GAZI UNIVERSITY

FACULTY OF ENGINEERING

ELECTRICAL-ELECTRONICS ENGINEERING

EEE311 ANALOG ELECTRONICS 2

Term Project: Laser Activated Alarm

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1. Introduction

This project is a simple, low-cost, and effective security system developed for disadvantaged (elderly) groups. The system is based on communication between a laser and an LDR (light-dependent resistor) sensor.

The working principle of the LDR sensor is as follows: Its resistance decreases as the amount of light falling on it increases. The laser changes the resistance of the LDR sensor, generating a signal. A laser fixed to the door continuously shines light onto the LDR sensor. In this state, the system is in passive mode. When the door is opened, the laser light is directed elsewhere, reducing the amount of light falling on the LDR. This reduction changes the resistance of the LDR, activating the system and triggering the alarm.

This project is designed for elderly individuals or other disadvantaged groups who live alone. It is intended to be integrated into doors that a potential intruder might open to ensure security.

In this project, the 555 Timer IC is used as a square wave oscillator. The signal from the LDR is processed by a comparator circuit and sent to the 555 Timer. The timer generates a square wave at a specific frequency, which activates the buzzer module to provide an audible warning. At the same time, the emergency LED lights up to give a visual alert.

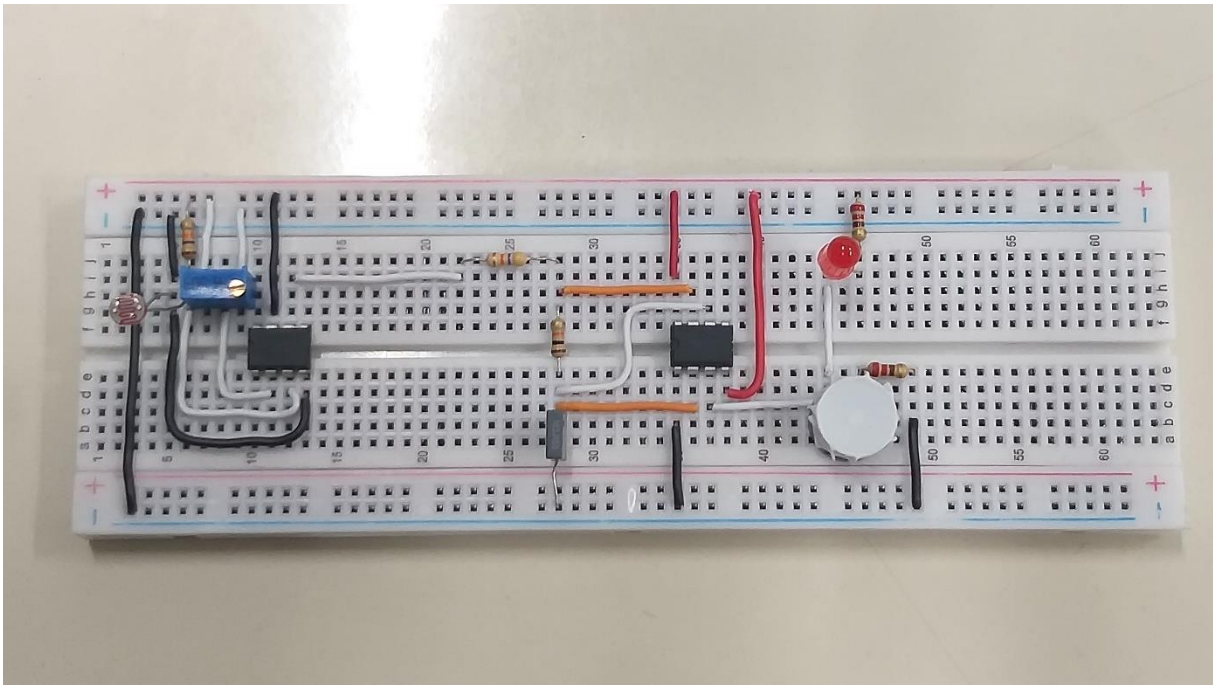

Figure 1. Prototype of Laser Activated Alarm Circuit

2. Block Diagram of The Circuit

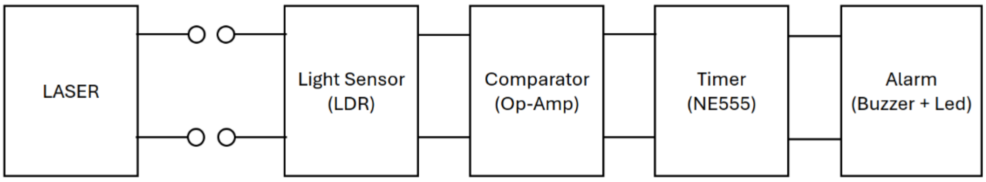

Figure 2. Block diagram of the circuit

3. Circuit Diagram & PCB Design

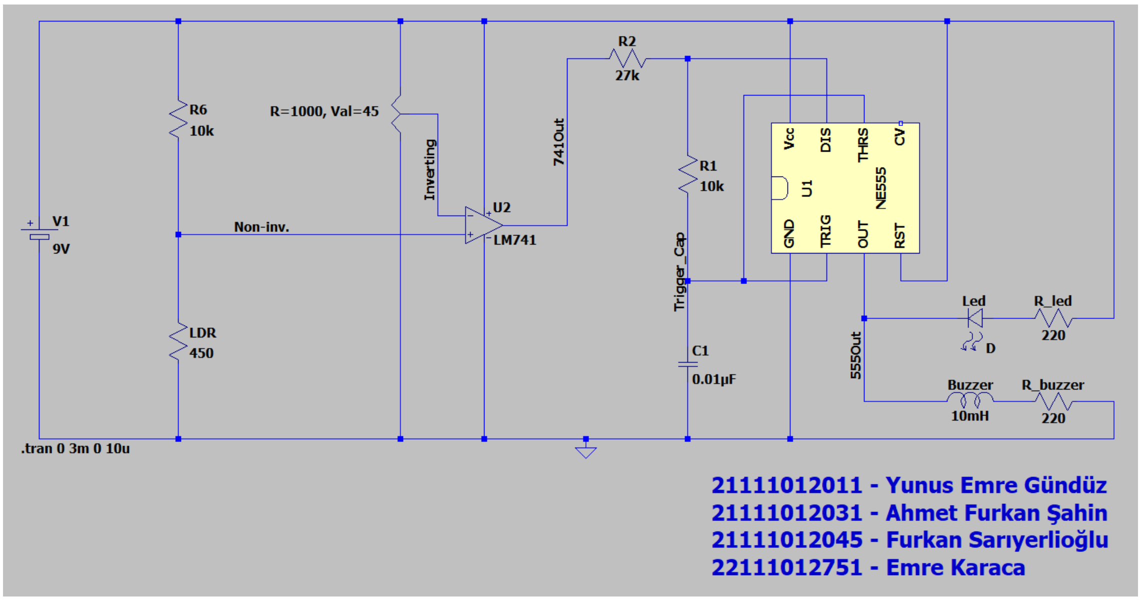

Figure 3. LTspice schematic of the circuit

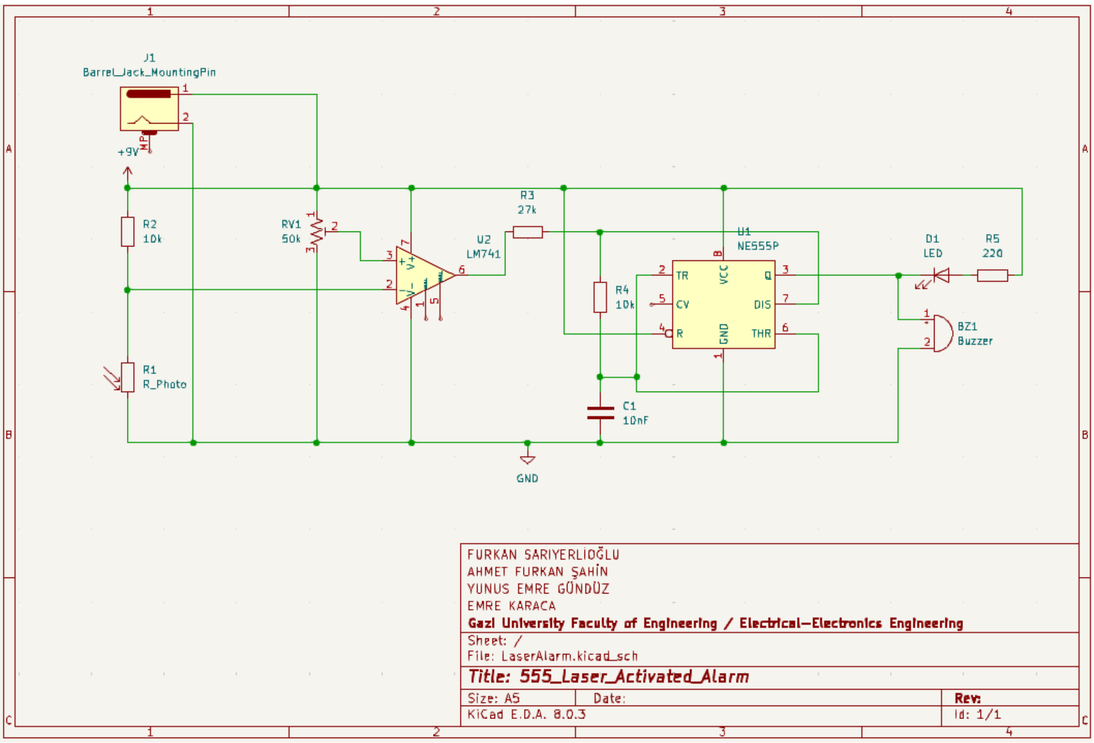

Figure 4. Circuit diagram used for the PCB design made by using the KiCAD software

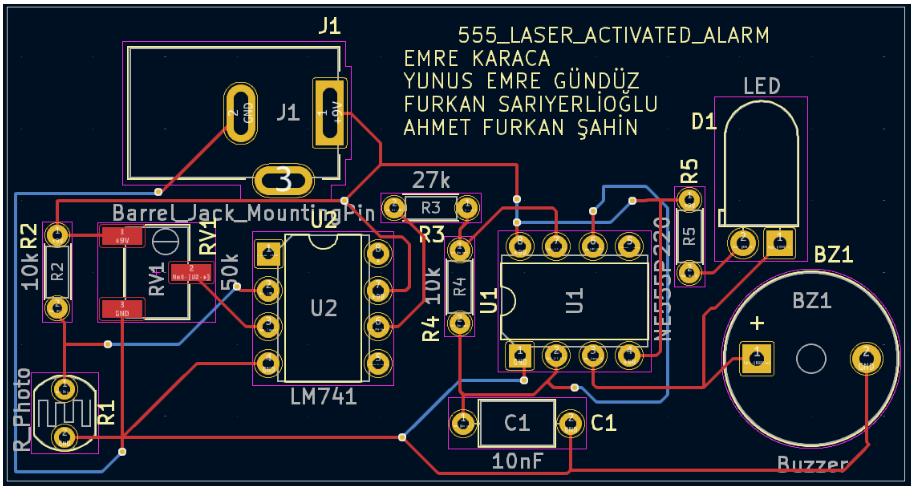

Figure 5. PCB Design

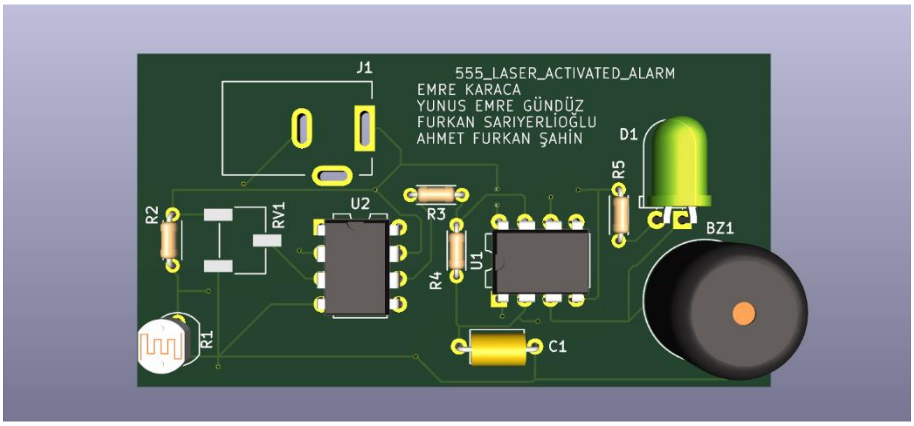

Figure 6. PCB design in 3D view mode

4. Project Working Principle

A. LASER

The laser is the component that activates or keeps the circuit in passive mode. It works by passing the light produced by an LED through a lens to concentrate all the light onto a single point. This provides focused light to illuminate the LDR sensor.

B. LDR

The LDR (Light Dependent Resistor) is a resistor that changes its resistance based on the light intensity falling on it. As the brightness of light increases, its resistance decreases. This principle is used to produce a signal in combination with a voltage divider. If the laser light illuminates the LDR, its resistance will be very low, resulting in approximately 9V being supplied to the Op-Amp via the voltage divider. If no light falls on the LDR, its resistance will be very high, and the voltage divider will supply approximately 0V to the Op-Amp.

C. COMPARATOR (OP-AMP)

The Op-Amp is used as a comparator in the circuit. It operates with a power supply of 0V to 9V. The Op-Amp’s V+ pin receives the signal voltage, while the V- pin is connected to a reference voltage. The Op-Amp compares these inputs and outputs the larger voltage at its output pin. We set our reference voltage to 4V. For example, we have built a voltage divider circuit consisting of a 9V source, an LDR sensor and a 10k resistor. A voltage divider point is connected to the V+ pin of the Op-Amp. When the laser illuminates the LDR, about 0 volts drop to the V+ pin. As a result of the comparison, 0 volts appear at the output end of the Op-Amp. When the laser does not illuminate the LDR, approximately 6 volts appear at the V+ terminal. Since this value exceeds the reference point, approximately 8 volts appear at the output of the Op-Amp.

D. TIMER (NE555)

The 555 timer is used as a switch that activates the output when the comparator (OP-AMP) gives a positive voltage from its output and the 555 timer's output is used as a square wave oscillator with a frequency and amplitude that can activate the alarm block of this project as intended. The connection is made in the astable mode to produce a stable output that can output the desired frequency. This configuration is made by connecting trigger input (pin 2) and the threshold input (pin 6) together, to make sure that 555 does not have a stable output and re-triggers itself. It continuously switches from one state to the other when the 555 is working. 555 operates with a 9V supply and the reset pin (pin 4) is also connected to the supply due to the reset pin being inverted. The output is a square wave that has an amplitude of 7.2 volts. Comparison to other modes, why this mode is chosen, and detailed working principle is explained in section 5.

E. <u>ALARM (BUZZER + LED)</u>
The system uses a buzzer and LED modules as output signals to indicate an emergency. The square wave generated by the NE555 timer drives the buzzer module at a specific frequency, triggering the emergency siren. Additionally, the square wave flashes the LED at regular intervals, providing a visual alert about the emergency.

5. 555 Timer

In this project, the 555 Timer IC is configured in its astable mode to generate a continuous square wave signal. This configuration allows the system to produce non-stop output pulses without requiring any external triggering once powered, making it ideal for activating the alarm block of this security system.

The astable mode was chosen because it generates a continuous square wave without requiring external triggering, unlike monostable mode, which needs repeated triggering pulses for periodic output. Similarly, bistable mode, functioning as a flip-flop, doesn't match our requirements because it lacks the ability to generate a periodic output. The alarm system needs a reliable and repetitive signal to activate the buzzer and LED.

When the circuit powers up, the capacitor (C) begins charging through both resistors (R1 and R2). During this phase, current flows from the comparator through R1, R2, and into the capacitor. The voltage across the capacitor (V_C) increases according to the formula below.

- $V_C = V_{final} + (V_{initial} - V_{final})\, e^{-t/\tau}$

V_{final} = Vcc(9V), $V_{initial}$ is the capacitor's starting voltage (0), and τ = (R1 + R2) *C is the time constant.

In the first cycle, until Vc becomes greater than Vcc/3, the trigger comparator's output goes high and sets the flip flop to high that makes the 555's output high.

After Vc becomes greater than Vcc/3 the trigger comparator's output goes low but the flip flop still has the high output until reset signal is given.

When V_C reaches 2Vcc/3, the threshold comparator's output goes high. This resets the flip-flop, which switches the output low from high. The discharge transistor is then activated due to the Q output going low that makes Q' go high. Q' is connected to the base of the transistor. That begins the discharge phase. During the charging phase, current flows through R1 and R2 into the capacitor.

In the discharge phase, the discharge transistor provides a low-impedance path to ground. The V_C decreases according to the discharge formula below.

- $V_C = V_{final} + (Vinitial - V_{final})\, e^{-t/\tau}$

Here, V_{final} = 0 (since the capacitor is discharging to ground), $V_{initial}$ is the voltage at the start of discharge that is 2Vcc/3, and τ = R2*C is the time constant for discharge.

When V_C falls below 2Vcc/3 of the threshold comparator's output goes low, but the flip flop's output does not change.

When V_C falls below one-third of Vcc, the trigger comparator's output goes high. This sets the flip-flop, turning the output high, disabling the transistor again and restarting the charging phase. In the discharge phase, current flows from the capacitor through R2 and the discharge transistor to ground. The alternation between these phases generates the square wave output.

To summarize the threshold comparator reacts to V_C reaching two-thirds of Vcc, initiating the discharge phase and the trigger comparator responds when V_C drops below one-third of Vcc, starting a new charging cycle. This makes the oscillation continue indefinitely while there is a voltage given to the discharge and threshold/trigger nodes. We can obtain the

- Capacitor Charging Time (t_{on}):

  $t_{on} = 0.693 \times (R1 + R2) \times C$

  The capacitor charges through both R1 and R2 until the voltage across it reaches 2/3 of the Vcc.

- Capacitor Discharging Time (t_{off}):

  $t_{off} = 0.693 \times R1 \times C$

  Then the capacitor discharges through R2 until the voltage drops to 1/3 of the Vcc.

- Total Period (T):

  $T = t_{on} + t_{off} = 0.693 \times [(R1 + R2) \times C + R2 \times C]$

- Output Frequency (f):

  $f = 1 / T = 1 / [0.693 \times (R1 + 2 \times R2) \times C]$

With the selected component values (R2 = 27kΩ, R1 = 10kΩ, C = 10nF), the output frequency is approximately 3.36 kHz

For conclusion the astable configuration of the 555 Timer IC enables the generation of a stable, periodic square wave signal. This mode was selected to ensure non-stop operation of the buzzer and LED indicators, compatible with the project's goal of a reliable cheap security solution.

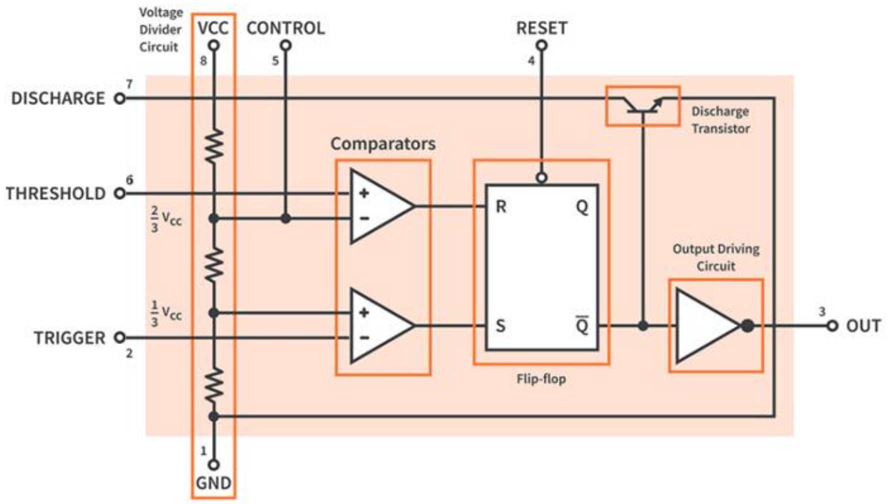

Figure 7. Representation of 555 timer IC's internal structure

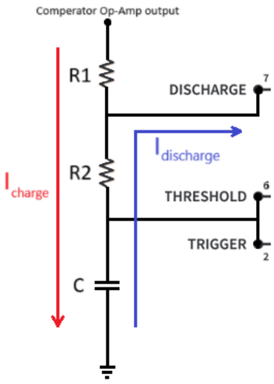

Figure 9. Capacitor Charging and Discharging Currents

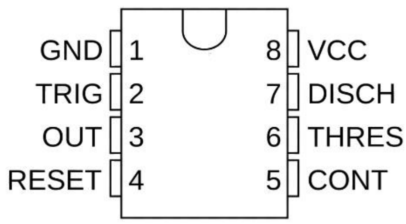

Figure 8. 555 timer IC pinout

6. Cost Analysis

Component	Quantity	Manufacturer	Unit Price (TRY)	Total Price (TRY)
NE555 IC	1	OEM	2.13	2.13
LM741CN Op-Amp	1	Texas	12.79	12.79
LDR	1	TZT	2.77	2.77
Buzzer	1	Weidily	5.12	5.12
LED	1	HQG	0.60	0.60
10kΩ Resistor	2	Yuetai	0.40	0.80
27kΩ Resistor	1	Yuetai	0.40	0.40
220Ω Resistor	2	Yuetai	0.40	0.80
50kΩ Trimpot	1	Bochen	8.00	8.00
10nF Capacitor	1	Faratronic	2.19	2.19
			Total Cost:	36.76

Table 1. Component List & Costs

7. Simulation Results

To better observe and explain the operation of the circuit we prepared in this project, we performed simulations in the LTspice program and added the results to this report.

In the measurements related to the first part of the circuit, the "comparator op-amp circuit", we recorded the voltages on the inverting, non-inverting and output pins of the LM741. We repeated the measurements when the laser light illuminated and did not illuminate the LDR and added them to our report.

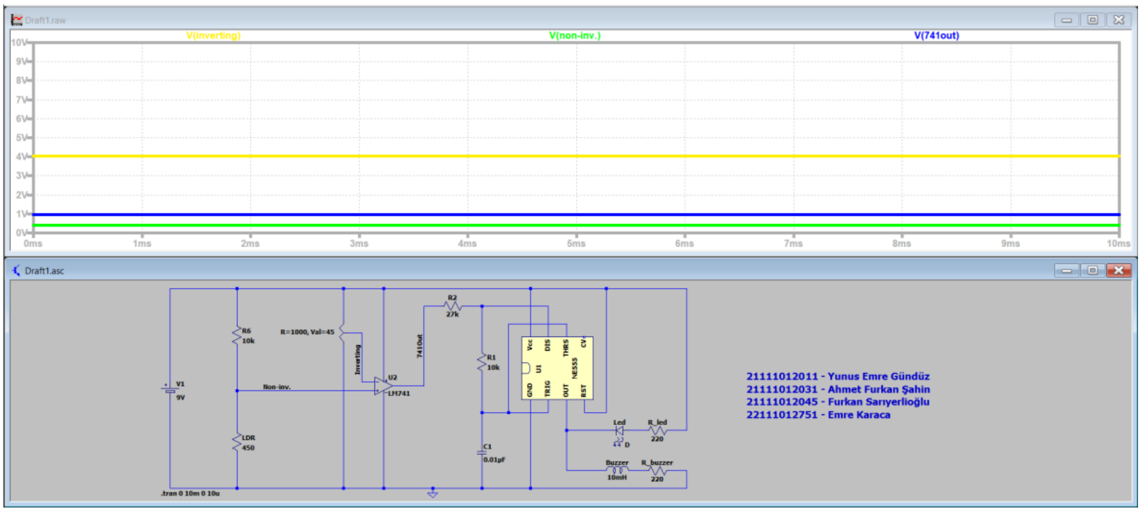

Figure 10. LM741 Voltages When the Laser Illuminates the LDR

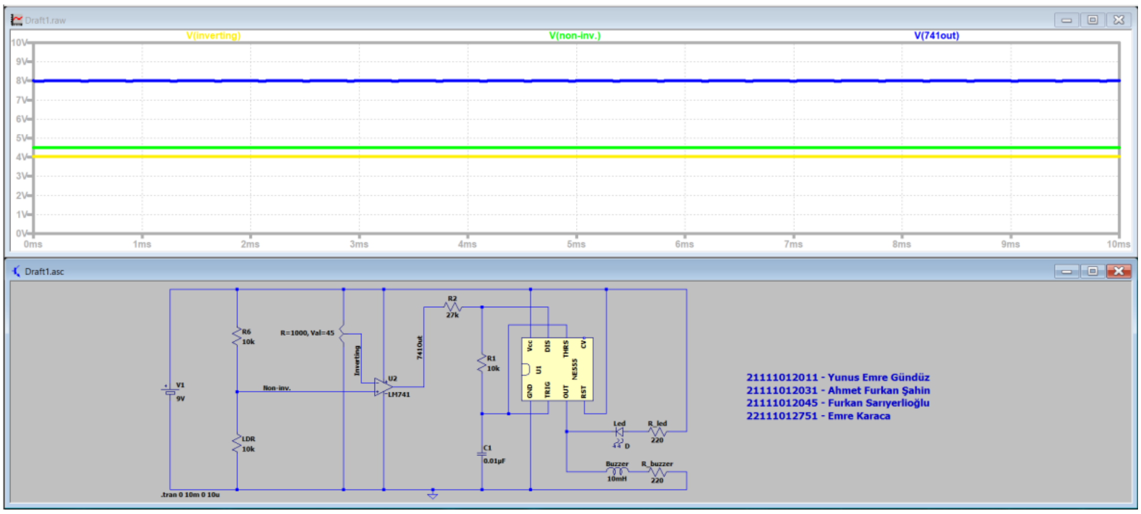

Figure 11. LM741 Voltages When the Laser does not Illuminate the LDR

In the second part of the circuit, “Generating square wave with NE555”, we recorded the voltage values we measured from the Output and Trigger pins. In addition to the voltage values, we calculated the period and positive width of the square wave signal we generated using NE555 by LTspice. As we did in the previous section, we repeated the measurements when the laser illuminated and did not illuminate the LDR and added them to our report.

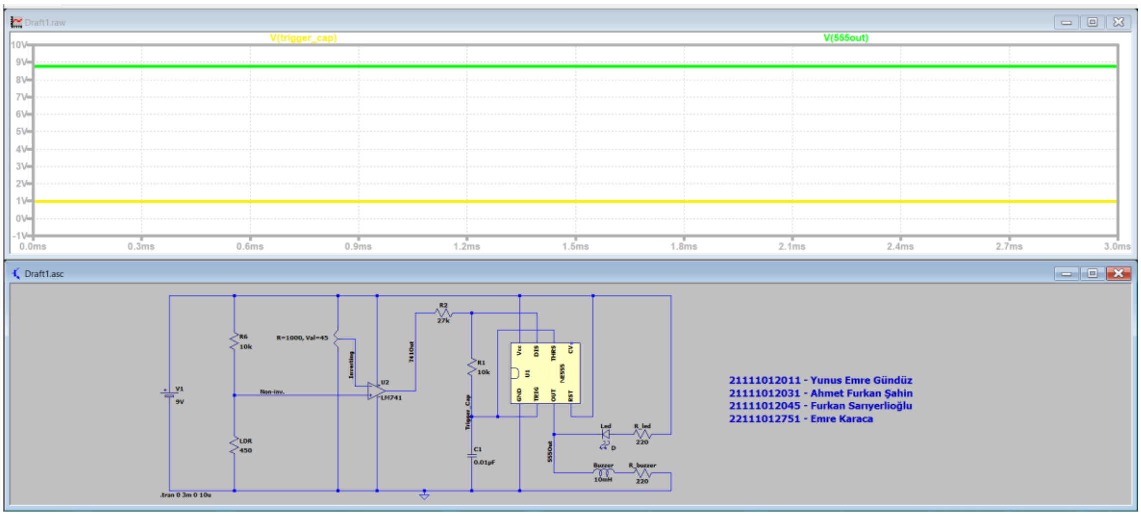

Figure 12. Voltages of NE555’s Output and Trigger Pins When the Laser Illuminates the LDR

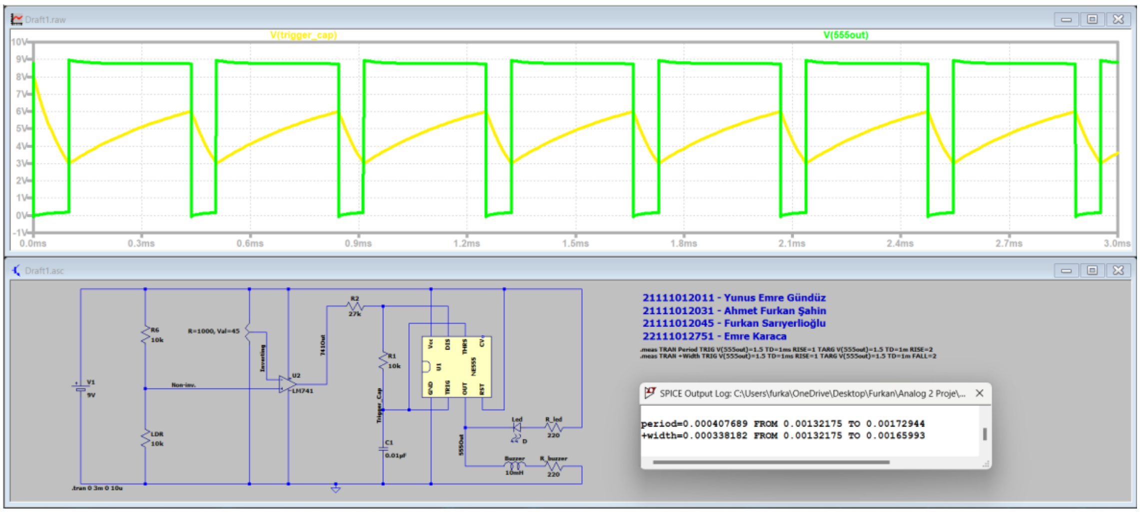

Figure 13. Period & Voltage values of NE555’s Trigger and Output Pins When the Laser does not Illuminate the LDR

8. Experimental Results

To better observe and explain the operation of the circuit we prepared in this project, we made measurements using an oscilloscope in the electronics laboratory and added the results to this report.

Like the measurements made in the simulation, we recorded the voltages on the inverting, non-inverting and output pins of the LM741 in the measurements related to the "comparator op-amp circuit", which is the first part of the circuit.

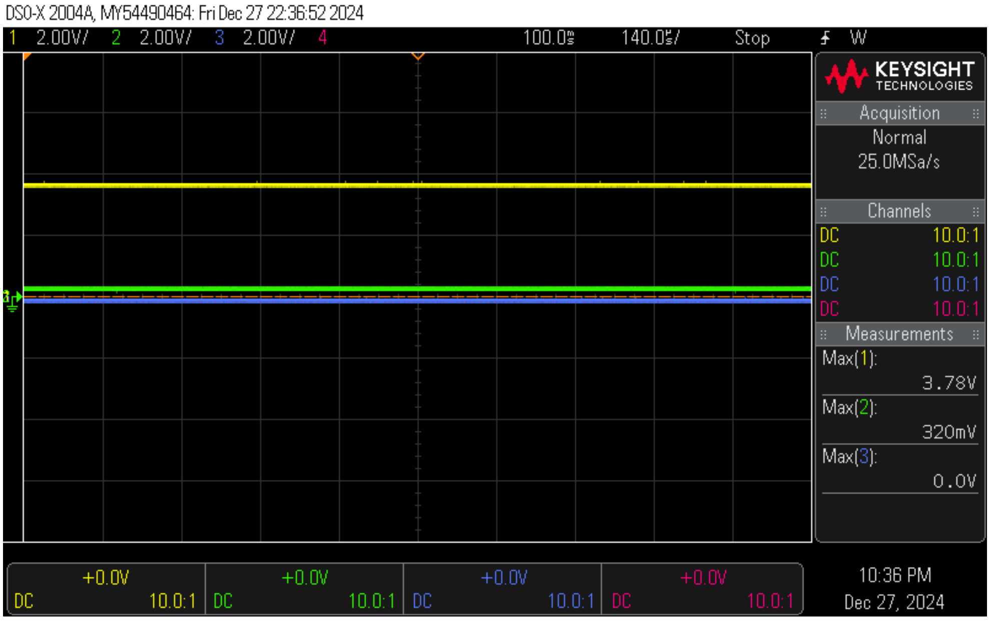

Figure 14. LM741 Voltages When the Laser Illuminates the LDR

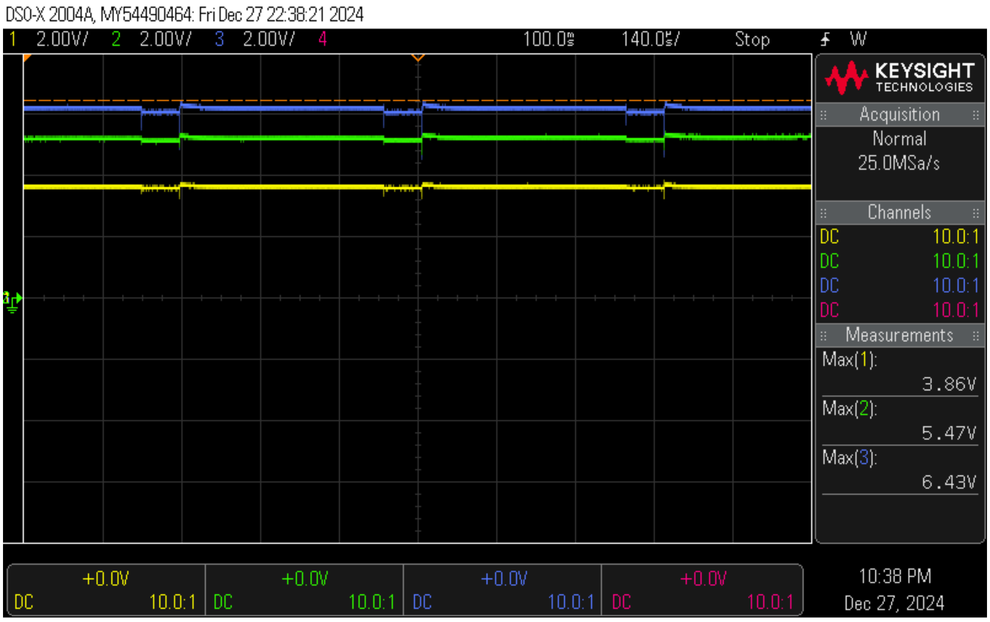

Figure 15. LM741 Voltages When the Laser does not Illuminate the LDR

Then, similar to the measurements made in the simulation, in the second part of the circuit, "Generating square wave with NE555", we recorded the voltage values we measured from the Output and Trigger pins. In addition to the voltage values, we calculated the period and positive width of the square wave signal we generated using NE555 by LTspice.

We observed that these measurements we made were similar to the results of the simulations we made in the LTspice Program.

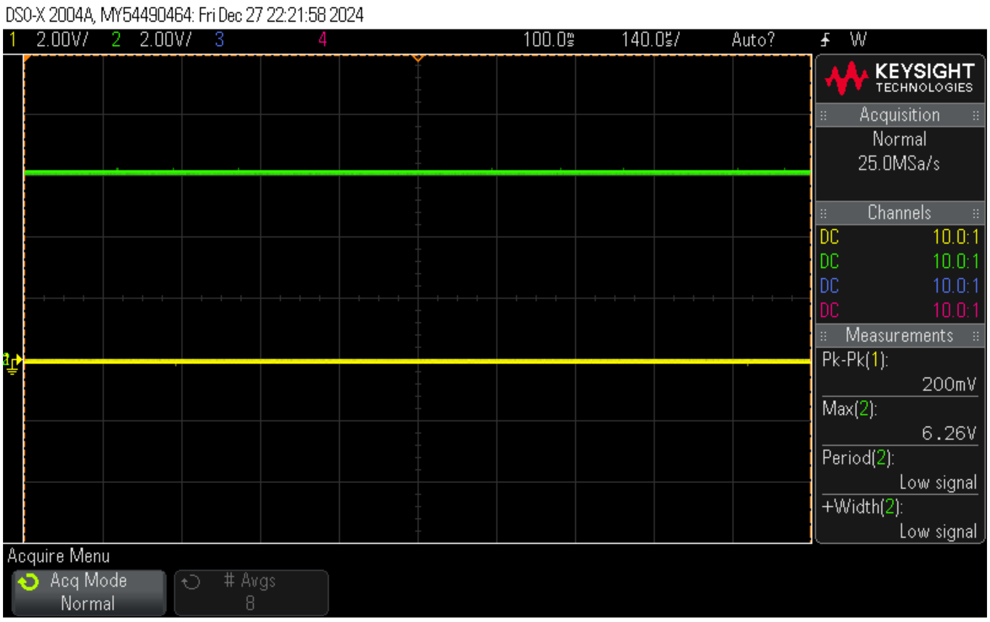

Figure 16. Voltages of NE555's Output and Trigger Pins When the Laser Illuminates the LDR

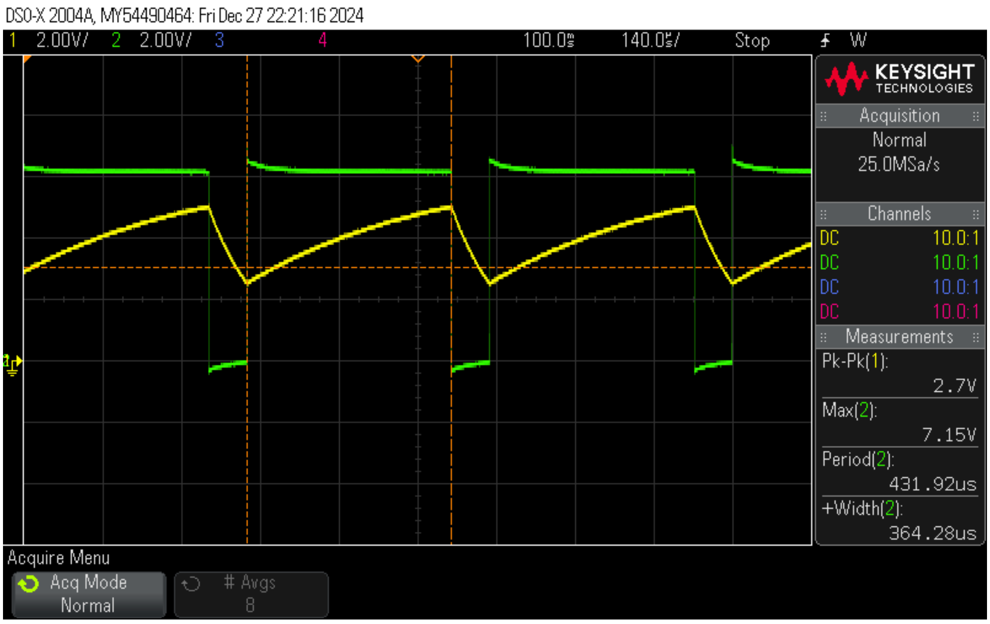

Figure 17. Period & Voltage values of NE555's Trigger and Output Pins When the Laser does not Illuminate the LDR

9. Result

The security system successfully meets its goal of providing a simple and affordable solution for disadvantaged (elderly) groups. When designing this circuit, we initially planned to use only a buzzer. Later, we decided to add an LED for a visual alert and incorporated it into the system. Throughout this experiment, we learned in detail how each component works. The system works effectively by using the laser, LDR, comparator, 555 Timer, and alarm components together.

The security system functions effectively, transitioning between passive and active modes as needed. In passive mode, the laser continuously illuminates the LDR, keeping its resistance low and the NE555 timer inactive. When the door is opened and the laser beam is interrupted, the LDR's resistance increases, causing the comparator to output a high signal that activates the NE555 timer. This, in turn, powers the buzzer and LED. The buzzer produces a loud sound to warn of an intrusion, while the LED provides a steady visual alert.

The components work reliably, with the laser providing a consistent light source, the LDR accurately detecting changes in light, and the comparator efficiently comparing voltage inputs. The NE555 timer generates a stable square wave signal, and the buzzer and LED modules deliver clear and immediate alerts. During real-life testing, the system demonstrated its ability to detect intrusions quickly and activate the alarm without delay. Its low cost and simple design make it a practical and reliable security solution, especially for elderly individuals living alone.

In conclusion, this project successfully creates a reliable and easy-to-use security system. Its simple design and low price make it suitable for protecting homes and helping disadvantaged groups feel safer.