

.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_{T1} and V_{T2}) 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_{HYST}). Similarly, OUT2 goes LOW when the temperature exceeds T2 and goes HIGH when the temperature goes below (T2–T_{HYST}). T_{HYST} 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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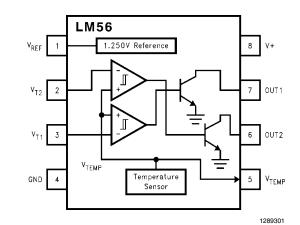
- Power Supply Current 230 µA (max)
- V_{BEF} 1.250V ±1% (max)
- Hysteresis Temperature
- Internal Temperature Sensor Output Voltage:

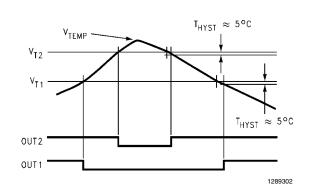
(+6.20 mV/°C x T) + 395 mV

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

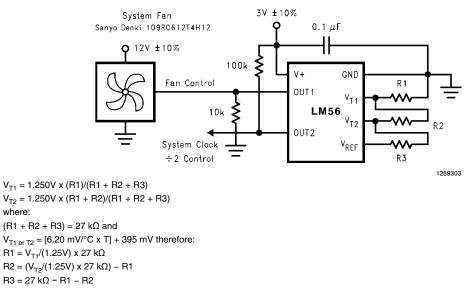


FIGURE 1. Microprocessor Thermal Management

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 _A = 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 _A ≤ +125°C
Positive Supply Voltage (V+)	+2.7V to +10V
Maximum V_{OUT1} and V_{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⁺ = 2.7 V_{DC}, and V_{REF} load current = 50 μ A unless otherwise specified. **Boldface limits apply for T_A = T_J = T_{MIN} to T_{MAX};** all other limits T_A = T_J = 25°C unless otherwise specified.

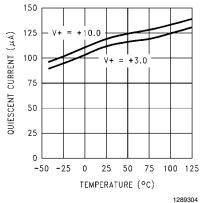
Symbol	Parameter	Conditions	Typical (Note 6)	LM56BIM Limits (Note 7)	LM56CIM Limits (Note 7)	Units (Limits)
Femperatu	re Sensor					
	Trip Point Accuracy (Includes			±2	±3	°C (max)
	V _{REF} , Comparator Offset, and	+25°C ≤ T _A ≤ +85°C		±2	±3	°C (max)
	Temperature Sensitivity errors)	–40°C ≤ T _A ≤ +125°C		±3	±4	°C (max)
	Trip Point Hysteresis	$T_A = -40^{\circ}C$	4	3	3	°C (min)
				6	6	°C (max)
		T _A = +25°C	5	3.5	3.5	°C (min)
				6.5	6.5	°C (max)
		T _A = +85°C	6	4.5	4.5	°C (min)
				7.5	7.5	°C (max)
		T _A = +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 _L ≤ +40 μA		1500	1500	Ω (max)
	Line Regulation	$+3.0V \le V^+ \le +10V$,		-0.72/	-0.72/	mV/V (max
		+25 °C ≤ T _A ≤ +85 °C		+0.36	+0.36	
		$+3.0V \le V^+ \le +10V$,		-1.14/	-1.14/	mV/V (max
		–40 °C ≤ T _A <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)
/ _{IN}	Analog Input Voltage Range		V+ – 1			V
			GND			V
/ _{os}	Comparator Offset		2	8	8	mV (max)
/ _{REF} Outpu	t					
/ _{REF}	V _{REF} Nominal		1.250V			V
	V _{REF} 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/ μA (max) Symbol Parameter Conditions Typical (Note 6) Limits (Note 7) Units (Limits) '+ Power Supply Supply Current V+ = +10V V+ = +2.7V 230 μA (max) Digital Outputs Dut("1") Logical "1" Output Leakage Current V+ = +5.0V 1 μA (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 ₁) 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 μA (max) Olifical Outputs V* = +10V Current V* = +5.0V 1 μA (max) OUT(*1) Logical "1" Output Leakage Current V* = +5.0V 1 μA (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 _{Jmax} (m	Symbol Parameter		Conditions		Typical (Note 6)	LM56BIM Limits (Note 7)	LM56CIM Limits (Note 7)	Units (Limits)
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Symbol Parameter Conditions Typical (Note 6) Limits (Note 7) Units (Limits) ** Power Supply 5 Supply Current V* = +10V V* = +2.7V 230 μA (max) μA (max) bigital Outputs 0 230 μA (max) DUT("1") Logical "1" Output Leakage Current V* = +5.0V 1 μA (max) 'outr("0") Logical "0" Output Voltage I I μA (max) 'outr("0") Logical "0" Output Voltage I I μA (max) 'outr("0") Logical "0" Output Voltage I I μA (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 μ A (max) μ A (max) Digital Outputs Out("1") Logical "1" Output Leakage Current V* = +5.0V 1 μ A (max) /OUT("0") Logical "0" Output Voltage I_OUT = +50 μ 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 _{BEE} /ΔI	Load Regulation Sourcing	+30 µA ≤ I ₁ ≤ -	+50 μA		0.15	0.15	mV/µA (max
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Supply Current V+ = +10V 230 μ A (max) Digital Outputs 230 μ A (max) DUT("1") Logical "1" Output Leakage V+ = +5.0V 1 μ A (max) Vour("1") Logical "0" Output Voltage $I_{=} + 5.0V$ 1 μ 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 ₁) at any pin exceeds the power supply (V ₁ < GND or V ₁ > V ⁺), 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). θ_{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 (θ_{jA}) of the different package types w	S Supply Current V+ = +10V 230 μ A (max) Digital Outputs 230 μ A (max) OUT("1") Logical "1" Output Leakage V+ = +5.0V 1 μ A (max) $M_{OUT("1")}$ Logical "0" Output Voltage I_{OUT} = +50 μ 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 ₁) at any pin exceeds the power supply (V ₁ < GND or V ₁ > V ⁺), 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 _k (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 _{j,max} = 125°C. For this device the typical thermal resistance ($\theta_{j,k}$) of the	Symbo	ol Parameter	Conc	litions				
S μm (max) V ⁺ = +2.7V 230 μA (max) Digital Outputs 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 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. Some performance characteristics may degrade when the device is not operated under the listed test conditions. Note 2: When the input voltage (V ₁) at any pin exceeds the power supplies with an input current of 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. Net 4: The maximum power dissipation must be derated at elevated temperatures and is dictated by T _{imax} (maximum junction temperature), θ _{iA} (iunction to ambient themperature is lower. For this device, T _{jimax} = 125°C. For this device the typical thermal resistance (θ _{jA}) of the different package types when board mounted follow: <td>S μr (ritid) V⁺ = +2.7V 230 μA (max) Digital Outputs Current 1 μA (max) 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) 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. Note 2: When the input voltage (V₁) at any pin exceeds the power supply (V₁ < GND or V₁ > V⁻), 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_{imax} (maximum junction temperature), θ_{iA} (junction to ambient temperature). The maximum allowable power dissipation at any temperature is P_D = (T_{imax} -T_A)/θ_{iA} or the number given in the Absolute Maximum Ratings, whichever is lower. For this device, T_{imax} = 125°C. For this device the typical thermal resistance (θ_{iA}) 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 ⁺ = +2.7V 230 μA (max) Digital Outputs Current 1 μA (max) 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) 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. Note 2: When the input voltage (V ₁) at any pin exceeds the power supply (V ₁ < GND or V ₁ > V ⁻), 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 _{imax} (maximum junction temperature), θ _{iA} (junction to ambient temperature). The maximum allowable power dissipation at any temperature is P _D = (T _{imax} -T _A)/θ _{iA} or the number given in the Absolute Maximum Ratings, whichever is lower. For this device, T _{imax} = 125°C. For this device the typical thermal resistance (θ _{iA}) 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 ₁) at any pin exceeds the power supply (V ₁ < GND or V ₁ > V ¹), 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 _{imax} (maximum junction temperature). $\theta_{j,k}$ (junction to ambient thermal resistance) and T _A (ambient temperature). The maximum allowable power dissipation at any temperature is P _D = (T _{imax} - T _A)/ $\theta_{j,A}$ or the number given in the Absolute Maximum Ratings, whichever is lower. For this device, T _{imax} = 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 ₁ < GND or V ₁ > V ⁺), 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 _{imax} (maximum junction temperature), θ _{inf} (junction to ambient thermal resistance) and T _A (ambient temperature). The maximum allowable power dissipation at any temperature is P _D = (T _{imax} T _A)/θ _{inf} 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: Wote 5: The human body model is a 100 pF capacitor discharge	S	Supply Current	V+ = +10V				230	µA (max)
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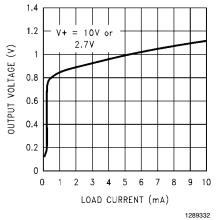
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Typical Performance Characteristics

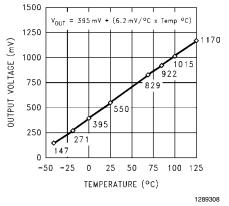
Quiescent Current vs Temperature

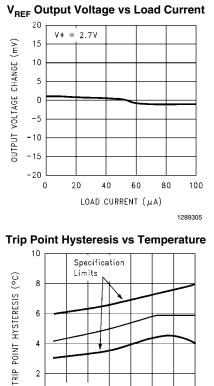


OUT1 and OUT2 Voltage Levels vs Load Current



Temperature Sensor Output Voltage vs Temperature





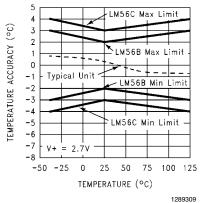
= 2.7 V-50 -25 0 25 50 75 100 125 TEMPERATURE (°C)

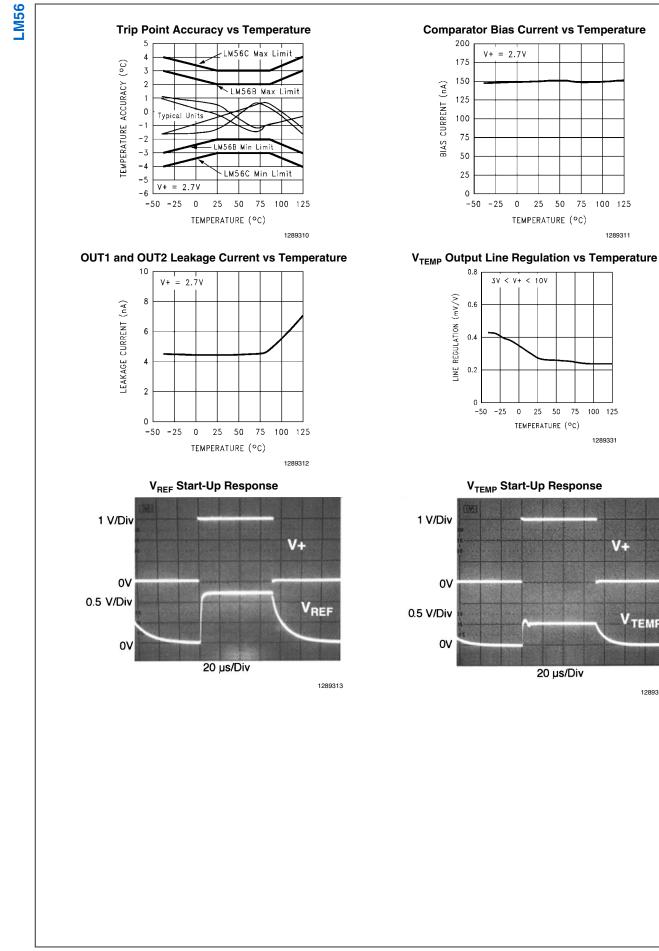
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Temperature Sensor Output Accuracy vs Temperature

٧+

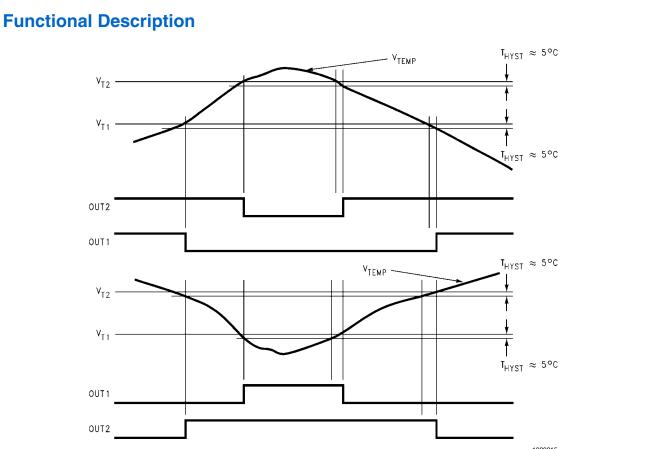
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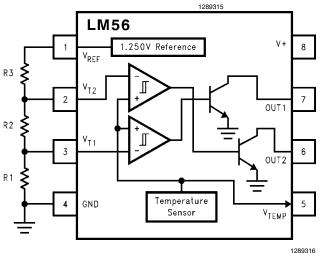
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Pin Descriptions

- $V^{+} \qquad \mbox{This is the positive supply voltage pin. This pin should} \\ \mbox{be bypassed with a 0.1 } \mu\mbox{F} \mbox{ capacitor to ground.} \\$
- 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_{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 T₁ and goes HIGH when the temperature drops below T₁– 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.

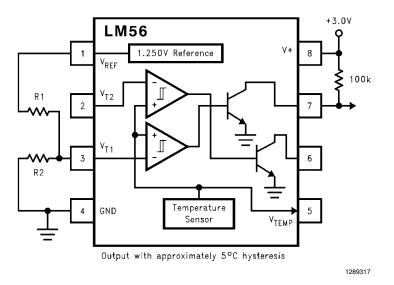


FIGURE 2. Single Output Configuration

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_{RE} = 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° 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 Ω 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 $V_{T1} = V_{T2} = V_{REF}/2$.

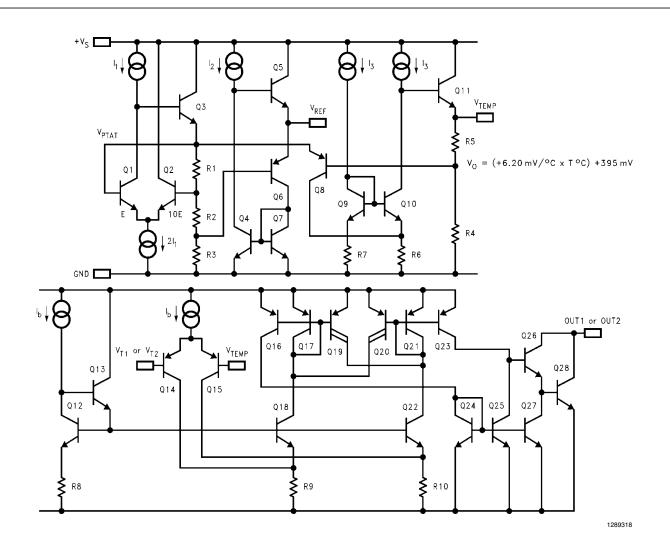


FIGURE 3. Simplified Schematic

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_{REF} AND V_{TEMP} CAPACITIVE LOADING

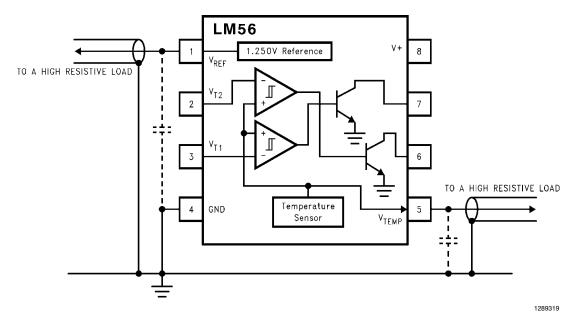


FIGURE 4. Loading of V_{REF} and V_{TEMP}

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 1500Ω . 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⁺ 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_{TEMP} output to ground. A 1 μ F output capacitor with the 1500 Ω output impedance will form a 106 Hz lowpass filter. Since the thermal time constant of the V_{TEMP} output is much slower than the 9.4 ms time constant formed by the RC, the overall response time of the V_{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

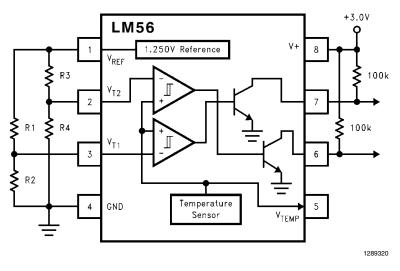


FIGURE 5. Reducing Errors Caused by Bias Current

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.

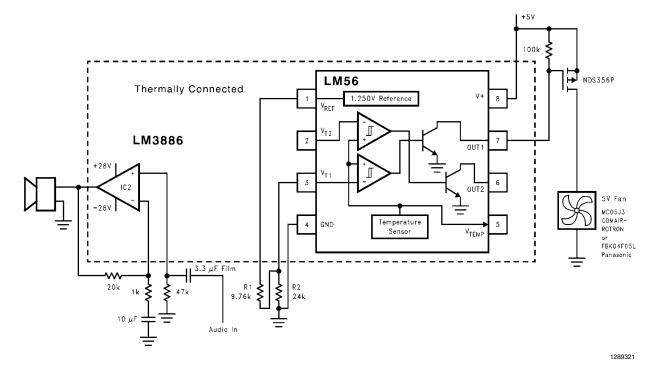
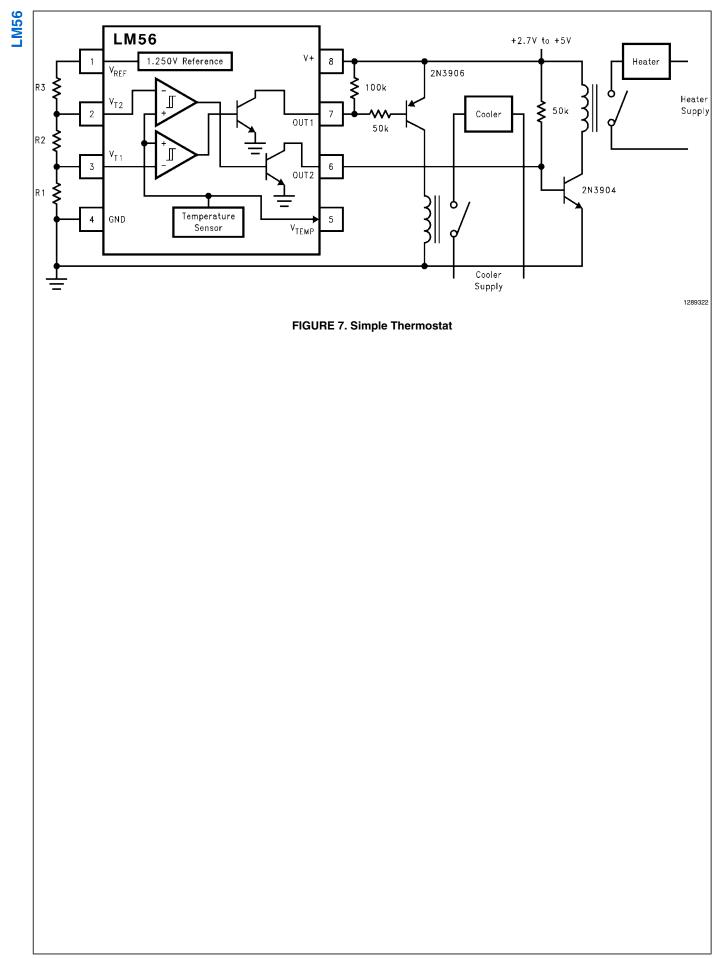
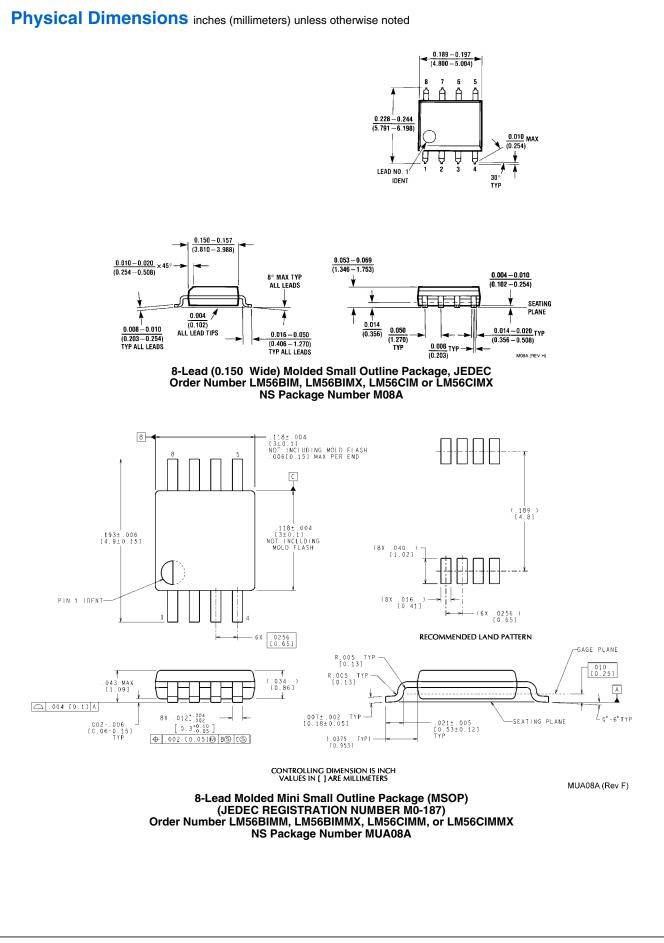


FIGURE 6. Audio Power Amplifier Overtemperature Detector





Notes

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LDOs	www.national.com/ldo	Quality and Reliability	www.national.com/quality		
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