ENGINEERING LAB II
ECE 1201
ELECTRONICS LAB MANUAL

SEMESTER ________
YEARS __________

NAME:

MATRIC NO:
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DRESS CODES AND ETHICS

24:31 And say to the believing women that they should lower their gaze and guard their modesty; that they should not display their beauty and ornaments except what (must ordinarily) appear thereof; that they should draw their veils over their bosoms and not display their beauty except to their husbands, their fathers, their husband's fathers, their sons, their husbands' sons, their brothers or their brothers' sons, or their sisters' sons, or their women, or the slaves whom their right hands possess, or male servants free of physical needs, or small children who have no sense of the shame of sex; and that they should not strike their feet in order to draw attention to their hidden ornaments. And O ye Believers! turn ye all together towards Allah, that ye may attain Bliss.

SAFETY

Safety in the electrical laboratory, as everywhere else, is a matter of the knowledge of potential hazards, following safety precautions, and common sense. Observing safety precautions is important due to pronounced hazards in any electrical/computer engineering laboratory. Death is usually certain when 0.1 ampere or more flows through the head or upper thorax and have been fatal to persons with coronary conditions. The current depends on body resistance, the resistance between body and ground, and the voltage source. If the skin is wet, the heart is weak, the body contact with ground is large and direct, then 40 volts could be fatal. Therefore, never take a chance on "low" voltage. When working in a laboratory, injuries such as burns, broken bones, sprains, or damage to eyes are possible and precautions must be taken to avoid these as well as the much less common fatal electrical shock. Make sure that you have handy emergency phone numbers to call for assistance if necessary. If any safety questions arise, consult the lab demonstrator or technical assistant/technician for guidance and instructions. Observing proper safety precautions is important when working in the laboratory to prevent harm to yourself or others. The most common hazard is the electric shock which can be fatal if one is not careful.

Acquaint yourself with the location of the following safety items within the lab.

a. fire extinguisher
b. first aid kit
c. telephone and emergency numbers

<table>
<thead>
<tr>
<th>ECE Department</th>
<th>03-6196 4530</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kulliyyah of Engineering Deputy</td>
<td>03-6196 4410</td>
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<tr>
<td>IIUM Security</td>
<td>03-6196 5555</td>
</tr>
<tr>
<td>IIUM Clinic</td>
<td>03-6196 4444</td>
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</tbody>
</table>

Electric shock

Shock is caused by passing an electric current through the human body. The severity depends mainly on the amount of current and is less function of the applied voltage. The threshold of electric shock is about 1 mA which usually gives an unpleasant tingling. For currents above 10 mA, severe muscle pain occurs and the victim can't let go of the conductor due to muscle spasm. Current between 100 mA and 200 mA (50 Hz AC) causes ventricular fibrillation of the heart and is most likely to be lethal.
What is the voltage required for a fatal current to flow? This depends on the skin resistance. Wet skin can have a resistance as low as 150 Ohm and dry skin may have a resistance of 15 kOhm. Arms and legs have a resistance of about 100 Ohm and the trunk 200 Ohm. This implies that 240 V can cause about 500 mA to flow in the body if the skin is wet and thus be fatal. In addition skin resistance falls quickly at the point of contact, so it is important to break the contact as quickly as possible to prevent the current from rising to lethal levels.

**Equipment grounding**

Grounding is very important. Improper grounding can be the source of errors, noise and a lot of trouble. Here we will focus on equipment grounding as a protection against electrical shocks. Electric instruments and appliances have equipments casings that are electrically insulated from the wires that carry the power. The isolation is provided by the insulation of the wires as shown in the figure a below. However, if the wire insulation gets damaged and makes contact to the casing, the casing will be at the high voltage supplied by the wires. If the user touches the instrument he or she will feel the high voltage. If, while standing on a wet floor, a user simultaneously comes in contact with the instrument case and a pipe or faucet connected to ground, a sizable current can flow through him or her, as shown in Figure b. However, if the case is connected to the ground by use of a third (ground) wire, the current will flow from the hot wire directly to the ground and bypass the user as illustrated in figure c.

Equipments with a three wire cord is thus much safer to use. The ground wire (3rd wire) which is connected to metal case, is also connected to the earth ground (usually a pipe or bar in the ground) through the wall plug outlet.
Always observe the following safety precautions when working in the laboratory:

1. Do not work alone while working with high voltages or on energized electrical equipment or electrically operated machinery like a drill.

2. Power must be switched off whenever an experiment or project is being assembled, disassembled, or modified. **Discharge any high voltage points to grounds with a well insulated jumper. Remember that capacitors can store dangerous quantities of energy.**

3. Make measurements on live circuits or discharge capacitors with well insulated probes keeping one hand behind your back or in your pocket. Do not allow any part of your body to contact any part of the circuit or equipment connected to the circuit.

4. After switching power off, discharge any capacitors that were in the circuit. Do not trust supposedly discharged capacitors. Certain types of capacitors can build up a residual charge after being discharged. Use a shorting bar across the capacitor, and keep it connected until ready for use. If you use electrolytic capacitors, do not:
   - put excessive voltage across them
   - put ac across them
   - connect them in reverse polarity

5. Take extreme care when using tools that can cause short circuits if accidental contact is made to other circuit elements. Only tools with insulated handles should be used.

6. If a person comes in contact with a high voltage, immediately shut off power. Do not attempt to remove a person in contact with a high voltage unless you are insulated from them. If the victim is not breathing, apply CPR immediately continuing until he/she is revived, and have someone dial emergency numbers for assistance.

7. Check wire current carrying capacity if you will be using high currents. Also make sure your leads are rated to withstand the voltages you are using. This includes instrument leads.

8. Avoid simultaneous touching of any metal chassis used as an enclosure for your circuits and any pipes in the laboratory that may make contact with the earth, such as a water pipe. Use a floating voltmeter to measure the voltage from ground to the chassis to see if a hazardous potential difference exists.

9. Make sure that the lab instruments are at ground potential by using the ground terminal supplied on the instrument. Never handle wet, damp, or ungrounded electrical equipment.

10. Never touch electrical equipment while standing on a damp or metal floor.

11. Wearing a ring or watch can be hazardous in an electrical lab since such items make good electrodes for the human body.

12. When using rotating machinery, place neckties or necklaces inside your shirt or, better yet, remove them.
13. Never open field circuits of D-C motors because the resulting dangerously high speeds may cause a "mechanical explosion".

14. Keep your eyes away from arcing points. High intensity arcs may seriously impair your vision or a shower of molten copper may cause permanent eye injury.

15. Never operate the black circuit breakers on the main and branch circuit panels.

16. **In an emergency all power in the laboratory can be switched off by depressing the large red button on the main breaker panel. Locate it. It is to be used for emergencies only.**

17. **Chairs and stools should be kept under benches when not in use. Sit upright on chairs or stools keeping the feet on the floor. Be alert for wet floors near the stools.**

18. Horseplay, running, or practical jokes must not occur in the laboratory.

19. **Never use water on an electrical fire. If possible switch power off, then use CO₂ or a dry type fire extinguisher. Locate extinguishers and read operating instructions before an emergency occurs.**

20. Never plunge for a falling part of a live circuit such as leads or measuring equipment.

21. Never touch even one wire of a circuit; it may be hot.

22. Avoid heat dissipating surfaces of high wattage resistors and loads because they can cause severe burns.

23. Keep clear of rotating machinery.

Precautionary Steps Before Starting an Experiment so as Not to Waste Time Allocated

a) Read materials related to experiment before hand as preparation for pre-lab quiz and experimental calculation.

b) Make sure that apparatus to be used are in good condition. Seek help from technicians or the lab demonstrator in charge should any problem arises.
   - Power supply is working properly ie \( I_{\text{max}} \) (maximum current) LED indicator is disable. Maximum current will retard the dial movement and eventually damage the equipment. Two factors that will light up the LED indicator are short circuit and insufficient supply of current by the equipment itself. To monitor and maintain a constant power supply, the equipment must be connected to circuit during voltage measurement. DMM are not to be used simultaneously with oscilloscope to avert wrong results.
   - Digital multimeter (DMM) with low battery indicated is not to be used. By proper connection, check fuses functionality (especially important for current measurement). Comprehend the use of DMM for various functions. Verify
measurements obtained with theoretical values calculated as it is quite often where 2 decimal point reading and 3 decimal point reading are very much deviated.

- The functionality of voltage waveform generators are to be understood. Make sure that frequency desired is displayed by selecting appropriate multiplier knob. Improper settings (ie selected knob is not set at minimum (in direction of CAL – calibrate) at the bottom of knob) might result in misleading values and hence incorrect results. Avoid connecting oscilloscope together with DMM as this will lead to erroneous result.

- Make sure both analog and digital oscilloscopes are properly calibrated by positioning sweep variables for VOLT / DIV in direction of CAL. Calibration can also be achieved by stand alone operation where coaxial cable connects CH1 to bottom left hand terminal of oscilloscope. This procedure also verifies coaxial cable continuity.

c) Internal circuitry configuration of breadboard or Vero board should be at students’ fingertips (ie holes are connected horizontally not vertically for the main part with engravings disconnecting in-line holes).

d) Students should be rest assured that measured values (theoretical values) of discrete components retrieved ie resistor, capacitor and inductor are in accordance the required ones.

e) Continuity check of connector or wire using DMM should be performed prior to proceeding an experiment. Minimize wires usage to avert mistakes.

f) It is unethical and unislamic for students to falsify results as to make them appear exactly consistent with theoretical calculations.
1. Basic Guidelines

All experiments in this manual have been tried and proven and should give you little trouble in normal laboratory circumstances. However, a few guidelines will help you conduct the experiments quickly and successfully.

1. Each experiment has been written so that you follow a structured logical sequence meant to lead you to a specific set of conclusions. Be sure to follow the procedural steps in the order which they are written.
2. Read the entire experiment and research any required theory beforehand. Many times an experiment takes longer that one class period simply because a student is not well prepared.
3. Once the circuit is connected, if it appears “dead” spend few moments checking for obvious faults. Some common simple errors are: power not applied, switch off, faulty components, lose connection, etc. Generally the problems are with the operator and not the equipment.
4. When making measurements, check for their sensibility.
5. It’s unethical to “fiddle” or alter your results to make them appear exactly consistent with theoretical calculations.

2. Lab Instructions

1. Each student group consists of a maximum of two students. Each group is responsible in submitting 1 lab report upon completion of each experiment.
2. Students are to wear proper attire i.e shoe or sandal instead of slipper. Excessive jewelleries are not advisable as they might cause electrical shock.
3. Personal belongings i.e bags, etc are to be put at the racks provided. Student groups are required to wire up their circuits in accordance with the diagram given in each experiment.
4. A permanent record in ink of observations as well as results should be maintained by each student and enclosed with the report.
5. The recorded data and observations from the lab manual need to be approved and signed by the lab instructor upon completion of each experiment.
6. Before beginning connecting up, it is essential to check that all sources of supply at the bench are switched off.
7. Start connecting up the experiment circuit by wiring up the main circuit path, then add the parallel branches as indicated in the circuit diagram.
8. After the circuit has been connected correctly, remove all unused leads from the experiment area, set the voltage supplies at the minimum value, and check the meters are set for the intended mode of operation.
9. The students may ask the lab instructor to check the correctness of their circuit before switching on.
10. When the experiment has been satisfactorily completed and the results approved by the instructor, the students may disconnect the circuit and return the components and instruments to the locker tidily. Chairs are to be slid in properly.

3. Grading
The work in the Electronics related lab carries 50% of total marks for the ECE 1201 subject (ENGINEERING LAB II). The distribution of marks for Electronics Lab is as follows:

<table>
<thead>
<tr>
<th>Evaluation Items</th>
<th>Marks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lab Report &amp; Prelab</td>
<td>70%</td>
</tr>
<tr>
<td>Quiz &amp; Final Test</td>
<td>30%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

Note: Final mark distribution

- Pre-Lab = 10 %
- Quiz = 15 %
- Final Test = 15 %
- Lab Report = 60%

4. Lab Reports

a. Report format and Evaluation:
The following format should be adhered to by the students in all their laboratory reports:

<table>
<thead>
<tr>
<th>No.</th>
<th>Evaluation Items</th>
<th>Marks 20%</th>
<th>Marks obtain</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Objectives</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Brief Theory</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Equipment list</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Experiment Set-up</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Results/Observations</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>PSPICE</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Discussion and Conclusion</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>TOTAL</strong></td>
<td><strong>20</strong></td>
<td></td>
</tr>
</tbody>
</table>
Evaluation Criteria

<table>
<thead>
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<td>15</td>
<td>16.5</td>
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<tr>
<td>17</td>
<td>20</td>
</tr>
</tbody>
</table>

Of those listed above each section included in a report should be clearly nominated with the appropriate heading. The information to be given in each section is set out below:

(i) **Objective**
This should state clearly the objective of the experiment. It may be the verification of law, a theory or the observation of particular phenomena. Writing out the objective of the experiment is important to the student as it emphasizes the purpose for which the experiment is conducted.

(ii) **Brief Theory**
In this section, the related theory of the experiment must be discussed briefly. This section is important to assist student in making conclusion by comparing the experimental results to the theory.

(iii) **Results**
All experimental results which have been approved by the lab instructor (including graphs) must be attached in the report.

(iv) **PSPICE**
PSPICE output (as instructed in the lab manual) must be attached in the report to show the comparison of simulation results and experimental results.

(vi) **Discussion & Conclusion**
Once the analysis of the results is complete, the student must forms some deductions on the results of his analysis. Usually this involves deducing whether the final results show that the aim of the experiment has been achieved or not, and if they verify some law or theory presented to the student during the lectures. **Comments and comparison asked in the lab manual must be discussed in this section.** In making a decision on the former point, the student should reread the aim; and on the latter, the text book should be referred to, to ascertain whether there is theoretical agreement or not.
The student should give considerable thought to the material that he intends to submit in this section. It is here that he is able to express his own ideas on the experiment results and how they were obtained. It is the best indication to his teacher of whether he has understood the experiment and of how well he has been able to analyze the results and make deductions from them.

It is recommended that the conclusion should be taken up by the student’s clear and concise explanation of his reasoning, based on the experimental results, that led to the deductions from which he was able to make the two statements with which he began the conclusion.

It is very rare for an experiment to have results which are entirely without some discrepancy. The student should explain what factors, in his opinion, may be the possible causes of these discrepancies. Similarly, results of an unexpected nature should form the basis for a discussion of their possible nature and cause. The student should not be reluctant to give his opinions even though they may not be correct. He should regard his discussion as an opportunity to demonstrate his reasoning ability.

Should the results obtained be incompatible with the aim or with the theory underlying the experiment, then an acceptable report may be written suggesting reasons for the unsatisfactory results. It is expected that the student should make some suggestions as to how similar erroneous results for this experiment might be avoided in the future. The student must not form the opinion that an unsatisfactory set of results makes a report unacceptable.

b. Presentation of Lab Reports:

All students are required to present their reports in accordance with the following instructions.

(i) Reports have to be handwritten for submission.

(ii) Writing should appear on one side of each sheet only.

(iii) The students’ name & matric number, section number, lab session and the lecturer’s name must be printed in block letters at the top left-hand corner of the first sheet of the report. This must be followed in the middle of the sheet by:
   - The course code
   - The experiment number
   - The title of the experiment
   - The date on which the student carried out the experiment.

(iv) All sections such as objective, brief theory and so on, should be titled on the left hand side of the working space of the page.
(v) Each type of calculation pertaining to the experiment should be preceded by a brief statement indicating its objective.

(vi) All graphs are to be drawn on graph paper in blue or black ink. Other colors may be used for identification. The abscissa and ordinate are to be drawn in all times and scaled with the value clearly indicated at each major division. The quantity at each axis represents and the unit in which it is calibrated should be clearly indicated. Each graph is to be titled so as to indicate clearly what it represents.

(vii) The report submitted by each student should contain a conclusion and discussion of more than 300 words.

(viii) The cover of the report must be as follows:
REPORTS ON

ECE 1201: ENGINEERING LAB - II

“EXPERIMENT NO. :”
“TITLE OF THE EXPERIMENT”

<table>
<thead>
<tr>
<th>No.</th>
<th>Evaluation Items</th>
<th>Marks 20%</th>
<th>Marks obtain</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Objectives</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Brief Theory</td>
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<td></td>
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<td>3</td>
<td>Equipment list</td>
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<td>6</td>
<td>PSPICE</td>
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<tr>
<td>6</td>
<td>Discussion and Conclusion</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
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</tr>
</tbody>
</table>

Date of Experiment: ________________  Date of Submission: ________________

Group No. :

Matric No: ________  Name: __________________________________________
Matric No: ________  Name: __________________________________________
Matric No: ________  Name: __________________________________________
5. Schedule & Experiment No. (Title)

<table>
<thead>
<tr>
<th>Tentative Week</th>
<th>Experiment No. (Title)</th>
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<tbody>
<tr>
<td>1</td>
<td>Introductory class</td>
</tr>
<tr>
<td>2 &amp; 3</td>
<td>Experiment No. 1 &amp; 2 (Diode Characteristics &amp; Zener Diode Characteristics)</td>
</tr>
<tr>
<td>4 &amp; 5</td>
<td>Experiment No. 3 (Wave Rectifier &amp; Clipper Circuit)</td>
</tr>
<tr>
<td>6</td>
<td>Experiment No. 4 (BJT Characteristics &amp; Common-Emitter Transistor Amplifier)</td>
</tr>
<tr>
<td>7</td>
<td>Experiment No. 5 (BJT Biasing Circuits)</td>
</tr>
<tr>
<td>8</td>
<td>Experiment No. 6 (JFET Characteristics &amp; Common Source Amplifier)</td>
</tr>
<tr>
<td>9 &amp; 10</td>
<td>Experiment No. 7 (FET Biasing Circuits)</td>
</tr>
<tr>
<td>11</td>
<td>Experiment no. 8 (Inverting and Non-Inverting OP Amp)</td>
</tr>
<tr>
<td>12 &amp; 13</td>
<td>Experiment no. 9 (Summing, Subtracting, Integrator and Differentiating OP Amps)</td>
</tr>
</tbody>
</table>

All lab report should be submitted **upon starting the lab session** of the following week to the lecturer/demonstrators on duty for your section. Late submission of the lab report will not be entertained and will be given **Nil** for the report. Strictly **no make up lab due to absenteeism is allowed** without sound reason.
Objective:

- To study the characteristics of silicon and germanium diodes.

Equipment:

**Instruments**
- DC power supply
- Function Generator
- Digital Multimeter (DMM)

**Components**
- Diodes: Silicon (D1N4002), Germanium (D1N4148)
- Resistors: 1kΩ, 1MΩ

Procedure:

Part A: Forward-bias Diode Characteristics

1. Construct the circuit of Fig. 1.1 with the supply (E) is set at 0 V. Record the measured value of the resistor.

   ![Circuit Diagram](image)

   *Fig. 1.1*

2. Increase the supply voltage until $V_D$ reads 0.1 V. Then measure current $I_D$ and record the results in Table 1.1.
3. Repeat step 2 for the remaining settings of $V_D$ shown in the Table 1.1.
4. Replace the silicon diode by a germanium diode and complete Table 1.2.
5. Plot on a graph paper $I_D$ versus $V_D$ for the silicon and germanium diodes. Complete the curves by extending the lower region of each curve to the intersection of the axis at $I_D=0$ mA and $V_D=0$ V.
6. How the two curves differ? What are their similarities?
Part B : Reverse-bias Diode Characteristics

1. Construct the circuit of *Fig. 1.2* with E is set at 20V. Record the measured value of the resistor.

![Circuit Diagram]

*Fig. 1.2*

2. Measure the voltage $V_D$. Measure the reverse saturation current, $I_s$.
3. Repeat the above step for germanium diode.
4. How do the results of Step 2 compare to Step 3? What are the similarities?

**PSPICE Instructions:**

1. Construct the circuit in *Fig. 1.1* using PSPICE.
2. From PSPICE simulation, obtain the forward bias characteristics for both Silicon and Germanium diodes.
Results and Calculations:

Part A (Forward Bias)

1. \( R \) (measured) = __________

2. \( I_D \) (measured). Fill in Table 1.1 and Table 1.2

<table>
<thead>
<tr>
<th>( V_D ) (V)</th>
<th>0.1</th>
<th>0.2</th>
<th>0.3</th>
<th>0.4</th>
<th>0.5</th>
<th>0.6</th>
<th>0.7</th>
<th>0.75</th>
</tr>
</thead>
<tbody>
<tr>
<td>( I_D ) (mA)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1.1 (Silicon Diode)

<table>
<thead>
<tr>
<th>( V_D ) (V)</th>
<th>0.1</th>
<th>0.2</th>
<th>0.3</th>
<th>0.4</th>
<th>0.5</th>
<th>0.6</th>
<th>0.7</th>
<th>0.75</th>
</tr>
</thead>
<tbody>
<tr>
<td>( I_D ) (mA)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1.2 (Germanium Diode)

Part B (Reverse Bias)

1. \( R \) (measured) = __________

2. **Silicon Diode**

   \( V_D \) (measured) = __________

   \( I_S \) (measured) = __________

3. **Germanium Diode**

   \( V_D \) (measured) = __________

   \( I_S \) (measured) = __________
Objectives:

- To study the characteristics of Zener diode.
- To study the voltage regulation in Zener diode regulation circuit.

Equipment:

**Instruments**
- DC power supply
- Digital Multimeter (DMM)

**Components**
- Diode: Zener (10-V)
- Resistors: 0.1kΩ, 1kΩ (2 pcs), 3.3kΩ

Procedure:

**Part A: Zener Diode Characteristics**

1. Construct the circuit of Fig. 2.1. Set the DC supply to 0 V and record the measured value of R.

![Fig. 2.1](image)

2. Set the DC supply (E) to the values appearing in Table 2.1 and measure both $V_Z$ and $V_R$. Calculate the Zener current, $I_Z$ using the Ohm’s law given in the table and complete the table.

3. Plot $I_Z$ versus $V_Z$ using the data in Table 2.1 on a graph paper.
Part B : Zener Diode Regulation

1. Construct the circuit of Fig. 2.2. Record the measured value of each resistor.


3. Change $R_L$ to 3.3 kΩ and repeat Step 2.

4. Comment on the results obtained in Steps 2 and 3.

**PSPICE Instructions:**

1. Construct the circuit in Fig. 2.2 using PSPICE.

2. Find the values of $V_L$, $V_R$, $I_Z$, $I_L$ and $I_R$ when $R_L$ = 1 kΩ.

3. Change $R_L$ to 3.3 kΩ, find the same values as Step 2.
Results and Calculations:

Part A

1. R (measured) = __________

2.

<table>
<thead>
<tr>
<th>E (V)</th>
<th>0</th>
<th>1</th>
<th>3</th>
<th>5</th>
<th>7</th>
<th>9</th>
<th>11</th>
<th>13</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>V_Z (V)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V_R (V)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I_Z = V_R / R_{meas} (mA)</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
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<td></td>
</tr>
</tbody>
</table>

Table 2.1

Part B

1. R (measured) = __________, R_L (measured) = __________

2. V_R (measured) = __________, V_L (measured) = __________

   I_R = V_R / R = __________, I_L = V_L / R_L = __________.

   I_Z = I_R - I_L = __________

3. Change R_L to 3.3kΩ;

   R_L (measured) = __________,
   V_R (measured) = __________, V_L (measured) = __________

   I_R = V_R / R = __________, I_L = V_L / R_L = __________.

   I_Z = I_R - I_L = __________
Objectives:

- To calculate and draw the DC output voltages of half-wave and full-wave rectifiers.
- To calculate and measure the output voltages of clipper circuits.

Equipment:

**Instruments**
- DC power supply
- AC power supply - (Model: PSU-3097, 12VAC ~0~ 12VAC).
- Digital Multimeter (DMM)
- Function Generator
- Oscilloscope

**Components**
- Diode: Silicon (D1N4002)
- Resistors: 2.2kΩ, 3.3kΩ

Procedure:

**Part A: Half Wave Rectification**

1. Construct the circuit of *Fig. 3.1*. Set the supply to 9 V p-p sinusoidal wave with the frequency of 1000 Hz. Put the oscilloscope probes at function generator and sketch the input waveform obtained.
2. Put the oscilloscope probes across the resistor and sketch the output waveform obtained. Measure and record the DC level of the output voltage using the DMM.
3. Reverse the diode of circuit of *Fig. 3.1*. Sketch the output waveform across the resistor. Measure and record the DC level of the output voltage.
4. Comment on the results obtained from step 2 and 3.
Part B: Full-Wave Rectification

1. Construct the circuit of Fig. 3.2 with 12VAC, AC Power Supply. (Model: PSU-3097, 12VAC ~0~ 12VAC).

2. Put the oscilloscope probes across the resistor and sketch the output waveform obtained. Measure and record the DC level of the output voltage using the DMM.

3. Replace diodes D_3 and D_4 of circuit of Fig. 3.2 by 2.2 kΩ. Draw the output waveform across the resistor. Measure and record the DC level of the output voltage.

4. What is the major effect of replacing the two diodes (D_3 and D_4) with resistors?

Part C: Parallel Clippers

1. Construct the circuit in Fig. 3.3. The input signal is an 8 V p-p square wave at frequency of 1000 Hz. Record the measured resistance value.

2. Set the oscilloscope in DC mode.

3. Put the oscilloscope probes at function generator and sketch the input waveform obtained.

4. Sketch the output waveform obtained from the oscilloscope.

5. Reverse the battery of the circuit and sketch the output waveform.

6. How do the waveforms differ? What is the function of the battery in the circuit?

7. Change the input signal of the circuit of Fig. 3.3 to an 8 V p-p sinusoidal signal with the same frequency of 1000 Hz. Repeat step 3 and 4 for this circuit.
Part D: Series Clippers

1. Construct the circuit in Fig. 3.4. The input signal is an 8 V p-p square wave at frequency of 1000 Hz. Record the measured resistance value.
2. Set the oscilloscope in DC mode.
3. Put the oscilloscope probes at function generator and sketch the input waveform obtained.

4. Sketch the output waveform obtained from the oscilloscope.
5. Reverse the battery of the circuit and sketch the output waveform.
6. Change the input signal of the circuit of Fig. 3.4 to an 8 V p-p sinusoidal signal with the same frequency of 1000 Hz. Repeat step 3 and 4 for this circuit.
7. How does the series clipper differ from the parallel clipper?

PSPICE Instructions:

Get the expected output waveform for circuits in Fig. 3.1 (Part A) & Fig. 3.3 (Part C) using PSPICE Simulation.
Results and Calculations:

Part A

1. Input waveform, $V_i$:

2. Output waveform, $V_o$:

   DC level of $V_o$ (measured) = __________

Part A (reversed diode)

3. Output waveform, $V_o$:

   DC level of $V_o$ (measured) = __________
Part B

1. Input waveform, $V_i$:

2. Output waveform, $V_o$:

   DC level of $V_o$ (measured) = __________

Part B (diodes replaced with resistors)

3. Output waveform, $V_o$:

   DC level of $V_o$ (measured) = __________
Part C \((v_{\text{in}} \text{ square-wave})\)

1. \(R \) (measured) = _______________

2. Input waveform :

3. Output waveform :

Part C \((v_{\text{in}} \text{ square-wave, battery reversed})\)

4. Output waveform :
Part C (v_{in} sine-wave)

5. Input waveform:

![Input waveform diagram]

6. Output waveform:

![Output waveform diagram]

Part C (v_{in} sine-wave, battery reversed)

7. Output waveform:

![Output waveform diagram]
Part D (\(v_{\text{in}}\) square-wave)

1. \(R\) (measured) = ______________

2. Input waveform:

![Input waveform graph]

3. Output waveform:

![Output waveform graph]

Part D (\(v_{\text{in}}\) square-wave, battery reversed)

4. Output waveform:

![Output waveform graph]
Part D (v\textsubscript{in} sine-wave)

5. Input waveform:

\[ \text{Part D (v\textsubscript{in} sine-wave, battery reversed)} \]

6. Output waveform:

\[ \text{Part D (v\textsubscript{in} sine-wave, battery reversed)} \]

7. Output waveform:
Objectives:

- To graph the collector characteristics of a transistor using experimental methods.
- To measure AC and DC voltages in a common-emitter amplifier.

Equipment:

Instruments
1 DC Power Supply
3 Digital Multimeter (DMM)
1 Function Generator
1 Oscilloscope

Components

Resistors: 1 kΩ, 3 kΩ, 10 kΩ, 33 kΩ, 330 kΩ, 10 kΩ potentiometer, 1MΩ potentiometer
Transistors: 2N3904

Procedure:

Part A: The Collector Characteristics (BJT)

1. Construct the circuit of Fig. 4.1. Vary the 1MΩ potentiometer to set $I_B = 10 \ \mu A$ as in Table 4.1.

2. Set the $V_{CE}$ to 2V by varying the 10kΩ potentiometer as required by the first line of Table 4.1.
3. Record the $V_{RC}$ and $V_{BE}$ values in Table 4.1.
4. Vary the 10 kΩ potentiometer to increase \( V_{CE} \) from 2V to the values appearing in Table 4.1. (Note: \( I_B \) should be maintained at 10 \( \mu \)A for the range of \( V_{CE} \) levels.)

5. Record \( V_{RC} \) and \( V_{BE} \) values for each of the measured \( V_{CE} \) values. Use the mV range for \( V_{BE} \).

6. Repeat step 2 through 5 for all values of \( I_B \) indicated in Table 4.1.

7. Compute the values of \( I_C \) (from \( I_C = \frac{V_{RC}}{R_C} \)) and \( I_E \) (from \( I_E = I_B + I_C \)). Use measured resistor value for \( R_C \).

8. Using the data of Table 4.1, plot the collector characteristics of the transistor on a graph paper. (Plot \( I_C \) versus \( V_{CE} \) for the various values of \( I_B \). Choose an appropriate scale for \( I_C \) and label each \( I_B \) curve).

Part B : Common-Emitter DC Bias

1. Measure all resistor values (\( R_1, R_2, R_C \) and \( R_E \)) from circuit in Fig. 4.2 using DMM.

2. Calculate DC Bias values (\( V_B, V_E, V_C \) and \( I_E \)) and record them.

3. Calculate AC dynamic resistance, \( r_e \).

4. Construct circuit as of Fig. 4.2 and set \( V_{CC} = 10 \) V.

5. Measure the DC bias values (\( V_B, V_E, V_C \) and \( I_E \)) and record them.

6. Calculate \( I_E \) using values obtained in Step 5.

7. Calculate \( r_e \) using the value of \( I_E \) from Step 6.

8. Compare value of \( r_e \) obtained both from Step 3 & 7.

**Fig. 4.2**

**PSPICE Instructions:**

Using PSPICE Simulation, find the DC Bias values (\( V_B, V_E, V_C \) and \( I_E \)) for the circuit in Fig. 4.2. Compare the values obtained from PSPICE with the experimental ones.
Results and Calculations:

Part A

3.

<table>
<thead>
<tr>
<th>$I_B$</th>
<th>$V_{CE}$</th>
<th>$V_{RC}$</th>
<th>$I_C$</th>
<th>$V_{BE}$</th>
<th>$I_E$</th>
</tr>
</thead>
<tbody>
<tr>
<td>(µA)</td>
<td>(V) meas</td>
<td>(V) meas</td>
<td>(mA)</td>
<td>(V) meas</td>
<td>(mA)</td>
</tr>
<tr>
<td>2</td>
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<tr>
<td>4</td>
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<td>10</td>
<td>6</td>
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<tr>
<td>2</td>
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<tr>
<td>4</td>
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<tr>
<td>30</td>
<td>6</td>
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<tr>
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<tr>
<td>2</td>
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<tr>
<td>50</td>
<td>4</td>
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<tr>
<td>6</td>
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<tr>
<td>8</td>
<td></td>
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</tr>
</tbody>
</table>

Table 4.1

Part B

1. $R_1$ (measured) = __________, $R_2$ (measured) = __________,
   $R_C$ (measured) = __________, $R_E$ (measured) = __________

2. $V_B$ (calculated) = __________, $V_E$ (calculated) = __________
   $V_C$ (calculated) = __________, $I_E$ (calculated) = __________

3. $r_e$ (calculated) = __________
   
   $r_e = \frac{26 (mV)}{I_E (mA)}$

5. $V_B$ (measured) = __________, $V_E$ (measured) = __________
   $V_C$ (measured) = __________.
6. \( I_E \) (calculated) using measured values of \( V_E \) and \( R_E = \) __________
\[
I_E = \frac{V_E}{R_E}
\]

7. \( r_e \) (measured) = __________, using \( I_E \) from Step 6.

8. Graph \( I_C \) versus \( V_{CE} \) for each value of \( I_B \) (use graph paper).
Objectives:

To determine the quiescent operating conditions of the fixed- and voltage-divider-bias BJT configurations.

Equipment:

**Instruments**
1 DC Power Supply
3 Digital Multimeter (DMM)

**Components**
Resistors: 680 Ω, 1.8 kΩ, 2.7 kΩ, 6.8 kΩ, 33 kΩ, 1 MΩ
Transistors: 2N3904, 2N4401

Procedure:

**Part A: Fixed-Bias Configuration**

1. Measure all resistor values ($R_B$ and $R_C$) from circuit in *Fig. 5.1* using DMM. Record them.
2. Construct circuit as of *Fig. 5.1* using 2N3904 transistor and set $V_{CC} = 20$ V.
3. Measure the voltages $V_{BE}$ and $V_{RC}$. Record them.
4. Calculate the resulting base current, $I_B$ and collector current, $I_C$. Using the values obtained, find $β$.
5. Using the values obtained in Step 4, calculate the values of $V_B$, $V_C$, $V_E$ and $V_{CE}$.
6. Energize the network in *Fig. 5.1*, measure $V_B$, $V_C$, $V_E$ and $V_{CE}$.
7. How do the measured values (Step 6) compare to the calculated values (Step 5)?
8. Simply remove the 2N3904 transistor and replace with 2N4401 transistor.
9. Then, measure the voltages $V_{BE}$ and $V_{RC}$. Using the same equations, calculate the values of $I_B$ and $I_C$. From the values obtained, determine the $β$ value for 2N4401 transistor.
10. Compile all the data needed for both transistors in Table 5.1.

---

**Fig. 5.1**
11. Calculate the magnitude (ignore the sign) of the percent change in each quantity due to a change in transistors.
12. Place the results of your calculations in Table 5.2.

Part B: Voltage-Divider-Bias Configuration

1. Measure all resistor values \( (R_1, R_2, R_B \text{ and } R_C) \) from circuit in Fig. 5.2 using DMM. Record them.
2. Using the \( \beta \) determined for 2N3904 transistor in Part B, calculate the theoretical values of \( V_B, V_E, I_C, V_C, V_{CE} \) and \( I_B \) for the network shown in Fig. 5.2. Record them in Table 5.3.
3. Construct the network of Fig. 5.2 and measure \( V_B, V_E, V_C \) and \( V_{CE} \). Record them in Table 5.3.

![Fig. 5.2]

4. Measure the voltages \( V_{R1} \) and \( V_{R2} \) (take readings to the hundredth or thousandth place). Calculate the currents \( I_E \) and \( I_C \) and the currents \( I_1 \) and \( I_2 \). Using Kirchoff’s current law, calculate the current \( I_B \). Record \( I_E, I_C \) and \( I_B \) values in Table 5.3.
5. How do the calculated and measured values of Table 5.3 compare?
6. Compile the measured values of \( V_{CE} \) (Step 3), \( I_C \) and \( I_B \) (Step 4) along with the magnitude of \( \beta \) in Table 5.4.
7. Simply remove the 2N3904 transistor and replace with 2N4401 transistor.
8. Then, measure the voltages \( V_{CE} \), Also, measure the voltages \( V_{R1} \) and \( V_{R2} \) (take readings to the hundredth or thousandth place). Calculate the current \( I_C \) and the currents \( I_1 \) and \( I_2 \). Using Kirchoff’s current law, calculate the current \( I_B \).
9. Complete Table 5.4 with the values of \( V_{CE}, I_C, I_B \) and \( \beta \).
10. Calculate the magnitude (ignore the sign) of the percent change in each quantity due to a change in transistors.
11. Place the results of your calculations in Table 5.5.

**PSPICE Instructions:**

Using PSPICE Simulation, find the values of \( V_B, V_E, V_C, V_{CE}, I_C, I_B \) and \( I_E \) for the circuit in Fig. 5.2. Compare the values obtained from PSPICE with the experimental ones.
Results and Calculations:

Part A

1. $R_B$ (measured) = _____________, $R_C$ (measured) = _____________

3. $V_{BE}$ (measured) = _____________, $V_{RC}$ (measured) = _____________

4. $I_B$ = ________________, $I_C$ = ________________, $\beta$ = _____________

\[ I_B = \frac{V_{RB}}{R_B} = \frac{V_{CC} - V_{BE}}{R_B} = \]

\[ I_C = \frac{V_{RC}}{R_C} = \]

\[ \beta = \frac{I_C}{I_B} = \]

5. $V_B$ (calculated) = ______________, $V_C$ (calculated) = ______________

$V_E$ (calculated) = ______________, $V_{CE}$ (calculated) = ______________

Show your works!

6. $V_B$ (measured) = ______________, $V_C$ (measured) = ______________

$V_E$ (measured) = ______________, $V_{CE}$ (measured) = ______________

7. Comparison of results from Step 5 & Step 6 :
9. \( V_{BE} \) (measured) = ______________, \( V_{RC} \) (measured) = ______________

\( I_B = \) ________________, \( I_C = \) ________________, \( \beta = \) ____________

\[ I_B = \frac{V_{RB}}{R_B} = \frac{V_{CC} - V_{BE}}{R_B} = \]

\[ I_C = \frac{V_{RC}}{R_C} = \]

\[ \beta = \frac{I_C}{I_B} = \]

10. 

<table>
<thead>
<tr>
<th>Trans. Type</th>
<th>( V_{CE} ) (V)</th>
<th>( I_C ) (mA)</th>
<th>( I_B ) (μA)</th>
<th>( \beta )</th>
</tr>
</thead>
<tbody>
<tr>
<td>2N3904</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2N4401</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5.1

11. 

\[ \% \Delta \beta = \frac{|\beta_{(440)} - \beta_{(390)}|}{|\beta_{(390)}|} \times 100\% = \]

\[ \% \Delta I_C = \frac{|I_{C(440)} - I_{C(390)}|}{|I_{C(390)}|} \times 100\% = \]

\[ \% \Delta V_{CE} = \frac{|V_{CE(440)} - V_{CE(390)}|}{|V_{CE(390)}|} \times 100\% = \]

\[ \% \Delta I_B = \frac{|I_{B(440)} - I_{B(390)}|}{|I_{B(390)}|} \times 100\% = \]
12.

<table>
<thead>
<tr>
<th>%Δβ</th>
<th>%ΔIC</th>
<th>%ΔVCE</th>
<th>%ΔIB</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5.2

Part B

1. $R_1$ (measured) = ___________, $R_2$ (measured) = ___________,

   $R_C$ (measured) = ___________, $R_E$ (measured) = ___________

2. $V_B$ (calculated) = ___________, $V_E$ (calculated) = ___________
   
   $I_E$ (calculated) = ___________, $I_C$ (calculated) = ___________
   
   $V_C$ (calculated) = ___________, $V_{CE}$ (calculated) = ___________
   
   $I_B$ (calculated) = ___________

Show your works!
4. Show your works for calculating $I_E$ and $I_C$ (using measured values recorded in Table 5.3).

$I_1 = \_\_\_\_\_\_, I_2 = \_\_\_\_\_\_

$I_1 = \frac{V_{R1}}{R_1} = $

$I_2 = \frac{V_{R2}}{R_2} = $

Using KCL, $I_B = \_\_\_\_\_\_\_\_\_

(Currents calculated from measured values; considered as measured $I_E$, $I_C$ & $I_B$)

5. Comparison of calculated and measured values of Table 5.3:

6. 

<table>
<thead>
<tr>
<th>Trans. Type</th>
<th>$V_{CE}$ (V)</th>
<th>$I_C$ (mA)</th>
<th>$I_B$ (μA)</th>
<th>$\beta$</th>
</tr>
</thead>
<tbody>
<tr>
<td>2N3904</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>2N4401</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Table 5.4

8. $V_{CE}$ (measured) = \_\_\_\_\_\_

$I_C = \frac{V_{CC} - V_{CE}}{R_C + R_E} =

I_1 = \_\_\_\_\_\_, I_2 = \_\_\_\_\_\_\_\_

- 40 -
\[ I_1 = \frac{V_{RL}}{R_1} = \]

\[ I_2 = \frac{V_{R2}}{R_2} = \]

Using KCL, \( I_B = \) _______________

9. Complete Table 5.4 (Step 6) with the values obtained in Step 8 and \( \beta \) value obtained for 2N4401 transistor.

10. \[ \%\Delta \beta = \frac{|\beta_{(4404)} - \beta_{(3904)}|}{|\beta_{(3904)}|} \times 100\% = \]

\[ \%\Delta I_C = \frac{|I_{C(4404)} - I_{C(3904)}|}{|I_{C(3904)}|} \times 100\% = \]

\[ \%\Delta V_{CE} = \frac{|V_{CE(4404)} - V_{CE(3904)}|}{|V_{CE(3904)}|} \times 100\% = \]

\[ \%\Delta I_B = \frac{|I_{B(4404)} - I_{B(3904)}|}{|I_{B(3904)}|} \times 100\% = \]

11. \[
\begin{array}{cccc}
\%\Delta \beta & \%\Delta I_C & \%\Delta V_{CE} & \%\Delta I_B \\
\hline
\hline
\end{array}
\]

Table 5.4
### Objective
- To establish the output and transfer characteristics for a JFET transistor.
- To measure DC and AC voltages in a common-source amplifier.

### Equipment:

**Instruments**
- DC power supply: 9V, 25V
- Digital Multimeter (DMM)
- Function generator
- Oscilloscope

**Components**
- Resistors: 510Ω, 1kΩ, 2.4kΩ, 10kΩ, 1MΩ, 100Ω, 1kΩ, 10kΩ, 10kΩ
- Potentiometer, 1MΩ potentiometer
- Transistor: 2N3819

### Procedure:

**Part A: Measurement of the Saturation Current $I_{DSS}$ and Pinch-Off Voltage $V_P$ for JFET**

![Fig. 6.1](image-url)
1. Referring to Fig. 6.1, construct the circuit. The function of 10kΩ resistor in the input circuit is to protect the circuit if the 9V supply is connected with wrong polarity and the potentiometer is set on its maximum value.

2. Measure R value.

3. Set $V_{DS}$ to 8V by varying the 10kΩ potentiometer. Measure the voltage across R, $V_R$.

4. Vary the 1MΩ potentiometer until $V_{GS} = 0V$. Measure $I_D$ at this time. ($I_D = I_{DSS}$ when $V_{GS} = 0V$). Record $I_D$ measured.

5. Calculate the saturation current, $I_{DSS}$ using the measured resistor, R and $V_R$ values. Record $I_{DSS}$ calculated.

6. Maintain $V_{DS}$ at about 8V and reduce $V_{GS}$ until $V_R$ drops to 1mV. At this level, $I_D = V_R/R = 1mV/100\Omega = 10\mu A \approx 0 mA$. Record $V_{GS}$ value. The $V_{GS}$ value (when $I_D$ is 0 mA) is the pinch-off voltage $V_P$.

7. Using the values of $I_{DSS}$ and $V_P$, sketch the transfer characteristics for the device using Shockley’s equation given (in the results section). Plot at least 5 points on the curve. (Use $V_P < V_{GS} < 0V$)

Part B: Output Characteristics (JFET)

1. Referring to Fig. 6.1, vary the two potentiometers until $V_{GS} = 0V$ and $V_{DS} = 0V$. Determine $I_D$ from $I_D = V_R/R$ using the measured value of R and record in Table 6.1.

2. Maintain $V_{GS}$ at 0V and increase $V_{DS}$ from 0 to 14V and record the calculated value of $I_D$ at every 1V increment (refer to Table 6.1). (Be sure to use the measured value of R in your calculations)

3. Vary the 1MΩ potentiometer until $V_{GS} = -1V$. Maintaining $V_{GS}$ at -1V, vary $V_{DS}$ through the levels of Table 6.1 and record the calculated value of $I_D$.

4. Repeat Step 3 for the values of $V_{GS}$ in Table 6.1. Discontinue the process if $V_{GS}$ exceeds $V_P$.

5. Plot the output characteristics for the JFET.

6. Compare the $I_{DSS}$ and $V_P$ values obtained from Step 5 with those measured in Part A. Give comments.

Part C: Transfer Characteristics (JFET)

1. Using the data from Table 6.1, record the values of $I_D$ for the range of $V_{GS}$ at $V_{DS} = 3V$ in Table 6.2.

2. Repeat step 1 for $V_{DS} = 6V$, 9V and 12V.

3. For each level of $V_{DS}$, plot $I_D$ vs $V_{GS}$ on the graph. Plot each curve carefully and label each curve with the value of $V_{DS}$. 
Part D: Measurement of $I_{DSS}$ and $V_P$ (Common-Source Amplifier)

1. Referring to Fig. 6.2, construct the circuit ($V_{DD} = +20V, R_G = 1M\Omega, R_D = 510\Omega$ and $R_S = 0\Omega$). Measure $V_D$ and record.
2. Calculate $I_{DSS}$ using the measured $V_D$ from Step 1. Then, measure $I_{DSS}$
3. Connect $R_S = 1k\Omega$. Measure and record the values of $V_{GS}$ and $V_D$.
4. Calculate $I_D$ and $V_P$ using the measured values from Step 3.

![Diagram of the circuit](image)

*Fig. 6.2*

Part E: DC Bias of Common-Source Amplifier

1. Calculate the DC bias expected in the circuit of Fig. 6.2 using $I_{DSS}$ and $V_P$ values from Part D. Draw graph of the equations to graphically obtain the equation intersection which will be the calculated values of $V_{GS}$ and $I_D$.
2. Using the calculated $I_D$ from Step 2, calculate $V_D$.
3. Construct the circuit of Fig. 6.3 using $V_{DD} = +20V, R_G = 1\ M\Omega, R_S = 510\Omega$ and $R_D = 2.4k\Omega$.
4. Measure the DC bias voltages which are $V_G, V_S, V_D$ and $V_{GS}$. Record the values.
5. Calculate $I_D$ using the measured $V_D$ from Step 5.
6. Compare the DC bias values calculated in Step 2 & Step 3 with those measured in Step 5 & Step 6. Give comments.

**PSPICE Instructions:**

1. Obtain the output characteristics for the n-channel JFET circuit shown in *Fig. 6.1*.
2. Obtain transfer characteristics for the same circuit.
Results and Calculations:

Part A

2. \( R \) (measured) = ______________

3. \( I_{DSS} \) (measured) = ______________

4. \( V_R \) (measured) = _____________

5. \( I_{DSS} \) (calculated) = _____________
   \[ I_{DSS} = I_D = V_R/R \]

6. \( V_{GS} \) (measured) = \( V_P = \) _____________

7. \( I_D = I_{DSS} \left( 1 - \frac{V_{GS}}{V_P} \right)^2 \)

5 points for plot (calculated):

\( V_{GS} = 0 \text{V}, I_D = I_{DSS} = \) ______________

\( V_{GS} = \) __________, \( I_D = \) ____________

\( V_{GS} = \) __________, \( I_D = \) ____________

\( V_{GS} = \) __________, \( I_D = \) ____________

\( V_{GS} = \) __________, \( I_D = \) ____________

\( V_{GS} = \) __________, \( I_D = \) ____________

Note: \( V_P < V_{GS} < 0 \)

Sketch \( I_D \) vs \( V_{GS} \):
Part B

1. \( R \) (measured) from Part 1: ______________

<table>
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<th>( V_{GS} ) (V)</th>
<th>0.0</th>
<th>-0.5</th>
<th>-1.0</th>
<th>-1.5</th>
<th>-2.0</th>
<th>-2.5</th>
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<tbody>
<tr>
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</tbody>
</table>

*Table 6.1*

5. Output characteristics (use graph paper).

Part C

1. 

<table>
<thead>
<tr>
<th>( V_{DS} ) (V)</th>
<th>3</th>
<th>6</th>
<th>9</th>
<th>12</th>
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<tbody>
<tr>
<td>( V_{GS} ) (V)</td>
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*Table 6.2*

3. Plot of \( I_D \) vs \( V_{GS} \) (use graph paper).
Part D

1. $V_D$ (measured) = ______________

2. $I_{DSS}$ (calculated) = ______________

\[ I_D = \frac{V_{DD} - V_D}{R_D} = \]

$I_{DSS}$ (measured) = $I_D$ (at $V_{GS} = 0V$) = __________

3. $V_{GS}$ (measured) = ______________

\[ V_D \text{ (measured) = __________} \]

4. $I_D$ (calculated) = ______________

\[ I_D = \frac{V_{DD} - V_D}{R_D} = \]

$V_P$ (calculated) = ______________

\[ V_P = \frac{V_{GS}}{1 - \frac{I_D}{\sqrt{I_{DSS}}}} = \]

Part E

1. $V_{GS}$ (calculated) = ______________

\[ I_D \text{ (calculated) = __________} \]

\[ V_{GS} = -I_D R_S \]

\[ V_{GS} = 0 V \quad I_D = \_________ \]

\[ V_{GS} = -1V \quad I_D = \_________ \]

2. $V_D$ (calculated) = ______________

\[ V_D = V_{DD} - I_D R_D \]

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4. \( V_G = \) __________
\( V_S = \) __________
\( V_D = \) __________
\( V_{GS} = \) __________

5. \( I_D \) (calculated) = __________
\( I_D = V_S / R_S \)
Objective:

- To analyze fixed-, self-, and voltage-divider-bias JFET circuits.

Equipment:

**Instruments**
DC power supply
Digital Multimeter (DMM)

**Components**
Resistors : 1kΩ, 1.2kΩ, 2.2kΩ, 3kΩ, 10kΩ, 10MΩ, 1kΩ potentiometer
Transistor : 2N4416

Procedure:

**Part A : Fixed-Bias Configuration**

1. Referring to *Fig. 7.1*, construct the circuit. Measure $R_D$ value.

2. Set $V_{GS}$ to 0V and measure the voltage $V_{RD}$. Calculate $I_D$ from $I_D = V_{RD} / R_D$ using the measured $R_D$ value. Since $V_{GS} = 0V$, the resulting drain current $I_D = I_{DSS}$ (saturation current). Record the value.
3. Make VGS increasing negatively until VRD = 1mV (and ID = VRD / RD ≈ 1 μA). Since ID is very small (ID ≈ 0A), the resulting value of VGS = VP (pinch-off voltage). Record the value.

4. Using the values obtained in Step 2 & Step 3, sketch the transfer curve using Schokley’s equation. (Use graph paper)!

5. Referring to the transfer curve plotted in Step 4, determine IQ if VGS = -1V. Show all your works. Label the straight line defined by VGS as the fixed-bias line.

6. For the circuit in Fig. 7.1, vary the potentiometer to set VGS = -1V. Measure VRD. Calculate IQ using the measured RD value. The IQ obtained is the measured value of ID.

7. Compare the measured (Step 6) and calculated (Step 5) values of IQ.

Part B : Self-Bias Configuration

1. Referring to Fig. 7.2, construct the circuit. Measure RD and RS values. Record them.

2. On the same graph in Part A, draw the self-bias line defined by VGS = -IDRS and find the Q-point. Show all your works. Record the quiescent values of IQ and VGSQ. Label the straight line as the self-bias line.

3. Calculate theoretical values of VGS, VD, VS, VDS, and VG. Record them.

4. Measure the voltages VGS, VD, VDS, and VG from the circuit. Record them.

5. Compare the measured (Step 4) and calculated (step 3) values.
Part C: Voltage-Divider-Bias Configuration

1. Referring to Fig. 7.3, construct the circuit. Measure $R_1$, $R_2$, $R_D$ and $R_S$ values. Record them.

2. On the same graph in Part A, draw the voltage-divider-bias line defined by $V_{GS} = V_G - I_D R_S$. Find the Q-point. Show all your works. Record the quiescent values of $I_{DQ}$ and $V_{GSQ}$. Label the straight line as the voltage-divider-bias line.

3. Calculate theoretical values of $V_D$, $V_S$, and $V_{DS}$. Record them.

4. Measure the voltages $V_{GS}$, $V_D$, $V_S$, and $V_{DS}$ from the circuit. Record them.

5. Compare the measured (Step 4) and calculated (step 3) values.

**Fig. 7.3**

**PSPICE Instructions:**

1. Perform a DC analysis of the circuit of Fig. 7.3 using PSPICE by finding the values of $V_{GS}$, $V_D$, $V_S$, and $V_{DS}$.

2. Compare the values obtained from PSPICE simulation with the experimental ones.
Results and Calculations:

Part A

1. $R_D$ (measured) = ____________

2. $V_{RD}$ (measured) = ____________

\[ I_D = \frac{V_{RD}}{R_D} = \]

Since $V_{GS} = 0V$, $I_D = I_{DSS} = ____________

3. $V_{GS}$ (measured) = ____________

$V_{RD} = 1mV$; $I_D = \frac{V_{RD}}{R_D} \approx 1\mu A \approx 0A$

Since $I_D \approx 0A$, $V_{GS} = V_P = ____________

4. Sketch transfer curve using Schokley’s equation on graph paper. To draw the curve, find for at least 4 points. Show all works below.

\[ I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2 \]

5 points for plot (calculated):

$V_{GS} = 0V$, $I_D = I_{DSS} = ____________

$V_{GS} = _____, I_D = ____________

$V_{GS} = _____, I_D = ____________

$V_{GS} = _____, I_D = ____________

$V_{GS} = _____, I_D = ____________

$V_{GS} = _____, I_D = ____________

Note : $V_P < V_{GS} < 0$

5. From transfer curve in Step 4, if $V_{GS} = -1V$, $I_{DQ} = ____________ (This is $I_{DQ}$ calculated)
6. If $V_{GS} = -1\text{V}$, $V_{RD}$ (measured) = __________

$$I_D = \frac{V_{RD}}{R_D}$$

(This is $I_{DQ}$ measured)

7. Comparison of $I_{DQ}$ measured (Step 6) & $I_{DQ}$ calculated (Step 5):

Part B

1. $R_D$ (measured) = ______________, $R_S$ (measured) = ______________

2. On the same transfer curve in Part A, draw the self-bias line which is given by $V_{GS} = -I_D R_S$ (To draw the line, find at least 2 points). Show all your works below.

From the graph, $I_{DQ}$ (calculated) = ________, $V_{GSQ}$ (calculated) = ________

3. $V_{GS}$ (calculated) = ______________ , $V_D$ (calculated) = ______________ ,

$V_S$ (calculated) = ______________ , $V_{DS}$ (calculated) = ______________ ,

$V_G$ (calculated) = __________

(Show your calculations)
4. \( V_{GS} \) (measured) = _____________ , \( V_D \) (measured) = _____________ , 
\( V_S \) (measured) = _____________ , \( V_{DS} \) (measured) = _____________ ,
\( V_G \) (measured) = _____________

5. Compare the difference of measured (Step 4) and calculated (Step 3) values using
\[
\%\text{difference} = \frac{|V_{meas} - V_{calc}|}{|V_{calc}|} \times 100\%
\]

\( %V_{GS} = \_____________ \), \( %V_D = \_____________ \), \( %V_S = \_____________ \)
\( %V_{DS} = \_____________ \), \( %V_G = \_____________ \)

Part C

1. \( R_1 \) (measured) = _____________ , \( R_2 \) (measured) = _____________
\( R_D \) (measured) = _____________ , \( R_S \) (measured) = _____________

2. On the same transfer curve in Part A, draw the voltage-divider-bias line which is
given by \( V_{GS} = V_G - I_D R_S \) where \( V_G = \frac{R_2 V_{DD}}{R_1 + R_2} \)
(To draw the line, find at least 2 points). Show all your works below.
From the graph, $I_{DQ \text{ (calculated)}} = \text{_________}, V_{GSQ \text{ (calculated)}} = \text{___________}$

3. $V_D \text{ (calculated)} = \text{_______________}, V_S \text{ (calculated)} = \text{_______________},$
   $V_{DS} \text{ (calculated)} = \text{_______________},$

   (Show your calculations below!)

4. $V_{GS} \text{ (measured)} = \text{_______________}, V_D \text{ (measured)} = \text{_______________},$
   $V_S \text{ (measured)} = \text{_______________}, V_{DS} \text{ (measured)} = \text{_______________},$

5. Compare the difference of measured (Step 4) and calculated (Step 3) values using
   \[ \%\text{difference} = \left( \frac{|V_{\text{meas}} - V_{\text{calc}}|}{|V_{\text{calc}}|} \right) \times 100\% \]

   \[ \%V_{GS} = \text{_______________}, \%V_D = \text{_______________}, \]
   \[ \%V_S = \text{_______________}, \%V_{DS} = \text{_______________}, \]
Objectives:

- To theoretically analyse the basic op-amp circuits.
- To build and test typical op-amp application circuits, such as inverting and non-inverting amplifier.

Equipment:

**Instruments**
- DC power supply
- Digital Multimeter (DMM)
- Function Generator
- Oscilloscope

**Components**
- Op Amp: LM 741
- Resistors: 1 k, 10 k (4), 22 k, 100 k (2), 5 M

Procedure:

**Part A: Inverting Amp**

1. Set up the oscilloscope to show a dual trace, one for the input of the op-amp and one for the output. Use DC input coupling. Set up the function generator to produce a sine wave with an amplitude >0.5 V and frequency 1 kHz. Make sure that the grounds of the function generator, oscilloscope, and prototyping board are somehow connected.
2. Measure the values of your resistors, then using the prototyping board, wire up the inverting amplifier shown in Figure 8.1.
3. Measure the gain $A_V$ for $R_{ref} = 1$ k, 10 k, and 100 k. Using measured values of $R_{ref}$ and $R_1 = 22$ k, compare to $A_V = - R_{ref} / R_1$ and verify that the amplifier inverts.
4. For the circuit with $R_{ref} = 100$ k, increase the input voltage until distortion occurs at the output. Record the input voltage and draw the distorted output waveform. Report the input at which this occurs.
5. For the circuit with $R_{\text{ref}} = 100 \, \text{k}$, measure the gain $A_V$ at the logarithmically-spaced frequencies of 100 Hz, 300 Hz, 10 kHz, ..., 1 MHz, 3 MHz. Repeat for $R_{\text{ref}} = 10 \, \text{k}$. Plot your results on log-log graph paper. (You will need 5 cycles for the log paper on the frequency axis.) Also show on this graph the theoretical gain $|A_V| = R_{\text{ref}} / R_1$.

6. Perform the experiment to calculate the input impedance of this amplifier.

**Part B: Non-Inverting Amp**

1. Construct the non-inverting amplifier designed in the prelab. (See Figure 8.2)
2. Apply a 1V amplitude, 1kHz sinusoidal input signal to the amplifier. Display $V_{\text{in}}$ and $V_{\text{o}}$ at the same time. (They need to be displayed simultaneously so that you can see the phase shift between them.) Draw the image. The phase measurement and peak-peak measurements must be turned on.
3. Report the phase shift as well as gain.
4. Increase the input voltage until distortion occurs at the output. Record the input voltage and capture the distorted output waveform. Report the voltage at which this distortion occurs.
5. Set the input to 4V Amplitude and place the scope in X-Y mode. Make sure that $V_{\text{in}}$ is on channel 1 and $V_{\text{o}}$ is on channel 2. Capture the curve and measure the slope of the line. The waveform must be captured with the cursors in the right place.
6. Now interchange the connections to terminals 2 and 3. Report what happens. Also capture the waveforms at the +/- input terminals(2 & 3) of the op-amp on the same frame.

**SPICE instruction:**
- Construct the circuit and obtain the input-output waveform for both of the inverting and non-inverting op-amp.
Results and Calculations:

Part A:

1. \( V_{\text{in(peak-to-peak)} \text{ (measured)}} = \) ______________

2. \( R_1 \text{ (measured)} = : \) ______________, \( R_{\text{ref}} \text{ (measured)} = \) ______________

3. Measure different values of \( R_{\text{ref}} \), to calculate \( A_v \), using \( A_v = -\frac{R_{\text{ref}}}{R_1} \)
   \( R_{\text{ref}} = \) ______________, \( A_v = \) ______________
   \( R_{\text{ref}} = \) ______________, \( A_v = \) ______________
   \( R_{\text{ref}} = \) ______________, \( A_v = \) ______________

4. \( V_{\text{in(peak-to-peak)} \text{ (measured)}} = \) ______________

   Draw the distorted output waveform.

5. Fill up the table measure gain \( A_v \) \( ( A_v = \frac{V_{\text{out(peak-to-peak)}}}{V_{\text{in(peak-to-peak)}}}) \).

<table>
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<tr>
<th></th>
<th>100Hz</th>
<th>300Hz</th>
<th>10kHz</th>
<th>100kHz</th>
<th>1MHz</th>
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<td>( R_{\text{ref}} = 100k )</td>
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<tr>
<td>( R_{\text{ref}} = 10k )</td>
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</table>

Plot your results on the graph paper.

The theoretical gain \( |A_v| = \frac{R_{\text{ref}}}{R_1} = \) ______________ (calculate).

6. The input impedance \( R_{\text{in (calculate)} = \) ______________
Part B:

1. \( R_1 \) (measured) = ________________  \( R_{ref} \) (measured) = ________________

2. Draw the input and output signal at the same graph.

3. The output signal’s phase, \( \Phi \) (measured) = ________________

   \( A_v \) (measured) = \( \frac{V_{out(peak-to-peak)}}{V_{in(peak-to-peak)}} \) = ________________

4. \( V_{in(peak-to-peak)} \) (measured) = ________________

   \( V_{out(peak-to-peak)} \) (measured) = ________________ (the voltage at which this distortion occurs.)

   Draw the distorted output waveform.
Objectives:

- To theoretically analyse the basic op-amp circuits.
- To build and test typical op-amp application circuits, such as summing, subtracting, integrating and differentiating amplifier

Equipment:

**Instruments**
- DC power supply
- Digital Multimeter (DMM)
- Function Generator
- Oscilloscope

**Components**
- Op Amp : LM 741
- Resistors: 1 k, 10 k (4), 22 k, 100 k (2), 5 M

Procedure:

**Summing op-amp:**

1. Build the circuit shown in Figure 9.1. At first, choose R1 = 10 k.

   ![Fig. 9.1](image)

2. Use a 4 Volt P-P sine wave for input 1. Use a + 5 V dc voltage from a power supply for input 2. Connect the oscilloscope, using DC input coupling, to monitor input 1 and the output.

3. Confirm that the output is the sum of the inputs. Sketch the waveforms.

4. Use the DC offset on your function generator to raise the dc input voltage until you see a pronounced clipping of the waveform. Sketch the waveforms.
Subtracting op-amp:
1. Connect the circuit in Fig. 9.2, using resistor values R1 = R2 = R3 = R4 = 10 k.

![Fig. 9.2](image)

2. Use the set-up with a sine wave and a dc signal set-up that you used for the summing amp. Verify that the output is the difference of the two inputs.
3. Apply the sine wave to input 1 and connect input 2 to ground. Measure $V_D = V_{out} / V_{in1}$. Compare to the value predicted by theoretical formula.
4. Connect both inputs to the sine wave. Measure $V_C = V_{out} / V_{in}$. Compare to the value predicted by the theoretical formula.
5. Compute $CMRR = V_D / V_C$.

Integrating op-amp:
1. Assemble an integrator circuit with $R=1K\Omega$ and $C=0.1\mu F$. Connect $R_{ref}$ of value $1M\Omega / 5 M\Omega$ across the capacitor.
2. Feed +1V, 500Hz square wave input.

![Fig. 9.3](image)

3. Observe the input and output voltages on an oscilloscope. Determine the gain of the circuit.
4. Plot the input and output voltages on the same scale on a linear graph sheet.
Differentiating op-amp:

1. Assemble a differentiator circuit with $R_2=100\,\text{K}\Omega$ and $C_1=0.05\,\mu\text{f}$. Connect a resistor $R_1$ of value $1\,\text{k}\Omega$ between the source and the capacitor.
2. Feed $+0.1\,\text{V}$, $5\,\text{KHz}$ triangular wave input.
3. Observe the input and output voltages on a oscilloscope. Determine the gain of the circuit.
4. Plot the input and output voltages on the same scale on a linear graph sheet.

![Fig. 9.4](image)

**SPICE instruction:**
- Construct the circuit for summing and differentiating op-amp and get the input-output waveshape.
Results and Calculations:

**Summing Op-Amp:**

1. \( R_1 \) (measure) = ___________________ \& ___________________
2. Sketch the waveform for input1:

3. Sketch the waveform for output:

4. Find the \( V_{dc} = \)______________, (at which point, a clipping output waveform is appearing.)
5. Sketch the clipping output waveform.

**Subtracting Op-Amp:**

1. \( R_1 \) (measure) =______________, \( R_2 \) (measure) =______________, \( R_3 \) (measure) =______________, \( R_4 \) (measure) =______________.
2. With sine wave (peak-to-peak voltage is 4V, frequency is 1KHz) and +5V dc input signals, to draw the output waveform.
3. (When in2 is connected to ground)

\[ V_D \text{ (measure)} = \frac{V_{out\text{pp}}}{V_{in\text{1pp}}} = \text{__________} \]

4. (When in1 and in2 both are connected to sine wave)

\[ V_C \text{ (measure)} = \frac{V_{out\text{pp}}}{V_{in\text{1pp}}} = \text{__________} \]

5. CMRR (Calculate) = \[ \frac{V_D}{V_C} = \text{______________} \]

Integrating Op-Amp:

1. \[ R1 \text{ (measure)} = \text{___________}, R2 \text{ (measure)} = \text{___________}. \]

2. \[ V_{in\text{pp}} \text{ (measure)} = \text{______________} \]

\[ V_{out\text{pp}} \text{ (measure)} = \text{______________} \]

3. \[ Av = \frac{V_{out\text{pp}}}{V_{in\text{pp}}} = \text{__________________ (calculate)} \]

4. Draw the waveform of output voltage and input voltage on the same scale.

Differentiating Op-Amp:

1. \[ R1 \text{ (measure)} = \text{___________}, R2 \text{ (measure)} = \text{___________}. \]

2. \[ V_{in\text{pp}} \text{ (measure)} = \text{______________} \]

\[ V_{out\text{pp}} \text{ (measure)} = \text{______________} \]

3. \[ Av = \frac{V_{out\text{pp}}}{V_{in\text{pp}}} = \text{__________________ (calculate)}. \]

4. Draw the waveform of output voltage and input voltage on the same scale.