The Department of Physics

University College Cork

PY2108 Experimental Methods I

Laboratory Manual B

Introduction to Electronics for Scientists

Table of Contents

Experiment 1 The Dual-Beam Oscilloscope and the Digital Multimeter

The dual-beam oscilloscope

The cathode ray oscilloscope, CRO, is a versatile instrument which may be used as a high impedance DC or AC voltmeter or for measuring the frequency and shape of electrical oscillations. The instrument consists essentially of a narrow beam of electrons which gives rise to a bright spot when it impinges on a fluorescent screen. Two pairs of plates enable the beam to be deflected either horizontally (x-plates) or vertically (y-plates) when a voltage is applied to them. In normal operation, an internally generated saw-tooth waveform is applied to the x-plates, causing the beam to be deflected horizontally at a constant rate in a repetitive fashion; this results in a horizontal line across the screen if no voltage is applied to the y-plates. If a time-varying voltage is applied to the y-plates, the electron beam is deflected by the resulting electric field, thus giving a display of voltage versus time on the screen.

The dual-beam oscilloscope used in this course (Figure 1.1) has two inputs (CH1 and CH2) so that the two signals can be displayed simultaneously, allowing direct comparisons to be made.

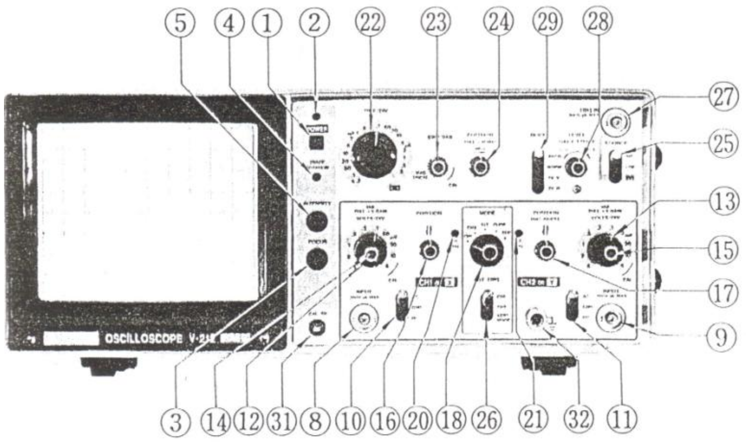


Figure 1.1: The cathode ray oscilloscope – note this image varies from the one in the lab but the functions are identical.

The functions of the various controls will become familiar with use. The brightness and sharpness of the beams are determined by the INTENSITY (5) and FOCUS (3) controls, respectively. The speed at which the beams are deflected horizontally (time base) is determined by the TIME/DIV control knob (22). For normal operation the red SWP VAR control knob (23) should be fully clockwise; only in this situation is the time base calibrated correctly. The POSITION controls (16, 17, 24) are used to position the trace on the screen. Electrical signals to be investigated are applied to the y-plates via the input connectors CH1 (8) and CH2 (9) through amplifiers of variable gain. The VOLTS/DIV control knobs (12, 13) select the appropriate gain of these amplifiers. The red VAR controls (14, 15) must be fully clockwise if the VOLTS/DIV scales are to be used for measurement.

CAUTION: *The 0 V side of the input connectors is joined to earth. If the generator of the signal under investigation also has an earthed terminal this must be connected to the oscilloscope earth, otherwise the signal source would be short-circuited.*

There are two buttons: one AC-DC and one GND switch. When an AC-DC switch (10, 11) is in the DC position (pushed in), the input is connected directly to the amplifier. In the AC position (pushed out) the input signal is first fed through an internal capacitor; this is useful for observing small AC signals superimposed on a large DC background, since the DC part of the signal will not be coupled through the capacitor. For many applications, the trigger MODE select switch (29) may be set in the AUTO position. The trigger LEVEL control (28) may be used to obtain a steady trace on the screen and the rising edge or lower edge is selected via the "+/-" bush button on the trigger panel. The lower centre MODE select switch (18) enables the signal on CH1 or on CH2 or both (ALT position) to be observed.

The digital multimeter

The digital multimeter, DMM, (Figure 1.2) is a versatile instrument, which may be used to measure DC and AC voltages, currents and resistance. It complements the oscilloscope and must always be used when accurate (i.e. better than 5%) measurements are required. When used to measure voltage the DMM has an input impedance of 10 MΩ.

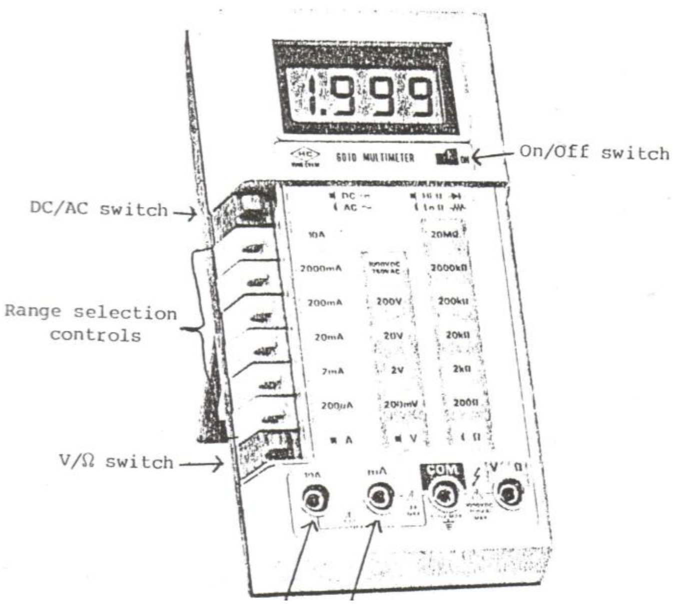


Figure 1.2: The digital multimeter.

Component and Equipment Requirements

- Resistor: 2.2 kΩ,
- Variable resistor
- Signal generator
- Digital Multimeter
- Oscilloscope and scope leads
- Low voltage DC power supply

Part 1: To measure a DC voltage using a CRO

To illustrate the use of the oscilloscope as a d.c. voltmeter, set up the circuit indicated in Figure 1.3, with $R' = 2.2\ k\Omega$. Initially, set $R = 1000\ \Omega$.

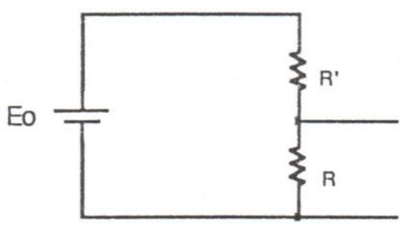


Figure 1.3: A potential divider.

Connect one of the inputs of the CRO across the resistor, *R*, and note the deflection of the trace. Change the volts/cm control knob to get maximum sensitivity. Measure the potential difference across *R* (remember to record the maximum error). Decrease *R* in steps of 100 Ω and record the potential difference, V_R, across the resistance, *R*, in each case.

Resistance, *R* (Ω)	Error in *R*	Voltage, V_R (V)	Error in V_R
1000			
900			
800			
700			
600			
500			
400			
300			
200			

100			

Also, use the oscilloscope to measure the e.m.f., E_0, of the power supply. Show that each of the measured values of V_R are consistent with the theoretical value, calculated assuming that the power supply has negligible internal resistance, *viz*.

$$V_R = \frac{RE_0}{R + R'}$$ [*prove this relationship*]

The circuit under study here is called a potential divider and has many important applications e.g. to produce stable voltage references, to set the dc bias of a common emitter amplifer, etc.

Finally, switch the AC-DC switch to the AC position and satisfy yourself that the introduction of the internal capacitor blocs the DC signal.

Part 2: To measure the amplitude and frequency of an AC signal

The signal to be investigated is that produced by a variable frequency signal generator. Output sockets, one of which is earthed, are at the lower right of the panel. The knob below the dial knob is the frequency range selector switch and the knob at the lower right controls the output amplitude.

Set the frequency control on the signal generator to around 1 kHz and the output amplitude to about half maximum.

[Make sure the SWP VAR and VAR controls on the oscilloscope are fully clockwise (CAL position).] Apply a sinusoidal signal from the signal generator to one input of the oscilloscope with the AC-DC switch in the DC position. Obtain a sharp steady trace and measure the peak-to-peak voltage, $V_{pp} = 2V \Rightarrow V = V_{pp}/2$, (where V is the amplitude of the signal) and period of the waveform. Draw a scale diagram of the trace for inclusion in your report. Calculate the rms voltage, $V_{rms} = V/\sqrt{2} = V_{pp}/2\sqrt{2}$ for the observed signal. Repeat for a number of other frequency ranges (say, approximately 100 Hz, 10 kHz and 100 kHz).

Repeat the experiment using the square waves from the signal generator. Finally, switch the AC-GND-DC switch to the AC position and observe the effect of introducing the internal capacitor in this case.

Part 3: To investigate the trigger LEVEL facility of the CRO

To enable a stationary pattern to be observed on the screen the start of the x-sweep must be synchronized with the signal being observed. The trigger LEVEL control

("+/-" push button on the trigger panel) allows the sweep to start on the appearance of either a positive going or negative going signal; the sweep is started only when the signal being observed exceeds some preselected amplitude determined by the control setting.

Apply a sinusoidal signal from the signal generator to one input of the oscilloscope. With the trigger level control in the AUTO position the sweep should start at the zero level of the sine wave. Set the trigger MODE switch to the NORM position and slowly turn the LEVEL control clockwise and counterclockwise with the +/- slope button pushed in (positive going signal). Note how the starting point of the sweep moves up or down the sine wave depending on the level set. Draw a number of scale diagrams to illustrate the effect observed. Repeat the procedure with the +/- slope button out (negative going signal).

Part 4: To use a digital voltmeter as (a) an ohmmeter and (b) a voltmeter

(a) To familiarise yourself with the digital multimeter used as an ohmmeter set the switches to ohms (Ω), 20 kΩ and DC and connect a resistance box between the ohms (Ω) and common (COM) terminals of the DMM. Measure the resistance of the box for some (four) different settings of the dials between 9999 Ω and 0 Ω, switching ranges as convenient. Check that your measurements agree with the dial readings.

(b) Connect the signal generator to the oscilloscope and adjust to give about 1 V peak-to-peak sine wave at 1 kHz. Use the oscilloscope to measure the peak-to-peak voltage of the signal and, hence, calculate the corresponding rms voltage. Now measure the AC and DC voltages with the DMM. Tabulate the results as indicated below. Switch to square waves and repeat the measurements. How do they compare?

	OSCILLOSCOPE		DIGITAL MULTIMETER	
	V_{pp} (Volts)	V_{rms} (Volts)	DC Voltage (Volts)	AC Voltage (Volts)
Sine wave				
Square wave				

With the signal generator set to give sine wave output increase the frequency of the signal generator to the maximum possible, and then decrease to the minimum, while checking the AC voltages recorded by the DMM and the oscilloscope display. Over what frequency range will the DMM operate satisfactorily in this mode?

Part 5: Measurement of the output impedance of the signal generator

When a voltage source supplies current to a load, R_L, the voltage across the terminals may drop below the unloaded value. This is exactly analogous to the effect of the internal resistance of a DC power supply. The output stage may be represented as an ideal voltage source, V_0, in series with an impedance, R_i (c.f. Figure 1.4). This predicts that the observed output voltage will be given by:

$$V = \frac{R_L}{R_L + R_i} V_0 .$$

Set up the circuit in Figure 1.4. The points A and B represent the terminals of the signal generator. Measure the observed output voltage when there is no load and when R_L = 3 kΩ. Hence, calculate R_i. Repeat for R_L = 1 kΩ and, again, calculate, R_i.

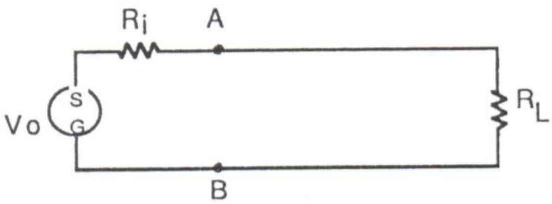


Figure 1.4: Circuit to measure the output impedance of a signal generator.

Experiment 2 Soldering Parallel and Series Circuits and using the Digital Multimeter

Introduction

Soldering is the most common means of joining components to each other or to circuit boards in electronics. Although it is one of the most reliable methods for making such connections, this reliability can be significantly reduced by poor soldering techniques, resulting in low quality soldered joints. During soldering, two or more metal parts are united by an alloy. The alloy melts at a lower temperature than either of the metals. The liquefied solder *permeates into* the molecular structure of each of the metals, forming a common bond on cooling that unites the metals. The melting point for solder depends on the composition of the alloy used.

The DMM is a basic test instrument. It can measure resistance, voltage, current and capacitance; it may also contain a diode tester and a transistor tester. It can measure both DC and AC quantities.

Objectives

The objective of this laboratory exercise is to practice:

2. Reading resistor colour codes;
3. Soldering simple circuits onto stripboards;
4. Using a DMM by taking measurements of many of the quantities which it is commonly used for.

Component and Equipment Requirements

- Resistors: 120 Ω, 150 Ω, 180 Ω, 56 Ω, 3.3 k Ω, 820 Ω, 2.7 k Ω, 1 k Ω and 390 Ω
- Red and black stranded wire
- Red and black single core wire
- Solder
- Stripboard
- Solder tip cleaner
- Digital Multimeter
- Oscilloscope and scope leads
- Low voltage DC power supply
- Low voltage AC power supply
- Soldering iron stand

Some simple rules

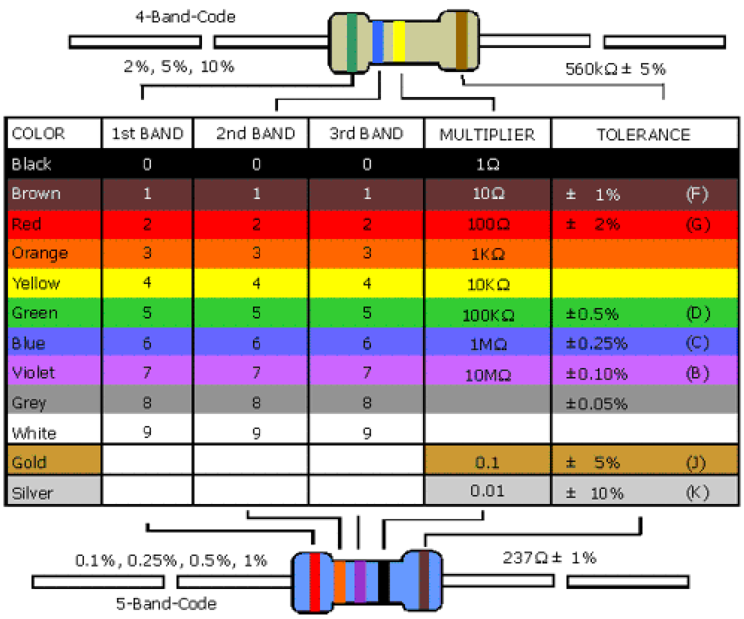
- Always keep the tip of your soldering iron clean by wiping it frequently on a damp sponge.

- Work in a well-ventilated area.
- When you burn yourself, quickly run cold tap water over the burn to limit damage to your skin.
- For safety, always park a hot soldering iron in a bench stand.
- Always turn off the soldering iron when it is not in use.
- After soldering, examine the join carefully. If the solder is dull grey in colour, you should reheat the joint and apply some more solder. The solder should have a bright, silver colour in the joint.

Part 1: Soldering parallel and series circuits

1. Use the digital multimeter (DMM) to measure the resistance of two resistors (R1 and R2) of nominal values 1 kΩ and 390 Ω. Use Figure 2.1 to select the resistors.

2. Mount the resistors onto the stripboard as shown in Figure 2.2. Bend the resistor leads as necessary and insert them through suitable holes on the board. To hold the resistor in place while you are soldering, you may find that it is useful to bend the leads at the bottom of the board at an angle. Once you are sure that the component is properly placed, you can more on to the next step.



COLOR	1st BAND	2nd BAND	3rd BAND	MULTIPLIER	TOLERANCE	
Black	0	0	0	1Ω		
Brown	1	1	1	10Ω	± 1%	(F)
Red	2	2	2	100Ω	± 2%	(G)
Orange	3	3	3	1KΩ		
Yellow	4	4	4	10KΩ		
Green	5	5	5	100KΩ	±0.5%	(D)
Blue	6	6	6	1MΩ	±0.25%	(C)
Violet	7	7	7	10MΩ	±0.10%	(B)
Grey	8	8	8		±0.05%	
White	9	9	9			
Gold				0.1	± 5%	(J)
Silver				0.01	± 10%	(K)

Figure 2.1: Resistor colour codes.

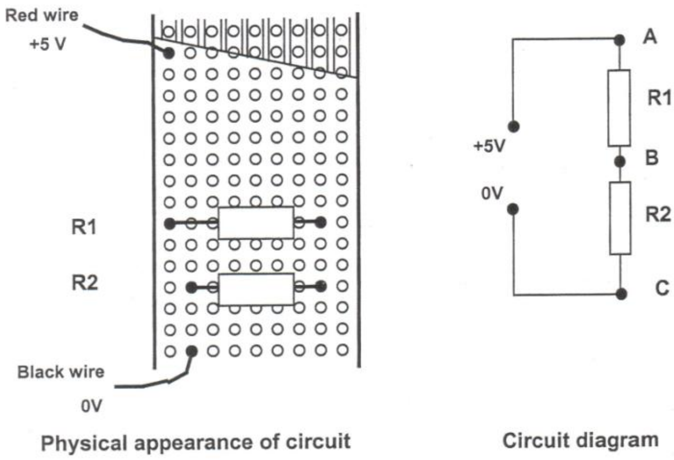


Figure 2.2: Schematic of the two resistors in series circuit.

3. Apply a very small amount of solder to the tip of the soldering iron (Figure 2.3). This will help to conduct the heat to the component and board, but is not the solder that will make up the joint. You are now ready to heat the resistor and board. Lay the iron tip so that it rests against both the resistor lead and the board. It may take one or two seconds to heat the component up enough to solder.

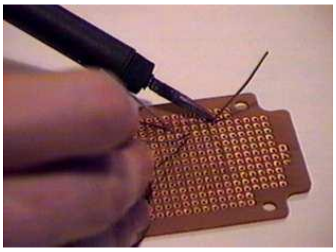


Figure 2.3: Placing the resistors on the stripboard.

4. Once the component lead and solder pad has heated up, you are ready to apply solder. Touch the tip of the strand of solder to the component lead and pad, but not the tip of the iron (Figure 2.4). The solder should flow freely around the lead and pad. Once the pad is coated, you can stop adding solder and remove the soldering iron (in that order). Don't move the joint for a few seconds to allow the solder to cool, otherwise you will end up with a weak, cold joint.

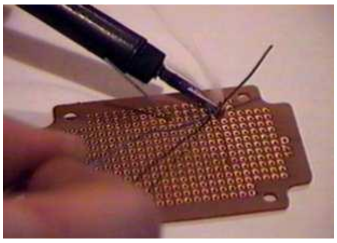


Figure 2.4: Applying solder to the joint.

5. Repeat the above steps so that the two resistors are soldered in place.

6. Solder two *flying leads* onto the board as shown in Figure 2.2. You now have a simple circuit of two resistors in series.

7. Use the DMM to measure the total circuit resistance (between points *A* and *C*). How does your measured value compared with your calculated value, allowing for the tolerances of the resistors?

8. Calculate the maximum voltage which can be applied to this circuit without overheating either of the resistors. Assume the power dissipation of the resistors is 0.5 W.

9. Set the output of the low voltage power supply to 5 V DC and, using the DMM to measure the voltage, connect it to the circuit as shown in Figure 2.2 and switch it on.

10. Measure the voltage between points *A* and *B*, and between points *B* and *C* using the DMM and, also, using an oscilloscope.

11. Measure the total current in the circuit using the DMM.

12. Select a resistor (R3) of nominal value 2.7 kΩ and measure its actual value using the DMM.

13. After switching off the power supply, mount this resistor in parallel with R1 as shown in Figure 2.5 and solder it in position.

14. Use the DMM to again measure the total circuit resistance and compare your measured value with the calculated one.

15. Calculate the maximum voltage which can be applied to this *series-parallel* circuit without causing any overheating in the resistors.

16. Measure the voltages between points A and B, and between points B and C, using the DMM and also using the oscilloscope.

17. Measure the total current taken by the circuit using the DMM.

18. In your calculations, compare the actual measured parameters against those obtained using theory.

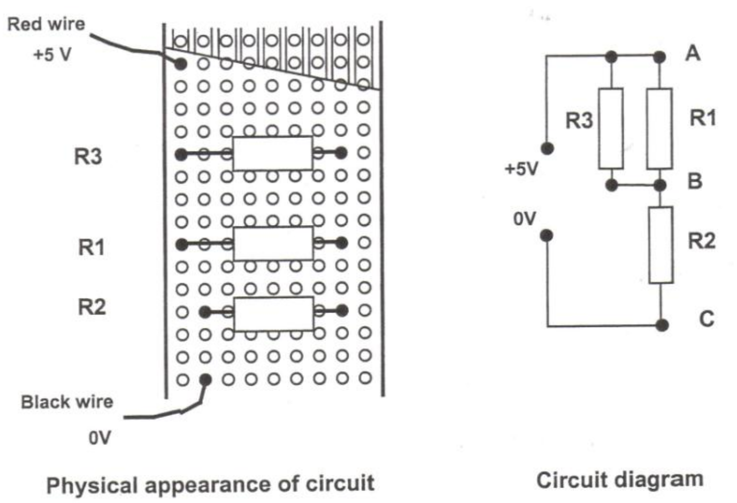


Figure 2.5: Schematic of the series-parallel circuit.

Part 2: The Digital Multimeter (DMM)

1. Construct the circuit shown in Figure 2.6 on a stripboard. NB: The view represents the top view of the stripboard (i.e. the side without the copper tracks).

2. Set the output of a power supply unit (PSU) to 9 V using the DMM to check the setting.

3. Connect the circuit to the power supply.

4. Measure the voltage across each resistor with the DMM.

5. Open the links as necessary and measure the current flowing in each resistor.

6. Disconnect the PSU.

7. Desolder the 56 Ω resistor and replace it with a parallel combination of 3.3 kΩ and 820 Ω.

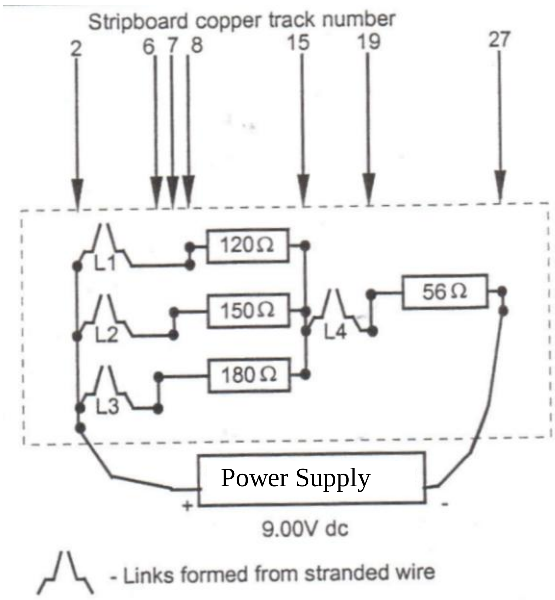


Figure 2.6: Circuit diagram.

8. Repeat steps 4 and 5 above.

9. Connect the modified circuit to an AC power supply. Check the supply is working by displaying the output on an oscilloscope.

10. Measure the output voltage of the power supply with the DMM. This is the root mean square voltage, V_{rms}.

11. Use the oscilloscope to display and measure the peak voltage of the power supply, V_p.

12. Using V_{rms} = 0.707 V_p compare the oscilloscope-derived value with that measured using the DMM.

13. Measure the voltage across each resistor with the DMM and, in each case, display the voltage on the oscilloscope and measure V_p. Hence, calculate V_{rms} for each voltage.

Experiment 3 Investigation of an RC Circuit

Introduction

This type of circuit, which consists of a resistor and capacitor in series, has a characteristic time, called the *time constant*, τ, associated with it. This time constant is used in many ways in electronic circuit design, for example in time delay circuits and in filters.

Objective

In this exercise, you are to examine the behaviour of RC circuits under DC and AC (square wave) conditions, using an RC circuit in each case, to determine the capacitance of an unknown capacitor.

Component and Equipment Requirements

- Resistors: 47 kΩ
- Capacitors 220 μF, 470 μF
- Stripboard
- Solder
- Stranded wire
- Solid core wire
- Oscilloscope
- Stopwatch
- Low voltage DC power supply
- Scope leads

Part 1: DC Operation

1. Construct, on stripboard, the circuit shown below, with flying leads to the breadboard for mounting the capacitor(s) and with R = 47 kΩ and C = 220 μF.

2. Take care to observe the correct polarities where appropriate. **Note**: Ideally you should use **red** (+) and **black** (-) single core wire for the connections to the breadboard and **red** (+) and **black** (-) stranded wire for the connections to the power supply. Use the lead marked X to connect and disconnect the DC supply as and when required.

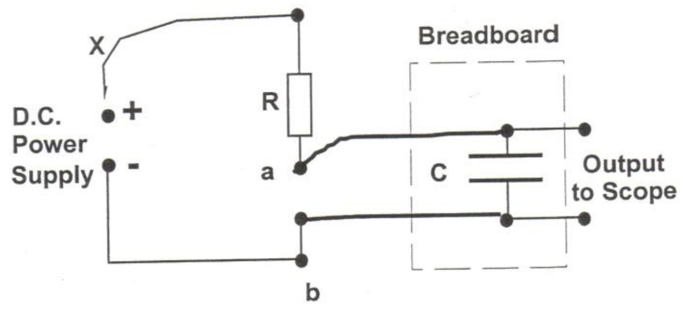


Figure 3.1: Circuit diagram

3. Se the power supply to 8 V and connect the circuit output to the oscilloscope. **Ask your supervisor to check your assembly before switching on the power supply.**

4. Connect X to the power supply to charge the capacitor. The oscilloscope will now show a slowly rising DC voltage.
   After one time constant, the voltage across the capacitor will have charged to 63.2% of the applied voltage change and, therefore, measuring this time will directly yield the time constant.

5. Discharge the capacitor by removing X from the power supply and shorting the positive side of the capacitor to the negative side with pliers or screwdriver, i.e. connect point a to point b.

6. Connect X once again and use a stopwatch to measure the time it takes for the voltage across the capacitor to reach the time constant value you have calculated. The value of this time is the time constant of this circuit. **Hint**: Use the oscilloscope in two-channel mode and set the second channel to ground. Its trace may be used to mark the desired voltage level on the screen of the oscilloscope.

7. Repeat steps 5 & 6 in order to get a second measurement of the time constant.

8. Take the average of your two timings as the time constant for the circuit and compare with the expected value of $\tau = RC$. If there is a significant difference in your two values, you should repeat the measurements. In fact, you should consider carrying out more than two measurements to improve your confidence in your result!

9. Find the time taken for the voltage across the capacitor to change by half the applied voltage change in each of the above situations. How does this time relate to the time constant, τ?

10. Repeat the above procedure with a second capacitor (C = 470 μF) connected in parallel with the existing capacitor.

Part II: AC (square wave) operation. This shows the process of integration.

1. Replace the capacitor(s) in the above circuit with a single 2000 pF capacitor.

2. Set the signal generator to square wave operation and use Channel 1 of the oscilloscope to set the peak-to-peak amplitude to 800 mV.

3. Replace the power supply in your circuit with a signal generator.

4. Observe the voltage across the capacitor (V_c) using Channel 2 of the oscilloscope. You should see a similar signal to the square wave input, but with the sharp transitions "rounded off". **Note**: The vertical sensitivity of Channel 2 should be the same as Channel 1.

5. Adjust the frequency of the signal generator until V_c ranges from 100 mV above the minimum to 100 mV below the maximum of the applied signal, i.e. one-eighth to seven-eighths of the applied signal. Monitor the applied signal and adjust the amplitude as necessary to maintain the 800 mV peak-to-peak.

6. Measure the period, T, of the applied signal and calculate the time constant from your circuit for $\tau = 0.254T$.

7. Adjust the frequency again until V_c ranges from 200 mV above the minimum to 200 mV below the maximum (i.e. from one-quarter to three-quarters) of the applied signal.

8. Measure the period T and calculate the time constant of your circuit from $\tau = 0.46T$.

9. Repeat Steps 7 and 8 until V_c ranges from 300 mV above the minimum to 300 mV below the maximum (i.e. from three-eighths to five-eighths) of the applied signal, calculating τ from $\tau = 0.98T$.

10. From this you should be able to determine an average time constant for the capacitor.

STUDENTS ARE REMINDED TO REPORT ALL ACCIDENTS IMMEDIATELY THEY OCCUR TO THE SUPERVISOR IN CHARGE OF THE LABORATORY SESSON.

Experiment 4 Characteristics of a Silicon Diode and the Zener Diode

Introduction

The diode is a device formed from a junction of n-type and p-type semiconductor material. The lead connected to the p-type material is called the **anode** and the lead connected to the n-type material is the **cathode**. In general, the cathode of a diode is marked by a solid line on the diode (Fig. 4.1).

Fig. 4.1: The symbol for a diode compared to an actual diode package.

The characteristic of a diode is a plot of junction current versus applied voltage. Since the junction current rises exponentially with increasing voltage - and too large a current would destroy the diode - it is normal practice to include a current limiting resistor in the circuit in order to protect the diode. The primary function of the diode is in rectification. When the diode is forward biased (the higher potential is connected to the anode lead), it can pass current. When it is reverse biased (the higher potential is connected to the cathode lead), the current is blocked.

The Zener diode is a silicon pn junction device optimised for operation in the reverse breakdown region (Fig. 4.2). The breakdown voltage of a Zener diode is set by carefully controlling the doping level during manufacture. When a Zener diode reaches reverse breakdown its voltage remains practically constant. This voltage is called the Zener voltage, V_z, and is a key property of the Zener diode, in that it allows it to be used as a voltage reference in a circuit. In addition, the Zener voltage does not change very much when the current through it changes: in other words, it is a good *regulator*. This is another key property of the Zener diode.

Fig. 4.2: The symbol for a Zener diode compared to an actual diode package.

Objectives

In this exercise you will examine:

- The characteristic of a silicon diode under both forward bias (and forward characteristic) and reverse bias (and reverse characteristic) conditions;
- The characteristics of a Zener diode.

Component and Equipment Requirements

- Resistors 560 Ω, 1.2 kΩ
- Diode such as IN4001
- Stripboard
- Solder
- Stranded wire
- Single core wire
- Breadboard
- Oscilloscope
- Signal Generator
- Digital multimeter
- Low voltage DC power supply
- Soldering iron and stand

Part 1: The V-I Characteristic of a Silicon Diode

1. Use the multimeter's diode test function to examine the diode. Carefully note the forward direction reading as this must be used later in this experiment.

2. Construct (on stripboard) the circuit shown in Fig. 4.3.

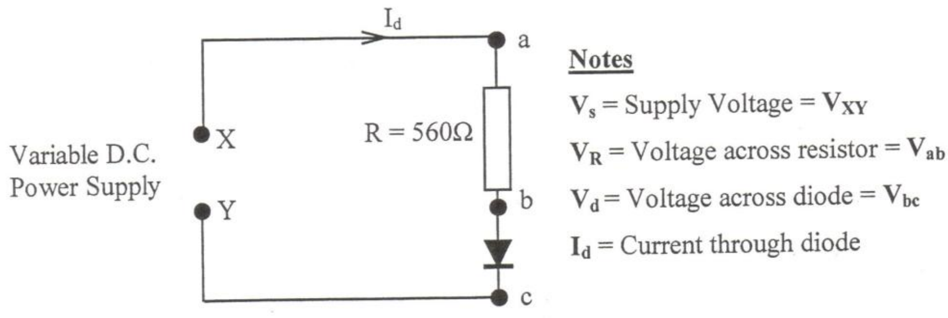


Fig. 4.3: Circuit diagram.

3. Measure and record the voltages V_s, V_R and V_d with a DMM for supply voltages of 0.30 V, 0.50 V, 0.60 V, 0.65 V, 0.70 V, 0.75 V, 0.80 V, 0.85 V, 0.90 V, 0.95 V, 1.00 V, 1.1 V, 1.2 V, 1.3 V, 1.4 V, 1.5 V, 2.0 V, 2.5 V, 3.0 V, 4.0 V, 5.0 V. Calculate (and record) the diode current from each of your readings using $V_R = RI_d$.

4. Tabulate your results in the form shown in the table below.

V_s (Volts)	V_R (Volts)	V_d (Volts)	I_d (mA)
0.30			
0.50			
0.60			

5. Rearrange your circuit by reversing the connections to the power supply. Record the voltage across the resistor in steps of 5 V up to 30 V.

6. Calculate the current in your circuit as before.

7. From all your data, plot a graph of diode current versus diode voltage. You may use different scales for the positive and negative x (voltage) and y (current) axes.

8. Identify the *forward characteristic* and *reverse characteristic* portions of your graph.

9. Determine the **cut-in voltage** V_c for the diode i.e. the point where the V-I characteristic intersects with the x-axis. Compare to earlier measured result.

Part 2: The Zener Diode

1. Construct (on stripboard) the circuit shown in Fig. 4.4.

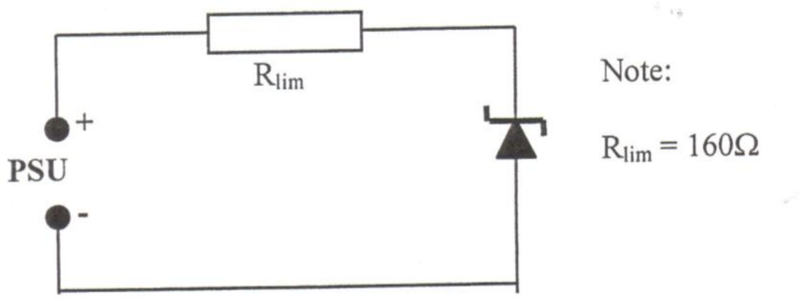


Fig. 4.4: Circuit diagram.

2. Set the power supply to 4 V and measure the voltage across the diode (V_d) and across the current limiting resistor (V_{lim}). Derive the diode current (I_d) and record it – along with the values of V_d and V_{lim} – in a table as shown below.

3. Repeat in steps of 1 V to the input voltage until the voltage across the Zener becomes almost constant and, thereafter, increase in steps of 0.5 V up to a maximum of 16 V (for the input voltage).

4. Plot a graph of diode current (I_d) against diode voltage (V_d).

5. From the graph, determine the value of V_Z, the breakdown voltage for the Zener diode.

6. Ideally, the voltage across the Zener should remain constant once V_Z has been exceeded. However, the diode has an internal resistance effectively in series with itself and, as the current flowing through the diode increases, the voltage across the diode also increases and may be determined by applying Ohm's Law, i.e. $\Delta V_Z = R_Z \Delta I_Z \Rightarrow R_Z = \Delta V_Z / \Delta I_Z$. Use your graph to determine the

slope resistance of the Zener. **Note**: This is the reciprocal of the slope of the graph.

7. Connect a 560 Ω (or 510 Ω depending on what is available) load resistor in parallel with the Zener diode.

8. Measure and record the input voltage and the voltage across the load resistor for the input voltage varying from 10 V to 16 V in 0.5 V steps.

9. Plot your results and determine the ratio of input voltage change to output voltage change. How does this compare with the expected value of the voltage change ratio of R_{lim}/R_Z ?

Experiment 5 The Transistor Switch and the Transistor Amplifier

Objective

The objective of this laboratory session is to (i) demonstrate the ability of a transistor to act as a switch and (ii) demonstrate the ability of a transistor to amplify small signals by constructing a simple amplifier circuit. The exercise also shows that the transistor amplifier is limited to a particular frequency range, the bandwidth.

Component and Equipment Requirements

- Resistors 2 x 300 Ω, 1 k Ω, 2 x 10 k Ω, 100 k Ω, 1 k Ω
- Capacitors 0.47 μF, 2.2 μF
- Potentiometer 47 k Ω
- Diode ORP12 photo cell or similar (ask the demonstrator for this)
- Solder
- Stripboard
- Semiconductors BC109 or similar, LED
- Stranded wire
- Single core wire
- 20 V DC power supply
- Signal Generator
- Oscilloscope
- Multimeter
- Breadboard
- Soldering iron

Part 1: The Transistor Switch

1. Identify the components to be used with the aid of Fig. 5.1.

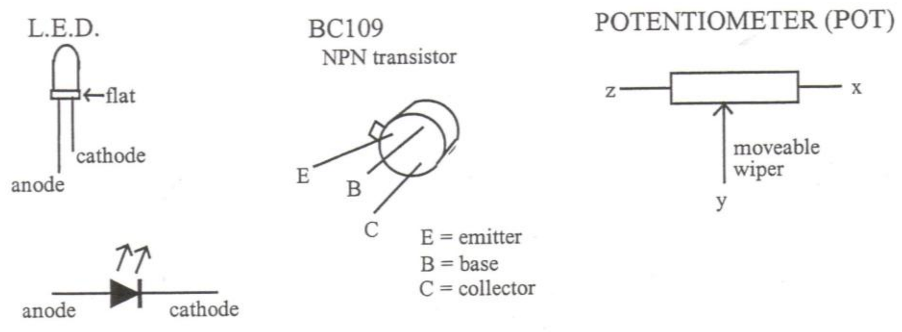


Fig. 5.1: Circuit components

2. Construct the circuit in Fig. 5.2 on a stripboard using stranded wire for the power supply connections and single core for the breadboard connections. Make sure you solder the transistor, LED and potentiometer correctly. **Note**: connect three short

pieces of single core wire to the pins of the potentiometer if there are none already attached.

3. Connect the potentiometer to the circuit on the breadboard at x, y and z.

4. Connect the circuit to a 10 V DC supply.

5. Adjust the pot and confirm that the LED switches on and off. **Do not proceed further until the circuit is functioning.**

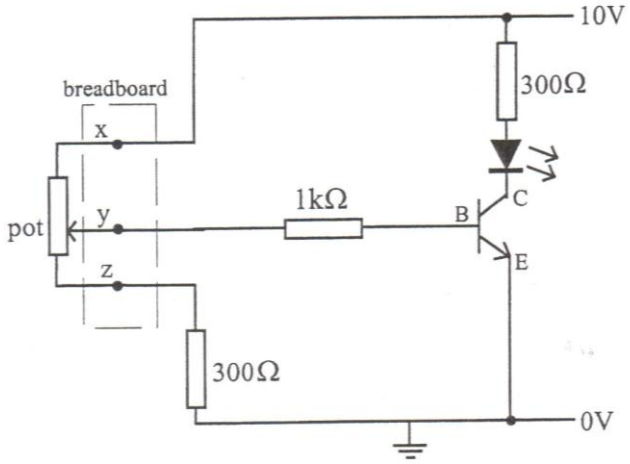


Fig. 5.2: Circuit diagram.

6. Measure the base emitter voltage, V_{BE}, under the following conditions:

Condition	V_{BE}
LED full on	
LED barely on	
LED off	

7. Examine the ORP 12 (or similar) light dependent resistor, supplied by demonstrator. Determine its resistance when fully covered (in the dark) and when lit. Do this before soldering into the circuit.

State	**Resistance Ω**
Dark	
Bright	

8. Replace the pot with the ORP 12 at x and y, connect y to z and confirm that the circuit still functions. Determine the following:

ORP 12 State	V_y	V_B	$V_{1k\Omega}$	I_B	V_{CE}	$V_{300\Omega}$ Collector	I_C
Bright							
Dark							

9. When V_{CE} is near 0 V, the transistor is said to be saturated. Determine the saturated current gain of the transistor, I_C / I_B .

Part 2: The Transistor Amplifier (Common Emitter)

1. Construct the circuit in Fig. 5.3, first on breadboard and then on stripboard.

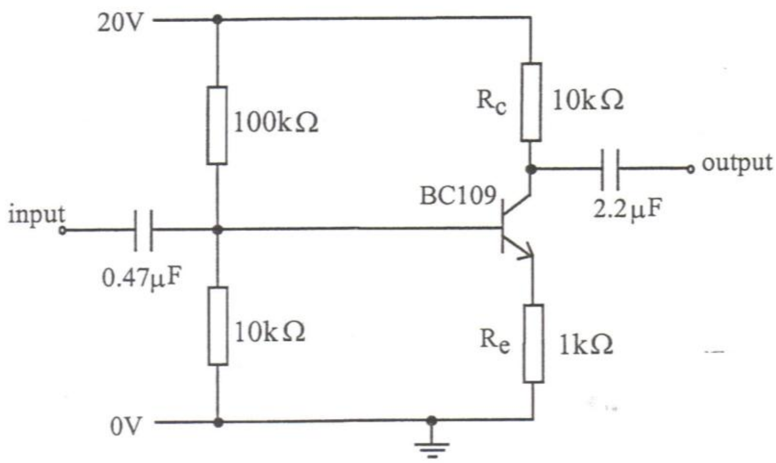


Fig. 5.3: Circuit diagram.

2. Inject signals (to input) at 500 mV for the following frequencies: 50 Hz, 100 Hz, 200 Hz, 500 Hz, 1 kHz, 2 kHz, 5 kHz, 10 kHz, 20 kHz, 50 kHz, 100 kHz, 120 kHz, 150 kHz, 200 kHz, 300 kHz, 400 kHz, 500 kHz, 600 kHz, 700 kHz, 800 kHz. Display the input and output simultaneously on the dual trace oscilloscope. Measure the input and output signal amplitudes in each case and calculate the gain.

3. Note the 180° phase change between the input and output signals.

4. Plot the gain of the amplifier versus $\log_{10}$ (frequency).

5. Estimate the gain of the amplifier and check that it is equal to R_c / R_e .

6. Estimate the bandwidth of the amplifier.

7. Calculate the DC voltage at the transistor base. Check your calculation by comparing it with the measured value.

8. Estimate the quiescent currents of the amplifier. This is achieved by measuring the voltages across each resistor and calculating the currents i.e. I_B, I_{B1}, I_{B2}, I_C and I_E. Also V_{CE} can be calculated.