Computer Analog Interfaces and How They Work

Analog Input/Output (I/O) (1536EB)

National Instruments E-Series DAQ Board:

(4) A/D Ranges: -10 to10V, -5 to +5, -0.5V to 0.5V, -0.05V to 0.05V

(16) A/D channels of Single-Ended or (8)Channels Differential channels, 12 bit Analog-to-Digital Converters (ADC) with 200k sample/sec maximum rate, digital trigger

(2) 12 bit Digital-to-Analog Converters (DAC)

(8) digital I/O lines

(2) independent 24 bit counter-timers with 8 MHz source clock

National Instruments PCI-GPIB:

Complete IEEE-488 Controller with 1.5 Mbyte/sec max transfer rate with IEEE 488.1 and 7.7 Mbyte/sec max transfer rate using HS488. DMA controller

Digital-to-Analog Converters (D/A):

The Digital-to-Analog (D/A) converter uses a combination of a TTL logic parallel output, a binary weighted resistor and an operational amplifier.

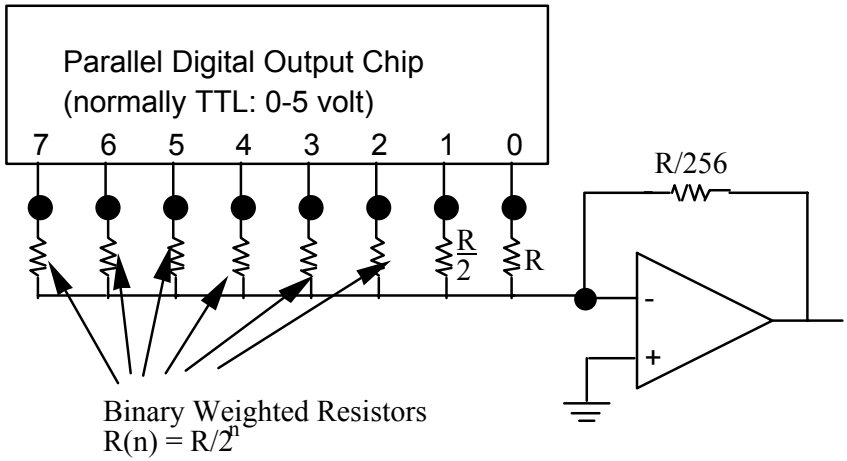


Figure 1: Internal details of a typical Digital-to-Analog Converter

Using standard op-amp analysis, the output voltage is

$$v_o = v_s(\frac{R}{256}) \sum_{n=0}^{7} \frac{b_n}{R/2^n} = \frac{v_s}{256} \sum_{n=0}^{7} 2^n b_n$$

where: v_o = output voltage

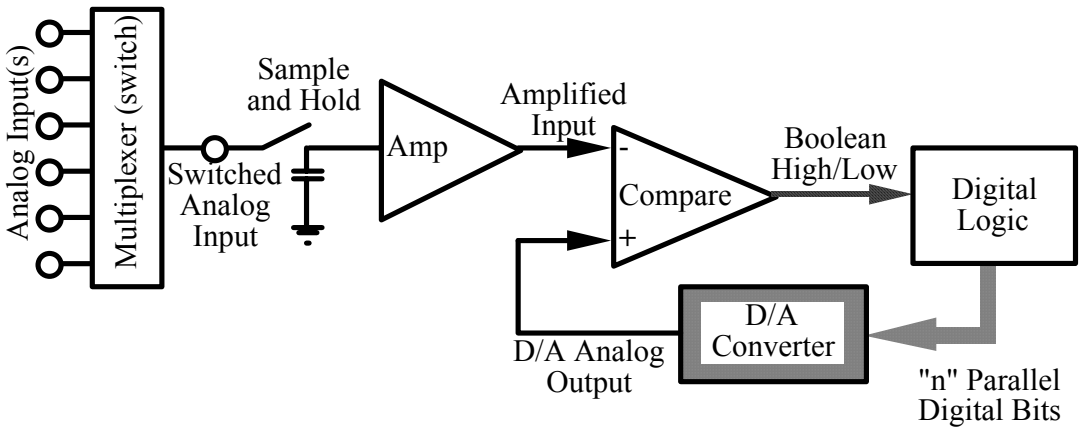
vs = s*upply* voltage

$b_n = 0$ or 1, the state of the n^{th} bit

Note that this result gives "binary weighted" outputs proportional to the eight bits of the digital output chip. The accuracy of the binary-weighted resistors determines the D/A accuracy.

Analog-to-Digital Converters (A/D):

The central element in a A/D converter is a D/A converter. As shown below, the D/A converter used determines resolution and scaling of the A/D conversion process.



The *Multiplexer* switches one input channel to the *Sample and Hold* that holds a constant value during the conversion process. The *Amp* amplifies the analog level to fit the analog conversion range and provides an analog voltage to the *Compare* element. The *Compare* element compares this analog level with the output of the *D/A Converter* and provides a *Boolean High or Low* signal to the converter's *Digital Logic*. In response to this High/Low signal, the *Digital Logic* changes its *"n" Parallel Digital Bit* output to the D/A circuit to best match the analog input to the Compare. The specific algorithm used by the Digital Logic determines the type of A/D converter.

There are two basic types of A/D converters in common laboratory use.

1. The Tracking A/D Converter samples at high rates (1-10 MHz.) and at each sample increments or decrements the "n" Parallel Digital Bits so as to change the D/A output at small increments and track a changing analog input. In this way, tracking A/D Converters achieve high sample rates but have difficulty following signals which change discontinuously such as those resulting from a change in the channel selected by the Multiplexer.
2. The Successive Approximation A/D Converter samples more slowly (<250 kHz.) and develops a new conversion at each sampling time. It successively sets each bit from the most significant to the least significant, testing the D/A output at each step. For "N" bits, "N" tests are required to complete the conversion. Although slower than the tracking A/D, the successive approximation A/D can deal with discontinuous inputs from the multiplexer and maintains a constant sampling interval. Because the successive approximation A/D converter works well with switched inputs and allows multi-channel sampling at moderate

rates, it is the most common (cost effective) A/D for laboratory use in computer data acquisition systems