Work-Ready Electronics

Synchronizing Curriculum to the Rapidly Changing Workplace

Module: **Data Conversion, Part 2**
Analog-to-Digital Conversion

WORKREADY ELECTRONICS

Data Conversion, Part 2

This is the second of two modules covering data conversion techniques. The first module (Part 1) introduced the concepts of data conversion and provided details on modern digital-to-analog conversion (DAC) methods and applications. This second module covers analog-to-digital conversion (ADC).

The most common methods are reviewed while new techniques are introduced. The coverage continues with an explanation of typical specifications and applications.

The module Data Conversion Part 1 is the prerequisite for this module.

What Technicians Need to Know

Basic concepts of data conversion including sampling rate, aliasing, and resolution

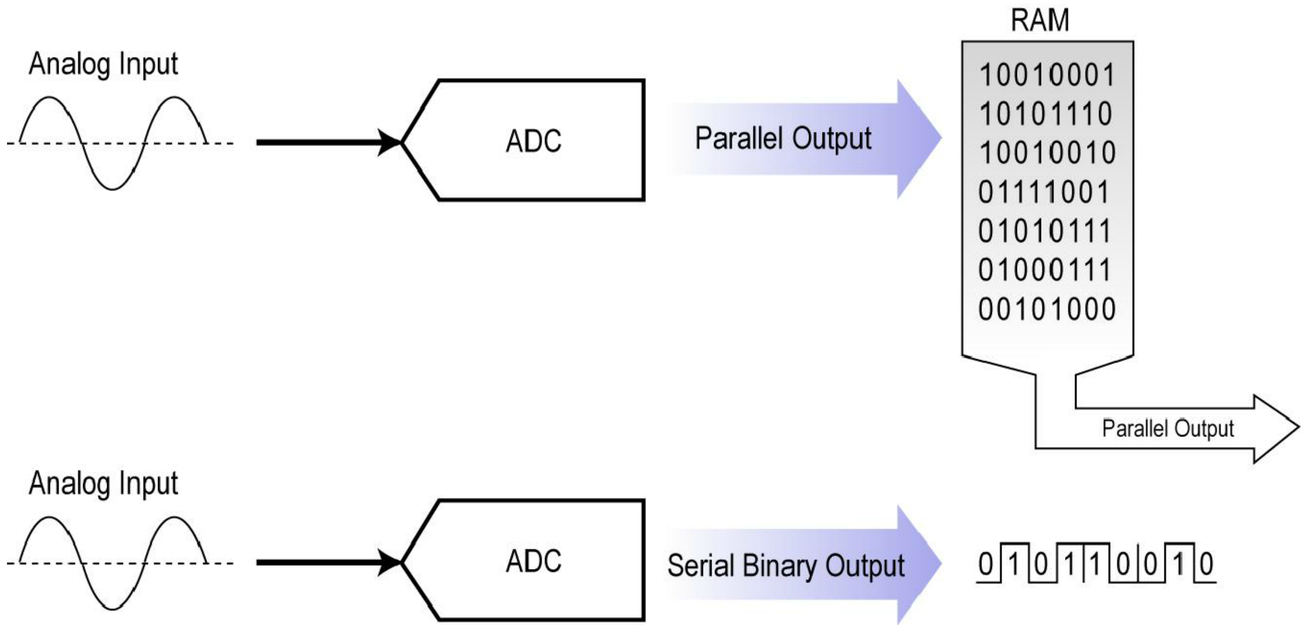
Operation of the switched capacitor successive approximations converter, flash converter, pipelined converter, and the sigma-delta converter

Primary specifications of ADCs

Common applications for ADCs

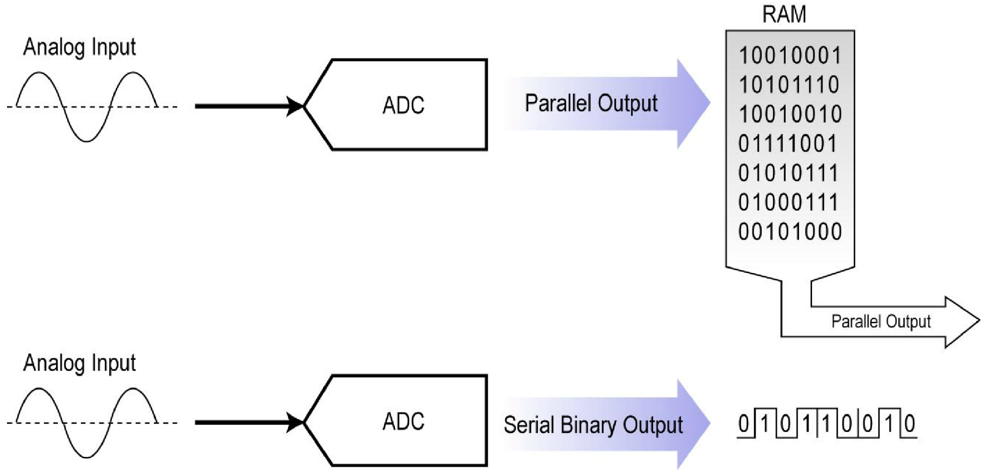
Review of Analog-to-Digital Conversion

Analog-to-Digital Conversion



A discussion of this graphic is presented in the pages that follow. You can print this graphic for study purposes before going on.

Analog-to-Digital Conversion

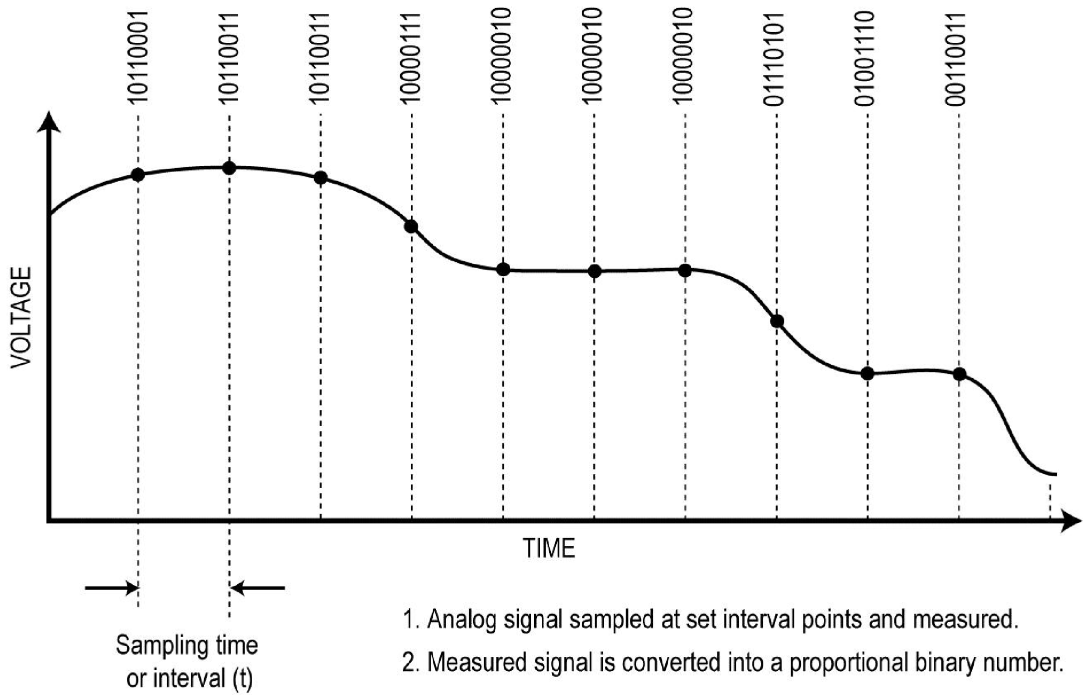


Some analog-to-digital conversion (ADC) circuits have a parallel binary output while other ADCs have a serial binary output.

ADCs with 8, 10, 12, 14, 16, 18, 20, 22, and 24 bits are available.

The binary output data can be stored either in a memory inside a computer or in an embedded controller. It can also be stored on a computer hard drive or transmitted over a network.

The Conversion Process



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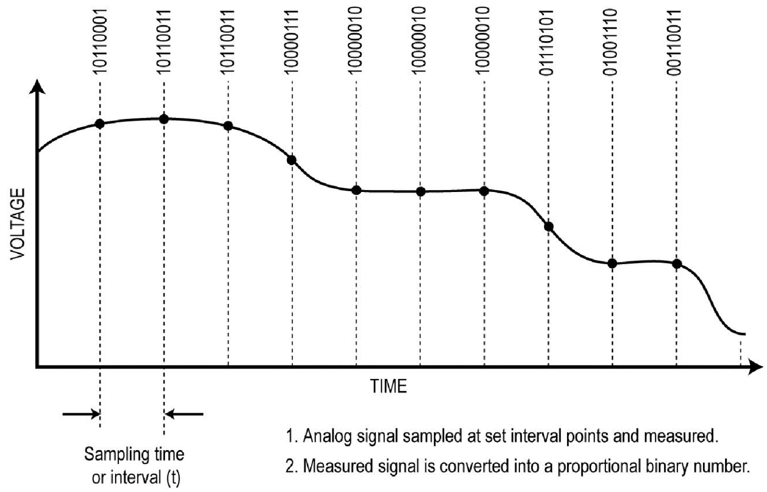
The Conversion Process



Analog-to-digital conversion is essentially a two part process: sampling and quantization.

Sampling is the process of capturing and measuring the analog input signal at evenly timed intervals.

Quantization is the process of translating the measured analog samples into proportional binary numbers.

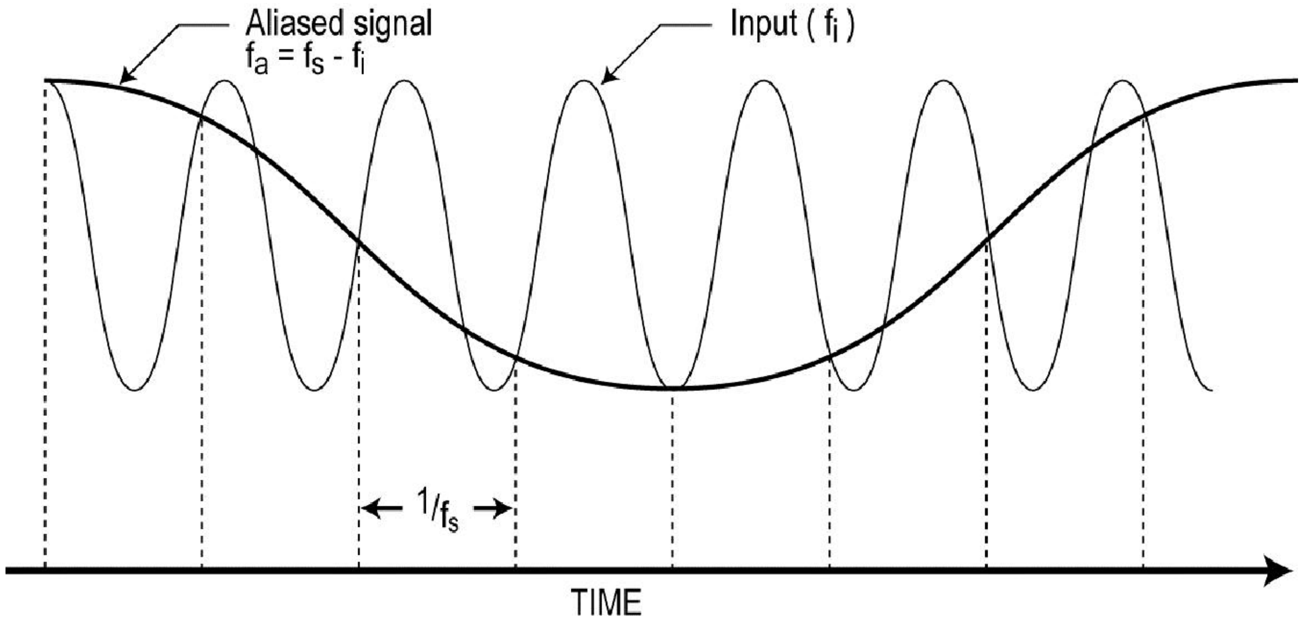
The Sampling Theorem

The sampling theorem, also called the Nyquist theorem after its founder, says that to faithfully capture and preserve the analog input information, the signal must be sampled at least two times the highest frequency content of the signal.

For example, to retain all of the information in an analog TV signal with frequencies up to 4 MHz, the signal would have to sampled at a rate greater than 2 x 4 MHz or 8 MHz. A reasonable sampling rate f_s would be 10 MHz.

The sampling interval t is the reciprocal of the sampling rate f_s or $t = 1/f_s$. In the example just given, the sampling time is t = 1/10 MHz or $1/10 \times 10^6 = 0.1 \times 10^{-6} = 100 \times 10^{-9} = 100$ nS. Samples are taken every 100 nS.

Aliasing



f_i = Input signal to be digitized
f_s = Sampling rate or frequency
f_a = Alias signal

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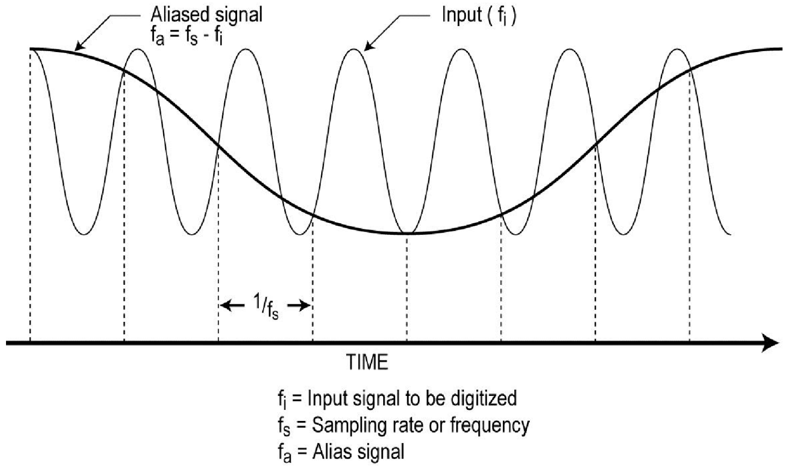
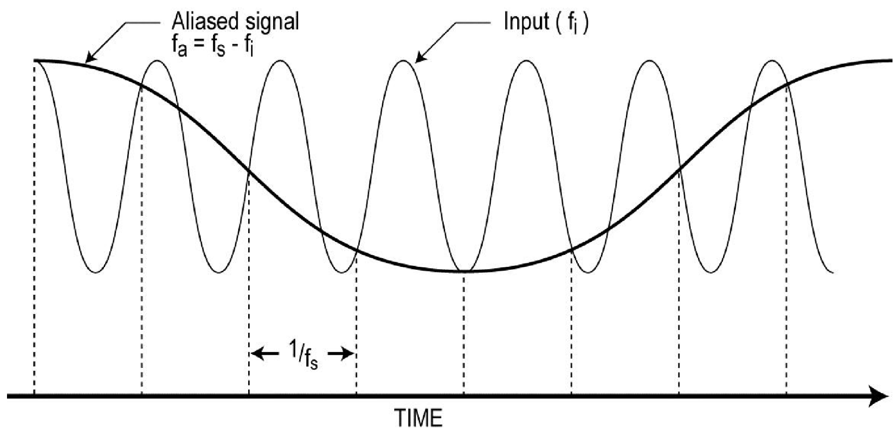
Aliasing



If the analog input signal is not sampled at a high enough rate, an error occurs when it is recovered in a DAC converter. The recovered signal will be at a different frequency. This is called aliasing.

In the aliasing example above, the input signal f_i is not sampled fast enough. When it is recovered it looks like f_a. The alias frequency is $f_a = f_s - f_i$.

Aliasing



f_i = Input signal to be digitized
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If an audio signal of 15 kHz is only sampled at 22 kHz, then the recovered signal will have a frequency of 22 – 15 = 7 kHz.

Aliasing is automatically prevented by placing a low pass filter between the analog input signal and the ADC. The cut-off frequency should be set below one half the sampling rate. If the sampling rate is 48 kHz, then the cut-off frequency should be less than 24 kHz to prevent signals from producing aliases.

Resolution

Resolution refers to the fineness of amplitude definition or representation.

The input voltage range of an ADC is defined by its design. The analog voltage range is effectively divided up into equal increments of voltage. Each increment is represented by a binary number.

The resolution is defined by the number of bits in the binary number and is equal to 2^N where N is the number of bits.

If an ADC has an 10-bit output, then the input range is divided up into $2^N = 2^{10} = 1024$ steps or increments.

Resolution

Resolution is sometimes expressed as a percentage. $(1/ 2^N)(100)$ or in this example, $(1/1024)(100) = .0009765 \times 100 = .09765$ %

If the input voltage range is 0 to +5 volts, each increment of resolution equals 5/1024 = .00488 volts or 4.88 millivolts (mV).

The resolution is the smallest increment produced by a single bit change. It is the increment represented by the least significant bit (LSB).

The greater the number of bits, the greater the resolution and the greater precision with which the analog signal is represented.

Test your knowledge

Data Conversion Knowledge Probe 1

Analog-to-Digital Conversion

Click on Course Materials at the top of the page.

Then choose **Knowledge Probe 1**.