

LM35

SNIS159F-AUGUST 1999-REVISED JANUARY 2016

LM35 Precision Centigrade Temperature Sensors

1 Features

- Calibrated Directly in Celsius (Centigrade)
- Linear + 10-mV/°C Scale Factor
- 0.5°C Ensured Accuracy (at 25°C)
- Rated for Full -55°C to 150°C Range
- Suitable for Remote Applications
- Low-Cost Due to Wafer-Level Trimming
- Operates from 4 V to 30 V
- Less than 60-µA Current Drain
- Low Self-Heating, 0.08°C in Still Air
- Non-Linearity Only ±¼°C Typical
- Low-Impedance Output, 0.1 Ω for 1-mA Load

2 Applications

- Power Supplies
- Battery Management
- HVAC
- Appliances

3 Description

The LM35 series are precision integrated-circuit temperature devices with an output voltage linearlyproportional to the Centigrade temperature. The LM35 device has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from the output to obtain convenient Centigrade scaling. The LM35 device does not require any external calibration or trimming to provide typical accuracies of $\pm \frac{1}{4}$ °C at room temperature and $\pm \frac{3}{4}$ °C over a full -55°C to 150°C temperature range. Lower cost is assured by trimming and calibration at the wafer level. The low-output impedance, linear output, and precise inherent calibration of the LM35 device makes interfacing to readout or control circuitry especially easy. The device is used with single power supplies, or with plus and minus supplies. As the LM35 device draws only 60 µA from the supply, it has very low self-heating of less than 0.1°C in still air. The LM35 device is rated to operate over a -55°C to 150°C temperature range, while the LM35C device is rated for a -40°C to 110°C range (-10° with improved accuracy). The LM35-series devices are available packaged in hermetic TO transistor packages, while the LM35C, LM35CA, and LM35D devices are available in the plastic TO-92 transistor package. The LM35D device is available in an 8-lead surface-mount small-outline package and a plastic TO-220 package.

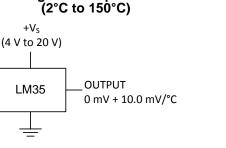
Device information**								
PART NUMBER	PACKAGE	BODY SIZE (NOM)						
	TO-CAN (3)	4.699 mm × 4.699 mm						
LM35	TO-92 (3)	4.30 mm × 4.30 mm						
LIVISS	SOIC (8)	4.90 mm × 3.91 mm						
	TO-220 (3)	14.986 mm × 10.16 mm						

Device Information⁽¹⁾

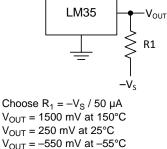
(1) For all available packages, see the orderable addendum at the end of the datasheet.

Full-Range Centigrade Temperature Sensor

+Vs



Basic Centigrade Temperature Sensor



An IMPORTANT NOTICE at the end of this data sheet addresses availability, warranty, changes, use in safety-critical applications, intellectual property matters and other important disclaimers. PRODUCTION DATA.



Functional Block Diagram 13

Feature Description..... 13 Device Functional Modes...... 13

Application Information..... 14 Typical Application 15

Application and Implementation 14

8.3 System Examples 16

Power Supply Recommendations 19 10.1 Layout Guidelines 19 10.2 Layout Example 20 11 Device and Documentation Support 21 11.1 Trademarks 21 11.2 Electrostatic Discharge Caution 21 11.3 Glossary...... 21

Information 21

12 Mechanical, Packaging, and Orderable

Table of Contents

7.2 7.3

7.4

8.1

8.2

8

9

1	Feat	tures 1
2	Арр	lications 1
3	Des	cription 1
4	Rev	ision History 2
5	Pin	Configuration and Functions 3
6	Spe	cifications 4
	6.1	Absolute Maximum Ratings 4
	6.2	ESD Ratings 4
	6.3	Recommended Operating Conditions 4
	6.4	Thermal Information 4
	6.5	Electrical Characteristics: LM35A, LM35CA Limits 5
	6.6	Electrical Characteristics: LM35A, LM35CA 6
	6.7	Electrical Characteristics: LM35, LM35C, LM35D
		Limits
	6.8	Electrical Characteristics: LM35, LM35C, LM35D 9
	6.9	Typical Characteristics 11
7	Deta	ailed Description 13
	7.1	Overview 13

Revision History

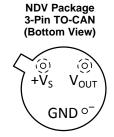
Cr	hanges from Revision E (January 2015) to Revision F	je
•	Changed NDV Package (TO-CAN) pinout from Top View to Bottom View	3
Cł	hanges from Revision D (October 2013) to Revision E Page	je
•	Added Pin Configuration and Functions section, ESD Ratings table, Feature Description section, Device Functional Modes, Application and Implementation section, Power Supply Recommendations section, Layout section, Device and Documentation Support section, and Mechanical, Packaging, and Orderable Information section	1
Cł	hanges from Revision C (July 2013) to Revision D Pa	ge
•	Changed W to Ω	1

Changed W to Ω in Abs Max tablenote. 4

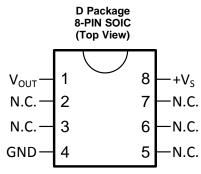
٢



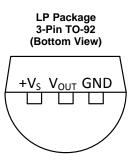
5 Pin Configuration and Functions

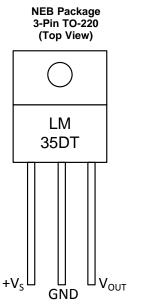


Case is connected to negative pin (GND)



N.C. = No connection





Tab is connected to the negative pin (GND).

NOTE: The LM35DT pinout is different than the discontinued LM35DP

	Pin Functions										
		PIN			TYPE	DESCRIPTION					
NAME	TO46	TO92	TO220	SO8	TYPE	DESCRIPTION					
V _{OUT}	—	—	—	1	0	Temperature Sensor Analog Output					
N.C.	_	_	_	2		No Connection					
N.C.		—	—	3	_	No connection					
GND	—	_	_	4	GROUND	Device ground pin, connect to power supply negative terminal					
	_	_	—	5							
N.C.	_	_	—	6] _	No Connection					
	_	_		7							
+V _S		—	—	8	POWER	Positive power supply pin					

6 Specifications

6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)⁽¹⁾⁽²⁾

			MIN	MAX	UNIT
Supply voltage			-0.2	35	V
Output voltage			-1	6	V
Output current			10 m		mA
Maximum Junction Temperature, T	Jmax	150 °		°C	
Storogo Tomporoturo, T	TO-CAN, TO-92 Package		-60	150	°C
Storage Temperature, T _{stg}	TO-220, SOIC Package		-65	150	

(1) If Military/Aerospace specified devices are required, please contact the Texas Instruments Sales Office/ Distributors for availability and specifications.

(2) Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. DC and AC electrical specifications do not apply when operating the device beyond its rated operating conditions.

6.2 ESD Ratings

			VALUE	UNIT
V _(ESD)	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 ⁽¹⁾	±2500	V

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.

6.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

		MIN	MAX	UNIT
Specified operating temperature: T_{MIN} to T_{MAX}	LM35, LM35A	-55	150	
	LM35C, LM35CA	-40	110	°C
• MAX	LM35C, LM35CA40 110 LM35D 0 100			
Supply Voltage (+V _S)		4	30	V

6.4 Thermal Information

		LM35					
	THERMAL METRIC ⁽¹⁾⁽²⁾ NDV LP D				NEB	UNIT	
		3 P	INS	8 PINS	3 PINS		
R_{\thetaJA}	Junction-to-ambient thermal resistance	400	180	220	90	°C/W	
R _{0JC(top)}	Junction-to-case (top) thermal resistance	24	—	—	—	C/VV	

(1) For more information about traditional and new thermal metrics, see the IC Package Thermal Metrics application report, SPRA953.

(2) For additional thermal resistance information, see *Typical Application*.

6.5 Electrical Characteristics: LM35A, LM35CA Limits

Unless otherwise noted, these specifications apply: $-55^{\circ}C \le T_{J} \le 150^{\circ}C$ for the LM35 and LM35A; $-40^{\circ}C \le T_{J} \le 110^{\circ}C$ for the LM35C and LM35CA; and $0^{\circ}C \le T_{J} \le 100^{\circ}C$ for the LM35D. $V_{S} = 5$ Vdc and $I_{LOAD} = 50 \ \mu$ A, in the circuit of Full-Range Centigrade Temperature Sensor. These specifications also apply from 2°C to T_{MAX} in the circuit of Figure 14.

		LM35A						
PARAMETER	TEST CONDITIONS	TYP	TESTED LIMIT ⁽¹⁾	DESIGN LIMIT ⁽²⁾	ТҮР	LM35CA TESTED LIMIT ⁽¹⁾	DESIGN LIMIT ⁽²⁾	UNIT
	$T_A = 25^{\circ}C$	±0.2	±0.5		±0.2	±0.5		
Accuracy ⁽³⁾	$T_A = -10^{\circ}C$	±0.3			±0.3		±1	°C
Accuracy	$T_A = T_{MAX}$	±0.4	±1		±0.4	±1		C
	$T_A = T_{MIN}$	±0.4	±1		±0.4		±1.5	
Nonlinearity ⁽⁴⁾	$T_{MIN} \le T_A \le T_{MAX},$ -40°C $\le T_J \le 125$ °C	±0.18		±0.35	±0.15		±0.3	°C
Sensor gain	$T_{MIN} \le T_A \le T_{MAX}$	10	9.9		10		9.9	mV/°C
(average slope)	$-40^{\circ}C \le T_{J} \le 125^{\circ}C$	10	10.1		10		10.1	mv/°C
Less dans and stices (5)	$T_A = 25^{\circ}C$	±0.4	±1		±0.4	±1		mV/mA
Load regulation ⁽⁵⁾ $0 \le I_L \le 1 \text{ mA}$	$T_{MIN} \le T_A \le T_{MAX},$ -40°C $\le T_J \le 125$ °C	±0.5		±3	±0.5		±3	
	$T_A = 25^{\circ}C$	±0.01	±0.05		±0.01	±0.05		
Line regulation ⁽⁵⁾	4 V ≤ V _S ≤ 30 V, -40°C ≤ T _J ≤ 125°C	±0.02		±0.1	±0.02		±0.1	mV/V
	V _S = 5 V, 25°C	56	67		56	67		
Quiescent current ⁽⁶⁾	$V_S = 5 \text{ V}, -40^{\circ}\text{C} \le \text{T}_J \le 125^{\circ}\text{C}$	105		131	91		114	
Quiescent current	V _S = 30 V, 25°C	56.2	68		56.2	68		μA
	$V_{\rm S} = 30 \text{ V}, -40^{\circ}\text{C} \le \text{T}_{\rm J} \le 125^{\circ}\text{C}$	105.5		133	91.5		116	
Channe of million and	4 V ≤ V _S ≤ 30 V, 25°C	0.2	1		0.2	1		
Change of quiescent current ⁽⁵⁾	4 V ≤ V _S ≤ 30 V, -40°C ≤ T _J ≤ 125°C	0.5		2	0.5		2	μA
Temperature coefficient of quiescent current	–40°C ≤ T _J ≤ 125°C	0.39		0.5	0.39		0.5	µA/°C
Minimum temperature for rate accuracy	In circuit of Figure 14, $I_L = 0$	1.5		2	1.5		2	°C
Long term stability	$T_J = T_{MAX}$, for 1000 hours	±0.08			±0.08			°C

(1) Tested Limits are ensured and 100% tested in production.

(2) Design Limits are ensured (but not 100% production tested) over the indicated temperature and supply voltage ranges. These limits are not used to calculate outgoing quality levels.

(3) Accuracy is defined as the error between the output voltage and 10 mv/°C times the case temperature of the device, at specified conditions of voltage, current, and temperature (expressed in °C).

(4) Non-linearity is defined as the deviation of the output-voltage-versus-temperature curve from the best-fit straight line, over the rated temperature range of the device.

(5) Regulation is measured at constant junction temperature, using pulse testing with a low duty cycle. Changes in output due to heating effects can be computed by multiplying the internal dissipation by the thermal resistance.

(6) Quiescent current is defined in the circuit of Figure 14.



6.6 Electrical Characteristics: LM35A, LM35CA

Unless otherwise noted, these specifications apply: $-55^{\circ}C \le T_{J} \le 150^{\circ}C$ for the LM35 and LM35A; $-40^{\circ}C \le T_{J} \le 110^{\circ}C$ for the LM35C and LM35CA; and $0^{\circ}C \le T_{J} \le 100^{\circ}C$ for the LM35D. $V_{S} = 5$ Vdc and $I_{LOAD} = 50 \ \mu$ A, in the circuit of Full-Range Centigrade Temperature Sensor. These specifications also apply from 2°C to T_{MAX} in the circuit of Figure 14.

PARAMETER	TEST CO		LM35A			LM35CA			
PARAMETER	TEST CO	NDITIONS	MIN	TYP	MAX	TYP	TYP	MAX	UNIT
				±0.2			±0.2		
	T _A = 25°C	Tested Limit ⁽²⁾			±0.5			±0.5	
		Design Limit ⁽³⁾							
				±0.3			±0.3		
	$T_A = -10^{\circ}C$	Tested Limit ⁽²⁾							
Accuracy ⁽¹⁾		Design Limit ⁽³⁾						±1	
Accuracy				±0.4			±0.4		°C
	$T_A = T_{MAX}$	Tested Limit ⁽²⁾			±1			±1	
		Design Limit ⁽³⁾							
				±0.4			±0.4		
	$T_A = T_{MIN}$	Tested Limit ⁽²⁾			±1				
		Design Limit ⁽³⁾						±1.5	-
				±0.18			±0.15		
Nonlinearity ⁽⁴⁾	$T_{MIN} \le T_A \le T_{MAX},$ -40°C $\le T_J \le 125$ °C	Tested Limit ⁽²⁾							°C
-	-40 C S IJ S 125 C	Design Limit ⁽³⁾		±0.35 ±0	±0.3	-			
	$T_{MIN} \le T_A \le T_{MAX}$			10			10		mV/°C
		Tested Limit ⁽²⁾			9.9				
Sensor gain		Design Limit ⁽³⁾						9.9	
(average slope)	–40°C ≤ T _J ≤ 125°C			10			10		
		Tested Limit ⁽²⁾			10.1				
		Design Limit ⁽³⁾						10.1	
				±0.4			±0.4		
	T _A = 25°C	Tested Limit ⁽²⁾			±1			±1	
Load regulation ⁽⁵⁾		Design Limit ⁽³⁾							
$0 \le I_L \le 1 \text{ mA}$				±0.5			±0.5		mV/mA
	T _{MIN} ≤ T _A ≤ T _{MAX} , –40°C ≤ T _J ≤ 125°C	Tested Limit ⁽²⁾							
	-40 C S IJ S 125 C	Design Limit ⁽³⁾			±3			±3	
				±0.01			±0.01		
	T _A = 25°C	Tested Limit ⁽²⁾			±0.05			±0.05	1
		Design Limit ⁽³⁾							
Line regulation ⁽⁵⁾				±0.02			±0.02		mV/V
	4 V ≤ V _S ≤ 30 V, –40°C ≤ T _J ≤ 125°C	Tested Limit ⁽²⁾							1
	$-40.0 \ge 1.1 \ge 1.25^{\circ}$	Design Limit ⁽³⁾			±0.1			±0.1	4

(1) Accuracy is defined as the error between the output voltage and 10 mv/°C times the case temperature of the device, at specified conditions of voltage, current, and temperature (expressed in °C).

(2) Tested Limits are ensured and 100% tested in production.

(3) Design Limits are ensured (but not 100% production tested) over the indicated temperature and supply voltage ranges. These limits are not used to calculate outgoing quality levels.

(4) Non-linearity is defined as the deviation of the output-voltage-versus-temperature curve from the best-fit straight line, over the rated temperature range of the device.

(5) Regulation is measured at constant junction temperature, using pulse testing with a low duty cycle. Changes in output due to heating effects can be computed by multiplying the internal dissipation by the thermal resistance.

Electrical Characteristics: LM35A, LM35CA (continued)

Unless otherwise noted, these specifications apply: $-55^{\circ}C \le T_{J} \le 150^{\circ}C$ for the LM35 and LM35A; $-40^{\circ}C \le T_{J} \le 110^{\circ}C$ for the LM35C and LM35CA; and $0^{\circ}C \le T_{J} \le 100^{\circ}C$ for the LM35D. $V_{S} = 5$ Vdc and $I_{LOAD} = 50$ µA, in the circuit of Full-Range Centigrade Temperature Sensor. These specifications also apply from 2°C to T_{MAX} in the circuit of Figure 14.

	TEST CONDITIONS			LM35A			LM35CA		
PARAMETER	TEST COND	MIN	TYP	MAX	TYP	TYP	MAX	UNIT	
				56			56		
	V _S = 5 V, 25°C	Tested Limit ⁽²⁾			67			67	
		Design Limit ⁽³⁾							
				105			91		
	V _S = 5 V, -40°C ≤ T ₁ ≤ 125°C	Tested Limit ⁽²⁾							
Quiescent	-40 C 3 1] 3 125 C	Design Limit ⁽³⁾			131			114	
current ⁽⁶⁾				56.2			56.2		μA
	V _S = 30 V, 25°C	Tested Limit ⁽²⁾			68			68	
		Design Limit ⁽³⁾							
	V _S = 30 V, –40°C ≤ T _J ≤ 125°C			105.5			91.5		
		Tested Limit ⁽²⁾							
		Design Limit ⁽³⁾			133			116	
	4 V ≤ V _S ≤ 30 V, 25°C			0.2			0.2		
		Tested Limit ⁽²⁾			1			1	
Change of		Design Limit ⁽³⁾							
quiescent current ⁽⁵⁾				0.5			0.5		μA
		Tested Limit ⁽²⁾							
$-40^{\circ}C \le T_{J} \le 125^{\circ}C$ Change of quiescent current ⁽⁵⁾ $4 \ V \le V_{S} \le 30 \ V, 25^{\circ}$ $4 \ V \le V_{S} \le 30 \ V, -40^{\circ}C \le T_{J} \le 125^{\circ}C$ Temperature coefficient of $-40^{\circ}C \le T_{J} \le 125^{\circ}C$	-40 0 3 1 3 3 125 0	Design Limit ⁽³⁾			2			2	
Temperature				0.39			0.39		
coefficient of	–40°C ≤ T _J ≤ 125°C	Tested Limit ⁽²⁾							µA/°C
quiescent current		Design Limit ⁽³⁾			0.5			0.5	
Minimum				1.5			1.5		
temperature for	In circuit of Figure 14, $I_L = 0$	Tested Limit ⁽²⁾							°C
rate accuracy		Design Limit ⁽³⁾			2			2	
Long term stability	$T_J = T_{MAX}$, for 1000 hours			±0.08			±0.08		°C

(6) Quiescent current is defined in the circuit of Figure 14.

6.7 Electrical Characteristics: LM35, LM35C, LM35D Limits

Unless otherwise noted, these specifications apply: $-55^{\circ}C \le T_{J} \le 150^{\circ}C$ for the LM35 and LM35A; $-40^{\circ}C \le T_{J} \le 110^{\circ}C$ for the LM35C and LM35CA; and $0^{\circ}C \le T_{J} \le 100^{\circ}C$ for the LM35D. $V_{S} = 5$ Vdc and $I_{LOAD} = 50 \ \mu$ A, in the circuit of Full-Range Centigrade Temperature Sensor. These specifications also apply from 2°C to T_{MAX} in the circuit of Figure 14.

			LM35	WIAA	L	M35C, LM35	5D		
PARAMETER	TEST CONDITIONS	ТҮР	TESTED LIMIT ⁽¹⁾	DESIGN LIMIT ⁽²⁾	ТҮР	TESTED LIMIT ⁽¹⁾	DESIGN LIMIT ⁽²⁾	UNIT	
	$T_A = 25^{\circ}C$	±0.4	±1		±0.4	±1			
Accuracy, LM35, LM35C ⁽³⁾	$T_A = -10^{\circ}C$	±0.5			±0.5		±1.5	°C	
LM35C ⁽³⁾	$T_A = T_{MAX}$	±0.8	±1.5		±0.8		±1.5		
	$T_A = T_{MIN}$	±0.8		±1.5	±0.8		±2		
	$T_A = 25^{\circ}C$				±0.6	±1.5			
Accuracy, LM35D ⁽³⁾	$T_A = T_{MAX}$				±0.9		±2	°C	
	$T_A = T_{MIN}$				±0.9		±2		
Nonlinearity ⁽⁴⁾	$\begin{array}{l} T_{MIN} \leq T_{A} \leq T_{MAX}, \\ -40^{\circ}C \leq T_{J} \leq 125^{\circ}C \end{array}$	±0.3		±0.5	±0.2		±0.5	°C	
Sensor gain (average slope)	$T_{MIN} \le T_A \le T_{MAX},$ -40°C $\le T_J \le 125$ °C	10	9.8		10		9.8	mV/°C	
		10	10.2		10		10.2		
1	$T_A = 25^{\circ}C$	±0.4	±2		±0.4	±2		mV/mA	
Load regulation ⁽⁵⁾ $0 \le I_L \le 1 \text{ mA}$	$T_{MIN} \le T_A \le T_{MAX},$ -40°C $\le T_J \le 125$ °C	±0.5		±5	±0.5		±5		
	$T_A = 25^{\circ}C$	±0.01	±0.1		±0.01	±0.1		2 mV/V	
Line regulation ⁽⁵⁾	4 V ≤ V _S ≤ 30 V, –40°C ≤ T _J ≤ 125°C	±0.02		±0.2	±0.02		±0.2		
	V _S = 5 V, 25°C	56	80		56	80			
Quiescent current ⁽⁶⁾	$V_{\rm S} = 5 \text{ V}, -40^{\circ}\text{C} \le \text{T}_{\rm J} \le 125^{\circ}\text{C}$	105		158	91		138		
Quiescent current ^(*)	V _S = 30 V, 25°C	56.2	82		56.2	82		μA	
	$V_{S} = 30 \text{ V}, -40^{\circ}\text{C} \le T_{J} \le 125^{\circ}\text{C}$	105.5		161	91.5		141		
Change of guiescent	$4 \text{ V} \leq \text{V}_{\text{S}} \leq 30 \text{ V}, 25^{\circ}\text{C}$	0.2	2		0.2	2			
current ⁽⁵⁾	$4 \text{ V} \le \text{V}_{\text{S}} \le 30 \text{ V},$ -40°C $\le \text{T}_{\text{J}} \le 125$ °C	0.5		3	0.5		3	μA	
Temperature coefficient of quiescent current	–40°C ≤ T _J ≤ 125°C	0.39		0.7	0.39		0.7	µA/°C	
Minimum temperature for rate accuracy	In circuit of Figure 14, $I_L = 0$	1.5		2	1.5		2	°C	
Long term stability	$T_J = T_{MAX}$, for 1000 hours	±0.08			±0.08			°C	

(1) Tested Limits are ensured and 100% tested in production.

(2) Design Limits are ensured (but not 100% production tested) over the indicated temperature and supply voltage ranges. These limits are not used to calculate outgoing quality levels.

(3) Accuracy is defined as the error between the output voltage and 10 mv/°C times the case temperature of the device, at specified conditions of voltage, current, and temperature (expressed in °C).

(4) Non-linearity is defined as the deviation of the output-voltage-versus-temperature curve from the best-fit straight line, over the rated temperature range of the device.

(5) Regulation is measured at constant junction temperature, using pulse testing with a low duty cycle. Changes in output due to heating effects can be computed by multiplying the internal dissipation by the thermal resistance.

(6) Quiescent current is defined in the circuit of Figure 14.

6.8 Electrical Characteristics: LM35, LM35C, LM35D

Unless otherwise noted, these specifications apply: $-55^{\circ}C \le T_{J} \le 150^{\circ}C$ for the LM35 and LM35A; $-40^{\circ}C \le T_{J} \le 110^{\circ}C$ for the LM35C and LM35CA; and $0^{\circ}C \le T_{J} \le 100^{\circ}C$ for the LM35D. $V_{S} = 5$ Vdc and $I_{LOAD} = 50 \ \mu$ A, in the circuit of Full-Range Centigrade Temperature Sensor. These specifications also apply from 2°C to T_{MAX} in the circuit of Figure 14.

			ĺ	LM35			5C, LM35	D		
PARAMETER	TEST CO	NDITIONS	MIN	TYP	MAX	MIN	TYP	MAX	UNIT	
				±0.4			±0.4			
	$T_A = 25^{\circ}C$	Tested Limit ⁽²⁾			±1			±1		
		Design Limit ⁽³⁾								
				±0.5			±0.5			
	$T_A = -10^{\circ}C$	Tested Limit ⁽²⁾								
Accuracy, LM35,		Design Limit ⁽³⁾						±1.5	°C	
LM35C ⁽¹⁾				±0.8			±0.8			
	$T_A = T_{MAX}$	Tested Limit ⁽²⁾			±1.5					
		Design Limit ⁽³⁾						±1.5		
	$T_A = T_{MIN}$			±0.8			±0.8			
		Tested Limit ⁽²⁾								
		Design Limit ⁽³⁾			±1.5			±2		
							±0.6			
	$T_A = 25^{\circ}C$	Tested Limit ⁽²⁾						±1.5		
		Design Limit ⁽³⁾								
							±0.9			
Accuracy, LM35D ⁽¹⁾	$T_A = T_{MAX}$	Tested Limit ⁽²⁾							°C	
LINCOD		Design Limit ⁽³⁾						±2		
	$T_A = T_{MIN}$						±0.9			
		Tested Limit ⁽²⁾								
		Design Limit ⁽³⁾						±2		
				±0.3			±0.2			
Nonlinearity ⁽⁴⁾	T _{MIN} ≤ T _A ≤ T _{MAX} , -40°C ≤ T _J ≤ 125°C	Tested Limit ⁽²⁾							°C	
	10 0 1 1 1 1 20 0	Design Limit ⁽³⁾			±0.5			±0.5		
				10			10			
	T _{MIN} ≤ T _A ≤ T _{MAX} , -40°C ≤ T _J ≤ 125°C	Tested Limit ⁽²⁾			9.8					
Sensor gain	10 0 1 1 1 1 20 0	Design Limit ⁽³⁾						9.8	mV/°C	
(average slope)				10			10		IIIV/ C	
		Tested Limit ⁽²⁾			10.2					
		Design Limit ⁽³⁾						10.2		
				±0.4			±0.4			
	$T_A = 25^{\circ}C$	Tested Limit ⁽²⁾			±2			<u>+</u> 2		
Load regulation ⁽⁵⁾		Design Limit ⁽³⁾							····) //···· ^	
0 ≤ I _L ≤ 1 mA				±0.5			±0.5		mV/mA	
	T _{MIN} ≤ T _A ≤ T _{MAX} , -40°C ≤ T _J ≤ 125°C	Tested Limit ⁽²⁾								
		Design Limit ⁽³⁾			±5			±5		

 Accuracy is defined as the error between the output voltage and 10 mv/°C times the case temperature of the device, at specified conditions of voltage, current, and temperature (expressed in °C).

(2) Tested Limits are ensured and 100% tested in production.

(5) Regulation is measured at constant junction temperature, using pulse testing with a low duty cycle. Changes in output due to heating effects can be computed by multiplying the internal dissipation by the thermal resistance.

⁽³⁾ Design Limits are ensured (but not 100% production tested) over the indicated temperature and supply voltage ranges. These limits are not used to calculate outgoing quality levels.

⁽⁴⁾ Non-linearity is defined as the deviation of the output-voltage-versus-temperature curve from the best-fit straight line, over the rated temperature range of the device.



Electrical Characteristics: LM35, LM35C, LM35D (continued)

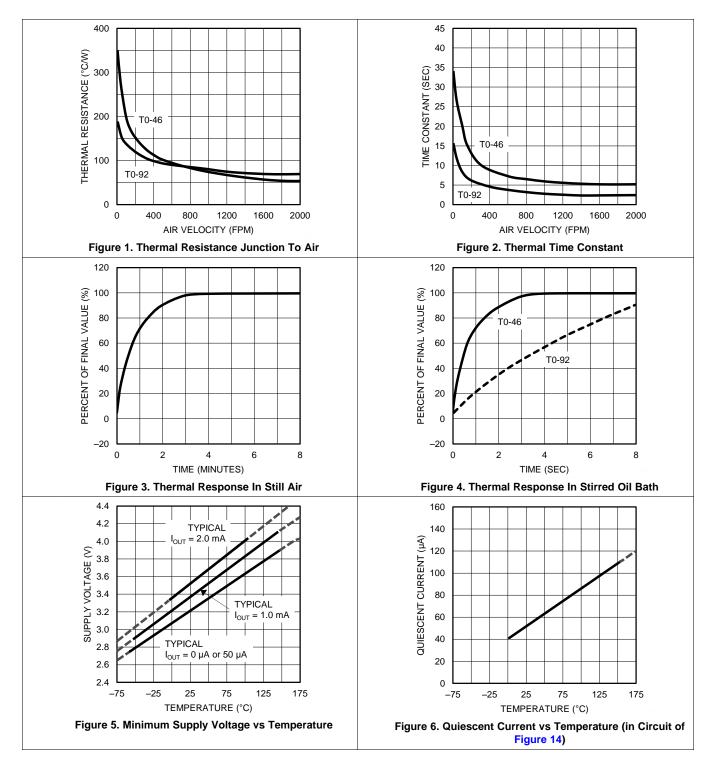
Unless otherwise noted, these specifications apply: $-55^{\circ}C \le T_{J} \le 150^{\circ}C$ for the LM35 and LM35A; $-40^{\circ}C \le T_{J} \le 110^{\circ}C$ for the LM35C and LM35CA; and $0^{\circ}C \le T_{J} \le 100^{\circ}C$ for the LM35D. $V_{S} = 5$ Vdc and $I_{LOAD} = 50 \ \mu$ A, in the circuit of Full-Range Centigrade Temperature Sensor. These specifications also apply from 2°C to T_{MAX} in the circuit of Figure 14.

	TEAT OONID	TIONO		LM35		LM3	85C, LM35	D		
PARAMETER	TEST CONDI	TIONS	MIN	TYP	MAX	MIN	TYP	MAX	UNIT	
				±0.01			±0.01			
	$T_A = 25^{\circ}C$	Tested Limit ⁽²⁾			±0.1					
		Design Limit ⁽³⁾						±0.1		
Line regulation ⁽⁵⁾				±0.02			±0.02		mV/V	
	4 V ≤ V _S ≤ 30 V, -40°C ≤ T _J ≤ 125°C	Tested Limit ⁽²⁾								
	-40 0 - 1 - 120 0	Design Limit ⁽³⁾			±0.2			±0.2		
				56			56			
V _S = 5 V, 25°C	V _S = 5 V, 25°C	Tested Limit ⁽²⁾			80			80		
		Design Limit ⁽³⁾								
	V _S = 5 V, −40°C ≤ T _J ≤ 125°C			105		· · ·	91			
		Tested Limit ⁽²⁾								
Quiescent current ⁽⁶⁾		Design Limit ⁽³⁾			158			138		
				56.2			56.2		μA	
	V _S = 30 V, 25°C	Tested Limit ⁽²⁾			82			82		
		Design Limit ⁽³⁾								
				105.5			91.5			
	V _S = 30 V, -40°C ≤ T _{.1} ≤ 125°C	Tested Limit ⁽²⁾								
	-40 C 3 1j 3 125 C	Design Limit ⁽³⁾			161			141		
	4 V ≤ V _S ≤ 30 V, 25°C			0.2			0.2			
		Tested Limit ⁽²⁾						2		
Change of		Design Limit ⁽³⁾			2					
quiescent current ⁽⁵⁾				0.5			0.5		μA	
	4 V ≤ V _S ≤ 30 V, -40°C ≤ T _J ≤ 125°C	Tested Limit ⁽²⁾								
	-40 0 - 1 - 120 0	Design Limit ⁽³⁾			3			3		
Temperature				0.39			0.39			
coefficient of	–40°C ≤ T _J ≤ 125°C	Tested Limit ⁽²⁾							µA/°C	
quiescent current		Design Limit ⁽³⁾			0.7			0.7		
Minimum				1.5			1.5			
temperature for	In circuit of Figure 14, $I_L = 0$	Tested Limit ⁽²⁾							°C	
rate accuracy		Design Limit ⁽³⁾			2			2		
Long term stability	$T_J = T_{MAX}$, for 1000 hours			±0.08		· · ·	±0.08		°C	

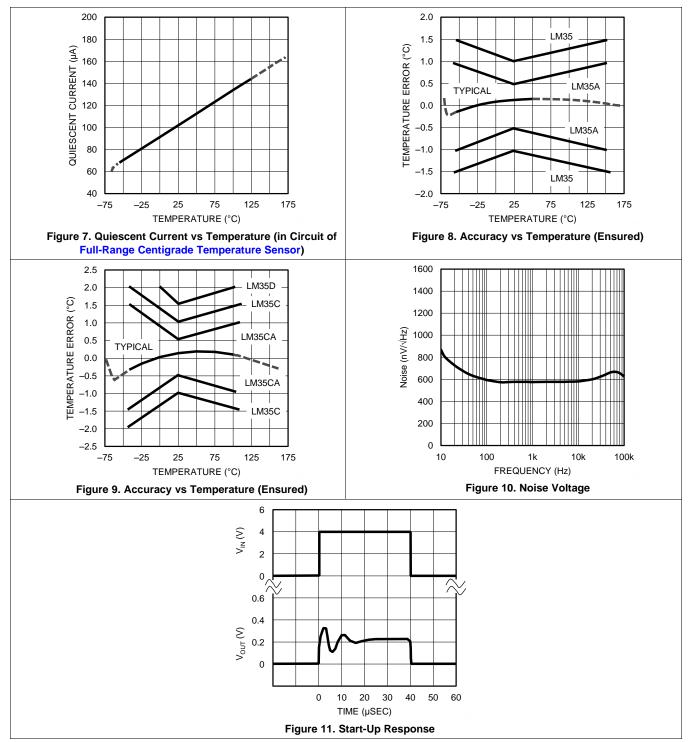
(6) Quiescent current is defined in the circuit of Figure 14.



6.9 Typical Characteristics



Typical Characteristics (continued)





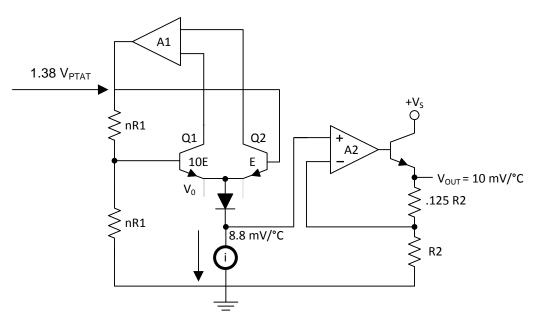
7 Detailed Description

7.1 Overview

The LM35-series devices are precision integrated-circuit temperature sensors, with an output voltage linearly proportional to the Centigrade temperature. The LM35 device has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from the output to obtain convenient Centigrade scaling. The LM35 device does not require any external calibration or trimming to provide typical accuracies of $\pm \frac{1}{4}$ °C at room temperature and $\pm \frac{3}{4}$ °C over a full -55°C to 150°C temperature range. Lower cost is assured by trimming and calibration at the wafer level. The low output impedance, linear output, and precise inherent calibration of the LM35 device makes interfacing to readout or control circuitry especially easy. The device is used with single power supplies, or with plus and minus supplies. As the LM35 device draws only 60 μ A from the supply, it has very low self-heating of less than 0.1°C in still air. The LM35 device is rated to operate over a -55°C to 150°C temperature range, while the LM35C device is rated for a -40°C to 110°C range (-10° with improved accuracy). The temperature-sensing element is comprised of a delta-V BE architecture.

The temperature-sensing element is then buffered by an amplifier and provided to the VOUT pin. The amplifier has a simple class A output stage with typical $0.5-\Omega$ output impedance as shown in the *Functional Block Diagram*. Therefore the LM35 can only source current and it's sinking capability is limited to 1 μ A.

7.2 Functional Block Diagram



7.3 Feature Description

7.3.1 LM35 Transfer Function

The accuracy specifications of the LM35 are given with respect to a simple linear transfer function:

 $V_{OUT} = 10 \text{ mv/}{}^{\circ}\text{F} \times \text{T}$

where

- V_{OUT} is the LM35 output voltage
- T is the temperature in °C

7.4 Device Functional Modes

The only functional mode of the LM35 is that it has an analog output directly proportional to temperature.

(1)



8 Application and Implementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

8.1 Application Information

The features of the LM35 make it suitable for many general temperature sensing applications. Multiple package options expand on it's flexibility.

8.1.1 Capacitive Drive Capability

Like most micropower circuits, the LM35 device has a limited ability to drive heavy capacitive loads. Alone, the LM35 device is able to drive 50 pF without special precautions. If heavier loads are anticipated, isolating or decoupling the load with a resistor is easy (see Figure 12). The tolerance of capacitance can be improved with a series R-C damper from output to ground (see Figure 13).

When the LM35 device is applied with a 200- Ω load resistor as shown in Figure 16, Figure 17, or Figure 19, the device is relatively immune to wiring capacitance because the capacitance forms a bypass from ground to input and not on the output. However, as with any linear circuit connected to wires in a hostile environment, performance is affected adversely by intense electromagnetic sources (such as relays, radio transmitters, motors with arcing brushes, and SCR transients), because the wiring acts as a receiving antenna and the internal junctions act as rectifiers. For best results in such cases, a bypass capacitor from V_{IN} to ground and a series R-C damper, such as 75 Ω in series with 0.2 or 1 µF from output to ground, are often useful. Examples are shown in Figure 13, Figure 24, and Figure 25.

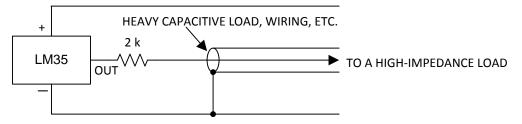


Figure 12. LM35 with Decoupling from Capacitive Load

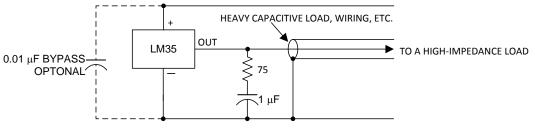


Figure 13. LM35 with R-C Damper



8.2 Typical Application

8.2.1 Basic Centigrade Temperature Sensor

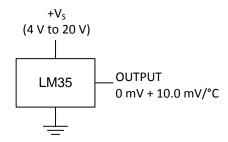


Figure 14. Basic Centigrade Temperature Sensor (2 °C to 150 °C)

8.2.1.1 Design Requirements

PARAMETER	VALUE				
Accuracy at 25°C	±0.5°C				
Accuracy from -55 °C to 150°C	±1°C				
Temperature Slope	10 mV/°C				

Table 1. Design Parameters

8.2.1.2 Detailed Design Procedure

Because the LM35 device is a simple temperature sensor that provides an analog output, design requirements related to layout are more important than electrical requirements. For a detailed description, refer to the *Layout*.

8.2.1.3 Application Curve

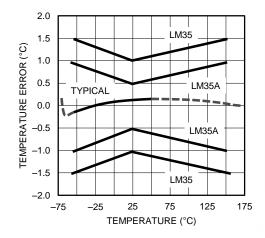
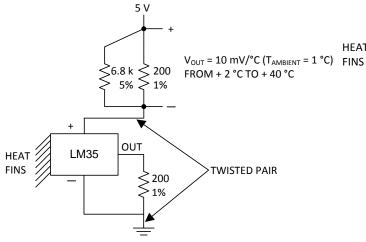
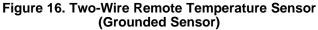


Figure 15. Accuracy vs Temperature (Ensured)

8.3 System Examples





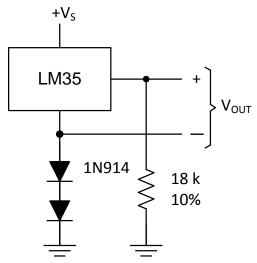


Figure 18. Temperature Sensor, Single Supply (-55° to +150°C)

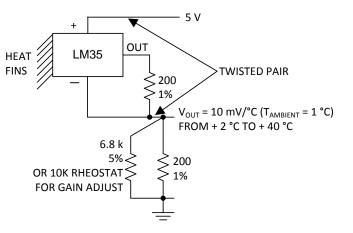


Figure 17. Two-Wire Remote Temperature Sensor (Output Referred to Ground)

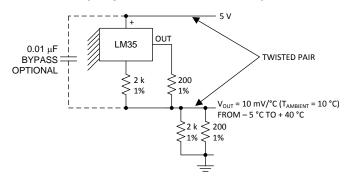
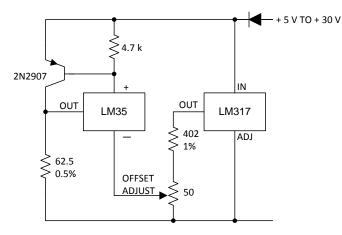


Figure 19. Two-Wire Remote Temperature Sensor (Output Referred to Ground)



System Examples (continued)



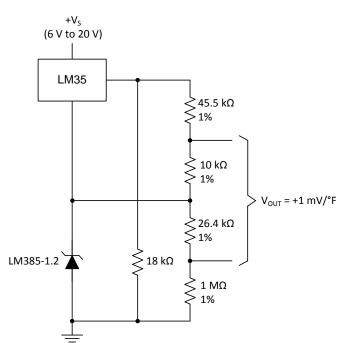


Figure 20. 4-To-20 mA Current Source (0°C to 100°C)

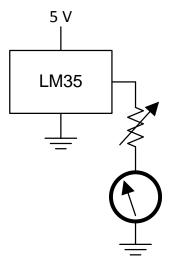


Figure 22. Centigrade Thermometer (Analog Meter)

Figure 21. Fahrenheit Thermometer

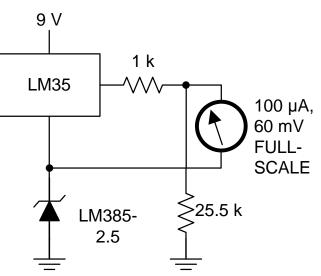


Figure 23. Fahrenheit Thermometer, Expanded Scale Thermometer (50°F to 80°F, for Example Shown)



System Examples (continued)

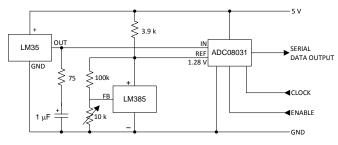
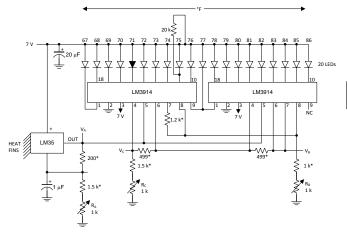


Figure 24. Temperature to Digital Converter (Serial Output) (128°C Full Scale)



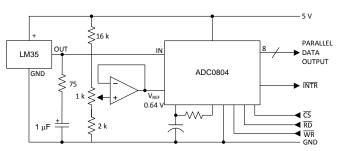
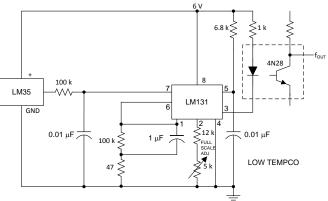


Figure 25. Temperature to Digital Converter (Parallel TRI-STATE Outputs for Standard Data Bus to µP Interface) (128°C Full Scale)



*=1% or 2% film resistor

Trim R_B for $V_B = 3.075$ V

Trim R_C for V_C = 1.955 V

Trim R_A for V_A = 0.075 V + 100 mV/°C \times T_{ambient}

Example, $V_A = 2.275 \text{ V}$ at 22°C

Figure 26. Bar-Graph Temperature Display (Dot Mode)

Figure 27. LM35 With Voltage-To-Frequency Converter and Isolated Output (2°C to 150°C; 20 to 1500 Hz)



9 Power Supply Recommendations

The LM35 device has a very wide 4-V to 5.5-V power supply voltage range, which makes it ideal for many applications. In noisy environments, TI recommends adding a 0.1 μ F from V+ to GND to bypass the power supply voltage. Larger capacitances maybe required and are dependent on the power-supply noise.

10 Layout

10.1 Layout Guidelines

The LM35 is easily applied in the same way as other integrated-circuit temperature sensors. Glue or cement the device to a surface and the temperature should be within about 0.01°C of the surface temperature.

The 0.01°C proximity presumes that the ambient air temperature is almost the same as the surface temperature. If the air temperature were much higher or lower than the surface temperature, the actual temperature of the LM35 die would be at an intermediate temperature between the surface temperature and the air temperature; this is especially true for the TO-92 plastic package. The copper leads in the TO-92 package are the principal thermal path to carry heat into the device, so its temperature might be closer to the air temperature than to the surface temperature.

Ensure that the wiring leaving the LM35 device is held at the same temperature as the surface of interest to minimize the temperature problem. The easiest fix is to cover up these wires with a bead of epoxy. The epoxy bead will ensure that the leads and wires are all at the same temperature as the surface, and that the temperature of the LM35 die is not affected by the air temperature.

The TO-46 metal package can also be soldered to a metal surface or pipe without damage. Of course, in that case the V- terminal of the circuit will be grounded to that metal. Alternatively, mount the LM35 inside a sealedend metal tube, and then dip into a bath or screw into a threaded hole in a tank. As with any IC, the LM35 device 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. Printed-circuit coatings and varnishes such as a conformal coating and epoxy paints or dips are often used to insure that moisture cannot corrode the LM35 device or its connections.

These devices are sometimes soldered to a small light-weight heat fin to decrease the thermal time constant and speed up the response in slowly-moving air. On the other hand, a small thermal mass may be added to the sensor, to give the steadiest reading despite small deviations in the air temperature.

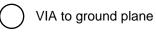
	TO, no heat sink	TO ⁽¹⁾ , small heat fin	TO-92, no heat sink	TO-92 ⁽²⁾ , small heat fin	SOIC-8, no heat sink	SOIC-8 ⁽²⁾ , small heat fin	TO-220, no heat sink
Still air	400°C/W	100°C/W	180°C/W	140°C/W	220°C/W	110°C/W	90°C/W
Moving air	100°C/W	40°C/W	90°C/W	70°C/W	105°C/W	90°C/W	26°C/W
Still oil	100°C/W	40°C/W	90°C/W	70°C/W	_		_
Stirred oil	50°C/W	30°C/W	45°C/W	40°C/W	_	_	_
(Clamped to metal, Infinite heat sink)	(24°	C/W)	_	_	(55°)	C/W)	_

Table 2. Temperature Rise of LM35 Due To Self-heating (Thermal Resistance, R_{0JA})

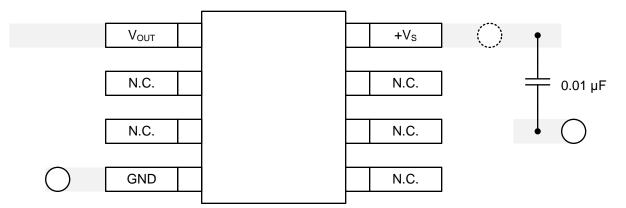
(1) Wakefield type 201, or 1-in disc of 0.02-in sheet brass, soldered to case, or similar.

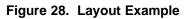
(2) TO-92 and SOIC-8 packages glued and leads soldered to 1-in square of 1/16-in printed circuit board with 2-oz foil or similar.

10.2 Layout Example



VIA to power plane







11 Device and Documentation Support

11.1 Trademarks

All trademarks are the property of their respective owners.

11.2 Electrostatic Discharge Caution



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

11.3 Glossary

SLYZ022 — TI Glossary.

This glossary lists and explains terms, acronyms, and definitions.

12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.



13-Jan-2016

PACKAGING INFORMATION

Orderable Device	Status	Package Type	•	Pins	•	Eco Plan	Lead/Ball Finish	MSL Peak Temp	Op Temp (°C)	Device Marking	Samples
	(1)		Drawing		Qty	(2)	(6)	(3)		(4/5)	
LM35AH	ACTIVE	то	NDV	3	500	TBD	Call TI	Call TI	-55 to 150	(LM35AH ~ LM35AH)	Samples
LM35AH/NOPB	ACTIVE	то	NDV	3	500	Green (RoHS & no Sb/Br)	Call TI	Level-1-NA-UNLIM	-55 to 150	(LM35AH ~ LM35AH)	Samples
LM35CAH	ACTIVE	то	NDV	3	500	TBD	Call TI	Call TI	-40 to 110	(LM35CAH ~ LM35CAH)	Sample
LM35CAH/NOPB	ACTIVE	то	NDV	3	500	Green (RoHS & no Sb/Br)	Call TI	Level-1-NA-UNLIM	-40 to 110	(LM35CAH ~ LM35CAH)	Sample
LM35CAZ/LFT4	ACTIVE	TO-92	LP	3	2000	Green (RoHS & no Sb/Br)	CU SN	N / A for Pkg Type		LM35 CAZ	Sample
LM35CAZ/NOPB	ACTIVE	TO-92	LP	3	1800	Green (RoHS & no Sb/Br)	CU SN	N / A for Pkg Type	-40 to 110	LM35 CAZ	Sample
LM35CH	ACTIVE	то	NDV	3	500	TBD	Call TI	Call TI	-40 to 110	(LM35CH ~ LM35CH)	Sample
LM35CH/NOPB	ACTIVE	ТО	NDV	3	500	Green (RoHS & no Sb/Br)	Call TI	Level-1-NA-UNLIM	-40 to 110	(LM35CH ~ LM35CH)	Sample
LM35CZ/LFT1	ACTIVE	TO-92	LP	3	2000	Green (RoHS & no Sb/Br)	CU SN	N / A for Pkg Type	LM35 CZ		Sample
LM35CZ/NOPB	ACTIVE	TO-92	LP	3	1800	Green (RoHS & no Sb/Br)	CU SN	N / A for Pkg Type	-40 to 110	LM35 CZ	Sample
LM35DH	ACTIVE	то	NDV	3	1000	TBD	Call TI	Call TI	0 to 70	(LM35DH ~ LM35DH)	Sample
LM35DH/NOPB	ACTIVE	то	NDV	3	1000	Green (RoHS & no Sb/Br)	Call TI POST-PLATE	Level-1-NA-UNLIM	0 to 70	(LM35DH ~ LM35DH)	Sample
LM35DM	NRND	SOIC	D	8	95	TBD	Call TI	Call TI	0 to 100	LM35D M	
LM35DM/NOPB	ACTIVE	SOIC	D	8	95	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	0 to 100	LM35D M	Sample
LM35DMX	NRND	SOIC	D	8	2500	TBD	Call TI	Call TI	0 to 100	LM35D M	
LM35DMX/NOPB	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	0 to 100	LM35D M	Sample
LM35DT	NRND	TO-220	NEB	3	45	TBD	Call TI	Call TI	0 to 100	LM35DT	
LM35DT/NOPB	ACTIVE	TO-220	NEB	3	45	TBD	Call TI	Call TI	0 to 100		Sample



PACKAGE OPTION ADDENDUM

13-Jan-2016

Orderable Device	Status	Package Type	•	Pins	•	Eco Plan	Lead/Ball Finish	MSL Peak Temp	Op Temp (°C)	Device Marking	Samples
	(1)		Drawing		Qty	(2)	(6)	(3)		(4/5)	
LM35DZ	OBSOLETE	TO-92	LP	3		TBD	Call TI	Call TI			
LM35DZ/LFT1	ACTIVE	TO-92	LP	3	2000	Green (RoHS & no Sb/Br)	CU SN	N / A for Pkg Type		LM35 DZ	Samples
LM35DZ/LFT4	ACTIVE	TO-92	LP	3	2000	Green (RoHS & no Sb/Br)	CU SN	N / A for Pkg Type		LM35 DZ	Samples
LM35DZ/NOPB	ACTIVE	TO-92	LP	3	1800	Green (RoHS & no Sb/Br)	CU SN	N / A for Pkg Type	0 to 100	LM35 DZ	Samples
LM35H	ACTIVE	то	NDV	3	500	TBD	Call TI	Call TI	-55 to 150	(LM35H ~ LM35H)	Samples
LM35H/NOPB	ACTIVE	то	NDV	3	500	Green (RoHS & no Sb/Br)	Call TI	Level-1-NA-UNLIM	-55 to 150	(LM35H ~ LM35H)	Samples



PACKAGE OPTION ADDENDUM

13-Jan-2016

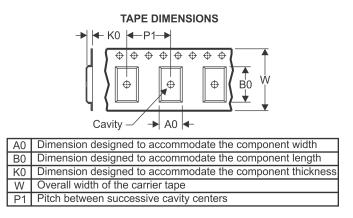
Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.



TAPE AND REEL INFORMATION





QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal												
Device	Package Type	Package Drawing		SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
LM35DMX	SOIC	D	8	2500	330.0	12.4	6.5	5.4	2.0	8.0	12.0	Q1
LM35DMX/NOPB	SOIC	D	8	2500	330.0	12.4	6.5	5.4	2.0	8.0	12.0	Q1



PACKAGE MATERIALS INFORMATION

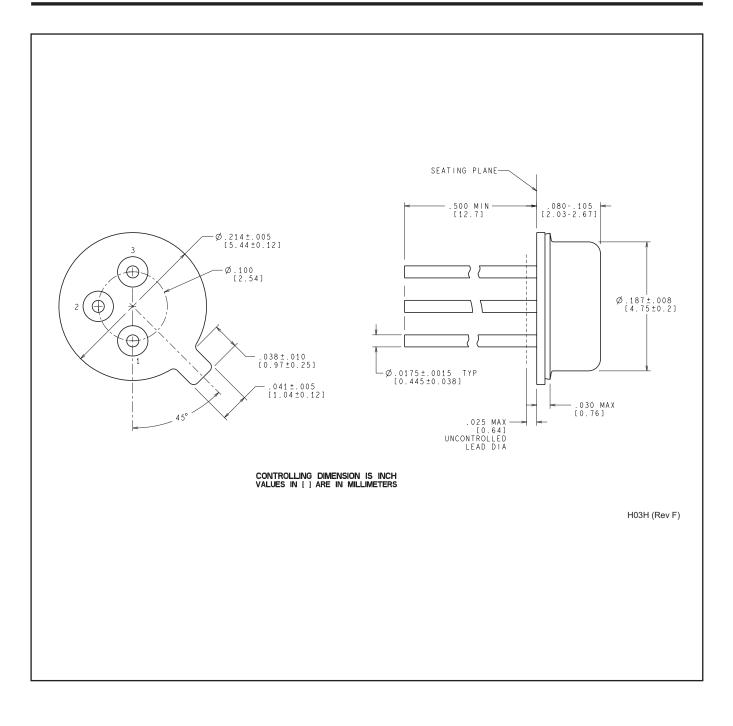
5-Jan-2016



*All dimensions are nominal

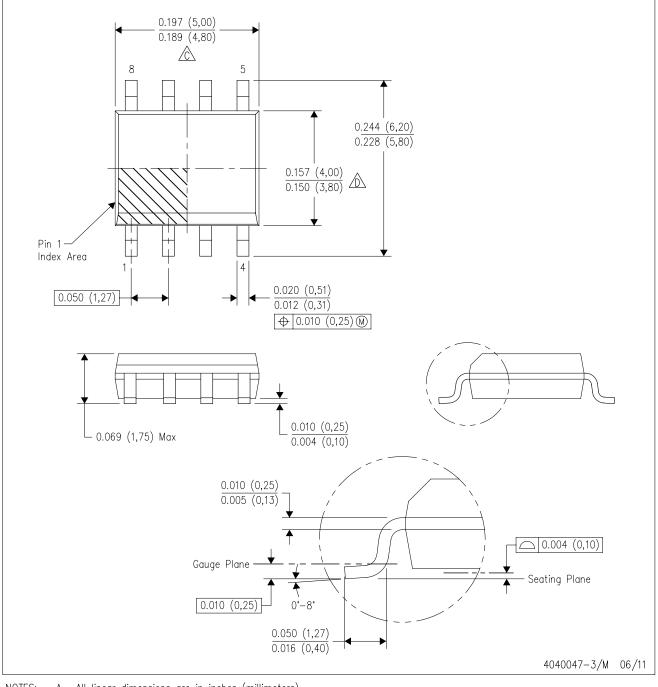
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LM35DMX	SOIC	D	8	2500	367.0	367.0	35.0
LM35DMX/NOPB	SOIC	D	8	2500	367.0	367.0	35.0

NDV0003H



D (R-PDSO-G8)

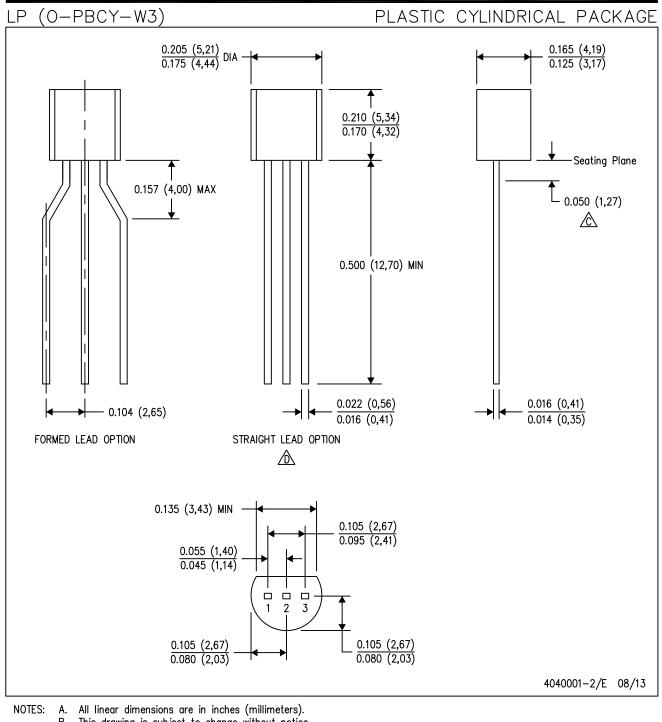
PLASTIC SMALL OUTLINE



NOTES: A. All linear dimensions are in inches (millimeters).

- B. This drawing is subject to change without notice.
- Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.
- Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
- E. Reference JEDEC MS-012 variation AA.

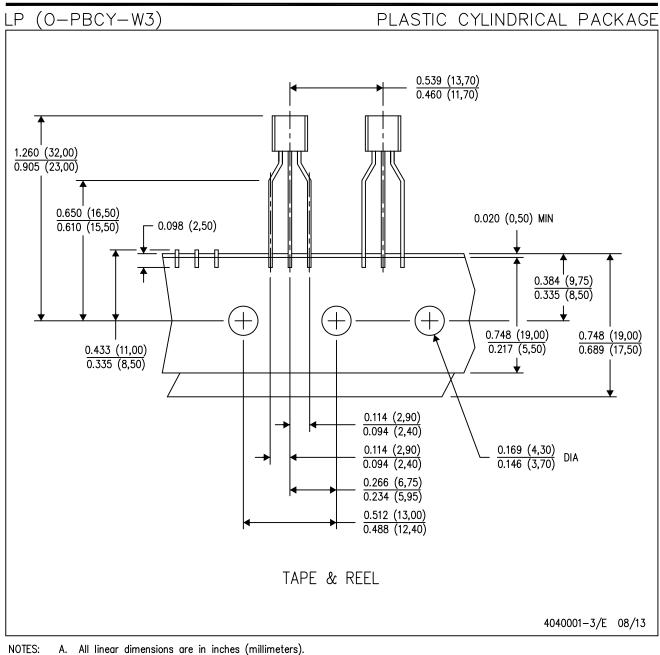




- B. This drawing is subject to change without notice. Lead dimensions are not controlled within this area.
- ⚠ Falls within JEDEC TO-226 Variation AA (TO-226 replaces TO-92).
- Shipping Method: E. Straight lead option available in bulk pack only. Formed lead option available in tape & reel or ammo pack. Specific products can be offered in limited combinations of shipping mediums and lead options. Consult product folder for more information on available options.



MECHANICAL DATA



- B. This drawing is subject to change without notice.
- C. Tape and Reel information for the Formed Lead Option package.



IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as "components") are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI's terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers' products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers' products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI's goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or "enhanced plastic" are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have *not* been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.