THE UNIVERSITY OF TEXAS AT ARLINGTON

COMPUTER SCIENCE AND ENGINEERING

MECHATRONICS
LAB 3 REPORT

ELECTROMECHANICAL SYSTEMS & SENSORS

Submitted toward the partial completion of the requirements for CSE 5355-001

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First seven steps of lab 3 guided us through the process of setting up the circuit and connecting it with the motor. Further down the line, these steps also described the setup for a PWM output to drive the motor, CCP input to determine the RPM, and set up an ADC input to sense the back EMF.

1. **For this lab, we will use a voltage of 10V on the bench motor power supply.**

2. **The permanent magnet DC (PMDC) motor will be controlled by a FQP20N06L n-channel MOSFET. The motor is connected between 10V and the drain of the MOSFET with a 1N5817-9 Schottky flyback diode across it.**

3. **Interface the optical slotted switch with the controller. The optical switch has an integrated IR LED (GREY = anode, BROWN = cathode) and a NPN phototransistor (VIOLET = collector, BLUE = emitter). When light is allowed to pass from LED to phototransistor, the phototransistor will turn on. Ground the cathode and emitter. Power the LED through a 220 ohm resistor from 3.3V. Connect the collector through a 4.7k ohm resistor to 3.3V. The collector is then connected to a timer CCP input on the TM4C123GXL board to read the status.**

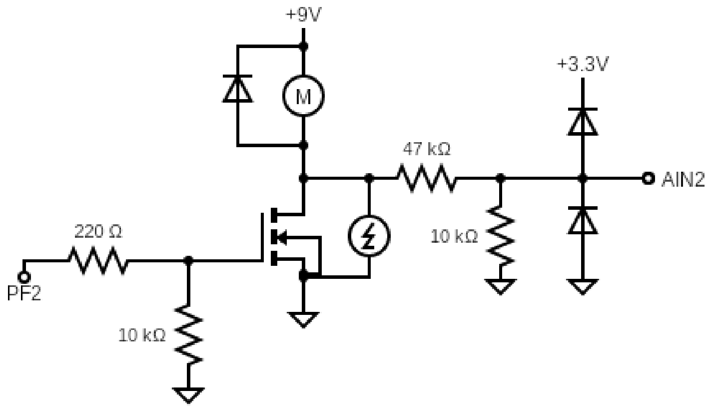
4. **Now configure the software to turn on the motor at a requested duty cycle (start with 50% DC). Use push button 1 and 2 on the red board to increase and decrease the PWM.**

5. **In the main loop, display the rpm of the motor, calculated by a timer interrupt based on the freq_time example, at regular intervals on the UART.**

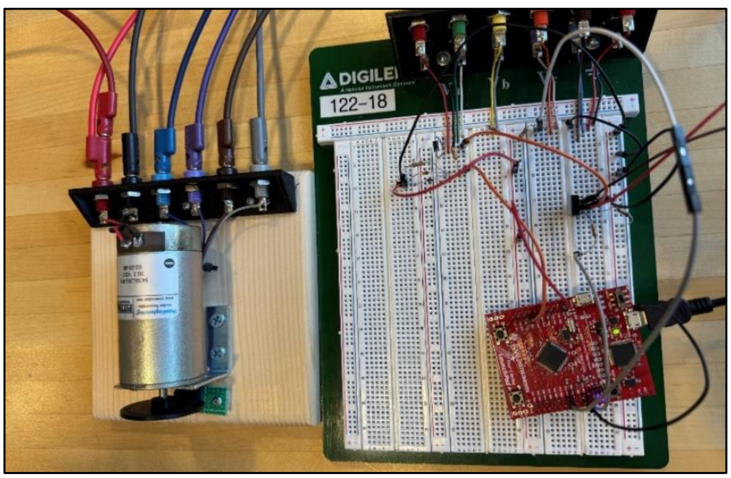
6. **To sense the back EMF voltage of the motor to determine speed, the drain is connected to a 47kohm resistor at the top of a resistor divider with a 10kohm resistor to ground. This output is then fed to an analog input on the controller.**

7. **Now, configure another timer fire at a 50 Hz rate. In that interrupt, momentarily stop the motor (zero the PWM), wait for the magnetic dump from the motor to complete, measure the back-emf voltage on the analog input, and then restore the previous PWM value.**

Circuit Diagram



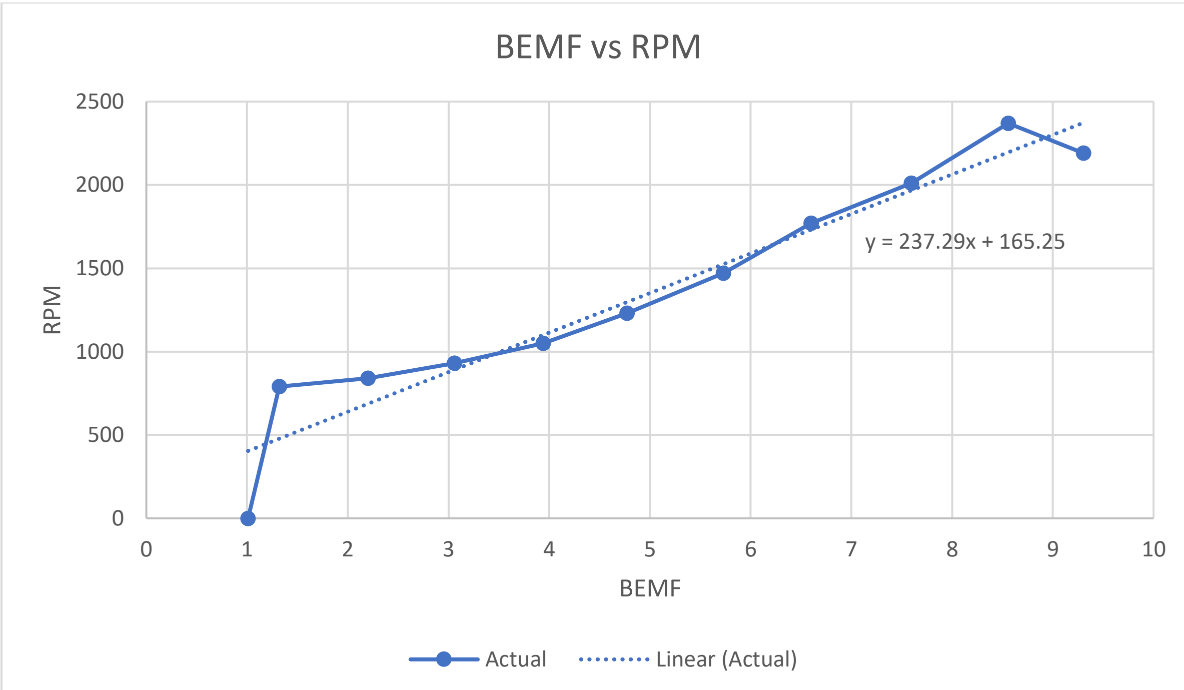
Actual Circuit Built



Oscilloscope Capture of Back EMF @ 50% duty Cycle

8. Then empirically derive the correlation between back-emf voltage and rpm (include this calculation in your report).

BEMF vs RPM Graph



The above graph shows the relationship between BackEMF and RPM based on our findings.

The RPM was calculated using the CCP input pin (PC4), which was read every second through an ISR. The captured value represented the number of pulses detected, corresponding to the slits on the disk. To convert this to RPM, the pulse count was divided by 32 (the number of slits on the encoder) and then multiplied by 60 to account for seconds per minute. The resulting RPM value was then displayed on Putty, to then use in Excel.

The BackEMF was calculated using the ADC input pin (PE1), which was read every 50hz through another ISR. The capture value of the ADC was the Inverse-BackEMF, so this raw value had to be changed accordingly to the 3.3V scale of the Tiva Board with the following equation:

$$InverseBEMF = \frac{(rawADC + 0.5)}{4096} * 3.3$$

Once the Inverse-BackEMF was calculated, it was used to calculate the actual Back-EMF votage with the following equation:

$$ActualBEMF = 10 - InverseBEMF * \frac{47 + 10}{10}$$

This value was then also displayed on Putty, to then use in Excel.

Several values of BackEMF and RPM were collected across different PWM percentages and averaged out in Excel to then be graphed.

Collected Data

PWM	RPM	Inverse Back EMF	Back EMF	Estimated RPM
0	0	1.58	1.01	404.90
10	790	1.53	1.319	478.22
20	840	1.37	2.20	687.50
30	930	1.22	3.06	890.80
40	1050	1.06	3.94	1099.61
50	1230	0.92	4.77	1297.87
60	1470	0.75	5.73	1524.15
70	1770	0.60	6.60	1731.06
80	2010	0.42	7.59	1967.15
90	2370	0.25	8.56	2195.42
100	2190	0.12	9.30	2372.90

The data above was gathered from multiple measurements to study the relationships between PWM, RPM, and Back EMF(BEMF). The PWM values were set through software, and the motor RPM was measured using a CCP input from the redboard, which counted the falling edges of a phototransistor attached to the motor. The BEMF was obtained by measuring the voltage at the MOSFET drain using an analog input pin, which was then used to determine the inverse BEMF.

The results show a positive linear relationship between both PWM and Back EMF, as well as between PWM and RPM. Using these relationships, a linear equation was derived to estimate RPM based on the measured Back EMF: 237.29(BEMF) + 165.25.

9. Display both the frequency counter derived speed and the back-emf derived speed on UART at regular intervals in the main loop.

```
PWM: 0  rpm: 0  Inv-BEMF: 1.61 V        Back-EMF: 0.81 V        estimate rpm: 257.11
PWM: 105        rpm: 600        Inv-BEMF: 1.56 V        Back-EMF: 1.10 V        estimate rpm: 326.85
PWM: 204        rpm: 540        Inv-BEMF: 1.39 V        Back-EMF: 2.10 V        estimate rpm: 564.40
PWM: 306        rpm: 660        Inv-BEMF: 1.22 V        Back-EMF: 3.06 V        estimate rpm: 792.15
PWM: 408        rpm: 840        Inv-BEMF: 1.07 V        Back-EMF: 3.90 V        estimate rpm: 991.57
PWM: 510        rpm: 1020       Inv-BEMF: 0.90 V        Back-EMF: 4.89 V        estimate rpm: 1225.85
PWM: 612        rpm: 1140       Inv-BEMF: 0.74 V        Back-EMF: 5.79 V        estimate rpm: 1439.44
PWM: 714        rpm: 1440       Inv-BEMF: 0.60 V        Back-EMF: 6.58 V        estimate rpm: 1626.87
PWM: 816        rpm: 1620       Inv-BEMF: 0.42 V        Back-EMF: 7.59 V        estimate rpm: 1865.51
PWM: 918        rpm: 1920       Inv-BEMF: 0.24 V        Back-EMF: 8.64 V        estimate rpm: 2116.14
PWM: 1023       rpm: 2160       Inv-BEMF: 0.10 V        Back-EMF: 9.46 V        estimate rpm: 2309.02
```

The above picture shows the measured readings at different PWM percentages (0%-100%). However, these values are not as accurate since the PWM was increased rather fast and this led to some fluctuations in the data.

10. Determine the range of rpm over which the back-emf derived speed calculation is correct (include this in your report).

The range of the PMP over which the Back EMF derived speed calculation is correct turned out to be 40%-90%.

This entails that the range for the RMP would be 800-2000.