

LM26LV

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

General Description

The LM26LV 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 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 **OVERTEMP** digital output, is active-low with an open-drain structure.

An analog output, V_{TEMP} , delivers an analog output voltage which is inversely proportional to the measured temperature.

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'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
- Wireless Transceivers
- Digital Cameras
- Personal Digital Assistants (PDA's)
- Battery Management

- Automotive
- Disk Drives
- Games
- Appliances

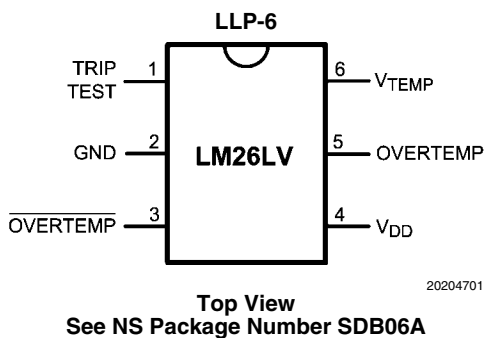
Features

- Low 1.6V operation
- Low quiescent current
- 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

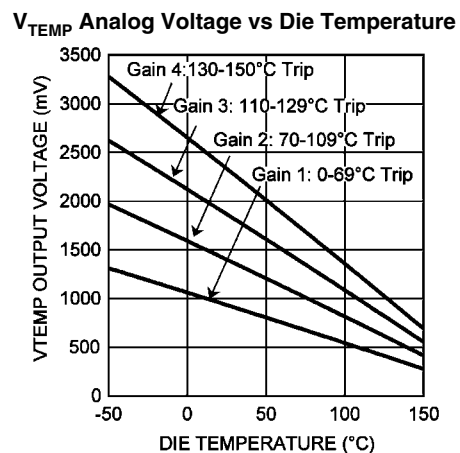
Key Specifications

■ Supply Voltage	1.6V to 5.5V
■ Supply Current	8 μ A (typ)
■ Accuracy, Trip Point Temperature	0°C to 150°C $\pm 2.2^\circ$ C
■ Accuracy, V_{TEMP}	0°C to 150°C $\pm 2.3^\circ$ C 0°C to 120°C $\pm 2.2^\circ$ C -50°C to 0°C $\pm 1.7^\circ$ C
■ V_{TEMP} Output Drive	$\pm 100 \mu$ A
■ Operating Temperature	-50°C to 150°C
■ Hysteresis Temperature	4.5°C to 5.5°C

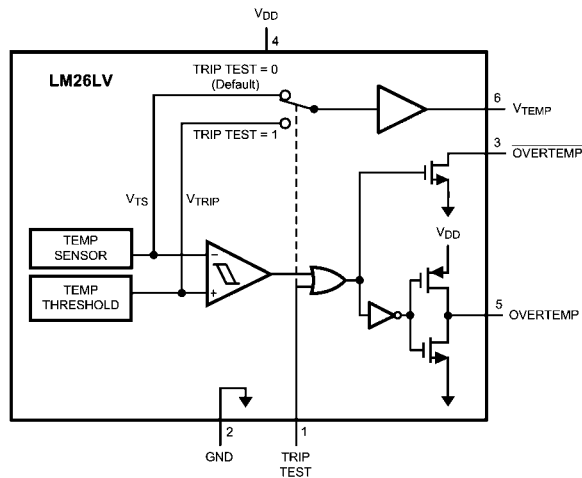
Connection Diagram



Typical Transfer Characteristic



Block Diagram

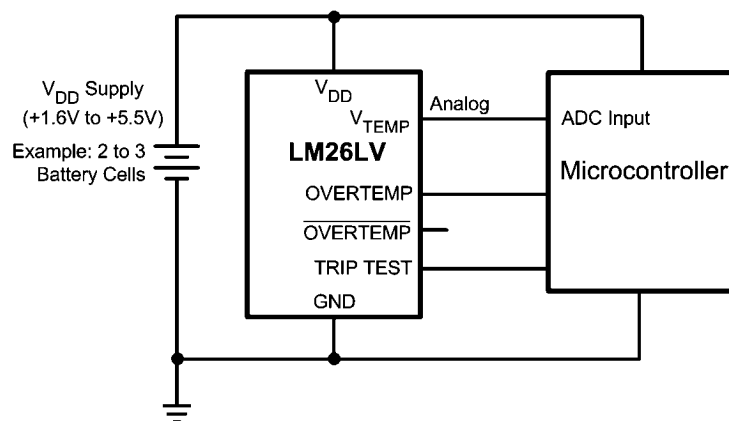


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Pin Descriptions

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: $\overline{OVERTEMP}$ and $\overline{OVERTEMP}$ 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	$\overline{OVERTEMP}$	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.
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

Typical Application



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Ordering Information

Order Number	Temperature Trip Point, °C	NS Package Number	Top Mark	Transport Media
LM26LVCISD-150	150°C	SDB06A	150	1000 Units on Tape and Reel
LM26LVCISDX-150	150°C	SDB06A	150	4500 Units on Tape and Reel
LM26LVCISD-145	145°C	SDB06A	145	1000 Units on Tape and Reel
LM26LVCISDX-145	145°C	SDB06A	145	4500 Units on Tape and Reel
LM26LVCISD-140	140°C	SDB06A	140	1000 Units on Tape and Reel
LM26LVCISDX-140	140°C	SDB06A	140	4500 Units on Tape and Reel
LM26LVCISD-135	135°C	SDB06A	135	1000 Units on Tape and Reel
LM26LVCISDX-135	135°C	SDB06A	135	4500 Units on Tape and Reel
LM26LVCISD-130	130°C	SDB06A	130	1000 Units on Tape and Reel
LM26LVCISDX-130	130°C	SDB06A	130	4500 Units on Tape and Reel
LM26LVCISD-125	125°C	SDB06A	125	1000 Units on Tape and Reel
LM26LVCISDX-125	125°C	SDB06A	125	4500 Units on Tape and Reel
LM26LVCISD-120	120°C	SDB06A	120	1000 Units on Tape and Reel
LM26LVCISDX-120	120°C	SDB06A	120	4500 Units on Tape and Reel
LM26LVCISD-115	115°C	SDB06A	115	1000 Units on Tape and Reel
LM26LVCISDX-115	115°C	SDB06A	115	4500 Units on Tape and Reel
LM26LVCISD-110	110°C	SDB06A	110	1000 Units on Tape and Reel
LM26LVCISDX-110	110°C	SDB06A	110	4500 Units on Tape and Reel
LM26LVCISD-105	105°C	SDB06A	105	1000 Units on Tape and Reel
LM26LVCISDX-105	105°C	SDB06A	105	4500 Units on Tape and Reel
LM26LVCISD-100	100°C	SDB06A	100	1000 Units on Tape and Reel
LM26LVCISDX-100	100°C	SDB06A	100	4500 Units on Tape and Reel
LM26LVCISD-095	95°C	SDB06A	095	1000 Units on Tape and Reel
LM26LVCISDX-095	95°C	SDB06A	095	4500 Units on Tape and Reel
LM26LVCISD-090	90°C	SDB06A	090	1000 Units on Tape and Reel
LM26LVCISDX-090	90°C	SDB06A	090	4500 Units on Tape and Reel
LM26LVCISD-085	85°C	SDB06A	085	1000 Units on Tape and Reel
LM26LVCISDX-085	85°C	SDB06A	085	4500 Units on Tape and Reel
LM26LVCISD-080	80°C	SDB06A	080	1000 Units on Tape and Reel
LM26LVCISDX-080	80°C	SDB06A	080	4500 Units on Tape and Reel
LM26LVCISD-075	75°C	SDB06A	075	1000 Units on Tape and Reel
LM26LVCISDX-075	75°C	SDB06A	075	4500 Units on Tape and Reel
LM26LVCISD-070	70°C	SDB06A	070	1000 Units on Tape and Reel
LM26LVCISDX-070	70°C	SDB06A	070	4500 Units on Tape and Reel
LM26LVCISD-065	65°C	SDB06A	065	1000 Units on Tape and Reel
LM26LVCISDX-065	65°C	SDB06A	065	4500 Units on Tape and Reel
LM26LVCISD-060	60°C	SDB06A	060	1000 Units on Tape and Reel
LM26LVCISDX-060	60°C	SDB06A	060	4500 Units on Tape and Reel
LM26LVCISD-050	50°C	SDB06A	050	1000 Units on Tape and Reel
LM26LVCISDX-050	50°C	SDB06A	050	4500 Units on Tape and Reel

Absolute Maximum Ratings (Note 1)

Supply Voltage	−0.2V to +6.0V
Voltage at $\overline{\text{OVERTEMP}}$ pin	−0.2V to +6.0V
Voltage at $\overline{\text{OVERTEMP}}$ and V_{TEMP} pins	−0.2V to ($V_{\text{DD}} + 0.5\text{V}$)
TRIP TEST Input Voltage	−0.2V to ($V_{\text{DD}} + 0.5\text{V}$)
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	
$T_{\text{J(MAX)}}$	+155°C
ESD Susceptibility (Note 3) :	
Human Body Model	4500V

Machine Model 300V
 Charged Device Model 1000V
Soldering process must comply with National's Reflow Temperature Profile specifications. Refer to www.national.com/packaging. (Note 4)

Operating Ratings (Note 1)

Specified Temperature Range:	$T_{\text{MIN}} \leq T_{\text{A}} \leq T_{\text{MAX}}$
LM26LV	−50°C $\leq T_{\text{A}} \leq$ +150°C
Supply Voltage Range (V_{DD})	+1.6 V to +5.5 V
Thermal Resistance (θ_{JA}) (Note 5)	
LLP-6 (Package SDB06A)	152 °C/W

Accuracy Characteristics**Trip Point Accuracy**

Parameter	Conditions		Limits (Note 7)	Units (Limit)
Trip Point Accuracy (Note 8)	0 – 150°C	$V_{\text{DD}} = 5.0 \text{ V}$	±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 Conversion Table.

Parameter	Conditions			Limits (Note 7)	Units (Limit)
V_{TEMP} Temperature Accuracy (Note 8)	Gain 1: for Trip Point Range 0 - 69°C	$T_{\text{A}} = 20^\circ\text{C to } 40^\circ\text{C}$	$V_{\text{DD}} = 1.6 \text{ to } 5.5 \text{ V}$	±1.8	°C (max)
		$T_{\text{A}} = 0^\circ\text{C to } 70^\circ\text{C}$	$V_{\text{DD}} = 1.6 \text{ to } 5.5 \text{ V}$	±2.0	
		$T_{\text{A}} = 0^\circ\text{C to } 90^\circ\text{C}$	$V_{\text{DD}} = 1.6 \text{ to } 5.5 \text{ V}$	±2.1	
		$T_{\text{A}} = 0^\circ\text{C to } 120^\circ\text{C}$	$V_{\text{DD}} = 1.6 \text{ to } 5.5 \text{ V}$	±2.2	
		$T_{\text{A}} = 0^\circ\text{C to } 150^\circ\text{C}$	$V_{\text{DD}} = 1.6 \text{ to } 5.5 \text{ V}$	±2.3	
		$T_{\text{A}} = -50^\circ\text{C to } 0^\circ\text{C}$	$V_{\text{DD}} = 1.7 \text{ to } 5.5 \text{ V}$	±1.7	
	Gain 2: for Trip Point Range 70 - 109°C	$T_{\text{A}} = 20^\circ\text{C to } 40^\circ\text{C}$	$V_{\text{DD}} = 1.8 \text{ to } 5.5 \text{ V}$	±1.8	°C (max)
		$T_{\text{A}} = 0^\circ\text{C to } 70^\circ\text{C}$	$V_{\text{DD}} = 1.9 \text{ to } 5.5 \text{ V}$	±2.0	
		$T_{\text{A}} = 0^\circ\text{C to } 90^\circ\text{C}$	$V_{\text{DD}} = 1.9 \text{ to } 5.5 \text{ V}$	±2.1	
		$T_{\text{A}} = 0^\circ\text{C to } 120^\circ\text{C}$	$V_{\text{DD}} = 1.9 \text{ to } 5.5 \text{ V}$	±2.2	
		$T_{\text{A}} = 0^\circ\text{C to } 150^\circ\text{C}$	$V_{\text{DD}} = 1.9 \text{ to } 5.5 \text{ V}$	±2.3	
		$T_{\text{A}} = -50^\circ\text{C to } 0^\circ\text{C}$	$V_{\text{DD}} = 2.3 \text{ to } 5.5 \text{ V}$	±1.7	
	Gain 3: for Trip Point Range 110 - 129°C	$T_{\text{A}} = 20^\circ\text{C to } 40^\circ\text{C}$	$V_{\text{DD}} = 2.3 \text{ to } 5.5 \text{ V}$	±1.8	°C (max)
		$T_{\text{A}} = 0^\circ\text{C to } 70^\circ\text{C}$	$V_{\text{DD}} = 2.5 \text{ to } 5.5 \text{ V}$	±2.0	
		$T_{\text{A}} = 0^\circ\text{C to } 90^\circ\text{C}$	$V_{\text{DD}} = 2.5 \text{ to } 5.5 \text{ V}$	±2.1	
		$T_{\text{A}} = 0^\circ\text{C to } 120^\circ\text{C}$	$V_{\text{DD}} = 2.5 \text{ to } 5.5 \text{ V}$	±2.2	
		$T_{\text{A}} = 0^\circ\text{C to } 150^\circ\text{C}$	$V_{\text{DD}} = 2.5 \text{ to } 5.5 \text{ V}$	±2.3	
		$T_{\text{A}} = -50^\circ\text{C to } 0^\circ\text{C}$	$V_{\text{DD}} = 3.0 \text{ to } 5.5 \text{ V}$	±1.7	
	Gain 4: for Trip Point Range 130 - 150°C	$T_{\text{A}} = 20^\circ\text{C to } 40^\circ\text{C}$	$V_{\text{DD}} = 2.7 \text{ to } 5.5 \text{ V}$	±1.8	°C (max)
		$T_{\text{A}} = 0^\circ\text{C to } 70^\circ\text{C}$	$V_{\text{DD}} = 3.0 \text{ to } 5.5 \text{ V}$	±2.0	
		$T_{\text{A}} = 0^\circ\text{C to } 90^\circ\text{C}$	$V_{\text{DD}} = 3.0 \text{ to } 5.5 \text{ V}$	±2.1	
		$T_{\text{A}} = 0^\circ\text{C to } 120^\circ\text{C}$	$V_{\text{DD}} = 3.0 \text{ to } 5.5 \text{ V}$	±2.2	
		$T_{\text{A}} = 0^\circ\text{C to } 150^\circ\text{C}$	$V_{\text{DD}} = 3.0 \text{ to } 5.5 \text{ V}$	±2.3	
		$T_{\text{A}} = -50^\circ\text{C to } 0^\circ\text{C}$	$V_{\text{DD}} = 3.6 \text{ to } 5.5 \text{ V}$	±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 $T_A = T_J = 25^\circ C$.

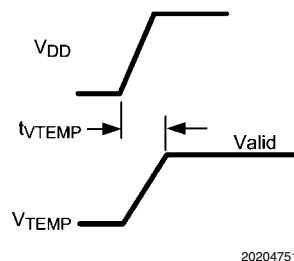
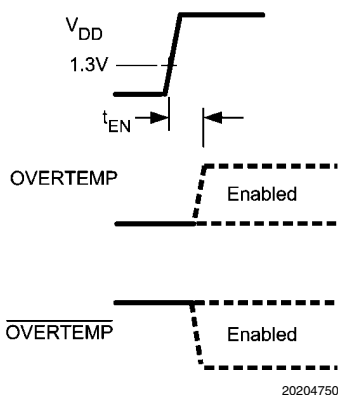
Symbol	Parameter	Conditions		Typical (Note 6)	Limits (Note 7)	Units (Limit)
GENERAL SPECIFICATIONS						
I _S	Quiescent Power Supply Current			8	16	μA (max)
	Hysteresis			5	5.5 4.5	°C (max) °C (Min)
OVERTEMP DIGITAL OUTPUT		ACTIVE HIGH, PUSH-PULL				
V _{OH}	Logic "1" Output Voltage	V _{DD} ≥ 1.6V	Source ≤ 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			
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			
OVERTEMP DIGITAL OUTPUT		ACTIVE LOW, OPEN DRAIN				
I _{OH}	Logic "1" Output Leakage Current (Note 12)	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 10)	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		Ohm
	V _{DD} Supply- to-V _{TEMP} DC Line Regulation (Note 13)	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 $T_A = T_J = 25^\circ C$.

Symbol	Parameter	Conditions	Typical (Note 6)	Limits (Note 7)	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 12)		0.001	1	μA (max)
TIMING					
t_{EN}	Time from Power On to Digital Output Enabled. See definition below. (Note 11).		1.1	2.3	ms (max)
$t_{V_{TEMP}}$	Time from Power On to Analog Temperature Valid. See definition below. (Note 11)		0.9	10	ms (max)

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



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Notes

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 ($V_I < \text{GND}$ or $V_I > V_{DD}$), the current at that pin should be limited to 5 mA.

Note 3: The Human Body Model (HBM) is a 100 pF capacitor charged to the specified voltage then discharged through a 1.5 k Ω resistor into each pin. The Machine Model (MM) is a 200 pF 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: Reflow temperature profiles are different for lead-free and non-lead-free packages.

Note 5: The junction to ambient temperature resistance (θ_{JA}) is specified without a heat sink in still air.

Note 6: Typicals are at $T_J = T_A = 25^\circ\text{C}$ and represent most likely parametric norm.

Note 7: Limits are guaranteed to National's AOQL (Average Outgoing Quality Level).

Note 8: 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 $^\circ\text{C}$). Accuracy limits include line regulation within the specified conditions. Accuracy limits do not include load regulation; they assume no DC load.

Note 9: Changes in output due to self heating can be computed by multiplying the internal dissipation by the temperature resistance.

Note 10: Source currents are flowing out of the LM26LV. Sink currents are flowing into the LM26LV.

Note 11: Guaranteed by design.

Note 12: The 1 μA 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 1 nA typical current at 25°C would increase to 16 nA at 85°C .

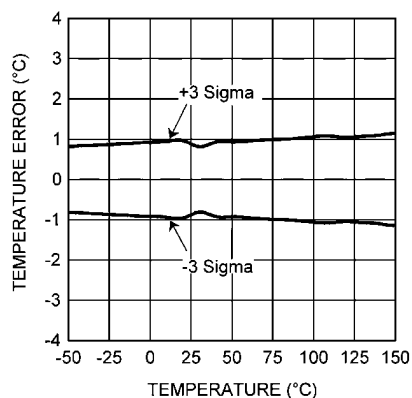
Note 13: Line regulation (DC) is calculated by subtracting the output voltage at the highest supply voltage from the output voltage at the lowest supply voltage. The typical DC line regulation specification does not include the output voltage shift discussed in Section 4.3.

Note 14: 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 15: The curves shown represent typical performance under worst-case conditions. Performance improves with larger V_{TEMP} , larger V_{DD} and lower temperatures.

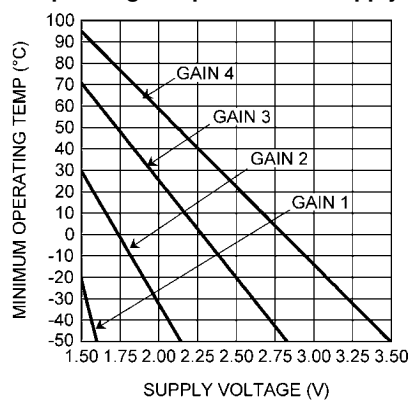
Typical Performance Characteristics

V_{TEMP} Output Temperature Error vs. Temperature



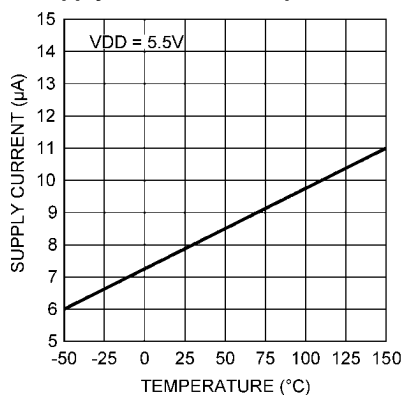
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Minimum Operating Temperature vs. Supply Voltage



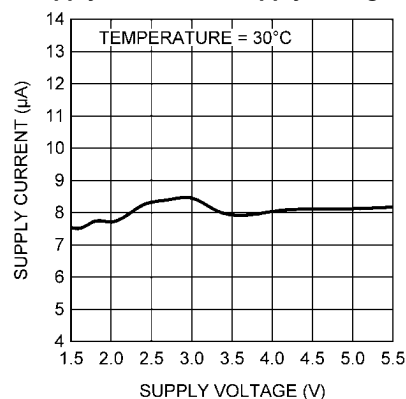
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Supply Current vs. Temperature



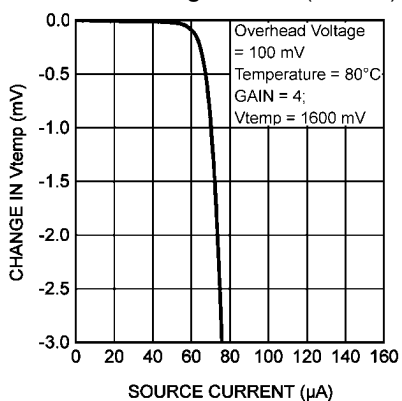
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Supply Current vs. Supply Voltage



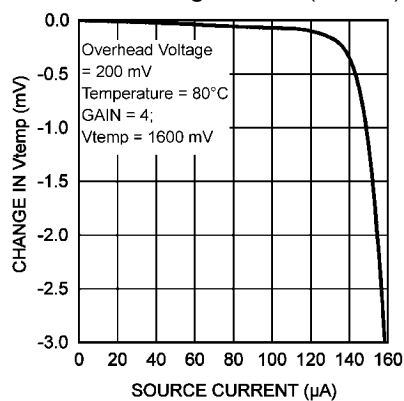
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**Load Regulation, 100 mV Overhead
T = 80°C Sourcing Current (Note 14)**



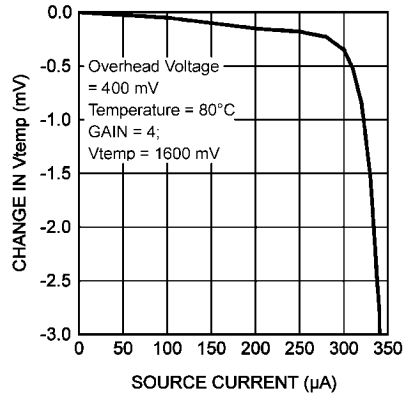
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**Load Regulation, 200 mV Overhead
T = 80°C Sourcing Current (Note 14)**



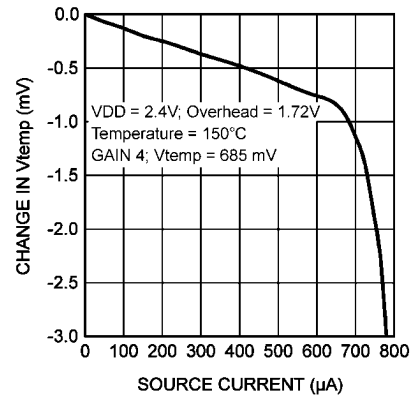
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Load Regulation, 400 mV Overhead
T = 80°C Sourcing Current (Note 14)



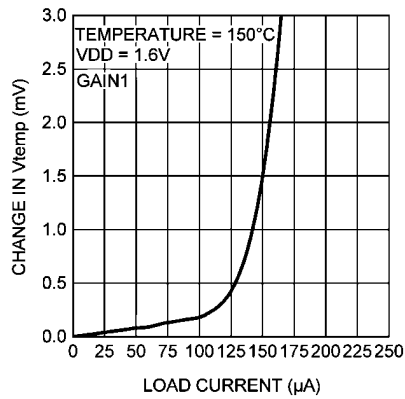
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Load Regulation, 1.72V Overhead
T = 150°C, V_{DD} = 2.4V
Sourcing Current (Note 14)



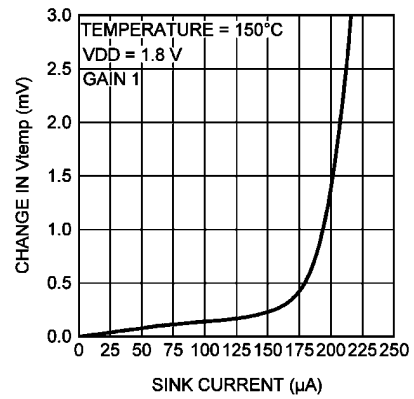
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Load Regulation, V_{DD} = 1.6V
Sinking Current (Note 15)



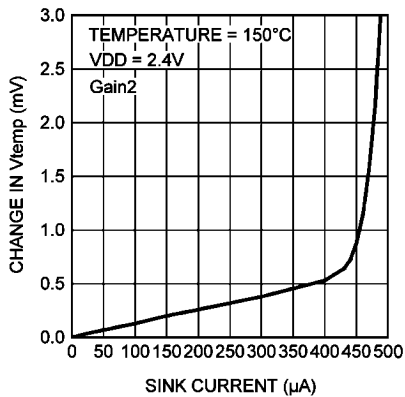
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Load Regulation, V_{DD} = 1.8V
Sinking Current (Note 15)



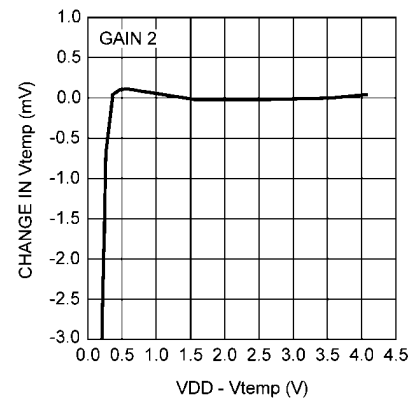
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Load Regulation, V_{DD} = 2.4V
Sinking Current (Note 15)

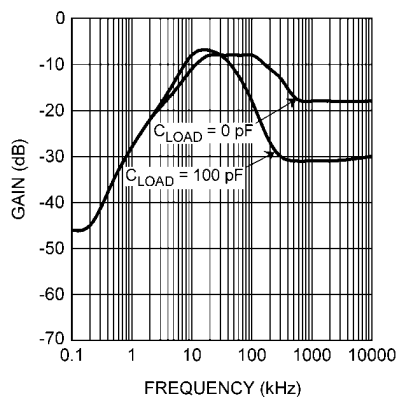


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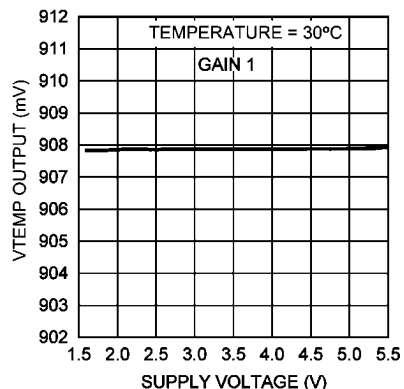
Change in V_{TEMP} vs. Overhead Voltage



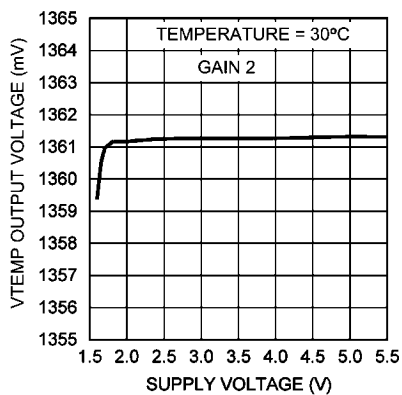
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V_{TEMP} Supply-Noise Gain vs. Frequency

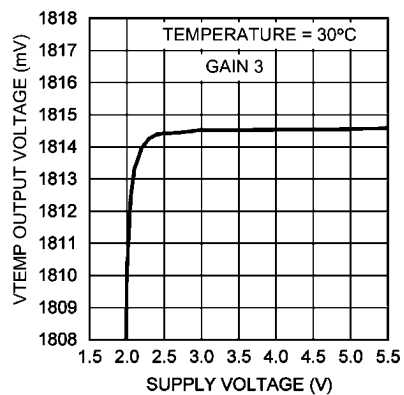
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**V_{TEMP} vs. Supply Voltage
Gain 1: For Trip Points
0 - 69°C**

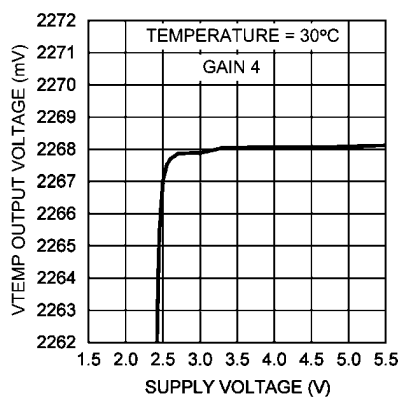
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**V_{TEMP} vs. Supply Voltage
Gain 2: For Trip Points
70 - 109°C**

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

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

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1.0 LM26LV V_{TEMP} vs Die Temperature Conversion Table

The LM26LV 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 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
-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
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
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
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'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.

$$\begin{aligned} \text{GAIN1: } V_{\text{TEMP}} &= 907.87 - 5.1321 \times (T_{\text{DIE}} - 30^{\circ}\text{C}) - 0.001076 \times (T_{\text{DIE}} - 30^{\circ}\text{C})^2 \\ \text{GAIN2: } V_{\text{TEMP}} &= 1361.35 - 7.7011 \times (T_{\text{DIE}} - 30^{\circ}\text{C}) - 0.001596 \times (T_{\text{DIE}} - 30^{\circ}\text{C})^2 \\ \text{GAIN3: } V_{\text{TEMP}} &= 1814.62 - 10.2703 \times (T_{\text{DIE}} - 30^{\circ}\text{C}) - 0.002117 \times (T_{\text{DIE}} - 30^{\circ}\text{C})^2 \\ \text{GAIN4: } V_{\text{TEMP}} &= 2268.14 - 12.8384 \times (T_{\text{DIE}} - 30^{\circ}\text{C}) - 0.002639 \times (T_{\text{DIE}} - 30^{\circ}\text{C})^2 \end{aligned}$$

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.

$$\text{GAIN1: } V_{\text{TEMP}} = 1059.9 - 5.1751 \times T_{\text{DIE}}$$

$$\text{GAIN2: } V_{\text{TEMP}} = 1589.9 - 7.765 \times T_{\text{DIE}}$$

$$\text{GAIN3: } V_{\text{TEMP}} = 2119.0 - 10.355 \times T_{\text{DIE}}$$

$$\text{GAIN4: } V_{\text{TEMP}} = 2648.6 - 12.944 \times T_{\text{DIE}}$$

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, T₁ and V₁ are the coordinates of the lowest temperature, T₂ and V₂ 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:

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

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

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

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

2.0 OVERTEMP and OVERTEMP Digital Outputs

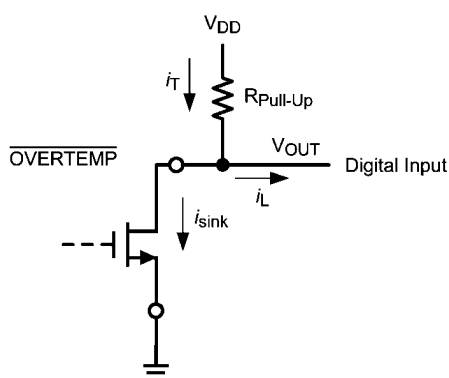
The OVERTEMP Active High, Push-Pull Output and the OVERTEMP Active Low, Open-Drain Output both assert at the same time whenever the Die Temperature reaches the factory preset Temperature Trip Point. They also assert simultaneously whenever the TRIP TEST pin is set high. Both outputs de-assert when the 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 OVERTEMP Digital Output pins can be left open if not used.

2.1 OVERTEMP OPEN-DRAIN DIGITAL OUTPUT

The 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:

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

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 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:

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

EXAMPLE CALCULATION

Suppose we have, for our example, a V_{DD} of $3.3 \text{ V} \pm 0.3 \text{ V}$, 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 OVERTEMP shows a maximum i_{sink} of $385 \mu\text{A}$.

(2) Let $i_L = 1 \mu\text{A}$, then i_T is about $386 \mu\text{A}$ max. If we select $35 \mu\text{A}$ as the current limit then i_T for the calculation becomes $35 \mu\text{A}$

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

$$R_{\text{Pull-up}} = (3.6 - 0.2)/35 \mu\text{A} = 97 \text{ k}\Omega$$

(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 $100 \text{ k}\Omega$.

2.2 NOISE IMMUNITY

The LM26LV is virtually immune from false triggers on the OVERTEMP and 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 2 V to 5 V , there were no false triggers.

3.0 TRIP TEST Digital Input

The TRIP TEST pin simply provides a means to test the OVERTEMP and 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 is ideal for this and other applications which require strong source or sink current.

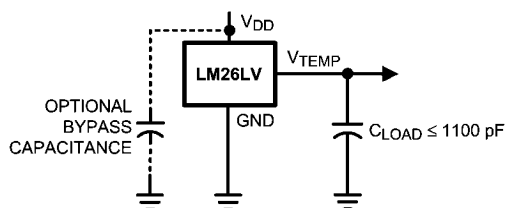
4.1 NOISE CONSIDERATIONS

The LM26LV's supply-noise gain (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.

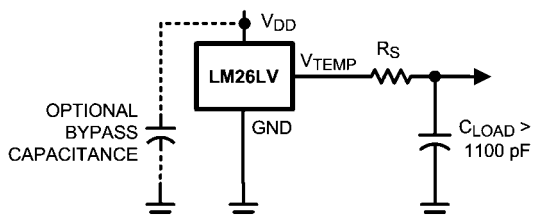
4.2 CAPACITIVE LOADS

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.



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



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C_{LOAD}	R_S
1.1 nF to 99 nF	3 k Ω
100 nF to 999 nF	1.5 k Ω
1 μ F	800 Ω

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

4.3 VOLTAGE SHIFT

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

To ensure good temperature conductivity, the backside of the LM26LV die is directly attached to the GND pin (Pin 2). The temperatures of the lands and traces to the other leads of the LM26LV will also affect the temperature reading.

Alternatively, the LM26LV 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 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 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's die temperature is

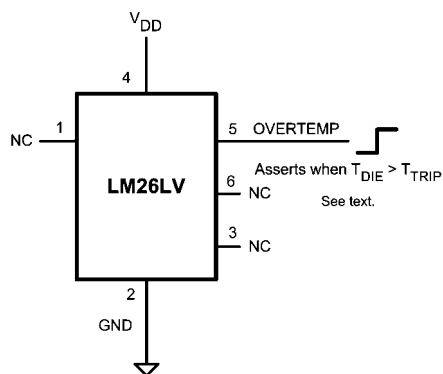
$$T_J = T_A + \theta_{JA} [(V_{DD} I_Q) + (V_{DD} - V_{TEMP}) I_L]$$

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 $T_A = 30^\circ\text{C}$, $V_{DD} = 5\text{ V}$, $I_{DD} = 9\text{ }\mu\text{A}$, Gain 4, $V_{TEMP} = 2231\text{ mV}$, and $I_L = 2\text{ }\mu\text{A}$, the junction temperature would be 30.021°C , showing a self-heating error of only 0.021°C . Since the LM26LV'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 $[(152^\circ\text{ C/W}) \times (5V)^2 / 100k] = 0.038^\circ\text{C}$ for a total self-heating error of 0.059°C . Figure 3 shows the thermal resistance of the LM26LV.

Device Number	NS Package Number	Thermal Resistance (θ_{JA})
LM26LVCISD	SDB06A	152° C/W

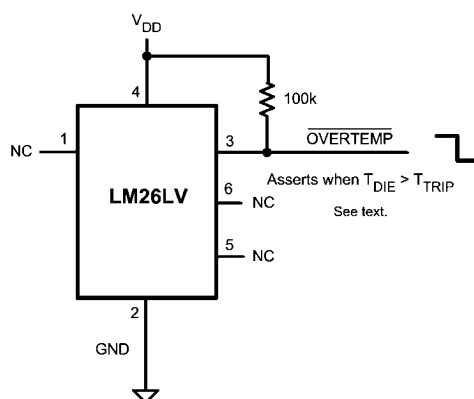
FIGURE 3. LM26LV Thermal Resistance

6.0 Applications Circuits



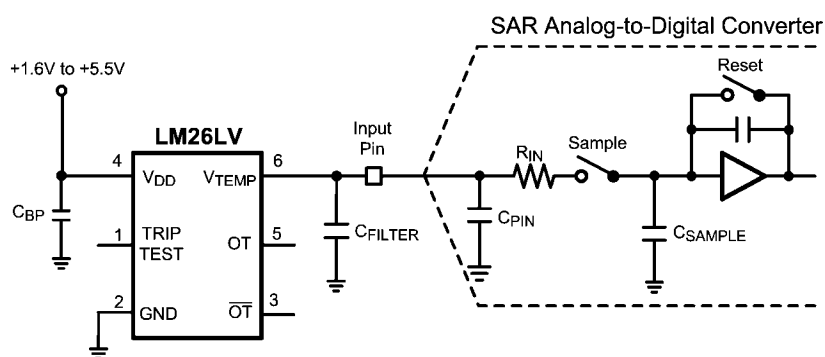
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FIGURE 4. Temperature Switch Using Push-Pull Output



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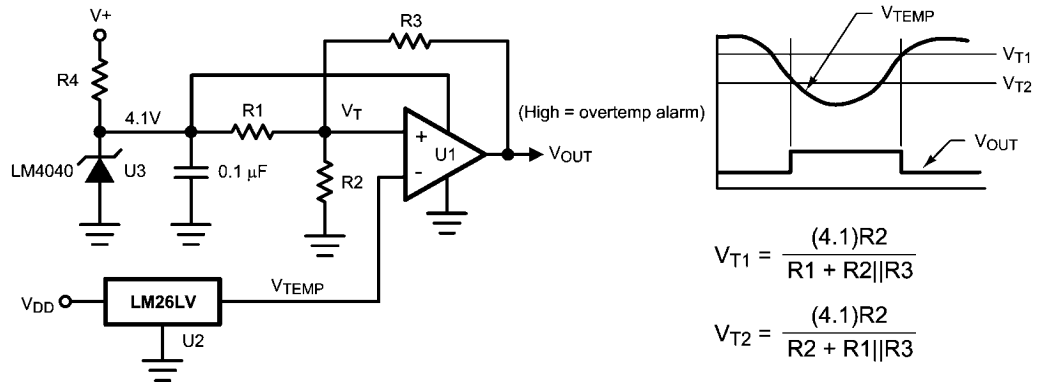
FIGURE 5. Temperature Switch Using Open-Drain Output



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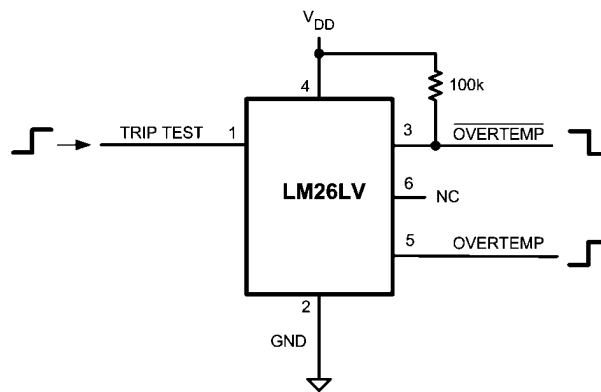
Most CMOS ADCs found in microcontrollers and ASICs have a sampled data comparator input structure. When the ADC charges the sampling cap, it requires instantaneous charge from the output of the analog source such as the LM26LV temperature sensor and many op amps. This requirement is easily accommodated 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.

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



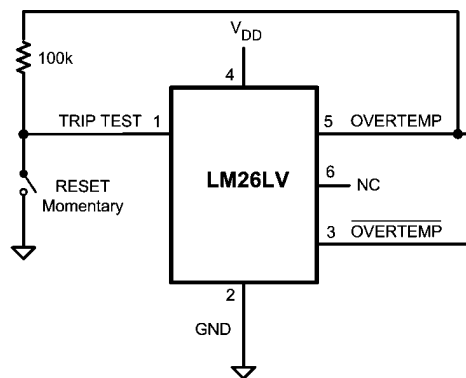
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FIGURE 7. Celsius Temperature Switch



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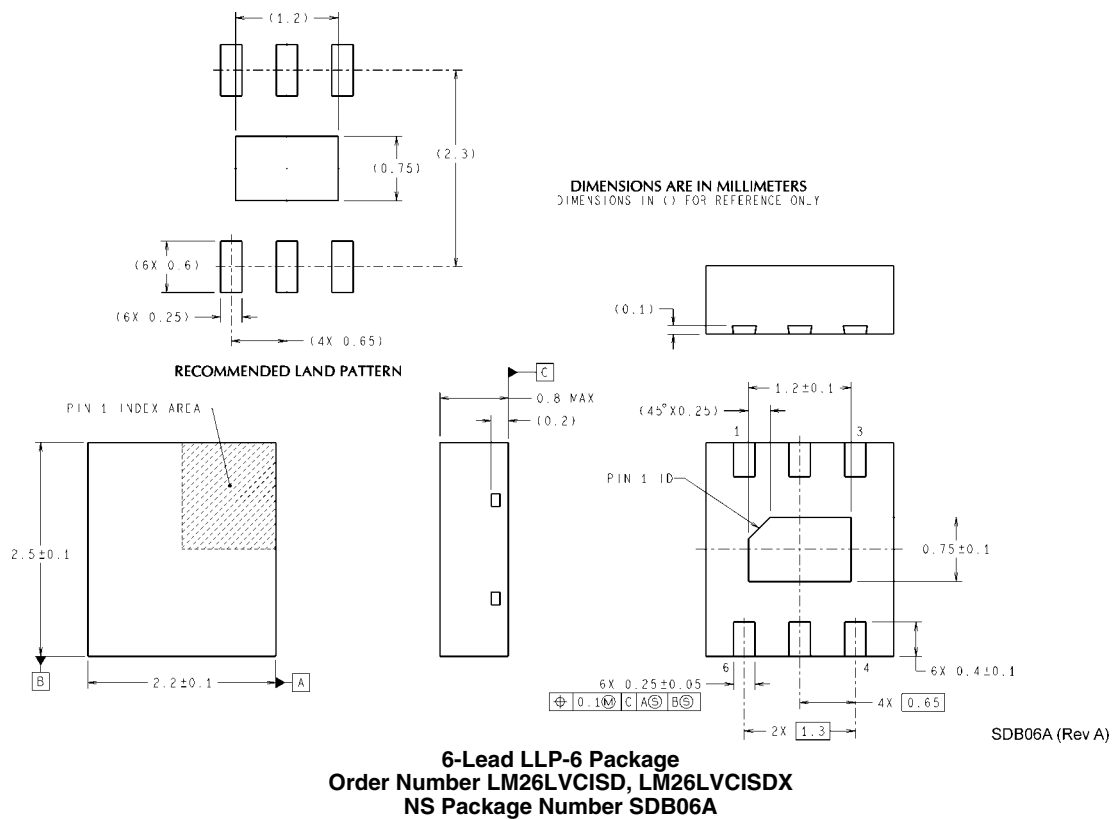
FIGURE 8. TRIP TEST Digital Output Test Circuit



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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. Momentarily switching the TRIP TEST input low will reset the LM26LV to normal operation. The resistor limits the current out of the OVERTEMP output pin.

FIGURE 9. Latch Circuit using OVERTEMP Output

Physical Dimensions inches (millimeters) unless otherwise noted

Notes

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