Islamic University of Gaza

Faculty of Engineering

Electrical Engineering Department

Power Electronics Laboratory Manual

February 2019

This manual was developed by:

Dr. Moayed Naser Almobaied – Supervisor
Mohammed Sameer Lubbad – Author
Israa Hamdi Abu Rayya – Author

CONTENTS

What is the Power Electronics Laboratory?

Power Electronics is the technology behind switching power supplies, power converters, power inverters, motor drives, and motor soft starters. In this laboratory, the fundamental of power electronics will be illustrated in practice. You will be building different kinds of circuits in order to convert between AC and DC. You are expected to apply the theoretical principle you learn in lectures, validate them by simulation using LTspice software and finally build them by yourself. Get ready for a great journey with power electronics laboratory!

Experiment 1: Introduction to Power Electronics Laboratory

1. Objectives

Through this laboratory, you will be involved in practical experiments that apply theoretical principles in power electronics theoretical classes. After this laboratory, you will be expected:

1. To be familiar with electronic components: their types, functionality, how to measure and test:
    - Passive components: resistors, inductors and capacitors.
    - Semiconductor components: diodes, transistors, thyristors, TRIACs, and DIACs.

2. To be familiar with lab instruments and its functions:
    - Voltage Source.
    - Function Generator.
    - LCR meter.
    - Digital Multimeter.
    - Oscilloscope.
    - Breadboard Kits.
    - Three-Phase units.

3. To be familiar with LTspice simulation software and be able to use different types of simulations:
    - Evaluate User-Defined Electrical Quantities.
    - Parameter Sweeps.
    - Do a Transient Analysis.
    - Compute a Fourier Component.

4. To be able to search in references and share knowledge in Prelab discussions.

2. Experiment

1. Measure the value of a resistor using DMM.
2. Measure the value of an inductor using LCR meter.
3. Measure the value of a capacitor using LCR meter.
4. Test the connectivity of wire.
5. Test a diode.
6. Test an NPN transistor.
7. Test a MOSFET.
8. Use the function generator (2 channels, types of an output signal, amplitude change, duty cycle change and frequency).
9. Use the oscilloscope:
    a. Save the graph into USB.

b. Measure frequency, RMS and DC of signal.

- ✓ Note I: The format of USB device should be FAT32.
- ✓ Note II: The ground is common ground for all channels.

10. LTspice: Draw a simple circuit then simulate it
    a. Obtain transient response
    b. Measure RMS, Average voltage, Current, and Power

Prelab 1: Diodes

I. Answer these questions indicating its reference:

1. Describe the function of each of the following diodes, sketch their I-V characteristic, and one practical application of each:
    a. Rectifier Diode.
    b. Light-Emitting Diode.
    c. Zener Diode.
    d. Schottky Diode.
2. Search for a type which is not listed above and do the previous task with it.
3. What is the reverse recovery time? Sketch its characteristic. Why it is occurred? What factors affect it?
4. How sharing reverse voltage is used? And why?
5. How sharing forward current is used? And why?

II. Do the following simulations:

Part I: I-V Characteristics:

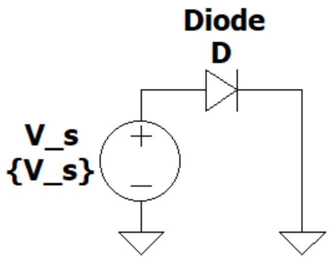

Figure 1.1 I-V Characteristics

1. Connect the Circuit as shown in Figure 1.1.
2. Obtain the I-V characteristics of the rectifier, light-emitting, Zener and Schottky diodes, using parameter sweep.

LTspice Hint: Use .STEP PARAM V_s -10 10 0.1

Part II: Reverse Recovery Time:

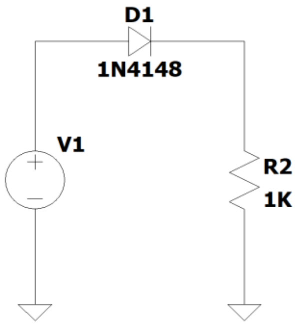

Figure 1.2 Reverse Recovery Time

1. Connect the Circuit as shown in Figure 1.2.
2. Obtain the reverse recovery time characteristic using square voltage source at 1KHz and 100KHz.

Part III: Series Revers Bias Diodes:

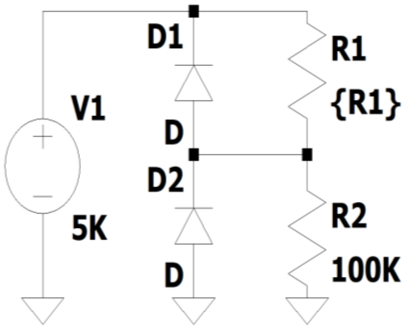

Figure 1.3 Series Revers Bias Diodes

1. Connect the Circuit as shown in Figure 1.3.
2. Obtain the sharing reverse voltage between two diodes due to change of R1 in Table 1.1.

Table 1.1 Sharing Reverse Voltage Diodes

R1(KΩ)	$V_{D1}(V)$	$V_{D2}(V)$
1		
4.7		
10		
100		
200		

Part IV: Parallel Forward Bias Diodes:

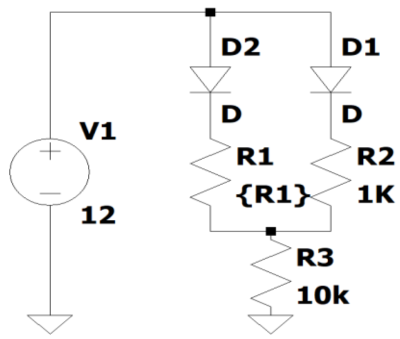

Figure 1.4 Parallel Forward Bias Diodes

1. Connect the Circuit as shown in Figure 1.4.
2. Obtain the sharing forward current between two diodes due to change of R1 in Table 1.2.

Table 1.2 Sharing Forward current Diodes

R1(KΩ)	$I_{D1}(mA)$	$I_{D2}(mA)$
1		
4.7		
10		
100		
200		

Experiments2:Diodes

1. Objectives

- To obtain the VI Characteristic of rectifier diode.
- To obtain the reverse recovery response.
- To obtain sharing reverse voltage and forward currents.

2. Experiment

Part I: I-V Characteristics:

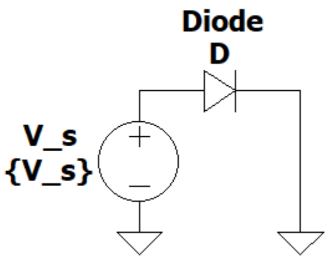

Figure 2.1 I-V Characteristics

1. Connect the Circuit as shown in Figure 2.1.
2. Measure the Currents for the following diodes, then Sketch the I-V characteristics:
   a. Rectifier Diode in Table 2.1.
   b. Light-Emitting Diode in Table 2.2.
   c. Zener Diode in Table 2.3.
   d. Schottky diode in Table 2.4.

Table 2.1 Current versus voltage using DC voltage source for Rectifier Diode

$V_S(V)$	-5	-3	0	0.1	0.2	0.3	0.5	0.6	0.65	0.7	0.8	0.9	1
$I_{DC}(mA)$													

Table 2.2 Current versus voltage using DC voltage source for Light-Emitting Diode

$V_S(V)$	-5	-3	0	0.1	0.2	0.3	0.5	0.6	0.65	0.7	0.8	0.9	1
$I_{DC}(mA)$													

Table 2.3 Current versus voltage using DC voltage source for Zener Diode

$V_S(V)$	-5	-3	0	0.1	0.2	0.3	0.5	0.6	0.65	0.7	0.8	0.9	1
$I_{DC}(mA)$													

Table 2.4 Current versus voltage using DC voltage source for Schottky Diode

$V_S(V)$	-10	-5	-3	0	0.1	0.3	0.5	0.6	0.65	0.7	0.8	0.9	1
$I_{DC}(mA)$													

<u>Part II: Reverse Recovery Time:</u>

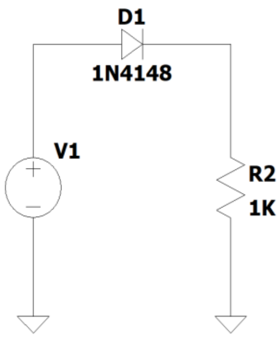

Figure 2.2 Reverse Recovery Time

1. Connect the Circuit as shown in Figure 2.2.
2. Obtain the reverse recovery time characteristic using square voltage source at 1KHz and 100KHz.

<u>Part III: Series Revers Bias Diodes:</u>

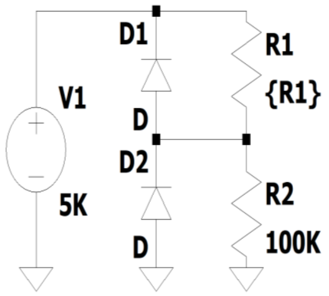

Figure 2.3 Series Revers Bias Diodes

1. Connect the Circuit as shown in Figure 2.3.
2. Measure the sharing reverse voltage between two diodes due to change of R1 in Table 2.5.

Table 2.5 Sharing Reverse Voltage Diodes

R1(KΩ)	$V_{D1}(V)$	$V_{D2}(V)$
1		
4.7		
10		
100		
200		

<u>Part IV: Parallel Forward Bias Diodes:</u>

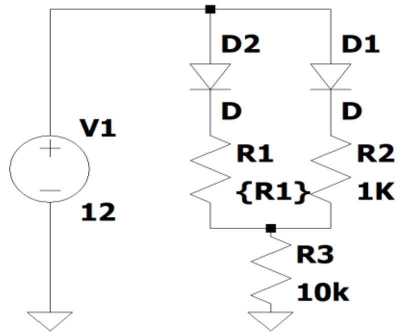

Figure 2.4 Parallel Forward Bias Diodes

1. Connect the Circuit as shown in Figure 2.4.
2. Measure the sharing forward current between two diodes due to change of R1 in Table 2.6.

Table 2.6 Sharing Forward current Diodes

R1(KΩ)	$I_{D1}(mA)$	$I_{D2}(mA)$
1		
4.7		
10		
100		
200		

3. Comments

In your own words, describe how results differ between theoretical expectation, simulation and practical results in each section.

Prelab 2: Uncontrolled Half-wave Rectifier

I. Answer these questions indicating its reference:

1. For half-wave rectifier with a purely resistive load, what is the DC component of the output?
2. For half-wave rectifier with a purely resistive load, what are the Fourier components of the output?
3. What is the effect of changing the capacitive load on the DC component of the output?
4. What is the effect of changing the inductive load on the DC component of the output? why?
5. How can the negative output of inductive load half-wave rectifier be eliminated?

II. Do the following simulations:

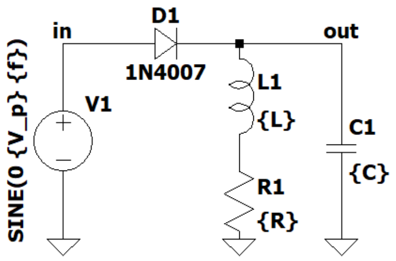

Figure2.1 Half Wave Rectifier with different loads

1. Connect the Circuit as shown in Figure 2.1.
2. Obtain the output for a resistive load, V_{rms} ,and its Fourier components.

LTspice Hint:
.step oct param R 1 100K 1
.param L=1p C=1p V_p=10 f=1K
.tran {10/f}
.four {f} V(out)
.four {f} V(in)

3. Obtain the output for a capacitive load, V_{rms} , and its Fourier components.
4. Obtain the output for an inductive load, V_{rms} , and its Fourier components.
5. Repeat 3 with replacing capacitor by freewheeling diode as shown in Figure 2.2, then obtain the output, V_{rms} ,and its Fourier components.

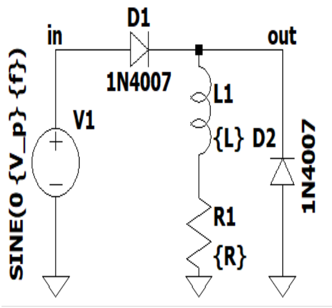

Figure2.2 Half Wave Rectifier with freewheeling diode

Experiment3: Uncotrolled Half-wave Rectifier

1. Objectives

- To build a half-wave rectifier.
- To obtain the effect of change load on the output: DC and its Fourier components.
- To obtain a half-wave rectifier flywheel diode.

2. Experiment

Part I: HWR with resistive load

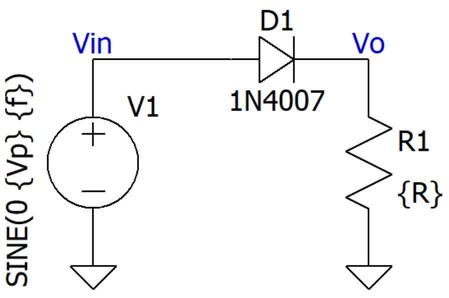

Figure 3.1 HWR with resistive load

1. Connect the Circuit as shown in Figure 3.1.
2. Put $V_P = 10$, and f=1KHz.
3. Measure the output voltage at R=1KΩ.
4. Measure the V_{DC} ,and V_{rms} for output voltage in Table 3.1.
5. Measure the FFT for output voltage.
6. Repeat step 2,3, and 4
    a. R=4.7KΩ.
    b. R=10KΩ.

Table 3.1 average, and effective output voltage

R(KΩ)	V_{DC}(V)	$V_{rms}(V)$
1		
4.7		
10		

Part II: HWR with capacitive load

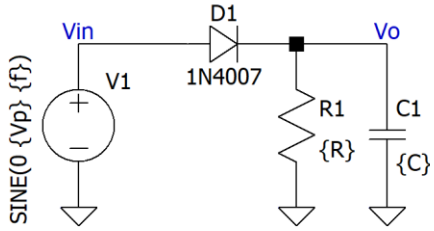

Figure 3.2 HWR with capacitive load

1. Connect the Circuit as shown in Figure 3.2.
2. Put $V_P = 10$, and f=1KHz.
3. Measure the output voltage.
4. Measure the V_{DC} ,and V_{rms} for output voltage in Table 3.2.
5. Measure the FFT for output voltage.

Table 3.2 average, and effective output voltage

R(KΩ), C(nF)	V_{DC}(V)	$V_{rms}(V)$
1,1		
4.7,1		
10,1		
1,10		
4.7,10		
10,10		
1,100		
4.7,100		
10,100		

Part III: HWR with inductive load

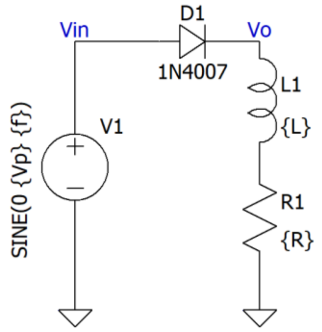

Figure 3.3 HWR with inductive load

1. Connect the Circuit as shown in Figure 3.3.
2. Put $V_P = 10$, and f=1KHz.
3. Measure the output voltage.
4. Measure the V_{DC} ,and V_{rms} for output voltage in Table 3.3.
5. Measure the FFT for output voltage.

Table 3.3 average, and effective output voltage

R(KΩ), L(mH)	V_{DC}(V)	$V_{rms}(V)$
1,1		
4.7,1		
10,1		
1,10		
4.7,10		
10,10		
1,100		
4.7,100		
10,100		

Part IV: HWR with freewheeling diode

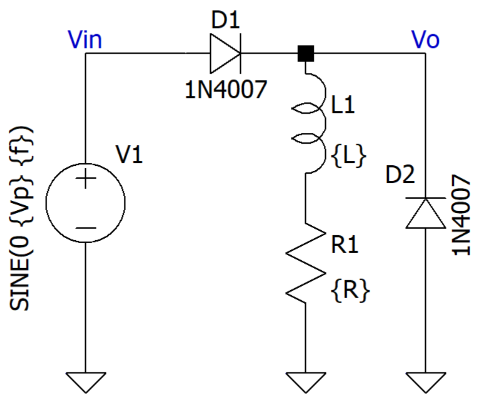

Figure 3.4HWR with freewheeling diode

1. Connect the Circuit as shown in Figure 3.4.
2. Put $V_P = 10$, and f=1KHz.
3. Measure the output voltage.
4. Measure the V_{DC} ,and V_{rms} for output voltage in Table 3.4.
5. Measure the FFT for output voltage.

Table 3.4 average, and effective output voltage

R(KΩ), L(mH)	V_{DC}(V)	$V_{rms}(V)$
1,1		
4.7,1		
10,1		
1,10		
4.7,10		
10,10		
1,100		
4.7,100		
10,100		

3. Comments

In your own words, describe how results differ between theoretical expectation, simulation and practical results in each section.

Prelab 3: Uncontrolled Full-wave Rectifier

I. Answer these questions indicating its reference:

1. For a full-wave rectifier with a purely resistive load, what is the DC component of the output?
2. For a full-wave rectifier with a purely resistive load, what are the Fourier components of the output?
3. What is the effect of changing the capacitive load on the DC component of the output?
4. What is the effect of changing the inductive load on the DC component of the output? why?
5. What is the difference between half-wave rectifier and full-wave rectifier?

2. Do the following simulations:

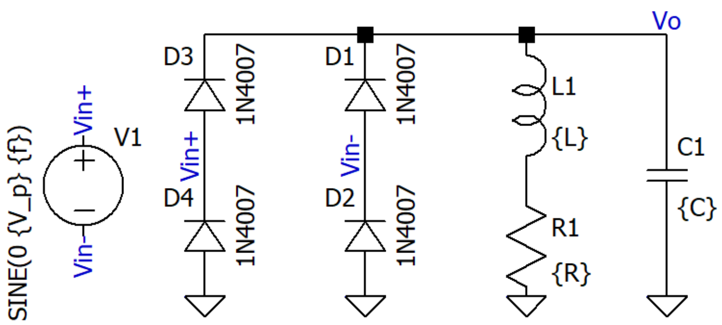

Figure3.1 Full Wave Rectifier with different loads

1. Connect the Circuit as shown in Figure 3.1.
2. Obtain the output for a resistive load, V_{rms} , and its Fourier components.
3. Obtain the output for a capacitive load, V_{rms} , and its Fourier components.
4. Obtain the output for an inductive load, V_{rms} , and its Fourier components.

Experiment4: Uncotrolled Full-wave Rectifier

1. Objectives

- To build a full-wave rectifier
- To obtain the effect of change load on the output: DC and its Fourier components

2. Experiment

Part I: FWR with resistive load

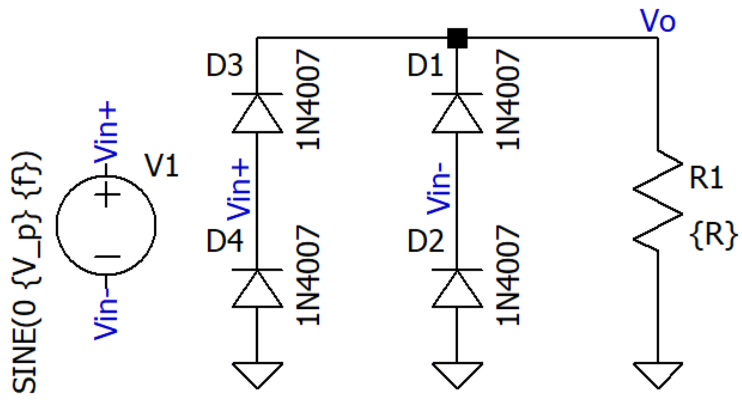

Figure 4.1 FWR with resistive load

1. Connect the Circuit as shown in Figure 4.1.
2. Put $V_P = 10$, and f=1KHz.
3. Measure the output voltage at R=1KΩ.
4. Measure the V_{DC} ,and V_{rms} for output voltage in Table 3.1.
5. Measure the FFT for output voltage.
6. Repeat step 2,3, and 4
   c. R=4.7KΩ.
   d. R=10KΩ.

Table 4.1 average, and effective output voltage

R(KΩ)	V_{DC}(V)	$V_{rms}(V)$
1		
4.7		
10		

<u>Part II: FWR with capacitive load</u>

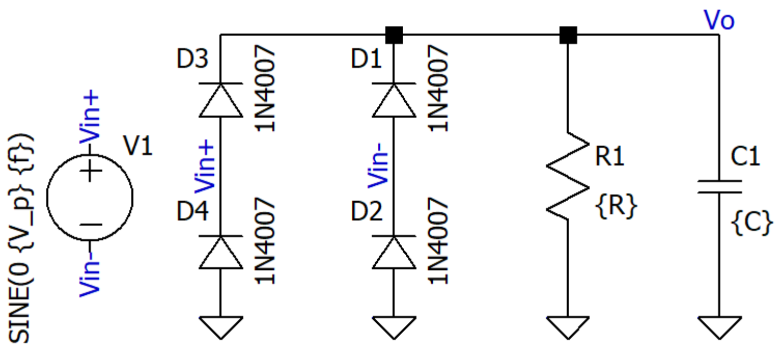

Figure 4.2 FWR with capacitive load

1. Connect the Circuit as shown in Figure 4.2.
2. Put $V_P = 10$, and f=1KHz.
3. Measure the output voltage.
4. Measure the V_{DC} ,and V_{rms} for output voltage in Table 4.2.
5. Measure the FFT for output voltage.

Table 4.2 average, and effective output voltage

R(KΩ), C(nF)	V_{DC}(V)	$V_{rms}(V)$
1,1		
4.7,1		
10,1		
1,10		
4.7,10		
10,10		
1,100		
4.7,100		
10,100		

Part III: FWR with inductive load

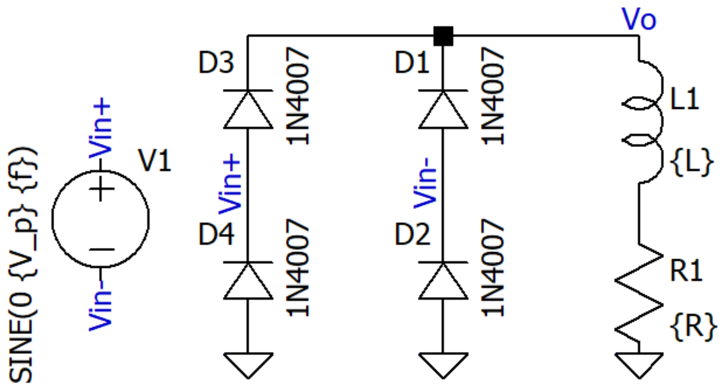

Figure 4.3 FWR with inductive load

1. Connect the Circuit as shown in Figure 4.3.
2. Put $V_P = 10$, and f=1KHz.
3. Measure the output voltage.
4. Measure the V_{DC} ,and V_{rms} for output voltage in Table 3.3.
5. Measure the FFT for output voltage.

Table .43 average, and effective output voltage

R(KΩ), L(mH)	V_{DC}(V)	$V_{rms}(V)$
1,1		
4.7,1		
10,1		
1,10		
4.7,10		
10,10		
1,100		
4.7,100		
10,100		

3. Comments

In your own words, describe how results differ between theoretical expectation, simulation and practical results in each section.

Prelab 4: Uncontrolled 3-Phase Full-wave Rectifier

I. Answer these questions indicating its reference:

1. Why we use the three-phase rectifiers?
2. If the three-phase voltage source has sequence a-c-b. Is the output voltage affected or not?
3. The maximum output voltage is equal the maximum phase voltage or line voltage?
4. What is the relationship between the fundamental frequency of the output voltage and the frequency of the three-phase source?
5. What is the fundamental frequency of the output voltage if you have twelve-phase source?

II. Do the following simulations:

Part I: 3-Phase voltage Sources

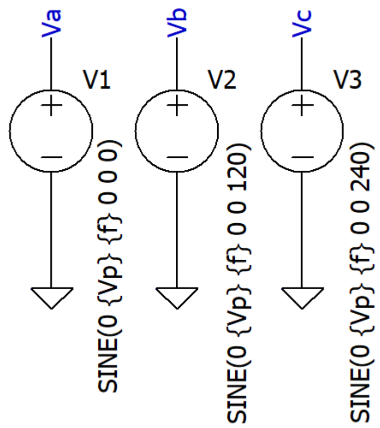

Figure 4.1 3-Phase Source

1. Connect the circuit as shown in Figure 4.1 in LT-spice Program.
2. Put V_p=15v, and f=50Hz.
3. Measure the three-phase voltages $V_a, V_b, and\ V_c$.

> LTspice Hint: .TRAN is used for perform a nonlinear transient analysis.

4. Measure the three-line voltages $V_{ab}, V_{bc}, and\ V_{ca}$.
5. For each phase voltages measure the V_{DC},and V_{rms} values in Table 4.1.

> LTspice Hint: .MEAS is used for evaluate user-defined electrical quantities.

6. For each line voltages measure the V_{DC},and V_{rms} values in Table 4.2.
7. Measure the fourier component for $V_{ab}, V_{bc}, and\ V_{ca}$.

> LTspice Hint: .FOUR is used for compute Fourier component.

8. Measure the FFT for $V_a, V_b, and\ V_c$.
9. Measure the FFT for $V_{ab}, V_{bc}, and\ V_{ca}$.

Table 4.1 average, and effective values for phase voltages

Phase Voltage	$V_{DC}(V)$	$V_{rms}(V)$
V_a		
V_b		
V_c		

Table 4.2 average, and effective values for line voltages

Line Voltage	V_{DC}(V)	$V_{rms}(V)$
V_{ab}		
V_{bc}		
V_{ca}		

Part II: Uncontrolled 3-Phase full wave rectifier with resistive load

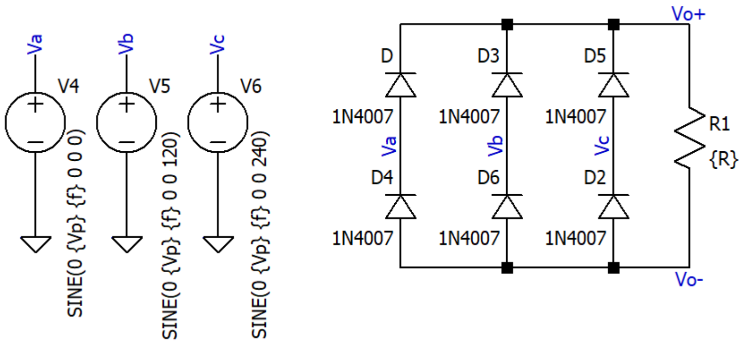

Figure 4.2 Uncontrolled 3-Phase full wave rectifier with resistive load

1. Connect the circuit as shown in Figure 4.2 in LT-spice Program.
2. Put V_p=15v, and f=50Hz.
3. Add the LT-spice Model for the diode $1N4007$.
4. Measure the output voltage at R=1KΩ.
5. Measure the following values for the output voltage in Table 4.3.
    a. Peak Value.
    b. Frequency.
    c. V_{DC}.
    d. V_{rms}.
6. Measure the fourier component for the output voltage.
7. Measure the FFT for the output voltage.

Table 4.3 average, and effective values for phase voltages

$R(K\Omega)$	$V_P(V)$	$f\,(HZ)$	$V_{DC}(V)$	$V_{rms}(V)$
1				

Part III: Uncontrolled 3-Phase full wave rectifier with inductive load

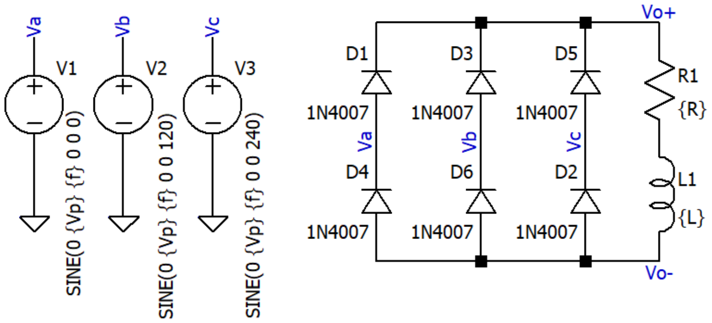

Figure 4.3 Uncontrolled 3-Phase full wave rectifier with inductive load

1. Connect the circuit as shown in Figure 4.3 in LT-spice Program.
2. Put V_p=15v, and f=50Hz.
3. Add the LT-spice Model for the diode $1N4007$.
4. Measure the output voltage at R=1KΩ, and L=1mH.
5. Measure the following values for the output voltage in Table 4.4.
   a. Peak Value.
   b. Frequency.
   c. V_{DC}.
   d. V_{rms}.
6. Measure the fourier component for the output voltage.
7. Measure the FFT for the output voltage.

Table 4.4 average, and effective values for phase voltages

$R(K\Omega),\,L(mH)$	$V_P(V)$	$f\,(HZ)$	$V_{DC}(V)$	$V_{rms}(V)$
1,1				

Part IV: Uncontrolled 3-Phase full wave rectifier with capacitive load

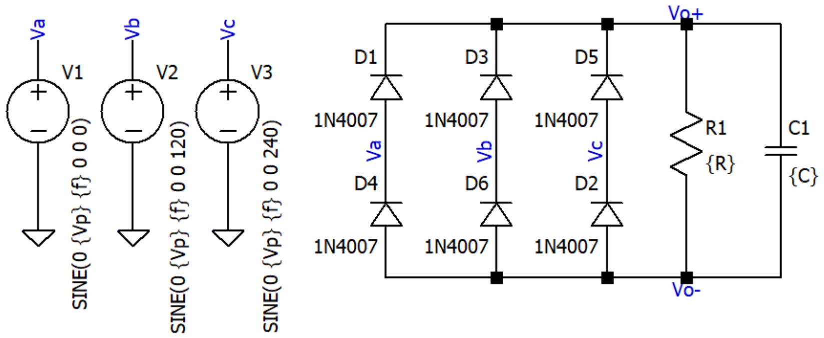

Figure 4.4 Uncontrolled 3-Phase full wave rectifier with capacitive load

1. Connect the circuit as shown in Figure 4.4 in LT-spice Program.
2. Put V_p=15v, and f=50Hz.
3. Add the LT-spice Model for the diode $1N4007$.
4. Measure the output voltage at R=1KΩ, and C=10nF.
5. Measure the following values for the output voltage in Table 4.5.
    a. Peak Value.
    b. Frequency.
    c. V_{DC}.
    d. V_{rms}.
6. Measure the Fourier component for the output voltage.
7. Measure the FFT for the output voltage.

Table 4.5 average, and effective values for phase voltages

$R(K\Omega)$, $C(nF)$	$V_P(V)$	$f\,(HZ)$	$V_{DC}(V)$	$V_{rms}(V)$
1,10				

Experiment 5: Uncontrolled 3-Phase Full-wave Rectifier

1. Objectives

To be familiar Uncontrolled 3-Phase Full Wave Rectifier with different loads.

2. Experiment

Part I: 3-Phase voltage Sources

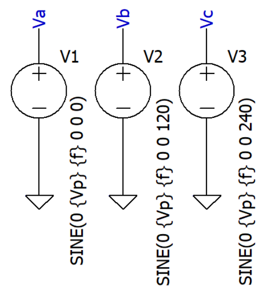

Figure 5.1 3-Phase Source

1. Connect the circuit as shown in Figure 5.1.
2. Put V_p=15v, and f=50Hz.
3. Measure the three-phase voltages $V_a, V_b, and\ V_c$.
4. Measure the three-line voltages $V_{ab}, V_{bc}, and\ V_{ca}$.
5. For each phase voltages measure the V_{DC},and V_{rms} values in Table 5.1.
6. For each line voltages measure the V_{DC},and V_{rms} values in Table 5.2.
7. Measure the Fourier component for $V_{ab}, V_{bc}, and\ V_{ca}$.
8. Measure the FFT for $V_a, V_b, and\ V_c$.
9. Measure the FFT for $V_{ab}, V_{bc}, and\ V_{ca}$.

Table 5.1 average, and effective values for phase voltages

Phase Voltage	$V_{DC}(V)$	$V_{rms}(V)$
V_a		
V_b		
V_c		

Table 5.2 average, and effective values for line voltages

Line Voltage	V_{DC}(V)	$V_{rms}(V)$
V_{ab}		
V_{bc}		
V_{ca}		

Part II: Uncontrolled 3-Phase full wave rectifier with resistive load

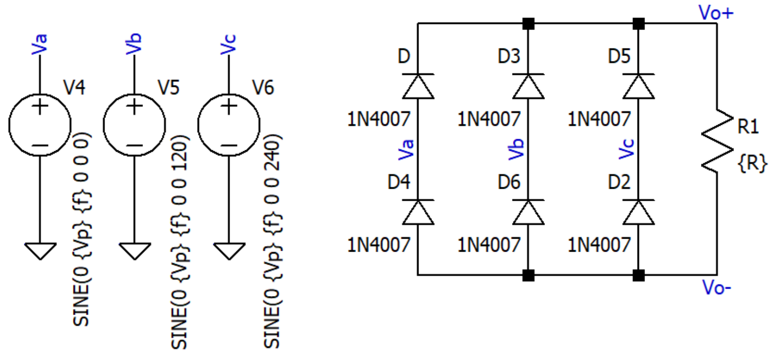

Figure 5.2 Uncontrolled 3-Phase full wave rectifier with resistive load

1. Connect the circuit as shown in Figure 5.2.
2. Put V_p=15v, and f=50Hz.
3. Measure the output voltage at R=1KΩ.
4. Measure the following values for the output voltage in Table 5.3.
   a. Peak Value.
   b. Frequency.
   c. V_{DC}.
   d. V_{rms}.
5. Measure the Fourier component for the output voltage.
6. Measure the FFT for the output voltage.

Table 5.3 average, and effective values for phase voltages

$R(K\Omega)$	$V_P(V)$	$f\,(HZ)$	$V_{DC}(V)$	$V_{rms}(V)$
1				

Part III: Uncontrolled 3-Phase full wave rectifier with inductive load

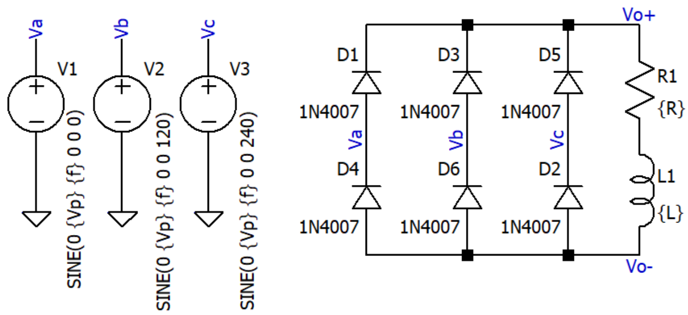

Figure 5. 3Uncontrolled 3-Phase full wave rectifier with inductive load

1. Connect the circuit as shown in Figure 5.3.
2. Put V_p=15v, and f=50Hz.
3. Measure the output voltage at R=1KΩ, and L=1mH.

4. Measure the following values for the output voltage in Table 5.4.
    a. Peak Value.
    b. Frequency.
    c. V_{DC}.
    d. V_{rms}.
5. Measure the Fourier component for the output voltage.
6. Measure the FFT for the output voltage.

Table 5.4 average, and effective values for phase voltages

$R(K\Omega)$, $L(mH)$	$V_P(V)$	$f\,(HZ)$	$V_{DC}(V)$	$V_{rms}(V)$
1,1				

Part IV: Uncontrolled 3-Phase full wave rectifier with capacitive load

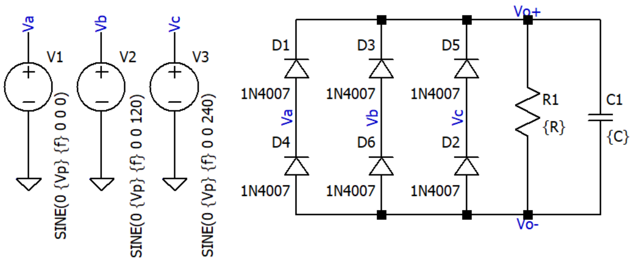

Figure 5. 4Uncontrolled 3-Phase full wave rectifier with capacitive load

1. Connect the circuit as shown in Figure 5.4.
2. Put V_p=15v, and f=50Hz.
3. Measure the output voltage at R=1KΩ, and C=10nF.
4. Measure the following values for the output voltage in Table 5.5.
    a. Peak Value.
    b. Frequency.
    c. V_{DC}.
    d. V_{rms}.
5. Measure the Fourier component for the output voltage.
6. Measure the FFT for the output voltage.

Table 5.5 average, and effective values for phase voltages

$R(K\Omega)$, $C(nF)$	$V_P(V)$	$f\,(HZ)$	$V_{DC}(V)$	$V_{rms}(V)$
1,10				

3. Comments

In your own words, describe how results differ between theoretical expectation, simulation and practical results in each section.

Prelab 5: DC-DC Converter

I. Answer these questions indicating its reference:

1. What is the difference between the line voltage regulator and DC-DC converter?
2. For Buck and Boost converter, what is the effect if you change the duty cycle, frequency, resistance, inductance, and capacitance on
   a. Output Voltage
   b. Input Power.
   c. Output Power.
   d. Efficiency.
3. Search for other types of DC-DC converter and what their uses.

II. Do the following simulations:

<u>Part I: Buck Converter</u>

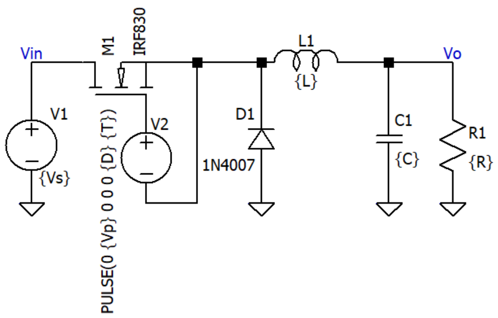

Figure 5.1 Buck Converter

1. Connect the circuit as shown in Figure 5.1.
2. Add the LT-spice Model for the MOSFET $IRF830$.
3. Measure the following values at different values of duty cycle in Table 5.1.
   a. Output Voltage
   b. Input Power.
   c. Output Power.
   d. Efficiency.

> LTspice Hint: .STEP is used for parameter sweep.

> LTspice Hint: .MEAS is used for evaluate user-defined electrical quantities.

4. Repeat step 3 at different values of resistance in Table 5.2.
5. Repeat step 3 at different values of inductance in Table 5.3.
6. Repeat step 3 at different values of capacitance in Table 5.4.
7. Repeat step 3 at different values of frequencies in Table 5.5.

Table 5.1 Readings at different duty cycle

$V_S = 5v, V_P = 10v, f = 1kHz, L = 1mH, C = 1nF, and\ R = 1k\Omega$				
$D\ (\%)$	$V_o(V)$	$P_{in}(W)$	$P_o(W)$	η
0				
10				
20				
30				
40				
50				
60				
70				
80				
90				
100				

Table 5.2 Readings at different resistance

$V_S = 5v, V_p = 10v, D = 50\%, f = 1kHz, L = 1mH, and\ C = 1nF$				
$R\ (K\Omega)$	$V_o(V)$	$P_{in}(W)$	$P_o(W)$	η
1				
4.7				
10				

Table 5.3 Readings at different inductance

$V_S = 5v, V_p = 10v, D = 50\%, f = 1kHz, C = 1nF, and\ R = 1k\Omega$				
$L\ (mH)$	$V_o(V)$	$P_{in}(W)$	$P_o(W)$	η
0				
10				
20				

Table 5.4 Readings at different capacitance

$V_S = 5v, V_p = 10v, D = 50\%, f = 1kHz, L = 1mH, and\ R = 1k\Omega$				
$C\ (nF)$	$V_o(V)$	$P_{in}(W)$	$P_o(W)$	η
1				
10				
100				

Table 5.5 Readings at different frequencies

$V_S = 5v, V_p = 10v, D = 50\%, L = 1mH, C = 1nF, and\ R = 1k\Omega$				
$f\ (KHz)$	$V_o(V)$	$P_{in}(W)$	$P_o(W)$	η
1				
10				
100				

Part II: Boost Converter

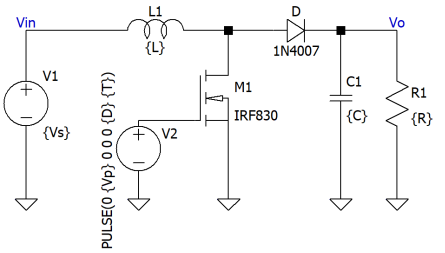

Figure 5.2 Boost Converter

1. Connect the circuit as shown in Figure 5.2.
2. Add the LT-spice Model for the MOSFET $IRF830$
3. Measure the following values at different values of duty cycle in Table 6.6.
   a. Output Voltage
   b. Input Power.
   c. Output Power.
   d. Efficiency.

   > LTspice Hint: .STEP is used for parameter sweep.

   > LTspice Hint: .MEAS is used for evaluate user-defined electrical quantities.

4. Repeat step 3 at different values of resistance in Table 5.7.
5. Repeat step 3 at different values of inductance in Table 5.8.
6. Repeat step 3 at different values of capacitance in Table 5.9.
7. Repeat step 3 at different values of frequencies in Table 5.10.

Table 5.6 Readings at different duty cycle

$V_S = 5v, V_P = 10v, f = 1kHz, L = 1mH, C = 1nF, and\ R = 1k\Omega$				
$D\ (\%)$	$V_o(V)$	$P_{in}(W)$	$P_o(W)$	η
0				
10				
20				
30				
40				
50				
60				
70				
80				
90				
100				

Table 5.7 Readings at different resistance

$V_S = 5v, V_p = 10v, D = 50\%, f = 1kHz, L = 1mH, and\ C = 1nF$				
$R\ (K\Omega)$	$V_o(V)$	$P_{in}(W)$	$P_o(W)$	η
1				
4.7				
10				

Table 5.8 Readings at different inductance

$V_S = 5v, V_p = 10v, D = 50\%, f = 1kHz, C = 1nF, and\ R = 1k\Omega$				
$L\ (mH)$	$V_o(V)$	$P_{in}(W)$	$P_o(W)$	η
0				
10				
20				

Table 5.9 Readings at different capacitance

$V_S = 5v, V_p = 10v, D = 50\%, f = 1kHz, L = 1mH, and\ R = 1k\Omega$				
$C\ (nF)$	$V_o(V)$	$P_{in}(W)$	$P_o(W)$	η
1				
10				
100				

Table 5.10 Readings at different frequencies

$V_S = 5v, V_p = 10v, D = 50\%, L = 1mH, C = 1nF, and\ R = 1k\Omega$				
$f\ (KHz)$	$V_o(V)$	$P_{in}(W)$	$P_o(W)$	η
1				
10				
100				

Experiment 6: DC-DC Converter

1. Objectives

To be familiar with different type of DC_DC Converter such as Buck Converter, and Boost Converter.

2. Experiment

<u>Part I: Buck Converter</u>

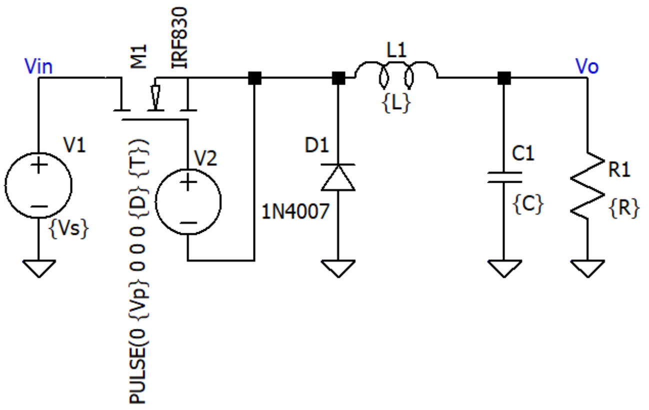

Figure 6.1 Buck Converter

1. Connect the circuit as shown in Figure 6.1.
2. Measure the following values at different values of duty cycle in Table 6.1.
   a. Output Voltage
   b. Input Power.
   c. Output Power.
   d. Efficiency.
3. Repeat step 2 at different values of resistance in Table 6.2.
4. Repeat step 2 at different values of inductance in Table 6.3.
5. Repeat step 2 at different values of capacitance in Table 6.4.
6. Repeat step 2 at different values of frequencies in Table 6.5.

Table 6.1 Readings at different duty cycle

$V_S = 5v, V_P = 10v, f = 1kHz, L = 1mH, C = 1nF, and\ R = 1k\Omega$				
$D\ (\%)$	$V_o(V)$	$P_{in}(W)$	$P_o(W)$	η
0				
10				
20				
30				
40				
50				

60				
70				
80				
90				
100				

Table 6.2 Readings at different resistance

$V_S = 5v, V_p = 10v, D = 50\%, f = 1kHz, L = 1mH, and\ C = 1nF$				
$R\ (K\Omega)$	$V_o(V)$	$P_{in}(W)$	$P_o(W)$	η
1				
4.7				
10				

Table 6.3 Readings at different inductance

$V_S = 5v, V_p = 10v, D = 50\%, f = 1kHz, C = 1nF, and\ R = 1k\Omega$				
$L\ (mH)$	$V_o(V)$	$P_{in}(W)$	$P_o(W)$	η
0				
10				
20				

Table 6.4 Readings at different capacitance

$V_S = 5v, V_p = 10v, D = 50\%, f = 1kHz, L = 1mH, and\ R = 1k\Omega$				
$C\ (nF)$	$V_o(V)$	$P_{in}(W)$	$P_o(W)$	η
1				
10				
100				

Table 6.5 Readings at different frequencies

$V_S = 5v, V_p = 10v, D = 50\%, L = 1mH, C = 1nF, and\ R = 1k\Omega$				
$f\ (KHz)$	$V_o(V)$	$P_{in}(W)$	$P_o(W)$	η
1				
10				
100				

Part II: Boost Converter

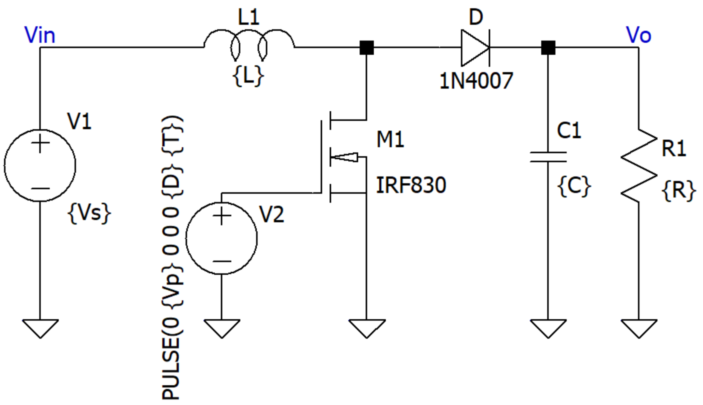

Figure 6.2 Boost Converter

1. Connect the circuit as shown in Figure 6.2.
2. Measure the following values at different values of duty cycle in Table 6.6.
   a. Output Voltage
   b. Input Power.
   c. Output Power.
   d. Efficiency.
3. Repeat step 2 at different values of resistance in Table 6.7.
4. Repeat step 2 at different values of inductance in Table 6.8.
5. Repeat step 2 at different values of capacitance in Table 6.9.
6. Repeat step 2 at different values of frequencies in Table 6.10.

Table 6.6 Readings at different duty cycle

$V_S = 5v, V_P = 10v, f = 1kHz, L = 1mH, C = 1nF, and\ R = 1k\Omega$				
$D\ (\%)$	$V_o(V)$	$P_{in}(W)$	$P_o(W)$	η
0				
10				
20				
30				
40				
50				
60				
70				
80				
90				
100				

Table 6.7 Readings at different resistance

$V_S = 5v, V_p = 10v, D = 50\%, f = 1kHz, L = 1mH, and\ C = 1nF$				
$R\ (K\Omega)$	$V_o(V)$	$P_{in}(W)$	$P_o(W)$	η
1				
4.7				
10				

Table 6.8 Readings at different inductance

$V_S = 5v, V_p = 10v, D = 50\%, f = 1kHz, C = 1nF, and\ R = 1k\Omega$				
$L\ (mH)$	$V_o(V)$	$P_{in}(W)$	$P_o(W)$	η
0				
10				
20				

Table 6.9 Readings at different capacitance

$V_S = 5v, V_p = 10v, D = 50\%, f = 1kHz, L = 1mH, and\ R = 1k\Omega$				
$C\ (nF)$	$V_o(V)$	$P_{in}(W)$	$P_o(W)$	η
1				
10				
100				

Table 6.10 Readings at different frequencies

$V_S = 5v, V_p = 10v, D = 50\%, L = 1mH, C = 1nF, and\ R = 1k\Omega$				
$f\ (KHz)$	$V_o(V)$	$P_{in}(W)$	$P_o(W)$	η
1				
10				
100				

3. Comments

In your own words, describe how results differ between theoretical expectation, simulation and practical results in each section.

Prelab 6: AC-AC Converter

I. Do the following simulations:

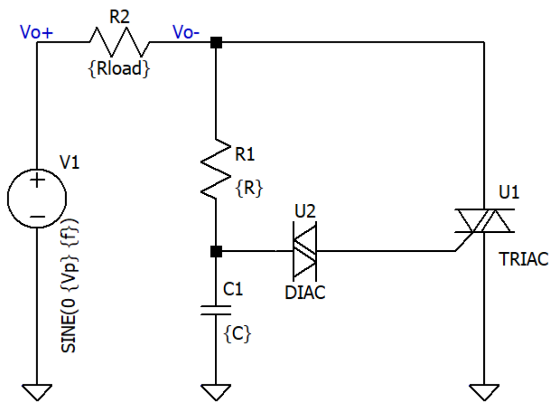

Figure 7.1 AC-AC Converter

1. Connect the circuit as shown in Figure 7.1.
2. Put V_p=15v, and f=50Hz, C=1μF, and Rload=100Ω.
3. Add the LT-spice Model for the TRIAC.
4. Add the LT-spice Model for the DIAC.
5. Measure the output voltage, and V_{rms} at different values of resistance in Table 7.1.

Table 7.1 V_{rms} *Reading*

$\mathrm{R}(K\Omega)$	1	5	10	50	100	150	200	250	300
$V_{rms}(v)$									

Annex

1. 1N4007

```
.MODEL 1N4007 D(IS=2.55E-9 RS=0.042 N=1.75 TT=5.76E-6 CJO=1.85E-11 VJ=0.75 M=0.333
BV=1000 IBV=9.86E-5 Iave=1000m Vpk=1000 mfg=GP1000V1A type=silicon )
```

2. IRF830

```
.SUBCKT IRF830 1 2 3
M1 9 7 8 8 MM L=100u W=100u
.MODEL MM NMOS LEVEL=1 IS=1e-32
+VTO=3.86308 LAMBDA=0.00289944 KP=2.00897
+CGSO=5.55536e-06 CGDO=1e-11
RS 8 3 0.0001
D1 3 1 MD
.MODEL MD D IS=3.21167e-09 RS=0.018759 N=1.44803 BV=500
+IBV=0.00025 EG=1.2 XTI=3.01692 TT=0
+CJO=5.33099e-10 VJ=3.77417 M=0.9 FC=0.5
RDS 3 1 2e+07
RD 9 1 1.27635
```

3. SCR

```
.subckt SCR A G C
D1 n1 G D
WSCR A n1 V1 Iswitch
V1 G C 0
.model D D
.model Iswitch CSW(Ron=0.1 Roff=1MEG It=1m)
.ends
```

4. DIAC

```
.subckt DIAC T1 T2
* default parameters
.param RS=10 ; series resistance
.param VK=20 ; breakdown voltage
Q1 N002 N001 T2 0 PN
Q2 N001 N002 N005 0 NP
R1 N002 N004 {20K*(VK-1)}
R2 N004 T2 9.5K
R3 N002 N005 9.5K
Q3 N004 N003 N005 0 PN
Q4 N003 N004 T2 0 NP
R4 T1 N005 {RS}
.model PN NPN Cjc=10p Cje=10p
.model NP PNP Cjc=10p Cje=10p
.ends
```

5. TRIAC

```
.subckt TRIAC MT2 G MT1
.param R=10K
Q1 N001 G MT1 0 NP
Q2 N001 N002 MT2 0 NP
Q3 N002 N001 MT1 0 PN
Q4 G N001 MT2 0 PN
R1 MT2 N002 {R}
R2 G MT1 {R}
.model PN NPN Cjc=10p Cje=10p
.model NP PNP Cjc=10p Cje=10p
.ends
```