YASKAWA

TRAINING

# Sigma-7 & SigmaWin+ Ver.7
# **Servo Tuning**

**Class No.** TRM010-Sigma7-Tuning-selfguided

**Rev.** 1.00

**Date:** February 16, 2018

# Contents

# Sigma-7 & SigmaWin+ Ver.7 **Connection**

How to establish communication between software and SERVOPACK

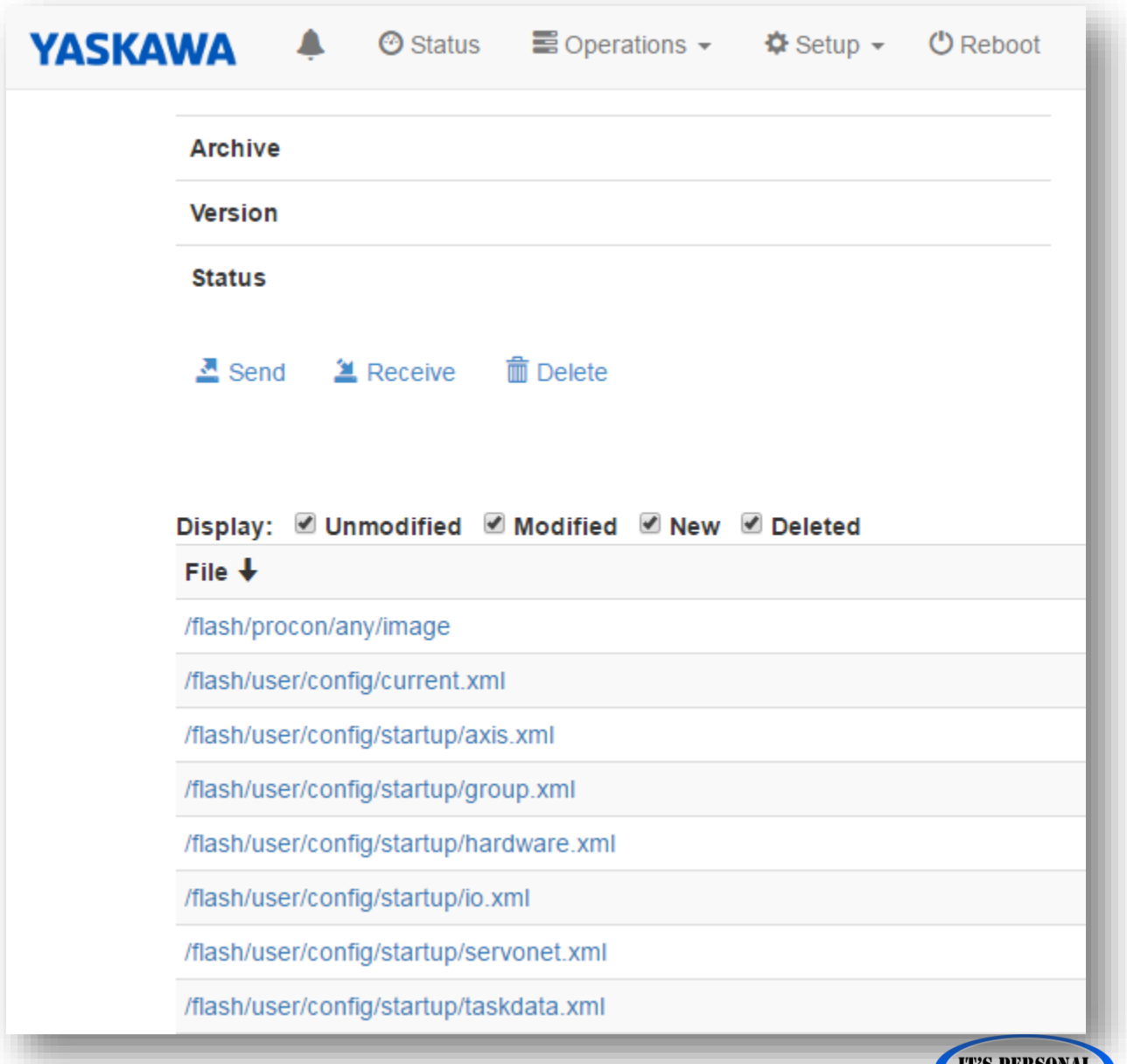
- *Load Demo Program*
- *SigmaWin+ Ver.7 Connection*

# Demo Program - Status

- *Camera*
- *Remote I/O*
- *Web UI*
- *Alarms?*
- *Remote I/O Interface?*

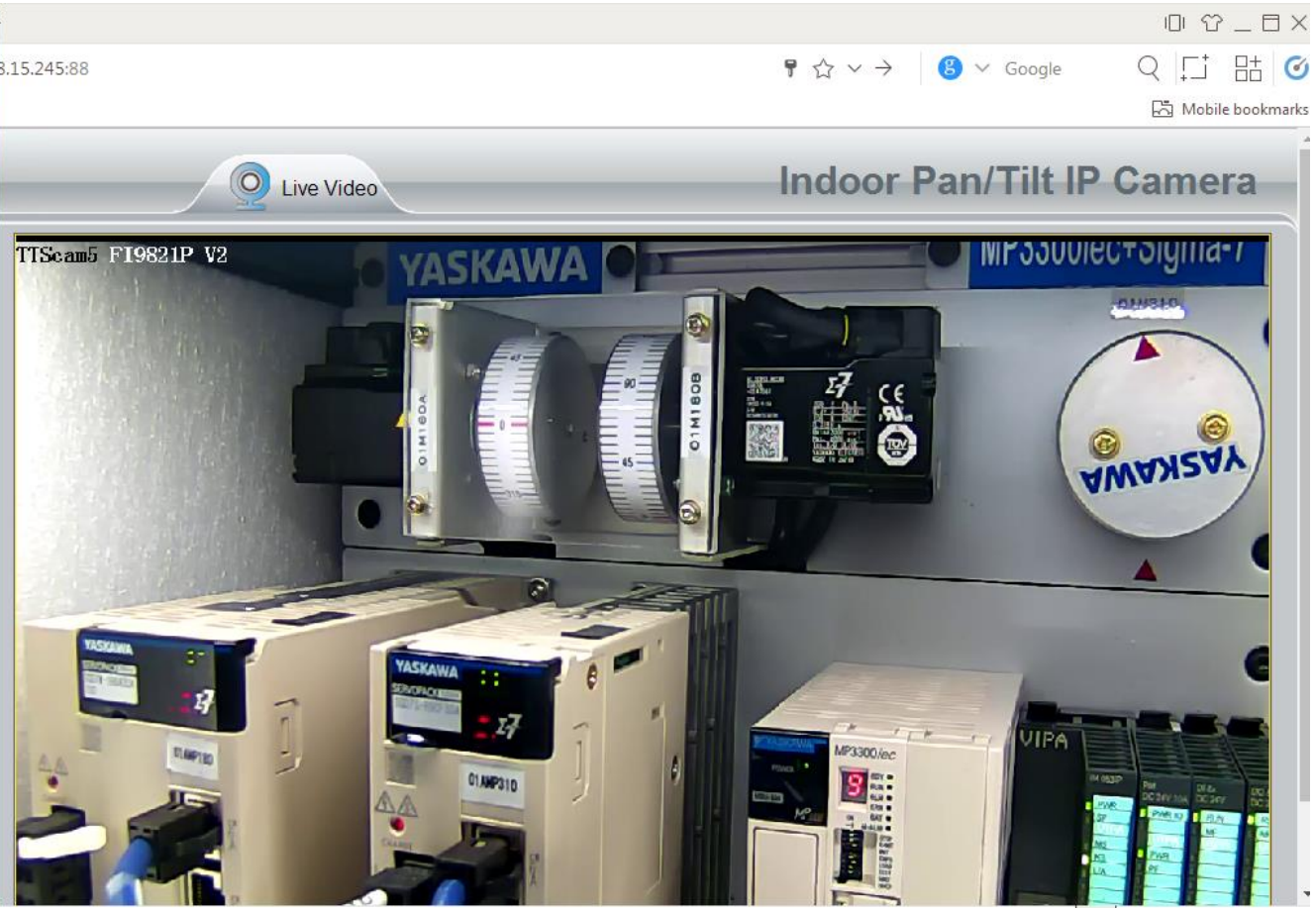
# Demo Program

1. *Web UI – User – Login – "Admin", "MP3300"*
2. *Setup – Archive – Send – Add Archive*
3. *Navigate, select archive, open, send, Install*
4. *Reboot (30 seconds)*
5. *Setup – Drive Parameters – Write All User Pns – Write*
6. *Reboot (30 seconds)*
7. *Alarms - Clear*

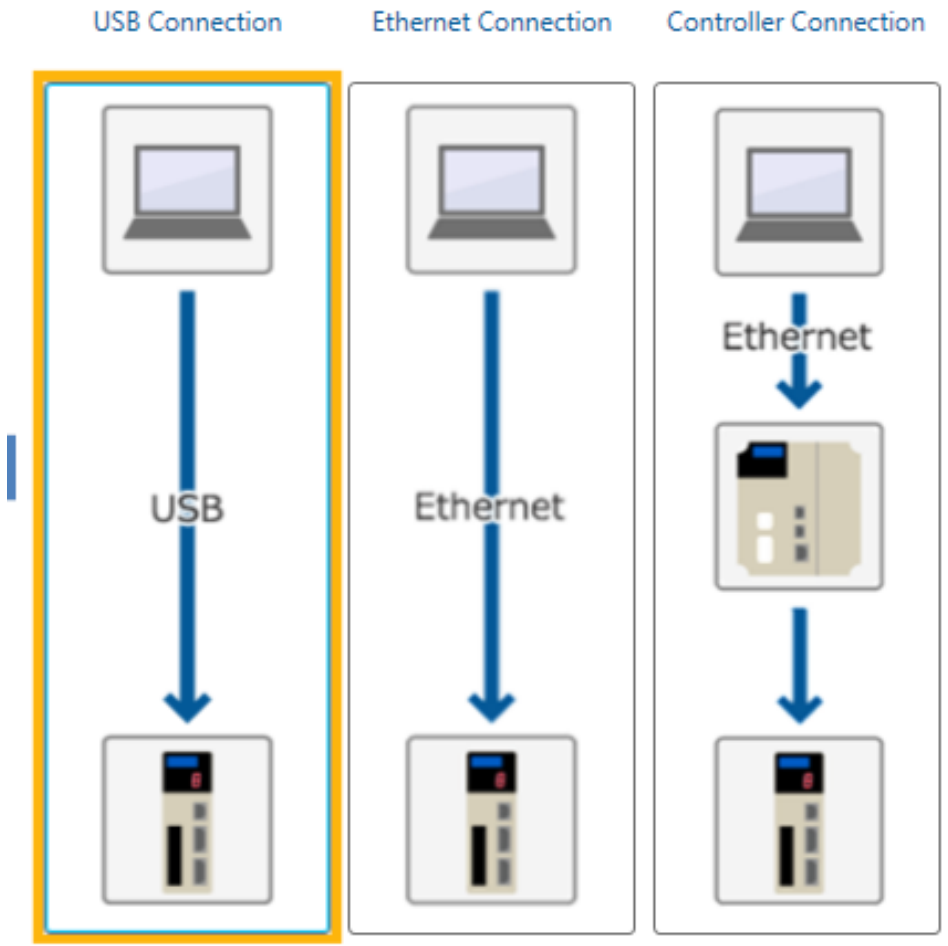


# Demo Program

- *Servo ON*
- *Speed = 10*
- *Jog+*
- *Jog-*

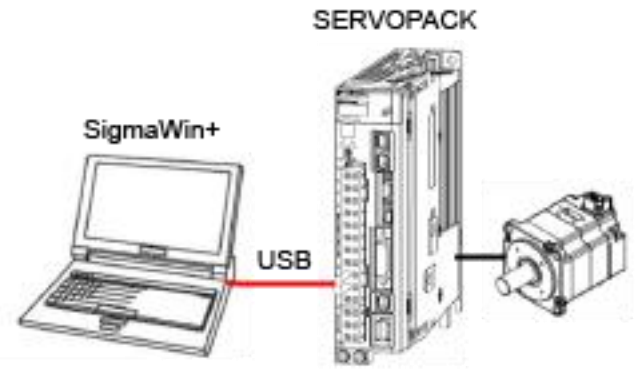



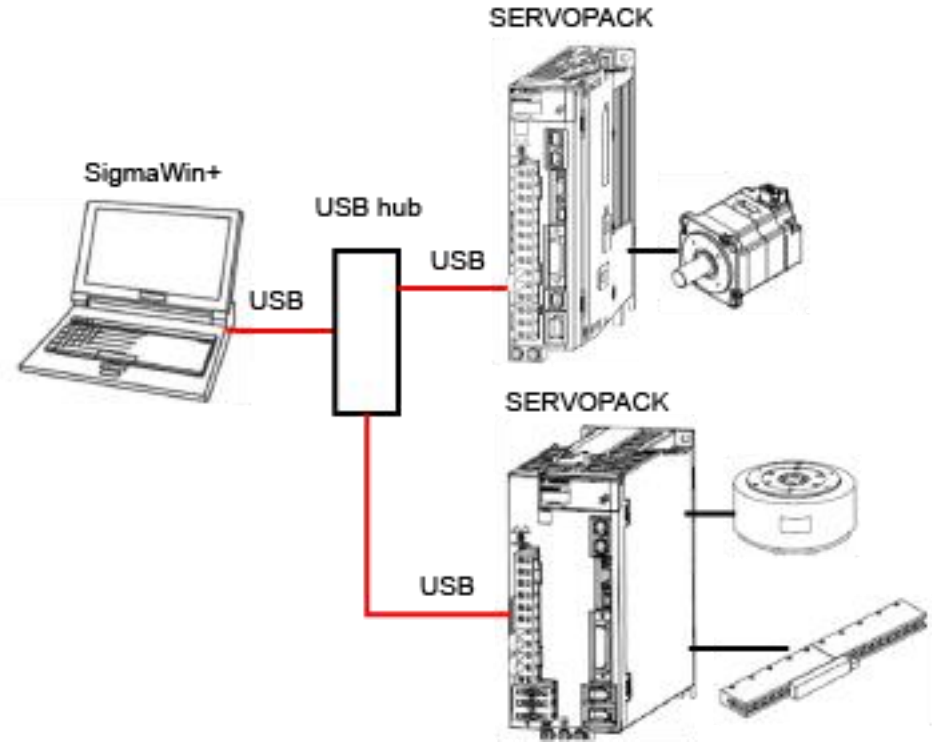
# SigmaWin+ Ver7. Connection

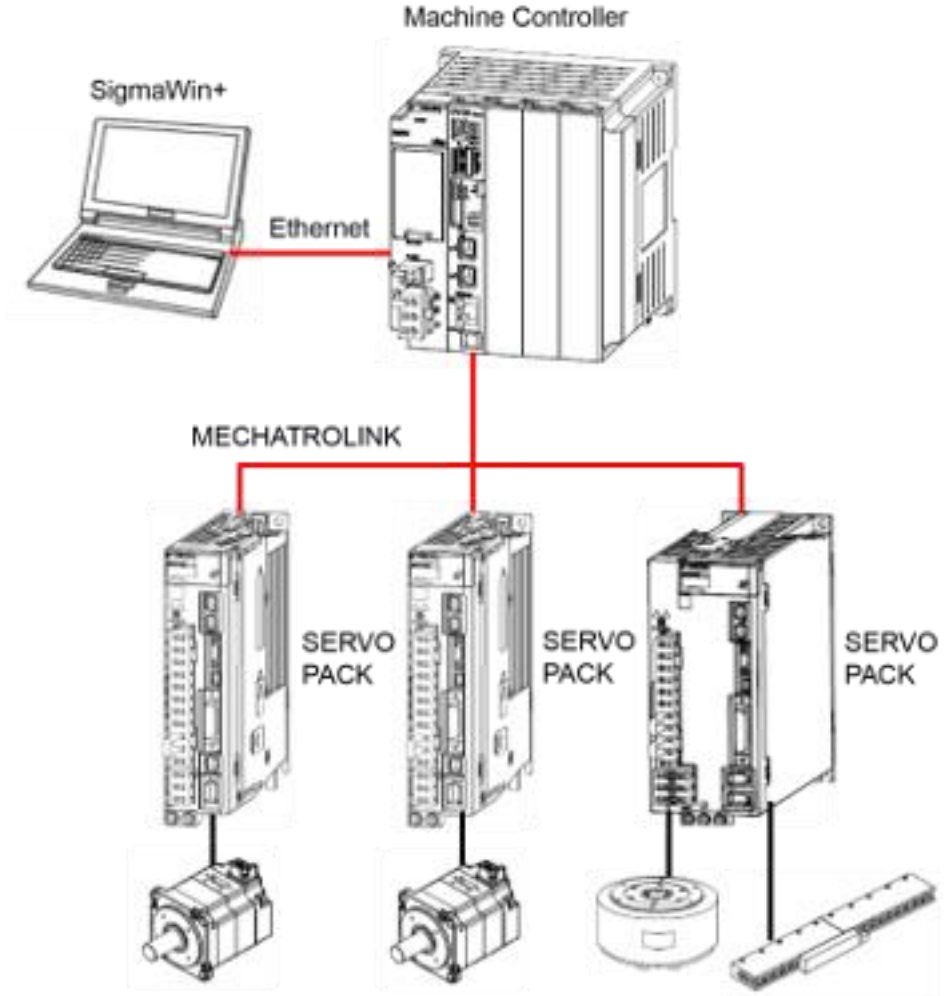
# USB Connection

- *Single Axis*
  - *Direct Cable*
- *Multi Axis*
  - *USB Hub*
  - *Multiple cables*
- *USB Driver*
  - *Manual installation required*



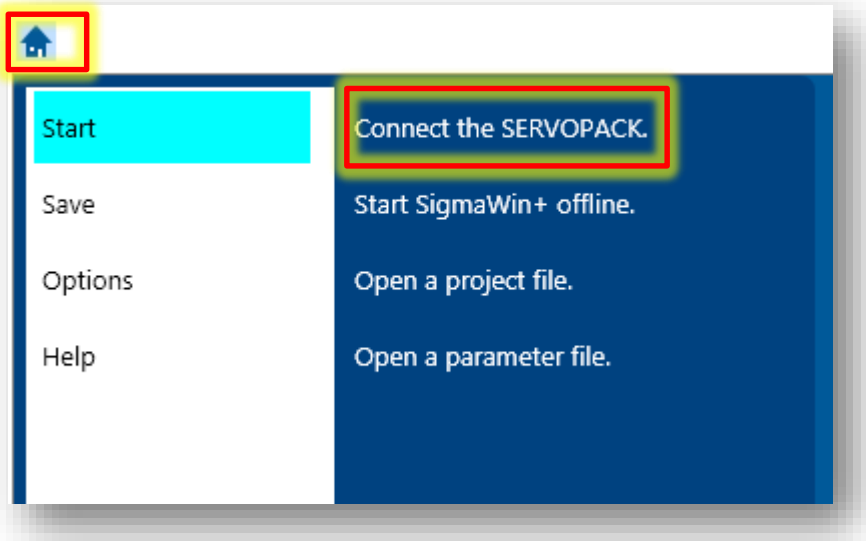



# Ethernet Connection

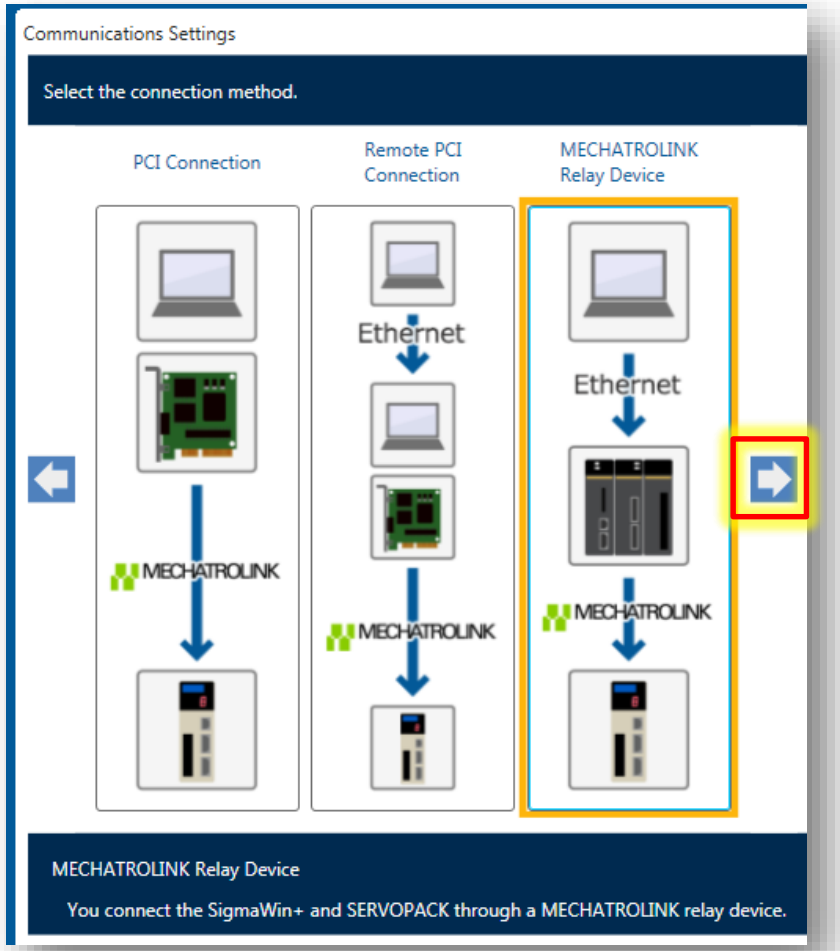



- *Ethernet Connection to Controller*
- *Mechatrolink Connection to Servos*

# Connection via MPiec



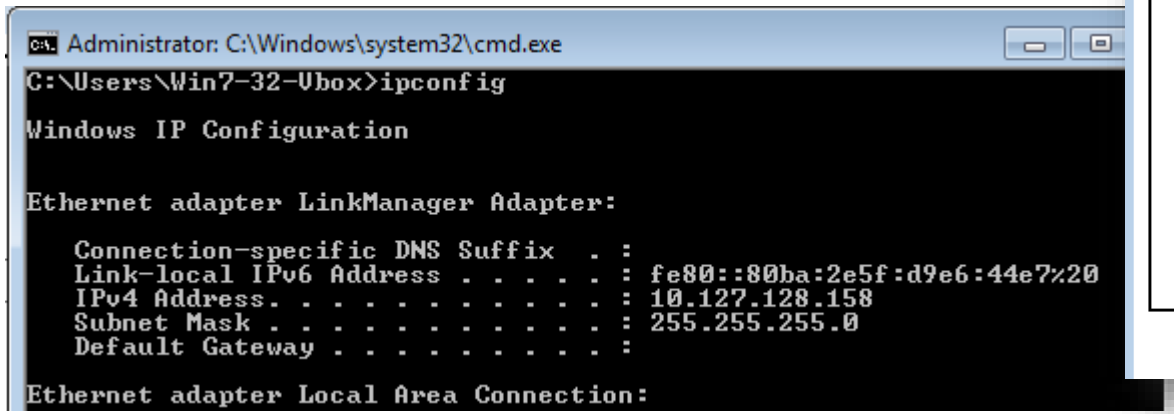

- *Mechatrolink Relay Device*

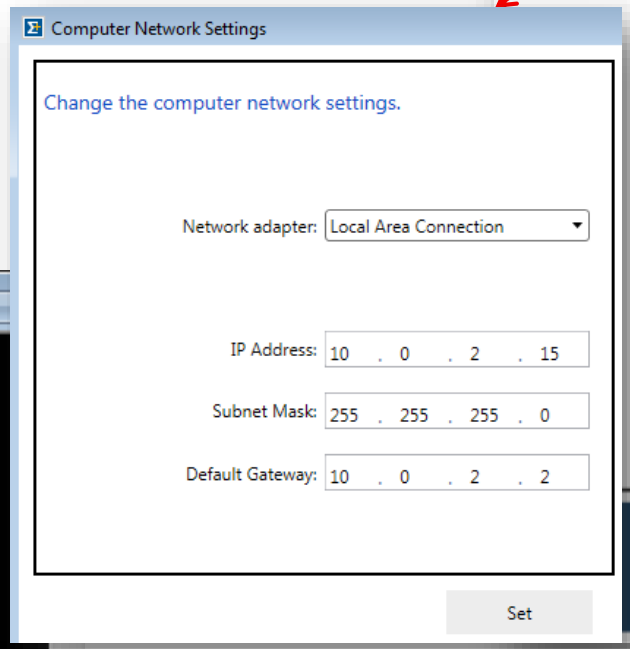


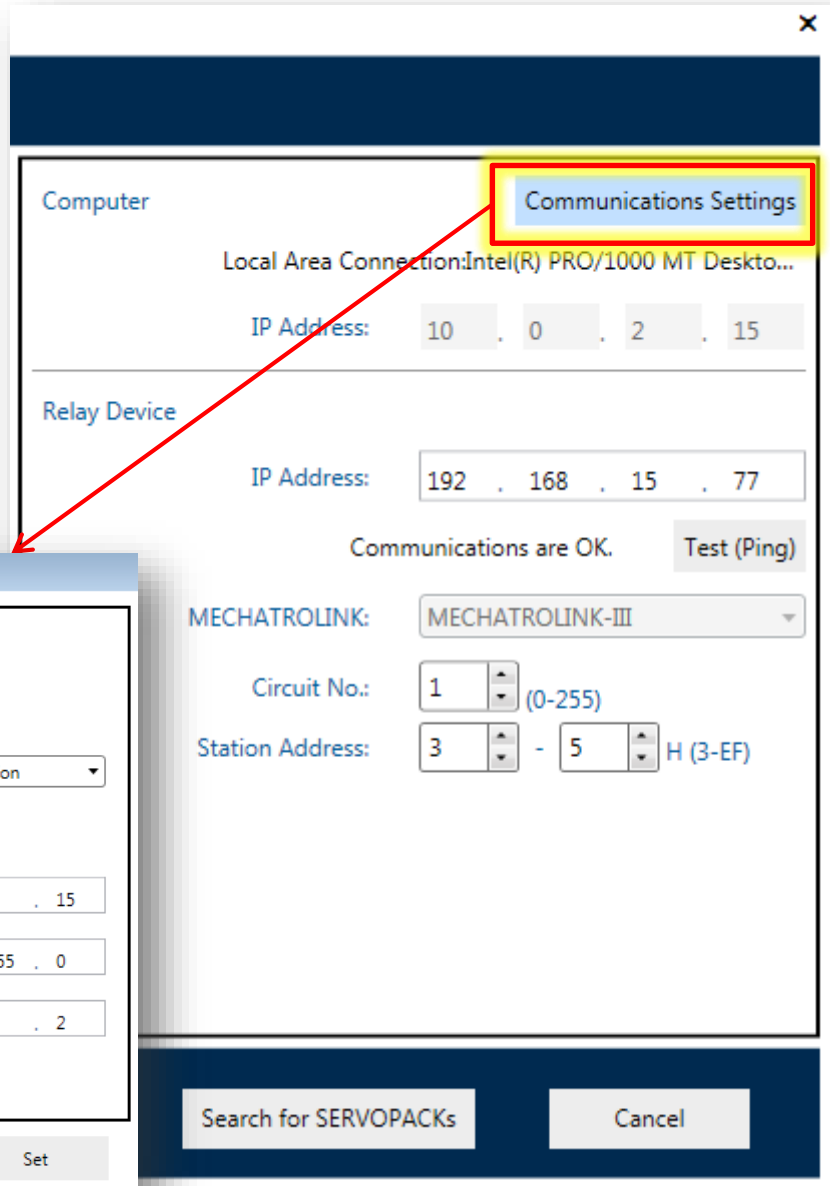
# Connection via MPiec

- *Computer Communication Settings*
  - *Choose network adapter*
  - *Start – cmd – ipconfig*
  - *Enter IP address of PC network adapter*

Find IP address of PC network adapter with ipconfig



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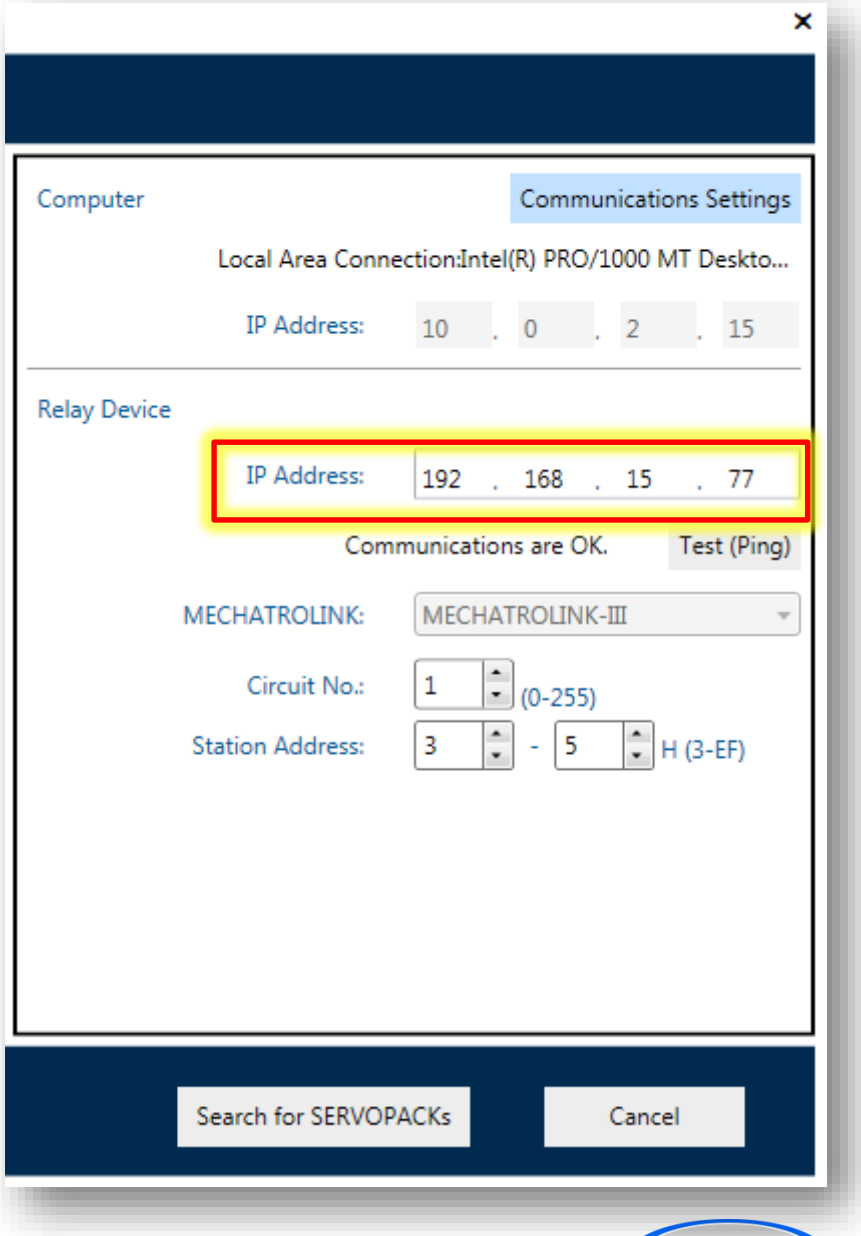
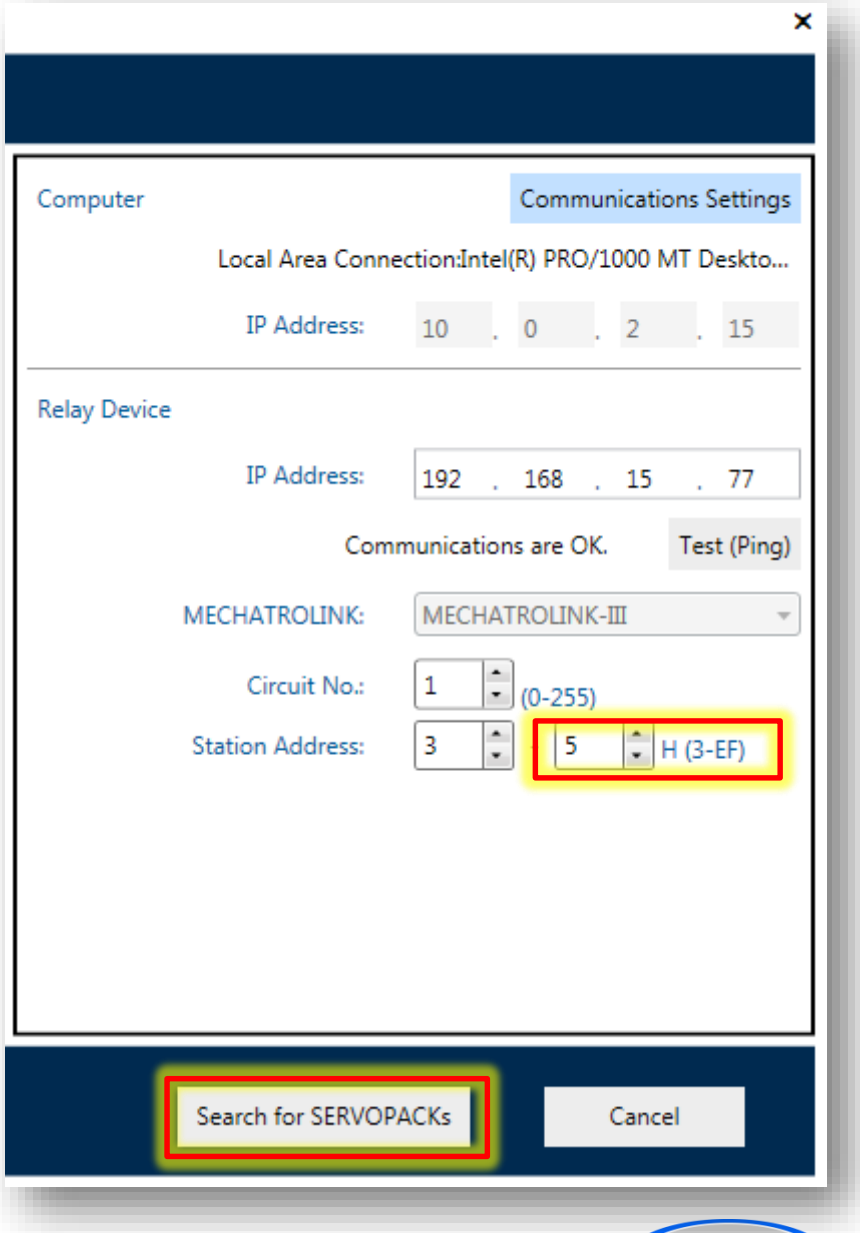
# Connection via MPiec

- *Relay Device*
  - *IP Address*
  - *Test (Ping)*



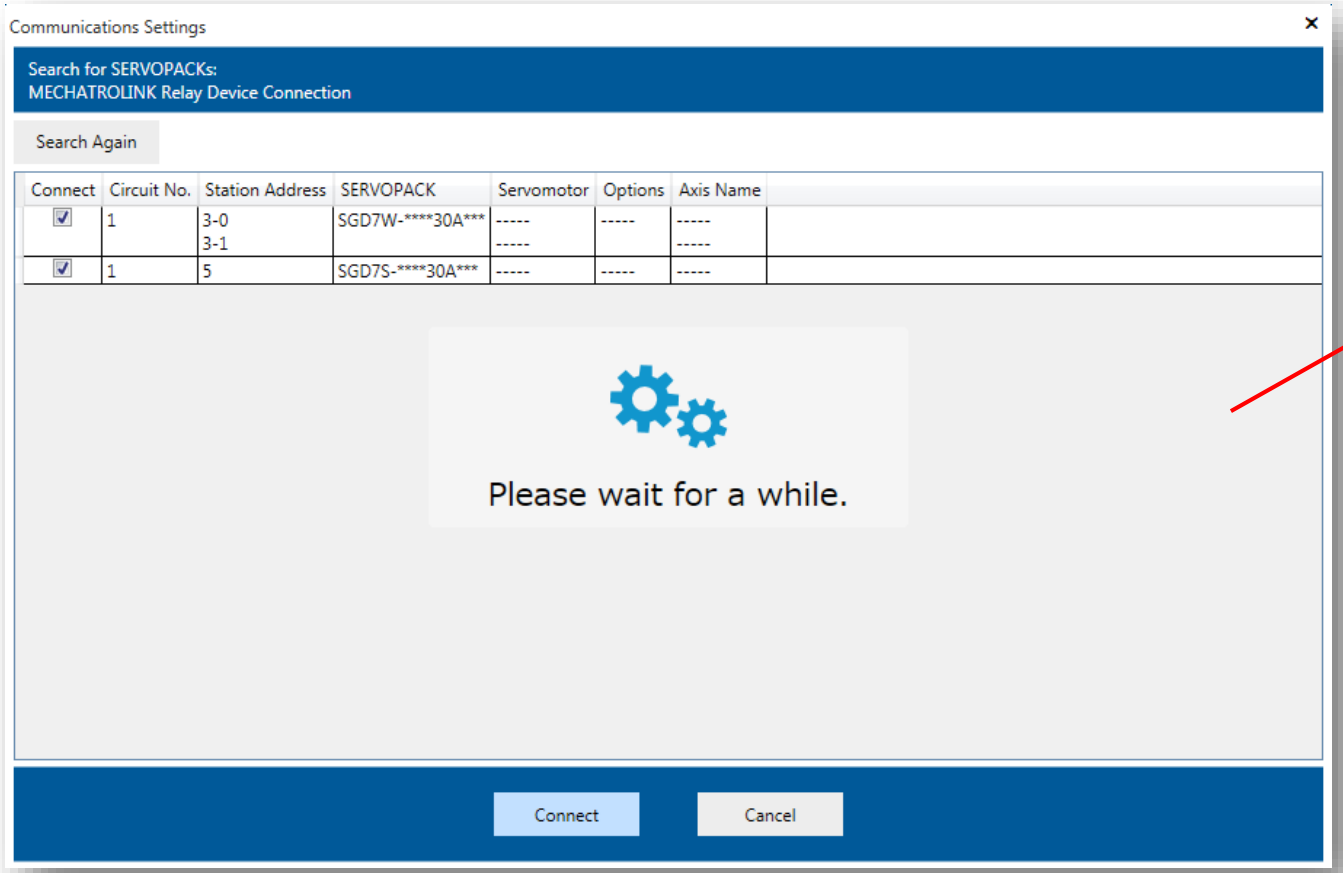
# Connection via MPiec

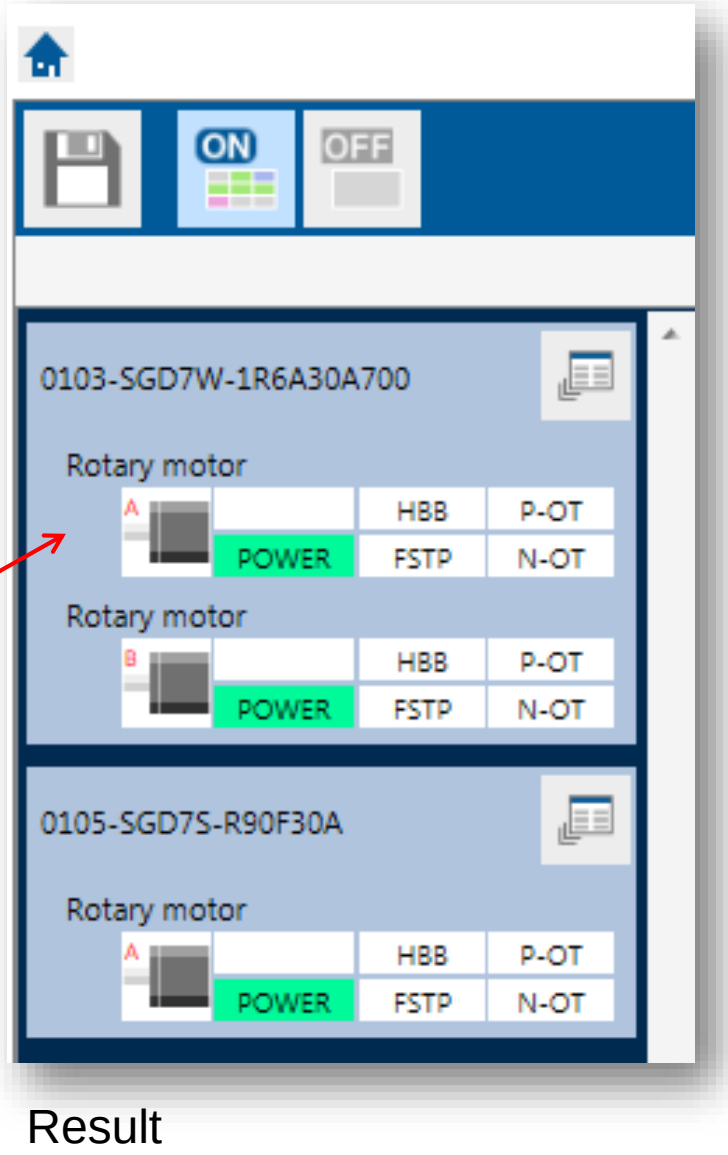
- *Mechatrolink-III*
  - *Station Address*
  - *3 to 5*



# Connection via MPiec

- *Successful Search and Connection*

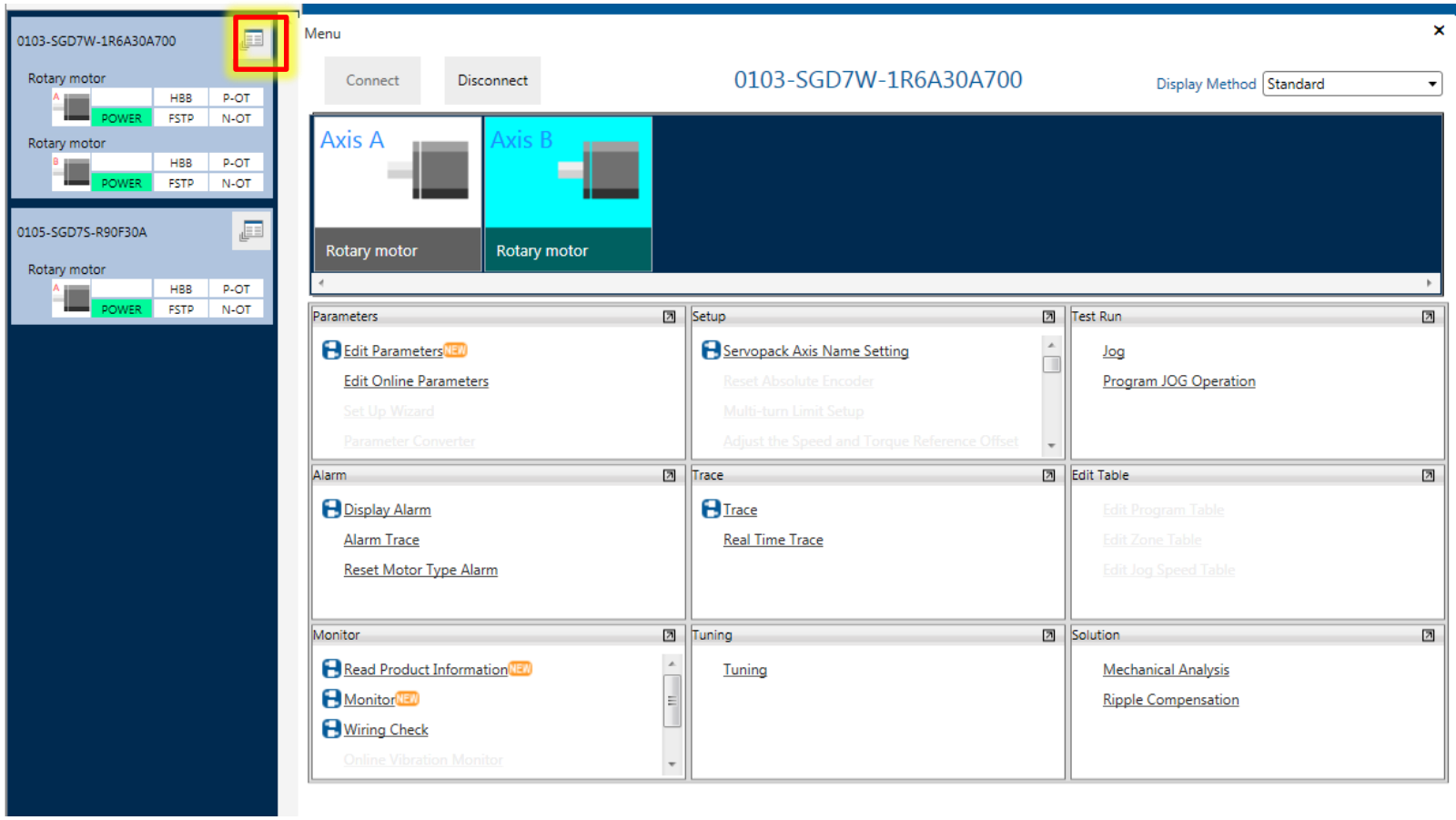


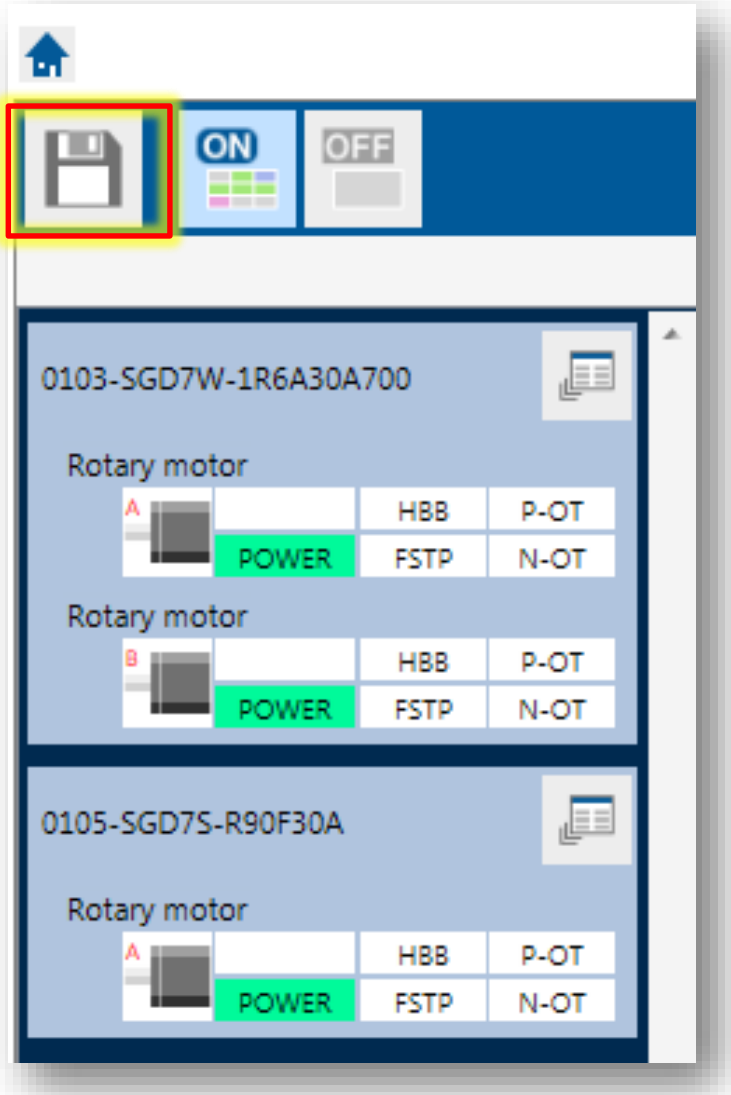

Result

# Software Navigation

- *Menu for each Amplifier*
  - *Choose Axis A or B*
- *Unavailable items grayed out*
  - *Close conflicting window or function*



# Save Project




- *Project file organizes saved data*
  - *Parameters*
  - *By Axis*
  - *By Date*

# Sigma-7 & SigmaWin+ Ver.7
# **Alarms & Monitors**

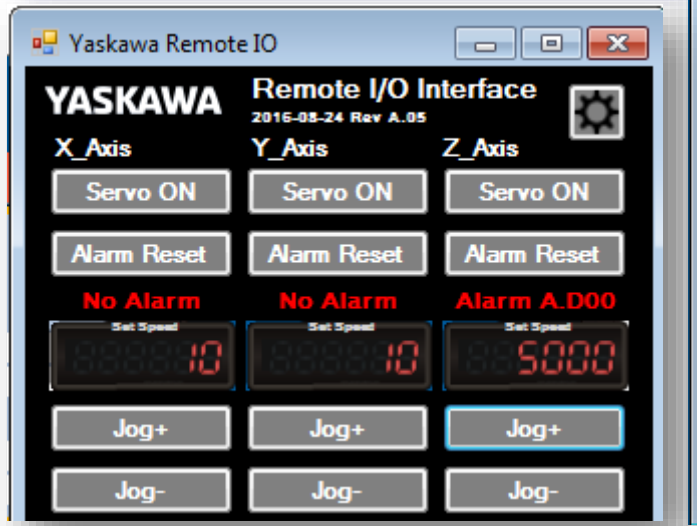
Basic Troubleshooting Tools

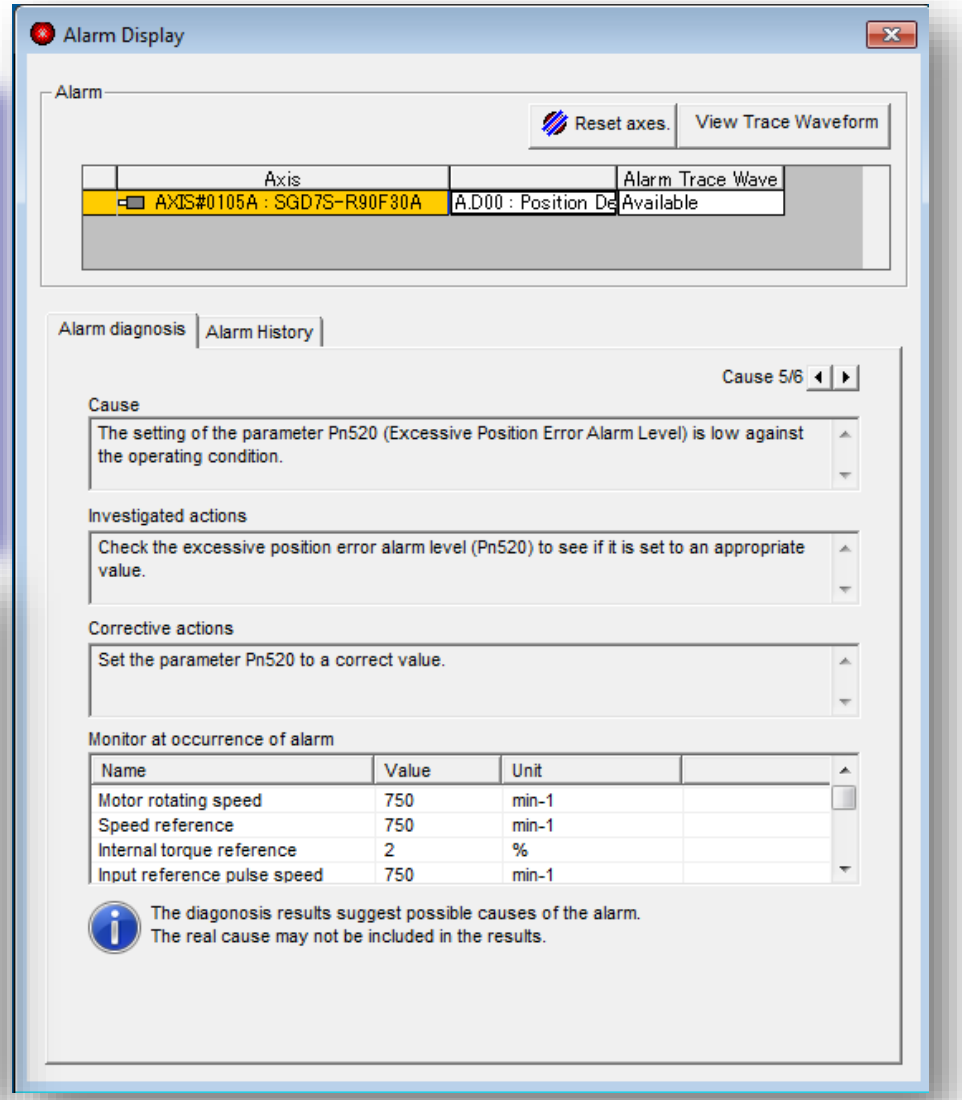
- *Alarm Diagnosis*
- *Alarm Trace*
- *Monitors*
- *Software Reset*

# Alarm Diagnosis

- *Alarm*
  - *Display Alarm*
- *Alarm Diagnosis*
  - *Causes*
  - *Investigate*
  - *Correct*
  - *Monitor at Occurrence*
  - *Alarm History*

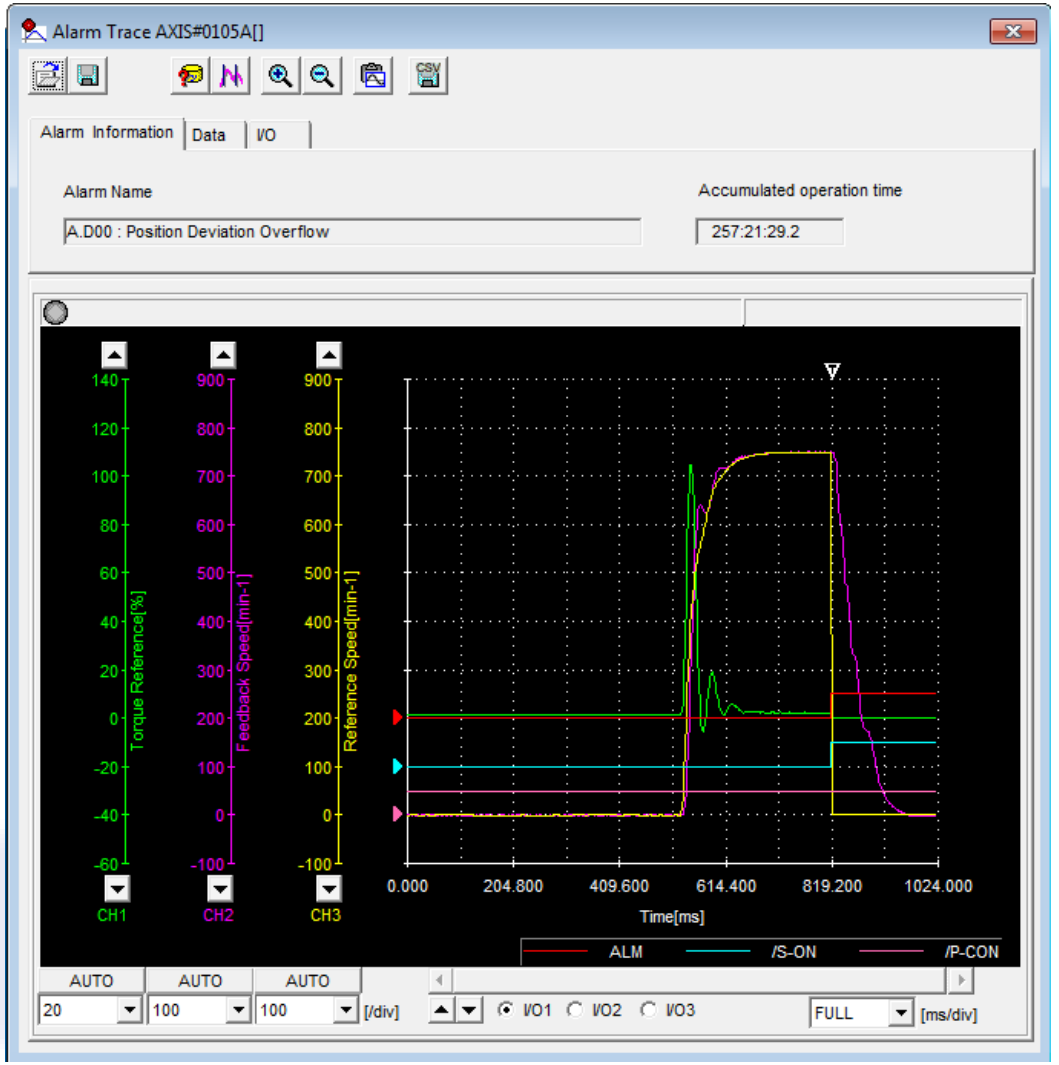
1. Close all SW+ windows
2. Use Remote IO
3. Z_Axis speed 4500 Jog+



# Alarm Trace

- *Alarm History*
  - *Up to 10 alarm traces stored*
- *Alarm – Alarm Trace*
  - *Current Alarm only*




To create alarm A.d00
1. Close all SW+ windows
2. Use Remote IO
3. Z_Axis speed 4500 Jog+

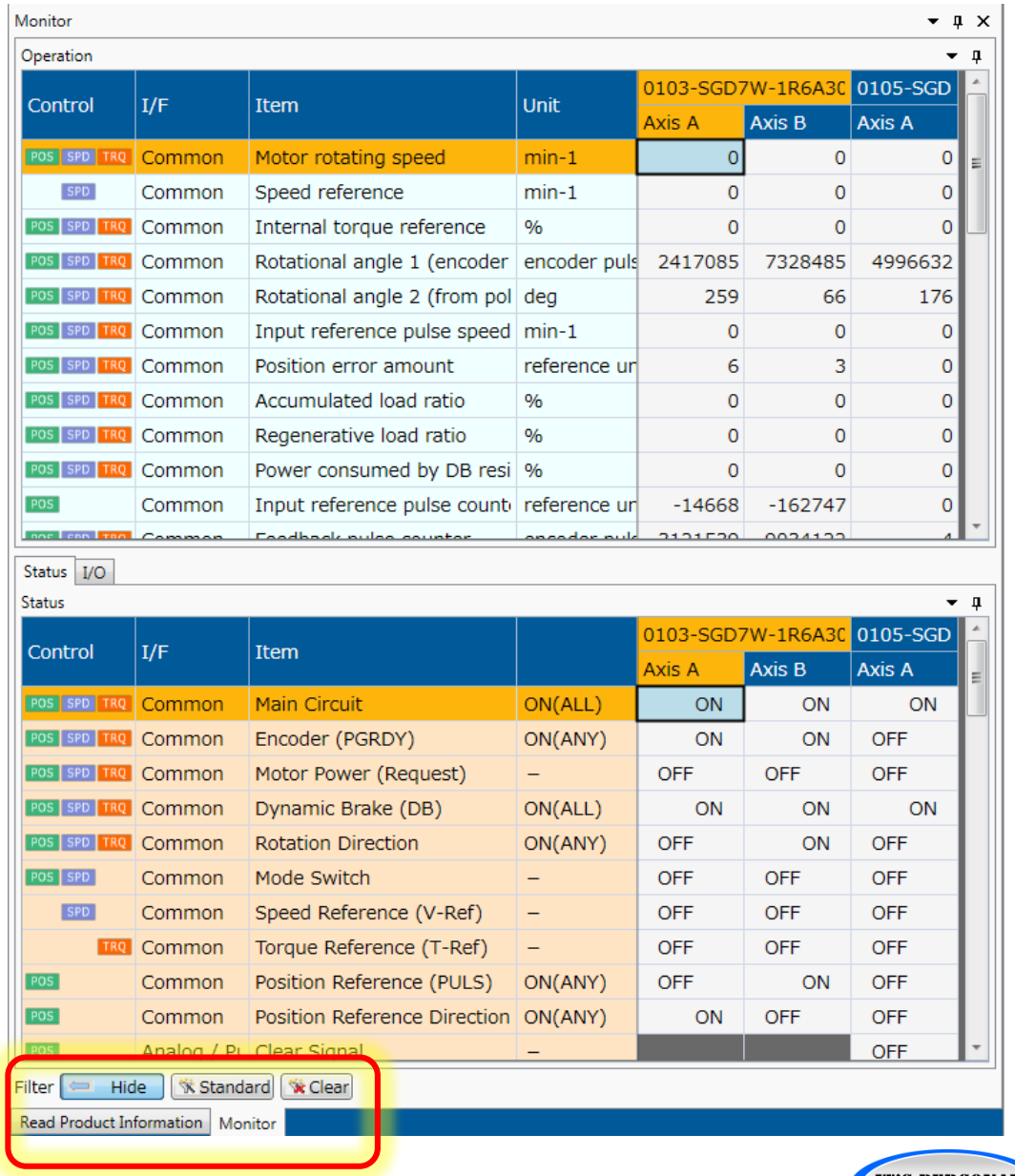
**Alarm Trace**
only available when SigmaWin+ functions are not open

# Alarm Diagnosis

- *Alarm*
  - *Motion cannot continue under current conditions*
  - *Servo Off*
  - *Display Code* **A.**☐☐☐
    - » *Reset may require power cycle*
  - *Examples*
    - » *A.d00 Position Error*
    - » *A.710 Overload: High Load*
    - » *A.410 Undervoltage*
    - » *A.510 Overspeed*
- *Warning*
  - *Future alarm under current conditions*
  - *Servo On*
  - *Display Code* **A.9**☐☐
    - » *Possible automatic reset*
  - *Examples*
    - » *A.900 Position Error*
    - » *A.910 Overload*
    - » *A.971 Undervoltage*
    - » *A.95A Command Warning*

# Monitors

- *Multiple Servo Display*
  - *Read Product Information*
  - *Monitor*
- *How to Use*
  - *Status and I/O Tabs*
    - » *Over-travel Inputs*
  - *Filter*
    - » *Show/Hide control mode*
    - » *Standard filter*
    - » *“Clear” to show all monitors*



# Monitors

- *IO Signal Allocation*
  - *Input Terminals*
  - *Forced Output Mode*

"Lo" = closed circuit

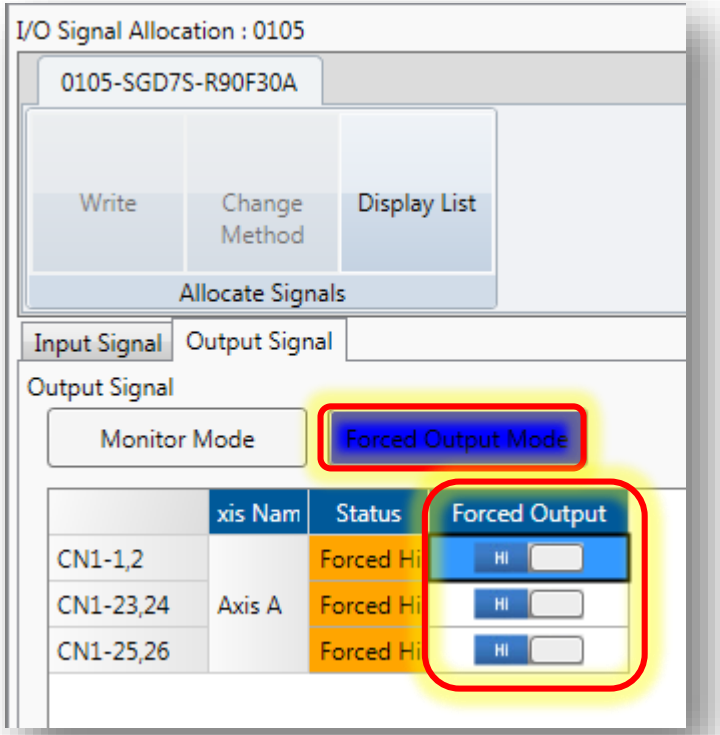


| Status | Forced Output |
|---|---|
| Forced Lo | Lo |

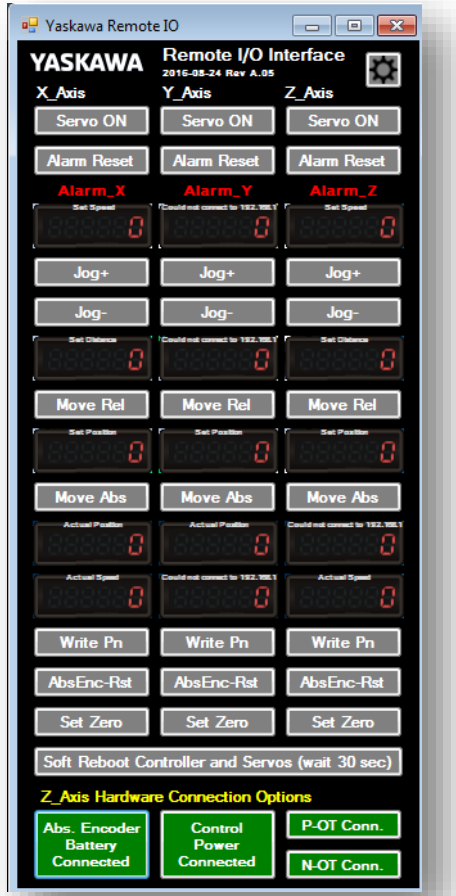
"Hi" = open circuit



| Status | Forced Output |
|---|---|
| Forced Hi | HI |

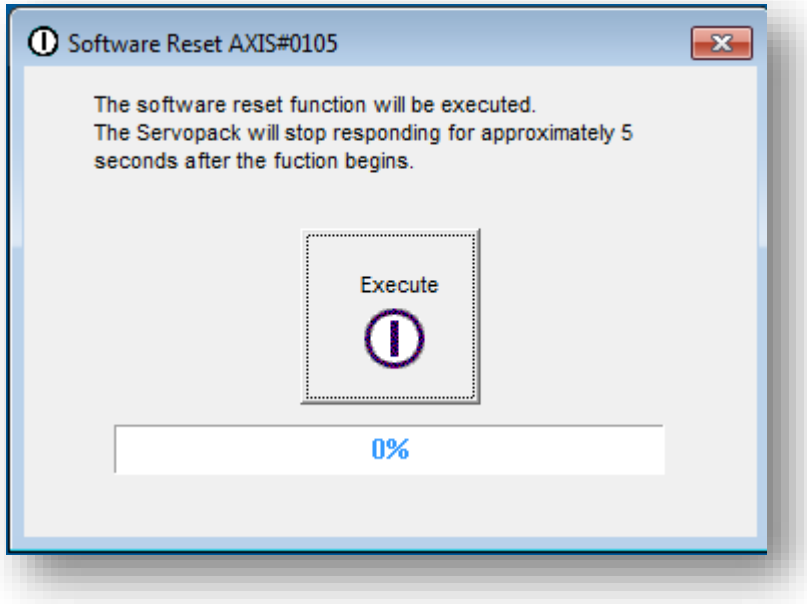



Activate SERVOPACK Outputs



# Software Reset

- *Basic Functions – Software Reset*
  - *Soft Reboot the SERVOPACK*
  - *Recover from alarms that cannot be cleared*
    - » *Example: A.0b0*
    - » *Example: A.810*

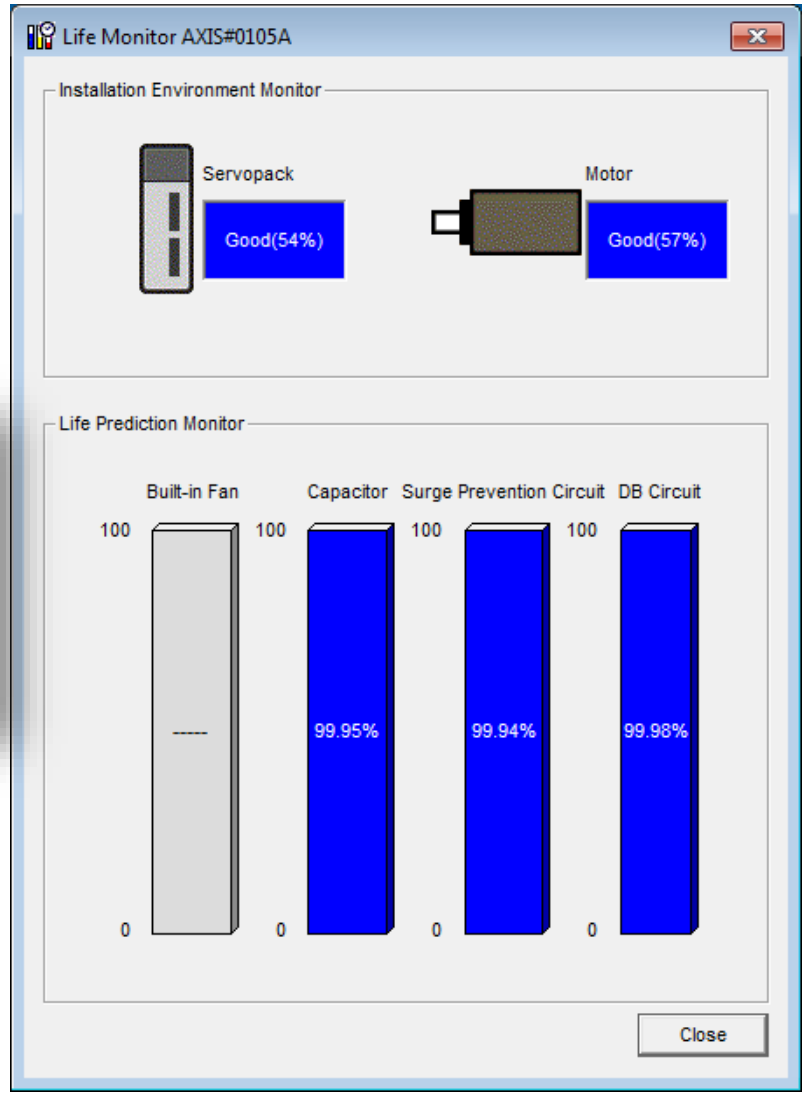


# Monitors

- *Life Monitor*
  - *Installation Environment Monitor*
    - » *Servopack Temperature*
      - – *Range: 0-115%*
      - – *100% = 85 C*
      - – *Un25A*
    - » *Servomotor Temperature*
      - – *Range: 0-115%*
      - – *Un25B*
      - – *100% = 85 C*
  - *Life Prediction Monitor*
    - » *If Level ≤ 10% ➔ warning A.9b0*
      - – *Disable warning Pn00F.0=1*

| Part | Standard Replacement Period |
|---|---|
| Cooling Fan | 4 to 5 years |
| Electrolytic Capacitor | 10 years |
| Relays | 100,000 power ON operations |
| Battery | 3 years without power supplied |

Product Manual 12.1.2



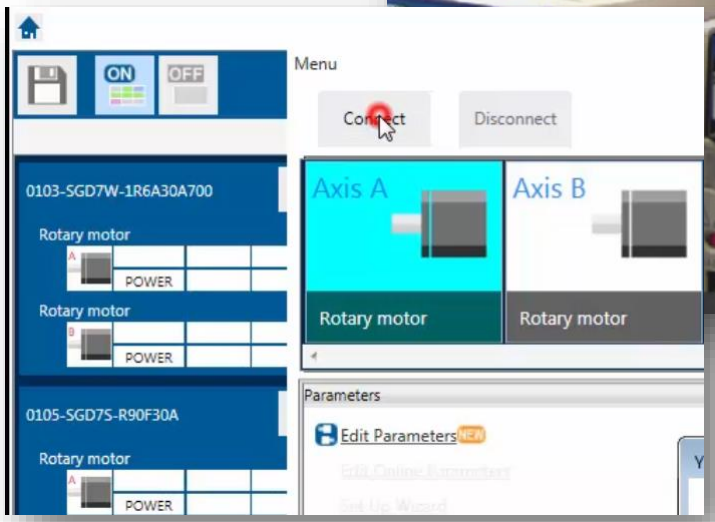
# Sigma-7 & SigmaWin+ Ver.7
# **Parameters**

Backup, restore, and change amplifier settings

- *Connect Project*
- *Backup Parameters*
- *Edit Parameter Settings*
- *Initialize to factory setting*
- *Parameter Restore*

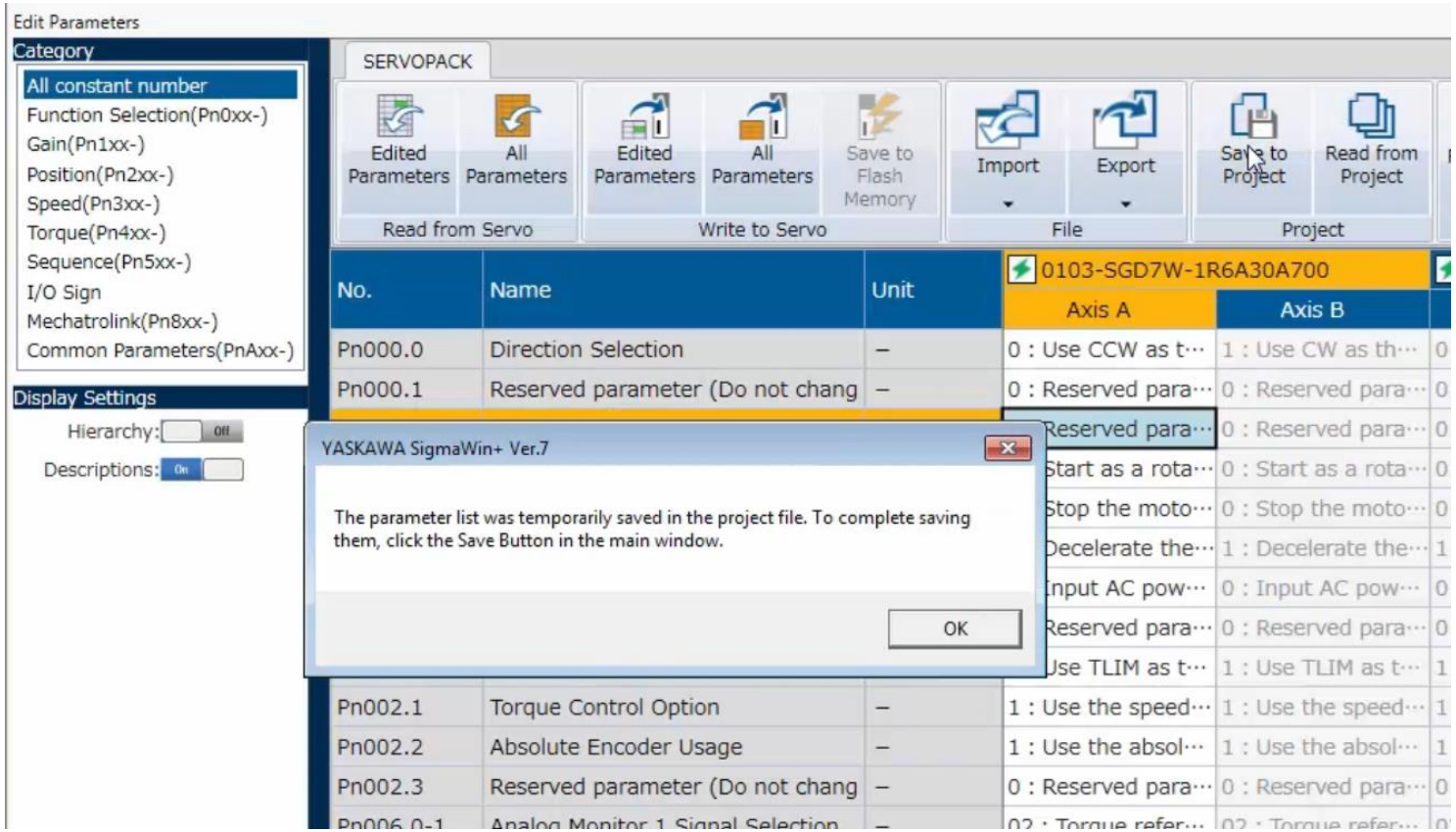
# Status

- *Remote Demo*
- *SW+7 online with project*
  - *Open SW+7*
  - *Home - Open Project*
  - *Menu*
  - *Connect*

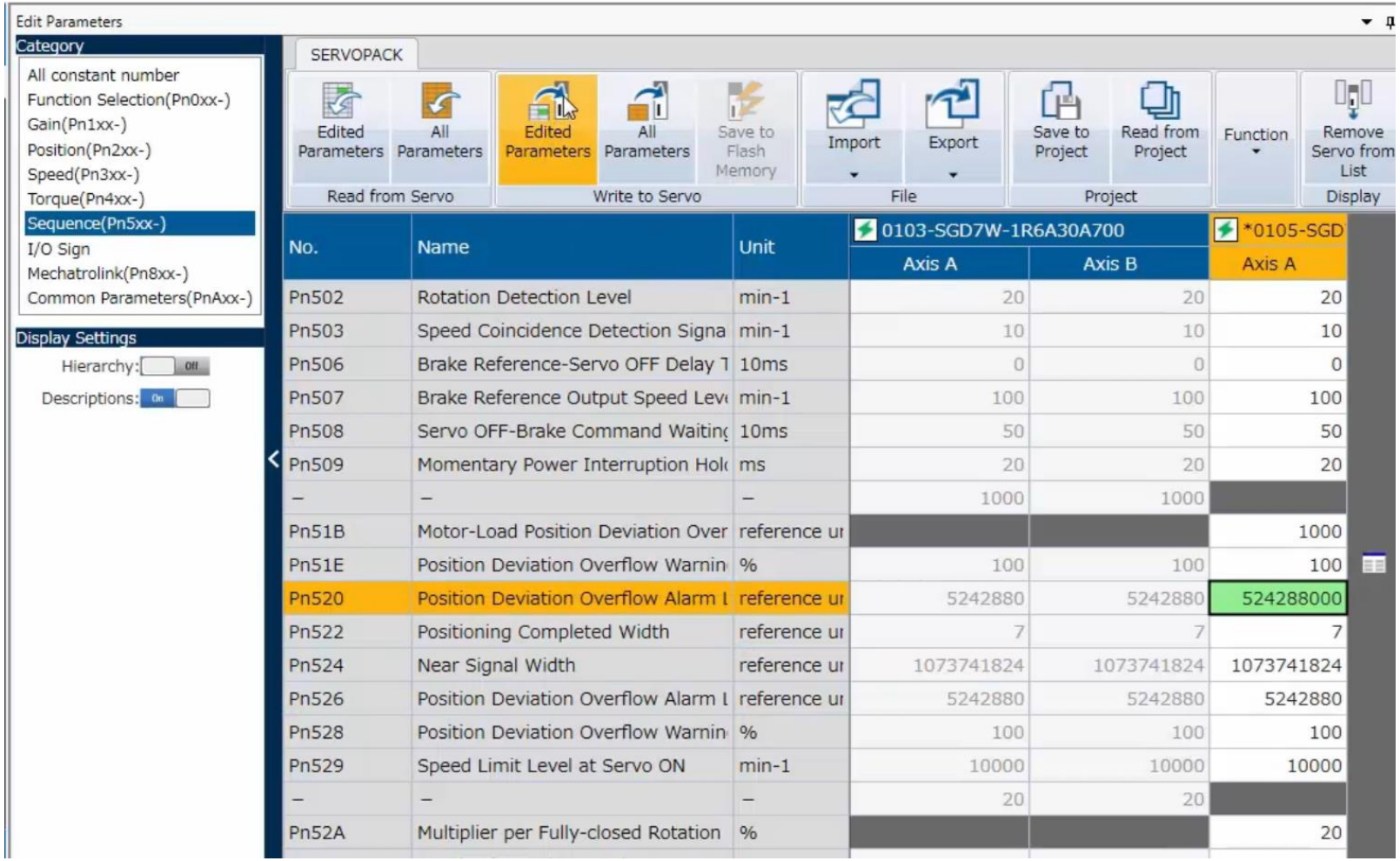
# Backup

- *Connect*
- *Open edit parameters for all axes*
- *Save to project*
  - *each servo (not each axis)*
  - *save project*
- *Export*
  - *To another system*



# Edit

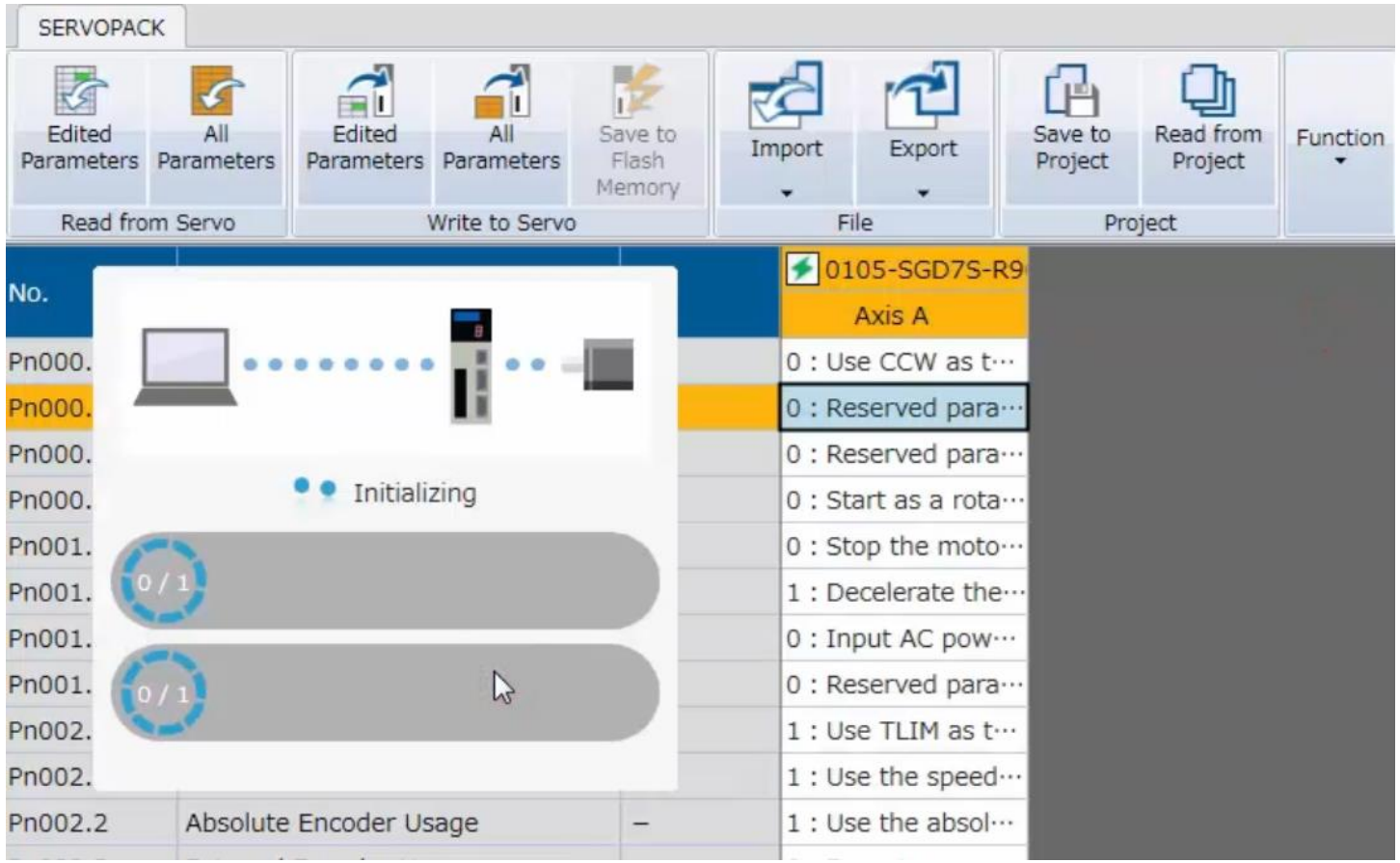
- *Category*
- *Edit*
  - *Pn520*
  - *Pn316*
- *Write*
- *Software Reset*
- *Save / Read*
- *Initialize*
- *Import / Export*




Details in Help section 4.2.3 “Setting Individual Parameters”

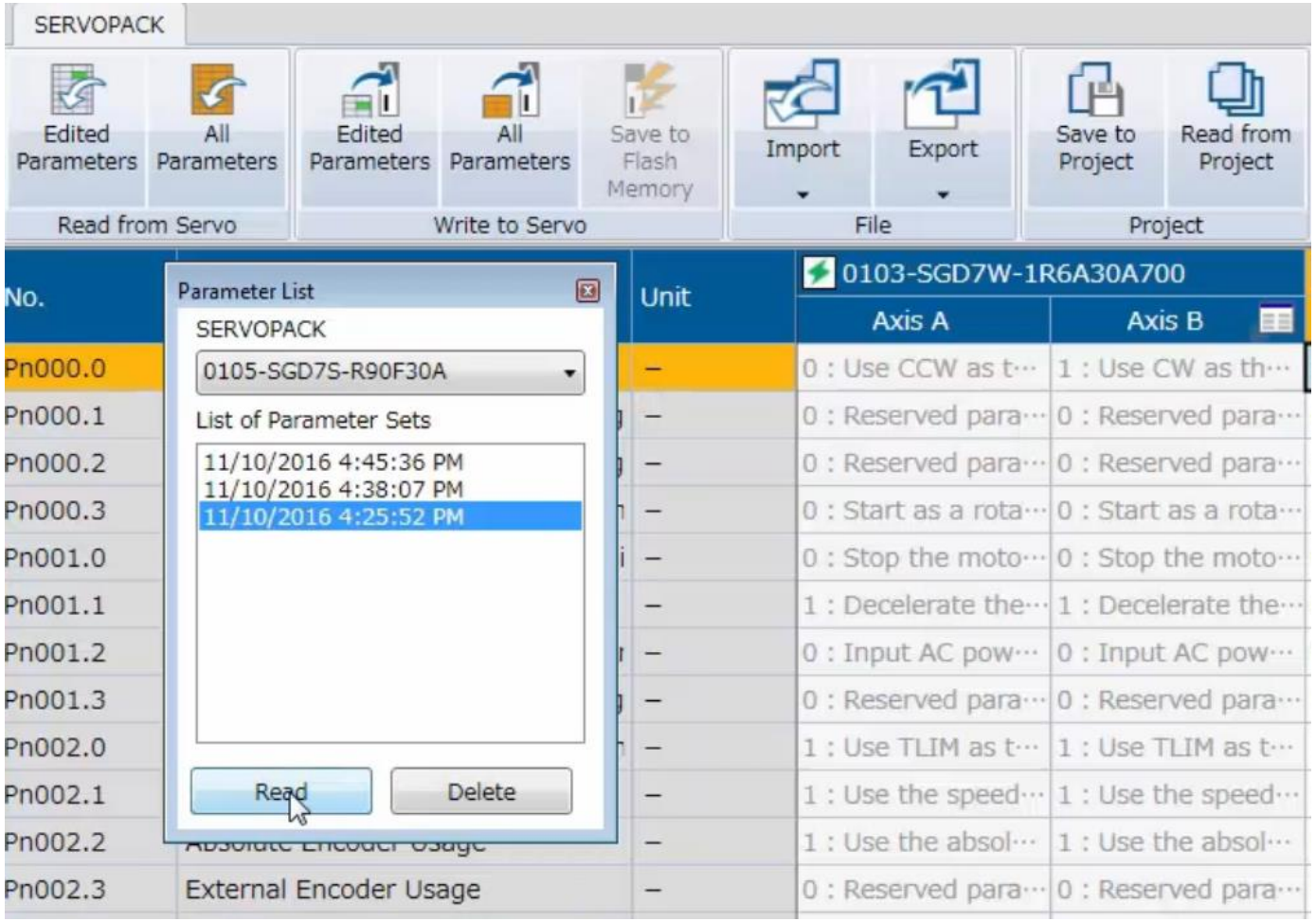
# Initialize to Factory Default

- *Compare*
- *Initialize*
- *SW reset*

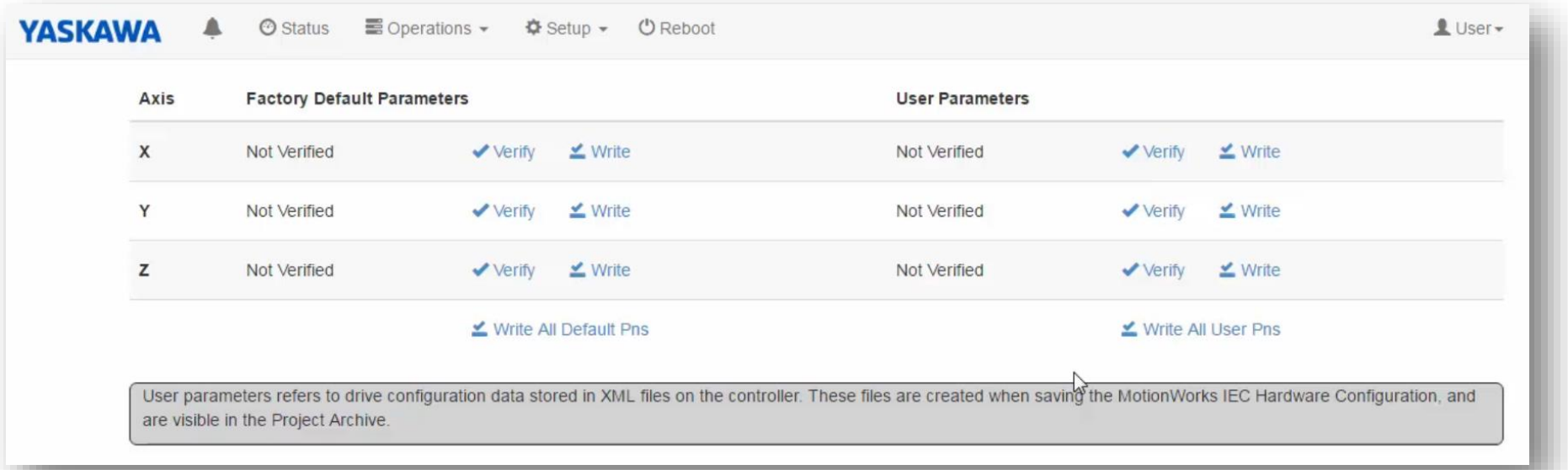


# Restore from Project

- *Read from Project*
- *Write Parameters*
- *Software Reset*



# Write All User Pns




- *Recover in Web UI*
  - *Login*
  - *Setup – Drive Parameters*
  - *Write All User Pns*

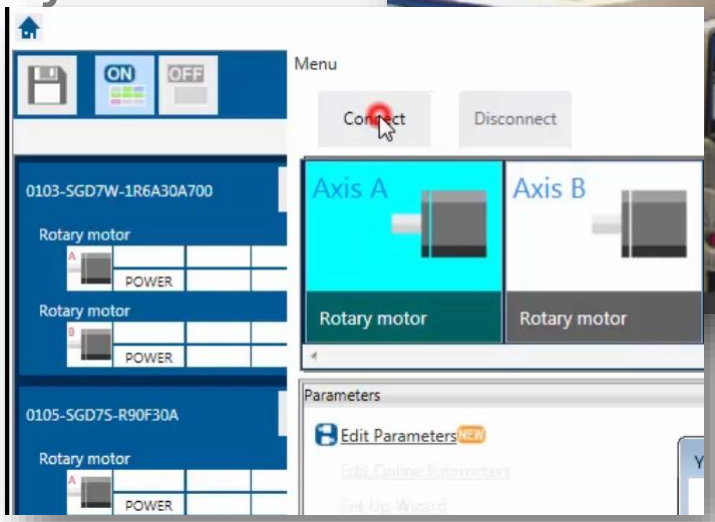
# Sigma-7 & SigmaWin+ Ver.7
# **Motor Test Run**

Basic motor Jog and positioning

- *Jog*
- *Program Jog*

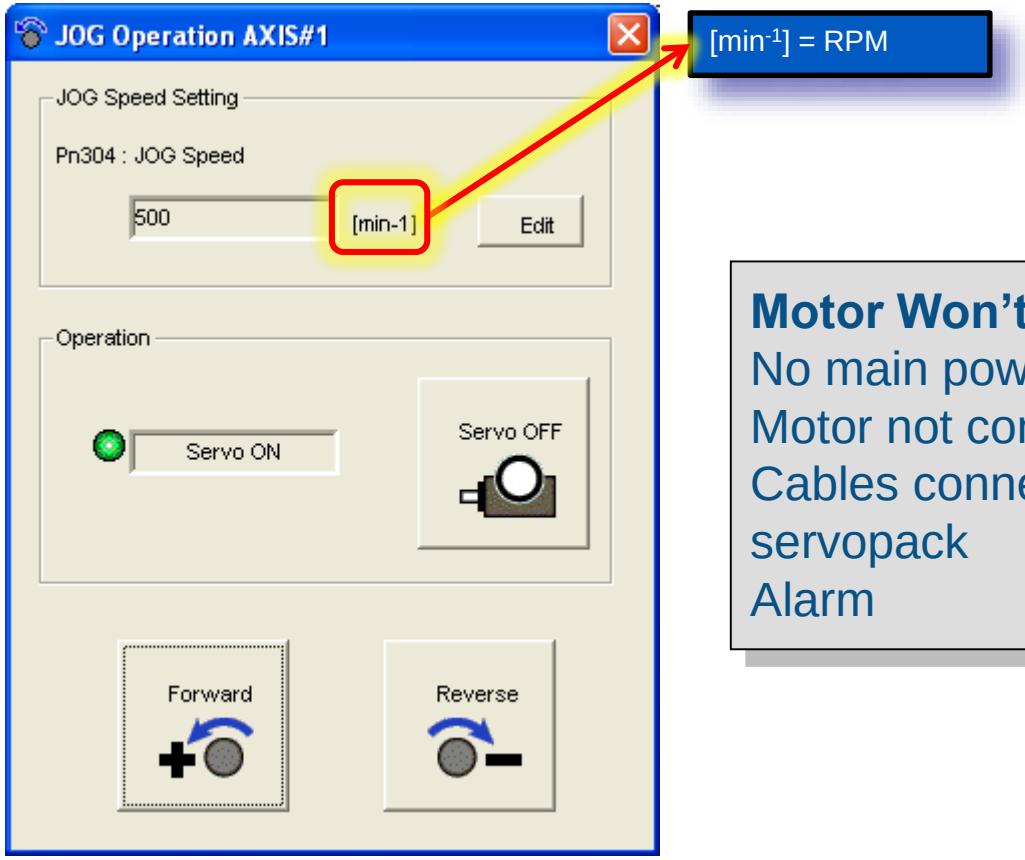
# Remote Demo

- *Demo Status*
  - *Servos off*
- *SW+7 online with project*
  - *Open SW+7*
  - *Home - Open Project*
  - *Menu*
  - *Connect*

# Jog Operation

- *SGD7S Menu*
- *Test Run – Jog*
- *Edit Speed*
- *Servo ON*
- *Hold “Forward”*

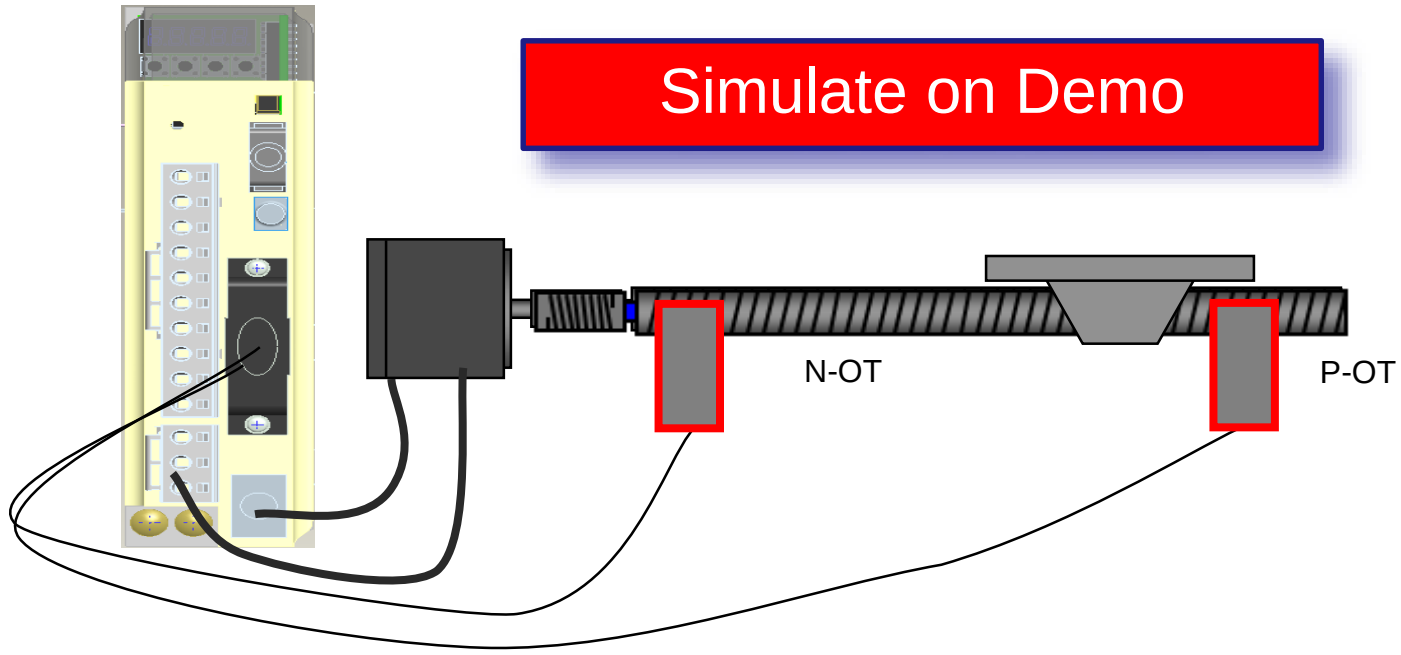



**Motor Won’t Jog?**
No main power
Motor not connected
Cables connected to wrong servopack
Alarm

# Jog & Over-Travel

- *Over-Travel are Amplifier Inputs*
- *No p-n display during Jog Operation*
- *Startup and maintenance*

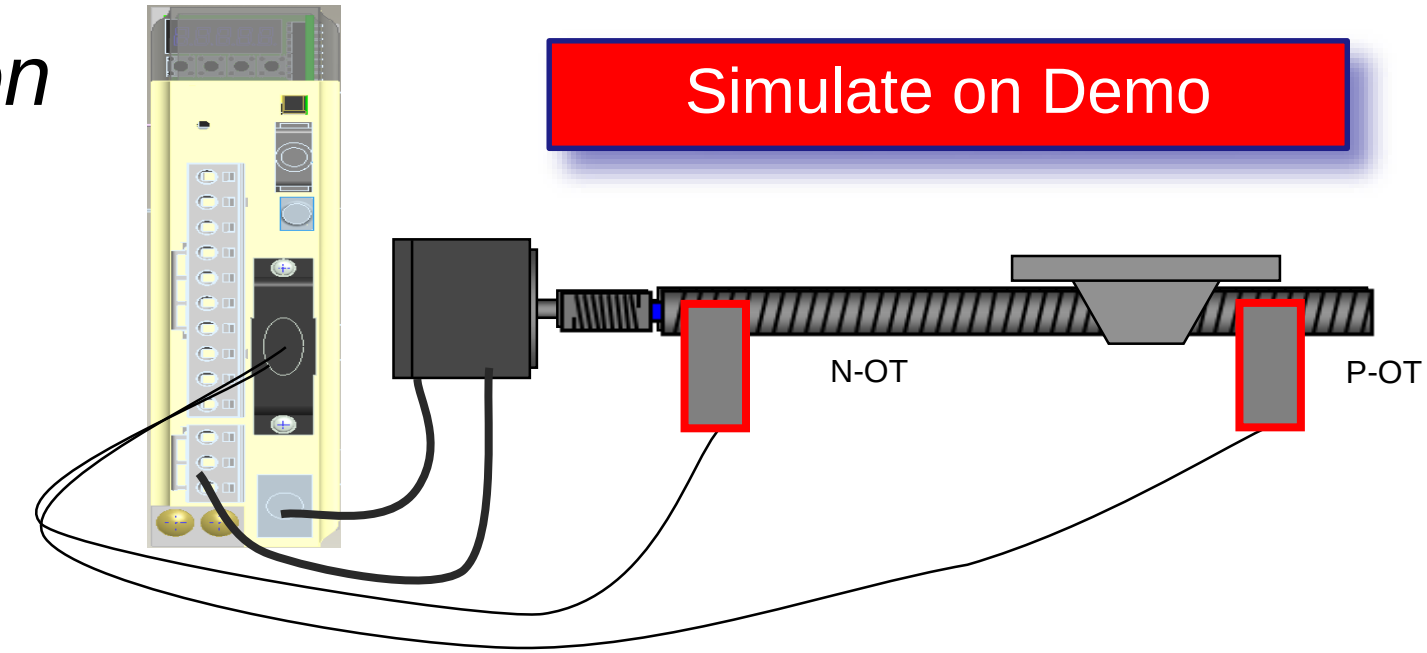
**Motor Won't Jog?**
Alarm
No main power
Motor not connected
Cables connected to wrong servopack




JOG Operation ignores P-OT and N-OT

# Troubleshooting

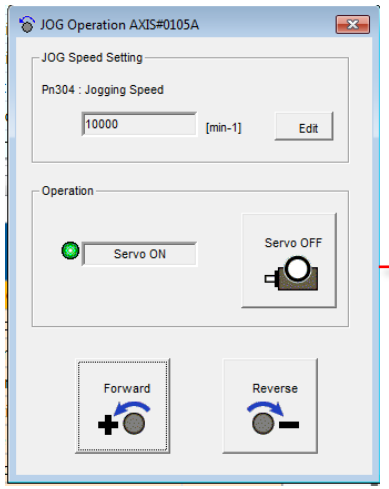
- *Alarm*
- *Main Power Connection*
- *Motor Connection*
  - *Cables mixed up?*



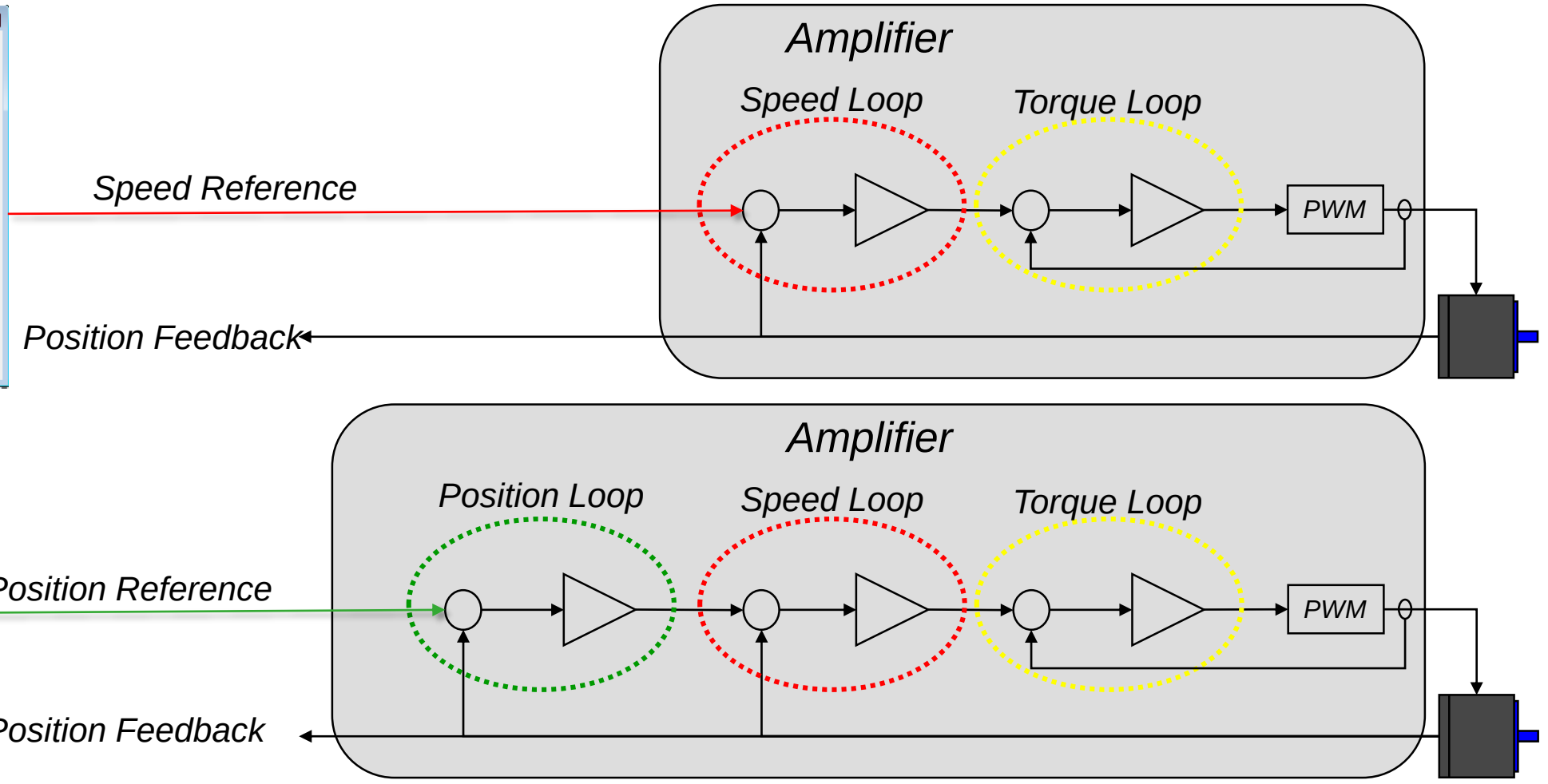

**Motor Won't Jog?**
Alarm
No main power
Motor not connected
Cables connected to wrong servopack

JOG Operation ignores P-OT and N-OT

# Jog Theory of Operation

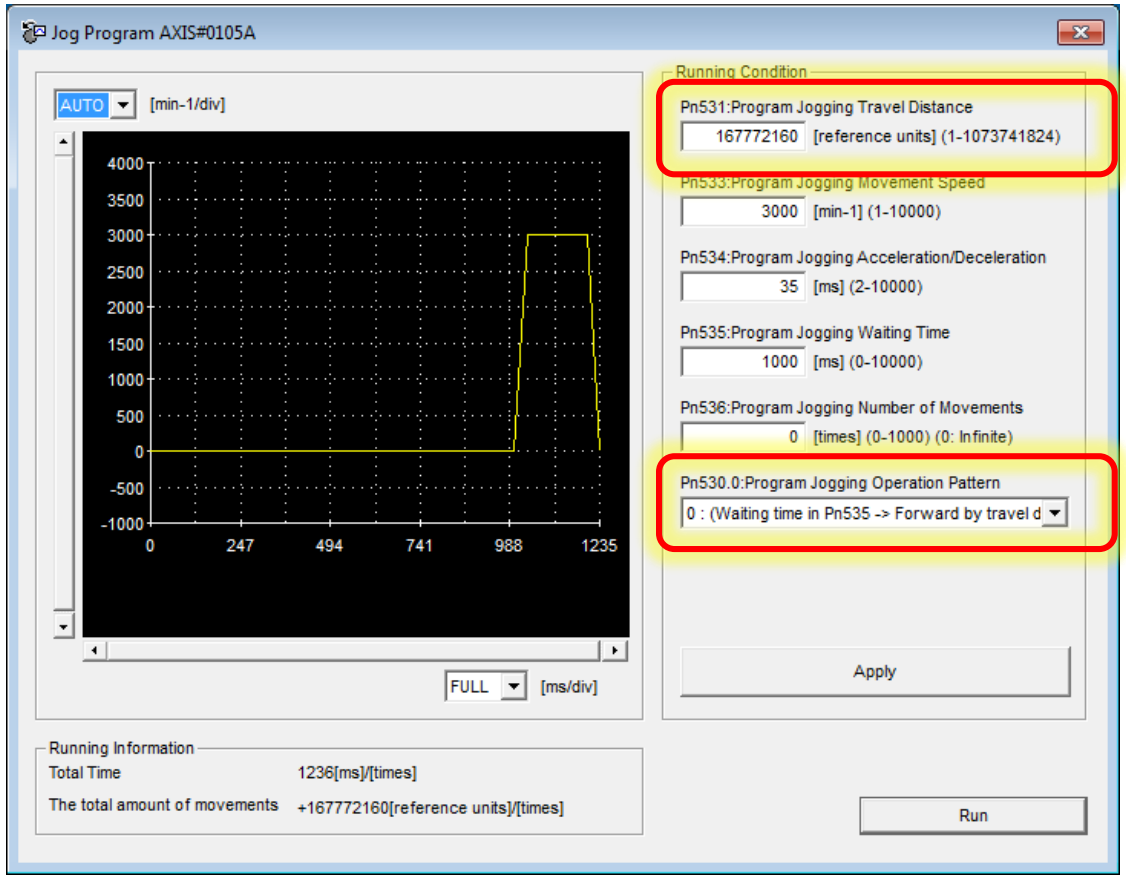






# Program Jog

- *Program Jog is a simple motion controller inside the servo*
  - *Move profile saved in Pn530 – Pn536*

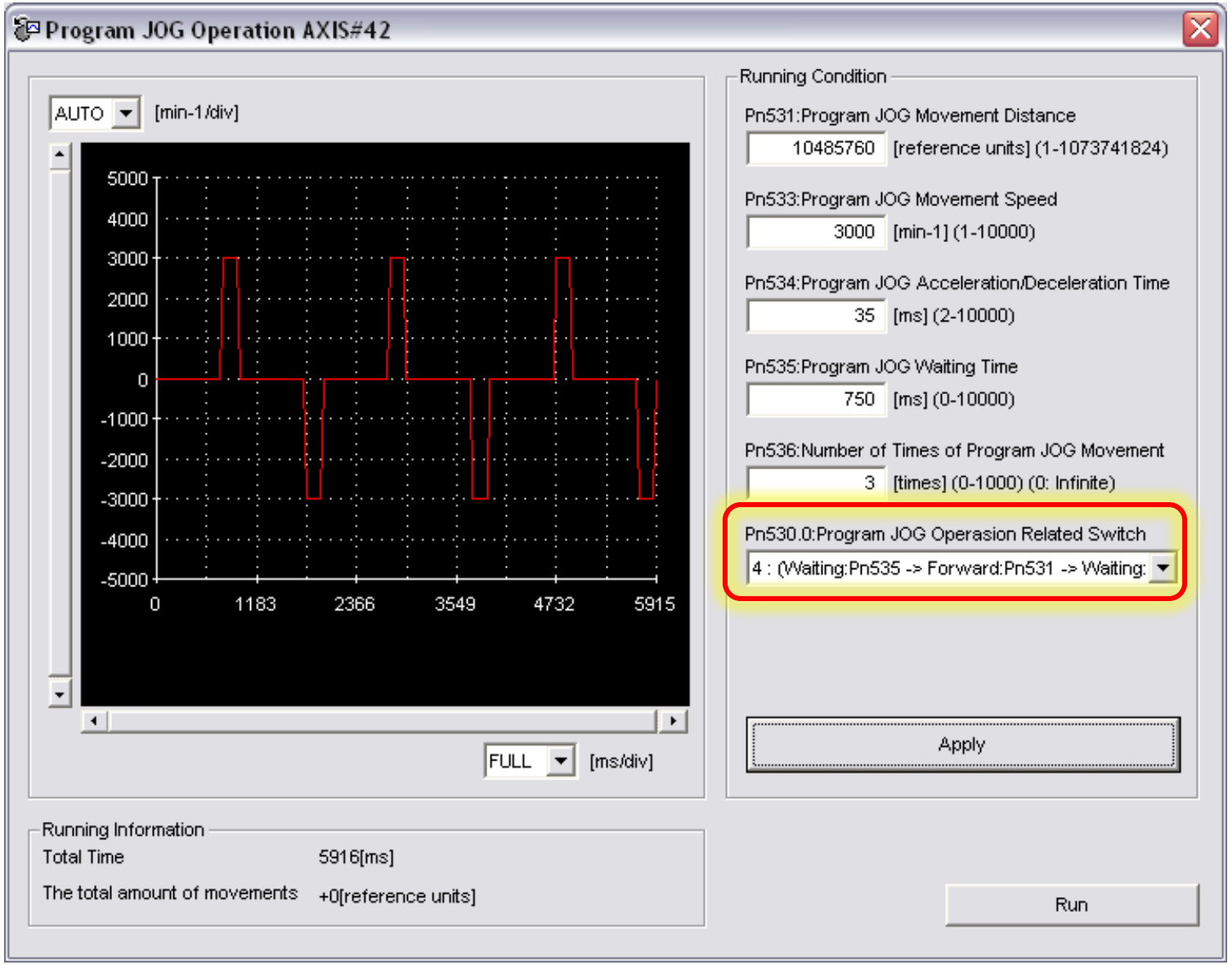



10 Rotations
Units = Encoder Pulse

Pn536=0 for infinite repeat

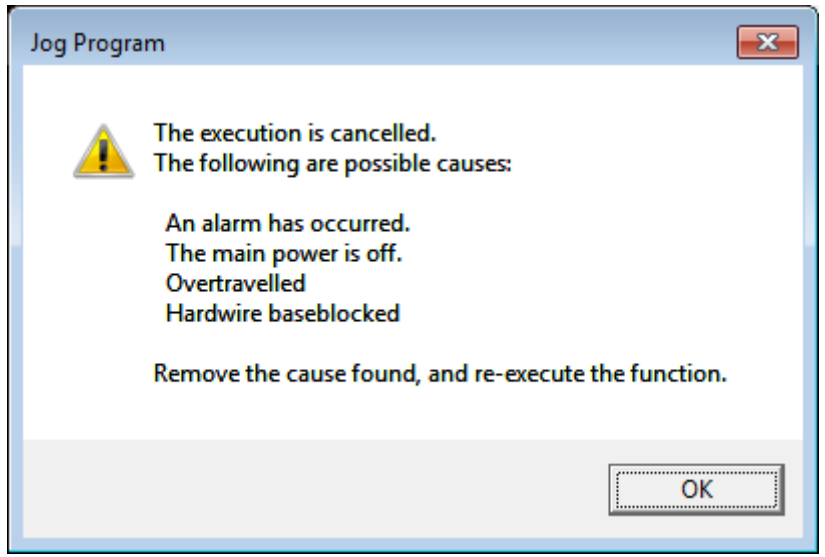
# Program Jog

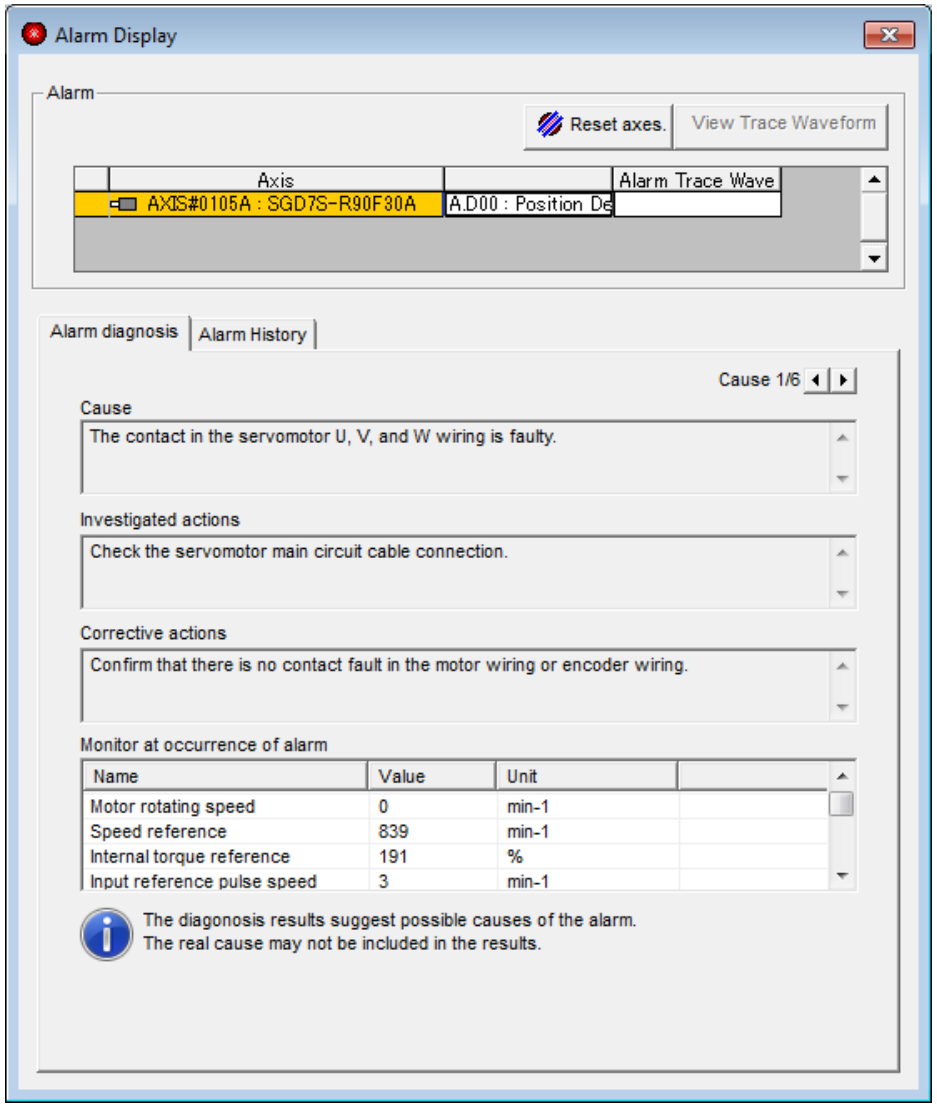
- *Repeat Options*
  - *0: Infinite*



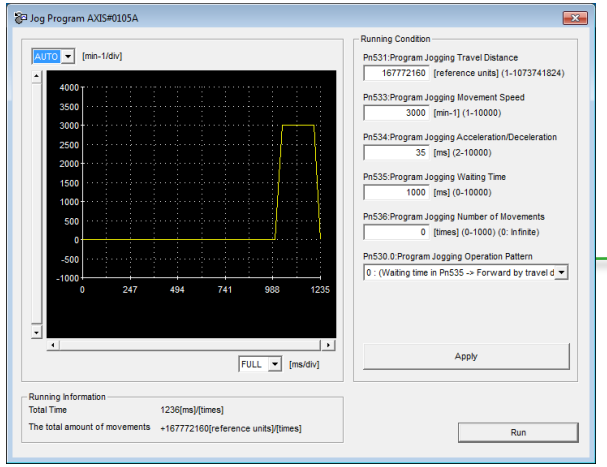
# Program Jog

- *Alarm A.D00: Position Deviation Overflow*
  - *What parameter setting may be involved?*
  - *Clear the alarm*
  - *Edit the parameter*
  - *Execute Program Jog*

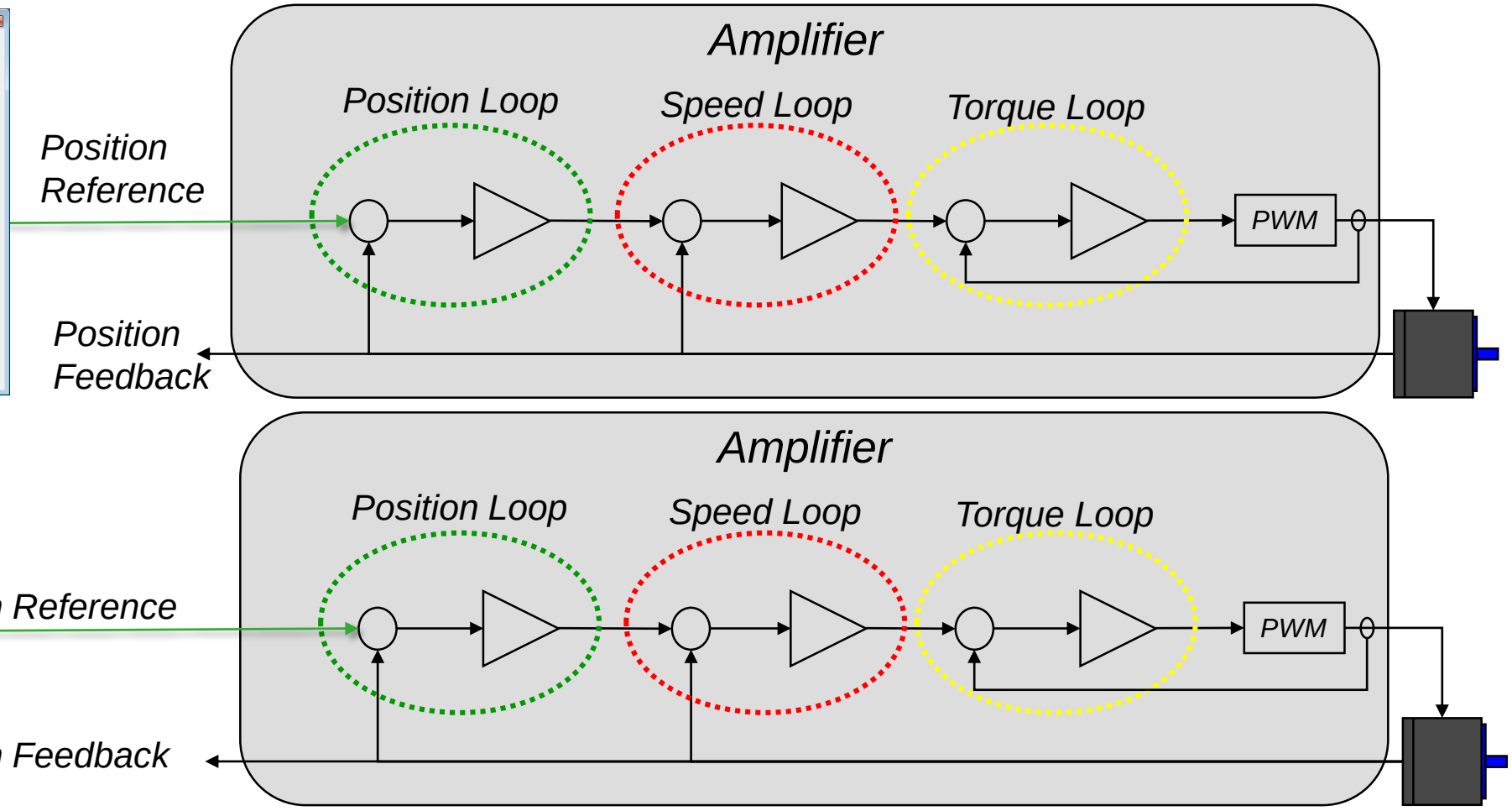


# Program Jog Theory of Operation







# Recovery

- *Cancel*
  - *Running condition resetting*
- *Parameter save to project*
- *System Reboot*
  - *Servo on results in A.0B0*
- *Verify machine position*

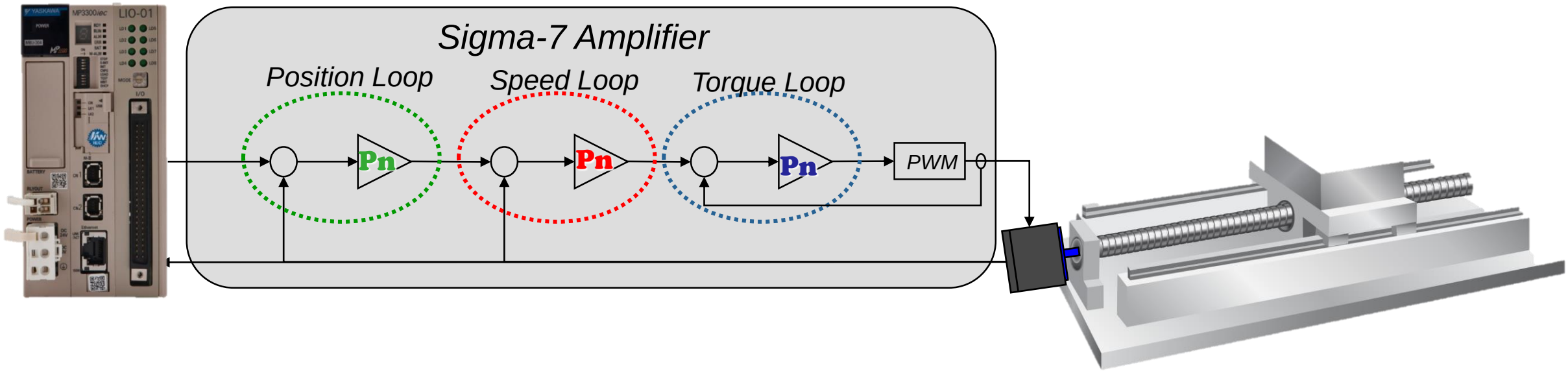
# Sigma-7 Servo Tuning
# **Servo Tuning Basics**

Basic Concepts for Sigma-7 Servo Tuning

- *What is Tuning?*
- *Control Loops*
- *Bandwidth*
- *Tuning Process*
- *Sigma-7 Tuning: Three Methods*
- *When is Tuning Required*
- *Mechanical System Check*

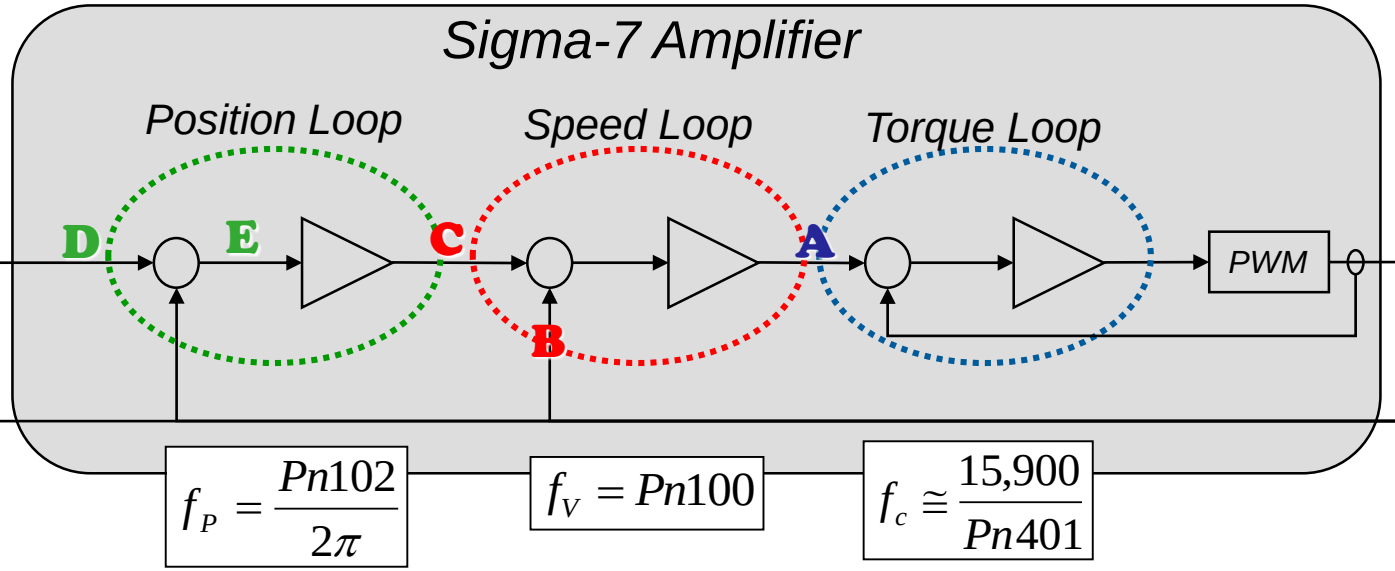
# What is Tuning?

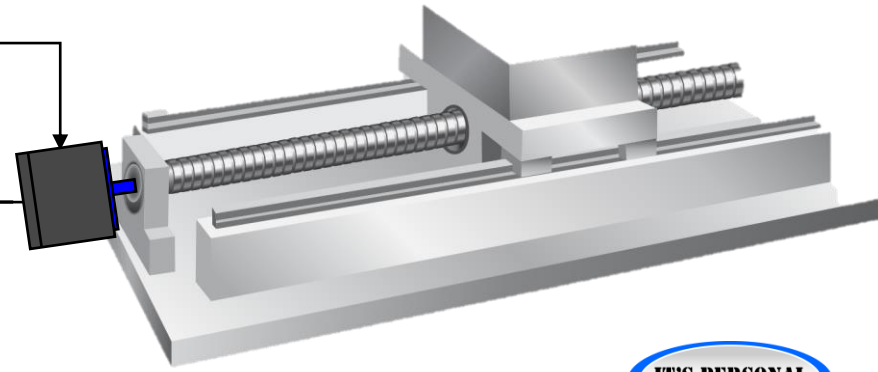
- *Optimizing how the amplifier responds to feedback*
- *Adjusting the error compensation of the control loops*
  - *Torque*
  - *Speed*
  - *Position*



# Control Loops

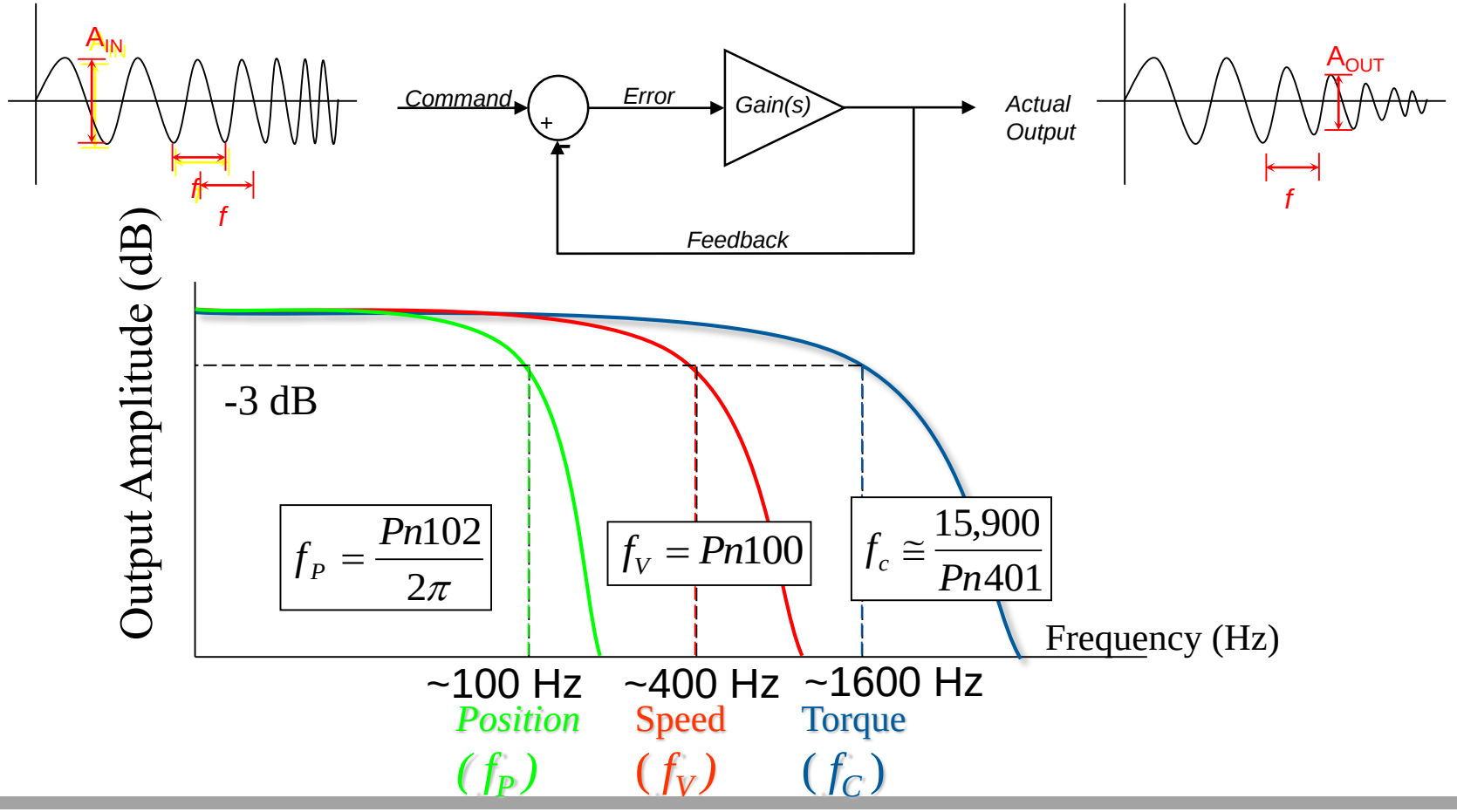
- *Position*
  - *Tune to load*
  - *Position Ref. Speed (D)*
  - *Position Error (E)*
- *Speed*
  - *Tune to load*
  - *Speed Ref. (C)*
  - *Feedback Speed (B)*
- *Torque*
  - *Torque Ref. (A)*
  - *Tune To motor*
  - *Factory Set*
  - *Filters*



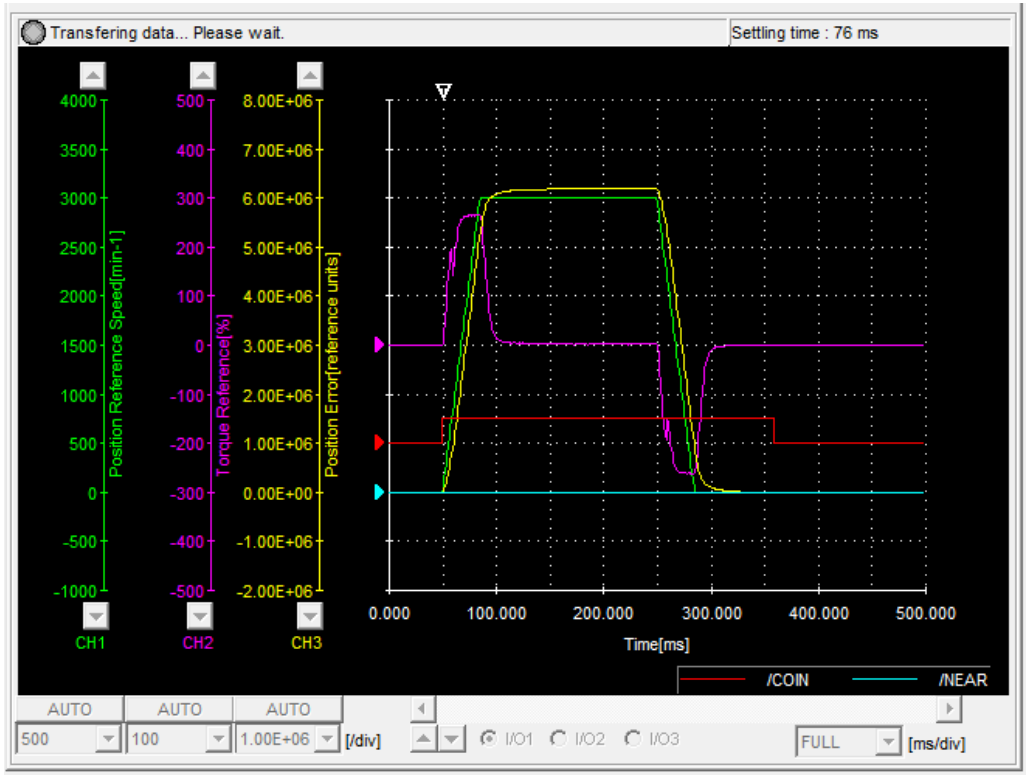
# Control Loop Bandwidth

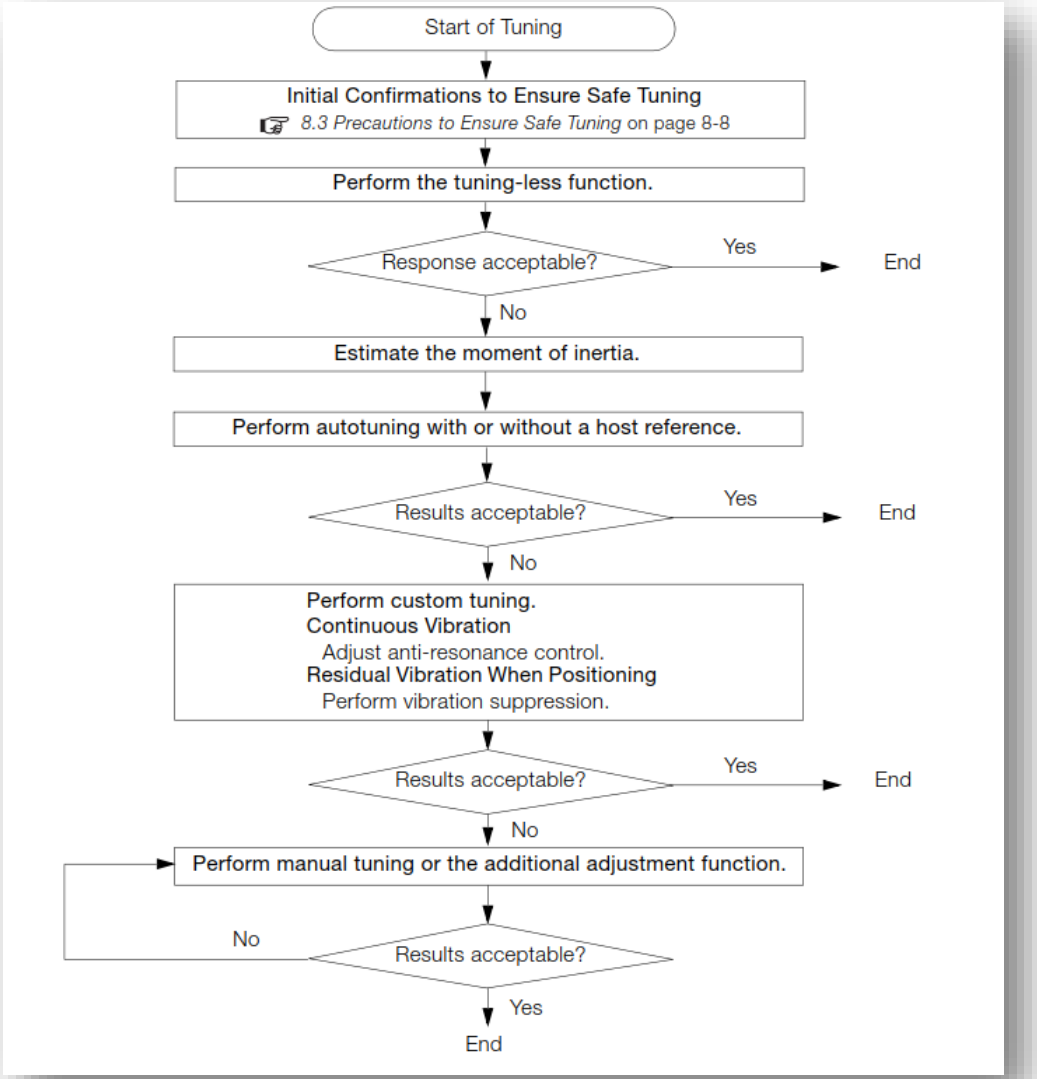
- *Bandwidth determined by tuning parameters*
- *Maintain stable bandwidth ~ 4x separation between loops*
- *Use SigmaWin+ Advanced Auto Tuning and Custom Tuning*



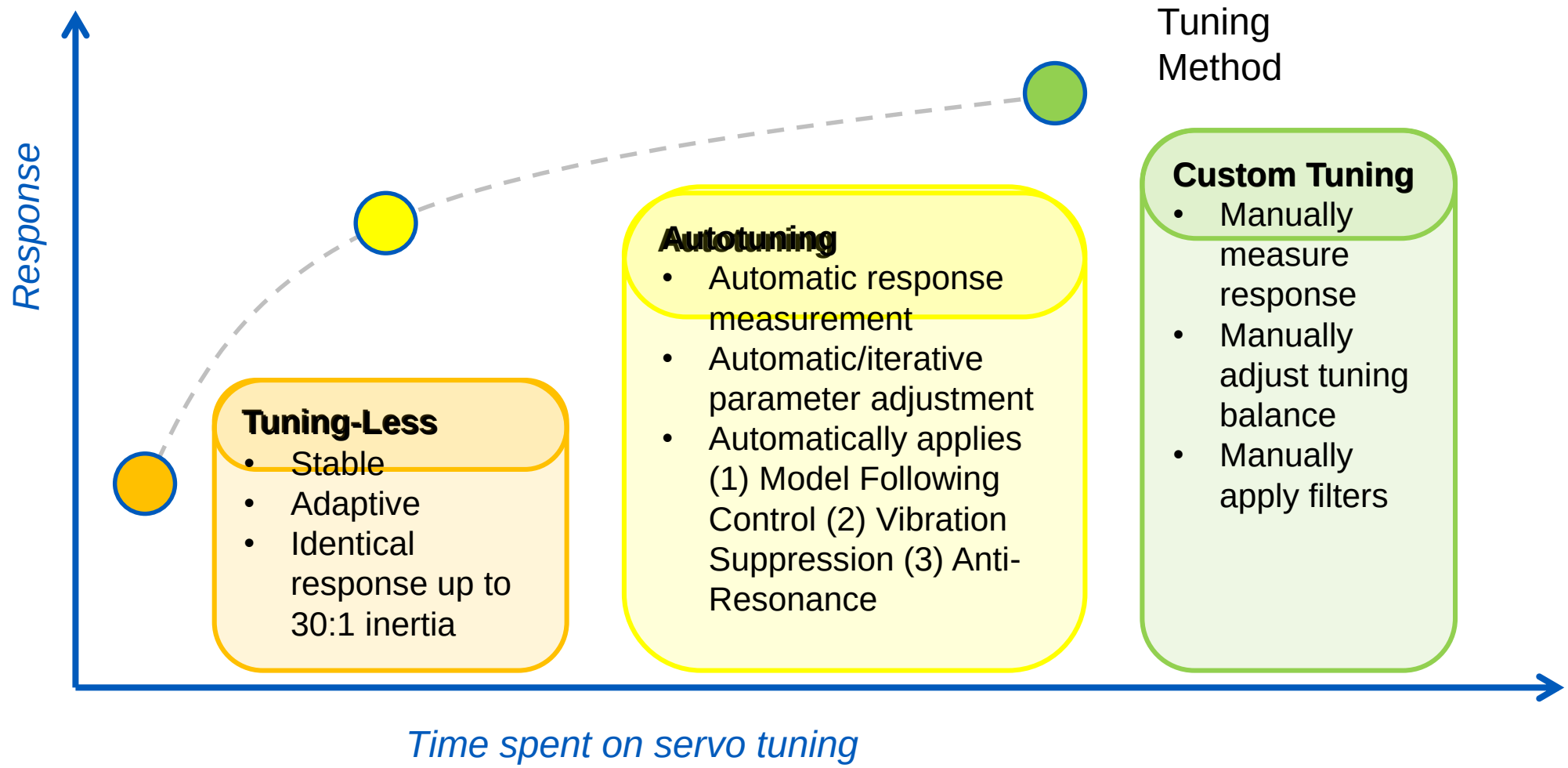
# Tuning Process

1. *Worst-case move profile*
2. *Is response acceptable?*
3. *Adjust or apply new tuning method*



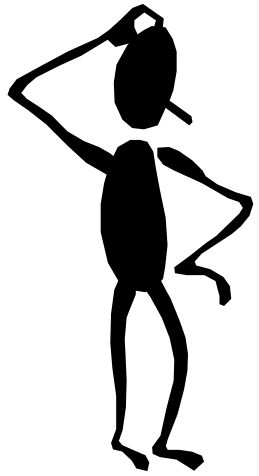
# Sigma-7 Tuning Methods

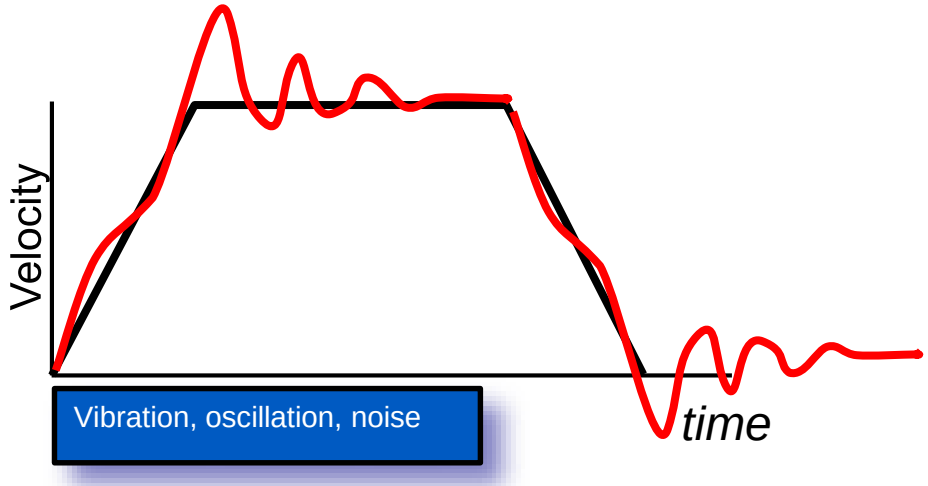


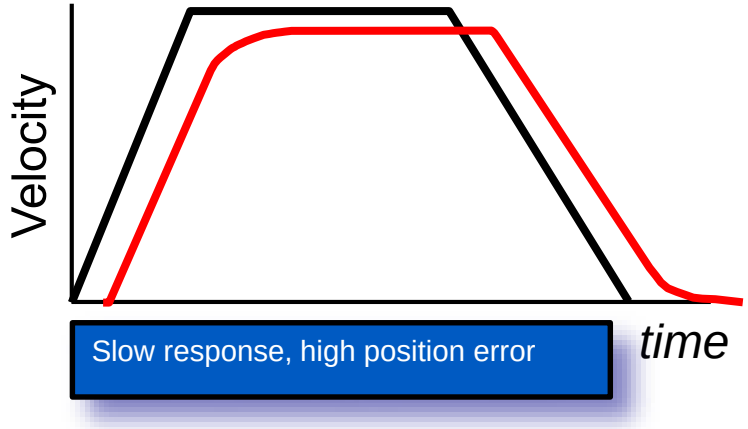
# When is Tuning Required?

- *Slow response*
- *Noisy operation*
- *Vibration or oscillation*
- *Alarms*
  - *Torque overload*
  - *Overspeed*
  - *Position error*
- *Graph Response*

For many applications the factory default tuning is OK

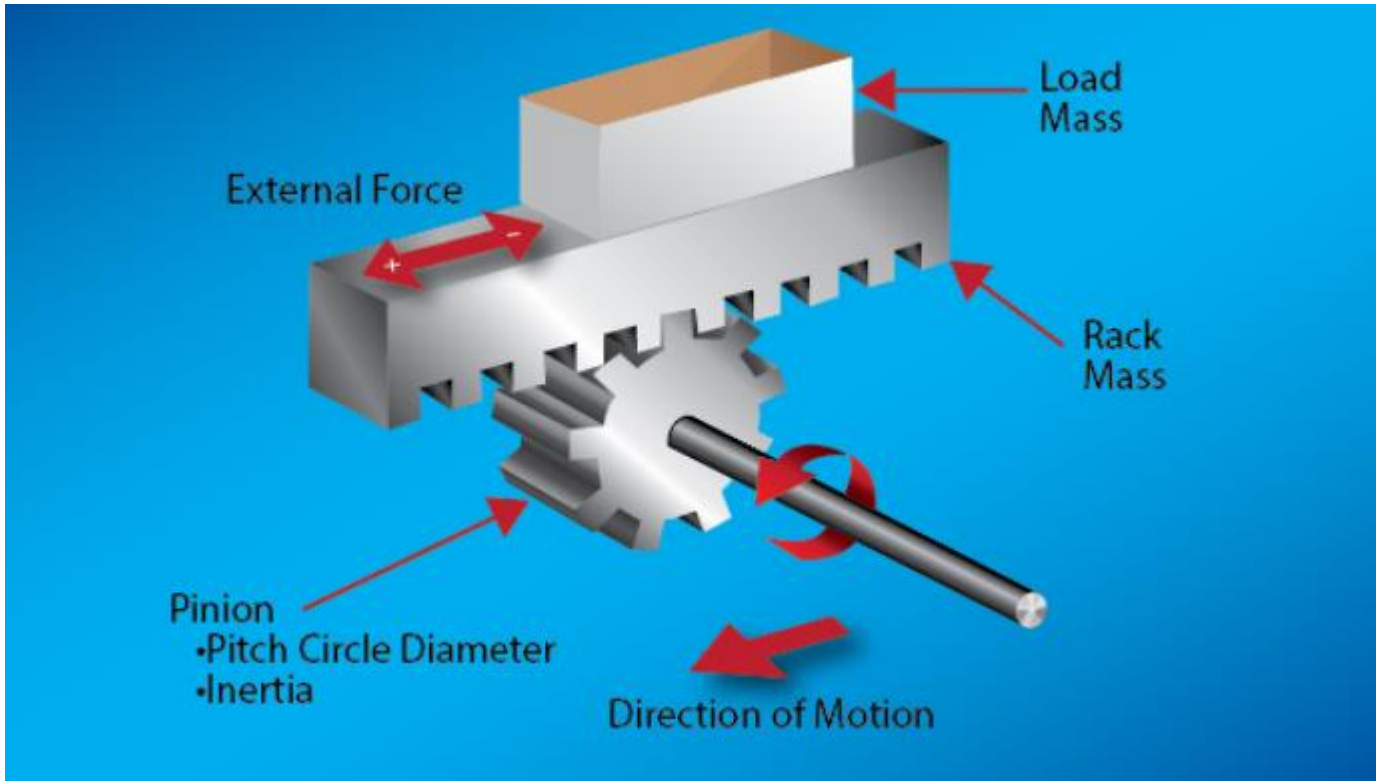




# Mechanical System Check

- *Loose parts*
  - *Belt*
  - *Coupling*
- *High Friction*
  - *Brakes*
  - *Components dragging*
  - *Lubricant*
- *Servo Flexible Coupling*
  - *Alignment*
  - *Zero Backlash*
  - *Torsional Stiffness*
  - *Bellows, Spider, Helical*
- *Large Inertia*
- *Mechanical Compliance*



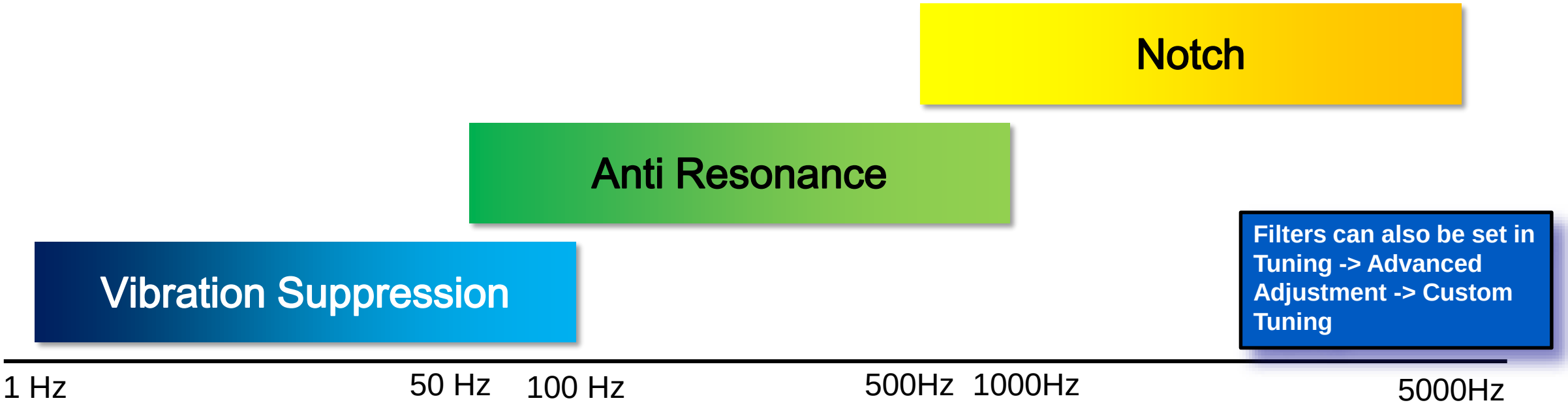

Check the mechanical system integrity before tuning!

# Sigma-7 Servo Tuning
# **Tuning Filters**

Reduce noise and vibration at different frequencies

- *Overview*
- *Mechanical Analysis (FFT)*
- *Notch Filter*
- *Anti-Resonance Filter*
- *Vibration Suppression Filter*

# Overview



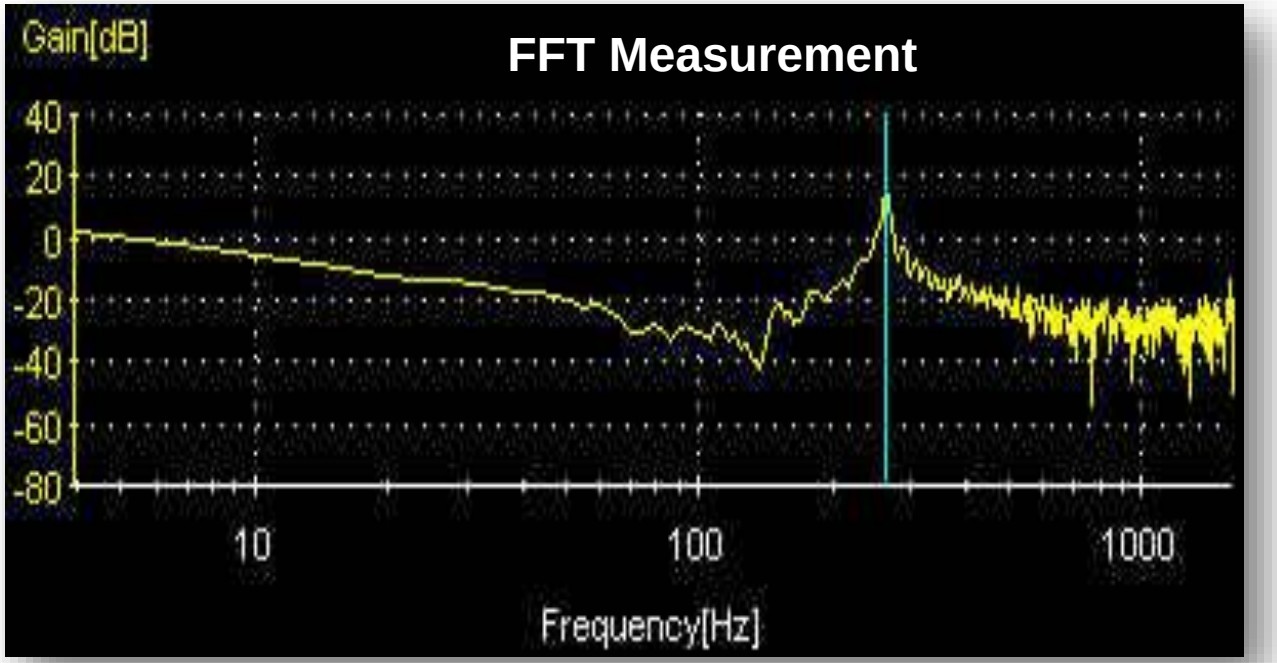

- *Control Mode: Position*
  - » *only when Model Following Control enabled Pn140.0=1*
- *Automatic Setting: During Advanced Auto-Tuning*
- *Manually Adjust*
  - » *Pn140, Pn145, Pn146, Pn14A, Pn14B*

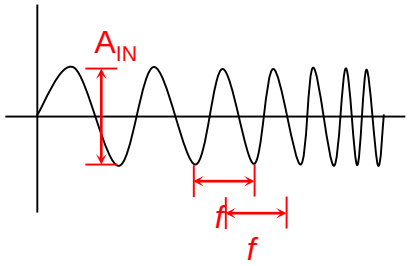
- *Control Mode: Speed, Position*
- *Automatic Setting: During Advanced Auto-Tuning*
- *Manually Adjust*
  - » *Pn160-Pn165*

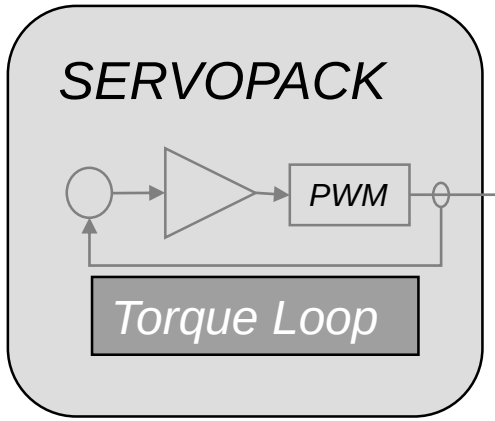
- *Control Mode: Torque, Speed, Position*
- *Automatic setting: Always active (Pn460)*
- *Manually adjust*
  - » *Pn409-Pn40E*

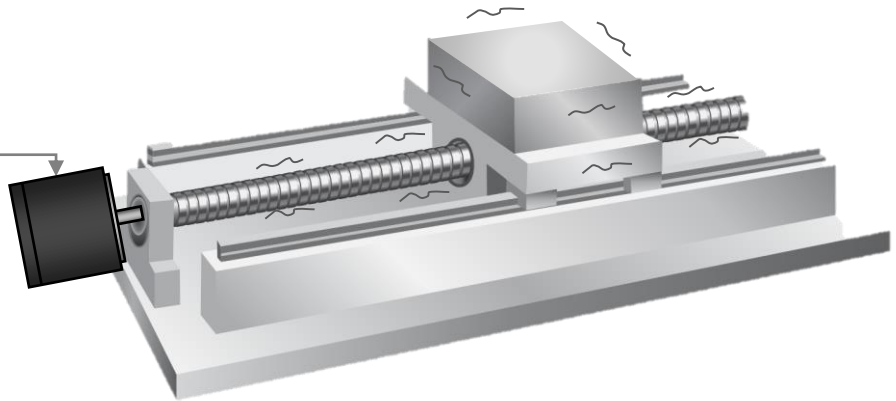
# Mechanical Analysis

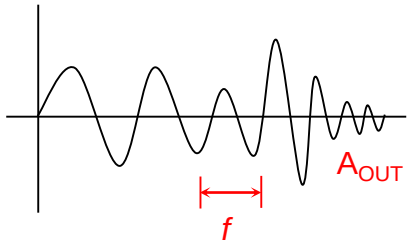
- *FFT*
  - *Fast Fourier Transform*
- *Bode plot*
  - *Gain vs. Frequency [Hz]*
- *Algorithms recognize and cancel frequencies*



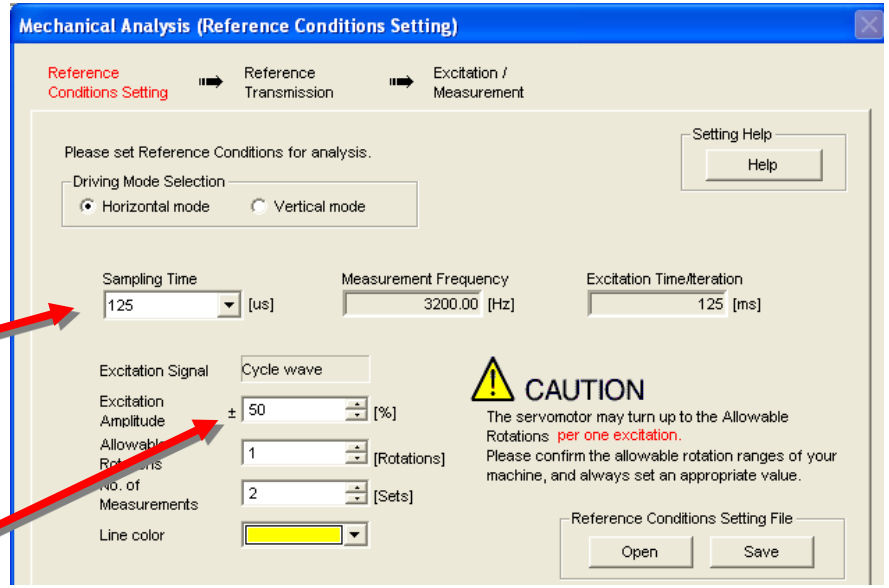



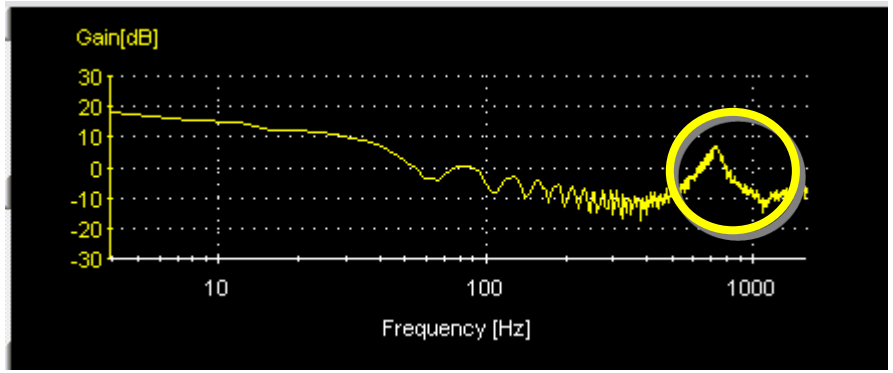





# Mechanical Analysis

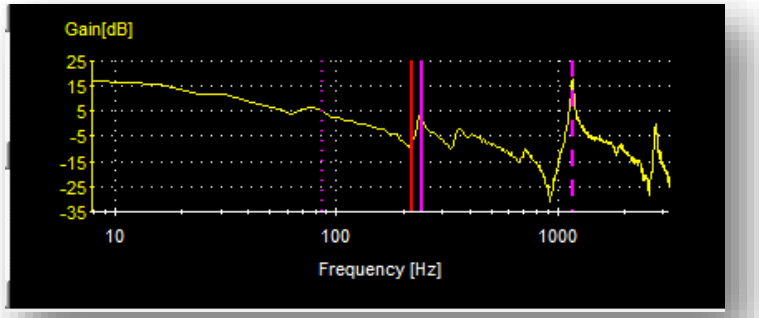
- *Machine response from 0 Hz to 3200 Hz*
- *A peak in the gain graph means there is resonance at that frequency*
  - *Sampling Time*
    - » *Controls the maximum measurement frequency.*
    - » *Increase the time to show more detail at low frequency.*
  - *Excitation Amplitude*
    - » *Peak-to-peak sinusoidal torque waveform that will be generated.*
    - » *Set according to machine's typical operating torque level*



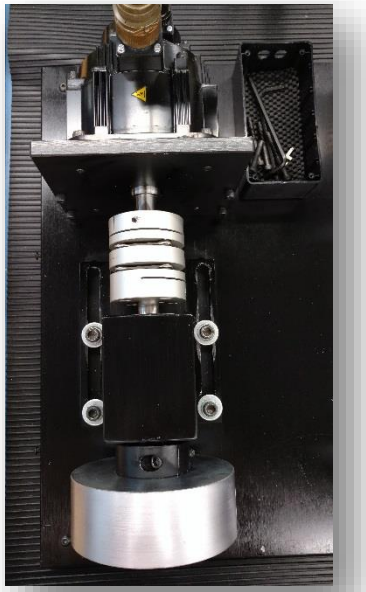



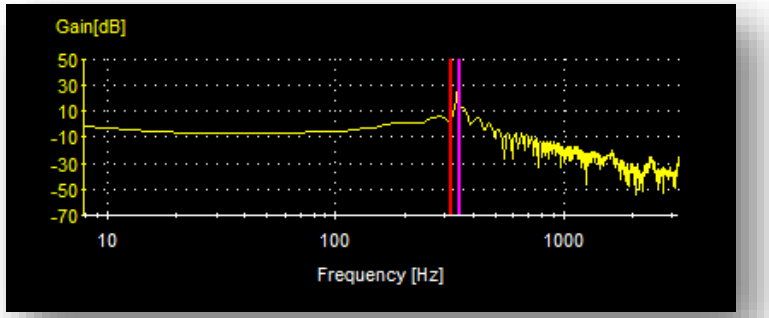
# Mechanical Analysis

- *Ballscrew*

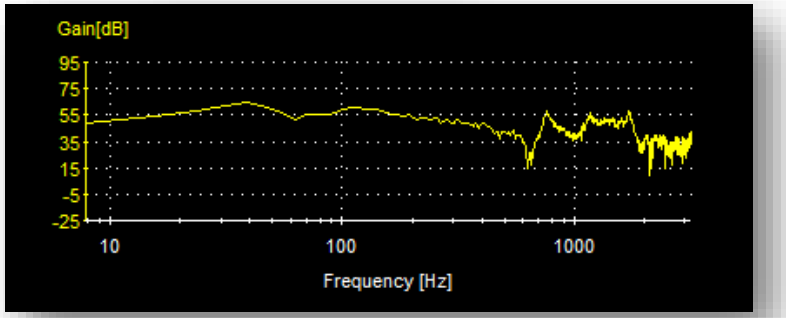



- *Rotary Drive*



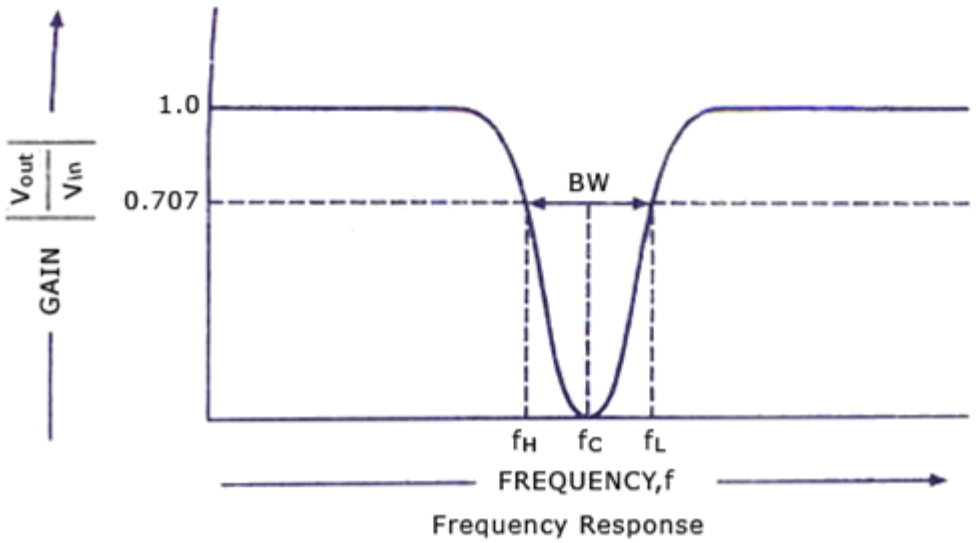


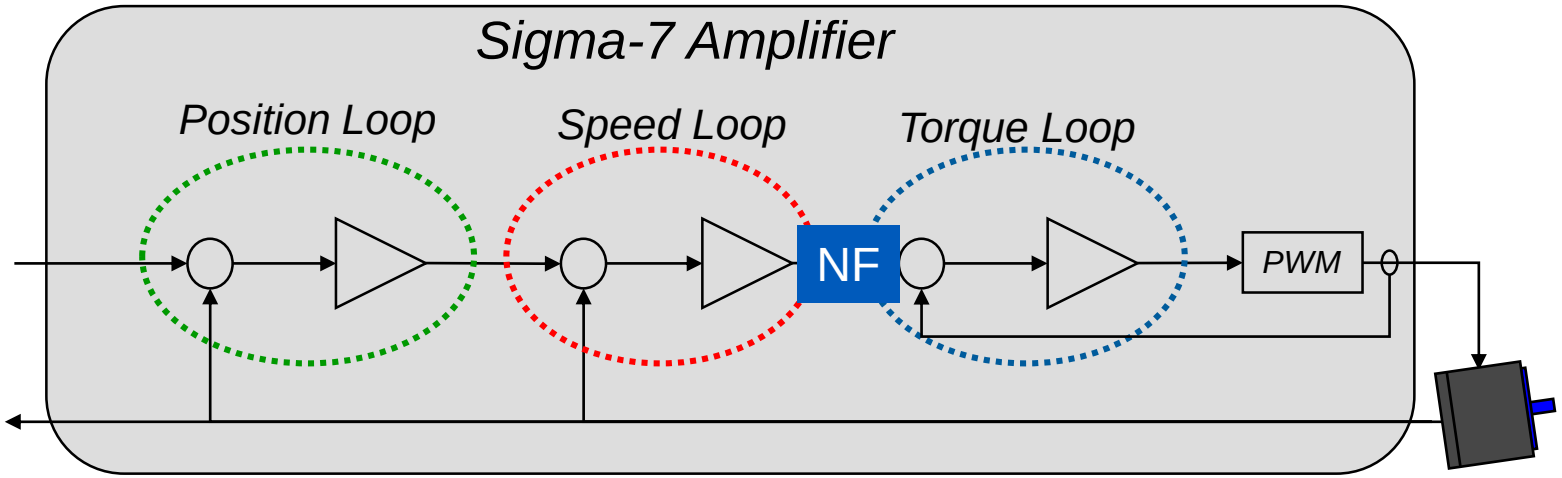

- *SigmaTrac*



# Notch Filter

- *Range: 50-5000 Hz*
  - *Most effective above 500Hz*
- *Automatic Notch Filter*
  - *Pn460*
  - *High Frequencies >500Hz*
- *5 Notch Filters*



# Notch Filter

- *Selection*
  - *Turn on/off*
- *Frequency*
  - *Center of frequency band most attenuated*
- *Depth*
  - *Strength of the filter*
- *Q Value*
  - *Depth-to-Width ratio*

| | | | | | |
|---|---|---|---|---|---|
| Pn408.0 | Notch Filter Selection 1 | – | 0 : Disable first st··· | 0 : Disable first st··· | 0 : Disable first st··· |
| Pn408.1 | Speed Limit Selection | – | 0 : Use the small··· | 0 : Use the small··· | 0 : Use the small··· |
| Pn408.2 | Notch Filter Selection 2 | – | 0 : Disable secon··· | 0 : Disable secon··· | 0 : Disable secon··· |
| Pn408.3 | Friction Compensation Function Sel | – | 0 : Disable frictio··· | 0 : Disable frictio··· | 0 : Disable frictio··· |
| Pn409 | First Stage Notch Filter Frequency | Hz | 5000 | 5000 | 5000 |
| Pn40A | First Stage Notch Filter Q Value | 0.01 | 70 | 70 | 70 |
| Pn40B | First Stage Notch Filter Depth | 0.001 | 0 | 0 | 0 |
| Pn40C | Second Stage Notch Filter Frequenc | Hz | 5000 | 5000 | 5000 |
| Pn40D | Second Stage Notch Filter Q Value | 0.01 | 70 | 70 | 70 |
| Pn40E | Second Stage Notch Filter Depth | 0.001 | 0 | 0 | 0 |
| Pn40F | Second Stage Second Torque Refer | Hz | 5000 | 5000 | 5000 |
| Pn410 | Second Stage Second Notch Filter ( | 0.01 | 50 | 50 | 50 |
| Pn412 | First Stage Second Torque Referenc | 0.01ms | 100 | 100 | 100 |
| Pn416.0 | Notch Filter Selection 3 | – | 0 : Disable third s··· | 0 : Disable third s··· | 0 : Disable third s··· |
| Pn416.1 | Notch Filter Selection 4 | – | 0 : Disable fourth··· | 0 : Disable fourth··· | 0 : Disable fourth··· |
| Pn416.2 | Notch Filter Selection 5 | – | 0 : Disable fifth st··· | 0 : Disable fifth st··· | 0 : Disable fifth st··· |
| Pn416.3 | Reserved parameter (Do not chang | – | 0 : Reserved para··· | 0 : Reserved para··· | 0 : Reserved para··· |
| Pn417 | Third Stage Notch Filter Frequency | Hz | 5000 | 5000 | 5000 |
| Pn418 | Third Stage Notch Filter Q Value | 0.01 | 70 | 70 | 70 |
| Pn419 | Third Stage Notch Filter Depth | 0.001 | 0 | 0 | 0 |
| Pn41A | Fourth Stage Notch Filter Frequenc | Hz | 5000 | 5000 | 5000 |
| Pn41B | Fourth Stage Notch Filter Q Value | 0.01 | 70 | 70 | 70 |
| Pn41C | Fourth Stage Notch Filter Depth | 0.001 | 0 | 0 | 0 |
| Pn41D | Fifth Stage Notch Filter Frequency | Hz | 5000 | 5000 | 5000 |
| Pn41E | Fifth Stage Notch Filter Q Value | 0.01 | 70 | 70 | 70 |
| Pn41F | Fifth Stage Notch Filter Depth | 0.001 | 0 | 0 | 0 |

# Notch Filter

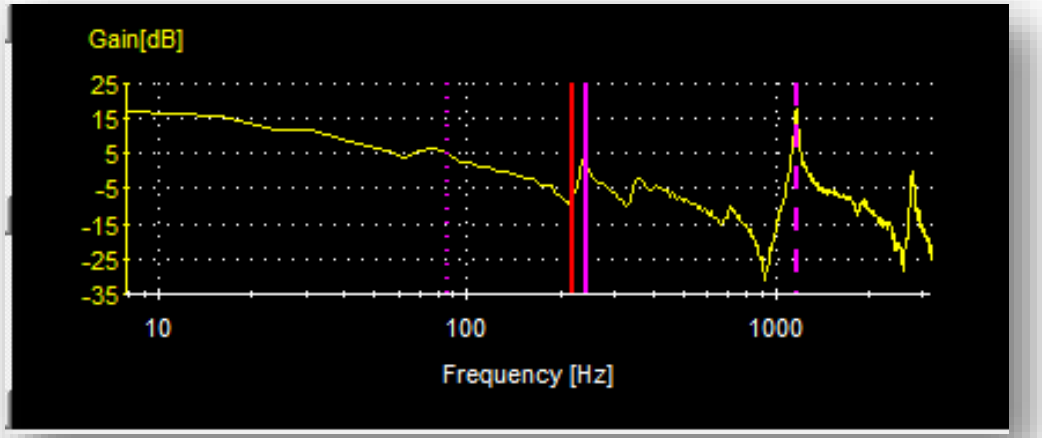
- *Example: Ballscrew*

Display Comparison

Export
File

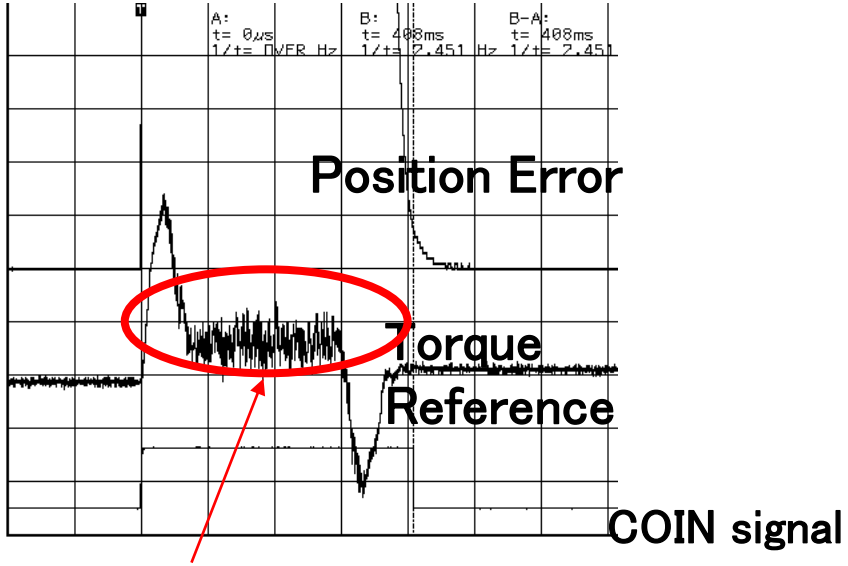
End Comparison Display
Close

| No. | Name | Unit | Default Setting | 0001-SGD7W-1F Axis A |
|---|---|---|---|---|
| Pn401 | First Stage First Torque Reference F | 0.01ms | 100 | 82 |
| Pn408.2 | Notch Filter Selection 2 | – | 0 : Disable second : | 1 : Enable secon··· |
| Pn40C | Second Stage Notch Filter Frequenc | Hz | 5000 | 1240 |
| Pn40D | Second Stage Notch Filter Q Value | 0.01 | 70 | 150 |



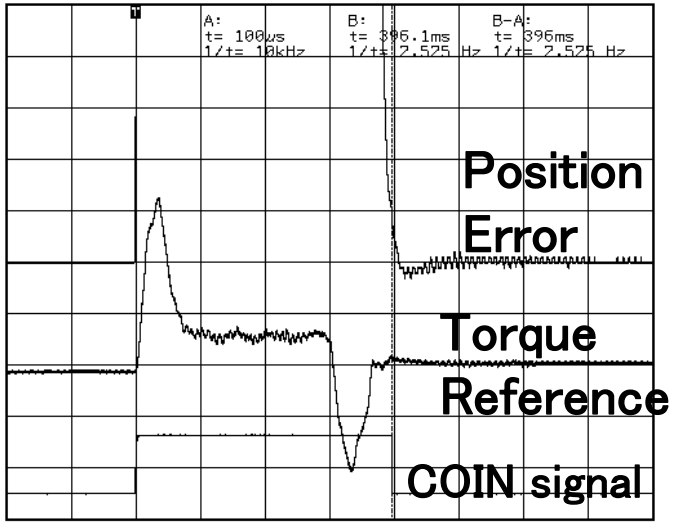
# Anti-Resonance

- *Anti-Resonance = OFF*




Vibration (sound) during movement

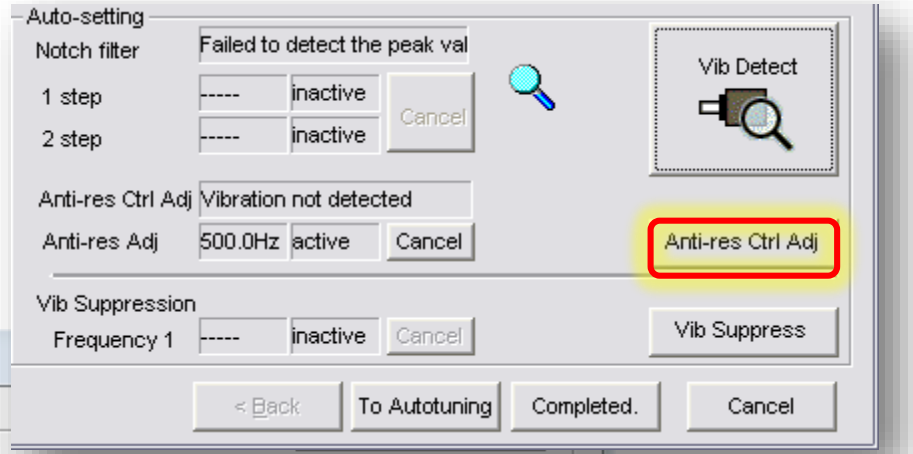
- *Anti-Resonance = ON*

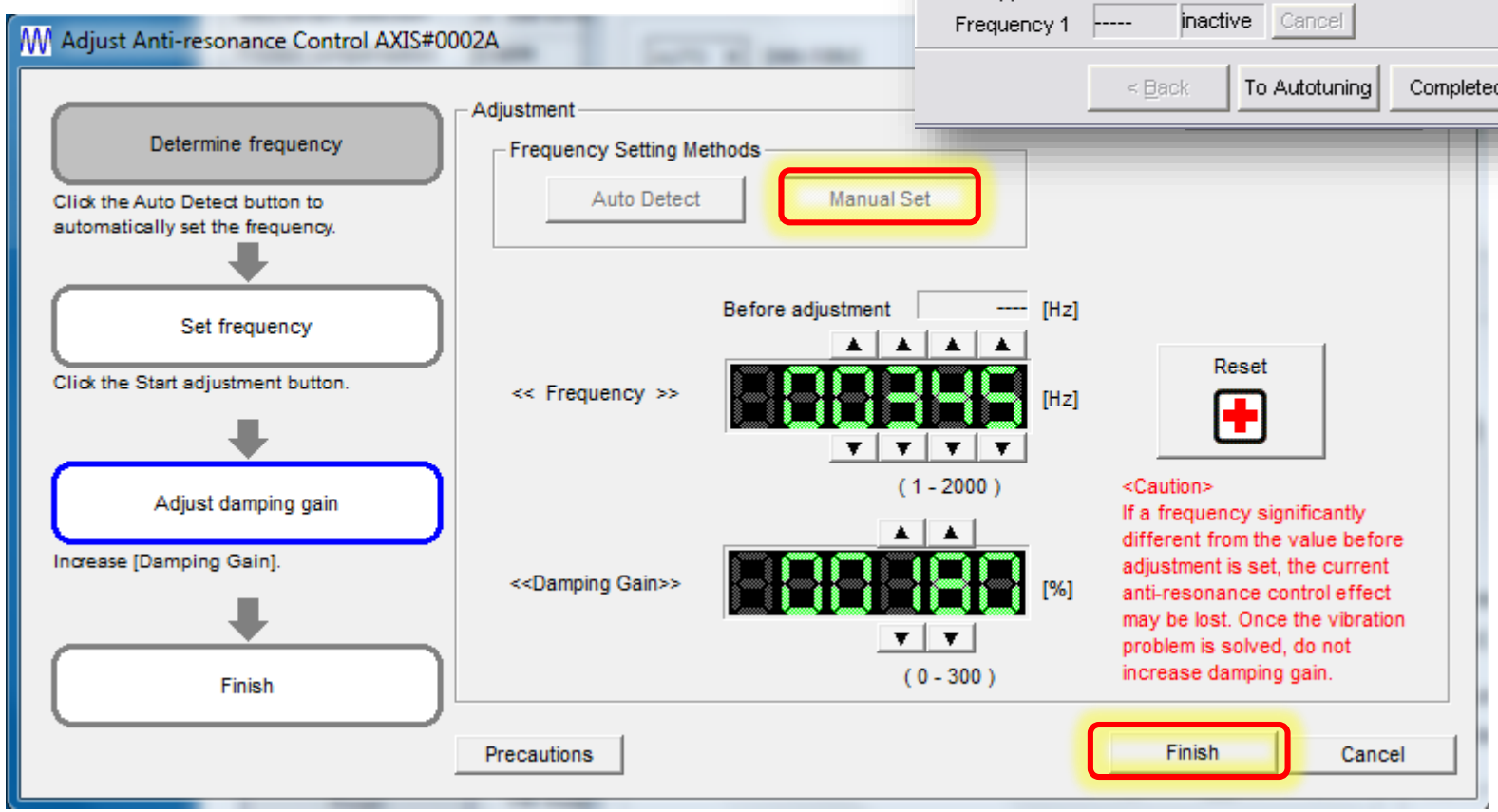



Vibration (sound) reduced

# Anti-Resonance

- *Range: 100-1000 Hz*
- *Auto Detect or Manual*
  - *Frequency*
  - *Damping Gain*

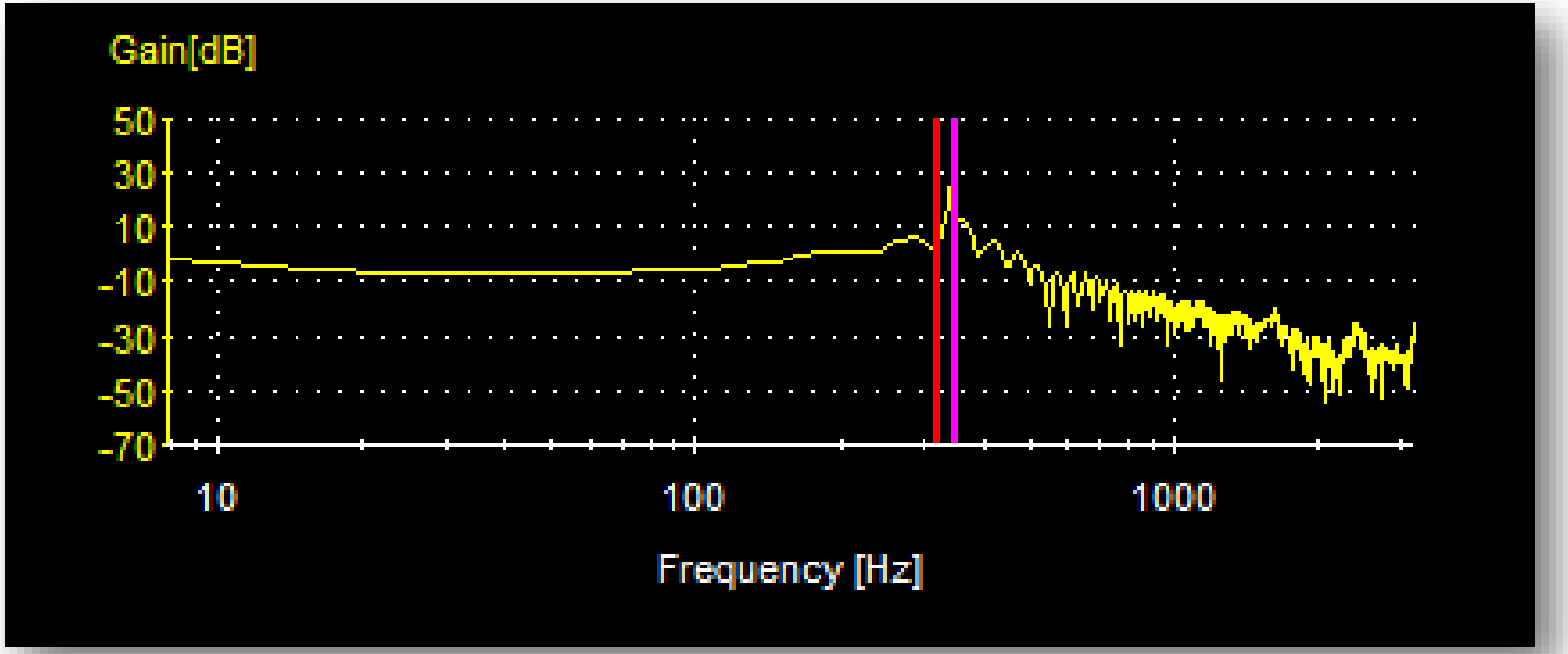


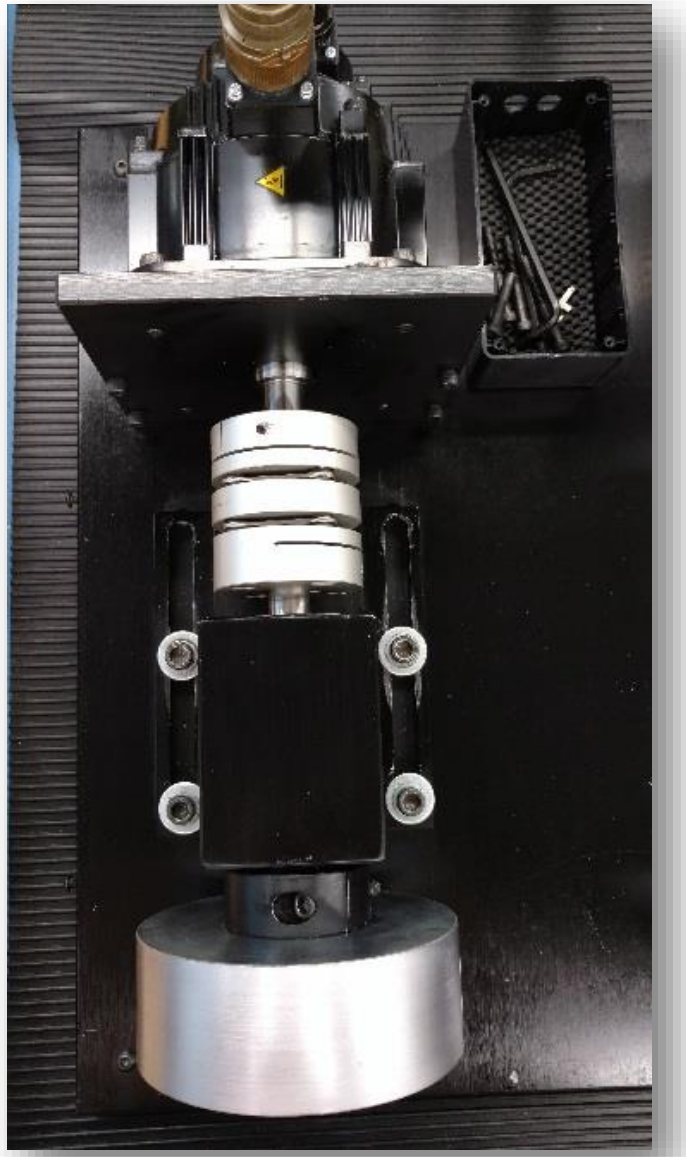



# Anti-Resonance

- *Example: Rotary Drive*

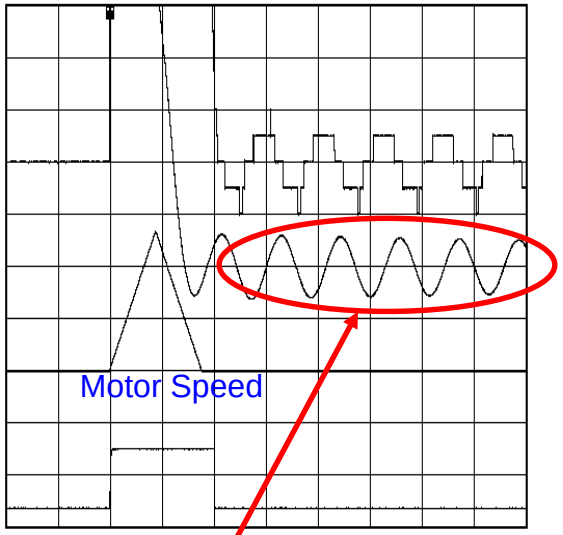
| No. | Name | Unit | Default Setting | 0105-SGD7S-R90F30A<br>Axis A |
|---|---|---|---|---|
| Pn103 | Moment of Inertia Ratio | % | 100 | 2600 |
| Pn160.0 | Anti-Resonance Control Selection | – | 0 : Do not use ant | 1 : Use anti-resonance control. |
| Pn161 | Anti-Resonance Frequency | 0.1Hz | 1000 | 3440 |
| Pn163 | Anti-Resonance Damping Gain | % | 0 | 180 |
| Pn170.0 | Tuning-less Selection | – | 1 : Enable tuning- | 0 : Disable tuning-less function. |



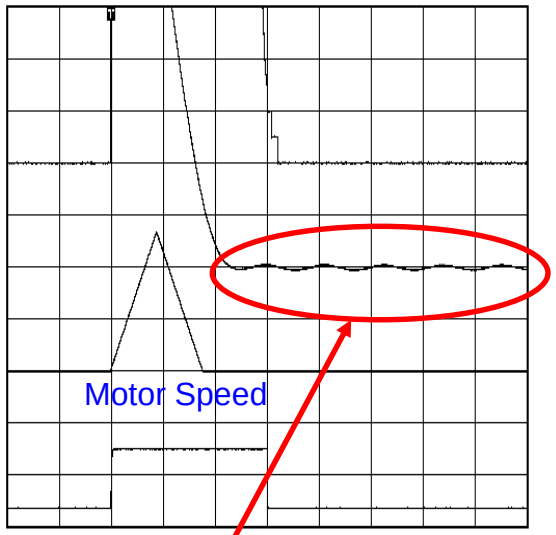



# Vibration Suppression

- *Low-Frequency Oscillations Cancelled Out*
- *Start and stop*
- *Anticipation of load reaction based on frequency setting*
- *Requires Model Following Control*



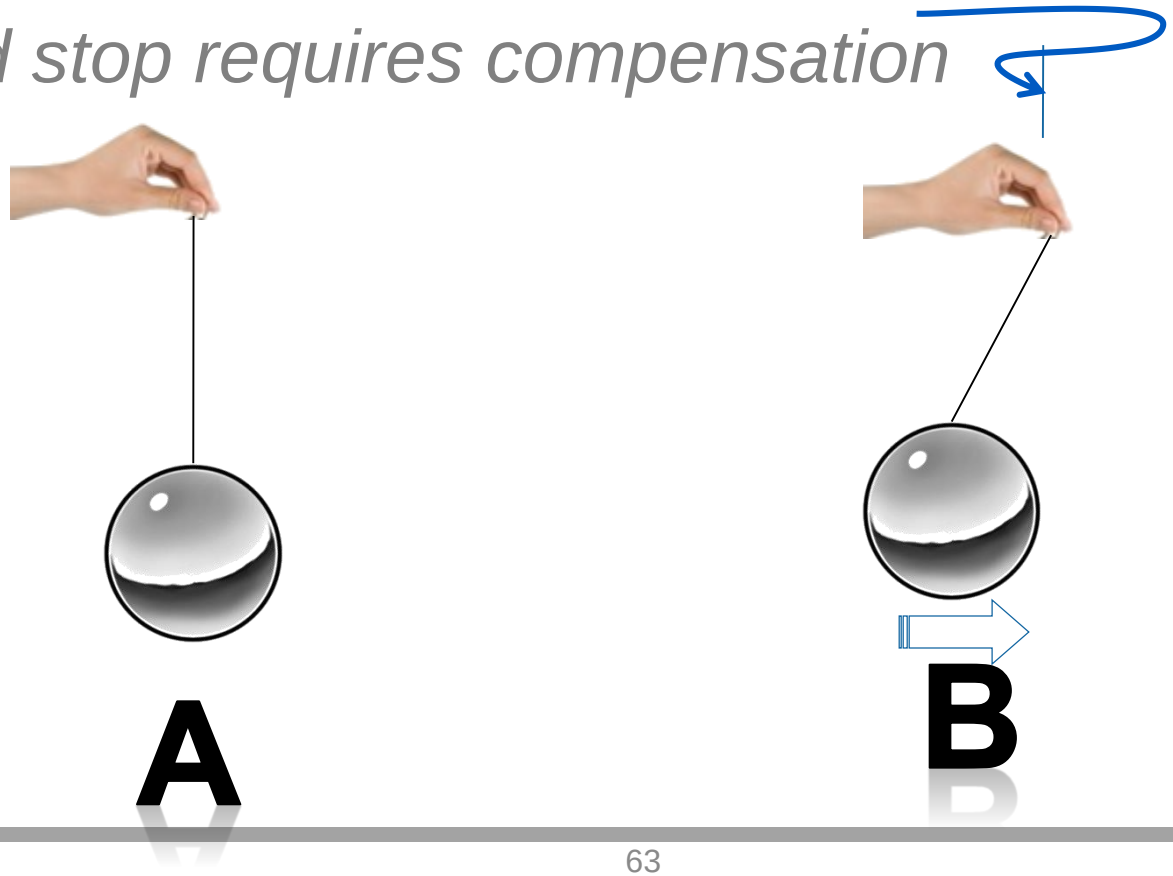

**Without Vibration Suppression**
Vibration in Position Error Signal is severe at move stop




**Vibration Suppression Active**
Position Error Signal shows reduced vibration at move stop

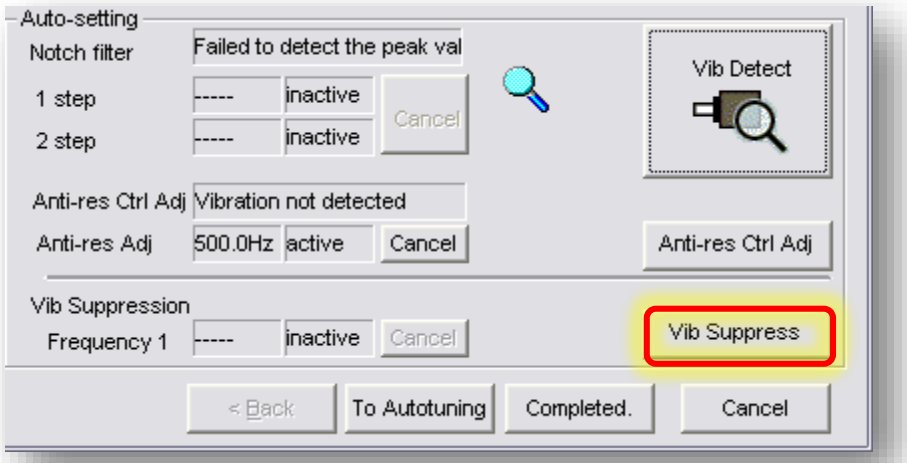
# Vibration Suppression

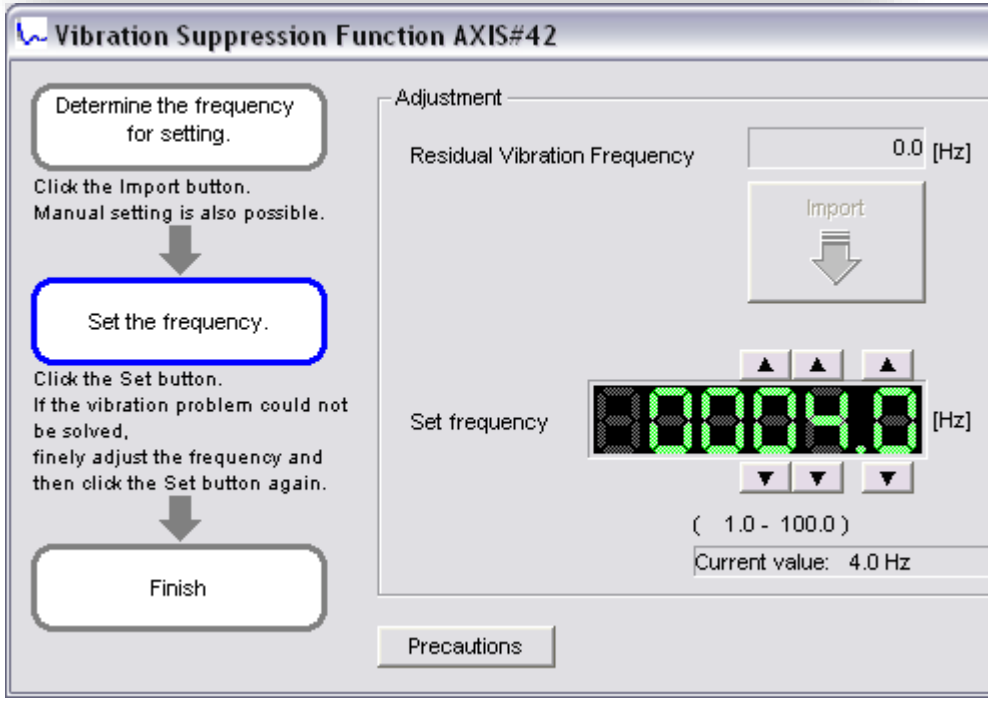
- *Position a pendulum from point A to point B*
- *Slow is easy*
- *Fast is difficult*
  - *Start and stop requires compensation*



# Vibration Suppression

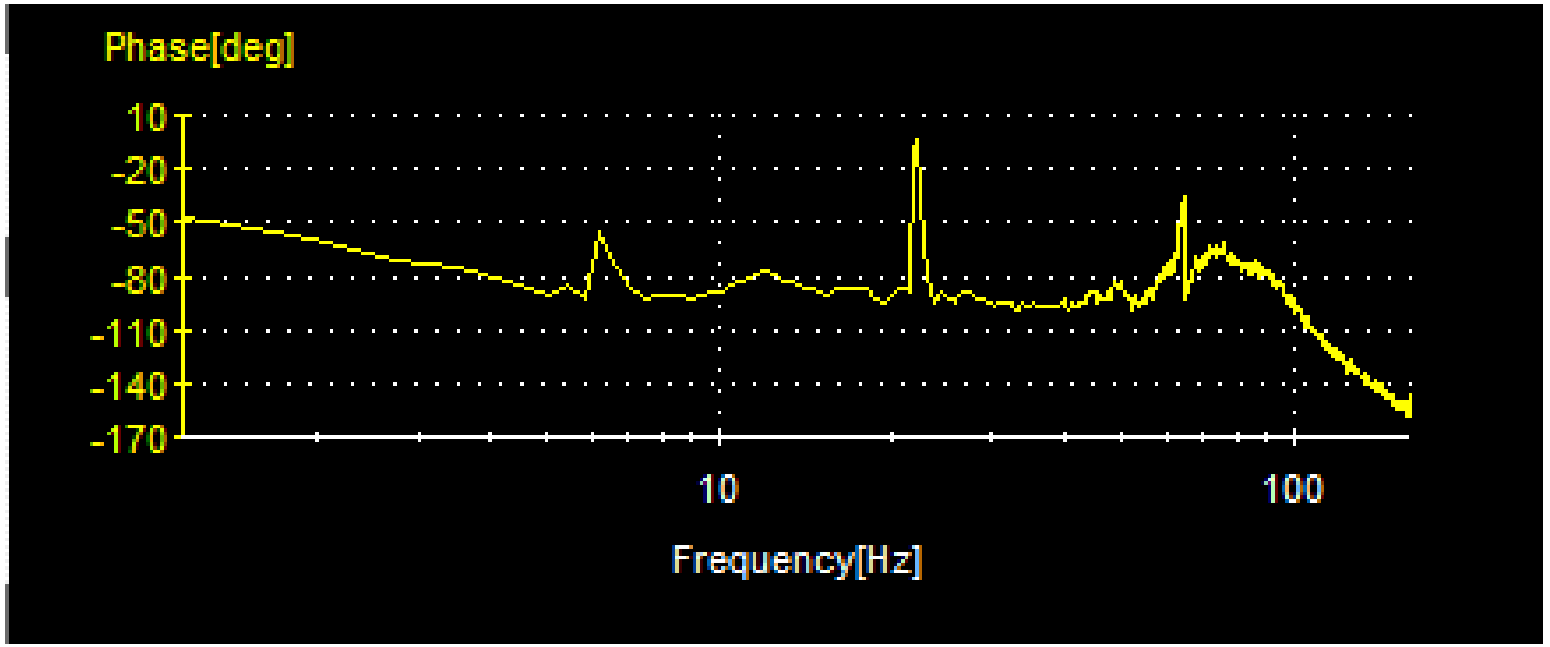
- *Effective Range: 1 Hz – 100 Hz*
- *Control Mode: Position*
  - *When Model Following Control enabled Pn140.0=1*
- *Automatic Setting: During Advanced Auto-Tuning*
- *Manually Adjust*
  - *Pn140, Pn145, Pn146, Pn14A, Pn14B*
- *Not Adaptive*



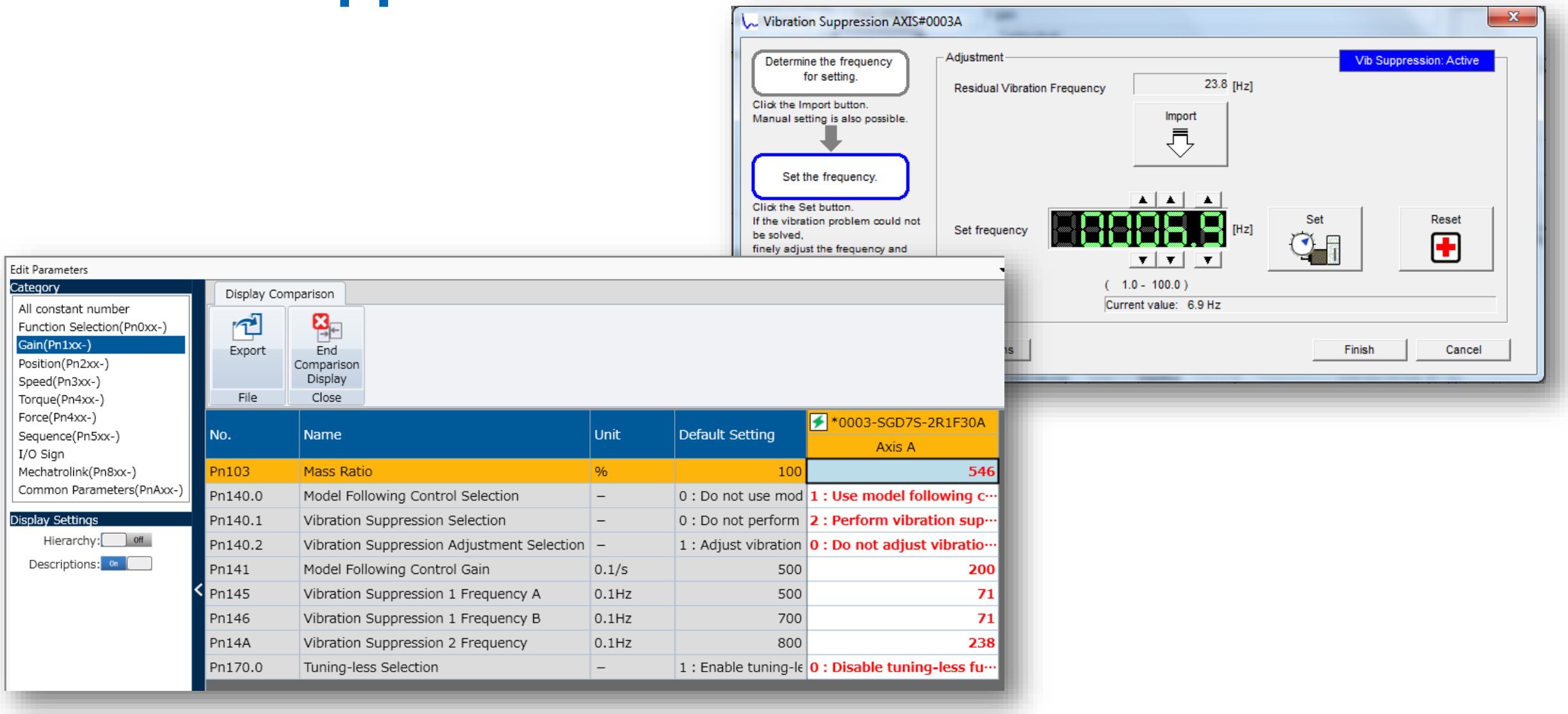



# Vibration Suppression

- *Example: Sigma Trac Linear motor with two vibrating loads*




# Vibration Suppression



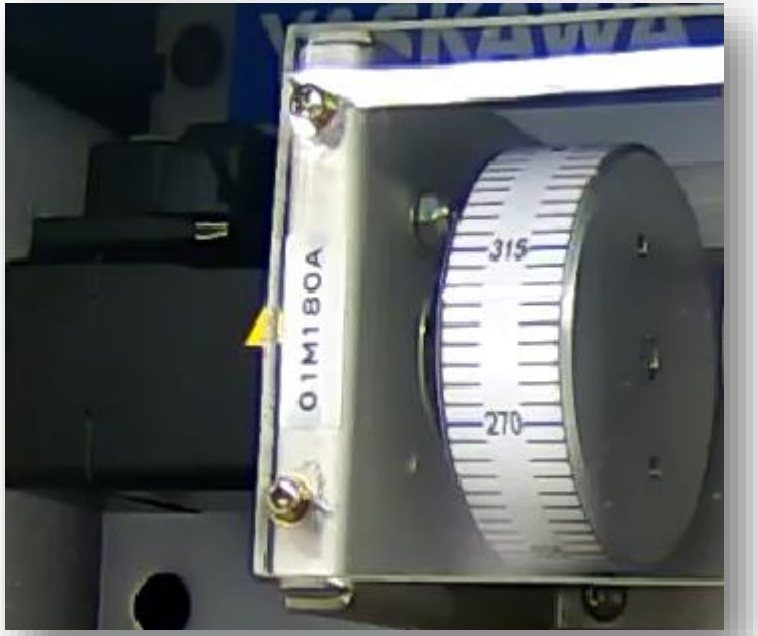
# Sigma-7 Servo Tuning
# **Data Trace**

Hands-on skills for Sigma-7 Servo Tuning

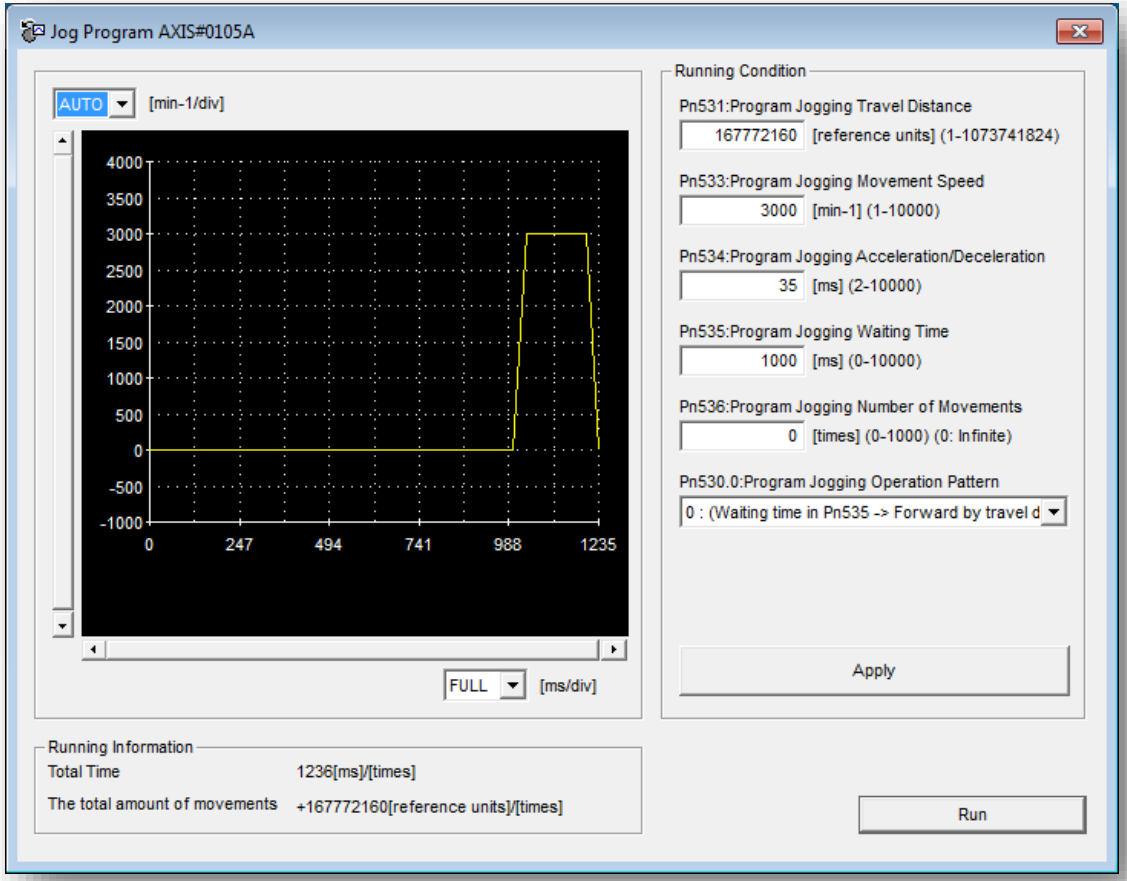
- *Trace Setup*
- *Measurement*
- *Position Settling Time*
- *Position Error*
- *Torque Ripple*

# Move Profile

- *X-Axis*
  - *Pn520*



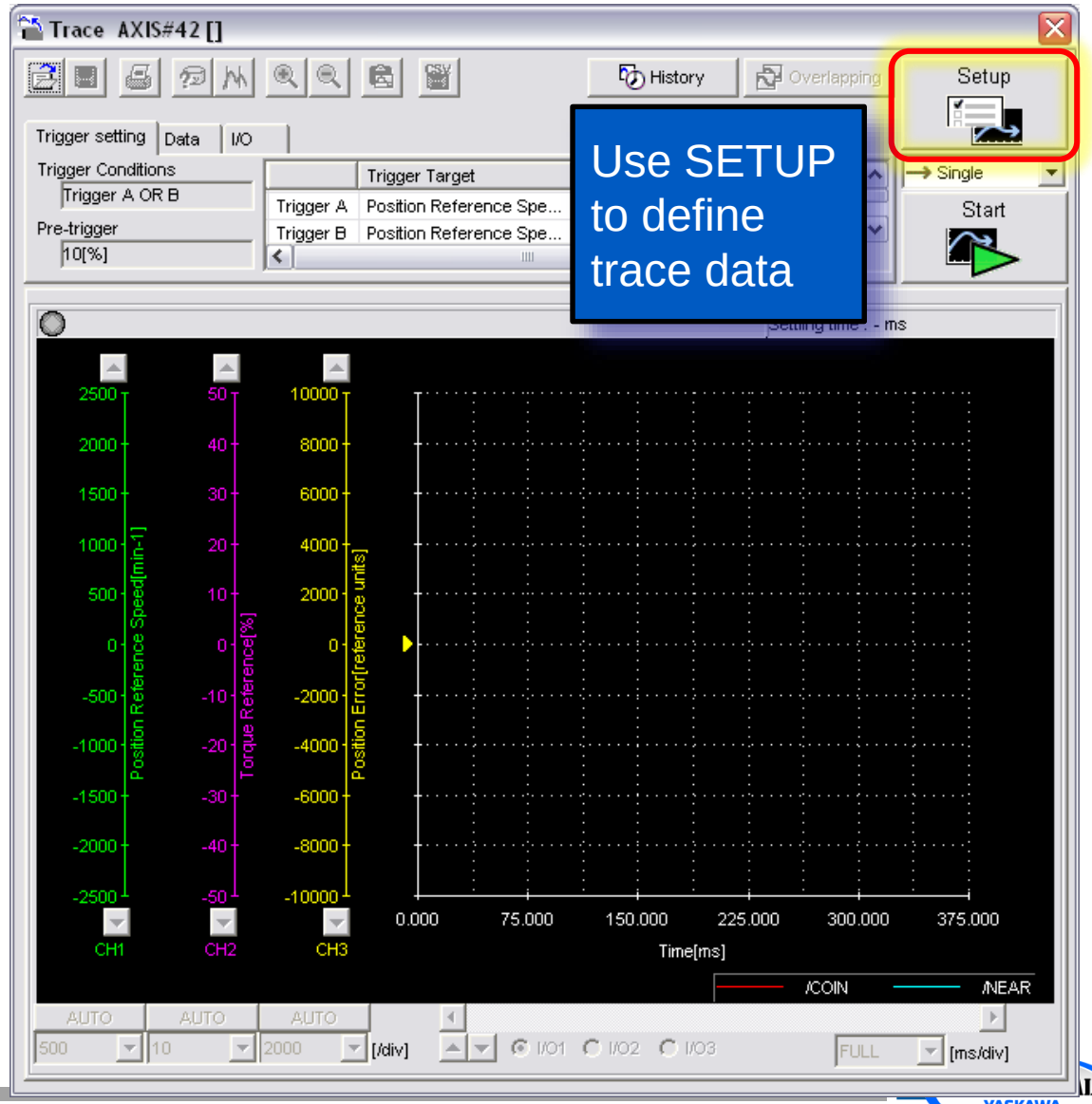

- *Set Program Jog to "worst case" move profile*
  - *Highest speed, accel, decel*
  - *Long time between moves*
  - *Use Controller or Program Jog*



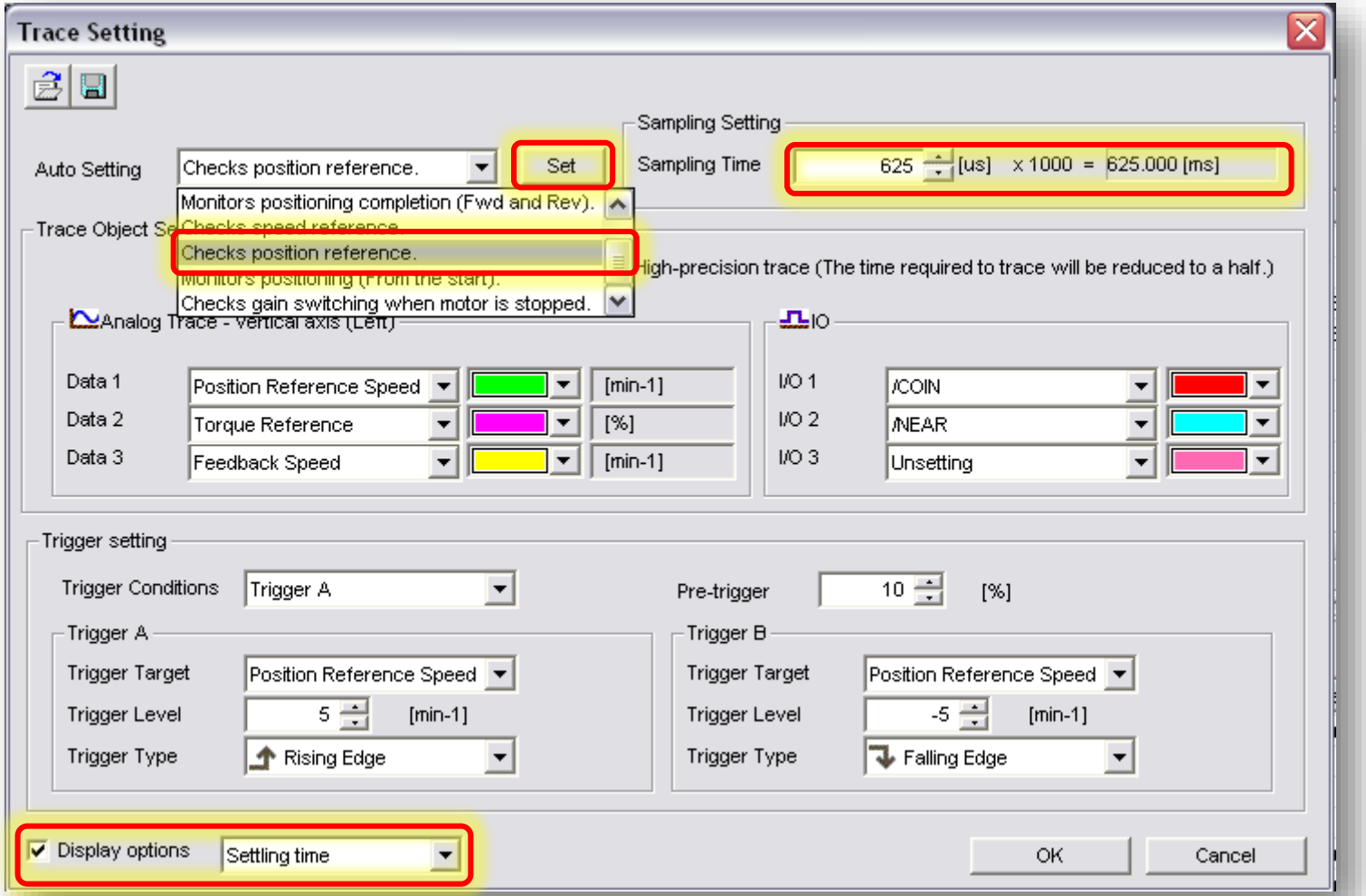

X-Axis worst case move profile in Program Jog

# Features Overview

- *Simultaneous operation*
  - *Program Jog*
  - *IEC controller*
- *Simultaneous trace of both axes in SGD7W dual-axis amplifier*
- *Zoom & Cursors*
- *Single / Continuous trace mode*
- *Overlapping History*
- *Hide unwanted data*



# Trace Setup




1000 Data Points captured on Servopack.

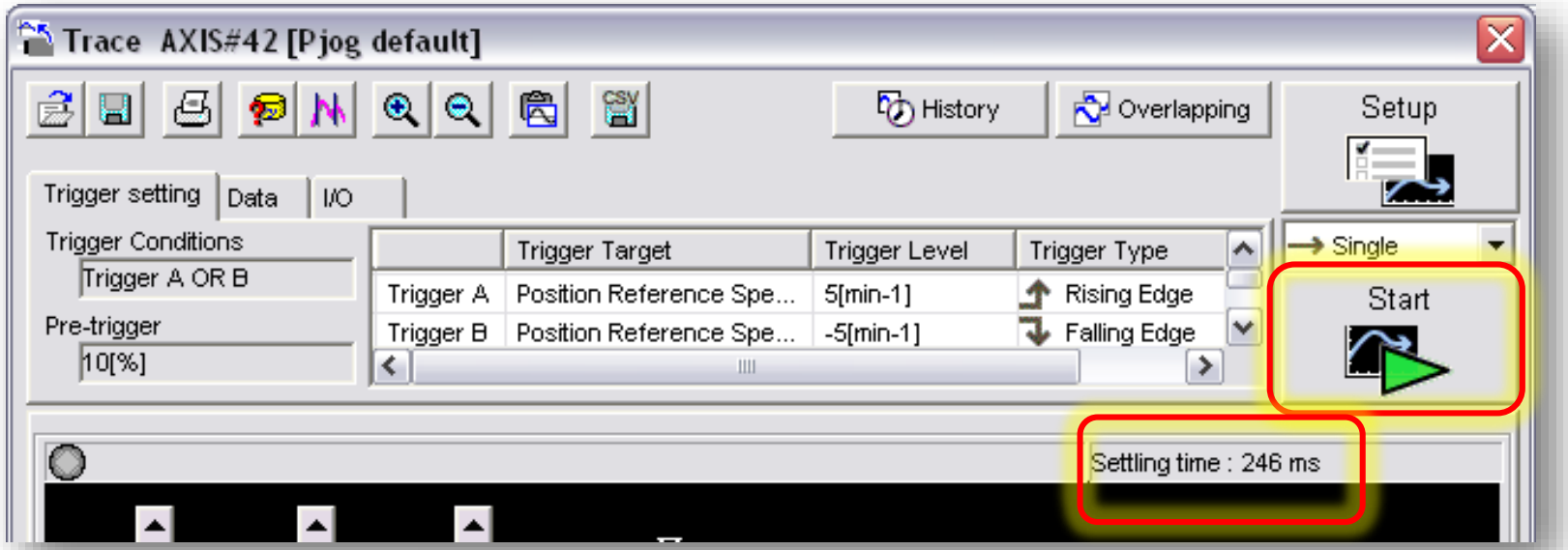
Data uploads to SigmaWin+ Trace

Settling time automatically measured.

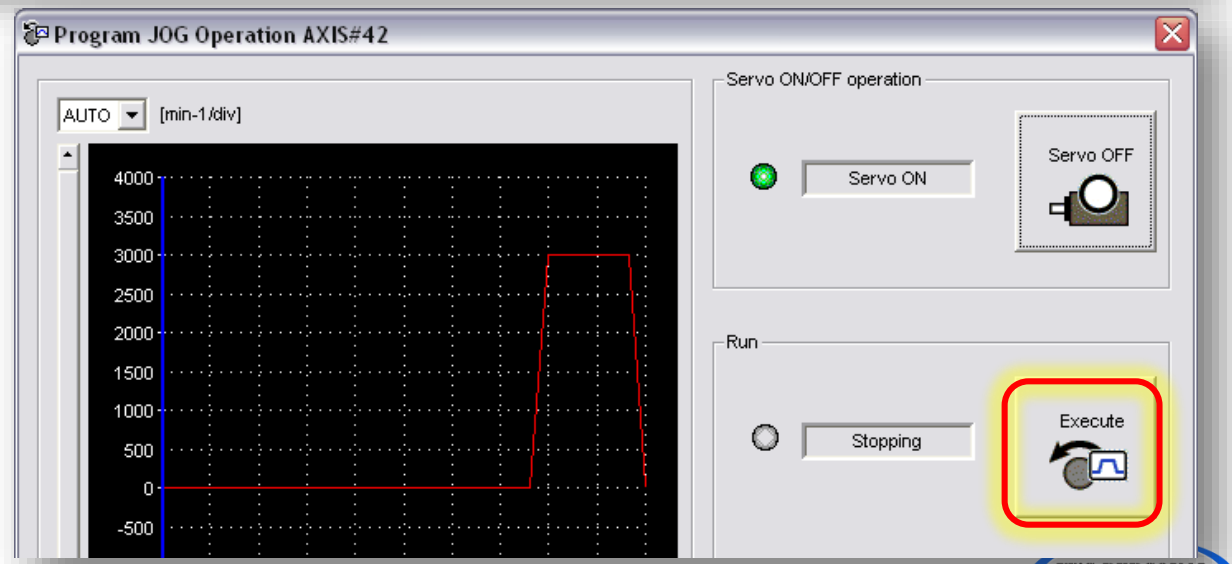
Trace must show one move with /COIN low after command complete

# Start Trace

- *Start Button*

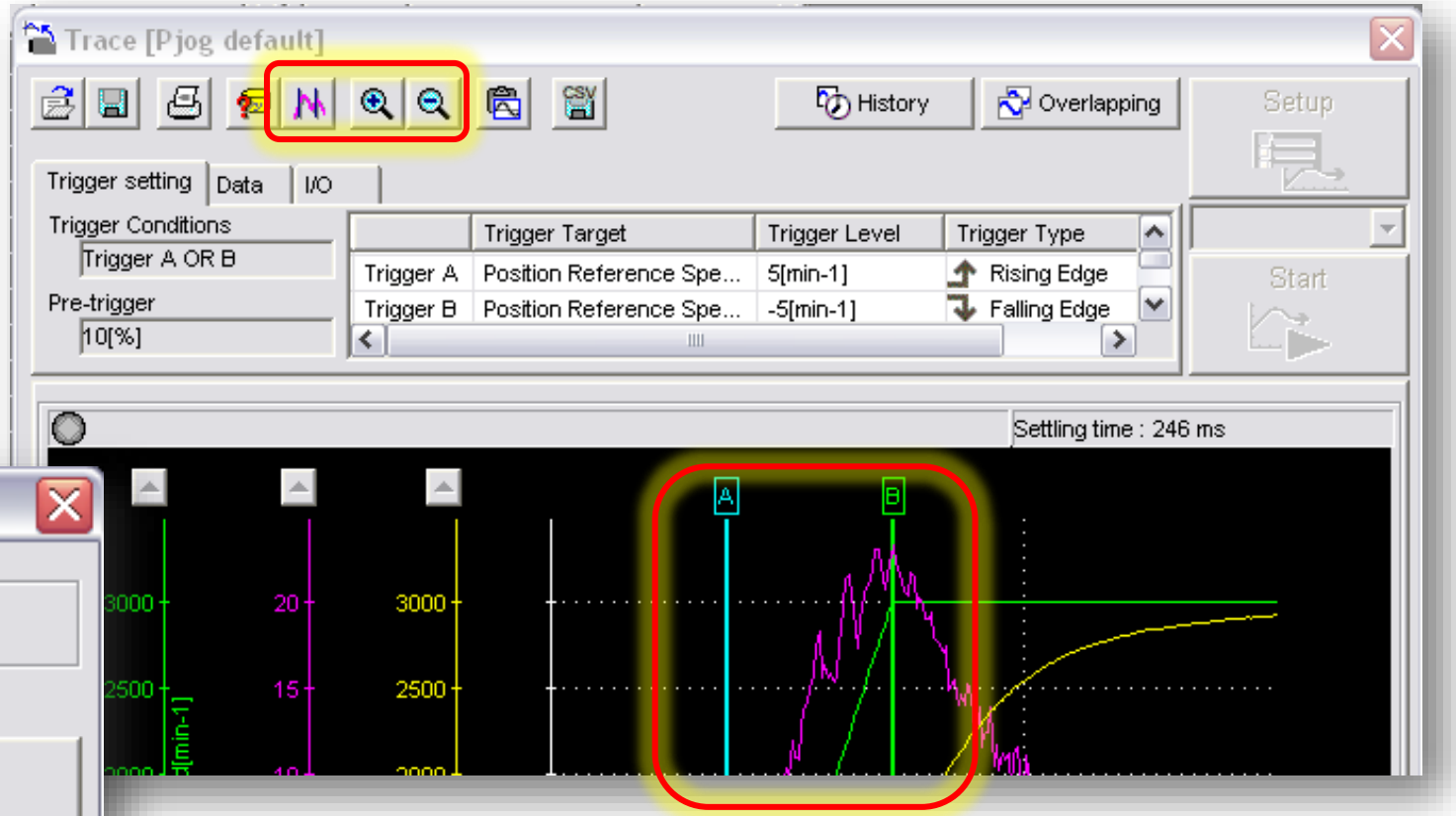


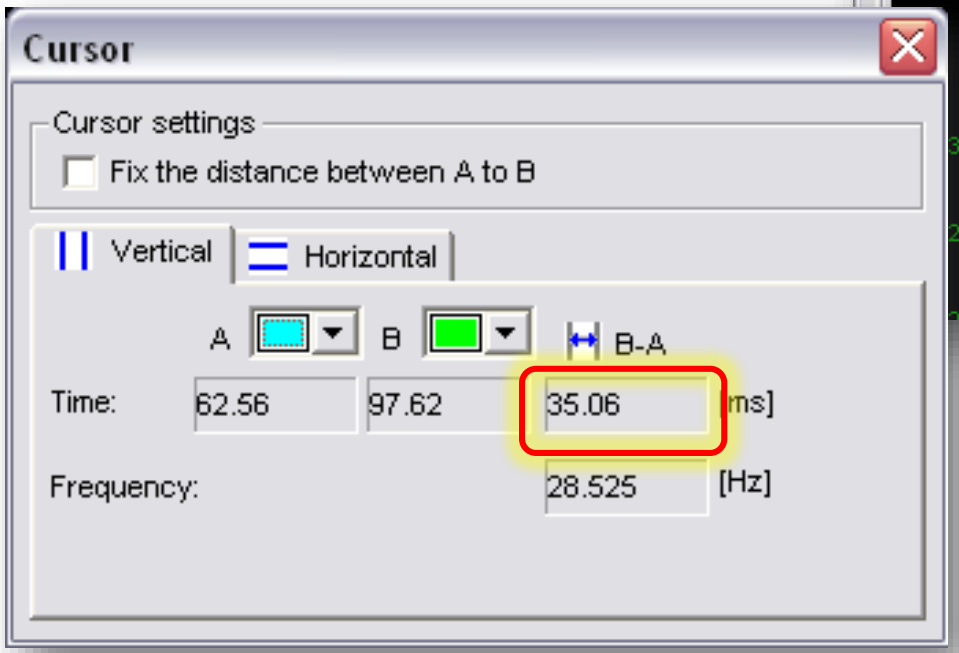

- *Execute Motion*



# Measurement

- *Zoom*
  - *Zoom to acceleration profile*
- *Cursors*
  - *Measure acceleration time*
  - *Confirm 35 ms*



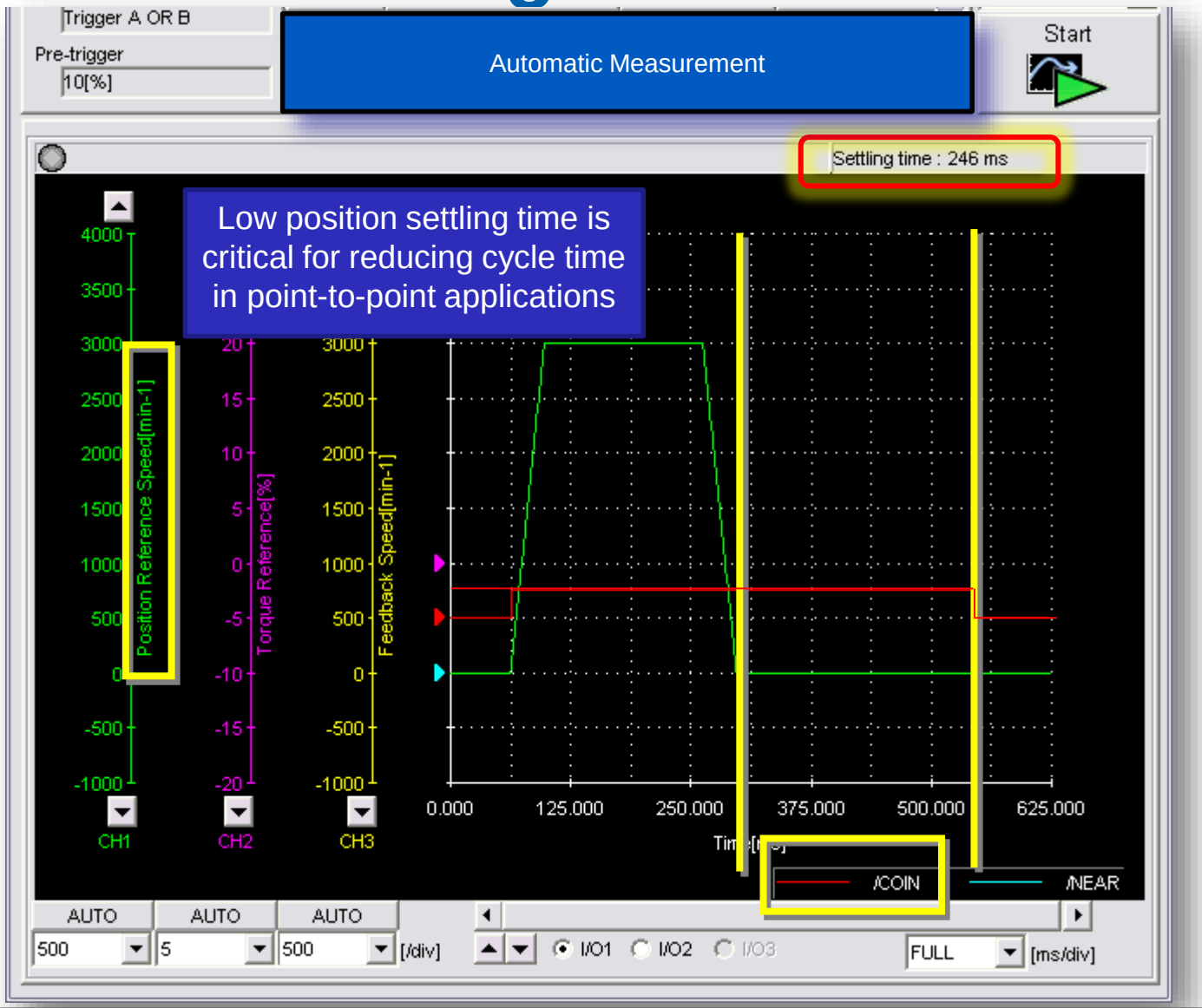
# Tuning Results Table

- *Measure and record values in the table*

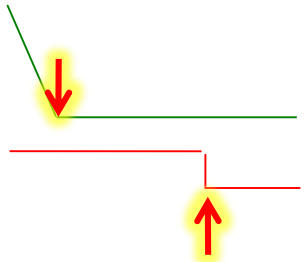
Tuning Results Table: MP3300iec & Sigma-7 Demo

| Axis | | Tuning Algorithm | Position Settling Time | Maximum Position Error | Torque Ripple / Noise |
|---|---|---|---|---|---|
| SGD7W Axis A | X_Axis | Default "Tuning-Less" | | | |
| SGD7W Axis A |  | Optimized Tuning-Less | | | |
| SGD7W Axis A | | Advanced Auto-Tuning | | | |
| SGD7W Axis A | | Custom Tuning | | | |
| SGD7W Axis B | Y_Axis | Default "Tuning-Less" | x | x | x |
| SGD7W Axis B |  | Optimized Tuning-Less | x | x | x |
| SGD7W Axis B | | Advanced Auto-Tuning | | | |
| SGD7W Axis B | | Custom Tuning | | | |
| SGD7S AxisA | Z_Axis | Default "Tuning-Less" | | | |
| SGD7S AxisA |  | Optimized Tuning-Less | x | x | x |
| SGD7S AxisA | | Advanced Auto-Tuning | | | |
| SGD7S AxisA | | Custom Tuning | | | |

# Position Settling Time




- *Measure Position Settling Time*
  - *Position Reference Pulse Speed*
  - */COIN*



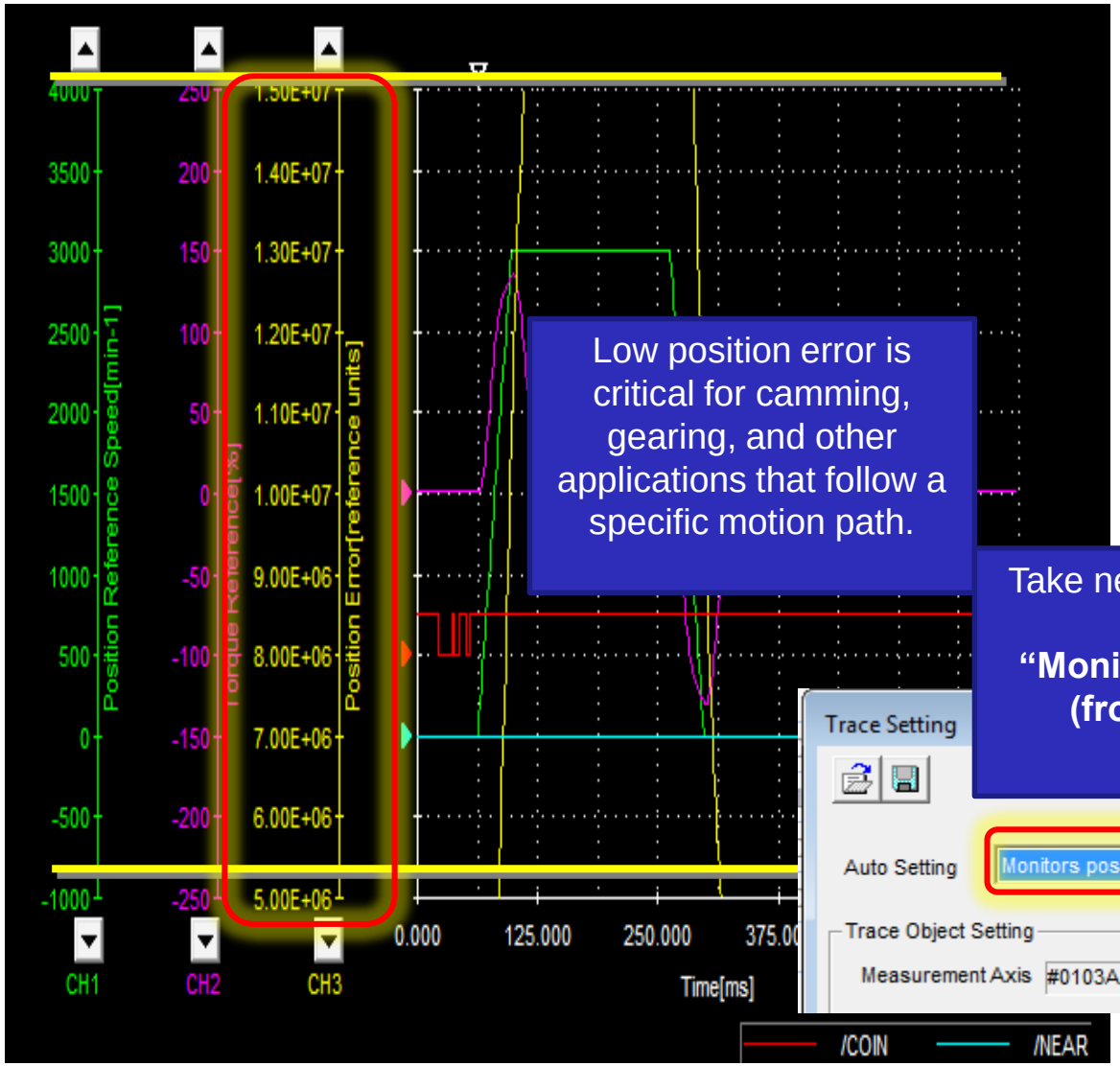
# Position Settling Time

- */COIN Signal*
  - *Pn522 [Encoder Pulse]*
  - *Set Pn522 to 0.1°*
    - » *Sigma-7: Pn522= 4660 (24-bit = 16,777,216 pulse/rev)*
    - » *Sigma-5: Pn522=291 (20-bit = 1,048,576 pulse/rev)*

| Pn522 | Positioning Completed Wi | referen | 4660 |
|---|---|---|---|

$$\frac{16{,}777{,}216\ encoder\ pulse}{rev} \times \frac{1\ rev}{360°} = 46603_{pulse/degree}$$

# Position Error

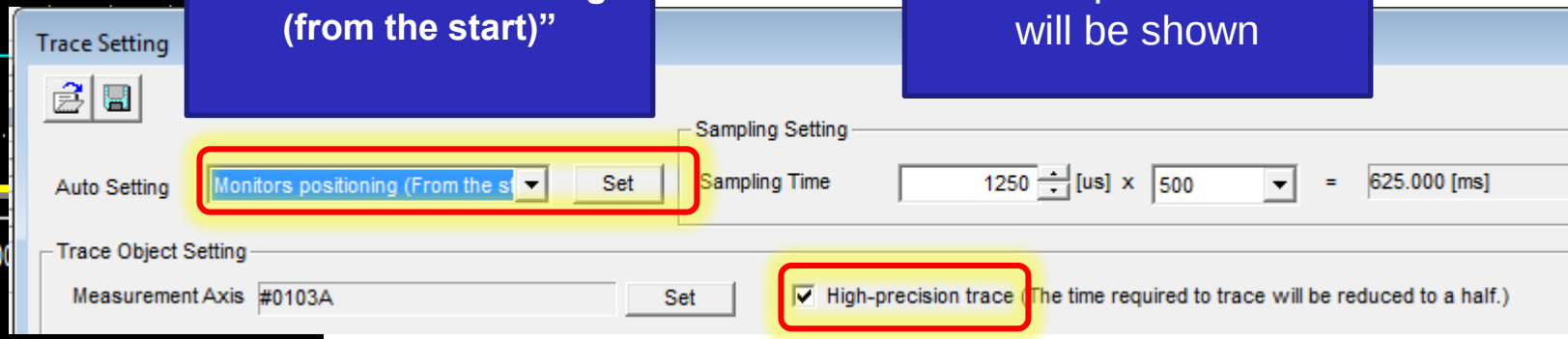



Low position error is critical for camming, gearing, and other applications that follow a specific motion path.

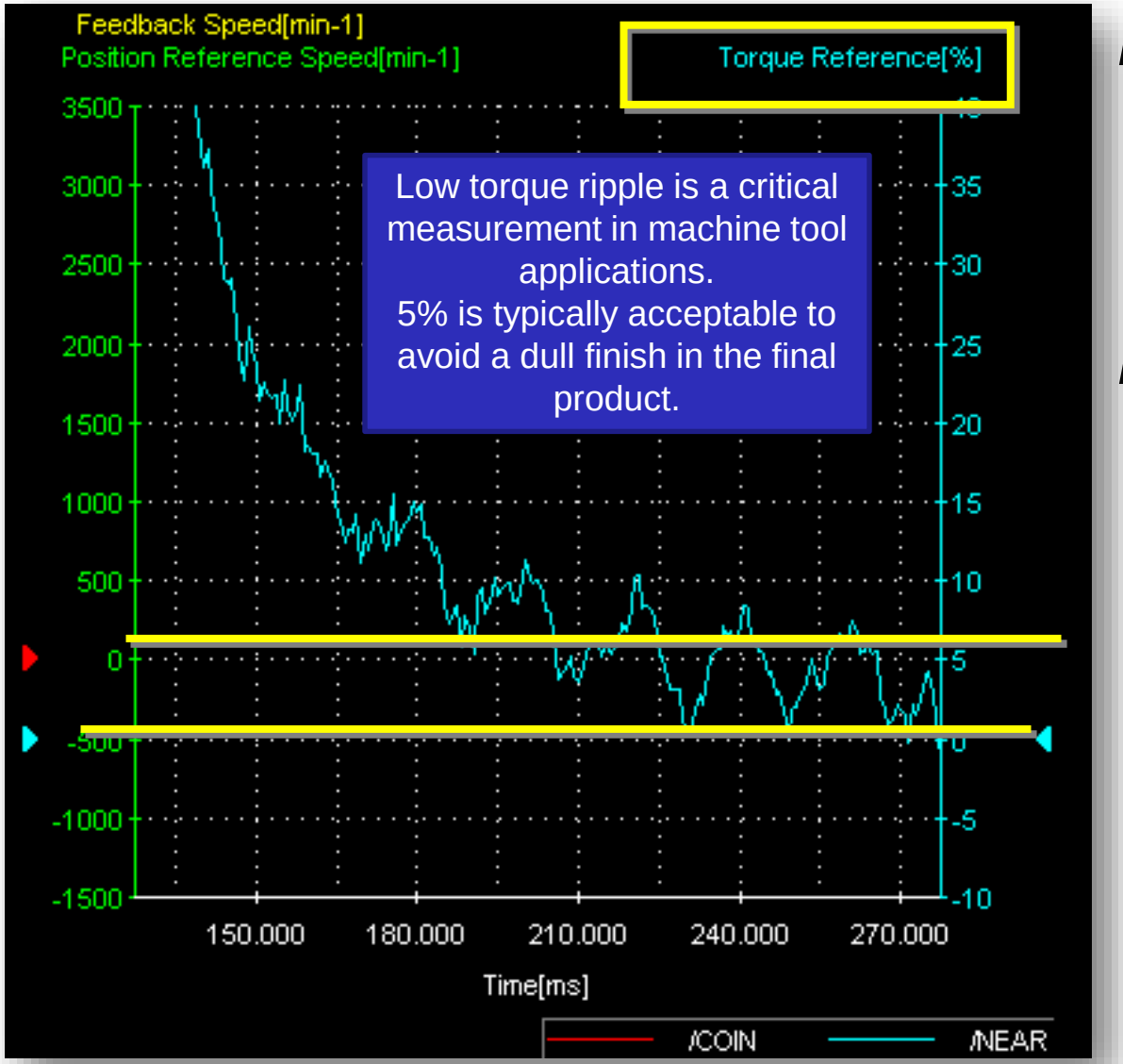
- *Measure Position Error*
  - *Maximum Position Error*
  - *Measure ZERO to Max*

Take new trace with Auto Setting **"Monitors Positioning (from the start)"**

**High-Precision Trace** Shows 32-bit data – the true position error will be shown



# Torque Ripple




## *Measure Torque Ripple*

- *Torque Reference*
- *During move*

## *Measure:*

- *Peak-to-peak average*
- *Zoom In*

# Overview

Tune for low position settling time.

**Axes synchronized to each other**


Tune for lowest position error.

**Synchronized to external axis**

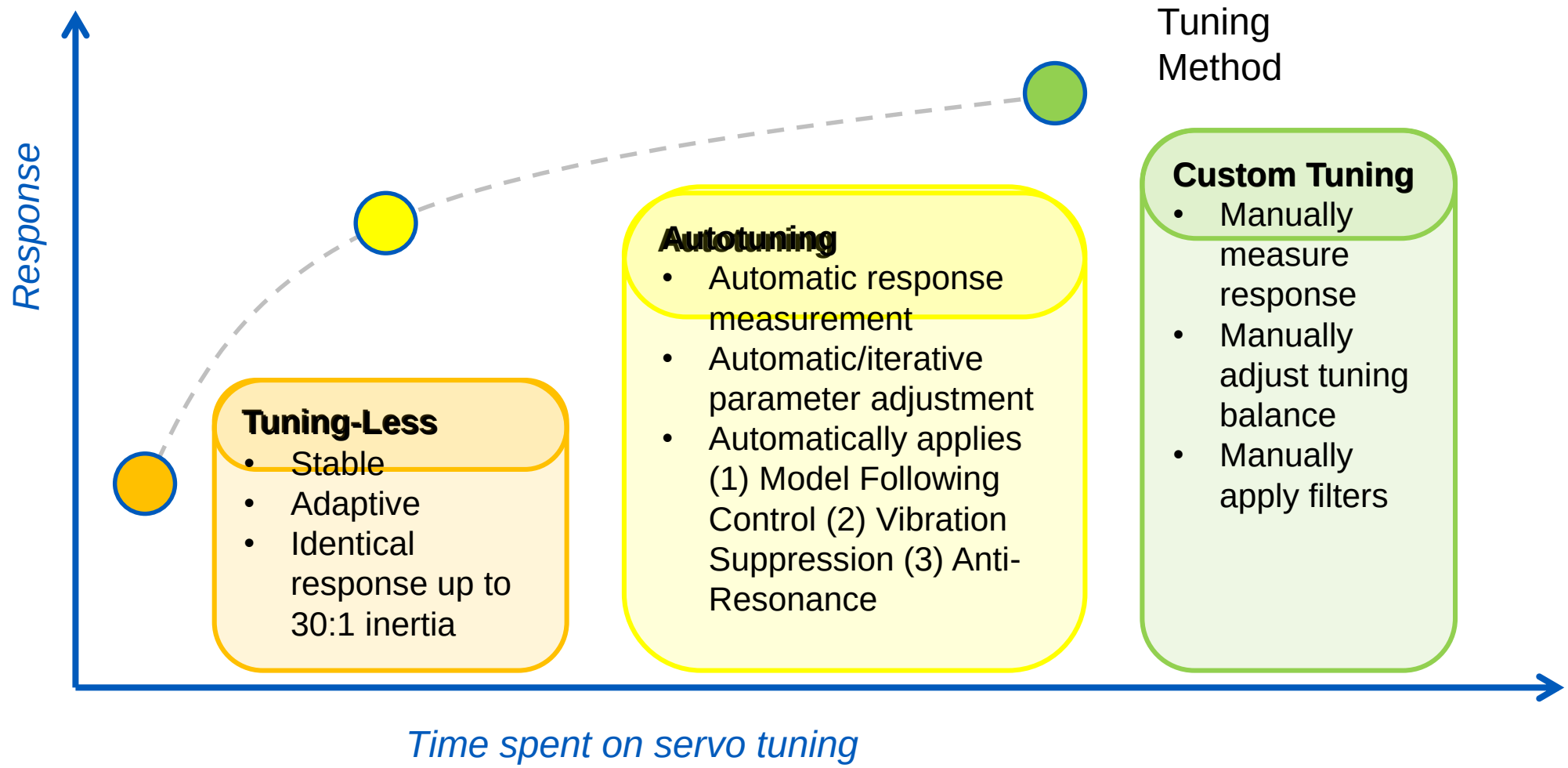
Typical electronic cam application; rotary knife

# Sigma-7 Servo Tuning
# **Tuning-Less**

Optimize the “Tuning-Less” Tuning Method on the Demo X Axis

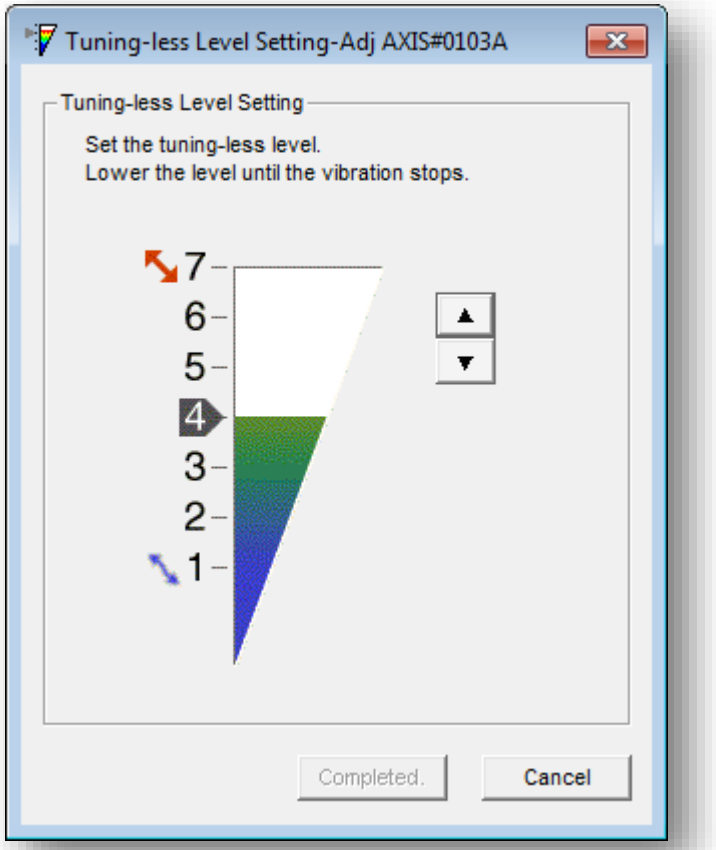
- *Overview*
- *Basic Adjustments*
- *Feed Forward*
- *Advanced Adjustments*

# Sigma-7 Tuning Methods



# Overview

- *How It Works*
  - *Adjusts the servo control loops internally*
  - *No parameters are automatically set*
  - *Standard tuning parameters have no effect when Tuning-Less is ON*
- *When To Use*
  - *Default is ON*
  - *Changing load*
  - *Any type of machine*
  - *Speed Mode or Position Mode*
- *How To Use*
  - *Turn up Rigidity Level*
  - *Turn down Rigidity Level if you hear resonance*
  - *Apply Feed Forward (Pn109)*
  - *Other Configuration Options in Pn170*

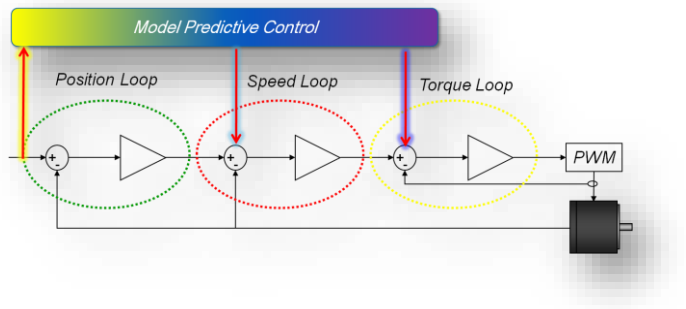


# Basic Adjustments

- *Feed-Forward (Pn109)*
- *Rigidity Level (Pn170.2)*
  - *If noisy, reduce level*

| | | | |
|---|---|---|---|
| Pn109 | Feedforward | % | 74 |

| | | | |
|---|---|---|---|
| Pn170.0 | Tuning-less Selection | – | 1 : Enable tuning-less function. |
| Pn170.1 | Speed Control Method | – | 0 : Use for speed control. |
| Pn170.2 | Rigidity Level | – | 7 : Tuning-less Level 7 |
| Pn170.3 | Tuning-less Load Level | – | 1 : Tuning-less Load Level 1 |

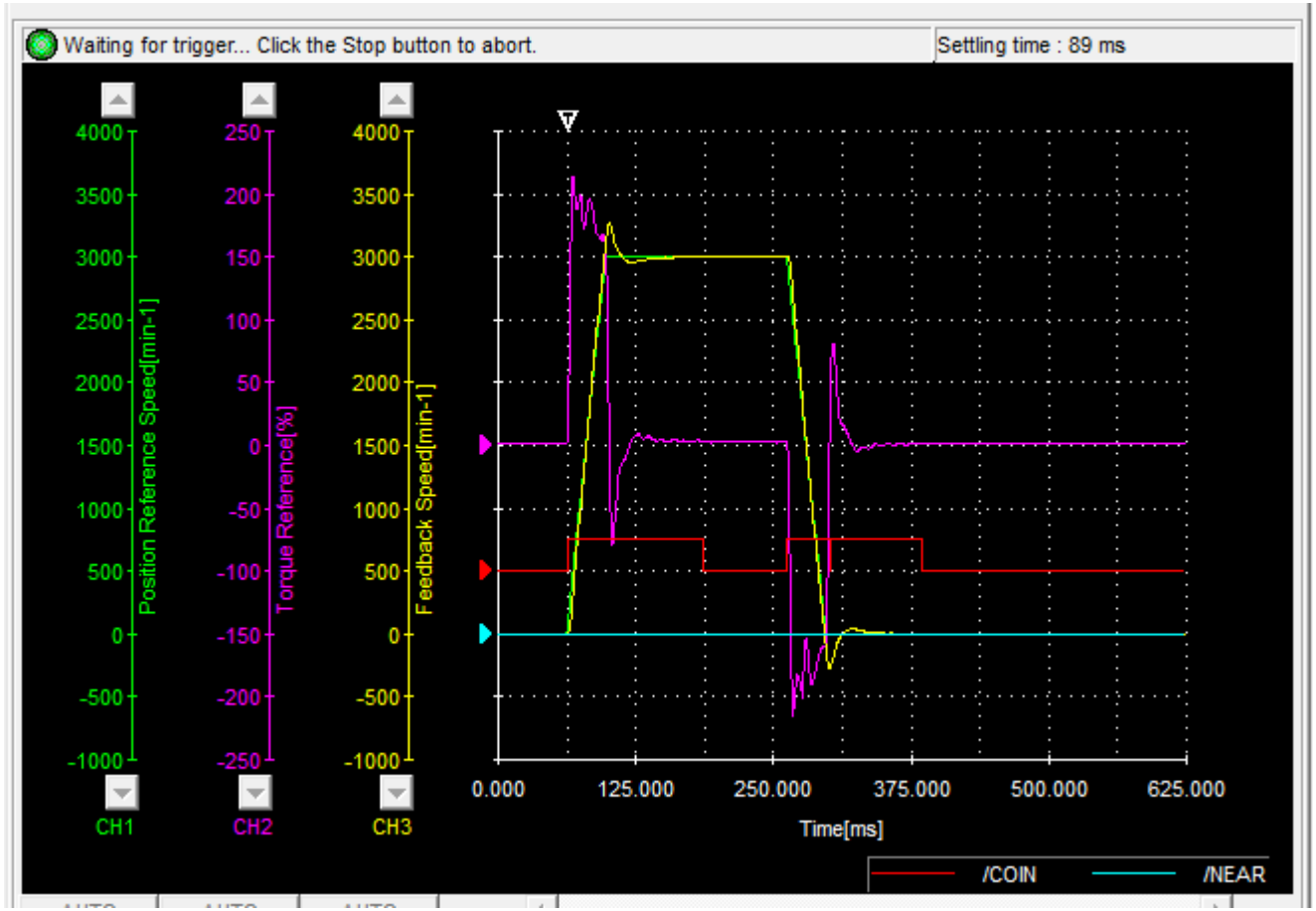


# Feed-Forward

- *Improve Tuning-Less with Feed Forward Pn109*
  - *Updates at 0.0625 ms*
  - *Settling time reduced to ~100ms*
- *Trace and measure the result*
- *Record results in the Tuning Results Table*

MP3300iec & Sigma-7 Demo Tuning

| Axis | Tuning Algorithm | Position Settling Time | Maximum Position Error | Torque Ripple / Noise |
|---|---|---|---|---|
| SGD7W Axis A | Default "Tuning-Less" | | | |
| SGD7W Axis A | Optimized Tuning-Less | | | |
| SGD7W Axis A | Advanced Auto-Tuning | | | |
| SGD7W Axis A | Custom Tuning | | | |
| SGD7W Axis B | Default "Tuning-Less" | | | |
| SGD7W Axis B | Optimized Tuning-Less | | | |
| SGD7W Axis B | Advanced Auto-Tuning | | | |
| SGD7W Axis B | Custom Tuning | | | |
| SGD7S AxisA | Default "Tuning-Less" | | | |
| SGD7S AxisA | Optimized Tuning-Less | | | |
| SGD7S AxisA | Advanced Auto-Tuning | | | |
| SGD7S AxisA | Custom Tuning | | | |



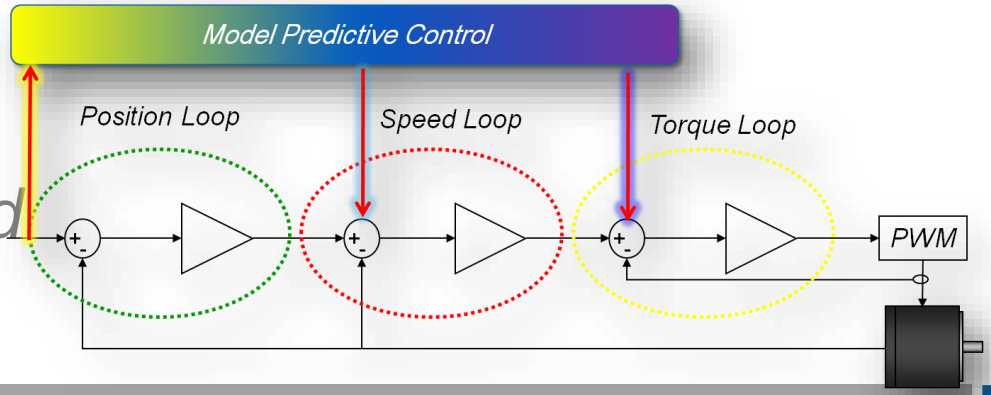
# Advanced Adjustments

- *Load Level*
  - *Pn170.3*
  - *Higher inertia, increase level*
- *Model Following Control*
  - *Pn140.0*
  - *Improve settling time by increasing gain Pn141*
  - *Set Pn103 =0*
  - *Feedforward Pn109 no effect*
- *Vibration Suppression*
  - *Only if Model Following is enabled*

| | | | |
|---|---|---|---|
| Pn140.0 | Model Following Control Selection | – | 0 : Do not use m··· |
| Pn140.1 | Vibration Suppression Selection | – | 0 : Do not perfor··· |
| Pn140.2 | Vibration Suppression Adjustment S | – | 1 : Adjust vibratio··· |
| Pn140.3 | Speed Feedforward (VFF)/Torque F | – | 0 : Do not use m··· |
| Pn141 | Model Following Control Gain | 0.1/s | 500 |
| Pn142 | Model Following Control Correction | 0.1% | 1000 |
| Pn143 | Model Following Control Bias in the | 0.1% | 1000 |
| Pn144 | Model Following Control Bias in the | 0.1% | 1000 |

**If you spend too much time adjusting Tuning-Less**, you will be…

"Tuning-More"

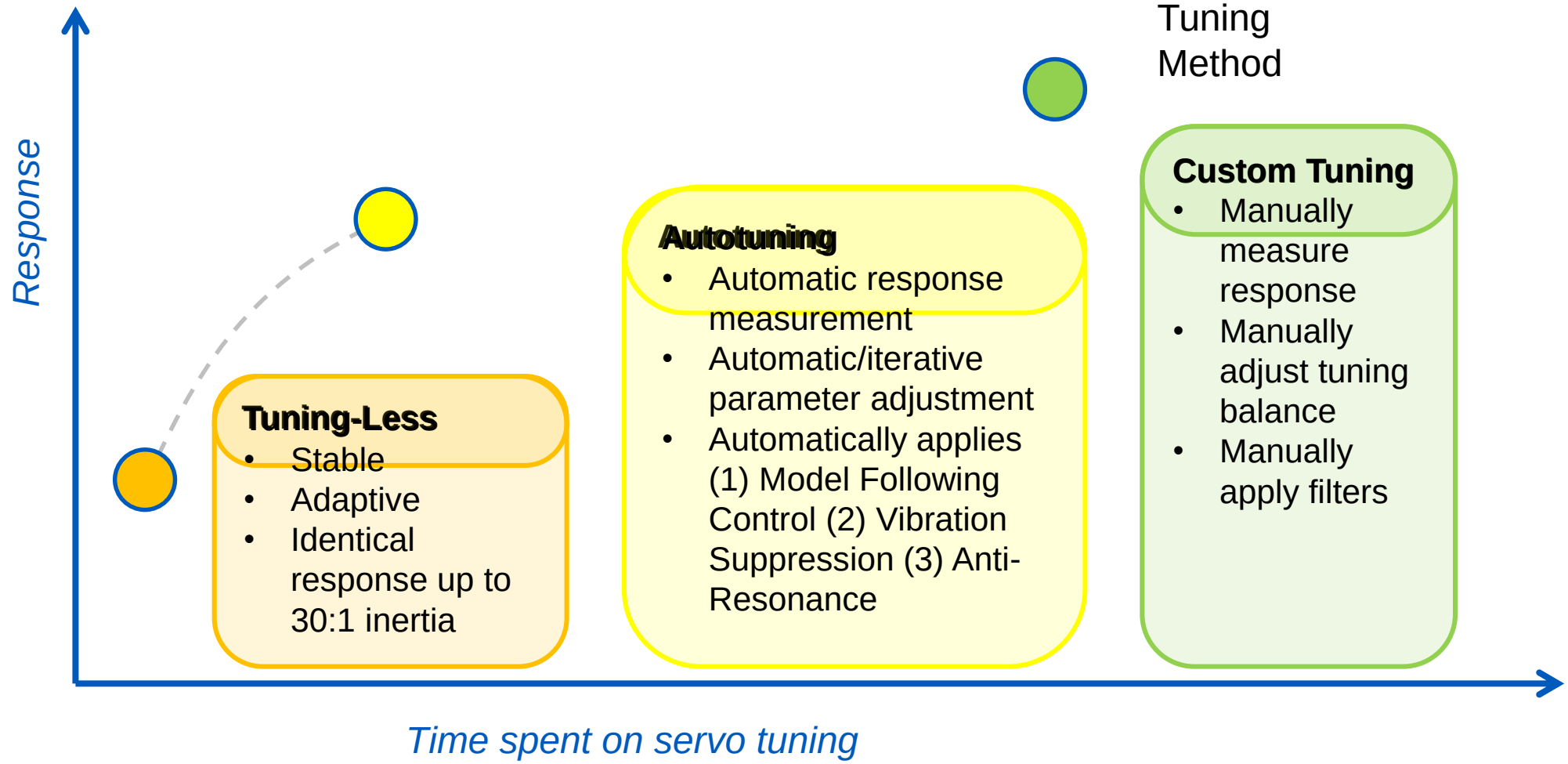


# Sigma-7 Servo Tuning
# **Autotuning**

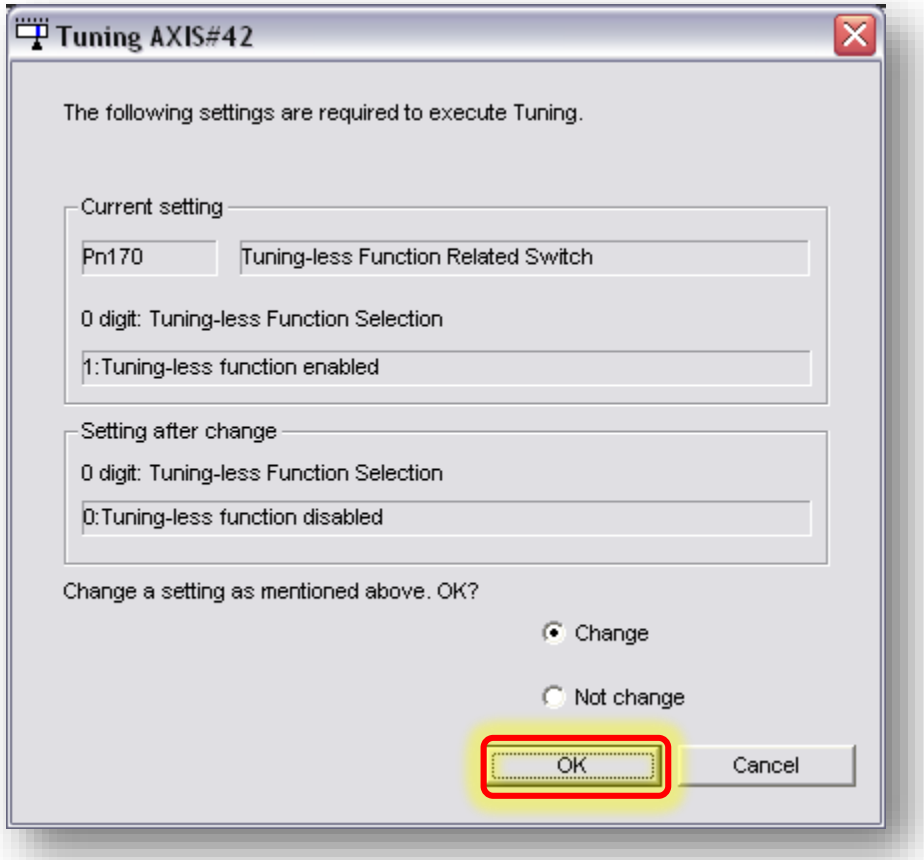
Run the Autotuning function on the Demo X Axis

- *Disable Tuning-Less*
- *Moment of Inertia Ratio*
- *Position Reference*
- *Mode and Mechanism*
- *Execute Autotuning*
- *Troubleshooting*

# Sigma-7 Tuning Methods



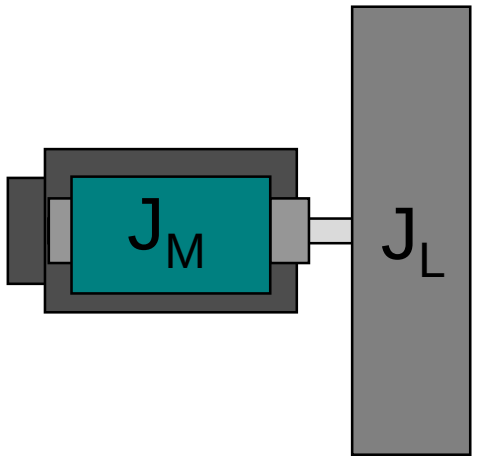
# Disable Tuning-Less

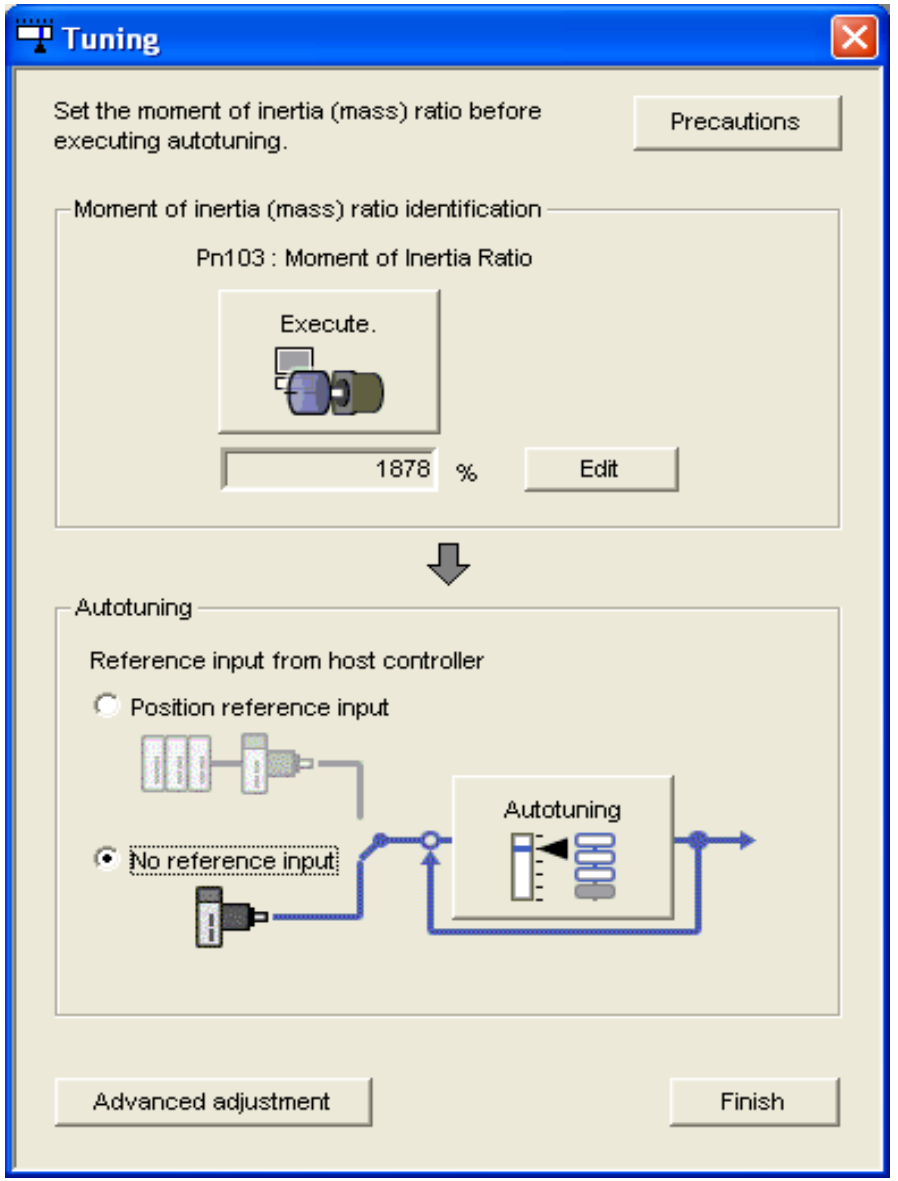

- *Autotuning requires Tuning-Less disabled*
  - *Adaptive tuning is cancelled*
  - *Pn170.0 = 0*
  - *Performance may change significantly*

# Moment of Inertia Ratio

- *Identify Pn103*
  - *Tuning-Less disabled*
  - *Pn103 scales system gains*
- *Motor will move*
  - *Stop controller motion*
  - *Servo Off*

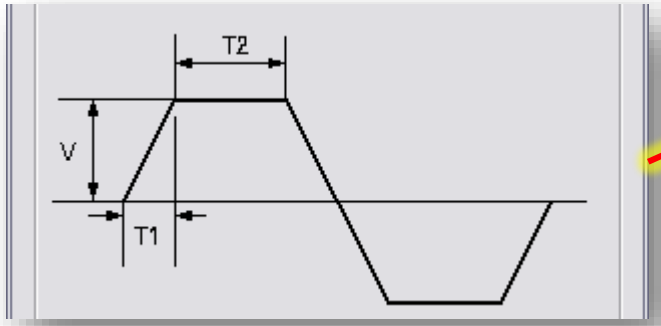



$$\text{Inertia Ratio} \frac{J_L}{J_M}$$



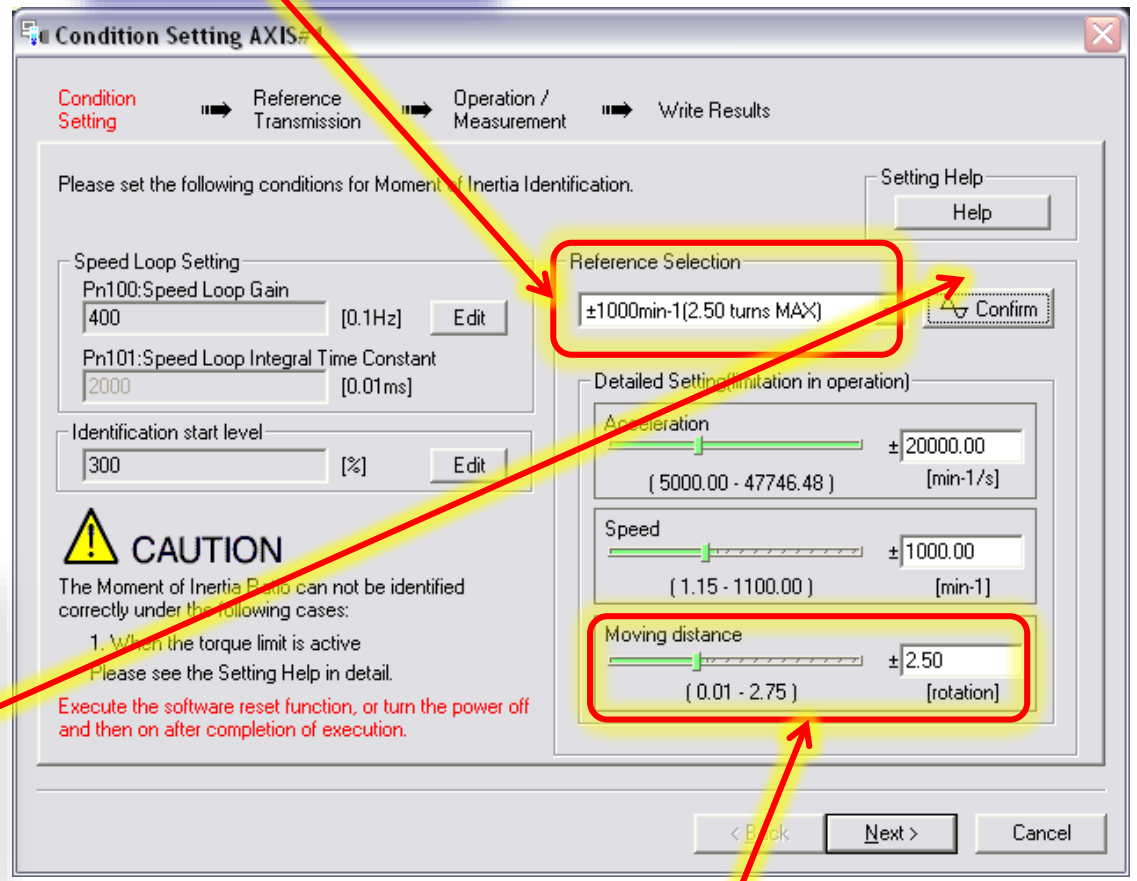
# Moment of Inertia Ratio

- *Motion Profile*
  - *Choose motor speed appropriate for mechanism*
  - *It is possible to customize the motion profile*
    - » *Acceleration*
    - » *Speed*
    - » *Distance*




Motor will move both directions

Use highest speed and acceleration applicable to the machine



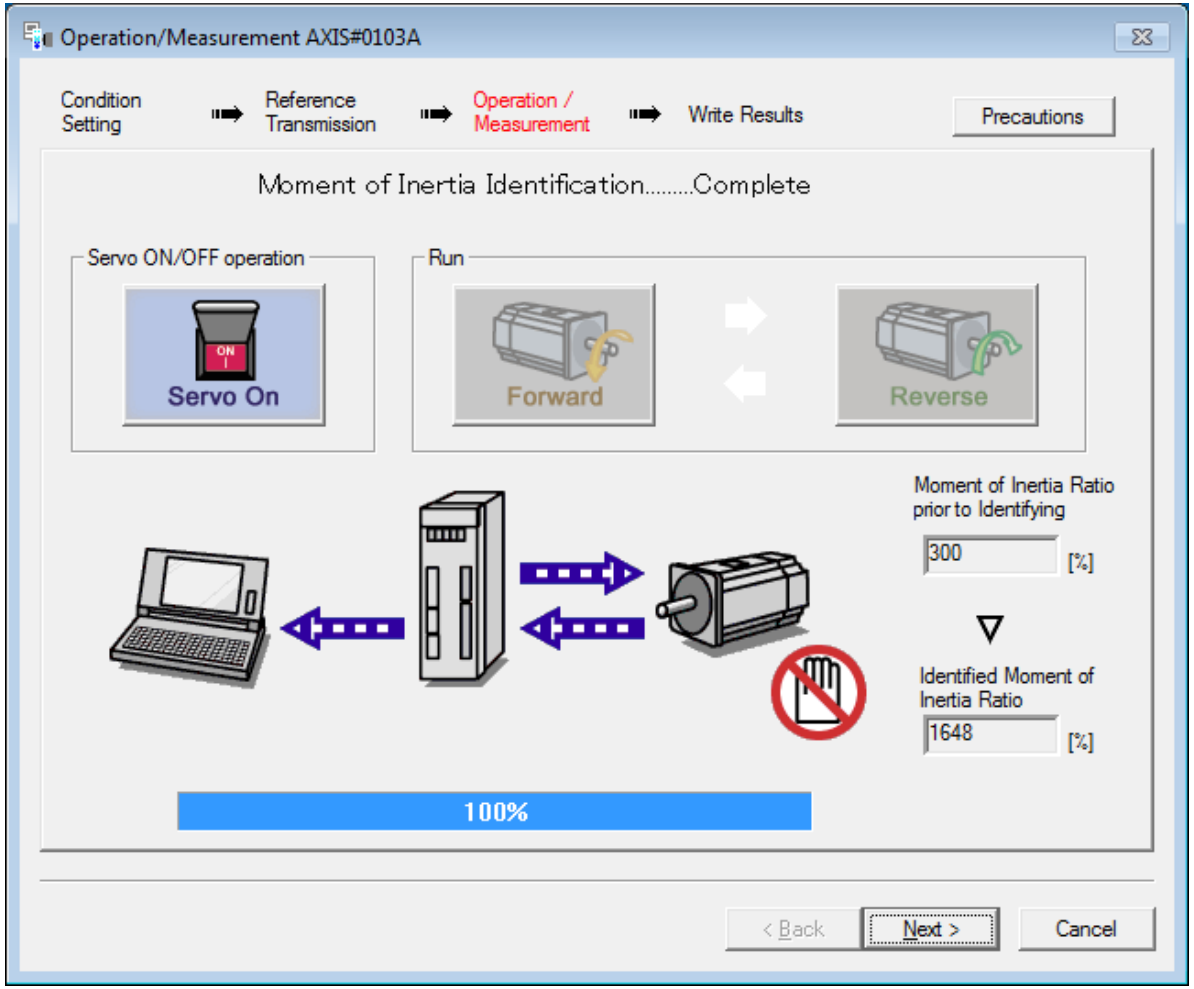

Verify distance allowed



IT'S PERSONAL YASKAWA

# Moment of Inertia Ratio

- *Execute the move*




**If the measurement fails**

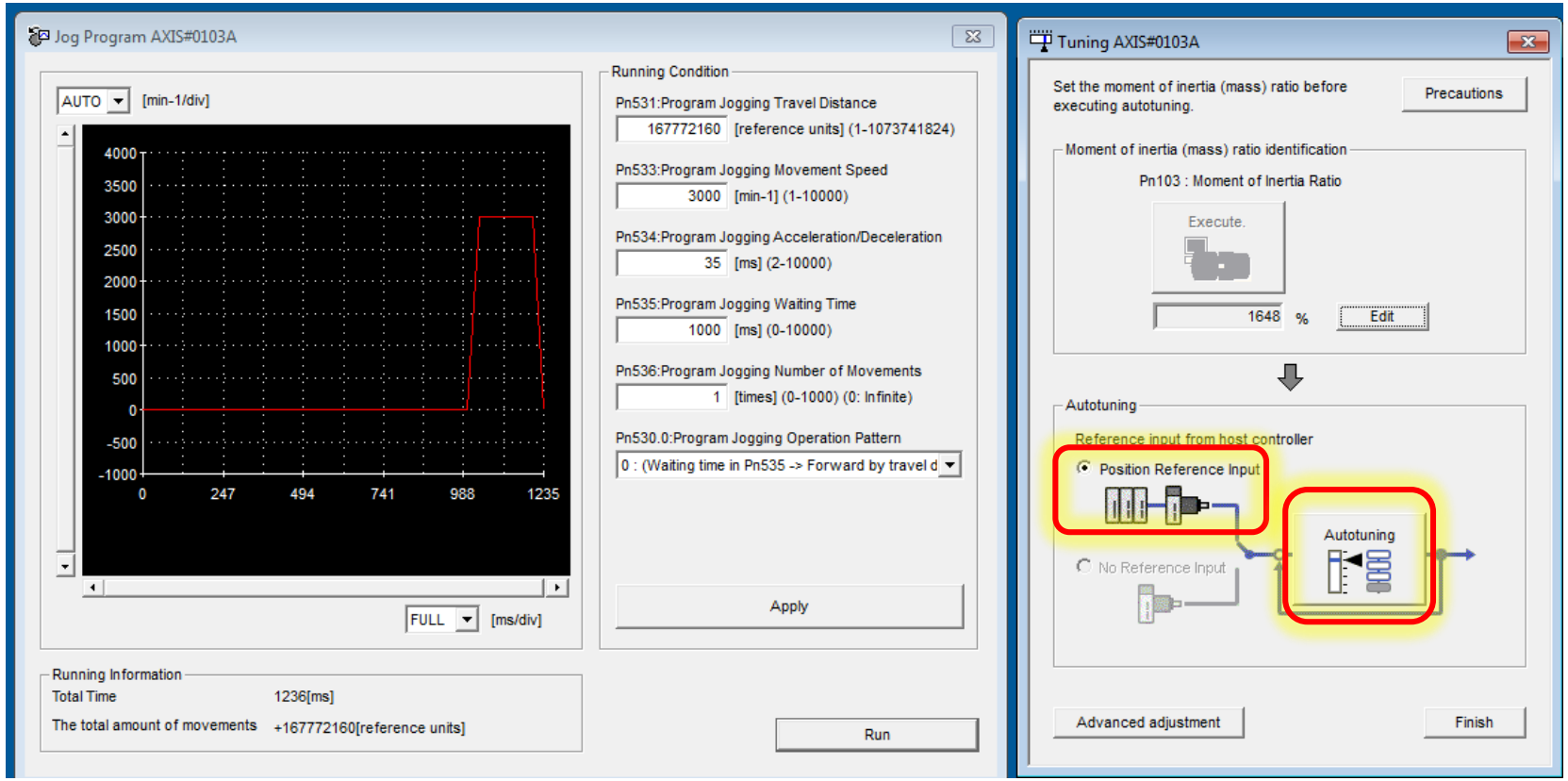
1. Change the profile settings from the previous screen, and try again

2. Reduce noise
   - Set filters
   - Lower Pn100

# Position Reference

- *Position Reference Input*
  - *External motion command*
  - *Controller*
  - *Program Jog*

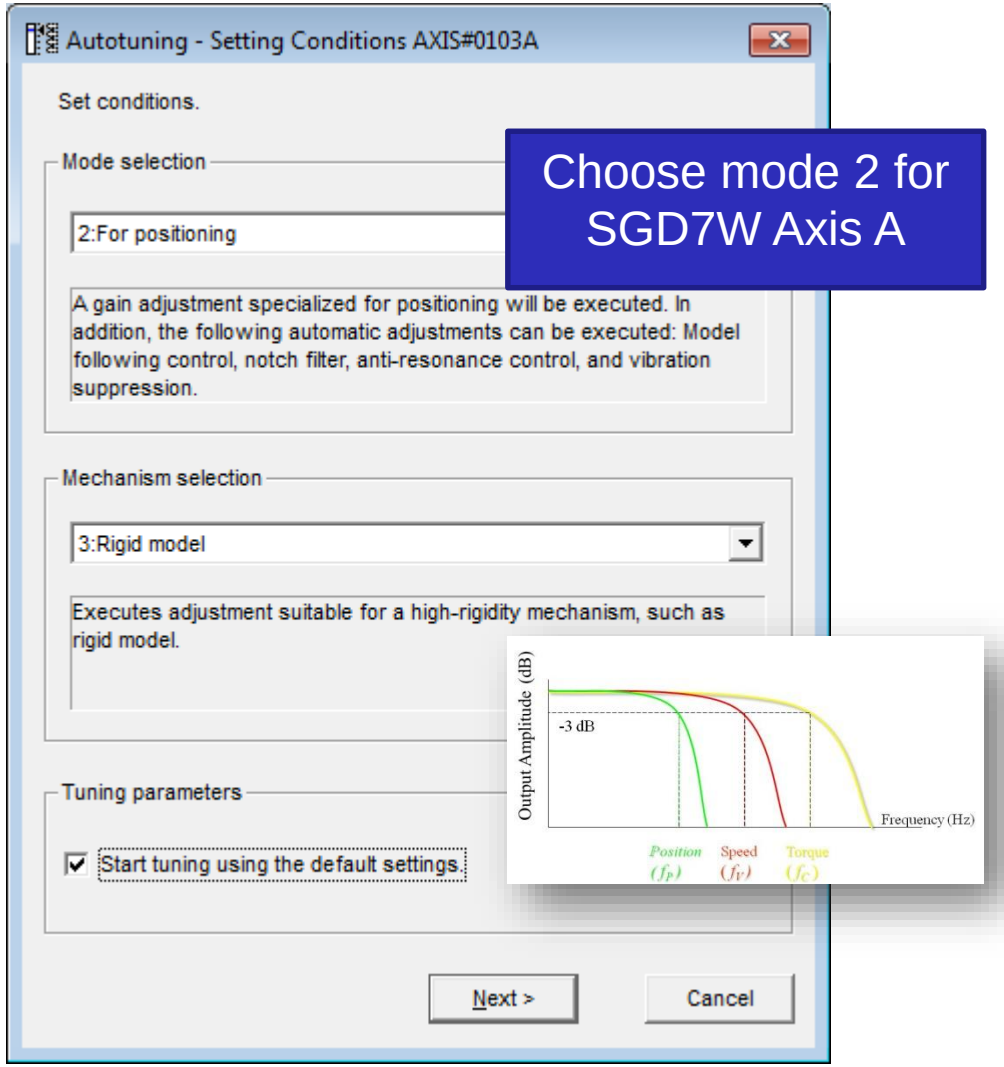
- *No Reference Input*
  - *Servopack generates motion command*
  - *When no controller is available*
  - *Simple*




Program Jog is the Position Reference Input

# Advanced Auto-Tuning

- *Mode Selection*
  - *1: Standard*
    - » *Lowest position error*
  - *2 & 3: For Positioning*
    - » *Lowest settling time*
    - » *Applies "Model Following Control"*
    - » *Required for Vibration Suppression*
- *Mechanism Selection*
  - *Balance of torque, speed, position loop bandwidth*
- *Tuning Parameters*
  - *Starting with default may give a better result*




Choose mode 2 for SGD7W Axis A

# Target Response

Tune for low position settling time.

**Axes synchronized to each other**

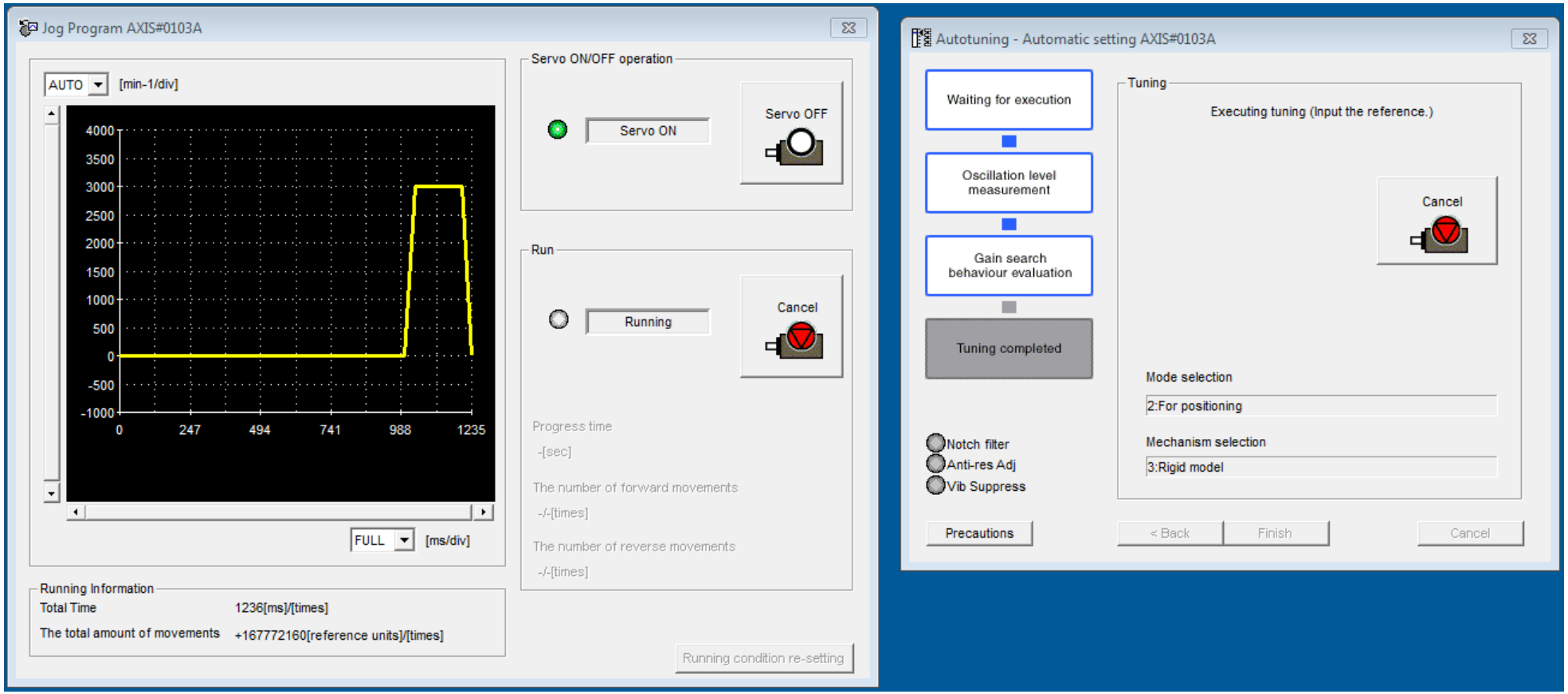

Tune for lowest position error.

**Synchronized to external axis**

Typical electronic cam application; rotary knife

# Execute Auto-Tuning

- *Start Program Jog*
- *Start Tuning*

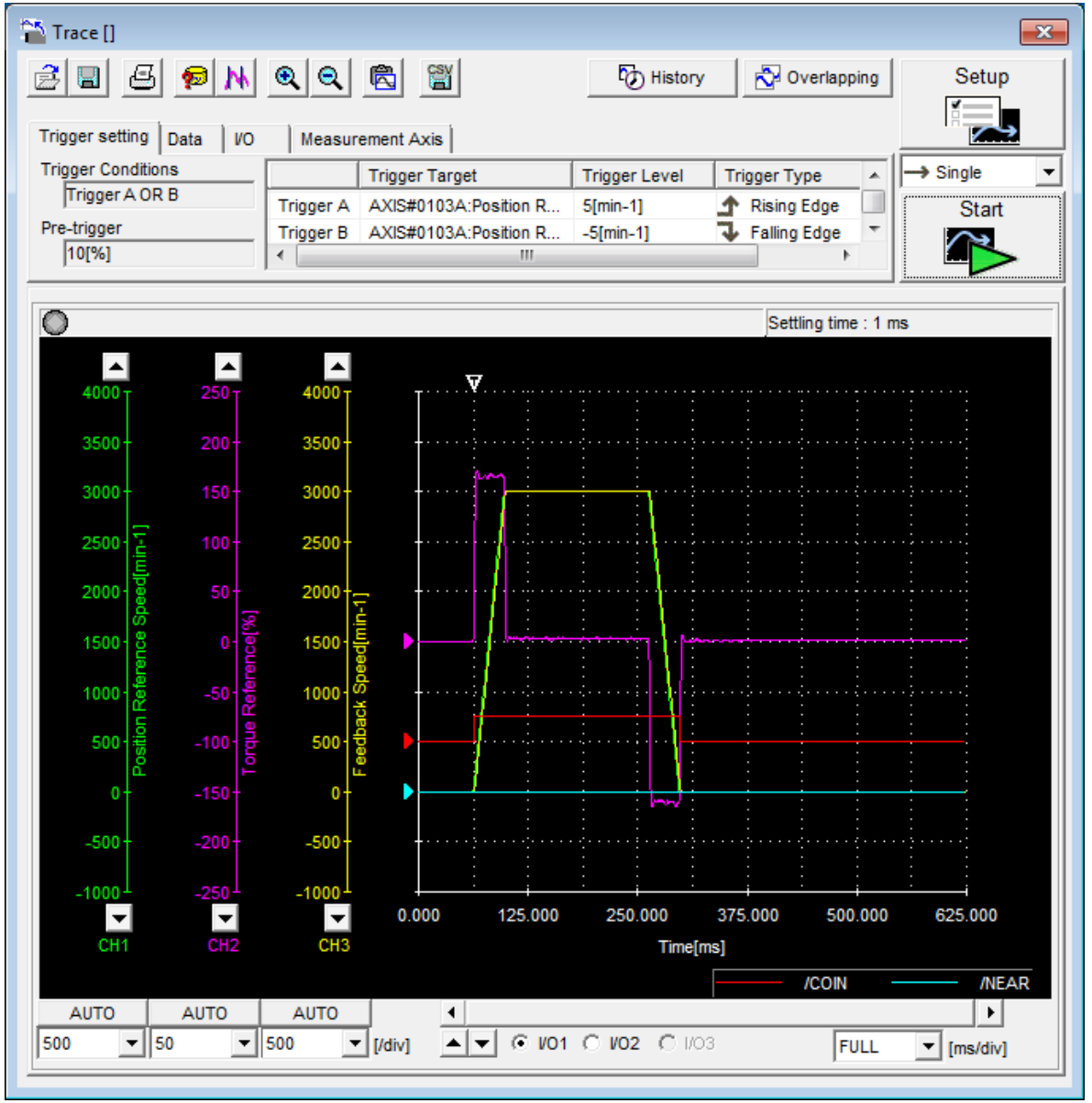


# Advanced Auto-Tuning

- *Trace and measure the result*
- *Record in the Tuning Results Table*

MP3300iec & Sigma-7 Demo Tuning

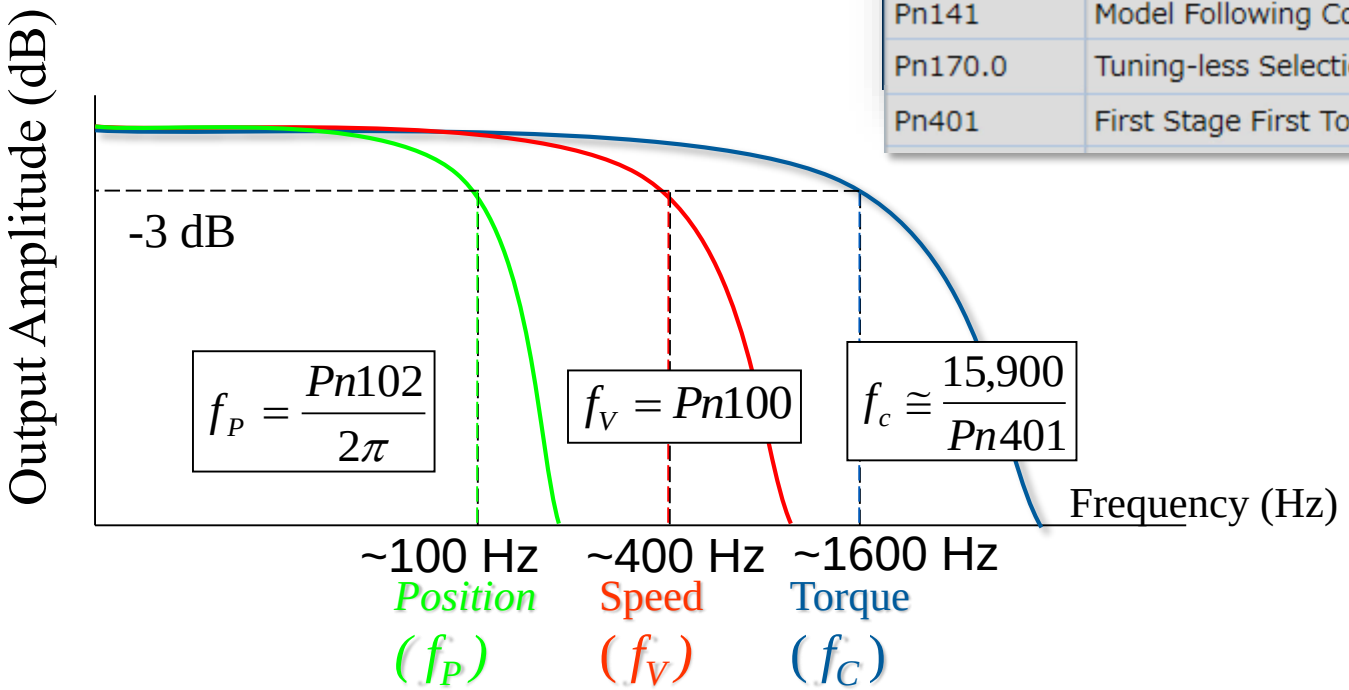
| Axis | Tuning Algorithm | Position Settling Time | Maximum Position Error | Torque Ripple / Noise |
|---|---|---|---|---|
| SGD7W Axis A | Default "Tuning-Less" | | | |
| SGD7W Axis A | Optimized Tuning-Less | | | |
| SGD7W Axis A | Advanced Auto-Tuning | | | |
| SGD7W Axis A | Custom Tuning | | | |
| SGD7W Axis B | Default "Tuning-Less" | | | |
| SGD7W Axis B | Optimized Tuning-Less | | | |
| SGD7W Axis B | Advanced Auto-Tuning | | | |
| SGD7W Axis B | Custom Tuning | | | |
| SGD7S AxisA | Default "Tuning-Less" | | | |
| SGD7S AxisA | Optimized Tuning-Less | | | |
| SGD7S AxisA | Advanced Auto-Tuning | | | |
| SGD7S AxisA | Custom Tuning | | | |



# Parameters

- *Pn102*
- *Pn100*
- *Pn401*

| No. | Name | Unit | Default Setting | 0103-SGD7W-1F Axis A |
|---|---|---|---|---|
| Pn100 | Speed Loop Gain | 0.1Hz | 400 | 1212 |
| Pn101 | Speed Loop Integral Time Constant | 0.01ms | 2000 | 525 |
| Pn102 | Position Loop Gain | 0.1/s | 400 | 1818 |
| Pn103 | Moment of Inertia Ratio | % | 100 | 1593 |
| Pn109 | Feedforward | % | 0 | 100 |
| Pn123 | Friction Compensation Coefficient | % | 0 | 85 |
| Pn140.0 | Model Following Control Selection | – | 0 : Do not use mod | 1 : Use model fo··· |
| Pn141 | Model Following Control Gain | 0.1/s | 500 | 6092 |
| Pn170.0 | Tuning-less Selection | – | 1 : Enable tuning-le | 0 : Disable tunin··· |
| Pn401 | First Stage First Torque Reference F | 0.01ms | 100 | 32 |



# Troubleshooting

- *Autotuning Fail*
  - */COIN signal must turn on between moves*
  - *Pn522 is too low*
  - *Not enough time between moves*
  - *Mechanical Problem*
- *Poor response*
  - *Pn522 is too low*

# Exercise

- *Autotune the Y axis*
  - *Mode 2: Position Settling Time*

MP3300iec & Sigma-7 Demo Tuning

| Axis | Tuning Algorithm | Position Settling Time | Maximum Position Error | Torque Ripple / Noise |
|---|---|---|---|---|
| SGD7W Axis A | Default "Tuning-Less" | | | |
| SGD7W Axis A | Optimized Tuning-Less | | | |
| SGD7W Axis A | Advanced Auto-Tuning | | | |
| SGD7W Axis A | Custom Tuning | | | |
| SGD7W Axis B | Default "Tuning-Less" | | | |
| SGD7W Axis B | Optimized Tuning-Less | | | |
| SGD7W Axis B | Advanced Auto-Tuning | | | |
| SGD7W Axis B | Custom Tuning | | | |
| SGD7S AxisA | Default "Tuning-Less" | | | |
| SGD7S AxisA | Optimized Tuning-Less | | | |
| SGD7S AxisA | Advanced Auto-Tuning | | | |
| SGD7S AxisA | Custom Tuning | | | |

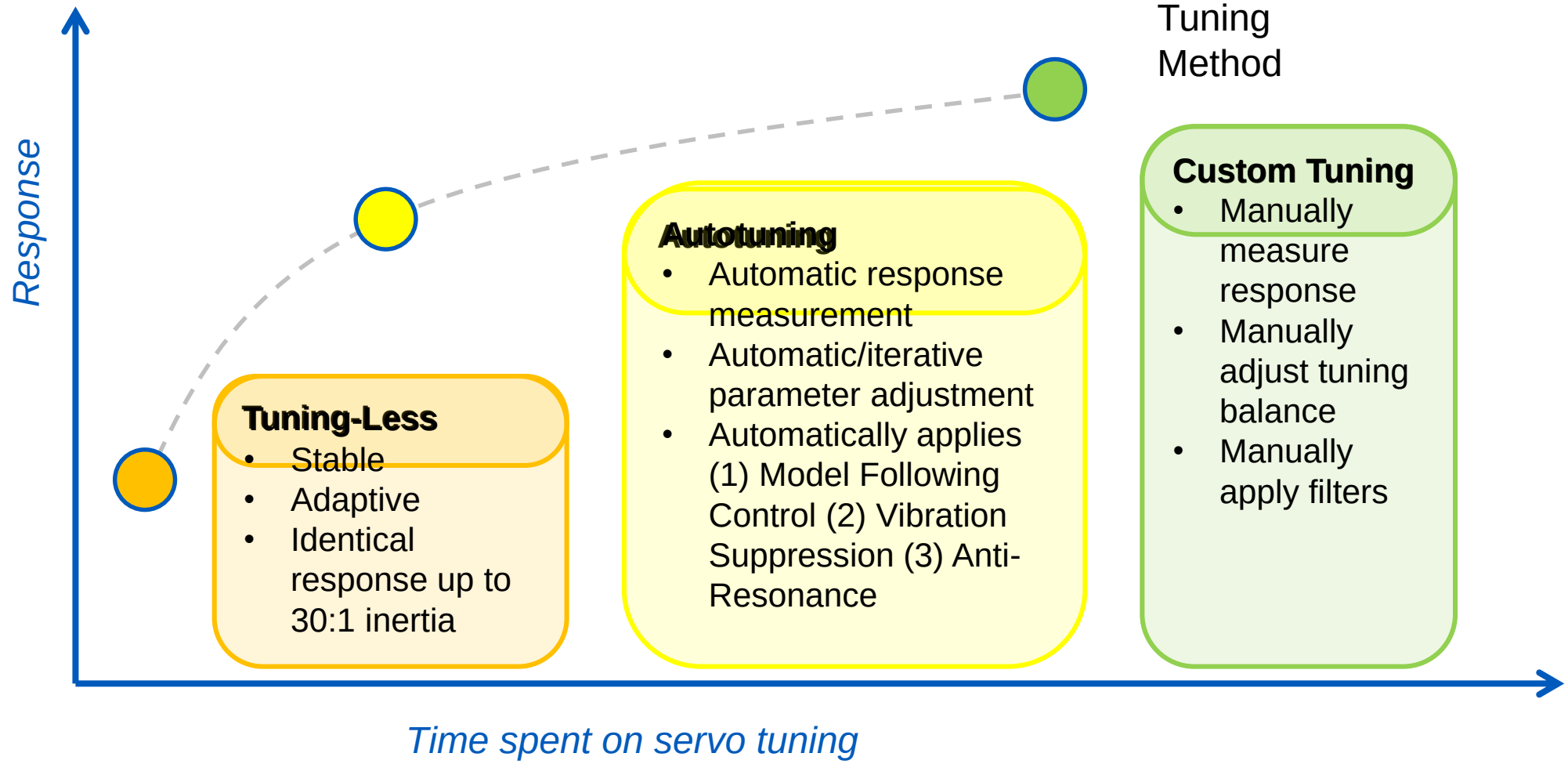
- *Axis B in SigmaWin+*
  - *"Axis B" in the menu*
  - *Trace measurement axis*
    - » *Trigger on Axis B*

# Sigma-7 Servo Tuning
# **Custom Tuning**

Optimize the result of Auto Tuning on the Demo X Axis

- *Basic Usage*
- *Filters*
- *Model Following Control*
- *Synchronize with MFC*

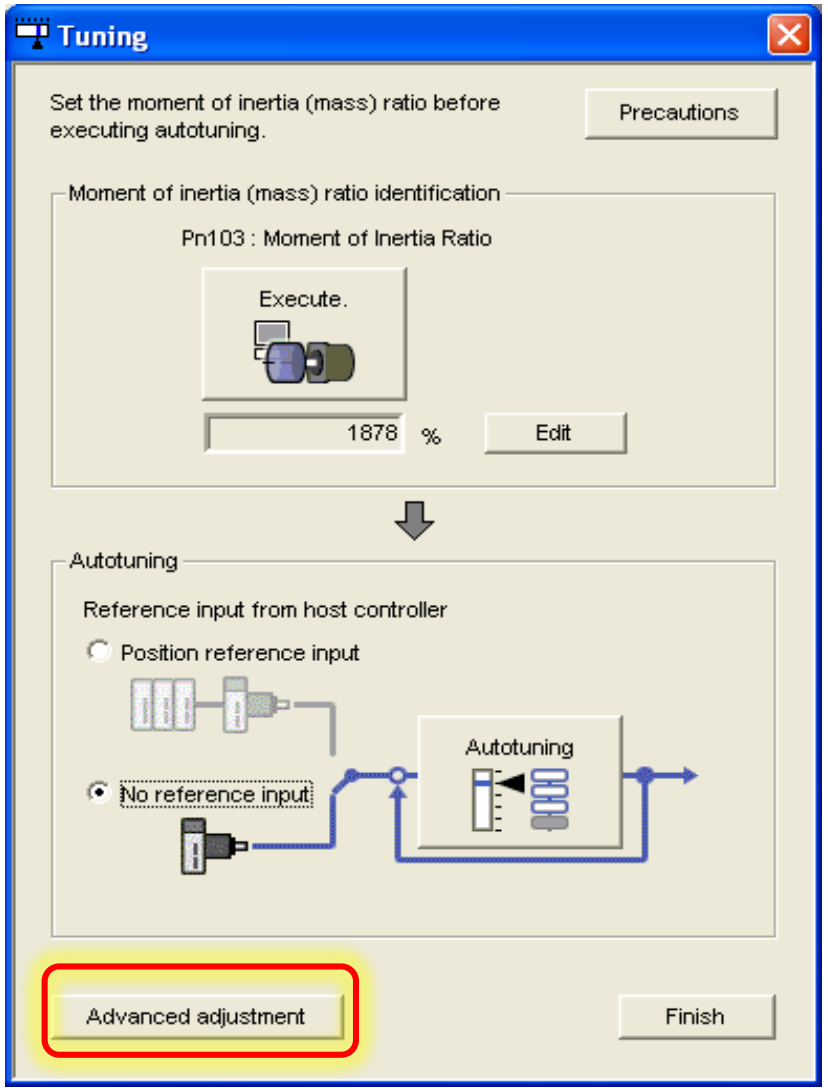
# Sigma-7 Tuning Methods



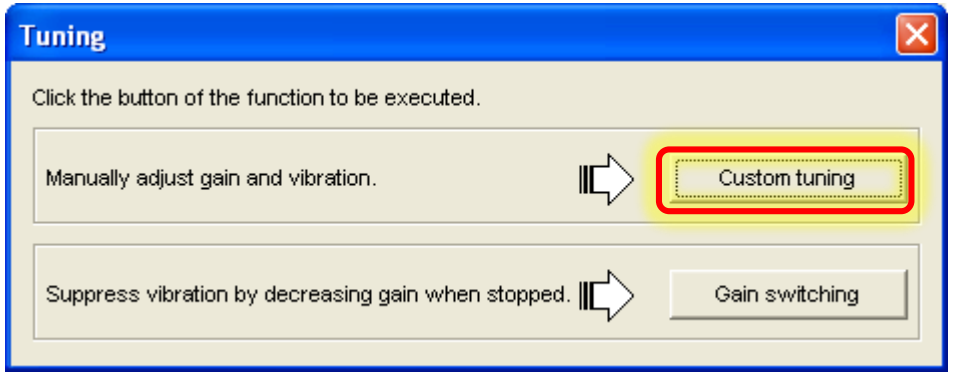
# Positioning Completed Width

- *Change in Application Requirement*
- *Now: 0.01 [degree]*
  - *Previously 0.1 [degree]*
- *Pn522= 466 [pulse]*

# Basic Usage



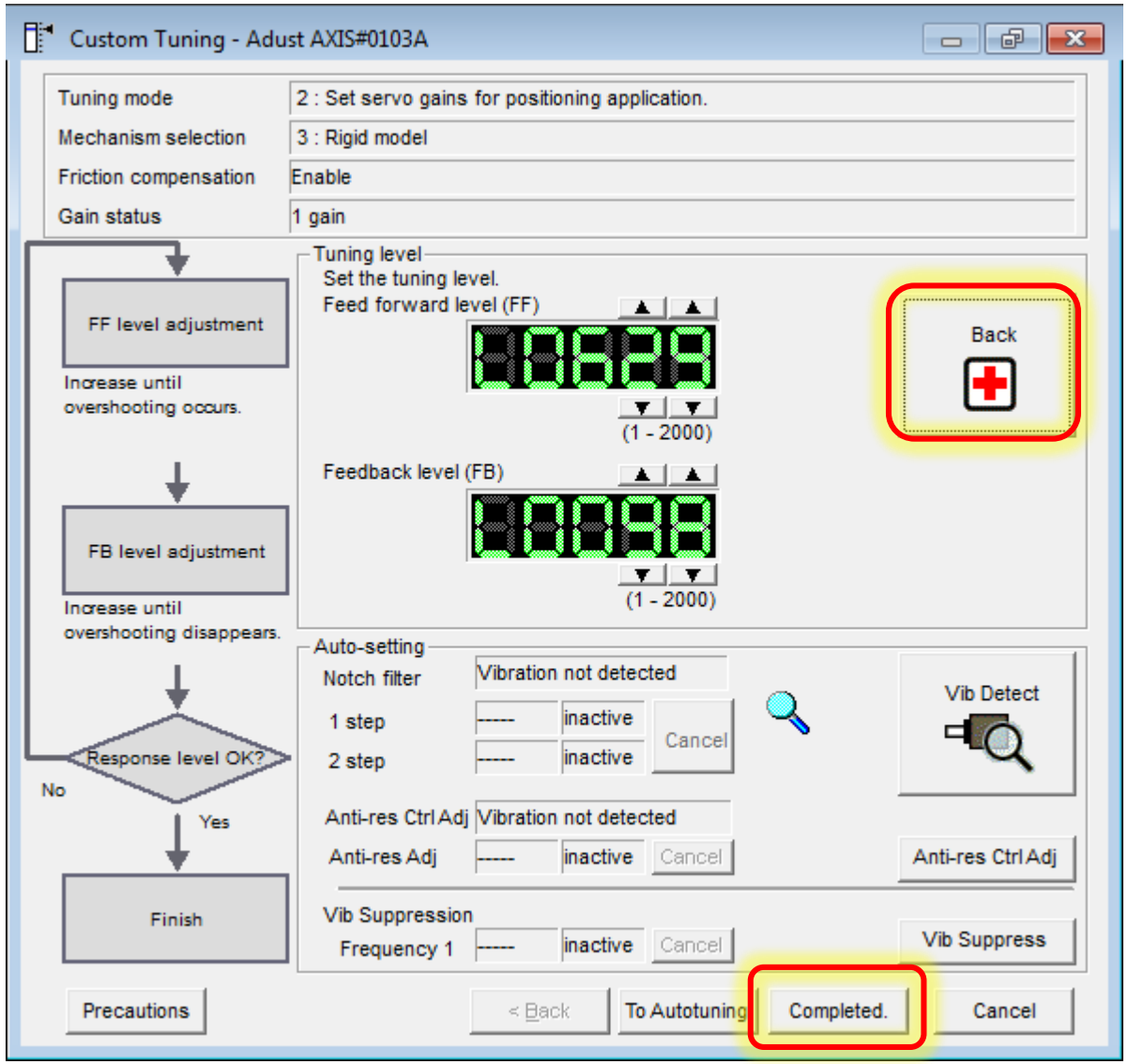

- *Use after Autotuning*
- *May be able to improve the response further*



# Basic Usage

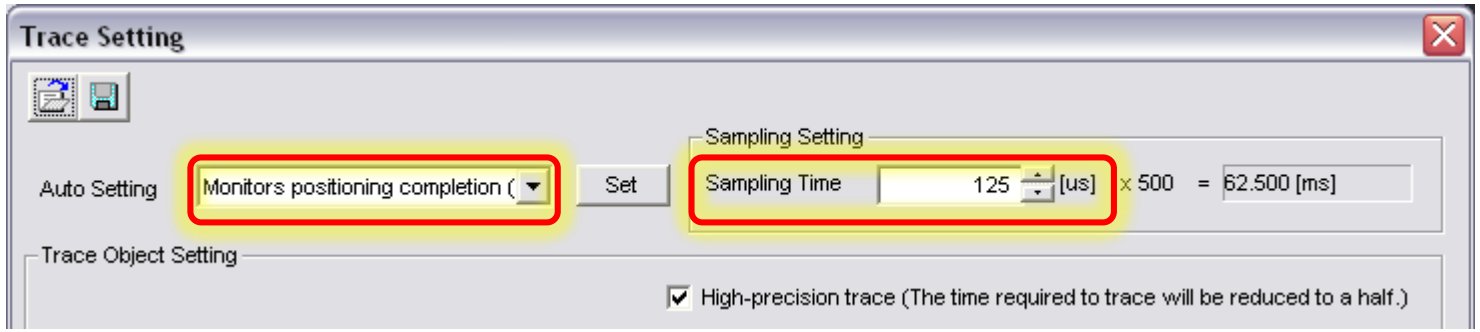
- *Increase levels for higher response*
- *Level too high produces noise*
- *Apply filters and increase level*

| | | | |
|---|---|---|---|
| Pn141 | Model Following Control Gain | 0.1/s | 6297 |
| Pn142 | Model Following Control Correction | 0.1% | 1000 |
| Pn143 | Model Following Control Bias in the Forward Direction | 0.1% | 1000 |
| Pn144 | Model Following Control Bias in the Reverse Direction | 0.1% | 1000 |
| Pn145 | Vibration Suppression 1 Frequency A | 0.1Hz | 500 |
| Pn146 | Vibration Suppression 1 Frequency B | 0.1Hz | 700 |
| Pn147 | Model Following Control Speed Feedforward Compensat | 0.1% | 1000 |
| Pn148 | Second Model Following Control Gain | 0.1/s | 500 |
| Pn149 | Second Model Following Control Correction | 0.1% | 1000 |
| Pn14A | Vibration Suppression 2 Frequency | 0.1Hz | 800 |
| Pn14B | Vibration Suppression 2 Correction | % | 100 |
| Pn14F.0 | Model Following Control Type Selection | – | 1 : Use model foll… |



# Basic Usage

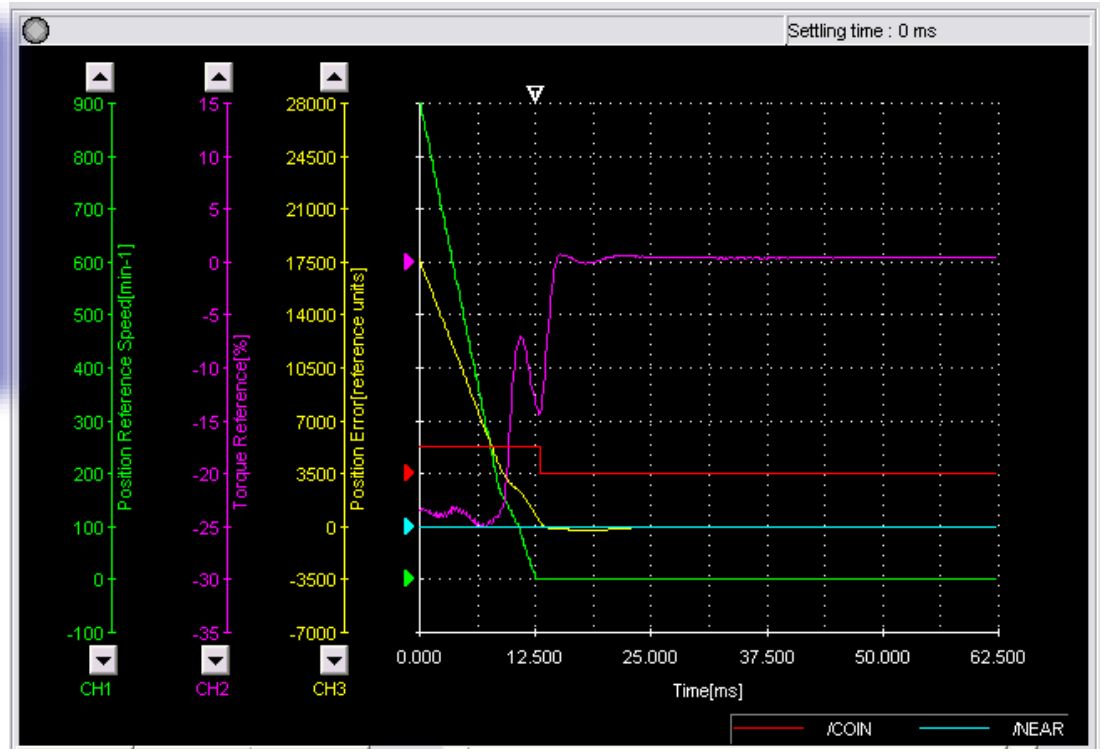
- *Trace Settings*
  - *Positioning Completion*
  - *Sampling Time low*
  - *Vertical Offset*
- *Exercise*
  - *Pn522=466*
  - *Program Jog*
  - *Adjust Levels*




**Positioning Accuracy of 0.01 Degrees**

Change /COIN level from 0.1 to 0.01

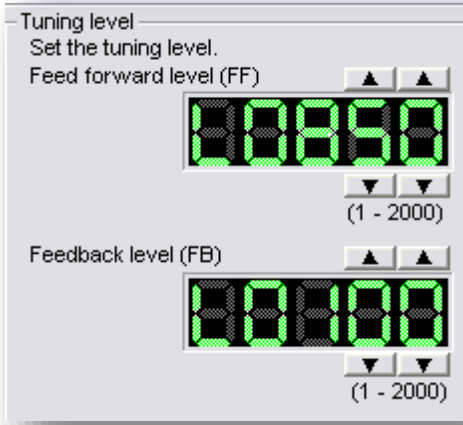
Pn522 = 4660 ➔ 466

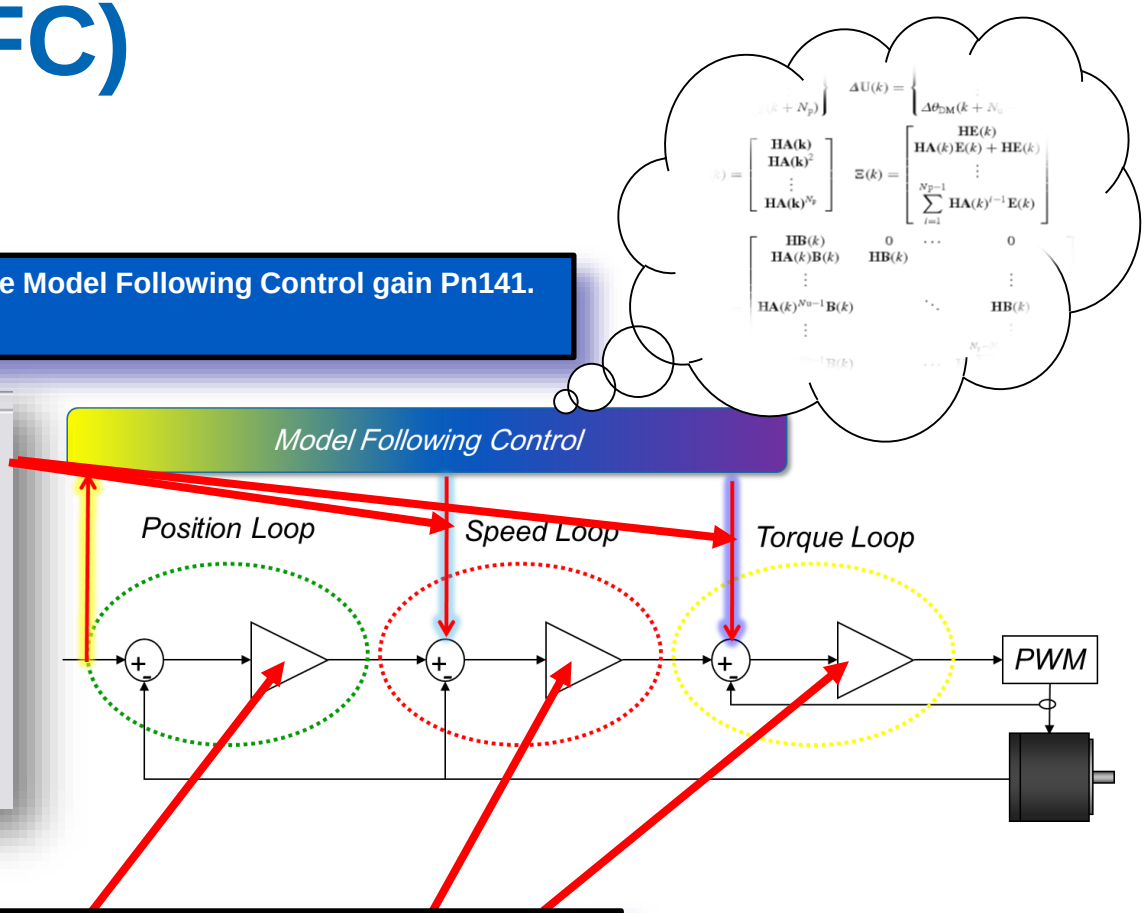


# Model Following Control (MFC)

- *Autotuning modes 2 and 3*
- *Inertia, Friction, Compliance describe the machine*
- *Predicted torque and speed sent as feed forward*
- *Find Balance between FF and FB*

**Feed Forward Level (FF) sets the Model Following Control gain Pn141.**



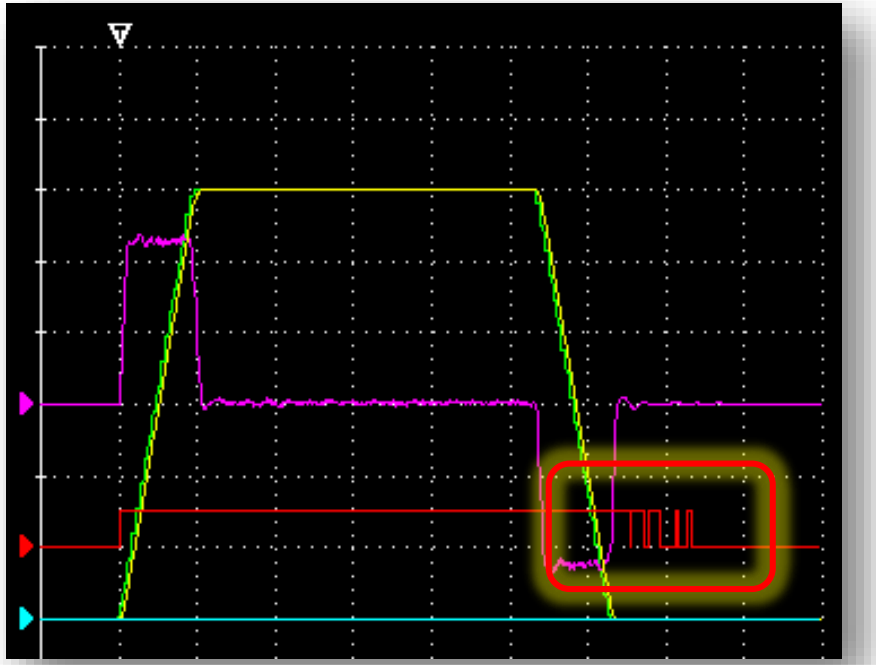



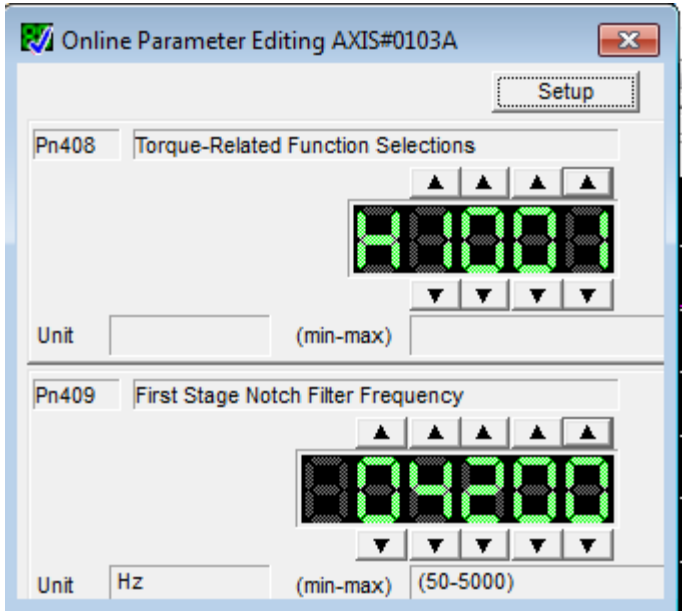

**Feedback Level (FB) sets the gains and filters for the control loops. Pn100, Pn101, Pn102, Pn401. Error is reduced. Noise can be produced.**

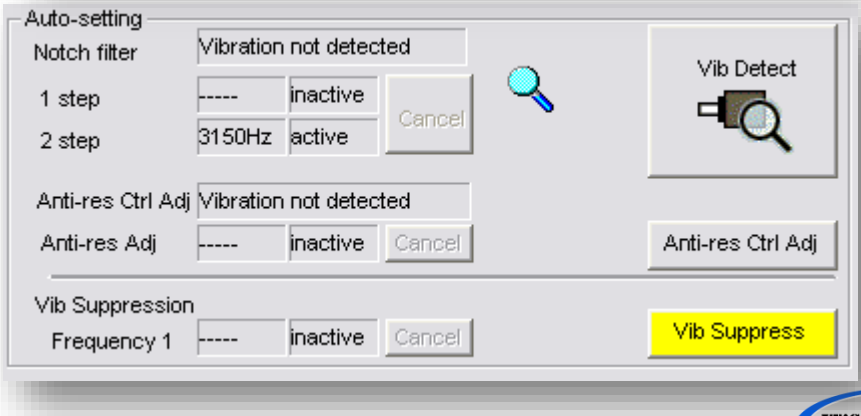
$$f_P = \frac{Pn102}{2\pi} \qquad f_V = Pn100 \qquad f_c \cong \frac{15{,}900}{Pn401}$$

# Filters

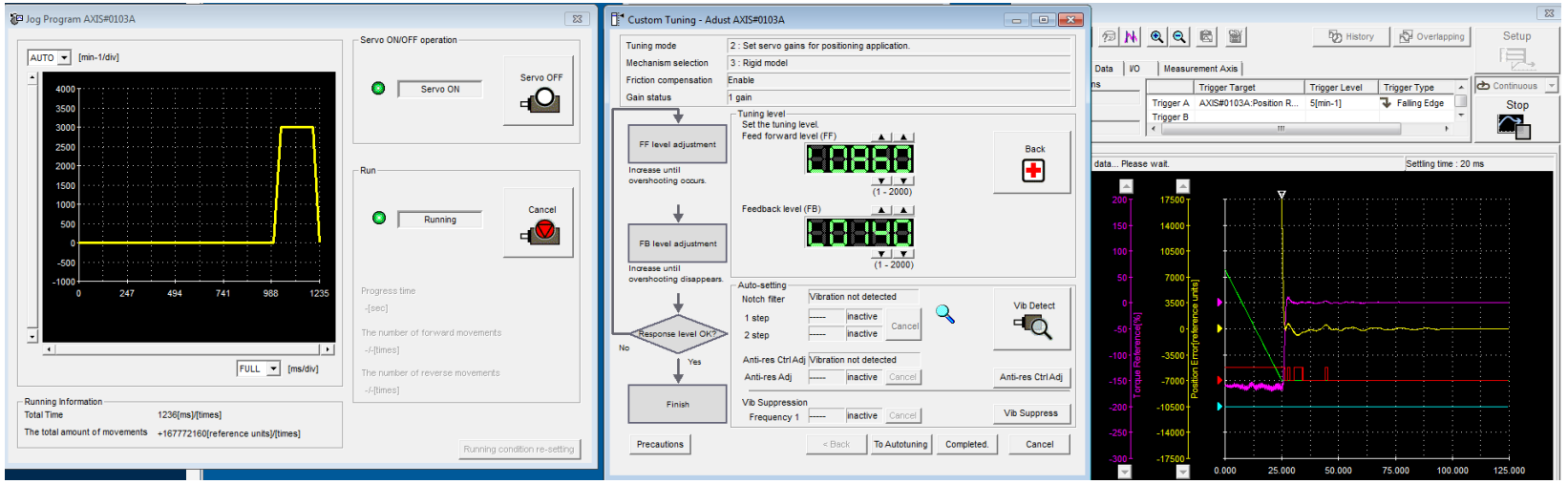
- *Vibration Suppression*
  - *Oscillation outside of the Position Complete Window Pn522 (/COIN) indicates vibration at end of move*
- *Notch Filter*
  - *Online Adjustment*





# Record Result



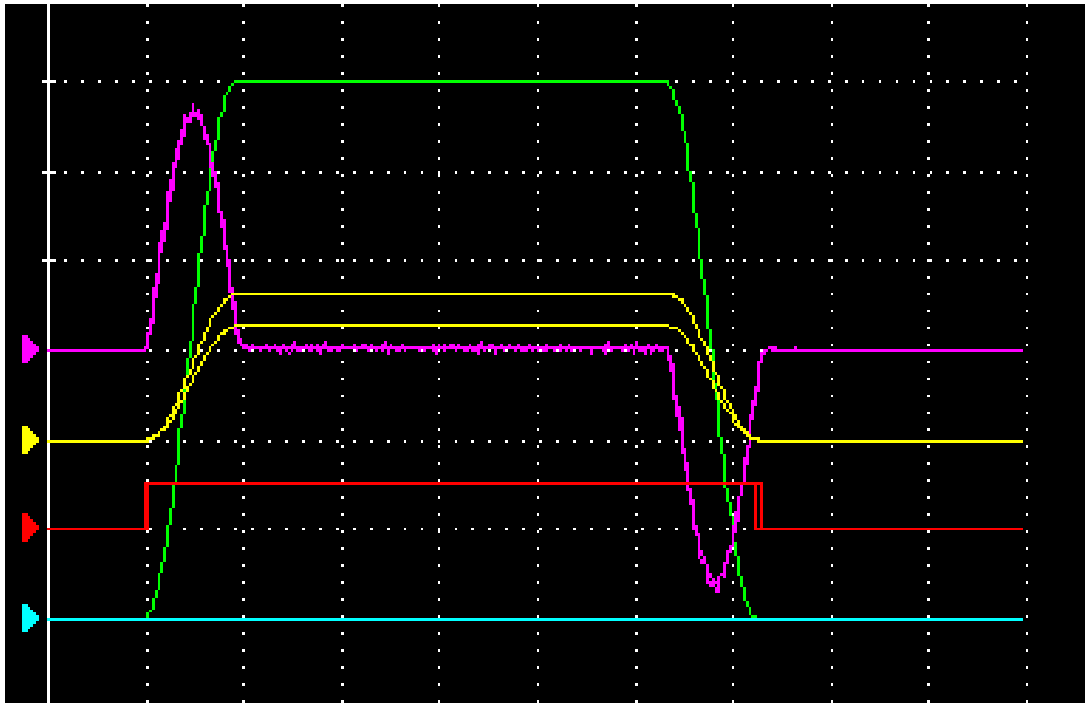

- *Measure final result*
- *Record results in table*
- *Save Trace*
- *Save Parameters*

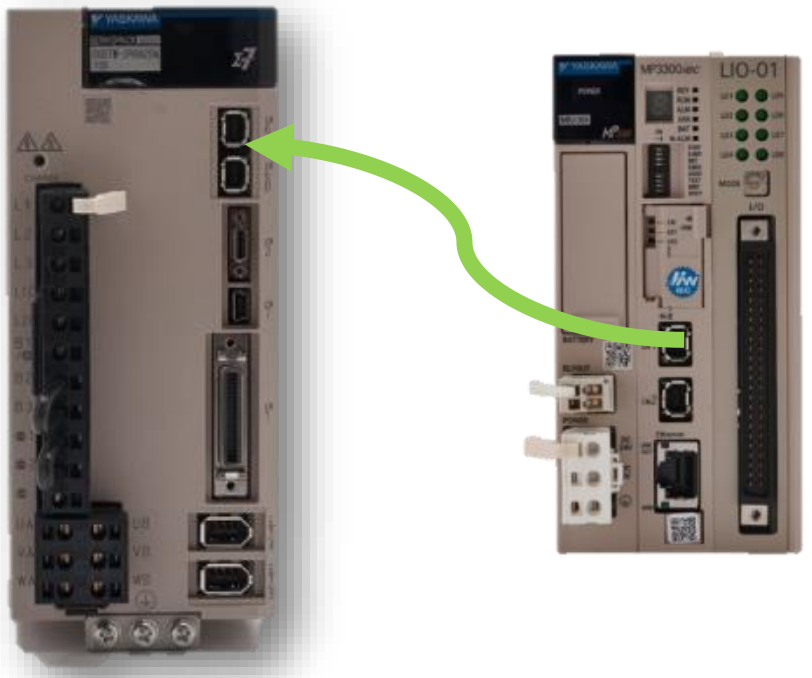
MP3300iec & Sigma-7 Demo Tuning

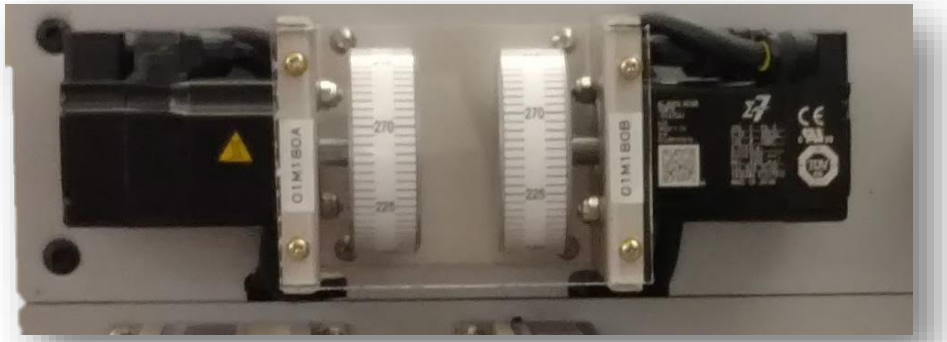
| Axis | Tuning Algorithm | Position Settling Time | Maximum Position Error | Torque Ripple / Noise |
|---|---|---|---|---|
| SGD7W Axis A | Default "Tuning-Less" | | | |
| SGD7W Axis A | Optimized Tuning-Less | | | |
| SGD7W Axis A | Advanced Auto-Tuning | | | |
| SGD7W Axis A | Custom Tuning | | | |
| SGD7W Axis B | Default "Tuning-Less" | | | |
| SGD7W Axis B | Optimized Tuning-Less | | | |
| SGD7W Axis B | Advanced Auto-Tuning | | | |
| SGD7W Axis B | Custom Tuning | | | |
| SGD7S AxisA | Default "Tuning-Less" | | | |
| SGD7S AxisA | Optimized Tuning-Less | | | |
| SGD7S AxisA | Advanced Auto-Tuning | | | |
| SGD7S AxisA | Custom Tuning | | | |

# Synchronize with MFC

- *Synchronized Command*
- *MFC Gain Pn141 not the same*
- *Response Not Synchronized*





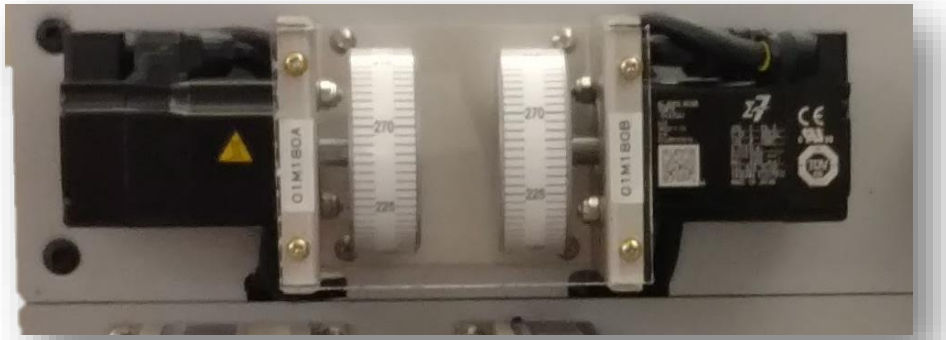
# Synchronize with MFC

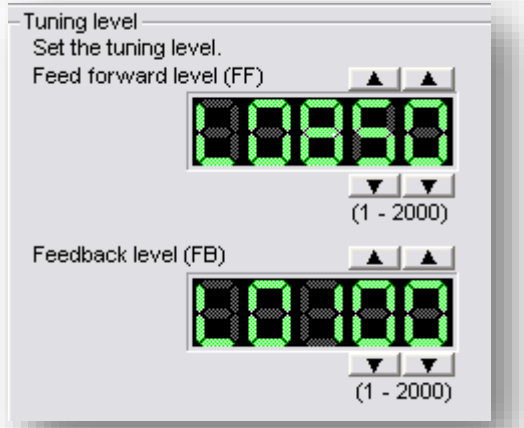
- *Repeat Custom Tuning for Y Axis*
  - *Set Feed Forward Level the same as X axis*

MP3300iec & Sigma-7 Demo Tuning

| Axis | Tuning Algorithm | Position Settling Time | Maximum Position Error | Torque Ripple / Noise |
|---|---|---|---|---|
| SGD7W Axis A | Default "Tuning-Less" | | | |
| SGD7W Axis A | Optimized Tuning-Less | | | |
| SGD7W Axis A | Advanced Auto-Tuning | | | |
| SGD7W Axis A | Custom Tuning | | | |
| SGD7W Axis B | Default "Tuning-Less" | | | |
| SGD7W Axis B | Optimized Tuning-Less | | | |
| SGD7W Axis B | Advanced Auto-Tuning | | | |
| SGD7W Axis B | Custom Tuning | | | |
| SGD7S AxisA | Default "Tuning-Less" | | | |
| SGD7S AxisA | Optimized Tuning-Less | | | |
| SGD7S AxisA | Advanced Auto-Tuning | | | |
| SGD7S AxisA | Custom Tuning | | | |

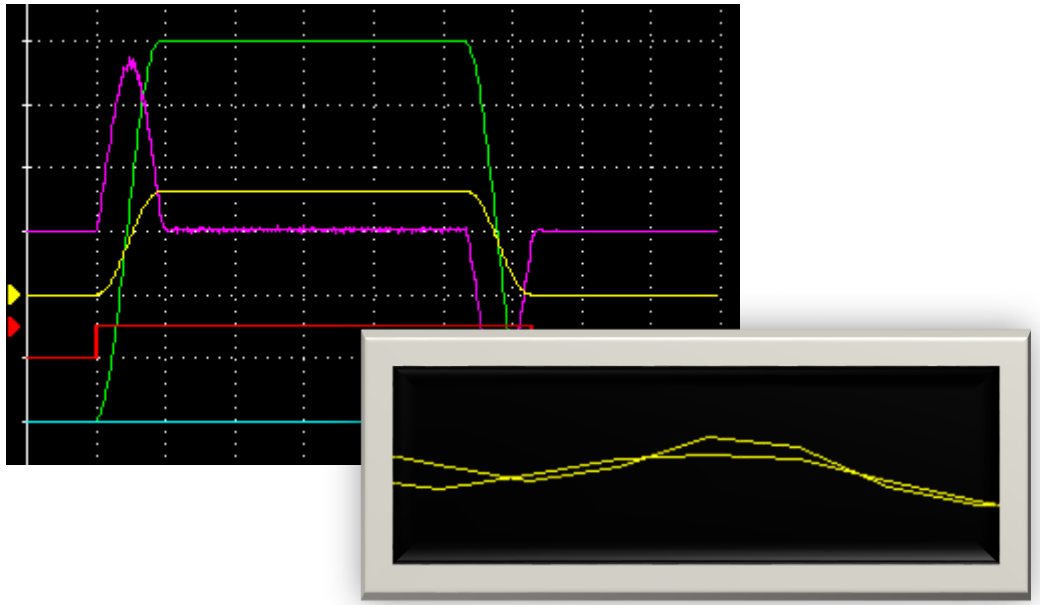
If Pn141 (Model Following Control Gain) is the same, then the same command results in the same profile and axes are synchronized even though position error is high

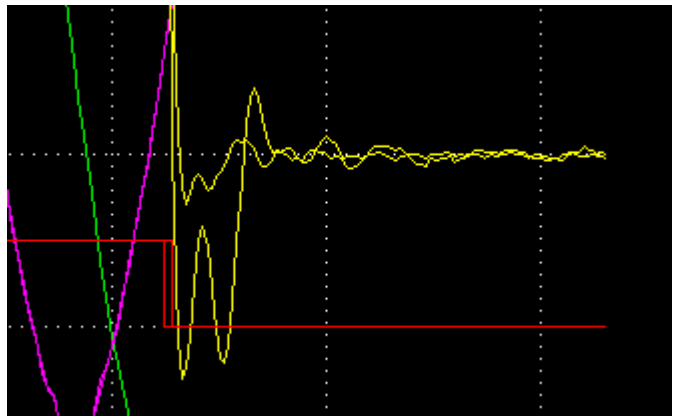




# Synchronize with MFC

- *Synchronized Command*
- *MFC Gain Pn141* ***IS*** *the same*
- *Response* ***IS*** *Synchronized*
- *Feedback Level (FB) affects end of move*





# Sigma-7 Servo Tuning
# **Tuning for Low Position Error**

Minimize Position Error on Z-Axis

- *Autotuning Mode 1*
- *100% Feed Forward*
- *Custom Tuning Mode 1*

# Target Response

Tune for low position settling time.

**Axes synchronized to each other**

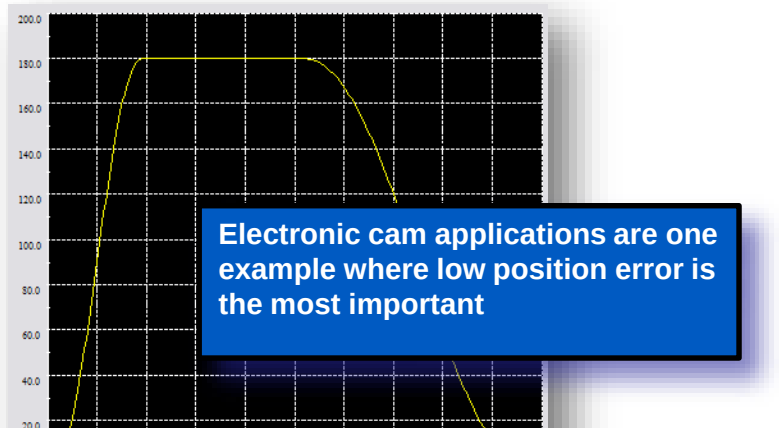

Tune for lowest position error.

**Synchronized to external axis**

Electronic cam application; rotary knife

# Process Overview

1. *Auto-Tune Mode 1: “Standard”*
2. *Set feed-forward Pn109 =100*
3. *Custom Tuning Mode 1*

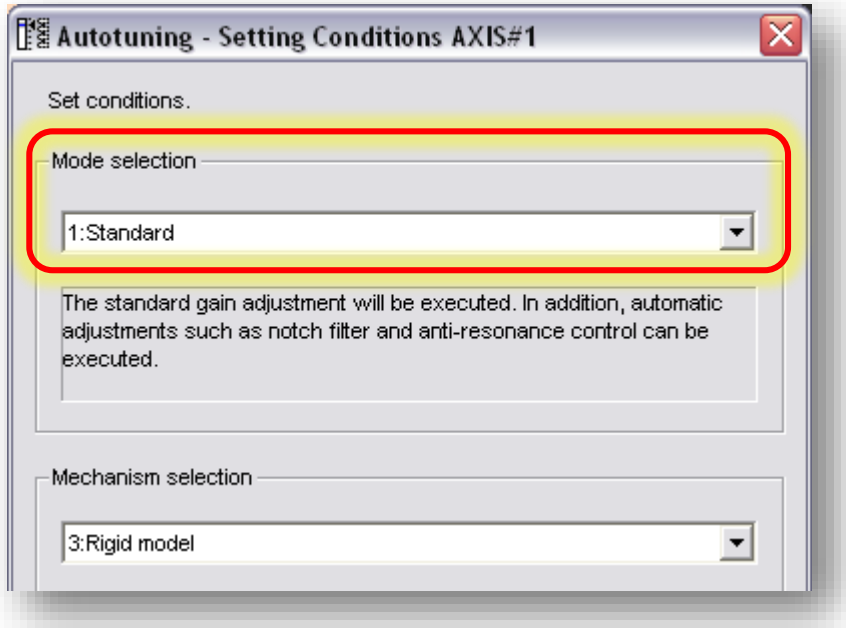


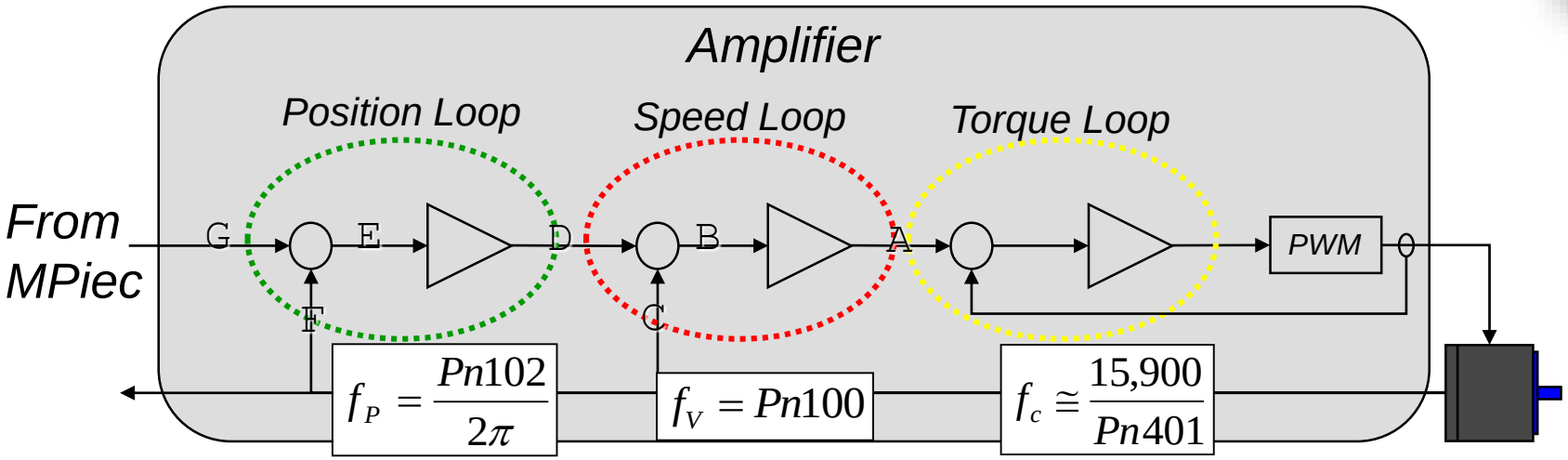

MP3300iec & Sigma-7 Demo Tuning

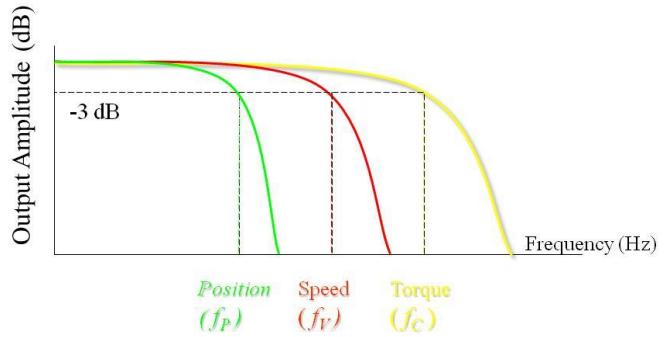
| Axis | Tuning Algorithm | Position Settling Time | Maximum Position Error | Torque Ripple / Noise |
|---|---|---|---|---|
| SGD7W Axis A | Default "Tuning-Less" | | | |
| SGD7W Axis A | Optimized Tuning-Less | | | |
| SGD7W Axis A | Advanced Auto-Tuning | | | |
| SGD7W Axis A | Custom Tuning | | | |
| SGD7W Axis B | Default "Tuning-Less" | | | |
| SGD7W Axis B | Optimized Tuning-Less | | | |
| SGD7W Axis B | Advanced Auto-Tuning | | | |
| SGD7W Axis B | Custom Tuning | | | |
| SGD7S AxisA | Default "Tuning-Less" | | | |
| SGD7S AxisA | Optimized Tuning-Less | | | |
| SGD7S AxisA | Advanced Auto-Tuning | | | |
| SGD7S AxisA | Custom Tuning | | | |

# 1. Autotuning, Mode 1: "Standard"

- *Model Following is OFF (Pn140.0=0)*
- *Vibration Suppression NOT available*
- *Bandwidths remain proportional, according to Mechanism Selection*
- *Execute with Feed-forward Pn109=0*



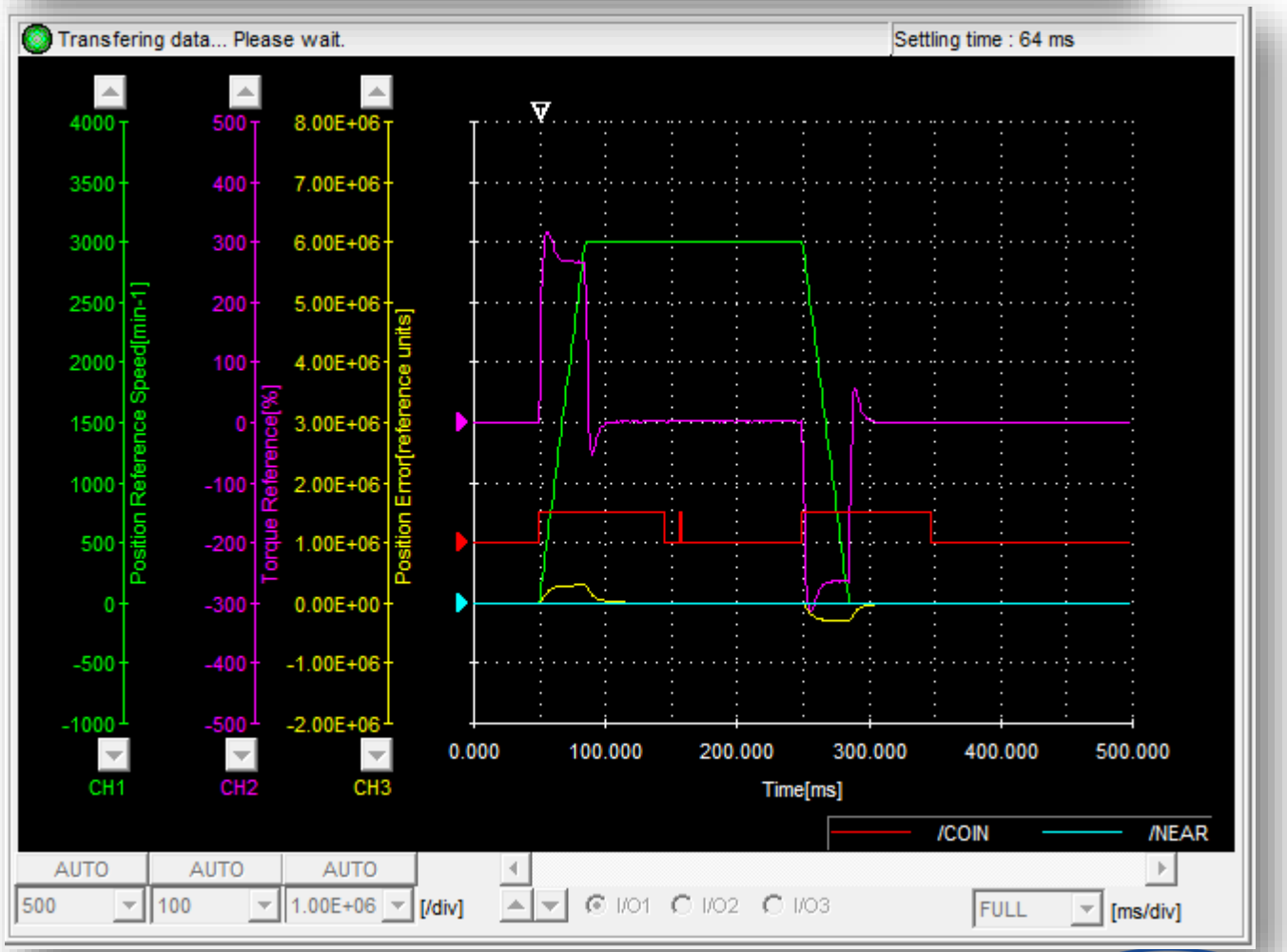



# 2. Feed Forward Pn109=100

- *Position Error near zero at constant speed*

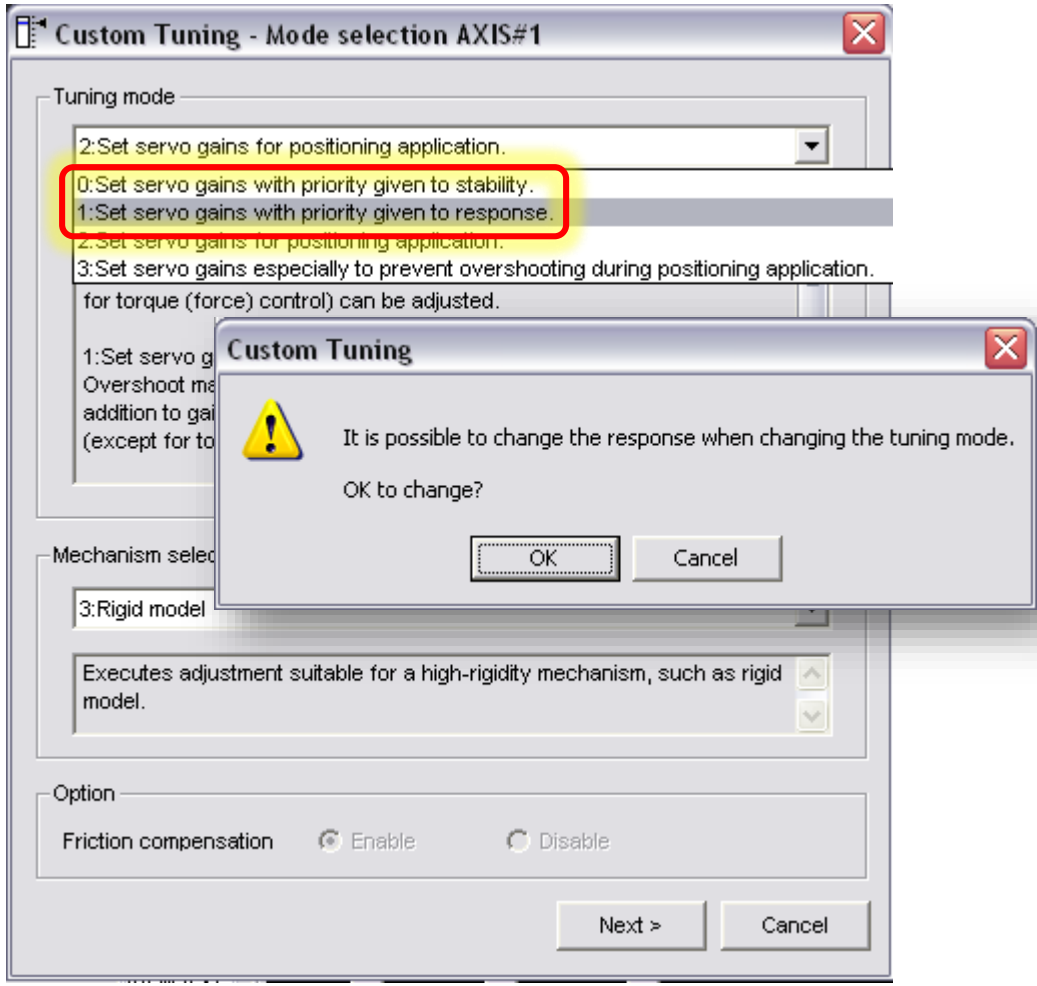
| | | | |
|---|---|---|---|
| Pn109 | Feedforward | % | 100 |
| Pn10A | Feedforward Filter Time Constant | 0.01ms | 0 |



# 3. Custom Tuning Mode 1

- *OK to warning*
- *Continuous Trace*
- *Increase Tuning Level*
- *Vibration Sound?*
  - *Adjust Notch Filter Frequency*

| | | | |
|---|---|---|---|
| Pn409 | First Stage Notch Filter Frequency | Hz | 5000 |
| Pn40A | First Stage Notch Filter Q Value | 0.01 | 70 |
| Pn40B | First Stage Notch Filter Depth | 0.001 | 0 |
| Pn40C | Second Stage Notch Filter Frequenc | Hz | 3860 |
| Pn40D | Second Stage Notch Filter Q Value | 0.01 | 70 |
| Pn40E | Second Stage Notch Filter Depth | 0.001 | 0 |

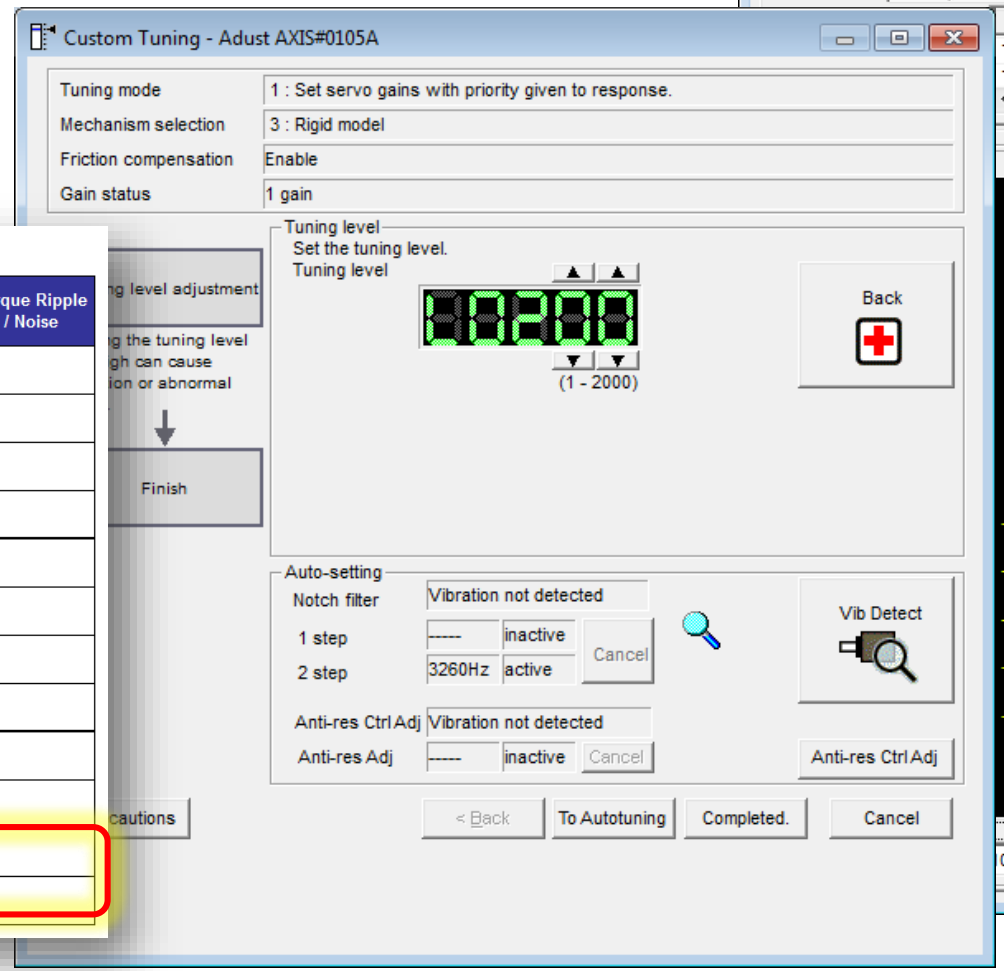


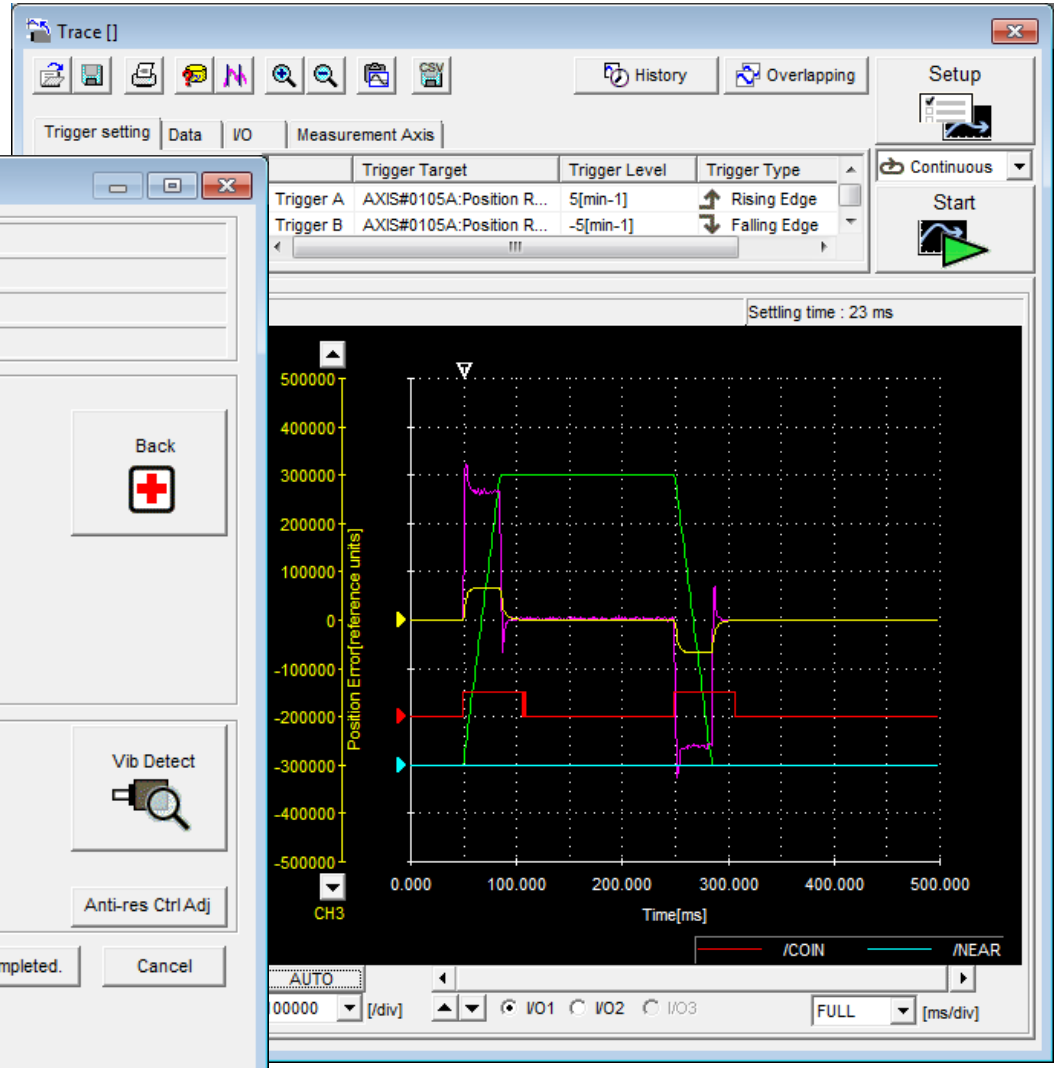
# Tuning for Low Position Error

- *Record Final Result*

MP3300iec & Sigma-7 Demo Tuning

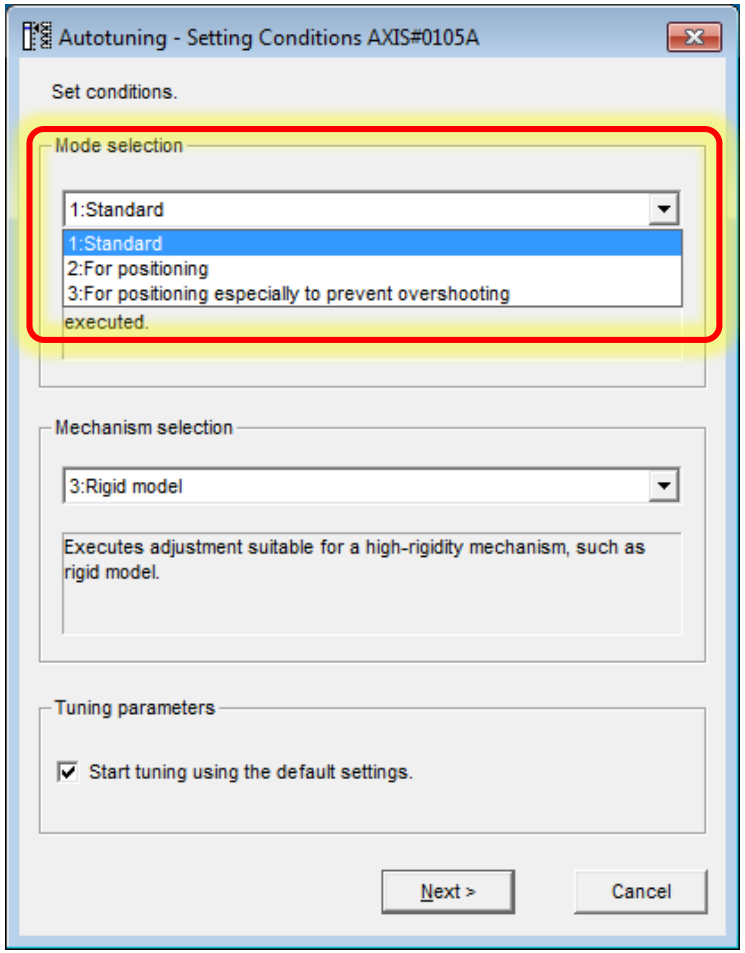
| Axis | Tuning Algorithm | Position Settling Time | Maximum Position Error | Torque Ripple / Noise |
|---|---|---|---|---|
| SGD7W Axis A | Default "Tuning-Less" | | | |
| SGD7W Axis A | Optimized Tuning-Less | | | |
| SGD7W Axis A | Advanced Auto-Tuning | | | |
| SGD7W Axis A | Custom Tuning | | | |
| SGD7W Axis B | Default "Tuning-Less" | | | |
| SGD7W Axis B | Optimized Tuning-Less | | | |
| SGD7W Axis B | Advanced Auto-Tuning | | | |
| SGD7W Axis B | Custom Tuning | | | |
| SGD7S AxisA | Default "Tuning-Less" | | | |
| SGD7S AxisA | Optimized Tuning-Less | | | |
| SGD7S AxisA | Advanced Auto-Tuning | | | |
| SGD7S AxisA | Custom Tuning | | | |



# Autotuning Modes

| Item | Mode 1 (Standard) | Mode 2, 3 (Positioning) |
|---|---|---|
| Low Settling Time | Good | **BEST** |
| Low Position Error | **BEST** | OK |
| Electronic Cam | **BEST** | Good |
| Point-To-Point | Good | **BEST** |
| Model Following | Not Available | **Used** |
| Vibration Suppression | Not Available | **Available** |
| Anti-Resonance | **Available** | **Available** |
| Notch Filter | **Available** | **Available** |
| FeedForward Pn109 | **Used** | Not Used |
| Speed Control Mode | **Available** | Not Available |



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