Analog and Interface Product Solutions

Analog-to-Digital Converter Design Guide

High-Performance, Stand-Alone A/D Converters for a Variety of Embedded Systems Applications

Design ideas in this guide are based on many of Microchip's ADC products.
A complete device list and corresponding data sheets or these products can be found at **www.microchip.com.**

Delta-Sigma A/D Converters		Dual-Slope A/D Converters	Successive Approximation Register (SAR) A/D Converters	BCD Output A/D Converters	Binary Output A/D Converter	Display A/D Converters
MCP3421	MCP3426	TC500A	MCP300X	TC14433A	TC850	TC7106A
MCP3422	MCP3427	TC7109A	MCP3021			TC7116A
MCP3423	MCP3428	TC510	MCP320X			TC7117A
MCP3424	MCP3550	TC514	MCP3221			TC7126A
MCP3425	MCP3551		MCP330X			TC7129
	MCP3553					

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Selecting the Right ADC

Selecting the Right ADC

Selecting the most suitable A/D Converter (ADC) for your application is based on more than just the precision or bits. Different architectures are available, each exhibiting advantages and disadvantages in various data acquisition systems. The required accuracy or precision of the system puts you in a category based on the number of bits required. It is important to always design your system to allow for more bits than initially required: if an application calls for 10 bits of accuracy, choose a 12-bit converter. The achievable accuracy of a converter will always be less than the total number of bits available.

Depending on the system requirements, your accuracy might be better expressed in micro-volts, dB (decibels) or LSBs (Least Significant Bits). A FFT showing the frequency spectrum of a device can be useful in determining the noise performance of a given device. Many Microchip stand-alone ADCs show typical performance data for AC specifications, such as THD, SINAD and SNR. The following table shows performance, in dB and V/V, for 8- through 24-bit converters.

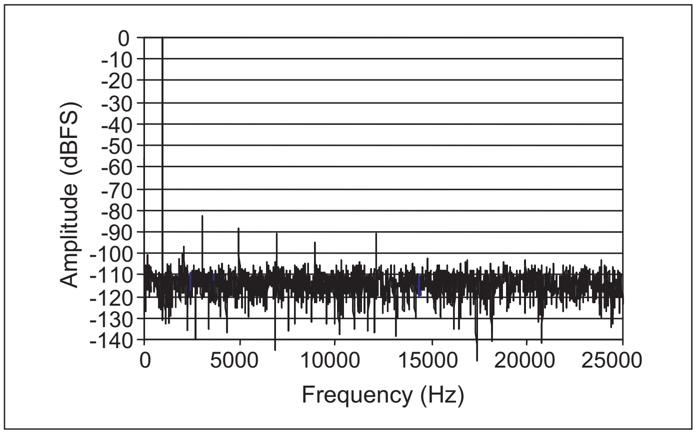
Typically, an amplifier is required if the magnitude of the input signal is significantly lower than the full-scale input range of the ADC. However, by selecting an ADC with a higher resolution, the need for an amplifier can be eliminated.

Performance Table: 8- Through 24-bit Converters

# of Bits	2^n	LSB (FS = 1V)	Resolution (%)	Resolution (ppm)	Resolution (dB)
8	256	3.91 mV	0.391	3910	48.16
10	1024	977 µV	0.0977	977	60.21
12	4096	244 µV	0.0244	244	72.25
14	16384	61 µV	0.0061	61	84.29
16	65536	15.3 µV	0.00153	15.3	96.33
18	262144	3.81 µV	0.000381	3.81	108.37
20	1048576	954 nV	9.54E-05	0.954	120.41
22	4194304	238 nV	2.38E-05	0.238	132.45
24	16777216	59.5 nV	5.95E-06	0.0595	144.49

Successive Approximation Register (SAR) converters typically range from 8 to 16 bits, while delta-sigma converters (ΔΣ) can achieve an accuracy of up to 24 bits.

If your application deals more with AC signals, the ADC performance can be viewed in the frequency domain using AC plots such as the signal to noise ratio (SNR) FFT below.

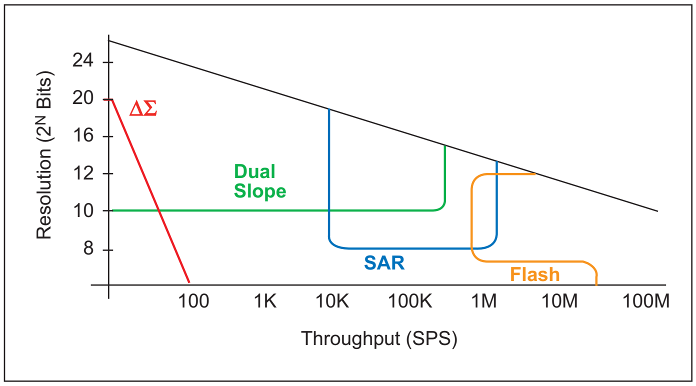


If your application is more DC related, than the effective resolution is best expressed as a ratio of the output noise floor in micro-volts RMS (smallest signal that can be measured), to the full scale range of your system. The following equation shows this relationship:

$$ENOB = \frac{\ln(FSR/RMS\ Noise)}{\ln(2)}$$

The figure below shows the different architectures vs. bits and bandwidth.

Architecture vs. Bits and Bandwidth



Selecting the Right ADC

Three Application Examples

Seismic Recording

Vibration monitoring applications have up to 16 different devices are connected to a central processing unit. Each device measures the signal at an extremely fast rate, less than 100 µS. High accuracy is not required due to the large signal size, but speed is of the utmost importance. A high-speed SAR converter would be the best selection for this application.

Voice-Band Recording

The human ear can detect signals from roughly 20 Hz up to 20 kHz. If the application is a telephone intercom system where high-fidelity audio is not a concern, 60-70 dB of dynamic range is sufficient. Based on these bandwidth and dynamic range requirements, either a medium speed (50-200 ksps) SAR or delta-sigma converter would work in this application.

Altimeter Watch

Sensors for temperature, pressure, load or other physical excition quantities are most often configured in a wheatstone bridge configuration. The bridge can have anywhere from 1 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.

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.

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 µVRMS.

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

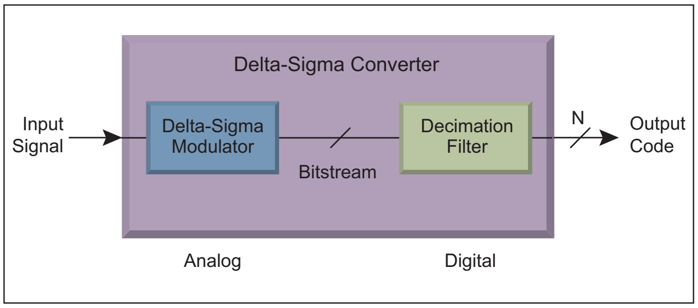
$$\log(P) \approx 5 - \frac{h}{15500}$$

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.

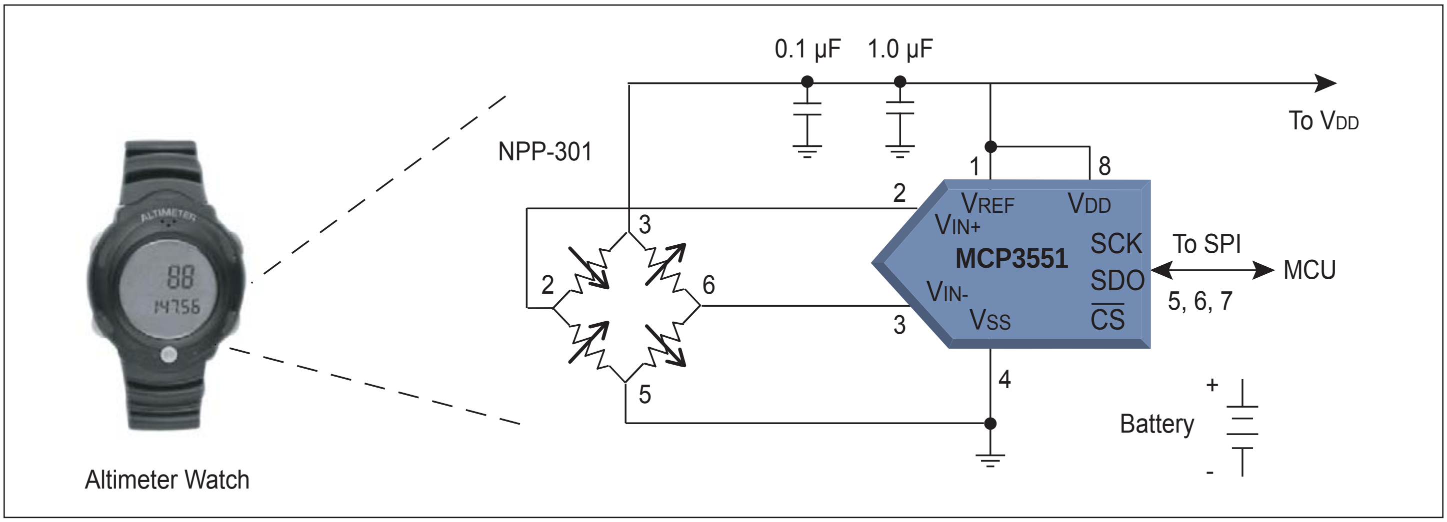
It should be noted that this is only used as an example for discussion; temperature effects and the error from a first order approximation must be included in final system design.

The delta-sigma ADC is an over-sampling converter with many benefits over the traditional successive approximation register (SAR) converter. High resolution, excellent line frequency ejection, limited external component requirement, and low power consumption top the list. The delta-sigma ADC architecture is comprised of two main blocks, the delta-sigma modulator and a digital decimation filter. In recent years these two blocks are now complemented by a serial interfaces, digital filter control and an oscillators for the over-sampling all on a single integrated circuit. This makes the most complex of delta- sigma modulators completely transparent to the user; the ADC operation and control is similar to other traditional ADCs, making the device an easy solution to many applications.

Delta-Sigma ADC Architecture



Example of Direct Digitization Application



ADC by Architecture – Delta-Sigma Converters

Why Not Just Over-sample With a SAR ADC?

The answer is easy: noise shaping. Simply over-sampling with a fast SAR ADC, such as those found on a PIC microcontroller, and averaging the results will not achieve the resolution performance of a delta-sigma ADC. Over-sampling and averaging only increase accuracy by 0.5 bit for each doubling of the sample frequency. A first order delta-sigma ADC however decreases in-band noise by 9 dB (or 1.5 bits) for every doubling of the over-sampling ratio, three times better than simple over-sampling. The third order modulator used in the MCP355X devices decreases in-band noise by 2.5 bits for every doubling of the sampling frequency. This design is how a device resolution of 2.5 µVRMS or effective resolution of 21.9 bits is achieved.

System Debug Using DataView™ Software

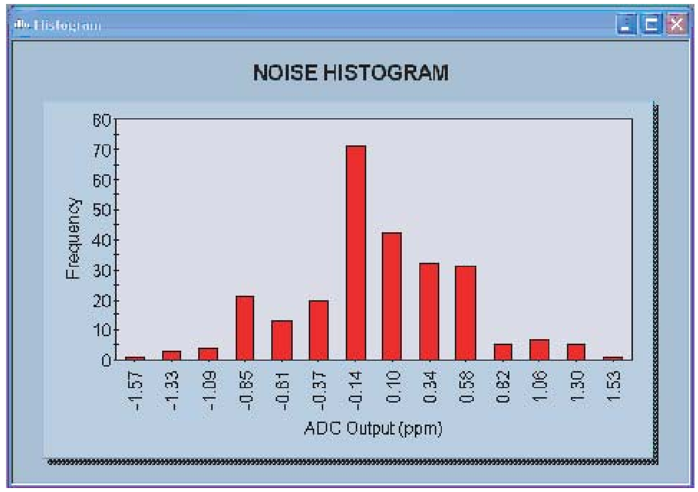
These devices have an LSB size that is smaller than the noise voltage, typical of any high resolution ADC. The output of the device can not be analyized my simply looking at the binary output. Collecting data and visually analyzing the result is required, and when designing circuits it is important to provide a way to get the data points to a PC. The MCP355X demonstration board circuitry and DataView software can be used to quickly evaluate sensor or system performance. This software allows real-time visual evaluation of system noise performance using histogram and scope plot graphs, pertaining to many of the issues discussed herein.

Typical Connection

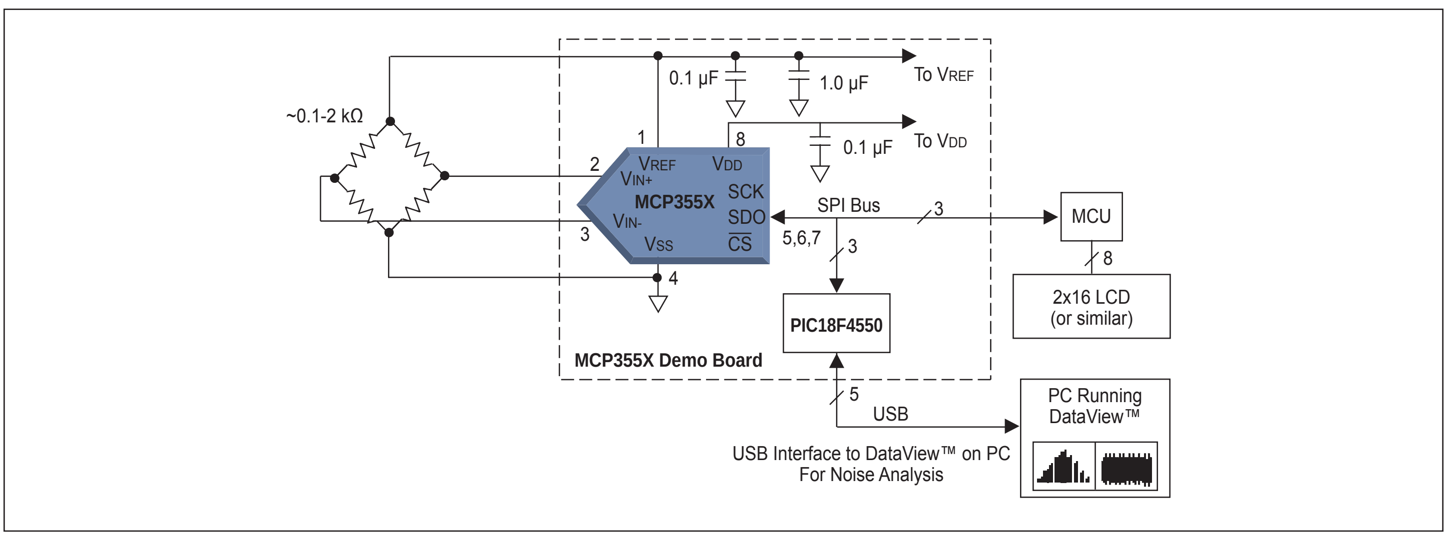
A typical application for the MCP355X device is shown in the following figure with the sensor connected to the MCP355X 22-bit Delta-Sigma ACD PICtail Demo Board for system noise analysis and debugging.

The DataView software tool is a visualization tool, showing real-time histograms using the MCP355X. The software also calculates the RMS noise of the current distribution. The number of samples in the distribution is also scalable, allowing post averaging experiments.

DataView™ Software Showing System Performance in a Histogram Format



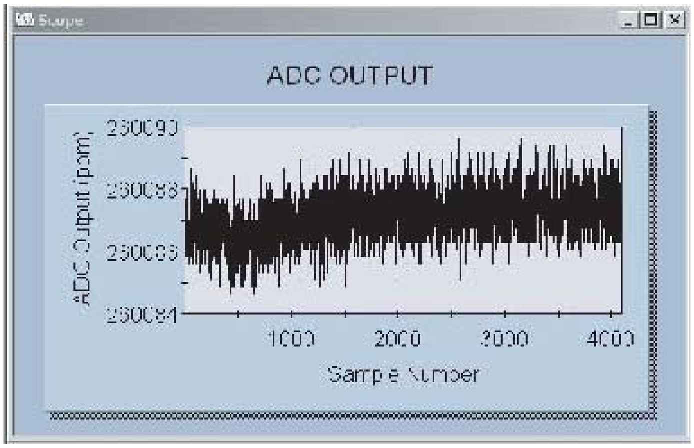
Typical Bridge Sensor Application Showing Connection for System Noise and Debug



ADC by Architecture – Delta-Sigma Converters

The software can also be used for time based system analysis using the scope plot window. Any system drift or other time based errors can be analyzed using this visual analysis tool.

DataView™ Scope Plot View



The following terms and diagrams are associated with delta-sigma converters:

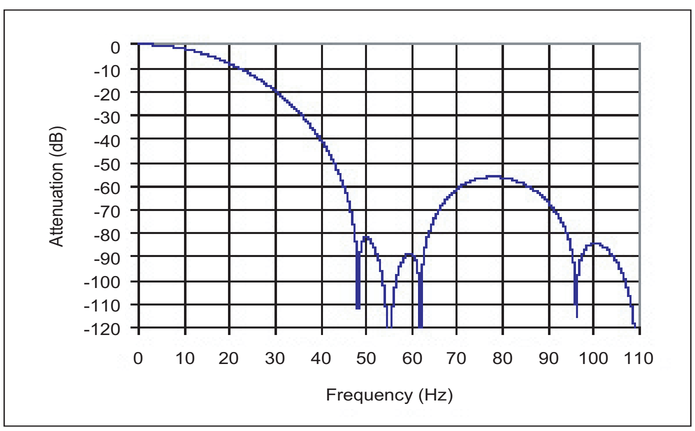
Definition and Terms

Over-sampling Rate – The actual sample rate at the signal is defined by the over-sampling ratio of the converter.

Data Rate – The output word rate, throughput rate or double the Nyquist frequency of the converter.

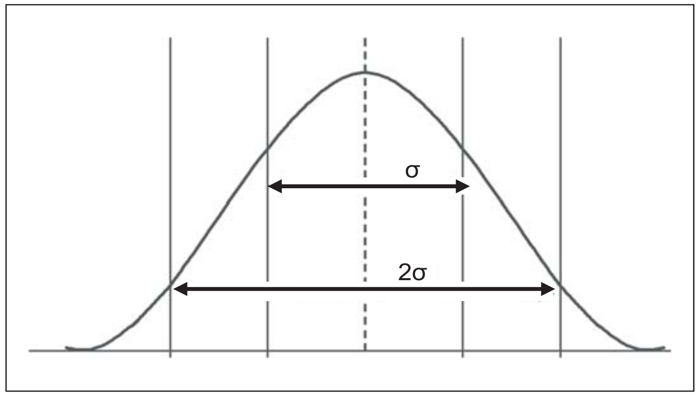
Decimation Filter – The digital filter that is part of the delta-sigma converter. Typically a SINC or comb type digital filter. The filter order is usually equal to the modulator order, plus one. The design of the digital filter can have strategically placed notches at line frequencies to allow high normal mode 50/60 Hz rejection.

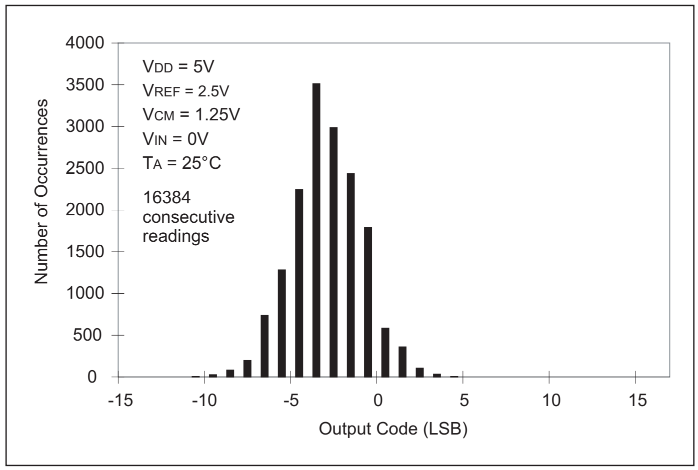
SINC Filter Response for MCP3551 Device



Output Noise – In higher resolution A/D converters, the output of the device will always be a distribution of bits rather than a single code. Twice the standard deviation of this distribution is a measure of the RMS noise, output noise or sigma (σ).

Output Noise Measurement





Effective Resolution (ER) or Effective Number of Bits (ENOB) – The software can also be used for time based system analysis using the scope plot window. Any system drift or other time based errors can be analyzed using this visual analysis tool.

The effective number of bits (ENOB) or effective resolution (ER) is a measure of the true resolution of the ADC. It is the ratio of RMS noise (smallest signal that can be measured), to the full scale input range of the device (largest signal that can be measured). Converting to base 2 yields ENOB, as defined by the following equation:

$$ENOB = \frac{\ln(FSR/RMS\ Noise)}{\ln(2)}$$

It should be noted that this formula assumes a purely DC signal. A sinewave signal has 1.76 dB more AC power than a random signal uniformly distributed between the same peak levels.

To calculate the effective number of bits using the relationship SNR (dB) = 6.02n+1.76 (which is derived using $V_{RMS} = V_{PEAK}/2\sqrt{(2)}$, or a pure sine wave as the signal), the following equation should be used:

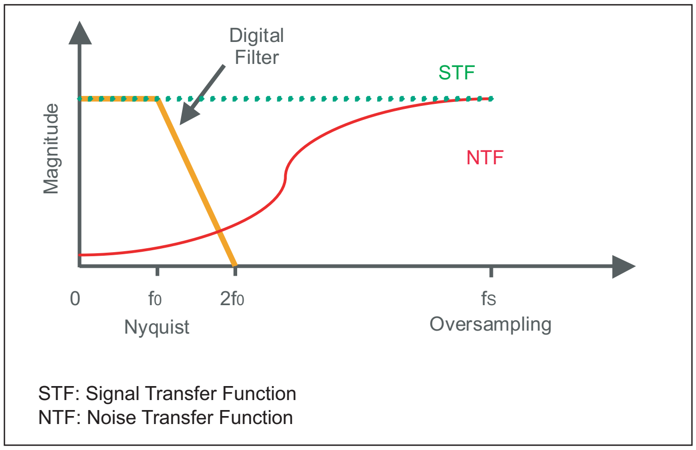
$$ENOB = \frac{20 \cdot \log\left(\frac{FSR}{\text{RMS Noise}}\right) - 1.76}{6.02}$$

The difference between the equations is 1.76 dB, or a difference of 0.292 bits.

The MCP3551 has a FSR of $2*V_{REF}$ and an RMS noise of 2.5 µV or 21.9 ENOB using the first equation.

Noise Shaping – Noise shaping is what separates the delta-sigma converter from simple over-sampling or averaging systems. The modulator of the delta-sigma converter is able to shift quantization noise towards the higher end of the frequency spectrum, which is then easily filtered out digitally. Noise-shaping is the key to delta-sigma architecture.

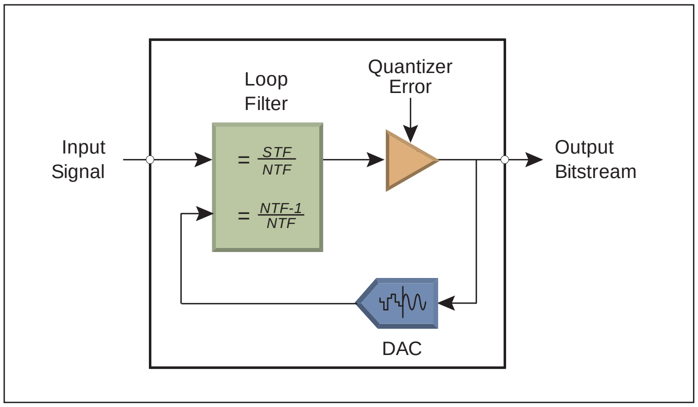
Digitally Filtered Noise



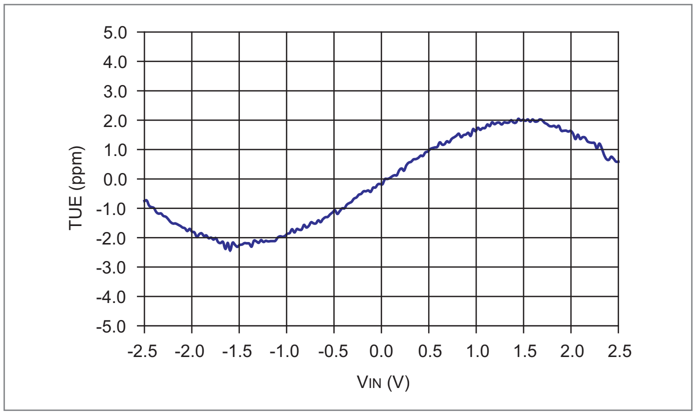
Modulator Order – The modulator order refers to the complexity of the delta-sigma architecture and amount of feedback in the analog design of the ADC. Higher order modulators can yield greater dynamic range due to a better noise-shaping. Noise falls by 3(2L-1) dB for each doubling of the over-sampling rate, where L is equivalent to the modulator order.

Total Unadjusted Error – A combination of the offset error, gain error and integral non-linearity (INL) error. The large number of output codes associated with high resolution ADCs allows for the device to cover all system errors many times with a limited number of codes. The Total Unadjusted Error (TUE), of the device allows the user to gauge what this window would be from device to device. The following figure shows a typical TUE response across the entire input range for V_{REF} = 2.5V. This shows the combination of offset, gain, and linearity for the MCP355X devices.

Representation of Simple First Order Modulator



Typical TUE Response for V_{REF} = 2.5V

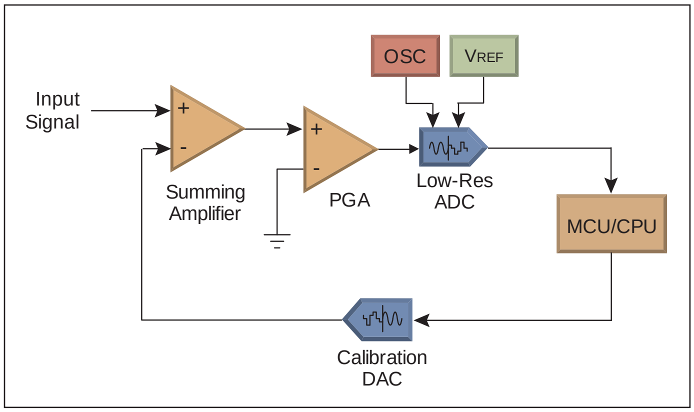


ADC by Architecture – Delta-Sigma Converters

Design Tip: Use higher resolution Delta-Sigma ADCs to replace signal conditioning circuitry.

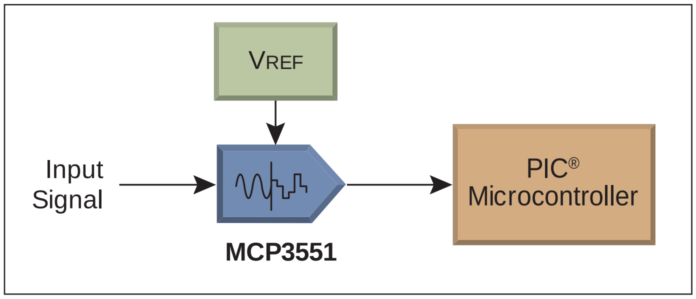
In addition to applications using small signals, applications that require only 10- or 12-bit accuracy are also candidates for high resolution ADCs. The following system block diagram shows a typical signal conditioning circuit. In this application example, the required accuracy was approximately 10 bits. A 12-bit ADC was selected, and a gain stage was required to gain the small signal prior to conversion. To achieve the required conversion accuracy, the input signal had to be gained to cover the entire input range of the ADC. In this example, the signal also has varying common mode voltage, which required some offset adjustment calibration; the signal must be centered prior to the gain.

Typical Signal Conditioning Circuit



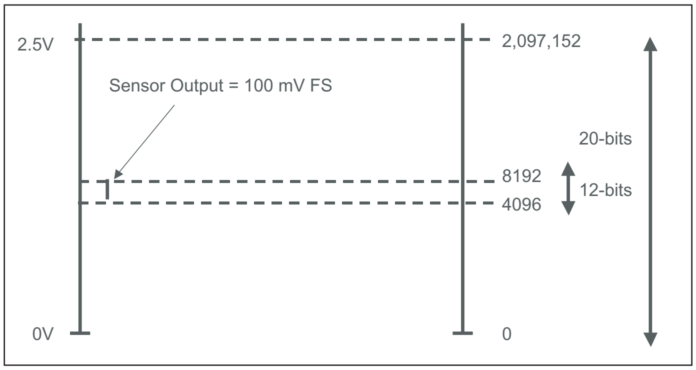
The design tip is to use a higher resolution ADC to your advantage when dealing with systems such as this. The entire signal conditioning circuitry can be eliminated if a higher resolution ADC such as the MCP355X is used:

Revised Circuit Using Higher Resolution ADC



The extremely large dynamic range of a high resolution ADC, e.g., 22-bits in the case of the MCP3551, eliminates the need for any signal conditioning circuitry. In the previous example, the gain circuitry and common mode offset are eliminated. With 22-bit dynamic range, 12-bit window exists anywhere within the input range of the ADC. There is no longer a need to use the entire input range of the ADC with the added bits. The following figure shows this comparison with V_{REF} = 2.5V (Note: not to scale).

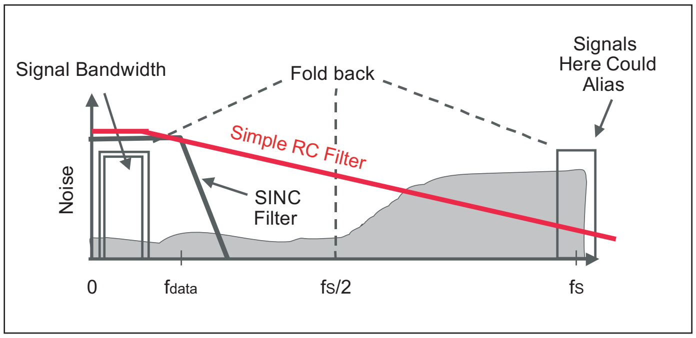
High Resolution Bit Comparison



Design Tip: Delta-Sigma ADCs require minimal anti-aliasing filtering.

All ADCs can experience aliasing, even delta-sigma ADCs. When there is noise or unwanted signals present around the sampling frequency, these signals can alias back into the bandwidth of interest and will then be impossible to discern from the signal you are trying to convert. However, with delta-sigma ADCs, the large ratio of sampling (over-sampling), to your data rate allows for a simple RC circuit to be used for your anti-aliasing filter. The following figure shows how a simple RC filter will give enough attenuation at the over-sampling frequency (fs) due to the large ratio of fs to f_{DATA}.

Simple RC Attenuation



Small, Low Power 32-bit Delta-Sigma A/D Converters

The **MCP3551/3** devices are 2.7V to 5.5V low-power, 22-bit delta-sigma Analog-to-Digital Converters (ADCs). The devices offer output noise as low as 2.5 µVRMS, with a total unadjusted error of less than 10 ppm. The family exhibits 6 ppm max. Integral Non-Linearity (INL) error, 3 µV offset error and 2 ppm full-scale error. The MCP3551/3 devices provide high accuracy and low noise performance for applications where sensor measurements (such as pressure, temperature and humidity) are performed. With the internal oscillator and high oversampling rate, minimal external components are required for high-accuracy applications.

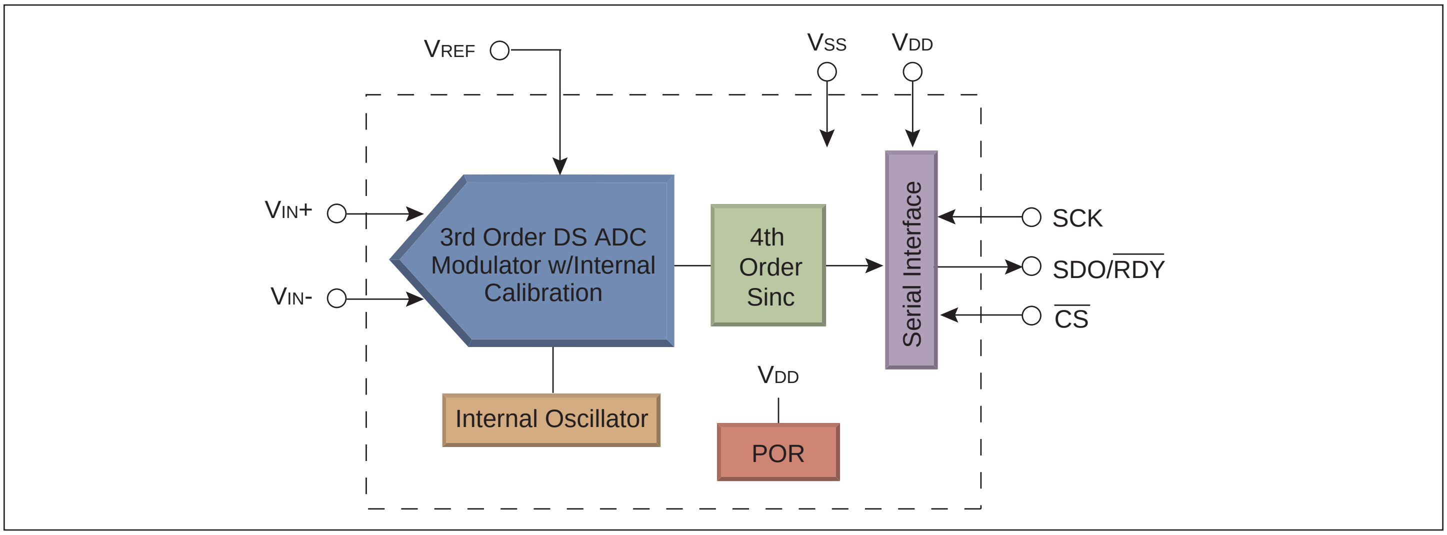
MCP3551/3 Key Features

- 22-bit ADC in small 8-pin MSOP package with automatic internal offset and gain calibration
- Low output noise of 2.5 µVRMS with effective resolution of 21.9 bits (MCP3551)
- 3 µV typical offset error
- 2 ppm typical full-scale error
- 6 ppm maximum INL error
- Total unadjusted error less than 10 ppm
- No digital filter settling time, single-command conversions through 3-wire SPI Interface
- Ultra-Low conversion current (MCP3551):
  100 µA typical (VDD = 2.7V)
  120 µA typical (VDD = 5.0V)
- Differential Input with VSS to VDD common mode range
- 2.7V to 5.5V single-supply operation
- Extended temperature range: -40°C to +125°C

Applications

- Weight Scales
- Direct Temperature Measurement
- 6-digit DVMs
- Instrumentation
- Data Acquisition
- Strain Gauge Measurement

MCP3551/3 Functional Block Diagram



Product Specifications

Device	Conversion Time (t_{CONV})(1)	Output Data Rate (sps)	Output Noise (µNRMS)	Primary Notch (Hz)	Sample Frequency (fs)	Internal Clock fosc	50/60 Hz Rejection	Temperature Range (°C)	Packages
MCP3551	72.73 ms	13.75	2.5	55	28160 Hz	112.64 kHz	-88 dB at both 50/60 Hz	-40 to +125	8 MSOP, SOIC
MCP3553	16.67 ms	60	6	240	30720 Hz	122.88 kHz	Not applicable	-40 to +125	8 MSOP, SOIC

Note 1: For the first conversion after exising shutdown, t_{CONV} must include and additional 154 fosc periods before the conversion is cimplete and the RDO flag appears on SDO. For a first conversion not exiting shutdown t_{CONV} includes an additional 112 fosc periods before the conversion is complete and the RDO flat appears on SDO. Second and subsequent conversions will be t_{CONV}.

18-bit ADC with I²C™ Interface and Onboard Reference

The **MCP3421** is a single channel low-noise, high accuracy delta-sigma A/D converter with differential inputs and up to 18 bits of resolution in a small SOT-23-6 package. The on-board precision 2.048V reference voltage enables an input range of ±2.048V differentially. The device uses a two-wire I²C compatible serial interface and operates from a single power supply ranging from 2.7V to 5.5V. The MCP3421 device performs conversions at rates of 3.75, 15, 60 or 240 samples per second depending on user controllable configuration bit settings using the two-wire I²C compatible serial interface. This device has an onboard programmable gain amplifier (PGA). User can select the PGA gain of x1, x2, x4 or x8 before the analog-to-digital conversion takes place. This allows the MCP3421 device to convert a smaller input signal with high resolution. The device has two conversion modes: (a) Continuous mode and (b) One-Shot mode. In One-Shot mode, the device enters a low current standby mode automatically after one conversion. This reduces current consumption greatly during idle periods. Two and four channel versions are also available for applications requiring inputs for multiple sensors. In addition, 16-bit versions, MCP3425/6/7/8 are available. The MCP3421 device can be used for various high accuracy analog-to-digital data conversion applications where ease of use, low power consumption and small footprint are major considerations.

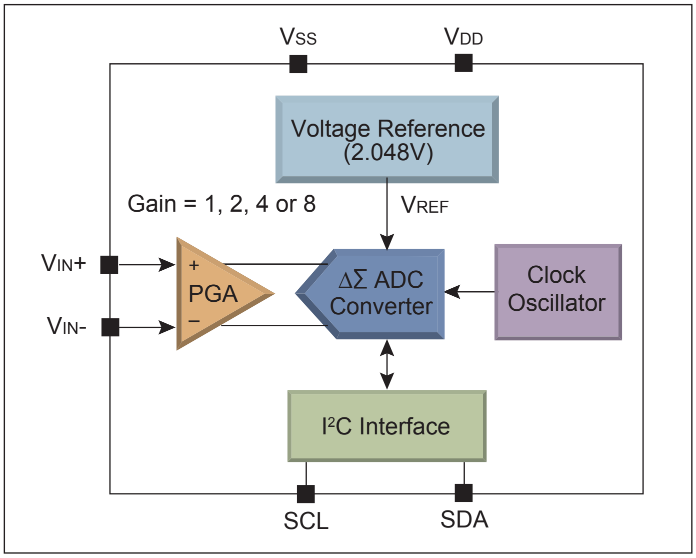
MCP3421 Key Features

- 18-bit resolution
- Small 6-lead SOT-23 packaging
- Differential input operation
- On-board voltage reference with 5 ppm/°C drift
- On-board PGA, gains of 1, 2, 4, 8
- Programmable data rate options
  - 3.75 SPS (18 bits)
  - 15 SPS (16 bits)
  - 60 SPS (14 bits)
  - 240 SPS (12 bits)
- INL 10 ppm of FSR max
- Low current consumption, 145 µA at 3V
- One-shot or continuous conversion options
- Supports I²C serial interface
- Extended temperature range: -40°C to +125°C

Applications

- Portable Instrumentation
- Weigh Scales and Fuel Gauges
- Temperature Sensing with RTD, Thermistor and Thermocouple
- Bridge Sensing for Pressure, Strain and Force

MCP3421 Block Diagram



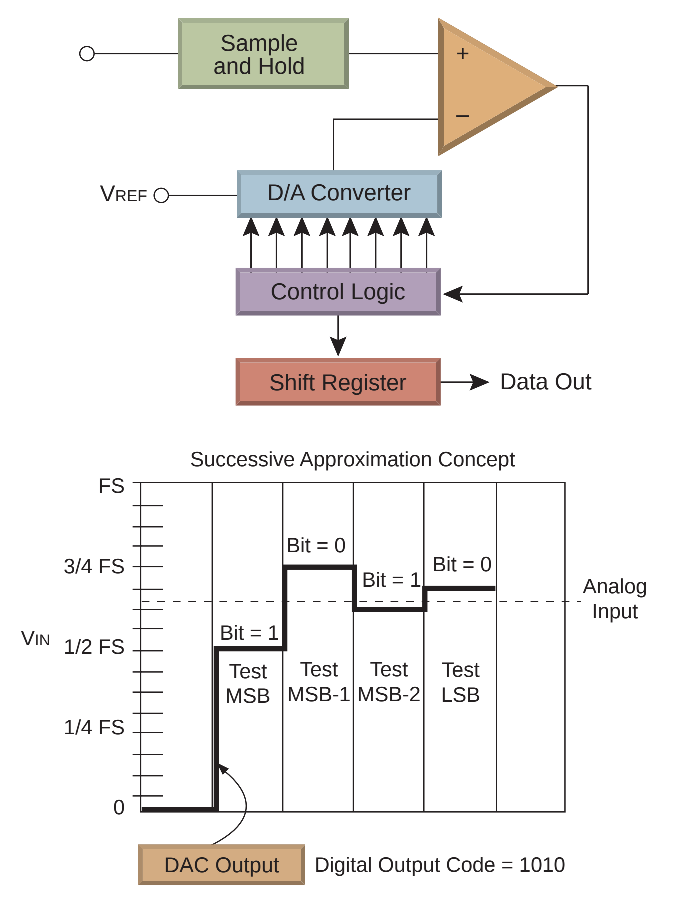
Product Specifications

Device	Resolution (bits)	Maximum Sampling Rate (samples/sec)	# of Input Channels	Interface	Supply Voltage Range (V)	Typical Supply Current (µA)	Typical INL (ppm)	Temperature Range (°C)	Features	Packages
MCP3421	18 to 12	4 to 240	1 Diff	I²C™	2.7 to 5.5	155	10	-40 to +125	PGA, VREF	6-pin SOT-23A
MCP3422	18 to 12	4 to 240	2 Diff	I²C	2.7 to 5.5	145	10	-40 to +125	PGA, VREF	8-pin SOIC, 8-pin MSOP, 8-pin 2x3 DFN
MCP3423	18 to 12	4 to 240	2 Diff	I²C	2.7 to 5.5	145	10	-40 to +125	PGA, VREF, Selectable I²C addressing	10-pin MSOP, 10-pin 3x3 DFN
MCP3424	18 to 12	4 to 240	4 Diff	I²C	2.7 to 5.5	145	10	-40 to +125	PGA, VREF, Selectable I²C addressing	14-pin SOIC, 14-pin TSSOP
MCP3425	16 to 12	15 to 240	1 Diff	I²C	2.7 to 5.5	155	10	-40 to +125	PGA, VREF	6-pin SOT-23A
MCP3426	16 to 12	15 to 240	2 Diff	I²C	2.7 to 5.5	145	10	-40 to +125	PGA, VREF	8-pin SOIC, 8-pin MSOP, 8-pin 2x3 DFN
MCP3427	16 to 12	15 to 240	2 Diff	I²C	2.7 to 5.5	145	10	-40 to +125	PGA, VREF, Selectable I²C addressing	10-pin MSOP, 10-pin 3x3 DFN
MCP3428	16 to 12	15 to 240	4 Diff	I²C	2.7 to 5.5	145	10	-40 to +125	PGA, VREF, Selectable I²C addressing	14-pin SOIC, 14-pin TSSOP

Successive Approximation Register (SAR) ADC

SAR (Successive Approximation Register) applies to the converter that uses approximation to convert the analog input signal into a digital output code. SAR converters typically lie in the 8- to 16-bit range and can have sample speeds up to 1 MSPS.

One major benefit of a SAR converter is its ability to be connected to multiplexed inputs at a high data acquisition rate. The input is sampled and held on an internal capacitor, and this charge is converted to a digital output code using the successive approximation routine. Since this charge is held throughout the conversion time, only the initial sample and hold period or acquisition time is of concern to a fast-changing input. The conversion time is the same for all conversions. This makes the SAR converter ideal for many real-time applications, including motor control, touch-screen sensing, medical and other data acquisition systems.



When designing a system with a SAR converter, the following specifications and terms should be understood:

Acquisition Time – The time required for the sampling mechanism to capture the voltage after the sample command is given for the hold capacitor to charge.

Conversion Time – The time required for the A/D converter to complete a single conversion once the signal has been sampled.

Throughput Rate or Samples Per Second (SPS) – The time required for the converter to sample, acquire, digitize, prepare and output a conversion.

Integral Non-Linearity (INL) – Specification most relevant to the overall accuracy of the converter. INL is the maximum deviation of a transition point of a conversion to the corresponding transition point of an ideal conversion. INL represents cumulative DNL errors.

Differential Non-Linearity (DNL) – The error in width between output conversion codes. The maximum deviation in code width from the ideal 1 LSB code width (FSR/2^n). DNL errors of less than -1 correspond to a missing code.

Missing Code – The situation where an A/D converter will never output a specified code regardless of the input voltage.

Monotonic – Implies that an increase (or decrease) in the analog input voltage will always produce no change or an increase (or decrease) in output code. Monotonicity does **not** imply that there are **no** missing codes.

Bipolar vs. Unipolar Output – Differential converters give a bipolar output corresponding to positive and negative numbers. The binary output scheme is usually two's complement. A unipolar output corresponding to a positive output, from 0 to VREF.

SAR Converters – Industry's Lowest-Power ADCs in SOT-23A Packages

The **MCP3021** and **MCP3221** are low-power, tiny 10- and 12-bit SAR ADCs that are ideal for battery powered or portable data acquisition systems. Based on advanced CMOS architecture, these devices draw only 180 µA at 400 kHz I²C™ clock. With a 33 kHz I²C clock, the current drops to less than 30 µA. With only 1 µA standby current, the MCP3221 is currently the world's lowest-power, 12-bit ADC in a small SOT-23A package. Communication to either device is performed using a 2-wire I²C compatible interface.

An on-chip conversion clock enables independent timing between the conversion clock, and the serial communication data rate.

The devices are also addressable, allowing up to eight devices on a single 2-wire bus. The MCP3021 and MCP3221 run on a single supply voltage that operates over a broad voltage range of 2.7V to 5.5V. Accuracy is superb, providing less than ±1 LSB of differential non-linearity (DNL) and less than ±2 LSB of integral non-linearity (INL).

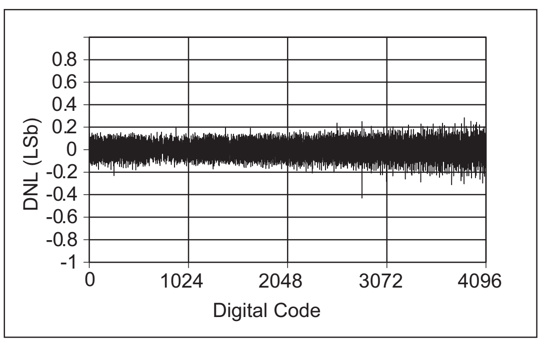
MCP3021 and MCP3221 Key Features

- 10-bit resolution (MCP3021)
- 12-bit resolution (MCP3221)
- 22 ksps in I²C Fast mode
- ±1 LSB DNL, ±1 LSB INL max. (MCP3021)
- ±1 LSB DNL, ±2 LSB INL max. (MCP3221)
- On-chip sample and hold
- I²C compatible serial interface with up to 8 devices on a single 2-wire bus:
  - 100 kHz I²C Standard mode
  - 400 kHz I²C Fast mode
- Single-supply specified operation: 2.7V to 5.5V
- Low-power CMOS technology:
  - 5 nA standby current
  - 250 µA max active current at 5V, 100 ksps
- Temperature range:
  - Industrial: -40°C to +85°C (MCP3221)
  - Extended: -40°C to +125°C

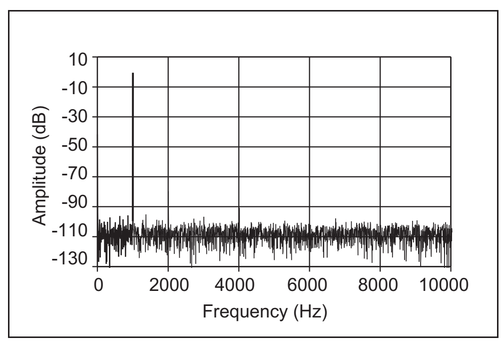
Applications

- Data Logging
- Multi-zone Monitoring
- Hand-held Portable Applications
- Battery-powered Test Equipment
- Remote or Isolated Data Acquisition
- Voice-band AC Applications up to 8 kHz

MCP3221 Functional Block Diagram and DNL vs. Digital Code Graph



MCP3221 Spectrum Using I²C™ Fast Mode
(Representative Part, 1 kHz Input Frequency)



Product Specifications

Device	Resolution (bits)	Maximum Sampling Rate (samples/sec)	# of Input Channels	Input Type	Interface	Input Voltage Range (V)	Active Current Max. (µA)	Max. INL	Temperature Range (°C)	Packages
MCP3021	10	22	1	Single-ended	I²C™	2.7 to 5.5	250	±1 LSB	-40 to +125	5 SOT-23A
MCP3221	12	22	1	Single-ended	I²C	2.7 to 5.5	250	±2 LSB	-40 to +125	5 SOT-23A

SAR Converters – Low Power 100 and 250 ksps, 10- and 12-bit ADCs

The **MCP3001** and **MCP3201** are 10- and 12-bit SAR ADCs that offer standby currents of less than 1 µA, and active currents of 300 µA at 100 ksps. Both devices offer on-board sample and hold circuitry.

Each device has one pseudo-differential input with exceptional linearity specifications of ±1 LSB DNL and ±1 LSB INL over temperature.

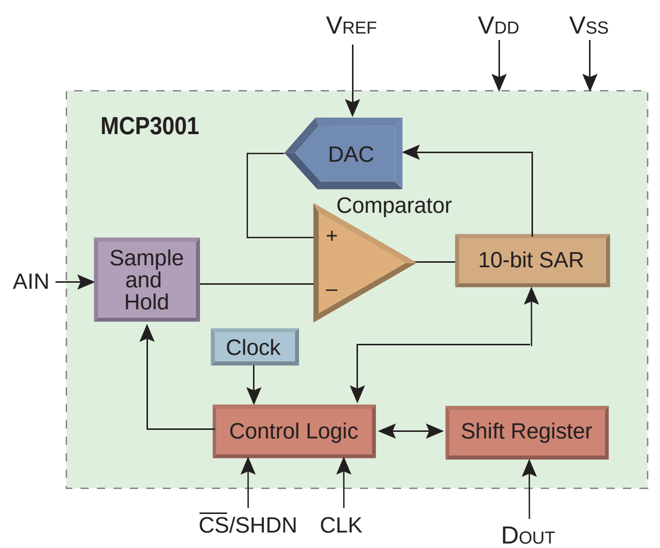
Communication with the device is accomplished by using a simple serial interface compatible with the SPI protocol. Both devices operate over a broad voltage range of 2.7V to 5.5V.

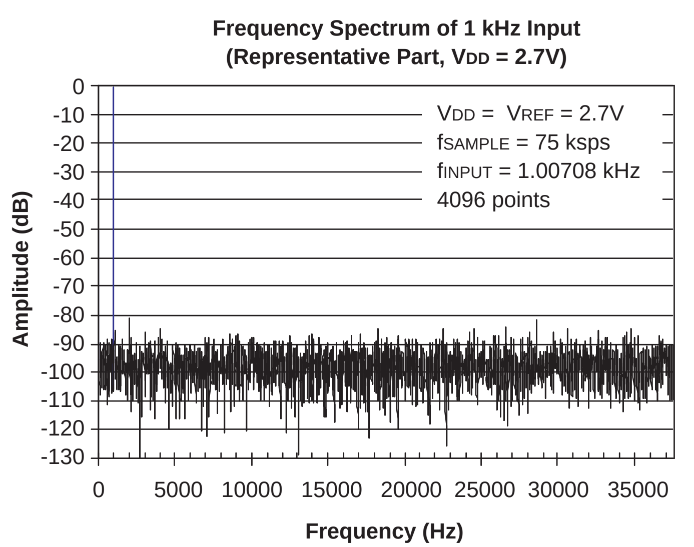
MCP3001 and MCP3201 Key Features

- 10-bit resolution (MCP3001)
- 12-bit resolution (MCP3201)
- ±1 LSB DNL, ±1 LSB INL max. (MCP3001)
- ±1 LSB DNL, ±1 LSB INL max. (MCP3201)
- On-chip sample and hold
- SPI serial interface (modes 0,0 and 1,1)
- Single-supply specified operation: 2.7V to 5.5V
- 10-bit, 75 ksps max sampling rate at V_{DD} = 2.7V (MCP3001)
- 10-bit, 200 ksps max sampling rate at V_{DD} = 5V (MCP3001)
- 12-bit, 50 ksps max sampling rate at V_{DD} = 2.7V (MCP3201)
- 12-bit, 100 ksps max sampling rate V_{DD} = 5V (MCP3201)
- Low-power CMOS technology:
  - – 500 nA standby current
  - – 300 µA active current at 5V, 100 ksps
- Temperature range:
  - – Industrial: -40°C to +85°C

Applications

- Sensor Interface
- Process Control
- Data Acquisition
- Battery-Operated Systems





Product Specifications

Device	Resolution (bits)	Maximum Sampling Rate (samples/sec)	# of Input Channels	Input Type	Interface	Input Voltage Range (V)	Active Current Max. (µA)	Max. INL	Temperature Range (°C)	Packages
MCP3001	10	200	1	Pseudo-Diff.	SPI	2.7 to 5.5	400	±1 LSB	-40 to +85	8 PDIP, MSOP, SOIC, TSSOP
MCP3201	12	100	1	Pseudo-Diff.	SPI	2.7 to 5.5	400	±1 LSB	-40 to +85	8 PDIP, MSOP, SOIC, TSSOP

SAR Converters – Low-Power, Multi-Channel ADCs – Ideal for Portables

With 2, 4 and 8 channels that are configurable as either pseduo-differential or single-ended, the **MCP3X02/4/8** converters are versatile and powerful ADCs. Industry-leading low-power technology offers low current consumption for these multi-channel devices: <1 µA standby and 250 µA at 100 ksps.

With exceptional INL and DNL performance (±1 LSB) across broad voltage and temperature ranges (2.7V to 5.5V and -40 to +85°C), multi-channel applications requiring superb linearity are ideal for these devices.

These dual-channel devices are programmable to either 2 pseduo-differential pairs or 4 single-ended inputs.

The quad-channel devices are programmable to provide 4 pseudo-differential pairs or 8 single-ended inputs.

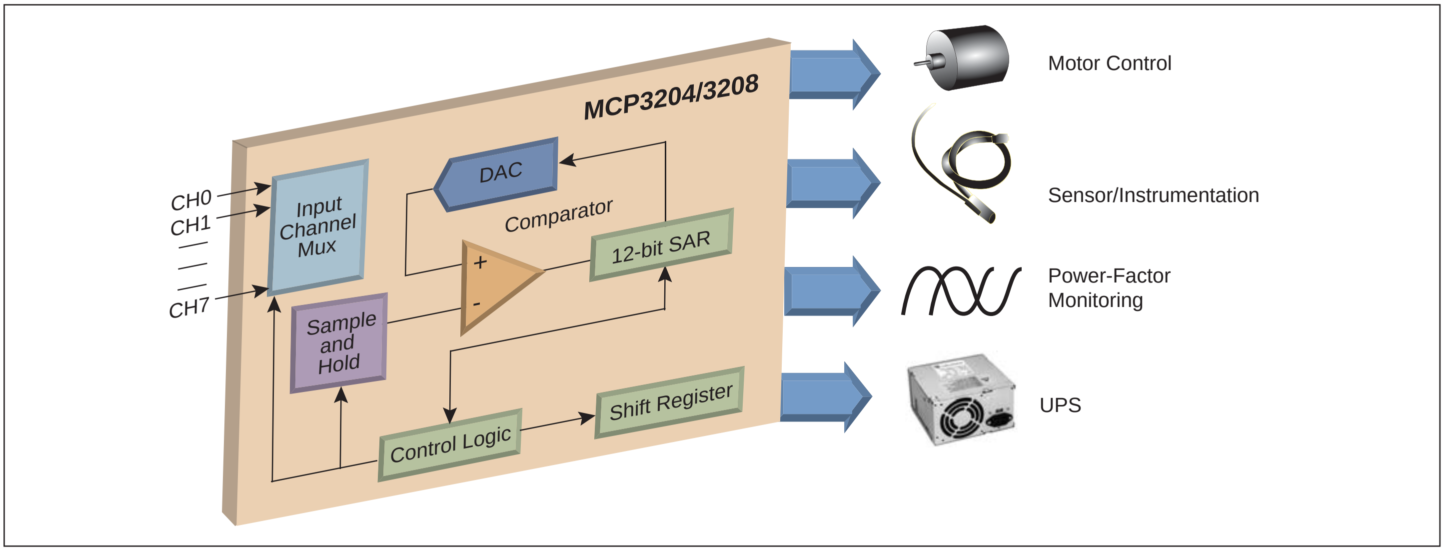
Communication is accomplished using an industry standard serial SPI protocol.

MCP3X02/4/8 ADC Key Features

- 10-bit and 12-bit resolution
- ±1 LSB DNL, ±1 LSB INL max.
- ±1 LSB DNL, ±1 LSB INL max.
- On-chip sample and hold
- SPI serial interface (modes 0,0 and 1,1)
- Single-supply specified operation: 2.7V to 5.5V
- Low-power CMOS technology:
  – 500 nA standby current
  – 300 µA active current at 5V, 100 ksps

Applications

- Multi-channel Data Acquisition Portables
- Sensor Interface
- Process Control
- Data Acquisition
- Battery Operated Systems



Product Specifications

Device	Resolution (bits)	Maximum Sampling Rate (samples/sec)	# of Input Channels	Input Type	Interface	Input Voltage Range (V)	Active Current Max. (µA)	Max. INL	Temperature Range (°C)	Packages
MCP3002	10	200	2	Single-ended or Pseudo-Differential	SPI	2.7 to 5.5	250	±1 LSB	-40 to +85	8 PDIP, MSOP, SOIC, TSSOP
MCP3004	10	200	4	Single-ended or Pseudo-Differential	SPI	2.7 to 5.5	400	±1 LSB	-40 to +85	14 PDIP, SOIC, TSSOP
MCP3008	10	200	8	Single-ended or Pseudo-Differential	SPI	2.7 to 5.5	400	±1 LSB	-40 to +85	16 PDIP, SOIC
MCP3202	12	100	2	Single-ended or Pseudo-Differential	SPI	2.7 to 5.5	550	±1 LSB	-40 to +85	8 PDIP, MSOP, SOIC, TSSOP
MCP3204	12	100	4	Single-ended or Pseudo-Differential	SPI	2.7 to 5.5	400	±1 LSB	-40 to +85	14 PDIP, SOIC, TSSOP
MCP3208	12	100	8	Single-ended or Pseudo-Differential	SPI	2.7 to 5.5	400	±1 LSB	-40 to +85	16 PDIP, SOIC

SAR Converters – 13-bit Differential Input ADC – Ideal for Interfacing to Sensors

The **MCP330X** family of data converters offers true differential input with a bipolar two's complement output. Strain gauges, wheatstone bridges and AC signals are all ideally interfaced to the differential input ADCs. These ADCs provide single differential input, two differential input or four differential inputs.

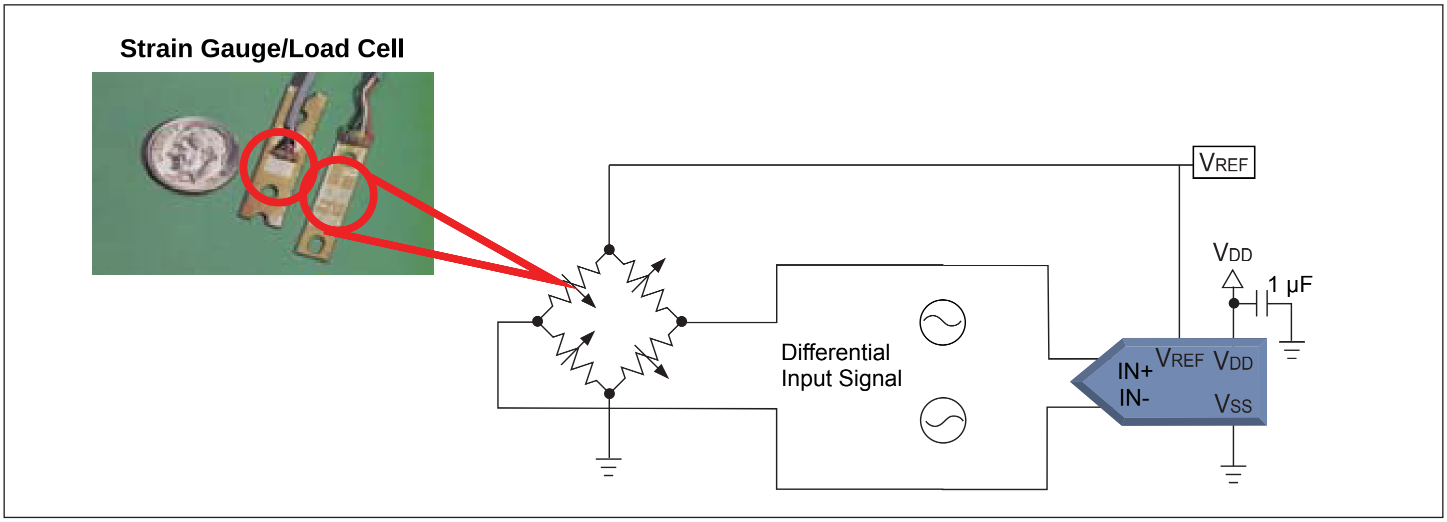
The low power consumption of these devices at up to 100 ksps, in addition to their high resolution, makes these sensors ideal for portable AC measurement applications.

MCP330X ADC Key Features

- Full Differential Inputs with a 13-bit Resolution
- ±1 LSB DNL max.
- ±1 LSB INL max.
- Number of Single-ended Inputs:
  - 1 (**MCP3301**)
  - 4 (**MCP3302**)
  - 8 (**MCP3304**)
- On-chip sample and hold
- SPI serial interface (modes 0,0 and 1,1)
- Single-supply specified operation: 2.7V to 5.5V
- Low-power CMOS technology:
  - 500 nA standby current
  - 300 µA active current at 5V, 100 ksps
- 100 ksps sampling rate with 5V supply current
- Temperature Range: -40°C to +85°C

Applications

- Remote Sensors
- Battery Operated Systems
- Transducer Interface



Product Specifications

Device	Resolution (bits)	Maximum Sampling Rate (samples/sec)	# of Input Channels	Input Type	Interface	Input Voltage Range (V)	Active Current Max. (µA)	Max. INL	Temperature Range (°C)	Packages
MCP3301	13	100	1	Differential	SPI	2.7 to 5.5	450	+1 LSB	-40 to +85	8 PDIP, MSOP, SOIC
MCP3302	13	100	2	Differential	SPI	2.7 to 5.5	450	±1 LSB	-40 to +85	14 PDIP, SOIC, TSSOP
MCP3304	13	100	4	Differential	SPI	2.7 to 5.5	450	±1 LSB	-40 to +85	16 PDIP, SOIC

ADC by Architecture – Dual Slope or Integrating

A dual-slope converter operates by charging a capacitor from the input voltage during a fixed time, and then discharging it to zero. Actual data conversion is accomplished in two phases: input signal integration and reference voltage de-integration.

The integrator output is initialized to 0V prior to the start of integration. During integration, analog switch S1 connects V_{IN} to the integrator input, where it is maintained for a fixed time period (t_{INT}).

The application of V_{IN} causes the integrator output to depart 0V at a rate determined by the magnitude of V_{IN}, and a direction determined by the polarity of V_{IN}. The de-integration phase is initiated immediately at the expiration of t_{INT}.

During de-integration, S1 connects a reference voltage (having a polarity opposite that of V_{IN}) to the integrator input. At the same time, an external precision timer is started. The de-integration phase is maintained until the comparator output changes states, indicating the integrator has returned to its starting point of 0V. When this occurs, the precision timer is stopped. The de-integration time period (t_{DEINT}), as measured by the precision timer, is directly proportional to the magnitude of the applied input voltage.

A simple mathematical equation relates the input signal, reference voltage and integration time:

$$(1/R_{INT}C_{INT})*\text{integral}\ [\ V_{IN}\ (t)\ dt\ ]\ \text{from}\ t = 0\ \text{to}\ t = t_{INT}$$

For a constant V_{IN}:

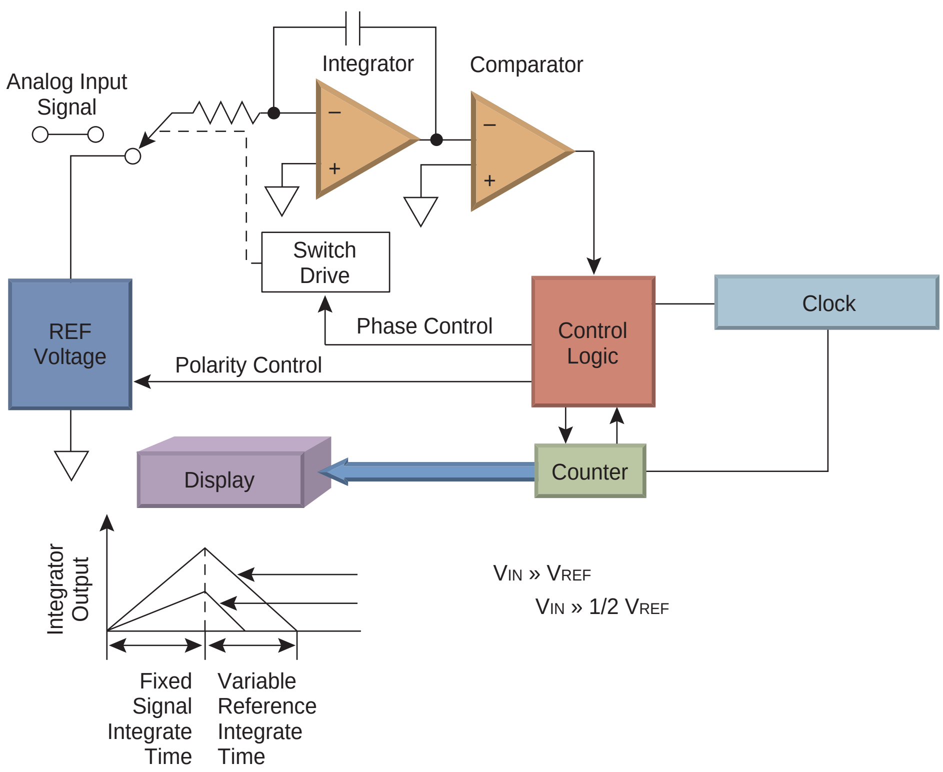
$$V_{IN} = V_{REF} * (t_{DEINT} / t_{INT})$$

The dual-slope converter accuracy is unrelated to the integrating resistor and capacitor values as long as they are stable during a measurement cycle.

An inherent benefit is noise immunity. Input noise spikes are integrated (averaged to zero) during the integration periods. Integrating ADCs are immune to the large conversion errors that plague successive approximation converters in high-noise environments.

Integrating converters provide inherent noise rejection, with at least a 20 dB/decade attenuation rate. Interference signals with frequencies at integral multiples of the integration period are, theoretically, completely removed since the average value of a sine wave of frequency (1/t) averaged over a period (t) is zero.

Basic Dual-Slope Converter



Dual Slope – 17-bit Plus Sign Serial ADC

Accepts Bipolar Inputs of Up to ±4.2V

The **TC5XX** family are precision analog front ends that implement dual-slope ADCs with a maximum resolution of 17 bits plus sign. The TC500 is the base device that requires both positive and negative power supplies, while the TC510 adds on-board power supply conversion for single-supply operation.

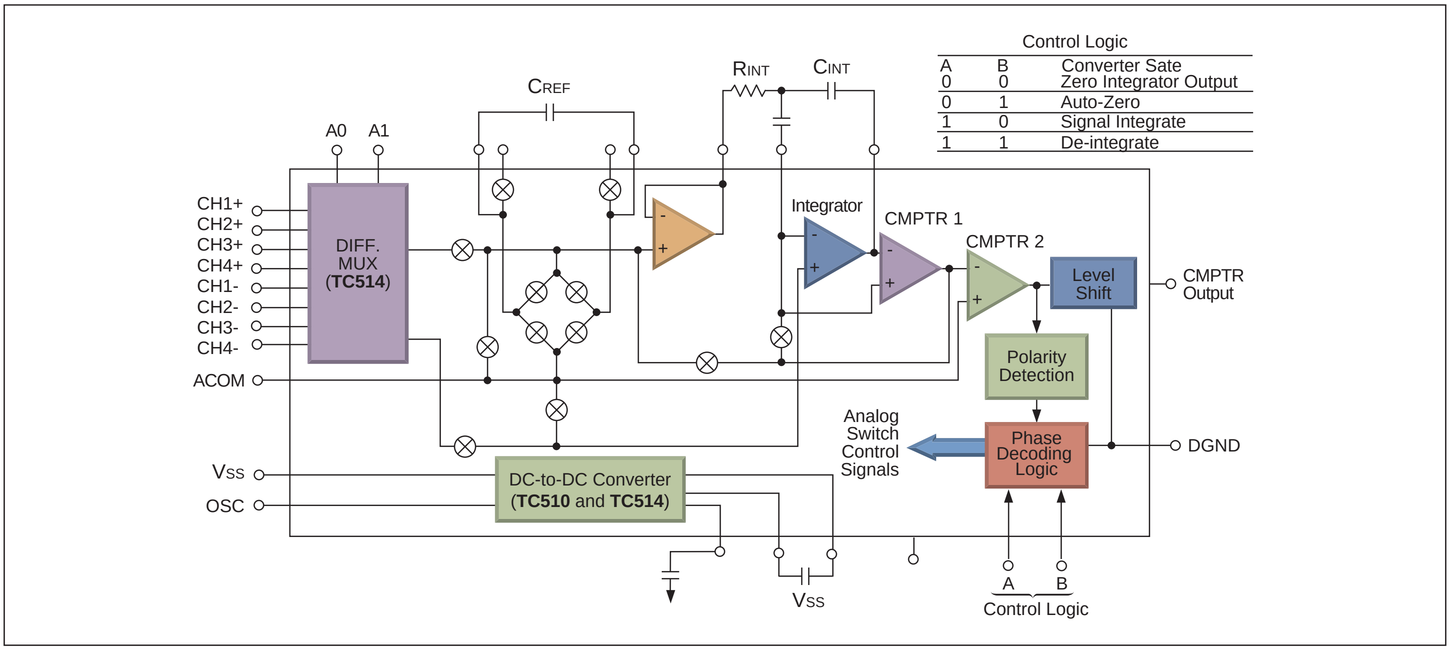
The conversion speed of the converter is configurable, with the user being able to trade conversion speed for resolution. With single and multi-channel devices, the TC5XX is a powerful family of dual-slope converters. A 50/60 Hz noise rejection, low-power operation, and minimum I/O connections, make these devices suitable for a variety of data acquisition systems.

TC5XX Key Features

- Precision (up to 17 bits) A/D Converter "Front End"
- 3-Pin Control Interface to Microprocessor
- Flexible: User Can Trade-off Conversion Speed for Resolution
- Single-Supply Operation (TC510/TC514)
- 4 Input, Differential Analog MUX (TC514)
- Automatic Input Voltage Polarity Detection
- Wide Analog Input Range: ±4.2V (TC500A/TC510)
- Directly Accepts Bipolar and Differential Input Signals
- Low Power Dissipation:
  – 10 mW - (TC500/TC500A), 18 mW - (TC510/TC514)

TC5XX Applications

- Precision Analog Signal Processor
- Precision Sensor Interface
- High-Accuracy DC Measurements



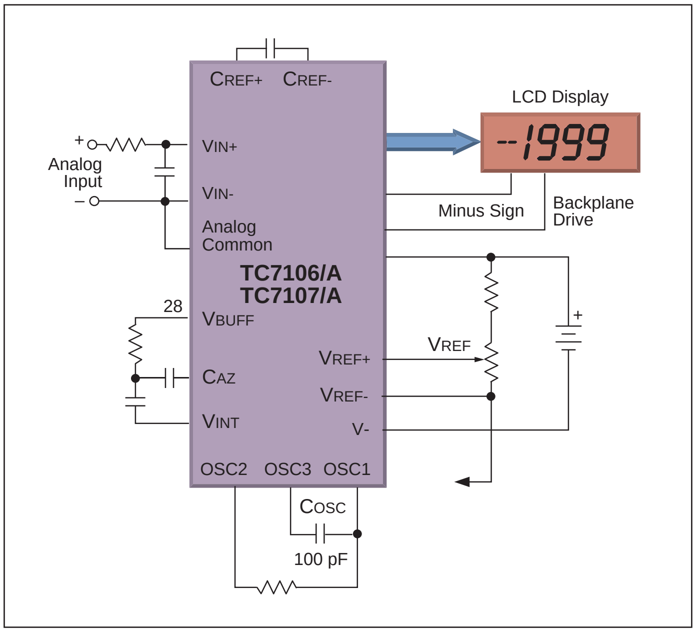
Product Specifications

Part	Supply Voltage (V)	Input Voltage Range (V)	Resolution Input (V)	Sampling Rate (Conv/s)	Input Channels	Data Interface	Temperature Range (°C)	Features	Packages
TC500A	±4.5 to ±7.5	V_{SS} + 1.5V to V_{DD} – 1.5V	Up to 17 bits	4 to 10	1	3-Wire	0 to +70	Differential input range, Programmable resolution/conversion time	16 PDIP, SOIC, CerDIP
TC510	+4.5 to +5.5	V_{SS} + 1.5V to V_{DD} – 1.5V	Up to 17 bits	4 to 10	1	3-Wire	0 to +70	Differential input range, Programmable resolution/conversion time, Charge pump (-V) output pin	24 PDIP, SOIC
TC514	+4.5 to +5.5	V_{SS} + 1.5V to V_{DD} – 1.5V	Up to 17 bits	4 to 10	4	3-Wire	0 to +70	Differential input range, Programmable resolution/conversion time, Charge pump (-V) output pin	28 PDIP, 28 SOIC
TC520A	+4.5 to +5.5	—	—	—	—	Serial Port	0 to +70	Optional serial interface adapter for TC500/A/510/514	14 PDIP, 16 SOIC

3½ and 4½-Digit ADCs with Segment Drive

With a complete data acquisition system on-chip, these devices directly drive multiplexed, liquid crystal displays (LCDs). The **TC7107A** drives common anode light emitting diode (LED) displays directly with 8 mA per segment. Seven segment decoders, digit and polarity drivers, voltage references and clock circuits are all integrated on the chips.

A low-cost, high-resolution indicating meter requires only a display and a handful of resistors and capacitors. 3½ digit and 4½ digit options, along with extended features and power options, make the **TC711X** and **TC712X** devices ideal for multimeters and digital measurement devices.



TC71XX Key Features

- Internal References with Low Temperature Drift
  - – TC7126A: 80 ppm/°C Typical
  - – TC7117A: 20 ppm/°C Typical
- Directly Drives LCD or LED display
- Convenient 9V Battery Operation
  - – TC7116A/TC7126A/TC7129
- Differential Input Operation
- Industrial Temperature Range: -25°C to 85°C

TC71XX Applications

- Full-featured Multimeters
- Digital Measurement Devices
- Bridge Readouts
- Portable Instrumentation

Product Specifications

Part	Display Type	Supply Voltage (V)	Resolution (Digits)	Resolution (Counts)	Power (mW)	Temperature Range (°C)	Features	Packages
TC7106A	LCD	9	3.5 Digit High Power LCD	±2,000	10	-25 to +85	For DMM, DPM, Data logger applications	40 PDIP, 44 PLCC, 44 PQFP, 40 CerDIP
TC7107A	LED	±5	3.5	±2,000	10	-25 to +85	For DMM, DPM, Data logger applications	40 PDIP, 44 PLCC, 44 PQFP, 40 CerDIP
TC7116A	LCD	9	3.5 with Hold	±2,000	10	-25 to +85	Hold function	40 PDIP, 44 PLCC, 44 PQFP, 40 CerDIP
TC7117A	LED	±5	3.5	±2,000	10	-25 to +85	Hold function	40 PDIP, 44 PLCC, 44 PQFP, 40 CerDIP
TC7126A	LCD	9	3.5	±2,000	0.5	-25 to +85	Low Power TC7106	40 PDIP, 44 PLCC, 44 PQFP, 40 CerDIP
TC7129	LCD	9	4.5 with LCD	±20,000	0.5	0 to +70	Lowest noise ±3 mV sensitivity	40 PDIP, 44 PLCC, 44 PQFP, 40 CerDIP

3½-Digit ADC with BCD Output

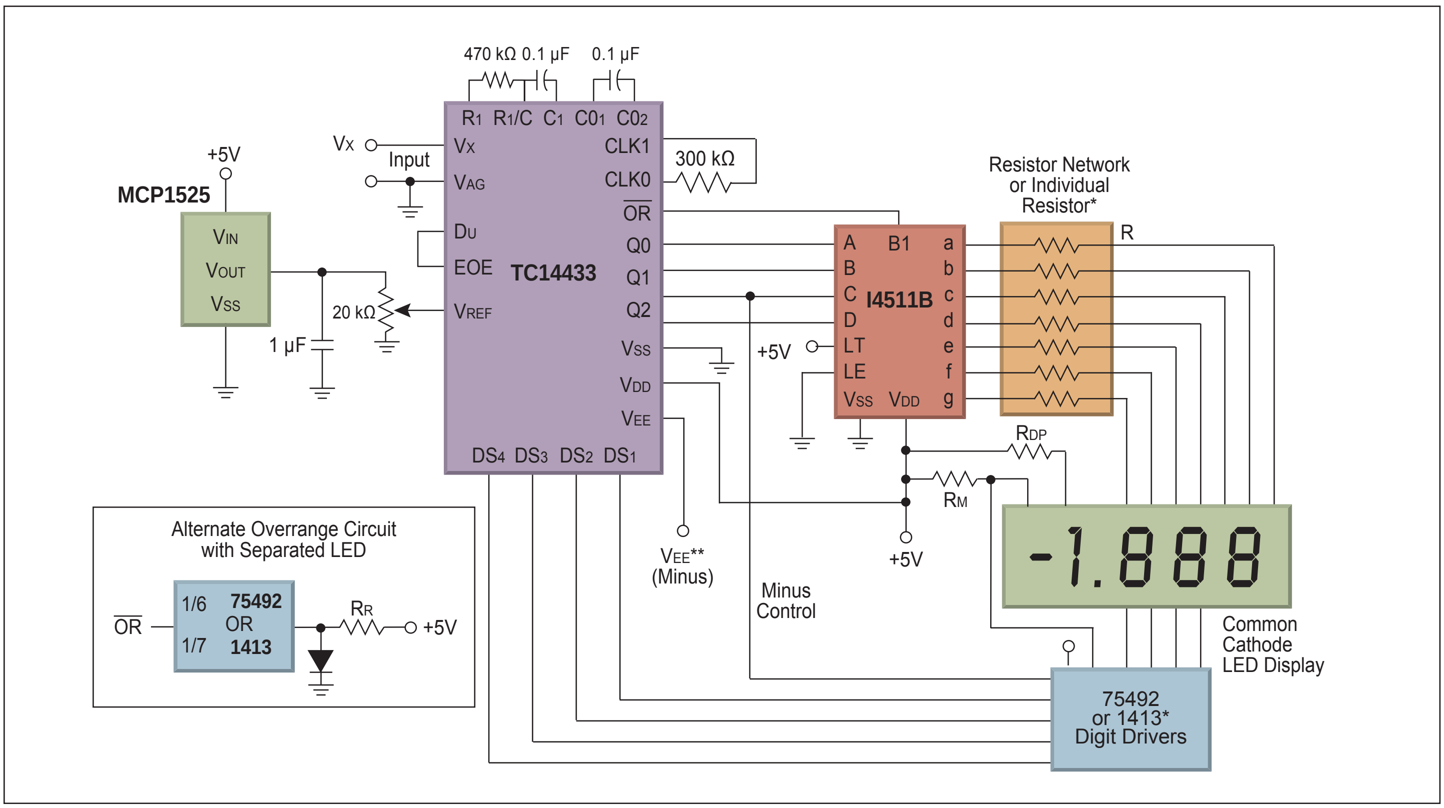
The **TC14433A** is a low power, high-performance, monolithic CMOS 3½-digit A/D converter. The TC14433A combines both analog and digital circuits on a single IC, thus minimizing the number of external components. This dual-slope A/D converter provides automatic polarity and zero correction with the addition of two external resistors and two capacitors. The full-scale voltage range of this ratiometric IC extends from 199.9 mV to 1.999V. The TC14433A can operate over a wide range of power supply voltages. The TC14433A features improved performance over the industry standard TC14433. Power consumption of the TC14433A is typically 4 mW, approximately one-half that of the industry standard TC14433.

TC14433A Key Features

- Accuracy: ±0.05% of Reading ±1 Count
- Two Voltage Ranges: 1.999V and 199.9 mV
- Up to 25 Conversions Per Second
- ZIN > 1000M Ohms
- Single Positive Voltage Reference
- Auto-Polarity and Auto-Zero
- Overrange and Underrange Signals Available
- Operates in Auto-Ranging Circuits
- Uses On-Chip System Clock or External Clock

TC14433A Applications

- Portable Instruments
- Digital Voltmeters
- Digital Panel Meters
- Digital Scales
- Digital Thermometers
- Remote A/D Sensing Systems



Product Specifications

Part	Description	Supply Voltage (V)	Input Voltage Range (V)	Resolution (Digits)	Resolution (Counts)	Max Power (mW)	Data Interface	Temperature Range (°C)	Features	Packages
TC14433A	BCD A/D	±4.5 to ±5	±199.9 mV to 1.999V	3.5	±2,000	20	MUXed BCD	-40 to +85	For DMM, Data loggers	24 PDIP, 28 PLCC, 24 CerDIP

15-bit Binary Output ADC Includes Auto-Zeroed Amplifiers

The **TC850** is a monolithic CMOS A/D converter (ADC) with a resolution of 15-bits plus sign. It combines a chopper-stabilized buffer and integrator with a unique multi-slope integration technique that increases conversion speed. The result is a 16-time improvement in speed over previous 15-bit, monolithic integrating ADCs (from 2.5 conversions per second up to 40 per second). Faster conversion speed is especially welcome in systems with human interface, such as digital scales.

The TC850 incorporates an ADC and a microprocessor-compatible digital interface. Only a voltage reference and a few, noncritical, passive components are required to form a complete 15-bit plus sign ADC. CMOS processing provides the TC850 with high-impedance and differential inputs. Input bias current is typically only 30 pA, permitting direct interface to sensors.

Input sensitivity of 100 µV per Least Significant Bit (LSB) eliminates the need for precision external amplifiers. The internal amplifiers are auto-zeroed, ensuring a zero digital output with 0V analog input. Zero-adjustment potentiometers or calibrations are not required.

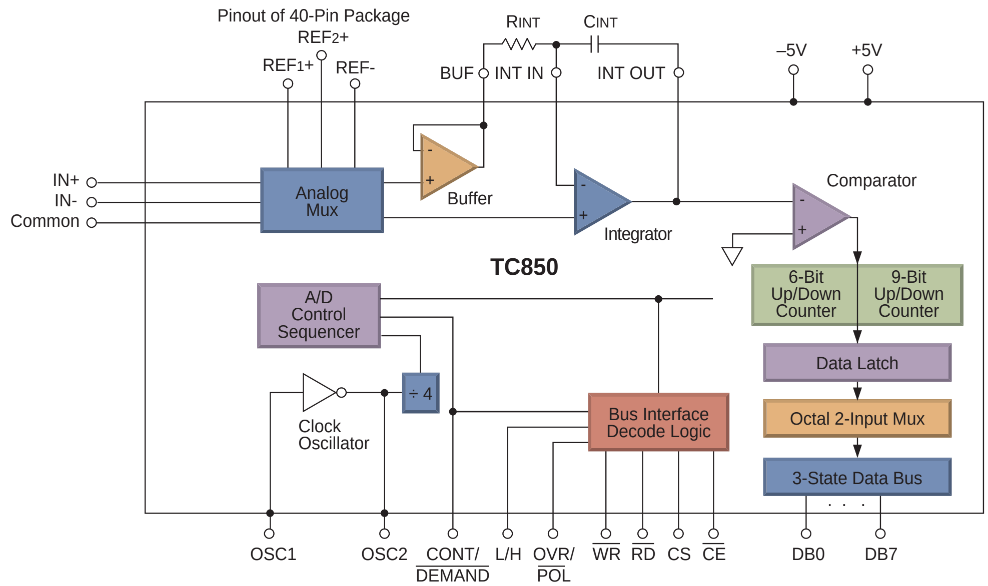
The TC850 outputs data on an 8-bit, 3-state bus. Digital inputs are CMOS-compatible, while outputs are TTL/CMOS-compatible. Chip-enable and byte-select inputs, combined with an end-of-conversion output, ensures easy interfacing to a wide variety of microprocessors. Conversions can be performed continuously or on command. In Continuous mode, data is read as three consecutive bytes and manipulation of address lines is not required. Operating from ±5V supplies, the TC850 dissipates only 20 mW.

TC850 Key Features

- 15-bit Resolution Plus Sign Bit
- Up to 40 Conversions per Second
- Integrating ADC Technique
  - Monotonic
  - High Noise Immunity
  - Auto-zeroed Amplifiers Eliminate Offset Trimming
- Wide Dynamic Range: 96 dB
- Low Input Bias Current: 30 pA
- Low Input Noise: 30 µVP-P
- Sensitivity: 100 µV
- Flexible Operational Control
- Continuous or On-demand Conversions
- Data Valid Output
- Bus Compatible, 3-State Data Outputs
  - 8-bit Data Bus
  - Simple µP Interface
  - Two Chip Enables
  - Read ADC Result Like Memory
- ± 5V Power Supply Operation: 20 mW

TC850 Applications

- Precision Analog Signal Processor
- Precision Sensor Interface
- High Accuracy DC Measurments



Product Specifications

Part	Description	Supply Voltage (V)	Input Voltage Range (V)	Resolution (Digits)	Resolution (Counts)	Max Power (mW)	Data Interface	Temperature Range (°C)	Features	Packages
TC850	Binary A/D	±5	V_{SS} + 1.5V to V_{DD} – 1.5V	15-bit	±32,768	35	8-bit Parallel	-25 to +70	Highest conversion speed (40 conv/sec)	44 PLCC, 40 PDIP, 40 CerDIP

12-bit Dual-Slope with Serial and Parallel Binary Output

The **TC7109A** is a 12-bit plus sign, CMOS low-power Analog-to-Digital converter. Only eight passive components and a crystal are required to form a complete dual-slope integrating ADC.

The improved V_{OH} source current and other TC7109A features make it an attractive per-channel alternative to analog multiplexing for many data acquisition applications. These features include typical input bias current of 1 pA, drift of less than 1 µV/°C, input noise typically 15 μV_{P-P} and auto-zero. True differential input and reference allow measurement of bridge-type transducers, such as load cells, strain gauges and temperature transducers.

The TC7109A provides a versatile digital interface. In the Direct mode, chip select and HIGH/LOW byte enable control parallel bus interface. In the Handshake mode, the TC7109/A will operate with industry standard UARTs in controlling serial data transmission – ideal for remote data logging. Control and monitoring of conversion timing is provided by the RUN/HOLD input and STATUS output.

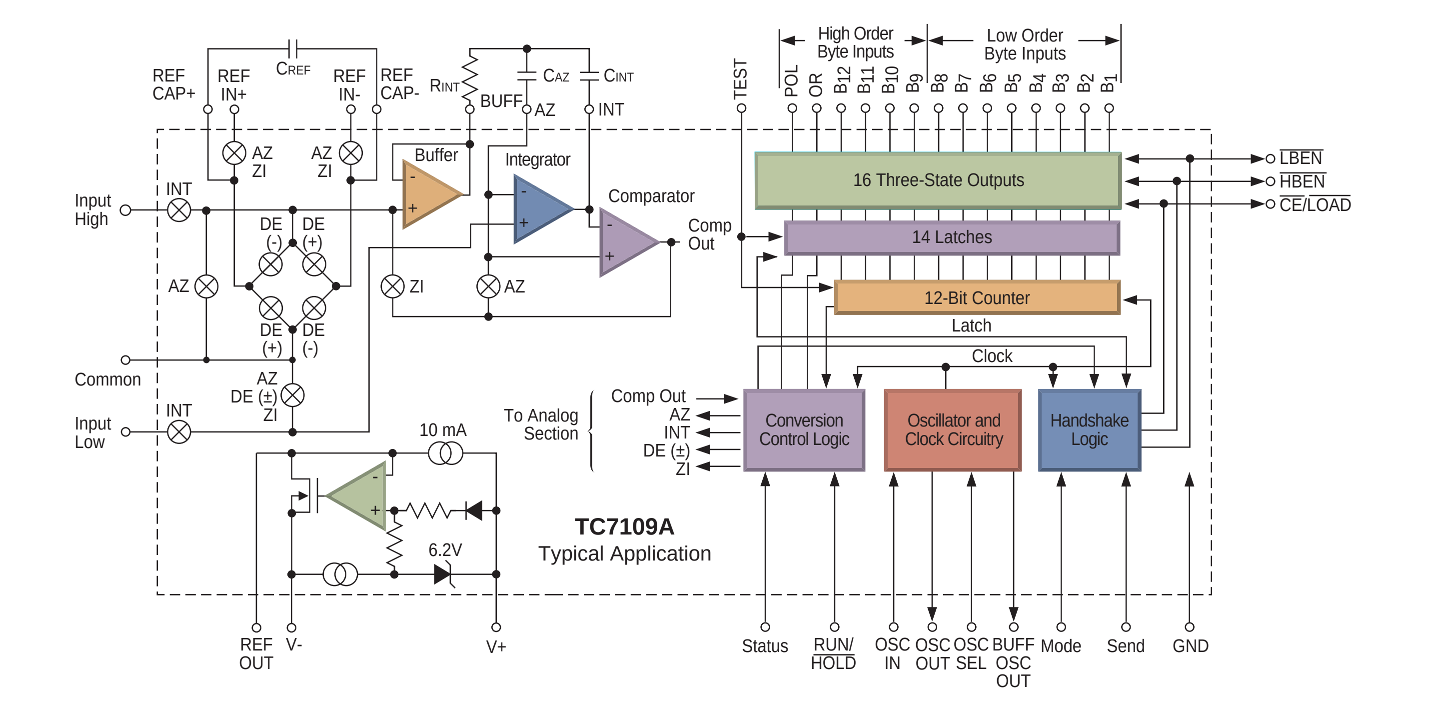
For applications requiring more resolution, see the TC500, 15-bit plus sign ADC data sheet.

TC7109A Key Features

- Zero Integrator Cycle for Fast Recovery from Input Overloads
- Eliminates Cross-Talk in Multiplexed Systems
- 12-bit Plus Sign Integrating A/D Converter with Overrange Indication
- Sign Magnitude Coding Format
- True Differential Signal Input and Differential Reference Input
- Low Noise: 15 μV_{P-P} Typ.
- Input Current: 1 pA Typ.
- No Zero Adjustment Needed
- TTL Compatible, Byte Organized Tri-state Outputs
- UART Handshake Mode for Simple Serial Data Transmissions

TC7109A Applications

- Ideal for Remote Data Logging
- Bridge-type Transducer Measurements
  - Load Cells
  - Strain Gauges
  - Temperature Transducers



Product Specifications

Part	Supply Voltage (V)	Input Voltage Range (V)	Resolution (Digits)	Sampling Rate (Conv/s)	Input Channels	Data Interface	Temperature Range (°C)	Features	Packages
TC7109A	±5	V_{SS} + 1.5V to V_{DD} – 1.0V	12 bits plus sign bit	±32,768	1	Parallel or Serial	-25 to +85	Differential Input Range	44 PDIP, 40 CerDIP, 44 PLCC, 44 PQFP

DataView™ Software Tool

DataView is a visualization tool showing real-time histogram and scope plots output for the MCP355X. The software also calculates the RMS noise of the current distribution. The number of samples in the distribution is also scalable, allowing post averaging experiments.

- Histogram
- Scope plot
- RMS noise calculation

MXLAB® Software Tool

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

MXDEV® Analog Evaluation System

The MXDEV® Analog Evaluation System is a versatile and easy-to-use system for evaluating Microchip's MCP mixed-signal products. 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 DVXXXX 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.

Microchip Development Boards

DVMCPA - MXDEV Analog Evaluation Driver Board Version 1

DV3201A - MCP3001/3002 and MCP3201/02 A/D Converter Evaluation Board

DV3204A - MCP3004/3008 and MCP3204/08 A/D Converter Evaluation Board

DV42XXX - MCP42XXX Digital Potentiometer

MCP3551DM-PCTL - MCP3551/3 Demonstration Board

MCP3421EV - MCP3421 SOT23-6 Evaluation Board

MCP3421DM-BFG - MCP3421 Battery Fuel Gauge Demo Board

MCP3422EV - MCP3422 Evaluation Board

MCP3423EV - MCP3423 Evaluation Board

MCP3424EV - MCP3424 Evaluation Board

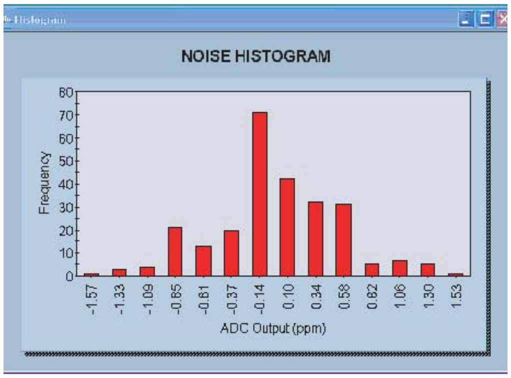
MCP3425EV - MCP3425 SOT23-6 Evaluation Board

MCP355XDM-TAS - MCP355X Tiny Application Sensor Board

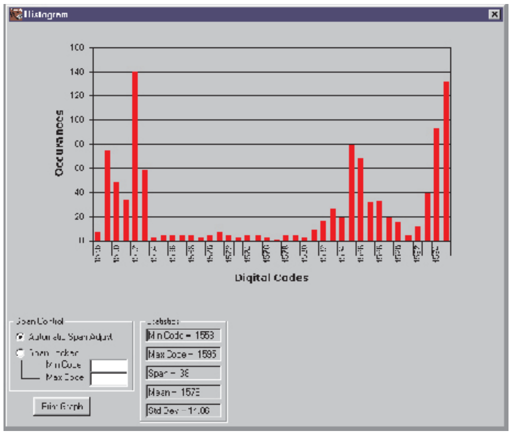
MCP355XDV-MS1 - MCP355X Sensor Application Developer's Board

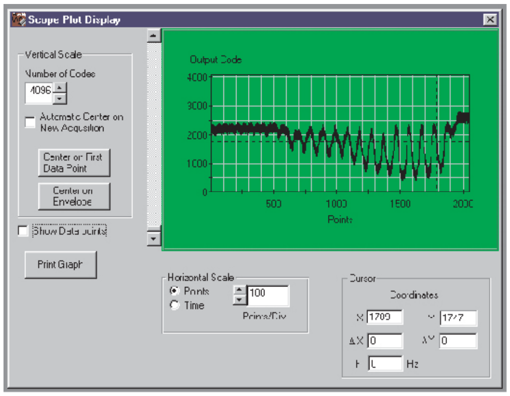
MCP3221DM-PCTL - MCP3221 PICtail™ Demo Board

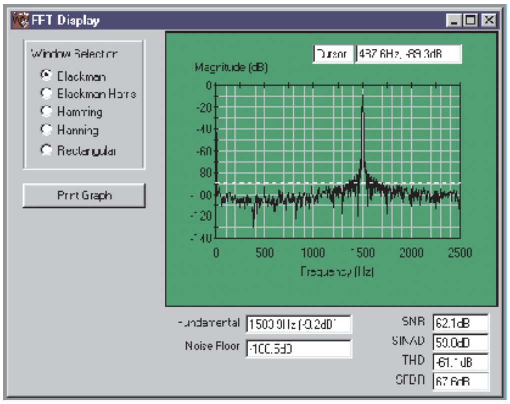
DataView™ Software System Performance Histogram



MXLAB® Screen Captures







Related Support Material

The following literature is available on the Microchip web site: www.microchip.com/appnotes. There are additional application notes that may be useful.

Application Notes

AN246: Driving the Analog Inputs of a SAR A/D Converter
Driving any A/D Converter (ADC) can be challenging if all issues and trade-offs are not understood from the beginning. With Successive Approximation Register (SAR) ADCs, the sampling speed and source impedance should be taken into consideration if the device is to be fully utilized. This application note discusses 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.

AN681: Reading and Using Fast Fourier Transformation (FFT)
This application note focuses on the use of FFT plots to illustrate the performance of A/D converters. FFTs can help identify noise interference, power supply, and analog device performance.

AN688: Layout Tips for 12-Bit A/D Converter Application
This application note describes basic A/D converter layout guidelines, ending with a review of issues to be aware of. Examples of good and bad layout techniques are provided.

AN693: Understanding A/D Converter Performance Specifications
This application note describes the specifications used to quantify the performance of A/D converters and gives the reader a better understanding of the significance of those specifications in an application.

AN695: Interfacing Pressure Sensors to Microchip's Analog Peripherals
This application note concentrates on the signal conditioning path of the piezoresistive sensing element from sensor to microcontroller. It shows how the electrical output of this sensor can be gained, filtered and digitized in order to prepare it for the microcontroller's calibration routines.

AN780: 15-Kilogram Scale Using the TC500A and the TC520
A 15 kg weighing scale was designed using Microchip's TC500A Analog Processor and the TC520 16-bit Controller. The scale is required to resolve down to 1/8 gram and correct to within 6-1/2 grams.

AN781: Solving Sensor Offset Problems with TC7106
Design engineers sometimes have to interface the TC7106 and similar ADCs to "non-ideal" sensors. A very common problem is that the sensor often does not give a "zero" output where the design wants a zero reading.

AN783: ±5V Power Supply Operation with TC7106A/7107A
This application note describes how the TC7106A/7107A 3-1/2 digit analog-to-digital converters with liquid crystal display drive can be powered from ±5V power supplies using low-cost regulators, such as the TC55 (+5V).

AN788: Numerical-Integration Techniques Speed Dual-Slope A/D Conversion
By using low-cost microprocessors and a program-controlled, numerical-integration technique, you can achieve good noise rejection and take full advantage of the higher speeds offered by dual-slope A/D converters, such as the TC7109.

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 (D/A) converters have greatly increased the flexibility of interface and control circuits.

AN796: TC7109 Records Remote Data Automatically
The TC7109 analog-to-digital converter, a 2 Kbytes CMOS static RAM, and some gates and counters can be combined to form a low-cost, flexible, stand-alone data-logging system.

AN842: Differential ADC Biasing Techniques, Tips and Tricks
This application note discusses differential input configurations and their operation circuits to implement these input modes and techniques in choosing the correct voltage levels.

AN845: Communicating with The MCP3221 Using PIC® Microcontrollers
This application note covers communications between the MCP3221 device and a PIC® microcontroller. Hardware and software implementations of the I^{2}C™ protocol are covered.

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.

AN1030: Weigh Scale Applications for the MCP3551
This application note discusses various design techniques when using the MCP3551 in weigh scale applications.

Demonstration/Evaluation Board and User Guide

MCP3XXX Evaluation Kit User's Guide (DS51220)
This document describes how to use the MCP3XXX Evaluation Board to evaluate Microchip's stand-alone MCP3XXX A/D converters.

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
- Li-Ion/Li-Polymer Battery Chargers

Linear
- Op Amps
- Programmable Gain Amplifiers
- Comparators

Safety & Security
- Photoelectric Smoke Detectors
- Ionization Smoke Detectors
- Ionization Smoke Detector Front Ends
- Piezoelectric Horn Drivers

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 Transceivers
- Serial Peripherals
- Ethernet Controllers

Analog and Interface Attributes

Robustness
- MOSFET Drivers lead the industry in latch-up immunity/stability
- High performance LIN and CAN transceivers

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
- 1.6 µA LDOs
- Low power ADCs with one-shot conversion

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
- Industry's first 12-bit quad DAC with non-volatile EEPROM
- Delta-Sigma ADCs feature on-board PGA and voltage reference
- Highly integrated charging solutions for Li-ion and LiFePO4 batteries

Space Savings
- Resets and LDOs in SC70 package, A/D and D/A converters in 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
- Industry's first op amp featuring on-demand calibration via mCal technology
- Digital potentiometers feature WiperLock™ technology to secure EEPROM

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

Support

Microchip is committed to supporting its customers in developing products faster and more efficiently. We maintain a worldwide network of field applications engineers and technical support ready to provide product and system assistance. In addition, the following service areas are available at www.microchip.com:

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If additional training interests you, then Microchip can help. We continue to expand our technical training options, offering a growing list of courses and in-depth curriculum locally, as well as significant online resources – whenever you want to use them.

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- Resources from our Distribution and Third Party Partners www.microchip.com/training

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