ELCT 201 – EE LABORATORY 3

MOTOR CURRENT AND TORQUE

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ABSTRACT

In this lab, a motor connected to a DC power supply was studied to see how voltage and current would affect the speed and torque of the motor. Current flowing through the motor was measured by connecting a 10 Ω resistor in series with the motor and then measuring the current flowing through the resistor using the oscilloscope. An RC lowpass filter was also connected in parallel to the 10 Ω resistor to reduce the amount of noise surrounding the current measurement. Motor torque was also measured in this lab by attaching a water bottle to the motor by a string and lifting the bottle to the edge of the table. Measurements taken from this experiment allowed us to estimate the torque constant, k as well as find the power generated by the motor and electrical power used to power the motor. Concepts such as torque, mechanical power, and electrical power were explored and studied throughout this lab. The connection between voltage and speed of the motor as well as current and torque of the motor were discovered as well.

INTRODUCTION

CIRCUIT SETUP

The first circuit setup that was used for this lab was a motor connected in series with a 10Ω resistor, being powered by a 10 V DC voltage source. This setup is shown in Figure 1:

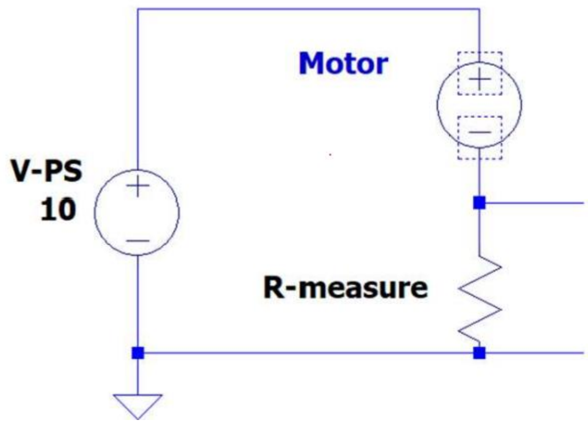

Figure 1: A 10 V DC voltage source connected to a motor and 10 Ω resistor

This setup was utilized to measure the voltage across and the current through the 10Ω resistor. This was useful to show how much current was being drawn by the motor when different stresses were applied to it.

The second circuit setup that was used for this lab was the same setup as Figure 1 but with the addition of a low pass RC filer. The setup is illustrated in the following figure:

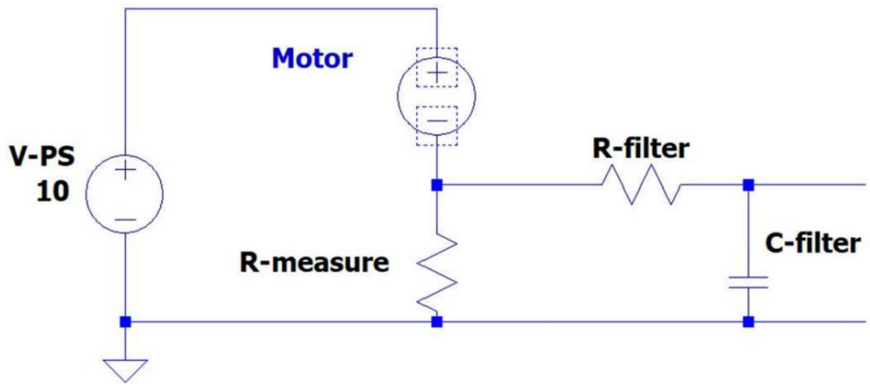

Figure 2: A RC lowpass filter consisting of a 100 kΩ resistor and a 0.1 µF capacitor, connected to Figure 1.

The RC lowpass filter helps to limit the noise created by the commutator brushes, allowing us to take a more accurate measurement of the average current drawn by the motor.

PRELAB CALCULATIONS

Before the lab we were asked for multiple different calculations that would be used during the lab. We were first asked to calculate a value for the current measuring resistor given the input voltage is 10 V, and the current can range between 100-300 mA. I found that a 3 Ω resistor could be a plausible value for this current measuring resistor. $V = IR$

Equation 1 was useful in testing to make sure that this resistor's voltage drop did not exceed 10% of the input voltage of 10 V. I found that the voltage drop across the resistor was 0.6, which is well under the 10% margin, when the current is at 200 mA.

$V = IR$ *Equation 1*

The power dissipated by this resistor can be found using $P = I^2R$

Equation 2. I found that the power dissipated by the 3 Ω resistor at a maximum current draw of 300 mA was 0.27 W. Therefore, the power rating for this current measuring resistor is ½ W.

$P = I^2R$ *Equation 2*

We were then asked to find values for a resistor and a capacitor in a lowpass filter that would suppress the fundamental frequency of 500 Hz by 20 Db (1 decade). The corner frequency equation, which is shown in $\omega_c = \frac{1}{2\pi RC}$

Equation 3, was used to estimate values for the new frequency. One possible combination of resistor and capacitor values that could be used are a 1 kΩ resistor and a 3.2 μF capacitor. Plugging in these values to $\omega_c = \frac{1}{2\pi RC}$

Equation 3 yields 49.74 Hz, which is very close to the 50 Hz target frequency.

$\omega_c = \frac{1}{2\pi RC}$ *Equation 3*

Lastly, we were asked to estimate the torque coefficient of a motor that is pulling a mass of 100g, draws 150 mA of current, and has a radius of .05 meters. I utilized $T = kI$

Equation 4 and $T = dF$

Equation 5 to solve for the torque coefficient for this motor. I first substituted the force of gravity into $T = dF$

Equation 5 and used the radius for the distance and found that the torque of the motor was 49.05 mili Newton-Meters. I then rearranged $T = kI$

Equation 4 to solve for the torque constant and plugged in my found value for torque and the given value of 150 mA for the current. Using these values, the torque constant for this motor is 0.327 Newton-Meters per Amp.

$T = kI$ *Equation 4*

$T = dF$ *Equation 5*

MEASUREMENTS

MOTOR CURRENT AND VOLTAGE WAVEFORMS

While the motor was arranged in the Figure 1 arrangement, the voltage across the motor was measured by the oscilloscope. Figure 3 illustrates the voltage measurement:

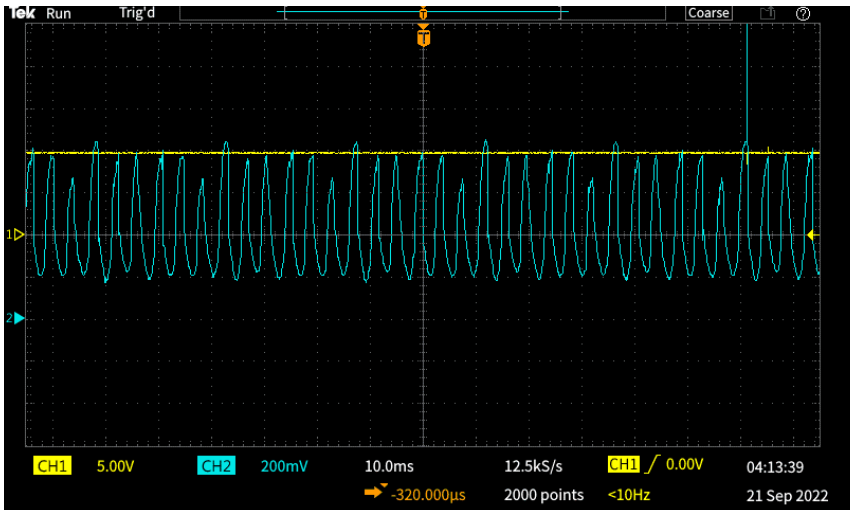

Figure 3: Oscilloscope screenshot of a 10 V DC input voltage and the voltage across a motor in the Figure 1 configuration.

In this screenshot, Channel 1 represents the input voltage of 10 V and Channel 2 represents the voltage across the motor. It is apparent that the voltage across the motor is oscillating but not uniformly.

While in the same arrangement as before, the probes for the oscilloscope were now set to measure the current drawn by the motor. This can be seen in Figure 4

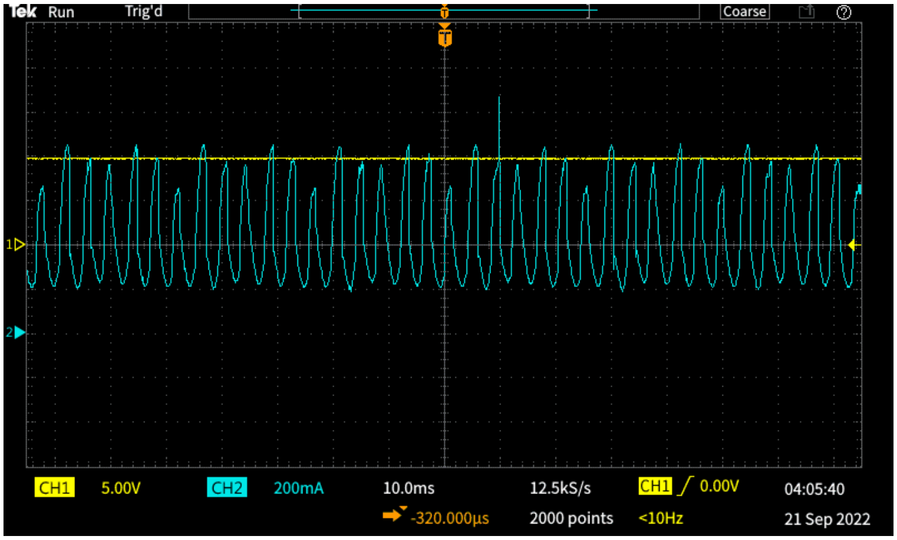

Figure 4: Oscilloscope screenshot of a 10V DC input voltage and the current drawn by a motor in the Figure 1 configuration.

Channel 1 still shows the input voltage of 10 V, but now Channel 2 shows the current drawn by the motor. Interestingly, the waveform measured by the current is very similar in shape to the voltage waveform from Figure 3.

Figure 5 shows a closer view of the current drawn by the motor:

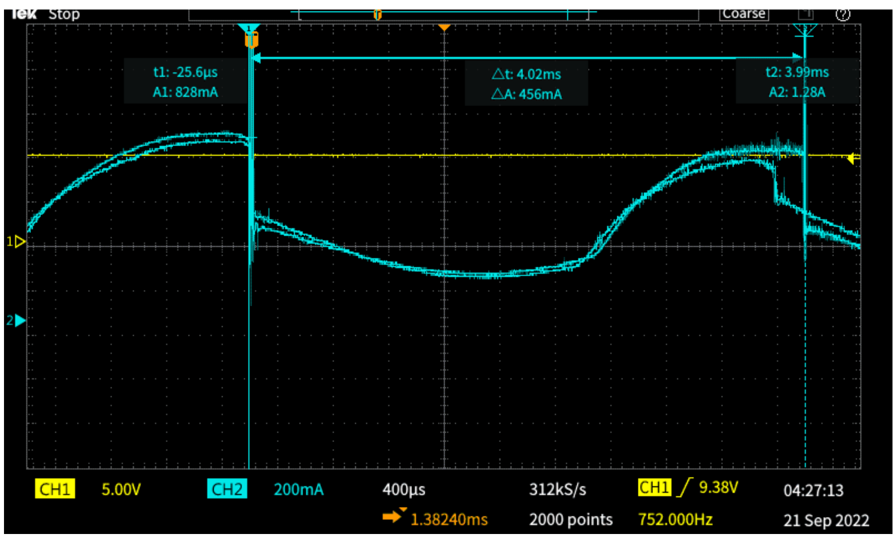

Figure 5: An Oscilloscope screenshot of the current drawn from a motor in the Figure 1 configuration.

This screenshot shows the noise that is created by the brushes inside the motor. This screenshot also allows us to get a very close estimate at the period of the current waveform. The noise does affect this measurement as we are unable to see exactly where the waveform rises and falls.

When the RC lowpass filter was added to the circuit (shown in Figure 2) the voltage probe (Channel 1) was changed to measure the current across the 10 Ω resistor. Thus, Channel 1 shows the unfiltered current flowing through the motor whereas Channel 2 shows the filtered current flowing through the motor. The oscilloscope was also adjusted to display a long duration event by setting the screen to contain 1 second per division on the time axis. The results can be seen in Figure 6:

Figure 6: Oscilloscope screenshot of the filtered and unfiltered current flowing through the motor in the Figure 2 configuration.

This screenshot shows how the motor reacts to a load being placed on it. Pressure was applied at various times throughout this screenshot and the current appears to increase when this occurs. Also, it is interesting to note that both the filtered and unfiltered currents appear to be in sync with each other, with little-to-no delay in between their response to stimuli.

MOTOR TORQUE AND POWER MEASUREMENTS

The next part of the experiment focused on the torque created by the motor when it raised a water bottle. Measurements such as current draw by the motor, mass of the bottle, and the time to raise the bottle were taken. The torque constant of the motor is estimated using $T = kI$ Equation 4 and $T = dF$ Equation 5 and the given values in the table (assuming the motor has a radius of 0.2 meters).

Mass (g)	Current drawn (mA)	Time (s)	Torque Constant
500	140	9.06	0.700714286
250	100	7.23	0.4905
125	80	6.1	0.3065625

Table 1: Various measurements of the motor when different masses are applied as a load.

These measurements were then used to calculate the mechanical power exerted by the motor to lift the weight and the electrical power applied to the motor. Then, the motor's efficiency was calculated by dividing the mechanical power by the electrical power. These measurements are shown in Table 2:

Mass (g)	Mechanical Power (W)	Electrical Power (W)	Motor Efficency (%)
500	0.0935	1.4	6.678571429
250	0.0568	1	5.68
125	0.0391	0.8	4.8875

Table 2: Measurements of the mechanical and electrical power of the motor at different masses, as well as their respective efficiency ratings.

The following equations were used to calculate the measurements recorded in Table 2:

$$P_m = \omega T = \omega r m g \qquad \textit{Equation 6}$$

$$P_e = IV \qquad \textit{Equation 7}$$

$$n = \frac{P_m}{P_e} \qquad \textit{Equation 8}$$

It is evident from Table 2 that the motor used in the experiment was not very efficient in converting electrical power into mechanical power. It is interesting to note that as the mass increases the efficiency increases, as I presumed that a heavier mass would cause the motor to become more inefficient.

VOLTAGE AND MOTOR SPEED MEASUREMENTS

Lastly, we had to measure the speed that the motor operated at when different voltages were applied. The results can be seen in the following table and graph:

Voltage (V)	Time (s)	Speed (m/s)	Voltage (V)	Time (s)
5	16.6	0.0753012	5	16.6
7.5	9.88	0.1265182	7.5	9.88
10	7.6	0.1644737	10	7.6

Table 3: Voltage applied to a motor and the time needed to raise a 125g bottle

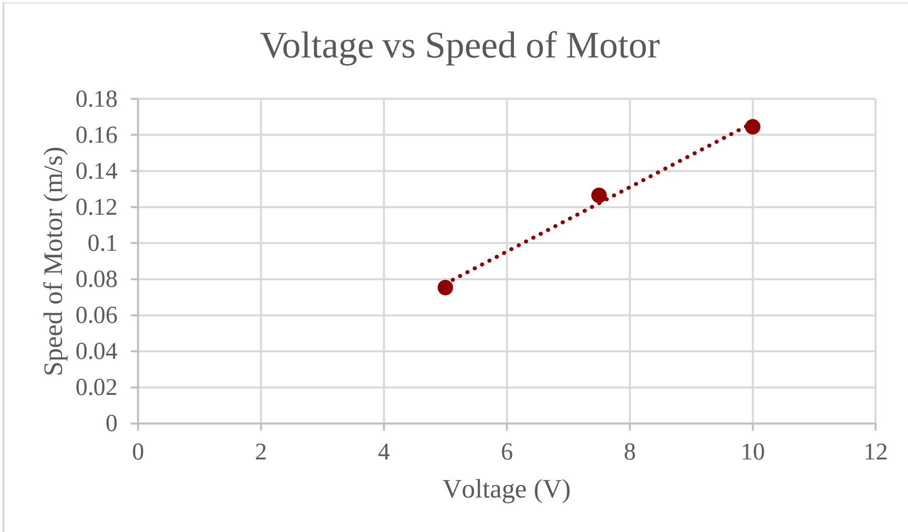

Figure 7: Graph of the voltage applied to a motor and its speed

It is apparent that there is a positive linear relationship between the voltage applied to the motor and the speed at which it raised the bottle. The motor speed was found by dividing the distance from the table to the floor (around 1.25 meters) by the time it took to raise the bottle to the edge of the table. It is interesting to see how motor speed and motor torque are independent of each other.

CONCLUSIONS

This lab provides insight into how motors operate when they are applied to a circuit. Voltage's effect on the speed of the motor as well as the current required to create torque or shown to be two independent aspects of the motor. The difference in electrical power that was supplied and the mechanical power that was delivered from the motor showed that the motor was very inefficient. Nearly 80-90% of the power that was delivered to the motor was not utilized to lift the bottle, thus a more efficient motor would have required less electrical power to operate.