Tuning with Motor Manager and Test Trajectories

Part I: Tune your motor with Motor Manager

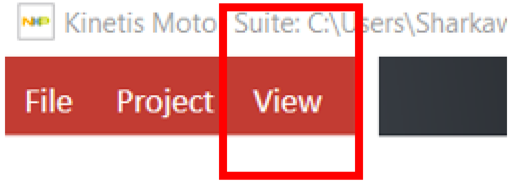
Objective

- With your motor successfully spinning, you can focus on optimizing your application.
- KMS incorporates proprietary disturbance compensating control from LineStream Technologies.
- This allows you to easily achieve excellent control of your motor’s velocity.
- In this lab, use step tests to observe the speed error of the motor at the default tuning set by KMS Motor Tuner.
- Increase and decrease a single tuning parameter, “Bandwidth,” to observe the impact on the speed error and understand KMS’ simple tuning process.

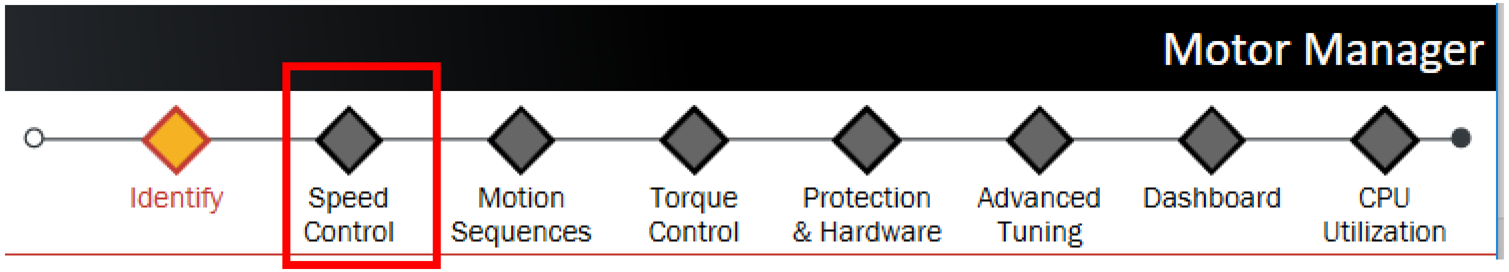
Procedure

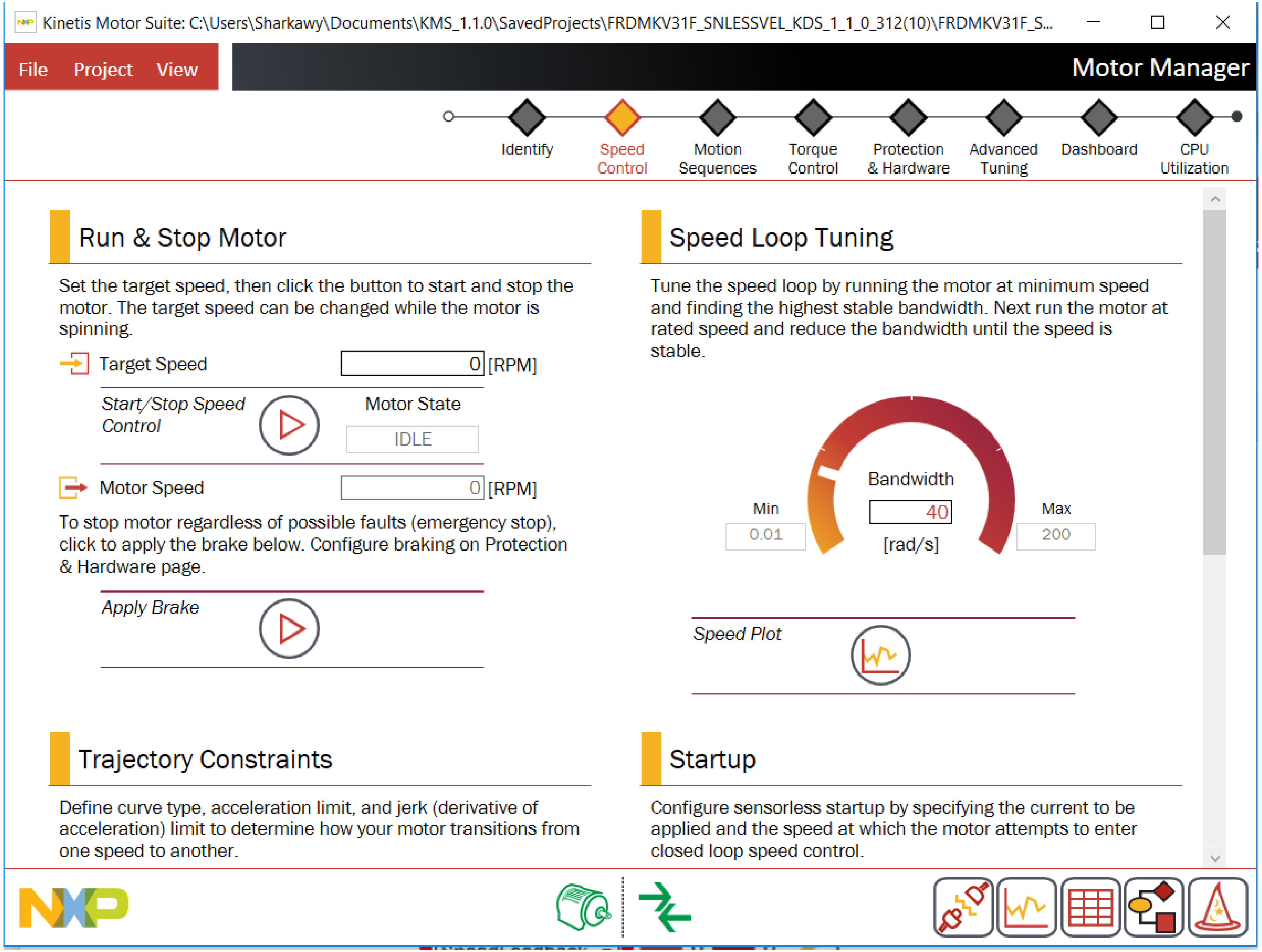
1. Observe the motor's behavior at the bandwidth generated by Motor Tuner.

- Launch KMS by double-clicking the Desktop icon.
- Click on “View” then select “Go to the Motor Manager”.



- Click on “Speed Control”.





Run & Stop Motor

Set the target speed, then click the button to start and stop the motor. The target speed can be changed while the motor is spinning.

Target Speed 0 [RPM]

Start/Stop Speed Control

Motor State: IDLE

Motor Speed 0 [RPM]

To stop motor regardless of possible faults (emergency stop), click to apply the brake below. Configure braking on Protection & Hardware page.

Apply Brake

Speed Loop Tuning

Tune the speed loop by running the motor at minimum speed and finding the highest stable bandwidth. Next run the motor at rated speed and reduce the bandwidth until the speed is stable.

Bandwidth 40 [rad/s]

Min 0.01

Max 200

Speed Plot

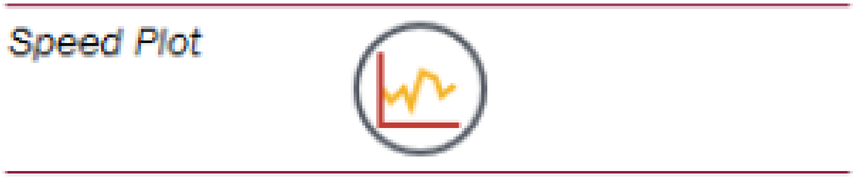
Trajectory Constraints

Define curve type, acceleration limit, and jerk (derivative of acceleration) limit to determine how your motor transitions from one speed to another.

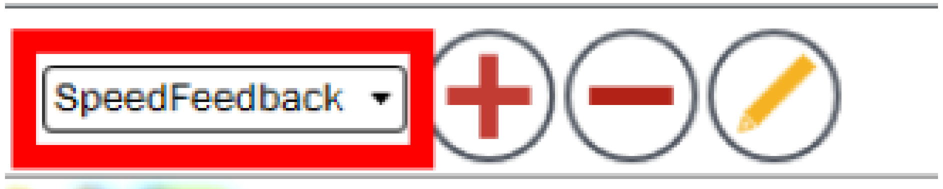
Startup

Configure sensorless startup by specifying the current to be applied and the speed at which the motor attempts to enter closed loop speed control.

- Click the Speed Plot button to open the Software Oscilloscope to the Speed Feedback plot .

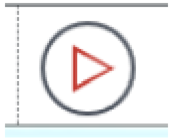


Speed plot button


SpeedFeedback

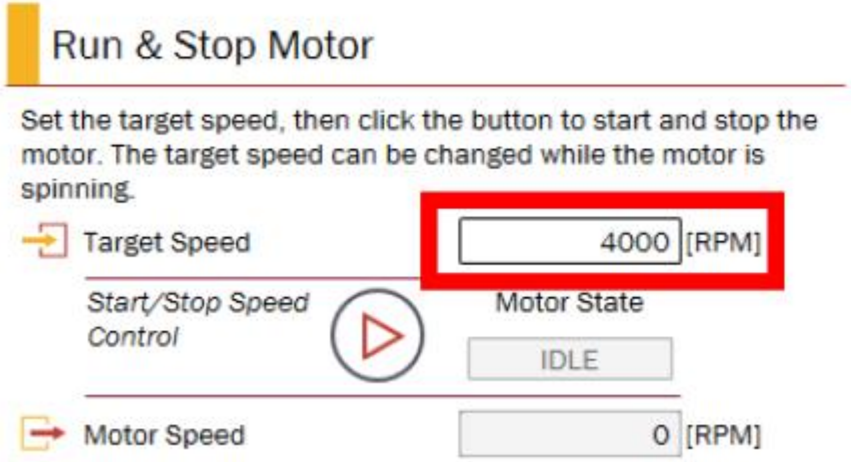
Dropdown box for selecting speed feedback plot

- Click the Run button. The plot starts sampling.



Click to begin sampling button

- Enter your motor’s rated speed as its Target Speed.



Run & Stop Motor

Set the target speed, then click the button to start and stop the motor. The target speed can be changed while the motor is spinning.

Target Speed: 4000 [RPM]

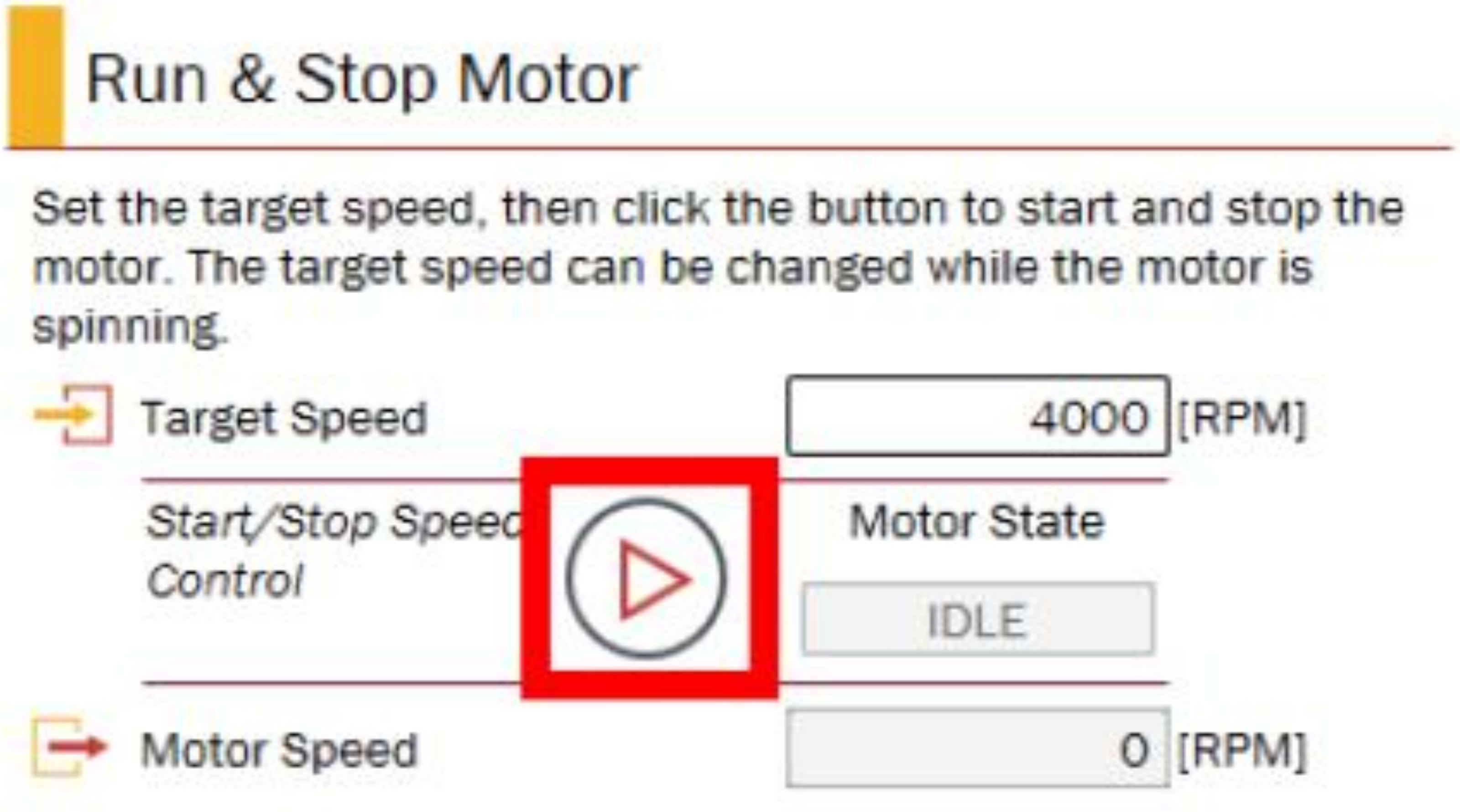
Start/Stop Speed Control

Motor State: IDLE

Motor Speed: 0 [RPM]

Target speed field (TWR example)

- Start the motor



Run & Stop Motor

Set the target speed, then click the button to start and stop the motor. The target speed can be changed while the motor is spinning.

Target Speed 4000 [RPM]

Start/Stop Speed Control

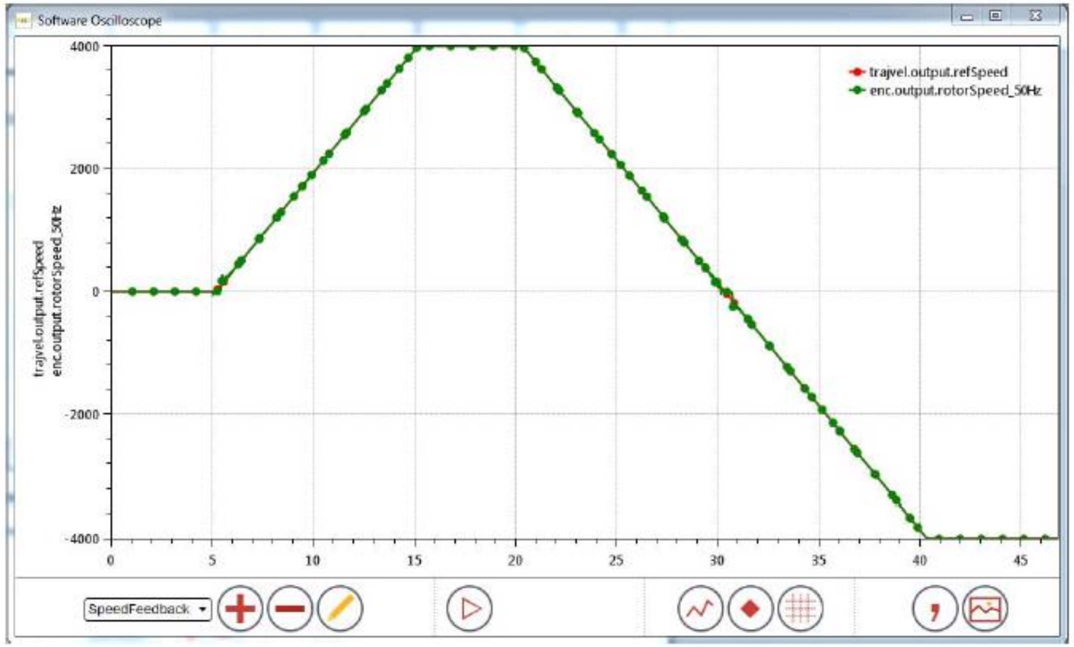
Motor State IDLE

Motor Speed 0 [RPM]

Button to start motor

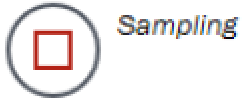
- In the Software Oscilloscope, observe the motor’s speed behavior.

- When the motor reaches the target speed, enter a Target Speed that is -100% of the motor's rated speed (i.e., Target Speed = negative rated speed).



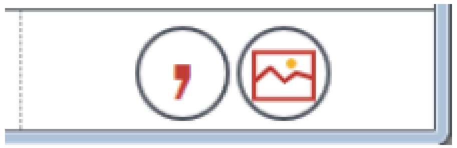
Plot showing operation at positive and negative rated speed (sensored)

- Stop sampling

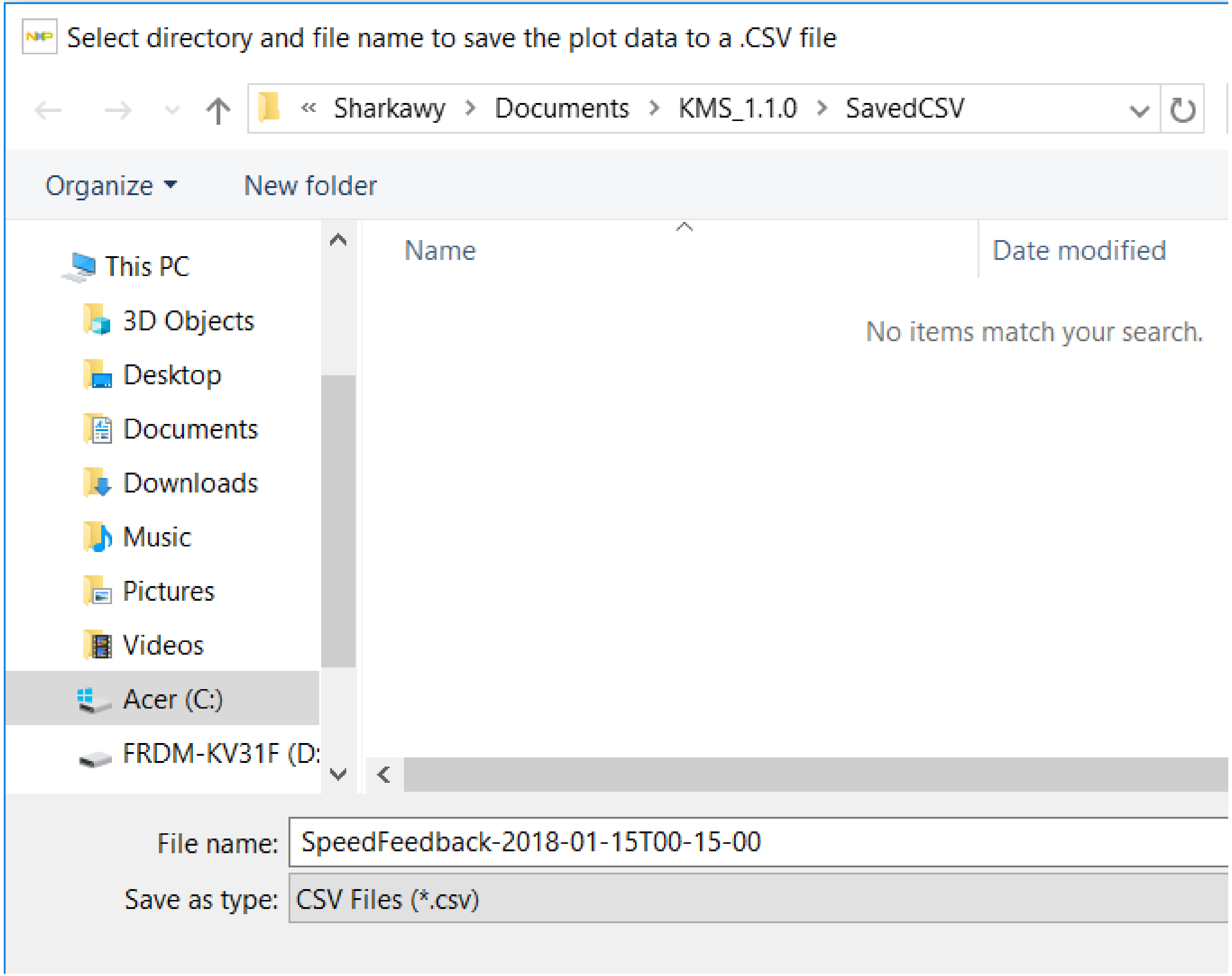


Click to stop sampling

- Click on , and 🖼 to save the csv and png file using default directories and filenames. This saves your data so that it can be analyzed and compared against other test runs.



Save CSV and PNG buttons



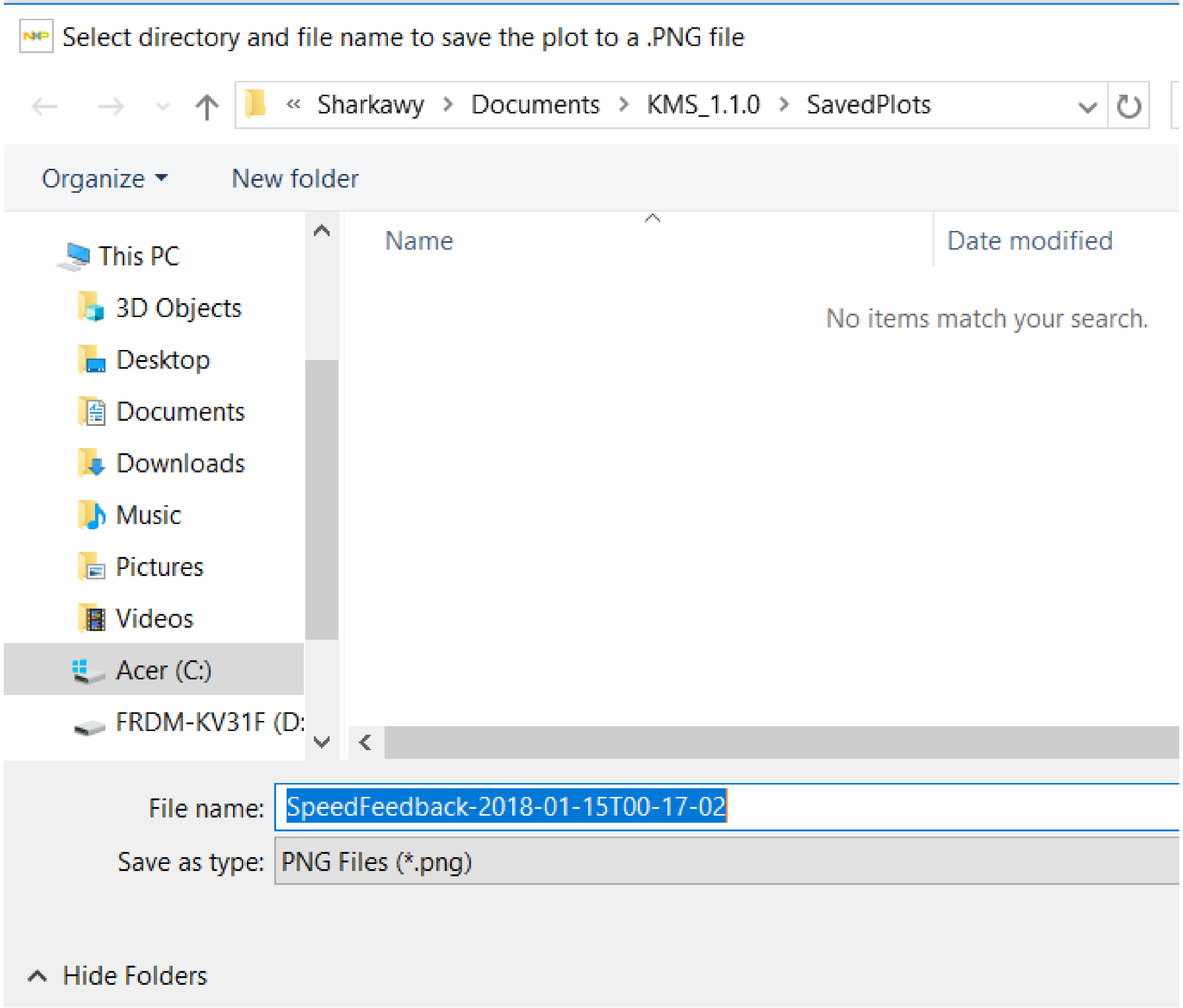
Select directory and file name to save the plot data to a .CSV file

« Sharkawy › Documents › KMS_1.1.0 › SavedCSV

No items match your search.

File name: SpeedFeedback-2018-01-15T00-15-00

Save as type: CSV Files (*.csv)



Select directory and file name to save the plot to a .PNG file

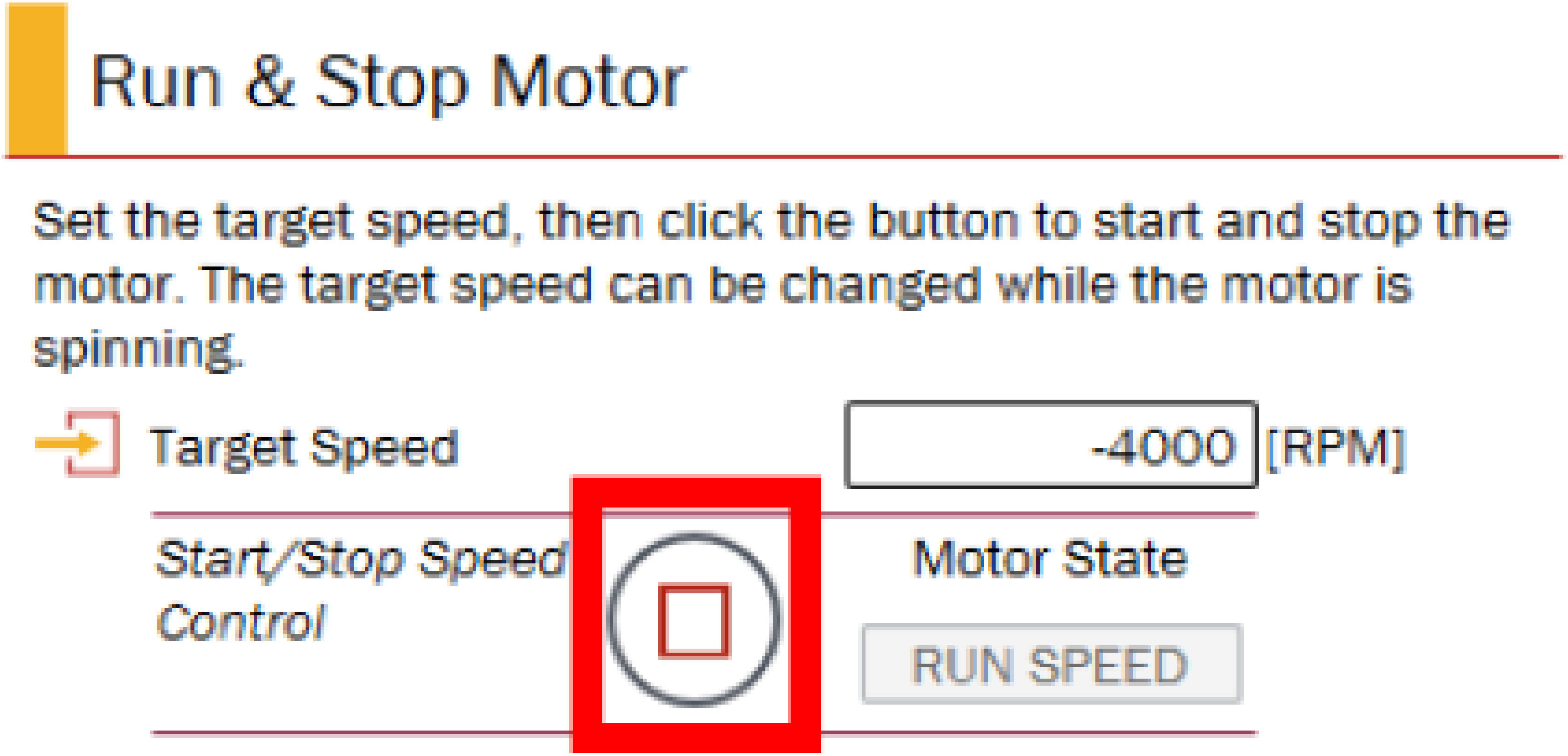
« Sharkawy › Documents › KMS_1.1.0 › SavedPlots

No items match your search.

File name: SpeedFeedback-2018-01-15T00-17-02

Save as type: PNG Files (*.png)

- Stop the motor



Run & Stop Motor

Set the target speed, then click the button to start and stop the motor. The target speed can be changed while the motor is spinning.

Target Speed: -4000 [RPM]

Start/Stop Speed Control

Motor State: RUN SPEED

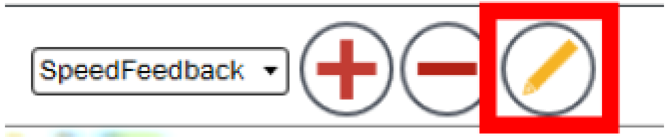
Button to stop motor

2. Observe the behavior when the motor is detuned

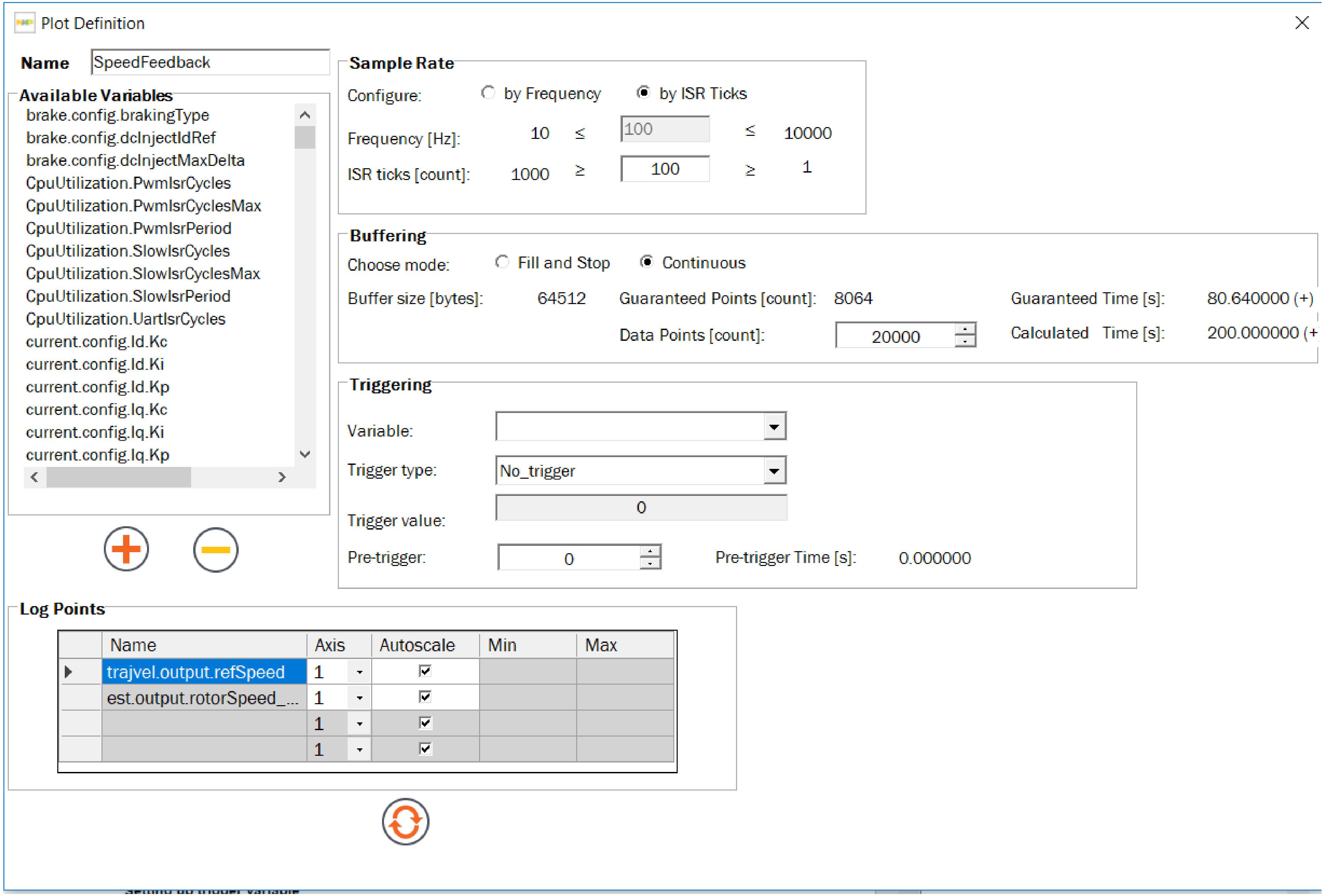
- Now that you have a baseline for motor operation, assess how performance may be affected by tuning.

- To do this, first customize the Speed Trajectory plot to make it more useful for closer examination.

- Click the “Edit” button.



Edit plot button



Plot Definition

Name SpeedFeedback

Available Variables

- brake.config.brakingType
- brake.config.dcInjectIdRef
- brake.config.dcInjectMaxDelta
- CpuUtilization.PwmIsrCycles
- CpuUtilization.PwmIsrCyclesMax
- CpuUtilization.PwmIsrPeriod
- CpuUtilization.SlowIsrCycles
- CpuUtilization.SlowIsrCyclesMax
- CpuUtilization.SlowIsrPeriod
- CpuUtilization.UartIsrCycles
- current.config.Id.Kc
- current.config.Id.Ki
- current.config.Id.Kp
- current.config.Iq.Kc
- current.config.Iq.Ki
- current.config.Iq.Kp

Sample Rate

Configure: ○ by Frequency ● by ISR Ticks

Frequency [Hz]: 10 ≤ 100 ≤ 10000

ISR ticks [count]: 1000 ≥ 100 ≥ 1

Buffering

Choose mode: ○ Fill and Stop ● Continuous

Buffer size [bytes]: 64512 Guaranteed Points [count]: 8064 Guaranteed Time [s]: 80.640000 (+)

Data Points [count]: 20000 Calculated Time [s]: 200.000000 (+

Triggering

Variable:

Trigger type: No_trigger

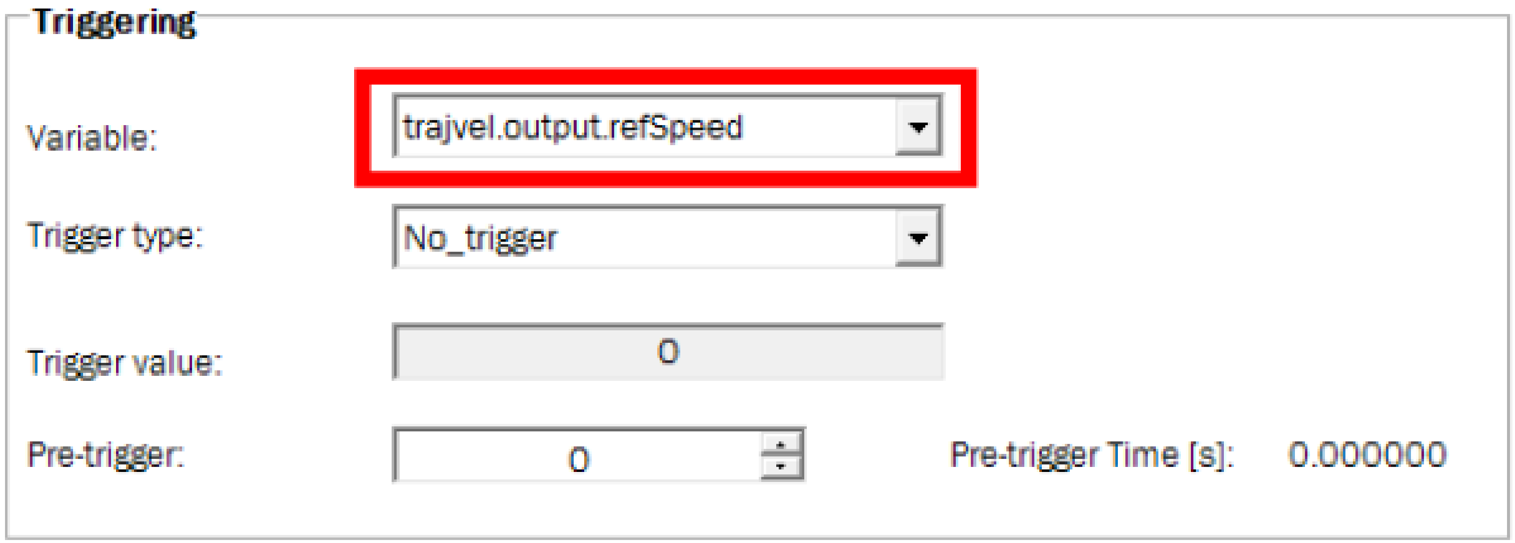
Trigger value: 0

Pre-trigger: 0 Pre-trigger Time [s]: 0.000000

Log Points

	Name	Axis	Autoscale	Min	Max
▶	trajvel.output.refSpeed	1	☑		
	est.output.rotorSpeed_...	1	☑		
		1	☑		
		1	☑		

- In the Triggering section, select the Variable trajvel.output.refSpeed. This is the Target Speed that is provided to the controller when the motor is started.



Triggering

Variable: trajvel.output.refSpeed

Trigger type: No_trigger

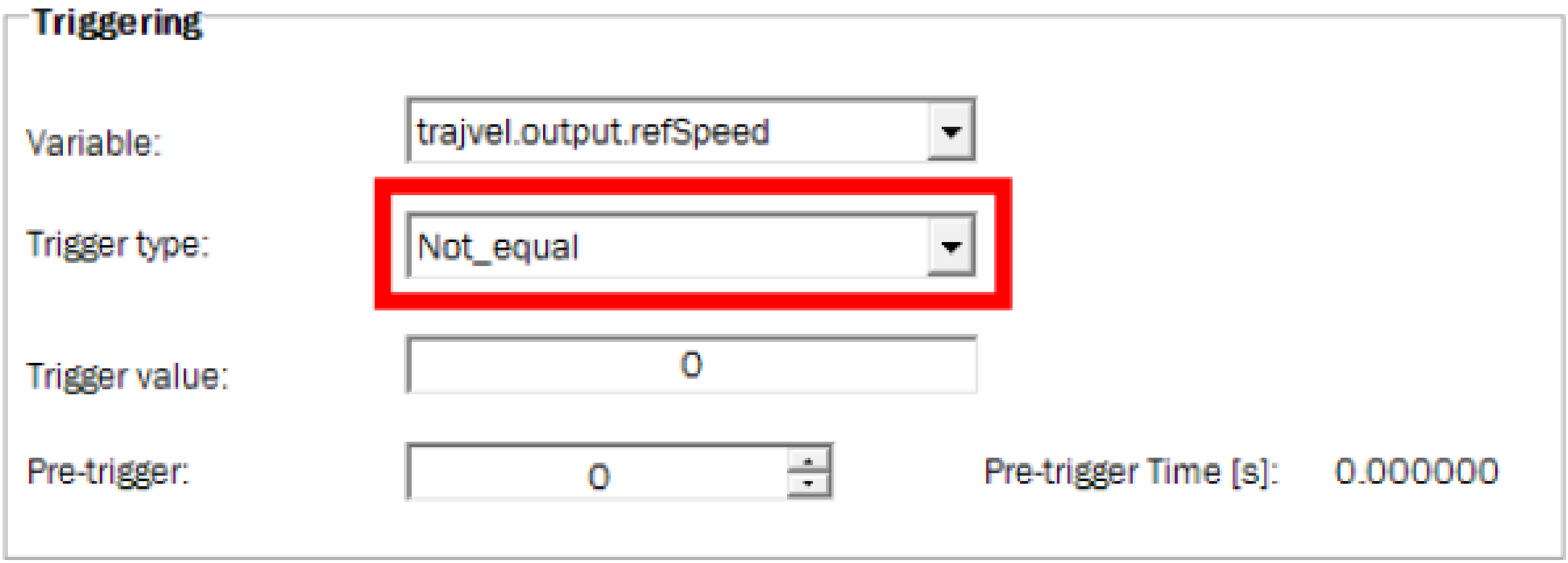
Trigger value: 0

Pre-trigger: 0

Pre-trigger Time [s]: 0.000000

Setting up trigger variable

- Set the Trigger type to "Not_equal"


Triggering

Variable: trajvel.output.refSpeed

Trigger type: Not_equal

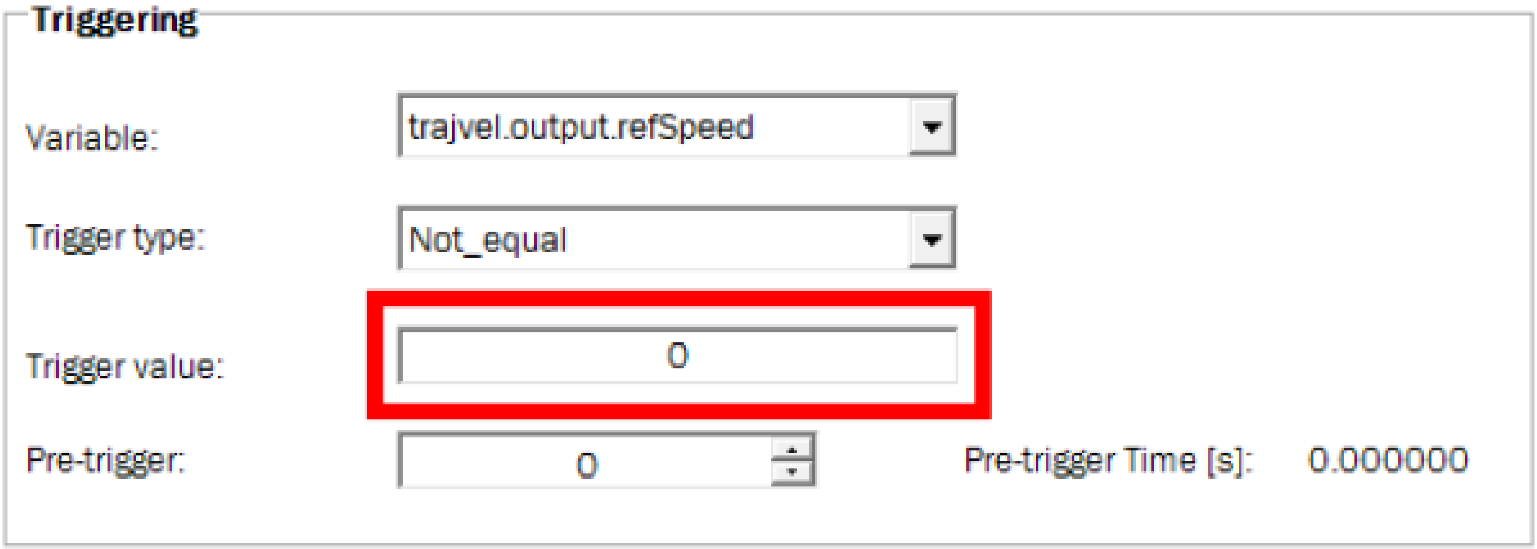
Trigger value: 0

Pre-trigger: 0

Pre-trigger Time [s]: 0.000000

Setting up trigger type

- Set the Trigger value to "0"



Triggering

Variable: trajvel.output.refSpeed

Trigger type: Not_equal

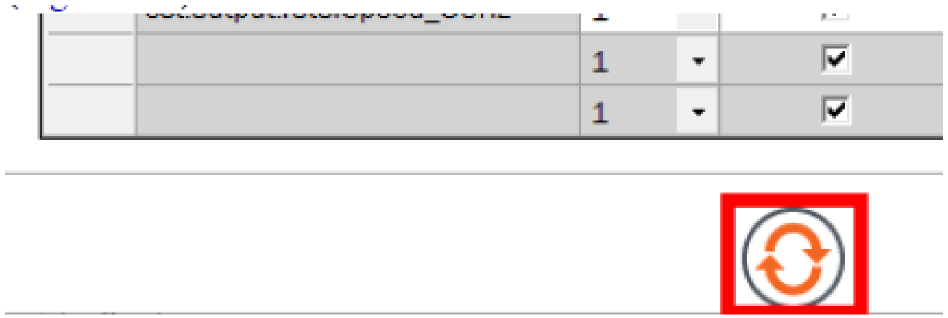
Trigger value: 0

Pre-trigger: 0

Pre-trigger Time [s]: 0.000000

Setting up trigger value

- Update the plot

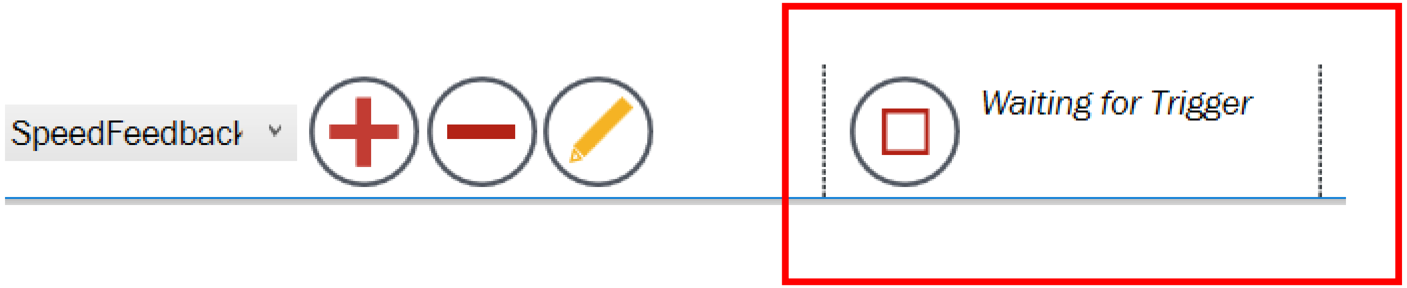


		1	☑
		1	☑

Update plot button

- Click the Run button to start sampling in plot.

- Notice that the plot is waiting for the trigger.



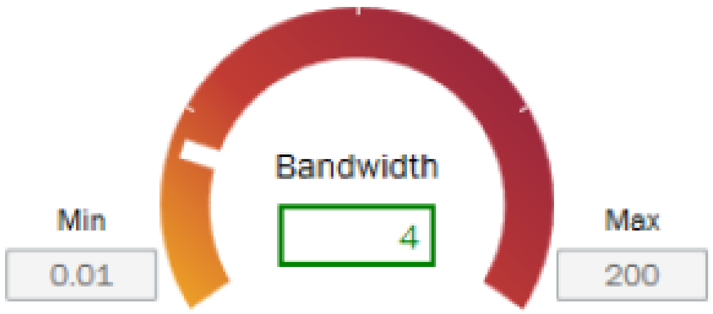
SpeedFeedback

Waiting for Trigger

- Return to the Speed Control page.

- Click and drag the knob handle or manually enter a value to reduce the Bandwidth to ~10% of the default value.

- Press Enter.



Bandwidth: 4

Min: 0.01

Max: 200

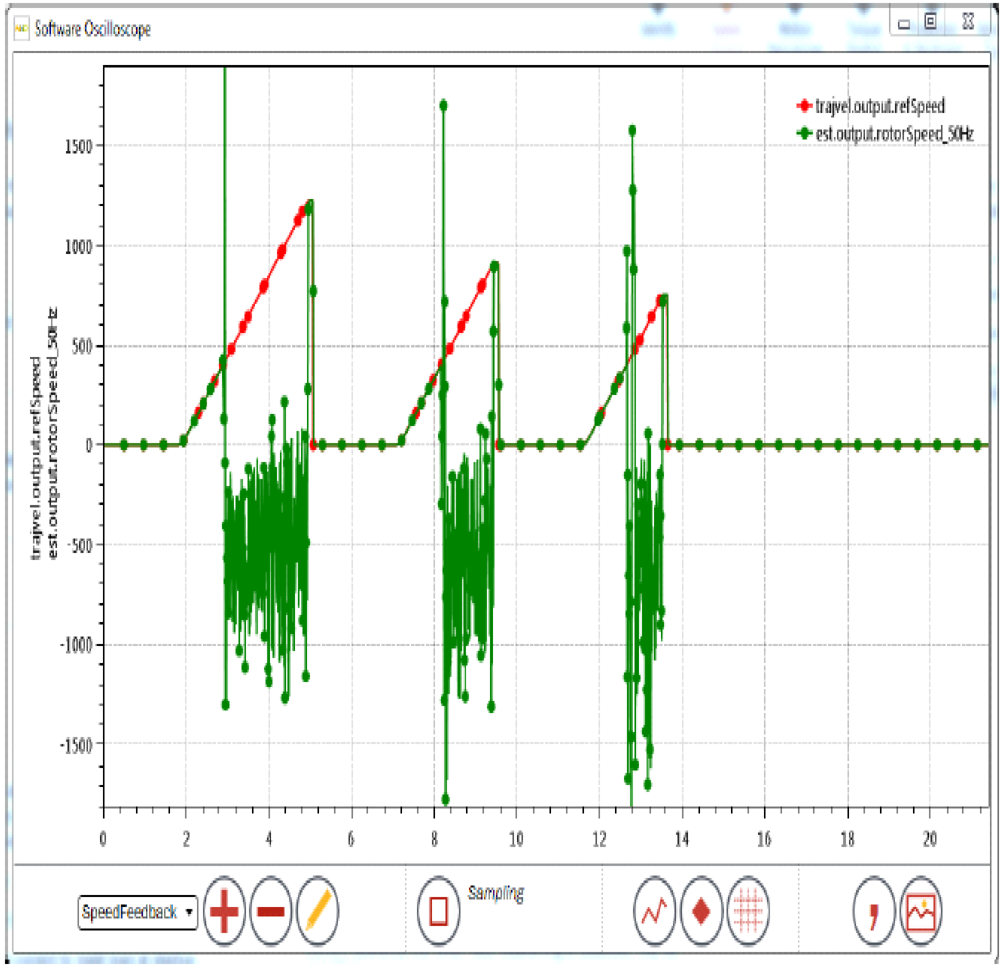
Bandwidth field

- Enter a Target Speed that is 100% of the motor's rated speed.

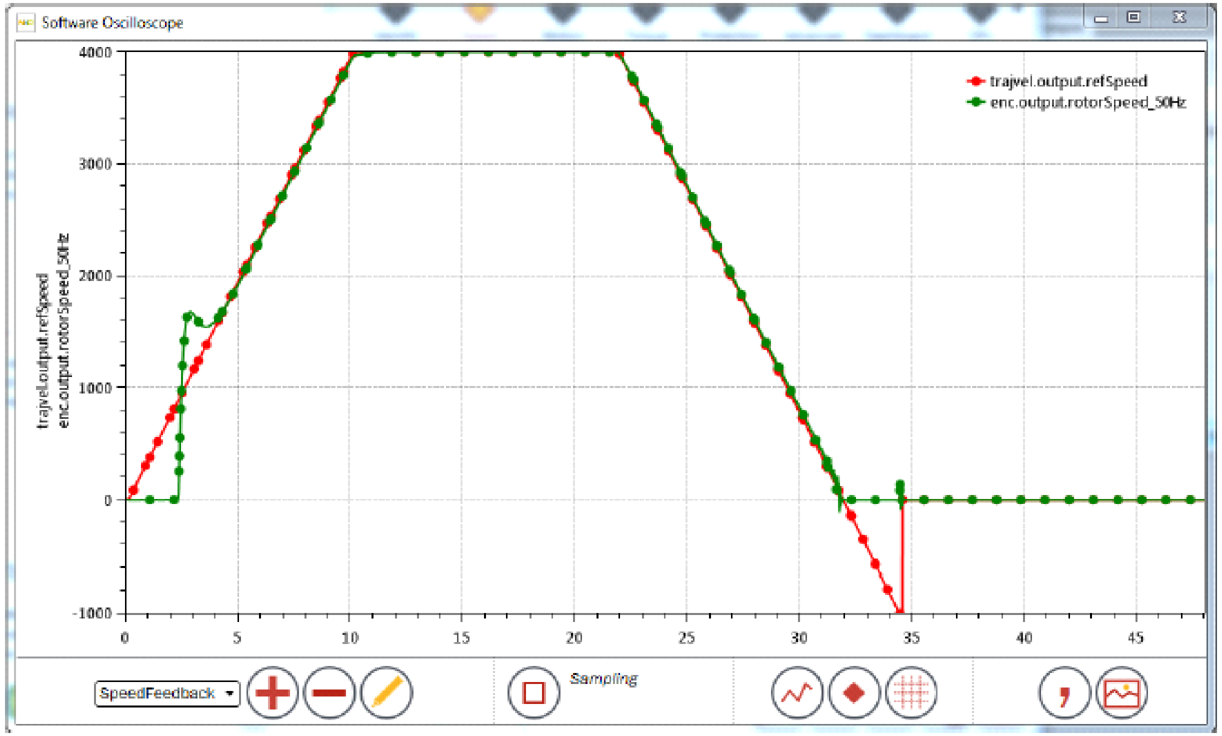
- Start the motor. Your motor may fault in this configuration and may attempt to automatically restart.

- If your motor is able to reach Target Speed, enter a new Target Speed that is -100% of the motor's rated speed.

- Whether your motor faults or successfully reaches Target Speed, you should observe behavior that is similar to the behavior in next figure: it is difficult for the motor to track the desired speed.

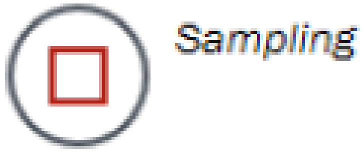


Example plot when undertuned (sensorless velocity) - motor cannot start



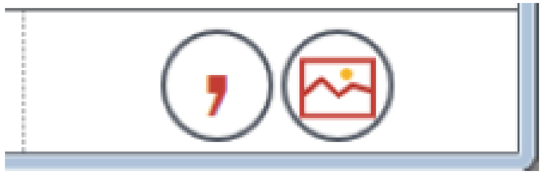
Example plot when undertuned (sensored velocity)

- Stop sampling.

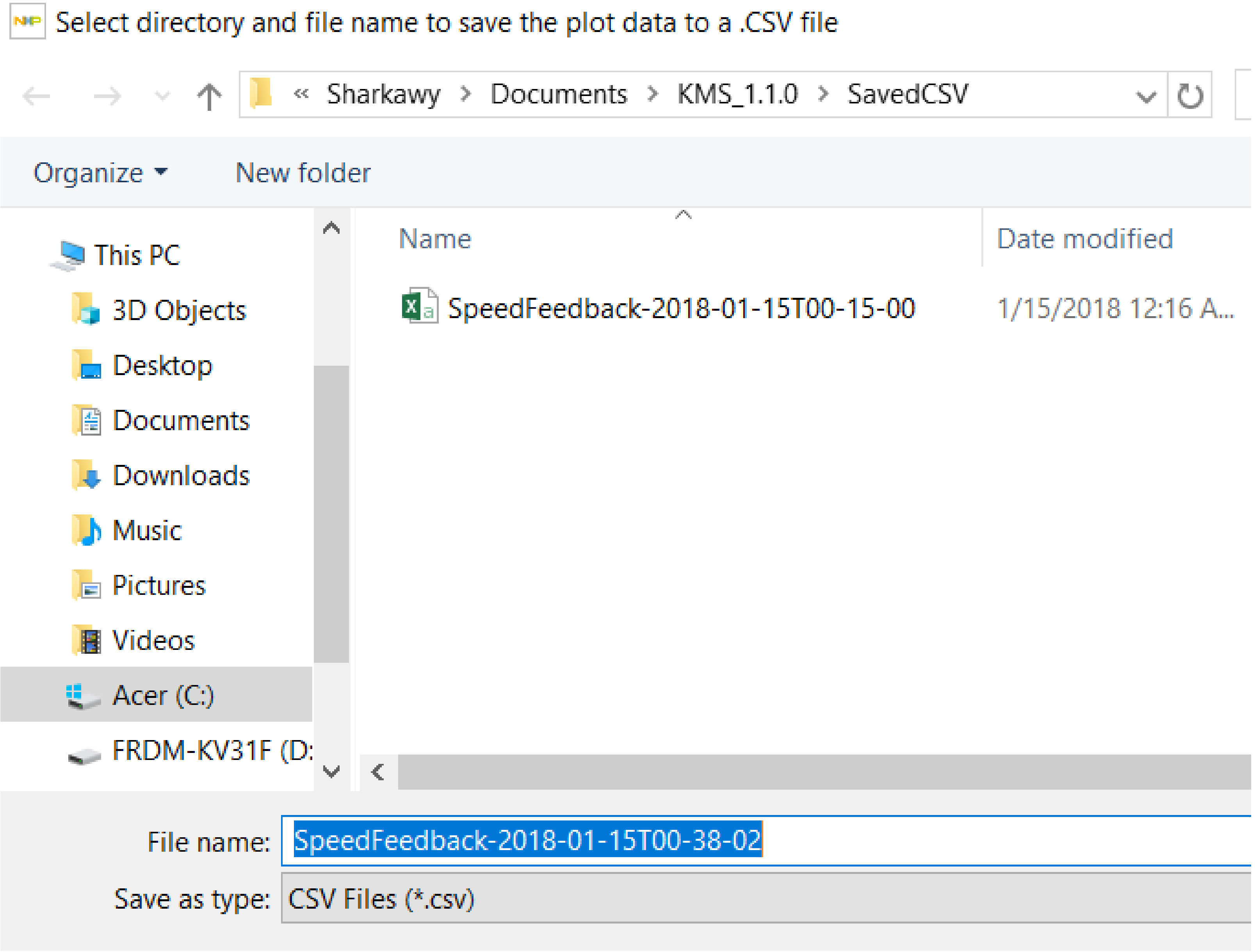


Stop sampling button

- Save the csv and png files as before using the corresponding buttons.



Save CSV and PNG buttons



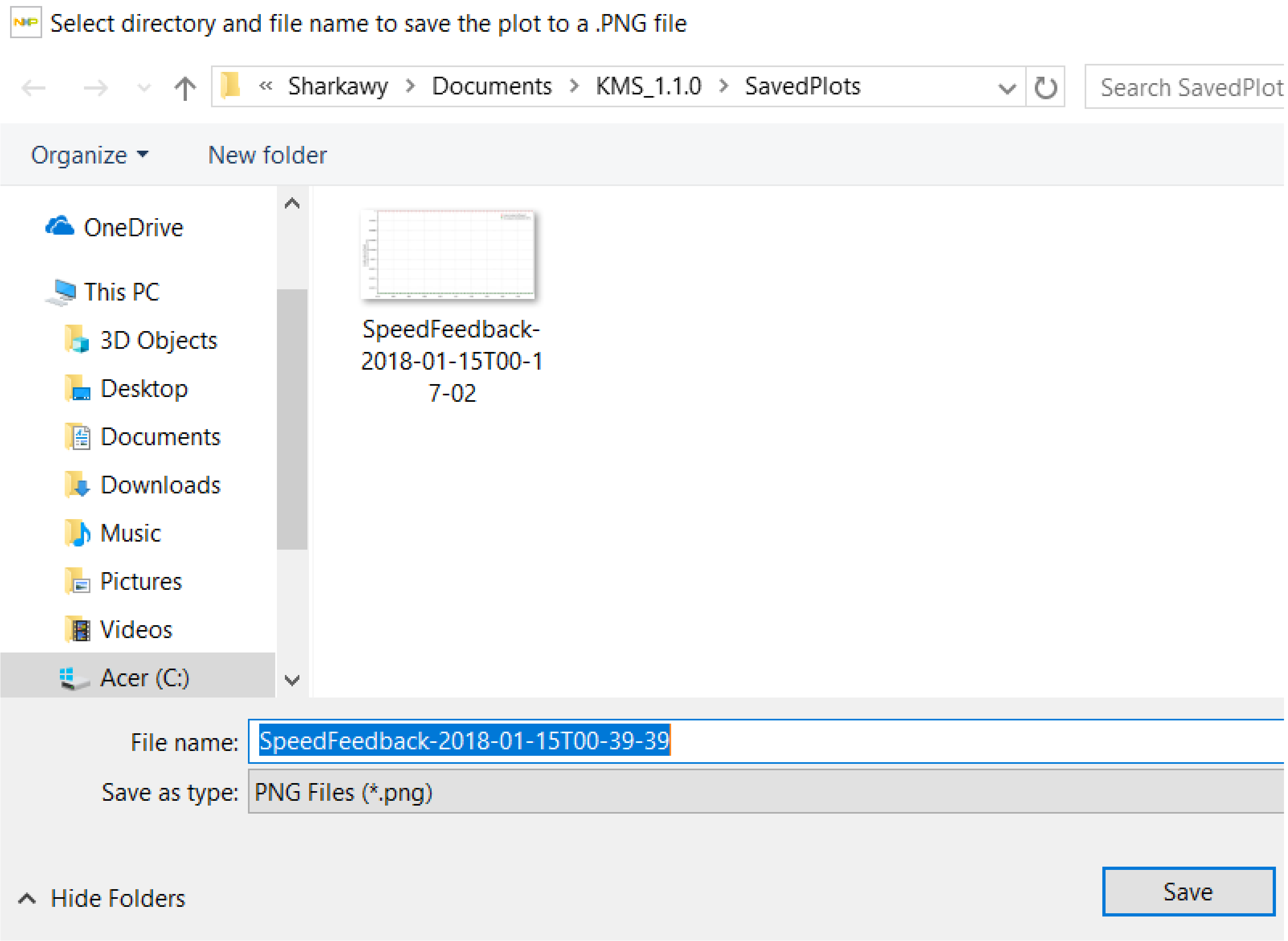
Select directory and file name to save the plot data to a .CSV file

« Sharkawy › Documents › KMS_1.1.0 › SavedCSV

Name	Date modified
SpeedFeedback-2018-01-15T00-15-00	1/15/2018 12:16 A...

File name: SpeedFeedback-2018-01-15T00-38-02

Save as type: CSV Files (*.csv)



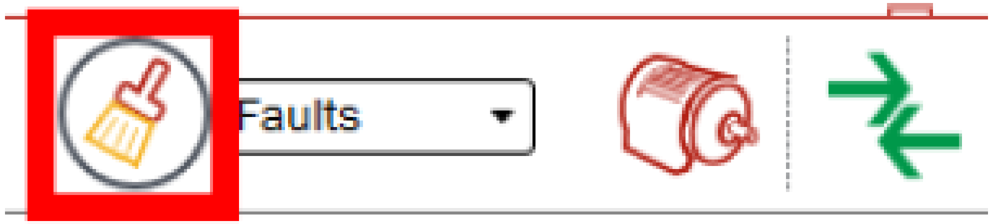
Select directory and file name to save the plot to a .PNG file

« Sharkawy › Documents › KMS_1.1.0 › SavedPlots

File name: SpeedFeedback-2018-01-15T00-39-39

Save as type: PNG Files (*.png)

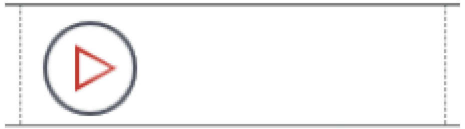
- Clear any motor faults at bottom of KMS main window or click to stop motor (if your motor is still running).



Clear faults button

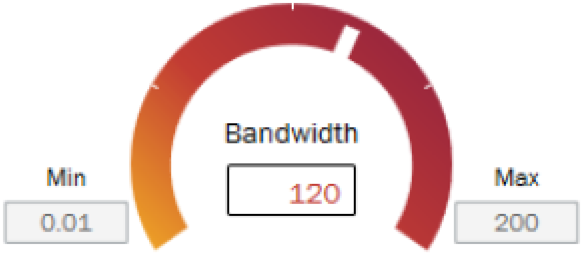
3. Observe the motor's behavior when it is over-tuned

- Click the Run button on the Speed Feedback plot.



Begin sampling button

- Return to the Speed Control page and use the knob or text field to increase the Bandwidth to 3x the default value (30x the current value).



Bandwidth
120

Min
0.01

Max
200

Bandwidth field (sensored velocity)

- Enter the motor’s rated speed as its Target Speed.

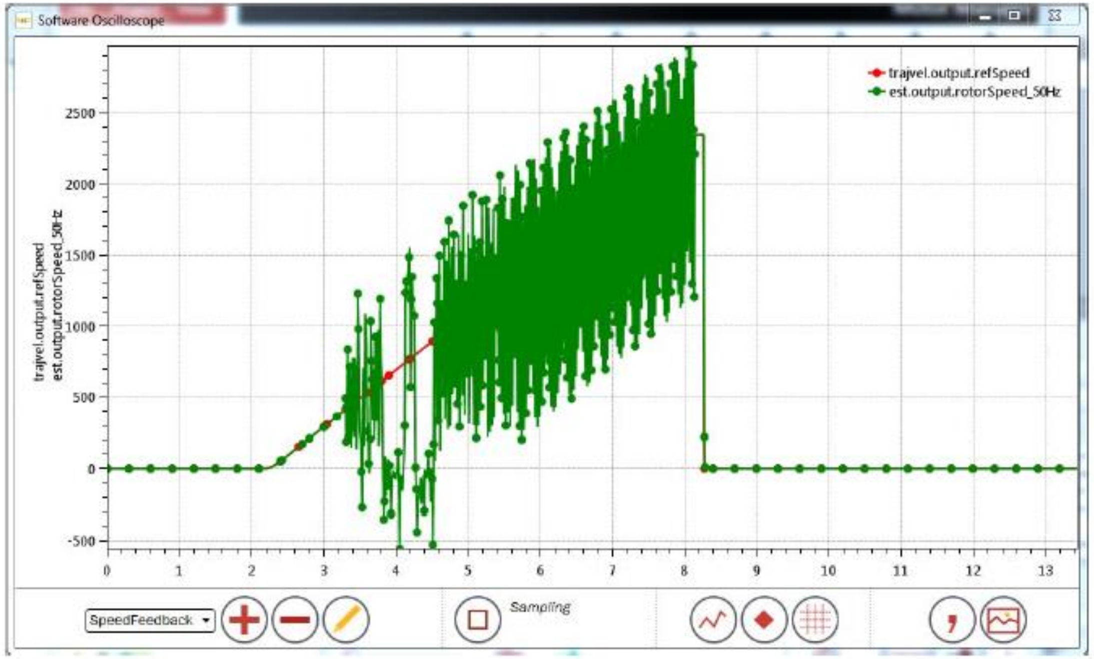
- Start the motor.

- Your motor may fault in this configuration and may attempt to automatically restart.

- If your motor is able to reach Target Speed, enter a new Target Speed that is -100% of the motor's rated speed.

- Whether your motor faults or successfully reaches Target Speed, you should observe behavior that is similar to the behavior in the following Figures:

Fault:

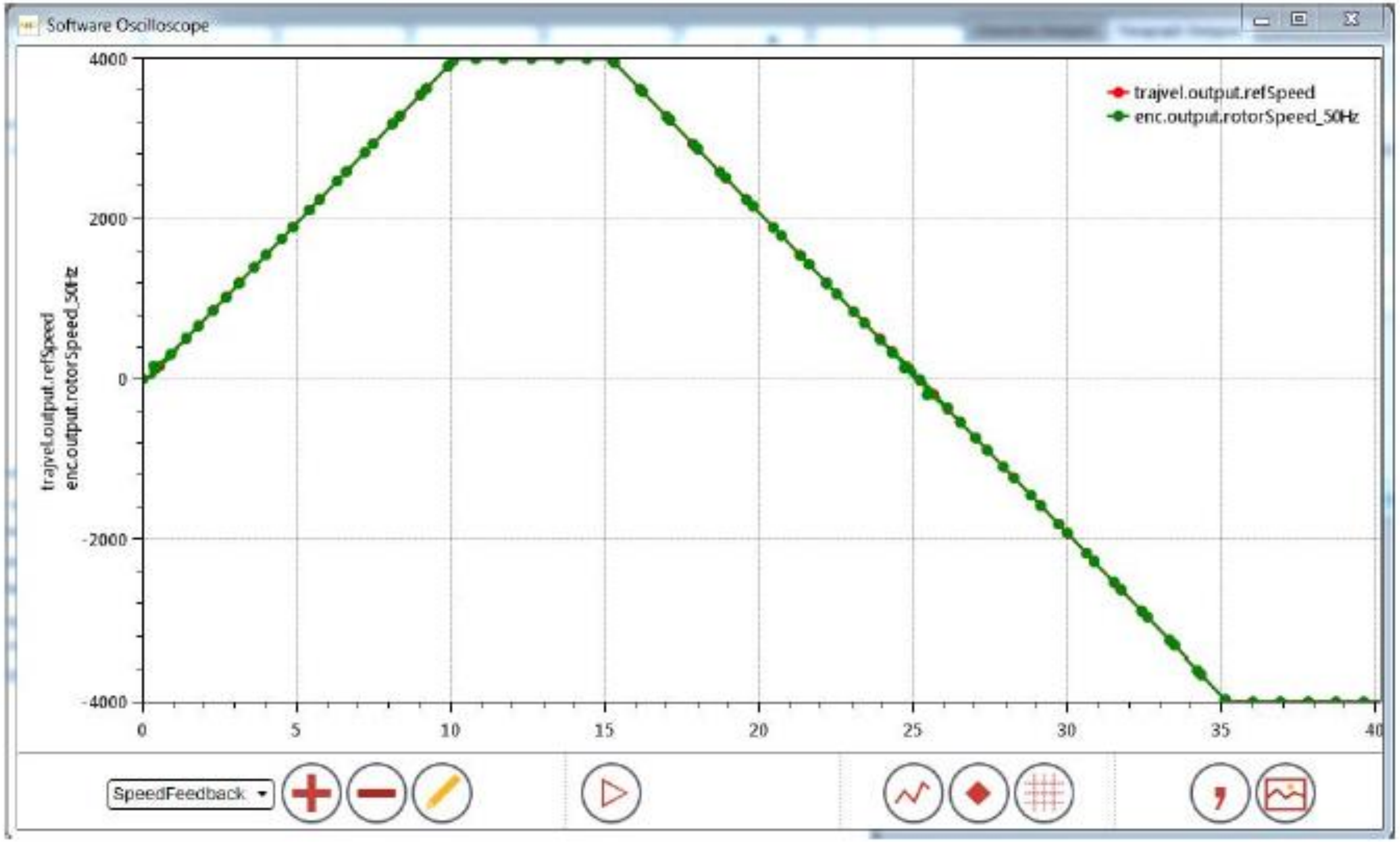


Sensorless velocity control with bandwidth 3x the default

- However, when running sensored velocity control or when running certain high speed motors, the system may remain stable across a broad range of Bandwidth values.

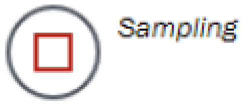
- If this is the case, your system may offer improved control performance at a value higher than the default or even than the 3x default value used in this example.

Success



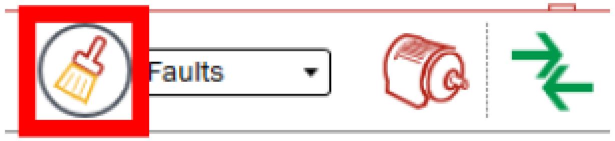
Example plot of behavior when "overtuned" value has little effect (sensored velocity)

- When you have observed unstable oscillation or are unable to force instability with bandwidth changes, click to stop sampling.



Click to stop sampling

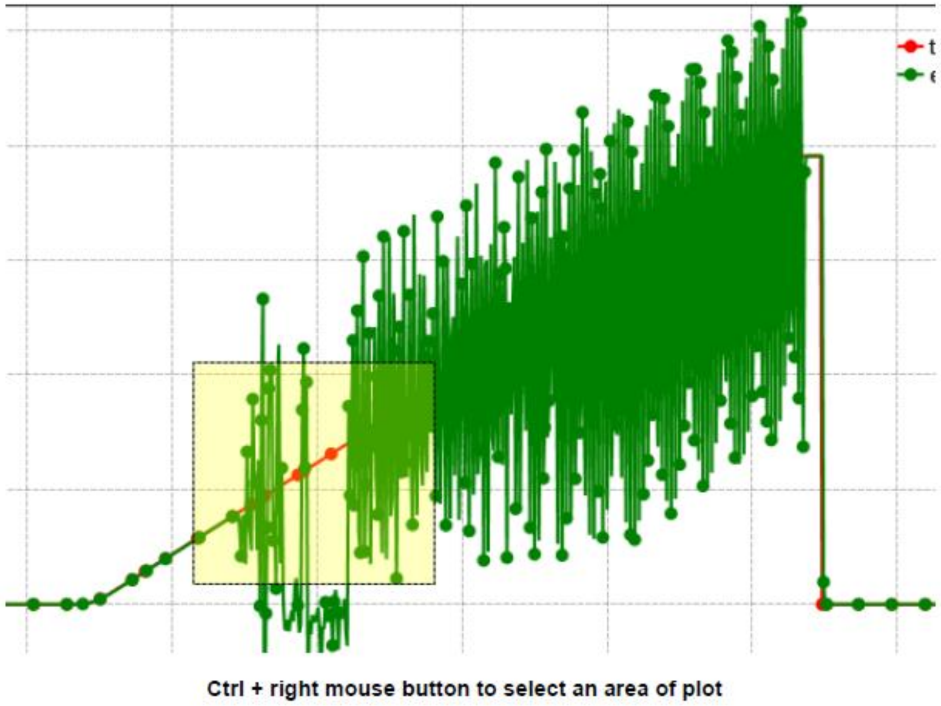
- Clear any motor faults or click to stop motor (if your motor is still running).



Clear faults button

- Analyze the motor’s behavior in the Software Oscilloscope.

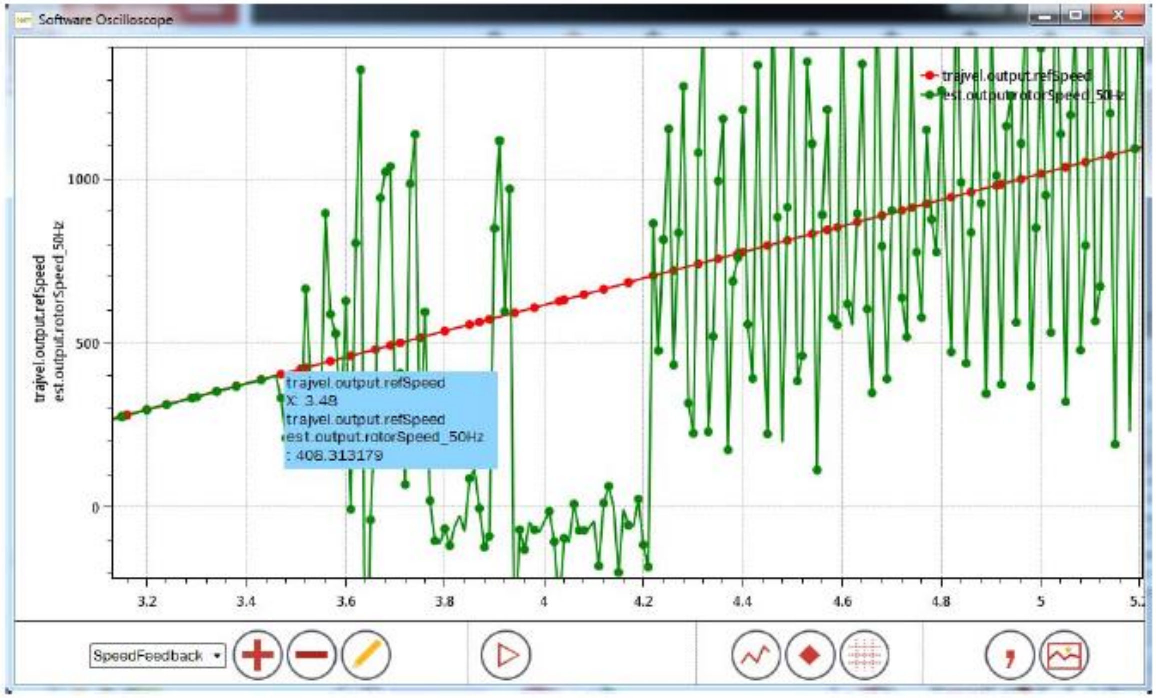
- Start by selecting an area of the plot by pressing Ctrl+Right mouse button. The system zooms in on the desired region.



Ctrl + right mouse button to select an area of plot

- Click the left mouse button to view the value of a specific data point on the grid.

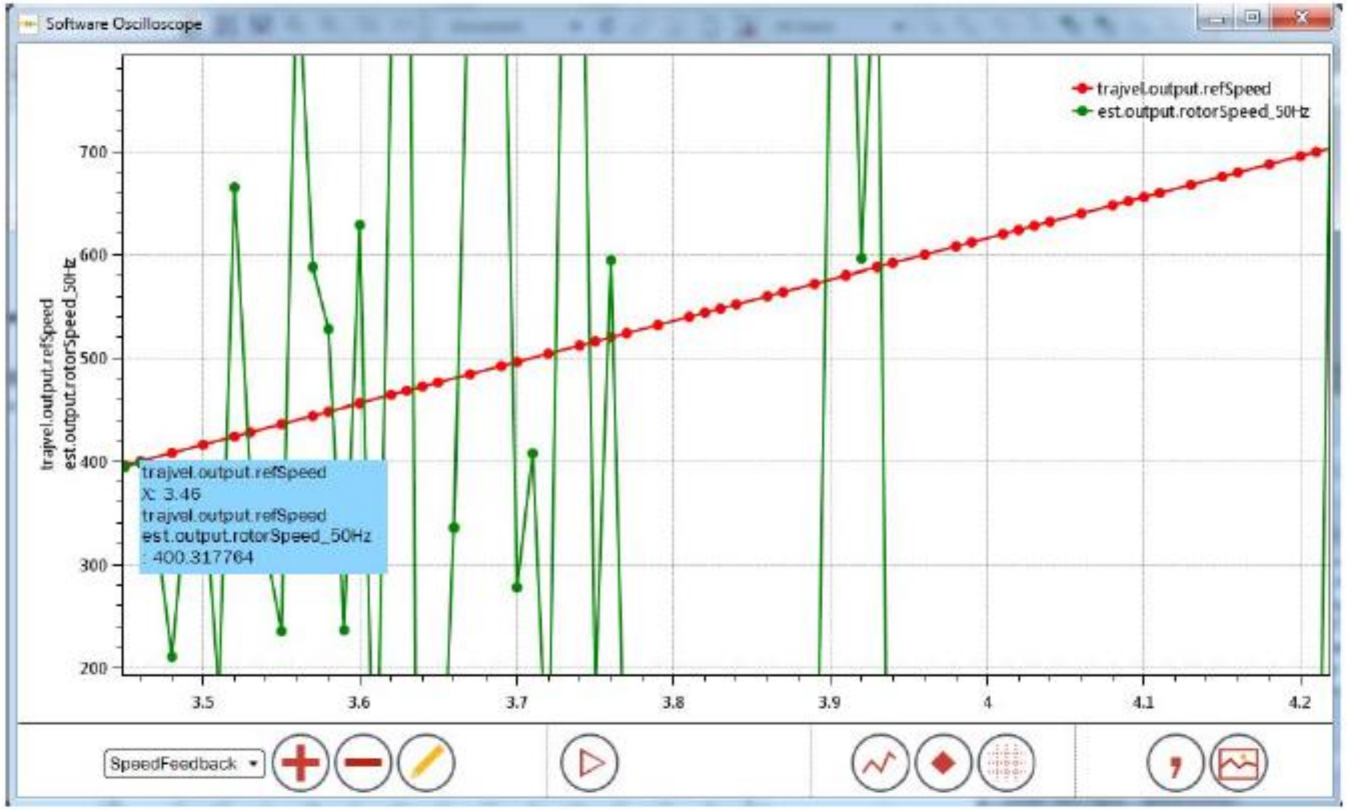
- This data reflects the variables being plotted, and the x and y coordinate values of the data point you have selected.



trajvel.output.refSpeed
X: 3.48
trajvel.output.refSpeed
est.output.rotorSpeed_50Hz
: 408.313179

Left click to view data point values

- Use your mouse wheel to zoom in and out of the selected area.

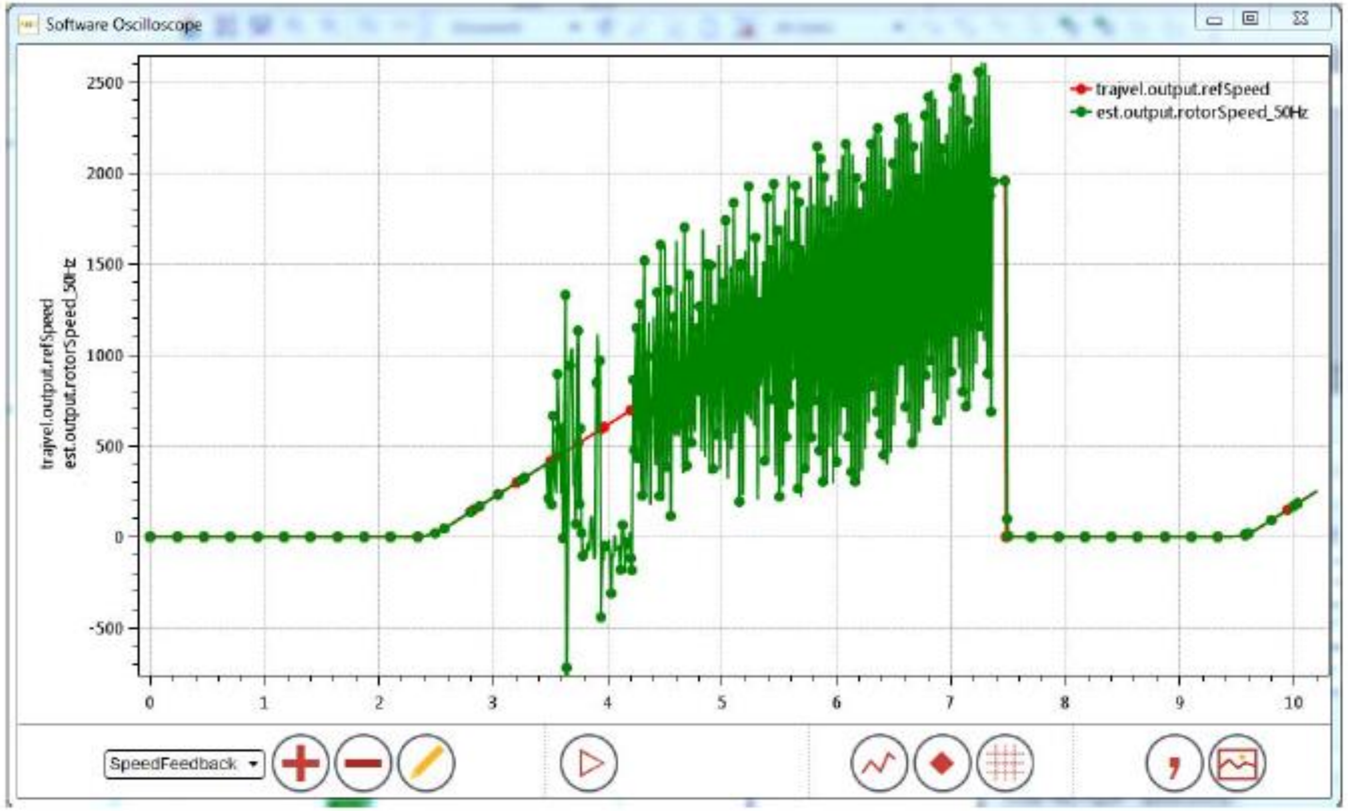

Software Oscilloscope

trajvel.output.refSpeed
X: 3.46
trajvel.output.refSpeed
est.output.rotorSpeed_50Hz
: 400.317764

SpeedFeedback

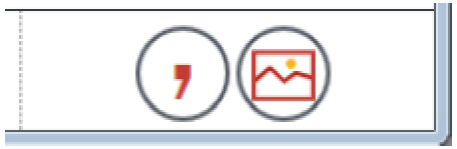
Zoom in and out using mouse wheel

- Press the "A" key to reset the axes.



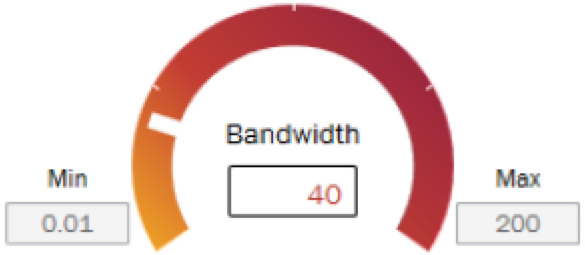
Plot reset by “A”

- Save the csv and png file.



Save CSV and PNG buttons

- Set the bandwidth back to approximately the default value.



Min 0.01

Bandwidth 40

Max 200

Bandwidth field

Summary

- In this first part of the lab, you performed the following steps to gauge the default tuning of your motor:
  - Viewed advanced parameters available in Motor Manager.
  - Tested different speed loop tunings to see the impact.
  - Saved the csv and image files so that the data can be analyzed at a later time.
  - Utilized the Software Oscilloscope to examine motor performance.
- This lab reflects KMS’ intuitive tuning process: find the boundary values where your motor performs poorly and/or unstably, then iteratively adjust the value of Bandwidth according to the performance shown by the Software Oscilloscope.

Part II: Test Trajectories

Objective

- Applications typically require motors to operate at a variety of speeds based on certain application or environmental conditions.

- Building such a motion sequence piecewise is easy in KMS.

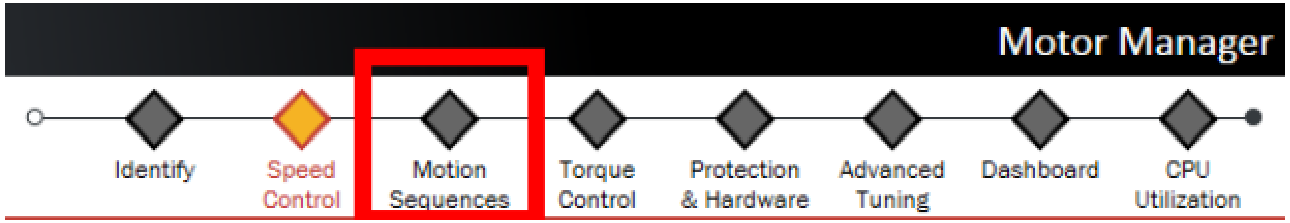
- In this part of the lab, use the Trajectory Test Mode to find the theoretical motion limits that should allow the motor to transition between two speeds in the desired amount of time.

- Once you find values that meet these requirements, test to see if your motor can actually run in this configuration.

- In the last part of this lab, open Motion Sequence Builder and see how discrete trajectories can be combined to build an application motion sequence in KMS.

Procedure

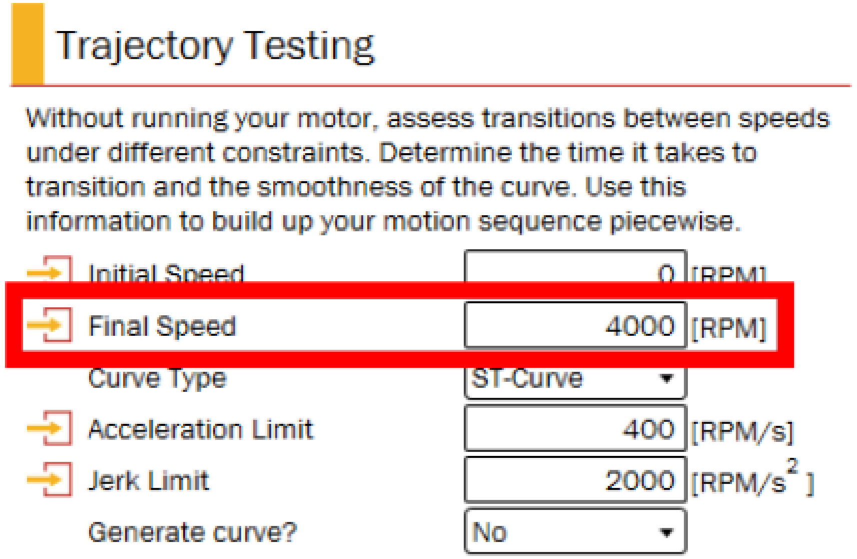
- 1. Define a trajectory from zero to rated speed
  - Navigate to the Motion Sequences page.



Motion sequences page

- Under the Trajectory Testing heading, enter the motor's rated speed into the Final Speed field.

- Figure displays the rated speed for the Linix 45ZWN24-40 reference motor.



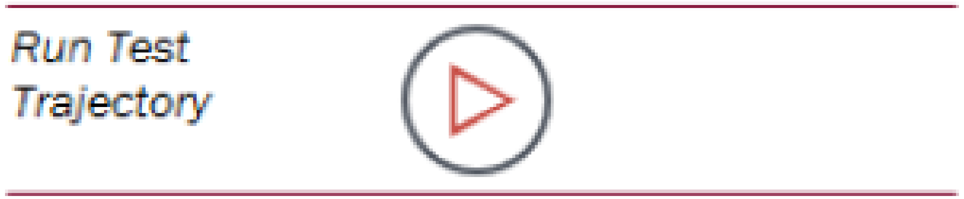
Trajectory Testing

Without running your motor, assess transitions between speeds under different constraints. Determine the time it takes to transition and the smoothness of the curve. Use this information to build up your motion sequence piecewise.

Initial Speed	0	[RPM]
Final Speed	4000	[RPM]
Curve Type	ST-Curve	
Acceleration Limit	400	[RPM/s]
Jerk Limit	2000	[RPM/s^2]
Generate curve?	No	

Final speed field

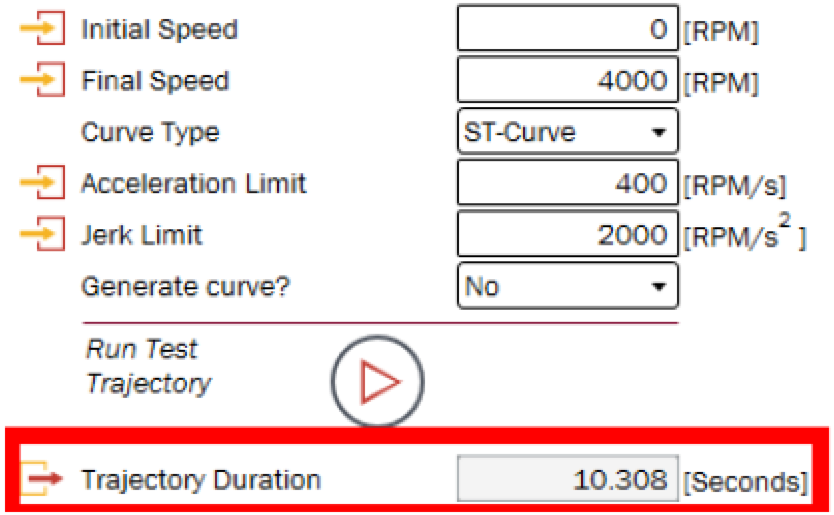
- Click to Run Test Trajectory



Run test trajectory button

- The system calculates the Trajectory Duration based on the Acceleration and Jerk Limits.

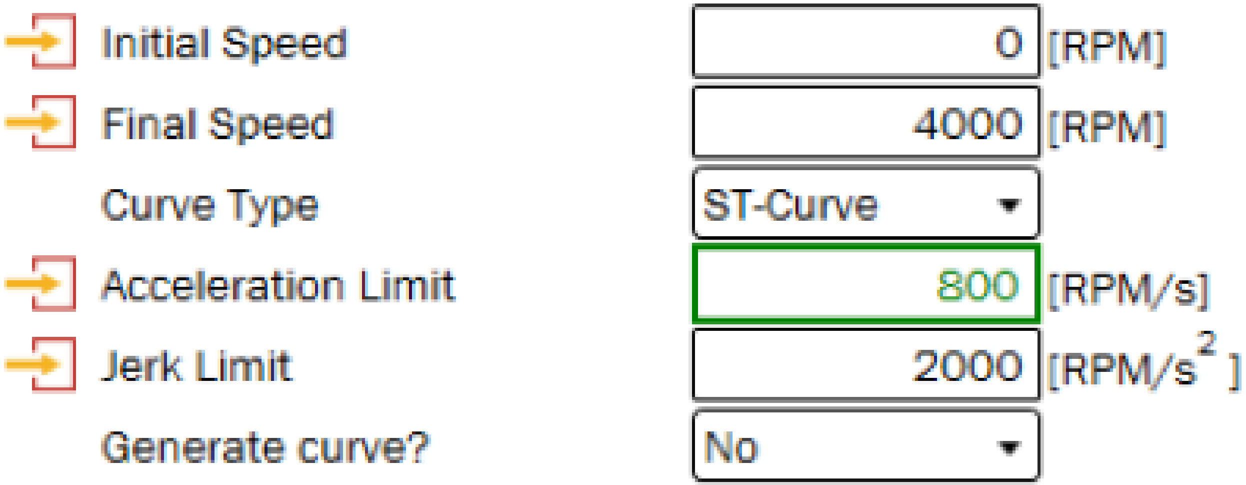
- The calculations are intuitive for velocity control: in Figure, going from 0 rpm to 4000 rpm with acceleration of 400 rpm per second should take approximately ten seconds.



Initial Speed	0	[RPM]
Final Speed	4000	[RPM]
Curve Type	ST-Curve	
Acceleration Limit	400	[RPM/s]
Jerk Limit	2000	[RPM/s^2]
Generate curve?	No	
Trajectory Duration	10.308	[Seconds]

Trajectory duration output field

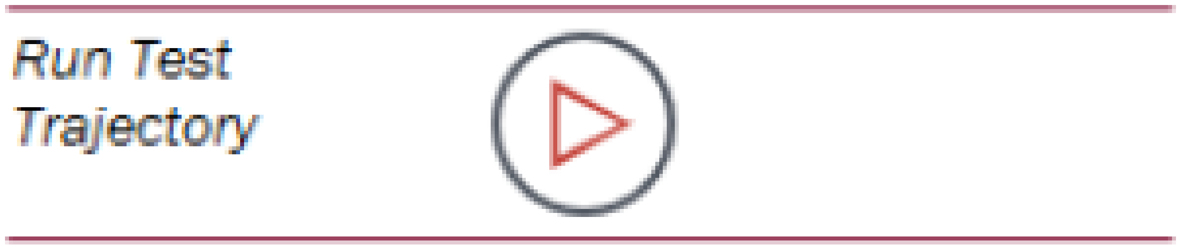
- Double the Acceleration Limit.



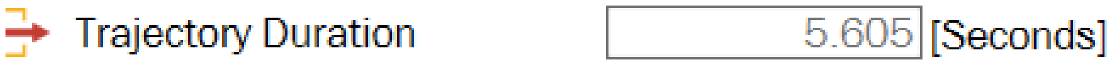
Initial Speed	0	[RPM]
Final Speed	4000	[RPM]
Curve Type	ST-Curve ▾	
Acceleration Limit	800	[RPM/s]
Jerk Limit	2000	[RPM/s^2]
Generate curve?	No ▾	

Test acceleration limit

- Click to Run Test Trajectory again and note the Trajectory Duration.

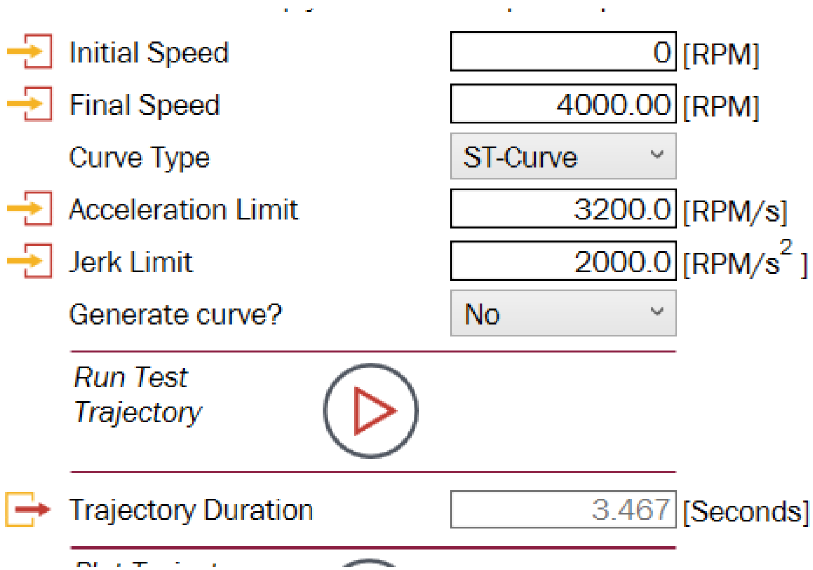


Run test trajectory button


Trajectory Duration 5.605 [Seconds]

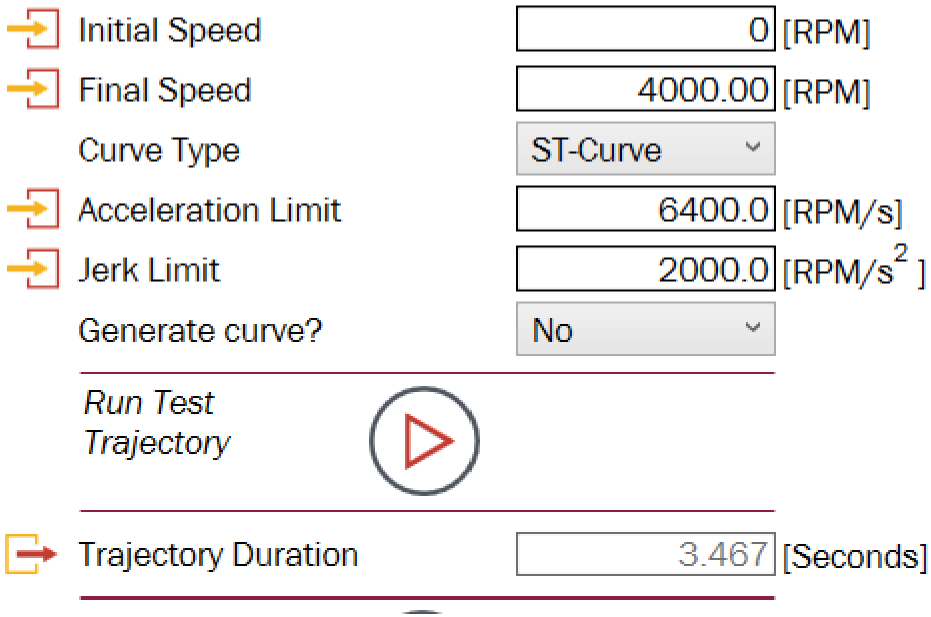
- Continue to double the Acceleration Limit until the Trajectory Duration no longer changes.

- This means that Acceleration Limit is no longer a significant constraint.



Initial Speed	0	[RPM]
Final Speed	4000.00	[RPM]
Curve Type	ST-Curve	
Acceleration Limit	3200.0	[RPM/s]
Jerk Limit	2000.0	[RPM/s^2]
Generate curve?	No	

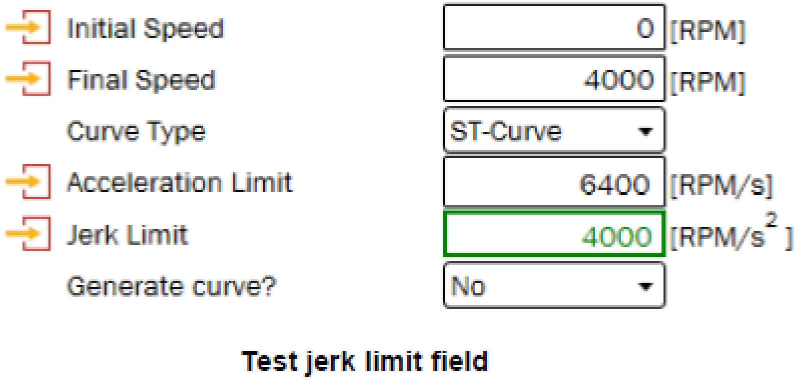
Trajectory Duration	3.467	[Seconds]



Initial Speed	0	[RPM]
Final Speed	4000.00	[RPM]
Curve Type	ST-Curve	
Acceleration Limit	6400.0	[RPM/s]
Jerk Limit	2000.0	[RPM/s^2]
Generate curve?	No	

Trajectory Duration	3.467	[Seconds]

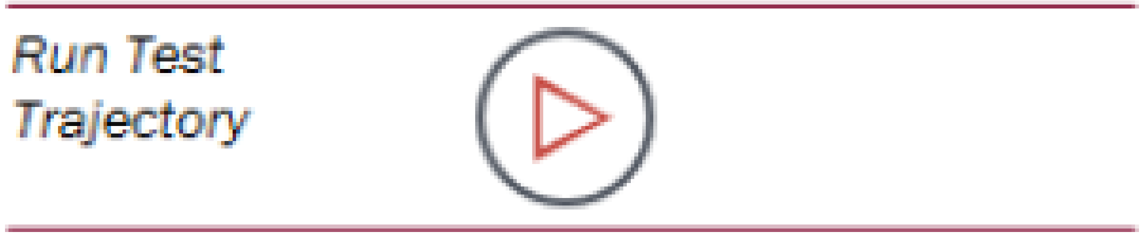
- Instead, the rate at which your acceleration is allowed to increase - the Jerk Limit - is the constraining factor. Double the Jerk Limit.



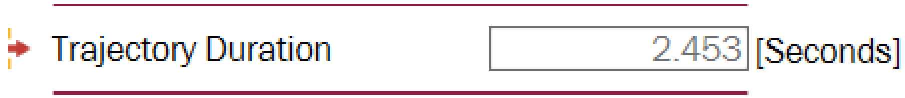
Initial Speed	0	[RPM]
Final Speed	4000	[RPM]
Curve Type	ST-Curve ▾	
Acceleration Limit	6400	[RPM/s]
Jerk Limit	4000	[RPM/s^2]
Generate curve?	No ▾	

Test jerk limit field

- Click to Run Test Trajectory.



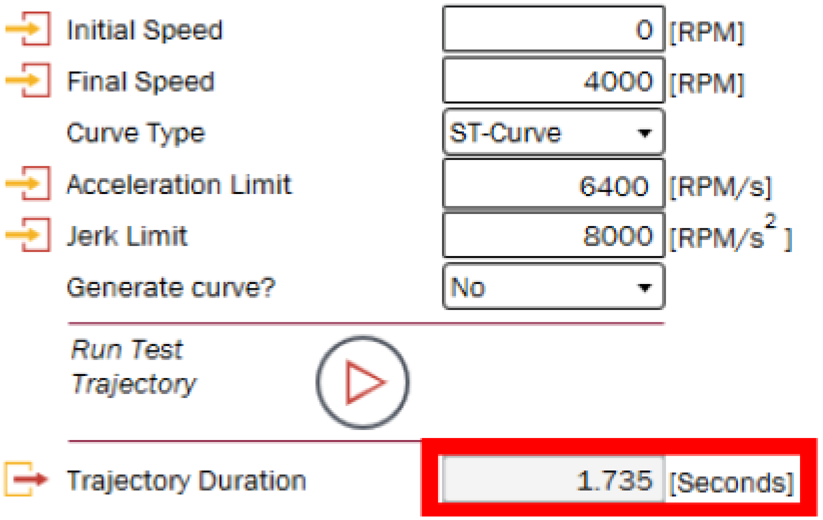
Run test trajectory button



Trajectory Duration 2.453 [Seconds]

- Continue to increase the Jerk Limit until the Trajectory Duration is approximately 2 seconds.

- Figure shows a set of limits for the Linix motor

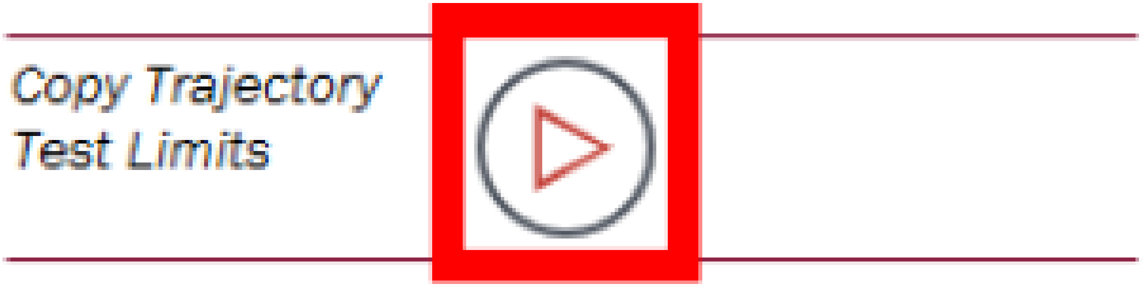


Initial Speed	0	[RPM]
Final Speed	4000	[RPM]
Curve Type	ST-Curve	
Acceleration Limit	6400	[RPM/s]
Jerk Limit	8000	[RPM/s^2]
Generate curve?	No	
Trajectory Duration	1.735	[Seconds]

Trajectory duration output field

- Find and click the button to Copy Trajectory Test Limits (located at the bottom of the Trajectory Testing step).

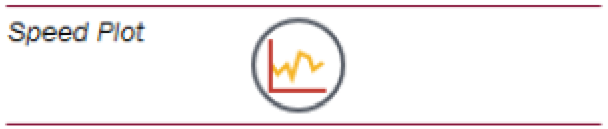
- This takes the kinematic values you have arrived at in testing and applies them to the actual trajectory constraints to be applied on the MCU when controlling the motor.



Copy trajectory test limits button

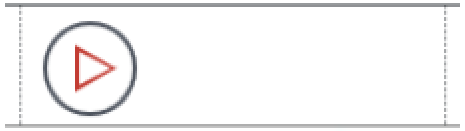
2. Determine whether your motor can execute this trajectory

- Go to the Speed Control page. Click to activate the Speed Plot.



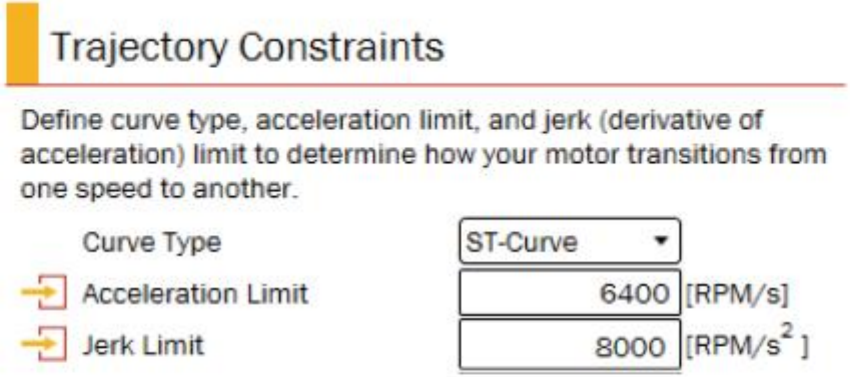
Open speed plot button

- Click to begin sampling at bottom of Software Oscilloscope window.



Begin sampling button

- Under Trajectory Constraints on the Speed Control page, verify that the Acceleration and Jerk Limits reflect the values that allowed you to achieve a Trajectory Duration of ~2 seconds in testing. Figure displays the values for the Linix reference motor.



Trajectory Constraints

Define curve type, acceleration limit, and jerk (derivative of acceleration) limit to determine how your motor transitions from one speed to another.

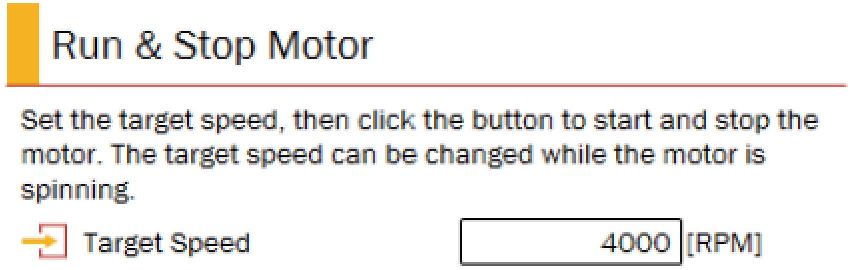
Curve Type: ST-Curve

Acceleration Limit: 6400 [RPM/s]

Jerk Limit: 8000 [RPM/s^2]

Actual acceleration and jerk limit fields

- In the Target Speed field, enter the motor’s rated speed. Figure displays the rated speed for the Linix motor.



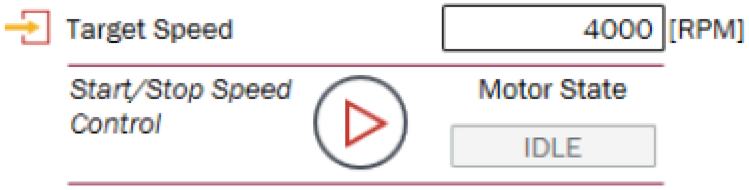
Run & Stop Motor

Set the target speed, then click the button to start and stop the motor. The target speed can be changed while the motor is spinning.

Target Speed 4000 [RPM]

Target speed field

- Click to Start Motor.



Target Speed 4000 [RPM]

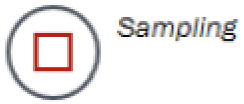
Start/Stop Speed Control

Motor State

IDLE

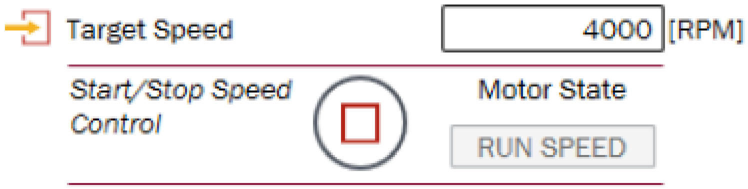
Start motor button

- Wait for the motor to run and attempt to reach rated speed. After five seconds, click to stop sampling.



Stop sampling button

- Stop the motor.


Target Speed 4000 [RPM]

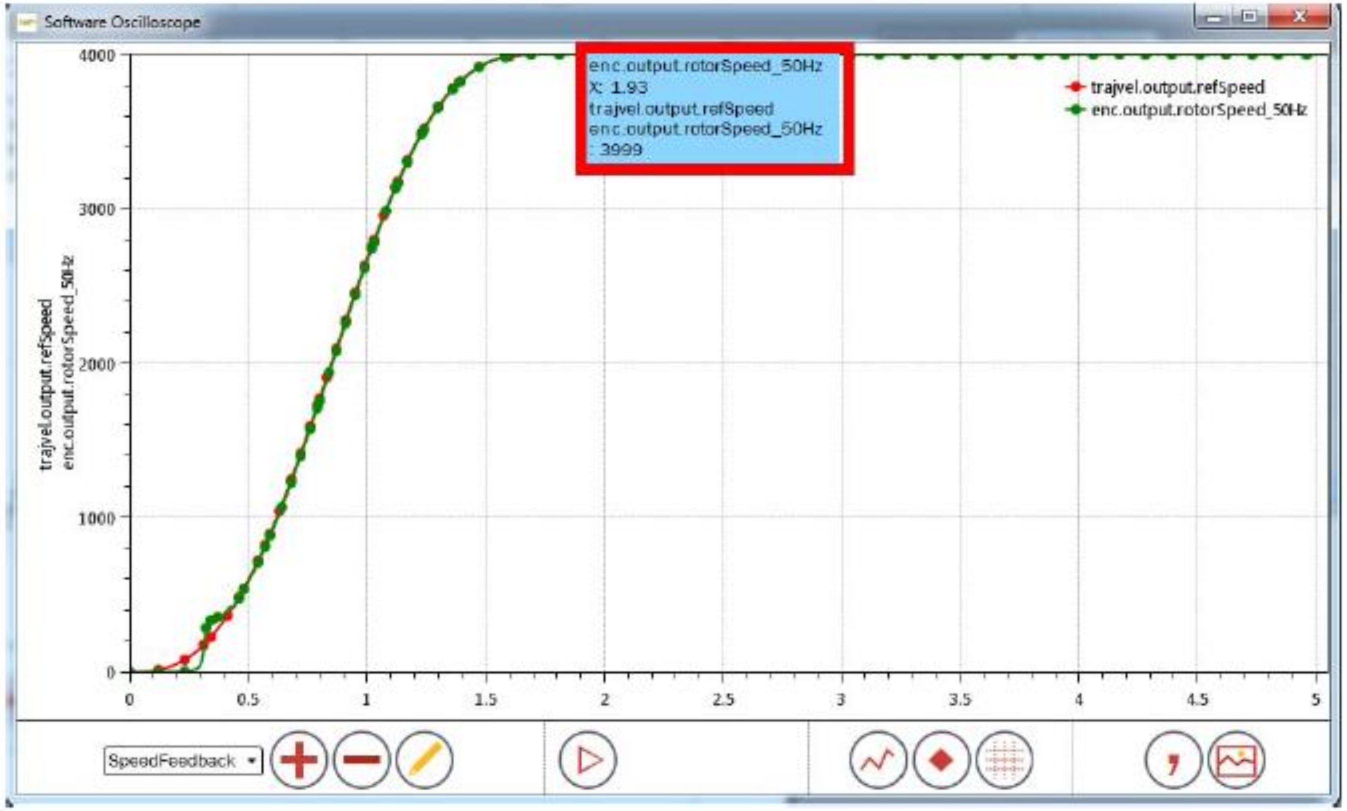
Motor State: RUN SPEED

Stop motor button

- If your motor was able to r un the trajectory, congratulations!

- You can verify that the motor reached the rated speed by positioning your cursor on the curve at the 2-second point (defined by x-axis) on the Speed Plot, and clicking the left mouse button, as shown in Figure.

- This displays the estimated speed at 2 seconds into the transition.



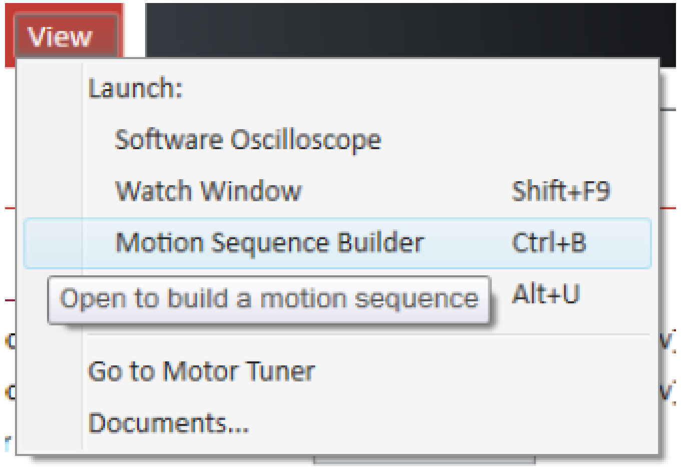
enc.output.rotorSpeed_50Hz
X: 1.93
trajvel.output.refSpeed
enc.output.rotorSpeed_50Hz
: 3999

Successful motion with data point values (sensored velocity example)

- If your motor was unable to run the trajectory, reduce the Acceleration Limit until you are successfully able to run from 0 rpm to rated speed.

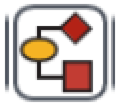
3. Learn how to incorporate a trajectory into an application's motion sequence

- Under the View menu, Launch Motion Sequence Builder.

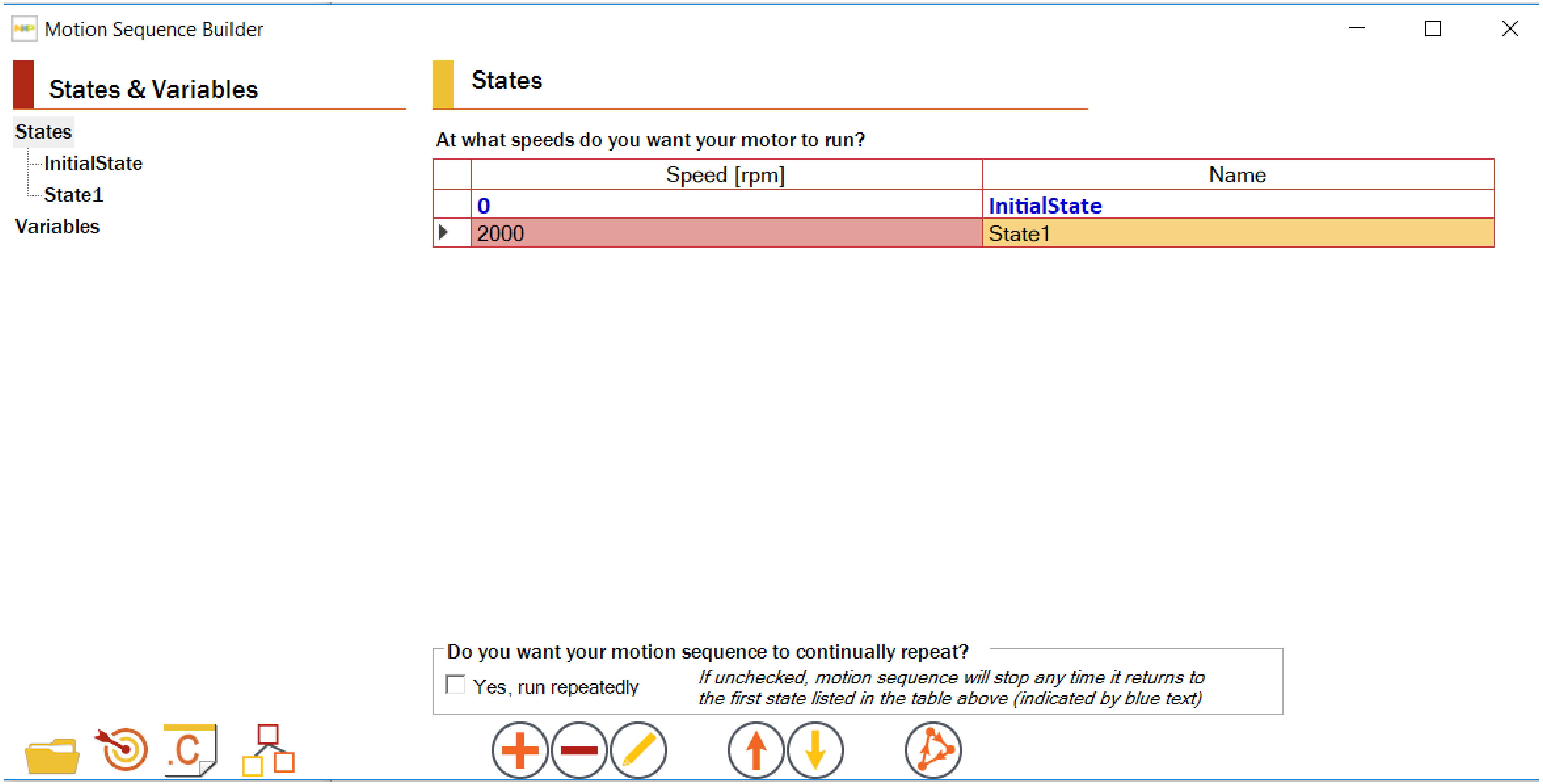


Start Motion Sequence Builder menu option

- You may also launch it from the Motion Sequence Builder icon at bottom right.



Click to launch Motion Sequence Builder



States

At what speeds do you want your motor to run?

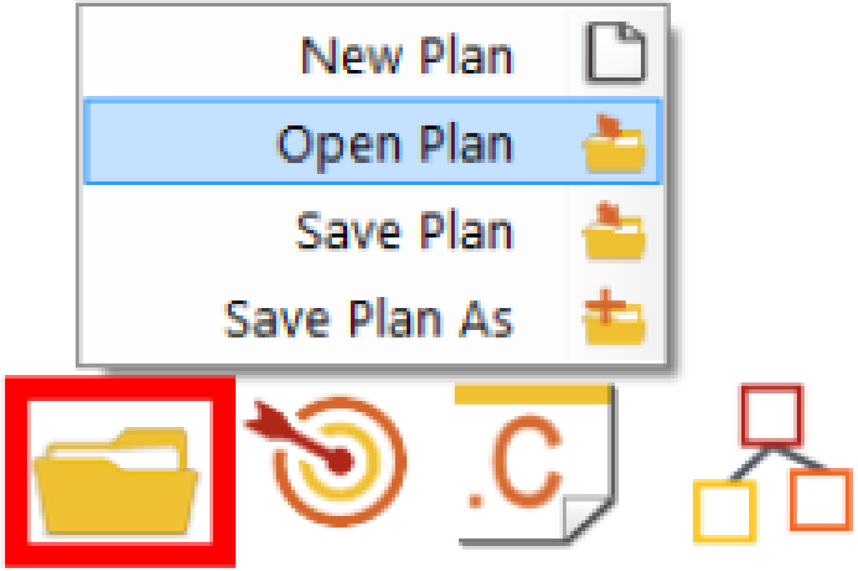
	Speed [rpm]	Name
	0	InitialState
▶	2000	State1

Do you want your motion sequence to continually repeat?

☐ Yes, run repeatedly

If unchecked, motion sequence will stop any time it returns to the first state listed in the table above (indicated by blue text)

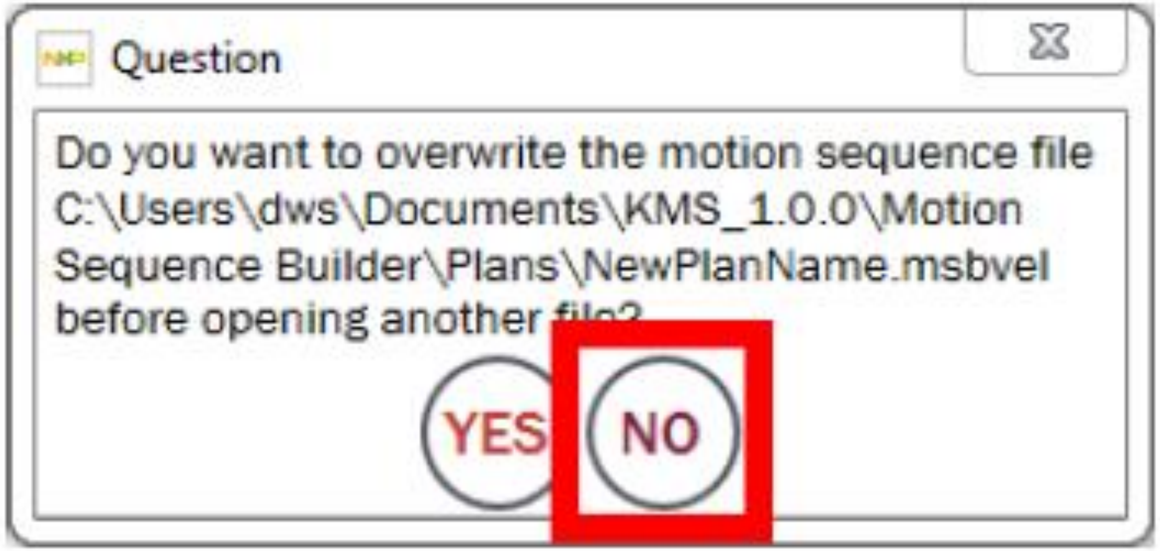
- Motion Sequence Builder includes a few sample motion sequences.
- Click on the file folder icon at bottom left, then select Open Plan.



Open plan menu option

- You may receive a notification asking if you wish to overwrite a motion sequence file.

- Click NO to proceed.



Question

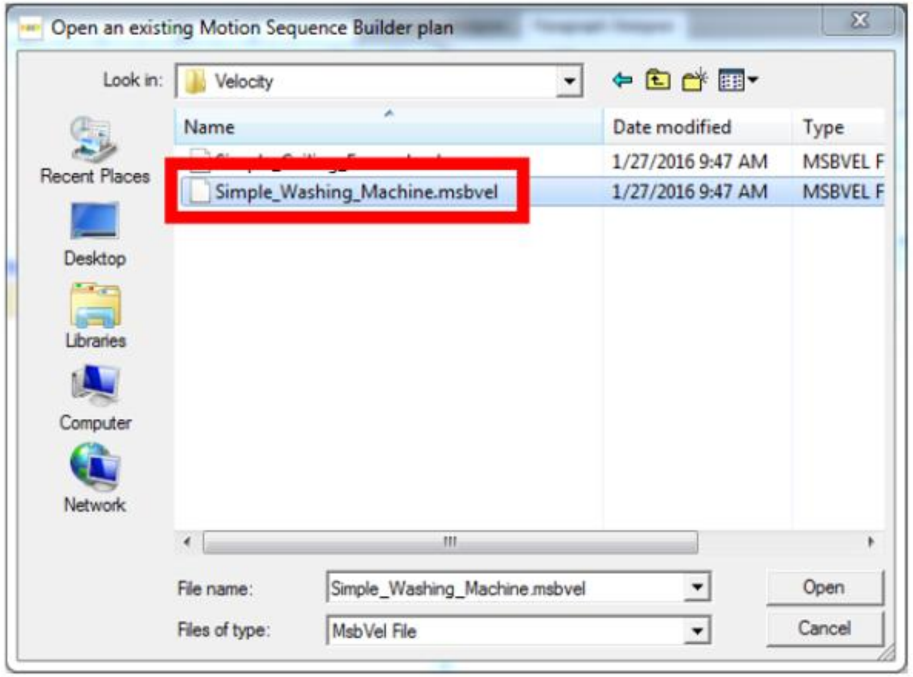
Do you want to overwrite the motion sequence file C:\Users\dws\Documents\KMS_1.0.0\Motion Sequence Builder\Plans\NewPlanName.msbvel before opening another file?

Click NO to avoid overwriting default motion sequence file

- Navigate to the velocity control Examples directory at:

C:\Users\<username>\Documents\KMS_<version>\Motion SequenceBuilder\Plans\Examples\Velocity

- Select Simple_Washing_Machine.msbvel, and click Open.



Open an existing Motion Sequence Builder plan

Look in: Velocity

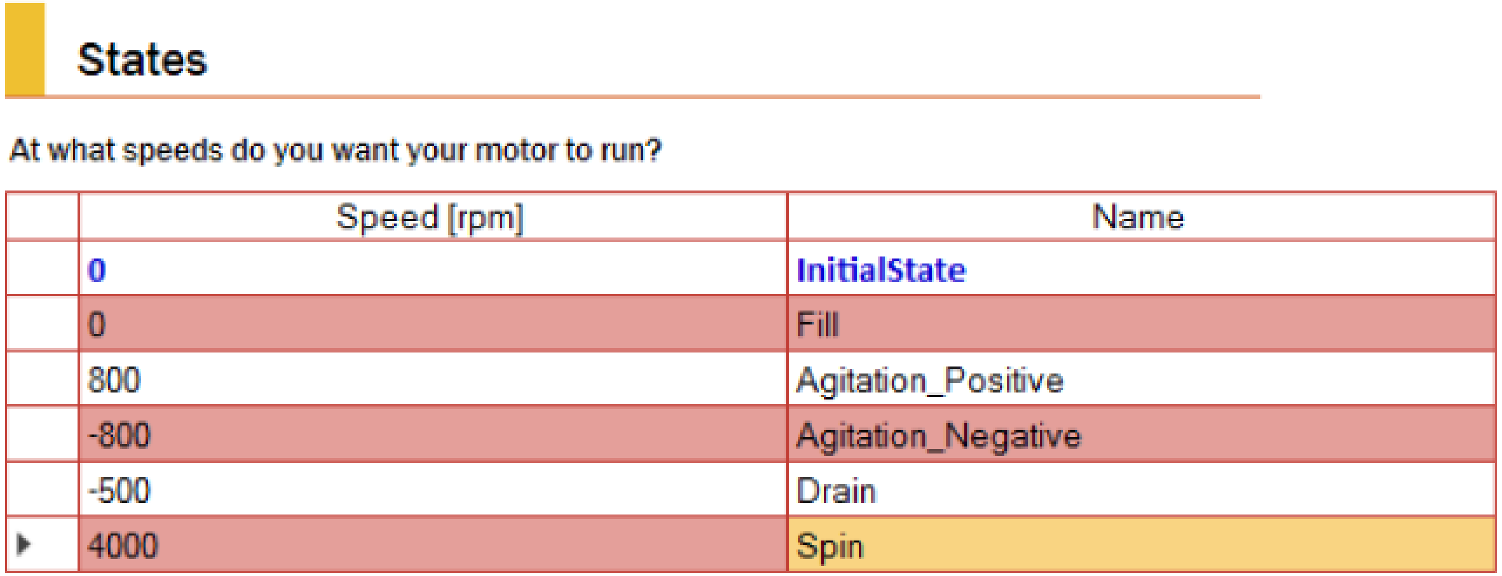
Name	Date modified	Type
[illegible]	1/27/2016 9:47 AM	MSBVEL F
Simple_Washing_Machine.msbvel	1/27/2016 9:47 AM	MSBVEL F

File name: Simple_Washing_Machine.msbvel

Files of type: MsbVel File

Directory for washing machine example

- Note the different speeds of operation that make up the washing machine motion sequence, especially for the states named Drain and Spin.



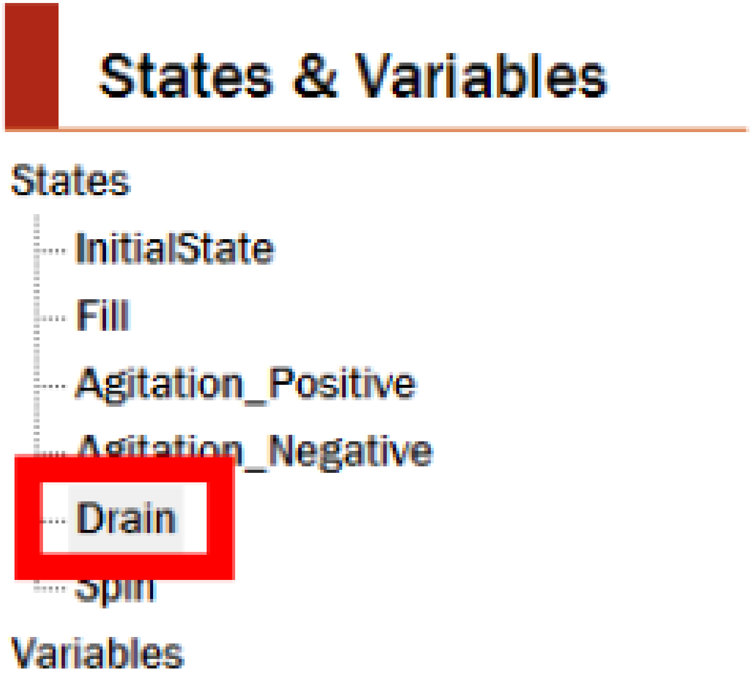
States

At what speeds do you want your motor to run?

	Speed [rpm]	Name
	0	**InitialState**
	0	Fill
	800	Agitation_Positive
	-800	Agitation_Negative
	-500	Drain
▶	4000	Spin

Enumeration of states in Motion Sequence Builder

- In the tree view at left, click Drain.



States & Variables

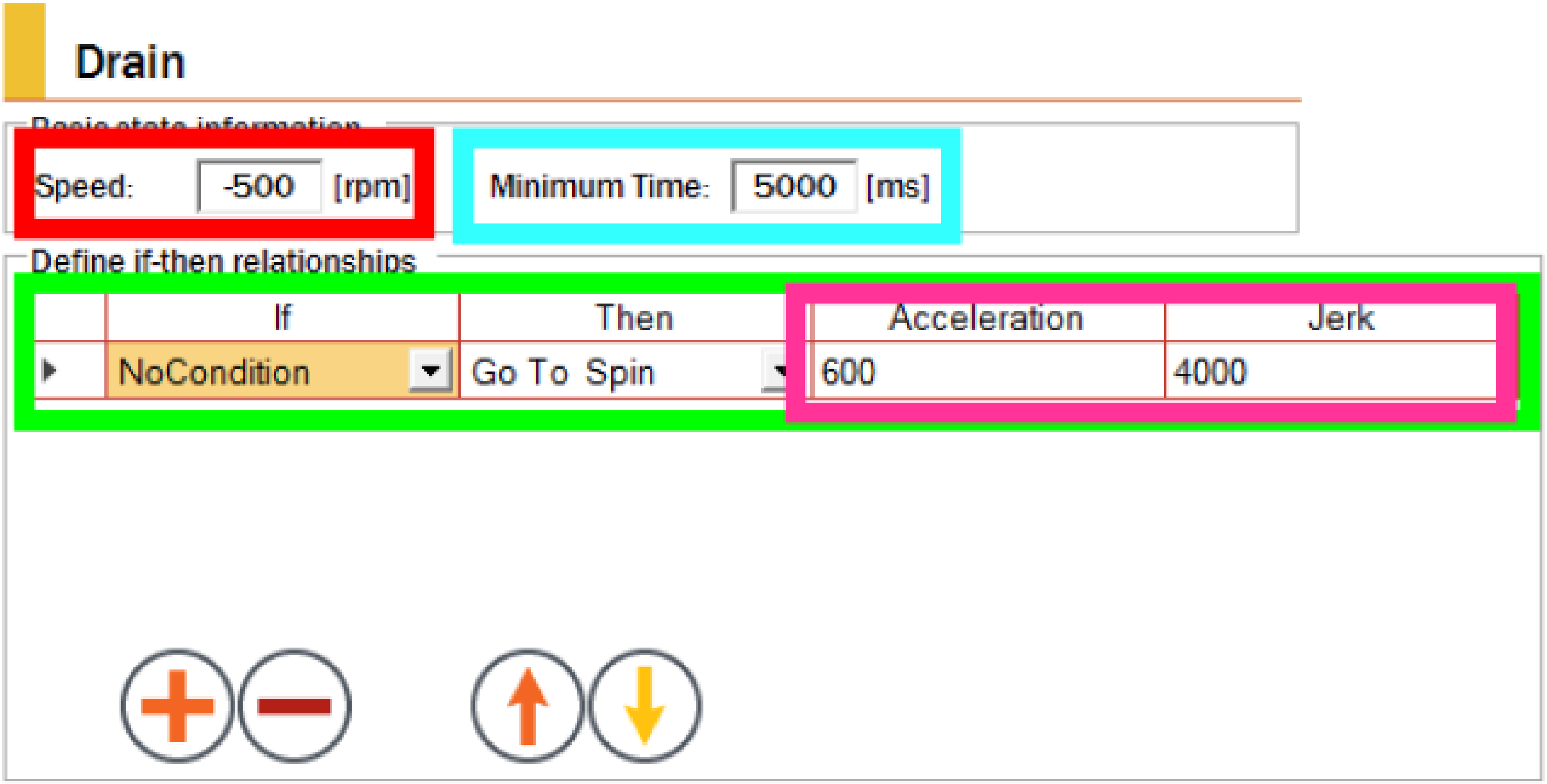
States
- InitialState
- Fill
- Agitation_Positive
- Agitation_Negative
- Drain
- Spin

Variables

Drain state in treeview

- Observe the options available to configure the Drain state, including:
  - Speed (red outline)
  - Minimum time that the motor must remain in this state (blue outline)
  - If-then relationships to trigger transition to a different speed (green outline)
  - Acceleration and jerk limits for transitions to different speeds (pink outline)

- Construction of such a motion sequence is the subject of "lab: build a simple motion sequence".



Drain

Basic state information

Speed: -500 [rpm]

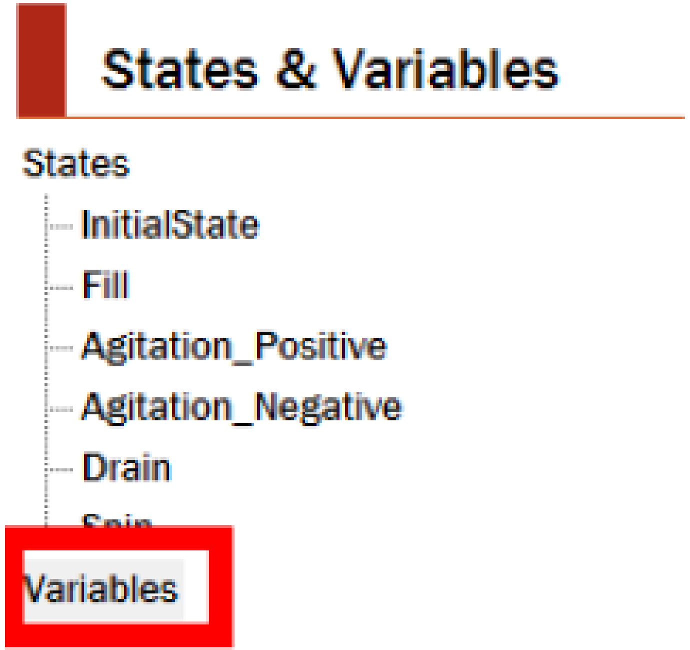
Minimum Time: 5000 [ms]

Define if-then relationships

If	Then	Acceleration	Jerk
NoCondition	Go To Spin	600	4000

Drain state definition

- In the tree view, click Variables.



States & Variables

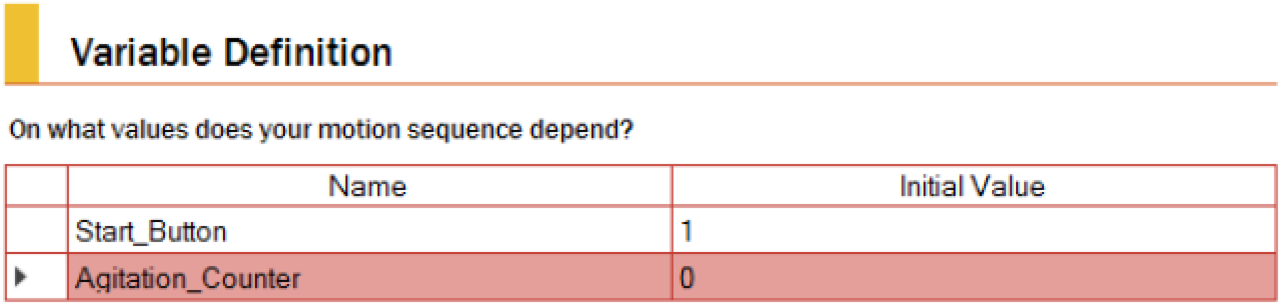
States
- InitialState
- Fill
- Agitation_Positive
- Agitation_Negative
- Drain
- Spin

Variables

Variables option in treeview

- Observe enumerated variables for the washing machine motion sequence.

- Variables allow you to tie operation to values elsewhere in the system



Variable Definition

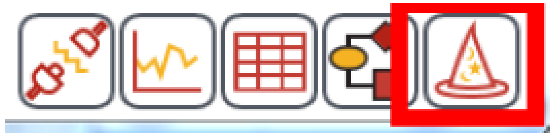
On what values does your motion sequence depend?

	Name	Initial Value
	Start_Button	1
▶	Agitation_Counter	0

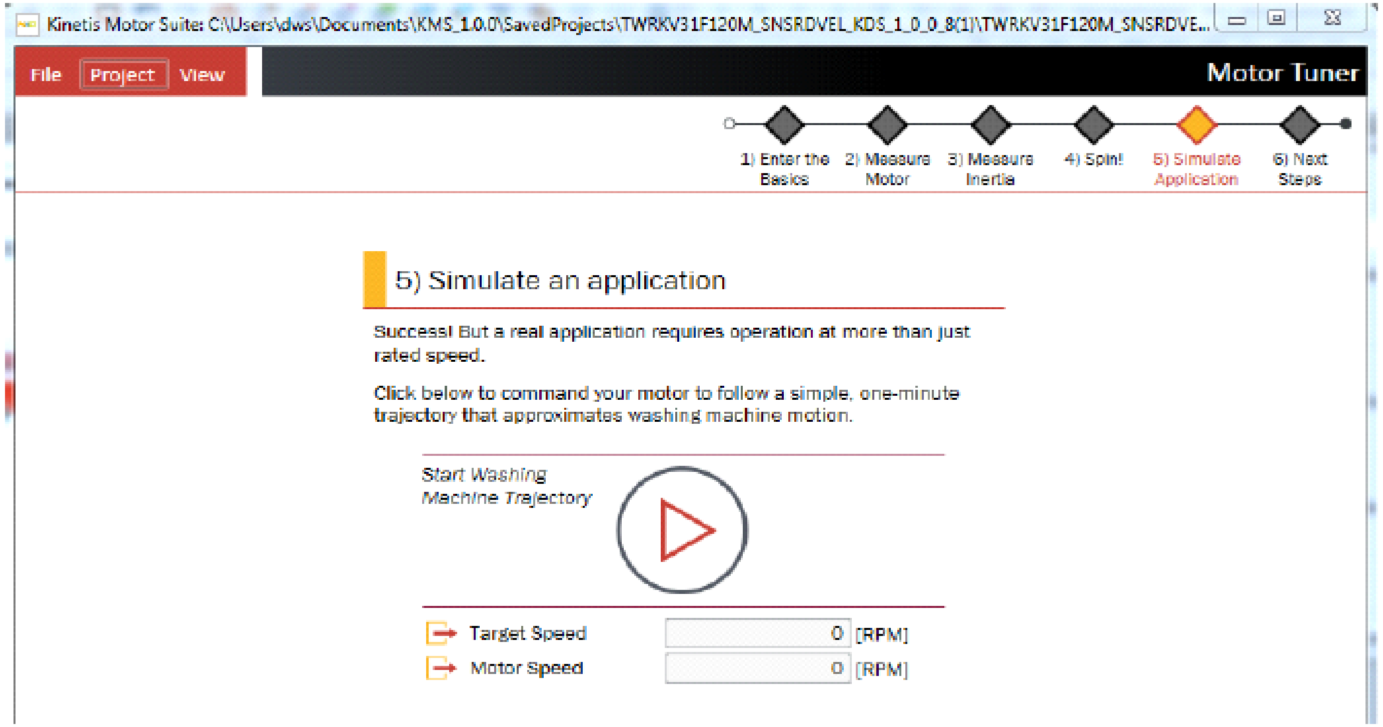
Enumerated variables for washing machine motion sequence

- Navigate to the main KMS window.

- Return to Motor Tuner by clicking the wizard hat icon at bottom right and go to Step 5 of Motor Tuner.



Button to go to Motor Tuner



Kinetis Motor Suite: C:\Users\dws\Documents\KMS_1.0.0\SavedProjects\TWRKV31F120M_SNSRDVEL_KDS_1_0_0_8(1)\TWRKV31F120M_SNSRDVE...

5) Simulate an application

Success! But a real application requires operation at more than just rated speed.

Click below to command your motor to follow a simple, one-minute trajectory that approximates washing machine motion.

Start Washing Machine Trajectory

Target Speed 0 [RPM]

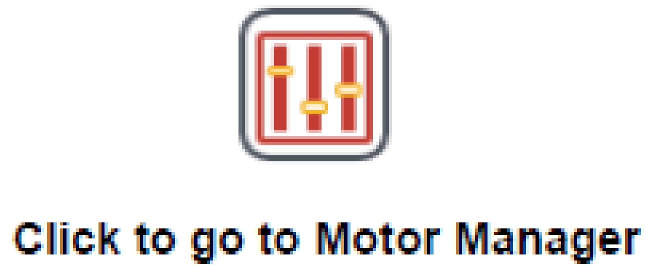
Motor Speed 0 [RPM]

Click to start the washing machine trajectory

- Click to run the example motion sequence.

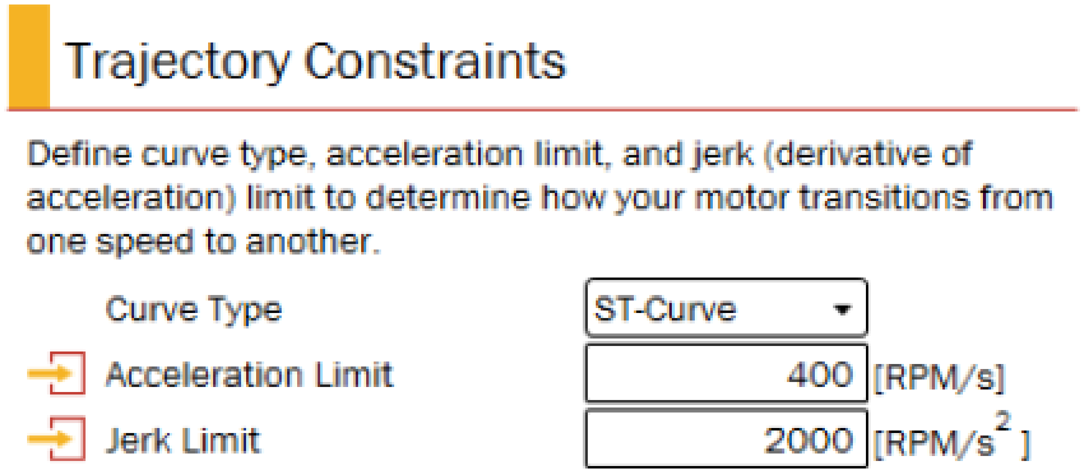
- Try to view the motor’s behavior as a series of discrete trajectories (like the one you just created) that can be combined into an application motion sequence.

- Return to Motor Manager by clicking the icon at bottom right.



Click to go to Motor Manager

- Return to the Speed Control page and return the Trajectory Constraints to their original values in order to proceed to the next lab.



Trajectory Constraints

Define curve type, acceleration limit, and jerk (derivative of acceleration) limit to determine how your motor transitions from one speed to another.

Curve Type	ST-Curve ▾	
Acceleration Limit	400	[RPM/s]
Jerk Limit	2000	[RPM/s^2]

Default trajectory constraints for Linix 45ZWN24-40 reference motor

Summary

- In this lab, you performed the following steps to start building an application motion sequence:
  - Considered transitions between speeds required by the application
  - Built and tested a transition using Motor Manager
  - Explored an example implementation in Motion Sequence Builder