# LM20 2.4-V, 10-µA, SC70, DSBGA Temperature Sensor

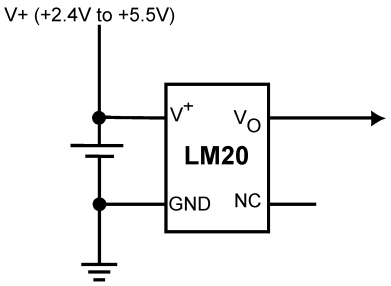
## 1 Features

- Rated for −55°C to 130°C Range
- Available in SC70 and DSBGA Package
- Predictable Curvature Error
- Suitable for Remote Applications
- Accuracy at 30°C ±1.5 to ±4°C (Maximum)
- Accuracy at 130°C and −55°C ±2.5 to ±5°C (Maximum)
- Power Supply Voltage Range 2.4 V to 5.5 V
- Current Drain 10 µA (Maximum)
- Nonlinearity ±0.4% (Typical)
- Output Impedance 160 Ω (Maximum)
- Load Regulation
  0 µA < $I_L$ < 16 µA −2.5 mV (Maximum)

## 2 Applications

- Cellular Phones
- Computers
- Power Supply Modules
- Battery Management
- FAX Machines
- Printers
- HVAC
- Disk Drives
- Appliances

### Simplified Schematic




## 3 Description

The LM20 is a precision analog output CMOS integrated-circuit temperature sensor that operates over −55°C to 130°C. The power supply operating range is 2.4 V to 5.5 V. The transfer function of LM20 is predominately linear, yet has a slight predictable parabolic curvature. The accuracy of the LM20 when specified to a parabolic transfer function is ±1.5°C at an ambient temperature of 30°C. The temperature error increases linearly and reaches a maximum of ±2.5°C at the temperature range extremes. The temperature range is affected by the power supply voltage. At a power supply voltage of 2.7 V to 5.5 V, the temperature range extremes are 130°C and −55°C. Decreasing the power supply voltage to 2.4 V changes the negative extreme to −30°C, while the positive extreme remains at 130°C.

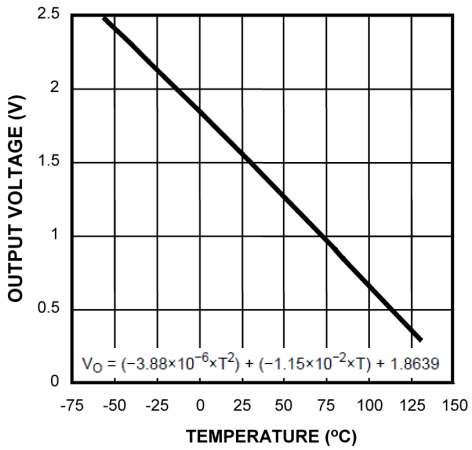
The LM20 quiescent current is less than 10 µA. Therefore, self-heating is less than 0.02°C in still air. Shutdown capability for the LM20 is intrinsic because its inherent low power consumption allows it to be powered directly from the output of many logic gates or does not necessitate shutdown.

### Device Information(1)

| PART NUMBER | PACKAGE | BODY SIZE (NOM) |
|---|---|---|
| LM20 | SC70 (5) | 2.00 mm × 1.25 mm |
| | DSBGA (4) | 0.96 mm × 0.96 mm |

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

### Output Voltage vs Temperature

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## 4 Revision History

**Changes from Revision P (Feburary 2013) to Revision Q** **Page**

- 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

**Changes from Revision O (February 2013) to Revision P** **Page**

- Changed layout of National Data Sheet to TI Format ... 14


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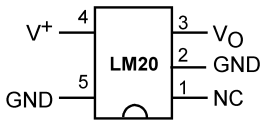
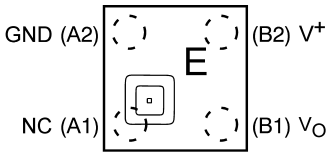
# 5 Pin Configuration and Functions

**DCK Package**
**5-Pin SC70**
**(Top View)**




**YZR Package**
**4-Pin DSBGA**
**(Top View)**




**Pin Functions**

| PIN | | | TYPE | DESCRIPTION |
|---|---|---|---|---|
| NAME | DSBGA | SC70 | | |
| GND | — | 2 | GND | Device substrate and die attach paddle, connect to power supply negative terminal. For optimum thermal conductivity to the PC board ground plane, pin 2 must be grounded. This pin may also be left floating. |
| GND | A2 | 5 | GND | Device ground pin, connect to power supply negative terminal. |
| NC | A1 | 1 | — | NC (pin 1) must be left floating or grounded. Other signal traces must not be connected to this pin. |
| $V_O$ | B1 | 3 | Analog Output | Temperature sensor analog output |
| $V^+$ | B2 | 4 | 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 | 6.5 | V |
| Output Voltage | −0.6 | ($V^+$ + 0.6 ) | V |
| Output Current | | 10 | mA |
| Input Current at any pin(3) | | 5 | mA |
| Maximum Junction Temperature ($T_{JMAX}$) | | 150 | °C |
| Storage temperature, $T_{stg}$ | −65 | 150 | °C |

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) Soldering process must comply with TI's Reflow Temperature Profile specifications. Refer to http://www.ti.com/packaging.
(3) When the input voltage ($V_I$) at any pin exceeds power supplies ($V_I$ < GND or $V_I$ > $V^+$), the current at that pin should be limited to 5 mA.

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## 6.2 ESD Ratings

| | | | VALUE | UNIT |
|---|---|---|---|---|
| $V_{(ESD)}$ | Electrostatic discharge | Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 (1) | ±2500 | V |
| | | Charged-device model (CDM), per JEDEC specification JESD22-C101 (2) | ±250 | |

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

## 6.3 Recommended Operating Conditions

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

| | MIN | MAX | UNIT |
|---|---|---|---|
| LM20B, LM20C with 2.4 V ≤ $V^+$ ≤ 2.7 V | −30 | 130 | °C |
| LM20B, LM20C with 2.7 V ≤ $V^+$ ≤ 5.5 V | −55 | 130 | °C |
| LM20S with 2.4 V ≤ $V^+$ ≤ 5.5 V | −30 | 125 | °C |
| LM20S with 2.7 V ≤ $V^+$ ≤ 5.5 V | −40 | 125 | °C |
| Supply Voltage Range ($V^+$) | 2.4 | 5.5 | V |

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

## 6.4 Thermal Information

| THERMAL METRIC (1) | | LM20 | | UNIT |
|---|---|---|---|---|
| | | DCK (SC70) | YZR (DSBGA) | |
| | | 5 PINS | 4 PINS | |
| $R_{\theta JA}$ | Junction-to-ambient thermal resistance | 282 | 197 | °C/W |
| $R_{\theta JC(top)}$ | Junction-to-case (top) thermal resistance | 93 | 2 | |
| $R_{\theta JB}$ | Junction-to-board thermal resistance | 62 | 40 | |
| $\psi_{JT}$ | Junction-to-top characterization parameter | 1.6 | 11 | |
| $\psi_{JB}$ | Junction-to-board characterization parameter | 62 | 40 | |
| $R_{\theta JC(bot)}$ | Junction-to-case (bottom) thermal resistance | — | — | |

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

## 6.5 Electrical Characteristics: LM20B

Unless otherwise noted, these specifications apply for $V^+$ = 2.7 $V_{DC}$. All limits $T_A$ = $T_J$ = $T_{MIN}$ to $T_{MAX}$, unless otherwise noted.

| PARAMETER | TEST CONDITIONS | MIN (1) | TYP (2) | MAX (1) | UNIT |
|---|---|---|---|---|---|
| Temperature to Voltage Error $V_O = (-3.88\times10^{-6}\times T^2) + (-1.15\times10^{-2}\times T) + 1.8639$ V (3) | $T_A$ = 25°C to 30°C | –1.5 | | 1.5 | °C |
| | $T_A$ = 130°C | –2.5 | | 2.5 | °C |
| | $T_A$ = 125°C | –2.5 | | 2.5 | °C |
| | $T_A$ = 100°C | –2.2 | | 2.2 | °C |
| | $T_A$ = 85°C | –2.1 | | 2.1 | °C |
| | $T_A$ = 80°C | –2.0 | | 2.0 | °C |
| | $T_A$ = 0°C | –1.9 | | 1.9 | °C |
| | $T_A$ = –30°C | –2.2 | | 2.2 | °C |
| | $T_A$ = –40°C | –2.3 | | 2.3 | °C |
| | $T_A$ = –55°C | –2.5 | | 2.5 | °C |
| Output Voltage at 0°C | | | 1.8639 | | V |
| Variance from Curve | | | ±1.0 | | °C |

(1) Limits are ensured to TI's AOQL (Average Outgoing Quality Level).
(2) Typicals are at $T_J$ = $T_A$ = 25°C and represent most likely parametric norm.
(3) Accuracy is defined as the error between the measured and calculated output voltage at the specified conditions of voltage, current, and temperature (expressed in °C).


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## Electrical Characteristics: LM20B (continued)

Unless otherwise noted, these specifications apply for $V^+$ = 2.7 $V_{DC}$. All limits $T_A$ = $T_J$ = $T_{MIN}$ to $T_{MAX}$, unless otherwise noted.

| PARAMETER | TEST CONDITIONS | MIN(1) | TYP(2) | MAX(1) | UNIT |
|---|---|---|---|---|---|
| Non-linearity(4) | –20°C ≤ $T_A$ ≤ 80°C | | ±0.4% | | |
| Sensor Gain (Temperature Sensitivity or Average Slope) to equation: $V_O$=−11.77 mV / °C×T+1.860 V | –30°C ≤ $T_A$ ≤ 100°C | –12.2 | –11.77 | –11.4 | mV/°C |
| Output Impedance | Sourcing $I_L$ 0 µA to 16 µA(5)(6) | | | 160 | Ω |
| Load Regulation(7) | Sourcing $I_L$ 0 µA to 16 µA(3)(6) | | | –2.5 | mV |
| Line Regulation(8) | 2.4 V ≤ $V^+$ ≤ 5.0 V | | | 3.3 | mV/V |
| | 5.0 V ≤ $V^+$ ≤ 5.5 V | | | 11 | mV |
| Quiescent Current | 2.4 V ≤ $V^+$ ≤ 5.0 V; $T_A$ = 25°C | | 4.5 | 7 | µA |
| | 5.0 V ≤ $V^+$ ≤ 5.5 V; $T_A$ = 25°C | | 4.5 | 9 | µA |
| | 2.4 V ≤ $V^+$ ≤ 5.0 V | | 4.5 | 10 | µA |
| Change of Quiescent Current | 2.4 V ≤ $V^+$ ≤ 5.5 V | | 0.7 | | µA |
| Temperature Coefficient of Quiescent Current | | | –11 | | nA/°C |
| Shutdown Current | $V^+$ ≤ 0.8 V | | 0.02 | | µA |

(4) Non-linearity is defined as the deviation of the calculated output-voltage-versus-temperature curve from the best-fit straight line, over the temperature range specified.
(5) The LM20 can at most sink 1 µA and source 16 µA.
(6) Load regulation or output impedance specifications apply over the supply voltage range of 2.4 V to 5.5 V.
(7) 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.
(8) Line regulation is calculated by subtracting the output voltage at the highest supply input voltage from the output voltage at the lowest supply input voltage.

## 6.6 Electrical Characteristics: LM20C

Unless otherwise noted, these specifications apply for $V^+$ = 2.7 $V_{DC}$. All limits $T_A$ = $T_J$ = $T_{MIN}$ to $T_{MAX}$, unless otherwise noted.

| PARAMETER | TEST CONDITIONS | MIN(1) | TYP(2) | MAX(1) | UNIT |
|---|---|---|---|---|---|
| Temperature to Voltage Error $V_O = (-3.88\times10^{-6}\times T^2) + (-1.15\times10^{-2}\times T) + 1.8639$ V(3) | $T_A$ = 25°C to 30°C | –4 | | 5 | °C |
| | $T_A$ = 130°C | –5 | | 5 | °C |
| | $T_A$ = 125°C | –5 | | 5 | °C |
| | $T_A$ = 100°C | –4.7 | | 4.7 | °C |
| | $T_A$ = 85°C | –4.6 | | 4.6 | °C |
| | $T_A$ = 80°C | –4.5 | | 4.5 | °C |
| | $T_A$ = 0°C | –4.4 | | 4.4 | °C |
| | $T_A$ = –30°C | –4.7 | | 4.7 | °C |
| | $T_A$ = –40°C | –4.8 | | 4.8 | °C |
| | $T_A$ = –55°C | –5.0 | | 5.0 | °C |
| Output Voltage at 0°C | | | 1.8639 | | V |
| Variance from Curve | | | ±1.0 | | °C |
| Non-Linearity (4) | –20°C ≤ $T_A$ ≤ 80°C | | ±0.4% | | |
| Sensor Gain (Temperature Sensitivity or Average Slope) to equation: $V_O$=−11.77 mV / °C×T+1.860 V | –30°C ≤ $T_A$ ≤ 100°C | –12.6 | –11.77 | –11.0 | mV/°C |
| Output Impedance | Sourcing $I_L$ 0 µA to 16 µA (5)(6) | | | 160 | Ω |

(1) Limits are ensured to TI's AOQL (Average Outgoing Quality Level).
(2) Typicals are at $T_J$ = $T_A$ = 25°C and represent most likely parametric norm.
(3) Accuracy is defined as the error between the measured and calculated output voltage at the specified conditions of voltage, current, and temperature (expressed in °C).
(4) Non-linearity is defined as the deviation of the calculated output-voltage-versus-temperature curve from the best-fit straight line, over the temperature range specified.
(5) The LM20 can at most sink 1 µA and source 16 µA.
(6) Load regulation or output impedance specifications apply over the supply voltage range of 2.4 V to 5.5 V.

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## Electrical Characteristics: LM20C (continued)

Unless otherwise noted, these specifications apply for $V^+ = 2.7\ V_{DC}$. All limits $T_A = T_J = T_{MIN}$ to $T_{MAX}$, unless otherwise noted.

| PARAMETER | TEST CONDITIONS | MIN(1) | TYP(2) | MAX(1) | UNIT |
|---|---|---|---|---|---|
| Load Regulation(7) | Sourcing $I_L$ 0 µA to 16 µA (5)(6) | | | –2.5 | mV |
| Line Regulation(8) | 2.4 V ≤ $V^+$ ≤ 5.0 V | | | 3.7 | mV/V |
| | 5.0 V ≤ $V^+$ ≤ 5.5 V | | | 11 | mV |
| Quiescent Current | 2.4 V ≤ $V^+$ ≤ 5.0 V; $T_A$ = 25°C | | 4.5 | 7 | µA |
| | 5.0 V ≤ $V^+$ ≤ 5.5 V; $T_A$ = 25°C | | 4.5 | 9 | µA |
| | 2.4 V ≤ $V^+$ ≤ 5.0 V | | 4.5 | 10 | µA |
| Change of Quiescent Current | 2.4 V ≤ $V^+$ ≤ 5.5 V | | 0.7 | | µA |
| Temperature Coefficient of Quiescent Current | | | –11 | | nA/°C |
| Shutdown Current | $V^+$ ≤ 0.8 V | | 0.02 | | µA |

(7) 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.
(8) Line regulation is calculated by subtracting the output voltage at the highest supply input voltage from the output voltage at the lowest supply input voltage.

## 6.7 Electrical Characteristics: LM20S

Unless otherwise noted, these specifications apply for $V^+ = 2.7\ V_{DC}$. All limits $T_A = T_J = T_{MIN}$ to $T_{MAX}$, unless otherwise noted.

| PARAMETER | TEST CONDITIONS | MIN(1) | TYP(2) | MAX(1) | UNIT |
|---|---|---|---|---|---|
| Temperature to Voltage Error $V_O = (-3.88\times10^{-6}\times T^2) + (-1.15\times10^{-2}\times T) + 1.8639\ V$(3) | $T_A$ = 25°C to 30°C | –2.5 | ±1.5 | 2.5 | °C |
| | $T_A$ = 125°C | –3.5 | | 3.5 | °C |
| | $T_A$ = 100°C | –3.2 | | 3.2 | °C |
| | $T_A$ = 85°C | –3.1 | | 3.1 | °C |
| | $T_A$ = 80°C | –3.0 | | 3.0 | °C |
| | $T_A$ = 0°C | –2.9 | | 2.9 | °C |
| | $T_A$ = –30°C | –3.3 | | 3.3 | °C |
| | $T_A$ = –40°C | –3.5 | | 3.5 | °C |
| Output Voltage at 0°C | | | 1.8639 | | V |
| Variance from Curve | | | ±1.0 | | °C |
| Non-Linearity (4) | –20°C ≤ $T_A$ ≤ 80°C | | ±0.4% | | |
| Sensor Gain (Temperature Sensitivity or Average Slope) to equation: $V_O$= −11.77 mV/ °C × T + 1.860 V | –30°C ≤ $T_A$ ≤ 100°C | –12.6 | –11.77 | –11.0 | mV/°C |
| Output Impedance | Sourcing $I_L$ 0 µA to 16 µA(5)(6) | | | 160 | Ω |
| Load Regulation(7) | Sourcing $I_L$ 0 µA to 16 µA(5)(6) | | | –2.5 | mV |
| Line Regulation(8) | 2.4 V ≤ $V^+$ ≤ 5.0 V | | | 3.7 | mV/V |
| | 5.0 V ≤ $V^+$ ≤ 5.5 V | | | 11 | mV |
| Quiescent Current | 2.4 V ≤ $V^+$ ≤ 5.0 V; $T_A$ = 25°C | | 4.5 | 7 | µA |
| | 5.0 V ≤ $V^+$ ≤ 5.5 V; $T_A$ = 25°C | | 4.5 | 9 | µA |
| | 2.4 V ≤ $V^+$ ≤ 5.0 V | | 4.5 | 10 | µA |

(1) Limits are ensured to TI's AOQL (Average Outgoing Quality Level).
(2) Typicals are at $T_J = T_A$ = 25°C and represent most likely parametric norm.
(3) Accuracy is defined as the error between the measured and calculated output voltage at the specified conditions of voltage, current, and temperature (expressed in °C).
(4) Non-linearity is defined as the deviation of the calculated output-voltage-versus-temperature curve from the best-fit straight line, over the temperature range specified.
(5) The LM20 can at most sink 1 µA and source 16 µA.
(6) Load regulation or output impedance specifications apply over the supply voltage range of 2.4 V to 5.5 V.
(7) 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.
(8) Line regulation is calculated by subtracting the output voltage at the highest supply input voltage from the output voltage at the lowest supply input voltage.


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## Electrical Characteristics: LM20S (continued)

Unless otherwise noted, these specifications apply for $V^+$ = 2.7 $V_{DC}$. All limits $T_A = T_J = T_{MIN}$ to $T_{MAX}$, unless otherwise noted.

| PARAMETER | TEST CONDITIONS | MIN(1) | TYP(2) | MAX(1) | UNIT |
|---|---|---|---|---|---|
| Change of Quiescent Current | 2.4 V ≤ $V^+$ ≤ 5.5 V | | 0.7 | | µA |
| Temperature Coefficient of Quiescent Current | | | –11 | | nA/°C |
| Shutdown Current | $V^+$ ≤ 0.8 V | | 0.02 | | µA |

## 6.8 Typical Characteristics

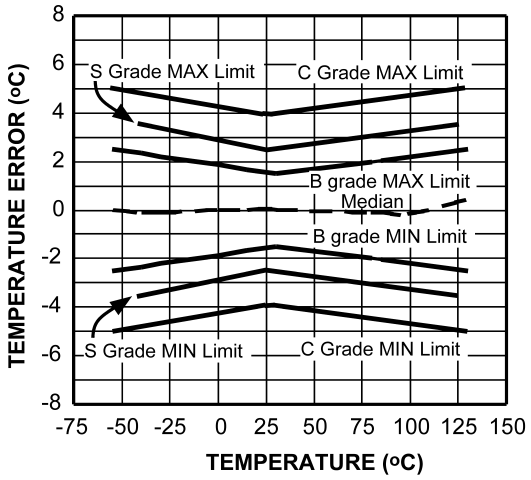



**Figure 1. Temperature Error vs Temperature**

# 7 Detailed Description

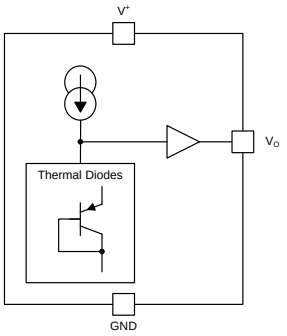
## 7.1 Overview

The LM20 device is a precision analog output CMOS integrated-circuit temperature sensor that operates over a temperature range of −55°C to 130°C. The power supply operating range is 2.4 V to 5.5 V. The transfer function of LM20 is predominately linear, yet has a slight predictable parabolic curvature. The accuracy of the LM20 when specified to a parabolic transfer function is typically ±1.5°C at an ambient temperature of 30°C. The temperature error increases linearly and reaches a maximum of ±2.5°C at the temperature range extremes for the LM20. The temperature range is affected by the power supply voltage. At a power supply voltage of 2.7 V to 5.5 V, the temperature range extremes are 130°C and −55°C. Decreasing the power supply voltage to 2.4 V changes the negative extreme to −30°C, while the positive remains at 130°C.

The LM20 quiescent current is less than 10 µA. Therefore, self-heating is less than 0.02°C in still air. Shutdown capability for the LM20 is intrinsic because its inherent low power consumption allows it to be powered directly from the output of many logic gates or, does not necessitate shutdown at all.

The temperature sensing element is comprised of a simple base emitter junction that is forward biased by a current source. The temperature sensing element is then buffered by an amplifier and provided to the OUT pin. The amplifier has a simple class A output stage thus providing a low impedance output that can source 16 µA and sink 1 µA.

## 7.2 Functional Block Diagram




## 7.3 Feature Description

### 7.3.1 LM20 Transfer Function

The LM20 transfer function can be described in different ways with varying levels of precision. A simple linear transfer function with good accuracy near 25°C is:

$$V_O = -11.69\ mV/°C \times T + 1.8663\ V \quad (1)$$

Over the full operating temperature range of −55°C to 130°C, best accuracy can be obtained by using the parabolic transfer function.

$$V_O = (-3.88\times10^{-6}\times T^2) + (-1.15\times10^{-2}\times T) + 1.8639 \quad (2)$$

Using Equation 2, the following temperature to voltage output characteristic table can be generated.

**Table 1. Temperature to Voltage Output Characteristic Table**

| TEMP (°C) | VOUT (V) | TEMP (°C) | VOUT (V) | TEMP (°C) | VOUT (V) | TEMP (°C) | VOUT (V) | TEMP (°C) | VOUT (V) | TEMP (°C) | VOUT (V) | TEMP (°C) | VOUT (V) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| -55 | 2.4847 | -28 | 2.1829 | -1 | 1.8754 | 26 | 1.5623 | 53 | 1.2435 | 80 | 0.9191 | 107 | 0.5890 |
| -54 | 2.4736 | -27 | 2.1716 | 0 | 1.8639 | 27 | 1.5506 | 54 | 1.2316 | 81 | 0.9069 | 108 | 0.5766 |
| -53 | 2.4625 | -26 | 2.1603 | 1 | 1.8524 | 28 | 1.5389 | 55 | 1.2197 | 82 | 0.8948 | 109 | 0.5643 |
| -52 | 2.4514 | -25 | 2.1490 | 2 | 1.8409 | 29 | 1.5271 | 56 | 1.2077 | 83 | 0.8827 | 110 | 0.5520 |
| -51 | 2.4403 | -24 | 2.1377 | 3 | 1.8294 | 30 | 1.5154 | 57 | 1.1958 | 84 | 0.8705 | 111 | 0.5396 |
| -50 | 2.4292 | -23 | 2.1263 | 4 | 1.8178 | 31 | 1.5037 | 58 | 1.1838 | 85 | 0.8584 | 112 | 0.5272 |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## Feature Description (continued)

**Table 1. Temperature to Voltage Output Characteristic Table (continued)**

| TEMP (°C) | VOUT (V) | TEMP (°C) | VOUT (V) | TEMP (°C) | VOUT (V) | TEMP (°C) | VOUT (V) | TEMP (°C) | VOUT (V) | TEMP (°C) | VOUT (V) | TEMP (°C) | VOUT (V) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| -49 | 2.4181 | -22 | 2.1150 | 5 | 1.8063 | 32 | 1.4919 | 59 | 1.1719 | 86 | 0.8462 | 113 | 0.5149 |
| -48 | 2.4070 | -21 | 2.1037 | 6 | 1.7948 | 33 | 1.4802 | 60 | 1.1599 | 87 | 0.8340 | 114 | 0.5025 |
| -47 | 2.3958 | -20 | 2.0923 | 7 | 1.7832 | 34 | 1.4684 | 61 | 1.1480 | 88 | 0.8219 | 115 | 0.4901 |
| -46 | 2.3847 | -19 | 2.0810 | 8 | 1.7717 | 35 | 1.4566 | 62 | 1.1360 | 89 | 0.8097 | 116 | 0.4777 |
| -45 | 2.3735 | -18 | 2.0696 | 9 | 1.7601 | 36 | 1.4449 | 63 | 1.1240 | 90 | 0.7975 | 117 | 0.4653 |
| -44 | 2.3624 | -17 | 2.0583 | 10 | 1.7485 | 37 | 1.4331 | 64 | 1.1120 | 91 | 0.7853 | 118 | 0.4529 |
| -43 | 2.3512 | -16 | 2.0469 | 11 | 1.7369 | 38 | 1.4213 | 65 | 1.1000 | 92 | 0.7731 | 119 | 0.4405 |
| -42 | 2.3401 | -15 | 2.0355 | 12 | 1.7253 | 39 | 1.4095 | 66 | 1.0880 | 93 | 0.7608 | 120 | 0.4280 |
| -41 | 2.3289 | -14 | 2.0241 | 13 | 1.7137 | 40 | 1.3977 | 67 | 1.0760 | 94 | 0.7486 | 121 | 0.4156 |
| -40 | 2.3177 | -13 | 2.0127 | 14 | 1.7021 | 41 | 1.3859 | 68 | 1.0640 | 95 | 0.7364 | 122 | 0.4032 |
| -39 | 2.3065 | -12 | 2.0013 | 15 | 1.6905 | 42 | 1.3741 | 69 | 1.0519 | 96 | 0.7241 | 123 | 0.3907 |
| -38 | 2.2953 | -11 | 1.9899 | 16 | 1.6789 | 43 | 1.3622 | 70 | 1.0399 | 97 | 0.7119 | 124 | 0.3782 |
| -37 | 2.2841 | -10 | 1.9785 | 17 | 1.6673 | 44 | 1.3504 | 71 | 1.0278 | 98 | 0.6996 | 125 | 0.3658 |
| -36 | 2.2729 | -9 | 1.9671 | 18 | 1.6556 | 45 | 1.3385 | 72 | 1.0158 | 99 | 0.6874 | 126 | 0.3533 |
| -35 | 2.2616 | -8 | 1.9557 | 19 | 1.6440 | 46 | 1.3267 | 73 | 1.0037 | 100 | 0.6751 | 127 | 0.3408 |
| -34 | 2.2504 | -7 | 1.9442 | 20 | 1.6323 | 47 | 1.3148 | 74 | 0.9917 | 101 | 0.6628 | 128 | 0.3283 |
| -33 | 2.2392 | -6 | 1.9328 | 21 | 1.6207 | 48 | 1.3030 | 75 | 0.9796 | 102 | 0.6505 | 129 | 0.3158 |
| -32 | 2.2279 | -5 | 1.9213 | 22 | 1.6090 | 49 | 1.2911 | 76 | 0.9675 | 103 | 0.6382 | 130 | 0.3033 |
| -31 | 2.2167 | -4 | 1.9098 | 23 | 1.5973 | 50 | 1.2792 | 77 | 0.9554 | 104 | 0.6259 | — | — |
| -30 | 2.2054 | -3 | 1.8984 | 24 | 1.5857 | 51 | 1.2673 | 78 | 0.9433 | 105 | 0.6136 | — | — |
| -29 | 2.1941 | -2 | 1.8869 | 25 | 1.5740 | 52 | 1.2554 | 79 | 0.9312 | 106 | 0.6013 | — | — |

Solving Equation 2 for T:

$$T = -1481.96 + \sqrt{2.1962 \times 10^{6} + \frac{(1.8639 - V_O)}{3.88 \times 10^{-6}}} \quad (3)$$

## 7.4 Device Functional Modes

The only functional mode of the LM20 is that it has an analog output inversely proportional to temperature.

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# 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 LM20 features make it suitable for many general temperature sensing applications. Multiple package options expand on its, flexibility.

### 8.1.1 Capacitive Loads

The LM20 handles capacitive loading well. Without any precautions, the LM20 can drive any capacitive load less than 300 pF as shown in Figure 2. Over the specified temperature range the LM20 has a maximum output impedance of 160 Ω. In an extremely noisy environment, it may be necessary to add some filtering to minimize noise pickup. It is recommended that 0.1 µF be added from $V^+$ to GND to bypass the power supply voltage, as shown in Figure 4. In a noisy environment, it may even be necessary to add a capacitor from the output to ground with a series resistor as shown in Figure 4. A 1-µF output capacitor with the 160-Ω maximum output impedance and a 200-Ω series resistor will form a 442-Hz lowpass filter. Because the thermal time constant of the LM20 is much slower, the overall response time of the LM20 will not be significantly affected.

In situations where a transient load current is placed on the circuit output the series resistance value may be increased to compensate for any ringing that may be observed.

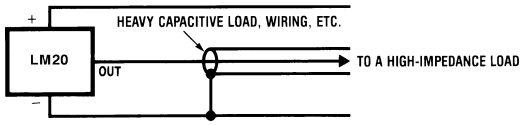


**Figure 2. LM20 No Decoupling Required for Capacitive Loads Less Than 300 pF**

**Table 2. Capacitive Loading Isolation**

| Minimum R (Ω) | C (µF) |
|---|---|
| 200 | 1 |
| 470 | 0.1 |
| 680 | 0.01 |
| 1 k | 0.001 |

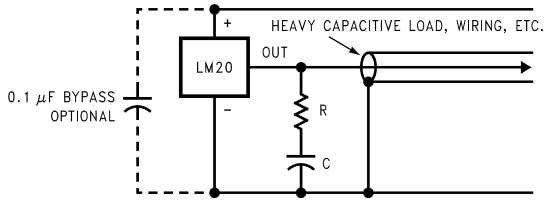


**Figure 3. LM20 With Compensation for Capacitive Loading Greater Than 300 pF**


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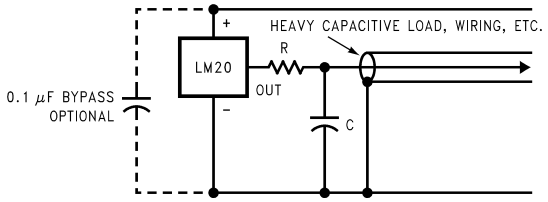


**Figure 4. LM20 With Filter for Noisy Environment and Capacitive Loading Greater Than 300 pF**

**NOTE**

Either placement of resistor, as shown in Figure 3 and Figure 4, is just as effective.

### 8.1.2 LM20 DSBGA Light Sensitivity

Exposing the LM20 DSBGA package to bright sunlight may cause the output reading of the LM20 to drop by 1.5 V. In a normal office environment of fluorescent lighting the output voltage is minimally affected (less than a millivolt drop). In either case, TI recommends that the LM20 DSBGA be placed inside an enclosure of some type that minimizes its light exposure. Most chassis provide more than ample protection. The LM20 does not sustain permanent damage from light exposure. Removing the light source will cause the output voltage of the LM20 to recover to the proper value.

## 8.2 Typical Applications

### 8.2.1 Full-Range Celsius (Centigrade) Temperature Sensor (−55°C to 130°C) Operating from a Single Li-Ion Battery Cell

The LM20 has a very low supply current and a wide supply range; therefore, it can easily be driven by a battery as shown in Figure 5.

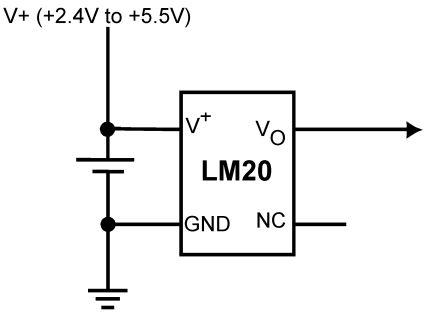


**Figure 5. Full-Range Celsius (Centigrade) Temperature Sensor (−55°C To 130°C) Operating from a Single Li-Ion Battery Cell**

#### *8.2.1.1 Design Requirements*

Because the LM20 is a simple temperature sensor that provides an analog output, design requirements related to layout are more important than electrical requirements. Refer to the *Layout* section for a detailed description.

#### *8.2.1.2 Detailed Design Procedure*

The LM20 transfer function can be described in different ways with varying levels of precision. A simple linear transfer function with good accuracy near 25°C is:

$$V_O = -11.69\ mV/°C \times T + 1.8663\ V \quad (4)$$

Over the full operating temperature range of −55°C to 130°C, best accuracy can be obtained by using the parabolic transfer function.

$$V_O = (-3.88\times10^{-6}\times T^2) + (-1.15\times10^{-2}\times T) + 1.8639 \quad (5)$$

Solving Equation 5 for T:

## Typical Applications (continued)

$$T = -1481.96 + \sqrt{2.1962 \times 10^{6} + \frac{(1.8639 - V_O)}{3.88 \times 10^{-6}}} \quad (6)$$

An alternative to the quadratic equation a second order transfer function can be determined using the least-squares method:

$$T = (-2.3654 \times V_O^{\ 2}) + (-78.154 \times V_O) + 153.857 \quad (7)$$

where

- T is temperature express in °C and $V_O$ is the output voltage expressed in volts.

A linear transfer function can be used over a limited temperature range by calculating a slope and offset that give best results over that range. A linear transfer function can be calculated from the parabolic transfer function of the LM20. The slope of the linear transfer function can be calculated using the Equation 8 equation:

$$m = -7.76 \times 10^{-6} \times T - 0.0115, \quad (8)$$

where

- T is the middle of the temperature range of interest and m is in V/°C.

For example for the temperature range of $T_{MIN}$ = −30 to $T_{MAX}$ = 100°C:

$$T = 35°C \quad (9)$$

and

$$m = -11.77 \text{ mV/°C} \quad (10)$$

The offset of the linear transfer function can be calculated using the Equation 11 equation:

$$b = (V_{OP}(T_{MAX}) + V_{OP}(T) - m \times (T_{MAX}+T))/2 \quad (11)$$

where

- $V_{OP}(T_{MAX})$ is the calculated output voltage at $T_{MAX}$ using the parabolic transfer function for $V_O$
- $V_{OP}(T)$ is the calculated output voltage at T using the parabolic transfer function for $V_O$.

The best fit linear transfer function for many popular temperature ranges was calculated in Table 3. As shown in Table 3, the error introduced by the linear transfer function increases with wider temperature ranges.

**Table 3. First Order Equations Optimized for Different Temperature Ranges**

| Temperature Range | | Linear Equation | Maximum Deviation of Linear Equation from Parabolic Equation (°C) |
|---|---|---|---|
| $T_{min}$ (°C) | $T_{max}$ (°C) | | |
| −55 | 130 | $V_O$ = −11.79 mV/°C × T + 1.8528 V | ±1.41 |
| −40 | 110 | $V_O$ = −11.77 mV/°C × T + 1.8577 V | ±0.93 |
| −30 | 100 | $V_O$ = −11.77 mV/°C × T + 1.8605 V | ±0.70 |
| -40 | 85 | $V_O$ = −11.67 mV/°C × T + 1.8583 V | ±0.65 |
| −10 | 65 | $V_O$ = −11.71 mV/°C × T + 1.8641 V | ±0.23 |
| 35 | 45 | $V_O$ = −11.81 mV/°C × T + 1.8701 V | ±0.004 |
| 20 | 30 | $V_O$ = –11.69 mV/°C × T + 1.8663 V | ±0.004 |


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**Table 4. Output Voltage vs Temperature**

| Temperature (T) | Typical $V_O$ |
|---|---|
| 130°C | 303 mV |
| 100°C | 675 mV |
| 80°C | 919 mV |
| 30°C | 1515 mV |
| 25°C | 1574 mV |
| 0°C | 1863.9 mV |
| –30°C | 2205 mV |
| −40°C | 2318 mV |
| −55°C | 2485 mV |

#### *8.2.1.3 Application Curve*

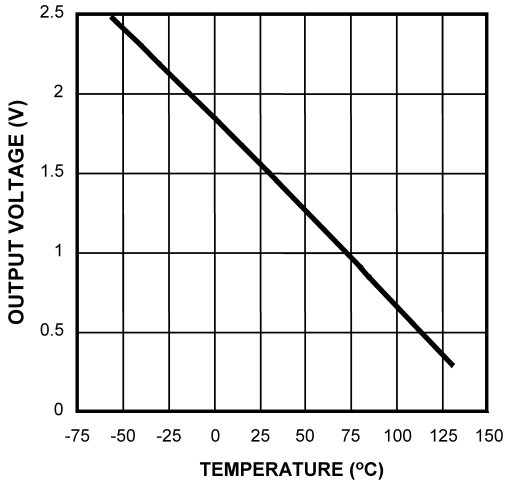


**Figure 6. Output Voltage vs Temperature**

### 8.2.2 Centigrade Thermostat

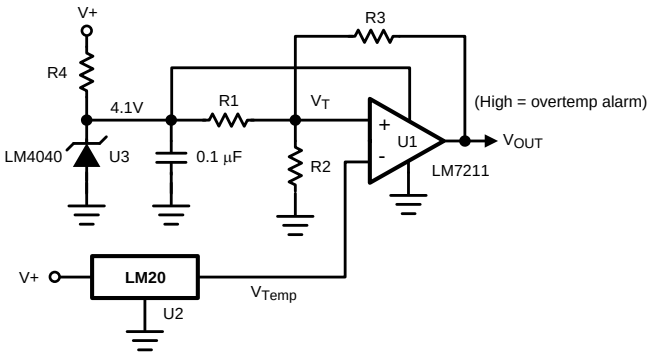


**Figure 7. Centigrade Thermostat**

#### *8.2.2.1 Design Requirements*

A simple thermostat can be created by using a reference (LM4040) and a comparator (LM7211) as shown in Figure 7.

#### *8.2.2.2 Detailed Design Procedure*

The threshold values can be calculated using Equation 12 and Equation 13.

$$V_{T1} = \frac{(4.1)R2}{R2 + R1||R3} \quad (12)$$

$$V_{T2} = \frac{(4.1)R2||R3}{R1 + R2||R3} \quad (13)$$

#### 8.2.2.3 Application Curve

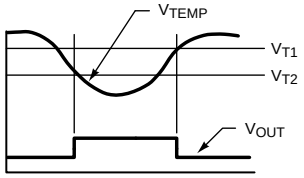


**Figure 8. Thermostat Output Waveform**

## 8.3 System Examples

### 8.3.1 Conserving Power Dissipation With Shutdown

The LM20 draws very little power; therefore, it can simply be shutdown by driving its supply pin with the output of an logic gate as shown in Figure 9.

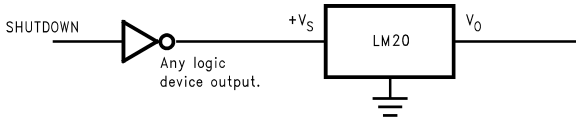


**Figure 9. Conserving Power Dissipation With Shutdown**

### 8.3.2 Analog-to-Digital Converter Input Stage

Most CMOS ADCs found in ASICs have a sampled data comparator input structure that is notorious for causing grief to analog output devices such as the LM20 and many operational amplifiers. The cause of this grief is the requirement of instantaneous charge of the input sampling capacitor in the ADC. This requirement is easily accommodated by the addition of a capacitor. Because not all ADCsFigure 10 have identical input stages, the charge requirements will vary necessitating a different value of compensating capacitor. This ADC is shown as an example only. If a digital output temperature is required, refer to devices such as the LM74.

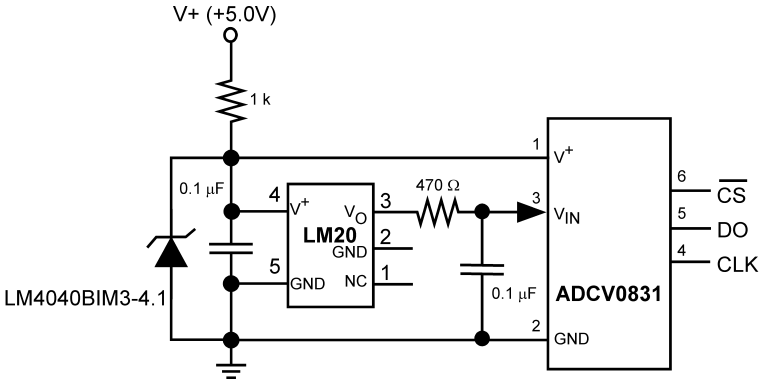


**Figure 10. Suggested Connection to a Sampling Analog to Digital Converter Input Stage**


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# 9 Power Supply Recommendations

The LM20 has a very wide 2.4-V to 5.5-V power supply voltage range that makes ideal for many applications. In noisy environments, TI recommends adding at minimum 0.1 µF 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 LM20 can be easily applied in the same way as other integrated-circuit temperature sensors. It can be glued or cemented to a surface. The temperature that the LM20 is sensing is within approximately 0.02°C of the surface temperature to which the leads of the LM20 are attached.

Implementing the integrated-circuit temperature sensors 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 measured would be at an intermediate temperature between the surface temperature and the air temperature.

To ensure good thermal conductivity, the backside of the LM20 die is directly attached to the pin 2 GND. The temperatures of the lands and traces to the other leads of the LM20 will also affect the temperature that is sensed.

Alternatively, the LM20 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 LM20 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 ensure that moisture cannot corrode the LM20 or its connections.

## 10.2 Layout Examples

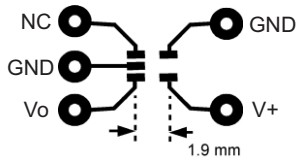


**Figure 11. Layout Used for No Heat Sink Measurements**

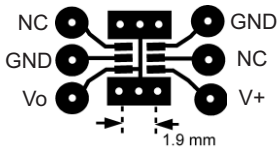


**Figure 12. Layout Used for Measurements With Small Heat Sink**

## 10.3 Thermal Considerations

The thermal resistance junction to ambient ($R_{\theta JA}$) is the parameter used to calculate the rise of a device junction temperature due to its power dissipation. For the LM20, the equation used to calculate the rise in the die temperature is as follows:

$$T_J = T_A + R_{\theta JA} [(V^+ I_Q) + (V^+ - V_O) I_L] \quad (14)$$

where

- $I_Q$ is the quiescent current and $I_L$ is the load current on the output. Because the junction temperature of LM20 is the actual temperature being measured, take care to minimize the load current that the LM20 is required to drive.

## Thermal Considerations (continued)

Table 5 summarizes the rise in die temperature of the LM20 without any loading and the thermal resistance for different conditions.

**Table 5. Temperature Rise of LM20 Due to Self-Heating and Thermal Resistance ($R_{\Theta JA}$)**
**See more *Layout Examples***

| | SC70-5 | | SC70-5 | |
|---|---|---|---|---|
| | No Heat Sink | | Small Heat Sink | |
| | $R_{\theta JA}$ | $T_J - T_A$ | $R_{\theta JA}$ | $T_J - T_A$ |
| | (°C/W) | (°C) | (°C/W) | (°C) |
| Still air | 412 | 0.2 | 350 | 0.19 |
| Moving air | 312 | 0.17 | 266 | 0.15 |

| | DSBGA | |
|---|---|---|
| | No Heat Sink | |
| | $R_{\theta JA}$ | $T_J - T_A$ |
| | (°C/W) | (°C) |
| Still air | 340 | 0.18 |


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# 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.

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## PACKAGING INFORMATION

| Orderable part number | Status (1) | Material type (2) | Package \| Pins | Package qty \| Carrier | RoHS (3) | Lead finish/ Ball material (4) | MSL rating/ Peak reflow (5) | Op temp (°C) | Part marking (6) |
|---|---|---|---|---|---|---|---|---|---|
| LM20BIM7 | NRND | Production | SC70 (DCK) \| 5 | 1000 \| SMALL T&R | No | SNPB | Level-1-260C-UNLIM | -55 to 130 | T2B |
| LM20BIM7.A | NRND | Production | SC70 (DCK) \| 5 | 1000 \| SMALL T&R | No | SNPB | Level-1-260C-UNLIM | See LM20BIM7 | T2B |
| LM20BIM7X | NRND | Production | SC70 (DCK) \| 5 | 3000 \| LARGE T&R | No | SNPB | Level-1-260C-UNLIM | -55 to 130 | T2B |
| LM20BIM7X.A | NRND | Production | SC70 (DCK) \| 5 | 3000 \| LARGE T&R | No | SNPB | Level-1-260C-UNLIM | See LM20BIM7X | T2B |
| LM20BIM7X/NOPB | Active | Production | SC70 (DCK) \| 5 | 3000 \| LARGE T&R | Yes | SN | Level-1-260C-UNLIM | -55 to 130 | T2B |
| LM20BIM7X/NOPB.A | Active | Production | SC70 (DCK) \| 5 | 3000 \| LARGE T&R | Yes | SN | Level-1-260C-UNLIM | See LM20BIM7X/ NOPB | T2B |
| LM20CIM7/NOPB | Obsolete | Production | SC70 (DCK) \| 5 | - | - | Call TI | Call TI | -55 to 130 | T2C |
| LM20CIM7X | NRND | Production | SC70 (DCK) \| 5 | 3000 \| LARGE T&R | No | SNPB | Level-1-260C-UNLIM | -55 to 130 | T2C |
| LM20CIM7X.A | NRND | Production | SC70 (DCK) \| 5 | 3000 \| LARGE T&R | No | SNPB | Level-1-260C-UNLIM | See LM20CIM7X | T2C |
| LM20CIM7X/NOPB | Active | Production | SC70 (DCK) \| 5 | 3000 \| LARGE T&R | Yes | SN | Level-1-260C-UNLIM | -55 to 130 | T2C |
| LM20CIM7X/NOPB.A | Active | Production | SC70 (DCK) \| 5 | 3000 \| LARGE T&R | Yes | SN | Level-1-260C-UNLIM | See LM20CIM7X/ NOPB | T2C |
| LM20SITL/NOPB | Obsolete | Production | DSBGA (YZR) \| 4 | - | - | Call TI | Call TI | -40 to 125 | |
| LM20SITLX/NOPB | Active | Production | DSBGA (YZR) \| 4 | 3000 \| LARGE T&R | Yes | SNAGCU | Level-1-260C-UNLIM | -40 to 125 | |
| LM20SITLX/NOPB.A | Active | Production | DSBGA (YZR) \| 4 | 3000 \| LARGE T&R | Yes | SNAGCU | Level-1-260C-UNLIM | See LM20SITLX/NOPB | |

(1) **Status:** For more details on status, see our product life cycle.

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.

(4) **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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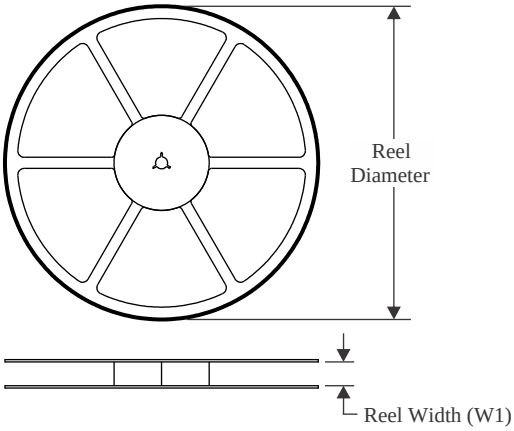
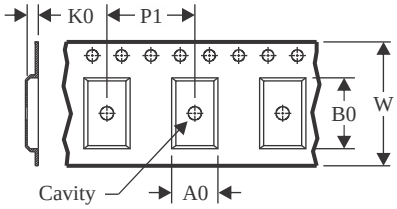
## TAPE AND REEL INFORMATION

**REEL DIMENSIONS**

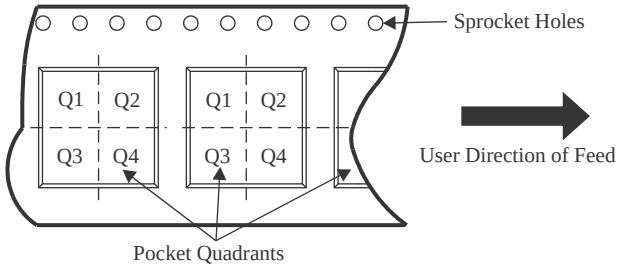



**TAPE DIMENSIONS**




| | |
|---|---|
| A0 | Dimension designed to accommodate the component width |
| B0 | Dimension designed to accommodate the component length |
| K0 | Dimension designed to accommodate the component thickness |
| W | Overall width of the carrier tape |
| P1 | Pitch between successive cavity centers |

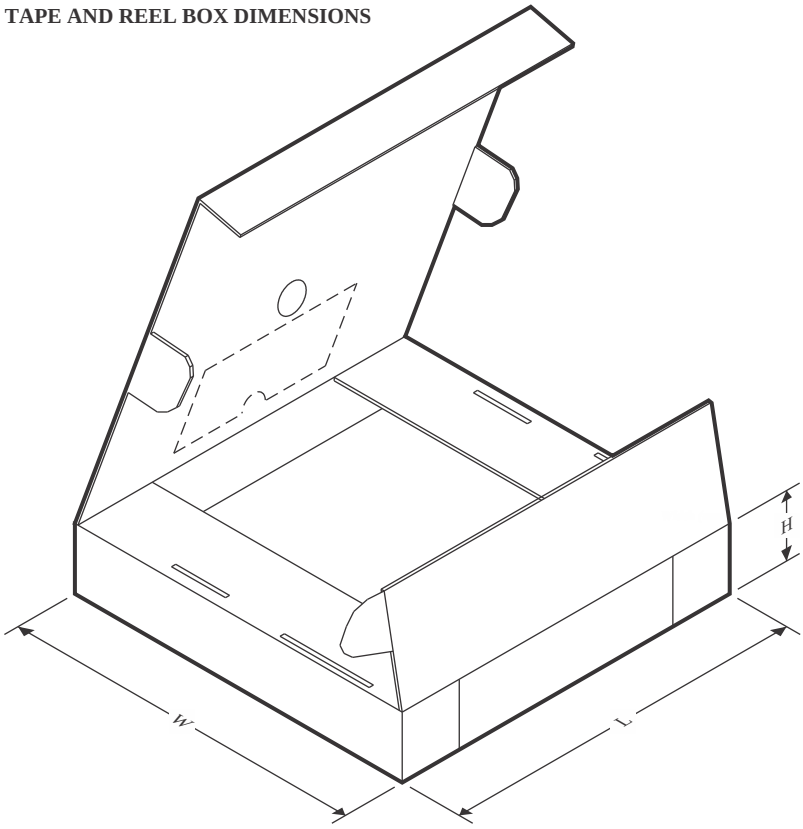
**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**




*All dimensions are nominal

| 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LM20BIM7X/NOPB | SC70 | DCK | 5 | 3000 | 178.0 | 8.4 | 2.25 | 2.45 | 1.2 | 4.0 | 8.0 | Q3 |
| LM20CIM7X/NOPB | SC70 | DCK | 5 | 3000 | 178.0 | 8.4 | 2.25 | 2.45 | 1.2 | 4.0 | 8.0 | Q3 |
| LM20SITLX/NOPB | DSBGA | YZR | 4 | 3000 | 178.0 | 8.4 | 1.04 | 1.04 | 0.76 | 4.0 | 8.0 | Q1 |

TAPE AND REEL BOX DIMENSIONS




*All dimensions are nominal

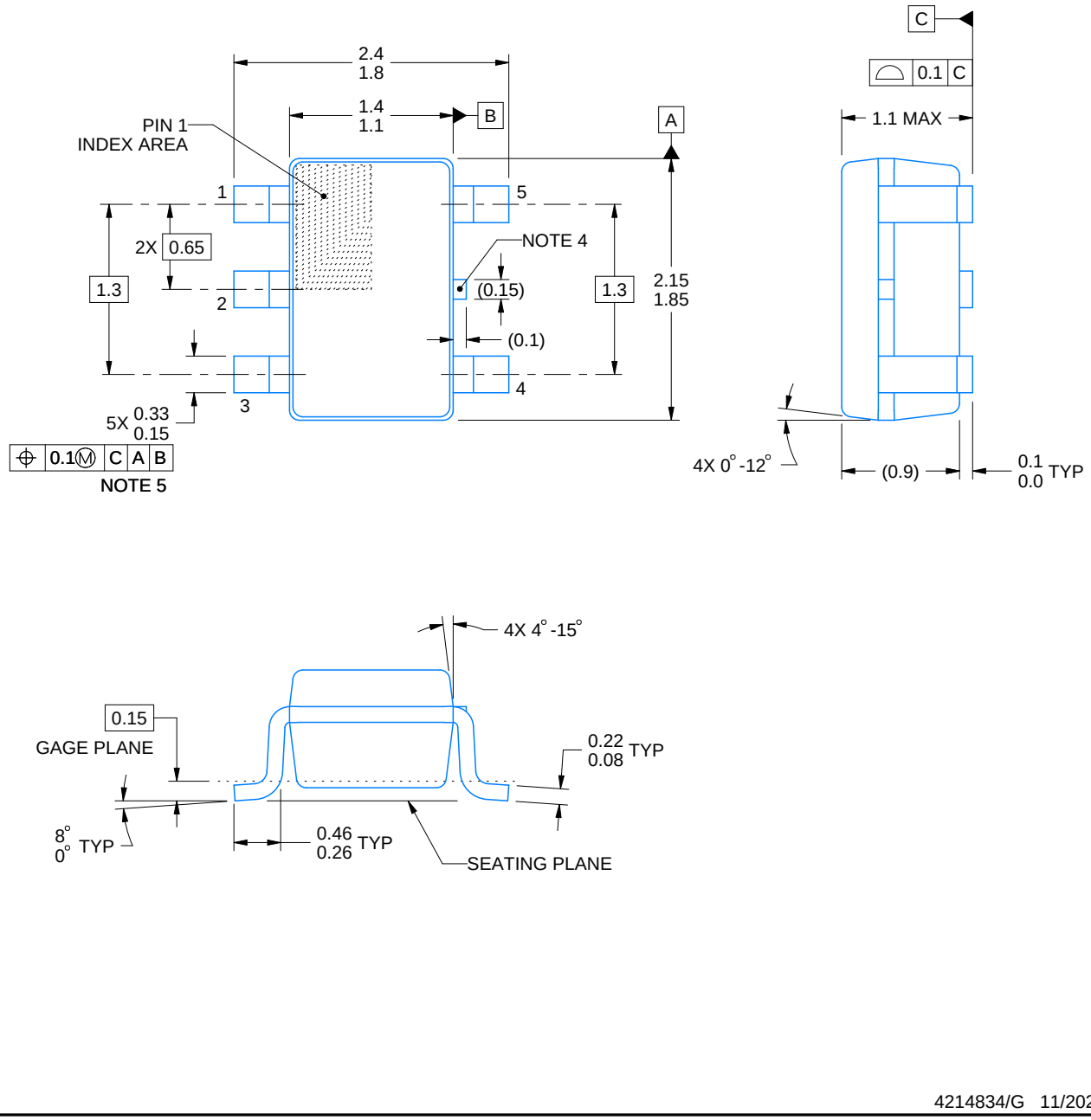
| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|---|---|---|---|---|---|---|---|
| LM20BIM7X/NOPB | SC70 | DCK | 5 | 3000 | 210.0 | 185.0 | 35.0 |
| LM20CIM7X/NOPB | SC70 | DCK | 5 | 3000 | 210.0 | 185.0 | 35.0 |
| LM20SITLX/NOPB | DSBGA | YZR | 4 | 3000 | 210.0 | 185.0 | 35.0 |

# PACKAGE OUTLINE

## DCK0005A

## SOT - 1.1 max height

SMALL OUTLINE TRANSISTOR

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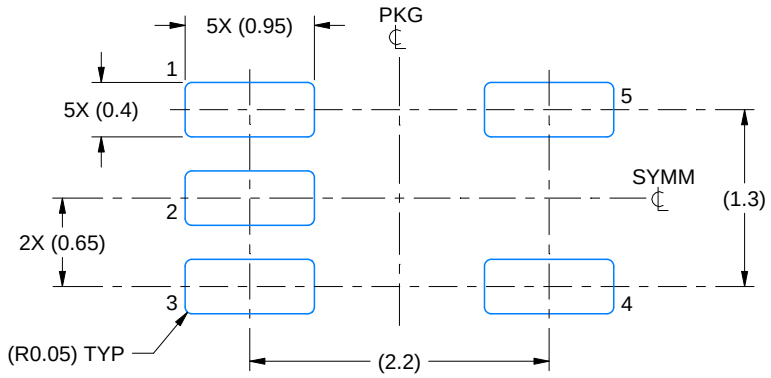
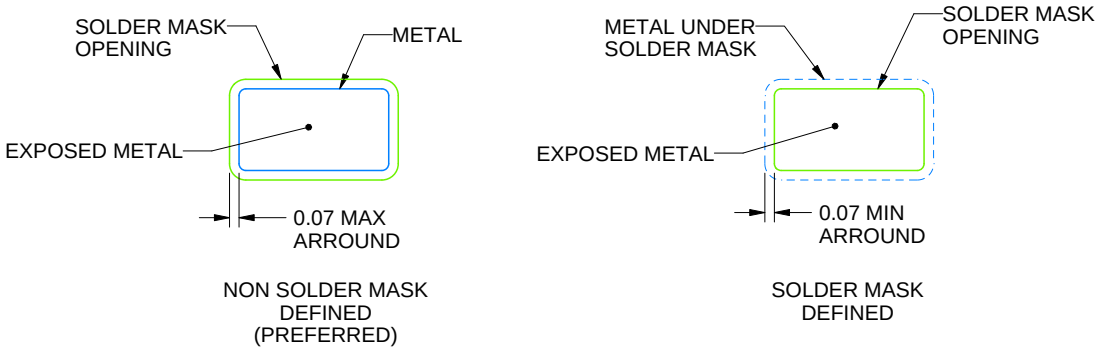
NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Refernce JEDEC MO-203.
4. Support pin may differ or may not be present.
5. Lead width does not comply with JEDEC.
6. Body dimensions do not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.25mm per side




LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:18X




SOLDER MASK DETAILS

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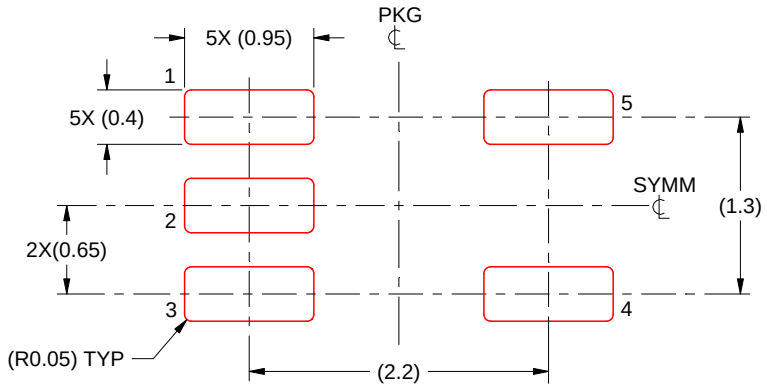
NOTES: (continued)

7. Publication IPC-7351 may have alternate designs.
8. Solder mask tolerances between and around signal pads can vary based on board fabrication site.




SOLDER PASTE EXAMPLE
BASED ON 0.125 THICK STENCIL
SCALE:18X

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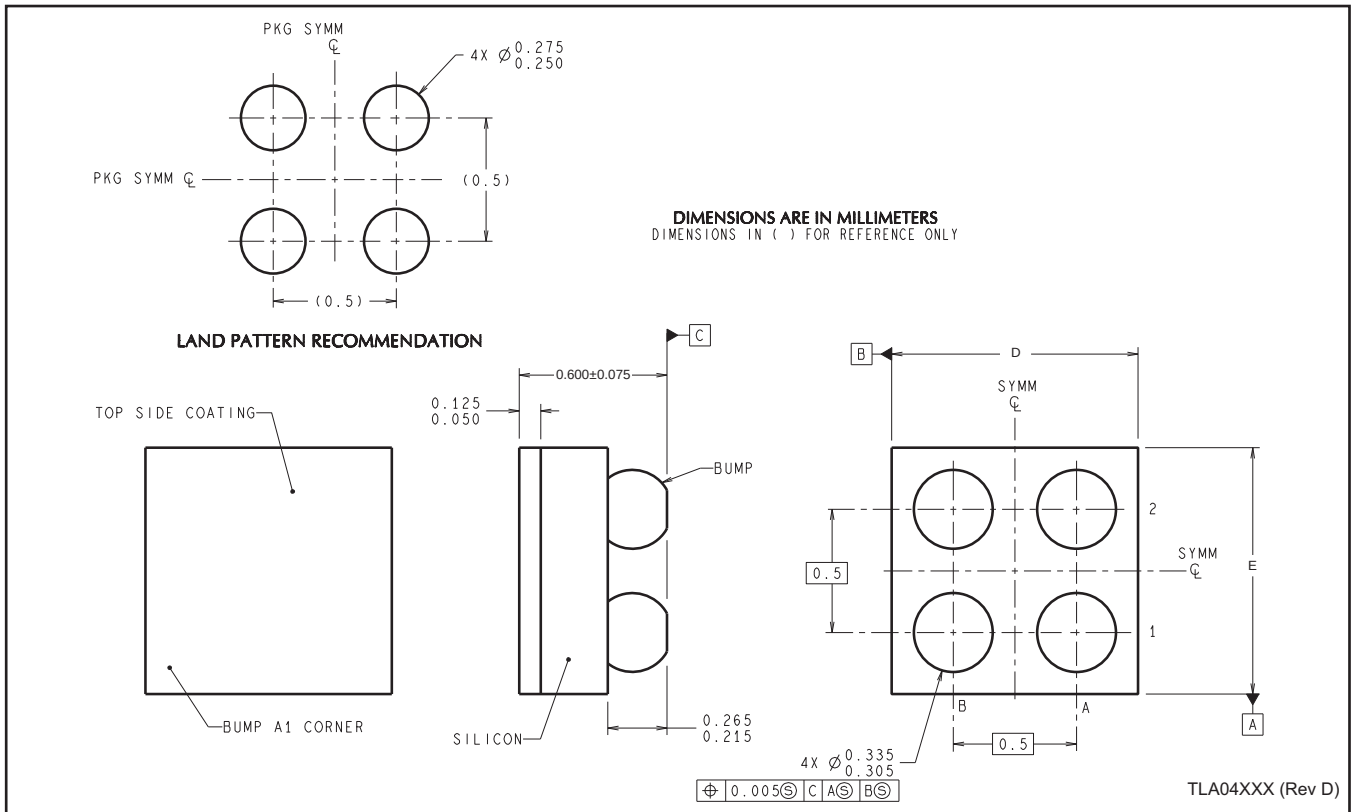
NOTES: (continued)

9. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
10. Board assembly site may have different recommendations for stencil design.

YZR0004




D: Max = 0.994 mm, Min =0.933 mm

E: Max = 0.994 mm, Min =0.933 mm

4215042/A 12/12

NOTES: A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
B. This drawing is subject to change without notice.

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