Sigma-7 & SigmaWin+ Ver.7 Servo Tuning

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  - Speed Ripple Compensation
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

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

- Connect the SERVOPACK.
- Start SigmaWin+ offline.
- Open a project file.
- Open a parameter file.

Connection types:
- USB Connection
- Ethernet Connection
- Controller 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**

Start
- Connect the SERVOPACK.
  - Start SigmaWin+ offline.

Options
- Open a project file.

Help
- Open a parameter file.
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
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

Please wait for a while.
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+
Alarms & Monitors

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 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
“Hi” = open circuit

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

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
Parameters

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

Simulate on Demo

JOG Operation ignores P-OT and N-OT
Jog Theory of Operation

Motor Test Run

Amplifier

Speed Loop

Torque Loop

PWM

Position Feedback

Speed Reference

Position Reference

Position Feedback

PWM

Position Loop

Speed Loop

Torque Loop
Program Jog

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

Motor Test Run

Position Reference
Position Feedback

Amplifier

Position Loop
Speed Loop
Torque Loop

PWM

Position Reference
Position Feedback
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

Sigma-7 Amplifier

\[
f_p = \frac{Pn102}{2\pi}
\]

\[
f_v = Pn100
\]

\[
f_c \approx \frac{15,900}{Pn401}
\]
Control Loop Bandwidth

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

![Diagram of Control Loop Bandwidth]

- Output Amplitude (dB)
- -3 dB
- $f_p = \frac{Pn102}{2\pi}$
- $f_v = Pn100$
- $f_c \approx \frac{15,900}{Pn401}$
- Frequency (Hz):
  - ~100 Hz Position ($f_p$)
  - ~400 Hz Speed ($f_v$)
  - ~1600 Hz Torque ($f_c$)
Tuning Process
1. Worst-case move profile
2. Is response acceptable?
3. Adjust or apply new tuning method
**Sigma-7 Tuning Methods**

**Tuning-Less**
- Stable
- Adaptive
- Identical response up to 30:1 inertia

**Autotuning**
- Automatic response measurement
- Automatic/iterative parameter adjustment
- Automatically applies (1) Model Following Control (2) Vibration Suppression (3) Anti-Resonance

**Custom Tuning**
- Manually measure response
- Manually adjust tuning balance
- Manually apply filters

---

**Time spent on servo tuning**

**Response**

---

**Tuning Method**
**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.

*Graphs showing time vs. velocity with labels Vibration, oscillation, noise and Slow response, high position error.*
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

Filters can also be set in Tuning -> Advanced Adjustment -> Custom Tuning

Vibration Suppression

- Notch

Anti Resonance

Tuning Filters

Filters

1 Hz 50 Hz 100 Hz 500Hz 1000Hz 5000Hz

- 1 Hz
- 50 Hz
- 100 Hz
- 500 Hz
- 1000 Hz
- 5000 Hz
Mechanical Analysis

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

![FFT Measurement](image)
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 Diagram](image_url)

**Sigma-7 Amplifier**

Position Loop  Speed Loop  Torque Loop

PWM

![Sigma-7 Amplifier Diagram](image_url)
Tuning 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

<table>
<thead>
<tr>
<th>PnH08.0</th>
<th>First Stage Notch Filter Selection 1</th>
<th>-</th>
<th>0 : Disable first stage...</th>
<th>0 : Disable first stage...</th>
<th>0 : Disable first stage...</th>
</tr>
</thead>
<tbody>
<tr>
<td>PnH08.1</td>
<td>Speed Limit Selection</td>
<td>-</td>
<td>0 : Use the small value</td>
<td>0 : Use the small value</td>
<td>0 : Use the small value</td>
</tr>
<tr>
<td>PnH08.2</td>
<td>Notch Filter Selection 2</td>
<td>-</td>
<td>0 : Disable second stage</td>
<td>0 : Disable second stage</td>
<td>0 : Disable second stage</td>
</tr>
<tr>
<td>PnH08.3</td>
<td>Friction Compensation Function Selection</td>
<td>-</td>
<td>0 : Disable friction...</td>
<td>0 : Disable friction...</td>
<td>0 : Disable friction...</td>
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</table>

<table>
<thead>
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<th>PnH09</th>
<th>First Stage Notch Filter Frequency Hz</th>
<th>5000</th>
<th>5000</th>
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<tbody>
<tr>
<td>PnH10</td>
<td>First Stage Notch Filter Depth</td>
<td>70</td>
<td>70</td>
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<tr>
<td>PnH11</td>
<td>First Stage Notch Filter Depth</td>
<td>0.01</td>
<td>0</td>
<td>0</td>
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<tr>
<td>PnH12</td>
<td>First Stage Notch Filter Depth</td>
<td>0.1</td>
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<tr>
<th>PnH16.0</th>
<th>Notch Filter Selection 3</th>
<th>-</th>
<th>0 : Disable third stage...</th>
<th>0 : Disable third stage...</th>
<th>0 : Disable third stage...</th>
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</thead>
<tbody>
<tr>
<td>PnH16.1</td>
<td>Notch Filter Selection 4</td>
<td>-</td>
<td>0 : Disable fourth stage...</td>
<td>0 : Disable fourth stage...</td>
<td>0 : Disable fourth stage...</td>
</tr>
<tr>
<td>PnH16.2</td>
<td>Notch Filter Selection 5</td>
<td>-</td>
<td>0 : Disable fifth stage...</td>
<td>0 : Disable fifth stage...</td>
<td>0 : Disable fifth stage...</td>
</tr>
<tr>
<td>PnH16.3</td>
<td>Reserved parameter (Do not change)</td>
<td>-</td>
<td>0 : Reserved parameter...</td>
<td>0 : Reserved parameter...</td>
<td>0 : Reserved parameter...</td>
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</tbody>
</table>

<table>
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<tr>
<th>PnH17</th>
<th>Third Stage Notch Filter Frequency Hz</th>
<th>5000</th>
<th>5000</th>
<th>5000</th>
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<tbody>
<tr>
<td>PnH18</td>
<td>Third Stage Notch Filter Q Value</td>
<td>0.01</td>
<td>0</td>
<td>0</td>
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<tr>
<td>PnH19</td>
<td>Third Stage Notch Filter Depth</td>
<td>70</td>
<td>70</td>
<td>70</td>
</tr>
<tr>
<td>PnH20</td>
<td>Third Stage Notch Filter Depth</td>
<td>0.01</td>
<td>0</td>
<td>0</td>
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<table>
<thead>
<tr>
<th>PnH21</th>
<th>Fourth Stage Notch Filter Frequency Hz</th>
<th>5000</th>
<th>5000</th>
<th>5000</th>
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<tbody>
<tr>
<td>PnH22</td>
<td>Fourth Stage Notch Filter Q Value</td>
<td>0.01</td>
<td>0</td>
<td>0</td>
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<tr>
<td>PnH23</td>
<td>Fourth Stage Notch Filter Depth</td>
<td>70</td>
<td>70</td>
<td>70</td>
</tr>
<tr>
<td>PnH24</td>
<td>Fourth Stage Notch Filter Depth</td>
<td>0.01</td>
<td>0</td>
<td>0</td>
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</table>

<table>
<thead>
<tr>
<th>PnH25</th>
<th>Fifth Stage Notch Filter Frequency Hz</th>
<th>5000</th>
<th>5000</th>
<th>5000</th>
</tr>
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<tr>
<td>PnH26</td>
<td>Fifth Stage Notch Filter Q Value</td>
<td>0.01</td>
<td>0</td>
<td>0</td>
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<td>PnH27</td>
<td>Fifth Stage Notch Filter Depth</td>
<td>70</td>
<td>70</td>
<td>70</td>
</tr>
<tr>
<td>PnH28</td>
<td>Fifth Stage Notch Filter Depth</td>
<td>0.01</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Notch Filter

- Example: Ballscrew
Anti-Resonance

- **Anti-Resonance = OFF**

![Graph showing Position Error, Torque Reference, and COIN signal with vibration (sound) during movement highlighted.]

- **Anti-Resonance = ON**

![Graph showing Position Error, Torque Reference, and COIN signal with vibration (sound) reduced.]

**Tuning Filters**

- Vibration (sound) during movement
- Vibration (sound) reduced
Anti-Resonance

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

- Example: Rotary Drive

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Unit</th>
<th>Default Setting</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pn103</td>
<td>Moment of Inertia Ratio</td>
<td>%</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Pn160.0</td>
<td>Anti-Resonance Control Selection</td>
<td>–</td>
<td>0: Do not use anti-resonance control, 1: Use anti-resonance control.</td>
<td></td>
</tr>
<tr>
<td>Pn161</td>
<td>Anti-Resonance Frequency</td>
<td>0.1Hz</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>Pn163</td>
<td>Anti-Resonance Damping Gain</td>
<td>%</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Pn170.0</td>
<td>Tuning-less Selection</td>
<td>–</td>
<td>1: Enable tuning, 0: Disable tuning-less function.</td>
<td></td>
</tr>
</tbody>
</table>
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

Motor Speed

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

Motor Speed
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

- Tuning Filters
- Vibration Suppression

[Image showing software interface for 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
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

Use SETUP to define trace data
Trace Setup

Data Trace

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.

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**

<table>
<thead>
<tr>
<th>Axis</th>
<th>Tuning Algorithm</th>
<th>Position Settling Time</th>
<th>Maximum Position Error</th>
<th>Torque Ripple / Noise</th>
</tr>
</thead>
<tbody>
<tr>
<td>SGD7W Axis A</td>
<td>X_Axis</td>
<td>Default &quot;Tuning-Less&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SGD7W Axis A</td>
<td>Optimized</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SGD7W Axis A</td>
<td>Tuning-Less</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>SGD7W Axis A</td>
<td>Advanced Auto-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SGD7W Axis A</td>
<td>Tuning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SGD7W Axis B</td>
<td>Y_Axis</td>
<td>Default &quot;Tuning-Less&quot;</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>SGD7W Axis B</td>
<td>Optimized</td>
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<td></td>
<td></td>
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<td>SGD7W Axis B</td>
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<td>SGD7W Axis B</td>
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<td>SGD7W Axis B</td>
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<td>SGD7W Axis B</td>
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<td>SGD7S Axis A</td>
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<td></td>
</tr>
<tr>
<td>SGD7S Axis A</td>
<td>Advanced Auto-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SGD7S Axis A</td>
<td>Tuning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SGD7S Axis A</td>
<td>Custom Tuning</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Low position settling time is critical for reducing cycle time in point-to-point applications.

- 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)

\[
\text{16,777,216 encoder pulse \over rev} \times \frac{1 \text{ rev}}{360°} = 4660 \text{ pulse/degree}
\]
Position Error

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

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

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
Data Trace

Torque Ripple

Measure Torque Ripple
- Torque Reference
- During move

Measure:
- Peak-to-peak average
- Zoom In
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

**Tuning-Less**
- Stable
- Adaptive
- Identical response up to 30:1 inertia

**Autotuning**
- Automatic response measurement
- Automatic/iterative parameter adjustment
- Automatically applies (1) Model Following Control (2) Vibration Suppression (3) Anti-Resonance

**Custom Tuning**
- Manually measure response
- Manually adjust tuning balance
- Manually apply filters

**Tuning Method**

*Time spent on servo tuning*
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
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

<table>
<thead>
<tr>
<th>Axis</th>
<th>Tuning Algorithm</th>
<th>Position Setting Time</th>
<th>Maximum Position Error</th>
<th>Torque Ripple / Noise</th>
</tr>
</thead>
<tbody>
<tr>
<td>SGDTW Axis A</td>
<td>Default &quot;Tuning-Less&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SGDTW Axis A</td>
<td>Optimized Tuning Less</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SGDTW Axis A</td>
<td>Advanced Auto.Tuning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SGDTW Axis A</td>
<td>Custom Tuning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SGDTW Axis B</td>
<td>Default &quot;Tuning-Less&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SGDTW Axis B</td>
<td>Optimized Tuning Less</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SGDTW Axis B</td>
<td>Advanced Auto.Tuning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SGDTW Axis B</td>
<td>Custom Tuning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SGDTW Axis A</td>
<td>Default &quot;Tuning-Less&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SGDTW Axis A</td>
<td>Optimized Tuning Less</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GDTS Axis A</td>
<td>Advanced Auto.Tuning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GDTS Axis A</td>
<td>Custom Tuning</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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

---

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

Response

Time spent on servo tuning

**Autotuning**
- Automatic response measurement
- Automatic/iterative parameter adjustment
- Automatically applies (1) Model Following Control (2) Vibration Suppression (3) Anti-Resonance

**Custom Tuning**
- Manually measure response
- Manually adjust tuning balance
- Manually apply filters

**Tuning-Less**
- Stable
- Adaptive
- Identical response up to 30:1 inertia

Tuning Method
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

Use highest speed and acceleration applicable to the machine

Motor will move both directions

Verify distance allowed
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

**MP330iec & Sigma-7 Demo Tuning**

<table>
<thead>
<tr>
<th>Axis</th>
<th>Tuning Algorithm</th>
<th>Position Setting Time</th>
<th>Maximum Position Error</th>
<th>Torque Ripple / Noise</th>
</tr>
</thead>
<tbody>
<tr>
<td>SGD7W Axis A</td>
<td>Default “Tuning-Less”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SGD7W Axis A</td>
<td>Optimized</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SGD7W Axis A</td>
<td><strong>Advanced Auto-Tuning</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SGD7W Axis A</td>
<td>Custom Tuning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SGD7W Axis B</td>
<td>Default “Tuning-Less”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SGD7W Axis B</td>
<td>Optimized</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SGD7W Axis B</td>
<td>Advanced Auto-Tuning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SGD7W Axis B</td>
<td>Custom Tuning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SGD7S Axis A</td>
<td>Default “Tuning-Less”</td>
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<td></td>
<td></td>
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<tr>
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<td>Optimized</td>
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<td>Advanced Auto-Tuning</td>
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<td>SGD7S Axis A</td>
<td>Custom Tuning</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Parameters

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

#### Frequency Domain Analysis

- Position Frequency: $f_p = \frac{Pn102}{2\pi}$
- Speed Frequency: $f_v = Pn100$
- Torque Frequency: $f_c \approx \frac{15,900}{Pn401}$

#### Plot

- Output Amplitude (dB)
  - -3 dB

#### Table

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Unit</th>
<th>Default Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pn100</td>
<td>Speed Loop Gain</td>
<td>0.1 Hz</td>
<td>400</td>
</tr>
<tr>
<td>Pn101</td>
<td>Speed Loop Integral Time Constant</td>
<td>0.01 ms</td>
<td>2000</td>
</tr>
<tr>
<td>Pn102</td>
<td>Position Loop Gain</td>
<td>0.1/s</td>
<td>400</td>
</tr>
<tr>
<td>Pn103</td>
<td>Moment of Inertia Ratio</td>
<td>%</td>
<td>100</td>
</tr>
<tr>
<td>Pn109</td>
<td>Feedforward</td>
<td>%</td>
<td>100</td>
</tr>
<tr>
<td>Pn123</td>
<td>Friction Compensation Coefficient</td>
<td>%</td>
<td>85</td>
</tr>
<tr>
<td>Pn140.0</td>
<td>Model Following Control Selection</td>
<td>–</td>
<td>0 : Do not use model</td>
</tr>
<tr>
<td>Pn141</td>
<td>Model Following Control Gain</td>
<td>0.1/s</td>
<td>500</td>
</tr>
<tr>
<td>Pn170.0</td>
<td>Tuning-less Selection</td>
<td>–</td>
<td>1 : Enable tuning-less</td>
</tr>
<tr>
<td>Pn401</td>
<td>First Stage First Torque Reference</td>
<td>0.01 ms</td>
<td>100</td>
</tr>
</tbody>
</table>
**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

---

![Diagram showing the relationship between commanded position, actual position, and in position conditions.](image-url)
Exercise

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

- **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

- **Tuning-Less**
  - Stable
  - Adaptive
  - Identical response up to 30:1 inertia

- **Autotuning**
  - Automatic response measurement
  - Automatic/iterative parameter adjustment
  - Automatically applies (1) Model Following Control (2) Vibration Suppression (3) Anti-Resonance

- **Custom Tuning**
  - Manually measure response
  - Manually adjust tuning balance
  - Manually apply filters

**Time spent on servo tuning**
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

<table>
<thead>
<tr>
<th>Pn141</th>
<th>Model Following Control Gain</th>
<th>0.1/s</th>
<th>6297</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pn142</td>
<td>Model Following Control Correction</td>
<td>0.1%</td>
<td>1000</td>
</tr>
<tr>
<td>Pn143</td>
<td>Model Following Control Bias in the Forward Direction</td>
<td>0.1%</td>
<td>1000</td>
</tr>
<tr>
<td>Pn144</td>
<td>Model Following Control Bias in the Reverse Direction</td>
<td>0.1%</td>
<td>1000</td>
</tr>
<tr>
<td>Pn145</td>
<td>Vibration Suppression 1 Frequency A</td>
<td>0.1Hz</td>
<td>500</td>
</tr>
<tr>
<td>Pn146</td>
<td>Vibration Suppression 1 Frequency B</td>
<td>0.1Hz</td>
<td>700</td>
</tr>
<tr>
<td>Pn147</td>
<td>Model Following Control Speed Feedforward Compensation</td>
<td>0.1%</td>
<td>1000</td>
</tr>
<tr>
<td>Pn148</td>
<td>Second Model Following Control Gain</td>
<td>0.1/s</td>
<td>500</td>
</tr>
<tr>
<td>Pn149</td>
<td>Second Model Following Control Correction</td>
<td>0.1%</td>
<td>1000</td>
</tr>
<tr>
<td>Pn14A</td>
<td>Vibration Suppression 2 Frequency</td>
<td>0.1Hz</td>
<td>800</td>
</tr>
<tr>
<td>Pn14B</td>
<td>Vibration Suppression 2 Correction</td>
<td>%</td>
<td>100</td>
</tr>
<tr>
<td>Pn14F0</td>
<td>Model Following Control Type Selection</td>
<td></td>
<td>1 : Use model fol...</td>
</tr>
</tbody>
</table>
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.

\[ f_p = \frac{Pn102}{2\pi} \]
\[ f_v = Pn100 \]
\[ f_c \approx \frac{15,900}{Pn401} \]
Filters

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

- **Notch Filter**
  - Online Adjustment
Custom Tuning

Record Result

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

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
Tuning for Low Position Error

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

Electronic cam applications are one example where low position error is the most important.
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

![Diagram of the Amplifier with Position Loop, Speed Loop, and Torque Loop](image)

\[
f_p = \frac{Pn102}{2\pi}
\]

\[
f_v = Pn100
\]

\[
f_c \approx \frac{15,900}{Pn401}
\]
2. Feed Forward Pn109=100

- Position Error near zero at constant speed
3. Custom Tuning Mode 1

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pn409</td>
<td>Hz 5000</td>
</tr>
<tr>
<td>Pn40A</td>
<td>0.01</td>
</tr>
<tr>
<td>Pn40B</td>
<td>0.001</td>
</tr>
<tr>
<td>Pn40C</td>
<td>Hz 3860</td>
</tr>
<tr>
<td>Pn40D</td>
<td>0.01</td>
</tr>
<tr>
<td>Pn40E</td>
<td>0.001</td>
</tr>
</tbody>
</table>
Tuning the Demo

Tuning for Low Position Error

- Record Final Result
## Autotuning Modes

<table>
<thead>
<tr>
<th>Item</th>
<th>Mode 1 (Standard)</th>
<th>Mode 2, 3 (Positioning)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Settling Time</td>
<td>Good</td>
<td>BEST</td>
</tr>
<tr>
<td>Low Position Error</td>
<td>BEST</td>
<td>OK</td>
</tr>
<tr>
<td>Electronic Cam</td>
<td>BEST</td>
<td>Good</td>
</tr>
<tr>
<td>Point-To-Point</td>
<td>Good</td>
<td>BEST</td>
</tr>
<tr>
<td>Model Following</td>
<td>Not Available</td>
<td>Used</td>
</tr>
<tr>
<td>Vibration Suppression</td>
<td>Not Available</td>
<td>Available</td>
</tr>
<tr>
<td>Anti-Resonance</td>
<td>Available</td>
<td>Available</td>
</tr>
<tr>
<td>Notch Filter</td>
<td>Available</td>
<td>Available</td>
</tr>
<tr>
<td>FeedForward Pn109</td>
<td>Used</td>
<td>Not Used</td>
</tr>
<tr>
<td>Speed Control Mode</td>
<td>Available</td>
<td>Not Available</td>
</tr>
</tbody>
</table>