MAC motors
Tuning overview and guide

1 Revisions

Ver.	Changes	Date	Init
1.0	Initial version of Motor Tuning Guide	2026-03-06	FOH

Review: 2026-03-11 JVA

2 Contents

3 Introduction

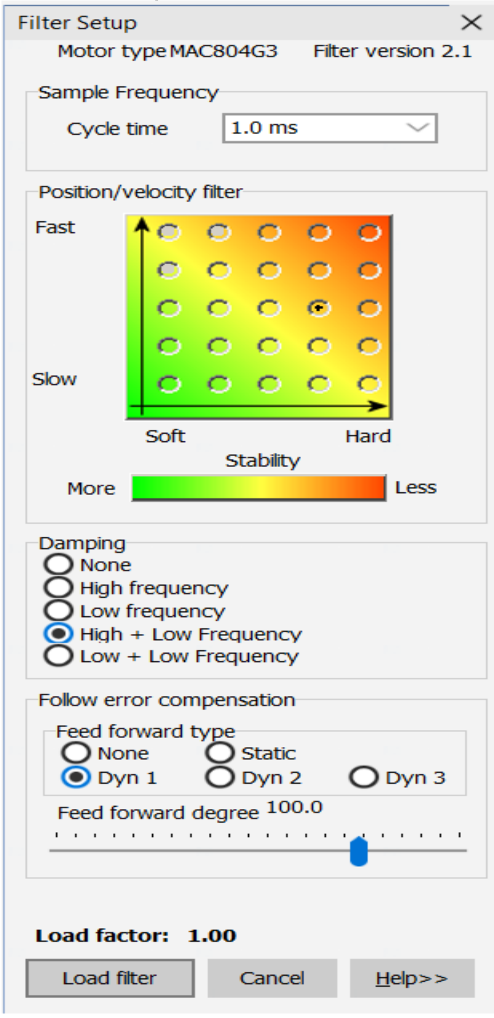
This guide covers tuning the outer (position/velocity) control loop of JVL MACxxx servo motors using MacTalk's Filter Selector. It explains what each parameter does, when to adjust it, and provides recommendations for common mechanical system types.
The outer control loop compares the commanded position/velocity to the actual measured values and outputs a torque command to the inner current (FOC) loop. The tuning parameters covered here control the behavior of this outer loop.

4 Control Loop Overview

The outer control loop processes the velocity setpoint through several stages before producing a torque command:

- Feed Forward Filter — Pre-shapes the velocity command to anticipate acceleration
- Position Integrator — Accumulates velocity error to correct steady-state position offset
- Damping Filter — Subtracts resonance-frequency components from the error signal
- Position/Velocity Filter (Controller) — The main controller that converts error into torque demand
- Load factor (KVOUT) — Scales the final torque output (overall loop gain)

These blocks interact — changing one affects the optimal setting of the others. This is why they should be tuned in a specific order.



5 Recommended Tuning Order

Always tune in this order. Each step builds on the stability established by the previous one:

Step	Parameter	Purpose
1	Load factor (KVOUT)	Set overall stiffness — how hard the motor pushes against errors
2	Damping	Suppress mechanical resonance (if present)
3	Hardness (Pos/Vel Filter)	Adjust controller bandwidth — how fast the motor reacts
4	Feed Forward Type	Select dynamic compensation to reduce lag during moves
5	Feed Forward Degree	Fine-tune the strength of feed-forward compensation
6	Cycle Time (Sample frequency)	How often the control loop executes; slower can help stabilize very compliant systems

6 Load Factor (KVOUT)

6.1 What It Does

Load factor controls the overall gain of the control loop — how much torque the motor produces per unit of position or velocity error. Higher Load factor means stiffer, more aggressive tracking. Lower Load factor means softer, more compliant behavior.

6.2 How to Tune

The standard tuning procedure:

- Start with Load factor = 1.0 (the default value).
- Gradually increase Load factor while the motor is running.
- When the motor starts buzzing or oscillating, back off approximately 25%.

If you hear no noise even at high Load factor values: This usually means the mechanical coupling is very compliant (belt, flexible coupling, long shaft) and absorbs the oscillation energy before it becomes audible. Check for vibration at the load side, not just at the motor. Alternatively, the Hardness setting may be too low, limiting the effect of Load factor. Try increasing Hardness first (see Section 9), then retry the Load factor tuning procedure.

6.3 When to Increase or Decrease

	Increase Load factor	Decrease Load factor
When	Motor is sluggish, large position error, slow settling, cannot hold position against external force	Motor buzzes, oscillates, or vibrates (especially at standstill or low speed)
What happens	More torque per unit error → stiffer, faster response, tighter position hold	Less torque per unit error → softer, more compliant, less prone to oscillation
Risk	Oscillation / buzzing if mechanical coupling cannot handle the stiffness	Sluggish response, poor disturbance rejection, large steady-state error

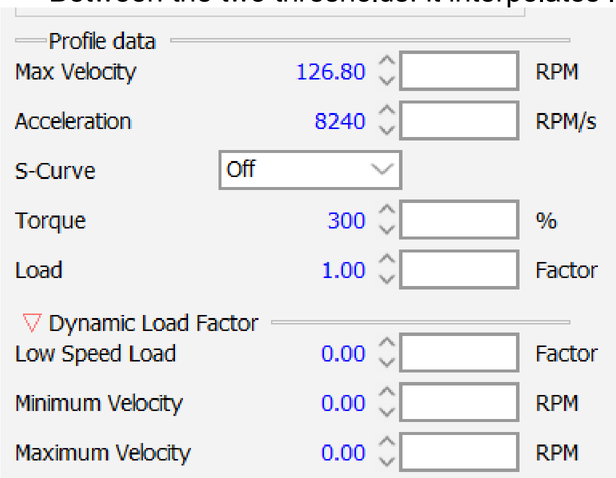
6.4 Recommended Settings by System Type

System Type	Typical Load Factor	Why
Direct-coupled rigid load (gearbox, ballscrew)	High (1.5–3.0+)	Stiff coupling can handle aggressive gain without resonance
Belt drive, long shaft	Low–Medium (0.5–1.5)	Compliant coupling oscillates easily at high gain
Large inertia mismatch (small motor, big load)	Medium–High (1.0–2.5)	Needs torque authority, but high inertia ratio limits stability
Friction-dominated (slide, linear guide)	Medium–High (1.0–2.0)	Must overcome stiction without chattering
No load / test bench	Low (0.5–1.0)	No mechanical damping to absorb oscillation energy

6.5 Velocity-Dependent Load Factor

If your system needs different stiffness at different speeds (for example, vibrates at low speed but works well at high speed), you can configure velocity-dependent Load factor interpolation using the LOAD presets (Register 81–84) together with velocity thresholds.

- Below the minimum velocity threshold: the motor uses the low-speed Load factor value.
- Above the maximum velocity threshold: it uses the high-speed Load factor value.
- Between the two thresholds: it interpolates linearly.



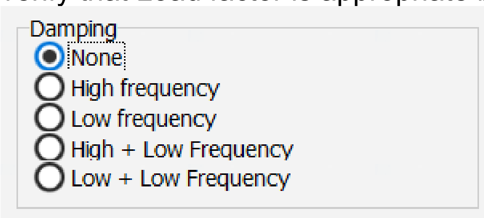
This is useful for mechanisms where compliance or friction changes with speed, such as belt drives or systems with speed-dependent friction characteristics.

7 Damping

7.1 What It Does

Damping suppresses mechanical resonance by filtering specific frequency components from the velocity feedback signal. It reduces the controller’s sensitivity to oscillations at particular frequencies without changing the controller’s fundamental behavior at other frequencies.

Important: Damping treats the symptom (resonance oscillation), not the cause. If vibration is caused by Load factor being set too high, Damping may reduce the oscillation but the system is still over-stiff. Always verify that Load factor is appropriate before adding Damping.



7.2 The Five Damping Options

Option	Use When
None	System is stable with no resonance. Rigid, well-coupled mechanism.
High freq.	Audible high-pitched whine or rattle. Common with gearboxes or direct coupling misalignment.
Low freq.	Visible slow wobble or hunting. Common with belt drives, long shafts, spring couplings.
High + Low	Both high and low frequency resonance present (e.g., belt drive with gearbox).
Low + Low	Severe low-frequency resonance not resolved by single "Low freq." setting.

7.3 How to Diagnose Resonance

Run the motor at various speeds and observe:

- Speed-dependent vibration (only at certain RPM ranges): This is mechanical resonance excited at that frequency. Add Damping matching the frequency range.
- Speed-independent vibration (present at all speeds): The control loop itself is oscillating. Reduce Load factor or Hardness first — this is not a Damping problem.

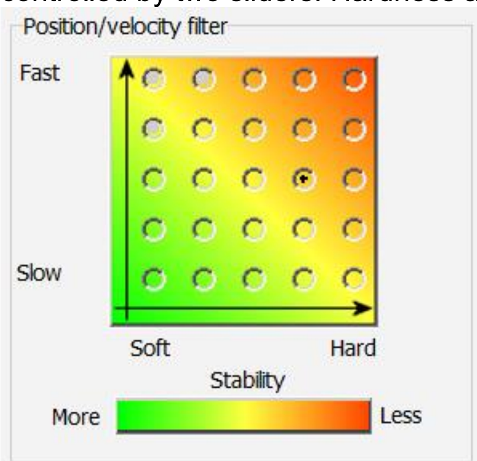
JVL A/S | Bregnerødvej 127 | DK-3460 Birkerød | Denmark | jvl@jvl.dk | www.jvl.dk | Tel: +45 4582 4440

7.4 Recommended Settings by System Type

System Type	Typical Damping	Why
Direct-coupled, rigid gearbox	None or High freq.	No low-freq. resonance; possible gear-tooth excitation at high freq.
Toothed belt drive	Low freq. or Low+Low	Belt compliance creates dominant low-freq. resonance mode
Long shaft / flexible coupling	Low freq.	Shaft torsional flexibility is inherently low-frequency
Belt + gearbox combination	High + Low	Two distinct resonance sources at different frequencies
Small motor, direct mount	None	Typically stiff enough that no resonance appears in operating range

8 Position/Velocity Filter (Hardness and Velocity)

The Position/Velocity Filter is the main controller in the outer loop. In MacTalk's Filter Selector, it is controlled by two sliders: Hardness and Velocity.



8.1 Hardness (Most Important Slider)

Hardness sets the controller bandwidth — how fast the motor reacts to errors and how aggressively it corrects them.

- Low Hardness (0–1): Soft, forgiving controller. Tolerates compliant couplings, long belts, and backlash. Less likely to oscillate.
- Medium Hardness (2–3): Balanced bandwidth. Good for most rigid couplings.
- High Hardness (4): Stiff, aggressive controller. Requires rigid mechanical coupling. Most likely to excite resonances.

8.1.1 When to Adjust Hardness

	Increase Hardness	Decrease Hardness
When	Motor is sluggish despite adequate Load factor, slow to reach setpoint	Motor oscillates at all speeds, regardless of Load factor setting
What happens	Higher controller bandwidth → faster error correction, tighter tracking	Lower bandwidth → slower but more stable, tolerates mechanical slop
Risk	Excites mechanical resonances the coupling cannot damp	Sluggish response, poor dynamic performance

8.1.2 Recommended Hardness by System Type

System Type	Typical Hardness	Why
Direct-coupled rigid load (gearbox, ballscrew)	High (3–4)	Stiff coupling supports high bandwidth without resonance
Belt drive, compliant coupling	Low–Medium (1–2)	Compliance creates resonance modes that high bandwidth excites
Large motor (MAC1500+)	Low (0–1)	Large rotor inertia + structural flexibility requires conservative bandwidth
Small motor, rigid mount (MAC141, MAC400)	Medium–High (2–4)	Low inertia, stiff structure can handle aggressive control
First commissioning / unknown system	Medium (2)	Safe starting point; adjust based on observed behavior

8.2 Velocity Slider

The Velocity slider optimizes the controller coefficients for the expected operating speed range.

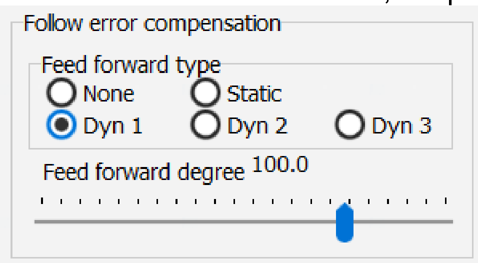
- Index 0: Optimized for low-speed positioning and accuracy.
- Index 4: Optimized for high-speed operation.

Choose based on where your application primarily operates. If the motor oscillates only at low speed despite appropriate Load factor, try moving the Velocity slider towards a lower index.

9 Feed Forward Type

9.1 What It Does

The Feed Forward filter pre-shapes the velocity command to anticipate acceleration. Without feed-forward, the controller only reacts after an error develops. With feed-forward, it injects torque proactively during acceleration and deceleration, keeping the motor closer to the commanded trajectory.



When to use: Only after Load factor, Damping, and Hardness are tuned and the motor is stable. Feed-forward improves dynamic tracking but can cause overshoot if the mechanical system cannot keep up.

9.2 The Five Options

Type	Effect	Best For
None	Pure feedback control, no anticipation	Static positioning, slow moves, first setup
Static	DC gain compensation only	Minor steady-state offset correction
Dyn 1	Mild dynamic compensation	Slow-to-moderate moves, compliant couplings
Dyn 2	Moderate compensation (default for most motors)	Fast point-to-point moves
Dyn 3	Maximum compensation, highest overshoot risk	Very fast continuous motion, rigid coupling, high inertia

9.3 When to Adjust

	More Aggressive (Dyn 2, Dyn 3)	Less / No FF (None, Static, Dyn 1)
When	Large follow-error during acceleration/deceleration	Motor overshoots at end of ramp moves
What happens	Injects anticipatory torque → motor tracks the profile proactively	Controller relies on feedback only → inherently lags but no FF overshoot
Risk	Overshoot if mechanical system has more lag than expected	Larger position lag during fast moves

9.4 Recommended Settings by System Type

System Type	FF Type	Why
Fast point-to-point (pick & place)	Dyn 2	Aggressive acceleration profiles need strong anticipation
Continuous motion (conveyor, winding)	Dyn 2 or Dyn 3	Constant velocity changes; minimize tracking lag
Slow precision positioning	None or Static	Feedback alone tracks well at low speeds; FF adds noise risk
Compliant coupling (belt, long shaft)	None or Dyn 1	Compliance absorbs anticipatory torque → causes overshoot instead
Rigid coupling, high inertia	Dyn 2 or Dyn 3	Rigid coupling delivers torque effectively; high inertia benefits from anticipation

10 Feed Forward Degree

10.1 What It Does

Feed Forward Degree controls the strength of the selected Feed Forward Type, from 0% (off) to 105% (over-compensation).

- 0%: Feed-forward disabled (equivalent to FF Type = None).
- 100%: Full compensation as designed in the filter table.
- >100% (up to 105%): Over-compensation for systems with extra mechanical lag.

10.2 How to Tune

- Start at 0%.
- Ensure the motor is stable from Load factor / Damping / Hardness tuning.
- Select a Feed Forward Type (Dyn 1 or Dyn 2).
- Gradually increase Degree while monitoring position follow-error during moves.
- Stop when follow-error is minimized. If the motor overshoots at the end of moves, reduce Degree.
- Only go above 100% if follow-error persists and the system is very compliant.

10.3 Recommended Settings by System Type

System Type	Typical Degree	Why
Rigid, well-characterized system	95–105%	Full compensation matches the system well
Compliant coupling	30–70%	Full degree overshoots due to unmodeled compliance
Unknown / first setup	0% (then increase)	Start safe, add gradually while monitoring
Systems with extra mechanical lag	100–105%	Over-compensation counters unmodeled lag (use cautiously)

11 Cycle Time (Sample Frequency)

Controls how often the motor checks and corrects its position. A shorter cycle time means faster corrections, giving snappier response and better accuracy during fast moves. A longer cycle time gives the motor more processing time per correction but reacts more slowly.
In the Filter Selector, this appears as the Sample Frequency setting:

Setting	What It Means	Use When
Standard	Motor corrects every 1 ms or 1.3ms	Most applications — this is the default
Extended	Motor corrects every 2 or 2,6 ms	Slow motion, very flexible mechanisms, or if the motor will not stabilize on Standard

Important: When you change this setting, the Filter Selector automatically adjusts all filter coefficients to match. Always change cycle time through the Filter Selector — never change it independently.
Rule of thumb: Leave it on Standard unless you have a specific reason to change it. Only switch to Extended if you cannot get the motor stable using Load factor, Hardness, and Damping adjustments alone.

JVL A/S | Bregnerødvej 127 | DK-3460 Birkerød | Denmark | jvl@jvl.dk | www.jvl.dk | Tel: +45 4582 4440

12 Application Starting Points

The tables below give recommended starting configurations for common application types. Every machine is different, so treat these as starting points — then fine-tune each parameter using the guidance in the sections above.

Hardness and Velocity values refer to the Filter Selector slider positions (0–4). Think of them as a 2D grid: Hardness goes from Soft (0) to Hard (4) on one axis, and Velocity goes from Slow (0) to Fast (4) on the other.

12.1 Pick-and-Place / Packaging / Fast Indexing

Short moves, quick stops, do-it-again. The motor must accelerate hard and settle fast. These machines typically have stiff, direct connections (gearbox, ballscrew).

Parameter	Setting	Why
Load factor	High (1.5–3.0)	Stiff connection can handle strong corrections
Hardness	3–4	Fast reaction to errors
Velocity	3–4	Optimized for high speed
Damping	None or High freq.	Only add if you hear a high-pitched rattle from gears
FF Type	Dyn 2	Helps the motor keep up during acceleration
FF Degree	80–100%	Reduce if the motor overshoots at the end of each move
Cycle Time	Standard	

Troubleshooting: Overshoot at end of moves → reduce FF Degree or switch to Dyn 1. High-pitched noise → add High freq. Damping. Vibration during moves → reduce Hardness by 1 step.

12.2 Conveyor Belt / Long-Travel Linear Axis

Smooth, steady motion over long distances. Belts and long shafts are flexible, which makes them prone to wobbling if the motor pushes too hard.

Parameter	Setting	Why
Load factor	Low–Medium (0.5–1.5)	Flexible belts wobble at high gain
Hardness	1–2	Gentle corrections avoid exciting belt vibration
Velocity	1–2	Typically moderate speed
Damping	Low freq. or High + Low	Targets the slow wobble that belts create
FF Type	None or Static	Belt flexibility absorbs anticipatory torque
FF Degree	0–30%	Higher values cause the belt to bounce
Cycle Time	Standard or Extended	Try Extended if wobble persists

Troubleshooting: Belt vibration or wobble → reduce Load factor, add Low freq. Damping. Motor does not reach target accurately → increase Load factor slightly.

12.3 Robotics / SCARA / Delta

Fast, smooth curved paths. These systems are lightweight and responsive, but very sensitive to noise — even small vibrations show up as jerky motion.

Parameter	Setting	Why
Load factor	Medium (1.0–1.5)	Enough force to follow paths, but not so much it shakes the structure
Hardness	2–3	Moderate speed of reaction
Velocity	3–4	Fast operation
Damping	High freq.	Suppresses lightweight structural vibrations
FF Type	Dyn 2	Keeps the path smooth during acceleration
FF Degree	70–95%	Fine-tune to balance path accuracy vs. overshoot
Cycle Time	Standard	Tight path tracking needs fast corrections

JVL A/S | Bregnerødvej 127 | DK-3460 Birkerød | Denmark | jvl@jvl.dk | www.jvl.dk | Tel: +45 4582 4440

Troubleshooting: Jerky or noisy motion → reduce Hardness, check High freq. Damping is enabled. Path deviation during curves → increase FF Degree.

12.4 Vertical Lift / Z-Axis (Fighting Gravity)

The motor must hold position firmly against gravity. If it is too soft, the axis sags when standing still or when load changes.

Parameter	Setting	Why
Load factor	High (2.0–3.0+)	Must push hard to counteract gravity
Hardness	3–4	Quick correction prevents sagging
Velocity	1–3	Depends on lift speed
Damping	None or High freq.	None if connection is stiff; High freq. if gearbox rattles
FF Type	Static or Dyn 1	Helps hold position under constant gravity load
FF Degree	50–80%	Full compensation may cause overshoot when lowering
Cycle Time	Standard	

Troubleshooting: Axis drifts or sags when holding → increase Load factor. Oscillation when holding position → add High freq. Damping, or reduce Hardness by 1.

12.5 Winding / Tension Control

Smooth, constant torque is everything. Any jerk or sudden correction from the motor shows up as tension spikes that can damage material.

Parameter	Setting	Why
Load factor	Low (0.5–1.0)	Gentle corrections keep tension smooth
Hardness	0–1	Slow, smooth motor response
Velocity	0–1	Slow operation
Damping	Low freq. or High + Low	Suppresses any oscillation that disturbs tension
FF Type	None	Feed-forward can cause sudden torque changes
FF Degree	0%	—
Cycle Time	Extended	Slower corrections = smoother torque output

Troubleshooting: Tension oscillates → reduce Load factor, ensure Damping is set. Motor cannot maintain speed under load → increase Load factor carefully.

12.6 High-Inertia Load (Heavy Table, Flywheel, Large Gearbox)

The load is much heavier than the motor expects. The motor must build up torque gradually — if it reacts too fast, the heavy load starts swinging back and forth.

Parameter	Setting	Why
Load factor	Medium–High (1.5–2.5)	Needs enough torque to move the load, but too much causes oscillation
Hardness	1–2	Slow reactions match the heavy load's slow response
Velocity	1–2	Usually moderate speed
Damping	Low freq.	Heavy loads oscillate slowly
FF Type	Static or Dyn 1	Mild anticipation — aggressive settings overshoot
FF Degree	30–60%	Keep conservative — the system responds slowly to corrections
Cycle Time	Standard	

Troubleshooting: Slow swinging oscillation → reduce Load factor, ensure Low freq. Damping is set. Motor too slow to start moving → increase Load factor, or try Dyn 1 FF.

13 Follow Error Detection (Stall / Overload Faulting)

By default, when the motor reaches the torque limit, it simply limits the torque output — it does not generate a fault. This is intentional, as many applications run against a torque limit by design (pressing, clamping, etc.).
To make the motor fault when it is stalled or torque-limited for too long, enable Follow Error Detection:

- Set Register 38 (FLWERRMAX) to a non-zero value. This monitors the difference between the commanded and actual velocity.
- When the motor is stalled (torque-limited, actual velocity differs from commanded), the follow error accumulates. When it exceeds FLWERRMAX, the motor faults and stops.
- Suggested starting value: 16,000-32,000. Lower values trigger faster but may trip during normal high-acceleration moves. Test with your motion profile and adjust accordingly.
- To clear the fault after it triggers: send a Reset errors command.

14 Important: Filter Coefficient Double-Buffering

Filter coefficient changes (all parameters set via the Filter Selector) are double-buffered in the firmware. This means:

- Writing new filter settings while the motor is actively running has no immediate effect.
- The new values take effect only when the motor returns to passive mode (Mode 0) and is then re-enabled.
- After changing filter settings in MacTalk, cycle the motor to passive mode and back for the changes to take effect, and remember to press the “Save in Motor” button.

15 Common Problems and Solutions

Problem	Likely Cause	Solution
Motor buzzes at all speeds	Load factor too high or Hardness too high	Reduce Load factor first, then reduce Hardness if needed
Vibration only at low speed	Load factor too high at low speed, or low-freq. mechanical resonance	Use velocity-dependent Load factor (softer at low speed), or try "Low freq." Damping
Vibration only at a specific speed	Mechanical resonance at that frequency	Add appropriate Damping (High or Low freq.)
Motor is sluggish, will not track setpoint	Load factor too low or Hardness too low	Increase Load factor; if still sluggish, increase Hardness
Large follow-error during acceleration	No feed-forward, or FF Degree too low	Set FF Type to Dyn 1 or Dyn 2; increase Degree
Overshoot at end of moves	FF Degree too high or FF Type too aggressive	Reduce Degree; try milder FF Type (e.g., Dyn 1 instead of Dyn 3)
Motor keeps forcing past torque limit (no fault)	Normal behavior — torque limiting does not fault by default	Enable Follow Error Detection (Register 38, FLWERRMAX)
Changed filter settings but no effect	Filter coefficients are double-buffered	Cycle motor to passive mode (Mode 0) and back
Increased Load factor to maximum but no buzzing heard	Compliant coupling absorbs energy, or Hardness is too low	Check for vibration at the load side; try increasing Hardness first

16 Quick Reference

Parameter	What It Affects	Increase If…	Decrease If…
Load factor (KVOUT)	Stiffness / torque per error	Motor is sluggish, large position error	Motor oscillates, buzzes, or vibrates
Hardness	Controller bandwidth	Sluggish despite adequate Load factor	Oscillation at all speeds
Velocity	Speed-range optimization	Index 0 = low speed, Index 4 = high speed	—
Damping	Resonance suppression	Vibration at specific frequencies	System is already stable
FF Type	Dynamic setpoint anticipation	Follow-error during accel/decel too large	Overshoot at end of moves
FF Degree	Feed-forward strength	Follow-error persists with FF Type set	Overshoot appears
Sampling Time	How often the correction loop is run	If you can't stabilize with the other settings	—

JVL A/S | Bregnerødvej 127 | DK-3460 Birkerød | Denmark | jvl@jvl.dk | www.jvl.dk | Tel: +45 4582 4440