PWM-BASED
DC MOTOR SPEED CONTROL USING
555 TIMER IC

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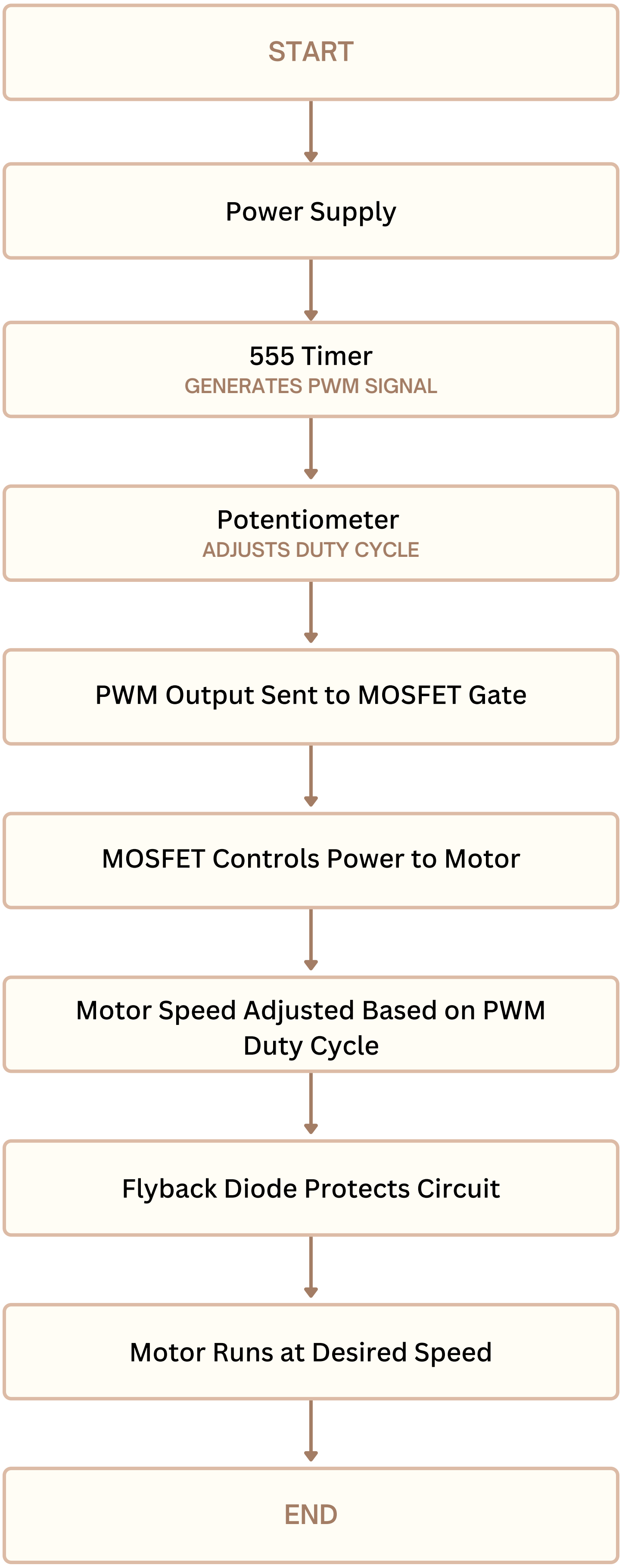
Components & Values:

Component	Value	Quantity
Resistors	1KΩ,100Ω	1 each
Potentiometer	47KΩ	1
Capacitors	100nF,10μF	1 each
MOSFET	IRFZ44N	1
PN Diode	1N4007	2
DC Motor	3 ~ 12V	1
Power Supply	9V	1
555 Timer IC	~5V–15V	1
Breadboard	-	1
Connecting Wires	-	-

Working Principle:

This project is based on Pulse Width Modulation (PWM) to control the speed of a DC motor efficiently. The 555 timer IC is configured in astable mode to generate a PWM signal. The duty cycle of this signal determines the motor's speed. The power transistor (MOSFET IRFZ44) acts as a switch to regulate power to the motor. A potentiometer is used to adjust the PWM duty cycle, allowing precise motor speed control.

Working Flowchart :



Detailed explanation :

Power Supply

- The circuit is powered by a DC source (e.g., 9V battery or adapter).
- This power is used for both:
  - Operating the 555 Timer IC (~5V–15V).
  - Driving the DC motor (~3V–12V).

555 Timer Circuit -Generation of PWM Signal

- The 555 Timer is in Astable Mode, continuously generating a square wave (PWM signal).
- A capacitor (C1) and resistors (R1, Potentiometer) determine the charging/discharging cycle, which controls the duty cycle of the PWM signal.
- The potentiometer adjusts the duty cycle, controlling how long the PWM signal stays HIGH vs. LOW.

PWM Signal to MOSFET

- The PWM output from the 555 Timer is fed into the Gate of an N-channel MOSFET (i.e: IRFZ44N).
- The MOSFET acts as a switch, controlling how much power reaches the DC motor.

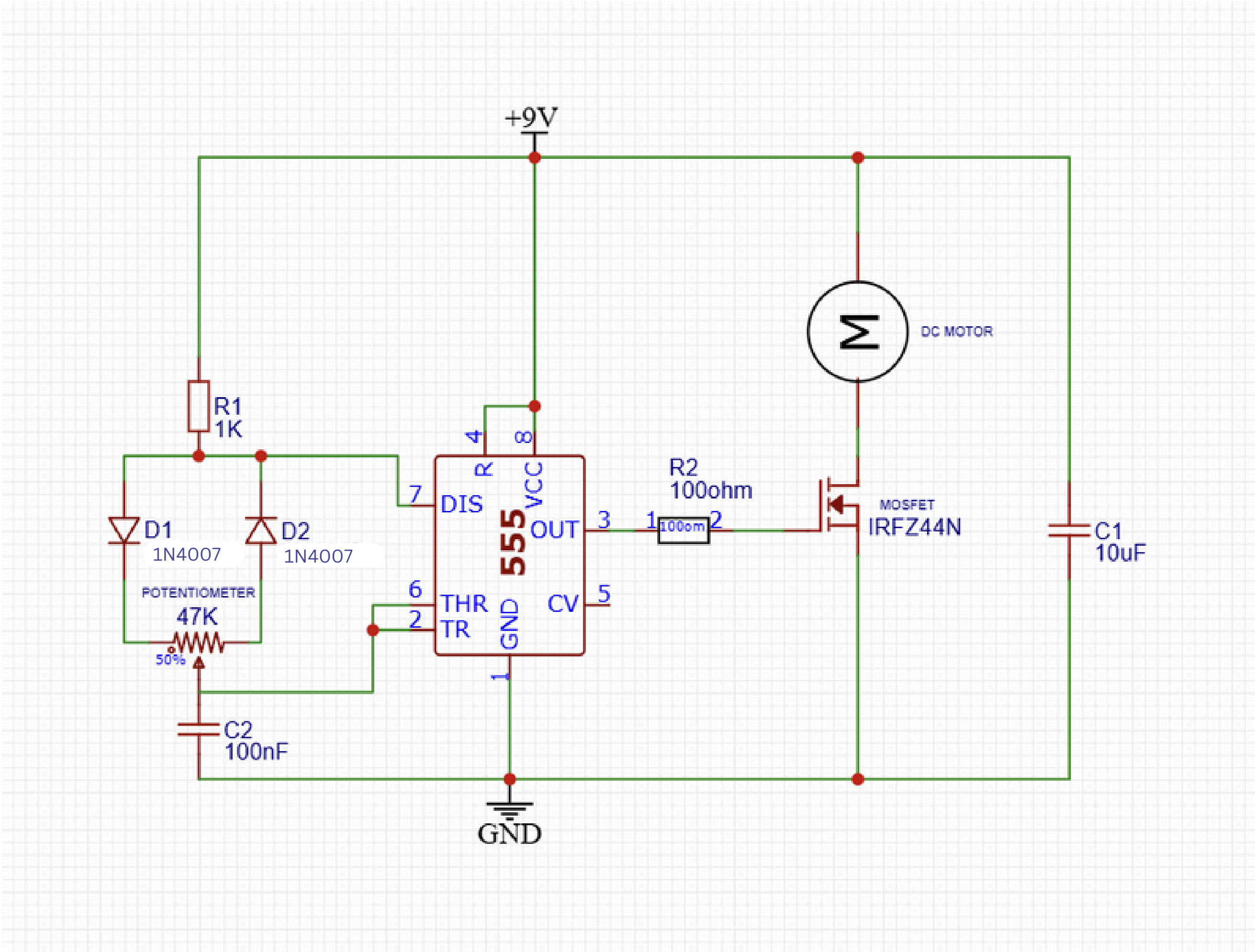
Motor Speed Control via PWM

- When PWM is HIGH → The MOSFET turns ON, allowing current to flow through the motor → Motor runs.
- When PWM is LOW → The MOSFET turns OFF, stopping current → Motor slows down.
- The motor speed depends on the duty cycle:
  - Higher duty cycle → More power → Faster motor speed.
  - Lower duty cycle → Less power → Slower motor speed.

Protection Components

- A flyback diode (i.e: 1N4007) is connected across the motor to prevent voltage spikes when the MOSFET turns OFF.
- This protects the MOSFET and 555 timer from damage due to inductive kickback from the motor.

Circuit Diagram:



Applications :

1. Fan Speed Control
   - Used in ceiling fans, exhaust fans, and cooling fans in electronic devices.
   - Allows smooth speed variation without overheating or wasting energy.
2. Electric Vehicles (EVs) & RC Cars
   - Controls the speed of DC motors in small electric bikes, scooters, and remote-controlled cars.
   - Helps improve battery efficiency by delivering power only when needed.
3. Conveyor Belt Systems
   - Used in manufacturing industries to adjust conveyor belt speeds.
   - Ensures proper material handling and automation.

4. Robotics & Drones
   - Controls servo and DC motors in robotic arms, autonomous vehicles, and drones.
   - Essential for precision movement and speed control.
5. Electric Pumps & Air Compressors
   - Used to regulate motor-driven water pumps and compressors.
   - Prevents power wastage and extends motor life.
6. LED Brightness Control (Dimmer)
   - The same PWM principle can be used for LED dimming.
   - Common in smart lighting, display backlights, and stage lighting systems.

? Why Do We Need a MOSFET to Switch the Motor ON and OFF If the 555 Timer Already Generates PWM?

The 555 Timer Generates a PWM Signal – But at Low Power

- The 555 timer outputs a PWM signal at Pin 3, but it can only supply a small current (~**200mA** max).
- A DC motor needs much more current (hundreds of milliamps to several amps).
- If we tried to connect the motor directly to the 555 timer, the IC would burn out because it's not designed to handle such high power.

The MOSFET Acts as a High-Power Switch

- The PWM signal from the 555 timer is a "control signal", not the actual power source for the motor.
- The MOSFET receives the PWM signal at its Gate and acts like a switch for the motor's 9V high-current power supply.
- The MOSFET is needed because it can handle high currents efficiently, while the 555 timer cannot.

Why Do We "Re-Switch" the Motor ON and OFF Using the MOSFET?

- The PWM signal from the 555 timer is not meant to power the motor directly—it just tells the MOSFET when to turn the actual motor power ON and OFF.
- The MOSFET ensures that the motor gets full 9V power when ON, instead of a weak signal from the 555 timer.
- This switching allows efficient speed control without wasting energy as heat, unlike a resistor-based speed control.

? Significance of Switching the Motor ON and OFF Rapidly Instead of Supplying Constant Power?

Speed Control Without Losing Power as Heat

- If we connect a motor directly to a battery, it runs at full speed.
- If we try to slow it down using a variable resistor (voltage control method), the resistor wastes energy as heat.
- PWM allows speed control without wasting energy because the motor gets full voltage but only for a controlled fraction of time.

Example:

- Instead of supplying 6V continuously, we supply 12V in pulses but for only 50% of the time → The motor sees an "average" of 6V and runs at half speed.
- This method maintains torque while reducing speed.

The Motor's Inertia Smooths the ON/OFF Effect

- Even though the MOSFET turns the motor ON and OFF rapidly, the motor's rotational inertia prevents it from stopping immediately.
- If the PWM frequency is high (above 1 kHz), the motor doesn't "see" the rapid switching —it just experiences a smooth speed reduction.

Analogy:

- Think of a ceiling fan running at full speed. If we quickly flip the switch ON and OFF, the fan doesn't stop instantly—it slows down smoothly because of momentum.

Full Power = Stronger Torque at Low Speeds

- If we reduce voltage (instead of using PWM), the motor loses torque and struggles to move at low speeds.
- With PWM, the motor still receives full voltage during ON time, so it maintains good torque even at lower speeds.

? PWM (Pulse Width Modulation) – Explained

PWM (Pulse Width Modulation) is a technique used to control power delivery to electronic devices by rapidly switching a signal ON and OFF at a high frequency.

How Does PWM Work?

- Instead of providing a continuous voltage, PWM delivers pulses of voltage.
- The duty cycle (ON time vs. OFF time) controls the average power supplied.
- Faster switching (high frequency) makes the output appear as a smooth voltage.

Formula for Duty Cycle

$$\text{Duty Cycle} = \left(\frac{\text{ON Time}}{\text{ON Time} + \text{OFF Time}}\right) \times 100\%$$

- 100% Duty Cycle → Always ON → Full Power
- 50% Duty Cycle → ON & OFF equally → Half Power
- 0% Duty Cycle → Always OFF → No Power

? Frequency of the PWM Signal in This Project

The frequency of the PWM signal in a 555 timer-based motor controller depends on the values of the resistor (R1), potentiometer (R2), and capacitor (C1) used in the circuit.

Formula for PWM Frequency in 555 Timer (Astable Mode)

$$f = \frac{1.44}{(R1 + 2R2) \times C1}$$

where:

- R1 = Fixed resistor (Ω) = 1kΩ
- R2 = Potentiometer (Ω) = 0Ω to 47kΩ
- C1 = Timing capacitor (F)=100nF

The PWM frequency range for R1 = 1kΩ, C1 = 100nF, and R2 (variable from 1Ω to 47kΩ) is approximately:

- **Minimum frequency (R2 = 47kΩ) → 151.58 Hz**
- **Maximum frequency (R2 = 0Ω) → 14.4 kHz**

This means our motor controller can operate anywhere between 151 Hz to 14.4 kHz, depending on the potentiometer setting.

Common Frequency Range for PWM Motor Control

- Typically, 1 kHz to 10 kHz is used for small DC motors.
- If the frequency is too low (e.g., <100 Hz), the motor may jerk instead of running smoothly.
- If the frequency is too high (e.g., >20 kHz), switching losses in the MOSFET increase.