Design of the Driving System of the Engine of Electrical Vehicle

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Outline

- **Abstract**
- **Introduction**
- **Methodology**
- **List of Apparatus**
- **Model Description**
- **Results**
- **Conclusion**

Abstract

- **PECs replace engine parts, driving the green energy shift.**
- **EVs use DC-AC inverters and DC-DC converters for power control.**
- **An H-bridge converter model controls motor speed and torque.**
- **Novel diode placement ensures current continuity and energy recovery.**
- **MATLAB® GUI enables remote monitoring and control.**

Introduction: H-Bridge

- Figure 1 shows the **MOSFET-based H-bridge** motor drive.
- Four switches (Q1–Q4) **control motor direction and speed.**
- Flyback diodes (D1–D4) protect against **voltage spikes**.
- Diodes provide **a path for current** when switches are **off.**
- Stored energy can **feed back to supply** or **dissipate through a resistor.**

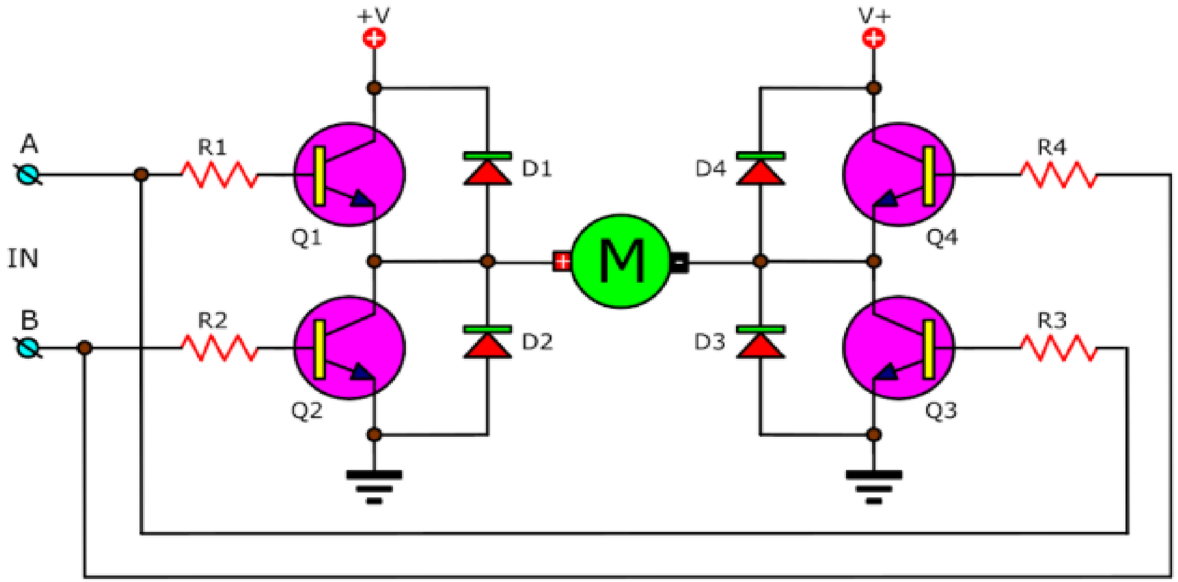


Figure 1: H-bridge DC motor drive [3]

Introduction: Motor Speed & Torque Control

- $Speed = K_s \times \frac{V - I_a R_a}{\phi}$ (in rpm)
- $Torque = \frac{60 \times E_b I_a}{2\pi \times speed}$ (in Nm)
- **Figure 2** compares speed control by armature resistance vs. DC-DC converter.
- Resistance control **wastes energy**; H-bridge PWM control is **efficient.**
- Speed and torque are regulated by adjusting **supply voltage and back emf (Eb).**

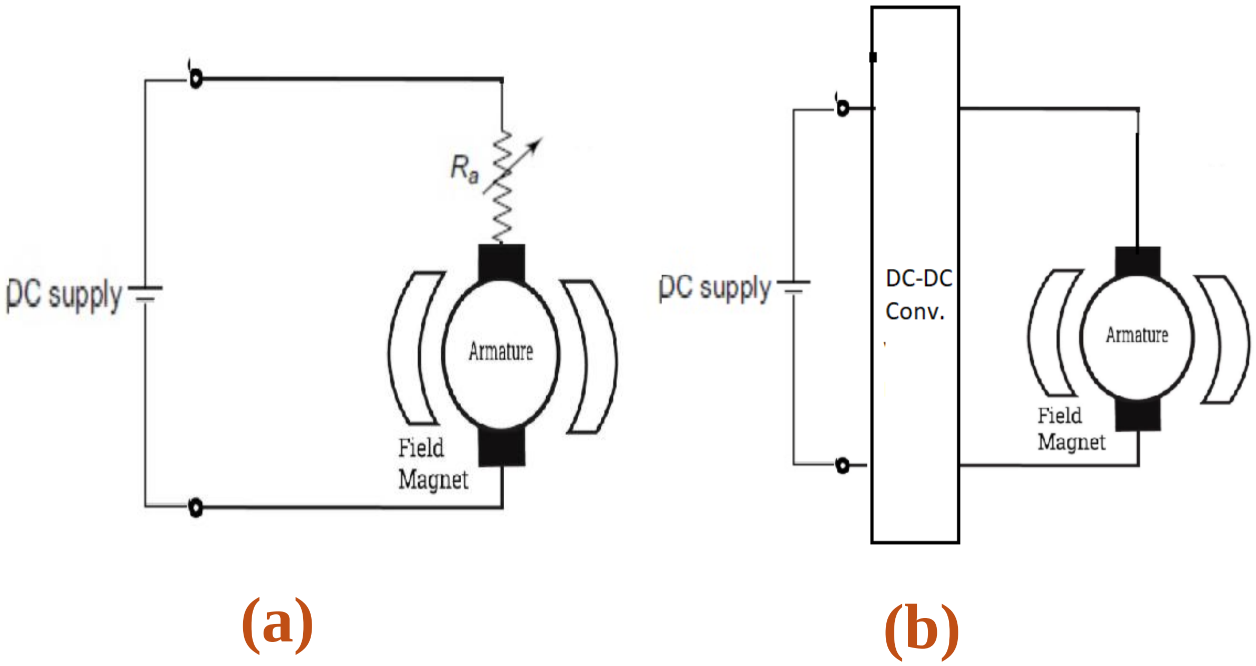


Figure 2: (a) DC motor speed control by varying armature resististance and (b) by using a DC-DC converter

Introduction: PID Controller in Closed Loop Operation

- **Figure 3** illustrates the motor speed control using **a PID feedback loop**.
- The PID controller compares **actual speed** with the **set point.**
- It adjusts the motor input to **minimize speed error** and maintain stability.

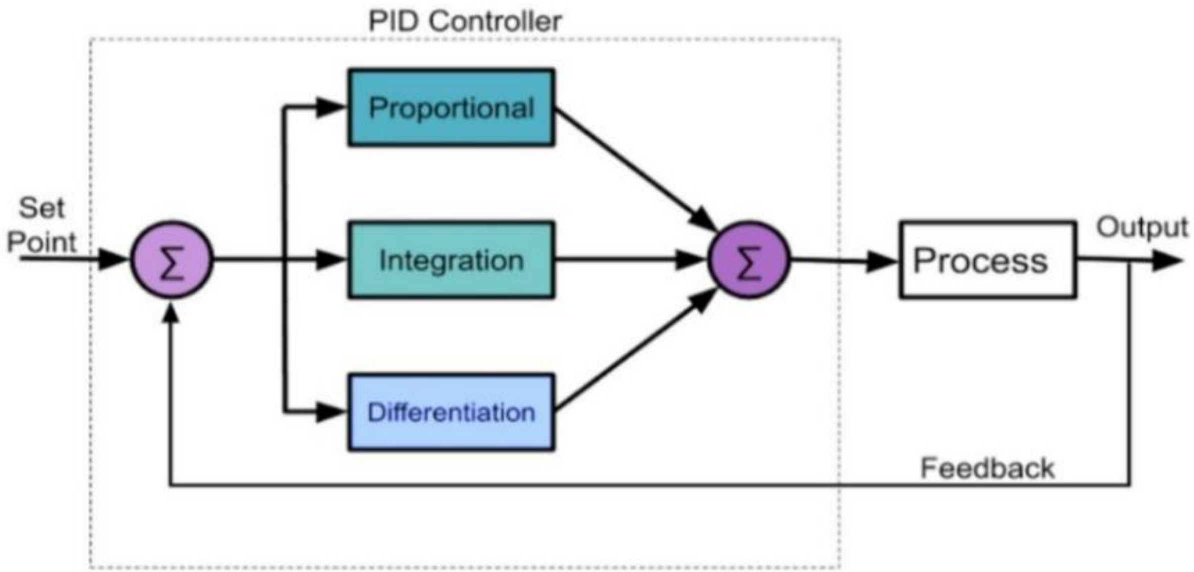
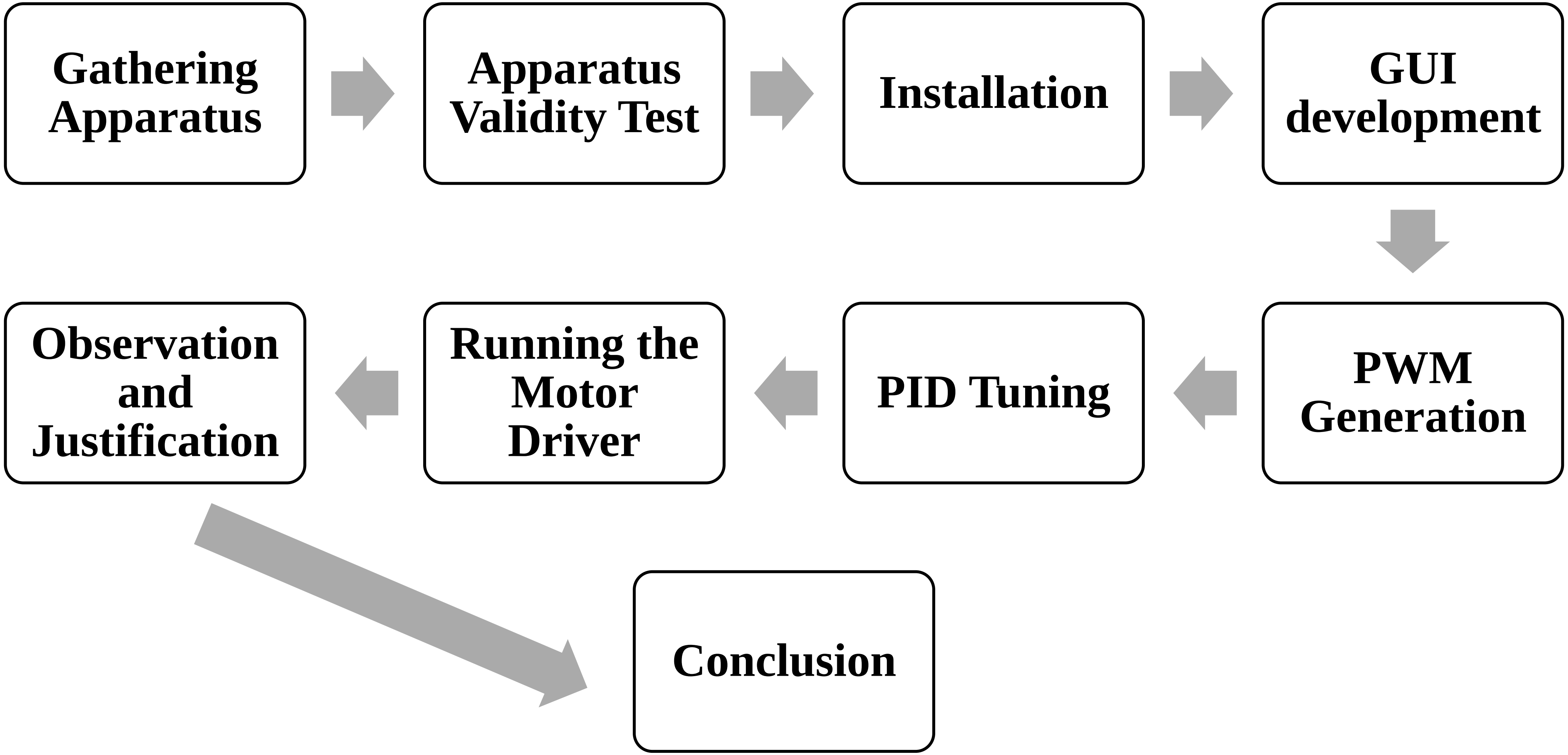


Figure 3: Block diagram of PID controller [5]

Methodology: Project Flow Chart



Methodology: Executation Steps

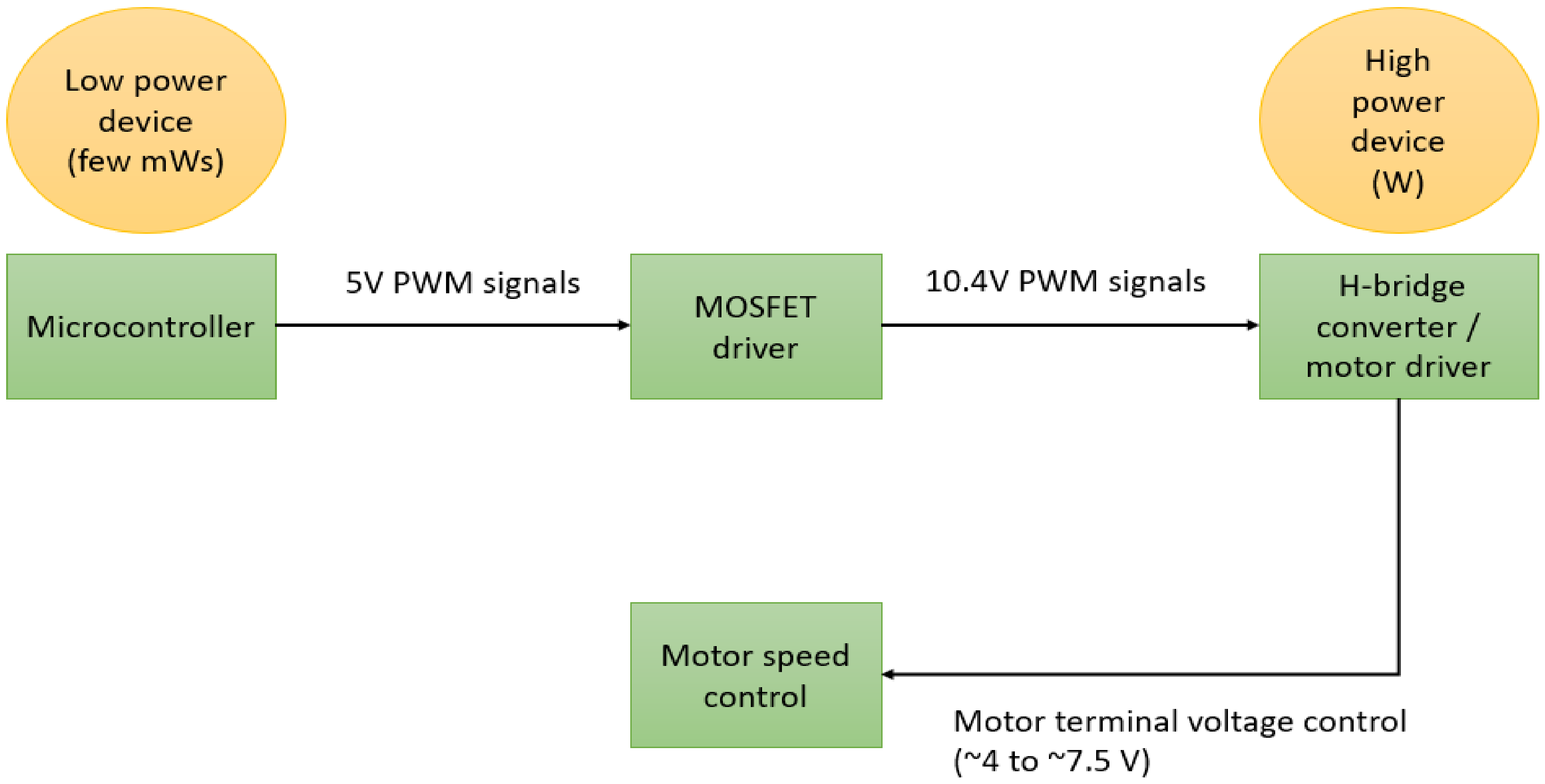
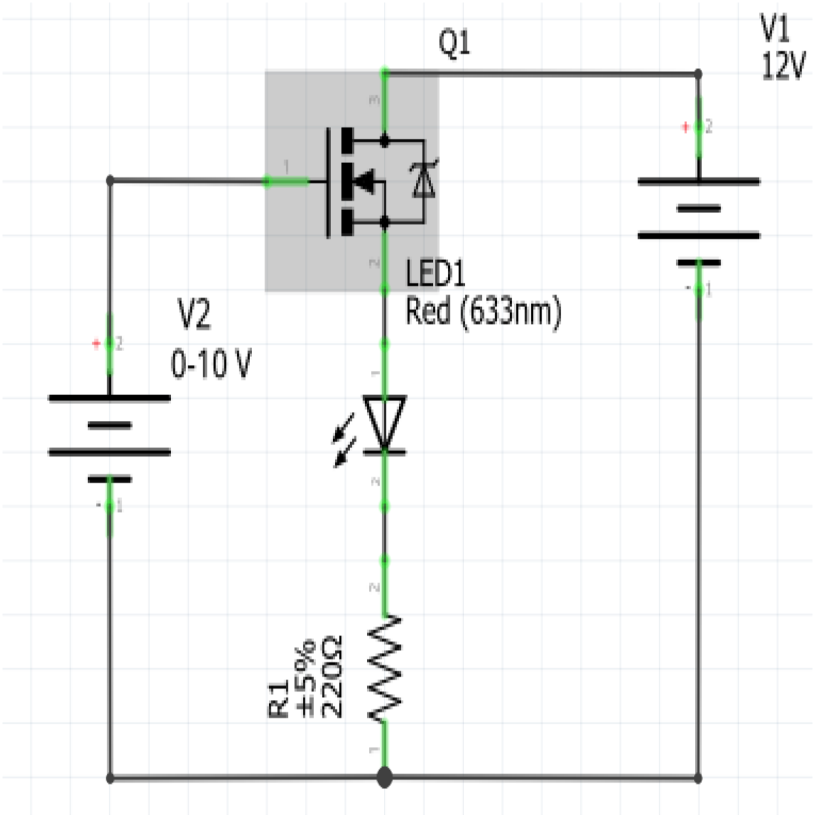


Figure 4: Execution steps to motor drive modelled for EV

Methodology: Pretesting Apparatus

(a)



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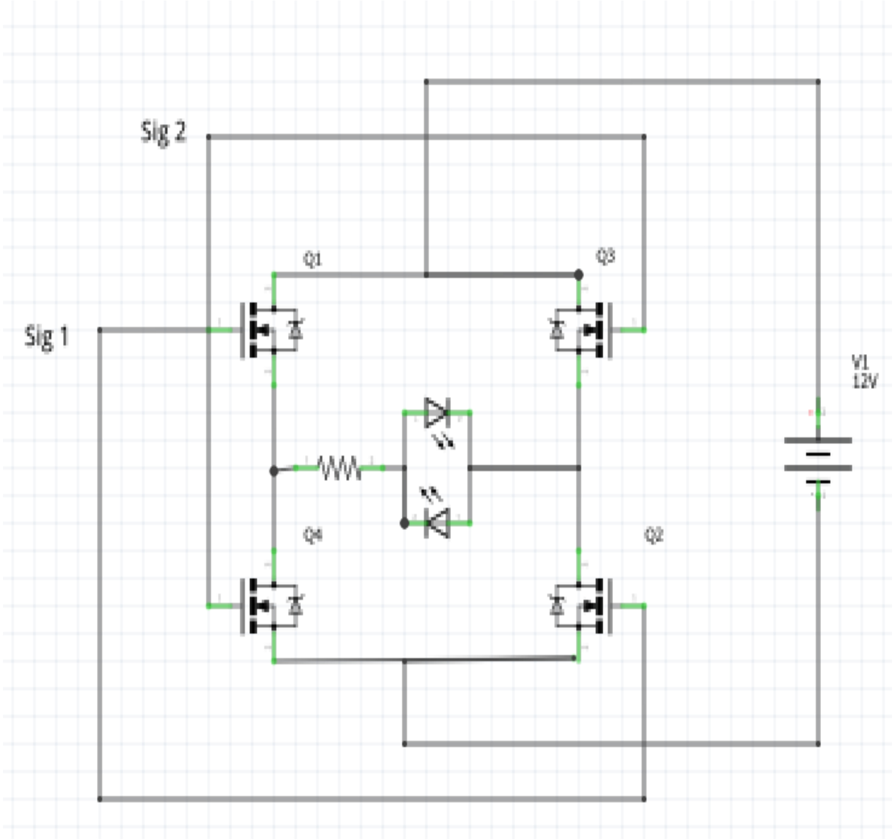


Figure 5: (a) MOSFET operability test — LED turns on at V_{GS}=10 V; off at lower V_{GS}. (b) Driver and H-bridge validity test — LEDs indicate correct operation based on Sig 1 and Sig 2 logic states.

Methodology: GUI Development

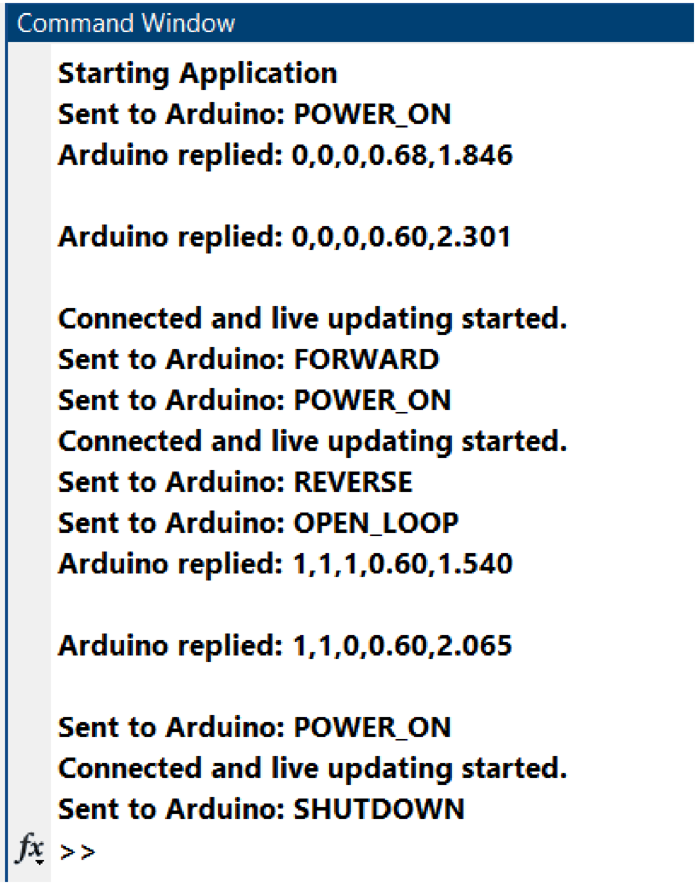


Figure 6: Acknowledgement from Arduino

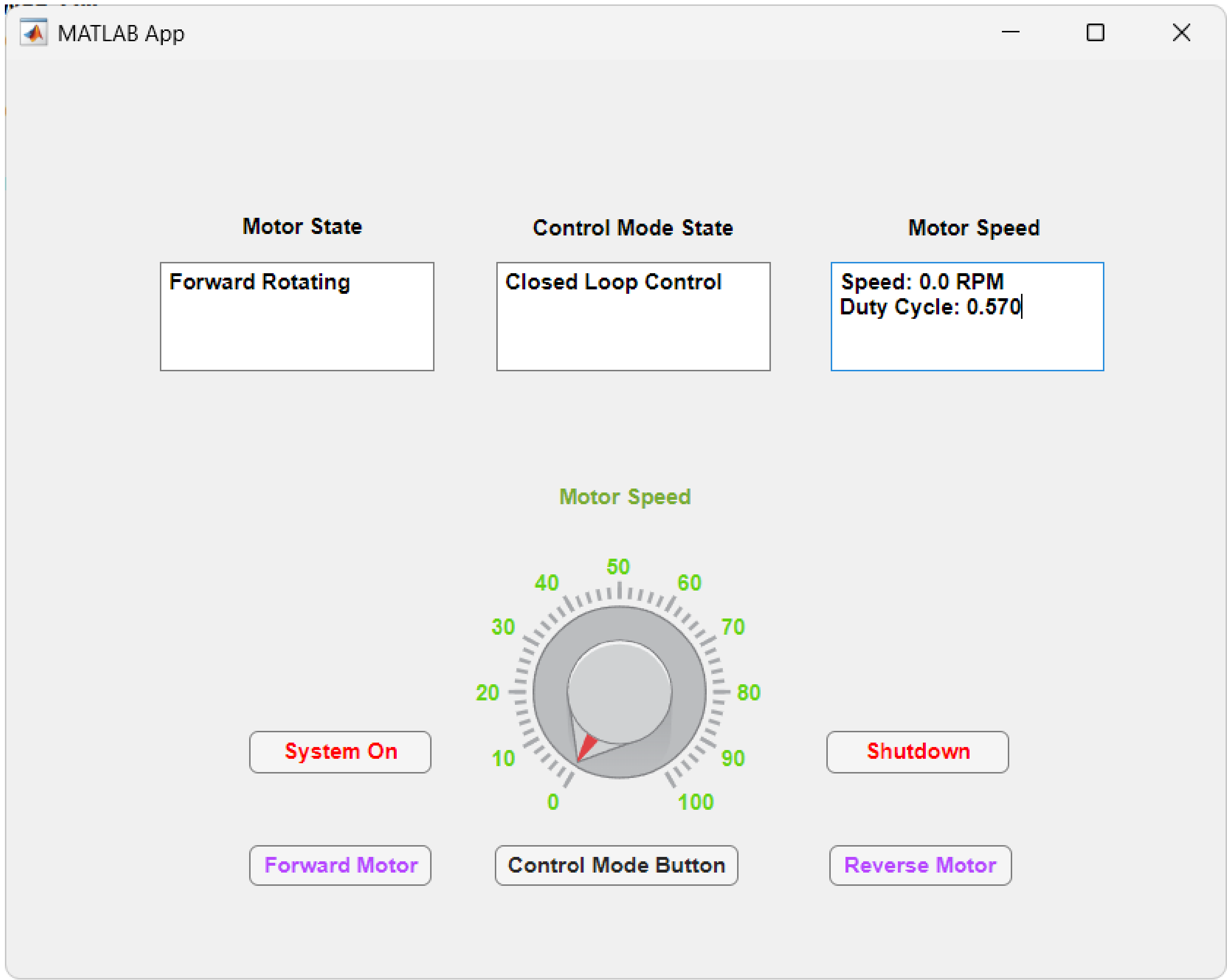
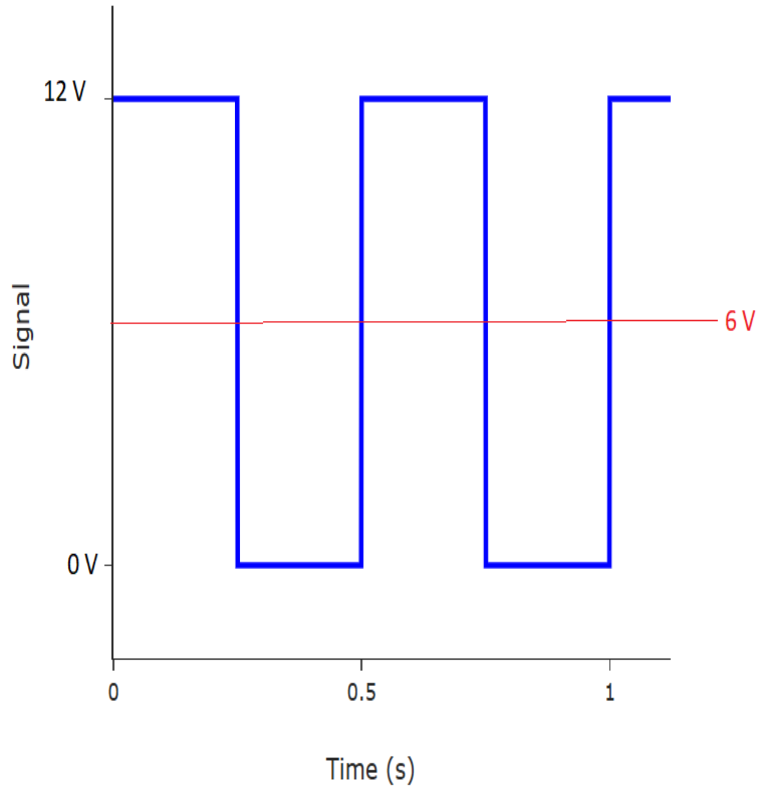


Figure 7: GUI window

Methodology: PWM Generation

(a)



(b)

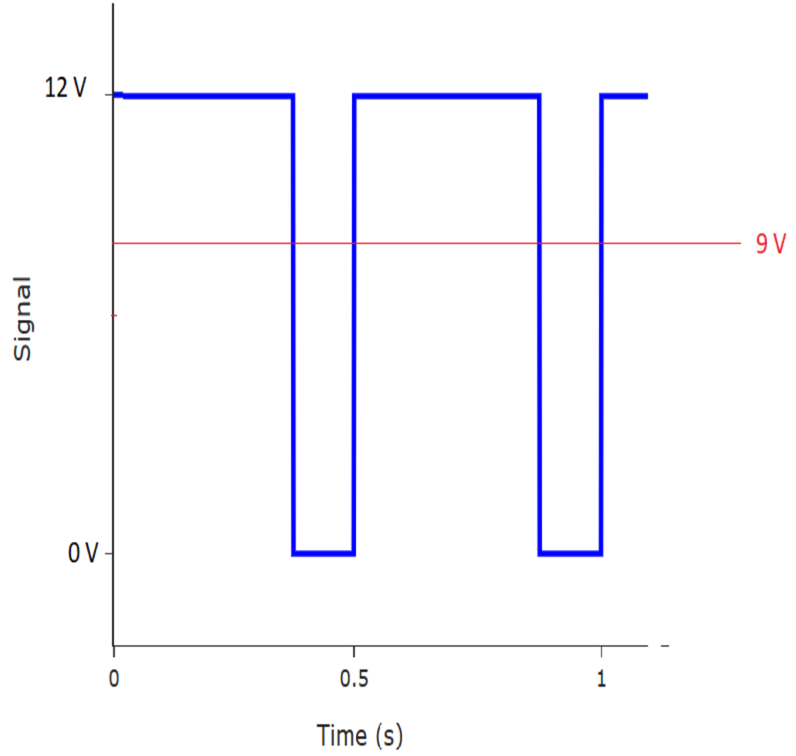


Figure 8: (a) 50% duty cycle that can produce an average voltage of 6V across motor terminals. (b) 75% duty cycle that can produce an average of 9V across motor terminals.

Methodology: PWM Generation

- Arduino **pins 2 and 3** generated **PWM signals** for motor control.
- A **potentiometer** adjusted the **PWM duty cycle**.
- **Pin 3 controlled forward** and pin **2 controlled reverse** rotation.
- **MOSFET driver** translated logic signals to **12 V or 0 V** at motor terminals.
- **Figure 8** shows **50% (≈6 V)** and **75% (≈9 V)** duty cycles controlling **motor speed.**

Methodology: PID Parameter Tuning

- **PID controller parameters: Kp = 0.1, Ki = 0.4 and Kd = 0.01**
- **Tuned for fast response and minimal speed oscillation.**
- **Ensures motor speed quickly settles to the user-set reference.**

List of Apparatus

Table 1: List of apparatus used in project

S.L No.	Name of Apparatus	Ratings / Specification	Quantity
1	DC power supply	11.5 V, 2 A	1
2	LM2596 DC-DC buck converter	Vin = 11.5 V, Vout = 10.4 V	1
3	Arduino UNO	-	1
4	PC817 optocoupler	IF = 50 mA, IC = 50 mA, VCEO = 35 V	2
5	IRFZ44N MOSFET	-	4
6	1N4007 diode	VPIV = 1000 V, VF = 0.7 V	1
7	DC motor (dynamo)	4–12 V, 4500 rpm	1
8	DC generator (dynamo)	4–12 V, 4500 rpm	1

List of Apparatus

S.L No.	Name of Apparatus	Ratings / Specification	Quantity
9	Resistor	220 Ω, 2.2 kΩ, 10 kΩ, 100 kΩ (0.25 W) – **5 each**; 15 Ω, 18 Ω (10 W) – **1 each**	-
10	Potentiometer	1 kΩ, 100 kΩ, 1 W	1 each
11	Relay switch	Vtrigg = 5 V	3
12	Rocker switch	3 A	1
13	Push buttons	0.5 mA	3
14	Fuse	10 A	1
15	Multimeter	0–50 V DC	1
16	Breadboard	-	3
17	Jumper wires and probes	-	As needed

Model Description: Proteus Blueprint

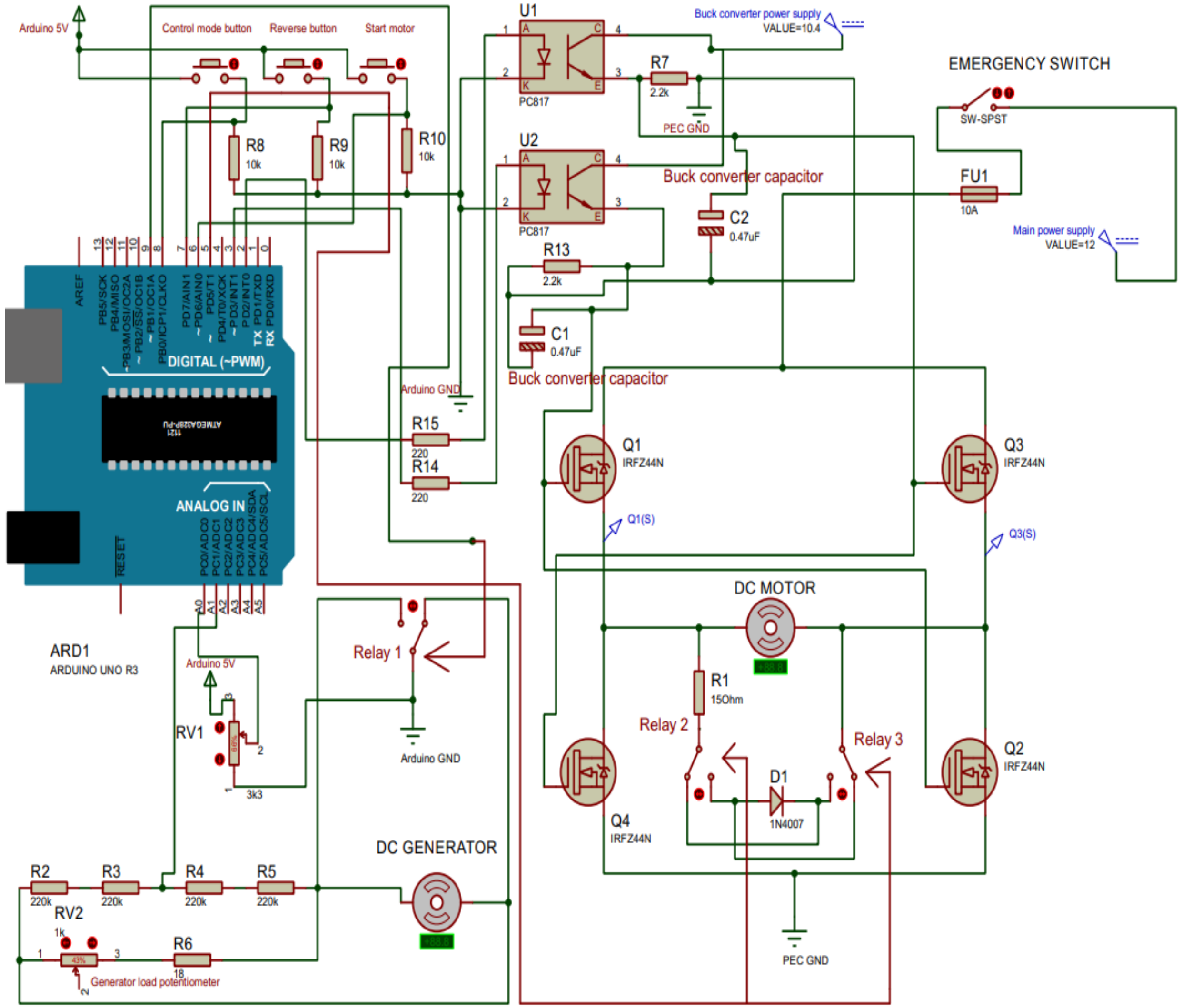


Figure 9: Circuit diagram of the whole prototype

Model Operation: Motor Rotation

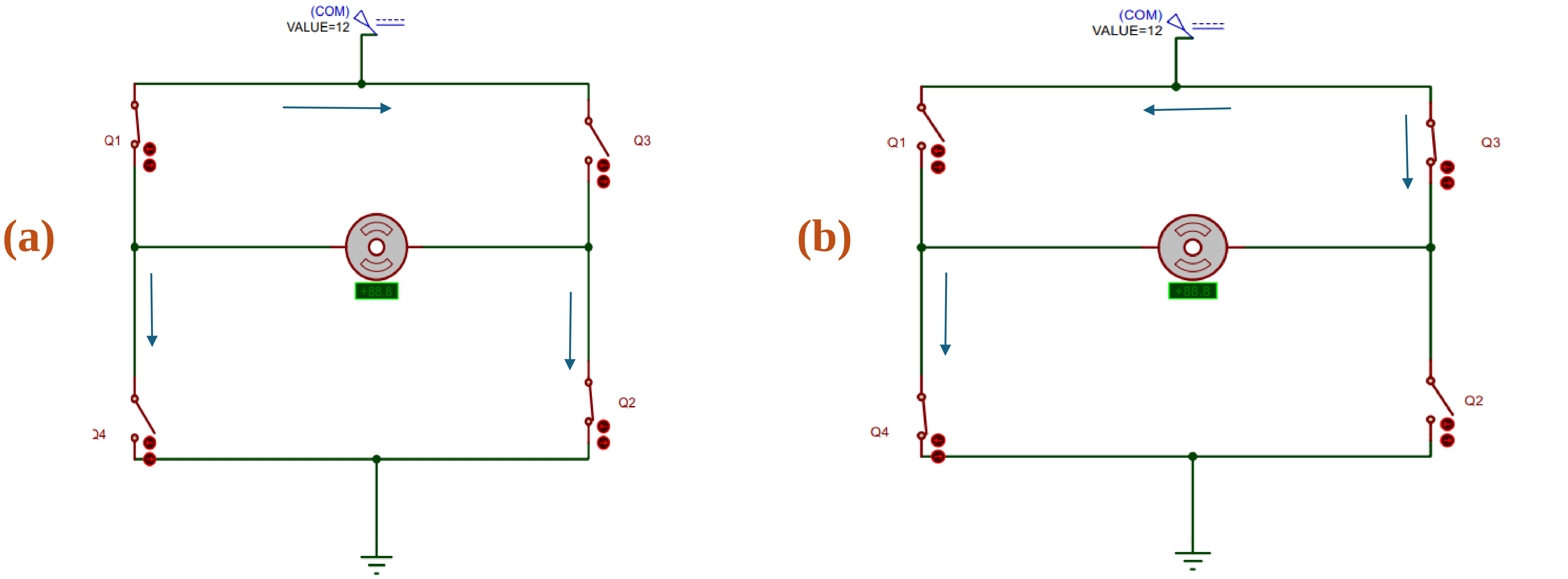


Figure 10: Equivalent single pole single throw (SPDT) switch circuit of H-bridge converter motor drive for the case of (a) Forward motoring and (b) reverse motoring. Blue arrows show current flow.

Model Operation: Monitoring

- **Potentiometer** on analog **pin A0** acts as both **accelerator and brake**
- Motor speed increases or decreases based on potentiometer rotation direction
- **50% duty cycle** (minimum) ensures smooth running and **prevents shutdown below 4 V**
- 100% duty cycle gives maximum motor speed
- **Reverse motion** is controlled via a dedicated **reverse gear button in the GUI.**

Model Operation: Control Modes

- Motor control mode can be toggled **between open and closed loop** via a **control mode button**
- In open loop mode, **speed varies with load changes** since **no feedback** is used
- **Increased load slows the motor** and **reduced load speeds it up** even at **fixed input**
- This behavior **mirrors real EV acceleration on uneven terrain**; hence, **feedback control** is essential for stable motor speed **under varying load**.

Model Operation: Open Loop Action

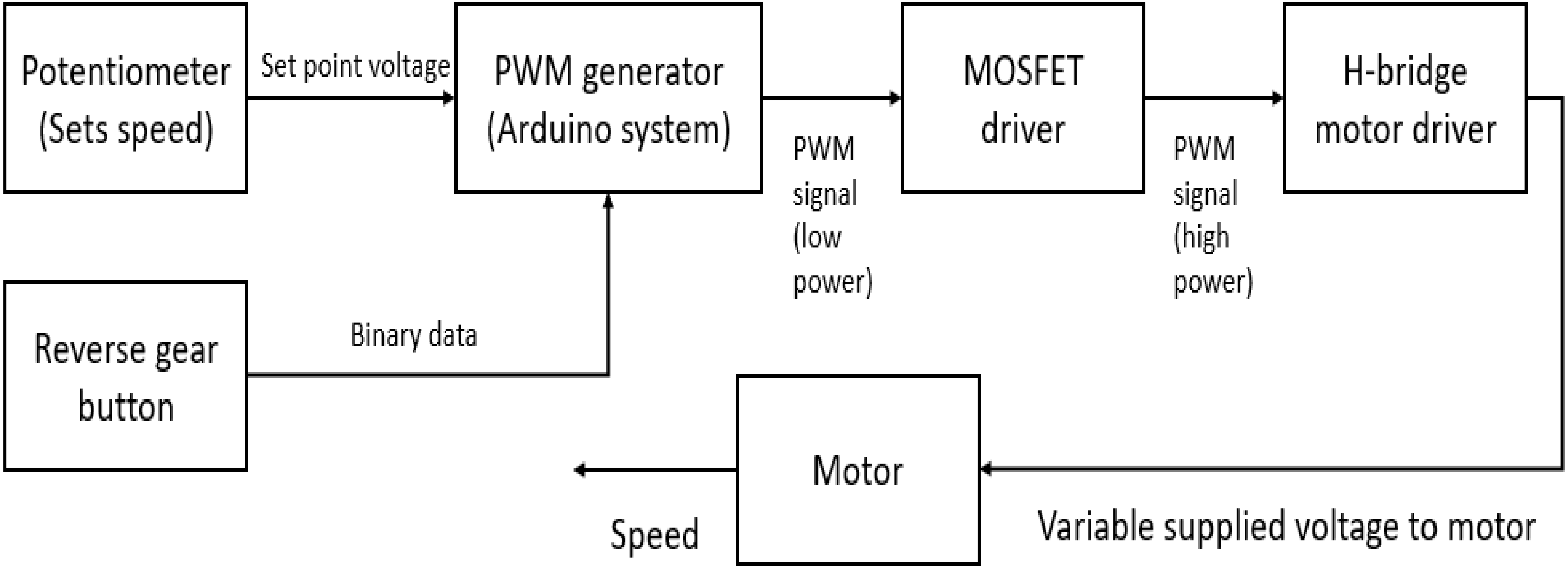


Figure 11: Open loop control of motor speed.

Model Operation: Closed Loop Action

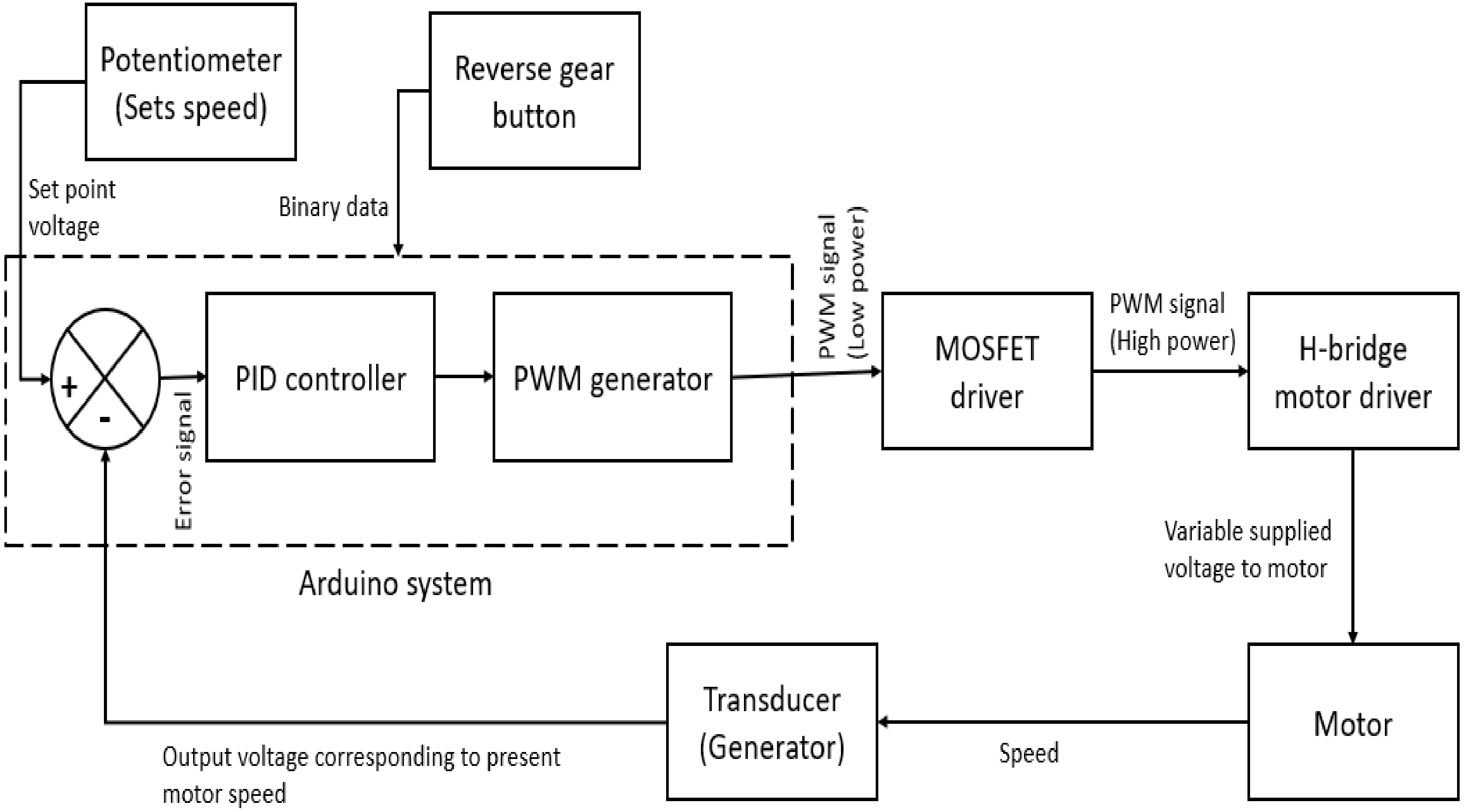


Figure 12: Closed loop control of motor speed

Results: Overview

Table 2: Overview of prefixed data

S.L. no.	Name of data	Value
1	Time period of PWM signal	30ms
2	Frequency of PWM signal	33.33 Hz
3	Buck converter output	10.4 (approx.)
4	Duty cycle of PWM for lowest motor speed	50 % (regular operation), 0% (open loop test), 50% (closed loop test)
5	Duty cycle of PWM for highest motor speed	100 %

Results: Open Loop Test

Table 3: Summary of open loop test

S.L no.	Parameter name	Value
1	Maximum motor terminal voltage	7.35V (approx.)
2	Minimum motor terminal voltage just before motor stops (for 40% duty cycle)	4V (approx.)
3	Maximum voltage across generator terminal (this corresponds to maximum motor speed)	5.5 V (approx.)
4	Minimum voltage across generator terminal just before motor stops (this corresponds to minimum motor speed at 40% duty cycle)	2.06 V (approx.)

Results: Motor-Generator Terminal Voltage Comparison

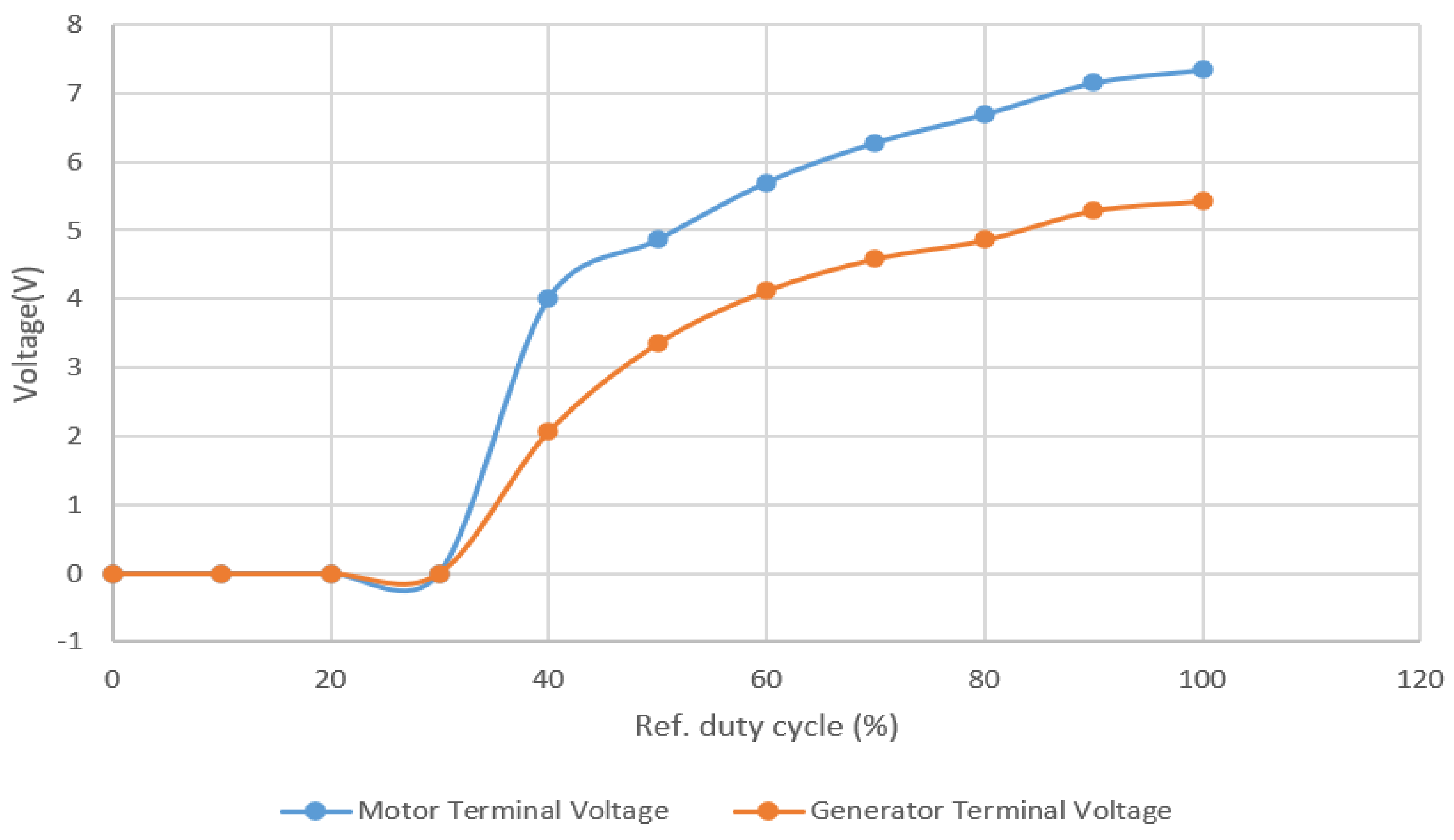


Figure 13: Motor–generator voltage comparison showing lower generator voltage, indicating frictional losses from coupling faults.

Results: Motor-Generator Terminal Voltage Comparison

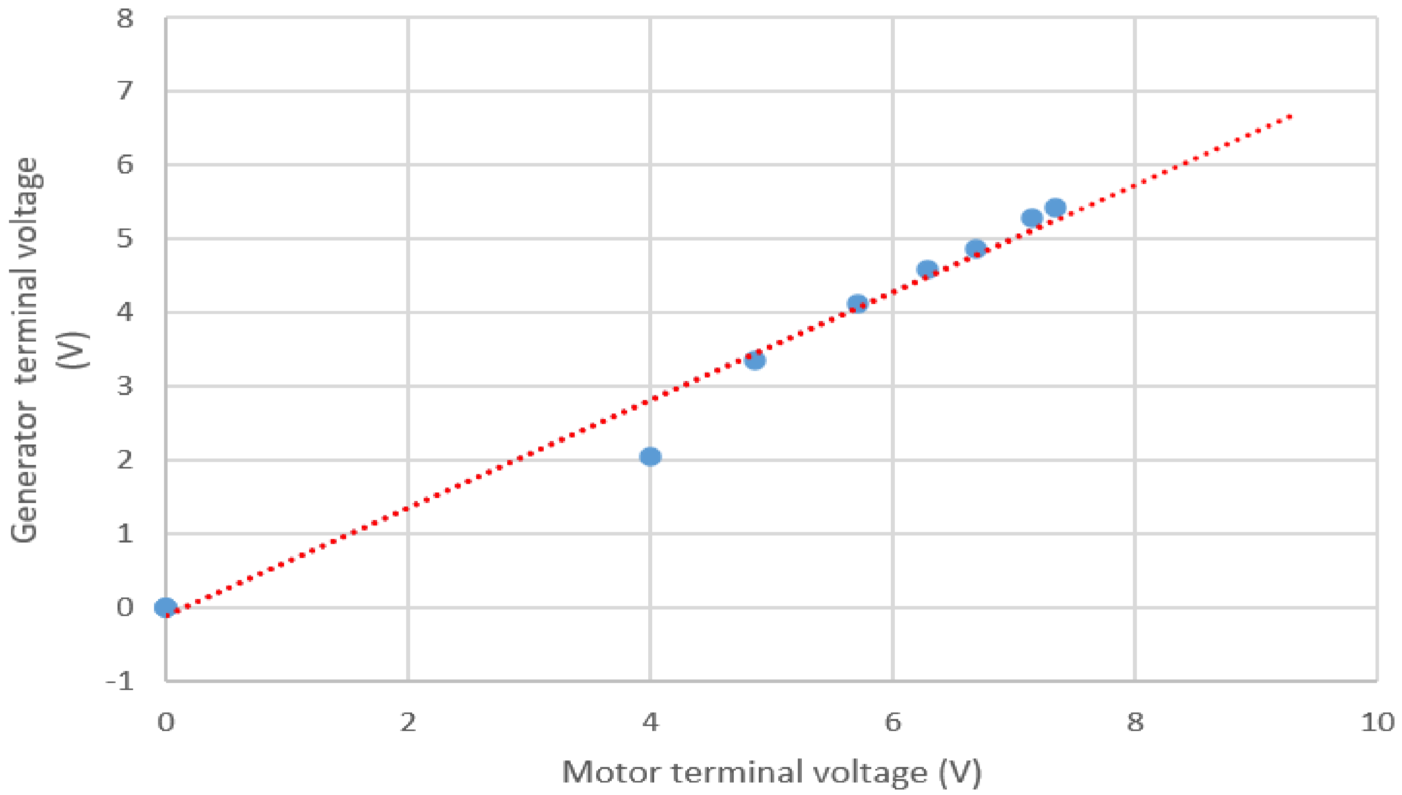


Figure 14: Linear trend relation between motor and generator terminal voltage. To measure motor speed correctly, the generator voltage should have a linear link with motor speed which in turns is expressed by motor terminal voltage.

Results: Closed Loop Test

Table 4: Summary of closed loop test

S.L no.	Parameter name	Value
1	Maximum voltage across generator terminal (this corresponds to maximum motor speed)	4.8 V (approx.)
2	Minimum voltage across generator terminal (this corresponds to minimum motor speed at 50 % duty cycle)	3.3 V (approx.)

Results: Variations of Duty Cycle

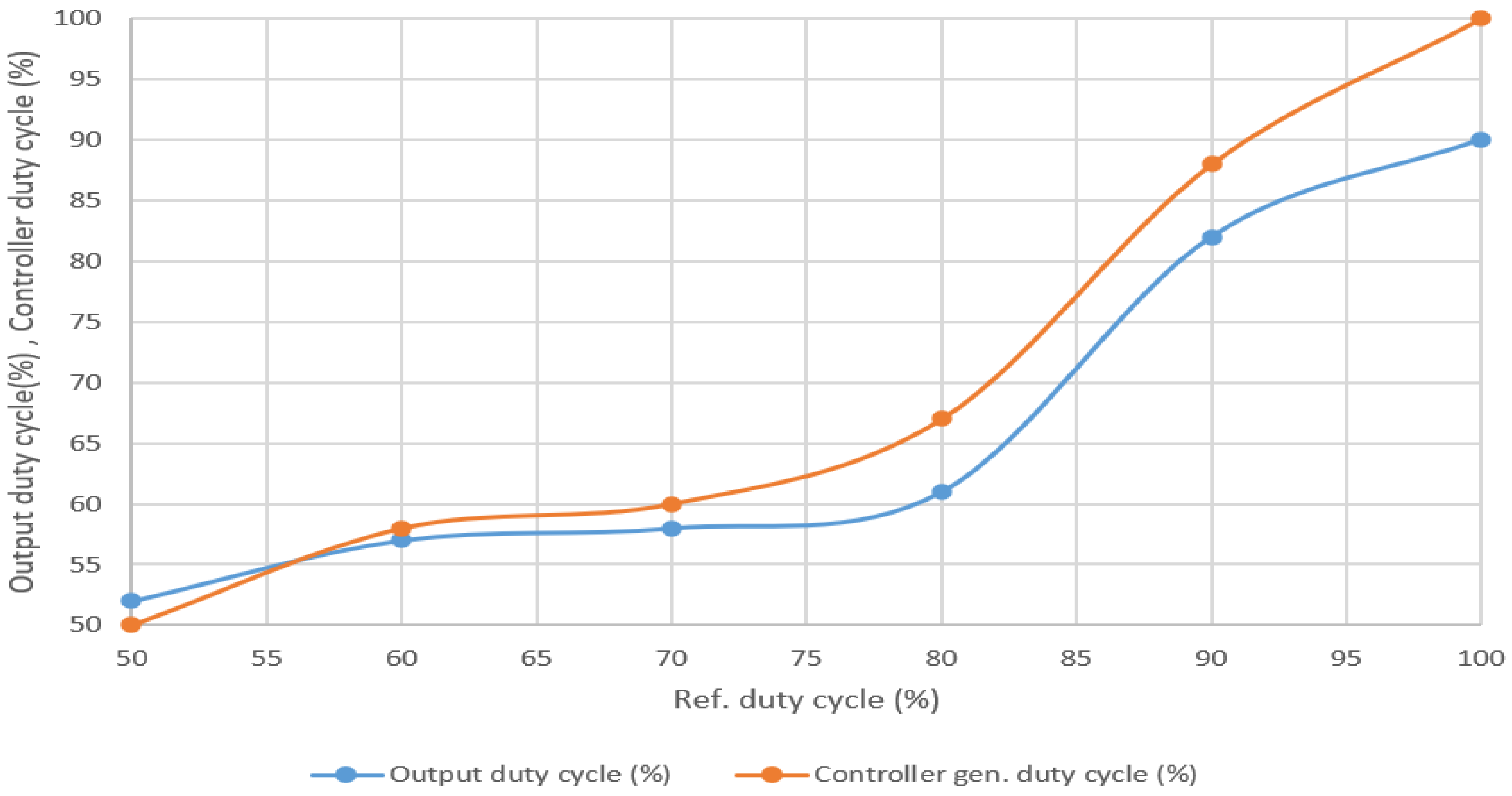


Figure 15: Variation of output and controller gen. duty cycle with ref. duty cycle

Results: PID Response Characteristics

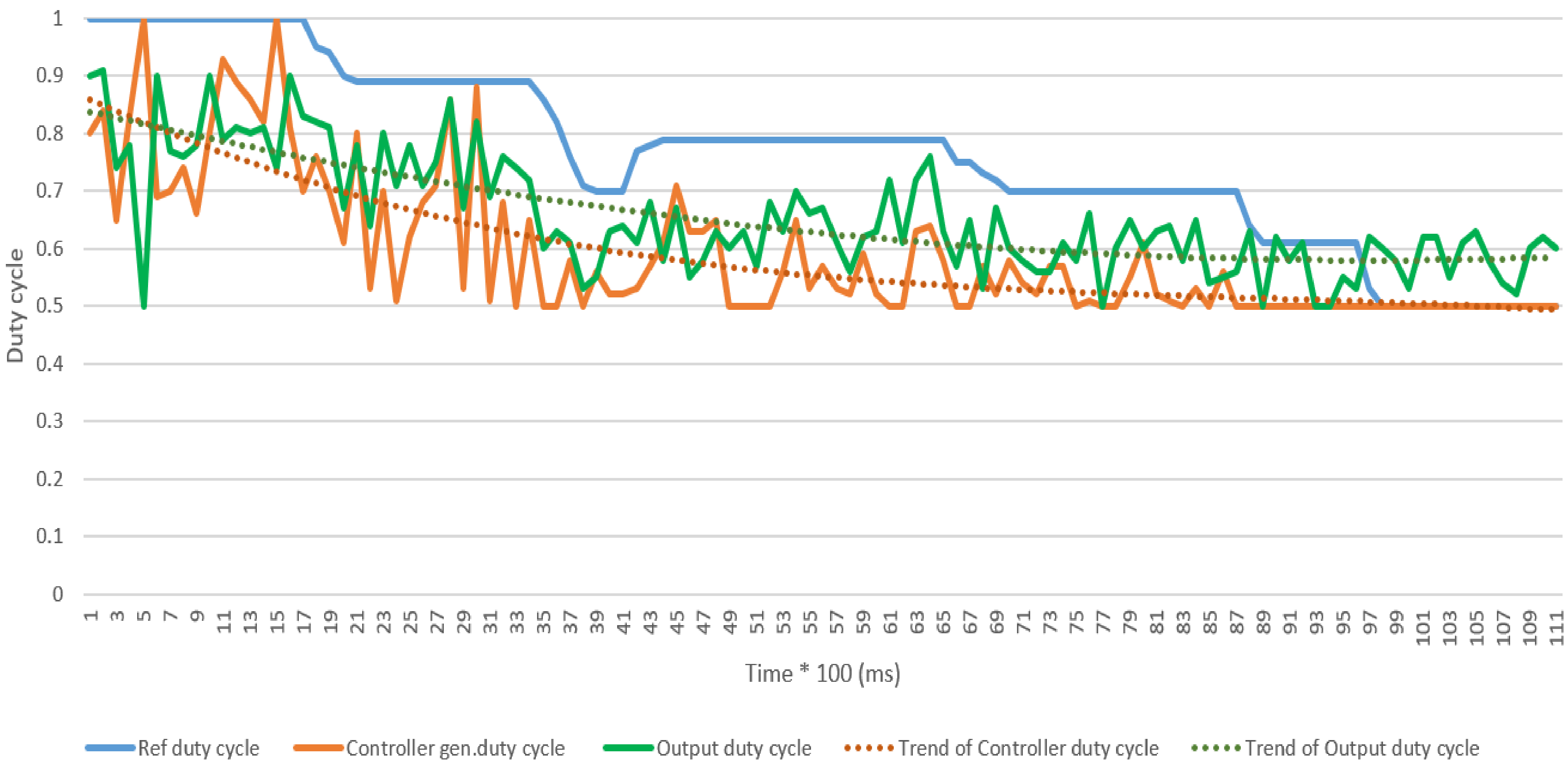


Figure 16: Real time data of PID response

Results: Calibration of Parameters

Table 5: List of calibrated Data

S.L no.	Name of Data	Calibrated value
1	Microcontroller ADC output for maximum generator output voltage	640
2	Proportional gain of PID controller, K_p	0.1
3	Integral gain of PID controller, K_i	0.4
4	Derivative gain of PID controller, K_d	0.01

Conclusion

- **H-bridge** driver prototype successfully drives **DC motors for Evs**
- It can operate in **both open and closed** loop control modes
- The design allows **excess inductive power to be transferred to an auxiliary low power source**
- Performance is **satisfactory** but design **improvements are possible**
- Using a **non-invasive speed sensor** instead of a generator **could reduce energy loss** from coupling faults.

Thank You

Any Questions?