Faculty Of Engineering and
Information Sciences
UOWD

ENGG104 – PART 2/2

Laboratory Workbook

Student Name:

Student Number:

Lab Partners Name:

Experiment 7

SECTION ONE

The aim of this section is to gain an introduction to the tools used in AC circuits. Function generators and oscilloscopes shall be used as the source and measurement tools, respectively.

Part 1:

An AC waveform with a DC offset can be expressed in the following form:

$$v(t) = D + A\sin(2\pi f t + \theta)$$

Where: D is the DC offset, A is the amplitude, f is the frequency in Hz and θ is the phase. An example waveform is given in Fig. 1 with a phase θ=0. Note that the period T=1/f.

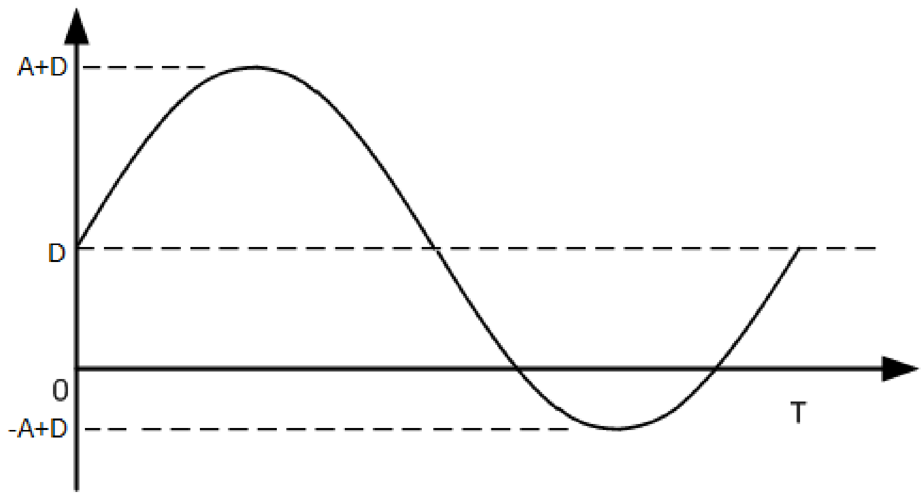

Figure 1: Sine wave with offset

The magnitude of a sine wave can be expressed in three different ways: peak-to-peak, peak (same as amplitude) or rms (same as effective value). These are shown graphically in Fig. 2. Generally, in most electrical theory, the rms value is assumed unless otherwise stipulated. The relationship between the three can be expressed as:

$$V_{pp} = 2V_{pk} = 2\sqrt{2}V_{rms}$$

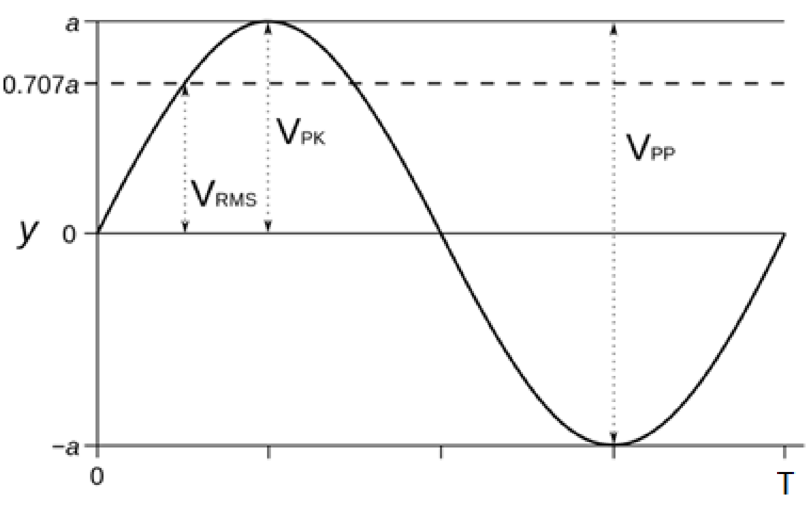

Figure 2: Sine wave magnitudes

For the sinusoidal waveform y(t)=1+3sin(2π50t) V, give the:

Table 1: Waveform Calculated Data

Amplitude	
Frequency	
Period	
DC Offset	
V (peak-to-peak)	
Phase	

The Tektronic function generator (as shown in Fig. 3) shall be used as the AC source for all experiments in ENGG104.

Follow the instructions below to create the waveform using the function generator.

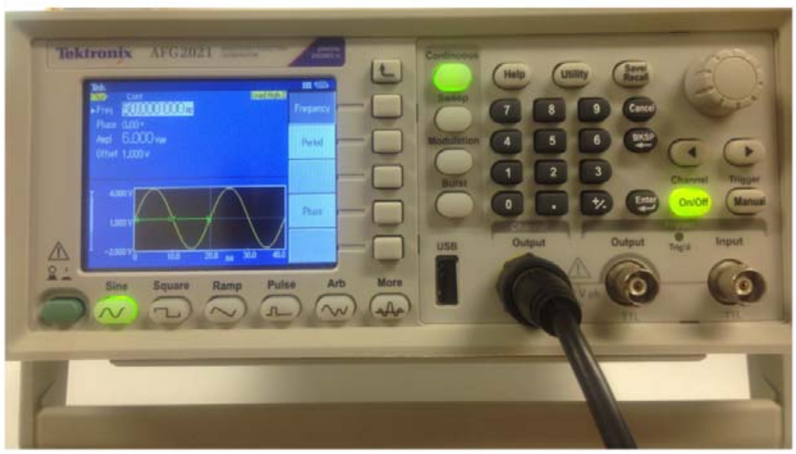

Figure 3: Function Generator

- Begin by turning on the function generator (green button). It usually takes a few seconds for the function generator to initialise.
- Different types of alternating waveforms can be used with the Tektronic function generator. Select the Sine option if not already selected.
- The white buttons to the right of the display are used to select from the menu. Once you have made a selection, you can return to the previous menu by pressing the ↳ button if needed.
- To change the waveform's amplitude to 3 V, select "Amplitude/level" → "Amplitude" → 6 → Vpp.
- To change the waveform's frequency to 50 Hz, select "Frequency/Period/Phase" → "Frequency" → 50 → Hz.
- To change the DC offset to 1 V, select "Amplitude/level" → "Offset" → 1 → V.
- In order to actually output the selected voltage waveform, the **yellow Channel button** must be turned on.

Part 2:

An oscilloscope may be used to observe a voltage waveform. An oscilloscope may be thought of as a voltmeter that plots voltage versus time on an axis. An oscilloscope should be connected to a circuit in the same fashion as a voltmeter. The Tektronix oscilloscope is shown in Fig. 4.

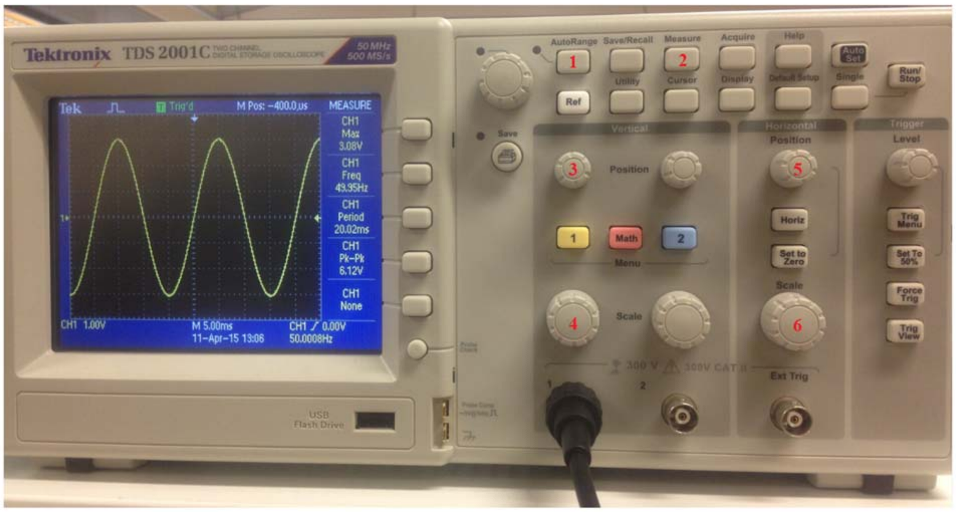

Figure 4: Oscilloscope

To view the voltage waveform produced by the function generator, the oscilloscope must be connected to the output of the function generator. The black oscilloscope leads (shown in Fig. 5) are used to connect to the functions generator and oscilloscope. The two-prong lead (shown on the right of Fig. 5) should be used for the function generator and the first channel of the oscilloscope. The single-prong lead (shown on the left of Fig. 5) should be used for the second channel of the oscilloscope (if required).

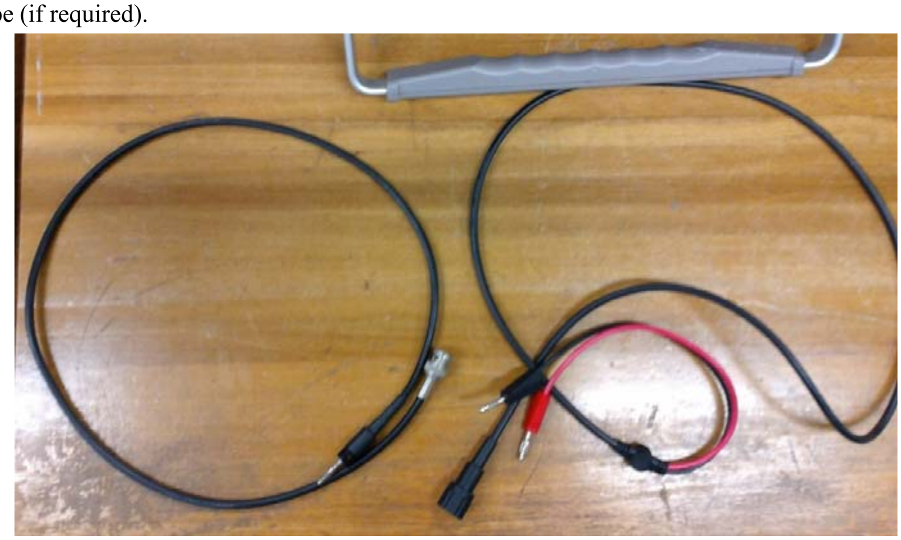

Figure 5: Leads

Use two sets of two-prong oscilloscope leads to connect the function generator and oscilloscope. Use Figs. 3 and 4 to observe how the leads should be connected to each device. The two red terminals should be connected together and kept separate from the two black terminals, which should also be connected together. Ensure that the red and black terminals do not contact one another to avoid a short circuit condition. The banana terminals of a breadboard may be helpful for this exercise.

The ON/OFF switch of the oscilloscope is located on top of the oscilloscope. After initialisation, the measured signal should appear on the screen. Often, the oscilloscope must be calibrated in order to view the measured waveform correctly. In many cases where a strong signal is measured, the oscilloscope will automatically select an appropriate range to view a measured waveform when the "Autorange" (labelled 1 in Fig. 4) is activated.

Press the yellow button on the oscilloscope to show the menu for the first channel. Ensure that the probe voltage is set to 1x. The probe voltage setting may be used to scale a voltage waveform when needed. Toggle the Coupling Button, comparing the effects of an AC and DC measurement.

How are the AC and DC measurements of the same waveform different? Explain.

The scales of the voltage and time axes may be manipulated using the vertical and horizontal scaling knobs, respectively (labelled 4 and 6 in Fig. 4). The AC waveform may be moved in any direction on the screen using the positioning knobs (labelled 3 and 5 in Fig. 4). Change the scaling such that one time division is 5 ms and and one voltage division is 1 V. Position the waveform such that the crests of the waveform align with the time and voltage division intersections. Observe and note the number of voltage divisions within the waveform's amplitude and the number of time divisions within one cycle.

Period = __________ divisions * 5 ms/div = ____________ ms
Amplitude = __________ divisions * 1 V/div = ____________ V

Are the results consistent with Table 1?

Next, press the measure button (labelled 2 in Fig. 4) to bring up the measurement menu. This menu allows the user to select what measurements are to be taken. Five measurements may be taken at any one time. Change the top measurement by pressing the top button on the menu, setting the source to CH1 and setting the type to "Max". Similarly, change the second, third and fourth measurements to "Freq", "Period" and "Pk-Pk", respectively. Record the measurements in Table 2 and compare with Table 1.

Table 2: Waveform Measured Data

Max	
Freq	
Period	
Pk-Pk	

Are the results consistent with Table 1?

SECTION TWO

The aim of this section is to investigate the relationship between peak-to-peak, peak and rms measurements and, hence, be able to use oscilloscopes and digital multimeters simultaneously in AC circuit measurements.

Part 1:

Recall that the relationships between sinusoidal measurement types can be expressed by:

$$V_{pp} = 2V_{pk} = 2\sqrt{2}V_{rms}$$

Note that the above relationships are identical for voltage and current waveforms. Oscilloscopes are most suitable for peak-to-peak measurements, whilst digital multimeters output rms measurements only. Hence, it is vital to ensure that any necessary conversions take place before any further calculations are undertaken. Circuit theory is identical for rms, peak and peak-to-peak representations of voltage and current waveforms: the only important thing to remember is that the same interpretation should be used across the entire circuit. However, the most common measurement type is rms – hence, unless otherwise specified, assume rms is used.

Build the circuit shown in Fig. 6 on a breadboard. Use a frequency of 100 Hz.

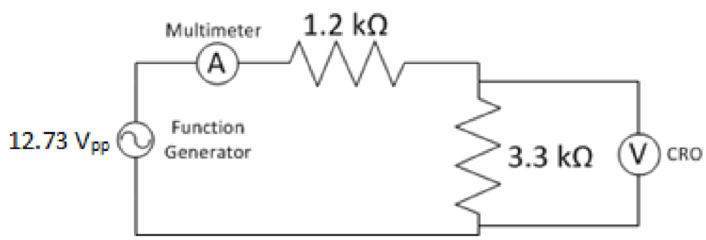

Figure 6: Oscilloscope and Multimeter Usage

Measure and record the actual resistance of the resistors. Remember to isolate resistors before measurement.

$R_{1.2\ k\Omega}$ = ____________

$R_{3.3\ k\Omega}$ = ____________

- Using the measured resistance values, calculate the expected rms current flow through the multimeter and the peak-to-peak voltage drop across the 3.3 kΩ resistor. Enter the calculated values into the Table under the Calculated column.
- Using the multimeter and Ohm’s Law, enter the measured values of the rms current flow and peak-to-peak voltage drop across the 3.3 kΩ resistor into the Multimeter Measurement column.
- Repeat using the oscilloscope measurement and record your results under the Oscilloscope Measurement column.

100 Hz	Calculated	Multimeter Measurement	Oscilloscope Measurement
Current (rms)			
3.3 kΩ Resistor Voltage (p-p)			

How do the calculated and measured results compare? Explain any discrepancies.

Part 2:

Repeat Part 1 with the function generator set to 250 Hz, 500 Hz and 1000 Hz, recording the results in the relevant Tables.

250 Hz	Calculated	Multimeter Measurement	Oscilloscope Measurement
Current (rms)			
3.3 kΩ Resistor Voltage (p-p)			

500 Hz	Calculated	Multimeter Measurement	Oscilloscope Measurement
Current (rms)			
3.3 kΩ Resistor Voltage (p-p)			

1000 Hz	Calculated	Multimeter Measurement	Oscilloscope Measurement
Current (rms)			
3.3 kΩ Resistor Voltage (p-p)			

Do your results indicate that your circuit is frequency dependent/independent? Explain.

End of Experiment 7

This table is completed by your supervisor.

Supervisor	
Date	
Comments	

Experiment 8

SECTION ONE
The aim of this section is to gain an introduction to the behaviour of AC circuits containing inductive and resistive elements.

Part 1:

The reactance of an inductor is a function of the applied frequency as defined by:

$$X_L = 2\pi f L = \omega L$$

For inductors in series, the total inductance is the sum of all inductances:

$$L_T = \sum L$$

For inductors in parallel, the total inductance can be expressed by:

$$L_T = [\sum \frac{1}{L}]^{-1}$$

Note that the concatenation of inductive elements is exactly the same as the concatenation of resistive elements. The total impedance (Z) of a series connected resistor and inductor can be expressed by:

$$Z = R + j\omega L$$

Where j is a complex operator. Much of DC circuit analysis is still applicable to AC circuits, including:

- Ohm's Law (V=IZ)
- KCL and KVL
- Voltage and Current Divider Rules
- Nodal Analysis

The major difference between representations of AC and DC circuits is the presence of vectors or complex numbers. AC voltages and currents are represented as both a magnitude (usually rms) and an angle to represent the phase, The frequency does not need to be represented as the frequency is constant across the circuit. Similarly, impedances are represented by vectors in AC circuits which are made up of a real part (resistance) and imaginary part (reactance). All calculations must be treated as vectors within calculations. Vectors may be represented in both polar and rectangular forms. Conversion between forms may be done using the Pol and Rec functions on most calculators.

Rectangular   Polar

$$A + jB \Leftrightarrow r\angle\theta$$

When multiplication or division of vectors is required, ensure that polar form is used.

$$r_1\angle\theta_1 . r_2\angle\theta_2 = (r_1 . r_2)\angle(\theta_1 + \theta_2)$$

$$\frac{r_1\angle\theta_1}{r_2\angle\theta_2} = \left(\frac{r_1}{r_2}\right)\angle(\theta_1 - \theta_2)$$

When addition or subtraction of vectors is required, ensure that rectangular form is used.

$$(A_1 + jB_1) + (A_2 + jB_2) = (A_1 + A_2) + j(B_1 + B_2)$$
$$(A_1 + jB_1) - (A_2 + jB_2) = (A_1 - A_2) + j(B_1 - B_2)$$

Given the circuit shown in Fig. 7, calculate the frequency for which the impedance across the inductor L1 has the same magnitude as the value of the resistor R1. Note that XFG1 is a function generator and XSC1 is an oscilloscope. What should the peak-to-peak voltage magnitude across the inductor be when R1 and L1 have the same impedance and the function generator outputs 10 $V_{p\text{-}p}$? (Hint: Use voltage divider rule with vectors for impedances. Note that the answer is not 5 $V_{p\text{-}p}$!) Record the calculated inductor voltage in Table 3 (two pages ahead).

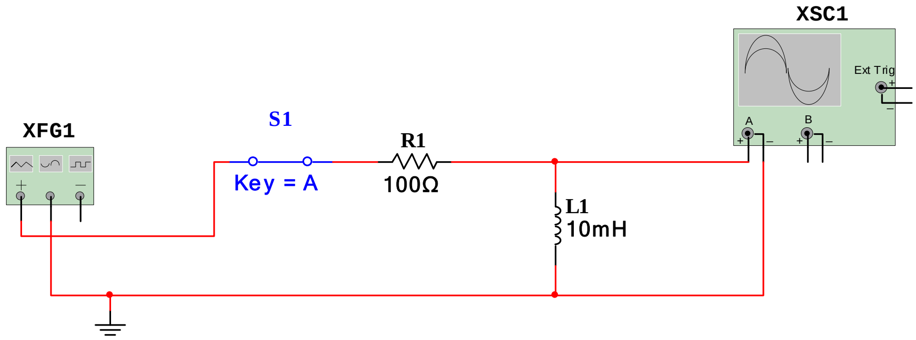

Figure 7: RL Circuit

Part 2:

Construct the circuit shown in Fig. 7 in the Multisim environment. Set the function generator to 10 $V_{p\text{-}p}$ with a frequency equal to your calculated value in Part 1. Verify that the simulated voltages across the inductor is the same as the calculated value. Record the simulated voltage in Table 3 (next page).

Part 3:

Build the circuit shown in Fig. 7 on a breadboard. Fig. 8 gives an image of the 10 mH inductors available in the laboratory. Note that practical inductors contain a small internal resistance as shown in Fig. 9. Set the function generator to 10 $V_{p\text{-}p}$ with a frequency equal to your calculated value in Part 1. Use the oscilloscope to verify the source voltage: note that the voltage exported by the function generator can be inaccurate when a significant current is drawn. Correct the source voltage as necessary to gain a 10 $V_{p\text{-}p}$ output.

Figure 8: Inductors

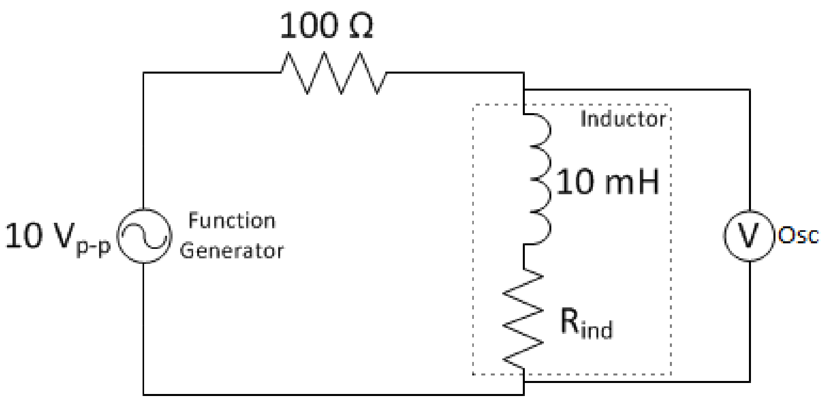

Figure 9: Equivalent Circuit

Use the oscilloscope to measure the voltage across the inductor. Enter the measured voltage in Table 3.

Table 3: RL Verification

	Calculated	Simulated	Measured
Inductor Voltage (peak-to-peak)			

Measure the actual resistance of the 100 Ω resistor.

R=_______________

Use the oscilloscope to measure the peak-to-peak voltage across the 100 Ω resistor.

100 Ω Resistor V_{p-p} = _____________

Use Ohm's Law of the resistor's voltage to calculate the current magnitude. ($|I_{p-p}|=|V_{p-p}|/|Z|=|V_{p-p}|/R$)

$|I_{p-p}|$ = _____________

Next, determine the magnitude of the total impedance of the circuit using Ohm's Law.

$|Z_{total}|$=_____________

The total impedance of the circuit (including the inductor's internal resistance) is $Z=R+R_{ind}+j\omega L$. The magnitude of the impedance can be calculated by $|Z_{total}| = \sqrt{(R+R_{ind})^2+(\omega L)^2}$

Hence, determine the internal resistance of the inductor for the circuit shown in Fig. 7. Then compare the calculated, simulated and measured results from Table 3.

SECTION TWO

The aim of this section is to gain an introduction to the behaviour of AC circuits containing capacitive and resistive elements.

Part 1:

The reactance of a capacitor is a function of the applied frequency as defined by:

$$X_C = \frac{1}{2\pi f C} = \frac{1}{\omega C}$$

For capacitors in series, the total capacitance can be expressed by:

$$\boldsymbol{C_T} = \left[\sum \frac{\mathbf{1}}{\boldsymbol{C}}\right]^{-\mathbf{1}}$$

For capacitors in parallel, the total capacitance is the sum of all capacitances:

$$C_T = \sum C$$

Note that the concatenation of capacitive elements is the opposite of the concatenation of resistive elements.

The total impedance (Z) of a series connected resistor, capacitor and inductor can be expressed by:

$$Z = R + j(\omega L - \frac{1}{\omega C})$$

Given the circuit shown in Fig. 10, determine the frequency for which the impedance across the capacitor C1 should have the same magnitude as the value of the resistor R1. What should the peak-to-peak voltage magnitude across the capacitor be when R1 and C1 have the same impedance and the function generator outputs 8 $V_{p\text{-}p}$? Record this voltage magnitude in the calculated column in Table 4 (over the page). Show all working.

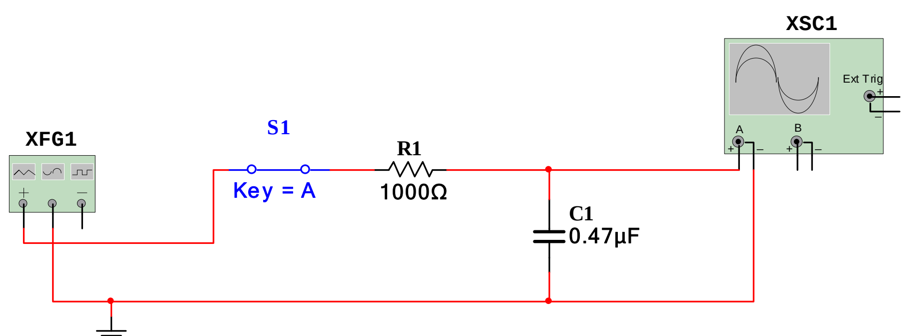

Figure 10: RC Circuit

Part 2:

Build the circuit shown in Fig. 10 on a breadboard and in the Multisim environment. Use a source voltage magnitude of 8 V_{p-p} and the frequency calculated in Part 1. Use the oscilloscope to ensure the function generator is exporting the desired voltage waveform. Record the simulated and measured peak-to-peak voltages across the capacitor in Table 4.

Table 4: RC Verification

	Calculated	Simulated	Measured
Capacitor Voltage (peak-to-peak)			

How do the calculated, simulated and measured results compare? Explain any discrepancies.

This table is completed by your supervisor.

Supervisor	
Date	
Comments	

Experiment 9

SECTION ONE
The aim of this section is to verify AC circuit calculations containing RLC components.

Part 1:

As explored in Experiment 8, in AC circuit analysis, all voltages, currents and impedances must be represented as vectors. If vectors are calculated correctly, circuit theory concepts such as Ohm's Law (V=IZ), KCL, KVL, Voltage and Current Divider Rules and Nodal Analysis apply similarly in DC circuits.
Recall that the impedance of series connected elements may be calculated by:

$$Z = R + j(\omega L - \frac{1}{\omega C})$$

Assuming $\mathbf{E} = 8\,\text{V}(p\text{-}p)\angle 0^\circ$, calculate the peak-to-peak value of $\mathbf{V}_R$ and the angle (θ_1) associated with $\mathbf{V}_R$. Show all work!

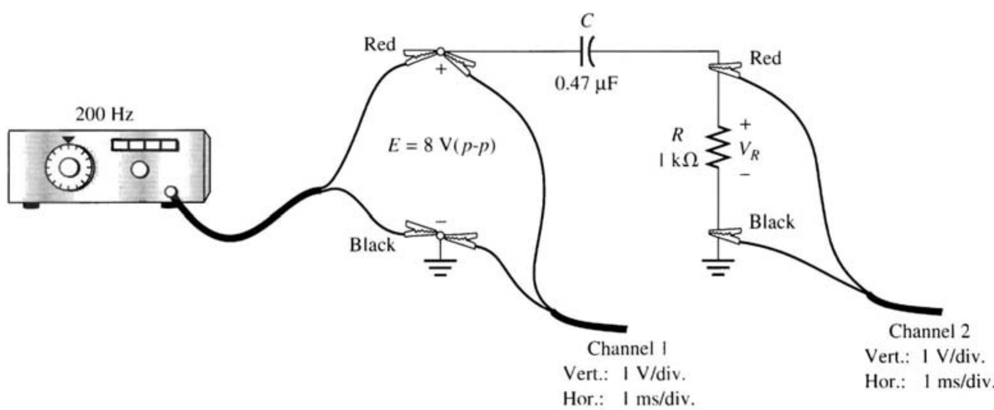

Figure 7: RC Circuit Voltage Divider Example

Part 2:

Build the circuit in Fig. 11 on a breadboard. Verify the function generator voltage using the oscilloscope and adjust the source voltage if necessary. The oscilloscope's Channel 2 lead requires only a single prong as the common is assumed to be the same as the first channel. A dual trace comparison of the two channel signals shall be used to determine the voltage phase shift between the source and the resistor as shown in Fig. 12.

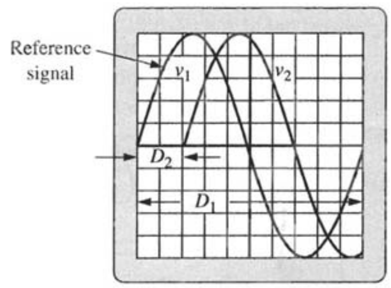

Figure 8: Dual Trace

One signal will be chosen as a reference, that is, zero-phase angle. The other signal can be considered leading (+θ) if it is to the left of the reference and lagging (-θ) if it is to the right of the reference. To use the dual trace phase measurement method, therefore, proceed as follows:

1. Connect the two signals to the two channels, making sure to observe proper grounding. For clarity, adjust the vertical sensitivity of each waveform until both signals have the same relative size.
2. Once the traces are on the screen, use the positioning knobs to ensure waveform crests (or, if preferred, zero crossings) align.
3. Measure the number of horizontal divisions (D1 in Fig. 12) required for one full cycle of either waveform (they both have the same frequency).
4. Measure the number of horizontal divisions in the phase shift (D2), as shown in Fig. 12.
5. Because D1 is associated with a full cycle of 360˚ and D2 is associated with the phase angle θ, we can set up the following ratio and solve for θ:

$$\boldsymbol{\theta = \frac{D_2}{D_1} \times 360°}$$

For the case of Fig. 12:

$$\boldsymbol{\theta} = \frac{2\ div.}{10\ div.} \times \mathbf{360° = 72°}$$

Measure and record in Table 5 the value of *R* used in your circuit as shown in Fig. 11. Enter the "Calculated" values of the voltage magnitude and phase into Table 5. These were determined in Part 1.

Table 5: RC Circuit Data

R (Ω)	$E_{(p-p)}$	$V_{R_{(p-p)}}$		θ_1	
		Calculated	Measured	Calculated	Measured
	8 V				

Using the oscilloscope, measure the peak-to-peak value of $\mathbf{V}_R$. Insert in the "Measured" column of Table 5. Determine the phase shift of the resistor voltage in degrees. Enter in the "Measured" section of Table 5. Assume the function generator voltage signal to be your reference.

Calculation:

How do the calculated and measured values for V_R and θ_1 compare?

SECTION TWO

The purpose of this section is to verify the frequency response of an inductor in an AC RL circuit.

The reactance of an inductor is linearly dependent on the frequency applied. That is, if we double the frequency, we double the reactance, as determined by $X_L = 2\pi fL.$ For very low frequencies, the reactance is correspondingly very small, whereas for increasing frequencies, the reactance will increase to a very large value. For DC conditions, we find that $X_L = 2\pi(0)L$ is 0 Ω. For very high frequencies, X_L is so high that we can often use an open-circuit approximation.

Construct the circuit of Fig. 13. The resistance of the inductor (R_l) will be ignored for this experiment, because $X_L >> R_l$. Insert the measured value of R_s (sensing resistor).

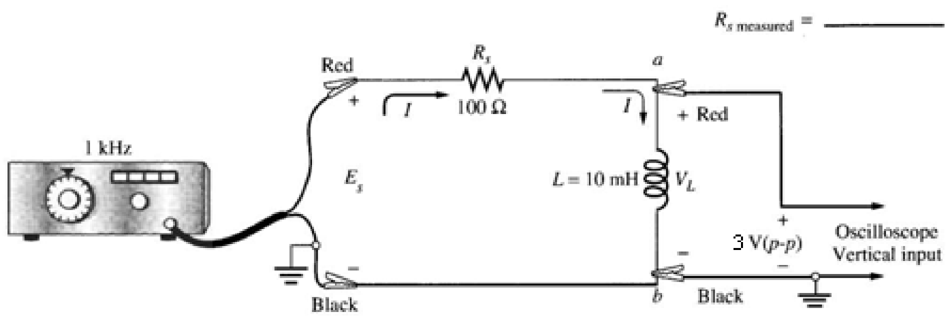

Figure 13 Circuit Layout

1. Set the frequency of the function generator. (It is initially 1 kHz).
2. Adjust the voltage across the **inductorl** (V_L) to 3 V (p-p) using the oscilloscope. (Do not measure the voltage of the source and do not use a multimeter). Note: V_L will change with the frequency. **You will have to check the voltage across the inductor EVERY TIME you change the frequency of the function generator.**
3. Turn off the supply.
4. Without changing any controls, swap the positive and negative lead positions of the function generator. **Remember: The oscilloscope and function generator commons (black leads) should ALWAYS be shorted together.**
5. Measure the resistor's voltage using the oscilloscope. Record in Table 6.
6. Swap the leads of the function generator back and repeat as necessary.

Table 6: RL Circuit Data

Frequency	$V_{L(p-p)}$	$V_{R_{s(p-p)}}$	$I_{p-p} = \dfrac{V_{R_{s(p-p)}}}{R_s\text{(meas.)}}$	$X_L\text{(measured)} = \dfrac{V_{L(p-p)}}{I_{p-p}}$	$X_L\text{(calculated)} = 2\pi fL$
1 kHz	3 V				
3 kHz	3 V				
5 kHz	3 V				
7 kHz	3 V				
10 kHz	3 V				

The multimeter was not used to measure the current in this part of the experiment because many commercial units are limited to frequencies of 1 kHz or less.

(a) Calculate the reactance X_L (magnitude only) at each frequency and insert the values in Table**Error! Reference source not found.** 6 under the heading "X_L (measured)".

(b) Calculate the reactance at each frequency of Table 6 using the nameplate value of inductance (10 mH), and complete the table.

(c) How do the measured and calculate values of X_L compare?

(d) Plot the measured value of X_L versus frequency on Fig. 14. Include the plot point of $f = 0$ Hz and $X_L = 0\ \Omega$ as determined by $X_L = 2\pi fL = 2\pi(0\text{ Hz})L = 0\ \Omega$.

(e) Is the resulting plot a straight line? Should it be? Why?

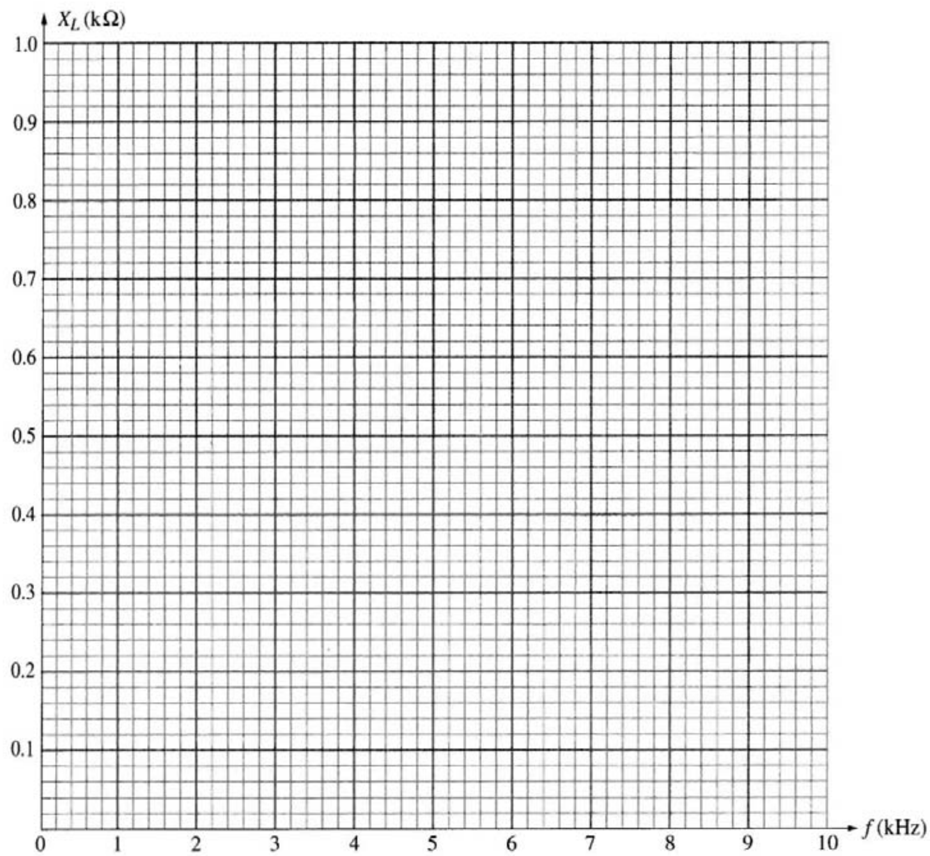

Figure 14: Frequency Response of Inductor

(f) Determine the inductance at 1.5 kHz using the plot of part 1(d). That is, determine X_L from the graph at $f = 1.5$ kHz, calculate L from $L = X_L / 2\pi f$ and insert the results in Table 7. Record the nameplate value of the coil in Table 7. Compare the nameplate value with the calculated value.

Calculation:

Comparison:

Table 7: Inductance Results

X_L	L (calc.)	L (nameplate)

End of experiment 9

This table is completed by your supervisor.

Supervisor	
Date	
Comments	

Experiment 10

SECTION ONE

The aim of this section is to verify AC circuit calculations containing more complex RL component arrangements.

Part 1:

Build the circuit shown in Fig. 15 on a breadboard. Measure the resistors and enter the measured values. Using the measured values, calculate the following:

- V_2 using nodal analysis.
- V_1 and V_3 using KVL.
- All currents using Ohm's Law.

Show all working. All answers should be given in polar form (i.e. magnitude∠angle in degrees) and the source voltage should be taken as your reference (i.e. E=8∠0). Use peak-to-peak values.

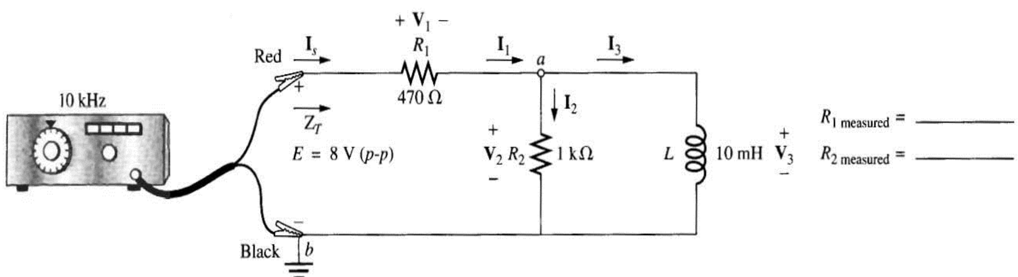

Figure 9: Example AC network

Part 2:

Fill out the Calculated column of Table 8 using the results of Part 1.

Table 8

	Calculated	**Measured**
$I_{s(p-p)}$		
$V_{1(p-p)}$		
$V_{2(p-p)}$		
$V_{3(p-p)}$		
$I_{2(p-p)}$		
$I_{3(p-p)}$		

Measure the peak-to-peak magnitude and phase angle of the voltages V_1, V_2 and V_3 with the oscilloscope. Use the function generator voltage as the reference when determining phase angles. You will have to swap the leads of the function generator for some measurements. Recall that the function generator ground should ALWAYS be shorted to the ground of the oscilloscope. Record your results in the "Measured" column of Table 8. Recall from the previous experiment that:

$$\theta = \frac{D_2}{D_1} \times 360°$$

Using these results and Ohm's Law, find the currents I_s, I_2 and I_3. Enter these in the Measured column of Table 8.

How does the results of the calculated and measured values compare? Do your measured results agree with KVL and KCL? Explain any discrepancies.

SECTION TWO

The aim of this section is to verify AC circuit calculations containing more complex RC component arrangements.

(a) Construct the network of Fig. 16. Insert the measured resistor values. Set the source to 8 V (p-p) with the oscilloscope. Verify the source voltages using an oscilloscope.

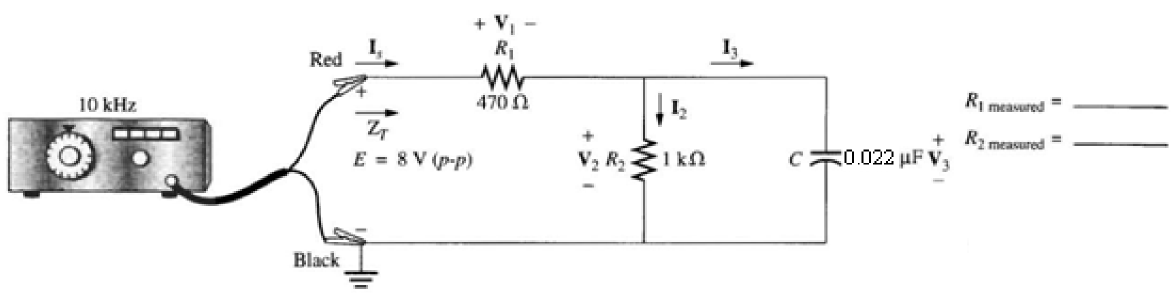

Figure 10: RC Circuit Example

(b) Calculate the magnitude of the total impedance Z_T at $f = 10$ kHz.

(c) **Reverse the leads to the function generator** (to ensure a common ground between the generator and the oscilloscope) and measure the peak-to-peak magnitude of the voltage $\mathbf{V}_1$ with the oscilloscope. Using the measured value for the voltage, calculate the peak-to-peak value of the current $I_s = I_1$.

(d) Determine Z_T from the measured value of $I_{s(p-p)}$ and the source voltage using the following equation:

$$Z_T = \frac{E_{(p-p)}}{I_{s(p-p)}}$$

(e) How does the measured value of Z_T compare with the calculated level of (b)?

(f) **Re-establish the network of Fig. 16** with R_1 connected as shown and measure the peak-to-peak magnitudes of V_2 and V_3 with the oscilloscope. What is the relationship between V_2 and V_3? Why?

(g) Using the results of part (f), calculate the peak-to-peak values of I_2 and I_3.

Calculation:

(h) Using the results of parts (c) and (g) determine whether the following relationship is satisfied using the peak-to-peak magnitudes. Explain why relationship exists (or doesn't exist).

$$I_1 = I_s = \sqrt{I_2^2 + I_3^2}$$

(i) If $\mathbf{E} = E\angle 0^\circ$, use the oscilloscope to measure the angles of $\mathbf{V}_1$ and $\mathbf{V}_2$. Use peak-to-peak values calculated in (f) for the magnitudes. Remember to swap the function generator leads where necessary.

$\mathbf{V}_1$ = __________ $\mathbf{V}_2$ = __________

(j) Is the following relationship satisfied? Use the peak-to-peak magnitude for voltages. If not, why not?

$$E = \sqrt{V_1^2 + V_2^2}$$

End of Experiment 10

This table is completed by your supervisor.

Supervisor	
Date	
Comments	

Experiment 11

SECTION ONE

This section will introduce power electronics concepts including various converter types.

Use Multisim to set up the circuit in Fig. 17. Adjust the function generator to generate an AC signal with an amplitude of 3V (peak) and frequency of 50 Hz. Channel A of the oscilloscope measures the input voltage and Channel B measures the voltage drop across the load resistor (R = 1 kΩ). Record the waveforms of both input and output voltages on the left hand side of Fig. 18. Then reverse the direction of the diode and re-run the simulation. Record the input and output waveforms on right hand side of Fig. 18. Clearly label each plot and axis. Use a virtual diode.

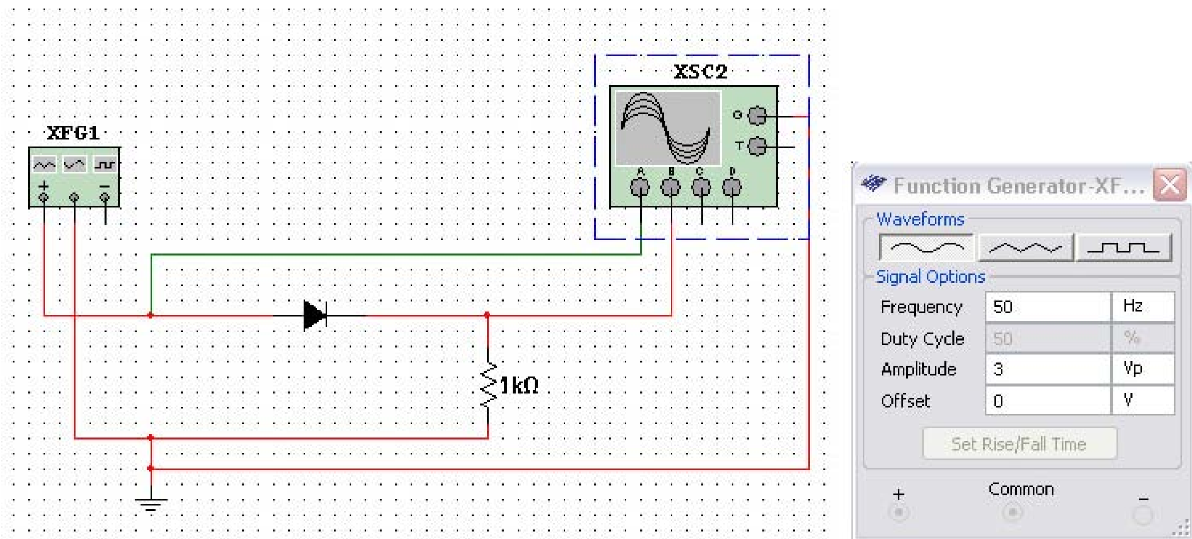

Figure 11: Half-wave Rectifier

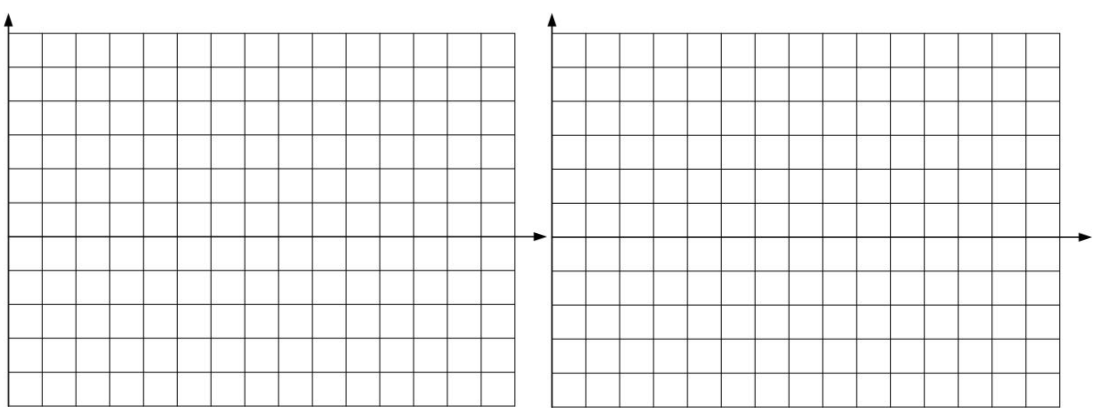

Figure 12: Half-wave Rectifier Plots

The voltage waveform across the load is called a "half-wave rectified sine wave". What is the average voltage across the load? You may assume that the diode is ideal for this calculation. Show full working!

$$V_{average} = \frac{Area\ under\ Waveform}{Length\ of\ Waveform} = \frac{\int_0^{\pi/2} V_{pk} \sin(\omega t) d(\omega t)}{\pi}$$

SECTION TWO

A rectified circuit is necessary to convert a signal having zero average value into one that has a nonzero average. The output resulting from a rectifier is a pulsating DC voltage and not yet suitable as a battery replacement. For DC supply voltages, such as those used in a radio, computer, and so on, the pulsating DC voltage from a rectifier is not good enough. A filter circuit is necessary to provide a steadier DC voltage.

Before going into the details of a filter circuit, it would be appropriate to consider the usual methods of rating filter circuits so that we can compare a circuit's effectiveness as a filter. Fig. 19 shows a typical filter output voltage, which will be used to define some of the signal factors. The filtered output of Fig. 19 has a DC value and some AC variation (ripple). The smaller the AC variation with respect to the DC level, the better is the filter circuit's operation.

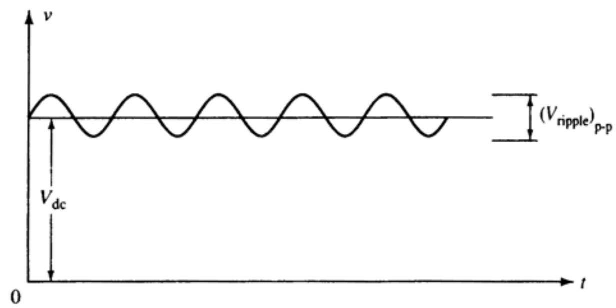

Figure 13: Filter Voltage Waveform Showing Ripple

Consider measuring the output voltage of a filter circuit using a DC voltmeter and an AC (rms) voltmeter. The DC voltmeter will read only the average or DC level of the output voltage. The AC (rms) meter will read only the rms value of the AC component of the output voltage (assuming the AC signal is coupled through a capacitor to block out the DC level).

Definition: Ripple factor is defined as

$$\boxed{r = \frac{\text{ripple voltage (rms)}}{\text{dc voltage}} = \frac{V_r(rms)}{V_{dc}} \times 100\%}$$

A very popular filter circuit is the capacitor-filter. A capacitor is connected at the rectifier output, and a DC voltage is obtained across the capacitor. Set up the circuit in Fig. 20 and adjust the function generator to generate an AC signal that the amplitude is 3V (peak) and the frequency is 50 Hz.

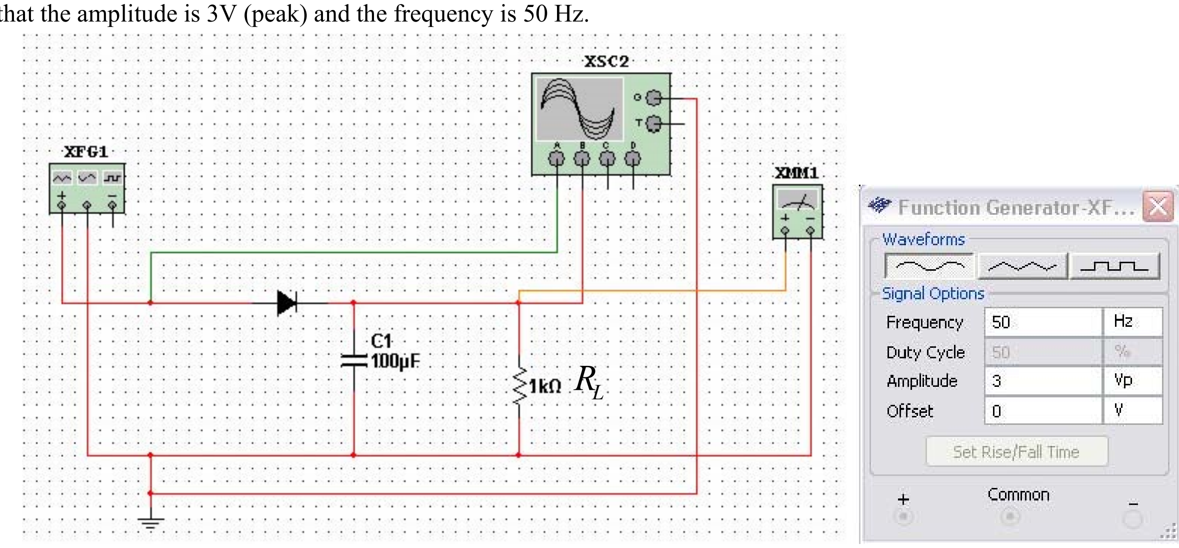

Figure 14: Capacitor Filter

Place a 100 µF capacitor in parallel with R_L and run the simulation. Record the waveform of the voltage across R_L with respect to the input voltage on Channel A of the oscilloscope in Fig. 21.

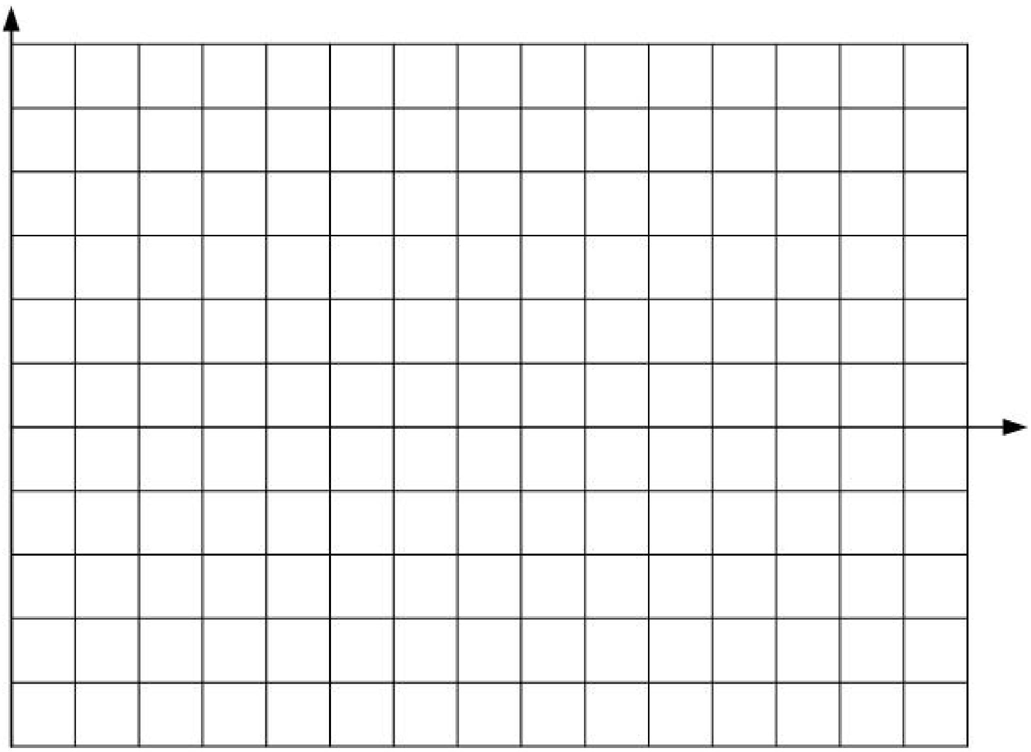

Figure 15: Voltage Waveforms

(a) Use the Multimeter to measure the DC level and ripple voltage of the waveform. Record in Table 9 and repeat with a 500 µF and 1000 µF capacitors.
- To measure the **DC level** of the output voltage, use the **DC tap** of the Multimeter (Fig. 22(a)).
- To measure the **ripple** of the output voltage, use the **AC tap** of the Multimeter (Fig. 22(b)).

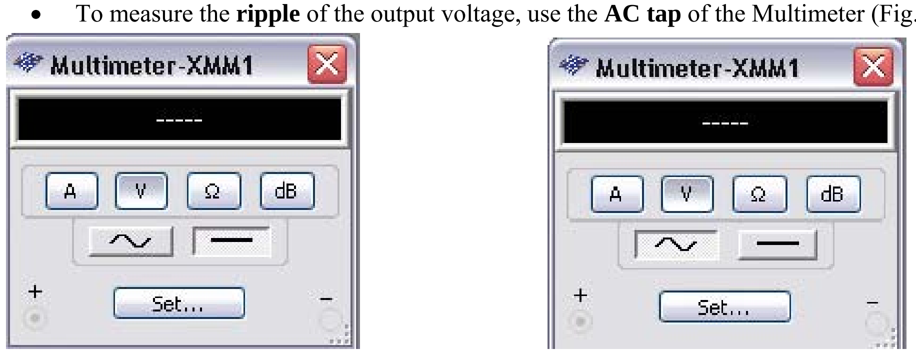

Figure 16: Multimeters measuring DC voltage (a) and AC voltage (b)

(b) Compute the percentage ripple and record in Table 9.

Table 9

Capacitor used (μF)	100	500	1000
Ripple voltage (rms)			
Average voltage (V)			
Percentage ripple (%)			

(c) State general conclusion about how the percentage ripple varies with the capacitor value.

SECTION THREE

In this section, we study the behaviour of a full wave rectifier circuit. Set up the circuit as shown in Fig. 23. The values for the function generator are 50 Hz in frequency and 3V peak in amplitude. Run the simulation while keeping the switch open. The waveform shown on channel A is the voltage across the resistor load. This waveform is called a full-wave rectified sine wave.

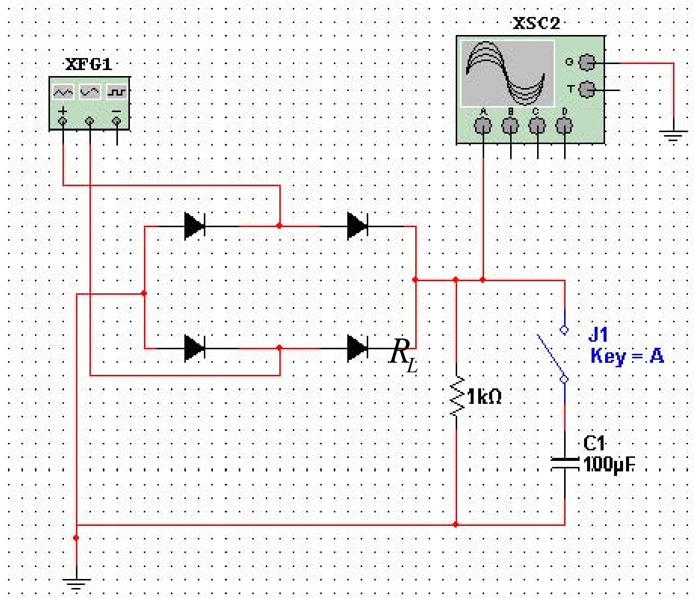

Figure 17: Full-wave Rectifier

(a) Record the waveform of the voltage across R_L on to Fig. 24, clearly indicate the key values and label the waveform.

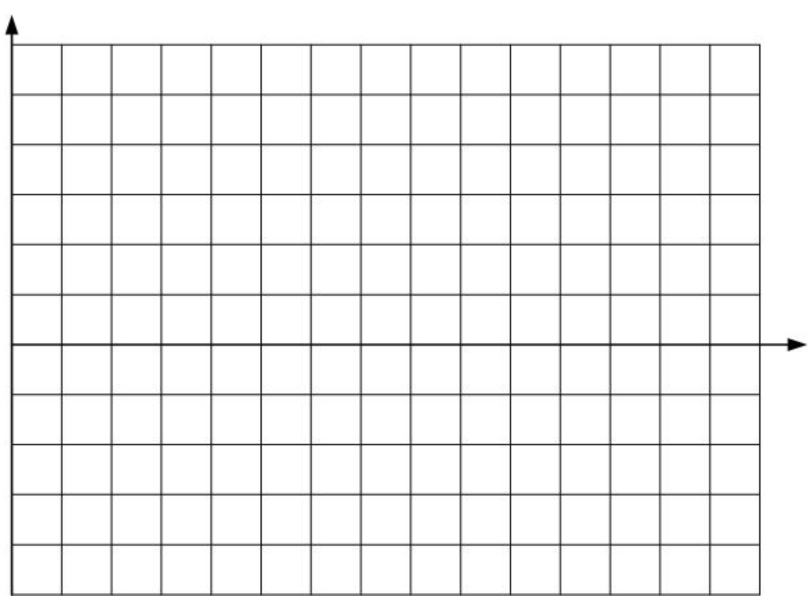

Figure 18: Full-wave Rectifier Voltage Waveforms

Now close the switch and re-run the simulation. The waveform at channel A is now a filtered waveform. Record this waveform on Fig. 24, clearly indicate the key values and label the waveform.

(b) Using the Multimeter to measure the DC level of the output voltage, and the $V_r(rms)$ – ripple voltage. Record the values in Table 10, also repeat this with a 250 μF and 500 μF capacitors.

(c) Compute the percentage ripple and record in Table 10.

Table 10

Capacitor used (μF)	100	250	500
Ripple voltage (rms)			
Average voltage (V)			
Percentage ripple (%)			

(d) What is your observation about the ripple factor of a half-wave rectified signal compare to a full-wave rectified signal?

End of Experiment 11

This table is completed by your supervisor.

Supervisor	
Date	
Comments	