EIE341
Analog Circuits Laboratory

Prof. Xiaodong Li

School of Computer Science and Engineering, Faculty of Innovation Engineering
Macau University of Science and Technology

December 14, 2023

Contents

List of Figures

List of Tables

Preface

0.1 Proper Behavior Guideline

- No food and drink is allowed in the lab for the purpose of safety of both personnel and devices.
- Do not switch on the power to your circuit until the TA/instructor has checked your connection.
- Be serious and active during the class.

0.2 Marking Schemes

- Class Performance 10%
- Pre-Lab Question 30%
- Lab Report 60%
  - English 20%
  - Written Style and Format 20%
  - Correctness of Data, Data Analysis 20%

0.3 Requirements of Lab Report

- A copy of final lab report is required for each student or group
- The report may be submitted as an electronics copy or a printed copy as requested.
- The report should be written in English only.
- The report is due seven days after the lab class. Late submission within three day after the due date results in 10% deduction per day, late submission after three days after the due date results in zero mark.

The report ***should***

- be written with LaTeX.

- explain the principle and list necessary equations, show the calculation of all theoretical values.
- collect all the test data and do necessary analysis using tables, graphs.
- make comparison between the test data and theoretical values.
- answer all the questions given in the manual, which are normally typed in bold.
- try to explain the reason of some errors and make proper comments and conclusions.

The report ***should not JUST***

- repeat the description of experiment procedures.
- copy any figures and tables directly from the lab manual or other publications.
- use exactly same sentences and expressions from the lab manual without any modification.

Chapter 1

Diode Circuits I

1.1 Objective

- To learn the basic property of a pn diode and a zener diode
- To construct simple diode circuits and verify their performance

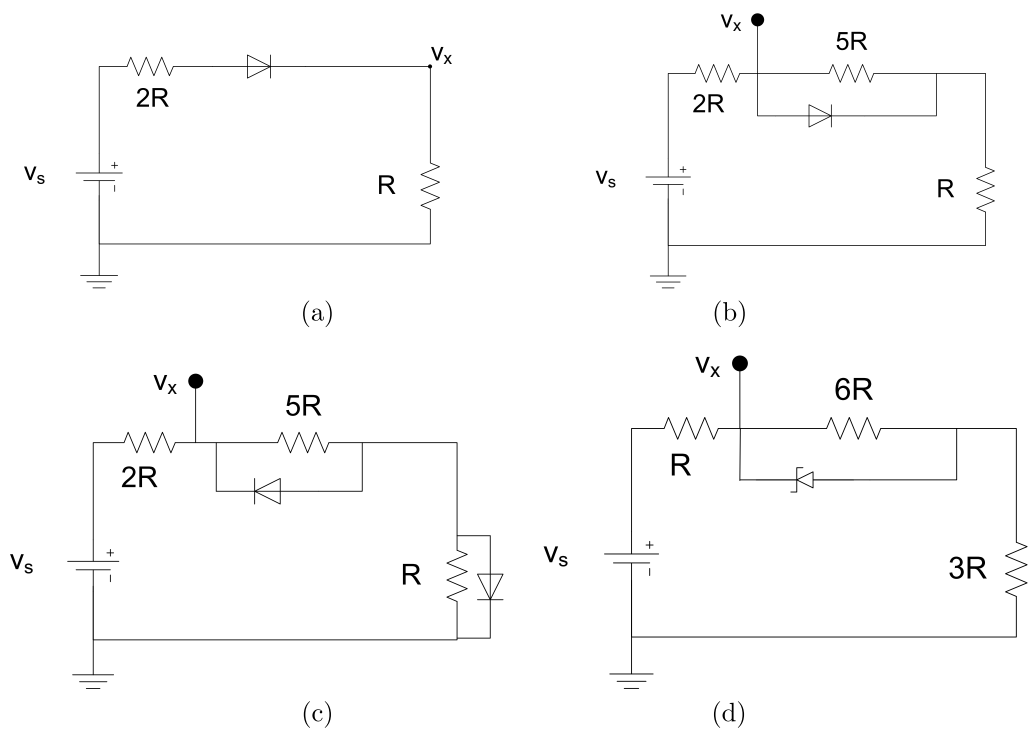

Figure 1.1: Simple diode circuits

1.2 Pre-lab Questions

Assuming the built-in voltage of diode is V_γ and the breakdown voltage of a Zener diode is V_Z in Fig. 1.1, find the relationship between V_x and V_s for each circuit theoretically.

1.3 Experiment Material

Equipment: Digital Multi-Meter, DC power supply, Breadboard

Components: Diode (1N4148), Zener diode (1N4728A), schottky diode (SR160), resistors

1.4 Part I

1. Pick one regular diode (1N4148) and use the digital multi-meter to identify the polarity of the two terminals, and find the threshold/built-in voltage of the diode
2. Pick one schottky diode (SR160) and repeat the last step
3. Pick one zener diode (1N4728A) and repeat the last step

1.5 Part II

Construct the circuits in Fig. 1.1 on a breadboard. For Fig. 1.1(a)∼(c), R=1000Ω and the type of diode is 1N4148. For Fig. 1.1(d), R=50Ω and the type of diode is 1N4728A.

1. For Fig. 1.1(a), measure V_x when V_s varies from -1∼2 V in a step of 0.2 V, design your own table and record all measured data
2. For Fig. 1.1(b), measure V_x when V_s varies from -1∼2 V in a step of 0.2 V, design your own table and record all measured data
3. For Fig. 1.1(c), measure V_x when V_s varies from -4∼7 V in a step of 0.5 V, design your own table and record all measured data
4. For Fig. 1.1(d), measure V_x when V_s varies from -4∼7 V in a step of 0.5 V, design your own table and record all measured data
5. Please use the measured data to derive:
   - the relationship between V_x and V_s data for each circuit and compared them with theoretical calculation;
   - the built-in voltage of the diode used in the circuit;
   - the breakdown voltage of the zener diode used in the circuit

Chapter 2

Diodes Circuits II

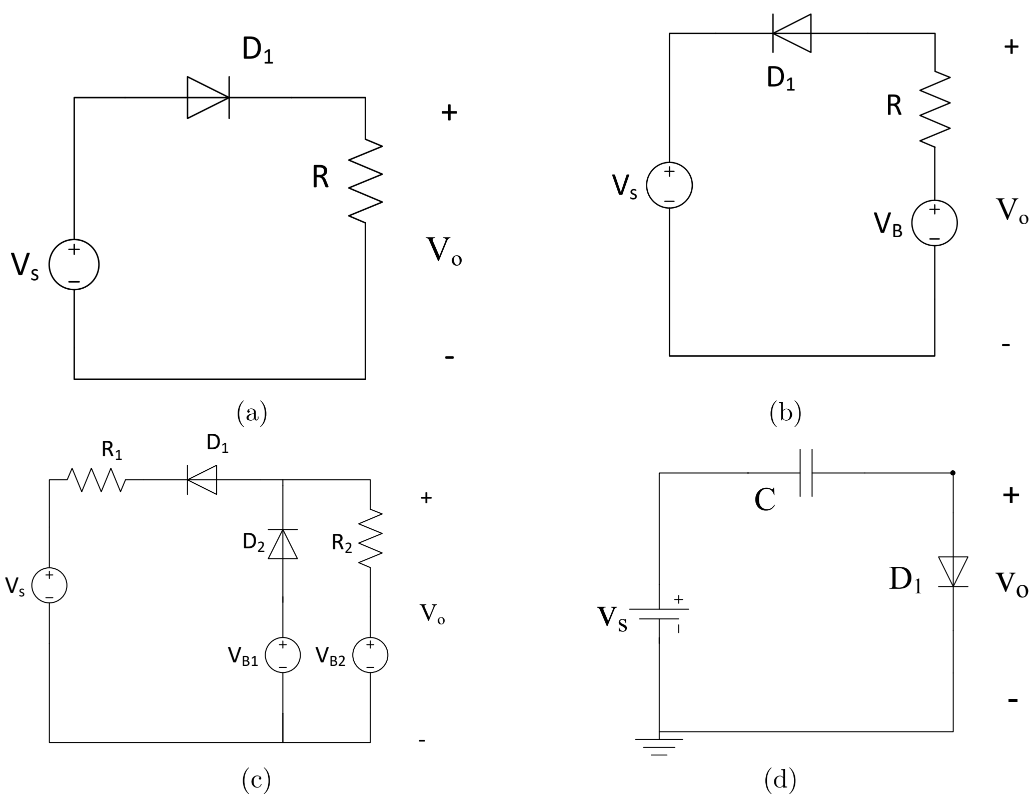

Figure 2.1: Different diode circuits: (a) a half-wave diode rectifier; (b) a clipper circuit with up limit; (c) a clipper circuit with two limits; (d) a clamper circuit.

2.1 Objective

- To verify a half-wave diode rectifier circuit
- To verify clipper circuits and clamper circuits

2.2 Pre-lab Question

It is assumed that the built-in voltage of diode is V_γ in Fig. 2.1; for Fig. 2.1(b), $V_B > V_\gamma$; for Fig. 2.1(c),$V_{B2} > V_{B1}$; for Fig. 2.1(d),$V_s = V_P \sin \omega t$, $V_P > V_\gamma$. Please find the relationship between V_o and V_s for each circuit theoretically.

2.3 Experiment Material

Equipment: Digital multi-meter, DC power supply, Breadboard, Oscilloscope, Function Generator

Components: Diode (1N4148), resistors, capacitor

2.4 Half-wave Diode Rectifier circuit

1. Construct the circuit of Fig.2.1(a) on a breadboard using the diode (1N4148) and $R = 1k\Omega$
2. Let V_s be a sinusoidal signal with 100Hz frequency and 3V peak, using the oscilloscope to observe V_s, V_o simultaneously, record the plot and make comments on it later in the final report
3. Let V_s be a triangular signal with 100Hz frequency and 3V peak, using the oscilloscope to observe V_s, V_o simultaneously, record the plot and make comments on it later in the final report
4. Let V_s be a dc voltage source, measure V_o when V_s varies from -3 to 3 V in a step of 0.2 V, design your own table and record all measured data.
5. **In the final report, find the relationship between V_s, V_o using measured data graphically and compare it with theoretical calculation, estimate the built-in voltage of the diode**

2.5 Clipper circuit I

1. Construct the circuit of Fig.2.1(b) on a breadboard using the diode (1N4148), $R = 1k\Omega$ and $V_B = 1$V
2. Let V_s be a sinusoidal signal with 100Hz frequency and 3V peak, using the oscilloscope to observe V_s, V_o simultaneously, record the plot and make comments on it later in the final report

3. Let V_s be a triangular signal with 100Hz frequency and 3V peak, using the oscilloscope to observe V_s, V_o simultaneously, record the plot and make comments on it later in the final report

4. Let V_s be a dc voltage source, measure V_o when V_s varies from -3 to 3 V in a step of 0.2 V, design your own table and record all measured data.

5. **In the final report, find the relationship between V_s, V_o using measured data graphically and compare it with theoretical calculation, estimate the built-in voltage of the diode**

2.6 Clipper circuit II

1. Construct the circuit of Fig.2.1(c) on a breadboard using the diode (1N4148), $R_1 = 1k\Omega$, $R_2 = 10k\Omega$ and $V_{B1} = 5$V, $V_{B2} = 8$V.

2. Let V_s be a sinusoidal signal with 100Hz frequency and 10V peak, using the oscilloscope to observe V_s, V_o simultaneously, record the plot and make comments on it later in the final report

3. Let V_s be a triangular signal with 100Hz frequency and 10V peak, using the oscilloscope to observe V_s, V_o simultaneously, record the plot and make comments on it later in the final report

4. Let V_s be a dc voltage source, measure V_o when V_s varies from 0 to 10 V in a step of 0.5 V, design your own table and record all measured data.

5. **In the final report, find the relationship between V_s, V_o using measured data graphically and compare it with theoretical calculation, estimate the built-in voltage of the diode**

2.7 Clamper circuit

1. Construct the circuit of Fig.2.1(d) on a breadboard using the diode (1N4148), C=100 nF.

2. Using the function generator to set V_s be a sinusoidal signal with 1 kHz frequency and 4V peak, **do not "ON" the output**;

3. On the oscilloscope, connect the CH1 probe to V_s, the CH2 probe to V_o; the voltage scales of Ch1 and Ch2 are all set to 2V/div; press "single" to pause the scope, then press "trigger" to activate trigger menu, set the source to be "CH1" with "rising edge" and the trigger mode to be "normal", adjust the trigger level to approximately 2V;

4. Enable the output of function generator by pressing "**ON**", observe and record the captured waveforms of V_s and V_o, compare them with the theoretical prediction from the pre-lab, estimate the built-in voltage of the diode from the plot.

Chapter 3

Diode Rectifier Circuits

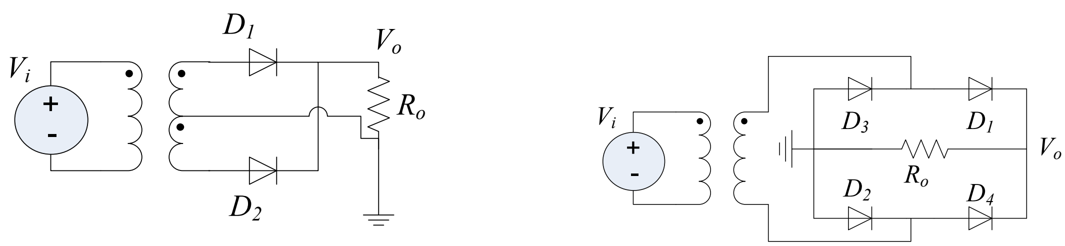

Figure 3.1: (a) a full-wave rectifier with center-tapped transformer; (b) a full-wave bridge rectifier.

3.1 Objective

- To verify a full-wave rectifier with center-tapped transformer;
- To verify a full-wave bridge rectifier

3.2 Pre-lab Question

It is assumed that the built-in voltage of diode is V_γ in Fig. 3.1, assume V_i is known, please find the expressions of V_o ,V_{D_1} , V_{D_2} for Fig. 3.1(a); V_o ,V_{D_1} , V_{D_4} for Fig. 3.1(b) theoretically.

3.3 Experiment Material

Equipment: Digital multi-meter, DC power supply, Breadboard, Oscilloscope, Function Generator

Components: Diode (1N4148), resistors

3.4 A full-wave diode rectifier with center-tapped transformer

1. Construct the circuit of Fig.3.1(a) on a breadboard using the diode (1N4148) and $R = 1k\Omega$, let V_i be a sinusoidal signal with 100Hz frequency and 3V peak
2. using the oscilloscope to observe V_o, record the plot and make comments on it later in the final report
3. Using the oscilloscope to observe V_{D_1},V_{D_2} simultaneously, record the plot and make comments on it later in the final report
4. Let V_i be a dc voltage source, measure V_o when V_i varies from -3 to 3 V in a step of 0.2 V, design your own table and record all measured data.
5. **In the final report, find the relationship between V_i, V_o using measured data graphically and compare it with theoretical calculation, estimate the built-in voltage of the diode**

3.5 A full-wave bridge diode rectifier

1. Construct the circuit of Fig.3.1(b) on a breadboard using the diode (1N4148) and $R = 1k\Omega$, let V_i be a sinusoidal signal with 100Hz frequency and 3V peak
2. using the oscilloscope to observe V_o, record the plot and make comments on it later in the final report
3. Using the oscilloscope to observe V_{D_1},V_{D_4} simultaneously, record the plot and make comments on it later in the final report
4. Let V_i be a dc voltage source, measure V_o when V_i varies from -3 to 3 V in a step of 0.2 V, design your own table and record all measured data.
5. **In the final report, find the relationship between V_i, V_o using measured data graphically and compare it with theoretical calculation, estimate the built-in voltage of the diode**

Chapter 4

Common-Emitter Current Gain

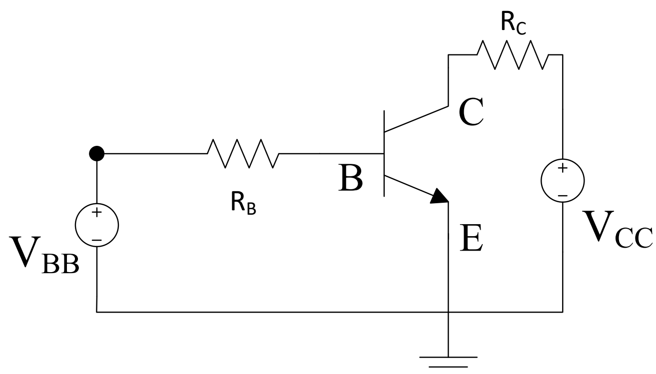

Figure 4.1: Test circuit of a npn BJT

4.1 Objective

- To find the Common-Emitter Current Gain of a npn BJT

4.2 Pre-lab Question

Review the principle of a npn BJT, the definition of the common-emitter current gain, the dc analysis technique of a BJT circuit.

4.3 Experiment Material

Equipment: Digital Multi-Meter, DC power supply, Breadboard

Table 4.1: Properties of common-emitter BJT circuit

V_{BB}=1.0 V															
V_{CC}	0.1	0.2	0.4	0.6	0.8	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
V_{BE}															
V_{CE}															

Components: BJT, resistors

4.4 Procedures

Construct the circuit in Fig. 4.1 with a npn BJT (2N3904), $R_B = 56k\Omega$, $R_C = 1k\Omega$

- Measure the actual values of $R_B,\ R_C$;
- Set $V_{BB} = 1.0$V and vary V_{CC} from 0 to 10 V, then measure $V_{CC},\ V_{BE},\ V_{CE}$, fill Table 4.1.
- When $V_{BB} = 1.3, 1.7, 2.0$ V, repeat the above procedures and using the similar tables
- In the final report,
    1. For each different V_{BB}, find the average of V_{BE} and I_B can be found; then calculate I_C using measured V_{CE} at different V_{CC};
    2. For each different V_{BB}, plot the relationship between V_{CE} and I_C for different I_B
    3. With the help of plots, identify the boundary points between forward-active and saturation mode, estimate the values of Early voltage V_A and the common-emitter current gain β

Chapter 5

Operation Modes of Bipolar Junction Transistor

5.1 Objective

- To test the different operation modes of a npn BJT
- To test the different operation modes of a pnp BJT

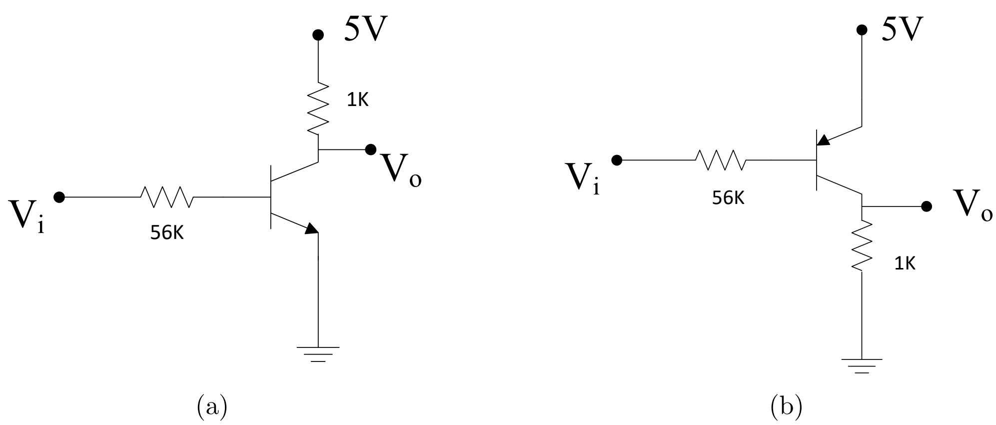

Figure 5.1: Operation modes of: (a) a npn BJT circuit; (b) a pnp BJT circuit.

5.2 Pre-lab Question

- In Fig. 5.1(a), derive the relationship between V_i and V_o if V_{BEon} is 0.6 and β is 200
- In Fig. 5.1(b), derive the relationship between V_i and V_o if V_{EBon} is 0.6 and β is 200

5.3 Experiment Material

Equipment: Digital Multi-Meter, DC power supply, Breadboard

Components: BJT, resistors

5.4 A npn BJT

- Construct the circuit in Fig. 5.1(a) using a 2N3904 npn BJT
- Measure V_o when V_i varies from 0 to 5V, design your own table and record all necessary data
- Derive the relationship between V_i and V_o graphically, estimate β and V_{BEon}, identify the mode of the npn BJT in different operation regions
- Compare the experimental results with the pre-lab solution and explain any difference

5.5 A pnp BJT

- Construct the circuit in Fig. 5.1(b) using a 2N3906 pnp BJT
- Measure V_o when V_i varies from 0 to 5V, design your own table and record all necessary data
- Derive the relationship between V_i and V_o graphically, estimate β and V_{EBon}, identify the mode of the pnp BJT in different operation regions
- Compare the experimental results with the pre-lab solution and explain any difference

Chapter 6

A Common-Emitter BJT Amplifier

6.1 Objective

- To measure the quiescent-point of a common-emitter BJT amplifier
- To evaluate the small-signal amplification function of a common-emitter amplifier

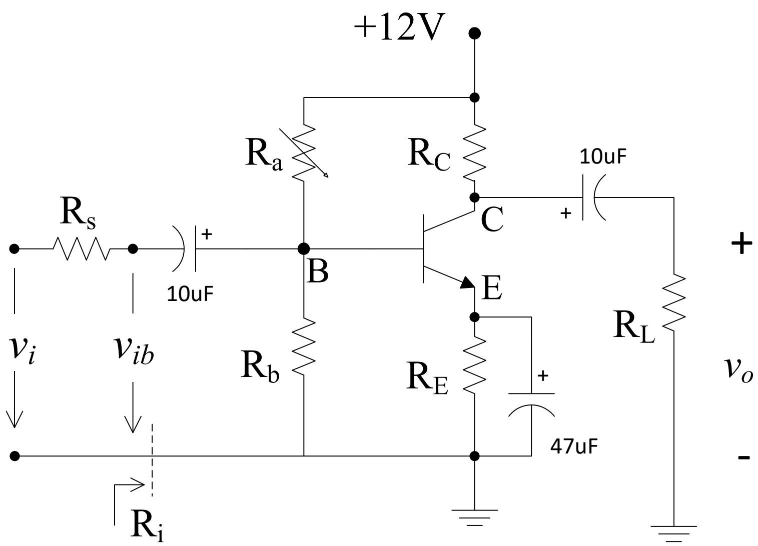

Figure 6.1: A common-emitter amplifier.

6.2 Pre-lab Question

In Fig. 6.1, assuming $V_{BEQ} = 0.65$V, $\beta = 160$, $R_s = 2.0$kΩ, $R_a = 56$kΩ, $R_b = 27$kΩ, $R_C = 1.0$kΩ, $R_E = 1.5$kΩ, (45k,25k,1k,1k)

- Do dc analysis of the amplifier to find I_{BQ}, I_{CQ}, I_{EQ}, V_B, V_C, V_E, V_{CEQ}.
- Do ac analysis of the amplifier to find A_v, R_i, R_o.

6.3 Experiment Material

Equipment: Digital Multi-Meter, DC power supply, Breadboard, Function Generator, Oscilloscope

Components: BJT 2N3904, resistors, capacitor

6.4 DC Analysis

- Construct the circuit in Fig. 6.1 using a npn BJT (2N3904) and $R_L = \infty$
- Let v_i to be zero (i.e. short it to the ground), use the multi-meter to measure three terminal voltages of the BJT V_B, V_C, V_E and calculate I_{BQ}, I_{CQ}, I_{EQ} and β, design your own table and record the data
- Compare the experimental results with the pre-lab solution and explain any difference, estimate the actual β

6.5 AC Analysis: Voltage Gain

- Let v_i to be a sinusoidal signal (1000 Hz, 0.5V peak) and $R_L = 300$kΩ, observe input and output voltages with the oscilloscope and record the plot.
- Now reduce the amplitude of v_i until that the output voltage is not distorted, record the particular amplitude of v_i as V^*, record the plots and use the digital multi-meter to measure the rms value of v_{ib} and v_o.
- Vary the input voltage amplitude from V^* to its 80%, 60%, 40% and 20% respectively, repeat the last step
- Calculate the voltage gain $A_v = v_o/v_{ib}$ for each case above and fill Table 6.1.
- In the final report, answer the following questions:
  1. Compare the experimental results with the pre-lab solution and explain any difference
  2. when the distortion emerges, which mode: saturation or cut-off does the BJT enter into? Then, should R_a be increased or decreased to enlarge the linear amplification range?

6.6 AC Analysis: Input Resistance

- Let v_i to be a 1000 Hz sinusoidal signal with the amplitude of V^* and $R_L = 300\text{k}\Omega$, make sure the output voltage is not distorted with the help of the oscilloscope
- Use the digital multi-meter to measure the rms values of v_{ib} and v_i, record the two values to calculate the input resistance R_i and fill Table 6.2.
- Compare the experimental results with the pre-lab solution and explain any difference

6.7 AC Analysis: Output Resistance

- Let v_i to be a 1000 Hz sinusoidal signal with the amplitude of V^*, make sure the output voltage is not distorted with the help of the oscilloscope
- Use the digital multi-meter to measure the rms values of output voltage v_o when $R_L = 300\text{k}\Omega$ (light-load) and when $R_L = 2\text{k}\Omega$ (heavy-load) respectively, record the two values to calculate the output resistance R_o and fill Table 6.2.
- Compare the experimental results with the pre-lab solution and explain any difference

Table 6.1: Voltage Gain

V_{ib}				
V_o				
A_v				

Table 6.2: Input/putput Resistance

R_s=470K, $R_i =$		R_o=	
$V_i =$	$V_{ib} =$	$R_L = 300K$,$V_o =$	$R_L = 1K$,$V_o =$

Chapter 7

A Common-Collector BJT Amplifier

7.1 Objective

- To measure the quiescent-point of an emitter follower
- To evaluate the small-signal amplification function of an emitter follower

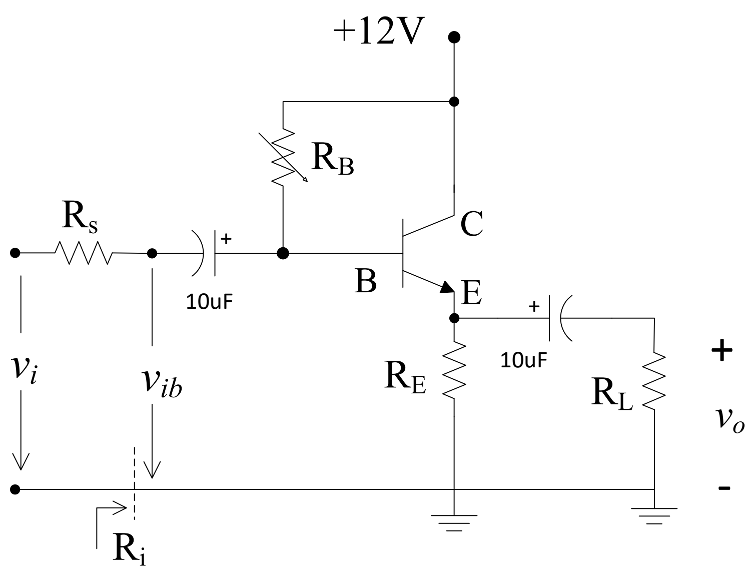

Figure 7.1: A common-collector BJT amplifier/emitter follower.

7.2 Pre-lab Question

In Fig. 7.1, assuming $V_{BEQ} = 0.6\text{V}$, $\beta = 160$, $R_s = 10\text{k}\Omega$, $R_B = 56\text{k}\Omega$, $R_E = 1\text{k}\Omega$,

- Do dc analysis of the amplifier to find I_{BQ}, I_{CQ}, I_{EQ}, V_B, V_C, V_E, V_{CEQ}.
- Do ac analysis of the amplifier to find $A_v,\ R_i,\ R_o$.

7.3 Experiment Material

Equipment: Digital Multi-Meter, Breadboard, Function Generator, Oscilloscope, DC power supply

Components: BJT 2N3904, resistors, capacitor

7.4 DC Analysis

- Construct the circuit in Fig. 7.1 using a npn BJT (2N3904) and $R_L = 300\text{k}\Omega$
- Let v_i to be zero (i.e. short it to the ground), use the digital multi-meter to measure the three terminal voltages of the BJT V_B, V_C, V_E and calculate I_{BQ}, I_{CQ}, I_{EQ} and β, design your own table and record the data
- Compare the experimental results with the pre-lab solution and explain any difference

7.5 AC Analysis: Voltage Gain

- Let v_i to be a sinusoidal signal (1000 Hz, 5V peak) and $R_L = 300\text{k}\Omega$, observe input and output voltages with the oscilloscope and record the plot.
- Now reduce the amplitude of v_i until that the output voltage is not distorted, record the particular amplitude of v_i as V^*, use the digital multi-meter to measure the rms value of v_{ib} and v_o and record the plot
- Vary the input voltage amplitude from V^* to its 80%, 60%, 40% and 20% respectively, repeat the last step
- Calculate the voltage gain $A_v = v_o/v_{ib}$ for each case above and fill Table 7.1
- In the final report, answer the following questions:
  1. Compare the experimental results with the pre-lab solution and explain any difference
  2. when the distortion emerges, which mode: saturation or cut-off does the BJT enter into? Then, should R_B be increased or decreased to enlarge the linear amplification range?

7.6 AC Analysis: Input Resistance

- Let v_i to be a 1000 Hz sinusoidal signal with the amplitude of 1 V, make sure the output voltage is not distorted with the help of the oscilloscope
- Use the digital multi-meter to measure the rms values of v_{ib} and v_i, record the two values to calculate the input resistance R_i and fill Table 7.2
- Compare the experimental results with the pre-lab solution and explain any difference

7.7 AC Analysis: Output Resistance

- Let v_i to be a 1000 Hz sinusoidal signal with the amplitude of 1 V, make sure the output voltage is not distorted with the help of the oscilloscope
- Use the digital multi-meter to measure the rms values of output voltage v_o when $R_L = 300\text{k}\Omega$ and when $R_L = 1\text{k}\Omega$ respectively, record the two values to calculate the output resistance R_o and fill Table 7.2.
- Compare the experimental results with the pre-lab solution and explain any difference

Table 7.1: Voltage Gain

V_{ib}				
V_o				
A_v				

Table 7.2: Input/putput Resistance

R_s=470K, $R_i =$		R_o=	
$V_i =$	$V_{ib} =$	$R_L = 300K$,$V_o =$	$R_L = 1K$,$V_o =$

Chapter 8

Properties of a n-channel enhancement MOSFET

8.1 Objective

- To find the voltage-current characteristics of a n-channel enhancement MOSFET
- To evaluate different operation modes of a n-channel enhancement MOSFET

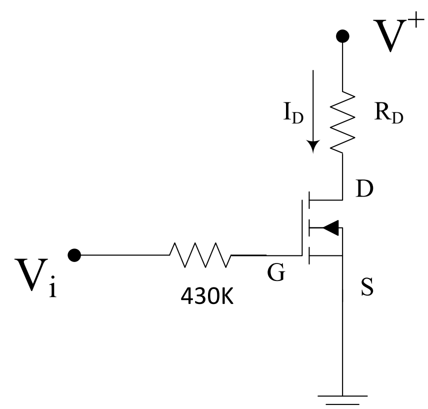

Figure 8.1: Test circuit of a N-channel enhancement MOSFET

8.2 Pre-lab Question

In Fig. 8.1, assuming $V^+ = 12$V, $R_D = 470\Omega$, $V_{TN} = 1.40$V, $K_n = 80mA/V^2$, find the relationship between V_i and V_{DS}

8.3 Experiment Material

Equipment: Digital Multi-Meter, DC power supply, Breadboard

Components: MOSFET, resistors, capacitor

8.4 Part I

Construct the circuit in Fig. 8.1 with a N-channel enhancement MOSFET (2N7000), $V^+ = 12.0$V, $R_D = 470\Omega$

- Let V_i to vary from 0 to 3.0 V in small step, measure V_{GS}, V_{DS}, fill Table 8.1, please take more measurements when V_i is in the range of 1.1-2.2V
- In final report, plot the relationship between V_{GS}, V_{DS}; plot the relationship between V_{GS} and I_D; plot the relationship between V_{GS} and $\sqrt{I_D}$, using the plot and curve interpolation technique to find V_{TN} and K_n

Table 8.1: Estimation of parameters for a MOSFET

V_i	0.5																		3.2
V_{DS}																			
V_{R_D}																			
$I_D = \frac{V_{R_D}}{R_D}$																			

8.5 Part II

Construct the circuit in Fig. 8.1 with a N-channel enhancement MOSFET (2N7000), $R_D = 470\Omega$

- When $V_i = 1.6$V, increase V^+ from 0 in small step, fill Table 8.2 , stop until V_{DS} approaches 5 V
- When $V_i = 2.0, 2.4, 2.8$V, repeat the above procedures
- In final report, plot the relationship between V_{DS} and I_D for different V_{GS}; identify the boundary points between saturation and non-saturation mode in the plot, estimate the value of V_A from the plot

Table 8.2: Transfer characteristics of a MOSFET

V_i=2.6V																		
V_+																		
V_{DS}																		
V_{R_D}																		
$I_D = \frac{V_{R_D}}{R_D}$																		
V_i=2.8V																		
V_+																		
V_{DS}																		
V_{R_D}																		
$I_D = \frac{V_{R_D}}{R_D}$																		
V_i=3.0V																		
V_+																		
V_{DS}																		
V_{R_D}																		
$I_D = \frac{V_{R_D}}{R_D}$																		
V_i=3.2V																		
V_+																		
V_{DS}																		
V_{R_D}																		
$I_D = \frac{V_{R_D}}{R_D}$																		

Chapter 9

A Common-Source Amplifier

9.1 Objective

- To measure the quiescent-point of a common-source amplifier
- To evaluate the small-signal amplification function of a common-source amplifier

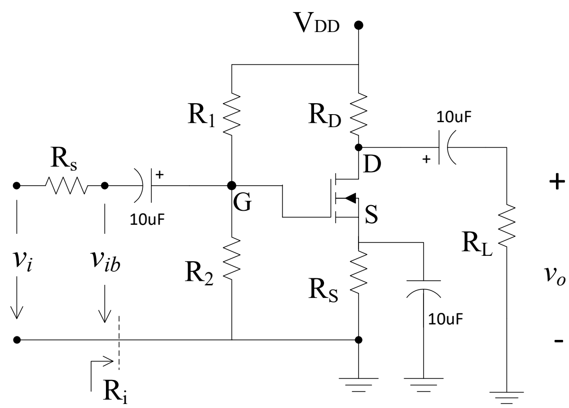

Figure 9.1: A common-source MOSFET amplifier.

9.2 Pre-lab Question

In Fig. 9.1, the model of MOSFET is 2N7000 (The parameters of 2N7000 are from last lab). $V_{DD} = 10V, R_1 = 100k\Omega, R_D = 200\Omega$, find R_2, R_S so that $I_{DQ} = 20$mA, V_{DSQ} =4V. Let $R_S = 4700\Omega$ and calculate the small-signal properties of the common-source amplifier: $A_v,\ R_i,\ R_o$

9.3 Experiment Material

Equipment: Digital Multi-Meter, DC power supply, Breadboard, Function Generator, Oscilloscope

Components: MOSFET, resistors, capacitor

9.4 Common source amplifier

Construct the circuit in Fig. 9.1 with a N-channel enhancement MOSFET (2N7000) and and $R_L =$ 300kΩ. Other components are same as the designed values in pre-lab

DC Analysis Let v_i to be zero (i.e. short it to the ground), use the digital multi-meter to verify the dc operation point $I_{DQ} = 20$mA, V_{DSQ} =4V. If the Q-point is not accurate, adjust R_2, R_S to reduce the deviation.

AC Analysis: Voltage Gain Let v_i to be a sinusoidal signal (1000 Hz, 100mV peak), make sure the output voltage is not distorted with the help of the oscilloscope and record the plot. Now use the digital multi-meter to measure the rms value of v_{ib} and v_o. Vary the input voltage amplitude to 80mV, 60mV, 40mV respectively, repeat the last step. Calculate the voltage gain $A_v = v_o/v_{ib}$ for each case above and fill Table 9.1.

AC Analysis: Input Resistance Let v_i to be a 1000 Hz sinusoidal signal with the amplitude of 100 mV, make sure the output voltage is not distorted with the help of the oscilloscope. Use the digital multi-meter to measure the rms values of v_{ib} and v_i, record the two values to calculate the input resistance R_i and fill Table 9.2.

AC Analysis: Output Resistance Let v_i to be a 1000 Hz sinusoidal signal with the amplitude of 100 mV, make sure the output voltage is not distorted with the help of the oscilloscope. Use the digital multi-meter to measure the rms values of output voltage v_o when $R_L = 300$kΩ and when $R_L = 1$kΩ respectively, record the two values to calculate the output resistance R_o and fill Table 9.2.

Table 9.1: Voltage Gain

V_{ib}				
V_o				
A_v				

Table 9.2: Input/putput Resistance

<table>
<tr><td colspan="2">R_s=470K, R_i =</td><td colspan="2">R_o=</td></tr>
<tr><td>$V_i =$</td><td>$V_{ib} =$</td><td>$R_L = 300K$,$V_o =$</td><td>$R_L = 1K$,$V_o =$</td></tr>
</table>

Chapter 10

Mathematical Circuits Using Op.Amp.

10.1 Objective

- To verify Op.Amp. circuits for addition/substraction/amplification operations
- To verify Op.Amp. circuits for differentiation/integration operations
- To verify Op.Amp. circuits for logarithm/exponentiation operations

10.2 Pre-lab Question

In Fig. 10.1,

- Find the output voltages v_o of each circuit in terms of their input voltages
- Identify the function of each circuit

10.3 Experiment Material

Equipment: Digital Multi-Meter, DC power supply, Breadboard, Function Generator, Oscilloscope

Components: LM741, resistors, capacitors, diodes

10.4 Circuit (i)-(iii)

Construct the circuits in Fig. 10.1(i)-(iii) using LM741 and resistors with the supply voltages at $\pm$12V,

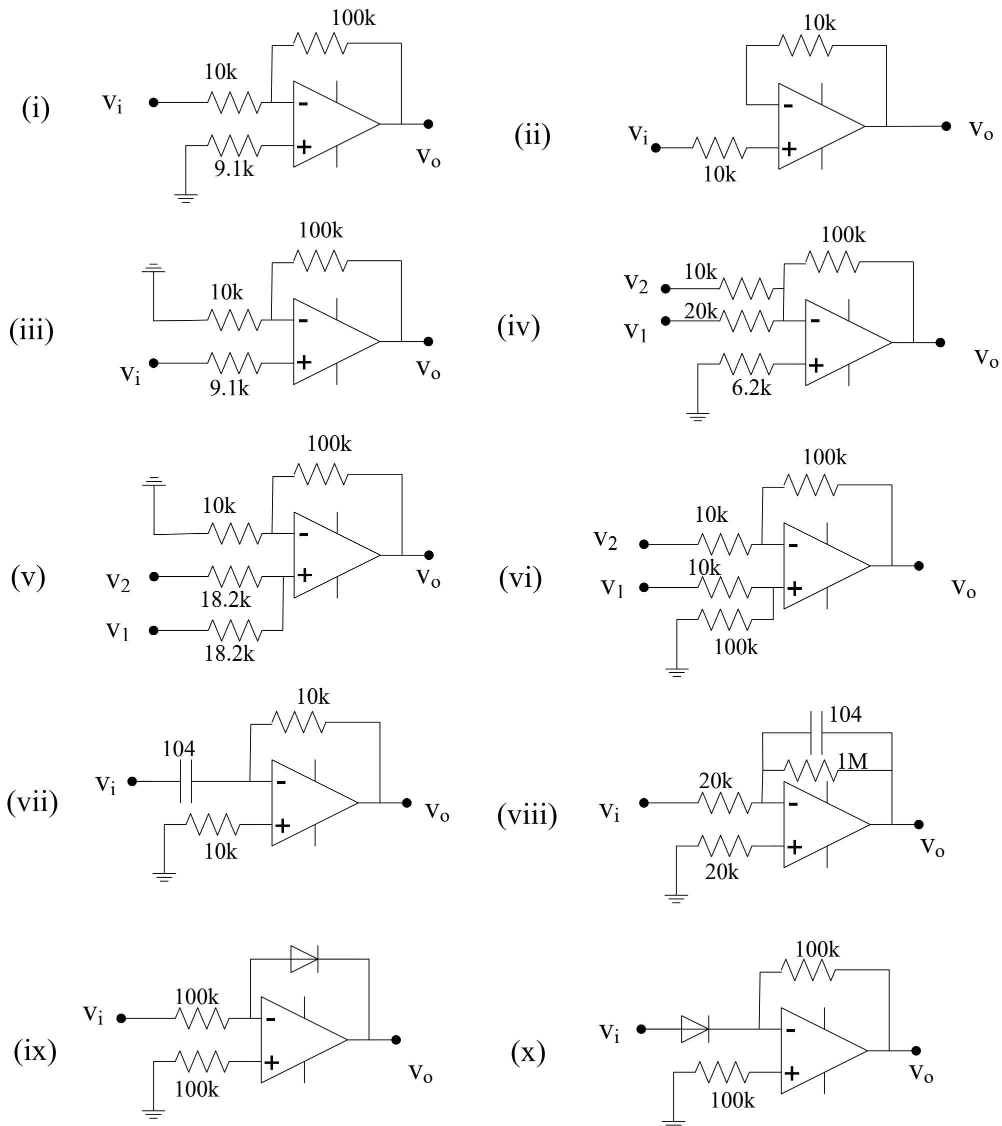

Figure 10.1: Different fundamental Op.Amp. circuits.

- Measure the output voltage v_o when v_i varies from 0.1V to 1.5 V, design your own table and record the data of both input and output
- Compare your results with the pre-lab solution and explain any difference

10.5 Circuit (iv)-(vi)

Construct the circuits in Fig. 10.1(iv)-(vi) using LM741 and resistors with the supply voltages at ±12V,

Fig. 10.1(iv): Measure the output voltage v_o, design your own table and record the data of both input and output

- when $v_1 = 0.1$V, $v_2 = 0.2$V
- when $v_1 = 0.5$V, $v_2 = 0.1$V
- when $v_1 = 0.1$V, $v_2 = 0.5$V
- when $v_1 = 1.0$V, $v_2 = 0.4$V

Fig. 10.1(v): Measure the output voltage v_o, design your own table and record the data of both input and output

- when $v_1 = 0.1$V, $v_2 = 0.2$V
- when $v_1 = 0.5$V, $v_2 = 0.3$V
- when $v_1 = 0.8$V, $v_2 = 0.5$V
- when $v_1 = 1.0$V, $v_2 = 1$V

Fig. 10.1(vi): Measure the output voltage v_o, design your own table and record the data of both input and output

- when $v_1 = 0.1$V, $v_2 = 0.4$V
- when $v_1 = 0.5$V, $v_2 = 0.1$V
- when $v_1 = 1.0$V, $v_2 = 0.4$V

10.6 Circuit (vii)-(viii)

Construct the circuits in Fig. 10.1(vii)-(viii) using LM741, capacitor and resistors with the supply voltages at ±12V,

Fig. 10.1(vii): using the oscilloscope to observe v_i and v_o simultaneously

- when v_i is a sinusoidal signal with peak value at 1V, frequency 200 Hz, find the phase angle of v_o with v_i as the reference; vary the frequency of v_i from 200 Hz to 1kHz, record the change of amplitude and phase angle of v_o and explain the reason
- when v_i is a square signal with peak value at 1V, frequency 200 Hz, explain the obtained plot

Fig. 10.1(viii): using the oscilloscope to observe v_i and v_o simultaneously

- when v_i is a sinusoidal signal with peak value at 1V, frequency 50 Hz, find the phase angle of v_o with v_i as the reference; vary the frequency of v_i from 50 Hz to 200 Hz, record the change of amplitude and phase angle of v_o and explain the reason
- when v_i is a square signal with peak value at 1V, frequency 50 Hz, explain the obtained plot

10.7 Circuit (ix)-(x)

Construct the circuits in Fig. 10.1(vii)-(viii) using LM741, 1N4148 and resistors with the supply voltages at $\pm$12V,

Fig. 10.1(ix): let v_i to be a triangular signal with peak value at 0.5V, frequency 1000 Hz, using the oscilloscope to observe v_i and v_o simultaneously, adjust the amplitude of v_i until the output v_o has a convex edge when v_i is increasing and a concave edge when v_i is decreasing

Fig. 10.1(x): let v_i to be a triangular signal with peak value at 1V, frequency 1000 Hz, using the oscilloscope to observe v_i and v_o simultaneously, adjust the amplitude of v_i until the output v_o decreases exponentially when v_i is increasing and increases exponentially when v_i is decreasing

Chapter 11

A Precise Rectifier: part I

11.1 Objective

- To verify a precise half-wave rectifier
- To design and verify a precise full-wave rectifier

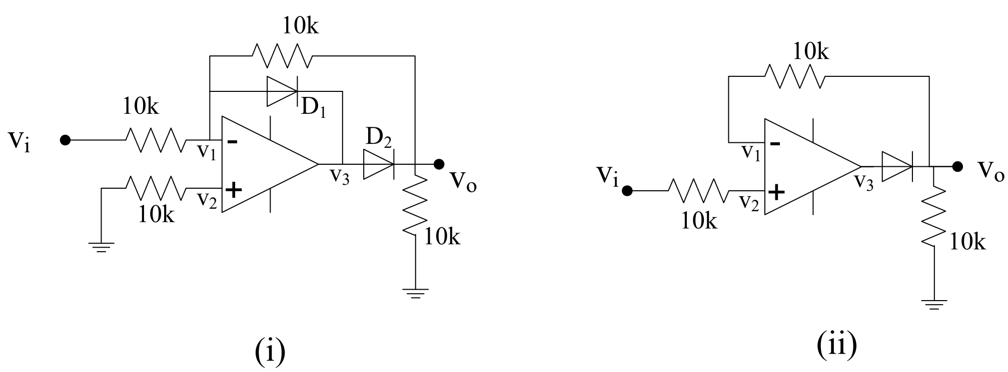

Figure 11.1: Two precise half-wave rectifiers

11.2 Pre-lab Question

In Fig. 11.1,

- Find the expressions of v_1, v_2, v_3, v_o in each circuit in terms of the input voltage and resistors when the Op.Amp is not saturated
- Find the expressions of v_1, v_2, v_3, v_o in each circuit in terms of the input voltage and resistors when the Op.Amp is saturated

11.3 Experiment Material

Equipment: Digital Multi-Meter, DC power supply, Breadboard, Function Generator, Oscilloscope

Components: Op. Amp, resistors, diodes

11.4 The 1^{st} precise half-wave rectifier

Construct the circuit in Fig. 11.1(i) using LM741, 1N4148 and resistors with the supply voltages at ±10V,

- let v_i to be a sinusoidal signal with a fixed frequency of 50 Hz, adjust the amplitude of v_i from 0.1 V to 5 V and use the oscilloscope to observe v_i and v_o simultaneously, record the plots and explain what you see
- let v_i to be a dc voltage signal with amplitude at -10V, -5 V, -1V, 1V, 5 V and 10 V respectively, use the multi-meter to measure v_i, v_1, v_2, v_3, v_o for each case, compare the results with the pre-lab solutions

11.5 The 2^{nd} precise half-wave rectifier

Construct the circuit in Fig. 11.1(ii) using LM741, 1N4148 and resistors with the supply voltages at ±10V,

- let v_i to be a sinusoidal signal with a fixed frequency of 50 Hz, adjust the amplitude of v_i from 0.1 V to 5 V and use the oscilloscope to observe v_i and v_o simultaneously, record the plots and explain what you see
- let v_i to be a dc voltage signal with amplitude at -10V, -5 V, -1V, 1V, 5 V and 10 V respectively, use the multi-meter to measure v_i, v_1, v_2, v_3, v_o for each case, compare the results with the pre-lab solutions

Chapter 12

A Precise Rectifier: part II

12.1 Objective

- To verify two different precise full-wave rectifiers

12.2 Pre-lab Question

In Fig. 12.1,

- Find the expressions of v_1, v_2, v_3, v_4, v_5, v_o in each circuit in terms of the input voltage and resistors when the Op.Amp is not saturated
- Find the expressions of v_1, v_2, v_3, v_4, v_5, v_o in each circuit in terms of the input voltage and resistors when the Op.Amp is saturated

12.3 Experiment Material

Equipment: Digital Multi-Meter, DC power supply, Breadboard, Function Generator, Oscilloscope

Components: Op. Amp, resistors, diodes

12.4 The 1^{st} precise full-wave rectifier

Construct the circuit in Fig. 12.1(i) using LM741, 1N4148 and resistors with the supply voltages at ±10V,

- let v_i to be a sinusoidal signal with a fixed frequency of 200 Hz, adjust the amplitude of v_i from 0.1 V to 5 V and use the oscilloscope to observe v_i and v_o simultaneously, record the plots and explain what you see

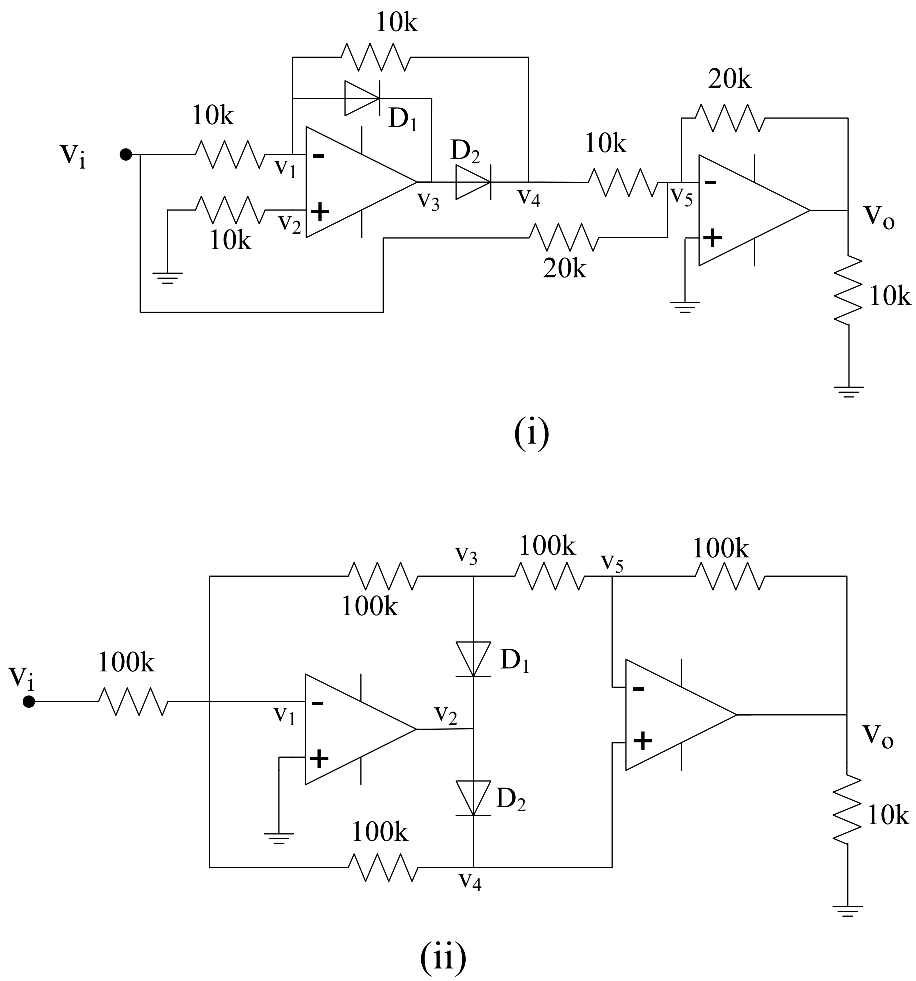

Figure 12.1: Two precise full-wave rectifiers.

- let v_i to be a dc voltage signal with amplitude at -12V, -5 V, -1V, 1V, 5 V and 12 V respectively, use the multi-meter to measure v_i, v_1, v_2, v_3, v_4, v_5, v_o for each case, compare the results with the pre-lab solutions

12.5 The 2^{nd} precise full-wave rectifier

Construct the circuit in Fig. 12.1(ii) using LM741, 1N4148 and resistors with the supply voltages at $\pm$10V,

- let v_i to be a sinusoidal signal with a fixed frequency of 200 Hz, adjust the amplitude of v_i from 0.1 V to 5 V and use the oscilloscope to observe v_i and v_o simultaneously, record the plots and explain what you see
- let v_i to be a dc voltage signal with amplitude at -12V, -5 V, -1V, 1V, 5 V and 12 V respectively, use the multi-meter to measure v_i, v_1, v_2, v_3, v_4, v_5, v_o for each case, compare the results with the pre-lab solutions

Chapter 13

Design Question: A precise full-wave rectifier

13.1 Objective

- To design a op-amp based precise full-wave rectifier

13.2 Requirements

Based on the circuit in Fig. 11.1, design a full-wave rectifier and construct it using LM741, 1N4148 and resistors with the supply voltages at ±10V,

- The designed circuit can not be same as any of Fig. 12.1.
- Explain the principle of the designed circuit, build and verify the function of the circuit in the lab