



PowerTools Pro Auto-Tune Feature

Revision: 1.0

Introduction

The purpose of this document is to demonstrate how properly use the Auto-Tune feature and to discuss how the algorithm functions. This document is intended for servo system users who would like a more detailed understanding of the Auto-Tune feature or for users with a non-Emerson servo motor.

The Auto-Tune feature of PowerTools Pro software is able to determine certain motor parameters that define the motor's electrical and mechanical characteristics. These parameters are typically stored in a motor.ddf file in PowerTools directory. These parameters are crucial for optimum motor control.

The parameters that can be measured by the drive through the Auto-Tune algorithm are:

1. encoder reference motion
2. encoder marker angle
3. encoder resolution
4. commutation u angle
5. phase to phase resistance
6. phase to phase inductance
7. motor back emf
8. motor inertia

Some motor parameters must be known before running the Auto-Tune, these parameters include:

1. motor peak current
2. encoder resolution
3. motor peak velocity
4. number of motor poles

To make the Auto-Tune work properly, the user will need to enter these parameters manually.

Auto-Tune Sub Modes

There are three sub-modes for the Auto-Tune, the sub modes determine what parameters the drive will measure:

- Mode 1: Determine encoder reference motion, encoder marker angle, and commutation u angle. It also verifies the encoder resolution.
- Mode 2: Determine resistance, inductance, and plus the parameters determined by Mode 1.
- Mode 3: Determine back emf, motor inertia, and plus the parameters determined by Mode 1 and Mode 2.

Abnormal Operation

Once the Auto-Tune procedure is started, there are two situations that suspend the procedure. One is aborted by the customer, either by clicking the "Abort" button or by disabling the drive. The other is aborted by a fault condition.

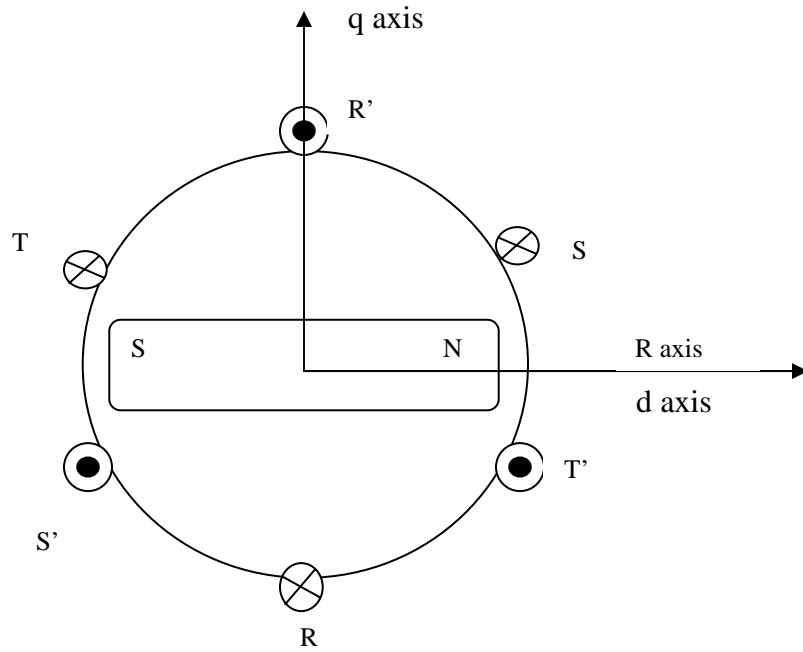
There exist two Auto-Tune faults:

- Fault 1: The encoder motion reference and the UVW motion reference are not the same. The user has an option of using encoder lines (A and B) or UVW lines (U and V) for commutation, changing to the other setting may correct this problem. This setting is found on the page shown in Figure 1, under Encoder Type
- Fault 2: The difference between the encoder lines entered by the customer and the encoder lines detected by the Auto-Tune procedure is greater than or equal to 20. Once this fault occurs, the customer needs to check if the encoder lines and the motor poles are correctly set.

Measured Values

1.1 Encoder Information

To detect the encoder information, the rotor is first aligned with R-axis (Phase R axis) as shown:

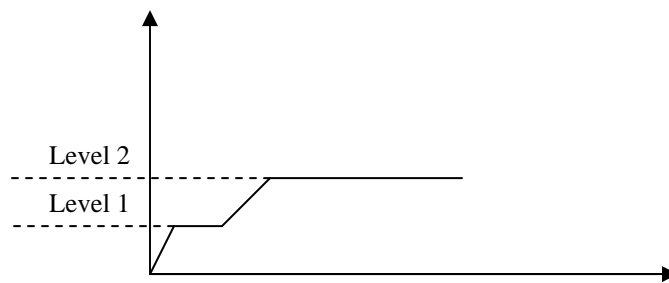


Aligned Rotor Position

Starting from the above aligned position, the encoder and UVW information can be extracted by slowly rotating the rotor by one mechanical revolution.

1.2 Resistance and Inductance

By injecting current to the stator windings, the resistance and inductance of the stator phase winding can be estimated. To minimize the effect caused by the voltage drop in the IGBT switches, the currents are built in two steps as shown below.



Current Build-Up

After the Level 1 current is stabilized, another voltage (higher than the voltage to set up Level 1 current) is applied to the stator winding to build Level 2 current. The voltage and current difference between two current levels can be used to estimate the stator phase winding resistance. The dynamic transition information from Level 1 current to Level 2 current can be used to estimate the phase winding inductance.

1.3 Motor Back EMF

To estimate the motor back emf, the motor is applied certain torque so it can run at an appropriate velocity (between 25% and 50% of the motor peak current). From the motor voltage equation, the motor back emf is estimated.

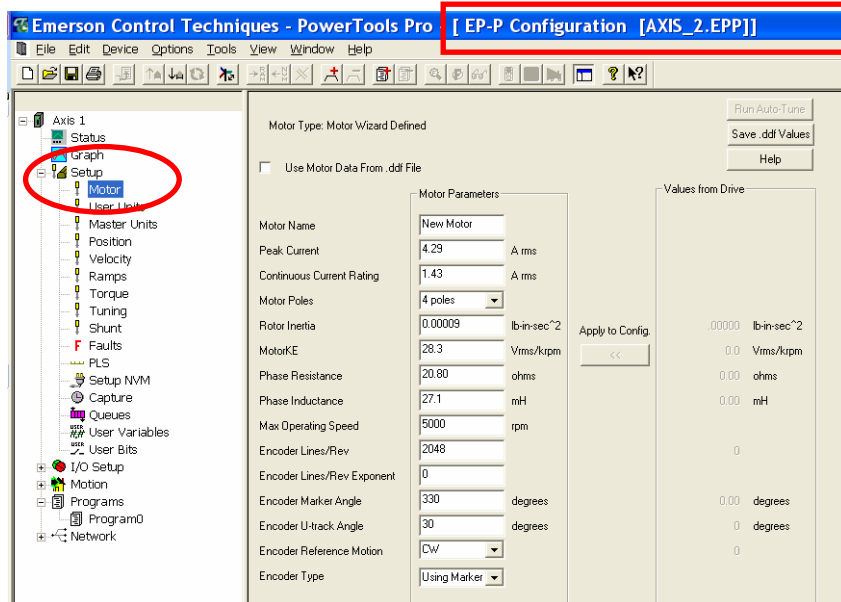
1.4 Motor Rotor Inertia

It is strongly recommended to remove the load if rotor inertia is to be estimated. During the operation, a torque will be applied to the motor so that the motor can accelerate to a proper velocity (between 25% and 75% of the motor peak velocity) in a short time (25.6 ms). The rotor inertia is then estimated from the motor equation.

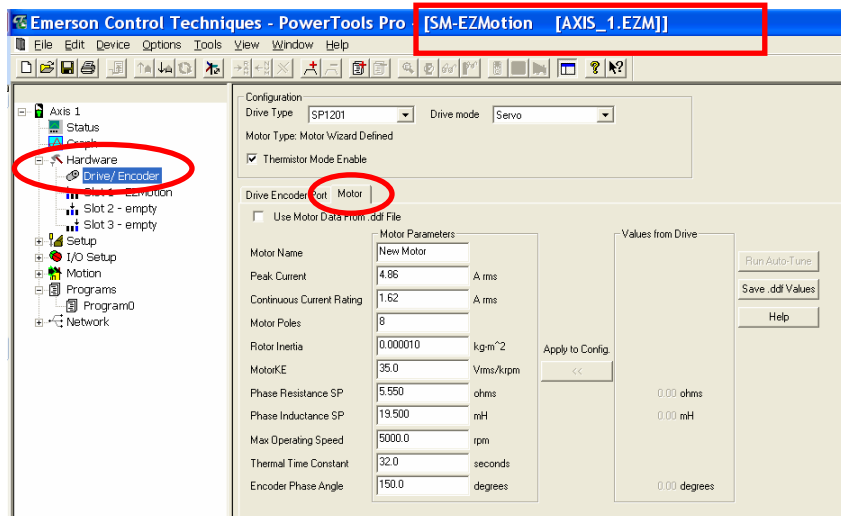
Using the Auto-Tune Feature

The Auto-Tune procedure is slightly different if using an Epsilon EP vs. using a UniDrive SP. The procedural description below will detail the general procedure and highlight exceptions or differences when using the EP or SP.

- 1) Open PowerTools Pro software and create a new file
- 2) Find the Motor Parameter screen
 - a. Epsilon EP
 - i. Expand the *Setup* branch on the hierarchy and click on the *Motor* branch.



- b. UniDrive SP
 - i. Expand the *Hardware* branch on the hierarchy and click on the *Drive/Encoder* branch.
 - ii. Then click on the Motor tab to display the motor data parameters



- 3) Uncheck the *Use Motor Data From .ddf File* check box to un-grey the motor data parameters.
- 4) Enter the known motor data into the un-greyed *Motor Parameters* column on the left. All parameters that don't have corresponding value in the *Values from Drive* column on the right should be entered by the user. Note that only the parameters that have corresponding values in the column on the right (i.e. Phase Resistance SP) are measured by the AutoTune. Notice that the measured Auto-Tune parameters will differ from different drive types and also when using Closed Loop Vector vs. Servo motor within the Unidrive SP

a. EP

Motor Parameters		Values from Drive
Motor Name	New Motor	
Peak Current	4.29 A rms	
Continuous Current Rating	1.43 A rms	
Motor Poles	4 poles	
Rotor Inertia	0.00009 lb-in-sec ²	.00000 lb-in-sec ²
MotorKE	28.3 Vrms/krpm	0.0 Vrms/krpm
Phase Resistance	20.80 ohms	0.00 ohms
Phase Inductance	27.1 mH	0.00 mH
Max Operating Speed	5000 rpm	
Encoder Lines/Rev	2048	0
Encoder Lines/Rev Exponent	0	
Encoder Marker Angle	330 degrees	0.00 degrees
Encoder U-track Angle	30 degrees	0 degrees
Encoder Reference Motion	CW	0
Encoder Type	Using Marker	

Apply to Config. <<

b. SP with Servo Motor

Use Motor Data From .ddf File

Motor Parameters		Values from Drive
Motor Name	New Motor	
Peak Current	4.86 A rms	
Continuous Current Rating	1.62 A rms	
Motor Poles	8	
Rotor Inertia	0.000010 kg-m ²	
MotorKE	35.0 Vrms/krpm	
Phase Resistance SP	5.550 ohms	0.00 ohms
Phase Inductance SP	19.500 mH	0.00 mH
Max Operating Speed	5000.0 rpm	
Thermal Time Constant	32.0 seconds	
Encoder Phase Angle	150.0 degrees	0.00 degrees

Apply to Config. <<

c. SP with Vector Motor

Use Motor Data From .ddf File

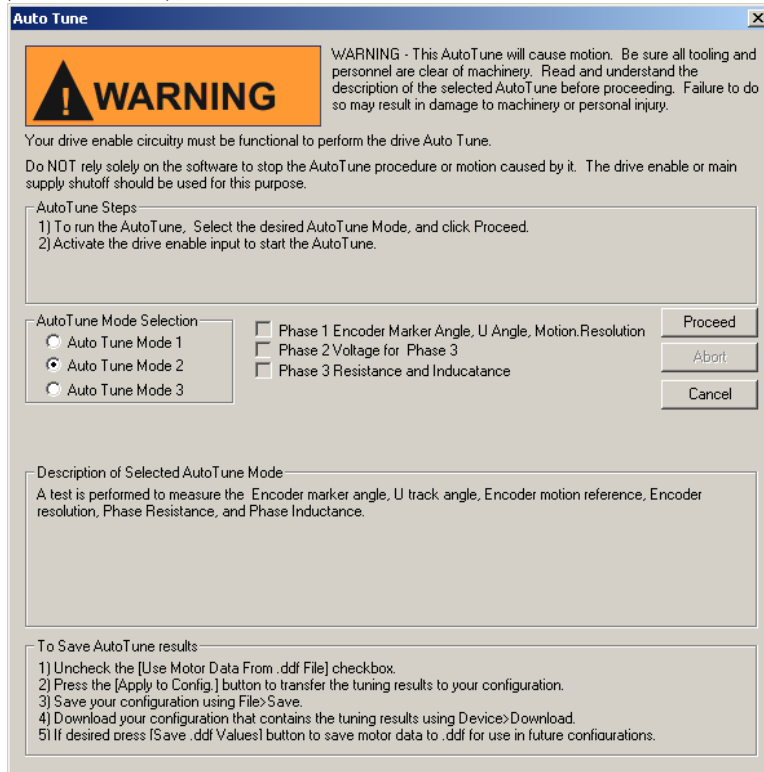
Motor Parameters		Values from Drive
Motor Name	New Motor	
Peak Current	8.60 A rms	
Full Load Rated Current	4.30 A rms	
Rated Voltage	230 VAC	
Motor Poles	4	
Rotor Inertia	0.002670 kg·m ²	
Rated Frequency	60.0 Hz	
Phase Resistance SP	0.937 ohms	0.000 ohms
Transient Inductance	10.499 mH	0.00 mH
Max Operating Speed	5400.0 rpm	
Full Load Rated Speed	1755.00 rpm	
Thermal Time Constant	400.0 seconds	
Rated power Factor	0.719	0.000
Stator Inductance	103.86 mH	0.00 mH
Motor Kt	1.84 Nm/Amp rms	0.00 Nm/Amp rms
Saturation Breakpoint 1	52 % of Rated	0 % of Rated
Saturation Breakpoint 2	77 % of Rated	0 % of Rated

Apply to Config <<

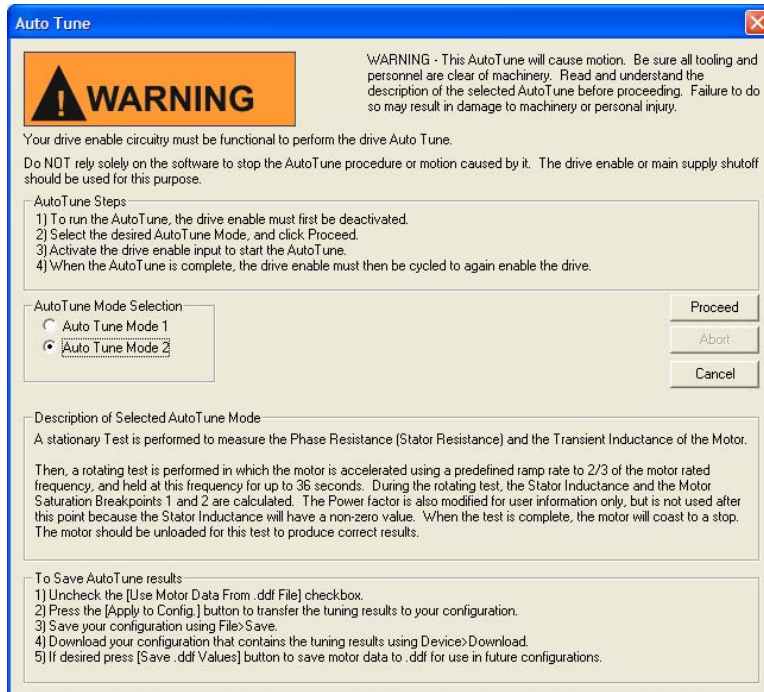
- 5) Enter 0 for the unknown parameters in the column on the left (only if there is an associated parameter in the column on the right).
- 6) Download the PowerTools file to the Drive (This also takes you online with the drive)

7) Click the "Run Auto-Tune" button. This will cause the Auto-Tune dialog box to appear

a. EP (3 Sub Modes)



b. SP (2 Sub Modes)



8) Select which Auto-Tune procedure you wish to perform using the AutoTune Mode Selection radio buttons **Warning: read the Auto-Tune description to understand what motion will occur!**

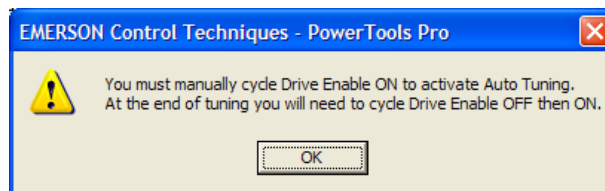
9) Click the **Proceed** button

a. EP

- i. The 14 segment LED display on the front of the drive will flash “R” when the Auto-Tune is running.
- ii. The procedure takes 60-90 seconds.
- iii. When complete, the LED display will stop flashing and display a solid “R”, any other value indicates an error condition.

b. SP

- i. This will cause a new pop-up to appear that tells you to turn the enable off and then on.



- ii. Click the OK button to close the pop-up dialog.
- iii. Now turn the drive enable OFF then back ON.
- iv. Be sure to leave the enable ON until Auto-Tune is complete, or an Auto-Tune error will occur indicated by the optional display showing “trip” “tunE”.
- v. The SP’s optional LED or LCD display will show “run” and “Auto tunE” during the Auto-Tune

10) When complete, the results from Auto-Tune will appear in the **Values from Drive** column

Motor Parameters		Values from Drive
Motor Name	New Motor	Measured results from Auto Tune. 0.00010 lb-in-sec ² 12.4 Vrms/krpm 3.05 ohms 6.9 mH 2048. 174. degrees 235. degrees 1.
Peak Current	4.64 A rms	
Continuous Current Rating	1.65 A rms	
Motor Poles	8 poles	
Rotor Inertia	0.00010 lb-in-sec ²	
MotorKE	12.4 Vrms/krpm	
Phase Resistance	2.50 ohms	
Phase Inductance	7.4 mH	
Max Operating Speed	5000 rpm	
Encoder Lines/Rev	2048	
Encoder Lines/Rev Exponent	0	
Encoder Marker Angle	180 degrees	
Encoder U-track Angle	240 degrees	
Encoder Reference Motion	CW	
Encoder Type	Using Marker	

Apply to Config. <<

Auto-Tune Feature
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- 11) If performing an Auto-Tune on a motor with known parameters, verify that the values in the ***Values from Drive*** column match the corresponding values in the ***Motor Parameters*** column. The values should match with a tolerance of +/- 10%.
- 12) In order to apply those values to the ***Motor Parameters*** column, click the ***Apply to Config*** button in the middle of the screen. This will copy the results from the ***Values from Drive*** column into the ***Motor Parameters*** column.
- 13) Optional step: Saving the custom motor
 - a. To save the motor parameters so that motor is available in dropdown list in future
 - i. Enter a text name in the ***Motor Name*** box, the file will not overwrite any “standard” motor files as these are saved in a separate file.
 - ii. Click ***Save .ddf Values*** on the right side of the screen.
- 14) ***You must download the PowerTools file to the drive in order to permanently save the new values though a power cycle!***