LM19
2.4V, 10μA, TO-92 Temperature Sensor

General Description
The LM19 is a precision analog output CMOS integrated-circuit temperature sensor that operates over a −55°C to +130°C temperature range. The power supply operating range is +2.4 V to +5.5 V. The transfer function of LM19 is predominately linear, yet has a slight predictable parabolic curvature. The accuracy of the LM19 when specified to a parabolic transfer function is ±2.5°C at an ambient temperature of +30°C. The temperature error increases linearly and reaches a maximum of ±3.8°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 remains at +130°C.

The LM19's quiescent current is less than 10 μA. Therefore, self-heating is less than 0.02°C in still air. Shutdown capability for the LM19 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.

Applications
- Cellular Phones
- Computers
- Power Supply Modules
- Battery Management

Features
- Rated for full −55°C to +130°C range
- Available in a TO-92 package
- Predictable curvature error
- Suitable for remote applications
- UL Recognized Component

Key Specifications
- Accuracy at +30°C ±2.5 °C (max)
- Accuracy at +130°C & −55°C ±3.5 to ±3.8 °C (max)
- Power Supply Voltage Range 2.4V to 5.5V
- Current Drain 10 μA (max)
- Nonlinearity ±0.4 % (typ)
- Output Impedance 160 Ω (max)
- Load Regulation 0 μA < I_L < +16 μA −2.5 mV (max)

Typical Application

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

or

\[ T = -1481.96 + \sqrt{2.1962 \times 10^6 + \frac{(1.8639 - V_O)}{3.68 \times 10^5}} \]

where:
- T is temperature, and \( V_O \) is the measured output voltage of the LM19.

FIGURE 1. Full-Range Celsius (Centigrade) Temperature Sensor (−55°C to +130°C)
Operating from a Single Li-Ion Battery Cell
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

Connection Diagram

### Ordering Information

<table>
<thead>
<tr>
<th>Order Number</th>
<th>Temperature Accuracy</th>
<th>Temperature Range</th>
<th>NS Package Number</th>
<th>Device Marking</th>
<th>Transport Media</th>
</tr>
</thead>
<tbody>
<tr>
<td>LM19CIIZ</td>
<td>±3.8°C</td>
<td>−55°C to +130°C</td>
<td>Z03A</td>
<td>LM19CIIZ</td>
<td>Bulk</td>
</tr>
</tbody>
</table>

See NS Package Number Z03A
### Absolute Maximum Ratings

- **Supply Voltage**: +6.5V to −0.2V
- **Output Voltage**: (V+ + 0.6 V) to −0.6 V
- **Output Current**: 10 mA
- **Input Current at any pin (Note 2)**: 5 mA
- **Storage Temperature**: −65°C to +150°C
- **Maximum Junction Temperature (TJMAX)**: +150°C
- **ESD Susceptibility (Note 3)**:
  - Human Body Model: 2500 V
  - Machine Model: 250 V
- **Lead Temperature**:
  - TO-92 Package: Soldering (3 seconds dwell) +240°C

### Operating Ratings

- **Specified Temperature Range**:
  - T_MIN ≤ T_A ≤ T_MAX
  - 2.4 V ≤ V+ ≤ 2.7 V
  - −30°C ≤ T_A ≤ +130°C
  - 2.7 V ≤ V+ ≤ 5.5 V
  - −55°C ≤ T_A ≤ +130°C
- **Supply Voltage Range (V+)**: +2.4 V to +5.5 V
- **Thermal Resistance, θ_JA (Note 4)**: 150°C/W

### Electrical Characteristics

Unless otherwise noted, these specifications apply for V+ = +2.7 V DC. **Boldface limits apply for T_A = T_J = T_MIN to T_MAX**; all other limits T_A = 25°C; Unless otherwise noted.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conditions</th>
<th>Typical (Note 5)</th>
<th>LM19C Limits (Note 6)</th>
<th>Units (Limit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature to Voltage Error</td>
<td>V_O = (−3.88×10^-6×T²) + (−1.15×10^-2×T) + 1.8639V (Note 7)</td>
<td>T_A = +25°C to +30°C</td>
<td>±2.5 °C (max)</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>T_A = +130°C</td>
<td>±3.5 °C (max)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>T_A = +125°C</td>
<td>±3.5 °C (max)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>T_A = +100°C</td>
<td>±3.2 °C (max)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>T_A = +85°C</td>
<td>±3.1 °C (max)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>T_A = +80°C</td>
<td>±3.0 °C (max)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>T_A = 0°C</td>
<td>±2.9 °C (max)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>T_A = −30°C</td>
<td>±3.3 °C (max)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>T_A = −40°C</td>
<td>±3.5 °C (max)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>T_A = −55°C</td>
<td>±3.8 °C (max)</td>
<td></td>
</tr>
<tr>
<td>Output Voltage at 0°C</td>
<td>+1.8639</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Variance from Curve</td>
<td>±1.0</td>
<td></td>
<td></td>
<td>°C</td>
</tr>
<tr>
<td>Non-Linearity (Note 8)</td>
<td>−20°C ≤ T_A ≤ +80°C</td>
<td>±0.4</td>
<td></td>
<td>%</td>
</tr>
<tr>
<td>Sensor Gain (Temperature Sensitivity or Average Slope) to equation: V_O=−11.77 mV/°C×T+1.860V</td>
<td>−30°C ≤ T_A ≤ +100°C</td>
<td>−11.77</td>
<td>−11.0 mV/°C (min)</td>
<td>mV/°C (max)</td>
</tr>
<tr>
<td>Output Impedance</td>
<td>0 μA ≤ I_L ≤ +16 μA (Notes 10, 11)</td>
<td>160 Ω (max)</td>
<td></td>
<td>Ω (max)</td>
</tr>
<tr>
<td>Load Regulation (Note 9)</td>
<td>0 μA ≤ I_L ≤ +16 μA (Notes 10, 11)</td>
<td>−2.5 mV (max)</td>
<td></td>
<td>mV (max)</td>
</tr>
<tr>
<td>Line Regulation</td>
<td>+2.4 V ≤ V+ ≤ +5.0V</td>
<td>+3.7 mV/V (max)</td>
<td></td>
<td>mV/V (max)</td>
</tr>
<tr>
<td>Quescent Current</td>
<td>+2.4 V ≤ V+ ≤ +5.0V</td>
<td>4.5 μA (max)</td>
<td></td>
<td>μA (max)</td>
</tr>
<tr>
<td>Change of Quescent Current</td>
<td>+2.4 V ≤ V+ ≤ +5.5V</td>
<td>+0.7 μA</td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>Temperature Coefficient of Quescent Current</td>
<td>−11 nA/°C</td>
<td></td>
<td></td>
<td>nA/°C</td>
</tr>
<tr>
<td>Shutdown Current</td>
<td>V+ ≤ +0.8 V</td>
<td>0.02 μA</td>
<td></td>
<td>μA</td>
</tr>
</tbody>
</table>
1.0 LM19 Transfer Function

The LM19’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

\[ V_O = -11.69 \text{ mV/°C} \times T + 1.8663 \text{ V} \]

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

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

solving for T:

\[ T = \frac{-1481.96 + \sqrt{2.1962 \times 10^6 + \frac{(1.8639 - V_O)}{3.88 \times 10^{-6}}}}{2} \]

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 LM19. The slope of the linear transfer function can be calculated using the following equation:

\[ m = -7.76 \times 10^{-6} \times T - 0.0115, \]

where T is the middle of the temperature range of interest and m is in V/°C. For example, for the temperature range of \( T_{\text{min}} = -30 \) to \( T_{\text{max}} = +100 \)°C:

\[ T = 35 \text{°C} \]

\[ m = -11.77 \text{ mV/°C} \]

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

\[ b = (V_{OP}(T_{\text{max}}) + V_{OP}(T) + m \times (T_{\text{max}}+T))/2 \]

where:

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

Using this procedure the best fit linear transfer function for many popular temperature ranges was calculated in Figure 2. As shown in Figure 2 the error that is introduced by the linear transfer function increases with wider temperature ranges.
2.0 Mounting

The LM19 can be applied easily in the same way as other integrated-circuit temperature sensors. It can be glued or cemented to a surface. The temperature that the LM19 is sensing will be within about ±0.02 °C of the surface temperature to which the LM19’s leads are attached.

This 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 LM19 die is directly attached to the GND pin. The temperatures of the lands and traces to the other leads of the LM19 will also affect the temperature that is being sensed.

Alternatively, the LM19 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 LM19 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 Humiseal and epoxy paints or dips are often used to ensure that moisture cannot corrode the LM19 or its connections.

The thermal resistance junction to ambient (θ_JA) is the parameter used to calculate the rise of a device junction temperature due to its power dissipation. For the LM19 the equation used to calculate the rise in the die temperature is as follows:

\[ T_J = T_A + \theta_{JA} [(V^+ I_Q) + (V^- - V_O) I_L] \]

where \( I_Q \) is the quiescent current and \( I_L \) is the load current on the output. Since the LM19’s junction temperature is the actual temperature being measured care should be taken to minimize the load current that the LM19 is required to drive.

The tables shown in Figure 3 summarize the rise in die temperature of the LM19 without any loading, and the thermal resistance for different conditions.

3.0 Capacitive Loads

The LM19 handles capacitive loading well. Without any precautions, the LM19 can drive any capacitive load less than 300 pF as shown in Figure 4. Over the specified temperature range the LM19 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 5. 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 5. 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. Since the thermal time constant of the LM19 is much slower, the overall response time of the LM19 will not be significantly affected.
4.0 Applications Circuits

FIGURE 5. LM19 with Filter for Noisy Environment and Capacitive Loading greater than 300 pF. Either placement of resistor as shown above is just as effective.

<table>
<thead>
<tr>
<th>R (Ω)</th>
<th>C (µF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>1</td>
</tr>
<tr>
<td>470</td>
<td>0.1</td>
</tr>
<tr>
<td>680</td>
<td>0.01</td>
</tr>
<tr>
<td>1 k</td>
<td>0.001</td>
</tr>
</tbody>
</table>

FIGURE 6. Centigrade Thermostat

\[
V_{T1} = \frac{(4.1)R2}{R1 + R2||R3}
\]

\[
V_{T2} = \frac{(4.1)R2}{R2 + R1||R3}
\]

FIGURE 7. Conserving Power Dissipation with Shutdown
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 LM19 and many op amps. 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. Since not all ADCs 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 please refer to devices such as the LM74.

**FIGURE 8. Suggested Connection to a Sampling Analog to Digital Converter Input Stage**
Physical Dimensions inches (millimeters) unless otherwise noted

3-Lead TO-92 Plastic Package (Z)
Order Number LM19CIZ
NS Package Number Z03A

DIMENSIONS ARE IN MILLIMETERS
Notes

THE CONTENTS OF THIS DOCUMENT ARE PROVIDED IN CONNECTION WITH NATIONAL SEMICONDUCTOR CORPORATION ("NATIONAL") PRODUCTS. NATIONAL MAKES NO REPRESENTATIONS OR WARRANTIES WITH RESPECT TO THE ACCURACY OR COMPLETENESS OF THE CONTENTS OF THIS PUBLICATION AND RESERVES THE RIGHT TO MAKE CHANGES TO SPECIFICATIONS AND PRODUCT DESCRIPTIONS AT ANY TIME WITHOUT NOTICE. NO LICENSE, WHETHER EXPRESS, IMPLIED, ARISING BY ESTOPPEL OR OTHERWISE, TO ANY INTELLECTUAL PROPERTY RIGHTS IS GRANTED BY THIS DOCUMENT.

TESTING AND OTHER QUALITY CONTROLS ARE USED TO THE EXTENT NATIONAL DEEMS NECESSARY TO SUPPORT NATIONAL'S PRODUCT WARRANTY. EXCEPT WHERE MANDATED BY GOVERNMENT REQUIREMENTS, TESTING OF ALL PARAMETERS OF EACH PRODUCT IS NOT NECESSARILY PERFORMED. NATIONAL ASSUMES NO LIABILITY FOR APPLICATIONS ASSISTANCE OR BUYER PRODUCT DESIGN. BUYERS ARE RESPONSIBLE FOR THEIR PRODUCTS AND APPLICATIONS USING NATIONAL COMPONENTS. PRIOR TO USING OR DISTRIBUTING ANY PRODUCTS THAT INCLUDE NATIONAL COMPONENTS, BUYERS SHOULD PROVIDE ADEQUATE DESIGN, TESTING AND OPERATING SAFEGUARDS. EXCEPT AS PROVIDED IN NATIONAL'S TERMS AND CONDITIONS OF SALE FOR SUCH PRODUCTS, NATIONAL ASSUMES NO LIABILITY WHATSOEVER, AND NATIONAL DISCLAIMS ANY EXPRESS OR IMPLIED WARRANTY RELATING TO THE SALE AND/OR USE OF NATIONAL PRODUCTS INCLUDING LIABILITY OR WARRANTIES RELATING TO FITNESS FOR A PARTICULAR PURPOSE, MERCHANTABILITY, OR INFRINGEMENT OF ANY PATENT, COPYRIGHT OR OTHER INTELLECTUAL PROPERTY RIGHT.

LIFE SUPPORT POLICY

NATIONAL'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS PRIOR WRITTEN APPROVAL OF THE CHIEF EXECUTIVE OFFICER AND GENERAL COUNSEL OF NATIONAL SEMICONDUCTOR CORPORATION. As used herein:

Life support devices or systems are devices which (a) are intended for surgical implant into the body, or (b) support or sustain life and whose failure to perform when properly used in accordance with instructions for use provided in the labeling can be reasonably expected to result in a significant injury to the user. A critical component is any component in a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system or to affect its safety or effectiveness.

National Semiconductor and the National Semiconductor logo are registered trademarks of National Semiconductor Corporation. All other brand or product names may be trademarks or registered trademarks of their respective holders.

Copyright© 2007 National Semiconductor Corporation

For the most current product information visit us at www.national.com

www.national.com