Bilkent University

EEE313 Lab 1 Report

Photo Diode and LED Characteristics

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Introduction

Purpose

This lab aims to generate a half-rectified sine wave using LED, photodiode, and OPAMP, then convert it into the DC voltage using a diode, capacitor, and resistor. The overall view of the circuit is as follows.

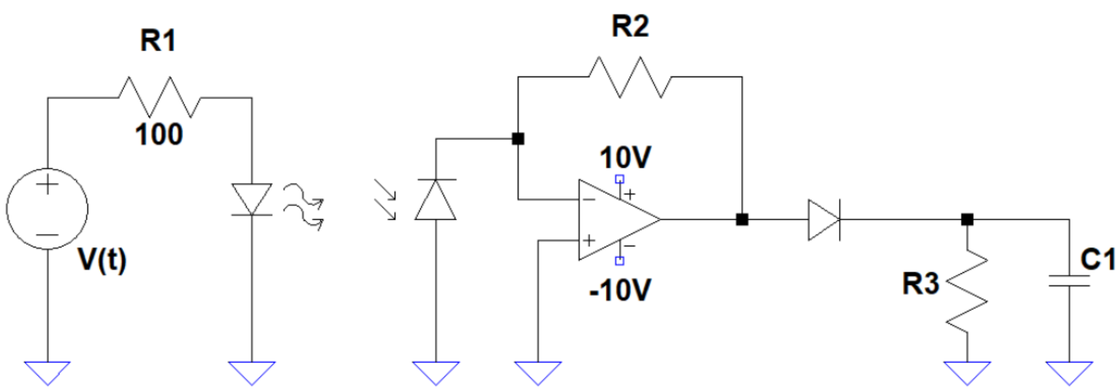


Figure 1: Circuit to be used in this lab

Preliminary Work

1.1 Working Principle of LEDs

The "Light Emitting Diode" is a semiconductor device that passes current in one direction, and the P-N junction emits light when current passes through it. A p-n junction, the functional component of an LED, is made of doped semiconductor materials. The N-type silicon and the P-type silicon contain electrons and holes. When the potential difference is applied, the electrons or holes flow to the opposite poles depending on the type of diode. As the electrons and holes unite again, photons are released.

1.2 The Operation of the Circuit

The V(t) causes the LED to emit light. The photons that strike the photodiode then cause it to produce a little current. Then, the OPAMP uses the photodiode's current to produce a voltage dependent on current. AC wave at the OPAMP output was converted to DC voltage using a diode, capacitor, and resistor. When current passes through the diode, the capacitor begins to charge. When no current passes, the capacitor discharges, but since no current can pass through the diode, the current created by the capacitor passes through R3. When current flows through the diode again before the capacitor is completely discharged, ripple voltage occurs; thus, the AC wave is converted into DC voltage.

2 Datasheets of photodiode (pd333-3b/h0/l2) and the LED (SB-5010IRB)

The LED operates at 940nm, and the photodiode operates from 840 to 1100nm. The infrared wavelength range was chosen because if visible light wavelength was used, external factors such as lights in the laboratory environment could affect the result.

Hardware

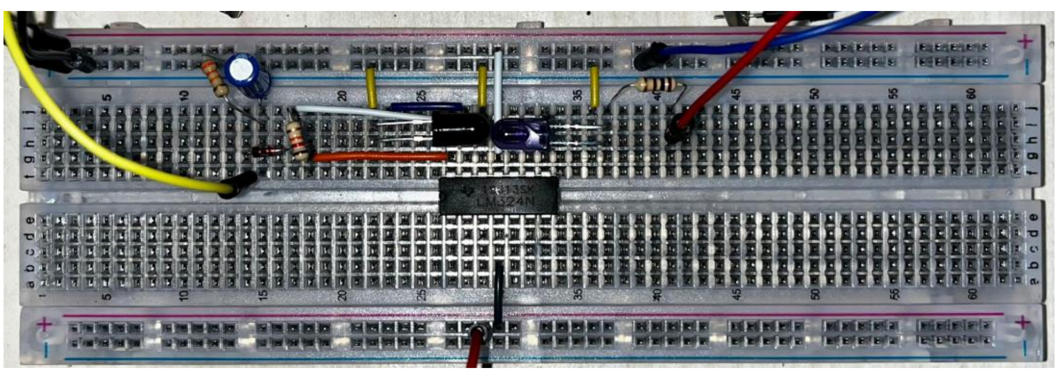


Figure 2: The Circuit

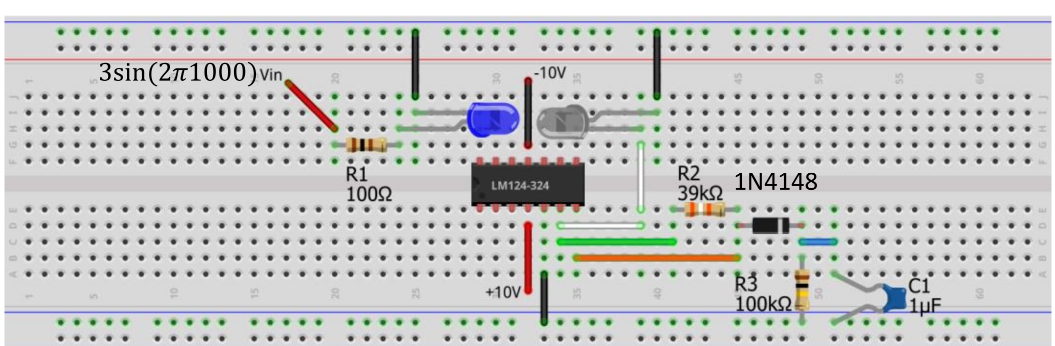


Figure 3: Schematic of the Circuit

When a sine wave is given as input, the diode turns on when it is greater than or equal to the threshold voltage, and the LED emits light; it turns off and behaves like an open circuit, that is, the output voltage of the LED is equal to the input voltage. When the output of the LED is measured, the image formed on the oscilloscope is as follows:

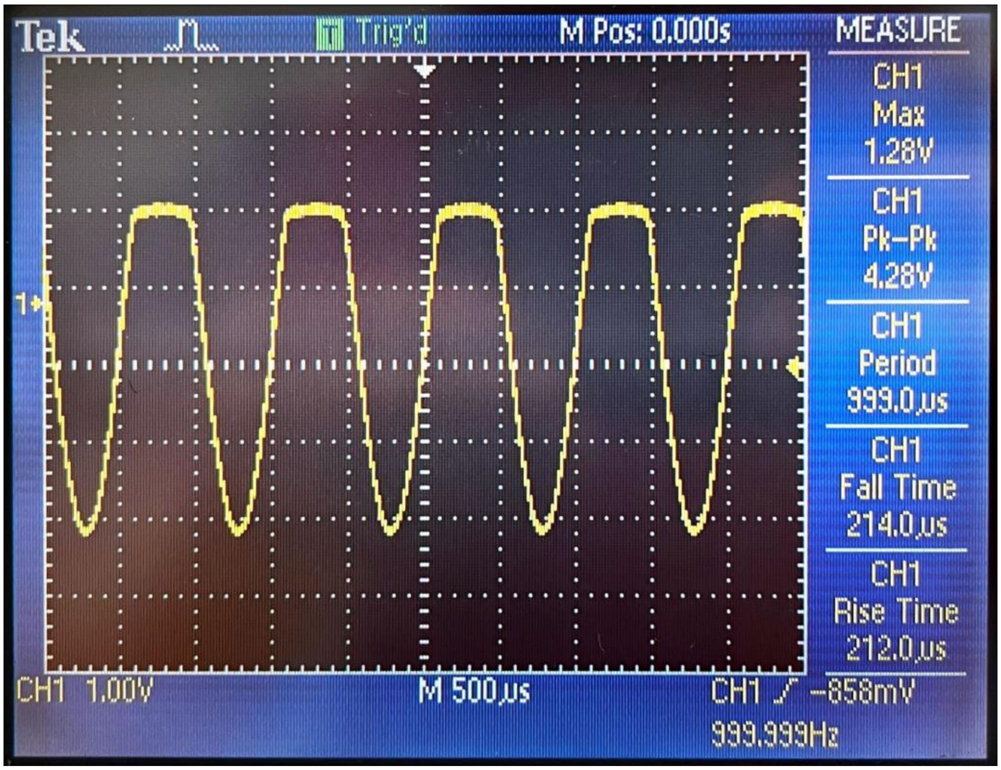
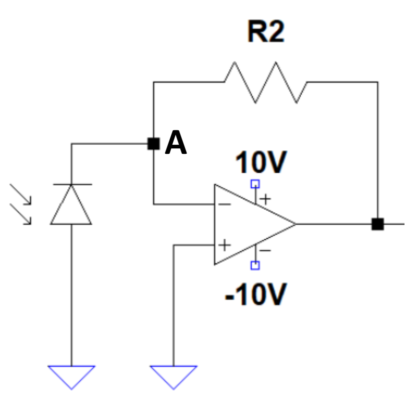


Figure 4: the Output Voltage of the LED

As the preliminary part states, the OPAMP uses the photodiode's current to produce a voltage dependent on current.



The Vout equation obtained using KCL at node A is as follows:

$$I_{photodiode} + \frac{V_A - V_{out}}{R_2} = 0$$

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

$$I_{photodiode} + \frac{-V_{out}}{R_2} = 0$$

$$V_{out} = I_{photodiode} * R_2$$

While R_2 resistance was selected by trial and error, V_{out} wanted to be as large as possible but not saturated. The maximum V_{out} value was measured as 8.48V with the minimum space between the LED and photodiode when R_2 was 39k ohm. Also, it was observed that the voltage value decreased when the gap was increased because the photodiode received less light.

$$I_{photodiode} = \frac{V_{out}}{R_2} = \frac{8.48}{39000} = 217{,}4\ \mu A$$

According to the photodiode's datasheet, the value that should have been 35 μA was found to be 217,4 μA with this calculation.

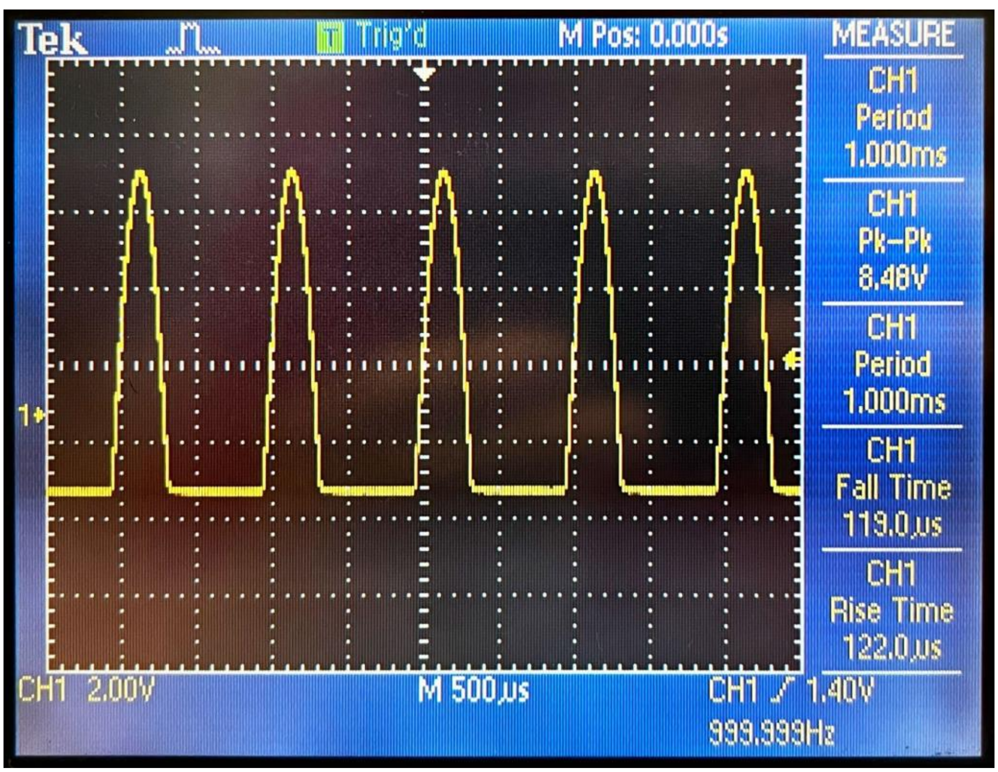


Figure 5: the Output of the OPAMP

As expected, the half-rectified sine wave measured from the output of the OPAMP can be seen above. i.e., OPAMP creates voltage only when the LED is on.

In the last part of the circuit, consisting of a diode and RC circuit that behaves like a low-pass filter, it is expected that the half-rectified sine wave at the output of the OPAMP will be filtered and converted into DC voltage. Here, the capacitor will recharge with the appropriate time constant value before it is completely discharged, and a ripple will be obtained.

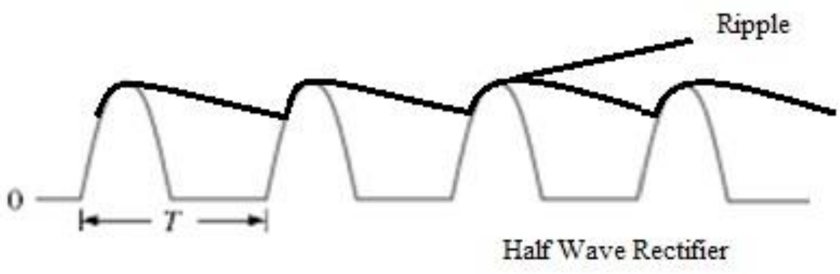


Figure 6: Ripple on Half-rectified wave

$$V_{ripple} = \left(V_{peak} - V_{diode}\right) * \frac{T}{\tau}$$

According to the above graph and equation, the aim here is to reduce V_{ripple} as much as possible, making the voltage constant and similar to DC voltage. A $\tau = R_3 * C_1$ value greater than the period must be selected for this. If the R_3 is chosen as 100k Ohm and C_1 is chosen as 1μ Farad, then the time constant becomes 100 ms, greater than the 1 ms input period. The resulting ripple is as follows:

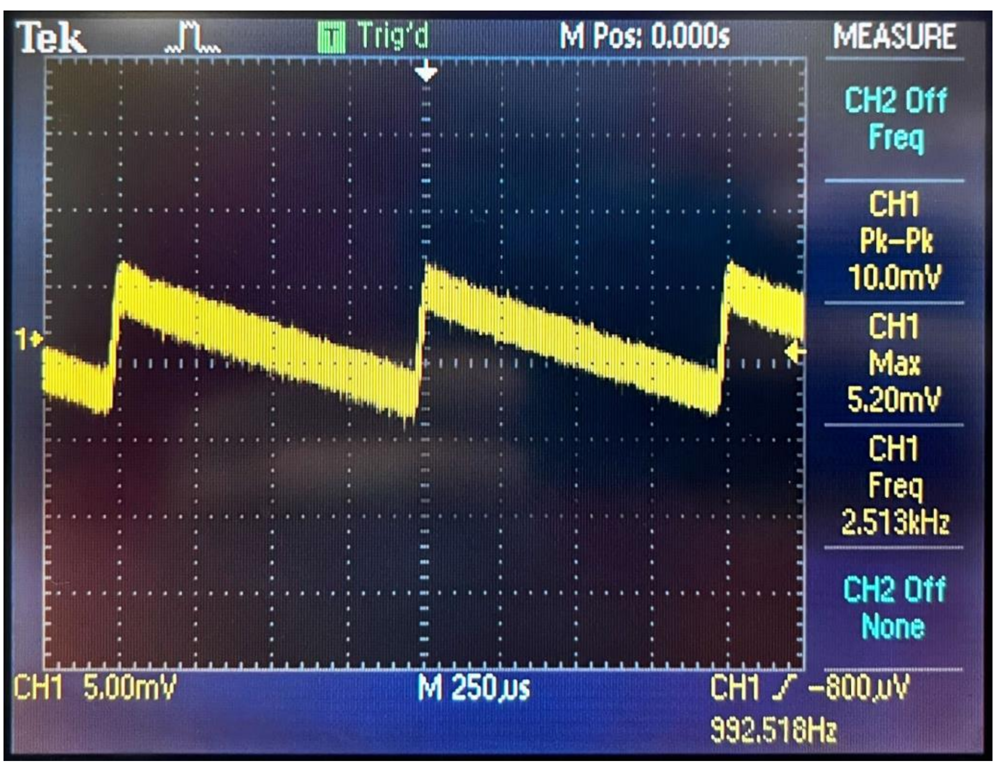


Figure 7: The Ripple

The value measured from the output of the circuit as a result of all operations is as follows:

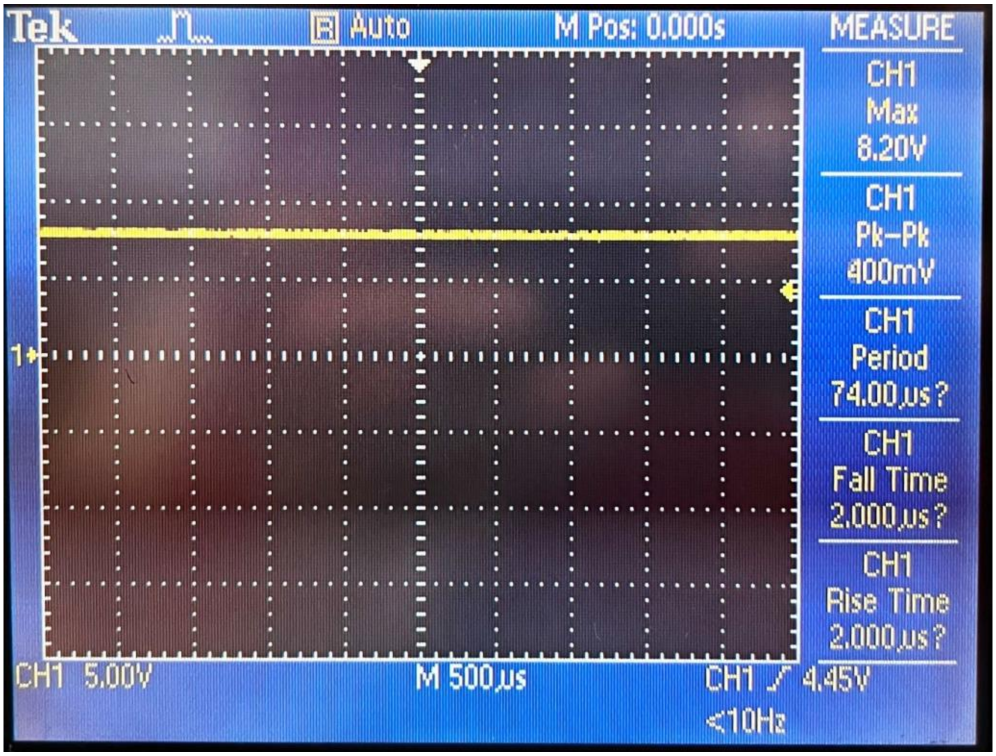


Figure 8: the Output Voltage

The constant voltage value measured as 8.20 V, with a small drop due to the threshold voltage of the diode, can be accepted as DC since the ripple value is relatively small compared to this value. Thus, the half-rectified AC wave is converted to DC voltage.

Conclusion

This lab aimed to familiarize with the use of infrared LEDs and photodiodes. Thanks to the invisible light emitted by the LED, the current produced by the photodiode was obtained, and voltage output was obtained with a transimpedance amplifier. While trying different values for R2 in this section, it was a bit difficult at first because the LED and photodiode were not placed securely. The distance between them changed when the resistor was installed or removed or when the measurement was made, and therefore, the value displayed on the oscilloscope was not stable. Afterward, this problem was solved when the LED and photodiode were fixed to face each other and be in contact. In the last part, appropriate calculations were made using the previously familiar RC circuits and low-pass filter logic, and the desired DC voltage was obtained on the second try. Some minor errors occurred due to the non-linear components in OPAMP, non-ideal LED and photodiode, imprecise component values, and the material quality or sensitivity of the oscilloscope, signal generator, and breadboard. Thanks to this lab, the working logic of infrared LEDs and photodiodes, frequently used in daily life in applications such as remote control, was learned, and information about RC circuits, rectifying a wave and ripple was developed.

References

Agarwal, T. (2020) *Light emitting diode : Construction, circuit, working & its applications*, *ElProCus*. Available at: https://www.elprocus.com/light-emitting-diode-led-working-application (Accessed: 11 October 2023).

5mm photodiode PD333-3B/H0/L2 - Mouser Electronics. Available at: https://www.mouser.com/datasheet/2/143/PD333-3B-H0-L2-1663378.pdf (Accessed: 11 October 2023).

Part numbers starting with S - page 1 - Datasheets360.com. Available at: https://www.datasheets360.com/browse/parts?char=S (Accessed: 11 October 2023).