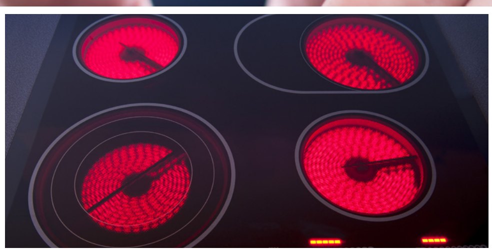
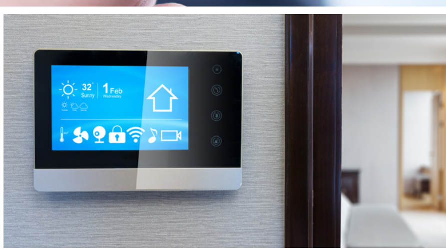
MICROCHIP

Temperature Sensors and Fan Control Design Guide

Silicon Temperature Sensors, Thermocouple, RTD, Fan Control and Thermistor Solutions





www.microchip.com/sensors

Temperature Sensing Technology Overview

In many systems, temperature control is fundamental. There are a number of passive and active temperature sensors that can be used to measure system temperature, including thermocouples, Resistance Temperature Detectors (RTDs) and silicon-based temperature sensors. These sensors provide temperature feedback to the system controller to make decisions such as over-temp shutdown, fan speed control, temperature compensation or temperature monitoring. Alternatively, some systems rely on stand-alone thermal management solutions that include both fan control and temperature sensoring.

Microchip offers a broad portfolio of thermal sensing and management products including temperature switches, digital temperature sensors, fan controllers and voltage-out temperature sensors. This array of products allow you to implement the device that best meets your application requirements. Key features include high temperature accuracy, integrated fan control, integrated EEPROM, low power and multi-channel temperature monitoring. Additionally, Microchip's products can be used to support thermocouple, RTD and thermistor based applications.

Temperature Management Applications

- Communications
- Computing, SSD and data centers
- Industrial
- Instrumentation
- Medical devices
- IoT
- Appliances
- Consumer Electronics

Single Channel Temperature Sensors

Temperature Switches

Temperature switches offer excellent temperature accuracy (±1°C, typical), with a very low operating current of less than 25 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 typical temperature coefficient of 6.25 mV/°C, 10 mV/°C and 19.5 mV/°C respectively. These temperature-to-voltage converters can sense temperatures ranging from –40°C to 150°C and feature an offset voltage that allows reading negative temperatures without requiring a negative supply voltage.

Resistance Temperature Detectors (RTDs)

RTDs are able to sense temperature with extreme accuracy, have consistent and repeatable performance and low drift error (–200°C to 1200°C). For precision, these sensors also require a linearization look-up table in the microcontroller due to sensor non-linearities.

Thermistors

Thermistors (–100°C to 150°C) are normally used for over temperature shutdown purposes. Although not as accurate as some of the other temperature sensor solutions, thermistors are inexpensive and come in small packages. They are also non-linear and require a temperature compensation look-up table.

Digital Output

Single channel digital output temperature sensors offer excellent temperature accuracy (±0.25°C, typical) with a very low operating current (250 µA, typical). Communication with these devices is accomplished via an industry standard SMBus-, I^2C- or SPI-compatible interface protocol. These devices feature fast conversion rate, with temperature resolution ranging from 0.0625°C to 0.5°C and some contain integrated EEPROM for customer preference storage and for datalogging.

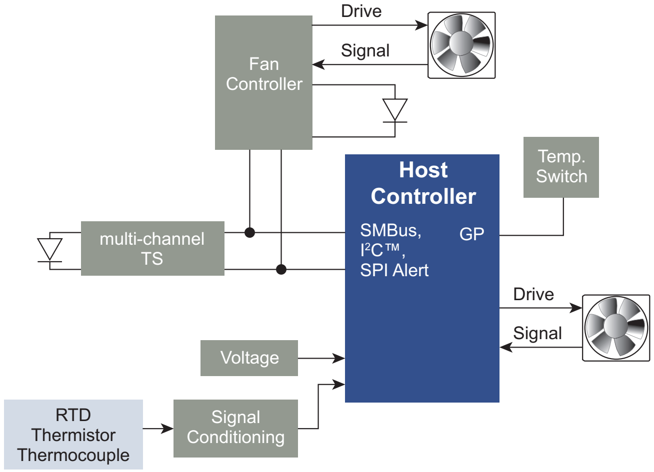


Figure 1: Temperature Sensing Overview

Multichannel Digital Temperature Sensors with Multi-channel Temperature Monitoring

In addition to local temperature sensing, Microchip offers digital temperature sensors with multi-channel TS Temperature monitoring channels. These devices offer excellent temperature accuracy (±0.25°C, typical) as well. The remote channels are inexpensively implemented by using PNP or NPN transistors connected to act as a diode. Analog filtering and resistance error correction allows for remote monitors to be placed several meters away from the IC.

Thermocouples

Thermocouples are usually selected because of their wide temperature range (–270°C to 1750°C), ruggedness and price. However, they are highly non-linear and often require significant linearization algorithms. Additionally, the voltage output of this temperature sensing element is relatively low compared to devices that can convert voltage signals to a digital representation, resulting in required analog gain stages in the circuit.

Fan Controller

Fans are used in cases where heat needs to be dissipated faster than the natural surroundings would accomplish on their own. Microchip has several levels of fan control. For simple fan speed control, there are stand-alone RPM closed-loop controllers. For a full thermal management solution, many devices integrate temperature monitoring in addition to the PWM control. Controllers also incorporate both spin-up and ramp-rate control algorithms to minimize acoustics.

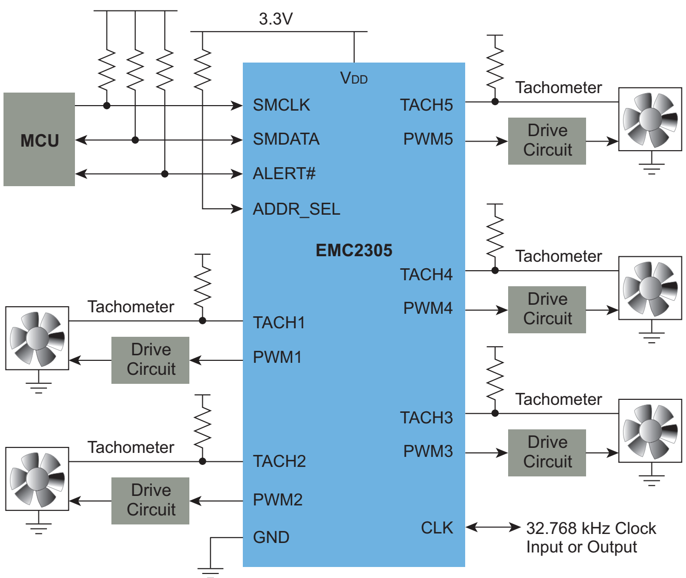


Figure 2: *System diagram*

Single-Channel Digital Output Temperature Solutions for Medical Applications

Single-Channel Digital Output Temperature Sensors such as the **AT30TS74** available in ultra-small Wafer Level Chip Scale Package (WLCSP) is a perfect fit for various products like Medical applications where board space is extremely limited and or constrained. The AT30TS74 WLCSP form factor takes up less than 1mm^2 of required board space allowing it to be placed closer to the heat source being monitored allowing for a faster thermal response to any temperature changes that occur. This is critically important for medical applications where temperature sensitivity is paramount for proper operation and enables the ability to adjust for and or take fast accurate temperature measurements. The AT30TS74 WLCSP provides a factory calibrated accuracy of ±1.0°C with programmable temperature window with Alert pin output to notify the host MCU of any temperature window violations. For hand-held battery powered medical applications, the AT30TS74 features two power saving features; a shutdown mode that turns off all of its internal circuitry saving power and a one-shot mode that allows the AT30TS74 to make a temperature measurement and update its internal temperature registers and then return to shutdown mode.

Single-Channel Digital Output Temperature Solutions for HVAC

Digital Temperature sensors such as the **MCP9808** provide greater design flexibility and simplicity for HVAC thermostat applications. Unlike resistance temperature detectors, these sensors do not require instrumentation circuit and circuit-calibration routines, while they do provide low power and superior accuracy. The MCP9808 provides a factory calibrated maximum accuracy of ±0.5°C, and programmable features such as a temperature window monitor output. If temperature exceeds the upper and lower temperature window plus hysteresis, the alert output asserts as an interrupt for microcontrollers or as comparator for thermostat applications.

Thermistor Solutions

Microchip provides various single-chip solutions for thermistors, which are used to assert alert signals to the microcontroller or switch on/off a fan or an LED indicator when temperature exceeds preset limits. For example, chilled water reservoir may use a thermistor to detect the change in temperature of the reservoir to detect water level.

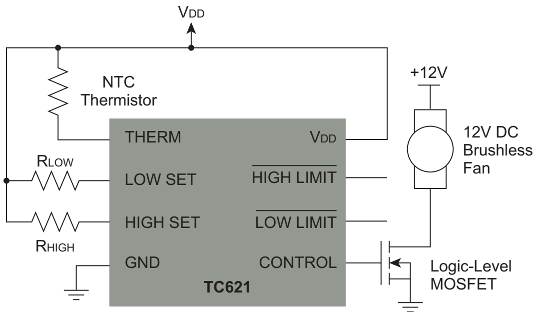


Figure 3: Configuration of the TC621 dual trip point temperature switch

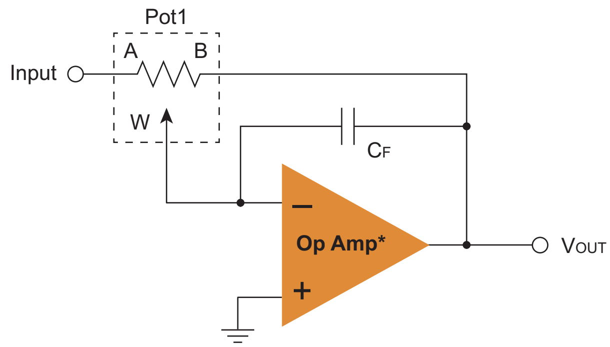
Figure 3 shows how to configure the **TC621** dual trip point temperature switch. The thermistor and the alert limit setting resistors directly connect to the device and the alert outputs trigger with ±0.3°C accuracy. The advantage of this device is that it provides a closed-loop temperature switch solution for thermistor applications.

Increasing the Sensor Sensitivity

Although thermistors provide a low-cost solution and are easy to implement, they are highly non-linear, particularly if the application temperature range exceeds approximately 50°C. Look up tables and correction factors are typically provided by the vendors. However, in the non-linear region, as temperature increases the change in resistance per degree Celsius or the sensitivity is reduced exponentially.

Figure 4: Hand-held thermometer

For example, a hand-held instrument with an integrated thermistor sensor to detect ambient temperature would need consistent measurement sensitivity in the Winter of Alaska as it would in the Summer of Arizona. Microchip provides various programmable gain amplifier solutions to increase the sensor sensitivity within the non-linear region. Figure 5 shows how to configure a digital potentiometer and a low-power amplifier as a programmable gain amplifier.



* A general purpose op amp, such as the MCP6001.

Figure 5: Configuration of a digital potentiometer and a low-power amplifier as a programmable gain aplifier

Refrigeration Solutions for Foodstuffs

Multichannel Temperature Sensors

The FDA Food Code 2001 for temperature measuring devices requires accurate temperature sensing to ensure quality of foodstuffs during transport and storage. Applications such as commerical refrigerators, freezers and transport vehicles require temperature accuracy at low temperatures.

Figure 6: *Foodstuffs refrigeration*

The **MCP9902/3/4** offers the required accuracy (±1°C) to maintain cooler temperatures for quality foodstuffs.

The key features of the MCP9902/3/4 are:

- Maximum error of ±1°C from –40°C to 105°C
- Automatic beta detection
- Resistance Error Correction (REC) up to 100Ω
- Programmable temperature limits

Commercial White Good Solutions

Multichannel Temperature Sensors

Dishwashers for residential or commercial implement a hot-temperature cleaning cycle. The reduction of water consumption, shorter cycle times, increased rack loads and sanitation of cookware are driving factors for increased efficiency in dishwashers. The National Sanitization Foundation (NSF) requires a final rinse temperature of 150°F for residential dishwashers (NSF/ANSI 184) and 180°F for commercial dishwashers (NSF/ANSI 3), pulling in water from the hot-water line.

A temperature sensor monitors the temperature of the dishwasher and if it is not maintained at a necessary temperature, the heating element turns on.

The EMC1812 provides ±1°C maximum error over the temperature range of interest. Features programmable temperature limits provides a level of notification that may be used to trigger the heating element during pre-wash and main wash cycles of the dishwasher to maintain a level temperature.

Other features of the EMC1812 are:

- Maximum error of ±1°C from –20°C to 105°C
- Automatic beta detection
- Anti-Parallel Diode (APD) functionality
- Resistance Error Correction (REC) up to 100Ω
- Rate of change measurement

Figure 7: *Dishwasher*

Thermocouple

Residential induction heating technology may be found in stand-alone cooktops, rice cookers and hot water pots. Induction-based cooking gives the fine temperature control of gas burners at much higher efficiencies than either gas or radiant heating elements. Insulated-Gate Bipolar Transistors (IGBTs) used in induction cooking applications dissipate a considerable amount of power, so to prevent the IGBT's junction temperature from rising above its recommended specification value, large heat sinks are usually employed.

For smart Induction Cooktops, monitoring the induction heating surface temperature and the pot temperature provides better control over cooking the recipe. For this application, Thermocouples can be imbedded in both the pan and the induction cooktop surface and the main controller maintains optimum cooking temperature for the food compared to the surface temperature via connected wireless communication. Microchip's **MCP9600** Plug & Play Thermocouple conditioning IC solution is ideal for such embedded applications.

Figure 8: *Induction Cooktop*

The **MCP9600** allows for four external sources, standard on a residential cooktop, to be monitored to ±1°C max accuracy up to 125°C. The IGBT modules are mounted on the heat sink to ensure the IGBTs do not exceed their junction temperature. The temperature information is sent back to the system's microcontroller in real time to mitigate over temperature conditions.

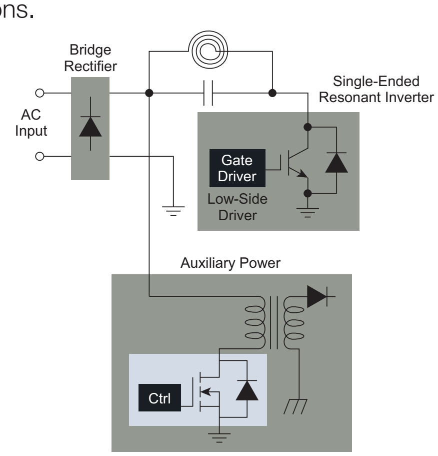


Figure 9: *Induction Cooktop Diagram*

Temperature Switches

Home and small office equipment like document shredders have sheet capacities often up to 18 sheets. The desire for continuous shredding with high capacities increases the heat in the shredder's which may cause it to seize. A cool-down period is necessary before the shredder is operational. A temperature switch like the **MCP9502** may be used to monitor the motor's temperature and alerting the user to thermal overload via an LED on the front panel.

The MCP9502 is available with factory preset temperature thresholds. This eliminates the need to program a thermal limit through software or using external components. A temperature above the limit will set a visual alert using an LED which identifies an increasing thermal condition.

Other features of the MCP9502 are:

- Push-pull output
- Factory presets from 5°C to 125°C
- Programmable hysteresis

Figure 10: *Home and small office equipment*

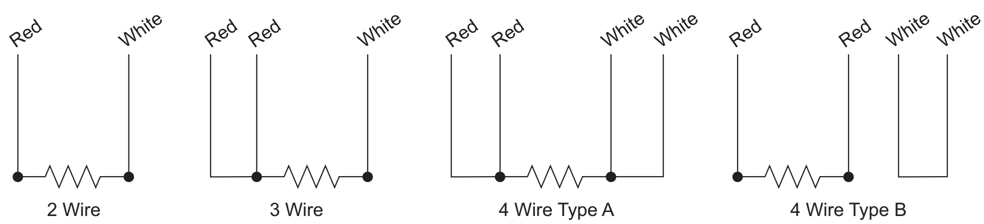
RTD Solutions

A Resistance Temperature Detector (RTD) is a temperature sensor that contain a resistor that changes resistance value as its temperature changes. An RTD is made from a pure material such as platinum. This sensor is typically used in precision applications such as laboratory equipment and medical instrumentation. In order to accurately detect change in temperature using an RTD, precision analog and digital circuits are also needed. For example, medical laboratory ovens require precision closed-loop temperature control systems. An RTD is the preferred sensor for this application for the superior repeatable characteristics as the unit temperature cycles from room temperature to the various preset levels.

Figure 11: *Laboratory oven*

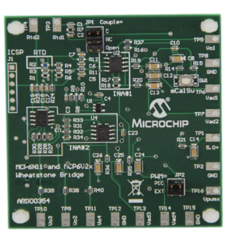
Microchip provides various precision solutions for RTDs, such as an Instrumentation Amplifier with an integrated self calibration (**MCP6N11**), an autozeroed op amp with extremely low input offset voltage (**MCP6V01**) and a high-resolution precision analog to digital converter (**MCP3551**).

RTD sensors are available with 2-wire, 3-wire and 4-wire elements. With the 2-wire sensors, both sensor leads are in series with the sensor element. As temperature increases the lead resistance also changes and the voltage drop across the leads reduces the measurement accuracy.



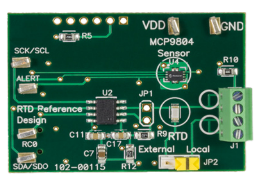
Reference Designs

MCP6N11 Wheatstone Birdge Reference Design (ARD00354)



Microchip provides a reference design which uses a Wheatstone Bridge balanced RTD circuit to analyze and compare the performance of the traditional three op amp instrumentation amplifier with the MCP6V01 family of op amps and the MCP6N11 instrumentation amplifier. This reference design enables users to perform noise analysis and study each circuit characteristics to identify the preferred solution using a software Graphical User Interface (GUI).

RTD Reference Design (TMPSNSRD-RTD2)

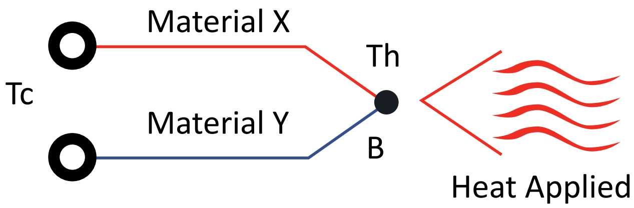


Microchip also provides a reference design which uses a current source to bias the RTD. This solution uses a high-performance Delta-Sigma Analog-to-Digital Converter (ADC), two external resistors and a reference voltage to measure temperature ratiometrically. A ±0.1°C accuracy and ±0.01°C measurement resolution can be achieved across the RTD temperature range of –200°C to +800°C with a single-point calibration.

Thermocouple Solutions

A Thermocouple is a rugged temperature sensor used to measure high temperatures. When the thermocouple Hot-Junction is exposed to high temperatures such as 1000°C, a small change in voltage can be measured at the open end of the Thermocouple, the Cold-Junction, which is normally at room temperature.

The thermocouple wires are made of two dissimilar materials which are typically categories by either base metal or precious metal compositions. There are several types of Thermocouple standards and the most common types are Type K and Type J Thermocouples. The other type of Thermocouples such as Type T, N, S, B, and R are more of application specific and provide increased sensitivity at various temperature ranges.



Common Applications for thermocouples include petrochemical, industrial ovens, engines, machinery used in the steel and iron industry with operating ambient temperatures ranges of approximately –200°C to 2000°C.

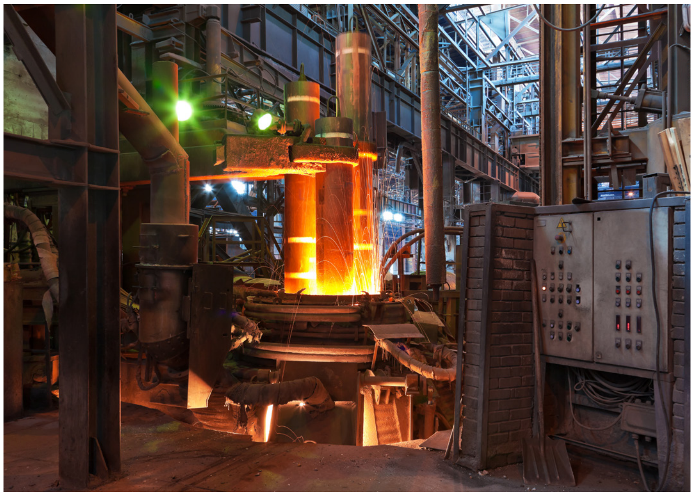
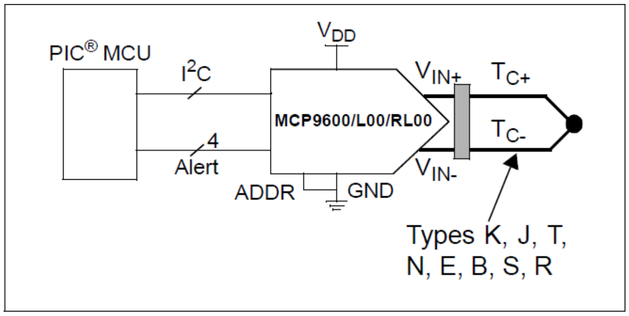
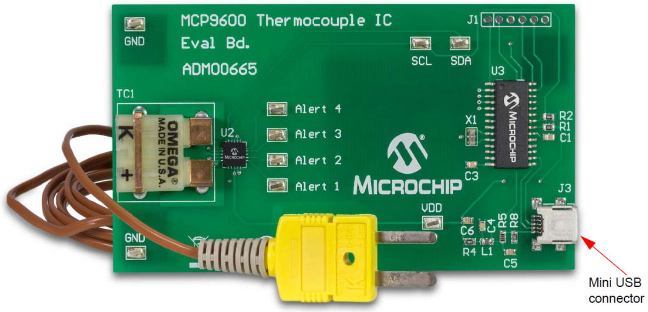


Figure 12: *Metallurgical furnace*

Microchip offers a Plug & Play integrated solutions for the common thermocouples, the MCP9600 family. This family of devices integrates the thermocouple error compensation equation and the Cold-Junction compensation sensor with a factory calibrated hot-Junction accuracy of ±1.5°C, ±4°C, and ±8°C maximum accuracy for a high, medium, and low accuracy applications.



In addition, the device provides various user programmable features for embedded applications such as Open-Circuit and Short-Circuit detection, 4-user programmable temperature alert limits, temperature averaging, programmable temperature resolution, and power saving features such as Burst-Mode temperature sampling.



Microchip offers an evaluation board for the MCP9600 which allows users to evaluate the various features.

Microchip also provides a number precision linear products such as op amps and instrumentation amplifiers, MCP6V01 and MCP6N11, respectively. Additionally, Microchip provides high resolution Delta-Sigma Analog-to-Digital Converters for thermocouple solution such as the MCP3461 16-bit, MCP3421 18-bit and MCP3465 24-bit ADCs.

One of the unique advantage of thermocouples is the fast-thermal response characteristics with a typical response time of approximately 5 ms. A typical application for such highspeed response is electrical arcing for industrial or high current breaker switches, and the MCP6V01 family op amps are ideal solutions for such applications (see AN1306 application note from Microchip for details).

Energy Efficient Thermal Solutions

Multichannel Temperature Sensors

The ever increasing power supply requirements and board densities in computing systems require efficient thermal management solutions. Factors such as cost, accuracy and system size help determine the type of temperature sensor applicable to manage the thermal load of the computing system.

Silicon-based temperature sensors use a fundamental property of bipolar transistors to determine temperature. Temperature may be calculated by measuring a change in voltage when two different currents are implemented. Figure 13 and Equation 1 illustrate the concept of a silicon-based temperature measurement.

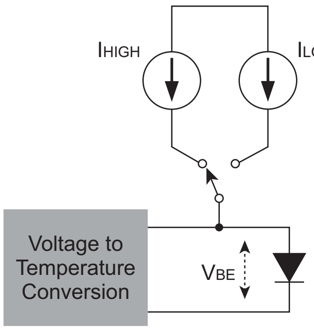


Figure 13: *Silicon-based temperature measurement*

$$\Delta V_{BE} = \left(\frac{kT}{q}\right) \times ln\left(\frac{I_{C1}}{I_{C2}}\right)$$

$$T = \frac{\Delta V_{BE} \times q}{nk \times ln\left(\frac{I_{C1}}{I_{C2}}\right)}$$

Equation 1: *Silicon-based temperature measurement*

Where T = temperature in Kelvin

ΔV_{BE} = change in diode base emitter voltage

k = Boltzman's constant

q = electron charge

n = diode ideality factor

I_{C1} and I_{C2} = currents with n:1 ratio

The **EMC18xx** is ideal for low-cost motherboards to monitor the ambient temperature at several locations. These may include the chassis, add-in card sockets and surrounding components as shown in Figure 14.

As temperatures increases due to high levels of processor load; whether it is the CPU, GPU or memory modules, the system may throttle the clocking frequency to mitigate the temperature rise in the system. The ±1°C maximum accuracy of the EMC18xx eliminates the concern of premature throttling or system shutdown due to increasing system temperature.

- Maximum error of ±1°C from –20°C to +105°C
- Programmable temperature limits
- Configurable ALERT function as a comparator mode or as system interrupt mode

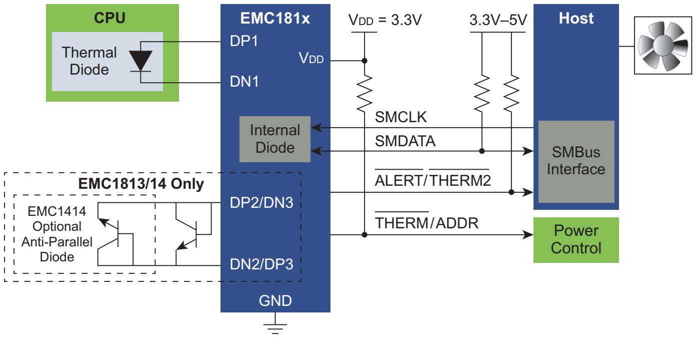


Figure 14: *System diagram*

For higher-density applications such as high-end system boards for laptops, server racks and tablets, a remote diode temperature sensor, such as the **EMC1814**, may be used for increased flexibility and reduced component count.

The Anti-Parallel Diode (APD) feature of the EMC1814 allows for a single device to monitor several zones at once, leveraging a stand-alone diode connected transistor or the discrete diode-connected transistor of a CPU, GPU or an ASIC processor.

It is important to understand the processor geometry in today's computing products. A substrate diode is often used as the temperature sensor. Decreasing geometries degrade the accuracy of the sensor. To ensure accuracy, the EMC1814 employs automatic beta detection before every conversion.

Microchip's patented frequency hopping technique mitigates noise coupling into the input traces from switching noise sources including backlight inverters, SMPS and other sources of EMI.

The EMC1814's Resistance Error Correction (REC) mitigates temperature error from long PCB traces, cabling and interconnects resistances. Without REC, every 1Ω of resistance in the measurement path would have added approximate +0.7°C error to the temperature measurement.

The key features of the EMC1814 are:

- Maximum error of ±1.5°C from –20°C to 105°C
- Programmable temperature limits
- Configurable ALERT and THERM functions for system interrupts

Fan Controllers

Temperature sensors may also work in conjunction with fan controllers ensuring a greater depth of thermal management. Microchip offers fan controllers with programmable features allowing for flexible solutions for modify to servers, LCD projectors, workstations, and networking equipment racks.

Audible noise from the fan spinning up or changing RPM too abruptly may dampen the end user experience. The spin-up routine (Figure 15) of Microchip's fan drivers, such as the **EMC2303**, mitigate audible noise during the initial start of the fan. During normal operation, programmable ramp-rate control may be implemented to reduce audible fan noise when the speed of the fan is required to change.

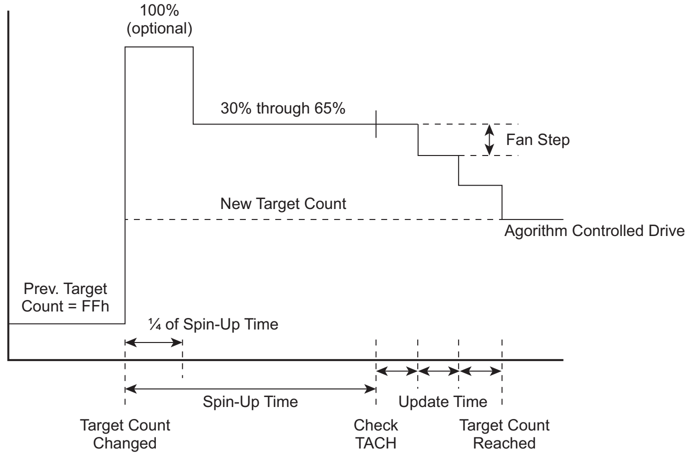


Figure 15: *Spin-up routine*

In servers and network racks the EMC2303 allows for multiple zones to be cooled. When a system detects a thermal condition from its array of temperature sensors, the CPU will drive the fan to increase air flow volume to lower the temperature.

Typically +12V fans are implemented in the server space requiring an interface circuit to isolate supply voltages as illustrated in Figure 16. The isolation circuit uses only two components, a FET and a Schottky diode.

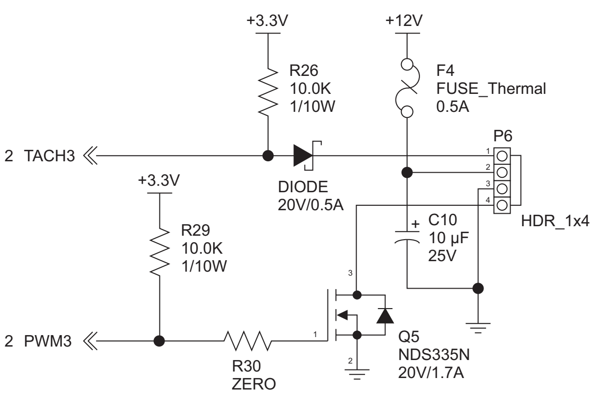


Figure 16: *12V isolation circuit for fan drive*

The key features of the EMC2305:

- Closed-loop, PID control
- High-frequency PWM (26 kHz) to reduce acoustical noise
- Stalled fan and aging fan detection

Figure 17: *Ethernet equipment rack*

Cloud computing solutions for modern datacenters further increase the need for thermal management. High-end servers rely on a distributed network of sensors and fans throughout the system. This network allows individual peripherals to be monitored for increased granular control for greater energy efficiency. Implementing APD, REC, automatic beta detection, spin-up and ramp-rate control in one solution while supporting five temperature zones (four external, one internal) to be monitored. Products such as the **EMC2106** combine temperature sensing and fan control in a 28-pin QFN package.

Combined with closed-loop fan control, the EMC2106 drives up to two fans to provide additional air flow in the server rack.

Other features of the EMC2106 are:

- Maximum error of ±2°C from 0°C to 125°C
- Stalled fan and aging fan detection

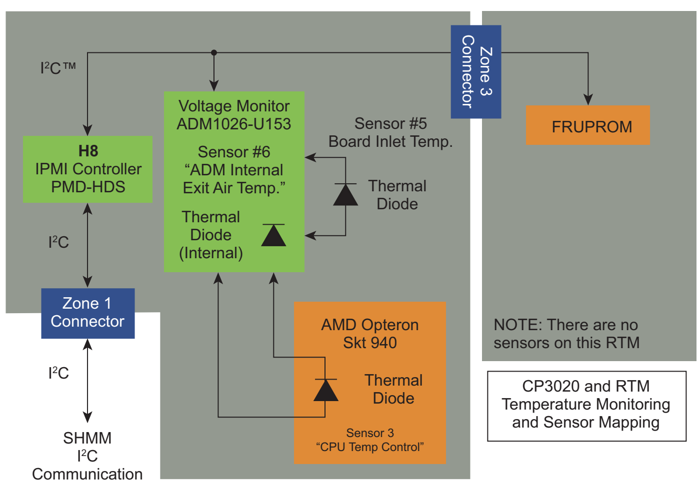
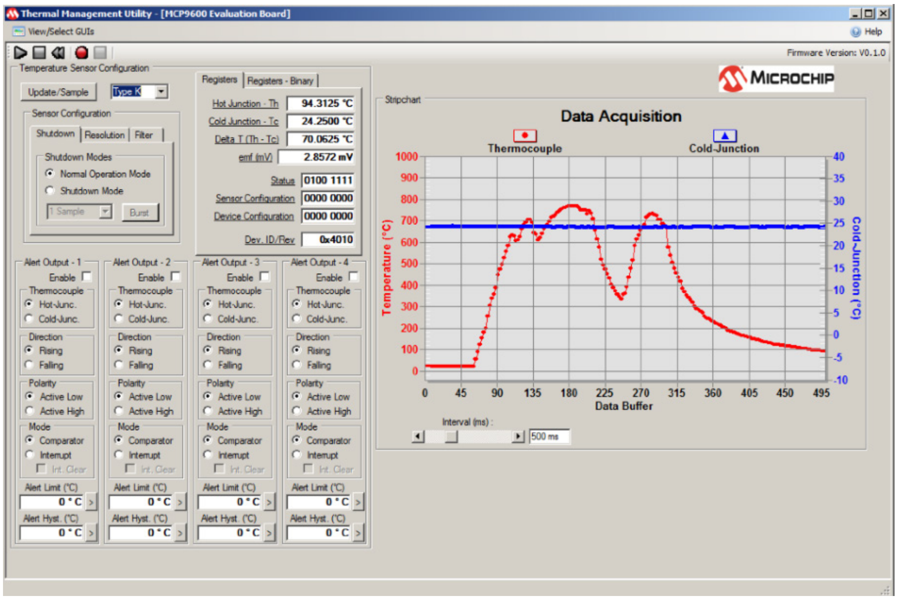


Figure 18: *Blade server*

Thermal Management Graphical User Interface

The Microchip Thermal Management Graphical User Interface allows users to evaluate various temperature-sensing evaluation boards. This software tool can be downloaded and installed from the evaluation board product page.

After the installation is successfully completed, the hardware is required to be connected via USB to start the Thermal Management GUI. Once the hardware is connected, the software recognizes the device ID and displays the corresponding GUI for the connected evaluation board. Disconnecting the USB will close the GUI. This tool allows the user to evaluate the sensor features and perform temperature data logging.



The figure above shows an example of the MCP9600 data acquisition interface with a plot of the Thermocouple Hot-Junction and Cold-Junction temperatures.

Thermal Management Graphical User Interface

List of Supported Evaluation Boards

Board Name	Order Number
Thermocouple Analog Discrete Component Demo Board	TMPSNSRD-TCPL1
RTD Demo Board	TMPSNSRD-RTD2
Thermistor Demo Board	MCP9700DM-TH1
MCP6N11 and MCP6V2x Wheatstone Bridge Ref Design	ARD00354
MCP9600 Evaluation Board	ADM00665
EMC1833 Evaluation Board	ADM00773
EMC1438/EMC2305 Fan Controller and Temperature Demo	ADM00879
EMC2103-4 Fan Controller and Temperature Demo	ADM00902

Application Notes

The following application notes are available on the Microchip website: www.microchip.com.

General Temperature Sensing

AN679: Temperature Sensing Technologies

The most popular temperature sensor technologies are discussed at a level of detail that will give you insight into the methods of determining which sensor is most appropriate for a particular application.

AN867: Temperature Sensing with a Programmable Gain Amplifier

The implementation of temperature measurement systems from senor to PIC® microcontroller using a NTC thermistor, silicon temperature sensor, and anti-aliasing filter, ADC and micrcon-troller are discussed.

AN929: Temperature Measurement Circuits for Embedded Applications

This application note explores selection techniques for tem-perature sensor and conditioning circuits to maximize the measurement accuracy, while simplifying the interface to a microcontroller.

AN1001: IC Temperature Sensor Accuracy Compensation with a PIC Microcontroller

The typical accuracy of analog and serial-output IC temperature sensors is within ±1°C, however, at hot or cold extremes, the accuracy decreases non-linearly. This application note is based on the analog output MCP9700/9701 and serial output MCP9800 temperature sensors. It derives an equation describ-ing the sensor's typical non-linear characteristics, which can be used to compensate for the sensor's accuracy error over the specified operating temperature range.

Silicon IC Temperature Sensors: Analog Output

AN938: Interfacing a TC1047A Analog Output Temperature Sensors to a PIC Microcontroller

This application note discusses system integration, firmware implementation and PCB layout techniques for using the TC1047A in an embedded system.

TB051: Precision Temperature Measurement Technical Brief

This technical brief provides a description for interfacing a TC1046 temperature sensor to a PIC16F872 microcontroller. A 2 × 20 dot matrix LCD is included in the design to provide additional functionality.

Silicon IC Temperature Sensors: 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 you face is system design and process control. This application note discusses the new generation of small, easy-to-use, temperature-sensing products provided by Microchip, namley the TC62X product family.

AN773: Application Circuits of the TC620/TC621 Solid-State Temperature Sensors

This application note discusses the benefits of the TC620/ TC621 solid-state temperature sensors.

Silicon IC Temperature Sensors: Serial Output

AN10.14: Using Temperature-Sensing Diodes with Remote Thermal Sensors

This application note describes how to maintain accuracy when diodes are used as remote sensors with the multi-channel TS devices from Microchip.

AN12.14: Remote Thermal Sensing Diode Selection Guide

This application note is aimed at designers who build systems that use thermal sensors with remote diodes; specifically, remote diodes that are discrete bipolar juntion transistors.

AN13.19: Resistance Error Correction

This application note describes the resistance error correc-tion feature available on many Microchip temperature sensor devices.

AN14.0: Microchip Dedicated Slave Devices in I²C Systems

This document describes the key differences that may affect successful application of Microchip's two-wire serial interface dedicated slaves devices in systems are are designed with an I²C master interface.

AN16.4: Using Anti-Parallel Diodes (APDs) with Microchip's Remote Temperature Sensing Devices

This application note provides information on maintaining temperature measurement accuracy and noise immunity when using APDs with Microchip's APD temperature sensing devices.

AN18.15: PCB Design Guidelines for QFN and DQFN Packages

This application note provides information on general Printed Circuit Board (PCB) layout considerations for Microchip products using QFN and DQFN packages. It is written for users who are familiar with PCB design, including signal integrity and thermal management implementation concepts.

AN871: Solving Thermal Measurement Problems Using the TC72 and TC77 Digital Silicon Temperature Sensors

This application note 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 PIC Microcontroller

This applications note 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 PIC Microcontroller

Techniques for integrating the TC72 into an embedded system are demonstrated in this application note 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: Multizone Temperature Monitoring with the TCN75 Thermal Sensor

This technical brief 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 PIC 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

This application note focuses on circuit solutions that use platinum RTDs in their design.

AN895: Oscillator Circuits fo RTD Temperature Sensors

This application note demonstrates how to design a temperature sensor scillator circuit using Microchip's low-cost MCP001 operational amplifier and the MCP6541 comparator.

ADM00768: MCP9904 Multi-Channel Temperature Sensor Evaluation Board

ADM00879: EMC2305/EMC1438 Fan Controller Evaluation Board

ADM00773: EMC1833 Multi-Channel Temperature Sensor Evaluation Board

ADM00902: EMC2103-4 Fan Controller With Multi-Channel Temperature Sensor Evaluation Board

See Microchip's Advanced Parts Selector (MAPS) software for complete product selection and specifications.

Serial Output Temperature Sensor Products

Device	Serial Communication	Accuracy@25°C (Typ. ±°C /Max. ±°C)	Temperature Range (°C)	Vdd Min. (V)	Vdd Max. (V)	Iq Max. (uA)	Packages	Development Tools
AT30TS00	SMBus	2/3 0.5/1 (+75°C to +95°C)	–20 to +125	2.7	3.6	500	8-pin DFN	-
AT30TS74	SMBus/I²C	2/3 1/2 (-20°C to +100°C)	–40 to +125	1.7	5.5	325	8-pin DFN, 8-pin MSOP,4/5-ball WLCSP, 8-pin SOIC	-
AT30TS75A	SMBus/I²C	2/3 1/2 (-20°C to +100°C)	–40 to +125	1.7	5.5	325	8-pin DFN, 8-pin MSOP, 8-pin SOIC	-
AT30TS750A	SMBus/I²C	2/3 1/2 (-20°C to +100°C)	–40 to +125	1.7	5.5	325	8-pin DFN, 8-pin MSOP, 8-pin SOIC	-
AT30TSE002B	SMBus	2/3 0.5/1 (+75°C to +95°C)	–20 to +125	2.7	5.5	500	8-pin DFN	-
AT30TSE004A	SMBus	2/3 0.5/1 (+75°C to +95°C)	–20 to +125	1.7	5.5	500	8-pin DFN	-
AT30TSE752A	SMBus/I²C	2/3 1/2 (-20°C to +100°C)	–40 to +125	1.7	5.5	325	8-pin DFN, 8-pin MSOP, 8-pin SOIC	-
AT30TSE754A	SMBus/I²C	2/3 1/2 (-20°C to +100°C)	–40 to +125	1.7	5.5	325	8-pin DFN, 8-pin MSOP, 8-pin SOIC	-
AT30TSE758A	SMBus/I²C	2/3 1/2 (-20°C to +100°C)	–40 to +125	1.7	5.5	325	8-pin DFN, 8-pin MSOP, 8-pin SOIC	-
MCP9800	I²C	0.5/1	–40 to +125	2.7	5.5	400	5-pin SOT-23	MCP9800DM-TS1
MCP9801	I²C	0.5/1	–40 to +125	2.7	5.5	400	8-pin MSOP, 8-pin SOIC	-
MCP9802	SMBus	0.5/1	–40 to +125	2.7	5.5	400	5-pin SOT-23	-
MCP9803	SMBus	0.5/1	–40 to +125	2.7	5.5	400	8-pin MSOP, 8-pin SOIC	-
MCP9804	SMBus/I²C	0.25/1	–40 to +125	2.7	5.5	400	8-pin DFN, 8-pin MSOP	-
MCP9805	SMBus	2/3 0.5/1 (+75°C to +95°C)	–20 to +125	3.0	3.6	500	8-pin DFN, 8-pin TSSOP	-
MCP9808	SMBus/I²C	0.25/1 0.25/0.5 (-20°C to +100°C)	–40 to +125	2.7	5.5	400	8-pin DFN, 8-pin MSOP	-
MCP98243	SMBus	1/3 0.2/1 (+75°C to +95°C)	–20 to +125	2.7	3.6	500	8-pin DFN	-
MCP9843	SMBus	1/3 0.2/1 (+75°C to +95°C)	–20 to +125	2.7	3.6	500	8-pin DFN	-
MCP98244	SMBus	1/3 0.2/1 (+75°C to +95°C)	–40 to +125	1.7	3.6	500	8-pin DFN	-
MCP9844	SMBus	1/3 0.2/1 (+75°C to +95°C)	–40 to +125	1.7	3.6	500	8-pin DFN	-
TC72	4-wire SPI	0.5/1	–40 to +125	2.65	5.5	400	8-pin MSOP, 8-pin DFN	-
TC74	SMBus/I²C	0.5/2	–40 to +125	2.7	5.5	350	5-pin TO-220 5-pin SOT-23	-
TCN75A	SMBus/I²C	0.5/2	–40 to +125	2.7	5.5	500	8-pin MSOP, 8-pin SOIC	-
TC77	3-wire SPI	0.5/1	–40 to +125	2.7	5.5	400	8-pin SOIC, 5-pin SOT-23	-

Multi-Channel Digital Temperature Sensors

Product	Description	# Temps Monitored	Typical Accuracy (Â°)	Max. Accuracy @ 25Â° (Â°)	Temp. Range (°C)	Vcc Range (V)	Typical Supply Current (ÂµA)	Resolution (bits)	Alert/THERM	Hardware Shutdown	Packages	Automotive Recommended
MIC184	SMBus/I^{2}C Multi Temperature Sensor	2	1	2	–55 to +125	2.7 - 5.5	500	9	1		8/MSOP 8/SOIC	No
MIC280	SMBus/I^{2}C Multi Temperature Sensor	2	1	2	–55 to +125	3 - 3.6	400		1		6/SOT-23	No
EMC1046	SMBus/I^{2}C Multi Temp Sensor with Hottest of Zones	6	0.25	1	–40 to +125	+3.0 - +3.6	395	11			10/MSOP	No
EMC1047	SMBus/I^{2}C Multi Temp Sensor with Hottest of Zones	7	0.25	1	–40 to +125	+3.0 - +3.6	395	11			10/MSOP	No
EMC1428	SMBus/I^{2}C Multi Temp Sensor with Hottest of Zones	8	0.25	1	–40 to +125	+3.0 - +3.6	450	11	1	1	16/QFN	No
EMC1438	SMBus/I^{2}C Multi Temp Sensor with Hottest of Zones	8	0.25	1	–40 to +125	+3.0 - +3.6	450	11	1	1	16/QFN	No
EMC1422	SMBus/I^{2}C Multi Temp Sensor with Shutdown	2	0.25	1	–40 – +125	+3.0 - +3.6	430	11	1	1	8/MSOP	No
EMC1423	SMBus/I^{2}C Multi Temp Sensor with Shutdown	3	0.25	1	–40 – +125	+3.0 - +3.6	430	11	1	1	10/MSOP	No
EMC1424	SMBus/I^{2}C Multi Temp Sensor with Shutdown	4	0.25	1	–40 to +125	+3.0 - +3.6	430	11	1	1	10/MSOP	No
EMC1412	SMBus/I^{2}C Multi Temperature Sensor	2	0.25	1	–40 to +125	+3.0 - +3.6	430	11	2		8/MSOP 8/TDFN	No
EMC1413	SMBus/I^{2}C Multi Temperature Sensor	3	0.25	1	–40 to +125	+3.0 - +3.6	430	11	2		10/MSOP 10/VDFN	No
EMC1414	SMBus/I^{2}C Multi Temperature Sensor	4	0.25	1	–40 to +125	+3.0 - +3.6	430	11	2		10/MSOP 10/VDFN	No
EMC1812	SMBus/I^{2}C Multi Temperature Sensor	2	0.25	1	–40 to +125	+3.0 - +3.6	20	11	2		8/WDFN	No
EMC1813	SMBus/I^{2}C Multi Temperatur Sensor	3	0.25	1	–40 to +125	+1.62 - +3.60	20	11	2		10/VDFN	No
EMC1814	SMBus/I^{2}C Multi Temperature Sensor	4	0.25	1	–40 to +125	+1.62 - +3.60	20	11	2		10/VDFN	No
EMC1815	SMBus/I^{2}C Multi Temperature Sensor	5	0.25	1	–40 to +125	+1.62 - +3.60	20	11	2		10/VDFN	No
EMC1822	SMBus/I^{2}C Multi Temperature Sensor	2	0.25	1	–40 to +125	+1.62 - +3.60	20	11	1	1	8/WDFN	No
EMC1823	SMBus/I^{2}C Multi Temperature Sensor	3	0.25	1	–40 to +125	+1.62 - +3.60	20	11	1	1	10/VDFN	No
EMC1824	SMBus/I^{2}C Multi Temperature Sensor	4	0.25	1	–40 to +125	+1.62 - +3.60	20	11	1	1	10/VDFN	No
EMC1825	SMBus/I^{2}C Multi Temperature Sensor	5	0.25	1	–40 to +125	+1.62 - +3.60	20	11	1	1	10/VDFN	No
EMC1833	SMBus/I^{2}C Multi Temperature Sensor	3	0.25	1	–40 to +125	+1.62 - +3.60	20	11	2		8/WDFN	No
EMC1843	SMBus/I^{2}C Multi Temperature Sensor	3	0.25	1	–40 to +125	+1.62 - +3.60	20	11	1	1	8/WDFN	No
MCP9902	SMBus/I^{2}C Multi Temperature Sensor	2	0.25	1	–40 to +125	+3.0 - +3.6	225	11	2		8/WDFN	No
MCP9903	SMBus/I^{2}C Multi Temperature Sensor	3	0.25	1	–40 to +125	+3.0 - +3.6	225	11	2		10/VDFN	No
MCP9904	SMBus/I^{2}C Multi Temperature Sensor	4	0.25	1	–40 to +125	+3.0 - +3.6	225	11	2		10/VDFN	No

Open-Loop Fan Controllers and Fan Fault Detectors

Part #	Description	# of Temp. Monitors	Typical Accuracy (°C)	Maximum Accuracy @ 25°C (°C)	Maximum Temperature Range (°C)	Vcc Range (V)	Maximum Supply Current (µA)	Features	Packages
EMC2101	Single SMBus I²C Fan Manager	2	±0.5	±1	−40 to +125	+3.0 to +3.6	1,000	Fan Controller with high-frequency PWM driver, programmable fan speed table and alert	8-pin MSOP, 8-pin SOIC
TC642	Fan Manager	1	Note 1	Note 1	−40 to +85	+3.0 to +5.5	1,000	FanSense™ Fan Monitor, Minimum fan speed control	8-pin PDIP, 8-pin SOIC, 8-pin MSOP
TC642B	Fan Manager	1	Note 1	Note 1	−40 to +85	+3.0 to +5.5	400	FanSense Fan Monitor, Minimum fan speed control, Fan auto-restart	8-pin PDIP, 8-pin SOIC, 8-pin MSOP
TC646	Fan Manager	1	Note 1	Note 1	−40 to +85	+3.0 to +5.5	1,000	FanSense Fan Monitor, Auto-shutdown	8-pin PDIP, 8-pin SOIC, 8-pin MSOP
TC646B	Fan Manager	1	Note 1	Note 1	−40 to +85	+3.0 to +5.5	400	FanSense Fan Monitor, Auto-shutdown, Fan auto-restart	8-pin PDIP, 8-pin SOIC, 8-pin MSOP
TC647	Fan Manager	1	Note 1	Note 1	−40 to +85	+3.0 to +5.5	1,000	FanSense Fan Monitor, Minimum fan speed control	8-pin PDIP, 8-pin SOIC, 8-pin MSOP
TC647B	Fan Manager	1	Note 1	Note 1	−40 to +85	+3.0 to +5.5	400	FanSense Fan Monitor, Minimum fan speed control, Fan auto-restart	8-pin PDIP, 8-pin SOIC, 8-pin MSOP
TC648	Fan Manager	1	Note 1	Note 1	−40 to +85	+3.0 to +5.5	1,000	Overtemperature alert, Auto-shutdown	8-pin PDIP, 8-pin SOIC, 8-pin MSOP
TC648B	Fan Manager	1	Note 1	Note 1	−40 to +85	+3.0 to +5.5	400	Overtemperature alert, Auto-shutdown, Fan auto-restart	8-pin PDIP, 8-pin SOIC, 8-pin MSOP
TC649	Fan Manager	1	Note 1	Note 1	−40 to +85	+3.0 to +5.5	1,000	FanSense Fan Monitor, Auto-shutdown	8-pin PDIP, 8-pin SOIC, 8-pin MSOP
TC649B	Fan Manager	1	Note 1	Note 1	−40 to +85	+3.0 to +5.5	400	FanSense Fan Monitor, Auto-shutdown, Fan auto-restart	8-pin PDIP, 8-pin SOIC, 8-pin MSOP
TC650	Fan Manager	1	±1	±3	−40 to +125	+2.8 to +5.5	90	Overtemperature alert	8-pin MSOP
TC651	Fan Manager	1	±1	±3	−40 to +125	+2.8 to +5.5	90	Overtemperature alert, Auto-shutdown	8-pin MSOP
TC652	Fan Manager	1	±1	±3	−40 to +125	+2.8 to +5.5	90	FanSense Fan Monitor, Overtemperature alert	8-pin MSOP
TC653	Fan Manager	1	±1	±3	−40 to +125	+2.8 to +5.5	90	FanSense Fan Monitor, Overtemperature alert, Auto-shutdown	8-pin MSOP
TC654	Dual SMBus Fan Manager	1	Note 1	Note 1	−40 to +85	+3.0 to +5.5	320	FanSense Fan Monitor, RPM data	10-pin MSOP
TC655	Dual SMBus Fan Manager	1	Note 1	Note 1	−40 to +85	+3.0 to +5.5	320	FanSense Fan Monitor, RPM data, Overtemperature alert	10-pin MSOP
TC664	Single SMBus Fan Manager	1	Note 1	Note 1	−40 to +85	+3.0 to +5.5	320	FanSense Fan Monitor, RPM data	10-pin MSOP
TC665	Single SMBus Fan Manager	1	Note 1	Note 1	−40 to +85	+3.0 to +5.5	320	FanSense Fan Monitor, RPM data, Overtemperature alert	10-pin MSOP
TC670	Predictive Fan Fault Detector	1	N/A	N/A	−40 to +85	+3.0 to +5.5	150	FanSense Fan Monitor, Programmable threshold	6-pin SOT-23

Closed-Loop Fan Controllers with SMBus/I²C Interface

Part #	# of Fan Drivers	PWM/Linear Control	# of Remote Temp. Monitors	Ambient Temp. Sensor	Typical Accuracy (°C)	Maximum Accuracy @ 25°C (°C)	Maximum Temperature Range (°C)	Vcc Range (V)	SMBus Alert	System Shutdown	Voltage Monitors	Description	Packages
EMC2112	1	Linear	3	1	±0.25	±1.0	0 to +85	+3.3 and +5	Yes	Yes	No	RPM-Based Fan Controller with Hardware Thermal Shutdown	20-pin QFN
EMC2103-1	1	PWM	1	1	±0.5	±1.0	–40 to +125	+3.0 to +3.6	Yes	Yes	No	RPM-Based Fan Controller with Hardware Thermal Shutdown	12-pin QFN
EMC2103-2	1	PWM	3	1	±0.5	±1.0	–40 to +125	+3.0 to +3.6	Yes	Yes	No	RPM-Based Fan Controller with Hardware Thermal Shutdown	16-pin QFN
EMC2103-4	1	PWM	3	1	±0.5	±1.0	–40 to +125	+3.0 to +3.6	Yes	Yes	No	RPM-Based Fan Controller with Hardware Thermal Shutdown and EEPROM loadable	16-pin QFN
EMC2104	2	PWM	4	1	±0.25	±1.0	–40 to +85	+3.0 to +3.6	Yes	Yes	Yes	Dual RPM-Based PWM Fan Controller with Hardware Thermal Shutdown	20-pin QFN
EMC2105	1	Linear	4	1	±0.25	±1.0	–40 to +85	+3.3 and +5.0	Yes	Yes	Yes	RPM-Based High-Side Fan Controller with Hardware Thermal Shutdown	20-pin QFN
EMC2106	2	PWM & Linear	4	1	±0.25	±1.0	–40 to +85	+3.3 and +5.0	Yes	Yes	Yes	RPM-Based High Side Fan Controller with Hardware Thermal Shutdown	28-pin QFN
EMC2113	1	PWM	3	1	±0.5	±1.0	–40 to +125	+3.0 to +3.6	Yes	Yes	No	Single RPM-Based Fan Controller with Multiple Temperature Zones and Hardware Thermal Shutdown	16-pin QFN
EMC2301	1	PWM	N/A	N/A	N/A	N/A	–40 to +125	+3.0 to +3.6	Yes	No	N/A	Single RPM-Based PWM Fan Speed Controller	8-pin MSOP
EMC2302	2	PWM	N/A	N/A	N/A	N/A	–40 to +125	+3.0 to +3.6	Yes	No	N/A	Dual RPM-Based PWM Fan Speed Controller	10-pin MSOP
EMC2303	3	PWM	N/A	N/A	N/A	N/A	–40 to +125	+3.0 to +3.6	Yes	No	N/A	Triple RPM-Based PWM Fan Speed Controller	12-pin QFN
EMC2305	5	PWM	N/A	N/A	N/A	N/A	–40 to +125	+3.0 to +3.6	Yes	No	N/A	Penta RPM-Based PWM Fan Speed Controller	16-pin QFN

Analog (Voltage Output) Temperature Sensor Products

Device	Accuracy @ 25°C (Typ./Max.)	Temperature Range (°C)	V_{DD} Min. (V)	V_{DD} Max. (V)	I_Q Max. (µA)	Slope (mV/°C)	Offset Voltage (Output @ 0°C) (mV)	Packages	Development Tools
MCP9700	1/4	−40 to +125	2.3	5.5	12	10	500	5-pin SOT-23, 5-pin SC-70, 3-pin TO-92	MCP9700DM-PCTL
MCP9700A	1/2	−40 to +125	2.3	5.5	12	10	500	5-pin SC-70	MCP9700DM-PCTL
MCP9701	1/4	−40 to +125	3.1	5.5	12	19.5	400	5-pin SC-70, 3-pin TO-92	–
MCP9701A	1/2	−40 to +125	3.1	5.5	12	19.5	400	5-pin SC-70	–
TC1046	0.5/2.0	−40 to +125	2.7	4.4	60	6.25	424	3-pin SOT-23	–
TC1047/A	0.5/2.0	−40 to +125	2.7	4.4	60	10	500	3-pin SOT-23	TC1047ADM-PCTL

Logic Output Temperature Sensor Products

Device	Accuracy @ 25°C (Typ./Max.)	Temperature Range (°C)	Temperature Set Points	V_{DD} Min. (V)	V_{DD} Max. (V)	I_Q Max. (µA)	Packages	Development Tools
TC620	1/3	−40 to +125	User-selectable, set by external resistor	4.5	18	400	8-pin PDIP, 8-pin SOIC	–
TC621	1/3	−40 to +125	User-selectable, set by external resistor	4.5	18	400	8-pin PDIP, 8-pin SOIC	–
TC622	1/5	−40 to +125	User-selectable, set by external resistor	4.5	18	600	8-pin PDIP, 8-pin SOIC, 5-pin TO-220	–
TC623	1/3	−40 to +125	User-selectable, set by external resistor	2.7	4.5	250	8-pin PDIP, 8-pin SOIC	–
TC624	1/5	−40 to +125	User-selectable, set by external resistor	2.7	4.5	300	8-pin PDIP, 8-pin SOIC	–
TC6501	0.5/4	−40 to +125	Factory programmed thresholds	2.7	5.5	40	5-pin SOT-23	–
TC6502	0.5/4	−40 to +125	Factory programmed thresholds	2.7	5.5	40	5-pin SOT-23	–
TC6503	0.5/4	−40 to +125	Factory programmed thresholds	2.7	5.5	40	5-pin SOT-23	–
TC6504	0.5/4	−40 to +125	Factory programmed thresholds	2.7	5.5	40	5-pin SOT-23	–

Thermocouple Conditioning IC Products

Device	Serial Communication	Cold–Junction Temperature Accuracy (Typ. ±°C)	Hot–Junction Temperature Accuracy (Typ. ±°C)	Thermocouple Open/short circuit detection	Temp. Range (°C)	Vdd Min. (V)	Vdd Max. (V)	Iq Max. (µA)	Packages	Development Tools
MCP9600	I²C	0.5	0.5	No	−40 to +125	2.7	5.5	500	20–pin MQFN	ADM00665
MCP9601	I²C	0.5	0.5	Yes	−40 to +125	2.7	5.5	500	20–pin MQFN	ADM00665
MCP96L00	I²C	0.5	2	No	−40 to +125	2.7	5.5	500	20–pin MQFN	ADM00665
MCP96L01	I²C	0.5	2	Yes	−40 to +125	2.7	5.5	500	20–pin MQFN	ADM00665
MCP96RL00	I²C	0.5	4	No	−40 to +125	2.7	5.5	500	20–pin MQFN	ADM00665
MCP96RL01	I²C	0.5	4	Yes	−40 to +125	2.7	5.5	500	20–pin MQFN	ADM00665

Selected Product Specifications

Operational Amplifiers

Device	# per Package	GBWP (kHz)	I_Q (Typ./Max.) (µA)	V_{OS} Max. (mV)	Temperature Range (°C)	Operating Voltage (V)	Packages	Development Tools
TC913A	2	1500	8500/1100	0.15	0 to +70	6.5 to 16	8-pin PDIP	
TC7650	1	2000	2000/3500	0.05	0 to +70	4.5 to 16	8-pin PDIP, 14-pin PDIP	–
TC7652	1	400	1000/3000	0.05	0 to +70	5 to 16	8-pin PDIP, 14-pin PDIP	–
MCP601	1, 2, 4	2800	230/325	2	–40 to +125	2.7 to 5.5	14-pin TSSOP, 8-pin PDIP, 8-pin SOIC, 5-pin SOT-23	–
MCP616	1, 2, 4	190	19/25	0.15	–40 to +85	2.3 to 5.5	PDIP-8, SOIC-8, MSOP-8	–
MCP6001	1, 2, 4	1000	100/170	7	–40 to +125	1.8 to 5.5	5-pin SOT-23, 5-pin SC-70	–
MCP6041	1, 2, 4	14	0.6/1	3	–40 to +125	1.4 to 5.5	14-pin TSSOP, 8-pin PDIP, 8-pin SOIC, 8-pin MSOP, 5-pin SOT-23	–
MCP6141	1, 2, 4	100	0.6/1	3	–40 to +125	1.4 to 5.5	14-pin TSSOP, 8-pin PDIP, 8-pin SOIC, 8-pin MSOP, 5-pin SOT-23	–
MCP6231	1, 2, 4	300	20/30	7	–40 to +125	1.8 to 5.5	14-pin TSSOP, 8-pin PDIP, 8-pin SOIC, 5-pin SOT-23, 5-pin SC-70	–
MCP6271	1, 2, 4	2000	120/240	3	–40 to +125	2.0 to 5.5	14-pin TSSOP, 8-pin PDIP, 8-pin SOIC, 8-pin MSOP, 5-pin SOT-23	–
MCP6281	1, 2, 4	5000	450/570	3	–40 to +125	7.2 to 5.5	14-pin TSSOP, 8-pin PDIP, 8-pin SOIC, 8-pin MSOP, 5-pin SOT-23	–
MCP6291	1, 2, 4	10,000	1000/1300	3	–40 to +125	2.4 to 5.5	14-pin TSSOP, 8-pin PDIP, 8-pin SOIC, 8-pin MSOP, 5-pin SOT-23	–

Voltage Reference

Device	V_{CC} Range	Output Voltage (V)	Max. Load Current (mA)	Initial Accuracy (%)	Temperature Coefficient (ppm/°C)	Max. Supply Current (µA @ 25°C)	Packages	Development Tools
MCP1525	2.7 to 5.5	2.5	±2	±1	50	100	3pin TO-92, 3-pin SOT-23B	–

Comparators

Device	# per Package	Typical Propagation Delay (µsec)	I_Q Max. (µA)	V_{OS} Max. (mV)	Operating Voltage (V)	Temperature Range (°C)	Packages	Development Tools
MCP6541	1	4	1	5	1.6 to 5.5	–40 to +85	8-pin PDIP, 8-pin SOIC, 8-pin MSOP, 5-pin SOT-23	–
MCP6542	2	4	1	5	1.6 to 5.5	–40 to +85	8-pin PDIP, 8-pin SOIC, 8-pin MSOP	–
MCP6543	1	4	1	5	1.6 to 5.5	–40 to +85	8-pin PDIP, 8-pin SOIC, 8-pin MSOP	–
MCP6544	4	4	1	5	1.6 to 5.5	–40 to +85	14-pin PDIP, 14-pin SOIC, 14-pin TSSOP	–

Programmable Gain Amplifiers (PGAs)

Device	Channels	–3 dB BW (MHz)	I_Q Typical (mA)	V_{OS} (µV)	Operating Voltage (V)	Temperature Range (°C)	Packages	Development Tools
MCP6S21	1	2 to 12	1.1	275	2.5 to 5.5	–40 to +85	8-pin PDIP, 8-pin SOIC, 8-pin MSOP	–
MCP6S22	2	2 to 12	1.1	275	2.5 to 5.5	–40 to +85	8-pin PDIP, 8-pin SOIC, 8-pin MSOP	–
MCP6S26	6	2 to 12	1.1	275	2.5 to 5.5	–40 to +85	14-pin PDIP, 14-pin SOIC, 14-pin TSSOP	–
MCP6S28	8	2 to 12	1.1	275	2.5 to 5.5	–40 to +85	16-pin PDIP, 16-pin SOIC	–

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