Applications of Analog-to-Digital Converters

Typical ADC Applications

ADCs are used in a high percentage of modern electronic equipment. Some common examples are covered here.

ADCs are used inside cell phones to convert the voice to digital for transmission. Others are used convert the received analog RF signal to digital for processing by DSP to recover the voice signal for the DAC.

Cell phone base stations use ADCs to digitize the received signals so that they may be processed by DSP including filtering, demodulation, decompression, and bit error correction. Cell phone and base station radios are called software-defined radios (SDRs).

ADCs are widely used in industrial instrumentation and control applications where they convert sensor data to digital for storage, processing, or display.

ADCs are used in CD/DVD audio recording and in PC sound cards.

All applications using digital signal processing (DSP) require an ADC.

Software-Defined Radios (SDR)

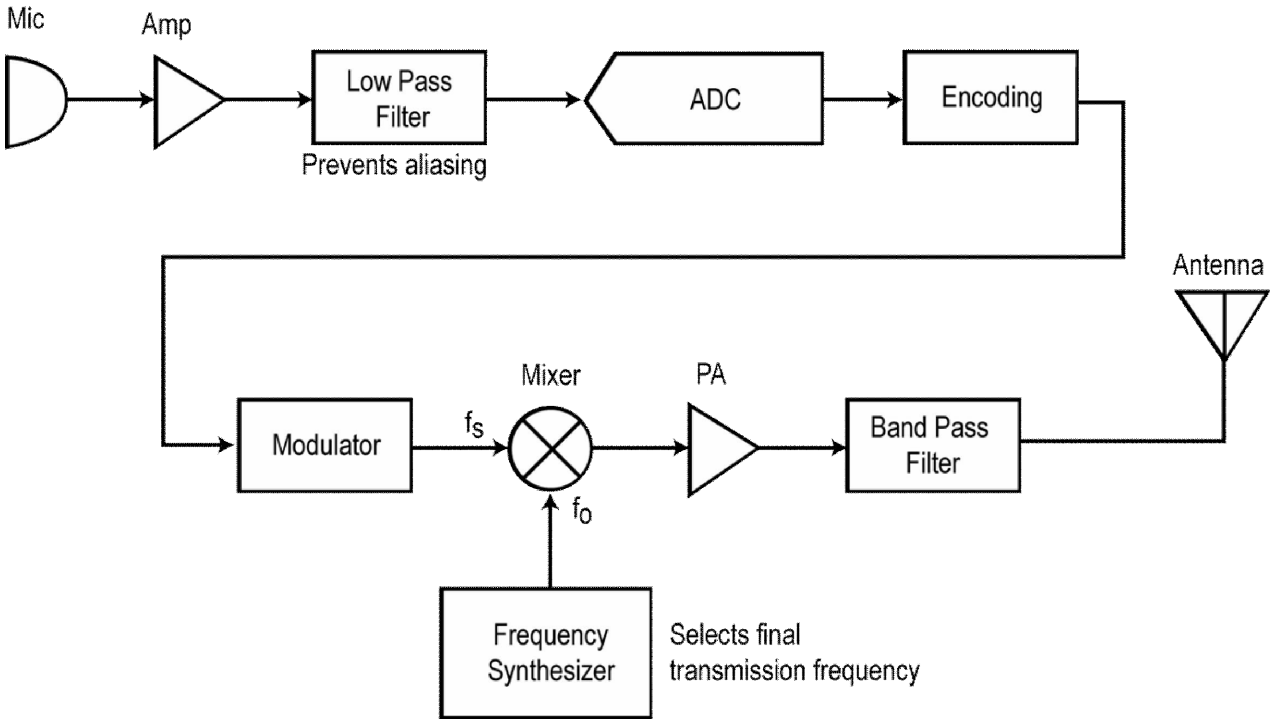
In the past, most radio communications (wireless) was analog in nature. The signals to be transmitted (voice, video, etc.) were analog and the radio signal itself was analog.

Today, the signals to be transmitted are still analog, but transmission is by digital techniques. The analog signals to be transmitted are digitized by an ADC and the binary coded information is used to modulate the analog radio carrier.

At the receiver, the signal is amplified and recovered. The analog radio signal is demodulated to obtain the originally transmitted digital data. The digital data is fed to a DAC for recovery.

Most of the processing of the radio signal in the receiver has been analog, but today, DSP methods are common. The signal processing is defined by software programs running on the DSP. As ADCs get faster, more and more processing is done digitally and less and less by analog methods.

The SDR Concept - Transmitter



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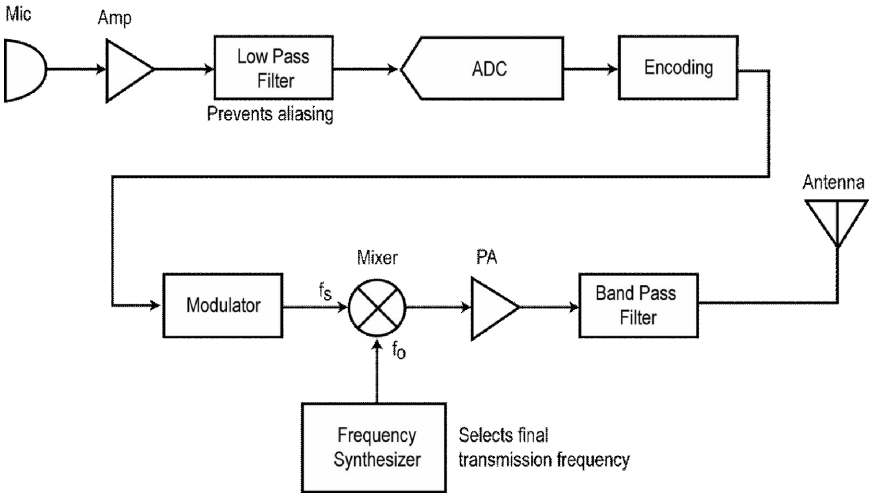
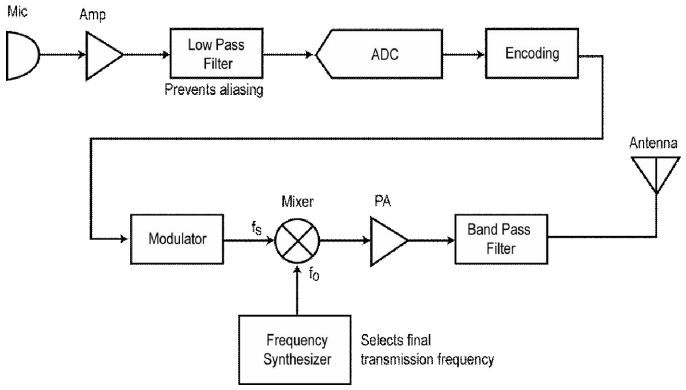


In a typical digital transmitter (TX), the voice or other analog signal from the microphone is first amplified and filtered to prevent aliasing. It is then converted to digital by an ADC.

The ADC output is then encoded to reduce the number of bits needed to represent voice. This encoding reduces the number of bits to be transmitted and permits faster transmission speeds.

The SDR Concept - Transmitter



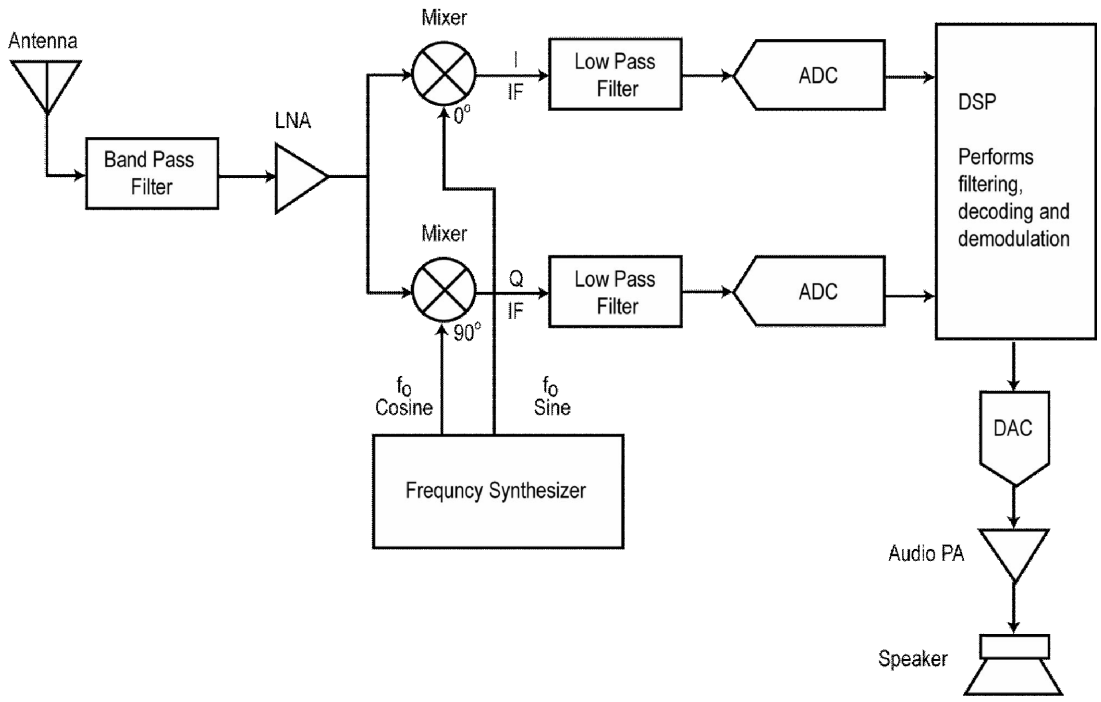
The encoded signal in serial format is then used to modulate the transmitter carrier using a form of digital modulation. Examples include frequency shift keying (FSK), binary phase shift keying (BPSK), and quadrature phase shift keying (QPSK).

After modulation, the signal is upconverted to the final carrier transmission by a mixer. The frequency synthesizer input to the mixer selects the desired frequency channel.

A power amplifier (PA) boosts the signal level prior to its application to the antenna.

This model fits cell phones, base stations, and any other digital radio transmitter.

The SDR Concept - Receiver



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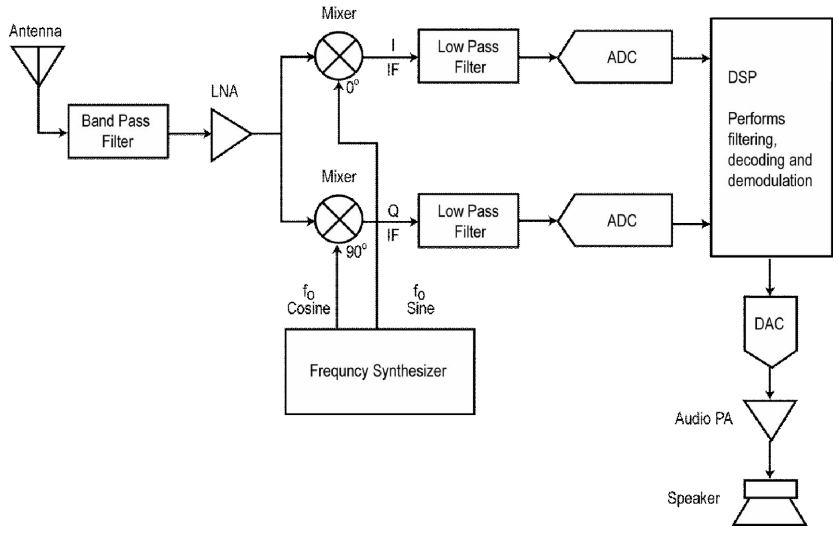
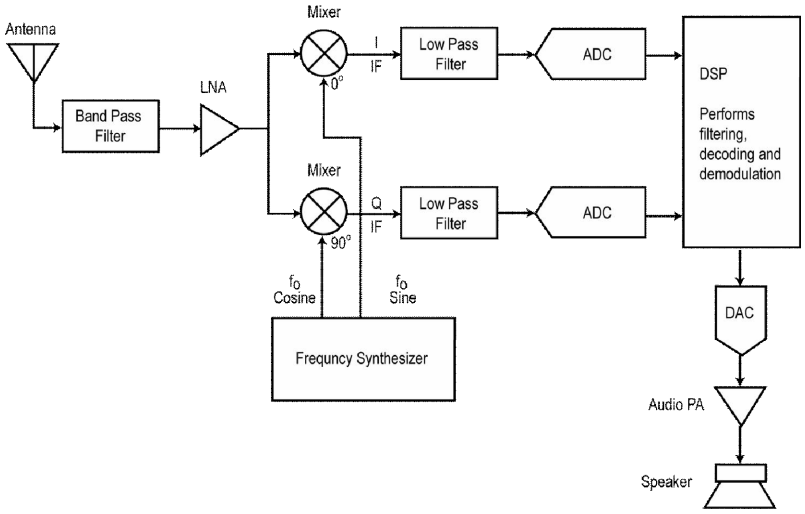


In the generic SDR superhetrodyne receiver, the carrier signal from the antenna is selected with a band pass filter and then applied to a low noise amplifier (LNA). The signal then goes to two mixers where it is downconverted to a lower intermediate (IF) frequency f_{IF}. Low pass filters select the IF and reduce the possibility of aliasing.

The SDR Concept - Receiver



The frequency synthesizer selects the receive channel. The synthesizer provides two local oscillator signals at f_o. One is a sine wave and the other is a cosine wave shifted by 90° from the sine. The mixer outputs are called the in-phase (I) and quadrature (Q) signals.

In traditional superhetrodyne receivers, there is only one IF path. Two paths with the I and Q signals are needed to recover modulation by DSP methods.

The SDR Concept – Receiver

The IF is the difference between the transmitter carrier frequency f_c and the local oscillator frequency f_o. $f_{IF} = f_o - f_c$. For example, if the carrier is 900 MHz and the local oscillator is 970 MHz, the IF is 970 – 900 = 70 MHz.

The IF signals also contain the original modulation of voice or data. The I and Q signals are then digitized by fast ADCs, usually flash or pipeline converters.

The ADC outputs go to a DSP where they are filtered, decoded, and demodulated to recover the original voice or other signal.

The DSP output is fed to a DAC for conversion to audio.

An audio power amplifier (PA) amplifies the signal for the speaker or headset.

Data Acquisition

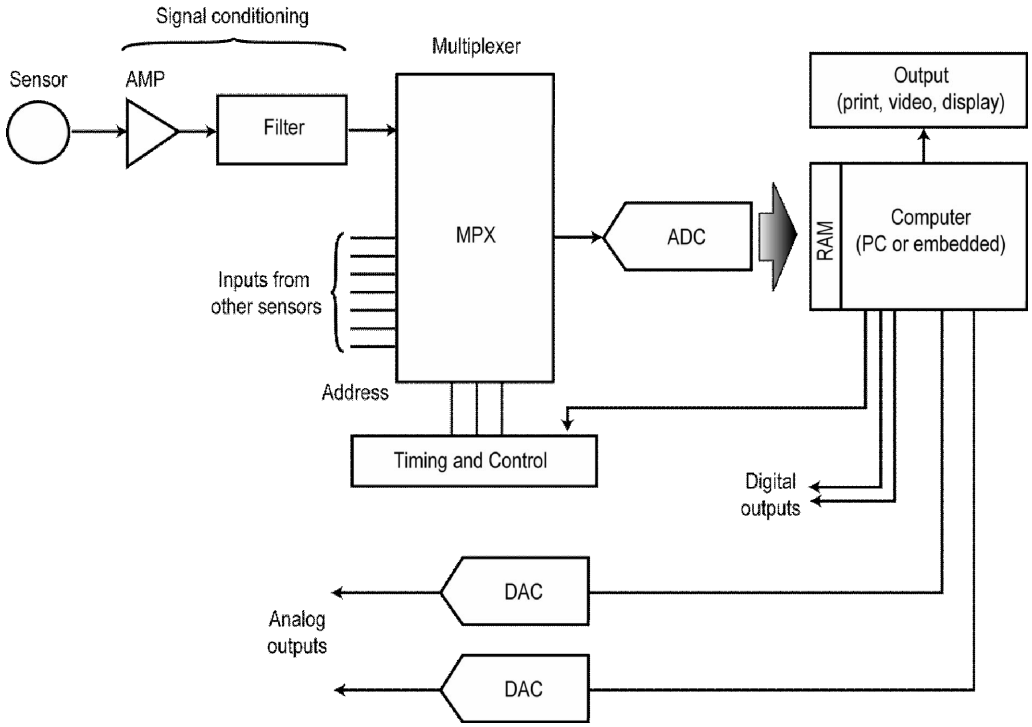
Data acquisition is the term used to describe the gathering of relevant data, recording it, storing it, displaying it, and processing it to get useful information about a system.

Examples include collecting data in an automated manufacturing factory to monitor assembly, in a chemical plant to monitor the process, or monitoring test data from an airplane, rocket, satellite, or weather station.

Most of the data comes from sensors that detect changes in physical characteristics such as temperature, pressure, stress, flow rate, physical position, speed of shaft rotation, and other conditions.

The sensor data is then digitized and transmitted to the system where it is then stored, processed, analyzed, and finally displayed.

Typical Data Acquisition System



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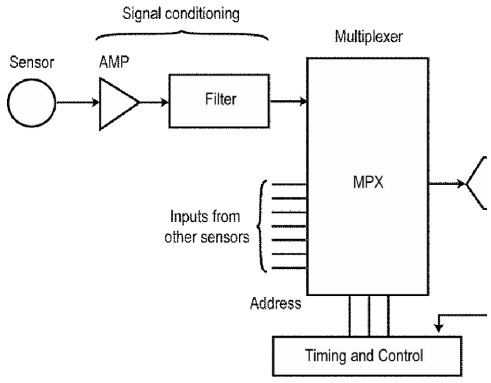
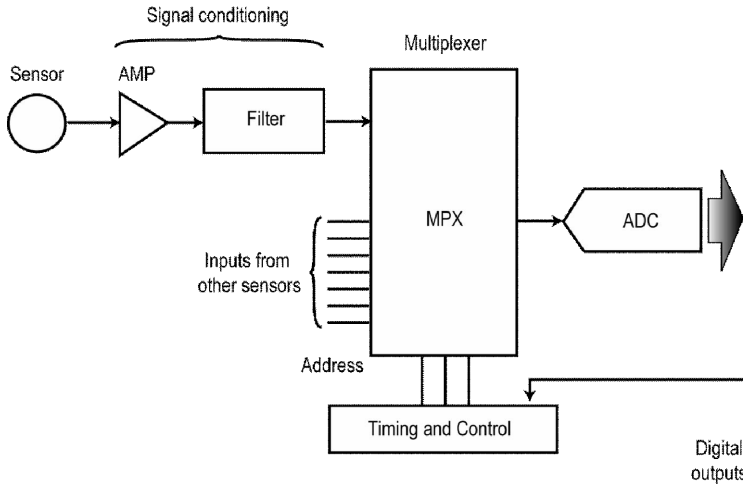


In a data acquisition system, the sensor outputs are analog. They are usually very low level signals that are sent to signal conditioners which consist of amplifiers, filters, and other circuits to make them compatible with the system.

The analog sensor signals are then sent to a multiplexer. A multiplexer is a high speed digital switching circuit with multiple inputs and a single output. A binary word called the address selects which input is to be passed to the output and the ADC.

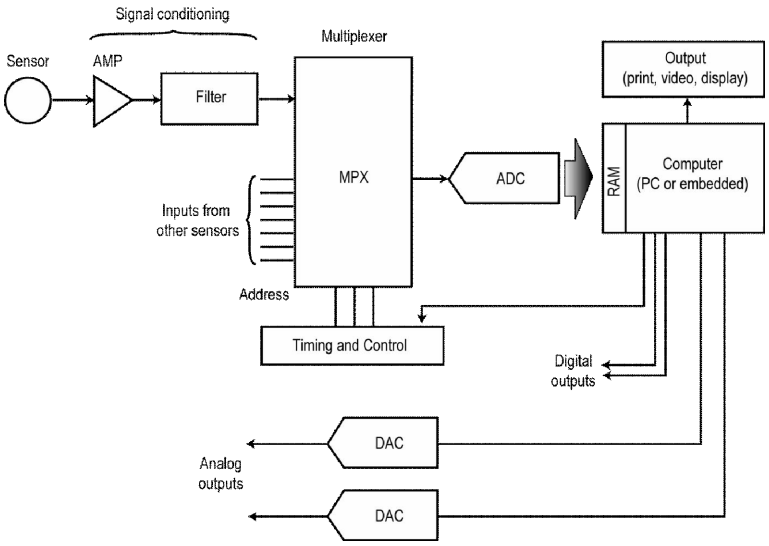
Typical Data Acquisition System



The multiplexer allows a single ADC to be used to digitize all of the analog inputs. The multiplexer (called a MPX or MUX) selects an input which is then sampled and digitized.

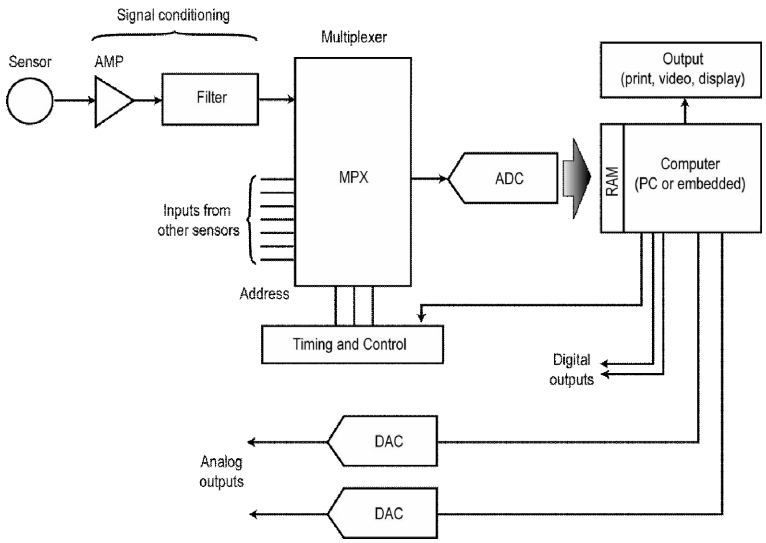
Since most analog sensor inputs are DC or very slowly changing AC, the sampling and digitizing rate is relatively low. Most systems use a successive approximations converter.

Data Acquisition



The ADC outputs go to a computer, either an embedded controller or a personal computer, where the data is stored in RAM or possibly on a hard drive. The data is then processed and displayed on the PC video monitor, special meters, or digital displays.

Data Acquisition



In some systems, the analyzed data is used to produce feedback control signals that are sent back to the system for modifying the behavior of the system. These outputs may be either digital directly from the computer or analog derived from DACs driven by the computer.

Complete data acquisition systems are actually available as a single chip device that is computer controlled.

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Applications of Analog-to-Digital Converters

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