Electronics Fundamentals
Chapter 0
Introduction

Introduction:

Electronics: Is the science and technology of the motion of charges in gas, vacuum or semiconductors.

The term of electronics can be attributed to the Lorentz (1895) who postulated the existence of discrete charges that called ELECTRONS.

Historically electronics can be divided by two times intervals

1- Vacuum tube era: In 1895 J. J. Thomson verified the existence of electrons. In the same year Braun built the first electron tube.
2- Transistor era: That begins with the invention of transistor at 1948 by the scientists Shockley, Brattain and Bardeen. The word transistor is come from Transfer- resistor.

Silicon transistor was manufactured by Texas instrument at 1954.

Integrated circuits (IC), (first called Solid circuits), was announced by Texas at 1959.

Microelectronics: refer to the design and fabrication of high component density of ICs. A large IC chip is only about 3x5 mm in area and 0.3 mm thick.

1948: Transistor invention.

1954: Transistor manufacturing.

1960: Small scale integration (SSI), 1-100 devices or component per chip.

!966: Medium scale integration (MSI), 100- 1000 devices per chip.

1969: large scale integration (LSI), 10^3- 10^4 devices per chip.

1975: Very large scale integration (VLSI), 10^4- 10^9 devices per chip.

1985: Ultra large scale integration (ULSI), or Giga scale Integration (GSI) above 10^9 devices per chip.

Electronic Signals:

The signals that electronic devices are designed to process can be classified into two broad categories: **analog and digital**. Analog signals can take on a continuous range of values, and thus represent continuously varying quantities; purely digital signals can appear at only one of several discrete levels. are all analog processes. Analog signals directly represent variables such as temperature, humidity, pressure, light intensity, or sound—all of which may take on any value, typically within some finite range.

In reality, classification of digital and analog signals is largely one of perception. Designers of high-speed digital systems soon realize that they are really dealing with analog signals. The time-varying voltage or current plotted in Fig. 1 could be the electrical representation of temperature, flow rate, or pressure versus time, or the continuous audio output from a microphone.

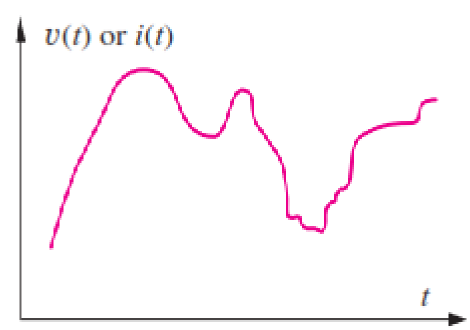

Figure 1. 1 A continuous analog signal;

In electronics, **dependent** (or **controlled**) **sources** are used extensively. Four types of dependent sources are summarized in Fig. 1.2, in which the standard diamond shape is used for controlled sources. The **voltage-controlled current source (VCCS), current-controlled current source (CCCS),** and **voltage-controlled voltage source (VCVS)** are used routinely.

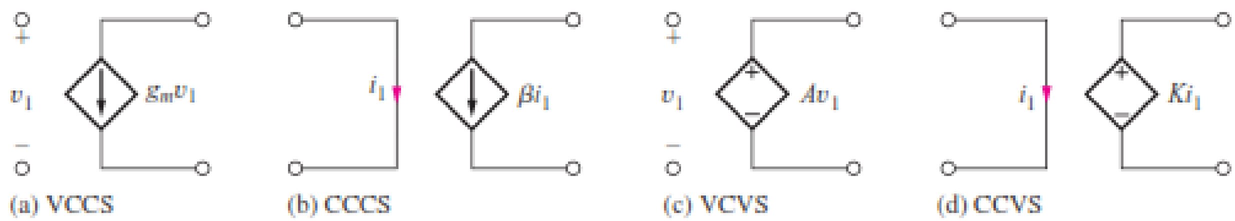

Figure 1.2 Controlled sources. (a) Voltage-controlled current source (VCCS). (b) Current-controlled current source (CCCS). (c) Voltage-controlled voltage source (VCVS). (d) Current-controlled voltage source (CCVS).

Analysis and design of electronic circuits make continuous use of a number of important techniques from basic network theory. Circuits are most often analyzed using a combination of **Kirchhoff's voltage law,** abbreviated **KVL,** and **Kirchhoff's current law,** abbreviated **KCL.** Occasionally, the solution relies on systematic application of **nodal** or **mesh analysis. Th´evenin** and **Norton circuit transformations** are often used to help simplify circuits, and the notions of voltage and current division also represent basic tools of analysis.

<u>Voltage and current division</u>

Voltage and current division are highly useful circuit analysis techniques that can be derived directly from basic circuit theory.

Voltage division is demonstrated by the circuit in Fig. 1.3(a) in which the voltages can be expressed as v_1 and v_2: $\mathbf{v_1 = i_i * R}$ and $\mathbf{v_2 = i_i * R_2}$

Applying KVL to the single loop,

$$v_i = v_1 + v_2 = i_i(R_1 + R_2) \qquad \text{and} \qquad i_i = \frac{v_i}{R_1 + R_2}$$

Combining Eqs. (1) and (2) yields the basic voltage division formula:

$$v_1 = v_i \frac{R_1}{R_1 + R_2} \qquad \text{and} \qquad v_2 = v_i \frac{R_2}{R_1 + R_2}$$

$$v_1 = 10\text{ V}\frac{8\text{ k}\Omega}{8\text{ k}\Omega + 2\text{ k}\Omega} = 8.00\text{ V} \qquad \text{and} \qquad v_2 = 10\text{ V}\frac{2\text{ k}\Omega}{8\text{ k}\Omega + 2\text{ k}\Omega} = 2.00\text{ V}$$

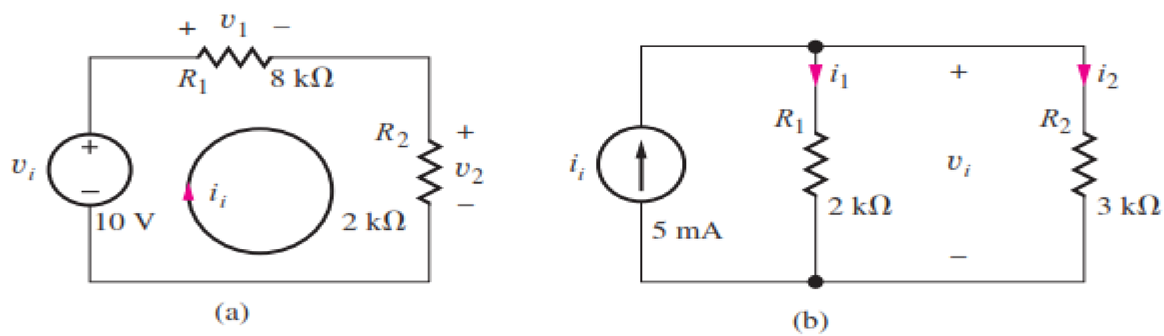

Figure 1.3 (a) A resistive voltage divider, (b) Current division in a simple network.

Current division is also very useful. Let us find the currents $i_1$and i_2 in the circuit in Fig. 1.3(b). Using KCL at the single node,

$$i_i = i_1 + i_2 \qquad \text{where } i_1 = \frac{v_i}{R_1} \text{ and } i_2 = \frac{v_i}{R_2}$$

and solving for v_S yields

$$v_i = i_i \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}} = i_i \frac{R_1 R_2}{R_1 + R_2} = i_i (R_1 \| R_2)$$

in which the notation $R_1 \| R_2$ represents the parallel combination of resistors $R_1$and R_2. Combining Eqs. (1) and (2) yields the current division formulas:

$$i_1 = i_i \frac{R_2}{R_1 + R_2} \qquad \text{and} \qquad i_2 = i_i \frac{R_1}{R_1 + R_2}$$

$$i_1 = 5\text{ mA} \frac{3\text{ k}\Omega}{2\text{ k}\Omega + 3\text{ k}\Omega} = 3.00\text{ mA} \qquad i_2 = 5\text{ mA} \frac{2\text{ k}\Omega}{2\text{ k}\Omega + 3\text{ k}\Omega} = 2.00\text{ mA}$$

<u>Th´evenin and Norton circuit representations</u>

Let us now review the method for finding **Th´evenin** and **Norton equivalent circuits,** including a dependent source; the circuit in Fig. 1.4(a) serves as our illustration. Because the linear network in the dashed box has only two terminals, it can be represented by either the Th'evenin or Norton equivalent circuits in Figs. 1.4(b) and 1.4(c). The work of Th'evenin and Norton permits us to reduce complex circuits to a single source and equivalent resistance.

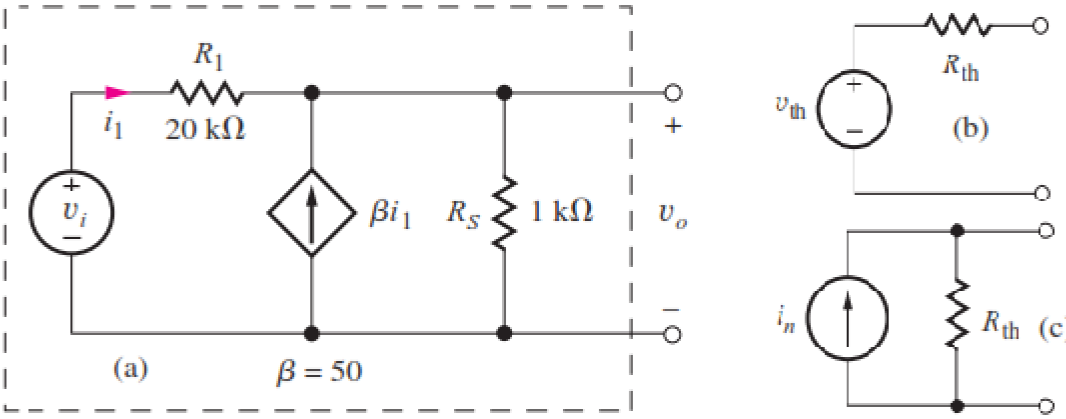

Figure 1.4 (a) Two-terminal circuit and its (b) Th'evenin and (c) Norton equivalents.

Example: Find the Th'evenin and Norton equivalent representations for the circuit in Fig. 1.4(a).

Known Information and Given Data: Circuit topology and values appear in Fig. 1. 4 (a).

Unknowns: Th'evenin equivalent voltage v_{th} ,Th'evenin equivalent resistance R_{th}, and Norton equivalent current i_n..

Approach: Voltage source v_{th} is defined as the open-circuit voltage at the terminals of the circuit. R_{th} is the equivalent at the terminals of the circuit terminals with all independent sources set to zero. Source i_n represents the short-circuit current at the output terminals and is equal to: **[v_{th}/R_{th}]**.

Analysis: We will first find the value of v_{th}, then R_{th} and finally i_n. Open-circuit voltage v_{th} can be found by applying KCL at the output terminals.

$$\beta i_1 = \frac{v_o - v_i}{R_1} + \frac{v_o}{R_S} = G_1(v_o - v_i) + G_S v_o \qquad i_1 = G_1(v_i - v_o)$$

Combining the above equations and rearrange the variables yields:

$$G_1(\beta + 1)v_i = [G_1(\beta + 1) + G_S]v_o$$

The Th´evenin equivalent output voltage is then found to be:

$$v_o = \frac{G_1(\beta + 1)}{[G_1(\beta + 1) + G_S]} v_i = \frac{(\beta + 1)R_S}{[(\beta + 1)R_S + R_1]} v_i$$

where the second relationship was found by multiplying numerator and denominator by (R_1R_S).
For the values in this example,

$$v_o = \frac{(50 + 1)1\ \text{k}\Omega}{[(50 + 1)\ 1\ \text{k}\Omega + 20\ \text{k}\Omega]} v_i = 0.718 v_i \qquad \text{and} \qquad v_{th} = 0.718 v_i$$

R_{th} represents the equivalent resistance present at the output terminals with all independent sources set to zero. To find the **Th´evenin equivalent resistance** R_{th}, we first set the independent sources in the network to zero. Remember, however, that any dependent sources must remain active. A test voltage or current source is then applied to the network terminals and the corresponding current or voltage calculated. In Fig. 1.5 v_i is set to zero, voltage source v_x is applied to the network, and the current i_x must be determined so that: $\boldsymbol{R_{th} = v_x/i_x}$ can be calculated.

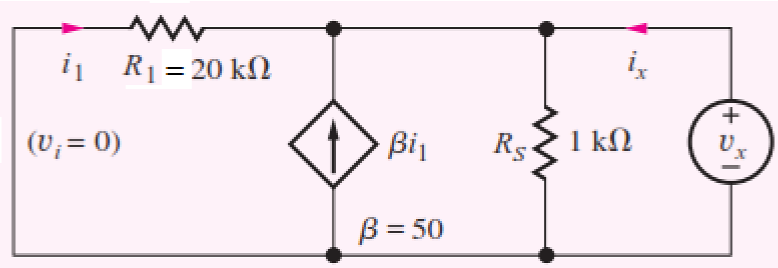

Figure 1.5 A test source v_x is applied to the network to find R_{th}.

$$i_x = -i_1 - \beta i_1 + G_S v_x \qquad \text{in which } i_1 = -G_1 v_x$$

Combining and simplifying these two expressions yields

$$i_x = [(\beta+1)G_1 + G_S]v_x \qquad \text{and} \qquad R_{th} = \frac{v_x}{i_x} = \frac{1}{(\beta+1)G_1 + G_S}$$

The denominator of the above Eq. represents the sum of two conductances, which corresponds to the parallel combination of two resistances. Therefore, Eq. can be rewritten as:

$$R_{th} = \frac{1}{(\beta+1)G_1 + G_S} = \frac{R_S \dfrac{R_1}{(\beta+1)}}{R_S + \dfrac{R_1}{(\beta+1)}} = R_S \left\| \frac{R_1}{(\beta+1)} \right.$$

$$R_{th} = R_S \left\| \frac{R_1}{(\beta+1)} \right. = 1\ k\Omega \left\| \frac{20\ k\Omega}{(50+1)} \right. = 1\ k\Omega \| 392\ \Omega = 282\ \Omega$$

Norton source in represents the short circuit current available from the original network. Since we already have the Th'evenin equivalent circuit, we can use it to find the value of i_n:

$$i_n = \frac{v_{th}}{R_{th}} = \frac{0.718 v_i}{282\Omega} = 2.55 \times 10^{-3} v_i$$

The Th´evenin and Norton equivalent circuits for Fig. 1.4 calculated in the previous example appear for comparison in Fig. 1.6.

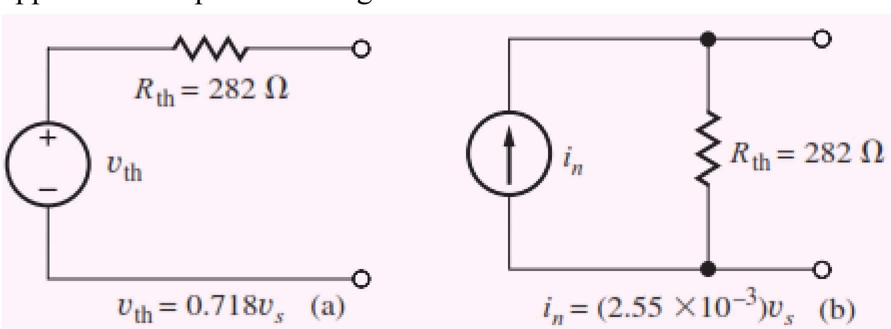

Figure 1.6 Completed (a) Th'evenin and (b) Norton equivalent circuits for the two-terminal network in Fig. 1.4(a).

Norton equivalent circuit

Example: Find the Norton equivalent (Fig. 1.4(c)) for the circuit in Fig. 1.6 (a).

Known Information and Given Data: Circuit topology and circuit values appear in Fig. 1.4(a). The value of *Rth* was calculated in the previous example.

Unknowns: Norton equivalent current *in*.

Approach: The Norton equivalent current is found by determining the current coming out of the network when a short circuit is applied to the terminals.

Analysis: For the circuit in Fig. 1.7, the output current will be: $i_n = i_1 + \beta i_1$ and $i_1 = G_1 v_i$

The short circuit across the output forces the current through R_s to be 0. Combining the two expressions yields;

$$i_n = (\beta + 1)G_1 v_i = \frac{(\beta + 1)}{R_1} v_i = \frac{(50 + 1)}{20\ \text{k}\Omega} v_i = \frac{v_i}{392\ \Omega} = (2.55\ \text{mS})v_i$$

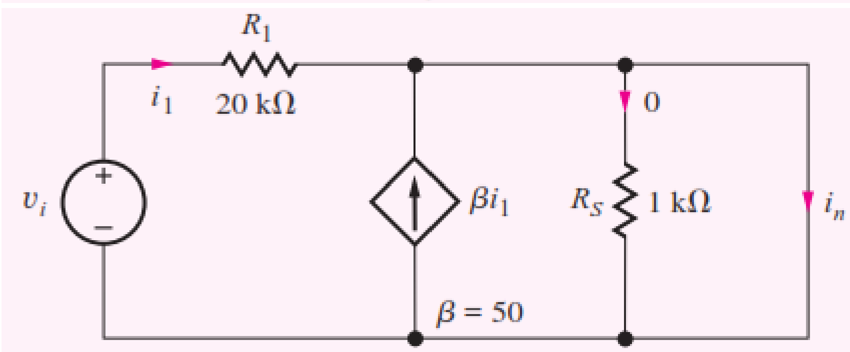

Figure 1.7 Circuit for determining short-circuit output current.