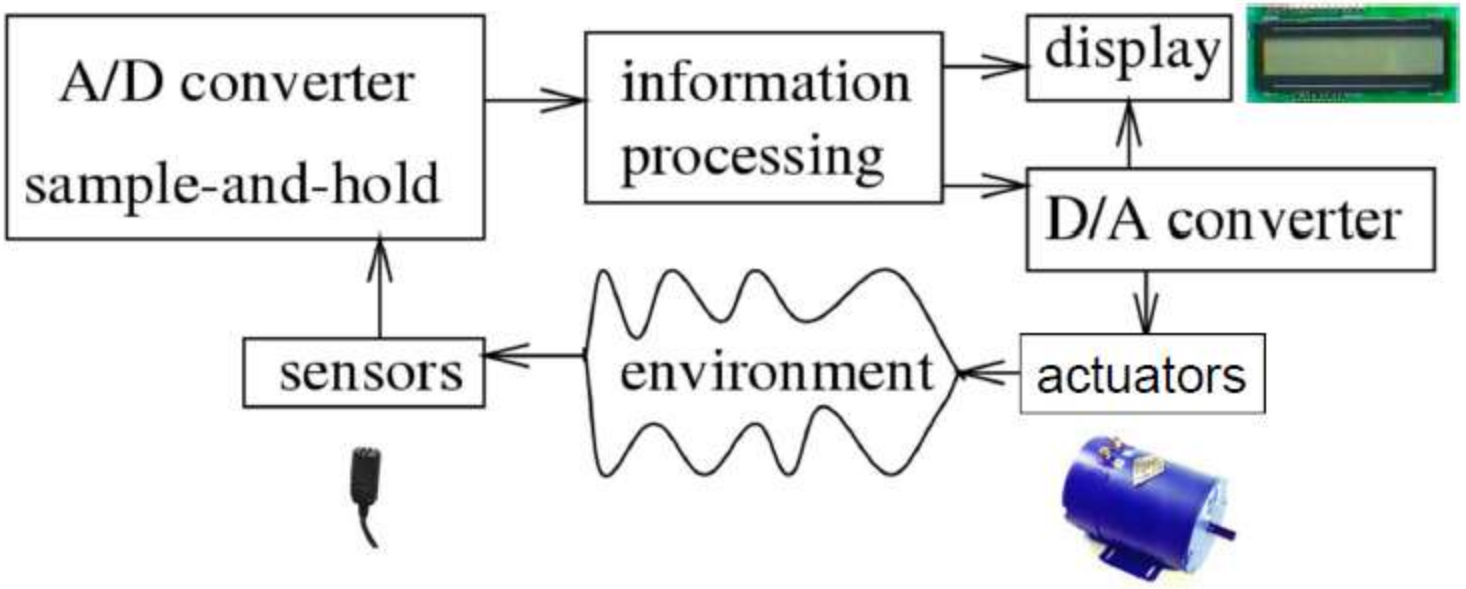
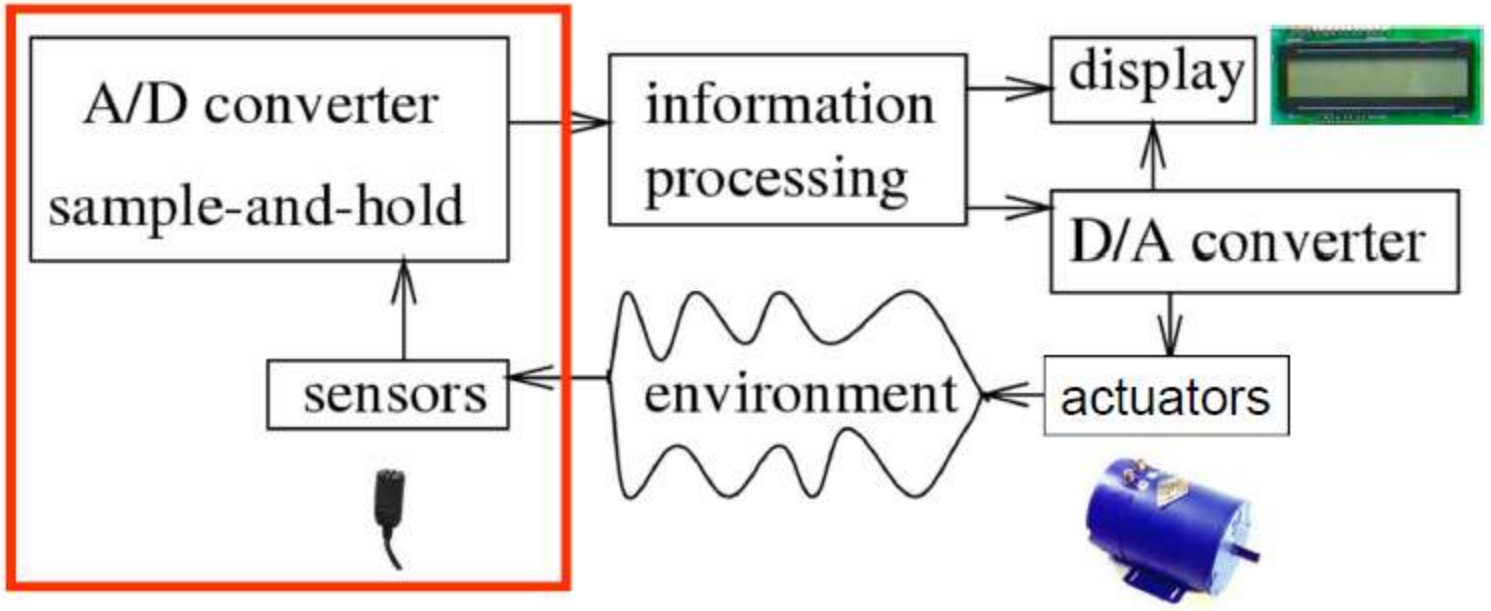
Embedded System Hardware

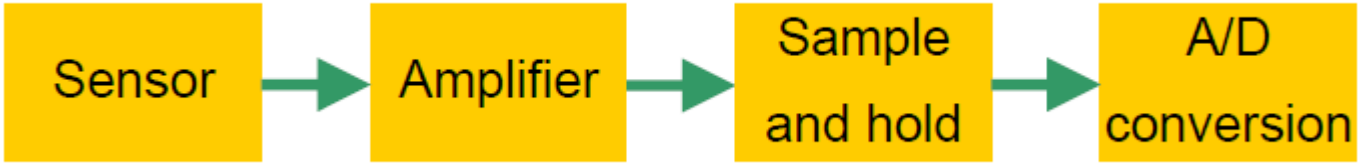
- Embedded system hardware is frequently used in a loop



Sensors

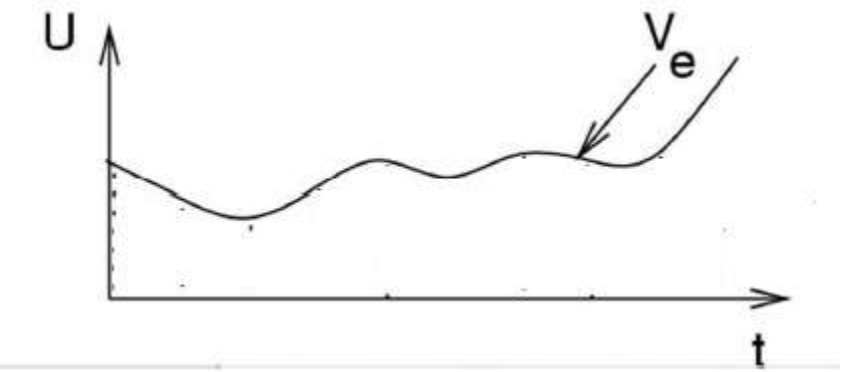

A/D converter
sample-and-hold
information processing
display
D/A converter
sensors
environment
actuators

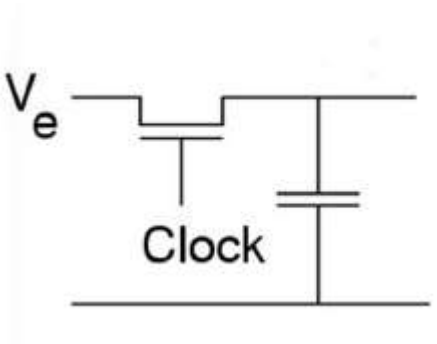
- Processing of physical data starts with capturing this data.
- Sensors can be designed for virtually every physical and chemical quantity:
  - including weight, velocity, acceleration, electrical current, voltage, temperatures etc.
  - chemical compounds.

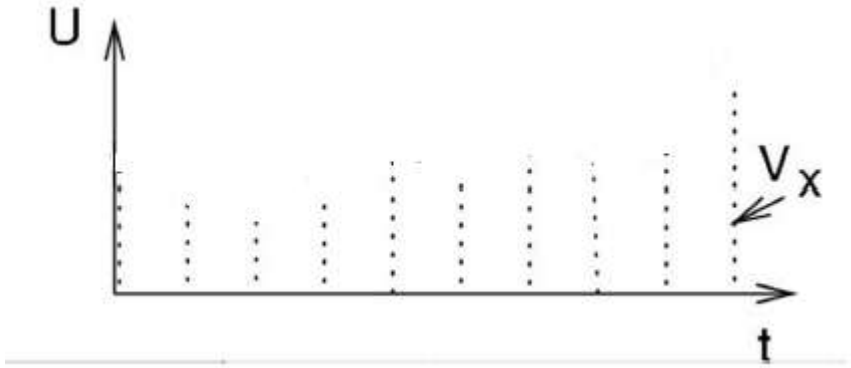


- Sensor: detects/measures entity and converts it to electrical domain
- Amplifier: adjusts signal to the dynamic range of the A/D Conversion
- Sample + hold: samples signal at discrete time instants
- A/D conversion: converts samples to digital domain

Discretization of time







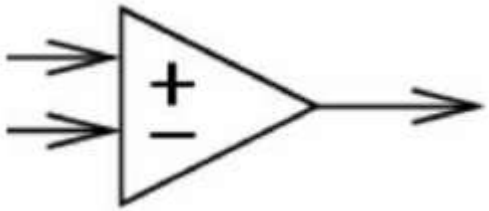
A/D-converters

- **Flash A/D converter:**

❑Basic element: analog comparator:

❖Output = ´1´ if voltage at input + exceeds that at input “- “ .

❖ Output = ´0´ if voltage at input - exceeds that at input “ + “.

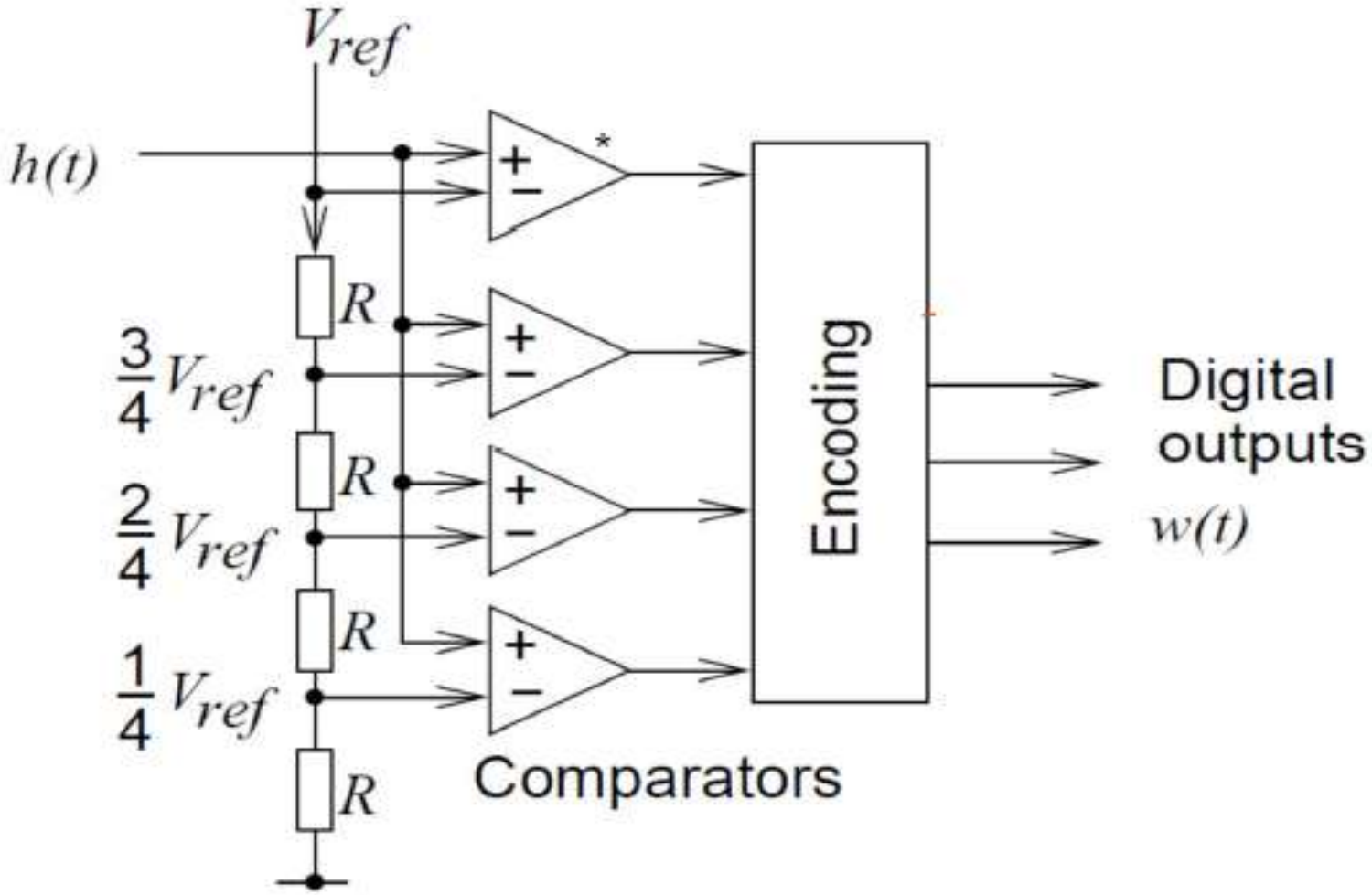


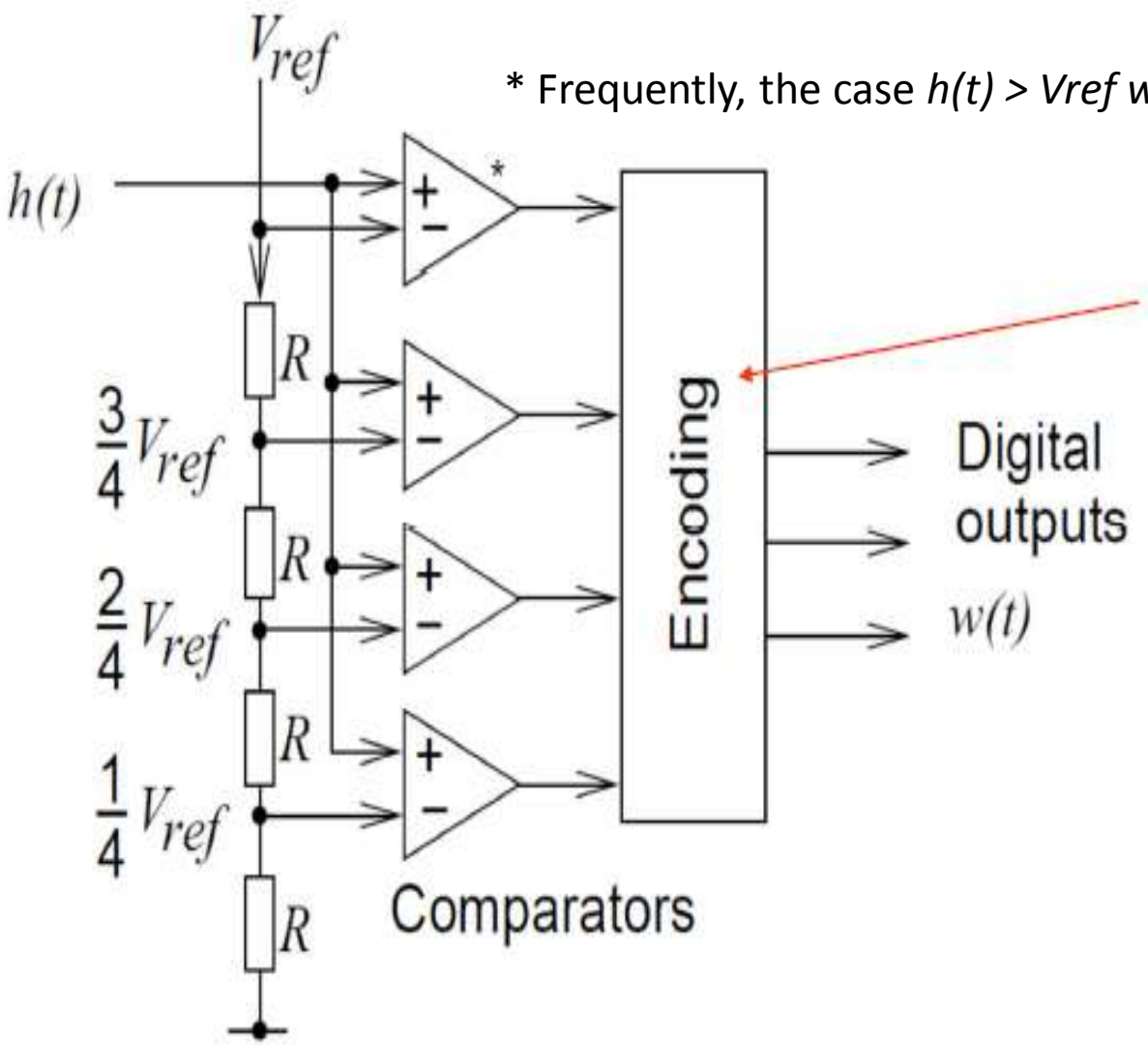
- Generate *n different voltages by voltage divider (resistors),*

e.g. Vref, ¾ Vref, ½ Vref, ¼ Vref.

- Use *n comparators for parallel comparison of input voltage Vx to these* voltages.
- Encoder to compute digital output.

Flash A/D converter

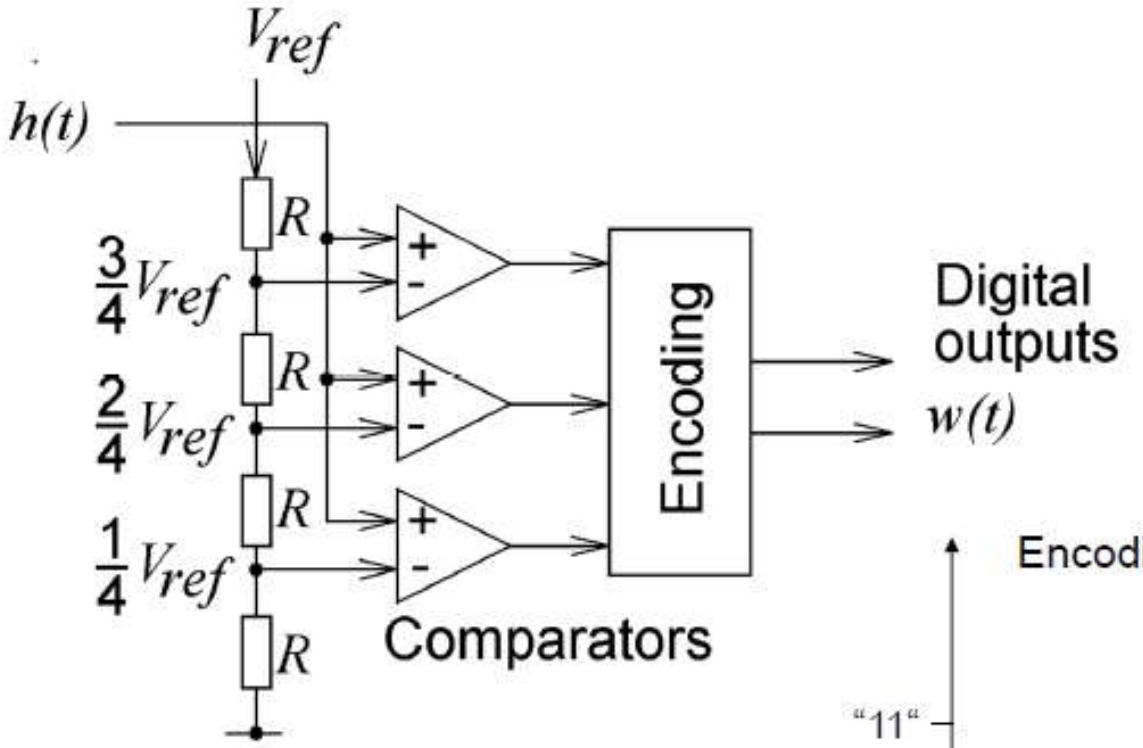


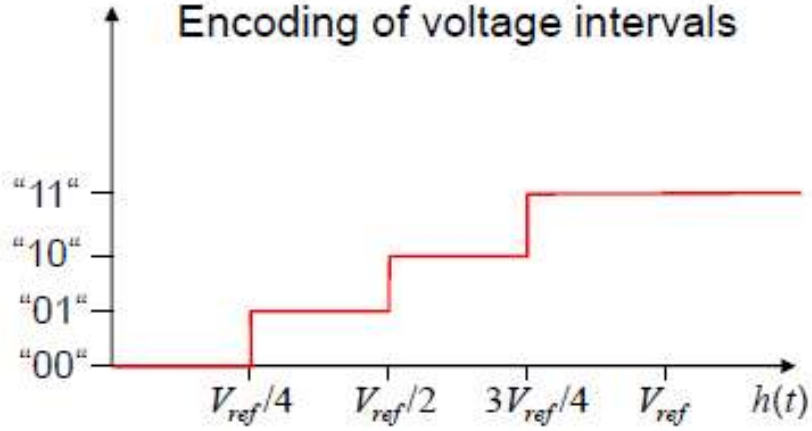


* Frequently, the case *h(t) > Vref would not be decoded*

- Encodes input number of most significant '1' as an unsigned number, e.g. "1111" -> "100", "0111" -> "011", "0011" -> "010", "0001" -> "001", "0000" -> "000" (Priority encoder).

Assuming $0 \le h(t) \le Vref$





Resolution and speed of Flash A/D-converter

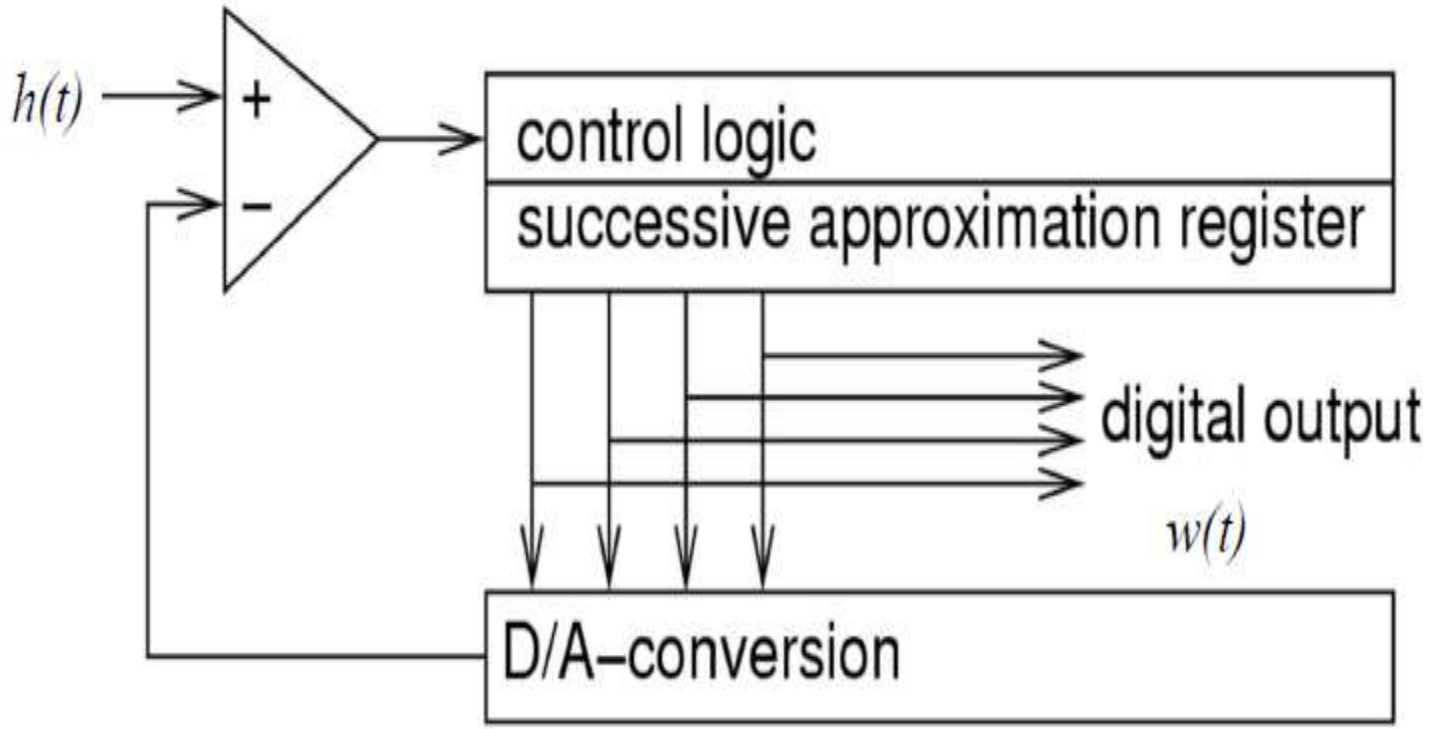
- Resolution (in bits): number of bits produced
- Resolution *Q (in volts): difference between two input voltages* causing the output to be incremented by 1

$$Q = \frac{V_{FSR}}{n}$$

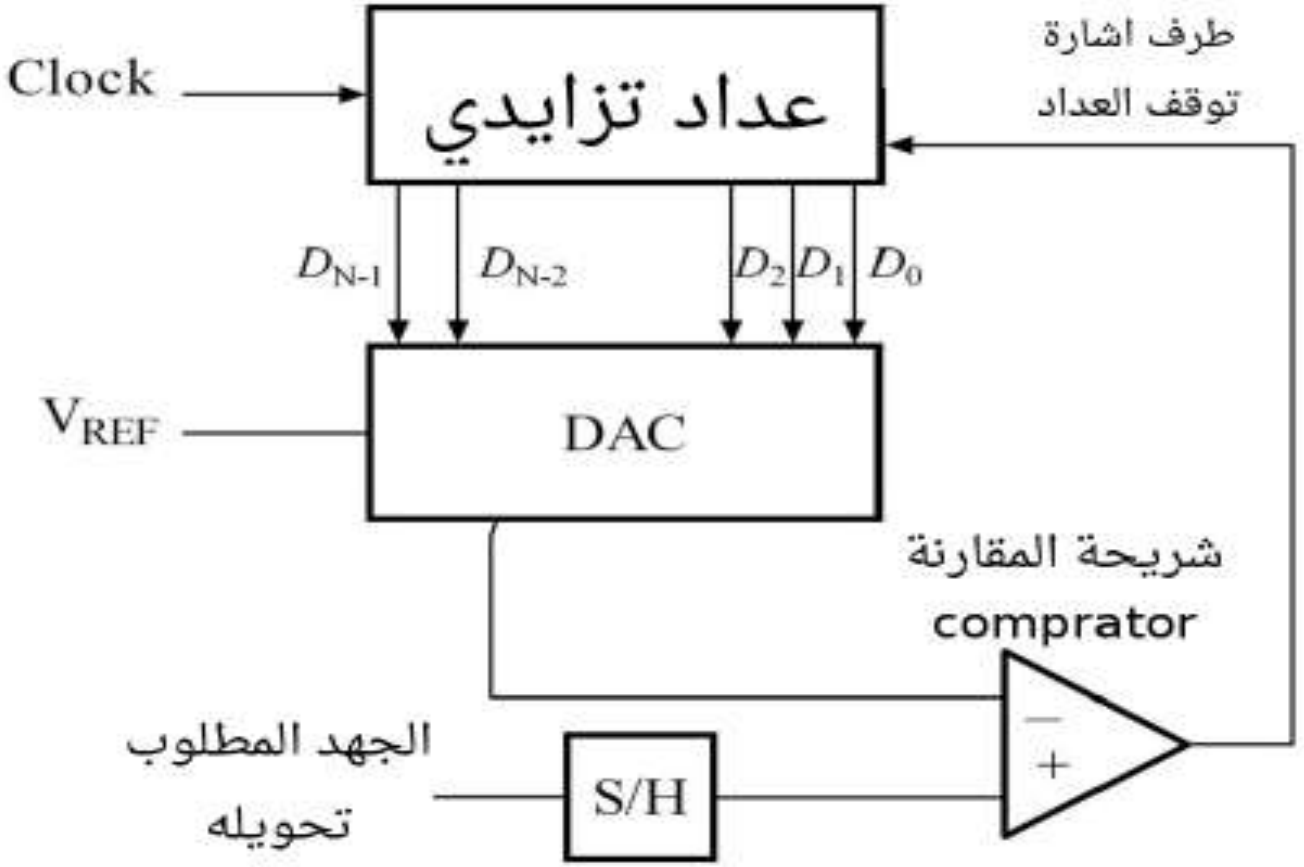
- *Q: resolution in volts per step*
- *VFSR: difference between largest* and smallest voltage
- *n: number of voltage interva*

- Example:
- *Q = Vref /4 for the*
- previous slide

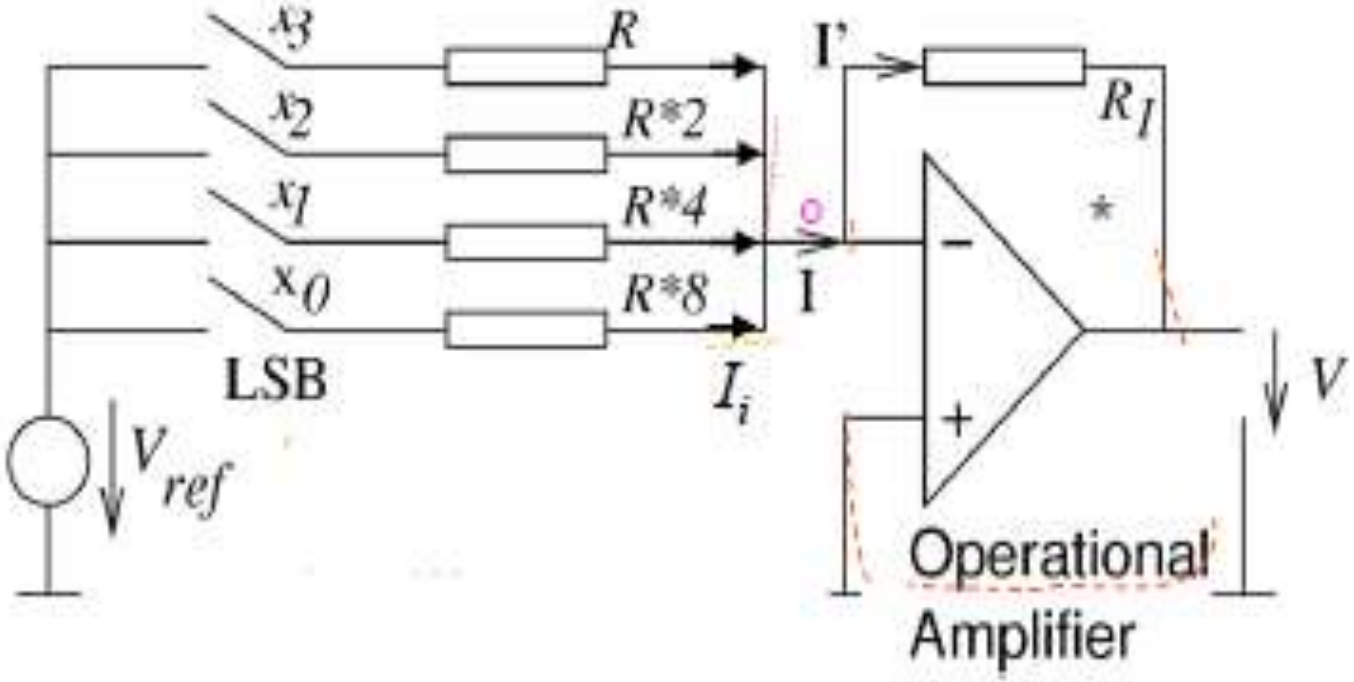
Higher resolution:



Higher resolution:

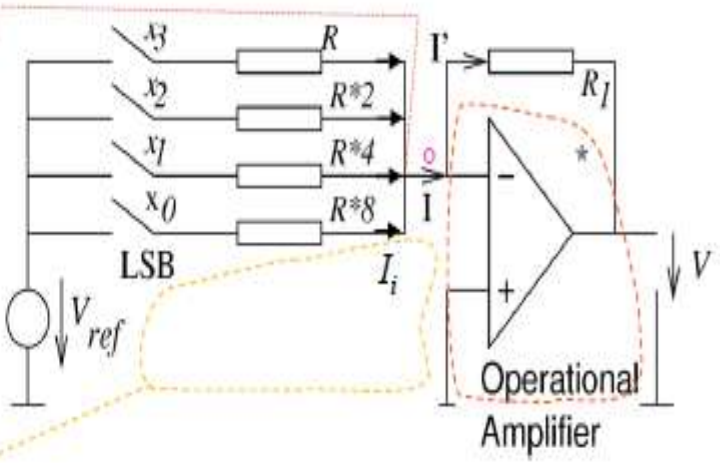


Digital-to-Analog (D/A) Converters

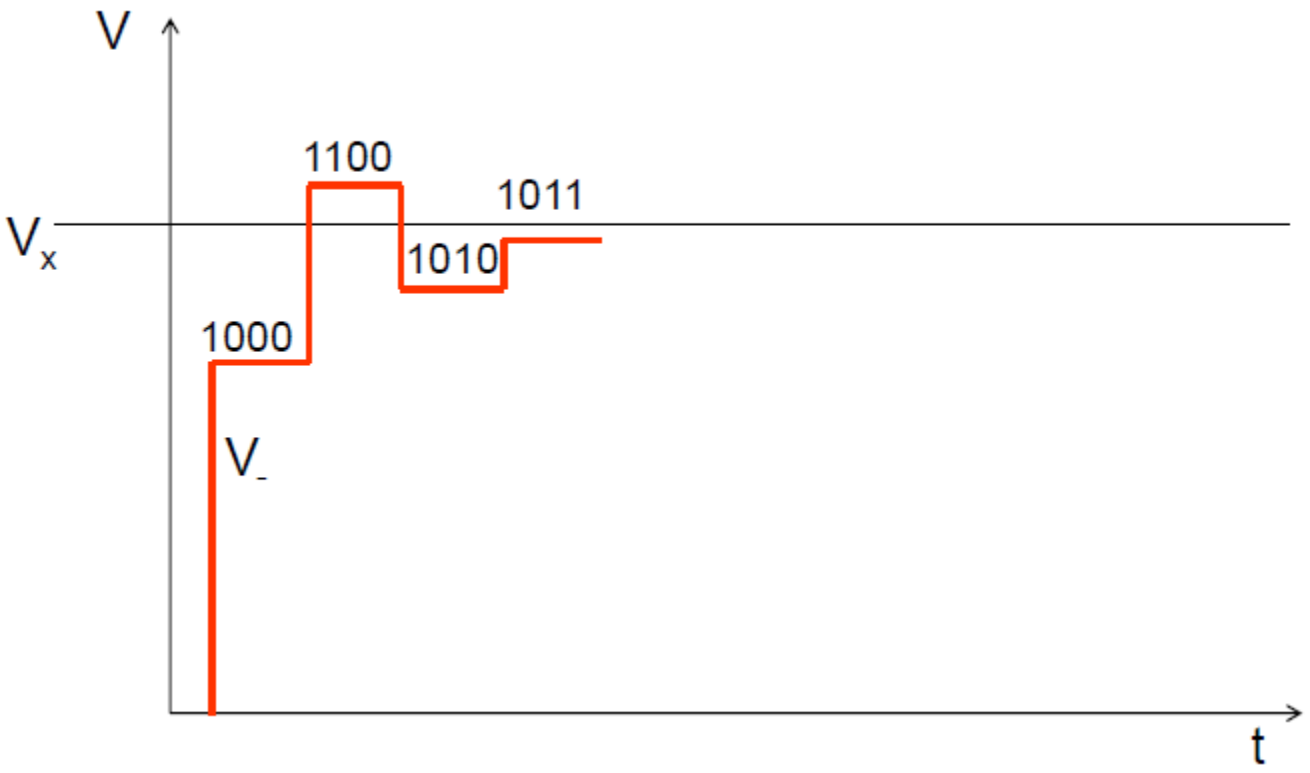


Junction rule: $I = \sum_i I_i$

Loop rule: $I_i = x_i \times \frac{V_{ref}}{2^{3-i} \times R}$



$$I = x_3 \times \frac{V_{ref}}{R} + x_2 \times \frac{V_{ref}}{2 \times R} + x_1 \times \frac{V_{ref}}{4 \times R} + x_0 \times \frac{V_{ref}}{8 \times R} = \frac{V_{ref}}{8 \times R} \times \sum_{i=0}^{3} x_i \times 2^i$$


V
1100
1011
V_x
1010
1000
V_-
t