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CHAPTER-5

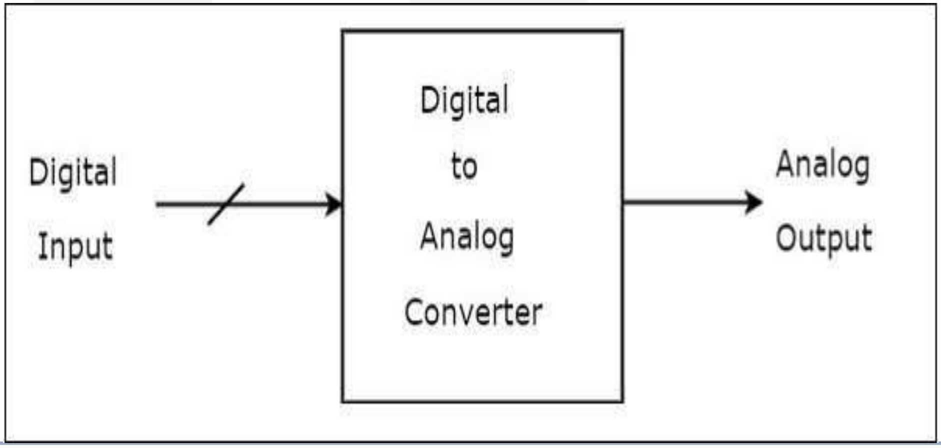
A/D and D/A converters

5.1: I. Introduction:

- Connection between digital devices and sensors is easy compared to connection of any sensor with analog devices. In such cases, the interfacing becomes more tedious.
- Conversion between analog to digital and digital to analog becomes important in such cases. The Analog to Digital converter (ADC) converts Analog signals to the Digital Signal, whereas the Digital to Analog converter (DAC) converts Digital signals to the Analog signals.

5.2: Digital to Analog Converters:

- 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.
- **There are two types of DACs**
  - **Weighted Resistor DAC**
  - **R-2R Ladder DAC**



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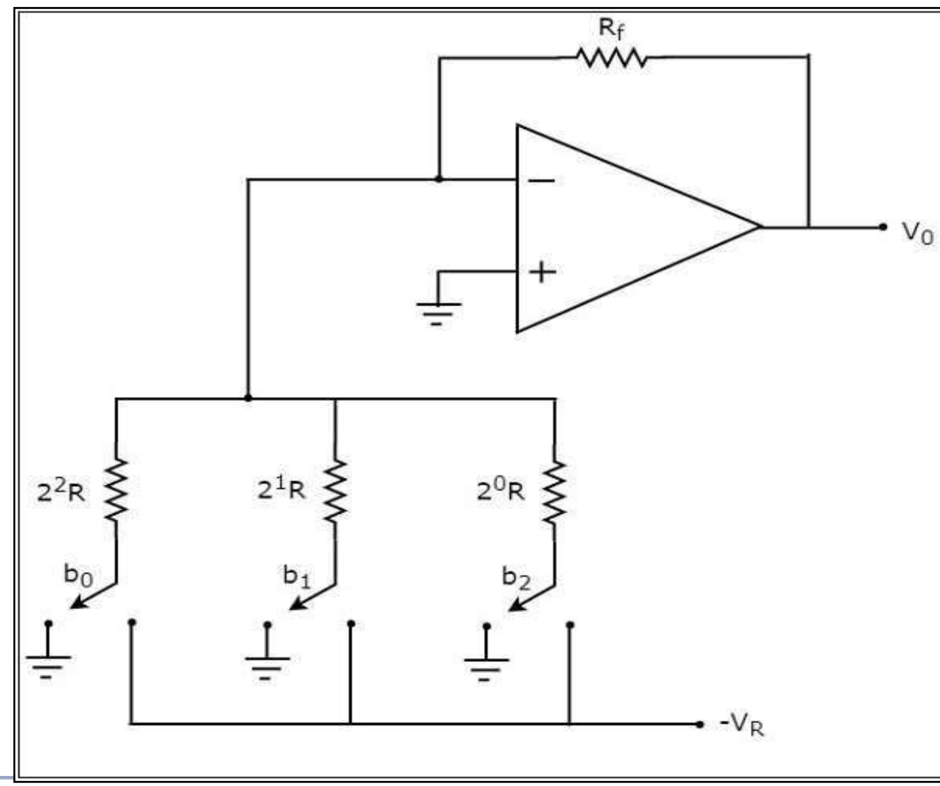
5.2.1: Weighted Resistor Digital to Analog Converter (DAC)

- A weighted resistor DAC produces an analog output, which is approximately equal to the digital (binary) input. It uses binary weighted resistors in the inverting adder circuit to accomplish the task.
- The circuit diagram of a 3-bit binary weighted resistor DAC is shown here.



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5.2.1: Weighted Resistor Digital to Analog Converter (Continue)

- The digital switches will be connected to ground, when the corresponding input bits are equal to ‘0’ whereas they will be connected to the negative reference voltage, −VR when the corresponding input bits are equal to ‘1’.
- The nodal equation at the inverting input terminal’s node, simplification and at last the generalized equation of N-bit weighted register DAC is as explained here.

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

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

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

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

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

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

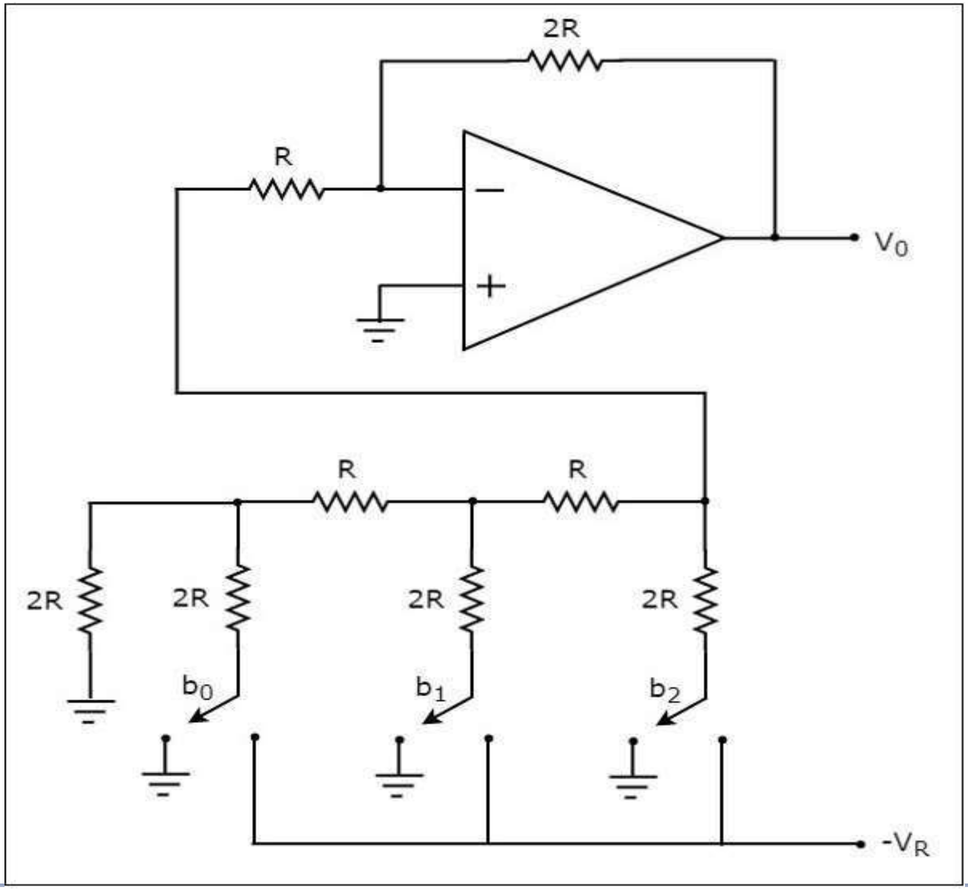
Image source Google

5.2.1: Weighted Resistor Digital to Analog Converter (Continue)

- The disadvantages of a binary weighted resistor DAC are as follows :
  - It is difficult to design more accurate resistors as the number of bits present in the digital input increases.
  - The difference between the resistance values corresponding to LSB & MSB will increase as the number of bits present in the digital input increases.

5.2.2: R-2R Ladder DAC

- 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 here.



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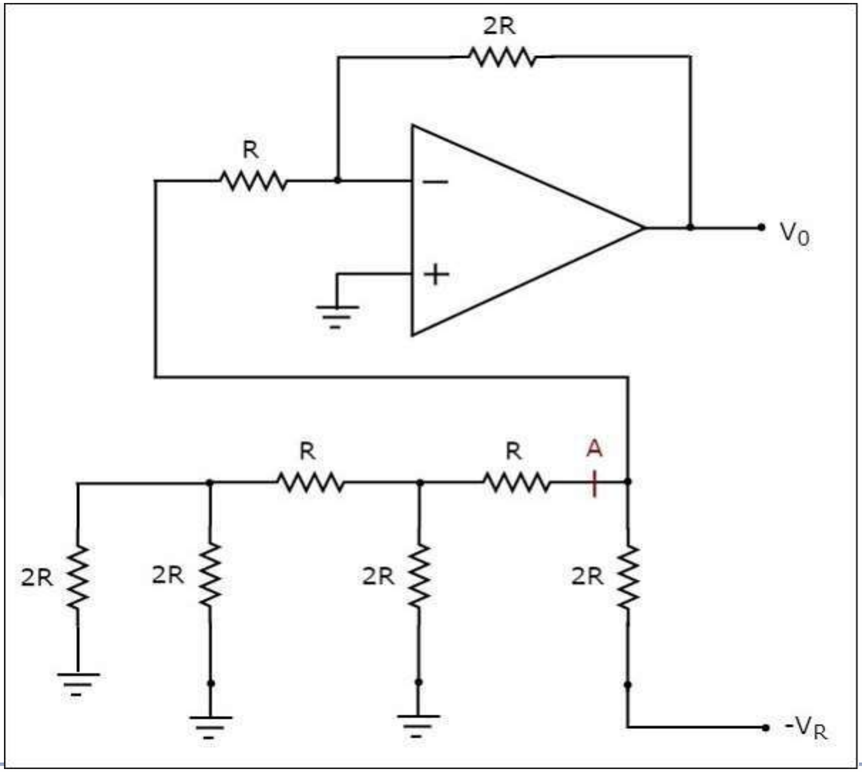
5.2.2: R-2R Ladder DAC (Continue..)

- 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 when the corresponding input bits are equal to ‘1’.
- The advantages of 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.

5.2.2: R-2R Ladder DAC (Continue..)

Example

Let us find the value of analog output voltage of R-2R Ladder DAC for a binary input, $b_2b_1b_0 = 100$.



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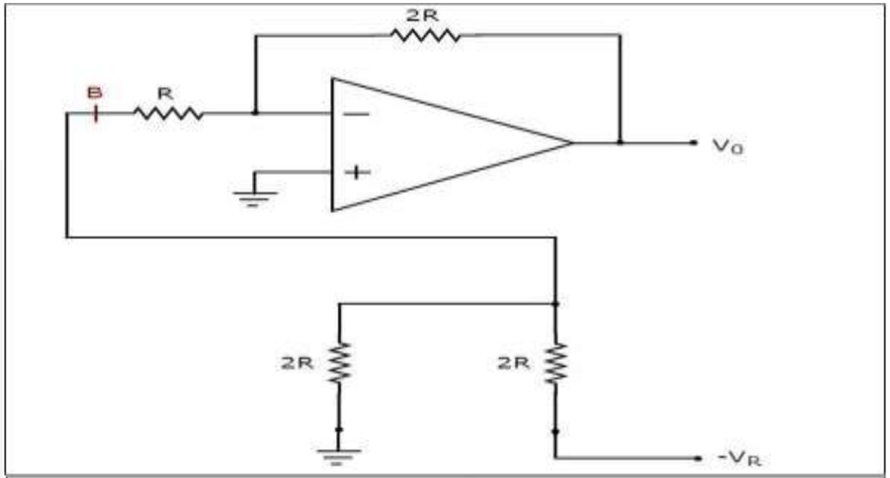
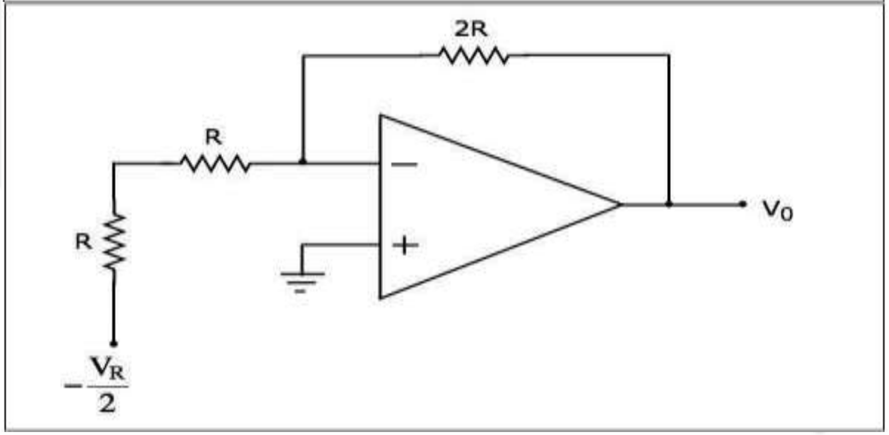
5.2.2: R-2R Ladder DAC (Continue..)

Example (Continue..)

Simplified Diagram →



Modified Diagram →



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5.2.2: R-2R Ladder DAC (Continue..)

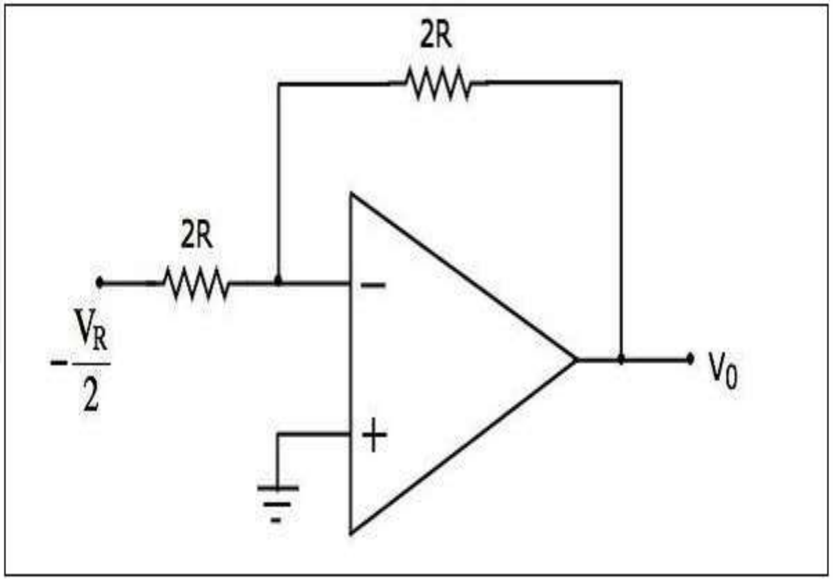
Example (Continue..)

- The final diagram looks like an inverting amplifier.
- It is having an input voltage of –VR/2 volts, input resistance of 2RΩ and feedback resistance of 2RΩ.
- The output voltage of the circuit will be –

Vo=-2R/2R (-VR/2)

Vo=-VR/2

Final Diagram ↓



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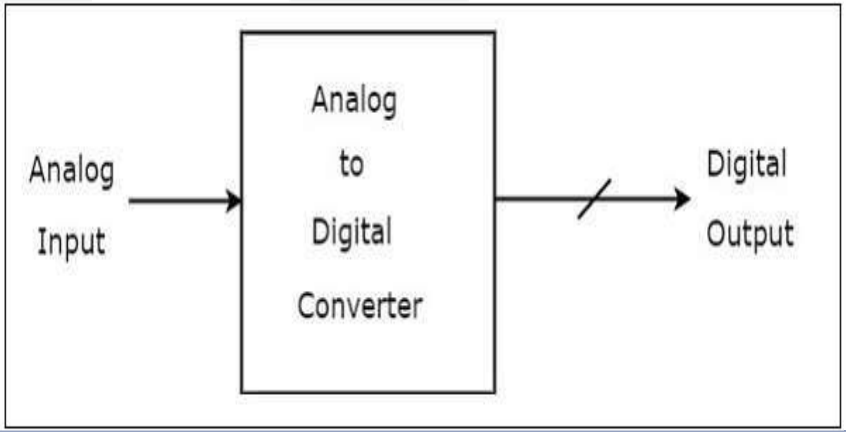
5.3 : Analog to Digital Converter (ADC)

- An Analog to Digital Converter (ADC) converts an analog signal into a digital signal.
- The number of binary outputs of ADC will be a power of two.
- There are two types of ADCs: Direct type ADCs and Indirect type ADC.



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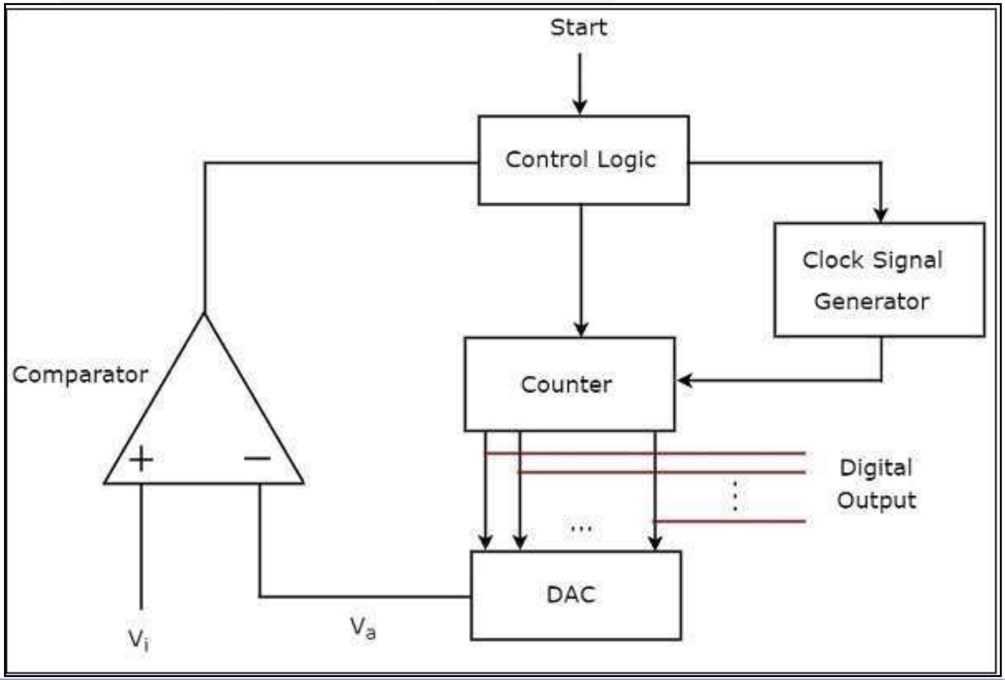
5.3.1 : Direct type ADCs

- In direct type ADCs, Analog to digital conversion takes place directly by utilizing the internally generated equivalent digital (binary) code for comparing with the analog input.
- The following are the examples of Direct type ADCs –
  - Counter type ADC
  - Successive Approximation ADC
  - Flash type ADC

5.3.1.1: Counter type ADC

- The counter type ADC mainly consists of 5 blocks: Clock signal generator, Counter, DAC, Comparator and Control logic.
- DAC converts the received binary (digital) input, which is the output of counter, into an analog output. Comparator compares this analog value, Va with the external analog input value Vi.



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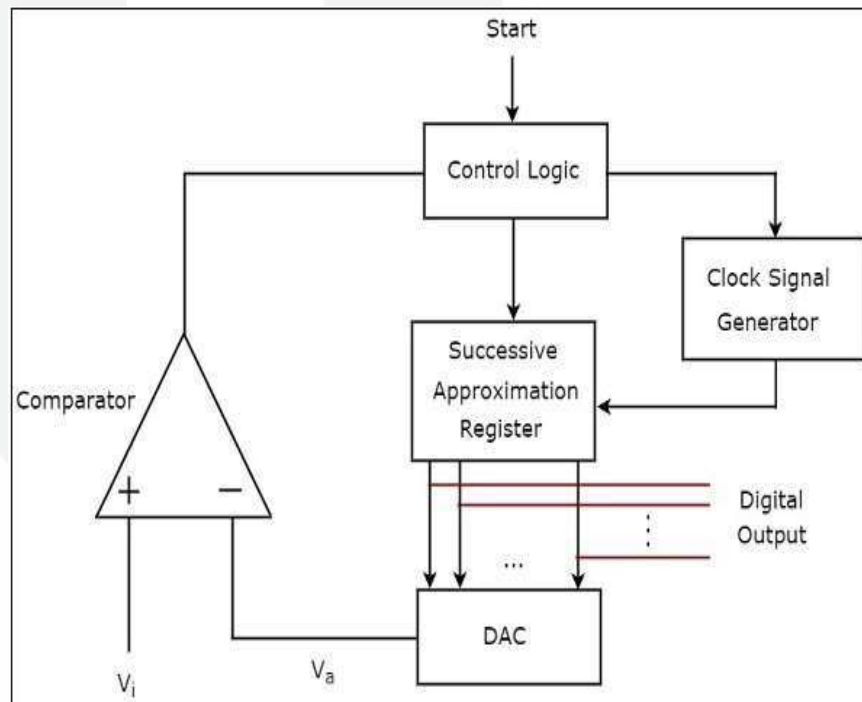
5.3.1.2: Successive Approximation ADC

- The counter type ADC mainly consists of 5 blocks: Clock signal generator, Successive Approximation Register (SAR), DAC, Comparator and Control logic.
- When circuit received the start signal. The binary data present in SAR will be updated for every clock pulse based on the output of comparator.
- The output of SAR is applied as an input of DAC, which is converted into an analog output.
- The comparator compares this analog value Va with the external analog input value Vi. The output of a comparator will be '1' as long as Vi is greater than Va and vice versa.



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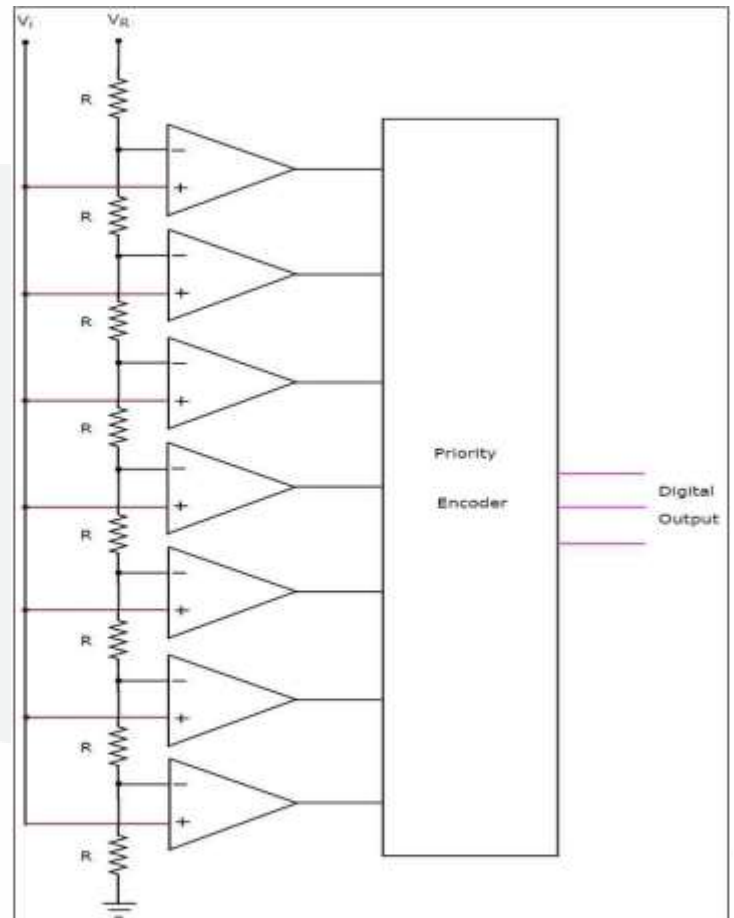
5.3.1.3: Flash type ADC

- A flash type ADC produces an equivalent digital output for a corresponding analog input in no time.
- Fastest ADC
- The circuit diagram of a 3-bit flash type ADC is shown here.
- Itconsists of a voltage divider network, 7 comparators and a priority encoder



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5.3.1.3: Flash type ADC (Continue..)

- The voltage divider network contains 8 equal resistors. A reference voltage VR is applied across that entire network with respect to the ground. The voltage drop across each resistor from bottom to top with respect to ground will be the integer multiples (from 1 to 8) of $V_R/8$.
- The external input voltage Vi is applied to the non-inverting terminal of all comparators.
- The comparison operations take place by each comparator in a parallel manner.

5.3.1.3: Flash type ADC (Continue..)

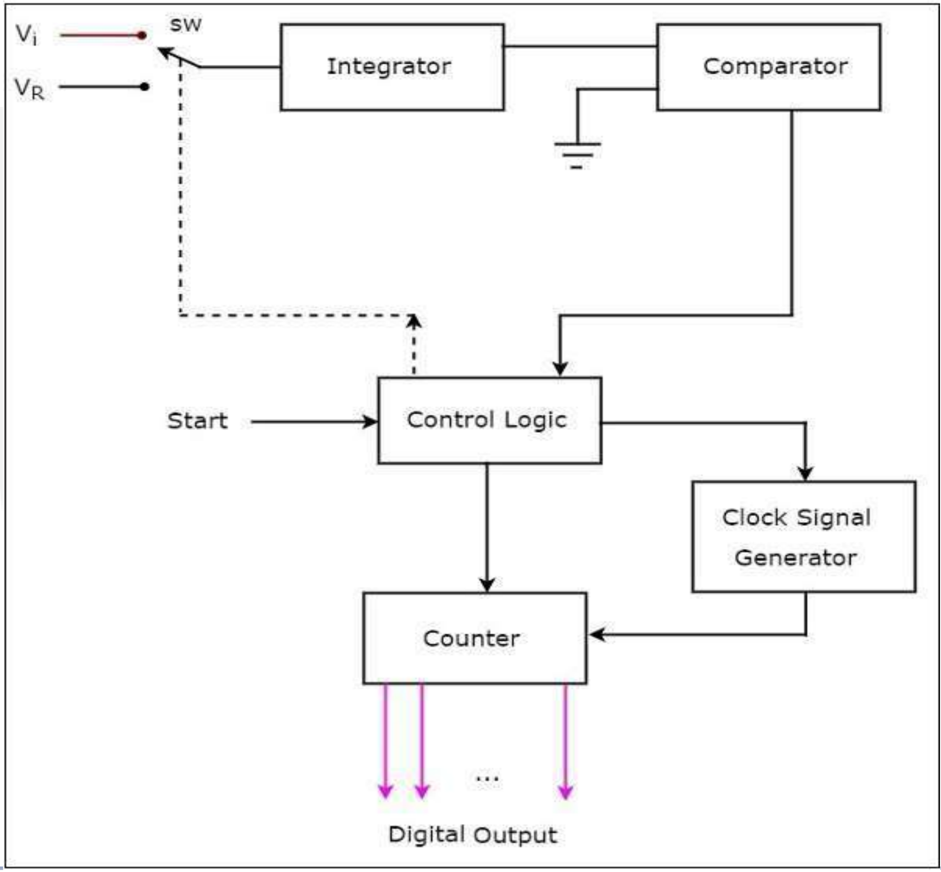
- All the outputs of comparators are connected as the inputs of priority encoder. This priority encoder produces a binary code (digital output), which is corresponding to the high priority input that has ‘1’.
- The output of priority encoder is nothing but the binary equivalent (digital output) of external analog input voltage, Vi.
- The flash type ADC is used in the applications where the conversion speed of analog input into digital data should be very high.

5.3.2: Indirect type ADC

- If an ADC performs the analog to digital conversion by an indirect method, then it is called an Indirect type ADC.
- First it converts the analog input into a linear function of time (or frequency) and then it will produce the digital (binary) output.
- Dual slope ADC is the best example of an Indirect type ADC.

5.3.2.1: Dual Slope ADC

- The dual slope ADC mainly consists of 5 blocks: Integrator, Comparator, Clock signal generator, Control logic and Counter.
- Control logic pushes the switch sw to connect to the external analog input voltage Vi, when it is received the start commanding signal. This input voltage is applied to an integrator.



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5.3.2.1: Dual Slope ADC

- The output of the integrator is connected to one of the two inputs of the comparator and the other input of comparator is connected to ground.
- Comparator compares the output of the integrator with zero volts (ground) and produces an output, which is applied to the control logic.
- The counter gets incremented by one for every clock pulse and its value will be in binary format. It produces an overflow signal to the control logic, when it is incremented after reaching the maximum count value.
- This type of ADC is used in the applications, where accuracy is more important.

5.3.4: Examples of A to D converter ICs

Following are the examples of A to D converter ICs

- ADC0808
- ADC0804

5.3.5: Examples of D to A converter ICs

Following are the examples of D to A converter ICs

- DAC7715
- DAC8814
- DAC8811

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