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Auto-Tune Configuration Attributes

These are the attributes that are associated with auto-tune configuration of a Motion Control Axis.

System Damping

Usage	Access	T	Data Type	Default	Min	Max	Semantics of Values
Required - C (Derived from Damping Factor)	Set/SSV		REAL	1	0.5	2.0	

A Set or SSV to the System Damping attribute value calculates and updates the System Bandwidth based on the current Drive Model Time Constant value (DMTC) and then calculates and updates the applicable loop gain attribute values. The System Damping attribute is designed to be used to implement a single 'knob' Manual Tuning procedure.

A larger damping factor increases the ratio between the inner and outer Loop Bandwidths. In general, the System Damping attribute controls the dynamic response of the overall control loop.

- Position Loop Operation
  If the drive is configured for Position Loop operation, the following calculation is performed and the resulting value applied to the System Bandwidth attribute:

  System Bandwidth = 1/16 Damping Factor^4 * 1/DMTC

- Velocity Loop Operation
  If the drive is configured for Velocity Loop operation the following calculation is applied:

  System Bandwidth = 1/4 Damping Factor^2 * 1/DMTC

- Load Coupling
  If the Load Coupling is a 'Compliant' selection and the Use Load Ratio bit is set in the Gain Tuning Configuration Bits attribute, then the resultant System Bandwidth above is divided by the Load Ratio value.

  System Bandwidth /= (Load Ratio + 1)

- System Bandwidth Value
  In addition to updating the System Bandwidth value, the equations associated with setting the System Bandwidth value are also run.

  The value for this attribute can also be updated using the Damping Factor attribute. When derived from the Damping Factor attribute, no calculations are performed; the System Damping attribute value is simply updated. An SSV to the System Damping attribute also updates the Damping Factor attribute value.

The value for this attribute can also be updated through a Set service to the Damping Factor attribute. When derived from the Damping Factor attribute, no calculations are performed; the System Damping attribute value is simply updated.

A Set or SSV to the System Damping attribute also updates the Damping Factor attribute value.

System Bandwidth

Usage	Access	T	Data Type	Default	Min	Max	Semantics of Values

Required - C (Derived from Servo Bandwidth)	Set/SSV		REAL	0	0	∞	Loop Bandwidth Units

A Set or SSV to the System Bandwidth attribute value calculates and updates the applicable loop gain attribute values based on the current System Damping (Z). The System Bandwidth attribute is designed to be used to implement a single 'knob' Manual Tuning procedure. If the drive is configured for Velocity Loop operation, the System Bandwidth is equivalent to the bandwidth of the velocity loop. If the drive is configured for Position Loop operation, the System Bandwidth is equivalent to the bandwidth of the position loop. In addition to calculating and updating the Loop Bandwidth attribute values, an update to this attribute also updates the Integral Bandwidth attributes as well as the Feedforward attributes according to the Gain Tuning Configuration Bits setting.

The following configurations impact the calculations for this attribute as follows:

- Position Loop Operation
  If the drive is configured for Position Loop operation the following calculations apply:

  Position Loop Bandwidth = System Bandwidth

  Position Integer Bandwidth = 0.25 Damping Factor^2 * System Bandwidth

  Velocity Loop Bandwidth = 4 * Damping Factor^2 * System Bandwidth

  Velocity Integer Bandwidth = System Bandwidth

  Velocity Error Tolerance = 2 * max(Max Accel, Max Decel) / Velocity Loop Bandwidth (rad/s)

- Velocity Loop Operation
  If the drive is configured for Velocity Loop operation the following calculations apply:

  Velocity Loop Bandwidth = System Bandwidth

  Velocity Integer Bandwidth = 0.25/Damping Factor^2 * System Bandwidth

  Velocity Error Tolerance = 2 * max(Max Accel, Max Decel) / Velocity Loop Bandwidth (rad/s)

- Load Observer Configuration
  If the Load Observer Configuration setting indicates the observer function is enabled, the following calculations are performed:

  Load Observer Bandwidth = Velocity Loop Bandwidth

- Gain Tuning Configuration
  If the Gain Tuning Configuration bit for Tune Torque LP Filter is set, the following calculation is performed:

  Torque LP Filter BW = 5 * Velocity Loop BW.

The System Bandwidth value can also be updated through a Set service to the Position Servo Bandwidth or Velocity Servo Bandwidth attributes depending on Axis Configuration. If configured for Position Loop, System Bandwidth is updated by a set to Position Servo Bandwidth. If configured for Velocity Loop, System Bandwidth is updated by a set to Velocity Servo Bandwidth. When derived from either of these attributes, no calculations are performed; the System Bandwidth attribute value is simply updated.

A Set or SSV to the System Bandwidth attribute also updates Position Servo Bandwidth or Velocity Servo Bandwidth attributes depending on Axis Configuration. If configured for Position Loop, the Position Servo Bandwidth is updated. If configured for Velocity Loop, Velocity Servo Bandwidth is updated.

Damping Factor

Usage	Access	T	Data Type	Default	Min	Max	Semantics of Values
Required - GPV	Set/SSV		REAL	FD	0.5	2.0	-

The Damping Factor attribute value is used in calculating the maximum Position and Velocity Servo Bandwidth values during execution of the Motion Run Axis Tune (MRAT) instruction. In general the Damping Factor attribute controls the dynamic response of the drive axis. When gains are tuned using a small damping factor (such as 0.7), a step response test performed on the axis would demonstrate under-damped behavior with velocity overshoot. A gain set generated using a larger damping factor (such as 1.0) would produce a system step response that has no overshoot and works well for most applications.

A set to the Damping Factor attribute also updates the System Damping attribute value to support Manual Tuning.

Position Servo Bandwidth

Usage	Access	T	Data Type	Default	Min	Max	Semantics of Values
Required - P	Set/SSV		REAL	FD	0	∞	Loop Bandwidth Units

The value for the Position Servo Bandwidth represents the unity gain bandwidth of the position loop that is to be used by software Autotune function to calculate the position loop gains. The unity gain bandwidth is the frequency beyond which the position servo is unable to provide any significant position disturbance correction. In general, within the constraints of a stable servo system, the higher the Position Servo Bandwidth the better the dynamic performance of the system. A maximum value for the Position Servo Bandwidth is generated by the MRAT instruction. Computing gains based on this maximum value software Autotune procedure results in a dynamic response in keeping with the current value of the Damping Factor.

A set to the Position Servo Bandwidth attribute while configured for Position Loop operation also updates the System Bandwidth attribute value to support Manual Tuning.

Velocity Servo Bandwidth

Usage	Access	T	Data Type	Default	Min	Max	Semantics of Values
Required - PV	Set/SSV		REAL	FD	0	∞	Loop Bandwidth Units

The value for the Velocity Servo Bandwidth represents the unity gain bandwidth of the velocity loop that is to be used by the software Autotune function to calculate the velocity loop gains. The unity gain bandwidth is the frequency beyond which the velocity servo is unable to provide any significant position disturbance correction. In general, within the constraints of a stable servo system, the higher the Velocity Servo Bandwidth is the better the dynamic performance of the system. A maximum value for the Velocity Servo Bandwidth is generated by the MRAT instruction. Computing gains based on this maximum value using the software's Autotune procedure results in a dynamic response in keeping with the current value of the Damping Factor.

A set to the Velocity Servo Bandwidth attribute while configured for Velocity Loop operation also updates the System Bandwidth attribute value to support Manual Tuning.

Drive Model Time Constant

Usage	Access	T	Data Type	Default	Min	Max	Semantics of Values
Required - C	Set/ SSV#		REAL	0.0015 FD	10^{-6}	1	Seconds

 # Indicates the attribute cannot be set while the tracking command (Tracking Command bit in CIP Axis Status is true).

The value for the Drive Model Time Constant represents a lumped model time constant for the drive's current loop and is used to calculate the Velocity and Position Servo Bandwidth values. The Drive Model Time Constant is the sum of the drive's current loop time constant, the feedback sample period, calculation delay, and the time constant associated with the velocity feedback filter. This value is set by software based on the specific drive amplifier and motor feedback selection.

Since the bandwidth of the velocity feedback filter is determined by the resolution of the feedback device, the value for the Drive Model Time Constant is smaller when high resolution feedback devices are selected.

Converter Model Time Constant

Usage	Access	T	Data Type	Default	Min	Max	Semantics of Values
Required - G	Set/ SSV#		REAL	0.0015 FD	10^{-6}	1	Seconds

 # Indicates the attribute cannot be set while the tracking command (Tracking Command bit in CIP Axis Status is true).

The value for the Converter Model Time Constant represents lumped model time constant for the converter’s current loop and used to calculate Bus Voltage loop bandwidth values. The Converter Model Time Constant is the sum of the converter’s current loop time constant, and the calculation delay. This value is set by software based on the specific converter selection.

(A set to the Converter Model Time Constant attribute while configured for Active Current Control operation also updates the System Bandwidth attribute value to support Manual Tuning.)

Application Type

Usage	Access	T	Data Type	Default	Min	Max	Semantics of Values
Required - PV	Set/GSV		USINT	1	-	-	Enumeration: 0 = Custom 1 = Basic 2 = Tracking 3 = Point-to-Point 4 = Constant Speed 5-255 = Reserved

This attribute specifies the type of motion control application and is used by configuration and auto-tune software to set the Gain Tuning Configuration Bits attribute that establishes the appropriate gain set the application.

The relationship between Application Type and Gain Tuning Configuration Bits is described in the following tables.

The first table shows which Integrator Bandwidth values are applicable based on the Application Type. Separate bits are defined in the Gain Tuning Configuration Bits attribute to enable tuning of Position Integrator Bandwidth, Kpi, and Velocity Integrator Bandwidth, Kvi. The Integrator Hold, iHold, setting applies to any active integrators.

Application Type	Kpi	Kvi	iHold
Custom	-	-	-
Basic	no	no	no
Tracking	no	yes	no
Point-Point	yes	no	yes
Const. Spd.	no	yes	no

The next table shows which Feedforward values are applicable based on the Application Type. Separate bits are defined in the Gain Tuning Configuration Bits attribute to enable tuning of Velocity Feedforward, Kvff, and Acceleration Feedforward, Kaff.

Application Type	Kvff	Kaff
Custom	-	-
Basic	yes	no
Tracking	yes	yes
Point-Point	no	no
Const. Spd.	yes	no

Finally, the Torque Low Pass Filter bit enables tuning of the Torque Low Pass Filter Bandwidth. This bit is set for all Application Types except Custom,

Application Type	Torque LP Filter
Custom	-
Basic	yes
Tracking	yes
Point-Point	yes
Const. Spd.	yes

If Application Type is set to Custom, individual gain calculations can be controlled directly by the user by changing the bit settings in the Gain Tuning Configuration Bits attribute. If the Application Type is not Custom, these bit settings may not be altered, thus maintaining the fixed relationship to the Application Type as defined in the preceding tables.

Loop Response

Usage	Access	T	Data Type	Default	Min	Max	Semantics of Values
Required - GPV	Set/GSV		USINT	1	-	-	Enumeration: 0 = Low 1 = Medium 2 = High 3-255 = Reserved

The Loop Response attribute is used by configuration and auto-tune software to determine the responsiveness of the control loops. Specifically, configuration software uses the Loop Response attribute to determine the value for the Damping Factor, Z, used in calculating individual gain values. The Damping Factor value applied is based on the enumerated Loop Response value according to the following table:

Loop Response	Damping Factor
Low	1.5
Medium	1.0
High	0.8

A High setting for Loop Response is best suited for systems that demand the highest level of control performance. Generally these are rigid mechanical systems with relatively light load inertia/mass, for example, Load Ratio < 3.

A Medium Loop Response setting is best suited for general purpose control applications with modest loading, for example Load Ratio < 10. This setting can accommodate both rigid and compliant mechanical systems.

A Low setting for Loop Response is best suited for systems that control heavy load inertia/mass, for example, Load Ratio > 10. The heavy load inertia/mass of these systems generally required lower position and velocity loop bandwidths to maintain stability and minimize motor heating.

Overall system performance can be improved for a given Loop Response setting by compensating for the load inertia/mass by setting the System Inertia value to the Total Inertia of the mechanical system.

Load Coupling

Usage	Access	T	Data Type	Default	Min	Max	Semantics of Values
Required - C	Set/GSV		USINT	0	-	-	Enumeration: 0 = Rigid 1 = Compliant 2-255 = Reserved

							2-255 = Reserved

The Load Coupling attribute is used by configuration and auto-tune software to determine how the loop gains are derated based on the current Load Ratio. In high performance applications with relatively low Load Ratio values or rigid mechanics, typically no derating is applied. For applications with relatively high Load Ratios and compliant mechanics, derating the loop gains based on the Load Ratio is recommended. The derating simply divides the nominal loop bandwidth values by a factor of the Load Ratio + 1.

Gain Tuning Configuration Bits

Usage	Access	T	Data Type	Default	Min	Max	Semantics of Values
Required - C	Set/ SSV#		WORD	1 Bits 4-7 FD	-	-	Bit Field 0 = Run Inertia Test 1 = Use Load Ratio 2 = Reserved 3 = Reserved 4 = Tune Pos Integrator 5 = Tune Vel Integrator 6 = Tune Vel Feedforward 7 = Tune Accel Feedforward 8 = Tune Toque LP Filter 9...15 = Reserved

 # Indicates the attribute cannot be set while the tracking command (Tracking Command bit in CIP Axis Status is true).

This Gain Tuning Configuration Bits attribute value is a bit field attribute that controls the loop gain-tuning calculations.

Bits 4-7 may not be updated programmatically by SSV instruction unless the Application Type is set to Custom.

The following table provides detailed descriptions for the bits of this attribute:

Bit Name	Description
Run Inertia Test	This bit determines whether or not the MRAT tuning instruction will send a Test Inertia service to the drive to perform an inertia measurement. If this bit is set the Inertia Test will be performed. If the bit is clear, the MRAT will immediately complete without an inertia measurement.
Use Load Ratio	This bit determines if Load Ratio is used in calculating Total Inertia and System Bandwidth calculations. If this bit is set, Load Ratio will be used in these calculations. If this bit is clear, Load Ratio will not have any impact on Total Inertia or System Bandwidth.
Tune Position Integrator	The Tune Position Integrator bit attribute determines whether or not the auto-tuning algorithm calculates a value for the Position Integrator Bandwidth. If this bit is clear (false) the value for the Position Integrator

	Bandwidth is set to zero, disabling the integrator.
Tune Velocity Integrator	The Tune Velocity Integrator bit attribute determines whether or not tuning algorithms calculate a value for the Velocity Integrator Bandwidth. If this bit is clear (false) the value for the Velocity Integrator Bandwidth is set to zero, disabling the integrator.
Tune Velocity Feedforward	The Tune Velocity Feedforward bit attribute determines whether or not tuning algorithms calculate a value for the Velocity Feedforward Gain. If this bit is clear (false) the value for the Velocity Feedforward Gain is set to zero.
Tune Acceleration Feedforward	The Tune Acceleration Feedforward bit attribute determines whether or not tuning algorithms calculate a value for the Acceleration Feedforward Gain. If this bit is clear (false) the value for the Acceleration Feedforward Gain is set to zero.
Tune Torque LP Filter	The Tune Torque LP Filter bit attribute determines whether or not tuning algorithms calculate a value for the Torque Low Pass Filter Bandwidth. If this bit is clear (false) the value for the Torque Low Pass Filter Bandwidth is not calculated or altered by the gain tuning algorithms.

See also

[Motor Test Status Attributes]

[Hookup Test Configuration Attributes]

[Inertia Test Configuration Attributes]

 How are we doing?