Veermata Jijabai Technological Institute Mumbai
400 019 Autonomous Institute
Affiliated Institute to University of Mumbai

वीरमाता जिजाबाई तांत्रिक संस्था, मुंबई

A Project Report

On

To control the speed of a DC motor by using a chopper

by

Name / Roll No: Samar Gamare (231040020)

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Submitted to (faculty),

Dr . Gyanesh Singh (Lecturer EE)

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Introduction :

"DC motors are commonly used in machines and automation systems where variable speed is required.
To control the speed of a DC motor, the voltage applied to it must be adjusted.
A chopper is a power electronic circuit that rapidly switches the supply ON and OFF, creating a controlled average voltage.
In this experiment, we study how the speed of a DC motor can be controlled using a chopper-based controller."

Abstract:

In this project, we explore how the speed of a DC motor can be controlled using a **chopper** circuit. A chopper is an electronic switch that rapidly turns the supply voltage on and off, which allows us to vary the *average voltage* applied to the motor. By changing this average voltage, we can control the motor's speed. We will design a chopper-based DC motor controller, implement a PWM (pulse-width modulation) signal to drive the chopper, and observe how different duty cycles affect the motor's speed. The experiment will be simulated (or done in hardware), and we will analyze the relationship between duty cycle and speed, studying both response time and stability.

Aim:

To control the speed of a DC motor by using a chopper (power electronic switching) technique and observe how varying the duty cycle of the chopper affects the motor speed.

Objectives:

1. To design a chopper circuit for controlling the DC motor's voltage.
2. To generate a PWM signal to drive the chopper and vary its duty cycle.
3. To study how changing the duty cycle affects the average output voltage of the chopper.
4. To measure the speed of the DC motor for different duty cycles.
5. To analyze the relationship between duty cycle, average voltage, and motor speed.
6. To observe the transient behavior of the motor when switching duty cycles (e.g., response time).
7. To understand the advantages and limitations of using a chopper for DC motor speed control (such as efficiency, ripple, etc.).

Apparatus and Requirements :

Serial No.	Description	Specifications	Quantity
1	Chopper / Chopper Control Unit	Power transistor (MOSFET / IGBT), driver circuit, PWM generator (square-to-triangle, comparator)	1
2	DC Motor	12 V permanent magnet DC motor	1
3	Power Supply	0-30 V DC supply	1
4	Speed/Tachometer	Tachogenerator ya digital RPM meter	1
5	Measuring Instruments	Digital voltmeter & ammeter (to measure motor voltage and current)	1 set
6	Oscilloscope	To observe PWM waveform, switching signals	1
7	Free-wheeling Diode	Diode for chopper circuit	1 (or as required)
8	Connecting Wires	Wires to make circuit connections	Multiple (depends on setup)
9	Load / Mechanical Load	(Optional) A lamp or resistor load,	1

Theory:

1. **Principle of a Chopper**
   A chopper is a power electronic switch (like a MOSFET or IGBT) that rapidly turns ON and OFF.
   By switching very fast between the supply and disconnecting it, the chopper effectively gives a pulsating (chopped) voltage to the load.
   Because of this fast switching, the **average voltage** seen by the motor is controlled, not just full supply all the time.

2. **Duty Cycle and Average Voltage**
   - The **duty cycle (α)** of the chopper is defined as:

$$\alpha = \frac{T_{on}}{T_{on} + T_{off}}$$

where $T_{on}$is the time the switch is ON, and $T_{off}$is the time it is OFF.

   - The **average output voltage (V_avg)** given to the motor is approximately:

$$V_{avg} = \alpha \times V_{supply}$$

This means if duty cycle increases, average voltage increases; if it decreases, average voltage goes down.

   - This change in average voltage is what controls the speed of the DC motor: higher average voltage → higher speed; lower voltage → lower speed.

3. **Free-Wheeling Diode**
   - A DC motor's armature winding has inductance, which tries to keep the current flowing even when the chopper switch is OFF.
   - To provide a path for this current when the switch is off, a **free-wheeling diode** is used.

   - This diode helps in reducing current spikes or sudden drops, makes the current more continuous, and reduces ripple.

4. **Motor Speed Relation**
   - In a DC motor, the **back EMF (E_b)** is proportional to the motor's speed.
   - Because of that, when you change the average voltage (via the chopper) and supply more voltage, the back EMF increases and motor speed increases.
   - Also, if you assume current ripple is small, you can approximate the motor's speed ω(in a simplified way) as:

$$\omega \approx \frac{V_{avg} - I_a R_a}{k_e}$$

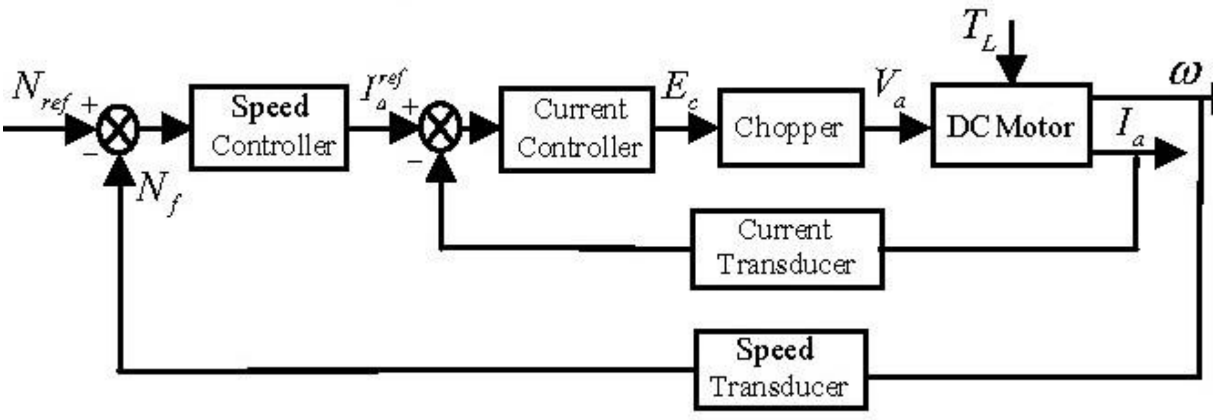
Here, I_a= armature current, R_a= armature resistance, and k_e= motor constant (relating speed to back EMF).

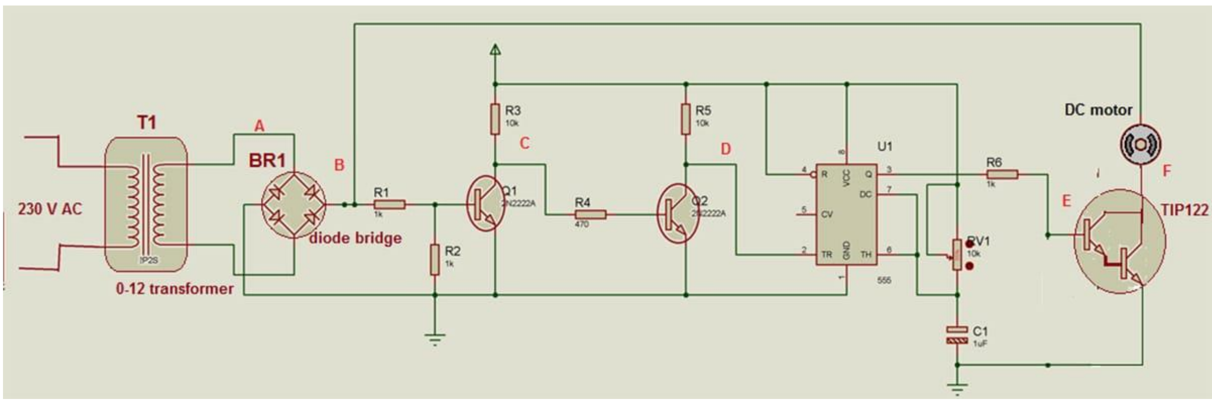
5. **Control Loop (Optional)**
   - In many real systems, there is a **speed controller** (like a PI controller) that measures the motor's actual speed, compares it with desired speed, and adjusts the duty cycle of the chopper accordingly.
   - There can also be a **current controller** loop to ensure the motor current stays within safe limits.
   - This dual-loop control (speed + current) helps in achieving stable and precise speed control.

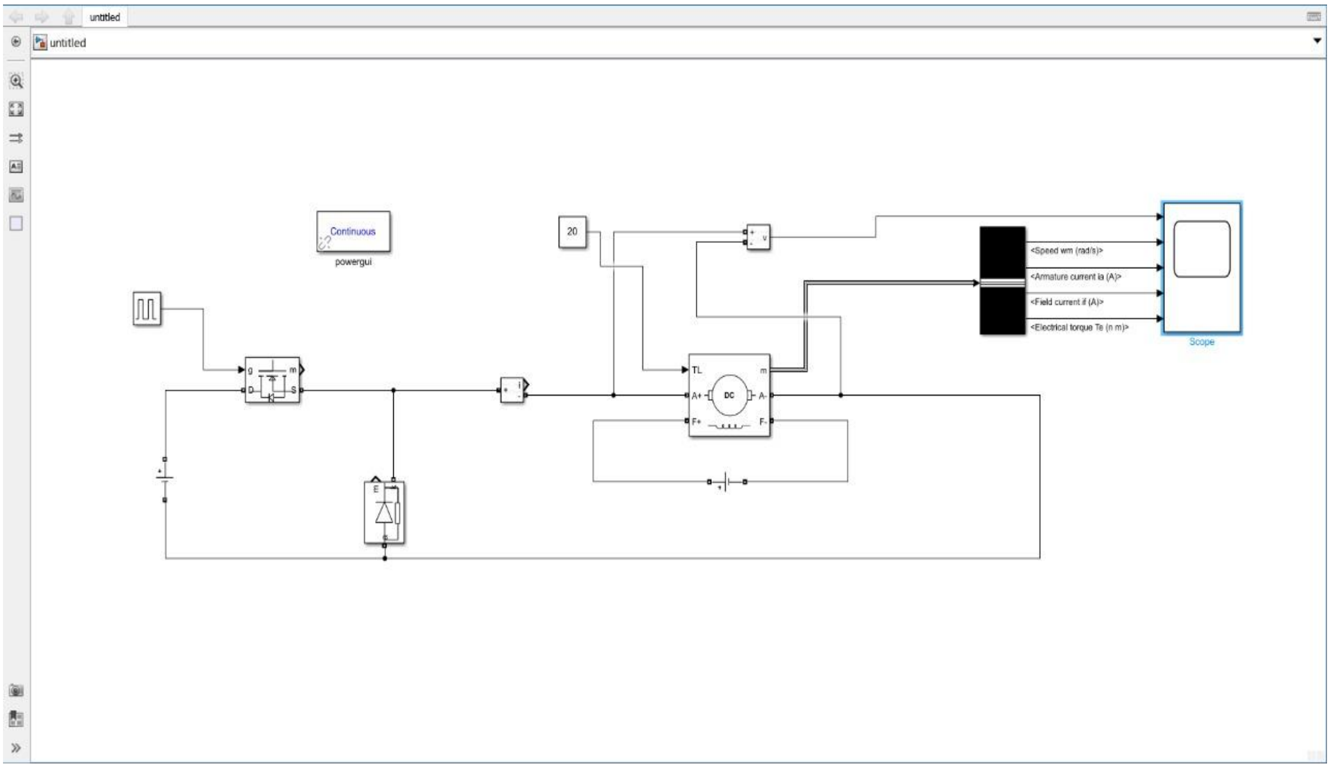
6. **Advantages of Chopper-Based Speed Control**
   - **High Efficiency**: Since the switch is either fully on or fully off (and not in a linear region), power losses can be quite low.

- **Fast Response**: Speed can be adjusted quickly by changing the duty cycle, giving good dynamic performance.
- **Regenerative Braking (in advanced designs)**: In some chopper circuits (e.g., four-quadrant choppers), the motor can act as a generator when braking and return energy to the supply.
- **Wide Speed Range**: By controlling the average voltage precisely, a broad range of speeds (from low to near rated) can be achieved.

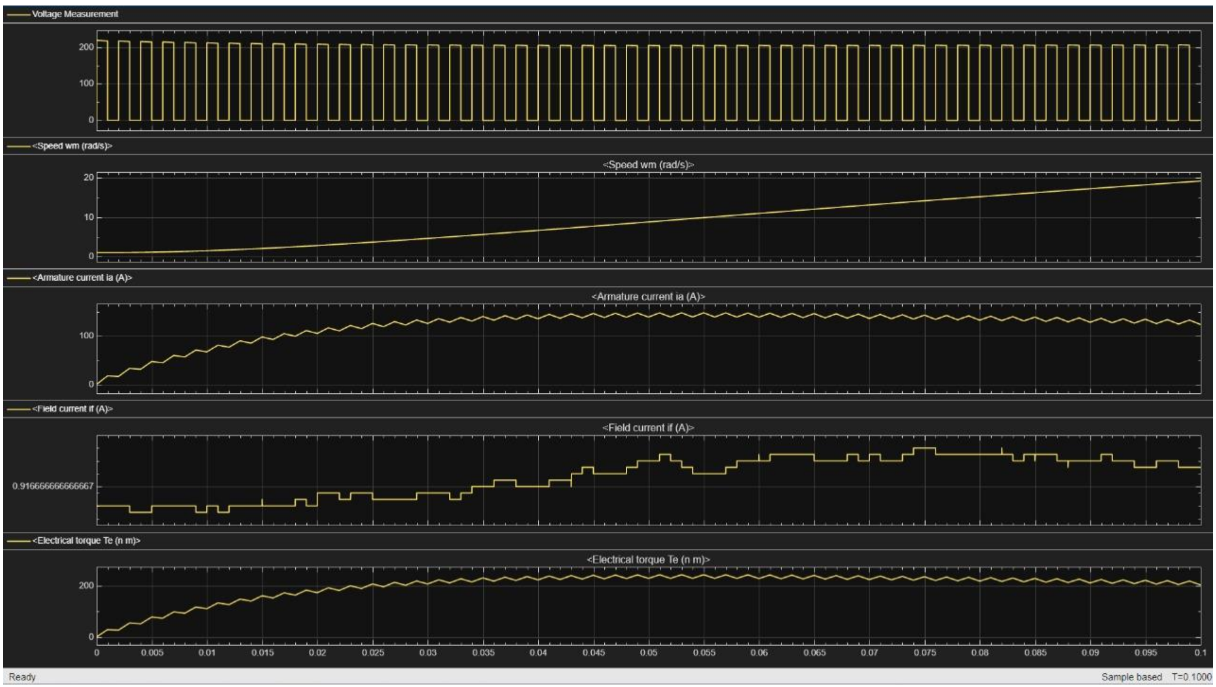
Circuit Diagram :







<u>Observation :</u>



Readings :

Statistics | Transitions | Cycles | Peaks | Aberrations

Voltage Measurement	P1	P2	P3
Time (ms)	2.0000	4.0000	6.0000
Value	218.2944	216.8049	215.4706

Ready | Sample based T=0.1000

Statistics | Transitions

Voltage Measurement	Max	Min	Peak to Peak
Time (ms)	2.0000	53.0000	
Value	218.29444529894158	-0.9478994988870453	219.2423

Statistics | Transitions | Cycles

Voltage Measurement	High	Low	Amplitude
+ Edges	205.5970	0.1566	205.4404
- Edges	205.5970	0.1566	205.4404

Cycles | Aberrations

Mean	Standard Deviation	Median	RMS
103.2963	104.4209	-0.8167	146.8552

Calculation Parameters :

Parameter	Formula
Duty Cycle (α)	α=Ton+Toff / Ton
Average Voltage (V_avg)	Vavg=α·Vsupply
Motor Speed (ω)	ω=αV−IaRa / Ke
Supply Current (I_s)	Isupply=α·Ia
Motor Torque (T)	T=kt·Ia
Back EMF (E_b)	Eb=ke·ω
Chopping Frequency (f)	F = 1 / T (where $T = T_{\text{on}} + T_{\text{off}}$)

Results :

As the duty cycle of the chopper increases, the speed of the DC motor also increases.

At low duty cycle values, the average voltage applied to the motor is low, which results in a comparatively low motor speed.

With increasing duty cycle, the armature current drawn by the motor increases, indicating more power delivery.

The motor shows a fairly linear increase in speed for a range of duty cycles, but at very high duty cycles, the speed gain starts to plateau.

The speed control via chopper is stable: the motor can maintain different steady speeds by adjusting the duty cycle.

The efficiency of the system improves as the duty cycle increases (because the motor is operating at higher average voltage and current).

Conclusion :

 In this project, we have successfully demonstrated that a chopper circuit can be used to effectively control the speed of a DC motor.

 By varying the duty cycle of the chopper, the average voltage applied to the motor can be adjusted, which leads to controllable variation in motor speed.

 The motor exhibited stable behavior across different duty cycles: as the duty cycle increased, the speed increased smoothly, and as it decreased, the speed dropped accordingly.

 This method is quite efficient, since switching in the chopper helps minimize power losses compared to linear voltage control.

 However, there are limitations: at very low or very high duty cycle values, the control may not be as linear, and issues like current ripple and saturation of speed may appear.