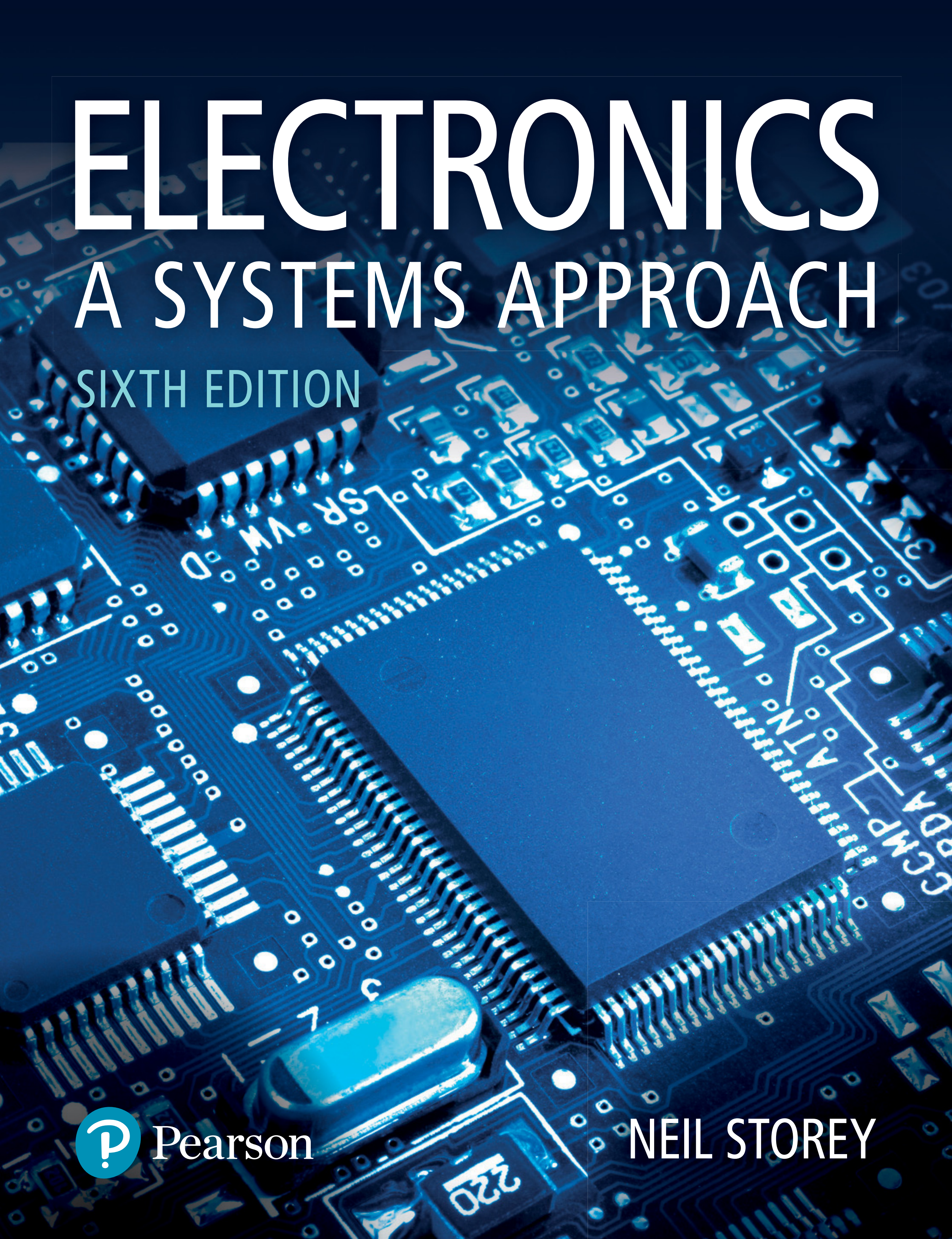
ELECTRONICS

A SYSTEMS APPROACH

SIXTH EDITION



Pearson

NEIL STOREY

ELECTRONICS

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To illustrate the operation of this arrangement, consider the situation where we wish to reduce the power produced by the heater to 500 W. If we define the voltage across the heater to be V_H then using Ohm's law

$$P = \frac{V_H^2}{R_H}$$

$$\therefore V_H = \sqrt{P \times R_H} = \sqrt{500 \times 62.5} = 176.8\,V$$

From our knowledge of potential dividers it follows that:

$$V_H = V\frac{R_H}{R_H + R_C}$$

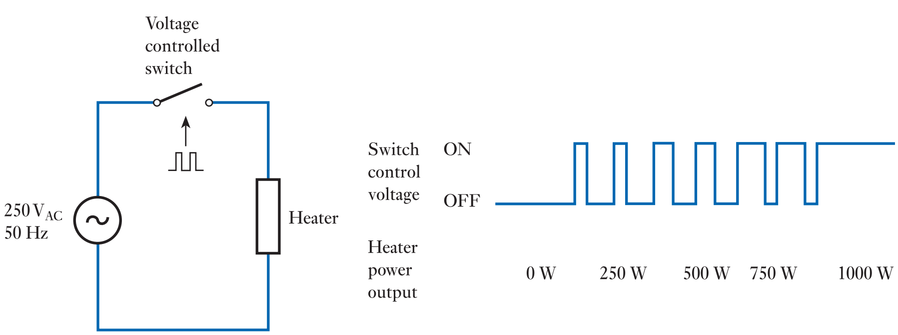
$$\therefore 176.8 = 250\frac{62.5}{62.5 + R_C}$$

$$\therefore R_C = 25.9\ \Omega$$

Thus adjusting our control resistor R_C to 25.9 Ω will reduce the power produced by the heater to 500 W and by selecting other values for the resistor we can adjust the heat output as required.

While the technique described above is simple, it does have one serious drawback, and that is the power dissipated in the control resistor. A simple calculation will show that in the example given above, when 500 W is dissipated in the heater, approximately 207 W is dissipated in the control resistor. This is a tremendous waste of power and would normally be unacceptable. We therefore need a more efficient method of controlling the heater.

One way of producing more efficient control is to use a **switch-mode controller**. Here the heater is connected to the supply through a switch that can be cycled ON and OFF very quickly. The switch is driven by a repetitive waveform that varies the fraction of the time for which the heater is active. The switching rate is much faster than the response rate of the heater and so the heater effectively responds to the average value of the voltage waveform. For example, if the switch is ON all the time the heater will produce its maximum output of 1000 W, while if it is OFF all the time its power output will be zero. If the switch is ON for 50% of the time the heater will produce 50% of its maximum output (500 W), while if it is ON for 75% of the time it will produce 750 W. In this way the power output of the heater can be varied from zero to 100% of its maximum output.



An *ideal* switch dissipates no power, since when it is switched ON it has current flowing through it but no voltage across it, and when it is switched OFF it has voltage across it but not current flowing through it. Thus in both cases the power (which is the product of the voltage and the current) is zero. Real switches do not match these idealised characteristics, but modern semiconductor switches (as discussed in later chapters) allow very rapid switching with very low power dissipation, and are a very good approximation to their idealised counterpart.

While this example has considered the control of a heater, a similar approach can be taken to the control of many high-power actuators. We will return to look at such techniques in more detail when we consider power electronics in more detail in Chapter 20.

Further study

Video 13B

A computer disk drive contains one or more rapidly spinning disks (or platters) that are coated with a magnetic material that allows digital information to be written and read using a magnetic head.

Clearly such drives contain several forms of actuator, but here we will concern ourselves only with those responsible for spinning the disks and for rotating the arm to position the read/write head over the appropriate part of the disk.

Consider the various actuators discussed in this chapter and decide which of these, if any, would be appropriate for use in this application.

Key points

- All useful systems need to affect their environment in order to perform their intended functions.
- Systems affect their environment using actuators.
- Most actuators take power from their inputs in order to deliver power at their outputs. The power required varies tremendously between devices.
- Some devices consume only a fraction of a watt. Others may consume hundreds or perhaps thousands of watts.
- In most cases, the energy conversion efficiency of an actuator is less than 100 per cent, and sometimes it is much less.
- Some actuators resemble resistive loads, while others have considerable capacitance or inductance. Others still are highly non-linear in their characteristics.
- The ease or difficulty of driving actuators varies with their characteristics.

Exercises

13.1 Explain the difference between a transducer and an actuator.

13.2 What form of device would normally be used as a heat actuator when the required output power is a few watts?

13.3 What form of heat actuator would be used in applications requiring a power output of several kilowatts?

13.4 Estimate the efficiency of a typical heat actuator.

13.5 What forms of light actuator would typically be used for general illumination? What would be a typical range for the output power for such devices?

13.6 Why are conventional light bulbs unsuitable for signalling and communication applications? What forms of transducer are used in such applications?

13.7 How do light-emitting diodes (LEDs) differ from conventional semiconductor diodes?

13.8 What would be a typical value for the operating voltage of an LED, and what would be a typical value for its maximum current?

13.9 From the information given for the last exercise, what would be a typical value for the maximum power dissipation of an LED?

13.10 In addition to displaying the digits 0–9, the seven-segment display of Figure 13.1 can be used to indicate some alphabetic characters (albeit in a rather crude manner). List the upper- and lower-case letters that can be shown in this way and give examples of simple status messages (such as 'Start' and 'Stop') that can be displayed using an array of these devices.

13.11 How is an LED flat panel display able to display full-colour images?

13.12 Briefly describe the operation and function of an opto-isolator.

13.13 What environmental factor causes problems for optical communication systems using conventional LEDs and photo detectors? How may this problem be reduced?

13.14 What form of optical fibre would be preferred for communication over a distance of several kilometres? What form of light source would normally be used in such an arrangement?

13.15 Explain how a single form of transducer might be used as a force actuator, a displacement actuator or a motion actuator.

13.16 Describe the operation of a simple solenoid.

13.17 Explain how a solenoid may be used as a binary position actuator.

13.18 Explain why a simple panel meter may be thought of as a rotary solenoid.

13.19 What is the most common form of analogue panel meter? What would be typical operating currents for such devices?

13.20 List three basic forms of electric motor.

13.21 What form of motor would typically be used in high-power applications?

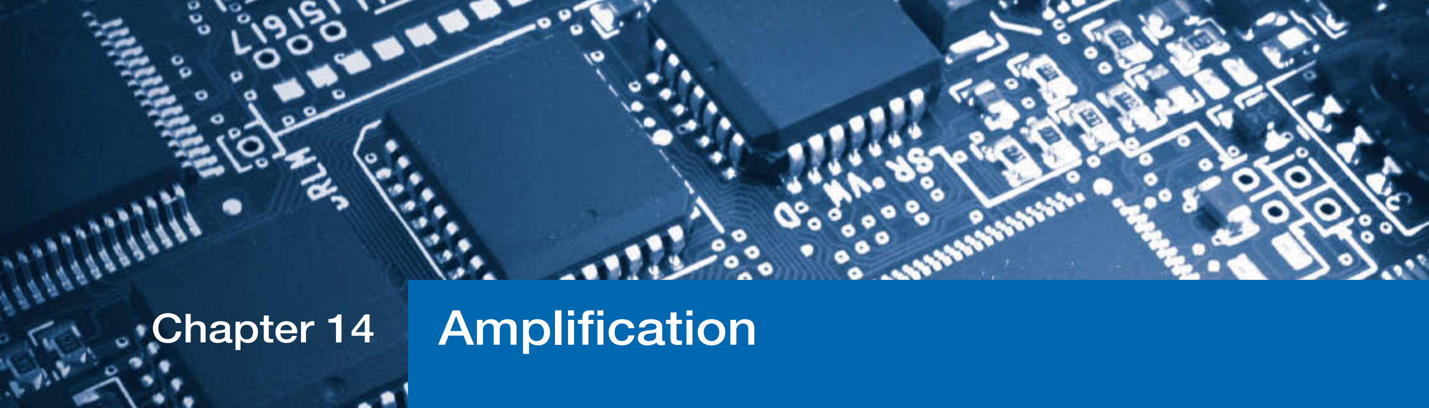
13.22 What form of motor might be used in an application requiring precise position control?

13.23 Briefly describe the characteristics of a stepper motor that make it an attractive option in some situations.

13.24 How is the speed of a stepper motor controlled?

13.25 What would be a typical value for the impedance of the coil of a loudspeaker?

13.26 Explain how the power dissipated in an actuator may be varied using an electrically operated switch.



Chapter 14 Amplification

Objectives

When you have studied the material in this chapter, you should be able to:

- explain the concept of amplification
- give examples of both active and passive amplifiers
- use simple equivalent circuits to determine the gain of an amplifier
- discuss the effects of input resistance and output resistance on the voltage gain of an amplifier and use these quantities to calculate loading effects
- define terms such as output power, power gain, voltage gain and frequency response
- describe several common forms of amplifier, including differential and operational amplifiers.

Video 14A

14.1 Introduction

In earlier chapters, we noted that many electronic systems are composed of one or more sensors that take information from the 'real world', one or more actuators that allow the system to output information to the real world, and some form of processing that makes signals associated with the former appropriate for use with the latter. Although the form of the processing that is required varies greatly from one application to another, one element that is often required is **amplification**.

Simplistically, **amplification** means making things bigger, and the converse operation, **attenuation**, means making things smaller. These basic operations are fundamental to many systems, including both electronic and non-electronic applications.

Examples of non-electronic amplification are shown in Figure 14.1. The first shows a lever arrangement. Here, the force applied at the output is greater than that applied at the input, so we have amplified the input force. However, the distance moved by the output is less than that moved at the input. Thus, although the force has been amplified, the displacement has been reduced, or attenuated. Note that, if the positions of the input and the output of the lever were reversed, we would produce an arrangement that amplified movement but attenuated force.

The second example in Figure 14.1 shows a pulley arrangement. As in the first example, this produces a greater force at the output than is applied at the input, but the distance moved at the output is less than that at the input. Thus, again, we have a force amplifier but a movement attenuator.

In the lever arrangement shown in Figure 14.1(a), the direction of the output force is the same as that of the input. Such an amplifier is referred to as a **non-inverting amplifier**. In the pulley arrangement of Figure 14.1(b), a downward force at the input results in an upward force at the output and we have what is termed an **inverting**

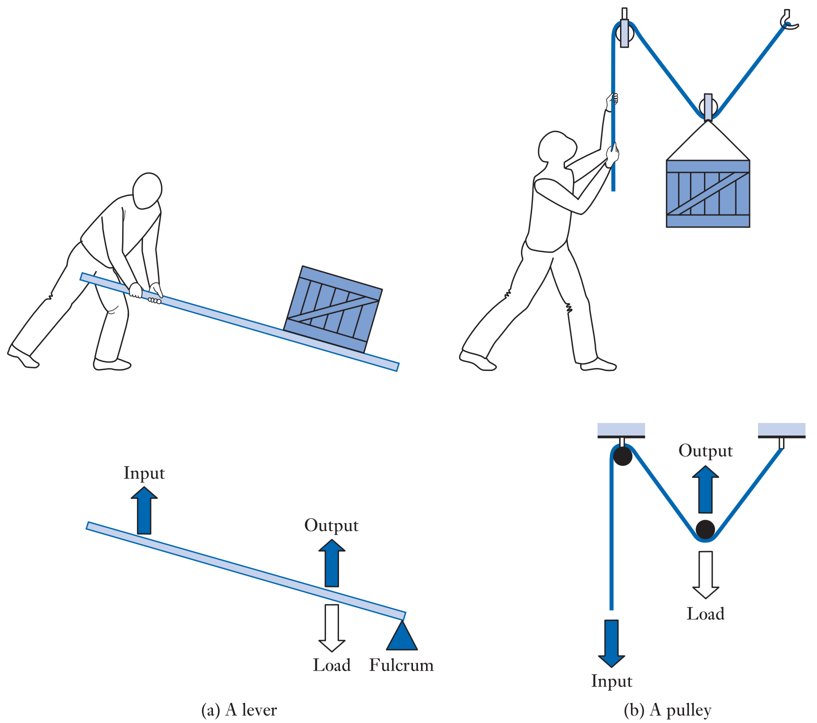


Figure 14.1 Examples of mechanical amplifiers.

amplifier. Different arrangements of levers and pulleys may be either inverting or non-inverting.

Both the examples in Figure 14.1 are **passive systems** – that is, they have no external energy source other than the inputs. For such systems, the **output power** – that is, the power delivered at the output – can never be greater than the **input power** – that is, the power absorbed by the input – and, in general, it will be less because of losses. In our examples, losses would be caused by friction at the fulcrum and pulleys.

In order to be able to provide power gain, some amplifiers are not passive but **active**. This means that they have some form of external energy source that can be harnessed to produce an output that has more power than the input. Figure 14.2 shows an

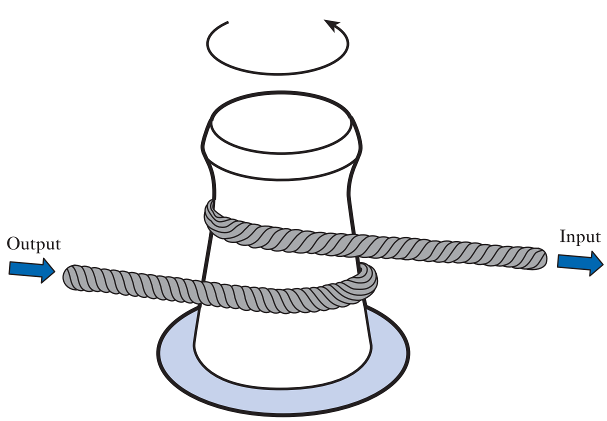


Figure 14.2 A torque amplifier.

example of such an amplifier called a **torque amplifier**. This consists of a rotating shaft with a rope or cable wound around it. The amplifier can be used as a power winch and is often found in boats and ships. One end of the rope (the output) is attached to a load and a control force is applied to the other end (the input). If no force is applied to the input, the rope will hang loosely around the rotating shaft and little force will be applied at the output. The application of a force to the input tightens the rope around the drum and increases the friction between them. This frictional force is applied to the rope and results in a force being exerted at the output. The greater the force applied to the input, the greater the frictional force experienced by the rope and the greater the force exerted at the output. We therefore have an amplifier where a small force applied at the input generates a larger force at the output. The magnitude of the amplification may be increased or decreased by changing the number of turns of the rope around the drum.

It should be noted that, as the rope is continuous, the distance moved by the load at the output is equal to the distance moved by the rope at the input. However, the force applied at the output is greater than that at the input and the arrangement therefore delivers more power at the output than it absorbs at the input. It therefore provides not only force amplification but also **power amplification**. The extra power available at the output is supplied by the rotating drum and will result in an increased drag being experienced by whatever force is causing it to rotate.

14.2 Electronic amplifiers

In electronics, there are also examples of both passive and active amplifiers. Examples of the former include a step-up transformer (as described in Section 5.12), where an alternating voltage signal applied to the input will generate a larger voltage signal at the output. Although the voltage at the output is increased, the ability of the output to provide current to an external load is reduced. The power supplied to a load will always be less than the power absorbed at the input. Thus, a transformer may provide voltage amplification but it *cannot* provide power amplification.

Although there are several examples of passive electronic amplifiers, the most important and useful electronic amplifiers are active circuits. These take power from an external energy source – usually some form of **power supply** – and use it to boost the input signal. Unless the text indicates differently, for the remainder of this book, when we use the term *amplifier*, we will be referring to an *active electronic amplifier*.

We saw earlier when looking at mechanical amplifiers that several different forms of amplification are possible. Such devices can, for example, be movement amplifiers or force amplifiers and provide power amplification or attenuation. Electronic amplifiers may also be of different types. One of the most common is the **voltage amplifier**, the main function of which is to take an input voltage signal and produce a corresponding amplified voltage signal. Also of importance is the **current amplifier**, which takes an input current signal and produces an amplified current signal. Usually both these types of amplifier, as a result of the amplification, also increase the power of the signal. However, the term **power amplifier** is usually reserved for circuits that have the primary function of supplying large amounts of power to a load. Clearly, power amplifiers must also provide either voltage or current amplification or both.

The amplification produced by a circuit is described by its **gain**, which is often given the symbol A. From the above, we can define three quantities – namely, **voltage gain**, **current gain** and **power gain**. These quantities are given by the expressions