CSE 4355/5355 - Mechatronics Lab 3

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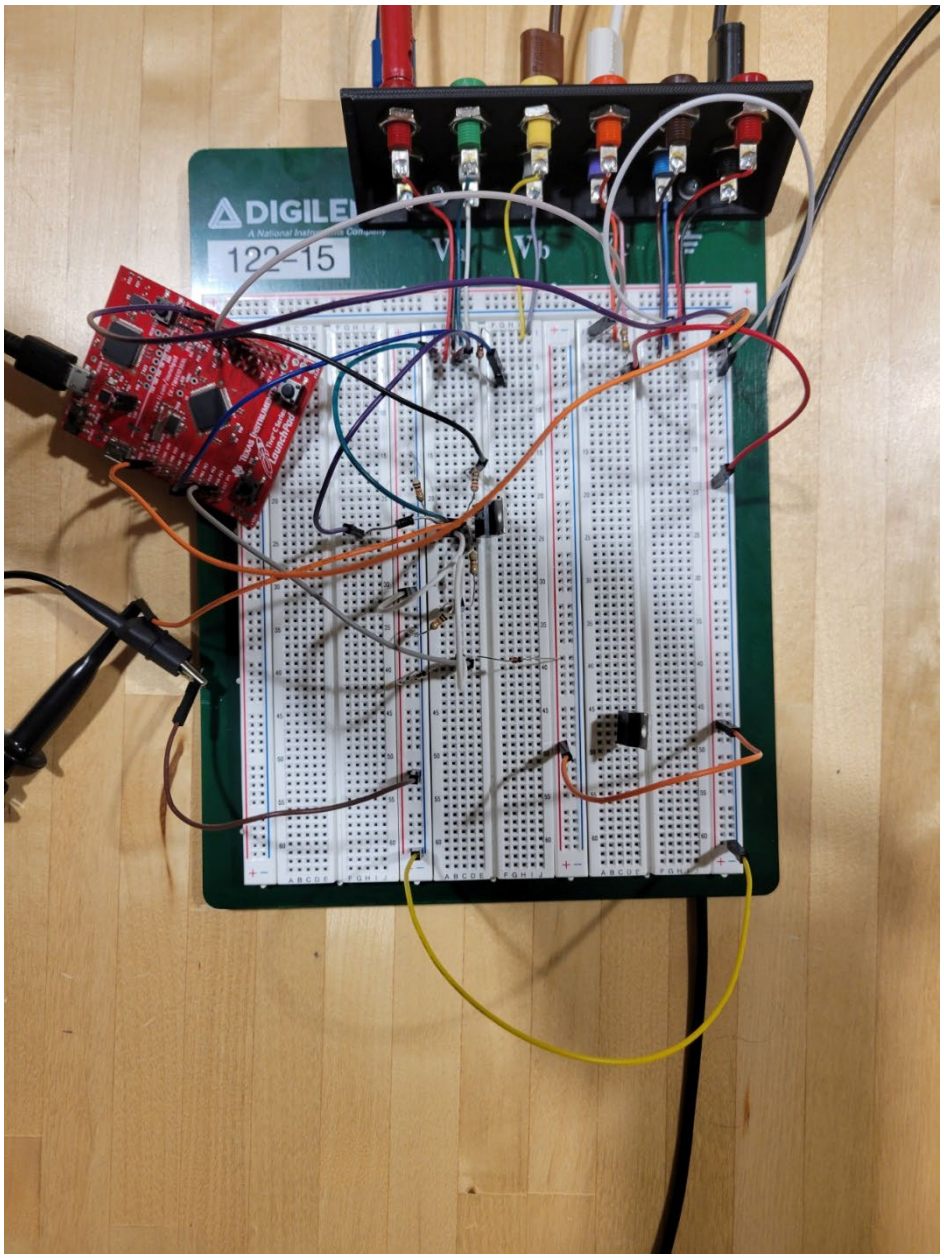
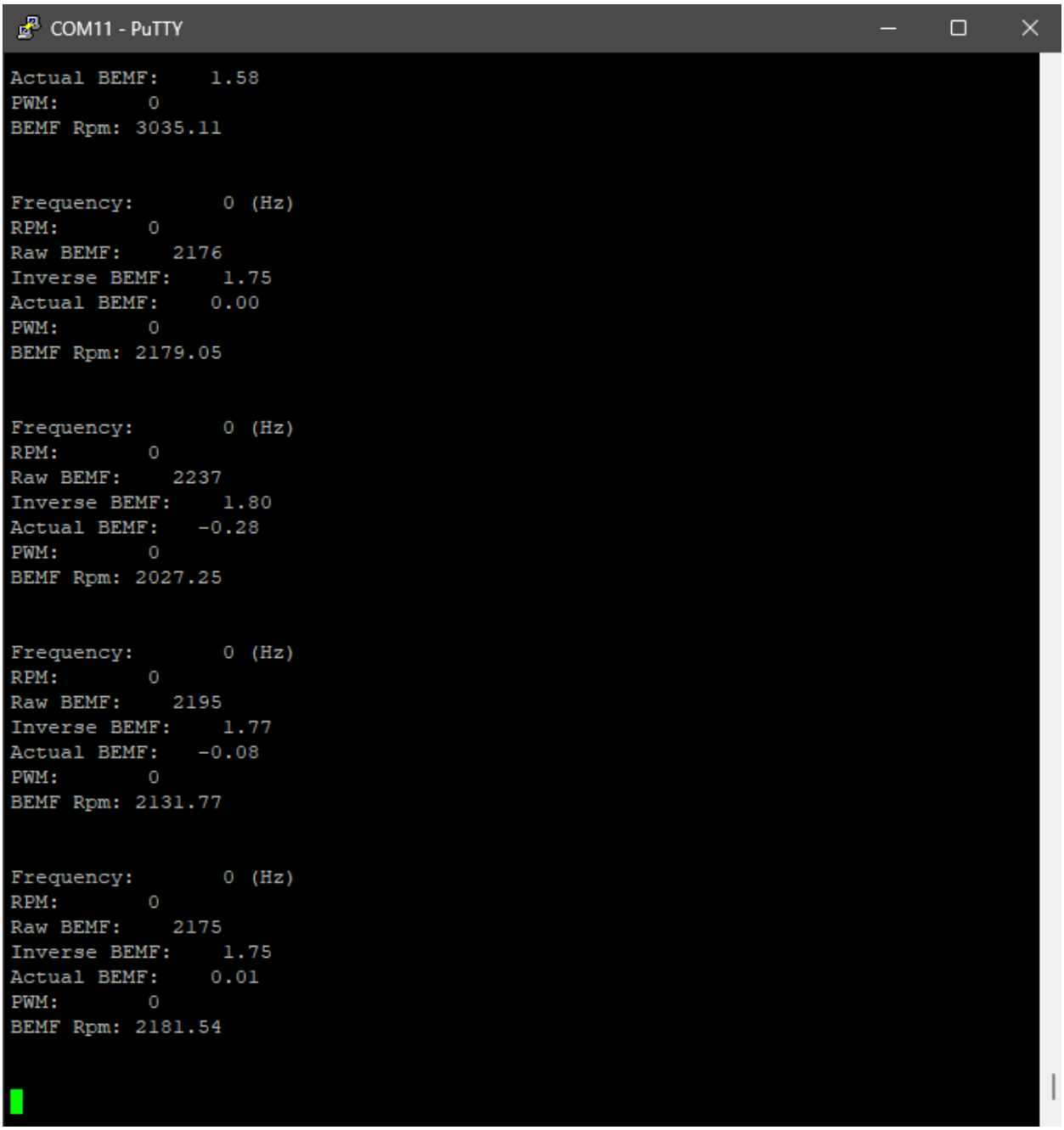
The circuit

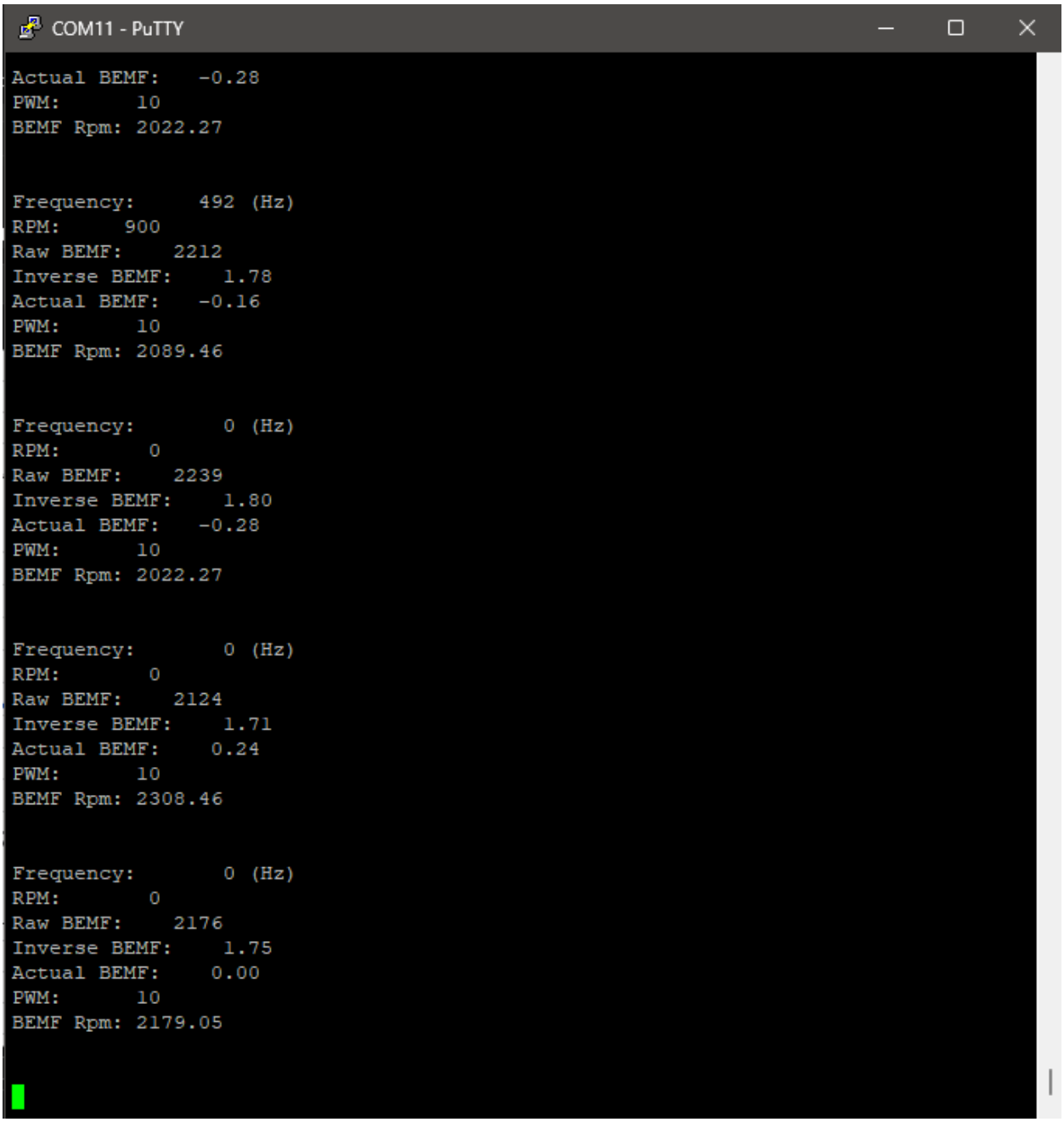


Back EMF Observations:

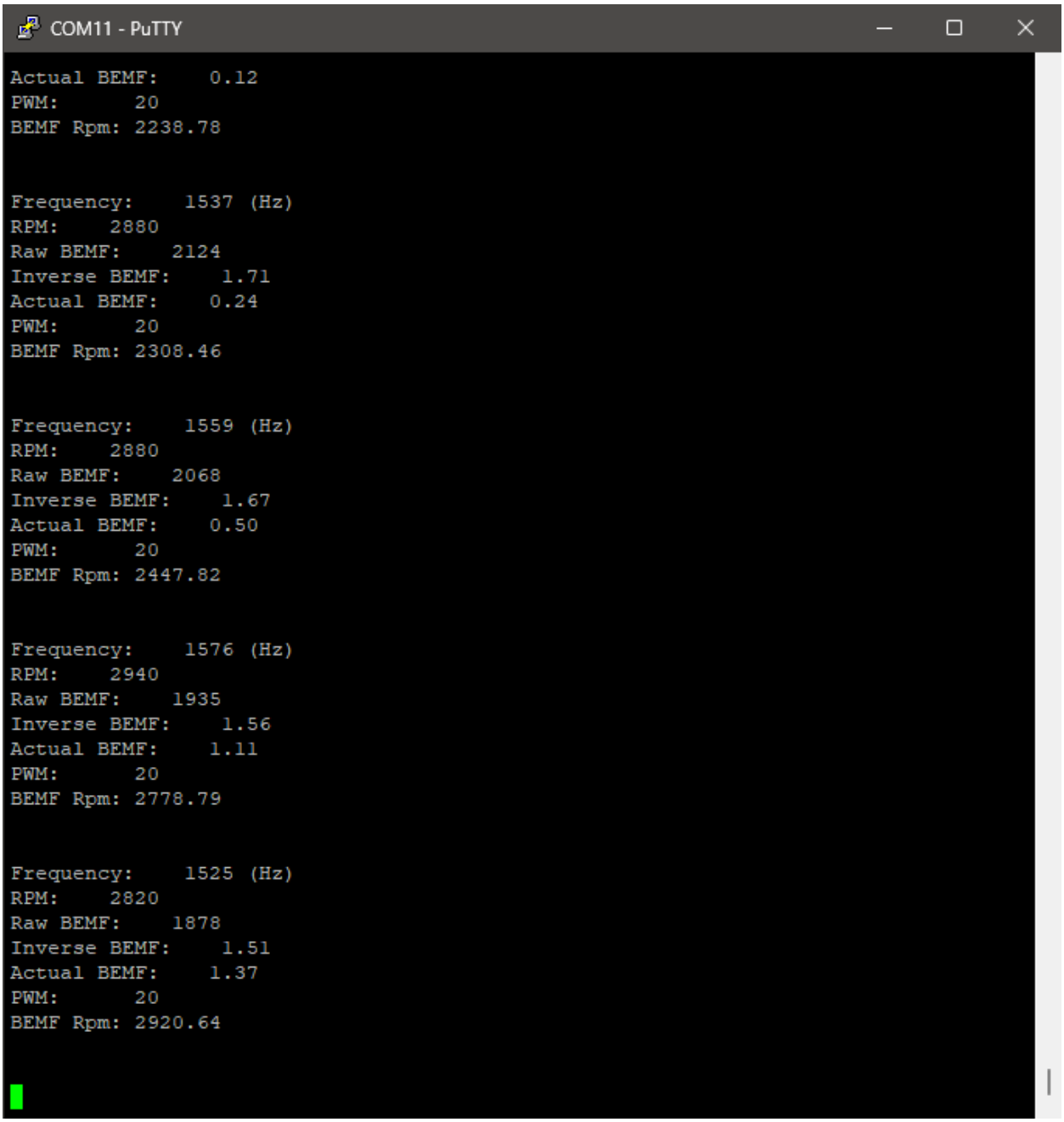
- PWM: 0



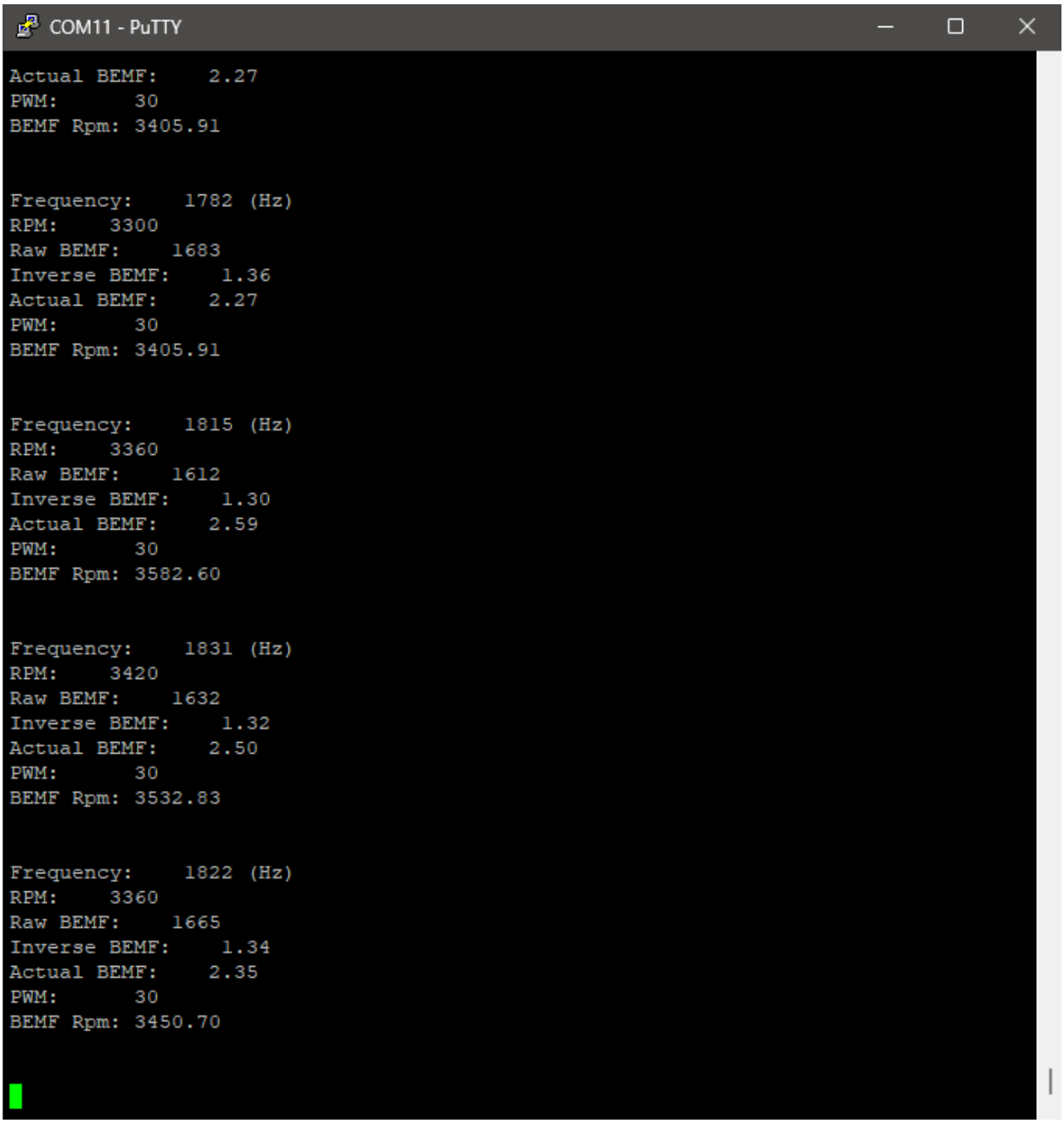
- PWM: 10


COM11 - PuTTY
Actual BEMF: -0.28
PWM: 10
BEMF Rpm: 2022.27
Frequency: 492 (Hz)
RPM: 900
Raw BEMF: 2212
Inverse BEMF: 1.78
Actual BEMF: -0.16
PWM: 10
BEMF Rpm: 2089.46
Frequency: 0 (Hz)
RPM: 0
Raw BEMF: 2239
Inverse BEMF: 1.80
Actual BEMF: -0.28
PWM: 10
BEMF Rpm: 2022.27
Frequency: 0 (Hz)
RPM: 0
Raw BEMF: 2124
Inverse BEMF: 1.71
Actual BEMF: 0.24
PWM: 10
BEMF Rpm: 2308.46
Frequency: 0 (Hz)
RPM: 0
Raw BEMF: 2176
Inverse BEMF: 1.75
Actual BEMF: 0.00
PWM: 10
BEMF Rpm: 2179.05

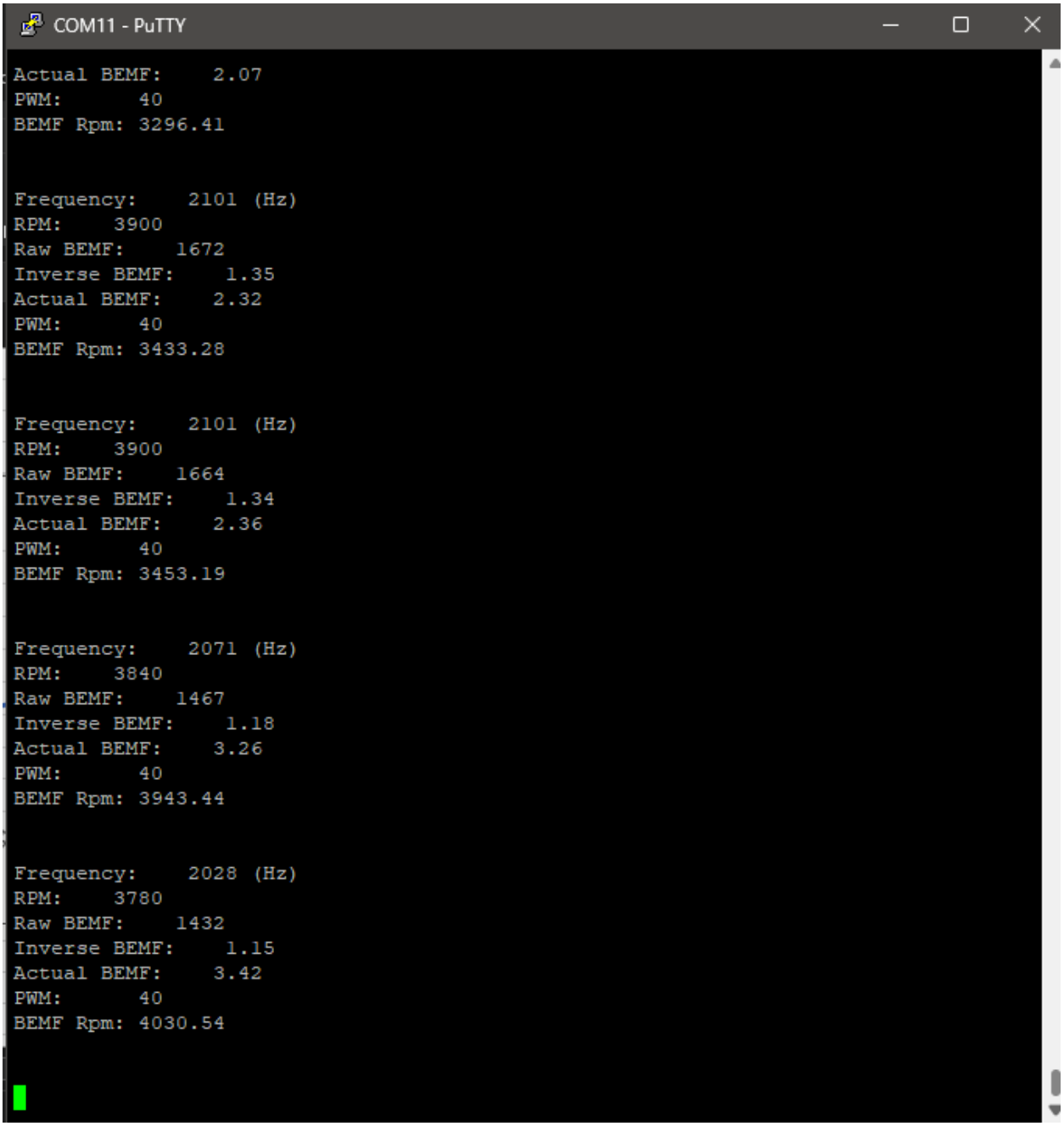
- PWM: 20


COM11 - PuTTY
Actual BEMF: 0.12
PWM: 20
BEMF Rpm: 2238.78
Frequency: 1537 (Hz)
RPM: 2880
Raw BEMF: 2124
Inverse BEMF: 1.71
Actual BEMF: 0.24
PWM: 20
BEMF Rpm: 2308.46
Frequency: 1559 (Hz)
RPM: 2880
Raw BEMF: 2068
Inverse BEMF: 1.67
Actual BEMF: 0.50
PWM: 20
BEMF Rpm: 2447.82
Frequency: 1576 (Hz)
RPM: 2940
Raw BEMF: 1935
Inverse BEMF: 1.56
Actual BEMF: 1.11
PWM: 20
BEMF Rpm: 2778.79
Frequency: 1525 (Hz)
RPM: 2820
Raw BEMF: 1878
Inverse BEMF: 1.51
Actual BEMF: 1.37
PWM: 20
BEMF Rpm: 2920.64

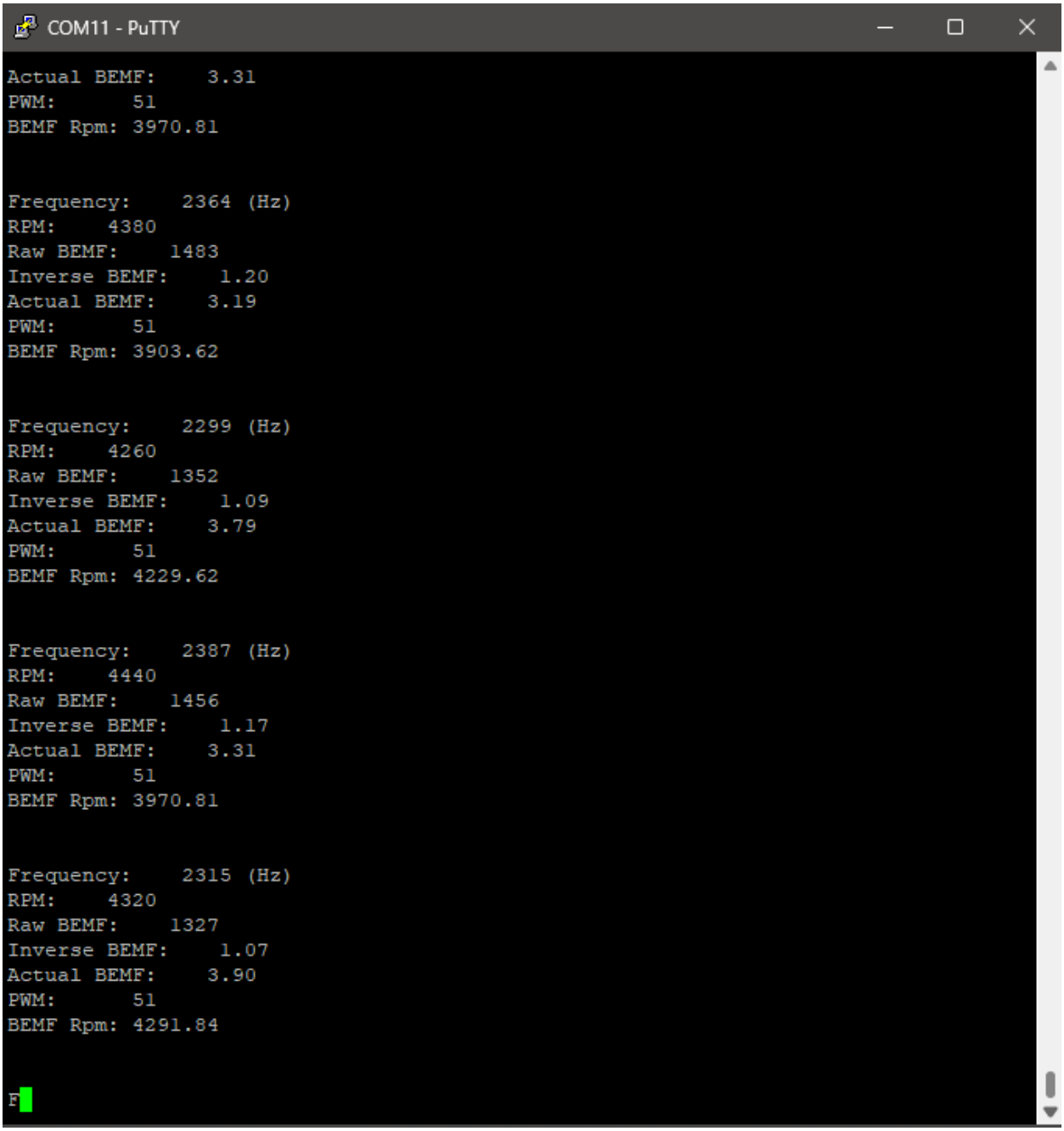
- PWM: 30


COM11 - PuTTY
Actual BEMF: 2.27
PWM: 30
BEMF Rpm: 3405.91
Frequency: 1782 (Hz)
RPM: 3300
Raw BEMF: 1683
Inverse BEMF: 1.36
Actual BEMF: 2.27
PWM: 30
BEMF Rpm: 3405.91
Frequency: 1815 (Hz)
RPM: 3360
Raw BEMF: 1612
Inverse BEMF: 1.30
Actual BEMF: 2.59
PWM: 30
BEMF Rpm: 3582.60
Frequency: 1831 (Hz)
RPM: 3420
Raw BEMF: 1632
Inverse BEMF: 1.32
Actual BEMF: 2.50
PWM: 30
BEMF Rpm: 3532.83
Frequency: 1822 (Hz)
RPM: 3360
Raw BEMF: 1665
Inverse BEMF: 1.34
Actual BEMF: 2.35
PWM: 30
BEMF Rpm: 3450.70

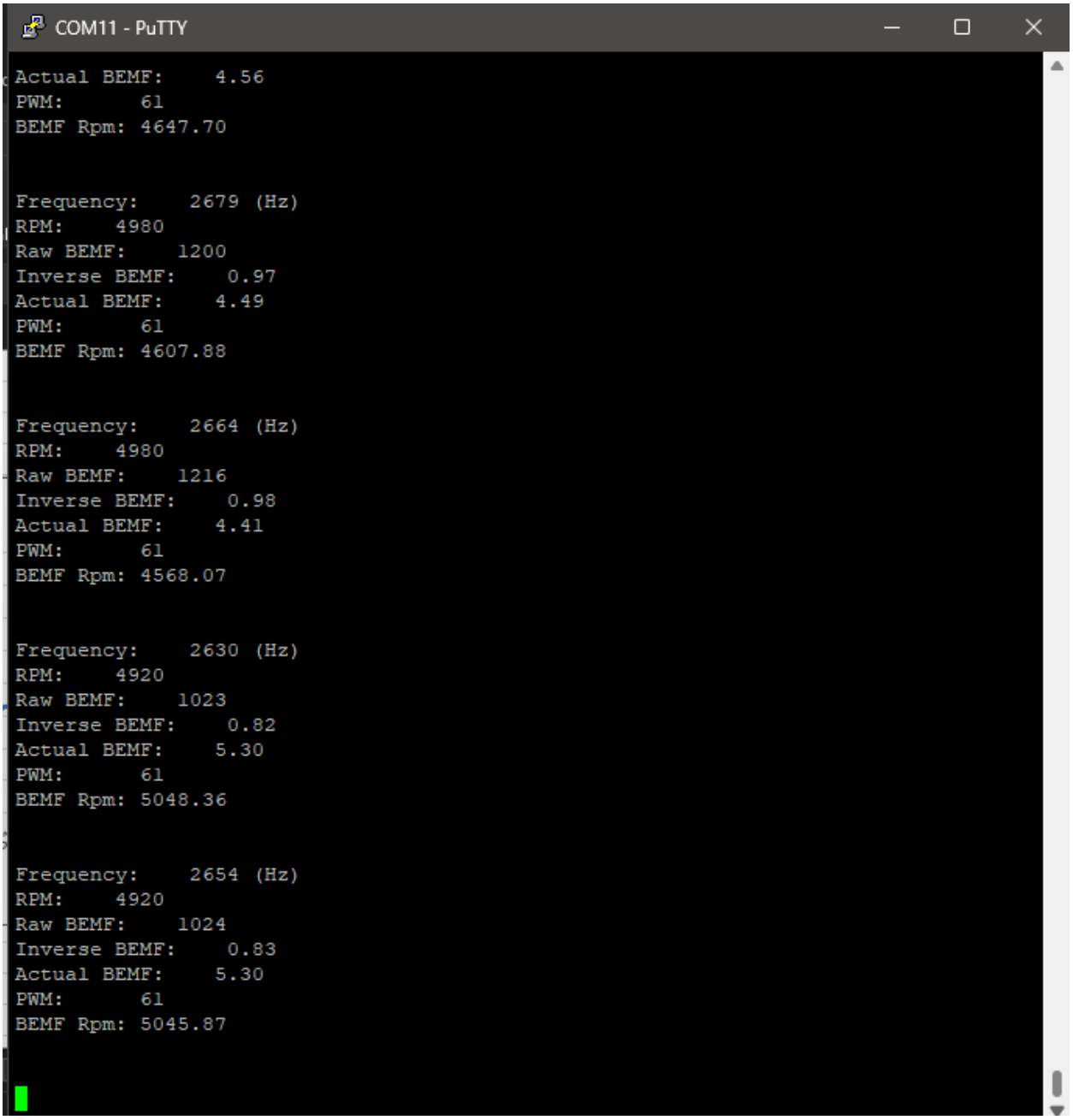
- PWM: 40


COM11 - PuTTY
Actual BEMF: 2.07
PWM: 40
BEMF Rpm: 3296.41
Frequency: 2101 (Hz)
RPM: 3900
Raw BEMF: 1672
Inverse BEMF: 1.35
Actual BEMF: 2.32
PWM: 40
BEMF Rpm: 3433.28
Frequency: 2101 (Hz)
RPM: 3900
Raw BEMF: 1664
Inverse BEMF: 1.34
Actual BEMF: 2.36
PWM: 40
BEMF Rpm: 3453.19
Frequency: 2071 (Hz)
RPM: 3840
Raw BEMF: 1467
Inverse BEMF: 1.18
Actual BEMF: 3.26
PWM: 40
BEMF Rpm: 3943.44
Frequency: 2028 (Hz)
RPM: 3780
Raw BEMF: 1432
Inverse BEMF: 1.15
Actual BEMF: 3.42
PWM: 40
BEMF Rpm: 4030.54

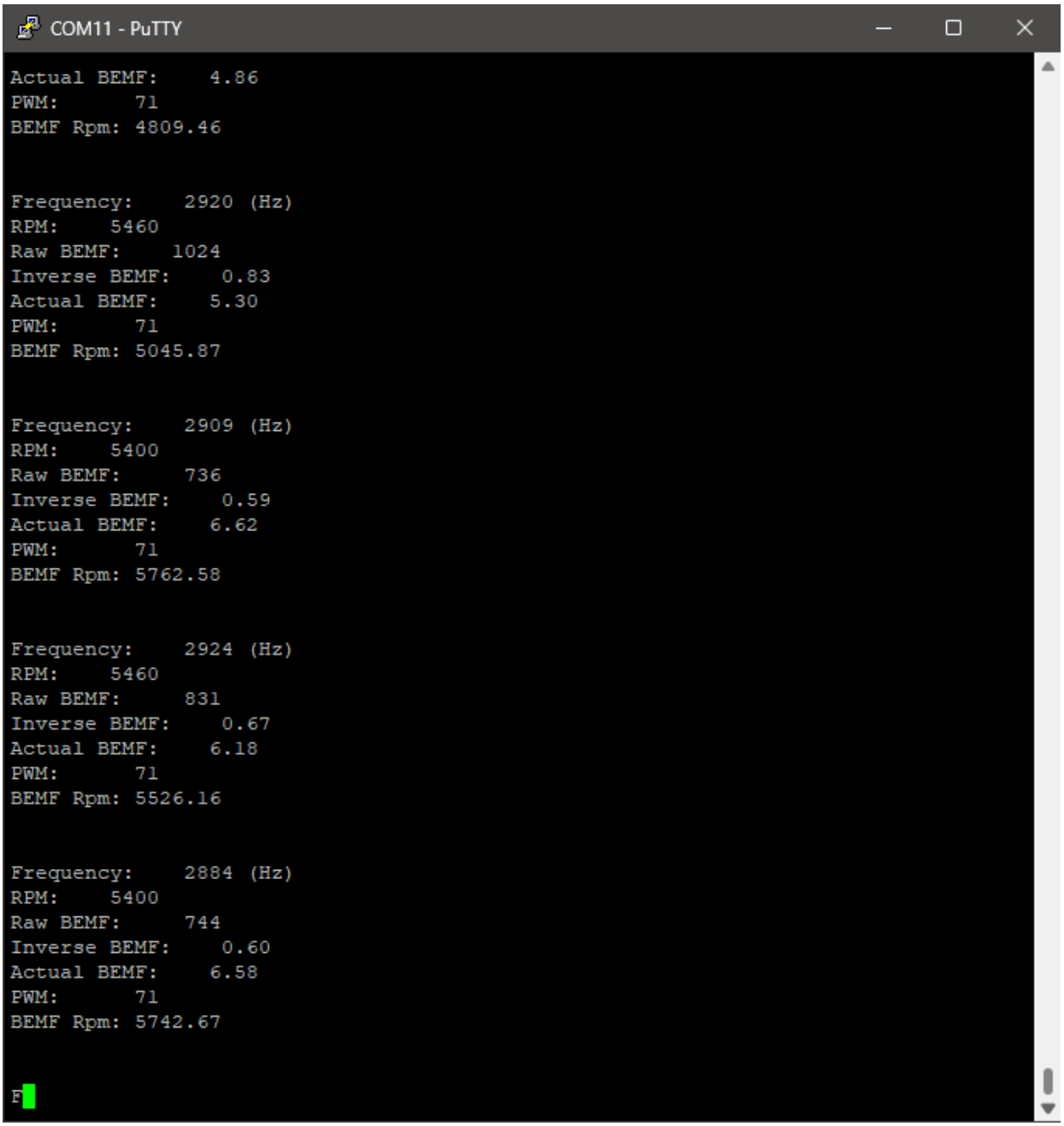
- PWM: 50


COM11 - PuTTY
Actual BEMF: 3.31
PWM: 51
BEMF Rpm: 3970.81
Frequency: 2364 (Hz)
RPM: 4380
Raw BEMF: 1483
Inverse BEMF: 1.20
Actual BEMF: 3.19
PWM: 51
BEMF Rpm: 3903.62
Frequency: 2299 (Hz)
RPM: 4260
Raw BEMF: 1352
Inverse BEMF: 1.09
Actual BEMF: 3.79
PWM: 51
BEMF Rpm: 4229.62
Frequency: 2387 (Hz)
RPM: 4440
Raw BEMF: 1456
Inverse BEMF: 1.17
Actual BEMF: 3.31
PWM: 51
BEMF Rpm: 3970.81
Frequency: 2315 (Hz)
RPM: 4320
Raw BEMF: 1327
Inverse BEMF: 1.07
Actual BEMF: 3.90
PWM: 51
BEMF Rpm: 4291.84
F

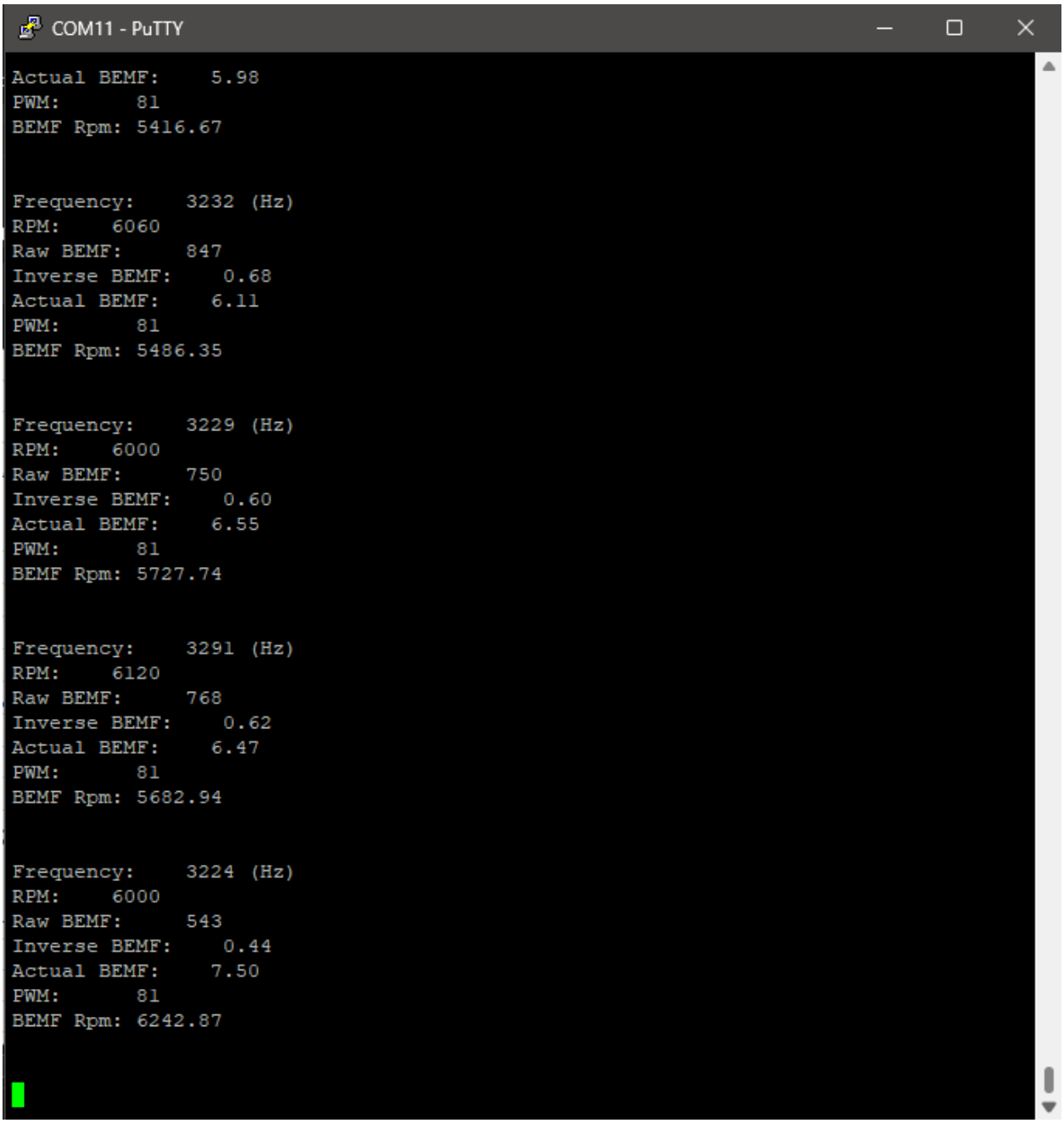
- PWM: 60


COM11 - PuTTY
Actual BEMF: 4.56
PWM: 61
BEMF Rpm: 4647.70
Frequency: 2679 (Hz)
RPM: 4980
Raw BEMF: 1200
Inverse BEMF: 0.97
Actual BEMF: 4.49
PWM: 61
BEMF Rpm: 4607.88
Frequency: 2664 (Hz)
RPM: 4980
Raw BEMF: 1216
Inverse BEMF: 0.98
Actual BEMF: 4.41
PWM: 61
BEMF Rpm: 4568.07
Frequency: 2630 (Hz)
RPM: 4920
Raw BEMF: 1023
Inverse BEMF: 0.82
Actual BEMF: 5.30
PWM: 61
BEMF Rpm: 5048.36
Frequency: 2654 (Hz)
RPM: 4920
Raw BEMF: 1024
Inverse BEMF: 0.83
Actual BEMF: 5.30
PWM: 61
BEMF Rpm: 5045.87

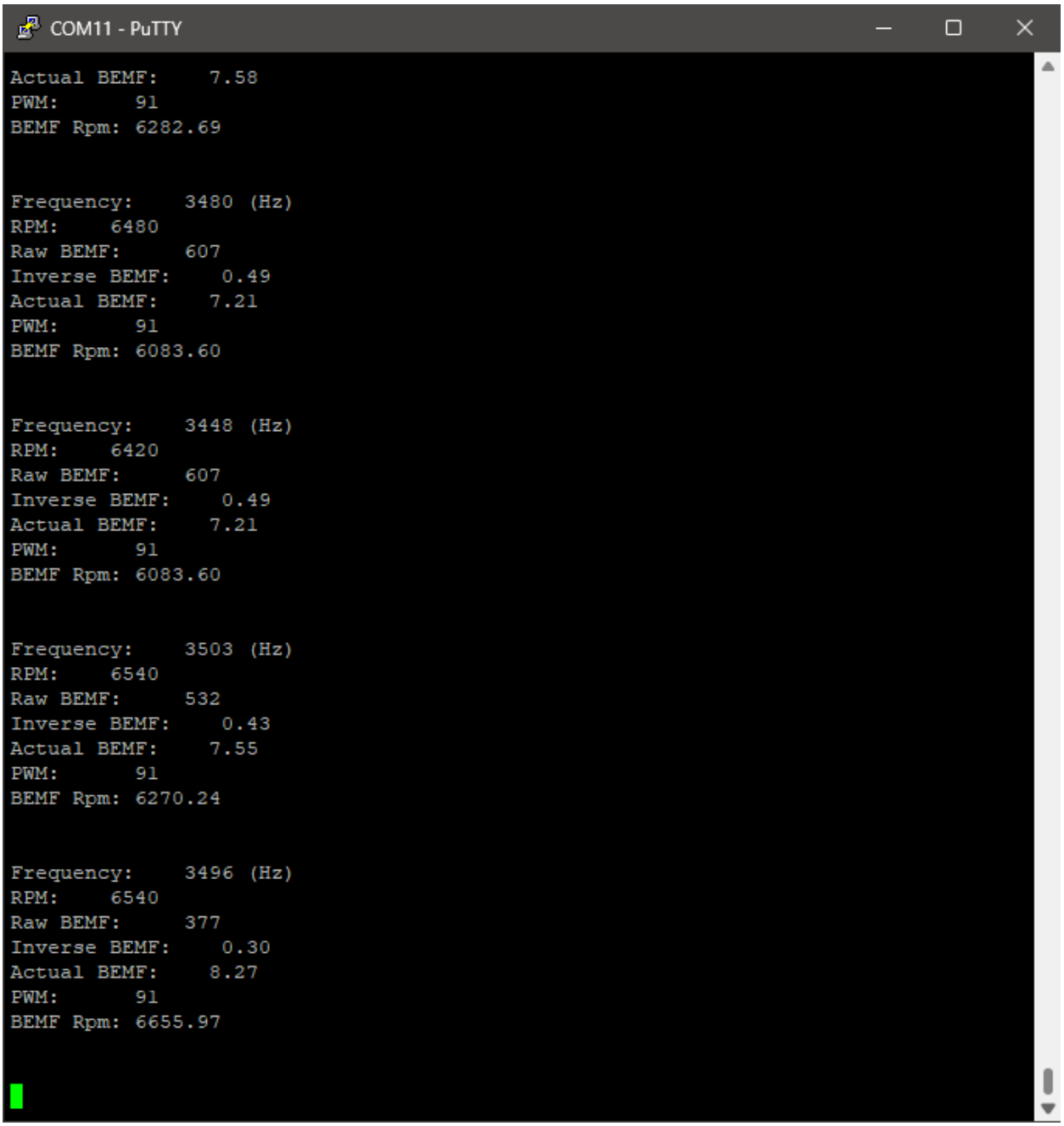
- PWM: 70


COM11 - PuTTY
Actual BEMF: 4.86
PWM: 71
BEMF Rpm: 4809.46
Frequency: 2920 (Hz)
RPM: 5460
Raw BEMF: 1024
Inverse BEMF: 0.83
Actual BEMF: 5.30
PWM: 71
BEMF Rpm: 5045.87
Frequency: 2909 (Hz)
RPM: 5400
Raw BEMF: 736
Inverse BEMF: 0.59
Actual BEMF: 6.62
PWM: 71
BEMF Rpm: 5762.58
Frequency: 2924 (Hz)
RPM: 5460
Raw BEMF: 831
Inverse BEMF: 0.67
Actual BEMF: 6.18
PWM: 71
BEMF Rpm: 5526.16
Frequency: 2884 (Hz)
RPM: 5400
Raw BEMF: 744
Inverse BEMF: 0.60
Actual BEMF: 6.58
PWM: 71
BEMF Rpm: 5742.67
F

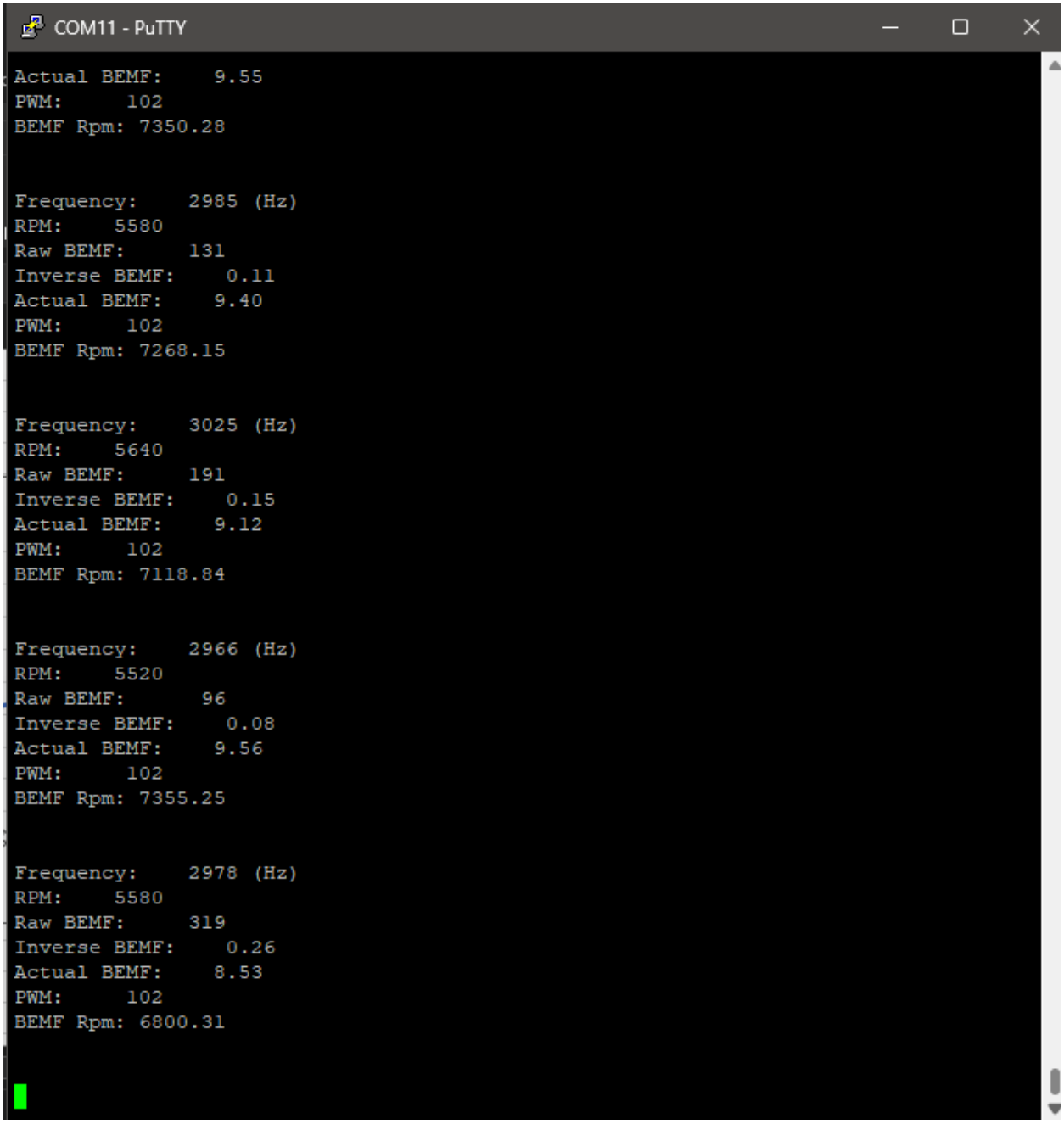
- PWM: 80


COM11 - PuTTY
Actual BEMF: 5.98
PWM: 81
BEMF Rpm: 5416.67
Frequency: 3232 (Hz)
RPM: 6060
Raw BEMF: 847
Inverse BEMF: 0.68
Actual BEMF: 6.11
PWM: 81
BEMF Rpm: 5486.35
Frequency: 3229 (Hz)
RPM: 6000
Raw BEMF: 750
Inverse BEMF: 0.60
Actual BEMF: 6.55
PWM: 81
BEMF Rpm: 5727.74
Frequency: 3291 (Hz)
RPM: 6120
Raw BEMF: 768
Inverse BEMF: 0.62
Actual BEMF: 6.47
PWM: 81
BEMF Rpm: 5682.94
Frequency: 3224 (Hz)
RPM: 6000
Raw BEMF: 543
Inverse BEMF: 0.44
Actual BEMF: 7.50
PWM: 81
BEMF Rpm: 6242.87

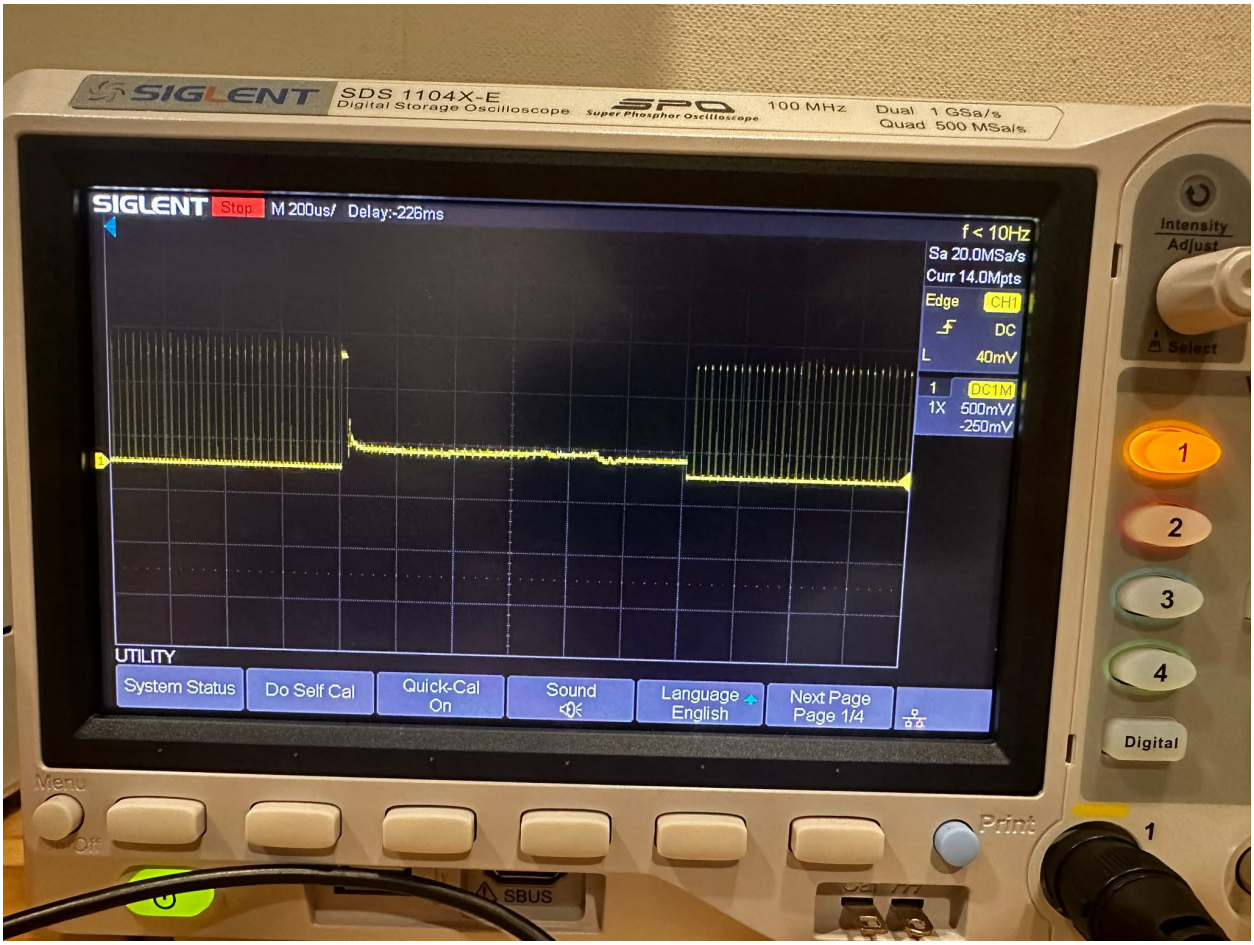
- PWM: 90


COM11 - PuTTY
Actual BEMF: 7.58
PWM: 91
BEMF Rpm: 6282.69
Frequency: 3480 (Hz)
RPM: 6480
Raw BEMF: 607
Inverse BEMF: 0.49
Actual BEMF: 7.21
PWM: 91
BEMF Rpm: 6083.60
Frequency: 3448 (Hz)
RPM: 6420
Raw BEMF: 607
Inverse BEMF: 0.49
Actual BEMF: 7.21
PWM: 91
BEMF Rpm: 6083.60
Frequency: 3503 (Hz)
RPM: 6540
Raw BEMF: 532
Inverse BEMF: 0.43
Actual BEMF: 7.55
PWM: 91
BEMF Rpm: 6270.24
Frequency: 3496 (Hz)
RPM: 6540
Raw BEMF: 377
Inverse BEMF: 0.30
Actual BEMF: 8.27
PWM: 91
BEMF Rpm: 6655.97

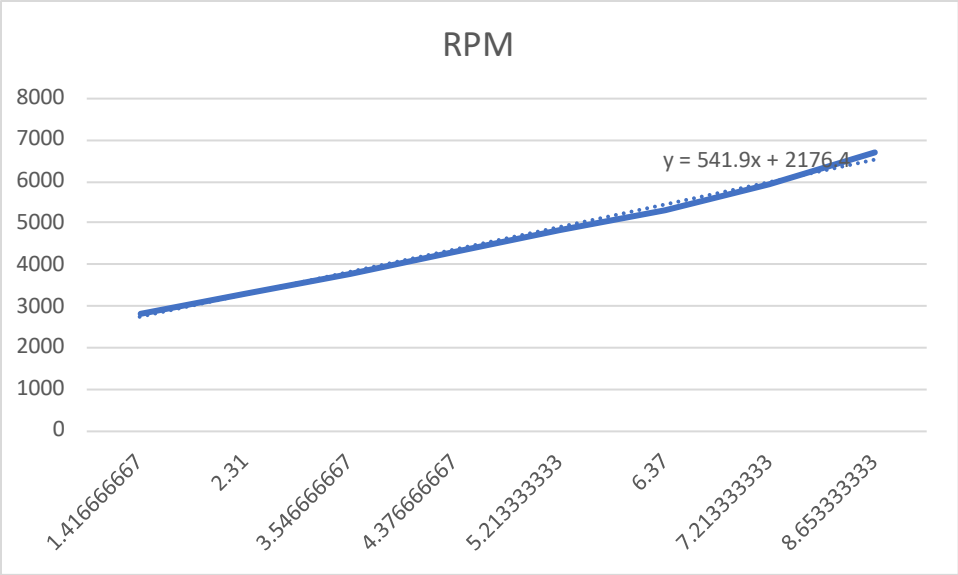
- PWM: 100


COM11 - PuTTY
Actual BEMF: 9.55
PWM: 102
BEMF Rpm: 7350.28
Frequency: 2985 (Hz)
RPM: 5580
Raw BEMF: 131
Inverse BEMF: 0.11
Actual BEMF: 9.40
PWM: 102
BEMF Rpm: 7268.15
Frequency: 3025 (Hz)
RPM: 5640
Raw BEMF: 191
Inverse BEMF: 0.15
Actual BEMF: 9.12
PWM: 102
BEMF Rpm: 7118.84
Frequency: 2966 (Hz)
RPM: 5520
Raw BEMF: 96
Inverse BEMF: 0.08
Actual BEMF: 9.56
PWM: 102
BEMF Rpm: 7355.25
Frequency: 2978 (Hz)
RPM: 5580
Raw BEMF: 319
Inverse BEMF: 0.26
Actual BEMF: 8.53
PWM: 102
BEMF Rpm: 6800.31

Back EMF Magnetic Dump Oscilloscope Observation:



Plotted Back EMF as Observed:



Back EMF RPM only works from ranges 20-90% PWM Duty cycle. In the other cases, the Back EMF can be observed but is not consistent with the plotted observation line attached later in the report. The Back EMF observed for 0, 10 and 100% PWM duty cycle does not follow a linear relationship to the rest of the duty cycle values.

Code:

The working of code has been demonstrated in the Lab. The Back EMF is calculated by stopping the motor momentarily using a 1Hz interrupt timer. The Back EMF is considered using the readings of the ADC on the TM4C123GH6PM microcontroller, and then scaled to observable RPM value in the code and then verified to the actual calculated RPM from the wide timer's Compare Capture output. This lab demonstrated to us that a motor can also be a generator as observed from the Back EMF generated from stopping the motor momentarily before resuming the PWM duty cycle.