EE1002 - Lab 8: PMDC Motors and MOSFET as a Switch

	Activities Completed	Verified By	Marks From 5
Name:_______________	**Preparatory Work**		
Matric. No._______________	**a**		
	b		
Group:_______________	**c**		

1. Objectives of the Experiment

a) To operate the PMDC motor and study the relationship between applied armature voltage vs. speed and armature current vs. torque

b) To use MOSFET as a switch in electrical circuits

c) To control the speed of a PMDC motor using MOSFET as a switch

d) To construct a Pulse-Width-Modulation (PWM) circuit using LM555 timer integrated circuit (IC), and study its operation for speed control of PMDC motor

2. Equipment Involved

- DC power supply
- Signal Generator
- Oscilloscope
- Digital Multimeter
- Breadboard

3. Components

- Resistors
- MOSFET
- PMDC Motor
- Diode
- LM555 Timer IC

4. Preparatory work (Individual)

<u>This component is to be completed at your own time before coming for your lab session.</u>

A simulation schematic circuit of DC motor is shown in Fig. 1. It consists of two sub-circuits: armature circuit and mechanical load circuit. The armature circuit is designed according to Eqn. (1):

$$V_T = e_{EMF} + R_A i_A + L_A \frac{di_A}{dt} \qquad (1)$$

The mechanical load circuit is represented by the <u>equation of motion</u> as indicated by eqn. (2) and the corresponding equivalent electrical circuit is shown in Fig. 1 and represented by eqn. (3) which is in electrical equivalent format of eqn. (2)

$$T_{DEV} = T_{LOAD} + B\omega + J\frac{d\omega}{dt} \qquad (2)$$

$$V_{T_{DEV}} = V_{T_{LOAD}} + R_B I_\omega + L_J \frac{dI_\omega}{dt} \qquad (3)$$

where T_{DEV} – developed motor torque in N.m, T_{LOAD} – load torque in N.m, B – frictional coefficient N.m/(rad/s), J – inertia of the drive system in kg.m^2, ω – motor speed in rad/s, $T_{DEV} = V_{TDEV}$, $T_{LOAD} = V_{TLOAD}$, $R_B = B$, $L_J = J$, and $I_\omega = \omega$.

Simulate the circuit in Fig. 1 using LTspice, according to following requirements:

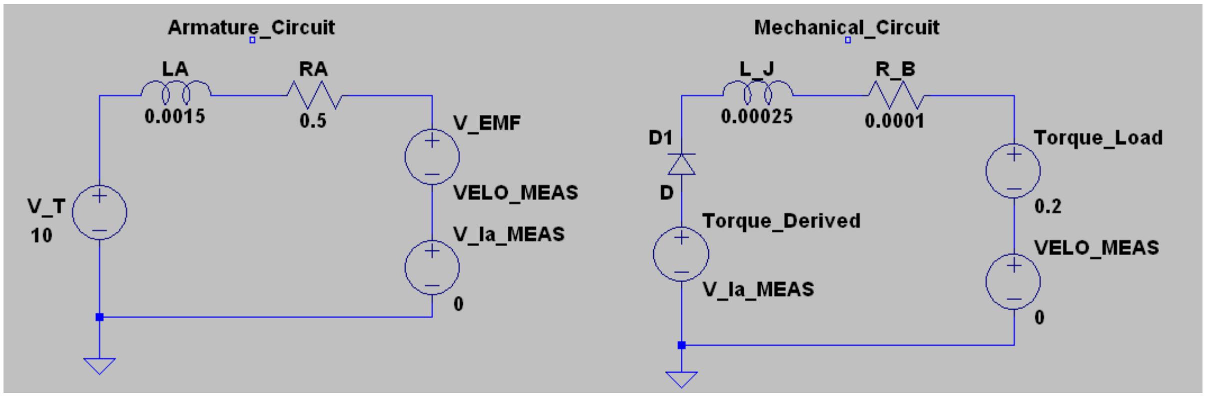
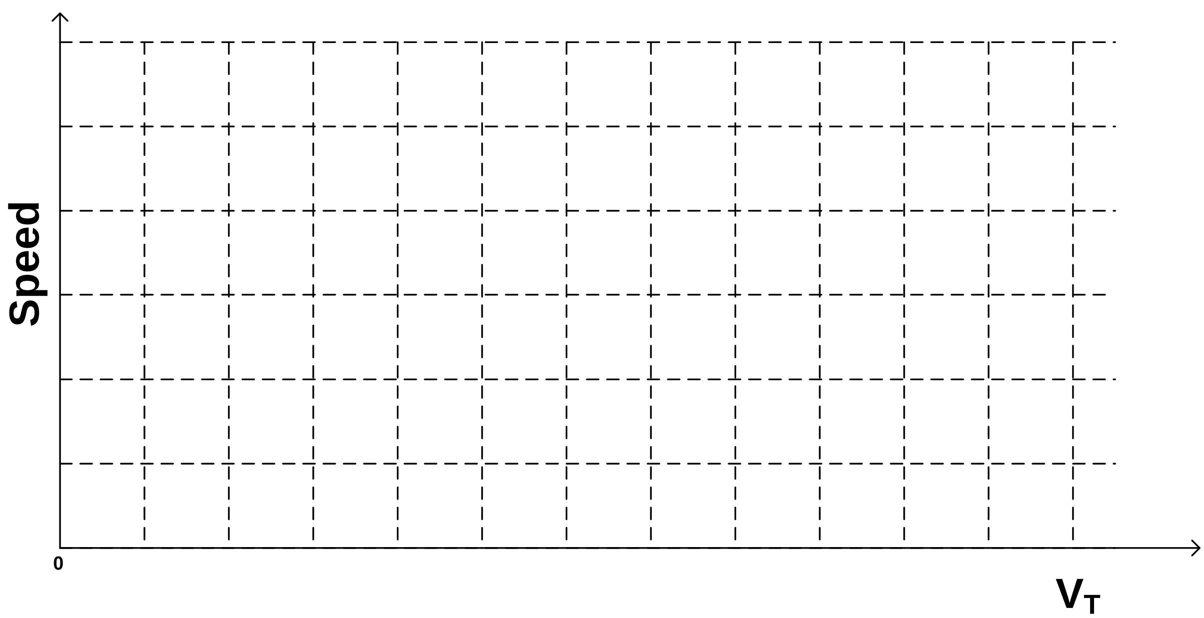


Fig.1: DC motor simulation circuit

i) Vary the supply voltage V_T from 10 V to 11 V in steps of 0.2V. Measure the motor angular velocity, ω (which is the current passing through Mechanical Circuit, I_ω). Fill the measurement results in Table 1, and sketch a graph of angular velocity, ω against supply voltage, V_T (the units in simulation can be neglected).

Table 1: V_T vs. angular speed

V_T in V	10	10.2	10.4	10.6	10.8	11
Angular velocity, ω in rad/s						

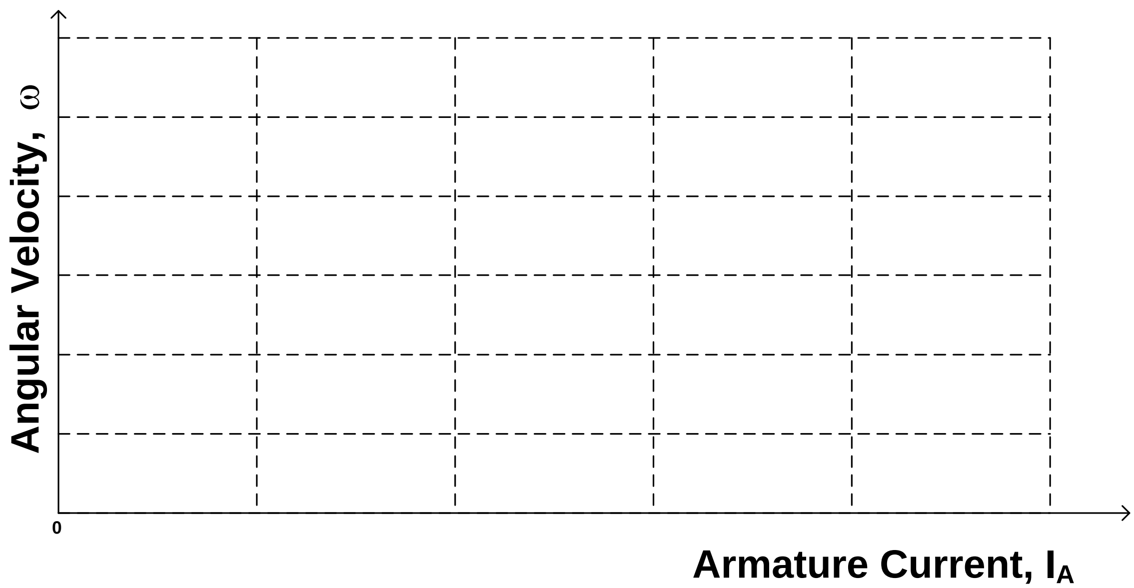


Keep V_T fixed at 10V and measure the armature current, I_A (which is the current passing through Armature Circuit) and the motor angular velocity, ω (which is the current passing through Mechanical Circuit) when the load torque, T_{LOAD} is changing (which is the voltage value of the Torque_Load source in Mechanical Circuit). Fill the measurement results in Table 2, and sketch a graph of angular velocity against armature current (the units in simulation can be neglected).

Study the relationship between V_T vs. ω and T_{DEV} and I_A.

Table 2: Armature current vs. angular speed

Torque load in N.m	0	0.025	0.05	0.075	0.1	0.125	0.15	0.175	0.2
Armature current in A									
Angular velocity in rad/s									



5. In-lab activities

a. PMDC machine

1) In this part, a motor-generator platform based on two PMDC machine is used, as shown in Fig. 2. First, connect a DC power supply directly to your PMDC motor. Observe the direction of rotation (clock-wise or anti clock-wise) with respect to polarity of the applied DC voltage.
   Make sure that you set the current limit of the power supply at 1.0 A. Do not connect any resistors to the generator part. Connect VCC and GND to power supply and vary the supply voltage from 7V to 12V. Measure the motor speed, N (angular speed of the shaft in rad/s) using the digital optical tachometer. Please aim the light beam of the optical tachometer to the reflection mark on the coupling between the motor and the generator. Fill the measurement results in Table 3, and sketch a graph of speed against supply voltage (Note: please do not make the DC voltage larger than 12V).

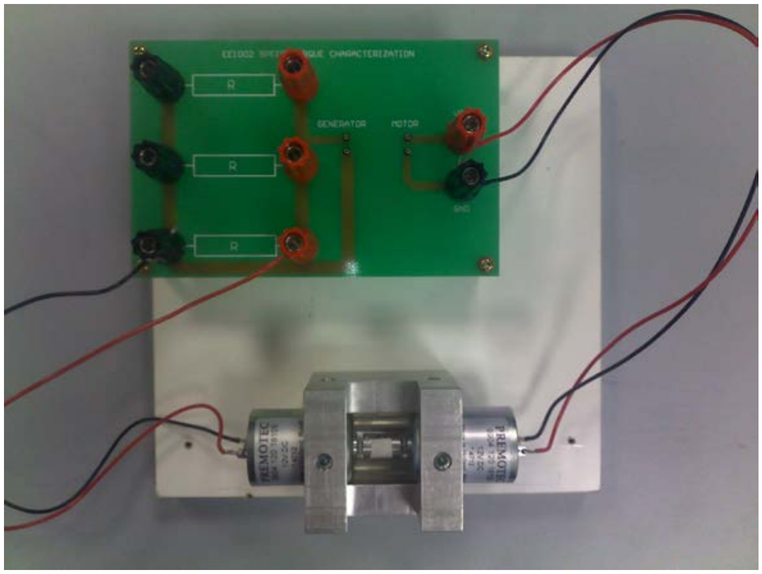
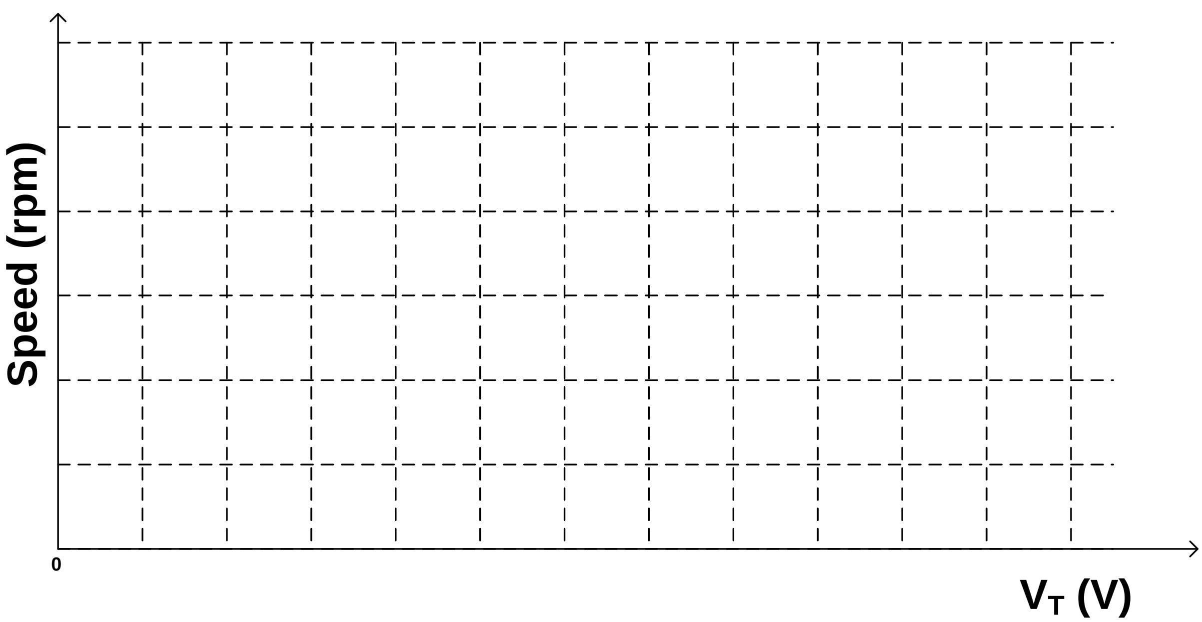


Fig. 2: Motor-generator platform

Table 3: VCC vs. angular speed

VCC (V)	7	8	9	10	11	12
N (rpm)						



2) Keep VCC fixed at 12V and adjust the current limit at 1.0 A, and measure the armature current I_a using analog ammeter at the generator side and the motor angular speed N for the following cases:

i) Open circuit at the generator output;

ii) One power resistor of 10Ω 10W connected at the generator output;

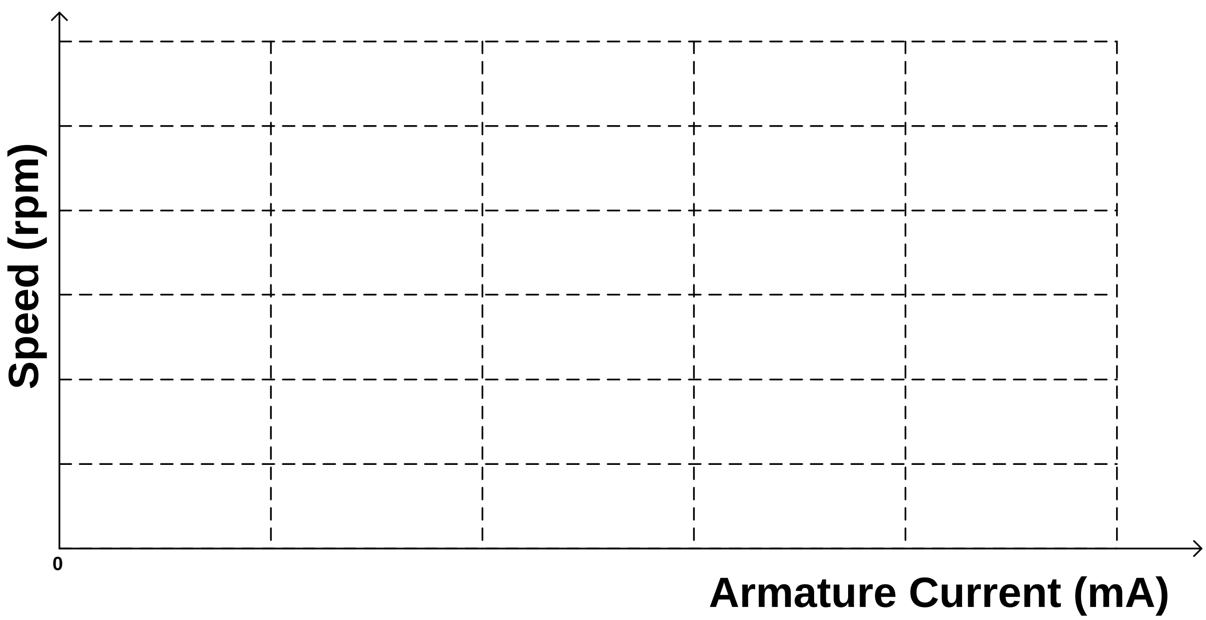
iii) Two power resistors connected at the generator output and

iv) Three power resistors connected at the generator output;

Fill the measurement results in Table 4, and sketch a graph of speed against armature current.

Table 4: Armature current vs. angular speed

Cases	O.C.	1R	2R	3R
I_a (mA)				
N (rpm)				



b. MOSFET as a switch

Patch up the following N-MOSFET circuit as shown in Fig. 3 on the breadboard. Supply a square wave voltage of 0V to 5V with 1 kHz frequency using TTL signal from the signal generator. Measure and sketch both the input PWM signal, V_{in} and the output signal, V_{out} with the help of an oscilloscope. From your observations, conclude on the working principles of MOSFET operating as a switch.

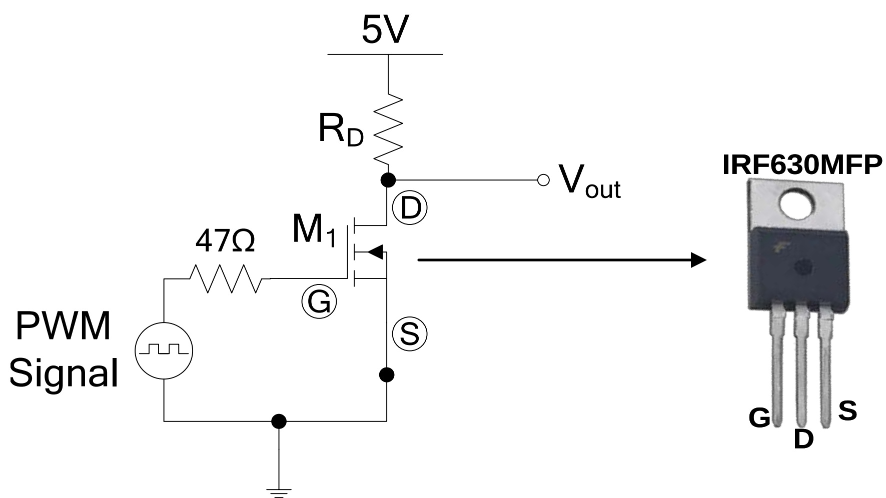


Fig. 3: MOSFET used as a switch

Next, measure how the average voltage of TTL output PWM signal varies for different duty cycles (you can vary the duty-cycle from the Signal Generator control knob) and fill the measurement results in Table 5:

Table 5: Duty cycle vs. V_{ave}

Duty Cycle (%)					
V_{ave} (V)					

Second, construct the motor driver circuit as shown in Fig. 4. Please use the Tamiya motor in the project pack. Make sure that you connect a **free-wheeling diode** across the motor terminal as shown in Fig. 4. Vary the duty cycle of the PWM signal and observe the change in the motor speed. Sketch a graph of speed against duty cycle (in terms of percentage 0 – 100%).

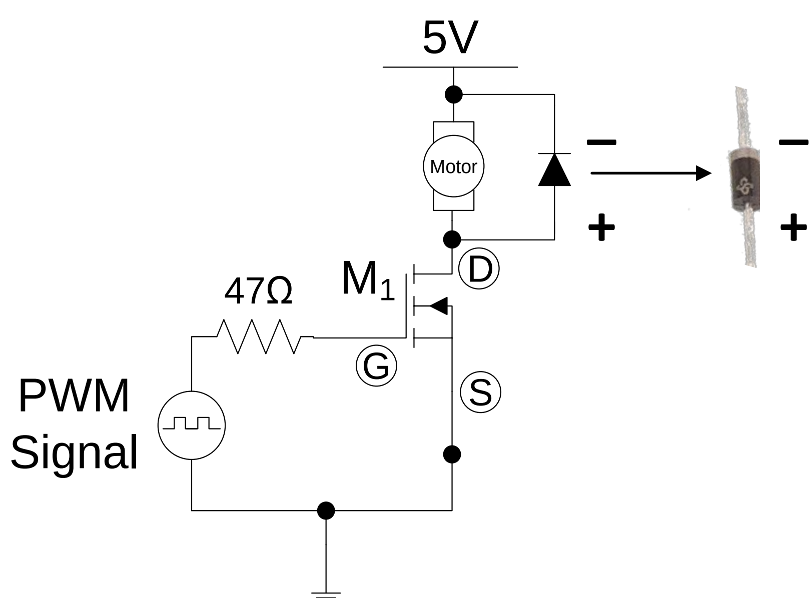
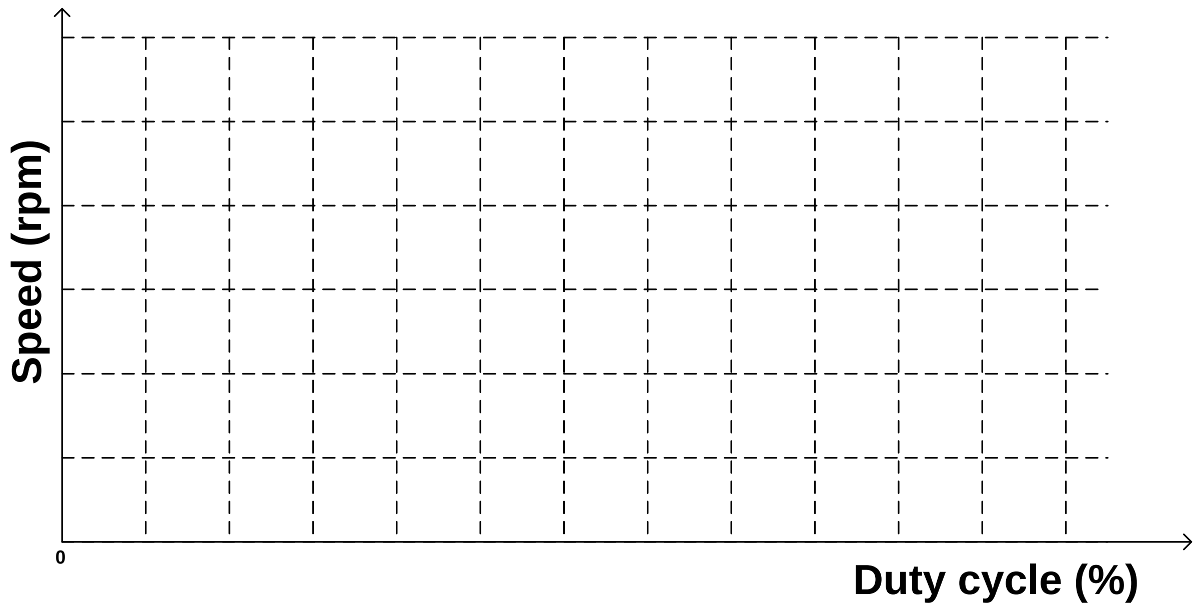


Fig. 4: MOSFET used as a switch to drive DC Motor



c. Build the PWM circuit using LM555 Timer IC

In the project, you need to have your own PWM signals to drive the DC motor, instead of using a signal generator. A PWM circuit can be implemented using a LM555 Timer IC and discrete components. Such a circuit schematic is provided to you as shown in Fig. 5. **** Do not dismantle this circuit as it will be used in the next lab****

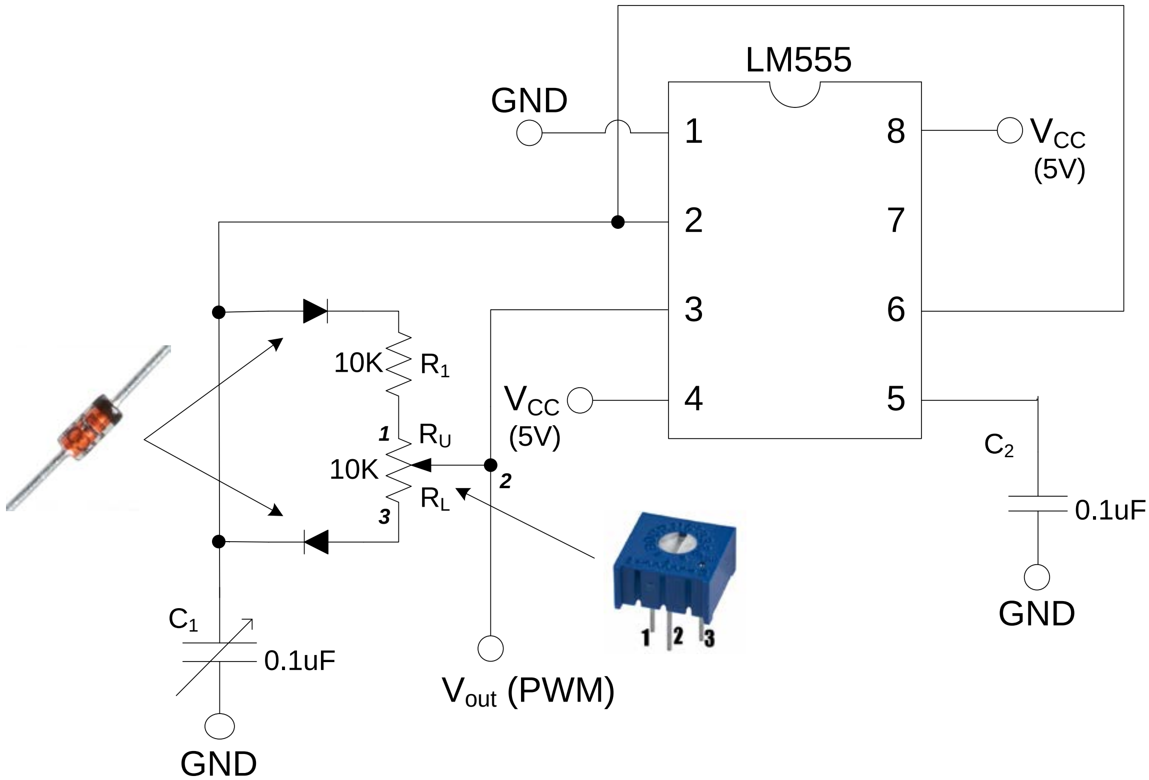


Fig. 5: PWM Generator

Frequency of the generated clock pulse (V_{out}) is determined by R_1, the variable resistor (R_U + R_L) and C_1 according to the following equation:

$$f_{out} = \frac{1.44}{[R_1 + (R_U + R_L)] \times C_1}$$

Additionally, the time (t_{high}) that V_{out} remains at HIGH (+5V) and the time (t_{low}) that it stays at LOW (0V) during a clock period are determined by the following equations:

$$t_{high} = 0.69 \times (R_L \times C_1)$$

$$t_{low} = 0.69 \times [(R_U + R_1) \times C_1]$$

Therefore, the duty cycle can be varied by tuning the variable resistor. Try different R_1 and C_1 values to observe the change in frequency of V_{out} using the oscilloscope.

Patch up this circuit on the breadboard, and then connect V_{out} to the MOSFET circuit in (b) by replacing the PWM source with your newly constructed PWM signal generator, as shown in Fig. 6.

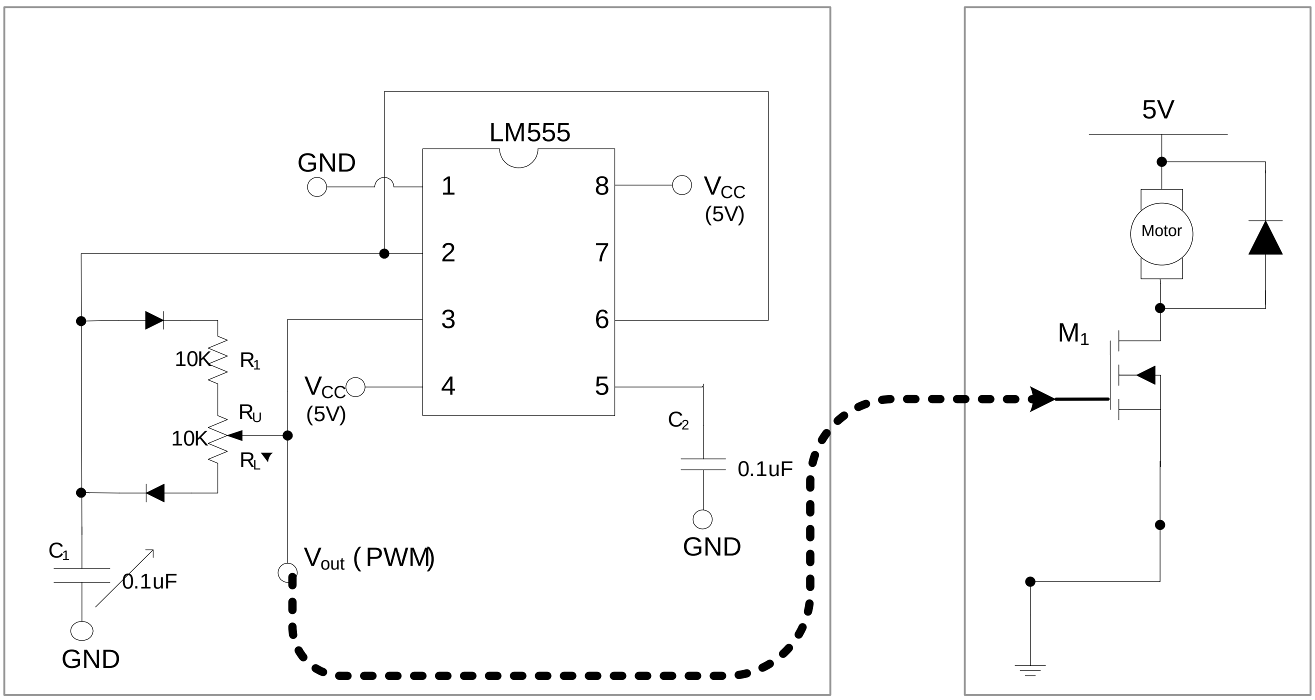


Fig. 6: PWM Generator and DC Motor Driver circuit

Demonstrate that you are able to control the motor speed by tuning the variable resistor.

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