Stepper Motors (Reluctance Machines)

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1 INTRODUCTION

The objective of this lab was to get hands on experience with Reluctance motors. We specifically used a stepper motor. The tests we completed were to find: series resistance, phase inductance, max step rate and minimum phases required. With the results from this test we could see the characteristics of the motor and make a circuit model of it. Further, we were also exposed to LabView software through which we controlled the motor. We could control step rate, phase transitions, number of steps etc. The lab gave us a complete overview of the basics of working with a stepper motor, a type of reluctance machine.

All data/measurements taken are provided in the appendix at the bottom of the document.

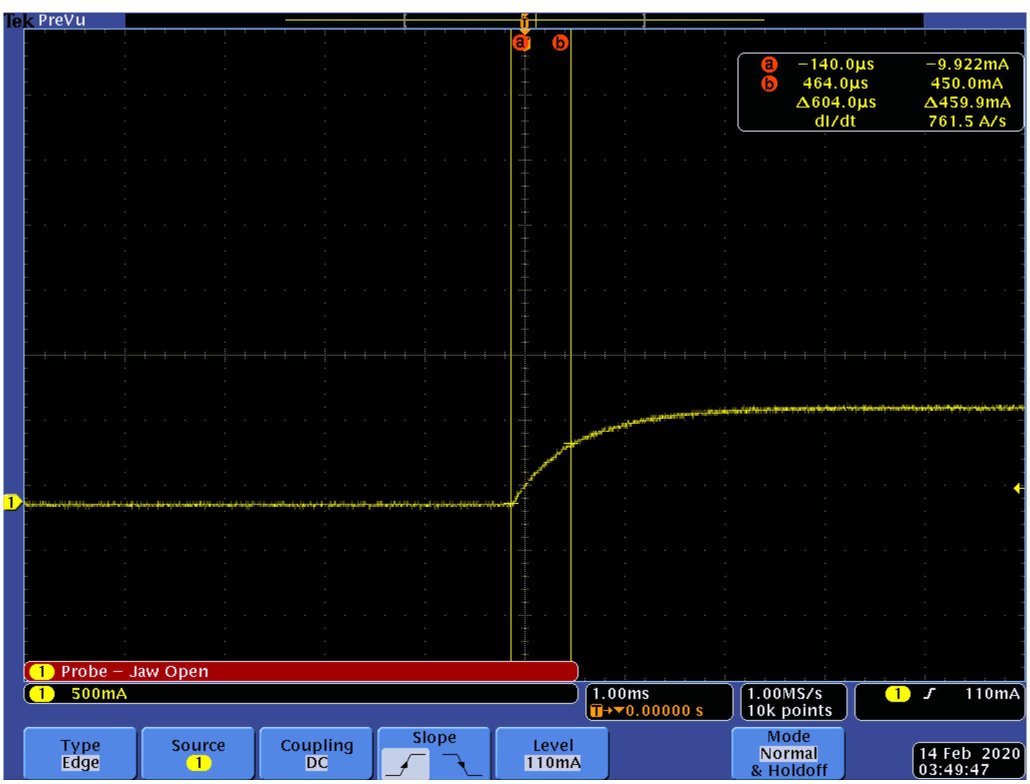
2 RESULTS

2.1 *Machine Parameterization*

We started off with collecting the series resistance of each phase while the motor was not connected to any power. This was a quick measurement as the stepper motor we used consisted of 4 phases and the Fluke multimeter provided quick readings.

Next to find the time constant of the motor we connected a power supply at 2.5V that was current limited at 2A to the motor and setup a slow step rate: 10Hz. We measured the current that the motor drew to find the time constant by seeing how much time it takes to reach 63% of max current draw.

Fig.1 Picture of Phase A of motor, Current(I) vs time(t):



With the time constant and series resistance we can find the inductance by using equation (1):

$$\tau = \frac{L}{R} \qquad \textbf{Equation 1.}$$

After following the calculation we can obtain the following values:

$\boldsymbol{Table1}$

	Series Resistance (ohms)	Inductance (Henrys)	Time Constant (uS)
Phase 1	3.04	0.001836	604
Phase 2	3.06	0.002118	692
Phase 3	3.05	0.002019	662
Phase 4	3.05	0.002050	672

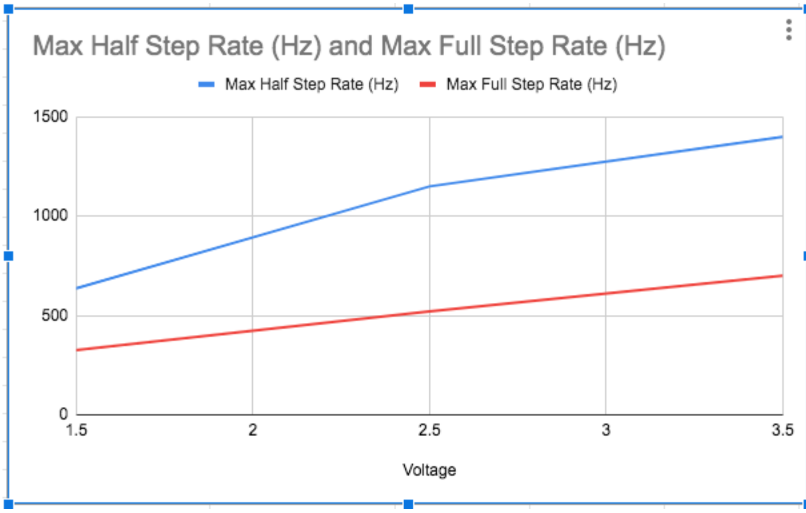
Next we calculated the maximum step rate of the motor by slowly increasing the number of steps until we see the motor skipping/missing steps:

$\boldsymbol{Table2}$

	Max Step Rate (Hz)
1.5V Full Step	325
1.5V Half Step	637
2.5V Full Step	520
2.5V Half Step	1150
3.5V Full Step	700
3.5V Half Step	1400

If we compare this max step rate to the time constant found in the previous part of the lab we can see that there is not a 1 to 1 match. For 2.5V full step the time constant calculated from max step rate is 1.92ms, where as the RL time constant is .6ms. From this it is observable that it is not the circuit components affecting the max step rate but rather the controller chip.

Fig.2 Max Step Rates Plot


Max Half Step Rate (Hz) and Max Full Step Rate (Hz)
Max Half Step Rate (Hz)
Max Full Step Rate (Hz)
1500
1000
500
0
1.5
2
2.5
3
3.5
Voltage

From this it is visible that at a higher voltage it is possible to control the motor with a higher frequency. This is because the higher voltage allows for higher current to flow faster, meaning that the magnetic field changes fast enough for the rotor to accurately catch each step. This is also similar to the time constant decreasing as current reaches 63% faster allowing for higher stepping rates. However, operating on a high voltage also causes power losses in the resistive components, making the motor less efficient. Also, this will increase the temperature of the motor which can potentially damage some components. So using the higher voltage only when necessary is the best way to go.

2.2 *Control Waveforms*

After the parameterization process, we next tested controlling the motor in various ways. We tested half-stepping and full stepping at 100Hz to see how the FET's actually change their gating operations.

Fig.3 Full Stepping Clockwise (Phase A-D Top to Bottom):

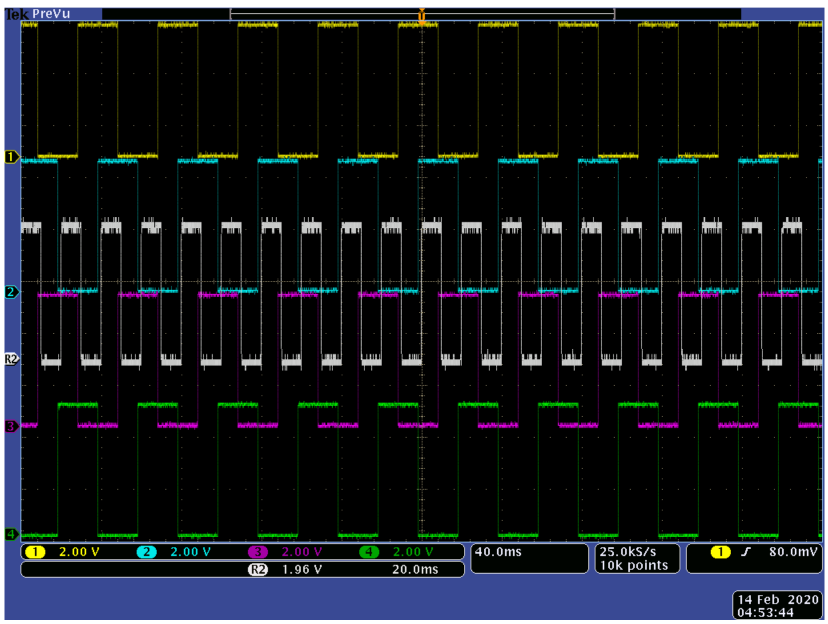
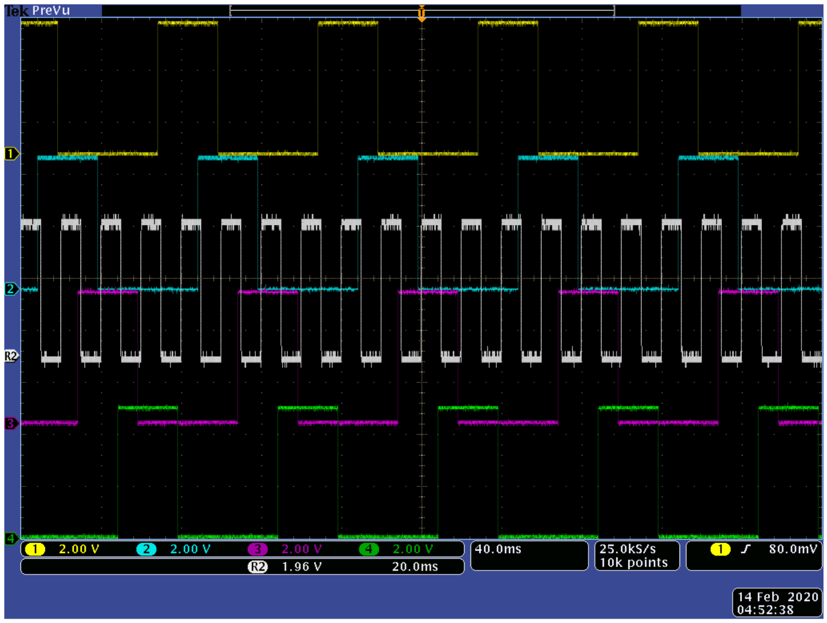
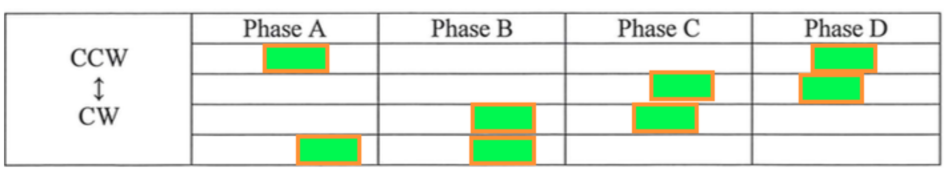


Fig.4 Half Stepping Clockwise (Phase A-D Top to Bottom):



This matches what we expected from the prelab as it is visible that the pattern of the phases A through D being on follow:

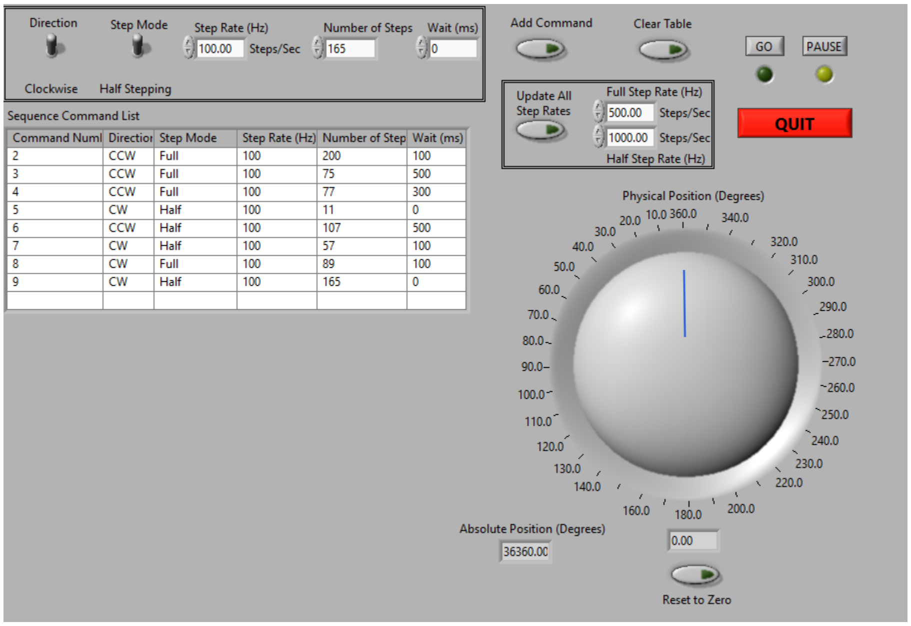
Fig.5 Full Stepping Clockwise Phase Transitions:



2.3 *Programming*

In this part of the lab, we programmed a set sequence in LabView to make transitions given by Table 3.2 on page 39 in the Lab Manual.

Fig.6 Sequence for Part C



Based on the number of steps, waiting time, and 100Hz frequency we can find the execution time to be exactly **9.41 seconds**. Since we wanted the fastest execution time, but still be as accurate as possible, we had to chose when to use half vs full steps. Full steps only gave us half as much resolution as half stepping so we could only use it in certain transitions.

Next, we started disconnecting phases one by one to find out the least number of phases we would need to spin the motor. Since there were 4 phases in the motor, it spun perfectly when all 4 phases were connected. As we decreased to 3 phases, the motor only spun from certain initial positions as only the phases connected at certain teeth of the stator were active. When only 2 or 1 phases were connected the motor did not spin at all as there was not a good flux path created.

3 CONCLUSION

This lab gave us a good look into stepper motors and their functionality. The tests we conducted are used in industry to characterize motors in a similar fashion. Further, the controls aspect was something very interesting as we could see when to use half vs full step, when to operate on a specific voltage, how many steps needed to turn certain degrees etc. We also got a view into why there is max step rate and the physical reasoning behind it. It was a very comprehensive lab overall and improved the understanding of reluctance motors by a huge factor.

4 REFERENCES

[1] P.W. Sauer, P.T. Krein, P.L. Chapman, *ECE 431 Electric Machinery Course Guide and Laboratory Information*, University of Illinois at Urbana-Champaign, 2005.

5 APPENDIX

Raw Data: