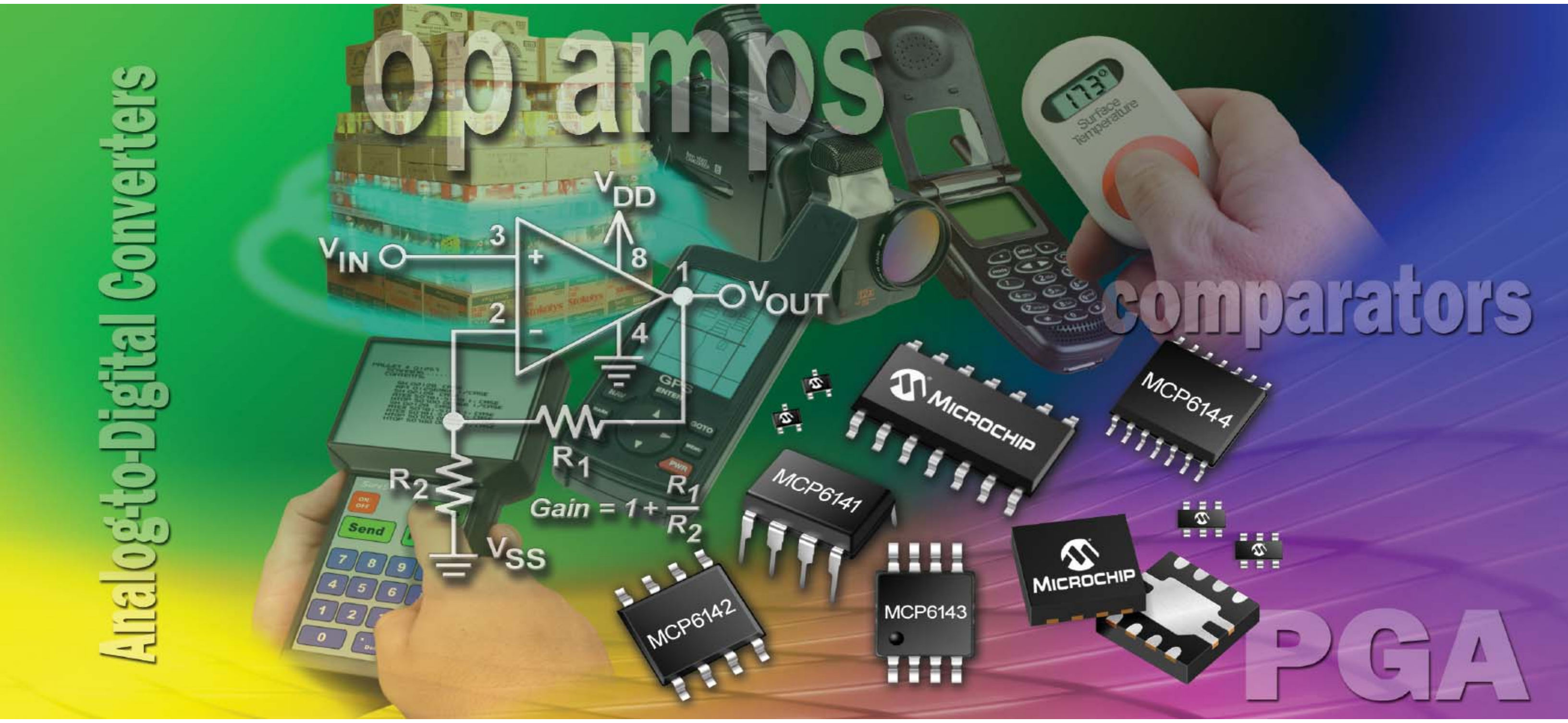
Analog and Interface Product Solutions

Signal Chain Design Guide

Devices For Use With Sensors



Design ideas in this guide use the following devices. A complete device list and corresponding data sheets for these products can be found at: www.microchip.com

Programmable Gain Amplifier
MCP6S2X Family (MCP6S21, MCP6S22, MCP6S26, MCP6S28)
MCP6S9X Family (MCP6S91, MCP6S92, MCP6S26, MCP6S93)

Analog-to-Digital Converters
MCP3002, MCP3301, MCP3550/1/3, MCP3221

Temperature Sensors
MCP9700, MCP9701, TC1047A

Operational Amplifiers
MCP602, MCP606/7/8/9, MCP607, MCP617, MCP619, MCP6022, MCP6024, MCP6042, TC7650/7652, TC913A/B

Comparators
MCP6541

DACs
MCP4821/2
MCP4921/2

Voltage References
MCP1525, MCP1541

Digital Potentiometers
MCP4011/2/3/4
MCP4021/2/3/4
MCP42010
MCP42050
MCP42100

MEASUREMENT OVERVIEW

Many system applications require the measurement of a physical or electrical condition, or the presence or absence of a known physical, electrical or chemical quantity. Analog sensors are typically used to indicate the magnitude or change in the environmental condition, by reacting to the condition and generating a change in an electrical property as a result.

Typical phenomena that are measured are:

- Electrical
- Magnetic
- Temperature
- Humidity
- Force, Weight, Torque and Pressure
- Motion and Vibration
- Flow
- Fluid Level and Volume
- Light and Infrared
- Chemistry

There are sensors that respond to these phenomena by producing the following electrical properties:

- Voltage
- Current
- Resistance
- Capacitance
- Charge

This electrical property is then conditioned by an analog circuit before being converted to a digital circuit. In this way, the environmental condition can be "measured" and the system can make decisions based on the result.

The table below provides an overview of typical phenomena, the type of sensor commonly used to measure the phenomena and electrical output of the sensor.

Summary Of Common Physical Conditions And Related Sensor Types

Phenomena	Sensor	Electrical Output
Magnetic	Hall Effect	Voltage
	Magneto-Resistive	Resistance
Temperature	Thermocouple	Voltage
	RTD	Resistance
	Thermistor	Resistance
	IC	Voltage
	Infrared	Current
	Thermopile	Voltage
Humidity	Capacitive	Capacitance
	Infrared	Current
Force, Weight, Torque, Pressure	Strain Gauge	Resistance
	Load Cell	Resistance
	Piezo-electric	Voltage or Charge
	Mechanical Transducer	Resistance, Voltage, Capacitance
Motion and Vibration	LVDT	AC Voltage
	Piezo-electric	Voltage or Charge
	Microphone	Voltage
	Ultrasonic	Voltage, Resistive, Current
	Accelerometer	Voltage
Flow	Magnetic Flowmeter	AC Voltage
	Mass Flowmeter	Resistance
	Ultrasound/Doppler	Frequency
	Hot-wire Anemometer	Resistance
	Mechanical Transducer (turbine)	Voltage
Fluid Level and Volume	Ultrasound	Time
	Mechanical Transducer	Resistance, Voltage
	Capacitor	Capacitance
	Switch	On/Off
	Thermal	Voltage
Light	Photodiode	Current
Chemical	pH Electrode	Voltage
	Solution Conductivity	Resistance
	CO Sensor	Voltage or Charge
	Photodiode (turbidity, colorimeter)	Current

MEASUREMENT OVERVIEW

Product Overviews

Operational Amplifiers and Comparators

Microchip Technology offers a broad portfolio of Operational Amplifiers (Op Amps), Comparators and Integrated Op Amp/ Comparators. These families offer single, dual or quad amplifiers in space-saving packages with low operating currents, and advanced CMOS technology.

The Op Amp families include devices that operate with quiescent current (I_Q) as low as 0.6 µA and others with Gain Bandwidth Product (GBWP) up to 10 MHz. These Op Amp families offer some of the lowest I_Q for a given GBWP in the industry. Additionally, these families operate on single supplies down to 1.4V, and have input offset voltages (V_{OS}) as low as ±15 µV (max.).

The Comparator families operate at low I_Q (0.6 µA to 7 µA). They offer better propagation delay and output drive than a similar op amp used as a comparator. The Integrated Op Amp/Comparators families have different combinations of op amps, comparators, and voltage references for the designer's convenience.

Programmable Gain Amplifier (PGA)

The MCP6S21/2/6/8 and MCP6S91/2/3 PGA families give the designer digital control over an amplifier using a serial interface (SPI bus). An input analog multiplexer with 1, 2, 6 or 8 inputs can be set to the desired input signal. The gain can be set to one of eight non-inverting gains: +1, 2, 4, 5, 8, 10, 16 and 32 V/V. In addition, a software shutdown mode offers significant power savings for portable embedded designs. This is all achieved in one simple integrated part that allows for considerably greater bandwidth, while maintaining a low supply current. Systems with multiple sensors are significantly simplified.

Analog-to-Digital Converters (ADC)

Microchip offers a broad portfolio of high-precision Delta-Sigma, SAR and Dual Slope A/D Converters. The MCP3550/ 1/3 delta-sigma ADCs offer up to 22-bit resolution with only 120 µA typical current consumption in a small 8-pin MSOP package. The MCP300X (10-bit), MCP320X (12-bit) and MCP330X (13-bit) SAR ADCs combine high performance and low power consumption in a small package, making them ideal for embedded control applications. The TC5XX Dual Slope ADC devices offer another alternative with up to 17-bits of conversion resolution.

Voltage References

Microchip offers the MCP15XX family of low power and low dropout precision Voltage References. The family includes the MCP1525 with an output voltage of 2.5V and the MCP1541 with an output voltage of 4.096V. Microchip's voltage references are offered in SOT23-3 and TO-92 packages.

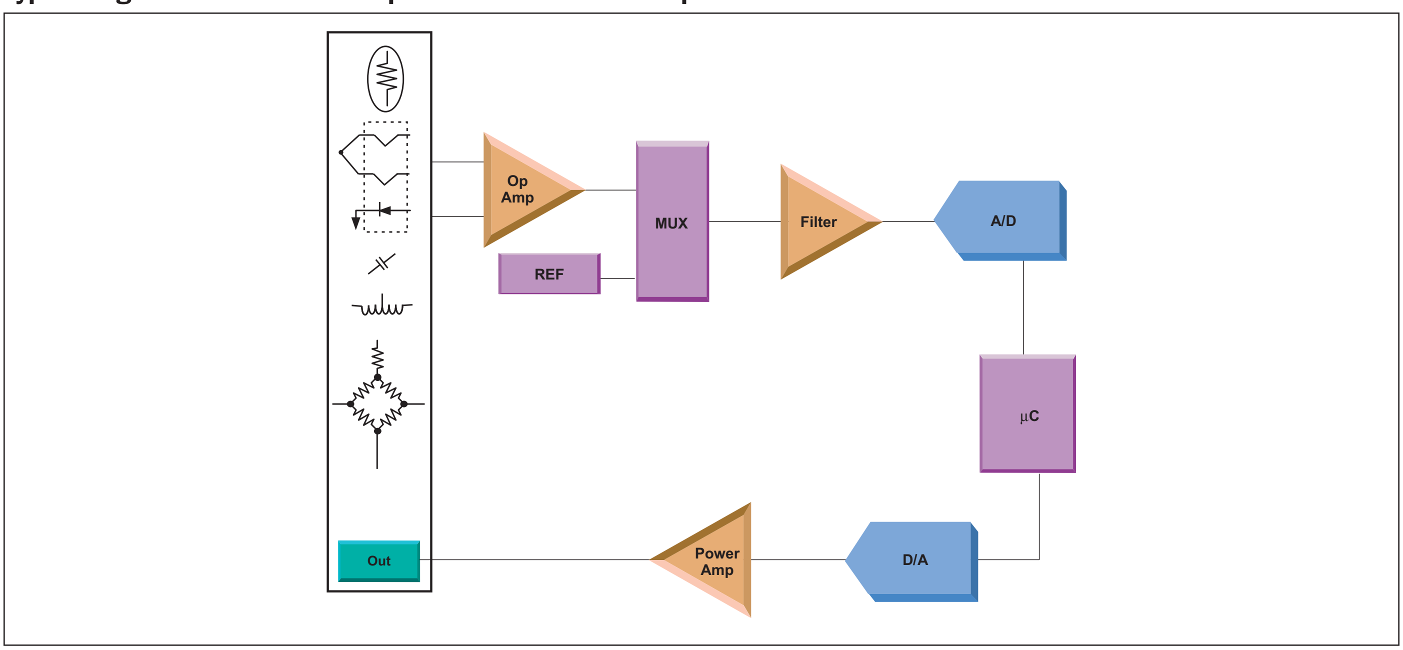
Digital Potentiometers

Microchip's families of digital potentiometers (MCP41XXX, MCP42XXX, MCP401X and MCP402X) offer high performance, low power and volatile/non-volatile options in small packages. The non-volatile devices offer a WiperLock™ Technology feature.

Digital-to-Analog Converters (DAC)

Microchip has a number of Digital-to-Analog Converters that range from high performance 12-bit devices to cost effective 8-bit devices. The MCP4821/2 family of 12-bit DACs combines high performance with an internal reference voltage and SPI interface. The MCP4921/2 family is similar and allows for an external reference. Both families provide high accuracy and low noise, and are ideal for industrial applications where calibration or compensation of signals (such as temperature, pressure and humidity) is required. The TC1320/1 family of DACs has 8 and 10 bit precision that uses the 2 wire SMBus/I²C™ serial interface protocol.

Typical Signal Chain Control Loop With Various Sensor Inputs



LOCAL SENSOR AMPLIFIER APPLICATIONS

Local Sensing

Local sensors are located relatively close to their signal conditioning circuits, and the noise environment is not severe. Non-inverting amplifiers are a good choice for amplifying the sensors' output because they require a minimal amount of discrete components. Either op amps or PGAs will support most of these applications.

Key Amplifier Features:

- Single-ended Input
- Rail-to-Rail Input/Output
- Amplifier Gain Bandwidth Product

Products:

- MCP601/2/3/4
- MCP606/7/8/9
- MCP6001/2/4
- MCP6041/2/3/4
- MCP6141/2/3/4
- MCP6231/2/4
- MCP6241/2/4
- MCP6271/2/3/4/5
- MCP6281/2/3/4/5
- MCP6291/2/3/4/5
- MCP6021/2/3/4
- MCP6S21/2/6/8
- MCP6S91/2/3

Sensors and Applications:

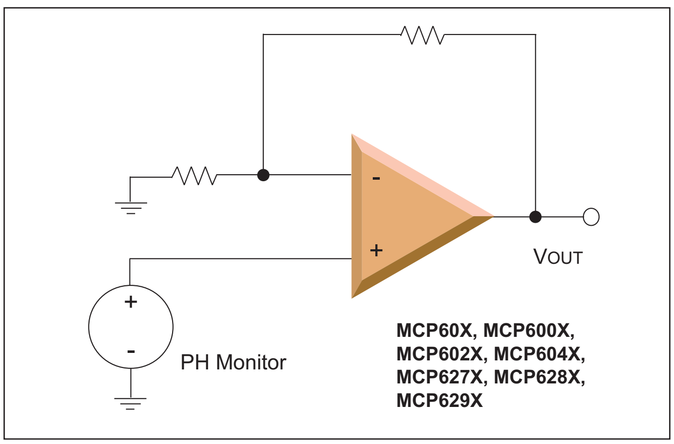
Single Sensors

- Thermistors for battery chargers and power supply temperature protection
- Humidity Sensors for process control
- Pyroelectric infrared intrusion alarms, motion detection and garage door openers
- Smoke and fire sensors for home and office
- Charge amplifier for Piezoelectric Transducer detection
- Thermistor for battery chargers and home thermostats
- LVDT position and rotation sensors for industrial control
- Hall effect sensors for engine speed sensing and door openers
- Photoelectric infrared detector
- Photoelectric motion detectors, flame detectors, intrusion alarms

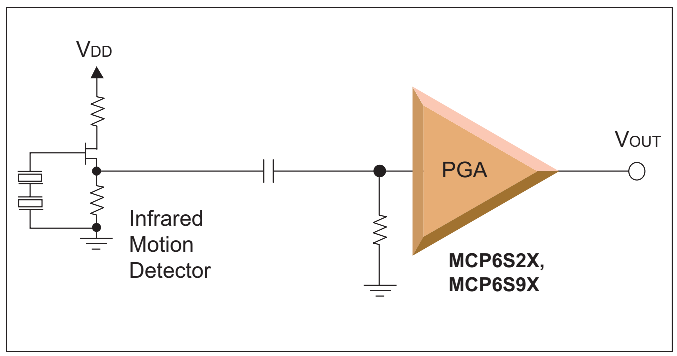
Multiple Local Sensor Applications

- Temperature measurement at multiple points on a Printed Circuit Board (PCB)
- Sensors that require temperature correction

Classic Gain Amplifier



Motion Detector Circuit



Product specifications can be found on pages 15-18.

REMOTE SENSOR AMPLIFIER APPLICATIONS

Remote Sensing

All sensors in a high noise environment should be considered as remote sensors. Also, sensors not located on the same PCB as the signal conditioning circuitry are remote. Remote sensing applications typically use a differential amplifier or an instrumentation amplifier.

Key Amplifier Features:

- Differential Input
- Large CMR
- Small Vos

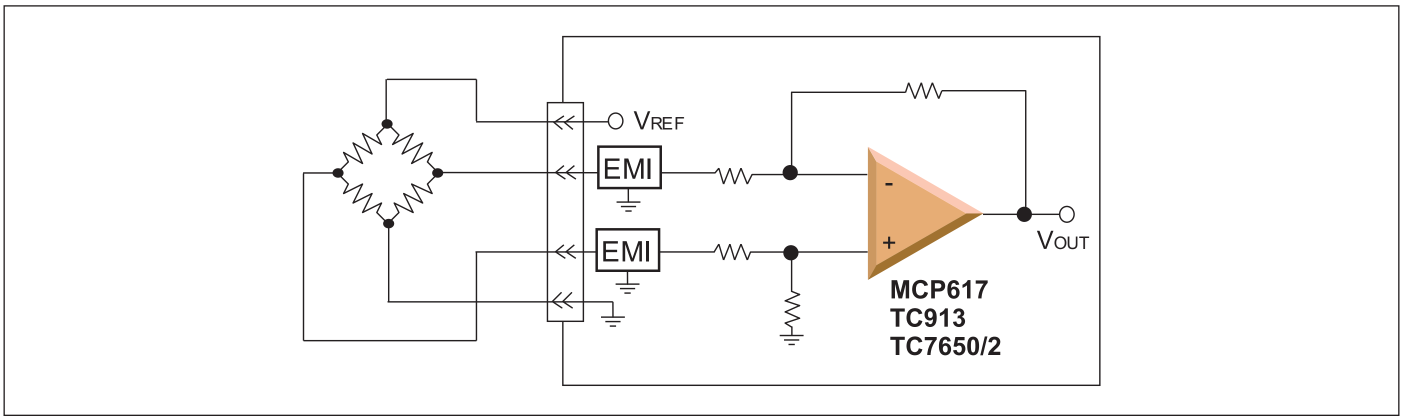
Products:

- MCP616/7/8/9
- TC913A/B
- TC7650/7652

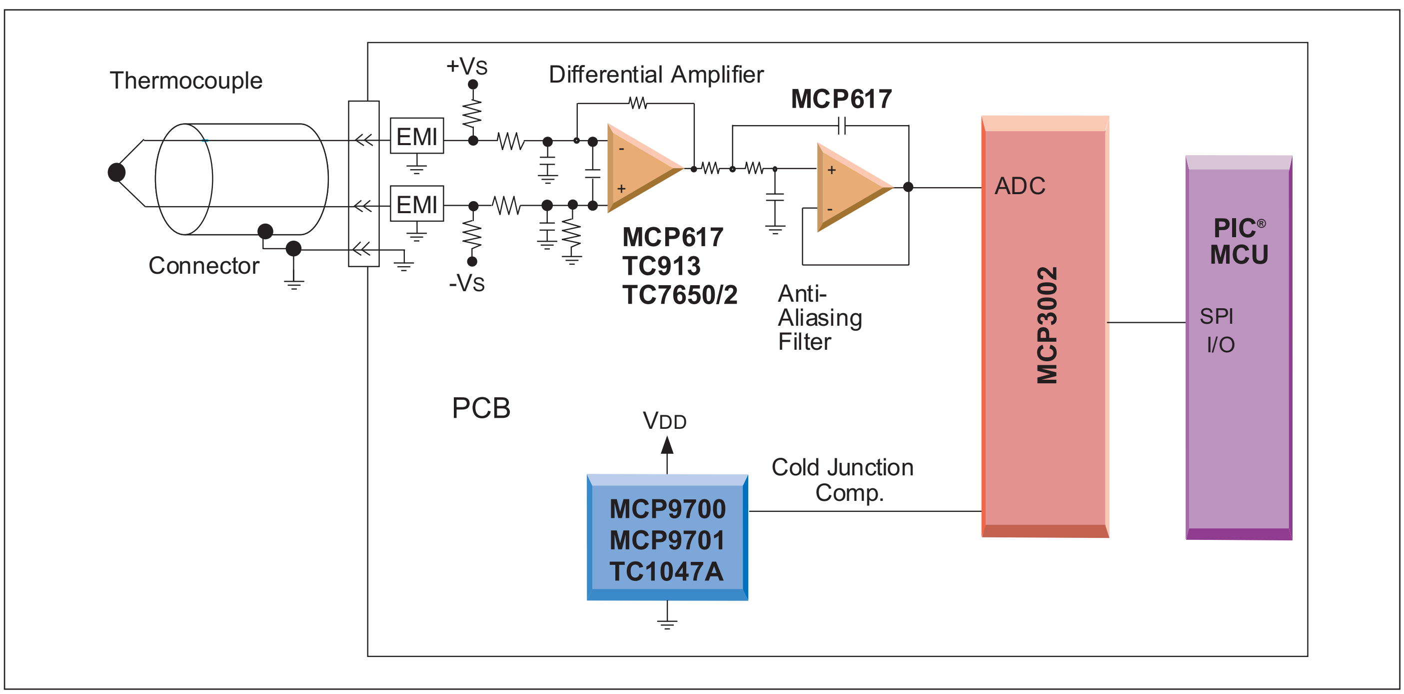
Sensors and Applications:

- High temperature sensors
- Thermocouples for stoves, engines and process control
- RTDs for ovens and process control
- Wheatstone Bridges
- Pressure Sensors for automotive and industrial control
- Strain gauges for engines
- Low side current monitors for motors and batteries

Differential Amplifier



Remote Thermal Sensor



Product specifications can be found on pages 15-18.

AMPLIFIER: EXAMPLE DESIGNS WITH OSCILLATORS FOR RESISTIVE AND CAPACITIVE SENSORS

RC Operational Amplifier Oscillators For Sensor Applications

Op Amp or state-variable oscillators can be used to accurately measure resistive and capacitive sensors. Oscillators do not require an analog-to-digital converter and provide a sensor measurement whose accuracy is only limited by the accuracy of the reference clock signal.

State-variable oscillators are often used in sensor conditioning applications because they have a reliable start-up and a low sensitivity to stray capacitance. Absolute quartz pressure sensors and humidity sensors are examples of capacitive sensors that can use the state-variable oscillator. Also, this circuit can be used with resistive sensors, such as RTDs, to provide temperature-to-frequency conversion.

The block diagram below shows a typical system level design, including the state-variable oscillator, PIC® microcontroller and temperature sensor (used for temperature correction).

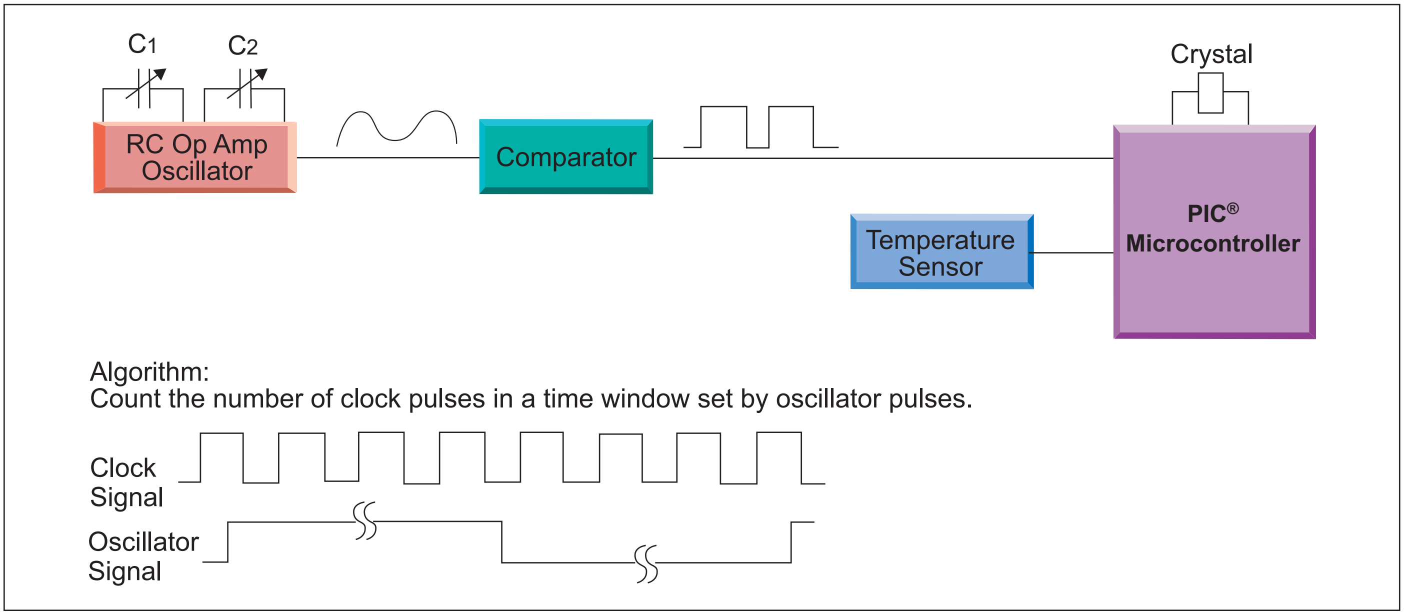
Resistive Sensors:

- RTDs
- Humidity
- Thermistors

Capacitive Sensors:

- Humidity
- Pressure
- Oil Level

Time-Based Resistor/Capacitor Measurement Circuit



Product specifications can be found on pages 15-18.

AMPLIFIER: EXAMPLE DESIGNS WITH OSCILLATORS FOR RESISTIVE AND CAPACITIVE SENSORS

State-Variable Oscillator

The state-variable's three op amp topology shown below provides for a more dependable oscillation start-up than a single op amp oscillator. The output frequency is proportional to the square root of the product of two capacitors (i.e., freq. $\propto (C_1 \times C_2)^{1/2}$).

Attributes:

- Precision circuit for either resistive or capacitive sensors
- Reliable oscillator start-up
- Circuit topology is relatively immune from stray capacitance, thus circuit can be used to accurately sense small valued capacitive sensors located off the PCB
- Can use a quad op amp, with the fourth op amp used to buffer the $V_{DD}/2$ voltage

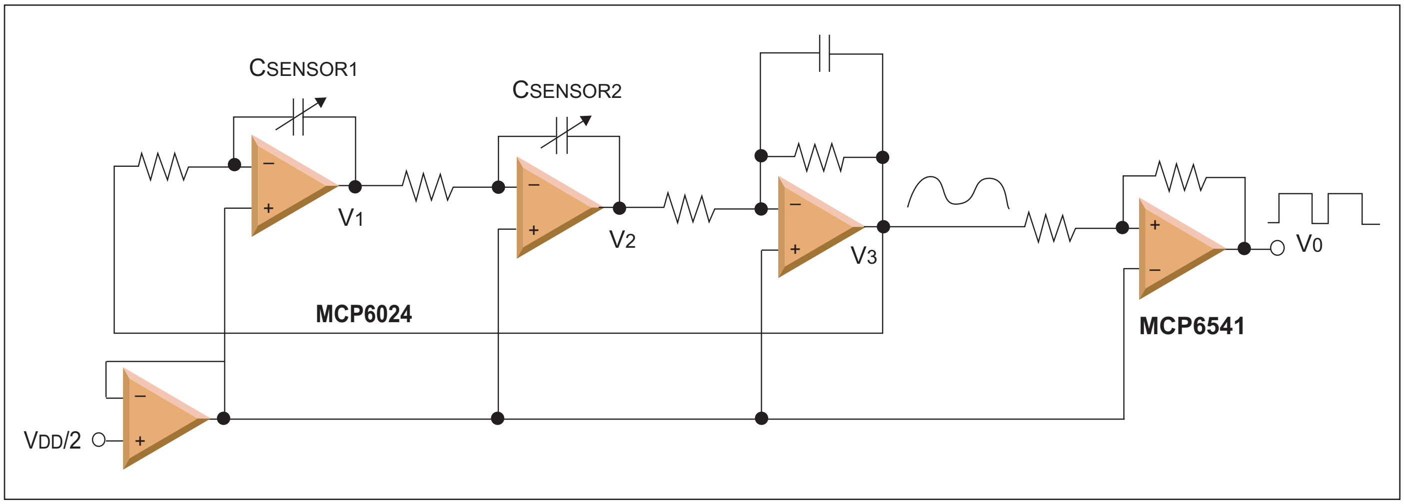
Products:

- MCP6001/2/4
- MCP6021/2/3/4
- MCP6231/2/4
- MCP6241/2/4
- MCP6271/2/3/4
- MCP6281/2/3/4
- MCP6291/2/3/4
- MCP6541/2/3/4
- MCP6546/7/8/9

Related Application Note:

AN866 Designing Operational Amplifier Oscillator Circuits for Sensor Applications (available on the Microchip web site at: www.microchip.com)

State-Variable Oscillator Measurement of Capacitive Sensors



Product specifications can be found on pages 15-18.

AMPLIFIER: EXAMPLE DESIGNS

Wheatstone Bridge Sensor Circuit

Sensors for temperature, pressure, load or other physical excitation quantities are most often configured in a Wheatstone bridge configuration. The bridge can have anywhere from one to all four elements reacting to the physical excitation, and should be used in a ratiometeric configuration when possible, with the system reference driving both the sensor and the ADC voltage reference. One example sensor from GE NovaSensor is an absolute pressure sensor, shown below, a four element varying bridge.

One solution is to use the MCP355X family of delta sigma ADCs. When designing with the MCP355X family of 22-bit delta-sigma ADCs, the initial step should be to evaluate the sensor performance and then determine what steps (if any) should be used to increase the overall system resolution when using the MCP355X. In many situations, the MCP355X devices can be used to directly digitize the sensor output, eliminating any need for external signal conditioning circuitry.

Using the absolute pressure sensor as our Wheatstone bridge example, the NPP-301 device has a typical full scale output of 60 mV when excited with a 3V battery. The pressure range for this device is 100 kPa. The MCP3551 has a output noise specification of 2.5 μV_{RMS}.

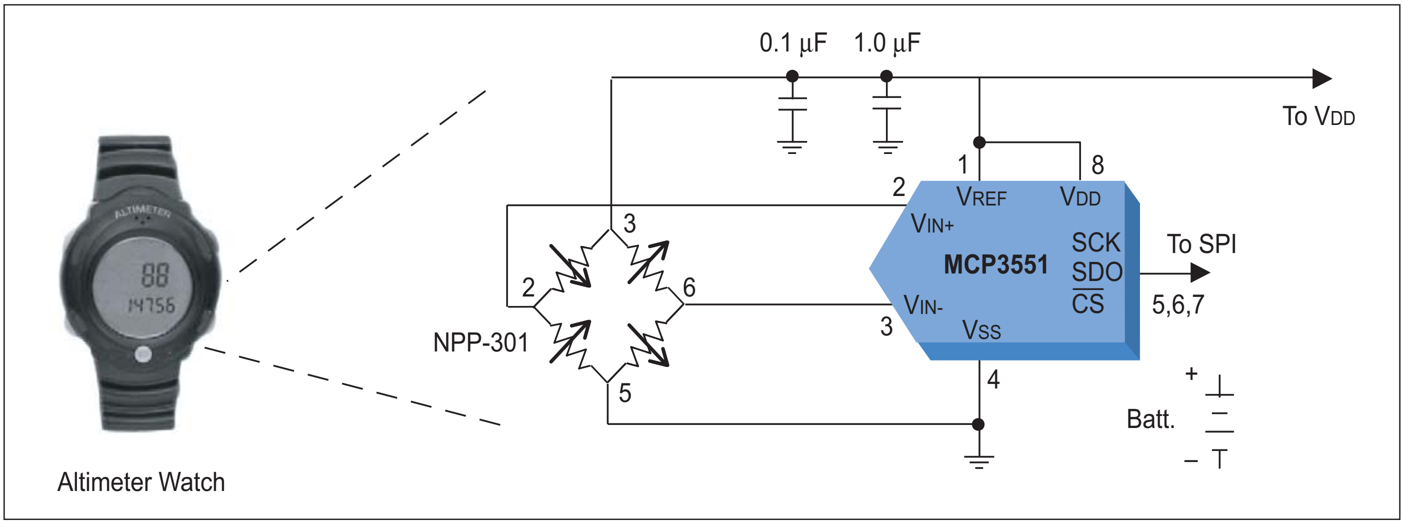
The following equation is a first order approximation of the relationship between pressure in pascals (P) and altitude (h), in meters.

$$\log(P) \approx 5 - \frac{h}{15500}$$

Using 60 mV as the full scale range and 2.5 µV as the resolution, the resulting resolution from direct digitization in meters is 0.64 meters or approximately 2 feet.

It should be noted that this is only used as an example for discussion; temperature effects and the error from a first order approximation must be included in final system design.

Example of Direct Digitization Application



Product specifications can be found on pages 15-18.

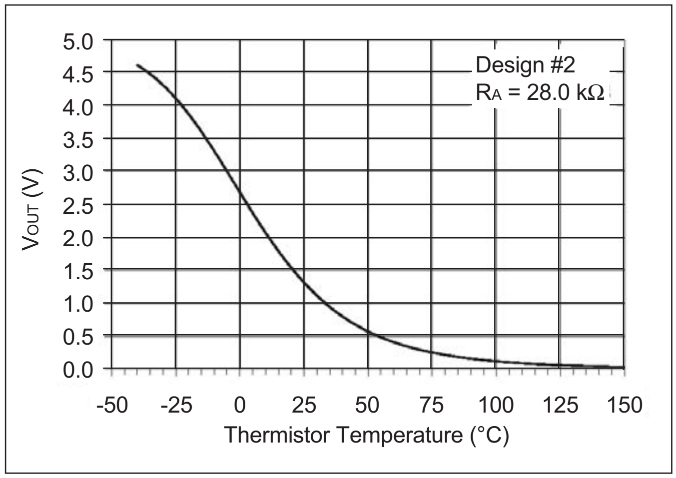
THERMISTOR SOLUTION

Thermistor Solution with PGA

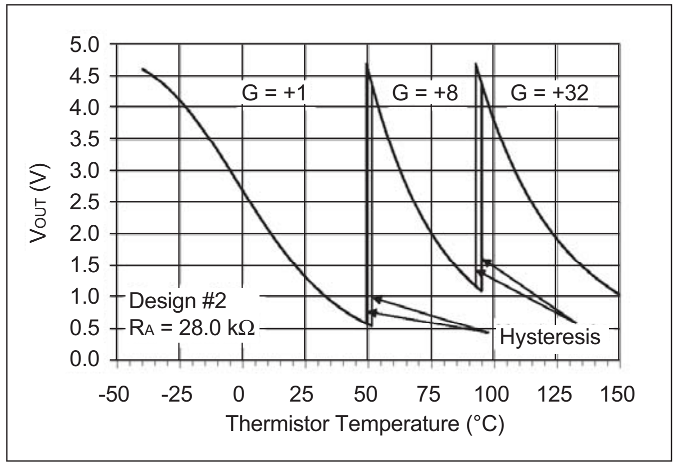
Typically, the inherent non-linearity of a thermistor is improved by biasing the thermistor in a resistive ladder circuit to linearize the temperature-to-voltage conversion. The divider voltage is directly connected to an ADC to digitize the measurement. However, at hot and cold temperature extremes the non-linearity of this approach is much greater with reduced change in voltage, which results in lower accuracy. This requires higher resolution and more costly ADC.

The solution to the reduced accuracy is to use a PGA (as shown in the circuit below) and gain the voltage at the non-linear region. For example, the “Voltage Divider Output” figure shows the output voltage of a 10 kΩ thermistor over the operating temperature. The divider resistor of 28 kΩ was selected to output approximately a linear temperature change from -40°C to +50°C. For temperatures greater than 50°C, the change cannot be accurately measured using a 10-bit ADC. The “PGA Output Voltage” figure shows how the PGA can be used to increases the dynamic range. The PGA gains the divider voltage by +8V/V from 50°C to 90°C and +32V/V from 90°C to 150°C. The gains are equivalent to a resolution increase of 3-bit and 5-bit, respectively. This increases the ADC resolution at a reasonable cost. A lookup table can be used to linearlize the temperature data (see Application Note AN897: *Thermistor Temperature Sensing with MCP6SX2 PGAs* for details).

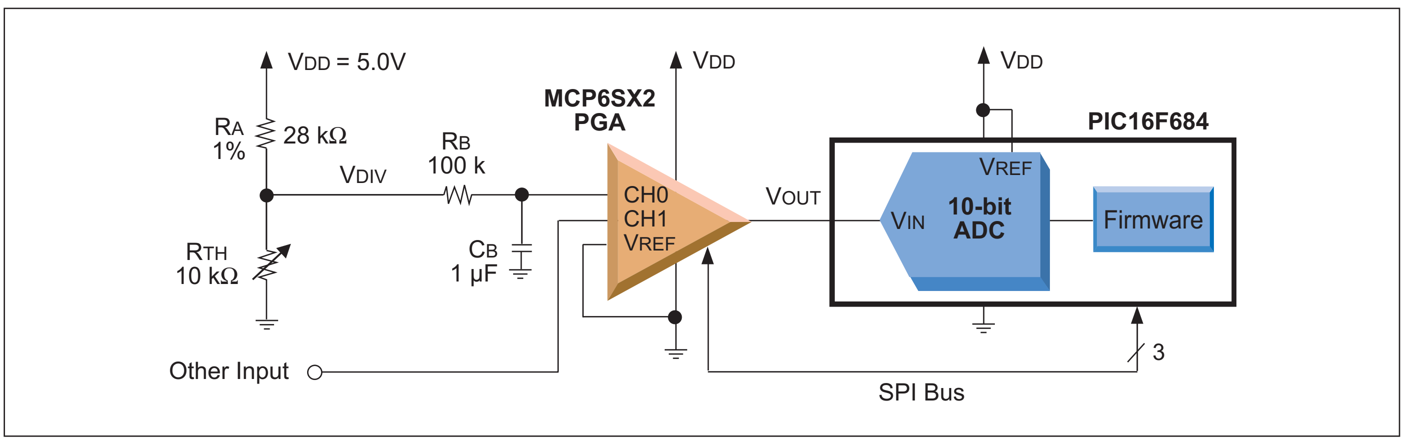
Voltage Divider Output



PGA Output Voltage



Thermistor PGA Circuit Block Diagram



Product specifications can be found on pages 15-18.

RESISTIVE TEMPERATURE DETECTOR (RTD) SOLUTIONS

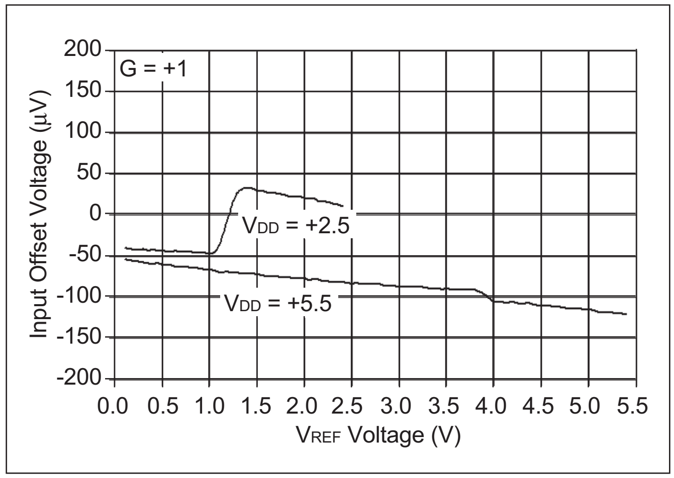
RTD Solution With PGA

Resistive Temperature Detectors (RTDs) are highly accurate and repeatable temperature sensing elements. When using these sensors a robust instrumentation circuit is required. If there is more than one sensor in the system, duplicating the instrumentation circuit for the additional sensors may be costly. The PGA's characteristics of low input offset voltage of 80 µV (typ.) at 2.5V reference voltage and gain error of 0.1% (typ.) for G ≥ +2V/V lends itself well for such applications. The PGA can be used to connect multiple sensors to a single instrumentation circuit and the user can digitally select and amplify each sensor using the SPI interface.

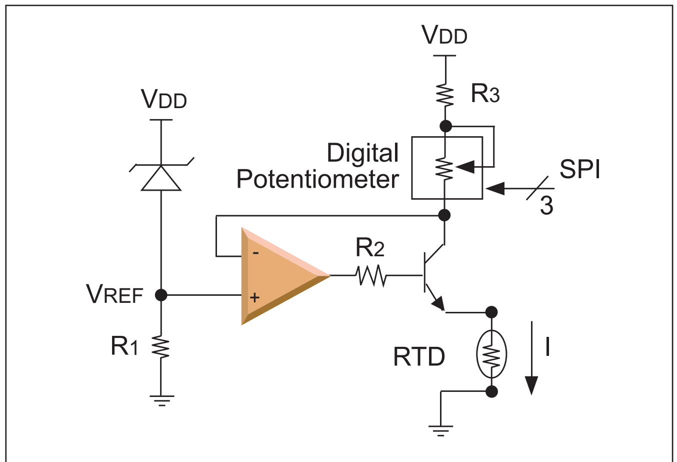
Since RTD is not a self-powered sensor such as a thermocouple, self-heating from the biasing current could compromise sensor accuracy. The biasing constant current source needs to be adjusted so that the sensor output voltage has adequate dynamic range to interface with an ADC. However, increasing the biasing current increases the system error due to self-heating. In such application, the PGA can be used to amplify the sensor output. This helps lower the biasing current magnitude and reduce the effect of self-heating. An instrumentation amplifier can be used to scale the PGA output.

The constant current source circuit for each sensor can be optimized using a digital potentiometer. Microchip provides a number of digital potentiometer families that allow the user to serially fine tune an analog circuits. The user can adjust the digital potentiometert wiper position using an SPI interface or a single wire interface for an up/down programming. The "constant current source" figure shows how to implement the digital potentiometer. The PGA and all digital potentiometers can be daisy-chained using a 3-wire SPI interface from the controller. This solution provides cost effective flexibility to the temperature sensing application.

Input Offset Voltage vs. VREF Voltage

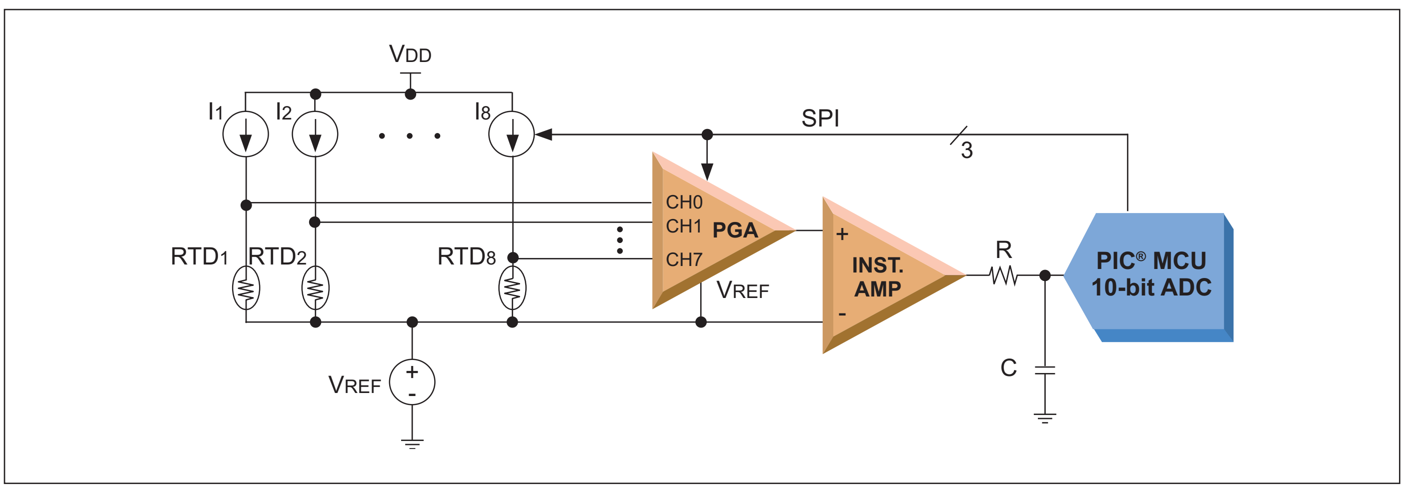


Constant Current Source



$$I = \frac{(V_{DD} - V_{REF})}{(R3 + R_{digitalpotentiometer})}$$

Multiple RTD Interface Using the PGA



Product specifications can be found on pages 15-18.

FilterLab® Active Filter Design Software Tool

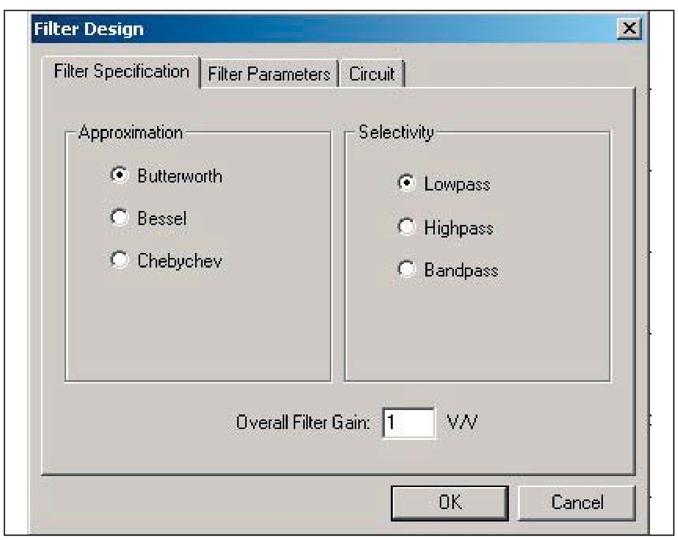
All signal conditioning and sensor circuits need filters. Analog filters are used to reduce noise and interference that may drive a design out of its linear operating range. They also serve as anti-aliasing filters for ADCs, and as smoothing or reconstruction filters for DACs. Digital filters provide further noise reduction, but cannot replace analog filters in these particular functions.

FilterLab is an innovative software tool that simplifies active op amp filter design. Available at no cost from Microchip's web site (www.microchip.com), the FilterLab active filter software design tool provides full schematic diagrams of the filter circuit with component values. In addition, FilterLab software provides plots of the frequency, group delay and phase response of the filter.

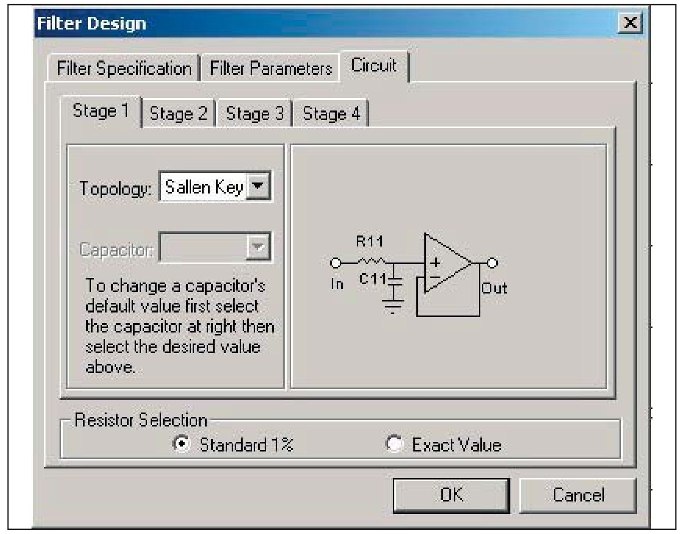
FilterLab allows the design of low pass, band pass and high pass filters up to an 8th order filter with Chebyshev, Bessel or Butterworth responses from frequencies of 0.1 Hz to 1 MHz. Users can select a flat passband or sharp transition from passband to stopband. Options, such as minimum ripple factor, sharp transition and linear phase delay, are available. Once the filter response has been identified, FilterLab software generates the frequency response and the circuit. For maximum design flexibility, changes in capacitor values can be implemented to fit the demands of the application. FilterLab will recalculate all values to meet the desired response, allowing real-world values to be substituted or changed as part of the design process.

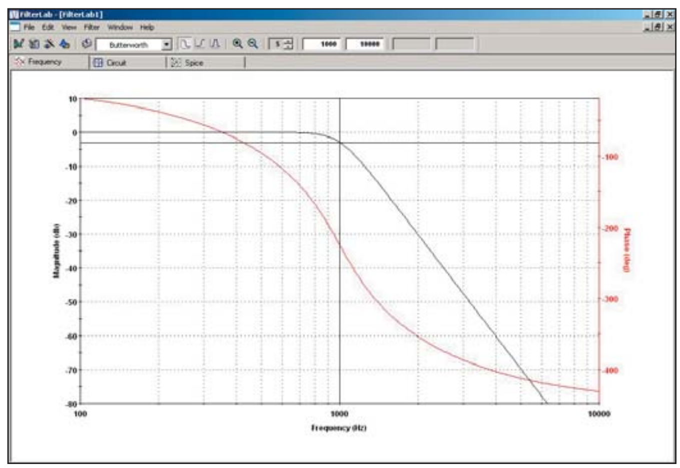
FilterLab also generates a SPICE model of the designed filter. Extraction of this model will allow time domain analysis in SPICE simulations, streamlining the design process.

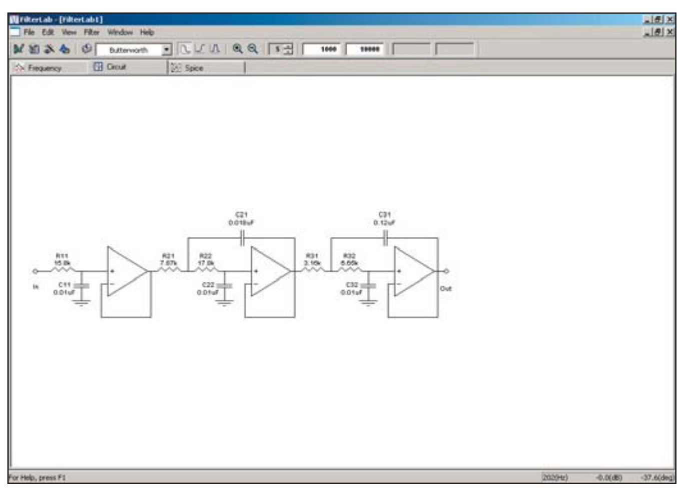
FilterLab® Screen Captures



FilterLab® Screen Captures (Continued)







DEVELOPMENT TOOLS

MXDEV® Analog Evaluation System

The MXDEV® Analog Evaluation System is a versatile and easy-to-use system for evaluating the mixed-signal products of the MCP product line. The system is used with a PC and consists of two parts: the DVMCPA Driver Board with associated MXLAB® software, which provides data acquisition, analysis and display in a Windows environment; and the DVXXXXX Evaluation Board, which contains the device to be evaluated.

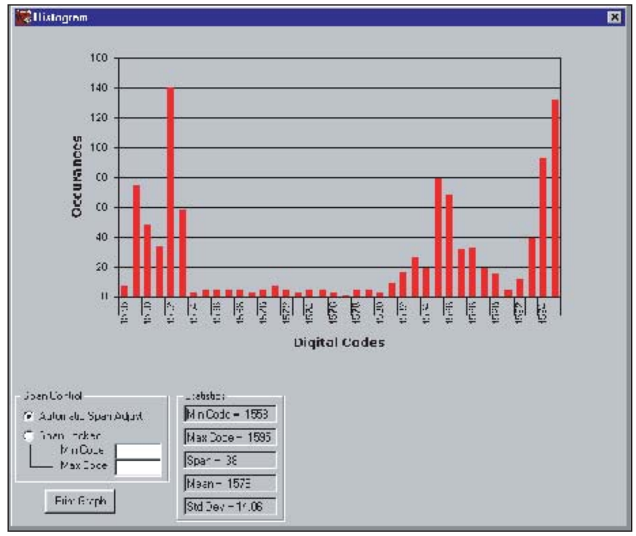
The DV42XXX digital potentiometer evaluation board shows the MCP42XXX being used in many popular digital applications. These circuits include programmable gain circuits, a programmable filter circuit and a programmable circuit. Digital potentiometer tools within the MXLAB system calculate wiper values for these circuits based on user inputs of gain (in dB or V/V), filter cutoff frequency and approximation method, and offset voltage. In addition, an ADC is on-board that allows analysis of these circuits, using the time and frequency domain tools of the MXLAB software.

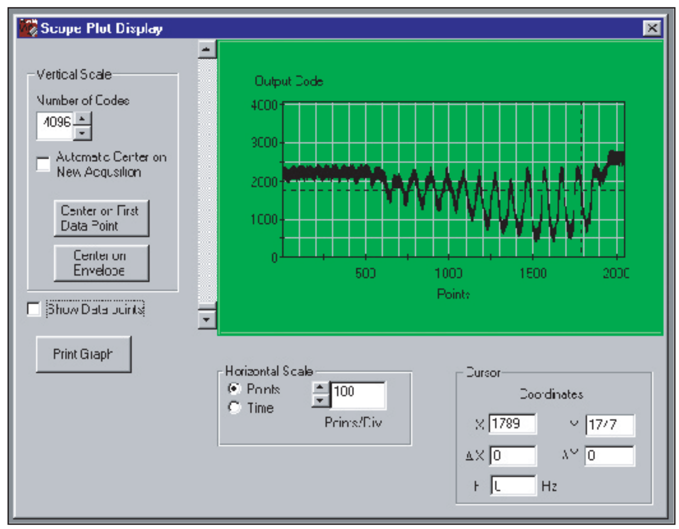
The MXLAB software tool provides data acquisition, analysis and display in a Windows® system environment. Additionally, analysis can be made of the digital potentiometer shutdown, reset and daisy-chain operations. The MXLAB software can determine digital potentiometer settings based on gain inputs (dB or V/V), filter cutoff frequencies and offset voltage levels. The MXLAB software can be downloaded free from the Microchip web site at www.microchip.com.

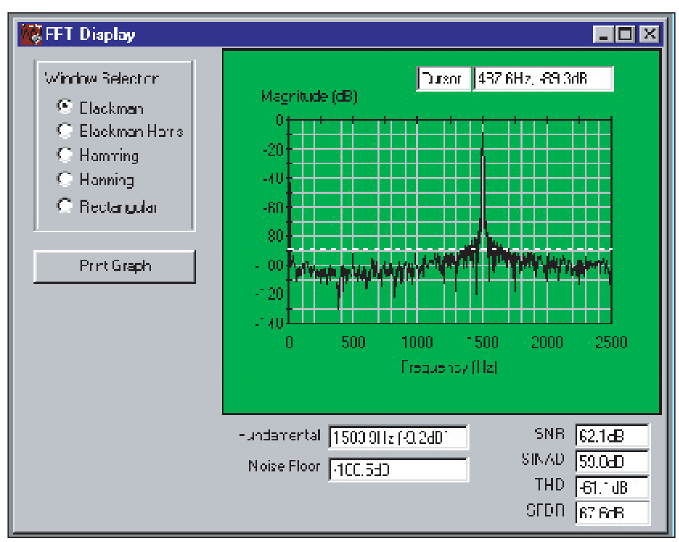
The following tools are associated with MXLAB software:

- Fast Fourier Transform (FFT)
- Histogram
- Oscilloscope
- Real-time numeric
- Real-time stripchart
- Data list

MXLAB® Screen Captures







RELATED SUPPORT MATERIAL

The following Application Notes are available on the Microchip web site: **www.microchip.com.**

Application Notes

Op Amps

AN679: *Temperature Sensing Technologies*

Covers the most popular temperature sensor technologies and helps determine the most appropriate sensor for an application.

AN681: *Reading and Using Fast Fourier Transformation (FFT)*

Discusses the use of frequency analysis (FFTs), time analysis and DC analysis techniques. It emphasizes Analog-to-Digital converter applications.

AN684: *Single Supply Temperature Sensing with Thermocouples*

Focuses on thermocouple circuit solutions. It builds from signal conditioning components to complete application circuits.

AN685: *Thermistors in Single Supply Temperature Sensing Circuits*

Shows several application circuits for thermistors. Discusses design tradeoffs and the advantages of thermistors.

AN687: *Precision Temperature Sensing with RTD Circuits*

Reviews RTDs (Resistive Temperature Devices) and their application circuits.

AN695: *Interfacing Pressure Sensors to Microchip's Analog Peripherals*

Shows how to condition a Wheatstone bridge sensor using simple circuits. A piezoresistive pressure sensor application is used to illustrate the theory.

AN699: *Anti-Aliasing, Analog Filters for Data Acquisition Systems*

A tutorial on active analog filters and their most common applications.

AN722: *Operational Amplifier Topologies and DC Specifications*

Defines op amp DC specifications found in a data sheet. It shows where these specifications are critical in application circuits.

AN723: *Operational Amplifier AC Specifications and Applications*

Defines op amp AC specifications found in a data sheet. It shows where these specifications are critical in application circuits.

AN866: *Designing Operational Amplifier Oscillator Circuits For Sensor Applications*

Gives simple design procedures for op amp oscillators. These circuits are used to accurately measure resistive and capacitive sensors.

AN884: *Driving Capacitive Loads With Op Amps*

Explains why all op amps tend to have problems driving large capacitive loads. A simple, one resistor compensation scheme is given that gives much better performance.

AN951: *Amplifying High-Impedance Sensors – Photodiode Example*

Shows how to condition the current out of a high-impedance sensor. A photodiode detector illustrates the theory.

AN990: *Analog Sensor Conditioning Circuits – An Overview*

Gives an overview of the many sensor types, applications and conditioning circuits.

AN1014: *Measuring Small Changes in Capacitive Sensors*

Small capacitive sensors require specialized circuitry to measure. The circuit discussed here focuses on a circuit that minimizes the parts count and resolves small changes in capacitance.

AN1016: *Detecting Small Capacitive Sensors Using the MCP6291 and PIC16F690 Devices*

The circuit discussed here uses an op amp and a microcontroller to implement a dual slope integrator and timer. It gives accurate results, and is appropriate for small capacitive sensors, such as capacitive humidity sensors.

Digital Potentiometers

AN691: *Optimizing the Digital Potentiometer in Precision Circuits*

In this application note, circuit ideas are presented that use the necessary design techniques to mitigate errors, consequently optimizing the performance of the digital potentiometer.

AN692: *Using a Digital Potentiometer to Optimize a Precision Single Supply Photo Detect*

This application note shows how the adjustability of the digital potentiometer can be used to an advantage in photosensing circuits.

RELATED SUPPORT MATERIAL

Delta-Sigma ADC

AN1007: *Designing with the MCP3551 Delta-Sigma ADC*

This application note discusses various design techniques to follow when using the MCP355X family of 22-bit ADCs.

SAR ADC

AN246: *Driving the Analog Inputs of a SAR A/D Converter*

This application note delves into the issues surrounding the SAR converter's input and conversion nuances to insure that the converter is handled properly from the beginning of the design phase.

AN688: *Layout Tips for 12-Bit A/D Converter Application*

This application note provides basic 12-bit layout guidelines, ending with a review of issues to be aware of. Examples of good layout and bad layout implementations are presented throughout.

AN693: *Understanding A/D Converter Performance Specifications*

This application note describes the specifications used to quantify the performance of A/D converters and give the reader a better understanding of the significance of those specifications in an application.

AN842: *Differential ADC Biasing Techniques, Tips and Tricks*

True differential converters can offer many advantages over single-ended input A/D Converters (ADC). In addition to their common mode rejection ability, these converters can also be used to overcome many DC biasing limitations of common signal conditioning circuits.

AN845: *Communicating With The MCP3221 Using PICmicro® Microcontrollers*

This application note will cover communications between the MCP3221 12-bit A/D Converter and a PICmicro® microcontroller. The code supplied with this application note is written as relocatable assembly code.

Dual Slope ADC

AN780: *15-Kilogram Scale Using the TC520 (TC500/A, TC520)*

This project takes into account all aspects of a functional scale: Dynamic Range, Strain Gauge Compensation, Zeroing, Oversampling, Units Conversion (kilograms to pounds).

AN789: *Integrating Converter Analog Processor (TC500A)*

Today, design engineers rely more on microprocessors and microcontrollers to support their applications. Compatible Analog-to-Digital (A/D) and Digital-to-Analog (A/D) converters have greatly increased the flexibility of interface and control circuits.

Programmable Gain Amplifier (PGA)

AN248: Interfacing MCP6S2X PGAs to PICmicro® Microcontroller

This application note shows how to program the six channel MCP6S26 PGA gains, channels and shutdown registers using the PIC16C505 microcontroller.

AN251: *Bridge Sensing with the MCP6S2X PGAs*

Describes how an external A/D converter and a PGA can easily be used to convert the difference voltage from resistor bridge sensors to usable digital words for manipulation by the microcontroller.

AN865: *Sensing Light with a Programmable Gain Amplifier*

This application notes discusses how Microchip's Programmable Gain Amplifiers (PGAs) can be effectively used in position photo sensing applications minus the headaches of amplifier stability.

AN897: *Thermistor Temperature Sensing with MCP6SX2 PGAs*

Shows how to use a Programmable Gain Amplifier (PGA) to linearize the response of a thermistor, and to achieve a wider temperature measurement range.

TB065: Linear Circuit Devices for Applications in Battery Powered Wireless Systems

This technical brief introduces the reader to Microchip broad portfolio of linear circuit devices.

SELECTED PRODUCT SPECIFICATIONS

See Microchip's Product Selector Guide for complete product selection and specifications.

Programmable Gain Amplifiers

Device	Channels	-3dB BW (MHz) Typ.	I_Q (µA) Max.	V_{OS} (±µV) Max.	Supply Voltage (V)	Temperature Range (°C)	Rail-to-Rail I/O	Features	Packages	Recommended Demo Boards
MCP6S21	1	2 to 12	1,350	275	2.5 to 5.5	-40 to +85	I/O	SPI, 8 gain steps, software shutdown	PDIP-8, SOIC-8, MSOP-8	MCP6S2XEV
MCP6S22	2	2 to 12	1,350	275	2.5 to 5.5	-40 to +85	I/O	SPI, 8 gain steps, software shutdown	PDIP-8, SOIC-8, MSOP-8	MCP6S22DM-PICTL
MCP6S26	6	2 to 12	1,350	275	2.5 to 5.5	-40 to +85	I/O	SPI, 8 gain steps, software shutdown	PDIP-14, SOIC-14, TSSOP-14	MCP6S2XEV
MCP6S28	8	2 to 12	1,350	275	2.5 to 5.5	-40 to +85	I/O	SPI, 8 gain steps, software shutdown	PDIP-16, SOIC-16	–
MCP6S91	1	1 to 18	1,600	4,000	2.5 to 5.5	-40 to +125	I/O	SPI, 8 gain steps, software shutdown	PDIP-8, SOIC-8, MSOP-8	MCP6S2XEV
MCP6S92(3)	2	1 to 18	1,600	4,000	2.5 to 5.5	-40 to +125	I/O	SPI, 8 gain steps, software shutdown	PDIP-8, SOIC-8, MSOP-8, MSOP-10	MCP6S22DM-PICTL

Operational Amplifiers - General Purpose

Device	# Amplifiers per Package	GBWP (kHz) Typ.	I_Q (µA) Max.	V_{OS} (±µV) Max.	Supply Voltage (V)	Temperature Range (°C)	Rail-to-Rail I/O	Features	Packages	Recommended Demo Boards
MCP6041(3)	1	14	1	3,000	1.4 to 5.5	-40 to +85	I/O	–	PDIP-8, SOIC-8, MSOP-8, SOT-23-5	SOIC8EV, VSUPEV2
MCP6042	2	14	1	3,000	1.4 to 5.5	-40 to +85	I/O	–	PDIP-8, SOIC-8, MSOP-8	SOIC8EV
MCP6044	4	14	1	3,000	1.4 to 5.5	-40 to +85	I/O	–	PDIP-14, SOIC-14, TSSOP-14	–
TC1026	1	90	9	500	1.8 to 5.5	-40 to +85	I/O	With Comparator and V_{REF}	PDIP-8, MSOP-8, SOIC-8	SOIC8EV
TC1029	2	90	8	500	1.8 to 5.5	-40 to +85	I/O	–	PDIP-8, MSOP-8, SOIC-8	SOIC8EV
TC1030	4	90	8	500	1.8 to 5.5	-40 to +85	I/O	Shutdown pins	QSOP-16	–
TC1034	1	90	10	500	1.8 to 5.5	-40 to +85	I/O	–	SOT-23A-5	VSUPEV2
TC1035	1	90	10	500	1.8 to 5.5	-40 to +85	I/O	Shutdown pin	SOT-23A-6	VSUPEV2
TC1043	2	90	8	500	1.8 to 5.5	-40 to +85	I/O	With Comparator and V_{REF}, Shutdown	QSOP-16	–
MCP6141(3)	1	100	1	3,000	1.4 to 5.5	-40 to +85, -40 to +125	I/O	G≥10 stable	PDIP-8, SOIC-8, MSOP-8, SOT-23-5, SOT-23-6	SOIC8EV, VSUPEV2
MCP6142	2	100	1	3,000	1.4 to 5.5	-40 to +85, -40 to +125	I/O	G≥10 stable	PDIP-8, SOIC-8, MSOP-8	SOIC8EV
MCP6144	4	100	1	3,000	1.4 to 5.5	-40 to +85, -40 to +125	I/O	G≥10 stable	PDIP-14, SOIC-14, TSSOP-14	–
MCP606(8)	1	155	25	250	2.5 to 5.5	-40 to +85	O	–	PDIP-8, SOIC-8, TSSOP-8, SOT-23-5	SOIC8EV, VSUPEV2
MCP607	2	155	25	250	2.5 to 5.5	-40 to +85	O	–	PDIP-8, SOIC-8, TSSOP-8	SOIC8EV
MCP609	4	155	25	250	2.5 to 5.5	-40 to +85	O	–	PDIP-14, SOIC-14, TSSOP-14	–
MCP616(8)	1	190	25	150	2.3 to 5.5	-40 to +85	O	–	PDIP-8, SOIC-8, MSOP-8	SOIC8EV
MCP617	2	190	25	150	2.3 to 5.5	-40 to +85	O	–	PDIP-8, SOIC-8, MSOP-8	SOIC8EV
MCP619	4	190	25	150	2.3 to 5.5	-40 to +85	O	–	PDIP-14, SOIC-14, TSSOP-14	–
MCP6231(1R,1U)	1	300	30	5,000	1.8 to 5.5	-40 to +125	I/O	–	PDIP-8, SOIC-8, MSOP-8, SOT-23-5, SC-70-5	SOIC8EV, VSUPEV2
MCP6232	2	300	30	5,000	1.8 to 5.5	-40 to +125	I/O	–	PDIP-8, SOIC-8, MSOP-8	SOIC8EV
MCP6234	4	300	30	5,000	1.8 to 5.5	-40 to +125	I/O	–	PDIP-14, SOIC-14, TSSOP-14	–

SELECTED PRODUCT SPECIFICATIONS

Operational Amplifiers - General Purpose (Continued)

Device	# Amplifiers per Package	GBWP (kHz) Typ.	Iq (µA) Max.	Vos (±µV) Max.	Supply Voltage (V)	Temperature Range (°C)	Rail-to-Rail I/O	Features	Packages	Recommended Demo Boards
MCP6241(1R,1U)	1	550	70	5,000	1.8 to 5.5	-40 to +125	I/O	–	PDIP-8, SOIC-8, MSOP-8, SOT-23-5, SC-70-5	SOIC8EV, VSUPEV2
MCP6242	2	500	70	5,000	1.8 to 5.5	-40 to +125	I/O	–	PDIP-8, SOIC-8, MSOP-8	SOIC8EV
MCP6244	4	500	70	5,000	1.8 to 5.5	-40 to +125	I/O	–	PDIP-14, SOIC-14, TSSOP-14	–
MCP6001(1R,1U)	1	1,000	170	4,500	1.8 to 5.5	-40 to +85, -40 to +125	I/O	–	SOT-23-5, SC-70-5	VSUPEV2
MCP6002	2	1,000	170	4,500	1.8 to 5.5	-40 to +85, -40 to +125	I/O	–	PDIP-8, SOIC-8, MSOP-8	SOIC8EV
MCP6004	4	1,000	170	4,500	1.8 to 5.5	-40 to +85, -40 to +125	I/O	–	PDIP-14, SOIC-14, TSSOP-14	–
MCP6271(1R,3)	1	2,000	240	3,000	2.0 to 5.5	-40 to +125	I/O	–	PDIP-8, SOIC-8, MSOP-8, SOT-23-5, SOT-23-6	SOIC8EV, VSUPEV2
MCP6272(5)	2	2,000	240	3,000	2.0 to 5.5	-40 to +125	I/O	–	PDIP-8, SOIC-8, MSOP-8	SOIC8EV
MCP6274	4	2,000	240	3,000	2.0 to 5.5	-40 to +125	I/O	–	PDIP-14, SOIC-14, TSSOP-14	–
MCP601(1R,3)	1	2,800	325	2,000	2.7 to 5.5	-40 to +85, -40 to +125	O	–	PDIP-8, SOIC-8, TSSOP-8, SOT-23-5, SOT-23-6	SOIC8EV, VSUPEV2
MCP602	2	2,800	325	2,000	2.7 to 5.5	-40 to +85, -40 to +125	O	–	PDIP-8, SOIC-8, TSSOP-8	SOIC8EV
MCP604	4	2,800	325	2,000	2.7 to 5.5	-40 to +85, -40 to +125	O	–	PDIP-14, SOIC-14, TSSOP-14	–
MCP6281(1R,3)	1	5,000	570	3,000	2.2 to 5.5	-40 to +125	I/O	–	PDIP-8, SOIC-8, MSOP-8, SOT-23-5, SOT-23-6	SOIC8EV, VSUPEV2
MCP6282(5)	2	5,000	570	3,000	2.2 to 5.5	-40 to +125	I/O	–	PDIP-8, SOIC-8, MSOP-8	SOIC8EV
MCP6284	4	5,000	570	3,000	2.2 to 5.5	-40 to +125	I/O	–	PDIP-14, SOIC-14, TSSOP-14	–
MCP6291(1R,3)	1	10,000	1,300	3,000	2.4 to 5.5	-40 to +125	I/O	–	PDIP-8, SOIC-8, MSOP-8, SOT-23-5, SOT-23-6	SOIC8EV, VSUPEV2
MCP6292(5)	2	10,000	1,300	3,000	2.4 to 5.5	-40 to +125	I/O	–	PDIP-8, SOIC-8, MSOP-8	SOIC8EV
MCP6294	4	10,000	1,300	3,000	2.4 to 5.5	-40 to +125	I/O	–	PDIP-14, SOIC-14, TSSOP-14	–
MCP6021(3)	1	10,000	1,350	250	2.5 to 5.5	-40 to +85, -40 to +125	I/O	Reference Voltage	PDIP-8, SOIC-8, TSSOP-8, MSOP-8, SOT-23-5	SOIC8EV
MCP6022	2	10,000	1,350	250	2.5 to 5.5	-40 to +85, -40 to +125	I/O	—	PDIP-8, SOIC-8, TSSOP-8	SOIC8EV
MCP6024	4	10,000	1,350	250	2.5 to 5.5	-40 to +85, -40 to +125	I/O	—	PDIP-14, SOIC-14, TSSOP-14	–

Operational Amplifiers - Auto-Zeroed

Device	# Amplifiers per Package	GBWP (kHz) Typ.	Iq (µA) Max.	Vos (±µV) Max.	Supply Voltage (V)	Temperature Range (°C)	Rail-to-Rail I/O	Features	Packages	Recommended Demo Boards
TC7652	1	400	3,000	5	6.5 to 16.0	0 to +70	–	Chopper stabilized, low noise	PDIP-8, PDIP-14	SOIC8EV
TC913A	2	1,500	850	15	6.5 to 16.0	0 to +70	–	Auto-zero, single & split supply	PDIP-8, SOIC-8	SOIC8EV
TC913B	2	1,500	1,100	30	6.5 to 16.0	0 to +70	–	Auto-zero, single & split supply	PDIP-8, SOIC-8	SOIC8EV
TC7650	1	2,000	3,500	5	6.5 to 16.0	0 to +70	–	Chopper stabilized	PDIP-8, PDIP-14	SOIC8EV

SELECTED PRODUCT SPECIFICATIONS

Analog-to-Digital Converters (Delta-Sigma)

Device	Resolution (bits)	Max. Sample Rate (samples/sec)	# of Input Channels	Interface	Supply Voltage Range (V)	Typical Supply Current (µA)	Typical INL (ppm)	Temperature Range (°C)	Features	Packages	Recommended Demo Boards
MCP3550-50	22	13	1 Diff	SPI	2.7 to 5.5	120	2	-40 to +125	50 Hz noise rejection > 120 dB	SOIC-8, MSOP-8	MCP3551DM-PCTL
MCP3550-60	22	15	1 Diff	SPI	2.7 to 5.5	140	2	-40 to +125	60 Hz noise rejection > 120 d	SOIC-8, MSOP-8	MCP3551DM-PCTL
MCP3551	22	14	1 Diff	SPI	2.7 to 5.5	120	2	-40 to +125	Simultaneous 50/60 Hz rejection	SOIC-8, MSOP-8	MCP3551DM-PCTL
MCP3553	20	60	1 Diff	SPI	2.7 to 5.5	140	2	-40 to +125		SOIC-8, MSOP-8	MCP3551DM-PCTL

Analog-to-Digital Converters (SAR)

Device	Resolution (bits)	Max. Sample Rate (ksamples/sec)	# of Input Channels	Input Type	Interface	Input Voltage Range (V)	Max. Supply Current (µA)	Max. INL	Packages	Recommended Demo Boards
MCP3001	10	200	1	Single-ended	SPI	2.7 to 5.5	500	±1 LSB	PDIP-8, SOIC-8, MSOP-8, TSSOP-8	
MCP3002	10	200	2	Single-ended	SPI	2.7 to 5.5	650	±1 LSB	PDIP-8, SOIC-8, MSOP-8, TSSOP-8	
MCP3004	10	200	4	Single-ended	SPI	2.7 to 5.5	550	±1 LSB	PDIP-14, SOIC-14, TSSOP-14	
MCP3008	10	200	8	Single-ended	SPI	2.7 to 5.5	550	±1 LSB	PDIP-16, SOIC-16	
MCP3021	10	22	1	Single-ended	I²C™	2.7 to 5.5	250	±1 LSB	SOT-23-5A	MCP3221DM-PCTL, MXSIGDM
MCP3221	12	22	1	Single-ended	I²C™	2.7 to 5.5	250	±2 LSB	SOT-23-5A	MCP3221DM-PCTL, MXSIGDM
MCP3201	12	100	1	Single-ended	SPI	2.7 to 5.5	400	±1 LSB	PDIP-8, SOIC-8, MSOP-8, TSSOP-8	DV3201A, DVMCPA, MXSIGDM
MCP3202	12	100	2	Single-ended	SPI	2.7 to 5.5	550	±1 LSB	PDIP-8, SOIC-8, MSOP-8, TSSOP-8	DV3201A, DVMCPA, MXSIGDM
MCP3204	12	100	4	Single-ended	SPI	2.7 to 5.5	400	±1 LSB	PDIP-14, SOIC-14, TSSOP-14	DV3204A, DVMCPA, MXSIGDM
MCP3208	12	100	8	Single-ended	SPI	2.7 to 5.5	400	±1 LSB	PDIP-16, SOIC-16	DV3204A, DVMCPA, MXSIGDM
MCP3301	13	100	1	Differential	SPI	2.7 to 5.5	450	±1 LSB	PDIP-8, SOIC-8, MSOP-8	DV3201A, DVMCPA, MXSIGDM
MCP3302	13	100	2	Differential	SPI	2.7 to 5.5	450	±1 LSB	PDIP-14, SOIC-14, TSSOP-14	DV3204A, DVMCPA, MXSIGDM
MCP3304	13	100	4	Differential	SPI	2.7 to 5.5	450	±1 LSB	PDIP-16, SOIC-16	DV3204A, DVMCPA, MXSIGDM

Voltage Output Temperature Sensors

Device	Typical Accuracy (°C)	Max. Accuracy @ 25°C (°C)	Max. Temperature Range (°C)	Vcc Range (V)	Max. Supply Current (µA)	Features	Packages	Recommended Demo Boards
MCP9700	±1	±4	-40 to +125	2.3 to 5.5	12	Low-power linear active thermistor, 10 mV/°C	SC-70-3	MCP9700DM-PCTL
MCP9701	±1	±4	-10 to +125	3.1 to 5.5	12	Low-power linear active thermistor, 19.5 mV/°C	SC-70-3	MCP9700DM-PCTL
TC1046	±0.5	±2	-40 to +125	2.7 to 4.4	60	High precision temperature-to-voltage converter, 6.25 mV/°C	SOT-23B-3	TC1047ADM-PCTL
TC1047	±0.5	±2	-40 to +125	2.7 to 4.4	60	High precision temperature-to-voltage converter, 10 mV/°C	SOT-23B-3	TC1047ADM-PCTL
TC1047A	±0.5	±2	-40 to +125	2.5 to 5.5	60	High precision temperature-to-voltage converter, 10 mV/°C	SOT-23B-3	TC1047ADM-PCTL

Voltage References

Device	Vcc Range (V)	Output Voltage (V)	Max. Load Current (mA)	Initial Accuracy (max. %)	Temperature Coefficient (ppm/°C)	Max. Supply Current (µA @ 25°C)	Packages	Recommended Demo Boards
MCP1525	2.7 to 5.5	2.5	±2	±1	50	100	TO-92-3, SOT-23-3	VSUPEV
MCP1541	4.3 to 5.5	4.096	±2	±1	50	100	TO-92-3, SOT-23-3	VSUPEV

Digital Potentiometers

Device	# of Taps	# per Package	Interface	Volatile/ Non-Volatile	Resistance (ohms)	INL (Max.)	DNL (Max.)	Temperature Range (°C)	Packages	Recommended Demo Boards
MCP4011	64	1	U/D	Volatile	2.1K, 5K, 10K, 50K	±0.5 LSB	±0.5 LSB	-40 to +125	SOIC-8	
MCP4012	64	1	U/D	Volatile	2.1K, 5K, 10K, 50K	±0.5 LSB	±0.5 LSB	-40 to +125	SOT-23-6	
MCP40134	64	1	U/D	Volatile	2.1K, 5K, 10K, 50K	±0.5 LSB	±0.5 LSB	-40 to +125	SOT-23-6	
MCP4014	64	1	U/D	Volatile	2.1K, 5K, 10K, 50K	±0.5 LSB	±0.5 LSB	-40 to +125	SOT-23-5	
MCP4021	64	1	U/D	Non-Volatile	2.1K, 5K, 10K, 50K	±0.5 LSB	±0.5 LSB	-40 to +125	SOIC-8	
MCP4022	64	1	U/D	Non-Volatile	2.1K, 5K, 10K, 50K	±0.5 LSB	±0.5 LSB	-40 to +125	SOT-23-6	
MCP4023	64	1	U/D	Non-Volatile	2.1K, 5K, 10K, 50K	±0.5 LSB	±0.5 LSB	-40 to +125	SOT-23-6	
MCP4024	64	1	U/D	Non-Volatile	2.1K, 5K, 10K, 50K	±0.5 LSB	±0.5 LSB	-40 to +125	SOT-23-5	
MCP41010	256	1	SPI	Volatile	10K	±1 LSB	±1 LSB	-40 to +85	PDIP-8, SOIC-8	
MCP41050	56	1	SPI	Volatile	50K	±1 LSB	±1 LSB	-40 to +85	PDIP-8, SOIC-8	
MCP41100	256	1	SPI	Volatile	100K	±1 LSB	±1 LSB	-40 to +85	PDIP-8, SOIC-8	
MCP42010	256	2	SPI	Volatile	10K	±1 LSB	±1 LSB	-40 to +85	PDIP-14, SOIC-14, TSSOP-14	
MCP42050	256	2	SPI	Volatile	50K	±1 LSB	±1 LSB	-40 to +85	PDIP-14, SOIC-14, TSSOP-14	
MCP42100	256	2	SPI	Volatile	100K	±1 LSB	±1 LSB	-40 to +85	PDIP-14, SOIC-14, TSSOP-14	

ANALOG AND INTERFACE PRODUCTS

Stand-Alone Analog and Interface Portfolio

Thermal Management
- Temperature Sensors
- Fan Speed Controllers/ Fan Fault Detectors

Power Management
- LDO & Switching Regulators
- Charge Pump DC/DC Converters
- Power MOSFET Drivers
- PWM Controllers
- System Supervisors
- Voltage Detectors
- Voltage References

Battery Management
- Li-Ion/Li-Polymer Battery Chargers
- Smart Battery Managers

Linear
- Op Amps
- Programmable Gain Amplifiers
- Comparators
- Linear Integrated Devices

Mixed-Signal
- A/D Converter Families
- Digital Potentiometers
- D/A Converters
- V/F and F/V Converters
- Energy Measurement ICs

Interface
- CAN Peripherals
- Infrared Peripherals
- LIN Transceiver
- Serial Peripherals
- Ethernet Controller

Analog and 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/14 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 LDO with Reset and Fan Controller with temperature sensor
- PGA integrates MUX, resistive ladder, gain switches, high-performance amplifier, SPI interface

Space Savings
- Resets and LDOs in SC70, A/D converters in a 5-lead SOT-23 package
- CAN and IrDA® Standard protocol stack embedded in an 18-pin package

Accuracy
- Low input offset voltages
- High gains

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

For more information, visit the Microchip web site at: www.microchip.com

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