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Analog to Digital Converter in Data Acquisition Systems

Introduction

Data acquisition systems use input/output devices to interact with the external world. It gathers important data in order to successfully prove theories or conduct experiments. Analog to digital converter (ADC) is a device that is essential for processing data that represent most phenomena from the real, analog world and translate them to digital language. [1] ADC is not a technological breakthrough by any means, but it is widely used. This paper reviews the basic theories of ADC as well as its uses in modern data acquisition systems.

Basics of ADC

Analog signals, after being captured by sensors or transducers, would be transformed into a voltage that is proportional to the amplitude of that signal by an ADC. It is a two-stage process and the two stages happening during such a conversion are sampling and quantization. [2]

Sampling

The first step consists of taking an instantaneous snapshot of the ADC's input voltage and freezing it for the duration of the conversion. There is a sample-and-hold (S/H) circuit built into the input side of the ADC, which captures new inputs on each rising edge of the clock signal, and for the rest of the clock signal interval the S/H would close to hold the output at the newly acquired level. [3]

Quantization

Quantization involves assigning a numerical value to the voltage level at the output of the S/H. It searches for the nearest value that can match to the amplitude of the S/H output signal out from a fixed number of values containing its complete range of amplitude. [2] This value would then be encoded as a N-bit binary number. The proposed range of amplitudes must therefore be in the set of 2^N in order to be contained in the set. The number of bits can also be used to address the resolution of the ADC.

Applications of ADC and its role in Data Acquisition

Types of ADCs

Some major types of ADCs include successive approximation ADC, voltage-to-frequency ADC, integrating ADC, sigma-delta ADC. [4]

Successive approximation ADC is the most common method. It is relatively slow due to it running its comparisons with regards to input and output voltages serially and thus making them inexpensive. It is mostly used in PC-based data acquisition systems. [5]

Voltage-to-frequency ADC is often used to convert slow and noisy signals, and can be used in remote sensing of these signals. The input voltage is converted to a frequency at a far location and the converted digital pulse is transmitted to the counter. This way, the noise caused by transmitting analog signals over long transmission lines can be eliminated.

Integrating ADC employs the technique where the input to the ADC is integrated over an interval, and thus the effect of noise pickup due to the ac line frequency when the integration time matches a multiple of the ac period is greatly reduced. It is often used in precision digital multi-meters and panel meters.

Sigma-Delta ADC is another type of integrating ADC. It requires few external components and can accept low-level signals without much input-signal conditioning circuitry. Sigma-Delta ADC comes in 16 to 24-bit resolution and are economical for most data acquisition and instrument applications.

ADCs and Data Acquisition

The role of the ADC in data acquisition systems is pivotal, it is the very important first step to processing analog data signals. Even though ADCs were invented in as early as 1951, what has been improving is its resolution. Sigma-Delta ADC is the predominant type of ADCs employed in data acquisition systems, and since it does not need much input-signal conditioning circuitry, the precision sensor can interface directly with the ADC. [6] Sigma-Delta ADC is highly digital and highly programmable. It may be more complex as compared to traditional ADC architectures, however there are much manufacturers' resources and data sheets that can ease the overall user experience.

[1] B. Malik, "ANALOG TO DIGITAL CONVERTER and how ADC works," in *Microcontrollers Lab*, 2015. [Online]. Available: http://microcontrollerslab.com/analog-to-digital-adc-converter-working/. Accessed: Mar. 4, 2017.

[2] Maude, "Part 2: The conversion process," in *From Analog to Digital*, Nutaq, 2017. [Online]. Available: https://www.nutaq.com/blog/analog-digital-%E2%80%93-part-2-conversion-process. Accessed: Mar. 4, 2017.

[3] Texas Instruments, "TMS320x2833x Analog-to-Digital Converter (ADC) Module Reference Guide" [Online]. Available: **http://www.ti.com/lit/ug/spru812a/spru812a.pdf**. Accessed: Mar 4, 2017

[4] "Chapter 2: Analog to Digital Conversion", *Data Acquisition Handbook*, 3rd Ed, Measurement Computing, Norton, MA, 2012

[5] J. Valvano, R. Yerraballi, "Chapter 14: ADC and Data Acquisition", *Embedded Systems – Shape The World*, University of Texas at Austin, 2016. [Online]. Available: http://users.ece.utexas.edu/~valvano/Volume1/E-Book/C14_ADCdataAcquisition.htm. Accessed: Mar. 3 2017.

[6] National Instruments, "Benefits of Delta-Sigma analog-to-digital conversion," 2010. [Online]. Available: http://www.ni.com/white-paper/11342/en/. Accessed: Mar. 5, 2017.