# ±1.5°C High Precision Ultra-low Current Analog Temperature Sensor

Datasheet (EN) 1.2

## Product Overview

The NST86 is a high precision CMOS analog output temperature sensor. The device offers a maximum accuracy of ±1.5°C at 25°C and a maximum of ±2.5°C over the full temperature range. The device is specified at the full temperature range of -50°C to 150°C and the power supply operating range is 2.7V to 5.5V, however, the minimum operating voltage can be as low as 2.4V when the temperature range is -30°C to 150°C.

The NST86 device provides a negative slope output of

-10.9mV/°C over -30°C to 100°C. it is highly linear and does not require complex calculations or lookup tables to derive temperature.

The NST86 is a low power device, and the typical operating current is 20µA. Therefore, self-heating is negligible. The NST86 is available in a SC70(5) package, making it suitable for on-board and off-line applications in the industrial, and consumer markets applications in the IoT.

## Key Features

- Operating Voltage Range: 2.4V to 5.5V
- Operating Temperature Range: –50°C to 150°C
- Accuracy at 25°C: ±1.5°C (Maximum)
- Accuracy at -55°C to 130°C: ±2.5°C (Maximum)
- Average Sensor Gain: -10.9mV/°C
- Output Impedance: 1Ω (Typical)
- Operating Current: 20µA (Typical)
- Push-Pull Output Current Drain: 500µA (Maximum)
- Predictable Curvature Error
- Output Short Protection
- Suitable for Remote Applications
- Package: SC70(5)

## Applications

- Smartphones
- Portable Medical Instruments
- Notebook Computers
- Industrial Internet of Things (IoT)
- Power Supply Modules
- Power-system Monitors
- Thermal Protection
- Environmental Monitoring and HVAC
- Disk Drives

## Device Information

| Part Number | Package | Body Size |
|---|---|---|
| NST86 | SC70(5) | 2.00mm × 1.25mm |

## Functional Block Diagram

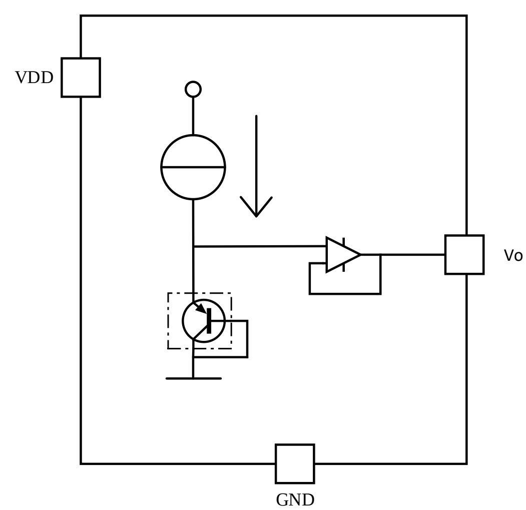


Figure 1 NST86 Functional Block Diagram

# Index

# 1 Pin Configuration and Functions

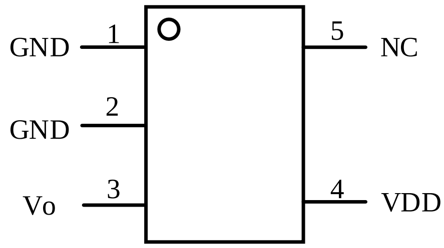


Figure 1.1 NST86 pin configuration

Table 1.1 NST86 Function Description

| Pin | | Type | Description |
|---|---|---|---|
| No. | Name | | |
| 1 | GND | GND | Ground pin, connect to power supply negative terminal. |
| 2 | GND | GND | Ground pin, connect to power supply negative terminal. This pin must be grounded for optimum thermal conductivity. |
| 3 | $V_O$ | Analog output | Vout, Analog voltage output |
| 4 | VDD | Power | Power supply input pin |
| 5 | NC | - | No Connection |

# 2 Specifications

## 2.1 Absolute Maximum Ratings

| Parameters | Symbol | Min | Typ | Max | Unit | Comments |
|---|---|---|---|---|---|---|
| Supply Voltage Pin(VDD) | VDD | -0.3 | | 6.5 | V | |
| Output Volatge | $V_O$ | -0.3 | | VDD+0.3 | V | |
| Storage Temperature | | -60 | | 155 | °C | |
| Operation Temperature | $TB_{operation}$ | -50 | | 150 | °C | |
| Maximum Junction Temperature | | | | 155 | °C | |
| ESD Susceptibility | HBM | ±4.5 | | | KV | |
| | CDM | ±0.5 | | | KV | |

## 2.2 Electrical Characteristics

at $T_A$ = +25°C and VDD = +2.4V to +5.5V, unless otherwise noted.

| ***Parameters*** | ***Symbol*** | ***Min*** | ***Typ*** | ***Max*** | ***Unit*** | ***Comments*** |
|---|---|---|---|---|---|---|
| ***Supply*** | | | | | | |
| Supply Voltage Range | VDD | 2.4 | 3.3 | 5.5 | V | |
| Supply Sensitivity | | | 0.1 | | °C/V | |
| Operation Current | Iconv | | 20 | | µA | |
| Shutdown Current | $I_{SD}$ | | 0.1 | | µA | VDD≤0.6V |
| ***Temperature Range*** | | | | | | |
| Temperature Range | | -50 | | 150 | °C | |
| Accuracy(Using equation 4-1) | | -1.5 | 0.5 | 1.5 | °C | at 25°C |
| | | -2.5 | | 2.5 | °C | from -50°C to -150°C |
| Output Voltage at 0°C | | | 2.1 | | V | |
| Vout Drive Capability | | | 500 | | µA | |
| Sensor Gain | | | -10.9 | | mV/°C | |
| Output Impedance | | | 1 | | Ω | |
| Load Regulation | | | 0.5 | | mV | Source ≤50uA |
| Temperature Coefficient of Quiescent Current | | | -44 | | nA/°C | |
| ***Thermal response*** | | | | | | |
| Stirred Oil Thermal Response Time to 63% of Final Value (Package Only) | | | 0.418 | | s | |
| ***Drift*** | | | | | | |
| Drift[1] | | | ±0.2 | | °C | |

Notes: 1. Drift data is based on a 1000-hour stress test at +130°C with VDD = 5.5V.

### 2.3 Typical Characteristics

at VDD = 3.3 V, Using SC70(5) test, unless otherwise noted.

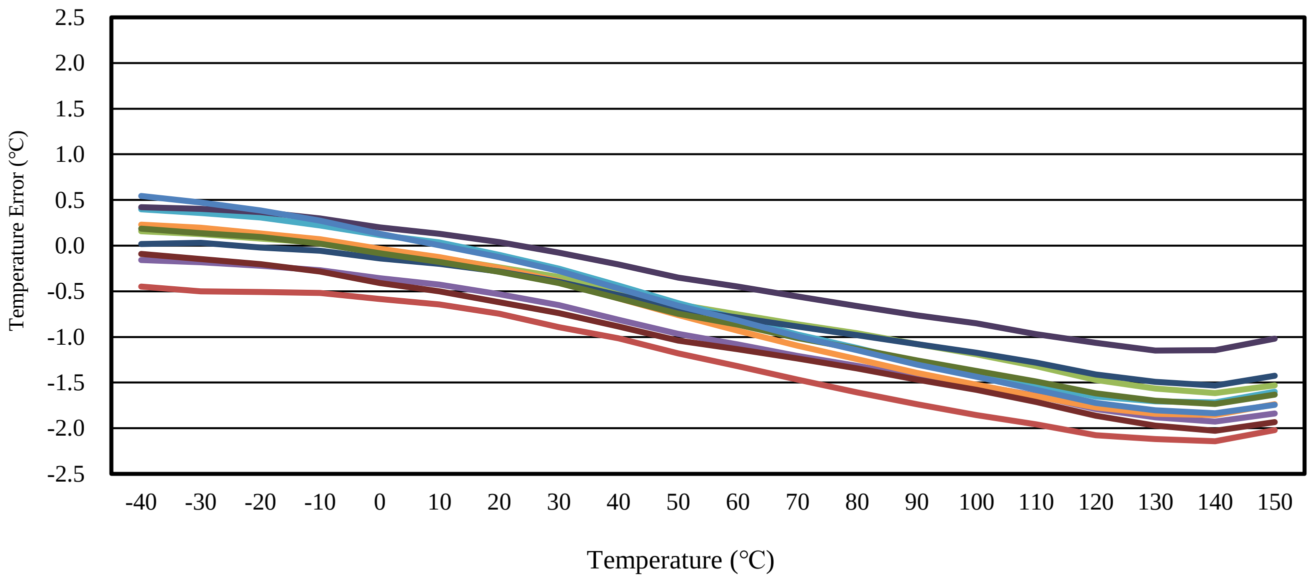


Figure 2.1 Temperature Error vs Temperature

# 3 Function Description

### 3.1 Overview

The NST86 is a high precision CMOS analog output temperature sensor. The device offers a maximum accuracy of ± 1.5°C at 25°C and a maximum of ±2.5°C over the full temperature range. The device is specified at the full temperature range of -50°C to 150°C and the power supply operating range is 2.7V to 5.5V, however, the minimum operating voltage can be as low as 2.4V when the temperature range is -30°C to 150°C.

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### 3.2 Functional Block Diagram

The NST86 Functional Block Diagram as shown in Figure 3.1.

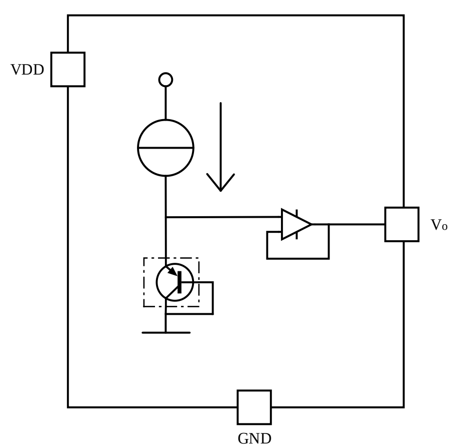



Figure 3.1 NST86 Functional Block Diagram

### 3.3 Feature Description

### 3.3.1 NST86 Transfer Function

The output voltage of NST86 over the entire operating temperature range as shown in Table 3.1, and it is a reference table for determining the NST86 accuracy specifications (listed in the accuracy section of Electrical Characteristics).

Table 3.1 NST86 Temperature to Voltage Output transfer Table

| TEMP (℃) | VOUT (mV) | TEMP (℃) | VOUT (mV) | TEMP (℃) | VOUT (mV) | TEMP (℃) | VOUT (mV) | TEMP (℃) | VOUT (mV) |
|---|---|---|---|---|---|---|---|---|---|
| -50 | 2616 | -10 | 2207 | 30 | 1777 | 70 | 1335 | 110 | 883 |
| -49 | 2607 | -9 | 2197 | 31 | 1766 | 71 | 1324 | 111 | 872 |
| -48 | 2598 | -8 | 2186 | 32 | 1756 | 72 | 1313 | 112 | 860 |
| -47 | 2589 | -7 | 2175 | 33 | 1745 | 73 | 1301 | 113 | 849 |
| -46 | 2580 | -6 | 2164 | 34 | 1734 | 74 | 1290 | 114 | 837 |
| -45 | 2571 | -5 | 2154 | 35 | 1723 | 75 | 1279 | 115 | 826 |
| -44 | 2562 | -4 | 2143 | 36 | 1712 | 76 | 1268 | 116 | 814 |
| -43 | 2553 | -3 | 2132 | 37 | 1701 | 77 | 1257 | 117 | 803 |
| -42 | 2543 | -2 | 2122 | 38 | 1690 | 78 | 1245 | 118 | 791 |
| -41 | 2533 | -1 | 2111 | 39 | 1679 | 79 | 1234 | 119 | 780 |
| -40 | 2522 | 0 | 2100 | 40 | 1668 | 80 | 1223 | 120 | 769 |
| -39 | 2512 | 1 | 2089 | 41 | 1657 | 81 | 1212 | 121 | 757 |
| -38 | 2501 | 2 | 2079 | 42 | 1646 | 82 | 1201 | 122 | 745 |
| -37 | 2491 | 3 | 2068 | 43 | 1635 | 83 | 1189 | 123 | 734 |
| -36 | 2481 | 4 | 2057 | 44 | 1624 | 84 | 1178 | 124 | 722 |
| -35 | 2470 | 5 | 2047 | 45 | 1613 | 85 | 1167 | 125 | 711 |
| -34 | 2460 | 6 | 2036 | 46 | 1602 | 86 | 1155 | 126 | 699 |
| -33 | 2449 | 7 | 2025 | 47 | 1591 | 87 | 1144 | 127 | 688 |
| -32 | 2439 | 8 | 2014 | 48 | 1580 | 88 | 1133 | 128 | 676 |
| -31 | 2429 | 9 | 2004 | 49 | 1569 | 89 | 1122 | 129 | 665 |
| -30 | 2418 | 10 | 1993 | 50 | 1558 | 90 | 1110 | 130 | 653 |
| -29 | 2408 | 11 | 1982 | 51 | 1547 | 91 | 1099 | 131 | 642 |
| -28 | 2397 | 12 | 1971 | 52 | 1536 | 92 | 1088 | 132 | 630 |
| -27 | 2387 | 13 | 1961 | 53 | 1525 | 93 | 1076 | 133 | 618 |
| -26 | 2376 | 14 | 1950 | 54 | 1514 | 94 | 1065 | 134 | 607 |
| -25 | 2366 | 15 | 1939 | 55 | 1503 | 95 | 1054 | 135 | 595 |

Table 3.1 NST86 Temperature to Voltage Output transfer Table (Continued)

| TEMP (℃) | VOUT (mV) | TEMP (℃) | VOUT (mV) | TEMP (℃) | VOUT (mV) | TEMP (℃) | VOUT (mV) | TEMP (℃) | VOUT (mV) |
|---|---|---|---|---|---|---|---|---|---|
| -24 | 2355 | 16 | 1928 | 56 | 1492 | 96 | 1042 | 136 | 584 |
| -23 | 2345 | 17 | 1918 | 57 | 1481 | 97 | 1031 | 137 | 572 |
| -22 | 2334 | 18 | 1907 | 58 | 1470 | 98 | 1020 | 138 | 560 |
| -21 | 2324 | 19 | 1896 | 59 | 1459 | 99 | 1008 | 139 | 549 |
| -20 | 2313 | 20 | 1885 | 60 | 1448 | 100 | 997 | 140 | 537 |
| -19 | 2302 | 21 | 1874 | 61 | 1436 | 101 | 986 | 141 | 525 |
| -18 | 2292 | 22 | 1864 | 62 | 1425 | 102 | 974 | 142 | 514 |
| -17 | 2281 | 23 | 1853 | 63 | 1414 | 103 | 963 | 143 | 502 |
| -16 | 2271 | 24 | 1842 | 64 | 1403 | 104 | 951 | 144 | 490 |
| -15 | 2260 | 25 | 1831 | 65 | 1391 | 105 | 940 | 145 | 479 |
| -14 | 2250 | 26 | 1820 | 66 | 1380 | 106 | 929 | 146 | 467 |
| -13 | 2239 | 27 | 1810 | 67 | 1369 | 107 | 917 | 147 | 455 |
| -12 | 2228 | 28 | 1799 | 68 | 1358 | 108 | 906 | 148 | 443 |
| -11 | 2218 | 29 | 1788 | 69 | 1346 | 109 | 895 | 149 | 432 |
| - | - | - | - | - | - | - | - | 150 | 420 |

As Table 3.1 show, although NST86 is highly linear, but there is still a small quadratic coefficient. The Transfer Table of NST86 can be calculated by using the parabolic equation (Equation 3-1).

$$V_{TEMP}(mV) = -\left[10.888\frac{mV}{°C}(T - 30°C)\right] - \left[0.00347\frac{mV}{°C^2}(T - 30°C)^2\right] + 1777.3mV \tag{3-1}$$

The parabolic equation above is the approximate value of the transfer table. Under extreme temperature conditions, the temperature accuracy calculated by using this equation decreases slightly. The value of t can be solved by equation 3-2:

$$T = \frac{10.888 - \sqrt{(-10.888)^2 + 4 \times 0.00347 \times \left(1777.3 - V_{TEMP}(mV)\right)}}{2 \times (-0.00347)} + 30 \tag{3-2}$$

In applications with low absolute accuracy requirements, the line can be easily calculated in a desired temperature range from a table using a two-point equation (Equation 3-3).

$$V - V_1 = (T - T_1) \times [(V_2 - V_1)/(T_2 - T_1)] \tag{3-3}$$

Where, the unit of V is mV, the unit of T is °C, $T_1$ and $V_1$ are the coordinates of the lowest temperature, and $T_2$ and $V_2$ are the coordinates of the highest temperature.

For instance, when users want to solve this equation for a temperature range of 30°C to 60°C, they would proceed as follows:

$$V - 1777mV = [(1448mV - 1777mV)/(60℃ - 30℃)] \times (T - 30℃) \tag{3-4}$$

$$V - 1777mV = (-10.9mV/℃) \times (T - 30℃) \tag{3-5}$$

$$V = (-10.9mV/℃) \times T + 2103mV \tag{3-6}$$

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

### 3.3.2 Application Curve

The NST86 is highly linear, and Output Voltage vs Temperature as shown in Figure 3.2.

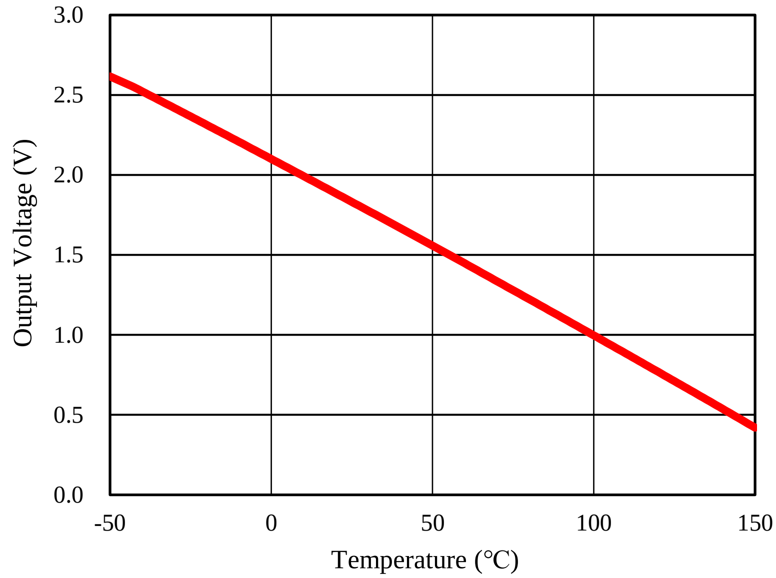



Figure 3.2 Output Voltage vs Temperature

# 4 Application Information

## 4.1 Capacitive Loads

As shown in the structure diagram, the output stage of NST86 is an amplifier. Generally, the output of the amplifier directly connected to the capacitive load is unstable. However, NST86 uses a special design, which makes it have 1000pF capacitive load capacity as shown in the Figure 4.1. If a larger capacitor is connected to filter the noise, an isolation resistance should be added between the output of NST86 and the capacitor as shown in the Table 4.1.

When the equipment is in an extremely noisy environment, it may be necessary to add an RC low-pass filter network to the output of NST86, such as a 1μF capacitor and a 800Ω series resistor. This low-pass filter will improve the thermal response time of NST86 and has the function of filtering high-frequency noise as shown in the Figure 4.2.

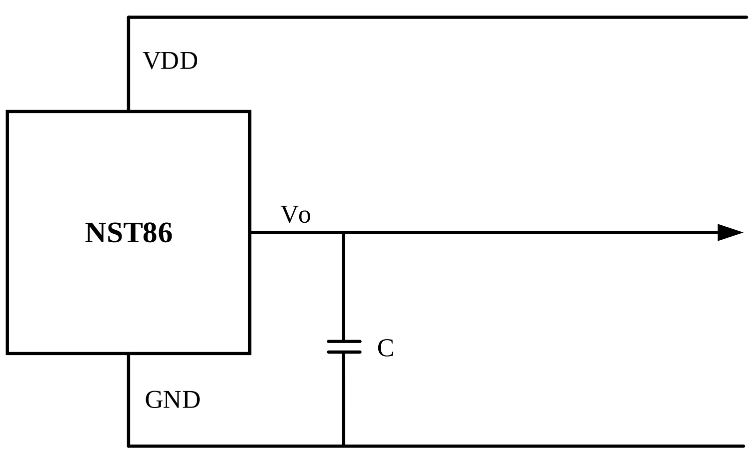



Figure 4.1 NST86 No Decoupling Required for Capacitive Loads Less than 1000pF

Table 4.1 Capacitive Loading Isolation

| C (µF) | Minimum R (Ω) |
|---|---|
| 1 | 800 |
| 0.1 to 1 | 1500 |
| 0.01 to 0.1 | 3000 |

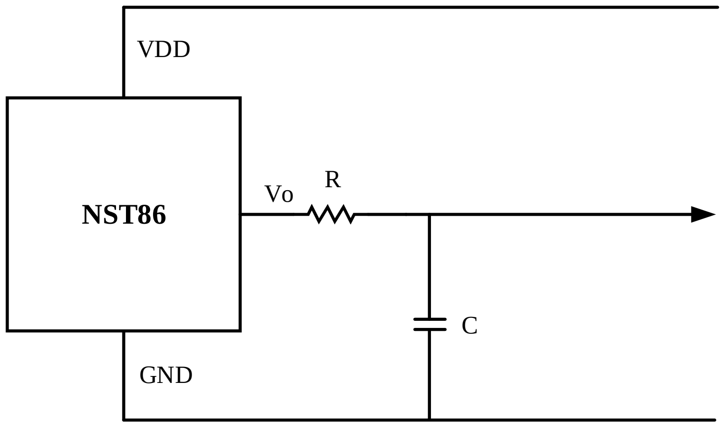



Figure 4.2 NST86 With RC Filter

## 4.2 Typical Application

As shown in Figure 4.3, the NST86 has an extremely low supply current and a wide supply range, therefore, it can be easily driven by a battery. In order to reduce the noise in the output voltage, it is recommended to add a 0.1µF capacitor between the power and the ground.

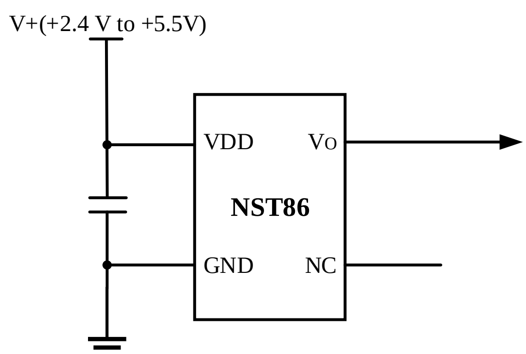



Figure 4.3 Typical Connections of the NST86

## 4.3 System Examples

### 4.3.1 Conserving Power Dissipation with Shutdown

Although NST86 has extremely low power consumption, for power-sensitive applications it can simply be shutdown by driving its supply pin with the output of a logic gate as shown in Figure 4.4.

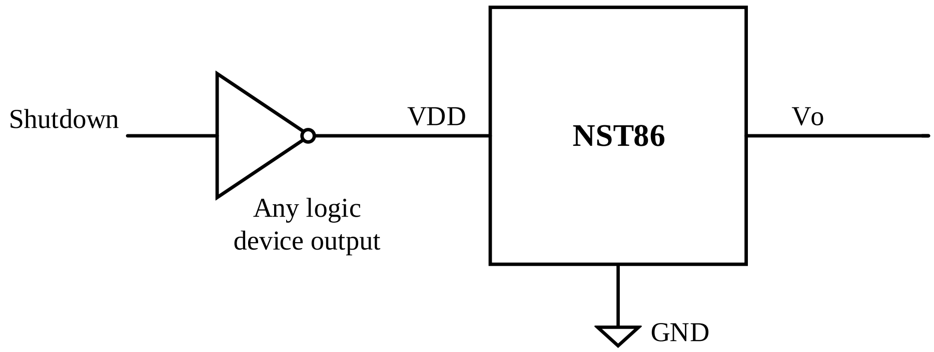



Figure 4.4 Conserving Power Dissipation with Shutdown

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

The input structure of most CMOS ADCs is sample and hold structure. When ADC charges the sampling capacitor, it needs to draw instantaneous current from the signal source (such as NST86 temperature sensor and many operational amplifiers). By adding RC filter to the output stage of NST86, this requirement can be met. At this time, the instantaneous current is provided by the output capacitor. This ADC is shown as an example only, in Figure 4.5.

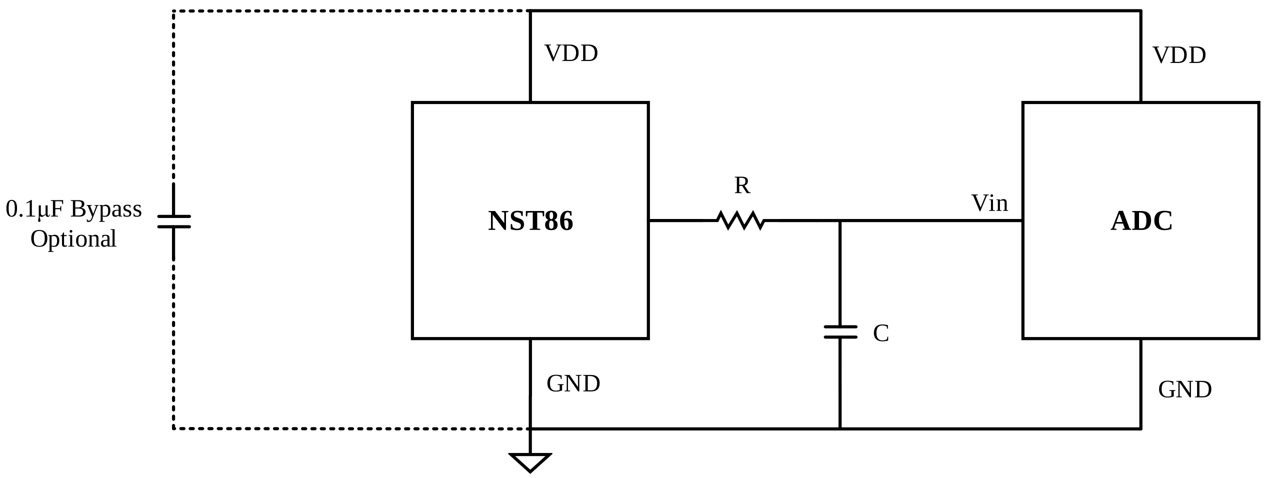
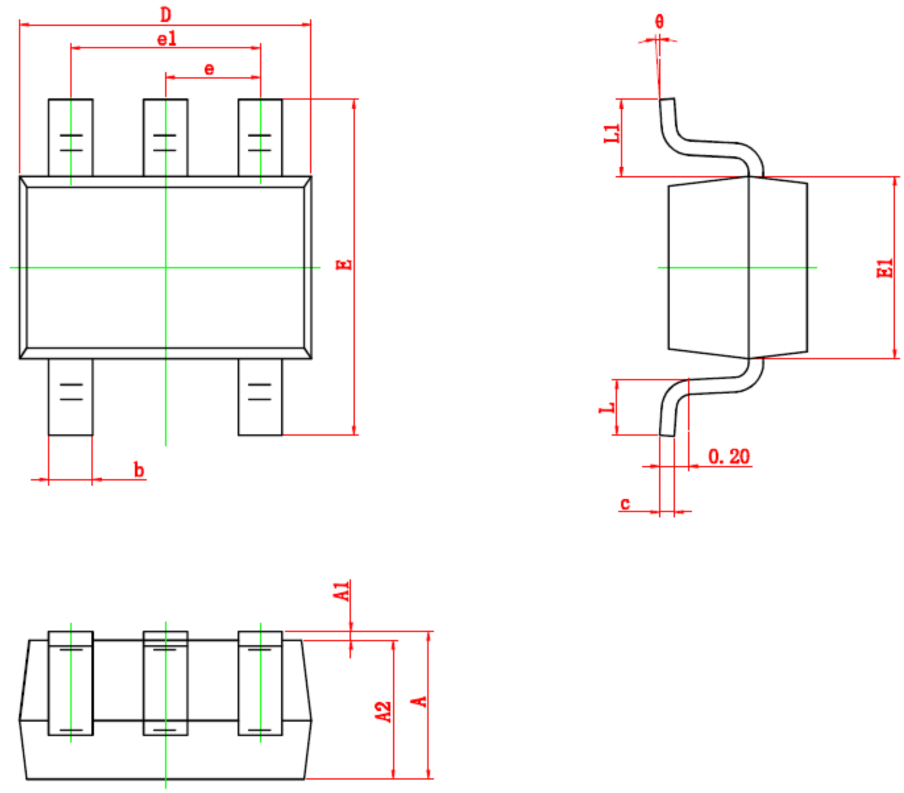



Figure 4.5 Suggested Connection to a Sampling Analog to Digital Converter Input Stage

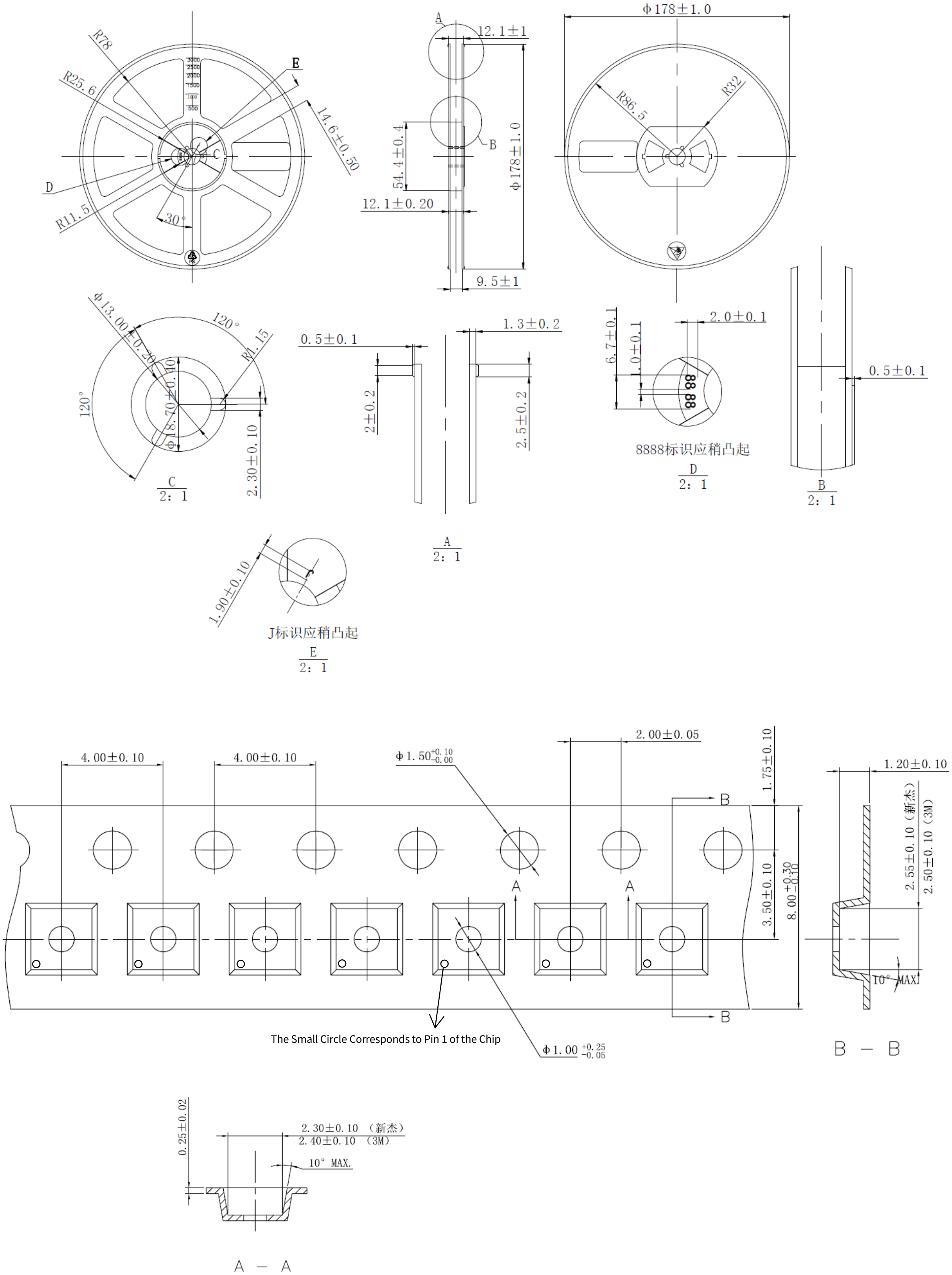
# 5 Package Information

### 5.1 SC70(5) Package




| Symbol | Dimensions In Millimeters | | Dimensions In Inches | |
|---|---|---|---|---|
| | Min. | Max. | Min. | Max. |
| A | 0.900 | 1.100 | 0.035 | 0.043 |
| A1 | 0.000 | 0.100 | 0.000 | 0.004 |
| A2 | 0.900 | 1.000 | 0.035 | 0.039 |
| b | 0.150 | 0.350 | 0.006 | 0.014 |
| c | 0.110 | 0.175 | 0.004 | 0.007 |
| D | 2.000 | 2.200 | 0.079 | 0.087 |
| E | 2.150 | 2.450 | 0.085 | 0.096 |
| E1 | 1.150 | 1.350 | 0.045 | 0.053 |
| e | 0.650 TYP. | | 0.026 TYP. | |
| e1 | 1.200 | 1.400 | 0.047 | 0.055 |
| L | 0.260 | 0.460 | 0.010 | 0.018 |
| L1 | 0.525 REF. | | 0.021 REF. | |
| θ | 0° | 8° | 0° | 8° |

## 5.2 SC70(5) Tape and Reel




Tape and Reel Information of SC70(5)

# 6 Order Information

| *Type* | *Unit* | *MSL* | *Marking* | *Description* |
|---|---|---|---|---|
| NST86-DSCR | 3000ea/Reel | 1 | 86XX | SC70(5) package, Reel |
| NOTE: All packages are RoHS-compliant with peak reflow temperatures of 260°C according to the JEDEC industry standard classifications and peak solder temperatures(Reflow profile:J-STD-020E). | | | | |

# 7 Revision History

| Revision | Description | Date |
|---|---|---|
| 1.0 | Initial Version | 2020/11/28 |
| 1.1 | Change Pinout information; Optimize text presentation | 2022/03/01 |
| 1.2 | Update Functional Description;<br>Update Pin Configuration Diagram;<br>Update Load Regulation of Electrical Characteristics;<br>Change Application Information;<br>Optimize Text Presentation;<br>Tape and reel show 1 pin; | 2022/07/28 |

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