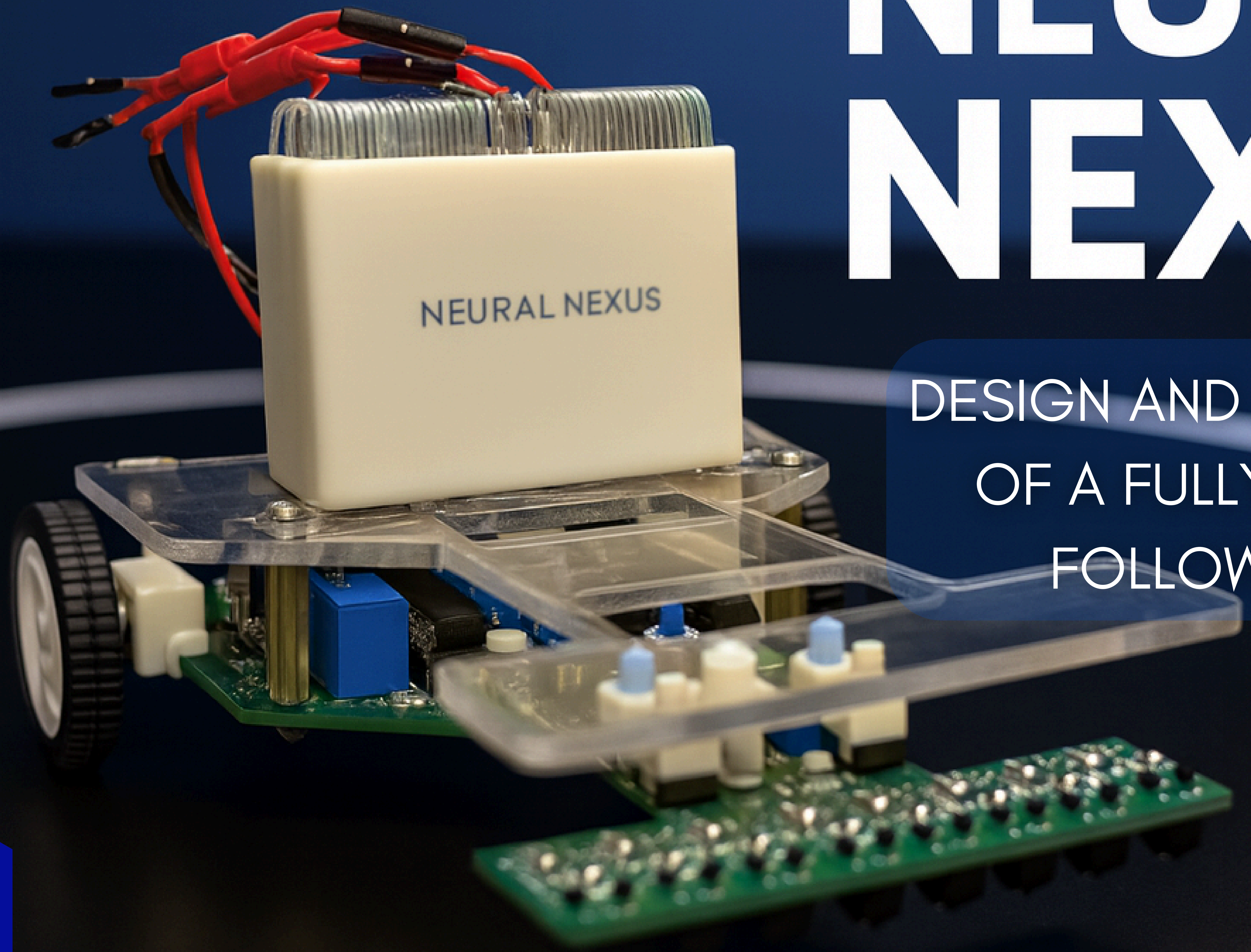
EN2091 - LABORATORY PRACTICE AND PROJECTS

NEURAL NEXUS

DESIGN AND IMPLEMENTATION OF A FULLY ANALOG LINE FOLLOWING ROBOT



UNIVERSITY OF MORATUNA

ENTC
Electronic and Telecommunication Engineering

FLOW DIAGRAM

1. INPUT FROM THE LINE FOLLOWING SENSOR ARRAY
2. WEIGHTING THE IR SENSOR OUTPUTS TO NECESSARY WEIGHTS
3. SUMMING WEIGHTS AND GET THE DIFFERENCE OF WEIGHTS
4. CALCULATE THE P&D FROM THE RAW ERROR
5. FEED THE CORRECTED ERROR TO THE BASE VOLTAGE ADDER/SUBTRACTOR
6. CORRECT THE POLARITY IF NEEDED
7. CLIP THE VOLTAGE TO PREVENT THE MOTOR FROM STOPPING FOR LOW PWMS
8. GENERATE THE TRIANGULAR WAVE FORM NEEDED FOR THE PWM GENERATOR
9. GET THE PWM SIGNAL FROM THE COMPARATOR
10. MAP THAT VOLTAGE AS NECESSARY TO THE MOTOR MAX VOLTAGE
11. GIVE THE PWM SIGNAL TO THE L293D MOTOR DRIVER
12. MOTOR OUTPUT FROM THE L293D MOTOR DRIVER

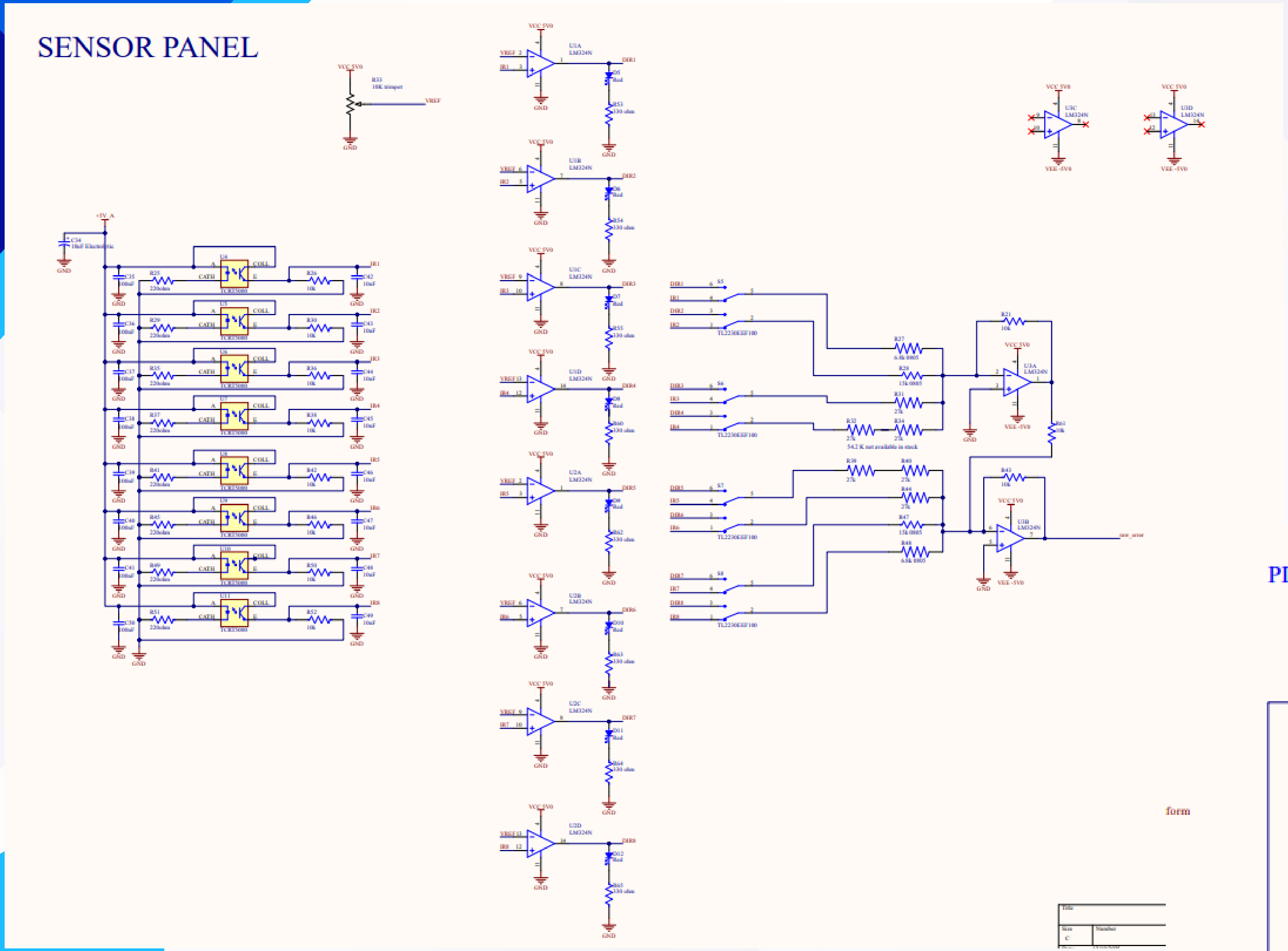
SENSOR ARRAY

- •We are using TCRT5000 IR emitter and receiver to detect the line and we are getting the analog read from that sensor.
- •We are using LM324 Quad Opamp IC.
- •Low-cost and readily available: The LM324 is inexpensive, easy to source, and provides four op-amps in one package, reducing both cost and space in our design.
- •LM324 (Slew rate 0.5V/us) 0-5V 10us.

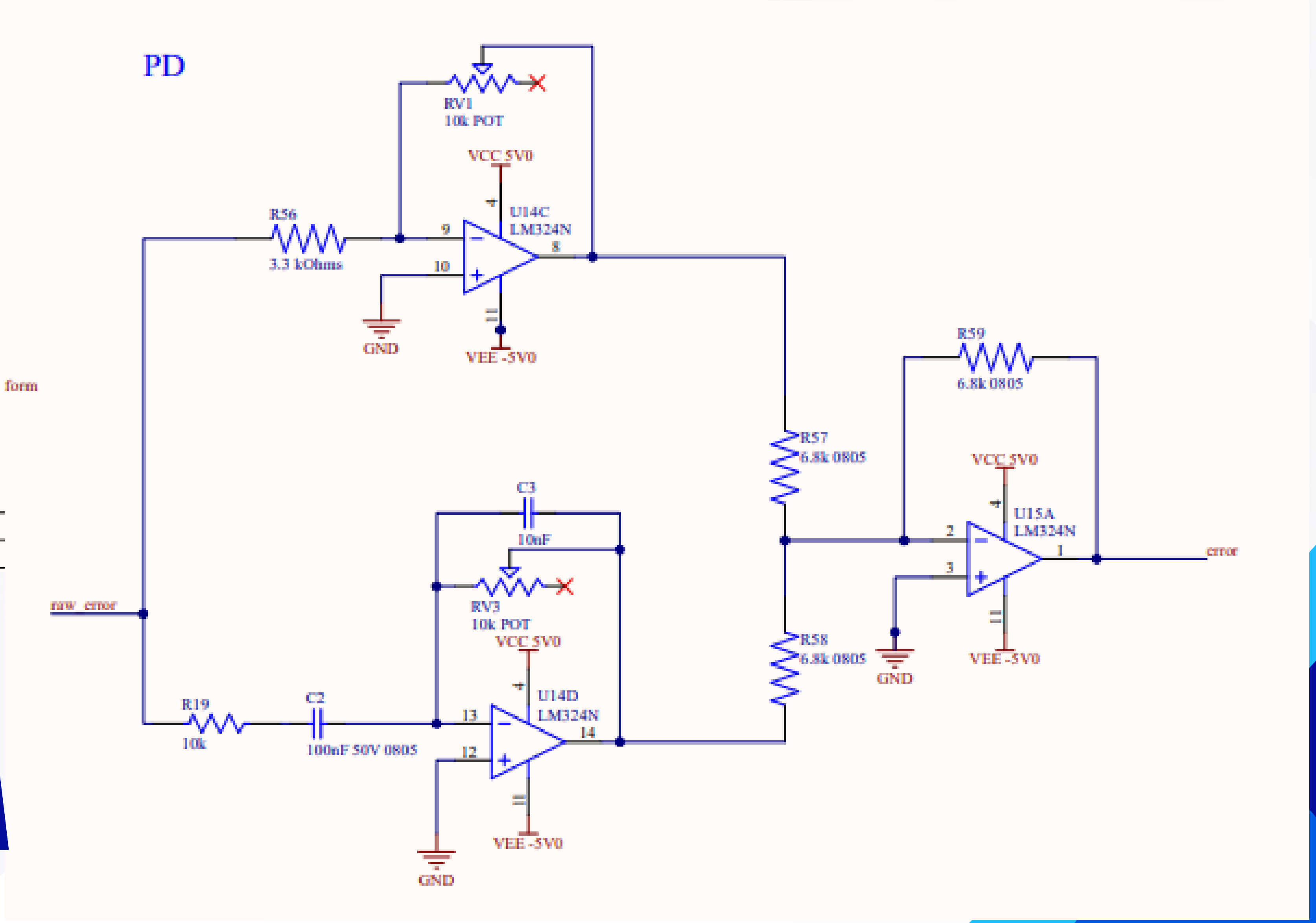
PD CONTROL SYSTEM

- We are passing the weighted raw error to the PD Control system.
- We don’t use I term here because The robot is constantly moving, so there’s no steady state error to correct.
- In here we Mean by the steady state error is the small remaining error that stays even after the system stops changing.
- We adjust Kp by changing the amplification of the opamp amplifier.
- We adjust Kd by changing the resisitance of the opamp differentiator.

SENSOR ARRAY



PD CONTROL SYSTEM



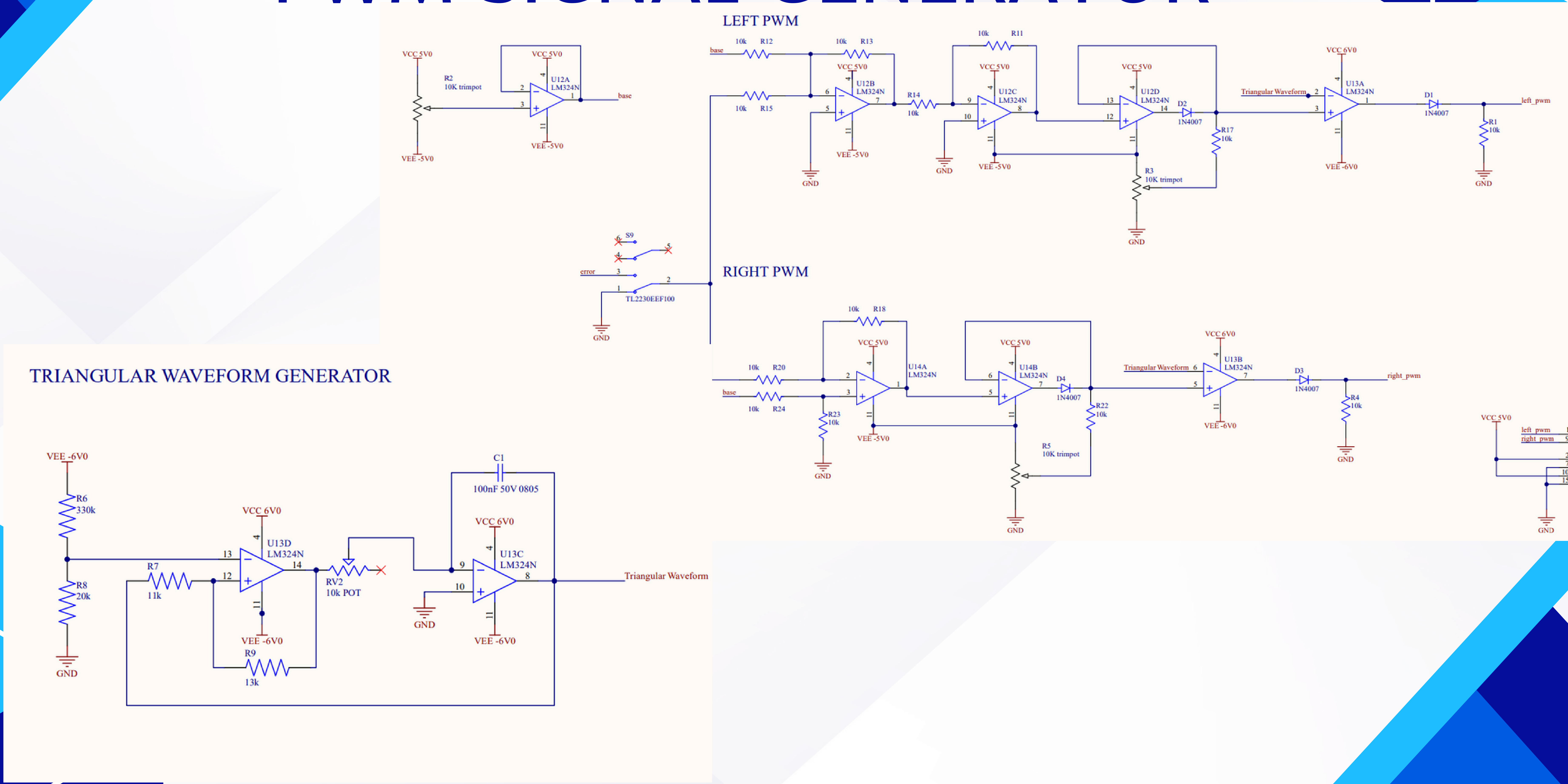
PWM SIGNAL GENERATOR

- This circuit generates the left and right PWM signals to control motor speeds through L293D motor driver.
- The error and base signals are processed by opamp stages to produce control voltages proportional to line deviation, so from the beginning we are using 2 lines as Vb+error and Vb-error and generate 2 PWM signals.
- Then we clip down that signal to avoid lower signals which make the wheels not to rotate for low PWM signals.
- These voltages are compared with a triangular waveform to create PWM signals.
- The PWM duty cycle changes according to the PD control output, allowing smooth and accurate steering correction.

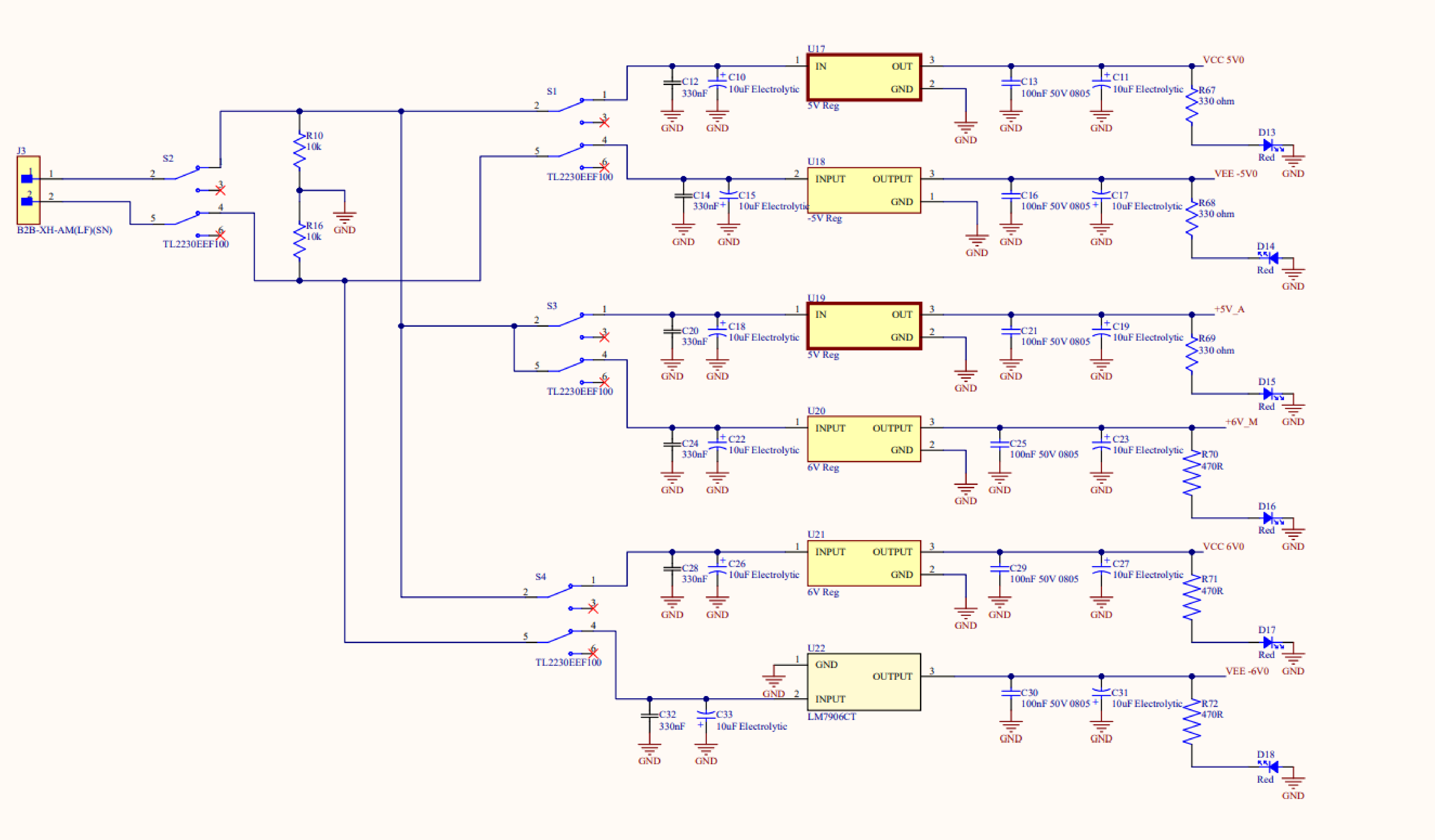
Our robot’s special features:

1. Adjustale PWM frequency
2. Adjustable base voltage of motors
3. Adjustable minimum clipping voltage (change the minimum speed of the motor)

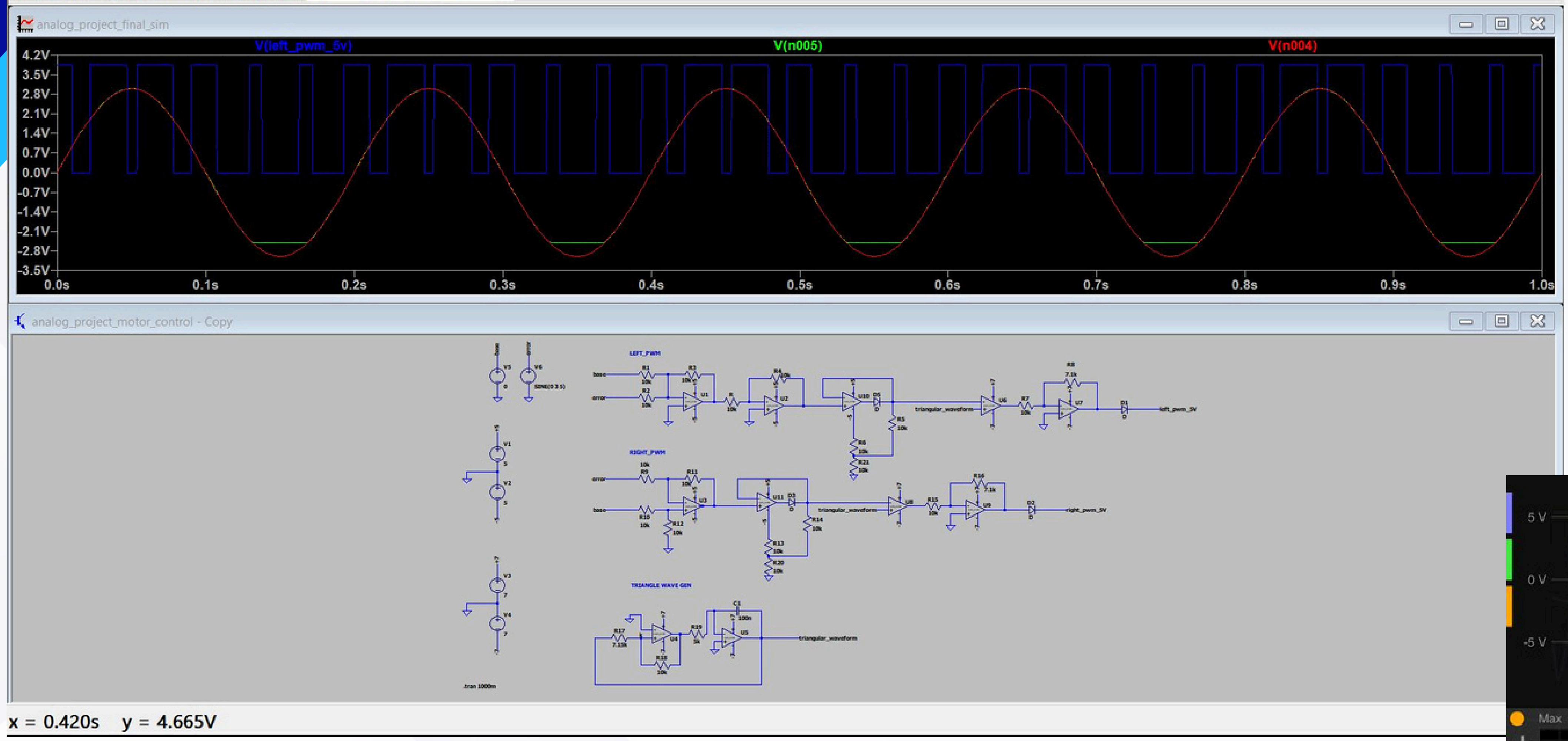
PWM SIGNAL GENERATOR



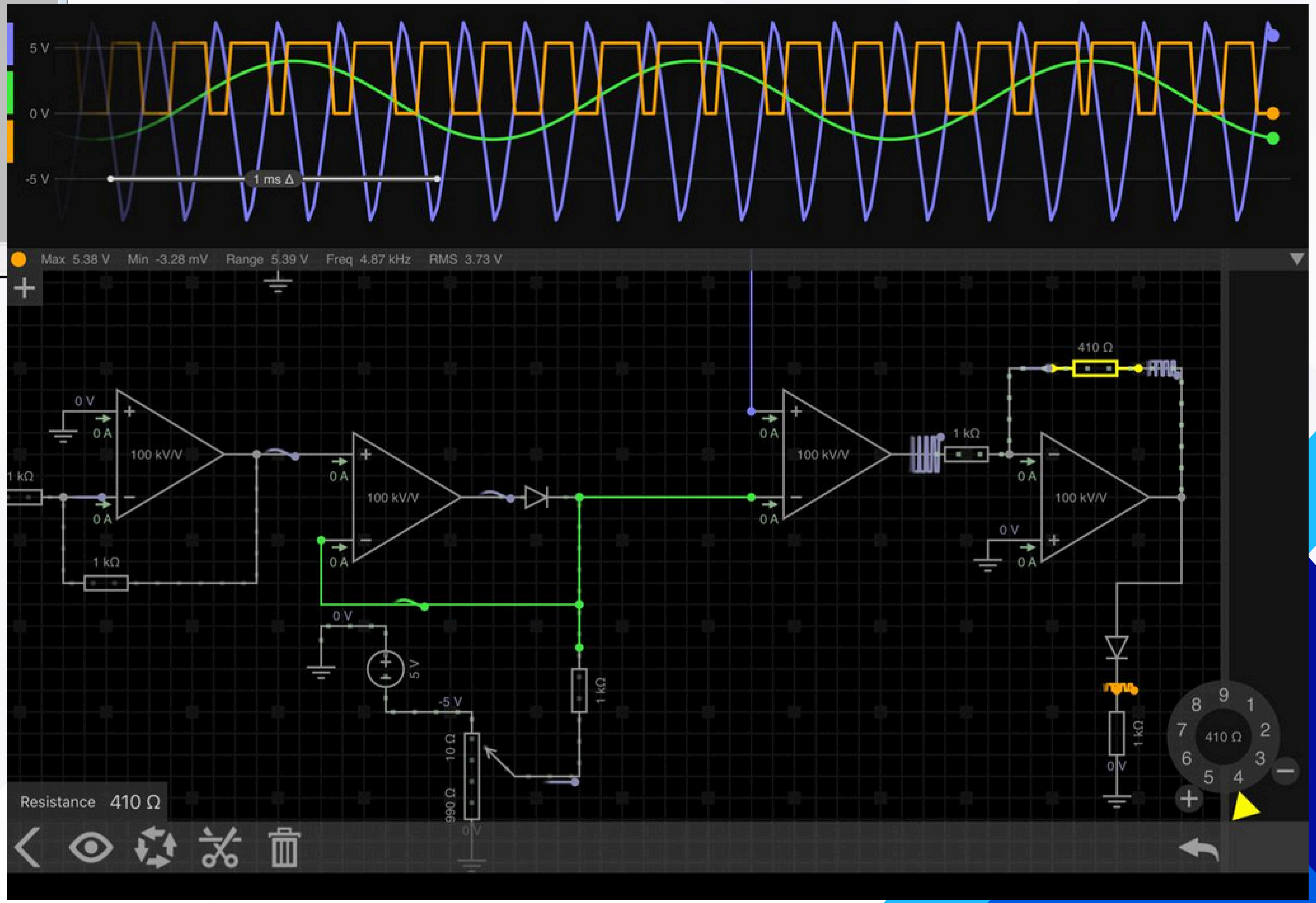
POWER DISTRIBUTION



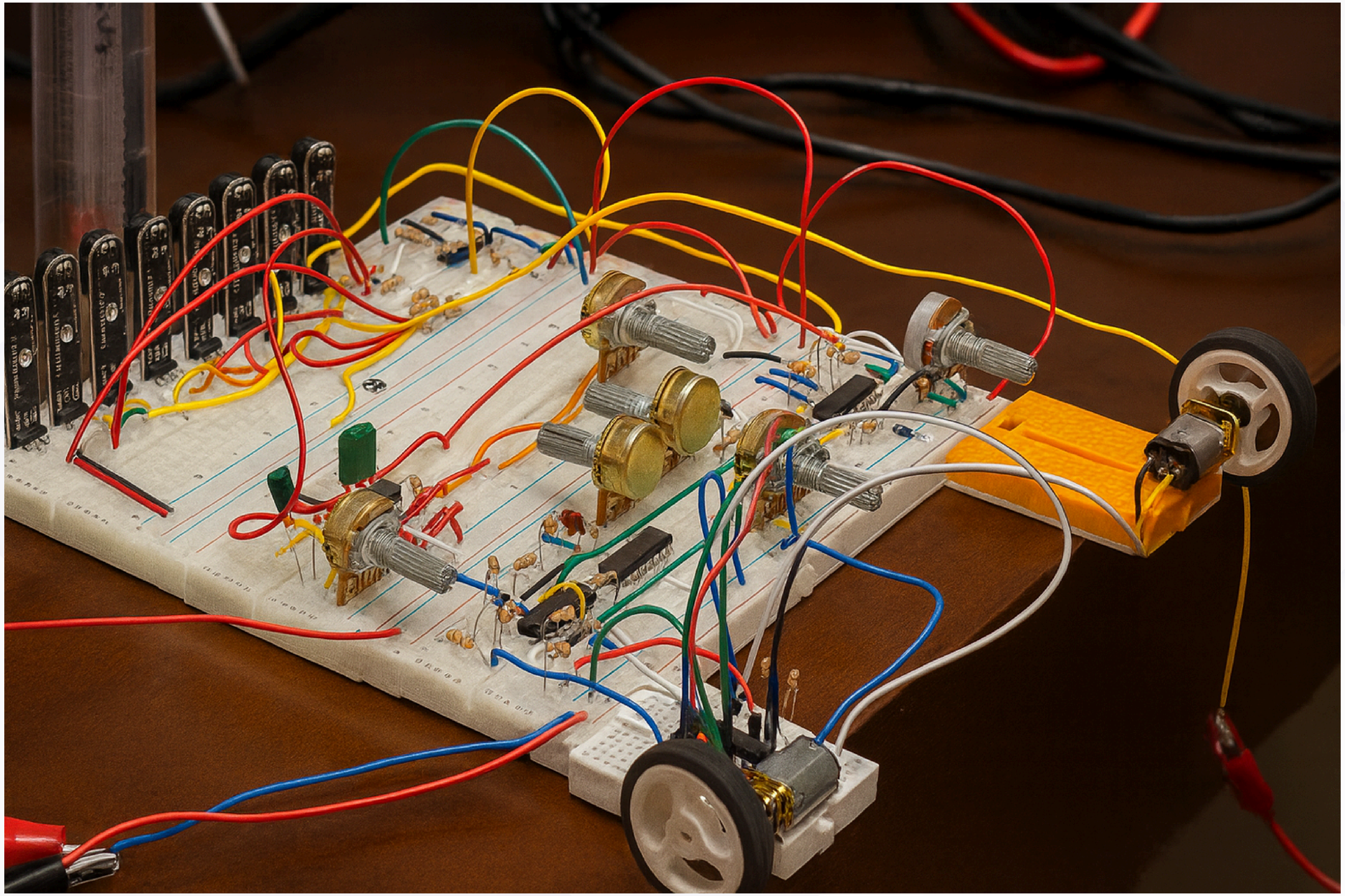
LT SPICE SIMULATION



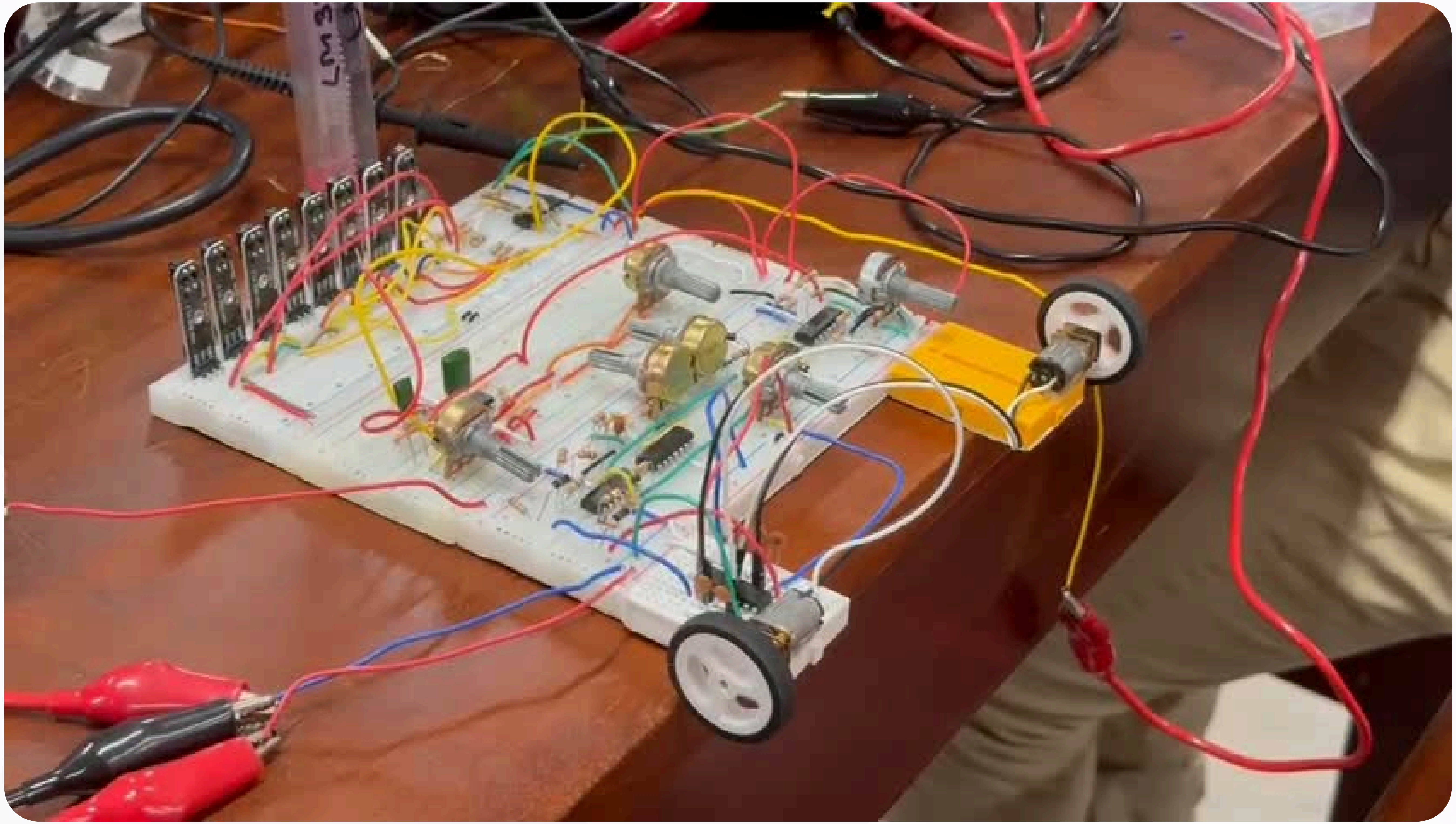
EVERYCIRCUIT SIMULATION



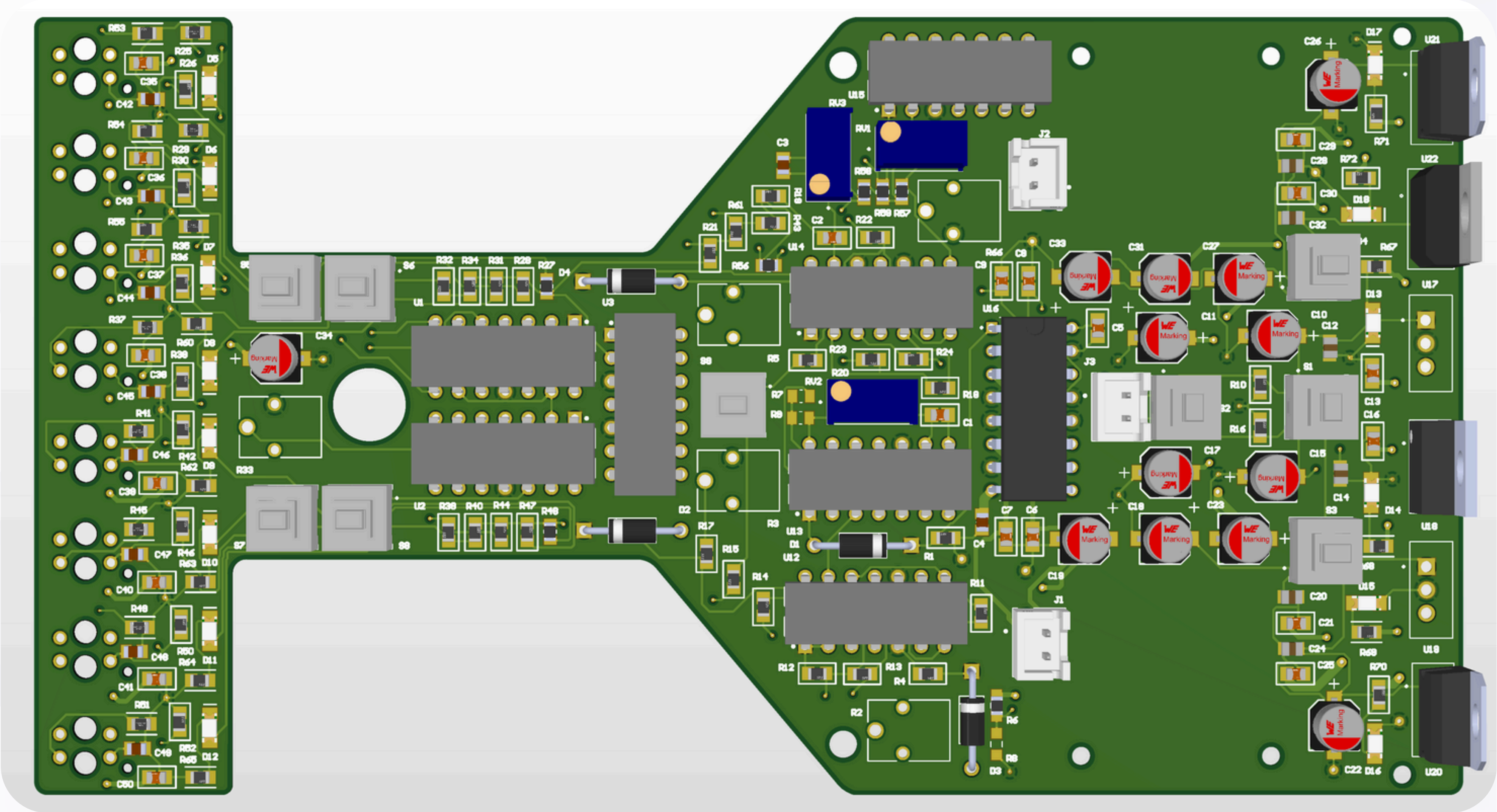
BREADBOARD IMPLEMENTATION

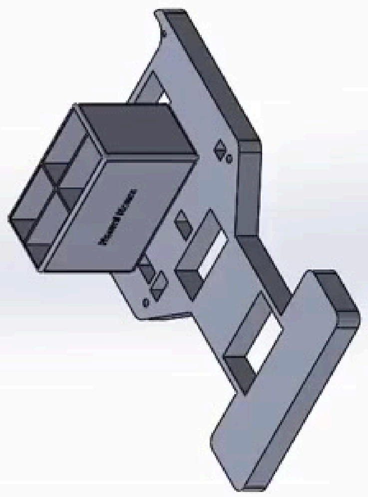


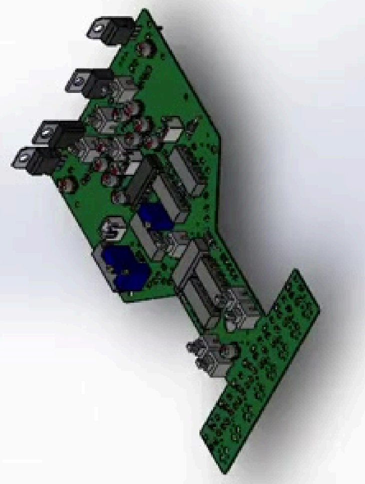
FINAL BREADBOARD IMPLEMENTATION

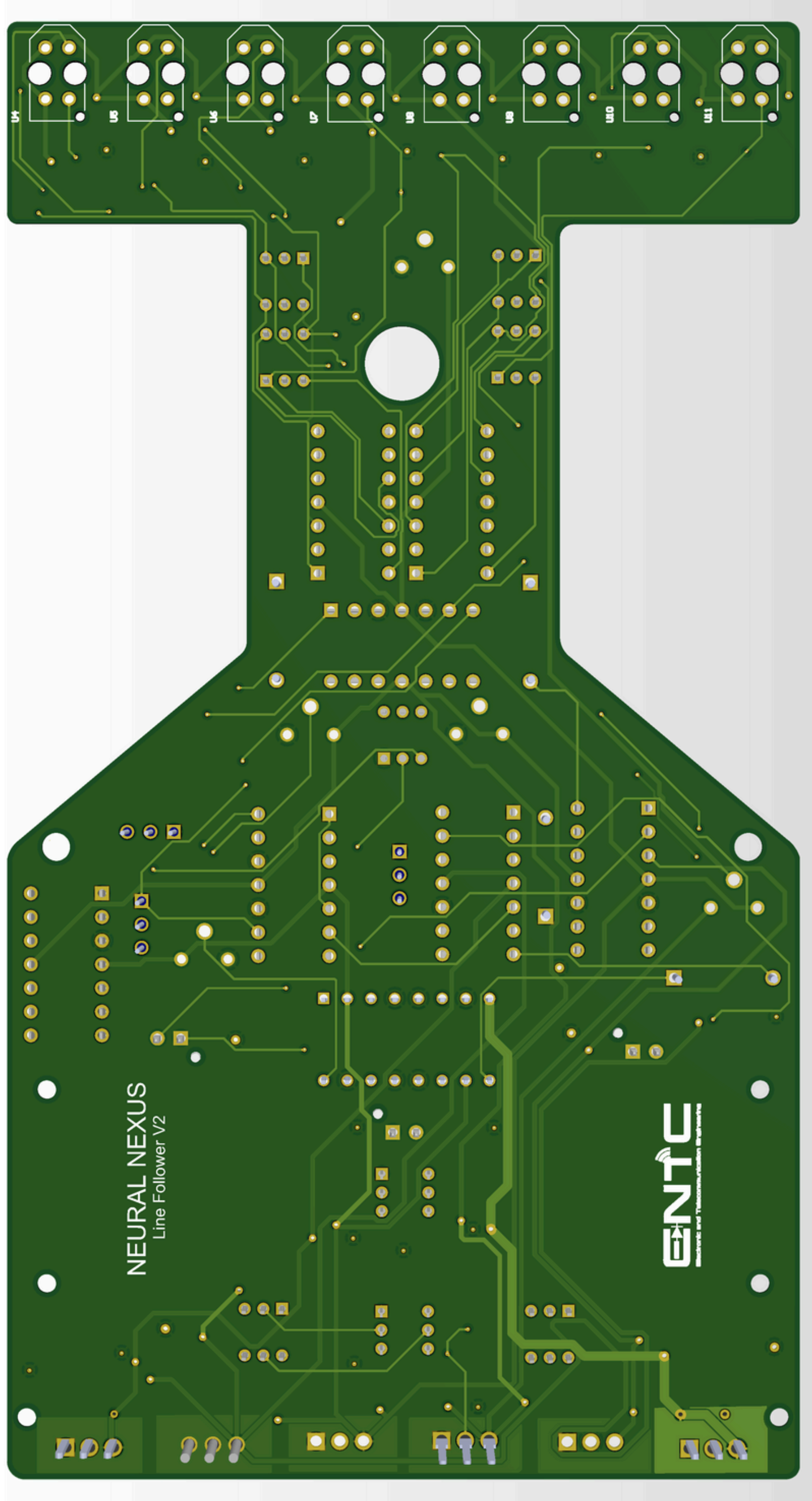


PCB DESIGN







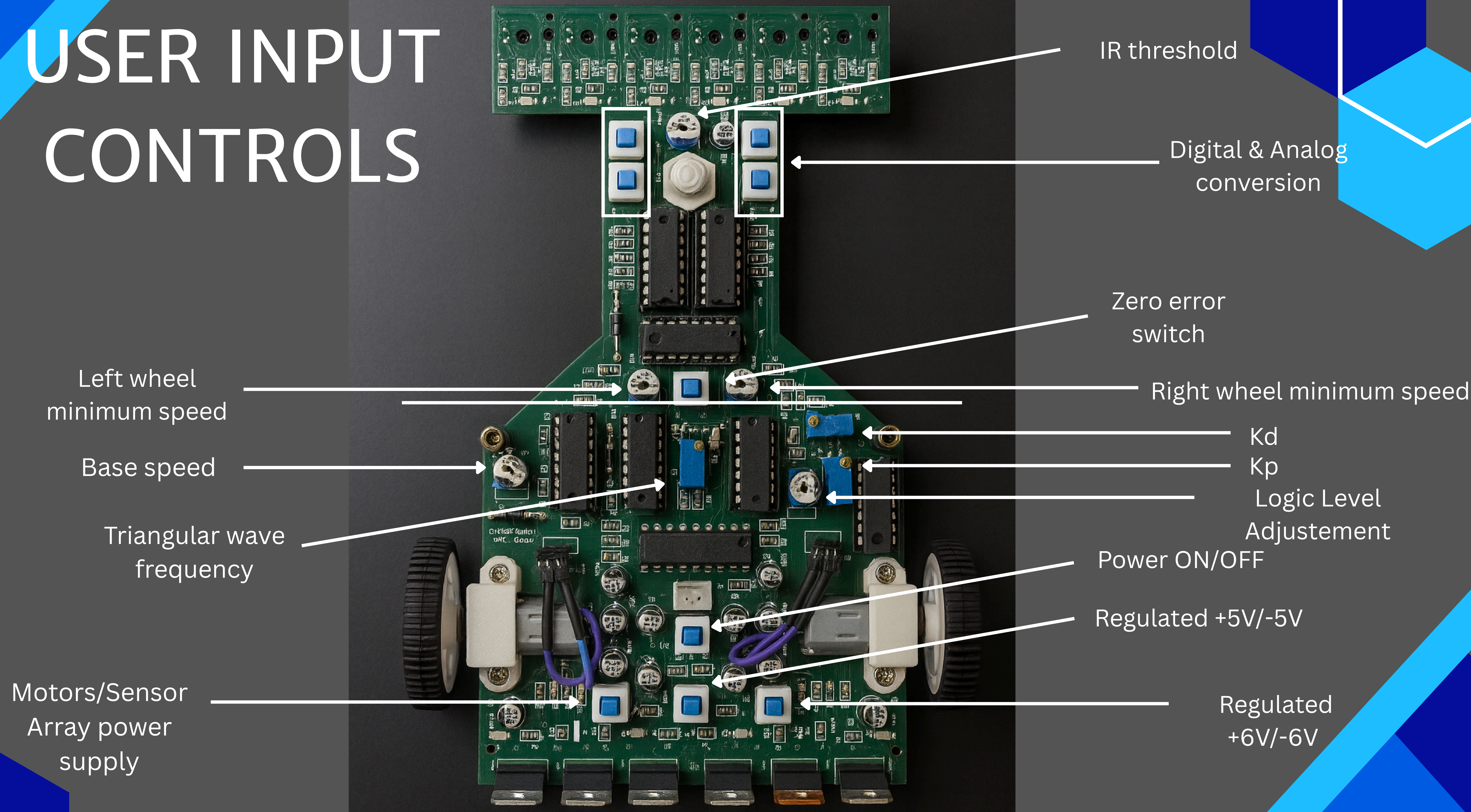


POWER BUDGET CALCULATION

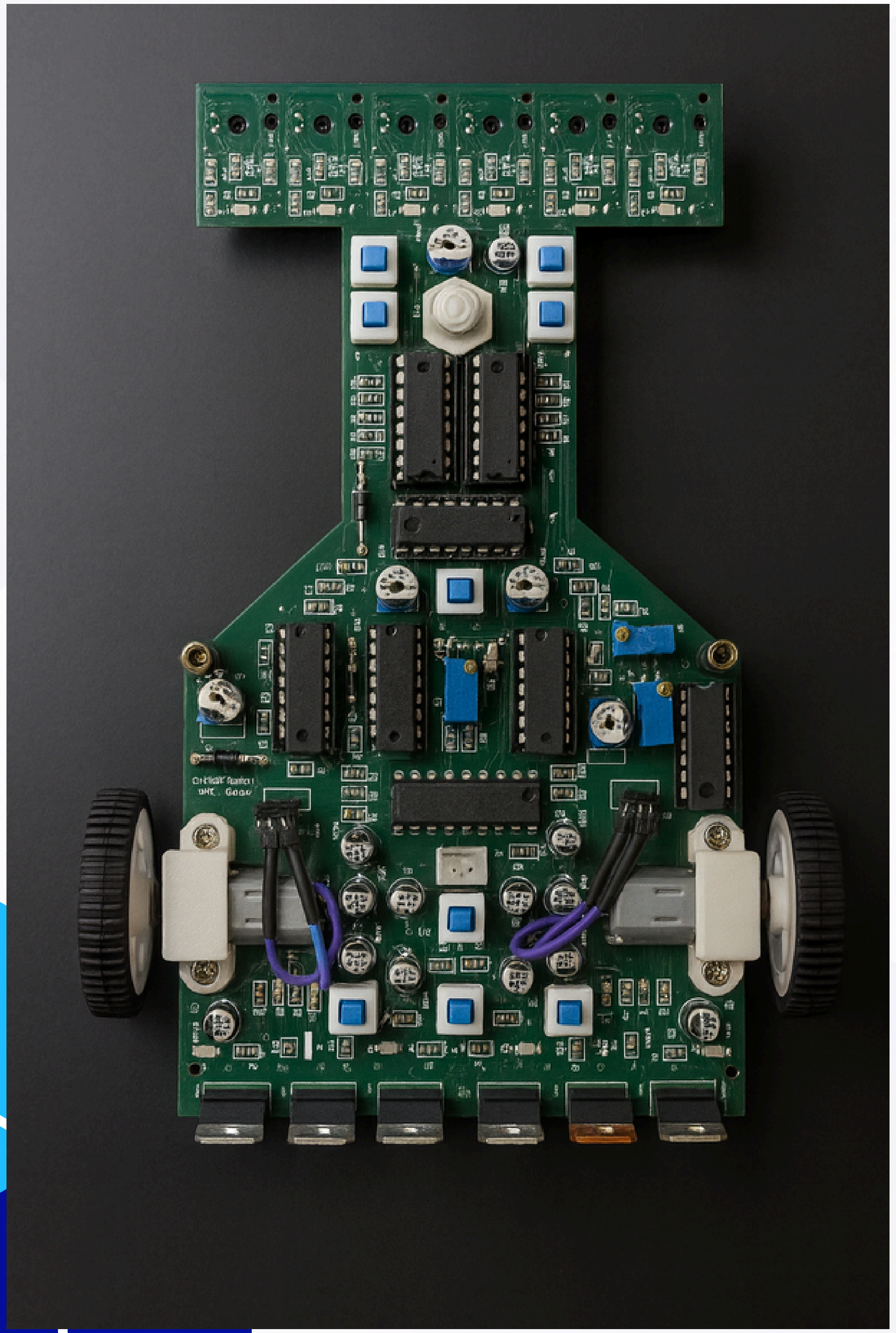
Item	Voltage (V)	Current (A)	Power (W)	Datasheets
Motor L (avg)	6	0.3	1.8	https://www.pololu.com/product/2368
Motor R (avg)	6	0.3	1.8	https://www.pololu.com/product/2368
Motors driver loss (total motors)	6	0.552	3.31	https://www.st.com/resource/en/datasheet/l293d.pdf
TCRT5000 IR LEDs (8)	5	0.144	0.72	https://www.vishay.com/docs/83760/tcrt5000.pdf
Op-amps + Misc analog	5	0.22	1.1	https://www.ti.com/lit/ds/symlink/lm324.pdf
Total System (approx)	7.4	0.75	5.6	

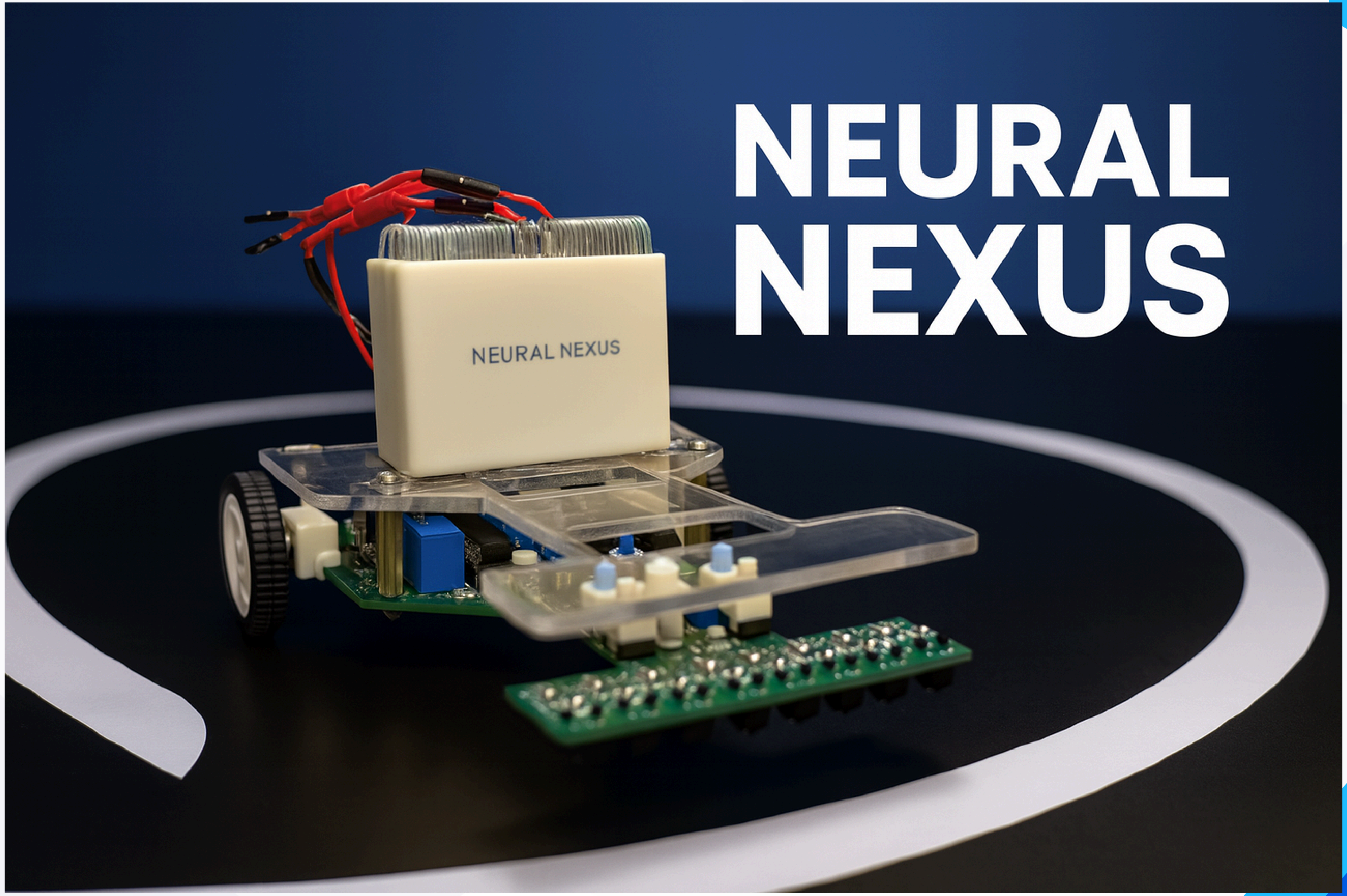
Battery Capacity (mAh)	Battery Capacity (Ah)	Total Draw (A)	Runtime (hours)	Runtime (minutes)
800	0.8	0.743	1.076716016	64.60296097

USER INPUT CONTROLS



FINAL PRODUCT





REFERENCES

Jojo. 2009. "Triangular Waveform Using Schmitt Trigger." CircuitsToday, September 22, 2009. https://circuitstoday.com/triangular-waveform-using-schmitt-trigger

National Instruments. 2025. "The PID Controller & Theory Explained." March 7, 2025. https://www.ni.com/en/shop/labview/pid-theory-explained.html

THANK YOU