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## **TMP122-EP**

SBOS454-NOVEMBER 2008

# 1.5°C ACCURATE PROGRAMMABLE DIGITAL TEMPERATURE SENSORS WITH SPI™ INTERFACE

### FEATURES

- Digital Output: SPI-Compatible Interface
- Programmable Resolution: 9 to 12 Bits + Sign
- Aaccuracy: ±1.5°C from -25°C to 85°C (max) ±2.0°C from -55°C to 125°C (max)
- Low Quiescent Current: 50 μA
- Wide Supply Range: 2.7 V to 5.5 V
- **Tiny SOT23-6 Package**
- Operation to 150°C .
- **Programmable High/Low Setpoints**

#### APPLICATIONS

- **Power-Supply Temperature Monitoring** •
- **Computer Peripheral Thermal Protection**
- **Notebook Computers**
- **Cell Phones** .
- **Battery Management** .
- **Office Machines**
- **Thermostat Controls**
- **Environmental Monitoring and HVAC**
- **Electromechanical Device Temperature**

#### SUPPORTS DEFENSE, AEROSPACE, AND MEDICAL APPLICATIONS

- **Controlled Baseline**
- **One Assembly/Test Site** •
- **One Fabrication Site**
- Available in Military (-55°C/125°C) Temperature Range<sup>(1)</sup>
- **Extended Product Life Cycle**
- **Extended Product-Change Notification**
- **Product Traceability**
- (1) Additional temperature ranges are available contact factory

### DESCRIPTION

The TMP122 is an SPI-compatible temperature sensor available in an SOT23-6 package. Requiring only a pull-up resistor for complete function, the TMP122 temperature sensor is capable of measuring temperatures within 2°C of accuracy over a temperature range of -55°C to 125°C, with operation up to 150°C. Programmable resolution. programmable set points and shut down function provide versatility for any application. Low supply current and a supply range from 2.7 V to 5.5 V make the TMP122 an excellent candidate for low-power applications.

The TMP122 is ideal for extended thermal measurement in a variety of communication, computer, consumer, environmental, industrial, and instrumentation applications.





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This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

#### ORDERING INFORMATION<sup>(1)</sup>

T <sub>A</sub>	PACK	AGE <sup>(2)</sup>	ORDERABLE PART NUMBER	TOP-SIDE MARKING		
–55°C to 125°C	SOT23-6	Tape and reel of 250	TMP122AMDBVTEP	122E		

(1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI web site at www.ti.com.

(2) Package drawings, thermal data, and symbolization are available at www.ti.com/packaging.

### **ABSOLUTE MAXIMUM RATINGS**

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

		VALUE	UNIT
V+	Power supply	7	V
VI	Input voltage	-0.3 to 7	V
	Inout current	10	mA
	Operating temperature range	-55 to 150	°C
	Storage temperature range	-60 to 150	°C
T <sub>J</sub> (max)	Junction temperature	150	°C
	Lead temperature (soldering)	300	°C

#### **PIN CONFIGURATION**





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#### **ELECTRICAL CHARACTERISTICS**

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

	PARAMETER	TEST CONDITIONS	MIN	ТҮР	MAX	UNIT
Temperature	Range		-55		125	°C
input		-25°C to 85°C		±0.5	±1.5	
	Accuracy (temperature error)	-55°C to 125°C		±1.0	±2.0	°C
		-55°C to 150°C		±1.5		
	vs supply			0.1		°C/V
	Resolution <sup>(1)</sup>	Selectable		±0.0625		°C
Digital	V <sub>IH</sub>		0.7 (V+)			V
input/output	V <sub>IL</sub>				0.3 (V+)	V
	Input current, SO/I, SCK, CS	$0 \vee \leq \vee_{IN} \leq \vee +$			±1	μA
	V <sub>OL</sub> SO/I	I <sub>SINK</sub> = 3mA			0.4	V
	V <sub>OH</sub> SO/I	I <sub>SOURCE</sub> = 2mA	(V+) - 0.4			V
	V <sub>OL</sub> ALERT	I <sub>SINK</sub> = 4mA			0.4	V
	Leakage current ALERT	0 V ≤ V <sub>IN</sub> ≤ 6 V			±1	μA
	Input capacitance, SO/I, SCK, $\overline{CS}$ , ALERT			2.5		pF
	Reolution	Selectable		9 to 12 + sign		bits
	Conversion time	9 bit + sign		30	40	
		10 bit + sign		60	80	~~~
		11 bit + sign		120	160	ms
		12 bit + sign		240	320	
Power supply	Operating range		2.7		5.5	V
	Quiescent current IQ	Serial bus inactive		50	75	^
	Shutdown current I <sub>SD</sub>	Serial bus inactive		0.1	1	μΑ
Temperature	Specified range		-55		125	
range C	Operating range		-55		150	°C
	Storage range		-60		150	
	Thermal resistance, $\theta_{JA}$	SOT23-6 surface-mount		200		°C/W

(1) Specified for 12-bit resolution.

## TMP122-EP

TEXAS INSTRUMENTS





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#### **APPLICATION INFORMATION**

The TMP122 digital temperature sensor is optimal for thermal management and thermal protection applications. The TMP122 is SPI interface-compatible and specified for a temperature range of -55°C to 125°C.

The TMP122 requires minimal external components for operation, needing only a pullup resistor on the ALERT pin and a bypass capacitor on the supply. Bypass capacitors of 0.1  $\mu$ F is recommended. Figure 1 shows typical connections for the TMP122.



Figure 1. Typical Connections

To maintain accuracy in applications requiring air or surface temperature measurement, care should be taken to isolate the package and leads from ambient air temperature.



Figure 2. Multiple Command Sequence

### **COMMUNICATING WITH THE TMP122**

The TMP122 converts continuously. If  $\overline{CS}$  is brought low during a conversion the conversion process continues, but the last completed conversion is available at the output register. Communication with the TMP122 is initiated by pulling  $\overline{CS}$  low. The first 16 clocks of data transfer will return temperature data from the temperature sensors. The 16-bit data word is clocked out sign bit first, followed by the MSB. Any portion of the 16-bit word may be read before raising  $\overline{CS}$ . If the user wishes to continue with  $\overline{CS}$  low, the following 16 clocks transfer in a READ or WRITE command. READ and WRITE commands are described in Table 1 and Table 2.

The READ command contains an embedded address in bits D4 and D3 to identify which register to read. Bits D4 and D3 are internally registered and will hold their value following a READ command until an entire 16-bit read is completed by the user. The completion of the 16-bit READ acknowledges that the READ command has been completed. If the user issues a READ command and then raises CS with less than 16 subsequent clocks, the data from that register will be available at the next fall of CS. Teh registered READ address will remain in effect until a full 16 clocks have been received. After the compleation of a 16-bit READ from the part, the READ address is reset to return data from the Temperature Register. A WRITE command to a register will not change the READ address registered. For further discussion on the READ address register, see the *Read Address Register* section.

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Multiple commands may be strung together as <u>illustrated</u> in Figure 2. The TMP122 accepts commands alternating with 16-bit response data. On lowering CS, the part always responds with a READ from the address location indicated by the READ address register. If the next command is a READ command then data is returned from the address specified by the READ command with the 16th clock resetting the READ address register to the default temperature register. The TMP122 then expects a 16-bit command. If the command is a WRITE command, then the 16 clocks following the command will again return temperature data.

Figure 3, Figure 4, Figure 5, and Figure 6 detail the communication sequences.

Table 1. READ Command

READ Command	D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
Temperature	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Configuration register	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Low temperature threshold	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
High temperature threshold	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0

#### **Table 2. WRITE Command**

WRITE Command	D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
Temperature	0	0	0	0	D1	D0	R1	R0	F1	F0	POL	TM1	TM0	0	1	0
Low temperature threshold	T12	T11	T10	Т9	Т8	Т7	Т6	T5	T4	Т3	T2	T1	Т0	1	0	0
High temperature threshold	T12	T11	T10	Т9	Т8	T7	Т6	T5	T4	Т3	T2	T1	Т0	1	1	0
Shutdown command	х	х	х	х	х	х	х	х	1	1	1	1	1	1	1	1



NOTE: (1) 0 indicates  $T_{LOW}$  register, 1 indicates  $T_{HIGH}$  register.









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Figure 6. Data READ

### **READ ADDRESS REGISTER**

Figure 7 shows the internal register structure of the TMP122/TMP124. Table III describes the addresses of the registers available. The READ address register uses the two bits to identify which of the data registers should respond to a read command. Following a complete 16-bit read, the READ address register is reset to the default power-up state of P1/P0 equal 0/0.





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#### Table 3. Pointer Addresses

P1	P0	REGISTER						
0	0	Temperature Register (READ only)						
0	1	Configuration Register (READ/WRITE)						
1	0	T <sub>LOW</sub> Register (READ/WRITE)						
1	1	T <sub>HIGH</sub> Register (READ/WRITE)						

### **TEMPERATURE REGISTER**

The Temperature Register of the TMP122 is a 16-bit, signed read-only register that stores the output of the most recent conversion. The TMP122 is specified for the temperature range of -55°C to 125°C with operation from -55°C to 150°C. Up to 16 bits can be read to obtain data and are described in Table 4. The first 13 bits are used to indicate temperature where bit D2 is 1, and D1, D0 are in a high impedance state. Data format for temperature is summarized in Table 5. Following power-up or reset, the Temperature Register will read 0°C until the first conversion is complete.

	Table 4. Temperature Register														
D15 D14 D13 D12 D11 D10 D9 D8 D7 D6 D5 D4 D3 D2 D1											D1	D0			
T12	T11	T10	Т9	T8	T7	T6	T5	T4	Т3	T2	T1	Т0	1	Z	Z

TEMPERATURE (°c)	DIGITAL OUTPUT <sup>(1)</sup> (BINARY)	HEX
150	0100 1011 0000 0111	4B07
125	0011 1110 1000 0111	3E87
25	0000 1100 1000 0111	0C87
0.0625	0000 0000 0000 1111	000F
0	0000 0000 0000 0111	0007
-0.0625	1111 1111 1111 1111	FFFF
-25	1111 0011 1000 0111	F387
-55	1110 0100 1000 0111	E487

Table 5. Temperature Data Format

(1) The last two bits are high impedance and are shown as 11 in the table.

The user can obtain 9, 10, 11, or 12 bits of resolution by addressing the Configuration Register and setting the resolution bits accordingly. For 9-, 10-, or 11-bit resolution, the most significant bits in the Temperture Register are used with the unused LSBs set to zero.

### CONFIGURATION REGISTER

The Configuration Register is a 16-bit read/write register used to store bits that control the operational modes of the temperature sensor. Read/write operations are performed MSB first. The format of the Configuration Register for the TMP122 is shown in Table 6, followed by a break-down of the register bits. The power-up/reset value of the Configuration Register bits R1/R0 equal 1/1, all other bits equal zero.

#### Table 6. Configuration Register

D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
0	0	0	0	D1	D0	R1	R0	F1	F0	POL	TM1	TM0	0	1	0

### SHUTDOWN MODE (SD)

The Shutdown Mode of the TMP122 can be used to shut down all device circuitry except the serial interface. Shutdown mode occurs when the last 8 bits of the WRITE command are equal to 1, and will occur once the current conversion is completed, reducing current consumption to less than 1  $\mu$ A. To take the part out of shutdown, send any command or pattern after the 16-bit read with the last 8 bits not equal to one. Power on default is in active mode.



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### THERMOSTAT MODE (TM1/TM0)

The Thermostat Mode bits of the TMP122 indicate to the device whether to operate in Comparator Mode, Interrupt Mode or Interrupt Comparator Mode. For more information on Comparator and Interrupt Mode, see text HIGH and LOW limit registers. The bit assignments for thermostat mode are described in Table 7. Power on default is comparator mode.

TM1	ТМО	MODE OF OPERATION
0	0	Comparator mode
0	1	Interrupt mode
1	0	Interrupt comparator mode
1	1	Reserved

#### Table 7. Mode Settings

### POLARITY (POL)

The Polarity Bit of the TMP122 adjusts the polarity of the ALERT pin output. By default, POL = 0 and the ALERT pin will be active LOW, as shown in Figure 8. For POL = 1 the ALERT Pin will be active HIGH, and the state of the ALERT Pin is inverted.



Figure 8. ALERT Output Transfer Function Diagrams

### FAULT QUEUE (F1/F0)

A fault condition occurs when the measured temperature exceeds the limits set in the  $T_{HIGH}$  and  $T_{LOW}$  registers. The Fault Queue is provided to prevent a false alert due to environmental noise and requires consecutive fault measurements to trigger the alert function of the TMP122. Table 8 defines the number of consecutive faults required to trigger a consecutive alert condition. Power-on default for F1/F0 is 0/0.

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Table 8. Fault Settings

F1	F0	CONSECUTIVE FAULTS
0	0	1
0	1	2
1	0	4
1	1	6

## HIGH AND LOW LIMIT REGISTERS

In Comparator Mode (TM1/TM0 = 0/0), the ALERT Pin of the TMP122 becomes active when the temperature equals or exceeds the value in  $T_{HIGH}$  and generates a consecutive number of faults according to fault bits F1 and F0. The ALERT pin will remain active until the temperature falls below the indicated  $T_{LOW}$  value for the same number of faults.

In Interrupt Mode (TM1/TM0 = 0/1) the ALERT pin becomes active when the temperature equals or exceeds  $T_{HIGH}$  for a consecutive number of fault conditions. The ALERT pin remains active until a read operation of any register occurs. The ALERT pin will also be cleared if the device is placed in Shutdown Mode. Once the ALERT pin is cleared, it will only become active again by the temperature falling below  $T_{LOW}$ . When the temperature falls below  $T_{LOW}$ , the ALERT pin becomes active and remains active until cleared by a read operation of any register. Once the ALERT pin is cleared, the above cycle will repeat with the ALERT pin becoming active when the temperature equals or exceeds  $T_{HIGH}$ .

In Interrupt/Comparator Mode (TM1/TM0 = 1/0), the ALERT Pin of the TMP122 becomes active when the temperature equals or exceeds the value in  $T_{HIGH}$  and generates a consecutive number of faults according to fault bits F1 and F0. The ALERT pin will remain active until the temperature falls below the indicated  $T_{LOW}$  value for the same number of faults and a communication with the device has occurred after that point.

Operational modes are represented in Figure 8. Table 9 and Table 10 describe the format for the  $T_{HIGH}$  and  $T_{LOW}$  registers. Power-up reset values for  $T_{HIGH}$  and  $T_{LOW}$  are:  $T_{HIGH} = 80^{\circ}$ C and  $T_{LOW} = 75^{\circ}$ C. The format of the data for  $T_{HIGH}$  and  $T_{LOW}$  is the same as for the Temperature Register. TABLE IX.  $T_{HIGH}$  Register.

All 13 bits for the Temperature,  $T_{HIGH}$ , and  $T_{LOW}$  registers are used in the comparisons for the ALERT function for all converter resolutions. The three LSBs in  $T_{HIGH}$  and  $T_{LOW}$  can affect the ALERT output even if the converter is configured for 9-bit resolution.

D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
H12	H11	H10	H9	H8	H7	H6	H5	H4	H3	H2	H1	H0	1	1	0

Table 9. THIGH Register

#### Table 10. T<sub>LOW</sub> Register

D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
L12	L11	L10	L9	L8	L7	L6	L5	L4	L3	L2	L1	L0	1	0	0

### **CONVERTER RESOLUTION (R1/R0)**

The Converter Resolution Bits control the resolution of the internal analog-to-digital (A/D) converter. This allows the user to maximize efficiency by programming for higher resolution or faster conversion time. Table 11 identifies the resolution bits and the relationship between resolution and conversion time. The TMP122 has a default resolution of 12 bits.

R1	R2	RESOLUTION	CONVERSION TIME (TYPICAL)
0	0	9 bits (0.5°C) + sign	30 ms
0	1	10 bits (0.25°C) + sign	60 ms
1	0	11 bits (0.125°C) + sign	120 ms
1	1	12 bits (0.0625°C) + sign	240 ms

#### Table 11. Resolution



### **DELAY TIME**

The Delay Bits control the amount of time delay between each conversion. This feature allows the user to maximize power savings by eliminating unnecessary conversions, and minimizing current consumption. During active conversion the TMP122 typically requires 50  $\mu$ A of current for approximately 0.25s conversion time, and approximately 20  $\mu$ A for idle times between conversions. Delay settings are identified in Table 12 as conversion time and period, and are shown in Figure 9. Default power up is D1/D0 equal 0/0. Conversion time and conversion periods scale with resolution. Conversion period denotes time between conversion starts.

D1	D2	CONVERSION TIME	CONVERSION PERIOD
0	0	0.25 s	0.25 s
0	1	0.25 s	0.5 s
1	0	0.25 s	1 s
1	1	0.25 s	8 s

Table 12. Conversion Delay for 12-Bit Resolution



12 Bit Resolution



### TIMING DIAGRAMS

The TMP122 is SPI compatible. Figure 10 to Figure 12 describe the various timing parameters of the TMP122 with timing definitions in Table 13.

	PARAMETER	MIN	MAX	UNIT
t <sub>1</sub>	SCK period	100		ns
t <sub>2</sub>	Data in to rising edge SCK setup time	20		ns
t <sub>3</sub>	SCK falling edge to output data delay		30	ns
t <sub>4</sub>	SCK rising edge to input data hold time	20		ns
t <sub>5</sub>	CS to rising edge SCK set-up time	40		ns
t <sub>6</sub>	CS to output data delay		30	ns
t <sub>7</sub>	CS rising edge to output high impedance		30	ns

#### **Table 13. Timing Description**

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SCK + t<sub>5</sub> + t<sub>1</sub> + t<sub>3</sub> + t<sub>5</sub> + t<sub>1</sub> + t<sub>3</sub>

Figure 10. Output Data Timing Diagram



Figure 11. High Impedance Output Timing Diagram



Figure 12. Input Data Timing Diagram

#### PACKAGING INFORMATION

Orderable Device	Status <sup>(1)</sup>	Package Type	Package Drawing	Pins I	Package Qty	e Eco Plan <sup>(2)</sup>	Lead/Ball Finish	MSL Peak Temp <sup>(3)</sup>
TMP122AMDBVTEP	ACTIVE	SOT-23	DBV	6	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
V62/09607-01XE	ACTIVE	SOT-23	DBV	6	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR

<sup>(1)</sup> The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSOLETE:** TI has discontinued the production of the device.

<sup>(2)</sup> Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details. **TBD:** The Pb-Free/Green conversion plan has not been defined.

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Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

<sup>(3)</sup> MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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#### OTHER QUALIFIED VERSIONS OF TMP122-EP : • Catalog: TMP122

NOTE: Qualified Version Definitions:

• Catalog - TI's standard catalog product

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### TAPE AND REEL INFORMATION





### QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are noming	nal
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Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TMP122AMDBVTEP	SOT-23	DBV	6	250	180.0	8.4	3.2	3.1	1.39	4.0	8.0	Q3



# PACKAGE MATERIALS INFORMATION

17-Oct-2009



\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TMP122AMDBVTEP	SOT-23	DBV	6	250	190.5	212.7	31.8

DBV (R-PDSO-G6)

# PLASTIC SMALL-OUTLINE PACKAGE



- Α. All linear dimensions are in millimeters.
  - Β. This drawing is subject to change without notice.
  - Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side. C.
  - D. Leads 1,2,3 may be wider than leads 4,5,6 for package orientation.
  - E. Falls within JEDEC MO-178 Variation AB, except minimum lead width.



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