

Chapter 1 Signals and Signal Processing

1.1 Signals, Information, Interference, and Noise

1.2 Signal Classification

Analog and Digital Signals

- Dc or ac
- Narrowband or broadband
- Signal conditioning
- ADC
- Quantization noise $\pm \frac{q}{2}$

time	amplitude
continuous	continuous
discrete (sampling)	discrete (quantization)

Reference to ground

Single-ended Signals

- Unipolar or bipolar
- Grounded or floating or driven off ground with common-mode signal

Ex. 1.1

Differential Signals

- Differential voltage and common-mode voltage
- Grounded or floating or isolated
- Balanced or unbalanced

$$V_d = V_H - V_L, \quad V_c = \frac{V_H + V_L}{2}$$

Ex 1.2

Low-impedance or High-impedance Signals

- Voltage source for low-impedance signal
- Current source for high-impedance signal
- Current signals: single-ended or differential

Thevenin
Norton

Ex 1.3

"Signal"
→ Noise

1.3 Dynamic Range (DR) and Signal-to-Noise Ratio (SNR)

Fig 1.7, Fig 1.8

Ex) ADC

- DR = Measurement range / Resolution or DR = $20 \log \left\{ \frac{\text{Max} - \text{Min}}{\text{Resolution}} \right\}$ [dB]
- Sensitivity \rightarrow detectable minimal variation
- SNR = $10 \log(\text{Signal Power} / \text{Noise Power})$ [dB]

Ex) Gaussian

\rightarrow useful for random signals

1.4 Functions in Analog Signal Processing

Linear and Nonlinear Functions

- Homogeneity and addition
- Superposition principle
- Time-invariant or time-varying
- Transfer function of a linear and time-invariant system
- Ideal transfer function
- Amplitude and phase distortion

~~time-invariant and time-varying~~
 ← linear and time-invariant

Fig 1.9

$$P(f) = H(f) S(f)$$

↑ ↑
output input

Amplitude and Level Matching

- Amplification: range matching
- Level shifting: level or zero matching

$$p(t) = k s(t - t_0)$$

$$P(f) = k e^{-j2\pi f t_0} S(f)$$

$$H(f) = k / e^{-j2\pi f t_0}$$

Ex 1.4

Impedance Adaptation (Buffering)

- Source and load
- Loading effect
- Buffering

Ex 1.5

Domain Conversions

- Voltage or current
- Frequency or time
- Amplitude or phase
- Pulse width and others

Fig 1.11

Table 1.1

Filtering

passive filter
 active filter

Linearization

- differential: $s(t) + u(t) - (-s(t) - u(t)) = 2s(t)$
- fitting
- division, etc.

Interference Compensation

Level Comparison and Threshold Detection

Fig 1.12

Fig. 1.13

Terminal Matching

1.5 Errors in Analog Signal Processing

Error Classification

- Absolute error or relative error
- Magnitude error or phase error
- Additive error or zero (offset) error
- Multiplicative (gain or slope) error
- Nonlinear error

$$\left\{ \begin{aligned} e &= \text{Actual value} - \text{Ideal Value} \\ \epsilon &= \frac{e}{\text{Ideal Value}} \times 100 (\%) \end{aligned} \right.$$

Ex 1.6

Systematic Errors

- Calibration

Random Errors

- Averaging

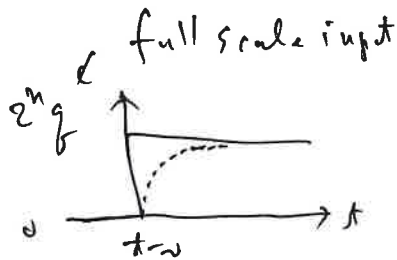
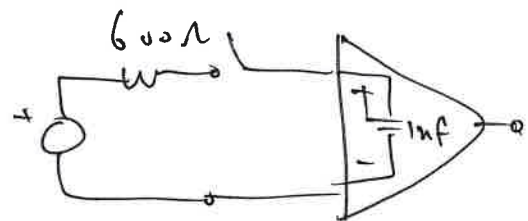
Static Errors

Dynamic Errors

- Transient error
- Steady-state error

$13 \mu s$
 $36-77$
 5.5

Ex 1.7



$$\epsilon = \frac{q/2}{2^n q} = 2^{-(n+1)}$$

$$t_\epsilon = -\tau \ln \epsilon = (600 \times 10^{-9}) \ln 2^{-(n+1)}$$

$$n = 12 \text{ bit} \Rightarrow t_\epsilon = 5.5 \mu s$$

Ex 1.8

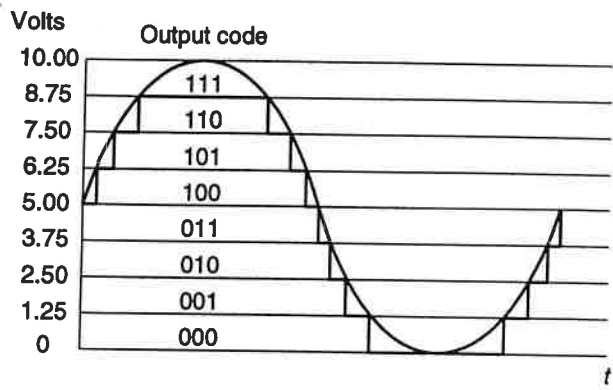


FIGURE 1.2 Sine waveform and its digitized version using a three-bit code.

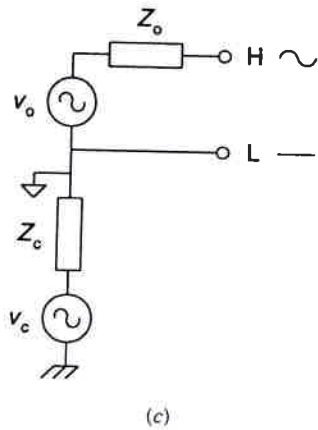
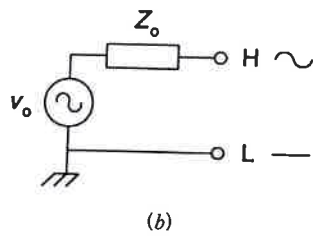
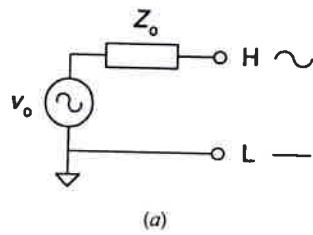


FIGURE 1.3 (a) Single-ended and floating signal. (b) Single-ended and grounded signal. (c) Single-ended signal with a common-mode voltage, v_c .

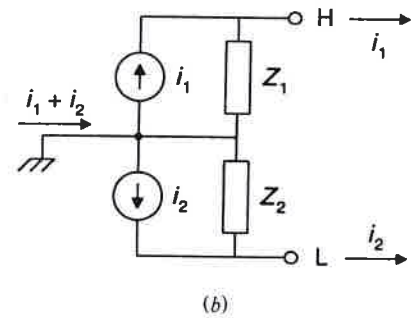
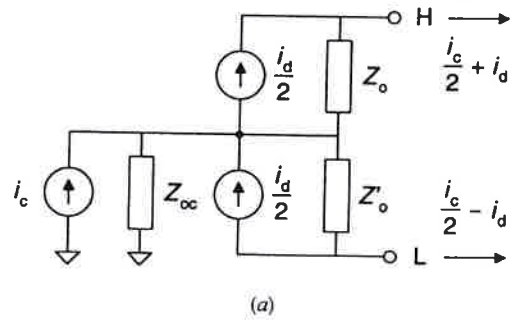
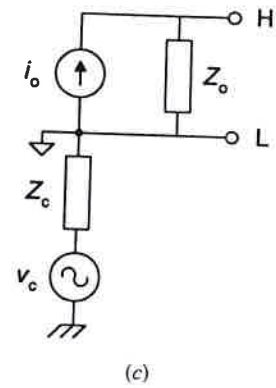
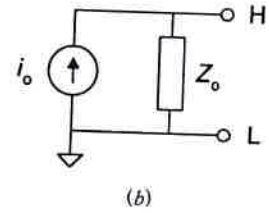
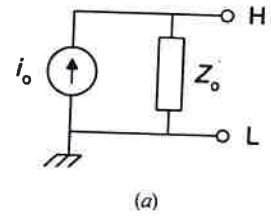
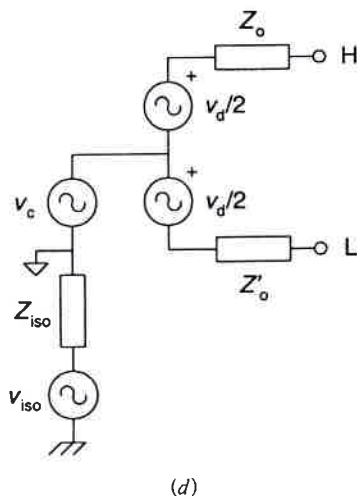
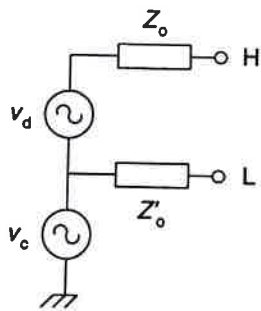
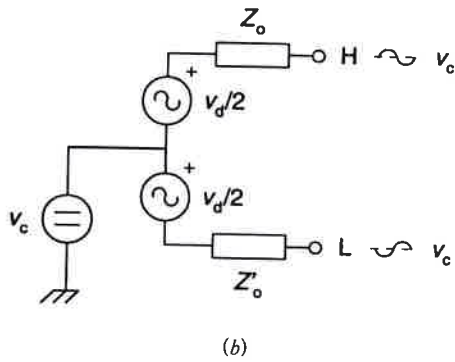
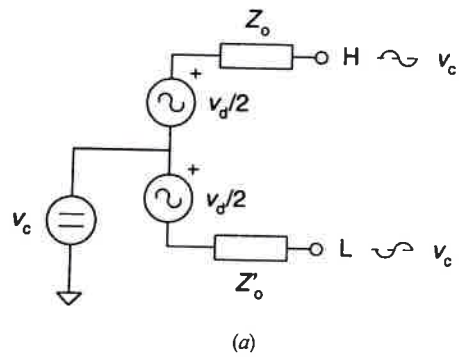


FIGURE 1.4 Differential signals. (a) Differential and floating signal. (b) Differential and grounded signal with common-mode voltage to ground. (c) Equivalent circuit for (b) when $v_d \ll v_c$. (d) Differential and floating signal with isolation-mode voltage.



FIGURE 1.7 General structure of a system that obtains a digital code D from a measurand x .

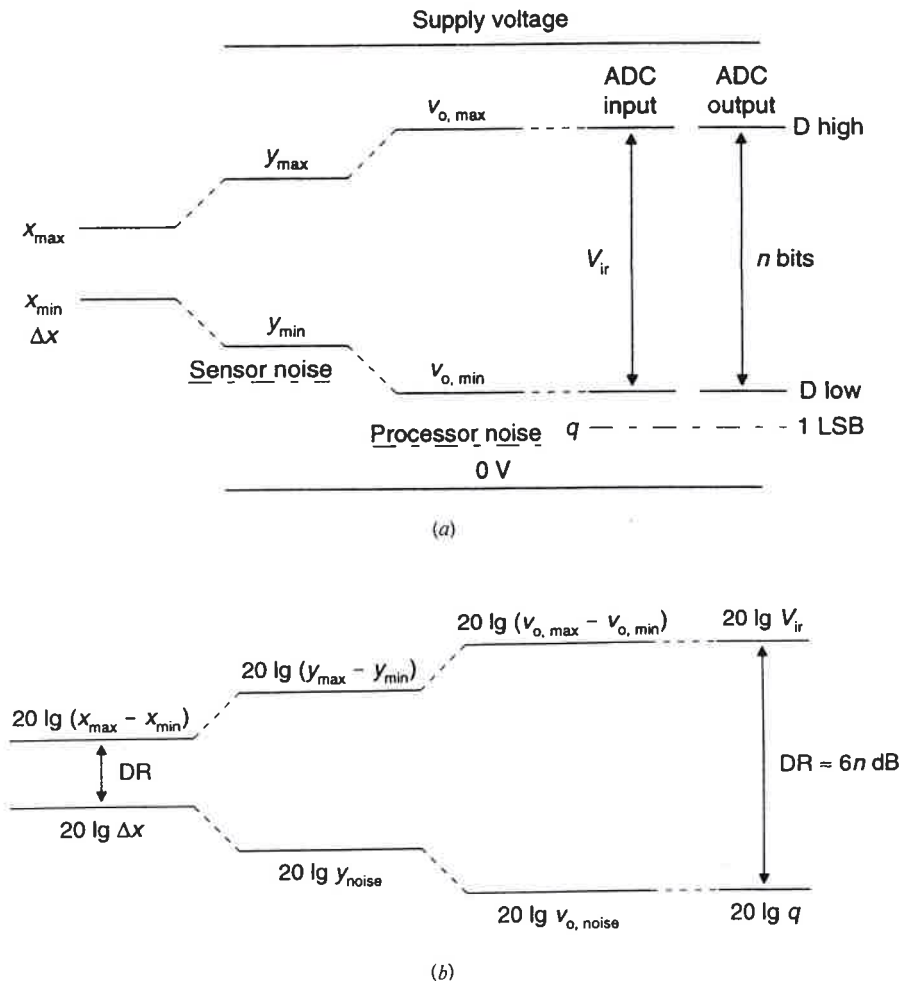


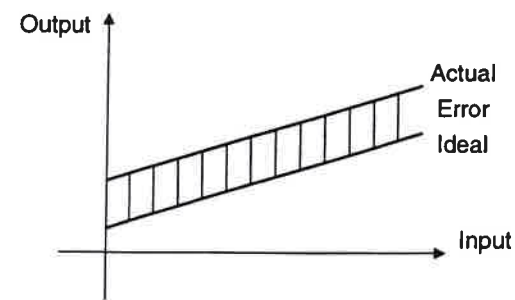
FIGURE 1.8 Measurement and signal range (a) and dynamic range (b) for the system in Figure 1.7.

TABLE 1.1 Common Terminology for Components and Circuits for Signal Amplification and Domain Conversion

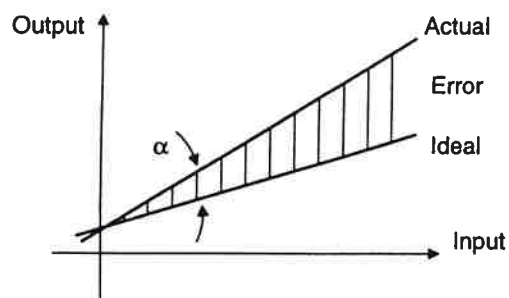
Input	Output	
	Voltage	Current
Voltage	Voltage amplifier Voltage buffer Voltage-controlled voltage source (VCVS)	Transconductance amplifier Transadmittance amplifier Voltage-controlled current source (VCCS)
Current	Norton amplifier Current integrator Transimpedance amplifier Current-controlled voltage source (CCVS)	Current mirror Current conveyor Current amplifier, current pump Current-controlled current source (CCCS)

TABLE 1.2 Time t_ϵ After Which the Relative Transient Error for a Step Input to a Low-Pass First-Order System with Time Constant τ Will Be Smaller Than a Given ϵ

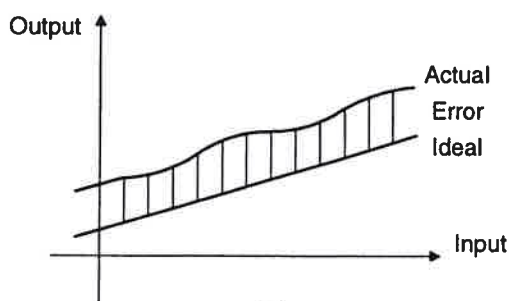
ϵ	t_ϵ	ϵ	t_ϵ
10^{-2}	4.6	10^{-4}	9.2
2^{-8}	5.5	2^{-14}	9.7
10^{-3}	6.9	2^{-16}	11.1
2^{-10}	6.9	2^{-18}	12.5
2^{-11}	7.6	2^{-20}	13.9
2^{-12}	8.3	2^{-22}	15.3
2^{-13}	9.0		



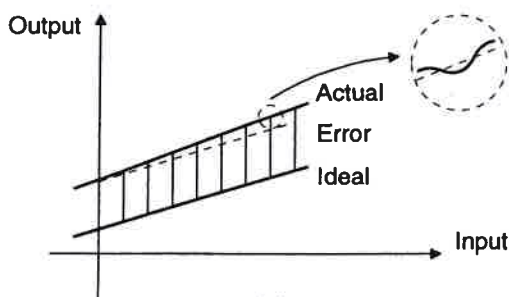
(a)



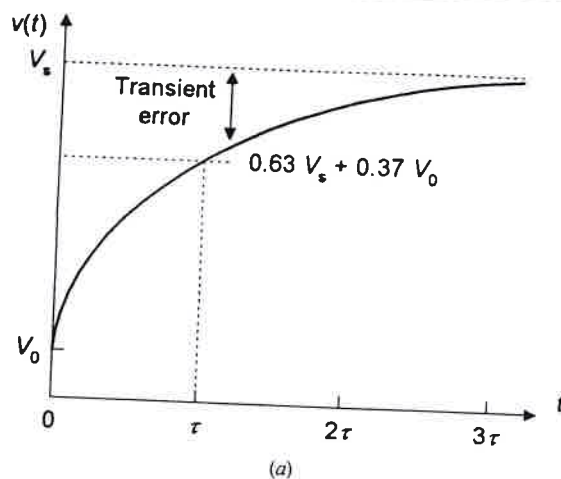
(b)



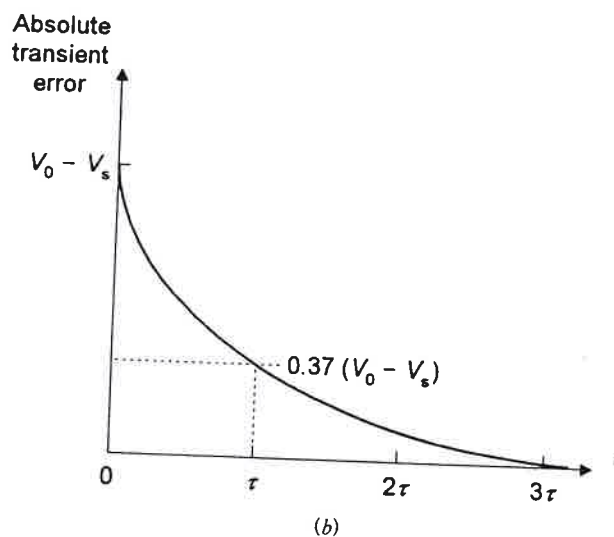
(c)



(d)



(a)



(b)

FIGURE 1.15 (a) Step response of a first-order low-pass system; (b) the resulting absolute transient error.

TABLE 1.3 Corner Frequency f_c for a Low-Pass First-Order System When the Maximal Amplitude Error Accepted for Frequencies Below f_c is ϵ

ϵ	f_c/f_ϵ	ϵ	f_c/f_ϵ
10^{-2}	7	10^{-4}	71
2^{-8}	11.3	2^{-14}	91
10^{-3}	22.4	2^{-16}	181
2^{-10}	22.6	2^{-18}	362
2^{-11}	32	2^{-20}	724
2^{-12}	45.5	2^{-22}	1448
2^{-13}	64		

* ASP p19 Ex 1.4

Temperature range: $-40^{\circ}\text{C} - +55^{\circ}\text{C}$

Resolution: 0.1°C

MLM Sensitivity: $1\text{mV}/^{\circ}\text{C}$

ADC input range: $0 - 10\text{V}$

①
$$\text{DR} = 20 \log_{10} \frac{55 - (-40)}{0.1} = 59.55 \text{ dB}$$

\Rightarrow 7th stage $\Rightarrow \text{DR} > 60 \text{ dB}$

ADC: $\text{DR} \approx \text{bn} = 60 \Rightarrow n = 10 \text{ bit}$

② MLM output

$$\begin{aligned} y_{\max} - y_{\min} &= S(x_{\max} - x_{\min}) \\ &= (1 \text{ mV}/^{\circ}\text{C})(55 + 40)^{\circ}\text{C} = 95 \text{ mV} \end{aligned}$$

③ Gain, $G = \frac{10 - 0}{0.095} = 105$

④ MLM ~~noise~~ ~~noise~~ ~~noise~~

$$y_{\text{noise}} = (1 \text{ mV}/^{\circ}\text{C})(0.1^{\circ}\text{C}) = 0.1 \text{ mV}$$

\pm noise ~~noise~~ ~~noise~~ ~~noise~~ $(\pm \frac{q}{2})$

$$\pm V_{\text{noise}} = \pm \frac{q}{2} = \pm \frac{1}{2} \cdot \frac{10}{2^{10}} = \pm 4.9 \text{ mV}$$

⑤ $(1 \text{ mV}/^{\circ}\text{C})(-40^{\circ}\text{C}) = -40 \text{ mV} \xrightarrow{\times G} -4.2 \text{ V}$

\Rightarrow level shifting of $+4.2 \text{ V}$

$\Rightarrow 0 - (1 \text{ mV}/^{\circ}\text{C})(55^{\circ}\text{C})(105) = 0 - 9.975 \text{ V}$



정확도 1%는 1비트 12;

$$\text{Res. lutron} : (0.1^\circ\text{C}) (1\text{mV}/^\circ\text{C}) = 0.1\text{mV}$$

$$2^n = \frac{10\text{V}}{0.1\text{mV}} = 10^5 \Rightarrow n = 16.6$$

\Rightarrow 17 bit ADC