Electrical, Controls, Instrumentation

Ricky Nguyen's knowledge bank

# EC&I Knowledge Encyclopedia

| Changed by: | Date | Comment |
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| Ricky N. | 16/07/2022 | |
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# 1 UQ Subjects

This chapter goes through the UQ courses that was undertaken from 2016-2019. The format will be as follows, for each section, where possible:

1. Lecture notes (Use "LEC##: TITLE HERE" for each heading)
2. Tutorial questions (Use "TUT##: TITLE HERE" for each heading)
3. Summary of all equations used (Use "EQU##: TITLE HERE" for each heading)
4. References & other helping material (Use "REF##: TITLE HERE" for each heading)
5. Australian Standards (Use "STD##: TITLE HERE" for each heading)

In terms of text colour and highlights, the format will be as follows where possible:

1. Black = normal text
2. Red = Important
3. Blue = References
4. Green = Key Takeaways

## 1.1 CSSE2002 - Java Language

## 1.2 CSSE2010 - Embedded Programming

## 1.3 CSSE2310 - C Language

### 1.4 CSSE3010 - Advanced Embedded

## 1.5 MATH1051 - Linear Calculus

### 1.6 MATH2001 - Advanced Calculus

### 1.7 MATH2010 - Partial Differential Equations

## 1.8 STAT2202 - Advanced Statistics

### 1.9 ELEC2003 - Electronics & Circuits Pt.1

## 1.10 ELEC2004 - Electronics & Circuits Pt.2

### 1.10.1 LEC01: Capacitors and Inductors, RL and RC Circuits

#### Capacitors

Capacitors and inductors are linear circuit elements that can store electrical energy. The ideal capacitor stores energy in the form of **charge**.

$$C = \frac{\epsilon A}{d} \tag{1}$$

Where:

- C = capacitance in Farads ($F$)
- A = conductor plates area (both top and bottom) ($mm^2$)
- $\epsilon$ = dielectric of permitivity (constant)
- d = plate separation distance ($m$)

$$Q = CV \tag{2}$$

Where:

- Q = stored charge
- C = capacitance ($F$)
- V = applied voltage ($V$)

In DC, a capacitor is effectively an open circuit; when a steady voltage is applied. When the voltage changes, the stored charge changes also as per equation (2) by taking the derivative. Thus,

$$i(t) = \frac{dq(t)}{dt} = C\frac{dv(t)}{dt} \tag{3}$$

KEY TAKEAWAY: Change in voltage induces a current because there are charges moving. This electrical energy is stored in "capacitance" in the form of an electric field.

Energy storage in capacitors is calculated by integrating the instantaneous power $P(t)$. Thus,

$$P(t) = v(t)i(t) = Cv(t)\frac{dv(t)}{dt} \tag{4}$$

Integrating the instanteous power:

$$W(t) = \frac{1}{2}Cv^2(t) \tag{5}$$

Capacitors can be combined in series and in parallel to yield a single equivalent capacitance. Note: the behaviour of equivalent capacitance is the opposite of resistors. Series:

$$C_{EQ} = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}...} \tag{6}$$

Parallel:

$$C_{EQ} = C_1 + C_2 + C_3 ... \tag{7}$$

### Inductors

The ideal inductor stores energy in an **induced magnetic field**.

$$\phi = LI \tag{8}$$

Where:

- $\phi$ = induced magnetic flux
- L = inductance in Henrys ($H$)
- I = applied current ($A$)

In DC, an inductor is effectively a short circuit (i.e. a wire with no resistance). When the current changes, the induced field also changes. Thus,

$$v(t) = \frac{d\phi(t)}{dt} = L\frac{di(t)}{dt} \tag{9}$$

KEY TAKEAWAY: The rate of change in magnetic flux induces a voltage. Thus, alternating current (AC) induces a change in magnetic field and thus produces a voltage. Inductance is the tendency of an electrical conductor to oppose a change in the electric current flowing through it.

Energy storage in inductors is calculated by integrating the instantaneous power $P(t)$. Thus,

$$P(t) = v(t)i(t) = Li(t)\frac{di(t)}{dt} \tag{10}$$

Integrating the instanteous power:

$$W(t) = \frac{1}{2}Li^2(t) \tag{11}$$

Inductors can be combined in series and in parallel to yield a single equivalent inductance. Note: the behaviour of equivalent inductance is the same as resistors. Series:

$$L_{EQ} = L_1 + L_2 + L_3 ... \tag{12}$$

Parallel:

$$L_{EQ} = \frac{1}{\frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3}...} \tag{13}$$

Other topics found:

- Solving RC Circuits & Forced responses & Transient analysis
- Approaches to solve circuits
- Class exercises

#### 1.10.2 LEC02: Nodal & Mesh Analysis and Network Theorems

### The Basics

These are the fundamental electrical basics:

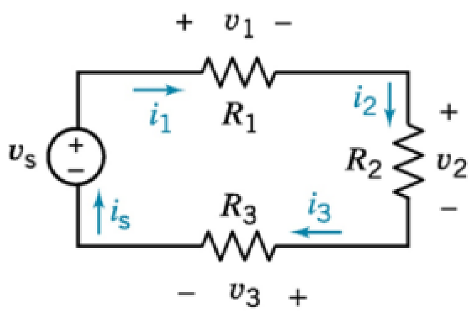
- $V = IR$ (Ohm's Law)
- $P = VI = \frac{V^2}{R} = I^2R$
- Kirchhoff's current law (KCL): Sum of currents into a node = 0
- Kirchhoff's voltage law (KVL): Sum of voltages around a loop = 0
- Series and parallel circuits (voltage and current dividers)

### Mesh and Node Analysis

- Nodal analysis: Set voltages at each node as the unknown variables, apply KCL. Note: Currents going into the node are positive, and currents going out of the node are negative. Use KCL when the source is a current source.
- Mesh analysis: set the current through each branch as the unknown variables, apply KVL; Note: choose a direction for a loop and stick to that direction for all loops. Voltages going from negative to positive (e.g. Voltage Sources) are positive and voltages going from positive to negative (e.g. resistors) are impedances. Use KVL when the source is a voltage source.

# Kirchhoff-based solution strategy

## How to obtain a solvable case with KCL and KVL?




KCL:

$$i_s - i_1 = 0$$
$$i_1 - i_2 = 0$$
$$i_2 - i_3 = 0$$
$$i_3 - i_s = 0$$

KVL:

$$v_s - v_1 - v_2 - v_3 = 0$$

Branch $v$-$i$:

$$v_1 = R_1 i_1$$
$$v_2 = R_2 i_2$$
$$v_3 = R_3 i_3$$

KCL gives

$$i_s = i_1 = i_2 = i_3.$$

Using Ohm's law gives

$$i_s = \frac{v_1}{R_1} = \frac{v_2}{R_2} = \frac{v_3}{R_3}.$$

KVL gives

$$v_1 = v_s - v_2 - v_3$$
$$\Rightarrow i_s = \frac{1}{R_1}(v_s - R_2 i_2 - R_3 i_3)$$
$$\Leftrightarrow i_s = \frac{v_s}{R_1 + R_2 + R_3}$$

## 1.11 ELEC3100 - Advanced Electrical Theory

### 1.12 ELEC3300 - Motors & Electrical Energy

## 1.13 ELEC3400 - Amplifiers & Electronics

### 1.14 ELEC4300 - Power System Analysis

### 1.15 ELEC4302 - Power System Protection

## 1.16 ELEC4620 - Signal Processing

### 1.17 ELEC4630 - Image Processing

## 1.18 ENGG4800 - Project Management

### 1.19 METR4201 - Control System Analysis