جامعة الأمير مقرن بن عبد العزيز
University of Prince Mugrin

Electrical Engineering Department

Year: 2022 Semester: spring 21/22

Course: EE-222

Course Project:

Bridge Rectifier + Touch Sensor Circuit + Comparator Circuit + Multiple Loads

Due Date: 25 / May / 2022

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I. Introduction

This project aims to apply the knowledge we gained during this semester in Electronics 1 course. Each task has a direct relationship with a significant division of our syllabus, and it is shown in **Table 1**.

Tasks	Topic
Task 1	Diodes.
Task 2	Online research and electrical circuit background.
Task 3	BJTs.
Task 4	

Table 1 – The relationship between tasks & topics

Overall, the main objectives are:

1. Designing a fully working circuit for the given requirements.
2. Incorporating ONLY the materials introduced in the course, unless specified.
3. Simulating the design in Multisim and performing data acquisition techniques.

II. Task 1

❖ Converting AC to DC

Converting Alternating current power to direct current power involves several steps, but in our project, we have assembled a Full Bridge Rectifier using diodes. Most essential diode characteristics are shown in **Figure 2**.

❖ Full Bridge Rectifier

In this rectifier circuit, we have used four diodes. The animation depicts a simplified representation of its response, which is explained below:

- **During the positive half-wave:**

Diodes **D2** and **D3** are forward-biased. Current flows from V_{in} via the anode of diode **D2** through the load resistor **RL** and capacitor. After that, it flows through the anode of diode **D3** to the negative terminal of V_{in}. Throughout this period, diodes **D1** and **D4** are reverse-biased and conduct no current.

- **During the negative half-wave:**

Diodes **D4** and **D1** are forward-biased. Current flows from the negative terminal of V_{in}. The current of diode **D4** through the load resistor **RL** and capacitor. After that, it flows through the anode of diode **D1** to the positive terminal of V_{in}. Throughout this period, diodes **D2** and **D3** are reverse-biased and conduct no current.

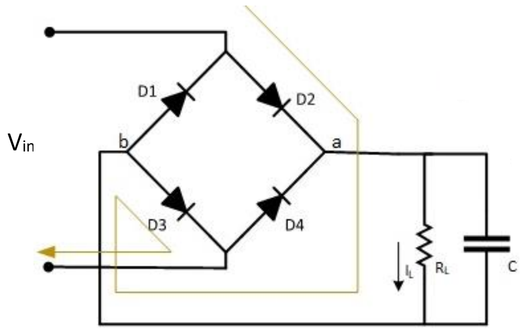

Figure 1: Schematic of the bridge rectifier circuit

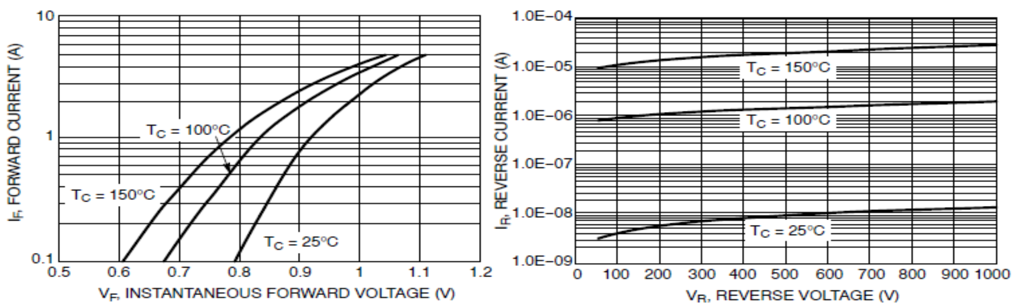

Figure 2: Diode Characteristics

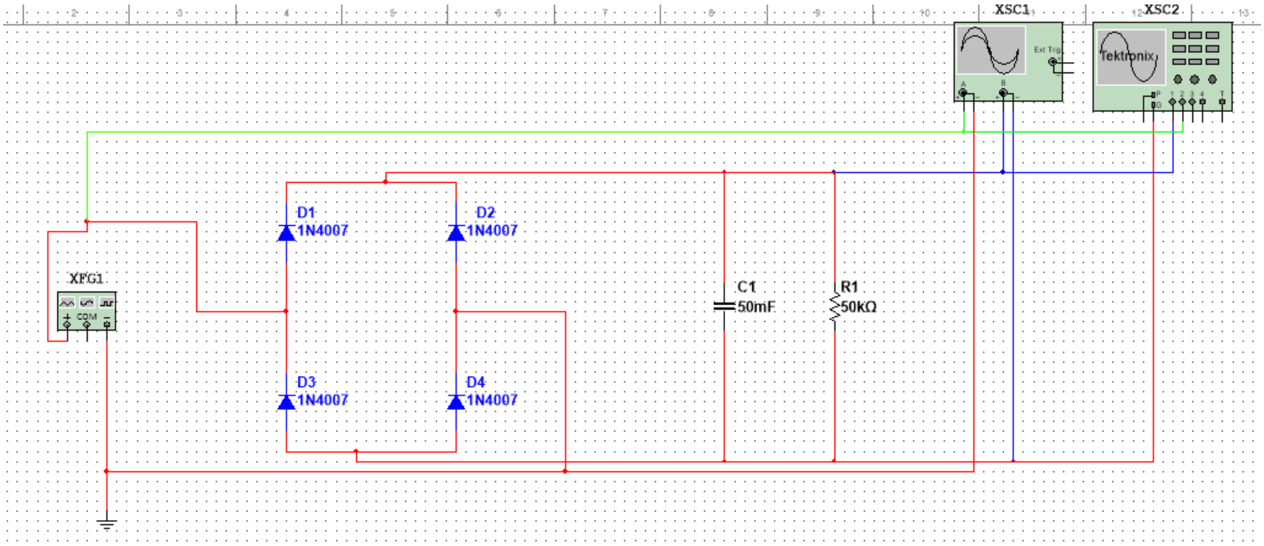

Figure 3: The simulation of the bridge rectifier circuit

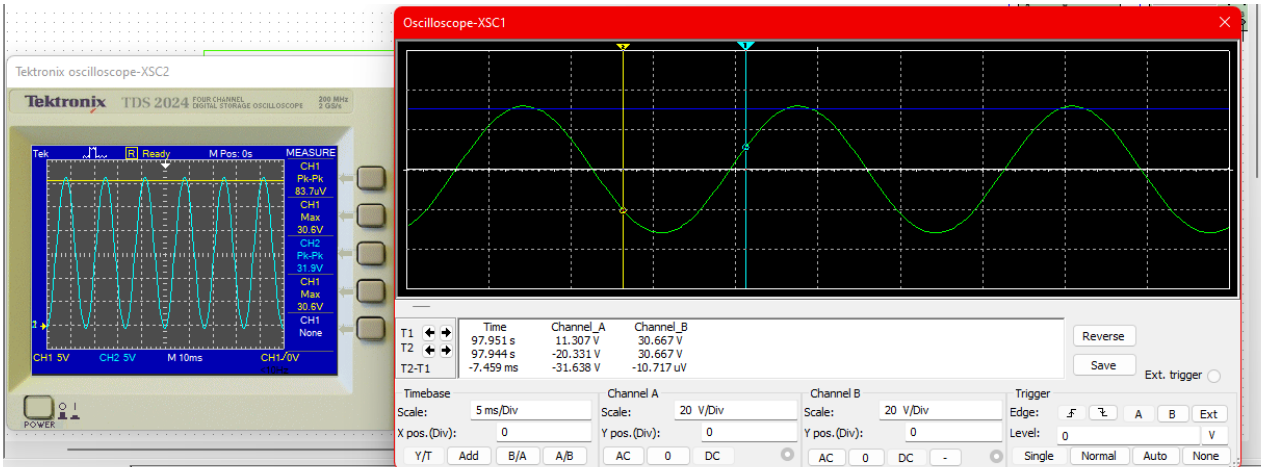

Figure 4: The minimal output Ripple Voltage (DC Voltage)

A full-wave rectifier was constructed using an AC voltage source with 4 diodes, a 50k ohm resistor, and a 5uF capacitor as shown in **Figure 2**. As expected, the peak-peak ripple voltage was found 83.7uV as shown in **Figure 3** which is hugely smaller than 32V from the source, considering a voltage drop of 0.7V across each of the two diodes in the forward-bias state. Also having the capacitor that affects output voltage into a ripple and increases its average value.

III. Task 2

❖ Touch Sensor Circuit

This second task focuses on determining a method, or a circuit for our case, which can distinguish the touch of a human finger.

Building a touch sensor is something you need to be careful with. First, the human finger can handle anything under 10mA in general. In addition, if any current under 1mA is passing, the human can not feel it, and it is harmless. If it secedes 1mA (till 5mA) it is a small shock, which does not do any harm usually (unless passing through the heart).

Secondly, the resistor of the human body is varying between 1k to 10k Ohms, depending on the skin thickness, and the area that the current passes. However, in this circuit, we represented this resistor by a 1k Ohm resistor, considering that it is passing through the finger.

❖ The Mechanism

Touch sensor circuits are, mostly, not simple. But representing this circuit using the proper component and with the help of the next comparator circuit has made it simple and clear, as shown in **Figure 4**.

The procedure is straightforward, just by closing the switch (or butting your finger), the circuit will work and a current under 1 mA will pass through.

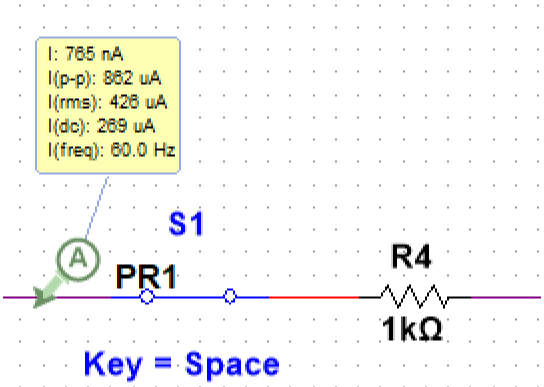

Figure 5: Simulation + Representation of the Touch Sensor

IV. Task 3

❖ Comparator Circuit

A circuit should be designed such that it can distinguish an input value and produce an output relative to the given input values. This is considered the comparison circuit that will perform the mathematical operation to determine if a human finger did encounter the circuit.

It is not allowed in our project to use external ICs or components (out of the syllabus). So, we used the best component that represents a comparator, which is an NPN BJT. The Bipolar Junction Transistor gives an output current concerning a certain input current.

The BJT has an input current (I_B) and an output current (I_C) that is directly affecting the collector-emitter voltage (V_{CE}), which is our output voltage that will be connected to the load. The table and figures below show the BJT characteristics.

Symbol	Parameter	Value		Unit
		BD235	BD237	
V_{CBO}	Collector-base voltage ($I_E = 0$)	60	100	V
V_{CER}	Collector-emitter voltage ($R_{BE} = 1\ k\Omega$)	60	100	V
V_{CEO}	Collector-emitter voltage ($I_B = 0$)	60	80	V
V_{EBO}	Emitter-base voltage ($I_C = 0$)	5		V
I_C	Collector current	2		A
I_{CM}	Collector peak current (t_p < ms)	6		A
P_{TOT}	Total dissipation at $T_{case} = 25°C$	25		W
T_{stg}	Storage temperature	-65 to 150		°C
T_J	Max. operating junction temperature	150		°C

Table 2: Absolute maximum ratings

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
I_{CBO}	Collector cut-off current ($I_E = 0$)	V_{CB} = rated V_{CBO} V_{CB} = rated V_{CBO} T_C= 150°C		-	0.1 2	mA mA
I_{EBO}	Emitter cut-off current ($I_C = 0$)	$V_{EB} = 5V$		-	1	mA
$V_{CEO(sus)}{}^{(1)}$	Collector-emitter sustaining voltage ($I_B = 0$)	$I_C = 100mA$ for BD235 for BD237	60 80	-		V V
$V_{CE(sat)}{}^{(1)}$	Collector-emitter saturation voltage	$I_C = 1A$ $I_B = 0.1A$		-	0.6	V
$V_{BE(on)}{}^{(1)}$	Base-emitter on voltage	$I_C = 1A$ $V_{CE} = 2V$		-	1.3	V
$h_{FE}{}^{(1)}$	DC current gain	$I_C = 150mA$ $V_{CE} = 2V$ $I_C = 1A$ $V_{CE} = 2V$	40 25	-		

Table 3: Electrical characteristics

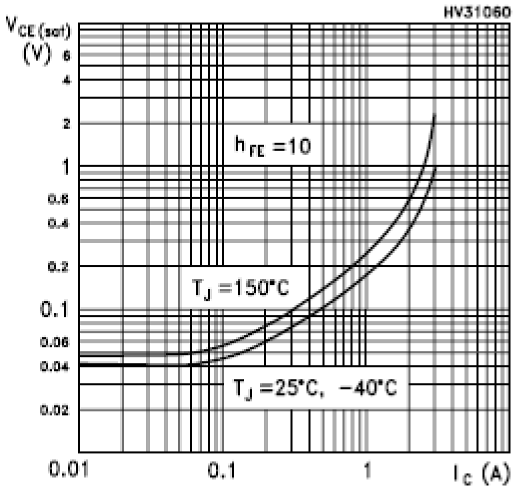

Figure 6: BJT characteristic curve

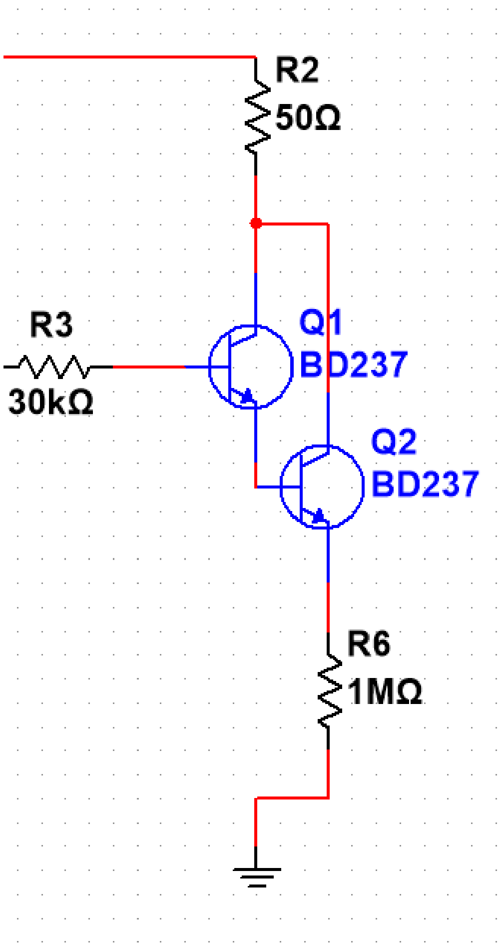

Figure 7: Comparator Circuit Simulation

V. Task 4

Now after the main circuit has been made, we needed to make sure that it can operate connected loads. The loads we are testing it on are different colored LEDs, LASERs, and buzzers.

We decided that we would test these loads at 311 peak input voltage. This is because the common household outlet voltage is 220Vrms which equals 311 Vmax.

We also added a 120KΩ resistor in series with the comparator circuit to protect the finger of the person touching the sensor.

❖ Circuit Limitations

At 311V input, the output on the buzzer is about 5V, while the current through the sensor is around 5mA. If the input voltage exceeds 311V then the current through the sensor reaches over 5mA which starts to shock the person. If the input voltage drops below 125V, then the buzzer will stop working.

Meaning that the input voltage should be limited between (311 – 125) Vpeak - AC.

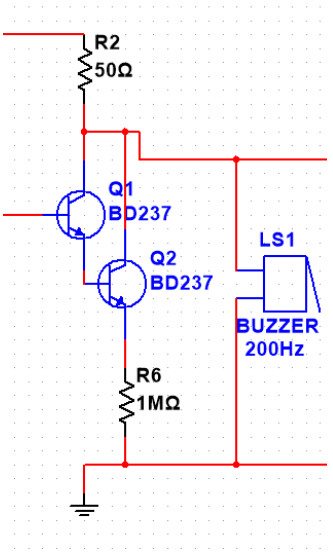

Figure 8: The Buzzer Connected to the Circuit

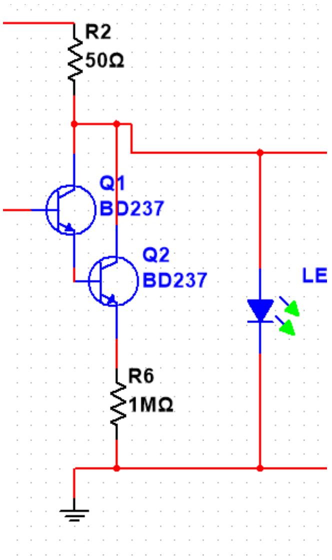

Figure 9: A LED Connected to the Circuit

VI. Circuit Parameters

When using BJTs in AC, it is important to identify our parameters for this BJT system. Considering the comparator circuit shown in **Figure 10**, the most important parameters are:

1- Zi: input impedance.
2- Zo: output impedance.
3- Ii: current entering the Base.
4- Io: current entering the Collector.

We can find some variables first:

- r_{e1} & r_{e2} (reverse emitter resistors): $r_{e1} = r_{e2}$ = 25mV / Ie = 25m / 111u = 225 Ohm.
- Beta: I_C / I_B = 153
- Zb (I_B path impedance) = Beta*R_E = 153M Ohm

So, our parameters will be:

1- Zi = Zb // R_B = 29994 Ohm
2- Zo = R_C = 50 Ohm
3- Ii = 458 nA
4- Io = 70.1 uA

And the final important parameter is the gain $A_V = -R_C/R_E$ = - 50 u

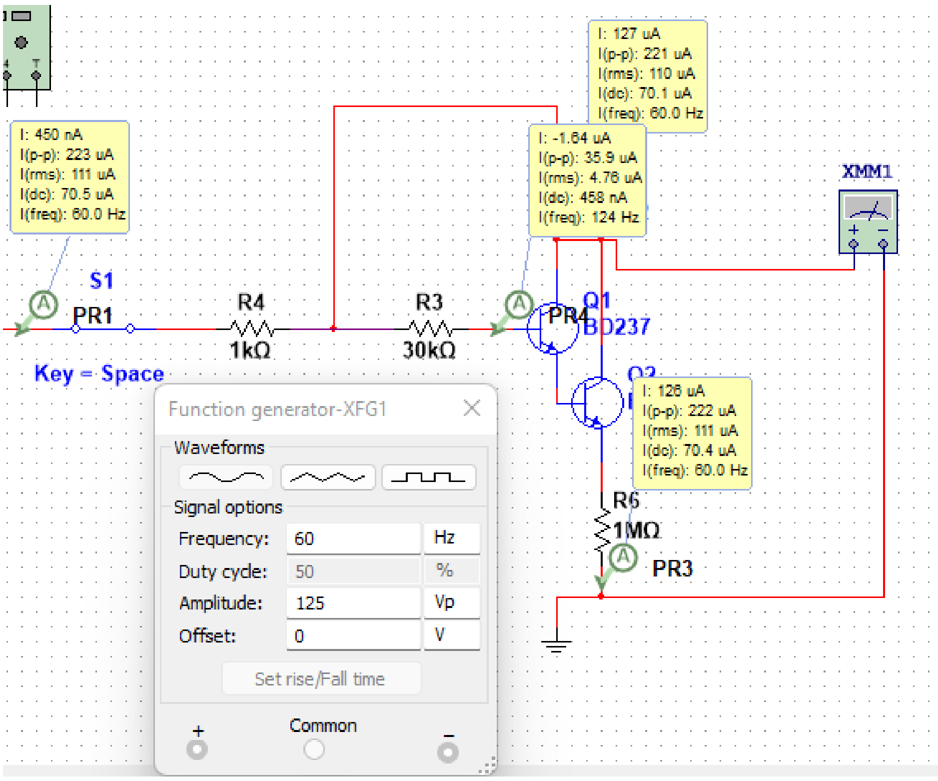

Figure 10: BJT parameters circuit

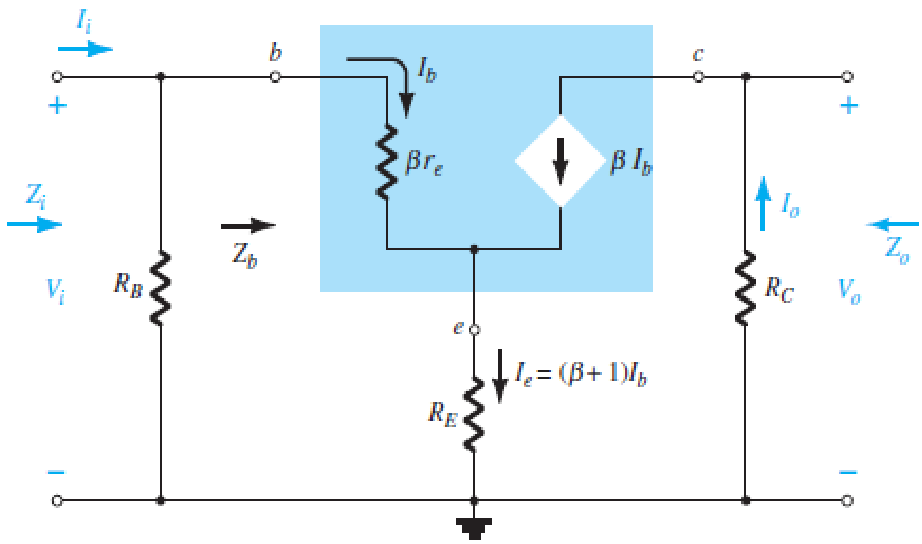

Figure 11: r_e equivalent model

VII. Conclusion

In the end, we were able to use the knowledge we gained in our electronics course to construct a functioning circuit. This circuit was able to take an AC input source and rectify it into DC, then we added a touch sensor connected with a comparator circuit that will switch on when the sensor is touched. Lastly, we made sure that it was able to operate basic devices without becoming unsafe for the user. Due to time restrictions, we were not able to fully optimize this circuit, so hopefully, we can work on it again in the future to make it better.

VIII. References

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