Department of Electrical Engineering
Islamic Azad University, Zahedan Branch

English for the Students of Power, Electronics, Control and Communications

Author: Manoochehr Haghani

Unit 3

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1 Relationship Between Voltage and Current

This is a long and interesting story. It is the heart of electronics. Crudely speaking, the name of the game is to make and use gadgets that have interesting and useful I-versus-V characteristics. Resistors (I simply proportional to V), capacitors (I proportional to rate of change of V), diodes (I flows in only one direction), thermistors (temperature-dependenl resistor), photoresistors (light-dependent resistor), strain gauges (strain-dependent resistor), etc., are examples. We will gradually get into some of these exotic devices; for now, we will start with the most mundane (and most widely used) circuit element, the resistor (Fig. **??**).

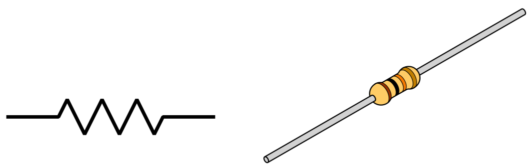

Figure 1.1: Resistor

It is an interesting fact that the current through a metallic conductor (or other partially conducting material) is proportional to the voltage across it. (In the case of wire conductors used in circuits, we usually choose a thick enough gauge of wire so that these "voltage drops" will be negligible.) This is by no means a universal law for all objects. For instance, the current through a neon bulb is a highly nonlinear function of the applied voltage (it is zero up to a critical voltage, at which point it rises dramatically). The same goes for a variety of interesting special devices -diodes, transistors, light bulbs, etc.

A resistor is made out of some conducting stuff (carbon, or a thin metal or carbon film, or wire of poor conductivity), with a wire coming out each end. It is characterized by its resistance:

$$R = \frac{V}{I}$$

R is in ohms for V in volts and I in amps. This is known as Ohm's law. Typical resistors of the most frequently used type (carbon composition) come in values from 1 ohm (1 Ω) to about 22 megohms (22 MΩ). Resistors are also characterized by how much power they can safely dissipate (the most commonly used ones are rated at 1/4 watt) and by other parameters such as tolerance (accuracy), temperature coefficient, noise, voltage coefficient (the extent to which R depends on applied V), stability with time, inductance, etc.

Roughly speaking, resistors are used to convert a voltage to a current, and vice versa. This may sound awfully trite, but you will soon see what we mean.

Capacitors (Fig. **??**) are devices that might be considered simply frequency-dependent resistors. They allow you to make frequency-dependent voltage dividers, for instance. For some applications (bypass, coupling) this is almost all you need to know, but for other applications (filtering, energy storage, resonant circuits) a deeper understanding is needed. For example, capacitors cannot dissipate power, even though current can flow through them, because the voltage and current are 90° out of phase.

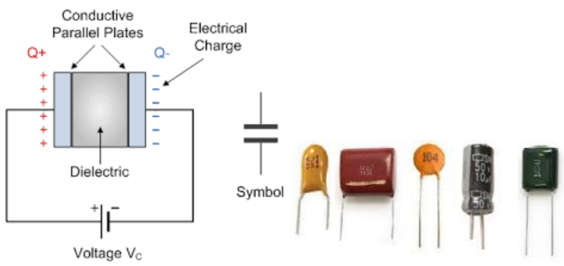

Figure 1.2: Capacitor

A capacitor (the old-fashioned name was condenser) is a device that has two wires sticking out of it and has the property

$$Q = CV$$

A capacitor of C farads with V volts across its terminals will contain Q coulombs of stored charge.

Taking the derivative, you get

$$I = C\frac{dV}{dt}$$

Capacitors come in an amazing variety of shapes and sizes. The basic construction is simply two conductors near each other; in fact, the simplest capacitors are just that. For greater capacitance, you need more area and closer spacing; the usual approach is to plate some conductor onto a thin insulating material (called a dielectric), for instance, aluminized Mylar film rolled up into a small cylindrical configuration. Other popular types are thin ceramic wafers, metal foils with oxide insulators (electrolytics), and metallized mica. Each of these types has unique properties. In general, ceramic and Mylar types are used for most noncritical circuit applications; tantalum capacitors are used where greater capacitance is needed, and electrolytics are used for power supply filtering.

Inductors (Fig. **??**) are closely related to capacitors; the rate of current change in an inductor depends on the voltage applie across it, whereas the rate of voltage change in a capacitor depends on the current through it. The defining equation for an inductor is

$$V = L\frac{dI}{dt}$$

where L is called the inductance and is measured in henrys (or mH , μH, etc.). Putting a voltage across an inductor causes the current to rise as a ramp (for a capacitor, supplying a constant current causes the voltage to rise as a ramp).

Figure 1.3: Inductor

The symbol for an inductor looks like a coil of wire; that is because, in its simplest form, that is all it is. Variations include coils wound on various core materials, the most popular being iron (or iron alloys, laminations, or powder) and ferrite, a black, nonconductive, brittle magnetic material. These are all ploys to multiply the inductance of a given coil by the 'permeability' of the core material. The core may be in the shape of a rod, a toroid (doughnut), or even more bizarre shapes, such as a 'pot core' (which has to be seen to be understood; the best description we can think of is a doughnut mold split in half, if doughnuts were made in molds).

Inductors find heavy use in radio frequency (RF) circuits, serving as RF 'chokes' and as parts of tuned circuits. A pair of closely coupled inductors form the interesting object known as a transformer.

PART I. COMPREHENSION EXERCISES

A. Put "T" for true and "F" for false statements. Justify your answers.

······ 1. The relationship between voltage and current is a crucial point in electronics.

······ 2. Resistors and capacitors provide for useful current versus voltage.

······ 3. Thermistors are light sensitive devices.

······ 4. Capacitors are of different types.

······ 5. Each capacitor has various applications.

······ 6. In order to produce coils with different rates of inductance, various core materials are employed.

B. Choose a, b, c, or d which best completes each item.

1. Ohm's law states that the current in a circuit is ....
   a. inversely proportional to the resistance of the circuit and is directly proportional to the electromotive force in the circuit
   b. directly proportional to the resistance of the circuit and is inversely proportional to the electromotive force in the circuit
   c. directly proportional to the resistance and the electromotive force in the circuit
   d. inversely proportional to the resistance and the electromotive force in the circuit

2. It is true that resistors ....
   a. separate signals
   b. generate waves
   c. dissipate power
   d. store energy

3. The current through a capacitor is ....
   a. independent of frequencies
   b. proportional to the voltage
   c. independent of the variations of voltage
   d. proportional to the rate of change of voltage

4. It is true that ....
   a. resistors may be used in bypass applications
   b. capacitors may be used for filtering
   c. resistors are identical with condensers
   d. capacitors are identical with thermistors

5. If you change the voltage across a farad by one volt per second, you are ....
   a. supplying an ampere
   b. supplying a farad
   c. increasing the voltage
   d. increasing the current

6. We may deduce from the text that 1 volt across 1 henry produces a curent that ....

a. decreases at 1 amp per second
b. increases at 1 amp per second
c. is constant up to a critical point
d. is zero up to a critical point

Part II. Language Practice

A. Choose a, b, c, or d which best completes each item.

1. A voltage or current that varies at a constant rate is referred to as

   a. a ramp
   b. a rise
   c. a drop
   d. a tap

2. A .... is an electron device that makes use of the change of resistivity of a semiconductor with change in temperature.

   a. thermocouple
   b. thermoelement
   c. thermostat
   d. thermistor

3. A .... consists of two electrodes separated by a dielectric for introducing capacitance into an electric circuit.

   a. capacitor
   b. resistor
   c. diode
   d. strain gauge

4. A .... introduces relatively small insertion loss to waves in one or more frequency bands and relatively large insertion loss to waves of other frequencies.

   a. bypass
   b. filter
   c. coupling
   d. condenser

5. The property of an electric circuit by virtue of which a varying current induces an electromotive force in that circuit or in a neighboring circuit is called ....

   a. conductance
   b. capacitance
   c. inductance
   d. resistance

B. Fill in the blanks with the following words.

inductor	resonant	tuned
parallel	capacitive	divided
composed	connected	circuit

A series tuned circuit is .... of a capacitor and an inductor .... in series. The frequency at which the .... and inductive reactances are equal is the .... frequency. The reactance value of the .... or capacitor at this frequency .... by the series resistance in the .... is the Q (quality factor). A Parallel .... circuit consists of an inductor in .... with a capacitor.

C. Put the following sentences in the right order to from a paragraph. Write the corresponding letters in the boxes provided

a. Inductors usually consist of many adjacent turns of insulated wire, wound on a single support of laminated iron for low frequency inductors and ferrite for high frequencies.

b. Resistors may be wire-wound to dissipate considerable heat, or they may be a thin film or a composition.

c. At very high frequencies, air-core inductors are generally used.

d. Resistors, inductors and capacitors are passive circuit components.

e. Capacitors may be fixed, with solid dielectrics, or variable with usually an air dielectric.

f. Rheostats and potentiometers are variable resistors with two and three terminals respectively.