EE 316 - Electronic Design Project

Group 1 Project:

Speed Control of a DC Motor

Final Project Report

10 June 2022

Objective

Our main objective is to control the speed of the dc motor by using a few techniques. We get the frequency information of the dc motor through the photodiode so that we are able to calculate the RPM which is the revolution per minute of the motor. The frequency of the motor that we obtain ought to be converted to a dc voltage value by using a frequency to voltage converter. Then we create a closed loop feedback system to adjust the speed of the motor according to the desired RPM value.The other minor objective is to display RPM value and to keep track of the system's desired outcomes and faults. We will design a BCD display circuit using timer, counter and other necessary elements and observe the desired RPM value. In addition, It will be one of our objectives that the circuits we will design work in harmony with each other.

Group Members

Common efforts: Controlling the speed of a DC motor

Oğuzhan Aydıner: To obtain PWM and adjustments

Mehmet Ali Özçekiç: Frequency to voltage conversion and to obtain error signal

Umut Can Altun: Displaying of the RPM

1. Background Information

As there is a disk on the motor which has 16 LED lights, lights fall on the photodiode so that we obtain a sinusoidal current through the photodiode while the motor is turning. We convert the current to the sinusoidal voltage signal because we control the motor by voltage value. The conversion can be done by many techniques, but we use op-amp to do it. The dc voltage value is linear with the frequency of the motor, so we are able to calculate the RPM value in every frequency of the motor by using this linearity property.The photodiode and the DC motor operates with a signal which has a frequency information so we use an IC to convert frequency to voltage.We use a potentiometer to control the RPM value. We do a voltage division by using potentiometer so that we obtain a voltage within the range of our supply voltage to the voltage division and zero. The voltage we obtain is a desired input so we create a closed loop feedback system and we subtract the desired voltage which is corresponding to a specific RPM value from the voltage that is the corresponding voltage of frequency of the motor. We use a differentiator op-amp to subtract them. If the error signal which we obtain by the subtraction is zero that means we get the desired output from the motor. In the Displaying Part, The purpose of this part is to observe the RPM value of the dc motor on the screen. The time information required for the desired speed will be adjusted with the timer circuit. time information and frequency information of speed will be transferred to the counter circuit. Then, to see the desired value, the output numbers will be increased with the help of the decoder and this rpm value will be displayed on the screen with the help of the shift register.

1.1. DC Motor

A DC motor is an electric machine that transforms electrical energy into mechanical energy. DC motors use direct current to convert electrical energy into mechanical rotation. Magnetic fields created by electrical currents are used in DC motors to power the movement of a rotor mounted within the output shaft. The speed of the motor can be controlled by the voltage.

Figure 1: Dc Motor

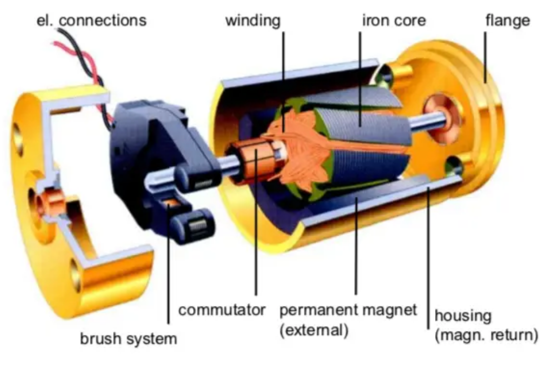

Figure 2: Inside of the DC Motor

1.2. Measuring The Speed of DC Motor

We use infrared LEDs on a disk which is connected to the shaft of the motor. While the motor is rotating, the disk is also rotating. The magnitude of the light is changing by time.We ought to obtain that light magnitude function by time. So we use a sensor to get that function. There are several light sensors such as photodiodes and phototransistors. We pick a photodiode because our light magnitude is so small so the photodiode provides our needs.We put a photodiode nearby the disk. The photodiode is induced by light and creates a sinusoidal current at microampere levels.The sinusoidal current is the function that we need.

Figure 3: Infrared LED

Figure 4: Photodiode

1.3. Conversion of Frequency to Voltage

We use voltage to control the DC motor so we ought to convert the frequency that we obtain from the photodiode to the DC voltage value. There are several techniques to convert frequency to voltage. We use an IC to do this conversion which is LM2907N.It is a single-chip frequency voltage converter with a high-gain comparator op-amp. We obtain a DC voltage with a ripple by using this IC so we add a low-pass filter to eliminate the ripple.

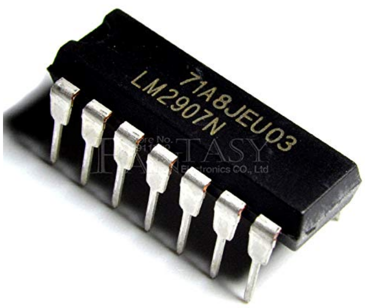

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Figure 5: LM2907N IC

1.4. Pulse Width Modulation

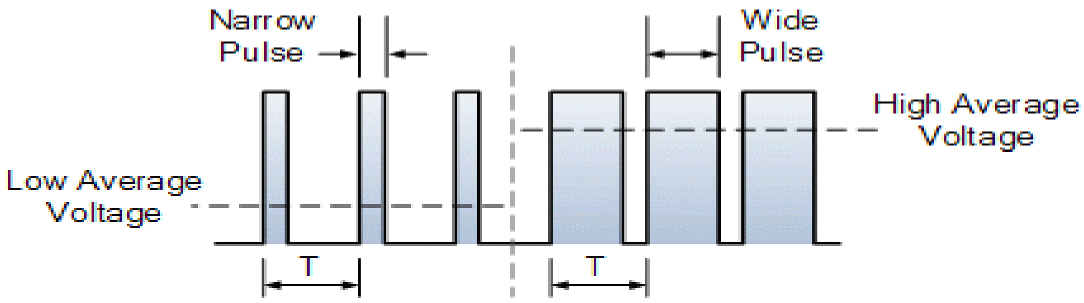


Figure 6: Duty Cycle

PWM (pulse width modulation) is a method of controlling analog devices with a digital output. Another way to phrase it is that you can operate an analog device with a modulating signal from a digital device like an MCU. It's one of the most common ways for MCUs to control analog devices such as variable-speed motors, dimmable lights, actuators, and speakers.

We use an integrator configuration and astable multivibrator to obtain a pwm signal. The astable multivibrator is used to get a square wave and by using integrator configuration we integrate the square wave so that we obtain a pwm signal.

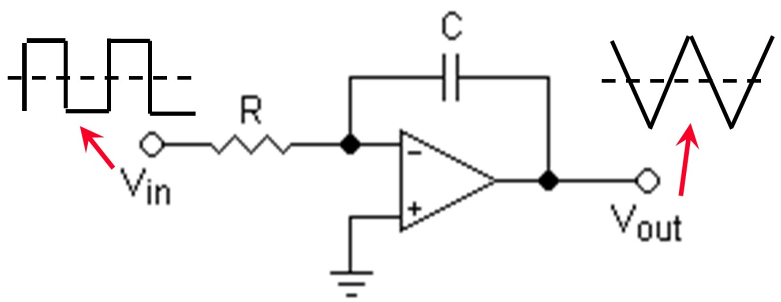


Figure 7: Integrator Circuit

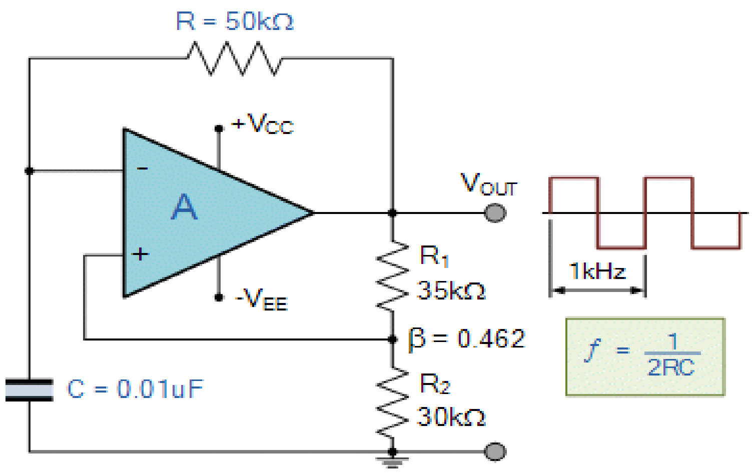


Figure 8: Astable Multivibrator

1.5. DC Motor Driver

Motor drivers serve as a connection between motors and control circuits. The controller circuit operates on low current signals, but the motor requires a large amount of current. The current of a DC motor is proportional to the torque it produces. Controlling the current to the motor will determine how much torque it produces. Without torque/current regulation, the DC motor is permitted to pull huge currents, resulting in torques supplied that are often greater than what is mechanically feasible for the system The purpose of motor drivers is to convert a low-current control signal into a higher-current signal capable of driving a motor. A motor driver takes signals from the microprocessor and converts them before sending them to the motors.

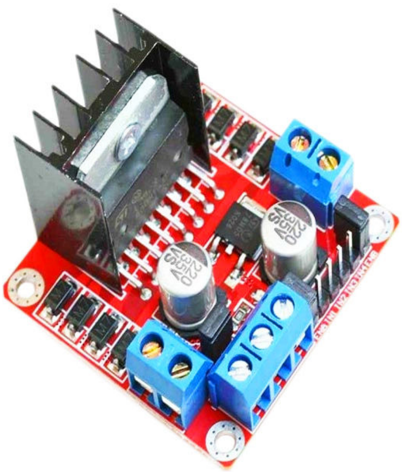


Figure 9 : L298 IC

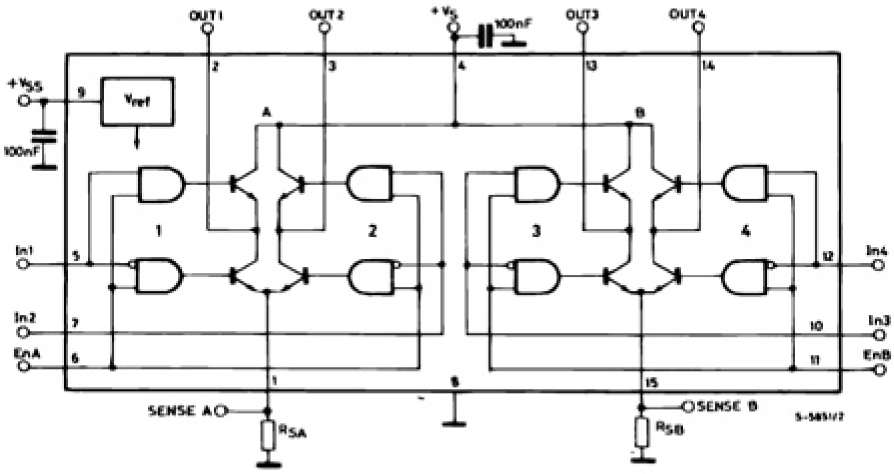


Figure 10 : Inner Scheme of the L298 IC

1.6.COUNTER

In digital circuits, a counter is a device that stores and sometimes displays the number of times a particular operation occurs, usually in relation to a clock. Most common type is a sequential logic circuit with one input called the clock and multiple outputs.There are two types of counter; Synchronous counters and Asynchronous counters. Clock pulses are applied simultaneously in Synchronous Counters, but clock pulses are not applied simultaneously in Asynchronous Counters. The values at the outputs of the counter represent a number in the binary or BCD number system.Each pulse applied to the clock input increments (up) or decrements (down) the number in the counter. In this project we will use the CD4510 up/down counter. The CD4510 up/down counter counts both up and down. and it can count from 0 to 9 or from 9 to 0 according to the setting state. CD4510 has been preferred in this project because it has a useful structure and has the features of the counter we need in the display part of the project.

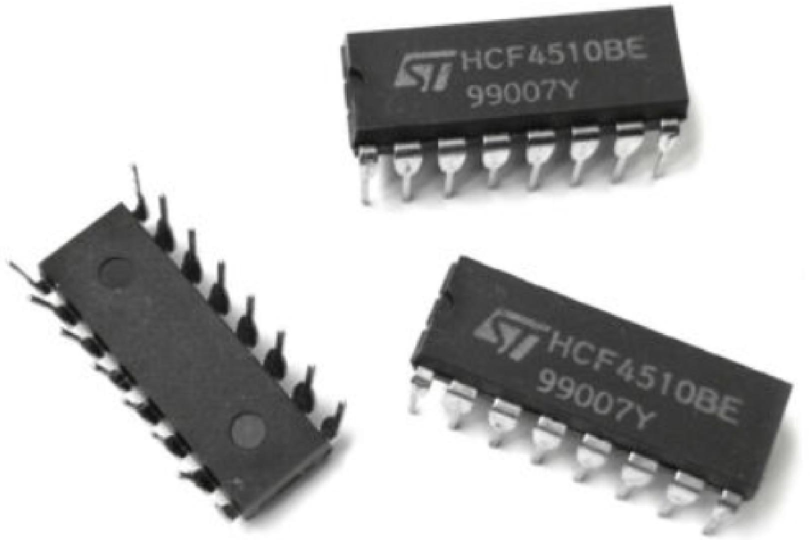


Figure 11: CD4510 Up/Down Counter

1.7.TIMER(OSCILLATOR)

The timer is an electronic circuit that produces periodic signals to the system which can change the state of that digital system. This timer provides more accurate results than traditional clocks. We will use the 555 timer in our project. The timer has the circuit structure necessary for us to create the time delay and pulse signal. The timing range is quite wide(micro seconds-hours). The 555 timer IC has 3 different operation modes. These modes are called Monostable, Bistable and Astable mode. Monostable circuits are circuits that keep the circuit in a logic 1 (High) state until a certain time when a signal is triggered from the outside. In Bistable Mode, our circuit works as a simple Flip Flop. The Astable mode can be called the operating mode as an Oscillator. Thanks to its working as an oscillator, various applications can be made. Due to this feature of the astable mod, and We can easily meet the requirements of the circuit we want to set up in our project. For this reason, we will use the Astable mode of the 555 Timer in our project.

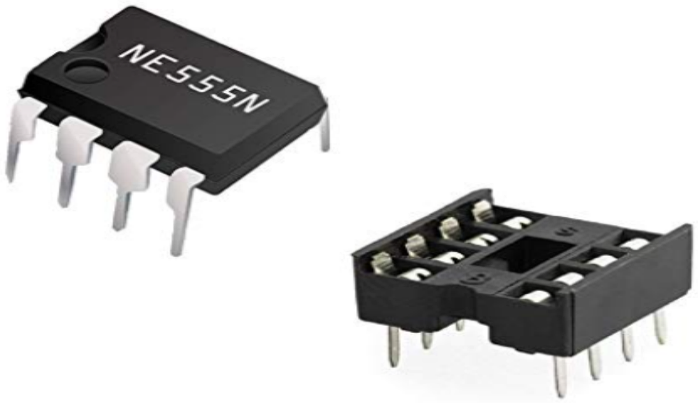


Figure 12: 555 Timer IC

1.8.BCD DISPLAY

We need to see the last 3 digits of the speed of the dc motor on the screen as a digital number. Our BCD(Binary coded Decimal) display circuit will enable us to observe the desired result by converting our numbers in the binary number system into a digital number. This circuit will consist of 3 parts: decoder, shift register and 7 segment display.

1.8.a) DECODER

Decoders are used to recover the initial version of the encoded data. The simple logic of decoders in digital electronics is to give a coded multiple input to the decoder and take a differently coded multiple output as output. Decoders convert given n inputs to 2^n outputs. Also, when select inputs are placed on the decoders, the chance to select multiple outputs can be provided. Decoders are used for 7 segment display or in many places such as data multiplexing. 74LS48 BCD - 7 Segment Decoder will be used in the project.

Figure 13: 74LS48 Decoder

1.8.b) SHIFT REGISTER

A shift register is a circuit that can store and transfer bits of data in a sequential manner. Shifting registers are a type of bidirectional FIFO circuit that can shift every bit of the data present in its input on each clock pulse. Registers are circuits that use flip-flops to store binary data. One bit of data is stored by each flip-flip simultaneously Multiple bits of data must be stored in multiple flip-flops in order to keep track of their state.

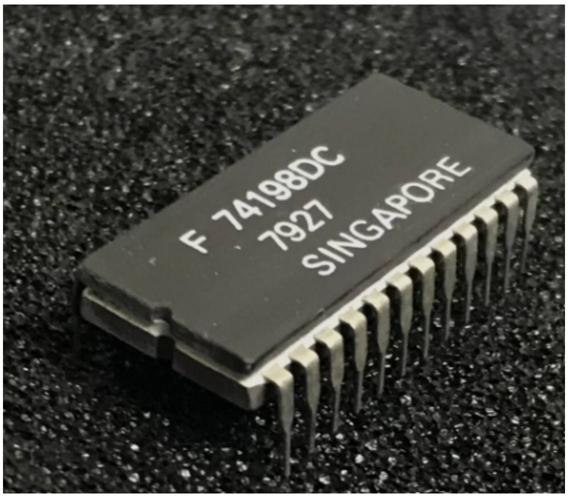
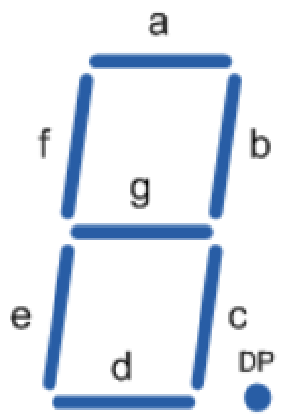


Figure 14: 74198 Shift Register

1.8.c) SEVEN SEGMENT DISPLAY

A seven-segment display is a common type of electronic display device used to display decimal numbers from 0 to 9 and some basic characters. LEDs(light emitting diodes) are more popular now than LCD displays, but lately liquid crystal displays (LCDs) have started to be used more. 7-segment displays are the most common instruments used to display numerical information found in many devices such as microwave ovens, calculators and washing machines. There are basically 2 types of 7 segment LED displays. These types are called common anode and common cathode. A common cathode 7 segment display will be used in the project.



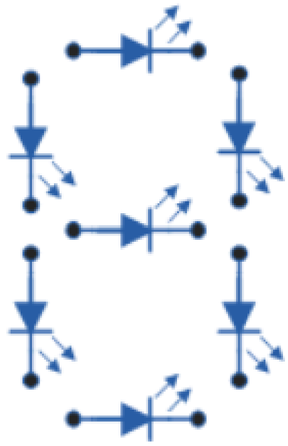


Figure 15: 7 Segment Display

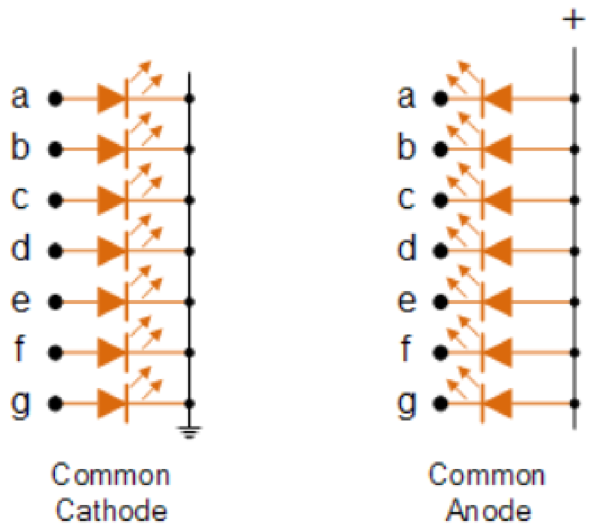
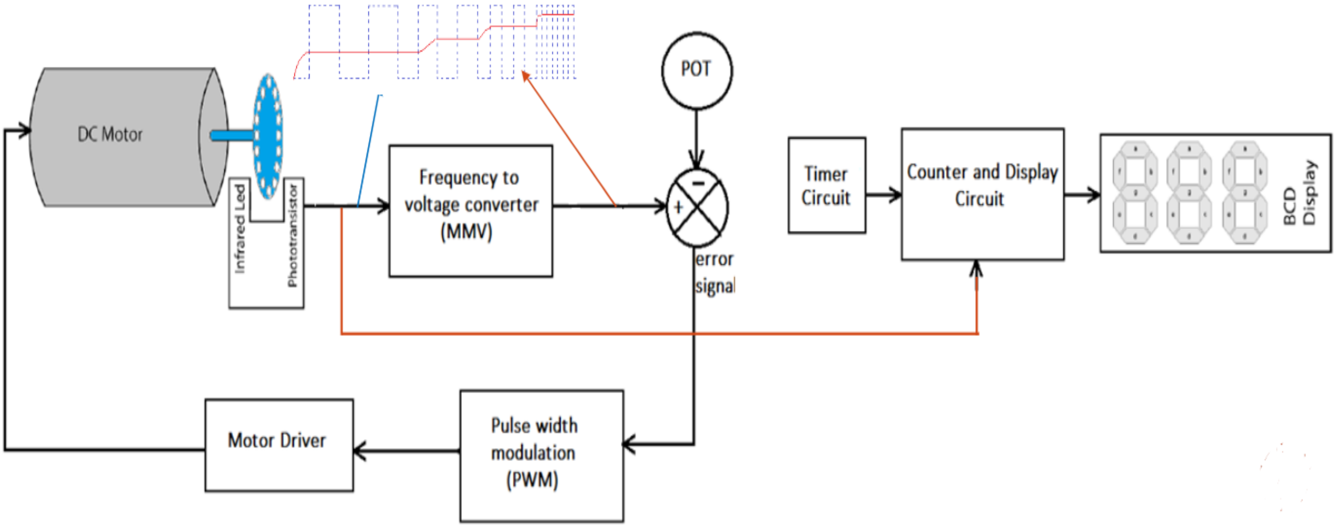


Figure 16: 7 Segment Display Common Cathode and Common Anode Modes

2. Methods and Proposed Solutions

2.1 Overview



The DC Motor Speed Control system is a closed-loop system which is driven by a "Desired Input". The desired input is generated by a potentiometer. In that way the speed of the DC motor could be physically controlled. The system also has an "Error Signal" produced by taking the difference of desired input and "Measured Output".

The 24V-DC motor drives a motor driver IC controlled by "PWM" signals, and its rotation speed is sensed by an infrared LED and a photodiode system. The rotation speed information basically is a square wave with frequency information. The square wave is converted to voltage levels according to its frequency by a "Frequency to Voltage Converter" IC. The output of the frequency to voltage converter is "Measured Output".

A comparator op-amp converts the error signal into "Pulse Wide Modulation" (PWM) signal by the amplitude of the error signal. Then, the PWM signal is sent to the motor driver IC ın that way, the DC motor speed is controlled by the PWM signal.

To adjust the time, the resistor and capacitor values used in the circuit are determined in the timer circuit . Then the time required to count the desired number of pulses is set. And the timer is connected to the counter circuit. In the counter circuit, a square wave signal is sent to the clock pin of the counter. And the pulses are counted according to the time information from the timer output. The desired RPM value appears on the BCD screen according to the information coming from the timer and counter circuit.

2.2. Measuring The Speed of DC Motor

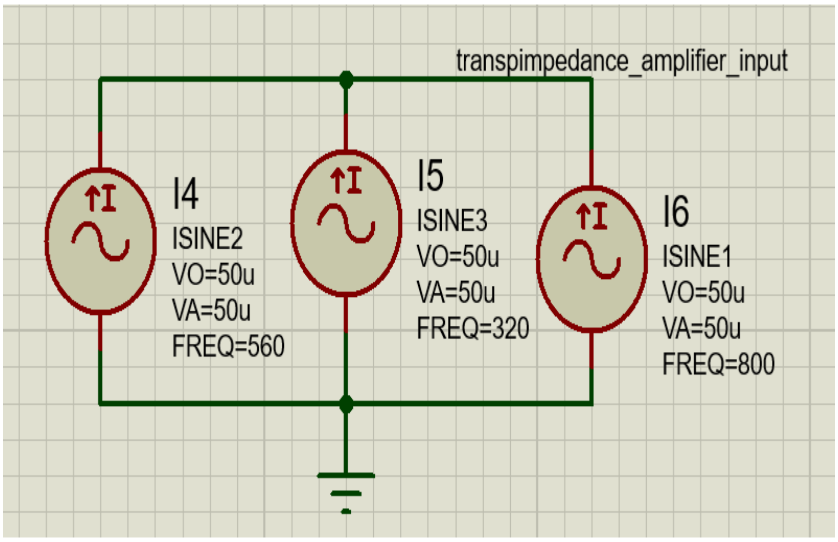


Figure 17: Photodiode Outputs

The photodiode output was simulated like in Figure 8-. When the light is absorbed by the photodiode, It allows the current flow. The amplitude of current was determined as 100 uA by the referenced datasheet. In order to see the effects of the motor on different frequency values, the frequency values were determined as 320 560 800Hz. There are 16 holes in the motor shaft. Therefore, 320,560 and 800 Hz refer to 1200, 2100 and 3000 RPM, respectively. The calculations were made below.

$$\frac{rpm}{60} = rps \qquad rps * 16holes = frequency$$

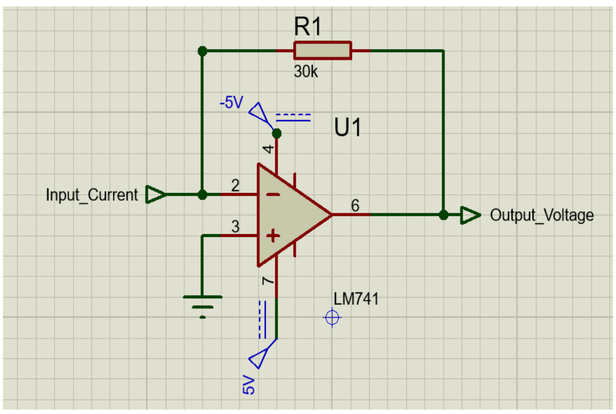
$$\frac{1200\,rpm}{60} = 20rps \Rightarrow 20rps * 16 = 320\,Hz$$

$$\frac{2100\,rpm}{60} = 35rps \Rightarrow 35rps * 16 = 560\,Hz$$

$$\frac{3000\,rpm}{60} = 50rps \Rightarrow 50rps * 16 = 800\,Hz$$

2.3. Current to Voltage Converter

To convert the current coming from the photodiode to convert voltage we used an LM741 op-amp in transimpedance configuration.(Figure 9 -Figure 10)



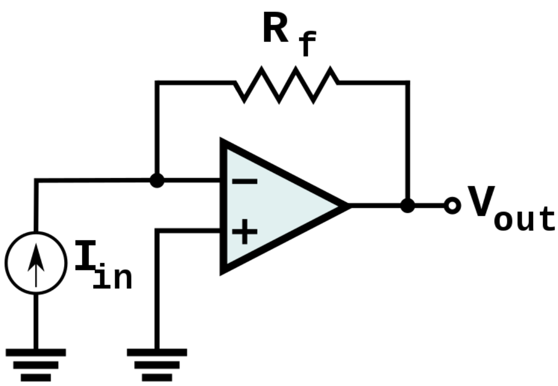


Figure 18: Voltage Converter Circuit in the simulation

Figure 19: Scheme of the Transimpedance Amp.

The DC and low-frequency gain of a transimpedance amplifier is determined by the equation

$$\frac{V_{\text{out}}}{I_{\text{in}}} = -R_{\text{f}} \qquad Vout =- Rf \times Iin = -(15k\Omega \times -100uA) = 1.5\,V$$

2.4. Square Wave Generator

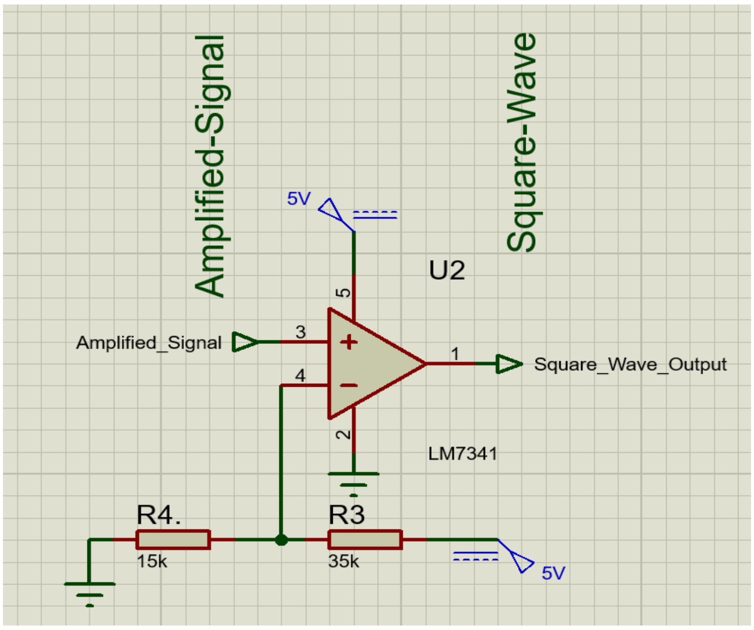


Figure 20: Square Wave Generator in the simulation

The sinusoidal signal has to be converted to square wave for both the “Frequency to Voltage Converter” and the counter in the digital part of the project. The LM741 op-amp is used in comparator configuration.

In that configuration, a reference voltage is applied to the inverting input of the op-amp and the input signal is applied to the non-inverting input of the op-amp. If the non-inverting signal is higher than the inverting input then the op-amp output will be VCC voltage, else the output will be ground voltage. In that way square wave output is generated.
We used a voltage divider to get 2.5 V reference voltage, basically half of the VCC (5V).

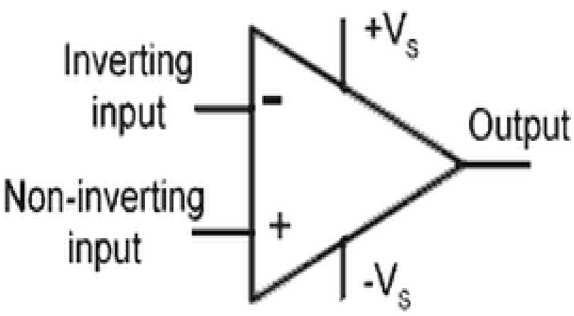


Figure 21: Scheme of the Op-amp

2.5. Frequency to Voltage Converter (FVC)

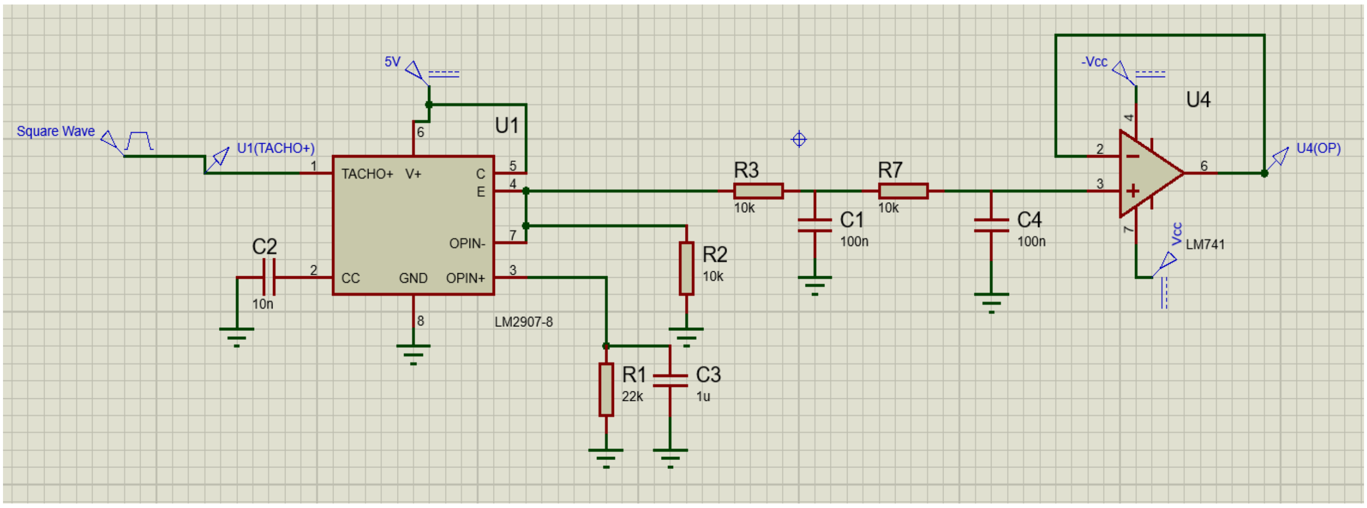


Figure 22: Frequency to Voltage Conversion Circuit with Active Low Pass Filter

The LM2907 IC has several configurations to serve several needs. Our aim to use this IC is to convert a square-wave signal which has frequency information in it to a specific DC voltage level according to square-wave signal frequency.

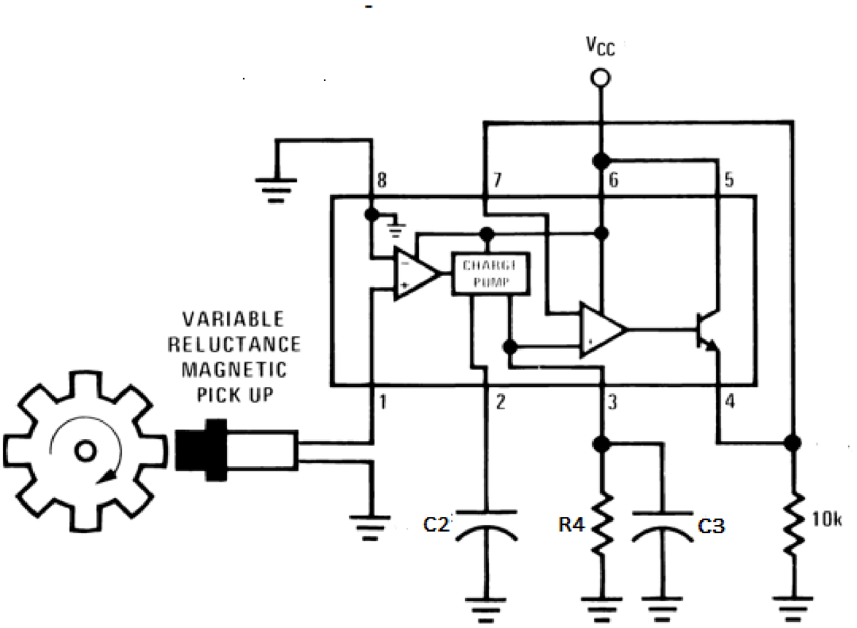


Figure 23: Internal Structure of the LM2907

The Configuration is taken from the LM2907 datasheet and We used the LM2907 IC in Figure 19 configuration. We adjusted C2 and R4 components values to get Vout, which is suitable for our purpose using that formula taken from the datasheet.

The frequency to voltage output will be compared to the 1k pot voltage output, so we aimed to get a maximum of 2.5 volts for the maximum input frequency which is 800 Hz. Calculations;

$$V_{OUT} = f_{IN} \times V_{CC} \times R4 \times C2$$

$$Vout = fin \times Vcc \times R4 \times C2 = 800Hz \times 5V \times 64k\Omega \times 10nF = 2.560\,V$$

$$Vout = fin \times Vcc \times R4 \times C2 = 560Hz \times 5V \times 64k\Omega \times 10nF = 1.792\,V$$

$$Vout = fin \times Vcc \times R4 \times C2 = 320Hz \times 5V \times 64k\Omega \times 10nF = 1.024\,V$$

The C3 capacitor value is inversely related to the output ripple value. The bigger capacitance of C3 is good for eliminating the output ripple. However, a bigger C3 value increases output response time for that reason the value of C3 is selected wisely.

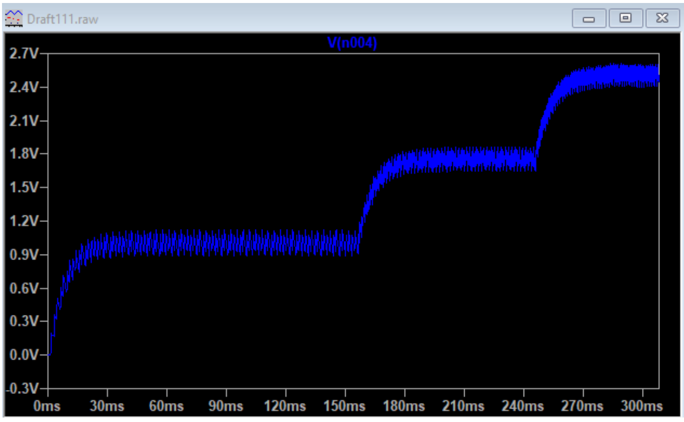


Figure 24:(FVC Output) Dc Voltages for 3 frequency

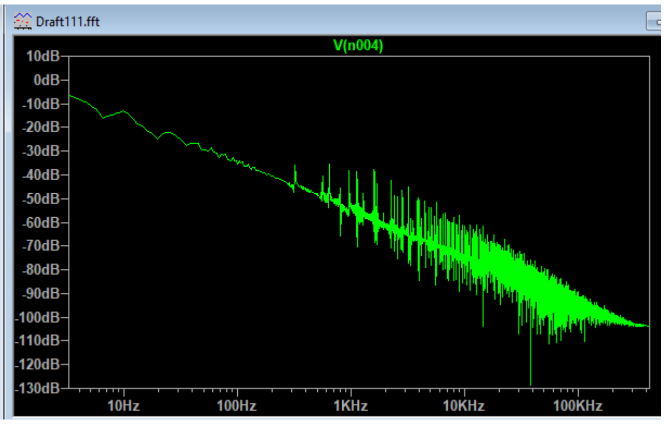
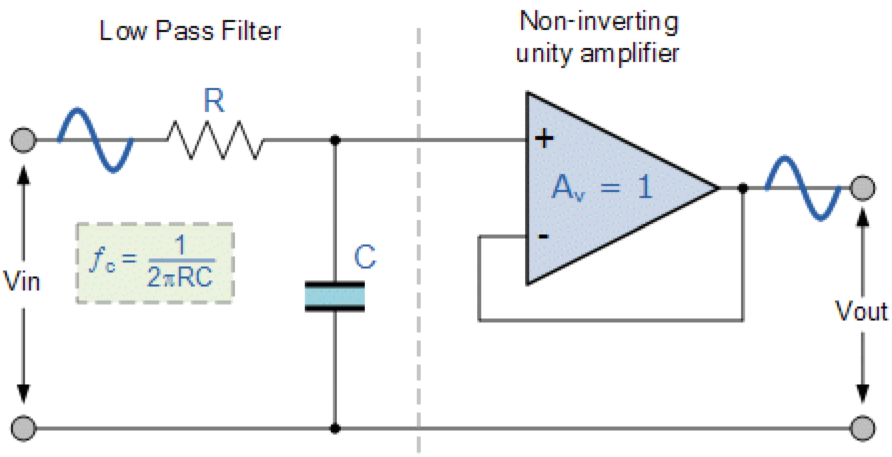


Figure 25: Frequency response of the FVC Output



To eliminate the output ripple of LM2907 IC we designed an active low pass filter with 160 Hz cut-off frequency by considering the frequency response of LM2907 output voltage.

Figure 26: Active Low Pass Filter

2.6. Error Signal System

Error signal system is a major part of controlling the DC motor. It is used to create a closed loop feedback system.

To find the error signal,we subtract the frequency to voltage converter(FVC) output from the voltage that we obtain by voltage division with the potentiometer. We chose a 1k potentiometer with a 1k resistor in series. In that way potentiometer voltage varies between 0 - 2.5 volt. The maximum voltage of the potentiometer (2.5V) also equals the frequency to voltage converter maximum voltage output. When the potentiometer voltage (Desired input) and FVC voltage are equal that means the DC motor rotational speed is desired. Therefore, the error signal becomes equal to zero.

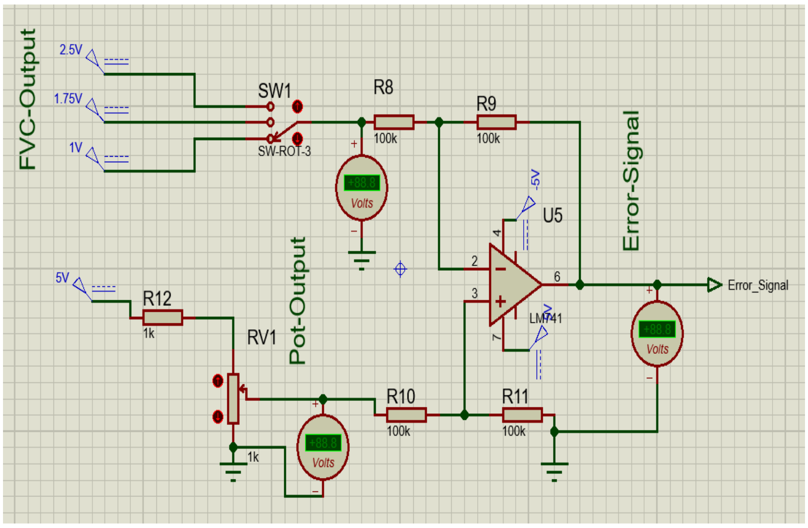


Figure 27: Error Signal Circuit

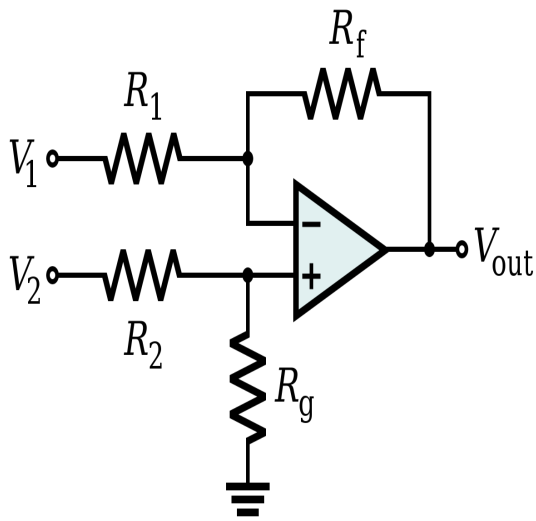


Figure 28: Differential Amplifier Configuration

$$Vout = \frac{(Rf + R1)Rg}{(Rg+R2)R1} \times V2 - \frac{Rf}{R1} \times V1$$

$$if\ R1 = R2\ and\ Rf = Rg \Rightarrow Vout = \frac{Rf}{R1}(V2 - V1)$$

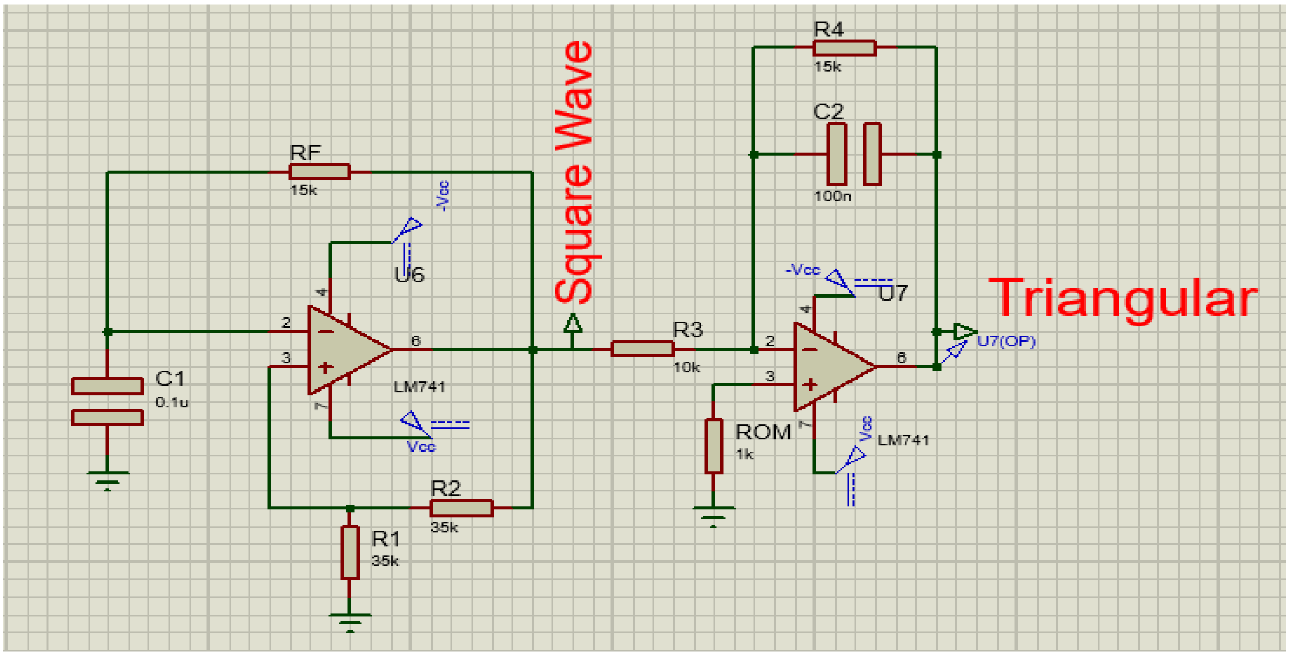
In Figure 18 we used an op-amp in differential amplifier configuration(Figure 19). According to the formula ;

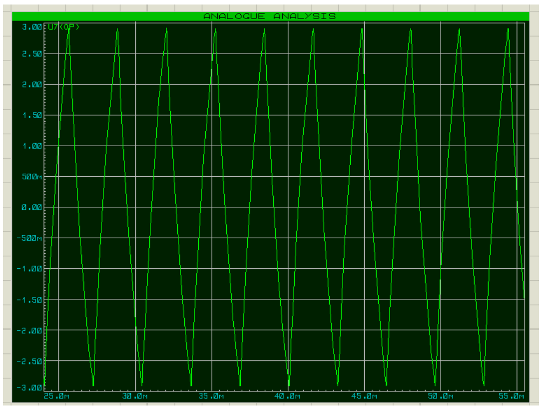
$$Vout = \frac{100k}{100k}(2.5V - 2.5V) = 0V \Rightarrow Potentiometer\ in\ 1K\ position\ and\ motor\ speed\ 3000\ rpm$$

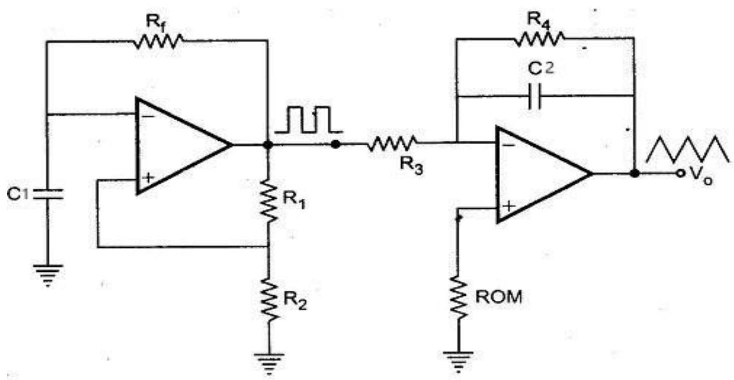
$$Vout = \frac{100k}{100k}(2.5V - 1.792V) = 0.708V \Rightarrow Potentiometer\ in\ 1K\ position\ and\ motor\ speed\ 2100\ rpm$$

$$Vout = \frac{100k}{100k}(2.5V - 1.024V) = 1.476V \Rightarrow Potentiometer\ in\ 1K\ position\ and\ motor\ speed\ 1200\ rpm$$

2.7. Pulse Width Modulation







To obtain the “Pulse Width Modulation” signal from the error signal we used a comparator with a triangular wave as a reference. For that reason firstly we generate a triangular wave generator. It consists of an astable multivibrator and comparator. The astable multivibrator creates square waves at the wanted frequency.

$$\lambda = \frac{R1}{R1+R2} = \frac{35K}{35K+35K} = 0.5$$

$$T = 2 \times Rf \times C1 \times ln(\frac{1+\lambda}{1-\lambda}) = 2 \times 15K \times 0.1u \times ln(\frac{1.5}{0.5}) = 3.3 \times 10^{-3}$$

$$F = \frac{1}{T} = 303\ Hz$$

After the square wave is produced,the integrator op-amp takes it as an input. Therefore the triangular wave is produced. However, to produce stable triangular waves the following condition must be met.

$$5 \times R3 \times C2 \geq T/2$$

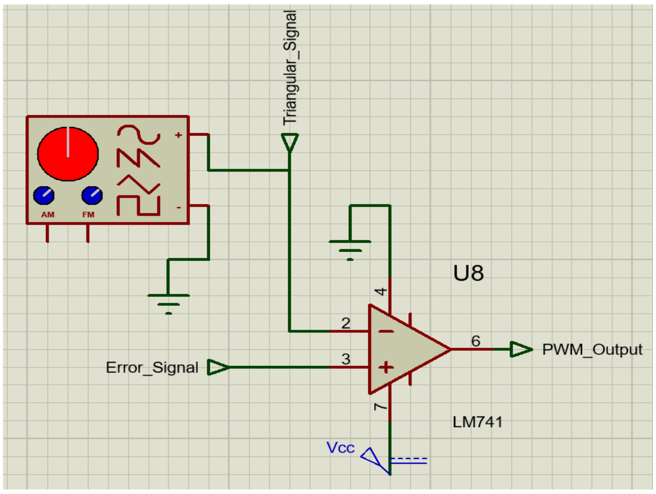


Figure 29:Scheme of the PWM Output

The triangular signal is a reference voltage to a comparator that we use to compare the error signal with a triangular signal so that we obtain a pulse width modulated signal.

Frequencyandamplitudedefinder.m *

```
clc ; clear all;
Rf = 15e3; %%input(" Rf = ");
R1 = 35e3; %%input(" R1 = ");
R2 = 35e3; %%input(" R2 = ");
R3 = 10e3; %%input(" R3 = ");
ROM = 1e3 ; %%input(" R4 = ");
C1 = 0.1*10^-6; %%input(" C1 = ");
C2 = 100e-9;%%input(" C2 = ");
Vin = 10; %% input(" VinMax = ");

B = R2/(R1+R2);

Ts = 2*Rf*C1*log((1+B)/(1-B)); %% Period of Square Wave
Fs = 1/Ts ; %% Frequency of Square Wave
TL = 5*R3*C2; %% Limit Period of Integrator
Vout = Vin*-1/(1i*2*pi*Fs*R3*C2);

if TL>Ts/2
    disp('It is OK');
else
    disp('Adjust the Limit Frequnecy');
end
disp( abs(Vout));
disp( abs(Fs));
```

In order to obtain the desired frequency and meet the condition we write a matlab code which calculates the frequency of the triangular wave and it also checks if the condition is met.

Figure : Matlab Code to specify the related calculations

2.8. Motor Driver (L298)

The L298 IC is used to drive the DC motor.An L298 IC is a twin full-bridge driver IC with high current and voltage that's primarily designed to control inductive loads such as DC motors, solenoids, relays, and stepper motors using standard TTL logic levels. A motor driver is a tiny current amplifier that converts a low current signal into a high current signal that may be used to drive an electric motor.

The L298 IC contains four distinct power amplifiers, two of which may be combined to produce H-bridge A while the other two types of amplifiers can be combined to form H-bridge B. One H Bridge is used to control the motor direction by switching the polarity, whereas a bipolar stepper motor is controlled by a pair of H bridges.

The driver expands the pwm output that is in a range of 0-5 V. The expanded signal by the driver, which is in a range of 0-24 V, operates the dc motor with a speed that is variable according to the duty cycle of the pwm output. The driver can operate two dc motors but we just operate a motor so we take output from OUT1 and OUT2 to rotate the motor.

.The PWM signal generated by the comparator goes into the fifth pin of the IC. IN2, IN3 and IN4 go to the ground because we have just 1 input. Also SENSA and SENSB pins go to the ground and we give 5 V dc input to the ENA. The driver contains two voltage pins (VCC1 and VCC2), one of which is used to switch on the motor driver and the other for applying electricity to the motor through this motor IC. The output signal of this motor IC will be toggled continually in response to the microprocessor's input wave.

We could also use a mosfet to operate the dc motor with pwm signal but there would be some issues. At the first start of the DC motor, the motor draws over current from the DC supply. We can eliminate this by using the motor driver.Also there is a back-emf generated by the motor. The driver also eliminates that back-emf.

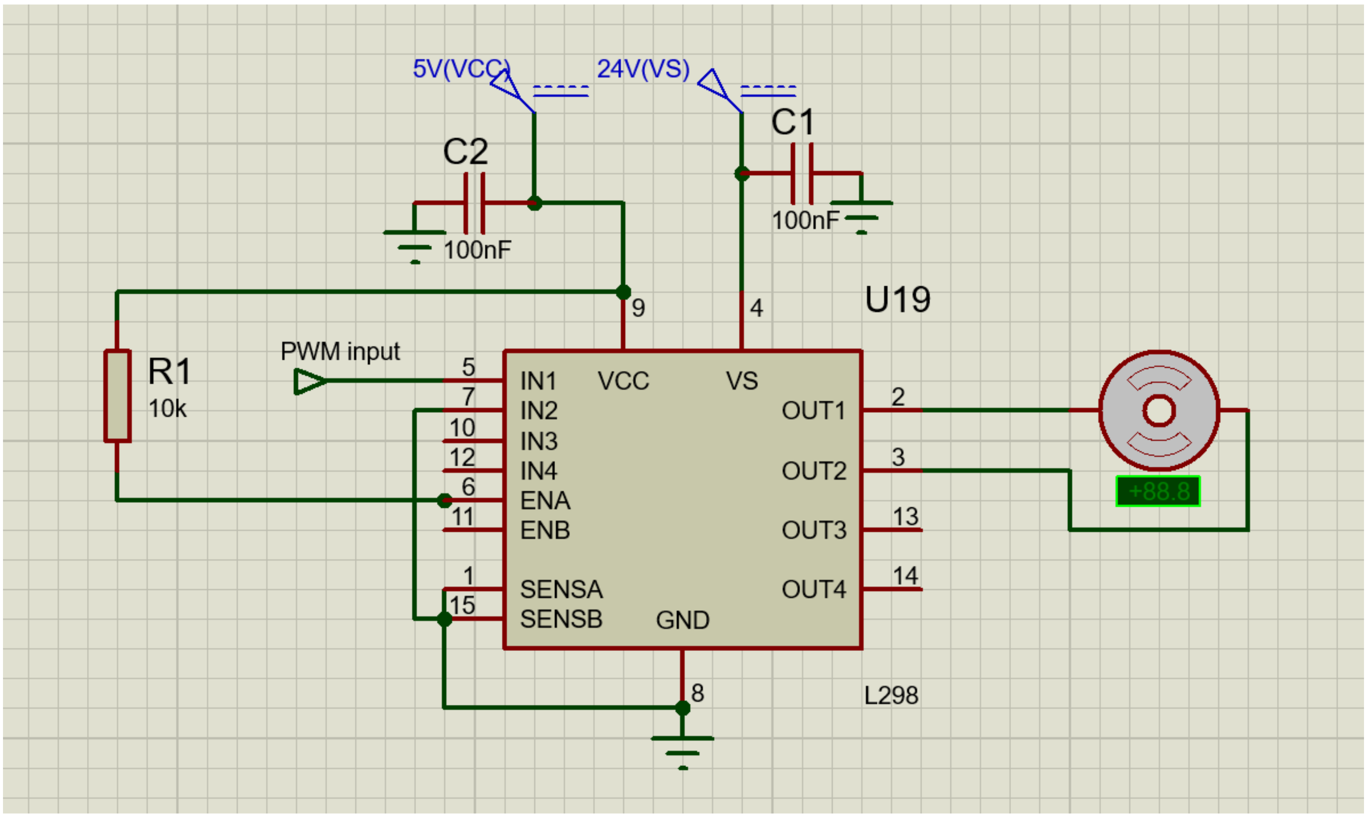
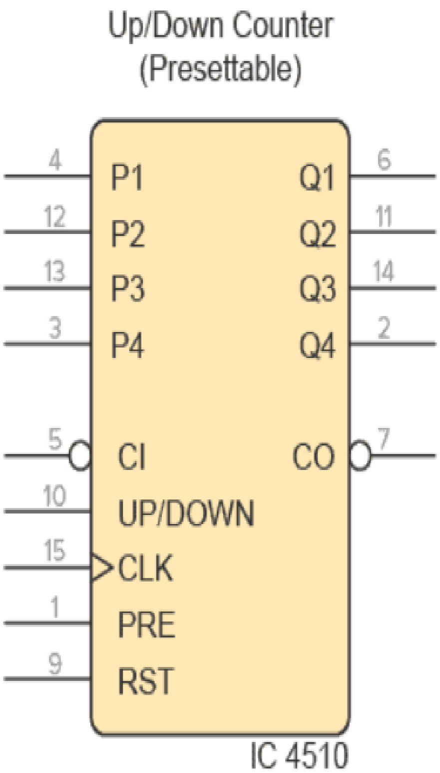


Figure 30: Scheme of the DC motor circuit that controlled with L298 IC

2.9. BCD UP/DOWN COUNTER

An Up/Down BCD Counter is a counter that can count either up or down. With every rising clock edge, the counter either increases by one (if the up/down pin is 1(high)) or it decreases by one (if the up/down pin is 0(low)). BCD is an abbreviation for Binary Coded Decimal. This means it only counts from 0 to 9. If we needed a counter with 4 bits and counting up to 15, we could use the CD4516 counter. Since we needed 3 digits in the display part of the project, three 4510 counters were used in the circuit. These counters were installed in conjunction with each other to affect the ones, tens and hundreds digits, respectively. A square wave signal comes from the photoresistor and the LED to the clock pin of the counter. We need to know that the counter counts square waves (pulses), not RPM. For example, when the motor is running at 1200 RPM, we need to see the number 120 on the screen because we have a 3-digit BCD display. This number that we will see on the screen will be the number of pulses counted by the counter. The disc connected to the motor has 16 holes. 1200 RPM means 1200 revolutions per minute. This means 1200/60=20 revolutions per second. Since there are 16 holes in the disc, the counter must count 16*20=320 pulses per second. but for 1200 RPM, we want to see the number 120 on the screen. Therefore, the time when our counter will stop is set as 120/320=0.375(375 milliseconds) seconds. Also, this means that the counter stops and resets itself every 375 millisecond.



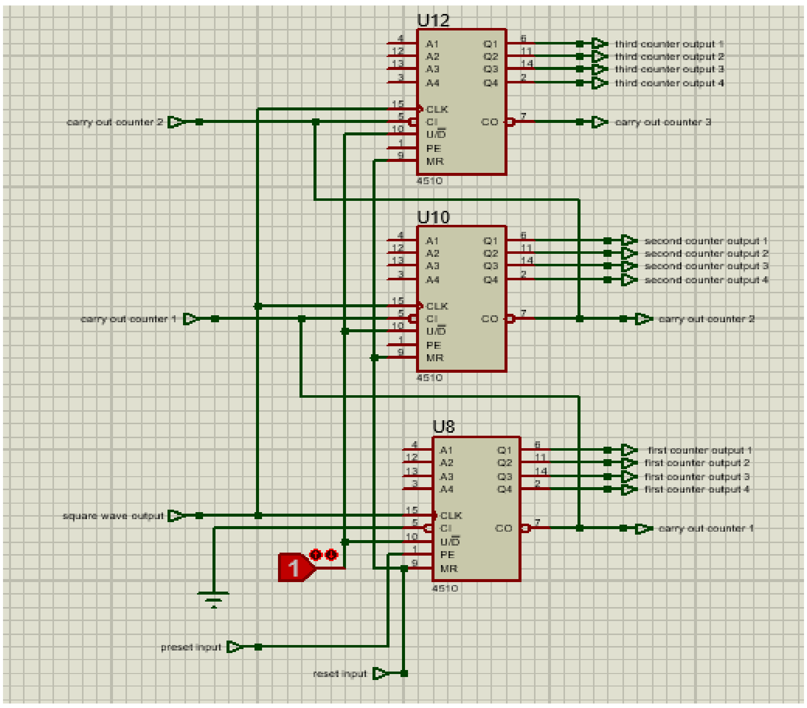


Figure 31: Up/Down Counter IC 4510

Figure 32: BCD Counter Circuit

2.10. ASTABLE 555 TIMER(OSCILLATOR)

The astable 555 IC circuit is used to keep the RPM value constant on the 3 digit 7 segment display and the counter to reset itself after a certain time. The astable 555 oscillator can produce square wave output with a duty cycle of 50-100% and a frequency of 500 kHz. In order to get the 555 Oscillator to operate as an astable multivibrator it is necessary to continuously re-trigger the 555 IC after each and every timing cycle. We can do this re-trigger event by connecting the 2nd (trigger) and 6th (threshold) pins together. The timing resistor is divided into two separate resistors, R1 and R2, depending on the discharge input (7th pin). Also, the external noise is filtered by the capacitor connected to the 5th pin. Then the capacitor charges up to 2/3Vcc (the upper comparator limit) which is determined by the 0.693(R1+R2)C combination and discharges itself down to 1/3Vcc (the lower comparator limit) determined by the 0.693(R2*C) combination.

Astable 555 Oscillator Charge and Discharge Times:

Charge time(t1)=0.693*(R2+R1)*C2

Discharge time(t2)=0.693*R1*C2

Where, R is in Ω and C in Farads.

555 Oscillator Cycle Time:

Period(T)=t1+t2=0.693(R2+2R1)*C2

555 Oscillator Duty Cycle:

Duty cycle=[Ton/(Ton+Toff)]*%100

Since the counter will be reset every 0.375 seconds (375 milliseconds) while in the up mode, the period time (T) should be 750 milliseconds.

0.750=T=0.693*(2R1+R2)*C2, The equation is obtained and the values of R1, R2 and C2 can be found by using this equation.**R1**=26.75 KOHM **,** **R2**=1KOHM **,** **C2**=20 uF

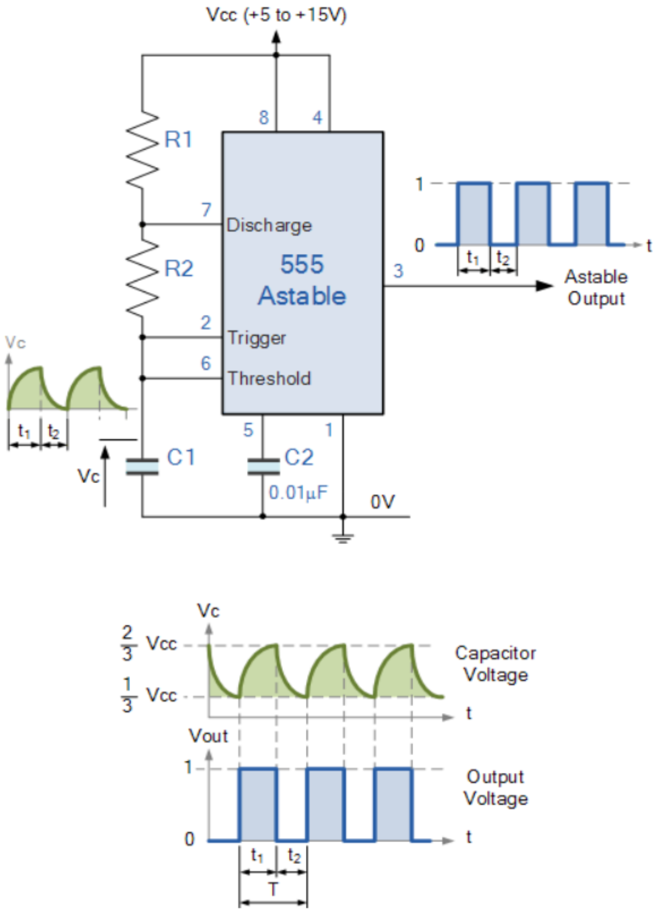


Figure 33: 555 IC

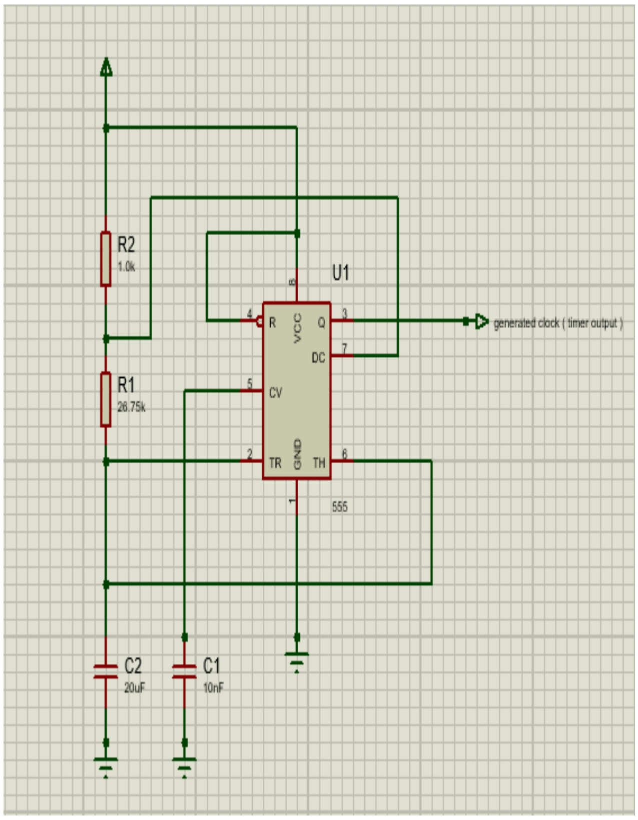


Figure 34: Astable 555 Timer Circuit

2.11. 74LS48 BCD - 7 SEGMENT DECODER

74LS48 BCD - 7 Segment Decoder Integration was used in this project. The 74LS48 Integration is in the Decoder - Encoder category and is a BCD - 7 Segment Decoder IC as a function. The 74LS48 BCD - 7 Segment Decoder Integration with 7 outputs works with a supply voltage in the range of 4.75 - 5.25 V. The purpose of using the 7 segment decoder is to get the 7 segment viewer we need in the project. The 4510 counter has four outputs. these outputs are connected to the input of the decoder. Finally, the information from the input is sent to the 7 outputs of the decoder. Also, since we use 3 counters in the circuit, we need to use 3 decoders. This allows us to get the 3-digit viewer.

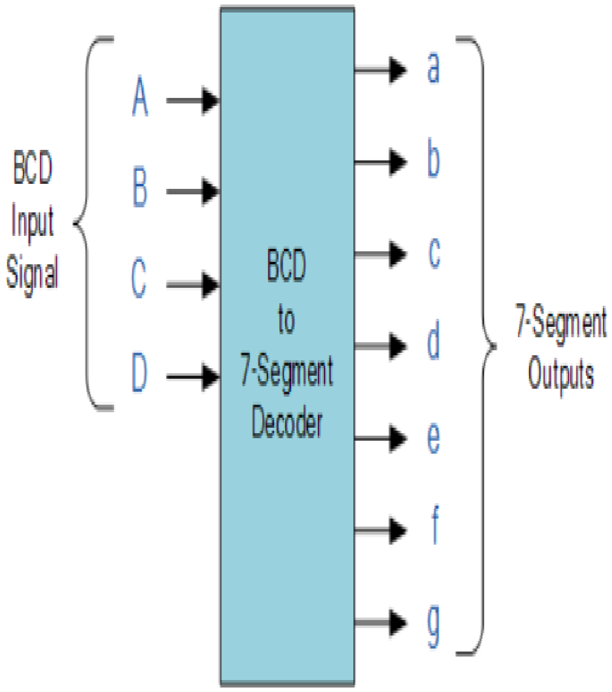


Figure 35:BCD to 7 Segment Decoder Datasheet

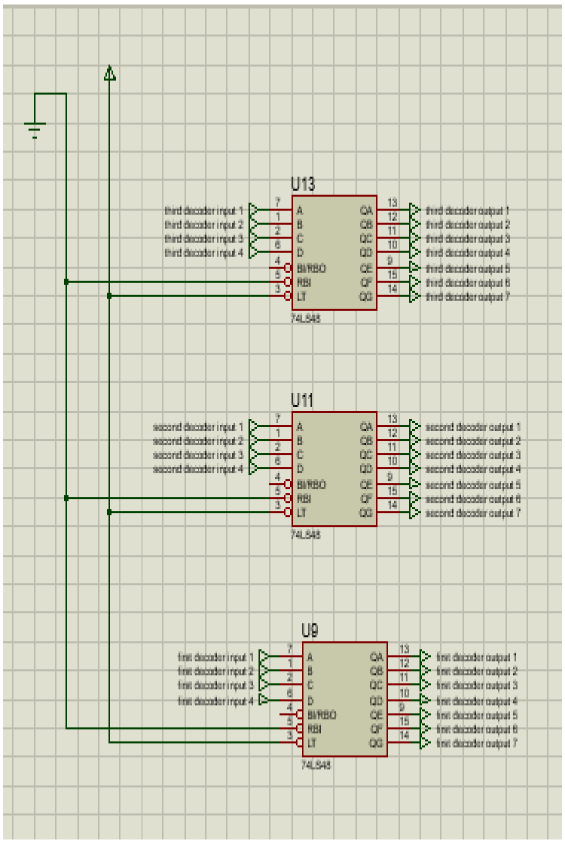


Figure 36: 74LS48 Decoder Circuit

2.12. 74198 SHIFT REGISTER

Shift registers are integrated with interconnected flip flops and used in logic circuits. 74198 8-bit Bidirectional universal shift register was used in this project. This shift register is used to display the rpm value of the engine on the screen. It gives the stored data to the output pins according to the signal coming to the clock input. Also, The ability of shift registers to prevent bit loss is one of the reasons they are used in this project. The outputs of the decoders are set as the inputs of the shift registers. As explained in the counter circuit part, the time required for us to see the desired rpm value should be 375 seconds in the rising part of the square wave. Therefore, the period value is set to be 750 ms in the 555 timer circuit. This square wave output from the timer circuit is given to the clock input of the shift register. The shift register receives the data from the decoder and sends it to the display. The latch operation is performed, and the RPM value is displayed on the 7-segment display. Since we used 3 decoders in the circuit, we used three 74198 shift registers.

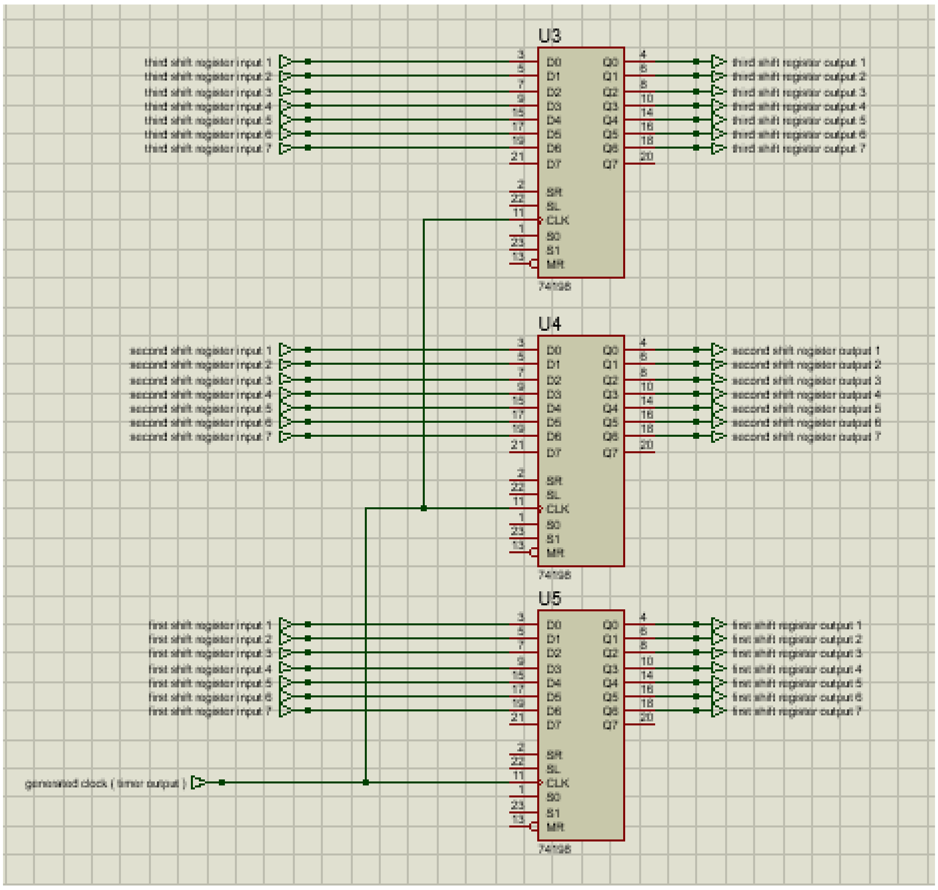


Figure 37: 74198 Shift Register Circuit

2.13. THREE DIGIT SEVEN SEGMENT DISPLAY

This is the last part of the display of the RPM circuit. At this stage, since we wanted to see the last three digital values of the RPM of the DC motor, three common cathode 7 segment displays were used. Common Cathode means that All the positive terminals (Cathode) of all the 8 LEDs are connected together. All the negative thermals are left alone. The rpm information from the shift registers was transferred to the inputs of the displays and the desired rpm value was observed on the screen.

Figure 38: 7-Segment Display Elements for all Numbers

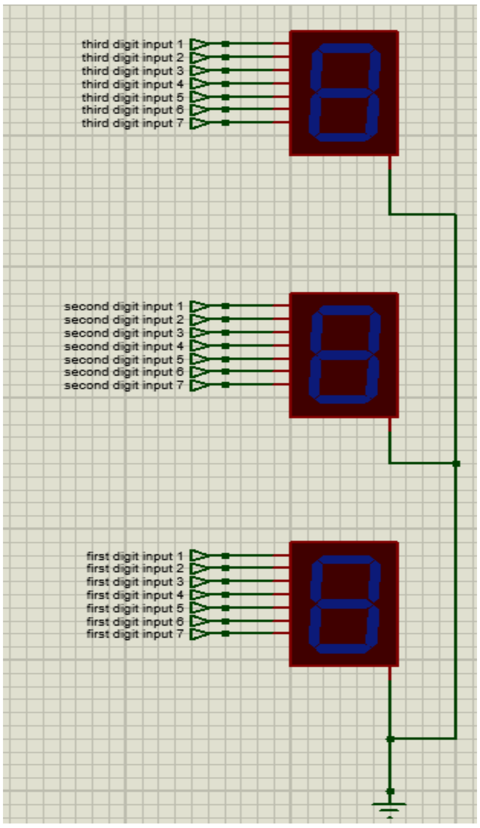


Figure 39: 3 Digit 7 Segment Display Circuit configuration

Number	g f e d c b a	Hex Code
0	0111111	3F
1	0000110	06
2	1011011	5B
3	1001111	4F
4	1100110	66
5	1101101	6D
6	1111101	7D
7	0000111	07
8	1111111	7F
9	1001111	4F

Table: Display numbers on a seven segment display in common cathode configuration

Figure 40: Display numbers on a seven segment display in common cathode

2.14. DISPLAYING PART CIRCUIT DIAGRAM

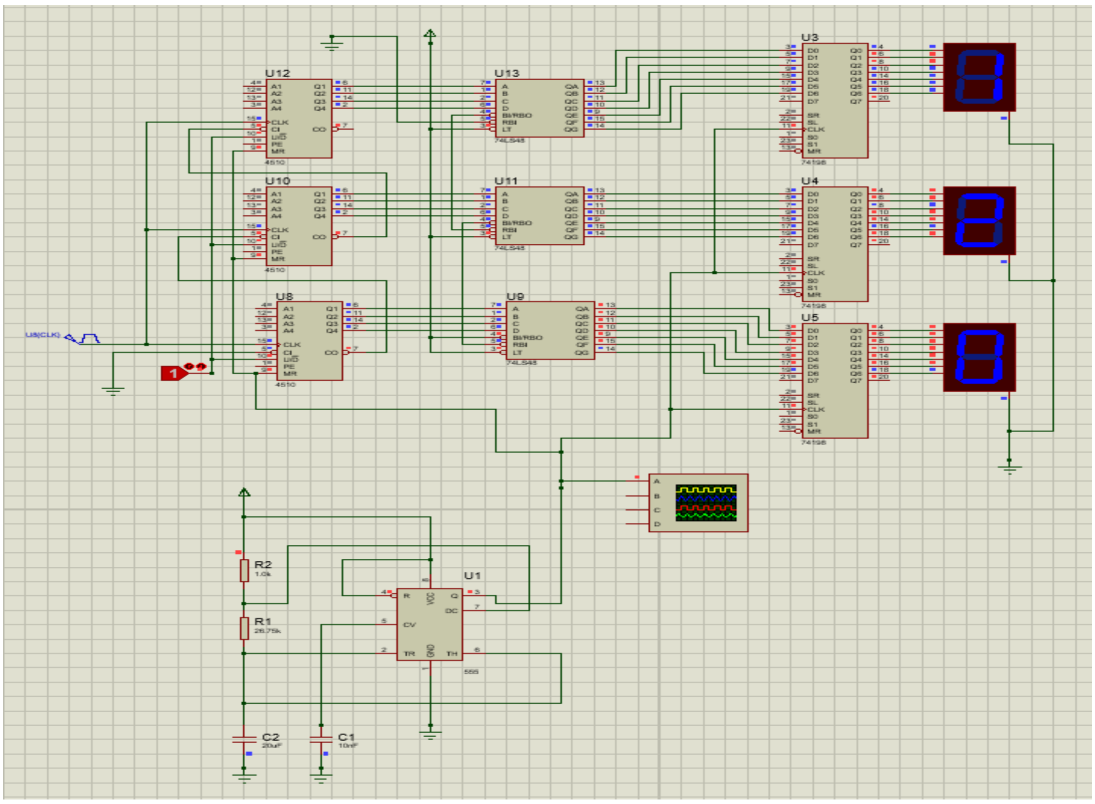


Figure 41: Displaying Part Circuit Diagram

3.Test Results

3.1. Measuring The Speed of DC Motor Test Results

Design Target	Measured Value
Revolution per minute	1200-3000 RPM
Frequency	320-800 Hz

Table 1: Measuring the Speed of a DC Motor Test Results

3.2. Conversion of Frequency to Voltage Test Results

Design Target	Measured Value
Input Voltage	0-5 V
Output Voltage	0-2.5 V
Input Frequency	320-800 Hz
Output Frequency	∞ Hz
Revolution Per Minute	1200-3000 RPM
Ripple Voltage	4-45 mV
Reaction Time	38 ms

Table 2: Conversion of Frequency to Voltage Test Results

3.3. Error Signal Test Results

Design Target	Measured Value
Input Voltage	0-2.5 V
Output Voltage	(-2.5)-2.5 V

Table 3: Error Signal Test Results

3.4. Pulse Width Modulation Test Results

Design Target	Measured Value
Triangular Wave Input voltage	5 V
Triangular Wave peak-to-peak voltage	6 V
Triangular Wave Output voltage	(-2.9)-2.93 V
Error Signal Input voltage	(-2.5)-2.5 V
Output Voltage	0-4.92 V
Output Frequency	302 Hz
Duty Cycle	7-90%

Table 4: Pulse Width Modulation Test Results

3.5. DC Motor Driver Test Results

Design Target	Measured Voltage
Input Voltage	0.2-4.85 V
Output Voltage	0-24 V

Table 5: DC Motor Driver Test Results

3.6. Timer Circuit Test Results

Design Target	Measured Value	Unit
Output Voltage	0-5	V
Period	755.37	ms

Table 6: Timer Circuit Test Results

Our timer circuit produced a clock signal that matches the expected period and voltage values. There is a 0.71% error in terms of the period, but it is not important. Because our timer circuit works as desired and expected. (percent error = [experimental value - theoretical value] / theoretical value x 100%)

4.Conclusion

In this DC motor speed controller project, many different techniques and components were used. The project was divided into several parts, each with its own specific focus. Parts were determining the RPM, converting the frequency to voltage, and using feedback to control the system. Then, the RPM was displayed.

Firstly, in order to simulate the photodiode three current sources were created. Since all 3 current sources are at different frequencies, they represent different signals produced by the photodiode at different rotational speeds of the motor. The frequencies vary from 320Hz to 800Hz. 320 Hz corresponds to 1200 rpm and 800 Hz corresponds to 3000 rpm. After that the currents are converted and amplified by a transimpedance amplifier. Secondly, the frequency information of the resulting sinusoidal wave was converted to a square wave with the help of a comparator so that it can be processed more easily by Integrated Circuits. The frequency information of the resulting square wave was converted into DC voltage levels with the help of An frequency to voltage converter(FVC), so we could see the current rotation speed of the motor as a certain DC voltage. 320 Hz, 560 Hz, 800 Hz frequencies correspond to 1.024V, 1.792V, 2.560V respectively. In order to eliminate the ripple at the output of the FVC, an active filter is used. Thus, the desired voltage value created with the help of a potentiometer and the motor rotation speed could be compared.Thirdly, With the help of a differential operational amplifier the FVC output and the desired voltage is compared. Thus, the error signal has been created. The desired voltage and FVC voltage range are set to 0-2.5V. It is taken the triangular wave as a reference which we obtained using astable multivibrator and integrator circuits and insert the error signal into the comparator. The pwm signal is in a range of 0-5 V.

As a result of this, 0-5 V square waves were created.In the proteus simulations, these 0-5V square waves were converted to 0-24V square pulses with the help of a driver.

The last and fourth part of this project is displaying the RPM. In this part, Firstly, the timer circuit was created by using the 555 timer. The time required for us to see the rpm values had to be 375 milliseconds in the rising part of the signal. In order to provide this situation, the period value of the circuit was adjusted as 750 ms and a time value of 375 milliseconds was obtained in the rising part. Secondly, the counter circuit was installed. The output of the timer circuit is connected to the input of the counter circuit so that the counter resets itself at the required time and counts using this time. The information of the speed of the dc motor was connected to the clock input of the counter circuit as a square wave. Our counter circuit has four outputs, but we needed an IC with seven outputs to obtain a seven segment viewer. For this, we used the seven segment 74LS48 decoder IC. The outputs of the counter circuit are connected to the inputs of this decoder, which has four inputs and seven outputs. Finally, we used the 74198 shift register integrated with flip flops so that we can display the rpm value counted in the counter circuit on the screen. The inputs of this IC and the outputs of the decoder IC were connected to each other and a seven segment viewer was used to see the desired RPM value. The input pins of the viewer are set to be connected to the output pins of the shift register. Also, since we need a 3 digit 7 segment display circuit, three of the integrated circuits were used, except for the 555 timer IC.

5.Component List

Component Description	Part Number	Manufacturer	Supplier
Operational amplifiers	7 x LM-741 LM-7341	Texas Instruments	direnc.net
Resistors	2 x 1kΩ 5 x 10kΩ 3 x 15kΩ 1 x 22kΩ 1 x 30kΩ 3 x 35kΩ 4 x 100kΩ	Texas Instruments	direnc.net
Potentiometer	1 x 1kΩ	Generic	direnc.net
Capacitors	1 x 0.1uF 1 x 1uF 1 x 10nF 5 x 100nF	Texas Instruments	direnc.net
Frequency to Voltage Converter	LM-2907	Texas Instruments	
DC Motor Driver	L-298	STM	direnc.net
Shift Register	74198	Texas Instruments	ti.com
Decoder	74LS48	Texas Instruments	direnc.net
Counter	CD4510	Texas Instruments	direnc.net
3 digit 7-segment Display	7 SEG-COM-CAT-BLU EΩΩ	Texas Instruments	p-tec.net
Timer	LM555	Texas Instruments	ti.com

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