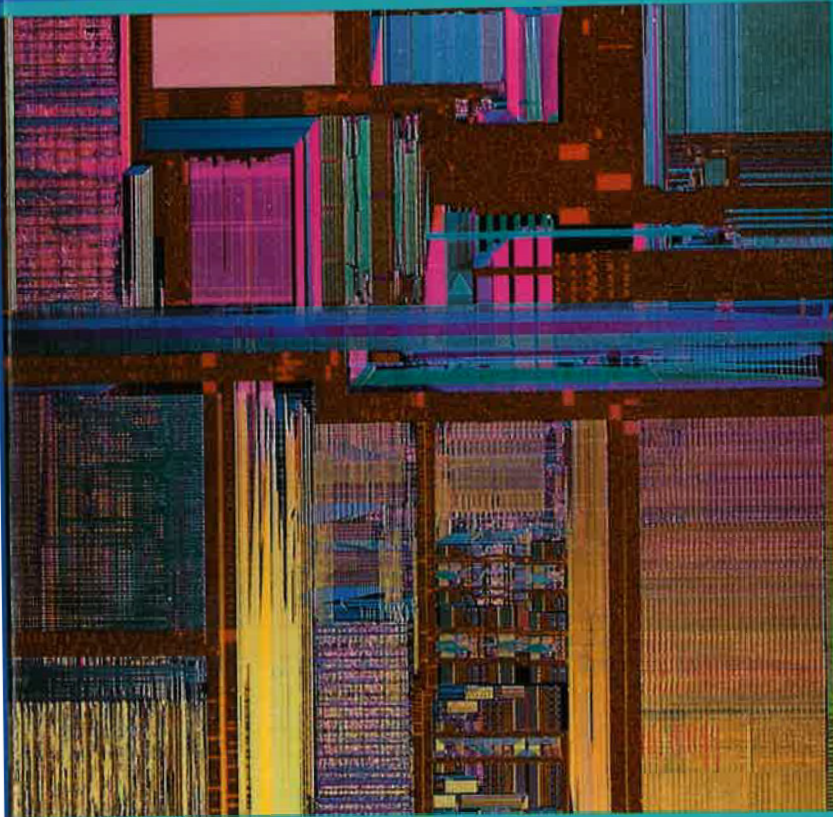


Introduction to

ELECTRICAL ENGINEERING



J. DAVID IRWIN

DAVID V. KERNS, JR.



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TK145
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Contents

Preface	xiii	Sources	24
P.1 Purpose	xiii	Ideal Circuit Model	27
P.2 Features	xiv	1.3 Summary	27
P.3 Using This Text	xv	Problems	29
P.4 System of Units	xvi		
P.5 Notation	xviii		
INTRODUCTION	1	PART I—CIRCUITS	33
1. Introduction	3	2. DC Circuits	35
1.1 Overview	3	2.1 Introduction	35
The Electrical Engineer	3	2.2 Ohm's Law	35
The Field of Electrical Engineering	4	2.3 Kirchhoff's Laws	38
1.2 Basic Concepts	11	2.4 Single-loop Circuits	42
Charge	11	2.5 Single-node-pair Circuits	48
The Force Between Two Charges	11	2.6 Resistor Combinations	53
Conductors and Insulators	12	2.7 Nodal Analysis	57
Current and Voltage	13	2.8 Loop and Mesh Analysis	63
Reference Directions and Polarities	19	2.9 Superposition	65
Power	21	2.10 Source Exchange	68
Modeling	22	2.11 Thevenin's and Norton's Theorems	70
Ideal Circuit Elements	23	2.12 DC Measurements	77
		The D'Arsonval Meter Movement	77
		Current Measurement	77
		Voltage Measurement	79

Resistance Measurement	80	5.4 Effective or RMS Values	176
Power Measurements	82	5.5 The Power Factor	179
2.13 Summary	82	5.6 Complex Power	181
Problems	83	5.7 Power Factor Correction	185
3. Transient Analysis	91	5.8 Power Measurements	187
3.1 Introduction	91	5.9 Typical Residential ac Power Circuits	189
3.2 Capacitors and Inductors	91	5.10 Three-Phase Circuits	193
Capacitors	91	Balanced Wye-Wye Connection	196
Inductors	95	Balanced Wye-Delta Connection	200
3.3 First-order Networks	100	Delta-Connected Source	203
Mathematical Development of the Response	100	Power Relationships	205
Equations	102	5.11 Summary	206
The Analysis Procedure	102	Problems	207
3.4 Second-order Circuits	110	6. Network Frequency Characteristics	213
Mathematical Development of the Response	110	6.1 Introduction	213
Equations	114	6.2 Sinusoidal Frequency Analysis	213
The Analysis Procedure	120	6.3 Passive Filter Networks	216
3.5 Summary	121	6.4 Resonant Circuits	223
Problems	121	6.5 Summary	233
4. AC Steady State Analysis	127	Problems	234
4.1 Introduction	127	PART II—BASIC ELECTRONICS	237
4.2 Sinusoidal Functions	127	7. Overview of Basic Concepts in Electronics	239
4.3 The Sinusoidal Function/Complex Number Connection	130	7.1 Introduction	239
4.4 Phasor Relationships for Circuit Elements	134	7.2 Energy and Power	239
4.5 Impedance and Admittance	136	7.3 Signals and Pulses; Analog and Digital	240
4.6 $Y \rightleftharpoons \Delta$ Transformations	142	7.4 Amplifiers and Analog Systems	242
4.7 Basic Analysis Using Kirchhoff's Laws	144	7.5 Modulation and Demodulation; Encoding and Decoding	246
4.8 Nodal Analysis	147	7.6 Digital Systems, Information, and Gates	248
4.9 Mesh and Loop Analysis	149	A/D and D/A Converters	249
4.10 Superposition	150	Logic Gates	250
4.11 Source Transformation	152	7.7 Summary	251
4.12 Thevenin's and Norton's Theorems	154	Problems	252
4.13 Nonsinusoidal Steady State Response	157	8. Semiconductors, Diodes, and Applications	255
Exponential Fourier Series	158	8.1 Introduction	255
Network Response	162	8.2 Historical Perspective	257
4.14 Summary	165	8.3 p- and n-Type Semiconductors	257
Problems	165		
5. Steady State Power Analysis	172		
5.1 Introduction	172		
5.2 Instantaneous Power	172		
5.3 Average Power	174		

8.4 Current Conduction in Semiconductors	260	BJT Modes of Operation: Saturation, Active, and Cutoff	326
Drift	261	The BJT in the Active Region	327
Diffusion	263	The Common Emitter (CE) Configuration	330
8.5 The p - n Junction Diode	265	BJT Circuit Models for Switching	330
8.6 Diode Circuit Models	267	9.10 The Ebers-Moll BJT Model	333
The Ideal Diode	268	9.11 BJT Output Curves	335
The Diode Equation and Model	272	9.12 The NOT Gate: BJT Implementation	337
The Piecewise Linear Diode Model	277	9.13 Turning the Saturated Transistor Off	338
8.7 Diode Logic Gates	281	9.14 The PNP Transistor	338
8.8 Power Supply Circuits	282	9.15 Summary	338
Half-Wave Rectification	283	Problems	340
Filter Circuits for Half-Wave Rectifiers	287		
Full-Wave Rectification	289		
8.9 Wave Shaping: Clippers and Clampers	291	PART III—DIGITAL SYSTEMS	345
Clipper Circuits	291		
Clamping Circuits	292		
8.10 The Zener or Avalanche Diode	293	10. Digital Switching Circuits: The Logic Gate	347
8.11 Graphical Solutions and Load Lines	295	10.1 Introduction	347
8.12 Photo-Diodes and Light Emitting Diodes	296	10.2 Ideal Logic Gates: Building Blocks for Digital Systems	348
8.13 Small Signals: The Diode as an Analog Attenuator	296	The NAND Gate	348
8.14 Summary	298	The NOR Gate	348
Problems	299	The Exclusive-OR Gate	349
		The NOT Gate	349
		10.3 Real Logic Gates: Speed, Noise Margin, and Fanout	350
		Finite Switching Speed	350
		Real Logic Levels—Noise Margin	353
		10.4 Basic Logic Gates Using Relays	354
		The NAND Gate: Using Relays	355
		The NOR Gate: Using Relays	356
		10.5 Basic Logic Gates Using MOSFETs:	
		NMOS and CMOS	356
		NMOS with Passive Loads	357
		NMOS with Active (Enhancement-Mode) Loads	359
		NMOS with Active (Depletion-Mode) Loads	362
		CMOS: Complementary MOS	363
		10.6 Basic Logic Gates Using BJTs: DTL, TTL, and ECL	366
		DTL: Diode Transistor Logic	367
		TTL: Transistor Transistor Logic	369
		Schottky TTL—A Nonsaturating Bipolar Logic Family	374
		ECL—Emitter-Coupled Logic	375
		Output Level Shifting	379
9. The Transistor as a Switch: FETs and BJTs for Digital Applications	308		
9.1 Introduction	308		
9.2 An Analogy: The Relay as a Current Control Device	309		
9.3 The NOT Gate: Relay Implementation	310		
9.4 The MOSFET as a Switch	311		
MOSFET Structure	312		
MOSFET Device Operation	313		
Threshold Voltage, V_T	314		
The Closed Switch: MOSFET in the Ohmic Region	315		
MOSFET Circuit Model for Switching	316		
The p -Channel MOSFET	317		
MOSFET Topology: The Top View	318		
9.5 The NOT Gate: MOSFET Implementation	319		
9.6 MOSFET Output Curves	321		
9.7 Depletion-Mode MOSFETs	322		
9.8 The JFET	323		
9.9 The BJT as a Switch	325		
BJT Structure	325		

x Contents

10.7 Summary	381	13.2 Integrated Circuit Technologies and Structures	448
Problems	382	13.3 Fabrication Technologies	450
11. Digital Logic Circuits	389	Grown Layers and Deposited Layers	450
11.1 Introduction	389	Photolithography	453
11.2 Number Systems	389	Doping	455
11.3 Boolean Algebra	392	A Simple Example of IC Processing	456
11.4 Truth Tables	394	13.4 Resistivity and Sheet Resistance	458
11.5 Switching Networks	395	13.5 IC Design and Layout	460
11.6 Canonical Forms	397	13.6 Design Approach: Custom, Standard Cells, and Gate Arrays	465
11.7 Function Minimization	401	13.7 IC Manufacturing: Yield, Wafer Cost, Packaging, and Testing	470
11.8 Combinational Logic Design	403	13.8 Summary	471
11.9 Sequential Logic Circuits	408	Problems	472
The Structure of Sequential Logic Circuits	409	PART IV—ANALOG SYSTEMS	475
State Tables and Diagrams	409	14. Op-Amps: Introduction to Amplifiers and Analog Systems	477
Clocked Memory	411	14.1 Introduction	477
Analysis of Synchronous Sequential Circuits	412	14.2 The Ideal Op Amp	479
Synthesis of Synchronous Sequential Circuits	414	14.3 The Inverting Amplifier	480
11.10 Summary	418	14.4 The Principle of Negative Feedback	481
Problems	418	14.5 The Noninverting Amplifier	483
12. Microprocessor Systems	424	14.6 The Unity-Gain Buffer	484
12.1 Introduction	424	14.7 The Summing Circuit	486
12.2 The Generic System	424	14.8 The Integrator	487
12.3 Microcomputers	426	14.9 The Active Filter	488
Personal Computers	426	14.10 The Current-to-Voltage Converter	490
Workstations	427	14.11 Summary	491
System Software	428	Problems	492
12.4 Microprocessor System Integration	429	15. The Large-Signal Analysis of MOSFETs and BJTs for Analog Applications	496
Considerations	430	15.1 Introduction	496
Speed Requirements	430	15.2 dc Biasing	497
Interface Design	430	15.3 Large-Signal Amplifiers: Using MOSFETs	497
Software Tools	430	The Common Source Amplifier	497
12.5 System Integration Using an IBM PC or Compatible	431	The Self-Bias Circuit	500
Speed Considerations	431	15.4 Other FET Amplifier Configurations	503
Interface Design	435	The Common Gate Amplifier	503
Software Tools	438	The Common Drain Amplifier	505
12.6 Summary	440	Current Mirrors	506
Problems	441	15.5 Power and Voltage Limits of MOSFETs	507
13. Microelectronics Design and Manufacturing	443		
13.1 Introduction	443		

15.6 Large-Signal Amplifiers: Using BJTs	509	17. Advanced Analog Circuit Concepts and Applications	562
The Common Emitter Amplifier	509	17.1 Introduction	562
The BJT Self-Bias Circuit	511	17.2 Multi-Stage Amplifiers	563
BJT Self-Bias Circuit—Complete Analysis	513	17.3 Frequency Response	565
15.7 Other BJT Amplifier Configurations	515	17.4 Amplifier Low-Frequency Response	566
The Common Base Amplifier	516	17.5 The Miller Effect	570
The Common Collector Amplifier	517	17.6 Amplifier High-Frequency Response	571
Current Mirrors Using BJTs	518	High-Frequency Model for MOSFETs	572
15.8 Power and Voltage Limits of BJTs	519	Common Source Amplifier	573
15.9 Thyristors and Silicon-Controlled Rectifiers (SCRs)	519	Common Gate Amplifier	574
Thyristors	520	High Frequency Model for BJTs	575
Silicon-Controlled Rectifiers	521	Common Emitter Amplifier	576
Motor Speed Control	521	Frequency Dependent Beta	578
15.10 Summary	522	Common Base Amplifier	580
Problems	523	Voltage Follower Circuits: Common Collector and Common Drain	581
16. The Small-Signal Analysis of MOSFETs and BJTs	529	17.7 The Differential Amplifier	581
16.1 Introduction	529	dc Analysis	583
Diode dc Resistance	530	Differential Mode Gain	584
Diode Small-Signal (Dynamic or ac) Resistance	530	Common Mode Gain	585
Nomenclature Review	531	Input Offset Voltage	586
16.2 General Linear Two-Port Models	531	Input Bias Current and Bias Current Offset	588
16.3 The MOSFET Small-Signal Model	534	Slew Rate	588
16.4 MOSFET Amplifier Circuits—Small-Signal Analysis	537	Comparators	588
The Common Source Amplifier	537	17.8 Oscillators	589
The Common Gate Amplifier	540	Phase Shift Oscillator	590
The Common Drain Amplifier	542	Resonant Circuit Oscillator	590
Summary of Important MOSFET Relationships	542	Relaxation Oscillator	591
Voltage Gain Loss at the Input Due to Finite Source Resistance	544	17.9 Power Amplifiers and Output Stages	592
16.5 The BJT Small-Signal Circuit Model	544	17.10 Summary	595
The Common Emitter Model	545	Problems	596
The Common Base Model	548	PART V—ELECTROMECHANICAL SYSTEMS AND SAFETY	601
16.6 BJT Amplifier Circuits—Small-Signal Analysis	550	18. Magnetically Coupled Circuits and Transformers	603
The Common Emitter Amplifier	550	18.1 Introduction	603
The Common Collector Amplifier	553	18.2 Magnetic Circuits	603
The Common Base Amplifier	554	18.3 Mutual Inductance	609
16.7 Summary of Important BJT Relationships	555	18.4 The Linear Transformer	613
16.8 Summary	555	18.5 The Ideal Transformer	616
Problems	558	18.6 Transformer Applications	620

18.7 Summary	623	Definition	692
Problems	623	Some Useful Transform Pairs	692
19. dc Machines	628	22.3 Transfer Functions	695
19.1 Introduction	628	22.4 Block Diagrams	698
19.2 Fundamental Concepts	628	22.5 System Stability	702
19.3 A Simple Rotating Machine	630	22.6 Root Loci	703
19.4 The Basic dc Machine	635	22.7 Bode Plots	707
19.5 Equivalent Circuits and Analysis	637	22.8 Compensation	710
19.6 Applications of dc Machines	643	22.9 Summary	713
19.7 Summary	649	Problems	713
Problems	649	23. Communications	716
20. ac Polyphase Machines	653	23.1 Introduction	716
20.1 Introduction	653	23.2 Example of Typical Communications System	716
20.2 The Revolving Magnetic Field	653	23.3 Types of Communication Systems	718
20.3 The Polyphase Induction Machine:		Direct Baseband Systems	718
Balanced Operation	656	Carrier Transmission Systems	720
Basic Principles of Operation	656	Radio Frequency Transmission	721
The Equivalent Circuit	657	Light Wave Transmission	724
20.4 The Polyphase Synchronous Machine:		23.4 Signals and Their Spectra	725
Balanced Operation	662	Periodic Signals	727
Basic Principles of Operation	662	Nonperiodic Signals	730
The Nonsalient Synchronous Machine		Bandwidth and Sampling	732
Equivalent Circuit	663	23.5 Modulation	734
20.5 ac Motor Applications	671	Amplitude Modulation	734
20.6 Summary	672	Frequency Modulation	740
Problems	672	23.6 AM Demodulation: A Diode in a Radio Receiver	743
21. Electrical Safety	675	23.7 Time Division Multiplexing; Frequency Division Multiplexing	744
21.1 Introduction	675	23.8 Examples of Communications Systems	746
21.2 Human Response to Electrical Shock	675	Television	746
21.3 Ground-Fault Interrupter	677	Satellite Communications	749
21.4 Modeling Techniques	679	Local Area Networks (LANS)	754
21.5 Some Guidelines for Avoiding Injury	685	Cellular Telephones	756
21.6 Summary	686	23.9 Summary	757
Problems	686	Problems	758
PART VI—CONTROLS AND COMMUNICATIONS	689	A Complex Numbers	761
22. Control Systems Analysis	691	B Computer Simulation Tools	764
22.1 Introduction	691	C Fundamentals of Engineering (FE) Exam Review	766
22.2 The Laplace Transform	691	Index	771

CHAPTER

7

Overview of Basic Concepts in Electronics

7.1

Introduction

As we described in Chapter 1, electrical engineering involves the transfer and use of electrical power or information. The utilization of electronics is essential for both of these applications. In general, the field of *electronics* involves the use of devices and circuits which specifically control the flow of electric current to achieve some purpose. All electronic systems involve circuits, and therefore this section of the text builds heavily on the first. Electronic circuits often contain resistors, capacitors, and inductors; however, they also utilize “electronic devices” such as transistors or diodes. These latter nonlinear elements are used to control or direct the current into desired paths in the circuit. Most modern electronic devices are termed *solid state*, because the current flow is achieved through solid materials called *semiconductors*.

This chapter will provide an overview of some of the concepts to be presented in the following chapters and set the stage for a closer look, with some initial understanding of the concepts already in hand.

7.2

Energy and Power

Power can be transferred from its point of generation to its point of use as either ac or dc, or first one and then the other. Alternating current (ac) is almost universally used for distributing power to households throughout the world. There are a number of reasons for this choice. However, the most important consideration is that transformers can only be used with ac, and they allow the voltage and current to be stepped up or down as needed with very little energy loss.

239

An automobile typically utilizes a dc power distribution system at approximately 12 volts. The electrical power, however, is created at the alternator as ac and converted to dc by a process called rectification using electronic devices called diodes. Many electronic circuits require dc to operate. Therefore, they receive their operating power from either batteries, which universally produce dc, or from ac (such as a wall socket), which has been rectified and thus converted to dc. The solar cell is being used more frequently as a power source, particularly in remote locations. When illuminated with a light of constant intensity, such as the sun, it produces dc.

In Chapter 8 we will examine the diode and several electronic circuits using this device that provide electrical power conversion, that is, the changing of electrical energy from one condition to another.

7.3

Signals and Pulses; Analog and Digital

A voltage or current which, in some manner, is varied over time in order to encode and transmit information is called a *signal*. Typically, signals are termed either *analog* if they vary continuously with time, or *digital* if they switch between discrete levels. In a digital signal there are typically two such levels, a “high” level and a “low” level, which are arbitrarily termed a “1” and a “0,” respectively. The information conveyed by the single presentation of a high or low is called a “*bit*.” In the analog signal in Fig. 7.1(a), the amplitude of the signal represents the information at every point in time. For the digital signal in Fig. 7.1(b), the information is conveyed by the presence or absence of a pulse.

A *positive pulse* is a single rectangular-shaped waveform representing a change of voltage or current which goes from a low level to a high level and returns. The waveform for both a positive and a negative pulse is shown in Fig. 7.2. A rectangular pulse always has two edges—one positive going and the other negative going. The digital signal of Fig.

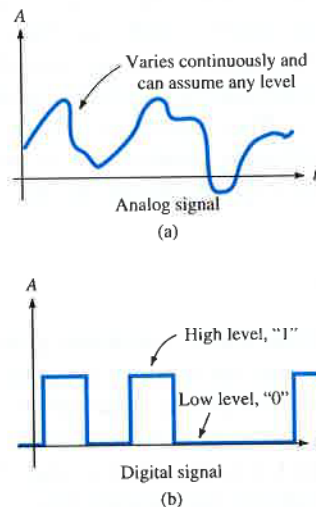


Figure 7.1 Analog and digital signals.

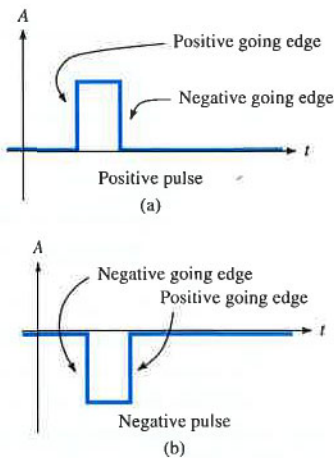


Figure 7.2 Positive and negative pulses.

7.1(b) conveys information as a result of the signal being high or low at sequential points in time. Such a digital signal is termed *serial* because on a single conductor, the pulses must all follow one after the other in time. This approach is viable; however, it is also time consuming.

In order to increase the rate of data transmission, many digital systems convey information by simultaneously presenting 1s or 0s on a number of parallel conductors. Such an arrangement is termed a *parallel* digital data bus, and the input or output (I/O) of such a bus is termed a parallel input or output port.

By operating at the same pulse transmission speed, an 8-bit parallel data bus can deliver information 8 times faster than a single conductor in a serial mode. Most modern personal computers have a serial port and a parallel port for connecting the computer to different types of peripheral equipment.

Since digital systems operate using 1s and 0s, the data in these signals is encoded in the *binary number system*. Therefore, prior to a detailed study of digital systems, a review of the binary system and basic logic will be presented in Chapter 11.

Each electronic circuit can generally be categorized as either *analog* (linear as it's

Table 7.1 Analog parameters measurable by electronic sensors

Pressure	Temperature
Light Intensity	Magnetic Fields
Electric Fields	Proximity
Position	Acoustic Waves
Seismic Vibrations	Humidity/Dew Point
Acceleration/Vibration	Force
Rotation	Radiation
Gas Concentrations	Gas Flow
Acidity (pH)	Imaging (visible/IR)
Biopotentials	Ion Concentrations
Gas Composition	Torque
Tactile/Touch	

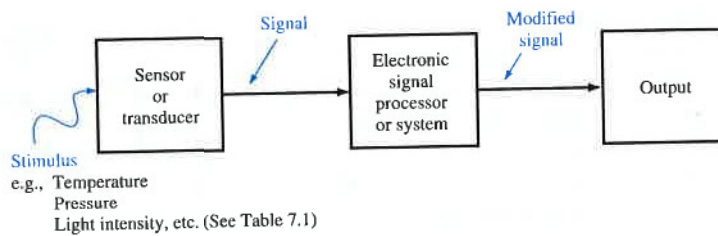


Figure 7.3 A typical electronic measurement system.

sometimes called) or *digital*. Until the 1960s, virtually all electronic circuitry was analog. Analog signals are very common today in certain applications. For example, in a stereo, an audio signal, which is actually a time-varying current, moves the cone of a speaker back and forth, reproducing the appropriate sound. Almost all of observable nature is analog, with continuously varying parameters such as temperature, pressure, light intensity, etc. Therefore, many systems receive as their input an analog signal representing an analog parameter. The electronic signal generally originates from a sensor or transducer which provides an analog signal proportional to the parameter it's designed to measure. Table 7.1 provides a partial list of analog parameters that various types of electronic sensors can measure. Many of the outputs from electronic systems are also analog, such as audio and video images. Therefore, many electronic systems contain: (1) one or more sensors which convert a measurement parameter to an electronic signal, (2) a signal processor which may use analog or digital electronics to modify the signal, and (3) an output device as illustrated in Fig. 7.3.

In the last several decades there has been an increasing trend toward digital systems, primarily as a result of the advances in digital electronic circuitry, for example the microprocessor, which is a computer on a single silicon chip (see Chapter 12). Digital circuitry has become increasingly less expensive and more powerful. Digital circuitry now dominates most electronic systems, in particular those which perform calculations. However, analog circuits remain essential in certain applications, especially those which interface electronics with the real world.

7.4

Amplifiers and Analog Systems

An analog signal can be a complex waveform such as that shown in Fig. 7.4(a), or it can be repetitive or periodic, like the sinusoidal signal shown in Fig. 7.4(b). The sinusoidal signal response is fundamental to understanding the performance of many electronic circuits and systems. First, as shown in Chapter 4, a complex waveform can be shown to be composed of the sum of a number of sinusoidal signals using Fourier analysis techniques. In addition, the waveform normally produced by an ac generator is sinusoidal.

Recall that a voltage that varies sinusoidally with time can be represented by the function

$$v(t) = A \sin(\omega t + \phi) \quad (7.1)$$

In such a sinusoidally varying signal there are three parameters that can be varied: the amplitude A , the angular frequency ω , and the phase angle ϕ . The value of each of these parameters determines certain characteristics of the sinusoidal signal.

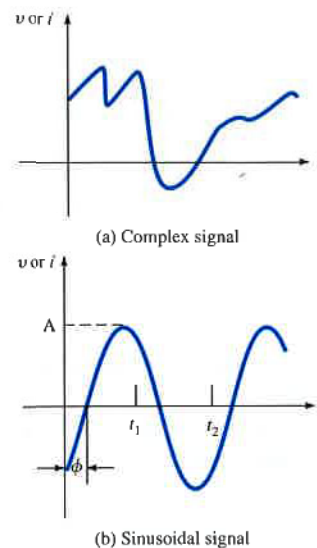


Figure 7.4 Complex and sinusoidal signals.

Recall the angular frequency, ω , in radians per second, is related to f , the frequency in hertz by the relation

$$\omega = 2\pi f \quad (7.2)$$

The standard frequency for the transmission of electric power in the United States and Canada is 60 hertz. The audio frequency range, or the range of frequencies the human ear can detect, is from approximately 30 hertz to 15,000 hertz, which is the frequency range of the electronic signal observed from the output of a high-quality microphone. The entire frequency spectrum was presented in Fig. 1.2.

The amplitude of a signal is an extremely important parameter and can vary over many orders of magnitude. The voltage received on the antenna of a television set may be in the order of microvolts (10^{-6} volts), whereas the voltage applied to the picture tube in the same set may be 20,000 volts (2×10^4 volts). This represents a voltage range of some ten orders of magnitude.

In many applications, an exact replica of a particular signal is needed, but with a larger amplitude. Consider the following example.

EXAMPLE 7.1.

Assume the voltage signal from an electric guitar is 20 millivolts in amplitude, and must be amplified in order to provide 100 watts of power to an 8-ohm speaker. Let us determine the required *rms* sinusoidal voltage across the speaker.

For this case, the voltage and power are related by the expression

$$P = \frac{V_{rms}^2}{R}$$

and therefore

$$V_{rms} = \sqrt{PR} = \sqrt{(100)(8)} = 28 \text{ volts}$$

Assuming this signal is sinusoidal, the amplitude is

$$V_m = \sqrt{2} V_{rms} = (1.41)(28) = 40 \text{ volts}$$

Since the guitar's output amplitude is 20 millivolts, the voltage must be increased by a factor of

$$\frac{40}{20 \times 10^{-3}} = 2000$$

An *amplifier*, shown symbolically in Fig. 7.5, is an electronic circuit which is used to increase the amplitude of a signal. The magnitude of the amplifier's *voltage gain*, A_v is defined as the ratio of the amplitude of the output voltage, v_o to the amplitude of the input voltage, v_i or

$$A_v = \frac{|v_o|}{|v_i|} \quad (7.3)$$

In the example just described, the voltage gain, A_v , of the required amplifier is 2000.

Thus far we have discussed only the magnitude of the gain; however, there is also a phase relation between the input and output signal. Thus, the voltage gain is more accurately represented as a complex quantity.

The complex voltage gain, $\mathbf{A}_v$, is the ratio of the phasor transform of the output voltage to that of the input voltage, assuming the signals are sinusoidal,

$$\mathbf{A}_v = \frac{\mathbf{V}_o}{\mathbf{V}_i} \quad (7.4)$$

Most electronic circuits are designed to operate in what is called the *midband frequency region*, and in this range the phase shift of amplifiers is either zero or 180° , that is, noninverting or inverting. For this reason, in the basic analysis of electronic amplifiers we most often speak only of the magnitude of the voltage gain and include a plus sign if the amplifier is noninverting and a minus sign if it is inverting. In Chapter 17 the effects of various *RC* networks that provide additional phase shifts will be considered.

There are also current amplifiers, which produce an output current that is larger than its input current by a constant factor called the *current gain*.

An amplifier requires dc power in order to operate. The supply voltage to the amplifier must be at least slightly larger than the maximum voltage swing possible at the output of the amplifier. For example, the amplifier just described in Example 7.1 delivers a peak voltage to the speaker of 40 volts. Therefore, the amplifier would require a dc volt-

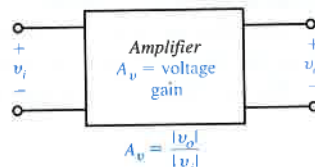


Figure 7.5 A voltage amplifier.

age source of more than 40 volts for proper operation. These concepts will become clear as amplifiers are described in more detail in Chapter 15.

EXAMPLE 7.2

A current of 3×10^{-5} amperes, dc, is derived from a solar cell illuminated by the sun. Let us determine the current gain required in order to activate a small electric motor requiring 5×10^{-2} amperes. The current gain, A_i , needed is

$$A_i = \frac{5.00 \times 10^{-2}}{3.00 \times 10^{-5}} = 1670$$

DRILL EXERCISE

D7.1. Determine the voltage gain required in Example 7.1 if a 4Ω speaker is used.

Ans: 1410.

Another important characteristic of an amplifier is its *frequency response*, that is, the way in which the gain varies as the frequency of a sinusoidal input signal is changed. No real amplifier can amplify an input signal over an infinite range of frequencies. At some high frequency the amplifier will no longer be able to produce the same amplitude of output signal as it could at a lower frequency, and hence the gain is said to “roll off.” Many amplifiers also roll off as frequency is decreased below some particular low-frequency value. The high frequency at which the gain is reduced by a factor of 0.707 from the mid-band value is termed the *upper or high-corner frequency*, f_{HI} , and the low-frequency at which the gain has dropped by a factor of 0.707 is termed the *low-corner frequency*, f_{LO} . These corner frequencies are also called *half-power frequencies* as outlined in Chapter 6.

The difference in frequency between the high-corner frequency and the low-corner frequency is called the *bandwidth*, *BW*. Some amplifiers do not have a lower corner frequency, and will amplify signals all the way down to dc or zero frequency. These amplifiers are called *dc amplifiers*. A plot of such an amplifier’s frequency response is shown in Fig. 7.6. In most plots of frequency response, the frequency, f , and the magnitude of the gain are plotted on logarithmic scales. Figure 7.7 shows a similar plot for an ac amplifier. These concepts will be described in more detail in Chapter 17.

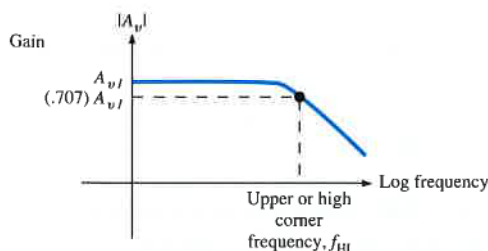


Figure 7.6 Frequency response of dc amplifier.

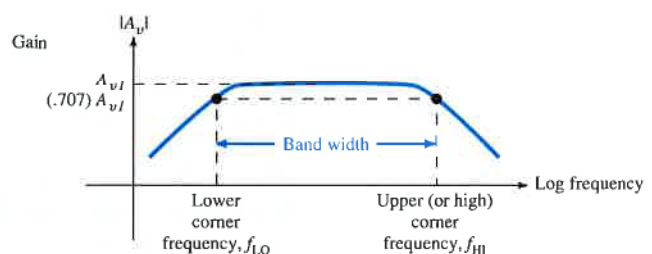


Figure 7.7 Frequency response of ac amplifier.

EXAMPLE 7.3

The mid-band gain of a voltage amplifier is 20. If the gain drops to 14.1 at a high frequency of 11 MHz, and the amplifier has a bandwidth of 3 MHz, let us determine the low-frequency half-power point.

Since the voltage gain drops to 0.707 of its mid-band value at 11 MHz, this frequency is the high-frequency half-power point. The bandwidth is the difference between the high- and the low-corner frequencies, and therefore, the low-frequency half-power point is

$$11 \text{ MHz} - 3 \text{ MHz} = 8 \text{ MHz}$$

DRILL EXERCISE

D7.2. An ac amplifier has a lower corner frequency of 0.5 MHz and a bandwidth of 1.0 MHz. (a) Determine the amplifier's upper corner frequency. (b) Determine the upper corner frequency of a dc amplifier with the same bandwidth.

Ans: (a) 1.5 MHz (b) 1.0 MHz.

7.5**Modulation and Demodulation; Encoding and Decoding**

Modulation is the process used to encode, or “attach and carry,” information on an analog signal. *Demodulation* is the reverse process in which the information is extracted from an analog signal. The various processes by which this is accomplished are fundamental topics in *communications*, which are discussed in Part VI of this text.

Recall that there are three basic ways of carrying information via a sinusoidal signal: by varying the amplitude, the frequency, or the phase. Assume, for example, the information we wish to send is represented by the “voltage ramp” shown in Fig. 7.8(a); this is called the *baseband signal*.

The sinusoidal wave, called the carrier wave, which is amplitude modulated with this information, would appear as shown in Fig. 7.8(b). Note that the amplitude of the sinusoidal signal varies in relation to the information desired to be transmitted. *Amplitude modulation* (AM) is commonly used for transmission of radio signals. For example, in the United States the Federal Communications Commission has established a range of frequencies for the commercial broadcast of AM signals. The AM band is available on most home and automobile radios.

Frequency Modulation, used, for example, on the commercial FM radio band, employs changes in frequency to represent the desired information. The same wave transmitted by FM would appear as shown in Fig. 7.8(c). Note that the frequency of the sinusoidal signal changes in proportion to the information to be transmitted.

Phase modulation is similar to frequency modulation; however, rather than varying the frequency, the phase of the sinusoidal signal is varied relative to some fixed reference.

When television was first developed and introduced in the United States, it utilized black and white transmission. It was decided early that the picture would be transmitted via AM and the sound via FM. Therefore, if you have an FM radio receiver with a little

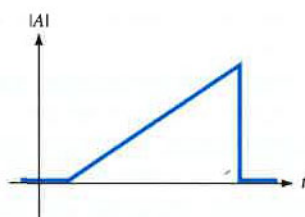


Figure 7.8(a) Baseband signal.

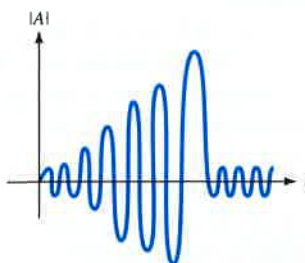


Figure 7.8(b) AM modulated signal.

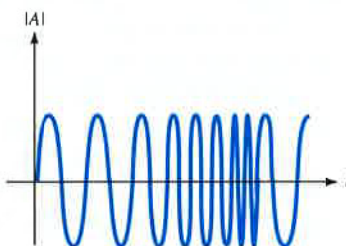


Figure 7.8(c) FM modulated signal.

extra range, you can receive the audio for television channel 6 at the very bottom of the FM dial. Later when color television was developed, one requirement imposed by the government was that the color transmission be compatible with the old black and white sets. An ingenious system was devised whereby the color information was added using phase modulation, and did not affect black and white reception on the older sets.

The telephone was designed as an instrument to transmit analog signals, primarily the tones of the human voice. With the advent of the computer, a need developed to transmit digital signals via phone lines. To accomplish this, a modulation system was designed that translated the digital information into analog tones which could be sent over the phone lines and reconstructed at the other end. Such a system is called a *MODEM*, an abbreviation for “*modulator-demodulator*.”

The process of modifying information so that it is suitable for transmission by a digital signal and constructing the digital signal to represent the information is called simply *encoding*. The opposite process, in which the encoded information is extracted from a digital signal, is termed *decoding*. Examples of modulation/demodulation and encoding/decoding will be presented in later chapters.

7.6

**Digital Systems,
Information,
and Gates**

Almost all digital systems utilize circuits with *binary logic*. In binary digital logic, data is represented by a voltage (or occasionally a current) switching between one of two possible levels, a low level called a logic 0, and a high level called a logic 1. This process is termed “asserted positive logic.” The system could be implemented using the opposite convention where the high level is considered a logic 0 and the low level a logic 1, and such a system is said to use “asserted negative logic.” Positive logic is by far the most common.

The single unit of digital information, the *bit*, is represented by the transmission of a 1 or a 0. The bit has been found to be a very useful means of quantizing information. Information theory, a subspecialty within the field of communications, has developed expressions for calculating the number of equivalent bits of information contained in various signals.

Each bit conveys to us whether the information or value is in the top half or lower half of its possible range. For example, if we consider a signal, v , which we know has values in the range $0 < v < 2$, one bit of information would tell us the following: if the voltage is in the range $0 < v < 1$, then the bit status could be 0, and if the voltage is in the range $1 < v < 2$, the bit status would be 1.

This is very coarse information about this signal, v . We originally knew its value was between zero and two, and now we have started to “pin it down” by breaking the total range into two zones. We use this first bit, the *most significant bit* (MSB), to tell us whether we are in the upper 50% or lower 50% of the entire range.

We can add a second bit to tell us whether we are in the top half or lower half of the smaller range just selected by the previous bit. We are now capable of quantifying the signal to within four possible “zones” using the following correspondence:

Range	Bit status	
	MSB	LSB
$0.0 < v < 0.5$	0	0
$0.5 < v < 1.0$	0	1
$1.0 < v < 1.5$	1	0
$1.5 < v < 2.0$	1	1

Where MSB = most significant bit and LSB = least significant bit.

We could now add a third bit which would give us a resolution of eight possible ranges, or zones. Note that in the binary system, the number of zones of resolution, Z , is related to the number of bits, n , by the expression

$$Z = 2^n \quad (7.5)$$

The series of bits that represent a particular analog level is termed a digital *word*. If this series of bits is presented at the same time via parallel conductors, that is, a parallel bus, we receive a parallel word; if they appear one after the other via a single conductor, that is, a serial data bus, then we receive a serial word. Eight-bit word segments are normally referred to as a *byte*.

EXAMPLE 7.4

Let us determine the voltage resolution that can be achieved if a signal with a maximum value of 12 volts and minimum value of 0 volts is represented by 10 bits.

The number of zones defined by 10 bits is:

$$Z = 2^n = 2^{10} = 1024 \text{ zones}$$

$$\text{Resolution} = \frac{12.0}{1024} = 0.0117 \text{ volts/zone}$$

DRILL EXERCISES

D7.3. A 4-bit parallel data bus can transmit 8 bits of information in 40 microseconds. If the same technology were used to transmit data serially over a single conductor, how many bits could be transmitted in the same 40 microseconds?

Ans: 2 bits.

D7.4. A signal that can have values between -10 to $+10$ volts is represented by a 12-bit digital word; what is the voltage resolution obtainable with this system?

Ans: 4.9 mV.

A/D and D/A Converters

Electronic circuits, which are designed to automatically convert an analog voltage into a digital or binary representation of that voltage, are called *Analog to Digital Converters*, or A/D Converters. Circuits that convert a digital word into an analog voltage level are called *Digital to Analog Converters*, or D/A converters. Both converters are shown symbolically in Fig. 7.9. A timing signal is used to specify the point in time at which a sample is taken.

An 8-bit A/D converter, for example, converts a continuously variable voltage within a specified range at its input, into an 8-bit digital word at its output which represents the

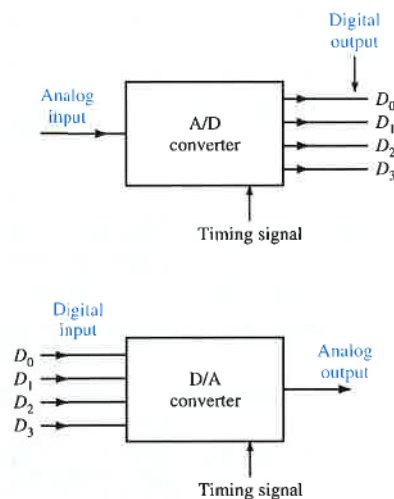


Figure 7.9 A/D and D/A converters.

quantized value of the input voltage at a specific point in time. Therefore, we are told which of 256 zones the input voltage is contained within ($2^8 = 256$) at the time of the sample. A/D and D/A converters are available from many manufacturers integrated on a single IC chip.

Logic Gates

Information represented as 1s and 0s in a digital system is processed primarily by elements called *logic gates*.

A practical *logic gate* is an electronic circuit which has a digital output that can assume voltage levels which correspond to a 1 or a 0 state, and one or more digital inputs, which determine the state of the output.

Three simple logic gates will be described here: the *inverter*, the *AND-gate*, and the *OR-gate*. Later, in Chapters 10 through 12, further details of these and more complex logical functions will be described.

The simplest logic gate is the inverter. The inverter has only one input and one output, and its output is always the opposite or *complement* of its input. *Truth tables* are often used in order to describe logic gate operation. A truth table is a chart showing the logical state of the output for every possible input combination. The truth table for the *inverter* is relatively simple since it has only one input. If *A* is the input and *B* is the output, then the truth table is

<i>A</i> (input)	<i>B</i> (output)
0	1
1	0

There are sets of standard symbols for the basic logic gates. The symbol for the inverter is shown in Fig. 7.10(a).

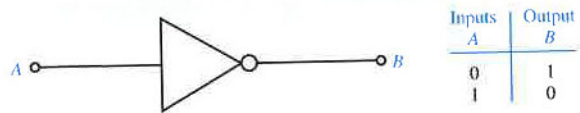


Figure 7.10(a) Inverter or NOT-gate.

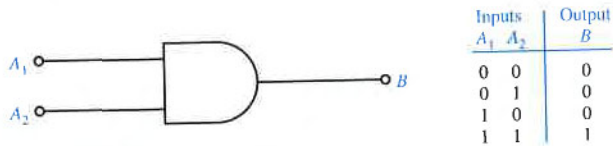


Figure 7.10(b) AND-gate.

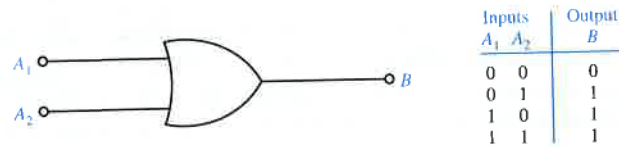


Figure 7.10(c) OR-gate.

Inputs			Output
A_1	A_2	A_3	B
0	0	0	1
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	0

Inputs			Output
A_1	A_2	A_3	B
0	0	0	1
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	0

Figure 7.11 NAND and NOR logic gates.

The *AND-gate* has a single output and can have any number of inputs greater than 1. The output of this gate is high only when all the inputs are high, and for any other combination of inputs, the output is low. The logic symbol and truth table for a two-input *AND-gate* are shown in Fig. 7.10(b).

The *OR-gate* has a single output and can have any number of inputs greater than 1. This gate produces a high level at its output if *any* of its inputs are high, and the output is low only if none of the inputs are high. The truth table and logic symbol for a two-input *OR-gate* are shown in Fig. 7.10(c).

In order to implement certain logic functions, it often becomes necessary to use an *AND-gate* followed by an inverter. This combination produces an output which is the exact complement of the *AND-gate*, and the combination is defined as a *NAND-gate*. Similarly, a gate which produces an output which is the complement of the *OR-gate* is called the *NOR-gate*. The logic symbols and truth tables for three input *NAND* and *NOR* gates are given in Fig. 7.11. Many electronic circuits utilized for implementing logic inherently invert the signal while performing the logic function, and therefore *NAND/NOR* logic is quite common in practical electronic systems.

7.7

Summary

- Electronic circuits contain linear and nonlinear elements.
- Electric power can be transmitted by ac or dc.
- Rectification is the process of converting ac to dc.
- A signal is a voltage or current which in some manner is varied over time in order to encode and transmit information.
- Signals are either analog if they vary continuously or digital if they switch between discrete levels.
- Digital signals typically have 2 levels, a high called a 1, and a low called a 0. The single presentation of a 1 or 0 is called a bit.
- An amplifier produces an output which is a factor of A larger than its input where A is called the gain.

- Modulation is the process of attaching information to an analog signal; demodulation is the reverse process of extracting information from an analog signal.
- An analog range can be quantized into Z zones where n is the number of bits by the expression $Z = 2^n$.
- An A/D converter samples an analog signal and creates a digital output. A D/A converter performs the opposite task of converting a digital word into an analog level.
- Practical logic gates are electronic circuits which have a digital output and one or more digital inputs; the logic state of the output is unequally determined by the logic values of the inputs.

PROBLEMS

7.1. For each of the following, decide if it is most analogous to digital information or analog information.

- the result of a coin toss
- the sound of a slide trombone
- the beat of a drum
- a human voice
- the ticking of a clock
- the sound of a siren
- the motion of a cat
- the motion of a frog

7.2. Construct digital voltage signals by drawing the pulse waveforms based on the following descriptions: high level = 5 V; low level = 0.3 V.

- low at $t = 0$, positive going edge at $t = 1$, negative going edge at $t = 1.5$, positive going edge at $t = 2$, negative going edge at $t = 3$.
- low at $t = 0$, positive going edge at $t = .5$, negative going edge at $t = 1.5$, positive going edge at $t = 1.75$, negative going edge at $t = 2$.
- low at $t = 0$, followed by 5 seconds of alternating positive and negative going edges equally spaced by 1 second.

7.3. Construct serial digital signals representing the following sequences of bits using pulses of width 0.5 seconds.

- 0 0 1 0 1 0 0 0 1 1 1 0 1
- 1 0 1 1 0 0 1 0 1 1 0 0 1

7.4. An 8-bit parallel data line is used to transmit 16 bits of information in 10 μs . If the same technology were used to transmit data serially over a conductor, how many bits could be transmitted in 80 μs ?

7.5. Assume a computer's output port sends out data serially to a printer, and that each character can be represented by an 8-bit word. If a single printed line contains

72 characters, how many lines can be sent out by the computer in 1 minute? The data transmission rate is 9600 bits/second.

7.6. The Central Processing Unit (CPU) of a microprocessor operates at a clock frequency of 12 MHz. Assuming that it takes 4 clock cycles to perform one memory fetch operation, how many 8-bit words can be fetched from memory in 1 ms if:

- the bits are fetched serially (1 bit per fetch operation)?
- the bits are fetched in parallel (8 bits per fetch operation)?

7.7. A temperature-sensitive resistor is an element often used to measure temperature in electronic systems. Assume that the resistance of such an element is given by $R(T) = R_0[1 + \alpha(T - T_0)]$ where T is temperature, R_0 is the resistance value at a temperature of T_0 ($^{\circ}\text{C}$), and α is a constant called the temperature coefficient. If $\alpha = 0.01$, $R_0 = 1 \text{ k}\Omega$, what constant dc current must be established in this element so that the voltage change across it will be 0.05 V when the temperature change is 10 degrees?

7.8. A thermistor is a resistor with a strong negative temperature coefficient (see equation in problem 7.7). Assume such a device shows a decrease in resistance of 7% per degree increase in temperature. If the room temperature current is 2 mA when connected across a 3 V source, what is the expected current when the temperature is lowered 5 degrees?

7.9. A solar cell is placed outdoors and has an output of 7 mA at peak sun intensity (noon), and 0.1 mA when exposed to moonlight. Plot the approximate current output expected versus time over a 24-hour period, assuming

- a cat does *not* stand over the cell.
- a cat stands over the cell for 1 hour beginning at noon. (Assume an opaque cat.)

7.10. The amplitude of the signal received by the antenna of an AM-radio receiver is $5 \mu\text{V}$. The signal is then amplified to supply 3 V to a speaker. What is the voltage gain of this system?

7.11. The input and the output signals of four different amplifiers are given below. Obtain the voltage gain and the phase shift for each of the amplifiers.

- (a) $v_{in}(t) = 3 \cos(\omega t)$ $v_{out}(t) = 27 \cos(\omega t)$
 (b) $v_{in}(t) = 5 \sin(10t)$ $v_{out}(t) = 15 \cos(10t)$
 (c) $v_{in}(t) = 4 \sin(\omega t)$ $v_{out}(t) = 20 \sin(\omega t + \pi/2)$
 (d) $v_{in}(t) = 7 e^{20jt}$ $v_{out}(t) = j5 e^{20jt}$

7.12. An electronic thermometer generates a voltage signal of 6 mV for every 1°C rise in temperature. This signal is used to activate a switch which requires an input signal of 5 V to operate. What is the voltage gain of the amplifier which will allow one to operate the switch at the boiling point of water (100°C) if the thermometer generates 0 V at 0°C ?

7.13. Calculate the upper and lower corner frequencies and the bandwidth of the amplifier whose frequency response is given in Fig. P7.13.

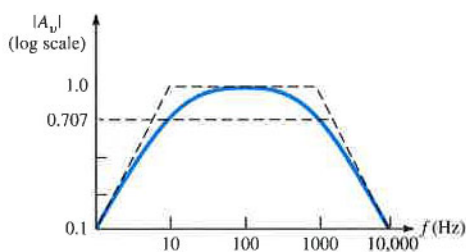


Figure P7.13

7.14. An audio amplifier is designed for signals in the frequency range of 10^2 Hz to 10^4 Hz. The amplifier has an input of 30 mV and its output is to provide 10 W to an 8Ω speaker. Plot the frequency response of this amplifier showing the mid-band gain, the two corner frequencies, and the bandwidth.

7.15. The signal in Fig. P7.15(a) modulates the high-frequency sinusoidal carrier signal shown in Fig. P7.15(b). Sketch the resulting waveform for (a) amplitude modulation and (b) frequency modulation. (Note different time scales on the figures.)

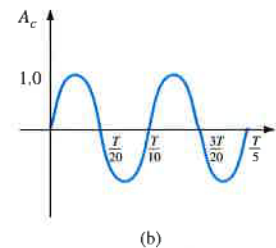
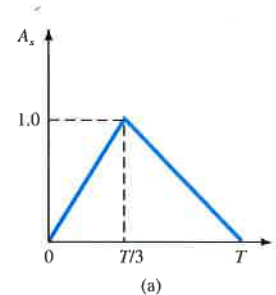


Figure P7.15

7.16. Find the minimum number of bits necessary to represent a 4 V analog signal with a resolution greater than 1 mV.

7.17. An analog signal having values from -4 V to 6 V is represented using 8 bits. (a) Calculate the voltage resolution obtained. (b) How many additional bits are required to double the voltage resolution?

7.18. An analog signal which has a maximum value of 5 V is represented digitally using a 7-bit word. Due to a fault in the digital circuit, the middle bit is incorrect. Find the magnitude of the error in the analog representation of the signal.

7.19. Obtain the digital words corresponding to the indicated analog signal levels, a through j , as shown in Fig. P7.19, that would be assigned by an A/D system with:

- (a) 2 bits
 (b) 3 bits

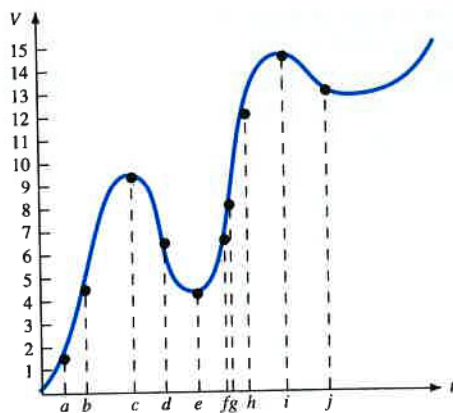


Figure P7.19

7.20. An analog signal with a maximum amplitude of 1 volt is sampled 15 times at one-second intervals. The samples are converted to 4-bit digital words as shown below. Reconstruct the analog signal as accurately as possible from this list and comment on the accuracy of your result. Identify two ways of obtaining a better digital representation of the analog signal.

Sample time(s)	4-bit digital word
1	0000
2	0010
3	0011
4	0001
5	0100
6	0101
7	0110
8	1010
9	1101
10	1111
11	1000
12	0110
13	0111
14	1011
15	1111

7.21. An Exclusive OR gate (XOR) is a logic gate with an output which is high only when all its inputs are at the same logic value. Construct the truth table for a 2-input XOR gate.

7.22. Construct the truth table for the logic circuit shown in Fig. P7.22. (Assume A_1 is the MSB.)

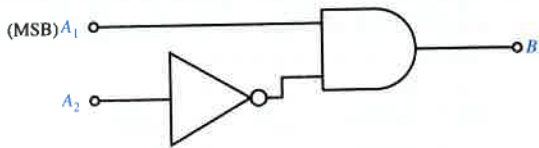


Figure P7.22

7.23. Construct the truth table for the logic circuit shown in Fig. P7.23. (Assume A_1 is the MSB.)

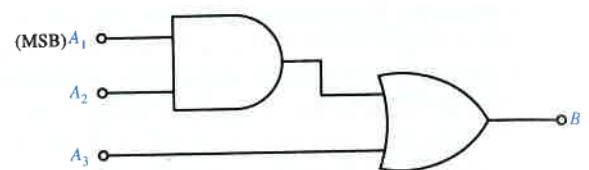


Figure P7.23

Introduction to **ELECTRICAL ENGINEERING**

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With sound, practical coverage of all the basic concepts in electrical engineering, this comprehensive text represents the most balanced, general introduction to the field available for non-majors. **Introduction to Electrical Engineering** superbly integrates conceptual discussions with current, relevant technological applications. Authors J. David Irwin and David V. Kerns, Jr. present modularized coverage of a wide range of topics, affording a flexible format, strong pedagogical support, and clear explanations, while steering clear of superficial, cursory treatment.

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