

## Example Data for Electric Drives Experiment 2

### Two-Pole Switch-Mode DC Converter and Experimental Characterization of a DC Motor's Electrical Parameters

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:

- Complete Table 2.1: Calculated duty ratios and output voltages.

**Table 2.1:** Calculated duty ratios and output voltages

$V_{in}$	$V_a$ , Desired	$d_{A1}$	$d_{B1}$	$V_{A1}$	$V_{B1}$	$V_a$ , Output
40	0	0.5	0.5	20	20	0
40	20	0.75	0.25	30	10	20
40	40	1	0	40	0	40
40	-20	0.25	0.75	10	30	-20
40	-40	0	1	0	40	-40

- Theoretically, given the two-pole switch-mode converter's duty ratio equations and  $V_{in} = 40$  V, what maximum and minimum values of  $V_a$  can be applied to the motor?

40 and -40 V

- Complete Table 2.2: Measured duty ratios and output voltages.

**Table 2.2:** Measured duty ratios and output voltages

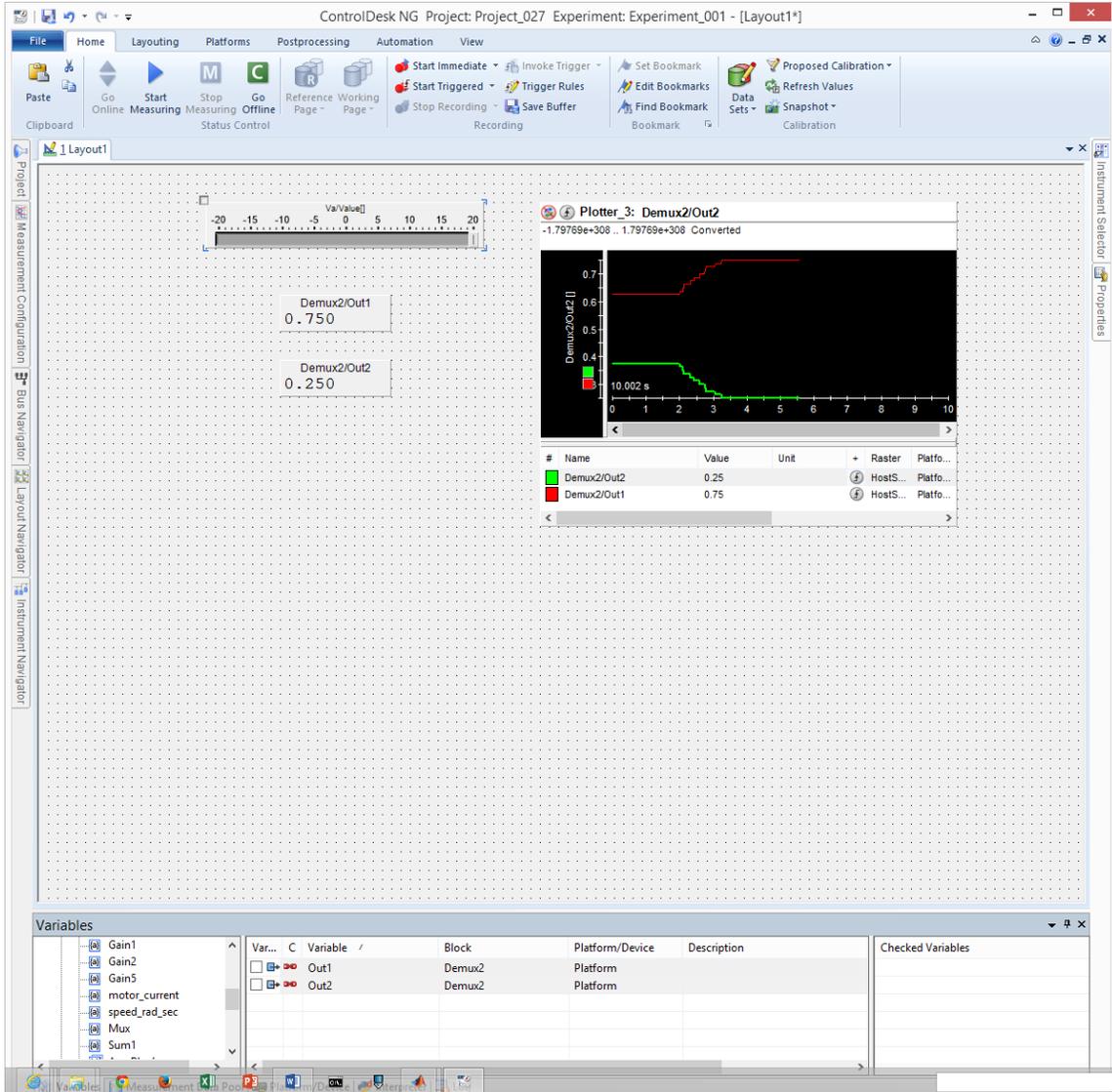
$V_a$ , Desired	$d_{A1}$	$d_{B1}$	$V_{A1}$	$V_{B1}$	$V_{A1} - V_{B1}$
0	.5	.5	19.6	19.6	0
10	.625	.375	24.2	14.8	9.4
20	.75	.25	29.0	9.9	19.1
-10	.375	.625	14.8	24.2	-9.4
-20	.25	.75	9.9	29.0	-19.1

- Compare the -20, 0, and 20 V duty ratios that you calculated for Table 2.1 with the measured duty ratios in Table 2.2. Also, how well did the measured armature voltage match the desired value, and what might be the cause of any differences?

The calculated and measured duty ratios were the same (as expected since we were measuring the control signals which used the same duty ratio equations). The measured armature voltage was several tenths of a volt lower than the desired value due to voltage

drops across the semiconductor devices (within the DC-DC converter on the inverter board).

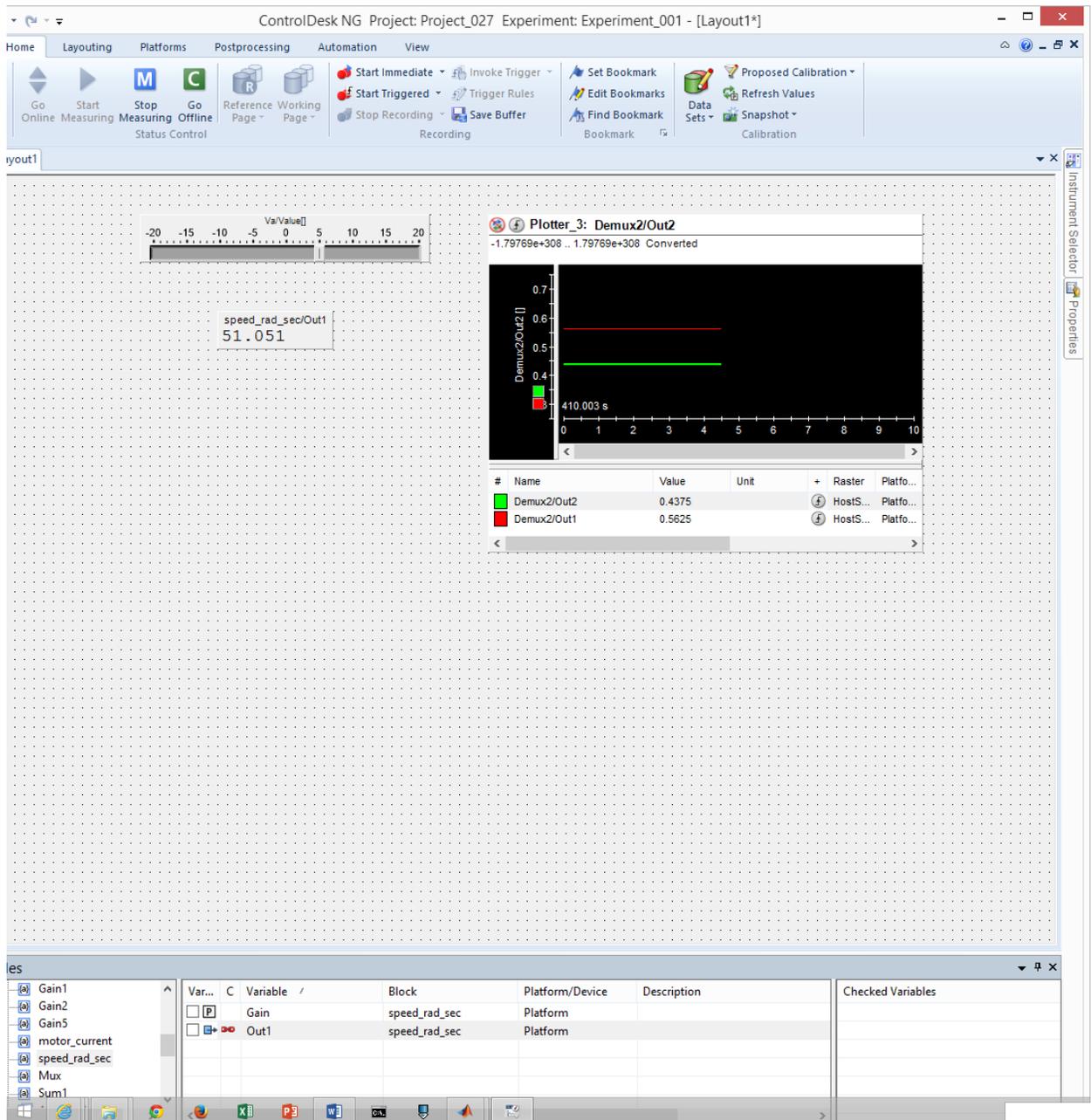
- Save a screen capture of the ControlDesk window showing an example set of duty ratios and the associated (desired) armature voltage.



- Complete Table 2.3: Induced EMF ( $e_a$ ) at different rotational speeds.  
 $RPM = \omega_m \times 60 / (2\pi)$

$V_a$ , Desired	$\omega_m$	RPM	$e_a$
5	50	477	4.2
10	109	1041	9.2
15	167	1595	14.2
20	226	2158	19.1

- Take one screenshot of the ControlDesk window showing the graphical displays during an example data acquisition for Table 2.3.



- Explain why the y-intercept of your ( $e_a$  vs.  $\omega_m$ ) line should be zero.

The mathematical equation indicates that the y-intercept is zero. Physically, you get no EMF if the motor isn't spinning (that is, if there is no change in magnetic flux through the coils).

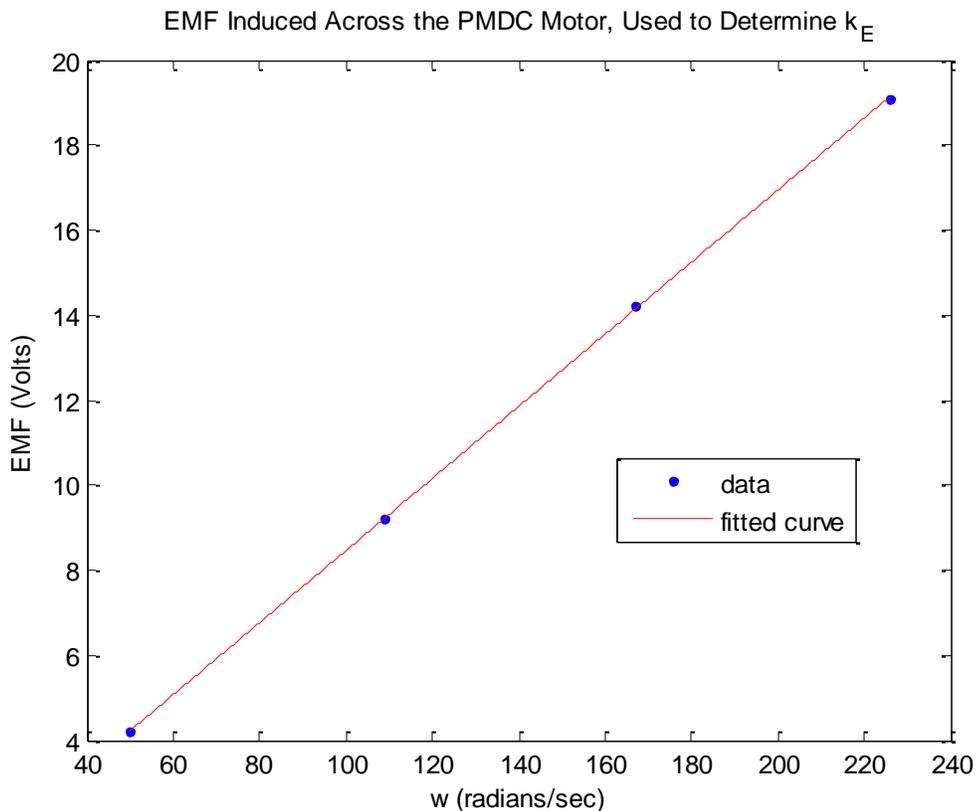
- Save the estimate for  $k_E$ , the slope of your ( $e_a$  vs.  $\omega_m$ ) data in V-s/radian, and comment on how the number of measured data points affects the accuracy of this estimate.

Here is the output of MATLAB's "fit" function:

```
f =  
Linear model Poly1:  
f(x) = p1*x + p2  
Coefficients (with 95% confidence bounds):  
p1 = 0.08481 (0.08299, 0.08663)  
p2 = -0.02888 (-0.3067, 0.2489)
```

So, the estimate of  $k_E$  is approximately 0.085 V-s/radian. As a general rule, more data points will improve the accuracy of the linear fit.

- Save the plot of ( $e_a$  vs.  $\omega_m$ ) which shows your data points as well as the linear approximation of your data.



- Save the estimate for  $k_E$  in V/RPM as the slope of your ( $e_a$  vs. RPM) data, and comment on how this estimate compares to the value listed on the kit's "DC Motor".

Here is the MATLAB output:

```
f =  
Linear model Poly1:  
f(x) = p1*x + p2
```

Coefficients (with 95% confidence bounds):

$$p1 = 0.008881 \text{ (0.008691, 0.009072)}$$

$$p2 = -0.02888 \text{ (-0.3067, 0.2489)}$$

So, the estimate of  $k_E$  is approximately 0.0089 V/RPM. The nameplate says 7.5 V/kRPM which would be 0.0075 V/RPM. Although in industry the nameplate values are reliable and should be used, unfortunately I don't trust the nameplate values displayed on this lab equipment.

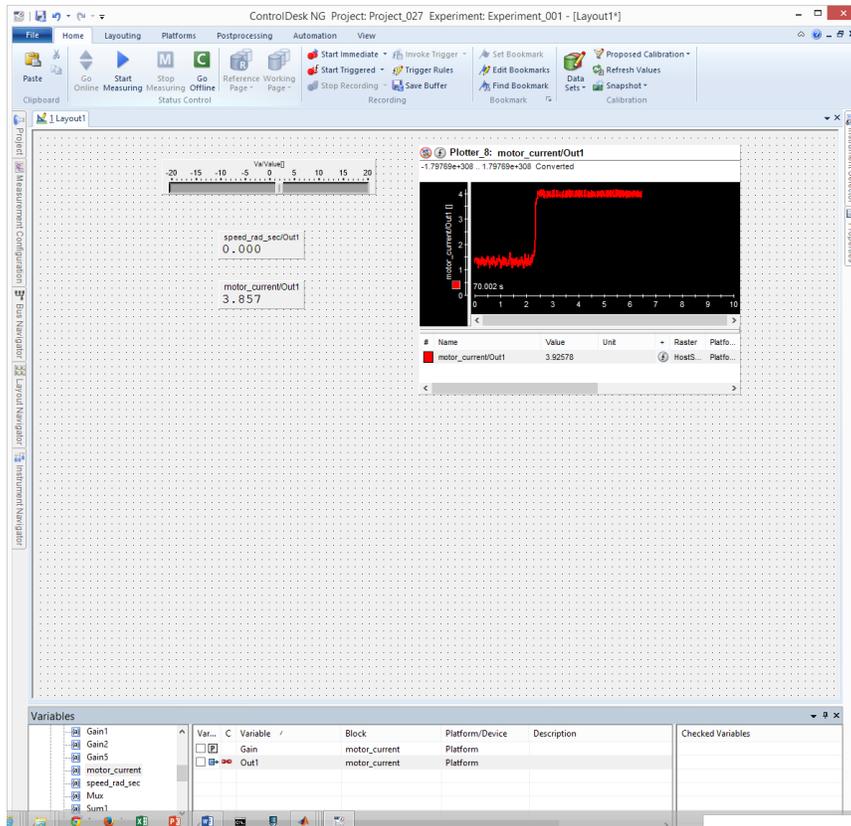
- Record the measured value of  $V_a$  to be used in calculating  $R_a$  and  $L_a$ .

1.7 V

- Record the steady-state value of  $I_a$  used to calculate  $R_a$ . How does this “short-circuit current” compare to the motor’s maximum allowable current of 6.0 Amps? What would happen if you increased  $V_a$  when conducting this experiment?

3.9 A. This is a safe amount below the maximum current of 6.0 Amps, but increasing  $V_a$  above even the tiny voltage of 3.0 V could cause us to exceed the limit.

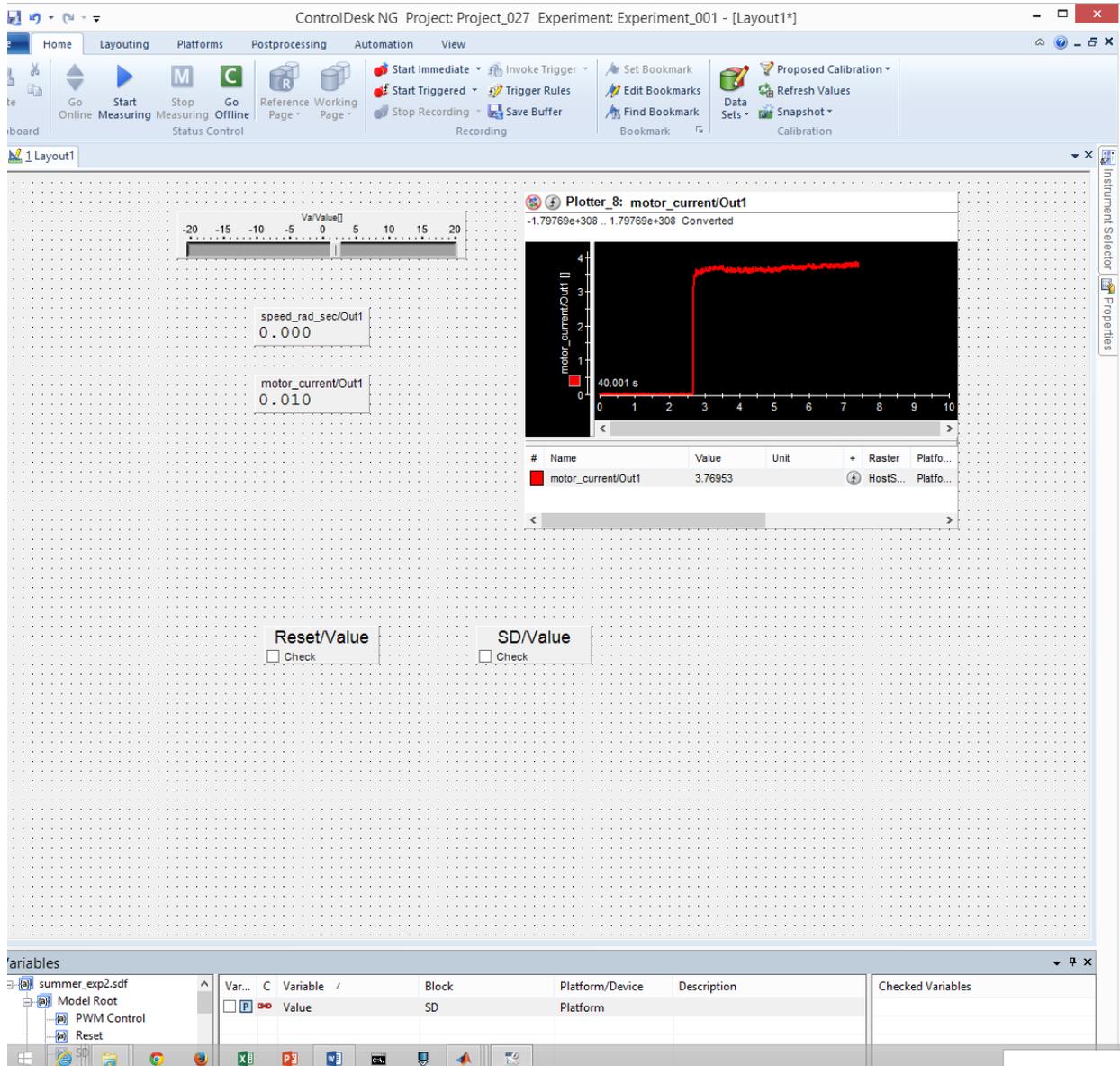
- Save a screenshot of the ControlDesk plot  $I_a$  of in steady-state conditions.

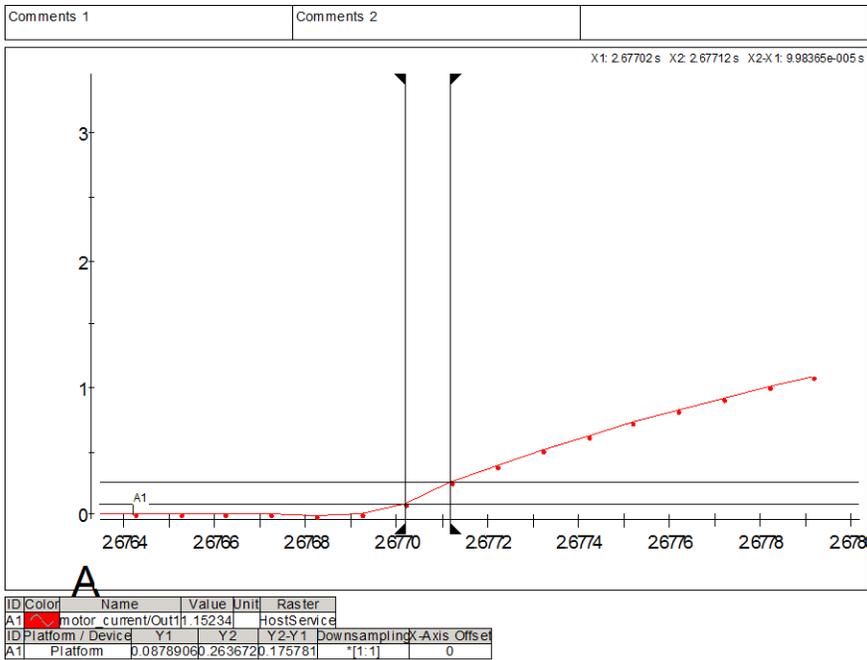


- Use  $V_a$  and  $I_a$  to estimate  $R_a$ .

$$R_a = 1.7 \text{ V} / 3.9 \text{ A} = 0.44 \text{ Ohms}$$

- Save two screen captures of the transient portion of the  $I_a$  waveform: one which shows the current starting from zero and reaching steady-state, and which is zoomed to show the individual data points when the current is initially turned on.





Calculate  $L_a$ .

$$L_a = V_a / \left( \frac{di_a}{dt} \right) = 1.7 \text{ V} / (0.175781/9.98365e-005) = 0.000966 \text{ or } 0.97 \text{ mH}$$