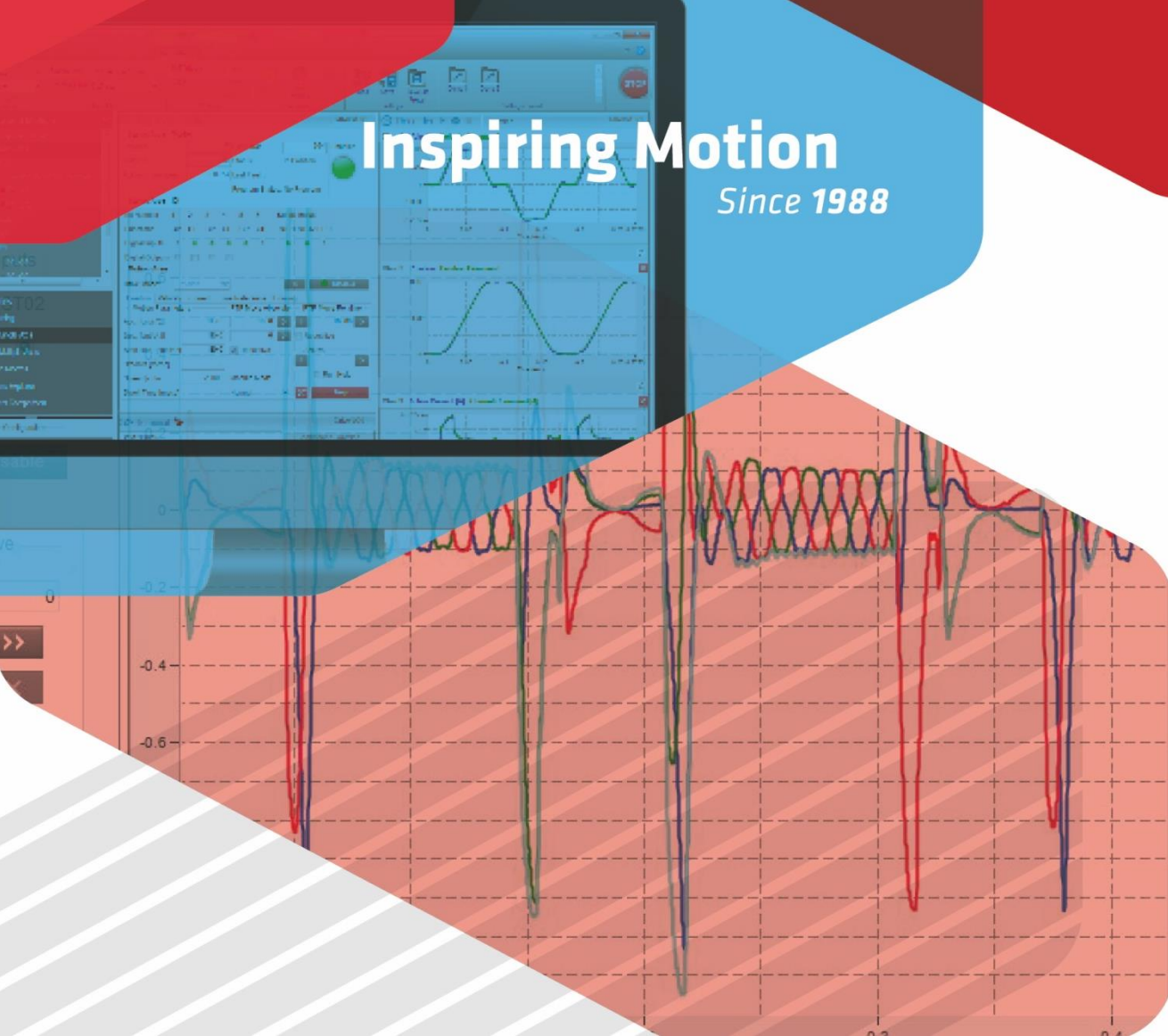


Inspiring Motion

Since 1988



Exercise #1

Expert Tuning

The key points of this demo show that:

- Tuning takes only minutes
- The tuning process is backed by powerful algorithms for optimization
- Elmo's tuning algorithms are based on high precision mathematical methods
- Even though the application is smarter and faster, tuning is still simple and friendly
- Elmo's software package offers multiple tools for additional "tweaking" and customization

List of parameters for this demo:				
Parameter	Value		Parameter	Value
Motor type	Rotary. Brushless		Feedback, Socket 1	Encoder Quad, Port A
Continuous. Stall Current	1		Feedback Resolution	2500
Peak current	2			
Max speed	3000		G-MAS IP	192.168.1.3
# Pole pairs	4		Computer IP	192.168.1.XXX

Exercise #1: Expert Tuning

1. Start by connecting the relevant drive via System Configuration.

2. G-MAS connection

1. System Configuration

4. Gateways connection

3. Pre Op Mode

Section	Parameter	Value
1. General	1.1 Target Name	G01
	1.2 Target Version	1.1.2.0 B4 Jul 3 2013
	1.3 Target Type	G-MAS EtherCAT
	1.4 Cycle Time	1000
	1.5 Mailbox Cycle Time	3000
	1.6 Background Cycle Time	100
	1.7 Receive I/O status	False
2. Target Connection	2.1 Connection Type	G-MAS TCP/IP
	2.2 IP Address	192.168.1.3
3. G-MAS Network	3.1 Network Type	ETHERCAT
	4. Gateway	False
5. Host TCP/IP Interface	5.1 Auto Connect Gateway	False
	5.1 Host IP Address	192.168.1.10

2. Setup the Axis Configuration.

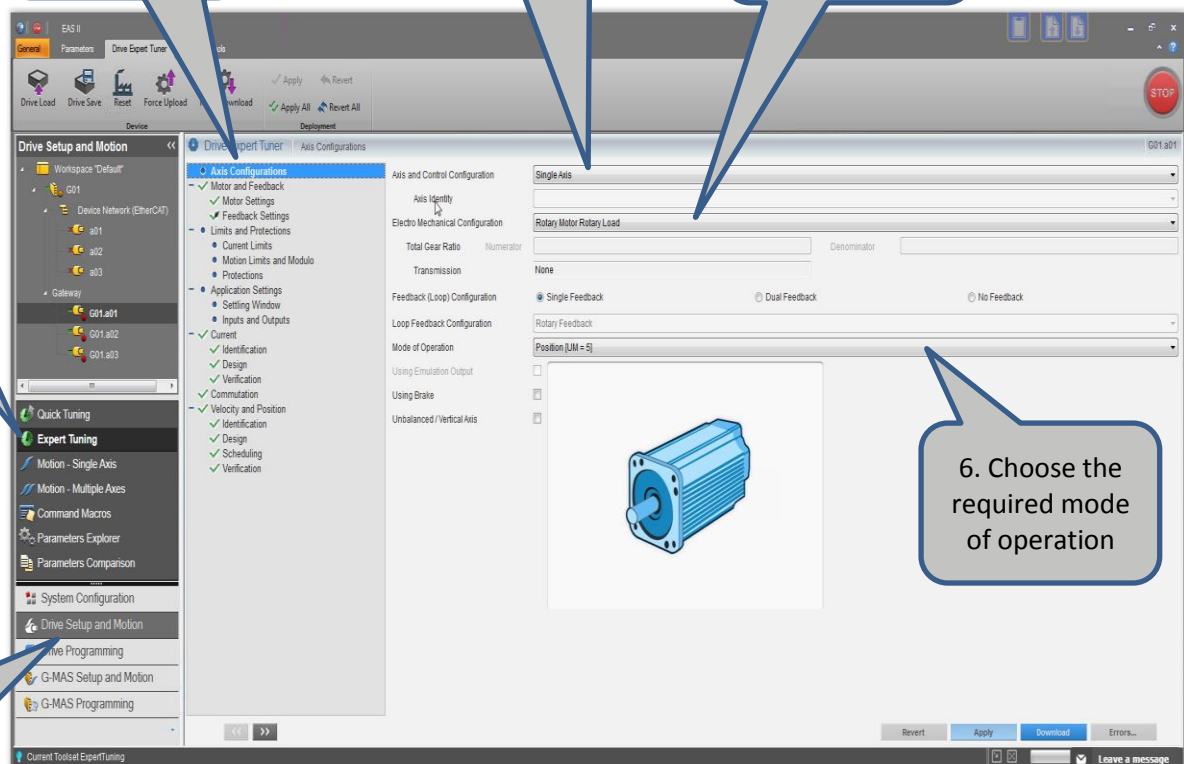
3. Axis Configurations

4. Choose the appropriate Axis and Control Configuration. For this demo choose: "Single Axis"

5. Choose the type of motor and load

2. Expert Tuning tool

1. Drive Setup and Motion



3. Fill in motor settings as listed in the motor data sheet.

1. Motor Settings

2. Choose the motor type and fill in the electrical and mechanical limitations of the motor according to its data sheet

The screenshot shows the Elmo EAS II software interface. The sidebar on the left contains a tree view with the following structure:

- Workspace "basisWS"
 - G01
 - Device Network (EtherCAT)
 - a01
 - a02
 - a03
 - Gateway
 - G01.a01
 - G01.a02
 - G01.a03
 - Groups
- Quick Tuning
- Expert Tuning
- Motion - Single Axis
- Motion - Multiple Axes
- Command Macros
- Parameters Explorer
- Parameters Comparison
- System Configuration
- Drive Setup and Motion
- Drive Programming
- G-MAS Setup and Motion
- G-MAS Programming

The central pane displays the 'Motor Settings' configuration for 'G01.a01'. The settings are organized into a list with checkboxes and sub-items:

- Axis Configurations
 - Motor and Feedback
 - Motor Settings** (highlighted)
 - Feedback Settings
 - Limits and Protections
 - Current Limits
 - Motion Limits and Module
 - Protections
 - Application Settings
 - Setting Window
 - Inputs and Outputs
 - Current
 - Identification
 - Design
 - Verification
 - Commutation
 - Velocity and Position
 - Identification
 - Design
 - Scheduling
 - Verification

The right pane shows the 'Motor Settings' input fields:

- From Data Base: ☐
- Motor Type C4[28]: Rotary Brushless (3 Phase)
- Peak Current [Arms]: 2
- Continuous Stall Current [Arms]: 1
- Maximal Motor Speed [RPM]: 3000
- Pole Pairs per Revolution C4[19]: 4

At the bottom of the right pane, there are buttons: Revert, Apply, Download, and Errors...

4. Fill in feedback settings as listed in the data sheet.

1. Feedback Settings

2. Choose the encoder type and port to which it is connected

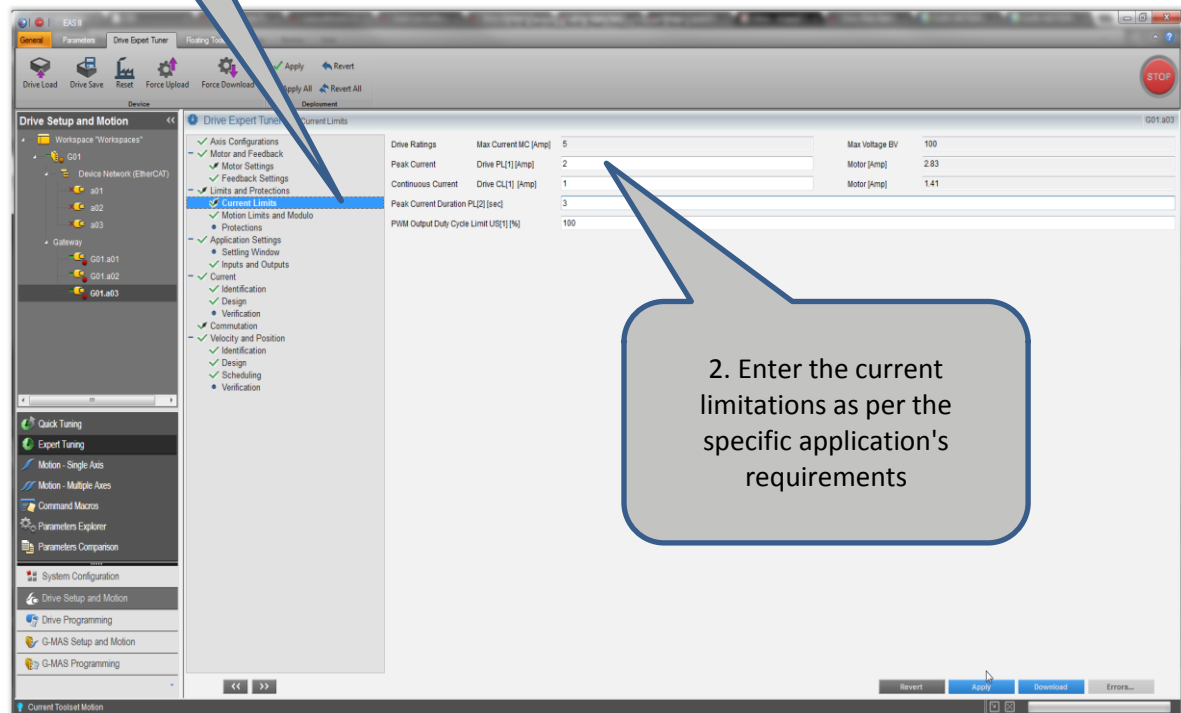
3. Choose whether or not the feedback is using digital halls or not

4. Fill in the feedback's resolution

The screenshot shows the EAS II Drive Expert Tuner software interface. The left sidebar contains a tree view of the device configuration, including a workspace named "3axisWS" and a device network (EtherCAT) with axes a01, a02, and a03. The main window displays the "Feedback Settings" tab, which is divided into "General" and "Advanced" sections. The "General" section includes fields for "Feedback on Motor" (Position: 0), "Feedback on Load" (Position: 0), "Encoder Quad, PortA", "Sensor Name", "Sensor Type" (Rotary), "Feedback control function" (Position + Velocity + Commutation), "Use Digital Halls" (Yes), "Sensor Parameters" (Invert, Glitch Filter (cnt/sec) 5000000, Velocity FIR Filter Window Disabled), and "Resolution" (Lines/revolution 2500, counts/revolution 10000). The "Advanced" section is currently empty. The bottom of the interface shows a status bar with the text "Drive Setup and Motion Activity" and a Windows taskbar at the bottom.

5. Fill in the current limits based on the application's requirements.

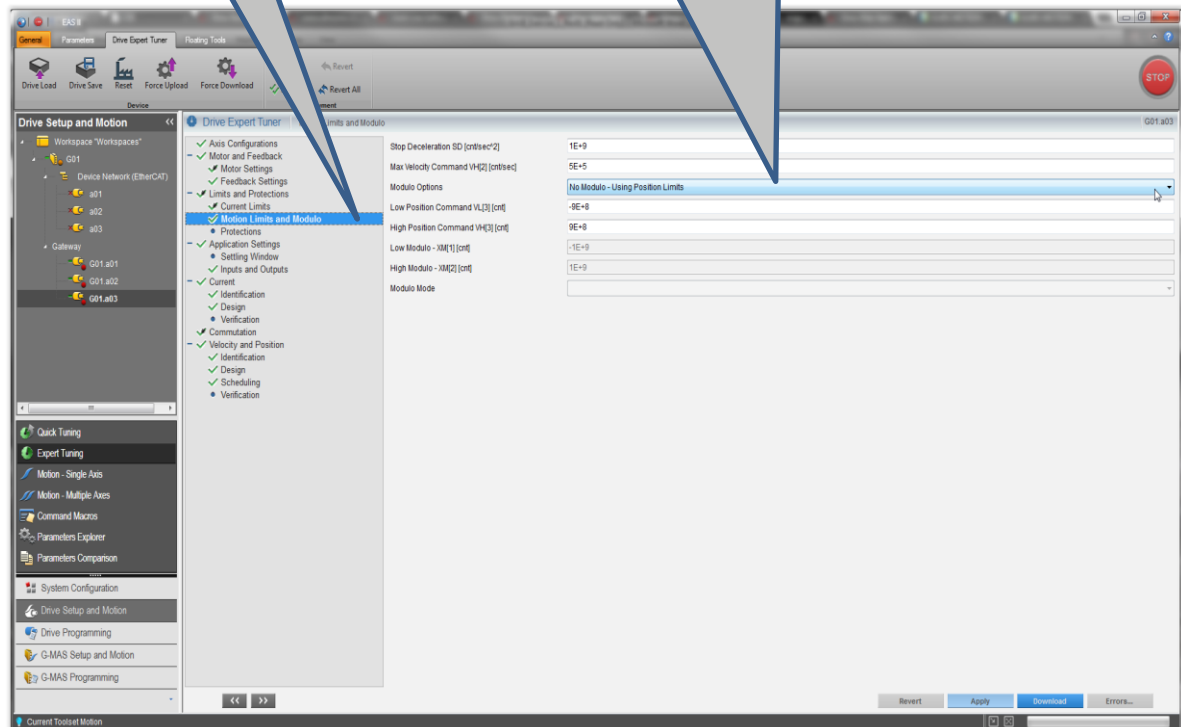
1. Current Limits



Exercise #1: Expert Tuning

3. Motion limits and modulo

4. In this screen you can choose whether you want to use a modulo – used in applications that require the motor position to be counted cyclically, and choose the motion limits



Exercise #1: Expert Tuning

5. Protections

6. Maximum tracking position and velocity errors; if the errors exceed these values, the motor is automatically disabled

The screenshot shows the 'Drive Expert Tuner' software interface. The left sidebar contains a tree view with 'Protections' selected under 'Drive Setup and Motion'. The main panel displays the 'Maximum Tracking Errors' section with the following values:

Parameter	Value
Position Error Window ER[0] [rpm]	1E+9
Velocity Error Window ER[2] [rpm/sec]	1E+8
Yaw Position Error ER[5] [rpm]	

Below this, the 'Motor Stuck' section shows:

Parameter	Value
Current Limit CL[2] [% of CL]	0
Velocity Limit CL[3] [rpm/sec]	0
Time Duration CL[4] [msec]	3000

The motor will be disabled (with Motor Stuck fault: MF=0x200000) when the following conditions apply:

- The actual motor Current is above CL[2] current limit (given in % of CL[1], max continuous current limit), and
- The actual motor Velocity is below CL[3] velocity limit (given in rpm/sec), and
- For at least CL[4] consecutive time duration (given in milliSeconds)

The 'Advanced' section is currently empty.

7. Motor Stuck parameters define the conditions which, if met for the specified amount of time, indicate that the motor is stuck and will be disabled

6. Application Settings.

2. These parameters define the target position and velocity windows needed to determine when the motor reaches the desired position/velocity

1. Settling Window

Parameter	Value
Target Position Window TRQ1[cm]	100
Target Velocity Window TRQ3[cm/sec]	100
Target Position Window Time TRQ2[msec]	20
Target Velocity Window Time TRQ4[msec]	20

Exercise #1: Expert Tuning

The screenshot shows the 'Drive Expert Tuner' window. The left sidebar contains a tree view with categories like 'Device Network (EtherCAT)', 'Gateway', and 'Quick Tuning'. The main area is divided into 'Inputs' and 'Outputs' sections, each with a table of settings. Callouts 1 through 9 highlight specific features: 1. Inputs and Outputs (points to the left sidebar), 2. Polarity states (points to the 'Polarity' column), 3. Polarity states if the Input is active high or low (points to the 'Polarity' column), 4. Filters the drive digital inputs in order to overcome switch bounding (points to the 'Filter (msec)' column), 5. Define the output settings the same as the input settings (points to the 'Set all Digital Inputs' button), 6. Choose a function for the input to perform (points to the 'Function' column), 7. Current switch status (on/off) (points to the 'Status' column), 8. All inputs can be set to have the same function and polarity by using this button (points to the 'Set all Digital Inputs' button), and 9. Define the output settings the same as the input settings (points to the 'Set all Digital Outputs' button).

1. Inputs and Outputs

2. Polarity states if the Input is active high or low

3. Polarity states if the Input is active high or low

4. Filters the drive digital inputs in order to overcome switch bounding

5. Define the output settings the same as the input settings

6. Choose a function for the input to perform

7. Current switch status (on/off)

8. All inputs can be set to have the same function and polarity by using this button

9. Define the output settings the same as the input settings

7. Perform the Identification process for the current loop.

The screenshot displays the EAS II Drive Expert Tuner software interface. The left sidebar shows the 'Drive Setup and Motion' tree with 'G01' selected. The main window is divided into several sections:

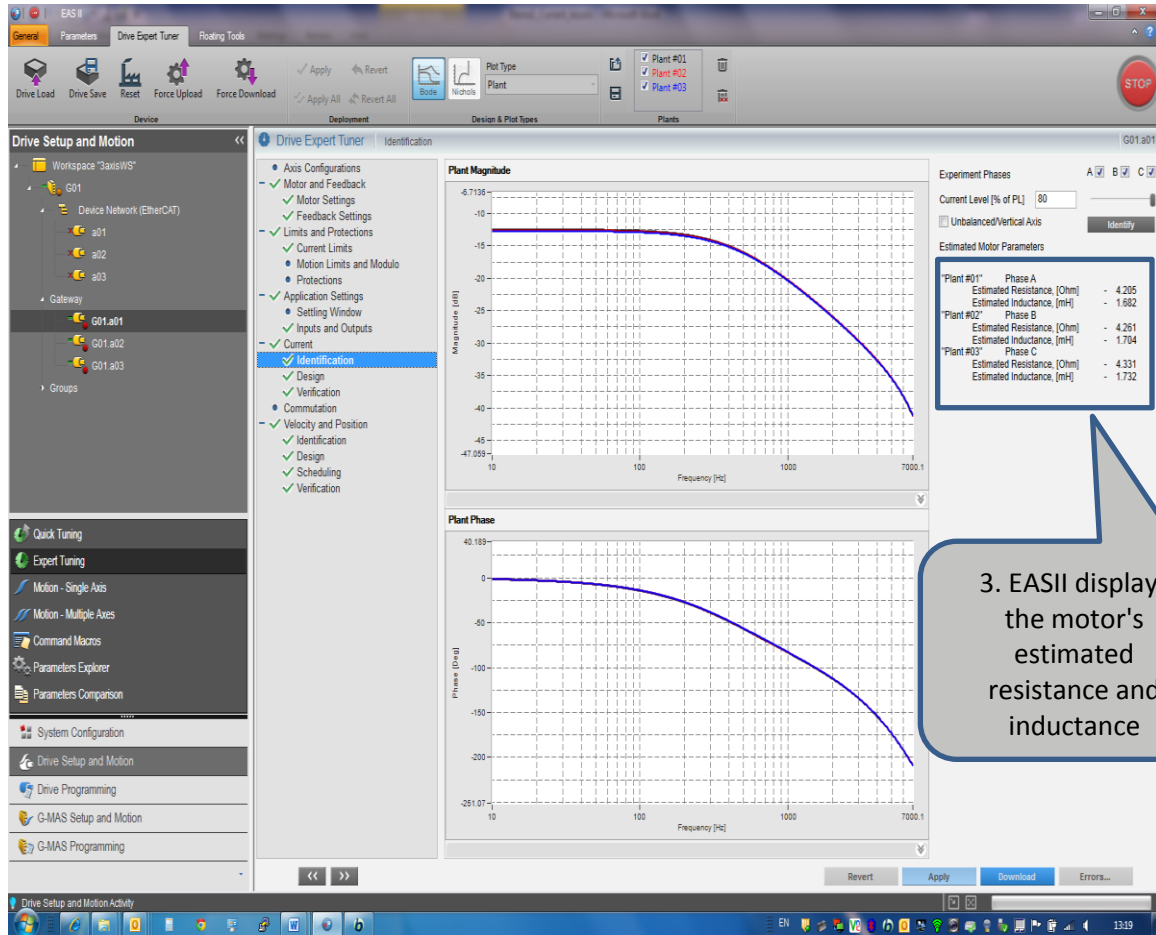
- Parameters:** A list of parameters with checkboxes. Under 'Current', the 'Identification' checkbox is checked.
- Plant Magnitude:** A graph showing Magnitude (dB) vs Frequency (Hz).
- Plant Phase:** A graph showing Phase (Deg) vs Frequency (Hz).
- Experiment Phases:** A section with a 'Current Level (% of PL)' set to 80 and an 'Identify' button.

Two callout boxes provide instructions:

1. Choose the current level as percentage of peak current
2. Click "Identify" to start the current Identification process.

Exercise #1: Expert Tuning

The Current loop Identification result:



3. EASII displays the motor's estimated resistance and inductance

8. Current Design

2. Choose the required bandwidth and phase margin

3. Click Design to start auto-design

1. Current Loop Design

5. The system's achieved performance can be reviewed here

4. Note that EASII automatically calculates the required proportional and integral gain and allows the user to fine tune it

Required Performance Limits

Parameter	Value
Bandwidth [Hz]	1800
Phase Margin [Deg]	50

Fine Tuning

Parameter	Value
Controller Gain $K_P[1]$ [V/A]	9.121
Controller Integral $K_I[1]$ [Hz]	1005.36

Achieved Performance

Parameter	Value
Bandwidth [Hz]	1840.3182
Phase Margin [Deg]	53.3172

9. Test the Current loop performance in real time.

The screenshot displays the EAS II Drive Expert Tuner software interface. The left sidebar shows a tree view of the workspace, with 'G01.a01' selected. The main window is divided into several sections:

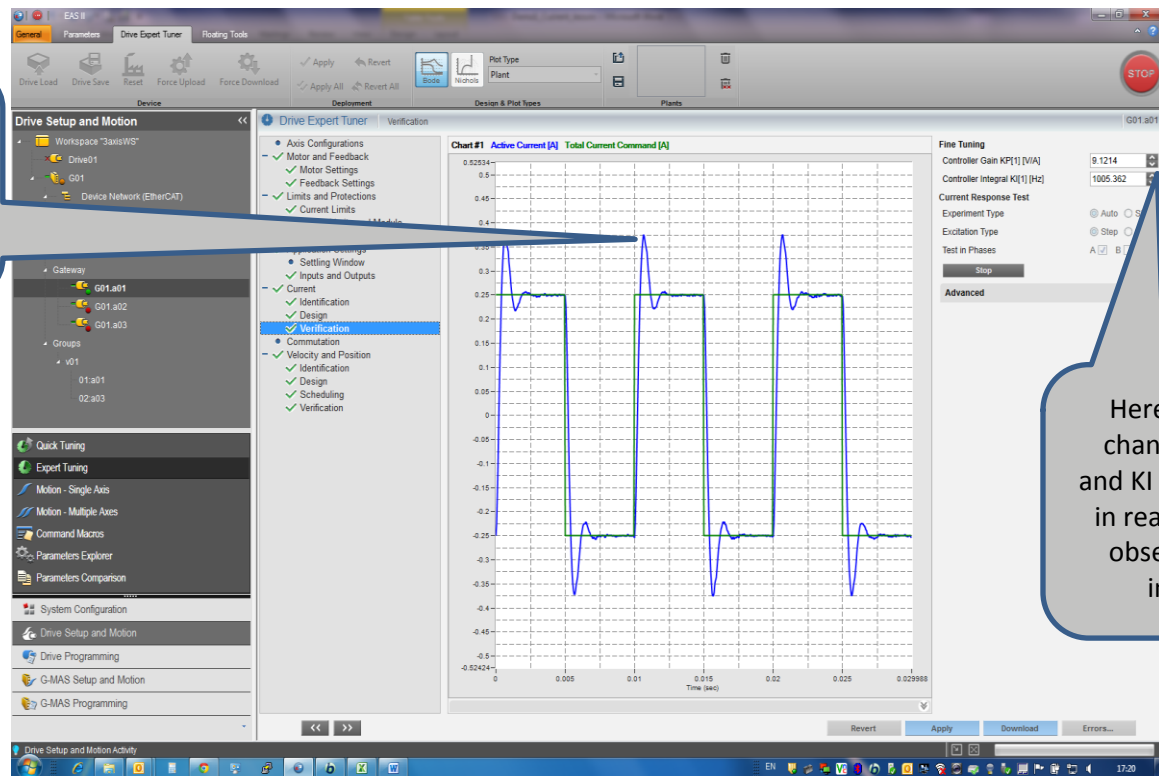
- Drive Setup and Motion:** A tree view on the left showing the hierarchy of the drive setup.
- Drive Expert Tuner:** A central panel with a 'Verification' tab selected. It lists various tuning steps, including 'Verification', 'Commutation', 'Velocity and Position', 'Identification', 'Design', 'Scheduling', and 'Verification'.
- Chart #1 and Chart #2:** Two empty plots for real-time data visualization.
- Fine Tuning:** A panel on the right showing parameters like 'Controller Gain $K_P[1]$ [V/A]' and 'Controller Integral $K_I[1]$ [Hz]', along with 'Current Response Test' options.

Two callout boxes provide instructions:

1. Verification
2. Click here Verify to start real time verification and calibration of the calculated proportional and integral gain

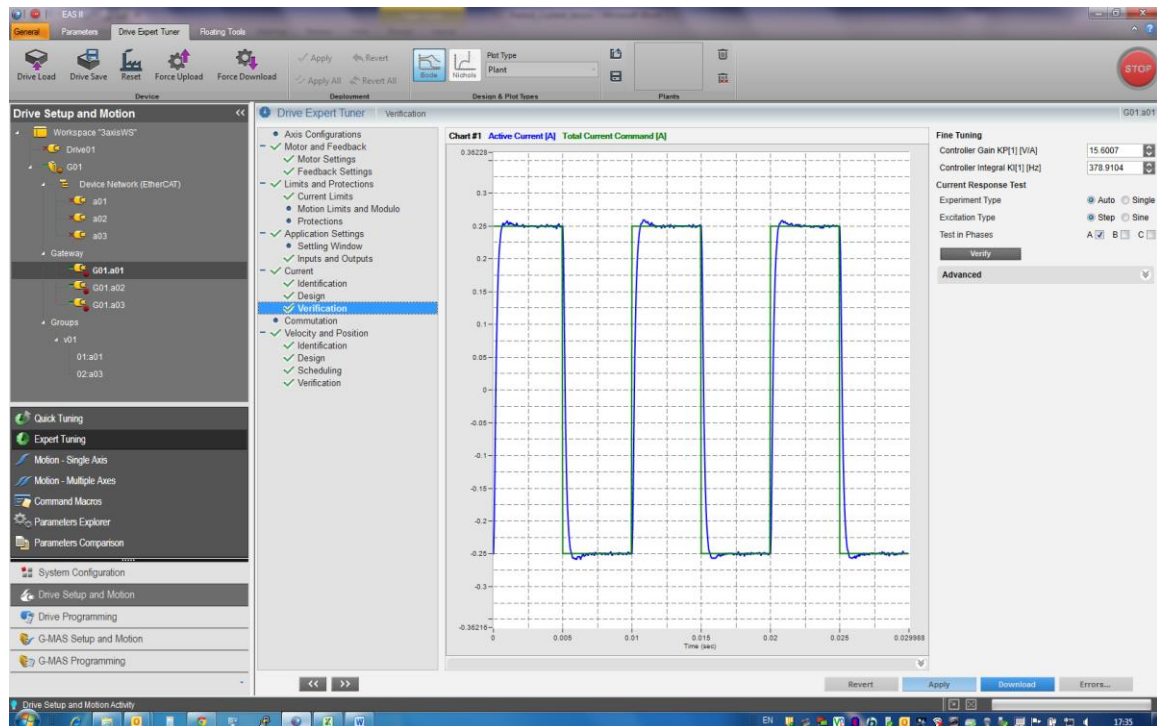
10. Change the Current loop performance in real time.

Current overshoot; has to be calibrated



Here you can change the KP and KI parameters in real time and observe their impact

11. Verify the Current loop performance after calibrating in real time.



12. Run Commutation

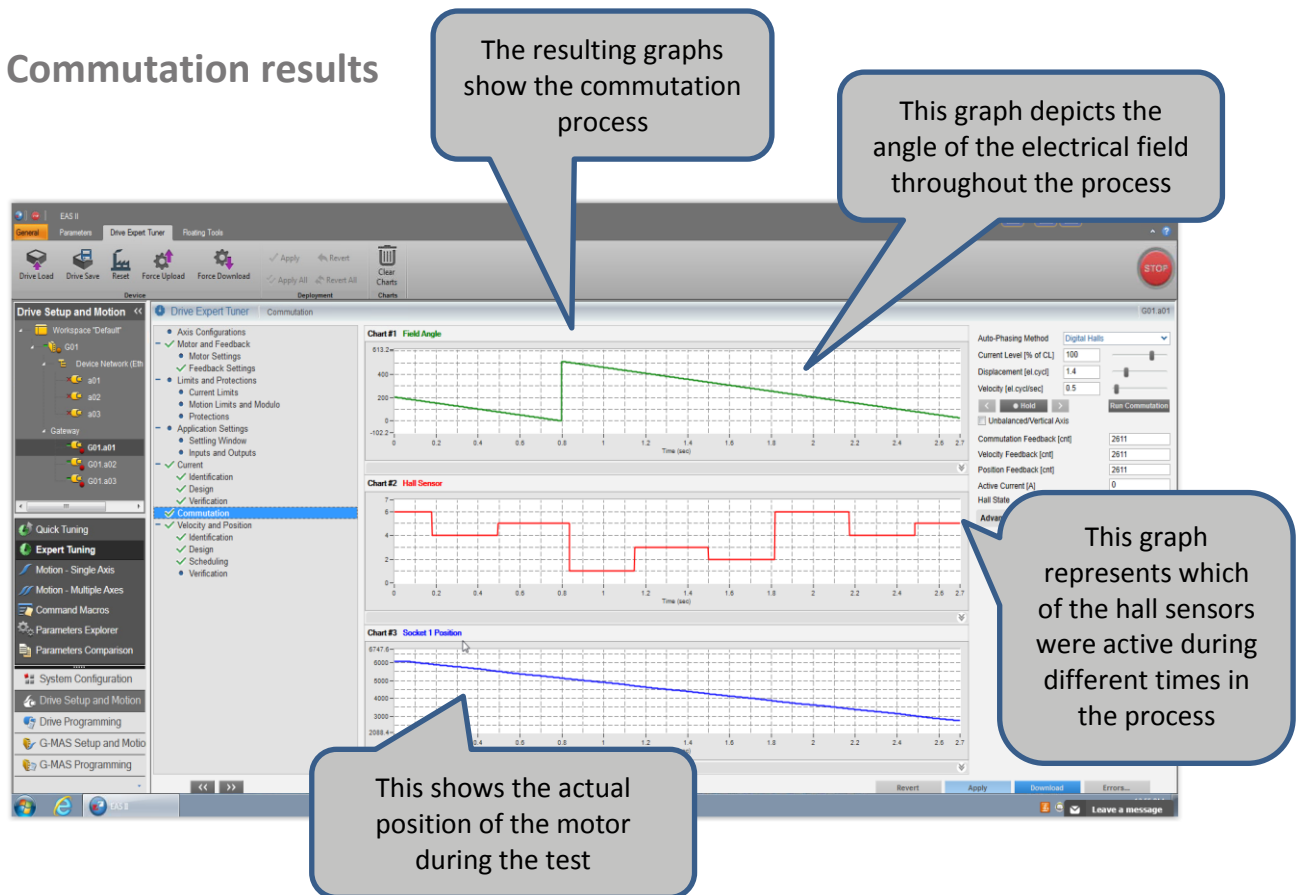
2. Choose method and adjust test parameters if required

1. Commutation

3. Run Commutation to determine the relationship between the commutation sensor reading and the motor phases

4. Define motor direction

Commutation results



13. Velocity and position.

The screenshot displays the Elmo Expert Tuning software interface. The left sidebar shows the 'Drive Setup and Motion' tree with 'G01' selected. The main window is titled 'Drive Expert Tuner' and shows the 'Identification' step for 'Velocity and Position'. The 'Current Level' is set to 100%. The 'Identification Tracking Limits' are set to 1E-8 for Max Velocity Error and 1E-5 for Max Position Error. The 'Velocity Plant Magnitude' and 'Velocity Plant Phase' plots are visible. Three callouts are present: '1. Identification' points to the 'Identification' step in the left sidebar; '2. Adjust the Current level' points to the 'Current Level' slider; and '3. Identify the Velocity loop' points to the 'Identify' button.

1. Identification

2. Adjust the Current level

3. Identify the Velocity loop

Exercise #1: Expert Tuning

4. Design

5. Choose a controller objective. In this demo, we have selected PI Controller with gain scheduling and a low pass filter

6. Select Scheduling Off

7. Click Design

8. View the result on either a Bode or Nichols diagram

The screenshot displays the Elmo Expert Tuning software interface. The main window shows a Nichols diagram for the Velocity Open Loop. The diagram has a grid of gain (0 dB to -40 dB) and phase (-360° to 0°). A blue curve represents the system's frequency response, and a yellow circle highlights a specific point on the curve. The left sidebar contains a tree view with 'Design' selected under 'Expert Tuning'. The right sidebar shows the 'Controller Tuning' panel with 'PI Controller + LPF' selected. The 'Scheduling' dropdown is set to 'Off'. The 'Design' button is highlighted in blue. The bottom status bar shows 'Current Toolset: ExpertTuning'.

14. Verification

1. Verification

2. This section allows you to test the velocity and position results

3. Enable the motor

4. Click the Sine/Step tab, and then select 'Step' for the input wave type

5. Enter the required frequency and amplitude of the input and click Start – the motor will start running

6. Control parameters/filters can be further adjusted in real-time in this section

Exercise #1: Expert Tuning

To observe the different parameters, use the recorder function

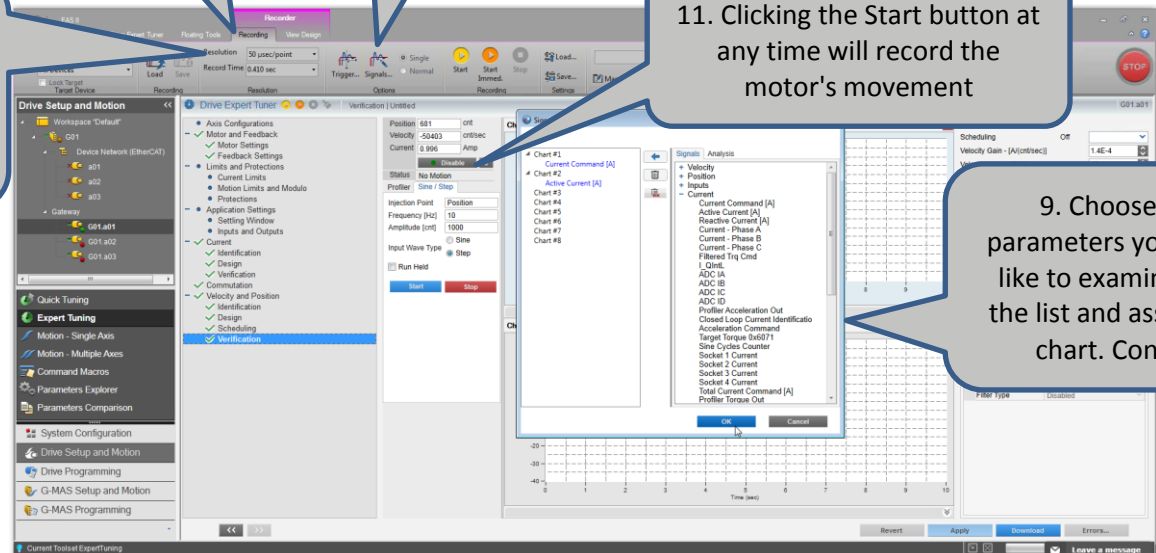
7. Recording

8. Signals

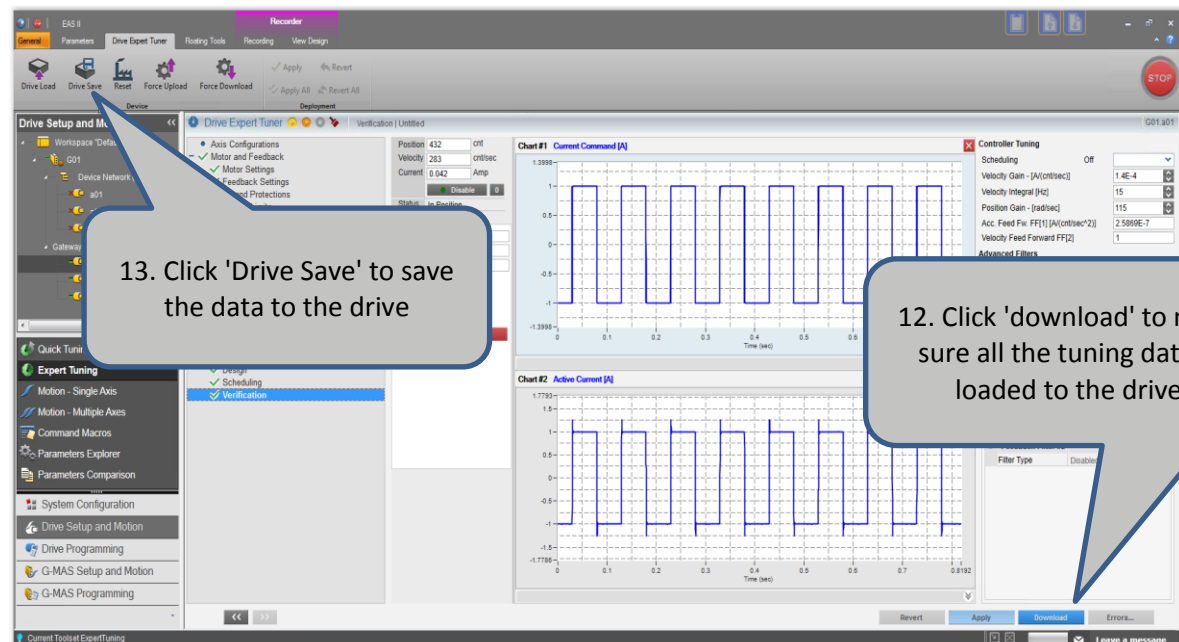
11. Clicking the Start button at any time will record the motor's movement

9. Choose the parameters you would like to examine from the list and assign to a chart. Confirm

10. Adjust the recording resolution and time as required



View the result and save data to the drive:



13. Click 'Drive Save' to save the data to the drive

12. Click 'download' to make sure all the tuning data is loaded to the drive