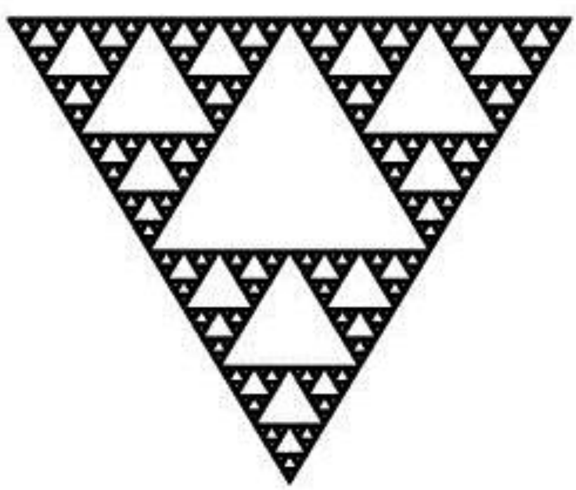
X3

Experimental Design and Practice

In this laboratory, you will complete two exercises that require you to devise procedures to meet defined goals. That is, the goals are specified but the methods by which you achieve them are left up to you. Each exercise involves a very simple circuit containing just two electronic components and while both circuits behave deterministically, the former is insensitive to initial conditions while the behaviour of the latter depends critically upon its initial state – it is chaotic.



Schedule

Preparation time : 3 hours

Lab time : 3 hours

Items provided

Tools : n/a

Components : Electrolytic capacitor (~100 μF), inductor (~10 mH), diode

Equipment : Power supply, decade resistance box, analogue multimeter, digital multimeter, function generator, oscilloscope, stopwatch

Software : n/a

Items to bring

Essentials. A full list is available on the Laboratory website at https://secure.ecs.soton.ac.uk/notes/ellabs/databook/essentials/

Before you come to the lab, it is essential that you read through this document and complete ***all*** of the preparation work in section 2. If possible, prepare for the lab with your usual lab partner. Only preparation which is recorded in your laboratory logbook will contribute towards your mark for this exercise. There is no objection to several students working together on preparation, as long as all understand the results of that work. Before starting your preparation, read through all sections of these notes so that you are fully aware of what you will have to do in the lab.

> **Academic Integrity** – *If you undertake the preparation jointly with other students, it is important that you acknowledge this fact in your logbook. Similarly, you may want to use sources from the internet or books to help answer some of the questions. Again, record any sources in your logbook.*

Revision History

September 04, 2013	Geoff Merrett (gvm)	Minor updates
September 19, 2012	Alun Vaughan (asv)	First version of this lab created

1 Aims, Learning Outcomes and Outline

This laboratory exercise aims to:

- Provide experience of designing experimental procedures
- Provide experience of recording and analysing measurements and observations

Having successfully completed the lab, you will be able to:

- Develop efficient and effective experimental designs to meet defined objectives
- Evaluate the uncertainties associated with practical procedures
- Record in detail processes and events that occurred during the laboratory

The two exercises that make up this laboratory both involve a very simple circuit containing just two electronic components. In the first you will monitor the current flowing through a known resistor as a capacitor discharges and, hence, determine the capacitance of the capacitor; in the second you will connect an inductor and diode in series and explore how the input and output voltage across the diode are linked. The associated procedures are deliberately not described in detail, since a key feature of working with such simple systems is to provide you with “space” to decide how you want to approach the problem. A key challenge for professional engineers involves devising ingenious solutions to problems: The real world does not come with a manual!

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2 Preparation

Read through the course handbook statement on safety and safe working practices, and your copy of the standard operating procedure. Make sure that you understand how to work safely. Read through this document so you are aware of what you will be expected to do in the lab.

You should also ensure that you have watched the online lectures on “Engineering Statistics” and “Experimental Design”.

2.1 Capacitor Discharge

This exercise is all about devising an experimental plan and implementing it. You should have a good idea of what you propose to do any why before entering the laboratory. Ensure that you understand the underlying theory behind the circuit shown in Figure 1 and ensure that you understand how to use an electrolytic capacitor correctly in this arrangement

- What is meant by a ‘polarised’ electronic component? What does this mean with respect to a capacitor? Is an electrolytic capacitor a polarised component?
- What is meant by the tolerance on a capacitor’s capacitance? What is a typical tolerance for an electrolytic capacitor rated at 100μF and 50V [hint: try to find a datasheet online]?
- What is a suitable value for your chosen resistance? Perform preliminary calculations to estimate this.
- What power supply voltage is most suitable for this exercise?
- What measurements do you propose to make and how will you analyse them? Why will this give the most accurate value of capacitance?
- How do you propose to evaluate the uncertainty in the capacitance?

2.2 Chaotic Oscillator

This exercise is all about making detailed and precise observations – sufficiently detailed that, at a future date, you will be able to describe in detail what you did. A key feature of this laboratory concerns a rather subtle distinction, namely the difference between genuine randomness and deterministic chaos. Deterministic chaos applies to highly non-linear systems where the future is strongly dependent upon the exact state of the present. As a consequence of this, it is very difficult to predict the future behaviour of a chaotic system.

Before starting this laboratory you should undertake some background reading and ensure you have an appreciation of the following terms, as they apply to a chaotic system:

- What is meant by "period doubling"
- What is meant by "bifurcation" and a "bifurcation diagram"
- What is meant by resonance?
- What is meant by a "fractal" and "self-similarity"
- What is a "Feigenbaum number"

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3 Laboratory Work

This laboratory is split into two different exercises, and you will spend an hour on each exercise. When you arrive at the lab, you will be told which exercise you should do first. You will be writing a technical report on part of the lab, so you must take good records. You don't have a lot of time, so adequate and effective preparation is essential!

3.1 Capacitor Discharge

The objective of this exercise is to determine the actual capacitance of an electrolytic capacitor, and evaluate the uncertainty in this value. To do this, you will charge an 100μF capacitor, *C*, to a voltage of your choice (**though this must be less than 10 V**), discharge it through a known resistance *R* of your choice, and time the process.

Note: You must ensure that the peak current that will flow through the multimeter will not exceed its capabilities!

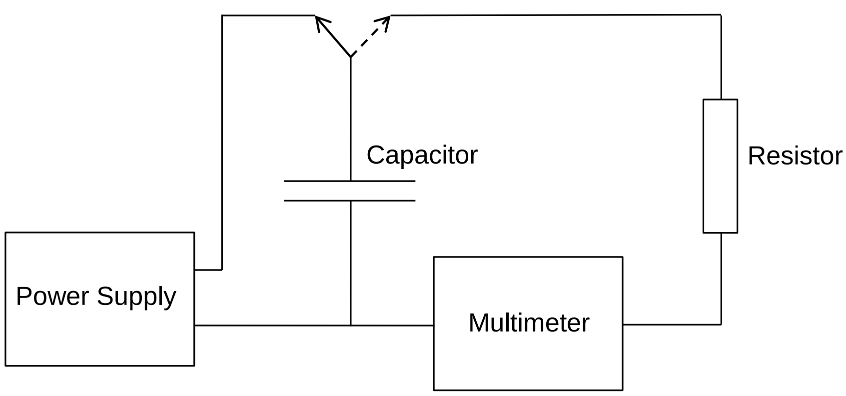

FIGURE 1: Suggested circuit diagram for capacitor discharge exercise. Note, the 'switch' connecting the power supply, capacitor and resistor is not the switch on the power supply, and can simply be a length of wire that you move between the power supply and resistor.

The key equation that relates to this process is:

$$I = I_0 exp - \left(\frac{t}{RC}\right)$$

What factors affect your choice of charging voltage and discharge resistor?

The equipment you are provided with includes the capacitor under test, a power supply, a digital multimeter and analogue multimeter, and a resistance box (that enables you conveniently to vary to value of *R* you can introduce into your circuit). In addition, **you may use any additional resistors available in the lab** that you feel will help you optimise your experimental design.

You can use either the analogue multimeter or digital multimeter. Which is more suitable for this exercise and why?

Connect up an appropriate circuit and implement your experimental plan. Capacitors, like all other electronic components are manufactured to a tolerance so, while you are provided with the nominal capacitance value, its actual value is likely to differ significantly from this.

Are your data consistent with the nominal value rating of the capacitance? There are only two possible answers to this question: definitely yes or definitely no. The two values are close is not an acceptable answer.

3.2 Chaotic Oscillator

In this exercise, you will explore the behaviour of the circuit shown below, which you should first assemble. You should monitor voltages v_1 and v_2 using an oscilloscope.

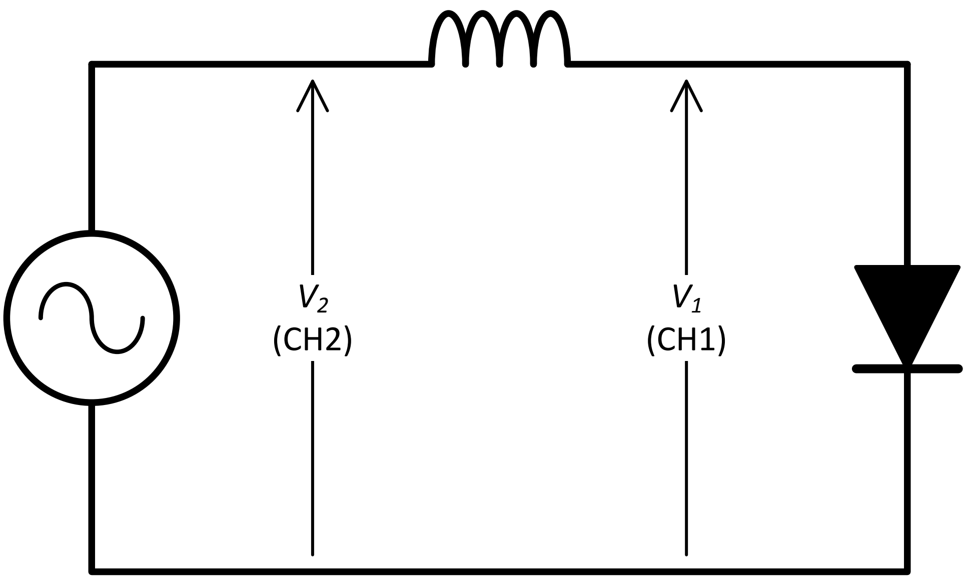

FIGURE 2: Circuit diagram for the chaotic oscillator exercise

Having assembled the above circuit, the first objective is to find the resonant circuit. To do this, you should set the function generator to provide a sinusoidal output of ~180 kHz and a peak-to-peak voltage of ~200 mV at v_2, as seen using channel 2 of the oscilloscope. Reduce the frequency and note the variation in output voltage (i.e. the voltage across the diode).

What is the frequency corresponding to the maximum output voltage?

Now chose a frequency close to but not at resonance and explore the effect of increasing the **amplitude** of the input signal. You need to record your observations in detail.

Specifically, you are looking for input voltages at which the output signal bifurcates – that is, the period of the output waveform doubles. The amplitudes of the input signal at which period doubling takes place follow a universal law for chaotic behaviour. If you can identify the amplitude at which the period doubles from 1→2 (A_1), from 2→4 (A_2) and 4→8 (A_3), you can estimate the Feigenbaum number, δ, where:

$$\delta = \frac{A_2 - A_1}{A_3 - A_2}$$

◈ *Based upon your measurements, what is the value of the Feigenbaum number?*

It is not easy to determine the bifurcation points accurately and therefore the amplitude values you used to estimate δ are likely to be quite unreliable. By repeating these measurements determine the uncertainty in each of the above amplitude values.

◈ *What is the uncertainty in your estimate of the Feigenbaum number?*

◈ *Are your data consistent with the accepted value of the Feigenbaum number? There are only two possible answers to this question: definitely yes or definitely no. The two values are close is not an acceptable answer.*

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4 Optional Additional Work

Marks will only be awarded for this section if you have already completed all of Section 3 to an excellent standard and with excellent understanding.

There is no specified additional work for this lab. 'Outstanding' marks will be awarded for students which can demonstrate outstanding understanding and have performed outstanding experimental investigation that has gone well beyond that specified in section 3.