arm Education

# Embedded Systems Essentials with Arm: Getting Started

## Module 5

### KV2 (5): Types of ADCs and DAC

An analog-to-digital converter, or ADC system usually consists of three stages: first, the multiplexer, which selects the input line to be converted. Because each ADC stage takes up chip area and is complex to build due to its need for precision, the number of ADCs in a microcontroller must be kept to a minimum. A multiplexer reduces the number of required ADC components, though at the expense of conversion speed.

Next is the sample-and-hold stage. It's usually a switched capacitor, which is loaded with the actual voltage of the analog signal and keeps it constant during the conversion time.

Finally, the ADC converts the analog signal into digital signal.

We will look at 3 common types of Analog to Digital Converters or ADCs: flash, integrating, and feedback.

Flash converters compare the input voltage with different reference voltage levels. A flash converter is very fast, but it needs an equal amount of comparators to possible represented digital values; for example, an 8-bit converter needs 256 comparators. The size, power consumption, and cost of large numbers of comparators makes larger flash converters impractical.

Under the category of integrating ADCs sit the "slope" variants. These are single and dual slope ADC. Generally, slope converters convert the voltage into a charge capacitor and measure the time it takes to charge and discharge. Slope converters are quite fast and easy to set up, but they need to be very stable during and between different measurements. Slope converters also require a very stable and fast clock, as accuracy of the result depends on the resolution of the clock.

Feedback converters often offer the best compromise between speed and resource usage. They generate a signal proportional to the input voltage. There are different types of feedback converters, such as delta-sigma, successive approximation, and so on.

Let's look at a successive approximation feedback conversion in more detail. The hardware for the successive approximation ADC uses a comparator to compare the input voltage against a test voltage, which is generated by an internal digital-to-analog converter. The internal DAC is driven by the successive approximation register based on a binary search sequence. Each bit is tested in turn to see if it should be set or not. The operation takes one cycle per bit, so the more bits there are, the longer the conversion takes.

We initiate the conversion process by signaling the converter, and then wait for the converter to tell us that the conversion is complete, often by using an interrupt.

This type of ADC converter is often implemented on microcontrollers.

A DAC transmits the digital input values to a resistor network. The network receives these inputs as a discrete, finite-precision number, usually in binary, and outputs continually varying physical signals such as voltage or pressure. The output voltage is the analog equivalent to the digital input number, weighted with the reference voltage.

The R-2R ladder is considered a scalable method for performing digital to analog conversion. It is a DAC architecture that uses *N* number of resistors of a value, *R,* and *N* resistors of twice that value, *2R.* Because it only uses two resistors, it is simpler to fabricate.

In this diagram we can see that across the top are the bits – arranged from least significant bit to most significant bit. Regardless of how many bits there are, the impedance of this network will be *R*.

Thevenin's theorem states that a linear circuit can be simplified into an equivalent circuit using just one single voltage and a single resistance connected to a load. Using Thevenin's theorem, the circuit can be simplified and an output voltage determined.

The relationship between a DAC's input and its output is the formula V-zero equals D over 2n times Vr. Here,

- V0 is the output voltage

- D is the value of the input binary word

- N is the number of bits in the word

- Vr is the value of the reference voltage

For example, a 3-bit value binary data input will result in an analog voltage output ranging from 0 to 7/8ths of the reference voltage, producing a triangular waveform, if we were to control the input digital word accordingly.