CHAPTER 24

Electronic Systems

24.1 INTRODUCTION

Semiconductor devices are able to do much more than rectify AC voltages. When semiconductors replaced the older vacuum-tube valve devices in electronic applications, the circuits were termed 'transistorised' or 'miniaturised' since the transistors were so robust and small compared with the delicate and bulky thermionic vacuum-tube valves that had been the mainstay of electronics until then. It has been said that if the car industry progressed at the same rate as the electronics industry, a Rolls Royce would be the size of a matchbox, cost fifty cents and get a million kilometres per litre!

In this chapter we will look at the development of electronic systems involving input–output transducers such as microphones, loudspeakers and motors as well as transistors and **integrated circuits** (ICs). The resistance of semiconductor material is dependent on the level of impurity doping. The capacitance of a reverse bias PN diode is altered by the voltage applied to the base–emitter junction of a transistor. These properties make it possible to combine arrays of resistors, capacitors and transistors onto a single piece (or **chip**) of silicon, which ultimately becomes an integrated circuit. These ICs can be mass-produced to accomplish any desired electronic function. Today, there exist hundreds of integrated circuit families. Very large scale integration (VLSI) circuits and very high speed integration (VHSI) circuits in recent years have seen tremendous improvements in device reliability, performance speed and lowering of cost within electronic systems such as audio, video, telephone and computer technology. There is hardly a domestic or industrial machine existing today that is not, in part at least, an electronic system.

In 1969 the American corporation Intel developed a range of medium-sized ICs for use in hand-held calculators. An Intel engineer, Edward Hoff, realised that it was simpler to design a single-purpose IC for all calculators and to make this chip 'programmable' so that it could be controlled by a unique external chip containing a specific set of instructions. This general-purpose chip was called a **microprocessor**, or single chip central processing unit (CPU). The microprocessor has become the heart of many modern electronic systems. The chip can perform a vast range of functions depending on the external instructions given to it. The modern personal computer is nothing more than a microprocessor joined to an array of external chips such as memory and the basic input–output system as well as keyboard input and video output circuitry.

24.2 INPUT—OUTPUT TRANSDUCERS

To produce the control functions carried out by circuits in electronics, **electrical signals** (the actual voltages and currents), usually, are manipulated by components in various ways. Electrical information is obtained as voltages and currents from the input to a particular circuit or circuit system. For example, a radio receives small electrical voltages (a radio signal) from the input antenna, or a public address system uses an input signal produced by a microphone. The circuit performs some function such as amplification and this new electrical information is available to the electronic system output. This output may be a loudspeaker or a visual display such as an LED array or a video screen. An electronic system allows us to control electrical information and usually allows several stages of electrical energy conversions to take place. Thus, an electronic system consists of a defined set of blocks of circuitry, as shown in Figure 24.1. This is called a schematic or an electronic **block diagram**.

Figure 24.1
Block diagram of an electronic system.

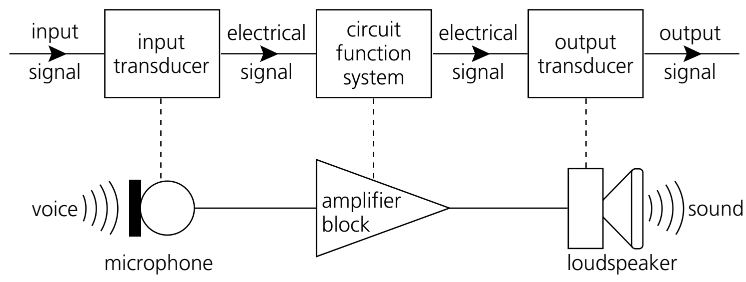
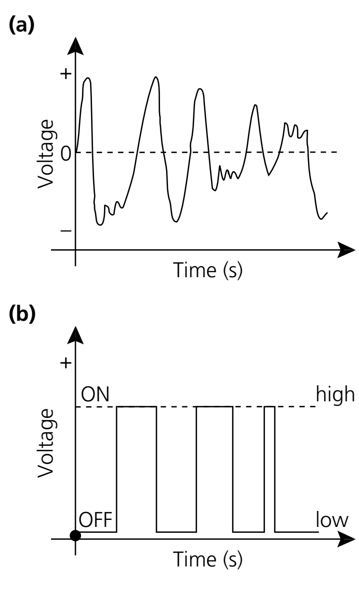


Table 24.1 TRANSDUCERS IN ELECTRONICS

INPUT TRANSDUCERS	OUTPUT TRANSDUCERS
Microphone	loudspeaker
Antenna	light bulb
Thermocouple	LED and display
Photocell	relay coil
LDR	electric motor
Thermistor	cathode ray tube
Laser diode	audio-video heads

Figure 24.2
Electrical signals: analog **(a)**; digital **(b)**.



Transducers are devices that convert energy from one form to another in electronic systems, usually involving electrical energy. Table 24.1 lists commonly used input and output transducers in electronics. Occasionally an input transducer can be the same as an output transducer. For example, in some simple intercom systems the loudspeaker can be both the input microphone as well as the output speaker, although, of course, not at the same time. For instance, the two functions may be controlled by a push-to-talk switch.

Analog to digital conversion (ADC)

Electronics is concerned with the control of electrical signals that carry information to devices that interpret the signals and perform a particular function. Block diagrams are often used to get an overall picture of the various functions performed within the system as a result of the electrical signals being interpreted. Two types of electrical signals are commonly found in modern electronic systems. These are **analog** or continuously varying electrical voltage signals, and **digital** or electrical voltage signals that are either ON or OFF. If a digital signal is ON it means that the voltage level is high or equal to the circuit supply voltage whereas if a digital signal is OFF then the voltage level is low or at zero volts.

Figure 24.2 illustrates the nature of these two different types of signals graphically.

Analog signals are widely used in audio, video and television systems, while digital signals are used in computers and microprocessor- or microcontroller-based consumer devices. Digital electronics is a well-established field, with many older analog devices now phased out and replaced by digital processing; examples include the digital DVD and audio CD revolution, and mobile phone technology. Underlying these processes is a technique called 'analog to digital conversion' or **ADC**. The reverse process, digital to analog conversion or DAC, is equally important.

The input to an ADC consists of a voltage that varies among a theoretically infinite number of values. Examples are sine waves, the waveforms representing human speech, and the signals from a conventional television camera. The output of the ADC has defined levels or states. The number of states is almost always a power of two — that is, 2, 4, 8, 16, etc. The simplest digital signals have only two states and are called **binary**. All whole numbers can be represented in binary form as strings of ones and zeros.

Information is stored in a computer as groups of bits. A **bit** stands for a binary digit, 0 or 1. The only practical way of representing these two states in an electronic circuit such as a computer is to use two-state logic, or ON and OFF. 'OFF' represents logic 0, and 'ON' represents logic 1. In electrical terms, for most digital logic circuits, 0 volts represents logic 0 and 5 volts represents logic 1. Due to the ever-decreasing power consumption and increasing speed of modern digital circuits, the logic 1 voltage is decreasing to around 3 volts. In general, microprocessors use bits in groups of eight, which are called **bytes**. Groups of four bits are also used, and these are called **nibbles**. There are two nibbles in a byte.

The maximum number that a single byte can hold equals 255, and there are 256 different combinations of binary numbers, including zero, that can be represented. In the binary system, each binary digit or bit represents a power of 2. In the decimal number system, each digit represents a power of 10.

Example. 0 0 0 0 1 1 0 1 in binary (from right to left) represents;

$1 \times 2^0 = 1 \times 1 = 1$
$0 \times 2^1 = 0 \times 2 = 0$
$1 \times 2^2 = 1 \times 4 = 4$
$1 \times 2^3 = 1 \times 8 = 8$

Add these up to get a decimal equivalent $1 + 0 + 4 + 8 = 13$.

In the hexadecimal system, which is used in coding or programming computers, each digit represents a power of 16. There are no numbers past the digit 9, so the letters A to F are used to represent the digits 10 to 15.

Example: 0 1 2 3 4 5 6 7 8 9 A B C D E F These hex digits fit very nicely into a nibble.

0 = 0000 = 0 decimal
1 = 0001 = 1 decimal
2 = 0010 = 2 decimal, etc.
down to the hexadecimal value
F = 1111 = 15 decimal.

As two nibbles fit into a byte, there are also two hexadecimal numbers that fit into a byte. It becomes easy to break down large binary numbers into more something more manageable by splitting them into nibbles and into hexadecimal numbers.

Let's take a quick look at the process of ADC. Refer back to the section of Chapter 16 on modern sound technology (Section 16.10) for audio digital devices that make use of ADC.

In analog technology a simple waveform is recorded and used in its original form. For example, in a cassette tape recorder the varying voltage wave output from a microphone is applied directly through the magnetic recording head onto the magnetic tape. (Refer to Section 25.4.) The pickup head takes the analog signal back off the tape and sends it to the amplifier and speakers. Typical audio frequencies range from about 20 Hz up to about 20 kHz, which represents the music fidelity.

In digital technology a process of sampling the analog wave at a fixed interval is used. The amplitude of the sampled wave section produces a voltage that is converted into a number that is stored in the digital device such as a music or data CD. The sampling rate used in normal music CD recorders is 44.1 kHz or 44 100 numbers per second of music, while that used in DVD audio discs is 192 kHz. When an ADC sampling recording is made, engineers have control over two factors (Refer to Figure 24.3.):

- the **sampling rate** — how many samples are taken per unit time
- the **sampling precision** — the number of different gradations in amplitude that are used when sampling.

NOVEL CHALLENGE

'It is said that there are 10 types of people in the world: those who understand binary and those who don't.' Explain.