Embedded Systems

Part 7: Analog Interfacing

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Analog Input/Output Interfacing

Digital to Analog Conversion (DAC):

- DAC is a circuit whose analog output depends on its digital input, and an associated reference voltage.
- The digital input may be presented in parallel or serial form.
- The output voltage (Vo) is given by:

$$V_o = \left(\frac{D}{2^n}\right)Vr$$

where D is n-bit digital input, Vr is the reference voltage.

- The resolution of the DAC is:

$$resolution = \left(\frac{1}{2^n}\right)Vr$$

- Resolution is quoted in three ways:
  - as a number of bits (8-bit resolution).
  - as a percentage (0.4% resolution).
  - as a voltage (resolution of 20 mV).

DAC Design:

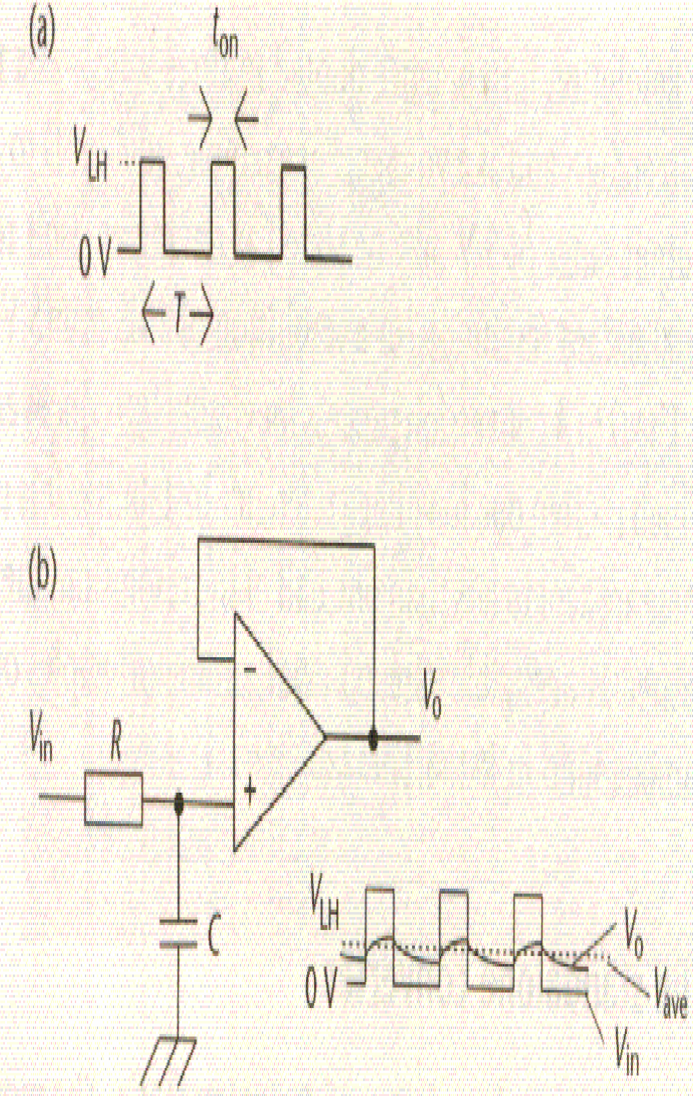
There are a number of ways of designing DACs.

The R-2R ladder DAC: The most common uses the R-2R ladder. This gives a fast response and good accuracy.

Pulse Width Modulation (PWM):

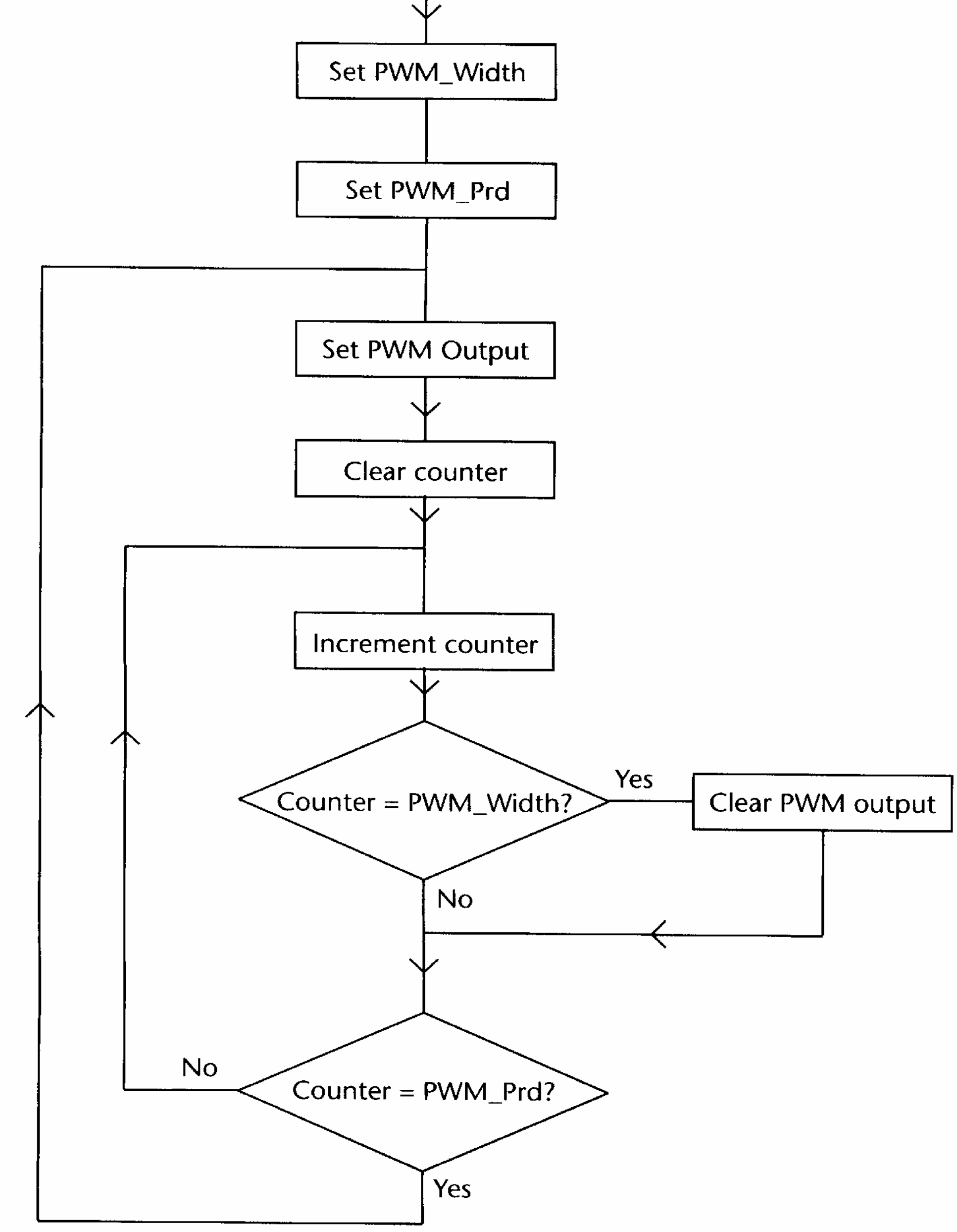
- It is possible to achieve DAC direct from a microcontroller digital output using PWM technique.
- PWM provides a means of controlling analog voltages and currents with a digital waveform, as shown bellow.
- The output voltage (Vo) is the average value which is given by:

$$V_o = \left(\frac{t_{ON}}{T}\right) V_{LH}$$



Generating PWM Signals in Software:

- A PWM signal can be generated in software as illustrated in this flowchart.
- Two memory locations PWM_Width and PWM_Prd are preset with numbers proportional to the PWM width and period.



Generating PWM Signals in Hardware:

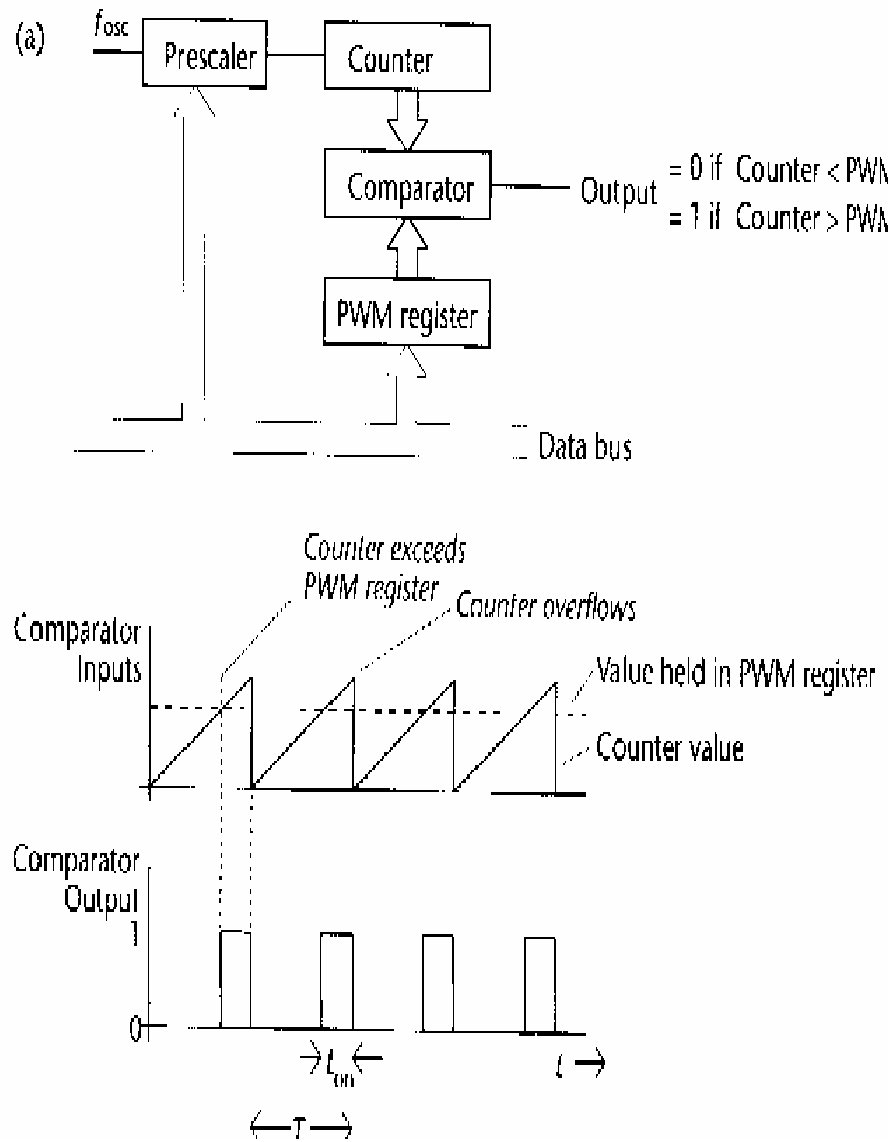
- A PWM signal can be generated in hardware by simple enhancements to the Counter/Timer structure as shown in this figure.
- The period of the PWM signal is given by:

$$T = 2^{n(PSC)} 2^{n(CNTR)} / f_{OSC}$$

- The PWM period can only be set to binary multiples of the oscillator clock frequency.
- The ON time is given by:

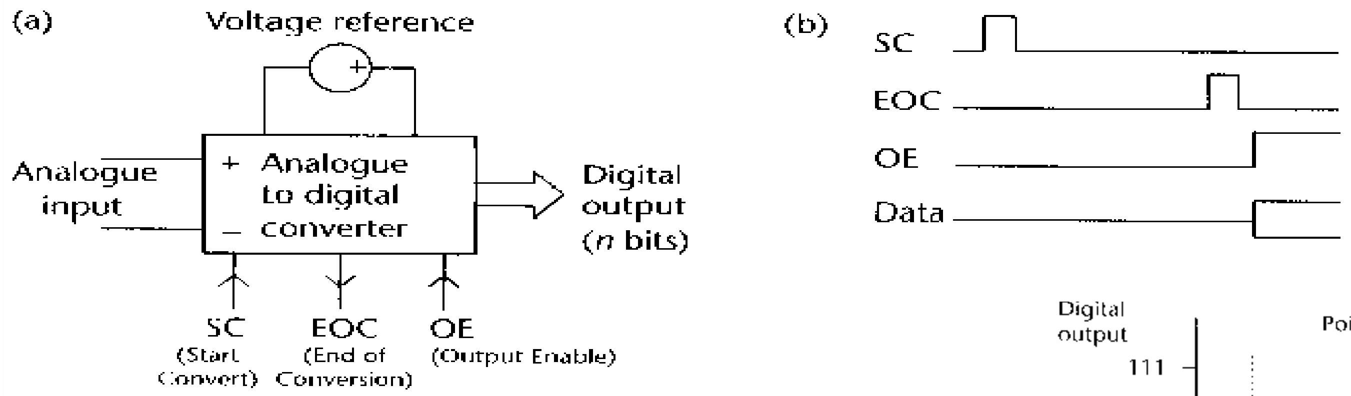
$$t_{ON} = \left[2^{n(CNTR)} - PWMR\right] 2^{n(PSC)} / f_{OSC}$$

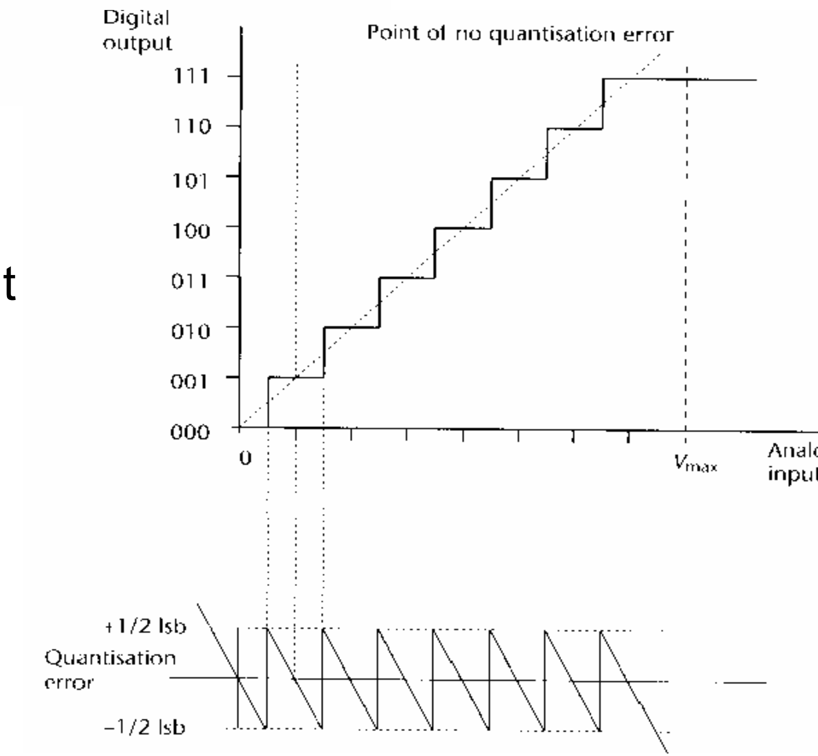
Where PWMR represents the contents of the PWM register.



Analog to Digital Conversion (ADC):

- An ADC is an electronic circuit whose digital output is proportional to its analog input.
- Due to the huge range of applications, many types of ADCs have been developed, with characteristics optimized for these differing applications.





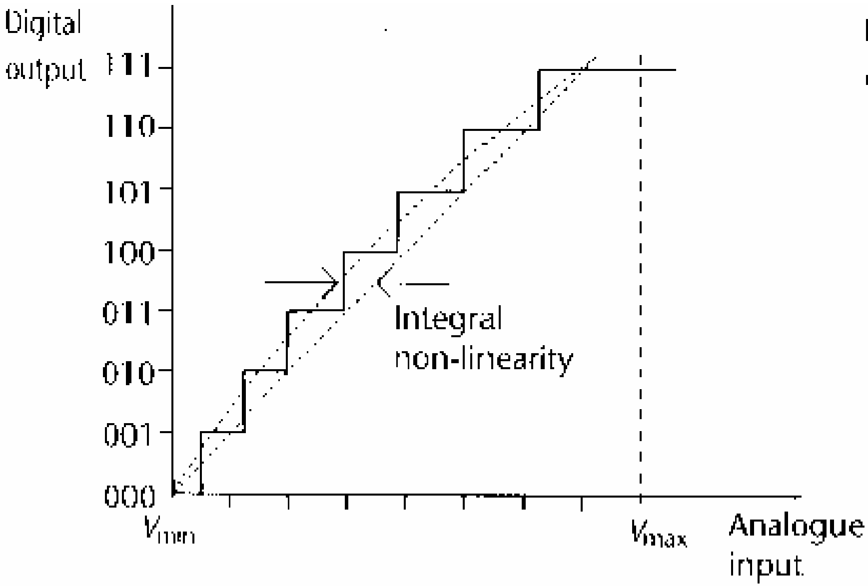
ADC Specifications:

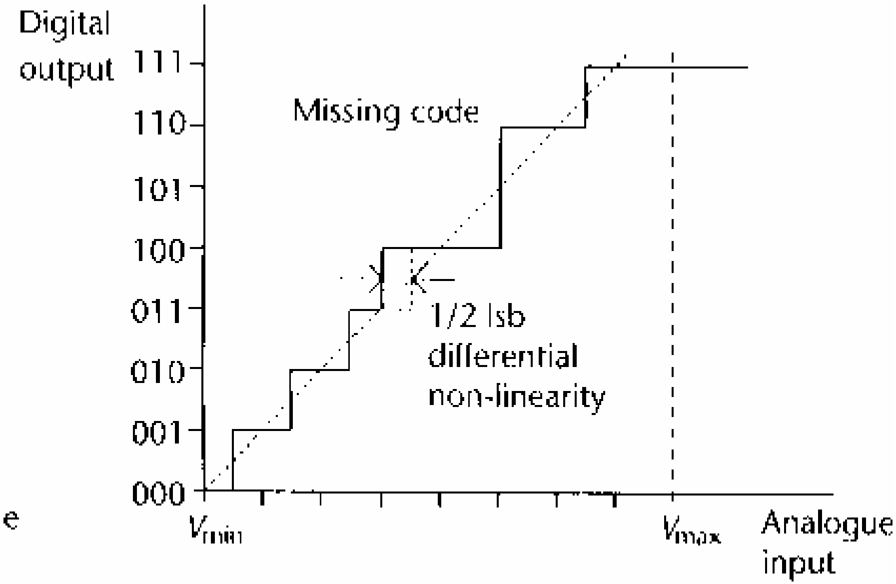
Resolution: The ADC resolution is the amount by which the input can change without a change in output.

Quantization Error: is a function of the input range and the number of bits output.

$$\max e_q = \left(\frac{V_{\max}}{2^{n+1}}\right) = \frac{resolution}{2}$$

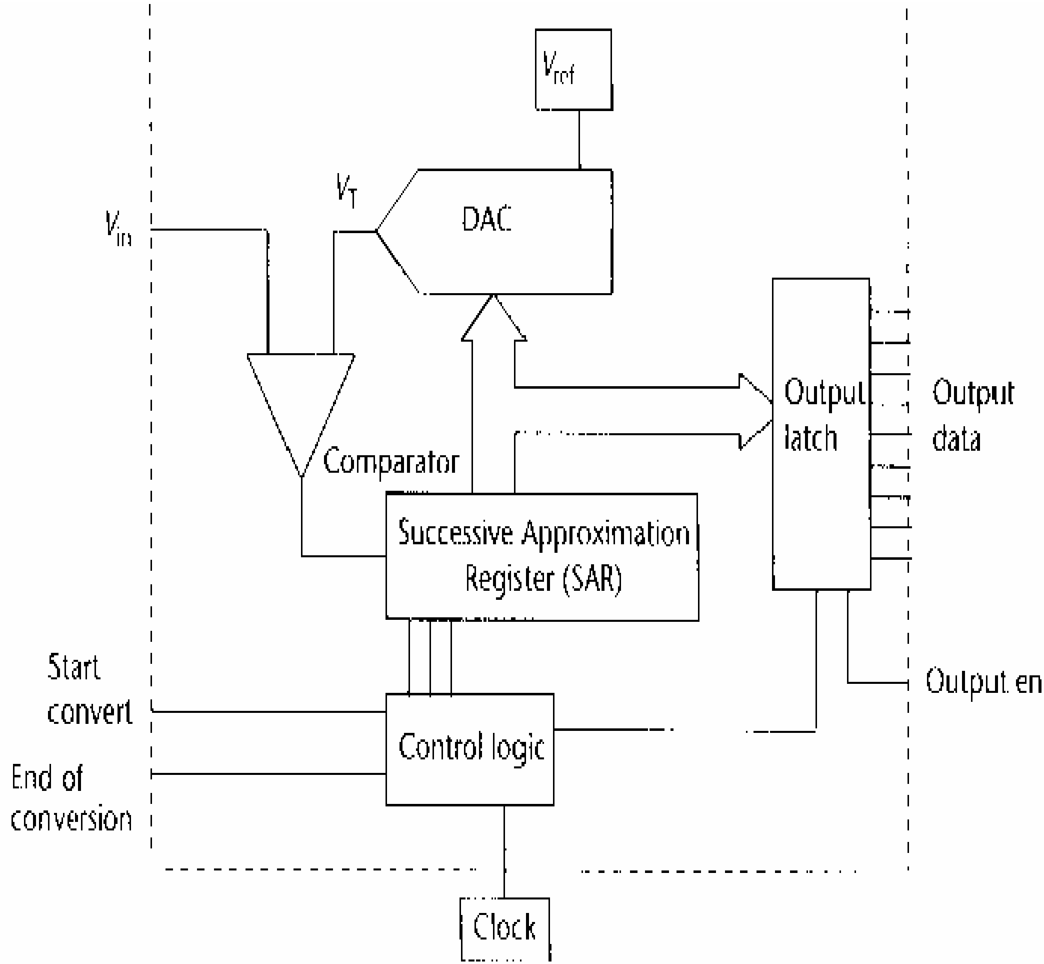
- **Linearity error:** errors due to inaccuracies introduced by the conversion.
  - Integer linearity error: the max deviation of the transfer function from the ideal straight line.
  - Differential linearity error: the deviation of any quantum from its ideal.

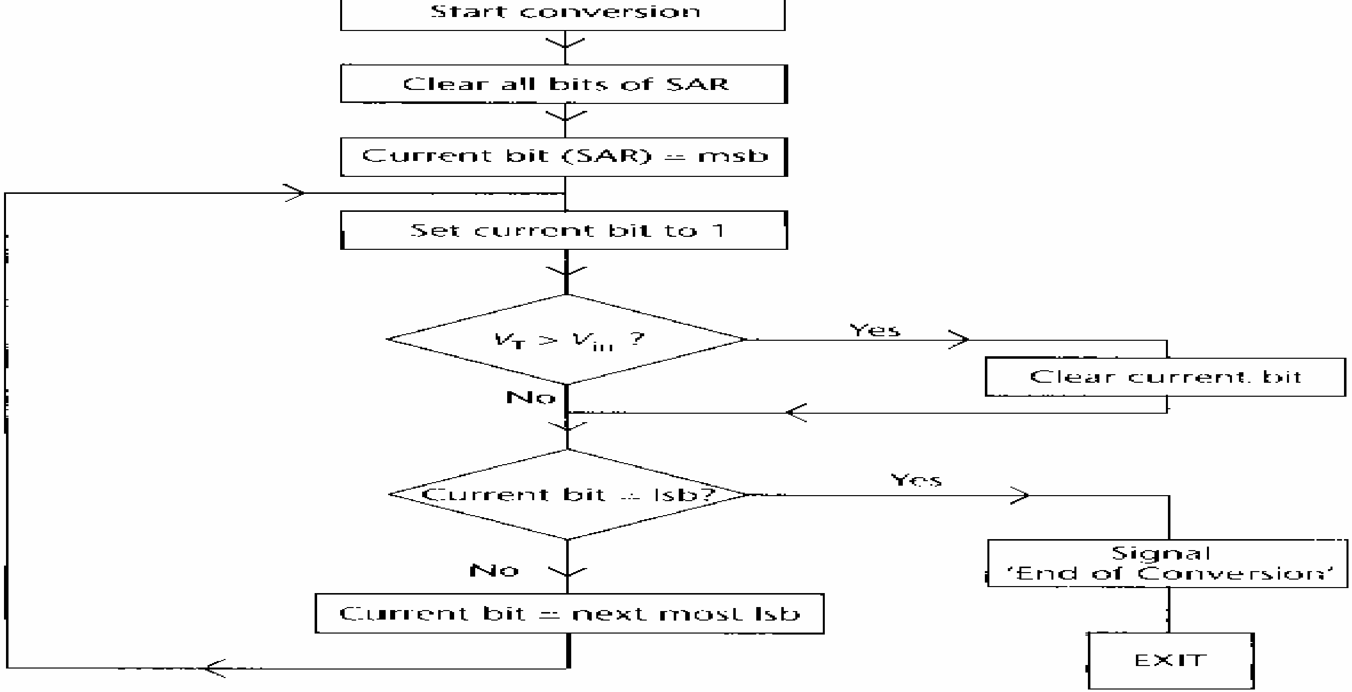




The Successive Approximation ADC:

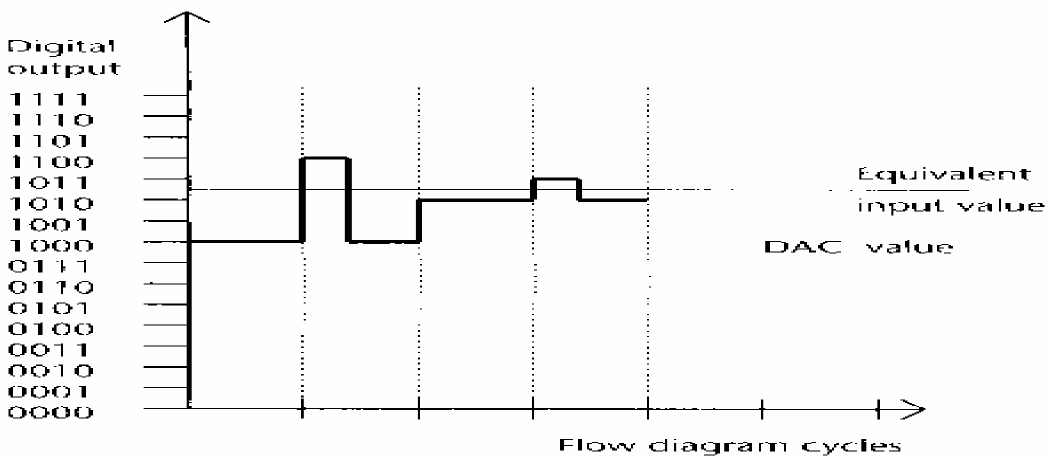
- This type of ADC is very commonly found in microcontroller systems, and its conversion times typically down to a few microseconds
- The accuracy of the system depends on a number of its components (DAC & Comparator).





SAR: Successive Approximation Register

Flow diagram of the successive approximation ADC.



Four-bit successive approximation ADC.

Selecting an ADC:

Check the following characteristics:

- Accuracy & resolution.
- Number of input channels.
- Input voltage range.
- Conversion time.
- Temperature stability.
- Cost.

Data Acquisition System (DAS):