

# PowerFlex 700S and PowerFlex 755 Drives Tuning

Catalog Numbers



# Important User Information

Read this document and the documents that are listed in the [Additional Resources](#) section about installation, configuration, and operation of this equipment before you install, configure, operate, or maintain this product. Users are required to familiarize themselves with installation and wiring instructions and requirements of all applicable codes, laws, and standards.

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**WARNING:** Identifies information about practices or circumstances that can cause an explosion in a hazardous environment, which may lead to personal injury or death, property damage, or economic loss.



**ATTENTION:** Identifies information about practices or circumstances that can lead to personal injury or death, property damage, or economic loss. Attentions help you identify a hazard, avoid a hazard, and recognize the consequence.

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**IMPORTANT**

Identifies information that is critical for successful application and understanding of the product.

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Labels may also be on or inside the equipment to provide specific precautions.



**SHOCK HAZARD:** Labels may be on or inside the equipment, for example, a drive or motor, to alert people that dangerous voltage may be present.



**BURN HAZARD:** Labels may be on or inside the equipment, for example, a drive or motor, to alert people that surfaces may reach dangerous temperatures.



**ARC FLASH HAZARD:** Labels may be on or inside the equipment, for example, a motor control center, to alert people to potential Arc Flash. Arc Flash will cause severe injury or death. Wear proper Personal Protective Equipment (PPE). Follow ALL Regulatory requirements for safe work practices and for Personal Protective Equipment (PPE).

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	<b>Preface</b>	
	Summary of Changes .....	7
	Additional Resources .....	8
	<b>Chapter 1</b>	
<b>Background</b>	Inertia .....	9
	Definitions of Mechanical Terms .....	11
	Backlash .....	11
	Resonance .....	11
	Bandwidth .....	12
	PowerFlex Control Loops .....	14
	PowerFlex Position Loop .....	14
	PowerFlex Velocity (Speed) Loop .....	16
	PowerFlex Torque Control .....	18
	Damping Factor .....	19
	PowerFlex Inertia Adaption .....	19
	Benefits of Inertia Adaption .....	20
	How Inertia Adaption Works .....	20
	PowerFlex 700S Drive Inertia Adaption Configuration .....	21
	PowerFlex 755 Drive Inertia Adaption Configuration .....	24
	PowerFlex Load Estimate and Load Observer .....	26
	Benefits .....	26
	How Load Observer and Load Estimate Work .....	26
	PowerFlex 700S Drive Load Estimate Configuration .....	27
	PowerFlex 755 Drive Load Observer Configuration .....	29
	<b>Chapter 2</b>	
<b>Tuning Configuration and Setup</b>	PowerFlex 700S Drive Startup Wizard .....	32
	Motor Control Configuration .....	33
	Motor Data .....	34
	Feedback Configuration .....	35
	Direction Test .....	35
	Auto Tune .....	36
	Inertia Auto Tune Test .....	37
	PowerFlex 700S Drive Additional Setup .....	38
	PowerFlex 700S Drive Movement Configuration for Tuning .....	40
	PowerFlex 755 Drive Startup Wizard .....	41
	Motor Control Configuration .....	41
	Motor Data .....	42
	Feedback Configuration .....	43
	Direction Test .....	44
	Auto Tune .....	44
	Inertia Auto Tune Test .....	45
	PowerFlex 755 Drive Additional Setup .....	46
	PowerFlex 755 Drive Movement Configuration for Tuning .....	48

	<b>Chapter 3</b>	
<b>Tuning Using Bandwidth</b>	PowerFlex 700S Drive .....	52
	Velocity (Speed) Loop Tuning Procedure.....	53
	Changing the Damping Factor (Z).....	57
	Position Loop Tuning Procedure (if Used) .....	59
	PowerFlex 755 Drive .....	59
	Velocity (Speed) Loop Tuning Procedure.....	60
	Changing the Damping Factor (Z).....	63
	Position Loop Tuning Procedure (if Used) .....	65
	<b>Chapter 4</b>	
<b>Manual Tuning</b>	Drive Setup .....	70
	Velocity (Speed) Loop Tuning .....	70
	Position Loop Tuning (if Used) .....	74
	<b>Chapter 5</b>	
<b>Regulator Compensation Filters</b>	Torque Reference Notch Filter .....	78
	Using the Torque Notch Filter .....	81
	Tools for Determining Resonant Frequencies.....	83
	Speed Regulator Lead/Lag Filters .....	83
	Using the Lead/Lag Filter .....	86
	Mechanical Backlash Application Example .....	89
	Inner Loop System Rolloff .....	90
	Lead/Lag Filter Application Example .....	92
	<b>Chapter 6</b>	
<b>Encoder Feedback Filters</b>	PowerFlex 700S Drive Encoder Feedback Filter.....	95
	Hardware Filter Time Constant .....	96
	PowerFlex 700S Drive FIR Filter .....	96
	Configuring the FIR Filter in the PowerFlex 700S Drive.....	97
	PowerFlex 755 Drive Encoder Feedback Filter.....	98
	Configuration Steps .....	99
	<b>Appendix A</b>	
<b>PowerFlex 755 Drive and CIP</b>	Using CIP Motion Control Loop Relationships with PowerFlex Drives .	101
	Example of Rationalizing PowerFlex Gains to CIP Gains .....	102
	PowerFlex 755 CIP Motion Drive Configuration.....	102
	PowerFlex 755 CIP Motion Drive Setup .....	103
	Drive Creation and Configuration .....	104
	PowerFlex 755 CIP Motion Axis Configuration .....	106



<b>Creating a Trend with Studio 5000 Logix Designer Application for Tuning</b>	<b>Appendix B</b>	
	PowerFlex 700S Drive Logix Designer Setup .....	113
	PowerFlex 755 Drive Logix Designer Setup.....	115
	Trend Properties Dialog Box .....	117
	Name Tab .....	117
	General Tab.....	117
	Display Tab.....	118
	Pens Tab.....	118
	X-Axis Tab .....	120
	Y-Axis Tab.....	120
	Sampling Tab .....	121
	Value Bar Information.....	122
<b>Setting Different Drive Position Modes</b>	<b>Appendix C</b>	
	PowerFlex 755 Drive Position Modes .....	125
	Configuration to Set Position Mode as ‘Direct Position’ .....	126
	Configuration to Set Position Mode as ‘Profiler’ .....	127
	Configuration to Set Position Mode as ‘Point to Point (PTP)’ ..	128
	PowerFlex 700S Drive Motion Planner Mode .....	129
<b>Index</b>	Index.....	131

## Notes:

## Summary of Changes

Topic	Page
Added Preface with Summary of Changes and Additional Resources	7
Updated the How Inertia Adaption Works section to show that Inertia Adaption feature uses acceleration feedback rather than a component of Torque Feedback.	20
Added bullet to the PowerFlex 700S Drive Inertia Adaption Configuration section to mention Inertia Adaption should not be used simultaneously as Load Observer.	22
Added bullet to the PowerFlex 700S Drive Inertia Adaption Configuration section to describe Inertia Adaption relation to Inertia Compensation.	22
Updated first bullet in PowerFlex 755 Drive Inertia Adaption Configuration section to show parameter 125.	24
Added bullet to PowerFlex 755 Drive Inertia Adaption Configuration section to mention that Inertia Adaption should not be used simultaneously as Load Observer.	24
Added two bullets to the PowerFlex 755 Drive Inertia Adaption Configuration section describing Inertia Adaption with parameter 76 [Total Inertia].	24
Changed load inertia to motor inertia in first paragraph of How Load Observer and Load Estimate Work.	26
Added bullets to PowerFlex 700S Drive Load Estimate Configuration section stating Load Observer should not be enabled in torque control and Load Estimate should not be used with Inertia Adaption.	27
Added two bullets to the PowerFlex 700S Drive Load Estimate Configuration section describing Inertia Adaption with parameter 9 [Total Inertia].	27
Added bullet to the PowerFlex 700S Drive Load Estimate Configuration section describing Inertia Adaption with Inertia Compensation.	27
Added text to first bullet in PowerFlex 755 Drive Load Observer Configuration section about the need for the drive to have a connected motor feedback device.	29
Edited second bullet in PowerFlex 755 Drive Load Observer Configuration section about using Load Observer.	29
Added bullets to PowerFlex 755 Drive Load Observer Configuration stating Load Observer cannot be enabled in Torque mode and cannot be used at the same time as Inertia Adaption.	29
Edited the last bullet in the PowerFlex 755 Drive Load Observer Configuration section regarding Load Observer, Torque reference, and Inertia Compensation.	29
Edited Step 3 in the PowerFlex 755 Drive Load Observer Configuration section to say the value of Parameter 76 [Total Inertia] is equal to only the motor inertia.	29
Edited introductory text of the Inertia Auto Tune Test section to clarify what the test is for with the PowerFlex® 700S Drive.	37
Edited introductory text of the Inertia Auto Tune Test section to clarify what the test is for with the PowerFlex 755 Drive.	45
Edited text in the Inertia Auto Tune Test section to add internally calculated parameters for the Speed Regulator to add Inertia Adaption, Load Observer, and Inertia Compensation.	45
Updated the first bullet after Step 14 in the PowerFlex 755 CIP Motion Axis Configuration section of Appendix A to show 1.0 ms.	110

## Additional Resources

These documents contain additional information concerning related products from Rockwell Automation.

Resource	Description
Motion System Tuning Application Techniques, publication <a href="#">MOTION-AT005</a> .	Provides proper methods to tune and apply filters to a CIP Kinetix® servo drive.
PowerFlex 750-Series AC Drives Reference Manual, publication <a href="#">750-RM002</a> .	Provides comprehensive information on the PowerFlex 755 CIP drive.
Integrated Motion on the EtherNet/IP Network Configuration and Startup User Manual, publication <a href="#">MOTION-UM003</a> .	Provides setup details for Integrated Motion on the EtherNet/IP Network.
Industrial Automation Wiring and Grounding Guidelines, publication <a href="#">1770-4.1</a>	Provides general guidelines for installing a Rockwell Automation industrial system.
Product Certifications website: <a href="http://rok.auto/certifications">rok.auto/certifications</a>	Provides declarations of conformity, certificates, and other certification details.

You can view or download publications at <http://www.rockwellautomation.com/global/literature-library/overview.page>.

## Background

This document is intended for drive users that are familiar with the following:

- PowerFlex® and PowerFlex 755 drives
- EtherNet/IP™ communication
- Use of the Studio 5000 Logix Designer® application
- Use of Connected Components Workbench™ software
- Use of DriveExecutive™ software
- Understanding how control loops work in a drive application

PowerFlex 700S and PowerFlex 755 drives use different modes of operation, including velocity and positioning modes, which are the focus of this publication.

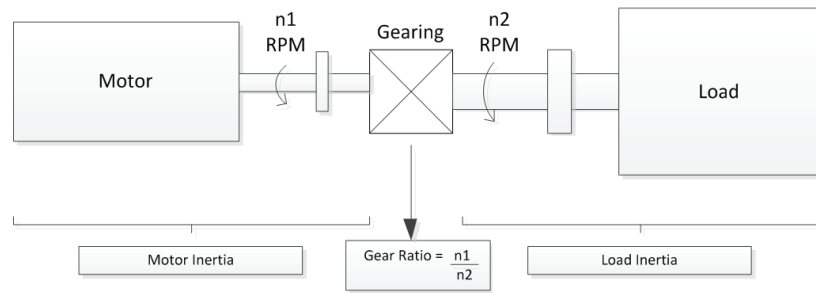
The PowerFlex 755 drive can be configured to operate as an AC drive or a CIP™ motion drive (Common Industrial Protocol; also known as real-time Motion). The CIP motion configuration is described in [PowerFlex 755 CIP Motion Drive Configuration on page 102](#). When the PowerFlex 755 drive is configured as a CIP motion drive, refer to Motion System Tuning, publication [MOTION-AT005](#), and PowerFlex 750-Series AC Drives Reference Manual, publication [750-RM002](#). These publications describe specific rules and properties for tuning because this drive configuration follows the same rules, properties, and behaviors as a CIP Kinetix® Servo Drive. When the PowerFlex 755 drive is configured as an AC drive, follow the rules that are provided in this publication.

## Inertia

Inertia is the physical property that states an object with any mass resists a change in velocity unless an external force is applied. Generally, units of measure for rotary inertia are  $\text{lb}\cdot\text{ft}^2$  in imperial units or  $\text{kg}\cdot\text{m}^2$  in metric units.

A typical motor drive train consists of a motor that is coupled to the high-speed input of a gear reducer, and a load that is coupled to the low-speed output of the gear reducer. A typical drive train is shown in this figure.

Figure 1 - Typical Mechanical Drive Train



The equivalent inertia reflected to the motor shaft can be expressed in imperial units with this formula:

$$\text{Equivalent Inertia (lb}\cdot\text{ft}^2) = \text{Motor Inertia (lb}\cdot\text{ft}^2) + \frac{\text{Load Inertia (lb}\cdot\text{ft}^2)}{(\text{Gear Ratio})^2}$$

In PowerFlex drives, Total Inertia  $J_t$  is a parameter that represents the time, in seconds, required to accelerate the equivalent inertia to rated motor RPM with rated motor torque applied.  $J_t$  is a representation of the Total Inertia of a particular system, and can be calculated as follows:

$$J_t (\text{sec}) = \frac{\text{Equivalent Inertia (lb}\cdot\text{ft}^2) \times \text{Rated Motor Speed (RPM)}}{308 \times \text{Rated Motor Torque (lb}\cdot\text{ft)}}$$

Note: 308 is a constant derived from: 
$$\frac{\left[ \left( 32.2 \frac{\text{ft}}{\text{sec}^2} \right) \times \left( 60 \frac{\text{sec}}{\text{min}} \right) \right]}{2\pi \frac{\text{rad}}{\text{rev}}}$$

Or:

$$J_t (\text{sec}) = \frac{\text{Equivalent Inertia (kgm}^2) \times \text{Rated Motor Speed (RPM)}}{9.55 \times \text{Rated Motor Torque (N}\cdot\text{m)}}$$

Note: 9.55 is a constant derived from  $60 \div 2\pi$ , which converts RPM to rads/sec.

PowerFlex drives include an Inertia Auto Tune test that measures the Total Inertia ( $J_t$ ) of the system. This test is described in [Chapter 2](#).

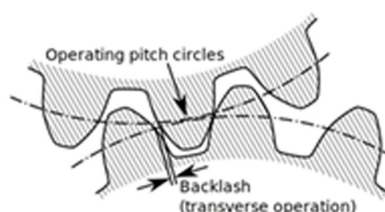
## Definitions of Mechanical Terms

The following subsections describe the various mechanical terms.

### Backlash

Backlash is the clearance between the teeth in gears or splines in a coupling. The clearance or play between drive and load causes lost motion because the load can be intermittently uncoupled from the motor. The greater the difference between load inertia to motor inertia and the larger the backlash, the more pronounced the effect is. If the drive can produce torque at frequencies high enough to move the driven gear or spline into the clearance or play, gear teeth or coupling splines can ‘chatter’ audibly.

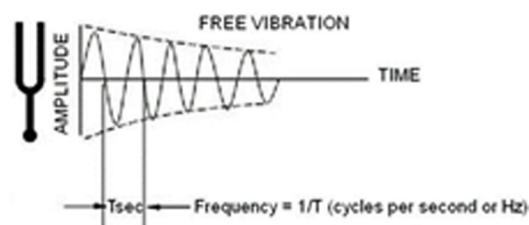
**Figure 2 - Gears Showing Backlash**



### Resonance

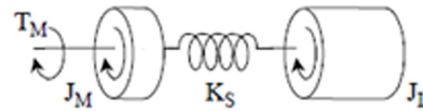
Resonance is the tendency of a system to oscillate with greater amplitude at some frequencies rather than others. Frequencies at which the response amplitude is a relative maximum are known as the system resonant, or natural frequencies. At these frequencies, even small periodic driving forces can produce large amplitude oscillations, because the system stores vibrational energy. There are two types of resonance that are associated with industrial drives:

- **High resonant frequency** is related to the natural frequency of the machine. High resonant frequency is the frequency of natural vibration if the machine is struck with an external torque, much like a tuning fork. High resonant frequency can cause instability in ‘rigid’ mechanical systems if high gains are used in the control loop system.





- **Low resonant frequency** is related to torsional compliance of the mechanical drive train components, such as couplings, shafts, and belt drives. Low resonant frequency due to torsional compliance is common in most industrial drive systems. The effect is similar to a spring-mass system where energy is stored when motor torque ( $T_M$ ) introduces energy that does not immediately produce rotation of the load. The energy that is stored in the system is released when the motor torque ( $T_M$ ) is removed, which causes the load to continue to accelerate. The resonant frequency that is associated with torsional compliance depends on the spring constant ( $K_S$ ) of the drive train and the relative inertia of the motor ( $J_M$ ) and load ( $J_L$ ). This representation is shown in this figure.



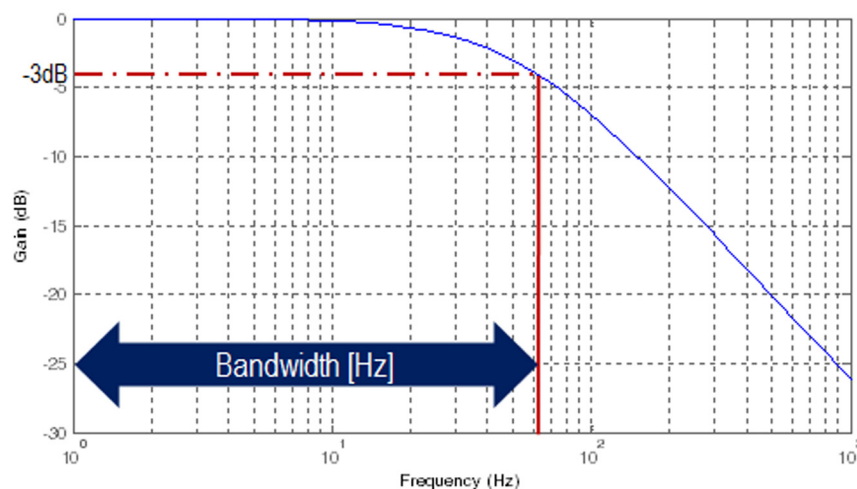
PowerFlex drives offer different filtering functions to compensate for backlash and the resonant frequencies. To attenuate the effect of these mechanical issues, these filter compensation techniques can be used.

Filter Compensation Technique	Description
Lead/Lag Filters	Compensates for instability oscillation due to mechanical backlash, which is discussed in <a href="#">Chapter 5</a> , Regulator Compensation Filters.
Notch Filter	Applies attenuation to a specific frequency to filter machine resonant frequencies due to torsional compliance and mechanical resonance, which is discussed in <a href="#">Chapter 5</a> , Regulator Compensation Filters.
Inertia Adaption	Compensates for severe instability oscillation due to mechanical backlash, which is discussed later in this chapter.
Load Observer	Compensates for unpredictable load torque disturbances, which are discussed later in this chapter.

## Bandwidth

Bandwidth (BW) is a widely used term that is critical to drive performance. Closed loop bandwidth is defined as the range of frequencies between 0 Hz and the frequency where the gain through the system is above -3 dB. This frequency range is where the system is usable. This document focuses on the closed loop configuration of the PowerFlex drives, which is the only mode where tuning would be applicable.

Figure 3 - System Gain Versus Frequency



Position, Velocity, and Torque Loop Bandwidth indicate the respective performance of each loop in a PowerFlex drive. Higher bandwidth improves transient response, decreases error, and makes the motor performance stiffer. Position and Velocity Loop tuning highly dictates the bandwidth of the drive system. The following figure shows how bandwidth affects actual response (solid) compared to its command motion profile (dashed).

Figure 4 - How Bandwidth Affects Transient Response



The following factors affect drive bandwidth.

Factors that Affect Bandwidth	Description
Feedback Resolution	Higher is better
Motor-to-Load inertia ratio	Lower is better
Drive regulator loop update rate	Faster is better
Load rigidity	Less compliance, backlash, lost motion, or indirect coupling is better

The maximum system bandwidth (including load) can be defined using this formula:

$$\text{System BW} = \text{Unloaded Motor Velocity Loop BW} \times \sqrt{\frac{J_M}{J_M + J_L}}$$

Where  $J_M$  is motor inertia and  $J_L$  is the reflected load inertia to the motor shaft.

Some examples of Loop Update Rates and Velocity Loop Bandwidth values for the PowerFlex drives connected to an unloaded motor are shown in this table.

Table 1 - Bandwidth Comparison for PowerFlex Drives Using FOC (Field-Oriented Control) Mode

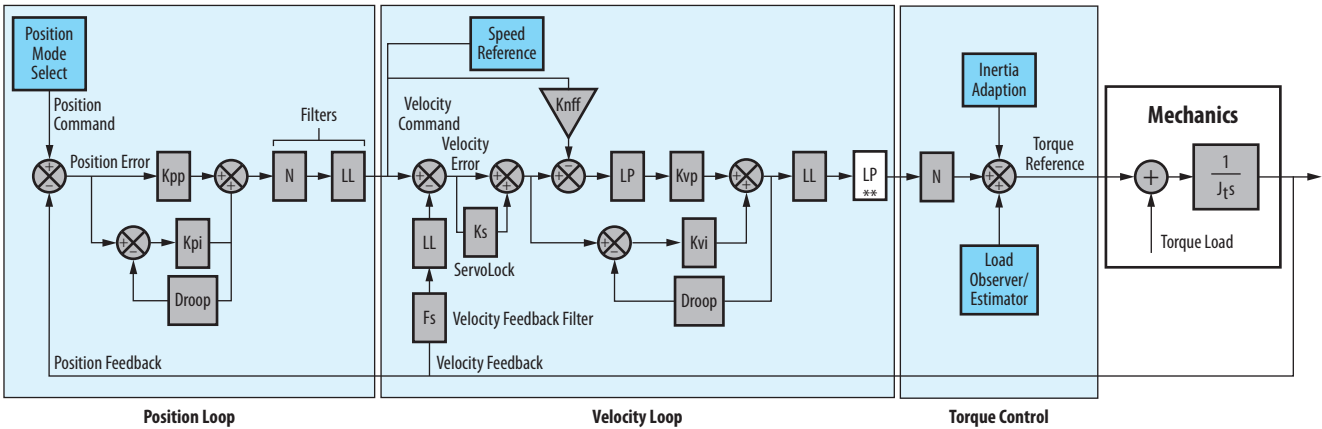
PowerFlex Drive	Loop Update Rate				Unloaded Motor Velocity Loop Bandwidth	
	Position (μs)	Velocity (μs)	Torque (μs)	Motor Nameplate	Hertz	Rad/sec
PowerFlex	1000	250	125	MPL-B560F	255	1602
PowerFlex 755	1024	1024	256	MPL-B560F	117	735

PowerFlex Control Loops

PowerFlex 700S and PowerFlex 755 drives have a Torque Loop, which is nested within a Velocity (Speed) Regulator Loop, which is nested within an outer Position Regulator Loop as shown in [Figure 5](#). Each loop (and its internal functions) shown in this figure is described in subsequent sections. A PowerFlex drive can operate in these modes:

- Torque mode (only Torque control is used)
- Velocity mode (Velocity and Torque Loop Regulators are used)
- Position mode (Position, Velocity, and Torque Loop Regulators are used)

Figure 5 - Simplified PowerFlex Control Loop Block Diagram

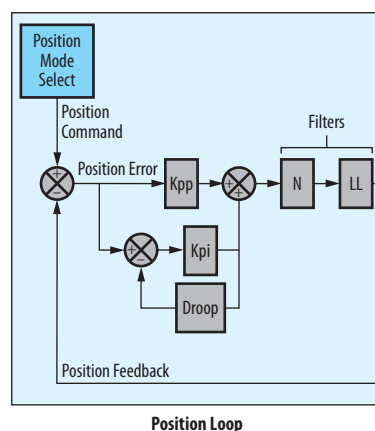


The advantages of this type of control system architecture include:

- Precise control of position, velocity, and torque
- Flexible configurations for position, velocity, and torque control
- Simple ‘inside-out’ tuning, is described in [Chapter 3](#) and [Chapter 4](#)

PowerFlex Position Loop

In PowerFlex drives, the Position Loop Regulator is optional and is used in one of the various positioning modes. The type of positioning mode depends on the application. The configuration of some of the positioning modes that can use the techniques that are described in this publication (Point-to-Point, Direct Reference, Position Profiler, Motion Planner, and so forth) are shown in [Appendix C](#).

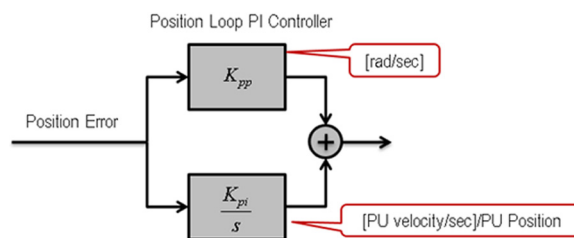
**Figure 6 - PowerFlex Position Loop Controller**

The terms that are shown in [Figure 6](#) are described as follows.

Term	Description	Units
Kpp	Position Proportional Gain	Rad/sec
Kpi	Position Integral Gain	(Per Unit velocity/sec)/(Per Unit position)
Droop	Droop	(Per Unit position/Per Unit speed) or sec
N	Notch Filter	Hz
LL	Lead/Lag Filter	Rad/sec
Position Mode Select	'Block' representing the Position Command generation	—

More details of these terms are provided in this section.

A position closed loop control requires a Position Command and Position Feedback. The Position Command depends on the configuration of the Position Mode Select 'block' shown in [Figure 6](#). The Position Feedback must be from a physical encoder.

**Figure 7 - PowerFlex Position Loop PI Controller (PU = Per Unit)**

A proportional control loop term,  $K_{pp}$ , which is shown in [Figure 7](#), sets the Position regulator gain as measured from Position Error (input) to Speed Reference (output). The proportional gain term  $K_{pp}$  is essentially a multiplier and is equal to Position Loop Bandwidth in units of rad/sec. For example, a  $K_{pp}$  gain of 10 means that a per unit position error of 0.1 seconds affects a 1.0 per unit speed change. (1 per unit position error is the distance that is traveled in 1 second at base motor speed.) Typically, the  $K_{pp}$  value is set based on the value of the Velocity Loop Bandwidth, which provides adequate loop spacing.

The integral term  $K_{pi}$ , which is shown in [Figure 7](#), is measured from Position Error (input) to Velocity Speed Reference (output). The  $K_{pi}$  value is measured in [Per Unit Velocity/sec] / [Per Unit Position]. For example, a gain of 25 means that a per unit Position Error of 0.1 sec affects a 2.5 per unit speed change per second. (1 per unit Position Error is the distance that is traveled in 1 second at base motor speed.)

The Droop term, which is shown in [Figure 6](#), limits the low frequency gain of the Position Regulator integral gain ( $K_{pi}$ ) to a value of  $1/\text{Droop}$ . It provides a means to fine-tune the stability for load-mounted feedback devices where lost motion can cause a problem. Droop is measured in units of per unit position/per unit speed. When used, it can be measured using  $1/K_{pp}$  as a guideline. However, most tightly coupled loads do not require the use of Droop.

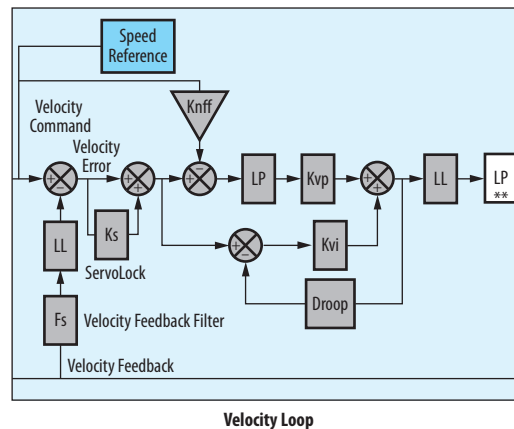
The Position Regulator Notch Filter (N) term is described in [Chapter 5](#), Regulator Compensation Filters. This filter can be used with the Notch Filter in the Torque Loop to provide more resonance filtering.

The Lead/Lag Filter (LL) term is described in [Chapter 5](#), Regulator Compensation Filters.

## PowerFlex Velocity (Speed) Loop

In PowerFlex drives, generally the Velocity Loop Regulator is used. The configurations where the Velocity Loop Regulator is not used are in V/Hz control mode or Torque Regulation mode. The Velocity Loop Regulator of a or PowerFlex 755 drive is shown in [Figure 8](#). The 'Speed Reference' or the output of the Position Loop Regulator (if used) provides the Velocity Command for the Velocity Loop Regulator.  $K_{vp}$  and  $K_{vi}$  gains are automatically calculated when the Speed Loop Bandwidth parameter is greater than zero. In the or PowerFlex 755 drive, the  $K_{vp}$  and  $K_{vi}$  calculations also include the  $J_t$  (Total Inertia) parameter. To manually adjust  $K_{vp}$  and/or  $K_{vi}$ , the Speed Loop Bandwidth value must be set to zero.

**Figure 8 - PowerFlex Velocity Loop Regulator**



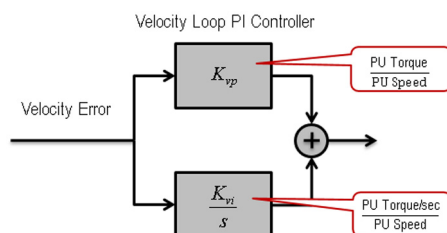
\*\* This Low Pass Filter (LP) is available only on the PowerFlex 755 drive when Inertia Adaption is active.

The terms that are shown in [Figure 8](#) are described as follows.

Term	Description	Units
Kvp	Velocity Proportional Gain	Unitless
Kvi	Velocity Integral Gain	1/sec
Ks	Servo Lock Gain	1/sec
Droop	Droop	(Per Unit speed/Per Unit torque) or RPM
Knff	Negative FeedForward	Unitless
LL	Lead/Lag Filter	Rad/sec
Fs	Velocity (Speed) Feedback Filter	Rad/sec
LP	Low Pass Filter	Rad/sec
Speed Reference	'Block' representing the Velocity Command generation	—

More details of these terms are provided in this section.

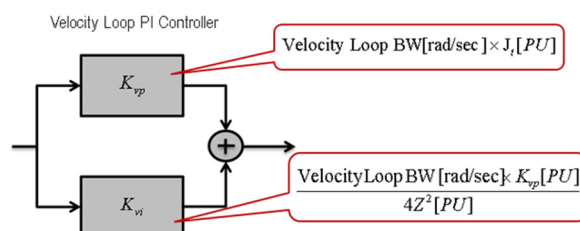
**Figure 9 - PowerFlex Velocity Loop PI Controller**



In [Figure 9](#),  $K_{vp}$  has a scaling of [Per Unit Torque] / [Per Unit speed] and so is unit less. For example, when  $K_{vp} = 20$ , the proportional gain block outputs 20% motor-rated torque for every 1% velocity (speed) error. Also shown in the same figure,  $K_{vi}$  has a scaling of [Per unit torque/sec] / [per unit speed] and has units of 1/sec. For example, when  $K_{vi} = 50$  and velocity (speed) error = 1%, the integral gain block integrates 0...50% motor-rated torque in 1 second.

In [Figure 10](#), a proportional term  $K_{vp}$  sets the Velocity Regulator gain. This gain is automatically calculated when the value of the Velocity (Speed) Loop Bandwidth parameter is greater than zero. The  $K_{vp}$  gain calculation is derived from the Velocity (Speed) Loop Bandwidth and the  $J_t$  (Total Inertia) parameter. An integral term  $K_{vi}$  is automatically calculated when the value of the parameter Speed Loop Bandwidth is greater than zero. The  $K_{vi}$  gain is derived from the  $K_{vp}$  gain value, the Velocity (Speed) Loop Bandwidth, and Z (Damping) parameters. The Speed Loop Bandwidth value must be zero to adjust  $K_{vp}$  and/or  $K_{vi}$ .

**Figure 10 -  $K_{vp}$  and  $K_{vi}$  Automatic Calculations When Velocity Loop BW > 0**



Droop, which is shown in [Figure 8](#), is used to 'shed' load, and is used when a compliant coupling exists between two motors.

The Droop term specifies the amount of base speed that the Speed Reference (or Velocity Command) is reduced when operating at full load torque. Use of the Droop function causes the motor speed to decrease with an increase in load.

Droop has different scaling for the drive [per unit speed] / [per unit torque] and PowerFlex 755 drive [RPM]. For example, when droop is set to 0.1 for a drive, and the drive is using 100% rated motor torque, the droop block subtracts 10% from the speed reference.

The ServoLock ( $K_s$ ) term, which is shown in [Figure 8](#), is an extra integrator in the Velocity Loop Regulator. The effect is to increase the stiffness of the speed response to a load disturbance. It behaves similar to having  $K_{pp}$  with Velocity Feedforward, but is not as accurate as a true Position Loop Regulator. The units are rad/sec. If this value is used, it is typically set for 1/3 the value of the Velocity Loop Bandwidth.

The Velocity (Speed) Feedback filter,  $F_s$ , which is shown in [Figure 8](#), is described in [Chapter 5](#), Regulator Compensation Filters.

Damping Factor zeta ( $Z$ ), shown in [Figure 10](#), defines actual overshoot relative to a critically damped system and affects the integral gain of the velocity loop. The Damping Factor is described later in this chapter.

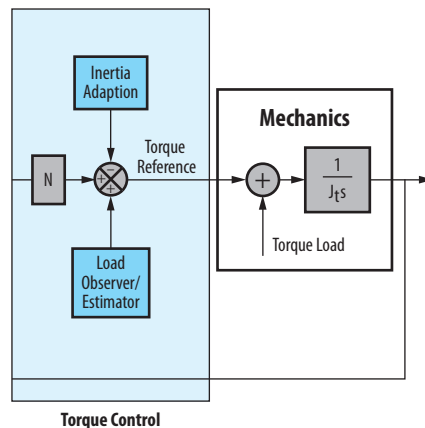
$J_t$  represents the Total Inertia and is described in [Chapter 2](#), Tuning Configuration and Setup.

The Lead/Lag Filter (LL) and Low Pass Filter (LP) terms are described in [Chapter 5](#), Regulator Compensation Filters.

## PowerFlex Torque Control

A simplified torque control block is shown in this figure.

**Figure 11 - PowerFlex Torque Control**





The Torque Notch Filter (N) term is described in [Chapter 5](#), Regulator Compensation Filters.

The 'Mechanics' block in [Figure 11](#) represents the mechanical load including the motor and driven load. The Torque Load term represents the work load of the machine. The  $J_t$  term is Total Inertia that is derived from the equivalent inertia and includes motor inertia and reflected load inertia. The  $1/J_t s$  term represents the integration of torque over time, which produces velocity at the output of the Mechanics block.

Inertia Adaption and Load Observer advanced features are described later in this chapter.

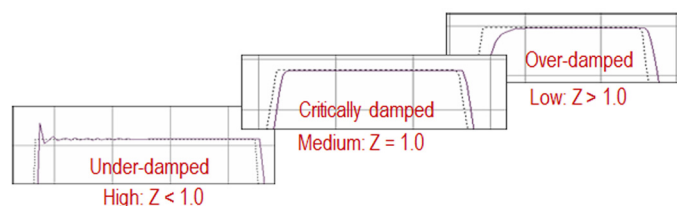
Some characteristics of these advanced features include the following:

- The PowerFlex 700S drive has the Load Estimate feature (similar in operation to Load Observer) and Inertia Adaption feature, but only one can be active simultaneously.
- The PowerFlex 755 drive has the Load Observer feature and Inertia Adaption feature, but only one can be active simultaneously.

## Damping Factor

Damping Factor is commonly referred to as zeta ( $Z$ ). It affects the rise time for a given bandwidth. The following figure and table show how the Damping Factor affects the actual response (solid) compared to its command reference (dashed).

**Figure 12 - How Damping Affects Transient Response**



Damping Factor (Z) Value	Responsiveness
$Z < 1.0$	Produces high responsiveness, characterized by a faster rise time but with overshoot.
$Z = 1.0$	Produces medium responsiveness, characterized by the fastest possible rise time without overshoot. We recommend this setting.
$Z > 1.0$	Produces low responsiveness, characterized by a slower response, similar to decreasing the bandwidth.

The default setting in a PowerFlex drive is  $Z = 1.0$ . A lower Damping Factor decreases the spacing between the position and velocity loop integral gains, which generates under-damped responses in Actual Position and Actual Velocity trends. A higher Damping Factor generates over-damped responses.

## PowerFlex Inertia Adaption

Inertia Adaption is a feature with the ability to increase System Bandwidth and can eliminate the use of filters in the control loops. Inertia Adaption can be used

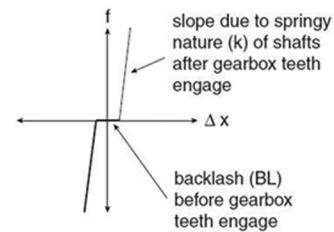
to create an ‘electronic’ inertia. This feature is not useful on a system with a rigid load or a mechanical load that does not exhibit any lost motion.

Inertia Adaption is especially useful in systems with backlash. Backlash can cause the load to be momentarily disconnected from the motor. A gearbox is a typical mechanism that presents backlash. A gearbox, represented by a spring torsional compliance ( $k$ ) and gear backlash ( $BL$ ), is shown in these figures.

**Figure 13 - Gearbox Representation**



**Figure 14 - Behavior of a Gearbox**



When the motor speed abruptly changes or there is a change in speed direction, there is a time (represented by  $\Delta x = \text{backlash}$ ) in which the gearbox teeth are disengaged. After that time, there is some twisting (like a spring) in the shaft after the teeth of the gearbox engage.

This lost motion causes mechanical instability and limits how high the Speed Regulator Bandwidth can be set without instability.

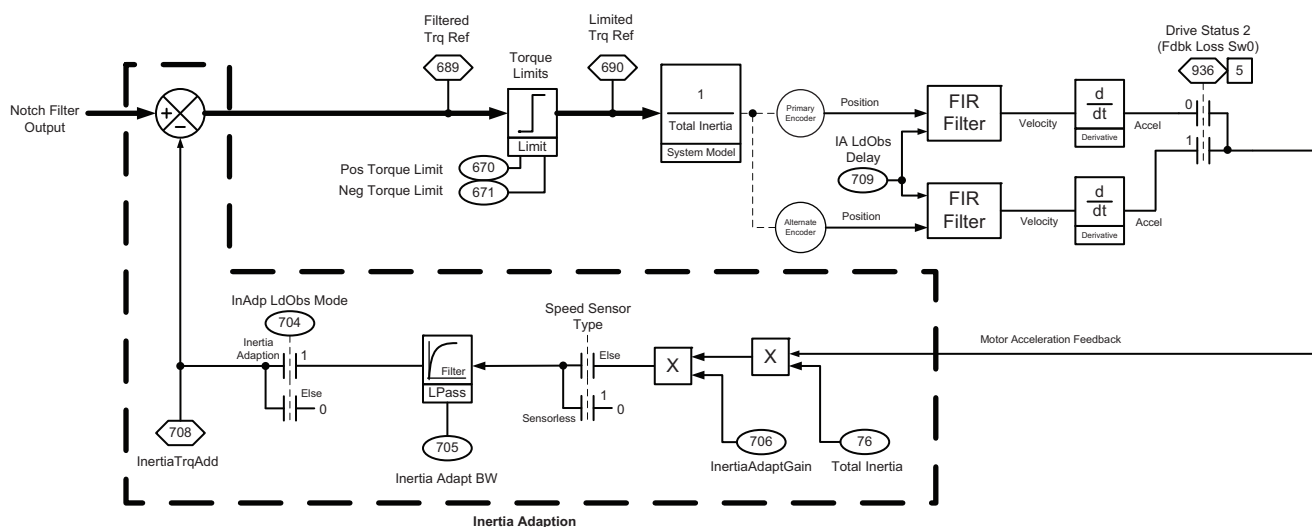
## Benefits of Inertia Adaption

Inertia Adaption is useful in systems with mechanical backlash. The lost motion that is created by backlash causes mechanical instability and yields a limited Velocity Loop Bandwidth. Inertia Adaption compensates for this lost motion without having the Velocity Loop try to respond to the ‘disconnect’. The result is a higher Velocity Loop Bandwidth without instability. The Inertia Adaption feature provides enhanced stability, higher bandwidths, dynamic stiffness, and can eliminate the need for filters in your control loops.

## How Inertia Adaption Works

The Inertia Adaption feature (dotted line section of [Figure 15](#)) uses Acceleration Feedback to create an ‘electronic’ inertia. This feature forces the drive to behave as if there was an artificial inertia at the load, even if the physical load inertia is small. The Inertia Adaption feature can be used with the Inertia Compensation feature to minimize the acceleration/deceleration torque that is required from the Velocity Loop. Inertia Adaption Gain sets a multiplier of  $J_t$  (Total Inertia). This multiplier is used to adjust the effect Inertia Adaption has on the torque reference. Higher gain can cause high frequency resonance, while smaller values can cause a load instability. Inertia Adaption Bandwidth sets the bandwidth of a low pass filter that is at the output of the Inertia Adaption feature. Inertia Adaption is typically set equal to the Velocity (Speed) Loop Bandwidth.

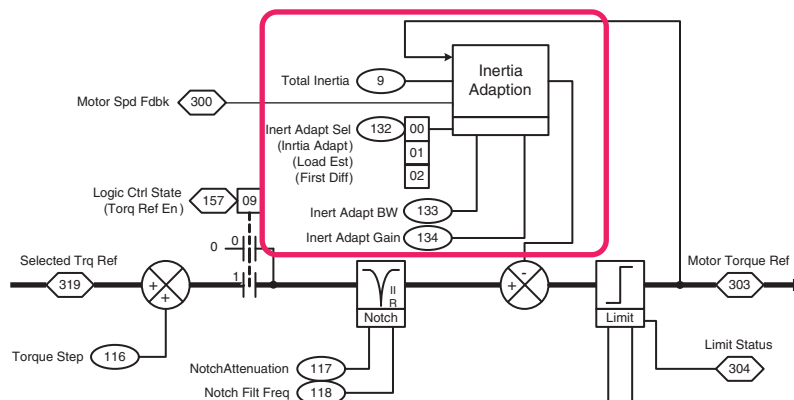
Figure 15 - PowerFlex 755 Drive Inertia Adaption Feature Block Diagram



## PowerFlex 700S Drive Inertia Adaption Configuration

The PowerFlex 700S Inertia Adaption and Load Estimate functions are shown in the red-highlighted area of this figure.

Figure 16 - PowerFlex 700S Drive Load Estimate and Inertia Adaption Block Diagram



### Drive Setup

Note these important criteria for the PowerFlex 700S drive Inertia Adaption feature:

- Use Par 485 [Motor Ctrl Mode] set to 0, 1, or 2 to configure the drive for field-oriented control.

Setting	Description
0	FOC Field-Oriented Control
1	FOC2 Field Oriented Control 2
2	Permanent Magnet (PMag) Motor

Also, the drive must have a connected motor feedback device, which is configured with Par 222 [Mtr Fdbk Pri Sel] set to 0 (Encoder 0).

- Inertia Adaption should not be used simultaneously with Load Estimate.
- Inertia Adaption is not enabled by default. When Inertia Adaption is activated, the two Lead/Lag filters present in the Speed Regulator must be disabled. One of these filters is located in the speed feedback path. To disable this filter, set Par 93 [SReg FB Filt Gain] to 1. The other filter is at the output of the Speed Regulator. To disable this filter, set Par 95 [SReg Out Filt Gain] to 1.

---

**IMPORTANT** An Inertia Auto Tune Test must be performed. For details, see [Chapter 2](#).

---

- Inertia Adaption can be enabled only when the value in Par 9 [Total Inertia] is greater than zero.
- When using Inertia Adaption, the total inertia ( $J_t$ ) should be entered for Par 9 [Total Inertia]. This value includes the motor + load. Total inertia is measured using the Inertia Tune Test with the motor coupled to the load.
- Setting Par 134 [Inert Adapt Gain] has no effect on the Load Estimate parameter.
- Inertia Adaption subtracts torque reference during velocity reference ramp speed changes. As a result, Inertia Compensation, Par 151 [Logic Command] Bit 10 'Inertia Comp', can be used to offset the effect of Inertia Adaption and minimize the acceleration and deceleration torque required from the velocity regulator.

To enable the Inertia Adaption feature in the PowerFlex 700S drive, set Par 132 [Inert Adapt Sel] Bit 0 'Inertia Adapt' to 1 (on). The configurations for Par 132 [Inert Adapt Sel] Bits 0, 1, and 2 are described in this table.

Bit Number	Bit Value	Effect
Bit 0 'Inertia Adapt'	When = 1 (on)	The Inertia Adaption feature affects enhanced stability, higher bandwidths, and dynamic stiffness. Inertia Adaption is useful when a system with a gearbox becomes disconnected from the load. It is also used with motors that have little inertia that otherwise lack dynamic stiffness, even at high bandwidths.
Bit 1 'Load Est'	When = 1 (on)	The Load Estimate option removes or reduces load disturbances and provides a quicker system response.
Bit 2 'First Diff'	When = 1 (on)	Selects the first difference feedback for Inertia Adaption. This bit must be set = 1 to ensure proper operation of the Inertia Adaption and Load Estimate functions.

*Configuration Steps*

1. Set Par 132 [Inert Adapt Sel] Bit 0 'Inertia Adapt' to 1 (on) to activate Inertia Adaption.

Also, we recommend that Bit 1 = 0 (off) and Bit 2 = 1 (on).

2. Set Par 134 [Inert Adapt Gain] so that:

$$0.3 \leq \text{Par 134 [Inert Adapt Gain]} \leq 1.0 \text{ (nominal value is 0.5)}$$

Higher values in this range can cause high resonant frequency, while smaller values can cause fundamental load instability.

3. Set Par 133 [Inert Adapt BW] to establish the frequency of the Inertia Adaption/Load Estimate Filter.

This parameter has rad/sec units and is typically set to match the Velocity Loop Bandwidth value of Par 90 [Spd Reg BW]. Typical final values range so that:

$$\text{Par 133 [Inertia Adapt BW]} = \text{Par 90 [Spd Reg BW]}$$

$$10 \leq \text{Par 133 [Inertia Adapt BW]} \leq 150 \text{ (nominal value is 100 rad/sec)}$$

A good starting point is 40 rad/sec.

Higher values are more responsive to disturbances but with increased system noise.

4. Gradually increase Par 90 [Spd Reg BW] while operating the motor/load.

The final Velocity (Speed) Loop Bandwidth will exceed the Bandwidth value before Inertia Adaption was activated (providing the system meets the previously mentioned criterion).

5. Set the Speed Error Filter so that:

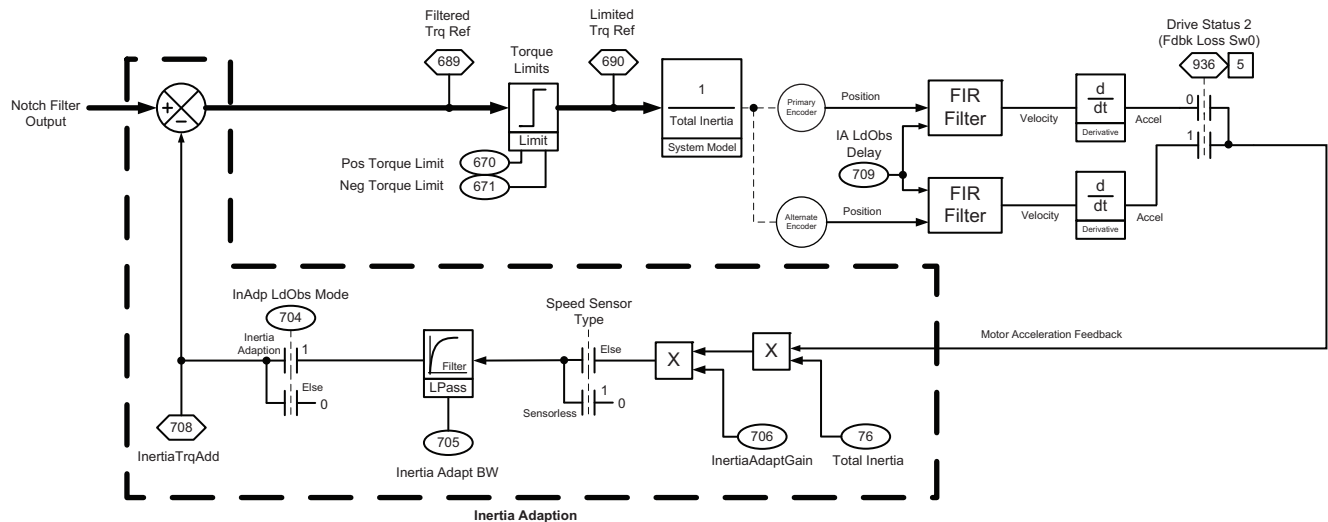
$$\text{Par 89 [Spd Err Fltr BW]} \geq 5 \times \text{Par 90 [Spd Reg BW]}$$

For details on this Feedback filter, see [Chapter 6](#), Encoder Feedback Filters.

## PowerFlex 755 Drive Inertia Adaption Configuration

The PowerFlex 755 drive Inertia Adaption feature is shown in the dotted line area of this figure.

Figure 17 - PowerFlex 755 Drive Inertia Adaption Feature Block Diagram



### Drive Setup

Note these important criteria for the PowerFlex 755 drive Inertia Adaption feature:

- The drive must be configured for flux vector induction or Permanent Magnet motor control. Use Par 35 [Motor Control Mode] set to 3, 6, or 10.

Setting	Description
3	Induction FV
6	PM - Permanent Magnet motor, FV control mode
10	IPM - Interior Permanent Magnet motor, FV control mode

The drive must also have a connected motor feedback device, which is configured with Par 125 [Pri Vel Fdbk Sel].

- Inertia Adaption is not enabled by default. To enable the adaptive torque calculation, set Par 107 [Trq Adapt En] to 1 (Enabled).
- Inertia Adaption cannot be used simultaneously with Load Observer.
- Inertia Adaption can be enabled only when the value in Par 76 [Total Inertia] is greater than zero.
- When using Inertia Adaption, the total inertia ( $J_t$ ) should be entered for Par 76 [Total Inertia]. This value includes the motor + load. Total inertia is measured using the Inertia Tune Test with the motor coupled to the load, which is described in [Chapter 2](#).

- The Inertia Adaption Load Observer Delay Par 709 [IA LdObs Delay] is set at a value of 190 rad/sec. If a value other than 190 rad/sec. is used, the load can be unstable.
- When Inertia Adaption is activated, verify that the two Lead/Lag Filters in the Speed Regulator are disabled (set to Off). One of these filters is located in the speed feedback path. To disable this filter, set Par 637 [SReg FB Fltr Sel] to 0. The other filter is at the output of the Speed Regulator. To disable this filter, set Par 657 [SRegOutFltrSel] to 0. Both filters are disabled by default.

### *Configuration Steps*

1. Set Par 107 [Trq Adapt En] to 1 (Enabled) to enable the Torque Adaption calculation.
2. Set Par 704 [InAdp LdObsMode] to 1 (InertiaAdapt) to enable the Inertia Adaption feature.
3. After Inertia Adaption is active and when Par 636 [Speed Reg BW] > 0, it automatically updates three filters:
  - Par 705 [Inertia Adapt BW]
  - Par 710 [InertAdptFltrBW]
  - Par 635 [Spd Err Fltr BW]

If Par 636 [Speed Reg BW] = 0, these filters must be manually adjusted. Set them so that:

$$\text{Par 710 [InertAdptFltrBW]}, \text{Par 635 [Spd Err Fltr BW]} \geq (5 \times \text{Par 636 [Speed Reg BW]})$$

4. Set Par 706 [InertiaAdaptGain] as follows:
  - a. If Velocity Loop Bandwidth Par 636 [Speed Reg BW] = 0, then manually change Par 706 [InertiaAdaptGain] so that:
 
$$0.3 \leq \text{Par 706 [InertiaAdaptGain]} \leq 1.0 \text{ (nominal value is 0.5)}$$
  - b. If Velocity Loop Bandwidth Par 636 [Speed Reg BW] > 0, then Par 706 [InertiaAdaptGain] is automatically set to the nominal value of 0.5.

Higher values can cause high resonant frequency, while smaller values can cause fundamental load instability.

Par 706 [InertiaAdaptGain] has no effect on Par 707 [Load Estimate].

5. Review Par 705 [Inertia Adapt BW] and:
  - a. If Par 636 [Speed Reg BW] > 0, then Par 705 [Inertia Adapt BW] is automatically set so that:
 
$$\text{Par 705 [Inertia Adapt BW]} = \text{Par 636 [Speed Reg BW]}$$
  - b. If Par 636 [Speed Reg BW] = 0, then Par 705 [Inertia Adapt BW] must be manually set so that it is close in range to Par 636 [Speed Reg BW].



6. Gradually increase Par 636 [Speed Reg BW] while operating the motor and load.

An increment of 2% is a safe value. The final Velocity (Speed) Loop Bandwidth will exceed the Bandwidth value before Inertia Adaption was activated (provided the system meets the previously mentioned criterion). For more details to change the Velocity Loop Bandwidth, see [Chapter 3](#).

## PowerFlex Load Estimate and Load Observer

Load Estimate and Load Observer are firmware features inside the drive that estimate the mechanical load on the motor and compensate for it. These features force the motor to behave as if it is unloaded and relatively easy to control. As a result, the Load Observer feature automatically compensates for disturbances and load dynamics, such as sudden inertia/torque changes, compliance, backlash, and resonances that are within the Velocity Loop Bandwidth.

### Benefits

When enabled, Load Observer automatically compensates for dynamically changing inertial loads. Consider these applications:

- A winder where a fully loaded roll exhibits a particular inertia, and as the roll unwinds, the inertia changes and becomes lower. Load Observer compensates for that changing inertia without having to change gains manually.
- A mechanical crank where the inertia at top stroke is different than inertia at bottom stroke. Load observer compensates for this dynamic inertial change.

### How Load Observer and Load Estimate Work

The Load Observer algorithm uses a component of Torque Reference to estimate the motor load torque. The Acceleration Feedback signal is subtracted from the Load Estimate parameter value (Par 221 for PowerFlex 700S drive or Par 707 for PowerFlex 755 drive) such that the Load Observer output signal is proportional to the estimated load and excludes the torque that is required to accelerate/decelerate the motor inertia.

The final filtered Load Estimate signal is then added to the Torque Reference.

The Load Estimate signal supplements the Torque Reference that is required when dynamic load changes occur. In this way, the Velocity Regulator is not required to provide the load change torque signal.

Figure 18 - PowerFlex 700S Drive Load Estimate and Inertia Adaption Block Diagram

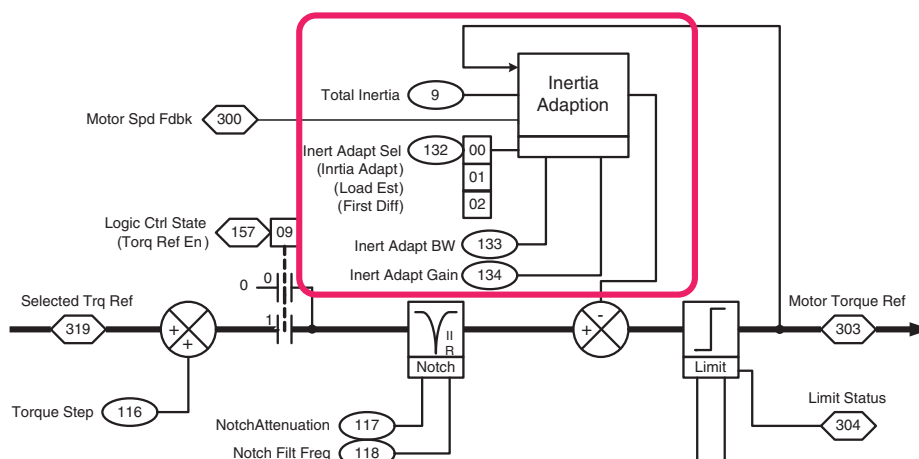
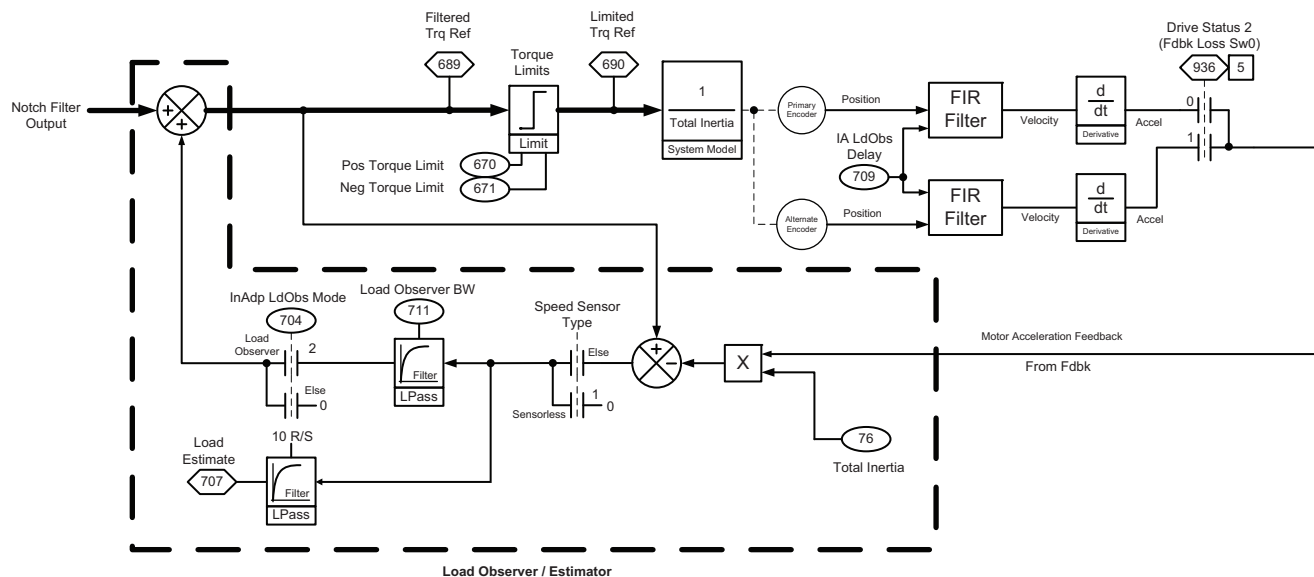


Figure 19 - PowerFlex 755 Drive Load Observer Block Diagram (dotted line section)



## PowerFlex 700S Drive Load Estimate Configuration

This information describes how to set up and configure the Load Estimate feature.

### Drive Setup

Note these important criteria for the PowerFlex 700S drive Load Estimate feature:

- The drive must be configured for field-oriented control. Use Par 485 [Motor Ctrl Mode] set to 0, 1, or 2.

Setting	Description
0	FOC Field Oriented Control
1	FOC2 Field Oriented Control 2
2	Permanent Magnet (PMag) Motor

Also, the drive must have a connected motor encoder feedback device, which is configured with Par 222 [Mtr Fdbk Pri Sel] set to 0 (Encoder 0).

- Load Estimate should not be enabled in torque control.
- Load Estimate is not enabled by default. When Load Estimate is used, the two Lead/Lag Filters present in the Speed Regulator must be set so that:  
     Par 93 [SReg FB Filt Gain] = 1  
     Par 95 [SReg Out Filt Gain] = 1
- Set the Speed Error Filter Bandwidth so that:  
     Par 89 [Spd Err Fltr BW]  $\geq 5 \times$  Par 90 [Spd Reg BW]
- Inertia Adaption can be enabled only when the value in Par 9 [Total Inertia] is greater than zero.
- When using Load Estimate, only the motor inertia (Jm) should be entered for Par 9 [Total Inertia]. The motor inertia is measured using the Inertia Tune Test with the motor uncoupled from the load, which is described in [Chapter 2](#).
- Inertia Adaption subtracts torque reference during velocity reference ramp speed changes. As a result, Inertia Compensation, Par 151 [Logic Command] Bit 10 'Inertia Comp', can be used to offset the effect of Inertia Adaption and minimize the acceleration and deceleration torque required from the velocity regulator.

### Configuration Steps

To enable the Load Estimate feature, set Par 132 [Inert Adapt Sel] Bit 1 'Load Est' to 1 (on). The configurations for Par 132 [Inert Adapt Sel] Bits 0, 1, and 2 are described in this table.

Bit Number	Bit Value	Effect
Bit 0 'Inrtia Adapt'	When = 1 (on)	The Inertia Adaption feature affects enhanced stability, higher bandwidths, and dynamic stiffness. Inertia Adaption is useful when a system with a gearbox becomes disconnected from the load. It is also used with motors that have little inertia that otherwise lack dynamic stiffness, even at high bandwidths.
Bit 1 'Load Est'	When = 1 (on)	The Load Estimate option removes or reduces load disturbances and provides a quicker system response.
Bit 2 'First Diff'	When = 1 (on)	Selects the first difference feedback for Inertia Adaption and Load Estimate. This bit must be set = 1 to ensure proper operation of the Inertia Adaption and Load Estimate functions.

1. Set Par 132 [Inert Adapt Sel] Bit 1 'Load Est' to 1 to activate Load Estimate.

Also, we recommend that Bit 0 = 0 (off) and Bit 2 = 1 (on).

2. Set Kop by using Par 133 [Inert Adapt BW], which sets the frequency of the Inertia Adaption/Load Estimate Filter.

Typical values range so that:

$$10 \leq \text{Par 133 [Inertia Adapt BW]} \leq 150$$

A good starting point is 40 rad/sec.

Higher values are more responsive to disturbances but with increased system noise.

3. Gradually increase Par 90 [Spd Reg BW] while operating the motor and load.

The final Velocity (Speed) Loop Bandwidth will exceed the value before Inertia Adaption was activated (providing the system meets the previously mentioned criterion).

4. Set the Speed Error Filter so that it is larger than the Velocity Loop Bandwidth:

$$\text{Par 89 [Spd Err Fltr BW]} \geq 5 \times \text{Par 90 [Spd Reg BW]}$$

## PowerFlex 755 Drive Load Observer Configuration

This information describes how to set up and configure the Load Observer feature.

### Drive Setup

Note these important criteria for the PowerFlex 755 drive Load Observer feature:

- The drive must be configured for flux vector induction or Permanent Magnet motor control. Use Par 35 [Motor Control Mode] set to 3, 6, or 10.

Setting	Description
3	Induction FV
6	PM - Permanent Magnet motor, FV control mode
10	IPM - Interior Permanent Magnet motor, FV control mode

Also, the drive must have a connected motor feedback device, which is configured with Par 125 [Pri Vel Fdbk Sel].

- When using Load Observer, only the motor inertia ( $J_m$ ) should be entered for Par 76 [Total Inertia], not the total inertia (motor + load). Motor inertia is measured using the Inertia Tune Test with the motor uncoupled from the load, which is described in [Chapter 2](#).
- Load Observer cannot be enabled in Torque mode.

- Load Observer cannot be used simultaneously with Inertia Adaption.
- When Load Observer is activated, the two Lead/Lag filters in the Speed Regulator should be disabled (setting 'Off'). These filters are located in the Speed Feedback path (Par 637 - [SReg FB Fltr Sel] set to '0') and at the output of the Speed Regulator (Par 657 - [SRegOutFltrSel] set to '0'). Both filters are disabled by default. See [Figure 66](#) for Lead/Lag filter locations.
- The Inertia Adaption Load Observer Delay Par 709 - [IA LdObs Delay] is set similar to the Speed Feedback filter (Par 127 - [Pri Vel Feedback]). See [Chapter 6](#) for details on this feedback filter. Set Par 709 - [IA LdObs Delay] so that:  
$$\text{Par 709 - [IA LdObs Delay]} = 190 \text{ rad/sec}$$
- Load Observer subtracts torque reference during velocity reference ramp speed changes. As a result, Inertia Compensation, Par 695 [Inertia Compensation], can be used to offset the effect of Load Observer and minimize the acceleration and deceleration torque required from the velocity regulator.

### *Configuration Steps*

1. Set Par 107 [Trq Adapt En] to 1 (Enabled) to enable the Torque Adaption calculation.
2. Set Par 704 [InAdp Ld Obs Mode] to 2 (LoadObserver) to enable Load Observer.
3. Verify Total Inertia ( $J_t$ ) value of Par 76 [Total Inertia] is equal to only the motor inertia ( $J_m$ ).
4. Set Kop by using Par 711 [Load Observer BW] following these guidelines:
  - a. Enter 40 rad/sec as a starting point.  
Typical settings for Load Observer Bandwidth (Kop) range from 10 to 150 rad/sec.
  - b. Increase Load Observer Bandwidth (Kop) at a safe increment of 2% at a time.

As Kop increases, the ability to respond to disturbances improves. However, increasing Kop can magnify noise in the system, which can require filtering. For details on filtering, see [Chapter 5](#), Regulator Compensation Filters.

# Tuning Configuration and Setup

To use the drive tuning techniques that are described in [Chapter 3](#) and [Chapter 4](#), you must configure various parameters and modes based on the physical machine—the drive, motor, and load.

This chapter steps through required parameter information and then various drive tests, including Auto Tune and Inertia Auto Tune measurement tests. This configuration and these tests prepare the drive to use the tuning techniques that are described in [Chapter 3](#) and [Chapter 4](#).

See the drive startup checklist in the respective PowerFlex® 700S or PowerFlex 755 drive programming manual as a supplement to this document. The General Startup includes applying power to the drive and establishing communication, which is outside the scope of this publication and is not discussed.

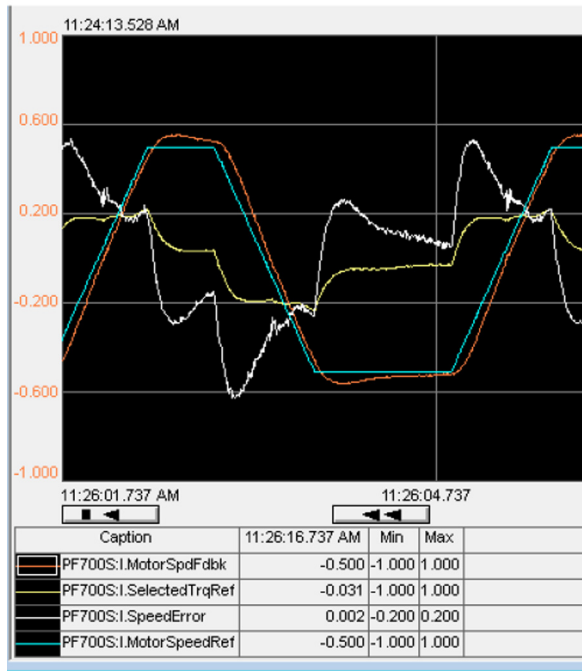
This chapter describes how to configure the drive and motor to be ready for using the tuning techniques that are described in [Chapter 3](#) and [Chapter 4](#). Many tools are available to configure a PowerFlex drive, including the following:

- **DriveExecutive™ software:** An intuitive tool that contains a simplified Startup Wizard, which steps you through drive configuration. DriveObserver™, launched within DriveExecutive software, can be used as a software trending tool.
- **Human Interface Module (HIM):** When software is not available, the HIM can be used to enter settings, but it is not the preferred tool to program the drive.
- **Connected Components Workbench™ software:** Uses the same Startup Wizard as DriveExecutive software, but it has no trending capabilities.
- **Studio 5000 Logix Designer® application** (and Ethernet communication): When used with a PowerFlex drive Add-on Profile, the Studio 5000 Logix Designer application accesses the Startup Wizard. This is the same wizard that is used in DriveExecutive and Connected Components Workbench software. The benefit to using Studio 5000 Logix Designer application is higher performing trends with better resolution. This publication ([Chapter 3](#) and [Chapter 4](#)) uses Studio 5000 Logix Designer application and Ethernet communication to trend drive signals. Example trends used for tuning in DriveObserver and Studio 5000 Logix Designer application are shown in [Figure 20](#) and [Figure 21](#) respectively. For Studio 5000 Logix Designer application trend configuration, see [Appendix B](#).

Figure 20 - DriveObserver Trends with 10 sec/division Resolution



Figure 21 - Studio 5000 Logix Designer Application Trends with three sec/division Resolution




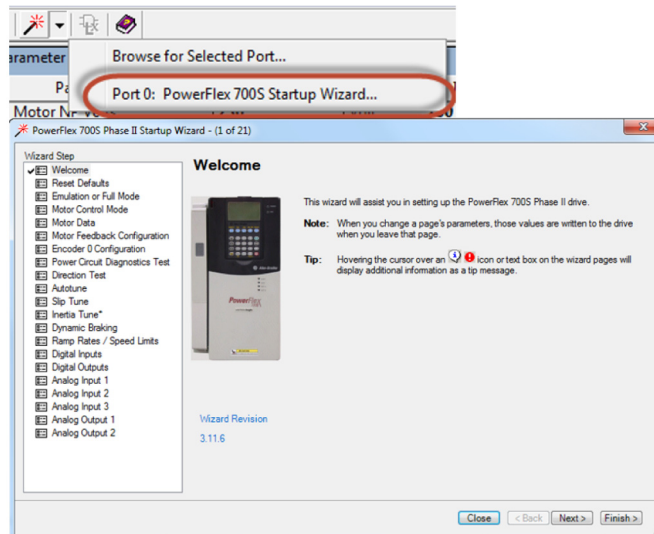
In this chapter, the Assisted Startup Wizard is used. It is available in Connected Components Workbench or DriveExecutive software, or in Studio 5000 Logix Designer application.

## PowerFlex 700S Drive Startup Wizard

**IMPORTANT** When using a Permanent Magnet (PM) motor, do not use the Startup Wizard to configure the motor. Use the PowerFlex drive HIM and the same steps described here to program the PM motor.



1. From the DriveExecutive or Connected Components Workbench software and with the appropriate drive Add-on Profile, click Drive/Connect to drive.
2. Click the Startup Wizard icon .
3. Click Port 0: PowerFlex 700S Startup Wizard as shown below.



4. Complete each step in the Startup Wizard to configure the drive.

---

**IMPORTANT** Follow the Startup Wizard steps exactly. If not, unexpected results can occur.

---

To use the drive tuning techniques, which are described in the next sections, various parameters must be entered and/or determined in the drive, based on the physical configuration of the drive.

## Motor Control Configuration

To use the tuning procedures described in this document, the drive is configured for FOC1 – Field-Oriented Control with Voltage Adaptation (see [Figure 22](#)). The Speed/Torque regulation mode is set for ‘Speed Reg’.

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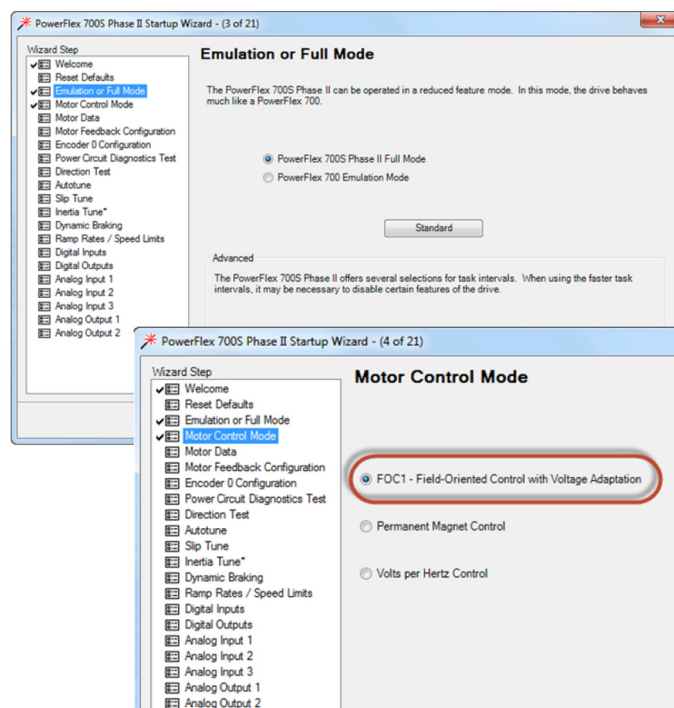
**IMPORTANT** If your application uses a PM motor, continue following this sequence, but use the PowerFlex HIM assisted startup for Surface Mount PM (SPM) motors and parameter-based startup for Internal PM Motors (IPM). Do not use this Startup Wizard to configure PM motors.

---

The drive must be configured for field-oriented control. Use Par 485 [Motor Ctrl Mode] set to 0, 1, or 2.

Setting	Description
0	FOC Field Oriented Control
1	FOC2 Field Oriented Control 2
2	Permanent Magnet (PMag) Motor

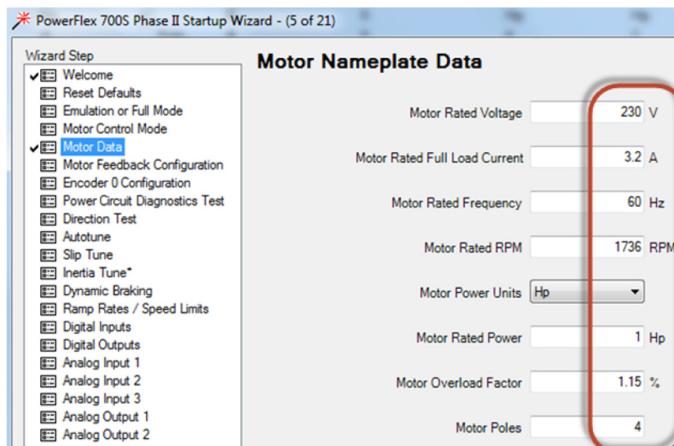
Figure 22 - Motor Control Mode Settings



## Motor Data

All of the motor parameters are available from the motor nameplate or motor manufacturer. Use the nameplate to populate the data shown in the following figure.

Figure 23 - Motor Nameplate Data



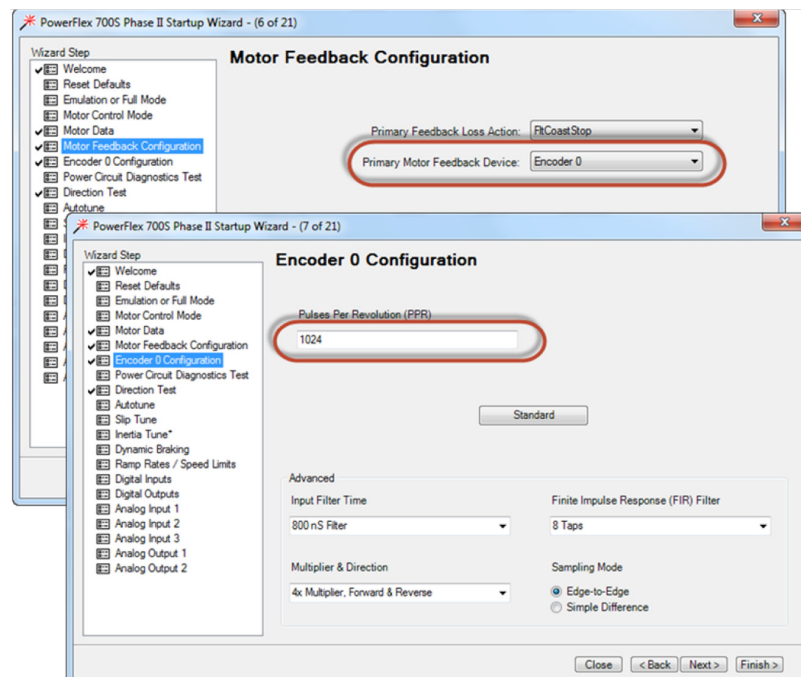
Motor Overload Factor value (or Service Factor that is obtained from the motor nameplate) sets a minimum level of current that causes a motor Overload trip under continuous operation. For example, a nameplate value of 1.15 implies continuous current operation up to 115% of nameplate continuous current.

## Feedback Configuration

The tuning techniques require that a motor-mounted encoder feedback device be installed and wired to the drive encoder input or encoder option modules. If your application uses another type of feedback device, verify that it is properly wired and configured as the drive primary speed feedback device.

Motor feedback device information must be entered into the Startup Wizard. Enter the Pulses per Revolution (PPR) and other information for the encoder that is used in your application. This data is available from the encoder manufacturer data sheet. In the following example figure, the Primary Motor Feedback Device is set to 'Encoder 0', and the PPR is set to '1024'.

**Figure 24 - Motor Feedback Configuration**



## Direction Test

The direction test can be performed with or without the load attached. Consider your application requirements when deciding to have the load that is attached or removed from the motor. This test runs the drive in V/Hz mode to verify the motor polarity relative to the feedback polarity. The test confirms motor rotation and feedback polarity. After the test is completed, a change can be made, if necessary.

---

**IMPORTANT** If the drive was never operated before (new installation), verify that safeguards are in place to remove power safely from the drive during an unstable situation where the drive can produce undesired motion.

---

Figure 25 - Direction Test from Startup Wizard

**Wizard Step**

- ✓ Welcome
- Reset Parameters
- System Time
- Ethernet Port
- Motor Control
- Motor Data
- Stop Mode
- ✓ **Direction Test**
- Auto Tune
- Inertia Auto Tune
- Ramp Rates / Speed Limits
- Speed Reference\*
- Torque Reference
- Position PTP Reference
- Start / Stop
- Other Digital Inputs
- Digital Output Port 7
- Digital Output Port 7
- Analog Output Port 7
- Ethernet Datalinks from Net
- Ethernet Datalinks to Net
- Pending Changes

**Direction Test**

**Danger:** This test will START and STOP a device. Misuse may result in death, injury, or damage to equipment. You should have an external safe method of controlling the device nearby when using this feature.

**Warning:** Ensure that Motor Data, Digital Inputs, Relay Outputs, and the Feedback type are correct before proceeding with this page. Direction Test causes some parameters in the drive to change immediately.

To begin the test Start and Stop the drive. Then answer if the direction was correct. If the primary feedback is setup from an encoder, its direction will be checked as well. When you leave this page the drive will be stopped.

Reference: 10 Hz

Jog Reference: 15 Hz

Is the direction of motor rotation correct for the application?

☒ Yes ☐ No ☒ Test Passed

If the direction of rotation still needs to be switched, use the button below.

[Change Direction](#)

## Auto Tune

The Auto Tune test is used to identify the correct motor flux and stator electrical properties, including:

- IR volt drop, which is voltage drop over resistance.
- Ixo volt drop, which is voltage drop over inductance.
- Flux current (estimated in Static Tune and measured during Rotate Tune test).
- Slip RPM, which is calculated from motor nameplate data. If an encoder is used, the Slip RPM becomes a measured value using the encoder.

Figure 26 - Auto Tune Window

**Wizard Step**

- ✓ Welcome
- Reset Parameters
- System Time
- Ethernet Port
- ✓ Motor Control
- Encoder Feedback Port 4
- ✓ Motor Data
- Stop Mode
- ✓ **Direction Test**
- ✓ **Auto Tune**
- Inertia Auto Tune
- Ramp Rates / Speed Limits
- Speed Reference\*
- Torque Reference
- Position PTP Reference
- Start / Stop
- Other Digital Inputs
- Digital Output Port 7
- Digital Output Port 7
- Analog Output Port 7
- Analog Output Port 7

**AutoTune**

**Danger:** This test will START and STOP a device. Rotate Tune will cause motor rotation. Misuse may result in death, injury, or damage to equipment. You should have an external safe method of controlling the device nearby when using this feature.

**Warning:** Ensure that Motor Data is correct before proceeding with this page. AutoTune causes some parameters in the drive to change immediately.

Running AutoTune allows the drive to sample the motor characteristics and properly set its bandwidth and gains. Use Rotate Tune if no load or a low friction load is attached or the drive is in Flux Vector mode. Otherwise use Static Tune. Only one tune is needed.

[Static Tune](#) ☒ Test Completed: Yes

[Rotate Tune](#) ☒ Test Completed: Yes

Increase Autotune Torque to allow motor to achieve test speed.

Autotune Torque: 50 %

A properly tested motor and drive help ensure higher starting torque and better performance at low speeds. Conversely, an improperly performed Auto Tune can cause the motor to exhibit instability at low speeds, uneven performance when running through the motor speed range, and can generate unnecessary faults such as overcurrent and overvoltage faults.

The 'Autotune Torque' can be adjusted to the amount of torque that will be used when executing the test. The types of Auto Tune test are Static Tune and Rotate Tune.

### *Static Tune*

This test is used when the motor is connected to a high friction load and cannot easily be uncoupled from the motor, or when the load cannot be rotated due to mechanical constraints or a limited range of movement. The Static Tune test does not generate any motor movement. The Static Tune test results may not be as accurate as the Rotate Tune test.

### *Rotate Tune*

This test is used when the motor is not coupled to the load, or the load is low friction. Rotate Tune is used to better identify motor flux and stator electrical properties, which are used to automatically tune the torque/current loop. The Rotate Tune test causes motor rotation at different speeds while it is executing.

---

**IMPORTANT** If the drive was never operated before (new installation), verify that safeguards are in place to remove power safely from the drive during an unstable situation where the drive can produce undesired motion.

---

## **Inertia Auto Tune Test**

This test measures the total system inertia ( $J_t$ ).

When using Load Observer, this test is executed with the load disconnected from the motor so that only motor inertia is measured.

Otherwise, this test is executed with the load connected to the motor so that motor + load inertia is measured.

---

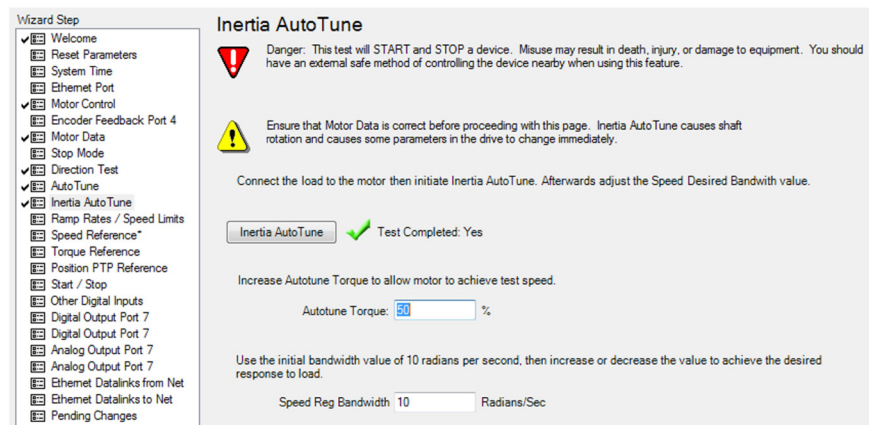
**IMPORTANT** If the drive was never operated before (new installation), verify that safeguards are in place to remove power safely from the drive during an unstable situation where the drive can produce undesired motion.

---

During the test, the drive/motor is accelerated using the entered 'Autotune Torque' value. The time required to accelerate the motor and load from zero speed to rated speed is measured. The value of Total Inertia ( $J_t$ ) is determined from this measurement and the value of Par 9 [Total Inertia] is updated to reflect this measurement.

The Par 9 [Total Inertia] value is used for a number of internally calculated parameters for the Speed Regulator. These relationships are described in [Chapter 3](#).

Figure 27 - Inertia Auto Tune Test Window



The Inertia Auto Tune test does not calculate any gain settings—it only measures the Total Inertia ( $J_t$ ) parameter. Gains or bandwidth settings, which are described in [Chapter 3](#) and [Chapter 4](#), must still be entered. Leave the default Speed Reg Bandwidth at 10 Radians/Sec. This setting is conservative for initial tuning and typically results in stable operation.

## PowerFlex 700S Drive Additional Setup

After completing the Assisted Startup, there are additional settings that must be made so that tuning techniques can be performed. Use DriveExecutive or Connected Components Workbench software to enter and/or verify the following parameters.

1. Set Par 196 [ParamAccelLvl] to 1 (Advanced) to access advanced parameters.
2. Set the Primary Velocity Feedback Par 222 [Mtr Fdbk Sel Pri] so it matches the feedback device, option board that is installed, and port location where the motor-mounted encoder feedback is connected.
3. Configure the 'Primary Feedback Configuration'.
  - a. Verify that the default values for Par 233 [Enc0/1 Config] Bits 0, 1, and 2 are each set to '0'.

These bits configure the encoder input filter. When set like this, the filter is 800 ns.

- b. Set Par 233 [Enc0/1 Config] Bit 10 to '1', Bit 11 to '1', and Bit 12 to '0' to help ensure that FIR filter BW  $\geq$  Par 90 [Speed Reg BW].

This combination of bits is an FIR Filter Bandwidth of 120 rad/sec and also automatically sets the Speed Error Limit Filter Par 89 [Spd Err Filt BW] to 600 rad/sec.

4. Set Par 485 [Motor CtrlMode] to 0, 1, or 2 to select the drive mode appropriate for your application.

This mode depends on whether you are using field-oriented control of an induction motor or a permanent magnet (PM) motor.

5. Set Par 110 [Speed/TorqueMode] to 1 (Speed Reg) to let the drive accept a speed/velocity command.

**TIP** Par 110 [Speed/TorqueMode] set to 1 is for Velocity Loop tuning. If the application uses a Position Loop, the setting for Par 110 [Speed/TorqueMode] needs to change when the Velocity Loop tuning is complete.

6. Set the default accel/decel ramps to values that are required by your application and verify that:
  - a. Par 32 [Accel Time 1] and Par 33 [Decel Time1] > Par 9 [Total Inertia]
  - b. Par 32 [Accel Time 1] > 0, and Par 33 [Decel Time 1] > 0.
7. If your load cannot tolerate bidirectional movement, set Par 75 [RevSpeedLimit] to 0.

**TIP** When Par 75 [RevSpeedLimit] is set to 0, the fwd/rev toggle button commands zero speed and helps prevent reverse rotation.

8. Set Par 153 [Control Options] Bit 0 'BipolarSRef' to 0 (Disabled).  
This enables speed steps to be introduced using the fwd/rev toggle buttons.
9. Set Par 27 [SpeedRefA Sel] to 5 (Preset Spd1).  
This enables a setpoint speed to be used during the testing. This is done for tuning purposes, as many other modes exist.
10. Set Par 14 [Preset Speed 1] to < 100 RPM.  
This is the speed of the 'speed steps' used while tuning and commissioning. Small steps are effective when making changes to tuning values.
11. Disable the following filters and regulator compensation functions.
  - a. Set Par 93 [SRegFBFilt Gain] to 1.
  - b. Set Par 95 [SregOutFiltGain] to 1.
  - c. Set Par 118 [NotchFilterFreq] to 0.
  - d. Set Par 86 [SpdRegDroop] to 0.
  - e. Set Par 84 [SpdRegAntiBckup] to 0.
  - f. Set Par 151 [Logic Command] Bit 11 'Friction Comp' to 0.
  - g. Set Par 151 [Logic Command] Bit 10 'Inertia Comp' to 0.
  - h. Set Par 132 [Inertia Adapt Sel] to 0.
12. Set Par 90 [Speed Reg BW] to 10 rad/sec for Speed Regulator Bandwidth.
13. Set Par 91 [Spd Reg Damping] to 1.0 for Speed Regulator Damping.

These settings provide stable operation before tuning.



## PowerFlex 700S Drive Movement Configuration for Tuning

A method to repeatedly move the drive and motor is required when tuning the drive.

While it is possible to operate the motor using the HIM, we recommend using DriveExecutive software (via DriveObserver, which can make online changes but has limited trending capabilities) or Studio 5000 Logix Designer application (via Add-on Profile, Logic programming, and trending) for this procedure. Connected Components Workshop software can be used to program the drive to make repetitive movements, but it does not have trending capabilities currently, which are required for the configuration steps in this section. The following procedure uses DriveExecutive software to execute movements and trend the results.

---

**IMPORTANT** If the drive was never operated before (new installation), verify that safeguards are in place to remove power safely from the drive during an unstable situation where the drive can produce undesired motion.

---

1. Launch DriveObserver from the Launch tab of the DriveExecutive software window.

2. Configure traces for the following drive parameters:

- Par 300 [Motor Spd Fdbk]
- Par 319 [Selected Trq Ref]
- Par 100 [Speed Error]
- Par 301 [Motor Speed Ref]

Note that scaling the values may be required.

3. Click the Control Bar icon  to activate these Control buttons.



4. Enter a low speed reference value for Par 14 [Preset Speed1].

An acceptable starting value is < 100 RPM.

If the DriveExecutive connection is the Speed Reference source, then the slider bar in the Control Bar can be used to change the speed.




---

**IMPORTANT** The PowerFlex 700S drive control bar Speed Reference is scaled in RPM x 8. Be cautious when using the PowerFlex 700S Speed Reference slider because small changes in slider position cause large changes in speed reference. Use of Preset Speed 1, scaled in RPM, is preferred with the PowerFlex 700S drive.

---

5. Click Start in the Control Bar.

The drive starts and jogs at the speed set in step 4. The drive may be sluggish, but not unstable.



- While the drive is running, click Dir in the Control Bar.

The motor ramps down to the reverse direction or to the reverse speed limit previously set. The Dir button is used to introduce speed changes during the tuning process.

- Click Stop in the Control Bar.


The drive will ramp stop to zero speed and disable.

## PowerFlex 755 Drive Startup Wizard

---

**IMPORTANT** When using a PM motor, do not use the Startup Wizard to configure the motor. Use the PowerFlex drive HIM and the same steps described here to program the PM motor.

---

- From DriveExecutive or Connected Components Workbench software and using the appropriate drive Add-on Profile, click Drive/Connect to connect the drive.
- Click the Startup Wizard icon .
- Click Port 0: PowerFlex 755 Startup Wizard as shown in the following figure.



- Complete each step in the Startup Wizard to configure the drive.

---

**IMPORTANT** Follow the Startup Wizard steps exactly. If not, unexpected results can occur.

---

## Motor Control Configuration

This tuning procedure is based on the drive being configured for Induction Flux Vector control with a motor speed feedback device. For our tuning exercise, the

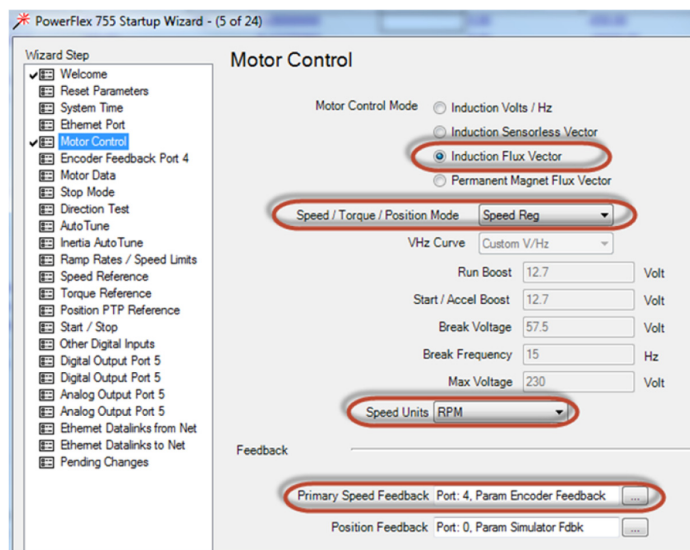
Speed/Torque/Position regulation mode is set to 'Speed Reg' (shown selected in [Figure 28](#)). Speed Reg is a speed control loop with the position control loop disabled. The Position Control Loop mode (prefaced in the pull-down menu selection by 'Psn') selects position and speed loops with the position command coming from the selected position control mode (direct position, profiler, or point-to-point).

---

**IMPORTANT** If your application uses a PM motor, continue following this sequence, but use the PowerFlex HIM assisted startup for Surface Mount PM (SPM) motors, and parameter based startup for Internal PM Motors (IPM). Do not use this Startup Wizard to configure PM motors.

---

**Figure 28 - Motor Control Configuration**



A motor-mounted encoder feedback device can be installed and wired to the encoder option module. If your application uses another type of feedback device, verify that it is properly wired and configured as the drive primary speed feedback device. The Motor Control Mode can be set for Induction Flux Vector or Permanent Magnet Flux Vector, depending on the motor being used. We recommend to use a HIM to configure the Permanent Magnet Flux Vector mode.

## Motor Data

All of the motor parameters are available from the motor nameplate or motor manufacturer. Use the motor nameplate to populate the data shown in [Figure 29](#).

**Figure 29 - Motor Nameplate Data**

PowerFlex 755 Startup Wizard - (7 of 24)

Wizard Step

- ✓ Welcome
- Reset Parameters
- System Time
- Ethernet Port
- ✓ Motor Control
- ✓ Encoder Feedback Port 4
- Motor Data**
- Stop Mode
- Direction Test
- Auto Tune
- Inertia Auto Tune
- Ramp Rates / Speed Limits
- Speed Reference
- Torque Reference
- Position PTP Reference

Motor Data

Power Units	HP	
Motor NP Power	2	HP
Motor NP FLA	6	Amps
Motor NP Volts	230	VAC
Motor NP Hertz	60	Hz
Motor NP RPM	1744	RPM
Motor OL Factor	1	
Motor Poles	4	Pole

Motor OL Factor value (or Service Factor obtained from the motor nameplate) sets a minimum level of current that causes a motor Overload trip under continuous operation. For example, a nameplate value of 1.15 implies continuous current operation up to 115% of nameplate continuous current.

## Feedback Configuration

The feedback device and option module port were chosen in [Motor Control Configuration on page 41](#).

The tuning techniques require that a motor-mounted encoder feedback device be installed and wired to the encoder option module. If your application uses another type of feedback device, verify that it is properly wired and configured as the drive primary speed feedback device.

**Figure 30 - Encoder Feedback Selection**

PowerFlex 755 Startup Wizard - (6 of 24)

Wizard Step

- ✓ Welcome
- Reset Parameters
- System Time
- Ethernet Port
- ✓ Motor Control
- ✓ Encoder Feedback Port 4
- Port 6 Encoder**
- Stop Mode
- Direction Test
- Auto Tune
- Inertia Auto Tune
- Ramp Rates / Speed Limits
- Speed Reference
- Torque Reference
- Position PTP Reference
- Start / Stop
- Other Digital Inputs
- Digital Output Port 5
- Digital Output Port 5
- Analog Output Port 5
- Analog Output Port 5
- Ethernet Datalinks from Net
- Ethernet Datalinks to Net
- Pending Changes

Port 6 Encoder

Encoder

Encoder Config ☐ Z Channel Enable ☐ A Channel Only

☒ Edge Mode ☐ Single Ended

☐ Direction

Encoder PPR 1024 PPR

Feedback Loss Config ☐ RCoastStop

Cancel < Back Next > Finish >>

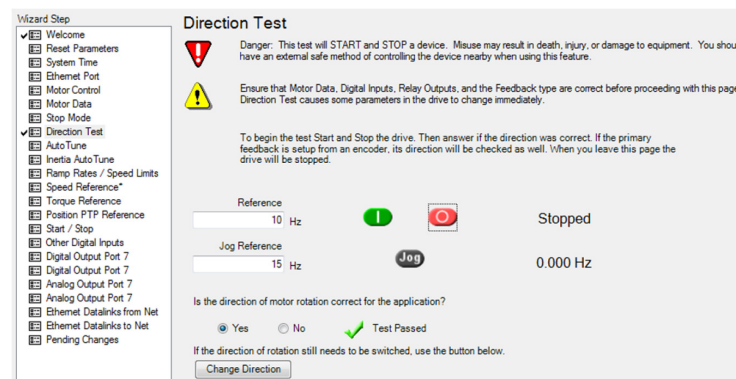
The default settings shown are for a quadrature encoder with differential outputs (A,  $\overline{A}$ , B,  $\overline{B}$ ). Speed feedback is determined using pulse transition. The checkbox for Edge Mode represents a quadrature encoder and, in this case, a PPR of 1024.

## Direction Test

The direction test can be performed with or without the load attached. Consider your application requirements when deciding to have the load attached or removed from the motor. This test runs the drive in V/Hz mode to verify the motor polarity relative to the feedback polarity. The test confirms motor rotation and feedback polarity. After the test is completed, a change can be made, if required.

**IMPORTANT** If the drive was never operated before (new installation), verify that safeguards are in place to remove power safely from the drive during an unstable situation where the drive can produce undesired motion.

Figure 31 - Direction Test from Startup Wizard

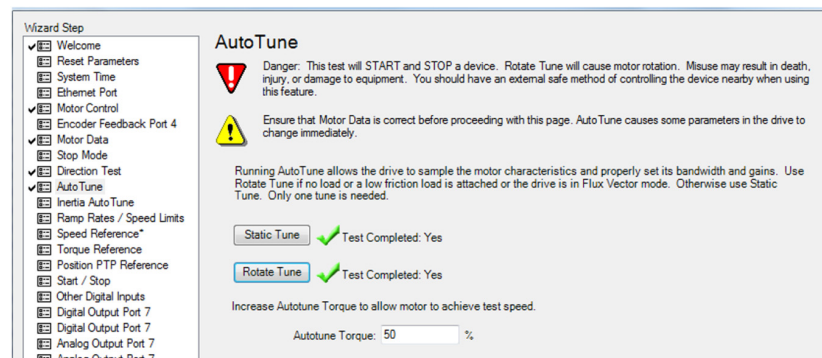


## Auto Tune

The Auto Tune test is similar to the one for the PowerFlex 700S drive. The Auto Tune is used to identify the correct motor flux and stator electrical properties, including the following:

- IR volt drop, which is voltage drop over resistance.
- Lxo volt drop, which is voltage drop over inductance.
- Flux current (estimated in Static Tune and measured in Rotate Tune test).
- Slip RPM, which is calculated from motor nameplate data. If an encoder is used, the Slip RPM becomes a measured value using the encoder.

Figure 32 - Auto Tune Window



A properly tested motor and drive helps ensure higher starting torque and better performance at low speeds. Conversely, an improperly performed Auto Tune can cause the motor to exhibit instability at low speeds, uneven performance when running through the motor speed range, and can generate unnecessary faults such as overcurrent and overvoltage faults.

The 'Autotune Torque' value can be adjusted to the amount of torque that will be used when executing the test. The types of Auto Tune test are Static Tune and Rotate Tune.

### *Static Tune*

This test is used when the motor is connected to a high friction load and cannot easily be uncoupled from the motor, or when the load cannot be rotated due to mechanical constraints or a limited range of movement. The Static Tune test does not generate any motor movement. The Static Tune test results may not be as accurate as the Rotate Tune test.

### *Rotate Tune*

This test is used when the motor is not coupled to the load or the load is low friction. Rotate tune is generally used to better identify motor flux and stator electrical properties, which are used to automatically tune the torque/current loop. The Rotate Tune test causes motor rotation at different speeds while it is executing.

---

**IMPORTANT** If the drive was never operated before (new installation), verify that safeguards are in place to remove power safely from the drive during an unstable situation where the drive can produce undesired motion.

---

## **Inertia Auto Tune Test**

This test measures the total system inertia ( $J_t$ ).

When using Load Observer, this test is executed with the load disconnected from to the motor so that only motor inertia is measured.

Otherwise, this test is executed with the load connected to the motor so that motor + load inertia is measured.

---

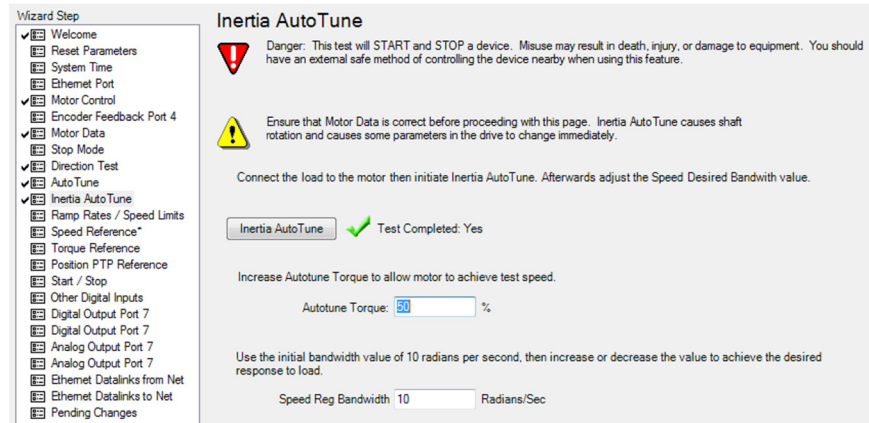
**IMPORTANT** If the drive was never operated before (new installation), verify that safeguards are in place to remove power safely from the drive during an unstable situation where the drive can produce undesired motion.

---

During the test, the drive/motor is accelerated using the entered 'Autotune Torque' value. The time required to accelerate the motor and load from zero speed to rated speed is measured. The value of Total Inertia ( $J_t$ ) is determined from this measurement and the value of Par 76 [Total Inertia] is updated to reflect this measurement.

The Par 76 [Total Inertia] value is used for a number of internally calculated parameters for the Speed Regulator, Inertia Adaption, Load Observer and Inertia Compensation. These relationships are described in [Chapter 3](#).

**Figure 33 - Inertia Auto Tune Test Window**



The Inertia Auto Tune test does not calculate any control loop gain settings—it only measures the Total Inertia ( $J_t$ ) parameter. Gains or bandwidth settings, which are described in [Chapter 3](#) and [Chapter 4](#), must still be entered. Leave the default Speed Reg Bandwidth at 10 Radians/Sec. This setting is conservative for initial tuning and typically results in stable operation.

## PowerFlex 755 Drive Additional Setup

After completing the Assisted Startup, there are additional settings that need to be made so that tuning techniques can be performed. Use DriveExecutive or Connected Components Workbench software to enter and/or verify the following parameters.

1. Set Par 301 [AccessLevel] to 2 (Expert) to access advanced parameters.
2. Set the Primary Velocity Feedback Par 125 [Pri Vel Fdbk Sel] so it matches the feedback device, option board installed, and port location where the motor-mounted encoder feedback is connected.
3. Configure the 'Primary Feedback Configuration'.
  - a. Verify that the FIR Filter is set so that:
 
$$\text{Par 126 [Pri Vel FdbkFltr]} \geq \text{Par 636 [Speed Reg BW]}$$
  - b. Set an initial value for Par 126 [Pri Vel FdbkFltr] to 1, which is equivalent to 160 rad/sec.

This also automatically sets Par 644 [Spd Err Filt BW] to 10 x (Par 126).

For additional filter settings, see [Chapter 5](#), Regulator Compensation Filters.

4. Use Par 35 [Motor Ctrl Mode] to configure the drive for flux vector induction, Permanent Magnet, or Interior Permanent Magnet motor control.

Setting	Description
3	Induction FV
6	PM - Permanent Magnet motor, FV control mode
10	IPM - Interior Permanent Magnet motor, FV control mode

In this tuning example, Par 35 [Motor Ctrl Mode] is set to 3 (Induction FV). Also, the drive must have a connected motor speed feedback device.

5. Set Par 309 [SpdTrqPsn Mode A] to 1 (Speed Reg) to let the drive accept a speed/velocity command.

**TIP** Par 309 [SpdTrqPsn Mode A] set to 1 is for Velocity Loop tuning. If the application uses a Position Loop, the setting for Par 309 [SpdTrqPsn Mode A] needs to change when the Velocity Loop tuning is complete.

6. Set the default accel/decel ramps to values that are required by your application and verify that:
  - a. Par 535 [Accel Time 1] and Par 537 [Decel Time1] > Par 76 [Total Inertia]
  - b. Par 535 [Accel Time 1] > 0, and Par 537 [Decel Time 1] > 0.

7. Set Par 545 [Spd Ref A Sel] for the port to which your programming personal computer is connected.

Typical personal computer connections are made with a 1203-USB module connected to a DPI port on the drive or via Ethernet port. Using the port to which the personal computer is connected lets the speed reference be changed by using the DriveExecutive Speed Reference slider bar.

8. Set Par 540 [S Curve Accel] to 0 and Par 541 [S Curve Decel] to 0.

This disables the S-curve, which must be completed for the tuning tests.

9. Set Par 308 [Direction Mode] to 0 (Unipolar).

This enables speed steps to be introduced using the fwd/rev toggle buttons.

10. If your load cannot handle bi-directional movement, set Par 521 [Max Rev Speed] to 0.

**TIP** When Par 521 [Max Rev Speed] is set to 0, the fwd/rev toggle button commands zero speed and prevents reverse rotation.

11. Set Par 153 [Control Options] Bit 0 'BipolarSRef' to 0 (Disabled).

This enables speed steps to be introduced using the fwd/rev toggle buttons.

12. Set Par 675 [Trq Ref A Sel] to be equal to Par 676 [Trq Ref A Stpt].

This enables a setpoint speed to be used during the testing. This is done for tuning purposes, as many other modes exist.

13. Disable the following filters and regulator compensation functions.
  - a. Set Par 637 [SReg FB Fltr Sel] to 0 (Off).
  - b. Set Par 657 [SReg OutFltr Sel] to 0 (Off).
  - c. Set Par 687 [Notch FltrFreq] to 0.
  - d. Set Par 643 [SpdReg AntiBckup] to 0.
  - e. Set Par 665 [Speed Comp Sel] to 0 (Disabled).
  - f. Set Par 695 [Inertia CompMode] to 0 (Disabled).
  - g. Set Par 704 [InAdp LdObs Mode] to 0 (Disabled).
  - h. Set Par 1560 [FrctnComp Mode] to 0 (Disabled).
14. Set Par 636 [Speed Reg BW] to 10 rad/sec for Speed Regulation Bandwidth.
15. Set Par 653 [Spd Loop Damping] to 1.0 for Speed Loop Damping.

These settings provide stable operation before tuning.

## PowerFlex 755 Drive Movement Configuration for Tuning

A method to repeatedly move the drive and motor is required when tuning the drive.

While it is possible to operate the motor using the HIM, we recommend using DriveExecutive software (via DriveObserver, which can make online changes but has limited trending capabilities) or Studio 5000 Logix Designer application (via Add-on Profile, Logic programming, and trending) for this procedure. Connected Components Workshop software can be used to program the drive to make repetitive movements, but it does not have trending capabilities at this time, which are required for the configuration steps in this section. The following procedure uses DriveExecutive software to execute movements and trend the results.

---

<b>IMPORTANT</b>	If the drive was never operated before (new installation), verify that safeguards are in place to remove power safely from the drive during an unstable situation where the drive can produce undesired motion.
------------------	---

---

1. Launch DriveObserver from the Launch tab of the DriveExecutive software window.
2. Configure traces for the following drive parameters:
  - Par 131 [Active Vel Fdbk]
  - Par 685 [Selected Trq Ref]
  - Par 641 [Speed Error]
  - Par 597 [Final Speed Ref]

Note that scaling the values may be required.



- Click the Control Bar icon  to activate these Control buttons.



- Set the Speed Reference slider bar to a low value ( $< 100$  RPM) for these tuning tests.

Large amplitude speed steps may not be required to effectively tune the Speed Regulator Loop.

- Click Start in the Control Bar.

The drive starts and jogs at the value set with the Speed Reference slider bar (step 4). The drive may be sluggish, but not unstable.

- While the drive is running, click Dir in the Control Bar.

The motor ramps down to the reverse direction or to the reverse speed limit previously set. Because the Direction Mode is presently set for 'Unipolar', the Dir button is used to introduce speed changes during the tuning process and is not to change motor direction.

- Click Stop in the Control Bar.

The drive will ramp stop to zero speed and disable.

## **Notes:**

## Tuning Using Bandwidth

PowerFlex® drives have control-loop-model calculations that are already implemented, which always provides a simple tuning method to be attempted first. This simple method yields a satisfactory result and works for many applications.

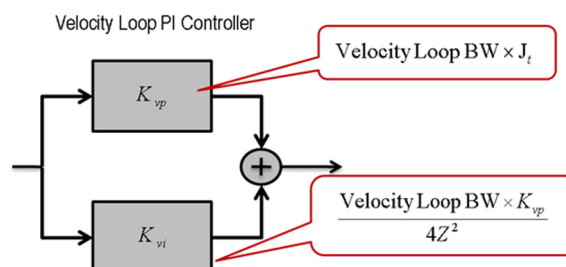
If the information in this chapter and the use of Regulator Compensation Filters ([Chapter 5](#)) cannot achieve operational stability with the application requirements, you can use the Manual Tuning procedure that is described in [Chapter 4](#). For difficult mechanical systems, you can use the Load Observer or Inertia Adaption features described in [Chapter 1](#). Also, consider that Regulator Compensation filters can be required. These filters are described in [Chapter 5](#).

The simple tuning method that is discussed in this chapter uses an inside-out approach, which is an accepted method to tune control loops. The procedure in this chapter uses Studio 5000 Logix Designer® application and trending to observe the behavior of the drive and motor during tuning. [Appendix B](#) shows how to configure a trend. DriveExecutive™ software with DriveObserver™ can also be used with this procedure, but with limited trending capability.

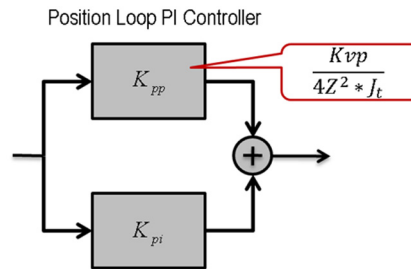
The Torque/Current inner loop is tuned first by using Auto Tune tests that are described in [Chapter 2](#). The Velocity Loop is tuned next. The gains  $K_{vp}$  and  $K_{vi}$  are automatically set using the values for Velocity Loop Bandwidth (BW), Damping Factor (Z), and Total Inertia ( $J_t$ ). The Position Loop (if used) is tuned last. The  $K_{pp}$  gain is set using a relationship with the Velocity Loop that is shown in [Figure 35](#). It is important to note that the  $K_{pp}$  gain value is manually derived and is not automatically set via Auto Tune.

The relationships that are set for  $K_{vp}$  and  $K_{vi}$  are shown in this figure. The Velocity Loop Bandwidth (BW) is given in rad/sec and the Total Inertia ( $J_t$ ) is given in seconds.

**Figure 34 - Simple Tuning Velocity Loop Relationships**



The Position Loop (if used) is shown in [Figure 35](#).

**Figure 35 - Simple Tuning Position Loop Values**

The Position Loop is then set based on the gain values of the Velocity Loop ( $K_{vp}$  is set based on  $K_{vp}$ ). The  $K_{pp}$  calculation yields stable operation.

When using Bandwidth to tune, note the following:

- $Z = 1$ , which yields a critically damped response.
- $J_t > 0$  ( $J_t$  is calculated from the Inertia Tune Test that was performed in [Chapter 2](#).)
- Velocity Loop BW (Speed Reg Bandwidth) = 10 as a default value and is described in [Chapter 2](#).

The next sections of this chapter describe the procedure to operate the drive and introduce speed or torque steps while adjusting the Velocity Loop Bandwidth to optimize the Speed Regulator.

## PowerFlex 700S Drive

Par 90 [Spd Reg BW] and Par 91 [Spd Reg Damping] are adjusted to accomplish Basic Speed Regulator Tuning.

When Par 485 [Motor Ctrl Mode] is set to 0, 1, or 2, and Par 90 [Spd Reg BW] is set to a nonzero value, Par 81 [Spd Reg P Gain] and Par 82 [Spd Reg I Gain] values are automatically calculated based on the values of Par 9 [Total Inertia], Par 90 [Spd Reg BW], and Par 91 [Spd Reg Damping] as shown in [Figure 34](#).

1. Set Par 91 [SpdLoopDamping] to 1.0 and Par 90 [Spd Reg BW] to 10.  
These initial tuning parameter values are adjusted during this procedure.
2. Verify that Par 9 [TotalInertia] > 0 (calculated from Inertia Auto Tune test).

The value of Par 97 [Act Spd Reg BW] can be limited by the setting of Par 92 [SpdReg P Gain Mx]. It may be necessary to increase Par 92 [SpdReg P Gain Mx] for high response systems.

3. Set Accel/Decel rates that are required by the application and verify that:
  - a. Par 32 [AccelTime1] > Par 9 [Total Inertia].
  - b. Par 33 [DecelTime1] > Par 9 [Total Inertia].
4. Monitor the following parameters:
  - a. Par 81 [SpeedRegPGain] =  $K_{vp}$
  - b. Par 82 [SpeedRegIGain] =  $K_{vi}$

## Velocity (Speed) Loop Tuning Procedure

The load must be coupled to the drive, and the drive must be able to operate and move at a slow speed. For details, see [PowerFlex 700S Drive Movement Configuration for Tuning on page 40](#).

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<b>IMPORTANT</b>	If the drive was never operated before (new installation), verify that safeguards are in place to remove power safely from the drive during an unstable situation where the drive can produce undesired motion.
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1. Use trending with Studio 5000 Logix Designer application or DriveObserver to monitor the drive performance with these parameter traces:
  - Par 300 [Motor Spd Fdbk]
  - Par 319 [Selected Trq Ref]
  - Par 100 [Speed Error]
  - Par 301 [Motor Speed Ref]

**TIP** If your application is dynamic and higher trend sampling is required, use Studio 5000 Logix Designer application. This application (with an Ethernet connection) is another way to get trending sample rates as low as 2 ms. If available, trend the Velocity Loop signals using Studio 5000 Logix Designer application trending. See [Appendix B](#) on how to configure a trend using Studio 5000 Logix Designer application. Logic can also be used to introduce the speed steps as opposed to using DriveExecutive™ software. Studio 5000 Logix Designer application trends are used for tuning in this chapter and [Chapter 4, Manual Tuning](#).

2. Set an initial small Speed Reference.

Use a value for the Speed Reference that is 25% (or less) of motor base speed as the speed step.
3. Click Start in the DriveExecutive software Control Bar to run the drive at the test Speed Reference.
4. Click Dir in the Control Bar to introduce speed step changes.

Motor direction reverses, which is shown in [Figure 36](#) and [Figure 37](#).

Figure 36 - Dir Button Pressed to Invoke Motor Speed and Direction Changes

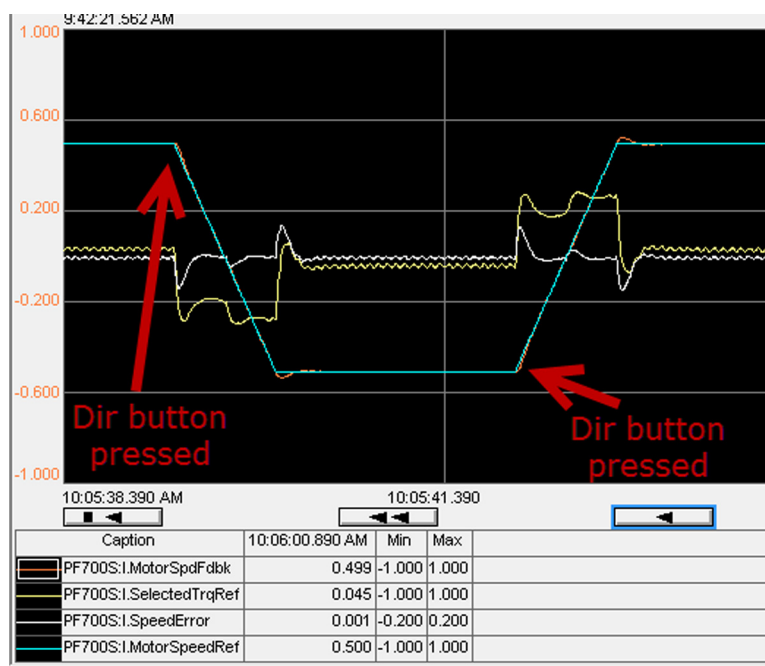
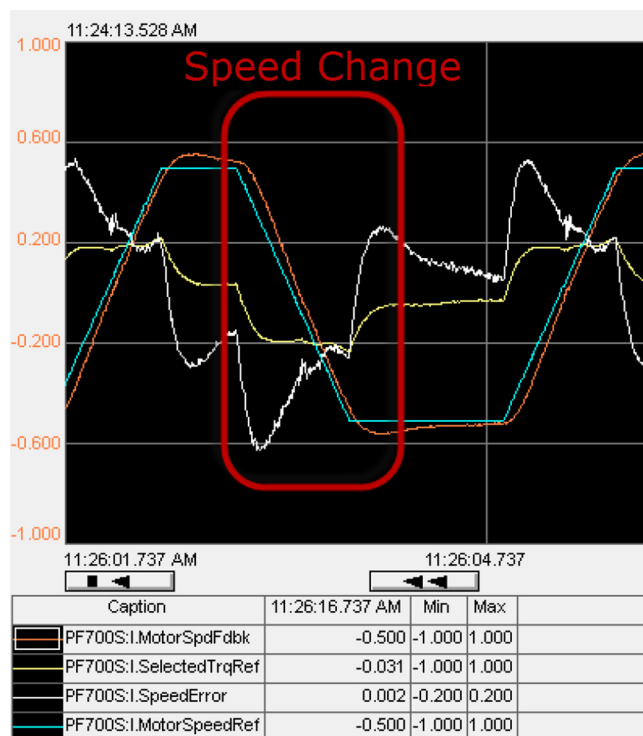


Figure 37 - Speed Change with Speed Reg BW = 10 rad/sec (Overshoot in SpdFdbk)



5. Observe the speed feedback signal and, while the speed is changing, make these tuning adjustments:
  - a. Set Par 90 [Spd Reg BW] to increase the Speed Bandwidth until the signal for Par 300 [Motor Spd Fdbk] follows the Par 301 [Motor Speed Ref] signal as close as possible, or is within the application requirements.

It is not necessary to change the damping set with Par 91 [Spd Reg Damping].

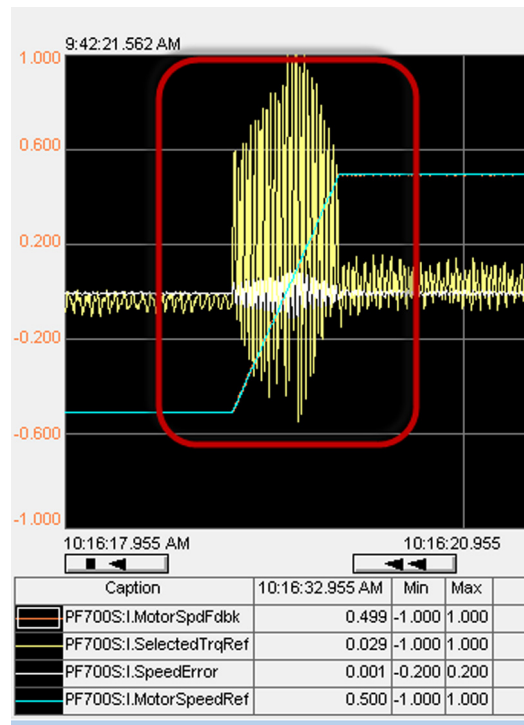
- b. As the Speed Bandwidth is increased, verify that:

Speed Feedback FIR filter BW  $\geq$  Par 90 [Spd Reg BW]

Use Par 233 [Enc0/1 Config] to set the Speed Feedback FIR filter. When changing the Speed Feedback FIR filter, be sure to update the value of Par 89 [Spd Err Filt BW]. For more information on how to set the FIR and speed error filters for your application, see [Chapter 6](#), Encoder Feedback Filters.

If the Speed Bandwidth is increased too high, the Speed Regulator can become unstable or produce audible vibrations, especially near zero speed as shown in this figure.

**Figure 38 - Example Speed Change with Large Speed Reg BW = 350 rad/sec (Oscillations and Instability Starting around Zero Speed)**



- c. Set Par 90 [Spd Reg BW] to lower the Speed Bandwidth until the response is stable and below the critically damped value and/or within application requirements.

The final Bandwidth is shown in [Figure 39](#) where the signal for Par 300 [Motor Spd Fdbk] is closely following the signal for Par 301 [Motor Speed Ref].

**Figure 39 - Example Speed Change with Final Speed Reg BW = 300 rad/sec**

6. Alternatively, set a constant Speed Reference, and then set Par 116 [Torque Step] to introduce small torque steps (approximately 10%) manually.

Torque steps are true steps that are not influenced by speed reference ramp functions. The torque step method is not shown here but can also be used.

7. Raise the initial Speed Reference set in step 2 until the required application speed is achieved.
8. Repeat steps 4 and 5 at the application speed.
9. After the optimal Par 90 [Speed Reg BW] value is determined, use a Bandwidth value that is lower than the instability point.

The amount to lower the Bandwidth depends on the application dynamics and load mechanics. It can be anywhere from ½ the instability amount up to a few rad/sec just below the instability point.

10. Lower the Speed Reference to a value near zero speed (5 RPM) and repeat steps 4 and 5.

If the speed feedback exhibits a high frequency decay or sustained oscillation that can produce an audible vibration, decrease the value of Par 90 [Speed Reg BW] in small increments until the audible vibration is gone. Decreasing the bandwidth reduces the oscillation and audible vibration.

11. If the speed bandwidth value for Par 90 [Speed Reg BW] was reduced at low RPM operation, repeat steps 4 and 5 at application speed to verify that the newly reduced Speed Bandwidth remains satisfactory for the application requirements.

If the speed bandwidth is set low (< 5 rad/sec) to reduce oscillations and/or audible vibrations, it can be necessary to introduce regulator compensation functions such as Lead/Lag and/or Notch Filters. For more information on applying these filters, see [Chapter 5](#), Regulator Compensation Filters. After the filters are configured and applied, it may be possible to further increase the Speed Bandwidth.



12. Test the regulator at various speeds including near zero speed to verify that system design requirements can be achieved with stable speed regulation.

Normally this speed testing is sufficient to complete basic Speed Regulator tuning.

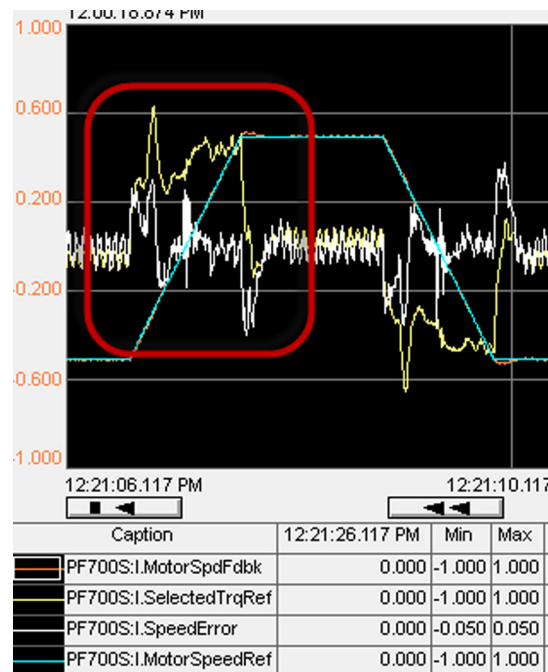
13. If the desired performance cannot be achieved after the Compensation Filters are introduced, go ahead to [Chapter 4](#), Manual Tuning.

## Changing the Damping Factor (Z)

If the Damping Factor is changed, the Integrator gain spacing is affected as shown in [Figure 12](#) and described in [Damping Factor on page 19](#). The Damping Factor can be changed only when Velocity Loop BW Par 90 [Spd Reg BW] is > 0. Typically, the Damping Factor does not need to be changed from 1.0.

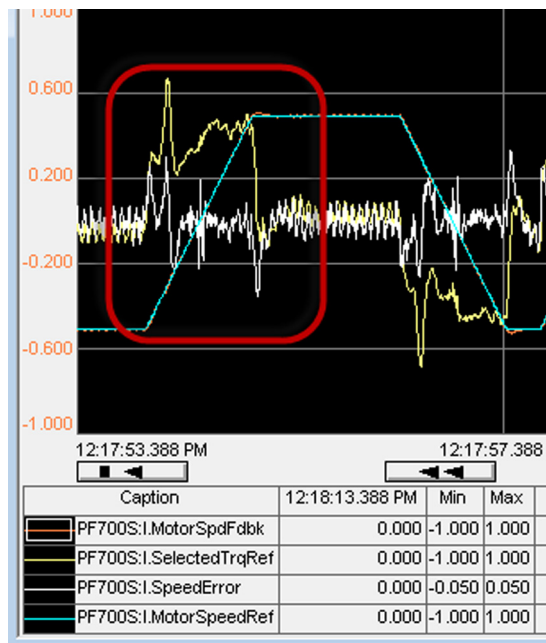
It may be useful to experiment by changing the Damping Factor after the Velocity Loop is tuned to see if the response is improved.

**Figure 40 - Example of Damping Factor = 1.0 and Speed Reg BW = 50 rad/sec**



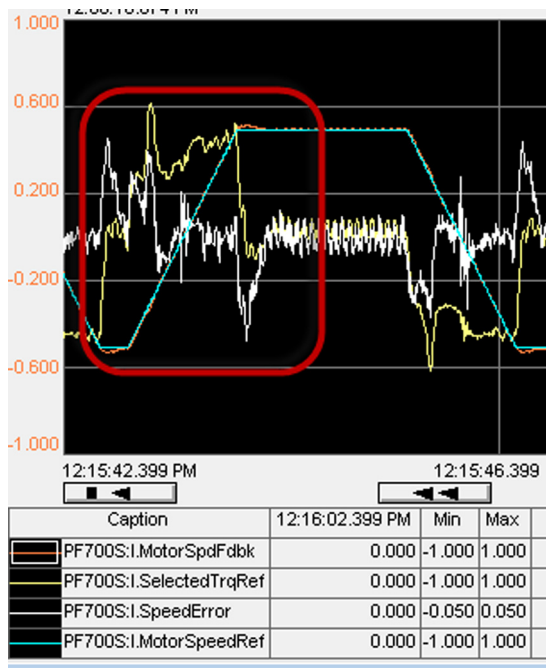
Decreasing Speed Loop Damping reduces the duration of the overshoot and reduces the settling time, but can increase the peak overshoot amplitude. Speed damping values of less than 0.7 are typically not required to obtain satisfactory reductions in the settling time and duration of first overshoot.

Figure 41 - Example of Damping Factor = 0.7 and Speed Reg BW = 50 rad/sec



Increases to Speed Loop Damping of more than 1.0 reduces the amplitude of the first overshoot. However, the settling time increases and steady speed regulation may not meet specifications.

Figure 42 - Example of Damping Factor = 1.2 and Speed Reg BW = 50 rad/sec



Experiment with the speed damping to obtain the optimal response without instability and audible vibrations.

The Velocity Loop tuning is complete.

## Position Loop Tuning Procedure (if Used)

If a Position Regulator is used, the proportional gain ( $K_{pp}$ ) value is chosen to provide stability. Because this is a simple tuning exercise,  $K_{pi}$  is not introduced in this chapter. If the application requires  $K_{pi}$  gain, see [Chapter 4](#), Manual Tuning, to evaluate typical applications that require  $K_{pi}$ , and for more information to calculate and use  $K_{pi}$ .

1. Verify that  $K_{pp}$  (Position Proportional gain) is initially set as follows:

$$\text{Par 768 [PositRegP Gain]} = \frac{\text{Par 81 [Spd Reg P Gain]}}{4Z^2 \times J_t}$$

2. With the Speed Reference still set for the application speed, click Start in the DriveExecutive software Control Bar and verify that the drive operates properly.

This value is satisfactory for most applications. If the desired performance cannot be achieved, go ahead to [Chapter 4](#), Manual Tuning.

**TIP** If a resonance occurs after introducing the Position Loop, see [Chapter 5](#), Regulator Compensation Filters to tune out resonant frequencies.

The Position Loop tuning is complete.

## PowerFlex 755 Drive

Par 636 [Speed Reg BW] and Par 653 [Spd Loop Damping] are adjusted to accomplish Basic Speed Regulator Tuning.

When Par 35 [Motor Ctrl Mode] is set to 3, 6, or 10 (Flux Vector or PMag Motor Control), and Par 636 [Speed Reg BW] is set to a nonzero value, the following parameters are automatically calculated:

- Par 645 [Speed Reg Kp] and Par 647 [Speed Reg Ki] are adjusted based on the value of Par 76 [Total Inertia], Par 636 [Speed Reg BW], and Par 653 [Speed Loop Damping] as shown in [Figure 34](#).
- The value of Par 666 [Speed Comp Gain] and Par 644 [Spd Err Filt BW] are based on the setting of Par 126 [Pri Vel Fdbk Fltr].

1. Set Par 653 [SpdLoopDamping] to 1.0 and Par 636 [Speed Reg BW] to 10. These initial tuning parameter values are adjusted during this procedure.
2. Verify that Par 76 [TotalInertia] > 0 (calculated from Inertia Auto Tune test).
3. Set Accel/Decel rates that are required by the application and verify that:
  - a. Par 535 [AccelTime1] > Par 76 [Total Inertia].
  - b. Par 537 [DecelTime1] > Par 76 [Total Inertia].
4. Monitor the following parameters:
  - a. Par 645 [SpeedRegPGain] =  $K_{vp}$
  - b. Par 647 [SpeedRegIGain] =  $K_{vi}$

## Velocity (Speed) Loop Tuning Procedure

The load must be coupled to the drive, and the drive must be able to operate and move at a slow speed. For details, see [PowerFlex 755 Drive Movement Configuration for Tuning on page 48](#).

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<b>IMPORTANT</b>	If the drive was never operated before (new installation), verify that safeguards are in place to remove power safely from the drive during an unstable situation where the drive can produce undesired motion.
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1. Use trending with Studio 5000 Logix Designer application or DriveObserver to monitor the drive performance with these parameter traces:
  - Par 131 [Active Vel Fdbk]
  - Par 685 [Selected Trq Ref]
  - Par 641 [Speed Error]
  - Par 597 [Final Speed Ref]

**TIP** If your application is dynamic and higher trend sampling is required, use Studio 5000 Logix Designer application. This application (with an Ethernet connection) is another way to get trending sample rates as low as 2 ms. If available, trend the Velocity Loop signals using Studio 5000 Logix Designer application trending. See [Appendix B](#) on how to set up a trend using Studio 5000 Logix Designer application. Logic can also be used to introduce the speed steps as opposed to using DriveExecutive software. Studio 5000 Logix Designer application trends are used for tuning in this chapter and [Chapter 4](#), Manual Tuning.

2. Set an initial small Speed Reference.

Use a value for the Speed Reference that is 25% (or less) of motor base speed as the speed step.
3. Click Start in the DriveExecutive software Control Bar to run the drive at the test Speed Reference.
4. Click Dir in the Control Bar to introduce speed step changes.

Motor direction reverses, which is shown in [Figure 43](#) and [Figure 44](#).

Figure 43 - Dir Button Pressed to Invoke Motor Speed and Direction Changes

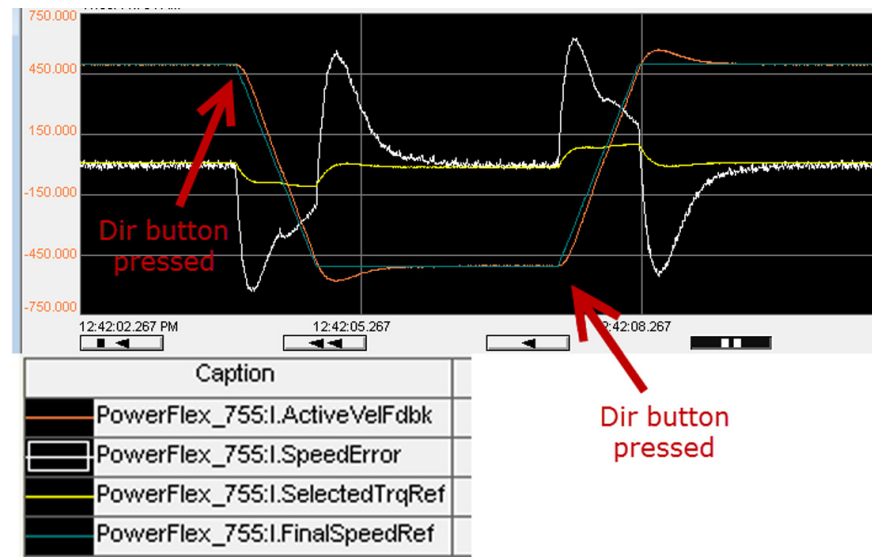
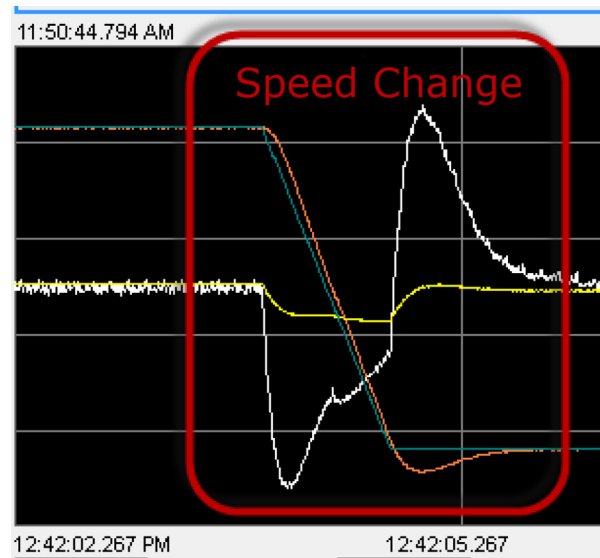


Figure 44 - Speed Change with Speed Reg BW = 10 rad/sec (overshoot in VelFdbk)



5. Observe the speed feedback signal and, while the speed is changing, make the following tuning adjustments:
  - a. Set Par 636 [Speed Reg BW] to increase the Speed Bandwidth until the signal for Par 131 [ActiveVelFdbk] follows the signal for Par 597 [FinalSpeedRef] as close as possible, or is within the application requirements.

It is not necessary to change the damping set with Par 653 [Speed Loop Damping].

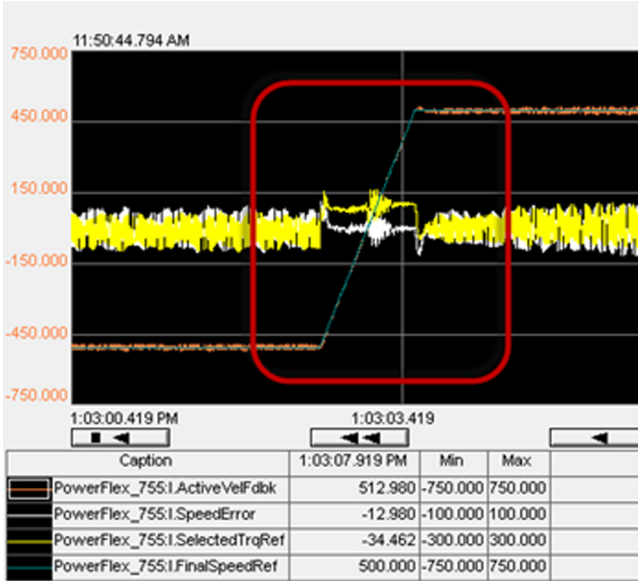
- b. As the Speed Bandwidth is increased, verify that:

$$\text{Vel Fdbk Filter Noise Frequency} \geq \text{Par 636 [Speed Reg BW]}$$

For more information on how to set the Encoder Feedback Filter for your application, see [Chapter 6](#), Encoder Feedback Filters.

If the Speed Bandwidth is increased too high, the speed regulator can become unstable or produce audible vibrations, especially near zero speed as shown in this figure.

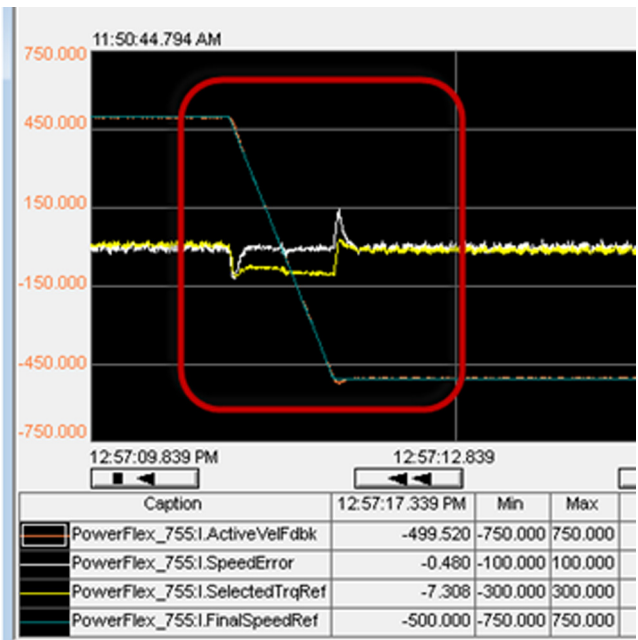
**Figure 45 - Example Speed Change with Speed Reg BW = 80 rad/sec (oscillations and instability starting around zero speed)**



- c. Set Par 636 [Speed Reg BW] to lower the Speed Bandwidth until the response is stable and below the critically damped value and/or within application requirements.

The final Bandwidth is shown in [Figure 46](#) where the signal for Par 131 [Active Vel Fdbk] is closely following the signal for Par 597 [Final Speed Ref].

**Figure 46 - Example Speed Change with Final Speed Reg BW = 60 rad/sec**



6. Alternatively, set a constant Speed Reference, and then set Par 686 [Torque Step] to introduce small torque steps (approximately 10%) manually.

Torque steps are true steps that are not influenced by Speed Reference ramp functions. The torque step method is not shown here but can also be used.

7. Raise the initial Speed Reference set in step 2 until the required application speed is achieved.
8. Repeat steps 4 and 5 at the application speed.
9. After the optimal Par 636 [Speed Reg BW] value is determined, use a Bandwidth value that is lower than the instability point.

The amount to lower the bandwidth depends on the application dynamics and load mechanics. It can be anywhere from ½ the instability amount up to a few rad/sec just below the instability point.

10. Lower the Speed Reference to a value near zero speed (5 RPM) and repeat steps 4 and 5.

If the speed feedback exhibits a high frequency decay or sustained oscillation that could produce an audible vibration, decrease the value of Par 636 [Speed Reg BW] in small increments until the audible vibration is gone. Decreasing bandwidth reduces the oscillation and audible vibration.

11. If the Speed Bandwidth value for Par 636 [Speed Reg BW] was reduced at low RPM operation, repeat steps 4 and 5 at application speed to verify that the newly reduced Speed Bandwidth remains satisfactory for the application requirements.

If the Speed Bandwidth is set low (< 5 rad/sec) to reduce oscillations and/or audible vibrations, it can be necessary to introduce regulator compensation functions such as Lead/Lag and/or Notch Filters. For more information to apply these filters, see [Chapter 5](#), Regulator Compensation Filters. After the filters are configured and applied, it may be possible to further increase the Speed Bandwidth.

12. Test the regulator at various speeds including near zero speed to verify that system design requirements can be achieved with stable speed regulation.

Normally this speed testing is sufficient to complete basic speed regulator tuning.

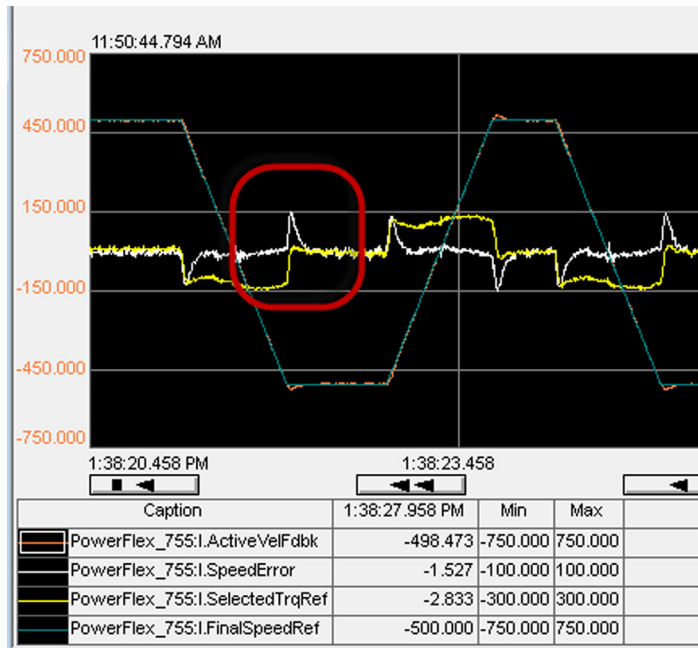
13. If the desired performance cannot be achieved after Regulator Compensation is introduced and tested, go ahead to [Chapter 4](#), Manual Tuning.

## Changing the Damping Factor (Z)

If the Damping Factor is changed, the Integrator gain spacing is affected as shown in [Figure 12](#) and described in [Damping Factor on page 19](#). The Damping Factor can be changed only when Velocity Loop BW Par 636 [Speed Reg BW] is > 0. Typically, the Damping Factor does not need to be changed from 1.0.

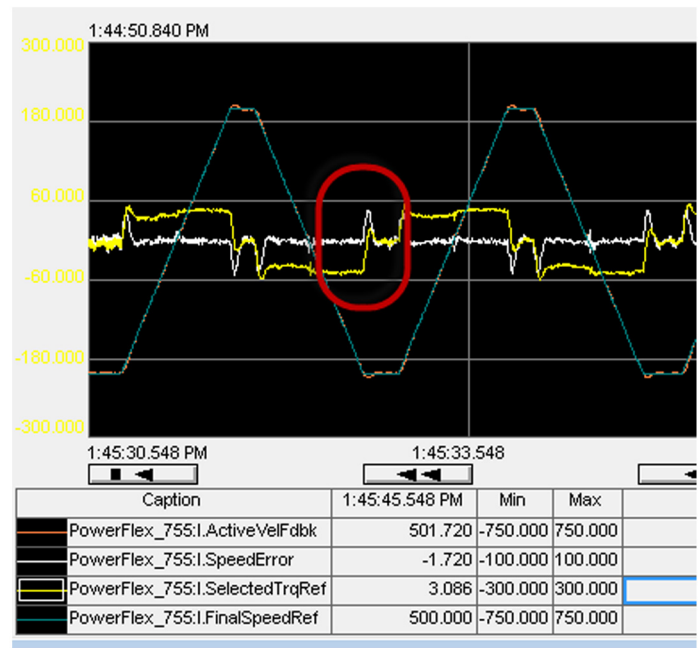
It may be useful to experiment by changing the Damping Factor at this point during this tuning test to see if the response is improved.

Figure 47 - Example of Damping Factor = 1.0 and Speed Reg BW = 60 Hz



Decreasing speed loop damping reduces the duration of the overshoot and reduces the settling time, but can increase the peak overshoot amplitude. Speed damping values of less than 0.7 are typically not required to obtain satisfactory reductions in the settling time and duration of first overshoot.

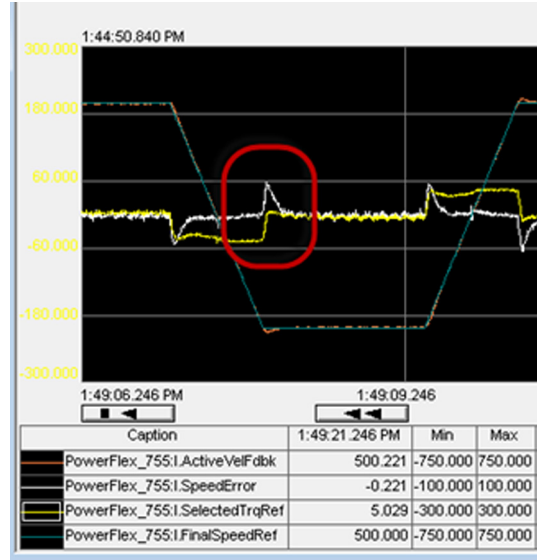
Figure 48 - Example of Damping Factor = 0.7 and Speed Reg BW = 60 Hz





Increases to speed loop damping of more than 1.0 reduces the amplitude of the first overshoot. However, the settling time increases and steady speed regulation may not meet specifications.

**Figure 49 - Example of Damping Factor = 1.2 and Speed Reg BW = 60 Hz**



Experiment with the Speed Bandwidth and Speed Damping to obtain the optimal response without instability and audible vibrations.

The Velocity Loop tuning is complete.

## Position Loop Tuning Procedure (if Used)

If a Position Regulator is used, the proportional gain ( $K_{pp}$ ) value is chosen to provide stability. Because this is a simple tuning exercise,  $K_{pi}$  is not introduced in this chapter. If the application requires  $K_{pi}$  gain, see [Chapter 4](#), Manual Tuning, to evaluate typical applications that require  $K_{pi}$ , and for more information on calculating and using  $K_{pi}$ .

1. Verify that  $K_{pp}$  (Position Proportional gain) is initially set as follows:

$$\text{Par 839 [Psn Reg Kp]} = \frac{\text{Par 645 [Speed Reg Kp]}}{4Z^2 \times J_t}$$

2. With the Speed Reference still set for the application speed, click Start in the DriveExecutive software Control Bar and verify that the drive operates properly.

This value should be satisfactory for most applications. If the desired performance cannot be achieved, go ahead to [Chapter 4](#), Manual Tuning.

**TIP** If a resonance occurs after introducing the Position Loop, see [Chapter 5](#), Regulator Compensation Filters to tune out resonant frequencies.

The Position Loop tuning is complete.

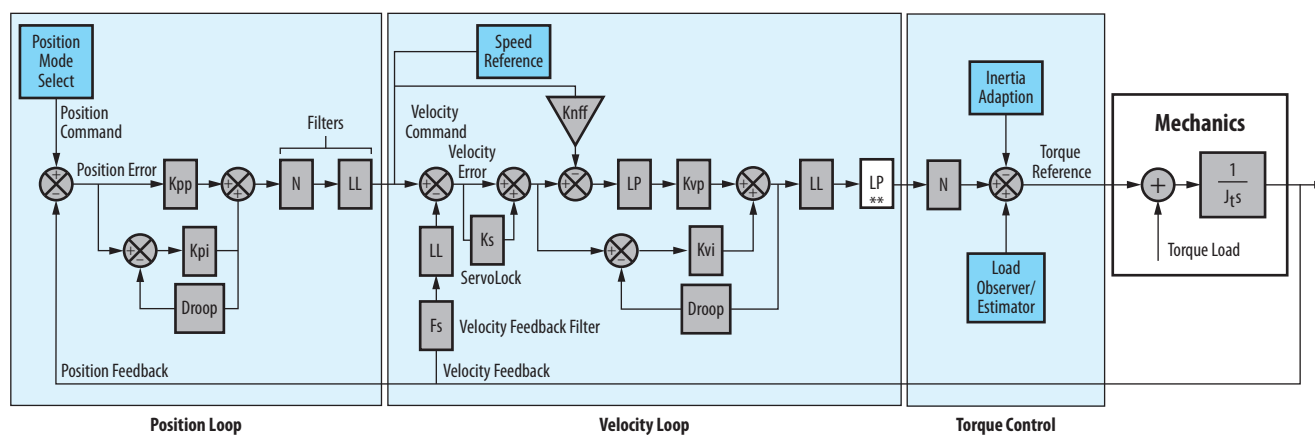
## **Notes:**

## Manual Tuning

This chapter describes tuning by using an inside-out approach, which is an accepted method to tune control loops. The Torque/Current inner loop is tuned first using Auto Tune tests from [Chapter 2](#). Next, the inner Velocity Loop is tuned, followed by tuning the outer position loop. This procedure increases control loop gains incrementally to the point of marginal stability, then backs them off by a given percentage. Typical ranges for various gains are also provided as guidelines. With tuning, the Velocity (Speed) Loop is the most critical because it is typically faster and 'nested' inside the Position Loop, and will require attention.

Tuning with the Bandwidth method yields satisfactory results. However, if you are comfortable with tuning, this method can help to optimize performance further when maximum performance is required.

**Figure 50 - Simplified PowerFlex® Control Loop Block Diagram**



[Table 2](#) lists various generic applications and which integrator gain (position integrator gain  $K_{pi}$ , or velocity integrator gain  $K_{vi}$ ) to use when tuning. If your application type is not one of the types that are listed in [Table 2](#), use the Constant Speed application as the default type.

**Table 2 - Application Type and Integrator Usage**

Application Type	Applications	Kpi	Kvi
Tracking	<ul style="list-style-type: none"> <li>• Converting</li> <li>• Printing</li> <li>• Web</li> <li>• Flying Shear</li> <li>• Coordinated Motion</li> <li>• Rotary Knife</li> <li>• Packaging</li> </ul>		✓
Point-to-point	<ul style="list-style-type: none"> <li>• Pick and Place</li> <li>• Indexing</li> <li>• Robotics</li> <li>• Palletizing</li> </ul>	✓	
Constant Speed	<ul style="list-style-type: none"> <li>• Conveyors</li> <li>• Line Shafts</li> <li>• Cranks</li> </ul>		✓
Positioning	High-Performance Position Control	✓	

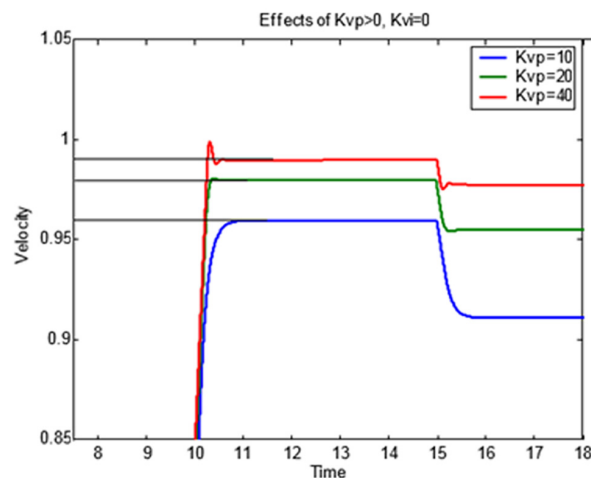
**TIP** Kpi and Kvi must not be activated simultaneously.

When manually tuning, consider [Figure 50](#) and the characteristics for these control loop terms:

- Kvp creates a torque command proportional to velocity (speed) error, so increasing Kvp increases the Velocity (Speed) Loop Bandwidth.
- Kvi creates a torque command proportional to the sum of velocity error over time ( $v/t$ ), so this term reduces or eliminates steady state velocity error.
- Velocity (Speed) Error Filter (LP in [Figure 50](#)) sets the Bandwidth of this second order Low Pass Filter, which reduces the signal that is derived from the Velocity (speed) error. Its purpose is to reduce quantization noise.

A Proportional (Kvp) only ( $Kvi = 0$ ) velocity loop includes these characteristics:

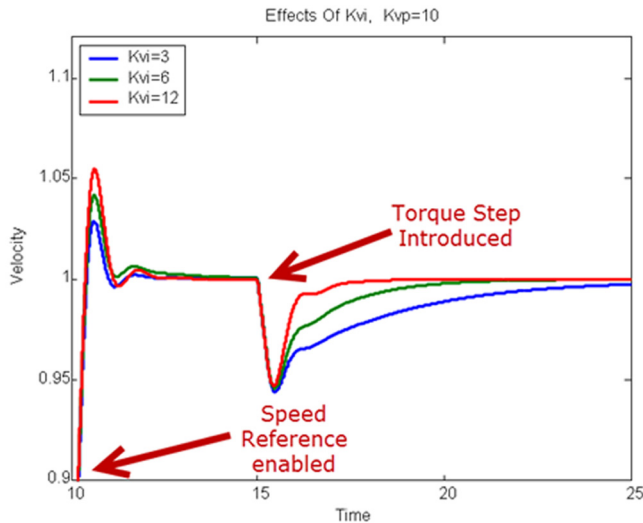
- Velocity (Speed) Error is multiplied by Kvp
- Steady State velocity error only
- Doubling Kvp reduces the steady state error by  $\frac{1}{2}$
- Increasing Kvp reduces step rise time and causes overshoot

**Figure 51 - Step Response Results from Increasing Kvp**

A Proportional ( $K_v$ ) and Integral ( $K_{vi} > 0$ ) velocity loop includes these characteristics:

- $K_{vi}$  reduces steady state error to zero by integrating the Velocity Error over time.
- $K_{vi}$  affects the recovery time from a load step change or disturbance.
- Increasing  $K_{vi}$  too large can cause overshoot and can cause a ringing (instability) in the output.

**Figure 52 - Step Response Results from Using Different  $K_{vi}$  Values ( $K_v = 10$ )**



Manual tuning requirements include the following:

- A Logix controller with Studio 5000 Logix Designer® application for programming logic and trending results. If your drive does not use a Logix controller with Studio 5000 Logix Designer application, simply follow the same procedure that is described here for your drive configuration.

If a Logix controller and Studio 5000 Logix Designer application is not available:

- Use DriveExecutive™ software with DriveObserver™ Trace capability to monitor the drive signals.
- Use analog outputs from the drive that is wired to a digital scope or even a Logix Controller via Analog Input module (and trend) with Studio 5000 Logix Designer application to monitor the signals.
- Verify that the latest PowerFlex drive firmware has been downloaded to the drive.

# Drive Setup

This manual tuning procedure is the same for PowerFlex 700S and PowerFlex 755 drives, so it is combined into one section with the different parameters that are listed in tabular format.

It is assumed that the following conditions have been met:

- The other sections of this document have been reviewed.
- The drive has power applied.
- Communication has been established.
- Drive configuration is completed.
- Tuning using Bandwidth ([Chapter 3](#)) has been attempted.

[Chapter 2](#) has the configuration that applies to manual tuning for your specific drive, including drive modes and filter settings.

The drive must be configured so it can be controlled ([Chapter 2](#)). The load must be coupled to the motor and the drive must be able to operate at a safe low speed.

**IMPORTANT** If the drive was never operated before (new installation), verify that safeguards are in place to remove power safely from the drive during an unstable situation where the drive can produce undesired motion.

# Velocity (Speed) Loop Tuning

1. Use these parameters to disable any position profilers or commands and set the Kpp and Kpi values to 0.

PowerFlex 700S Drive	PowerFlex 755 Drive
Kpi = Par 770 [PositReg Integ] = 0	Kpi = Par 838 [Psn Reg Ki] = 0
Kpp = Par 768 [PositReg P Gain] = 0	Kpp = Par 839 [Psn Reg Kp] = 0

2. Use trending with Studio 5000 Logix Designer application or DriveObserver software to monitor the velocity feedback and velocity (speed) error signals with the following parameter traces.

PowerFlex 700S Drive	PowerFlex 755 Drive
Par 300 [Motor Spd Fdbk]	Par 131 [Active Vel Fdbk]
Par 319 [Selected Trq Ref]	Par 685 [Selected Trq Ref]
Par 100 [Speed Error]	Par 641 [Speed Error]
Par 301 [Motor Speed Ref]	Par 597 [Final Speed Ref]

For details to configure Studio 5000 Logix Designer application trending, see [Appendix B](#).

3. Use this parameter to set a low Speed Reference for the test speed reference.

PowerFlex 700S Drive	PowerFlex 755 Drive
Par 14 [Preset Speed 1]	Control Bar Speed Reference Slider

Use a low value Speed Reference (25% of motor base speed, or less) for the speed step. The Speed Reference slider in the DriveExecutive software Control Bar can be used in the PowerFlex 700S drive.

**IMPORTANT** The PowerFlex 700S drive Control Bar Speed Reference is scaled in RPM x 8—not RPM like the PowerFlex 755 drive. Be cautious when using the PowerFlex 700S Speed Reference slider because small changes in slider position cause large changes in speed reference. Use of Preset Speed 1, scaled in RPM, is preferred with the PowerFlex 700S drive.

4. Verify that these Speed Reference ramp rate parameters are set higher than the Total Inertia.

PowerFlex 700S Drive	PowerFlex 755 Drive
Par 32 [Accel Time 1] > Par 9 [Total Inertia]	Par 535 [Accel Time 1] > Par 76 [Total Inertia]
Par 33 [Decel Time 1] > Par 9 [Total Inertia]	Par 537 [Decel Time 1] > Par 76 [Total Inertia]

5. Use this parameter to set the Velocity Loop Bandwidth to zero.

PowerFlex 700S Drive	PowerFlex 755 Drive
Par 90 [Spd Reg BW] = 0	Par 636 [Speed Reg BW] = 0

6. Use this parameter to set Kvi to zero initially.

PowerFlex 700S Drive	PowerFlex 755 Drive
Par 82 [Spd Reg I Gain] = 0	Par 647 [Speed Reg Ki] = 0

7. Use this parameter to set the Velocity (Speed) Loop Proportional Gain (Kvp) value to 10 initially.

PowerFlex 700S Drive	PowerFlex 755 Drive
Par 81 [Spd Reg P Gain] = 10	Par 645 [Speed Reg Kp] = 10

8. Click Start in the DriveExecutive software Control Bar to run the drive.

The drive starts and the motor rotates at the preset speed reference. If the drive speed is not stable, reduce the proportional gain (Kvp).

9. Click Dir in the Control Bar to introduce speed steps.

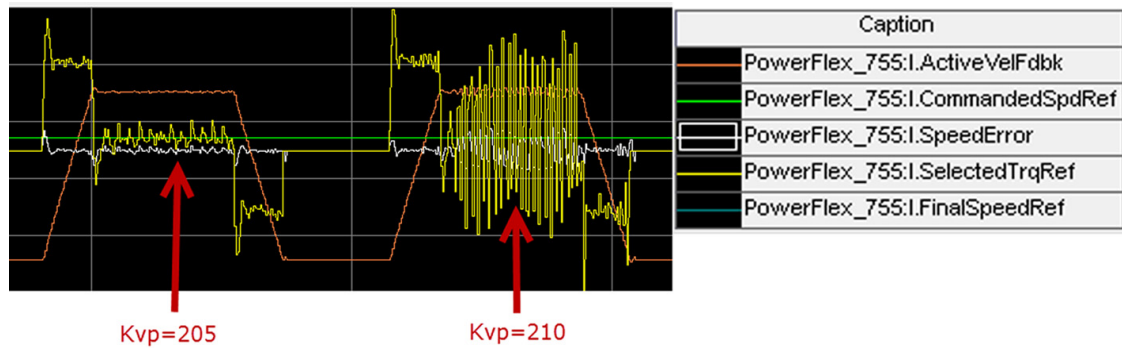
Details are described in [PowerFlex 700S Drive Movement Configuration for Tuning on page 40](#) or [PowerFlex 755 Drive Movement Configuration for Tuning on page 48](#).

10. See [Figure 53](#).

Begin increasing the proportional gain (Kvp) in small increments (2% is a good increment) while monitoring the Velocity Feedback (ActiveVelFdbk - orange pen in the trend), the Torque Feedback (SelectedTrqRef - yellow pen in trend), and Velocity Error (SpeedError - white pen in trend) signals for oscillation as shown in [Figure 53](#).

Figure 53 shows the oscillations begin  $205 < K_{vp} < 210$ .

Figure 53 - Example of Instability When Increasing Kvp



- 11. Continue increasing the Kvp value until the point of marginal instability (see Figure 53, where  $K_{vp} = 205$ ).
- 12. When this instability point is found (characterized by velocity and torque oscillations that are shown in Figure 53), click Stop in the Control Bar to stop the drive.
- 13. Set proportional gain ( $K_{vp}$ ) to  $\frac{1}{2}$  the value that caused the instability (in this example,  $K_{vp} = 102$ ).
- 14. Use Method 1 or Method 2 of this step to determine the required integral gain ( $K_{vi}$ ) value and enter it into this parameter.

PowerFlex 700S Drive	PowerFlex 755 Drive
Par 82 [Spd Reg I Gain]	Par 647 [Speed Reg Ki]

Method 1 – Calculating the Integral Gain ( $K_{vi}$ )

Use this equation to determine the normalized Total Inertia ( $J_t$ ) in seconds:

$$J_t = J_m + J_L,$$

where  $J_m$  is motor inertia and  $J_L$  is load inertia.

Use the [Inertia Auto Tune Test on page 37](#) or [Inertia Auto Tune Test on page 45](#) to measure the Total Inertia  $J_t$  [sec], which is automatically set.

Alternatively, the Total Inertia  $J_t$  [sec] can be calculated as follows:

- a. Identify the continuous stall motor torque ( $T_m$ ) in N•m.
- b. Use mechanical data to calculate  $J_L$  (Load Inertia).
- c. Use this equation to calculate Total Inertia  $J_t$ .

$$J_t \left[ \frac{\text{kg}}{\text{m}^2} \right] = J_m \left[ \frac{\text{kg}}{\text{m}^2} \right] + J_L \left[ \frac{\text{kg}}{\text{m}^2} \right]$$

- d. Use this equation to calculate the maximum accel rate.

$$a \left[ \frac{\text{revs}}{\text{sec}^2} \right] = \frac{T_m \left[ \text{N} \cdot \text{m} \right]}{J_t \left[ \frac{\text{kg}}{\text{m}^2} \right]}$$



- e. Use this equation to convert the rated motor speed  $V_{max}$  to revs/sec.

$$V_{max} \left[ \frac{\text{revs}}{\text{sec}} \right] = \frac{V_{max} \left[ \frac{\text{revs}}{\text{min}} \right]}{60}$$

- f. Use this equation to calculate the Total Inertia in seconds.

$$J_t [\text{sec}] = \frac{V_{max} [\text{rev/sec}]}{a [\text{rev/sec}^2]}$$

- g. Use this parameter to update Total Inertia  $J_t$  in the drive.

PowerFlex 700S Drive	PowerFlex 755 Drive
Par 9 [Total Inertia]	Par 76 [Total Inertia]

- h. Use this equation, with the  $K_{vp}$  gain that was calculated in step 13, to calculate Velocity Bandwidth (Vel BW) in Hz.

$$\text{Vel BW [Hz]} = \frac{K_{vp}}{(J_t \times 2\pi)}$$

- i. Use this equation to calculate the Velocity Integrator Bandwidth (Vel Int BW).

$$\text{Vel Int BW [Hz]} = \frac{\text{Vel BW [Hz]}}{4Z^2}$$

The Damping Factor ( $Z$ ) is typically 1.0.

- j. Use this equation to convert Vel Int BW into  $K_{vi}$  in drive units that are applied to the speed loop regulator I-Gain parameter.

$$K_{vi} = \text{Vel BW [Hz]} \times \text{Vel Int BW [Hz]} \times 2\pi \times J_t [\text{sec}]$$

Also, verify that  $0 \leq \text{Vel Int BW} \leq (\text{Vel BW} \div 4Z^2)$ , and that  $K_{vi}$  is set so the velocity (speed) error is below your application requirements.

## Method 2 – Tuning the Integral Gain ( $K_{vi}$ )

- Click Start in the DriveExecutive software Control Bar to enable and jog the drive.
- Click Dir in the Control Bar, which changes jog direction, to introduce speed steps.

Details are described in [PowerFlex 700S Drive Movement Configuration for Tuning on page 40](#) or [PowerFlex 755 Drive Movement Configuration for Tuning on page 48](#).

- Monitor the Velocity Feedback and Velocity (Speed) Error signals, and click Dir in the Control Bar to make speed changes.
- Use this parameter to monitor the Speed Error in the drive.

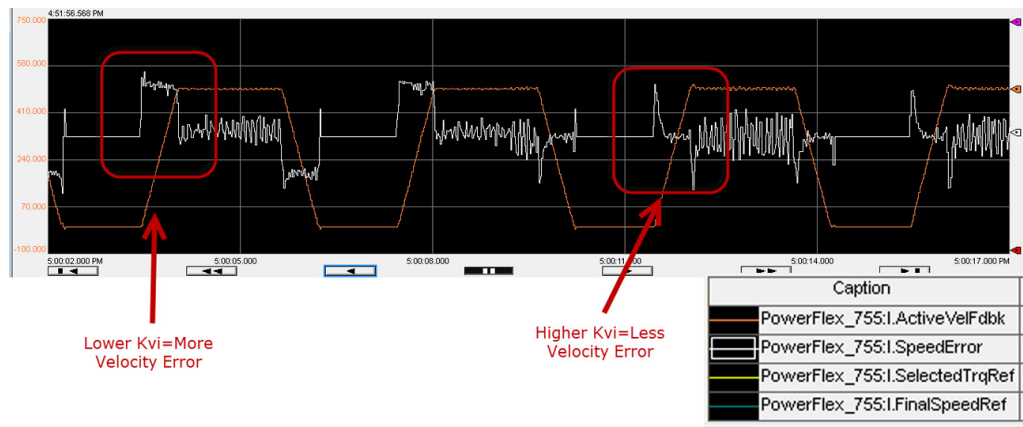
PowerFlex 700S Drive	PowerFlex 755 Drive
Par 100 [Speed Error]	Par 641 [Speed Error]

- Increase the  $K_{vi}$  gain until the Velocity Error is less than the application requirements.

A good increment to use is 2%.

- f. Verify that the Kvi value has a limit so that:
- $0 \leq \text{Vel Int BW} \leq (\text{Vel BW} \div 4Z^2)$
  - Velocity (Speed) Error is below the application requirements.
- Increased Kvi introduces overshoot into the profile, so carefully consider the Kvi value. This figure shows the difference between low and high values of Integral Gain (Kvi).

Figure 54 - Effects of a Low and High Kvi Value



- g. Enter the resulting Kvi parameter value during tuning.
15. Operate the drive throughout the desired speed range, including at or near zero speed, and verify that there is smooth operation.

If instability or audible vibration is apparent, it can be necessary to readjust the gains or settings of the Regulator Compensation filters. See [Chapter 5](#) for information on setting Regulator Compensation filters.

## Position Loop Tuning (if Used)

It is important to note that many PowerFlex applications operate without a Position Loop. If so, tuning is finished after completing the Velocity Loop tune. If the drive uses an external encoder and Position Loop, continue on with Position Loop Tuning as described in this section.

1. Verify that the parameters are set so the Position Loop profiler being used is active.  
  
Details are provided in [Appendix C](#). This tuning exercise uses a point-to-point configuration that was activated by using the 'PowerFlex 755 Profile Setup Wizard'.
2. Use trending with Studio 5000 Logix Designer application or DriveObserver to monitor the Position Regulator with these parameter traces.

PowerFlex 700S Drive	PowerFlex 755 Drive
Par 769 [Position Error]	Par 835 [Psn Error]
Par 747 [Position Cmmd]	Par 723 [Psn Command]

For details to configure Studio 5000 Logix Designer application trending, see [Appendix B](#).

- Use this parameter to set  $K_{pi}$  to 0.

PowerFlex 700S Drive	PowerFlex 755 Drive
Par 770 [PositReg Integ] = 0	Par 838 [Psn Reg Ki] = 0

This setting is done initially as the  $K_{pp}$  must be initially obtained. After  $K_{pp}$  is obtained,  $K_{vi}$ , if it was used, can be inserted again later.

- Use this parameter to set  $K_{vi}$  to 0.

PowerFlex 700S Drive	PowerFlex 755 Drive
Par 82 [Spd Reg I Gain] = 0	Par 647 [Speed Reg Ki] = 0

- Retain the  $K_{vp}$  value that is used in the Velocity tune section of this chapter.
- Use these parameters to enter the  $K_{pp}$  value initially so that:

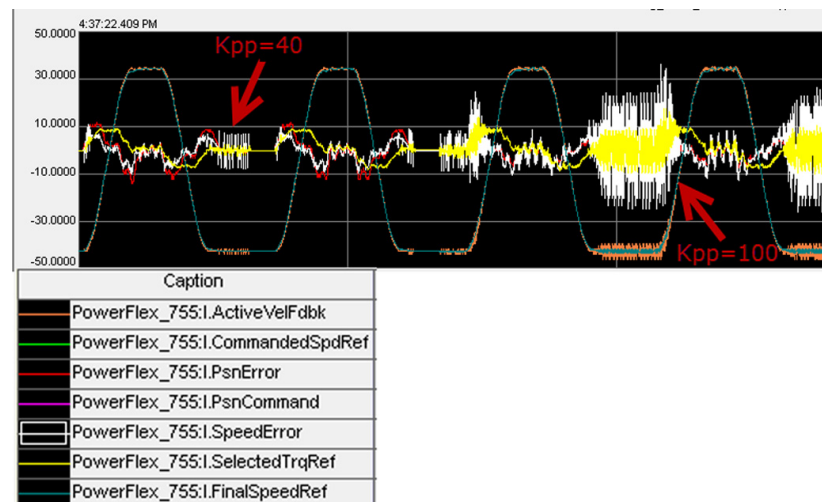
$$K_{pp} = \frac{K_{vp}}{4Z^2 \times Jt}$$

PowerFlex 700S Drive	PowerFlex 755 Drive
$K_{pp}$ = Par 768 [PositReg P Gain]	$K_{pp}$ = Par 839 [Psn Reg Kp]
$K_{vp}$ = Par 81 [Spd Reg P Gain]	$K_{vp}$ = Par 645 [Speed Reg Kp]

- See [Figure 55](#).

Increase  $K_{pp}$  in small increments (a good increment is 2%) until you audibly hear ringing or see oscillations while trending Par 131 [ActiveVelFdbk] (orange pen in trend) in Studio 5000 Logix Designer application.

**Figure 55 - Tuning  $K_{pp}$  with the PowerFlex Drive**  
(marginal stability with  $K_{pp} = 40$ ; instability with  $K_{pp} = 100$ )



**TIP** During this process, another (or possibly a first occurrence) audible resonance can become excited. This resonance can be removed by using regulator compensation filters. For details, see [Chapter 5](#), Regulator Compensation Filters.

- Click Stop in the Control Bar to stop and disable the drive.

9. Set the Kpp value to ½ the value that caused the instability in step 6.
10. If your application requires Kpi, which can be used to reduce following (position) error, use Method 1 or Method 2 of this step to determine the Kpi value and enter it with this parameter.

PowerFlex 700S Drive	PowerFlex 755 Drive
Par 770 [PositReg Integ]	Par 838 [Psn Reg Ki]

### Method 1 – Calculating Kpi

- a. Set the Kpi value so that:

$$0 \leq Kpi \leq \frac{(Kpp)^2}{4Z^2}$$

- b. Check to see if resonance occurs as you increase Kpi.  
If a resonance occurs, see [Chapter 5](#), Regulator Compensation Filters to remove the resonance.

### Method 2 – Tuning Kpi

- a. Use trending with Studio 5000 Logix Designer application or DriveObserver to monitor the Position Error (following error) with this parameter trace.

PowerFlex700S Drive	PowerFlex 755 Drive
Par 769 [Position Error]	Par 835 [Psn Error]

- b. Increase the Kpi value in 2% increments while jogging and reversing the direction of movement until the Position Error (following error) is below your application requirements.
11. If your application required Kvi, restore the value to what it was determined to be before the Position Loop Tuning procedure.

**TIP** During this process, another (or possibly a first occurrence) audible resonance can become excited. This resonance can be removed by using regulator compensation filters. For details, see [Chapter 5](#), Regulator Compensation Filters.

## Regulator Compensation Filters

PowerFlex® 700S and PowerFlex 755 drives include Lead/Lag and Notch Filters that are in the Velocity (Speed) and Position regulation loops. This chapter describes the Velocity (Speed) regulator filters available, how to configure them for your application, and shows examples of how to use them.

See [Definitions of Mechanical Terms on page 11](#) to understand and identify the mechanical issues and their behaviors to help choose the appropriate regulator compensation filters to use.

The PowerFlex Lead/Lag and Notch Filters are only available in FVC or FOC motor control modes with speed feedback.

The type of filter that is used depends on the issue that is causing the resonance or instability. This table lists each filter type and its function.

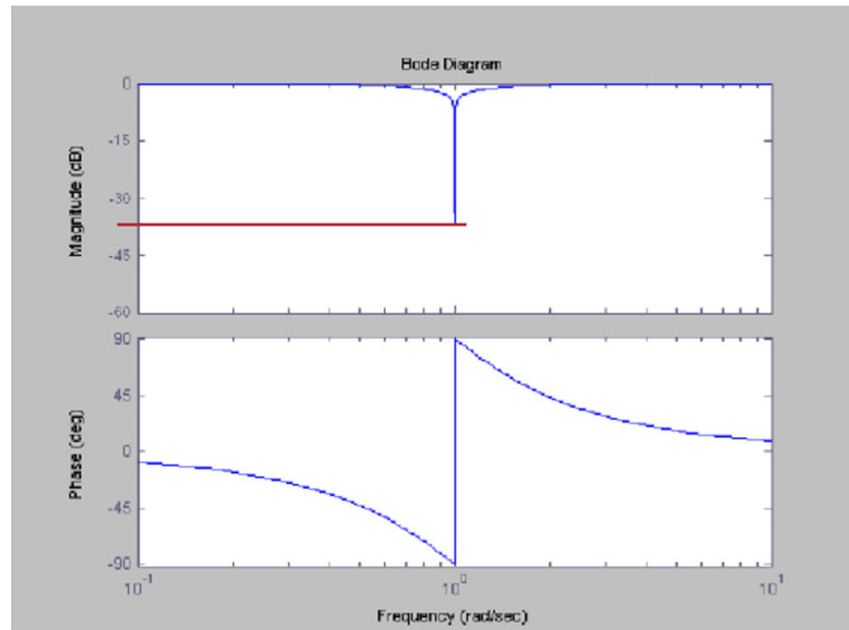
Filter Type	Function
Lead/Lag Filter	Compensates for instability oscillation due to mechanical backlash. If backlash is severe, the Inertia Adaption function can be more suitable. See <a href="#">PowerFlex Inertia Adaption on page 19</a> for the respective PowerFlex drive used. Lead/Lag filters can also be used to compensate for inner loop regulator bandwidth roll off. A discussion and example of this is given later in this chapter.
Notch Filter	Applies attenuation to a specific frequency to remove or lessen that frequency. The specific frequency is the frequency that is causing resonance on the machine. (Resonance can be due to torsional compliance and/or mechanical resonance.)
Encoder Feedback Filter	Encoder feedback noise is typically higher in frequency and must be filtered by using the Encoder Feedback filters. Feedback noise is not considered a tuning function, but can affect drive stability and, ultimately, performance. Encoder Feedback filters are discussed in <a href="#">Chapter 6</a> , Encoder Feedback Filters.

Many drive applications can exhibit a high resonant frequency that is apparent by an audible high-frequency 'squealing' of the load mechanics. All applications ultimately exhibit resonance when gains are increased to their limit while optimizing performance. It is also possible that a low frequency oscillation or noise is present because of compliance and/or gearbox backlash.

## Torque Reference Notch Filter

A Notch Filter is a filter that passes most frequency signals unaltered but attenuates signals within a specific range of frequencies. The following figure shows gain and phase through the filter as a function of the frequency content of a signal that is passed through it.

**Figure 56 - Notch Filter Bode Plot**

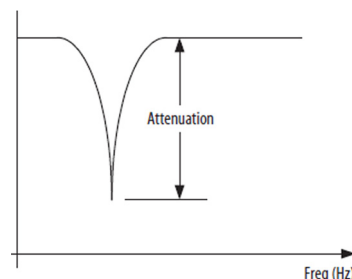


Notch Filters typically have a relatively narrow and deep attenuation band. Maximum attenuation is achieved at the Notch Filter frequency.

As with any filter, its output is shifted in phase from the input. The shift is present for all frequencies. The output lags the input up to the notch frequency and leads the input for frequencies above the notch frequency.

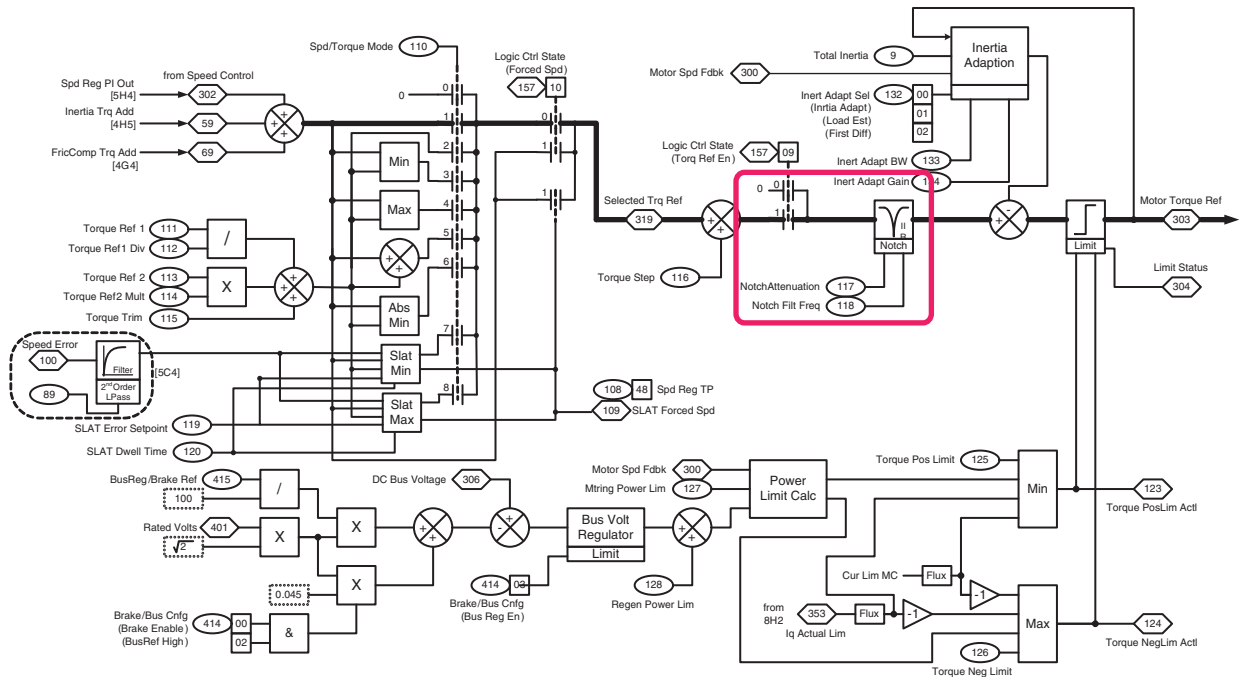
The Notch Filter is effective in resonance control when the resonant frequency is higher than the control loop bandwidth. The Notch Filter works by significantly reducing the amount of energy in the device output that can excite high frequency resonances. It can be used even when resonant frequencies are relatively close to the control loop bandwidth because the phase lag, introduced by the Notch Filter, is localized around the notch frequency. For the Notch Filter to be effective, the Notch Filter frequency must be set close to the natural resonance frequency of the load.

**Figure 57 - Notch Filter Attenuation**



One notch filter block is in the Torque Control output path. Another notch filter is located in the Position Loop output. The red-highlighted areas in [Figure 58](#) and [Figure 59](#) show the location of the torque reference notch filters for the PowerFlex 700S and PowerFlex 755 drives respectively.

**Figure 58 - PowerFlex 700S Drive Torque Reference Filter**



**Figure 59 - PowerFlex 755 Drive Torque Reference Filter**

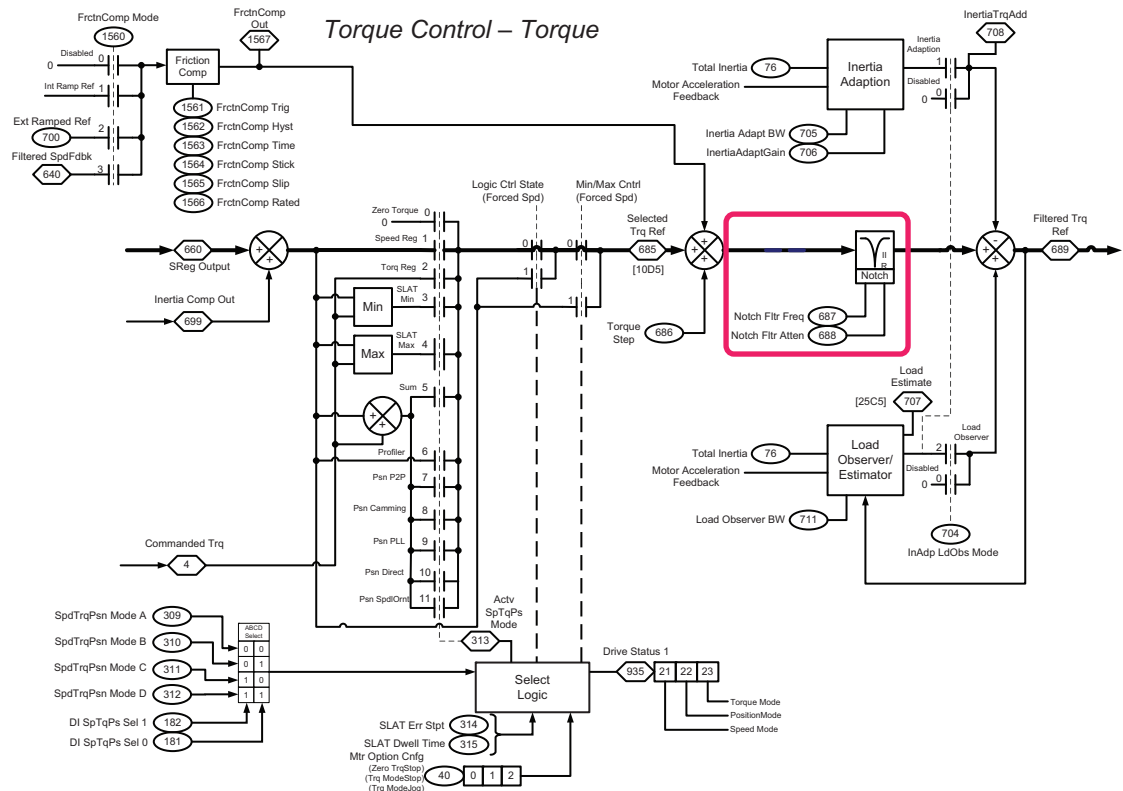
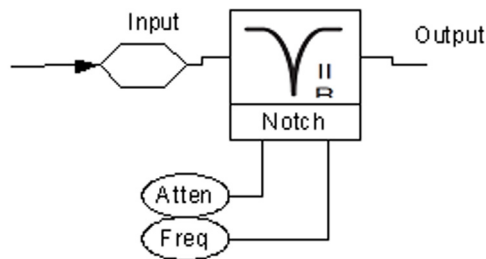


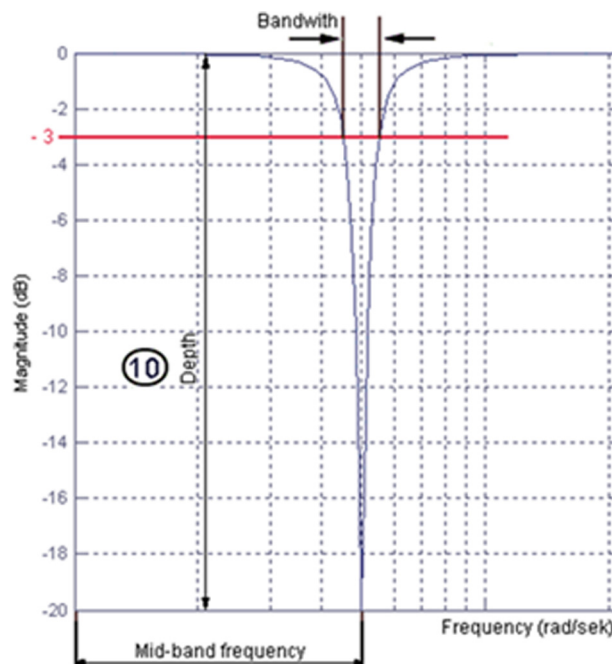
Figure 60 shows the typical notch filter block that is used by both PowerFlex 700S and PowerFlex 755 drives.

**Figure 60 - PowerFlex Notch Filter Block and Transfer Function**



The Notch Filter is a second-order band rejection filter with 40 dB/decade attenuation. The bandwidth of the Notch Filter is defined as frequency range where the gain is less than -3 dB. This relationship is shown in Figure 61. It is not possible to adjust the Notch Filter bandwidth in the PowerFlex drive.

**Figure 61 - Notch Filter Frequency Response**



Notch Filter parameter definitions are as follows:

- 'Atten' sets the attenuation or depth for the Notch Filter.  
Attenuation is the ratio of the output to the input at the notch frequency.  
For example, an attenuation of 30 means that the notch output is 1/30th of the input at the center frequency.
- 'Freq' is the center frequency of the Notch Filter in Hertz (Hz).  
Set the notch Freq = 0 to disable the Notch Filter function.



## Using the Torque Notch Filter

As described in [Chapter 3](#), Tuning Using Bandwidth, and [Chapter 4](#), Manual Tuning, the Speed Regulator Bandwidth/Proportional Gain is increased to improve the regulator performance. As the gain is increased, the speed feedback signal ultimately shows instability oscillation as the speed bandwidth/proportional gain parameter is increased. The instability oscillation can also cause audible noise and vibration from the machine.

If a decaying or constant high frequency oscillation is apparent in the Speed Feedback and Torque Reference after introducing a speed step, the cause can be the natural resonant frequency or torsional compliance of the machine.

If the Speed Feedback has a high frequency oscillation, typically with decaying amplitude, mechanical resonance usually causes the instability. Mechanical resonance due to compliance is typically lower in frequency than resonance due to the natural frequency of a system.

In either case, it is necessary to cancel the resonant frequency with a Notch Filter so the Speed Regulator Bandwidth can be set high enough to meet system performance requirements.

1. Use these parameters to set the initial Torque Notch Filter values as shown.

PowerFlex 700S Torque Notch Initial Settings	PowerFlex 755 Torque Notch Initial Settings
Par 95 [SRegOut FiltGain] = 1	Par 637 [SReg FB Fltr Sel] = Off
...or	...or
Par 96 [SReg Out Filt BW] = 2000 rad/sec	Par 659 [SReg OutFltr BW] = 2000 rad/sec
Par 95 [SRegOut FiltGain] = 0.7	Par 658 [SReg OutFltrGain] = 0.7

2. Increase the Speed Regulator Bandwidth until the Speed Regulator becomes unstable and exhibits decaying or continuous sinusoidal oscillation in response to a step test.
3. Measure the frequency of the oscillation using Studio 5000 Logix Designer® application trending or an oscilloscope that is connected to the drive analog outputs.

Expand the time scale to allow measurement of the period or frequency of the resonant frequency.

When measuring the period of the oscillation, use the following equation to convert to frequency in Hertz:

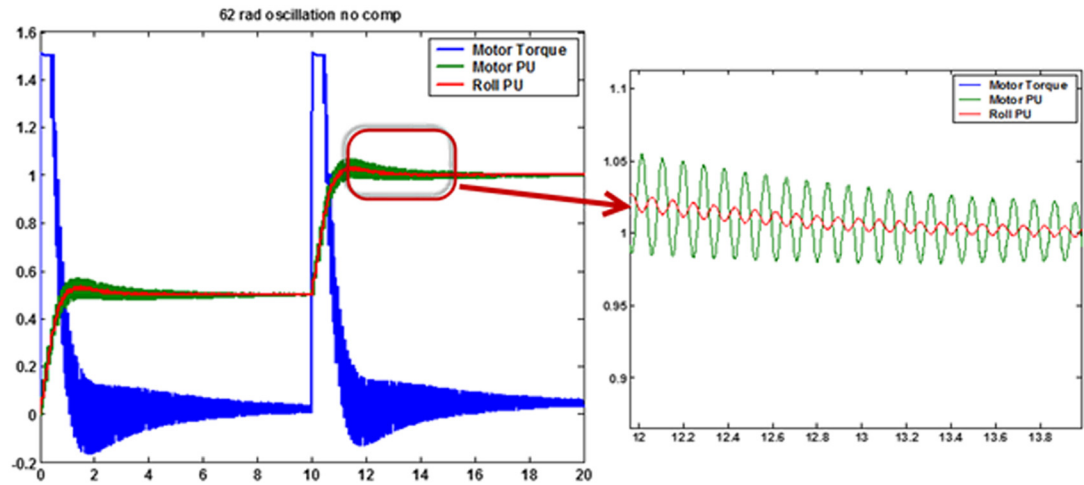
$$\text{Freq (Hz)} = 1 / \text{Period of 1 cycle (sec)}$$

It can be more accurate to measure the period of several (x) oscillation cycles to get an average frequency. Use the following equation:

$$\text{Freq (Hz)} = (x) / \text{Period of (x) cycle (sec)}$$

[Figure 62](#) shows step responses of a system with machine resonance oscillations. The expanded time trace is used to measure the period of the resonance oscillation. In this example, the dominant resonant frequency is approximately 10 Hz.

Figure 62 - Step Response with Resonance or Torsional Compliance Oscillation (without Notch Filter)



- 4. If multiple resonances have nearly the same amplitude, set the Notch Filter Frequency to the lowest resonant frequency.
- 5. Use the following parameter to set the Notch Filter center frequency to the frequency of the oscillation (in this example, Frequency = 10 Hz).

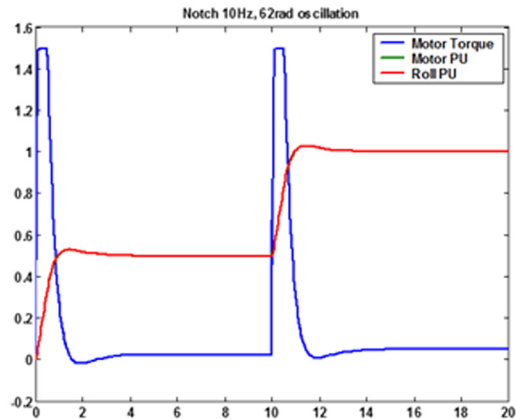
PowerFlex 700S Drive Torque Notch Filter Freq Parameter	PowerFlex 755 Drive Torque Notch Filter Freq Parameter
Par 118 [Notch Fltr Freq]	Par 687 [Notch Fltr Freq]

- 6. Use the following parameter to set the Notch Filter attenuation so it cancels the resonant frequency oscillation.

Use the PowerFlex maximum value, where Attenuation = 500.

PowerFlex 700S Drive Torque Notch Filter Attenuation Parameter	PowerFlex 755 Drive Torque Notch Filter Attenuation Parameter
Par 117 [NotchAttenuation]	Par 688 [Notch Fltr Atten]

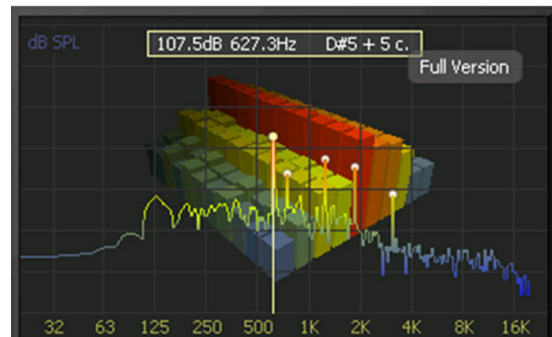
Figure 63 - Step Response with Notch Filter Enabled and Configured



## Tools for Determining Resonant Frequencies

It is also possible to measure the frequency of audible machine resonance oscillation by using an audio analyzer capable of Fast Fourier Transform (FFT) functionality. A software application to identify the dominant resonant frequencies can be installed on many smartphones and tablets. [Figure 64](#) shows an FFT measured by using software that is called iAnalyzer Lite™. This example screen shows that the predominant audible frequency is around 627 Hz, so the Notch Filter frequency would be set to  $\text{Freq} = 627 \text{ Hz}$ .

**Figure 64 - Screen Showing Notch Filter Frequency Using iAnalyzer Lite Software**



Consider the following important point about the use of FFT analyzer software in a drive application.

If the oscillation frequency is low ( $< 50 \text{ Hz}$ ), it is possible that the iAnalyzer Lite tool frequency bandwidth is not able to measure the amplitude of these frequencies. Then, it is necessary to use DriveObserver, Studio 5000 Logix Designer application trending, or an oscilloscope to identify and measure the resonant frequencies.

## Speed Regulator Lead/Lag Filters

The function of the Lead/Lag filter is to modify the gain of a system at certain frequencies, and to compensate for mechanical backlash, torsional compliance/resonance, and regulator characteristics. These factors can interact with the drive regulator loops to cause oscillations and instability.

The Lead/Lag filter can be used as a Lead/Lag or Lag/Lead function. The function depends on the values that are used for the Lead (wld) and Lag (wlg) frequencies. Some characteristics of the Lead/Lag function are shown in this table.

Function	Characteristic
Lag/Lead	Filters unwanted oscillations that are typically low frequency, which are caused by mechanical backlash. Also can be used to compensate for torsional compliance and resonance. However, the Notch Filter provides a simpler solution to tune out torsional compliance/resonance problems.
Lead/Lag	Used as a feed forward term to compensate for system lags, and to modify regulator rise time and the settling time response for specialized applications. System lags, caused by inner Velocity (Speed) Regulator Loop Bandwidth roll off when using outer position regulation loops, can be compensated for by using the position output Lead/Lag block. A discussion and example that is used for the position output Lead/Lag function is discussed in <a href="#">Inner Loop System Rolloff on page 90</a> , with an example of the Lead/Lag function in <a href="#">Lead/Lag Filter Application Example on page 92</a> .

There are two Lead/Lag filters that are associated with the Speed Regulator. One filter is in the velocity feedback path and a second filter is in the Speed Regulator output path (forward path). Any combination of either or both Lead/Lag filters can be used. [Figure 65](#) and [Figure 66](#) show the locations of the Lead/Lag filters (in red-highlighted notch filters) for the PowerFlex 700S and PowerFlex 755 drives respectively.

Figure 65 - PowerFlex 700S Drive Lead/Lag Filter Block Locations

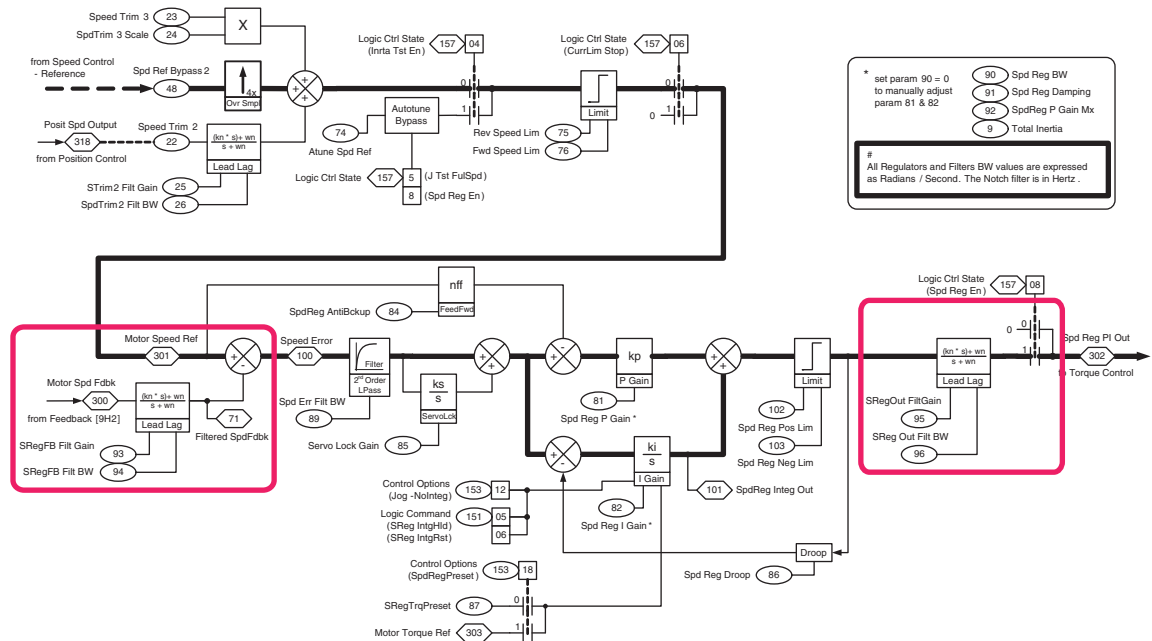
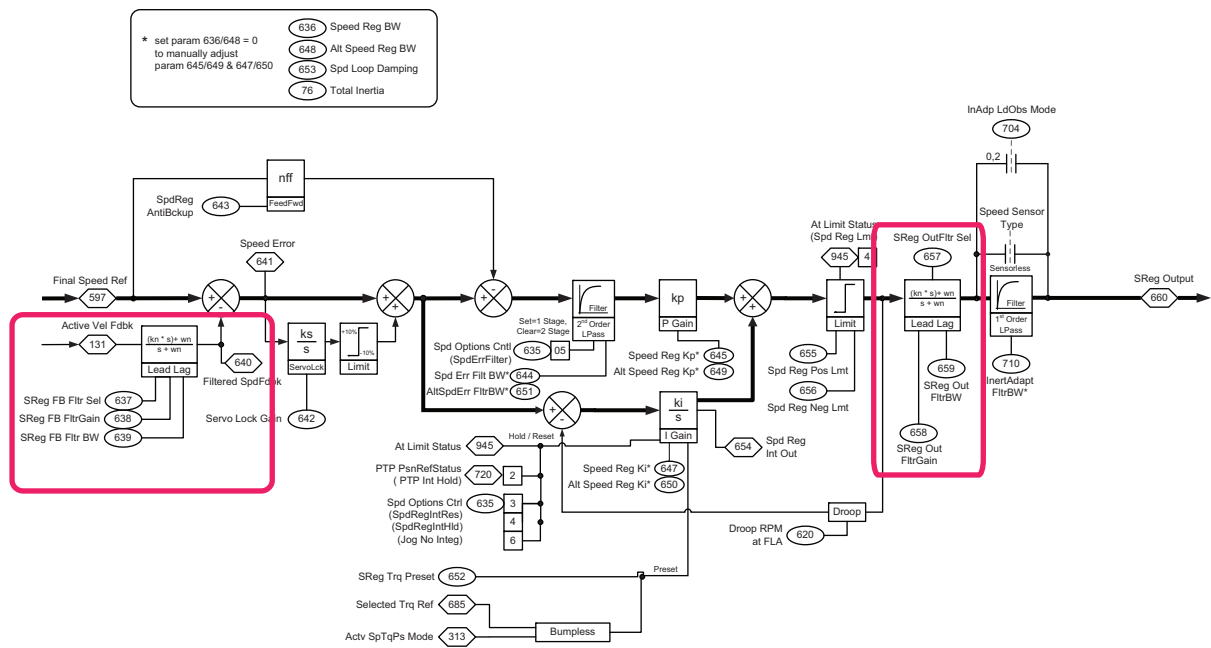
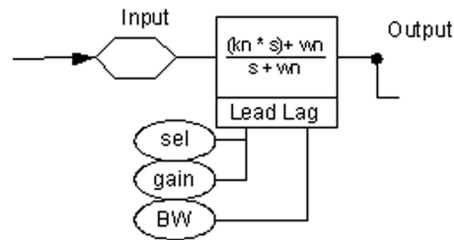


Figure 66 - PowerFlex 755 Drive Lead/Lag Filter Block Locations



The Lead/Lag filter block and transfer function is shown in [Figure 67](#), which is typical for PowerFlex 700S and PowerFlex 755 drives.

**Figure 67 - PowerFlex Lead/Lag Block Transfer Function and Parameters**

The Lead/Lag filters are first-order filters with 20 dB/decade decay. Using both filters at the same break frequencies effectively provides a second-order filter with 40 dB/decade slope. The transfer function within the Lead/Lag block that is shown in [Figure 67](#) is defined as follows:

$$G(s) = \frac{(kn \times s) + wn}{(s + wn)} = \frac{(gain \times s + BW)}{(s + BW)} = \frac{(1 + s/wld)}{(1 + s/wlg)}$$

Lead/Lag parameter definitions are as follows:

- ‘sel’ selects one of the following filter settings.

Setting	Description
Off	Disables the Lead/Lag function.
Light or Heavy	Presets the filter parameters for a Lag/Lead function.
Custom	Enables the filter parameters to be configured.

The PowerFlex 700S drive does not have this filter setting.

- ‘gain’ (kn) is the multiplier that sets the Lead break frequency (wld) relative to the Lag (wlg).

Gain (kn) Setting	Description
= 1.0	Disables or turns off (wlg = wld) the filter.
< 1.0	Sets filter to a Lag/Lead filter.
> 1.0	Sets filter to a Lead/Lag filter.

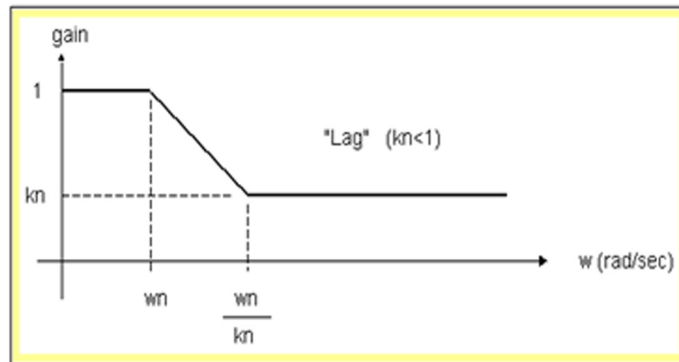
- ‘BW’ (wn) sets the filter Lag break frequency (wlg) in [rad/sec].

The Lead (wld) break frequency in [rad/sec] is calculated as:

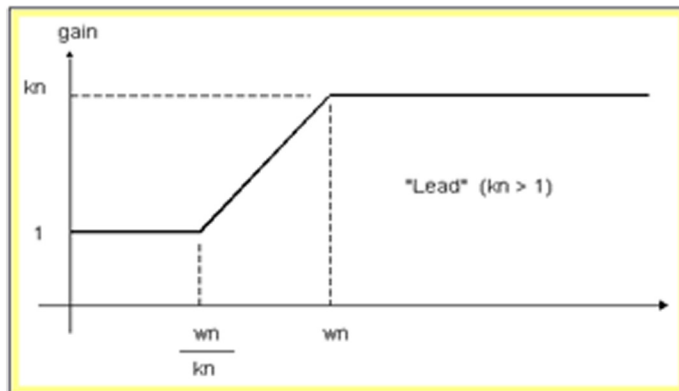
$$wld \text{ (rad/sec)} = \frac{\text{Filter BW (wn)}}{\text{Filter gain (kn)}} = \frac{wlg}{\text{Filter gain (kn)}}$$

If the filter gain (kn) is set = 1.0, the filter break frequencies are equal and the filter has unity gain for all frequencies, which effectively disables the filter.

If the filter gain (kn) is set < 1.0, the filter break frequencies are spaced so the Lag break frequency is lower than the Lead break frequency. This setting defines the filter as a Lag/Lead filter. [Figure 68](#) shows this effect.

**Figure 68 - Lead/Lag Filter Configured as a Lag/Lead Function**

If the filter gain ( $kn$ ) is set  $> 1.0$ , the filter break frequencies are spaced so the Lead break frequency is lower than the Lag break frequency. This setting defines the filter as a Lead/Lag filter. [Figure 69](#) shows this effect.

**Figure 69 - Lead/Lag Filter Configured as a Lead/Lag Function**

## Using the Lead/Lag Filter

As described in the basic Tuning Using Bandwidth ([Chapter 3](#)) and Manual Tuning ([Chapter 4](#)), the Speed Regulator Bandwidth/Proportional Gain is increased to improve the regulator performance. The speed feedback signal is observed for instability oscillation as the Speed Bandwidth/Proportional Gain parameter is increased. The instability oscillation can also cause audible noise and vibration from the machine. Backlash noise is typically low/mid frequency and varies with the speed bandwidth setting and load/motor inertia ratio. Mechanical backlash can be filtered by using the Speed Feedback Lead/Lag filter and/or the Speed Regulator Output Lead/Lag filter that is configured as a Lag/Lead filter.

If mechanical backlash is severe and cannot be reduced or minimized with the Lead/Lag filters, it can be necessary to implement the Inertia Adaption function. This feature is described in [PowerFlex Inertia Adaption on page 19](#).

### Lead/Lag Filter Presets

The PowerFlex 755 drive includes preset Lead/Lag filter settings that configure the filter as a Lag/Lead function with 'Light' or 'Heavy' filter settings.

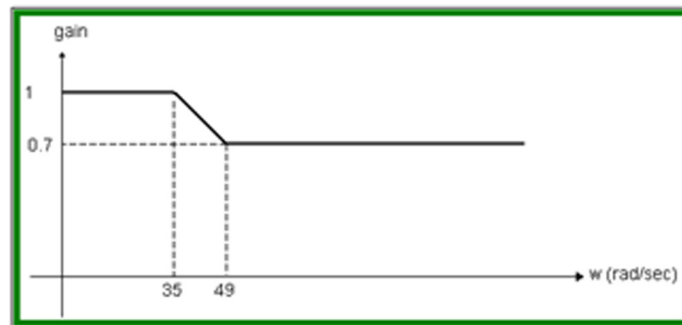
Try the Lead/Lag filter presets. Start with the Speed Feedback Lead/Lag filter set to 'Light'. If this reduces, but does not remove the backlash instability oscillation, set the Speed Regulator Output Lead/Lag filter to 'Light'.

If a more aggressive filter is required, use the 'Heavy' filter preset.

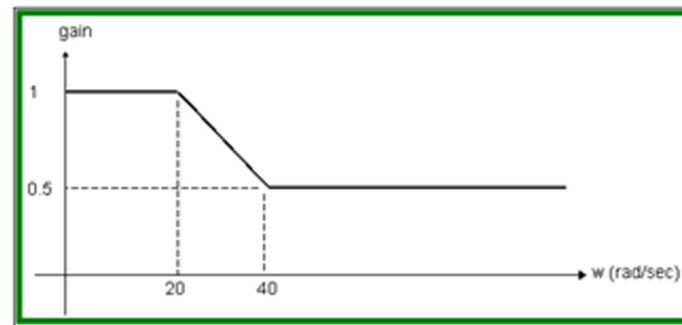
It is sometimes effective to set the Speed Feedback Filter and Speed Regulator Output filters to the same preset to achieve greater attenuation at the chosen frequencies. These same presets effectively create a second-order filter with -40 dB/decade overall gain.

PowerFlex 700S Drive Lead/Lag Filter Presets	PowerFlex 755 Drive Lead/Lag Filter Presets
No Parameter	Speed Fdbk Par 637 [SReg FB Fltr Sel] = 1 (Light) Speed Reg Out Par 657 [SReg OutFltr Sel] = 1 (Light) Lag/Lead Function w/BW ( $\omega_n$ ) = 35 rad/sec, gain ( $k_n$ ) = 0.7
No Parameter	Speed Fdbk Par 637 [SReg FB Fltr Sel] = 2 (Heavy) Speed Reg Out Par 657 [SReg OutFltr Sel] = 2 (Heavy) Lag/Lead Function w/BW ( $\omega_n$ ) = 20 rad/sec, gain ( $k_n$ ) = 0.5

**Figure 70 - Lag/Lead Filter Response with 'Light' Preset (one filter active, -20 dB/decade)**



**Figure 71 - Lag/Lead Filter Response with 'Heavy' Preset (one filter active, -20 dB/decade)**



Similar settings can be used for the PowerFlex 700S drive. Manually set the Lead/Lag filter BW ( $\omega_n$ ) and gain ( $k_n$ ) values to equal the preset values previously

described for the PowerFlex 755 drive. The next section describes the parameter numbers that are set for PowerFlex 700S and PowerFlex 755 drives when the 'Custom' setting is used.

### Custom Setting of Filter Parameters

When a PowerFlex 700S drive is tuned, or when the PowerFlex 755 drive preset filter settings do not correct the backlash instability oscillation, it is necessary to use custom settings for the Lead/Lag filter parameters.

PowerFlex 700S Drive Lead/Lag Filter Presets	PowerFlex 755 Drive Lead/Lag Filter Presets
No parameter; set filter gain and BW	Speed Fdbk: Par 637 [SReg FB Fltr Sel] = 3 (Custom) Speed Reg Out: Par 657 [SReg OutFltr Sel] = 3 (Custom) Set filter gain and BW using parameters
No parameter; set filter gain and BW	Speed Fdbk: Par 637 [SReg FB Fltr Sel] = 4 (SetCustLight) Speed Reg Out: Par 657 [SReg OutFltr Sel] = 4 (SetCustLight) Presets filter gain and BW with Light preset values, which can be modified by setting filter gain and BW using parameters.
No parameter; set filter gain and BW	Speed Fdbk: Par 637 [SReg FB Fltr Sel] = 5 (SetCustHeavy) Speed Reg Out: Par 657 [SReg OutFltr Sel] = 5 (SetCustHeavy) Presets filter gain and BW with Heavy preset values, which can be modified by setting filter gain and BW using parameters.

Use an initial value of 0.7 for the filter gain (kn) to configure the Lead/Lag filter as a Lag/Lead filter. If possible, measure the frequency of the speed feedback backlash instability oscillation. Then set the filter BW (wn) equal to the measured frequency in rad/sec because the filter BW (wn) parameter is actually the Lag break frequency (wlg).

If it is not possible to measure the frequency of the feedback noise, calculate a start value by using this equation:

$$\text{LL Filter BW (wn)} = 4 \times \left[ \text{Velocity Loop BW} \left( \frac{\text{rad}}{\text{sec}} \right) \right]$$

1. Use these parameters to reduce the filter BW (wn) frequency until the instability oscillation amplitude starts to be affected (lower amplitude).

PowerFlex 700S Drive Lead/Lag Filter Parameters	PowerFlex 755 Drive Lead/Lag Filter Parameters
Gain (kn) Par 93 [SRegFB Fltr Gain]	Gain (kn) Par 638 [SReg FB FltrGain]
BW (wn) Par 94 [SReg FB Fltr BW]	BW (wn) Par 639 [SReg FB Fltr BW]
Gain (kn) Par 95 [SRegOut FltrGain]	Gain (wn) Par 658 [SReg OutFltrGain]
BW (wn) Par 96 [SReg Out Fltr BW]	BW (wn) Par 659 [SReg OutFltr BW]

2. Use the parameters that are shown in the previous step to reduce the filter gain (kn) in small increments (0.1) until the instability oscillation is canceled.

It is now possible to increase the Speed Bandwidth (Velocity Loop BW) or proportional gain value (Kvp) to achieve better step response.



Repeat this procedure if instability occurs again after Speed Bandwidth is increased.

It is sometimes effective to set the Speed Feedback Filter and Speed Regulator Output filters with the same BW (wn) and gain (kn) settings to achieve greater attenuation at the selected frequencies. Using the same frequency effectively creates a second-order filter with -40 dB/decade overall gain.

See the [Lead/Lag Filter Application Example on page 92](#) for more information on setting the Lead/Lag compensation filters.

## Mechanical Backlash Application Example

A low frequency instability is apparent in the speed feedback and torque reference after a speed step is introduced, which can be due to mechanical backlash.

If a Lead/Lag filter is not used, it would be necessary to reduce the Bandwidth or Proportion Gain of the Speed Regulator below the frequency of this backlash. The result is a drive that cannot meet the system performance requirements.

If the instability can be removed with a Lead/Lag filter that is configured as a Lag/Lead filter, it is possible to increase the Bandwidth or Proportional Gain of the Speed Regulator. Then the required Speed Regulator Bandwidth can be set to meet system performance requirements.

The filter gain (kn) and BW (wn) or Lag (wlg) frequency values are entered into the drive. The Lead (wld) frequency is determined in the drive by the relative settings of the gain (kn) and BW (wn) as previously described.

### *Application with Load Ratio (R) < 12:1*

This example describes a system with moderate gear backlash and a load-to-motor inertia ratio (R) of < 12:1.

- The load inertia ratio (R) in this example is 6:1.
- The filter Lead frequency (wld) is set equal to the Speed Bandwidth setting at which the backlash oscillation starts or, in this case, Speed BW = wld = 49 rad/sec.
- The filter lag (wlg) frequency is calculated by the drive using the following equation:

$$wlg \left( \frac{\text{rad}}{\text{sec}} \right) = \sqrt{\frac{3}{R}} \times wld = \sqrt{\frac{3}{6}} \times 49 = 34.65 \text{ rad/sec}$$

- Equivalent gain and BW settings for the drive Lead/Lag filter function are calculated as follows:

$$\text{Gain (kn)} = \frac{wlg}{wld} = \frac{35}{49} = 0.7$$

$$\text{BW (kn)} = wlg = 35 \text{ rad/sec}$$

These settings are equivalent to using the PowerFlex 755 drive 'Light' filter preset selection.

#### *Application with Load Ratio (R) > 48:1*

This example describes a system with severe gear backlash and a load-to-motor inertia ratio (R) of > 48:1.

- The load inertia ratio (R) in this example is 50:1.
- The filter Lead frequency (wld) is set equal to the Speed Bandwidth setting at which the backlash oscillation starts or, in this case, speed BW = wld = 40 rad/sec.
- The filter lag (wlg) frequency is calculated by the drive using the following equation:

$$wlg \left( \frac{\text{rad}}{\text{sec}} \right) = \frac{wld}{2} = \frac{40}{2} = 20 \text{ rad/sec}$$

- Equivalent gain and BW settings for the drive Lead/Lag filter function are calculated as follows:

$$\text{Gain (kn)} = \frac{wlg}{wld} = \frac{20}{40} = 0.5$$

$$\text{BW (kn)} = wlg = 20 \text{ rad/sec}$$

These settings are equivalent to using the PowerFlex 755 drive 'Heavy' filter preset selection.

## Inner Loop System Rolloff

Inner loop system rolloff can occur when manually tuning. Consider that ideal control loop spacing between Velocity (Speed) Regulator and Position Regulator loops is approximately 4:1.

However, because of Velocity (Speed) Regulation Bandwidth rolloff, it may not be possible to achieve the desired position regulator loop spacing. The inner loop system rolloff occurs when the required Position Loop Bandwidth approaches the actual Velocity (Speed) Regulator Bandwidth, and the desired 4:1 Loop Bandwidth spacing cannot be achieved. The Velocity (Speed) Regulation Bandwidth rolloff causes a system Lag near the -3 dB closed loop frequency. This Lag causes sufficient phase shift such that the Position Regulator becomes unstable and oscillates.

It is necessary to compensate for the Velocity (Speed) Regulator Bandwidth rolloff (which is a Lag) by using the position Lead/Lag filter. The position Lead/Lag filter is shown in [Figure 72](#) (for PowerFlex 700S drives) or [Figure 73](#) (for PowerFlex 755 drives).

Figure 72 - PowerFlex 700S Drive Position Lead/Lag Filter

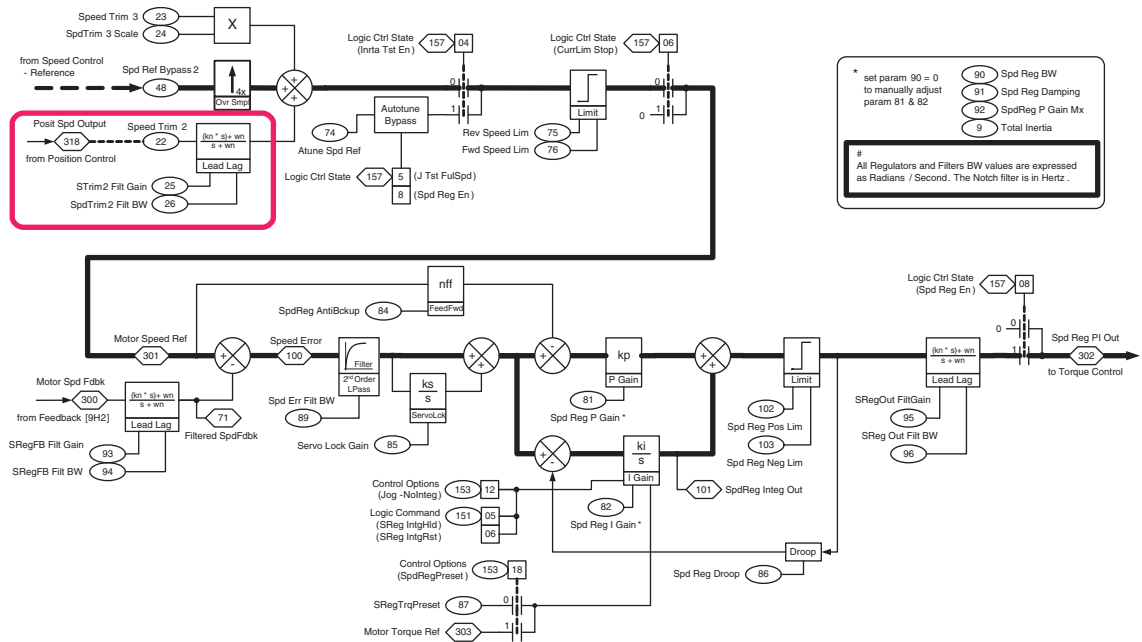
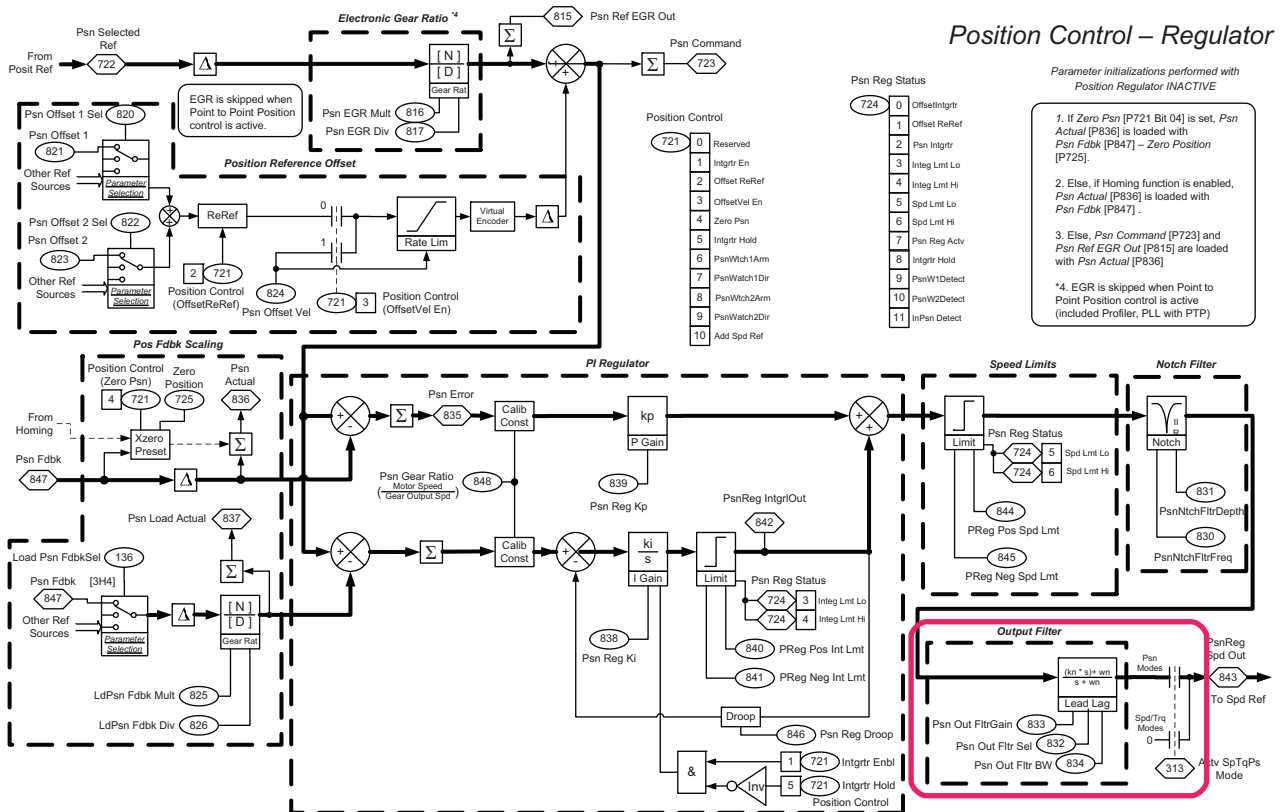


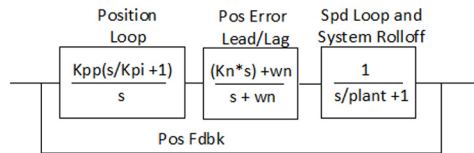
Figure 73 - PowerFlex 755 Drive Position Lead/Lag Filter



## Lead/Lag Filter Application Example

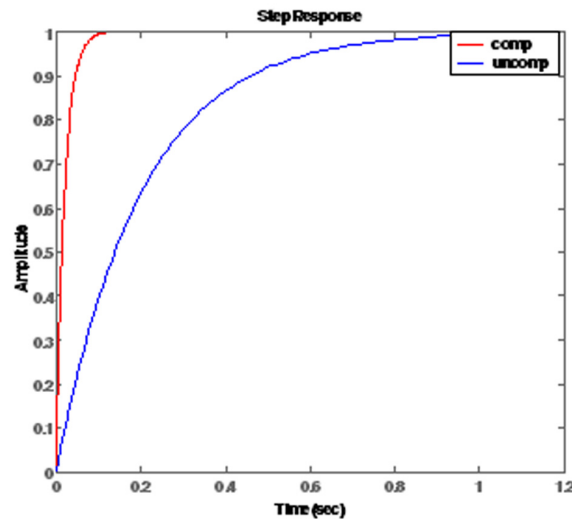
A system is composed of a drive with an outer Position Regulator Loop and an inner Speed Regulator Loop. The closed loop Speed Regulator Bandwidth and other system rolloff terms are shown in [Figure 74](#) as the 'plant' term. The 'plant' represents a lag in the overall regulation scheme that is usually equal to the Speed Regulator actual closed loop bandwidth.

**Figure 74 - Position Outer Loop with Speed Minor Loop (plant)**



Review [Figure 75](#). The step response of the outer Position Loop has a slow rise time due to low position proportional gain ( $K_{pp}$ ) as shown by the blue (uncompensated) position step response trace. Because of speed regulation tuning, the necessary position regulator performance cannot be met (4:1 loop spacing).

**Figure 75 - Lead/Lag Filter (comp) Versus No Lead/Lag Filter (uncomp)**



It is necessary to cancel the 'plant' system rolloff using the position error Lead/Lag filter so the outer position regulator gain can be set high enough to meet system performance requirements. The Position Regulator output Lead/Lag filter is configured as a Lead/Lag filter.

In this example, the 'plant' system rolloff closed loop bandwidth (-3 dB) frequency is roughly 5 rad/sec.

- The PowerFlex position error Lead/Lag filter is configured as a Lead/Lag filter with the Lead (wld) frequency set equal to the plant closed loop bandwidth, or  $wld = 5$  rad/sec.
- The BW (wn) or wlg is set between 5 and 10 times the Lead (wld) frequency or roughly 50 rad/sec.

- Equivalent Lead/Lag filter gain (kn) and BW (wn) settings for the position error Lead/Lag filter are as follows:
  - Gain (kn) = 10
  - BW (wn) or wlg = gain (kn) x wld = 10 x 5 rad/sec = 50 rad/sec

The position step response is improved by a factor of 10x as shown by the red (comp) position step response trace in [Figure 75](#).

## **Notes:**

## Encoder Feedback Filters

Encoder feedback filters are low pass filters that reduce the level of noise from the feedback device. These filters are not used specifically in tuning regulator loops. However, if unused or set improperly, the encoder feedback filters can cause the regulator loops to become unresponsive or unstable.

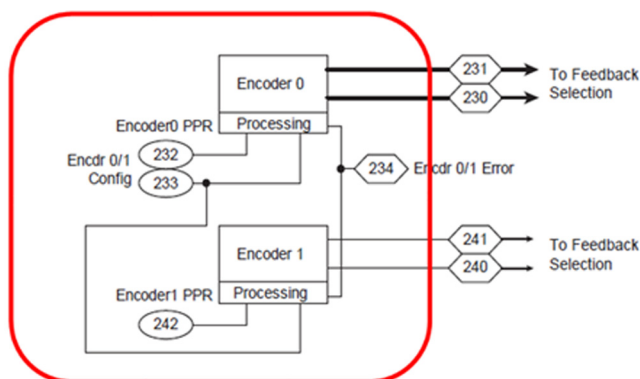
### PowerFlex 700S Drive Encoder Feedback Filter

There are two components to the PowerFlex 700S drive encoder feedback filter:

- A hardware filter time constant that requires the input signal to be stable for the specified time.
- An FIR Low Pass Filter that reduces the level of noise on the encoder feedback signal.

Par 233 [Encdr 0/1 Config] configures the encoder feedback filters to adjust the filter settings that are applied to the motor velocity feedback source.

**Figure 76 - PowerFlex 700S Drive Encoder Feedback Processing**



## Hardware Filter Time Constant

The hardware filter time constant requires the input signal to be stable for the specified time period that is shown in this figure.

**Figure 77 - Encoder 0/1 Feedback Processing Filter Settings (Encoder 1 shown)**

3/19	2/18	1/17	0/16	Encoder Bit Filter Settings
0	0	0	0	Filter disabled
0	0	0	1	100 ns filter
0	0	1	0	200 ns filter
0	0	1	1	300 ns filter
0	1	0	0	400 ns filter
0	1	0	1	500 ns filter
0	1	1	0	600 ns filter
0	1	1	1	700 ns filter
1	0	0	0	800 ns filter (default setting)
1	0	0	1	900 ns filter
1	0	1	0	1000 ns filter
1	0	1	1	1100 ns filter
1	1	0	0	1200 ns filter
1	1	0	1	1300 ns filter
1	1	1	0	1400 ns filter
Bit	1	1	1	1500 ns filter

When setting the Hardware Filter Time Constant, consider the following:

- Input transitions within the filter time setting are not processed by the drive.
- The default (800 ns) must not be modified unless a high resolution (high PPR) encoder is used, or there are high motor speeds.

To adjust the filter, if necessary, set Bits 0...3 and/or Bits 16...19 of Par 233 [Encdr 0/1 Config] as shown in [Figure 77](#) and the following table.

Encoder 0: Par 233 [Encdr 0 Config], Bits 0...3	Configures the encoder 0 input signal filter time constant.
Encoder 1: Par 233 [Encdr 1 Config], Bits 16...19	Configures the encoder 1 input signal filter time constant.

## PowerFlex 700S Drive FIR Filter

The FIR (Finite Impulse Response) Filter is a special type of low pass filter that reduces overall velocity feedback noise. The FIR Filter uses a 'number of taps' setting. This 'number of taps' value represents an amount of internal processing to achieve a given filtering response.

This filter must be set to a value higher than the Velocity (Speed) Regulator Bandwidth. To adjust the FIR Filter, change Bits 10...12 or Bits 26...28 of Par 233 [Encdr 0/1 Config] as shown in [Figure 78](#) and in this table.

Encoder 0: Par 233, Bits 10...12 (En0SmplRtb)	Configures the encoder 0 FIR Filter.
Encoder 1: Par 233, Bits 26...28 (En1SmplRtb)	Configures the encoder 1 FIR Filter.

- If Par 146 [FW TaskTime Sel] = 0 or 1 (0.5 ms for task 1), we recommend setting the FIR Filter to 8 taps. This sets the noise bandwidth to 120 rad/sec.



- If Par 146 [FW TaskTime Sel] = 2 (0.25 ms for task 1), we recommend setting the FIR Filter to 16 taps. This sets the noise bandwidth for 120 rad/sec.

Use [Figure 78](#) to pair the setting of the FIR Filter and Speed Error Filter Par 89 [Spd Err Filt BW].

**Figure 78 - PowerFlex 700S Drive FIR and Speed Error Filter Settings**

FIR and P89 [Spd Err Filt BW] Settings when P146 [FW TaskTime Sel] = 0 or 1:

FIR filter setting (taps)	1	2	4	8	16	32	64	127
Spd Err Filt BW (rad/sec)	2000	1500	1300	600	300	150	75	38
Noise bandwidth (rad/sec)	400	300	220	120	60	30	18	8

FIR and P89 [Spd Err Filt BW] Settings when P146 [FW TaskTime Sel] = 2:

FIR filter setting (taps)	1	2	4	8	16	32	64	127
Spd Err Filt BW (rad/sec)	4100	3200	2200	1300	600	300	150	75
Noise bandwidth (rad/sec)	690	530	380	240	120	60	30	15

Bit	12/28	11/27	10/26	Taps
0	0	0	0	1
0	0	1	2	
0	1	0	4	
0	1	1	8	
1	0	0	16	
1	0	1	32	
1	1	0	64	
1	1	1	127	

Speed Regulator Bandwidth settings greater than 120 rad/sec may not be effective. In some cases, it is necessary to increase the filter noise bandwidth to allow a Speed Regulator Bandwidth higher than 120 rad/sec. Use Par 89 [Spd Err Filt BW] to change the FIR Filter and Speed Error Filter setting to achieve a higher noise bandwidth according to the tables in [Figure 78](#).

## Configuring the FIR Filter in the PowerFlex 700S Drive

1. Determine if the hardware filter time constant requires change.  
Do not modify the default (800 ns) unless a high resolution (high PPR) encoder is used, or there are high motor speeds. See [Hardware Filter Time Constant on page 96](#) to configure the hardware filter time constant.
2. Use DriveObserver, Studio 5000 Logix Designer application trending, or a scope-meter that is connected to the drive analog output to monitor Par 300 [Motor Spd Fdbk], the speed feedback signal.
3. Operate the drive in open loop (V/Hz or sensorless vector) control mode.
4. See [Figure 78](#) and start with a value in Par 233 [Encdr 0/1 Config], Bits 10...12 for Encoder 0 and Bits 26...28 for Encoder 1, which provides a filter frequency that is greater than the value of Par 90 [Spd Reg BW].
5. Observe the noise on the speed feedback analog signal and decrease the value in Par 233 [Encdr 0/1 Config], Bits 10...12 for Encoder 0 and Bits 26...28 for Encoder 1, to a value that reduces the level of noise to less than 0.1% of the maximum speed feedback signal.
6. Set the FIR Filter as high as possible because it affects the maximum bandwidth setting for the Speed Regulator.

The higher the number, the less filtering is applied, which helps ensure that:

$$\text{FIR Filter Noise Bandwidth} \geq \text{Par 90 [Spd Reg BW]}$$

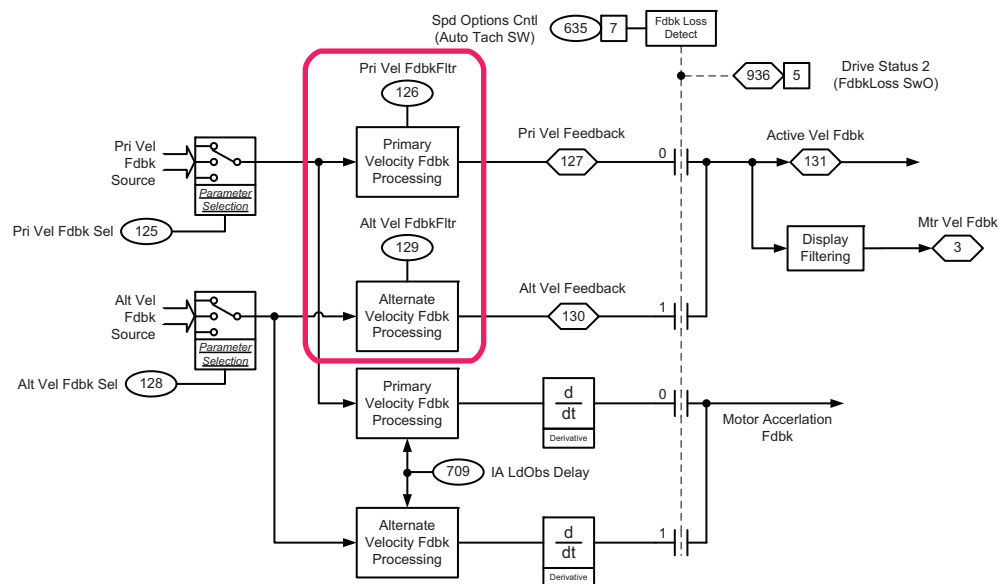
7. Pair the settings of the FIR Filter and Speed Error Filter Par 89 [Spd Err Filt BW] as shown in [Figure 78](#).
8. If a filtering value is fewer than 32 taps, check the encoder device, cable type, shield grounding, and routing practice.

Correct hardware problems and readjust the filter to the highest possible value.

## PowerFlex 755 Drive Encoder Feedback Filter

The Velocity Feedback processing filter is a moving average type filter that has a delay setting of N, where N is an integer number (0, 1, 2, ...) that is applied to the primary and alternate velocity feedback. The purpose of this filter is to reduce the level of noise in the velocity feedback signals.

**Figure 79 - PowerFlex 755 Drive Encoder Feedback Processing**



Setting N = zero provides minimal Velocity Feedback filtering and no significant delay. Larger values of N result in more filtering and more delay.

The noise frequency of this filter should be set as high as possible because it affects the maximum bandwidth setting for the Speed Regulator. The higher Velocity Feedback noise filter frequency (lower N), the less filtering is applied.

When the Flux Vector induction or PMag motor control selections for Par 35 [Motor Ctrl Mode] = 3, 6, or 10, and Par 636 [Speed Reg BW] is set:

- To a nonzero value, Par 644 [Spd Err Filt BW] is automatically set based on the N value used in the Velocity Feedback Filter N setting.
- To a zero value or Par 704 [InAdp LdObs Mode] = 1 (InertiaAdapt), then Par 644 [Spd Err Filt BW] must be set manually.

The automatic setting of Par 644 [Spd Err Filt BW] becomes independent of the Velocity Feedback Filter N setting when Par 636 [Speed Reg BW] = 0 or Par 704 [InAdp LdObs Mode] = 1 (InertiaAdapt).

## Configuration Steps

1. Use a scope-meter that is connected to the drive analog output to monitor Par 131 [Active Vel Fdbk], the speed feedback signal.  
If this is not possible, use DriveObserver.
2. Operate the drive in open loop (V/Hz or sensorless vector) control mode.
3. Observe the noise on the speed feedback analog signal.
4. Set Par 126 Pri Vel FdbkFltr] or Par 129 [Alt Vel FdbkFltr]) so that the level of noise is less than 0.1% of the maximum speed feedback signal.

**Figure 80 - Settings for Par 126 [Pri Vel FdbkFltr]**

Options: Default 3 =  
 0 = "190R/S Noise"  
 1 = "160R/S Noise"  
 2 = "100R/S Noise"  
 3 = "50R/S Noise"  
 4 = "25R/S Noise"  
 5 = "12R/S Noise"  
 6 = "6R/S Noise"  
 7 = "3R/S Noise"

The optimum setting for the Velocity Feedback Filter depends on the level of noise in the feedback signal and the bandwidth setting of the Velocity Regulator.

The Velocity Feedback Filter must be set so that:

$$\text{Vel Fdbk Filter Noise Frequency} \geq \text{Par 636 [Speed Reg BW]}$$

5. If a filtering N value is less than '2', check the encoder device, cable type, shield grounding, and routing practices.  
Correct hardware problems and readjust the filter to the highest possible value.

## **Notes:**

## PowerFlex 755 Drive and CIP

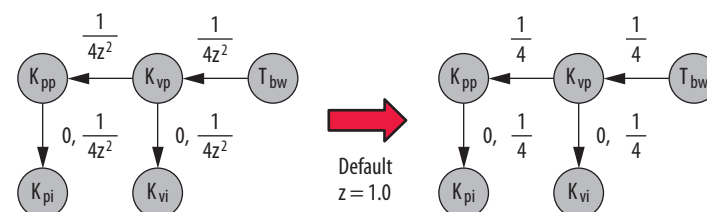
### Using CIP Motion Control Loop Relationships with PowerFlex Drives

It can be useful to use CIP gain values, which are units of Hz, and convert them into rad/sec (and vice-versa). PI loop gains in PowerFlex 755 CIP Motion drives are based on traditional PI control loops. Thus, when using a PowerFlex (non-CIP) drive and converting PowerFlex (non-CIP) units to Hz, the units become meaningful and provide usable relationships between loops. In fact, the CIP loop relationships can be applied to the PowerFlex gains after they are converted to Hz. The CIP gains can be entered into the PowerFlex drive by using these conversions. Consider a comparison of the final PowerFlex tuning parameters (after completion of [Chapter 3](#) or [Chapter 4](#)) to a model set of gains from a CIP control loop.

**Table 3 - Conversion of CIP Gains to PowerFlex Units**

PowerFlex Drive Gain Value	Calculation
$K_{vp}$	$K_{vp} \text{ (CIP in Hz)} \times 2\pi \times Jt \text{ (Par 76 [Total Inertia in sec])}$
$K_{vi}$	$[K_{vp} \text{ (CIP in Hz)} \times 2\pi] \times Jt \text{ (Par 76 [Total Inertia in Hz])} \times [K_{vi} \text{ (CIP in Hz)} \times 2\pi]$ or... $K_{vp} \text{ (PowerFlex Drive)} \times [K_{vi} \text{ (CIP)} \times 2\pi]$
$K_{pp}$	$[K_{pp} \text{ (CIP in Hz)} \times 2\pi]$
$K_{pi}$	$K_{pp} \text{ (CIP)} \times 2\pi \times K_{pi} \text{ (CIP)} \times 2\pi = K_{pp} \text{ (PowerFlex Drive)} \times K_{pi} \text{ (CIP)} \times 2\pi$ or... $[K_{pp} \text{ (PowerFlex Drive)}]^2 \div 4Z^2$

**Figure 81 - CIP Motion Loop Relationships for Rigid Auto Tune Configuration**



## Example of Rationalizing PowerFlex Gains to CIP Gains

After tuning is complete, use the CIP drive relationships to compare or rationalize the PowerFlex 755 drive gains.

PowerFlex drive, motor, and load characteristics are as follows:

- 5:1 load ratio
- $J_t = 0.096$  sec
- $K_v$  (PowerFlex Drive) = 74
- $K_v$  (PowerFlex Drive) = 0 (1/sec)
- $K_{pp}$  (PowerFlex Drive) = 200 rad/sec
- $K_{pi}$  (PowerFlex Drive) = 10000
- $Z = 0.8$

$$K_v \text{ (PowerFlex Drive)} = K_v \text{ (CIP)} \times 2\pi \times J_t \text{ (Par 76 [Total Inertia])}$$

$$K_v \text{ (CIP)} = \frac{K_v \text{ (PowerFlex Drive)}}{2\pi \times J_t} = \frac{74}{0.603} = 122.7 \text{ Hz}$$

Now,  $K_v = 122.7$  Hz and the CIP rules show the  $K_{pp}$  (CIP) is close to 4 times smaller than  $K_v$ , so  $K_{pp}$  (CIP) should be approximately 30 Hz. When converted to PowerFlex units, a gain is provided that should be acceptable, reviewing the value of  $K_{pp}$  (PowerFlex Drive) = 200.

$$K_{pp} \text{ (PowerFlex Drive)} = [K_{pp} \text{ (CIP)} \times 2\pi]$$

$$K_{pp} \text{ (CIP)} = \frac{K_{pp} \text{ (PowerFlex Drive)}}{2\pi} = \frac{200}{2\pi} = 31.8 \text{ Hz}$$

Now,  $K_{pp}$  (CIP) = 31.8 Hz, so  $K_{pi}$  (CIP) can be calculated as follows:

$$K_{pi} \text{ (PowerFlex Drive)} = [K_{pp} \text{ (CIP)} \times 2\pi] \times [K_{pi} \text{ (CIP)} \times 2\pi]$$

$$K_{pi} \text{ (CIP)} = \frac{K_{pi} \text{ (PowerFlex Drive)}}{K_{pp} \text{ (CIP)} \times 4\pi^2} = \frac{10000}{31.8 \times 4 (\pi^2)} = 7.96 \text{ Hz}$$

The value of the tuned  $K_{pi}$  (PowerFlex) is also in the range of the  $K_{pi}$  (CIP) rules.

## PowerFlex 755 CIP Motion Drive Configuration

The PowerFlex 755 CIP (Common Industrial Protocol, also known as real-time Motion) drive configuration is shown in this appendix. Regulator Loops, tuning functions, and filtering properties of the PowerFlex 755 CIP drive are not discussed in this publication. The PowerFlex 755 CIP motion drive follows the motion tuning rules and properties, so it behaves like a CIP Kinetix® Servo drive. For the proper methods to tune and apply filters to a CIP Kinetix Servo drive, see Motion System Tuning Application Techniques, publication [MOTION-AT005](#).

The PowerFlex 755 drive hardware does not have a specific build for CIP Motion. In fact, any PowerFlex 755 drive can be used for a CIP Motion configuration. The CIP Motion configuration is invoked when the drive device is created in the Logix controller, inside of Studio 5000 Logix Designer application.

This is described in [PowerFlex 755 CIP Motion Drive Setup](#) and [Drive Creation and Configuration](#). When the CIP motion configuration is used, the PowerFlex 755 drive rules and parameters are set as required by CIP Motion and the CIP Axis Object. An Ethernet connection is made to the PowerFlex 755 drive using its embedded Ethernet port. Or, when a Dual-port Ethernet option module (catalog number 20-750-ENETR) is installed, the module is set to 'tap' mode, and the Ethernet jumper is installed from ENET3 on the dual-port module to the embedded Ethernet port on the PowerFlex 755 drive.

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**IMPORTANT** When a PowerFlex 755 drive is configured for use in CIP motion mode, its characteristics and parameters as described in this document are disabled.

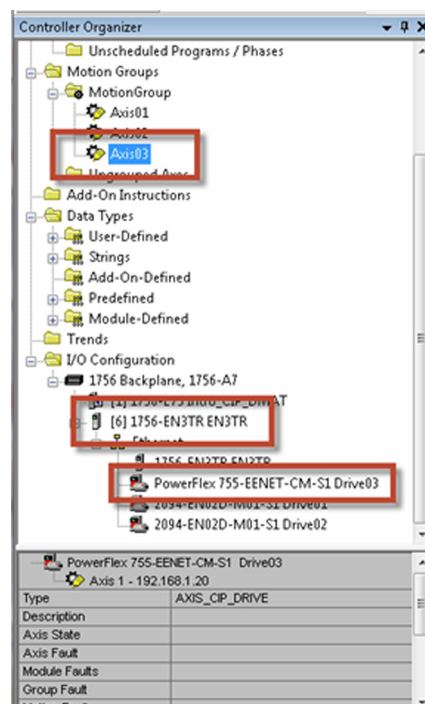
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For tuning and filtering properties of the PowerFlex 755 CIP Motion drive, see Motion System Tuning Application Techniques, publication [MOTION-AT005](#). For comprehensive information on the PowerFlex 755 CIP drive, see the PowerFlex 750 Reference Manual, publication [750-RM002](#).

## PowerFlex 755 CIP Motion Drive Setup

The drive is set up entirely by using Studio 5000 Logix Designer application. For setup details, see Integrated Motion on the EtherNet/IP Network Configuration and Startup User Manual, publication [MOTION-UM003](#). This document describes a simple configuration example and key characteristics. This configuration consists of a hardware setup and a software setup (Motion Group + Axis). The key Controller Organizer settings are highlighted in this figure.

**Figure 82 - Logix Controller Organizer Configuration Settings**



Some hardware requirements include:

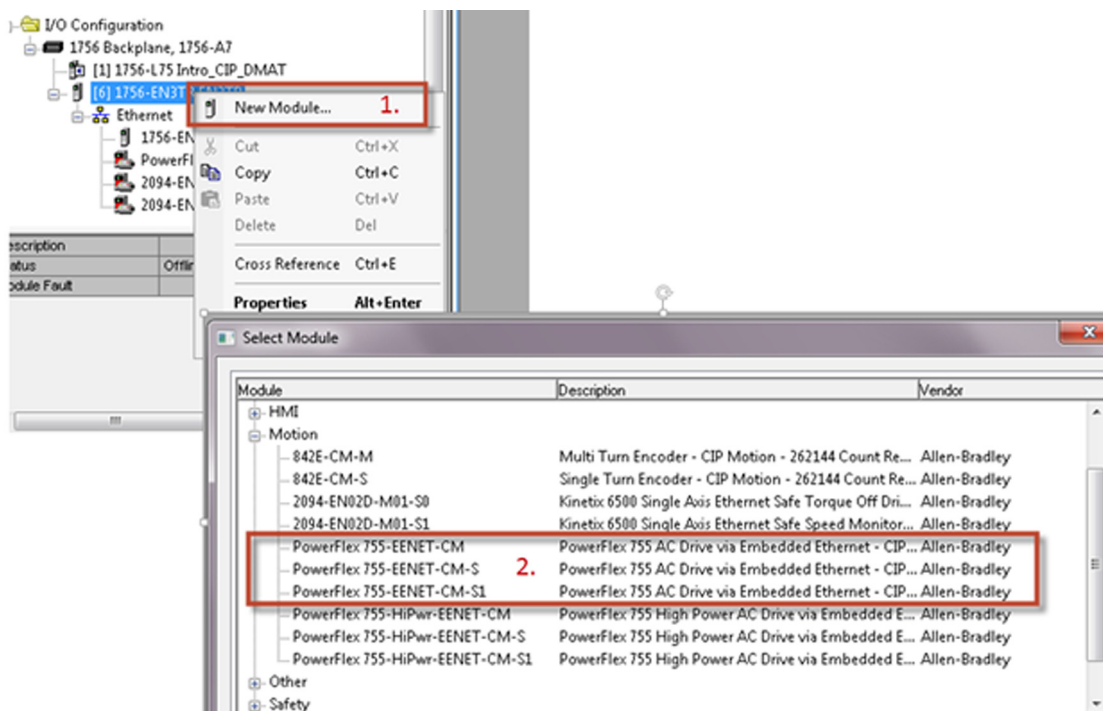
- A minimum of EN2T/R (8 CIP axes total) or EN3T/R (128 CIP axes total). A CIP axis is considered a PowerFlex CIP drive setup with closed loop control and not operating as V/Hz.
- Option Modules—presently the PowerFlex 755 CIP Motion drive supports up to two feedback modules and one safety module. See the following table for detailed slot locations.

**Table 4 - PowerFlex 755 Drive Slot Locations for Feedback and Safety Functions**

Description	Single Incremental Encoder 20-750-ENC-1	Dual Incremental Encoder 20-750-DENC-1	Universal Feedback 20-750-UFB-1	Safety (-S or -S1)
Non-safety	Slots 4...8	Slots 4...8	Slots 4...8	—
Safe Torque-off (-S)	Slot 4 or 5	Slot 4 or 5	Slot 4 or 5	Slot 6
Safe Speed Monitor (-S1)	Slot 4 or 5	Slot 4 or 5	Slot 4 or 5	Slot 6

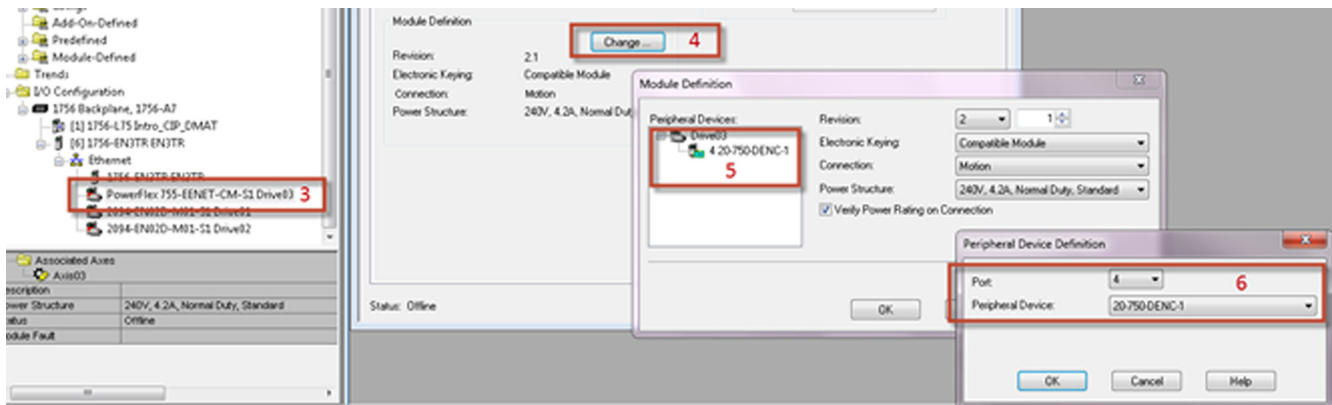
## Drive Creation and Configuration

1. Right-click ENxT/R and choose New Module.
2. Choose the appropriate CIP drive Model.  
CM indicates CIP Motion.

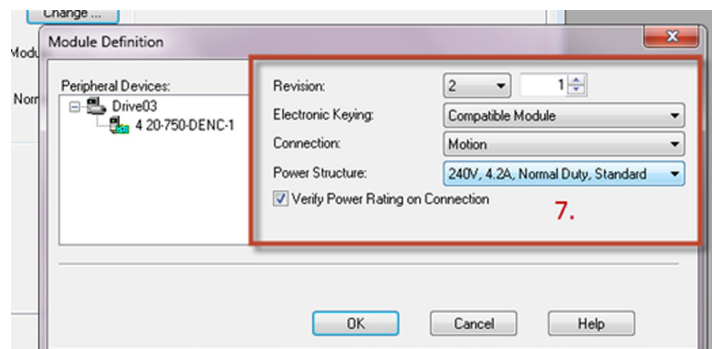




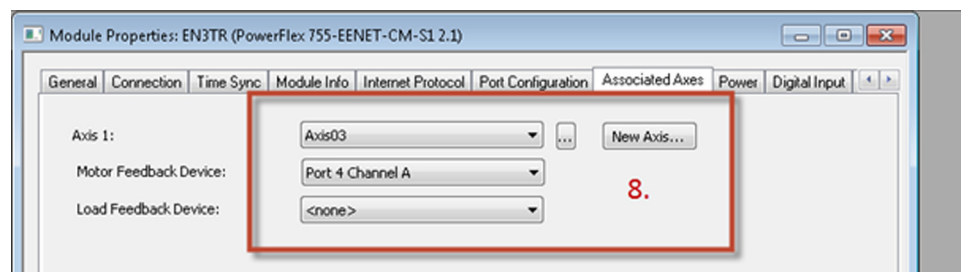
3. Double-click the PowerFlex drive and set the IP address of the drive on this menu.
  4. Click Change.
  5. Double-click the Encoder location.
  6. From the Peripheral Device Definition pull-down menu, add a new, or change the Encoder Port and Peripheral Device catalog number.
- Click OK.



7. Verify the Revision, choose the Electronic Keying method, and choose the correct power structure (frame and voltage).

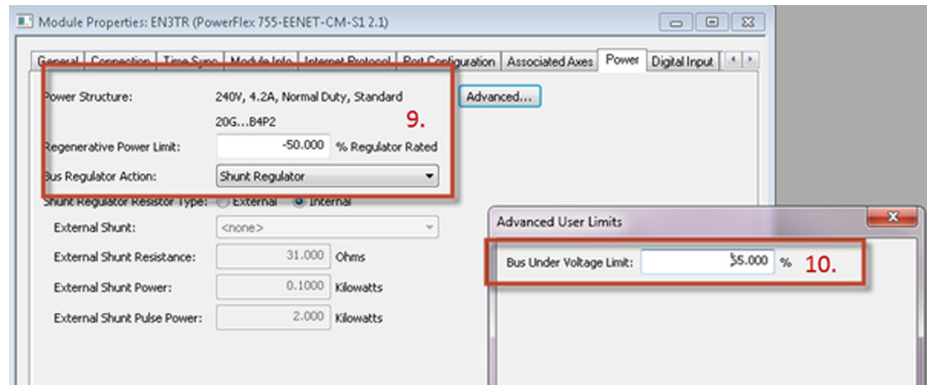


8. From the Module Properties dialog box, click the Associated Axes tab and verify the physical configuration of your drive, including if there is a 'dual loop' function (using the Load side with an auxiliary encoder), or single loop closure (Motor Feedback Device shown here).

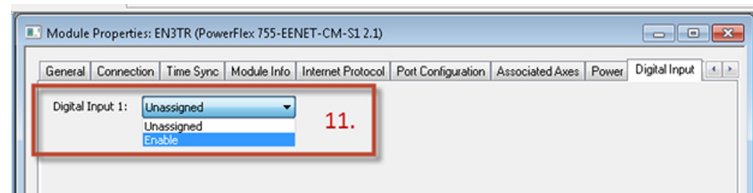


For more details and configurations, see Chapter 4 of Integrated Motion on the EtherNet/IP Network Configuration and Startup User Manual, publication [MOTION-UM003](#).

9. From the Module Properties dialog box, click the Power tab and set the parameters as required.
10. Click Advanced and change the Bus Under Voltage Limit to -200%.



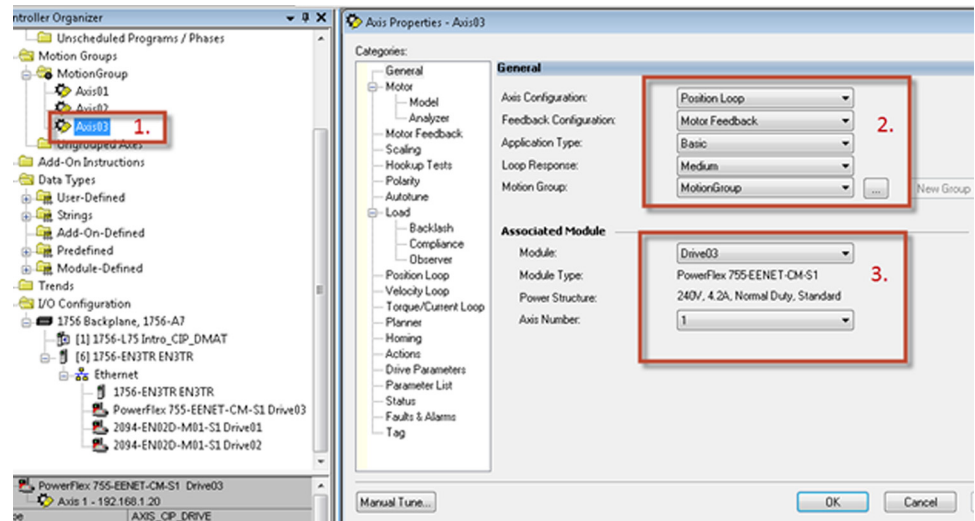
11. From the Module Properties dialog box, click the Digital Input tab and select whether the hardware enable is used or unassigned.



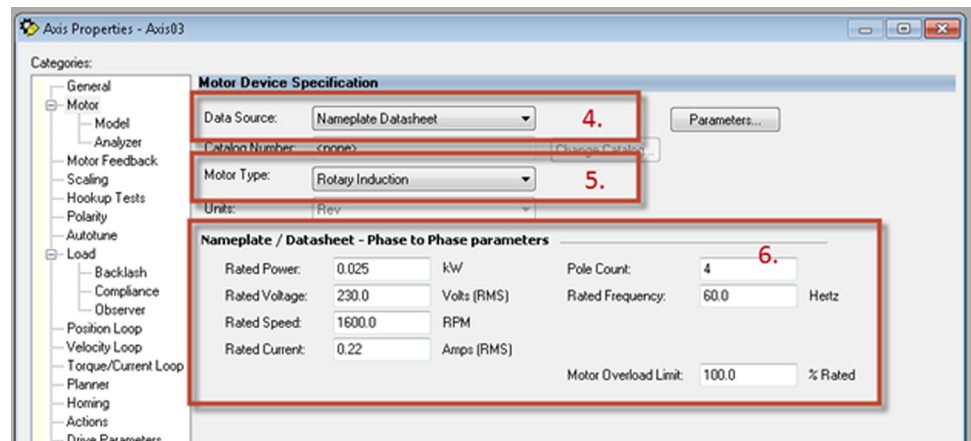
## PowerFlex 755 CIP Motion Axis Configuration

1. In the treeview, create or double-click the Axis (AXIS\_CIP\_DRIVE).
2. In the Axis Properties dialog box, verify that the axis uses a Position or Velocity Loop axis configuration, and verify the other data field selections in the General section.
3. In the Associated Module section, verify the Module (Drive03) is 'tied' to the Axis Object (Axis03).

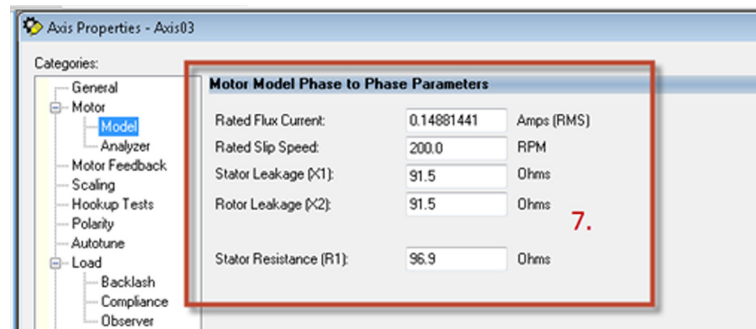
Also verify the power structure (frame and voltage) previously set in [step 7](#) of [Drive Creation and Configuration on page 104](#), and the Axis Number.



4. In the treeview, click 'Motor' and select the source for the motor data.  
With some intelligent motor encoders, the motor nameplate data can be populated automatically. In this example, the data is entered manually.
5. From the Motor Type pull-down menu, choose the motor type.  
Induction or PM motor types are available to use with this drive.
6. Enter the nameplate data from the motor.  
This data is available from the motor nameplate.



7. In the Motor treeview, click Model to either enter the data for the motor, or click Calculate Model Test to calculate this information.



8. In the Motor treeview, click Analyzer and, with the motor detached from the load, click Start.

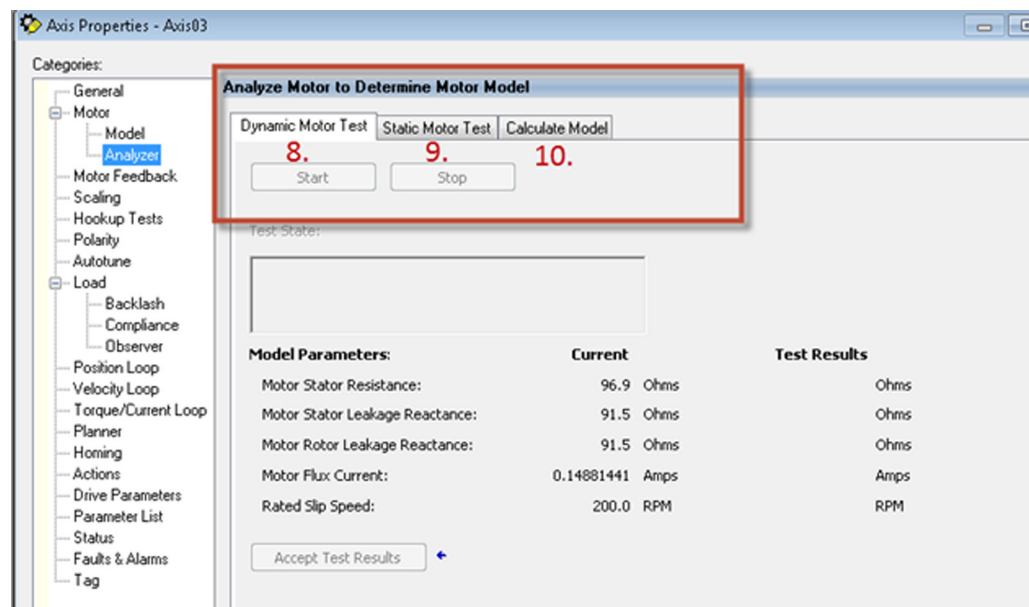
The motor spins and measures the information that is required. After the test is finished, click Accept Test Results.

9. If the load is unable to be detached from the motor, execute the Static Motor Test.

After the test is finished, click Accept Test Results.

10. If the information from [step 7](#) is not available from the motor data sheets, click Calculate Model, and then click Start to measure this information.

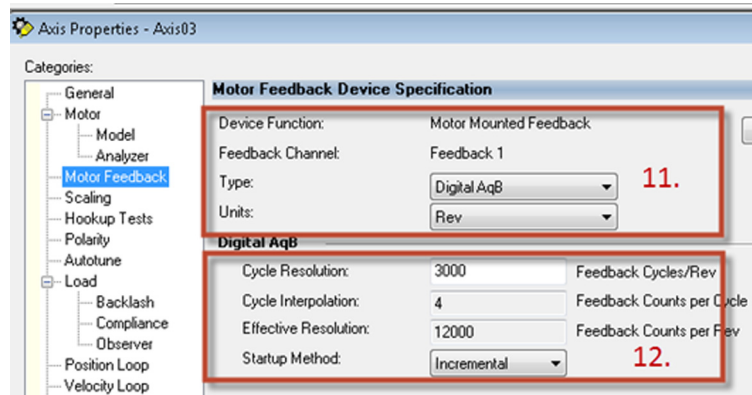
After the test is finished, click Accept Test Results.



11. In the treeview, click Motor Feedback, and choose the type of feedback and the units.

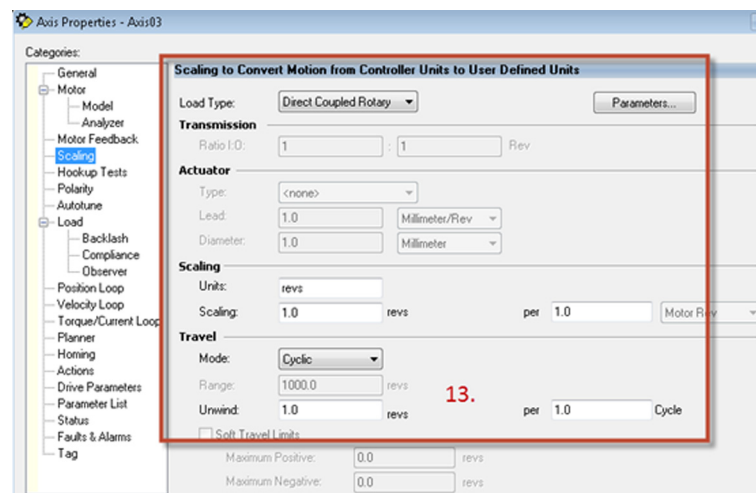
The selections that are shown in this example are defaults, and are used in most applications.

12. Set the resolution based on the line count of the encoder being used.



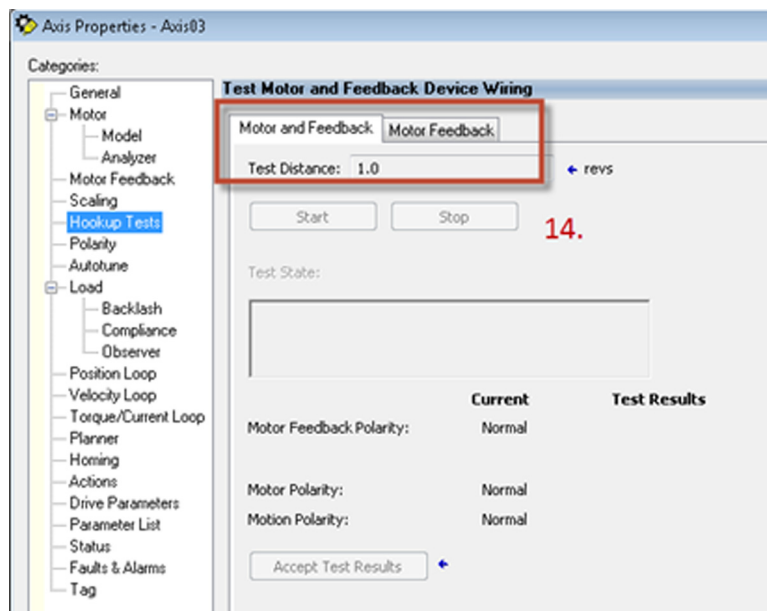
In this example, the encoder is 3000 lines (Cycle Resolution) and with a 'times 4' (Cycle Interpolation), the output is effectively 12000 ppr (Effective Resolution).

13. In the treeview, click Scaling and set the scaling according to your application.



In this example, we simply use the motor revs as the units of scale, which means all gains and units for the load are configured as revs. If mm or inches are desired, for example, we would set the translation of inches/motor rev here. This example also uses a rotary type axis with an unwind of 1, which means that the position of the drive goes from 0 to 1 and repeats back at 0, so the range of position is simply 0...1.

14. In the treeview, click Hookup Tests and execute the tests to adjust the Output and Motor Feedback.

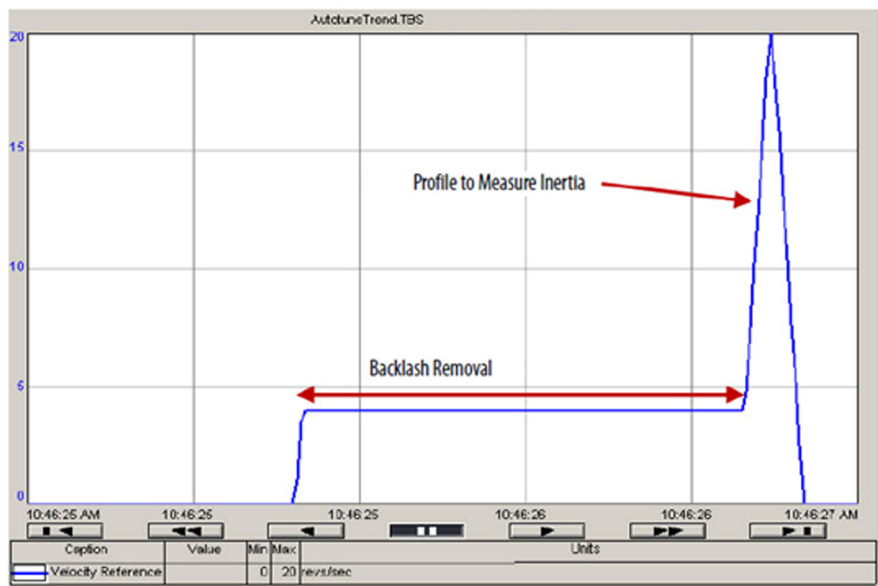


To change the output and feedback polarity manually, click Polarity in the treeview, which is similar to the Direction Test used by other PowerFlex drives.

From this point on, the Auto Tune test and other features, including tuning are discussed in detail in Motion System Tuning Application Techniques, publication [MOTION-AT005](#), with the following differences:

- While a Kinetix Servo drive can have a Coarse Update Rate (from the Motion Group) with a minimum update of 1.0 ms, the PowerFlex 755 CIP drive has a minimum coarse update period of 3.0 ms. For more information, see PowerFlex 750-Series AC Drives Reference Manual, publication [750-RM002](#).
- Measure Inertia using Tune Profile. Check this box to calculate the inertia tuned values as part of the Auto Tune. The Inertia Test results are shown in the Inertia Tuned grid control (at bottom right of dialog box) when the test completes. When 'Measure Inertia using Tune Profile' is selected as a part of the Auto Tune test, the PowerFlex 755 CIP drive first jogs or rotates the motor in one direction to remove any backlash present in the system (as depicted in [Figure 83](#)). After the backlash has been removed, the 'bump' profile is then applied to measure the system inertia (system acceleration). Note that systems with a mechanical restriction or travel limit may not complete the Auto Tune test because of the additional travel that is created for Backlash Removal.

**Figure 83 - Backlash Removal during Auto Tune Test**



## **Notes:**



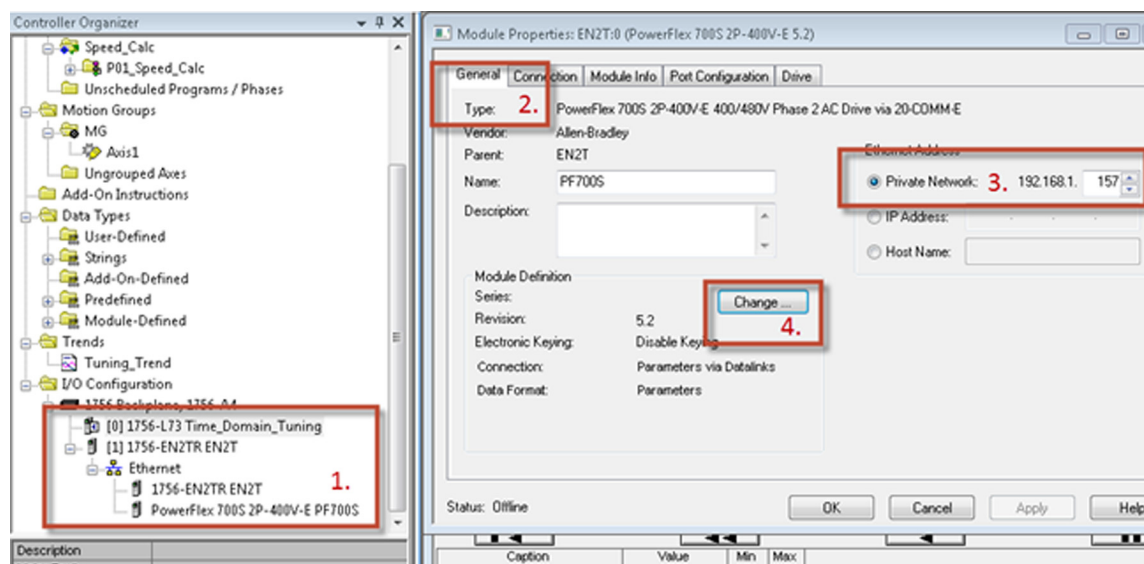
## Creating a Trend with Studio 5000 Logix Designer Application for Tuning

This appendix shows how to configure different trends in the Logix Designer application to observe the behavior of a drive and motor while tuning.

### PowerFlex 700S Drive Logix Designer Setup

This section describes the configuration of the PowerFlex 700S drive to show trending pens that can be used for tuning.

1. After your drive is created, double-click the PowerFlex 700S drive in the treeview under I/O Configuration.
2. In the Module Properties dialog box, click the General tab.
3. Enter the IP Address for the PowerFlex drive.
4. In the Module Definition section, click Change.



5. In the Module Definition dialog box, choose the drive firmware Revision, Electronic Keying, and Drive Rating to match your system.
6. In the 'Input Data' column, choose the Datalinks as shown in the following example screen.

The tags are defined in the following table.

Datalink Input Data Tag	Description
MotorSpdFdbk - 300	The Speed Feedback signal that comes in the option card 0. (Verify that it matches your hardware configuration.)
SelectedTrqRef - 319	The Torque (Current) signal from the Torque Regulator.
SpeedError - 100	The Velocity Error from the Speed Regulator.
MotorSpeedRef - 301	The Commanded Speed value to the Speed Regulator.
Position Cmd - 747 (if used)	The command Position from the Position Planner.
PositionError - 769 (if used)	The error between command position and feedback position.

The 'Output Data' column choices do not affect the trend.

7. In the Module Definitions dialog box, choose the Connection and Data Format as shown, and click OK.

**Module Definition\***

Revision: 5 2

Electronic Keying: Compatible Module

Drive Rating: 240V 4.2A

**5.**

Datalink	Input Data	Output Data
	LogicStatus	LogicCommand
	SpeedFeedback	SpeedReference
		<input type="checkbox"/> Use Network Reference
<input checked="" type="checkbox"/> A	MotorSpdFdbk - 300	SpdRegB/W - 90
	SelectedTrqRef - 319	Undefined_A2
<input checked="" type="checkbox"/> B	SpeedError - 100	Undefined_B1
	MotorSpeedRef - 301	Undefined_B2
<input checked="" type="checkbox"/> C	PositionCmd - 747	Undefined_C1
	PositionError - 769	Undefined_C2
<input type="checkbox"/> D		

**6.**

☒ Sort Input/Output selection lists by Parameter Name

**7.**

Connection: Parameters via Datalinks

Data Format: Parameters

**7.**

**DANGER:** Unexpected, hazardous motion of machinery may occur when improperly using software to configure a drive.

Parameter names selected for the Input and Output Data appear as member names in the drive Module-Defined Data Types and defines necessary Datalink parameters in the RSLogix 5000 project. Actual data transfer between controller and drive is determined by Datalink parameters.

You must download configuration to the drive to ensure that the controller, drive and communication module configurations are consistent with each other.

If the revision of your drive is not listed:  
- click Create Database... button below if drive is online.  
- click Web Update... to download the database from the web if drive is offline.

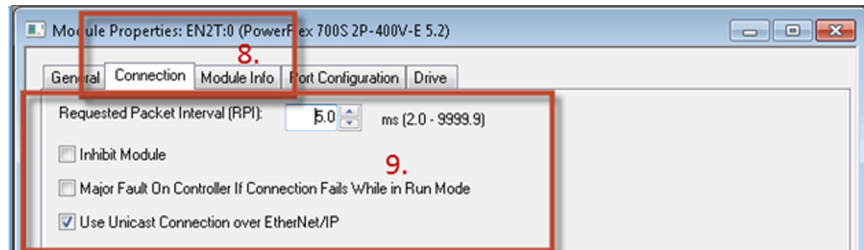
To match revision and upload the configuration of an online drive:  
- click Match Drive.

Create Database... Web Update...

Match Drive OK Cancel Help

8. In the Module Properties dialog box, click the Connection tab.
9. Set the Requested Packet Interval (RPI) of the drive that your network and application can accommodate.

Consider that the lower the RPI, the better the sampling is to the drive. This example has a sample rate of 5 ms. Also, check Use Unicast Connection over EtherNet/IP checkbox.

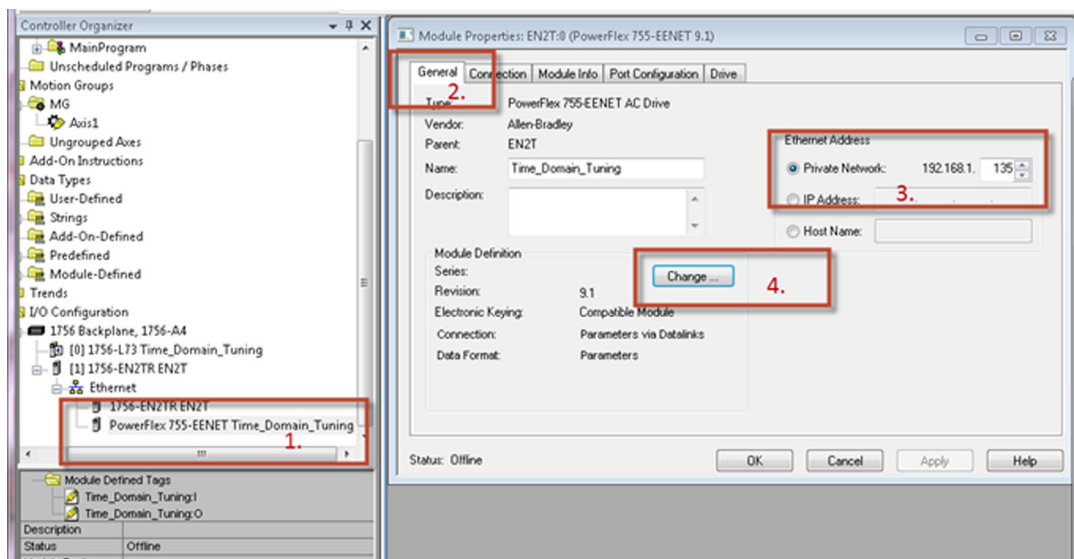


10. Click OK.

## PowerFlex 755 Drive Logix Designer Setup

This section describes the configuration of the PowerFlex 755 drive to show trending pens that can be used for tuning.

1. After your drive is created, double-click the PowerFlex 755 drive in the treewiew under I/O Configuration.
2. In the Module Properties dialog box, click the General tab.
3. Enter the IP Address for the PowerFlex drive.
4. In the Module Definition section, click Change.



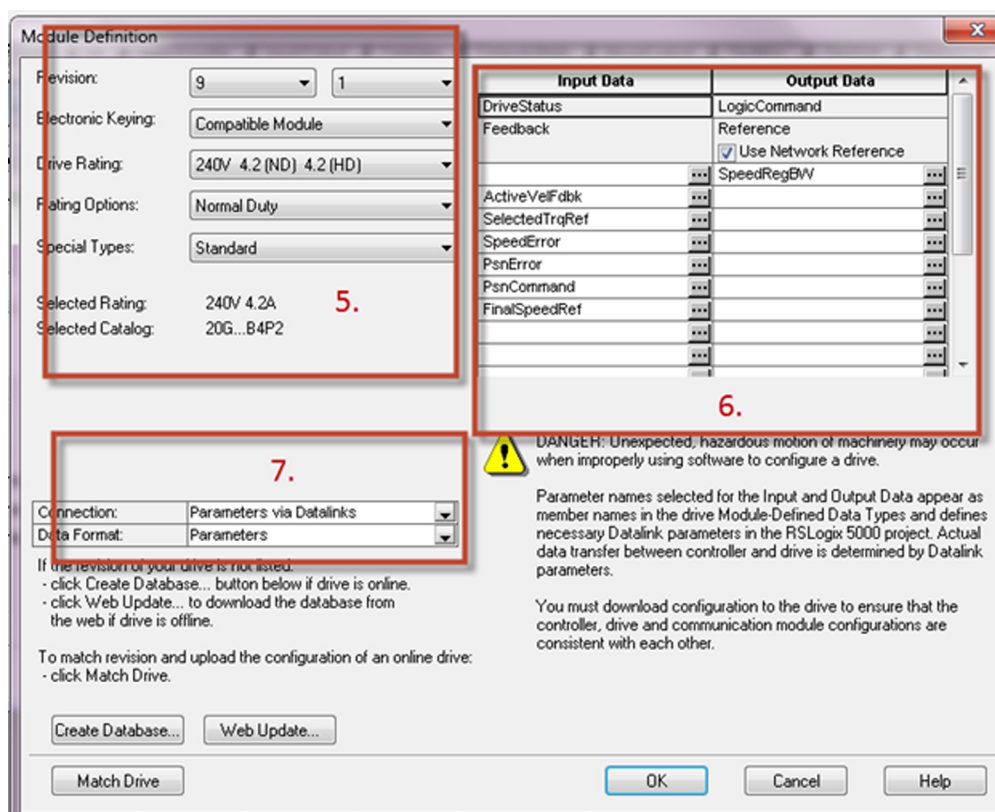
5. In the Module Definition dialog box, choose the drive firmware Revision, Electronic Keying, and Drive Rating to match your system.
6. In the 'Input Data' column, choose the Datalinks as shown in the following example screen.

The tags are defined in the following table.

Datalink Input Data Tag	Description
ActiveVelFdbk	The Speed Feedback signal.
SelectedTorqueRef	The Torque (Current) signal from the Torque Regulator.
SpeedError	The Velocity Error from the Speed Regulator.
PsnError (if used)	The Position error from the Position Regulator.
PsnCommand (if used)	The Command Position from the Position Planner.
FinalSpdRef	The Commanded Speed value to the Speed Regulator.

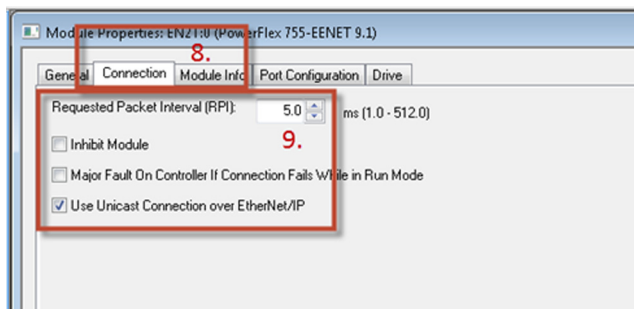
The 'Output Data' column choices do not affect the trend.

7. In the Module Definitions dialog box, choose the Connection and Data Format as shown, and click OK.



8. In the Module Properties dialog box, click the Connection tab.
9. Set the Requested Packet Interval (RPI) of the drive that your network application can accommodate.

Consider that the lower the RPI, the better the sampling is to the drive. This example has a sample rate of 5 ms. Also, check Use Unicast Connection over Ethernet/IP.



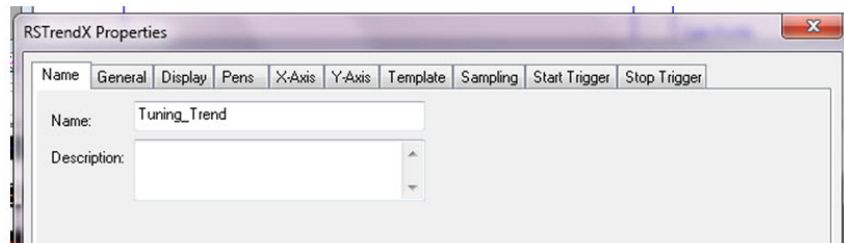
10. Click OK.

## Trend Properties Dialog Box

This section describes tabs on the trend properties dialog box that are used to set trends.

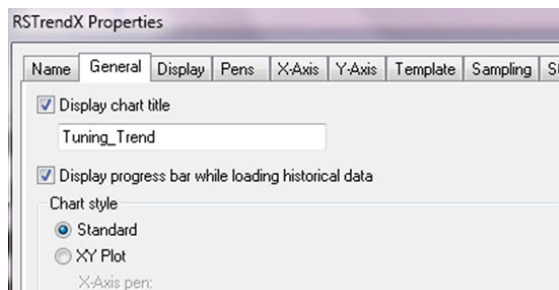
### Name Tab

The Name tab is where you can change the name of the trend itself, which is useful when you copy and paste a trend.



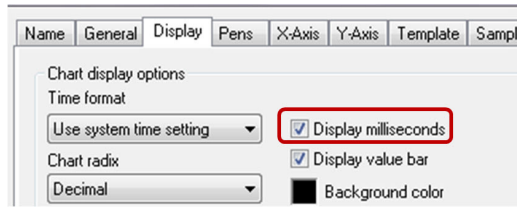
### General Tab

An important part of the General tab is that the trend is typically set against time, like an oscilloscope. You can have an X-Y plot that is useful when dealing with coordinated systems, like robots.



## Display Tab

Displayed milliseconds are useful when using the value bar of the trend. The other settings are defaults.



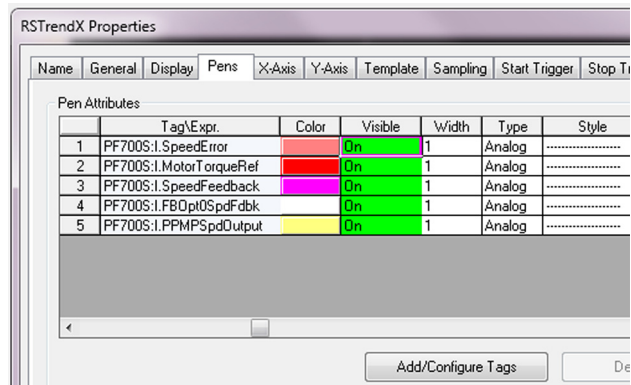
## Pens Tab

The Pens tab is the most important tab in the trend properties dialog box. You must select the correct pens to use in your trend.

Click Add/Configure Tags to add and remove pens.

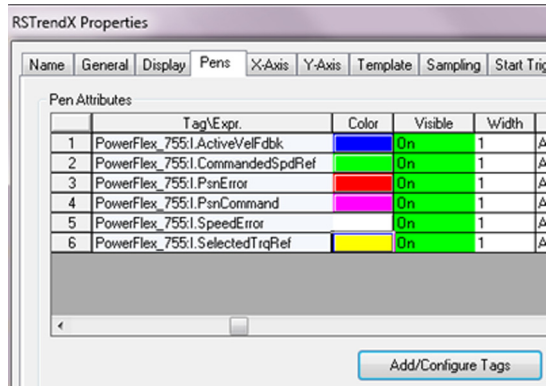
### PowerFlex 700S Drives

This example shows typical pens that are used to tune a PowerFlex 700S drive.



### PowerFlex 755 Drives

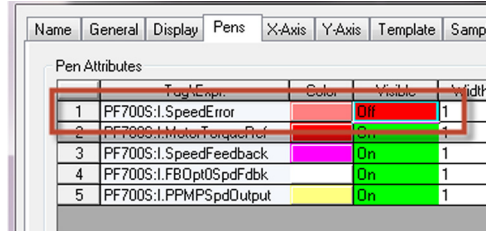
This example shows typical pens that are used to tune a PowerFlex 755 drive.



## Useful Pens Tab Tips

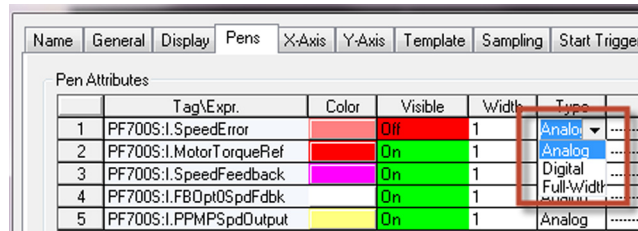
Here are some useful tips about the Pens tab:

- You can turn the pen on/off by clicking 'On' in the Visible tab, which is useful when the trend window is too busy with several pens.



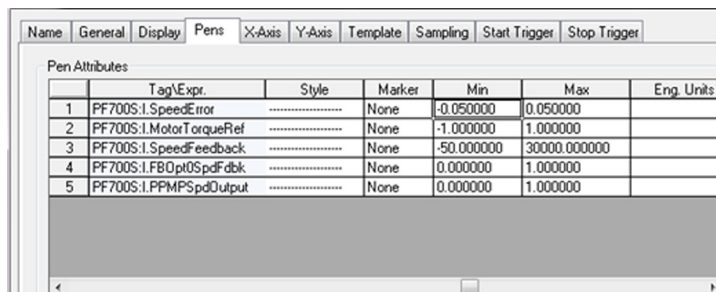
	Tag\Expr.	Color	Visible	Width
1	PF700S:I.SpeedError	Red	On	1
2	PF700S:I.MotorTorqueRef	Red	On	1
3	PF700S:I.SpeedFeedback	Magenta	On	1
4	PF700S:I.FB0pt0SpdFdbk	Green	On	1
5	PF700S:I.PPMPSpdOutput	Yellow	On	1

- If you are trending a digital signal, that is, a start cycle, stop, E-stop button, and so forth, you can remove the rise and fall slope due to the sampling of the trend and change the Type from Analog to Digital.



	Tag\Expr.	Color	Visible	Width	Type
1	PF700S:I.SpeedError	Red	On	1	Analog
2	PF700S:I.MotorTorqueRef	Red	On	1	Analog
3	PF700S:I.SpeedFeedback	Magenta	On	1	Digital
4	PF700S:I.FB0pt0SpdFdbk	Green	On	1	Full-width
5	PF700S:I.PPMPSpdOutput	Yellow	On	1	Analog

- If the Automatic Mode does not suit the way the trend visually appears, you can set the Min and Max pen values. For example, set the Min and Max pen values for SpeedError and MotorTorqueRef, where you want these values to be relatively small. Make sure to balance out the value across the X-Axis by setting both Min and Max values the same.

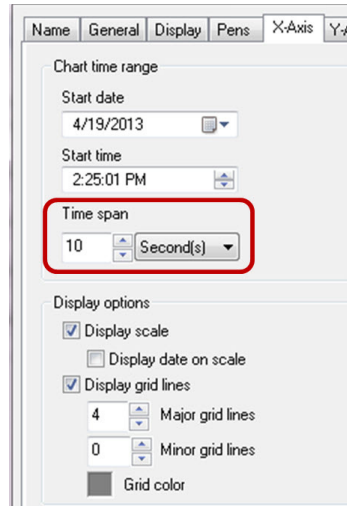


	Tag\Expr.	Style	Marker	Min	Max	Eng. Units
1	PF700S:I.SpeedError	-----	None	-0.050000	0.050000	
2	PF700S:I.MotorTorqueRef	-----	None	-1.000000	1.000000	
3	PF700S:I.SpeedFeedback	-----	None	-50.000000	30000.000000	
4	PF700S:I.FB0pt0SpdFdbk	-----	None	0.000000	1.000000	
5	PF700S:I.PPMPSpdOutput	-----	None	0.000000	1.000000	



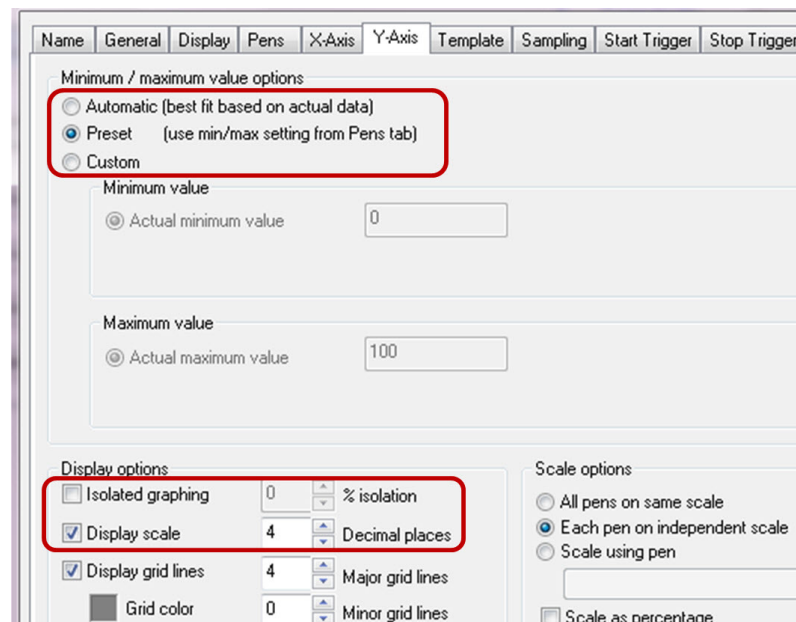
## X-Axis Tab

In the X-Axis tab, the only pertinent information for tuning is the scale of time for the axis. Change this scale to where you can comfortably see one or more cycles of the movements. You can always click and highlight the area to zoom in.



## Y-Axis Tab

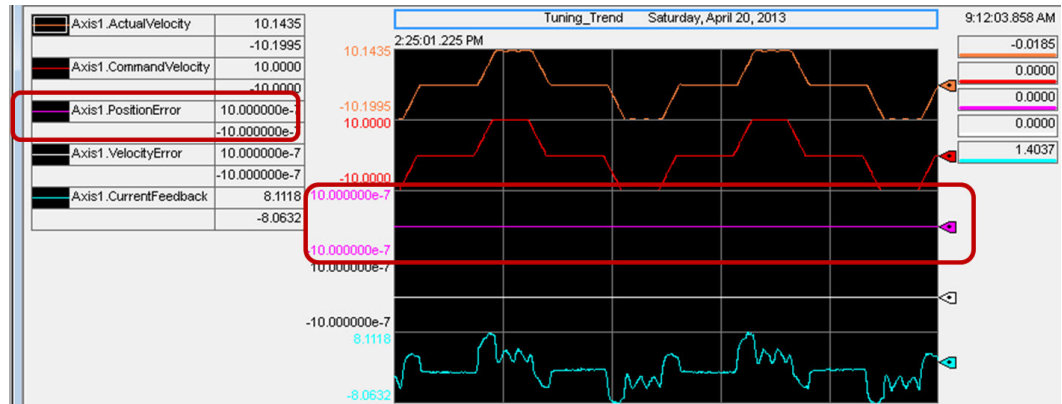
The Y-Axis tab has some important settings that can be useful in different situations.



- Minimum / maximum value options—the simplest setting is to click Automatic. However, when tuning specific values, it can be more useful to click Preset, which uses the Min and Max pen values you have previously set.



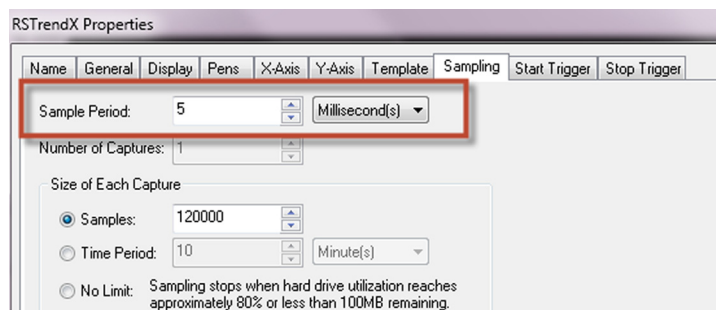
- Isolated graphing—check this box to display all pens in a time chart format, which is useful to plot digital signals against motion. Also, when used with the Automatic checkbox, it can provide a window that spans the minimum and maximum values of the pen across the trend window. This combination of settings is useful when manual tuning to reduce error. An example is shown here.



- Display scale—it is important to check this box when you are fine tuning. You can choose how many decimal places to use for values like Velocity Error and Position Error pens (see previous example screen). In this example, four decimals are selected, and the real value is shown on the trend to four decimal places.

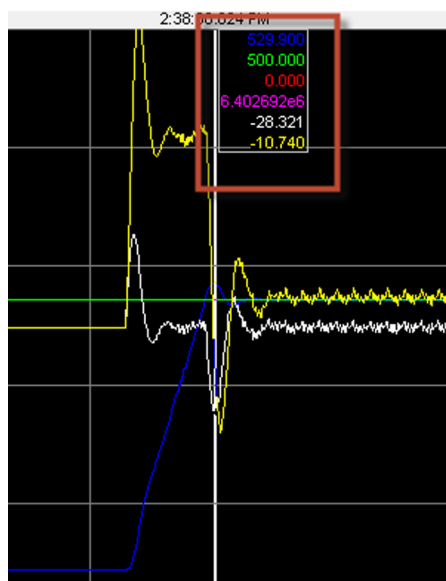
## Sampling Tab

The Sampling tab sets the sample rate of the pens. When tuning, you want the sampling rate set as high as possible without affecting the processor speed. Because the trend runs as a service in the Logix Designer application, consider other online trends and processor utilization. We recommend that the sample period is set the same as the Requested Packet Interval. If that is not possible, set the sample rate as small as possible.

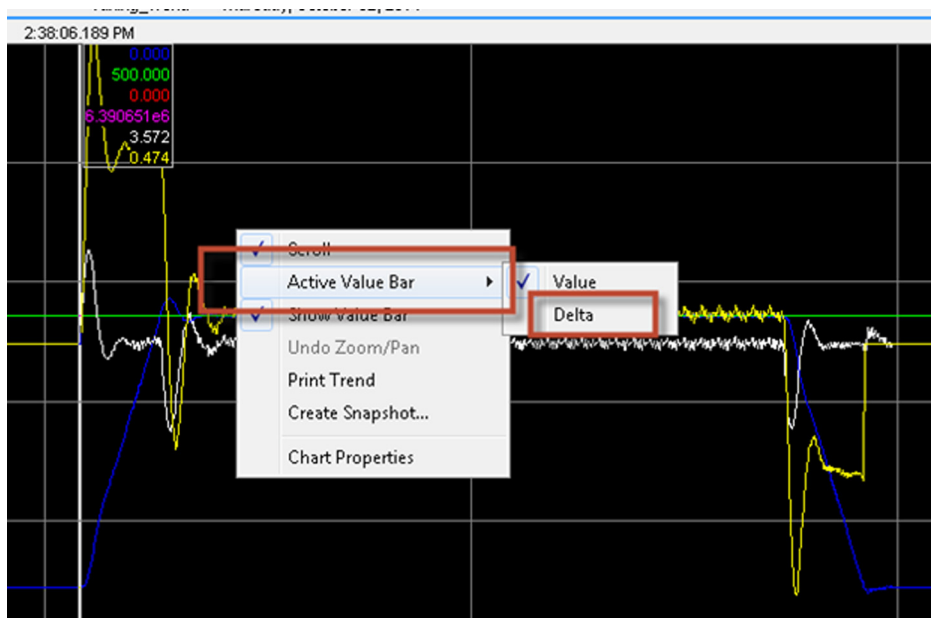


## Value Bar Information

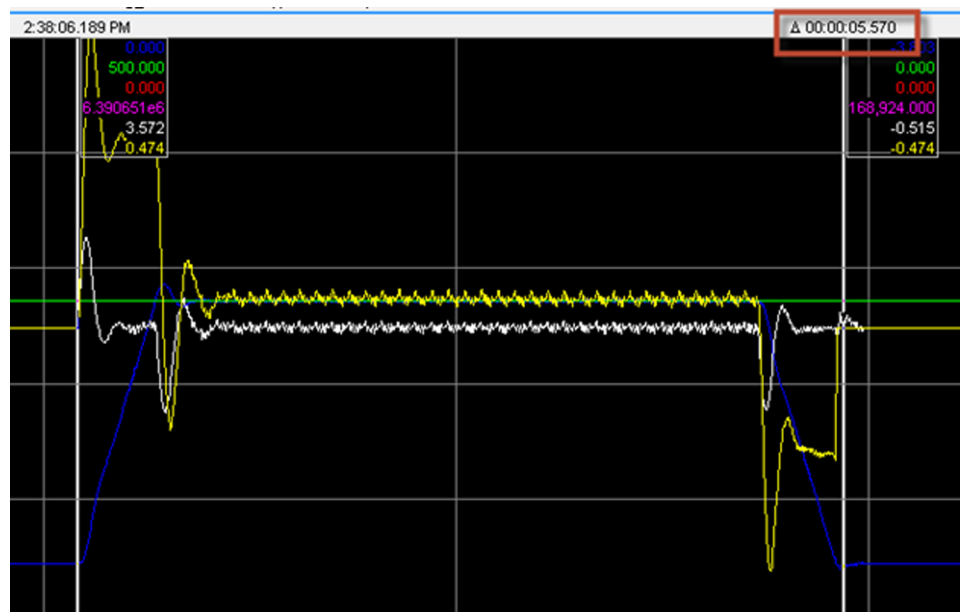
The value bar is important because it shows instant values of each pen at the same point in time. It also provides a time stamp that can be correlated to other trends if they are running simultaneously.



Another useful way to use the value bar is in Delta mode where you can measure the width and magnitude differences of values in terms of time. To set the Delta mode, right-click inside the trend window and choose Delta from the Active Value Bar.



After choosing Delta, the value bar locks on the starting point. When you click on the second location, the delta value appears as time and the pen values are displayed (5.57 sec) as shown in this example.



To clear the value bar and return to normal, do the following.

1. Right-click inside the trend window and choose Value from the Active Value Bar.
2. Uncheck Show Value Bar.
3. Check Show Value Bar again.

## **Notes:**

## Setting Different Drive Position Modes

This appendix describes how to configure the PowerFlex 755 drive to operate as a Position Regulator using the Direct Position mode, Point-to-Point (PTP) mode, or Profiler mode. The PowerFlex 700S drive can be configured to operate as a speed regulator using the Motion Planner mode.

### PowerFlex 755 Drive Position Modes

Verify that the following settings are made. Most of these settings have been completed in Chapter 2.

1. Update PowerFlex 755 drive firmware to the latest revision.
2. Set Par 301 [Access Level] to 2 (Expert) to access required parameters.
3. Use Parameters 25...31 to enter the motor nameplate data, which is shown in [Motor Data on page 34](#).
4. Set Par 35 [Motor Ctr Mode] to the type of motor and type of control mode.

Type of Motor	Type of Control
Induction	SV (Sensorless Vector control)
PM (Permanent Magnet)	VHz (Volts/Hertz)
SyncRel (Synchronous Reluctance)	FV (Flux Vector control)

5. Set Par 36 [Maximum Voltage] to the rated voltage of the motor or the maximum voltage that the motor can operate.
6. Set Par 37 [Maximum Freq] to the maximum frequency at which the motor can operate.
7. Set Par 125 [Pri Vel Fdbk Sel] as follows:
  - No feedback device—set Par 125 to 'Port 0: Open Loop Fdbk'.
  - Installed feedback device—set Par 125 to 'Port x: FB0 Position' or 'Port x: FB1 Position', where 'x' is the number of the port in which the encoder module is installed.
8. Set Par 520 [Max Fwd Speed] to the maximum forward speed that the motor is to operate.
9. Set Par 521 [Max Rev Speed] to the maximum reverse speed that the motor is to operate.
10. Set Par 522 [Min Fwd Speed] to the minimum forward speed that the motor is to operate.

Usually, it is set to zero.

11. Set Par 523 [Min Rev Speed] to the minimum reverse speed that the motor is to operate.  
Usually, it is set to zero.
12. Perform the Auto Tune test (see [Auto Tune on page 44](#)).
13. Perform the Inertia Auto Tune test when required (see [Inertia Auto Tune Test on page 45](#)).

## Configuration to Set Position Mode as 'Direct Position'

Direct position can be used to follow either an auxiliary encoder or a position command. Although velocity rate of the move can be controlled, the acceleration and deceleration rates cannot be controlled. The drive simply attempts to accelerate and decelerate as quickly as possible.

1. Set Par 135 [Psn Fdbk Sel] to the port in which the position feedback device is connected.
2. Set Par 309 [SpdTrqPsn Mode A] to 10 (Psn Direct), and read the status of Par 313 [Actv SpTqPs Mode], which should show '10' (Psn Direct) to confirm that the operation mode was successfully changed.
3. Set Par 765 [Psn Ref Select] as follows:
  - If the drive is following the position of an auxiliary (secondary) encoder, set Par 765 to the encoder position of the encoder module as follows.

Encoder Module Type	Par 765 Setting
Universal Feedback	<ul style="list-style-type: none"> <li>• Port x: FB0 Position (Port x - Universal Fdbk, Parameter 5 - FB0 Position)</li> <li>or</li> <li>• Port x: FB1 Position (Port x - Universal Fdbk, Parameter 5 - FB1 Position)</li> </ul>
Incremental	Port x: Encoder Feedback (Port x - Encoder, Parameter 4 - Encoder Feedback)
Dual Incremental	<ul style="list-style-type: none"> <li>• Port x: Enc 0 FB (Port x - Encoder, Parameter 4 - Enc 0 FB)</li> <li>or</li> <li>• Port x: Enc 1 FB (Port x - Encoder, Parameter 14 - Enc 1 FB)</li> </ul>

- If the drive is following a position command from a controller, set Par 765 to Par 766 [Psn Direct Stpt].  
Otherwise, set Par 765 or Par 140 [Virtual EncDelay] or Par 142 [Virtual Enc Psn].
4. If the drive is following a position command from a controller, set the following Datalinks of the EtherNet/IP module.
    - a. Set Port 13 - EtherNet/IP - Par 1 [DL From Net 01] to Port 0: Par 766 [Psn Direct Setpoint].
    - b. Set Port 13 - EtherNet/IP - Par 17 [DL To Net 01] to Port 0: Par 847 [Psn Fdbk].

**TIP** If a communication module other than the embedded EtherNet module is used, set the Datalinks to Par 766 [Psn Direct Stpt] and Par 17 [Elpsd Rgn MWHrs] accordingly.

5. Use Par 766 [Psn Direct Stpt] to set the position command in encoder counts as a default unit.
6. Use Par 844 [PReg Pos Spd Lmt] and Par 845 [PReg Neg Spd Lmt] to set the velocity command.

The acceleration and deceleration cannot be controlled in Direct Position. The drive simply attempts to accelerate as quickly as possible.

## Configuration to Set Position Mode as 'Profiler'

In 'Profiler' mode, the drive can be configured to perform absolute moves, incremental moves, or speed profiles. A sequence of moves can be programmed, and each segment of the sequence is programmed independently.

1. Set Par 135 [Psn Fdbk Sel] to the port in which the position feedback device is connected.
2. Set Par 309 [SpdTrqPsn Mode A] to 6 (Profiler), and read the status of Par 313 [Actv SpTqPs Mode], which should show '6' (Profiler) to confirm that the operation mode was successfully changed.
3. Set Parameters 1230, 1240, ...1380 [Step xx Type] to 1 (Position Abs) or 2 (PositionIncr).
4. Set Parameters 1231, 1241, ...1381 [Step xx Velocity] to the peak speed of the move (in Hz or RPM).
5. Set Parameters 1232, 1242, ...1382 [Step xx Accel] to the acceleration time in seconds of each move.
6. Set Parameters 1233, 1243, ...1383 [Step xx Decel] to the deceleration time in seconds of each move.
7. Set Parameters 1234, 1244, ...1384 (Step xx Value] to absolute or incremental position.
8. Set Parameters 1235, 1245, ...1385 (Step xx Dwell] to the dwell time in seconds between each move.
9. Set Parameters 1236, 1246, ...1386 (Step xx Batch] to the number of times to repeat each move.
10. Set Parameters 1237, 1247, ...1387 [Step xx Next] to the index number of the next move to execute.
11. Set Parameters 1238, 1248, ...1388 (Step xx Action] to the action after each move.

For a description of each action, see the PowerFlex 750-Series AC Drives Programming Manual, publication [750-PM001](#).

12. Set the following Datalinks of the EtherNet/IP module.
  - a. Set Port 13 - EtherNet/IP - Par 1 [DL From Net 01] to Port 0: Par 1213 [Profile Command].

- b. Set Port 13 - EtherNet/IP - Par 17 (DL To Net 01) to Port 0: Par 1210 [Profile Status].
- c. Set Port 13 - EtherNet/IP - Par 18 (DL To Net 02) to Port 0: Par 836 [Psn Actual].

#### NOTES:

- If a communication module other than the embedded EtherNet module is used, set the Datalinks accordingly.
- Par 1213 [Profile Command] can be used to hold step, restart step, and define the first step to start, and so forth. Par 1210 [Profile Status] and Par 836 [Psn Actual] can be used to check the status and the actual position respectively of the present segment of motion profile.
- If the segments of the motion profile need to be configured via controller, more Datalinks must be configured. Any of the parameters of the 16 Steps of the profile can be added to the Datalinks. However, the Datalinks are limited to 16 in and 16 out. Thus, if a motion profile is constituted of several Steps, the drive might not have enough Datalinks to configure all Steps. In this case, one Step can be used to run all segments of the motion profile, while a second Step is used to allow the configuration of the next segment of the motion profile. For example, the move can start in Step 1 and, when completed, it goes to Step 2 that is configured only with Dwell. The next Step of Step 2 is Step 1. While in Step 2, the controller sends the configuration of the next motion segment to Step 1. The Dwell of Step 2 is set to the communication delay between controller and drive to update the configuration of Step 1. Par 1213 [Profile Command] Bit 8 can be used to hold the execution of the profile after the drive completes any segment of the motion profile.

### Configuration to Set Position Mode as 'Point to Point (PTP)'

1. Set Par 135 [Psn Fdbk Sel] to the port in which the position feedback device is connected.
2. Set Par 309 [SpdTrqPsn Mode A] to 7 (Psn PTP), and read the status of Par 313 [Actv SpTqPs Mode], which should show '7' (Psn PTP) to confirm that the operation mode was successfully changed.
3. Set Par 771 [PTP Mode] to 0 (Absolute) for absolute moves or 1 (Index) for incremental moves.

In Index mode for incremental moves, the position value set in Par 780 [PTP Setpoint] is added to the position reference in Par 776 [PTP Reference], which is the same as Par 723 [Psn Command].

4. Set Par 780 [PTP Setpoint] to the position command in encoder counts. Position command can be either positive or negative.
5. Set Par 781 [PTP Accel Time] to the acceleration time in seconds.



6. Set Par 782 [PTP Decel Time] to the deceleration time in seconds.
7. Set Par 785 [PTP Fwd Vel Lmt] to the maximum velocity of the move in Hz (or rpm if drive is set to rpm in Par 300 [Speed Units]).
8. Set Par 786 [PTP Rev Vel Lmt] to the maximum negative velocity of the move in Hz (or rpm if drive is set to rpm in Par 300 [Speed Units]).
9. Set Par 787 [PTP S Curve] to the amount of jerk compensation of the move (given in per unit).
10. Set Par 778 [PTP Ref Scale] to the unit conversion factor if necessary.

For example, if a 1024PPR incremental encoder is used and the units are to be Revolutions (Rev), one Rev results in 4096 encoder counts (1024 times 4). Thus, set Par 778 [PTP Ref Scale] to a value of 4096. In this case, a value of 2 in Par 780 [PTP Setpoint] results in two motor revolutions.

11. Monitor status by using Par 720 [PTP PsnRefStatus].

## PowerFlex 700S Drive Motion Planner Mode

The PowerFlex 700S drive has one positioning mode of operation that allows tuning to be completed—the Motion Planner enable mode.

If a Logix controller is being used to control the PowerFlex 700S drive, set the drive Requested Packet Interval to 5.0 ms.

To configure the 'Motion Planner' mode, perform these steps.

1. Set Par 147 [FW Functions En] Bit 19 (Motin Planner) to 1.
2. Set the following bits of Par 1134 [PPMP Control].
  - a. Bit 0 (Absolute) to 0 or Bit 1 (Incremental) to 1 to establish an incremental index.
  - b. Bit 2 (Start) to 0.
  - c. Bit 4 (Scaling En) to 0.
  - d. Bit 5 (Over Ride En) to 0.
  - e. Bit 6 (S Curve En) to 1.
  - f. Bit 8 (Pause) to 0.

1134 PPMP Control	
Establishes the operating condition for the Motion Planner. The operating mode(s) is selected if the corresponding bit is set.	
Bit 0 "Absolute" Absolute mode. When using the Homing function while in Absolute mode, the value in Par 758 [Pt-Pt Posit Ref] must be set relative to the value in Par 763 [Position Actual] after homing is complete. For example: When homing is complete Par 763 [Position Actual] = 1000 counts. If you want to move to an absolute position of 2000 counts relative to the home switch, you must enter a value of 3000 counts into Par 758 [Pt-Pt Posit Ref] (i.e., 1000 + 2000 = 3000). If you want to move back to the home switch, using the same value in Par 763 [Position Actual] after homing (1000), you must enter a value of 1000 into Par 758 [Pt-Pt Posit Ref] (i.e., 0 + 1000 = 1000).	
<ul style="list-style-type: none"> <li>• Bit 1 "Incremental" Incremental mode</li> <li>• Bit 2 "Start" Start</li> <li>• Bit 4 "Scaling En" Scaling enabled</li> <li>• Bit 5 "Over Ride En" Override enabled</li> <li>• Bit 6 "S Curve En" S Curve Enabled</li> <li>• Bit 7 "Cond Hold" Conditional Hold</li> <li>• Bit 8 "Pause" Pause</li> <li>• Bit 9 "Re-Synch" Re-Synch</li> </ul>	
Note: This parameter was added for firmware version 3.001.	
Options	
Reserved	Reserved
Reserved	Reserved
Reserved	Reserved
Reserved	Reserved
Reserved	Reserved
Reserved	Reserved
Re-Synch	Re-Synch
Pause	Pause
Cond Hold	Cond Hold
S Curve En	S Curve En
Over Ride En	Over Ride En
Scaling En	Scaling En
Reserved	Reserved
Start	Start
Incremental	Incremental
Absolute	Absolute
Default	x x x x x x x 0 0 0 0 0 0 x 0 0 0
Bit	15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0

3. Set Par 742 [Position Ref Sel] to 1 (AuxPosit Ref).

4. Set Par 151 [Logic Command] Bit 13 (Position En) to 1.
5. Set Par 147 [FW Functions En] Bit 16 (PositionCtrl) to 1.
6. Set the following bits of Par 740 [Position Control].
  - a. Bit 10 (Pt-Pt ReRef) to 0.
  - b. Bit 6 (AbsPositCtrl) to 0.
  - c. Bit 1 (Speed Out En) to 1.

740

### Position Control

Set bits to enable various position control functions.

- Setting bit 1 "Speed Out En" enables position regulator output at [Par 318](#) [Posit Spd Output].
- Setting bit 2 "Integ En" enables integrator operation. Resetting it resets the integrator.
- Setting bit 3 "Integ Hold" holds integrator in present state.
- Setting bit 4 "X Offset Pol" reverses polarity of offset parameters.
- Setting bit 5 "X Offset Ref" permits changing the value of position offsets without changing actual position. Resetting it makes the position offset relative to the re-referenced value or the latched value upon enable if re-reference was not performed.
- Bit 6 "AbsPositCtrl" may be set when a multi-turn, absolute feedback device is used for Point-to-Point positioning. Activating this bit will ReRef the position reference to the absolute feedback when position control is activated in bit 7 "Regulator On" of [Par 741](#) [Position Status]. If the value at [Par 758](#) [Pt-Pt Posit Ref] is different than the feedback in [Par 763](#) [Position Actual], a position error will exist and the machine will move to position when activated. When bit 6 "AbsPositCtrl" is high, bit 9 "SetZeroPosit" of [Par 740](#) [Position Control] may be used to set the zero "home" position accumulators. This can only be used when the drive is not in run and [Par 740](#) [Position Control] bit 6 = 1 (true).
- Setting bit 7 "AbsoluteMode" puts the position regulator in Absolute mode. When using the Homing function while in Absolute mode, the value in [Par 758](#) [Pt-Pt Posit Ref] must be set relative to the value in [Par 763](#) [Position Actual] after homing is complete. For example: When homing is complete [Par 763](#) [Position Actual] = 1000 counts. If you want to move to an absolute position of 2000 counts relative to the home switch, you must enter a value of 3000 counts into [Par 758](#) [Pt-Pt Posit Ref] (i.e., 1000 + 2000 = 3000). If you want to move back to the home switch, using the same value in [Par 763](#) [Position Actual] after homing (1000), you must enter a value of 1000 into [Par 758](#) [Pt-Pt Posit Ref] (i.e., 0 + 1000 = 1000).
- Setting bit 8 "Xzero Preset" presets [Par 744](#) [PositRef EGR Out], [Par 747](#) [Position Cmmnd], [Par 763](#) [Position Actual] and [Par 765](#) [Posit Acti Load] with the value in [Par 762](#) [Position Fdbk] minus [Par 757](#) [Abs Posit Offset] upon drive enable.
- Setting bit 10 "Pt-Pt ReRef" enables setting or changing [Par 758](#) [Pt-Pt Posit Ref] without changing the actual position.
- Setting bit 16 "X Watch1 En" enables position Watch 1. Resetting it clears [Par 741](#) [Position Status] bit 8 "Posit Watch1".
- Setting bit 17 "X Watch1 Dir" causes Position Watch 1 output to be set when [Par 763](#) [Position Actual] is greater than [Par 780](#) [PositDct1 Stpt]. Re-setting bit 17 causes Position Watch 1 output to be set when [Par 763](#) [Position Actual] is less than [Par 780](#) [PositDct1 Stpt].
- Setting bit 18 "X Watch2 En" enables position Watch 2. Resetting it clears [Par 741](#) [Position Status] bit 9 "Posit Watch2".
- Setting bit 19 "X Watch2 Dir" causes Position Watch 2 output to be set when [Par 763](#) [Position Actual] is greater than [Par 781](#) [PositDct2 Stpt]. Re-setting bit 19 causes Position Watch 2 output to be set when [Par 763](#) [Position Actual] is less than [Par 781](#) [PositDct2 Stpt].
- Setting bit 20 "Pt-Pt RampStop" enables the Ramp to Stop function for point-to-point positioning. When reset and the stop command is given during a move, the drive will stop at 0 ramp time. When set and the stop command is given during a move, the drive will ramp to zero at [Par 760](#) [Pt-Pt Decel Time]. Note: Coast Stop or Removing Enable always causes a Coast to Stop function.
- Bit 24 "Find Home" - when this bit is on and the drive is started, a homing sequence is initiated.
- Bit 25 "Pos Reline" - when this bit is set the position will be set to zero.
- Bit 26 "Home Dir" - when this bit is set the homing direction will be opposite of the Home Speed commanded in [Par 1122](#) [Home Speed].
- Bit 27 "Return Home" - when this bit is set the homing direction will be opposite of the Home Speed commanded in [Par 1122](#) [Home Speed]. Note: The position reference will not change, but [Par 763](#) [Posit Load Fdbk] will return to zero. The Position reference should also be redefined to zero to synchronize the position with the command. This can be useful for returning to Home after a jog type operation.
- Bit 28 "Home Switch" - when this bit is set the Homing sequence will look for the home switch to make a transition from it's current state when the homing sequence is started. Do not set with bit 29 "Home Marker".
- Bit 29 "Home Marker" - when set, the Homing Sequence will look for the Marker pulse. When the marker pulse is found the drive will decelerate and return to the position where the marker was found. Do not set with bit 28 "Home Switch".

Note: Bits 24 - 29 were added for future use - not active for use with firmware version 3.001 and above.

Options	Reserved	Reserved	Home Marker	Home Switch	Return Home	Home Dir	Pos Reline	Find Home	Reserved	Reserved	Pt-Pt RampStop	X Watch2 Dir	X Watch2 En	X Watch1 Dir	X Watch1 En	BicIndStpRy	BicIndRst	BicIndRev	BicIndStp	BicIndEnbl	Pt-Pt ReRef	SetZeroPosit	Xzero Preset	AbsoluteMode	AbsPositCtrl	XOff ReRef	X Offset Pol	Integ Hold	Integ En	Speed Out En	Reserved	
Default	x	x	0	0	0	0	0	0	x	x	x	0	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	1	x		
Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

0 = False  
1 = True

0 = False  
1 = True

## A

### Auto Tune

PowerFlex 700S drive 36  
PowerFlex 755 drive 44

### axis configuration for PowerFlex 755 CIP

Motion drive 106

## B

### background on drive tuning 9

### backlash 11

### bandwidth 12

## C

### configuring PowerFlex 755 CIP Motion drive

102

### create trends for tuning

Logix Designer setup  
PowerFlex 700S drive 113  
PowerFlex 755 drive 115  
Trend Properties dialog box  
display tab 118  
general tab 117  
name tab 117  
pens tab 118  
sampling tab 121  
X-Axis tab 120  
Y-Axis tab 120  
value bar information 122

## D

### Damping Factor (Z)

changing in PowerFlex 700S drive 57  
changing in PowerFlex 755 drive 63  
description 19

### definitions of mechanical terms 11

### direction test

PowerFlex 700S drive 35  
PowerFlex 755 drive 44

### display tab to create trends for tuning 118

### drive creation and configuration for PowerFlex 755 CIP Motion drive 104

### drive setup for manual tuning PowerFlex 700S and PowerFlex 755 drives 70

### drive tuning background 9

## E

### encoder feedback filter

PowerFlex 700S drive 95  
PowerFlex 755 drive 98

### example of rationalizing PowerFlex gains to CIP gains 102

## F

### feedback configuration

PowerFlex 700S drive 35  
PowerFlex 755 drive 43

### FIR (Finite Impulse Response) filter for PowerFlex 700S drive

configuration 97  
description 96

## G

### general tab to create trends for tuning 117

## H

### hardware filter time constant for PowerFlex 700S drive 96

## I

### inertia 9

### Inertia Auto Tune test

PowerFlex 700S drive 37  
PowerFlex 755 drive 45

### inner loop system rolloff 90

## L

### Lead/Lag filters for speed regulator

application example 92  
description 83  
mechanical backlash application example 89  
using 86

### Load Estimate configuration

PowerFlex 700S 27

### Load Observer configuration

PowerFlex 755 29

### Logix Designer setup to create trends for tuning

PowerFlex 700S drive 113  
PowerFlex 755 drive 115

## M

### manual tuning 67

### manual tuning for PowerFlex 700S and PowerFlex 755 drives

drive setup 70  
position loop tuning 74  
velocity (speed) loop tuning 70

**mechanical terms definitions 11****Motion Planner mode for PowerFlex 700S drive 129****motor control configuration**

PowerFlex 700S drive 33  
PowerFlex 755 drive 41

**motor data**

PowerFlex 700S drive 34  
PowerFlex 755 drive 42

**movement configuration for tuning**

PowerFlex 700S drive 40  
PowerFlex 755 drive 48

**N****name tab to create trends for tuning 117****Notch Filter**

description 78  
using 81

**P****pens tab to create trends for tuning**

PowerFlex 700S drive 118  
PowerFlex 755 drive 118  
useful pens tab tips 119

**position loop tuning**

manual tuning 74  
using bandwidth  
PowerFlex 700S drive 59  
PowerFlex 755 drive 65

**position modes for PowerFlex 755 drive 125****PowerFlex**

control loops 14  
position loop 14  
torque control 18  
velocity (speed) loop 16  
Inertia Adaption 19  
benefits 20  
how it works 20  
PowerFlex 700S drive configuration 21  
PowerFlex 755 drive configuration 24  
Load Estimate and Load Observer 26  
Load Estimator and Load Observer  
benefits 26  
Load Observer  
how it works 26

**PowerFlex 700S drive**

Auto Tune 36  
changing Damping Factor (Z) 57  
create trends for tuning - Logix Designer setup 113  
direction test 35  
drive setup for manual tuning 70  
encoder feedback filter 95  
feedback configuration 35  
FIR (Finite Impulse Response) filter  
configuration 97  
description 96  
hardware filter time constant 96  
Inertia Auto Tune test 37  
Load Estimate configuration 27  
Motion Planner mode 129  
movement configuration for tuning 40  
pens tab to create trends for tuning 118  
Startup Wizard 32  
tuning configuration - additional setup 38  
tuning using bandwidth 52

**PowerFlex 755 CIP Motion drive**

axis configuration 106  
configuration 102  
drive creation and configuration 104  
example of rationalizing PowerFlex gains to CIP gains 102  
setup 103  
using CIP Motion control loop relationships 101

**PowerFlex 755 drive**

Auto Tune 44  
changing Damping Factor (Z) 63  
create trends for tuning - Logix Designer setup 115  
direction test 44  
drive setup for manual tuning 70  
encoder feedback filter 98  
feedback configuration 43  
Inertia Auto Tune test 45  
Load Observer configuration 29  
movement configuration for tuning 48  
pens tab to create trends for tuning 118  
position mode  
descriptions 125  
set as Direct Position mode 126  
set as Point-to-Point (PTP) mode 128  
set as Profiler mode 127  
Startup Wizard 41  
tuning configuration and additional setup 46  
tuning using bandwidth 59

**R****rationalizing PowerFlex gains to CIP gains example 102****regulator compensation filters 77****resonance 11****S****sampling tab to create trends for tuning 121**

**set position mode for PowerFlex 755 drive**

- as Direct Position mode 126
- as Point-to-Point (PTP) mode 128
- as Profiler mode 127

**set up PowerFlex 755 CIP Motion drive 103****Startup Wizard**

- PowerFlex 700S drive 32
- PowerFlex 755 drive 41

**T****torque reference Notch Filter**

- description 78
- using 81

**trend information with value bar for tuning 122****Trend Properties dialog box to create trends for tuning**

- display tab 118
- general tab 117
- name tab 117
- pens tab 118
- sampling tab 121
- value bar information 122
- X-Axis tab 120
- Y-Axis tab 120

**trends for tuning (created with Trend Properties dialog box)**

- display tab 118
- general tab 117
- name tab 117
- pens tab 118
- sampling tab 121
- value bar information 122
- X-Axis tab 120
- Y-Axis tab 120

**tuning background 9****tuning configuration and setup**

- overview 31
- PowerFlex 700S drive additional setup 38
- PowerFlex 700S drive Startup Wizard 32
  - Auto Tune 36
  - direction test 35
  - feedback configuration 35
  - Inertia Auto Tune test 37
  - motor control configuration 33
  - motor data 34
- PowerFlex 755 drive additional setup 46
- PowerFlex 755 drive Startup Wizard 41
  - Auto Tune 44
  - direction test 44
  - feedback configuration 43
  - Inertia Auto Tune test 45
  - motor control configuration 41
  - motor data 42

**tuning using bandwidth**

- overview 51
- PowerFlex 700S drive 52
  - position loop tuning 59
  - velocity (speed) loop tuning procedure 53
- PowerFlex 755 drive 59
  - position loop tuning 65
  - velocity (speed) loop tuning procedure 60

**U****using CIP Motion control loop relationships for PowerFlex 755 CIP Motion drive 101****V****value bar trend information for tuning 122****velocity (speed) loop tuning**

- manual tuning 70
- tuning using bandwidth
  - PowerFlex 700S drive 53
  - PowerFlex 755 drive 60

**X****X-Axis tab to create trends for tuning 120****Y****Y-Axis tab to create trends for tuning 120**





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