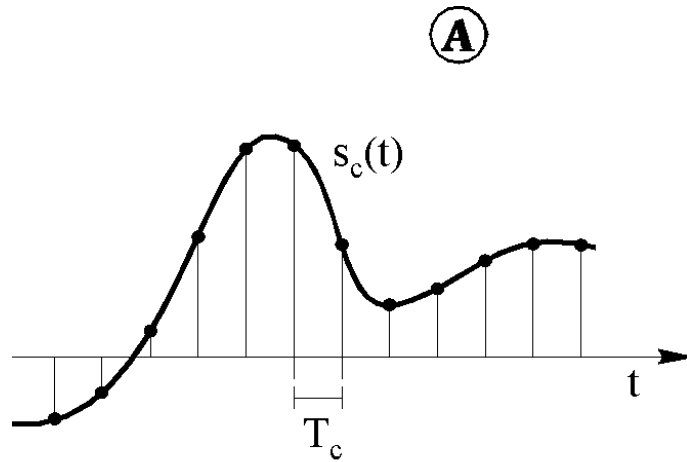


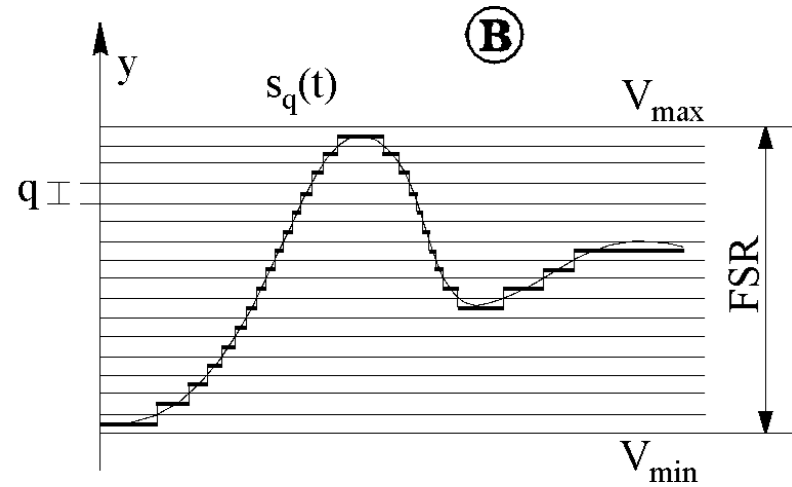
## Conversione *AD* e *DA*



## Campionamento e quantizzazione



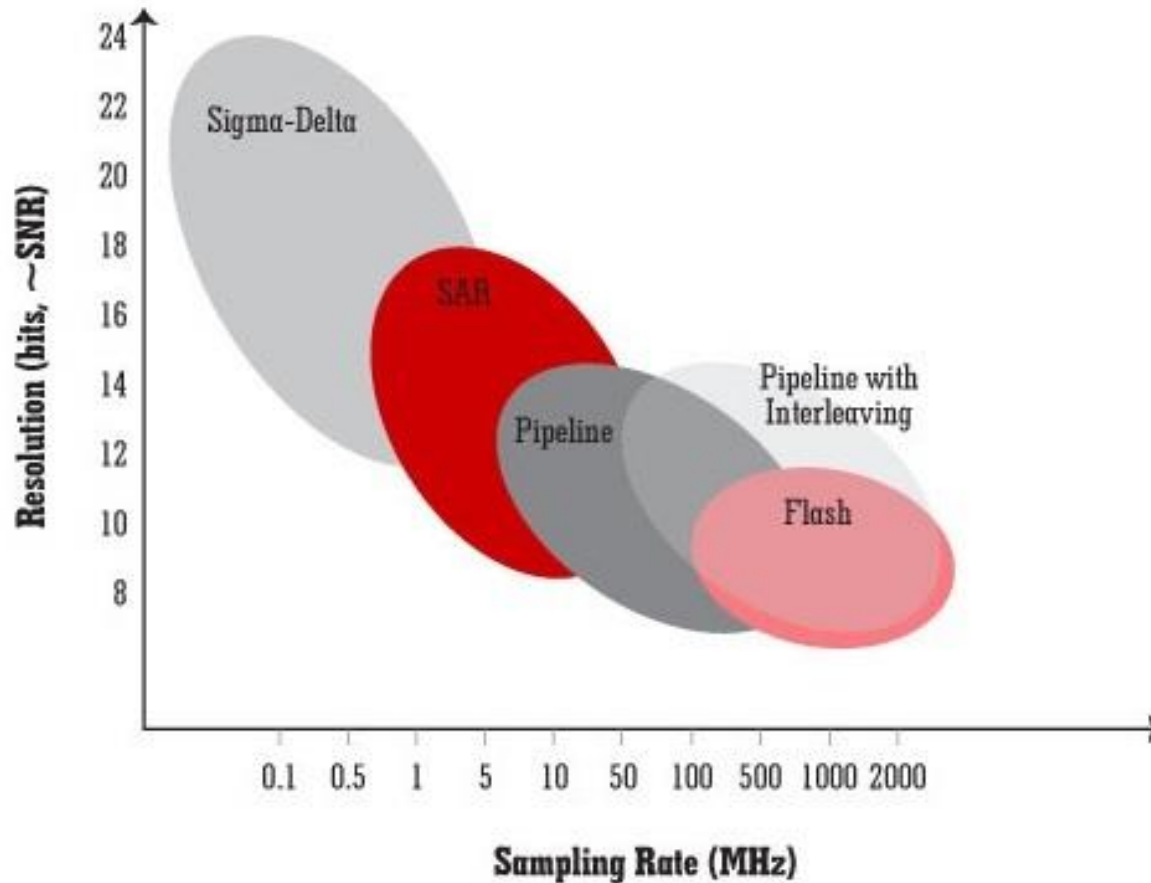
$$f_c = \frac{1}{T_c}$$



$$FSR = V_{\max} - V_{\min}$$

## Convertitori AD

**ADC Architecture  
vs Resolution and Sample Rate**



## Codifica in binario naturale

$B_{n-1} \dots B_i \dots B_1 B_0$  simboli binari : 0,1

$2^{n-1} \dots 2^i \dots 2^1 2^0$  pesi

0	1	2	3	4	5	6	7
000	001	010	011	100	101	110	111

$B_{n-1}$  = MSB (*Most Significant Bit*), associato al peso maggiore:  $2^{n-1}$   
 $B_0$  = LSB (*Least Significant Bit*), associato al peso minore:  $2^0$

$$A = \sum_{i=0}^{n-1} 2^i B_i$$

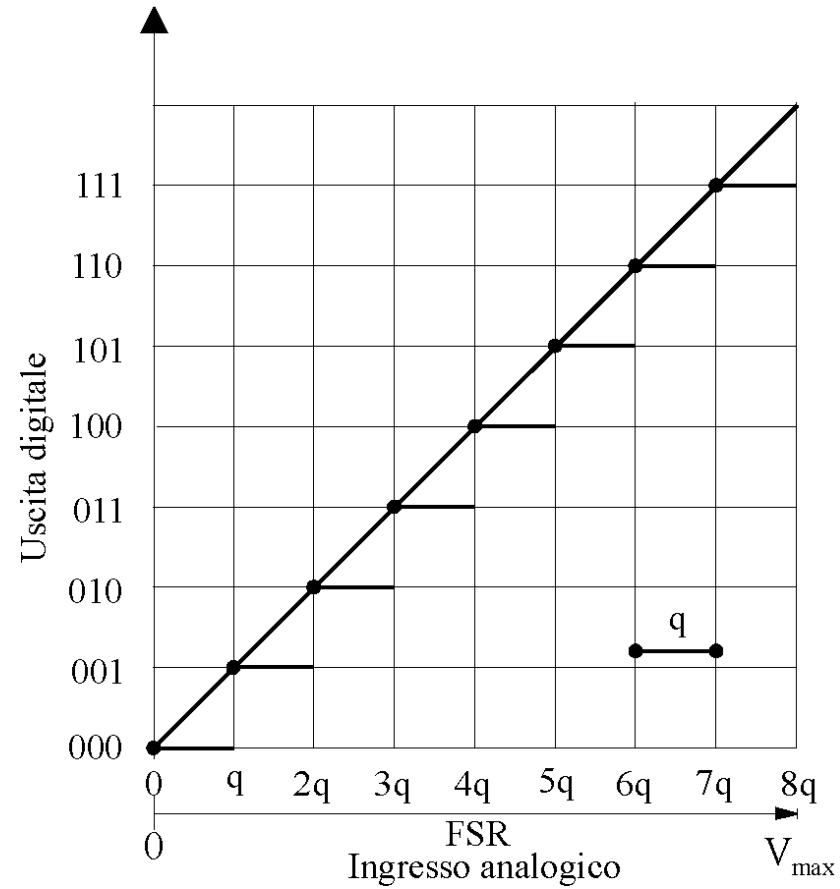
## Risoluzione dei convertitori

$$q = \frac{FSR}{2^n} \quad \text{quantità elementare}$$

Numero di bit	$n$	8	12	16
Numero di livelli	$2^n$	256	4096	65536
Risoluzione relativa	$1/2^n$	$3,9 \cdot 10^{-3}$	$2,4 \cdot 10^{-4}$	$1,5 \cdot 10^{-5}$

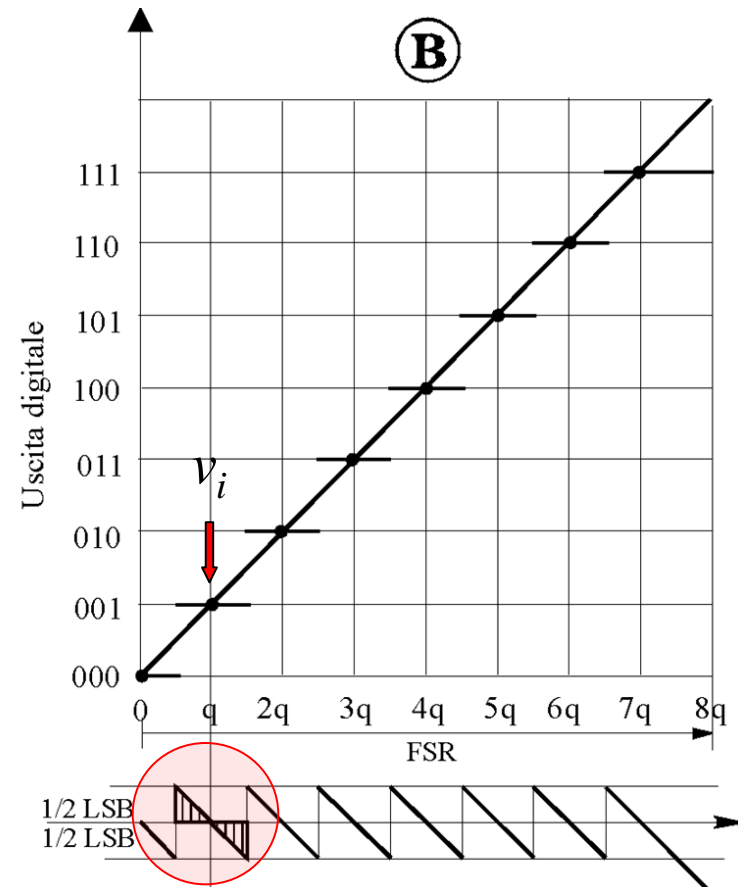
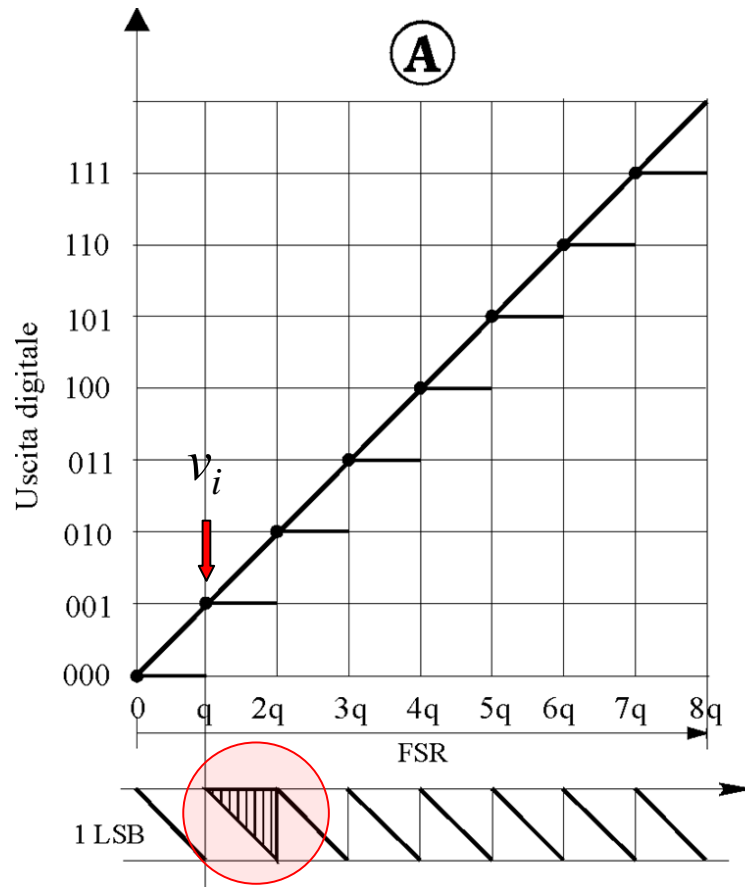
$$V = q \cdot A = q \cdot \sum_{i=0}^{n-1} 2^i B_i$$

## Diagrammi ingresso-uscita ideali (Segnali unipolari)

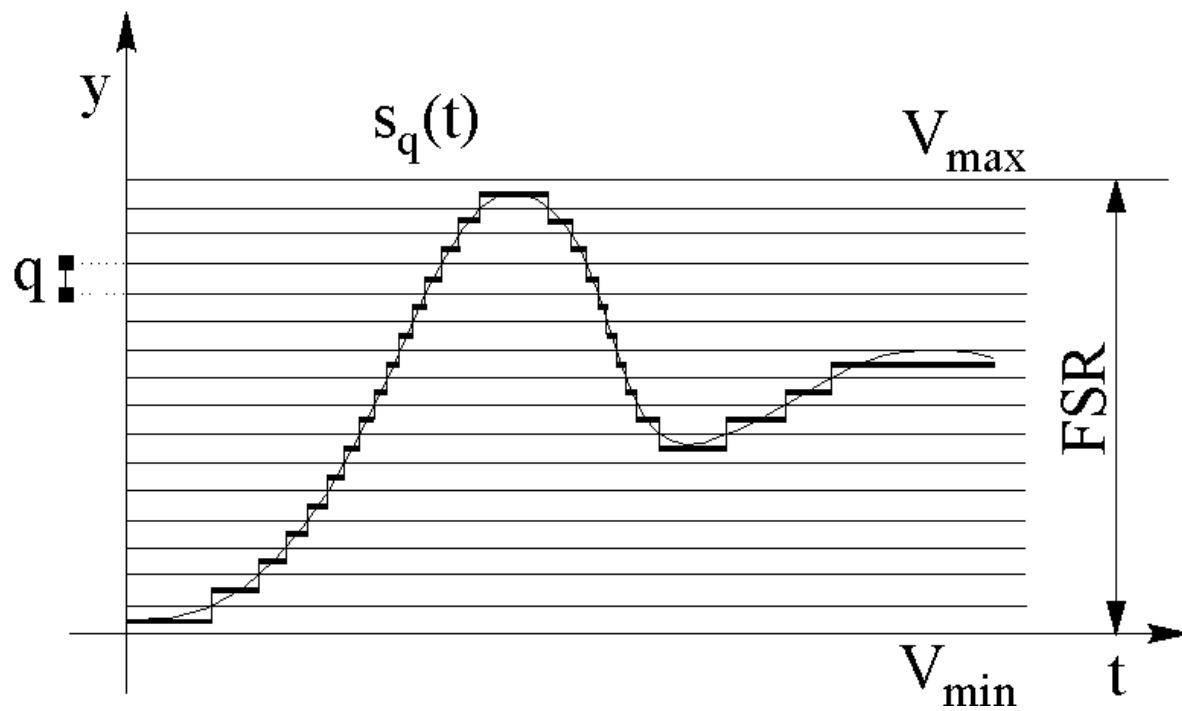


## Disturbo di quantizzazione

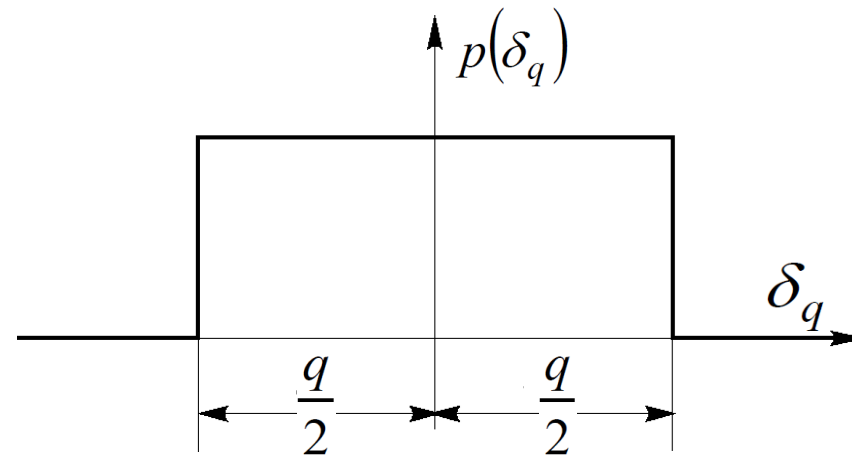
Due casi per il valore nominale dell'intervallo



## Il disturbo di quantizzazione come variabile aleatoria (Intervallo simmetrico $\pm q/2$ )



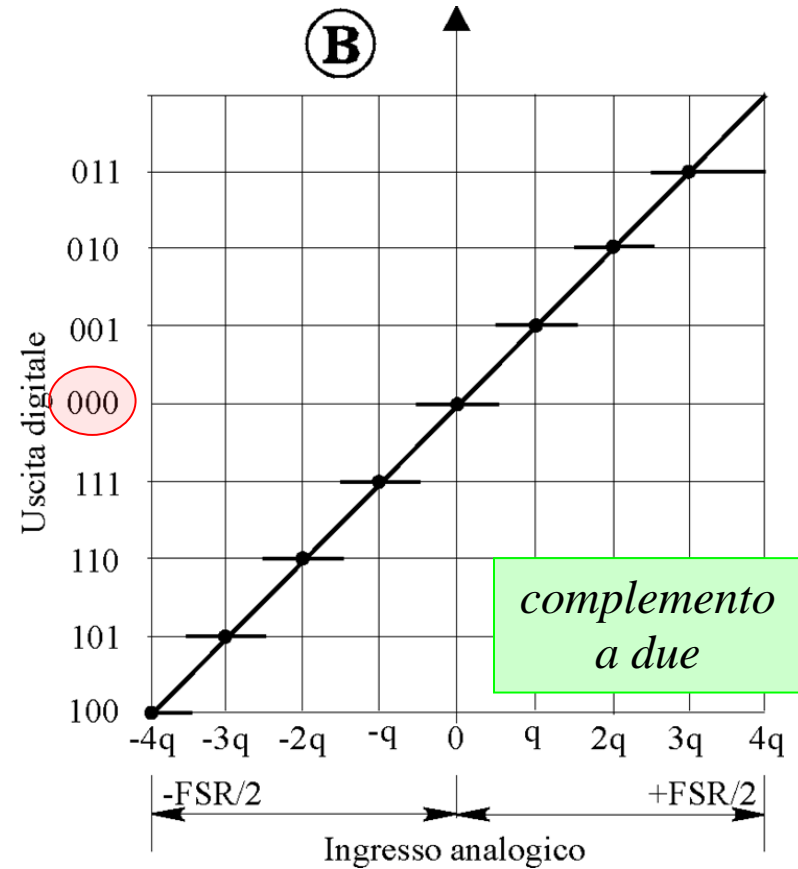
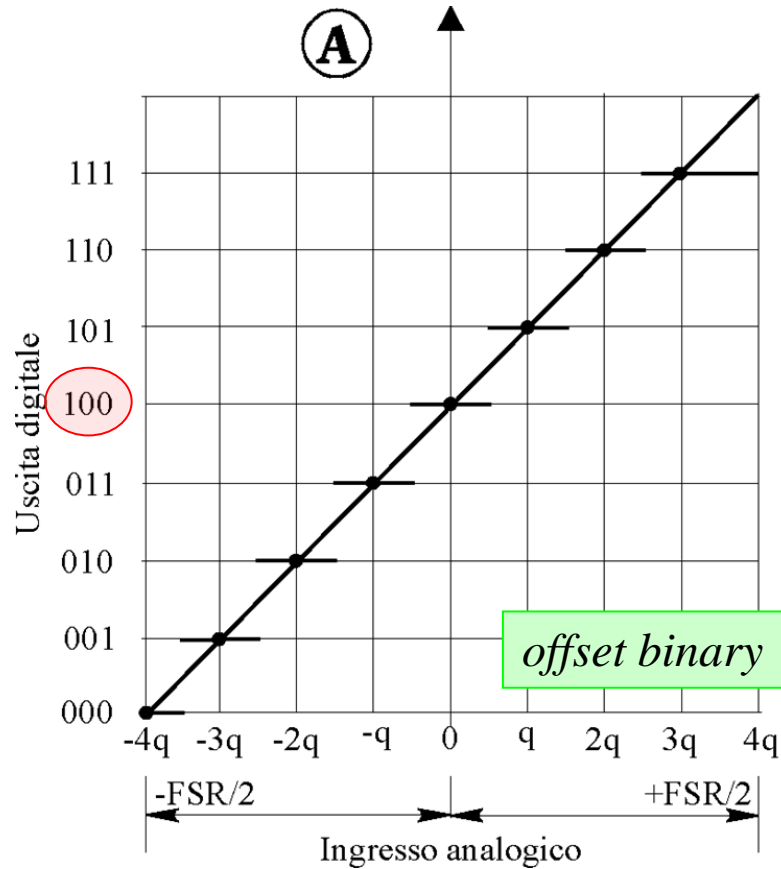
## Il disturbo di quantizzazione come variabile aleatoria (Intervallo simmetrico $\pm q/2$ )



$$p(\delta_q) = \begin{cases} \frac{1}{q} & \text{per } -\frac{q}{2} \leq \delta_q \leq \frac{q}{2} \\ 0 & \text{altrove} \end{cases}$$

$$\sigma_q^2 = \int_{-\infty}^{+\infty} (\delta_q - \mu_q)^2 \cdot p(\delta_q) d\delta_q =$$

## Codifica di segnali bipolari



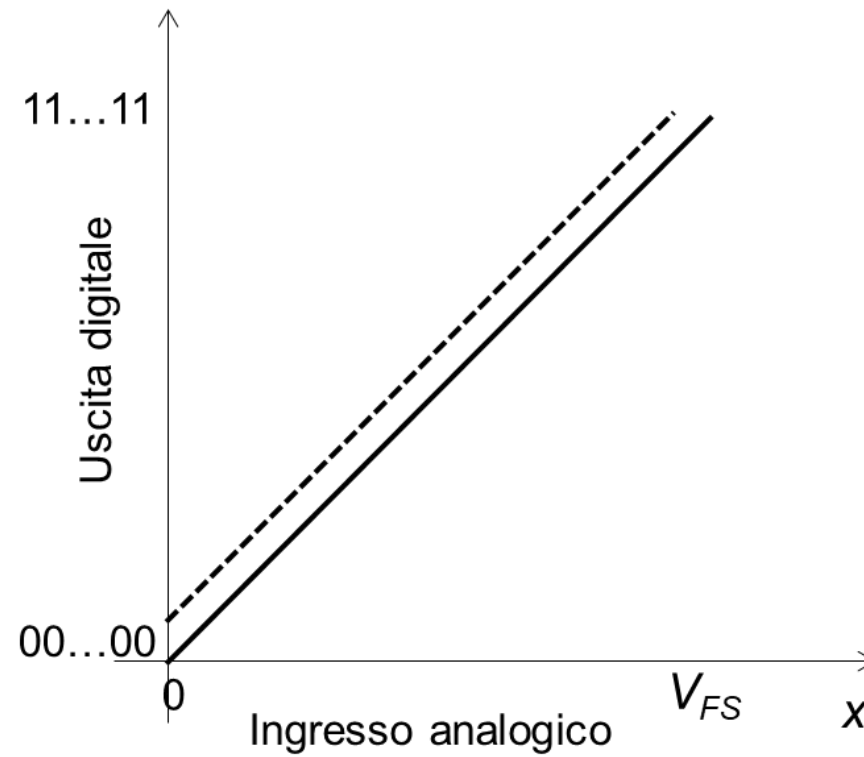
$$+3q \Rightarrow 011 \Rightarrow 0 \cdot 2^2 + 1 \cdot 2^1 + 1 \cdot 2^0 = 3$$

$$-3q \Rightarrow 101 \Rightarrow -1 \cdot 2^2 + 0 \cdot 2^1 + 1 \cdot 2^0 = -3$$

# Caratteristiche dei convertitori AD

## Parametri statici

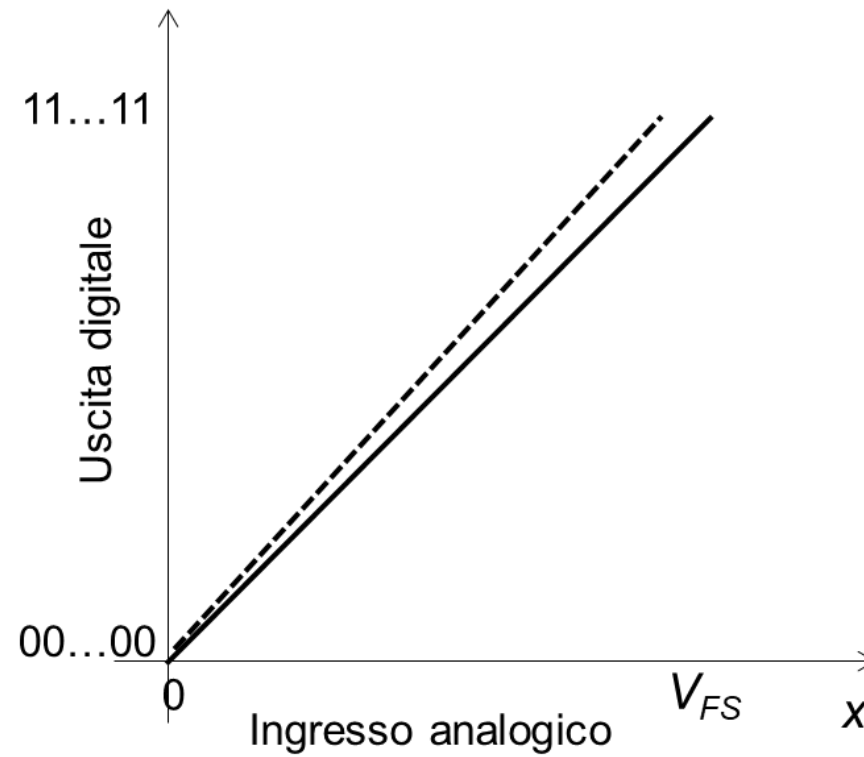
### *Offset*



# Caratteristiche dei convertitori AD

## Parametri statici

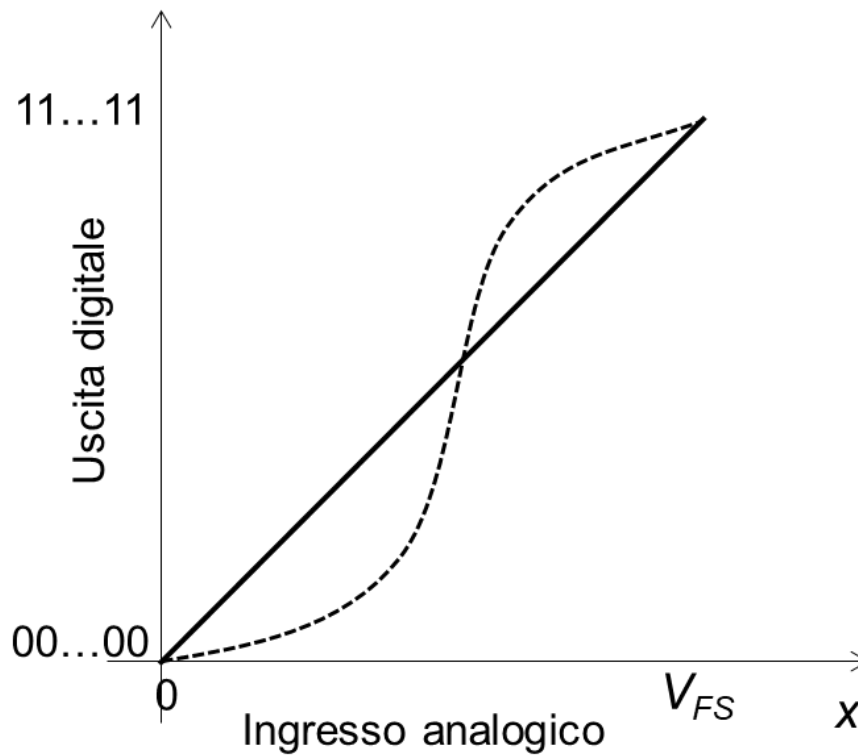
### *Gain error*



## Caratteristiche dei convertitori AD

### Parametri statici

#### Non linearità



**INL** - *Non linearità integrale*

$$INL = v_{ideale} - v_{reale}$$

**DNL** - *Non linearità differenziale*

$$DNL = q - (L_i - L_{i-1})$$

## **Caratteristiche dei convertitori AD e DA**

Alcuni parametri dinamici

*Signal to Noise Ratio (SNR)*

***Effective Number Of Bits (ENOB)***

*Signal to Noise And Distortion ratio (SINAD)*

*Spurious-Free Dynamic Range (SFDR)*

*Total Harmonic Distortion (THD)*

## Numero effettivo di bit

$$\sigma_q^2 = \frac{1}{12} q^2 = \frac{FSR^2}{12 \cdot 2^{2n}}$$



$$n = \frac{1}{2} \log_2 \left( \frac{FSR^2}{12 \cdot \sigma_q^2} \right)$$



$$EB = \frac{1}{2} \log_2 \left( \frac{FSR^2}{12 \cdot \sigma_c^2} \right) = \frac{1}{2} \log_2 \left( \frac{FSR^2}{12 \cdot \sigma_q^2} \cdot \frac{\sigma_q^2}{\sigma_c^2} \right) = n - \frac{1}{2} \log_2 \left( \frac{\sigma_c^2}{\sigma_q^2} \right)$$