LM26LV/LM26LV-Q1

1.6 V, LLP-6 Factory Preset Temperature Switch and Temperature Sensor

General Description

The LM26LV/LM26LV-Q1 is a low-voltage, precision, dual-output, low-power temperature switch and temperature sensor. The temperature trip point (T_{TRIP}) can be preset at the factory to any temperature in the range of 0°C to 150°C in 1°C increments. Built-in temperature hysteresis (T_{HYST}) keeps the output stable in an environment of temperature instability.

In normal operation the LM26LV/LM26LV-Q1 temperature switch outputs assert when the die temperature exceeds T_{TRIP}. The temperature switch outputs will reset when the temperature falls below a temperature equal to (T_{TRIP} – T_{HYST}). The OVERTEMP digital output, is active-high with a push-pull structure, while the $\overline{\text{OVERTEMP}}$ digital output, is active-low with an open-drain structure.

The analog output, V_{TEMP}, delivers an analog output voltage with Negative Temperature Coefficient (NTC).

Driving the TRIP TEST input high: (1) causes the digital outputs to be asserted for in-situ verification and, (2) causes the threshold voltage to appear at the V_{TEMP} output pin, which could be used to verify the temperature trip point.

The LM26LV/LM26LV-Q1's low minimum supply voltage makes it ideal for 1.8 Volt system designs. Its wide operating range, low supply current , and excellent accuracy provide a temperature switch solution for a wide range of commercial and industrial applications.

Applications

- Cell phones and Wireless Transceivers
- Digital Cameras
- Battery Management
- Automotive
- Disk Drives
- Games and Appliances

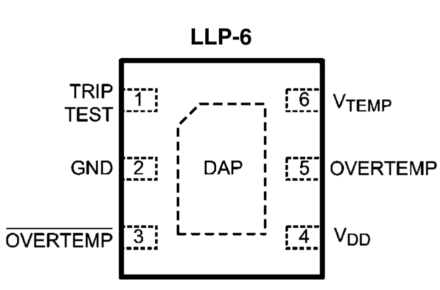
Features

- Low 1.6V operation
- Low quiescent current
- Latching function: device can latch the Over Temperature condition
- Push-pull and open-drain temperature switch outputs
- Wide trip point range of 0°C to 150°C
- Very linear analog V_{TEMP} temperature sensor output
- V_{TEMP} output short-circuit protected
- Accurate over –50°C to 150°C temperature range
- 2.2 mm by 2.5 mm (typ) LLP-6 package
- Excellent power supply noise rejection
- LM26LVQISD–130 and LM26LVQISD-135 are AEC-Q100 Grade 0 qualified and is manufactured on an Automotive Grade flow. For other trip points, contact your sales office.

Key Specifications

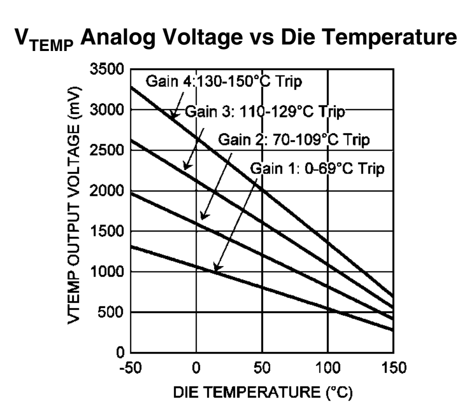
■ Supply Voltage		1.6V to 5.5V
■ Supply Current		8 µA (typ)
■ Accuracy, Trip Point Temperature	0°C to 150°C	±2.2°C
■ Accuracy, V_{TEMP}	0°C to 150°C	±2.3°C
	0°C to 120°C	±2.2°C
	–50°C to 0°C	±1.7°C
■ V_{TEMP} Output Drive		±100 µA
■ Operating Temperature		–50°C to 150°C
■ Hysteresis Temperature		4.5°C to 5.5°C

Connection Diagram

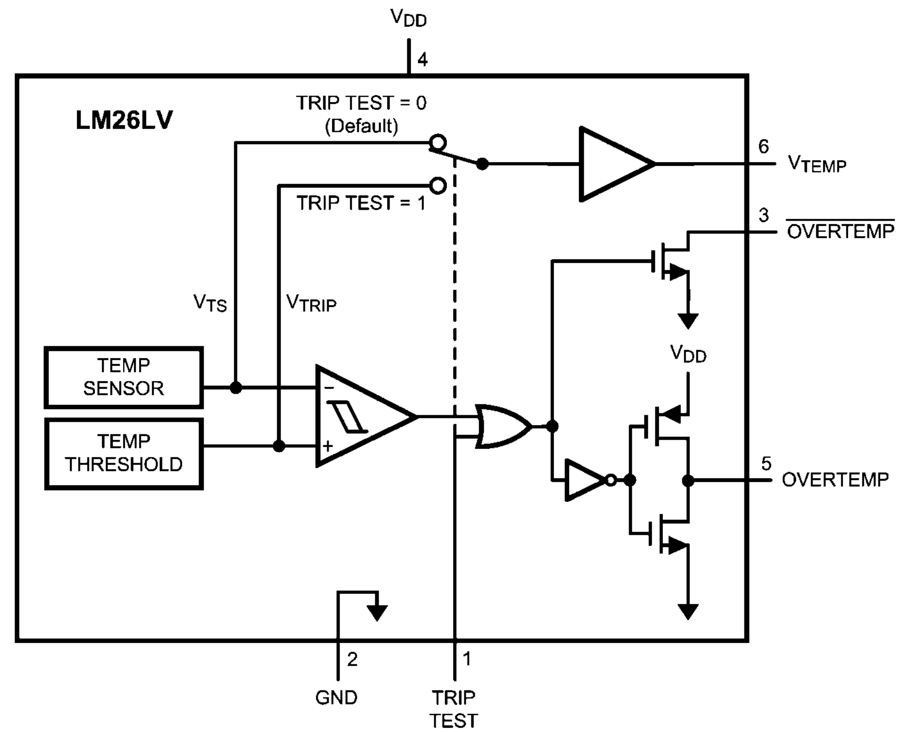


Top View
See NS Package Number SDB06A

Typical Transfer Characteristic



Block Diagram



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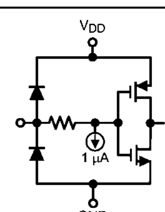
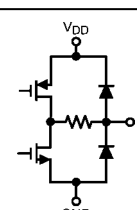
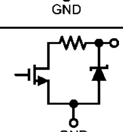
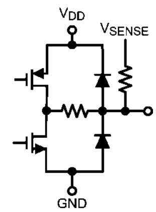
Pin Descriptions

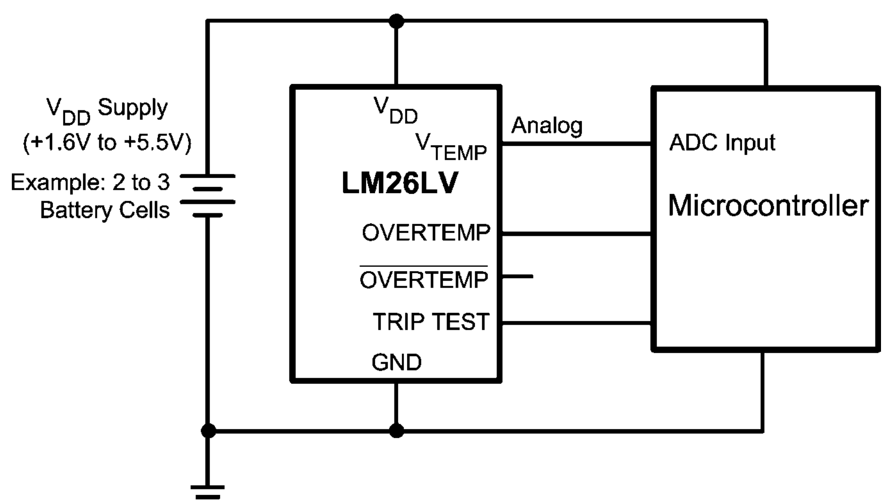
Pin No.	Name	Type	Equivalent Circuit	Description
1	TRIP TEST	Digital Input		TRIP TEST pin. Active High input. If TRIP TEST = 0 (Default) then: $V_{TEMP} = V_{TS}$, Temperature Sensor Output Voltage If TRIP TEST = 1 then: OVERTEMP and $\overline{\text{OVERTEMP}}$ outputs are asserted and $V_{TEMP} = V_{TRIP}$, Temperature Trip Voltage. This pin may be left open if not used.
5	OVERTEMP	Digital Output		Over Temperature Switch output Active High, Push-Pull Asserted when the measured temperature exceeds the Trip Point Temperature or if TRIP TEST = 1 This pin may be left open if not used.
3	$\overline{\text{OVERTEMP}}$	Digital Output		Over Temperature Switch output Active Low, Open-drain (See Section 2.1 regarding required pull-up resistor.) Asserted when the measured temperature exceeds the Trip Point Temperature or if TRIP TEST = 1 This pin may be left open if not used.

Pin No.	Name	Type	Equivalent Circuit	Description

6	V_{TEMP}	Analog Output		V_{TEMP} Analog Voltage Output
				If TRIP TEST = 0 then
				$V_{TEMP} = V_{TS}$, Temperature Sensor Output Voltage
				If TRIP TEST = 1 then
				$V_{TEMP} = V_{TRIP}$, Temperature Trip Voltage
				This pin may be left open if not used.

4	V_{DD}	Power		Positive Supply Voltage
2	GND	Ground		Power Supply Ground
DAP	Die Attach Pad			The best thermal conductivity between the device and the PCB is achieved by soldering the DAP of the package to the thermal pad on the PCB. The thermal pad can be a floating node. However, for improved noise immunity the thermal pad should be connected to the circuit GND node, preferably directly to pin 2 (GND) of the device.

Typical Application



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Ordering Information

Order Number	Q Grade	Temp Trip Point, °C	Package Number	Top Mark	Transport Media
LM26LV/ LM26LVCISD-150		150°C	SDB06A	150	1000 Units on Tape and Reel
LM26LV/ LM26LVCISDX-150		150°C	SDB06A	150	4500 Units on Tape and Reel
LM26LV/ LM26LVCISD-145		145°C	SDB06A	145	1000 Units on Tape and Reel
LM26LV/ LM26LVCISDX-145		145°C	SDB06A	145	4500 Units on Tape and Reel
LM26LV/ LM26LVCISD-140		140°C	SDB06A	140	1000 Units on Tape and Reel
LM26LV/ LM26LVCISDX-140		140°C	SDB06A	140	4500 Units on Tape and Reel
LM26LV/ LM26LVCISD-135		135°C	SDB06A	135	1000 Units on Tape and Reel
LM26LV/ LM26LVCISDX-135		135°C	SDB06A	135	4500 Units on Tape and Reel
LM26LV/ LM26LVCISD-130		130°C	SDB06A	130	1000 Units on Tape and Reel
LM26LV/ LM26LVCISDX-130		130°C	SDB06A	130	4500 Units on Tape and Reel
LM26LV/ LM26LVCISD-125		125°C	SDB06A	125	1000 Units on Tape and Reel
LM26LV/ LM26LVCISDX-125		125°C	SDB06A	125	4500 Units on Tape and Reel
LM26LV/ LM26LVCISD-120		120°C	SDB06A	120	1000 Units on Tape and Reel
LM26LV/ LM26LVCISDX-120		120°C	SDB06A	120	4500 Units on Tape and Reel
LM26LV/ LM26LVCISD-115		115°C	SDB06A	115	1000 Units on Tape and Reel
LM26LV/ LM26LVCISDX-115		115°C	SDB06A	115	4500 Units on Tape and Reel
LM26LV/ LM26LVCISD-110		110°C	SDB06A	110	1000 Units on Tape and Reel
LM26LV/ LM26LVCISDX-110		110°C	SDB06A	110	4500 Units on Tape and Reel
LM26LV/ LM26LVCISD-105		105°C	SDB06A	105	1000 Units on Tape and Reel
LM26LV/ LM26LVCISDX-105		105°C	SDB06A	105	4500 Units on Tape and Reel
LM26LV/ LM26LVCISD-100		100°C	SDB06A	100	1000 Units on Tape and Reel
LM26LV/ LM26LVCISDX-100		100°C	SDB06A	100	4500 Units on Tape and Reel
LM26LV/ LM26LVCISD-095		95°C	SDB06A	095	1000 Units on Tape and Reel
LM26LV/ LM26LVCISDX-095		95°C	SDB06A	095	4500 Units on Tape and Reel
LM26LV/ LM26LVCISD-090		90°C	SDB06A	090	1000 Units on Tape and Reel

Order Number	Q Grade	Temp Trip Point, °C	Package Number	Top Mark	Transport Media
LM26LV/ LM26LVCISDX-090		90°C	SDB06A	090	4500 Units on Tape and Reel
LM26LV/ LM26LVCISD-085		85°C	SDB06A	085	1000 Units on Tape and Reel
LM26LV/ LM26LVCISDX-085		85°C	SDB06A	085	4500 Units on Tape and Reel
LM26LV/ LM26LVCISD-080		80°C	SDB06A	080	1000 Units on Tape and Reel
LM26LV/ LM26LVCISDX-080		80°C	SDB06A	080	4500 Units on Tape and Reel
LM26LV/ LM26LVCISD-075		75°C	SDB06A	075	1000 Units on Tape and Reel
LM26LV/ LM26LVCISDX-075		75°C	SDB06A	075	4500 Units on Tape and Reel
LM26LV/ LM26LVCISD-070		70°C	SDB06A	070	1000 Units on Tape and Reel
LM26LV/ LM26LVCISDX-070		70°C	SDB06A	070	4500 Units on Tape and Reel
LM26LV/ LM26LVCISD-065		65°C	SDB06A	065	1000 Units on Tape and Reel
LM26LV/ LM26LVCISDX-065		65°C	SDB06A	065	4500 Units on Tape and Reel
LM26LV/ LM26LVCISD-060		60°C	SDB06A	060	1000 Units on Tape and Reel
LM26LV/ LM26LVCISDX-060		60°C	SDB06A	060	4500 Units on Tape and Reel
LM26LV/ LM26LVCISD-050		50°C	SDB06A	050	1000 Units on Tape and Reel
LM26LV/ LM26LVCISDX-050		50°C	SDB06A	050	4500 Units on Tape and Reel
LM26LV/ LM26LVQISD-130	0	130°C	SDB06A	Q30	1000 Units on Tape and Reel
LM26LV/ LM26LVQISDX-130	0	130°C	SDB06A	Q30	4500 Units on Tape and Reel
LM26LV/ LM26LVQISD-135	0	135°C	SDB06A	Q35	1000 Units on Tape and Reel
LM26LV/ LM26LVQISDX-135	0	135°C	SDB06A	Q35	4500 Units on Tape and Reel

Absolute Maximum Ratings (Note 1)

Supply Voltage	−0.3V to +6.0V
Voltage at $\overline{\text{OVERTEMP}}$ pin	−0.3V to +6.0V
Voltage at OVERTEMP and V_{TEMP} pins	−0.3V to (V_{DD} + 0.5V)
TRIP TEST Input Voltage	−0.3V to (V_{DD} + 0.5V)
Output Current, any output pin	±7 mA
Input Current at any pin (Note 2)	5 mA
Storage Temperature	−65°C to +150°C
Maximum Junction Temperature $T_{J(MAX)}$	+155°C
ESD Susceptibility (Note 3) :	
Human Body Model	4500V
Machine Model	300V
Charged Device Model	1000V

For soldering specifications: see product folder at www.national.com and www.national.com/ms/MS/MS-SOLDERING.pdf

Operating Ratings (Note 1)

Specified Temperature Range:	**$T_{MIN} \le T_A \le T_{MAX}$**
LM26LV/LM26LV-Q1	−50°C ≤ T_A ≤ +150°C
Supply Voltage Range (V_{DD})	+1.6 V to +5.5 V
Thermal Resistance (θ_{JA}) (Note 4)	
LLP-6 (Package SDB06A)	152 °C/W

Accuracy Characteristics

Trip Point Accuracy

Parameter	Conditions		Limits (Note 6)	Units (Limit)
Trip Point Accuracy (Note 7)	0 – 150°C	V_{DD} = 5.0 V	**±2.2**	°C (max)

V_{TEMP} Analog Temperature Sensor Output Accuracy

There are four gains corresponding to each of the four Temperature Trip Point Ranges. Gain 1 is the sensor gain used for Temperature Trip Point 0 - 69°C. Likewise Gain 2 is for Trip Points 70 - 109 °C; Gain 3 for 110 - 129 °C; and Gain 4 for 130 - 150 °C. These limits do not include DC load regulation. These stated accuracy limits are with reference to the values in the LM26LV/LM26LV-Q1 Conversion Table.

Parameter	Conditions			Limits (Note 6)	Units (Limit)
V_{TEMP} Temperature Accuracy (Note 7)	Gain 1: for Trip Point Range 0 - 69°C	T_A = 20°C to 40°C	V_{DD} = 1.6 to 5.5 V	**±1.8**	°C (max)
		T_A = 0°C to 70°C	V_{DD} = 1.6 to 5.5 V	**±2.0**	
		T_A = 0°C to 90°C	V_{DD} = 1.6 to 5.5 V	**±2.1**	
		T_A = 0°C to 120°C	V_{DD} = 1.6 to 5.5 V	**±2.2**	
		T_A = 0°C to 150°C	V_{DD} = 1.6 to 5.5 V	**±2.3**	
		T_A = –50°C to 0°C	V_{DD} = 1.7 to 5.5 V	**±1.7**	
	Gain 2: for Trip Point Range 70 - 109°C	T_A = 20°C to 40°C	V_{DD} = 1.8 to 5.5 V	**±1.8**	°C (max)
		T_A = 0°C to 70°C	V_{DD} = 1.9 to 5.5 V	**±2.0**	
		T_A = 0°C to 90°C	V_{DD} = 1.9 to 5.5 V	**±2.1**	
		T_A = 0°C to 120°C	V_{DD} = 1.9 to 5.5 V	**±2.2**	
		T_A = 0°C to 150°C	V_{DD} = 1.9 to 5.5 V	**±2.3**	
		T_A = –50°C to 0°C	V_{DD} = 2.3 to 5.5 V	**±1.7**	
	Gain 3: for Trip Point Range 110 - 129°C	T_A = 20°C to 40°C	V_{DD} = 2.3 to 5.5 V	**±1.8**	°C (max)
		T_A = 0°C to 70°C	V_{DD} = 2.5 to 5.5 V	**±2.0**	
		T_A = 0°C to 90°C	V_{DD} = 2.5 to 5.5 V	**±2.1**	
		T_A = 0°C to 120°C	V_{DD} = 2.5 to 5.5 V	**±2.2**	
		T_A = 0°C to 150°C	V_{DD} = 2.5 to 5.5 V	**±2.3**	
		T_A = –50°C to 0°C	V_{DD} = 3.0 to 5.5 V	**±1.7**	
	Gain 4: for Trip Point Range 130 - 150°C	T_A = 20°C to 40°C	V_{DD} = 2.7 to 5.5 V	**±1.8**	°C (max)
		T_A = 0°C to 70°C	V_{DD} = 3.0 to 5.5 V	**±2.0**	
		T_A = 0°C to 90°C	V_{DD} = 3.0 to 5.5 V	**±2.1**	
		T_A = 0°C to 120°C	V_{DD} = 3.0 to 5.5 V	**±2.2**	
		T_A = 0°C to 150°C	V_{DD} = 3.0 to 5.5 V	**±2.3**	
		T_A = –50°C to 0°C	V_{DD} = 3.6 to 5.5 V	**±1.7**	

Electrical Characteristics

Unless otherwise noted, these specifications apply for $+V_{DD}$ = +1.6V to +5.5V. **Boldface limits apply for $T_A = T_J = T_{MIN}$ to T_{MAX}** ; all other limits $T_A = T_J$ = 25°C.

Symbol	Parameter	Conditions		Typical (Note 5)	Limits (Note 6)	Units (Limit)
GENERAL SPECIFICATIONS						
I_S	Quiescent Power Supply Current			8	**16**	µA (max)
	Hysteresis			5	**5.5**	°C (max)
					4.5	°C (min)
OVERTEMP DIGITAL OUTPUT		**ACTIVE HIGH, PUSH-PULL**				
V_{OH}	Logic "1" Output Voltage	V_{DD} ≥ 1.6V	Source ≤ 340 µA		**V_{DD} – 0.2V**	V (min)
		V_{DD} ≥ 2.0V	Source ≤ 498 µA			
		V_{DD} ≥ 3.3V	Source ≤ 780 µA			
		V_{DD} ≥ 1.6V	Source ≤ 600 µA		**V_{DD} – 0.45V**	V (min)
		V_{DD} ≥ 2.0V	Source ≤ 980 µA			
		V_{DD} ≥ 3.3V	Source ≤ 1.6 mA			

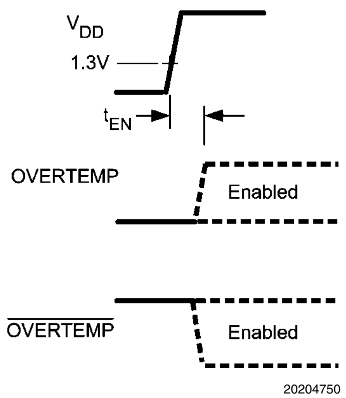
Symbol	Parameter	Conditions		Typical (Note 5)	Limits (Note 6)	Units (Limit)
BOTH OVERTEMP and $\overline{\text{OVERTEMP}}$ DIGITAL OUTPUTS						
V_{OL}	Logic "0" Output Voltage	V_{DD} ≥ 1.6V	Sink ≤ 385 μA		**0.2**	V (max)
		V_{DD} ≥ 2.0V	Sink ≤ 500 μA			
		V_{DD} ≥ 3.3V	Sink ≤ 730 μA			
		V_{DD} ≥ 1.6V	Sink ≤ 690 μA		**0.45**	
		V_{DD} ≥ 2.0V	Sink ≤ 1.05 mA			
		V_{DD} ≥ 3.3V	Sink ≤ 1.62 mA			
$\overline{\text{OVERTEMP}}$ DIGITAL OUTPUT		**ACTIVE LOW, OPEN DRAIN**				
I_{OH}	Logic "1" Output Leakage Current (Note 10)	T_A = 30 °C		0.001	1	μA (max)
		T_A = 150 °C		0.025		
V_{TEMP} ANALOG TEMPERATURE SENSOR OUTPUT						
	V_{TEMP} Sensor Gain	Gain 1: If Trip Point = 0 - 69°C		–5.1		mV/°C
		Gain 2: If Trip Point = 70 - 109°C		–7.7		mV/°C
		Gain 3: If Trip Point = 110 - 129°C		–10.3		mV/°C
		Gain 4: If Trip Point = 130 - 150°C		–12.8		mV/°C
	V_{TEMP} Load Regulation (Note 9)	1.6V ≤ V_{DD} < 1.8V	Source ≤ 90 μA (V_{DD} – V_{TEMP}) ≥ 200 mV	–0.1	**–1**	mV (max)
			Sink ≤ 100 μA V_{TEMP} ≥ 260 mV	0.1	**1**	mV (max)
		V_{DD} ≥ 1.8V	Source ≤ 120 μA (V_{DD} – V_{TEMP}) ≥ 200 mV	–0.1	**–1**	mV (max)
			Sink ≤ 200 μA V_{TEMP} ≥ 260 mV	0.1	**1**	mV (max)
		Source or Sink = 100 μA		1		Ω
	V_{DD} Supply- to-V_{TEMP} DC Line Regulation (Note 11)	V_{DD} = +1.6V to +5.5V		0.29		mV
				74		μV/V
				–82		dB
C_L	V_{TEMP} Output Load Capacitance	Without series resistor. See Section 4.2		1100		pF (max)

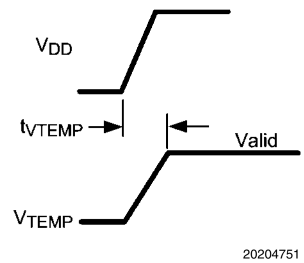
Electrical Characteristics

Unless otherwise noted, these specifications apply for +V_{DD} = +1.6V to +5.5V. **Boldface limits apply for T_A = T_J = T_{MIN} to T_{MAX}**; all other limits T_A = T_J = 25°C.

Symbol	Parameter	Conditions	Typical (Note 5)	Limits (Note 6)	Units (Limit)
TRIP TEST DIGITAL INPUT					
V_{IH}	Logic "1" Threshold Voltage			**V_{DD}– 0.5**	V (min)
V_{IL}	Logic "0" Threshold Voltage			**0.5**	V (max)
I_{IH}	Logic "1" Input Current		1.5	**2.5**	μA (max)
I_{IL}	Logic "0" Input Current (Note 10)		0.001	**1**	μA (max)
TIMING					
t_{EN}	Time from Power On to Digital Output Enabled. See definition below.		1.1	**2.3**	ms (max)
$t_{V_{TEMP}}$	Time from Power On to Analog Temperature Valid. See definition below.	V_{TEMP} C_L = 0 pF to 1100 pF	1.0	**2.9**	ms (max)

Definitions of t_{EN} and $t_{V_{TEMP}}$





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_I) at any pin exceeds power supplies (V_I < GND or $V_I > V_{DD}$), the current at that pin should be limited to 5mA.

Note 3: The Human Body Model (HBM) is a 100pF capacitor charged to the specified voltage then discharged through a 1.5kΩ resistor into each pin. The Machine Model (MM) is a 200pF capacitor charged to the specified voltage then discharged directly into each pin. The Charged Device Model (CDM) is a specified circuit characterizing an ESD event that occurs when a device acquires charge through some triboelectric (frictional) or electrostatic induction processes and then abruptly touches a grounded object or surface.

Note 4: The junction to ambient temperature resistance (θ_{JA}) is specified without a heat sink in still air.

Note 5: Typicals are at $T_J = T_A = 25°C$ and represent most likely parametric norm.

Note 6: Limits are guaranteed to National's AOQL (Average Outgoing Quality Level).

Note 7: Accuracy is defined as the error between the measured and reference output voltages, tabulated in the Conversion Table at the specified conditions of supply gain setting, voltage, and temperature (expressed in °C). Accuracy limits include line regulation within the specified conditions. Accuracy limits do not include load regulation; they assume no DC load.

Note 8: Changes in output due to self heating can be computed by multiplying the internal dissipation by the temperature resistance.

Note 9: Source currents are flowing out of the LM26LV/LM26LV-Q1. Sink currents are flowing into the LM26LV/LM26LV-Q1.

Note 10: The 1µA limit is based on a testing limitation and does not reflect the actual performance of the part. Expect to see a doubling of the current for every 15°C increase in temperature. For example, the 1nA typical current at 25°C would increase to 16nA at 85°C.

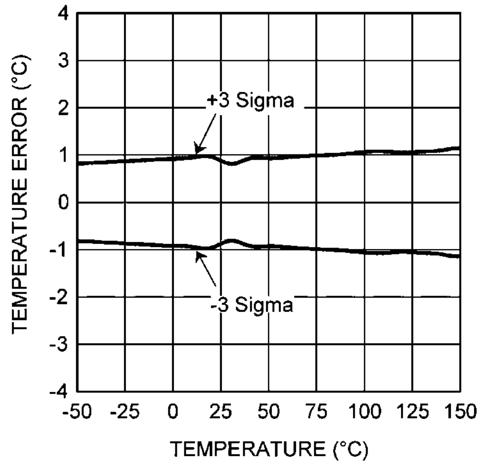
Note 11: Line regulation (DC) is calculated by subtracting the output voltage at the highest supply voltage from the output voltage at the lowest supply voltage. The typical DC line regulation specification does not include the output voltage shift discussed in Section 4.3.

Note 12: The curves shown represent typical performance under worst-case conditions. Performance improves with larger overhead ($V_{DD} – V_{TEMP}$), larger V_{DD}, and lower temperatures.

Note 13: The curves shown represent typical performance under worst-case conditions. Performance improves with larger V_{TEMP}, larger V_{DD} and lower temperatures.

Typical Performance Characteristics

V_{TEMP} Output Temperature Error vs. Temperature



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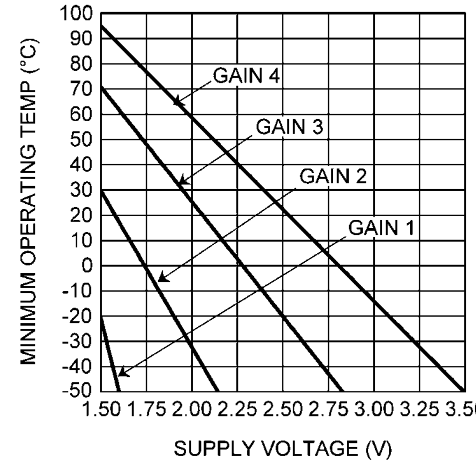
Minimum Operating Temperature vs. Supply Voltage



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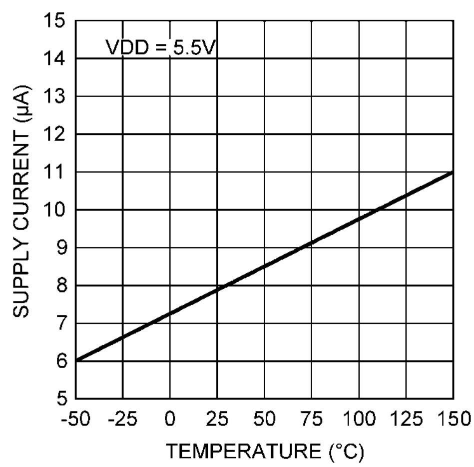
Supply Current vs. Temperature



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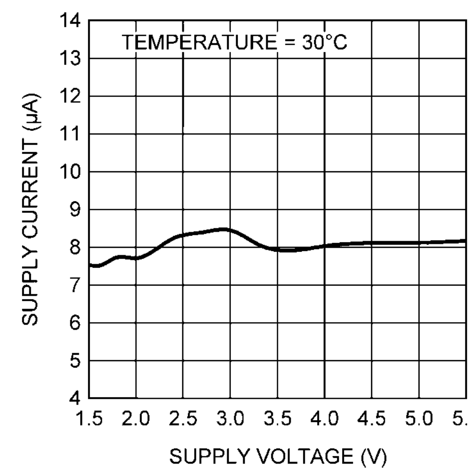
Supply Current vs. Supply Voltage



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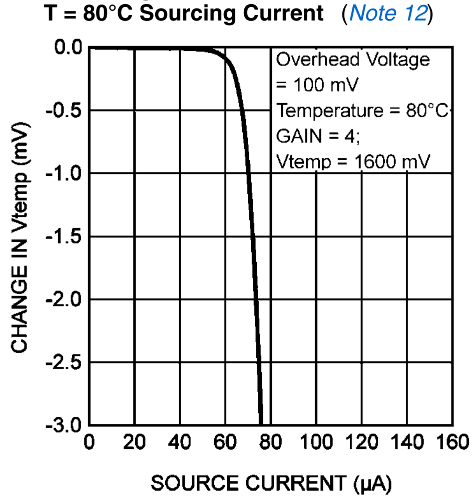
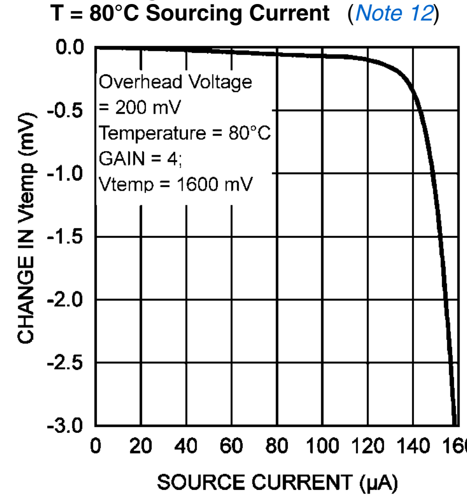
Load Regulation, 100 mV Overhead
T = 80°C Sourcing Current (Note 12)



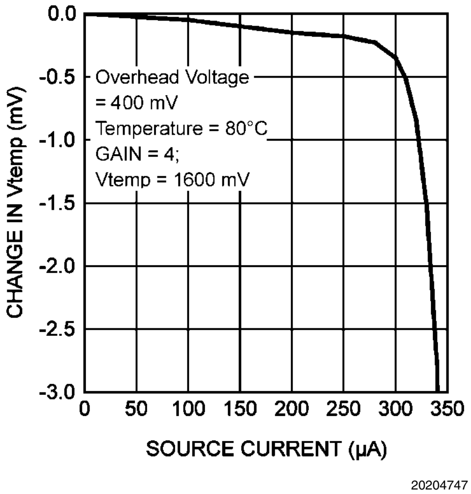
20204740

Load Regulation, 200 mV Overhead
T = 80°C Sourcing Current (Note 12)

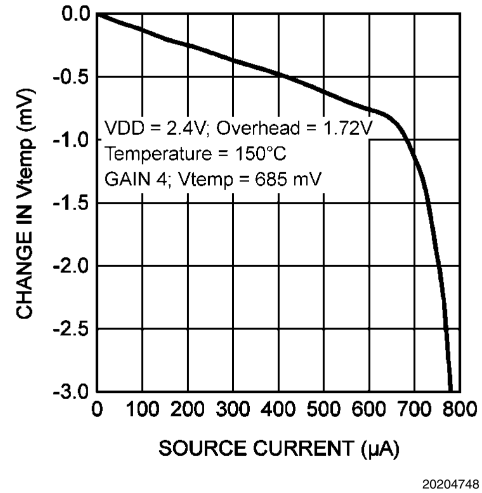


20204746

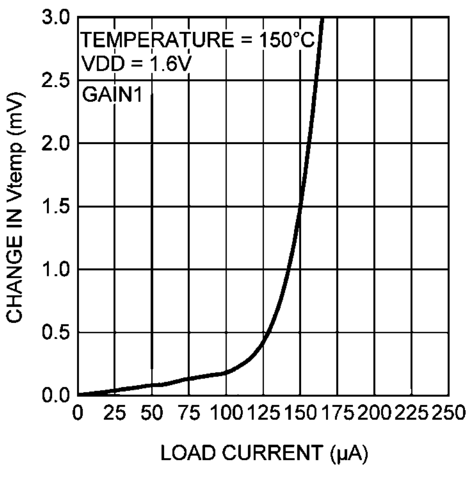
Load Regulation, 400 mV Overhead
T = 80°C Sourcing Current (Note 12)



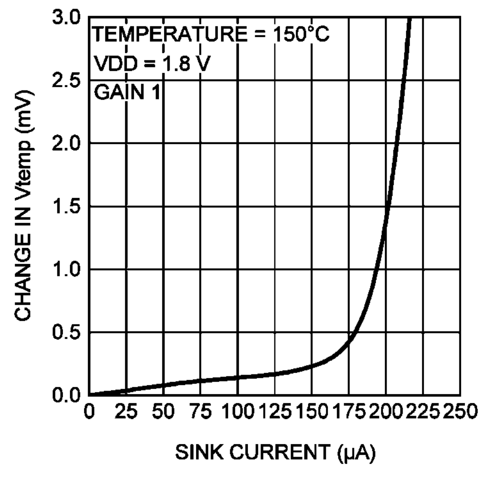
Load Regulation, 1.72V Overhead
T = 150°C, V_{DD} = 2.4V
Sourcing Current (Note 12)



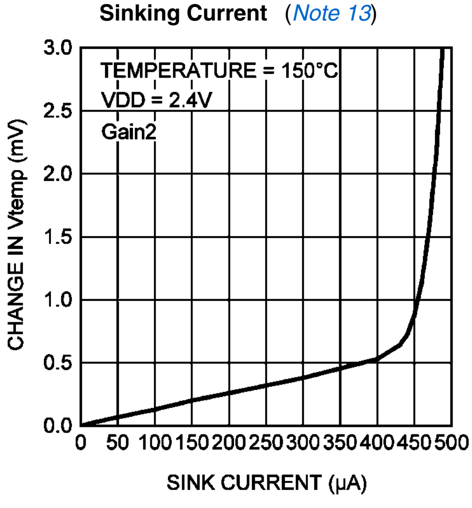
Load Regulation, V_{DD} = 1.6V
Sinking Current (Note 13)



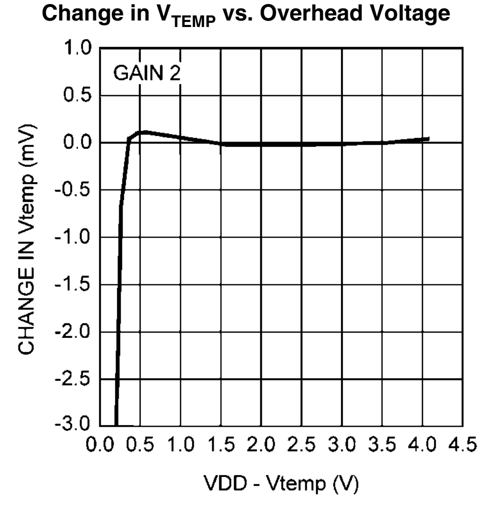
Load Regulation, V_{DD} = 1.8V
Sinking Current (Note 13)



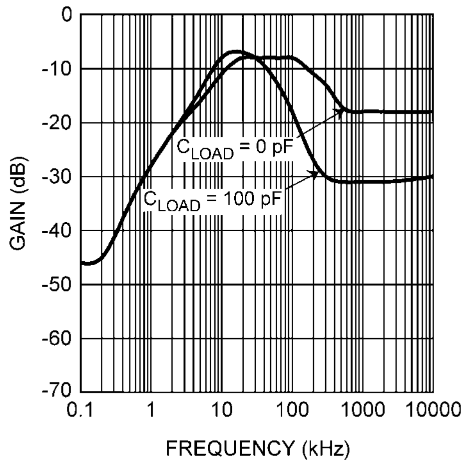
Load Regulation, V_{DD} = 2.4V
Sinking Current (Note 13)



Change in V_{TEMP} vs. Overhead Voltage



V_{TEMP} Supply-Noise Rejection vs. Frequency



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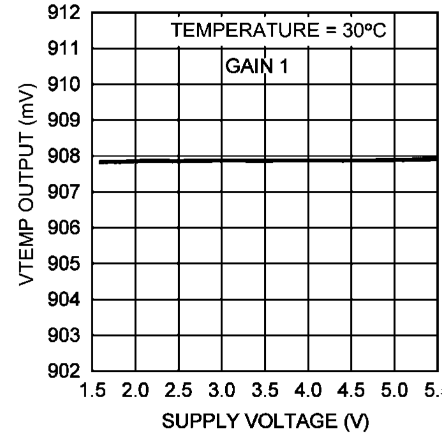
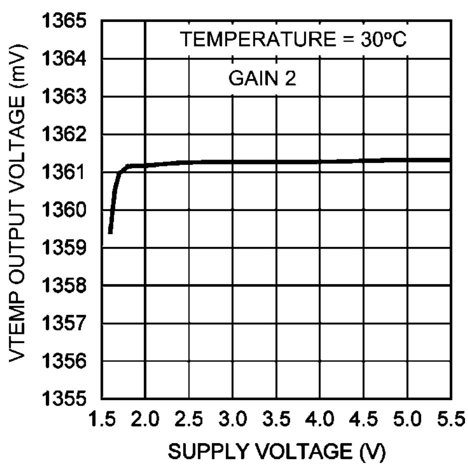
Line Regulation
V_{TEMP} vs. Supply Voltage
Gain 1: For Trip Points
0 - 69°C



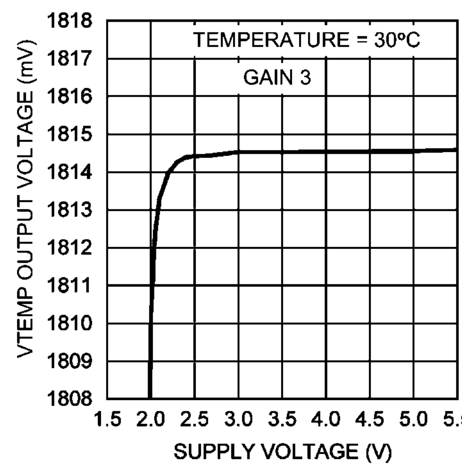
20204734

Line Regulation
V_{TEMP} vs. Supply Voltage
Gain 2: For Trip Points
70 - 109°C



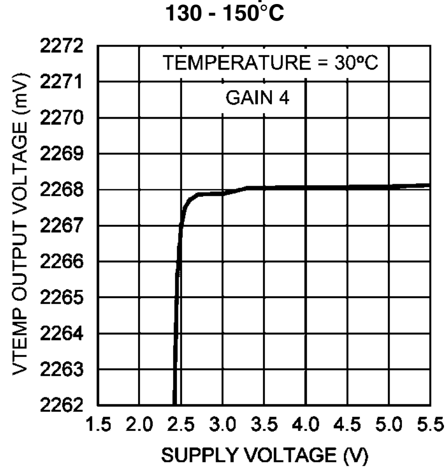
20204735

Line Regulation
V_{TEMP} vs. Supply Voltage
Gain 3: For Trip Points
110 - 129°C



20204736

Line Regulation
V_{TEMP} vs. Supply Voltage
Gain 4: For Trip Points
130 - 150°C



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1.0 LM26LV/LM26LV-Q1 V_{TEMP} vs Die Temperature Conversion Table

The LM26LV/LM26LV-Q1 has one out of four possible factory-set gains, Gain 1 through Gain 4, depending on the range of the Temperature Trip Point. The V_{TEMP} temperature sensor voltage, in millivolts, at each discrete die temperature over the complete operating temperature range, and for each of the four Temperature Trip Point ranges, is shown in the Conversion Table below. This table is the reference from which the LM26LV/LM26LV-Q1 accuracy specifications (listed in the Electrical Characteristics section) are determined. This table can be used, for example, in a host processor look-up table. See Section 1.1.1 for the parabolic equation used in the Conversion Table.

V_{TEMP} Temperature Sensor Output Voltage vs Die Temperature Conversion Table

The V_{TEMP} temperature sensor output voltage, in mV, vs Die Temperature, in °C, for each of the four gains corresponding to each of the four Temperature Trip Point Ranges. Gain 1 is the sensor gain used for Temperature Trip Point 0 - 69°C. Likewise Gain 2 is for Trip Points 70 - 109 °C; Gain 3 for 110 - 129 °C; and Gain 4 for 130 - 150 °C. V_{DD} = 5.0V. The values in **bold** font are for the Trip Point range.

Die Temp., °C	V_{TEMP}, Analog Output Voltage, mV			
	Gain 1: for T_{TRIP} = 0-69°C	Gain 2: for T_{TRIP} = 70-109°C	Gain 3: for T_{TRIP} = 110-129°C	Gain 4: for T_{TRIP} = 130-150°C
–50	1312	1967	2623	3278
–49	1307	1960	2613	3266
–48	1302	1952	2603	3253
–47	1297	1945	2593	3241
–46	1292	1937	2583	3229
–45	1287	1930	2573	3216
–44	1282	1922	2563	3204
–43	1277	1915	2553	3191
–42	1272	1908	2543	3179
–41	1267	1900	2533	3166
–40	1262	1893	2523	3154
–39	1257	1885	2513	3141
–38	1252	1878	2503	3129
–37	1247	1870	2493	3116
–36	1242	1863	2483	3104
–35	1237	1855	2473	3091
–34	1232	1848	2463	3079
–33	1227	1840	2453	3066
–32	1222	1833	2443	3054
–31	1217	1825	2433	3041
–30	1212	1818	2423	3029
–29	1207	1810	2413	3016
–28	1202	1803	2403	3004
–27	1197	1795	2393	2991
–26	1192	1788	2383	2979
–25	1187	1780	2373	2966
–24	1182	1773	2363	2954
–23	1177	1765	2353	2941
–22	1172	1757	2343	2929
–21	1167	1750	2333	2916
–20	1162	1742	2323	2903
–19	1157	1735	2313	2891
–18	1152	1727	2303	2878
–17	1147	1720	2293	2866
–16	1142	1712	2283	2853
–15	1137	1705	2272	2841

Die Temp., °C	V_{TEMP}, Analog Output Voltage, mV			
	Gain 1: for T_{TRIP} = 0-69°C	Gain 2: for T_{TRIP} = 70-109°C	Gain 3: for T_{TRIP} = 110-129°C	Gain 4: for T_{TRIP} = 130-150°C
–14	1132	1697	2262	2828
–13	1127	1690	2252	2815
–12	1122	1682	2242	2803
–11	1116	1674	2232	2790
–10	1111	1667	2222	2777
–9	1106	1659	2212	2765
–8	1101	1652	2202	2752
–7	1096	1644	2192	2740
–6	1091	1637	2182	2727
–5	1086	1629	2171	2714
–4	1081	1621	2161	2702
–3	1076	1614	2151	2689
–2	1071	1606	2141	2676
–1	1066	1599	2131	2664
0	**1061**	1591	2121	2651
1	**1056**	1583	2111	2638
2	**1051**	1576	2101	2626
3	**1046**	1568	2090	2613
4	**1041**	1561	2080	2600
5	**1035**	1553	2070	2587
6	**1030**	1545	2060	2575
7	**1025**	1538	2050	2562
8	**1020**	1530	2040	2549
9	**1015**	1522	2029	2537
10	**1010**	1515	2019	2524
11	**1005**	1507	2009	2511
12	**1000**	1499	1999	2498
13	**995**	1492	1989	2486
14	**990**	1484	1978	2473
15	**985**	1477	1968	2460
16	**980**	1469	1958	2447
17	**974**	1461	1948	2435
18	**969**	1454	1938	2422
19	**964**	1446	1927	2409
20	**959**	1438	1917	2396
21	**954**	1431	1907	2383
22	**949**	1423	1897	2371
23	**944**	1415	1886	2358
24	**939**	1407	1876	2345
25	**934**	1400	1866	2332
26	**928**	1392	1856	2319
27	**923**	1384	1845	2307
28	**918**	1377	1835	2294
29	**913**	1369	1825	2281
30	**908**	1361	1815	2268
31	**903**	1354	1804	2255

Die Temp., °C	V_{TEMP}, Analog Output Voltage, mV			
	Gain 1: for T_{TRIP} = 0-69°C	Gain 2: for T_{TRIP} = 70-109°C	Gain 3: for T_{TRIP} = 110-129°C	Gain 4: for T_{TRIP} = 130-150°C
32	**898**	1346	1794	2242
33	**892**	1338	1784	2230
34	**887**	1331	1774	2217
35	**882**	1323	1763	2204
36	**877**	1315	1753	2191
37	**872**	1307	1743	2178
38	**867**	1300	1732	2165
39	**862**	1292	1722	2152
40	**856**	1284	1712	2139
41	**851**	1276	1701	2127
42	**846**	1269	1691	2114
43	**841**	1261	1681	2101
44	**836**	1253	1670	2088
45	**831**	1245	1660	2075
46	**825**	1238	1650	2062
47	**820**	1230	1639	2049
48	**815**	1222	1629	2036
49	**810**	1214	1619	2023
50	**805**	1207	1608	2010
51	**800**	1199	1598	1997
52	**794**	1191	1588	1984
53	**789**	1183	1577	1971
54	**784**	1176	1567	1958
55	**779**	1168	1557	1946
56	**774**	1160	1546	1933
57	**769**	1152	1536	1920
58	**763**	1144	1525	1907
59	**758**	1137	1515	1894
60	**753**	1129	1505	1881
61	**748**	1121	1494	1868
62	**743**	1113	1484	1855
63	**737**	1105	1473	1842
64	**732**	1098	1463	1829
65	**727**	1090	1453	1816
66	**722**	1082	1442	1803
67	**717**	1074	1432	1790
68	**711**	1066	1421	1776
69	**706**	1059	1411	1763
70	701	**1051**	1400	1750
71	696	**1043**	1390	1737
72	690	**1035**	1380	1724
73	685	**1027**	1369	1711
74	680	**1019**	1359	1698
75	675	**1012**	1348	1685
76	670	**1004**	1338	1672
77	664	**996**	1327	1659

Die Temp., °C	V_{TEMP}, Analog Output Voltage, mV Gain 1: for T_{TRIP} = 0-69°C	Gain 2: for T_{TRIP} = 70-109°C	Gain 3: for T_{TRIP} = 110-129°C	Gain 4: for T_{TRIP} = 130-150°C
78	659	**988**	1317	1646
79	654	**980**	1306	1633
80	649	**972**	1296	1620
81	643	**964**	1285	1607
82	638	**957**	1275	1593
83	633	**949**	1264	1580
84	628	**941**	1254	1567
85	622	**933**	1243	1554
86	617	**925**	1233	1541
87	612	**917**	1222	1528
88	607	**909**	1212	1515
89	601	**901**	1201	1501
90	596	**894**	1191	1488
91	591	**886**	1180	1475
92	586	**878**	1170	1462
93	580	**870**	1159	1449
94	575	**862**	1149	1436
95	570	**854**	1138	1422
96	564	**846**	1128	1409
97	559	**838**	1117	1396
98	554	**830**	1106	1383
99	549	**822**	1096	1370
100	543	**814**	1085	1357
101	538	**807**	1075	1343
102	533	**799**	1064	1330
103	527	**791**	1054	1317
104	522	**783**	1043	1304
105	517	**775**	1032	1290
106	512	**767**	1022	1277
107	506	**759**	1011	1264
108	501	**751**	1001	1251
109	496	**743**	990	1237
110	490	735	**979**	1224
111	485	727	**969**	1211
112	480	719	**958**	1198
113	474	711	**948**	1184
114	469	703	**937**	1171
115	464	695	**926**	1158
116	459	687	**916**	1145
117	453	679	**905**	1131
118	448	671	**894**	1118
119	443	663	**884**	1105
120	437	655	**873**	1091
121	432	647	**862**	1078
122	427	639	**852**	1065
123	421	631	**841**	1051

Die Temp., °C	V_{TEMP}, Analog Output Voltage, mV			
	Gain 1: for T_{TRIP} = 0-69°C	Gain 2: for T_{TRIP} = 70-109°C	Gain 3: for T_{TRIP} = 110-129°C	Gain 4: for T_{TRIP} = 130-150°C
124	416	623	**831**	1038
125	411	615	**820**	1025
126	405	607	**809**	1011
127	400	599	**798**	998
128	395	591	**788**	985
129	389	583	**777**	971
130	384	575	766	**958**
131	379	567	756	**945**
132	373	559	745	**931**
133	368	551	734	**918**
134	362	543	724	**904**
135	357	535	713	**891**
136	352	527	702	**878**
137	346	519	691	**864**
138	341	511	681	**851**
139	336	503	670	**837**
140	330	495	659	**824**
141	325	487	649	**811**
142	320	479	638	**797**
143	314	471	627	**784**
144	309	463	616	**770**
145	303	455	606	**757**
146	298	447	595	**743**
147	293	438	584	**730**
148	287	430	573	**716**
149	282	422	562	**703**
150	277	414	552	**690**

1.1 V_{TEMP} vs DIE TEMPERATURE APPROXIMATIONS

The LM26LV/LM26LV-Q1's V_{TEMP} analog temperature output is very linear. The Conversion Table above and the equation in Section 1.1.1 represent the most accurate typical performance of the V_{TEMP} voltage output vs Temperature.

1.1.1 The Second-Order Equation (Parabolic)

The data from the Conversion Table, or the equation below, when plotted, has an umbrella-shaped parabolic curve. V_{TEMP} is in mV.

$$\text{GAIN1:}\quad V_{TEMP} = 907.9 - 5.132 \times (T_{DIE} - 30°C) - 1.08e\text{-}3 \times (T_{DIE} - 30°C)^2$$

$$\text{GAIN2:}\quad V_{TEMP} = 1361.4 - 7.701 \times (T_{DIE} - 30°C) - 1.60e\text{-}3 \times (T_{DIE} - 30°C)^2$$

$$\text{GAIN3:}\quad V_{TEMP} = 1814.6 - 10.270 \times (T_{DIE} - 30°C) - 2.12e\text{-}3 \times (T_{DIE} - 30°C)^2$$

$$\text{GAIN4:}\quad V_{TEMP} = 2268.1 - 12.838 \times (T_{DIE} - 30°C) - 2.64e\text{-}3 \times (T_{DIE} - 30°C)^2$$

1.1.2 The First-Order Approximation (Linear)

For a quicker approximation, although less accurate than the second-order, over the full operating temperature range the linear formula below can be used. Using this formula, with the constant and slope in the following set of equations, the best-fit V_{TEMP} vs Die Temperature performance can be calculated with an approximation error less than 18 mV. V_{TEMP} is in mV.

$$\text{GAIN1: } V_{TEMP} = 1060 - 5.18 \times T_{DIE}$$

$$\text{GAIN2: } V_{TEMP} = 1590 - 7.77 \times T_{DIE}$$

$$\text{GAIN3: } V_{TEMP} = 2119 - 10.36 \times T_{DIE}$$

$$\text{GAIN4: } V_{TEMP} = 2649 - 12.94 \times T_{DIE}$$

1.1.3 First-Order Approximation (Linear) over Small Temperature Range

For a linear approximation, a line can easily be calculated over the desired temperature range from the Conversion Table using the two-point equation:

$$V - V_1 = \left(\frac{V_2 - V_1}{T_2 - T_1}\right) \times (T - T_1)$$

Where V is in mV, T is in °C, T_1 and V_1 are the coordinates of the lowest temperature, T_2 and V_2 are the coordinates of the highest temperature.

For example, if we want to determine the equation of a line with Gain 4, over a temperature range of 20°C to 50°C, we would proceed as follows:

$$V - 2396\text{ mV} = \left(\frac{2010\text{ mV} - 2396\text{ mV}}{50°\text{C} - 20°\text{C}}\right) \times (T - 20°\text{C})$$

$$V - 2396\text{ mV} = (-12.8\text{ mV/°C}) \times (T - 20°\text{C})$$

$$V = (-12.8\text{ mV/°C}) \times (T - 20°\text{C}) + 2396\text{ mV}$$

Using this method of linear approximation, the transfer function can be approximated for one or more temperature ranges of interest.

2.0 OVERTEMP and $\overline{\text{OVERTEMP}}$ Digital Outputs

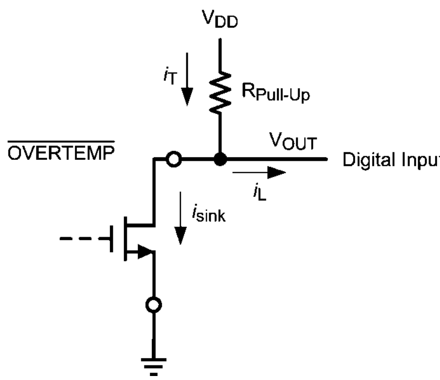
The OVERTEMP Active High, Push-Pull Output and the $\overline{\text{OVERTEMP}}$ Active Low, Open-Drain Output both assert at the same time whenever the Die Temperature reaches the factory preset Temperature Trip Point. They also assert simultaneously whenever the TRIP TEST pin is set high. Both outputs de-assert when the die temperature goes below the Temperature Trip Point - Hysteresis. These two types of digital outputs enable the user the flexibility to choose the type of output that is most suitable for his design.

Either the OVERTEMP or the $\overline{\text{OVERTEMP}}$ Digital Output pins can be left open if not used.

2.1 $\overline{\text{OVERTEMP}}$ OPEN-DRAIN DIGITAL OUTPUT

The $\overline{\text{OVERTEMP}}$ Active Low, Open-Drain Digital Output, if used, requires a pull-up resistor between this pin and V_{DD}. The following section shows how to determine the pull-up resistor value.

Determining the Pull-up Resistor Value



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The Pull-up resistor value is calculated at the condition of maximum total current, i_T, through the resistor. The total current is:

$$i_T = i_L + i_{sink}$$

where,

i_T	i_T is the maximum total current through the Pull-up Resistor at V_{OL}.
i_L	i_L is the load current, which is very low for typical digital inputs.
V_{OUT}	V_{OUT} is the Voltage at the $\overline{\text{OVERTEMP}}$ pin. Use V_{OL} for calculating the Pull-up resistor.
$V_{DD(Max)}$	$V_{DD(Max)}$ is the maximum power supply voltage to be used in the customer's system.

The pull-up resistor maximum value can be found by using the following formula:

$$R_{pull\text{-}up} = \frac{V_{DD\,(Max)} - V_{OL}}{i_T}$$

EXAMPLE CALCULATION

Suppose we have, for our example, a V_{DD} of 3.3 V ± 0.3V, a CMOS digital input as a load, a V_{OL} of 0.2 V.

(1) We see that for V_{OL} of 0.2 V the electrical specification for $\overline{\text{OVERTEMP}}$ shows a maximim i_{sink} of 385 µA.

(2) Let i_L= 1 µA, then i_T is about 386 µA max. If we select 35 µA as the current limit then i_T for the calculation becomes 35 µA

(3) We notice that $V_{DD(Max)}$ is 3.3V + 0.3V = 3.6V and then calculate the pull-up resistor as

$R_{Pull\text{-}up}$ = (3.6 – 0.2)/35 µA = 97k

(4) Based on this calculated value, we select the closest resistor value in the tolerance family we are using.

In our example, if we are using 5% resistor values, then the next closest value is 100 kΩ.

2.2 NOISE IMMUNITY

The LM26LV/LM26LV-Q1 is virtually immune from false triggers on the OVERTEMP and $\overline{\text{OVERTEMP}}$ digital outputs due to noise on the power supply. Test have been conducted showing that, with the die temperature within 0.5°C of the temperature trip point, and the severe test of a 3 Vpp square wave "noise" signal injected on the V_{DD} line, over the V_{DD} range of 2V to 5V, there were no false triggers.

3.0 TRIP TEST Digital Input

The TRIP TEST pin simply provides a means to test the OVERTEMP and $\overline{\text{OVERTEMP}}$ digital outputs electronically by causing them to assert, at any operating temperature, as a result of forcing the TRIP TEST pin high.

When the TRIP TEST pin is pulled high the V_{TEMP} pin will be at the V_{TRIP} voltage.

If not used, the TRIP TEST pin may either be left open or grounded.

4.0 V_{TEMP} Analog Temperature Sensor Output

The V_{TEMP} push-pull output provides the ability to sink and source significant current. This is beneficial when, for example, driving dynamic loads like an input stage on an analog-to-digital converter (ADC). In these applications the source current is required to quickly charge the input capacitor of the ADC. See the Applications Circuits section for more discussion of this topic. The LM26LV/LM26LV-Q1 is ideal for this and other applications which require strong source or sink current.

4.1 NOISE CONSIDERATIONS

The LM26LV/LM26LV-Q1's supply-noise rejection (the ratio of the AC signal on V_{TEMP} to the AC signal on V_{DD}) was measured during bench tests. It's typical attenuation is shown in the Typical Performance Characteristics section. A load capacitor on the output can help to filter noise.

For operation in very noisy environments, some bypass capacitance should be present on the supply within approximately 2 inches of the LM26LV/LM26LV-Q1.

4.2 CAPACITIVE LOADS

The V_{TEMP} Output handles capacitive loading well. In an extremely noisy environment, or when driving a switched sampling input on an ADC, it may be necessary to add some filtering to minimize noise coupling. Without any precautions, the V_{TEMP} can drive a capacitive load less than or equal to 1100 pF as shown in *Figure 1*. For capacitive loads greater than 1100 pF, a series resistor is required on the output, as shown in *Figure 2*, to maintain stable conditions.

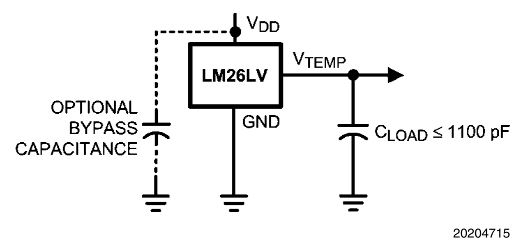
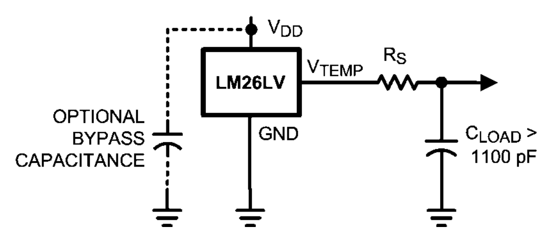


FIGURE 1. LM26LV/LM26LV-Q1 No Decoupling Required for Capacitive Loads Less than 1100pF.



C_{LOAD}	Minimum R_S
1.1 nF to 99 nF	3 kΩ
100 nF to 999 nF	1.5 kΩ
1 µF	800 Ω

FIGURE 2. LM26LV/LM26LV-Q1 with series resistor for capacitive loading greater than 1100pF.

4.3 VOLTAGE SHIFT

The LM26LV/LM26LV-Q1 is very linear over temperature and supply voltage range. Due to the intrinsic behavior of an NMOS/PMOS rail-to-rail buffer, a slight shift in the output can occur when the supply voltage is ramped over the operating range of the device. The location of the shift is determined by the relative levels of V_{DD} and V_{TEMP}. The shift typically occurs when $V_{DD} - V_{TEMP} = 1.0V$.

This slight shift (a few millivolts) takes place over a wide change (approximately 200 mV) in V_{DD} or V_{TEMP}. Since the shift takes place over a wide temperature change of 5°C to 20°C, V_{TEMP} is always monotonic. The accuracy specifications in the Electrical Characteristics table already includes this possible shift.

5.0 Mounting and Temperature Conductivity

The LM26LV/LM26LV-Q1 can be applied easily in the same way as other integrated-circuit temperature sensors. It can be glued or cemented to a surface.

The best thermal conductivity between the device and the PCB is achieved by soldering the DAP of the package to the thermal pad on the PCB. The temperatures of the lands and traces to the other leads of the LM26LV/LM26LV-Q1 will also affect the temperature reading.

Alternatively, the LM26LV/LM26LV-Q1 can be mounted inside a sealed-end metal tube, and can then be dipped into a bath or screwed into a threaded hole in a tank. As with any IC, the LM26LV/LM26LV-Q1 and accompanying wiring and circuits must be kept insulated and dry, to avoid leakage and corrosion. This is especially true if the circuit may operate at cold temperatures where condensation can occur. If moisture creates a short circuit from the V_{TEMP} output to ground or V_{DD}, the V_{TEMP} output from the LM26LV/LM26LV-Q1 will not be correct. Printed-circuit coatings are often used to ensure that moisture cannot corrode the leads or circuit traces.

The thermal resistance junction-to-ambient (θ_{JA}) is the parameter used to calculate the rise of a device junction temperature due to its power dissipation. The equation used to calculate the rise in the LM26LV/LM26LV-Q1's die temperature is

$$T_J = T_A + \theta_{JA} \left[(V_{DD} I_Q) + (V_{DD} - V_{TEMP}) \; I_L \right]$$

where T_A is the ambient temperature, I_Q is the quiescent current, I_L is the load current on the output, and V_O is the output voltage. For example, in an application where T_A = 30 °C, V_{DD} = 5 V, I_{DD} = 9 µA, Gain 4, V_{TEMP} = 2231 mV, and I_L = 2 µA, the junction temperature would be 30.021 °C, showing a self-heating error of only 0.021°C. Since the LM26LV/LM26LV-Q1's junction temperature is the actual temperature being measured, care should be taken to minimize the load current that the V_{TEMP} output is required to drive. If The $\overline{\text{OVERTEMP}}$ output is used with a 100 k pull-up resistor, and this output is asserted (low), then for this example the additional contribution is [(152° C/W)x(5V)²/100k] = 0.038°C for a total self-heating error of 0.059°C. *Figure 3* shows the thermal resistance of the LM26LV/LM26LV-Q1.

Device Number	NS Package Number	Thermal Resistance (θ_{JA})
LM26LVCSID/ LM26LVQCISD	SDB06A	152° C/W

FIGURE 3. LM26LV/LM26LV-Q1 Thermal Resistance

6.0 Applications Circuits

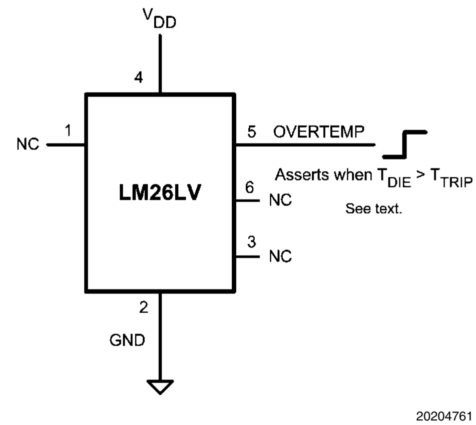


FIGURE 4. Temperature Switch Using Push-Pull Output

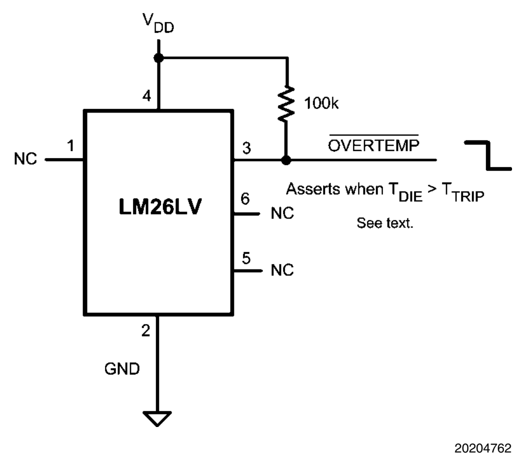


FIGURE 5. Temperature Switch Using Open-Drain Output

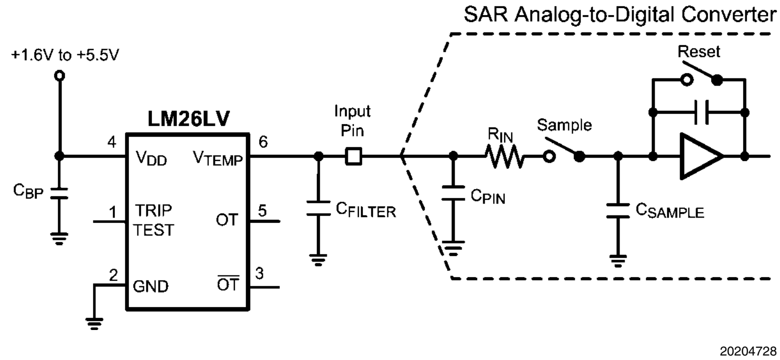
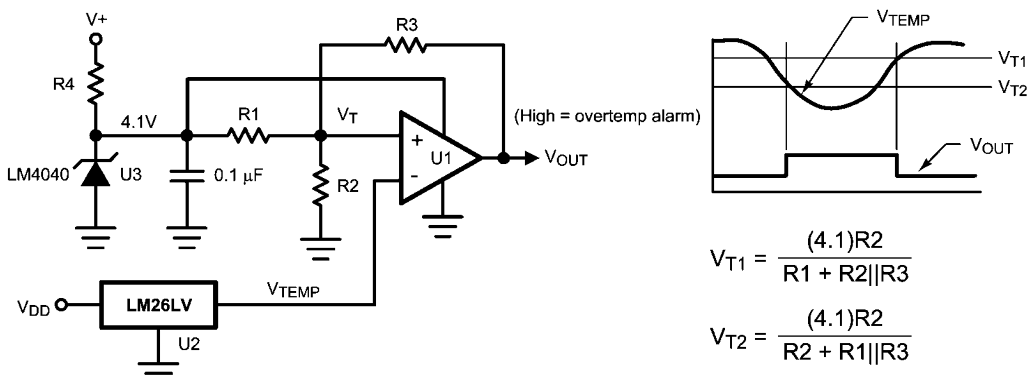


FIGURE 6. Suggested Connection to a Sampling Analog-to-Digital Converter Input Stage

Most CMOS ADCs found in microcontrollers and ASICs have a sampled data comparator input structure. When the ADC charges the sampling cap, it requires instantaneous charge from the output of the analog source such as the LM26LV/LM26LV-Q1 temperature sensor and many op amps. This requirement is easily accommodated by the addition of a capacitor (C_{FILTER}). The size of C_{FILTER} depends on the size of the sampling capacitor and the sampling frequency. Since not all ADCs have identical input stages, the charge requirements will vary. This general ADC application is shown as an example only.



$$V_{T1} = \frac{(4.1)R2}{R1 + R2||R3}$$

$$V_{T2} = \frac{(4.1)R2}{R2 + R1||R3}$$

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FIGURE 7. Celsius Temperature Switch

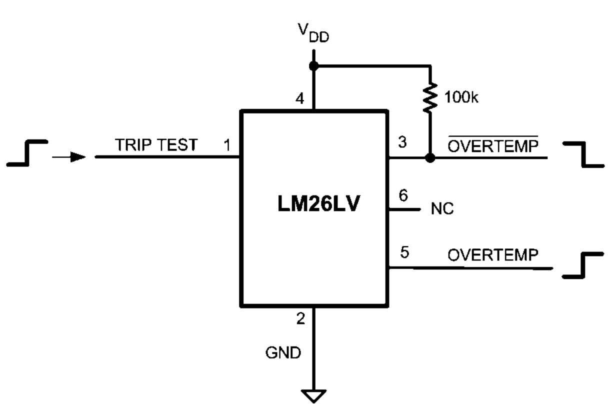


FIGURE 8. TRIP TEST Digital Output Test Circuit

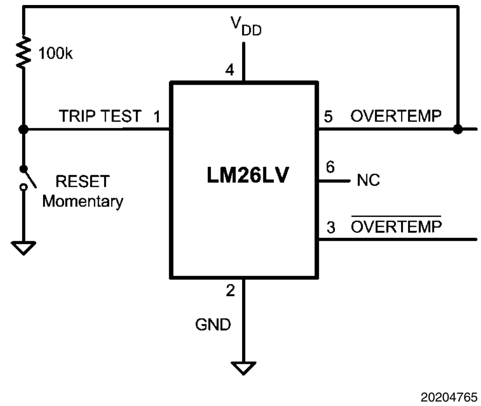
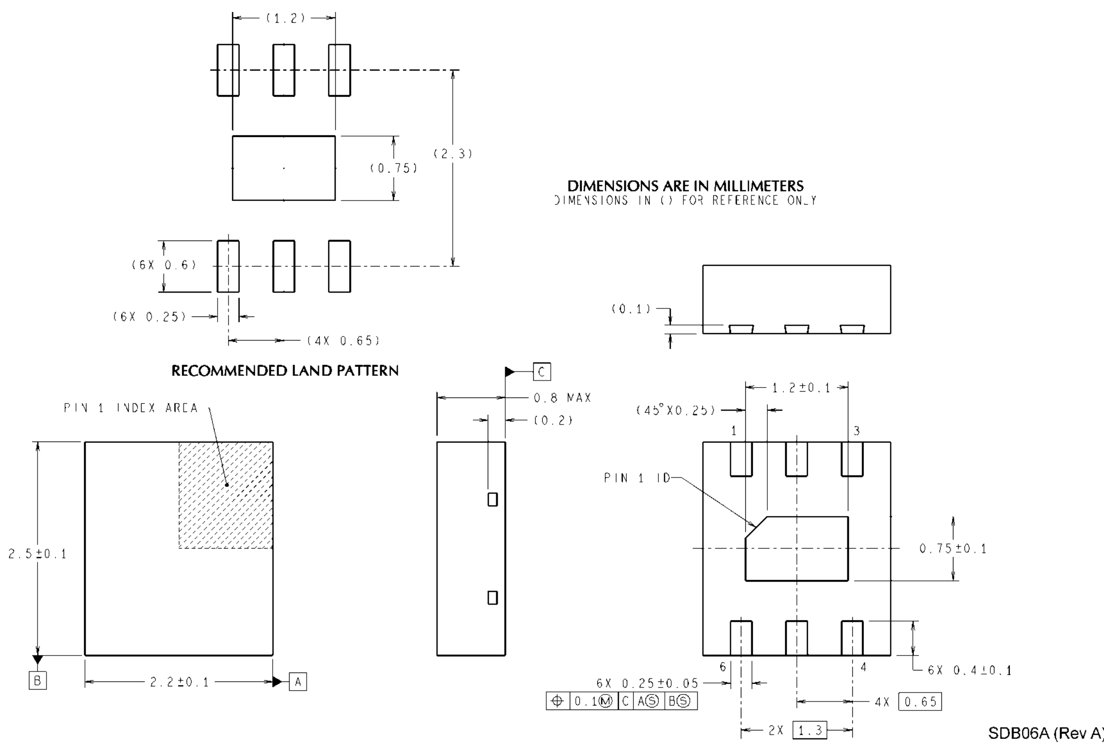


FIGURE 9. Latch Circuit using OVERTEMP Output

The TRIP TEST pin, normally used to check the operation of the OVERTEMP and $\overline{\text{OVERTEMP}}$ pins, may be used to latch the outputs whenever the temperature exceeds the programmed limit and causes the digital outputs to assert. As shown in the figure, when OVERTEMP goes high the TRIP TEST input is also pulled high and causes OVERTEMP output to latch high and the $\overline{\text{OVERTEMP}}$ output to latch low. The latch can be released by either momentarily pulling the TRIP TEST pin low (GND), or by toggling the power supply to the device. The resistor limits the current out of the OVERTEMP output pin.

Physical Dimensions inches (millimeters) unless otherwise noted



6-Lead LLP-6 Package
Order Number LM26LVCISD/LM26LVCISDX, LM26LVQISD/LM26LVQISDX
NS Package Number SDB06A

Notes