Batu Arda Düzgün
21802633
EEE313 – Section 3
17.10.2020

EEE 313 Electronic Circuit Design – Lab Report 1

1. Introduction:

In this lab assignment, we were tasked with detecting the radiation emitted by a LED using a photodiode. After that, we needed to amplify the detected signal with an OPAMP and turn it into a DC signal using a half-wave rectifier circuit. We were given the OPAMP, LED and photodiode in the circuit but we needed to choose the resistances R2 and R3, the capacitor C1 ourselves.

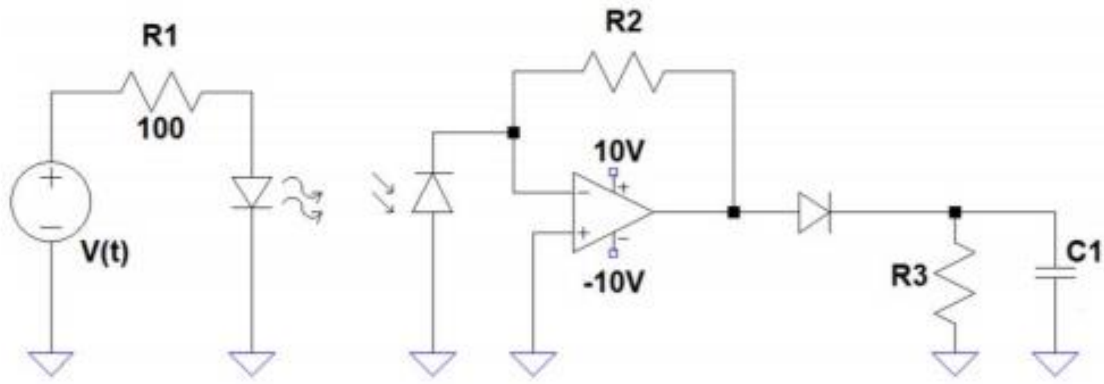

Figure 1: Circuit schematic we used in the lab

I set up this circuit in the lab on a breadboard. Then took my measurement using an oscilloscope.

2. Lab Work:

a. Part A:

In part A we were asked to chouse R2 such that it doesn't saturate the output of the OPAMP. I assembled the circuit on a breadboard.

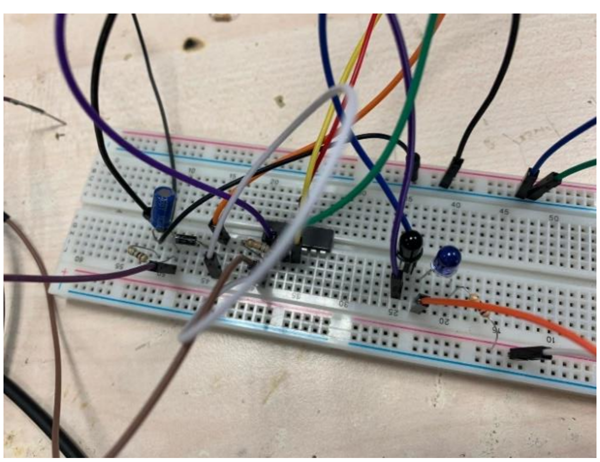

Figure 2: my circuit on the bread board

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I used a signal generator to give the input voltage of $V(t) = 3 * \sin(2\pi * 1000)$.

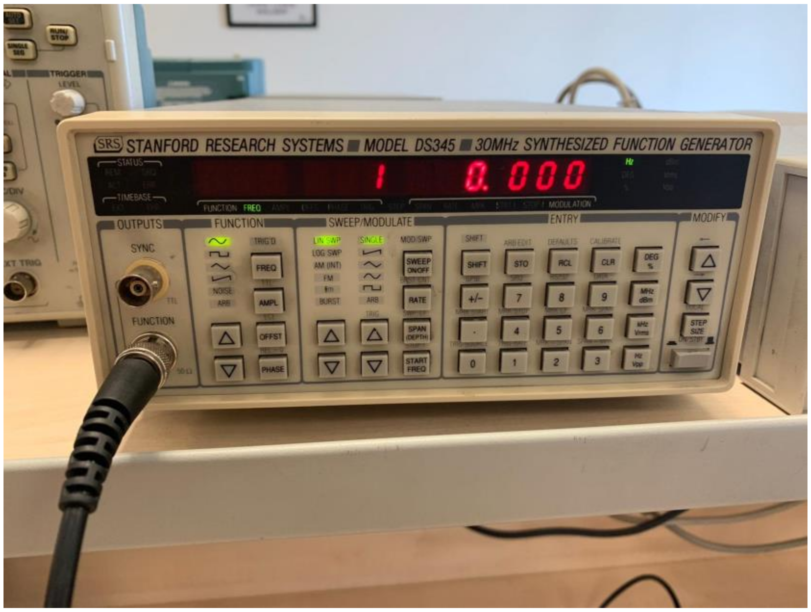

Figure 3: signal generator.

Also, I used a DC voltage source for the OPAMPs supply voltage of +10V and -10V. To do this I set up both outputs of the voltage source to 10 volts then connected the positive terminal of one output to the positive supply voltage of the OPAMP and the negative terminal to the ground of the circuit. Then I connected the negative terminal of the other output to the negative supply voltage of the OPAMP and the positive terminal to the ground of the circuit.

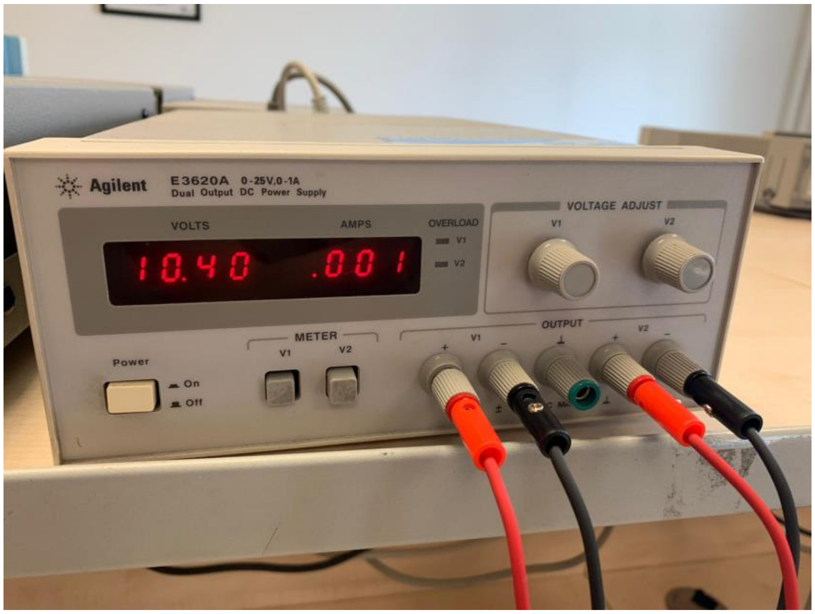

Figure 4: DC voltage source.

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The LED radiates light from the current coming out of the V(t). Then the photodiode generates a small current from the photons that hit it. This happens because when the photons from the LED hit the depletion region in the photodiode, they excite some electrons in there and these electrons move due to the drift current in the reverse bias direction. This is the current the photodiode generates. [1]

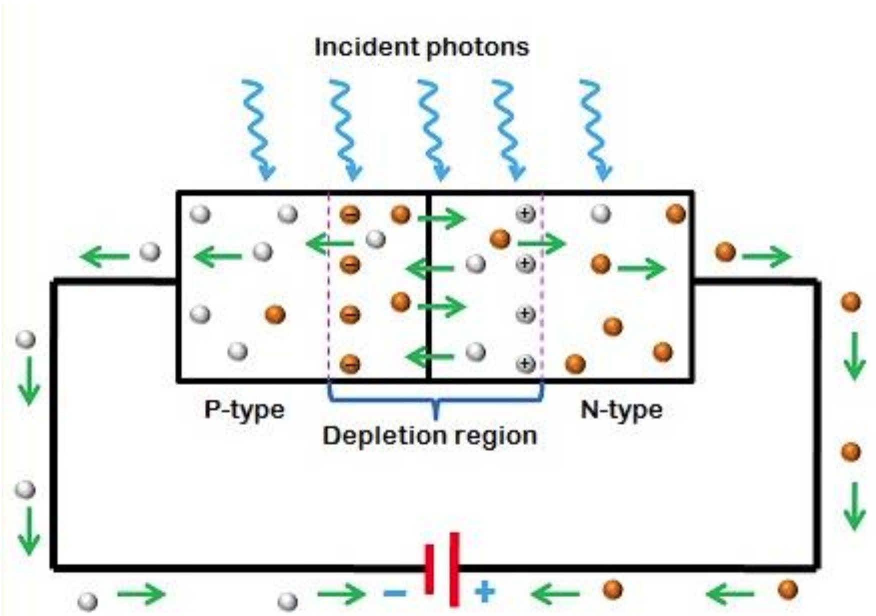

Figure 5: picture of a working photodiode

Then the OPAMP generates a current dependent voltage from the current generated by the photodiode.

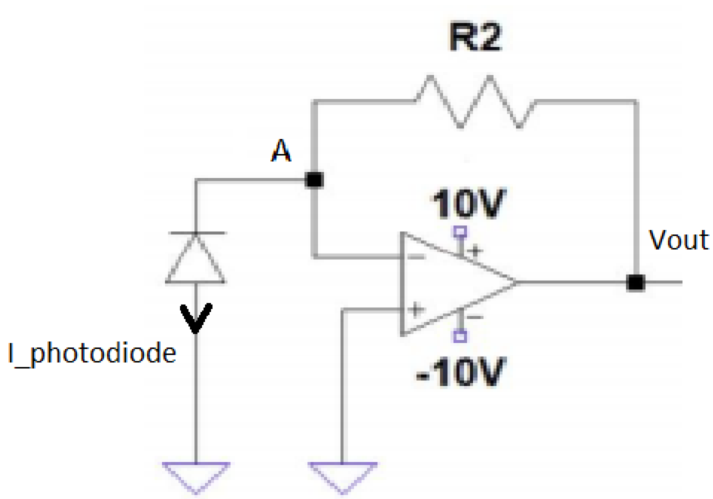

Figure 6: schematic of the diode operation

Vout can be found from writing KCL at A on figure 6. OPAMP is in linear region so there is no current trough the legs of the OPAMP.

$$I_{photodiode} + \frac{V_A - V_{out}}{R2} = 0$$

We made sure the diode is in linear region so.

$$V_A = V_- = V_+ = 0V$$

$$I_{photodiode} + \frac{-V_{out}}{R2} = 0$$

$$I_{photodiode} = \frac{V_{out}}{R2}$$

$$I_{photodiode} * R2 = V_{out}$$

Here I Chose my R2 as 490KΩ by trial and error. While choosing it I wanted my output voltage to be sufficiently high and I also I didn't want it to pass the V saturation of the OPAMP.

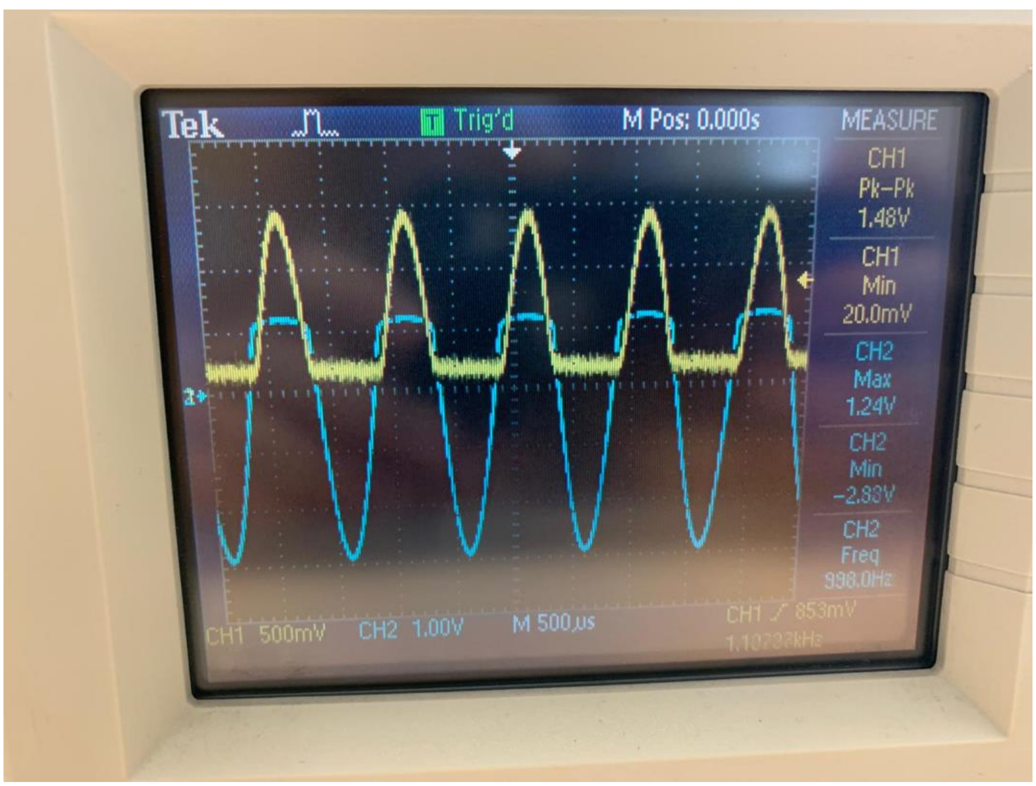

Figure 7: voltage on the LED (blue) and Vout of the OPAMP (yellow) graph

As we guessed the OPAMP only puts out a voltage when the LED diode is on. We can see when the LED diode is on because while the LED diode is on the voltage on the LED diode is constant.

b. Part B:

In this part, we are asked to find R3 and C1 such that the output of the circuit becomes a DC voltage. We know the voltage output of half-wave sin rectifier circuits can be written as

$$V_{out} = V_{max}e^{\frac{-t}{RC}}\ for\ R3 * C1 \gg T$$

Then we can define V ripple as

$$V_{ripple} = V_m - V_m e^{\frac{-t}{RC}}$$
$$V_{ripple} = V_m(1 - e^{\frac{-t}{RC}})$$

We also know

$$if\ x\ \cong 0 \quad e^{-x} \cong 1 - x$$

So we can write

$$V_{ripple} = V_m(1 - \left(1 - \frac{T}{RC}\right))$$
$$V_{ripple} = V_m \frac{T}{RC}$$

In our circuit we can calculate T.

$$T = \frac{1}{F}$$
$$F = 1000Hz$$
$$T = 1ms$$

So, we need R3 and C1 such that.

$$R3 * C1 \ll 10^{-3}$$

Because of this I chose

$$R3 = 1M\Omega\,, C1 = \ 22\mu F$$

Then I got

$$V_{ripple} = V_m \frac{1}{22 * 10^3}$$

For these R3 and C1 values I got these graphs of Vout of OPAMP (figure 8) and Voltage on the R3 and C1 (figure 9).

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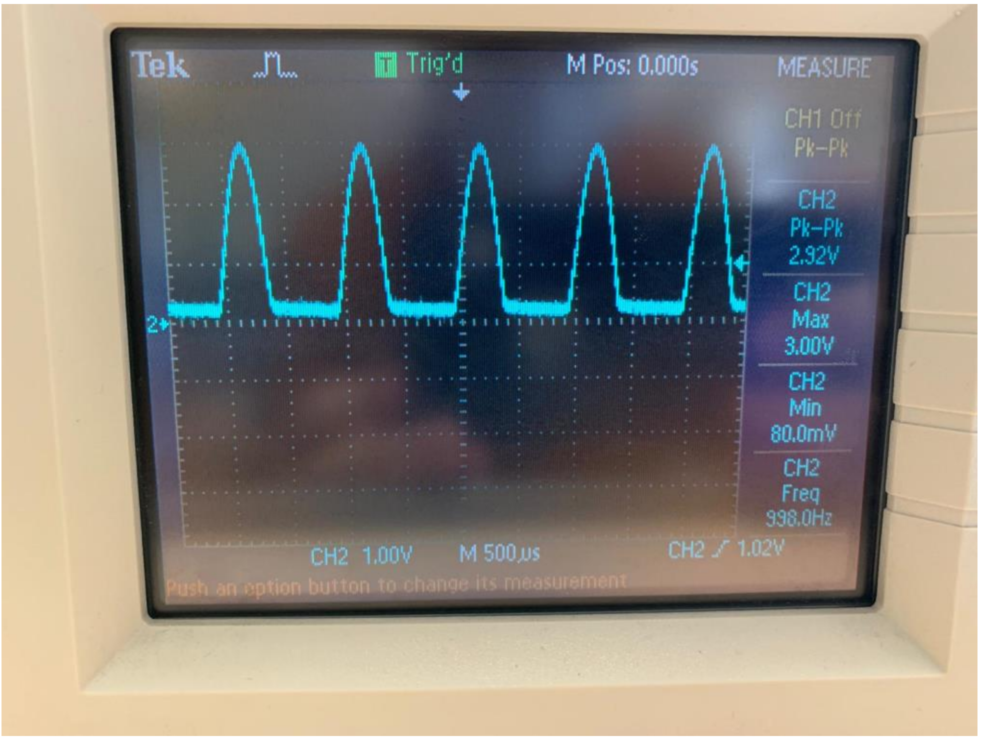

Figure 8: Vout of the OPAMP

Figure 9: Voltage on R3 and C1 graph

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3. Discussion & Conclusion:

a. Discussion:

In figure 7 we can see that the right side of the circuit only gets a signal when the LED diode on the left side of the circuit is on. We can see when the diode is on from the voltage on it, it is on when the voltage on it is constant. This is exactly what we were expecting. We can also see OPAMP output is positive, this proves that the photodiode creates a revers biased current. Also even though not exactly correct it looks like the yellow signal (OPAMP output) completes the blue signal (voltage on the LED). From figures 8 and 9 we can see we are getting an almost perfect DC signal. This is expected as the ripple voltage for the circuit is 0.000045V. We cannot see such a small value on the graph because we are so zoomed out in the oscilloscope but if we could zoom in to such an extent, we could see a ripple voltage close to 0.000045V. In the end, we accomplished our goal of getting a DC signal.

b. Conclusion:

The goal of this lab was to get us familiarized with diodes, photodiodes and OPAMPs. This was my first time using an OPAMP in a circuit I made. Before this lab, OPAMPs always felt too idealistic to me and I thought they could never predictably work in a real circuit. After doing this lab I see OPAMPs act close to what we idealized them as most of the time if we are careful. Because of this, I feel a lot more confident in using OPAMPs now in my circuits. Also, this lab made me more comfortable with diodes too. Before this lab, I didn't fully understand the inner working of a diode and I feared they would mess up the circuit in some unpredictable way. Something else which is really interesting to me was the OPAMP output increased when I placed my hands close to the circuit. This happens because my body is 37 degrees and I too radiate infrared light. The photodiode we used was capturing light frequency close to that so I acted as another input source for the right side of the circuit. This made me happy as it reminded me that what we are learning in this course is not exclusive to electronics and the circuits we are making are a part of the real world. This lab was productive and exciting for me as it helped me get past some of my old fears and made me get a newfound appreciation for the things we are learning in this course.

References:

[1] Henry, "Introduction to Photodiodes," The Engineering Knowledge, [Online]. Available: https://www.theengineeringknowledge.com/introduction-to-photodiode/. [Accessed 17 10 2020].