

AC Induction Current Loop Tuning

Introduction

ADVANCED Motion Controls[®], DigiFlex[®] Performance[™] Servo Drives support closed loop vector control for driving 3-phase AC induction motors. A feedback device is required to run an AC induction motor.

Tuning Setup

Before beginning current loop tuning, make sure that the motor is free to move and de-coupled from the load, as sudden motion may occur. You must be connected to a drive, and the motor and drive limits information must be correctly specified in the appropriate Motor Parameters and Limits windows before tuning the current loop. For current loop tuning, the Loop Configuration in the active Configuration can be set to any of the available options.

It is recommended to disable the drive by clicking on the *Disable*  icon on the toolbar before beginning tuning. The procedures below will prompt you to enable the drive when necessary for tuning.

Inhibit/Enable Configuration

1. From the Setup Panel in DriveWare, expand the *Inputs/Outputs* heading. Open the *Digital Inputs* limits window.
2. If an external Inhibit/Enable circuit is used during setup, assign the digital input that will be used to the User Disable function, and set the proper polarity (e.g., active high or active low).
3. If no external Inhibit/Enable circuit is to be used during setup, then the Enable/Disable icons on the toolbar will be used to control drive enabling.
4. Click the *Apply*  button in the toolbar to save changes.

Requirements

To configure an AC induction motor in DriveWare[®] 7, extra steps must be taken compared to a typical brushless servo motor. In an AC induction application, correct motor data is critical for motor operation.

The AC induction tuning process will depend on the motor name plate parameters available.

Determine the tuning process to use based on the descriptions below and the name plate parameter information given in Table 1.

Note: For details on the motor parameter terminology used in DriveWare, see the *DriveWare Terminology* section at the end of this document.

- **Calculated Tuning:** Basic method to quickly tune the current loop. All available motor parameters are required to achieve Torque and Flux Loop Gain values. No additional gains adjustment is necessary.
- **Optimized Tuning:** Advanced method of current loop tuning, and can be based off the calculated tuning method. Uses the minimum set of motor parameters to achieve a suitable starting point for the Torque and Flux Loop Gains. Additional gains adjustment will be required to complete tuning.

	Optimized	Calculated
No Load Current	✓	✓
Rated Current	✓	✓
Peak Current		✓
Max Speed	✓	✓
Rated Speed	✓	✓
Motor Poles	✓	✓
Base Frequency	✓	✓
Rated Voltage	✓**	✓
Max Motor Temp		
Motor Power	✓**	✓
Stator Resistance	✓*	✓
Stator Inductance	✓*	✓
Power Factor	**	✓
Efficiency	**	✓
Equivalent Circuit or Name Plate Parameters		✓

*Can be measured or estimated if necessary

**Optional

Table 1 Required AC Induction Motor Parameters

Note: If *Optimized Tuning* is to be used, skip to the *Optimized Tuning* section of this document.

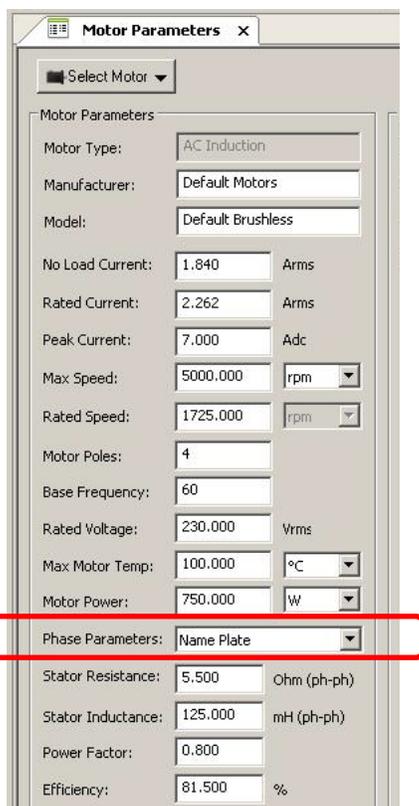
Calculated Tuning

Step 1: Input Motor Data

1. From the Setup Panel within DriveWare, select *Motor > Parameters*.
2. Choose AC Induction from the *Select Motor* drop down menu.

AC Induction Current Loop Tuning

- Enter all of the available motor parameters. If all motor parameters are not available, use the Optimized tuning processes.
- Depending on which parameters are available, select either Name Plate or Equivalent Circuit from the *Phase Parameters* selections, and enter the appropriate values.



Motor Parameters	
Motor Type:	AC Induction
Manufacturer:	Default Motors
Model:	Default Brushless
No Load Current:	1.840 Arms
Rated Current:	2.262 Arms
Peak Current:	7.000 Adc
Max Speed:	5000.000 rpm
Rated Speed:	1725.000 rpm
Motor Poles:	4
Base Frequency:	60
Rated Voltage:	230.000 Wrms
Max Motor Temp:	100.000 °C
Motor Power:	750.000 W
Phase Parameters:	Name Plate
Stator Resistance:	5.500 Ohm (ph-ph)
Stator Inductance:	125.000 mH (ph-ph)
Power Factor:	0.800
Efficiency:	81.500 %

Figure 1 DriveWare AC Induction Motor Parameters

If using Equivalent Circuit parameters, values for R_1 , R_2 , X_1 (leakage), X_2 (leakage), and X_M are all required. Figure 2 below gives a circuit representation of the necessary parameters.

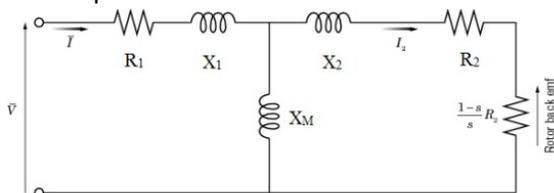


Figure 2 AC Induction Equivalent Circuit Diagram

- In the *Feedback Type* panel, enter the parameters for the feedback device in use.
- Click the *Apply* button in the toolbar to save changes.

Step 2: Set Drive Limits

- From the Setup Panel in DriveWare, expand the *Limits* heading.
 - DriveWare automatically sets certain drive limits based on the parameters entered in the motor Parameters window. Verify that the current, velocity, position and voltage limits are all set to appropriate values for the specific system setup from the *Current*, *Velocity*, *Position*, and *Voltage* windows, respectively.
 - If different limits are required for the specific setup, adjust the limits accordingly based on the guidelines in the following steps.
 - The *Continuous* current limit should be set to the *Rated Current* value as given by the motor name plate or datasheet.
 - Verify the *Peak Current* value is set to a level within the drive and motor capabilities.
 - Set velocity and position limits according to the motor and system safety requirements.
 - Voltage limits should be set to the nominal DC bus voltage.
- Note:** The action taken by DriveWare when the above limits are reached can be set in the Events > Basic and Events > Advanced windows in the Setup Panel.
- Apply all changes.

Step 3: Torque and Flux Loop Tuning

- From the Setup Panel, select *Tuning > Current Loop Gains*.
- Click the *Calculate Gains* buttons for both the Torque and Flux Loop. *Calculate Gains* utilizes the values entered into the Motor Parameters, Feedback, and Limits windows. The specified motor inductance, resistance, and bus voltage determine the accuracy of the calculated values.
- Leave the *Field Weakening Threshold Speed* at the default value. DriveWare automatically sets this value to 90% of

the Rated Speed (see Field Weakening Threshold Speed section at the end of this document for further information on this value).

4. Close the *Current Loop Gains window*. Make sure the *Keep Changes* box is checked in the *Save Changes* dialog box, then click *Ok*.

Step 4: Verify Feedback Polarity

1. Click the *Multimeter*  icon in the toolbar to open the Digital Multimeter.
2. Use the *Change Signal* button to view Position Measured.
3. Manually rotate the motor shaft one full revolution. Verify that the Position Measured value in the Multimeter matches the feedback *Resolution* value entered into the motor Parameters window.
4. Open the digital oscilloscope by clicking the *Scope* icon from the toolbar.
5. Enable the Waveform Generator by selecting the *Enabled* checkbox in *Waveform Generator* panel.
6. Set the waveform *Type* to DC.
7. Set the waveform *Target* to Current Loop.
8. Set the waveform *Offset* to the No Load Current as entered in the Motor *Parameters* window.
9. Be prepared to have the motor spin at the Rated Speed. Enable the drive by clicking the *Enable*  icon on the toolbar.
10. The motor should spin quickly and smoothly. If the motor does not spin, spins very slowly, or is jerky, it is likely the feedback polarity is not correct due to the particular wiring for different types of AC induction motors. Disable the drive by clicking the *Disable*  icon and uncheck the Waveform Generator Enabled checkbox. Open *Motor > Parameters* from the Setup Panel. Change the Feedback *Polarity* under the *Feedback Type* panel. Return to the Scope window and command a DC current again as described above to verify proper operation.

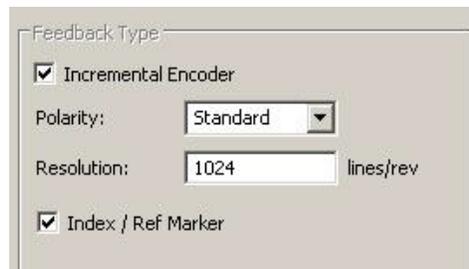


Figure 3 DriveWare Feedback Type Options

11. The Calculated Tuning process is now complete. If the current loop response is not satisfactory for application requirements, follow Steps 3-9 of the Optimized Tuning process below.
12. The motor and drive are now configured for operation and Velocity and Position Loop tuning. Click the *Store* icon on the toolbar to store the parameters to the drive's non-volatile memory.

Optimized Tuning

If the Calculated Tuning process has been successfully completed but more tuning is required, proceed to Step 3 below.

Step 1: Input Motor Data

1. From the Setup Panel within DriveWare, select *Motor > Parameters*.
2. Choose AC Induction from the *Select Motor* drop down menu.
3. Enter the available motor parameters.
4. Depending on which parameters are available, select either Name Plate or Equivalent Circuit from the *Phase Parameters* selections, and enter the appropriate values.

Note: If values are not available, estimated or measured values are acceptable to achieve starting gains values. If measurements or estimates are not possible and not available from the motor manufacturer, contact ADVANCED Motion Controls.

5. Click the *Apply* button in the toolbar to save changes.

Step 2: Set Drive Limits

1. From the Setup Panel in DriveWare, expand the *Limits* heading.
2. DriveWare automatically sets certain drive limits based on the parameters

AC Induction Current Loop Tuning

- entered in the motor Parameters window. Verify that the current, velocity, position and voltage limits are all set to appropriate values for the specific system setup from the *Current*, *Velocity*, *Position*, and *Voltage* windows, respectively.
- If different limits are required for the specific setup, adjust the limits accordingly based on the guidelines in the following steps.
 - The *Continuous* current limit should be set to the *Rated Current* value as given by the motor name plate or datasheet.
 - Verify the *Peak Current* value is set to a level within the drive and motor capabilities.
 - Velocity and position limits should be set within the motor and system safety requirements.
 - Voltage limits should be set to the nominal DC bus voltage.

Note: The action taken by DriveWare when the above limits are reached can be set in the Events > Basic and Events > Advanced windows in the Setup Panel.

- Apply all changes.

Step 3: Oscilloscope Setup – Current (Torque) Loop

- Open the digital oscilloscope by clicking the *Scope* icon from the toolbar.
- Select the Current oscilloscope preset from the Presets drop down menu, or to manually configure the settings follow the steps below.
- Change the Channel 1 signal to Current Target.
- Change the Channel 2 signal to Current Measured.
- Change the trigger *Source* to Current Target with the *Level* set to zero.
- Ensure trigger *Mode* is Normal.
- Change *Time/Div* to either 1 msec or 500 μ s.

Step 4: Waveform Generator Setup – Current (Torque) Loop

- Select the *Enabled* checkbox in the Waveform Generator panel to enable the Waveform Generator.
- Set the waveform *Type* to Square.

- Set the waveform *Target* to Current Loop.
- Set the *Frequency* to 100 Hz.
- Ensure *Offset* is zero.
- Ensure *Symmetry* is 50%.
- Set the waveform *Amplitude* to the No Load Current value.

Step 5: Tuning –Torque Loop

- Select *Tuning > Current Loop Gains* from the Setup Panel.
- Click the *Scope* icon on the toolbar again to allow both the Scope and Current Loop Gains windows to be visible.
- Get starting values for proportional (Kp) and integral (Ki) gains by clicking the *Calculate Gains* buttons for **both** the Torque and Flux Loop (proper Torque Loop tuning requires appropriate starting gain values for the Flux Loop). *Calculate Gains* utilizes the values entered into the Motor Parameters, Feedback, and Limits windows. The specified motor inductance, resistance, and bus voltage determine the accuracy of the calculated values.
- Enable the drive by clicking the *Enable*  button. The motor should emit an audible noise but remain still.
- Begin by increasing the Torque Loop Kp until a knee begins to form in the Current Measured response as shown in Figure 4. The motor will begin to make an audible noise and vibrate but will not move.

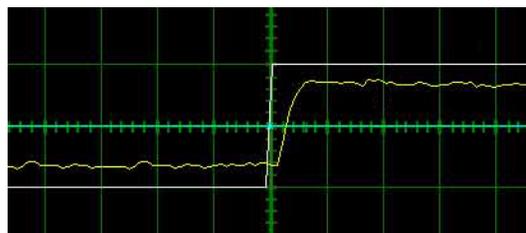


Figure 4 Current Loop Tuning Knee

- Next, increase the Torque Loop Ki to reduce the steady state error until the response looks similar to Figure 5. The noise and vibration may increase.

AC Induction Current Loop Tuning

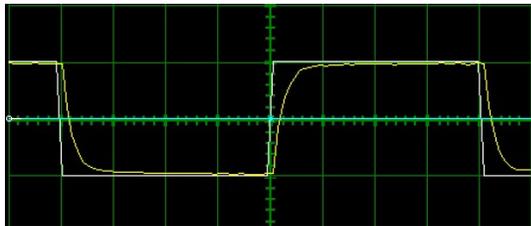


Figure 5 Current Loop Response

Tuning changes with signal amplitude; therefore, you should now re-adjust the current amplitude in the Waveform Generator panel according to the most common application current requirements, and adjust the Torque Loop Kp and Ki accordingly.

- When current loop gain adjustments are complete, disable the drive by clicking the *Disable*  icon.
- Disable the Waveform Generator to remove the command signal from the drive by unchecking the *Enabled* checkbox in the Waveform Generator field.
- Click the *Store* icon on the toolbar to store the parameters to the drive's non-volatile memory.

Step 6: Oscilloscope Setup – Flux Loop

- Change the oscilloscope channels to measure the Flux Reference Current. The Flux Reference Current signals can be found by clicking on the *Change* button to open the signal menu, then selecting *Advanced Menu > Current*.

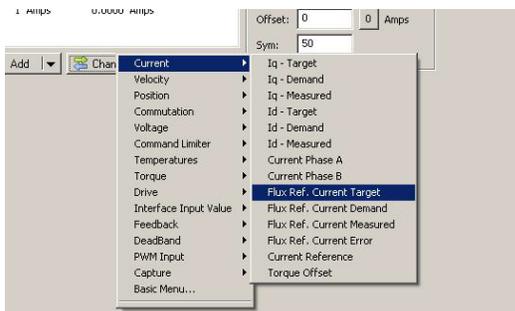


Figure 6 Advanced Signal Menu

- Change the Channel 1 signal to Flux Ref. Current Target.
- Change the Channel 2 signal to Flux Ref. Current Measured.
- Change the trigger *Source* to Flux Ref. Current Target with the *Level* set to zero.

- Ensure trigger *Mode* is Normal.
- Change *Time/Div* to 100 ms.

Step 7: Waveform Generator Setup – Flux Loop

- Select the *Enabled* checkbox in the Waveform Generator panel to enable the Waveform Generator.
- Set the waveform *Type* to Square.
- Set the waveform *Target* to Flux Reference Current.
- Set the *Frequency* to 1 Hz.
- Ensure *Offset* is zero.
- Ensure *Symmetry* is 50%.
- Set the *Amplitude* to the No Load Current as entered in the *Motor > Parameters* window.

Step 8: Tuning – Flux Loop

- Both the Scope and Current Loop Gains windows should still be open. If necessary, click the Scope icon on the toolbar to allow both windows to be visible simultaneously.
- The gains adjustment procedure for the Flux Loop will be the same as for the Torque Loop. A rough gain value for the Flux Loop has already been calculated in the Torque Loop tuning section.
- Enable the drive by clicking the *Enable*  button. The motor should emit an audible noise but remain still.
- Proper tuning will look similar to Figure 7. Adjust the Flux Loop Kp and Ki accordingly to remove any overshoot.

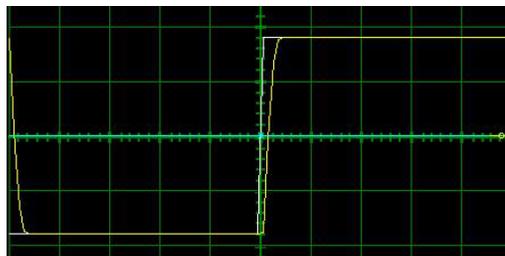


Figure 7 Flux Loop Response

- Adjust the *Field Weakening Threshold Speed* as necessary. DriveWare automatically sets this value to 90% of the Rated Speed (see Field Weakening Threshold Speed section at the end of this document for further information on this value).

AC Induction Current Loop Tuning

6. When gain adjustments are complete, disable the drive using the Disable  icon.
7. Close the *Current Loop Gains window*. Make sure the *Keep Changes* box is checked in the *Save Changes* dialog box, then click *Ok*.
8. Disable the Waveform Generator to remove the command signal from the drive by unchecking the Enabled checkbox in the Waveform Generator field.
9. Click the Store icon on the toolbar to store the parameters to the drive's non-volatile memory.

Step 9: Verify Feedback Polarity

This section can be skipped if the Calculated Tuning method has already been completed and verified successfully.

1. Click the *Multimeter*  icon in the toolbar to open the Digital Multimeter.
2. Use the *Change Signal* button to view Position Measured.
3. Manually rotate the motor shaft one full revolution. Verify that the Position Measured value in the Multimeter matches the feedback *Resolution* value entered into the motor Parameters window.
4. Be prepared to have the motor spin at the Rated Speed.
5. Open the digital oscilloscope by clicking the *Scope* icon from the toolbar.
6. Enable the Waveform Generator by selecting the *Enabled* checkbox in *Waveform Generator* panel.
7. Set the waveform *Type* to DC.
8. Set the waveform *Target* to Current Loop.
9. Set the waveform *Offset* to the No Load Current as entered in the Motor *Parameters* window.
10. Enable the drive by clicking the *Enable*  icon on the toolbar.
11. The motor should spin quickly and smoothly. If the motor does not spin, spins very slowly, or is jerky, it is likely the feedback polarity is not correct due to the particular wiring for different types of AC induction motors. Disable the drive by clicking the *Disable*  icon, then

open *Motor > Parameters* from the Setup Panel. Change the Feedback *Polarity* under the *Feedback Type* panel. Return to the Scope window and command a DC current again as described above to verify proper operation.

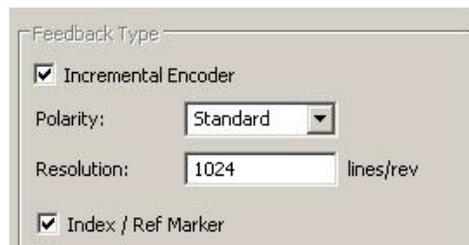


Figure 8 DriveWare Feedback Type Options

12. The motor and drive are now configured for operation and Velocity and Position Loop tuning. Click the *Store* icon on the toolbar to store the parameters to the drive's non-volatile memory.

Field Weakening Threshold Speed Setup

Field weakening allows a motor to spin faster than its rated speed. This happens at the expense of the torque produced by the motor. The motor will enter a "constant" power region at a specified speed. Figure 9 shows example field weakening curves and how the power and torque achieve a constant state for a given field weakening speed. Note that these curves will vary with the motor in use.

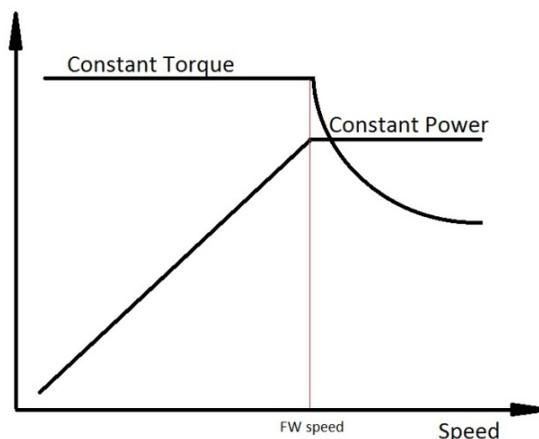


Figure 9 Field Weakening Torque and Power Curves

Typically, the Field Weakening Threshold Speed should be set slightly below the rated base

speed of the motor for optimal performance, or as high as possible while being able to achieve the application requirements. DriveWare automatically sets the Field Weakening Threshold Speed to 90% of the Rated Speed as a starting point. The Field Weakening Threshold Speed should be tuned to each specific application.

Tuning Velocity and Position Loops

Velocity and position loops may be tuned in a similar fashion to a permanent magnet brushless DC motor. See the DriveWare Software Manual for Velocity and Position Loop Tuning procedures.

DriveWare Terminology

In the *Motor > Parameters* window in DriveWare, some of the terminology used for the motor parameters can be synonymous with different terminology used by various motor manufacturers. Use Table 2 below to help determine which parameters should be entered into the *Motor > Parameters* fields.

DriveWare Value	Description
No Load Current	Magnetization Current
Rated Current	Full Load Current or Continuous Current
Peak Current	Typically not provided by motor manufacturers. It is usually acceptable to estimate the Peak Current to be 1 to 2.5 times the Rated Current.
Motor Poles	<p>Typically not specified by motor manufacturers. To solve for the number of poles, use the following equation:</p> $p = \frac{120 \times f}{n_s}$ <ul style="list-style-type: none"> n_s = synchronous rotor speed; typically 1200, 1800, 3600 RPM f = supply frequency to the motor p = number of poles <p>Example: A motor with a rated speed of 1725 RPM with a 60 Hz supply frequency. The synchronous speed of this motor is 1800 RPM. Use the equation to determine this motor has 4 poles.</p>

Table 2 DriveWare AC Induction Terminology