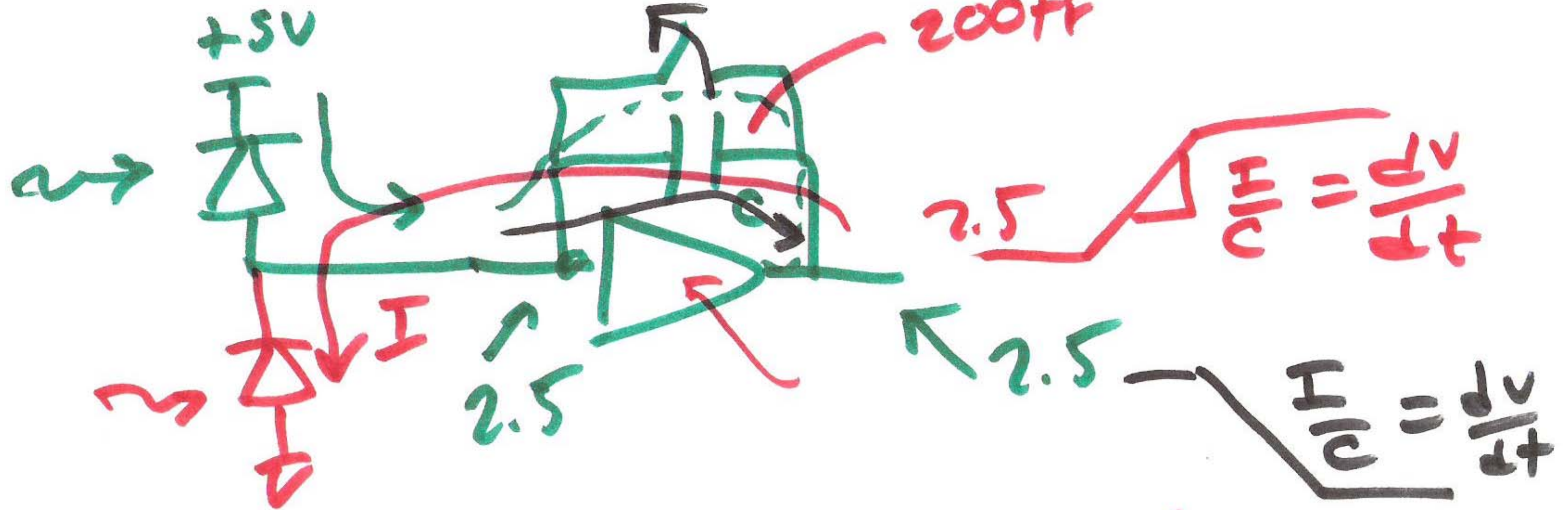
ECE 611 Advance Analog IC Design

OCT. 6, 2011 Lecture 14



$CV = Q$

200fF · ~~300~~mV
50μV

$$\sqrt{\frac{\cancel{K\,200fF}\ 50K}{\cancel{50K}}}$$

Kelvin

$$\sqrt{\frac{K \cdot 50K}{200f}} \overset{?}{=} 50\mu V = \sigma$$

rms

$Q = 10{,}000 \cdot 10^{-18}$ Columbs

\# of electrons

$Q \cdot \frac{1\ \text{electron}}{1.6 \cdot 10^{-19}\ C} \Rightarrow$ # of electrons

peak → peak = 300mV

pages 248-249!

1)

$$\frac{10 \cdot 10^{-15}\,C}{1.6 \times 10^{-19}\,C/e} = 100 \text{ electrons (Rms)}$$

OUT $\swarrow$

$$\Delta V = \frac{I}{C} \cdot \Delta t$$

$$200\,pA \cdot 2ms = 600 \cdot 10^{-12}\,C$$

$pA \downarrow \frac{C}{s}$

$$I \qquad \frac{\Delta V}{I} = \frac{\Delta t}{C}$$

$\nwarrow$ INPUT

$$\frac{600 \cdot 10^{-12}\,C}{1.6 \times 10^{-19}\,C/e} =$$

$$3.7 \times 10^{9} \text{ electrons}$$

$$100 \text{ electrons} \cdot 1.6 \times 10^{-19} \frac{C}{\text{elect.}}$$

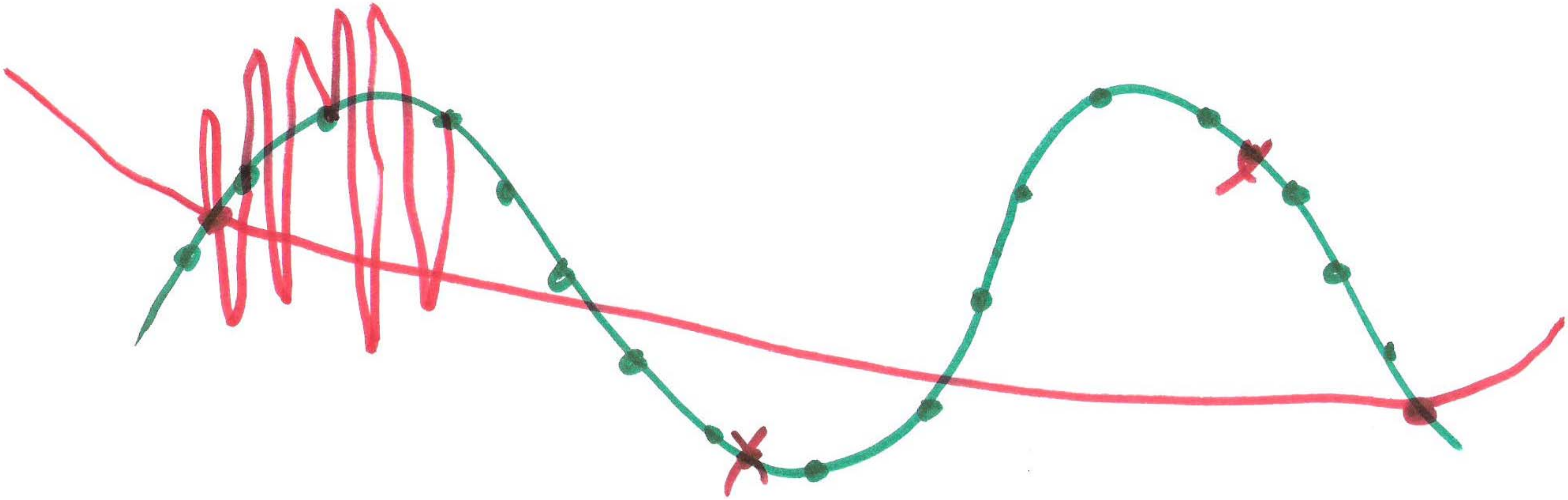
$$= 160 \times 10^{-19} \text{ columbs}$$

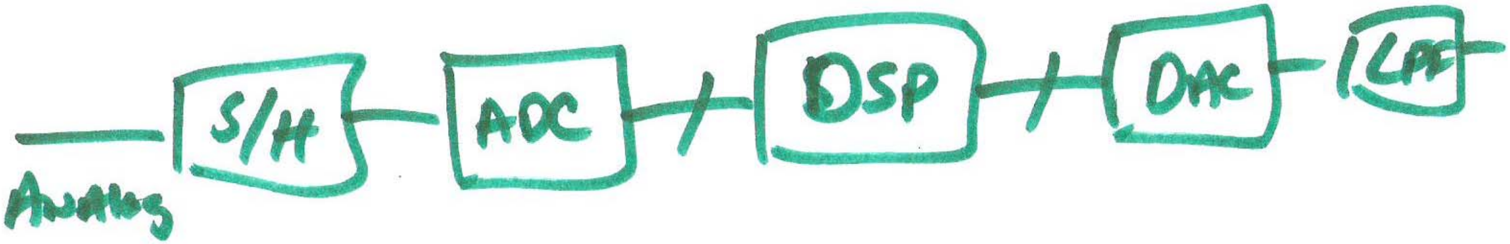
$$i_{\text{noise, Rms}} = \frac{160 \times 10^{-19}}{2\ ms} = 80 \cdot 10^{-16}$$

$$= \underline{\underline{8\ fA}}$$

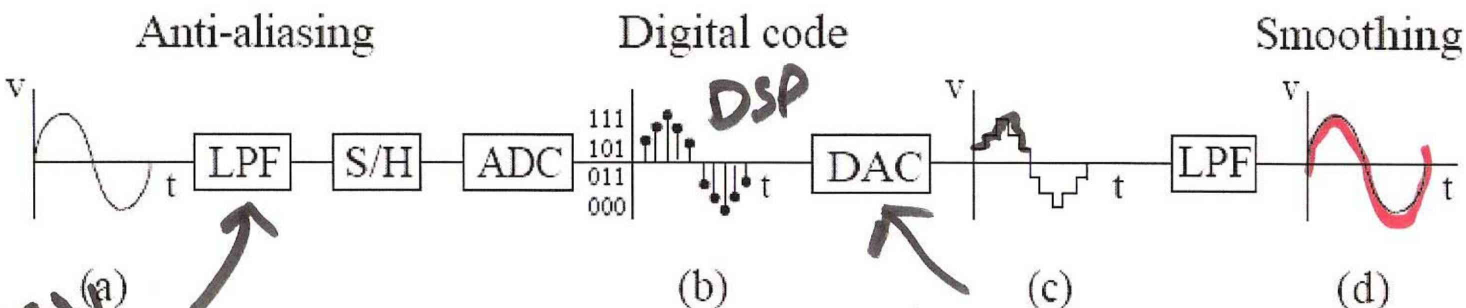
2)

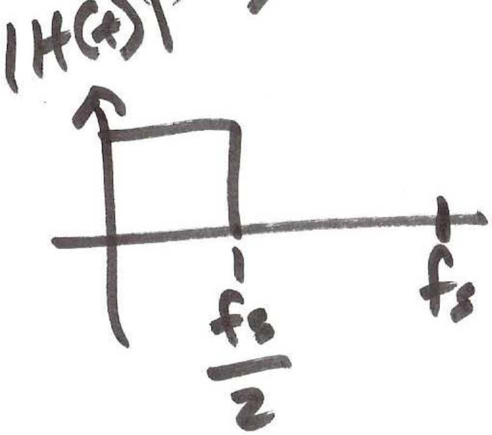
Aliasing

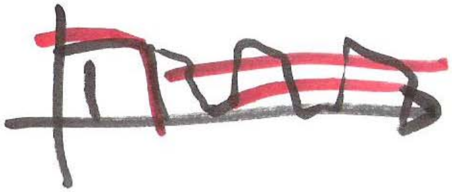




3)







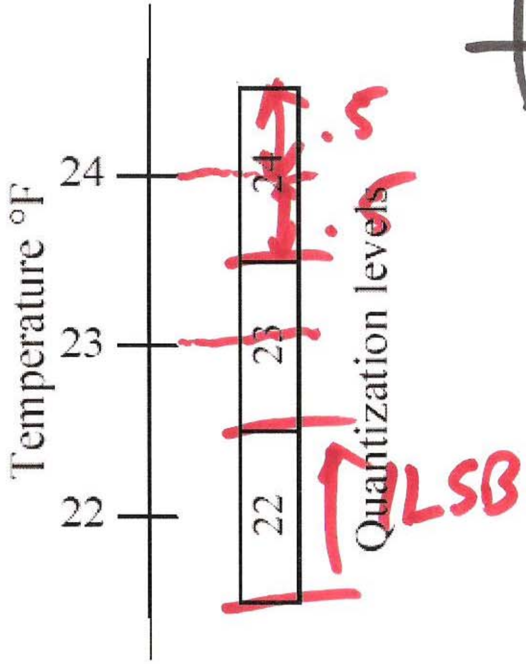
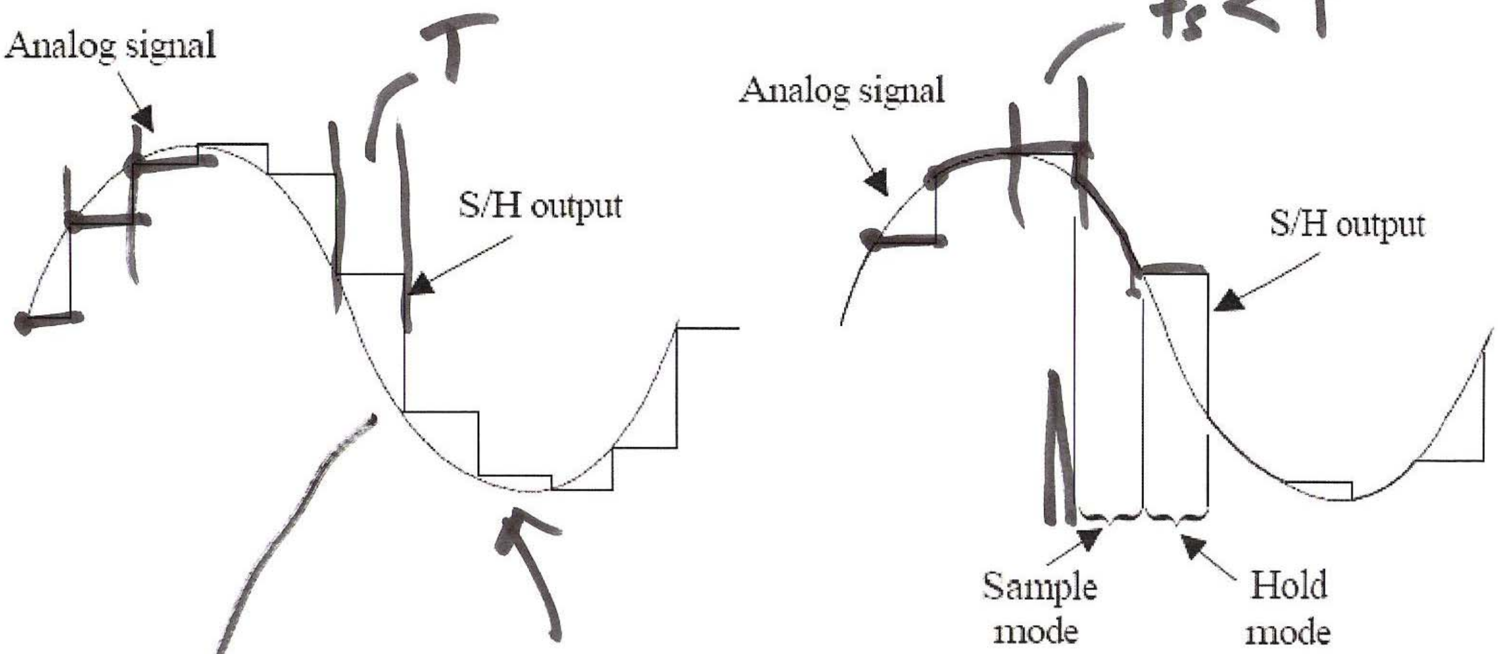


Figure 28.4 Quantization levels overlap actual temperature by ± ½ °F.

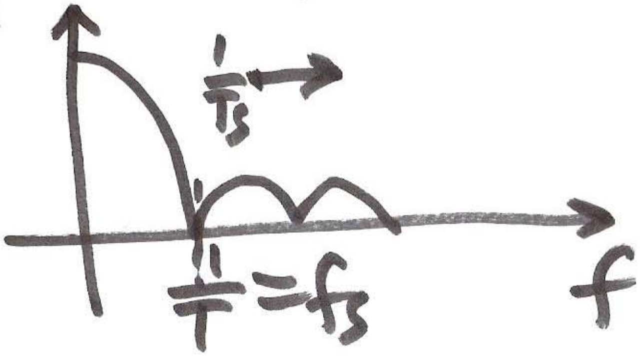
4)



(a) (b)

Figure 28.5 The output of (a) an ideal S/H circuit and (b) a track-and-hold (T/H).

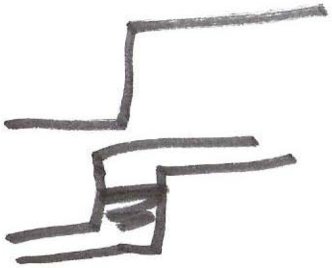
filter

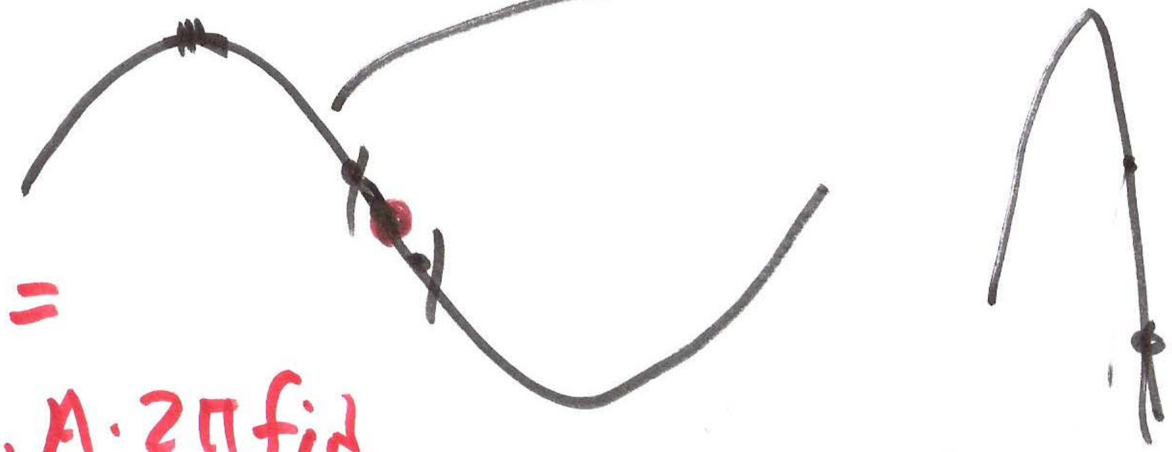


5)

TIMING jitter

Aperture Error





$\Delta V =$

$\Delta t \cdot A \cdot 2\pi f_{in}$

$10\,ps \cdot 2 \cdot 2\pi \cdot 10^9$

$10^{-11} \cdot 10^9 \cdot 4\pi$

$10^{-2} \cdot 4\pi = \underline{\underline{125\,mV}}$!

$\frac{d}{dt} A \sin 2\pi f_{in} \cdot t = A \cdot 2\pi f_{in} \cdot \overset{1}{\cancel{\cos}} 2\pi f_{in} \cdot t$

MAX error $= A \cdot 2\pi \cdot f_{in} = \frac{\Delta V}{\Delta t}$

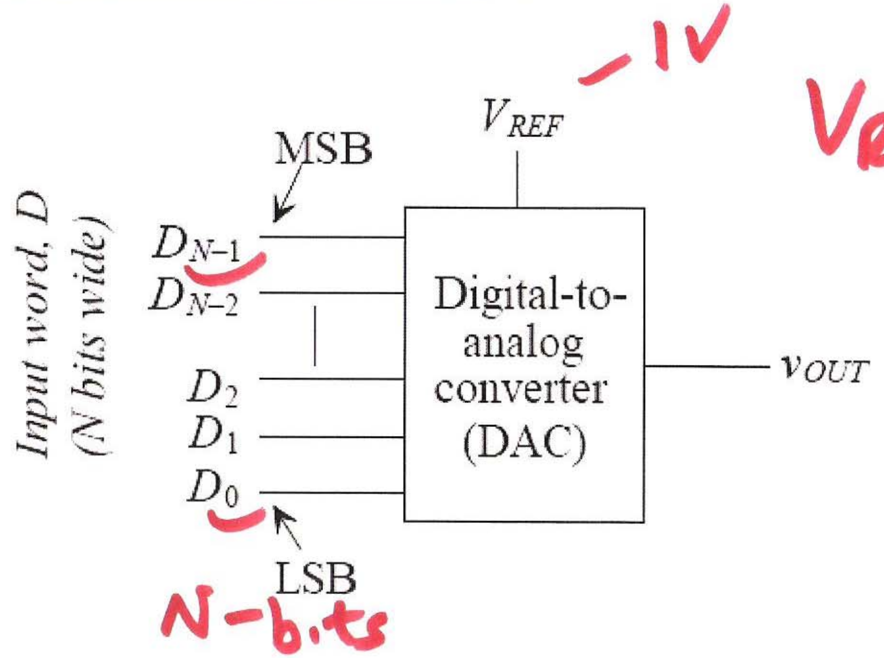
$2 \cdot 2\pi \cdot 10$

$\frac{001}{1000} \cdot V_{REF}$

$= 1\,LSB$

$= \frac{1}{8} V_{REF}$

$V_{REF} \cdot F = \frac{V_{REF} \cdot D}{2^N}$



$\frac{000}{1000} \cdot V_{REF} = 0$

$\frac{111}{1000} \cdot V_{REF} = \frac{7}{8} V_{REF}$

Figure 28.9 Block diagram of the digital-to-analog converter.

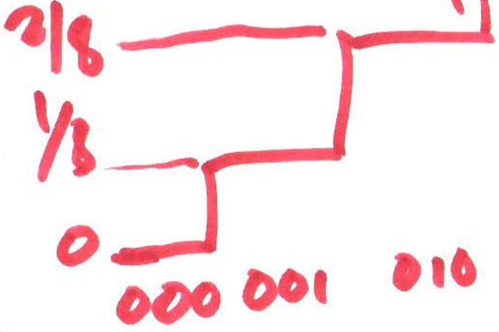
$\frac{V_{REF}}{2^N} = 1\,LSB$

$N = 3$

$F = \frac{D}{2^N}$

$\frac{001}{1000} \Rightarrow \frac{1}{8}$

$\frac{010}{1000} \to \frac{1}{4}$



7)

$$V_{REF} = V_{REFP} - V_{REFM}$$

$$1\,LSB = \frac{V_{REFP} - V_{REFM}}{2^N}$$

MINIMUM DAC OUTPUT, all zeroes in,

V_{REFM}

MAXIMUM DAC OUTPUT, all ones in,

$$V_{REF} - 1\,LSB = V_{REFP} - \frac{V_{REFP} - V_{REFM}}{2^N}$$

$V_{REFP} = 900mV$ $1\,LSB = 100mV = \frac{800mV}{8}$

$V_{REFM} = 100mV$ $N=3$ DAC

MAX OUTPUT $= 800mV$ min $= 100mV$ $2^N \nearrow$

DAC

(Not monotonic

$\frac{v_{OUT}}{V_{REF}} = \frac{V_{OUT}}{V_{REFP} - V_{REFN}}$

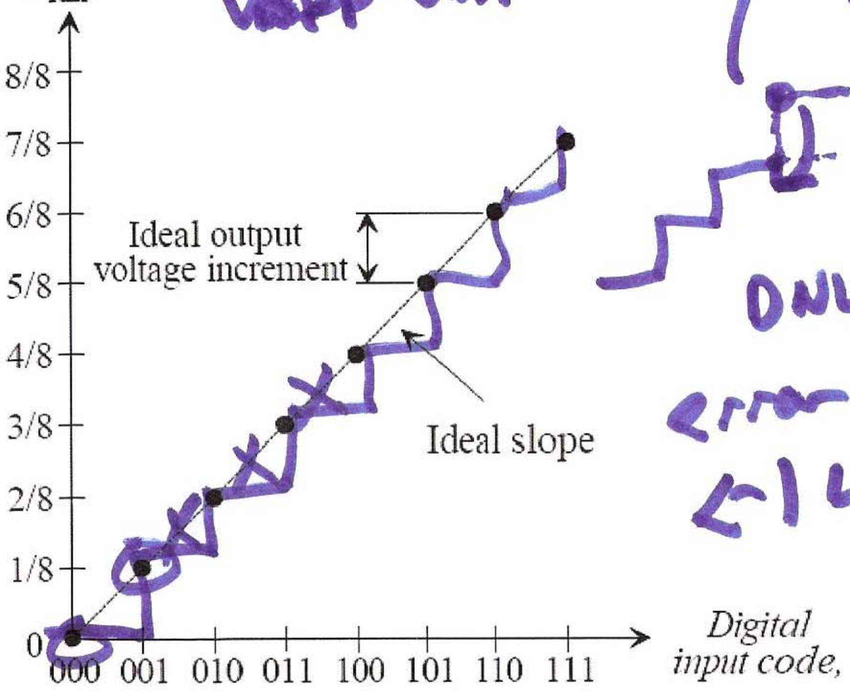
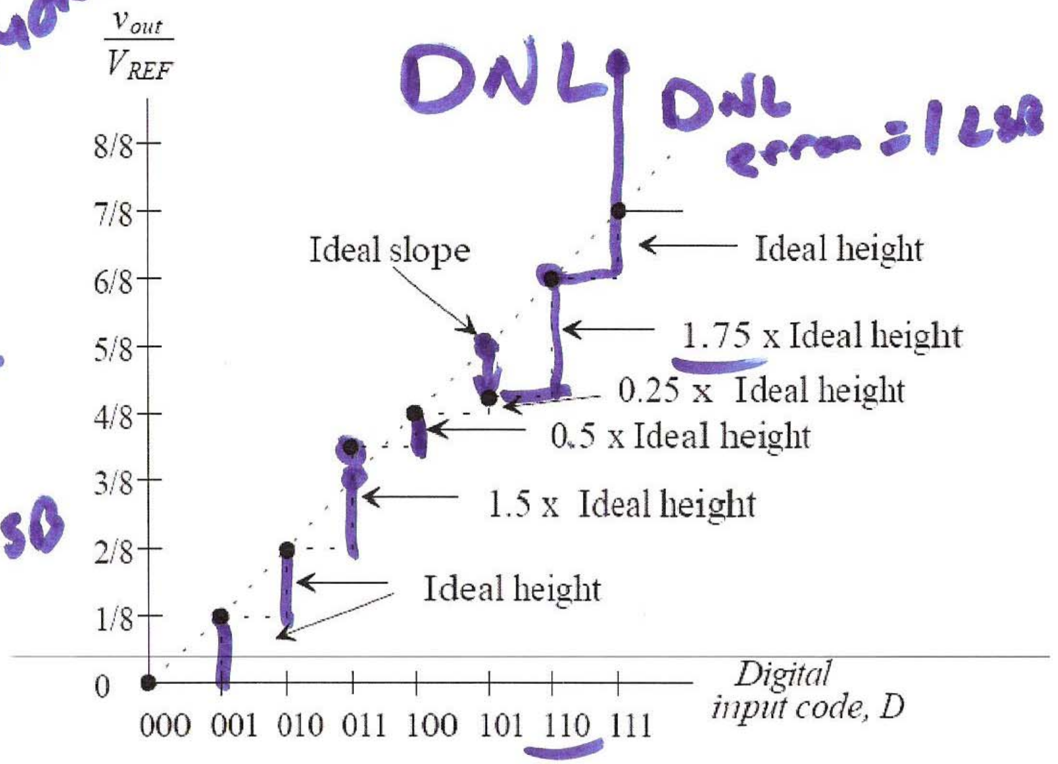


Figure 28.10 Ideal transfer curve for a 3-bit DAC.

DNL error < -1 LSB



DNL

DNL error = 1 LSB

Figure 28.11 Example of differential nonlinearity for a 3-bit DAC.

DC errors

DNL error ≥ 1 LSB

<

< -1 LSB

DNL = -1 LSB or less for ADC has a missing code!

9)

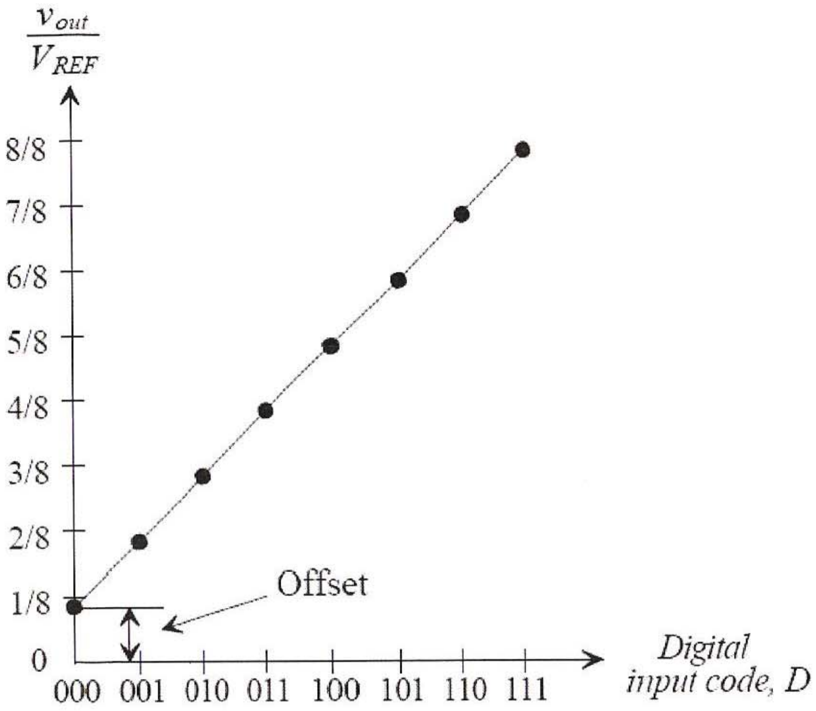


Figure 28.16 Illustration of offset error for a 3-bit DAC.

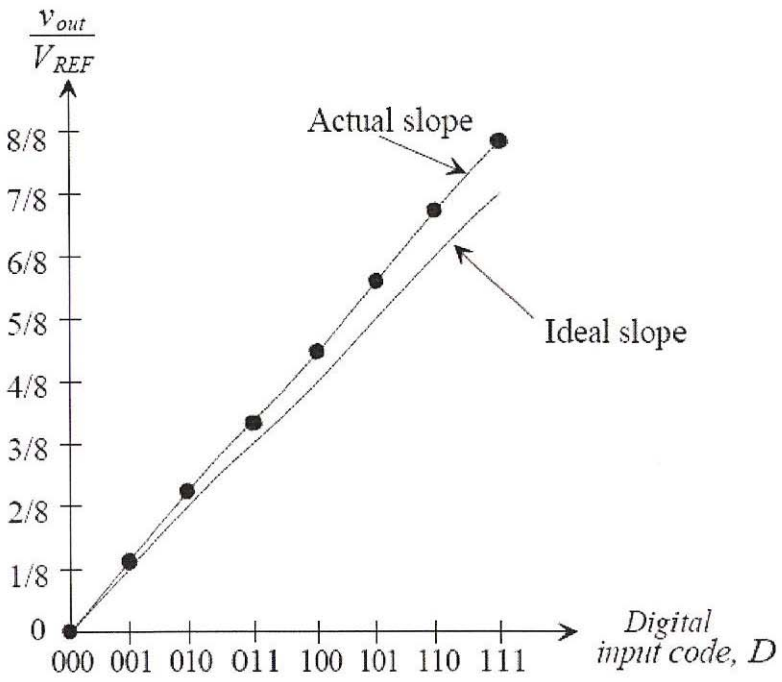


Figure 28.17 Illustration of gain error for a 3-bit DAC.

Integral nonlinearity

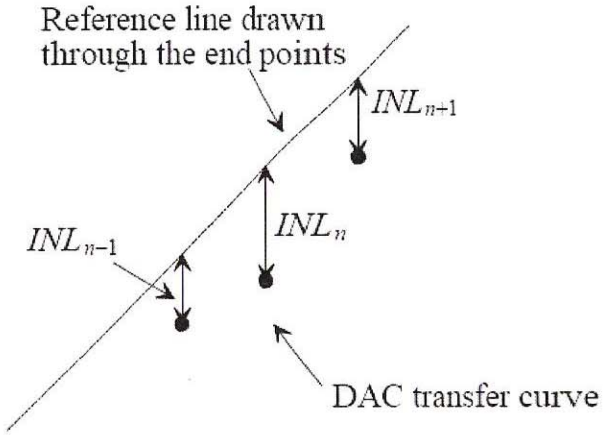


Figure 28.13 Measuring the INL for a DAC transfer curve.

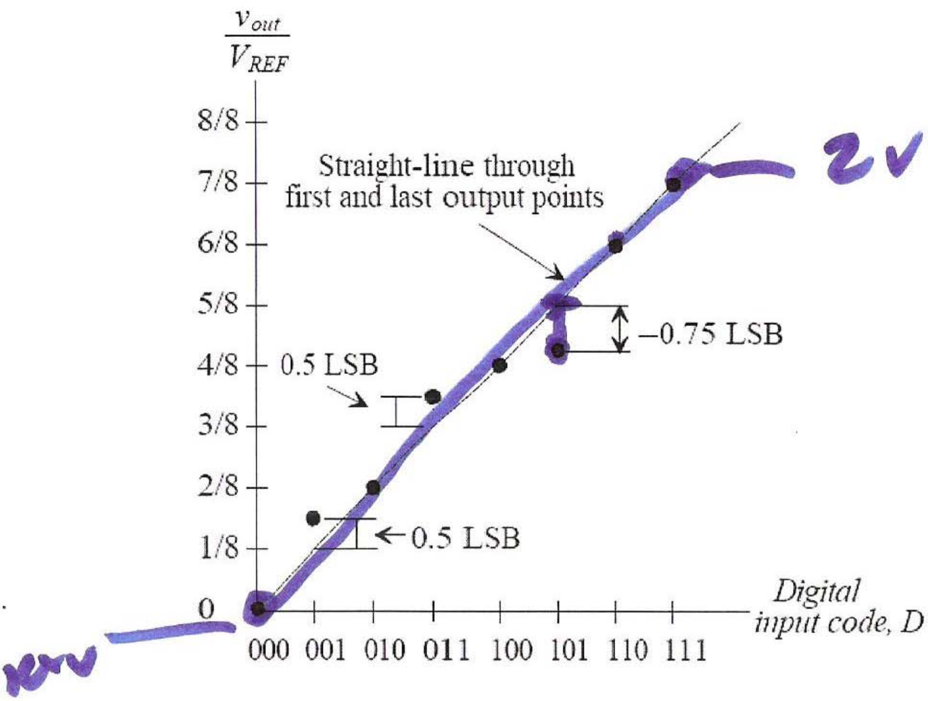
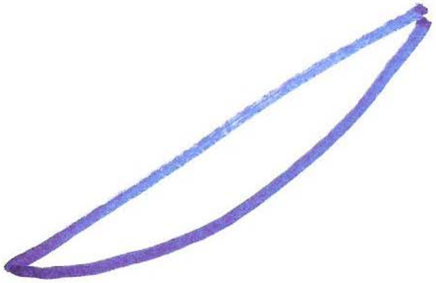


Figure 28.14 Example of integral nonlinearity for a DAC.



$ax = y$

$ax + bx^2 = y$