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**Ultra-low current 2.4 V precision analog temperature sensor**

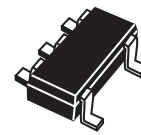
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**Features**

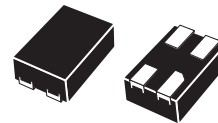
- Precision analog voltage output temperature sensor
- $\pm 1.5$  °C temperature accuracy at 25 °C
- Ultra-low quiescent supply current: 8.0  $\mu$ A (max)
- Operating voltage range: 2.4 V to 5.5 V
- Operating temperature range:
  - 55 °C to 130 °C (grade - 7)
  - 40 °C to 85 °C (grade - 9)
- SOT323-5 (SC70-5) 5-lead package
- UDFN 4-lead package

**Applications**

- Third generation (3G) cell phones
- Multimedia PDA devices
- GPS devices
- Portable medical instruments
- Voltage-controlled crystal oscillator temperature monitors
- RF power transistor monitor



SOT323-5, SC70-5 (W8)



UDFN 4-lead (DD)

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# Contents

|   |   |    |
|---|---|----|
| 1 | Description . . . . .                       | 5  |
| 2 | Transfer function . . . . .                 | 6  |
| 3 | Maximum ratings . . . . .                   | 8  |
| 4 | DC and AC characteristics . . . . .         | 9  |
| 5 | Capacitive load . . . . .                   | 10 |
| 6 | Typical operating characteristics . . . . . | 11 |
| 7 | Package mechanical data . . . . .           | 12 |
| 8 | Part numbering . . . . .                    | 16 |
| 9 | Revision history . . . . .                  | 17 |

## List of tables

|           |  |    |
|-----------|--|----|
| Table 1.  | Signal names . . . . .   | 5  |
| Table 2.  | First order equations optimized for different temperature ranges. . . . .  | 6  |
| Table 3.  | Quadratic output equation ( $V_{CC} = 2.7\text{ V}$ ) . . . . .  | 7  |
| Table 4.  | Quadratic output equation for operations over the full voltage range<br>( $V_{CC} = 2.4\text{ V to }5.5\text{ V}$ ). . . . . | 7  |
| Table 5.  | Absolute maximum ratings . . . . .   | 8  |
| Table 6.  | DC and AC characteristics . . . . .  | 9  |
| Table 7.  | Resistor/capacitor combinations for the filter network . . . . .   | 10 |
| Table 8.  | SOT323-5 – 5-lead small outline transistor package mechanical data. . . . .  | 13 |
| Table 9.  | UDFN – 4-lead package mechanical data . . . . .  | 14 |
| Table 10. | Carrier tape dimensions for SOT323-5L and UDFN-4L packages . . . . .   | 15 |
| Table 11. | Ordering information scheme . . . . .  | 16 |
| Table 12. | Marking description. . . . .   | 16 |
| Table 13. | Document revision history . . . . .  | 17 |

## List of figures

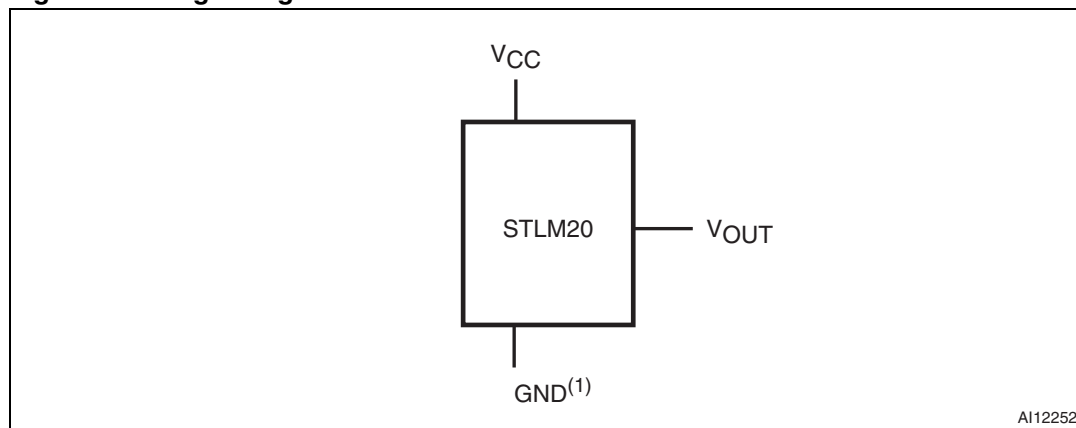
|           |   |    |
|-----------|---|----|
| Figure 1. | Logic diagram . . . . .   | 5  |
| Figure 2. | Connections (top view) . . . . .  | 5  |
| Figure 3. | Filter network for noisy environments or capacitive loads > 300 pF. . . . . | 10 |
| Figure 4. | $V_{OUT}$ vs. temperature . . . . .   | 11 |
| Figure 5. | SOT323-5 – 5-lead small outline transistor package outline . . . . .        | 13 |
| Figure 6. | UDFN – 4-lead package outline . . . . .                                     | 14 |
| Figure 7. | Carrier tape for SOT323-5L and UDFN-4Lpackages . . . . .                    | 15 |

# 1 Description

The STLM20 is a precision analog output temperature sensor for low current applications where maximizing battery life is important. It operates over a  $-55\text{ }^{\circ}\text{C}$  to  $130\text{ }^{\circ}\text{C}$  (grade 7) or  $-40\text{ }^{\circ}\text{C}$  to  $85\text{ }^{\circ}\text{C}$  (grade 9) temperature range. The power supply operating range is 2.4 V to 5.5 V. The accuracy of the STLM20 is  $\pm 1.5\text{ }^{\circ}\text{C}$ , at an ambient temperature of  $25\text{ }^{\circ}\text{C}$ . The temperature error increases linearly and reaches a maximum of  $\pm 2.5\text{ }^{\circ}\text{C}$  at the temperature range extremes. The temperature range is affected by the power supply voltage. For the temperature grade 7 device, a power supply voltage of 2.7 V to 5.5 V, the temperature range extremes are  $+130\text{ }^{\circ}\text{C}$  and  $-55\text{ }^{\circ}\text{C}$ . Decreasing the power supply voltage to 2.4 V changes the negative extreme to  $-30\text{ }^{\circ}\text{C}$ , while the positive remains at  $+130\text{ }^{\circ}\text{C}$ .

The STLM20 has a maximum quiescent supply current of  $8\text{ }\mu\text{A}$ . Therefore, self-heating is negligible.

**Figure 1. Logic diagram**

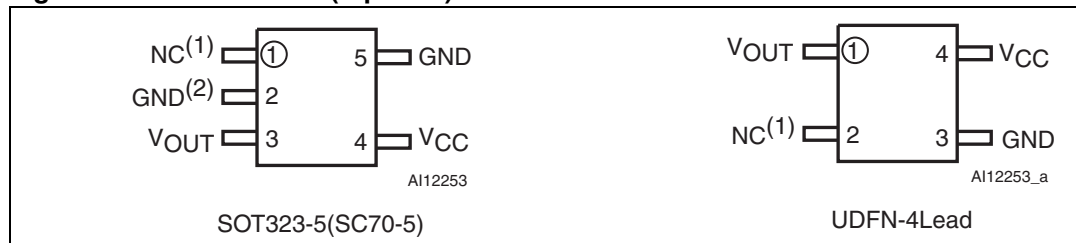


1. Pin 2 GND may be grounded or left floating (SC70-5 only). For optimum thermal conductivity to the PC board ground plane, it should be grounded.

**Table 1. Signal names**

|                  |                |
|------------------|----------------|
| V <sub>CC</sub>  | Supply voltage |
| GND              | Ground         |
| V <sub>OUT</sub> | Output voltage |
| NC               | No connect     |

**Figure 2. Connections (top view)**



1. Pin 1 NC should be left floating or grounded.
2. Pin 2 GND may be grounded or left floating. For optimum thermal conductivity to the PC board ground plane, it should be grounded.

## 2 Transfer function

The STLM20's 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 expressed as:

### Equation 1

$$V_O = (-11.69\text{mV})/^{\circ}\text{C} \times T + 1.8663\text{V}$$

Over the specified operating temperature range, the best accuracy can be obtained by using the parabolic transfer function:

### Equation 2

$$V_O = (-3.88 \times 10^{-6} \times T^2) + (-1.15 \times 10^{-2} \times T) + 1.8639$$

and solving for T:

### Equation 3

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

The best fit linear transfer function for many popular temperature ranges was calculated in [Table 2](#), where the error introduced by the linear transfer function increases with wider temperature ranges.

**Table 2. First order equations optimized for different temperature ranges**

| Temperature range |                 | Linear equation<br>$V_O =$                                  | Maximum deviation of linear equation from parabolic equation (°C) |
|-------------------|-----------------|---|---|
| $T_{\min}$ (°C)   | $T_{\max}$ (°C) |   |   |
| -55               | 130             | $-11.79 \text{ mV}/^{\circ}\text{C} * T + 1.8528 \text{ V}$ | $\pm 1.41$  |
| -40               | 110             | $-11.77 \text{ mV}/^{\circ}\text{C} * T + 1.8577 \text{ V}$ | $\pm 0.93$  |
| -30               | 100             | $-11.77 \text{ mV}/^{\circ}\text{C} * T + 1.8605 \text{ V}$ | $\pm 0.70$  |
| -40               | 85              | $-11.67 \text{ mV}/^{\circ}\text{C} * T + 1.8583 \text{ V}$ | $\pm 0.65$  |
| -10               | 65              | $-11.71 \text{ mV}/^{\circ}\text{C} * T + 1.8641 \text{ V}$ | $\pm 0.23$  |
| 35                | 45              | $-11.81 \text{ mV}/^{\circ}\text{C} * T + 1.8701 \text{ V}$ | $\pm 0.004$   |
| 20                | 30              | $-11.69 \text{ mV}/^{\circ}\text{C} * T + 1.8663 \text{ V}$ | $\pm 0.004$   |

**Table 3. Quadratic output equation ( $V_{CC} = 2.7\text{ V}$ )**

| Parameter   | Conditions            | Min   | Typ   | Max   | Unit |
|---|-----------------------|-------|-------|-------|------|
| Temperature error based on:<br>$V_{OUT} = (-3.88e^{-6} \times T^2) + (-1.15e^{-2} \times T) + 1.8639$<br>where T is the temperature | $T_A = -55\text{ °C}$ | 2.457 | 2.485 | 2.512 | V    |
|   | $T_A = -40\text{ °C}$ | 2.292 | 2.318 | 2.343 |      |
|   | $T_A = -30\text{ °C}$ | 2.181 | 2.205 | 2.230 |      |
|   | $T_A = -20\text{ °C}$ | 2.069 | 2.092 | 2.116 |      |
|   | $T_A = 0\text{ °C}$   | 1.842 | 1.864 | 1.886 |      |
|   | $T_A = 25\text{ °C}$  | 1.556 | 1.574 | 1.592 |      |
|   | $T_A = 50\text{ °C}$  | 1.255 | 1.279 | 1.303 |      |
|   | $T_A = 85\text{ °C}$  | 0.833 | 0.859 | 0.884 |      |
|   | $T_A = 130\text{ °C}$ | 0.272 | 0.303 | 0.335 |      |

**Table 4. Quadratic output equation for operations over the full voltage range ( $V_{CC} = 2.4\text{ V to }5.5\text{ V}$ )**

| Parameter <sup>(1)</sup>  | Conditions                     | Min   | Max   | Unit |
|---|--------------------------------|-------|-------|------|
| Temperature error based on:<br>$V_{OUT} = (-3.88e^{-6} \times T^2) + (-1.15e^{-2} \times T) + 1.8639$ ,<br>where T is the temperature | $T_A = -55\text{ °C}^{(2)(3)}$ | 2.457 | 2.531 | V    |
|   | $T_A = -40\text{ °C}^{(2)}$    | 2.292 | 2.362 |      |
|   | $T_A = -30\text{ °C}$          | 2.180 | 2.249 |      |
|   | $T_A = -20\text{ °C}$          | 2.068 | 2.135 |      |
|   | $T_A = 0\text{ °C}$            | 1.841 | 1.904 |      |
|   | $T_A = 25\text{ °C}$           | 1.555 | 1.610 |      |
|   | $T_A = 50\text{ °C}$           | 1.254 | 1.322 |      |
|   | $T_A = 85\text{ °C}$           | 0.832 | 0.903 |      |
|   | $T_A = 130\text{ °C}^{(3)}$    | 0.271 | 0.353 |      |

1.  $V_{OUT}$  tolerance is  $\pm 4\%$  (temperature grade 9 only).
2. Valid for  $V_{CC}$  min = 2.7 V.
3. Valid for temperature grade 7 only.

### 3 Maximum ratings

Stressing the device above the rating listed in the absolute maximum ratings table may cause permanent damage to the device. These are stress ratings only and operation of the device at these or any other conditions above those indicated in the operating sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability. Refer also to the STMicroelectronics SURE Program and other relevant quality documents.

**Table 5. Absolute maximum ratings**

| Symbol          | Parameter                              |                   | Value                  | Unit |
|-----------------|--|-------------------|------------------------|------|
| $T_{STG}$       | Storage temperature                    |                   | -65 to +150            | °C   |
| $T_{SLD}^{(1)}$ | Lead solder temperature for 10 seconds |                   | 260                    | °C   |
| $V_O$           | Output voltage                         |                   | -0.3 to $V_{CC} + 0.3$ | V    |
| $V_{CC}$        | Supply voltage                         |                   | -0.2 to 6.5            | V    |
| $I_O$           | Output current                         |                   | 10                     | mA   |
| $T_{J(max)}$    | Maximum junction temperature           |                   | 150                    | °C   |
| $\theta_{JA}$   | Thermal resistance                     | SOT323-5 (SC70-5) | 331.4                  | °C/W |
|                 |  | UDFN              | 160.2                  | °C/W |
| $T_A^{(2)}$     | Ambient operating temperature          | Grade 7           | -55 to 130             | °C   |
|                 |  | Grade 9           | -40 to 85              | °C   |

1. Reflow at peak temperature of 260 °C. The time above 255 °C must not exceed 30 seconds.
2. Grade 7: STLM20W87F, STLM20DD7F  
Grade 9: STLM20DD9F



## 4 DC and AC characteristics

This section summarizes the DC and AC characteristics of the device. The parameters in the DC and AC characteristics table that follows are derived from tests performed under the test conditions. Designers should check that the operating conditions in their circuit match the operating conditions when relying on the quoted parameters.

**Table 6. DC and AC characteristics**

| Sym                           | Description  | Test condition <sup>(1)</sup>                           | Min   | Typ <sup>(2)</sup> | Max   | Unit  |
|-------------------------------|--|---|-------|--------------------|-------|-------|
| V <sub>CC</sub>               | Supply voltage   | T <sub>A</sub> = -30 °C to 130 °C                       | 2.4   |                    | 5.5   | V     |
|                               |  | T <sub>A</sub> = -55 °C to 130 °C or<br>-40 °C to 85 °C | 2.7   |                    | 5.5   | V     |
| V <sub>O</sub>                | Output voltage   | T <sub>A</sub> = 0 °C                                   |       | 1.8639             |       | V     |
|                               | Temperature to voltage error <sup>(3)</sup><br>V <sub>O</sub> = (-3.88E-6 * T2) +<br>(-1.15E-2 * T) + 1.8639 V | T <sub>A</sub> = 25 °C to 30 °C                         |       |                    | ±1.5  | °C    |
|                               |  | T <sub>A</sub> = 125 °C to 130 °C                       |       |                    | ±2.5  | °C    |
|                               |  | T <sub>A</sub> = 80 °C to 85 °C                         |       |                    | ±2.1  | °C    |
|                               |  | T <sub>A</sub> = 0 °C                                   |       |                    | ±1.9  | °C    |
|                               |  | T <sub>A</sub> = -40 °C                                 |       |                    | ±2.3  | °C    |
|                               |  | T <sub>A</sub> = -55 °C                                 |       |                    | ±2.5  | °C    |
| I <sub>Q</sub>                | Quiescent current  | 2.4V ≤ V <sub>CC</sub> ≤ 5.5 V                          |       | 4.8                | 8     | μA    |
|                               | Sensor gain (temperature sensitivity or average slope),<br>V <sub>O</sub> = -11.77 mV/°C * T + 1.860 V         | -30 °C ≤ T <sub>A</sub> ≤ 100 °C                        | -11.4 | -11.77             | -12.2 | mV/°C |
|                               | Non-linearity  | -20 °C ≤ T <sub>A</sub> ≤ 80 °C                         |       | ±0.4               |       | %     |
| ΔI <sub>Q</sub>               | Change of quiescent current  | 2.4 V ≤ V <sub>CC</sub> ≤ 5.5 V                         |       | 0.7                |       | μA    |
| T <sub>C</sub> V <sub>O</sub> | Temperature coefficient of quiescent current   |   |       | -11                |       | nA/°C |
| I <sub>SD</sub>               | Shutdown current   | V <sub>CC</sub> ≤ 0.8 V                                 |       | 0.02               |       | μA    |
| Z <sub>O</sub>                | Output impedance   | 0 μA ≤ I <sub>L</sub> ≤ 16 μA <sup>(4)(5)</sup>         |       |                    | 160   | Ω     |
| RegL                          | Load regulation <sup>(6)</sup>   |   |       |                    | -2.5  | mV    |
| RegI1                         | Line regulation  | 2.4 V ≤ V <sub>CC</sub> ≤ 5.0 V                         |       |                    | 3.3   | mV/V  |
| RegI2                         |  | 5.0 V ≤ V <sub>CC</sub> ≤ 5.5 V                         |       |                    | 11    | mV    |

1. Valid for ambient operating temperature: T<sub>A</sub> = -55 to 130 °C or T<sub>A</sub> = -40 to 85 °C; V<sub>CC</sub> = 2.7 V (except where noted).

2. T<sub>J</sub> = T<sub>A</sub> = 25 °C.

3. Error accuracy is between the measured and calculated output voltage at specified conditions of voltage, current, and temperature.

4. With negative current flowing into STLM20 and positive current flowing out, can typically sink less than 1 μA and source is 16 μA.

5. Over the supply range of 2.4 to 5.5 V.

6. Measured at constant junction temperature, with pulse testing and low duty cycle. Output changes due to heating may be calculated by multiplying internal dissipation by thermal resistance.

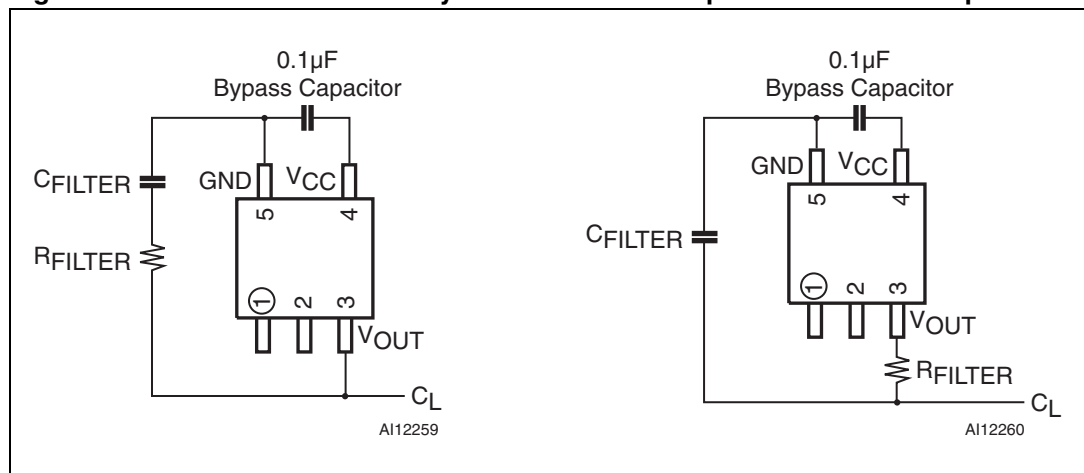
## 5 Capacitive load

The STLM20 will handle capacitive loads of up to 300 pF. Over the specified temperature range, the STLM20 has a maximum output impedance of 160 Ω.

In a noisy environment, it may be advisable to add some filtering to minimize noise in the output voltage. A 0.1 μF capacitor added between the supply voltage and ground is recommended.

In an extremely noisy environment, it may be necessary to add a low-pass filter network to the output of the device. A 1 μF capacitor, in addition to the output impedance of the device, and a 200 Ω series resistor, will provide a low-pass filter that will pass the slow thermal time constant of the STLM20, while filtering the higher frequency noise.

**Figure 3. Filter network for noisy environments or capacitive loads > 300 pF**



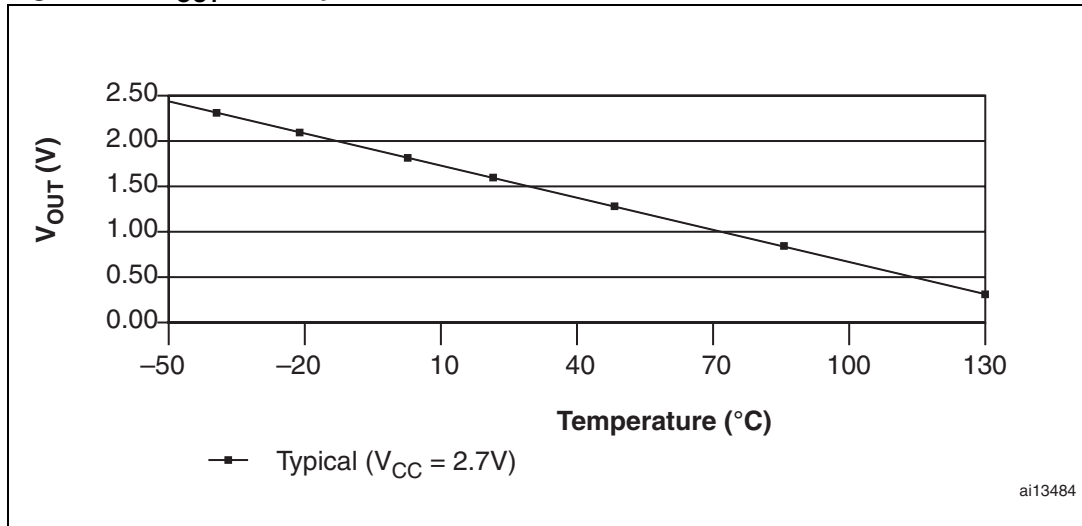
**Table 7. Resistor/capacitor combinations for the filter network**

| $R_{\text{FILTER}}$ | $C_{\text{FILTER}}$ |
|---------------------|---------------------|
| 200 Ω               | 1 μF                |
| 470 Ω               | 0.1 μF              |
| 680 Ω               | 0.01 μF             |
| 1000 Ω              | 1000 pF             |
| 10 kΩ               | 100 pF              |
| 100 kΩ              | 10 pF               |

## 6 Typical operating characteristics

The graph shown in [Figure 4](#) represents  $V_{OUT}$  according to temperature.

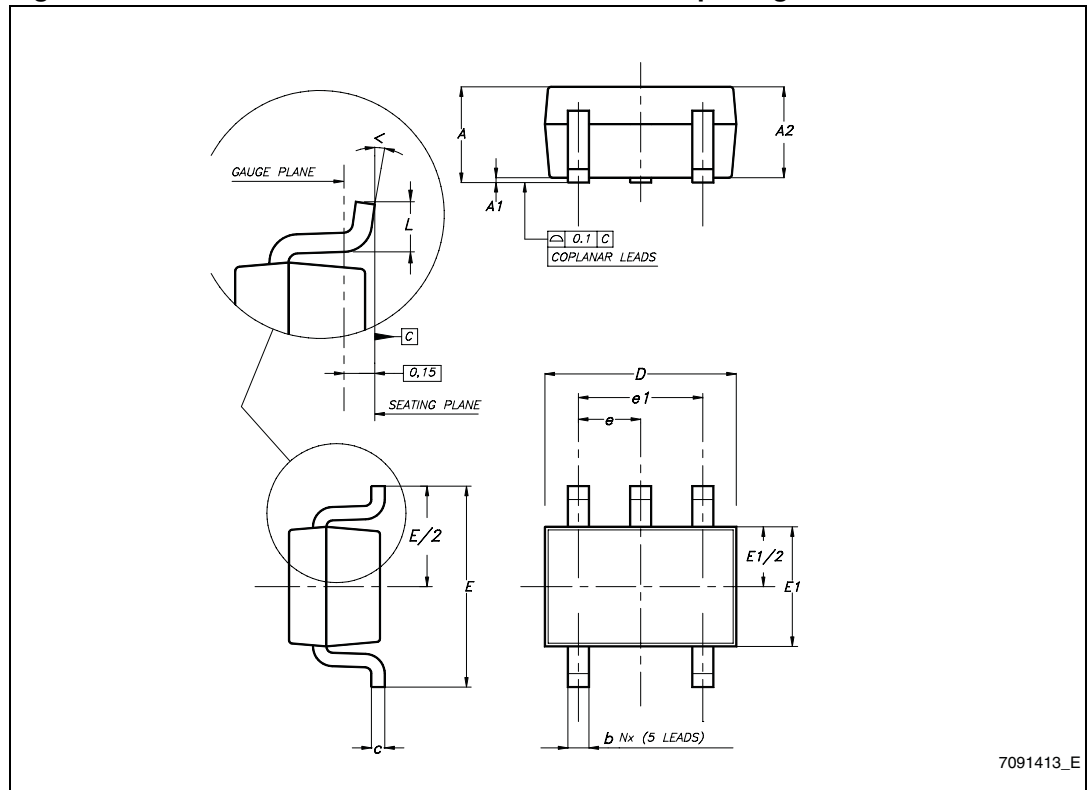
**Figure 4.**  $V_{OUT}$  vs. temperature



## 7 Package mechanical data

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK<sup>®</sup> packages, depending on their level of environmental compliance. ECOPACK<sup>®</sup> specifications, grade definitions and product status are available at: [www.st.com](http://www.st.com). ECOPACK<sup>®</sup> is an ST trademark.

Figure 5. SOT323-5 – 5-lead small outline transistor package outline



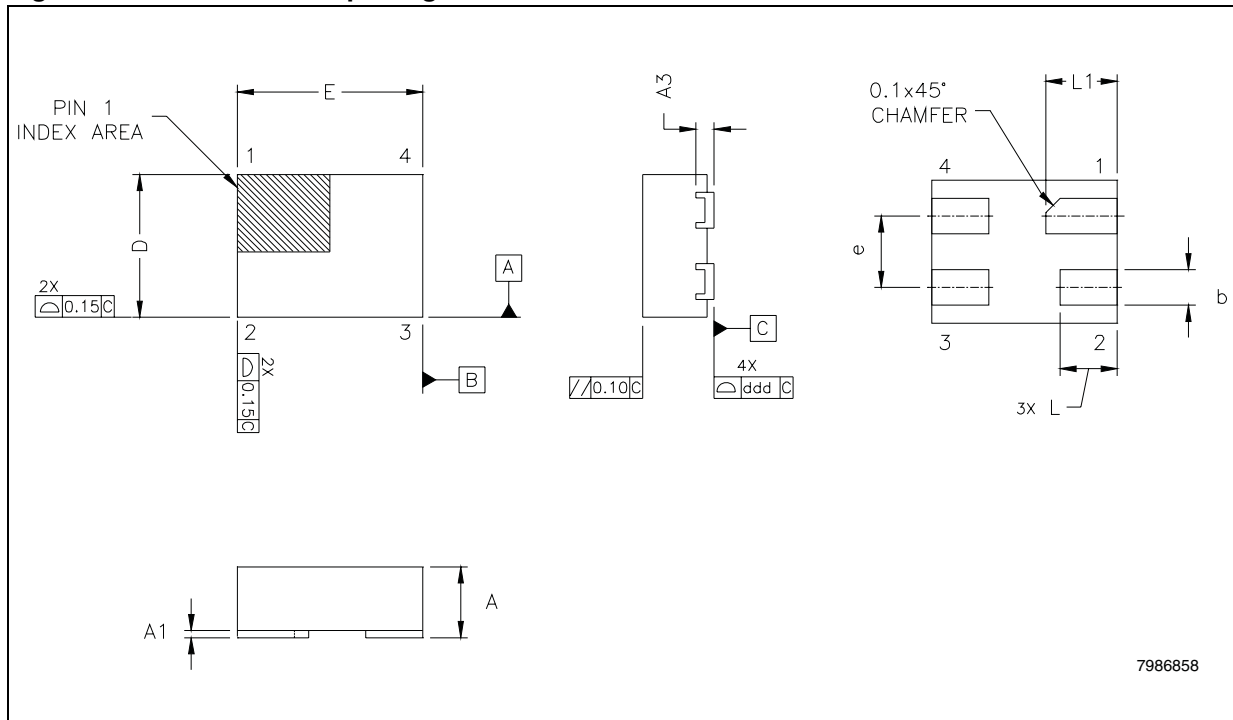
7091413\_E

1. Drawing is not to scale.

Table 8. SOT323-5 – 5-lead small outline transistor package mechanical data

| Symbol   | mm   |      |      | inches |       |       |
|----------|------|------|------|--------|-------|-------|
|          | Typ  | Min  | Max  | Typ    | Min   | Max   |
| A        | –    | 0.80 | 1.10 | –      | 0.031 | 0.043 |
| A1       | –    | 0    | 0.10 | –      | 0.000 | 0.004 |
| A2       | 0.90 | 0.80 | 1.00 | 0.035  | 0.031 | 0.039 |
| b        | –    | 0.15 | 0.30 | –      | 0.006 | 0.012 |
| c        | –    | 0.10 | 0.22 | –      | 0.004 | 0.009 |
| D        | 2.00 | 1.80 | 2.20 | 0.079  | 0.071 | 0.087 |
| E        | 2.10 | 1.80 | 2.40 | 0.083  | 0.071 | 0.094 |
| E1       | 1.25 | 1.15 | 1.35 | 0.049  | 0.045 | 0.053 |
| e        | 0.65 | –    | –    | 0.026  | –     | –     |
| e1       | 1.30 | –    | –    | 0.051  | –     | –     |
| L        | 0.36 | 0.26 | 0.46 | 0.014  | 0.010 | 0.018 |
| $\alpha$ | –    | 0°   | 8°   | –      | 0°    | 8°    |

Figure 6. UDFN – 4-lead package outline



Note: Drawing is not to scale.

Table 9. UDFN – 4-lead package mechanical data

| Symbol | mm    |       |       | inches |        |        |
|--------|-------|-------|-------|--------|--------|--------|
|        | Min   | Typ   | Max   | Min    | Typ    | Max    |
| A      | 0.45  | 0.50  | 0.55  | 0.018  | 0.020  | 0.022  |
| A1     | 0     | 0.025 | 0.05  | 0      | 0.001  | 0.002  |
| A3     | 0.119 | 0.127 | 0.177 | 0.0046 | 0.0050 | 0.0069 |
| b      | 0.20  | 0.25  | 0.30  | 0.008  | 0.010  | 0.012  |
| D      | 0.95  | 1.00  | 1.05  | 0.037  | 0.039  | 0.041  |
| E      | 1.25  | 1.30  | 1.35  | 0.049  | 0.051  | 0.053  |
| e      | 0.45  | 0.50  | 0.55  | 0.018  | 0.020  | 0.022  |
| L      | 0.35  | 0.40  | 0.45  | 0.014  | 0.016  | 0.018  |
| L1     | 0.45  | 0.50  | 0.55  | 0.018  | 0.020  | 0.022  |
| ddd    | 0     | 0.04  | 0.08  | 0      | 0.0016 | 0.0031 |

Figure 7. Carrier tape for SOT323-5L and UDFN-4L packages

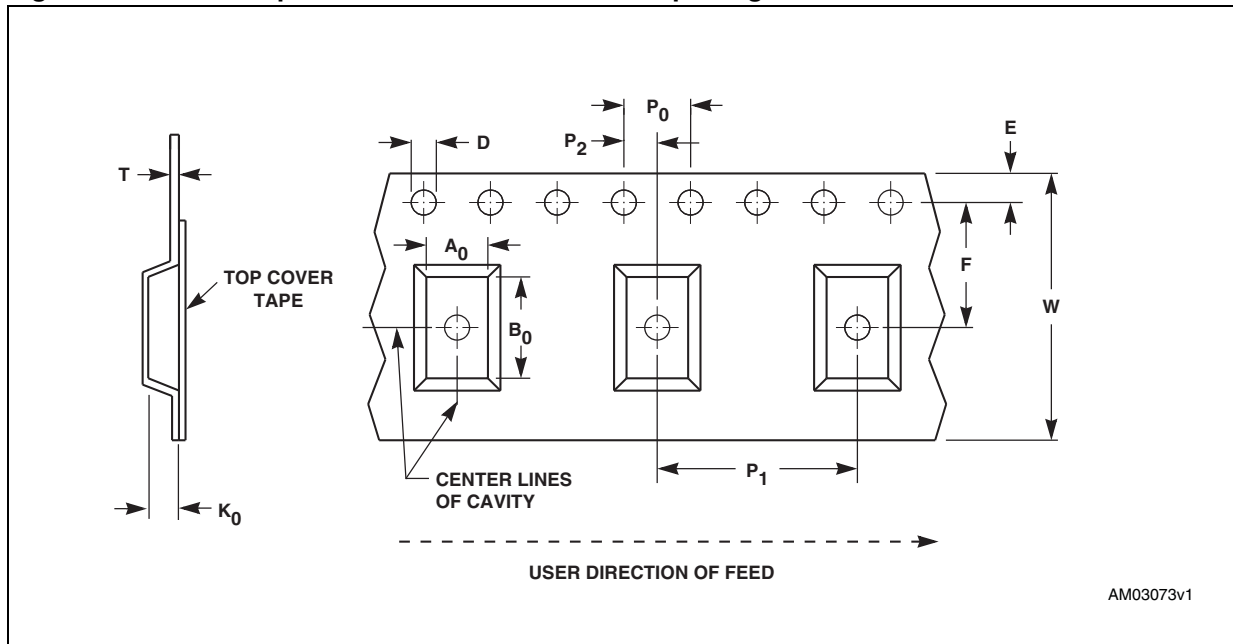


Table 10. Carrier tape dimensions for SOT323-5L and UDFN-4L packages

| Package   | W                      | D                       | E             | P <sub>0</sub> | P <sub>2</sub> | F             | A <sub>0</sub> | B <sub>0</sub> | K <sub>0</sub> | P <sub>1</sub> | T              | Unit | Bulk Qty |
|-----------|------------------------|-------------------------|---------------|----------------|----------------|---------------|----------------|----------------|----------------|----------------|----------------|------|----------|
| SOT323-5L | 8.00<br>+0.30<br>-0.10 | 1.50<br>+0.10/<br>-0.00 | 1.75<br>±0.10 | 4.00<br>±0.10  | 2.00<br>±0.10  | 3.50<br>±0.05 | 2.25<br>±0.10  | 2.40<br>±0.10  | 1.22<br>±0.10  | 4.00<br>±0.10  | 0.30<br>±0.05  | mm   | 3000     |
| UDFN-4L   | 8.00<br>+0.30<br>-0.10 | 1.50<br>+0.10/<br>-0.00 | 1.75<br>±0.10 | 4.00<br>±0.10  | 2.00<br>±0.10  | 3.50<br>±0.05 | 1.25<br>±0.10  | 1.55<br>±0.10  | 0.65<br>±0.05  | 4.00<br>±0.10  | 0.250<br>±0.05 | mm   | 3000     |

## 8 Part numbering

**Table 11. Ordering information scheme**

|   |        |    |   |   |
|---|--------|----|---|---|
| Example:  | STLM20 | DD | 9 | F |
| <b>Device type</b>  |        |    |   |   |
| STLM20  |        |    |   |   |
| <b>Package</b>  |        |    |   |   |
| W8 = SOT323-5 (SC70-5) <sup>(1)</sup>   |        |    |   |   |
| DD= UDFN - ultra thin DFN 4-lead <sup>(2)</sup>                                     |        |    |   |   |
| <b>Temperature range</b>  |        |    |   |   |
| 7 = -55 to 130°C  |        |    |   |   |
| 9 = -40 to 85°C   |        |    |   |   |
| <b>Shipping method</b>  |        |    |   |   |
| F = ECOPACK <sup>®</sup> package, tape & reel                                       |        |    |   |   |
| 1. Available in temperature grade 7 (-55 to 130 °C) only                            |        |    |   |   |
| 2. Available in both temperature grade 7 (-55 to 130 °C) and grade 9 (-40 to 85 °C) |        |    |   |   |

**Table 12. Marking description**

| Part number | Package           | Marking |
|-------------|-------------------|---------|
| STLM20W8    | SOT323-5 (SC70-5) | M20     |
| STLM20DD    | UDFN              | 20      |

For other options, or for more information on any aspect of this device, please contact the ST sales office nearest you.



## 9 Revision history

**Table 13. Document revision history**

| Date        | Revision | Changes   |
|-------------|----------|---|
| 28-Jun-2006 | 1        | Initial release.  |
| 19-Jul-2006 | 2        | Added <a href="#">Table 12: Marking description</a>   |
| 28-Aug-2006 | 3        | Added a footnote concerning package availability in <a href="#">Features on page 1</a> and to <a href="#">Table 11</a> and <a href="#">Table 12</a> ; updated package mechanical data in <a href="#">Table 9</a>  |
| 05-Sep-2006 | 4        | Amended text in the <a href="#">Features on page 1</a> , <a href="#">Section 1: Description</a> , <a href="#">Section 2: Transfer function</a> , <a href="#">Table 6</a> , and <a href="#">Table 11</a> to elucidate that two packages exist each with specific temperature ranges: SOT323-5 (SC70-5) 5-lead package (–55 to 130 °C) and UDFN 4-lead package (–40 to 85 °C)             |
| 25-Sep-2006 | 5        | Updated Operating Temperature Ranges (now 7 and 9); updated <a href="#">Table 6: DC and AC characteristics</a>  |
| 10-Oct-2006 | 6        | <a href="#">Table 3: Quadratic output equation (<math>V_{CC} = 2.7 V</math>)</a> and <a href="#">Table 4: Quadratic output equation for operations over the full voltage range (<math>V_{CC} = 2.4 V</math> to <math>5.5 V</math>)</a> added. <a href="#">Section 6: Typical operating characteristics</a> added.<br>$T_A$ added to <a href="#">Table 5: Absolute maximum ratings</a> . |
| 04-Dec-2006 | 7        | Document status updated to full datasheet; updated text in the title of <a href="#">Table 4: Quadratic output equation for operations over the full voltage range (<math>V_{CC} = 2.4 V</math> to <math>5.5 V</math>)</a> ; added footnotes regarding temperature ranges in <a href="#">Table 11: Ordering information scheme</a> .   |
| 08-Feb-2007 | 8        | Added thermal resistance in <a href="#">Table 5: Absolute maximum ratings</a> .   |
| 09-May-2007 | 9        | Modified <a href="#">Equation 1</a> , <a href="#">2</a> , and <a href="#">3</a> .   |
| 26-Nov-2007 | 10       | Updated footnote 2 in <a href="#">Table 5</a> ; minor text updates.   |
| 07-Nov-2008 | 11       | Updated <a href="#">Figure 6: UDFN – 4-lead package outline</a> to reflect location of pin 1 with respect to the orientation of the topside marking; updated <a href="#">Figure 5</a> , <a href="#">Table 5</a> , <a href="#">8</a> , <a href="#">11</a> .  |
| 10-Sep-2009 | 12       | Updated <a href="#">Table 5</a> , text in <a href="#">Section 7: Package mechanical data</a> ; added tape and reel specifications ( <a href="#">Figure 7</a> and <a href="#">Table 10</a> ); reformatted document.  |

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