Seminar on Industrial Automation

A/D and D/A Conversion :

Analog to Digital Converters

Digital to Analog Converters

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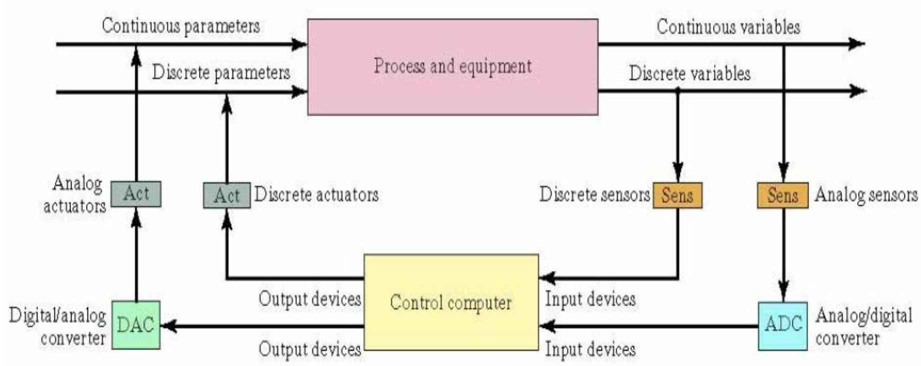
Sensors and Actuators

Sections:

1. Analog-to-Digital Conversion
2. Digital-to-Analog Conversion

Computer process control system

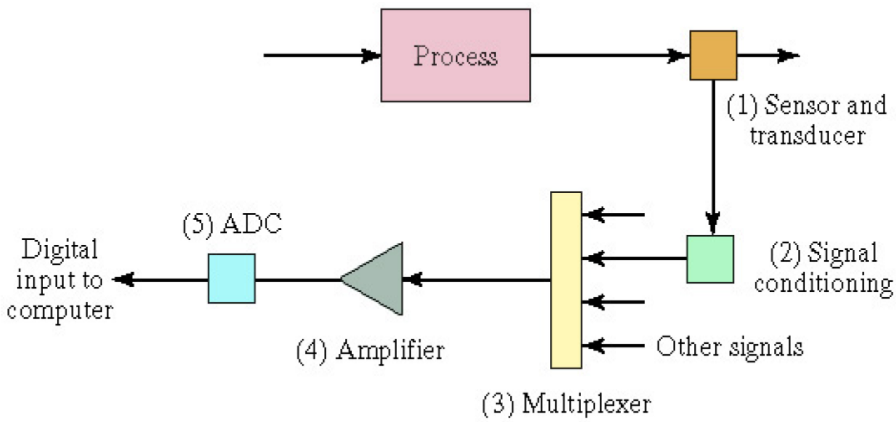


Analog-to-Digital Converters (ADC)

An ADC converts a continuous analog signal from transducer into digital code for a computer

- ADC consists of three phases:
  1. Sampling –converts the continuous signal into a series of discrete analog signals at periodic intervals
  2. Quantization –each discrete analog is converted into one of a finite number of (previously defined) discrete amplitude levels
  3. Encoding –discrete amplitude levels are converted into digital code

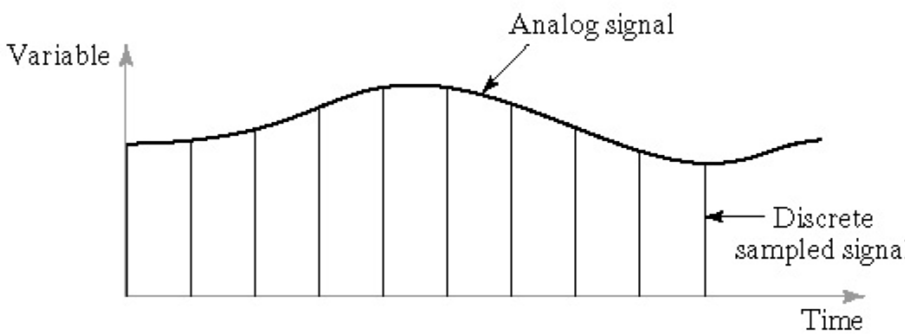
Hardware devices in AD conversion



Features of an ADC

- Sampling rate –rate at which continuous analog signal is polled
- Conversion time –how long it takes to convert the sampled signal to digital code
- Resolution –depends on number of quantization levels
- Conversion method –means by which analog signal is encoded into digital equivalent
  - Example –Successive approximation method

Analog signal converted into a series of discrete data by ADC

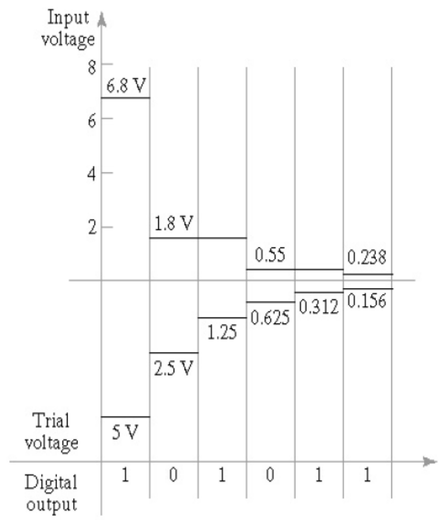


Successive approximation method for ADC

- A series of trial voltages are successively compared to the input signal whose value is unknown
- Number of trial voltages = number of bits used to encode the signal
- First trial voltage is 1/2 the full scale range of the ADC
- If the remainder of the input voltage exceeds the trial voltage, then a bit value of 1 is entered, if less than trial voltage then a bit value of zero is entered
- The successive bit values, multiplied by their respective trial voltages and added, becomes the encoded value of the input signal

Successive approximation method for ADC

Example for
input voltage
of 6.8 V



For six digit precision, the resulting binary digital value is 101011, which is interrupted as:

1×5.0 V
0×2.5 V
1×1.25 V
0×0.625 V
1×0.312 V
1×0.156 V

Total = 6.718 V

Resolution

Quantisation levels is defined as:

$$N_q = 2^n$$

where N_q = quantisation levels; and n is the number of bits.

Resolution is defined as:

$$R_{ADC} = \frac{L}{N_q - 1} = \frac{L}{2^n - 1}$$

where R_{ADC} is the resolution of the ADC;
L is the full-scale range of the ADC

Quantisation generates an error, because the digitised signal is only sampled from the original analogue signal. The maximum possible error occurs when the true value of the analogue signal is on the borderline between two adjacent quantisation levels, in which case the error is half the quantisation-level spacing; this gives us the following for quantisation error (*Qerr*):

$$\mathrm{Qerr} = \pm\frac{1}{2}\mathrm{R}_{\mathrm{ADC}}$$

where R_{ADC} is the resolution of the ADC.

Example

- Using an analogue-to-digital converter, a continuous voltage signal is to be converted into its digital counterpart.
- The maximum voltage range is ±25 V. The ADC has a 16-bit capacity, and full scale range of 60 V.
- Determine
  - (1) number of quantization levels,
  - (2) resolution,
  - (3) the spacing of each quantisation level, and the quantisation error for this ADC.

Solution

$$N_q = 2^n$$

$$R_{ADC} = \frac{L}{N_q - 1} = \frac{L}{2^n - 1}$$

$$\mathrm{Qerr} = \pm\frac{1}{2}\mathrm{R}_{\mathrm{ADC}}$$

(1) Number of quantization levels:
= 2^{16} = 65,536

(2) Resolution:
R_{ADC} = 60 / 65,536 -1 = ± 0.0009155 volts

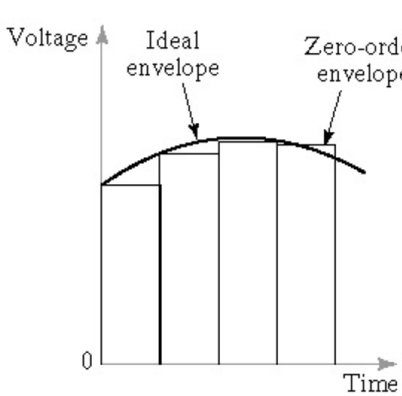
(3) Quantisation error:
= ± (0.0009155)/2 = ± 0.00045778 volts

Digital-to-Analog Conversion (DAC)

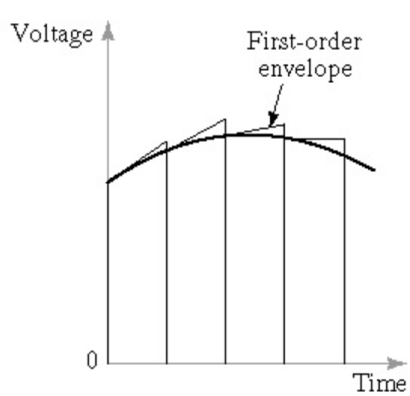
A DAC converts the digital output of the computer into a continuous analog signal to drive an analog actuator (or other analog device)

- DAC consists of two steps:
    1. Decoding –digital output of computer is converted into a series of analog values at discrete moments in time
    2. Data holding –each successive value is changed into a continuous signal that lasts until the next sampling interval

Data holding step in DAC



Zero-order hold



Firts-order hold

Digital-to-Analog Conversion

- Convert digital values into continuous analogue signal
  - Decoding digital value to an analogue value at discrete moments in time based on value within register

$$E_0 = E_{ref}\left\{0.5B_1 + 0.25B_2 + \cdots + \left(2^n\right)^{-1} B_n\right\}$$

Where E_o is output voltage; E_{ref} is reference voltage; B_n is status of successive bits in the binary register

  - Data Holding that changes series of discrete analogue signals into one continuous signal

Example

- A DAC has a reference voltage of 10 V and has 6-bit precision. Three successive sampling instances 0.5 sec apart have the following data in the data register:

Instant	Binary Data
1	101000
2	101010
3	101101

- Output Values:

E_{01} = 10{0.5(1)+0.25(0)+0.125(1)+0.0625(0)+0.03125(0)+0.015625(0)}
E_{01} = 6.25V

E_{02} = 10{0.5(1)+0.25(0)+0.125(1)+0.0625(0)+0.03125(1)+0.015625(0)}
E_{02} = 6.56V

E_{03} = 10{0.5(1)+0.25(0)+0.125(1)+0.0625(1)+0.03125(0)+0.015625(1)}
E_{03} = 7.03V

Bibliography

- *Automation, Production Systems, and Computer-Integrated Manufacturing, Third Edition, by Mikell P. Groover, Third Edition, Prentice Hall, 2008*