Temperature Sensor Design Guide

Precision Temperature Measurement with Silicon IC Temperature Sensors, Thermocouples, RTD Circuits and Thermistors

A complete listing of products offered by Microchip Technology Inc. and their corresponding data sheets can be found at www.microchip.com.

Design ideas in this guide use the following devices:

Voltage Output Temperature Sensors:
- TC1046
- TC1047A

Logic Output Temperature Sensors:
- TC620
- TC621
- TC622
- TC623
- TC624
- TC6501
- TC6502
- TC6503
- TC6504

Comparators and Operational Amplifiers:
- TC913A
- TC7650
- TC7652
- MCP6541
- MCP6542
- MCP6543
- MCP6544

Serial Output Temperature Sensors:
- TC72
- TC74
- TC77
- TCN75
Temperature sensors are useful in thermometer circuits, temperature compensation applications, as well as a wide array of general purpose applications.

Microchip Technology Inc. offers a broad portfolio of thermal management products, including Logic Output, Voltage Output and Serial Output Temperature Sensors.

Common Methods of Interfacing a Sensor

Silicon Output Temperature Sensors

Logic Output Temperature Sensors:
Logic output temperature sensor families offer excellent temperature accuracy (±1°C, typical), with a very low operating current of less than 600 µA. These devices can replace mechanical switches in a variety of sensing and control applications.

Voltage Output Temperature Sensors:
Voltage output temperature sensors develop an output voltage proportional to temperature, with a nominal temperature coefficient of 6.25 mV/°C and 10 mV/°C, respectively. These temperature-to-voltage converters can sense a −40°C to +125°C temperature range and feature an offset voltage that allows reading negative temperatures without requiring a negative supply voltage. The extremely low operating current minimizes self-heating and maximizes battery life.

Serial Output Temperature Sensors:
Serial (digital) output temperature sensors offer excellent temperature accuracy (±0.5°C, typical) with a very low operating current of less than 250 µA. Communication with these devices is accomplished via an industry standard SMBus, I²C™ or SPI™ compatible interface protocol. These devices feature very fast temperature conversion times, with temperature resolution for the entire family ranging from 0.0625°C to 1°C.

Thermocouples

While thermocouples are usually selected because of their wide temperature range, ruggedness and price, they are highly non-linear and require significant linearization algorithms. In addition, the voltage output of this temperature sensing element is relatively low when compared to devices that can convert voltage signals to a digital representation. Consequently, analog gain stages are required in the circuit.

Resistive Temperature Detectors (RTDs)

RTDs are able to sense temperatures with extreme repeatability and low drift error (−200°C to +850°C). For precision, these sensors also require a look-up table in the controller due to non-linearities.

Thermistors

Thermistors (−100°C to +150°C) are normally used for overtemperature shutdown purposes. These sensors are non-linear and require a look-up table in the controller.

Temperature Measurement Applications:

- Computing:
  - CPU overtemperature protection
  - Fan Control
- Cellular/PCS:
  - Power amplifier temperature compensation
  - Thermal sensing of display for contrast control
- Power Supply Embedded Systems:
  - Overtemperature shutdown
  - Battery management

Temperature Sensors Design Guide
LOGIC OUTPUT TEMPERATURE SENSORS

Logic output sensors typically function as a thermostat, notifying the system that a minimum or maximum temperature limit has been reached. Sometimes referred to as temperature switches, these devices can be used to turn-on either a fan or warning light when high temperature conditions are detected. Since the output is typically not latched, the switch will turn off when the temperature falls below the temperature set point. Note that it is necessary to have hysteresis so the switch does not “chatter” when crossing the temperature set point.

Logic Output Temperature Sensors Used as Temperature Switches

Most logic output temperature sensors are available in either a Hot (for temperature-increasing applications) or Cold (for temperature-decreasing applications) option. The hot and cold options ensure that the hysteresis is in the appropriate position, either below or above the temperature set point.

Hot and Cold Options

Logic Output Temperature Sensor Key Features:
- Logic-Level Output
- Notifies System When Temperature is Above (or Below) a Preset Value
- Factory and User-programmable Temperature Settings
- Available in a Variety of Output Configurations

Logic Output Temperature Sensor Applications:
- Fan Controllers
- Power Supplies
- Motor Drives
- RF Power Amplifiers

TC6501/2/3/4 Key Features:
- Factory-programmed Temperature Set Points
- No External Components Required
- Small SOT-23 Packages

TC620/1 Key Features:
- Dual Trip Point Temperature Sensor
- Wide Voltage Supply Range: +4.5V to +18V
- User-programmable Trip Point and Hysteresis

TC623 Key Features:
- Dual Trip Point Temperature Sensor
- User-programmable Trip Point and Hysteresis

TC622/4 Key Features:
- Low-Cost Single Trip Point Temperature Sensor
- Temperature Set Point Easily Programs with a Single External Resistor
- TO-220 Package for Direct Mounting to Heatsink
The TC1046 and TC1047A are analog (or voltage output) temperature-sensing products in space-saving SOT packages. These devices develop an output voltage proportional to temperature, with a nominal temperature coefficient of 6.25 mV/°C and 10 mV/°C, respectively. Both temperature-to-voltage converters can sense a −40°C to +125°C temperature range and feature an offset voltage that allows the reading of negative temperatures without the need of a negative supply voltage. The extremely low operating current minimizes self-heating and maximizes battery life.

Using the TC1046 to Create a Simple Temperature Measurement System

The TC1046 and TC1047A can be combined with operational amplifiers (op amps) and a PICmicro® microcontroller unit (MCU) to build a simple temperature measurement system. The contrast of a LCD display varies as a function of temperature due to the transmission changes with the LCD material.
The circuit shown below can be used to measure the LCD panel's temperature at multiple locations. The operational amplifier functions as an averaging circuit to provide a composite voltage output that can be used to adjust the contrast.

**LCD Contrast Control**

Voltage Output Temperature Sensor Key Features:
- Easy System Integration
- Reduces PCB Space
- Low Current Consumption
- Minimizes Design Time

Voltage Output Temperature Sensor Typical Applications:
- Cellular Phones
- Temperature Measurement/Instrumentation
- Consumer Electronics

**TC1046 Key Features:**
- Wide Temperature Measurement Range: –40°C to +125°C
- High Temperature Conversion Accuracy: ±0.5°C
- Linear Temperature Slope: 6.25 mV/°C

**TC1047A Key Features:**
- Wide Temperature Measurement Range: –40°C to +125°C
- High Temperature Conversion Accuracy: ±0.5°C
- Linear Temperature Slope: 10 mV/°C

**MCP1525 (Voltage Reference) Key Features:**
- 2.5V Output Voltage
- Initial Accuracy of ±1% max.
- Output Current Drive: ±2 mA

**MCP601 (Op Amp) Key Features:**
- Single-Supply: 2.7V to 5.5V
- Rail-to-Rail Output
- Unity-Gain Stable

**PIC16F872A (MCU) Key Features:**
- Only 35 Single-Word Instructions to Learn
- Operating speed: DC – 20 MHz Clock Input
  DC – 200 ns Instruction Cycle
- 64 Bytes of EEPROM Data Memory (RAM)
- 128 Bytes of Data Memory (RAM)
Serial (digital) output temperature sensors can be used in many different applications, including the monitoring of multiple temperatures on the same Printed Circuit Board (PCB). High accuracy, low operating current, small size and ease-of-use make these devices ideal for implementing sophisticated thermal management schemes in a variety of systems.

The TC77 Precision Silicon Serial Output Temperature Sensor

The TC77 is a serial output temperature sensor that provides a 13-bit measurement to a microcontroller. The SPI™ bus uses the SCK, SI/O and CS pins to transmit and receive data. Temperature is measured by monitoring the voltage of a diode with a 13-bit Analog-to-Digital Converter (ADC). This temperature data is then stored in the temperature register. If a temperature register read operation occurs while an ADC conversion is in progress, the initially completed conversion will be output. The configuration register is used to select either the Continuous Temperature Conversion or Shutdown operating modes. Shutdown mode disables the temperature-conversion circuitry to minimize power consumption. However, the serial I/O communication port remains active.

The TC77 Precision Silicon Serial Output Temperature Sensor Provides 13 Bits of Temperature Data
The TCN75 serial output temperature sensor is used to notify the host controller when the ambient temperature exceeds a user-specified set point. Communication with the TCN75 is accomplished via a two-wire serial bus. The microcontroller can monitor the temperature of each sensor by either reading the temperature data register or functioning as a stand-alone thermostat. The temperature threshold trip point is programmed by writing to the set point register. The INT pin is an open-drain output that can be connected to the microcontroller's interrupt pin, facilitating monitoring of up to eight sensors. Three address pins are used to uniquely identify each sensor.

A Multi-zone Temperature Measurement System Using the Two-wire Serial Communication Port of the TCN75

**Serial Output Temperature Sensor Key Features:**
- Temperature-to-Digital Conversion
- Industry Standard Serial I/O Interface
- Low Power Consumption
- Multi-zone Temperature Monitoring

**Serial Output Temperature Sensor Applications:**
- Personal Computers
- Set-top Boxes
- Cellular Phones
- General Purpose Temperature Monitoring

**TC72 Key Features:**
- 10-Bit Temperature-to-Digital Converter
- Power-saving One-shot Temperature Measurement
- Low Power Consumption

**TC74 Key Features:**
- Simple 2-wire Serial Interface
- Digital Temperature-sensing in SOT-23-5 or TO-22-5 Packages
- Low Power Consumption

**TC77 Key Features:**
- 13-Bit Temperature-to-Digital Converter
- Low Power Consumption
- ±1°C (max.) Accuracy From +25°C to +65°C
- SPI™ Compatible Communications Interface

**TCN75 Key Features:**
- Industry Standard SMBus/I^2^C™ Interface
- Programmable Trip Point and Hysteresis
- Thermal Event Alarm Output Functions as Interrupt or Comparator/Thermostat Output
Precision Temperature Measurement with Silicon IC Sensors, Thermocouples, RTDs and Thermistors

**THERMOCOUPLES**

The thermocouple can quantify temperature as it relates to a reference temperature. While this temperature is usually sensed using a RTD, Thermistor or Integrated Silicon Sensor, the thermal mass of the thermocouple is smaller, making its response time faster. The wide temperature ranges of the thermocouple make it appropriate for many hostile sensing environments.

**Thermocouple Amplifier Circuit**

This circuit can be used for remote thermocouple sensing applications. The thermocouple is connected to the circuitry via a shielded cable and EMI filters. The thermocouple is tied to a positive and negative supply via large resistors so that the circuit can detect a failed open-circuit thermocouple.

The TC913A auto-zeroed op amp is selected because of its low offset voltage of 15 µV (max.) and high Common Mode Rejection Ratio (CMRR) of 116 dB (typ.). Auto-zero and chopper amplifiers are good thermocouple amplifiers due to their good $V_{OS}$ and CMRR specifications.

The cold junction compensation circuit is implemented with the TC1047A silicon IC temperature sensor located on the PCB.

**Thermocouple Key Features**

- Self-powered
- 0 to 1500°C
- Remote Sensing
- Robust Sensor

**Thermocouple Applications**

- Stoves
- Engines
- Thermopiles

**Silicon Sensors for Cold Junction Compensation**

- TC1047A Analog Temperature Sensor
- TC77 13-Bit Serial Output Temperature Sensor

**RTDS**

RTDs serve as the standard for precision temperature measurements due to their excellent repeatability and stability characteristics. RTDs provide the designer with an absolute result that is fairly linear over temperature. The RTD’s linear relationship between resistance and temperature simplifies the implementation of signal-conditioning circuitry.

Circuit A below is easy to modify for a desired temperature-to-frequency range. It requires either precision, low-drift components or a calibration step to achieve high accuracy. Circuit B utilizes pull-up and pull-down resistors to excite the RTD, employing the TC913A op amp to amplify the small voltage changes that correspond to temperature.

**RTD Temperature Measurement Circuits**

**RTD Key Features**

- Extremely Accurate with Excellent Linearity
- Variety of Packages
- Wire-wound or Thin-film

**RTD Applications**

- Industrial Instrumentation
- Hot Wire Anemometers
- Laboratory-quality Measurements

**Recommended Products**

- TC913A/B – Auto-zero Op Amps
- TC7650/2 – Chopper-stabilized Op Amps
- MCP616/7/8/9 – Micropower Bi-CMOS Op Amps
- MCP6001/2/4 – 1 MHz Bandwidth Low-power Op Amps
- MCP6041/2/3/4 – 600 nA, Rail-to-Rail Input/Output Op Amps
- MCP6541/2/3/4 – Push-Pull Output Sub-Microamp Comparators
- MCP6S21/2/6/7 – Single-ended, Rail-to-Rail Input/Output Low-gain Programmable Gain Amplifiers (PGAs)
The main advantages of thermistors are that they are inexpensive and available in a wide variety of packages. Thermistors are built with semiconductor materials and can have either positive (PTC) or a negative (NTC) temperature coefficient. However, the NTC is typically used for temperature sensing. The main drawback of thermistors is that the change in resistance with temperature is very non-linear at temperatures below 0°C and greater than 70°C.

A Conventional Fixed Gain Thermistor Amplifier

The advantage of the PGA circuit (below) is illustrated by comparing the $V_{\text{OUT}}$ slope plots of the conventional circuit with the PGA circuit. The $V_{\text{OUT}}$ slope for the PGA circuit has a minimum value of 30 mV for temperatures greater than 35°C, which means that only a 9-bit ADC is required. In contrast, a voltage divider with a gain of 1 will require an 11-bit, or higher, ADC to provide an equivalent temperature resolution. The resolution of a thermistor circuit is important in applications such as overtemperature shutdown circuits.

Advantages of a PGA Circuit Interfaced with a Thermistor

Thermistor Key Features
- Inexpensive
- Two-wire Measurement
- Variety of Packages

Thermistor Applications
- Battery Chargers
- Power Supplies
- Cold Junction Compensation
## Selected Temperature Specifications

### Logic Output Temperature Sensor Products

<table>
<thead>
<tr>
<th>Device</th>
<th>Accuracy @ 25°C (Typ./Max)</th>
<th>Temperature Range (°C)</th>
<th>Temperature Set Points</th>
<th>$V_{DD}$ Min. (V)</th>
<th>$V_{DD}$ Max. (V)</th>
<th>$I_{Q}$ Max. (µA)</th>
<th>Packages</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCP601</td>
<td>0.5/4</td>
<td>–40 to +125°C</td>
<td>User-selectable, set by external resistor</td>
<td>4.5</td>
<td>18</td>
<td>400</td>
<td>SOP8, SOIC-8</td>
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<tr>
<td>MCP602</td>
<td>0.5/4</td>
<td>–40 to +125°C</td>
<td>User-selectable, set by external resistor</td>
<td>4.5</td>
<td>18</td>
<td>600</td>
<td>SOP8, SOIC-8, SOIC-8, SOT220-5</td>
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<tr>
<td>MCP603</td>
<td>0.5/4</td>
<td>–40 to +125°C</td>
<td>User-selectable, set by external resistor</td>
<td>2.7</td>
<td>4.5</td>
<td>300</td>
<td>SOP8, SOIC-8</td>
</tr>
<tr>
<td>MCP604</td>
<td>0.5/4</td>
<td>–40 to +125°C</td>
<td>Factory programmed thresholds</td>
<td>2.7</td>
<td>5.5</td>
<td>40</td>
<td>SOT23-5</td>
</tr>
</tbody>
</table>

### Analog (Voltage Output) Temperature Sensor Products

<table>
<thead>
<tr>
<th>Device</th>
<th>Accuracy @ 25°C (Typ./Max)</th>
<th>Temperature Range (°C)</th>
<th>$V_{DD}$ Min. (V)</th>
<th>$V_{DD}$ Max. (V)</th>
<th>$I_{Q}$ Max. (µA)</th>
<th>Offset Voltage (Output @ 0°C)(mV)</th>
<th>Packages</th>
</tr>
</thead>
<tbody>
<tr>
<td>TC1046</td>
<td>0.5/2.0</td>
<td>–40°C to +125°C</td>
<td>2.7</td>
<td>4.4</td>
<td>60</td>
<td>6.25</td>
<td>SOT23-3</td>
</tr>
<tr>
<td>TC1047</td>
<td>0.5/2.0</td>
<td>–40°C to +125°C</td>
<td>2.7</td>
<td>4.4</td>
<td>60</td>
<td>10</td>
<td>SOT23-3</td>
</tr>
<tr>
<td>TC1047A</td>
<td>0.5/2.0</td>
<td>–40°C to +125°C</td>
<td>2.5</td>
<td>5.5</td>
<td>60</td>
<td>10</td>
<td>SOT23-3</td>
</tr>
</tbody>
</table>

### Serial Output Temperature Sensor Products

<table>
<thead>
<tr>
<th>Device</th>
<th>Accuracy @ 25°C (Typ./Max)</th>
<th>Temperature Range (°C)</th>
<th>$V_{DD}$ Min. (V)</th>
<th>$V_{DD}$ Max. (V)</th>
<th>$I_{Q}$ Max. (µA)</th>
<th>Packages</th>
</tr>
</thead>
<tbody>
<tr>
<td>TC74</td>
<td>0.5/2</td>
<td>–40°C to +125°C</td>
<td>2.7</td>
<td>5.5</td>
<td>350</td>
<td>SOT23-5, TO-206</td>
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<tr>
<td>TC75</td>
<td>0.5/2</td>
<td>–40°C to +125°C</td>
<td>2.7</td>
<td>5.5</td>
<td>100</td>
<td>SOIC-8, MSOP-8</td>
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<tr>
<td>TC76</td>
<td>0.5/2</td>
<td>–40°C to +125°C</td>
<td>2.65</td>
<td>5.5</td>
<td>400</td>
<td>MSOP-8, DFN-8</td>
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<tr>
<td>TC77</td>
<td>0.5/1</td>
<td>–40°C to +125°C</td>
<td>2.7</td>
<td>5.5</td>
<td>400</td>
<td>SOT23-5, SOIC-8</td>
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### Operational Amplifiers

<table>
<thead>
<tr>
<th>Device</th>
<th># per Package</th>
<th>GBWP (kHz)</th>
<th>$I_{Q}$ (Typ./Max)(µA)</th>
<th>$V_{DD}$ Max. (mV)</th>
<th>Temperature Range (°C)</th>
<th>Operating Voltage Range (V)</th>
<th>Packages</th>
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<tbody>
<tr>
<td>MCP913A</td>
<td>2</td>
<td>500</td>
<td>0.15</td>
<td>0 to 70</td>
<td>6.5 to 16</td>
<td>PDP-8</td>
<td></td>
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<tr>
<td>TC6502</td>
<td>1</td>
<td>2000</td>
<td>0.05</td>
<td>0 to 70</td>
<td>4.5 to 16</td>
<td>PDP-8, PDP-14</td>
<td></td>
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<tr>
<td>MCPP011</td>
<td>1</td>
<td>2000/3500</td>
<td>0.05</td>
<td>0 to 70</td>
<td>5 to 16</td>
<td>PDP-8</td>
<td></td>
</tr>
<tr>
<td>MCPP018</td>
<td>1</td>
<td>250</td>
<td>0.2</td>
<td>–40 to –125</td>
<td>2.7 to 5.5</td>
<td>PDP-8, SOIC-8, TSSOP-8, SOT-23-5</td>
<td></td>
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<tr>
<td>MCPP16</td>
<td>2</td>
<td>190</td>
<td>0.15</td>
<td>–40 to –125</td>
<td>2.3 to 5.5</td>
<td>PDP-8, SOIC-8, MSOP-8</td>
<td></td>
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<tr>
<td>MCPP17</td>
<td>2</td>
<td>190</td>
<td>0.15</td>
<td>–40 to –125</td>
<td>2.3 to 5.5</td>
<td>PDP-8, SOIC-8, MSOP-8</td>
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<td>MCPP18</td>
<td>2</td>
<td>190</td>
<td>0.15</td>
<td>–40 to –125</td>
<td>2.3 to 5.5</td>
<td>PDP-8, SOIC-8, MSOP-8</td>
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<tr>
<td>MCPP19</td>
<td>2</td>
<td>190</td>
<td>0.15</td>
<td>–40 to –125</td>
<td>2.3 to 5.5</td>
<td>PDP-14, SOIC-14, TSSOP-14</td>
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<tr>
<td>MCP1001</td>
<td>1</td>
<td>1000</td>
<td>7</td>
<td>–40 to –125</td>
<td>1.8 to 5.5</td>
<td>SOT-23-5, SC-70-5</td>
<td></td>
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<tr>
<td>MCP1002</td>
<td>2</td>
<td>1000</td>
<td>7</td>
<td>–40 to –125</td>
<td>1.8 to 5.5</td>
<td>PDP-8, SOIC-8, MSOP-8</td>
<td></td>
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<tr>
<td>MCP1004</td>
<td>4</td>
<td>1000</td>
<td>7</td>
<td>–40 to –125</td>
<td>1.8 to 5.5</td>
<td>PDP-14, SOIC-14, TSSOP-14</td>
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<tr>
<td>MCP1041</td>
<td>1</td>
<td>0.8/1</td>
<td>3</td>
<td>–40 to –85</td>
<td>1.4 to 5.5</td>
<td>PDP-8, SOIC-8, MSOP-8</td>
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<tr>
<td>MCP1042</td>
<td>2</td>
<td>0.8/1</td>
<td>3</td>
<td>–40 to –85</td>
<td>1.4 to 5.5</td>
<td>PDP-8, SOIC-8, MSOP-8</td>
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<tr>
<td>MCP1043</td>
<td>1</td>
<td>0.8/1</td>
<td>3</td>
<td>–40 to –85</td>
<td>1.4 to 5.5</td>
<td>PDP-8, SOIC-8, MSOP-8</td>
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<tr>
<td>MCP1044</td>
<td>4</td>
<td>0.8/1</td>
<td>3</td>
<td>–40 to –85</td>
<td>1.4 to 5.5</td>
<td>PDP-14, SOIC-14, TSSOP-14</td>
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</table>

### Temperature Reference

<table>
<thead>
<tr>
<th>Device</th>
<th>$V_{DD}$ Range</th>
<th>Output Voltage (V)</th>
<th>Max Load Current (mA)</th>
<th>Initial Accuracy (%)</th>
<th>Temperature Coefficient (ppm/°C)</th>
<th>Max. Supply Current (µA @ 25°C)</th>
<th>Packages</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCP1525</td>
<td>2.7 to 5.5</td>
<td>2.5</td>
<td>s2</td>
<td>±3</td>
<td>50</td>
<td>s2</td>
<td>TO-92-3, SOT238-3</td>
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### Comparators

<table>
<thead>
<tr>
<th>Device</th>
<th># per Package</th>
<th>Typical Propagation Delay (ns)</th>
<th>$I_{Q}$ Typical (µA)</th>
<th>$V_{DD}$ Max. (mV)</th>
<th>Operating Voltage (V)</th>
<th>Temperature Range (°C)</th>
<th>Packages</th>
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<tbody>
<tr>
<td>MCPP541</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1.6 to 5.5</td>
<td>–40 to +85</td>
<td>SOT23-5, PDP-8, SOIC-8, MSOP-8</td>
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<td>MCPP542</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1.6 to 5.5</td>
<td>–40 to +85</td>
<td>PDP-8, SOIC-8, MSOP-8</td>
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<tr>
<td>MCPP543</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1.6 to 5.5</td>
<td>–40 to +85</td>
<td>PDP-8, SOIC-8, MSOP-8</td>
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<tr>
<td>MCPP544</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1.6 to 5.5</td>
<td>–40 to +85</td>
<td>PDP-14, SOIC-14, TSSOP-14</td>
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### Programmable Data Amplifiers (PDAs)

<table>
<thead>
<tr>
<th>Device</th>
<th>Channels</th>
<th>-3 dB BW (MHz)</th>
<th>$I_{Q}$ Typical (mA)</th>
<th>$V_{DD}$ (µV)</th>
<th>Operating Voltage (V)</th>
<th>Temperature Range (°C)</th>
<th>Packages</th>
</tr>
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<tbody>
<tr>
<td>MCPP521</td>
<td>1</td>
<td>2 to 12</td>
<td>1.1</td>
<td>275</td>
<td>2.5 to 5.5</td>
<td>–40 to +85</td>
<td>PDP-8, SOIC-8, MSOP-8</td>
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<td>MCPP522</td>
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<td>1.1</td>
<td>275</td>
<td>2.5 to 5.5</td>
<td>–40 to +85</td>
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### PICmicro® Microcontroller

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<tr>
<th>Device</th>
<th>EEPROM Data Memory Bytes</th>
<th>I/O Pins</th>
<th>ADC Channels</th>
<th>PWM 10-Bit</th>
<th>Serial I/O</th>
<th>Packages</th>
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<td>PIC16F872A</td>
<td>64</td>
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<td>5 x 10-Bit</td>
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*Temperature Sensors Design Guide*
The following literature is available on the Microchip web site: www.microchip.com

Application Notes

General Temperature Sensing

**AN679: Temperature Sensing Technologies**
The most popular temperature sensor technologies are discussed at a level of detail that will give the reader insight into the methods for determining which sensor is most appropriate for a particular application.

**AN929: Temperature Measurement Circuits for Embedded Applications**
Explores selection techniques for temperature sensor and conditioning circuits to maximize the measurement accuracy, while simplifying the interface to a microcontroller.

**AN867: Temperature-Sensing with a Programmable Gain Amplifier**
The implementation of temperature measurement systems from sensor to PICmicro® microcontroller using a NTC thermistor, silicon temperature sensor, anti-aliasing filter, A/D converter and microcontroller are discussed.

Silicon IC Temperature Sensors

Analog Output

**Tech Brief 051: Precision Temperature Measurement Technical Brief**
Provides a description for interfacing a TC1046 temperature sensor to a PIC16F872 microcontroller. A 2 x 20 dot matrix LCD is included in the design to provide additional functionality.

**AN938: Interfacing a TC1047A Analog Output Temperature Sensors to a PICmicro® Microcontroller**
Discusses system integration, firmware implementation and PCB layout techniques for using the TC1047A in an embedded system.

Logic Output

**AN762: Applications of the TC62X Solid-State Temperature Sensor**
Sensing temperature and comparing that temperature to preset limits is the basis for a variety of problems that designers face in system design and process control. This Application Note discusses the new generation of small, easy-to-use, temperature-sensing products provided by Microchip Technology Inc.; namely, the TC62X product family.

**AN773: Application Circuits of the TC620/TC621 Solid-State Temperature Sensors**
Discusses the benefits of the TC620/TC621 solid-state temperature sensors.

Serial Output

**AN871: Solving Thermal Measurement Problems Using the TC72 and TC77 Digital Silicon Temperature Sensors**
Discusses the benefits of the TC72/TC77 temperature sensors by analyzing their internal circuitry, illustrating the principles these sensors employ to accurately measure temperature.

**AN913: Interfacing the TC77 Thermal Sensor to a PICmicro® Microcontroller**
Discusses system integration, firmware implementation and PCB layout techniques for using the TC77 in an embedded system.

**AN940: Interfacing the TC72 SPI™ Digital Temperature Sensor to a PICmicro® Microcontroller**
Techniques for integrating the TC72 into an embedded system are demonstrated using the PICkit™ Flash Starter Kit.

**TB050: Monitoring Multiple Temperature Nodes Using TC74, Thermal Sensors and a PIC16C505**
The PIC16C505 is a 14-pin MCU that can easily interface to the TC74. This Technical Brief illustrates the ease of interfacing these two products.

**TB052: Multi-Zone Temperature Monitoring with the TCN75 Thermal Sensor**
Presents an example of a simple, multi-zone thermal-monitoring system using the Hardware mode of the Master Synchronous Serial Port (MSSP) module of a PICmicro® microcontroller.

Thermocouples

**AN684: Single-Supply Temperature Sensing with Thermocouples**
This Application Note focuses on circuit solutions that use thermocouples in their design. The signal-conditioning path for the thermocouple system is discussed, followed by complete application circuits.

RTDs

**AN687: Precision Temperature Sensing with RTD Circuits**
Focuses on circuit solutions that use platinum RTDs in their design.

**AN895: Oscillator Circuits for RTD Temperature Sensors**
Demonstrates how to design a temperature sensor oscillator circuit using Microchip's low-cost MCP6001 operational amplifier and the MCP6541 comparator.

Thermistors

**AN685: Thermistors in Single-Supply Temperature Sensing Systems**
Focuses on circuit solutions that use Negative Temperature Coefficient (NTC) thermistors in their design.

**AN897: Thermistor Temperature Sensing with MCP6S2X PGA**
Presents two circuits that employ a precise, Negative Temperature Coefficient (NTC) thermistor for temperature measurement.
High-Performance Devices for a Variety of Precision and Embedded Systems Applications

Microchip Technology Inc.’s Analog Device Product Tree

Analog & Interface Attributes

Robustness
- MOSFET drivers lead the industry in latch-up immunity/stability

Low-Power/Low-Voltage
- Op Amp family with the lowest power for a given gain bandwidth
- 600 nA/1.4V/10 kHz bandwidth Op Amps
- 1.8V charge pumps and comparators
- Lowest-power 12-bit ADC in a SOT-23 package

Integration
- One of the first to market with integrated LDOs with Reset and Fan Controllers with temperature sensor
- PGA integrates MUX, resistive ladder, gain switches, high-performance amplifier, SPI™ interface

Space Savings
- Resets, Comparators, Op Amps and LDOs in a SC-70, ADCs in a 5-lead SOT-23
- CAN and IrDA® standard protocol stack embedded in an 18-pin package

Accuracy
- Offset trimmed after packaging using non-volatile memory

Innovation
- Low pin-count embedded IrDA standard stack, FanSense™ technology
- Select Mode™ operation

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