CSE 4355/5355 - Mechatronics Lab 3

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Objective

The objective of this lab was to analyze the operation of a brushless DC (BLDC) motor using various steps to explore commutation control through hardware and software. We examined the relationship between hall effect sensor outputs and the commutation of motor windings, with the goal of developing a routine to optimize motor speed and control based on sensor feedback. Additionally, we observed back electromotive force (back-EMF) in the motor when the coils were de-energized and recorded results.

Procedure

We started by powering the motor with a 6V power supply. The coil resistance of 0.13 ohms combined with the 10A power supply ensured the motor's current remained within a safe operating range. The motor windings were connected to the power supply via the RED, BLACK, and GREEN jacks for phases A, B, and C.

Using a compass protractor, we aligned the disc to 0 degrees relative to the motor base and began by energizing a coil pair. This initiated the first step of the motor's commutation.

By manually energizing each of the coils through six steps, we completed one electrical cycle. After recording the motor's physical rotation (in degrees) for each step, we continued until a full physical rotation (360 degrees) was achieved.

The physical rotation per electrical cycle was noted to ensure proper alignment and to correlate with the hall sensor output (as recorded later).

Next, the hall effect sensors were powered using the 5V supply on the YELLOW jack, and their outputs were connected through 10kΩ resistors to the 5V source. The outputs were then attached to the BROWN, BLUE, and ORANGE jacks, representing sensors 1, 2, and 3, respectively.

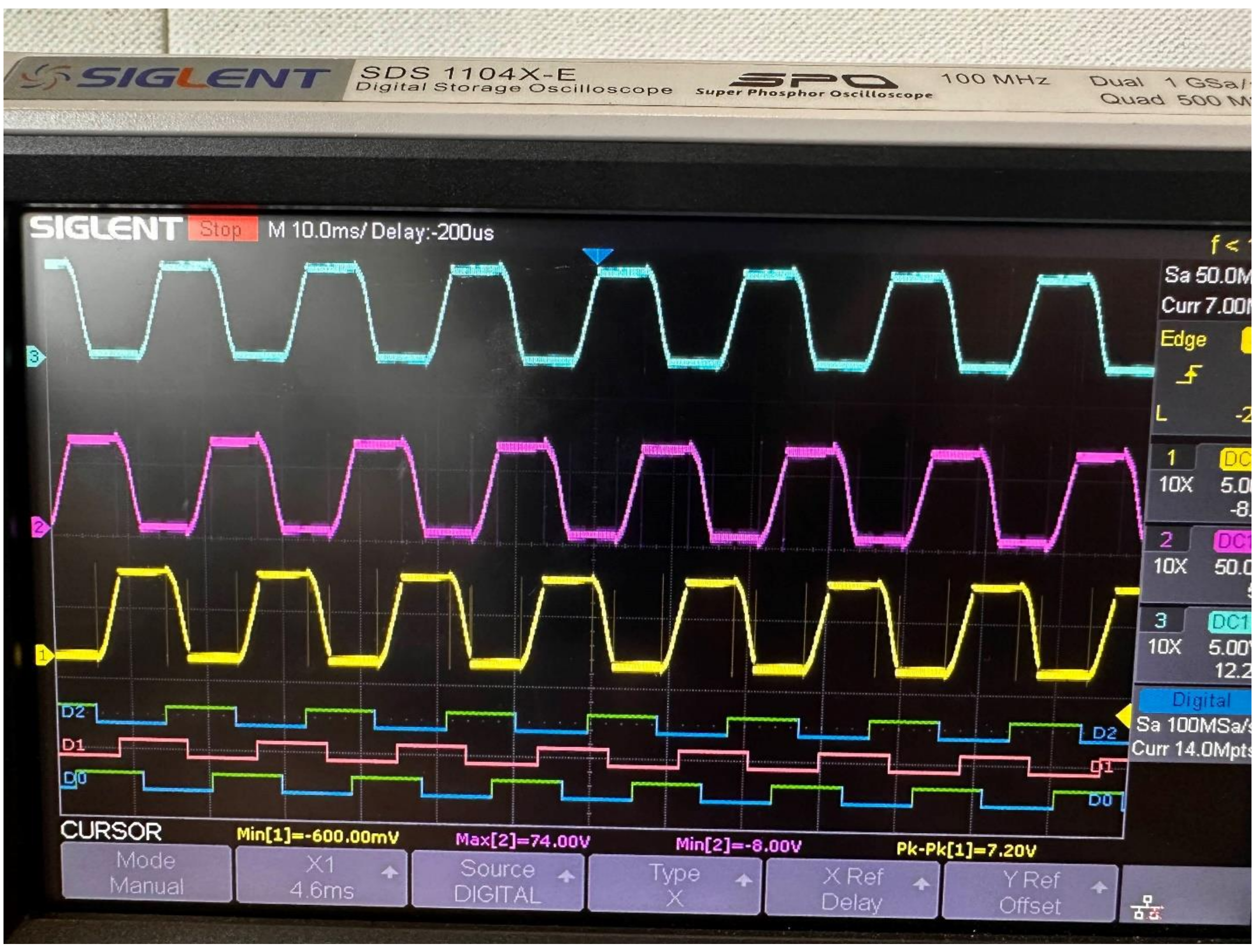
Observations for Step 5:

By slowly rotating the motor's disc, we noted the precise angles at which the hall sensors activated or deactivated. These values were critical for plotting the relationship between sensor output and physical disc rotation.

Mech. Angle:	0°	30°	60°	90°	120°	150°	180°	{Same as 0° & repeats}
H_A	1	1	0	0	0	1	1	
H_B	0	1	1	1	0	0	0	
H_C	0	0	0	1	1	1	0	
*	1 – High ; 0 – Low							

Observations for Step 6:

To get a clear visualization of the relationship between the sensors and the motor's commutation cycle, we connected the hall sensors and coils to the oscilloscope.



Observations for Open Loop Commutation:

We connected the BLDC motor to the BTS7960 half H-bridge module, utilizing three channels to control phases A, B, and C. The enable and PWM signals were connected to general-purpose outputs (GPO) on the TM4C123GXL board.

A simple loop was written to rotate the motor at one step per second. The program was modified to gradually increase the commutation speed, and we observed the motor's behavior at various speeds until slippage occurred.

The maximum commutation rate was observed to be: **386.1 Hz** at a delay of **2590 us** delay between the commutations.

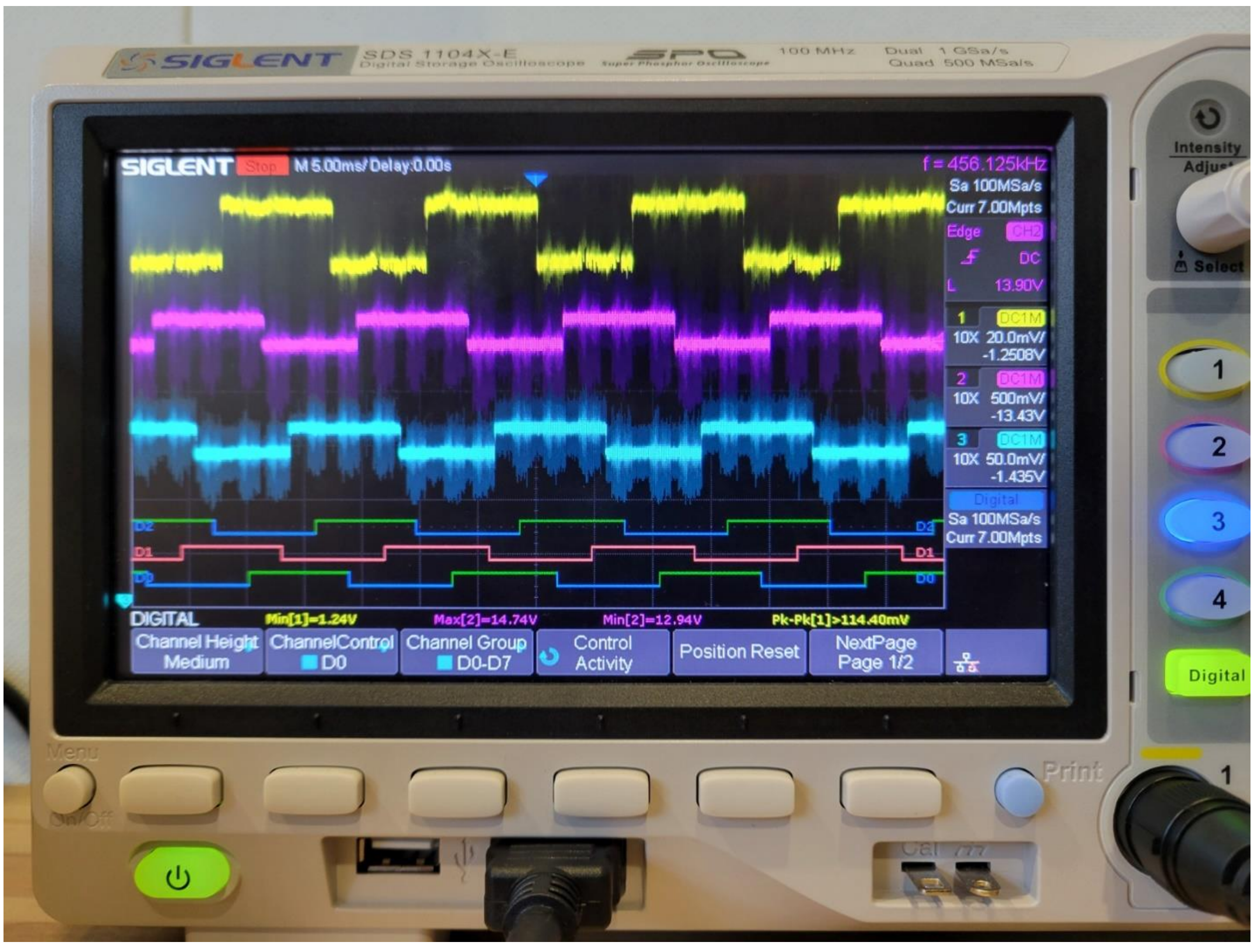
Observations for Closed Loop Commutation:

The software-controlled commutation was then modified to operate based on hall sensor input, ensuring accurate commutation timing even as the motor's speed increased. The coils were charged based on the hall effect sensor outputs observed in steps 5 and 6 to drive the motor to its maximum commutation rate.

Finally, we used the oscilloscope to monitor the voltage on phase C during commutation. The range of voltages observed on phase C, when it was not energized, indicated the presence of back-EMF. The measured back-EMF values provided insights into the motor's efficiency and energy recovery during operation.

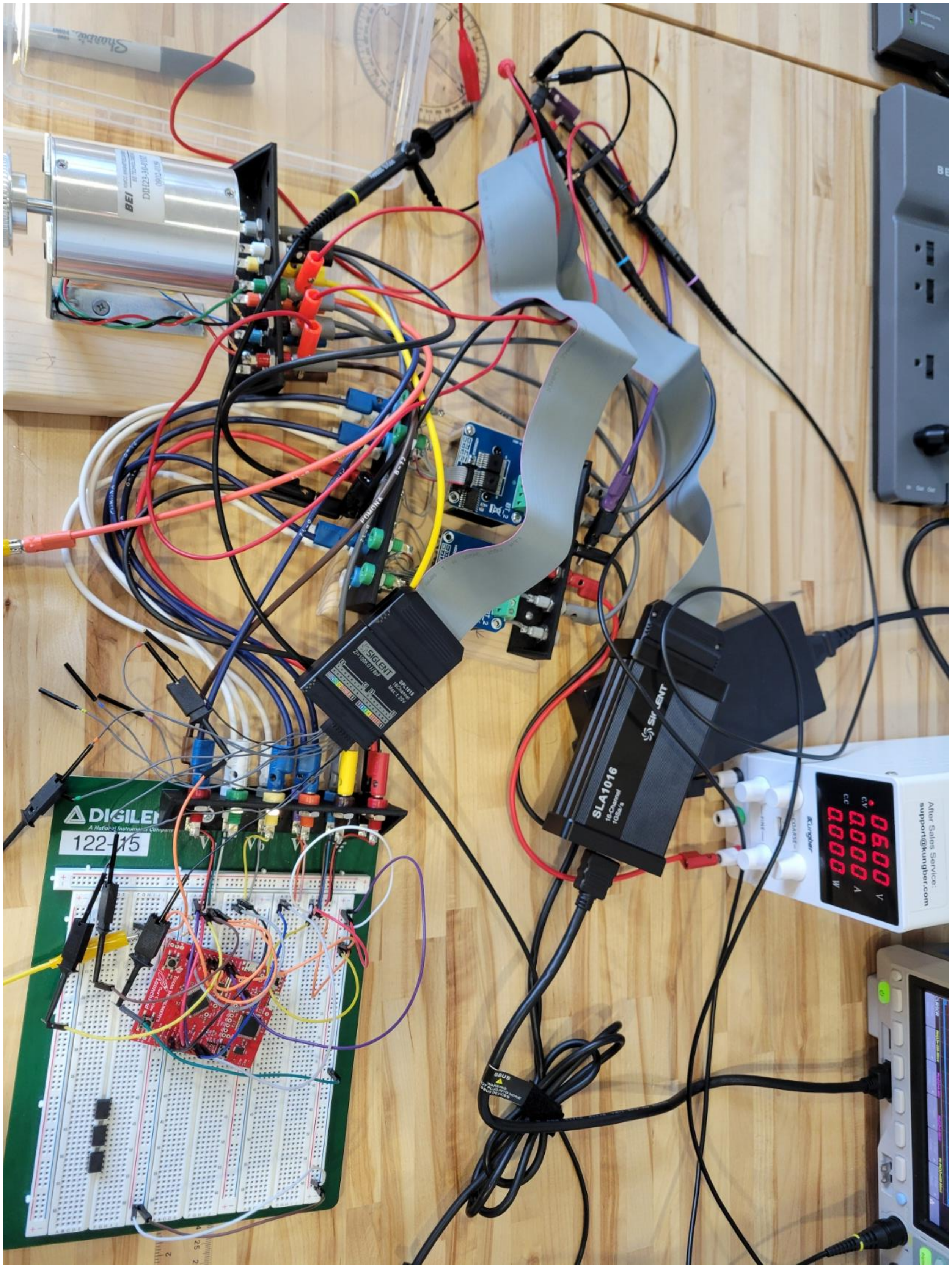
Observations for the Optional Part:

The 3 Comparator outputs correlating with the Hall Sensor Outputs with some offset was observed and recorded as below.



Conclusion

In this lab, we successfully demonstrated the commutation of a BLDC motor using hall effect sensors and controlled coil energization. The use of hall sensor feedback significantly improved the motor's performance, allowing for optimized commutation timing. We observed that back-EMF is a useful indicator of motor performance and can be measured to assess the motor's efficiency. Future work could involve using the optional comparator circuits to further enhance motor control and refine sensor data analysis.



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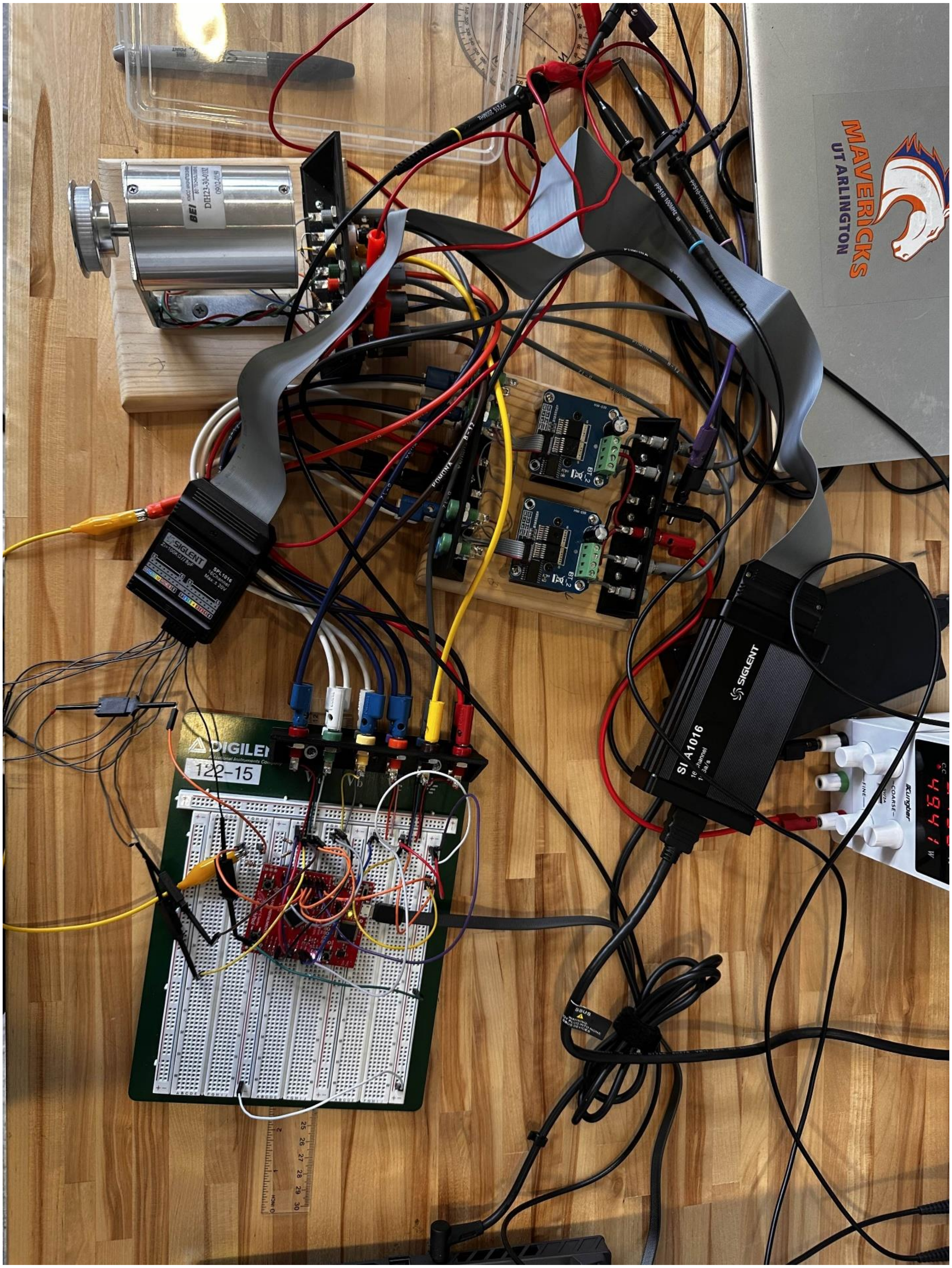

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