Department of Electronics and Telecommunications Engineering

University of Moratuwa

EN2090 – LABORATORY PRACTICE II

Analog Line Follower Robot – Simulation Results

Group No. : 29

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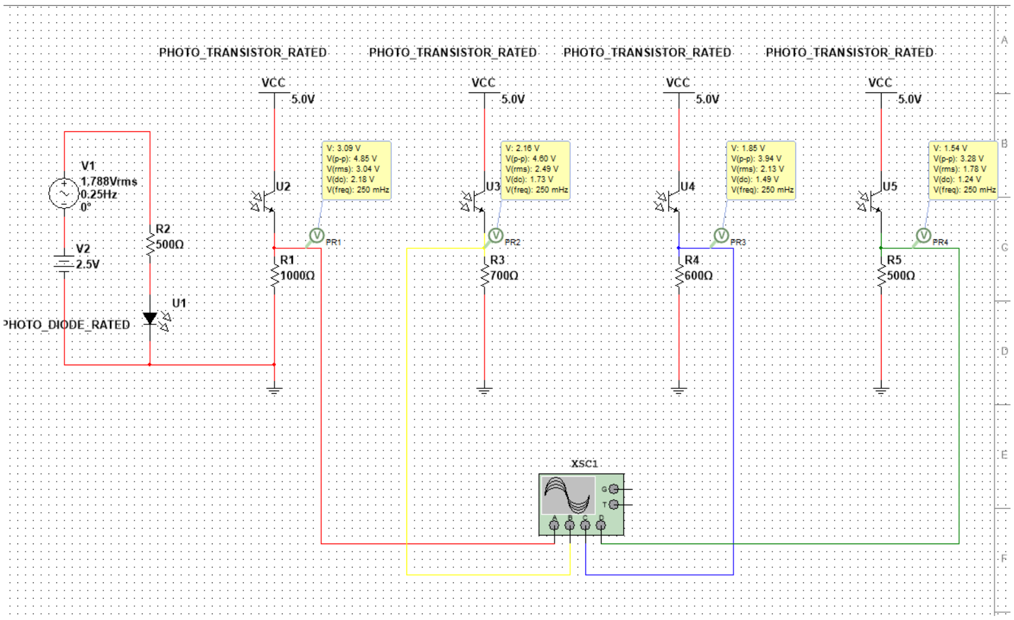
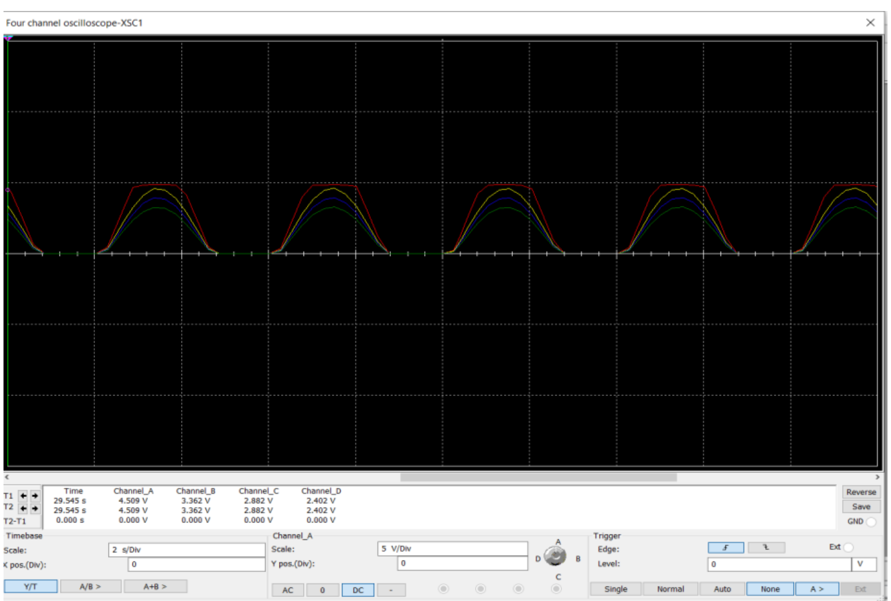
SENSOR PANEL

For the sensor panel, we have decided to use eight TCRT5000L IR sensors. In the simulation, we used rated photo transistors and IR LEDs (Because IR sensors are not available in MultiSim). To take readings with different gains, we changed the values of the voltage divider resistors connected across each sensor. Circuit and simulation results are shown below.

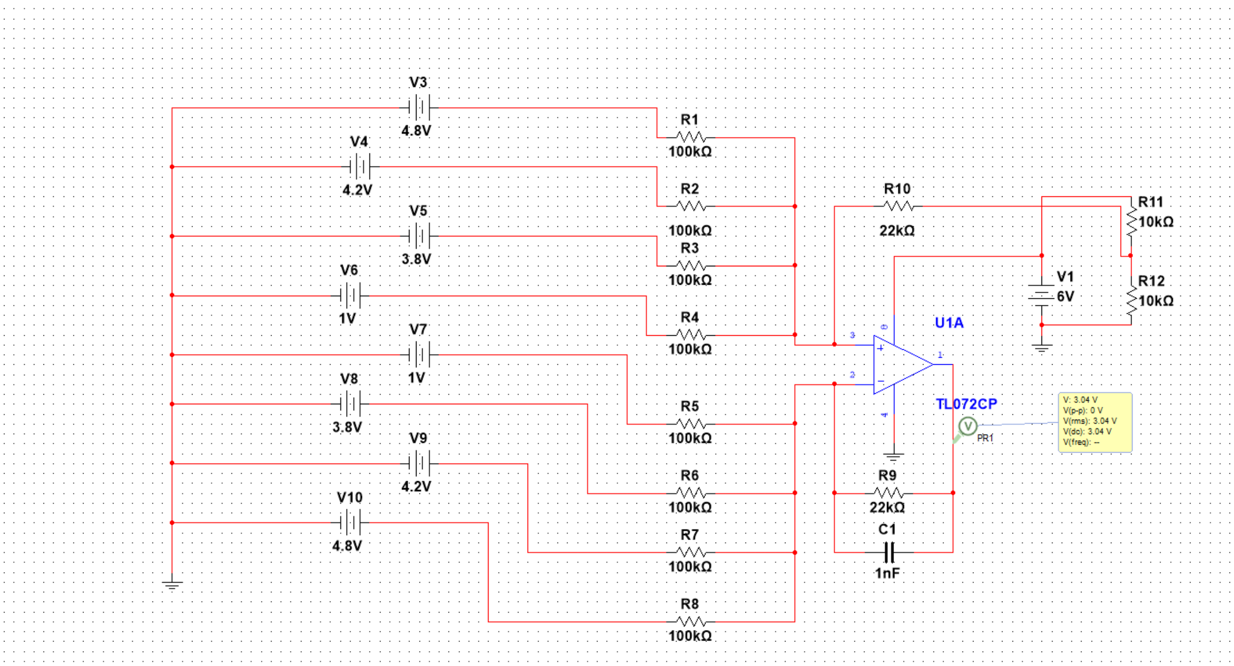




Note that, this only shows 4 sensors (to be used in the left side). Placement of other 4 sensors will be similar. Corner sensors will be assigned with higher gains whereas the gains in the middle sensors will be minimum.

ERROR CALCULATION

For this project, we are only considering positive voltages. Therefore, we are setting VCC/2 as the op-amp reference. Hence, the output value will be relative to the VCC/2. For simulation purposes, VCC was set to 6V. Accordingly, our reference is 3V. We combine the readings from the left sensors and the right sensors separately and after that calculate the difference between them. The schematic is shown below.



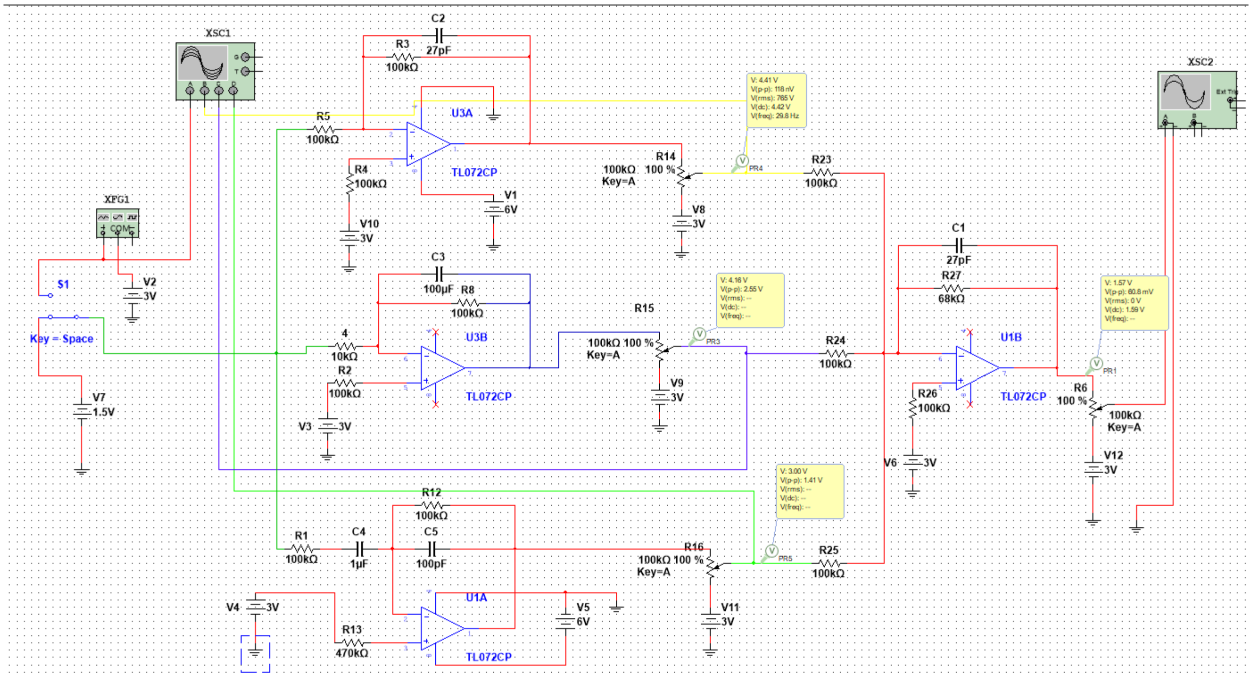
In the above schematic, sensor readings are represented using voltage sources. When a sensor is facing a black line, then the output of that sensor is 1V. If a sensor is on the white line, then the output sensor reading is larger than 1V and approximately equal to maximum gained value. Therefore, if the error is zero, then the output value will be 3 (because the reference is 3). This value will be then fed to the PID circuit.

PID

The PID control system is the control system that navigates the line following robot. PID stands for proportional, integral, derivative. The alternative to a PID control system is an "Off-On" control system where the sensors would simply indicate if the robot is on the white line or not and move accordingly. However, this results in a jerky motion and this can be avoided by a PID system.

As in the name, the PID system has a proportional, integral and derivative component which will be sent to a summing junction and then be used as feedback. The inputs to the system are the set point and the feedback, the difference of which gives the error of the system. The error is sent through the system and depending on this value, the motor will rotate in the required direction.

For our line follower, we have set the set-point to 3V, which is equal to the expected voltage when the robot is placed exactly on the center-line. When the line is to the extreme left of the robot, the expected voltage is 1.5V, while the corresponding voltage for the right side is 4.5V. Therefore, the error will be between +1.5V and -1.5V. This error voltage is then sent through the proportional, integral and derivative sections of the PID circuit, simultaneously. The error will be inverted through the comparator. The circuit schematic is given below.



The proportional segment is simply a gain circuit with a gain of 1. A small bypass capacitor of 27pF has been added to the circuit to improve the stability of the Op-Amp.

The integrator circuit consists of a feedback capacitor which will charge and discharge when the applied input changes. This results in an output voltage that is proportional to the integral of the input voltage. However, there is an issue where real op amps can charge the capacitor even when no input is present. To prevent this, a resistor is added in parallel with this capacitor. The derivative circuit basically acts as a high-pass filter where low frequencies are attenuated whereas the high frequencies are allowed to pass through. This helps us to get an output which is proportional to the rate of change of the input voltage. To improve the circuit, a small capacitor is added in parallel to the feedback resistor and a resistor is added in series to the input capacitor, helping to restrict the gain at higher frequencies and thereby, reducing impact of noise.

These 3 functions will be sent to the summing junction and the output will determine the direction and speed in which the motor should rotate. To tune the PID system, potentiometers have been added to the output of the proportional, integral and derivative functions as well as the output of the summing junction to control the gain.

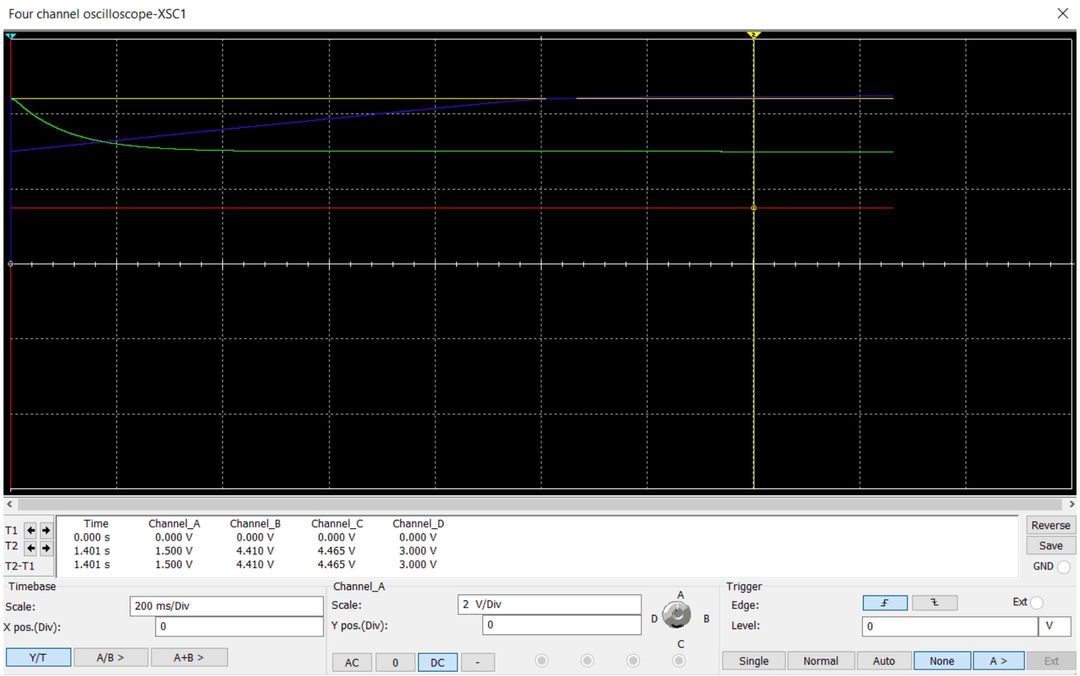
In the simulations, we have considered two scenarios.

1). Constant error

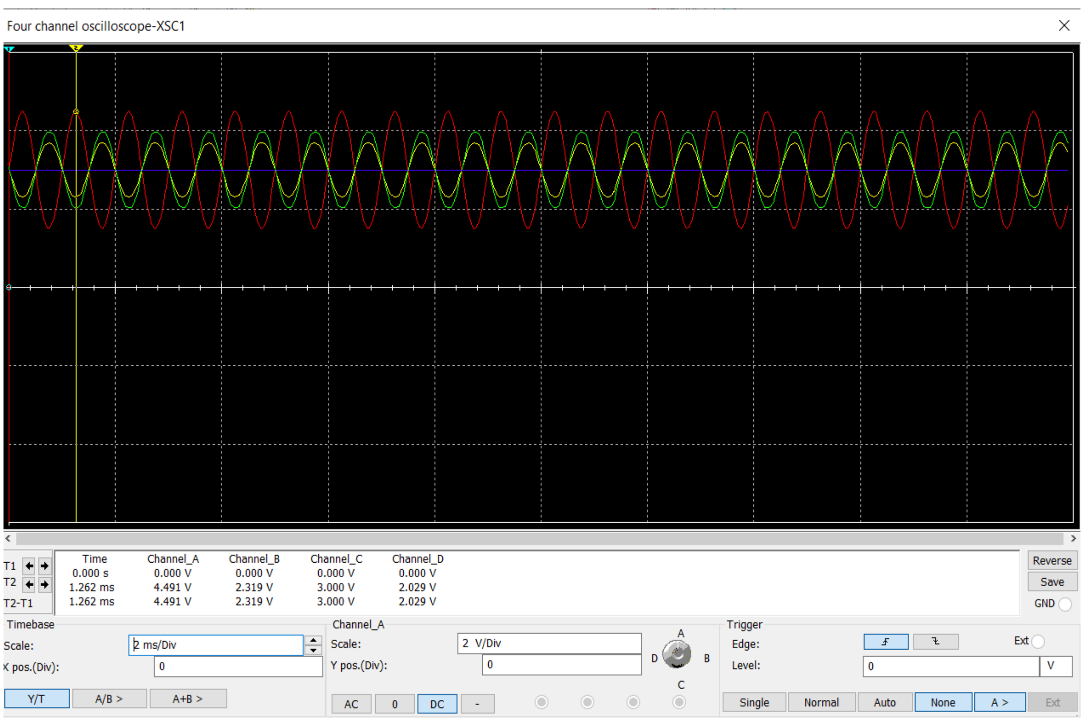
2). Varying error

Red plot shows the error. Yellow, Blue and green depict the P,I and D responses.

a).

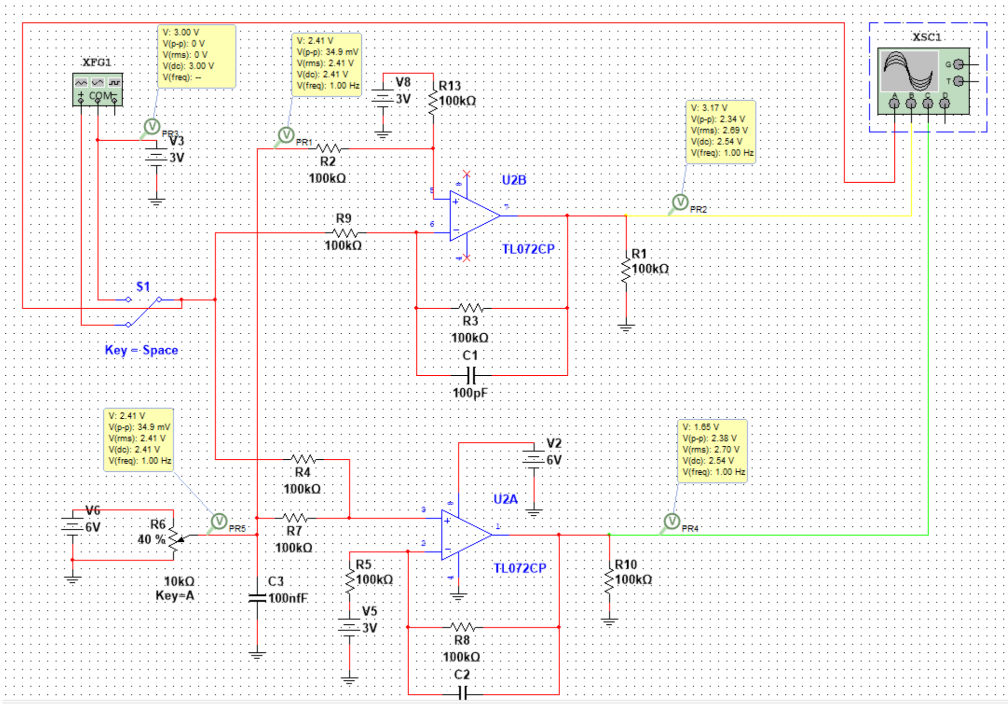


b).



MOTOR SPEED CALCULATION

The output of the PID response will be varying with respect to VCC/2 (3V). Accordingly, the output consists of a 3V DC component and an AC component. As we only want the AC component, we should filter out that component. The circuit schematic is shown below.



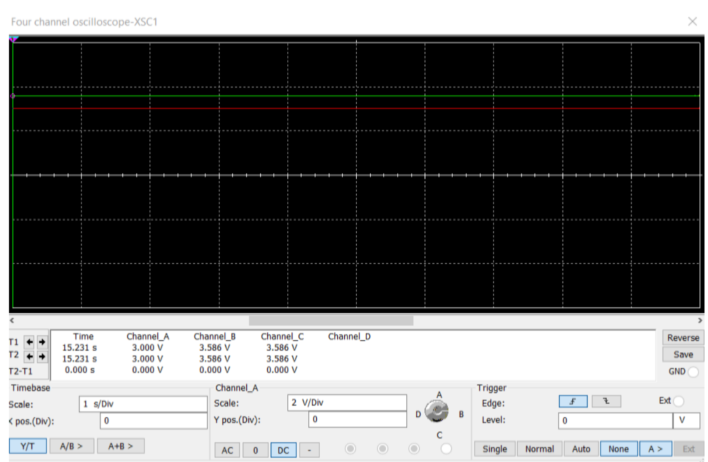
In the schematic, the upper op amp acts as the differentiator. The lower circuit acts as the adder. Moreover, two circuits will get rid of the DC component of the PID response.

We carried out the simulations for three cases.

a). zero error (only 3V DC)

b). varying error and the set speed is greater than 3

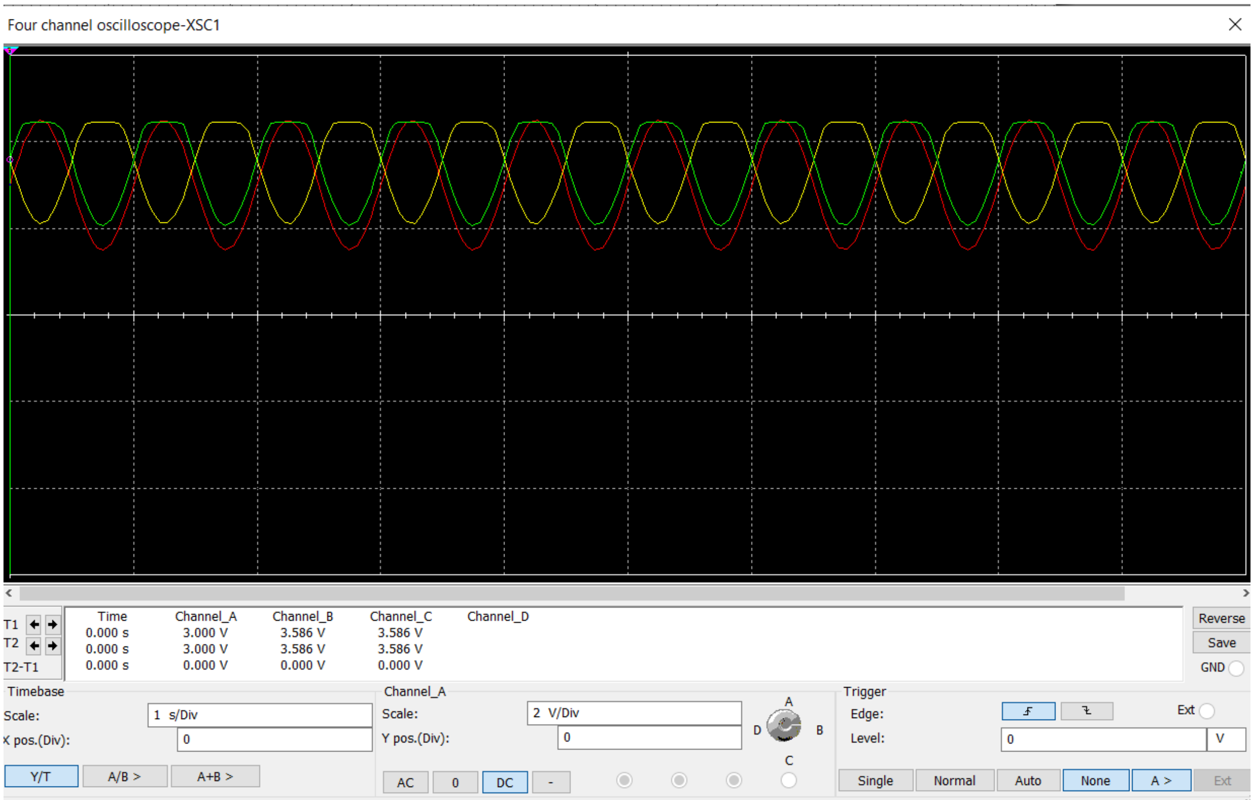
c). varying error and the set speed is lower than 3



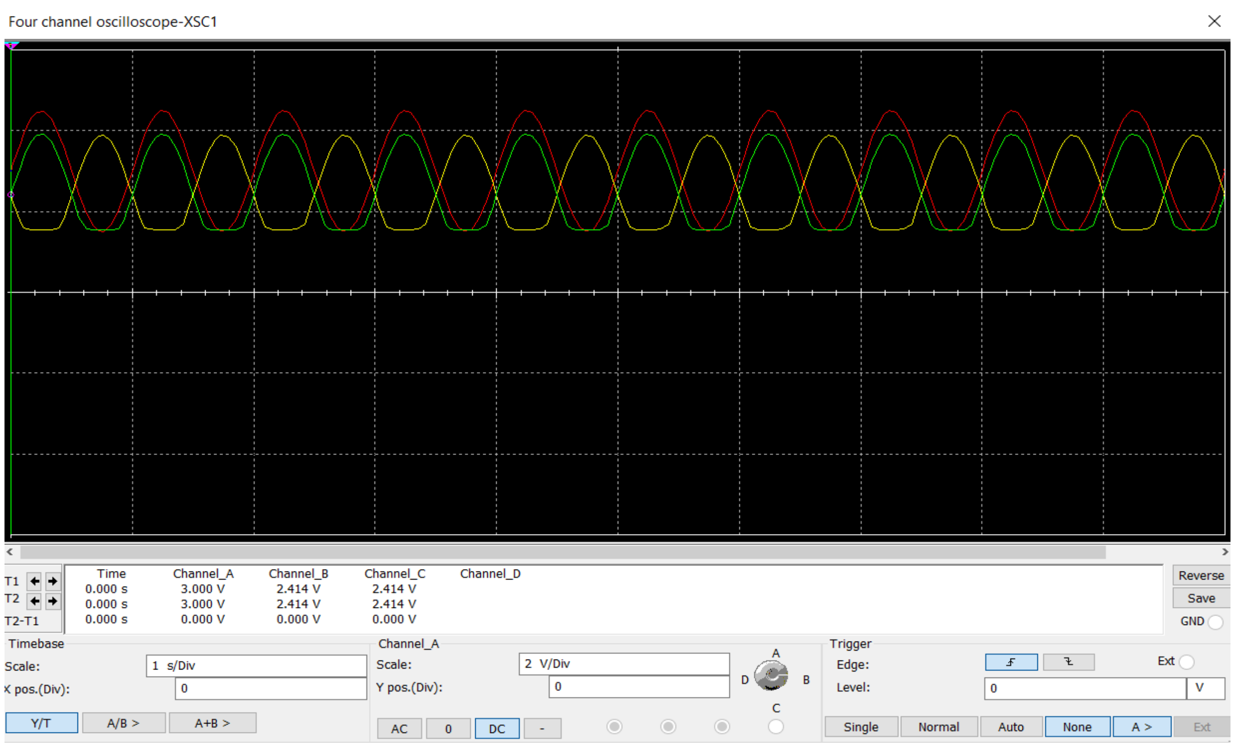
a). red-error (dc)

green, yellow-speeds

b). set speed voltage > 3

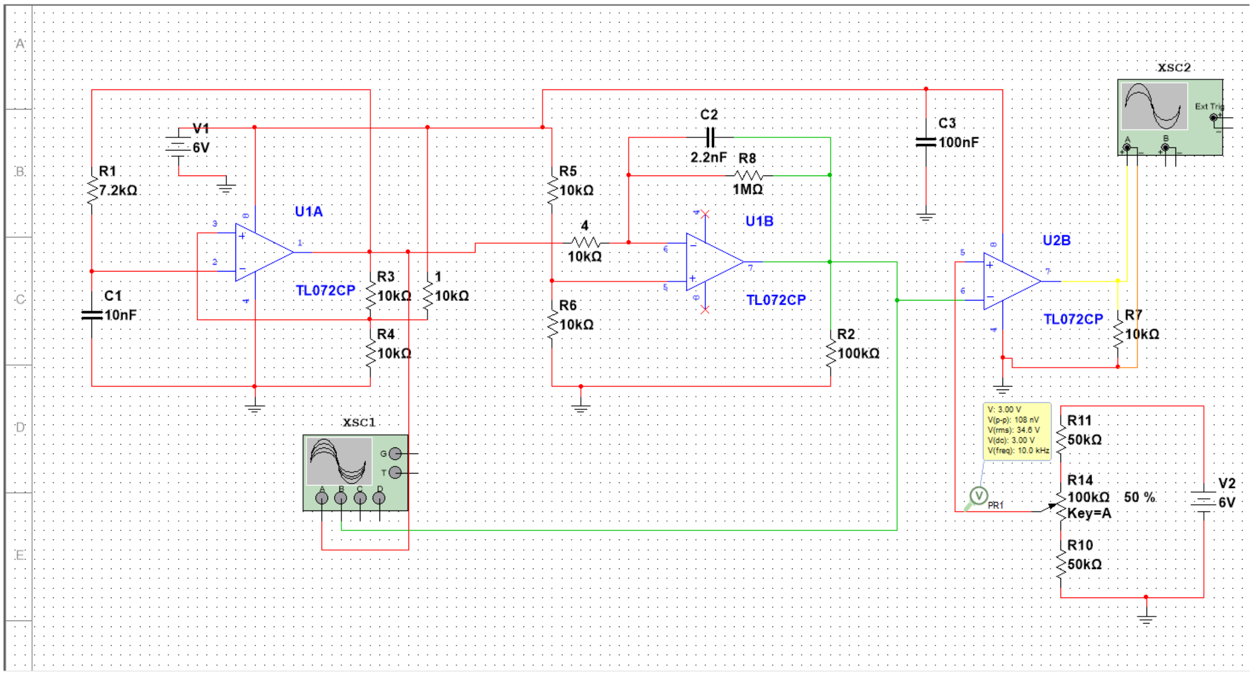


c). set speed voltage < 3

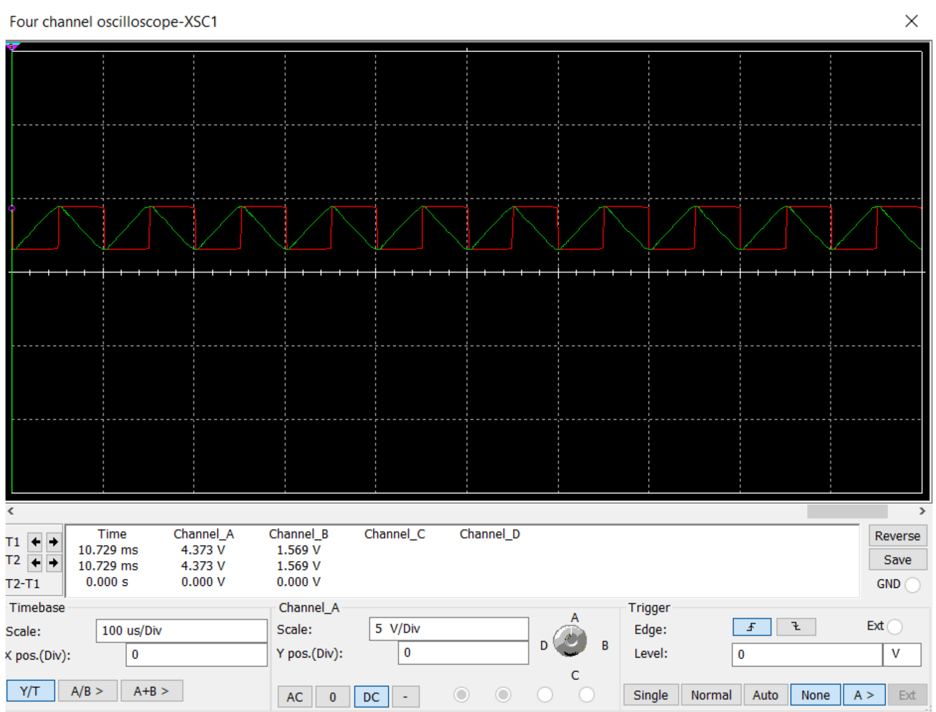


PWM GENERATOR

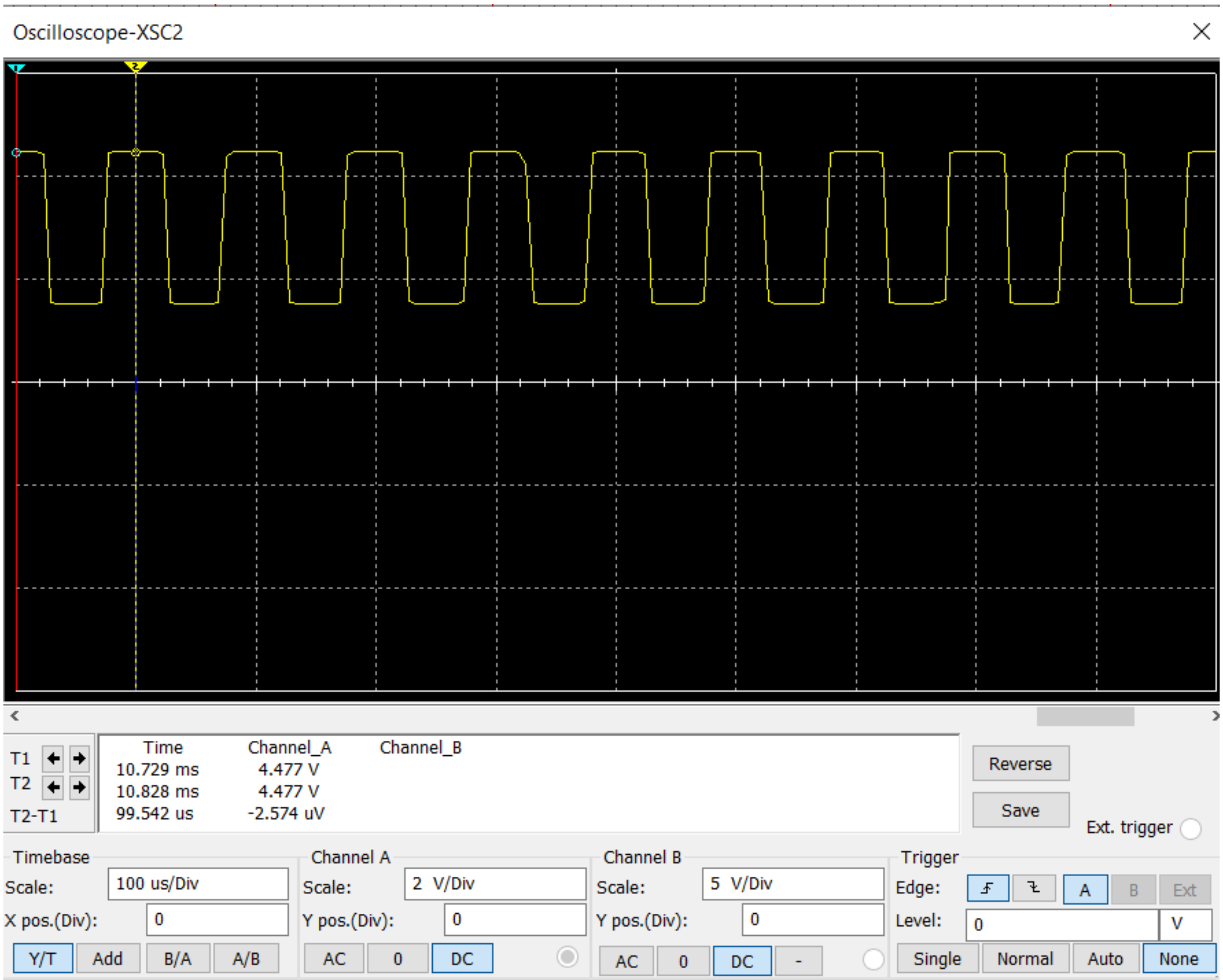
Output of the previous section will be fed to two PWM generators. For PWM generation, first we have to generate square wave pulses at 10kHz using a stable multi-vibrator. After that, we integrate that to get a 10kHz triangular waveform. Then, we generate our PWM signal using a comparator. The motor speed voltage value will be the threshold of triangular wave form which gives PWM signal. The schematic is shown below.



The output of the stable multi-vibrator and the results by integrating are shown below.

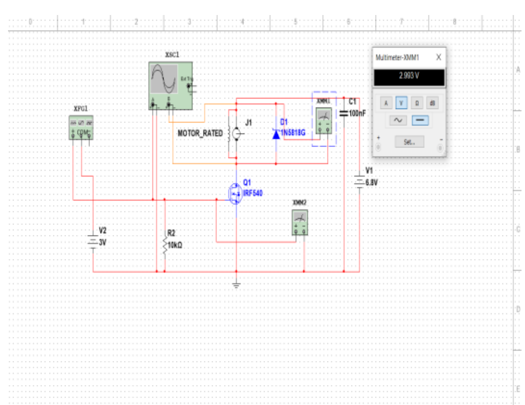


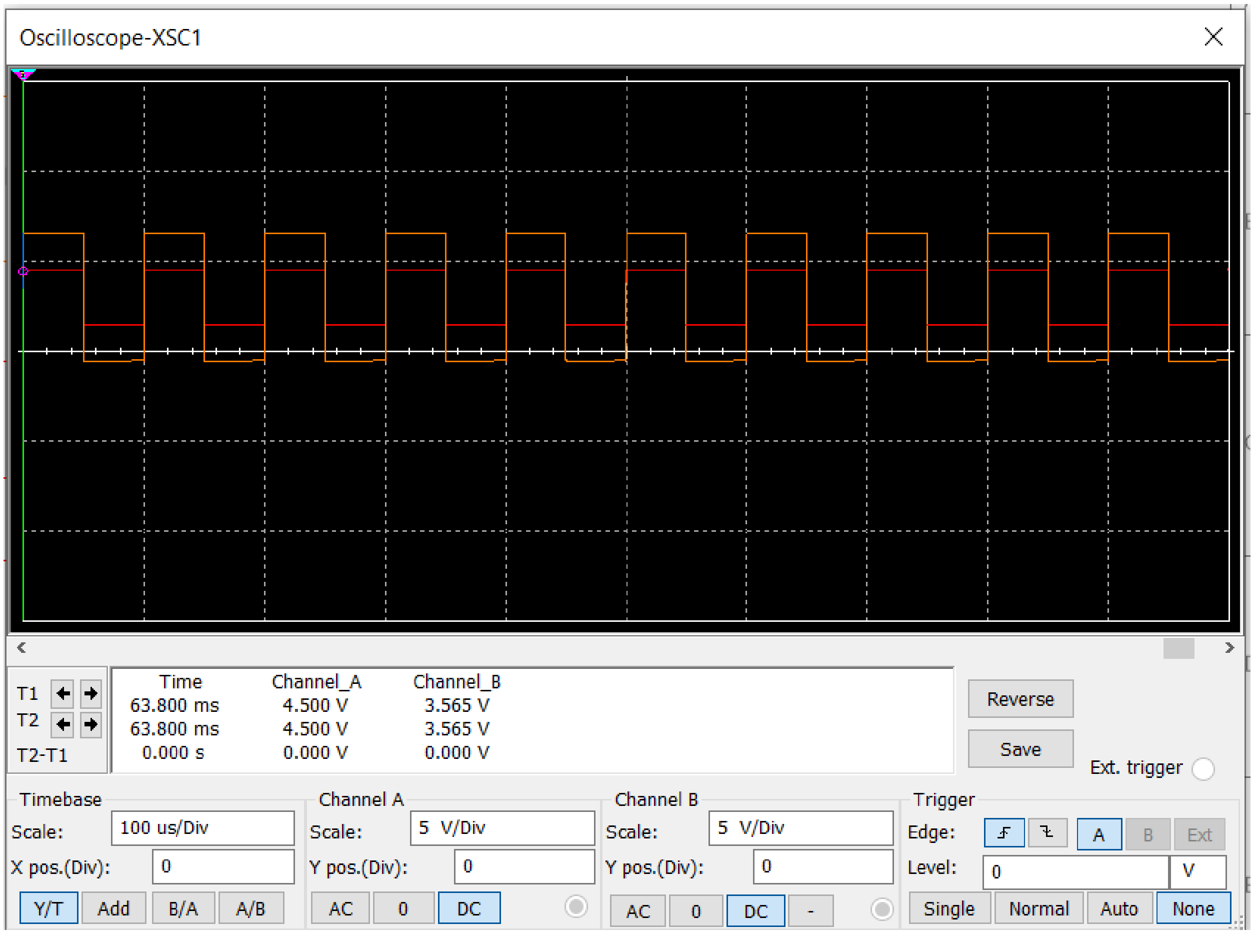
For the simulation, we set the threshold as 3V (50% of the pulse width)



MOTOR DRIVER

For the motor driver, we used a power MOSFET. The MOSFET will switch on/off the motor according to signal. For simulation, we gave a '50% 10kHz PWM signal'.





orange-motor potential

red- PWM