UNIT-IV

Data Acquisition System (DAQ)

The systems, used for data acquisition are known as **data acquisition systems**. These data acquisition systems will perform the tasks such as conversion of data, storage of data, transmission of data and processing of data.

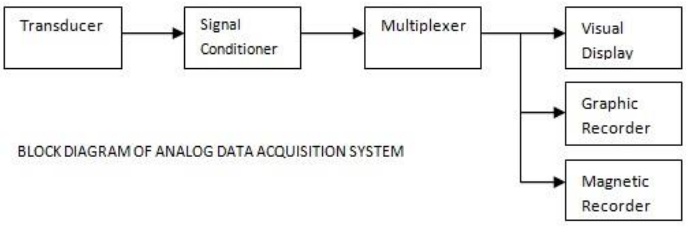
Types of Data Acquisition Systems

Data acquisition systems can be classified into the following **two types**.

- Analog Data Acquisition Systems
- Digital Data Acquisition Systems

Analog Data Acquisition Systems

The data acquisition systems, which can be operated with analog signals are known as analog data acquisition systems.



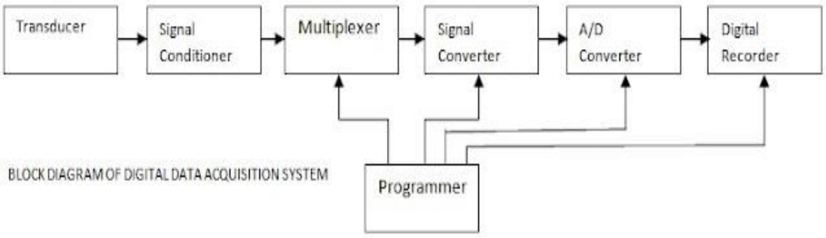
- **Transducer** − It converts physical quantities into electrical signals.
- **Signal conditioner** − It performs the functions like amplification and selection of desired portion of the signal.
- **Multiplexer:** A multiplexer for scanning different signal sources, The multiplexer receives multiple analog inputs and provides a single output signal according to the requirements.
- **Display device** − It displays the input signals for monitoring purpose.
- **Graphic recording instruments** − These can be used to make the record of input data permanently.
- **Magnetic recording** − It is used for acquiring, storing & reproducing of input data.

Digital Data Acquisition Systems

The data acquisition systems, which can be operated with digital signals are known as digital data acquisition systems. So, they use digital components for storing or displaying the information.

Mainly, the following operations take place in digital data acquisition.

- Acquisition of analog signals
- Conversion of analog signals into digital signals or digital data
- Processing of digital signals or digital data



- **Transducer** − It converts physical quantities into electrical signals.
- **Signal conditioner** − It performs the functions like amplification and selection of desired portion of the signal.
- **Multiplexer** − connects one of the multiple inputs to output. So, it acts as parallel to serial converter.
- **Signal converter**- Signal converter to translate the analog signal to a form acceptable by the A/D converter.
- **Analog to Digital Converter** − It converts the analog input into its equivalent digital output.
- **Display device** − It displays the data in digital format.
- **Digital Recorder** − It is used to record the data in digital format.
- **Programmer**- It is used to control the data processing.

Applications

- Analog systems are used when wide bandwidth is required or when lower accuracy can be allowed.
- Digital systems are used when the physical process being monitored slowly varies and when high accuracy and low per-channel cost is required.

Data acquisition systems are being used in various applications such as biomedical and aerospace. So, we can choose either analog data acquisition systems or digital data acquisition systems based on the requirement.

Analog and Digital IO:

At the simplest level, data acquisition hardware is characterized by the subsystems it possesses. A subsystem is a component of your data acquisition hardware that performs a specified task.

Common subsystems include

- Analog input
- Analog output
- Digital input/output
- Counter/timer

Analog input subsystems are also referred to as AI subsystems, A/D converters, or ADCs.

Analog Output Subsystems - Analog output subsystems convert digital data stored on your computer to a real-world analog signal.

Digital Input/output Subsystems- Digital input/ output (DIo) subsystems are designed to input and output digital values (logic levels) to and from hardware.

Counters and Timers

The function of the Counter/Timer is to measure rise time, fall time, frequency, period, duty cycle, phase angle, event counting, time interval, and pulse width.

The various general Configuration of Data Acquisition System are

1. **Single channel data acquisition system**
    - Analog Signal output of transducer is processed converted into standard voltage level, suitable for A/D converter.
    - Output of signal processing unit is given to analog to digital converter for converting analog signal into digital signal.
    - Data processing unit receives the digital signal and performs arithmetic or logical operation on data if required. Digital signal is also processed, for different types of transmissions and display purposes.

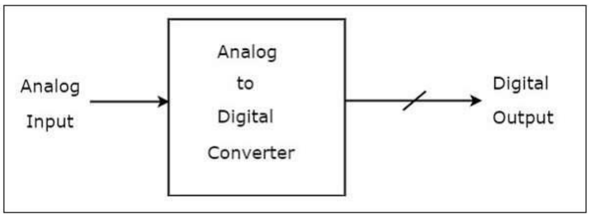
2. **Multi-channel data acquisition system**
    - In a multichannel data acquisition system, more number of transducers can be connected for transferring signal.
    - For each channel, Separate Analog Signal Processing Unit (SPU) is assigned SPU does necessary biasing reference voltage generation and amplification.

- Analog scanner or multiplexer selects any one input at a time. This analog signal is then converted into digital signal using A/D converter.
- Digital output of A/D converter is processed in data processing unit.
- Digital inputs from sensors or control systems are directly applied to data processing unit through digital scanner.
- Finally digital data is either stored or transmitted in data transfer/display unit.

Analog to Digital Converter (ADC)

An Analog to Digital Converter **(ADC)** converts an analog signal into a digital signal. The digital signal is represented with a binary code, which is a combination of bits 0 and 1.

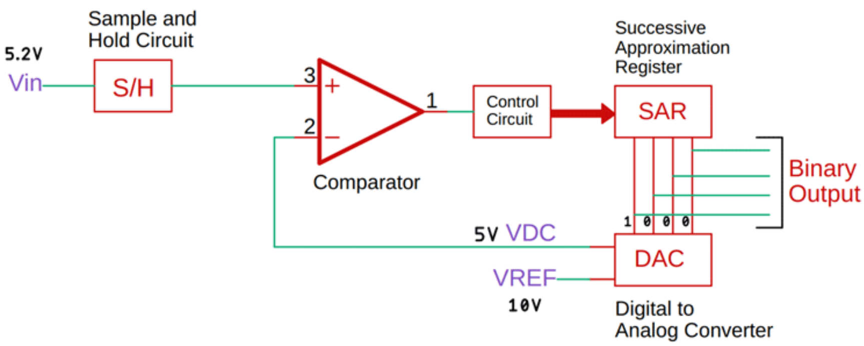
The **block diagram** of an ADC is shown in the following figure −



Observe that in the figure shown above, an Analog to Digital Converter **(ADC)** consists of a single analog input and many binary outputs. In general, the number of binary outputs of ADC will be a power of two.

Types of ADC

Successive Approximation



Successive Approximation ADC

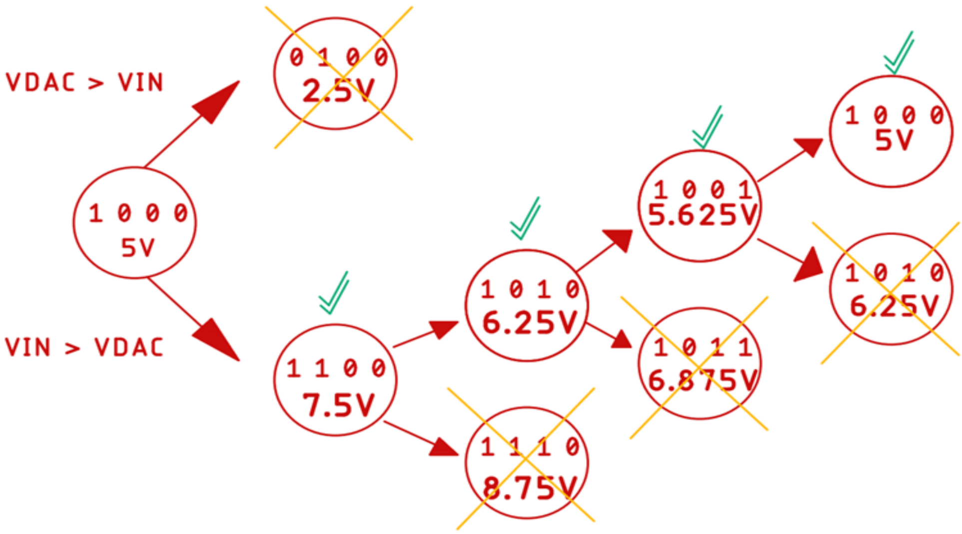
- ADC consists of a comparator, a digital to analog converter, and a successive approximation register along with the control circuit.

- **Let's take an example of 4-bit ADC,**
- Whenever a new conversation starts, the sample and hold circuit samples the input signal. And that input signal is compared with the output signal of the DAC.
- Consider the sampled input signal is 5.2V. The reference of the ADC is 10V.
- When the conversion starts, the successive approximation register sets the most significant bit to 1 and all other bits to zero.
- **This means we can say that input to the DAC is 1,0,0,0 which means, for a 10V reference voltage, the DAC will produce a value of 5V which is half of the reference voltage.**

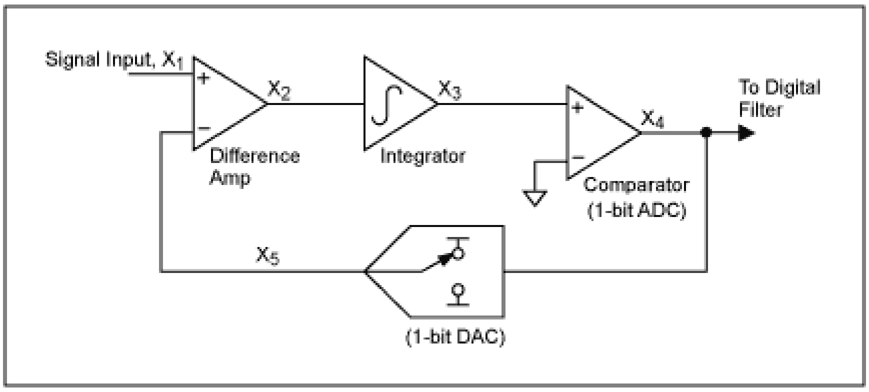
$$1000 \rightarrow V_{Ref}\left(\frac{B_0}{16} + \frac{B_1}{8} + \frac{B_2}{4} + \frac{B_2}{2}\right) = 5V$$

- Now DAC output voltage will be compared to the input voltage and based on the comparator output, the output of the successive approximation register will be changed.

- This means if Vin is greater than the output of the DAC, the most significant bit wall stay as it is, and the next bit will be set for a new comparison. Otherwise, if the input voltage is less than the DAC value, the most significant bit wall be set to zero, and the next bit will be set to 1 or a new comparison. This process will continue until the value closest to the input voltage reaches.



Sigma-Delta



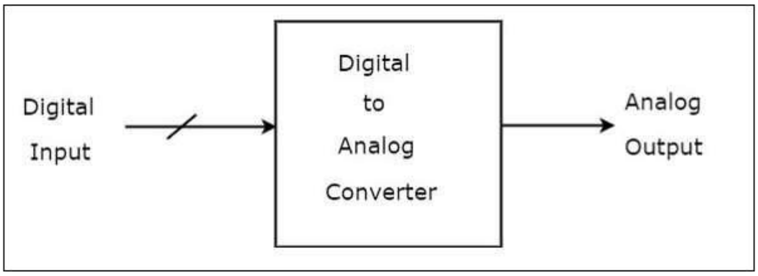
- It is a high resolution and low-cost ADC.
- It consists of difference amplifier, integrator, comparator (1-bit ADC) and 1-bit DAC
  - **Difference Amplifier-** It is an input subtractor circuit which produces an output voltage proportional to the voltage difference of two input signals applied to the inputs of inverting and non-inverting terminals.
  - **Integrator-** It means sigma (Σ) which provides summation of previous inputs and present inputs.
  - **Comparator- It means delta** (Δ) which compare the inputs and give difference.

- Suppose, X_1 input signal is given to difference amplifier and another X_5 input signal is coming from 1-bit DAC which is a feedback signal connection.
- The resultant voltage of difference amplifier will be $\mathbf{X_2 = X_1 - X_5}$ which will send to integrator then output from integrator will be $\mathbf{X_3 = X_3 + X_3(n-1)}$.
- Now we have comparator (1-bit DC), when its +ve terminal voltage is greater than -ve terminal voltage which is grounded then we will get $\mathbf{X_4}$**= Logic 1** as comparator output otherwise $\mathbf{X_4}$**=Logic 0** as comparator output.
- If comparator is giving 1 as an output to 1-bit DAC then its output **X5=+1** and if comparator is giving 0 as an output to 1-bit DAC then its output **X5= -1**
- This process will continue with respect to clock and here we are generating digital data on output side with respect to clock.
- Clock is used to generate conversion timing. It serves as the time reference such that all components can operate synchronously. For analog-to-digital converters (ADCs), accurate and stable clocks ensure that the host sends commands to the ADC and the ADC receives commands from the host in the correct order and without corruption.

Digital to Analog Converter (DAC)

A Digital to Analog Converter (DAC) converts a digital input signal into an analog output signal. The digital signal is represented with a binary code, which is a combination of bits 0 and 1. This chapter deals with Digital to Analog Converters in detail.

The block diagram of DAC is shown in the following figure −



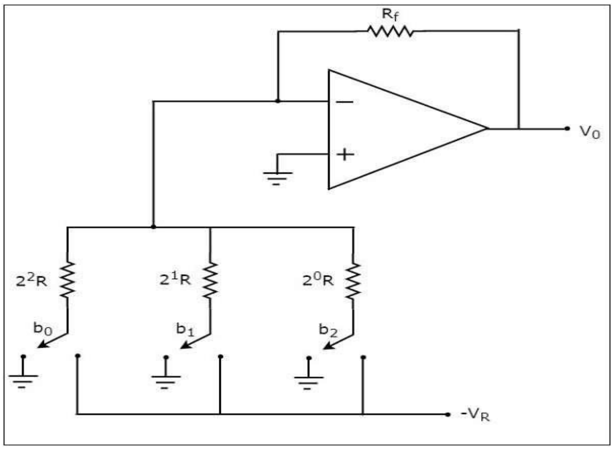
A Digital to Analog Converter (DAC) consists of a number of binary inputs and a single output. In general, the number of binary inputs of a DAC will be a power of two.

Types of DAC

Weighted Resistor

- A weighted resistor DAC produces an analog output, which is almost equal to the digital (binary) input by using binary weighted resistors in the inverting adder circuit. In short, a binary weighted resistor DAC is called as weighted resistor DAC.

The circuit diagram of a 3-bit binary weighted resistor DAC is shown in the following figure −



- Recall that the bits of a binary number can have only one of the two values. i.e., either 0 or 1. Let the 3-bit binary input is $b_2b_1b_0$. Here, the bits b_2

and b_0 denote the Most Significant Bit (MSB) and Least Significant Bit (LSB) respectively.

- The digital switches shown in the above figure will be connected to ground, when the corresponding input bits are equal to ‘0’. Similarly, the digital switches shown in the above figure will be connected to the negative reference voltage, −VR−VR when the corresponding input bits are equal to ‘1’.
- In the above circuit, the non-inverting input terminal of an op-amp is connected to ground. That means zero volts is applied at the non-inverting input terminal of op-amp.
- According to the virtual short concept, the voltage at the inverting input terminal of opamp is same as that of the voltage present at its non-inverting input terminal. So, the voltage at the inverting input terminal’s node will be zero volts.

The nodal equation at the inverting input terminal’s node is:

$$\frac{0+V_R b_2}{2^0 R} + \frac{0+V_R b_1}{2^1 R} + \frac{0+V_R b_0}{2^2 R} + \frac{0-V_0}{R_f} = 0$$

$$=> \frac{V_0}{R_f} = \frac{V_R b_2}{2^0 R} + \frac{V_R b_1}{2^1 R} + \frac{V_R b_0}{2^2 R}$$

$$=> V_0 = \frac{V_R R_f}{R}\left\{\frac{b_2}{2^0} + \frac{b_1}{2^1} + \frac{b_0}{2^2}\right\}$$

Substituting, $R=2R_f$ f in above equation.

$$=> V_0 = \frac{V_R R_f}{2R_f}\left\{\frac{b_2}{2^0} + \frac{b_1}{2^1} + \frac{b_0}{2^2}\right\}$$

$$=> V_0 = \frac{V_R}{2}\left\{\frac{b_2}{2^0} + \frac{b_1}{2^1} + \frac{b_0}{2^2}\right\}$$

- The above equation represents the output voltage equation of a 3-bit binary weighted resistor DAC. Since the number of bits are three in the binary (digital) input, we will get seven possible values of output voltage by varying the binary input from 000 to 111 for a fixed reference voltage, VRVR.

- We can write the generalized output voltage equation of an N-bit binary weighted resistor DAC as shown below based on the output voltage equation of a 3-bit binary weighted resistor DAC.

$$=> V_0 = \frac{V_R}{2}\left\{\frac{b_{N-1}}{2^0}+\frac{b_{N-2}}{2^1}+\ldots.+\frac{b_0}{2^{N-1}}\right\}$$

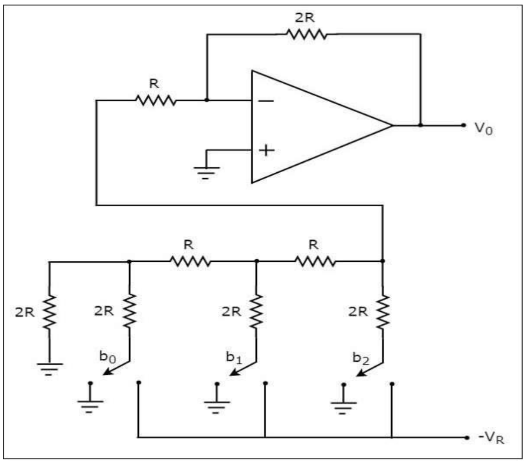
The disadvantages of a binary weighted resistor DAC are as follows −

- The difference between the resistance values corresponding to LSB & MSB will increase as the number of bits present in the digital input increases.
- It is difficult to design more accurate resistors as the number of bits present in the digital input increases.

R-2R Ladder DAC

- The R-2R Ladder DAC overcomes the disadvantages of a binary weighted resistor DAC.
- As the name suggests, R-2R Ladder DAC produces an analog output, which is almost equal to the digital (binary) input by using a R-2R ladder network in the inverting adder circuit.

The circuit diagram of a 3-bit R-2R Ladder DAC is shown in the following figure



- Recall that the bits of a binary number can have only one of the two values. i.e., either 0 or 1.
- Let the **3-bit binary input** is $b_2b_1b_0$. Here, the bits b_2 and b_0 denote the Most Significant Bit (MSB) and Least Significant Bit (LSB) respectively.

- The digital switches shown in the above figure will be connected to ground, when the corresponding input bits are equal to ‘0’.
- Similarly, the digital switches shown in above figure will be connected to the negative reference voltage, −VR−VR when the corresponding input bits are equal to ‘1’.
- It is difficult to get the generalized output voltage equation of a R-2R Ladder DAC. But, we can find the analog output voltage values of R-2R Ladder DAC for individual binary input combinations easily.

The advantages of a R-2R Ladder DAC are as follows –

- R-2R Ladder DAC contains only two values of resistor: R and 2R. So, it is easy to select and design more accurate resistors.
- If more number of bits are present in the digital input, then we have to include required number of R-2R sections additionally.

Due to the above advantages, R-2R Ladder DAC is preferable over binary weighted resistor DAC.

Use of Data Sockets for Networked Communication

A socket is created by concatenating the IP Number of a system and a software port number. This allows the process to know the address of the system the IP address and the address where the information needs to be sent the port number. The IP number and the port number are separated by a:

Data Sockets

The diagram above shows two different applications communicating with one another through sockets. In this diagram, application 1 sends the data to ID number 192.168.16.21 of application 2, port 100 while application 2 sends the data to IP number 192.168.1.1 of application 1, port 80.