University of Sheffield
Department of Electronic and Electrical Engineering
First Year Laboratories

Computer Aided Design

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1. Introduction

This laboratory exercise is intended to give you experience of using computer simulation to analyse electronic circuits. It should be stressed that simulation is not an alternative to careful design, but can be useful to verify the circuit functionality. The software you will use is a proprietary package called "Electronic Workbench", but this is a simply a Windows based graphical front end for a very widely used simulator called "SPICE".
The circuit that you will be analysing is called a Wien-bridge and you will find it useful to have read about this circuit prior to the class.

NOTE: To obtain a pass mark for the lab exercise it is essential that you record all of your results into your lab book. The demonstrator will ask to see your results at the end of the exercise. Students who have forgotten their lab book will have to copy their results into their lab book in their own time, and arrange an appointment with the demonstrator to verify that they have recorded their work in a satisfactory manner.

2. Getting Started

This first exercise is to familiarise you with the simulation environment. Boot up Windows and launch the "Electronics Workbench" application. This should be straightforward, but ask a demonstrator for advice if you have problems. First, enter the circuit shown in figure 1.

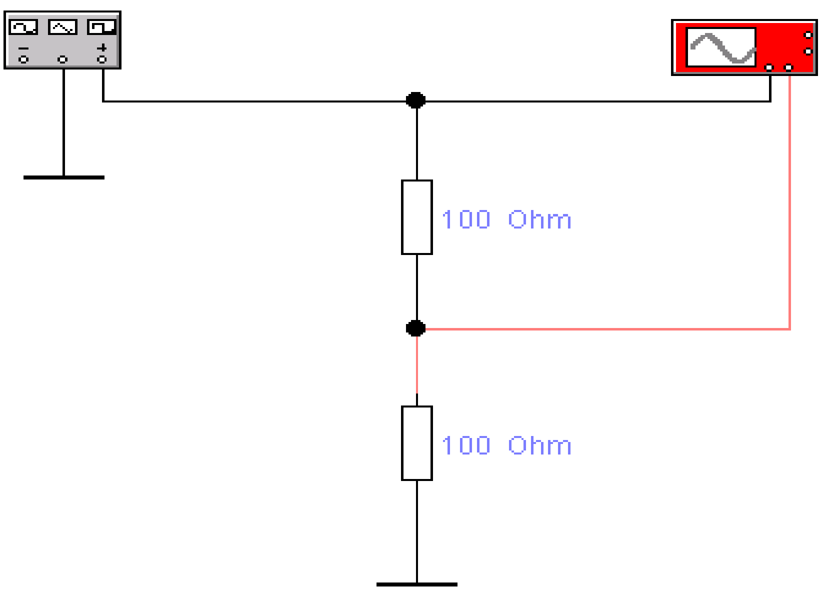

Figure 1 - A Simple Voltage Divider

This process of entering the circuit is called "Schematic Capture". Much of the process is self-explanatory, but the following tips will help:

- Select components from the Parts Bin toolbar and drag them onto the circuit window
- To rotate a component, select it by Ctrl-click, and then select circuit/rotate.
- To change the value of a component, (e.g. the resistance of a resistor) double click on it, a menu will appear in which you can alter the device values.
- To connect components together, drag a wire from the terminal of one to the other by dragging the mouse (This can be a bit temperamental, but persist and you'll get the hang of it).
- The function generator can be selected from Instruments section of the Parts Bin toolbar and has the connections shown in figure 2.
- The oscilloscope is also from the Instruments section of the Parts Bin and has the connections in figure 2.
- Set the output from the signal generator by double clicking on the signal generator and entering appropriate values (for the initial experiment a sine wave, **2V peak-to-peak** at **1Hz frequency** would be suitable).
- Change the colour of one of the input lines into the oscilloscope by double clicking on the line and choosing a new colour (It will become clear why this is useful shortly).

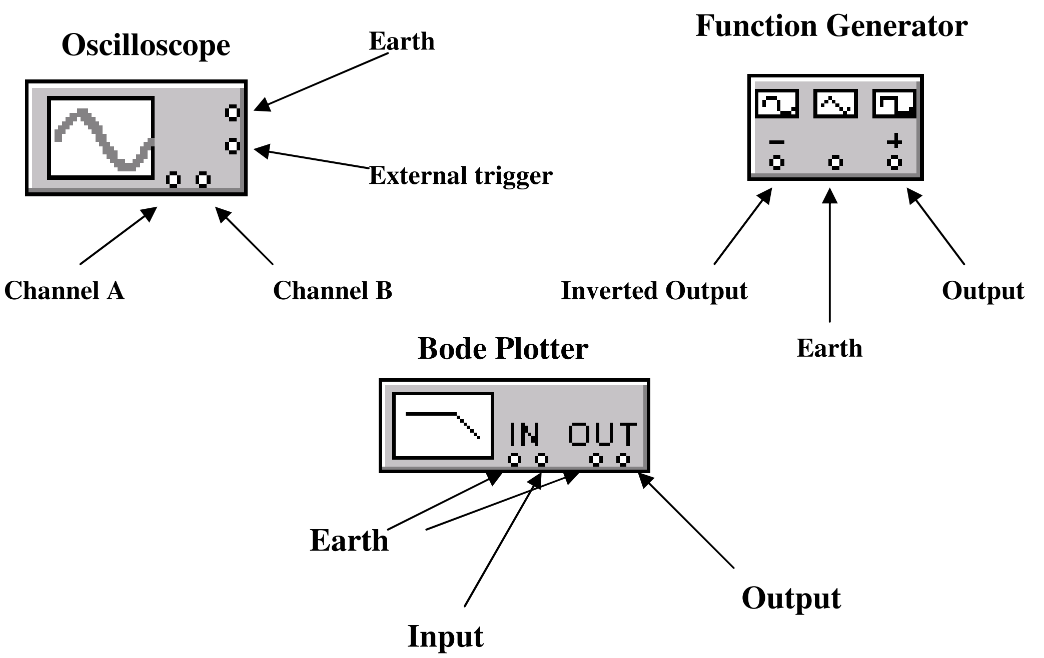

Figure 2 Instruments

To carry out the simulation, first open the oscilloscope window by double clicking on the oscilloscope and then press the **"ON"** switch on the simulator (at the top right-hand corner of the screen). **Make a note of the waveforms on the oscilloscope (a simple sketch will do) and compare the input waveform to the output waveform.**

Q1. Compare the input and output waveforms what does the circuit in figure 1 do?

3. The Resonant Circuit

It is now time to start on the Wien-bridge. First we will look at the resonant circuit section of the bridge. Enter the circuit shown in figure 3.

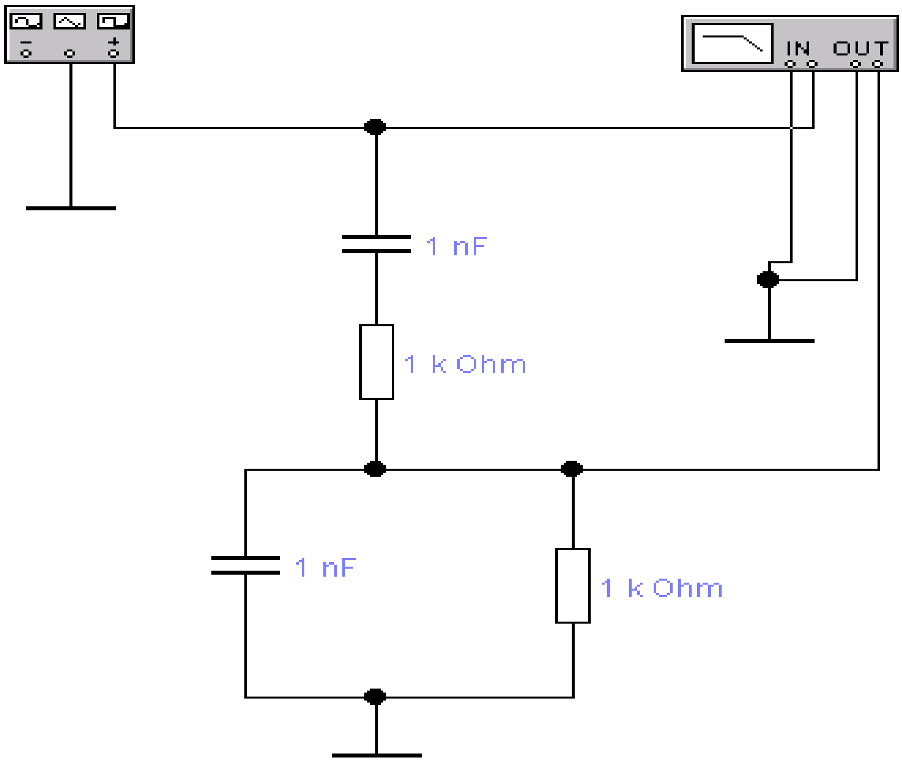

Figure 3 – A Resonant Circuit

The new component is a Bode Plotter (from the Instruments section of the Parts Bin, connections as in figure 2). This is a convenience that exists only within simulators, but has similarities to a spectrum analyser. It generates a range of frequencies at the input connection and plots the ratio of the output signal to the input signal as a function of the frequency. Double click the Bode Plotter to choose the frequency range to study and start the simulator (remember to press the "**ON**" button). Note that you have a vertical cursor, which you can drag from the left of the Bode plotter results screen.

Q2. By studying the frequency response of the circuit in figure 3, can you say what the circuit is doing and suggest what applications it might be used in?

You might find it useful to change the vertical scale of the Bode plotter from log to lin (or vice versa) to compare how the same results appear in the two types of presentation.

3. The Resonant Circuit continued

In the circuit shown in figure 3 there is a simple relationship between R, C and the output of the Bode plotter, which can be found experimentally. It can be obtained by keeping the value of one pair of components in the circuit constant, whilst varying the values of the other pair of components, i.e. keeping the resistor values the same, but vary the capacitor values. Copy the table given below into your lab book and record the effect that varying the component values has on the output of the circuit. To help things along, record the results of constant values of R and varying values of C in the top half of the table. And then do the reverse in the bottom half of the table, i.e. varying values of R, constant values of C.

Resistor (Ω)	Capacitor (F)	Frequency (Hz)	Amplitude

Q3. From your data, can you say what the relationship between R, C and the output is?
Verify your answer with the demonstrator.

4. The Op Amp

Figure 4 shows the schematic for an op-amp (operational amplifier). An op-amp is an analogue device and the symbol should not be confused with a logic gate. You will deal with op-amps in detail later in your course, but for this lab exercise the important points to remember about op-amps are:

- very high gain (or amplification)
- very high input impedance
- wide bandwidth due to negative feedback
- the voltage that appears at one of the inputs also appears at the other input. In other words, the input voltages follow each other, so that the voltage difference between the inputs is zero. This is known as virtual ground (having zero volts but not physically connected to ground).

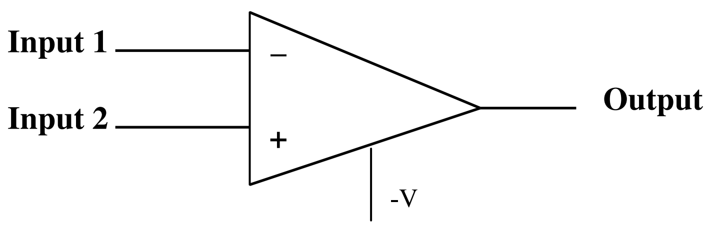

Figure 4 – An Op-Amp

4. The Op Amp continued

Figure 5 shows a standard non-inverting amplifier circuit incorporating an op amp. This circuit demonstrates the effect of negative feedback via the 1kΩ at the top of the circuit. Build this circuit (you will find the op amp in the Analogue IC's section of the Parts Bin) and. set the function generator to produce a sine wave of 5mV peak to peak.

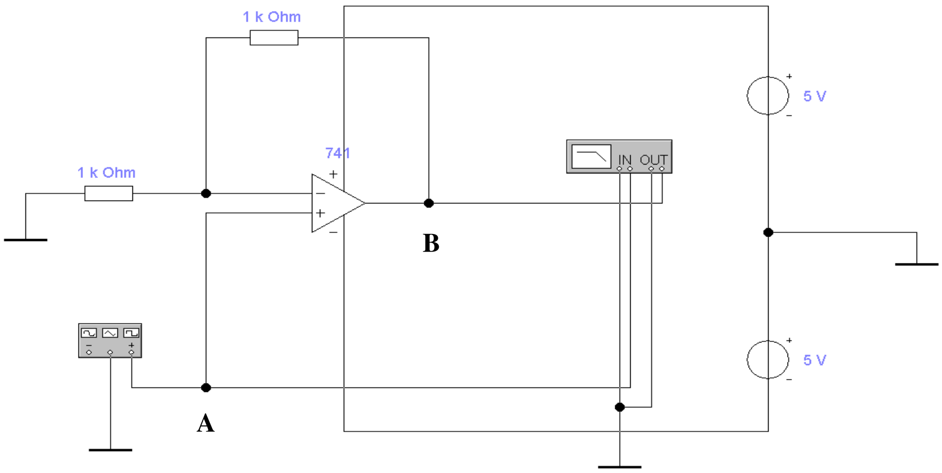

Figure 5 – A standard Non-Inverting Amplifier

Q4. Using the circuit from Figure 5, vary the values of the two resistors (call them R1 and R2). Can you find a relationship between the resistors and the gain (G) of the op-amp? Once again draw up a table in your lab book to collect the data. <u>Note: Only measure the gain in the flat region of the frequency response.</u>

Q5. Can you explain what has happened to the high frequency response of the circuit in figure 5, over the MHz to GHz range?

Q6. Set R1 to 1kΩ and R2 to 20kΩ. Move to a point where the gain has dropped by 3dB. What is the frequency at this point and its significance for the amplifier?

Q7. Can you think of any applications where a wide bandwidth is an advantage?

Q8. Now try changing R1 and R2 to give you a much higher gain (say 500). What happens to the bandwidth?

Hopefully you can now see why we often talk about *gain-bandwidth* product. The compromise caused by limited gain-bandwidth product has an effect on the design of the receiver for your first year project.

Q9. Increase the magnitude of the function generator output (to say 2V), and connect one channel of the oscilloscope to point "A" and the other channel to point "B" of figure 5. Do not forget the ground connection to the oscilloscope. Can you explain what is happening to the signal on the oscilloscope?

5 The Wien-Bridge

In figure 6 we show a feedback connection from the output of the amplifier to the input of the resonant circuit. Note that here we have used an oscilloscope rather than the Bode plotter.
Enter this circuit (perhaps by modifying the previous circuit) and look at the output signal. Do this for amplifier gains slightly above and slightly below 3 and contrast the results.
Record your results and discuss them with a demonstrator (the demonstrator will expect you to have thought about the significance of your observations).

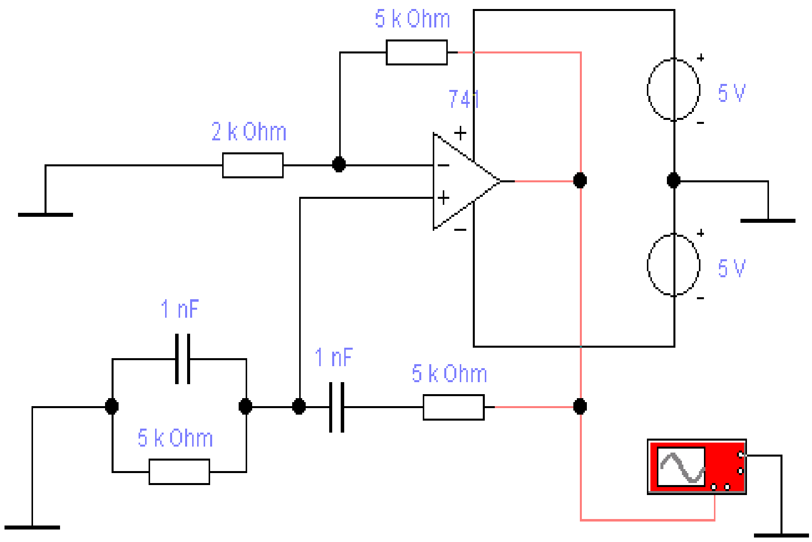

Figure 6 – The Simple Wien - Bridge

If the circuit does not oscillate when you switch it on, try setting the time base of the oscilloscope to 1 microsecond and then switch the circuit off and on again. You may have to repeat switching it off and on again several times, but it should start to oscillate.

Q10. Tricking the circuit into oscillation by varying the time base on the oscilloscope is not a satisfactory solution.
What does this say about the limitations of the simulation software?

7. A More Practical Wien-Bridge

You should have realised that an amplifier gain of exactly 3 is crucial for the Wien-Bridge to give a sinusoidal output, but that resistor tolerances make this impossible to achieve with the circuit shown in figure 6. Figure 7 shows a more practical circuit. Build the circuit and observe its behaviour.

Q11. In order to maintain the oscillations, how is the gain of the amplifier in figure 7 kept at approximately 3? Hint: think about the current-voltage behaviour of a diode.

Q12. Why do you need two diodes in the feedback section of this circuit?

You have now completed the analysis of the Wein-bridge but for interest's sake you might like to see what happens if the values for the two resistors in the resonant circuit are slightly different.

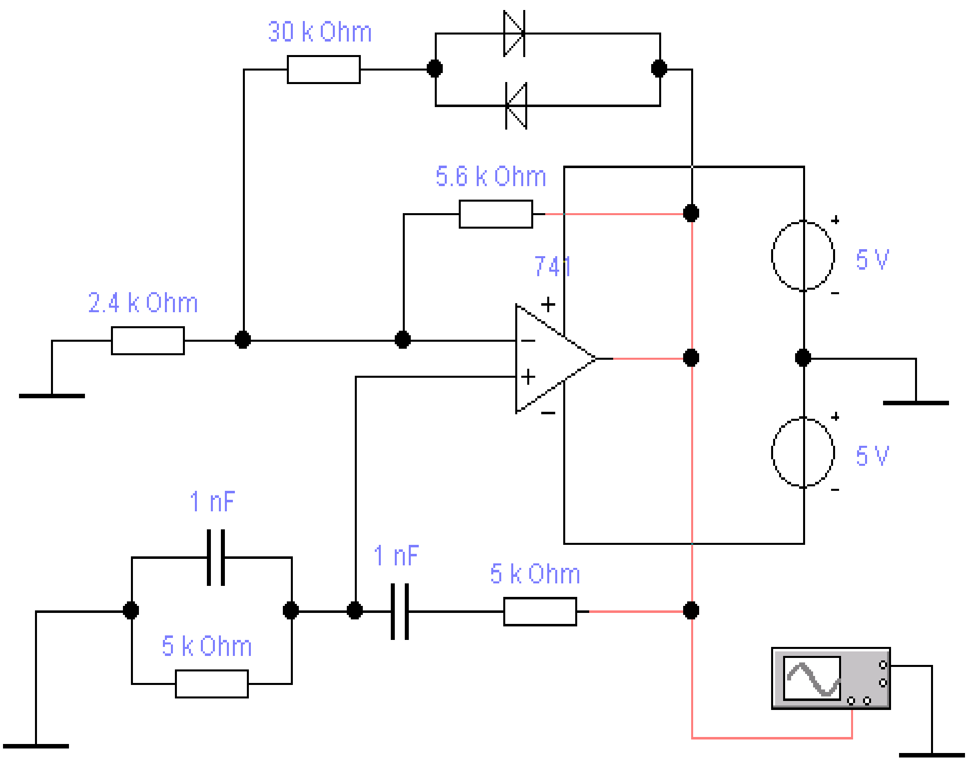

Figure 7 – A Practical Wien – Bridge

8. Finally

Show your results to a demonstrator and ask them to record your work as satisfactory. No report is required for this class, but your results and understanding may come in useful when you come upon op-amps later in your degree course.