PHYS2641 – Laboratory Skills and Electronics

Electronics

Background course information

It will be assumed in both the lectures and lab classes that you have read and understood all of this background information.

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November 2019

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Course aims – ‘Research Skills’

Officially:

‘to teach electronics as a theoretical and a practical subject’

In reality:

We want to teach basic electronics as a practical skill/tool for physics research...

- to be able to connect and use commonplace lab instrumentation
    - *Oscilloscope, Multimeter, Power Supply, Signal-Generator etc.*
- to understand simple circuit diagrams and be able to set up simple, useful, electronic circuits based on them

Ability to work through a practical problem in an ordered, logical, fashion – exactly as one would in experiment design, computing, data analysis, etc.

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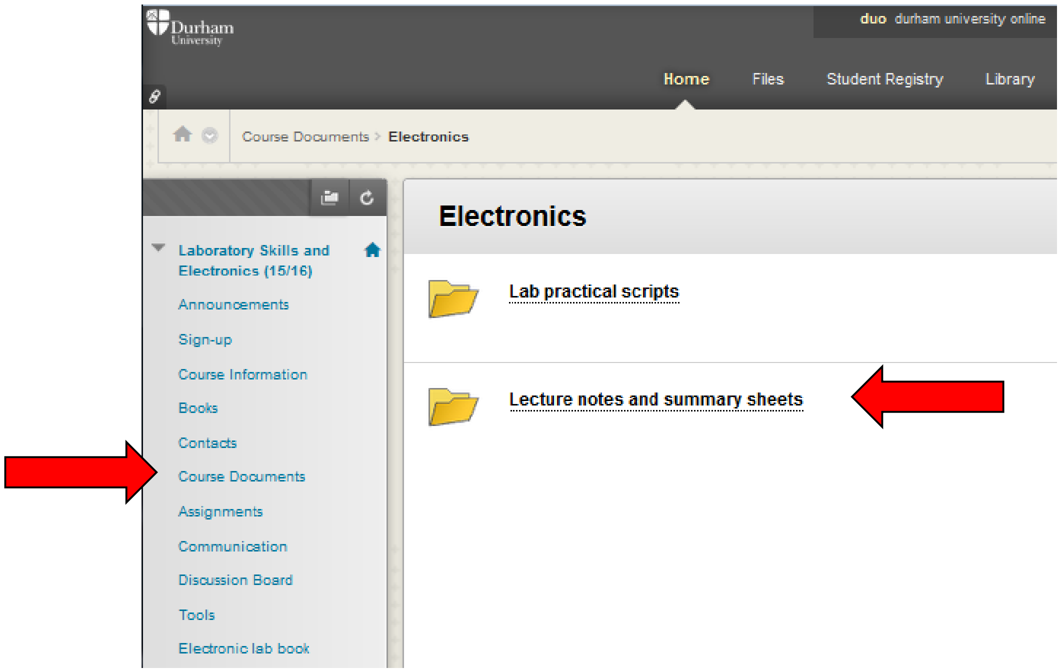
Lecture notes

- Lecture viewgraphs and summary sheet will be made available on DUO



- Lecture content corresponds to work undertaken in the labs – if you attend the lectures, you should have covered everything you need to complete the tasks in the electronics lab sessions

Lab classes

- **Four** experiments (non-assessed) in weeks 8, 9, 10 (Michaelmas term) and 11 (Epiphany term). Usually work in teams of 2

  – These **develop the skills** that you will use in your assessed practical
  – You will attend a session in the same room & time-slot as your Skills lab

- You complete a practical assessment in one of week **12 *or* 13**: a schedule will be posted before the end of term

- Lab scripts use Jupyter Notebooks: both (interactive) Notebooks and (less-interactive, on DUO) pdf versions of the scripts are available in advance of the sessions

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Roles and responsibilities

- **Supervisors & demonstrators:**
  - Assist you with experimental problems
  - Explain operation of instruments etc.
  - Are ***NOT*** there to help you with theory – there is insufficient time for detailed explanation during the lab sessions

- **Lab technical staff**
  - Equipment problems – but see a demonstrator first

- **You – the students**
  - Read the script in advance of each session – pdf copies on DUO
  - Ensure that both team members understand, and are able to complete, the tasks set during the lab sessions: If you sit back and let your partner do everything, you will not understand what to do in the assessment!

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Assessed Practical

- Whilst you work in pairs for the experiments during the first 4 lab weeks, you will work **alone** for the electronics assessed practical

- Assessed practical is NOT under ‘exam conditions’, so feel free to discuss (reasonably quietly) amongst yourselves if you wish

- It is ‘**Open book’** – so you may bring in lab books, printed and annotated course notes, view the course notes on DUO, look at Jupyter notebooks from previous lab sessions, etc., but you may ***not*** use the wider internet (web, e-mail, facebook, etc.)

- There are 10 minute rest breaks for all students after each hour of work

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Assessed Practical (2)

- The ‘script’ Jupyter notebook for the assessed practical will be made available to all students at the start of term: This is 7 days before the first assessment session. The lecture where I explain it in more detail will be on the Thursday prior to the assessment, with slides released on the prior Monday.

- Your scheduled assessment week (12 or 13) will be posted on DUO and on the lab notice boards also at the start of next term

- Your performance at the practical assessment will **benefit strongly** from:
  - Attendance at lectures
  - Making the most of all lab sessions; contributing to your team’s work
  - Good preparation: You may bring notes, a lab book etc. to the assessment

- There is an **additional task** for those taking **PHYS 3681 *only***

Concessions

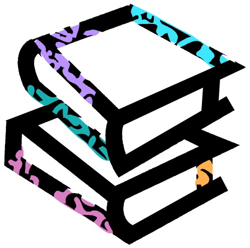
The experimental nature of this course means that concessions for ***exams*** are ***not automatically applied*** to the practical assessment.

Rest breaks are inclusive for all students, so such concessions are not needed here.

A reminder of the departmental policy:

"Students with disabilities should note that examination concessions (such as for extra time) granted for written timed assessments will ***not*** *automatically apply to the* ***Electronics practical assessment****. Any student who feels that he/she might need a concession for the Electronics practical assessment, or wishes to discuss any additional support for this type of assessment, should contact Disability Support to discuss the matter, and should also inform the Departmental Disability Representative, Dr Vincent Eke. This should be done by the* ***6th December*** *at the latest, to allow any concession applications (if appropriate) to be processed before Christmas"*

Recommended texts



These **not** required reading, DO NOT buy copies of them!

Most general purpose electronics textbooks will cover the necessary topics

Electronics: A Systems Approach (4th, 5th or 6th ed.); N. Storey

Easy to follow, with clear examples

The Art of Electronics; P. Horowitz & W. Hill

Comprehensive, classic text (occasionally inaccurate...)

Microelectronic Circuits and Devices; M.N. Horenstein

Comprehensive, lots of examples and problems

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Electronics course overview

LECTURES MAP ONE-TO-ONE TO LAB PRACTICALS

Lectures		Labs
1. Intro & passive circuits	→	Passive Filters
2. Operational amplifiers	→	Operational amplifiers 1
3. Operational amplifiers (cont.)	→	Operational amplifiers 2
4. Modulation	Christmas vacation	Modulation
5. Phase-sensitive detection	→	Assessed practical (week 1)
		Assessed practical (week 2)

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jupyter

Online Jupyter Notebook system will be used for all of the practical classes. I will demonstrate using it in the first lecture.

Benefits:

- Replaces printed laboratory scripts and (largely) laboratory notebooks
- NO python programming is required! (from you, I have done it all)
- You do NOT need to do battle with Excel (or matplotlib) to plot graphs!

Drawbacks:

- None! So long as you use the system sensibly…

Jupyter notebooks on shared PCs

Treat the Jupyter system like you online banking!

You need to ensure that you log in to the Jupyter system under **your own** user account: If you have NOT entered your CIS username and password at the Jupyter prompt, you are not logged in to your account.

You also NEED to explicitly LOG OUT at the end of the session – closing the browser and turning off the computer is insufficient, you remain logged in when the computer restarts.

The result of this is that if, say, a student in Monday labs doesn't log out, you can end up with a student on Tuesday labs overwriting all of their data.

The end result of this is that NEITHER student any longer has access to the data that they collected in the lab!

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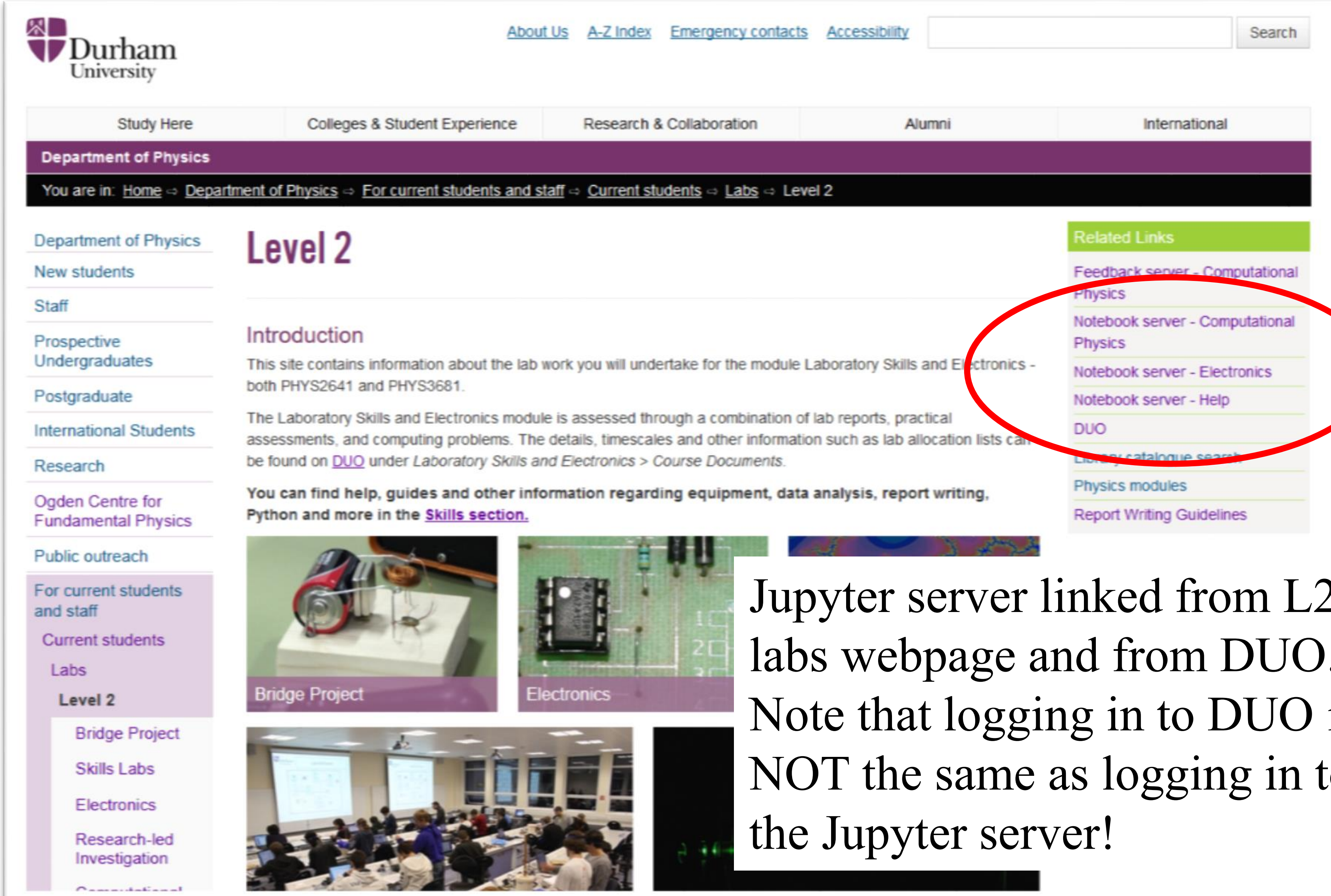
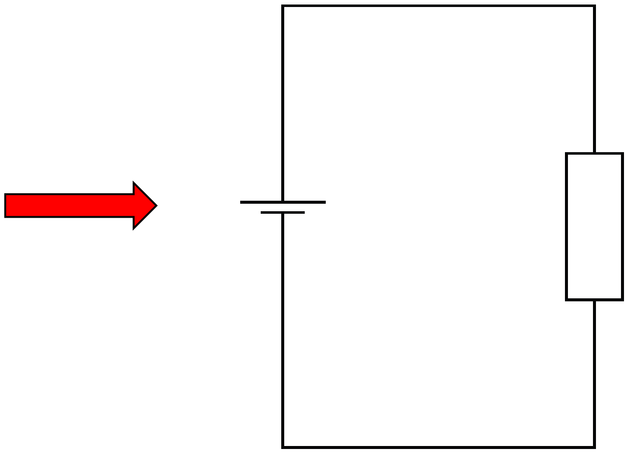


Jupyter server linked from L2 labs webpage and from DUO. Note that logging in to DUO is NOT the same as logging in to the Jupyter server!

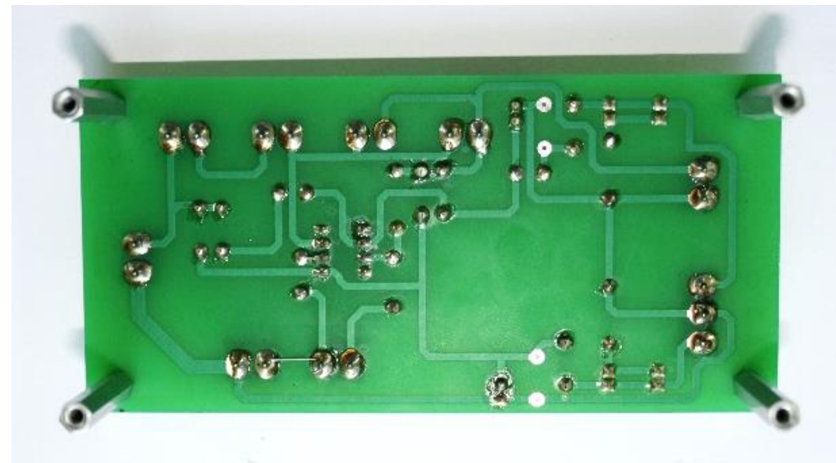
Circuit diagrams

Components are connected by wires, drawn with straight lines:
e.g. A power supply connected to a resistor

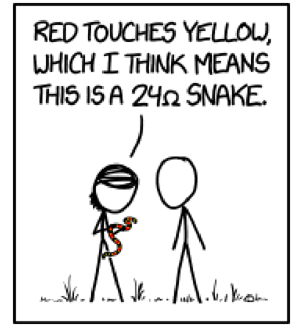


Crocodile clips make a sufficiently good connection

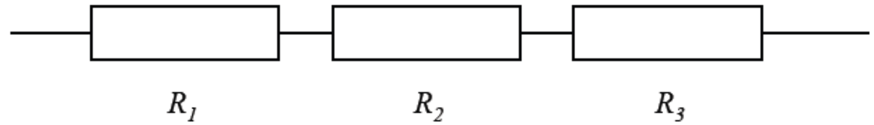
Printed circuit-board (PCB)



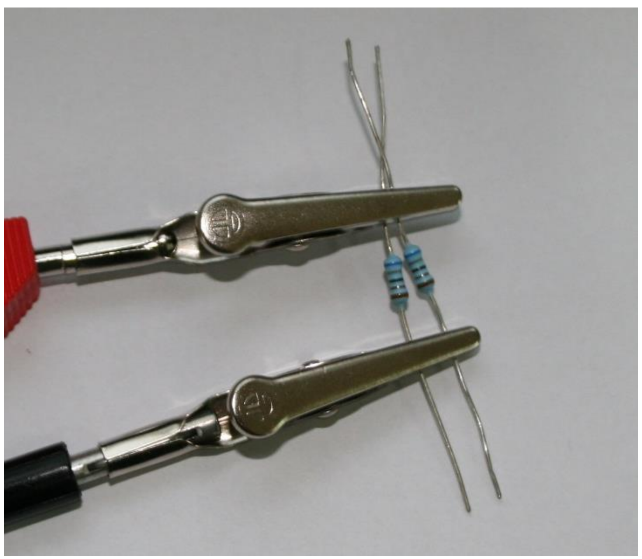
Screw terminal blocks connected to components as depicted by the white lines. These correspond to the copper traces on the back side of the board (right)

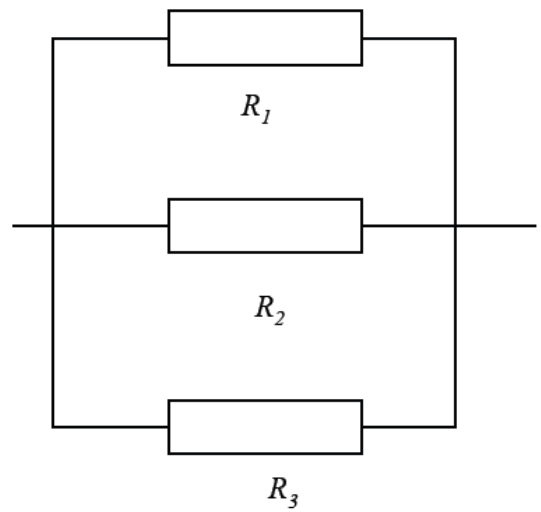


Resistor networks



$$R_{TOTAL} = R_1 + R_2 + R_3$$





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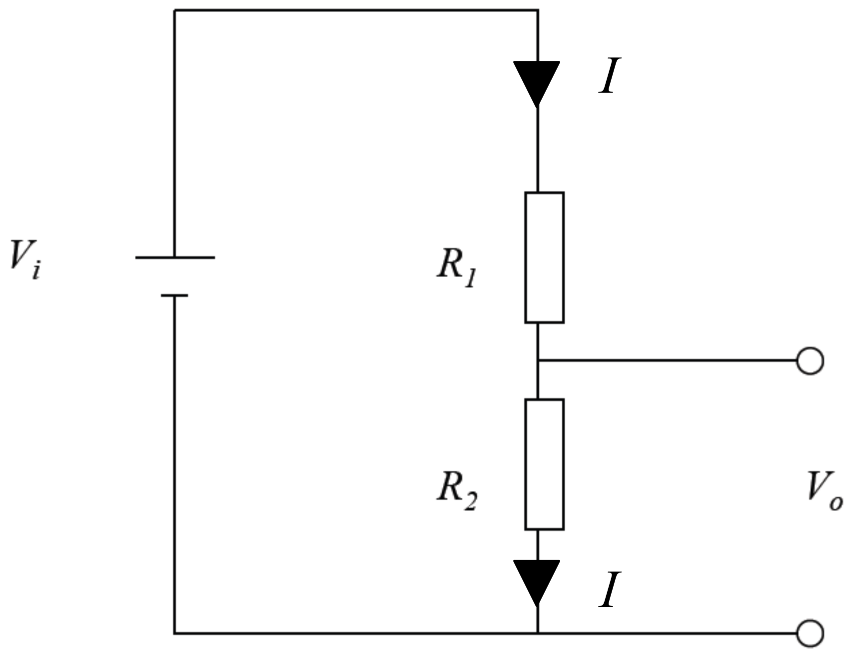
No need to solder components – can hold together with crocodile clips

Potential divider circuits



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

$$= \frac{V_i}{R_1 + R_2} = \frac{V_0}{R_2}$$

$$\boxed{V_0 = \frac{R_2}{R_1 + R_2} V_i}$$

What is V_0?

I assume that you know this already.

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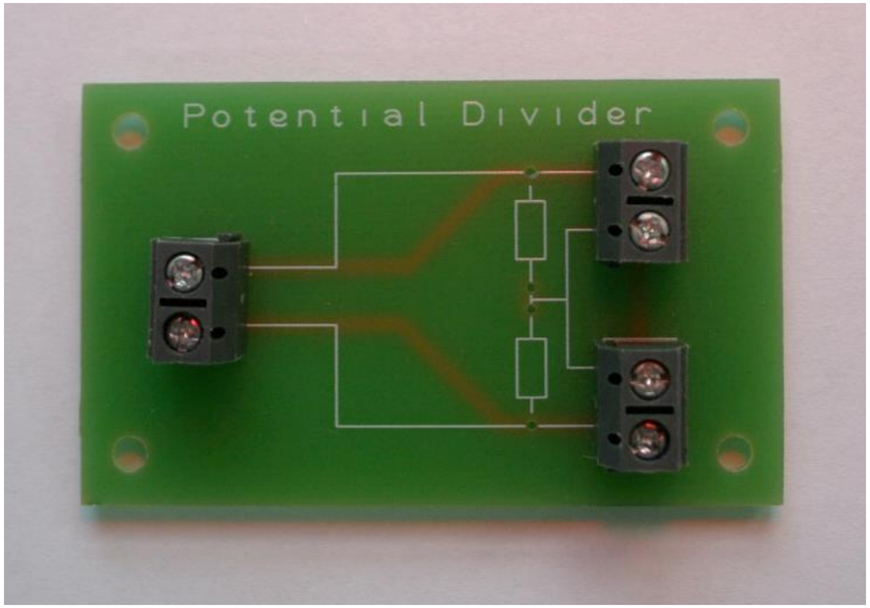
Printed circuit-board (PCB)



This is what the potential divider circuit board that we will be using looks like. You can see which terminal is connected to which by following the white lines

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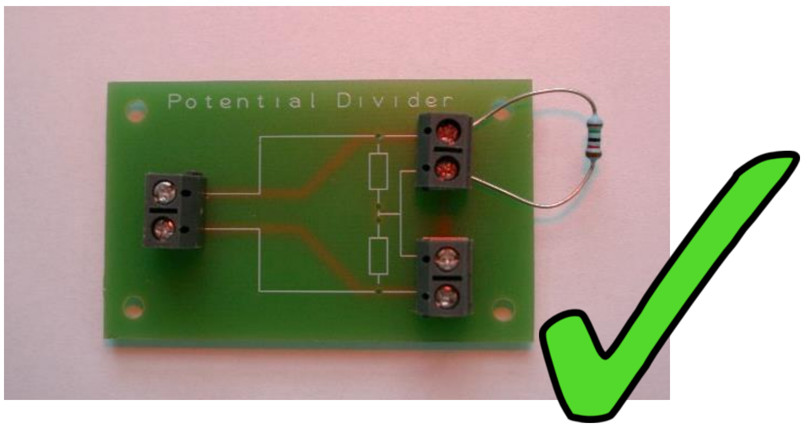
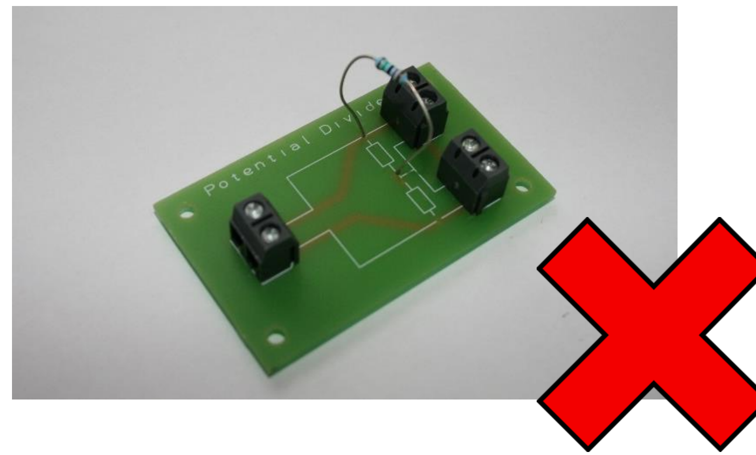
Attaching components





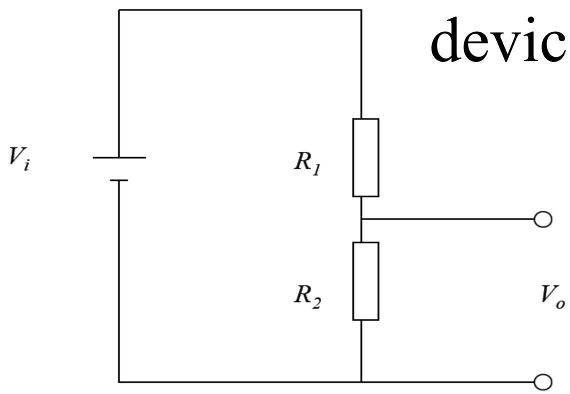
Attach components using screw-terminal blocks

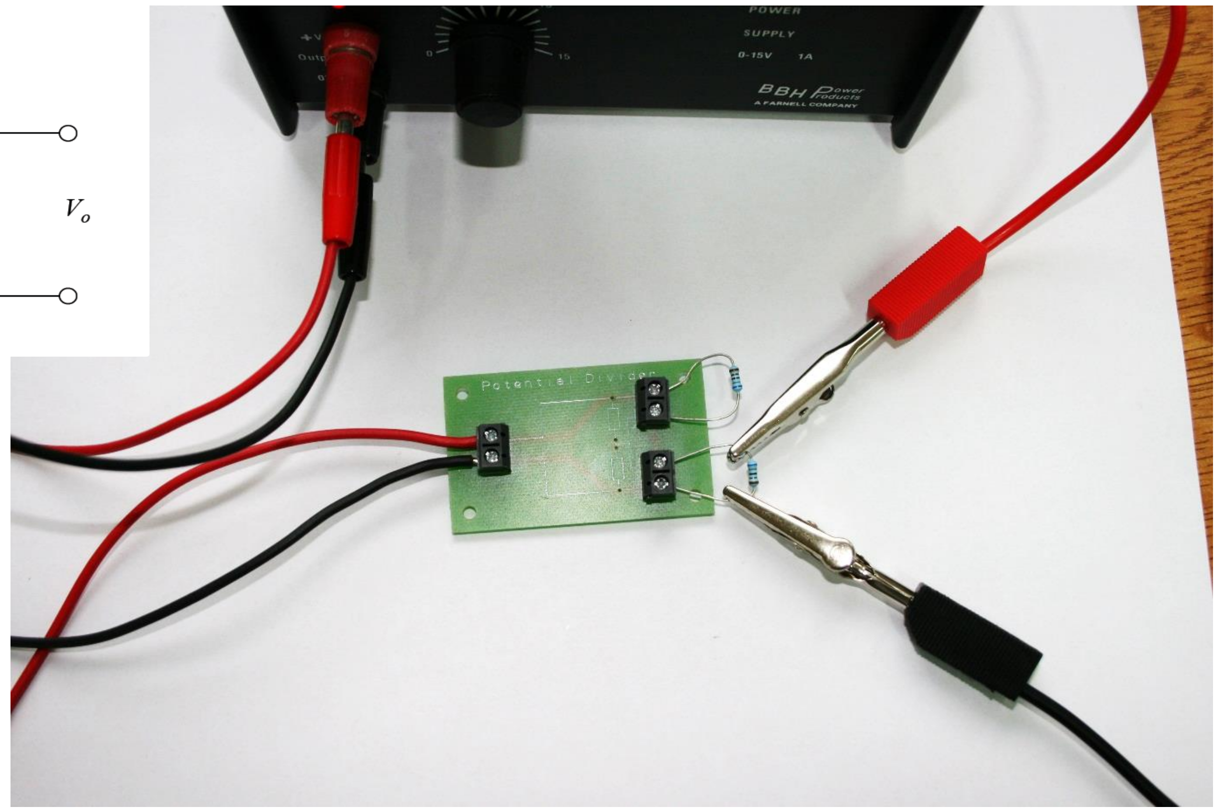
- Tighten using screwdriver – with PCB flat on table

Don’t fit components through holes in PCB – won’t work

‘Real’ potential divider

We can make connections to our measurement device (DVM, oscilloscope) using crocodile clips





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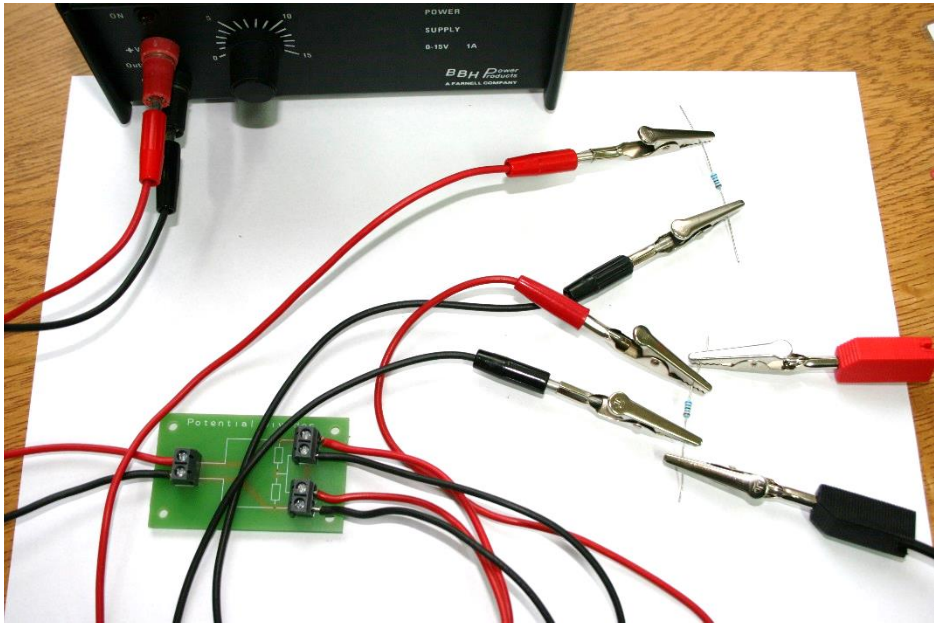
Keep it simple…



- Same circuit, but built using more wires than necessary
- Much harder to follow what is connected to what, and to diagnose faults
- Many more connections that may be loose

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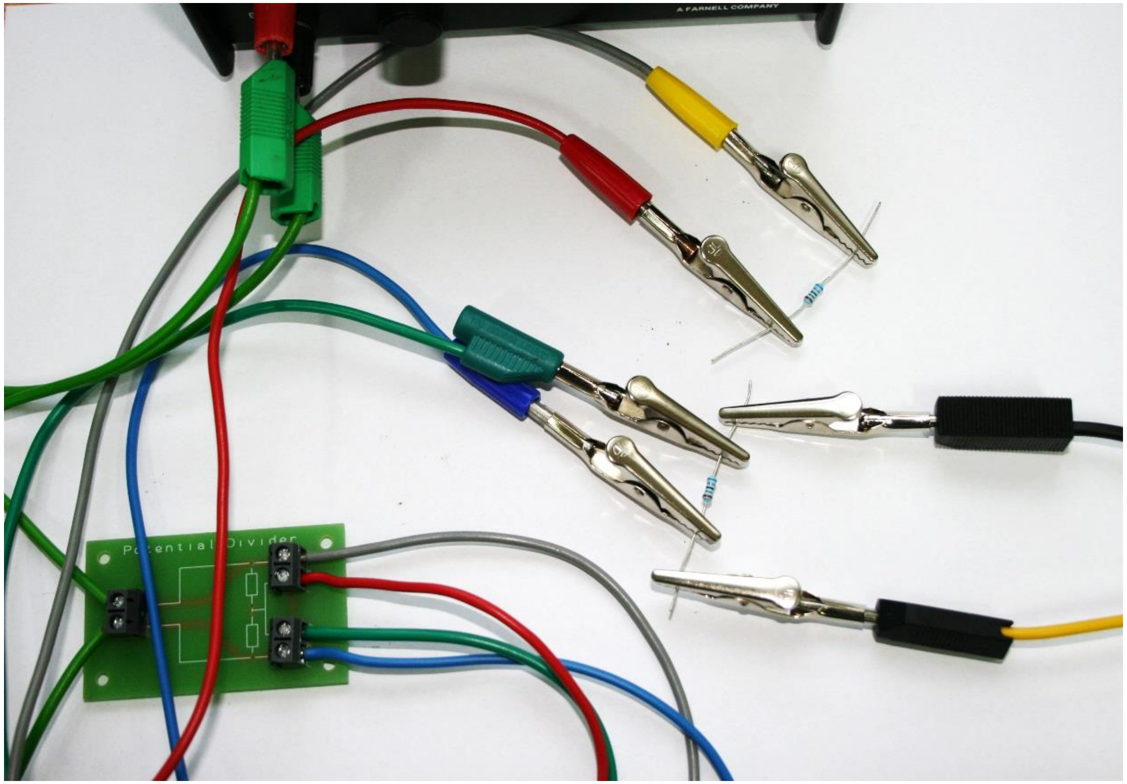
But, at least the wires are colour-coded…

Colour convention: good reason!



Randomly coloured wiring makes the circuit difficult to follow, even for a very simple circuit.

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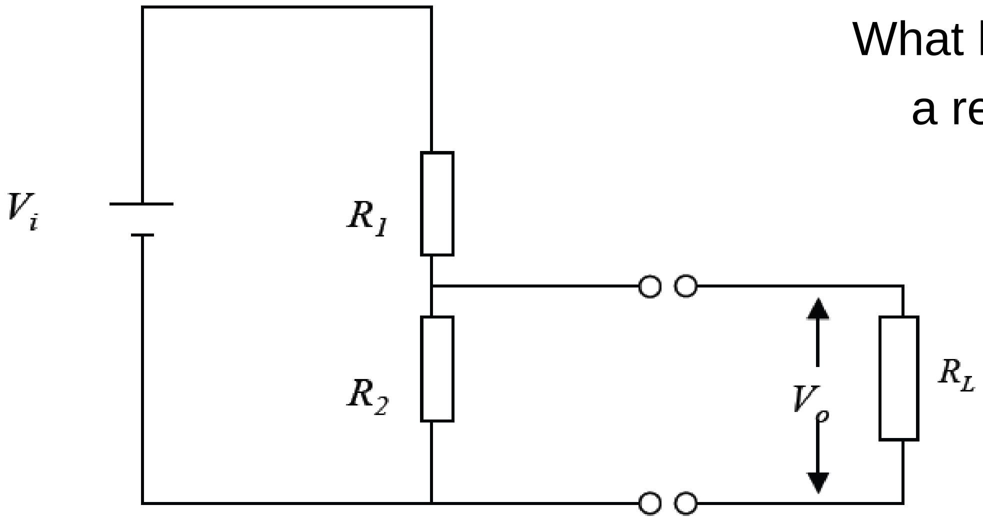
Potential divider circuits (2)

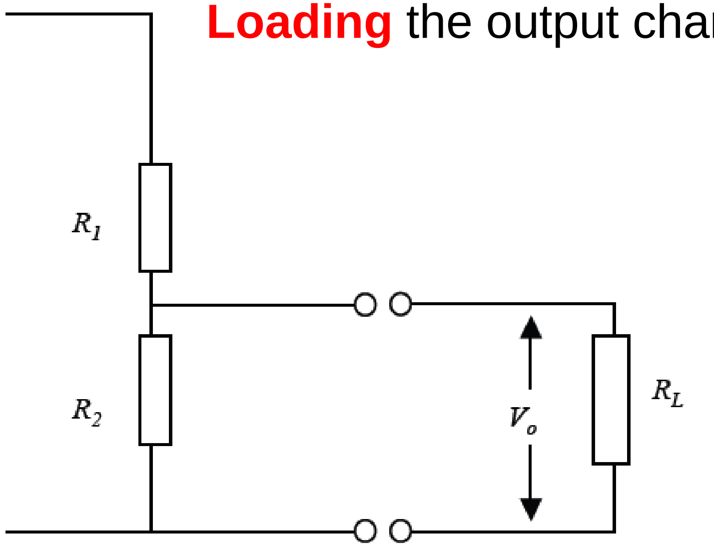
$$V_0 = \frac{R_2}{R_1 + R_2} V_i$$ is the result for an *'open-circuit'* (i.e. no load across the output)



What happens when we connect a resistive **load** to the output?

Potential divider circuits (3)

Loading the output changes the **output voltage**!



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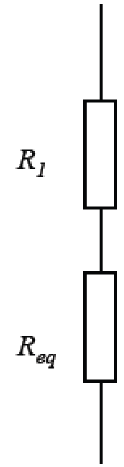

R_2 and R_L are in parallel – we can combine them as an equivalent resistor R_{eq}

$$\frac{1}{R_{eq}} = \frac{1}{R_2} + \frac{1}{R_L} \quad \& \quad V_0 = \frac{R_{eq}}{R_1 + R_{eq}} V_i$$

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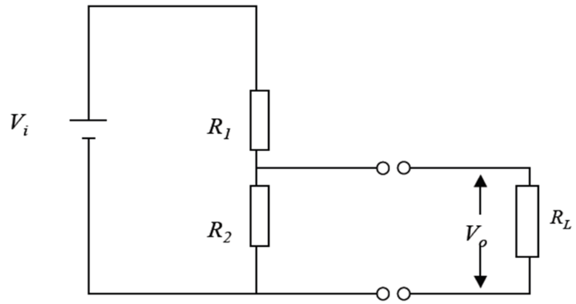
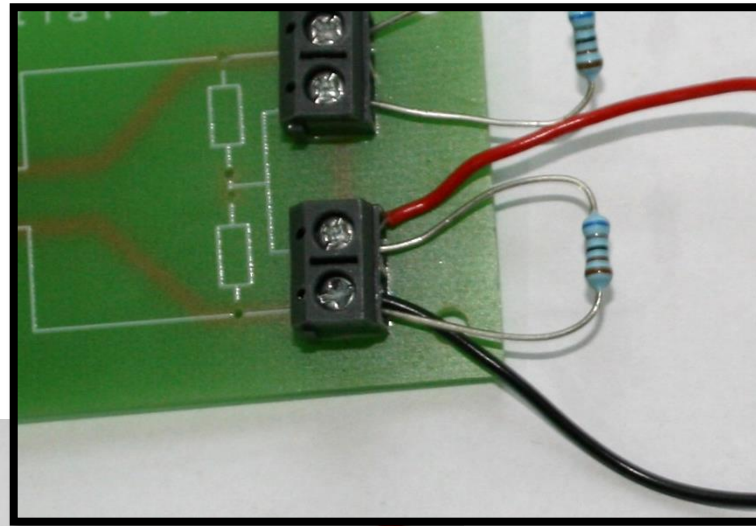
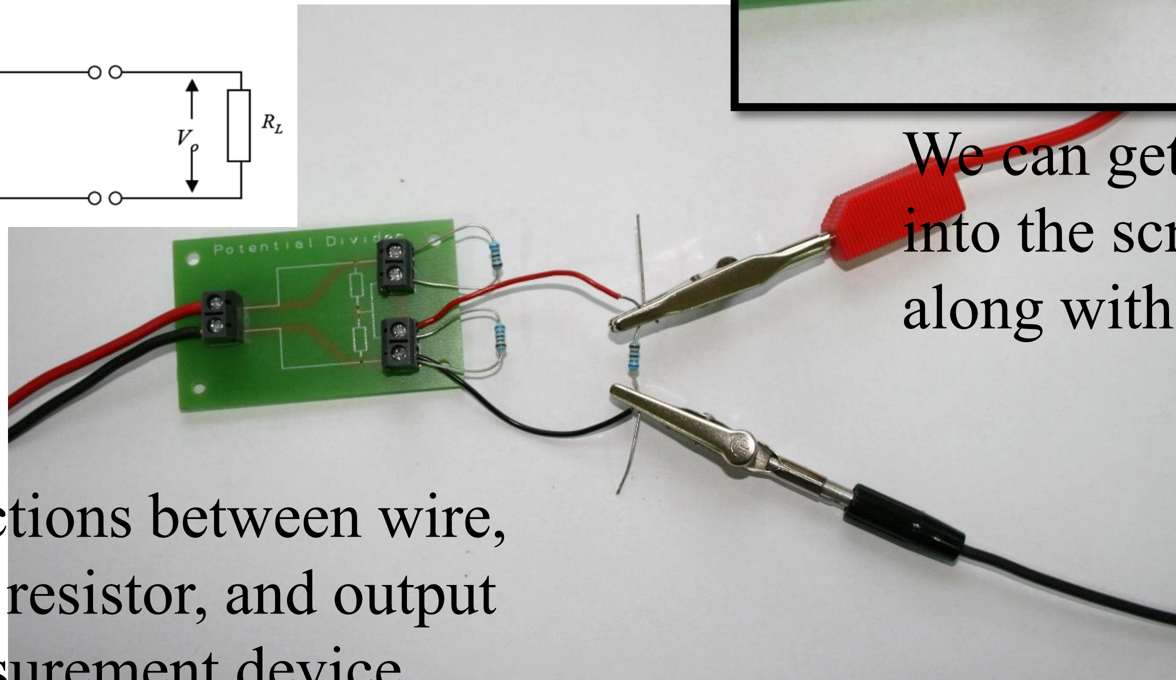
‘Real’ example



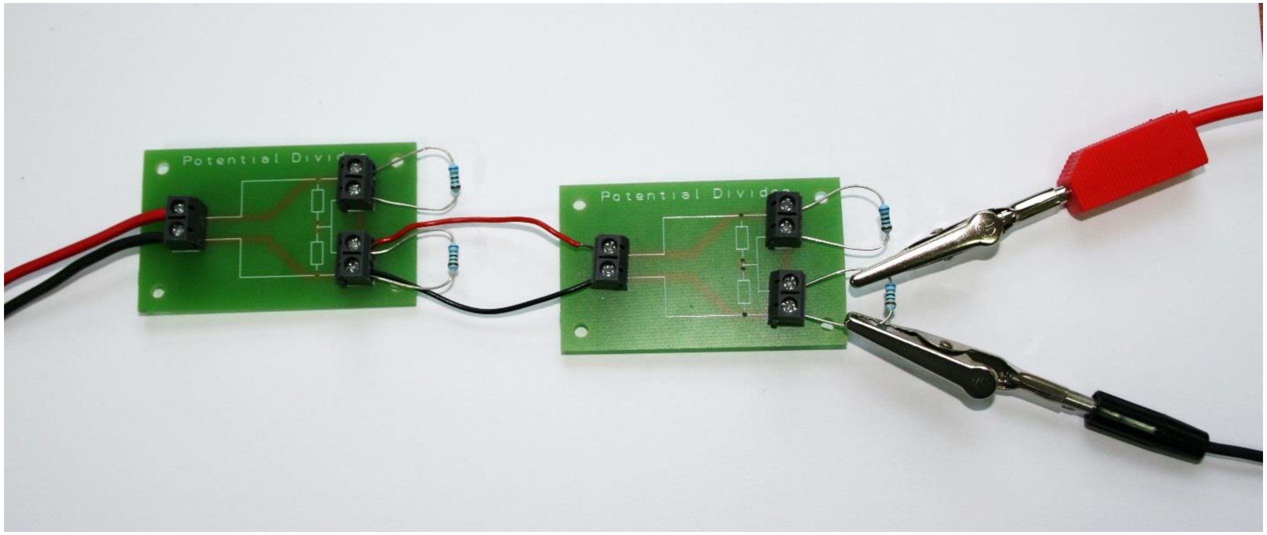




We can get a thin wire into the screw terminal along with the resistor

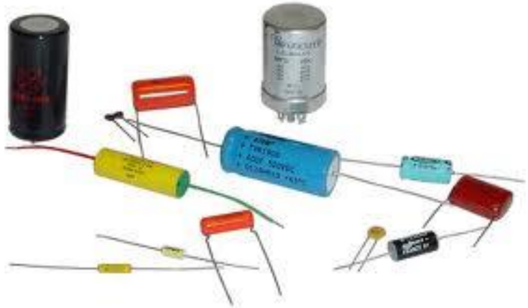
Connections between wire, second resistor, and output to measurement device using crocodile clips

Network loading



Potential divider boards can be daisy-chained together to make more complex networks.

Capacitors



- S.I. unit of capacitance is the ***Farad (F)****;* most practical capacitors are ~μF

- The charge on a capacitor is $Q = CV$

  and the current flowing is $I = C\dfrac{\partial V}{\partial t}$

- 'Resistance' of a capacitor is known as *'Capacitive reactance',* given by

$$X_C = \frac{1}{j\omega C} \quad \text{where} \quad \omega = 2\pi f, \quad j = \sqrt{-1}$$

Convention in electronics textbooks

- Reactance is a *complex* quantity, and is higher at lower frequency (no d.c. conduction) and drops with increasing frequency – this property can be used in electrical signal **filters**

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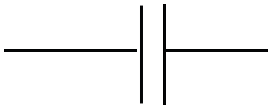
Reactance & Impedance

R

$$X_r = R$$

$$Z_R = R$$

C



$$X_c = \frac{1}{j\omega C}$$

$$Z_C \equiv X_C = \frac{1}{j\omega C}$$

L

$$X_L = j\omega L$$

$$Z_L \equiv X_L = j\omega L$$

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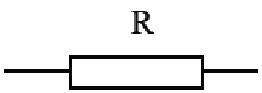
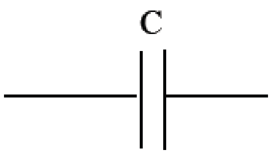
Reactance & Impedance (2)

Some (engineering) texts use alternative definitions:



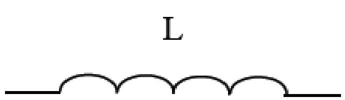
$$X_r = R$$

$$Z_R = R$$



$$X_c = \frac{1}{\omega C}$$

$$Z_C = -jX_C = \frac{1}{j\omega C}$$



$$X_L = \omega L$$

$$Z_L = jX_L = j\omega L$$

These definitions ‘avoid’ using complex numbers until the very end...

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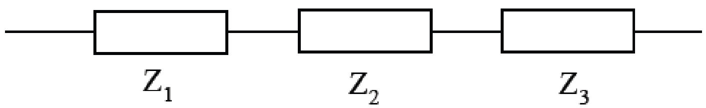
Impedance of networks

Total impedance of series and parallel networks of impedances behave exactly the same as resisitive networks:

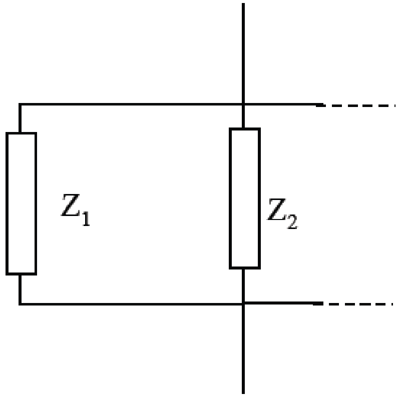
Series:

$$Z_{tot} = Z_1 + Z_2 + ...$$



Parallel

$$\frac{1}{Z_{tot}} = \frac{1}{Z_1} + \frac{1}{Z_2} + ...$$



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Having this material given as background reading means that I can finish lectures 1 and 2 fairly early, leaving time at the end of the lecture slots where you can come and ask me any questions that you may have about data analysis for your Skills lab reports