Electronic Circuits
ELEC1200

USMC campus: Dr Low Siow Yong
Highfield campus: Dr Dan Spencer
Prof Neil White
Housekeeping

- Lectures (Check your timetable weekly)
  - One 2-hour lecture and one 1-hour weekly
  - Primary source of information

- Tutorials
  - One 1-hour tutorial weekly
  - Feedback on problem sheets etc

- Laboratory – ELEC1029 (Part 1 EEE labs)
  - ELEC1200 -> Two 3-hour dedicated sessions (T1 & T2)
  - ELEC1029 -> Other generic first year labs (Xs)
  - X0 starts tomorrow, X1 next week.
  - T1 next Tuesday
Assessment

- No final examination
- 0% Problem Sheets (PS) (8 in total)
  - First PS due next week (Wk2)
  - [https://forms.office.com/Pages/ResponsePage.aspx?id=-XhTSvQpPk2-iWadA62p2H4tItromDBAnE3TrN6PTNIUQVI4WUszU01aN0haWU9XS1lV M0VNWTExUS4u](https://forms.office.com/Pages/ResponsePage.aspx?id=-XhTSvQpPk2-iWadA62p2H4tItromDBAnE3TrN6PTNIUQVI4WUszU01aN0haWU9XS1lV M0VNWTExUS4u)
- 65% In-Class Tests (2x), in-class exams, Wks 6 & 15, respectively
  - Test 1, 5-6pm, 5-6pm Wed 7th Nov 2018 (Week 6)
  - Test 2, 5-6pm, 5-6pm Wed 9th Jan 2019 (Week 15)
- 10% Technical labs, Ts (only T1 & T2)
- 10% Skills labs, Xs, e.g., X0, X1 etc
- 15% Design project (D1), Wks 16-17
- Self paced maths on complex numbers ~%
Resources

https://secure.ecs.soton.ac.uk/notes_my/elec1200/

Core textbook


Other references

• Senturia S D, Wedlock B.D. Electronic Circuits and Applications, Wiley, 1975
• www
Syllabus ELEC1200

• PRINCIPLES OF CIRCUITS
• STEP RESPONSE OF RL AND RC CIRCUITS
• COMPLEX NUMBERS
• AC THEORY
• RESONANCE
• THREE PHASE SYSTEMS
• Non-Linear Circuits - DIODE CIRCUITS
Electronic Circuits 1200

• To explain the mathematical techniques needed to analyse linear and simple non-linear electronic circuits (ideal)

"Learning is by nature curiosity
... prying into everything, reluctant to leave anything, material or immaterial, unexplained."
— Alexandrinus Philo

Wisdom
-Knowledge
-Experience
->Good judgement
Aims and Objectives

• A1. Understand the ideal building blocks of circuit theory.
• A2. Understand the key ideas in circuits, such as impedance, power and resonance.
• A3. Analyse ideal analogue AC circuits, in the context of both single and three phase systems.
• A4. Analyse AC circuits using complex numbers and phasors.
• A5. Analyse transient behaviour in RC and RL circuits in the time domain.
Electronic Circuits 1200

- Circuit theory
  - Studies the behaviour of ideal electrical systems
  - All about voltages/currents
Physical System

Q?: Which causes which, current or voltage?
Revisiting Voltage: An illustration

One Joule of energy is needed to create 1V.
An Analogy: Water pump

Images adapted from http://www.allaboutcircuits.com/vol_1/chpt_1/4.html
Ideal components – a circuit building blocks

- Resistor, R
- Capacitor, C
- Inductor, L
- Power sources – voltage/current
- Diode
- Transistor (next semester)

Don’t forget the wires
Defns: Branch, node, loop

- **Branch (B)** - any two terminal element
- **Node (N)** - Two or more branches connected at the same point
- **Loop (L)** - A closed path in the circuit
Power supply

Diagram showing different voltage levels and configurations.
Passive sign convention

The \( v \) in red denotes one way of specifying the voltage across the element.
Notational reminder

Single subscript $V_a$
Double subscript $V_{ab}$
An example

Find $V_{ab}$

$$V_{ab} = V_a - V_b = 10 - 4 = 6V$$

$$V_a = V_{6\Omega} + V_{4\Omega} = 6 + 4 = 10V$$

$$V_a = +E = 10V$$
Q?: Find $V_1$ and $V_2$
Voltage & Current Sources
Ohm’s Law

\[ I = \frac{V}{R} \]

Adapted from http://www.sengpielaudio.com/calculator-ohmslaw.htm
Ohm’s Law

Q?: So what can we say about the straight line?

Q?: Does it hold for all V and I?
Ohm’s Law

Large resistance

Small resistance

Diode

Battery

Adapted from http://upload.wikimedia.org/wikipedia/commons/d/d7/FourIVcurves.svg

<table>
<thead>
<tr>
<th>Material</th>
<th>Resistivity (Ω·m)</th>
<th>Usage</th>
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<tr>
<td>Copper</td>
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<td>Silicon</td>
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<td>Glass</td>
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<tr>
<td>Teflon</td>
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### Standard values of commercially available resistors.

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<tr>
<th>Ohms (Ω)</th>
<th>Kilohms (kΩ)</th>
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<td>1.6 16.0</td>
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### The E12 Resistor Series

![E12 Resistor Series Diagram](image-url)
A simple series circuit

Q?: What’s the current across R?
Parallel circuit

By inspection $E = V_1 = V_2$

Is $I_s = I_1 + I_2$?

Q?: Parallel hence same voltage or same voltage hence parallel
Kirchhoff’s Law

• Kirchhoff’s current law (KCL)
  – Algebraic sum of the currents entering and leaving a node at any instant is zero

• Kirchhoff’s voltage law (KVL)
  – Algebraic sum of the voltages around any loop in a circuit is zero for all time
KCL: Conservation of Charge

KCL: Algebraic sum of the currents entering and leaving a node at any instant is zero

\[ \sum I_i = \sum I_o \]

\[ I_1 + I_4 = I_2 + I_3 \]

\[ 4 \text{ A} + 8 \text{ A} = 2 \text{ A} + 10 \text{ A} \]
Q?: Negative current, what does it mean?

\[ \Sigma I_i = \Sigma I_o \]

\[ I_1 + 22 \text{ mA} = 17 \text{ mA} \]

\[ I_1 = 17 \text{ mA} - 22 \text{ mA} = -5 \text{ mA} \]
KVL: Conservation of energy

KVL: Algebraic sum of the voltages around any loop in a circuit is zero

Q?: What has this to do with conservation of energy?

\[ +V_1 + V_2 - E = 0 \]
Q?: Why parallel branches have the same voltage?

\[ V_1 = E = 12V \]
\[ V_2 = E = 12V \]
\[ V_1 = V_2 = E = 12V \]
Kirchhoff’s versus Ohm’s

- Ohm’s law – provides local information across each individual element in a circuit
- Kirchhoff’s laws – gives the relationships among all the elements in a circuit
Resistors

• Recall Ohm’s Law, $V=IR$

• Series

• Parallel

Q: What is $R_{eq}$
Another example:

- Voltage divider
- Current divider
Find the current in the circuit below.
Open and Short Circuits

(a) Open circuit

\[ I = 0 \text{ A} \]

\[ V \]

System

(b) \[ V_{\text{open circuit}} = E \text{ volts} \]

(c) Open circuit

\[ I = 0 \text{ A} \]

120 V

Fuse

Internal connection in system

System

Contact

Open circuit

Reflector

Battery

Filament in bulb

Open circuit

120 V
Short Circuit

(a) Short circuit

(b) Will open due to excessive current

V_{\text{short circuit}} = 0 \text{ V}
Open and Short Circuits

I_T = 12 mA

Find I
a) Find the open circuit voltage $V_L$

b) If the 2.2$k\Omega$ resistor is short circuits, what is the value of $V_L$?

c) Determine $V_L$ if the 4.7$k\Omega$ is open circuit
Loading effects
Now we can analyse this circuit.
What next?

- Circuit Analysis: compute/simulate a known circuit
  - What for?
- Circuit Synthesis: Synthesise/design a circuit to meet a particular solution/requirement
  - Visualises a desired outcome
  - Another round of analysis, synthesis and evaluation!
    - Analysis - Understand the problem
    - Synthesis – Finding solutions
    - Evaluation – validity of the solutions, alternatives?
      - power consumption, performance etc

This is what you should be getting at the end of this course!
Complex numbers
Definitions/Refreshers
Capacitors
<table>
<thead>
<tr>
<th>MULTIPLE</th>
<th>PREFIX</th>
<th>SYMBOL</th>
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<tbody>
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<tr>
<td>$10^{-15}$</td>
<td>femto</td>
<td>f</td>
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</tbody>
</table>
Recap: Definitions

- **Charge, q** – unit Coulomb (C), 1C = 6.242x10^{18} electrons
- **Current, I** – unit Ampere (A), \( I = \frac{dq}{dt} \), 1A is the current in which 1C of charge move through a cross section of a conductor in 1s.
- **Voltage, v** – unit Volt (V), electrical potential difference or amount of work/energy needed to move a unit charge between 2 points, \( v = \frac{dw}{dq} \).
- **Power, P** – unit Watt (W), rate of change of work done, \( P = \frac{dw}{dt} \)

A charge of 1C delivers an energy of 1J as it moves through 1V
Questions

• What’s the difference between power and energy?

A 1.2-kW toaster takes roughly 4 minutes to heat four slices of bread. Find the cost of operating the toaster once per day for 1 month (30 days). Assume energy costs => TNB ~21.8cents/kWh

\[
\text{Cost (\$)} = 1.2kW \times \frac{4}{60} \times 30 \times 21.8c/kWh = ?
\]
Q: Will the circuit breaker trip?
Q?: Find $I_1$, $I_2$, $I_3$ and $I$ and their respective directions.
For the circuit shown in Figure 1:

a) Find $V_a$, $V_b$ and $V_{ab}$.

b) Find $i_1$, $i_2$, $i_3$ and use the results to find $i$.

Q?: What can you conclude about the 10V source?