Chapter 28 - Data Converter fundamentals

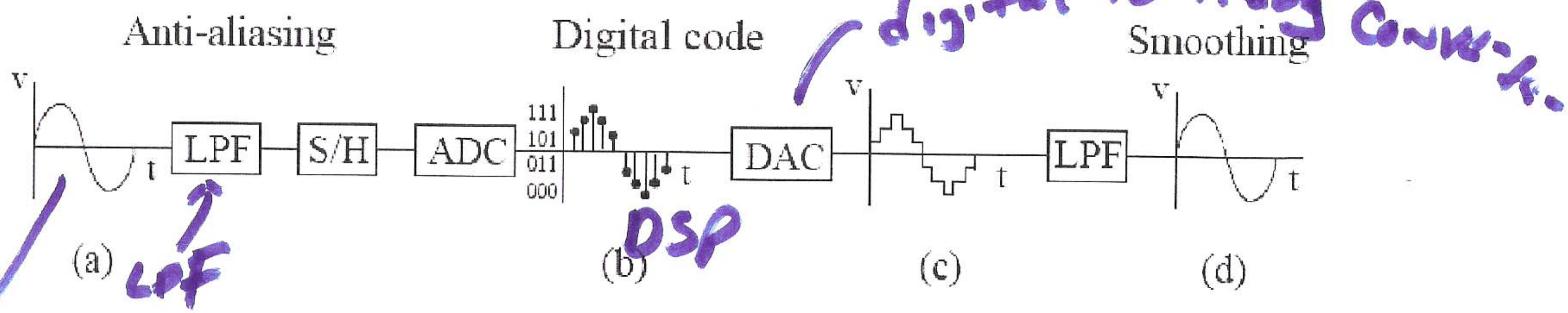
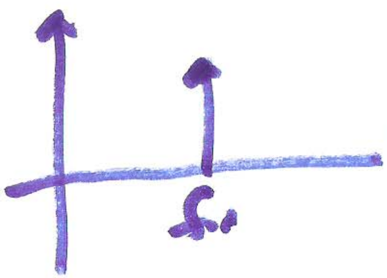


Figure 28.1 Signal characteristics caused by A/D and D/A conversion.



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

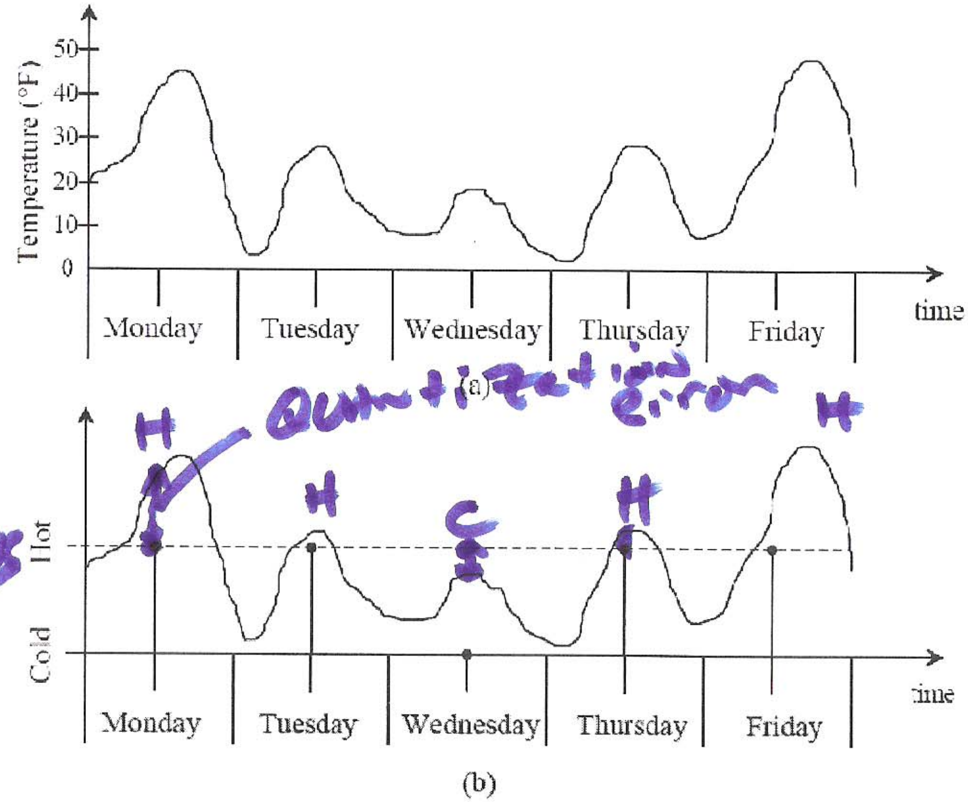
N = number of bits in data converter

DR - dynamic range

ENOB - effective # of bits

DNL - Differential nonlinearity

INL - Integral nonlinearity

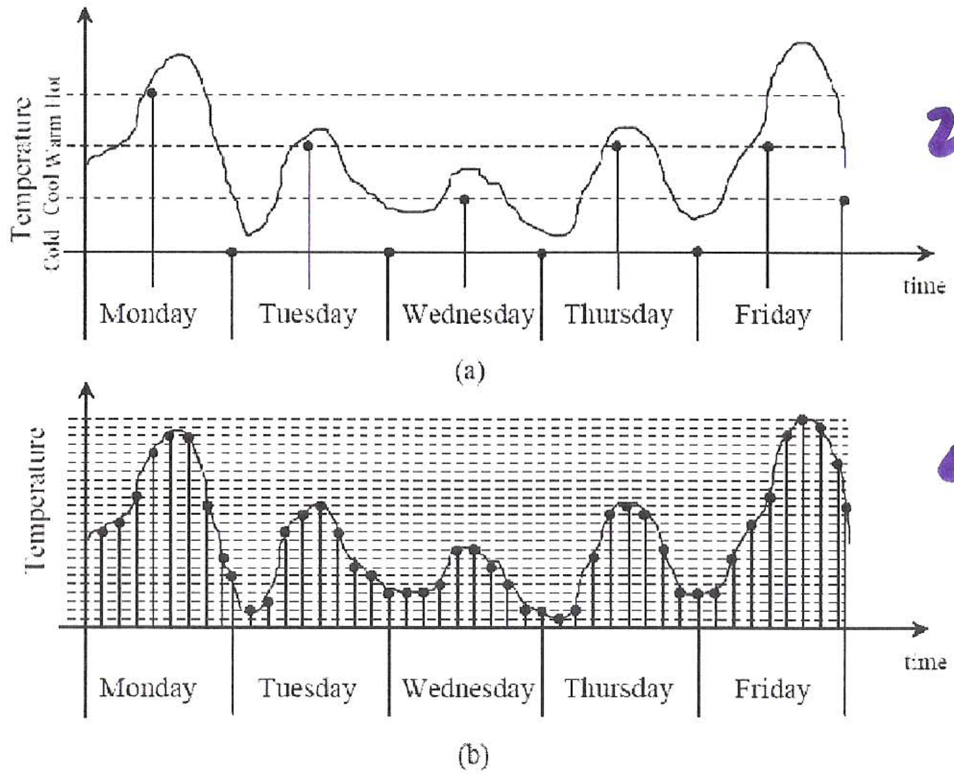


Quantizing

2¹
1-bit quantizer

Figure 28.2 (a) An analog signal representing the temperature where you live and (b) a digital representation of the analog signal taking one sample per day with two quantization levels.

2)



2-bit quantizer or ADC

4-bit ADC

Figure 28.3 Digital representation of the temperature taking (a) two samples per day with four quantization levels and (b) nine samples per day with 25 quantization levels.

3)

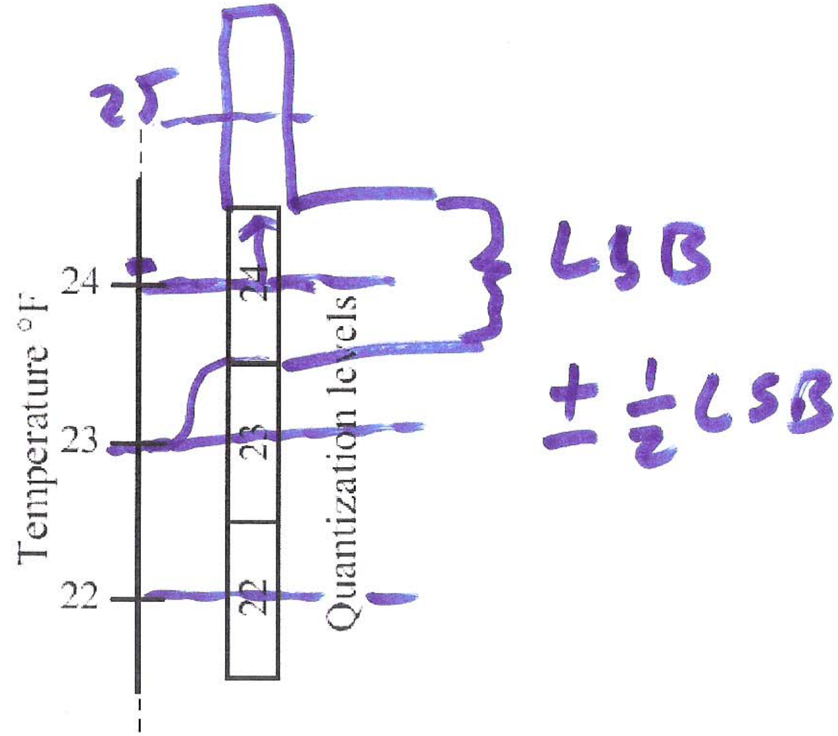


Figure 28.4 Quantization levels overlap actual temperature by ±½° F.

4)

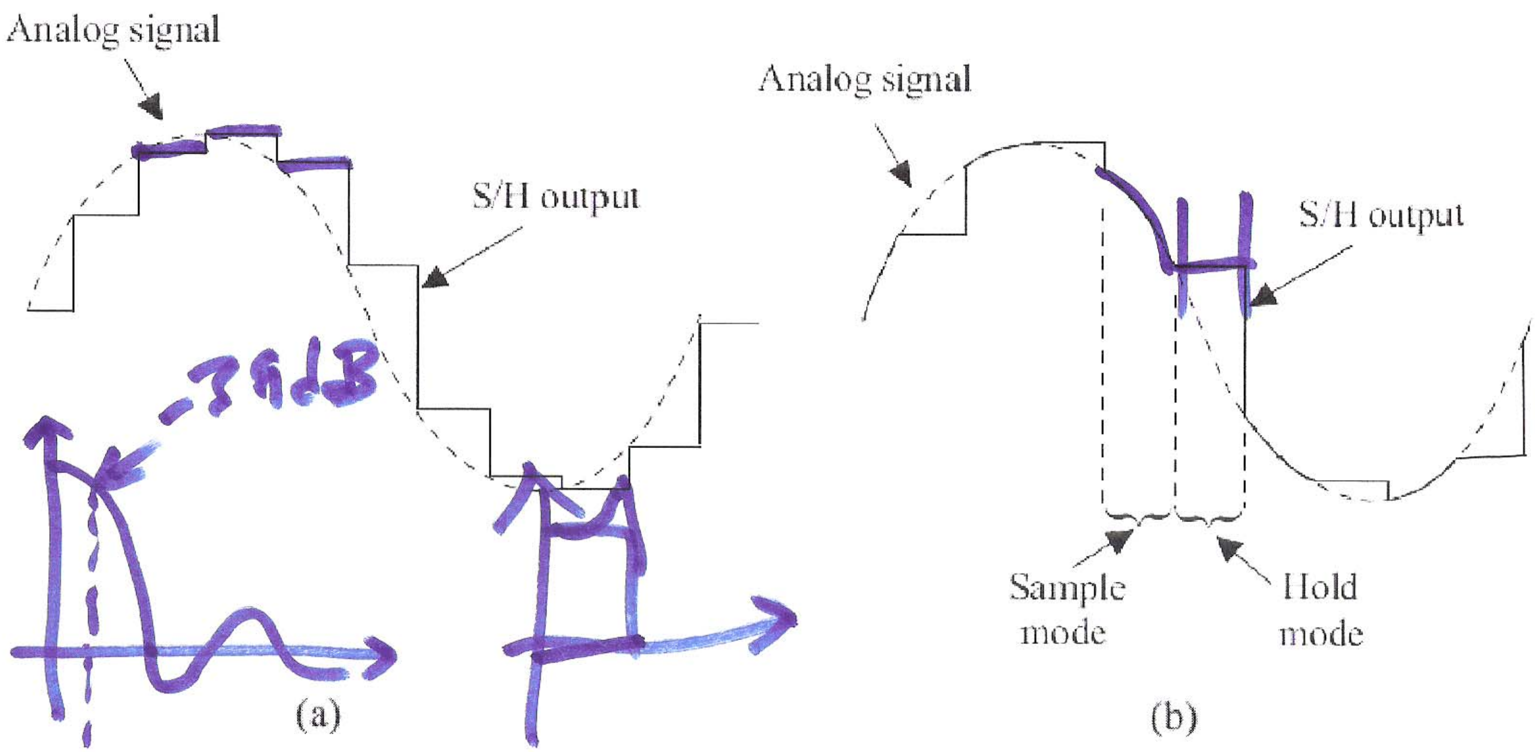


Figure 28.5 The output of (a) an ideal S/H circuit and (b) a track-and-hold (T/H).

$\frac{f_s}{2}$ = Nyquist frequency

f_s = sample frequency

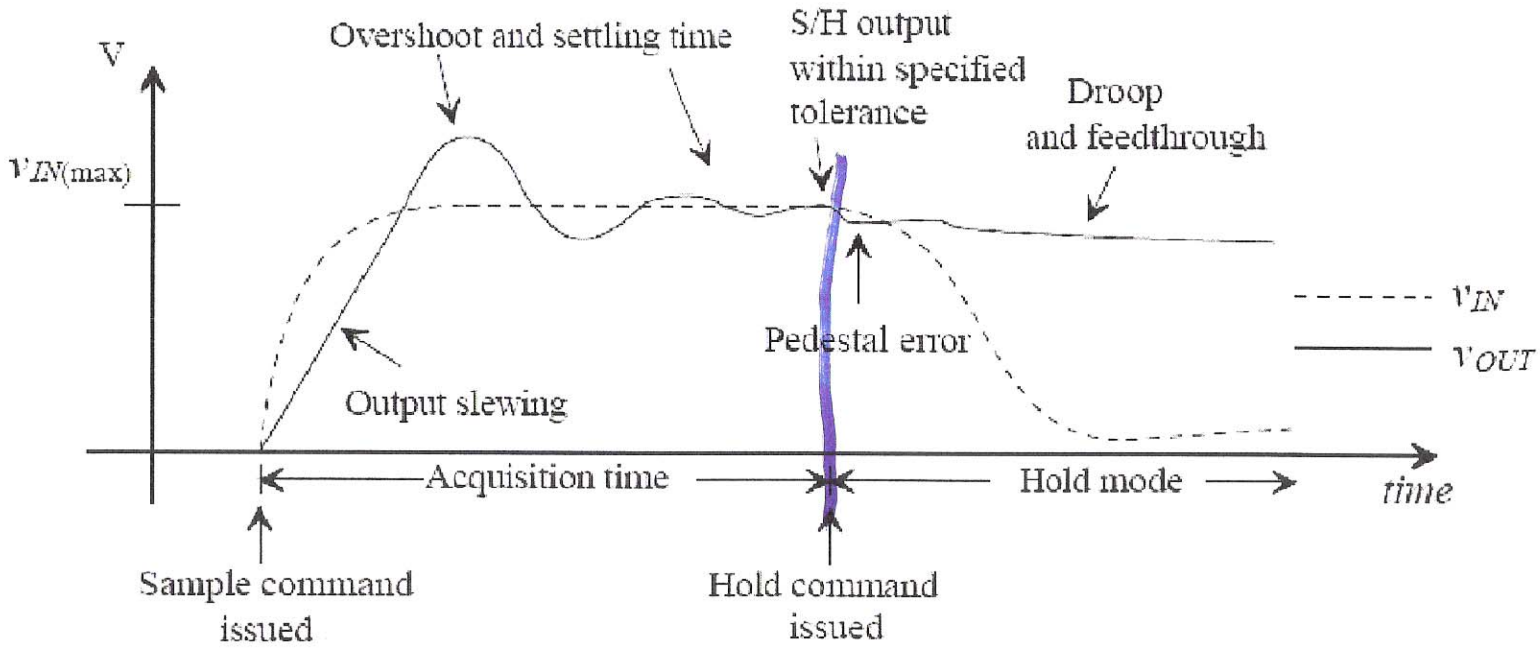
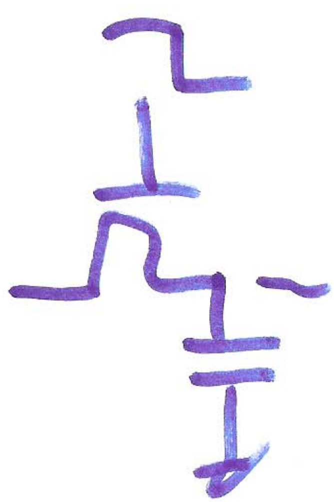
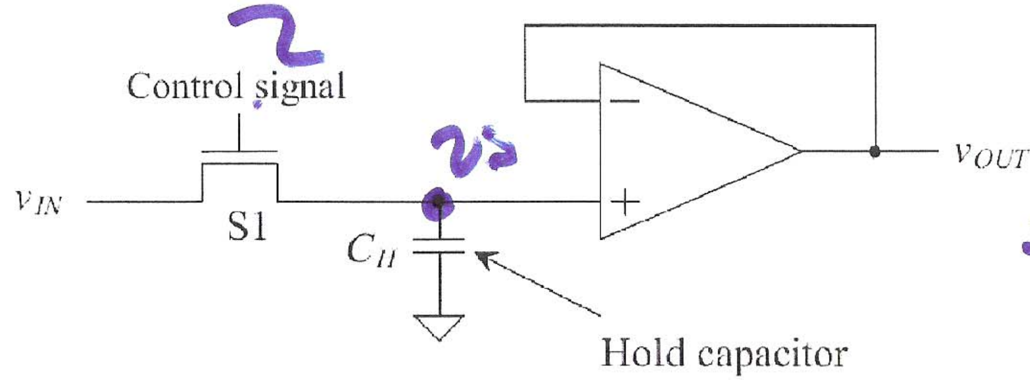


Figure 28.6 Typical errors associated wth an S/H.



Characteristics

6)



= v_{in}

control

⇒ v_{out} (going low)

Figure 28.7 Track-and-hold circuit using an output buffer.

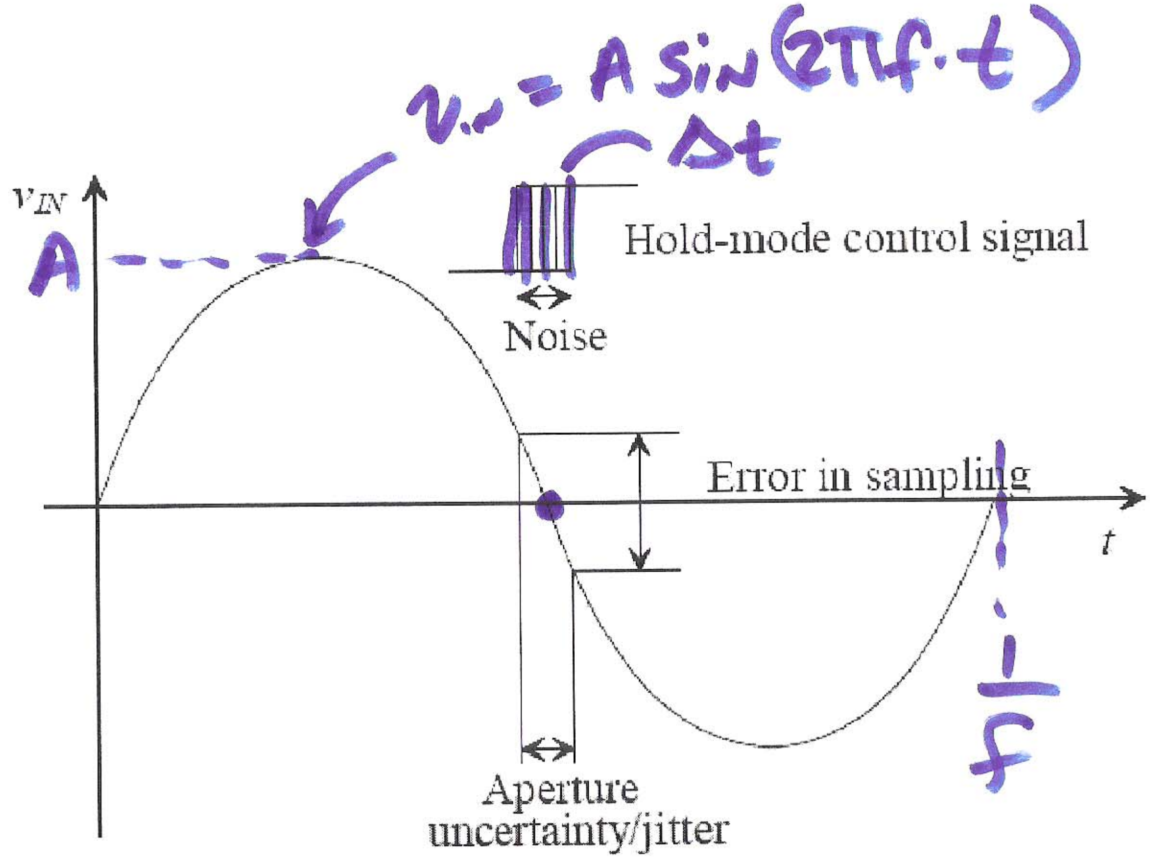
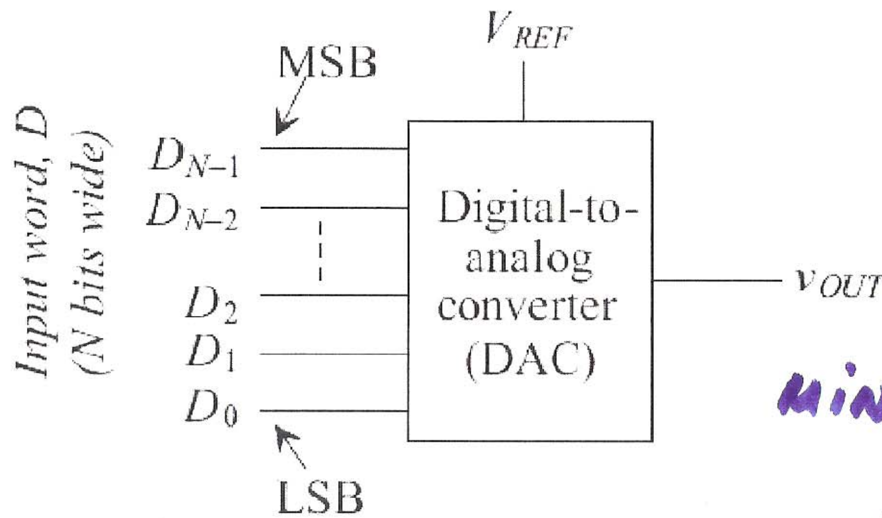


Figure 28.8 Aperture error.

$$\frac{dv_{in}}{dt} = A \cdot 2\pi f \cdot \cancelto{1}{\cos 2\pi f t} \cdot \frac{dt}{\cancel{dt}}$$

$$A \cdot 2\pi f = \frac{\text{ERROR}}{\Delta t} \qquad \text{ERROR} = 1 \cdot 2\pi \cdot 10^{9} \cdot 10^{-11}$$

$$= 62.8\,mV \text{ error}$$



$= D \cdot 1LSB$

MINIMUM OUTPUT

$0LSB \rightarrow 2^N - 1$ LSBs

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

$F.S. = 2^N - 1$ LSBs

9)

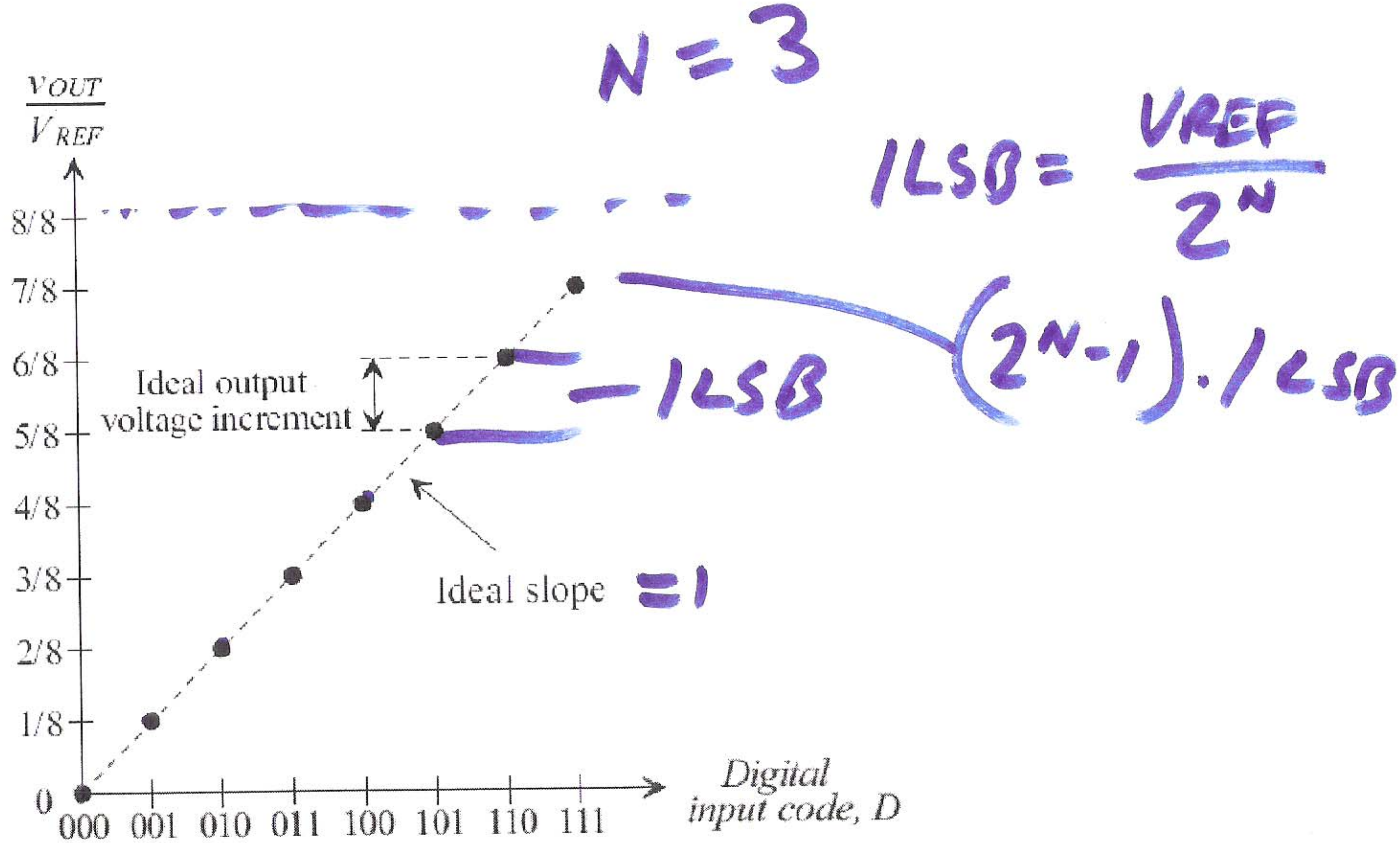


Figure 28.10 Ideal transfer curve for a 3-bit DAC.

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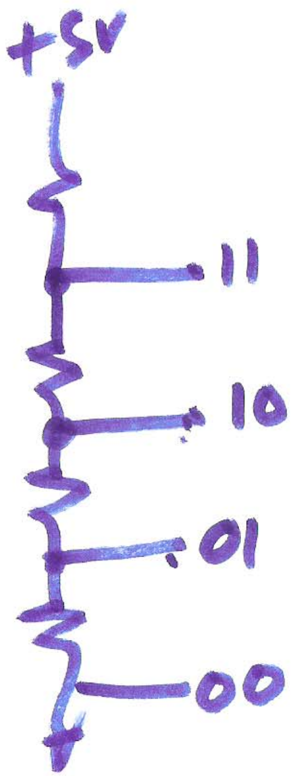


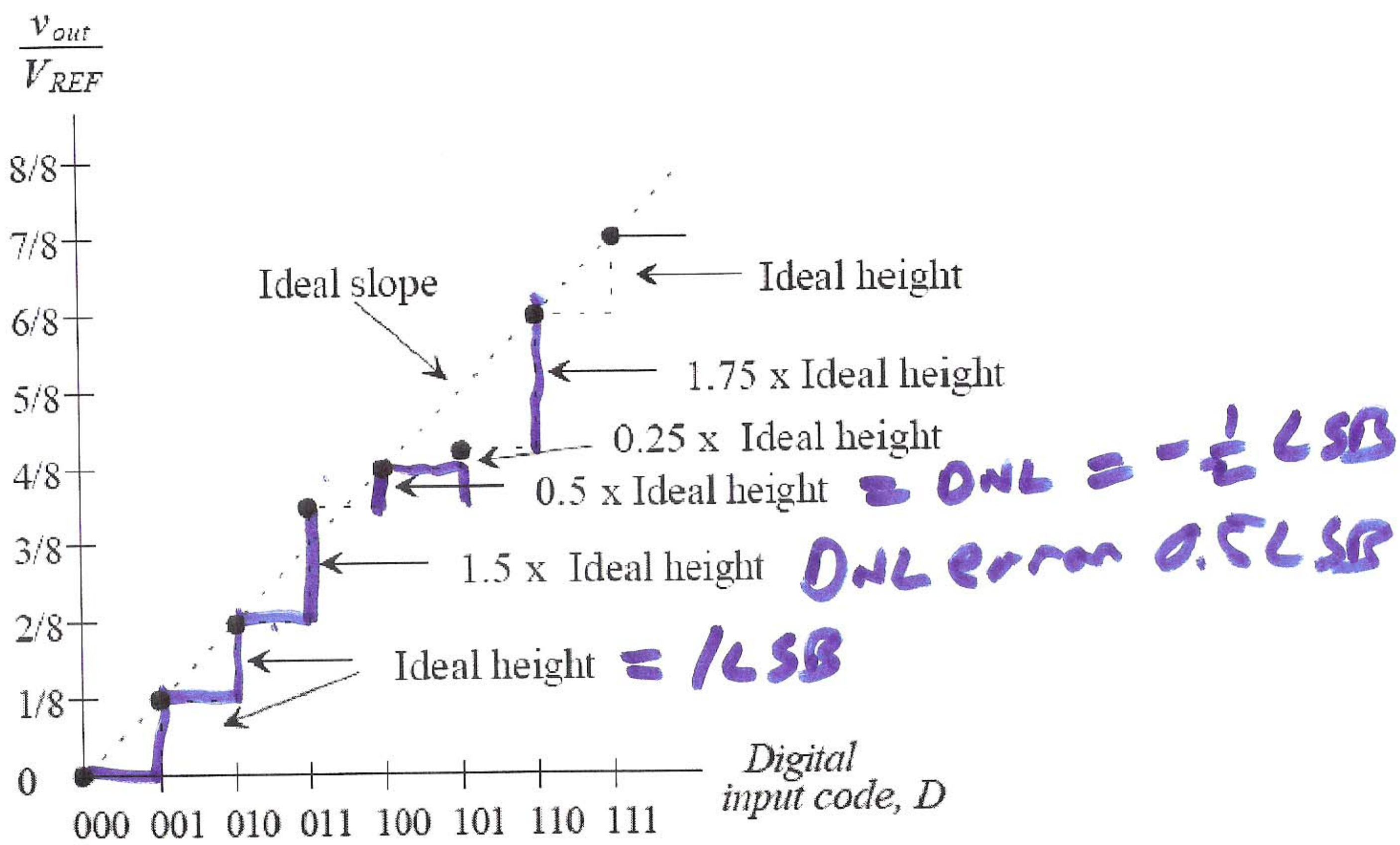


Figure 28.11 Example of differential nonlinearity for a 3-bit DAC.

2-bit Resistor String DAC

Monotonicity D↗ Vout↗

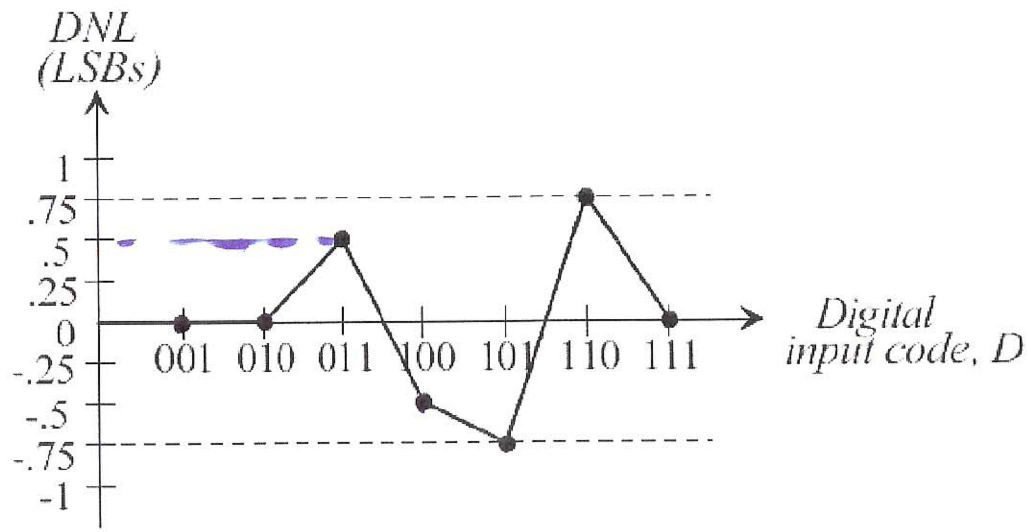
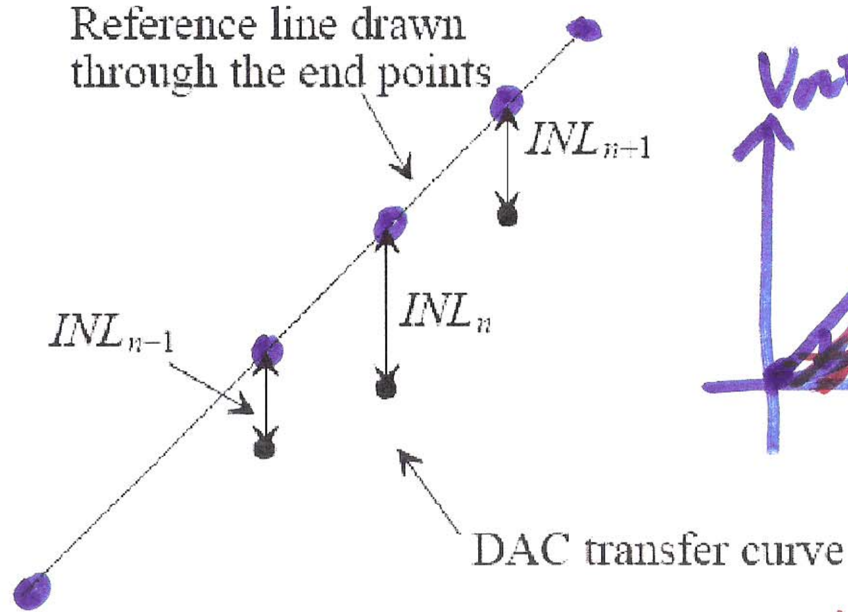
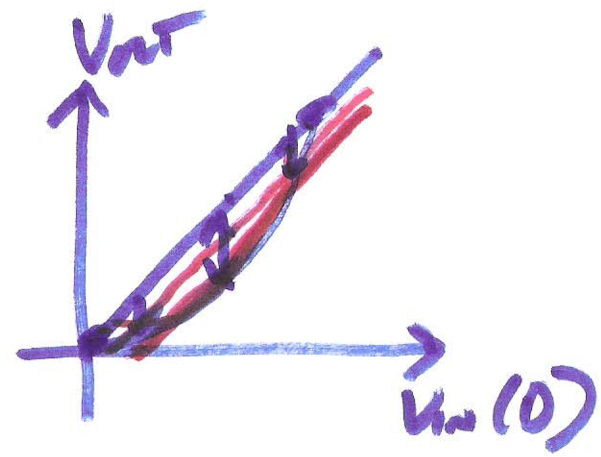


Figure 28.12 DNL curve for the nonideal 3-bit DAC.

12)





$V_{out} = A \cdot V_{in}$

$V_{out} = A\, V_{in}^{1.3}$

Figure 28.13 Measuring the INL for a DAC transfer curve.

Large signal linearity

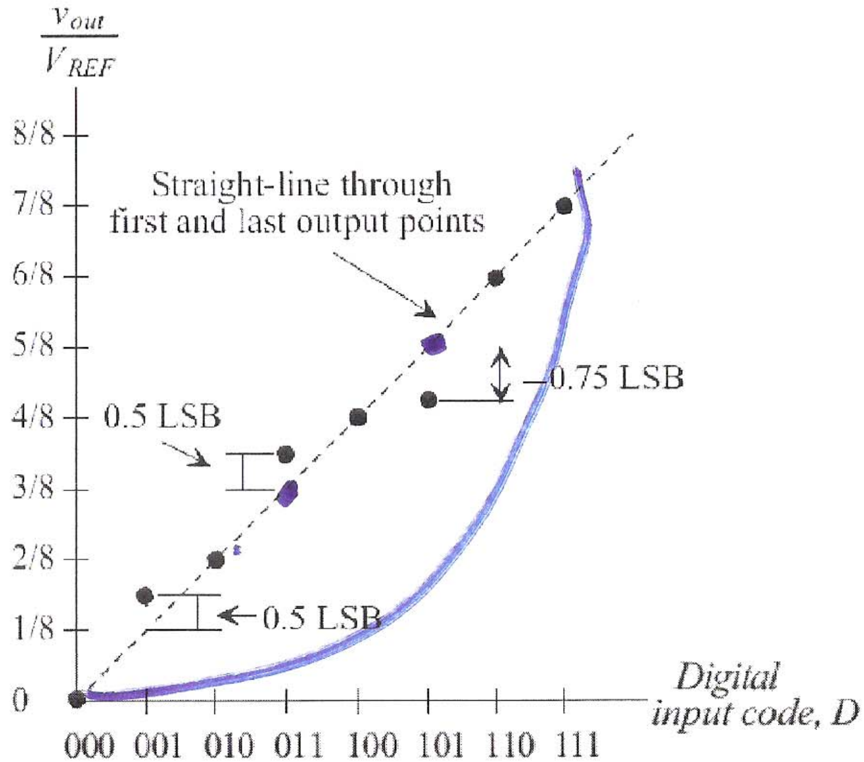


Figure 28.14 Example of integral nonlinearity for a DAC.

14)

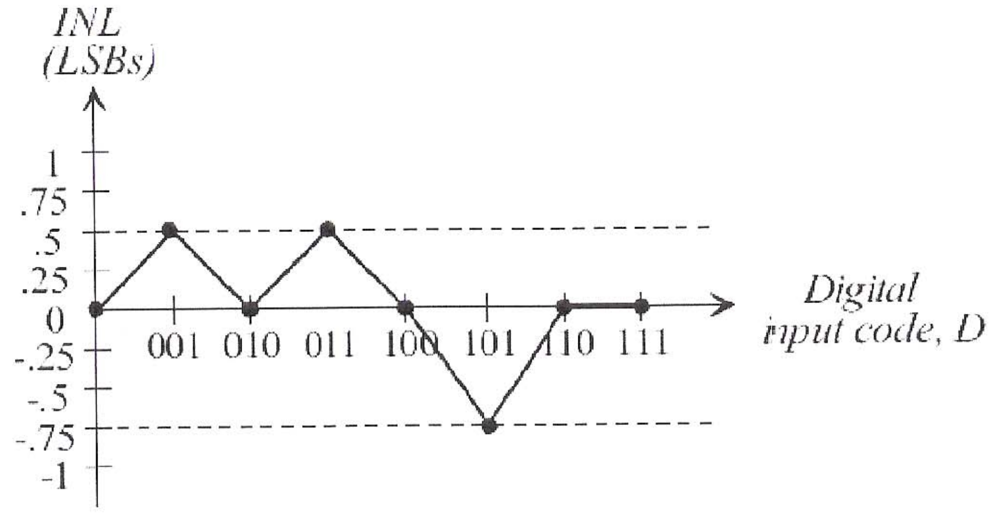


Figure 28.15 INL curve for the nonideal 3-bit DAC.

DNL & INL

are DC measurements

15)

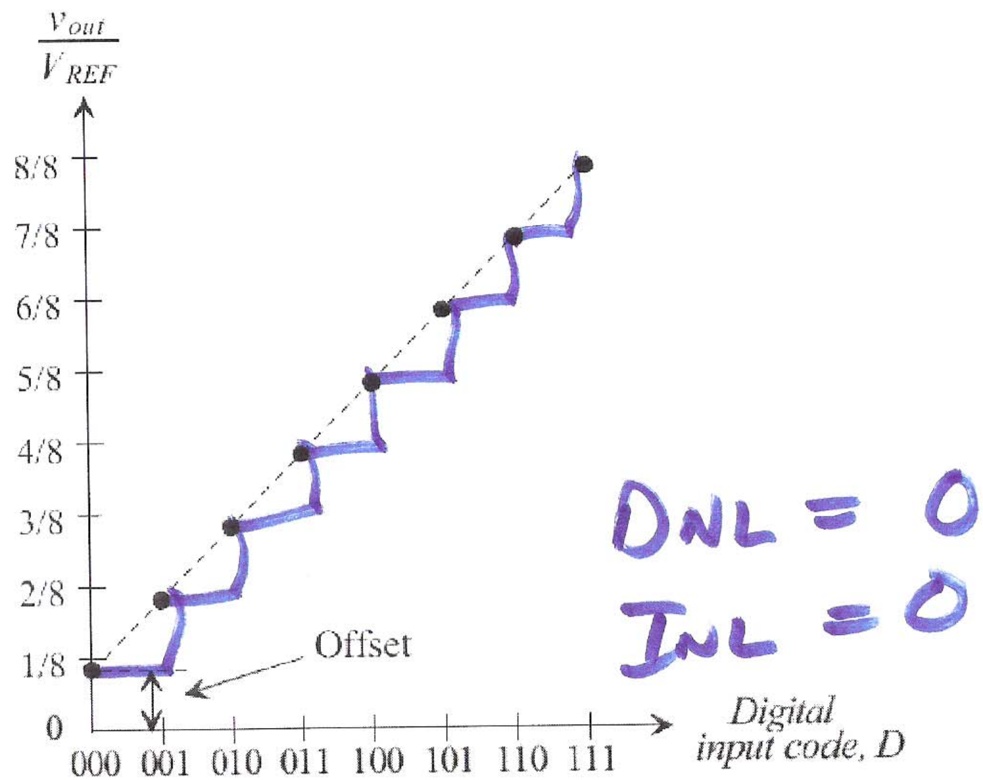


Figure 28.16 Illustration of offset error for a 3-bit DAC.

Offset, no distortion

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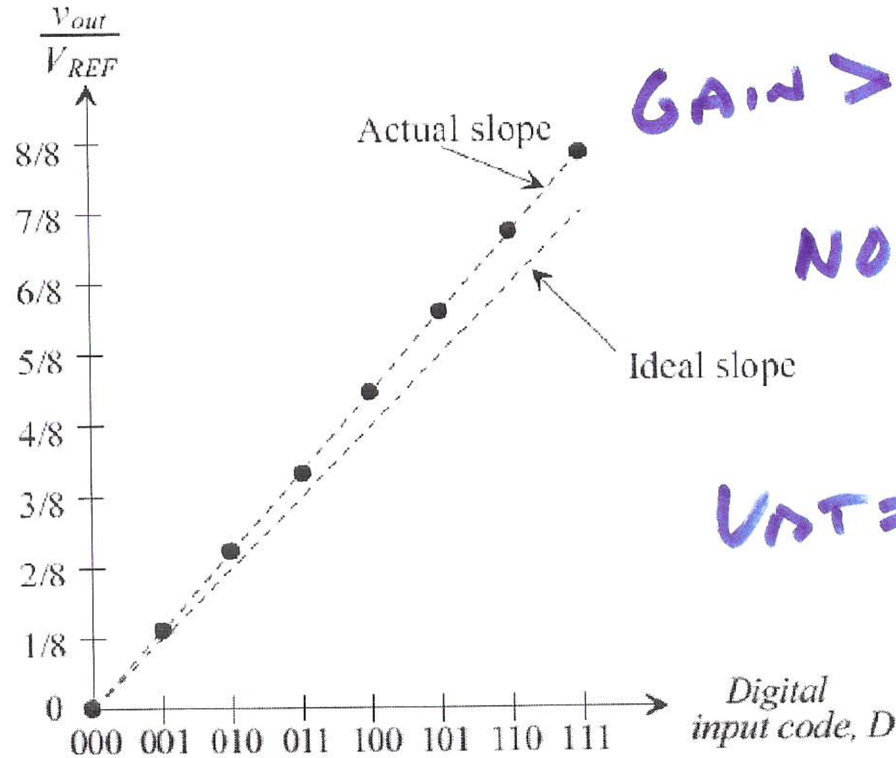
16)



GAIN > 1

NO distortion

$V_{OUT} = V_{IN} \cdot G$

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

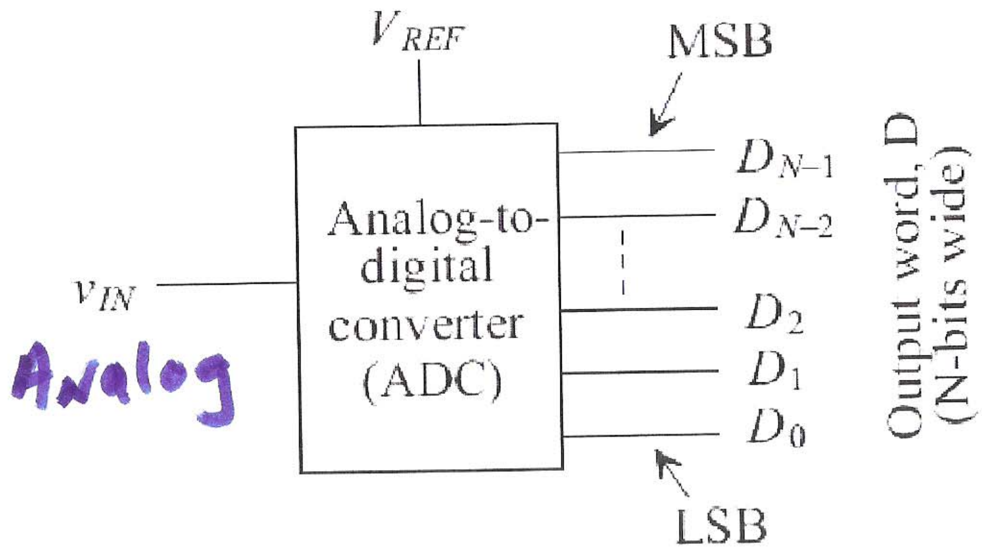


Figure 28.18 Block diagram of the analog-to-digital converter.

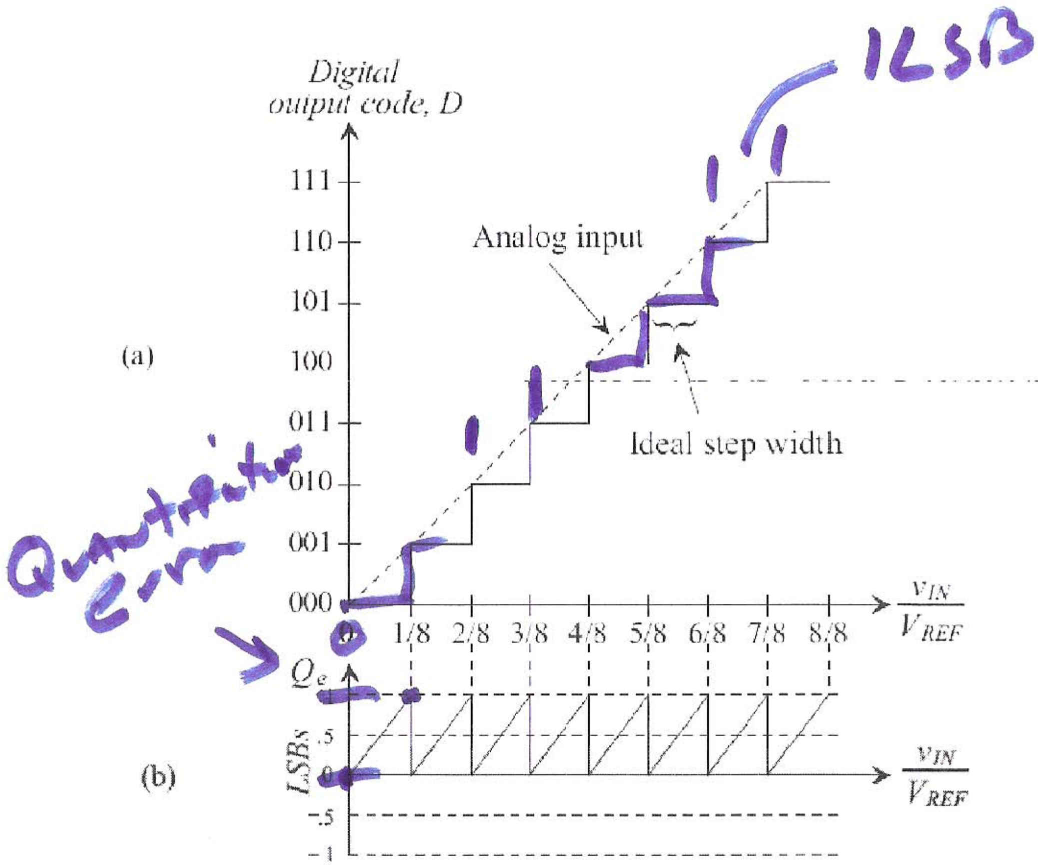


Figure 28.19 (a) Transfer curve for an ideal ADC and (b) its corresponding quantization error.

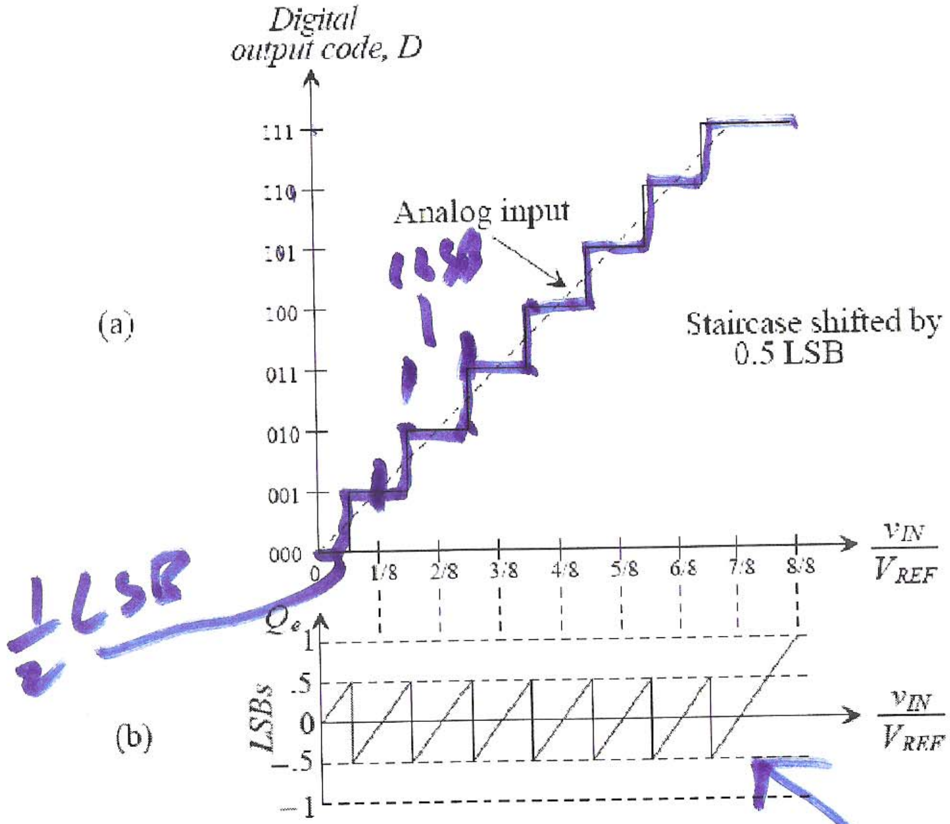
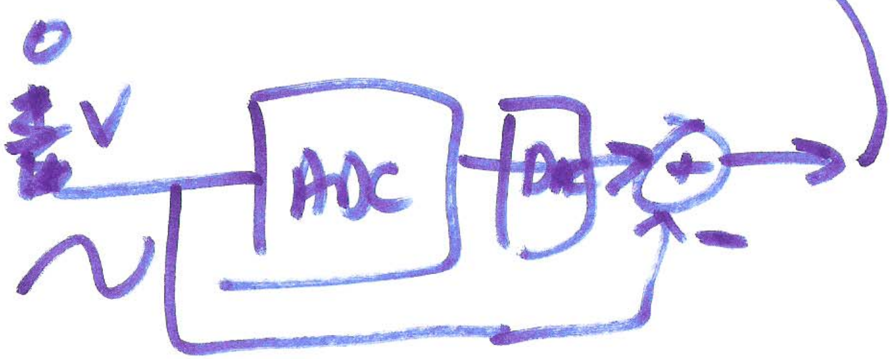


Figure 28.20 (a) Transfer curve for an ideal 3-bit ADC with (b) quantization error centered about zero.



$$V_{Q_e,rms} = \frac{1\,LSB}{\sqrt{12}}$$

20)

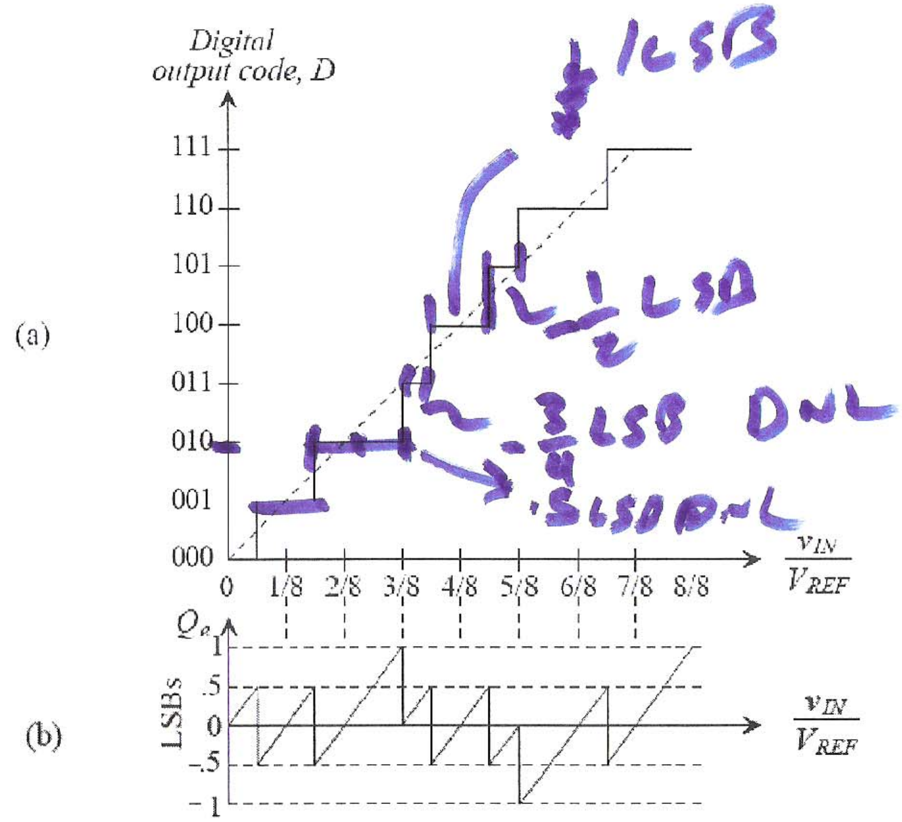


Figure 28.21 (a) Transfer curve for a nonideal 3-bit ADC used in Ex. 28.4 with (b) quantization error illustrating differential nonlinearity.

DNL eRRor

21)

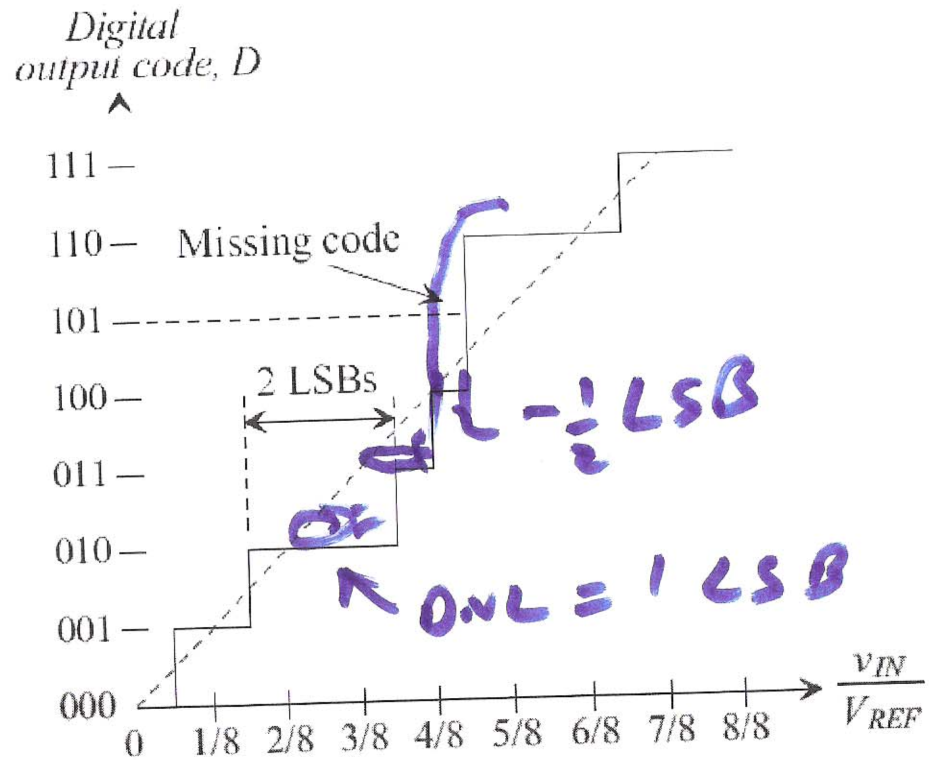


Figure 28.22 Transfer curve for a nonideal 3-bit ADC with a missing code.

22)

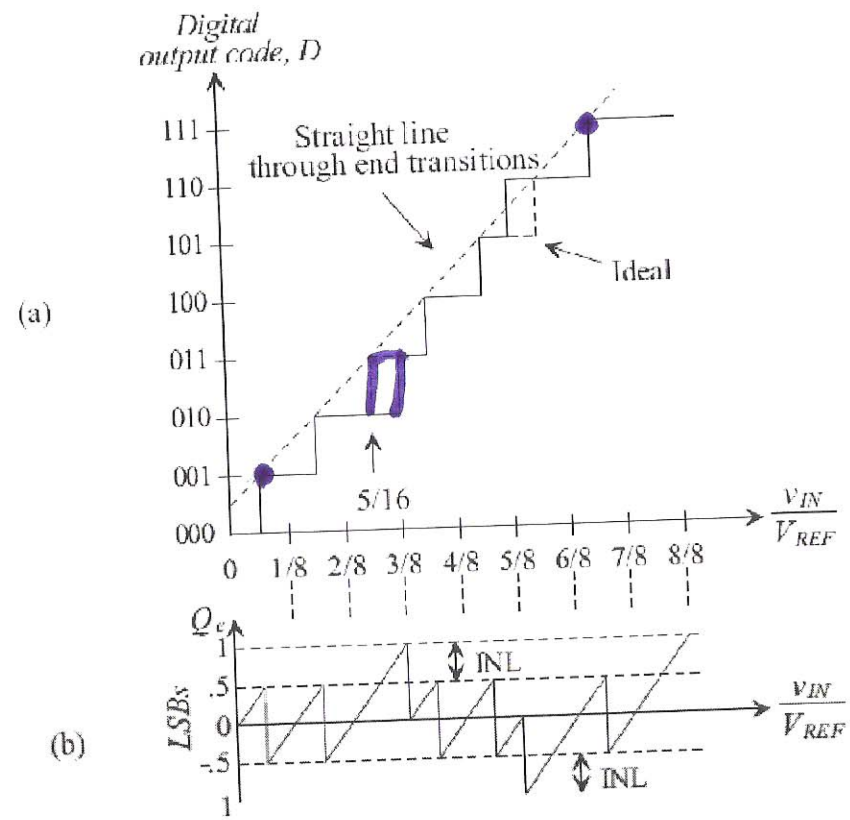


Figure 28.23 (a) Transfer curve of a nonideal 3-bit ADC and (b) its quantization error illustrating INL.

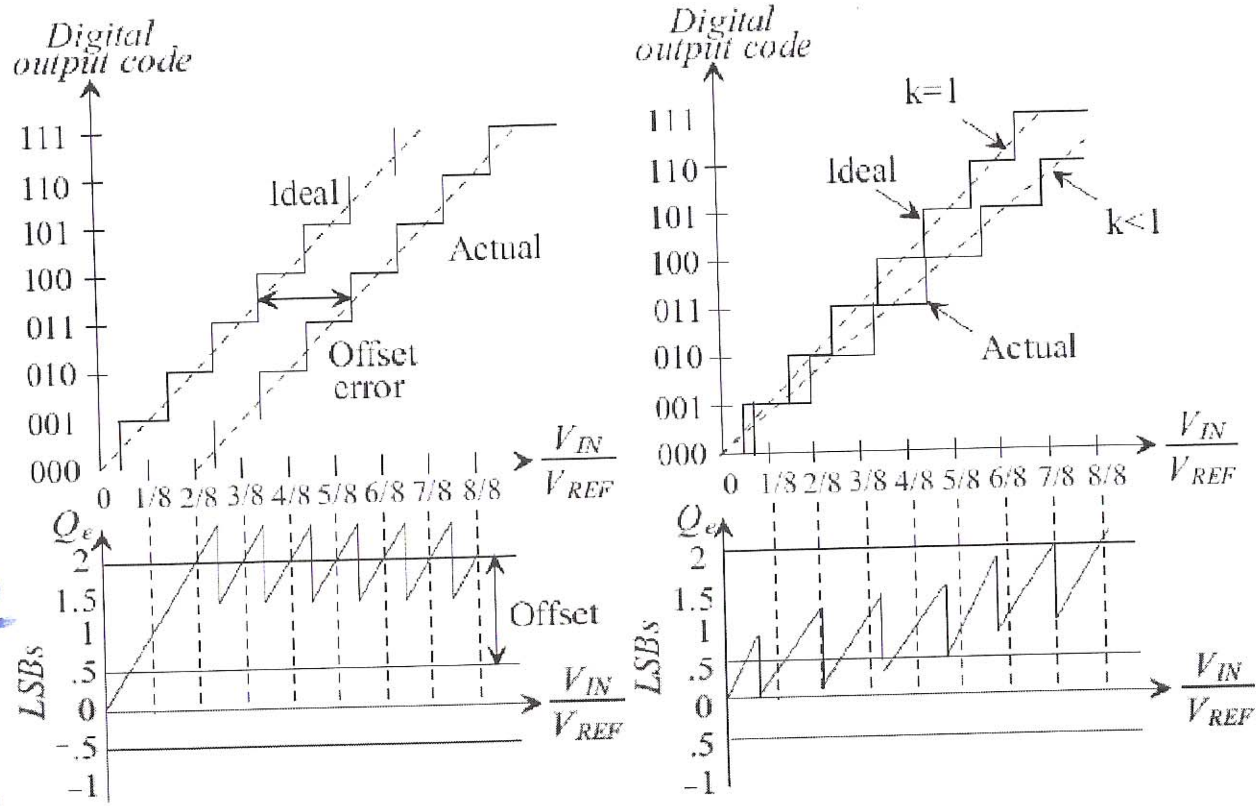
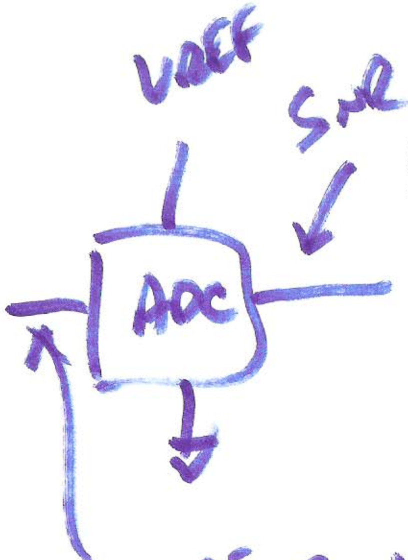


Figure 28.24 Transfer curve illustrating (a) offset error and (b) gain error.



$\frac{VREF}{2}\sin 2\pi f \cdot t + \frac{VREF}{2}$ no distortion SNR

$$SNR_{OT} = \frac{\frac{VREF}{2\sqrt{2}}}{VREF/2^N} = \frac{2^N}{2\sqrt{2}} = \frac{2^{N-1}}{\sqrt{2}}$$

Dynamic Range

$$DR = \frac{\text{MAX OUTPUT}}{\text{MIN OUTPUT}} = \frac{V_{REF} - V_{REF}/2^N}{V_{REF}/2^N}$$

$$= 2^N - 1$$

So $$DR = 20 \log(2^N - 1)$$

$$\approx \underline{\underline{6.02 \cdot N}} \text{ dB}$$

$$SNR = 20\log\frac{V_{REF}/2\sqrt{2}}{Q_e}$$

$$= 20\log\frac{V_{REF}/2\sqrt{2}}{V_{LSB}/\sqrt{12}}$$

$$= 20\log\frac{V_{REF}/2\sqrt{2}}{V_{REF}/(2^N\cdot\sqrt{12})}$$

$$\boxed{SNR = 6.02N + 1.76}$$

ENOB

$$= \frac{2^N\cdot\sqrt{12}}{2\sqrt{2}} = 2^{N-1}\cdot\sqrt{6}$$

$$SNR = 20\log\left(2^{N-1}\cdot\sqrt{6}\right)$$

$$= 20\log 2\cdot(N-1) + 20\log\sqrt{6}$$

7.78

$$= \overset{6.02}{\cancel{7.78}}\,(N-1)$$

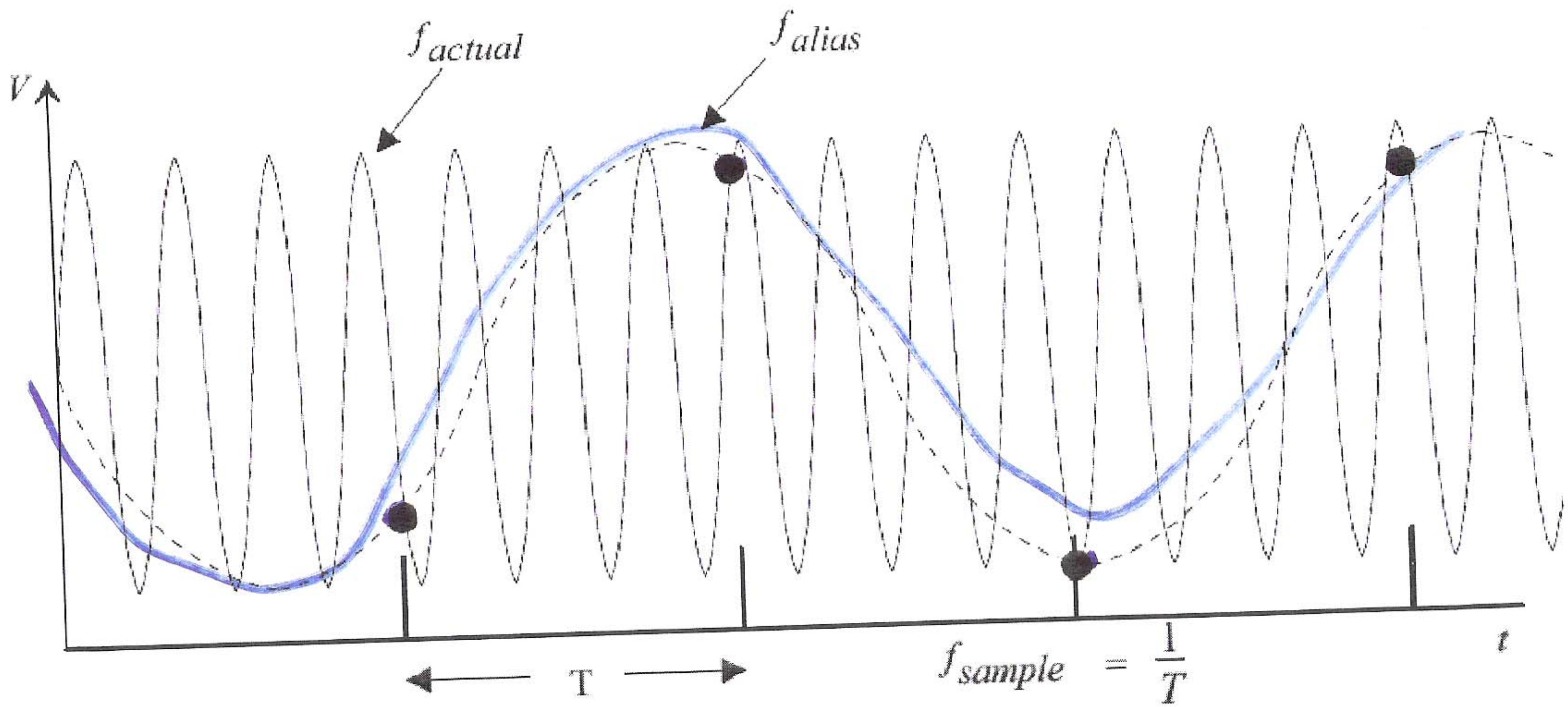


Figure 28.25 Aliasing caused by undersampling.

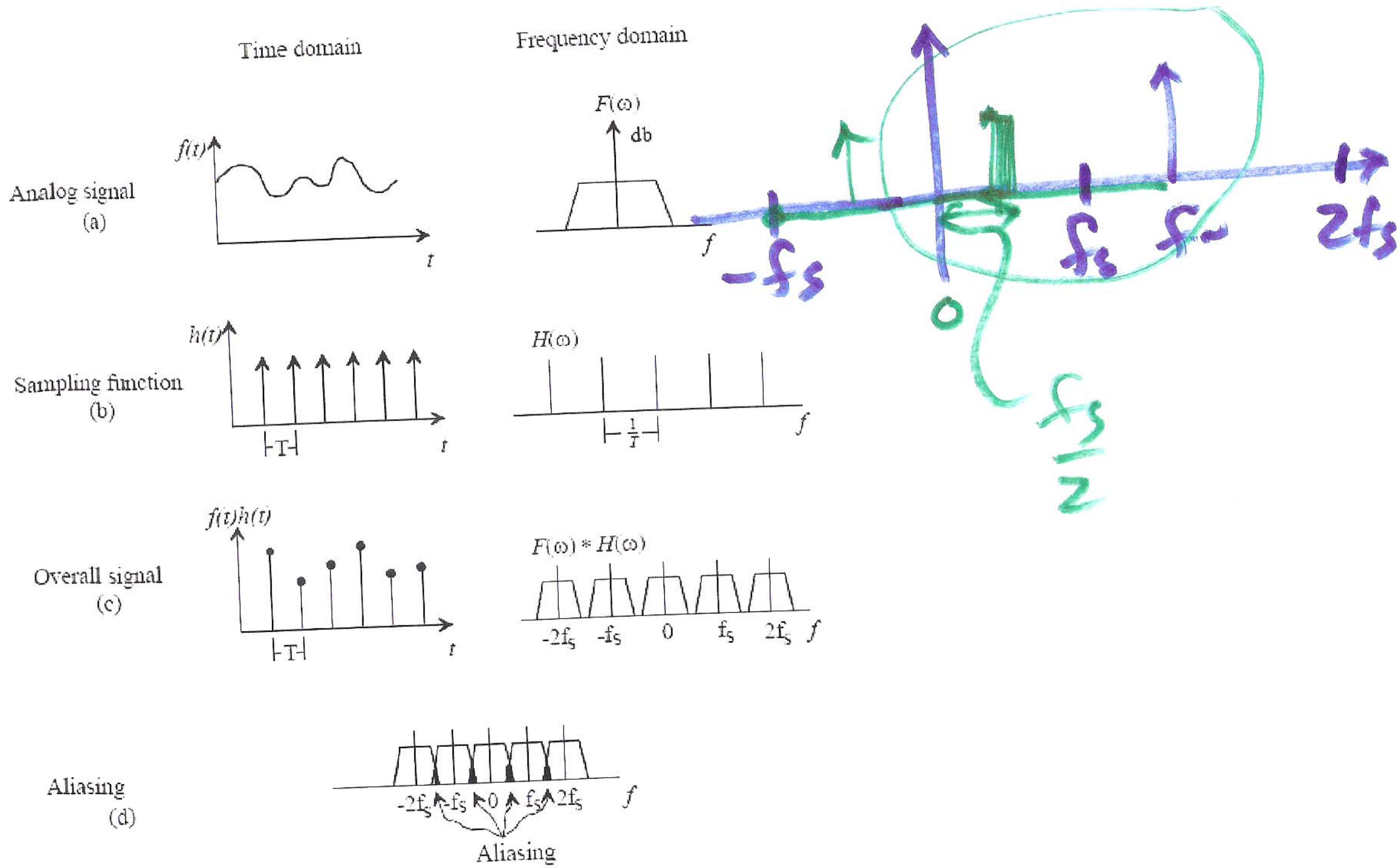


Figure 28.26 Illustration of aliasing in the time and frequency domain. (a) The analog signal; (b) the sampling function; (c) the overall signal; and (d) aliasing in the frequency domain.

28)