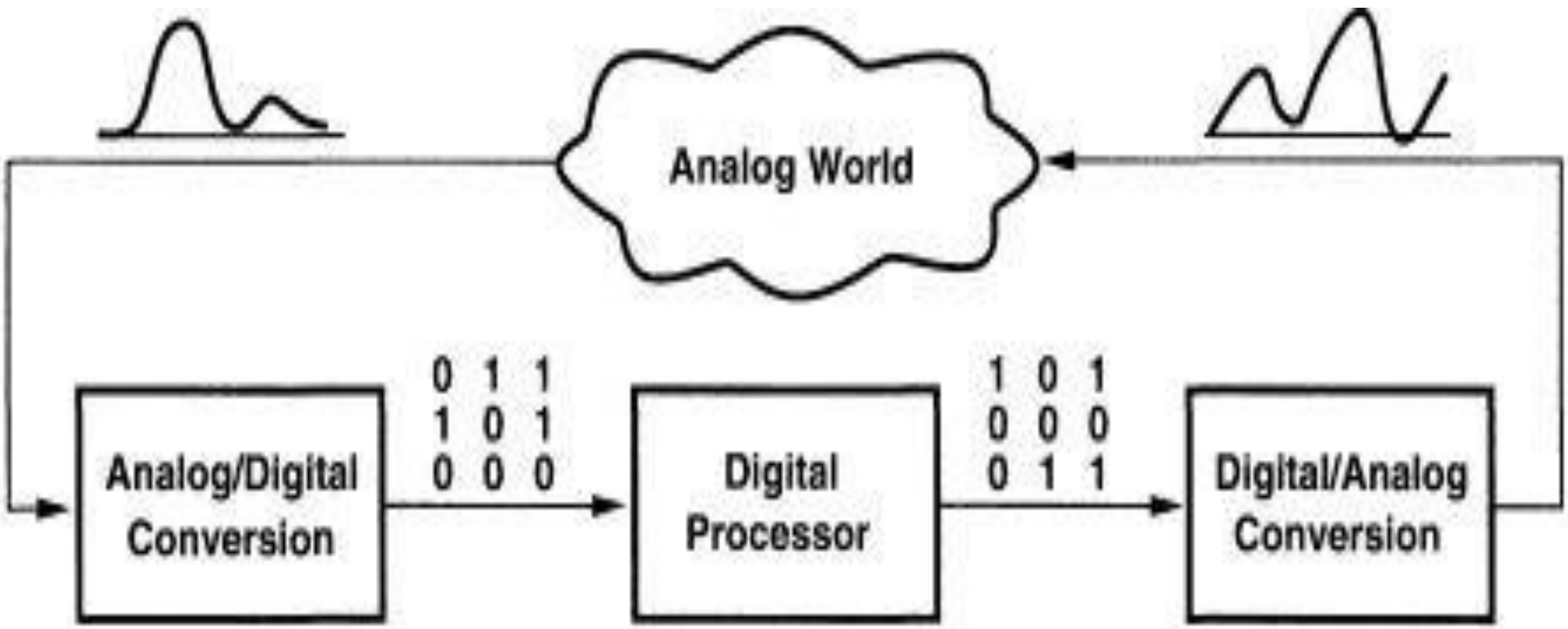
Interfacing Data Conversion

Data Conversion System

- **Data Conversion** is the process of changing or converting one form of data in to another form. In processing and communication there are only two types of data forms i.e analog and digital data.
- Real world signals are analog signals continuous time & amplitude (temp, pressure, position, sound, light, speed, etc.).
- Digital processors can only process digital signals which are discrete time and discrete amplitude.

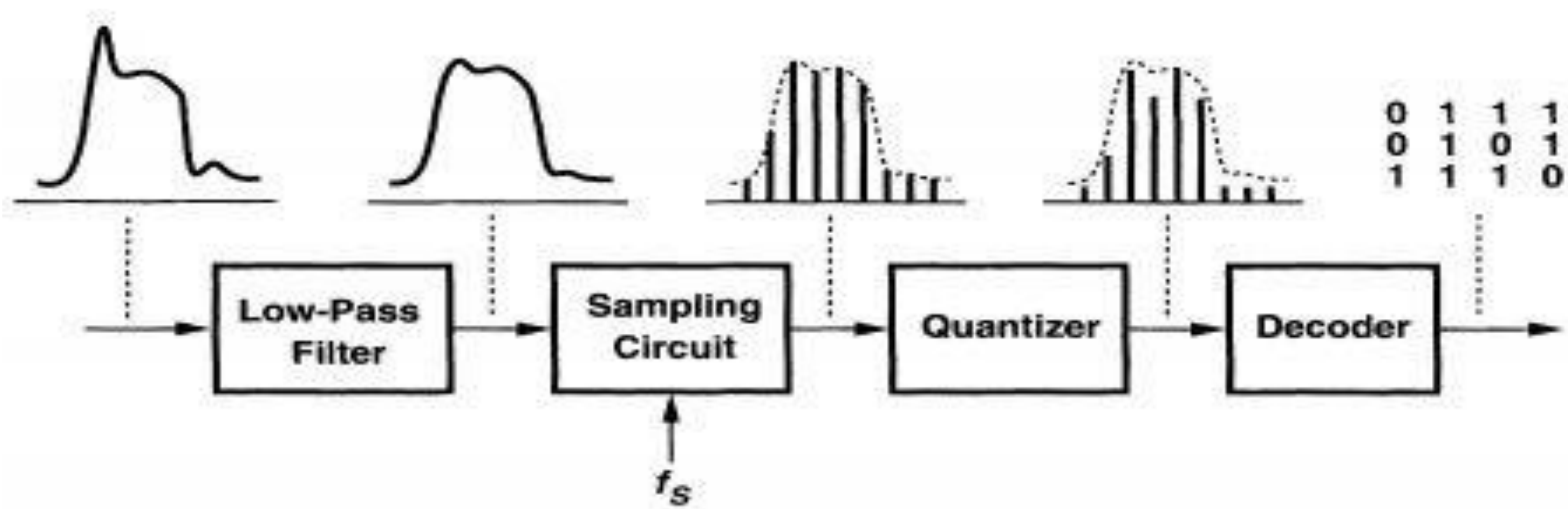
- In order to interface digital processors with the analog world, data acquisition and reconstruction circuits must be used:
  analog-to-digital converters (ADCs) to acquire and digitize the analog signal at the front end, and digital-to-analog converters (DACs) to reproduce the analog signal at the back end.
- ? Digital data conversion system requires ADC and DAC.



Analog World
Analog/Digital Conversion
0 1 1
1 0 1
0 0 0
Digital Processor
1 0 1
0 0 0
0 1 1
Digital/Analog Conversion

Analog-to-Digital Converter (ADC)

- The analog-to-digital converter (ADC) converts a continuous-amplitude, continuous-time input to a discrete-amplitude, discrete-time signal.



1. An analog low-pass (anti-alias) filter limits the input signal bandwidth so that subsequent sampling does not alias any unwanted noise or signal components into the actual signal band.
2. The filter output signal is sampled at a rate of f_S samples per second to produce a discrete-time signal.
3. The amplitude of this discrete-time signal is "quantized," i.e., approximated with a level from a set of fixed references, thus generating a discrete-amplitude signal.
4. The discrete-amplitude signal is decoded to a digital representation of that level is established at the output.

ADC Applications

- ADC are used virtually everywhere an analog signal has to be processed, stored, pr transported in digital form
  - Microphones
  - Strain Gages
  - Thermocouple
  - Voltmeters
  - Digital Multimeters

A/D Converter Types

- Flash ADC
- Delta-Sigma ADC
- Dual Slope (integrating) ADC
- Successive Approximation ADC

Flash ADC

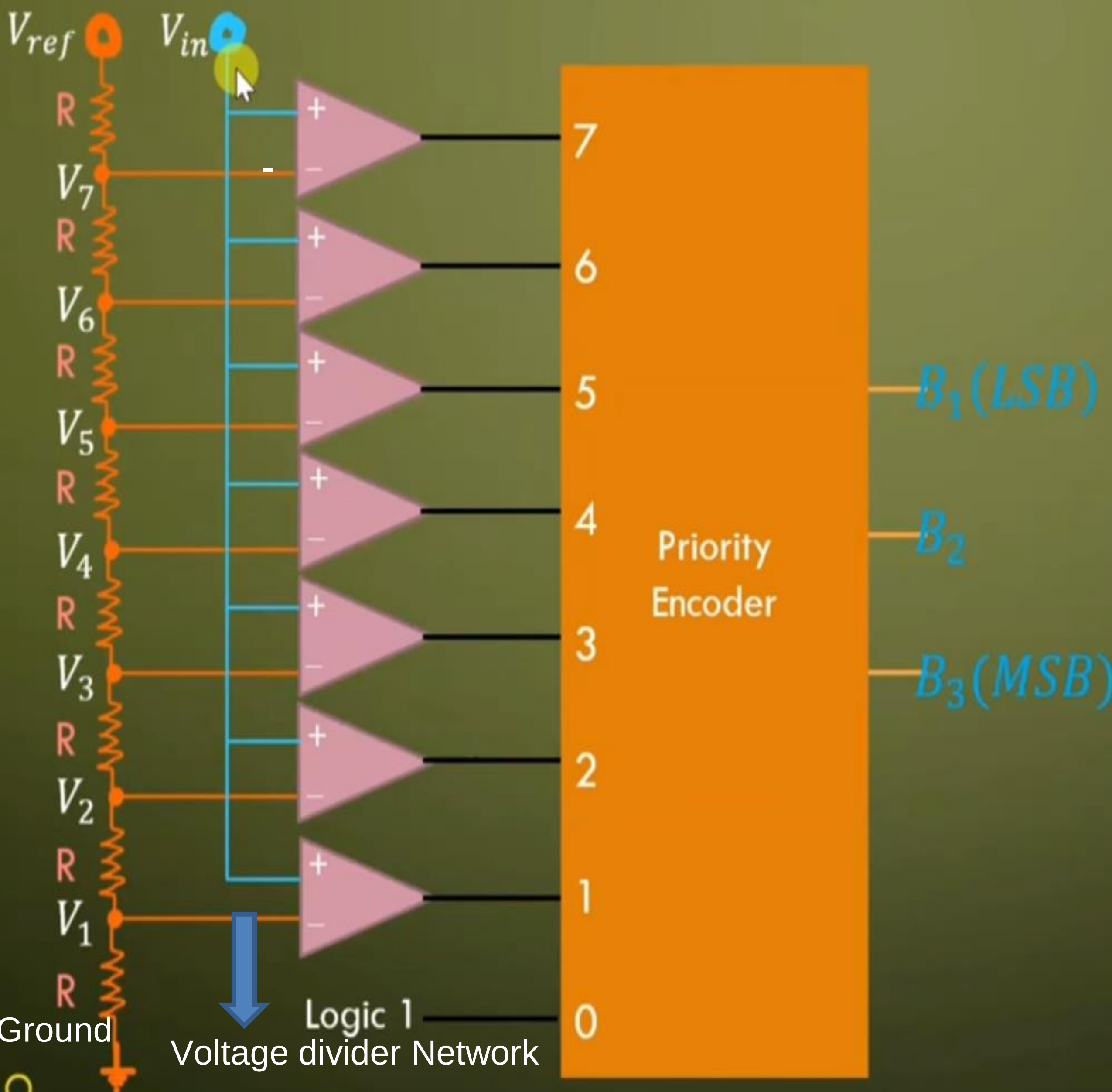
- Flash ADC is fastest among all ADC
- It takes only one clock cycle to have conversion
- Consists of a series of comparators, each one comparing the input signal to a unique reference voltage.

- The comparator outputs connect to the inputs of a priority encoder circuit, which produces a binary output

Components of Flash ADC

- Structure of Flash ADC consist three major components
  1. High Speed Comparator $[2^n - 1]$
  2. Resistive voltage divider Network $[2^n]$
  3. Priority Encoder [1]

Structure of Flash ADC



$$V_1 = V_{ref}\left[\frac{R}{8R}\right] = \frac{V_{ref}}{8}$$

$$V_2 = V_{ref}\left[\frac{2R}{8R}\right] = \frac{2V_{ref}}{8}$$

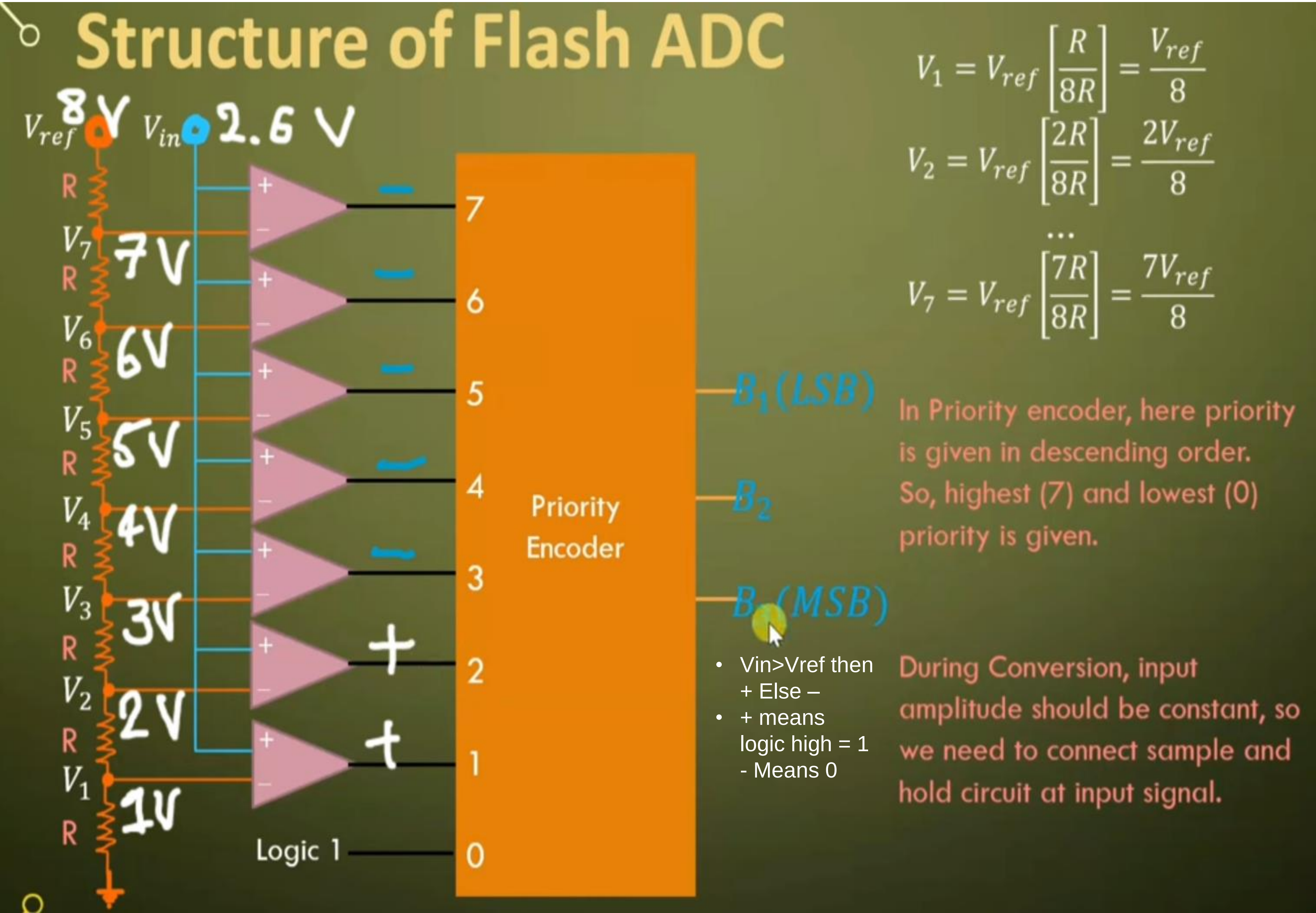
...

$$V_7 = V_{ref}\left[\frac{7R}{8R}\right] = \frac{7V_{ref}}{8}$$

In Priority encoder, here priority is given in descending order. So, highest (7) and lowest (0) priority is given.

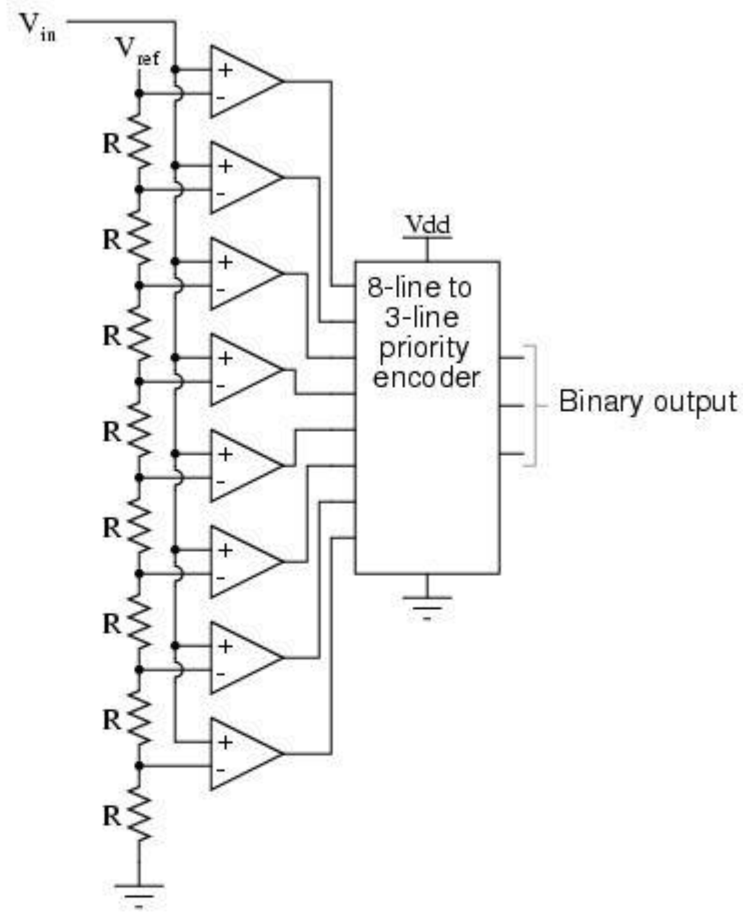
During Conversion, input amplitude should be constant, so we need to connect sample and hold circuit at input signal.

Working of Flash ADC

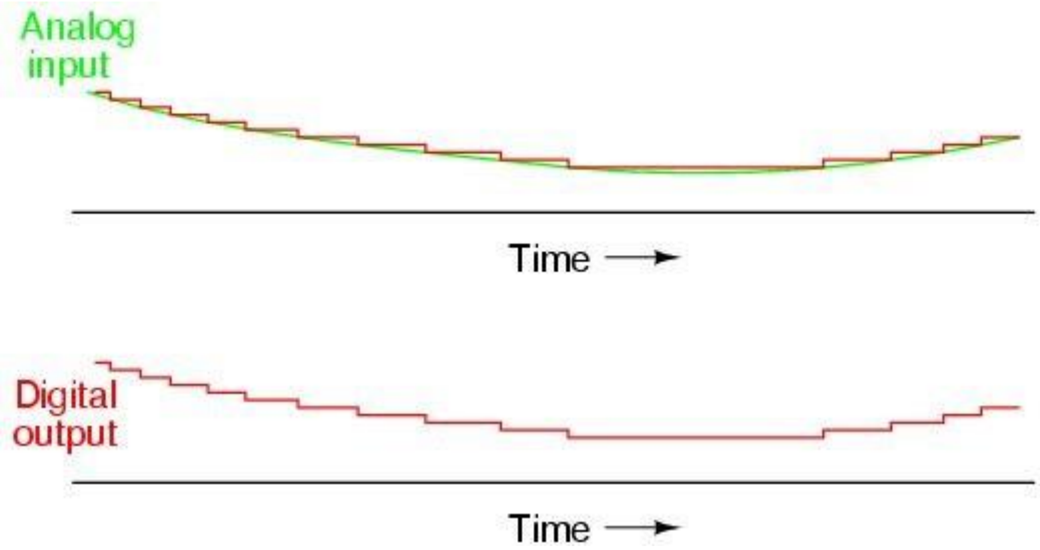


- Vin>Vref then + Else –
- + means logic high = 1 - Means 0

Flash ADC Circuit



ADC Output



Flash

Advantages

- **Simplest** in terms of operational theory
- Useful with **large bandwidth**
- Most efficient in terms of speed, very fast (Giga samples per second)
- limited only in terms of comparator and gate propagation delays

Disadvantages

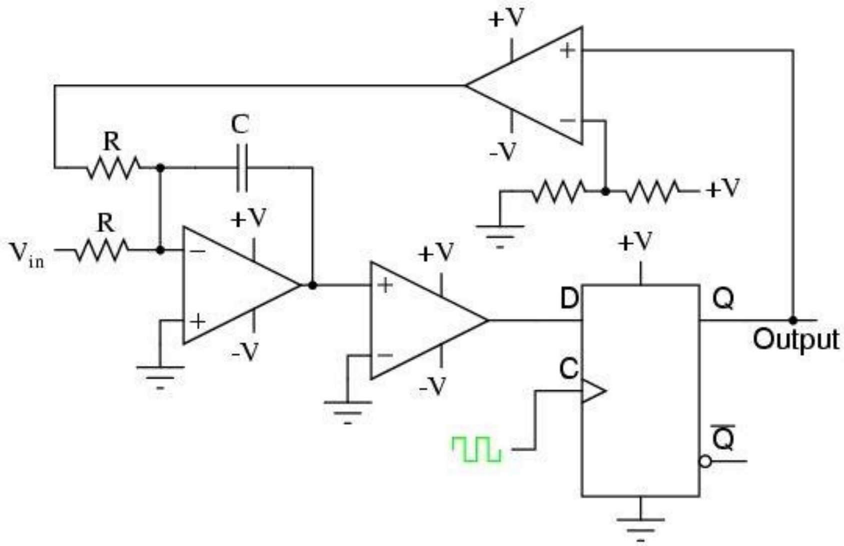
- Lower resolution (Up to 8 bits)
- Expensive
- High power consumption because For each additional output bit, the number of comparators is doubled i.e. for 8 bits, 256 comparators needed

Applications of Flash ADC

1. Satellite Communication
2. RADAR processing
3. Oscilloscope

Sigma Delta ADC

- Over sampled input signal goes to the integrator
- Output of integration is compared to GND
- Iterates to produce a serial bit stream
- Output is serial bit stream with # of 1's proportional to V_{in}



Sigma-Delta

Advantages

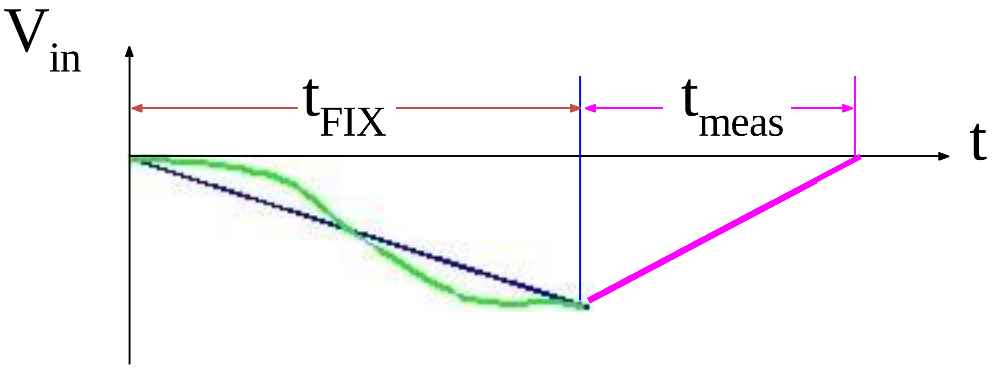
- High resolution oversampling
- No precision external components needed

Disadvantages

- Slow due to

Dual Slope Converter

- The sampled signal charges a capacitor for a fixed amount of time
- By integrating over time, noise integrates out of the conversion
- Then the ADC discharges the capacitor at a fixed rate with the counter counts the ADC's output bits. A longer discharge time results in a higher count



Dual Slope Converter

Advantages

- Input signal is averaged
- Greater noise immunity than other ADC types
- High accuracy

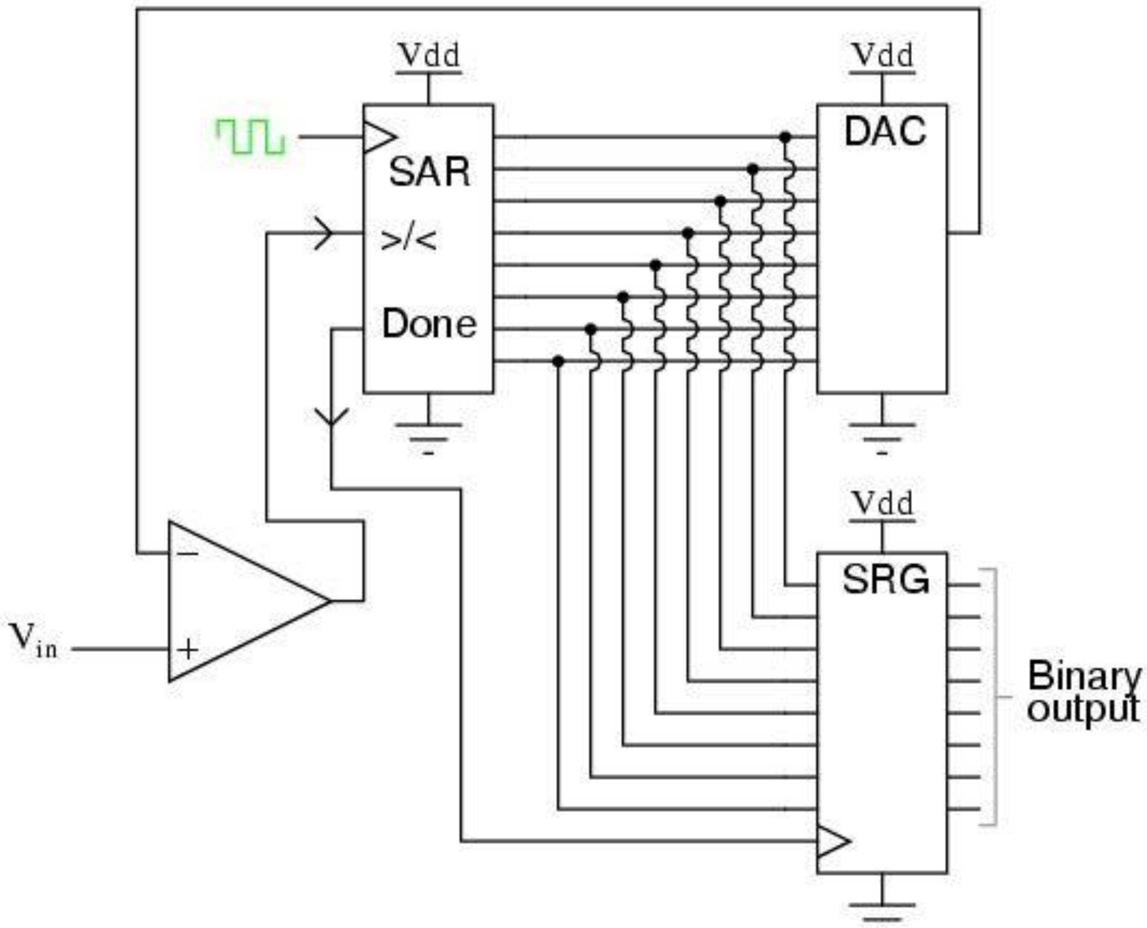
Disadvantages

- Slow
- High precision external components required to achieve accuracy

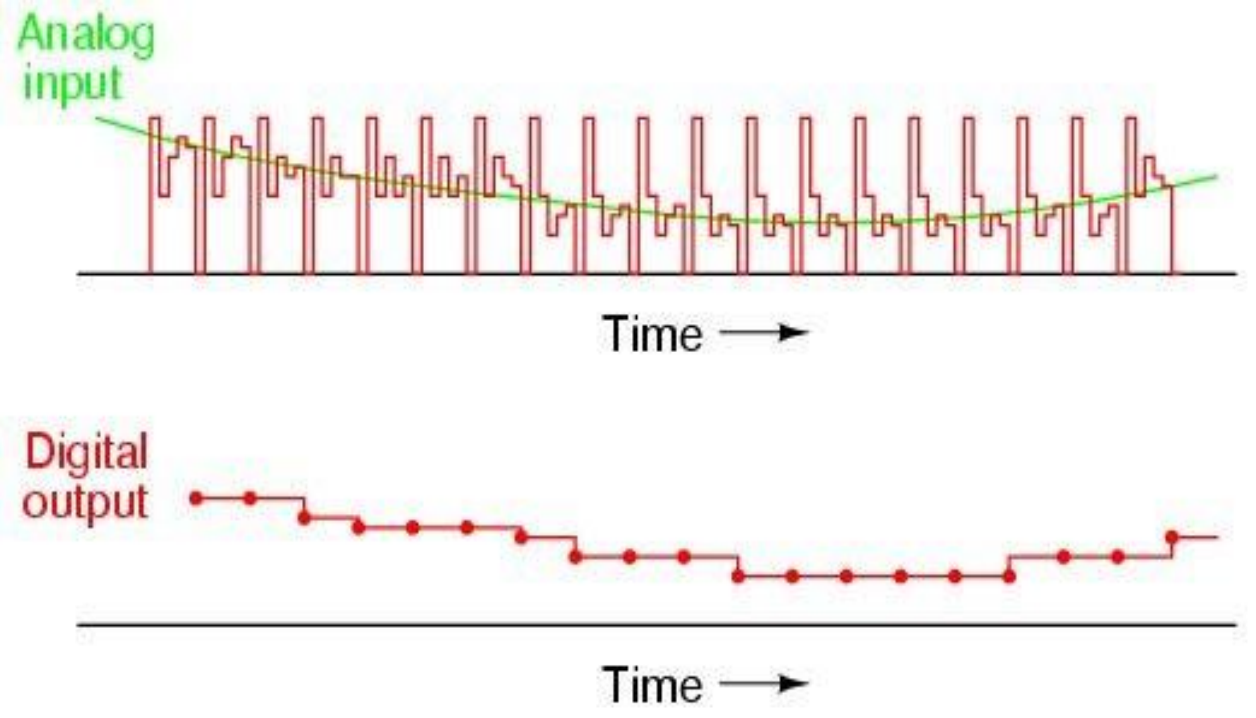
Successive Approximation ADC

- A Successive Approximation Register (SAR) is added to the circuit
- Instead of counting up in binary sequence, this register counts by trying all values of bits starting with the MSB and finishing at the LSB.
- The register monitors the comparators output to see if the binary count is greater or less than the analog signal input and adjusts the bits accordingly

Successive Approximation ADC Circuit



ADC Output



Successive Approximation

Advantages

- Capable of high speed and reliable
- Medium accuracy compared to other ADC types
- Good tradeoff between speed and cost

- Capable of outputting the binary number in serial (one bit at a time) format.

Disadvantages

- Higher resolution successive approximation ADC's will be slower
- Speed limited to ~5Msps

ADC Types Comparison

Type	**Speed (relative)**	**Cost (relative)**
Dual Slope	Slow	Med
Flash	Very Fast	High
Successive Appox	Medium – Fast	Low
Sigma-Delta	Slow	Low

AD570

- The AD570 is an 8-bit successive approximation A/D converter consisting of a DAC, voltage reference, clock, comparator, successive approximation register and output buffers---all fabricated on a single chip.
- The AD570 incorporates the most advanced integrated circuit design and processing technology available today.

ADC 0801

- The ADC 0801
  is a 8-bit successive-appr oximation A/D converter.

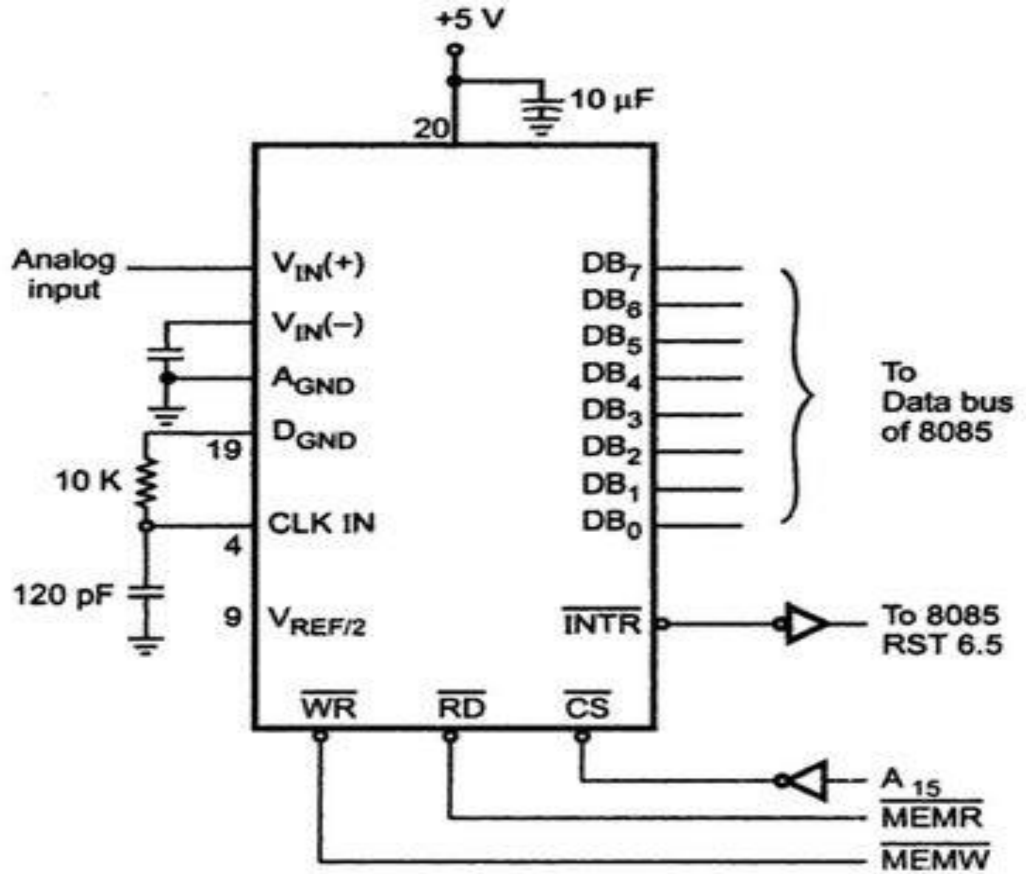
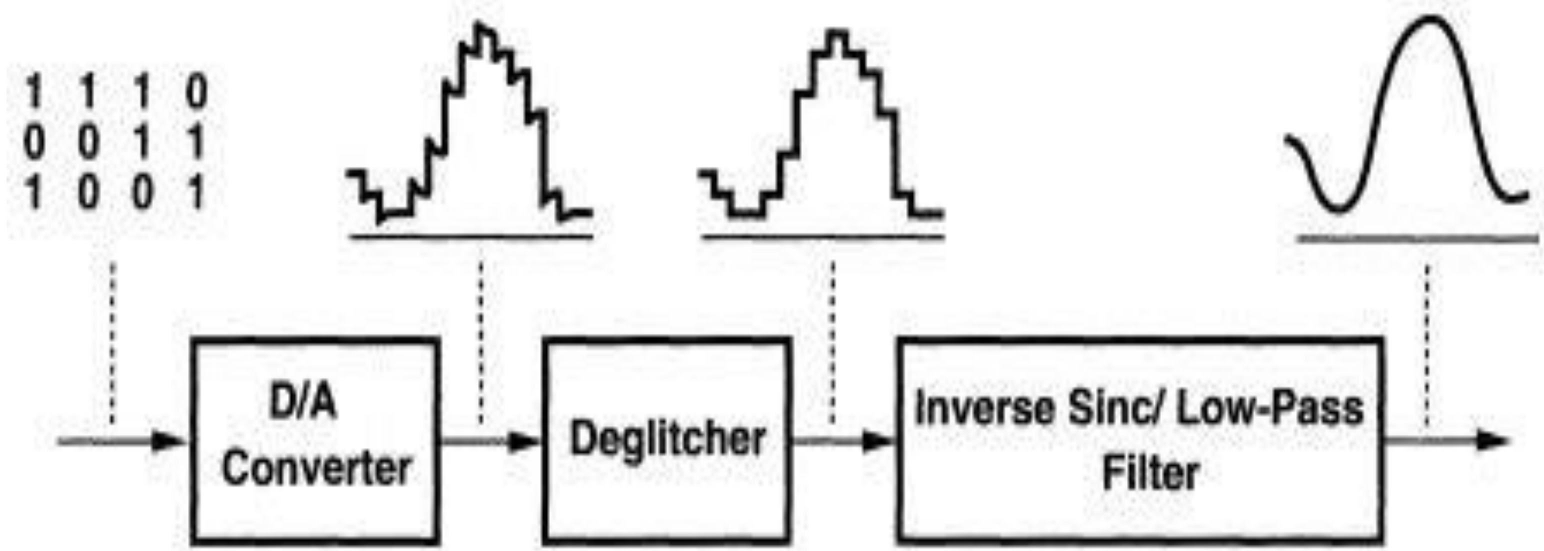


Fig. 1 (a) Interfacing of ADC 0801 with 8085

Digital-to-Analog Converter (DAC)

- The digital data is processed by a digital processor and output to the digital-to analog converter (DAC).
- The DAC reverses the ADC process, it converts a discrete time, discrete amplitude into continuous time, continuous amplitude. The DAC is usually operated at same frequency as the ADC.

1. A DAC selects and produces an analog level from a set of fixed references according to the digital input.
2. If the DAC generates large glitches during switching from one code to another, a "deglitching" circuit (usually a sample-and-hold amplifier) follows to mask the glitches.
3. The reconstruction function performed by the DAC introduces sharp edges in the waveform as well as a sine envelope in the frequency domain, an inverse-sine filter and a low-pass filter are required to suppress these effects. The resulting staircase-like signal is finally passed through a smoothing filter to ease the effects of quantization noise.


1 1 1 0
0 0 1 1
1 0 0 1
D/A Converter
Deglitcher
Inverse Sinc/ Low-Pass Filter

Pin diagram of DAC

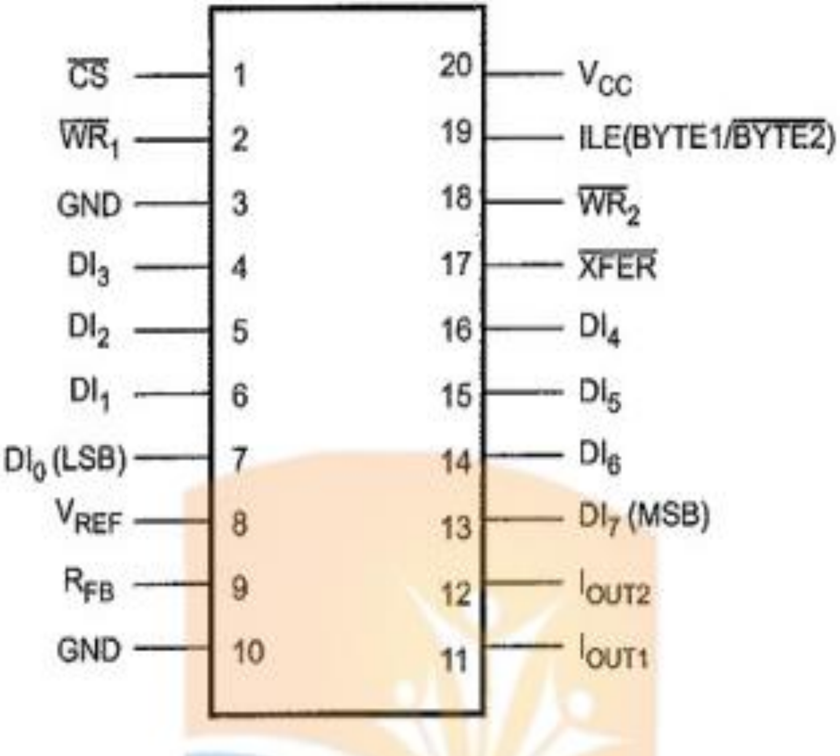


Fig. 23.1 Pin diagram of DAC

Pin	Name	Description
1	CS	Chip Select (Active Low) needed to be grounded for enabling the chip
2	WR	Write (Active Low) needed to be grounded for successful data transmission
3	GND	Ground
4	DI3	Digital Input 3 will take data for conversion
5	DI2	Digital Input 2 will take data for conversion
6	DI1	Digital Input 1 will take data for conversion
7	DI0(LSB)	Digital Input 0(Least Significant Bit) will take data for conversion
8	VREF	Voltage Reference for the chip is given at this pin
9	Rfb	Feedback Resistor will be connected to this pin
10	GND	Ground
11	IOUT1	Current Output 1 will give analog output after conversion
12	IOUT2	Current Output 2 will give analog output after conversion

13	DI7(MSB)	Digital Input 7(Most Significant Bit) will take data for conversion
14	DI6	Digital Input 6 will take data for conversion
15	DI5	Digital Input 5 will take data for conversion
16	DI4	Digital Input 4 will take data for conversion
17	XFER	Transfer Control Signal (Active Low)
18	WR2	Write 2 (Active Low)
19	ILE	Input Latch Enable pin needed to be high for successful data transmission
20	VCC	Positive Power Supply

DAC Applications

- Digital Motor Control
- Computer Printers
- Sound Equipment (e.g. CD/MP3 Players, etc.)
- Electronic Cruise Control
- Digital Thermostat

D/A Converter Types

- Many types of DACs available.
- Usually switches, resistors, and op-amps used to implement conversion
- Two Types:
  - Binary Weighted Resistor
  - R-2R Ladder

Binary Weighted Resistor

- Utilizes a summing op-amp circuit
- Weighted resistors are used to distinguish each bit from the most significant to the least significant
- Transistors are used to switch between V and ground (bit high or low)

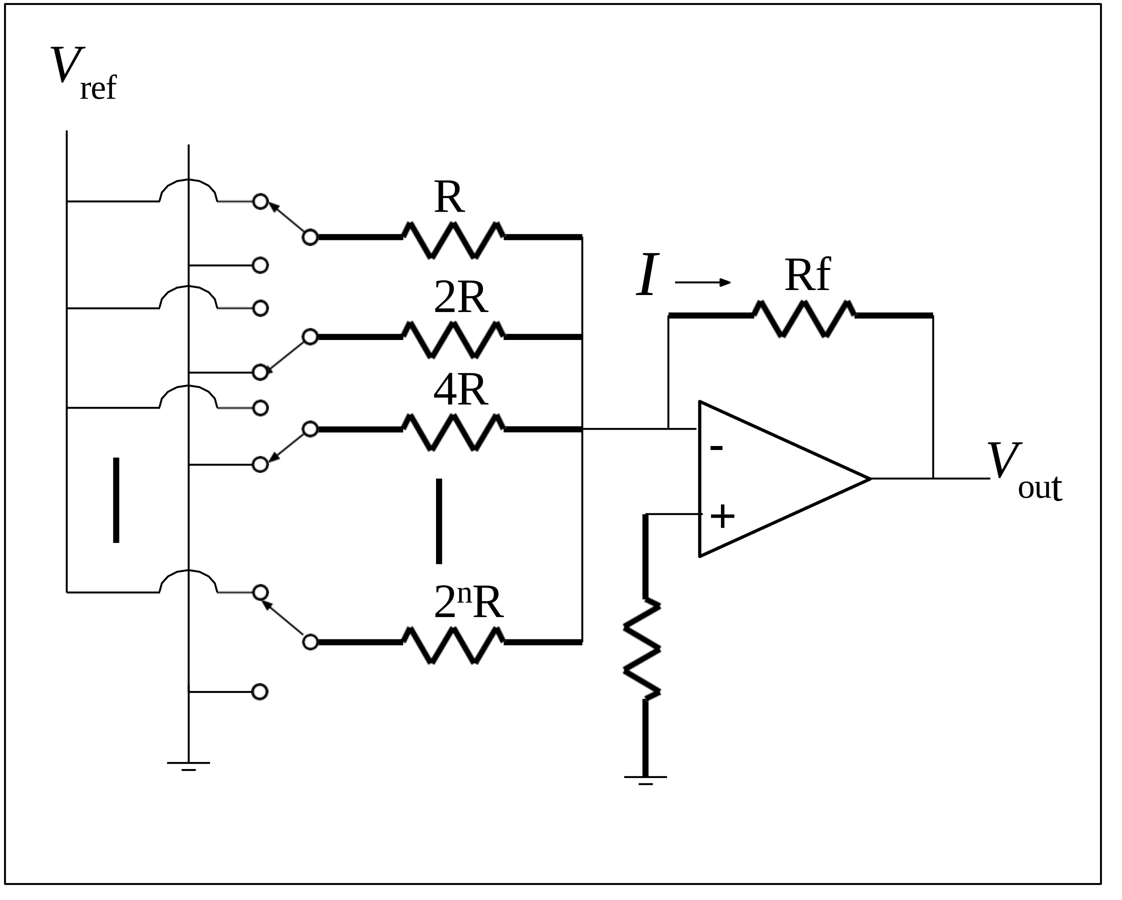
ref

Binary Weighted Resistor (Cont.)

- Assume Ideal Op-amp
- No current into op-amp

- Virtual ground at inverting input

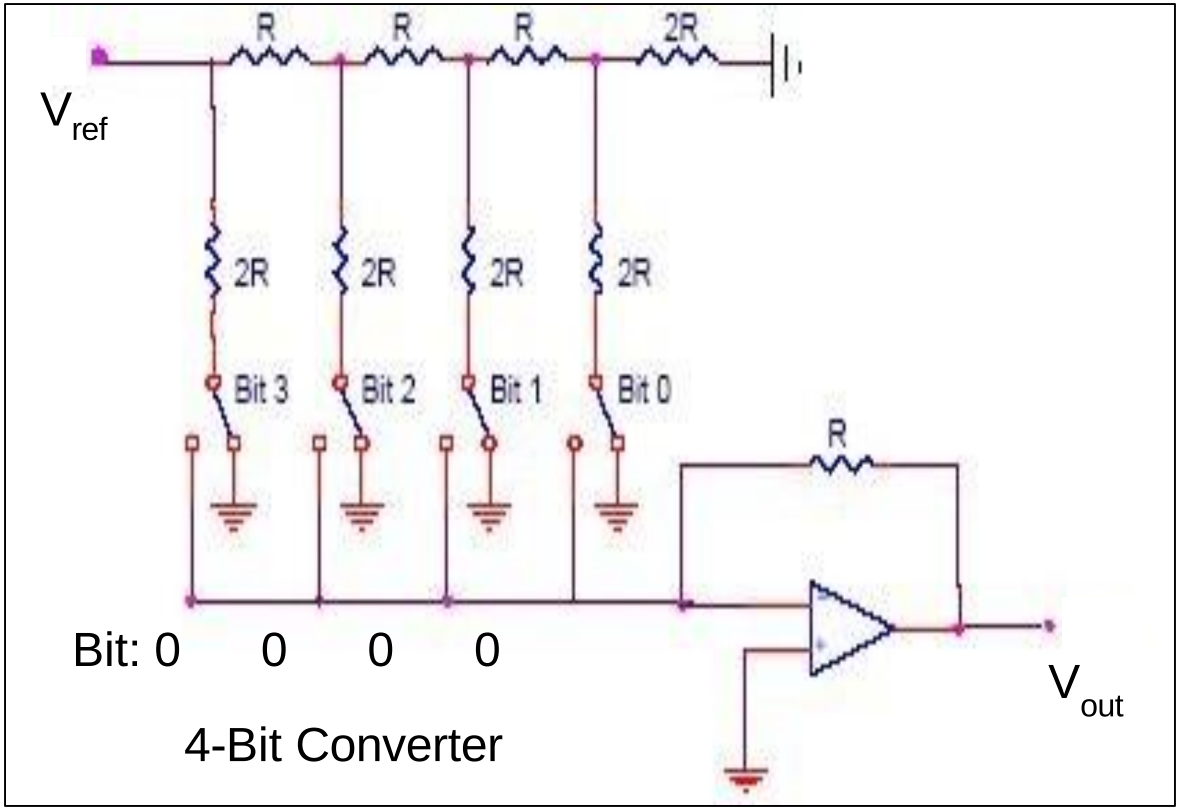
  - $V_{out} = -IR_f$



Binary Weighted Resistor (Cont.)

- Advantages
  - Simple Construction/Analysis
  - Fast Conversion
- Disadvantages
  - Requires large range of resistors (2000:1 for 12-bit DAC) with necessary high precision for low resistors
  - Requires low switch resistances in transistors
  - Can be expensive. Therefore, usually limited to 8-bit resolution.

R-2R Ladder



Each bit corresponds to a switch:

If the bit is high, the corresponding switch is connected to the inverting input of the op-amp.

If the bit is low, the corresponding switch is connected to ground.

R-2R Ladder (Cont.)

- Advantages
  - Only two resistor values (R and 2R)
  - Does not require high precision resistors
- Disadvantage
  - Lower conversion speed than binary weighted DAC

AD 7522

- The AD 7522 is a systems-compatible 10-bit multiplying D/A converter, fabricated on a single 3 x 2.2mm (118 x 89 mil) silicon die, and packaged in a 28-pin plastic or ceramic dual
in-line package.

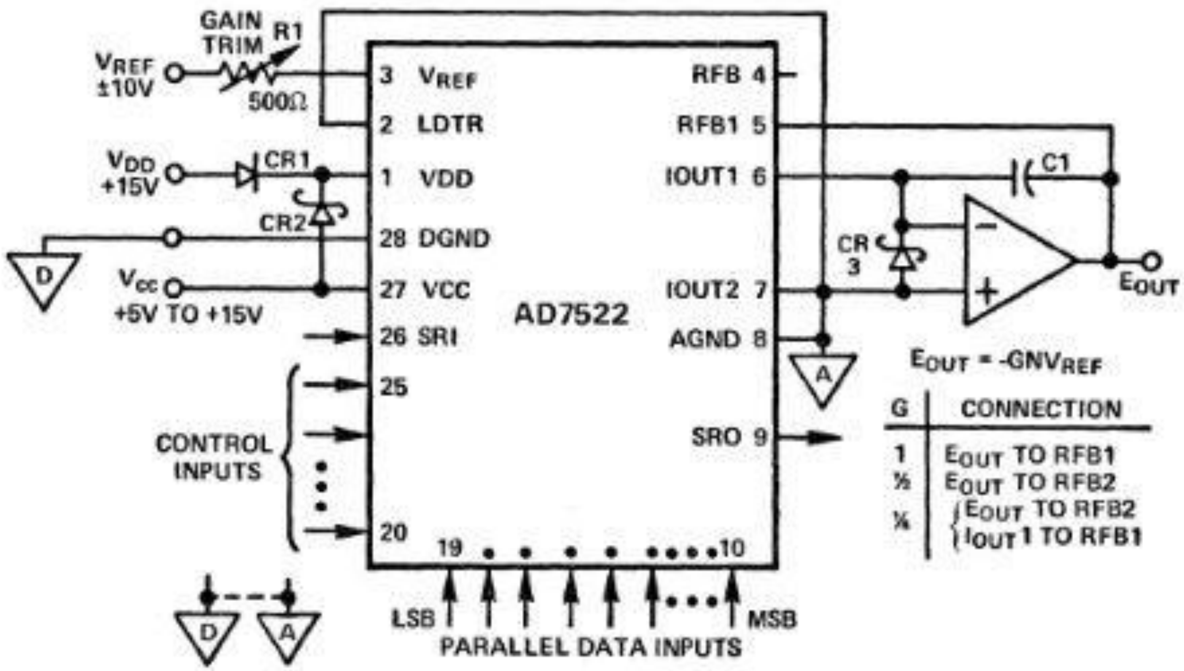


Figure 24. Connecting the AD7522 for unipolar D/A conversion. N is a fractional 10-bit binary number from 0 to $(1 - 2^{-10})$.

Interfacing DAC 0830 with 8086:

The DAC0830 Digital to Analog Converter is connected to 8086 microprocessor, as shown in the Fig. 14.118. Here, I/O port address is decoded using_ OR gate. The digital data is loaded into DAC0830 when A_0-A_7 lines, WR and IO/M signals are low. This gives us the address for DAC0830 as 00H and the data can be loaded in the DAC0830 by OUT 00H,AL instruction, where AL register contains the digital data to be sent to DAC0830. The IC 741, the operational amplifier is used to convert current output of DAC0830 to voltage output. The voltage output of the operational amplifier is used to drive the DC motor after increasing the driving capacity. The driving capacity is increased by using the darlington transistor.

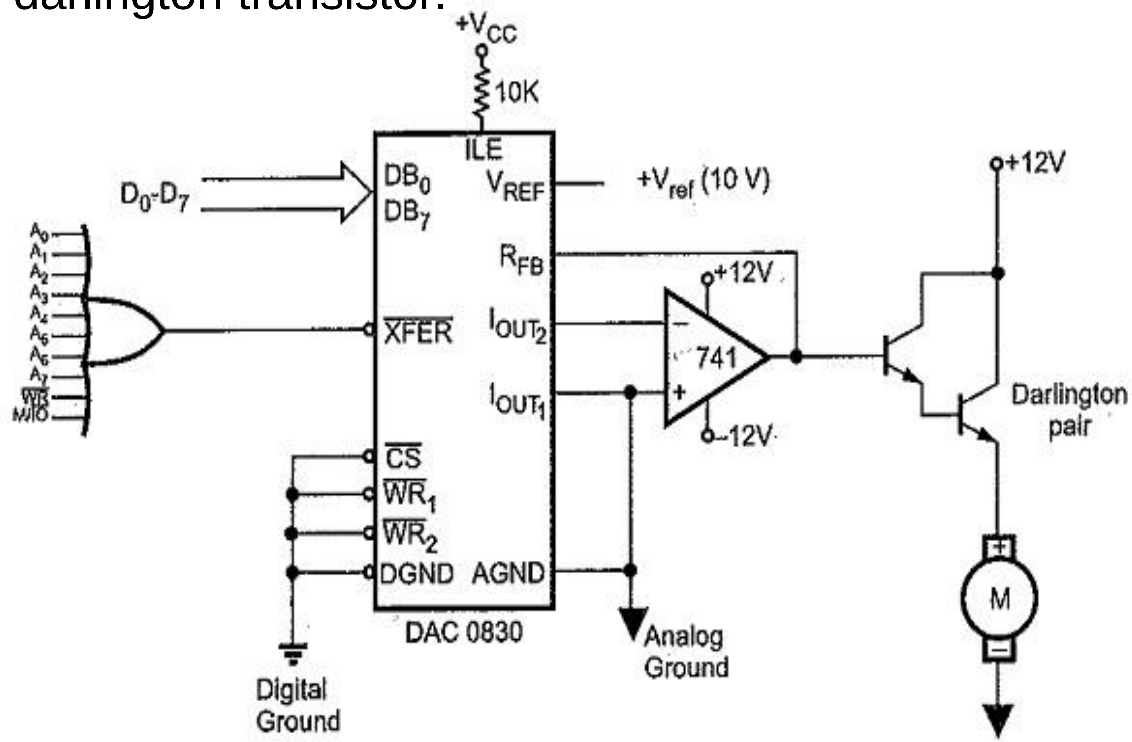


Fig. 14.118 Interfacing DAC0830 to 8086 Microprocessor