DAC input/output

The digital input to a DAC is given in a binary representation

$$B = \langle b_1, b_2, b_3 \rangle = b_1 2^{-1} + b_2 2^{-2} + \ldots + b_N 2^{-N}$$

Minimum input change is 1 LSB = 2^{-N}

The converter translates this to an analog output as

$$V_{out} = B \cdot V_{ref}$$

where V_{ref} often is a constant voltage, but could be current or charge

Minimum output change is $V_{LSB} = 2^{-N} \cdot V_{ref}$

Ex: Converter with N = 3 bit, V_{ref} = 1.0 V $\Rightarrow$

$$V_{out} = \left(b_1 \frac{1}{2} + b_2 \frac{1}{4} + b_3 \frac{1}{8} \right) \cdot 1.0 \text{ V}$$

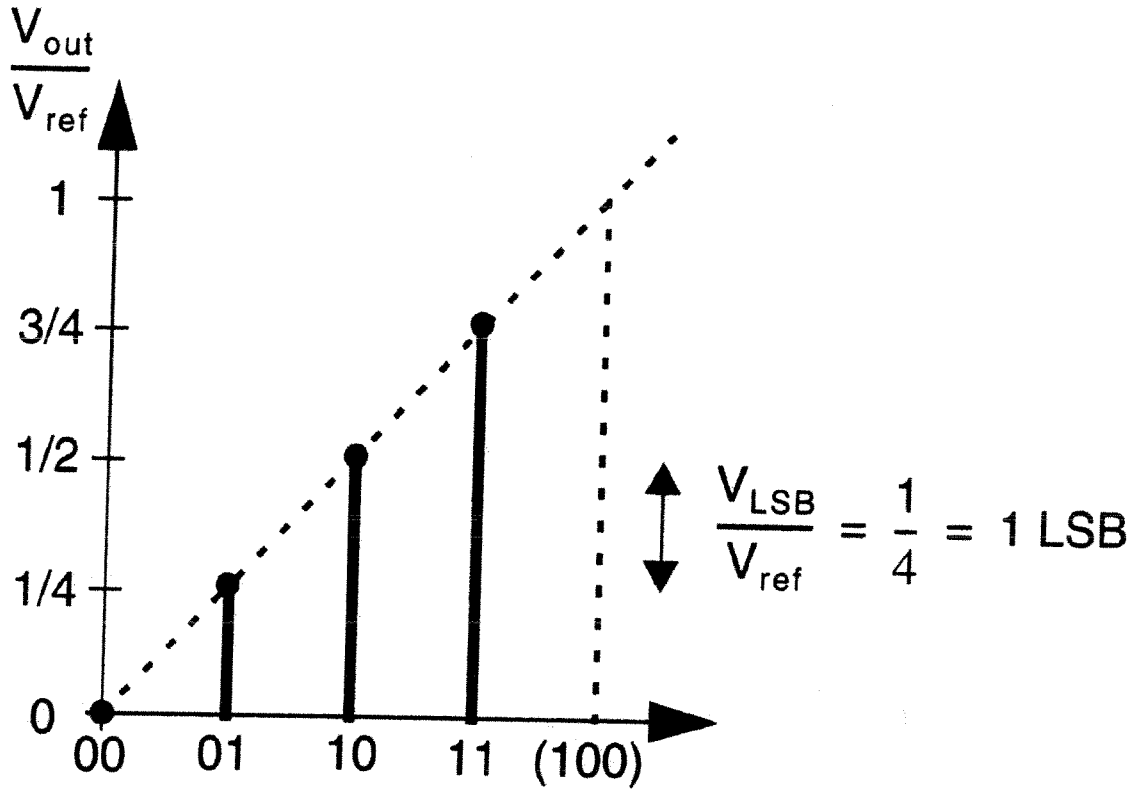
Min value is given by B = <0, 0, 0> = 0 V

Max value is given by B = <1, 1, 1> = 7/8 V

V_{LSB} is $1/8 \cdot V_{ref}$

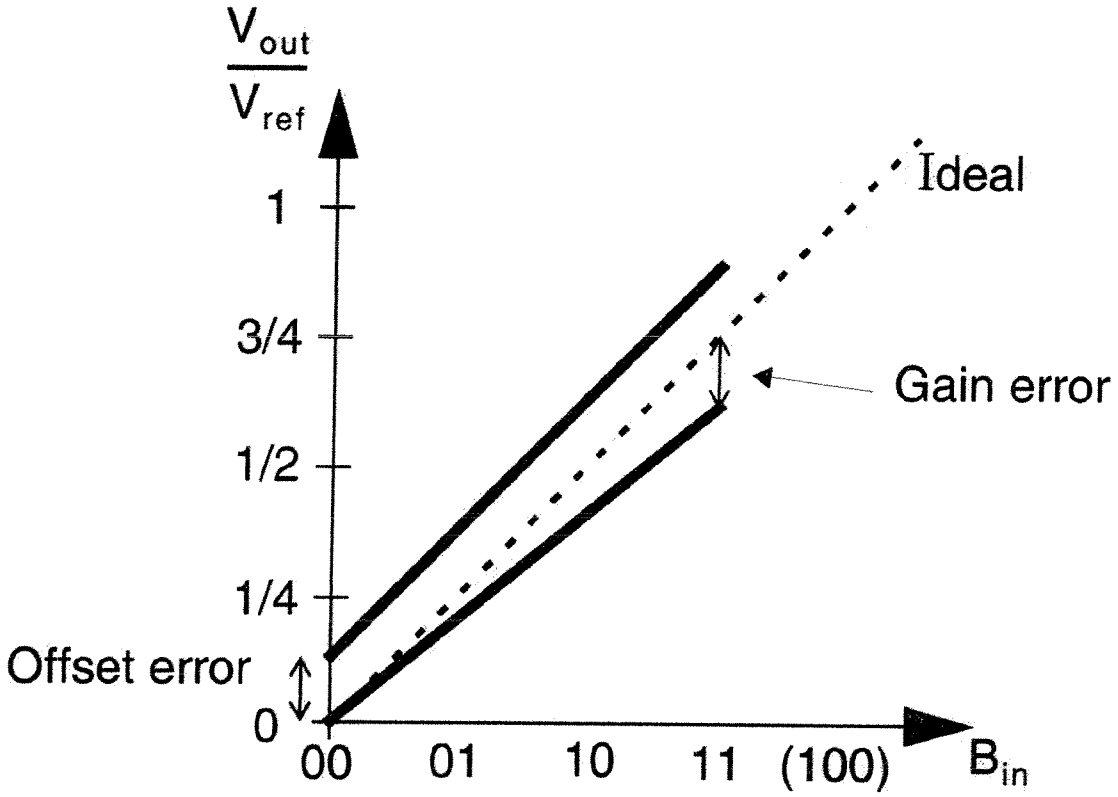
DAC transfer curve

Ideal 2-bit DAC



DAC performance

Offset and gain error



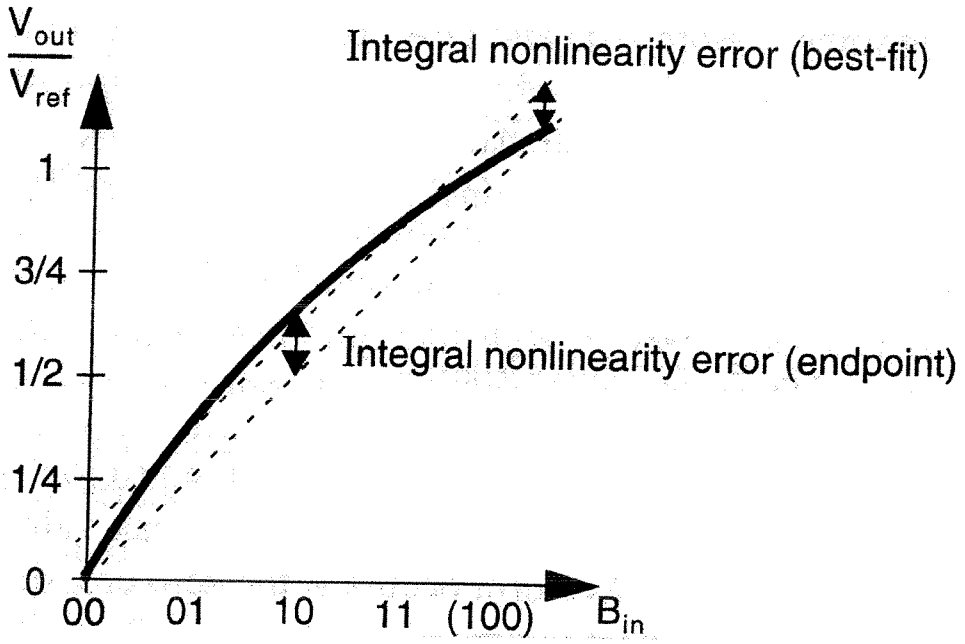
Resolution is the number of input bits

Accuracy is the effective number of bits

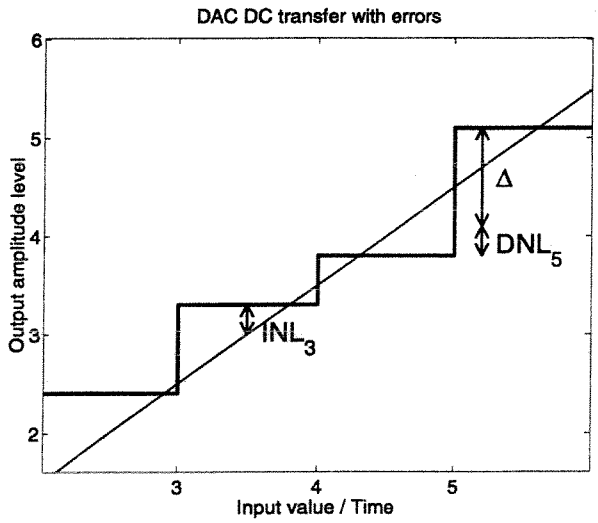
Ex: N-bit resolution corresponds to 2^N analog output levels

M-bit accuracy corresponds to Error < $V_{ref} \cdot 2^{-M}$

Integral nonlinearity (INL) is the transfer function's deviation from a straight line

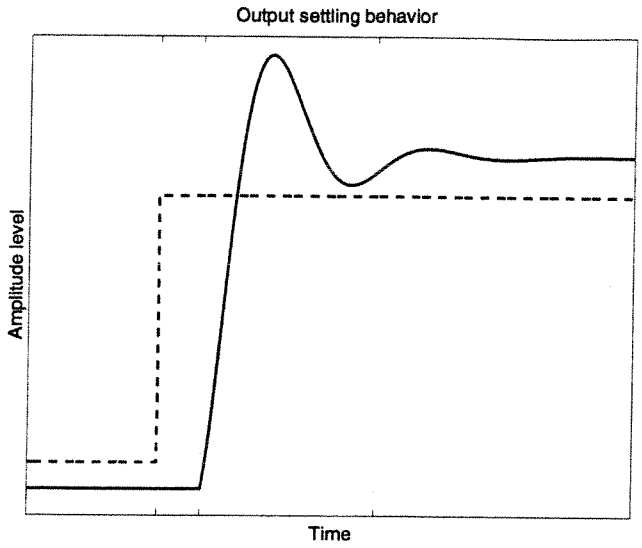


Differential nonlinearity (DNL) is the deviation of a transfer function step from an ideal 1 LSB step



(Monotonicity of a DAC is when the output always increases for increasing input)

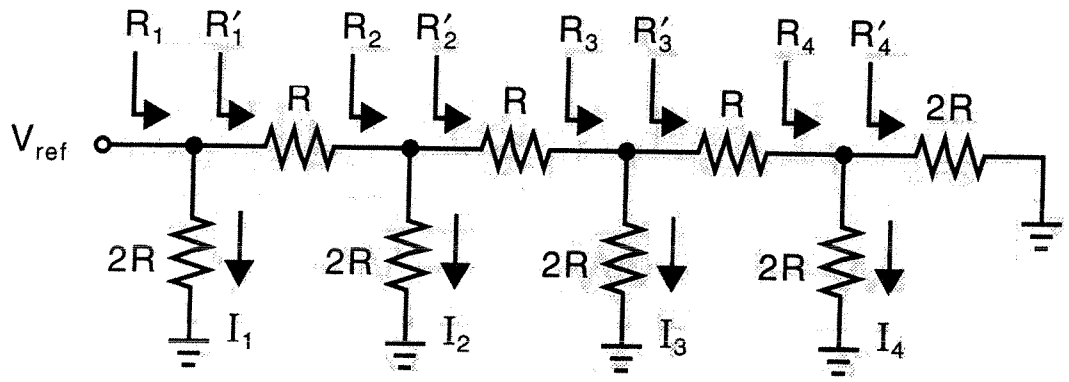
Settling time τ is the time it takes for a DAC output to settle within a ½ LSB



Sampling rate $f_{sample} = 1/\tau$

R-2R-based converters

R-2R ladder



Resistance in nodes

$R'_4 = 2R$

$R_4 = 2R \,||\, 2R = R$

$R'_3 = R + R_4 = 2R$

$R_3 = 2R \,||\, R'_3 = R$

...

i.e., $R'_i = 2R$ for all i

Currents

$I_1 = V_{ref}/2R$

$I_2 = V_{ref}/4R = I_1/2$

$I_3 = V_{ref}/8R = I_2/2$

...

i.e., $I_i = I_{i-1}/2$