PMAC Servo Loop Tuning

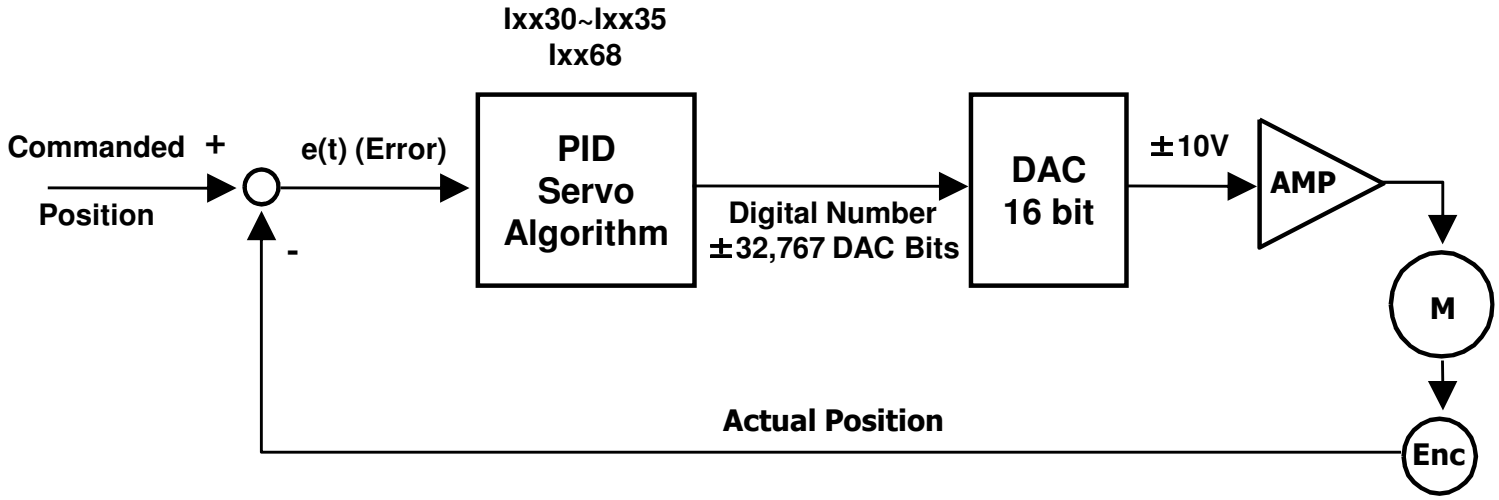
Interactive Tuning

Servo Tuning

- PMAC's Servo Algorithm must be configured to properly control any given system with motors and amplifiers
- Configuration is done by adjusting I-Variables (Ixx30 through Ixx35) pertaining to the PID gains
- Ixx68 (Friction Feedforward) is also needed
- The process of determining proper values of PID gains is called "Tuning"

PID Servo Loop

Adjust Servo Algorithm parameters for desired position response, including how quickly and accurately the motor can move to a target position



e(t) = Commanded Position – Actual Position

- **Ixx30** Proportional **Gain** (K_p)
- **Ixx31** Derivative **Gain** (K_d)
- **Ixx32** **Velocity Feedforward** (K_{vff})
- **Ixx33** Integral **Gain** (K_i)
- **Ixx34** **Integration Mode**
- **Ixx35** **Acceleration Feedforward** (K_{aff})
- **Ixx68** **Friction Feedforward** (K_{fff})

Steps for Tuning

1. **Perform the DAC Calibration as described in the Motor Setup section**

2. **Set Ixx34 (Motor xx PID Integration Mode) – can be changed on the fly as needed**
   =1, position error integration is performed only when Motor xx is not commanding a move (when desired velocity is zero)
   =0, position error integration is performed always

3. **Using the Step Response, tune the following parameters in this order:**
   1. Proportional Gain, K_p (Ixx30)
   2. Derivative Gain, K_d (Ixx31)
   3. Integral Gain, K_i (Ixx33)

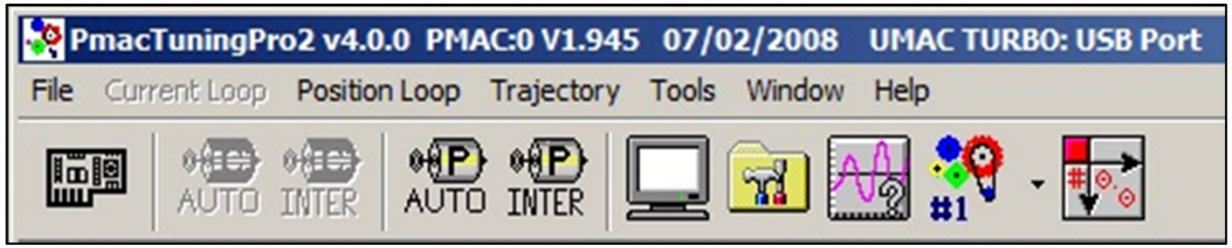
4. **Using the Parabolic Move, tune the following parameters, not necessarily in this order:**
   - Velocity Feedforward, K_{vff} (Ixx32)
   - Acceleration Feedforward, K_{aff} (Ixx35)
   - Friction Feedforward, K_{fff} (Ixx68)

Note

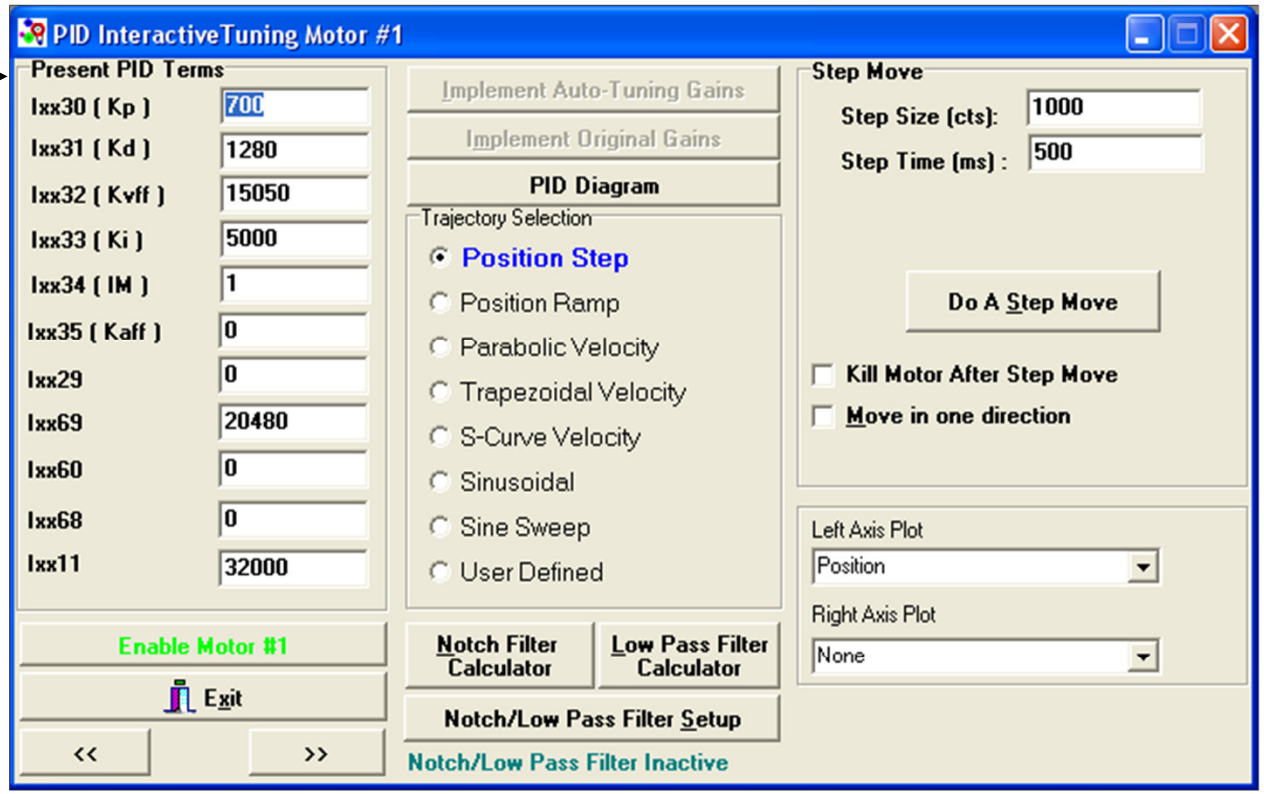
- **When tuning the feedforward gains, set Ixx34=1 so that the dynamic behavior of the system may be observed without integrator action.**
- **Setting Kvff = Kd (Ixx32 = Ixx31) is a good place to start when tuning Kvff.**

Interactive Tuning

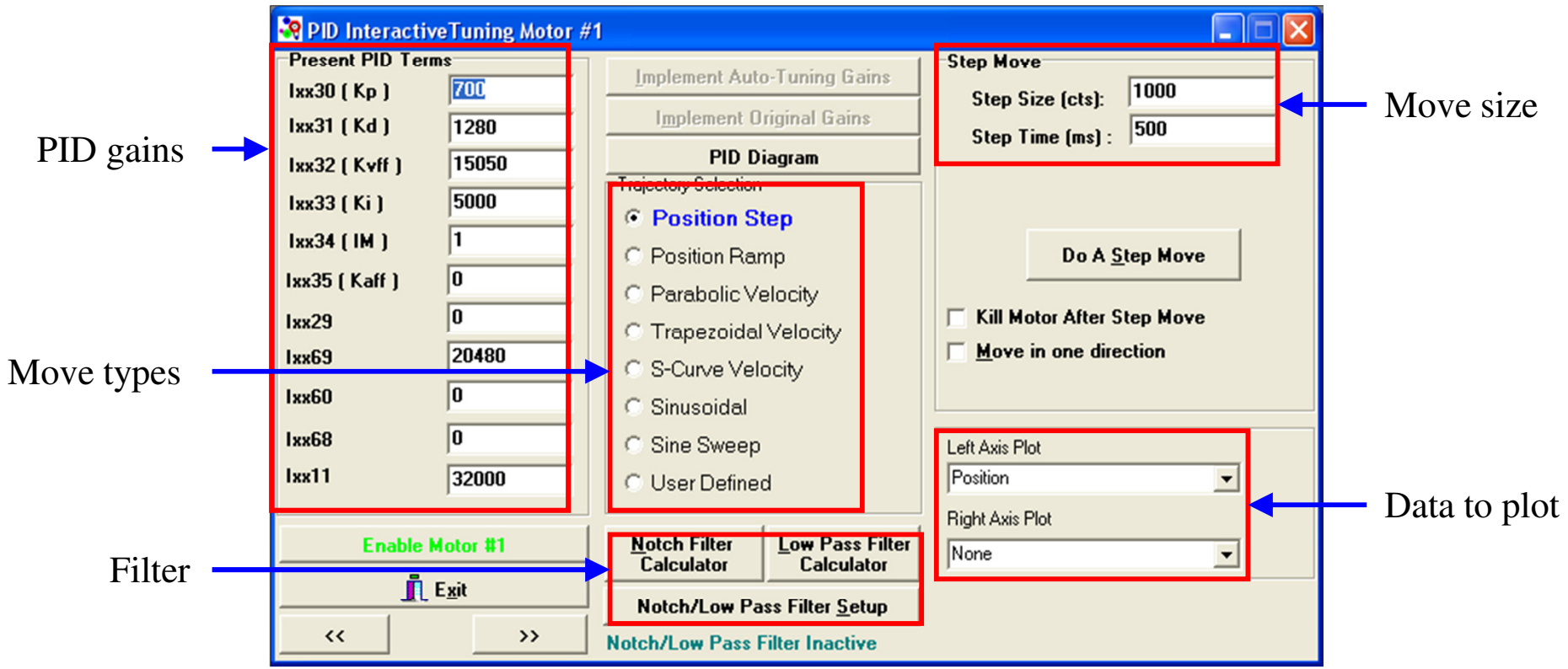
- Interactive Tuning can be accessed in PMAC Tuning Pro2



Interactive Tuning for Position

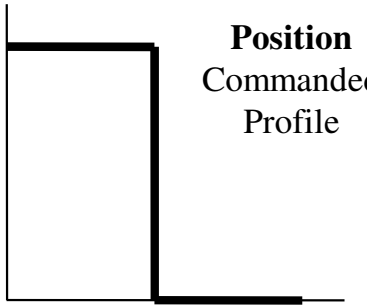


- **Use the controller gains obtained from Auto Tuning as the starting point for Interactive Tuning**
- **Change one gain at a time to adjust the response**
- **Different types of moves are available for tuning purposes**



Step Tuning (Ixx30, Ixx31, Ixx33)

½ to ¼ rev.

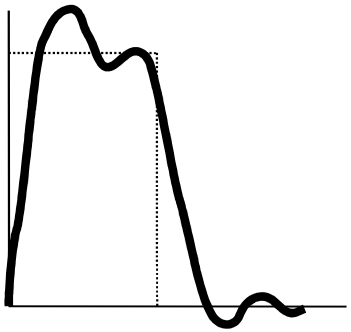


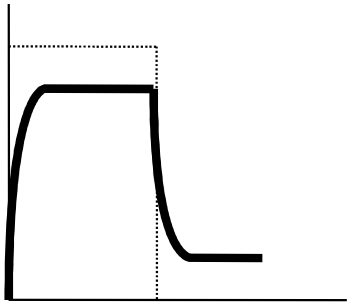
Position
Commanded
Profile

Note:
The intent is to operate within the linear range of the system.
This is usually a step size approx. **½ to ¼ revolution**

Overshoot and Oscillation

Cause:
Too much Proportional gain or
too little Damping
Fix:
Decrease K_p (Ixx30)
Increase K_d (Ixx31)



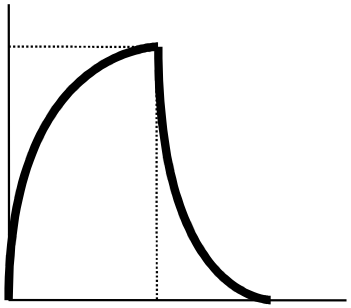


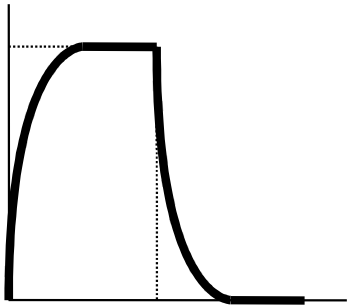
Position Offset

Cause:
Friction or Constant Force
Fix:
Increase K_i (Ixx33)
Increase K_p (Ixx30)

Sluggish Response

Cause:
Too much Damping or
too little Proportional gain
Fix:
Increase K_p (Ixx30) or
Decrease K_d (Ixx31)



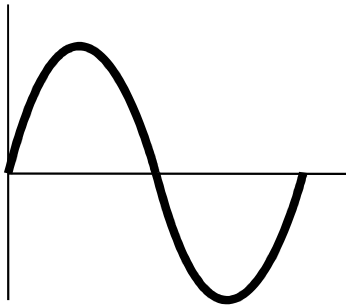


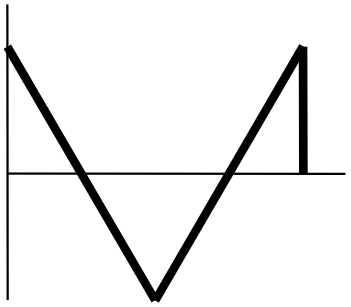
Physical System Limitation

Cause:
Limit of the Motor/Amplifier/Load
and gain combination
Fix:
Evaluate Performance and
maybe add K_p (Ixx30)

Parabolic Tuning (Ixx32-Ixx35, Ixx68)

Velocity
Commanded
Profile



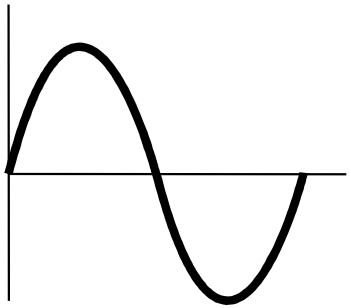


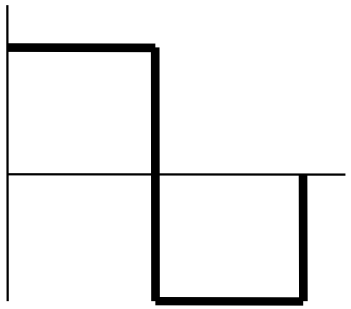
Acceleration
Commanded
Profile

Following Error Profile (F.E.)

High Vel./F.E. Correlation

Cause: Damping
Fix: Increase K_{vff} (Ixx32)



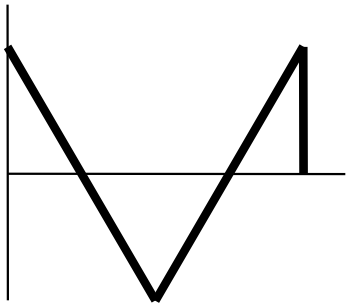


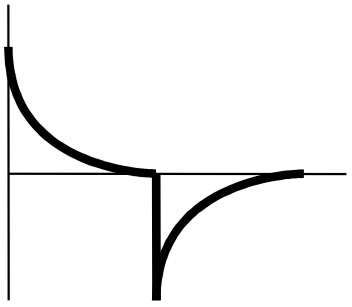
High Vel./F.E. Correlation

Cause: Friction
Fix:
Add Friction Feedforward (Ixx68)
and/or turn on Integral Gain
(Ixx33, Ixx34)

High Acc./F.E. Correlation

Cause: Inertial Lag
Fix:
Increase K_{aff} (Ixx35)



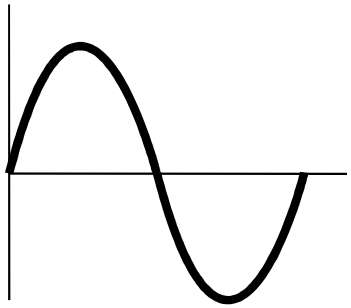


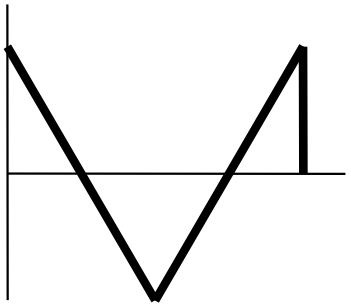
High Acc./F.E. Correlation

Cause:
Physical System Limitation
Fix:
Use softer acceleration
or add more Ixx68

Parabolic Tuning (Ixx32-Ixx35, Ixx68)

Velocity
Commanded
Profile

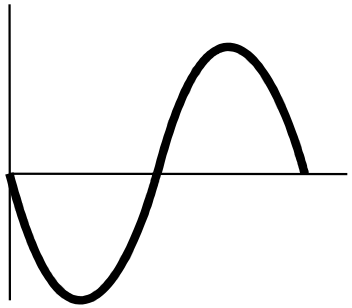


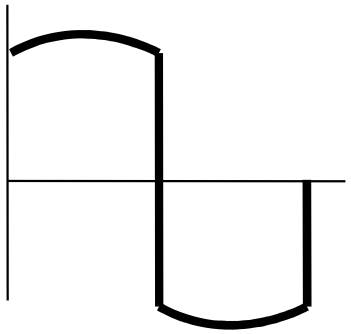


Acceleration
Commanded
Profile

Following Error Profile (F.E.)

Negative Vel./F.E. Correlation
Cause:
Too much Velocity Feedforward
Fix:
Decrease K_{vff} (Ixx32)

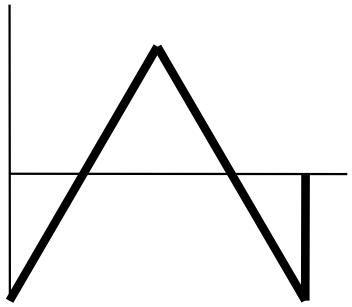


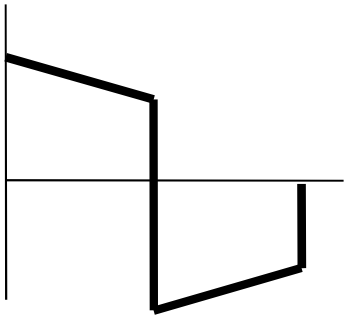


High Vel./F.E. Correlation

Cause: Damping & Friction
Fix:
Increase K_{vff} first (Ixx32)
Possibly adjust Ixx68

Negative Acc./F.E. Correlation
Cause:
Too much acceleration Feedforward
Fix:
Decrease K_{aff} (Ixx35)





High Vel./F.E. & Acc./F.E. Correlation

Cause:
Inertial Lag & Friction
Fix:
Increase K_{aff} (Ixx35)
Possibly adjust Ixx68

Tuning Exercise

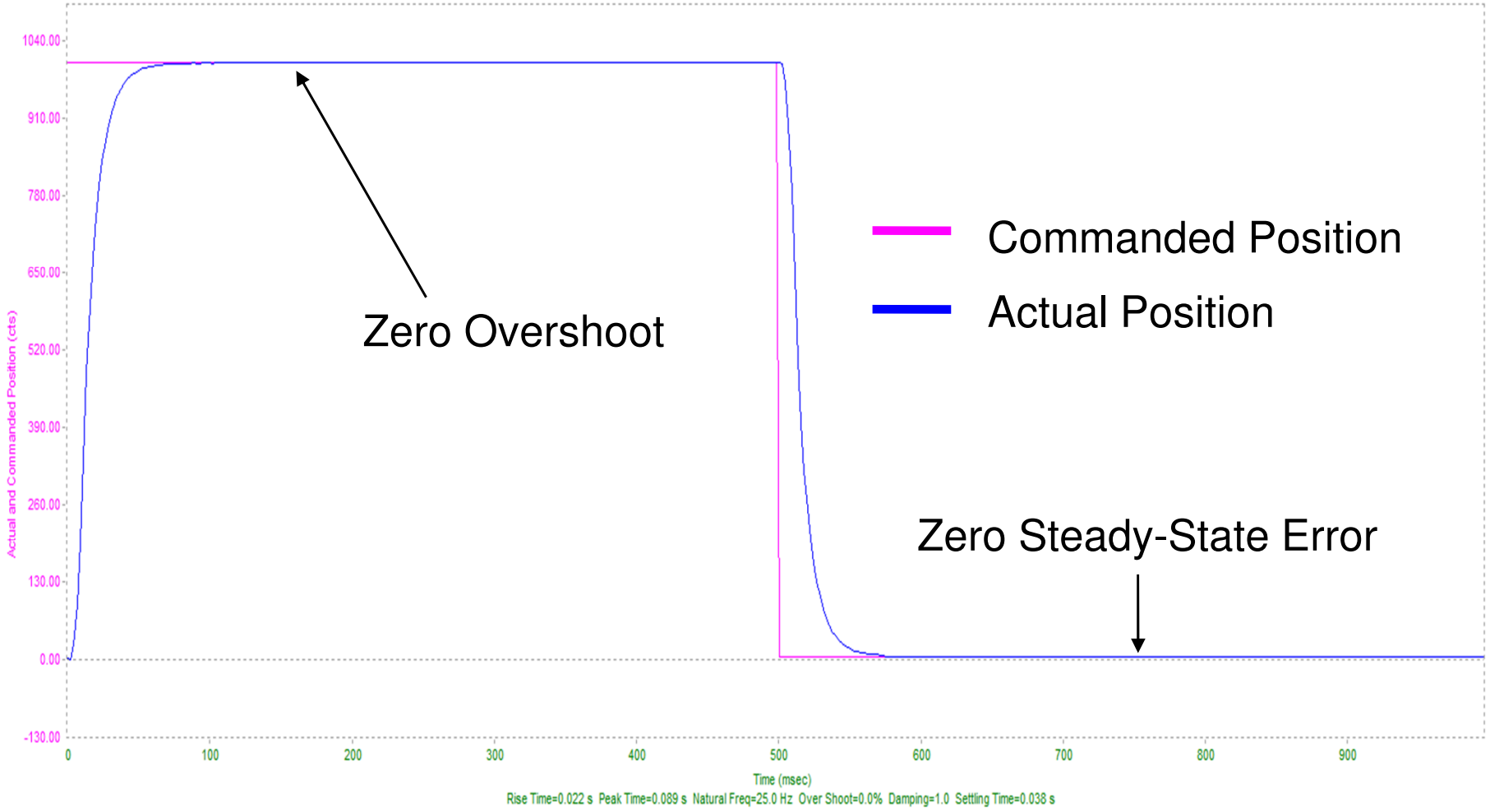
- In the Terminal Window, set Ixx30 through Ixx39 to 0. This will clear the servo loop tuning for Motor xx.

```
// Reset PID gains of Motor 1 ~ 4
I130..139=0          ; Set Motor 1 PID gains to 0
I230..239=0          ; Set Motor 2 PID gains to 0
I330..339=0          ; Set Motor 3 PID gains to 0
I430..439=0          ; Set Motor 4 PID gains to 0
```

Turbo PMAC Script

- Launch PMAC Tuning Pro2 from Tool menu. Tune all available PMAC motors for minimum following error.
- Use previous slides as references to change I-Variables for servo tuning to have better performance.

Well-Tuned Step Response



Well-Tuned Parabolic Move