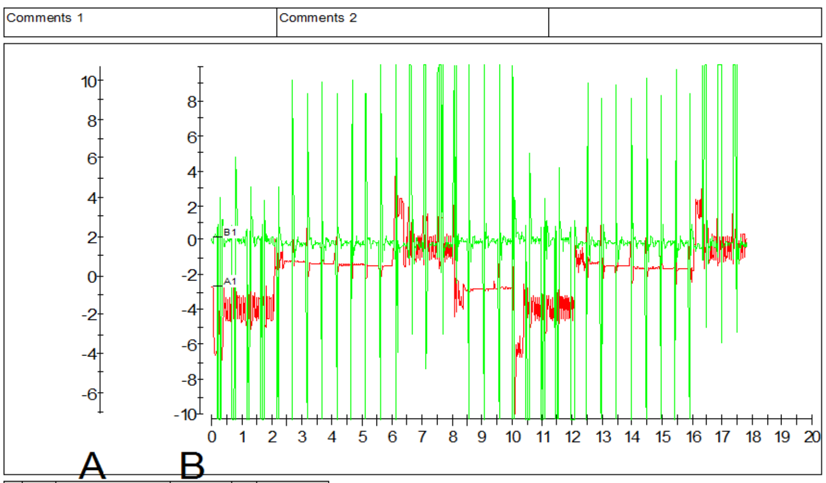
# *Example Data for* Electric Drives Experiment 5

## Four-Quadrant Operation of a PMDC Motor

The intent of this document is to provide example data for instructors and TAs, to help them prepare for the electric drives laboratory activities. This document is informal and does not represent a laboratory report.

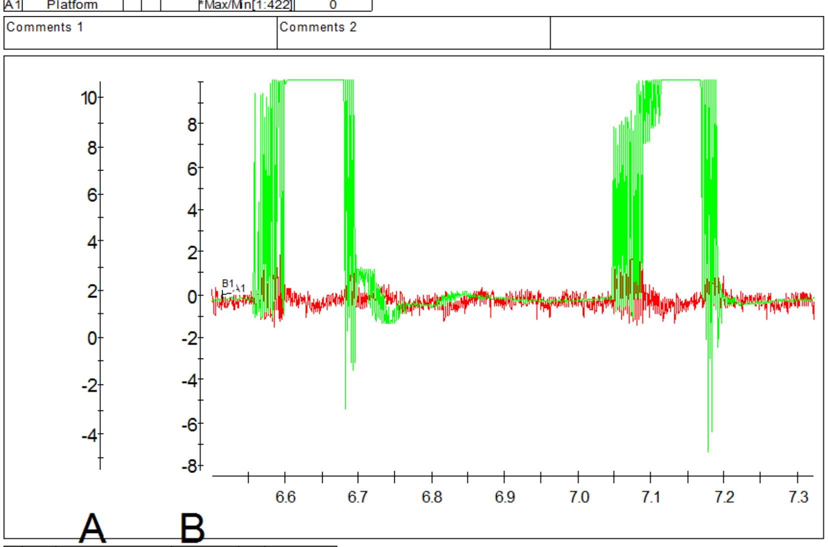
Checklist of items requested in these lab procedures:

☐ Save two images showing the PMDC motor's PWM-generated armature voltage – one image showing the waveform for at least 10 seconds and the other image showing a zoomed view of a few PWM cycles.




| ID | Color | Name | Value | Unit | Raster |
|---|---|---|---|---|---|
| B1 | | Va_Measured/Out1 | -0.112305 | | HostService |
| A1 | | Ia_Measured/Out1 | 1.62109 | | HostService |

| ID | Platform / Device | Y1 | Y2 | Y2-Y1 | Downsampling | X-Axis Offset |
|---|---|---|---|---|---|---|
| B1 | Platform | | | | *Max/Min[1:422] | 0 |
| A1 | Platform | | | | *Max/Min[1:422] | 0 |

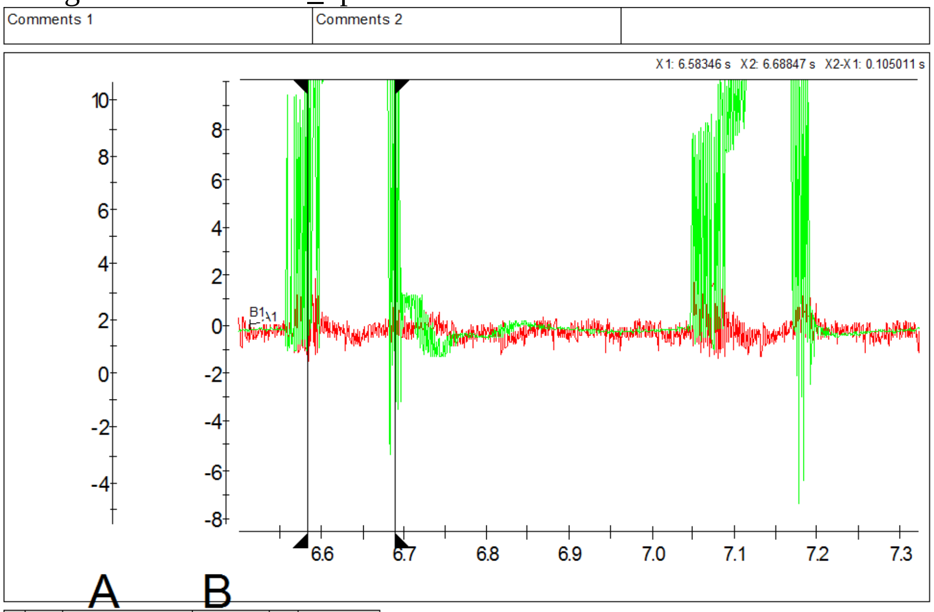



| ID | Color | Name | Value | Unit | Raster |
|---|---|---|---|---|---|
| B1 | | Va_Measured/Out1 | -0.0830078 | | HostService |
| A1 | | Ia_Measured/Out1 | 1.83594 | | HostService |

| ID | Platform / Device | Y1 | Y2 | Y2-Y1 | Downsampling | X-Axis Offset |
|---|---|---|---|---|---|---|
| B1 | Platform | | | | *Max/Min[1:17] | 0 |
| A1 | Platform | | | | *Max/Min[1:17] | 0 |

☐ Estimate the duty ratio of the PWM signal from the zoomed graph. Show your work.

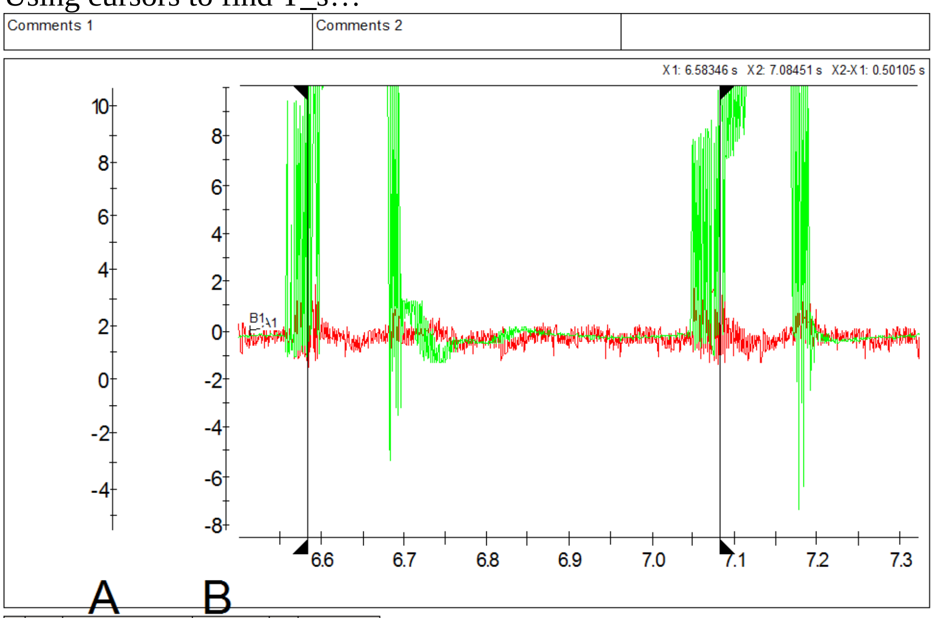
Using Cursors to find T_up…




| ID | Color | Name | Value | Unit | Raster |
|---|---|---|---|---|---|
| B1 | | Va_Measured/Out1 | -0.0830078 | | HostService |
| A1 | | Ia_Measured/Out1 | 1.83594 | | HostService |

| ID | Platform / Device | Y1 | Y2 | Y2-Y1 | Downsampling | X-Axis Offset |
|---|---|---|---|---|---|---|
| B1 | Platform | 9.99512 | 9.99512 | 0 | *Max/Min[1:17] | 0 |
| A1 | Platform | 0.791016 | 1.025390 | 0.234375 | *Max/Min[1:17] | 0 |

Using cursors to find T_s…




| ID | Color | Name | Value | Unit | Raster |
|---|---|---|---|---|---|
| B1 | | Va_Measured/Out1 | -0.0830078 | | HostService |
| A1 | | Ia_Measured/Out1 | 1.83594 | | HostService |

| ID | Platform / Device | Y1 | Y2 | Y2-Y1 | Downsampling | X-Axis Offset |
|---|---|---|---|---|---|---|
| B1 | Platform | 9.99512 | 9.99512 | 0 | *Max/Min[1:17] | 0 |
| A1 | Platform | 0.791016 | 0.859375 | 0.0683594 | *Max/Min[1:17] | 0 |

Duty ratio = T_up / T_s = .105/.501 = 0.21

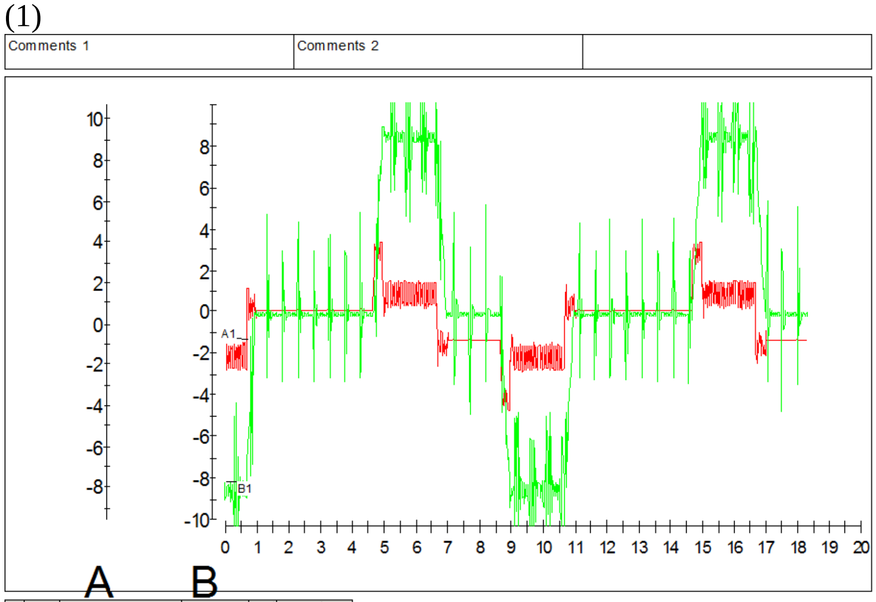
☐ Use the lab bench's multimeter to measure the RMS DC voltage across the motor's armature coil as the motor goes through the cycle of desired speeds. Record your observed RMS armature voltages. Given that the power electronic board's input DC voltage is 40 V, does your estimate for the duty ratio match with the measured RMS armature voltage? Explain your answer.

Va is approximately 9.0 Volts when the motor's speed is 100 radians/second, 0 V when the motor is not spinning, and -9.0 volts for -100 rad/s.

Expect Va = Vin x duty ratio = 40 x 0.21 = 8.4 V. The difference between this estimate and the measured value of 9.0 V is likely due to errors in measuring the times used to calculate the duty ratio (it's difficult to tell exactly when the transistor is on or off, due to the ringing).

☐ Save images showing the PMDC motor's (1) induced EMF and current, (2) torque and speed, and (3) electrical and mechanical power when a cascaded control system is in place and the speed is varied between 0, 100, and -100 radians/second.

(1)

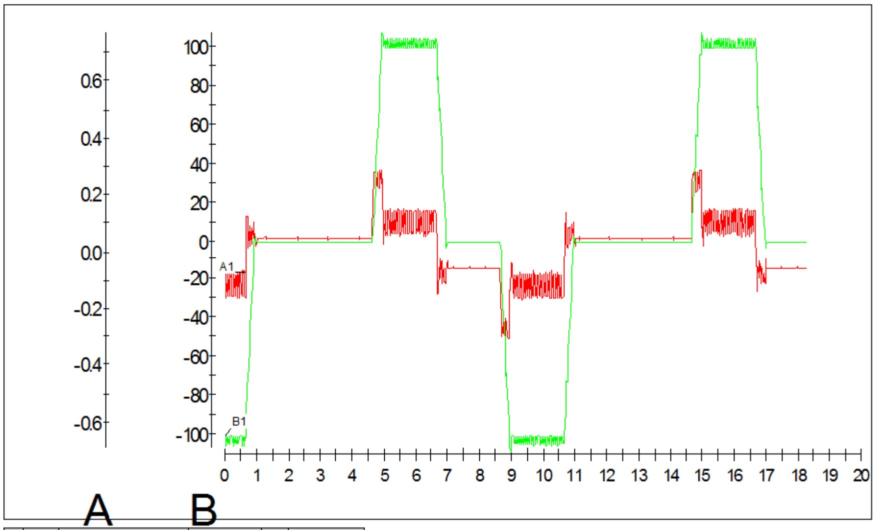



| ID | Color | Name | Value | Unit | Raster |
|---|---|---|---|---|---|
| B1 | | Va_Measured/Out1 | 0.0244141 | | HostService |
| A1 | | Ia_Measured/Out1 | -0.673828 | | HostService |

| ID | Platform / Device | Y1 | Y2 | Y2-Y1 | Downsampling | X-Axis Offset |
|---|---|---|---|---|---|---|
| B1 | Platform | | | | *Max/Min[1:422] | 0 |
| A1 | Platform | | | | *Max/Min[1:422] | 0 |

(2)

| Comments 1 | Comments 2 | |
|---|---|---|

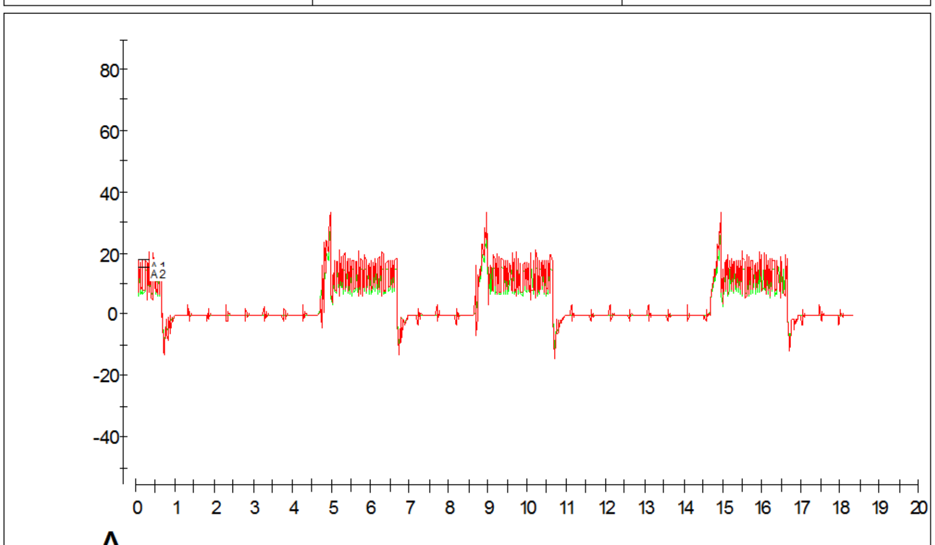



| ID | Color | Name | Value | Unit | Raster |
|---|---|---|---|---|---|
| B1 | | Wm_Measured/Out1 | 0 | | HostService |
| A1 | | Tem/In1 | -0.0485156 | | HostService |

| ID | Platform / Device | Y1 | Y2 | Y2-Y1 | Downsampling | X-Axis Offset |
|---|---|---|---|---|---|---|
| B1 | Platform | | | | *Max/Min[1:420] | 0 |
| A1 | Platform | | | | *Max/Min[1:420] | 0 |

(3)

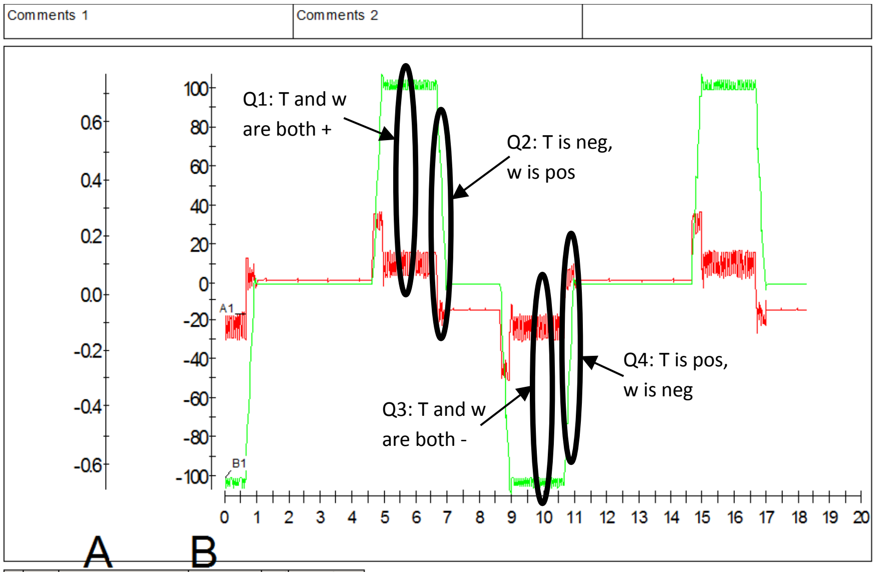
| Comments 1 | Comments 2 | |
|---|---|---|




| ID | Color | Name | Value | Unit | Raster |
|---|---|---|---|---|---|
| A2 | | P_mech/Out1 | 0 | | HostService |
| A1 | | P_elec/Out1 | -0.0164509 | | HostService |

| ID | Platform / Device | Y1 | Y2 | Y2-Y1 | Downsampling | X-Axis Offset |
|---|---|---|---|---|---|---|
| A2 | Platform | | | | *Max/Min[1:400] | 0 |
| A1 | Platform | | | | *Max/Min[1:400] | 0 |

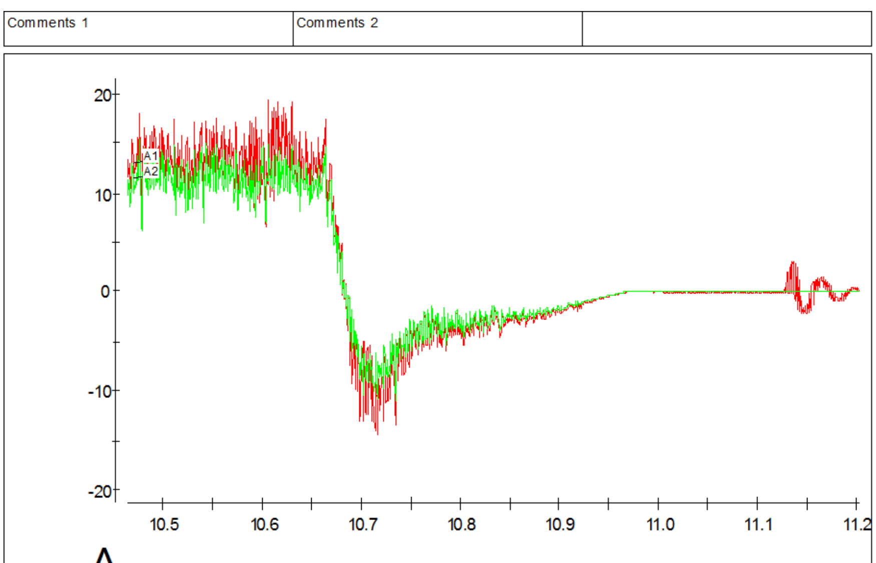
☐ Analyze the three images described in the previous bullet. For example, indicate sections of the plots where the motor is operating in quadrant 1, 2, 3, and 4 modes.




| ID | Color | Name | Value | Unit | Raster |
|---|---|---|---|---|---|
| B1 | | Wm_Measured/Out1 | 0 | | HostService |
| A1 | | Tem/In1 | -0.0485156 | | HostService |

| ID | Platform / Device | Y1 | Y2 | Y2-Y1 | Downsampling | X-Axis Offset |
|---|---|---|---|---|---|---|
| B1 | Platform | | | | *Max/Min[1:420] | 0 |
| A1 | Platform | | | | *Max/Min[1:420] | 0 |

☐ Zoom into the plot of $P_{elec}$ and $P_{mech}$ when the motor is in a regenerating mode. Save a copy of this image.




| ID | Color | Name | Value | Unit | Raster |
|---|---|---|---|---|---|
| A2 | | P_mech/Out1 | 0 | | HostService |
| A1 | | P_elec/Out1 | -0.0905991 | | HostService |

| ID | Platform / Device | Y1 | Y2 | Y2-Y1 | Downsampling | X-Axis Offset |
|---|---|---|---|---|---|---|
| A2 | Platform | | | | *Max/Min[1:14] | 0 |
| A1 | Platform | | | | *Max/Min[1:14] | 0 |

☐ Estimate the maximum mechanical power in the chosen regenerating mode.
Something like -8 Watts. (I should have used cursors.)

☐ Estimate the energy regenerated by the motor during the regeneration period, showing your work.

Something like ½ x 8 Watts x (10.96-10.68 seconds) = 1.12 J

☐ How does this regenerated energy compare to the motor's kinetic energy before it was turned off, $KE = \frac{1}{2} J_{eq} \omega_m^2$?

KE = .5 * 5 x 10^-4 x (100 rad/s)^2 = 2.5 J

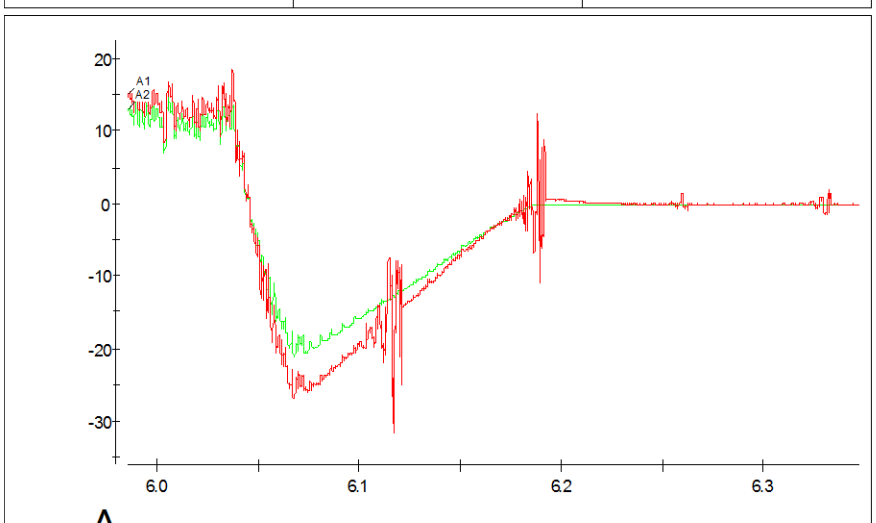
The initial kinetic energy is the maximum possible energy that could be regenerated. Since there are losses in any system, the regenerated energy is expected to be less than the initial KE.

☐ How did you expect the faster ramp to affect the power regenerated by the controlled PMDC motor during quadrant 2 or quadrant 4 operation?

You're starting with the same KE, so you'll have the same max possible regenerated energy. Since the area under the power curve will be about the same but the time has been cut in half, the maximum power observed in the regeneration period should be approximately twice the value seen in the previous data.

☐ For the case when the ramp was changed from 0.3 to 0.15 seconds: Save a zoomed image of a regeneration period. (Students take data showing the regenerated energy is about the same, the max power is approximately double.)

| Comments 1 | Comments 2 | |
|---|---|---|



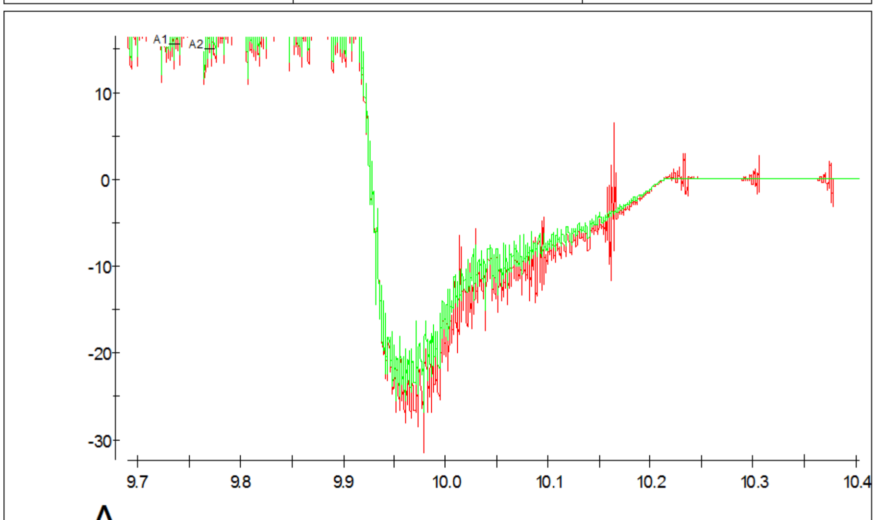

| ID | Color | Name | Value | Unit | Raster |
|---|---|---|---|---|---|
| A2 | | P_mech/Out1 | 0 | | HostService |
| A1 | | P_elec/Out1 | 0.00238419 | | HostService |

| ID | Platform / Device | Y1 | Y2 | Y2-Y1 | Downsampling | X-Axis Offset |
|---|---|---|---|---|---|---|
| A2 | Platform | | | | [1:1] | 0 |
| A1 | Platform | | | | [1:1] | 0 |

☐ For the case when the speed's magnitude was changed from 100 to 150 radians per second: Save a zoomed image of a regeneration period. Estimate the maximum negative mechanical power in the chosen regenerating mode. Estimate the mechanical energy regenerated by the motor during the regeneration period, showing your work. How do these values compare to the original case, when the initial speed and therefore kinetic energy was smaller but the regeneration time was the same? Explain.

In this case, we're starting with a higher KE (150^2/100^2 = 2.25), so there's 2.25 times more energy that can possibly be regenerated. Since the regeneration time period is the same, the maximum power should be around 2.25 times larger than the original value.

| Comments 1 | Comments 2 | |
|---|---|---|




| ID | Color | Name | Value | Unit | Raster |
|---|---|---|---|---|---|
| A2 | | P_mech/Out1 | 0 | | HostService |
| A1 | | P_elec/Out1 | -0.00600815 | | HostService |

| ID | Platform / Device | Y1 | Y2 | Y2-Y1 | Downsampling | X-Axis Offset |
|---|---|---|---|---|---|---|
| A2 | Platform | | | | [1:1] | 0 |
| A1 | Platform | | | | [1:1] | 0 |