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MIDDLE EAST TECHNICAL UNIVERSTY

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

EE213 ELECTRICAL CIRCUITS LABORATORY

2017-2018 FALL

TERM PROJECT

SOLAR TRACKING SYSTEM

PRE-REPORT

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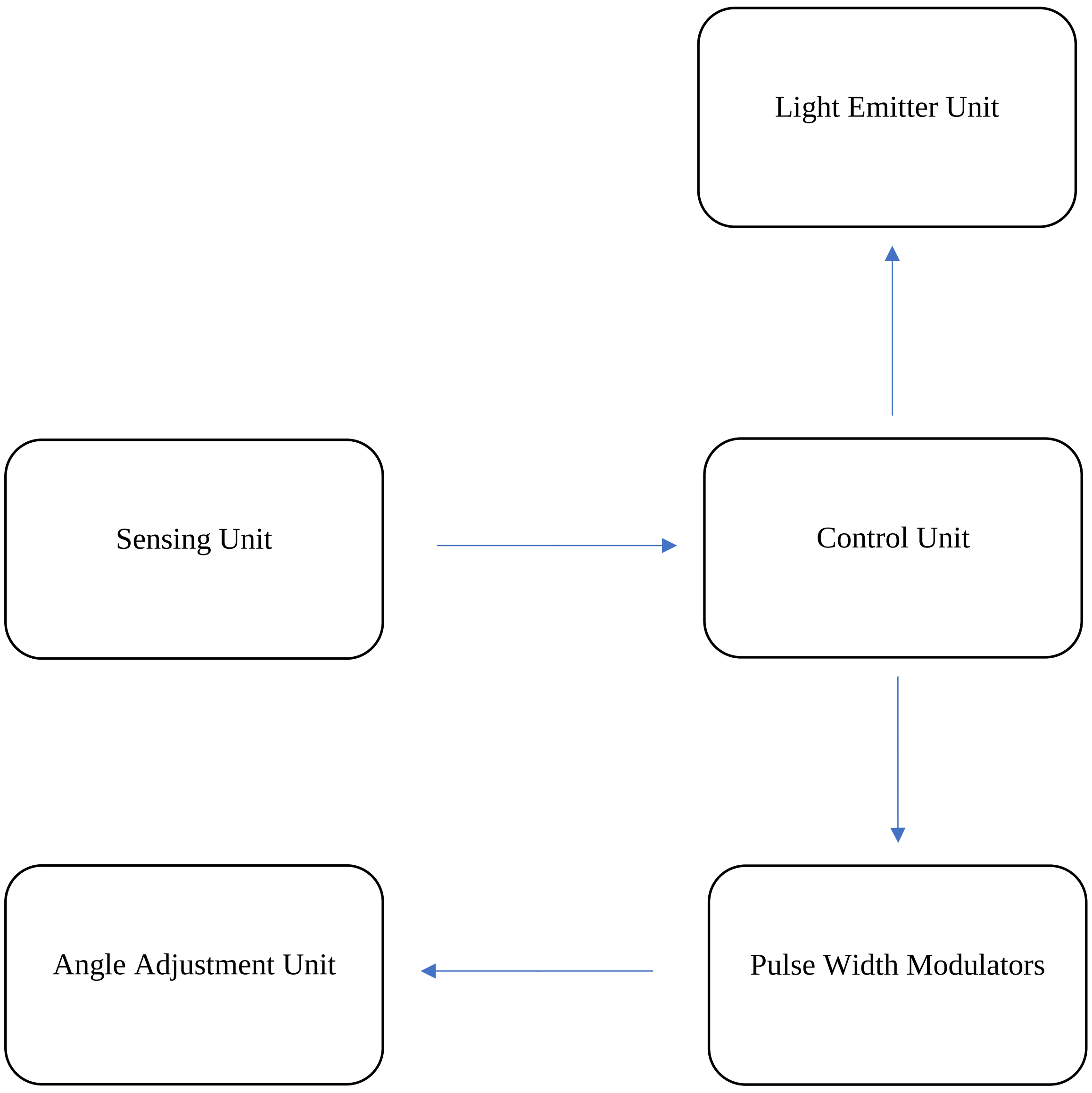
1. INTRODUCTION

In this project, our objective is to design a solar panel taking certain positions in accordance with the direction light is incoming. This way, we aim to obtain maximum energy from the sun. Furthermore, in accordance with which side takes more sunlight, we need to obtain a different color from the RGB LED. While designing the circuit, we made use of special circuit designs we have learned from the laboratory sections such as square wave generator or light sensor unit. We decomposed the circuit in 5 parts as below.

- Sensing Unit
- Control Unit
- Light Emitter Unit
- Pulse Width Modulator Unit
- Angle Adjustment Unit

2. BASIC DESIGN DIAGRAM



Firstly, the sensing unit will observe the light coming from three different directions. Afterwards, the control unit, by comparing the results obtained from the sensing unit, will decide which light is the most intense. Then, in the light emitter unit, RGB will produce a color according to the direction light is incoming. Also, with the help of pulse width modulators, a square wave which contains the information which direction the panel should be rotated to will be generated. Finally, the angle adjustment unit, taking this square wave as an input, will rotate the servo motor to the desired angle.

3. CIRCUIT SCHEMATICS

A) SENSING UNIT

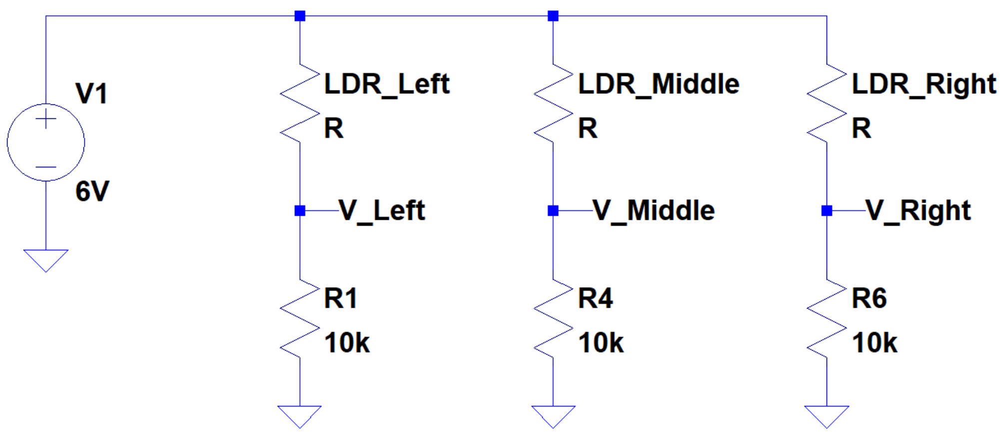


Figure 1: The circuit schematic of the sensing unit

The sensing unit will obtain three voltages in accordance with the resistance values of the LDRs. As the incident light gets more intense, the resistance value of an LDR decreases, and the current passing through the LDR increases. Hence, the voltage difference between the resistors with 10KΩ increases. Therefore, this part of the circuit gives three voltage outputs whose values are proportional to the intensity of light incident on that part of the unit.

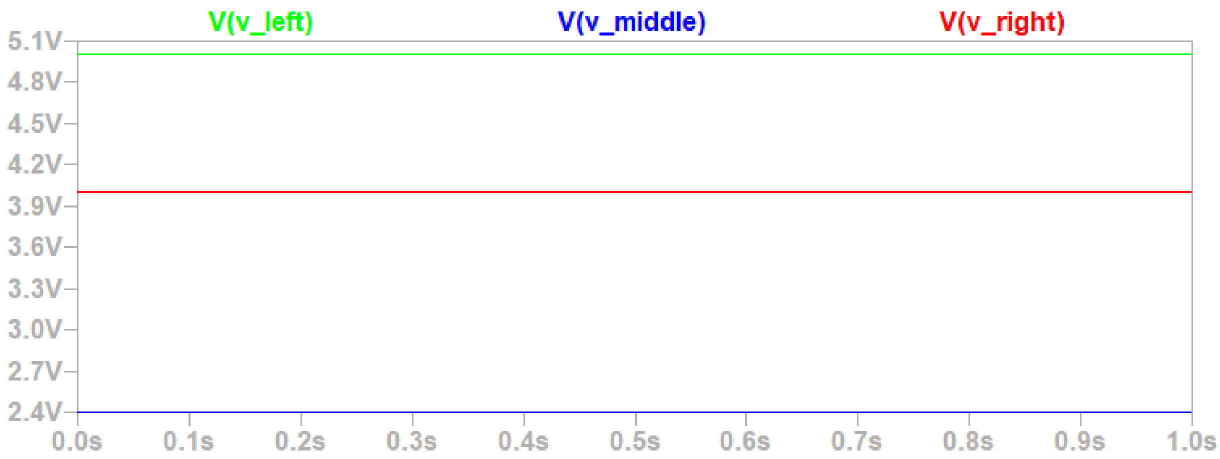


Figure 2: Voltage values of V_Left(=+5V), V_Middle(=+2.4V), and V_Right(=+4V) when LDR_Left = 2KΩ, LDR_Middle = 15KΩ, and LDR_Right = 5KΩ

B) CONTROL UNIT

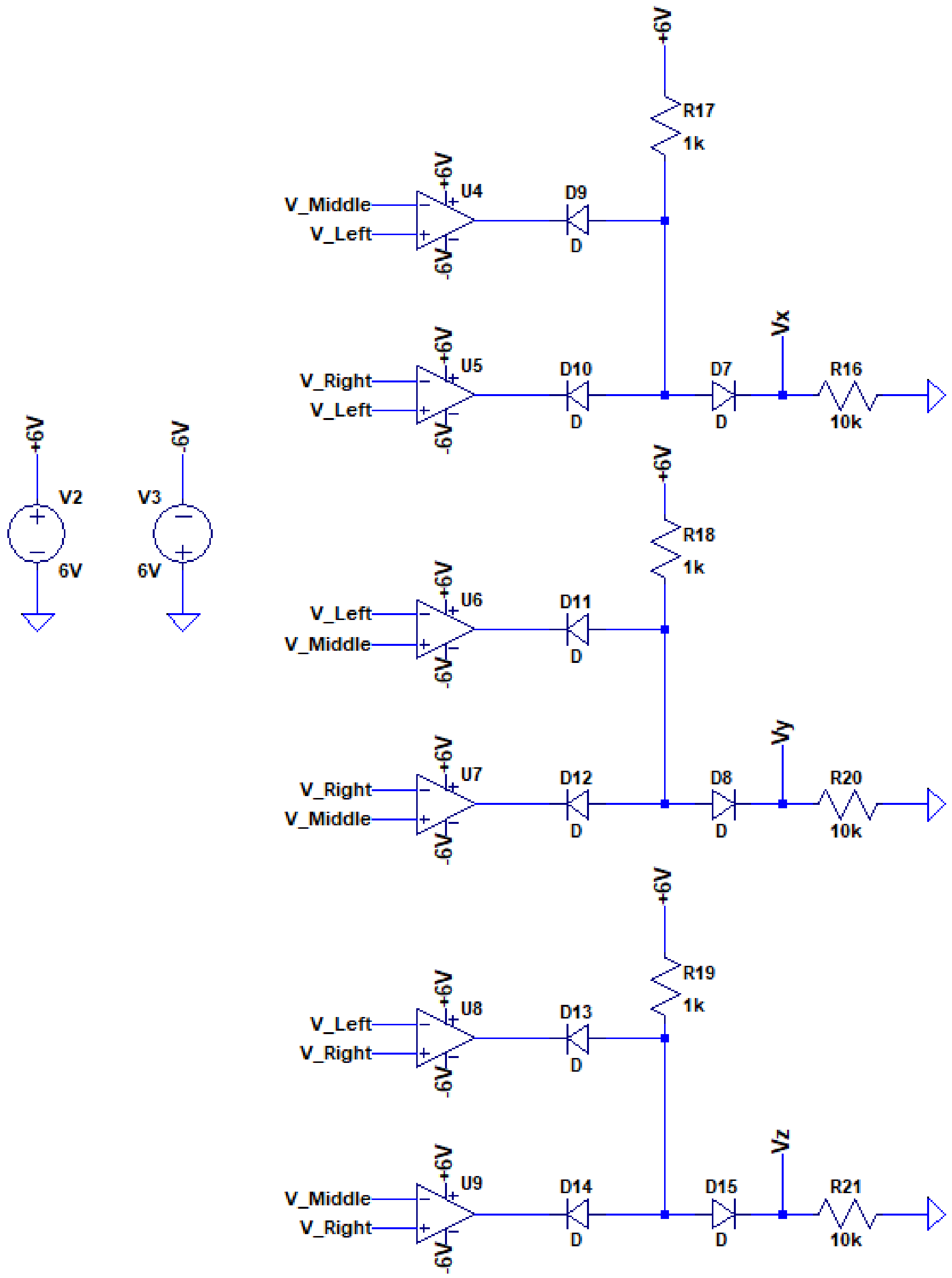


Figure 3: The circuit schematic of the control unit

In the control unit, three voltages obtained in the sensing unit are compared. In the first two operational amplifiers, V_Left and the other two are compared, and if it has the highest voltage, both operational amplifiers will give an output of +6V which is the positive saturation voltage. Because the other side of the diodes has less voltage, the current will not pass through them, and current will pass through the other part of the circuit. Thus, comparators will not influence that part. In that case, Vx will be approximately +5V because of the diode and the resistor with 1KΩ. However, if V_Left is not the highest one, even if one of the comparators gives a negative saturation voltage, all the current will pass through the diode connected to the operational amplifier with negative saturation value, and affect the other part of the circuit. In that case, Vx will be 0V as no current passes through it and there is no voltage difference across the resistor with 10KΩ. Therefore, if three exact copies of this small circuit are used, only one of the Vx, Vy or Vz will be +5V, while the others will be 0V, as only one them can have a highest value among them.

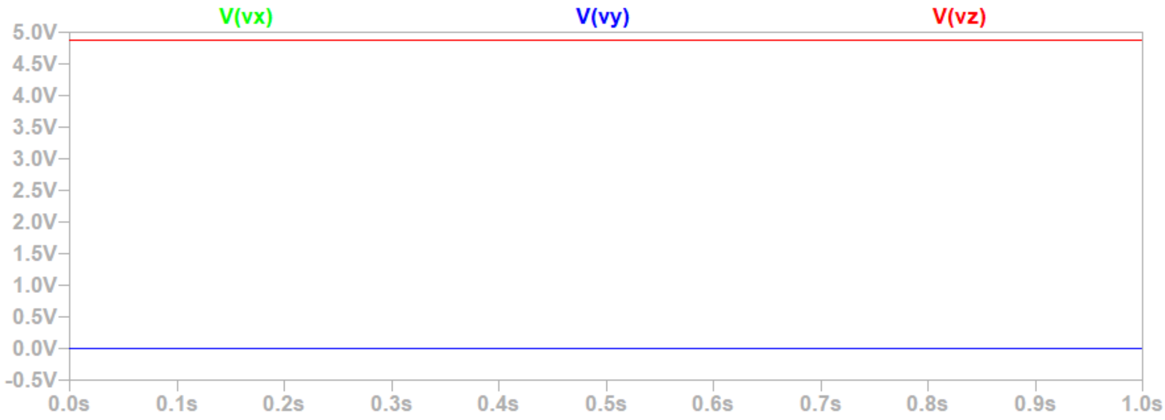


Figure 4: Voltage values of Vx(=0V), Vy(=0V), and Vz(=~+5V) when V_Left = +3V, V_Middle = +4V, and V_Right = +5V

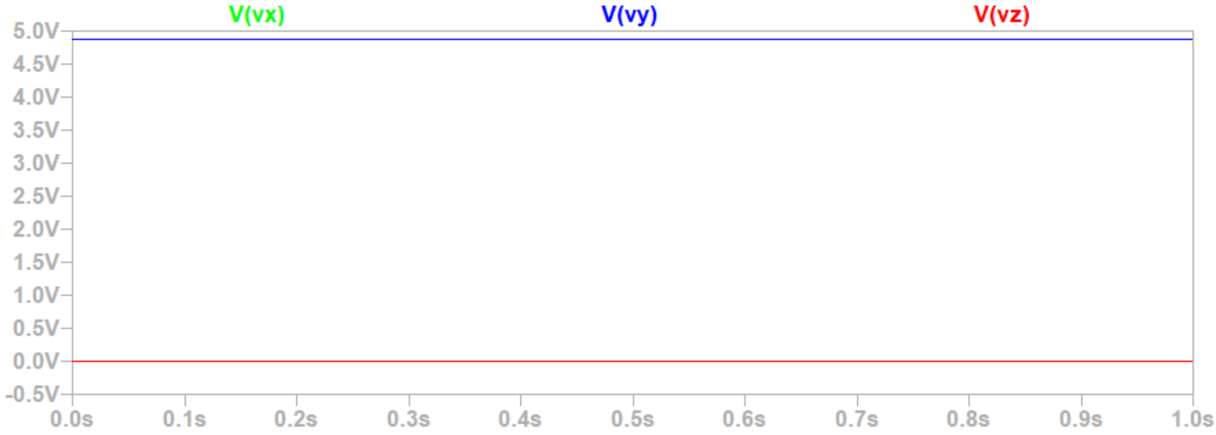


Figure 5: Voltage values of Vx(=0V), Vy(=~+5V), and Vz(=0V) when V_Left = +4V, V_Middle = +5V, and V_Right = +3V

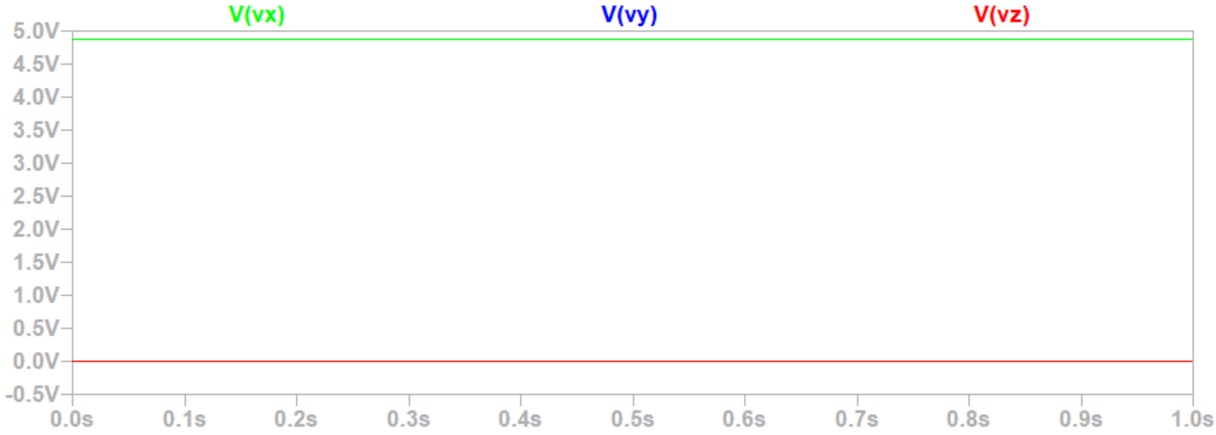


Figure 6: Voltage values of Vx (=~+5V), Vy(=0V), and Vz(=0V) when V_Left = +5V, V_Middle = +3V, and V_Right = +4V

C. LIGHT EMITTER UNIT

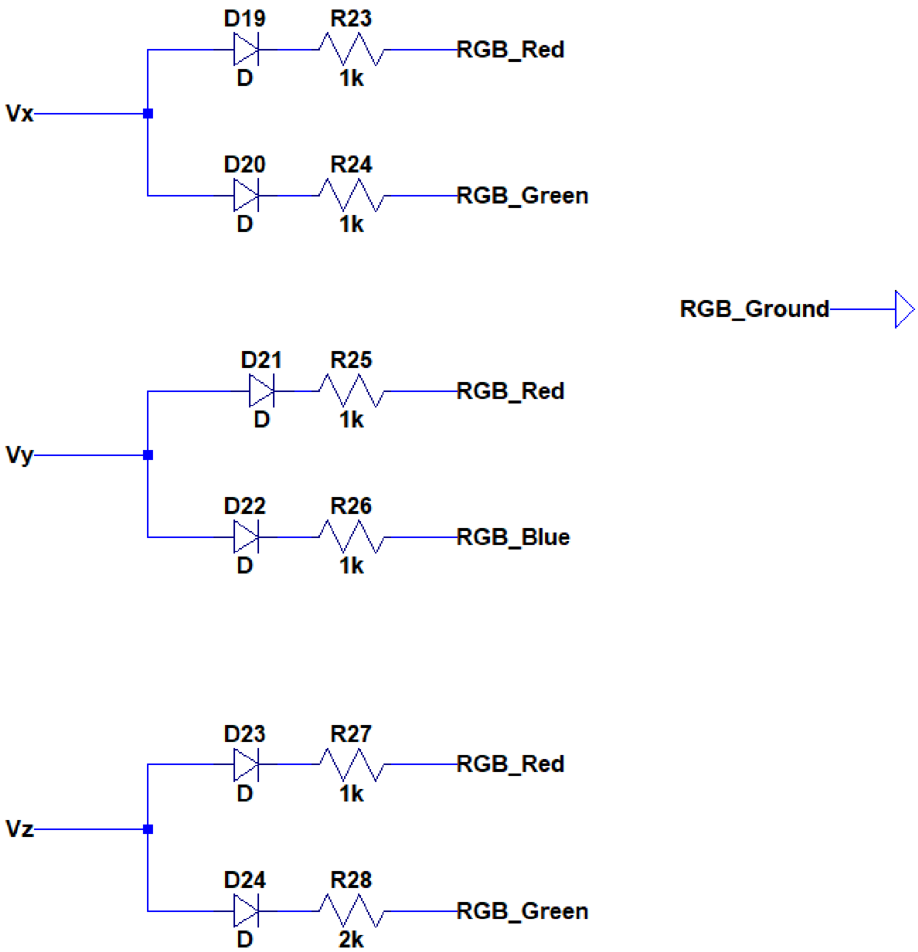


Figure 7: The circuit schematic of the light emitting unit

In light emitting unit, for every different direction light incomes, a different color of light will be produced. When V_Left is the highest one, and Vx is +5V (others will be 0V), equal amount of currents will pass through RGB_Red and RGB_Green, and a yellow color will be obtained as yellow is an equal mixture of red and green. When V_Middle is the highest one, and Vy is +5V (others will be 0V), equal amount of currents will pass through RGB_Red and RGB_Blue, and a purple color will be obtained as purple is an equal mixture of red and blue. When V_Right is the highest one, and Vz is +5V (others will be 0V), the current passing through RGB_Red will be twice the current passing through RGB_Green, and an orange color will be obtained as orange is a mixture of red and green, but red must be more intense [1]. Diodes are used to prevent current flowing to Vx, Vy or Vz in case they are 0V.

D. PULSE WIDTH MODULATOR UNIT

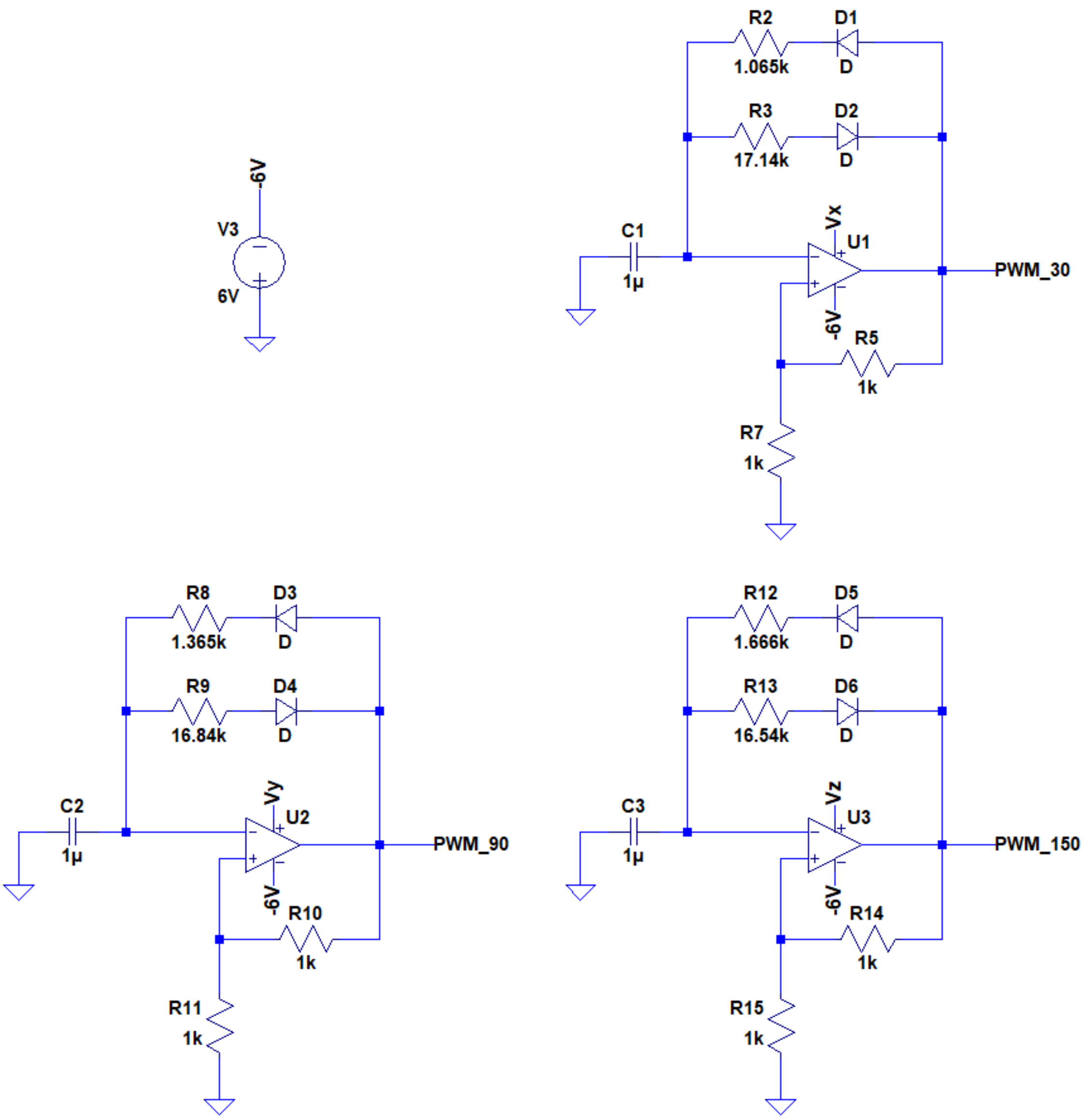


Figure 8: The circuit schematic of pulse width modulator unit

The pulse width modulator unit will produce a square wave according to the direction the panel should rotate. Positive supply sources of the operational amplifiers come from the control unit, so when one of them is +5V and the others are 0V, only one of the operational amplifier will produce a square wave. Corresponding resistances are calculated by the formula $\boldsymbol{T = R * C * \ln\left(\frac{1+\lambda}{1-\lambda}\right)}$, $\boldsymbol{\lambda = \frac{R1}{R1+R2}}$ as follows.

Servo motors rotates to 0° when T_H = 1ms and rotates to 180° when T_H = 2ms, so T_H values are calculated by interpolation.

For 30°, T_H = 1.17ms, T=20ms, then T - T_H = 18.83ms
t = 1.17ms = R * 1µ * ln (3), then R = 1.065kΩ
t = 18.83ms = R * 1µ * ln (3), then R = 17.14kΩ

For 90°, T_H = 1.5ms, T=20ms, then T - T_H = 18.5ms
t = 1.5ms = R * 1μ * ln (3), then R = 1.365kΩ
t = 18.5ms = R * 1μ * ln (3), then R = 16.84kΩ

For 150°, T_H = 1.83ms, T=20ms, then T - T_H = 18.17ms
t = 1.83ms = R * 1μ * ln (3), then R = 1.666kΩ
t = 18.17ms = R * 1μ * ln (3), then R = 16.54kΩ

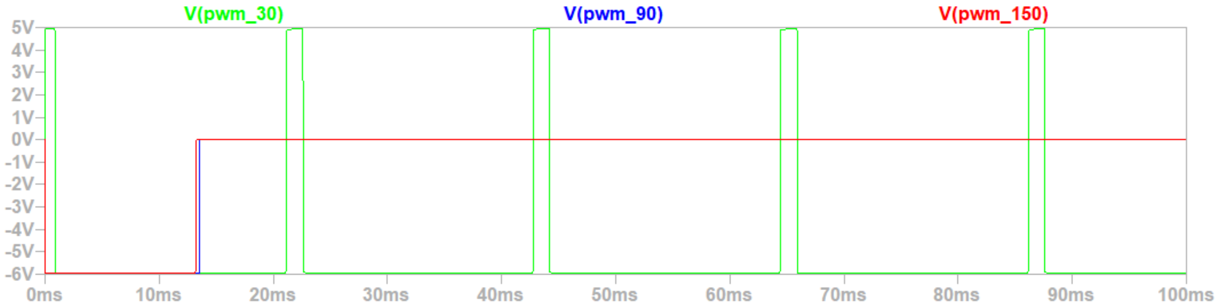


Figure 9: Voltage waveforms of PWM_30, PWM_90 and PWM_150 when Vx = +5V, Vy = 0V, and Vz = 0V

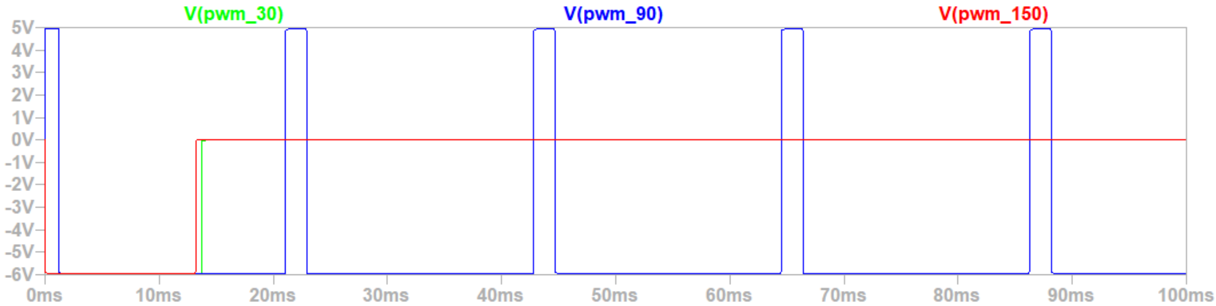


Figure 10: Voltage waveforms of PWM_30, PWM_90 and PWM_150 when Vx = 0V, Vy = +5V, and Vz = 0V

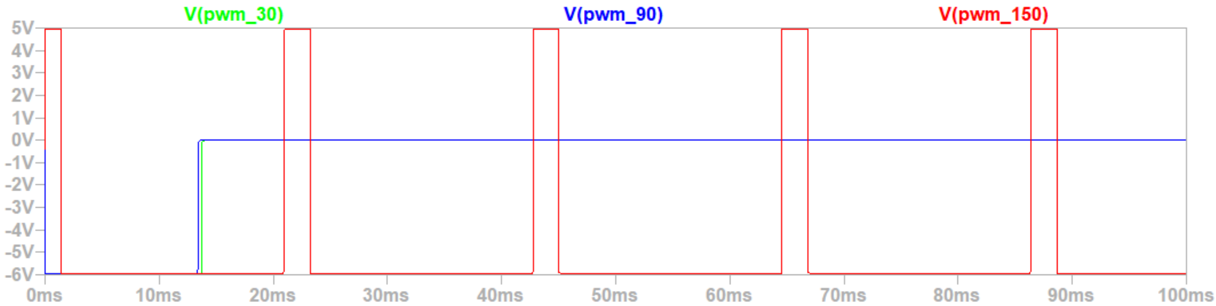


Figure 11: Voltage waveforms of PWM_30, PWM_90 and PWM_150 when Vx = 0V, Vy = 0V, and Vz = +5V

E. ANGLE ADJUSTMENT UNIT

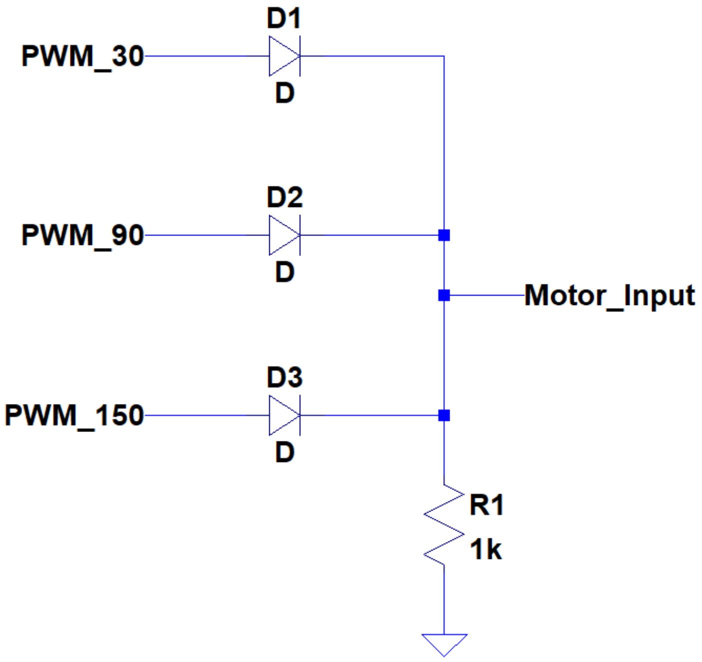


Figure 12: The circuit schematic of the angle adjustment unit

The angle adjustment unit will be connected to all the pulse width modulators and one of them will supply a square waveform, while others will be just 0V. When the square waveform is on the on mode, because its voltage is higher than ground, a current will pass, and the motor output will be equal to the peak voltage of the square waveform. When the square waveform is on the off mode, because its voltage is -6V, no current will pass because of the diode, and the motor output will be equal to the ground voltage. Therefore, this unit basically sums the voltage waveforms coming from pulse width modulators, and eliminates negative voltage values taking the ground as a reference node.

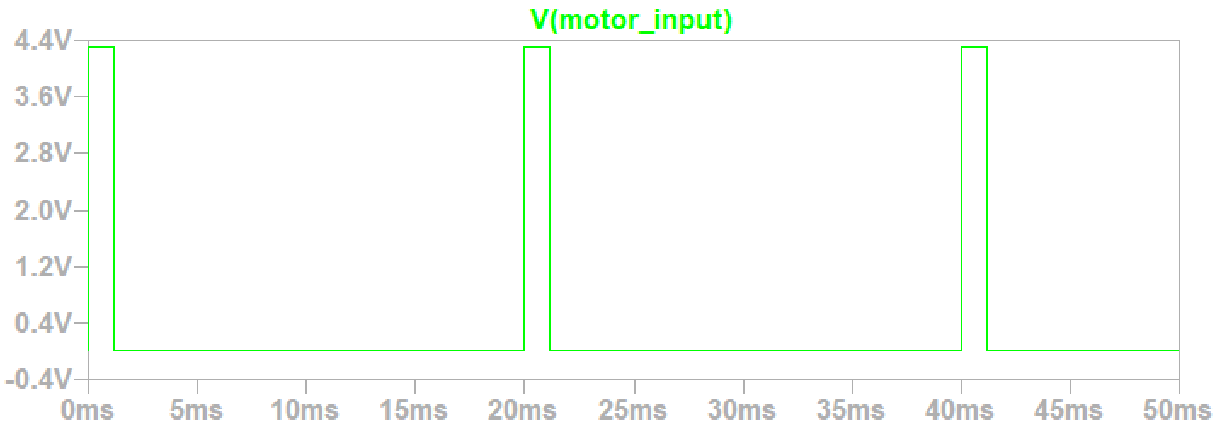


Figure 13: Voltage waveform of the motor input when PWM_30 is a square wave with T_H = 1.17ms and T = 20ms, PWM_90 = 0V and PWM_150 = 0V

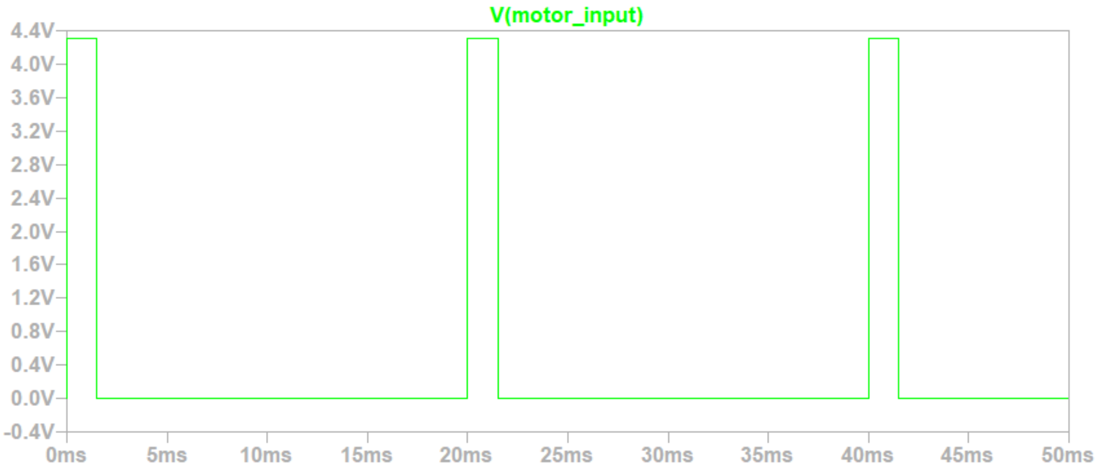


Figure 14: Voltage waveform of the motor input when PWM_30 = 0V, PWM_90 is a square wave with T_H = 1.50ms and T = 20ms and PWM_150 = 0V

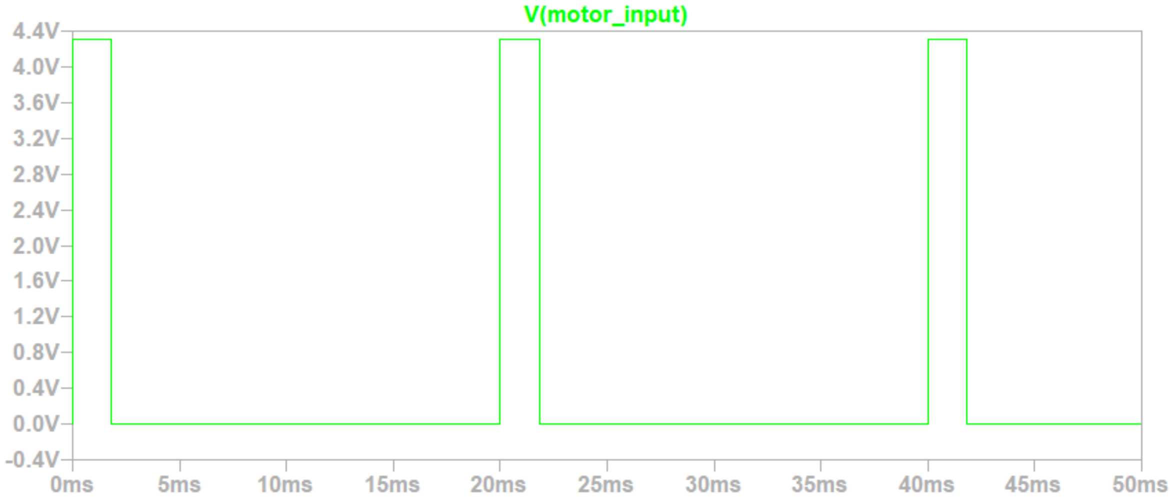


Figure 15: Voltage waveform of the motor input when PWM_30 = 0V, PWM_90 = 0V and PWM_150 is a square wave with T_H = 1.87ms and T = 20ms

4. SELECTION OF EQUIPMENT

- LM741: A basic, general-purpose operational amplifier
- RGB LED: To obtain different colors for different inputs
- Diodes: To prevent the current flow from the opposite direction
- Potentiometer: To obtain resistance values which we can not get from practical resistor
- Servo Motor SG90: A tiny servo motor capable of rotating approximately 180 degrees

5. CONCLUSION

In conclusion, in this project, we practiced what we have learned from the laboratory sections such as using a comparator to compare two voltage values, making a light sensor using an LDR, using an operational amplifier with a capacitor to obtain a square wave. Also, while designing our circuit, we learned the working principle of RGB, how to sum different voltage values by using diodes and how to make or gate or and gate with the use of diodes [2]. Throughout our designing, we consulted the Internet and made a lot of research. Therefore, this project was an excellent way to put our theoretical knowledge to practical use.

6. REFERENCES

[1] RGB Color Codes Chart [Online]. Available:
https://www.rapidtables.com/web/color/RGB_Color.html

[2] OR and AND logic gates made with diodes [Online]. Available:
https://electronicsarea.com/or-and-and-logic-gates-with-diodes/