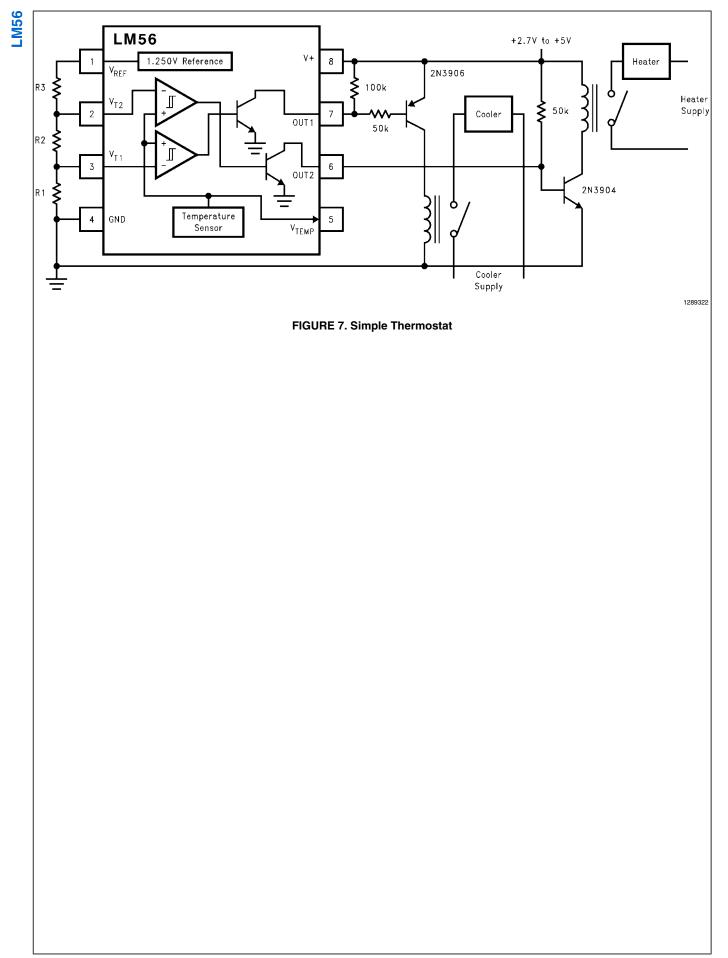
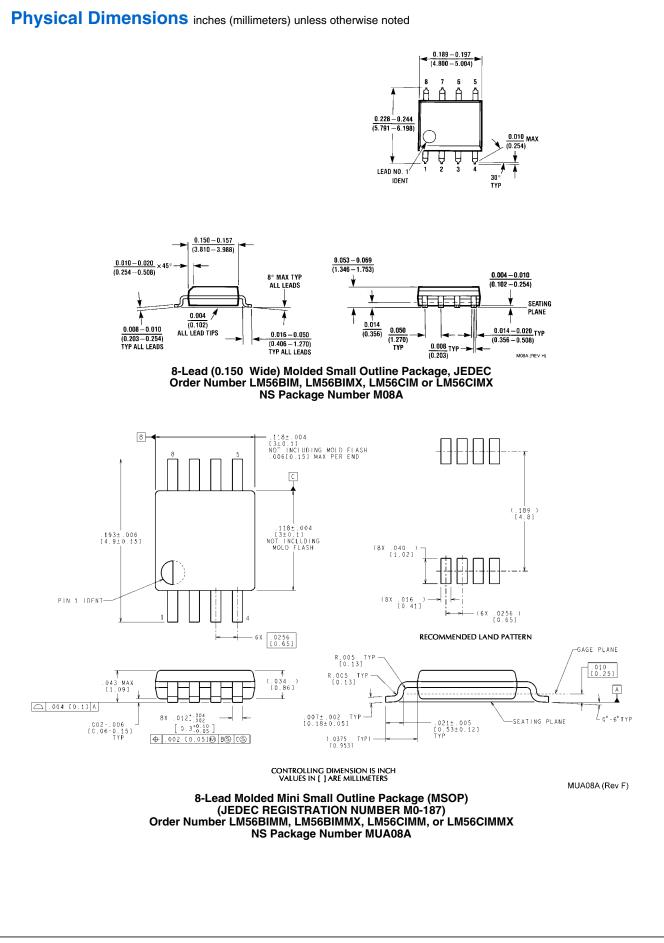


FIGURE 6. Audio Power Amplifier Overtemperature Detector





## Notes

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Switching Regulators	www.national.com/switchers	Distributors	www.national.com/contacts		
LDOs	www.national.com/ldo	Quality and Reliability	www.national.com/quality		
LED Lighting	www.national.com/led	Feedback/Support	www.national.com/feedback		
Voltage Reference	www.national.com/vref	Design Made Easy	www.national.com/easy		
PowerWise® Solutions	www.national.com/powerwise	Solutions	www.national.com/solutions		
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