Servo Sürücü Projesi

Arçelik Benchmark Dökümanı

Kontrol Yöntemlerinin İncelenmesi

Doküman Revizyonları

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23/01/2020	OA	1.0	İlk versiyon

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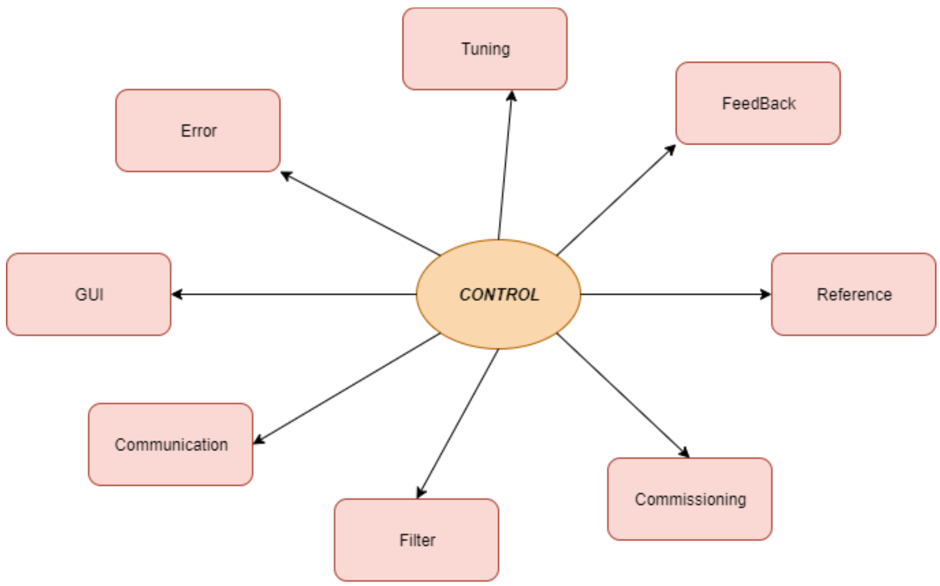
1 Giriş

Bu dökümanda servoların kontrol konularını içeren yöntemleri manuelleri incelenerek ele alınmıştır. Benzer temeller üzerine kurulduğu görülsede kullanıma sunuş biçimleri özellikler incelenmiştir. Ayrıca bazı sürücülerin kendine has yöntemlerde kullandığı görülmüştür. Genel bir bakış açısıyla benzer tuning özellikleri, kontrol yapıları ve kullanım tool'ları sunulmaktadır. Bu çalışmada yaratılan mind map ve alt kırımında gözlemlenen yapılar verilmiştir. Detayları ise ayrıca çalışılmalıdır. Çünkü her kontrol parametresi ve başlık altında farklı kırınım parametre ve detaylara sahiptir.



- Referans
    - Referanslar haberleşme protokolü üzerinden(EtherCAT, CANopen), analog veya pulse formunda olmaktadır. Pulse ile hız veya pozisyon referansı gönderilmektedir.
    - Modlar ise temelde pozisyon, hız, tork olarak kategorilendirilmiştir. Haberleşme protokolüne bağlı olarak standart olan sürüş modları veya sürücü firmasının kendi türettiği özel modlar bulunmaktadır.
    - Referans güncelleme hızları 125us gibi yüksek hızlardadır. Mevcut sistemlerde kullandığımız 1 ms standart bir yapı yoktur ve özellikle haberleşme protokolü üzerinden çalışmayan sürücülerde tamamen farklı değerler bulunmaktadır.
    - Pulse input için kriter ne kadar pulse'i desteklediği ile tanımlanmaktadır.
    - Analog input için analog devrenin karakteristiği verilmektedir.
    - Referans değerler direk olarak uygulanmamaktadır filtre veya referans generator modülden geçmektedir.
    - Analog sıfır referans için ölü bölge tanımlamaların olduğu sürücüler görülmüştür.

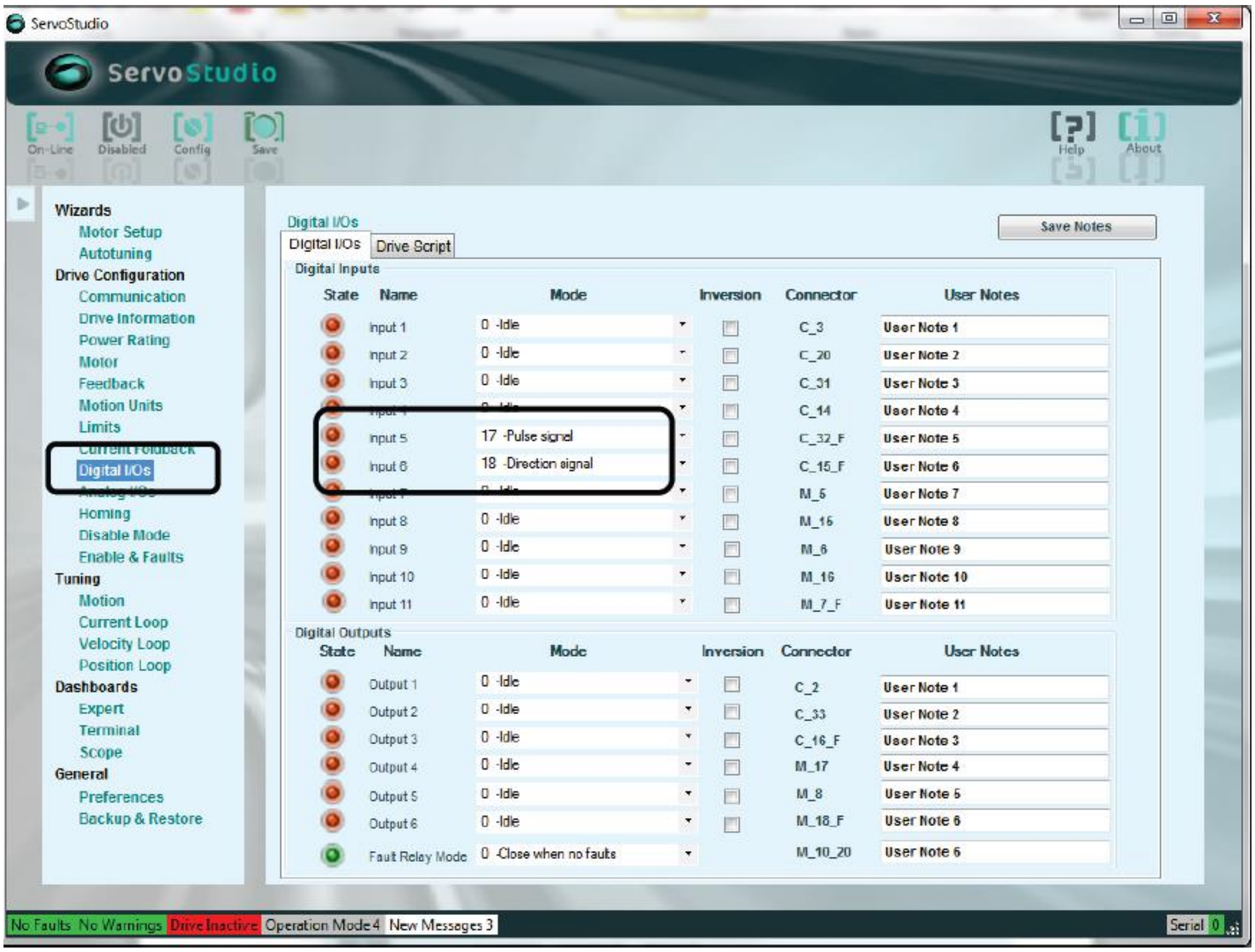
- Feedback
  - Pek çok farklı pozisyon feedback sensörü desteklenmektedir.
  - Çok hassas sürücüler için 24 bit çözünürlüklü sensörler desteklensede 12 bit 14 bit çözünürlükteki pozisyon feedback'leri de çok bulunmaktadır.
  - Feedback filter
- Tuning
  - Temelde 3 farklı tuning metodu sunulmaktadır.
    - Autotune(One touch tune)
    - Advenced tune
    - Manual tune
  - Farklı isimlerle aynı tune seçenekleri kullanılmıştır(easy, comfort, expert)
  - Bazı sürücüler tune edilecek özelikleri kullanıcının anlayacağı daha teknik olmayan terimlerle vermektedir.(Stiffness, aggressive controller)
  - Tune metodları altında farklı metodları seçenek olarak sunmaktadır.
  - Pek çok parametre otomatik olarak tune edilmektedir. Tune edilen parametreler sürücü manuellerinde listelenmektedir.
    - Pozisyon kontrolörü, hız kontrolörü, filtre parametreleri otomatik olarak tune edilir.
  - Sistem tanımada yapılmaktadır. Inertia estimation gibi başlıklar altında.
    - Load characteristic estimation
    - Unbalanced load compensation
    - Damping control
    - RL estimation
  - Tuningless, tak-çalıştır gibi özellikler sunulmaktadır. Sistem çalışmaya başladığında tanıyıp çalışabileceği özellikleri içermektedir.
  -
- Filtre
  - Referans ve feedback hatlarında low pass filter bulunmaktadır.
  - Bazı noktalarda birden fazla notch filtre eklenebilmektedir.
  - Eklenen filtrelerin parametreleri sürücüden sürücüye değişmektedir.
    - Bandwidth, freq, gain, depth, Q factor
    - Birimleri hertz, rad/s veya unit bir değer vererek ona scale edilmiş değerler şeklinde olmaktadır.
  - Aynı hat üzerine birden fazla filtre eklenebilmektedir. Birden fazla frekans için
  - Düşük frekanslar için anti vibration filter
  - Yüksek frekanslar için notch filter kullanılmaktadır.
    - 2 – 5 ayrı notch
  -
- Devreye alma
  - Pek çok sürücü hızlı devreye alma özelliğini öne çıkarmaktadır.
- Configuration

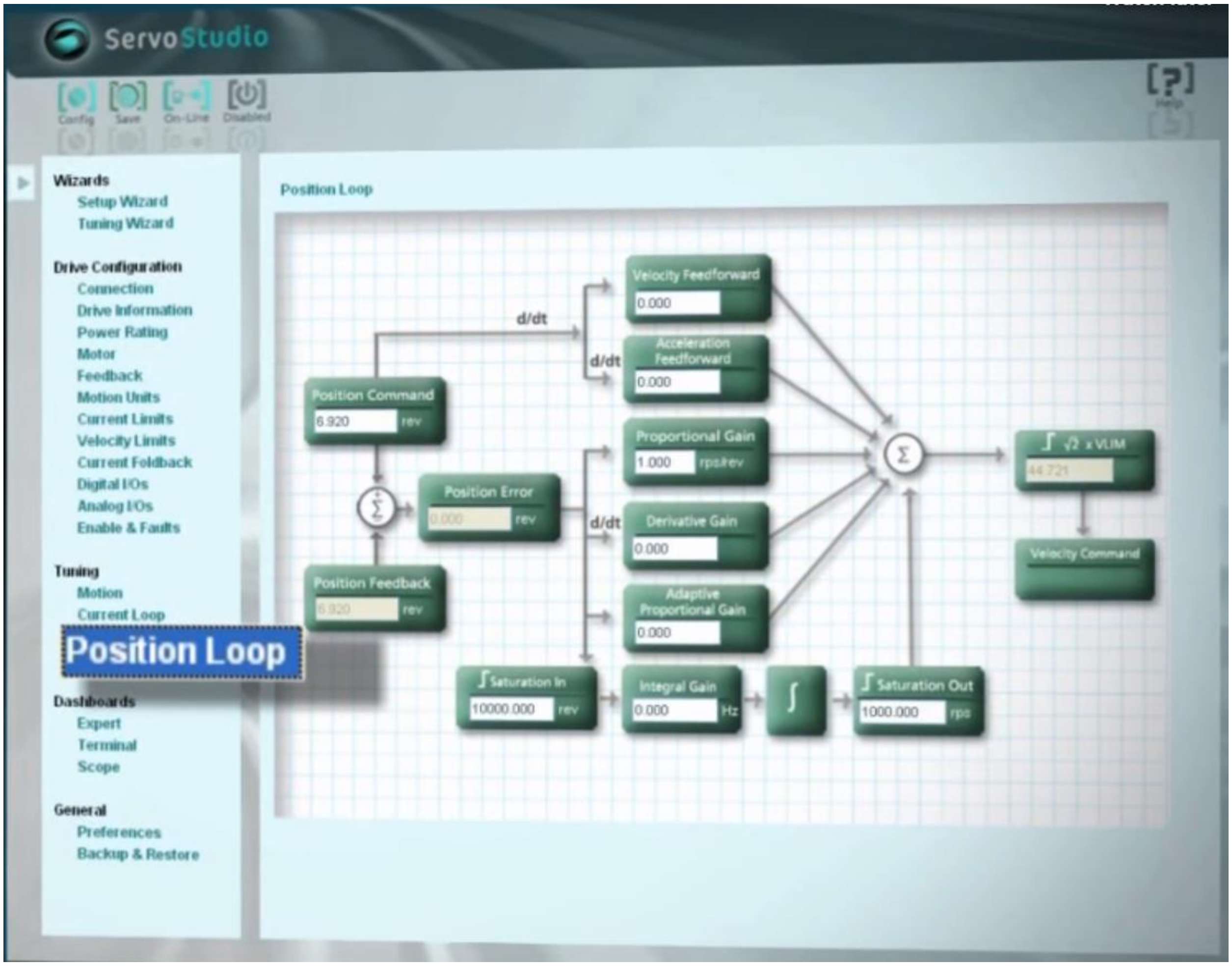
  - Parameter list
  - Type
  - Read/write özelliği
- Drive
  - Genellikle 8 kHz, 16 kHz pwm frekansı varken, control frekansının daha yüksek hızlarda olduğu (16, 32, 40kHz) görülmektedir.
  - Sürüş sırasındaki bilgiler lojik olarak dijital çıkışlara aktarılmaktadır. Örneğin sıfır hız bilgisi, istenen referansa istenen bantta oturulduğu bilgisi gibi bilgiler dijital olarak verilmektedir.
  - Gain switching ile farklı özelliklere bağlı olarak kontrolör kazançlarını güncelleyen yapılar konfigüre edilebilir şekilde sunulmuştur.
  - PI/P switching ile farklı anlarda kontrol yöntemi kendi içerisinde switch edilebilmektedir.
  - Sürücülerin bant genişlikleri, tork/current loop'un bant genişliği olarak tanımlanmaktadır. 1kHz, 1.6kHz, 3kHz, 3.1kHz, 5kHz(servotronix) bant genişliği değerleri görülmüştür.
  - Sıfır hız bölgesi için farklı özelliklere sahip sürücüler görülmüştür.
  - Genellikle klasik olarak tork kontrolünde PI, hız kontrolünde PI, pozisyon kontrolünde P kontrolörler kullanılmıştır. Bunların yanına ekstra özellikler eklenerek kontrol yöntemleri güçlendirilmiştir.
  - Pozisyon loop için özel yöntemler kullanıldığı görülmüştür.
  - Hız ve pozisyon kontrol loop'ları 16,8,4,2 kHz olan yapılar
  - External(secondary, auxiliary) enkoder kullanılması durumunda pozisyon loop için, direk extarnal sensörün dataları kullanılmaktadır.
  - Electronik gear veya benzer isimlerle tanılanmış dönüşüm oranları kullanıcıya sunulmuştur. Bu hatta filtre vs eklenmesi seçenekler arasında verilmektedir.
  - Friction compensation için farklı yöntemler göze çarpmaktadır. Friction tiplerine göre hıza göre referansa offset ekleyen yapılar görülmüştür.
  - Limitler
    - Akım, hız, pozisyon, ivme
  - S ramp
  - Observer
    - Speed Observer
    - Disturbance observer
    - Load observer
  - Adaptif filter, controller
  - Scaling Factor
  - State machine
- GUI
  - Gui üzerinde FFT alınıp görüntülenebilmektedir.
    - FFT işlemci ile mi alınmaktadır, yoksa gui üzerinde mi
  - Gui üzerinde parametre listesine liste şeklinde ulaşılabilmektedir.
  - Dijital I/O'lar gui üzerinden ayarlanabilmektedir.
  - Referans kanalların seçimleri gui üzerinden yapılabilmektedir.

  - Kontrol path'leri ve bu path'teki parametreler filtreler limit değer gui üzerinden görüntülenip konfigüre edilebilmektedir.
  - Bode plot çizdirilmektedir.
  - Mekanik analiz için çeşitli özellikler verilmiştir.
  - Test run sekmesi
  - S ramp özellikleri
  - Kontrol loop'ları parametrelerine kolay erişim
  - Uygulama seçimi
    - Ball screw, belt drive
- Donanım
  - FPGA, CPLD gibi yapılar içerdiği görülmüştür. Bazı sürücülerde kontrol yöntemlerinin bir kısmınında bu yapılarda uygulandığı görülmüştür.
  - Bazı sürücüler mikroişlemci olarak tanımlarken, bazıları DSP olarak tanımlamıştır kontrol unit içerisindeki entegreyi.
  - Parametreler eeprom'a kaydedilip okunmaktadır.
  - Power on timing diyagramları
  - Sistem durumunu gösteren led
- Error
  - STO içeren sistemlerde farklı STO seçenekleri sunulmaktadır.
  - Hatalar belirlenen hata kodları ile 7segment ile kullanıcıya yansıtılmaktadır.
  - Hata akış diyagramları, timing diyagramları

2 Servotronix

- 8 16 32 khz switching ve control sunan sürücüler farklı ürünler olarak bulunmaktadır.
- 32 khz control freq
- 2 cycle'da cevap verme
- DQ, PI, FF




ServoStudio
Config
Save
On-Line
Disabled
Help
Wizards
Setup Wizard
Tuning Wizard
Drive Configuration
Connection
Drive Information
Power Rating
Motor
Feedback
Motion Units
Current Limits
Velocity Limits
Current Foldback
Digital I/Os
Analog I/Os
Enable & Faults
Tuning
Motion
Current Loop
Position Loop
Dashboards
Expert
Terminal
Scope
General
Preferences
Backup & Restore
Position Loop
d/dt
Velocity Feedforward
0.000
Acceleration Feedforward
0.000
Position Command
6.920
rev
Proportional Gain
1.000
rps/rev
Position Error
0.000
rev
Derivative Gain
0.000
Position Feedback
6.920
rev
Adaptive Proportional Gain
0.000
Saturation In
10000.000
rev
Integral Gain
0.000
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Saturation Out
1000.000
rps
Velocity Command
44.721

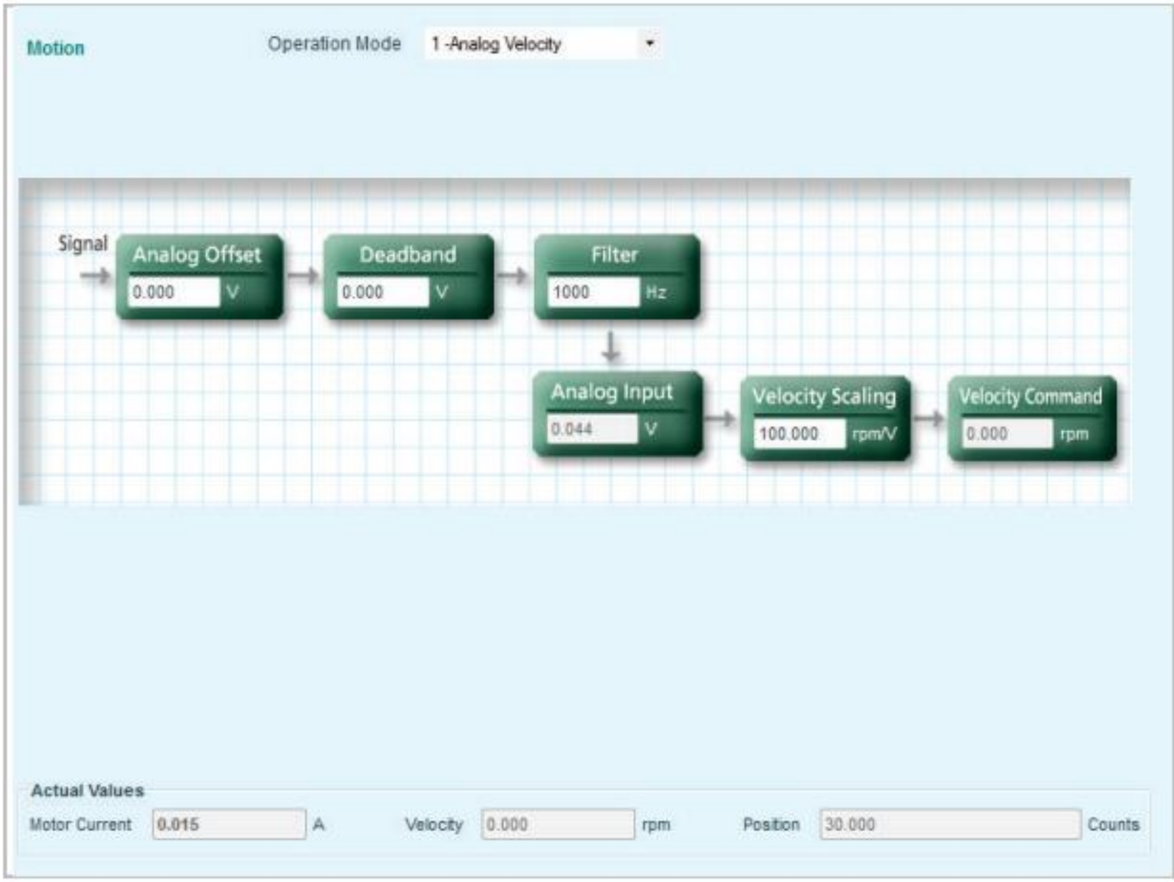


Figure 6-16. Velocity Command Scaling

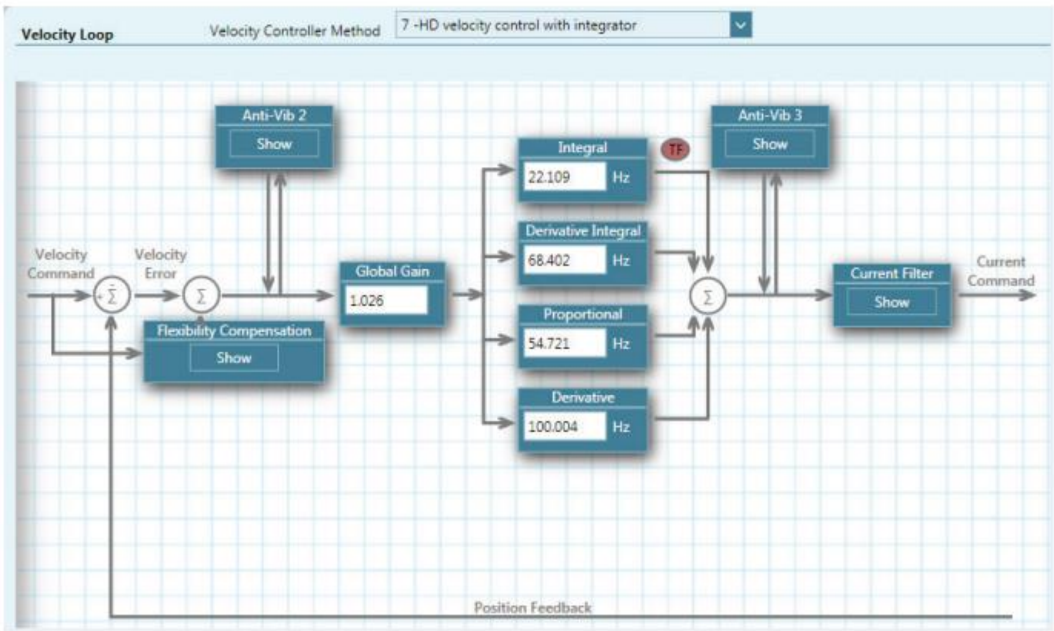
HD Velocity Control with Integrator (Recommended)

Refer to VarCom VELCONTROLMODE 7.

Before using the HD velocity controller, first execute the ServoStudio Autotuning wizard, and then manually adjust the tuning, if necessary.

You can then proceed to use the HD velocity controller.

VELCONTROLMODE 7 provides the advantages of the HD nonlinear controller for velocity control.



Proportional and Integral (PI) Controller

Refer to VarCom VELCONTROLMODE 0.

The following figure shows a PI controller.

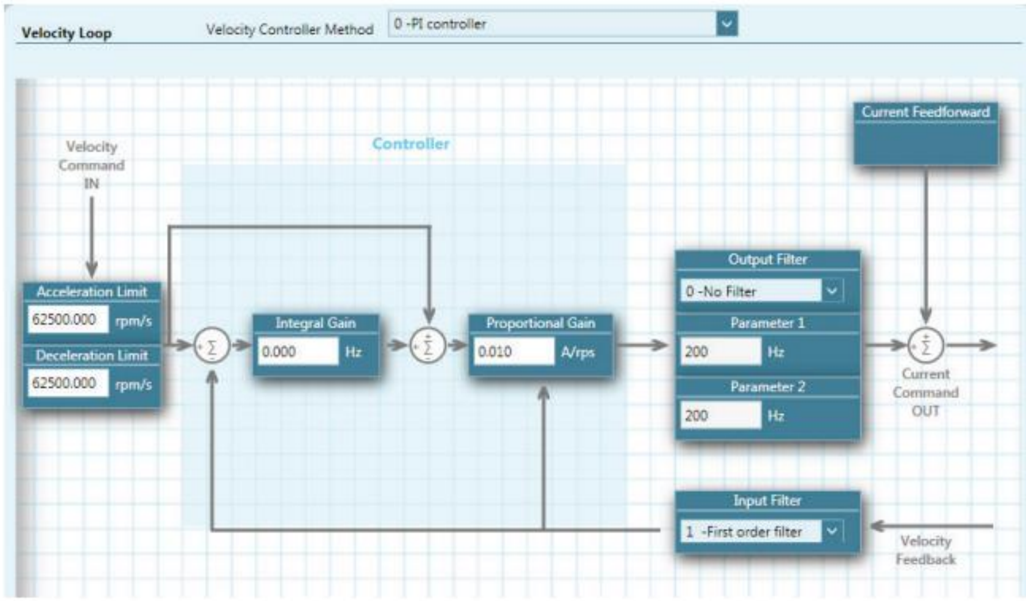


Figure 8-2. Velocity Control – PI Controller

Standard Pole Placement (PP) Controller

Refer to VarCom VELCONTROLMODE 2.

For PP controller tuning, only two parameters are needed: load inertia ratio (LMJR) and closed-loop system bandwidth (BW).

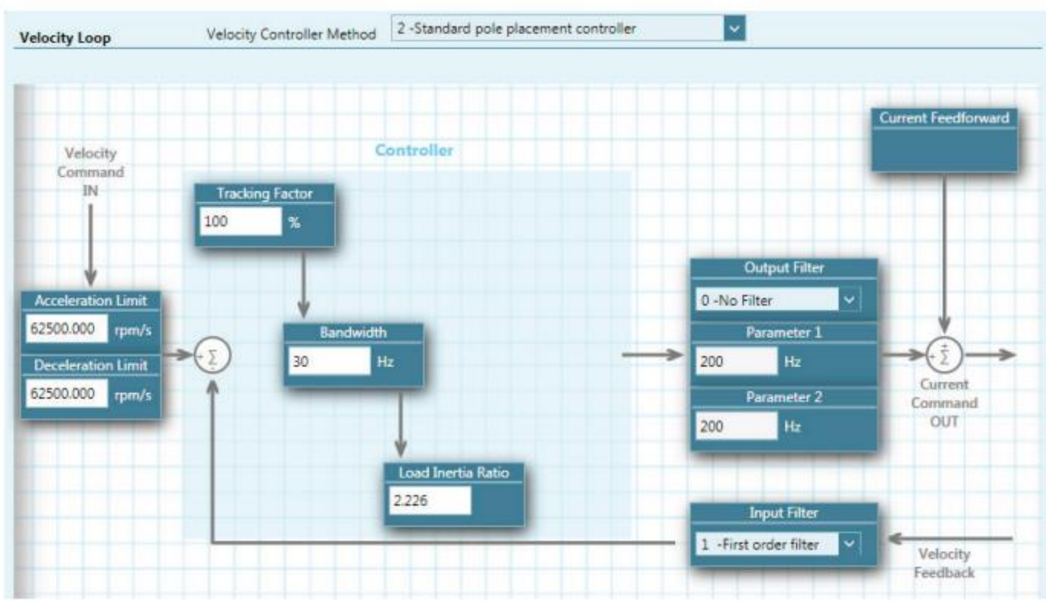


Figure 8-4. Velocity Control – Standard PP Controller

8.6.1 Pulse and Direction Mode

In Pulse and Direction position control, the drive is synchronized to a master input command signal in the form of a pulse train.

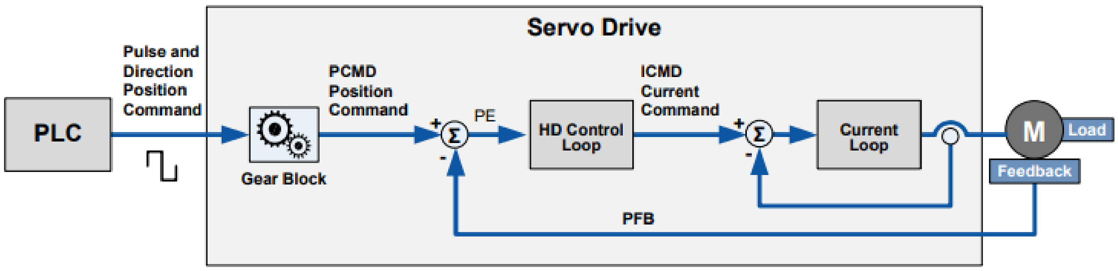


Figure 8-5. Pulse and Direction Position Control

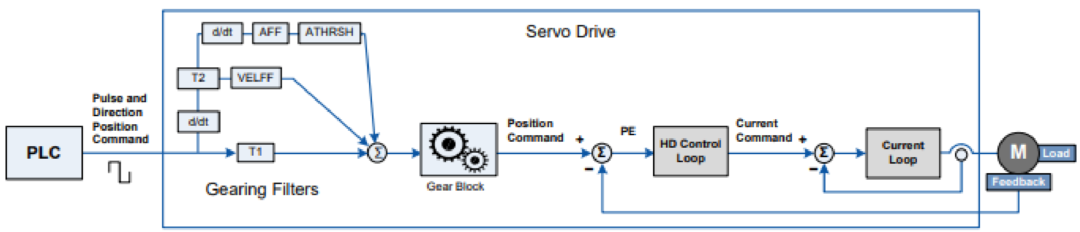
9.8 Gearing Filters

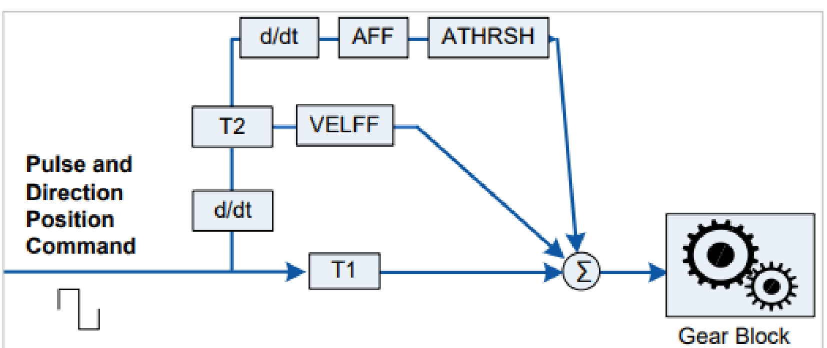
Gearing filters may be useful if the system displays characteristics such as:

- Pulse and direction command has a low resolution
- Coupling between motor and load is not stiff
- Movement is too short
- Motor is noisy after tuning
- Current is very choppy during settling
- Motor temperature is unusually high

Before applying gearing filters, make sure GEARINMODE = 1

When a system has multiple axes, gear filter values must be the same for all axes.





T1	GEARFILTT1: Gear filter depth
T2	GEARFILTT2: Gear filter velocity and acceleration depth
ATHRSH	GEARACCTHRESH* Gear acceleration threshold
VELFF	GEARFILTVELFF* Gear filter velocity feedforward
AFF	GEARFILTAFF* Gear filter acceleration feedforward

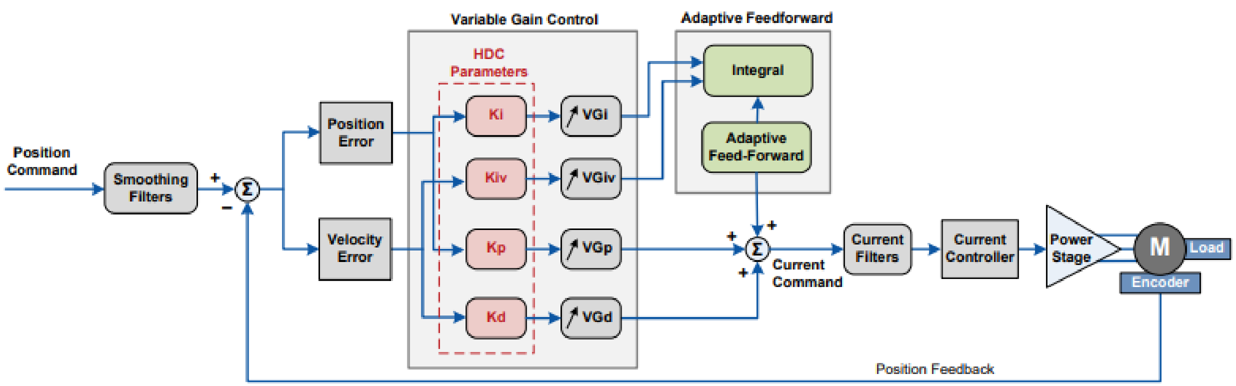


Figure 9-1. CDHD HD Controller

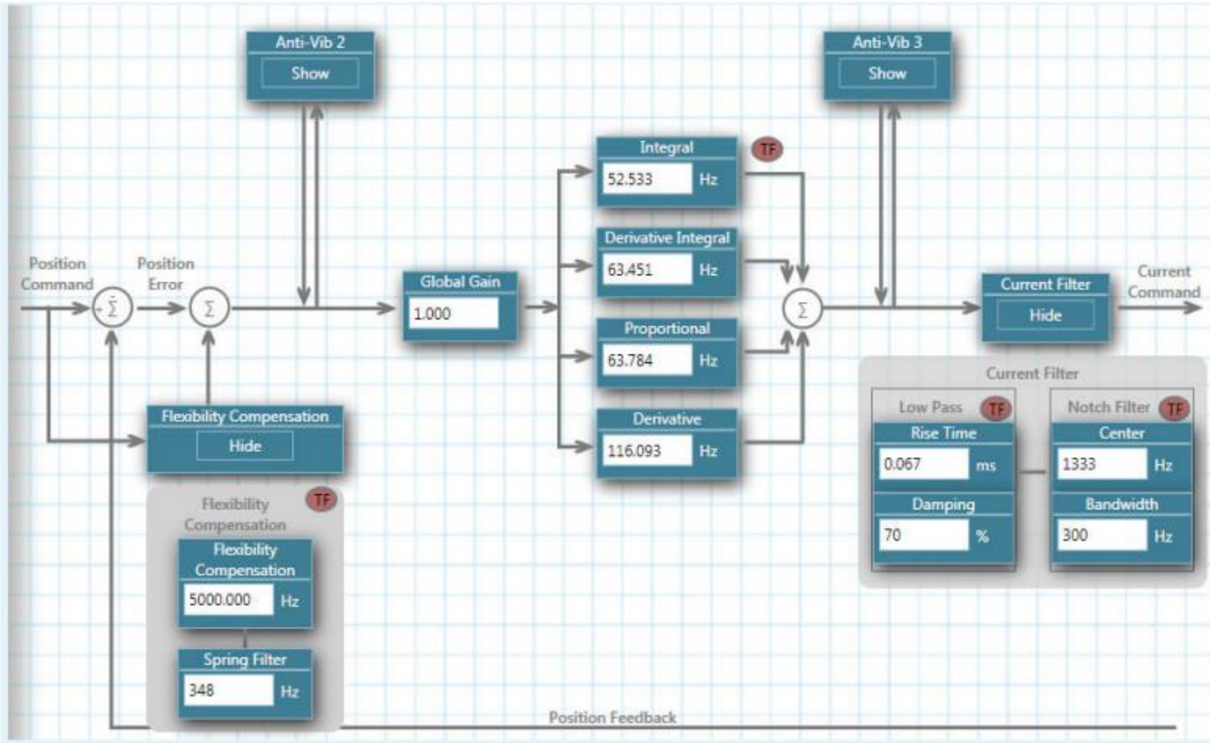


Figure 9-2. CDHD HD Control Loop

9.10 Notch Filters

Notch filters can be used to eliminate high frequency oscillations that may occur in systems having a flexible link between motor and load, such as:

- Ballscrew linear slide with coupling
- Belt drive
- Harmonic drive

Oscillations usually occur during the first steps in tuning (feedback gain). Tuning is done by checking the frequency of the oscillation, and setting the notch accordingly. Once notch parameters are set, the tuning procedure can continue.

HD control notch filters are used at any time during tuning to damp oscillations at a fixed frequency greater than 300 Hz:

- NLNOTCHCENTER (HD Current Filter – Notch Filter Center)
- NLNOTCHBW (HD Current Filter – Notch Filter Bandwidth)

A second set of HD control notch filters (NOTCH2CENTER and NLNOTCH2BW) is available through Terminal, but does not appear in the ServoStudio control loop screen.

9.11 Anti-Vibration Filters

Anti-Vibration Overview

The HD control anti-vibration function is based on proprietary control algorithms and serves to suppress vibrations at constant frequencies.

The vibration suppression function runs in a closed loop, detecting oscillations as they occur, and damping them immediately. Actively damping load oscillations significantly reduces the time it takes for a heavy load or an end effector to settle at the target position. Although the position error at the encoder level may be higher, the overall performance of the system, as evaluated at load position, is significantly improved.

A typical example is a load fixed to a servo controlled motor by means of a shaft that has a certain amount of flexibility. If the servo control of the motor is set for near-zero position error during movement, then the load will oscillate strongly. Every change in the acceleration (jerk) will apply a perturbation, resulting in oscillations of the load. While the stiff HD control loop will overcome these oscillations at motor position level, the load will still oscillate strongly.

The anti-vibration function can handle systems with an oscillation frequency of up to 100 Hz.

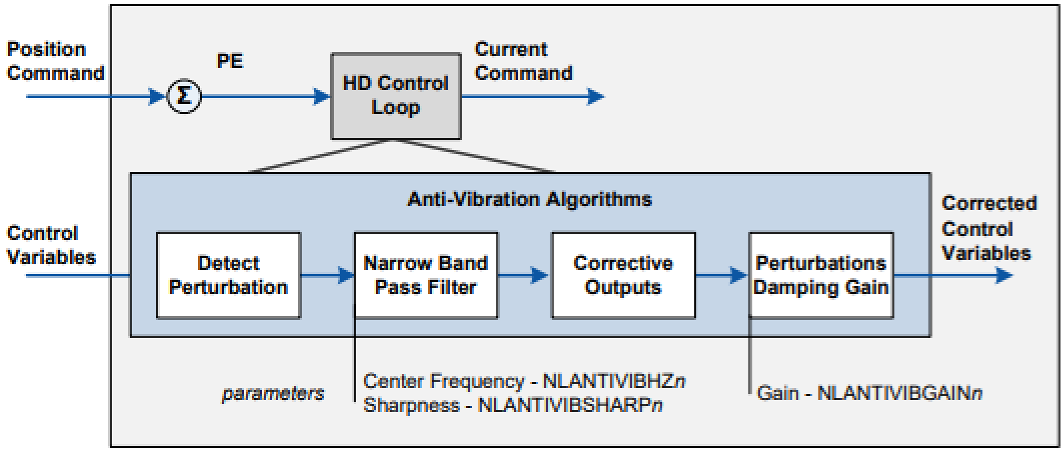


Figure 9-27. Anti-Vibration Filters

Phase 1: The perturbations induced to the system are detected using various control variables, such as position error and current, as input. A perturbation value is calculated for use in the next phase.

Phase 2: The perturbation value is passed through a narrow band pass filter in order to select the perturbations that are induced by the system oscillations. The center frequency and the width of the band pass filter are set, respectively, by the parameters **NLANTIVIBHZ*n*** and **NLANTIVIBSHARP*n***.

Phase 3: Corrective outputs to be added to the control variables are calculated.

Phase 4: Corrective outputs are added to control variables using a damping gain (parameter **NLANTIVIBGAIN*n***).

nti-Vibration Tuning Procedure

After autotuning, more anti-vibration tuning may be required.

If an additional vibration frequency needs to be suppressed, the turning process can be repeated using the second set of anti-vibration filters.

The following table shows the parameters whose values are modified by the HD tuning procedures.

HD Anti-Vibration Filter	Parameter	Default	Range
Center Frequency 2	**NLANTIVIBHZ2**	**100**	**5 to 800 [Hz]**
Center Frequency 3	NLANTIVIBHZ3	400	5 to 800 [Hz]
Sharpness 2	**NLANTIVIBSHARP2**	**0.5**	**0.01 to 10**
Sharpness 3	NLANTIVIBSHARP3	0.2	0.01 to 10
Damping Gain 2	**NLANTIVIBGAIN2**	**0**	**0 to 99**
Damping Gain 3	NLANTIVIBGAIN3	0	0 to 6

Operation Mode	Selectable Modes	Current (Torque) Control, Velocity Control, Position Control, HD Control

Current (Torque) Control	Input/Output	Current command / 3 phase PWM command
	Performance	Update rate 31.25 μs (32 kHz), Output waveform sinusoidal
	Step Response Time	Actual current reaches command in two cycles, 62.5 μs
	Control Loop	DQ, PI, Feed-forward
	Reference Command	Analog Voltage ±10 VDC, Serial RS232 or USB*, CANopen*
	Autotuning	Automatic self-tuning of current control loop parameters

Velocity Control	Input/Output	Velocity command / Current command
	Performance	Update rate 125 μs (8 kHz)
	Selectable Velocity Control Loops	PI , PDFF, Standard pole placement, Advance pole placement, Standard pole placement high frequency, Pole placement with active dumping
	Filters	First order low pass filter, Double first order low pass filter, Notch, High pass filter, Band pass filter, User defined polynomial filter
	Reference Command	Analog Voltage ±10 VDC, Serial RS232 or USB*, CANopen*

Position Control	Input/Output	Position command / Velocity command
	Performance	Update rate 250 μs (4 kHz)
	Control loop	PID and feed-forward
	Reference Command	Pulse and direction with electronic gearing, Serial, Serial RS232 or USB*, CANopen*

HD Control	Input/Output	Position command or Velocity command/Current command
	Performance	Update rate 250 μs (4 kHz)
	Control Loop	Nonlinear control algorithm provides very low tracking error, zero or minimum settling time and smooth movement; includes an adaptive feed-forward feature that is applied at end of movement to achieve zero or minimum settling time.
	Filters	One second order low pass, two notch filters, and other filters to handle flexible and resonant systems
	Reference Command	Velocity: Analog Voltage ±10 VDC, Serial RS232 or USB*, CANopen* Position: Pulse and direction with electronic gearing, Serial, Serial RS232 or USB*, CANopen*
	Auto tuning	Automatic inertia load measurement, self-tuning and optimization of HD control loop parameters. Optimal settling time up to 0-2 ms

Referans

CANopen*	CANopen – CiA 301 application layer and CiA 402 device profile for drives and motion control
	Baud rate 0.5M 1M bit/s
EtherCAT*	CiA 301 application layer and CiA 402 device profile for drives and motion control
	Communication cycle time: up to 250 µs
RS232	ASCII-based, ServoStudio, HyperTerminal
	Baud rate 115200 bit/s
	Maximum cable length 10 m
USB*	ASCII-based, ServoStudio, HyperTerminal
	Baud rate 115200 bit/s
	Maximum cable length 3 m
Daisy Chain	Up to 8 axes. Axis address setting from 0-99 using two rotary switches.
	Maximum cable length 10 m

First Analog Input	Voltage Range	Analog ±10 VDC differential
	Input Resolution	16 bit (14-bit on version with two analog inputs)
	Input Impedance	8 kΩ (when using two analog inputs 20k Ω.)
	Zero attenuation	200 Hz
	Band width (-3 db)	1 KHz
Second Analog Input*	Voltage Range	Analog ±10 VDC differential 14 bit
	Input Resolution	14 bit
	Input Impedance	20 kΩ
	Zero attenuation	200 Hz
	Band width (-3 db)	1 KHz
Pulse & Direction	Signal	RS 422 Line receiver
	Max Input Frequency	4 MHz
Equivalent Encoder Output	Signal	A-quad-B and index differential, RS422 line transmitter
	Max Output Frequency	4 MHz

Feedback

General	Supply Voltage from Drive	5 VDC (7 VDC*)
	Max. Supply Current from Drive	250 mA @5V 140 mA @7V
	Max. Cable Length	AWG 28 – 3 m AWG 24 – 10 m
Incremental Encoder	Signal	A-quad-B with or without index/Halls, 8-channel Tamagawa, RS422 or RS485 line receiver, Differential
	A-quad-B Max Input Frequency	4 MHz (before quadrature)
	Min Index Pulse Width	1 μs
Hall Sensor	Signal	Open collector single-ended (optional differential-ended)
Resolver	Signal	Sine/cosine differential
	Transformation Ratio	0.45 – 0.8
	Excitation Frequency	8 kHz
	Input Voltage from Drive	6-22 Vpp
	Max. DC Resistance	120 Ω (stator)
	Max. Drive Current	55 mA rms
	Output Voltage to Drive	10 Vpp
Sine Encoder	Signal	Sine/Cosine differential, with or without Halls
	Signal Level	1 Vpp @ 2.5 V
	Max. Input Frequency	100 kHz
	Protocols	EnDat 2.1, HIPERFACE
	Input Impedance	120 Ω
	Interpolation	Up to 65536 (16 bit)
	Effective Interpolation	Up to 16384 (14 bit)
Serial Encoder	Signal	Differential data and clock for synchronous encoders Data only for asynchronous encoders
	Protocols	Can be supported upon request: EnDat 2.2, BiSS-C, other SSI
Motor Temperature	Signal	Thermal resistor PTC or NTC, User-defined fault threshold

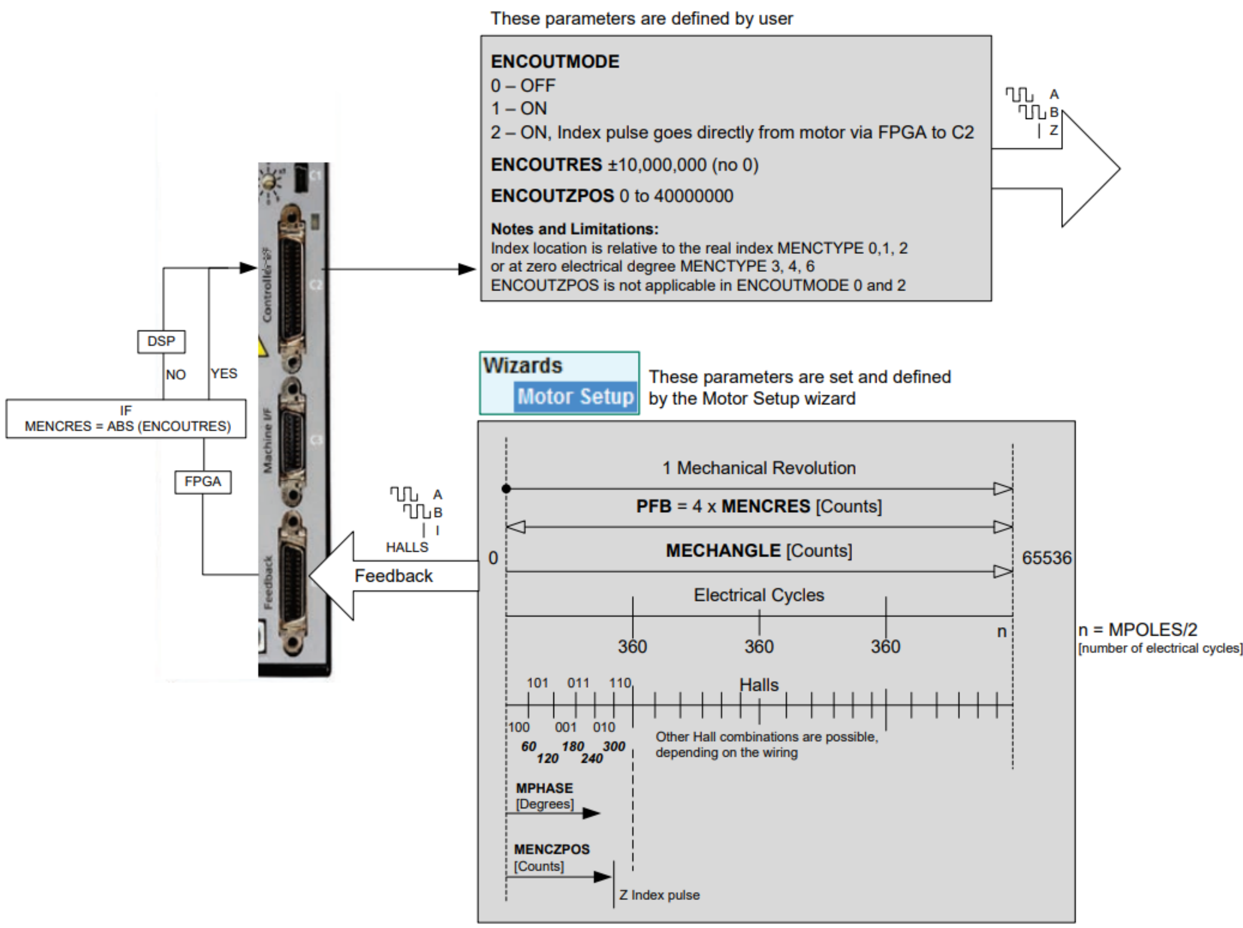
Encoder Index

Encoders often have an additional channel, referred to as a marker channel, zero pulse, or index channel. This channel outputs one pulse per revolution, and is typically an extremely narrow pulse equal to about one-quarter of the width of an A or B channel pulse, but may be wider. The encoder index can be used for homing (absolute position reference) and for commutation alignment.

You can also use the command **Find Index** in the ServoStudio **Motor Feedback** screen to determine the position of the index signal.

The following parameter is used to set and monitor the encoder index.

VarCom	Description
MENCZPOS	The encoder index position.



6.6.2 Motor Revolutions Required for Calibration

If your application has limited travel, you can run the motor back and forth 128 times. The length of each of these 128 movements must be at least 1.5 sine cycles. If running the motor in one direction, the number of revolutions required for the calibration is calculated as follows:

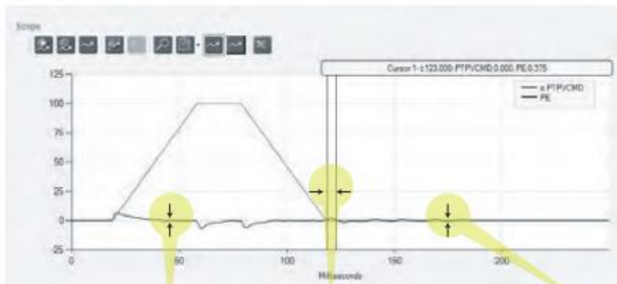
Resolver: $128 \div \frac{\text{MRESPOLES}}{2}$

> Where MENRESPOLES is the number of individual poles in the resolver feedback device.

For example, if MRESPOLES=4, the motor needs to make 64 revolutions for calibration.

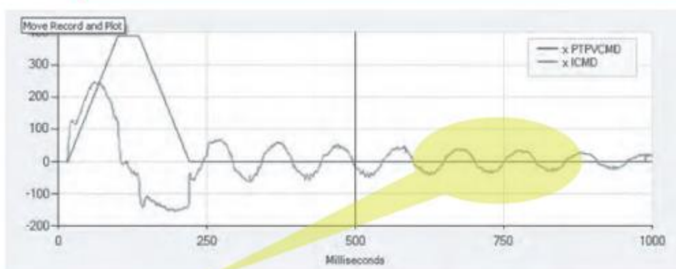
New current loop design achieves an industry-leading frequency response of 3-5 kHz
High sampling rates and flexible filtering options provide a faster response, and ensure maximum machine accuracy and throughput.

Advanced autotuning minimizes position error and settling time to almost zero
Engineering experience and expertise has been implemented in a sophisticated autotuning function that performs optimal configurations for a difference making performance.

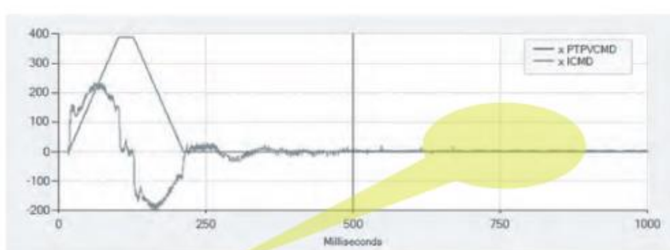


Minimum position error **Settling time of almost zero** **No oscillations at stand-still**

Innovative anti-vibration control algorithm eliminates mechanical resonance
An active non-linear algorithm eliminates vibration in highly flexible resonant systems. Commissioning is easy, using just a few gain parameters.



Without anti-vibe control



With anti-vibe control

ServoStudio™ wizard for simple commissioning in 4 steps
- Step-by-step guidance through the setup and tuning process
- Excellent results for novice users within minutes
- Real-time data recording and plotting
- Easy integration of servo axes
- Plug-and-play motor and feedback wiring

Communication:
CANopen®*
EtherCAT®*
USB*
RS232
Daisy Chain
PWM**

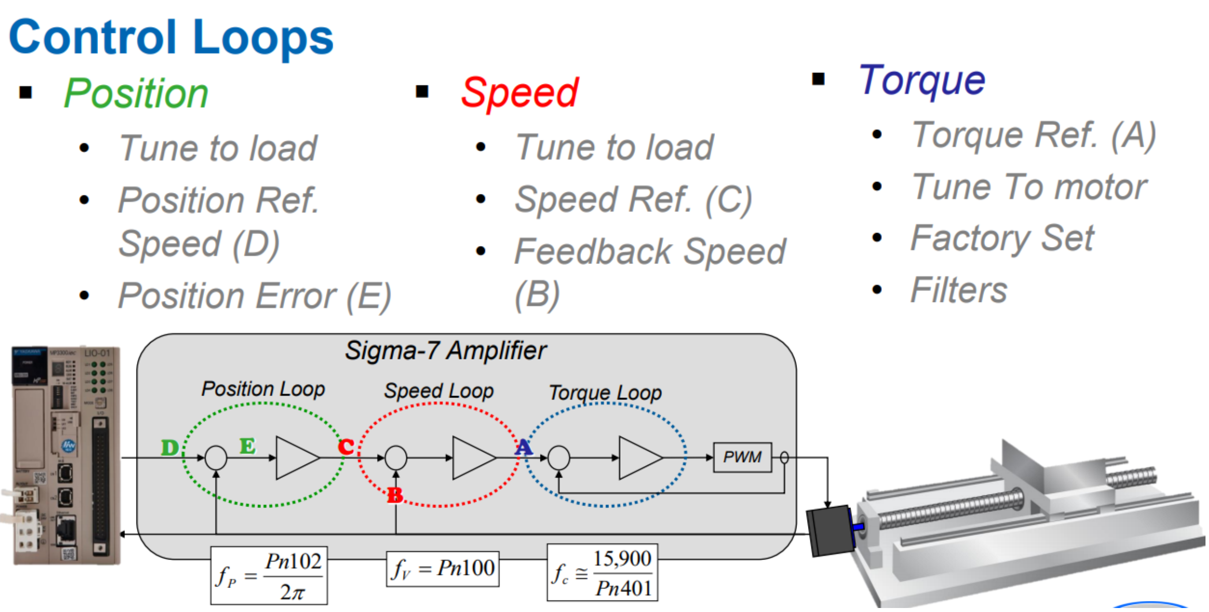
Motor feedback:
Incremental Encoder
Hall Sensors
Resolver*
Sine Encoder (e.g., EnDat®, HIPERFACE®)
sensAR absolute encoder
SSI Encoder (e.g., EnDat®, Nikon®, Tamagawa®)
Motor Temperature

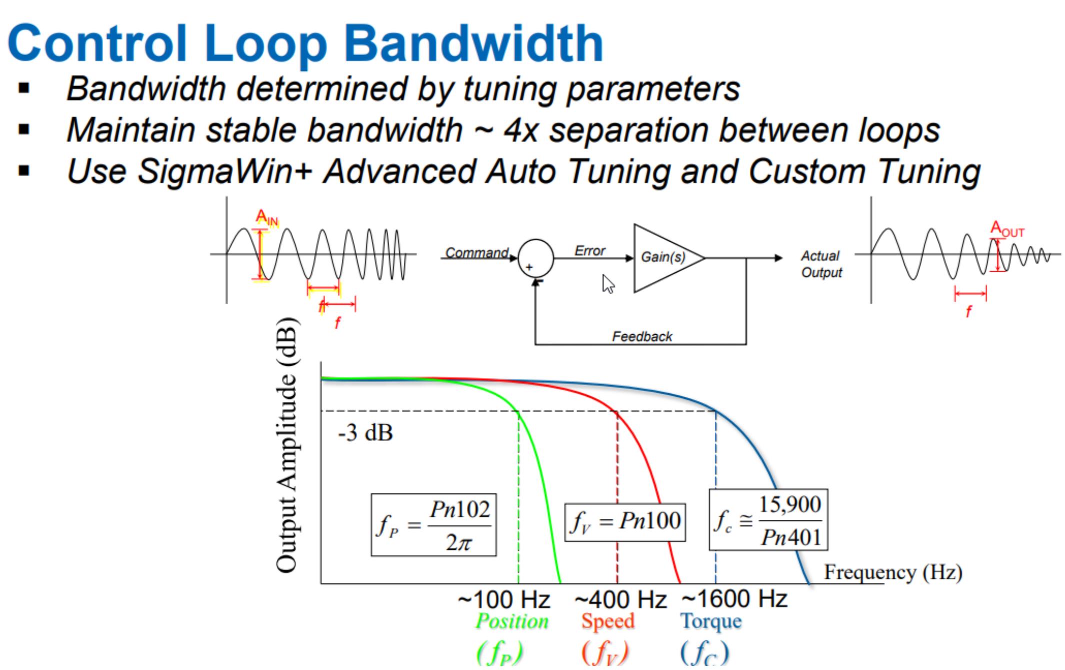
I/Os:*
Digital: 11 x Input, 6 x Output
Analog: 1 x Input or 2 x Input*, 1 x Output
Pulse & Direction
Equivalent Encoder Output
Secondary Feedback
Fault Output Relay

*Some features are not available on all models. |**Power block only, without motor feedback and I/Os

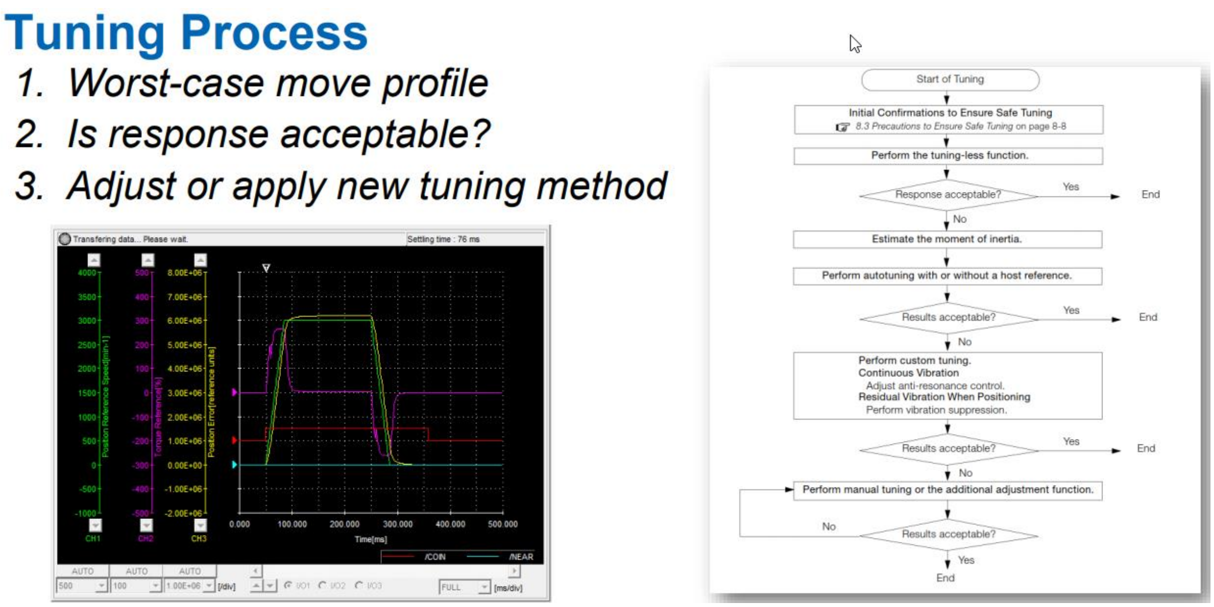
3 Sigma7 Servo

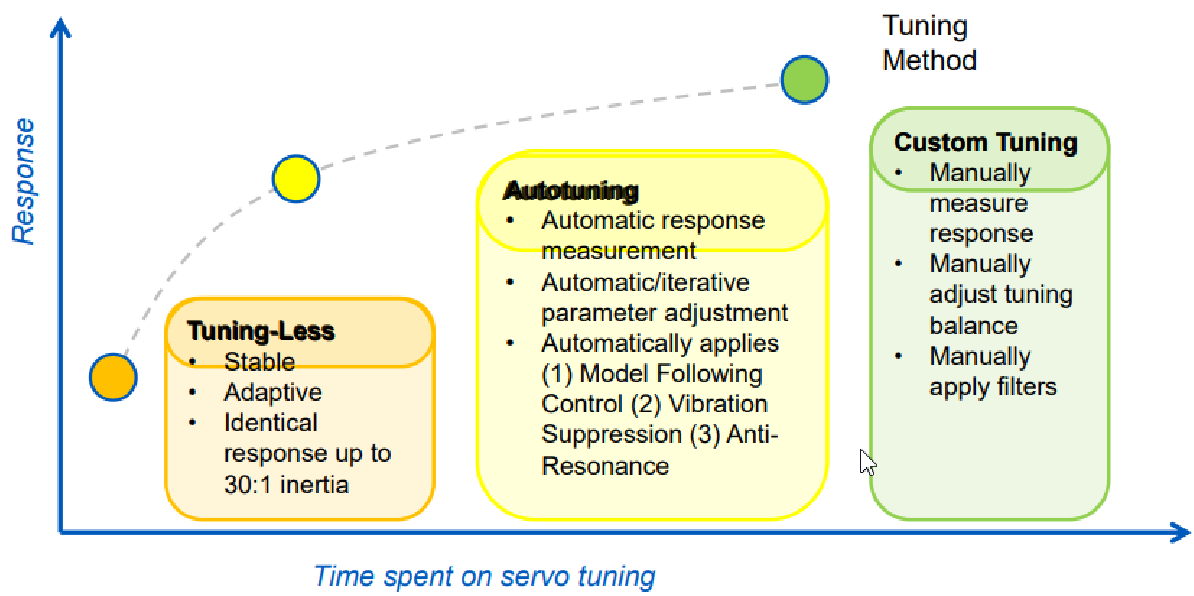
SGD7S Sigma 7 Servolar için öne çıkarılan özellikler aşağıdaki gibi listelenmiştir. Farklı haberleşme ve farklı güç seçenekleri olsa da servoların temel özellikleri aynıdır.





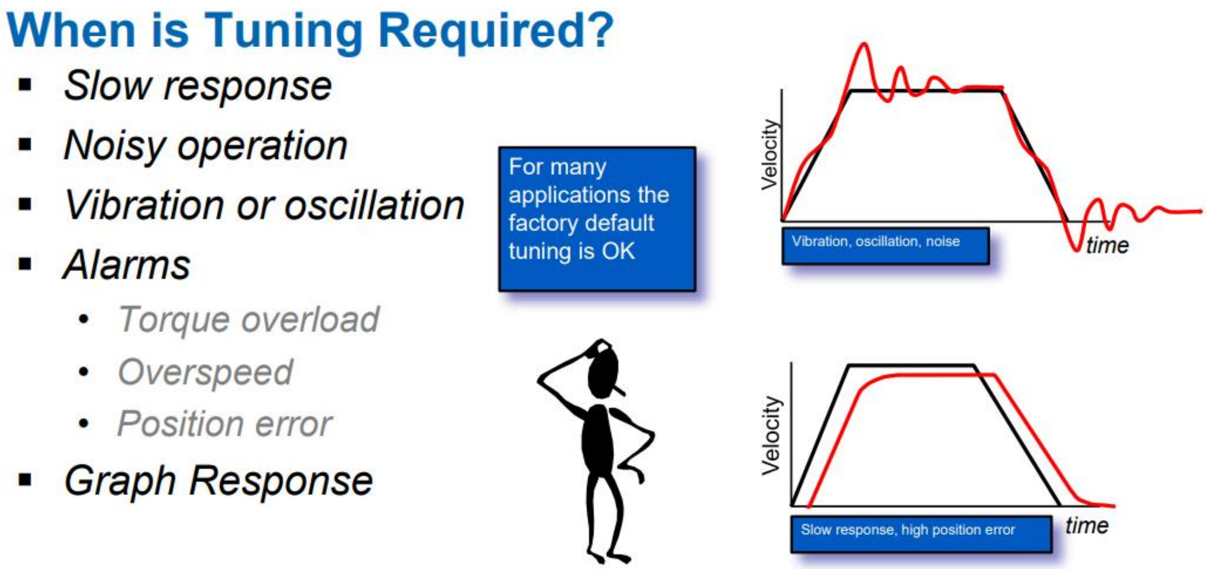
- Tuning Prosesi ve üç farklı tüne seçeneği sunmuştur.

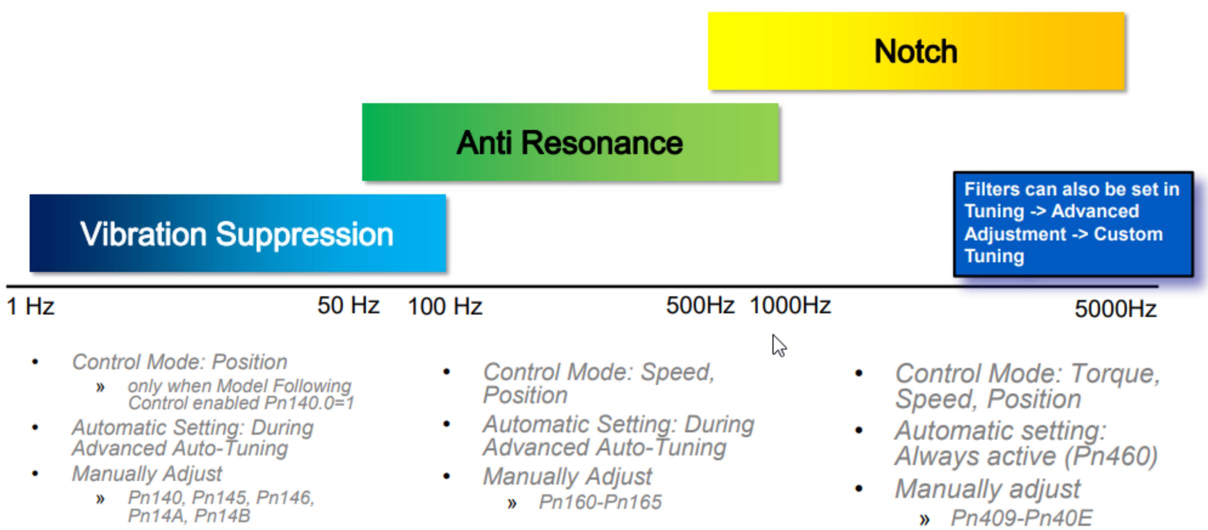




Şekil 1 : Tuning Seçenekleri

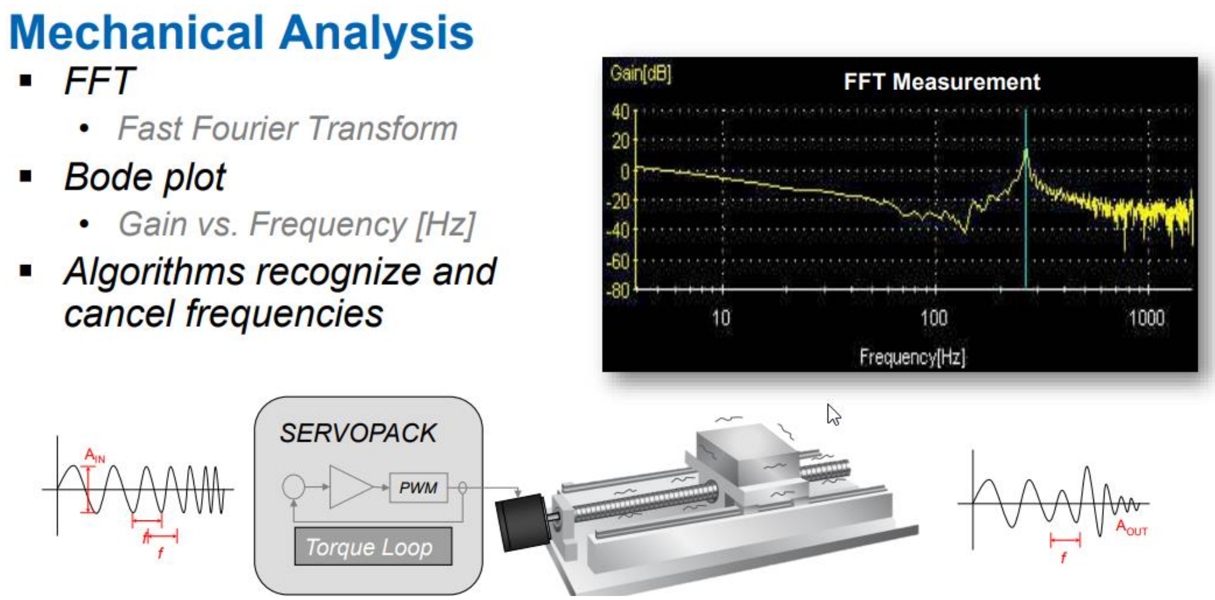
- Tuning sürecinde tüm sistemi ele almaktadır. Kontrolörlerin tüne işlemi, filtrelerin tüne işlemi ayrıca tüm bu detayları kullanıcıya açmıştır. Kullanıcı parametreleri görüp müdahale edebilmektedir.

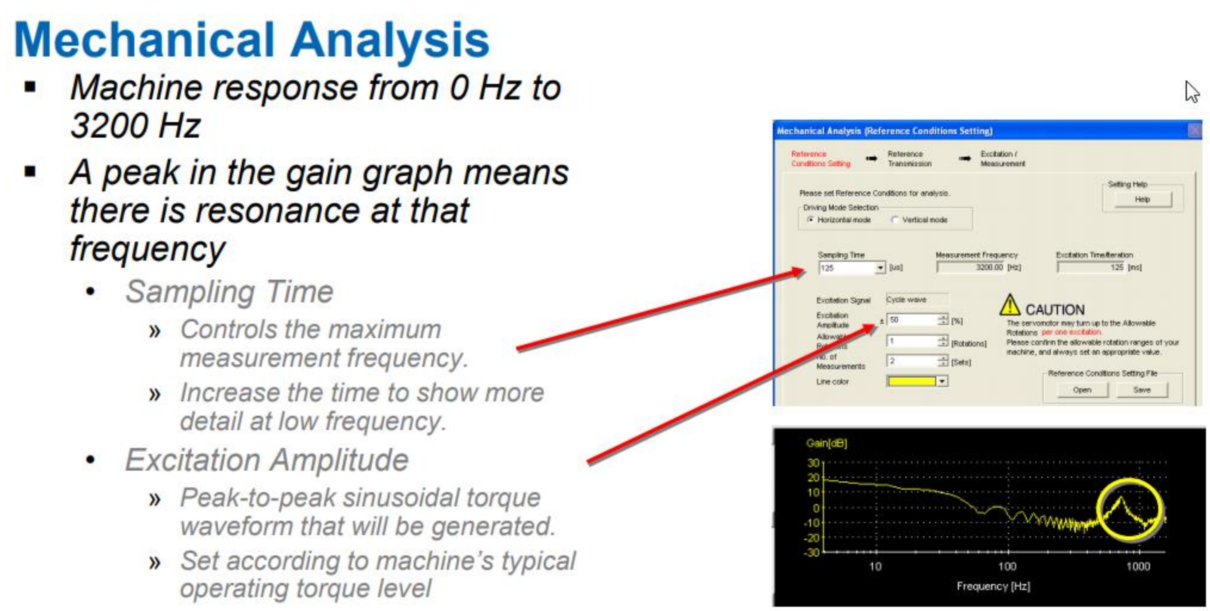




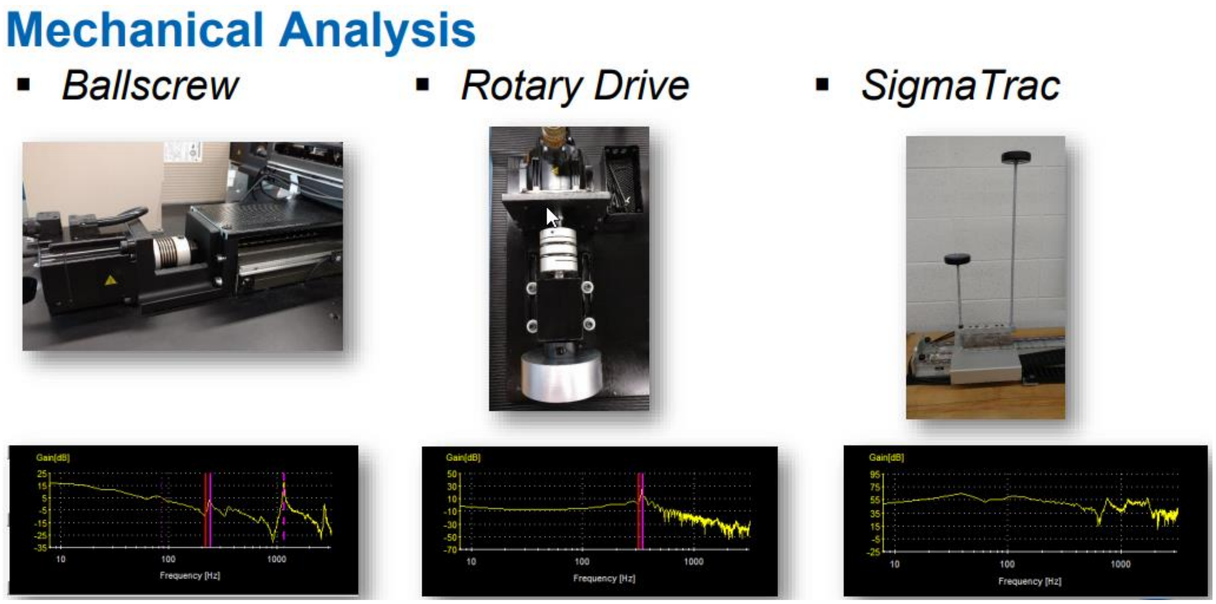
Şekil 2 : Filtrelerin etkili olduğu bölgeler ve modlar

- FFT işleminin işlemcide mi yoksa bilgisayarda mı yapıldığına dair bir detay bulunanamamıştır.





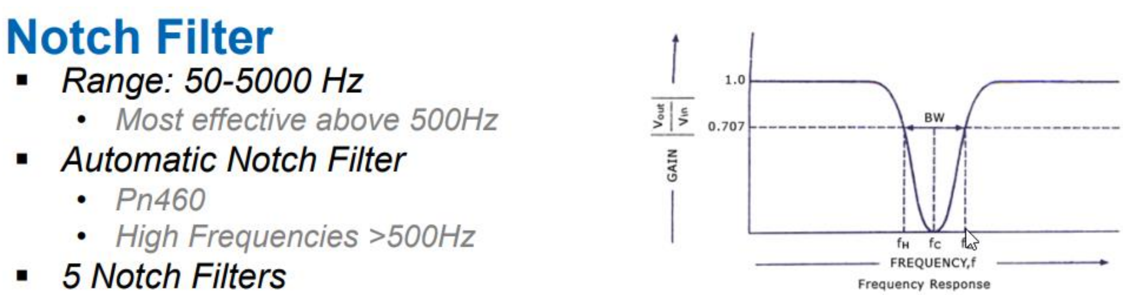
Şekil 3 : Mekanik analiz

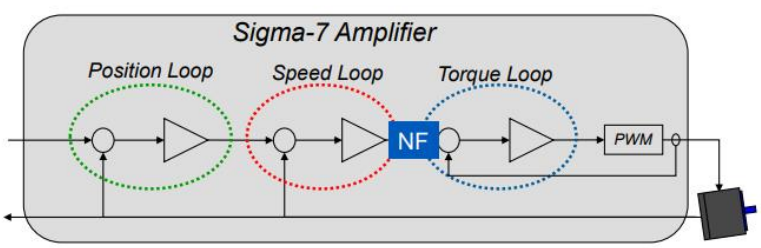


Şekil 4 : Farklı uygulamaların mekanik analizleri

3.1 Notch Filter

Yaskawa beş ayrı notch filter'ı frekans ve gain'i ayarlanabilecek şekilde sunmaktadır.

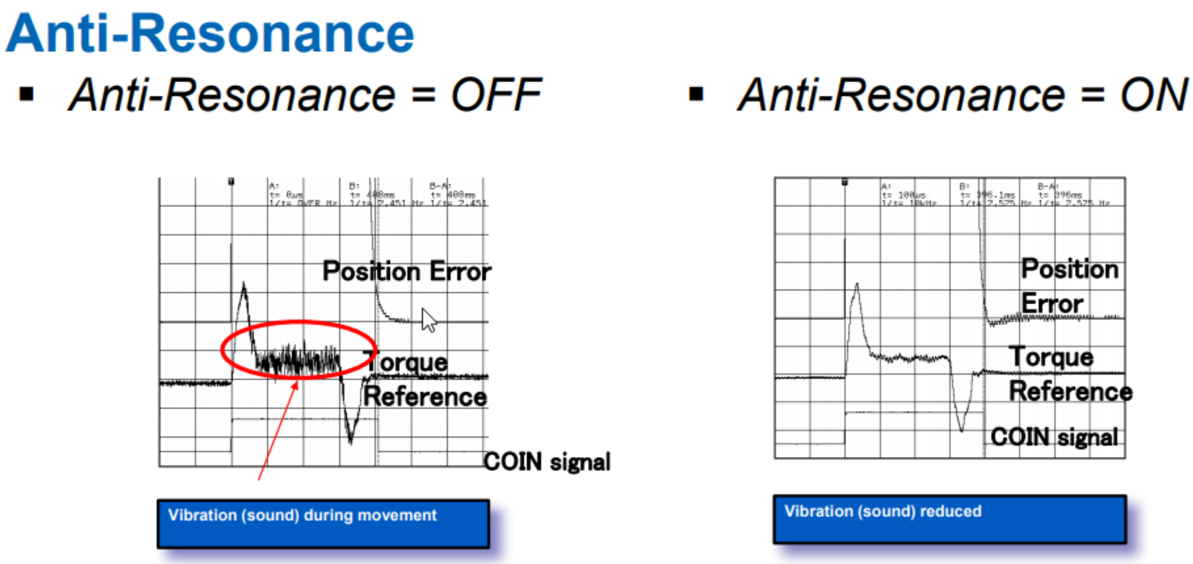


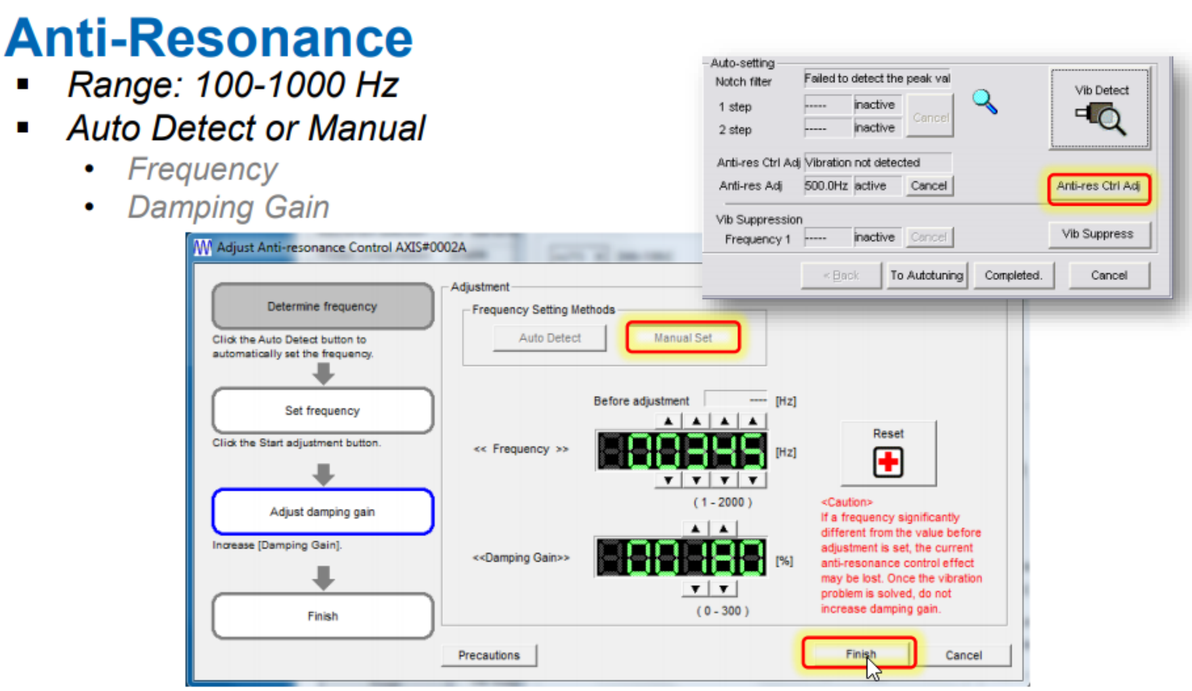


Şekil 5 : Tork referansı notch filter

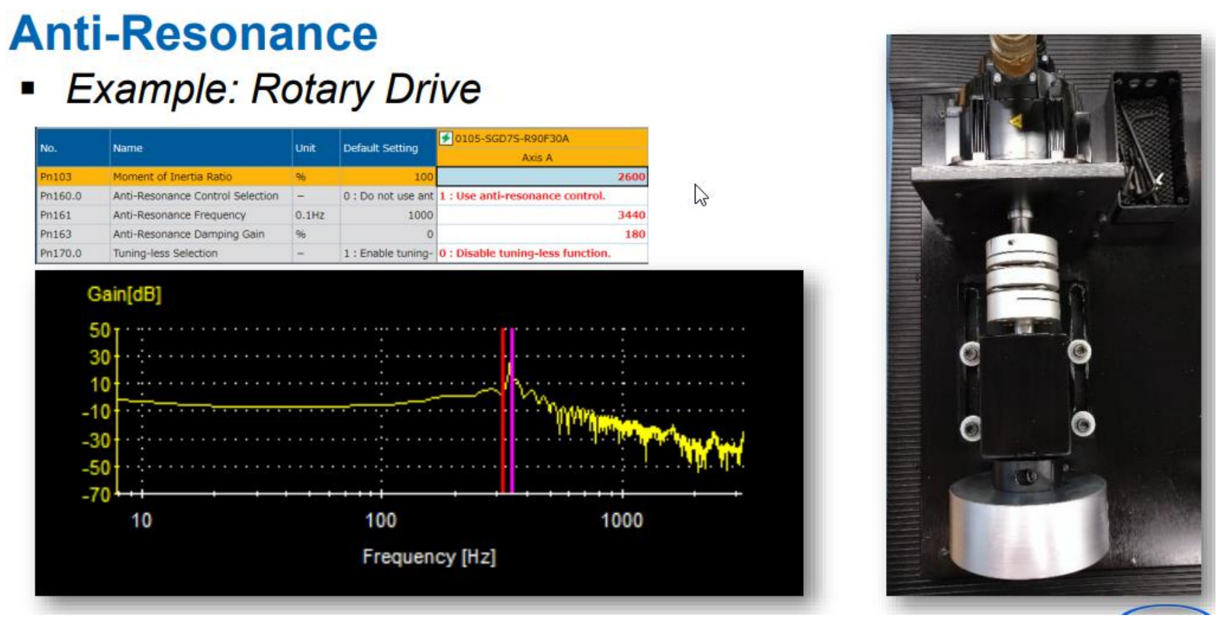
3.2 Anti Resonance Özelliği

Tork referansına uygulanan bir diğer filtre olarak görülmektedir. Kullanıcıya tüne edilebilir form'da sunmaktadır.



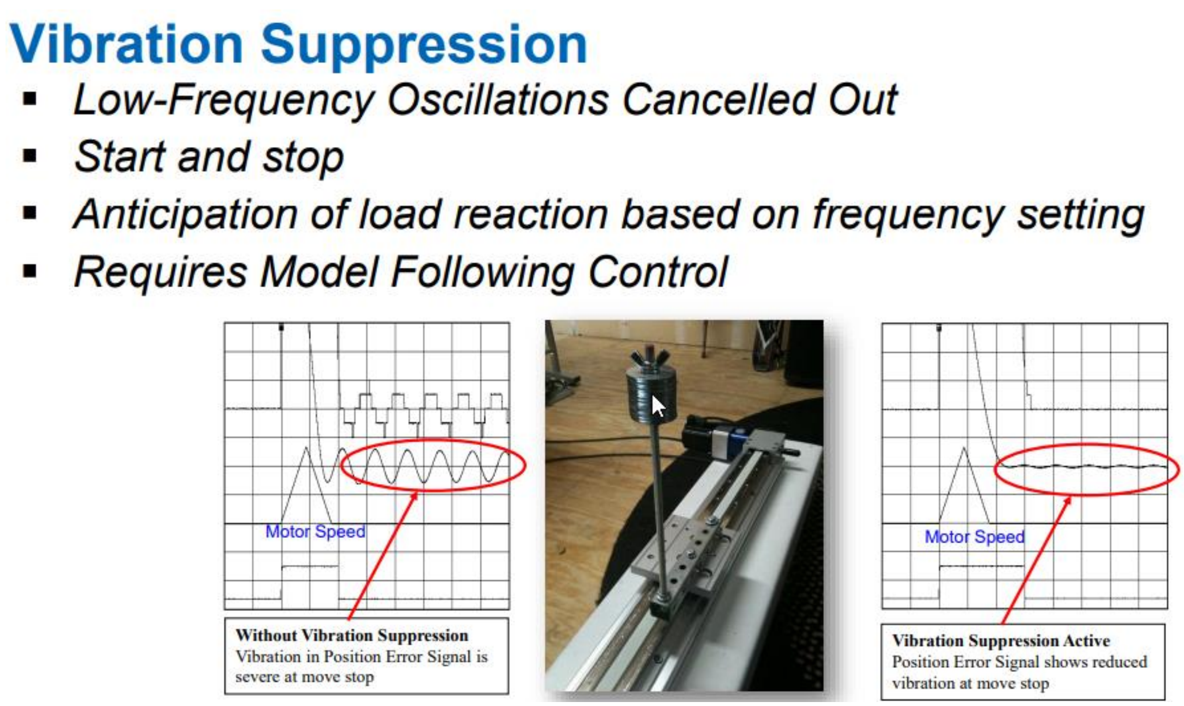


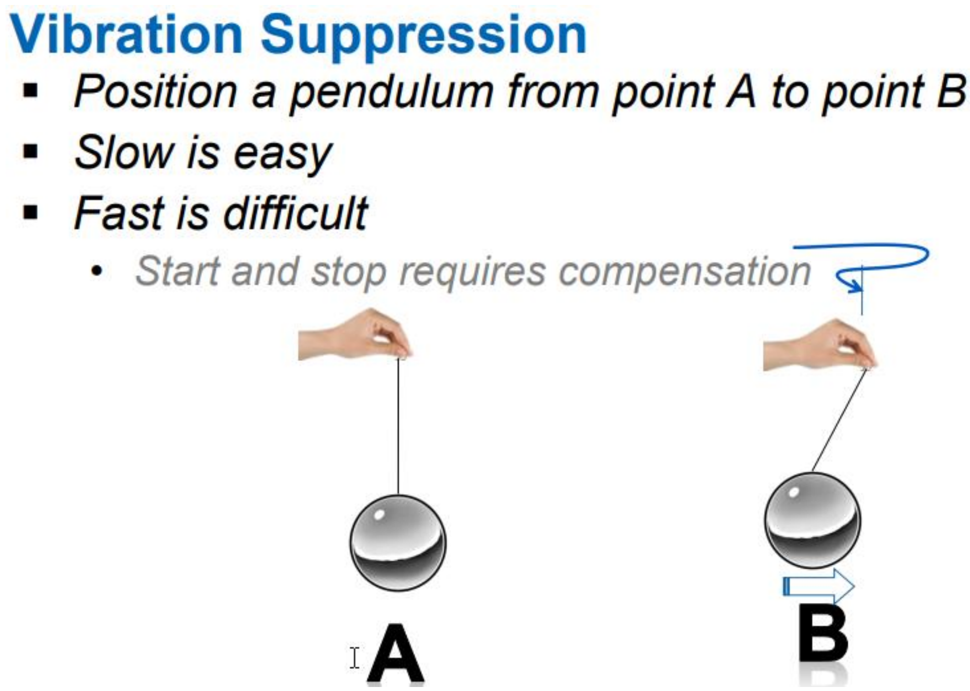
Şekil 6 : Antiresonance filter

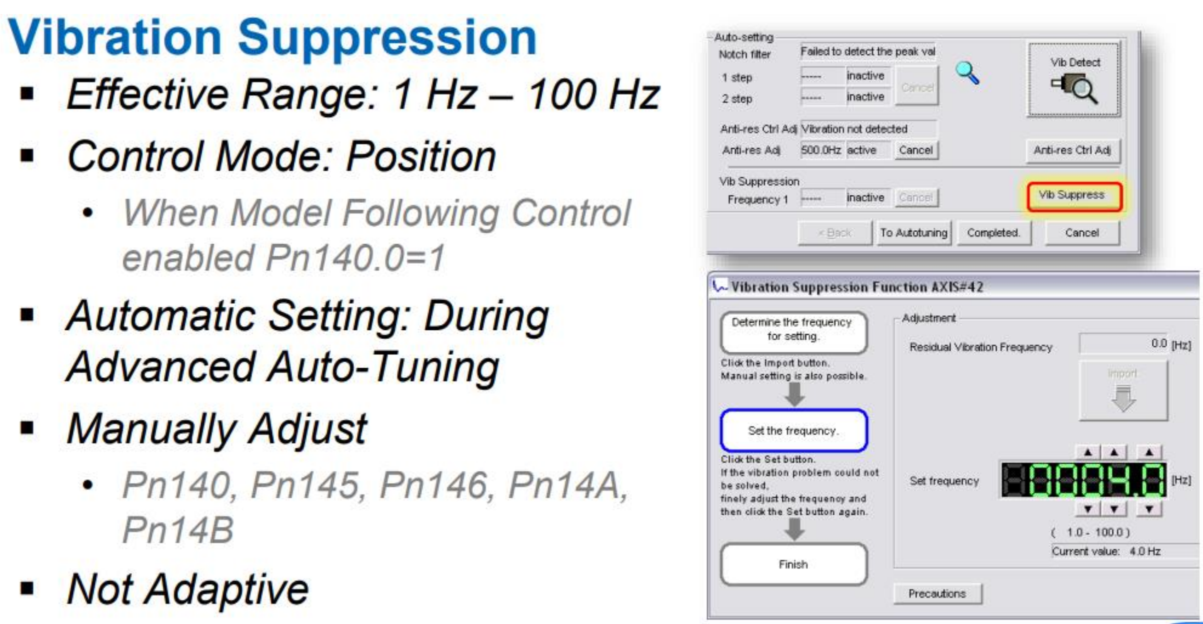


3.3 Vibration Supression

Özellikle duruş-kalkış, ivmeli hareketlerdeki salınımları bastırmak için kullanılmıştır. MFC tabanlı adaptif bir yöntem olduğu görülmüştür.





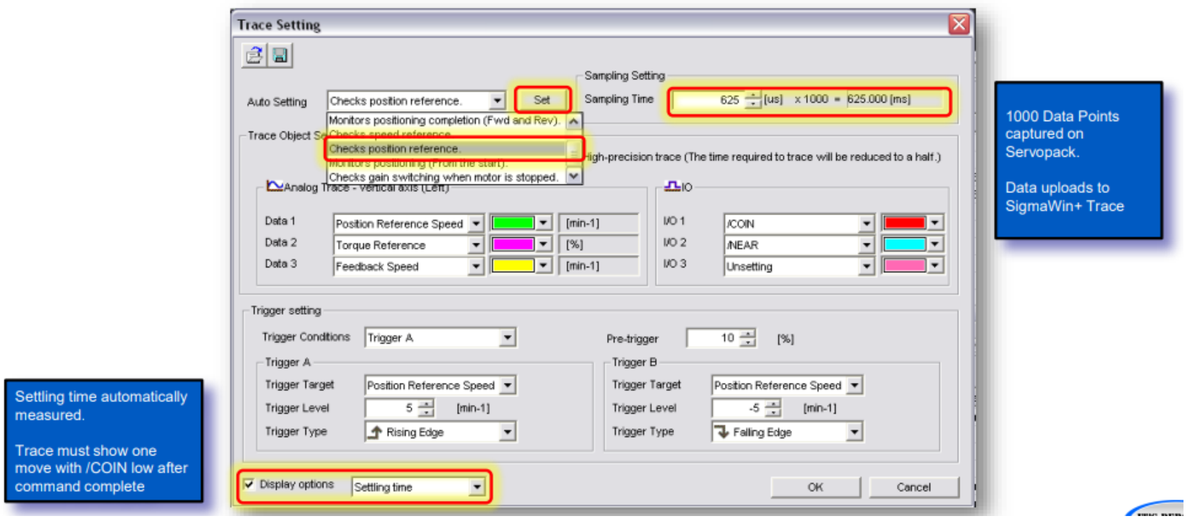


Şekil 7 : Vibration supression

3.4 Trace Tool

Trace tool'u istenen parametreleri store edip gui'ye yollamaktadır. Trigger gibi seçenekleride bulunmaktadır.

Trace Setup



3.4.1 Sigma-7 Servo Tuning Tuning-Less

- Feedforward yapıda 62.5us'lik update hızı olduğundan bahsedilmiş 16khz'de bir kontrolörün çalıştığı çıkarımına sebep olabilir.

Tuning-Less

- Stable
- Adaptive
- Identical response up to 30:1 inertia

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

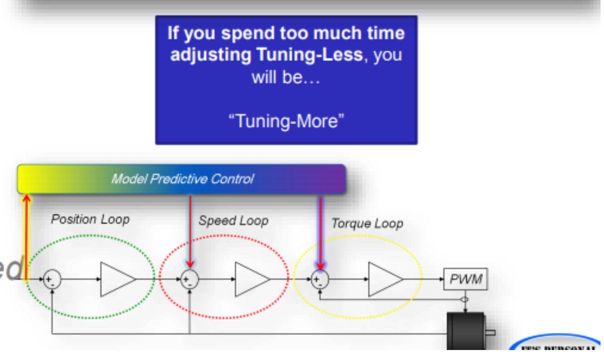
Feed-Forward

- *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*

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 ‹	–	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

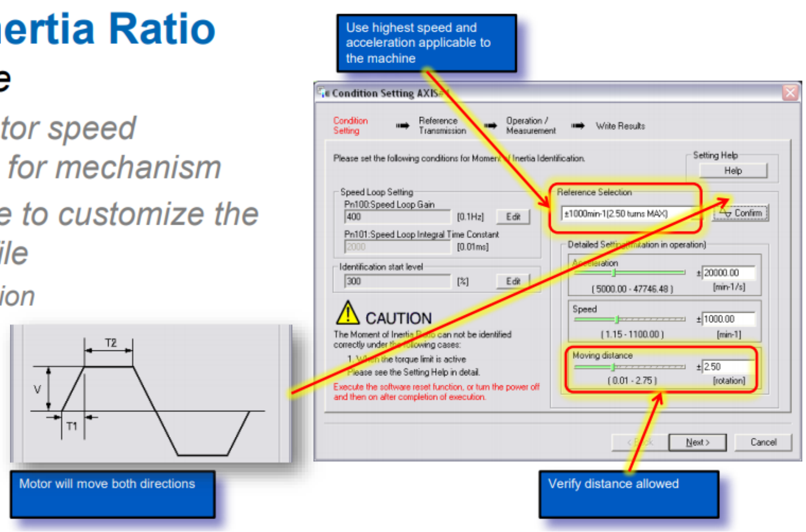


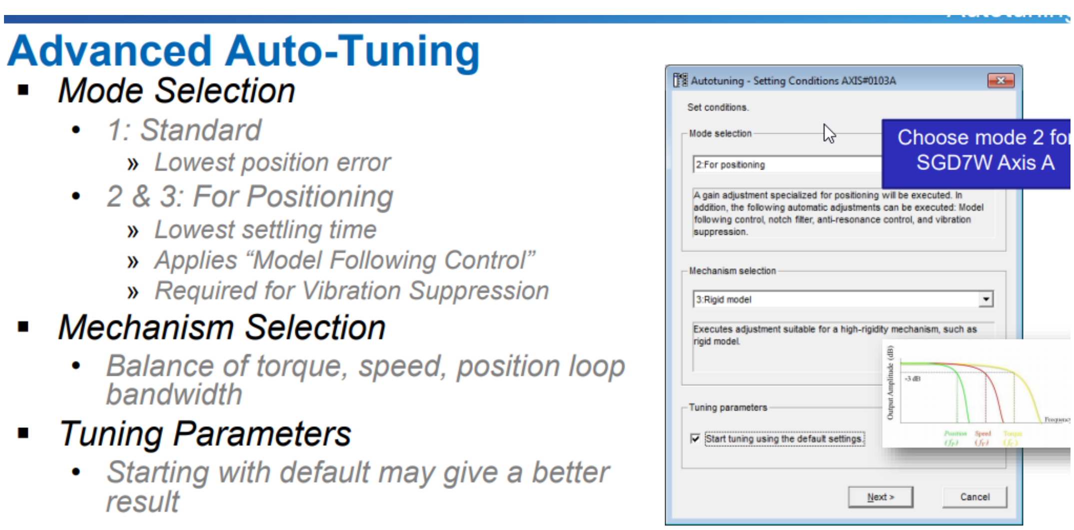
3.4.2 Autotuning

- Auto tune için profil tanımlaması yaptıktan sonra seçilen mod ile sistem parametreleri tune edilir.

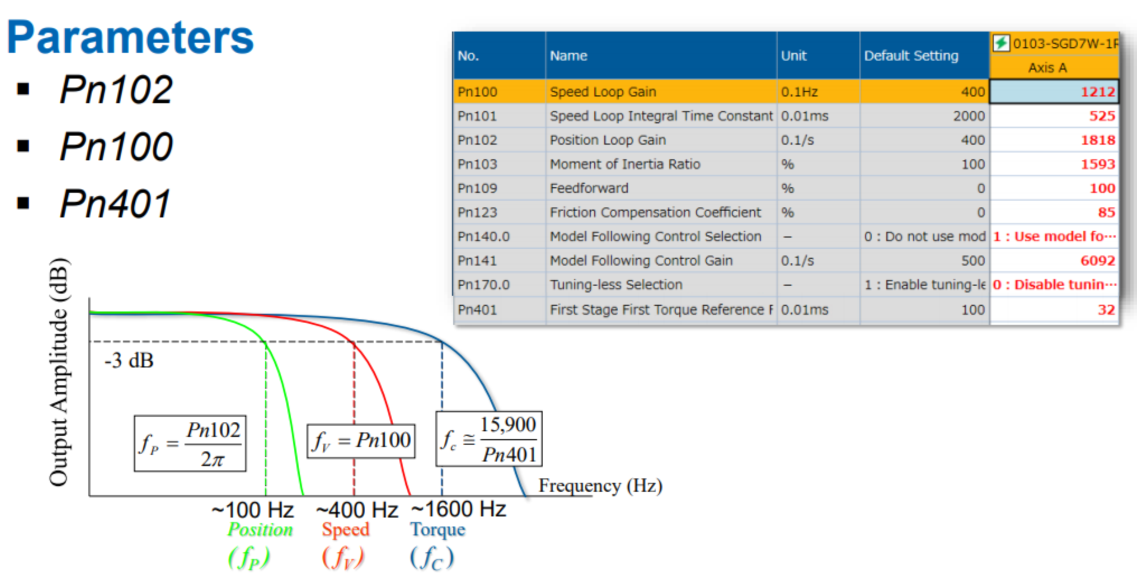
Moment of Inertia Ratio

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





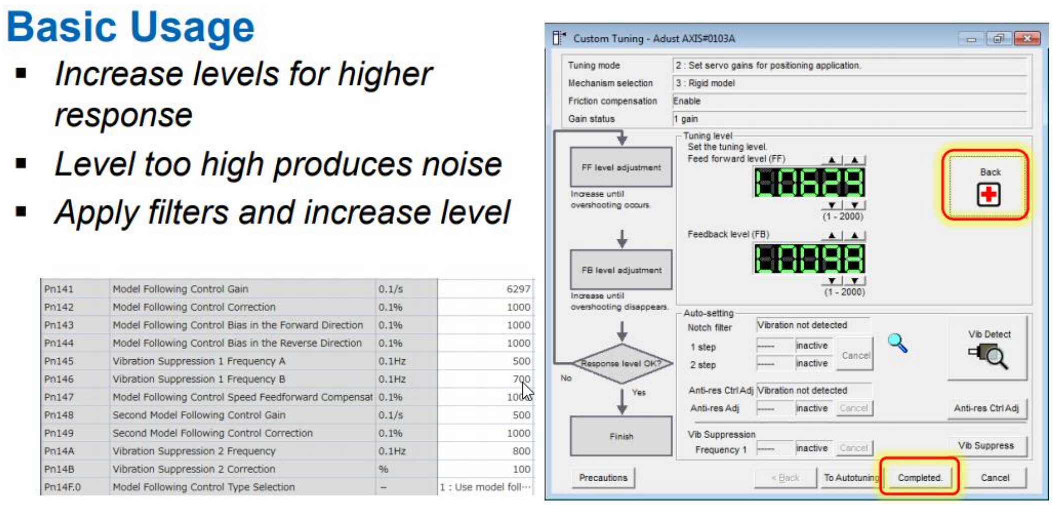
Şekil 8 : Advenced tuning seçenekleri

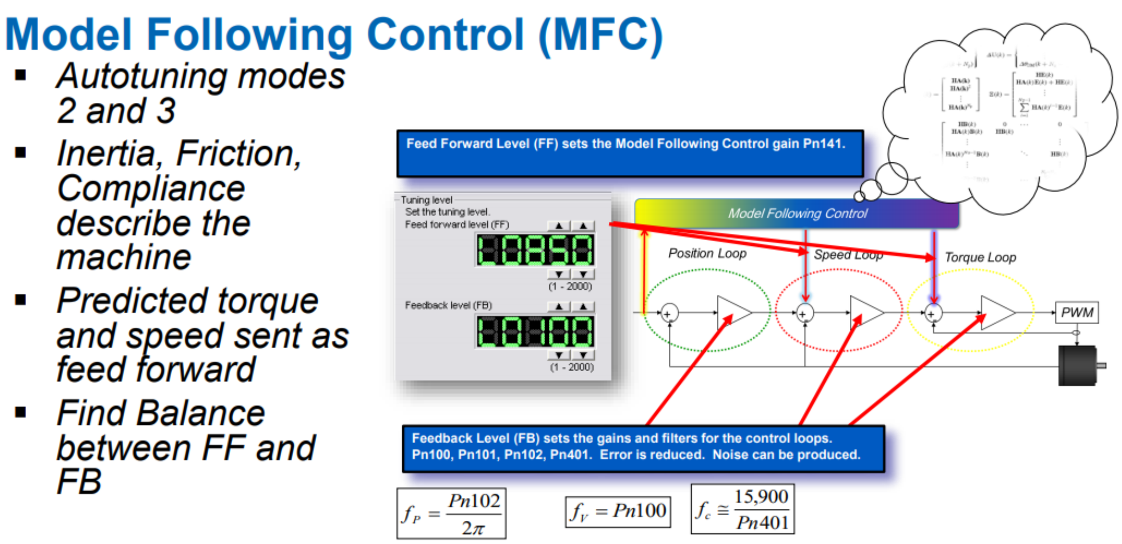


No.	Name	Unit	Default Setting	0103-SGD7W-1F Axis A
Pn100	Speed Loop Gain	0.1Hz	400	1212
Pn101	Speed Loop Integral Time Constant	0.01ms	2000	525
Pn102	Position Loop Gain	0.1/s	400	1818
Pn103	Moment of Inertia Ratio	%	100	1593
Pn109	Feedforward	%	0	100
Pn123	Friction Compensation Coefficient	%	0	85
Pn140.0	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

3.4.3 Custom Tuning

- Ayrıca sistem özel tune seçeneğinede olanak vermektedir. Parametre setine el ile erişilip düzeltilebilir.

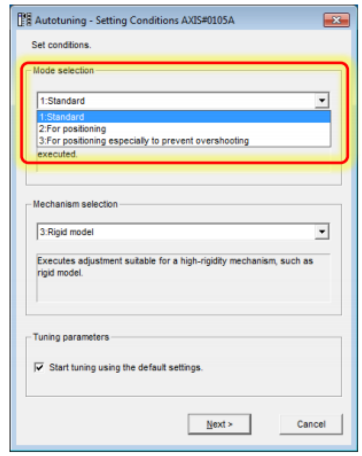




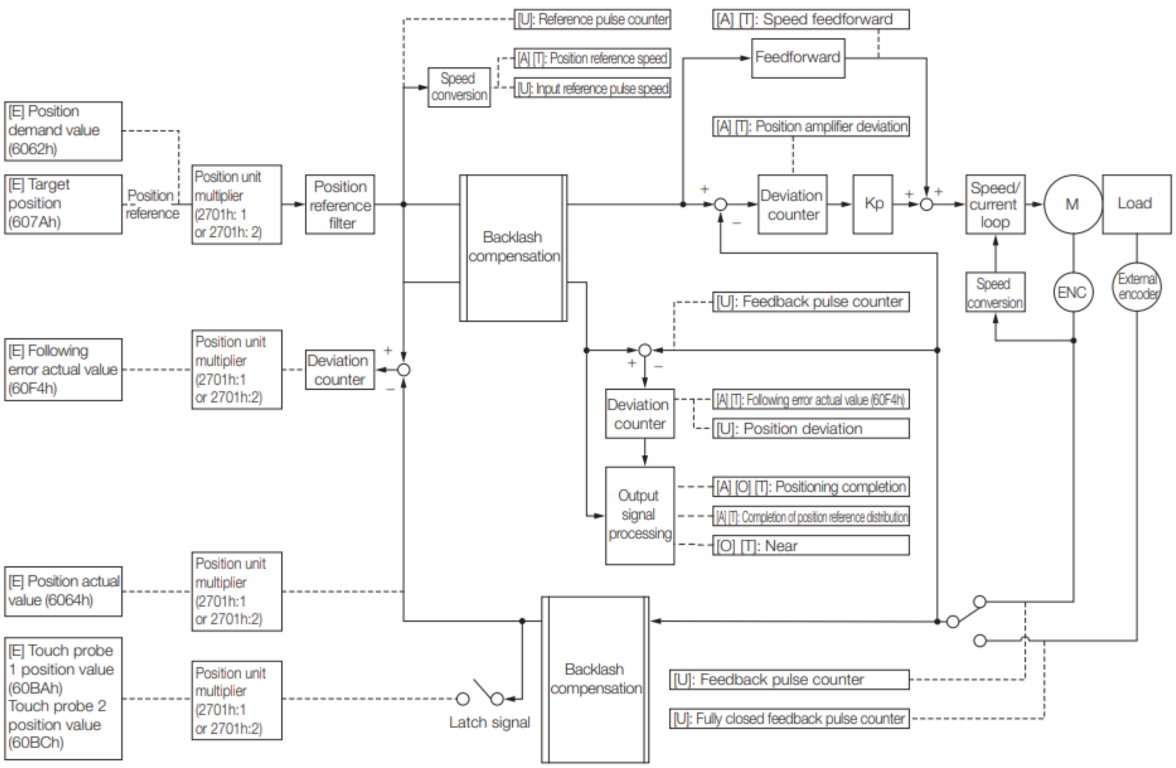
Şekil 9 : MFC

Autotuning Modes

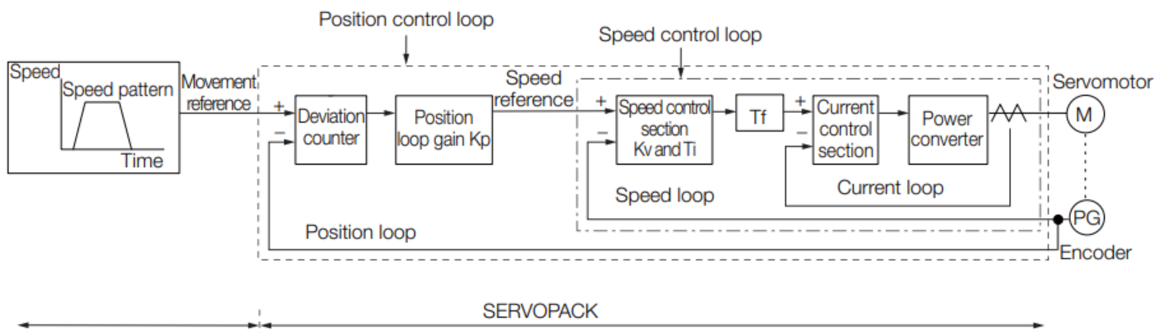
Item	Mode 1 (Standard)	Mode 2, 3 (Positioning)
Low Settling Time	Good	BEST
Low Position Error	BEST	OK
Electronic Cam	BEST	Good
Point-To-Point	Good	BEST
Model Following	Not Available	Used
Vibration Suppression	Not Available	Available
Anti-Resonance	Available	Available
Notch Filter	Available	Available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



Şekil 10 : Autotune metotlarının avantaj/dezavantajları



Servo Gains

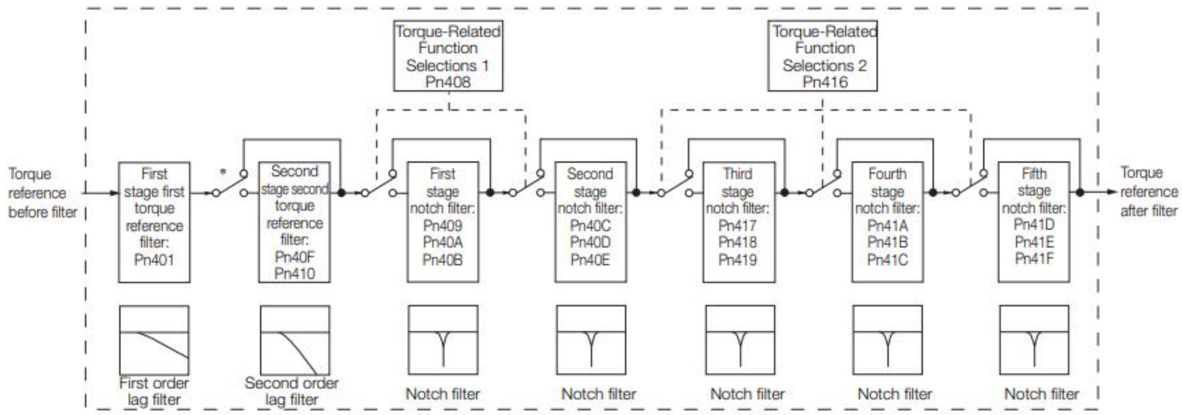


Kp: Position loop gain (Pn102)
Kv: Speed loop gain (Pn100)
Ti: Speed loop integral time constant (Pn101)
Tf: First stage first torque reference filter time constant (Pn401)

◆ Torque Reference Filter

As shown in the following diagram, the torque reference filter contains a first order lag filter and notch filters arranged in series, and each filter operates independently.

The notch filters can be enabled and disabled with Pn408 = n.□X□X and Pn416 = n.□XXX.



* The second stage second torque reference filter is disabled when Pn40F is set to 5,000 (default setting) and it is enabled when Pn40F is set to a value lower than 5,000.

■ Torque Reference Filter

If you suspect that machine vibration is being caused by the Servo Drive, try adjusting the torque reference filter time constant. This may stop the vibration. The lower the value, the better the control response characteristic will be, but there may be a limit depending on the machine conditions.

Pn401 (2401h)	First Stage First Torque Reference Filter Time Constant				Speed Position Torque
	Setting Range	Setting Unit	Default Setting	When Enabled	Classification
	0 to 65,535	0.01 ms	100	Immediately	Tuning
Pn40F (240Fh)	Second Stage Second Torque Reference Filter Frequency				Speed Position Torque
	Setting Range	Setting Unit	Default Setting	When Enabled	Classification
	100 to 5,000	1 Hz	5,000*	Immediately	Tuning
Pn410 (2410h)	Second Stage Second Torque Reference Filter Q Value				Speed Position Torque
	Setting Range	Setting Unit	Default Setting	When Enabled	Classification
	50 to 100	0.01	50	Immediately	Tuning

* The filter is disabled if you set the parameter to 5,000.

■ Notch Filters

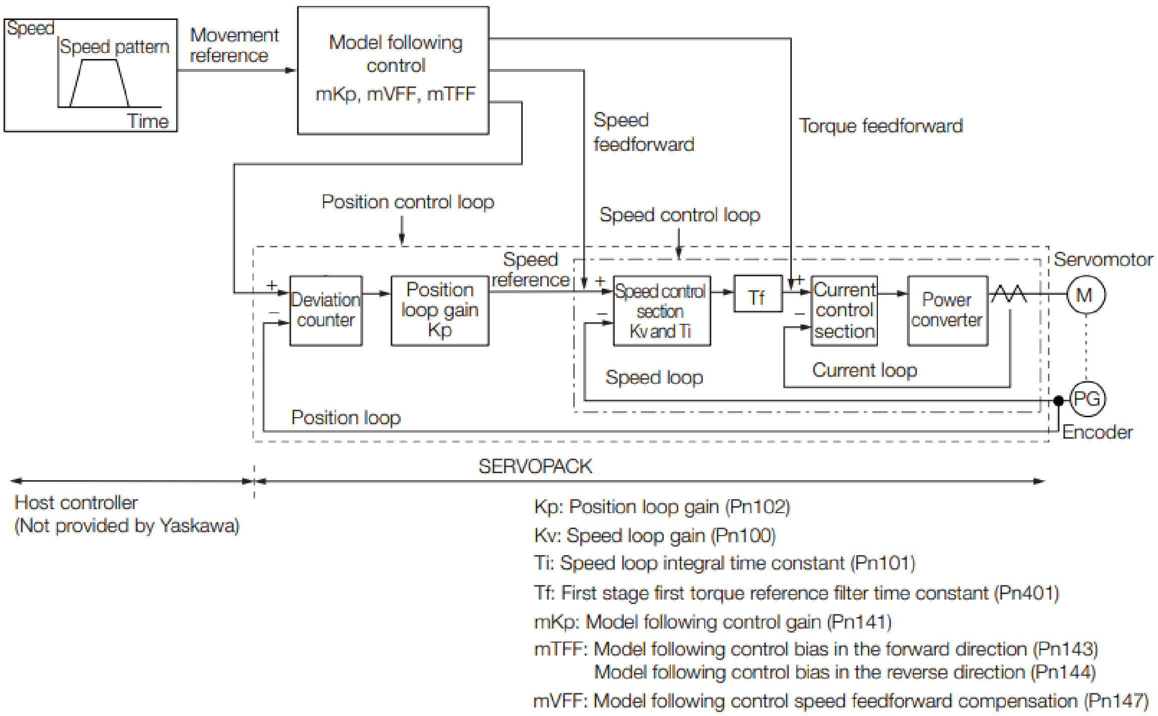
The notch filter can eliminate specific frequency elements generated by the vibration of sources such as resonance of the shaft of a ball screw.

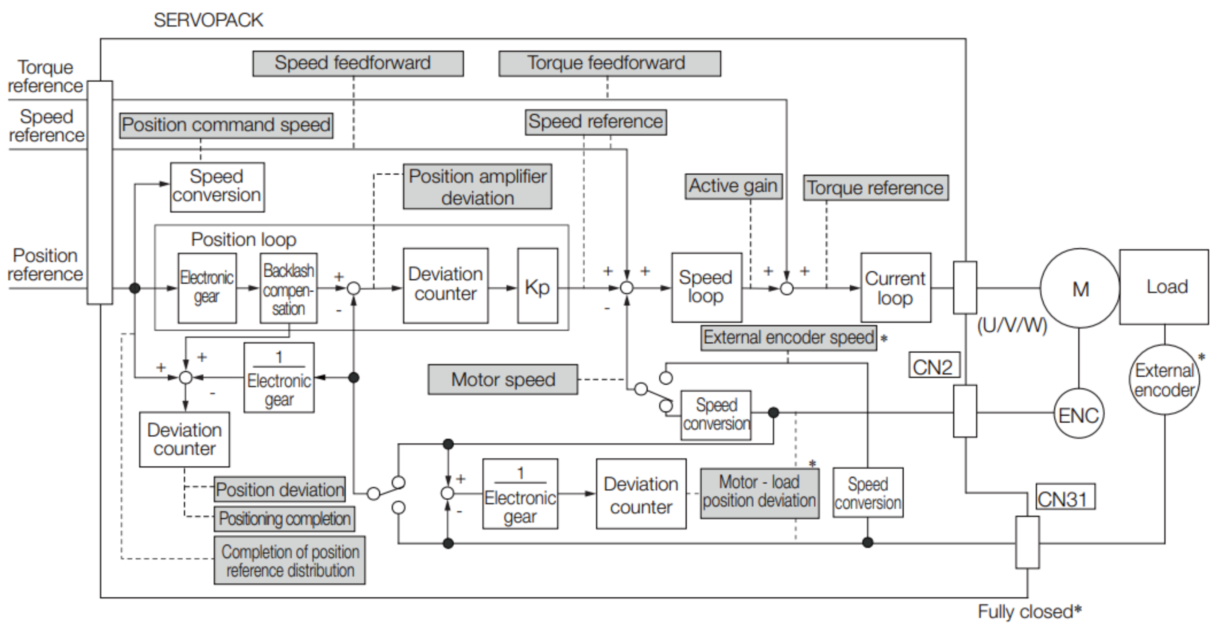
The notch filter puts a notch in the gain curve at the specific vibration frequency (called the notch frequency). The frequency components near the notch frequency can be reduced or removed with a notch filter.

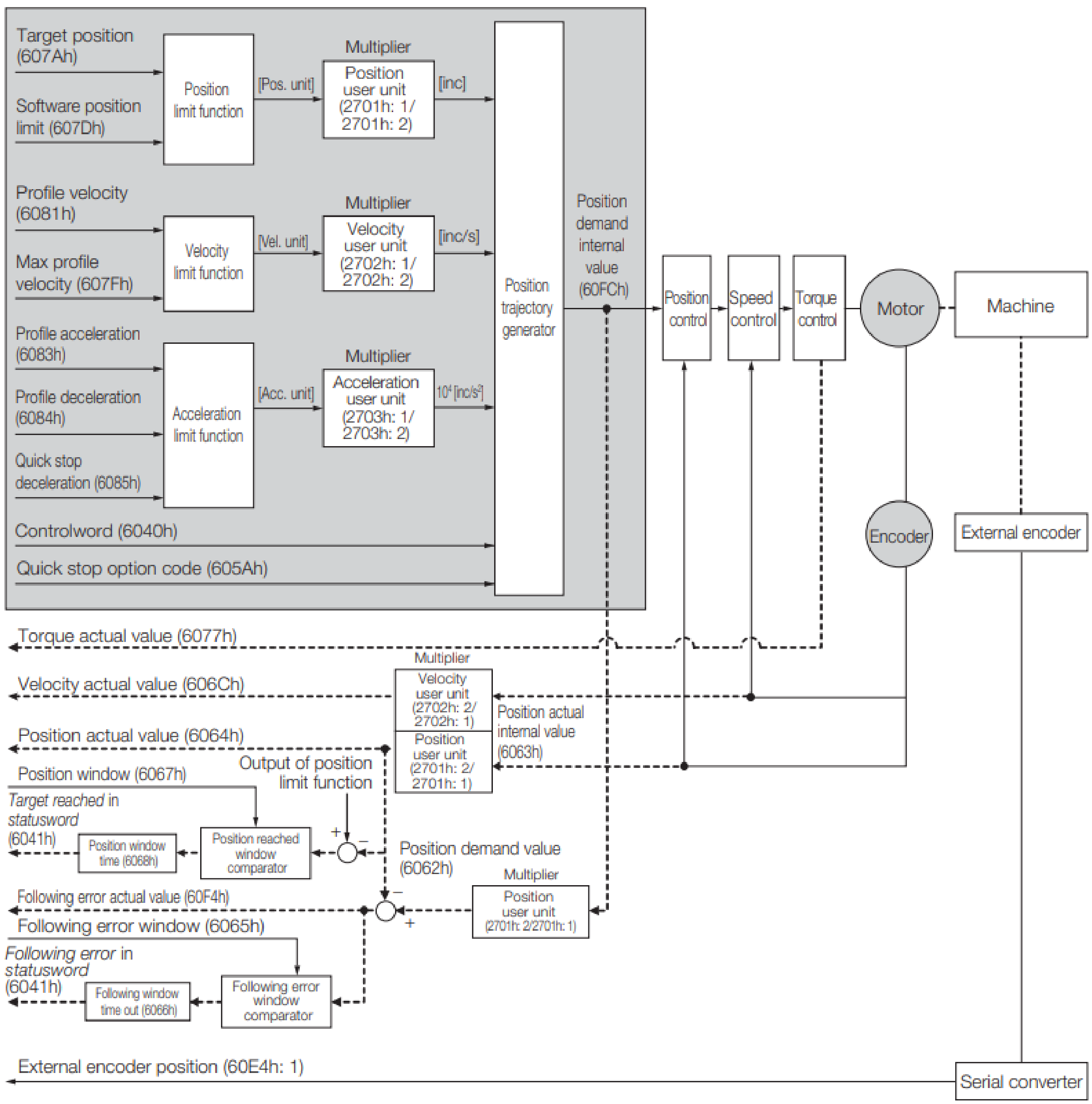
Notch filters are set with three parameters for the notch filter frequency, notch filter Q value, and notch filter depth. This section describes the notch filter Q value and notch filter depth.

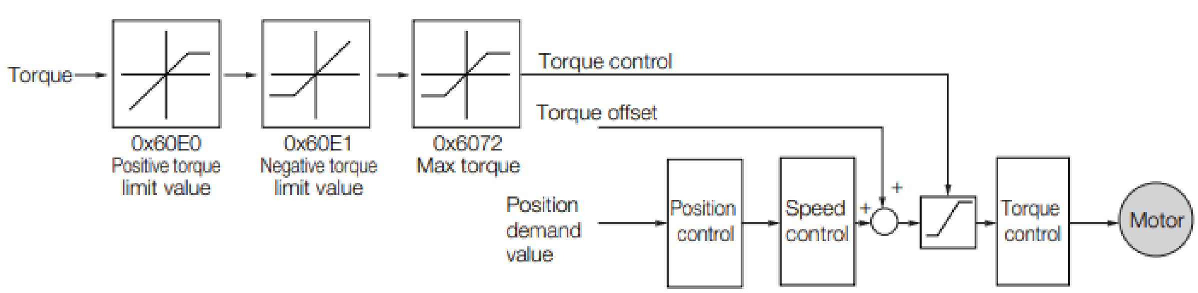
• **Notch filter Q Value**

The setting of the notch filter Q value determines the width of the frequencies that are filtered for the notch filter frequency. The width of the notch changes with the notch filter Q value. The larger the notch filter Q value is, the steeper the notch is and the narrower the width of frequencies that are filtered is.


Speed
Speed pattern
Time
Movement reference
Model following control
mKp, mVFF, mTFF
Speed feedforward
Torque feedforward
Position control loop
Speed control loop
Speed reference
Servomotor
Deviation counter
Position loop gain Kp
Speed control section Kv and Ti
Tf
Current control section
Power converter
M
Speed loop
Current loop
PG
Position loop
Encoder
SERVOPACK
Host controller
(Not provided by Yaskawa)
Kp: Position loop gain (Pn102)
Kv: Speed loop gain (Pn100)
Ti: Speed loop integral time constant (Pn101)
Tf: First stage first torque reference filter time constant (Pn401)
mKp: Model following control gain (Pn141)
mTFF: Model following control bias in the forward direction (Pn143)
Model following control bias in the reverse direction (Pn144)
mVFF: Model following control speed feedforward compensation (Pn147)


SERVOPACK
Torque reference
Speed reference
Position reference
Speed feedforward
Torque feedforward
Position command speed
Speed reference
Speed conversion
Position amplifier deviation
Active gain
Torque reference
Position loop
Electronic gear
Backlash compen-sation
Deviation counter
Kp
Speed loop
Current loop
M
Load
(U/V/W)
External encoder speed *
CN2
1
Electronic gear
Deviation counter
Motor speed
Speed conversion
External encoder *
ENC
Position deviation
Positioning completion
Completion of position reference distribution
1
Electronic gear
Deviation counter
Motor - load position deviation *
Speed conversion
CN31
Fully closed*


Target position (607Ah)
Software position limit (607Dh)
Position limit function
[Pos. unit]
Multiplier
Position user unit (2701h: 1/ 2701h: 2)
[inc]
Profile velocity (6081h)
Max profile velocity (607Fh)
Velocity limit function
[Vel. unit]
Multiplier
Velocity user unit (2702h: 1/ 2702h: 2)
[inc/s]
Profile acceleration (6083h)
Profile deceleration (6084h)
Quick stop deceleration (6085h)
Acceleration limit function
[Acc. unit]
Multiplier
Acceleration user unit (2703h: 1/ 2703h: 2)
10⁴ [inc/s²]
Controlword (6040h)
Quick stop option code (605Ah)
Position trajectory generator
Position demand internal value (60FCh)
Position control
Speed control
Torque control
Motor
Machine
Encoder
External encoder
Torque actual value (6077h)
Multiplier
Velocity actual value (606Ch)
Velocity user unit (2702h: 2/ 2702h: 1)
Position actual value (6064h)
Position user unit (2701h: 2/ 2701h: 1)
Position actual internal value (6063h)
Position window (6067h)
Output of position limit function
Target reached in statusword (6041h)
Position window time (6068h)
Position reached window comparator
Position demand value (6062h)
Multiplier
Position user unit (2701h: 2/2701h: 1)
Following error actual value (60F4h)
Following error window (6065h)
Following error in statusword (6041h)
Following window time out (6066h)
Following error window comparator
External encoder position (60E4h: 1)
Serial converter

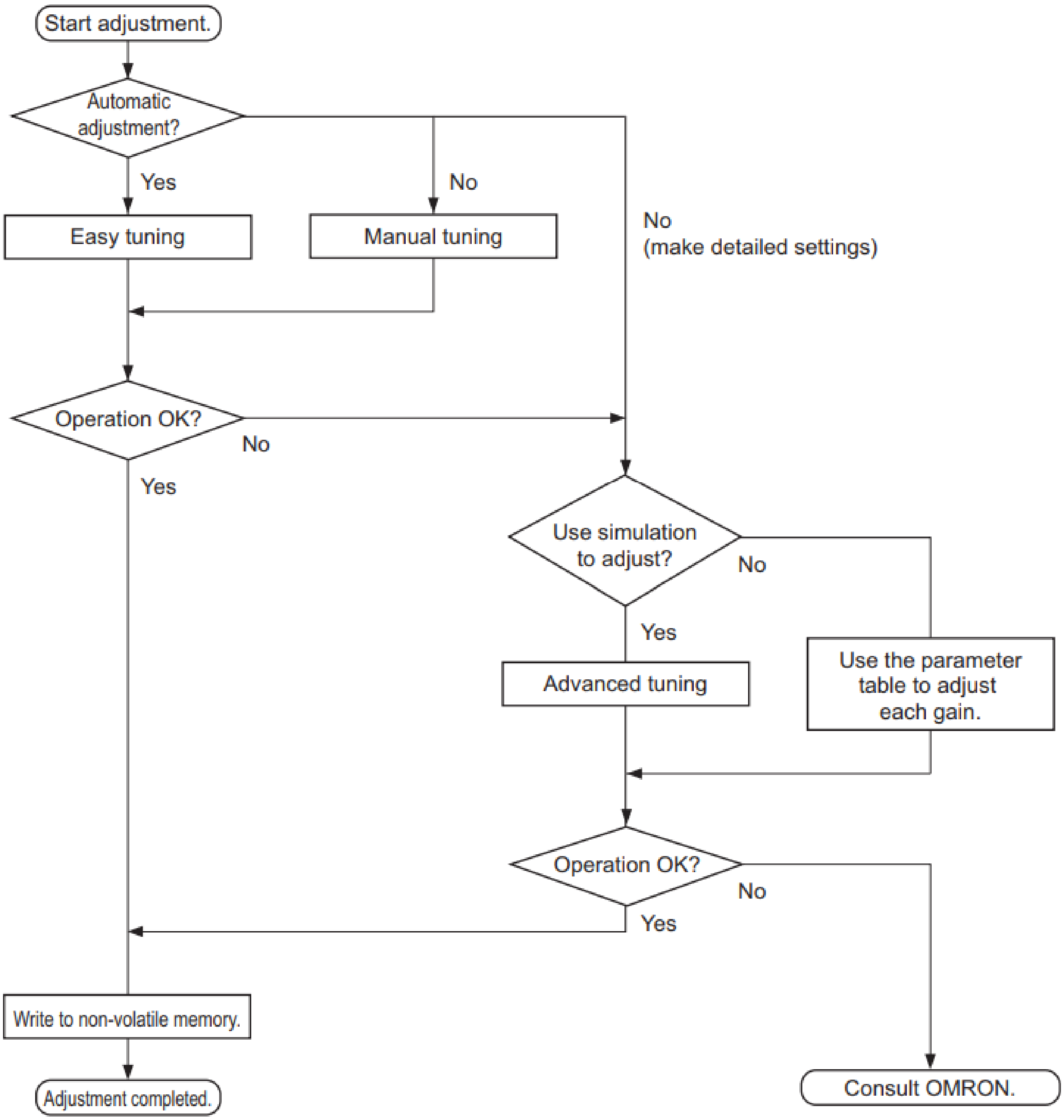

Torque
0x60E0 Positive torque limit value
0x60E1 Negative torque limit value
0x6072 Max torque
Torque control
Torque offset
Position demand value
Position control
Speed control
Torque control
Motor

4 Omron

Manuel içerisinde referanslar için kullanılan filtreler, özel fonksiyonlar ve bu fonksiyonların timing diyagramları vs bulunmaktadır. Detaylı bir manuel'e sahiptir.

Item	Description	Reference
Installation and mounting	Install the Servomotor and Servo Drive according to the installation conditions. Do not connect the Servomotor to mechanical systems before checking the operation without any load.	Section 4, 4-1
↓		
Wiring and connections	Connect the Servomotor and Servo Drive to the power supply and peripheral equipment. Satisfy specified installation and wiring conditions, particularly for models that conforms to the EU Directives.	Section 4, 4-2
↓		
Preparing for operation	Check the necessary items and then turn ON the commercial power supply. Check on the display to see whether there are any internal errors in the Servo Drive.	Section 10, 10-2
↓		
Function settings	Set the objects related to the functions required for application conditions.	Section 9
↓		
Test run	First, check motor operation without any load. Then turn the power supply OFF and connect the Servomotor to mechanical systems. When you use a Servomotor with an absolute encoder, set up the absolute encoder. Execute the Unit Restart or cycle the power supply, and check to see whether protective functions, such as the immediate stop and operational limits, operate properly. Check operation at both low speed and high speed using the system without a workpiece, or with dummy workpieces.	Section 10, 10-3
↓		
Adjustment	Manually adjust the set values of objects such as gain if necessary.	Section 11
↓		
Operation	Operation can now be started. If any problems should occur, refer to *Section 12 Troubleshooting*.	Section 12

Farklı tuning metotları bulunmaktadır. Tune metodlarına ve gelişmişlik seviyesine göre ayarlanan parametreler değişmektedir.



Objects That Are Adjusted Automatically

The values of the following objects are adjusted automatically when the easy tuning is executed.

Index (hex)	Subindex (hex)	Name	Reference
3011	---	Position Command Filter	P. 9-17
	04	IIR Filter Cutoff Frequency	P. 9-17
3120	---	TDF Position Control	P. 9-29
	11	Command Following Gain 2*1	P. 9-30
3213	---	1st Position Control Gain	P. 9-34
	01	Proportional Gain	P. 9-34
3214	---	2nd Position Control Gain	P. 9-35
	01	Proportional Gain	P. 9-35
3223	---	1st Velocity Control Gain	P. 9-37
	01	Proportional Gain	P. 9-37
	02	Integral Gain	P. 9-37
3224	---	2nd Velocity Control Gain	P. 9-38
	01	Proportional Gain	P. 9-38
	02	Integral Gain	P. 9-38
3233	---	1st Torque Command Filter	P. 9-40
	02	Cutoff Frequency	P. 9-40
3234	---	2nd Torque Command Filter	P. 9-41
	02	Cutoff Frequency	P. 9-41

*1. This object is automatically adjusted only when the multiple drives tuning method is selected.

Index (hex)	Subindex (hex)	Name	Reference
3001	---	Machine	P. 9-12
	01	Inertia Ratio	P. 9-12
3120	---	TDF Position Control	P. 9-29
	01	Command Following Gain*1	P. 9-30
	10	Command Following Gain Selection*1	P. 9-30
3310	---	Torque Compensation	P. 9-42
	01	Viscous Friction Coefficient	P. 9-42
	02	Unbalanced Load Compensation	P. 9-42
	03	Positive Dynamic Friction Compensation	P. 9-42
	04	Negative Dynamic Friction Compensation	P. 9-43
3320	---	Adaptive Notch Filter	P. 9-44
	01	Adaptive Notch Selection	P. 9-44
3321	---	1st Notch Filter	P. 9-45
	01	Enable	P. 9-45
	02	Frequency	P. 9-45
	03	Q-value	P. 9-45
	04	Depth	P. 9-46
3322	---	2nd Notch Filter	P. 9-47
	01	Enable	P. 9-47
	02	Frequency	P. 9-47
	03	Q-value	P. 9-47
	04	Depth	P. 9-48
3323	---	3rd Notch Filter	P. 9-49
	01	Enable	P. 9-49
	02	Frequency	P. 9-49
	03	Q-value	P. 9-49
	04	Depth	P. 9-50
3324	---	4th Notch Filter	P. 9-51
	01	Enable	P. 9-51
	02	Frequency	P. 9-51
	03	Q-value	P. 9-51
	04	Depth	P. 9-52
3B51	---	Positioning Completion Notification	P. 9-72
	01	Position Window	P. 9-72
3B80	---	Load Characteristic Estimation	P. 9-77
	01	Inertia Ratio Update Selection	P. 9-77
	02	Viscous Friction Compensation Update Selection	P. 9-77
	03	Unbalanced Load Compensation Update Selection	P. 9-78
	04	Dynamic Friction Compensation Update Selection	P. 9-78

*1. This object is changed only in two-degree-of-freedom (TDF) control.

Objects That Are Set to Fixed Values

The following objects are set to the fixed values when the easy tuning is executed.

Index (hex)	Subindex (hex)	Name	Unit	Set value	Reference
3011	---	Position Command Filter	---	---	P. 9-17
	03	IIR Filter Enable	---	1	P. 9-17
3112	---	ODF Velocity Feed-forward	---	---	P. 9-27
	01	Gain	0.1%	300	P. 9-27
	02	LPF Enable	---	0	P. 9-27
	03	LPF Cutoff Frequency	0.1 Hz	50,000	P. 9-27
3113	---	ODF Torque Feed-forward	---	---	P. 9-28
	01	Gain	0.1%	0	P. 9-28
	02	LPF Enable	---	0	P. 9-29
	03	LPF Cutoff Frequency	0.1 Hz	50,000	P. 9-29
3233	---	1st Torque Command Filter	---	---	P. 9-40
	01	Enable	---	1	P. 9-40
3234	---	2nd Torque Command Filter	---	---	P. 9-41
	01	Enable	---	1	P. 9-41
3B80	---	Load Characteristic Estimation	---	---	P. 9-77
	05	Viscous Friction Tuning Coefficient	%	100	P. 9-78

Gui ile fft alınıp frekans karakteristiği gözlenebilir

11-6 FFT

When you use the Sysmac Studio, you can measure the frequency characteristics of velocity closed loop.

For how to use, refer to the *Sysmac Studio Drive Functions Operation Manual* (Cat. No. I589).

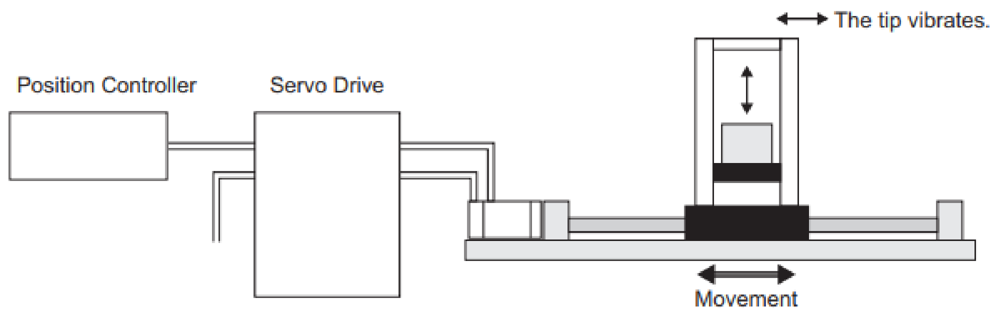
Damping control

11-7 Damping Control

If the tip of the mechanical unit vibrates, you can use the damping control function to reduce vibration.

This is effective on vibration generated by a low-rigidity machine. The applicable frequencies are from 0.5 to 300 Hz.

Two damping filters, the Damping Filter 1 and 2, are provided to control two vibration frequencies simultaneously. Up to four damping frequencies can be set for each damping filter. This enables you to switch the damping frequency from one to another when it varies depending on the position.



Precautions for Correct Use

If you change the operation mode while damping control is used, stop the Servomotor before you change the mode. Changing the operation mode during motor operation may result in unexpected operation.

11-7-1 Objects Requiring Settings

Index (hex)	Subindex (hex)	Name	Description	Reference
3012	---	Damping Control	Selects the damping filters.	P. 9-18
	01	Damping Filter 1 Selection	Selects the setting to use for the damping filter 1. 0: Disabled 1: 1st Frequency and 1st Damping Time Coefficient 2: 2nd Frequency and 2nd Damping Time Coefficient 3: 3rd Frequency and 3rd Damping Time Coefficient 4: 4th Frequency and 4th Damping Time Coefficient	P. 9-18
	02	Damping Filter 2 Selection	Selects the setting to use for the damping filter 2. The function is the same as 01 hex.	P. 9-18

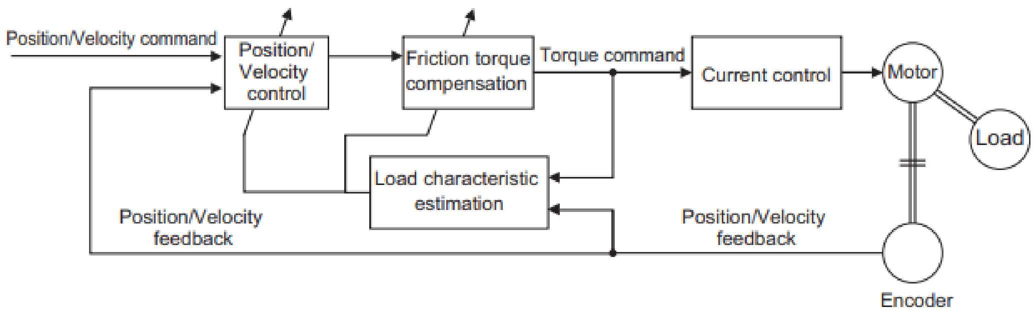
Load estimation

11-8 Load Characteristic Estimation

The Load Characteristic Estimation function estimates the load characteristics of the machine in realtime, and sets values of the inertia ratio, viscous friction coefficient, unbalanced load compensation, and dynamic friction compensation automatically according to the result of estimation.

You can check the values that are set automatically with **Machine – Inertia Ratio Display** (3001-81 hex), **Torque Compensation – Viscous Friction Coefficient Display** (3310-81 hex), **Unbalanced Load Compensation Display** (3310-82 hex), and **Dynamic Friction Compensation Display** (3310-83 hex and 3310-84 hex).

This Load Characteristic Estimation function is enabled in the position control, velocity control, and torque control.



Precautions for Correct Use

- The Load Characteristic Estimation function may not operate properly under the following conditions. In such cases, set the related objects manually.

	Conditions that interfere with the Load Characteristic Estimation function
Load inertia	• If the load inertia is small, i.e. less than 3 times the rotor inertia or large, i.e. the applicable load inertia or more • If the load inertia changes easily
Load	• If the machine rigidity is extremely low • If there is a non-linear element (play), such as a backlash
Operation	• If the speed continues at lower than 100 r/min • If the acceleration/deceleration is 2,000 r/min/s or lower • If the acceleration/deceleration torque is small compared with the unbalanced load and the friction torque • If the speed or torque oscillates due to the high gain or small effect of each filter.

Adaptive Notch filter

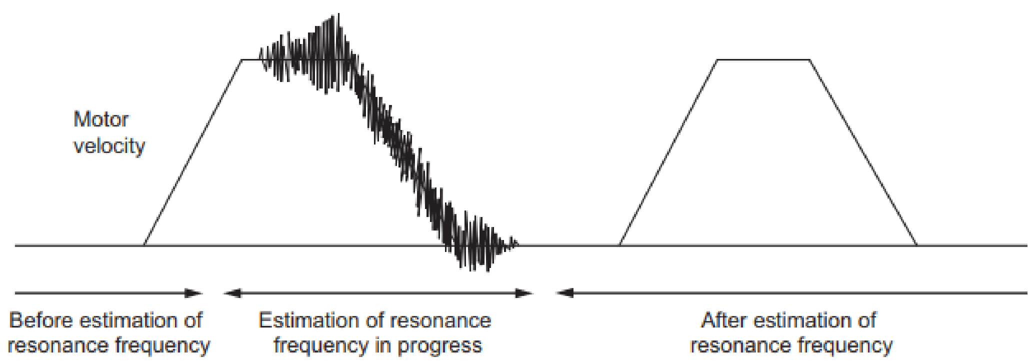
11-9 Adaptive Notch Filter

The Adaptive Notch Filter reduces resonance frequency vibration by estimating the resonance frequency from the vibration component that appears in the motor speed during actual operation and automatically setting the frequency of the notch filter, which removes the resonance component from the internal torque command.

You can check the values that are set automatically with **1st Notch Filter** (3321 hex)/**2nd Notch Filter** (3322 hex)/**3rd Notch Filter** (3323 hex)/**4th Notch Filter** (3324 hex) – **Frequency Display** (Subindex 82 hex), **Q-value Display** (Subindex 83 hex), and **Depth Display** (Subindex 84 hex).

Refer to *11-10 Notch Filters* on page 11-23 for information on notch filter.

Operation Example



11-9-1 Objects Requiring Settings

Index (hex)	Subindex (hex)	Name	Description	Reference
3320	---	Adaptive Notch Filter	Sets the adaptive notch filter.	P. 9-44
	01	Adaptive Notch Selection	Selects the notch filter to adapt the estimation result. This object is disabled when 0 is set. 0: Disabled 1: 1st Notch Filter 2: 2nd Notch Filter 3: 3rd Notch Filter 4: 4th Notch Filter	P. 9-44
	03	Resonance Detection Threshold	Sets the torque output to detect the resonance, as a percentage of the rated torque.	P. 9-44

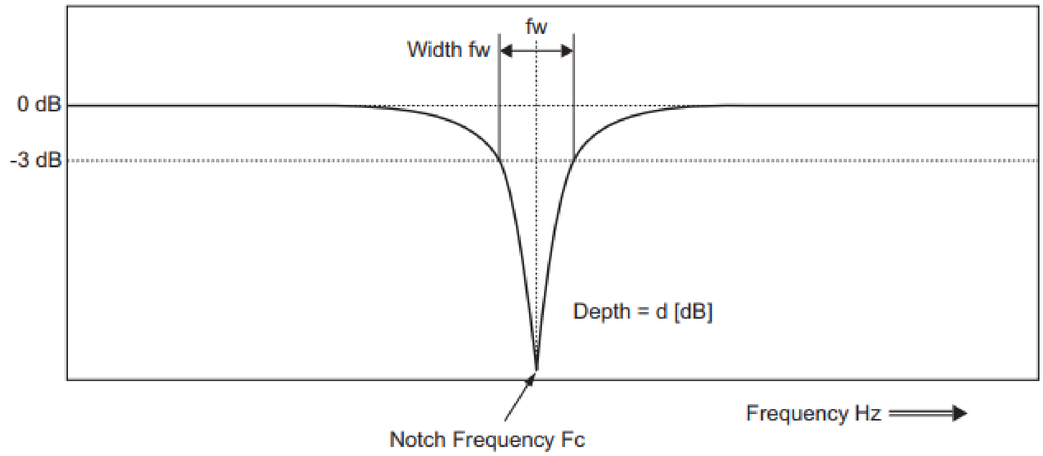
Adaptive notch filter

11-10 Notch Filters

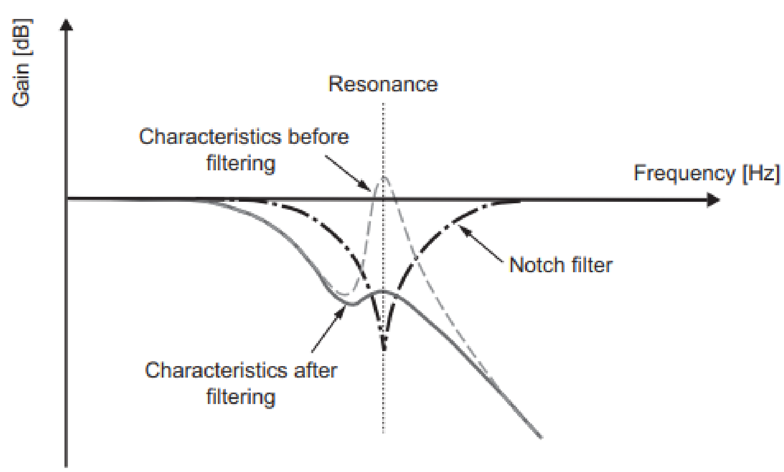
A notch filter reduces a specified frequency component.

When the machine rigidity is low, factors such as axis torsion may produce resonance which results in vibration and noise. Thus you may not be able to set a high gain. The notch filter suppresses the resonance peak to reduce vibration and noise, and allows you to set a high gain.

The 1S-series Servo Drives provide four notch filters for which you can adjust each frequency, width and depth.



If mechanical resonance occurs, use this notch filter to eliminate resonance.



Friction compensation

11-11 Friction Torque Compensation Function

You can set the following three types of friction torque compensations to reduce the influence of mechanical frictions.

- Unbalanced load compensation: Offsets the constantly applied unbalance torque
- Dynamic friction compensation: Compensates friction that changes its direction in accordance with the operating direction.
- Viscous friction compensation: Compensates friction that varies in accordance with velocity.

11-11-1 Operating Conditions

The friction torque compensation function is enabled under the following conditions.

- Position control or velocity control
- The Servo is ON.

The following table shows the relationship between the control method and enabled compensation functions.

Control method	Viscous friction compensation	Unbalanced load compensation	Dynamic friction compensation
TDF control	Enabled	Enabled	Enabled
ODF control	Disabled	Enabled	Enabled

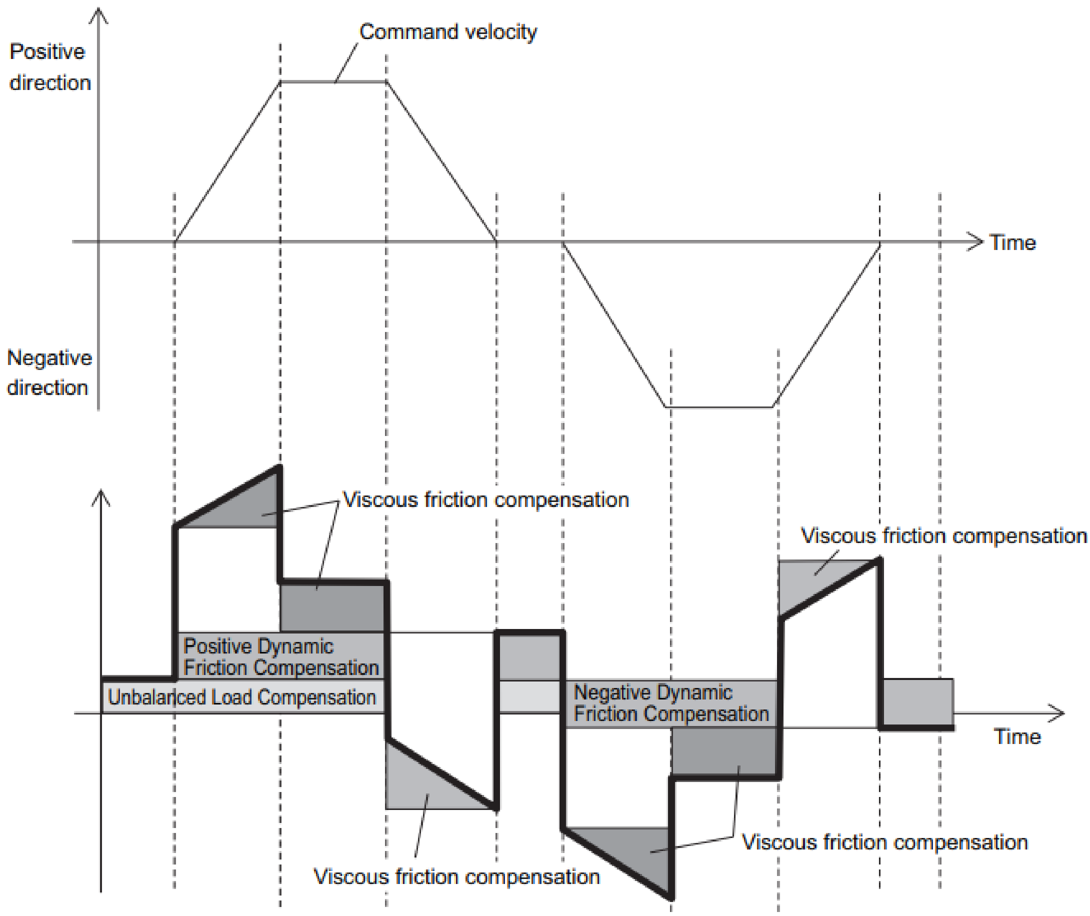
11-11-2 Objects Requiring Settings

The friction torque compensation function needs the combined settings of the following four objects.

Index (hex)	Subindex (hex)	Name	Description	Reference
3310	---	Torque Compensation	Sets the torque compensation.	P. 9-42
	01	Viscous Friction Coefficient	Adjusts the amount of viscous friction compensation torque. This object is enabled only in two-degree-of-freedom (TDF) control.	P. 9-42
	02	Unbalanced Load Compensation	Sets the amount of unbalanced load torque compensation.	P. 9-42
	03	Positive Dynamic Friction Compensation	Sets the amount of dynamic friction compensation in the positive direction.	P. 9-42
	04	Negative Dynamic Friction Compensation	Sets the amount of dynamic friction compensation in the negative direction.	P. 9-43

11-11-3 Operation Example

The friction torque compensation is applied according to the operation as shown in the drawing below.



Note The dynamic friction compensation holds the compensation value until the command direction changes, in order to sustain the position during stabilization.

By setting the torque command value in **Unbalanced Load Compensation** (3310-02 hex), you can reduce the variations of positioning operations that occur depending on the movement directions. This object is useful when a constant amount of unbalanced load torque is always applied to the Servomotor at axes such as a vertical axis.

By setting the friction torque for each rotation direction in **Positive Dynamic Friction Compensation** (3310-03 hex) and **Negative Dynamic Friction Compensation** (3310-04 hex), you can reduce deterioration of and inconsistencies in the positioning stabilization time due to dynamic friction. These objects are useful for loads that require a larger amount of dynamic friction torque for a radial load, such as the belt-driven shaft.

Feedforward

11-12 Feed-forward Function

The feed-forward function is used to improve the following performance for the target position and velocity.

11-12-1 Feed-forward Control in TDF Control

In the normal TDF control, do not add **Velocity offset** (60B1 hex) and **Torque offset** (60B2 hex), because the optimized feed-forward amount is input from the TDF control section.

TDF Control-related Objects

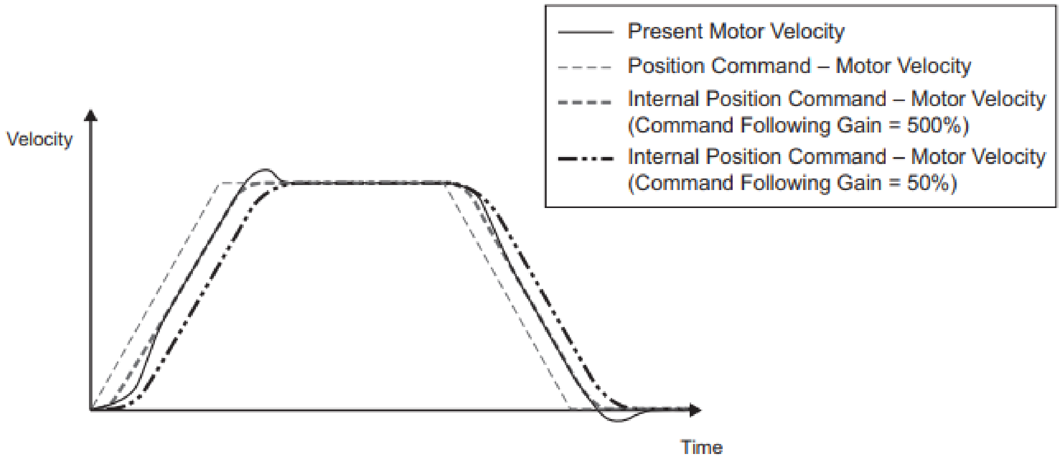
The following are the feed-forward setting objects used in the TDF control.

Index (hex)	Subindex (hex)	Name	Description	Refer-ence
3120	---	TDF Position Control	Sets the operation in the two-degree-of-freedom position control.	P. 9-29
	01	Command Following Gain	Sets the following performance for the target position. The higher the gain is, the higher the following performance of the internal command is for the target position.	P. 9-30
	10	Command Following Gain Selection*1	Selects the command following gain switching method. 0: Use the Command Following Gain. 1: Use the Command Following Gain 2.	P. 9-30
	11	Command Following Gain 2 *1	Sets the cutoff frequency to the position command. The higher the set value is, the higher the following performance of the internal command is for the target position.	P. 9-30
3121	---	TDF Velocity Control	Sets the operation in the two-degree-of-freedom velocity control.	P. 9-30
	01	Command Following Gain	Sets the following performance for the target velocity. The higher the gain is, the higher the following performance of the internal command is for the target velocity.	P. 9-31
	10	Command Following Gain Selection*1	Selects the command following gain switching method. 0: Use the Command Following Gain. 1: Use the Command Following Gain 2.	P. 9-31
	11	Command Following Gain 2*1	Sets the cutoff frequency to the velocity command. The higher the set value is, the higher the following performance of the internal command is for the target velocity.	P. 9-31

*1. These objects are available for the unit version 1.1 or later.

Adjustment of TDF Command Following Gain

In the TDF control, the smooth internal commands are generated in the TDF control section so that rapid changes in target position or velocity do not cause overshooting. However, the smoother the internal commands are, the longer the delay of the internal commands gets. This trade-off between the overshooting suppression and internal command delay is adjusted with the command following gain.



The smaller the set value of Command Following Gain is, the more the overshooting can be suppressed.

Normally, set Command Following Gain to 50%. Set a value of approximately 30% when you want to suppress overshooting.

11-12-2 Feed-forward Control in ODF Control

The feed-forward function that can be used in the ODF control comes in 2 types: velocity feed-forward and torque feed-forward. In the ODF control, the responsiveness can be increased by changing these feed-forward amounts.

ODF Control-related Objects

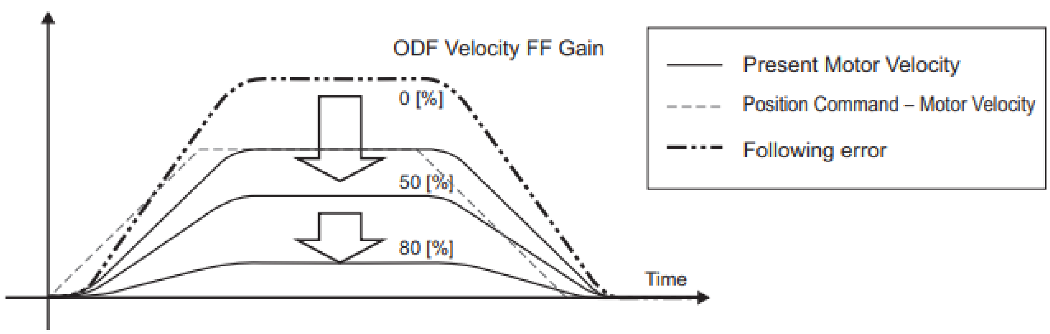
The following are the feed-forward setting objects used in the ODF control.

Index (hex)	Subindex (hex)	Name	Description	Reference
3112	---	ODF Velocity Feed-forward	Sets the velocity feed-forward in the one-degree-of-freedom control.	P. 9-27
	01	Gain	Sets the velocity feed-forward gain. Normally, use the default setting.	P. 9-27
	02	LPF Enable	Selects whether to enable or disable the low-pass filter in the velocity feed-forward. 0: Disabled 1: Enabled	P. 9-27
	03	LPF Cutoff Frequency	Sets the cutoff frequency for the feed-forward low-pass filter.	P. 9-27
3113	---	ODF Torque Feed-forward	Sets the torque feed-forward in the one-degree-of-freedom control.	P. 9-28
	01	Gain	Sets the torque feed-forward gain. Normally, use the default setting.	P. 9-28
	02	LPF Enable	Selects whether to enable or disable the low-pass filter in the torque feed-forward. 0: Disabled 1: Enabled	P. 9-29
	03	LPF Cutoff Frequency	Sets the cutoff frequency for the feed-forward low-pass filter.	P. 9-29

Operating Method of ODF Velocity Feed-forward

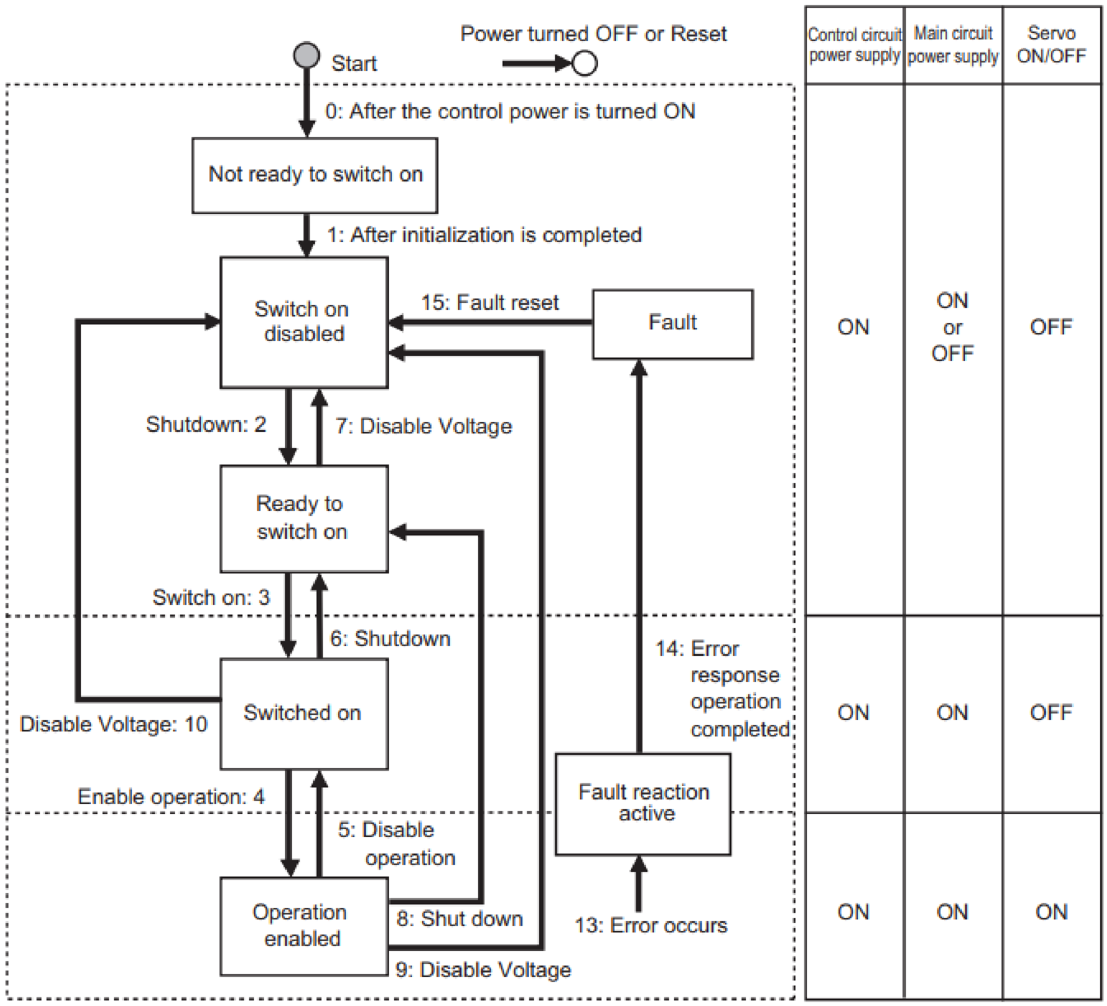
Increase the value of **ODF Velocity Feed-forward – Gain** (3112-01 hex) little by little to adjust the gain so that overshooting does not occur during acceleration/deceleration.

If you set **ODF Velocity Feed-forward - Gain** to 1,000 (100%), the calculated following error will be 0. However, large overshooting may occur during acceleration/deceleration.

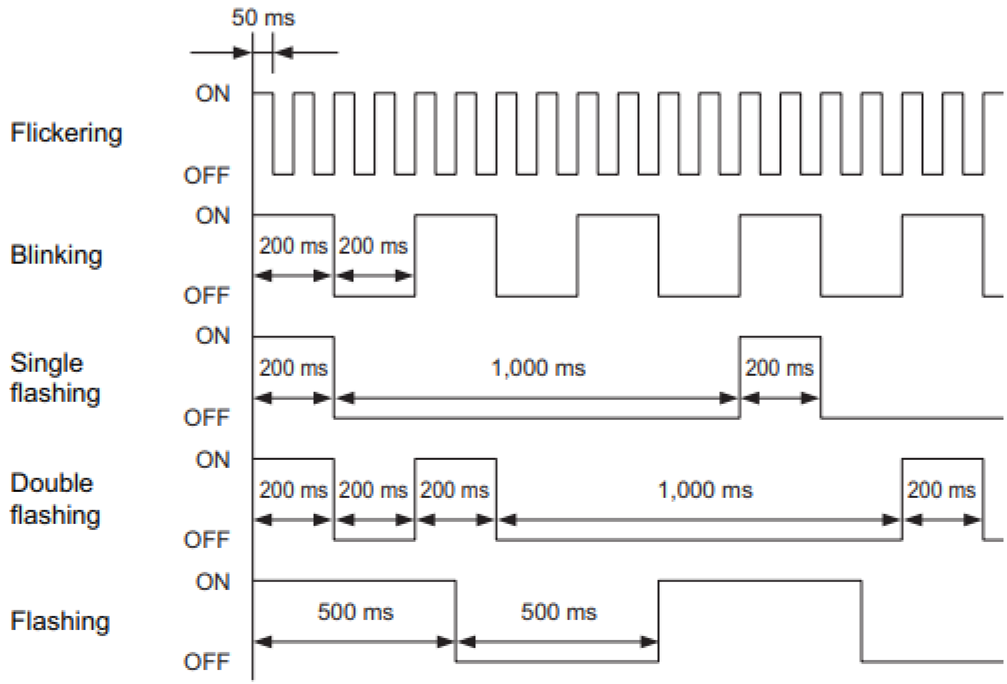


The following error in a constant velocity range gets smaller as you increase the velocity feed-forward gain.

State machine



Note Quick stop active state is not supported. Even if a Quick stop command is received, it will be ignored.



Encoder

3-2-2 Encoder Specifications

The encoder specifications are shown below.

Item	Specifications
Encoder system	Optical batteryless absolute encoder
Resolution per rotation	23 bits
Multi-rotation data hold	16 bits
Power supply voltage	5 VDC±10%
Current consumption	230 mA max.
Output signal	Serial communications
Output interface	RS485 compliant

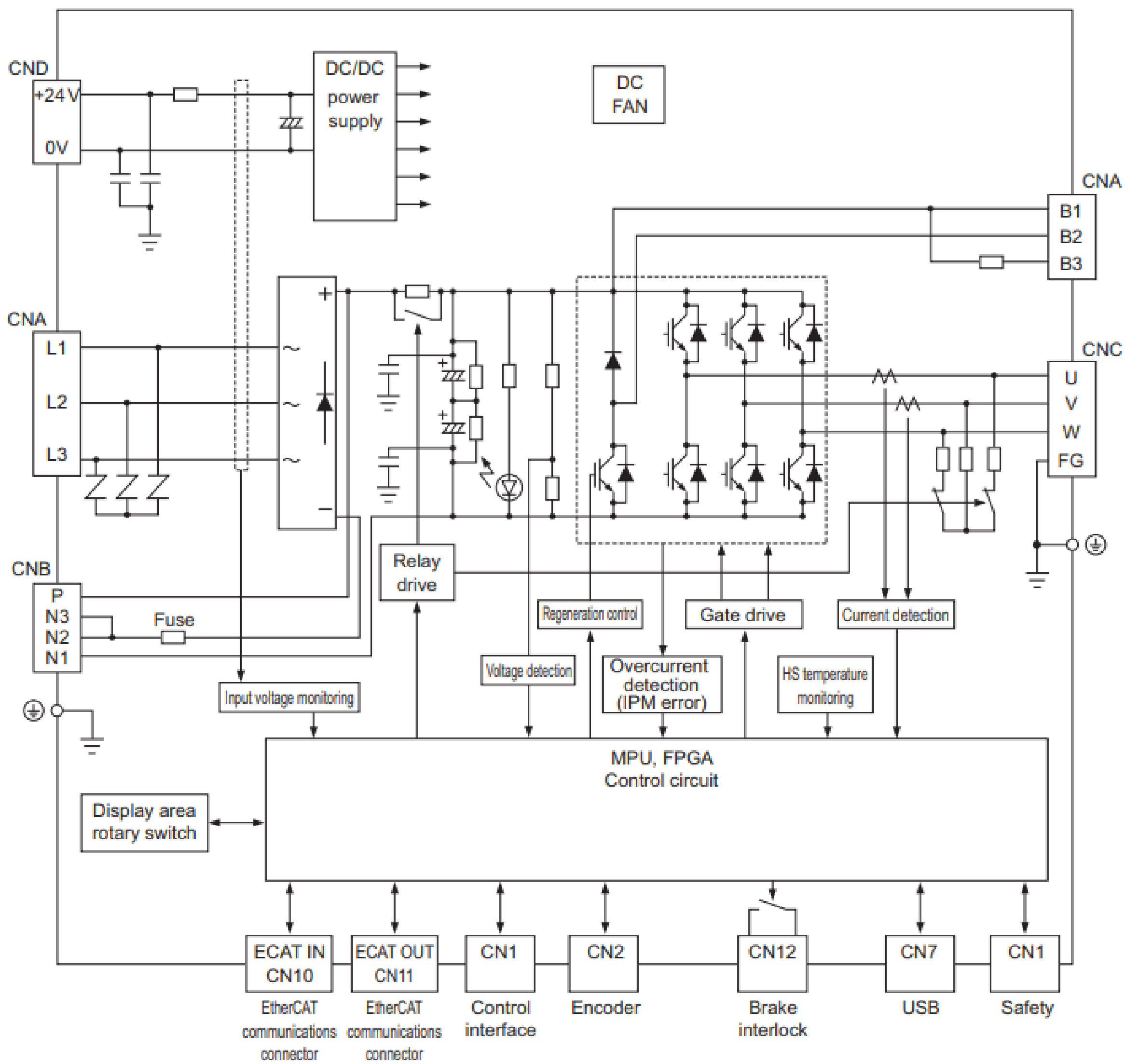
It is possible to use an absolute encoder as an incremental encoder.

Refer to *9-13 Encoder-related Objects* on page 9-102 for setting.

9-13 Encoder-related Objects

These objects are used for the encoder setting.

Index (hex)	Sub-index (hex)	Object name	Setting range	Unit	Default setting	Data attri-bute	Size	Access	PDO map	Complete access	Modes of opera-tion
4510	---	Encoder	---	---	---	---	---	---	---	Possible	---
	00	Number of entries	---	---	FF hex	---	1 byte (U8)	RO	---	---	---
	01	Operation Selection when Using Absolute Encoder	0 to 2	---	2	R	4 bytes (INT32)	RW	---	---	---
	02	Absolute Encoder Counter Overflow Warning Level	0 to 32,767	rotation	32,000	A	4 bytes (INT32)	RW	---	---	---
	81	Serial Number	---	---	---	---	16 bytes (VS)	RO	---	---	---
	82	Resolution per Rotation	---	---	---	---	4 bytes (INT32)	RO	---	---	---
	84	One-rotation Data	---	Encoder unit	---	---	4 bytes (U32)	RO	---	---	---
	85	Multi-rotation Data	---	rotation	---	---	4 bytes (INT32)	RO	---	---	---
	86	Encoder Communications Error Count	---	---	---	---	4 bytes (INT32)	RO	---	---	---
	87	Electric Angle	---	°	---	---	4 bytes (INT32)	RO	---	---	---
	88	Mechanical Angle	---	°	---	---	4 bytes (U32)	RO	---	---	---
	89	Encoder Temperature	---	°C	---	---	4 bytes (INT32)	RO	---	---	---
	F1	Absolute Encoder Setup	0000 0000 to FFFF FFFF hex	---	0	A	4 bytes (U32)	W	---	---	---
	F2	Encoder Communications Error Count Clear	0000 0000 to FFFF FFFF hex	---	0	A	4 bytes (U32)	W	---	---	---
	FF	Clear Status	---	---	---	---	4 bytes (U32)	RO	---	---	---

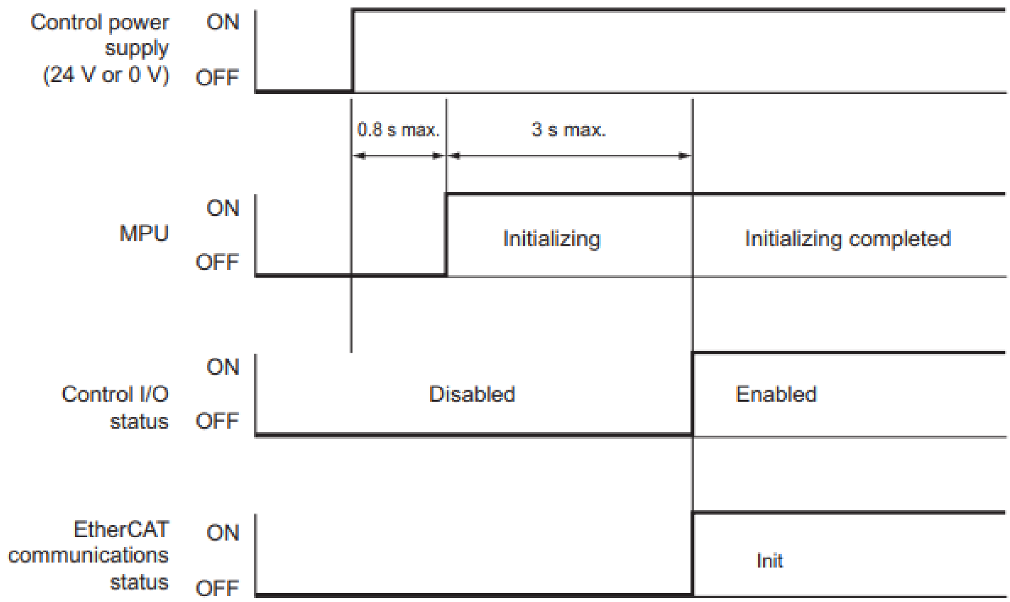


Power on sequence

3-1-16 Power ON Sequence

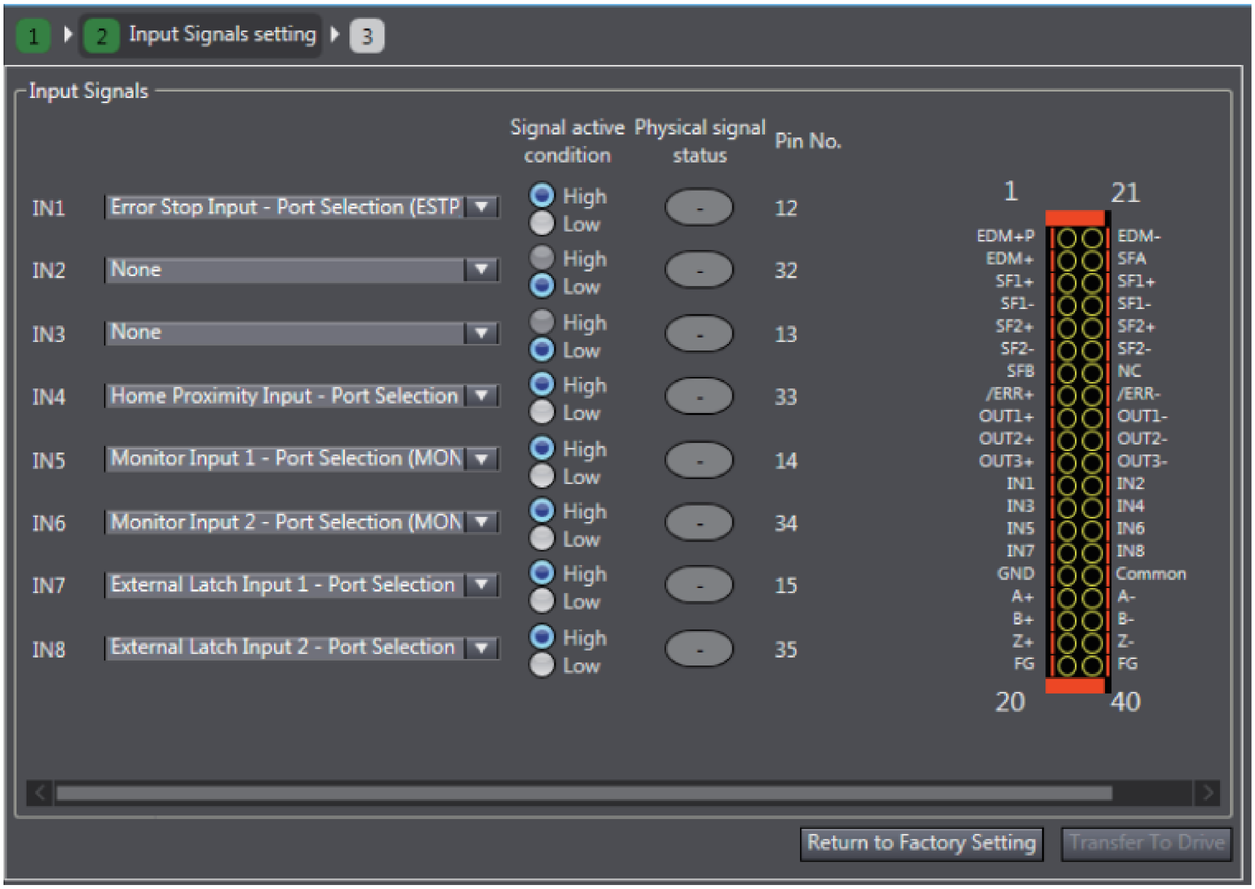
This section gives the time from when the control power supply for the Servo Drive is turned ON until the control I/O and EtherCAT communications are enabled.

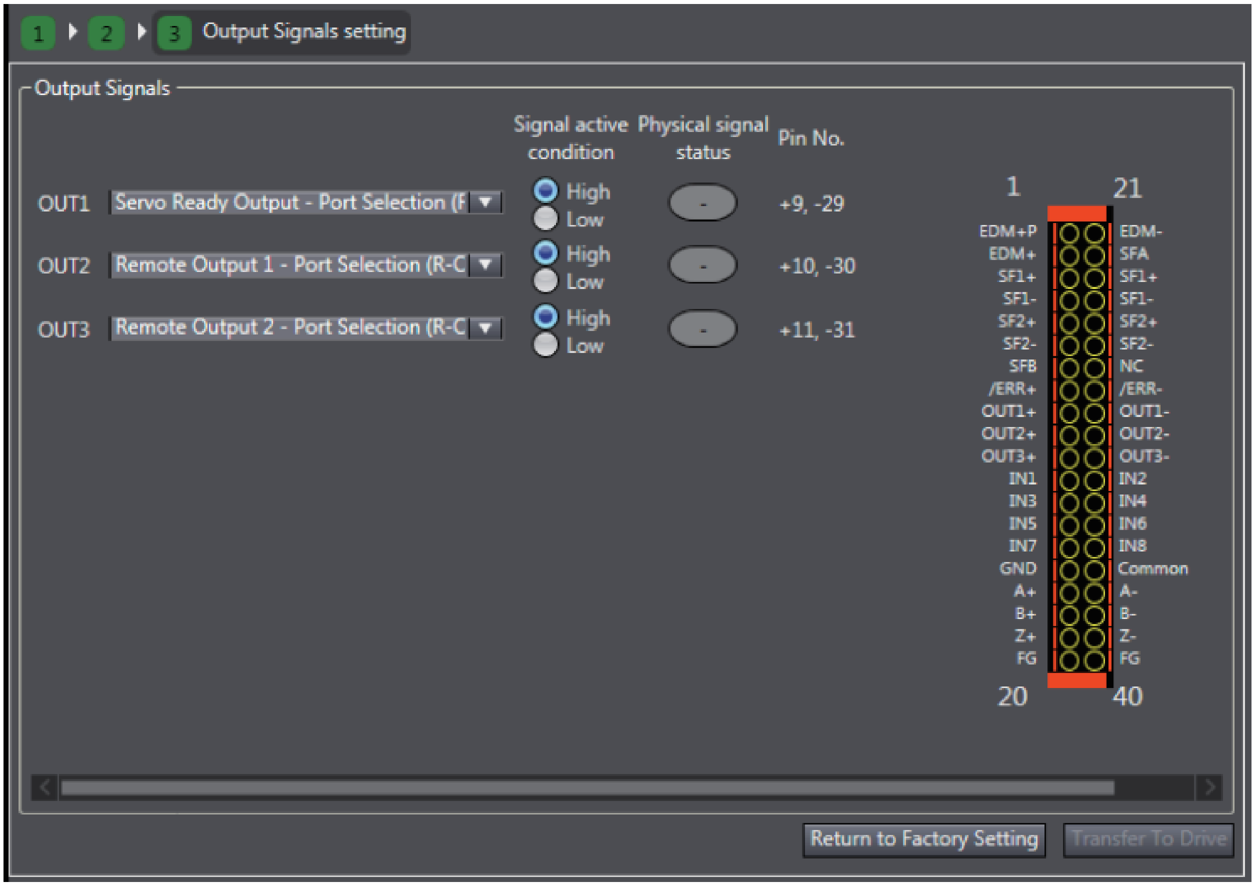
Communications with the master is started after the EtherCAT communications are enabled. Perform Servo ON and send commands only after the EtherCAT communications are established.



Gui

Moda göre (test, run) input output parametreleri gui ile configüre edilebilir.


1
2 Input Signals setting
3
Input Signals
Signal active condition
Physical signal status
Pin No.
IN1 Error Stop Input - Port Selection (ESTP High Low 12
IN2 None High Low 32
IN3 None High Low 13
IN4 Home Proximity Input - Port Selection High Low 33
IN5 Monitor Input 1 - Port Selection (MON High Low 14
IN6 Monitor Input 2 - Port Selection (MON High Low 34
IN7 External Latch Input 1 - Port Selection High Low 15
IN8 External Latch Input 2 - Port Selection High Low 35
1 21
EDM+P EDM-
EDM+ SFA
SF1+ SF1+
SF1- SF1-
SF2+ SF2+
SF2- SF2-
SFB NC
/ERR+ /ERR-
OUT1+ OUT1-
OUT2+ OUT2-
OUT3+ OUT3-
IN1 IN2
IN3 IN4
IN5 IN6
IN7 IN8
GND Common
A+ A-
B+ B-
Z+ Z-
FG FG
20 40
Return to Factory Setting
Transfer To Drive


1
2
3 Output Signals setting
Output Signals
Signal active condition
Physical signal status
Pin No.
OUT1
Servo Ready Output - Port Selection (F
High
Low
+9, -29
OUT2
Remote Output 1 - Port Selection (R-C
High
Low
+10, -30
OUT3
Remote Output 2 - Port Selection (R-C
High
Low
+11, -31
1
21
EDM+P
EDM-
EDM+
SFA
SF1+
SF1+
SF1-
SF1-
SF2+
SF2+
SF2-
SF2-
SFB
NC
/ERR+
/ERR-
OUT1+
OUT1-
OUT2+
OUT2-
OUT3+
OUT3-
IN1
IN2
IN3
IN4
IN5
IN6
IN7
IN8
GND
Common
A+
A-
B+
B-
Z+
Z-
FG
FG
20
40
Return to Factory Setting
Transfer To Drive

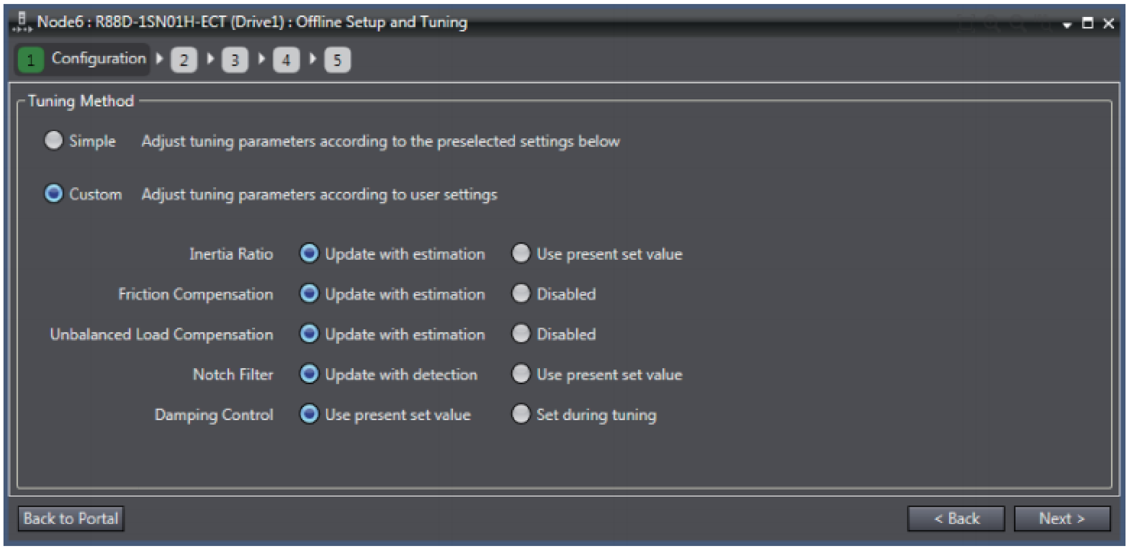
3-8-4 Easy Tuning (Single Drive)

Click the **Easy Tuning** button in Tuning (Single Drive).

You can easily adjust the gains using the easy tuning function. The optimum gains are automatically attained while repeating the motor operation.

Step 1: Configuration

Select *Simple* or *Custom* for the tuning method.



● Selecting the Tuning Method

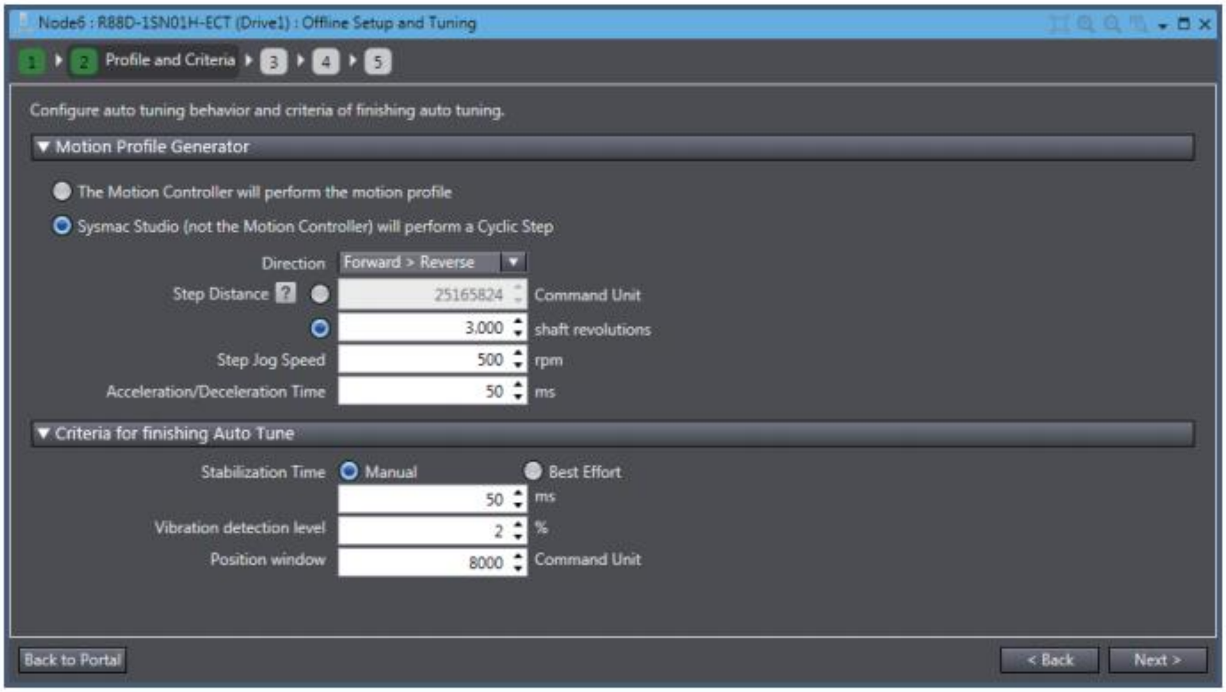
1 Select *Simple* or *Custom*.

Simple: Tuning for inertia ratio, torque compensation, and notch filter.

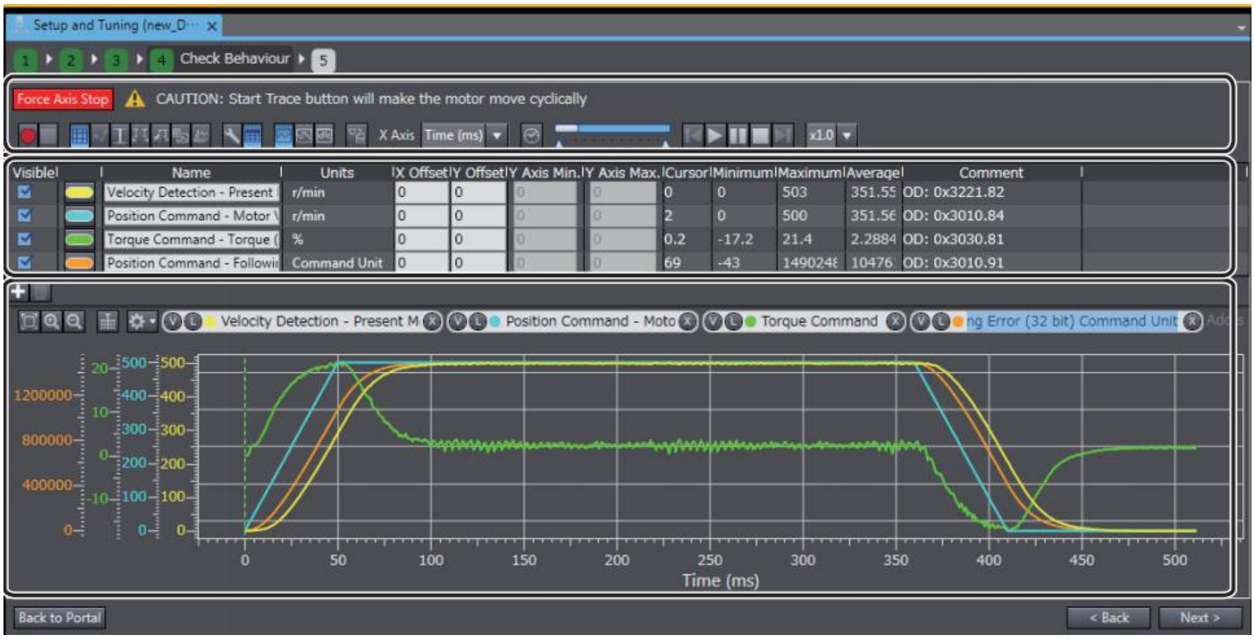
Custom: Tuning based on the selection for the following items.

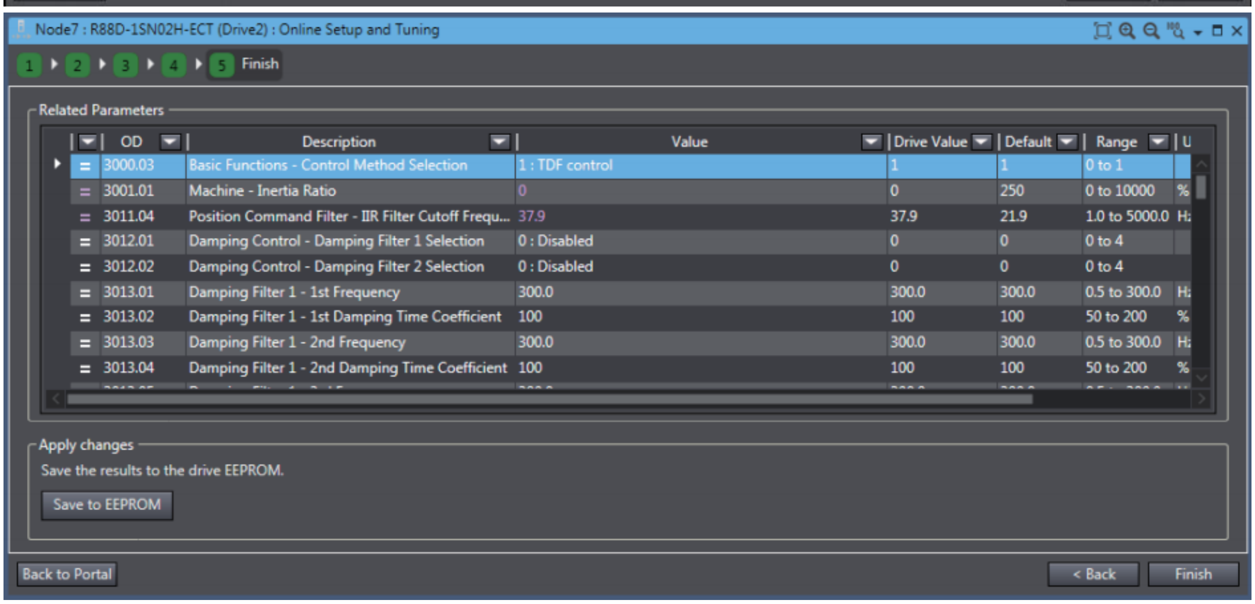
Item	Option	Description
Inertia Ratio	Update with estimation	The amount of load inertia is automatically estimated and the setting of Inertia Ratio (3001 hex - 01 hex) is updated based on the result.
	Use present set value	The Drive's present setting of Inertia Ratio (3001 hex - 01 hex) is maintained.
Friction Compensation	Update with estimation	The load friction is automatically estimated and the torque compensation settings (Viscous Friction Coefficient (3310 hex - 01 hex), Positive Dynamic Friction Compensation (3310 hex - 03 hex), and Negative Dynamic Friction Compensation (3310 hex - 04 hex)) are updated based on the result.
	Disabled	The torque compensation values (Viscous Friction Coefficient (3310 hex - 01 hex), Positive Dynamic Friction Compensation (3310 hex - 03 hex), and Negative Dynamic Friction Compensation (3310 hex - 04 hex)) are set to 0 to disable the friction compensation.
Unbalanced Load Compensation	Update with estimation	The amount of unbalanced load of the load is automatically estimated and the setting of the toque compensation value (Unbalanced Load Compensation (3310 hex - 02 hex)) are updated based on the result.
	Disabled	The toque compensation value (Unbalanced Load Compensation (3310 hex - 02 hex)) is set to 0 to disable the friction compensation.
Notch Filter	Update with estimation	The resonance frequency of the load is automatically estimated and the settings of Notch Filters (3321 hex to 3324 hex) are updated based on the result. After the tuning, Adaptive Notch Filter (3320 hex - 01 hex) is set to *Disabled*.
	Use present set value	The Drive's present settings of Adaptive Notch Filter (3320 hex - 01 hex) and Notch Filters (3321 hex to 3324 hex) are maintained.
Damping Control	Use present set value	The Drives present settings of Damping Control (3012 hex to 3014 hex) are maintained.
	Set during tuning	The setting of Damping Control (3012 hex to 3014 hex) is made while adjusting the gain.

Set the motion profile generator and criteria for finishing auto tuning.

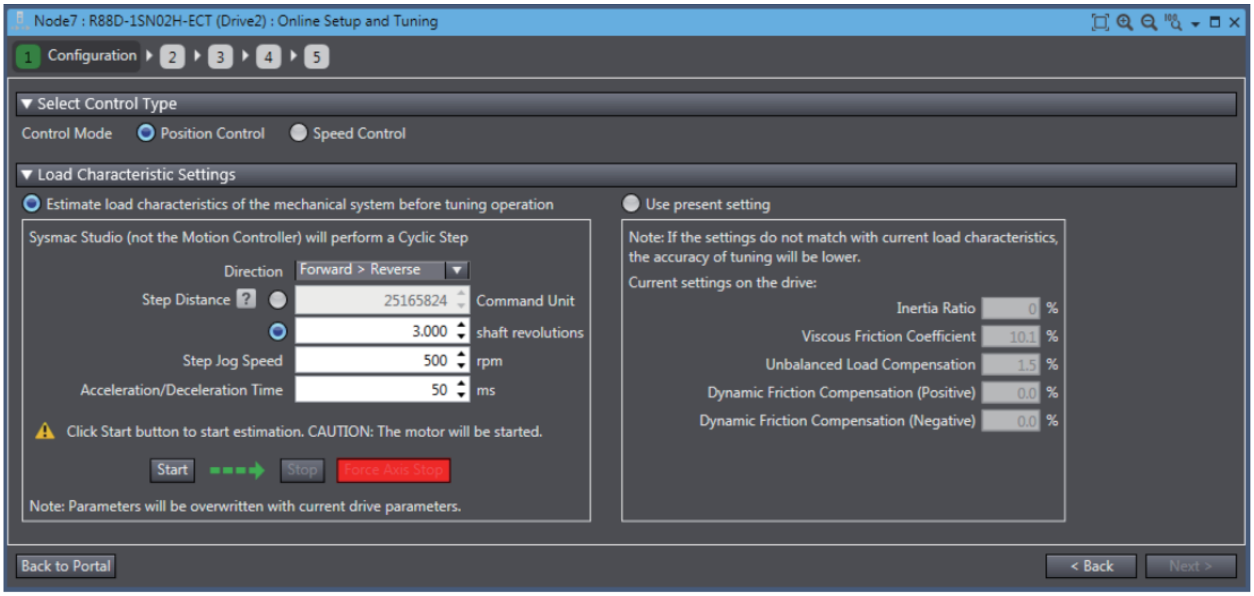


Item	Option	Description
Stabilization Time	Manual	Set the stabilization time that is applied as the tuning completion condition.
	Best Effort	Sysmac Studio automatically sets the stabilization time as short as possible within the range that does not cause micro vibration in the Drive.
Vibration detection level		Adjust the gain so that the torque vibration does not exceed this setting value. Set the percentage to the rated torque of the motor.
Position window		Set the in-position width used for measuring the stabilization time. This setting value is applied to the Positioning Completion Notification - Positioning Window (3B51 hex - 01 hex).
Responsiveness*1		Focus on positioning: Priority is given to reducing the stabilization time. Depending on the device and tuning conditions, overshoot may occur. Focus on overshoot suppression: Priority is given to suppression of overshoot in the tuning.

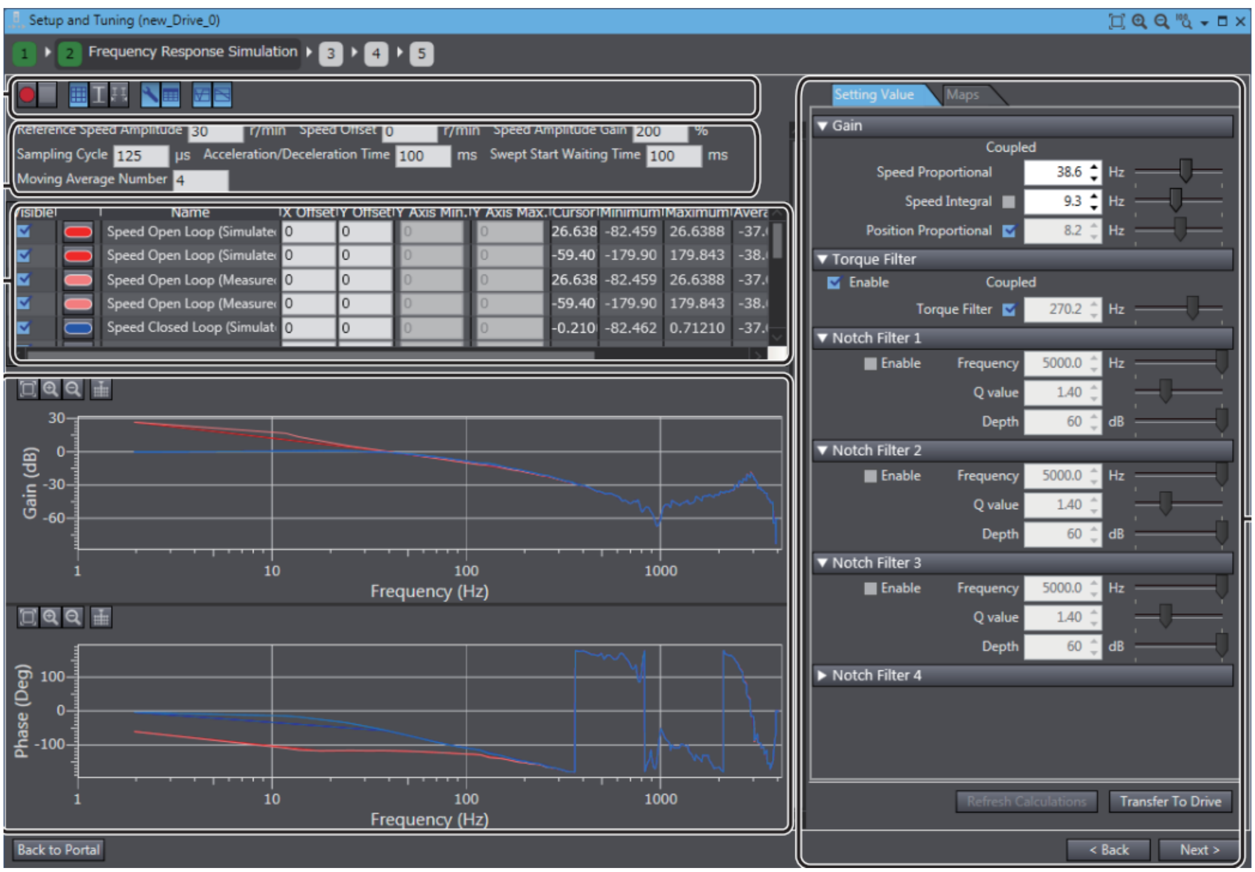




Advenced tunning

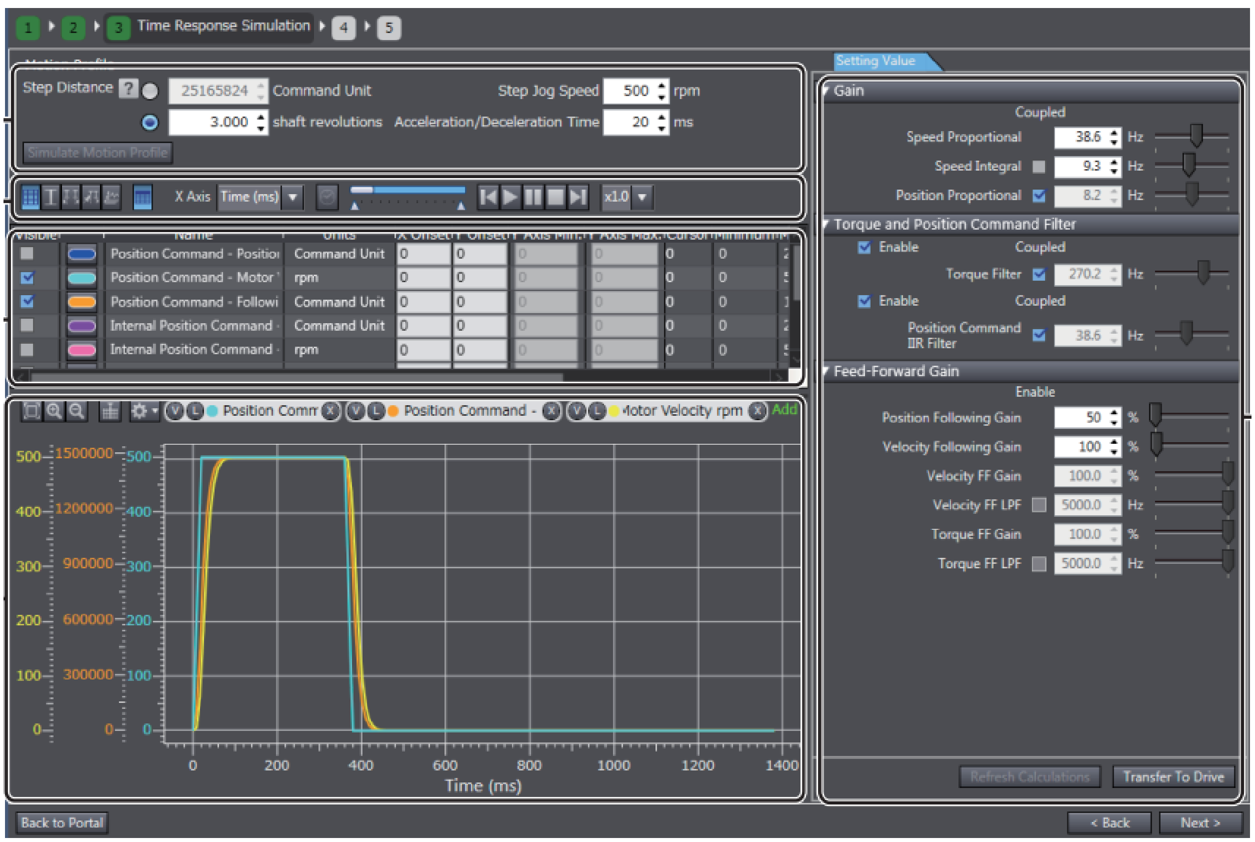


Sistemi tanıdıktan sonra simülasyonda yapılabilir



Item			Description
Setting Value	Gain	Speed Proportional	Set the 1st speed proportional gain.
		Speed Integral	Set the 1st speed integral gain.
		Position Proportional	Set the 1st position proportional gain.
	Torque Filter	Enable	Select this check box to enable the torque filter.
		Torque Filter	Set the cutoff frequency for the 1st torque command filter.
	Notch Filter 1/2/3/4	Enable	Select this check box to enable resonance suppression notch filter.
		Frequency	Set the notch frequency of the resonance suppression notch filter.
		Q value	Set the Q-value of the resonance suppression notch filter.
		Depth	Set the notch depth of the resonance suppression notch filter.

Time response simulation yapılıp parametreler ayarlanır ve eeprom'a yazılır.



Item			Description
Setting Value	Gain	Speed Proportional	Set the 1st speed proportional gain.
		Speed Integral	Set the 1st speed integral gain.
		Position Proportional	Set the 1st position proportional gain.
	Torque and Position Command Filter	Enable	Select this check box to enable the torque filter.
		Torque Filter	Set the cutoff frequency for the 1st torque command filter.
		Position Command IIR Filter	Set the IIR filter cutoff frequency for the position command filter.
	Feed-forward Gain	Enable	Select this check box to enable each filter.
		Position Following Gain	Set the command following gain for the TDF position control. This can be set only for the TDF control.
		Velocity Following Gain	Set the command following gain for the TDF velocity control. This can be set only for the TDF control.
		Velocity FF Gain	Set the gain for velocity feed-forward.
		Velocity FF LPF	Set the LPF cutoff frequency for the ODF velocity feed-forward. This can be set only for the ODF control.
		Torque FF Gain	Set the gain for torque feed-forward.
		Torque FF LPF	Set the LPF cutoff frequency for the ODF torque feed-forward. This can be set only for the ODF control.

6-1-2 Control Method

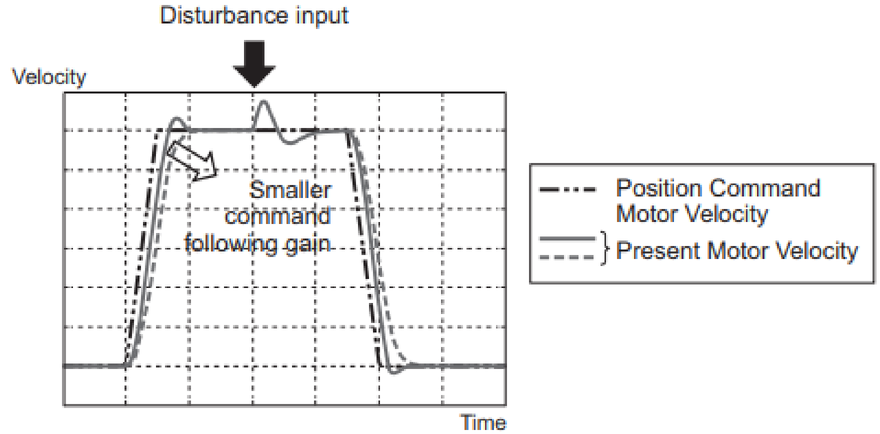
For the 1S-series Servo Drives, TDF control and ODF control are available.

In the TDF control, you can adjust the servo rigidity against disturbance and the target path following performance separately.

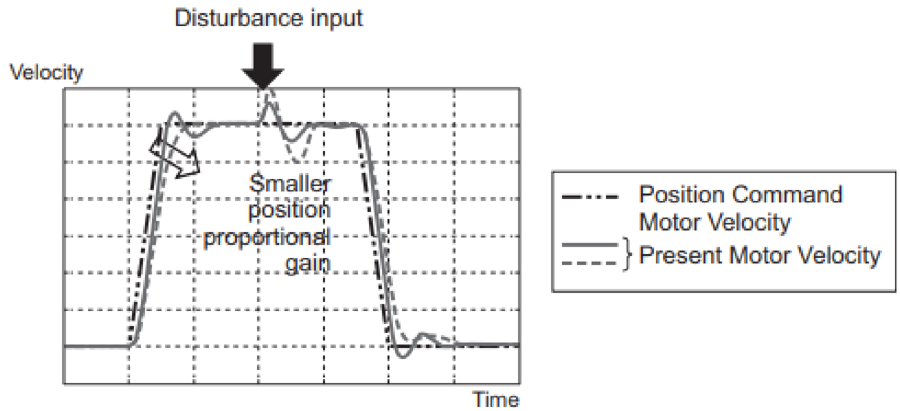
Therefore, you can perform the adjustment to suppress overshooting without lowering servo rigidity.

In the ODF control, the offset can be input as you expect because there is no interruption due to feed-forward input from the TDF control section.

Use TDF control in normal operation. Use ODF control when Velocity offset and Torque offset are input from the host controller.

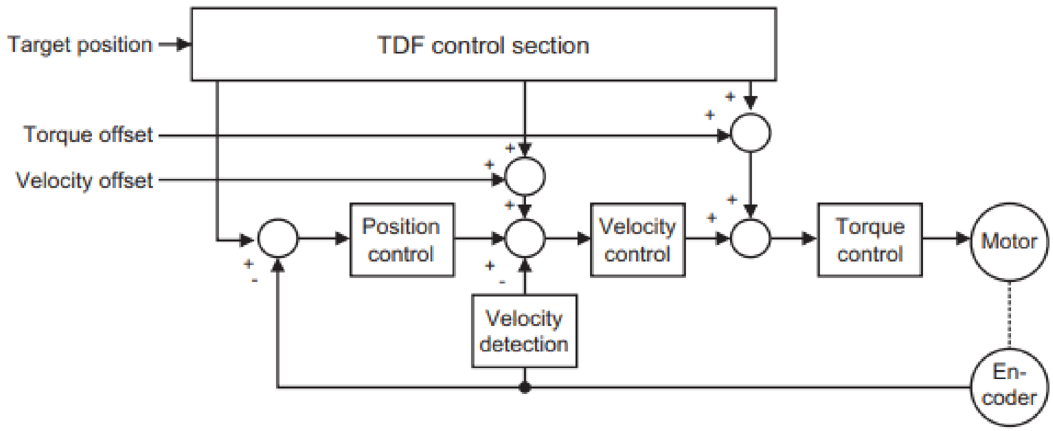


Time response waveform in TDF control

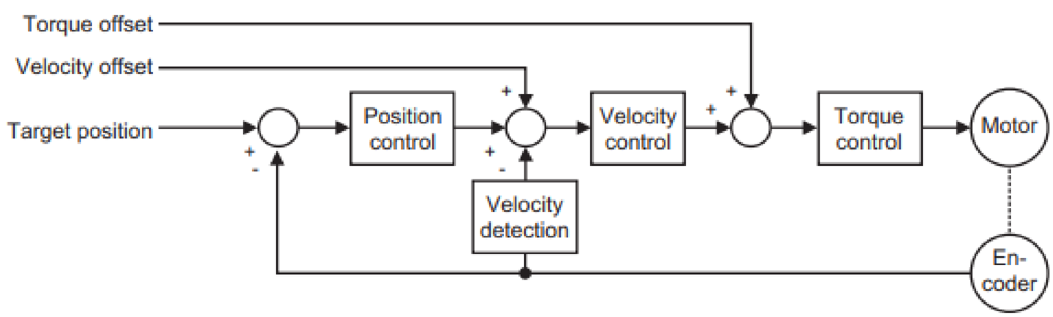


Time response waveform in ODF control

TDF Control Structure Diagram



ODF Control Structure Diagram

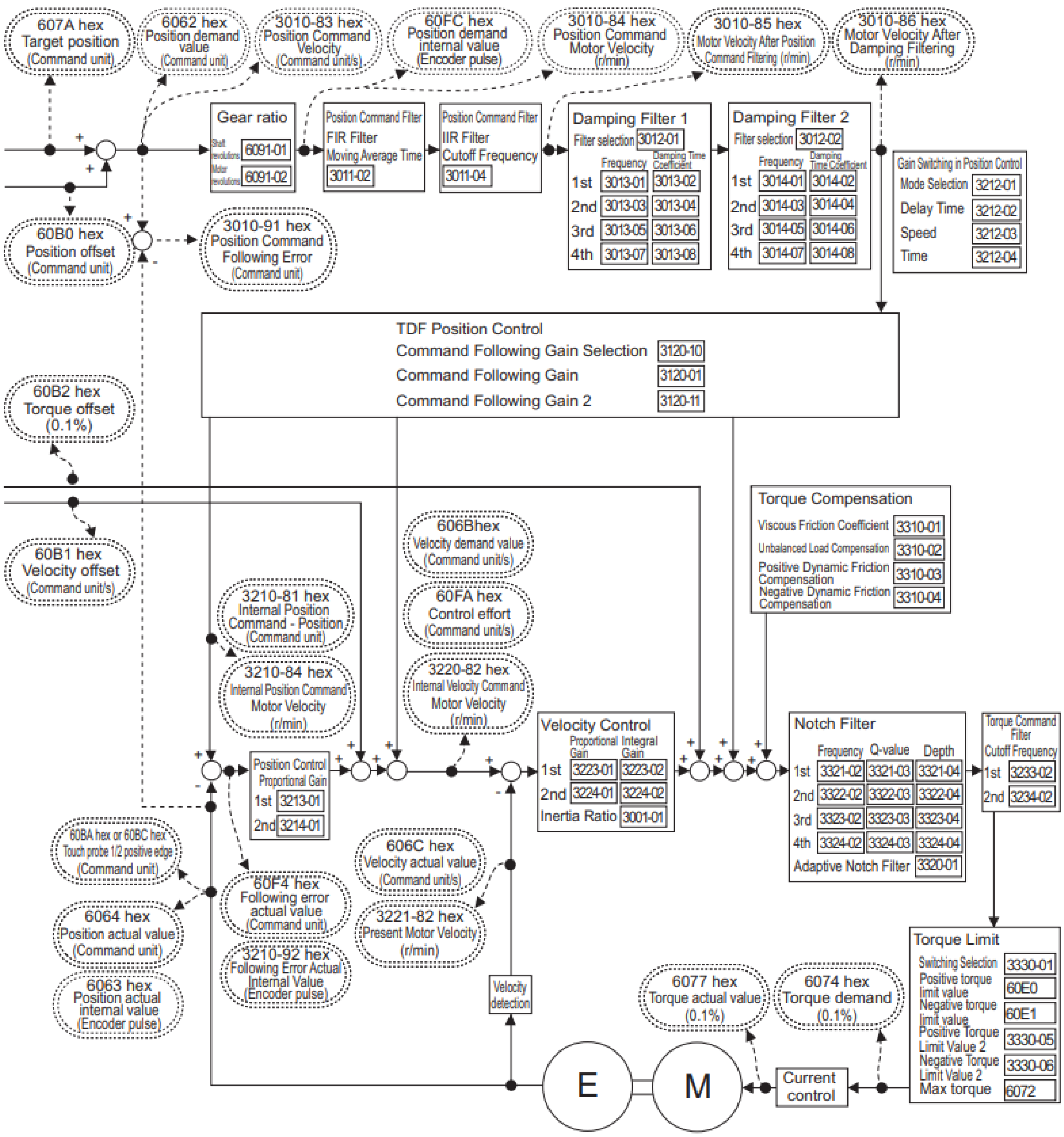


Related Objects

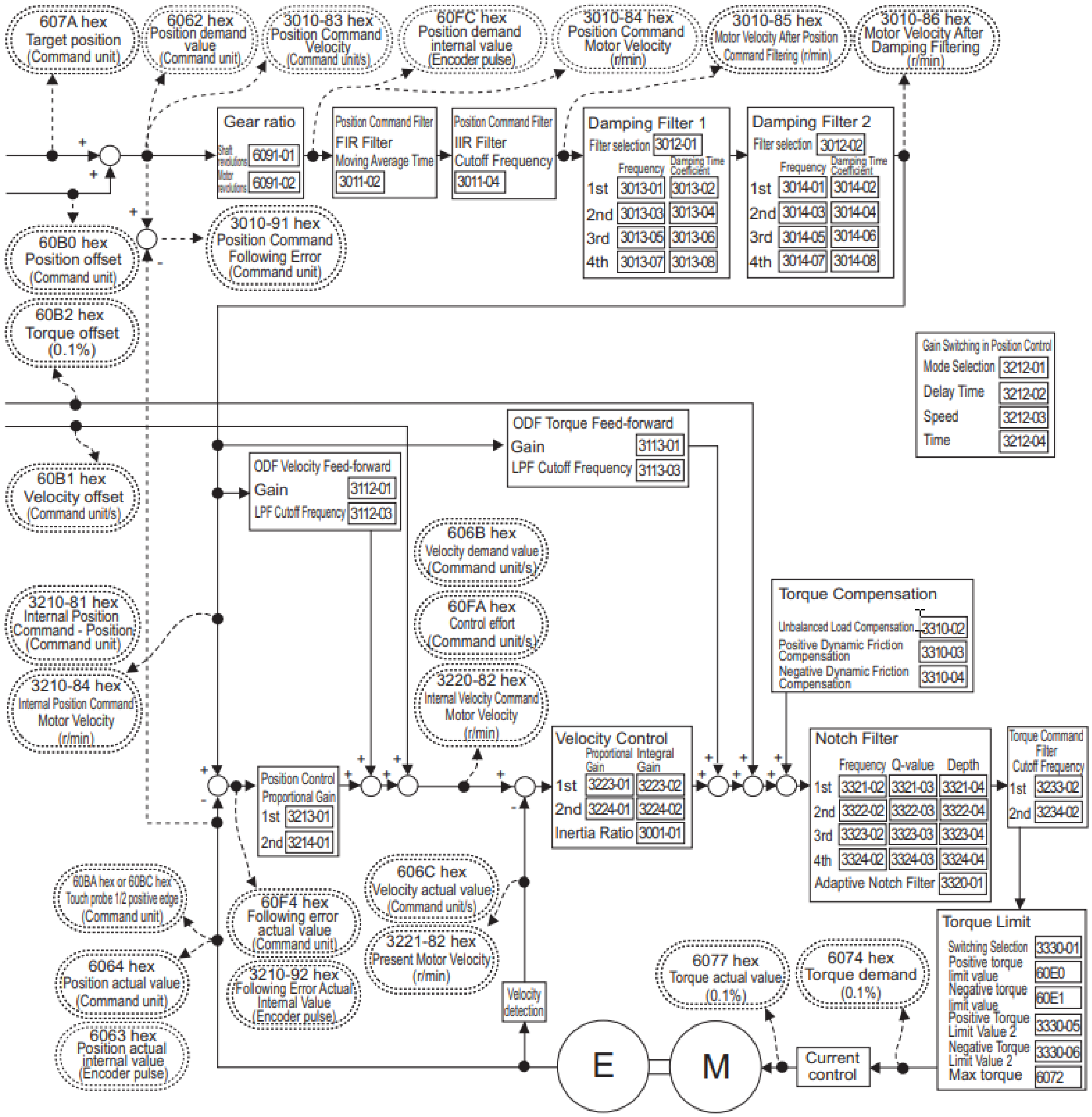
Use **Control Method Selection** (3000-03 hex) to switch between TDF control and ODF control.

Index (hex)	Subindex (hex)	Name	Description	Refer-ence
3000	---	Basic Functions	Set the basic functions.	P. 9-6
	03	Control Method Selection	Switches the control method between one-degree-of-freedom control and two-degree-of-freedom control. 0: ODF control 1: TDF control	P. 9-7

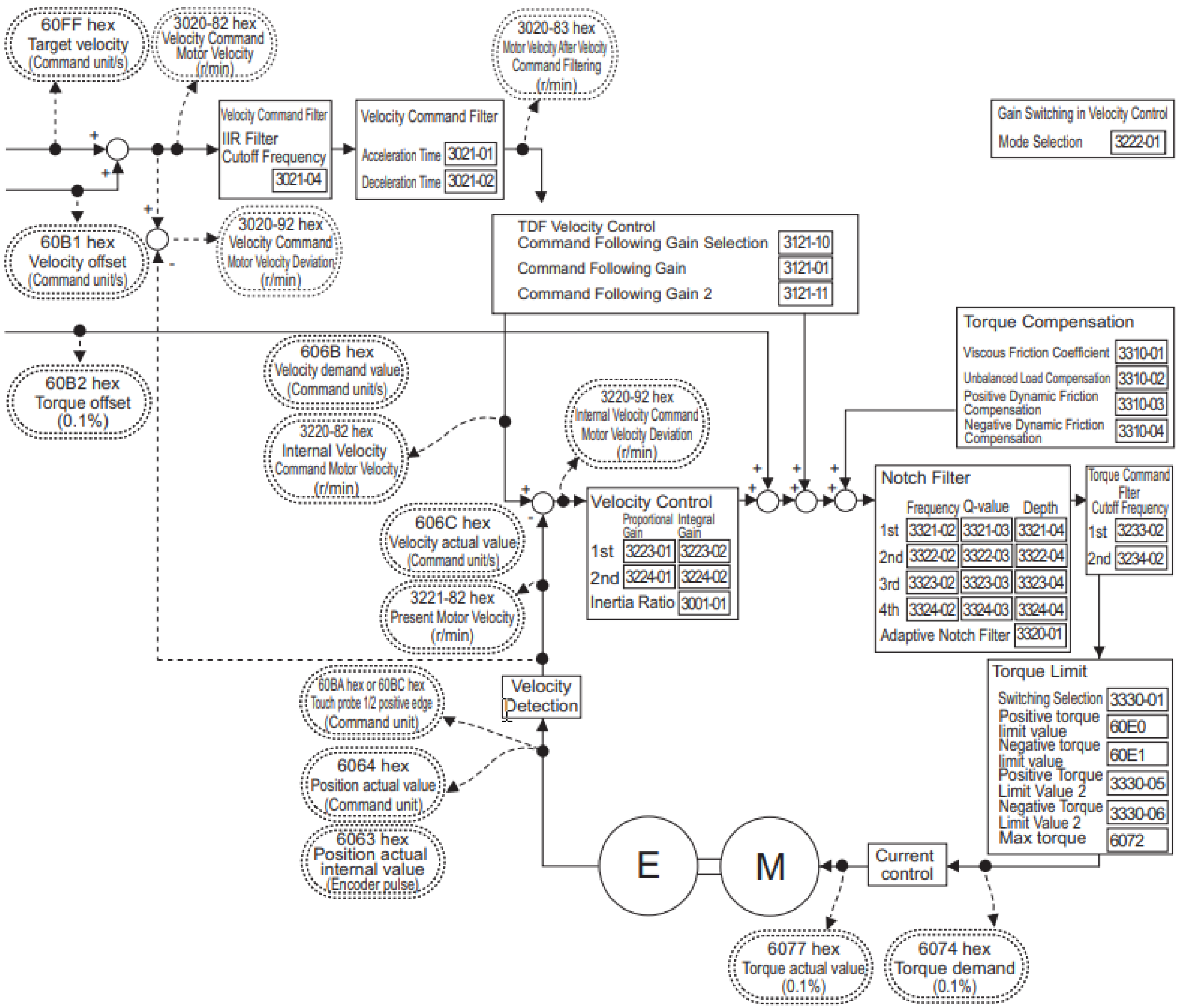
TDF Position Control



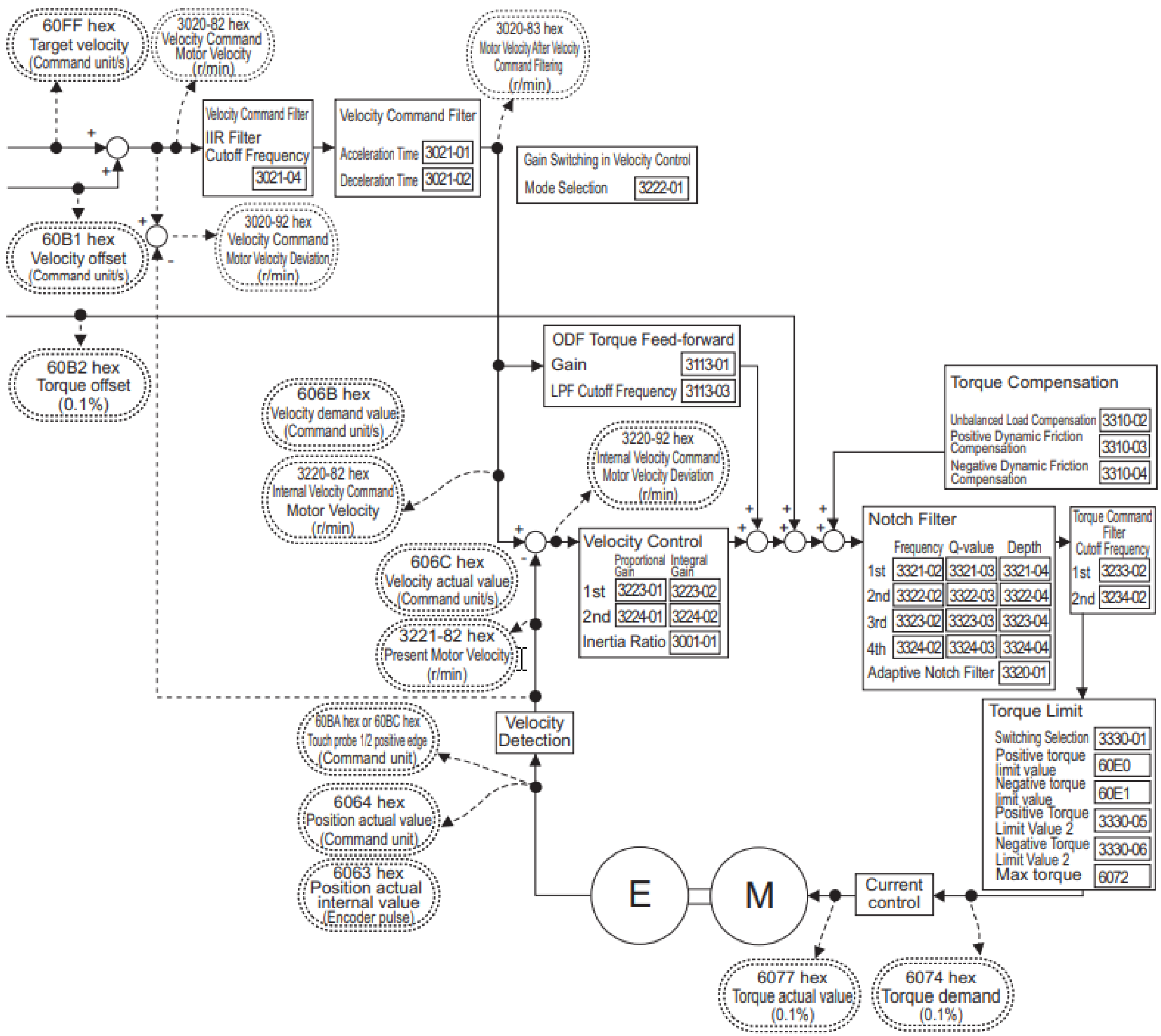
ODF Position Control



TDF Velocity Control

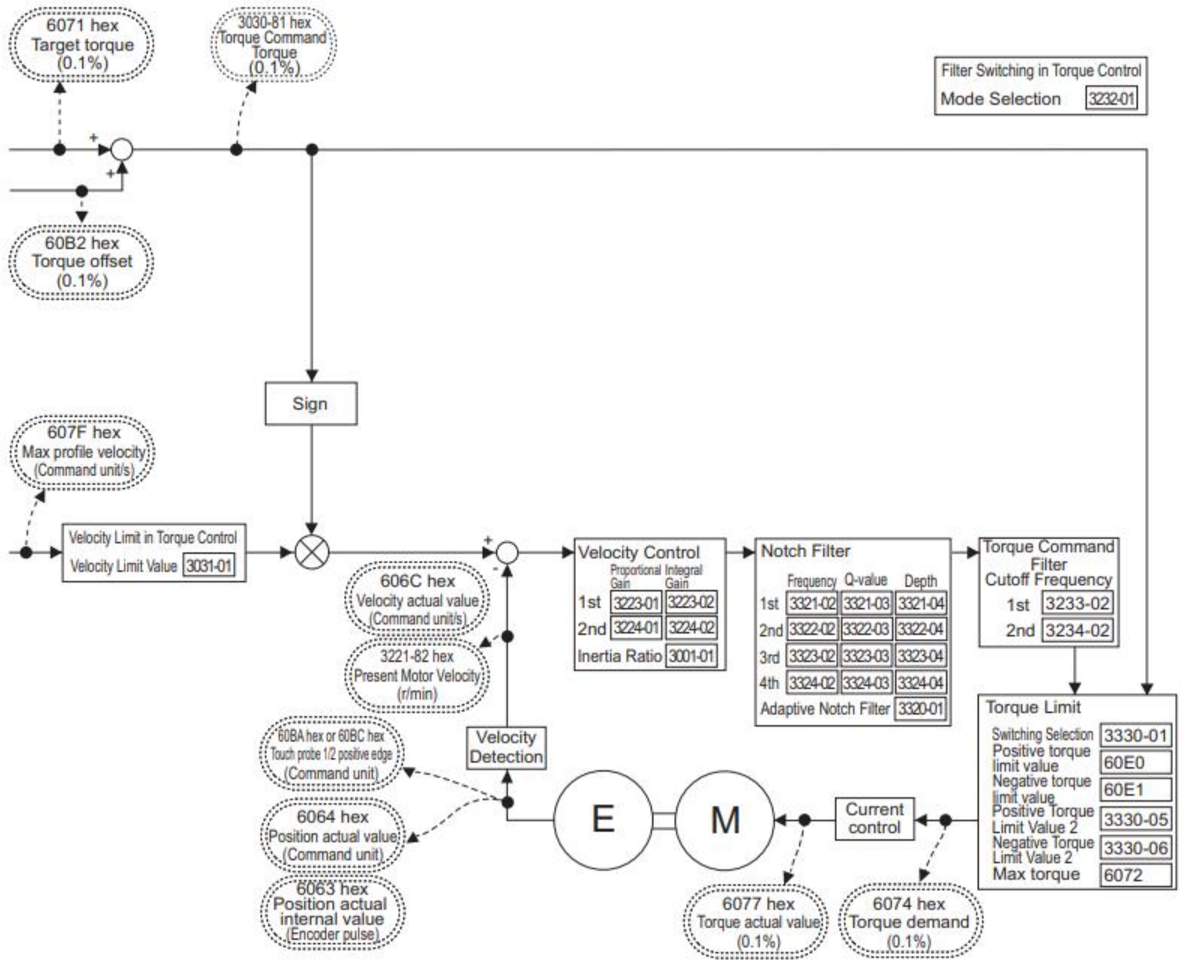


ODF Velocity Control



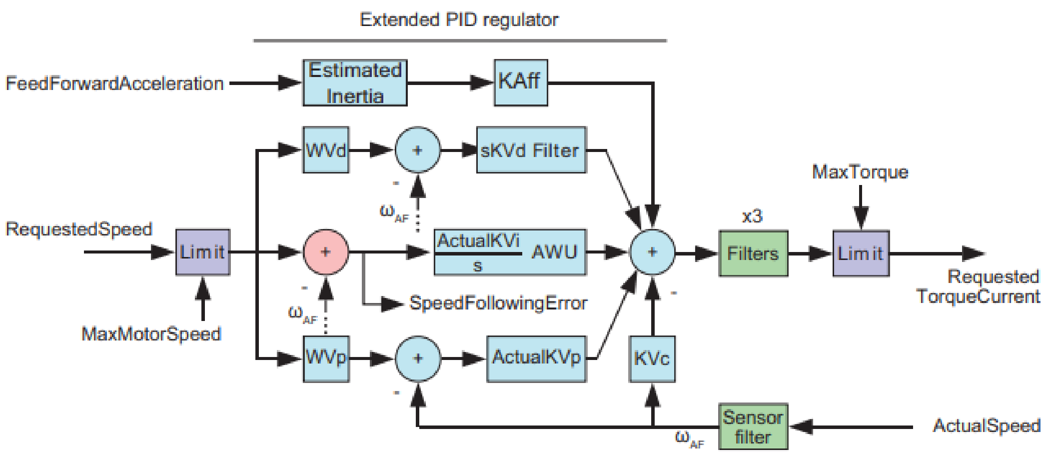
6-2-3 Block Diagram for Torque Control

The block diagram for torque control is given.

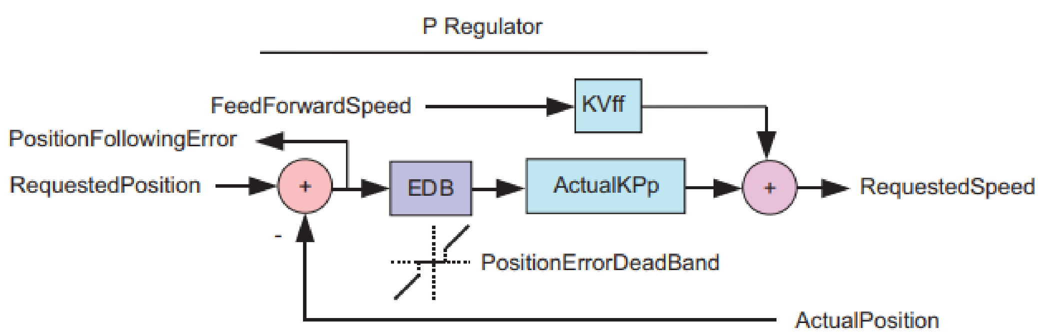


Omron motora entegre servo

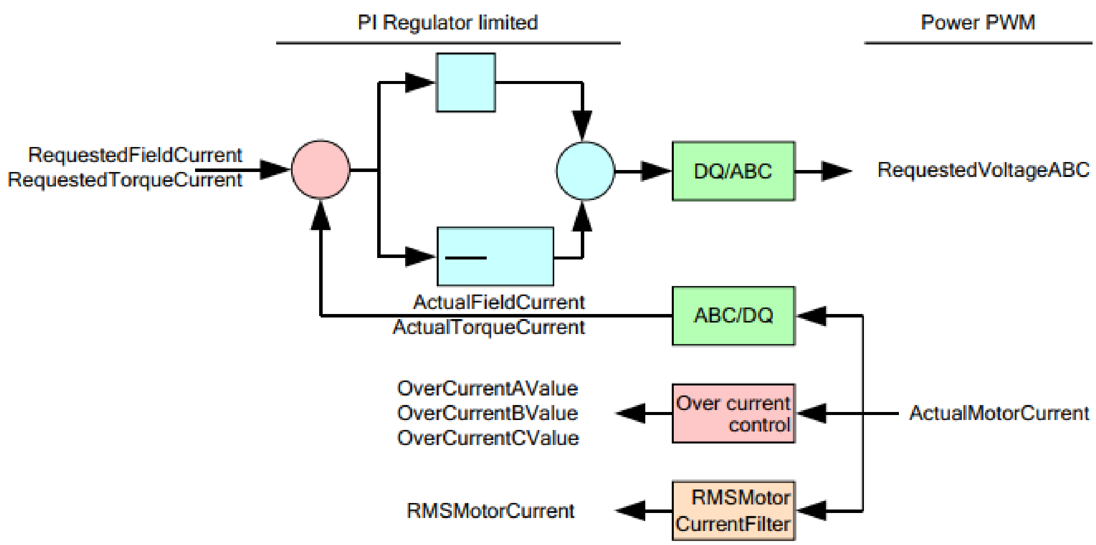
VelocityLoop



PositionLoop



CurrentLoop

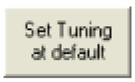


12-3 Fast Tuning Guide

This guide contains the quick criterion in 4 points to tune the drives of the Integrated Servo Motor series. The tuning must be carried out together with IM-TOOL according to the instructions in the **Section 12-1 How to Determine the Tuning Criterion**: each tuning operation must be carried out together with the check of the performances through the motor motion.

1. Setting the default configuration

The first operation to do is to set the drive on the default tuning configuration: press the



button in the Configuration Tuning tab. If the performances were not satisfactory, continue with the following points.

2. RL estimation

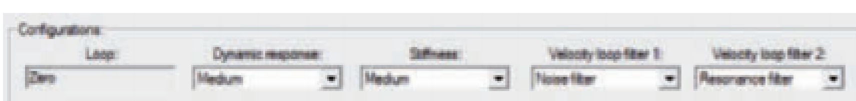
To optimize the **CurrentLoop [60F6.xx]** performances it's necessary to estimate the effective value of the phase resistance and of the synchronous motor inductance, by using the RL estimator (see **Section 12-9 RL estimator**). To estimate RL follow the instructions reported in the RL estimator area in the Tuning current Tab.

3. Estimating the inertia moment

Get the total inertia moment as to the shaft with the Inertia Estimator in the Tuning motion Tab (**Section 12-8 Inertia estimator**). If it is not possible to move the motor with the estimator or if it does not provide any reliable estimate, it is necessary to value the total inertia moment and calculating the parameters (**Section 12-7 Gains calculation**).

4. Modification of the tuning configurations

If necessary modify the TuningConfigurations considering the following.



- The option **DynamicResponse [3502.01]** acts on the motor dynamic performances. When the requested dynamic response increases, the motor reaction times and the following errors are reduced. But in contrast, when the dynamic response increases, the stability margins are reduced and any possible electrical and mechanical resonances amplified. These resonances are not always eliminated by using the filters but you have to accept a more limited dynamic response.

- The option **Stiffness** modifies the motor stiffness when it is stopped in torque. When the stiffness increases, the motor is more able to stay steady; on the contrary the stability margins are reduced and any possible electrical and mechanical resonances amplified as happening for the option **DynamicResponse [3502.01]**.

- The **VelocityLoopFilter1 [3502.03]** option works on the first filter of **VelocityLoop [60F9.xx]** and on the sensor filter and can take the following values:
  - User: the recalculation commands don't modify the filter parameters.
  - Soft filter: the filters are modified to make a heavy filtering action of the noise that's present in the loop.
  - Disable: the filtering action for the noise that's present in the **VelocityLoop [60F9.xx]** is deleted. But in this case it's possible to obtain a faster dynamic response.
  - Noise filter: the filters are modified to make a sweet filtering action of the noise that's present in the loop.

- The **VelocityLoopFilter2 [3502.04]** option works on the second **VelocityLoop [60F9.xx]** filter and can take the following values:
  - User: the filter parameters are not modified.
  - Resonance filter: a **Band-eliminating** filter is inserted to remove the mechanical resonances.
  - Disable: the filtering action is deleted.
  - Debounce filter: a The low-pass filter of the first order is inserted to remove the mechanical elasticity.

Note As default third velocity loop filter a **All-pass filter** is inserted.

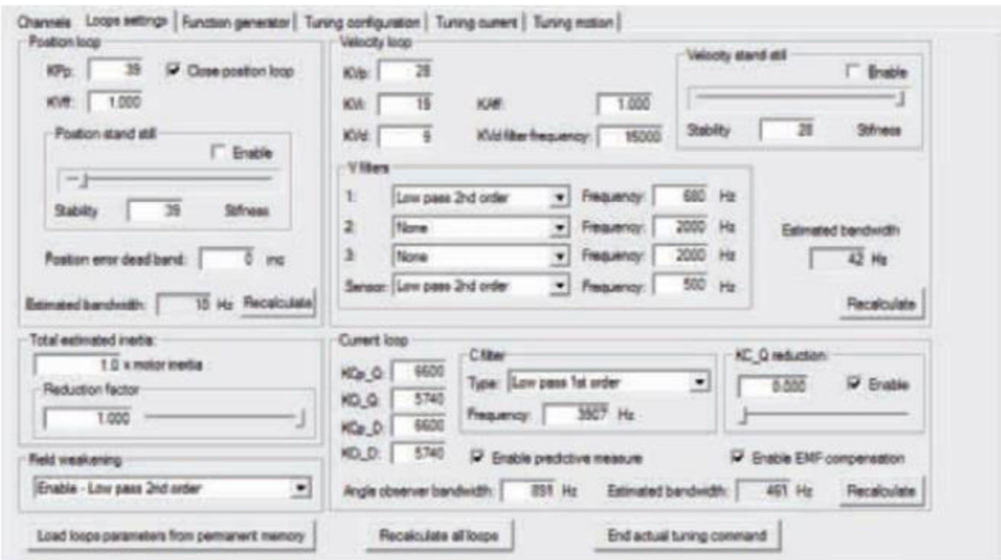
If the performances were not satisfactory use the criterion described in **Section 12-4 Detailed Tuning Guide**.

12-4 Detailed Tuning Guide

This guide contains the criterion described in 11 points about the drive tuning of the Integrated Servo Motor series. The tuning must be carried out together with IM-TOOL according to the instructions in the **Section 12-1 How to determine the tuning criterion**: each tuning operation must be carried out together with the check of the performances through the motor motion.

Unless differently specified the operations can be run from the tab Loops settings of IM-TOOL. Access:

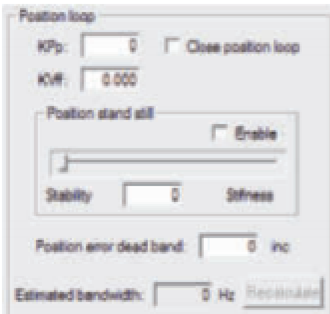
Main menu > Drive > Loop settings and tunning... > Tab Loop settings
or
Toolbar > > Tuning Loops setting.



2. PositionLoop inhibition

In this first phase concentrate on the tuning of the **VelocityLoop [60F9.xx]**. The **PositionLoop [60FB.xx]** must be strongly inhibited so that it cannot influence the dynamics of the **VelocityLoop [60F9.xx]**. In this phase it is accepted that **PositionFollowingError [60F4.00]** is slowly controlled. Proceed in this way:

- Disable the **EnablePositionStandStill [60FB.03]** option.
- Set **KPp [60FB.01]** equal to 4÷5 units when you have **EstimatedInertia [3503.05]** lower than 8 Jm.
- Set **KPp [60FB.01]** equal to 2÷3 units when you have **EstimatedInertia [3503.05]** higher than 8 Jm.
- Prefer lower values than **KPp [60FB.01]** in case of increase of **EstimatedInertia [3503.05]**.
- **KPp [60FB.01]** can be reset, if it is not important to hold the position or you are going to control the motor only in the speed modes.



3. Velocity stand still (only if the feedback sensor is an incremental encoder)

Regulate the bar **VelocityStandStill [3523.00]** by moving the motor at low speed. Low speeds are meant as those 30% of the parameter **HighSpeed [60F9.08]**. Move the bar towards Stability to attenuate any possible noise or resonances and towards Stiffness to increase the motor promptitude and stiffness. Do not take the bar to values of few units-; values lower than 20 units can damage the motor stiffness.

If the only way to attenuate the resonances is to seriously compromise the motor stiffness, it could be necessary to modify the filters configuration as shown in the next point.

4. Inertia moment reduction

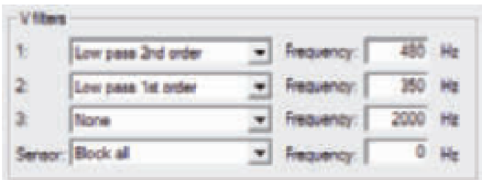
It occurs in the following cases:

- Load with inertia moment greater than 5Jm without moving
- Not rigid mechanical transmission
- Consistent plays and tolerance in the mechanical transmission

It's necessary to tune the motor as the whole inertia moment is lower than the estimated value. To do this it's necessary to decrease the value of the **InertiaReductionFactor [3503.06]** parameter that's present on the point 3 in the Gains calculation area in the Tuning motion Tab (try with 0.8, 0.5, 0.3). Too low values of **InertiaReductionFactor [3503.06]** cut down the motor dynamic performances. In this case it's advisable to even consider the following point.

5. Filters

The filters tuning of the **VelocityLoop [60F9.xx]** is useful to eliminate eventual resonances and regulation noises. The solutions closely depend on the load and transmission mechanical characteristics. There is no systematic regulation method, but it is advisable to act on the three regulator filters and then on the feedback sensor filter.



Proceed with some trials and progressively define the strategy to improve the performances. Test the following strategies (some may not be effective):

- Eliminate the Band-eliminating filter; choose as Type None, instead of Band stop.
- Insert a Low-pass filter of the second order as first filter and increase or decrease the frequency with steps of 50-100-200 Hz; if you get an improvement with frequencies higher than 1800 Hz, it is maybe possible to eliminate the filter by selecting Type None.
- Insert a low-pass filter of the first order instead of Low-pass filter of the second order as first filter; look again for an optimal filter frequency.
- Enable the other two filters to increase and modify the filtering action.
- Increase or decrease the sensor filter frequency with steps of 10-20-50 Hz.
- Insert a low-pass filter of the first order in place of Low-pass filter of the second order as feedback sensor filter.
- Search again for the filter frequency on the feedback sensor.
- Insert a Band-eliminating filter in the regulator to eliminate specific resonance frequencies. If the second filter is used, increase the **VFilter2QFactor [60F9.1B]** parameter to increase the selectivity of the filter.

If the feedback sensor is an incremental encoder and if the filters have improved the drive performances in low velocities, try to increase the system quickness by increasing **VelocityStandStill [3523.00]**, otherwise consider the following point.

6. Special parameters

If the resonances persist, try to modify the following parameters (not all of them are reported in the Loop settings Tab), while testing the motor with low velocities:

- Modify **KVd [60F9.11]**, even reset it. Also try to modify only the filtering action through the **KVdFilterFrequency [60F9.10]** parameter.
- Decrease **WVd [60F9.12]** and **WVp [60F9.13]** until they are reset.
- Increase **KVc [60F9.14]** progressively to increase the damping effect; try with steps of 20-50-100 units.

7. Stopped motor

Run some stability tests when the motor is stopped in torque. If possible, disturb the mechanical load from outside with the motor stopped in torque to test the motor ability to absorb and dampen the resonances. In case of unwanted effects, try to modify the filters or the **VelocityStandStill [3523.00]** parameter (verify that the **EnableVelocityStandStill [60F9.17]** option is enabled).

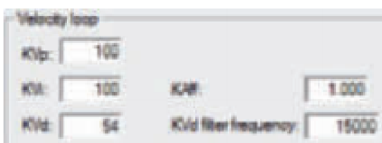
8. Quick decelerations

When the deceleration increases, the possibility to get resonances increases when the motor ends the deceleration ramp. Run some tests with the requested decelerations, in case of unwanted effects readjust the filters or the parameter **VelocityStandStill [3523.00]**. If the resonances persist, it's necessary to limit the required working decelerations.

9. Working speed

Proceed with tests with greater velocities, but never greater than the limits; start with a velocity equal to 50% of the **HighSpeed [60F9.08]** parameter and increase the velocity over the required working velocity. The speed profile to generate can be the one the machine is designed for. In these tests modify the parameters **KVp** and **KVi**, with the following criteria:

- Increase **KVp [60F9.01]** and **KVi [60F9.03]** to make the system more quick, try with steps of 20% till the system becames unstable. These parameters have greater effect for speeds higher than **HighSpeed [60F9.08]** if the **EnableVelocityStandStill [60F9.17]** option is enabled.
- Decrease **KVp [60F9.01]** and **KVi [60F9.03]** to make the system more stable and eliminate the resonances, proceed with decreases of 20% until the system becomes stable. If the option **EnableVelocityStandStill [60F9.17]** is enabled, these parameters have less effect for speeds lower than **HighSpeed [60F9.08]**. If there are some resonances for speeds much lower than **HighSpeed [60F9.08]**, readjust **VelocityStandStill [3523.00]** and the filters.



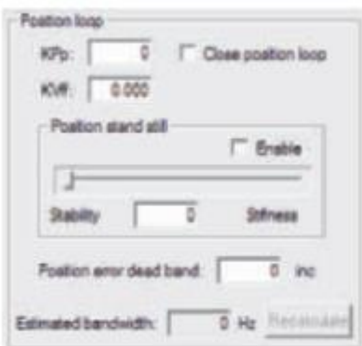
10. Feed forward acceleration

To adjust the parameter **KAff [60F9.16]** move the motor by commanding accelerations and decelerations similar to the machine working ones. Increase or decrease **KAff [60F9.16]** in order to minimize SpeedFollowingError during the acceleration and deceleration ramps. Try with steps of 100-500-1000 units. If FeedForwardAcceleration is noisy, it may be useful to reset to zero **KAff [60F9.16]** in order to reduce the noise that enters in the loop.

11. PositionLoop

When the **VelocityLoop [60F9.xx]** is adjusted in the best possible way, the **PositionLoop [60FB.xx]** adjustment becomes very easy. Follow these rules:

- Push the Recalculate button in the **PositionLoop [60FB.xx]** area.
- Increase **KPp [60FB.01]** till the appearance of some not damped resonances or oscillations of the **PositionFollowingError [60F4.00]**. Try with steps of 5-10 units.
- Enable the **EnablePositionStandStill [60FB.04]** option and set the value of **PositionStandStill [60FB.03]** equal to **KPp [60FB.01]**.
- Modify **PositionStandStill [60FB.03]** by valuing the effects on the **PositionFollowingError [60F4.00]**. This parameter has a greater effect for speeds lower than **HighSpeed [60F9.08]** and with stopped motor in torque. Increase its value to increase the resetting speed of the **PositionFollowingError [60F4.00]**; decrease its value to eliminate not damped oscillations at low speeds. With the bar at 0, **PositionFollowingError [60F4.00]** is not controlled.
- Check if **PositionLoopEstimatedBandwidth [3501.03]** is lower at least 0.7 times **VelocityLoopEstimated-Bandwidth [3501.02]**.

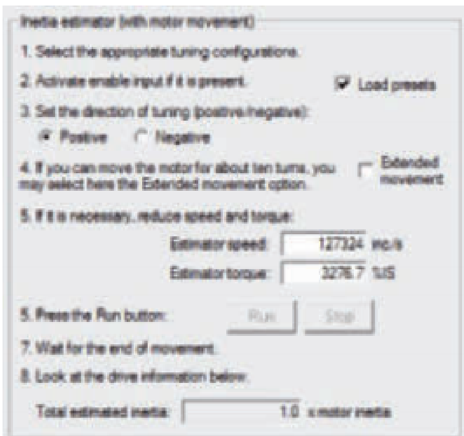


12-8 Inertia Estimator

Note Before enabling the Inertia estimator, check if you can stop the motor in safety. To avoid unwanted motions or collisions, take all the necessary precautions and configure precisely the drive limits.

The Inertia estimator runs a controlled motor motion to estimate the total inertia moment, calculating it as compared to the motor shaft. According to the estimated inertia moment (Total **EstimatedInertia [3503.05]**) and of the **TuningConfigurations [3502.xx]**, the parameters of the speed and position loops are calculated again. Follow the instructions in the Inertia estimator area of the Tuning motion Tab. Access with IM-TOOL:

Main menu > Drive > Loop settings and tunning... > Tab Tuning motion
or
Toolbar > > Tab Tuning motion.



Advised procedure to estimate the inertia moment

(a) Choose the following **TuningConfigurations [3502.xx]**: Medium, Noise filter and Resonance filter.

(b) Set the motor in order to run the requested motion. Take all the necessary precautions and configure precisely the drive limits.

(c) Select the wanted direction and the option Load preset, which sets a series of oscilloscope parameters.

(d) Only if the shaft cannot run about ten revolutions go to the point g, otherwise select the option Extended movement.

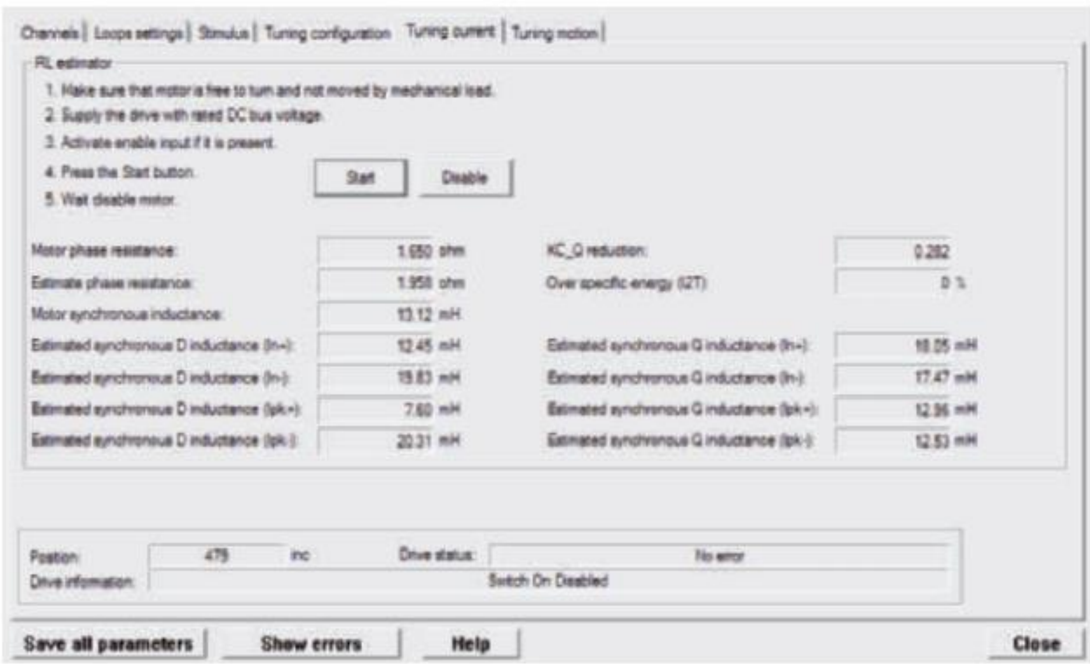
Note If you do not select the option Extended movement, a torque impulse is applied to the motor and the motor runs a fourth of a revolution maximum. If you select the option Extended movement, a more complex motion is run and the motor runs ten revolutions maximum. If the shaft can run only a limited revolution number, it is better to position it so that during the tuning it does not overcome its race limits. In any case it is advisable to enable the position limits.

12-9 RL Estimator

To optimize the current loop performances it's necessary to estimate the effective value of the phase resistance and of the synchronous motor inductance. RL Estimator executes an off line estimation of this parameters through the application of some ramps and pulses of current to the motor phases. During the RL estimation command the drive may move the motor shaft up to 1 polar step. According to the estimated inductance (see **RLEstimator [3504.xx]** group parameters), the parameters of the speed and position loops are calculated again.

To estimate RL follow the instructions reported in the RL estimator area in the Tuning current Tab. Access with IM-TOOL:

Main menu > Drive > Loop settings and tunning... > Tab Tuning current
or
Toolbar > > Tab Tuning current.



Note During the RL estimation the **I2TValue [3405.05]** value, that can be read in the "Over specific energy (I2T)" box of the same page, increases. Always wait that it takes the 0 value. The end of the RL estimation command, coincides with the automatic disabling of the motor. Always wait its disable.

Note Considering that the current pulses reach **MotorPeakCurrent [6410.02]**, be sure that the voltage supply **DCBusVoltage [3310.01]** remains stable during the command.

Note To correctly estimate RL follow the instruction list in the Tuning current Tab.

Note The oscilloscope is not activated because a video diagnostics is not necessary. The results are reported in the Tuning current Tab.

8-9 Digital Filters

The Integrated Servo Motor provide a library of programmable digital filters. The available filters are:

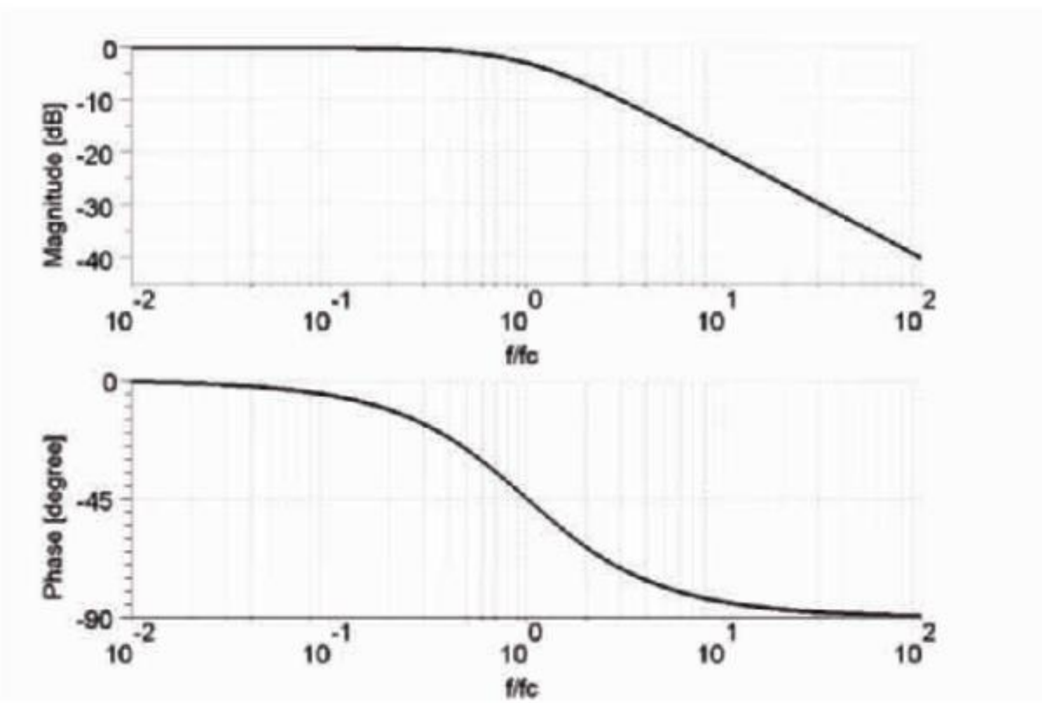
- All-pass filter
- Low-pass filter of the first order
- Low-pass filter of the second order
- Band-eliminating filter
- All-stop filter

The parameters of every filter can be modified in any moment, even during the working of the filter. The output of the filter adjusts in real time to the new settings.

Note Do not set the frequencies of the filters at 0 Hz or at values which are one third higher than the frequency of the filter sampling.

Low-pass filter of the first order

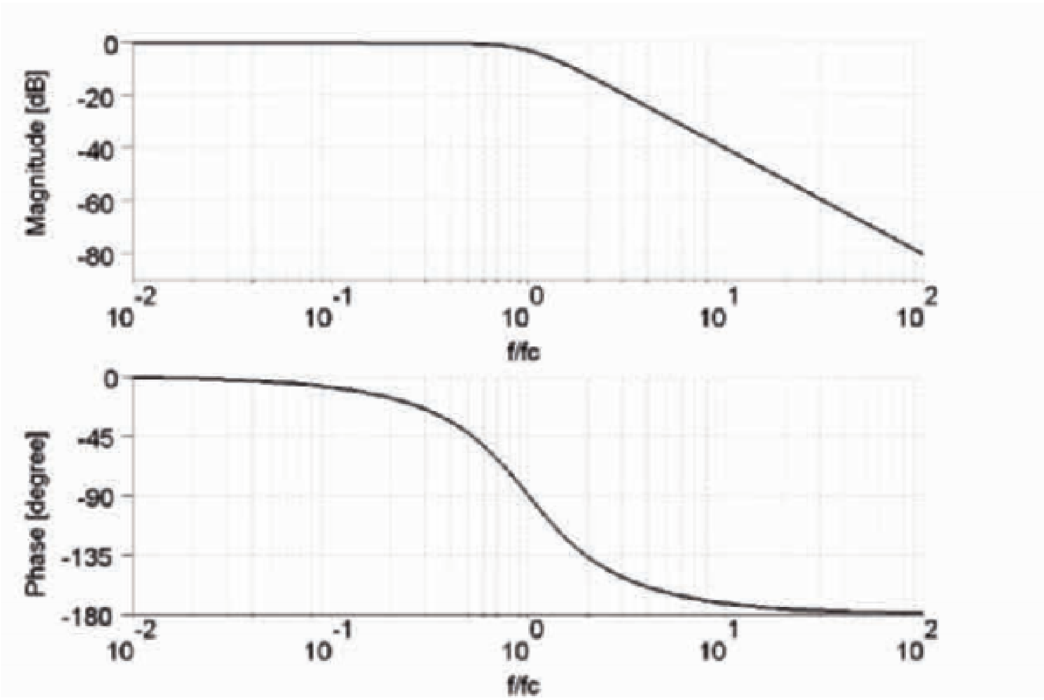
The low-pass filter of the first order is implemented in the Integrated Servo Motors as a Butterworth low-pass digital filter of the first order with pre-warping compensation. Here you can find the Bode diagrams of the function of filter transfer as the frequency changes, normalized at the value of the critical frequency. You can notice that for frequencies higher than the critical frequency, the module slope is -20dB/decade and the maximum phase delay is 90°.



Note Setting the frequency at 0 means having a filter with an infinite attenuation band. This condition cannot be accepted because the filter loses its low-pass property. It is not recommended to use the filter under these conditions.

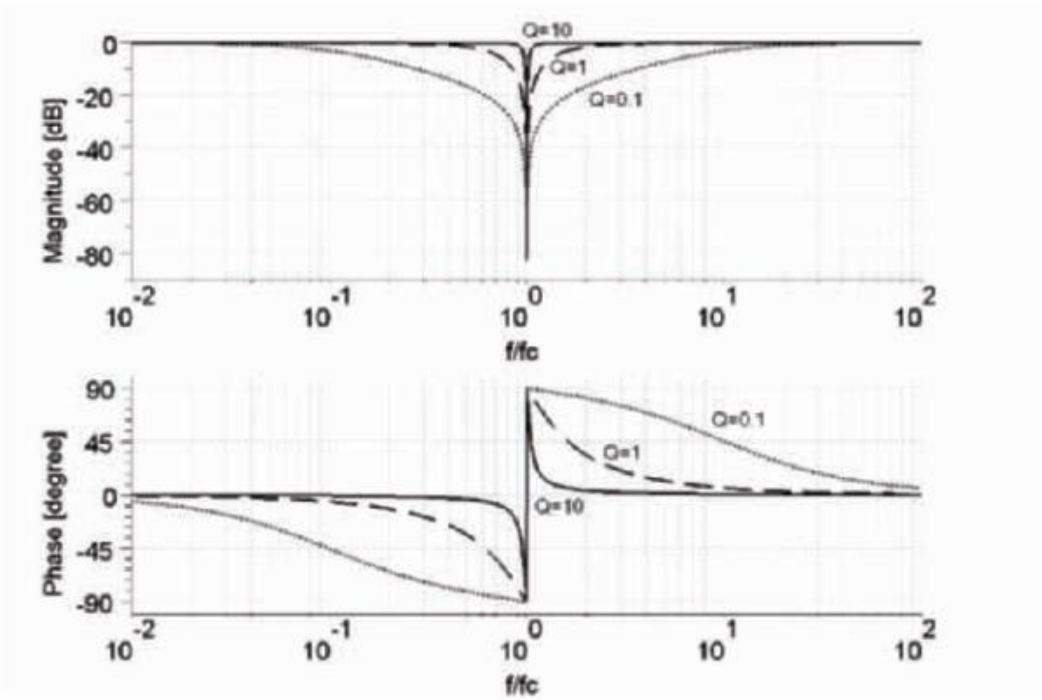
Low-pass filter of the second order

The low-pass filter of the second order is implemented in the Integrated Servo Motors as a Butterworth low-pass digital filter of the second order with pre-warping compensation. Here you can find the Bode diagrams of the function of filter transfer as the frequency changes, normalized at the value of the critical frequency. You can notice that for frequencies higher than the critical frequency, the module slope is -40dB/decade and the maximum phase delay is 180°.



Band-eliminating filter

The band-eliminating filter is implemented in the Integrated Servo Motors as a Notch filter of the second order with pre-warping compensation. Here you can find the Bode diagrams of the function of filter transfer as the frequency changes, normalized at the value of the central frequency, for different values of the Q quality factor.



Note Setting a Q quality factor at 0 means having a filter with an infinite attenuation band. This condition cannot be accepted because the filter loses its band-eliminating property. Furthermore when the Q quality factor increases and the central frequency decreases, the filter convergence time increases. It is not recommended to use the filter under these conditions.

Usage

Those filters can be applied to:

- Analogue input
- Rms torque calculation
- Speed and torque regulation loops
- Encoder feedback

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switching frequency	8 kHz

discrete input number	2 safety discrete input(s) 6 logic discrete input(s)
discrete input type	Logic (DI terminals) Safety (compliment of STO_A, compliment of STO_B terminals)
sampling duration	ANA1+/ANA1-, ANA2+/ANA2-: 0.25 ms analog DI: 0.25 ms discrete
discrete input voltage	24 V DC for logic 24 V DC for safety
discrete input logic	Positive (compliment of STO_A, compliment of STO_B) at State 0: < 5 V at State 1: > 15 V conforming to EN/IEC 61131-2 type 1 Positive (DI) at State 0: > 19 V at State 1: < 9 V conforming to EN/IEC 61131-2 type 1 Positive or negative (DI) at State 0: < 5 V at State 1: > 15 V conforming to EN/IEC 61131-2 type 1
response time	<= 5 ms compliment of STO_A, compliment of STO_B
discrete output number	5
discrete output type	Logic output(s) (DO)24 V DC
discrete output voltage	<= 30 V DC
discrete output logic	Positive or negative (DO) conforming to EN/IEC 61131-2
contact bounce time	<= 1 ms for compliment of STO_A, compliment of STO_B 0.25 µs...1.5 ms for DI
analogue input number	2
response time on output	250 µs (DO) for discrete output(s)
absolute accuracy error	< +/- 0.5 %
linearity error	< +/- 0.1 %
analogue input type	ANA1+/ANA1-, ANA2+/ANA2- analog input: differential +/- 10 V, impedance: >= 20 Ohm, resolution: 14 bits
control signal type	Servo motor encoder feedback Pulse train output (PTO) RS422 <500 kHz <100 m Pulse/direction (P/D), A/B, CW/CCW 5 V, 24 V link (open collector) <10 kHz <1 m Pulse/direction (P/D), A/B, CW/CCW 5 V, 24 V link (push-pull) <200 kHz <10 m Pulse/direction (P/D), A/B, CW/CCW RS422 <1000 kHz <100 m

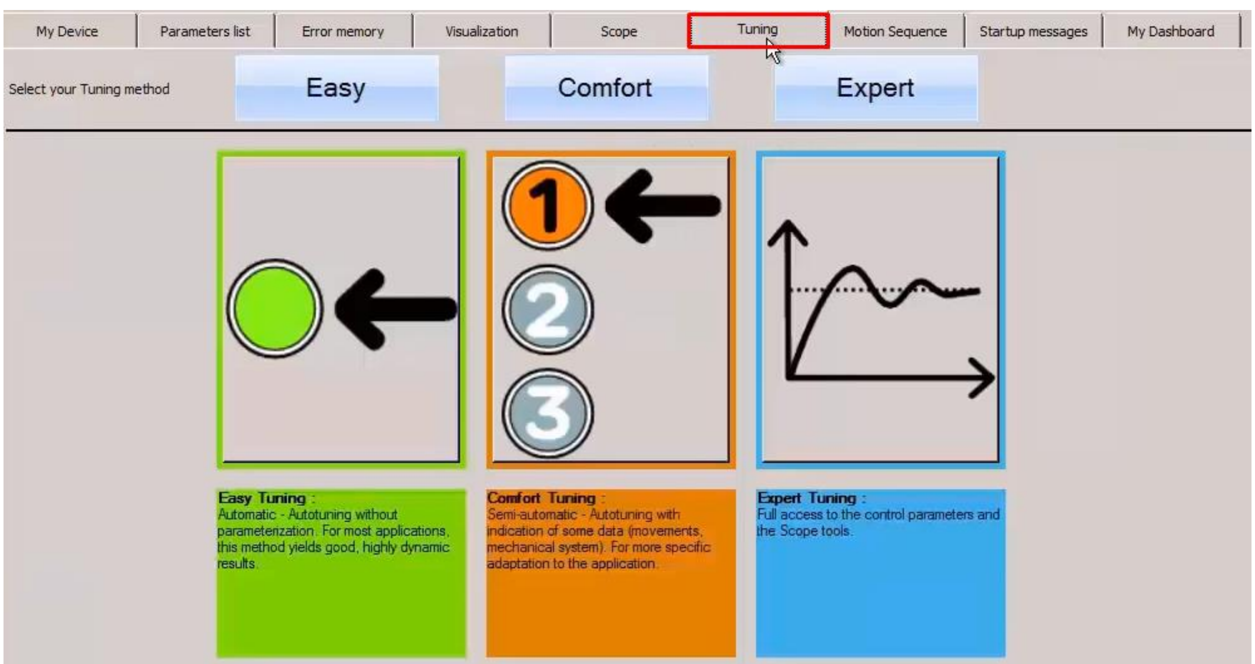
Gui

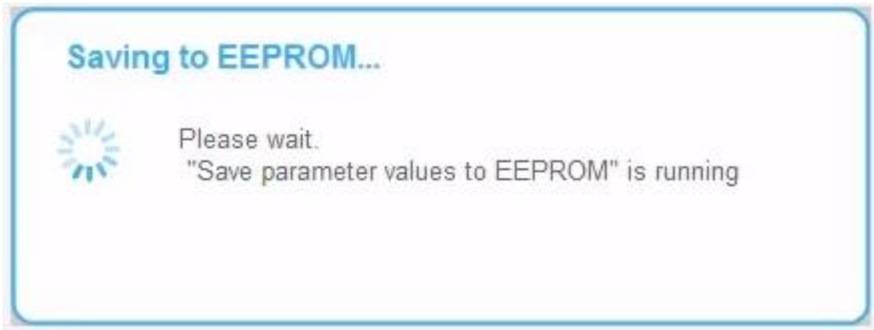
Control parameter set 1

Name	Value	Long Label	Min. value	Max. value	Logical address
CTRL1_KPp	21.2 1/s	Position controller P gain	2.0 1/s	900.0 1/s	4614
CTRL1_KPn	0.0234 A/(1/min)	Velocity controller P gain	0.0001 A/(1/min)	2.5400 A/(1/min)	4610
CTRL1_TNn	7.86 ms	Velocity controller integral action time	0.00 ms	327.67 ms	4612
CTRL1_KFPp	0.0 %	Velocity feed-forward control	0.0 %	200.0 %	4620
CTRL1_TAUnref	9.00 ms	Filter time constant of the reference velocity value filter	0.00 ms	327.67 ms	4616
CTRL1_TAUiref	0.50 ms	Filter time constant of the reference current value filter	0.00 ms	4.00 ms	4618
CTRL1_Nf1freq	1500.0 Hz	Notch filter 1: Frequency	50.0 Hz	1500.0 Hz	4626
CTRL1_Nf1damp	90.0 %	Notch filter 1: Damping	55.0 %	99.0 %	4624
CTRL1_Nf1bandw	70.0 %	Notch filter 1: Bandwidth	1.0 %	90.0 %	4628
CTRL1_Osupdamp	0.0 %	Overshoot suppression filter: Damping	0.0 %	50.0 %	4636
CTRL1_Osupdelay	0.00 ms	Overshoot suppression filter: Time delay	0.00 ms	75.00 ms	4638
CTRL1_Nf2freq	1500.0 Hz	Notch filter 2: Frequency	50.0 Hz	1500.0 Hz	4632
CTRL1_Nf2damp	90.0 %	Notch filter 2: Damping	55.0 %	99.0 %	4630
CTRL1_Nf2bandw	70.0 %	Notch filter 2: Bandwidth	1.0 %	90.0 %	4634
CTRL1_Kfric	0.00 Arms	Friction compensation: Gain	0.00 Arms	10.00 Arms	4640

Control parameter set 2

Name	Value	Long Label	Min. value	Max. value	Logical address
CTRL2_KPp	21.2 1/s	Position controller P gain	2.0 1/s	900.0 1/s	4870
CTRL2_KPn	0.0234 A/(1/min)	Velocity controller P gain	0.0001 A/(1/min)	2.5400 A/(1/min)	4866
CTRL2_TNn	7.86 ms	Velocity controller integral action time	0.00 ms	327.67 ms	4868
CTRL2_KFPp	0.0 %	Velocity feed-forward control	0.0 %	200.0 %	4876
CTRL2_TAUnref	9.00 ms	Filter time constant of the reference velocity value filter	0.00 ms	327.67 ms	4872
CTRL2_TAUiref	0.50 ms	Filter time constant of the reference current value filter	0.00 ms	4.00 ms	4874
CTRL2_Nf1freq	1500.0 Hz	Notch filter 1: Frequency	50.0 Hz	1500.0 Hz	4882
CTRL2_Nf1damp	90.0 %	Notch filter 1: Damping	55.0 %	99.0 %	4880
CTRL2_Nf1bandw	70.0 %	Notch filter 1: Bandwidth	1.0 %	90.0 %	4884
CTRL2_Osupdamp	0.0 %	Overshoot suppression filter: Damping	0.0 %	50.0 %	4892
CTRL2_Osupdelay	0.00 ms	Overshoot suppression filter: Time delay	0.00 ms	75.00 ms	4894
CTRL2_Nf2freq	1500.0 Hz	Notch filter 2: Frequency	50.0 Hz	1500.0 Hz	4888
CTRL2_Nf2damp	90.0 %	Notch filter 2: Damping	55.0 %	99.0 %	4886
CTRL2_Nf2bandw	70.0 %	Notch filter 2: Bandwidth	1.0 %	90.0 %	4890
CTRL2_Kfric	0.00 Arms	Friction compensation: Gain	0.00 Arms	10.00 Arms	4896

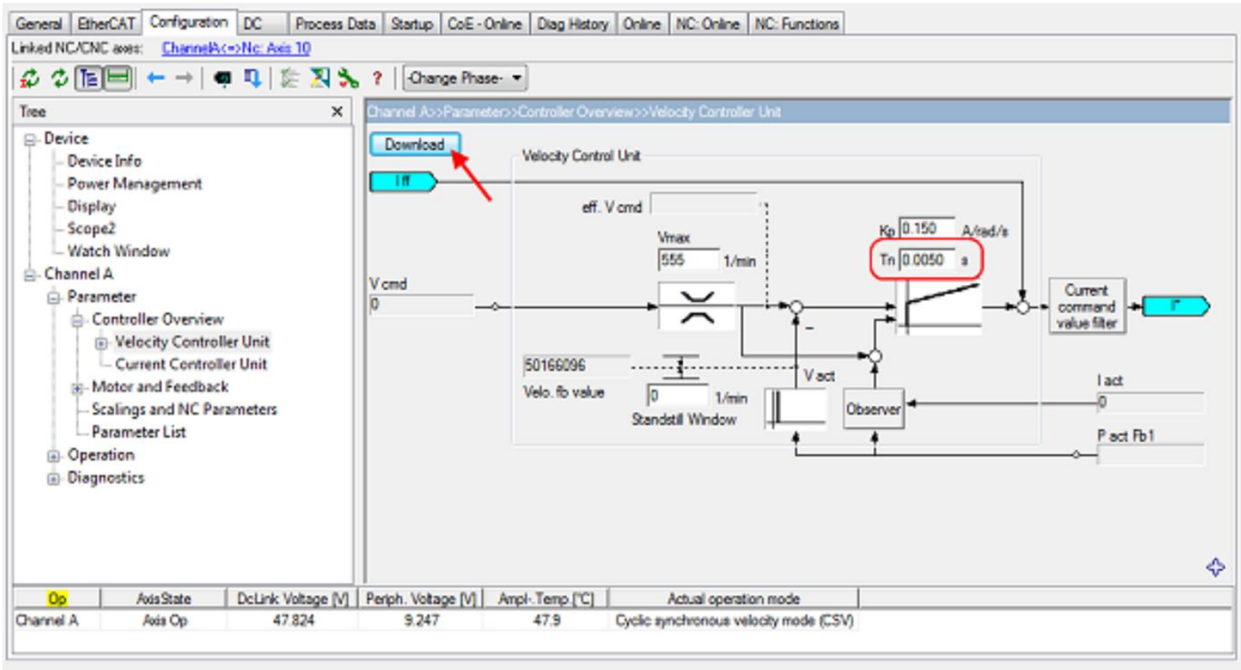




Third party motor

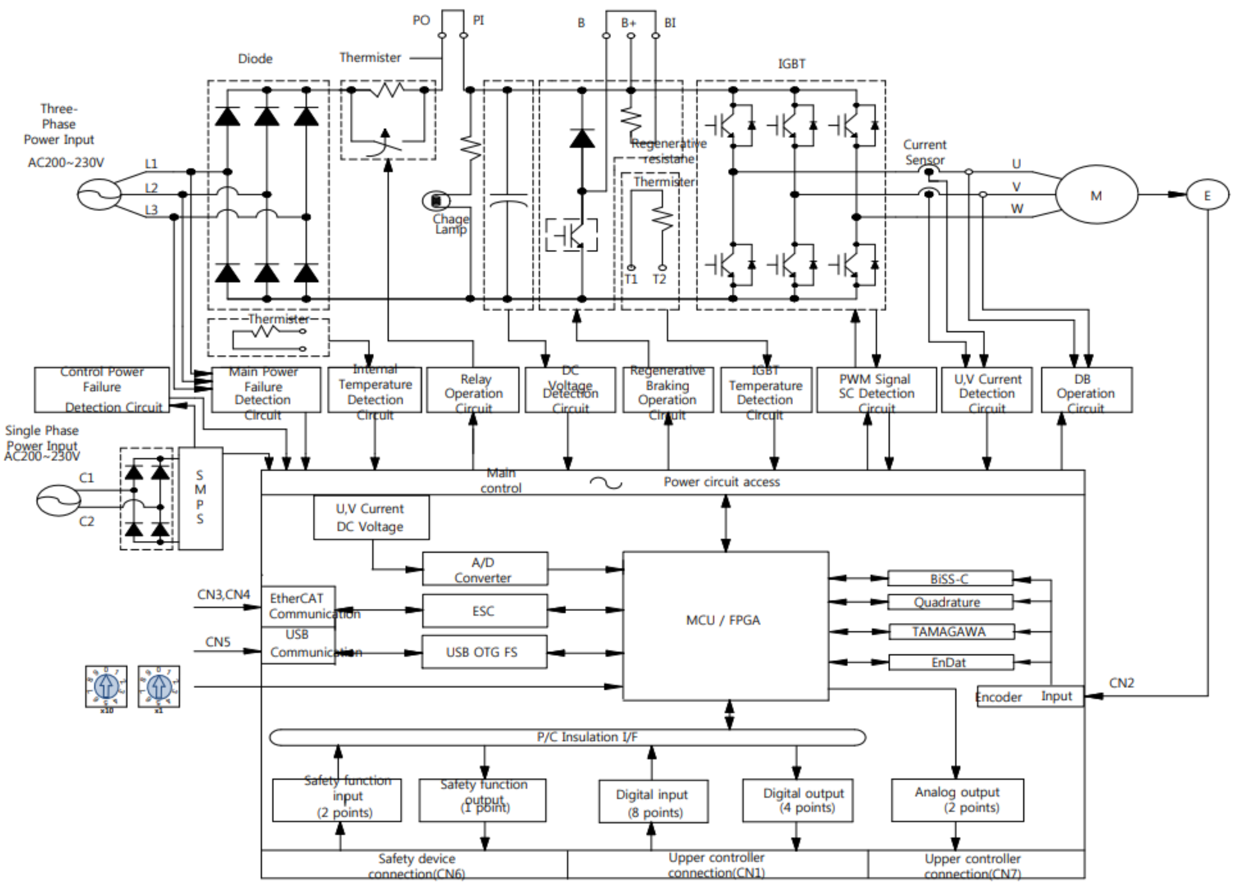
Name	Value	Long Label	Min. value
Motor data			
M_n_nom	0 min^{-1}	[Rated speed]	0 min^{-1}
M_I_max	300.00 Arms	Maximum motor current	0.01 Arms
M_I_nom	0.00 Arms	[Rated current]	0.00 Arms
M_I_0	0.07 Arms	[Cont. stall current]	0.07 Arms
M_U_max	0.0 V	[Max. line voltage]	0.0 V
M_Polepair	1	[Pole pairs]	1
M_M_0	1 Ncm	[Cont. stall torque]	1 Ncm
M_R_UV	0.01 Ohm	[Phase resistance (line to line)]	0.01 Ohm
M_L_q	0.01 mH	[L (q-direction, line to line)]	0.01 mH
M_L_d	0.01 mH	[L (d-direction, line to line)]	0.01 mH
M_Lq_Sat_1	0 %	[Lq-saturation table 1*I0]	0 %
M_Lq_Sat_2	0 %	[Lq-saturation table 2*I0]	0 %
M_Lq_Sat_3	0 %	[Lq-saturation table 3*I0]	0 %
M_Lq_Sat_4	0 %	[Lq-saturation table 4*I0]	0 %
M_Lq_Sat_5	0 %	[Lq-saturation table 5*I0]	0 %
M_Fieldrotation	0	[Rot. field dir. right]	
M_kE	0.1 Vrms/1000 min^{-1}	[EMF]	0.1 Vrms/1000 min^{-1}
M_I2t	0 ms	[Max. time I peak]	0 ms
M_n_max	26400 min^{-1}	[Max. speed]	1 min^{-1}
M_Jrot	0.001 $kgcm^2$	[Inertia (or mass)]	0.001 $kgcm^2$

Name	Value	Long Label	Min. value
Motor data			
M_n_nom	1200 min^{-1}	[Rated speed]	0 min^{-1}
M_I_max	27.50 Arms	Maximum motor current	0.01 Arms
M_I_nom	9.12 Arms	[Rated current]	0.00 Arms
M_I_0	9.20 Arms	[Cont. stall current]	0.07 Arms
M_U_max	230.0 V	[Max. line voltage]	0.0 V
M_Polepair	5	[Pole pairs]	1
M_M_0	1880 Ncm	[Cont. stall torque]	1 Ncm
M_R_UV	1.34 Ohm	[Phase resistance (line to line)]	0.01 Ohm
M_L_q	11.80 mH	[L (q-direction, line to line)]	0.01 mH
M_L_d	11.80 mH	[L (d-direction, line to line)]	0.01 mH
M_Lq_Sat_1	0 %	[Lq-saturation table 1*I0]	0 %
M_Lq_Sat_2	0 %	[Lq-saturation table 2*I0]	0 %
M_Lq_Sat_3	0 %	[Lq-saturation table 3*I0]	0 %
M_Lq_Sat_4	0 %	[Lq-saturation table 4*I0]	0 %
M_Lq_Sat_5	0 %	[Lq-saturation table 5*I0]	0 %
M_Fieldrotation	0	[Rot. field dir. right]	
M_kE	147.0 Vrms/1000 min^{-1}	[EMF]	0.1 Vrms/1000 min^{-1}
M_I2t	1000 ms	[Max. time I peak]	0 ms
M_n_max	26400	[Max. speed]	1 min^{-1}
M_Jrot	0.001 kgcm	[Inertia (or mass)]	0.001 $kgcm^2$


General
EtherCAT
Configuration
DC
Process Data
Startup
CoE - Online
Diag History
Online
NC: Online
NC: Functions
Linked NC/CNC axes:
ChannelA<=>Nc: Axis 10
-Change Phase-
Tree
Device
Device Info
Power Management
Display
Scope2
Watch Window
Channel A
Parameter
Controller Overview
Velocity Controller Unit
Current Controller Unit
Motor and Feedback
Scalings and NC Parameters
Parameter List
Operation
Diagnostics
Channel A>>Parameter>>Controller Overview>>Velocity Controller Unit
Download
Velocity Control Unit
eff. V cmd
Vmax
555
1/min
Kp
0.150
A/rad/s
Tn
0.0050
s
V cmd
0
Current command value filter
50166096
Velo. fb value
0
1/min
Standstill Window
V act
Observer
I act
0
P act Fb1
Op
AxisState
DcLink Voltage [V]
Periph. Voltage [V]
Ampl.-Temp.[°C]
Actual operation mode
Channel A
Axis Op
47.824
9.247
47.9
Cyclic synchronous velocity mode (CSV)

6 Parker

Asd

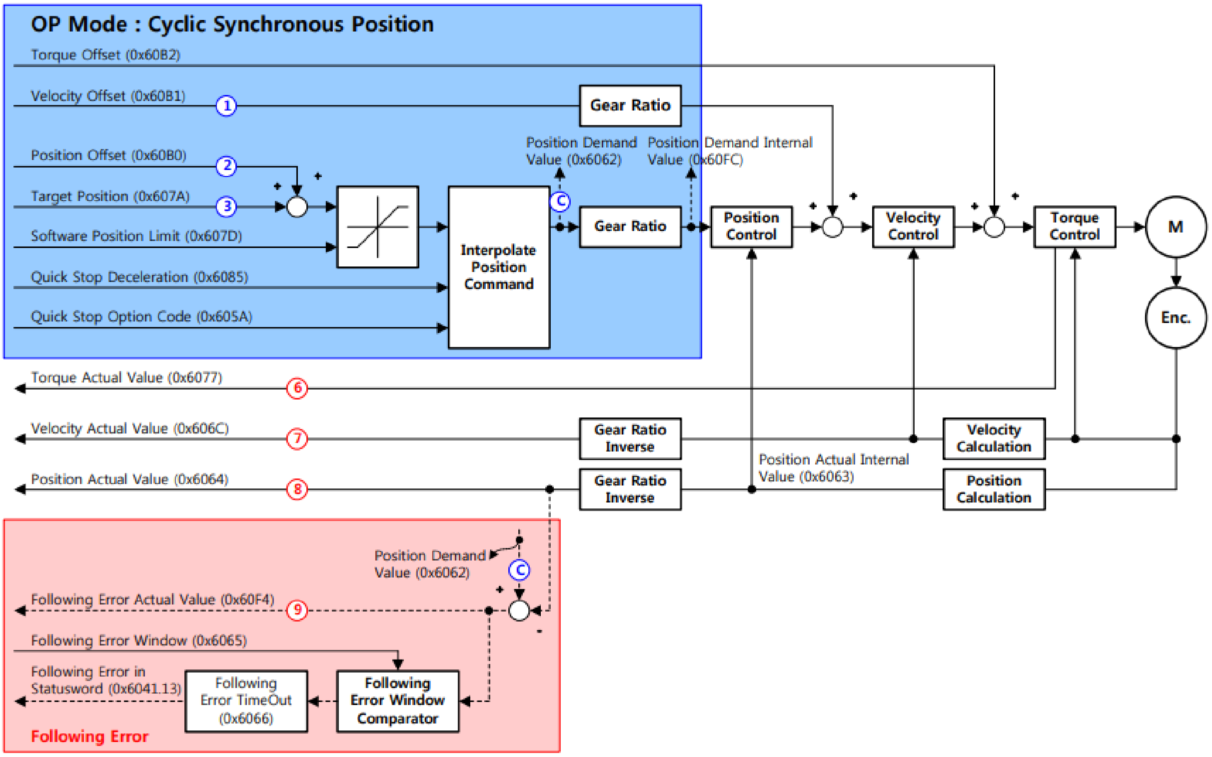


5.2 Position Control Modes

5.2.1 Cyclic Synchronous Position(CSP) Mode

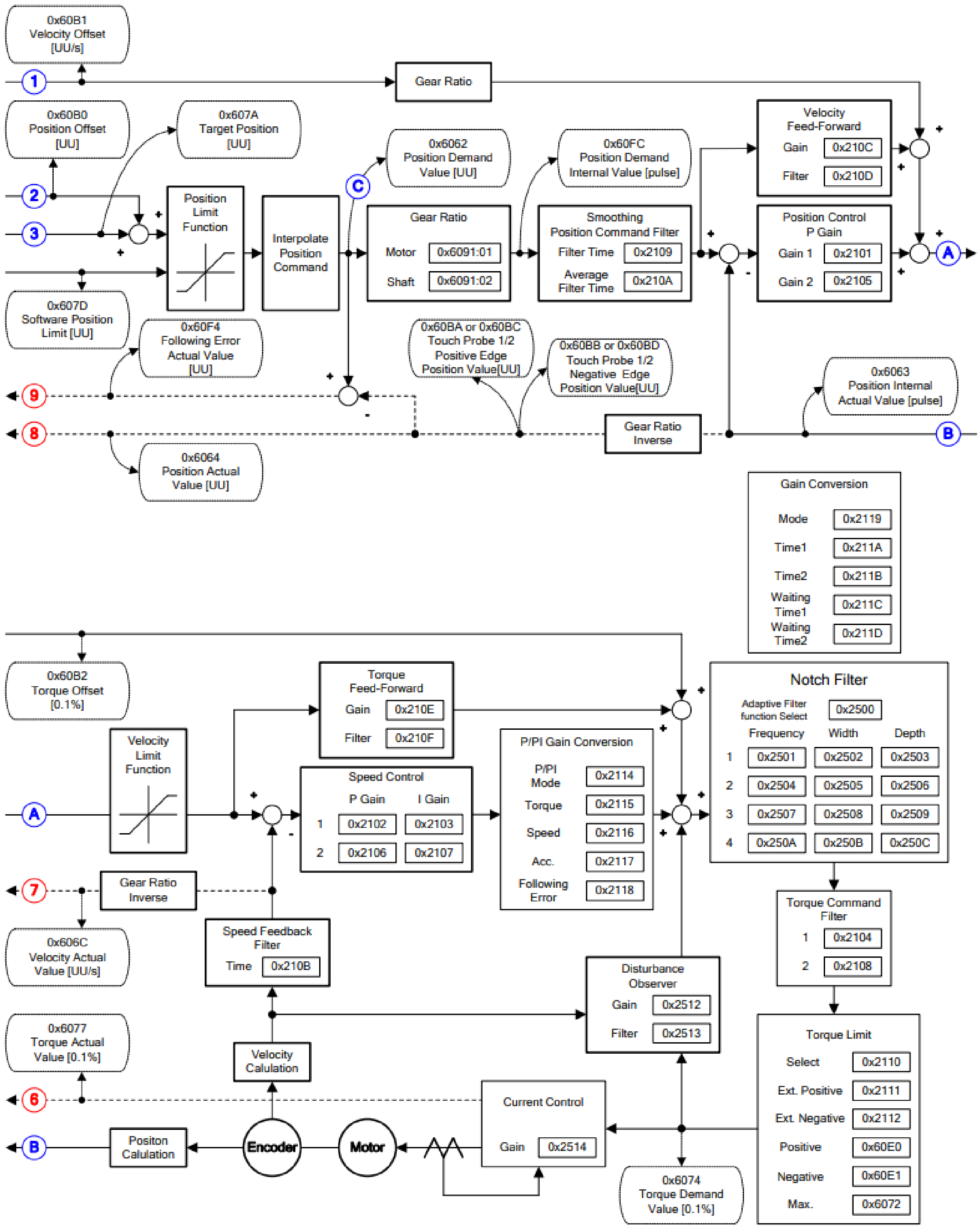
The Cyclic Synchronous Position (CSP) mode receives the target position (0x607A), renewed at every PDO update cycle, from the upper level controller, to control the position. In this mode, the controller is able to calculate the velocity offset (0x60B1) and the torque offset (0x60B2) corresponding the speed and torque feedforward respectively, and pass them to the drive.

The block diagram of the CSP mode is as follows:



OP Mode : Cyclic Synchronous Position
Torque Offset (0x60B2)
Velocity Offset (0x60B1)
Position Offset (0x60B0)
Target Position (0x607A)
Software Position Limit (0x607D)
Quick Stop Deceleration (0x6085)
Quick Stop Option Code (0x605A)
Gear Ratio
Position Demand Value (0x6062)
Position Demand Internal Value (0x60FC)
Interpolate Position Command
Gear Ratio
Position Control
Velocity Control
Torque Control
M
Enc.
Torque Actual Value (0x6077)
Velocity Actual Value (0x606C)
Position Actual Value (0x6064)
Gear Ratio Inverse
Gear Ratio Inverse
Velocity Calculation
Position Calculation
Position Actual Internal Value (0x6063)
Position Demand Value (0x6062)
Following Error Actual Value (0x60F4)
Following Error Window (0x6065)
Following Error in Statusword (0x6041.13)
Following Error TimeOut (0x6066)
Following Error Window Comparator
Following Error

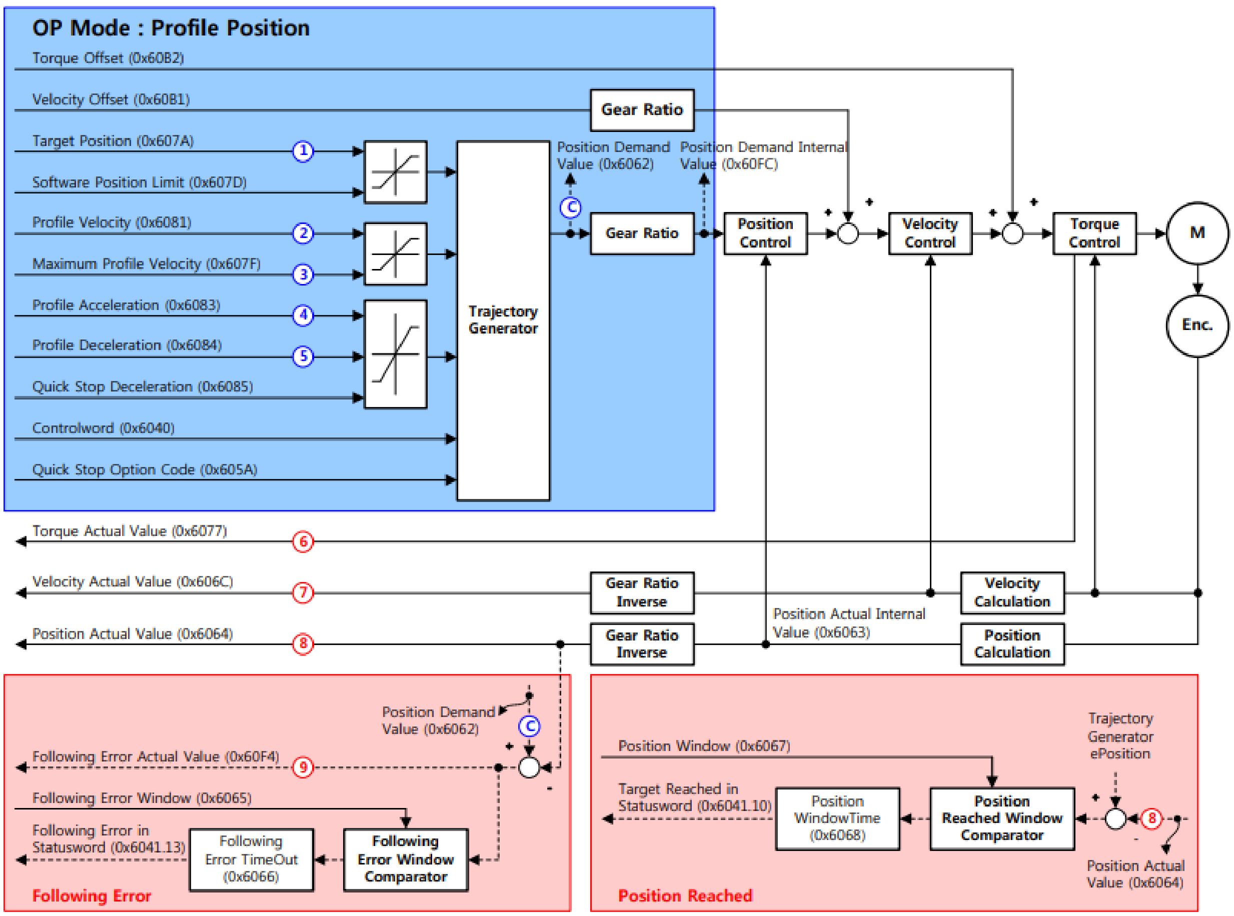
- **Internal Block Diagram of CSP Mode**



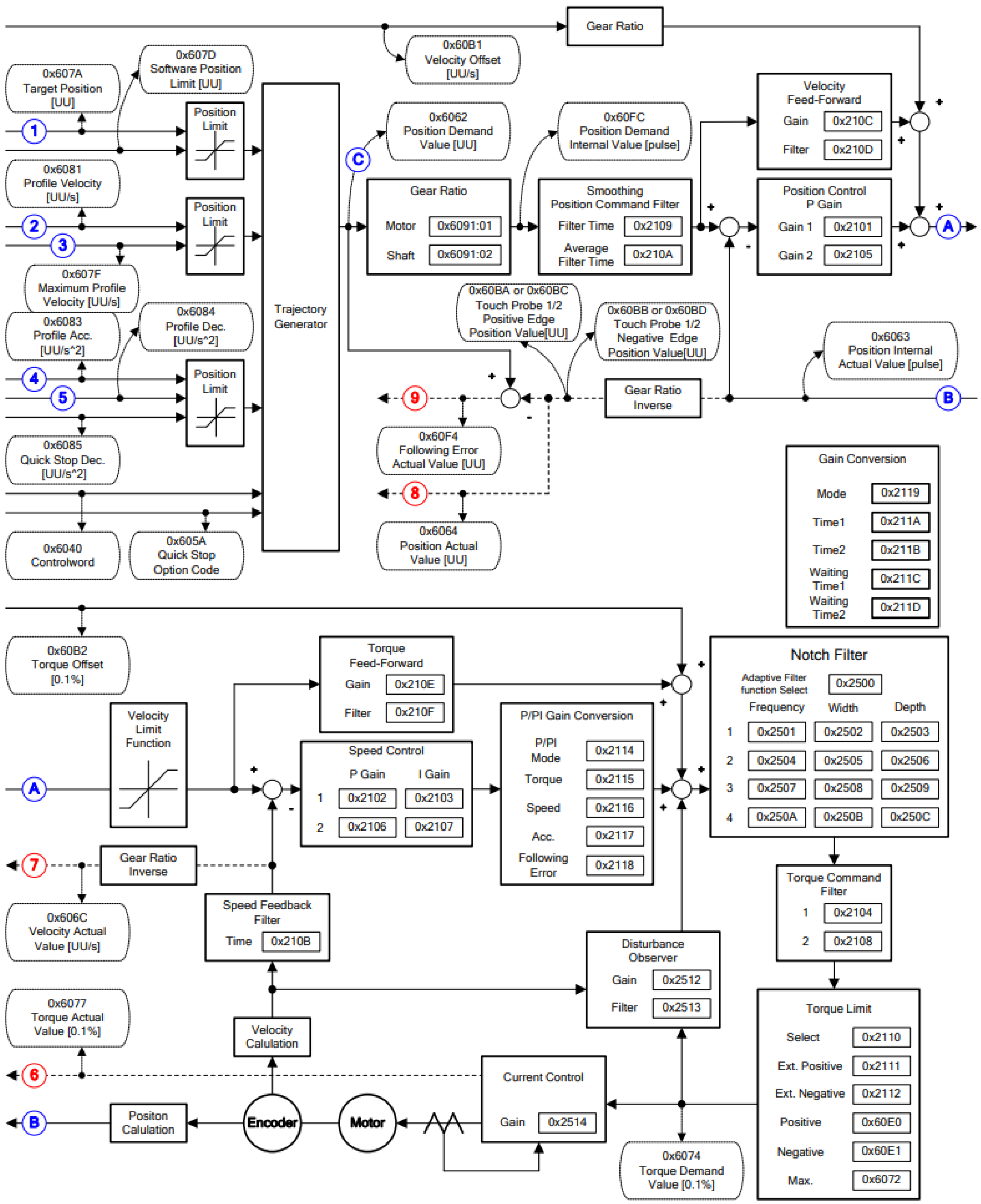
5.2.2 Profile Position(PP) Mode

Unlike the CSP mode receiving the target position, renewed at every PDO update cycle, from the upper level controller, in the Profile Position (PP) mode, the drive generates a position profile internally to operate up to the target position (0x607A) using the profile velocity (0x6081), acceleration (0x6083), and deceleration (0x6084).

The block diagram of the PP mode is as follows:



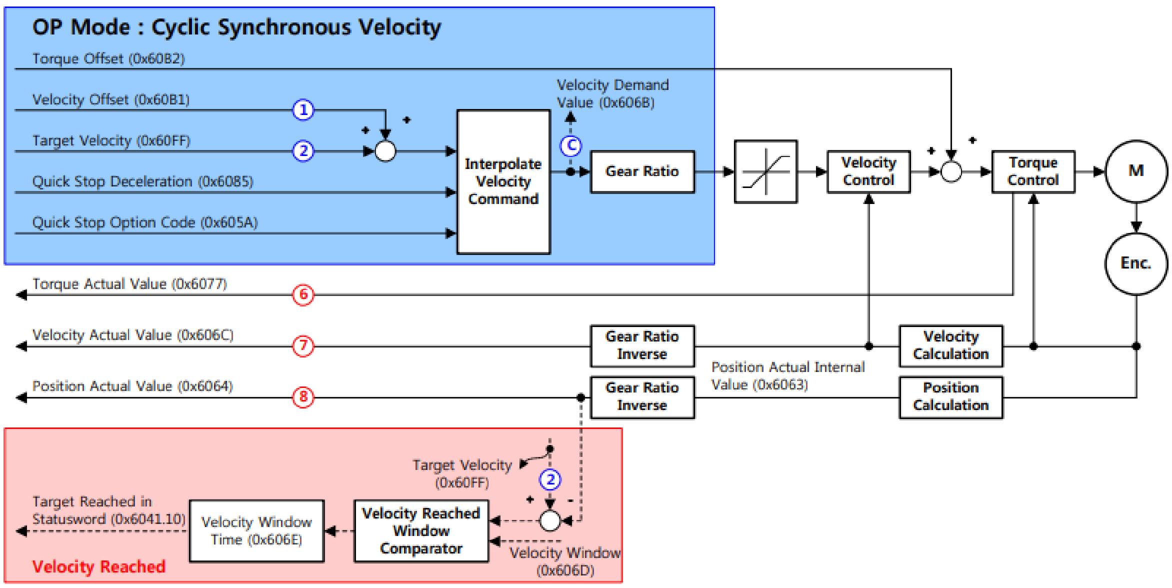
- **Internal Block Diagram of PP Mode**



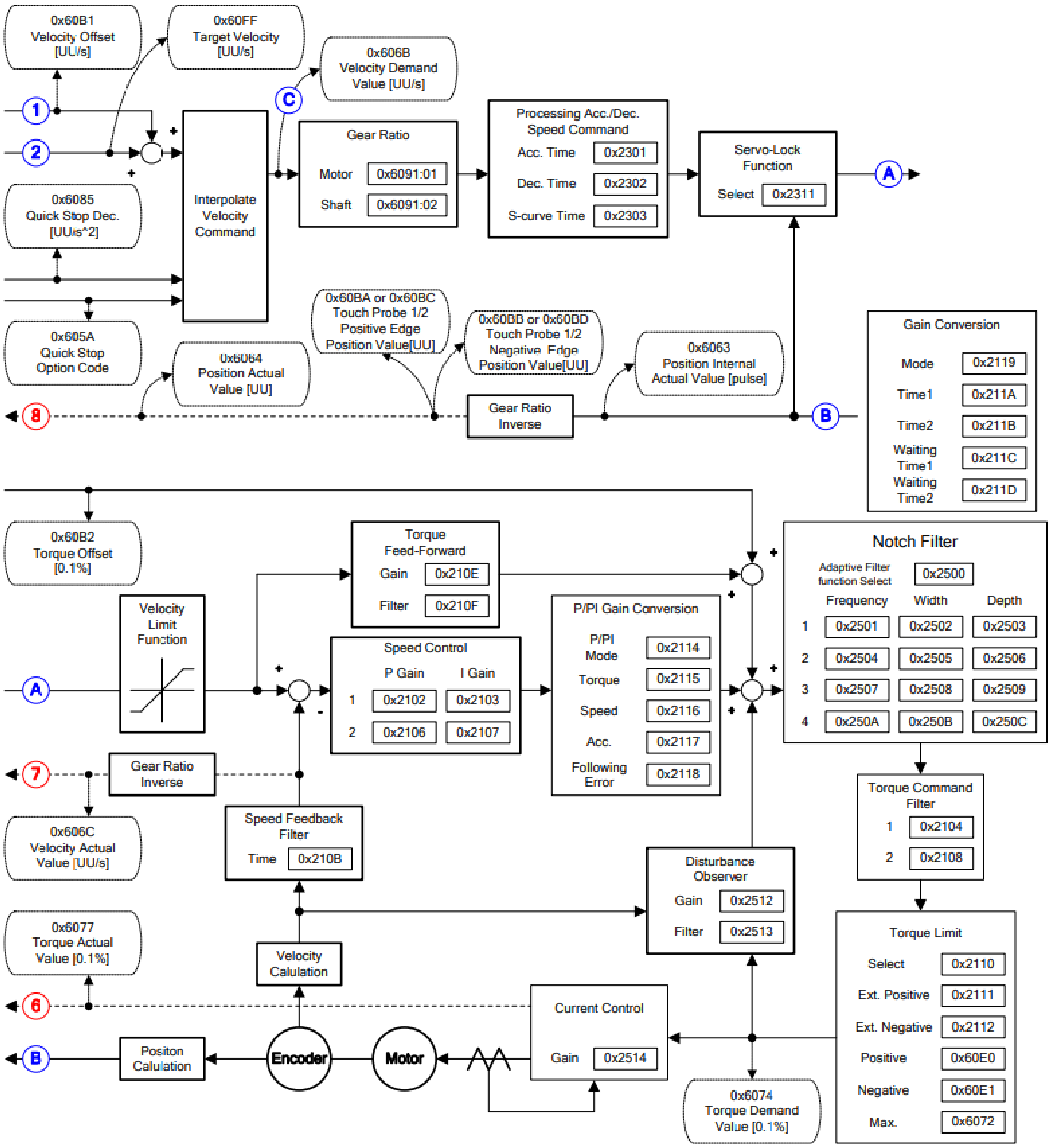
5.3 Velocity Control Modes

5.3.1 Cyclic Synchronous Velocity(CSV) Mode

The Cyclic Synchronous Velocity (CSV) mode receives the target velocity (0x60FF), renewed at every PDO update cycle, from the upper level controller, to control the velocity. This mode allows the upper level controller to calculate the torque offset (0x60B2) corresponding the torque feedforward and pass it to the drive. The block diagram of the CSV mode is as follows:

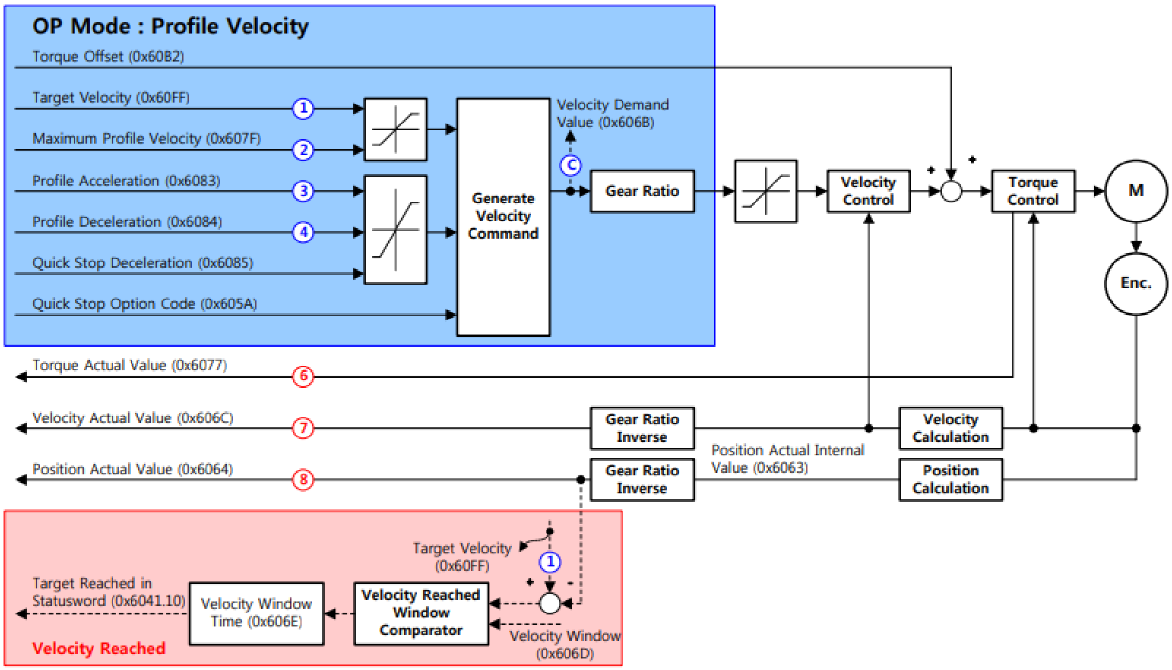


- **Internal Block Diagram of CSV Mode**

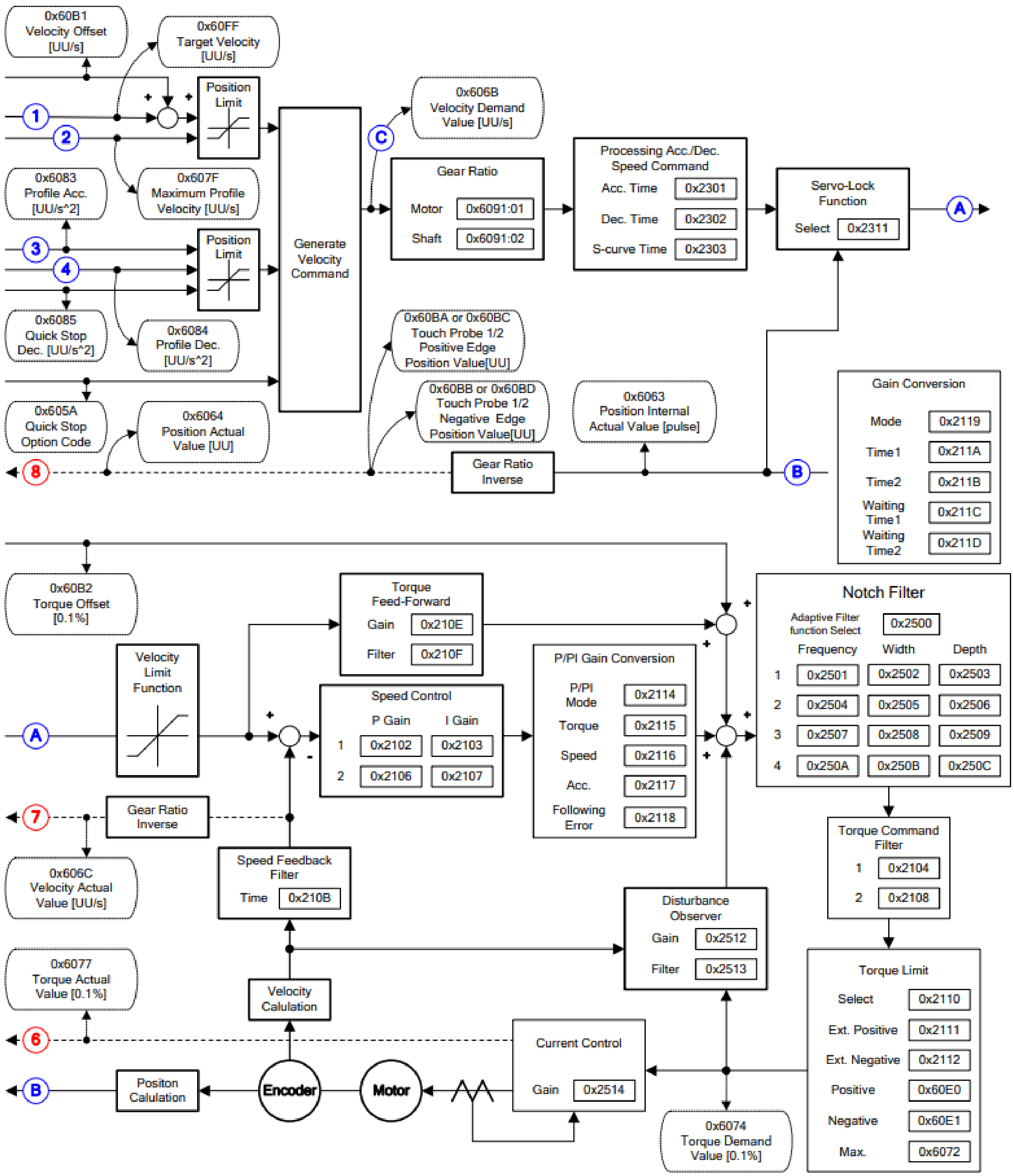


5.3.2 Profile Velocity(PV) Mode

Unlike the CSV mode receiving the target velocity, renewed at every PDO update cycle, from the upper level controller, in the Profile Velocity (PV) mode, the drive generates a velocity profile internally up to the target velocity (0x60FF) using the profile acceleration (0x6083) and deceleration (0x6084), in order to control its velocity. At this moment, the max. profile velocity (0x607F) limits the maximum velocity. The block diagram of the PV mode is as follows:



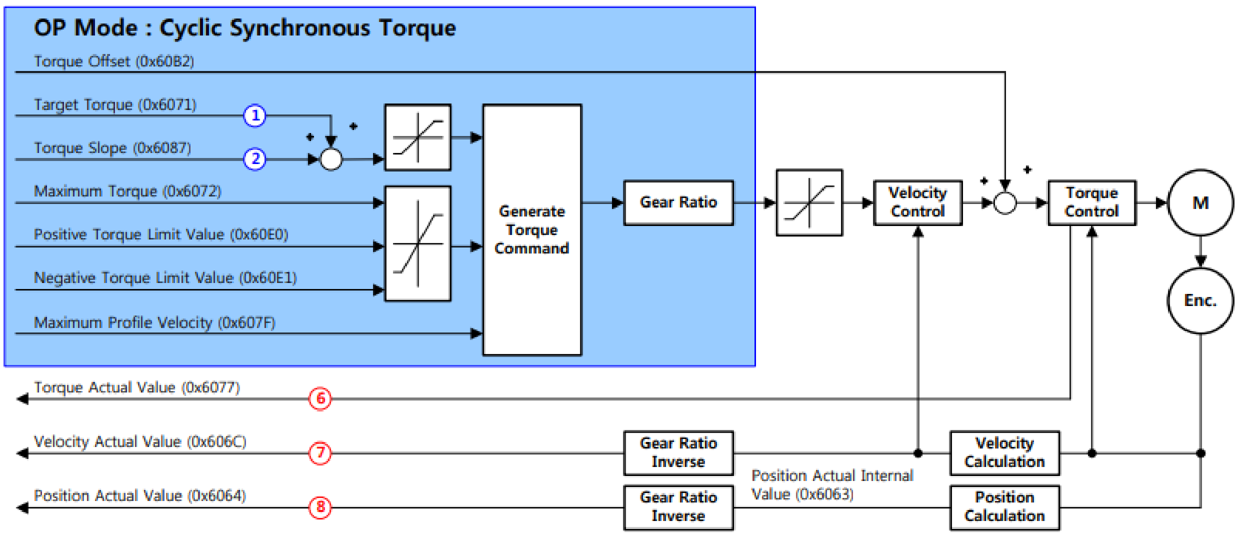
- **Internal Block Diagram of PV Mode**



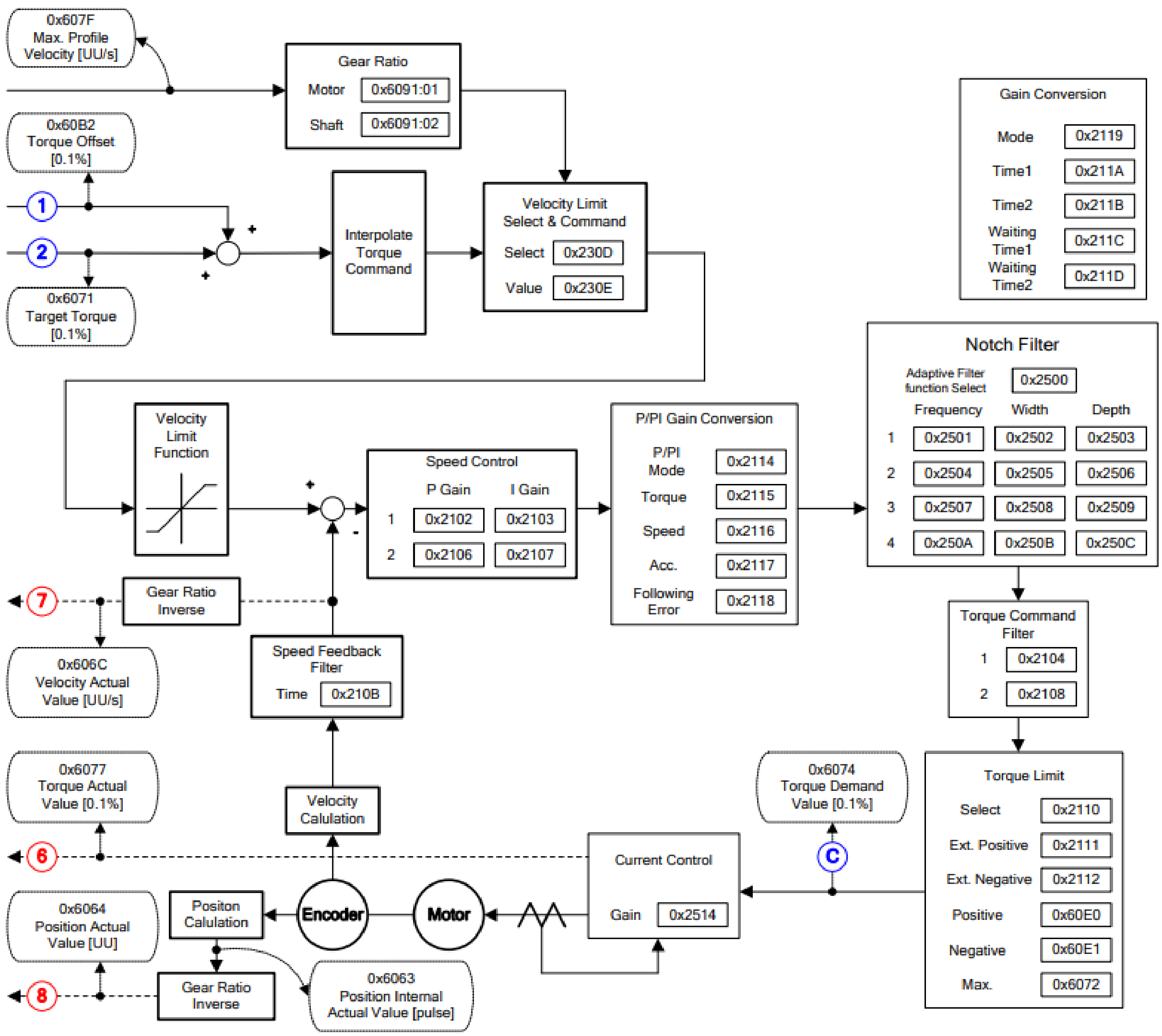
5.4 Torque Control Modes

5.4.1 Cyclic Synchronous Torque(CST) Mode

The Cyclic Synchronous Torque (CST) mode receives the target torque (0x6071), renewed at every PDO update cycle, from the upper level controller, to control the torque. This mode allows the upper level controller to calculate the torque offset (0x60B2) corresponding the torque feedforward and pass it to the drive. The block diagram of the CST mode is as follows:

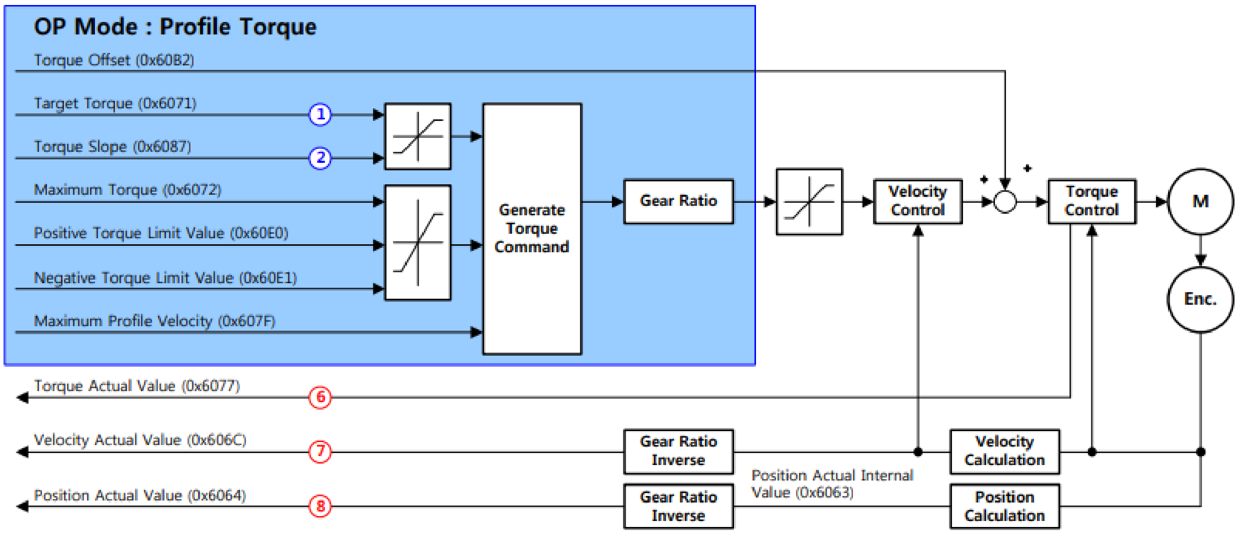


- **Internal Block Diagram of CST Mode**

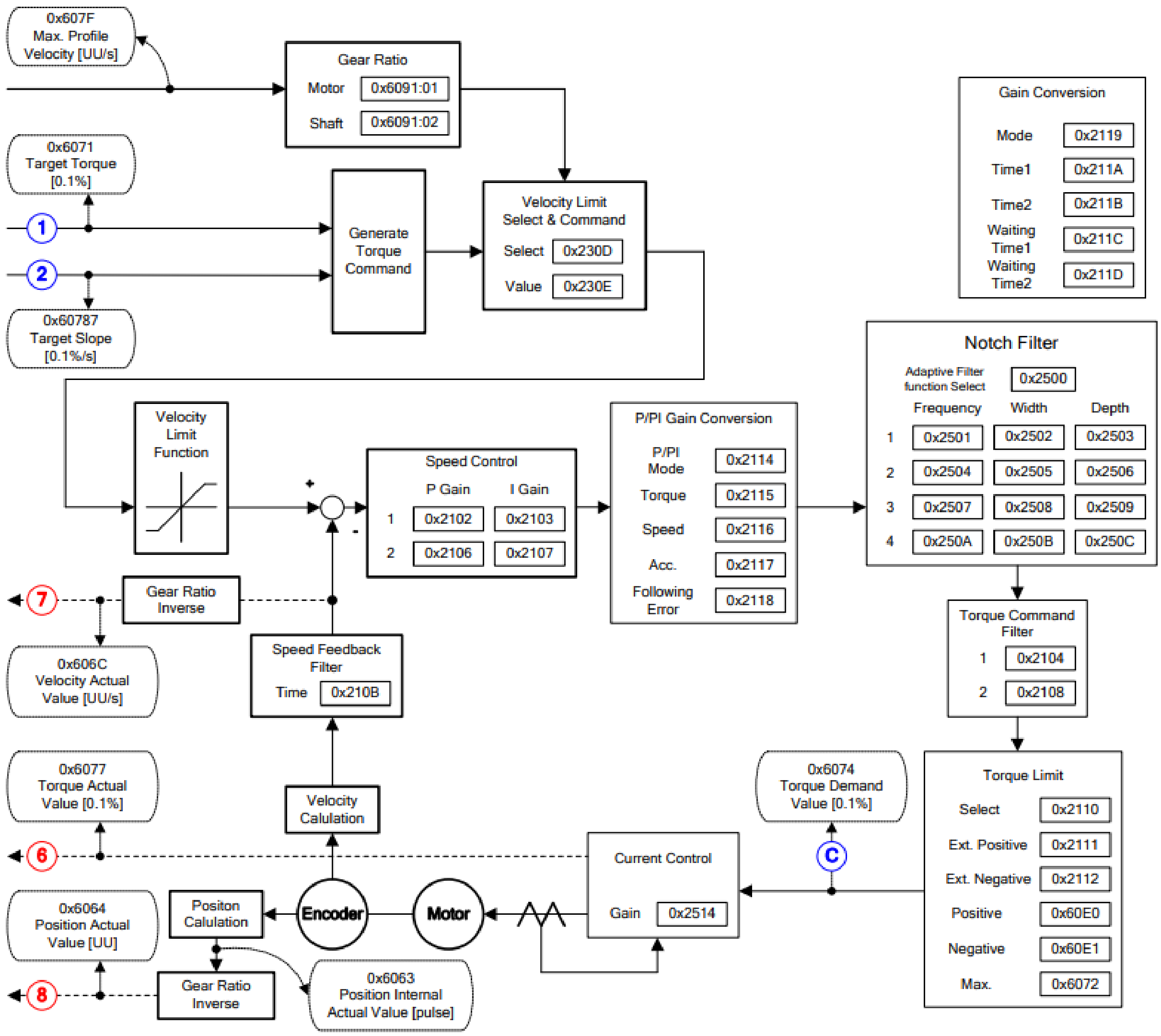


5.4.2 Profile Torque(PT) Mode

Unlike the CST mode receiving the target torque, renewed at every PDO update cycle, from the upper level controller, in the Profile Torque (PT) mode, the drive generates a torque profile internally up to the target torque (0x6071) by the torque slope (0x6087), in order to control its torque. At this moment, the torque applied to the motor is limited depending on the Positive/Negative Torque Limit Value (0x60E0 and 0x60E1) and the Maximum Torque (0x6072) based on its driving direction. The block diagram of the PT mode is as follows:



- **Internal Block Diagram of PT Mode**



Speed control için

6.5.1 Smooth Acceleration/Deceleration

For smooth acceleration/deceleration during speed control, you can operate the motor by creating acceleration/deceleration profile in trapezoidal and s-curve shapes. In addition, you can perform s-curve operation by setting the speed command s-curve time to 1[ms] or more.

The speed command acceleration/deceleration time (0x2301, 0x2302) is the time it takes to accelerate to the rated speed or decelerate from the rated speed to full stop. (See the figure below)

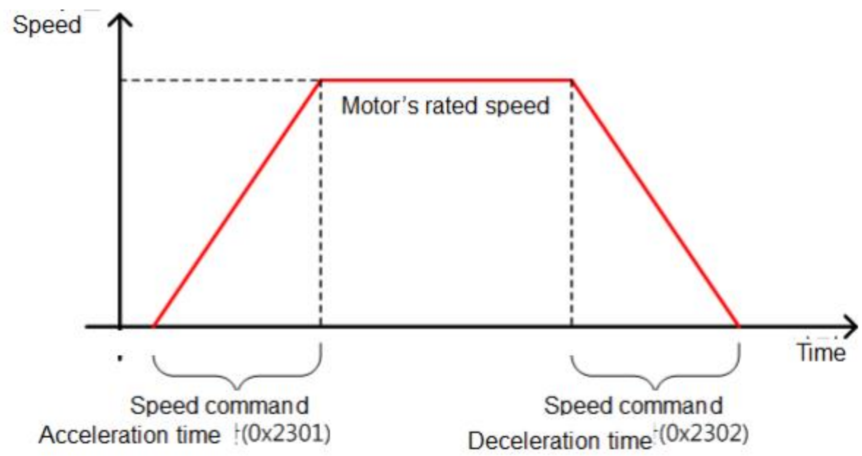


Figure 23. Speed Control

The actual acceleration/deceleration time can be calculated as follows.

Acceleration time = speed command/ rated speed x speed command deceleration time (0x2301)

Deceleration time = speed command/ rated speed x speed command acceleration time (0x2302)

As shown in the figure below, you can operate the machine by creating a S-curve acceleration/deceleration profile by setting the speed command s-curve time to 1[ms] or more. Please note the relationship between acceleration/deceleration time and S-curve time.

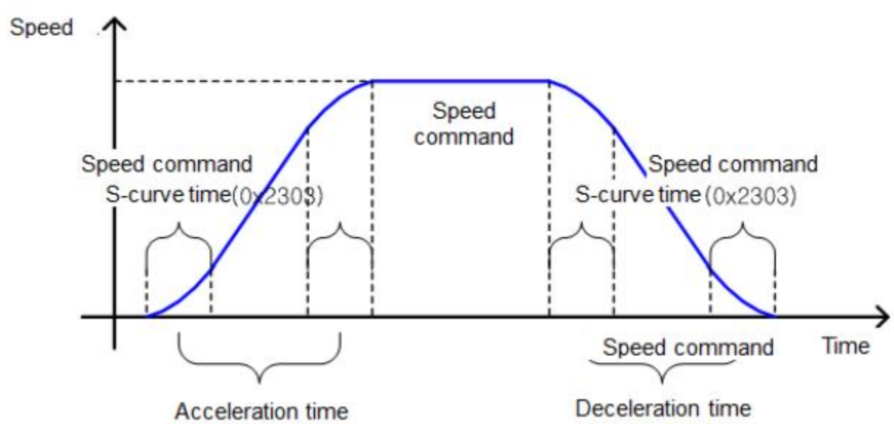


Figure 24. Smooth Acceleration and Deceleration

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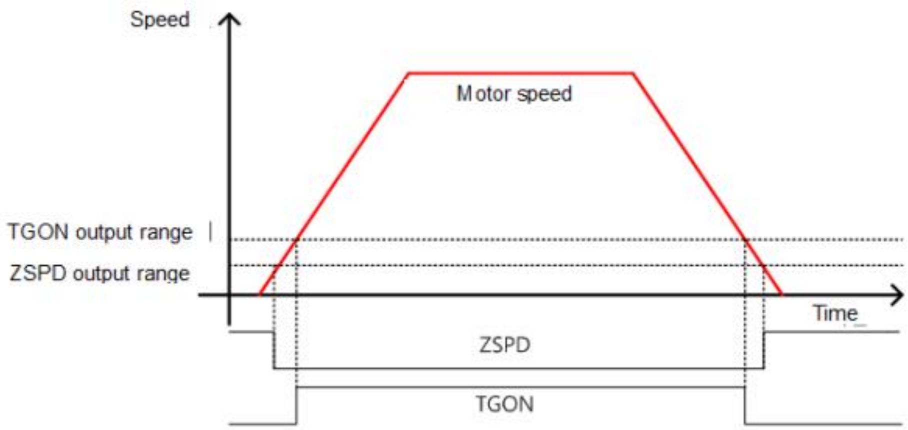


And when the difference between the command and the speed feedback, that is, the speed error is within the INSPD output range (0x2406), the INSPD(speed match) signal is displayed.

- **Related Objects**

Index	Sub Index	Name	Variable Format	Accessibility	PDO Allocation	Unit
0x2404	-	ZSPD Output Range	UINT	RW	Yes	rpm
0x2405	-	TGON Output Range	UINT	RW	Yes	rpm
0x2406	-	INSPD Output Range	UINT	RW	Yes	rpm

6.6 Settings Related to Position Control

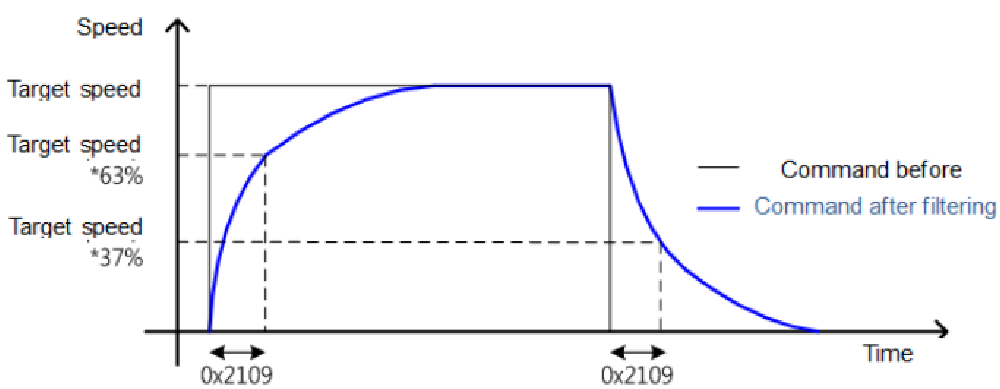
6.6.1 Position Command Filter

This section describes how to operate the drive more smoothly by applying a filter to a position command. For the purpose of filtering, you can set position command filter time constant (0x2109) using the primary low pass filter and position command average filter time constant (0x210A) using the moving average.

You can use a position command filter if:

(1) the electric gear ratio is more than 10 times, or

(2) the acceleration/deceleration profile cannot be generated from the upper level controller.



Position command filter using the position command filter time constant (0x2109).

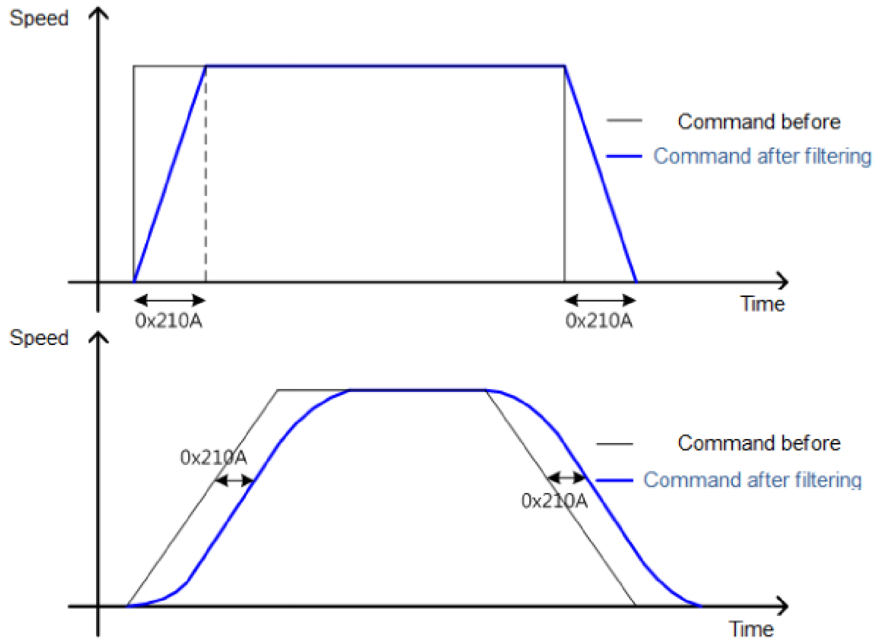


Figure 25. Position Command Filter

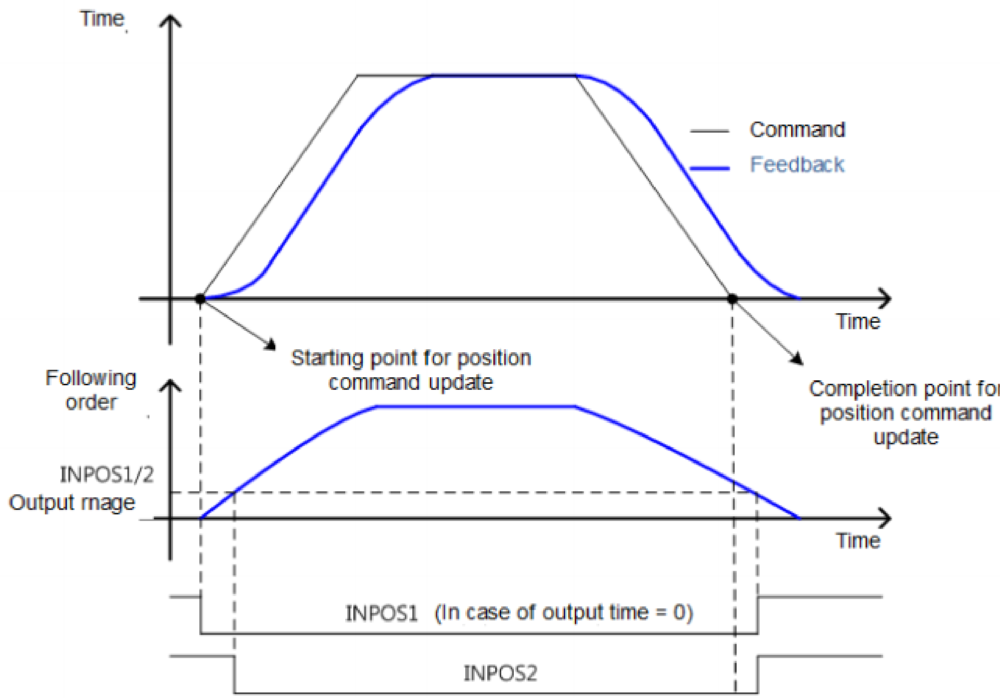
Position command filter using position command average filter time constant (0x210A).

- **Related Objects**

Index	Sub Index	Name	Variable Format	Accessibility	PDO Allocation	Unit
0x2109	-	Position Command Filter Time Constant	UINT	RW	Yes	0.1ms
0x210A	-	Position Command Average Filter Time Constant	UINT	RW	Yes	0.1ms

Table 30. Position Command Filter Related Objects

Fiziksel sinyaller



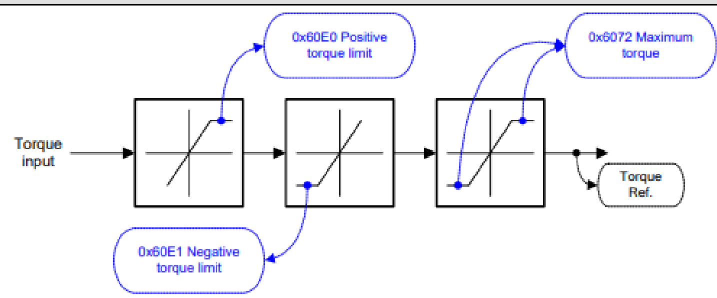
● Related Objects

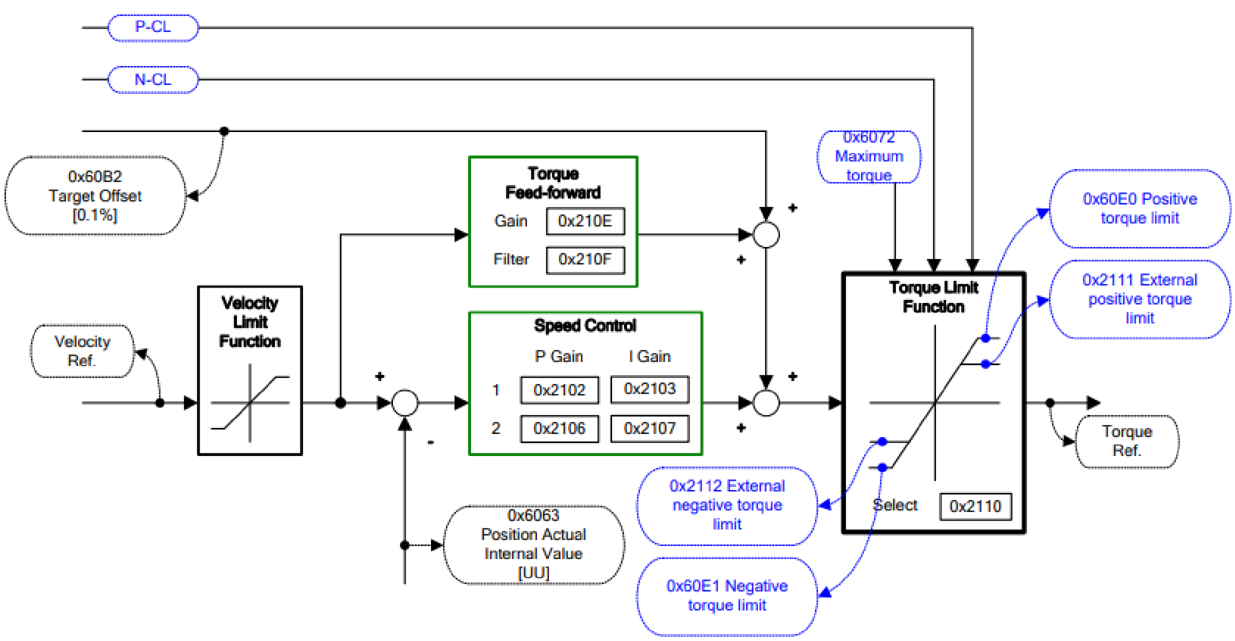
Index	Sub Index	Name	Variable Format	Accessibility	PDO Allocation	Unit
0x2401	-	INPOS1 Output Range	UINT	RW	Yes	UU
0x2402	-	INPOS1 Output Time	UINT	RW	Yes	ms
0x2403	-	INPOS2 Output Range	UINT	RW	Yes	UU

6.10 Torque Limit Function

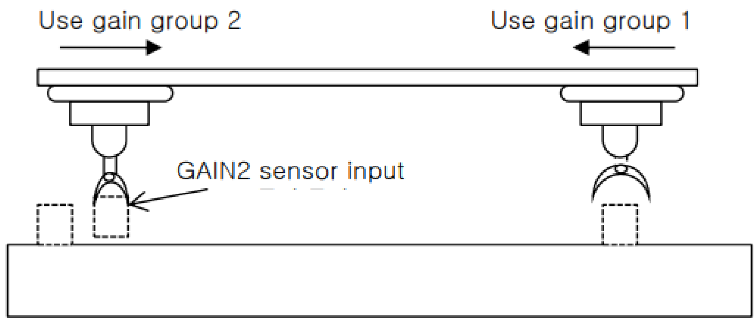
You can limit the drive output torque to protect the machine. It can be set by the torque limit function (0x2110). The setting unit of torque limit value is 0.1%.

- **Description of Torque Limit Function Setting (0x2110)**

Limit function	Details
Internal torque limit 1 (set value 0)	 Limits the torque using positive/negative torque limit value according to the driving direction; the maximum value is limited by the maximum torque (0x6072). ▪ Forward: 0x60E0, Reverse: 0x60E1



6.11 Gain Switching Function



This function is to switch between the gain groups 1 and 2, as one of gain adjustment methods. You can reduce the time required for positioning through switching gains.

A gain group consists of position loop gain, speed loop gain, speed loop integral time constant, and torque command filter time constant. The gain switching function (0x2119) can be set as follows:

- **Description of Gain Switching Function (0x2119)**

Setting values	Setting details
0	Only the gain group 1 is used.
1	Only the gain group 2 is used.
2	Gain is switched according to the GAIN2 input status. ▪ 0: Use the gain group 1. ▪ 1: Use the gain group 2.
3	Reserved
4	Reserved
5	Reserved
6	Gain is switched according to the ZSPD output status. ▪ 0: Use the gain group 1. ▪ 1: Use the gain group 2.
7	Gain is switched according to the INPOS1 output status. ▪ 0: Use the gain group 1. ▪ 1: Use the gain group 2.

- **P/PI Control Switching**

PI control uses both proportional (P) and integral (I) gains of the speed controller, while P control uses only proportional gain.

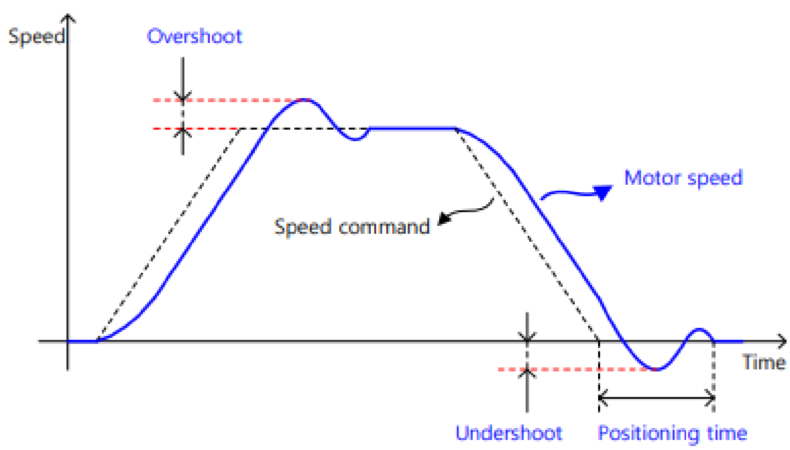
The proportional gain determines the responsiveness of the entire controller, and the integral gain is used to eliminate an error in the steady state. Too high of an integral gain will result in an overshoot during acceleration or deceleration.

The PI/P control switching functions are used to switch between the PI and P controls under the condition of the parameters within the servo (such as torque, speed, acceleration, and position deviation); specifically, they are used under the following situations:

- Speed control: To suppress any overshoot or undershoot during acceleration/deceleration.

  Position control: To suppress undershoot during positioning, resulting in a reduced positioning time.

You can accomplish similar effect by setting the acceleration/deceleration of the upper level controller, the soft start of the servo drive, the position command filter, or etc.



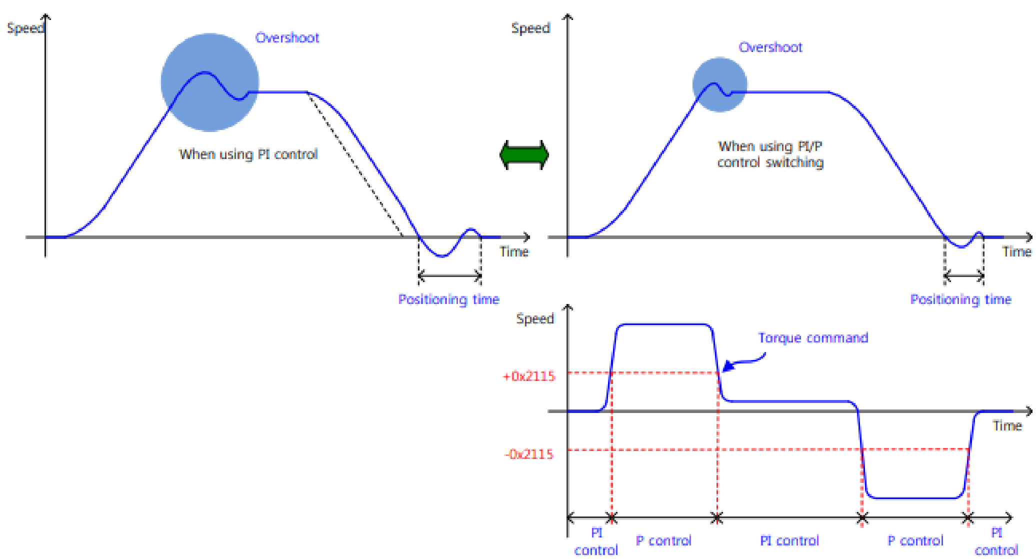
You can configure these settings in the P/PI control switching mode (0x2114). Please see the details below: PCON

Setting values	Setting details
0	Always uses the PI control.
1	Switches to the P control if the command torque is larger than the P control switching torque (0x2115).
2	Switches to the P control if the command speed is larger than the P control switching speed (0x2116).
3	Switches to the P control if the acceleration command is larger than the P control switching acceleration (0x2117).
4	Switches to the P control if the position error is larger than the P control switching position error (0x2118).

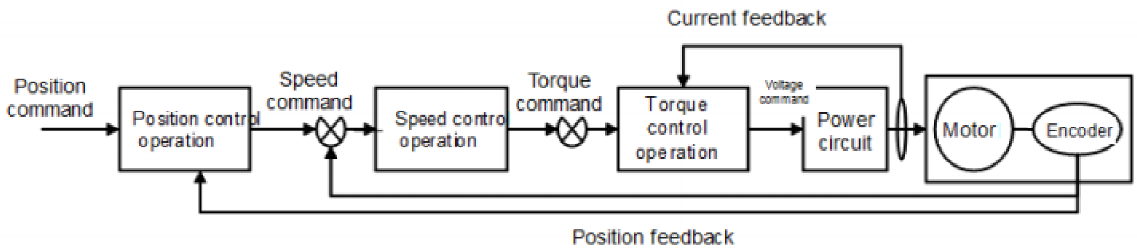
Index	Sub Index	Name	Variable type	Accessibility	PDO assignment	Unit
0x2114	-	P/PI Control Switching Mode	UINT	RW	Yes	-
0x2115	-	P Control Switching Torque	UINT	RW	Yes	0.1%
0x2116	-	P Control Switching Speed	UINT	RW	Yes	Rpm
0x2117	-	P Control Switching Acceleration	UINT	RW	Yes	rpm/s
0x2118	-	P Control Switching Positional Error	UINT	RW	Yes	Pulse

- **Example of P/PI Switching by Torque Command**

When always using the PI Control rather than P/PI control switching for speed control, the integral term of acceleration/deceleration error is accumulated, resulting in an overshoot and an extended positioning time. At this moment, you can reduce the overshoot and the positioning time using an appropriate P/PI switching mode. The figure below shows an example of switching mode by torque command:



Tuning



You can use the drive at the torque control mode, speed control mode or position control mode, depending on the connection method with the host device. The drive's control structure takes the cascade form, where the position control is positioned at the outermost and the current control is positioned at the innermost. Depending on the drive's operation mode, you can tune the gain-related parameters of the torque controller, speed controller or position controller to suit your purposes.

8.3.3 Performance Measurements

If you plot of the position response versus time, you can make a few measurements to quantitatively assess the performance of the servo. These three measurements are made before or shortly after the motor stops moving:

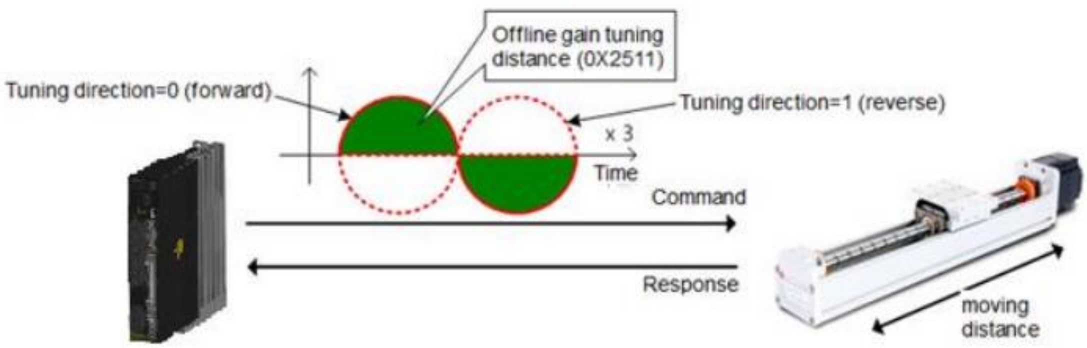
- **Overshoot**—The measurement of the maximum magnitude that the actual position exceeds the position set-point. It is usually measured in terms of the percentage of the set-point value.

- **Rise Time**—The time it takes the actual position to pass the Set-point.

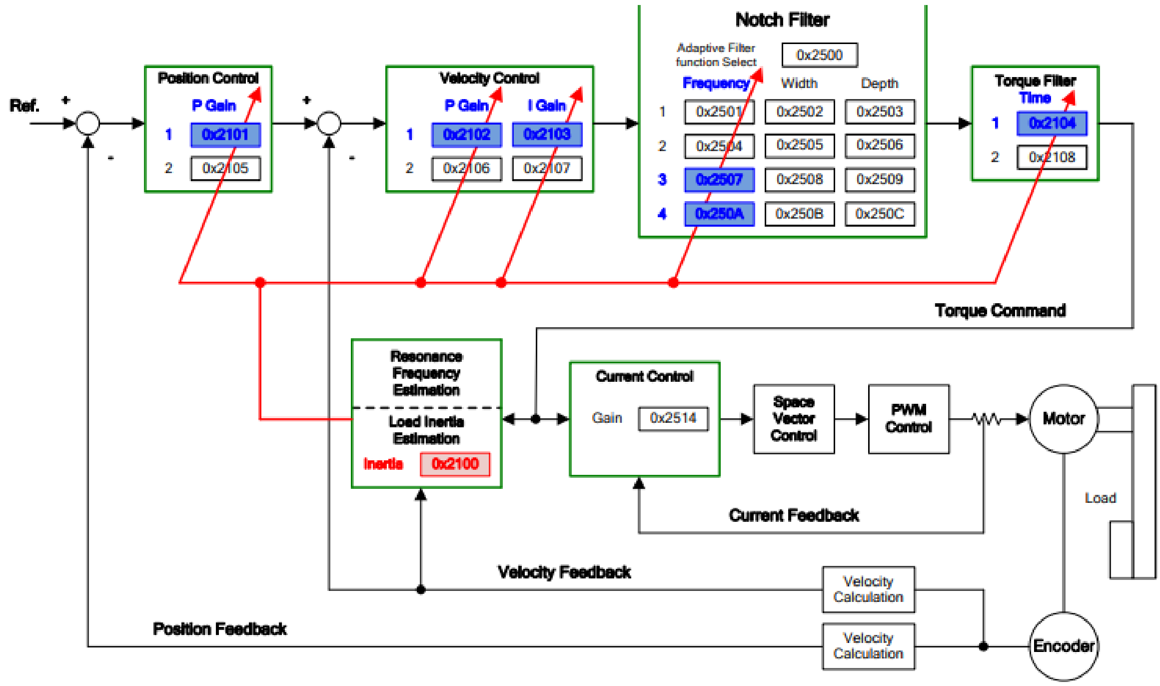
- **Settling Time**—The time between when the commanded position reaches the set-point and the actual position settles within a certain percentage of the position set-point. (Note the settling time definition here is different from that of a control engineering text book, but the goal of the performance measurement is still intact.).

8.4 Automatic Gain Tuning

You can automatically set gains corresponding to the load conditions, using commands generated by the drive itself. The gain-related parameters subject to change are as follows.
Inertia, inertia ratio, position loop gain, speed loop gain, speed integral time constant, torque command filter time constant, notchfilter3frequency, notch filter frequency.
The overall gain is set to either high or low, depending on the set value of the system rigidity for gain tuning. Please set the appropriate value depending on the rigidity of the load being operated.
As shown in the figure below, commands in the sinusoidal form are generated either in the forward or reverse direction depending on the set value of the offline gain tuning direction. You can set the distance covered during tuning with the offline gain tuning distance (0x2511). The distance increases along with the set value: please set the appropriate



distance depending on the situation. Please secure a sufficient distance before gain tuning (1 rotation or above).



8.5 Manual Gain Tuning

When using a cascade-type controller, first tune the gain of the speed controller positioned inside, and then tune the gain of the position controller positioned outside.

That is, the order tuning is proportion gain→integral gain→ Feed forward gain.

The role of each gain is as follows.

Proportion gain: determines controller BW Integral gain: determines error of the steady state, causes overshoot Feed forward gain: improves the system's lag characteristic Differential gain: damping for the system (not provided)

8.5.1 Speed Controller Tuning

A. Inertial ratio setting

- Use automatic inertia estimation function, or manual tuning

B. Proportion gain setting

- Torque/noise monitoring before vibration occurs

C. Integral gain setting

- Speed overshoot and steady-state error monitoring
- If you want to increase integral gain but overshoot occurs, you can use the P/PI conversion mode
- The integral gain of this drive is integral time constant,

D. Speed command filter and speed feedback filter setting

8.5.2 Position Controller Tuning

A. Proportion gain setting

- Torque, position error, noise monitoring before vibration occurs

B. Feed forward setting

- Position error monitoring
- Feed forward filter can be set
- If you want to increase feed forward but overshoot occurs, set filter
- Feed forward value can be set from 0 to 100%. The value is the ratio of the position command value currently being input against the difference

C. Position command filter setting

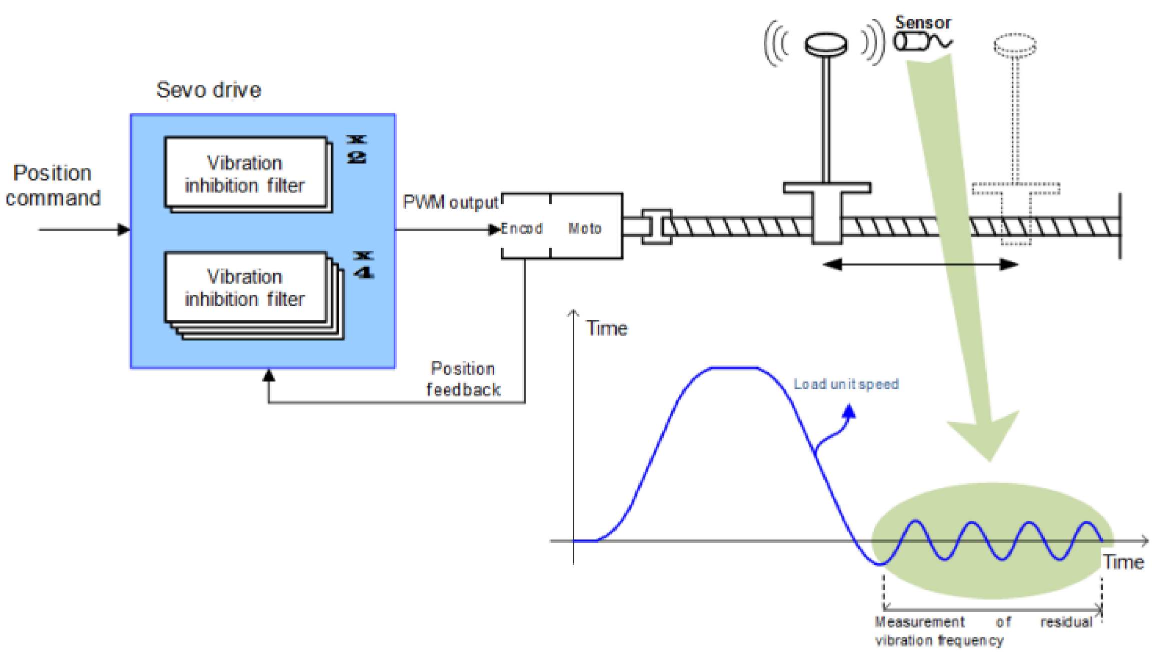
- It provides smoother position command

8.6 Vibration Control

The vibration control function has the following features.

- Provides 4-layer notch filter
  - Frequency, width, depth setting
  - Automatic setting through real-time FFT
  - 50[Hz] ≤setting range≤ 5000[Hz]

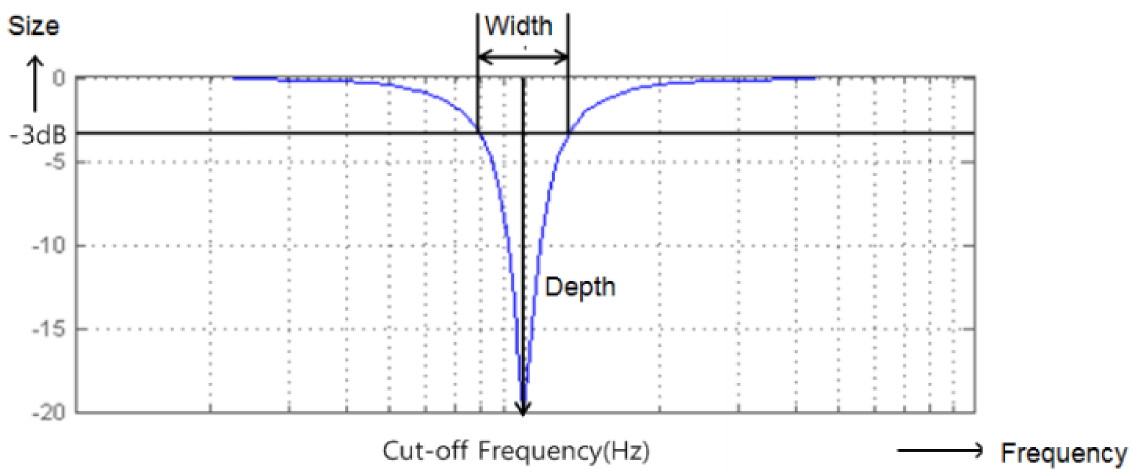
- Provides 2-layer vibration inhibition filter, for vibration inhibition of the load
  - Measures the vibration frequency of the load
  - 1.0[Hz] ≤setting range≤ 100.0[Hz]



8.7 Filters

Notch filter is a type of Band Stop filter which removes certain frequency components. By removing resonance frequency component of the mechanic unit using the notch filter, you can remove vibration while setting high gains.

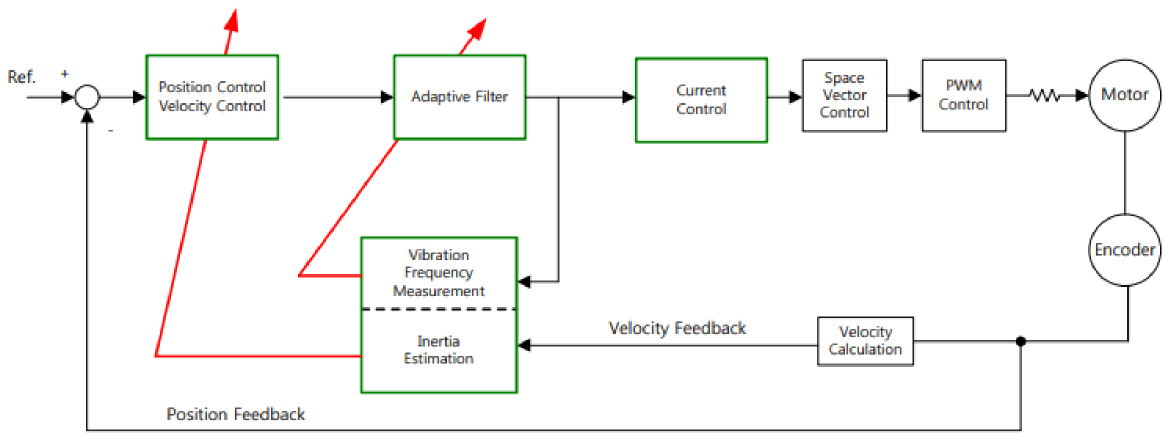
This drive provides a total of 4 layers of notch filters, and the frequency, width, depth can be set separately for each filter. One or two notch filters can be used as adaptive filters with automatic frequency and width setting, through real-time frequency analysis (FTT).



8.4.2 Adaptive Filter

Adaptive filter reduces vibration by automatically setting the notch filters by performing real-time analysis on vibration frequency generated from the load during drive operation through speed feedback signals.

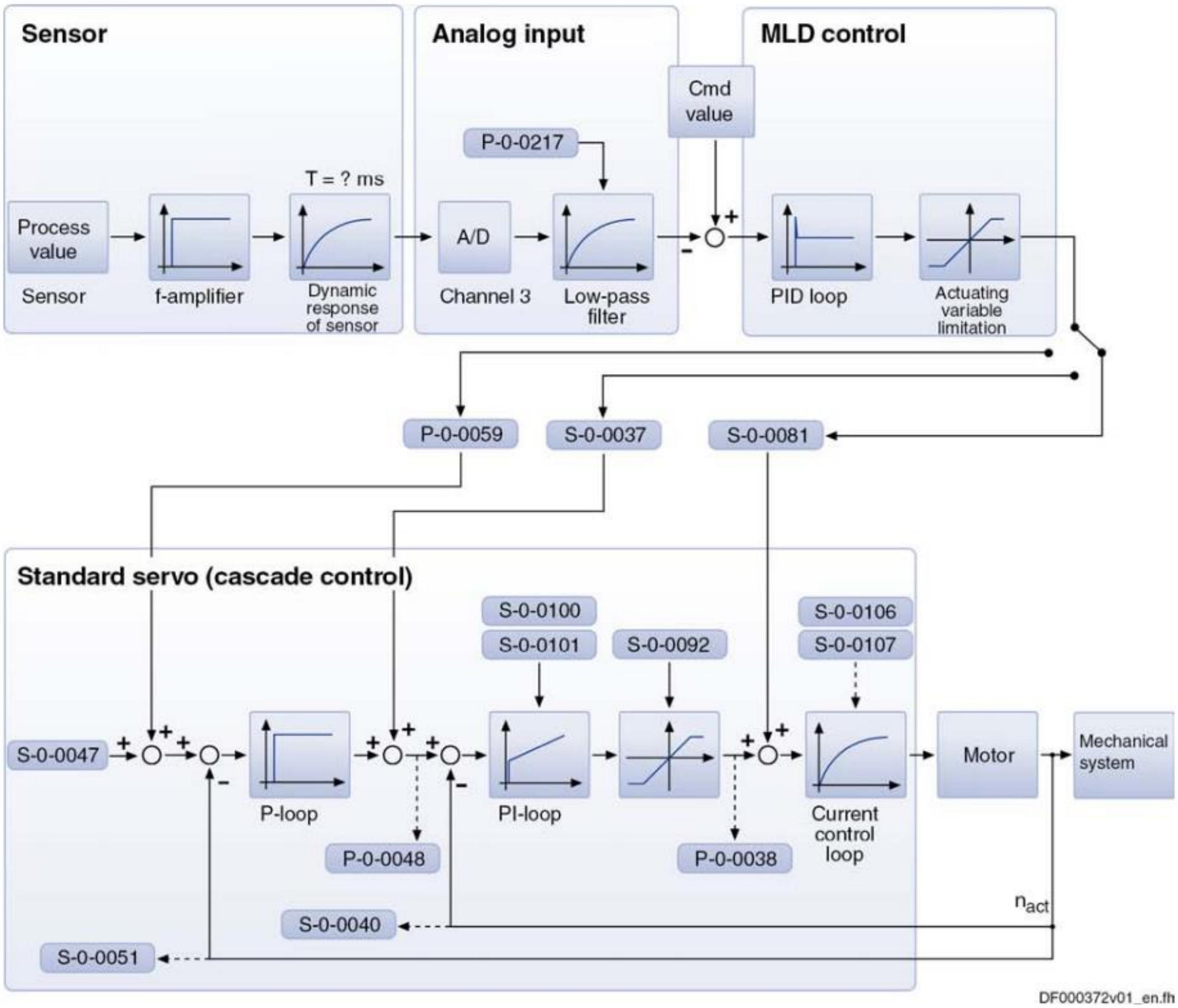
One or two notch filters can be automatically set by detecting the vibration frequency through frequency analysis. The frequency and width are automatically set, and the set value is used for depth.



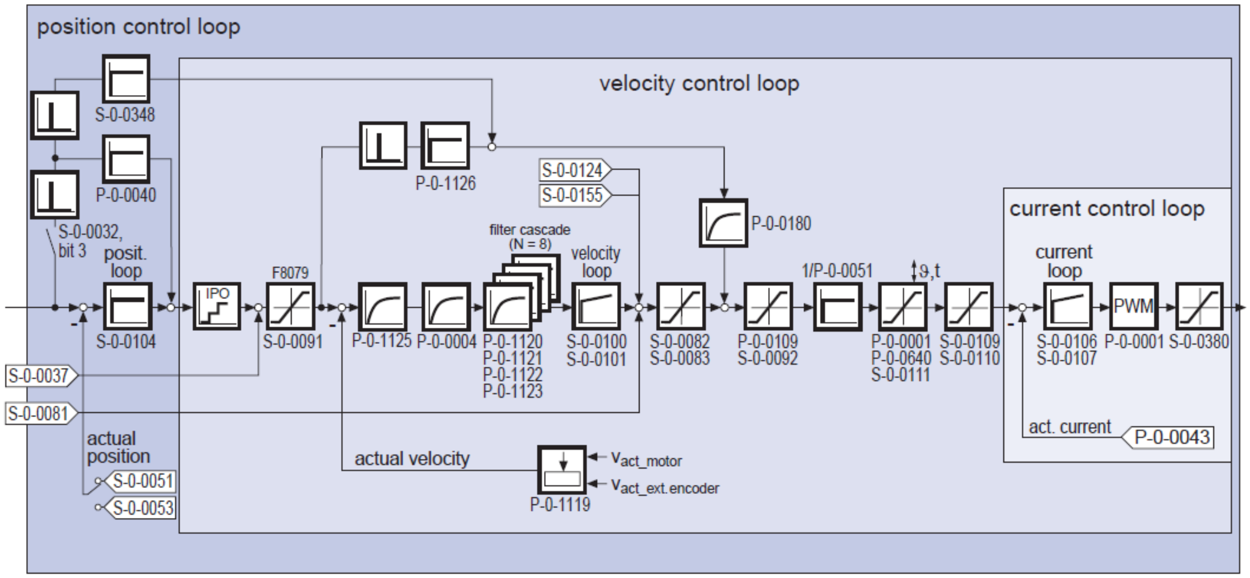
7 Bosch Rexroth

Asd

Eski manual



In our example, we use an axis which is operated in position control. The actuating variable of the process loop, which is to suppress/compensate unwanted vibration, is an additive command value to the outermost control loop. In this case, the parameter "P-0-0059, Additive position command value, controller" consequentially is the target parameter of the actuating variable. In this case, the command value for process control would be the twofold derived position profile which is preset by the external PLC. With infinite stiffness, this would simultaneously be the ideal acceleration profile at the sensor's point of installation.



S-0-0032, Primary mode of operation
S-0-0037, Additive velocity command value
S-0-0051, Position feedback 1 value
S-0-0053, Position feedback 2 value
S-0-0081, Additive Torque/Force command
S-0-0082, Torque/force limit value positive
S-0-0083, Torque/force limit value negative
S-0-0091, Bipolar velocity limit value
S-0-0092, Bipolar torque/force limit value
S-0-0100, Velocity loop proportional gain
S-0-0101, Velocity loop integral action time
S-0-0104, Position loop Kv-factor
S-0-0106, Current loop proportional gain 1
S-0-0107, Current loop integral action time 1
S-0-0109, Motor peak current
S-0-0110, Amplifier peak current
S-0-0111, Motor current at standstill
S-0-0124, Standstill window
S-0-0155, Friction compensation
S-0-0348, Acceleration feedforward gain
S-0-0380, Intermediate DC bus voltage

P-0-0001, Switching frequency of the power output stage
P-0-0004, Velocity loop smoothing time constant
P-0-0040, Velocity feedforward evaluation
P-0-0043, Torque-generating current, actual value
P-0-0051, Torque/force constant
P-0-0109, Torque/force peak limit
P-0-0180, Acceleration feedforward smoothing time constant
P-0-0640, Cooling type
P-0-1119, Velocity mix factor feedback 1 & 2
P-0-1120, Velocity control loop filter: filter type
P-0-1121, Velocity control loop filter: limit frequency low pass
P-0-1122, Velocity control loop filter: band-stop filter of band width
P-0-1123, Vel. cont. loop filter: band-stop filter of center frequen
P-0-1125, Velocity control loop: average value filter clock
P-0-1126, Velocity control loop: acceleration feedforward

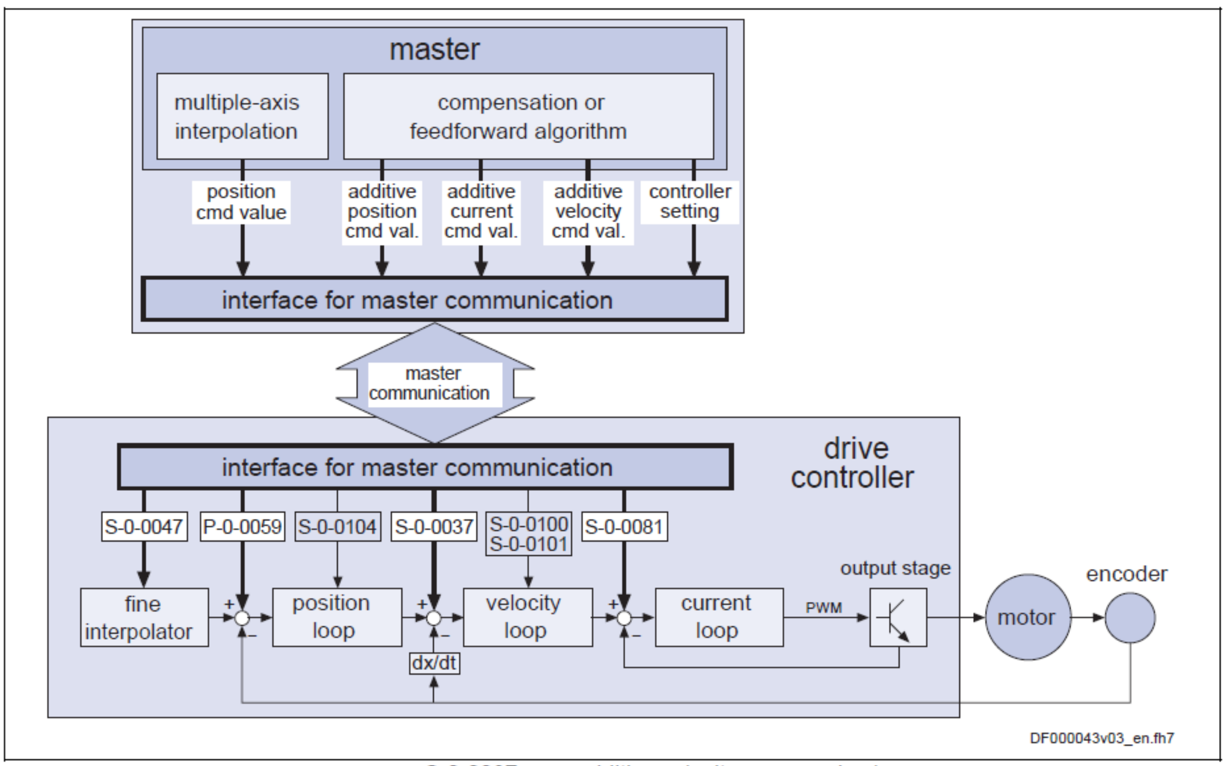
DF0001v2.fh7

With IndraDrive and ADVANCED control sections (and firmware) the following cycle and switching times can be obtained:

- PWM switching frequency max. 16 kHz
- current loop clock $T_{A\_current}$ = 62.5 µs
- velocity loop clock $T_{A\_velocity}$ = 125 µs
- position loop clock $T_{A\_position}$ = 250 µs

With IndraDrive and BASIC control sections (and firmware) the following cycle and switching times can be obtained:

- PWM switching frequency max. 8 kHz
- current loop clock $T_{A\_current}$ = 125 µs
- velocity loop clock $T_{A\_velocity}$ = 250 µs
- position loop clock $T_{A\_position}$ = 500 µs



S-0-0037:	additive velocity command value
S-0-0047:	position command value
S-0-0081:	additive torque/force command value
S-0-0100:	velocity loop proportional gain
S-0-0101:	velocity loop integral action time
S-0-0104:	position loop Kv-factor
P-0-0059:	additive position command value, controller

Örnek uygulama

8 Vibration Damping With Superimposed Process Loop (Process Control With Intelligent Servo Axis)

8.1 Task Definition – Application Description

8.1.1 Task Definition

Using an external sensor, active vibration damping (process control) for low resonance frequencies is to be implemented by means of "IndraMotion MLD".

The objective is to minimize the vibration behavior of the axis and, consequently, to achieve higher contour precision of the axis. In order that the normal positioning process is not inhibited, the process loop is a cascade superimposed to the drive control loop structure. That is to say, the command value must continue taking effect in the respective operation mode and a command value of the process loop is simply added to it.

For this purpose, the MLD-S library "DRIVE_LIB_01V02.lib" makes available a comprehensive PID loop function block!

8.1.2 Functional Overview/Concept

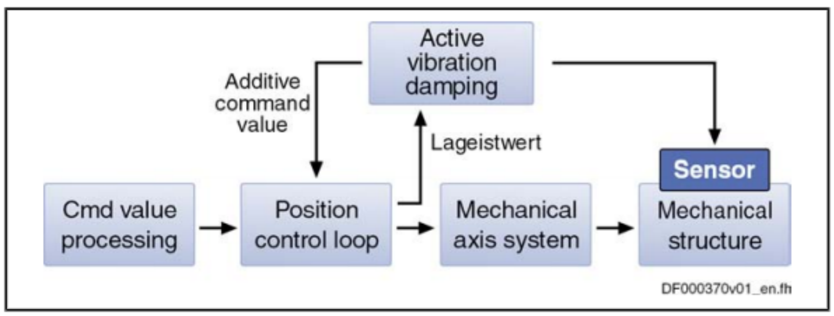


Fig.8-1: Functional Concept

Detecting the Actual Value (Acceleration)

The output signal of an acceleration sensor ist to be read in via an analog input at the IndraDrive control section. This sensor is mounted at a point of the mechanical system which is susceptible to vibration. After the sensor signal has been adjusted, it is used as the actual value for process control.

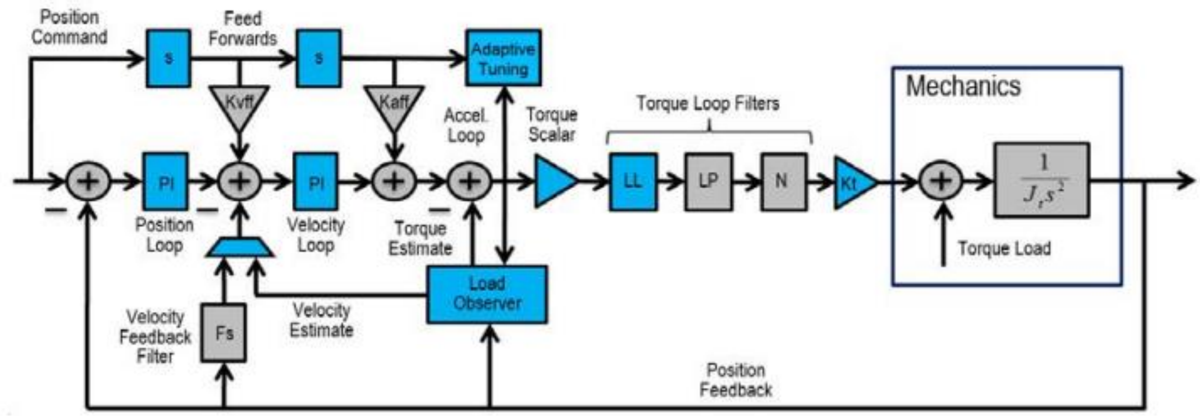
8 Beckhoff

Asd

PWM switching frequency	16 kHz
Current controller frequency	double PWM switching frequency
Velocity controller frequency	16 kHz

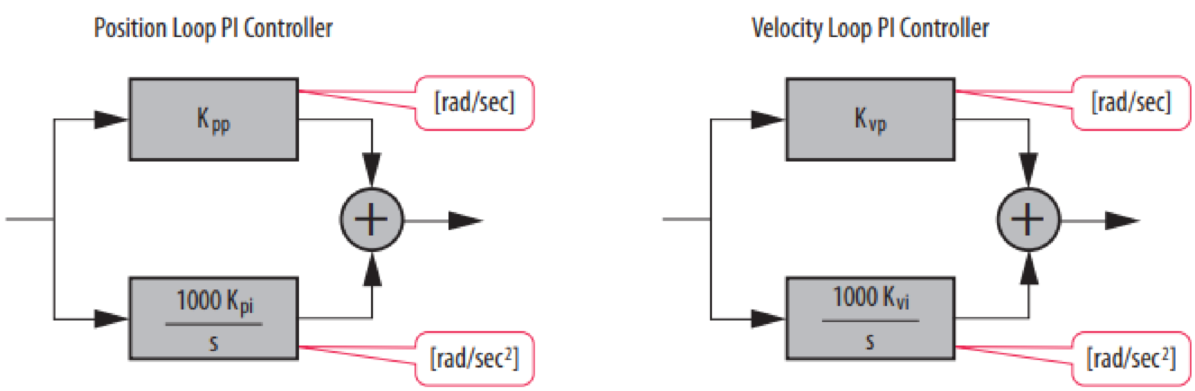
9 Allen Brandley

Asd



Position and Velocity Loop Controllers - In a Sercos drive, the position and velocity loop controllers are configured with a proportional term (top) in parallel with an integral term (bottom) as shown in Figure 2. The proportional term equals the control loop bandwidth in units of [rad/sec]. However, the integral term has a squared relationship to the control loop bandwidth in units of [rad/sec^2]. A factor of 1000 is applied to numerically keep the integral gain in the same range as the proportional gain and attempt to counteract the squared relationship.

Figure 2 - Sercos PI Controllers - Parallel Form

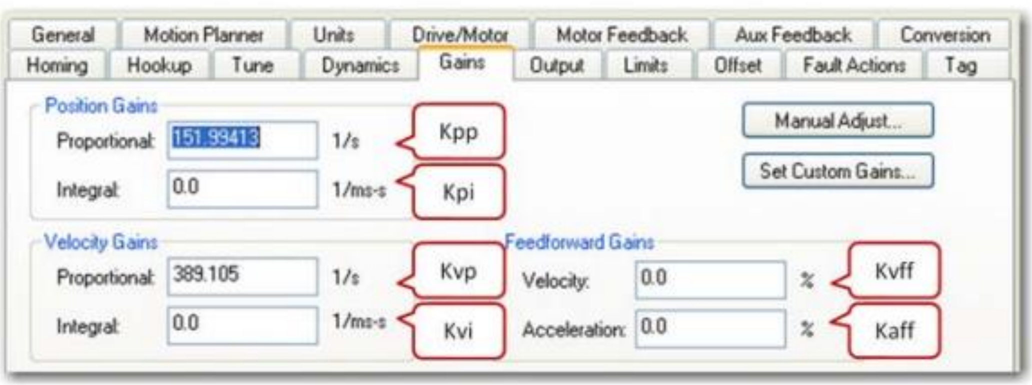


This configuration is standard in classical control theory, minus the factor of 1000. The following definitions are control loop gains of a Sercos drive:

- K_{pp} = Position Proportional Gain [rad/s]
- K_{pi} = Position Integral Gain [rad/s/ms]
- K_{vp} = Velocity Proportional Gain [rad/s]
- K_{vi} = Velocity Integral Gain [rad/s/ms]
- K_{vff} = Velocity Feedforward [%]
- K_{aff} = Acceleration Feedforward [%]

These gains can be accessed on the Gains tab of the Axis Properties dialog box in the Studio 5000 Logix Designer® application.

Figure 3 - Sercos Control Loop Gains in the Logix Designer Application

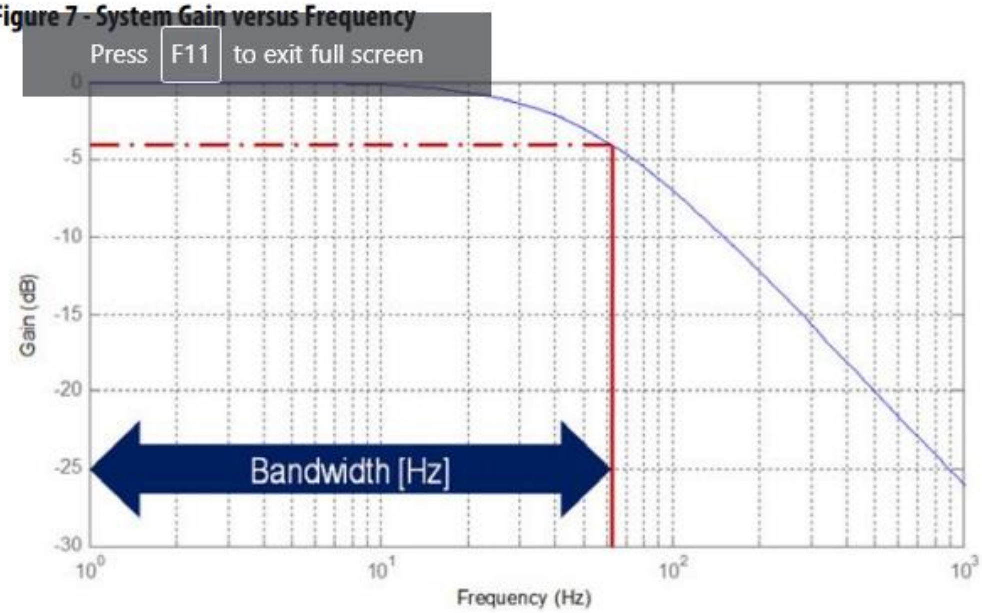


In an EtherNet/IP drive, the position and velocity loop controllers are configured with a proportional term (top) in series with an integral term (bottom) as shown in Figure 4. A factor of 2 π is also applied to each gain. This configuration places all control loop gains in units of [Hz]. As a result, all gains are proportional to each other and represent bandwidths that relate directly to physically measurable signals that are easy to understand. More importantly, removing any squared relationships simplifies the math when tuning an axis, because all gains are related to each other by simple ratios.

Servo Loop Bandwidth

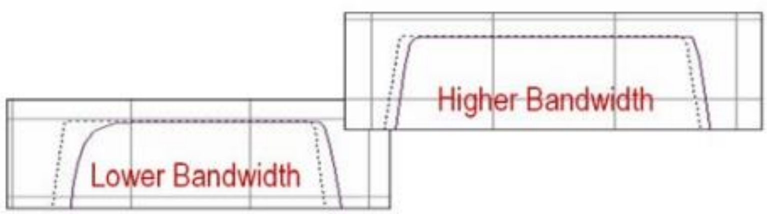
Bandwidth (BW) is a widely used term that is critical to servo drive performance. It is defined as the usable range of frequencies in [Hz] where the gain through the system is above -3 dB. Bandwidth indicates servo drive performance and directly equates to transient response and how fast the servo physically responds to the load. There must be a way to qualify performance for different servo axes, and the metric that makes the most sense is Bandwidth that is measured in [Hz].

Figure 7 - System Gain versus Frequency



Position, velocity, and torque loop bandwidth indicate the respective performance of each loop in a servo drive. Higher bandwidth improves transient response, decreases error, and makes the motor performance stiffer. Figure 8 shows how bandwidth affects actual response with feed forwards disabled (solid) compared to its command motion profile (dashed).

Figure 8 - How Bandwidth Affects Transient Response



These factors affect Servo drive bandwidth:

- Feedback resolution (higher is better)
- Motor-to-Load inertia ratio (lower is better)
- Drive loop update rate (higher is better)
- Load compliance (rigid coupling is better)
- Drive Model Time Constant (lower is better)

Table 1 - Bandwidth Comparison for Various Drive and Motor Combinations

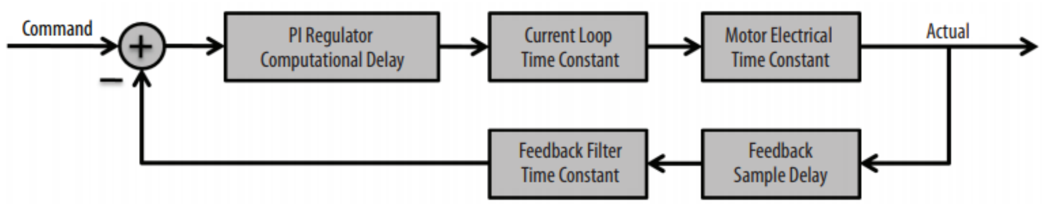
Drive or Servo Control Module	Loop Update Rate			Motor Bulletin Number	Drive Model Time Constant µs	Torque Loop Bandwidth Hz
	Position µs	Velocity µs	Torque µs			
Kinetix 6000 Kinetix 6200 Kinetix 6500	125	125	125	MPL-S/M [(1)]	510.9	311.5
				MPL-E/V [(1)]	538.25	295.6
				MPL-H [(2)]	1531	103.95
Kinetix 350	500	500	125	MPL-S/M [(1)]	1003.9	158.53
				MPL-E/V [(1)]	1031.25	154.33
				MPL-H [(2)]	2024	78.65
				TLY	1062.5	149.8
Kinetix 5500	125	125	125	VPL	537	296.34
1756-M02AE Servo Module	500	250	–	–	1502	106

(1) This motor has a high-resolution encoder.
(2) This motor has an incremental (low resolution) encoder.

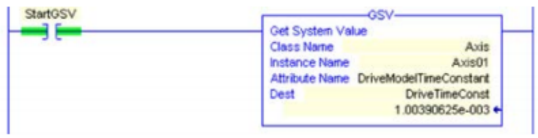
Drive Model Time Constant

Drive model time constant (DMTC) is the sum of all delays around the torque loop for a given drive and motor. Figure 10 shows the delays that are associated with the DMTC.

Figure 10 - Delays Associated with DMTC



DMTC values for different Kinetix drives are shown in Table 1 on page 16. It can be obtained in the Logix Designer application through a GSV instruction as shown in this example.

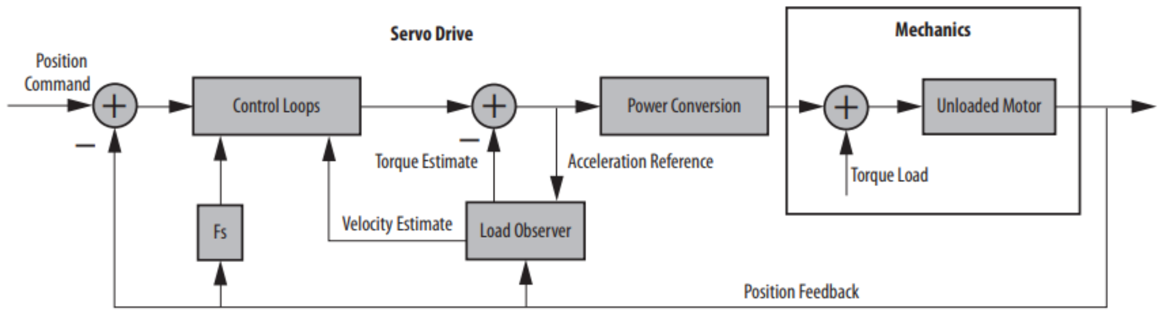


The DMTC is used to calculate the torque loop bandwidth out-of-box and during an autotune. The position and velocity loop gains are then auto-calculated from the Torque Loop Bandwidth.

$$\text{Torque Loop Bandwidth } (T_{bw}) = \frac{1}{2\pi DMTC} \text{ [Hz]}$$

The Torque Loop Bandwidth displays a default of 1000 Hz under the Torque/Current tab in the Axis Properties dialog box of the Logix Designer application. It is important to note that this value actually represents the Current Loop Bandwidth and must not be confused with the Torque Loop Bandwidth described here.

Figure 15 - Load Observer Block Diagram

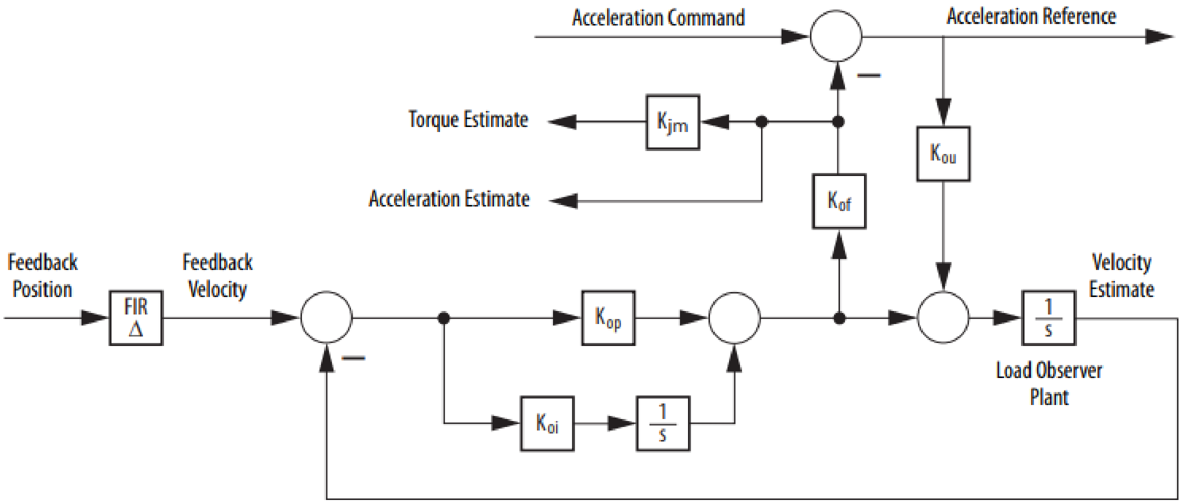


The load observer also generates a Velocity Estimate signal that you can apply to the velocity loop. The Velocity Estimate has less delay than the Velocity Feedback signal derived from the actual feedback device. It also helps to reduce high frequency output noise caused by the load observer's aggressive action on the acceleration reference. Together, the Load Observer with Velocity Estimate provides the best overall performance for positioning applications. Table 2 describes the Load Observer mode settings that can be configured.

Table 2 - Load Observer Configuration Settings

Mode	IDN P-431 Value	Description	
Disabled (default)	0	Load observer is inactive.	
Load Observer Only	1	Provides a Torque Estimate only	This setting is similar to Acceleration Feedback but uses a second input signal, Acceleration Reference, for increased low frequency disturbance rejection (stiffness). It corrects error but is fairly aggressive. As a result, the bandwidth must often be cut in half or significantly reduced. It does not provide a Velocity Estimate in place of Velocity Feedback.
Load Observer with Velocity Estimate	2	Standard Operation: Provides Torque and Velocity Estimates	This setting combines the best of the Load Observer Only and Velocity Estimate Only settings. Separately, velocity estimate provides a smooth response and reduces phase lag, but creates error, whereas load observer removes error, including steady state error in the velocity estimate, but it increases phase lag and is fairly aggressive. Together, they remove error and provide a smooth response. With the recommended out-of-box configuration, load observer performs extremely well in situations with changing inertia and unknown levels of compliance and backlash (vibration suppression).
Velocity Estimate Only	3	Provides a Velocity Estimate only	This setting provides a Velocity Estimate in place of Velocity Feedback. This produces a smooth feedback signal but can add steady state error, generating a fictitiously lower velocity error. As a result of the potential error, it is not recommended to use in Velocity mode. Also, position integrator or observer integrator should be used with setting in Position mode.
Acceleration Feedback	4	Provides Acceleration Feedback by disconnecting the Acceleration Reference to Load Observer	This setting creates a filtered acceleration feedback signal. It corrects errors but is fairly aggressive. As a result, the observer bandwidth must often be cut in half or significantly reduced for stable operation. This setting is similar to Load Observer Only but doesn't use an Acceleration Reference input signal to mitigate additional phase lag (delay) created by necessary filtering. It does not provide a Velocity Estimate in place of Velocity Feedback.

Figure 21 - Load Observer Internal Gains for Kinetix 5500, Kinetix 6000, Kinetix 6200, and Kinetix 6500 Drives



Load observer gains that require user interaction are Load Observer Bandwidth (K_{op}) and Load Observer Integral Bandwidth (K_{oi}). They are set by IDN P-432 and IDN P-433, respectively. Guidelines for setting these gains are provided in the following sections. In general, K_{op} acts like a velocity integrator without windup and K_{oi} acts like a position integrator without windup. Typically, $K_{oi} = 0$.

Load observer gains that do not require user interaction are Load Observer Feedback Gain (K_{of}) and Load Observer Input Gain (K_{ou}). They are automatically set internally based on the Load Observer Configuration. However, when in Acceleration Feedback mode, K_{of} can also be set manually by using IDN P-434 with typical values between zero and one.

Table 3 - Load Observer Gain Parameters

IDN	Name	Drive Variable	Units	Format	Value, min	Value, max
P:0:432	Load Observer Bandwidth (K_{op})	K_{op}	Rad/s	16-bit unsigned integer	0	12,500 (1) 65,535 (2)
P:0:433	Load Observer Integral Bandwidth (K_{oi})	K_{oi}	Rad/s			
P:0:434	Load Observer Feedback Gain (K_{of})	K_{of}	–			200

(1) This value applies to drive firmware revision 1.124 and 1.125.
(2) This value applies to drive firmware revision later than 1.125.

Table 8 - Adaptive Tuning Attributes

Parameter Name	Description	Default Value	Range/Units
Torque Notch Filter Low Frequency Limit	Adaptive tuning identifies resonances not associated with command signals between these low and high frequency limits with magnitudes above this tuning threshold.	Torque Loop BW	20...2000 Hz
Torque Notch Filter High Frequency Limit		2000	20...2000 Hz
Torque Notch Filter Tuning Threshold		5	0...100 % motor rated torque
Torque Notch Filter Frequency Estimate	Adaptive tuning sets this frequency estimate equal to the center frequency of the identified resonance with the highest magnitude.	Torque Notch Filter Frequency or 0 when disabled	20...2000 Hz
Torque Notch Filter Magnitude Estimate	Adaptive tuning sets this magnitude estimate equal to the magnitude of the identified resonance with the highest magnitude.	0	0...100 % motor rated torque
Torque Low Pass Filter Bandwidth Estimate	In modes with Gain Stabilization, adaptive tuning decreases this bandwidth estimate from its default value in 200 Hz increments to suppress additional resonances above the low frequency limit if required. Additional resonances are ones that are not already suppressed by notch filters.	Torque Low Pass Filter BW or 1500 when disabled	20...2000 Hz
Adaptive Tuning Gain Scaling Factor	In modes with Gain Stabilization, adaptive tuning incrementally decreases this gain scaling factor from its default value to stabilize the system if required. The instability is caused from resonances that are not already suppressed by filters or it is caused by filter bandwidths that are too close to the closed loop bandwidth.	1	0...max float
Adaptive Tuning Configuration	Controls the adaptive tuning modes of operation. See below for a detailed description of each mode.	Disabled	0 = Disabled 1 = Tracking Notch Filter 2 = Gain Stabilization 3 =Tracking Notch Filter and Gain Stabilization

Resonances are characterized in the following way:

- HF resonances are above the low frequency limit.
- LF resonances are below the low frequency limit.
- MF resonances are slightly above the low frequency limit.

Mechanical Resonances

Mechanical loads exhibit resonances that limit performance, damage hardware, consume energy, and are noisy. It is often left to the user to suppress these resonances through manual tuning, a challenging and time consuming task. Resonances result from various levels of compliance, backlash, and misalignment and can range in frequency from a few Hz to a few thousand Hz. They typically increase in number and severity as controller gains are increased. Resonances are classified in the following ways.

Motor Side Resonances - Most mechanical resonances are reflected back to the motor and 'seen' by the encoder. As a result, they are suppressed by tuning control loop gains, the load observer, and torque loop filter parameters.

- Low Frequency (LF) Resonances - LF resonances are below the Torque Loop Bandwidth. Since they are within the closed loop bandwidth (in-band), they are automatically suppressed when load observer is applied with the recommended out-of-box settings. Otherwise, they can cause classical instability that generates an audible low-pitch growling noise and requires detuning of control loop gains.

- High Frequency (HF) Resonances - HF resonances are above the Torque Loop Bandwidth. Because they are outside the closed loop bandwidth (out-of-band), they are suppressed using torque loop notch filters. It is often left to the user to identify the resonant frequencies and manually configure the notch filters. HF resonances typically generate an audible high pitch squealing noise. If there are more HF resonances than there are notch filters available, a torque loop low pass filter can be applied to suppress resonances at the highest frequencies. Adaptive tuning addresses HF resonance by automatically configuring these filters. A last resort is detuning control loop gains until resonances go away.
- Mid Frequency (MF) Resonances - When resonances occur in the neighborhood of the Torque Loop Bandwidth, torque loop notch filters are applied at frequencies close to the closed loop bandwidth. This close proximity allows phase lag generated by the notch filter to interfere with closed loop dynamics and cause instability. As a result, control loop gains must be lowered to restore stability or notch filter width can be decreased to reduce the impact of phase lag, if the drive supports this feature. Similarly, torque loop low pass filters impact stability when they are applied at frequencies as low as three to five times the closed loop bandwidth because they generate more phase lag than notch filters. As a result, low pass filters should only be applied if you run out of notch filters and should only be reserved for resonances at the highest frequencies. Adaptive tuning addresses MF resonance as well.

Load Side Resonances - Even with a tightly controlled motor shaft and all motor side resonances suppressed, the end effector may still oscillate at a few Hz through a compliant connection to the motor. These resonances typically cannot be monitored through the motor encoder. This is common in applications with robots, cranes, liquid sloshing, laser cutting, and other cantilevered loads. End effector vibration suppression requires one of the following techniques:

- Determine the load oscillation frequency with a stopwatch and apply a command notch filter at that frequency if the drive supports this feature.
- Determine the load oscillation frequency with a stopwatch and modify the input CAM motion profile to be smoother and without load oscillation frequency content.
- Place a feedback device on the load in Dual Feedback mode.

Tracking Notch Filter

In modes with Tracking Notch Filters, the Torque Notch Filter Frequency Estimate is applied to the torque notch filter instead of the Torque Notch Filter Frequency that is visible on the Compliance tab of the Axis Properties dialog box.

Figure 26 - Tracking Notch Filter Mode

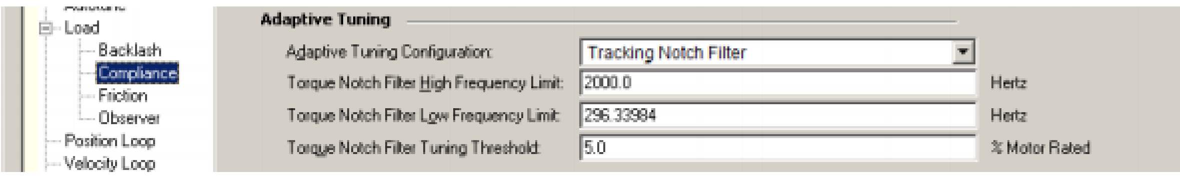
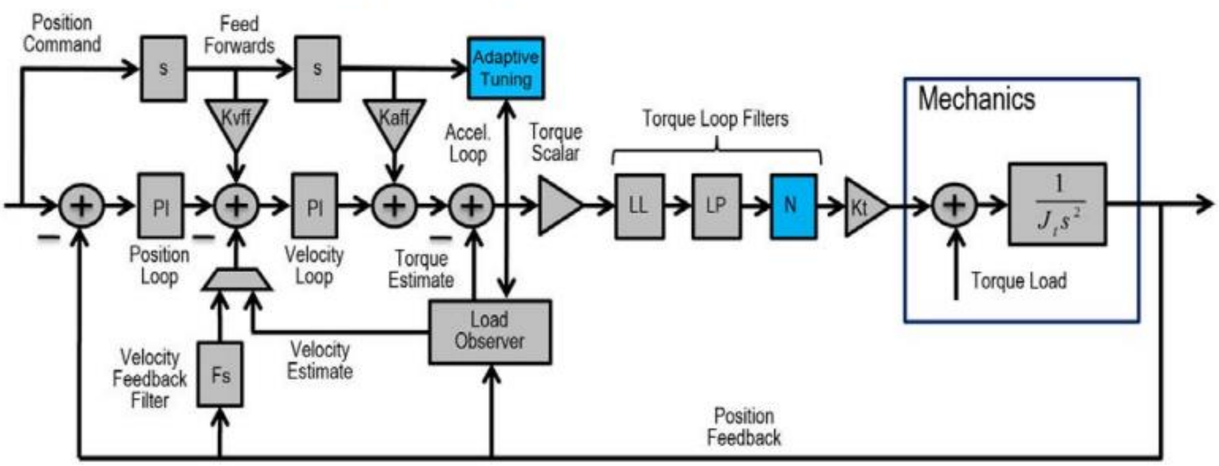


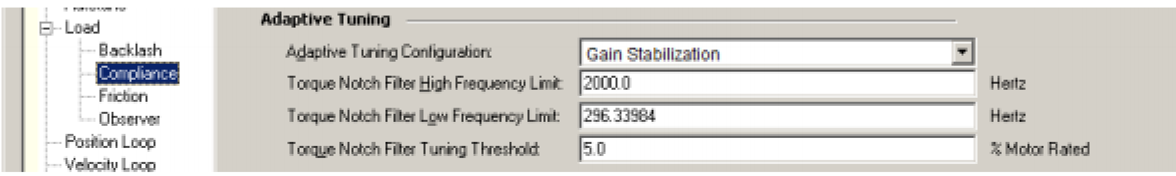
Figure 27 - Tracking Notch Filter Configuration



Gain Stabilization

In modes with Gain Stabilization, adaptive tuning does two main things. First, it enables and tunes the low pass filter to suppress resonances if any are identified above the low frequency limit. Here, the Torque Low Pass Filter Bandwidth Estimate is applied to the torque low pass filter instead of the Torque Low Pass Filter Bandwidth that is visible on the Compliance tab of the Axis Properties dialog box. The bandwidth estimate is incrementally decreased from its default value until the identified HF resonances are suppressed or until a LF resonance or instability occurs.

Figure 28 - Gain Stabilization Mode



Second, adaptive tuning detunes control loop gains to suppress any remaining resonances and stabilize the system. Here, the following gains are scaled by the Adaptive Tuning Gain Scaling Factor:

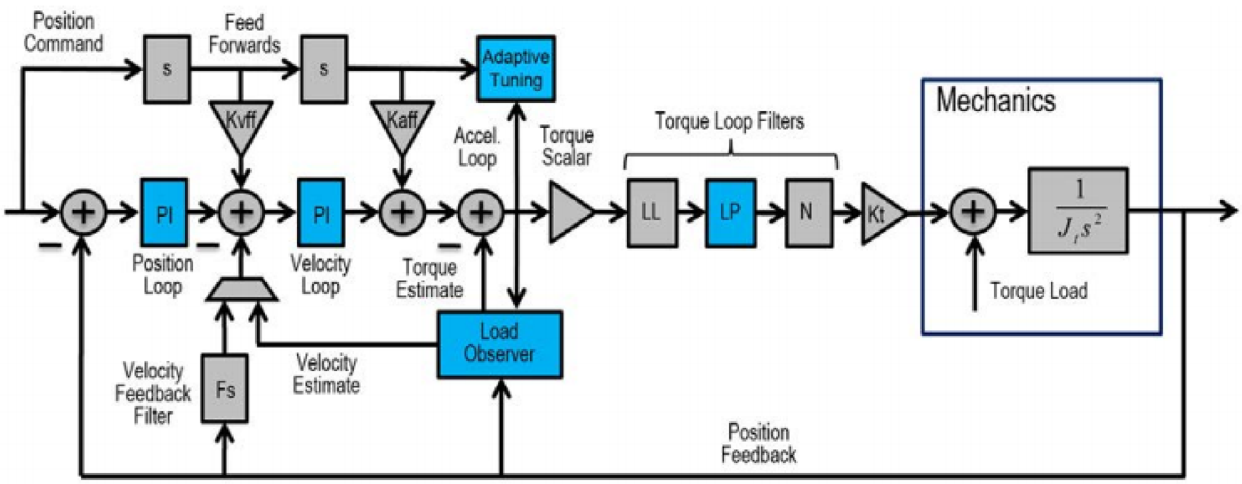
- Load Observer Bandwidth
- Load Observer Integrator Bandwidth
- Velocity Loop Bandwidth
- Velocity Loop Integrator Bandwidth
- Position Loop Bandwidth
- Position Loop Integrator Bandwidth

This means that the actual control loop gains are the values shown in the Axis Properties dialog box multiplied by the gain scaling factor. The scaling factor is incrementally decreased from its default value until the system is stable. When

Gain Stabilization is not enabled, the scaling factor is reset to its default value of one so that control loop gains are not affected.

In Figure 29, the parts of the control loop structure affected by Gain Stabilization are highlighted in blue.

Figure 29 - Gain Stabilization Configuration



Gain Stabilization is good for situations where there are more resonances than there are notch filters and for keeping the axis stable. Instability and audible noise are caused from the following situations:

- HF resonances that are not already suppressed by filters
- MF resonances that are suppressed by filters but the filter bandwidths that are too close to the closed loop bandwidth
- LF resonances that result when load observer is not applied with the recommended out-of-box settings
- LF resonances that result from classical instability

Autotuning

This chapter provides autotuning information for Sercos and EtherNet/IP servo drives.

Topic	Page
Sercos Drives	45
EtherNet/IP Drives	53
Is Further Tuning Required?	63

Out-of-box refers to default control loop gain settings that are pre-configured for a new axis when it is created. Because the load is unknown at this point, the motor is assumed to be unloaded and the load ratio R = 0. However, when the load is known or an autotune has been performed, the control loop gains are configured for a load ratio R > 0. This is the primary difference affecting out-of-box and autotuning rules. Thus, the phrase out-of-box implies R = 0 and the term 'autotune' implies R > 0.

Autotune automatically performs two basic functions with minimal intervention:

- Autotune momentarily initiates motion in a 'bump test' to measure the load ratio (R). The torque scalar and system acceleration are calculated from R and the axis dynamics and limits are calculated from these parameters.
- Control loop gains are calculated based on the torque-loop bandwidth (T_{bw}), which is determined from the drive model time constant (DMTC), depending on the drive and motor selected.

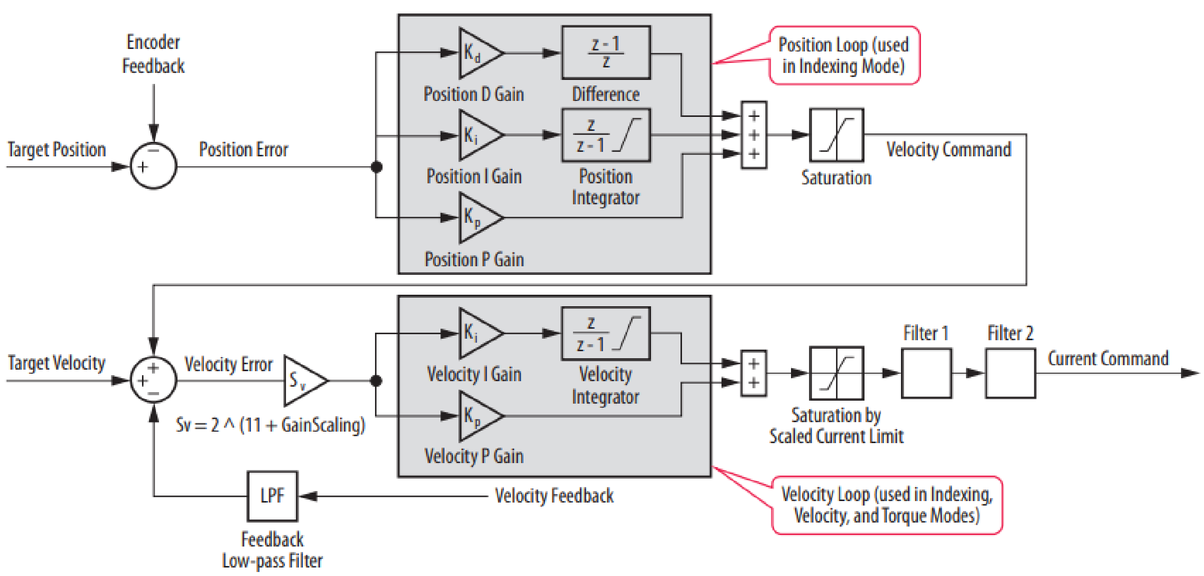
Table 11 - Sercos Drive Gain Selection Based on Application Type

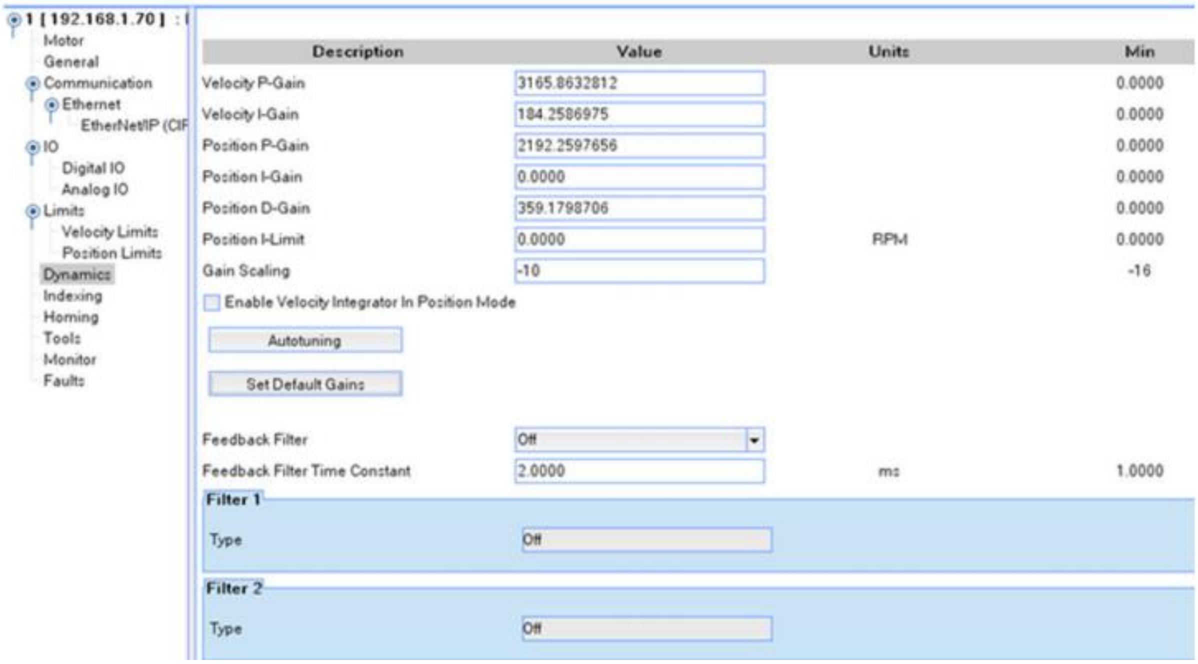
Application Type	Applications	K_{pi}	K_{vi}	Integrator Hold	K_{vff}	K_{aff}
Basic	Basic smooth motion				X	
Tracking	• Converting • Printing • Web • Flying shear • Coordinated motion • Rotary knife • Packaging		X		X	X
Point to Point	• Pick and place • Indexing • Robotics • Palletizing	X		X		
Constant Speed	• Conveyors • Line shafts • Cranks		X		X	
Positioning	High performance position control	X			X	X

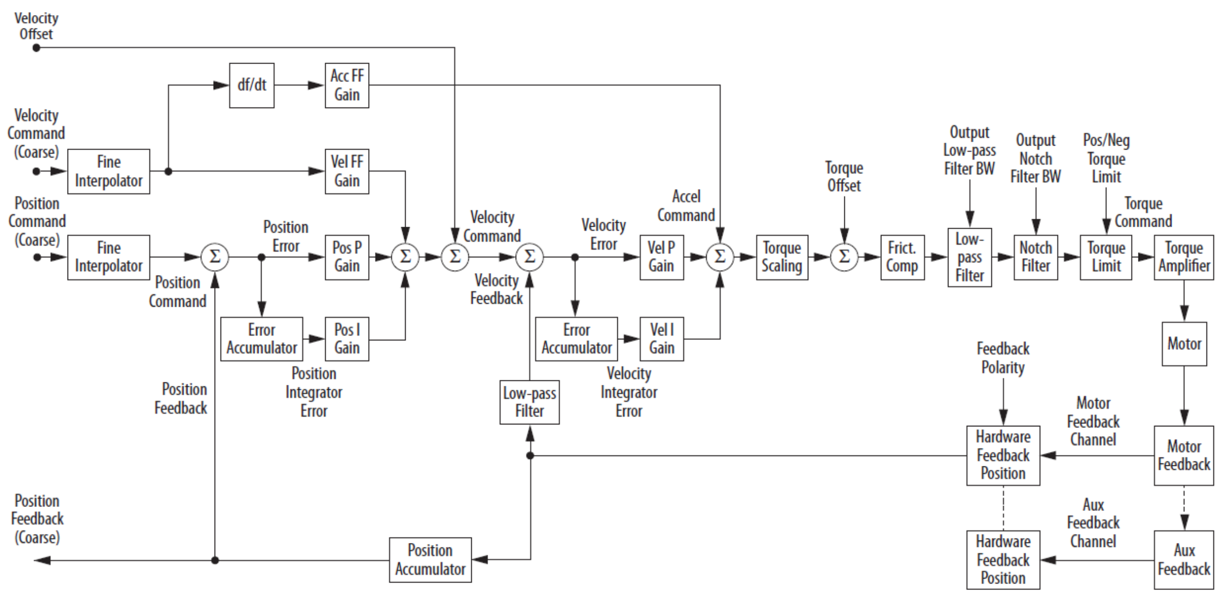
Control Loops

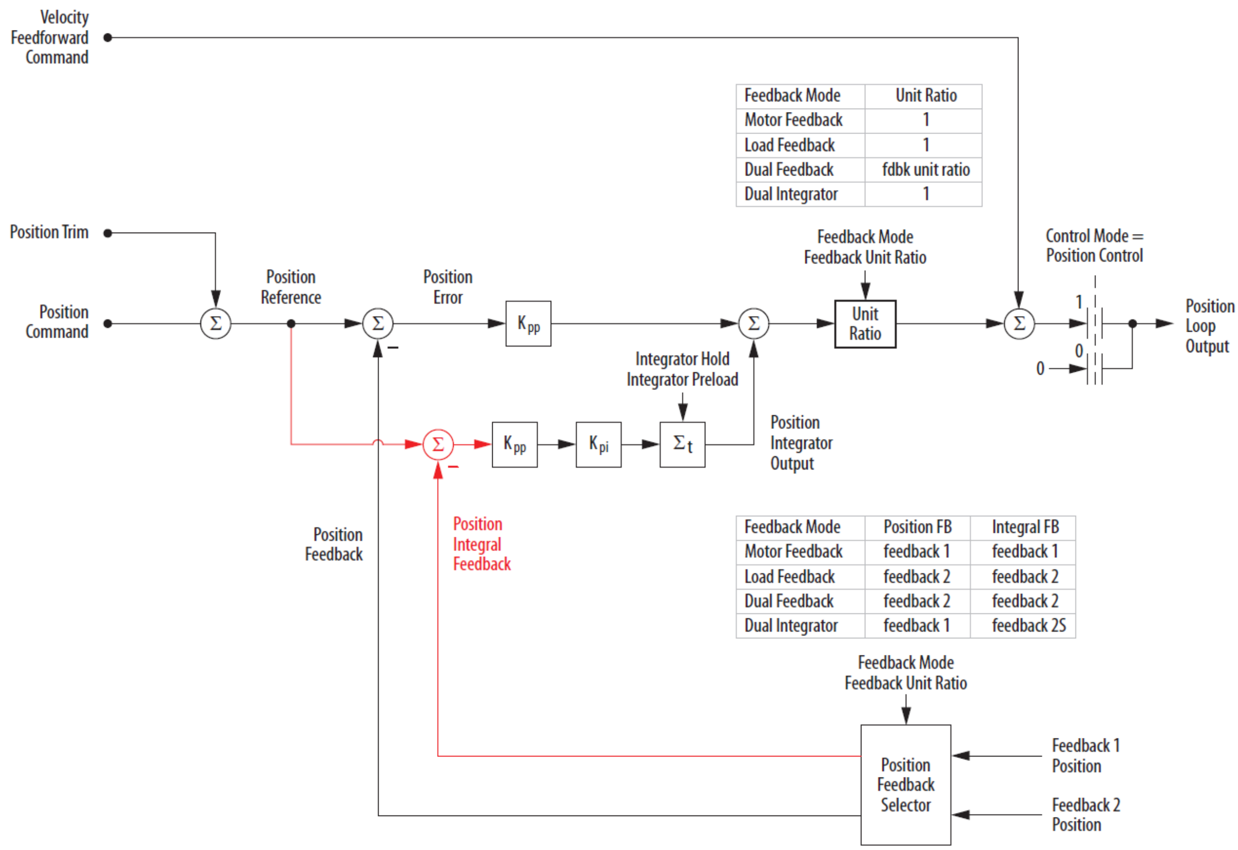
The control loops within a Kinetix 300 servo drive are shown below.

Figure 64 - Kinetix 300 Drive Control Loops

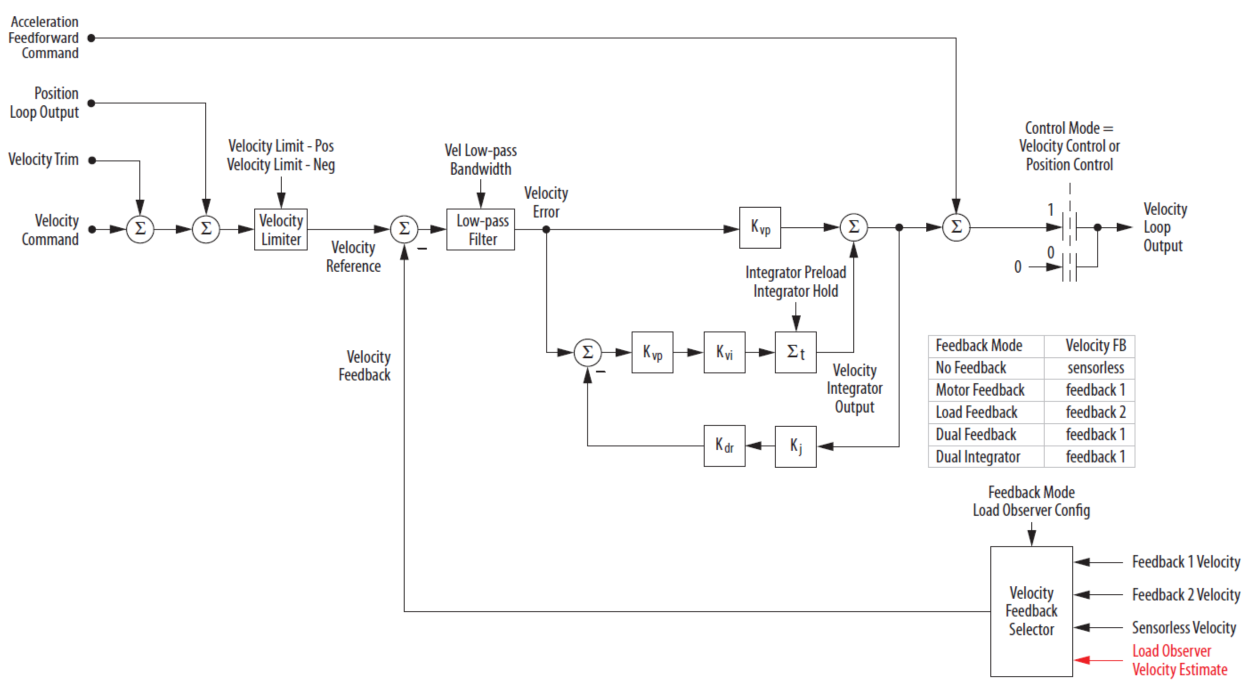



1 [192.168.1.70]
Motor
General
Communication
Ethernet
EtherNet/IP (CIF
IO
Digital IO
Analog IO
Limits
Velocity Limits
Position Limits
Dynamics
Indexing
Homing
Tools
Monitor
Faults
Description
Value
Units
Min
Velocity P-Gain
3165.8632812
0.0000
Velocity I-Gain
184.2586975
0.0000
Position P-Gain
2192.2597656
0.0000
Position I-Gain
0.0000
0.0000
Position D-Gain
359.1798706
0.0000
Position I-Limit
0.0000
RPM
0.0000
Gain Scaling
-10
-16
Enable Velocity Integrator In Position Mode
Autotuning
Set Default Gains
Feedback Filter
Off
Feedback Filter Time Constant
2.0000
ms
1.0000
Filter 1
Type
Off
Filter 2
Type
Off


Velocity Offset
df/dt
Acc FF Gain
Velocity Command (Coarse)
Fine Interpolator
Vel FF Gain
Position Command (Coarse)
Fine Interpolator
Position Command
Position Error
Pos P Gain
Error Accumulator
Pos I Gain
Position Integrator Error
Position Feedback
Velocity Command
Velocity Feedback
Low-pass Filter
Velocity Error
Vel P Gain
Error Accumulator
Vel I Gain
Velocity Integrator Error
Accel Command
Torque Scaling
Torque Offset
Frict. Comp
Output Low-pass Filter BW
Low-pass Filter
Output Notch Filter BW
Notch Filter
Pos/Neg Torque Limit
Torque Limit
Torque Command
Torque Amplifier
Motor
Feedback Polarity
Motor Feedback Channel
Hardware Feedback Position
Motor Feedback
Aux Feedback Channel
Hardware Feedback Position
Aux Feedback
Position Feedback (Coarse)
Position Accumulator

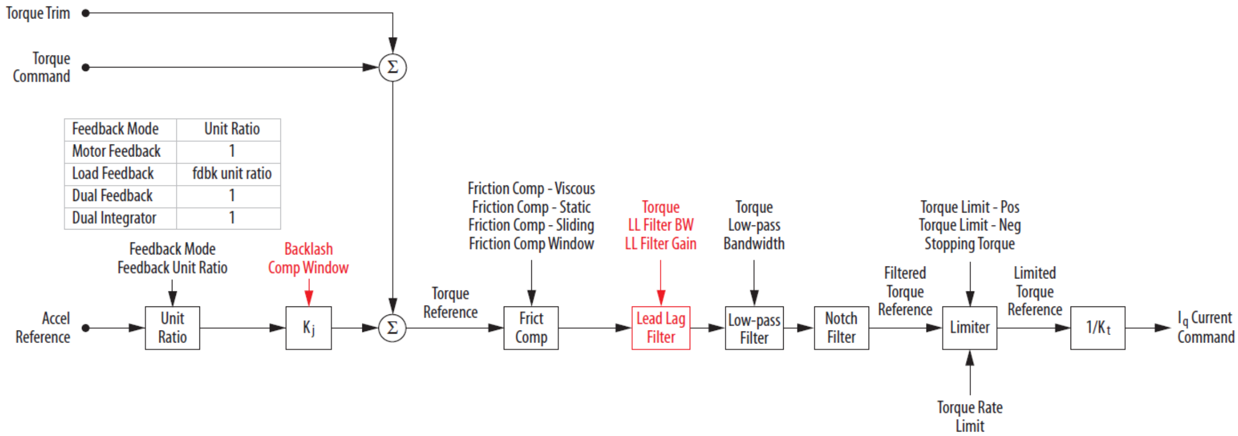


Kinetix 6500, Kinetix 5500, and Kinetix 350 drive velocity loop architecture is shown in the following diagram.



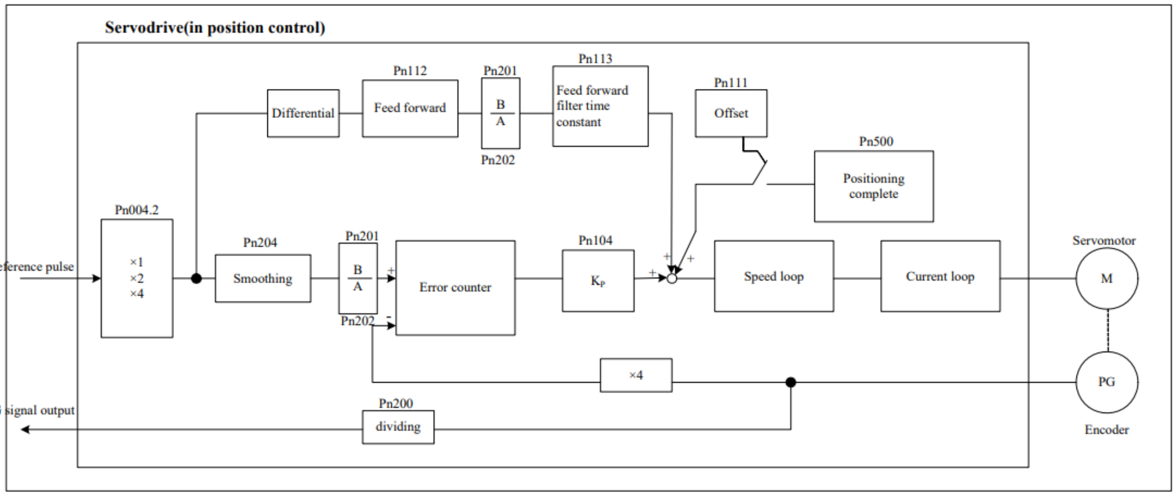
Torque/Current Loop

Kinetix 6500, Kinetix 5500, and Kinetix 350 drive torque/current loop architecture is shown in the following diagram.



10 Estun

asd

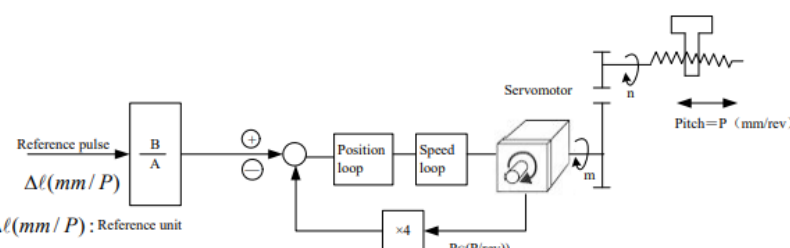


5	Calculate the electronic gear ratio	$\frac{B}{A}=\frac{16384\times4}{6000}\times\frac{1}{1}$		$\frac{B}{A}=\frac{16384\times4}{3600}\times\frac{3}{1}$		$\frac{B}{A}=\frac{16384\times4}{31400}\times\frac{2}{1}$	
6	Set parameters	Pn201	65536	Pn201	196608	Pn201	131072
		Pn202	6000	Pn202	3600	Pn202	31400
7	Final Result	Pn201	16384	Pn201	16384	Pn201	16384
		Pn202	1500	Pn202	300	Pn202	3925

• Reduce the fraction (both numerator and denominator) if the calculated result will not be within the setting range.

• For example, reduce the above numerators and denominators by four or other numbers to obtain the final results in step 7 and complete the settings.

(5)Electronic Gear Ratio Equation



$\Delta\ell(mm/P)$: Reference unit

PG(P/rev)): Encoder pulses

P（mm/rev）: Ball screw pitch

$\frac{m}{n}$: Deceleration ratio

$$\frac{n\times p}{\Delta\ell}\times\left(\frac{B}{A}\right)=4\times P_G\times m$$

$$\left(\frac{B}{A}\right)=\frac{4\times P_G\times m\times\Delta\ell}{n\times p}=\frac{4\times P_G}{\frac{P}{\Delta\ell}}\times\frac{m}{n}$$

Set A and B with the following parameters:

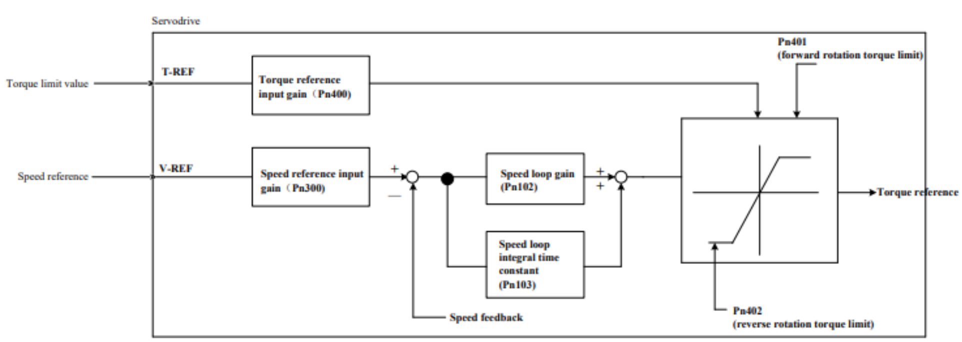
$\boxed{A}$: Pn202 $\boxed{B}$: Pn201

Speed Control	Analog Input Reference	Reference Voltage	±10VDC at rated speed（Variable setting range:±0～10VDC） Max. input voltage：±12V
		Input	About 10MΩ or above
		Circuit	10μs
	Speed Selection	Rotation Direction Selection	With /P-CON signal
		Speed	Speed 1 to 7
	Function	Soft start Setting	0~10s (Can be set individually for acceleration and deceleration)
Position Control	Pulse Reference	Type	Sign + pulse train;CCW + CW pulse train; 90°phase difference 2-phase (phase A + phase B)
		Form	Non-insulated linde driver (about + 5V), open collector
		Frequency	×1 multiplier：4Mpps ×2 multiplier：2Mpps ×4 multiplier：1Mpps Open collector：200Kpps Frequency will begin to decline when the duty ratio error occurs..
	Position Reference Setting	Position Setting	16 postion nodes can be set.

4.9.3 Torque Limiting Using an Analog Voltage Reference

Torque limiting by analog voltage reference limits torque by assigning a torque limit in an analog voltage to the T-REF terminals (CN1-26,27). This function can be used only during speed or position control, not during torque control.

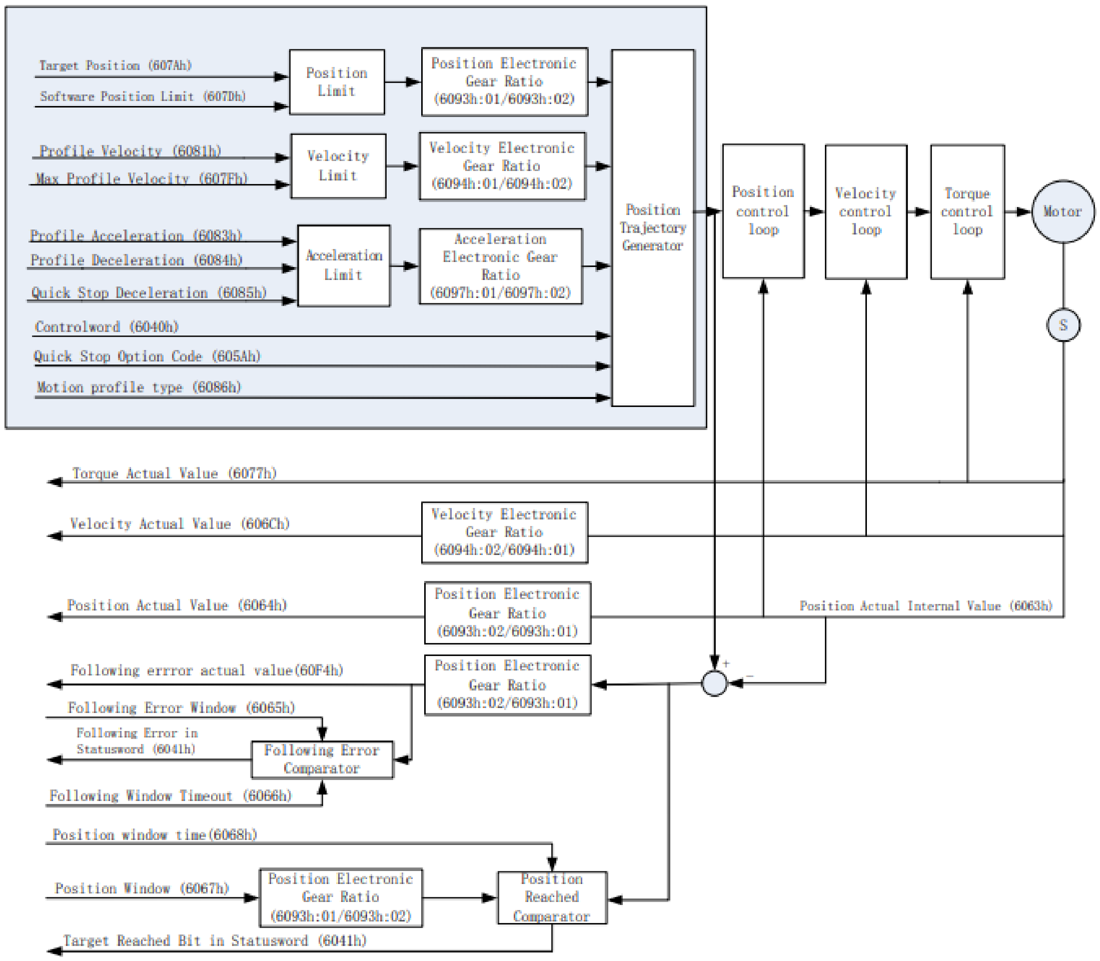
Refer to the following block diagram when the torque limit with an analog voltage reference is used for speed control.



Parameter		Control Method
Pn005	H. □□4□	Speed control (contact reference)⟺Speed control (analog voltage reference)
	H. □□5□	Speed control (contact reference)⟺Position control (pulse train reference)
	H. □□6□	Speed control (contact reference)⟺Torque control (analog voltage reference)
	H. □□7□	Position control (pulse train reference)⟺Speed control (analog voltage reference)
	H. □□8□	Position control (pulse train reference)⟺ Torque control (analog voltage reference)
	H. □□9□	Torque control (analog voltage reference)⟺ Speed control (analog voltage reference)
	H. □□A□	Speed control (analog voltage reference)⟺ Zero clamp
	H. □□B□	Position control (pulse train reference)⟺ Position control (inhibit)
	H. □□C□	Position control (contact reference)
	H. □□D□	Speed control (Parameter reference)
	H. □□E□	Special control

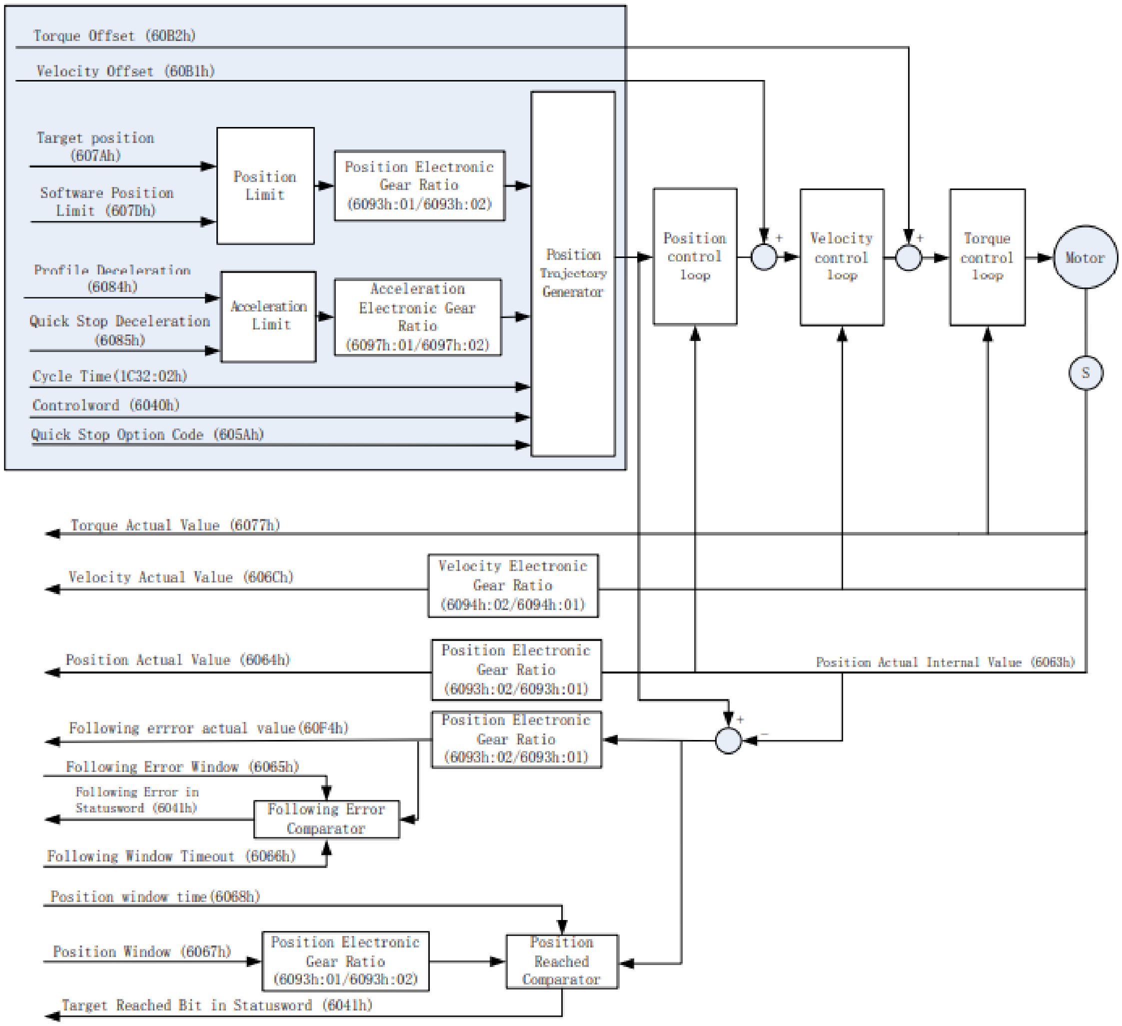
5.7 Profile position mode

In the profile position mode, the motor position is controlled in accordance with the target position, target velocity , acceleration and deceleration, until it reaches the target position.
The following figure shows the block diagram of the profile position mode.



5.10 Cyclic synchronous position mode

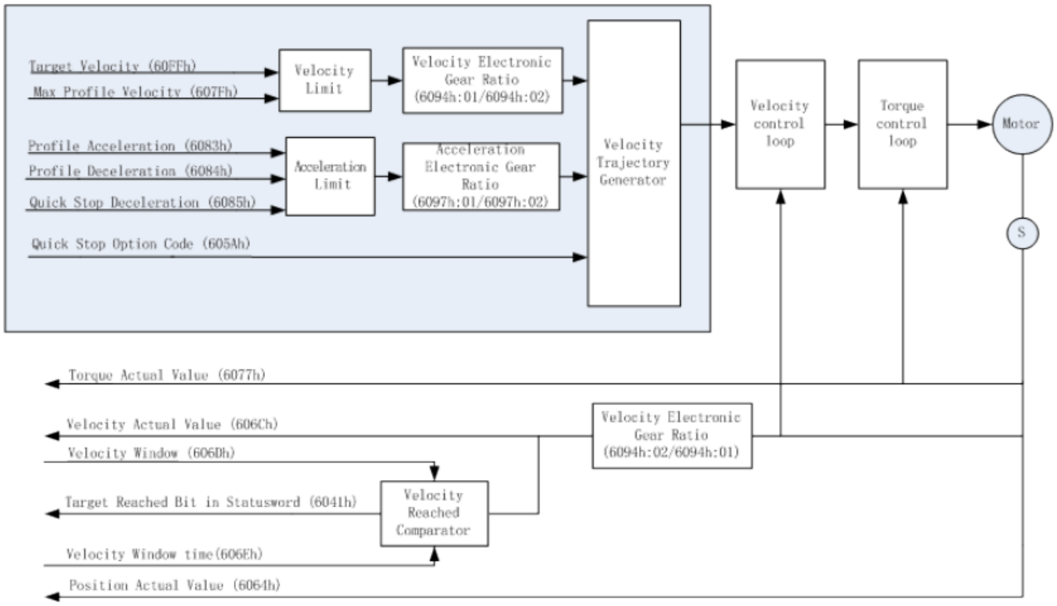
Cyclic synchronous position mode is similar to position interpolation mode. In this control mode, the master could offer extra speed and torque to achieve speed and torque feed forward control. The interpolation cycle time defines the time for target position updating. In this case, interpolation cycle time is the same as sync time.



Torque Offset (60B2h)
Velocity Offset (60B1h)
Target position (607Ah)
Software Position Limit (607Dh)
Position Limit
Position Electronic Gear Ratio (6093h:01/6093h:02)
Profile Deceleration (6084h)
Quick Stop Deceleration (6085h)
Acceleration Limit
Acceleration Electronic Gear Ratio (6097h:01/6097h:02)
Cycle Time(1C32:02h)
Controlword (6040h)
Quick Stop Option Code (605Ah)
Position Trajectory Generator
Position control loop
Velocity control loop
Torque control loop
Motor
S
Torque Actual Value (6077h)
Velocity Actual Value (606Ch)
Velocity Electronic Gear Ratio (6094h:02/6094h:01)
Position Actual Value (6064h)
Position Electronic Gear Ratio (6093h:02/6093h:01)
Position Actual Internal Value (6063h)
Following errror actual value(60F4h)
Position Electronic Gear Ratio (6093h:02/6093h:01)
Following Error Window (6065h)
Following Error in Statusword (6041h)
Following Error Comparator
Following Window Timeout (6066h)
Position window time(6068h)
Position Window (6067h)
Position Electronic Gear Ratio (6093h:01/6093h:02)
Position Reached Comparator
Target Reached Bit in Statusword (6041h)

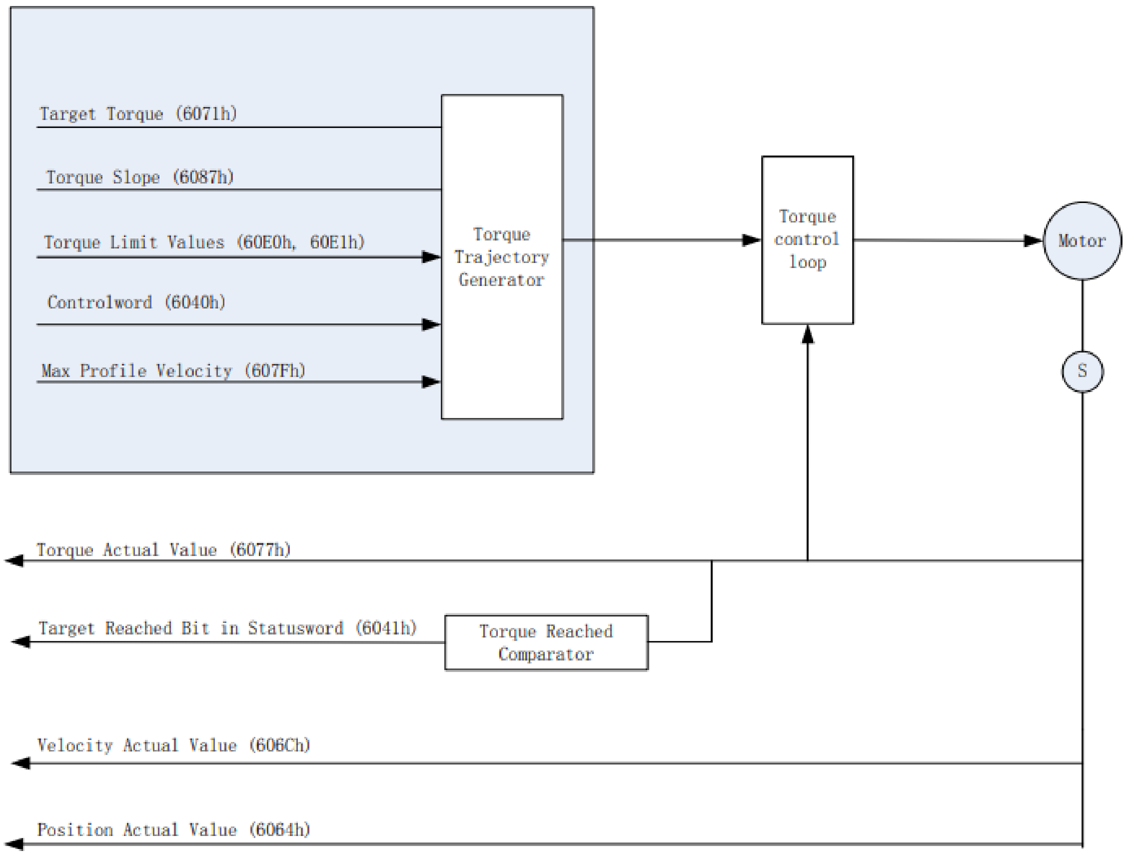
5.6 Profile velocity mode

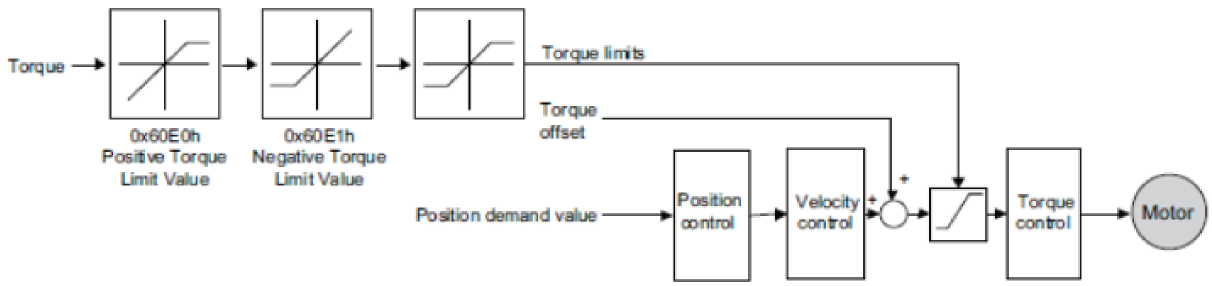
In the profile velocity mode, the speed is output in accordance with the acceleration and deceleration, until it reaches the target velocity. The following figure shows the block diagram of the profile velocity mode.

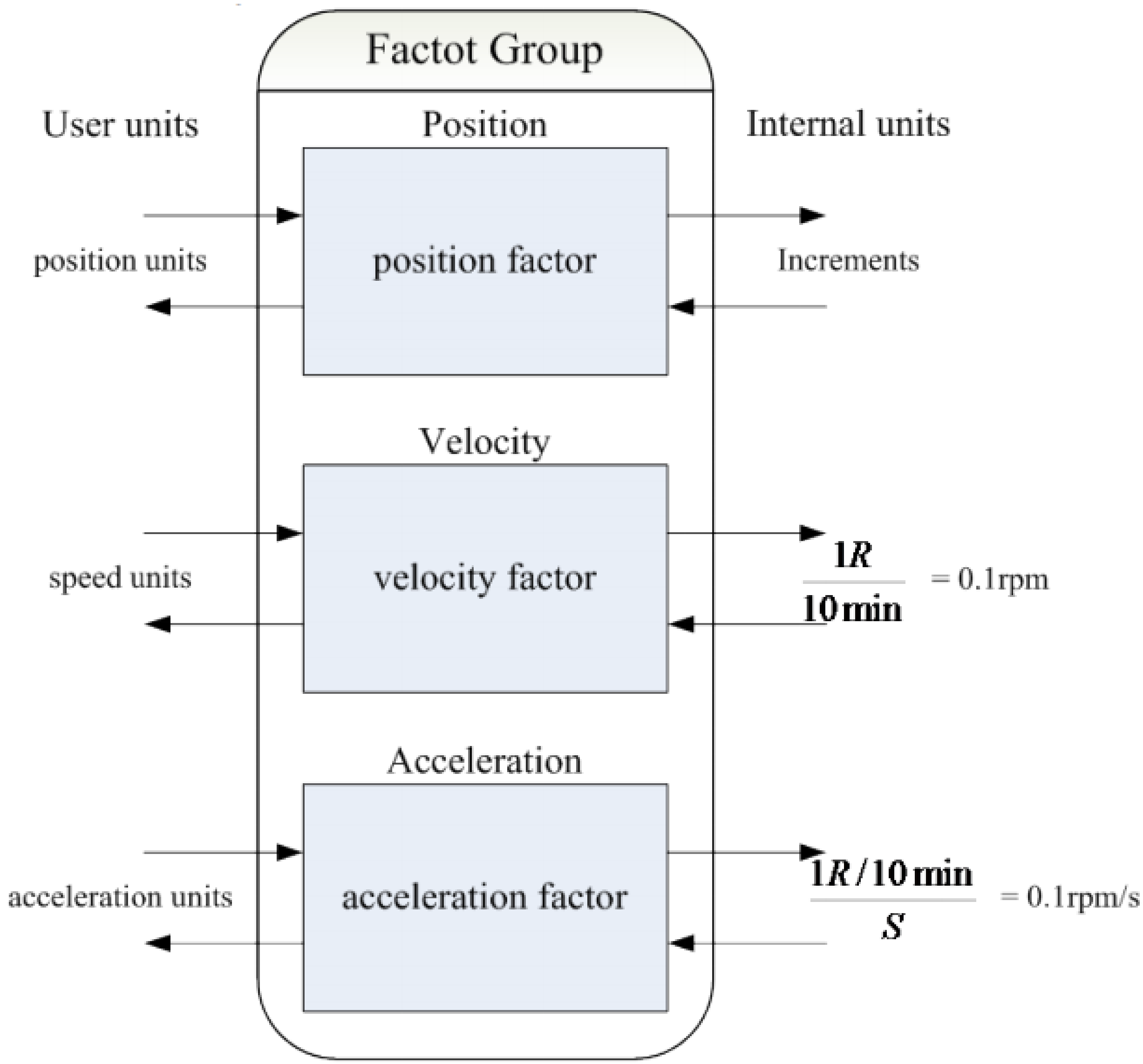


5.9 Profile torque mode

Profile torque mode operates the controller outputs a target torque. Servo drive outputs signal to control the motor according to the target torque and acceleration. Speed limit is $607F_h$.
The following figure shows the block diagram of the profile torque mode.




Torque
0x60E0h
Positive Torque
Limit Value
0x60E1h
Negative Torque
Limit Value
Torque limits
Torque
offset
Position demand value
Position
control
Velocity
control
Torque
control
Motor


Factot Group
User units
Position
Internal units
position units
position factor
Increments
Velocity
speed units
velocity factor
$\frac{1R}{10\,min} = 0.1rpm$
Acceleration
acceleration units
acceleration factor
$\frac{1R/10\,min}{S} = 0.1rpm/s$

5.2.7 Software Version Display

Set the Fn007 to select the software version check mode to check the servodrive software version.

1. Press the MODE key to select the utility function mode.
2. Press the INC or DEC key to select the utility function number Fn007.

3. Press the ENTER key to display the DSP software version (the highest bit displays d or E or F or 0).

4. Press the MODE key to display the FGPA/CPLD software version (the highest bit displays P).

5. Press the MODE key to return to DSP software version display.
6. Press the ENTER key to return to the utility function mode display Fn007.

11 Astraada

Asd

Chapter 7 Commissioning

7.1 Operation instruction of inertia identification

Inertia identification is divided into online mode and offline mode.

1. Online inertia identification:

It is necessary to set following parameters when online inertia identification is selected:

1).P1.00; 2.P1.08. If P1.00 and P1.08 is larger than 0, the online mode is valid. If the inertia identification requirements are met, (1. the speed is larger than 150r/min;

2). the ACC time is longer than 20 ms;

3).the continuous acceleration range is more than 150r/min;

4). in 0.3 seconds, the speed can accelerate from 0r/min to 3000 r/min), the identification result will be updated to P1.01 and written into EEPROM in every 30 minutes automatically.

2. Offline inertia identification:

It is necessary to set following parameters when offline inertia identification is selected: 1.P1.05; 2.P1.06. 3. P1.07. The offline mode is available by the auxiliary function EF-JId of the panel operation. Refer to chapter 5.2.5.5 for the EF-JId procedure. The offline mode is not affected by P1.00 and P1.08.

Before executing the auxiliary function of EF-JId, set P1.05 according to the operation mode of the motor, set P1.06 according to the rotating cycle and set P1.07 according to the mechanical rigidity. The stronger the mechanical rigidity, the smaller the ACC/DEC time constant. Set P1.05 to 1 or 2. The smaller the value of P1.06 and P1.07 is, the more correct the identification result.

When executing the auxiliary function of EF-JId, please ensure P1.05 and P1.06 meet the needs; otherwise, there may be damage to the machine. Press Mode key can stop the execution.

If the execution EF-JId is finished normally, the identification result will be saved into P1.01 automatically. If there is fault, P1.01 will keep the result before identification. If it reports Er25-7, increase P1.06 or reduce P1.07.

The precision of the identification result will be affected if following occur: 1. Mechanical rigidity is low; 2. The load inertia change too fast; 3.There is a space; 4. The external disturbance changes too fast.

7.2 General method for parameters adjusting

There are two kinds of parameters adjustment:

1. Automatic adjustment setting of rigidity choice. The inertia ratio of the load can be counted manually. There are 32 rigidity sets for the gain setting of the loop.

- The adjustment needs to be carried out to the actual situation:

Mechanical structure	Rigidity set
Big handling, transmission equipment	0~13
Belt drive mechanism	5~16
Ball screw + Belt drive	5~16
Manipulator	15~22
Direct ball screw or rigid bodies	18~25

The bigger the set value, the faster the system response, however, noise and vibration may come along. Please make corresponding setting according to the action of mechanical device.

2. Manual adjustment. If the servo system has vibration or the control performance is not good, adjusting the parameters of speed loop and position loop to improve system performance or remove vibration.

Gain of the speed loop: mainly used to determine the response speed of the speed loop. Under the precondition the mechanical system does not vibrate, the larger the set value, the faster the response speed.

Speed loop integration time constant: the speed loop has an integrator which can reflect minor input. This integrator can delay the operation of the servo system. Therefore, when time constant increases, the response becomes slower, and the required positioning setting time is longer. When the load inertia is large or the mechanical system is likely to vibrate, the loop integration time parameter must be large enough to avoid the vibration of the mechanical system.

Torque command filter: in some cases the mechanical system may resonate, generating vibration noise in sharp tone. At this time filtering via notch filter must be performed to eliminate resonance.

Gain of the position loop: the response of the servo system is determined by the gain of the position loop. When the gain of the position loop is set to a high value, the response speed will increase and the time required for positioning will be shortened. If you want to set the gain of the position loop to a high value, the rigidity and natural frequency of the mechanical system must be very high.

Generally, the gain of the speed loop should be larger than the gain of the position loop whenever possible. When the position gain is much larger than the speed gain, the system may overshoot under the action of the step signal, which will seriously damage the system performance. Parameters of the system always mutually limit each other. If the gain of the position loop increases only, the command outputted by the position loop may become unstable. This may cause the reaction of the servo system to become unstable. In general cases, we can adjust the system by referring to the follow procedures:

1) First set the gain of the position loop to a low value, then, under the precondition that abnormal sound and vibration are not generated, gradually increase the gain of the speed loop to the maximum.

2) Gradually decrease the gain of the speed loop while increasing the gain of the position loop. Under the precondition that the whole response is free from overshoot and vibration, set the gain of the position loop to the maximum.

3) Speed loop integral time constant depends on the length of the positioning time. Please decrease this value as small as possible under the precondition that the mechanical system does not vibrate.

4) After that, finely adjust the gain of the position loop, speed loop and the integration time constant to find their optimal values.

Hereunder we illustrate several typical cases (in each case, only one parameter is changed relative to a case when the parameters are appropriate):

- Parameters are appropriate

In this case the parameters are set relatively appropriate. The motor speed can closely follow the position command, the speed has basically no overshoot, and the positioning time is relatively short.

- Speed loop integral time constant is relatively small

The speed loop of the servo drive must have high reaction speed. When the speed fluctuates, it indicates that the stability of the speed loop is damaged due to the shorting integration time of the speed loop. This causes the servo motor to run unstably at fluctuating speed.

- Speed loop integration time constant is relatively large

In this case, there is no apparent difference with the case when the parameters are appropriate. The influence of the speed loop integration on the speed follow-up position command is not very high, but too large speed loop integration time will delay the reaction time of the speed loop.

- Gain of the speed loop is relatively high

In this case, the motor speed will fluctuate. The influence is the same as the case when the speed loop integration time is too short. Both of them must keep coordinated. While increasing the gain of the speed loop, the speed loop integration time must also be increased. Otherwise the servo system will oscillate.

- Gain of the speed loop is too low

Decreasing the gain of the speed loop will cause fluctuation of the motor speed to fluctuate. By comparing with the case when the speed gain is too high we can know that the fluctuation frequency of the motor speed is lower in this case which fully indicates that increasing the gain of the speed loop can heighten the operating frequency of the system, improve the quick response performance of the system, and effectively overcome the influence of the interference.

- Gain of the position loop is excessively low

In the servo system, the operating frequency of the position loop is much lower than the speed loop. When the gain of the position loop is too low, the system is difficult to eliminate the position deviation formed during speed response. This can cause prolongation of the time interval of the motor speed follow-up position command.

- Gain of the position loop is excessively high

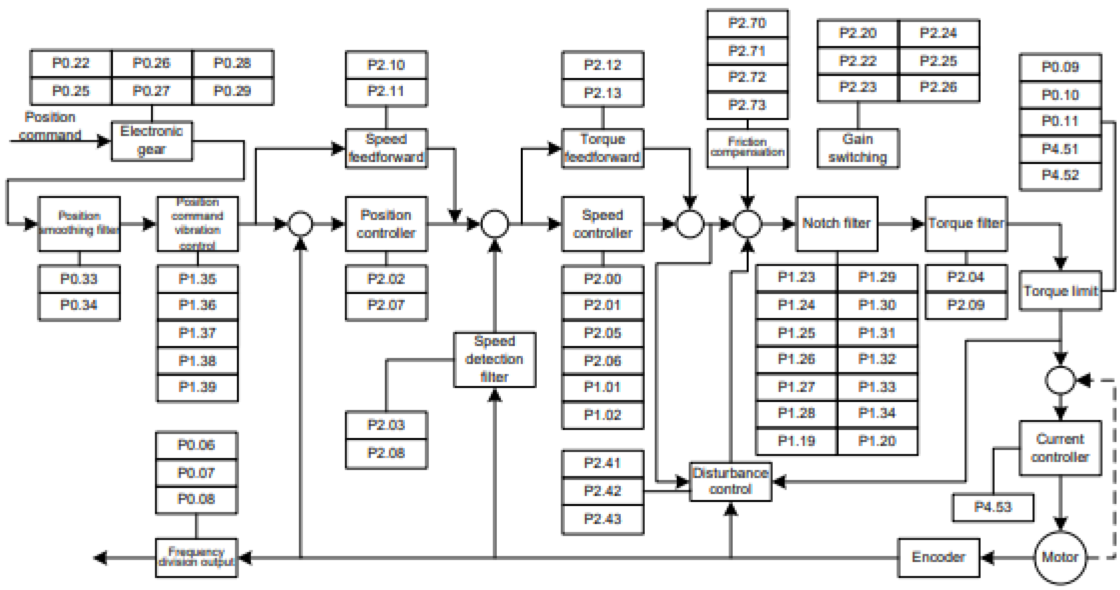
In the position servo system, the gain of the position loop also affects the stability. At this time, as the gain of the position loop is excessively high, it makes the motor speed to fluctuate. Additionally, comparing with the case when the gain of the position loop is too low we can know that the pure time delay of the response to the position command of the motor speed is decreased.

- Gain of the position loop is too low

When we adjust the gain of the position loop to a low value, the motor speed follow-up position command represents obvious lag and the positioning time is prolonged largely. The high accuracy and high response performance of the positioning system are seriously affected.

7.2.1 Adjustment of the gain of the position loop

The position control block diagram of the SRV-63 series servo drive is shown in the figure below. The gain parameters that can be adjusted in the position mode are marked out on the block diagram.



The general procedures for parameter adjustment in the position mode are:

1) Initial setting of the parameters

The defaults of the parameters can be recovered by the default parameter recovering operation (see chapter 5.2.5.3 for details).

2) Adjustment of the gain of the position loop

When the servo motor is running with default parameters, if the system oscillation occurs with buzz, the position gain (P2.02, P2.07) should be adjusted smaller. If the system rigidity is relatively small, the position gain should be adjusted larger.

3) Adjustment of the position smoothing filter

During position control, if the position pulse commands input frequency varies largely, it may be caused by a larger impulse. At this time the position smoothing filters time constant(P0.33) or position command FIR filter (P0.34) should be adjusted to moderate the impulse.

4) Adjustment of the electronic gear

If the pulse transmission frequency of the pulse generator is restricted, or the transmission frequency does not meet the mechanical requirements, we can change the pulse input frequency by adjusting the value of the electronic gear parameters (P0.25, P0.26, P0.27, P0.28 and P0.29) to meet the requirements for position control.

5) Adjustment of position feed-forward

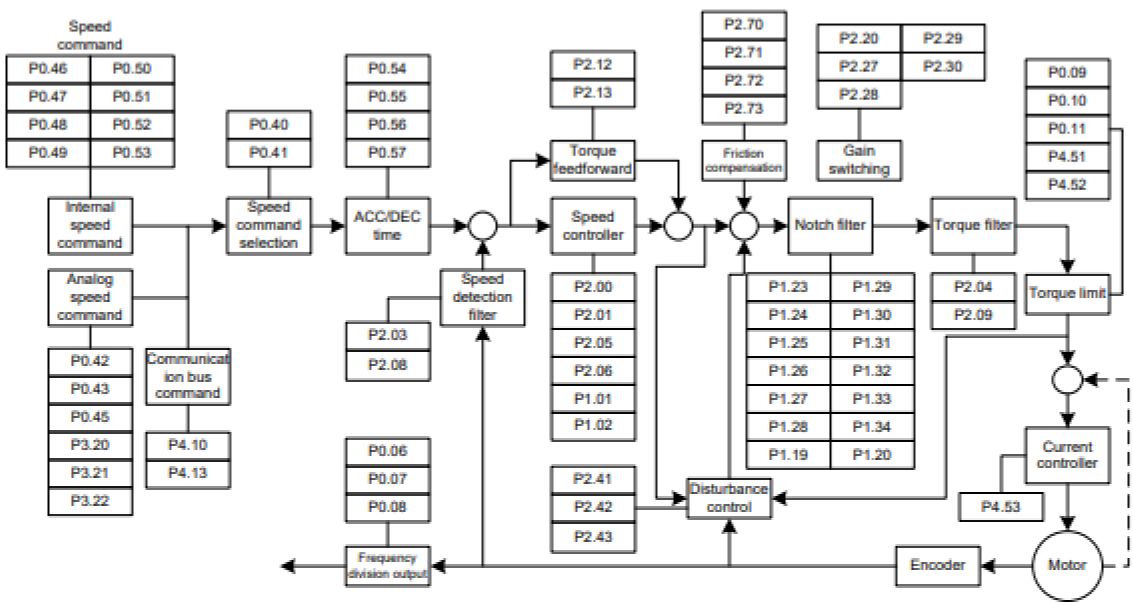
In the case the retention pulse is large or fault-free follow-up is required, we can improve the position follow-up performance by adjusting the speed feed-forward gain parameter (P2.10) and speed feed-forward gain filter parameter (P2.11). However, it should be noted that if the speed feed-forward gain is too large, it may cause system oscillation.

6) Frequency division of the feedback pulse output

If the feedback pulse needs to be outputted, the frequency division coefficient of pulse output (P0.06, P0.07) can be used to change the frequency of the output pulse.

7.2.2 Adjustment of the gain of the speed loop

The speed control block diagram of the SRV-63 series servo drive is shown in the figure below. The gain parameters that can be adjusted in the speed mode are marked on the block diagram.



The general procedures for parameter adjustment in the speed mode are:

1) Initial setting of the parameters

The defaults of the parameters can be recovered by the default parameter recovering operation (see chapter 5.2.5.3 for details).

2) Adjustment of the gain of the speed loop

When the servo motor is running with default parameters, if the system oscillation occurs with buzz, the speed gain (P2.00, P2.05) should be adjusted smaller. If the system rigidity is relatively small or the speed fluctuates largely, the speed gain should be adjusted larger.

3) Adjustment of the speed integration time constant

When the gain of the speed loop is increased, the speed integration time constant (P2.01, P2.06) should be increased at the same time. Similarly, when the gain of the speed loop is decreased, the speed integration time constant should be decreased at the same time.

4) Adjustment of the ACC/DEC time

If the speed varies violently during starting, it may cause large impulse or even overcurrent. At this time we adjust the ACC time (P0.54) to smoothen the speed rise. Similarly, we can adjust the DEC time (P0.55) to smoothen the speed fall during stopping.

5) S curve ACC/DEC adjustment

If the requirement for smooth variation of speed cannot be met by adjusting the ACC/DEC time, we can adjust the S curve ACC/DEC time (P0.56, P0.57) to make it change more smoothly.

6) Adjustment of the speed smoothing filter

In the case where the analog speed command is inputted, we can adjust the analog speed command filter (P3.21) to make the speed change smoothly.

7) Adjustment of torque feed-forward

If the speed follow-up performance is still poor after above parameter adjustment, we can adjust the torque feed-forward gain (P2.12) and torque forward feedback filter time (P2.13) to improve the speed follow-up performance. It should be noted however that too large torque feed-forward gain may affect the stability of the system.

8) Adjustment of speed filter

The performance of the speed loop can be improved by adjusting P2.04/P2.09 and P2.03/P2.08.

9) Adjustment of notch filtering

Refer to chapter 7.3.

10) Frequency division of the feedback pulse output

If the feedback pulse of the encoder needs to be outputted, the frequency division output coefficient (P0.06, P0.07) can be used to change the frequency of the output pulse.

11) Interference control adjustment

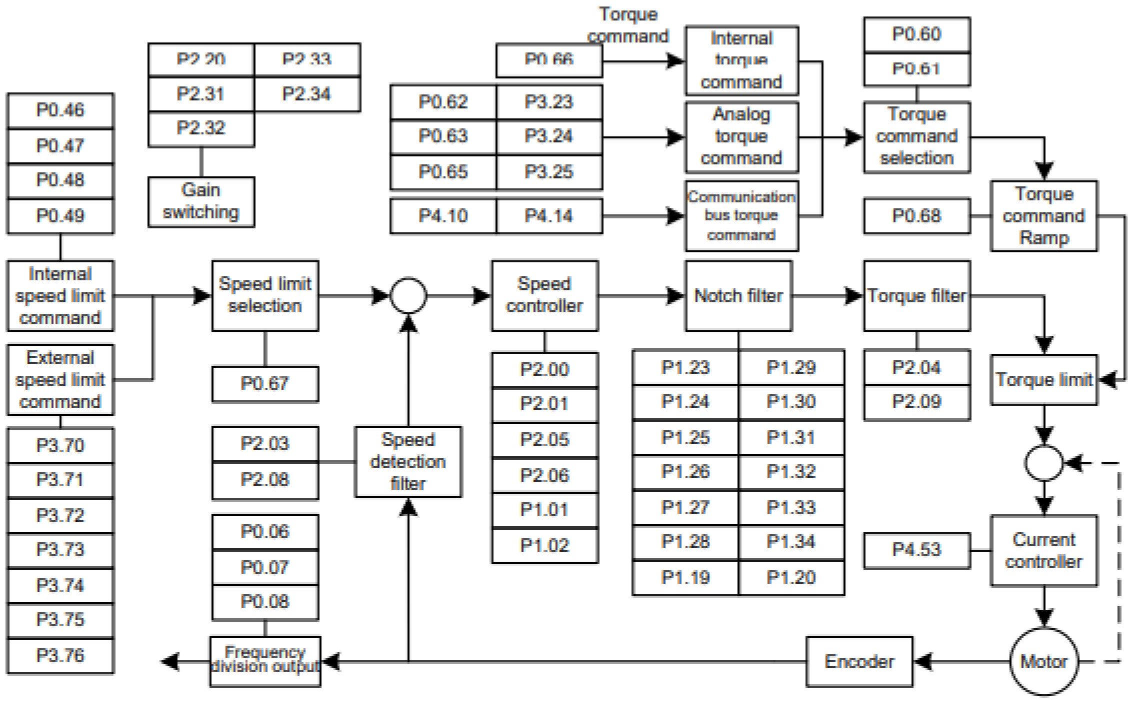
If the gain is small, the load changes or there is sudden external interference torque, users can adjust P2.42 and P2.43 of the disturbance observer to reduce the interference and improve the speed loop performance.

12) Friction compensation adjustment

If the following performance of the motor is bad during the direction changing of forward and reverse rotation, it can adjust P2.71 and P2.72 to improve the speed loop performance during commutation.

7.2.3 Adjustment of the gain of the torque loop

The torque control block diagram of the SRV-63 series servo drive is shown in the figure below. The gain parameters that can be adjusted in the torque mode are marked out on the block diagram.



The general procedures for parameter adjustment in the torque mode are:

1) Initial setting of the parameters

The defaults of the parameters can be recovered by the default parameter recovering operation (see chapter 5.2.5.3 for details).

2) Adjustment of the torque smoothing filter

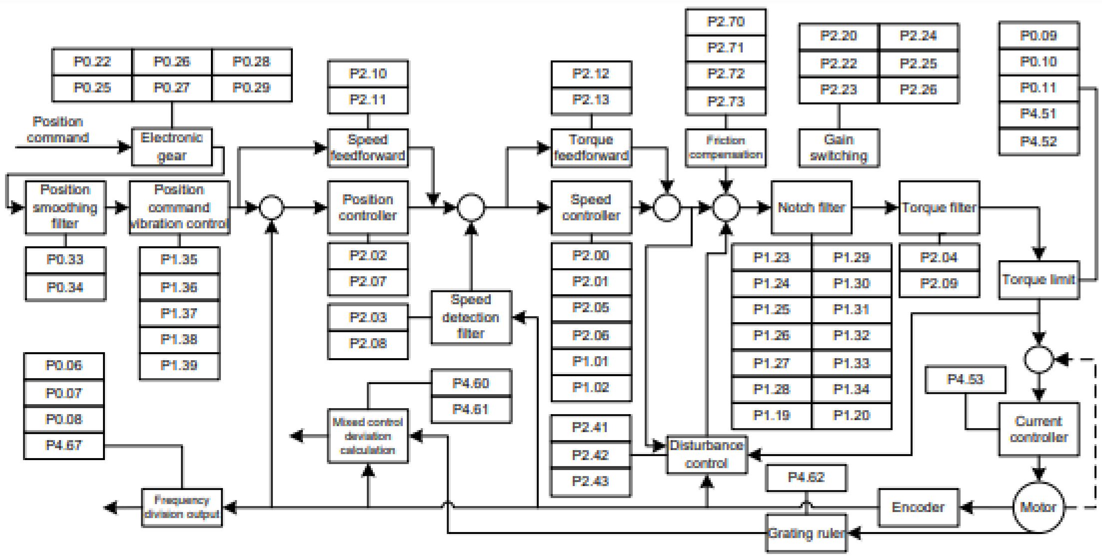
In the case the analog torque command is inputted, we can adjust the torque smoothing filter time constant to make the torque change smoothly.

3) Frequency division of the feedback pulse output

If the feedback pulse of the encoder needs to be outputted, the frequency division coefficient of pulse output can be used to change the frequency of the output pulse.

7.2.4 Fully-closed loop gain adjustment

The gain parameters which can be adjusted are listed as the figure below:



Refer to the adjustment steps of position mode in chapter 7.2.1.

7.3 Suppression of mechanical resonance

The mechanical system has a certain resonant frequency. If the response speed of the servo is improved, the system may resonate (oscillation and abnormal noise) near the mechanical resonant frequency. The resonance of the mechanical system can be effectively suppressed by setting the parameters of the notch filters.

The notch filters achieve the goal of suppressing mechanical resonance by decreasing the gain of certain frequency. We can set the frequency to be suppressed as well as the suppression extent with relevant parameters.

This servo drive is equipped with four notch filters which can be set by 1st notch filter parameter (P1.23, P1.24, P1.25), 2nd notch filter parameter (P1.26, P1.27, P1.28), 3rd notch filter parameter (P1.29, P1.30, P1.31) and 4th notch filter parameter (P1.32, P1.33, P1.34). 1st and 2nd notch filter parameters need to be set manually; 3rd and 4th notch filter parameters can be set by online self-adaption. The position of notch filter in speed loop is shown in the figure in chapter 7.2.2. The setup of notch filter is shown in the diagram below.

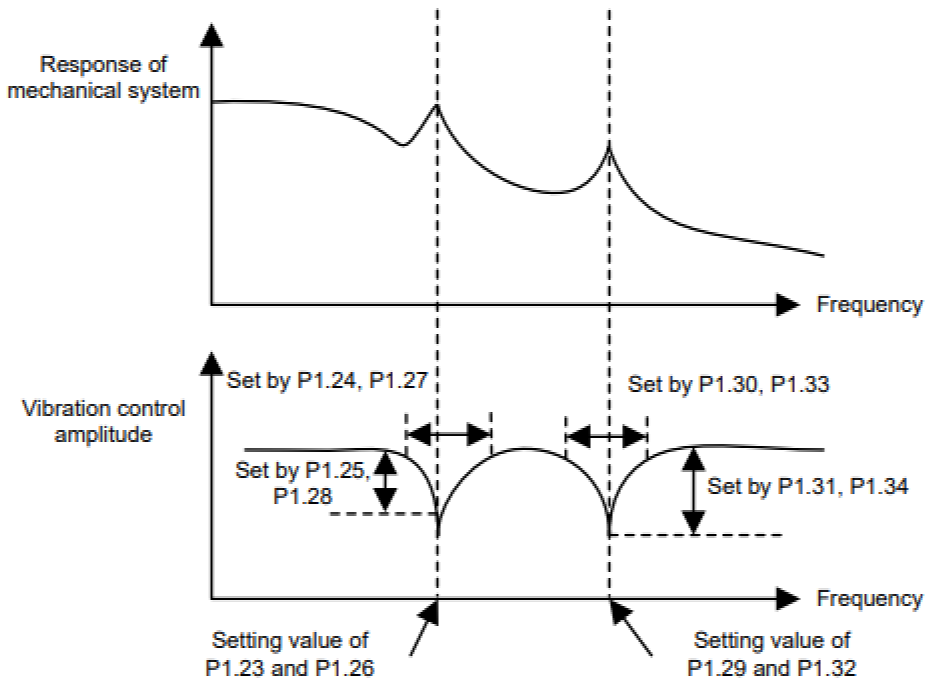
Note:

The notch filter is the lag factor for the servo system, so, if the center frequency of control width is large, the vibration may be strengthened. It is recommended to increase the width unit it meets the requirements.

The relationship between the Q value, width and depth is as below:

- Q value of the notch filter=Center frequency of the notch wave /Width of the notch wave;
- If the width of the notch is 0, the width of the filter is the deviation between two frequencies when the power of the center frequency drops to -3dB;
- The depth of the filter means the ratio of input and output, and its power spectrum strength

attenuates by 20log (P1.25%, P1.28%, P1.31%, P1.34%) dB.



7.4 Gain switching function

Gain switching operation is performed through internal data or external signal:

1) Can switch to lower gain to suppress vibration in the state when the motor is stopped;
2) Can switch to higher gain to shorten the positioning time in the state the motor is stop;
3) Can switch to high gain to obtain better command follow-up performance in the state when the motor is running.
4) Can switch between different gain settings through external signal according to the conditions of load, equipment and so on.

●Position control and fully-closed loop control (●: valid, —: invalid)

Condition setting of gain switching			Parameters setting of position control and fully-closed loop control mode		
P2.22	Switch to 2nd gain	Figure	Delay time*1 P2.23	Level P2.24	Lag*2 P2.25
0	Fixed on 1st gain		-	-	-
1	Fixed on 2nd gain		-	-	-
2	Gain switch input		-	-	-
3	Torque command	1	●	●(0.1%)	●(0.1%)
4	Speed command	3	●	●(r/min)	●(r/min)
5	Position deviation	4	●	●*3(reference unit)	●*3(reference unit)

6	With position command	5	●	-	-
7	Position not finished	6	●	-	-
8	Actual speed	3	●	●(r/min)	●(r/min)
9	With position command +speed command	7	●	●(r/min)[*5]	●(r/min)[*5]

●Speed control mode

Condition setting of gain switching			Parameters setting of speed control mode		
P2.27	Switch to 2nd gain	Figure	Delay time[*1]	Level	Lag[*2]
			P2.28	P2.29	P2.30
0	Fixed on 1st gain		-	-	-
1	Fixed on 2nd gain		-	-	-
2	Gain switch input		-	-	-
3	Torque command	1	●	●(0.1%)	●(0.1%)
4	Speed command variable	2	-	●[*4](10(r/min)/s)	●[*4](10(r/min)/s)
5	Speed command	3	●	●(r/min)	●(r/min)

●Torque control mode

Condition setting of gain switching			Parameters setting of torque control mode		
P2.31	Switch to 2nd gain	Figure	Delay time[*1]	Level	Lag[*2]
			P2.32	P2.33	P2.34
0	Fixed on 1st gain		-	-	-
1	Fixed on 2nd gain		-	-	-
2	Gain switch input		-	-	-
3	Torque command	1	●	●(0.1%)	●(0.1%)

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6.6. Advanced gains

Important tasks of the servo drive include the time it takes for the motor to move from start point to the specified position (of Move & Settle), the position error and the velocity ripple. The improvement of these performances is to be achieved through tuning of gains and parameters. Tuning common gain is the simplest way for the D2 drive to improve the motion performance of motor. The higher common gain causes higher servo stiffness. However, if the servo stiffness is too high, it will bring about system vibration or electric noise depending on the mechanical status.

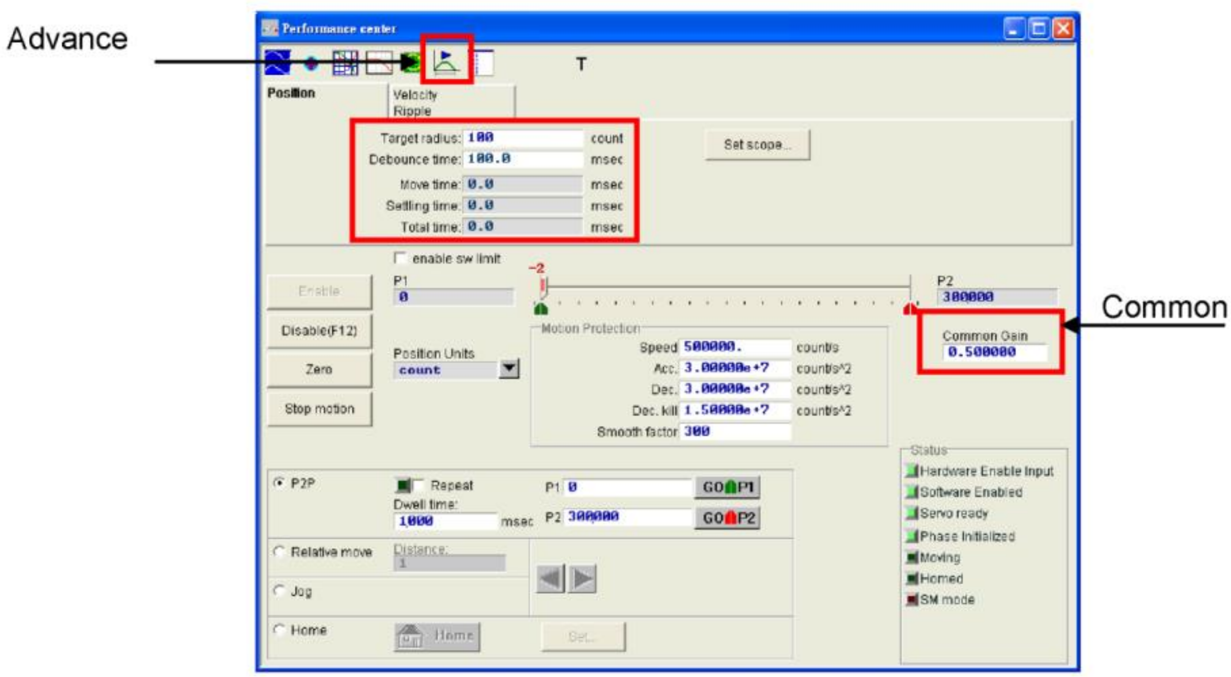


Fig. 6-23 Performance center

The system also provides advanced gain tuning functions in case that the common gain cannot fulfill required performance. These functions include the Filter, Acc feedforward, Gain Schedule, Analog input and current loop.

6.6.1. Filter

The filter is located inside of servo control loop and mainly used to eliminate the problem caused by high frequency vibration of the system or deal with the resonant frequency of the mechanical system to improve the control performance of system. The D2 drive has two filters that can be used concurrently and set as a low pass filter or a notch filter. To design a filter is often done by analyzing the system characteristic in frequency domain. User can click the button in Fig. 6-24 to open the emulated interface of Bode plot. The settings of two commonly used filters are described as follows.

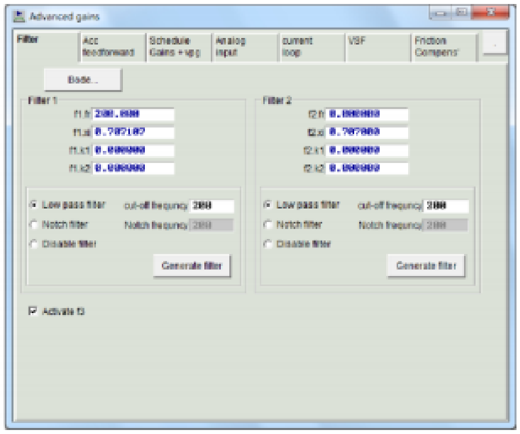


Fig. 6-24 Filter

(1) Low pass filter

A setting of a typical low pass filter is set as follows:

Fr: Cutoff frequency. The unit is Hz. 500Hz can produce an excellent result in general applications and reduction of the frequency can be considered in some cases. However, control performance will be affected if the cutoff frequency is too low.

xi: Damping ratio of the filter. The value ranges from 0 to 1.;

k1: 0.

k2: 0.

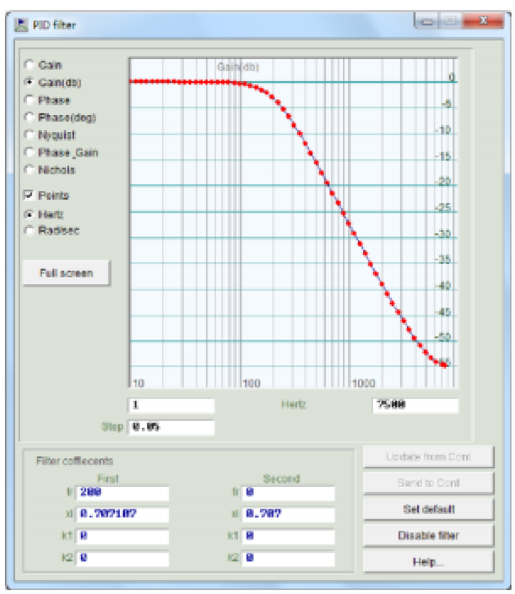


Fig. 6-25 Low pass filter

(2) Notch Filter

When there is an improper resonate frequency in the mechanical system, (e.g., 10~250Hz) and the resonance cannot be eliminated through mechanical correction or design, a notch filter can be used to solve this problem. The setting of a notch filter is usually configured with reference result of the frequency analysis.

A setting of a typical notch filter is set as follows:

Fr: Cutoff frequency. The unit is Hz.
xi: Damping ratio of the filter. The value ranges from 0 to 1. The band of the filter becomes narrower when the ratio is closer to 0. It becomes wider when the ratio is closer to 1.
k1: 0.
k2: 1.

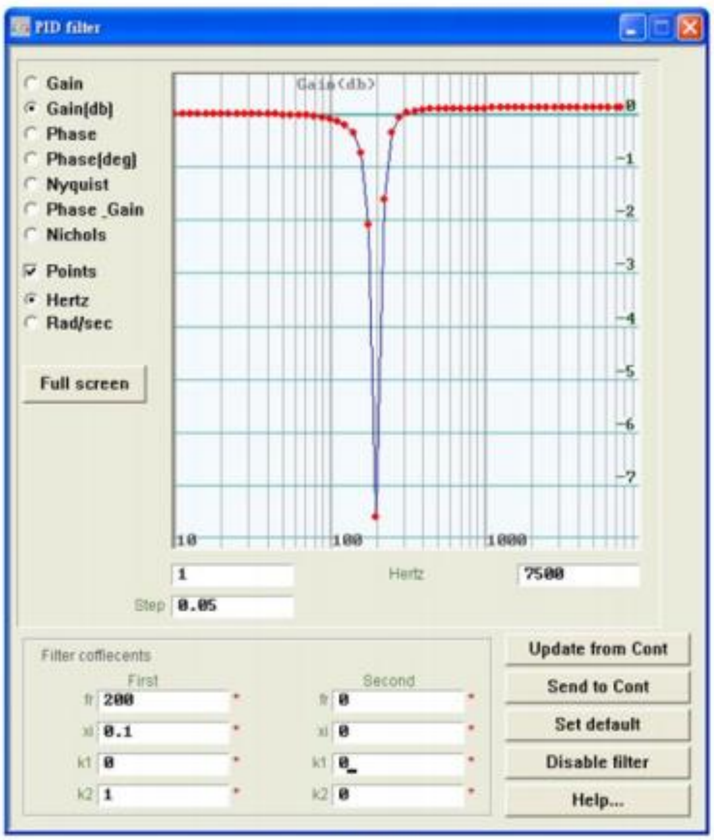
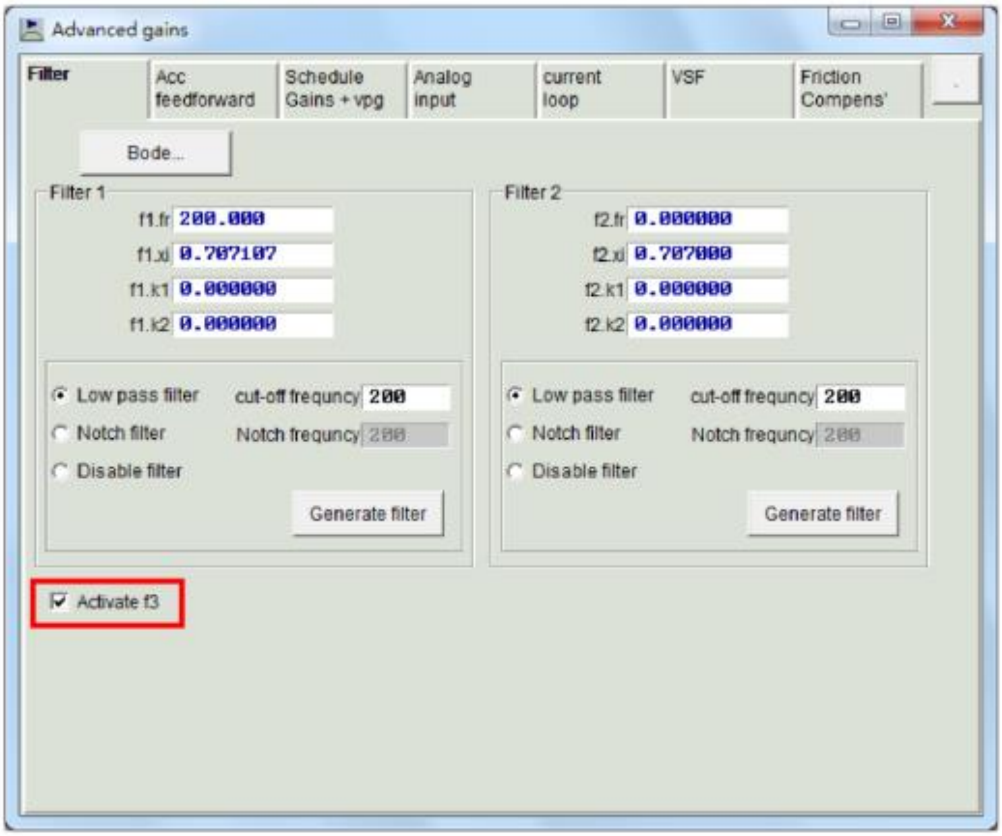


Fig. 6-26 Notch filter

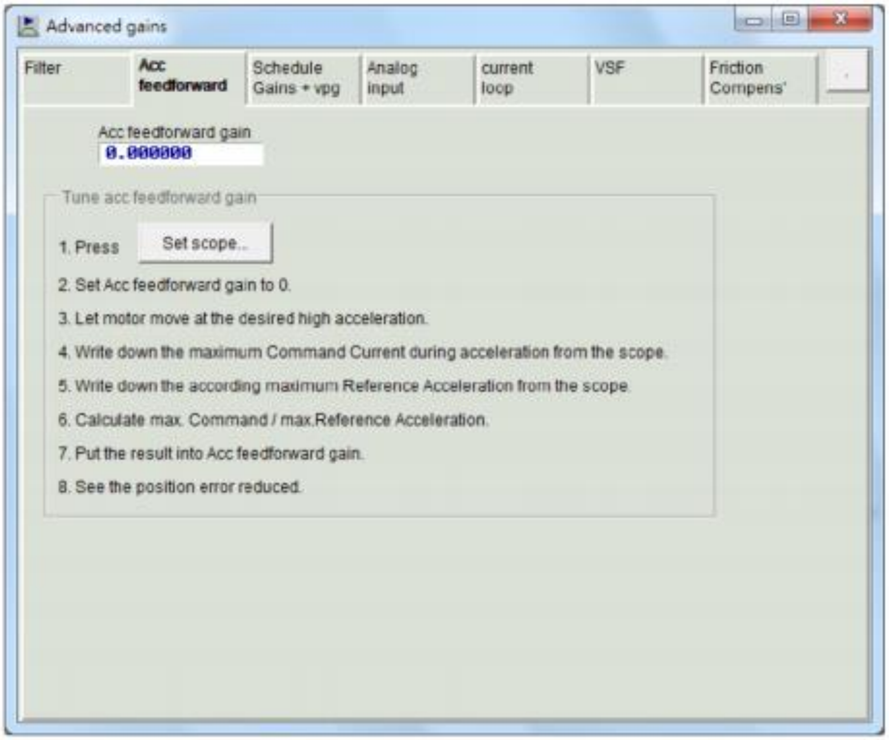
(3) Automatic resonance suppression filter (f3)

The completion of the auto gain tuning will also start the f3 filter. However, when user drives the motor and finds that system vibration is not effectively suppressed by f3 filter, user can uncheck the Activate f3 option (the red frame in Fig. 6-27) in the Filter tab of the Advanced Gains, and manually set up Filter 1 and Filter 2 to suppress resonance effectively.



6.6.2. Acceleration feedforward

The position error is usually more significant during acceleration and deceleration, especially when a higher moving mass or moment of inertia is applied. Setting the acc feedforward parameter can effectively reduce the position error during acceleration and deceleration.



6.6.3. Schedule gains and velocity loop gain

(1) Schedule gains

A complete motion control can be divided to three stages:

Move: From the start to the end of trajectory planning.

Settling: From the end of trajectory planning to the in-position stage.

In-position: Completion of the position settling.

The purpose of the schedule gain is to adjust the servo stiffness to be output at each motion stage (Move, Settling, In-position) based on the common gain. Adjustment of the gain at each stage is conducted proportionally. The original common gain is used when the setting value is 1 and the gains are reduced when the setting value is less than 1.

The corresponding parameters at each stage:

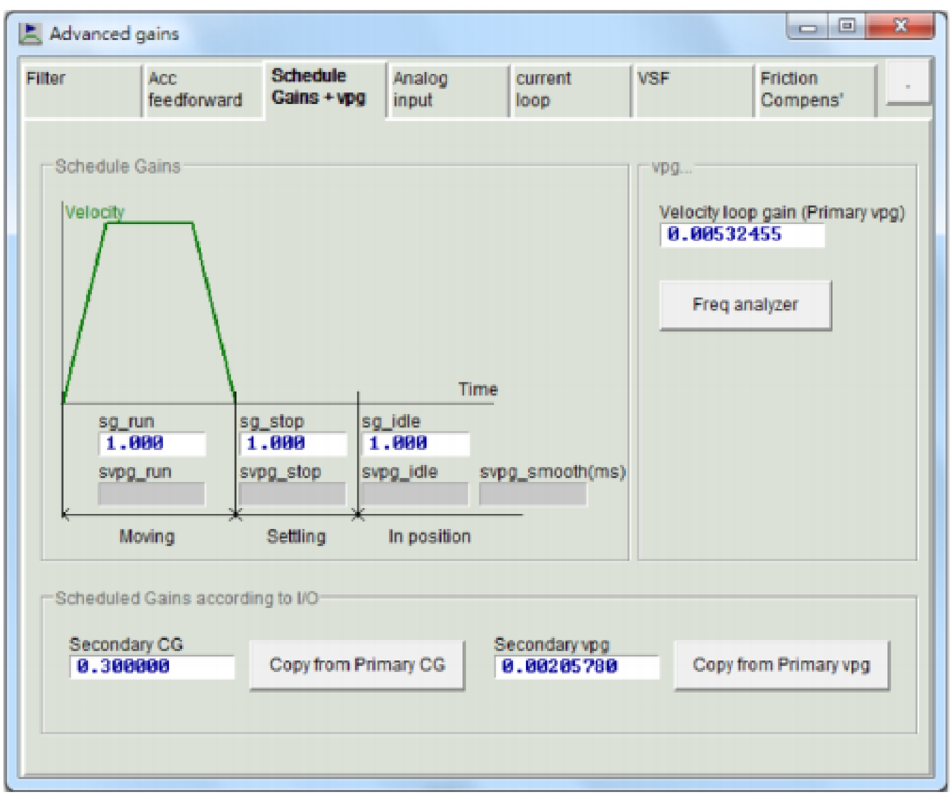
Move: sg_run.

Settling: sg_stop.

In-position: sg_idle.

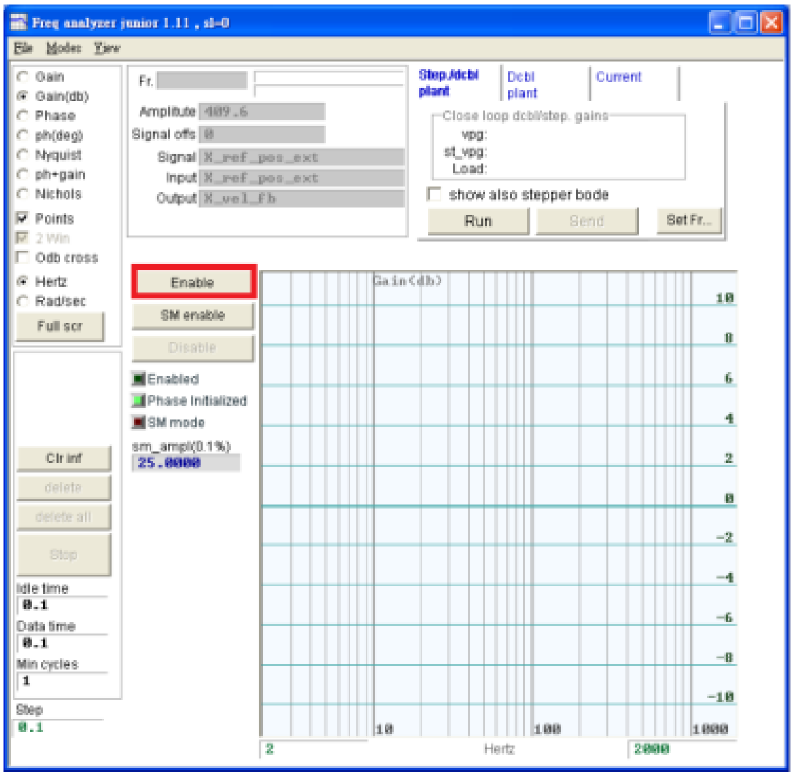
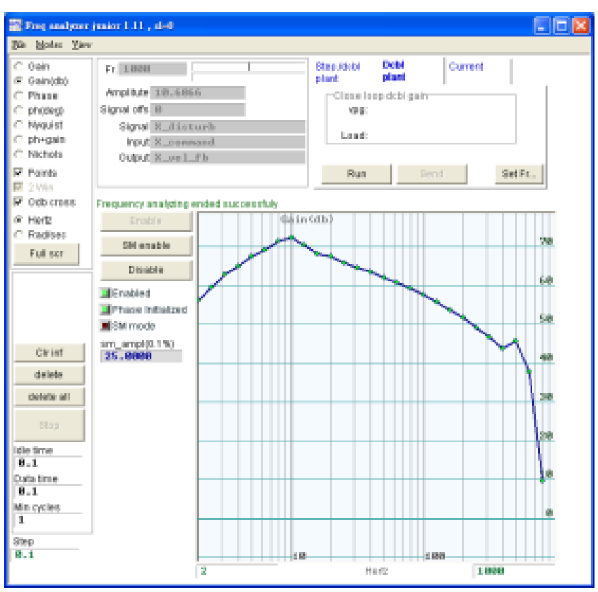
If common gain=0.5 and sg_run=1.2, the common gain that is practically used at the Move stage is changed to 0.5*1.2=0.6..

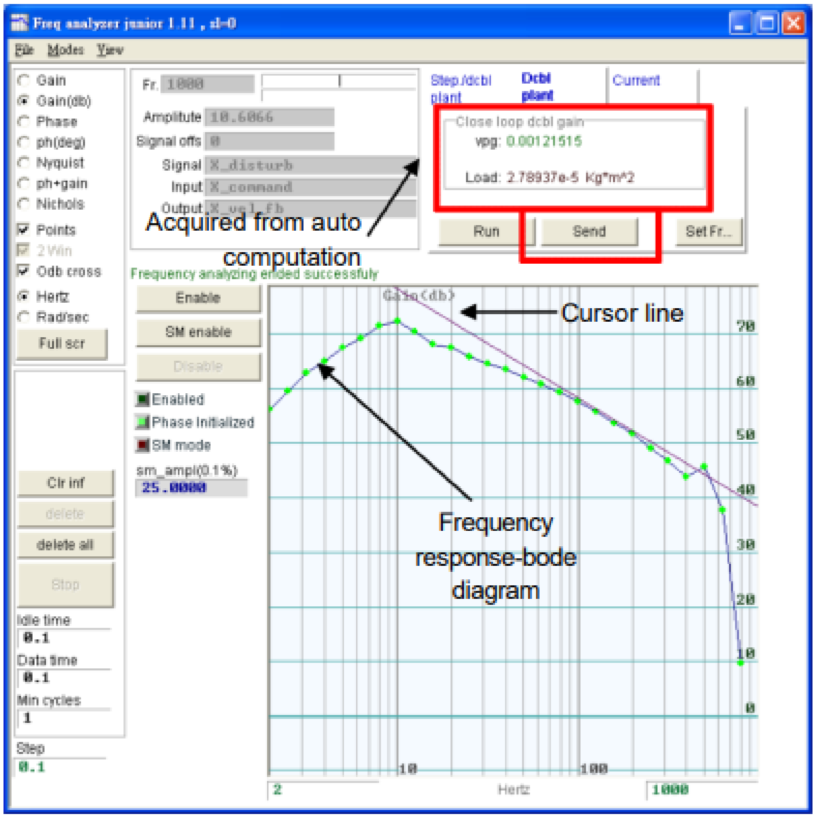
The same is applicable at the Settling and In-position stages. The constant common gain is changed appropriately by using the schedule gain to meet the requirements at different stages.



(2) Velocity loop gain (vpg)

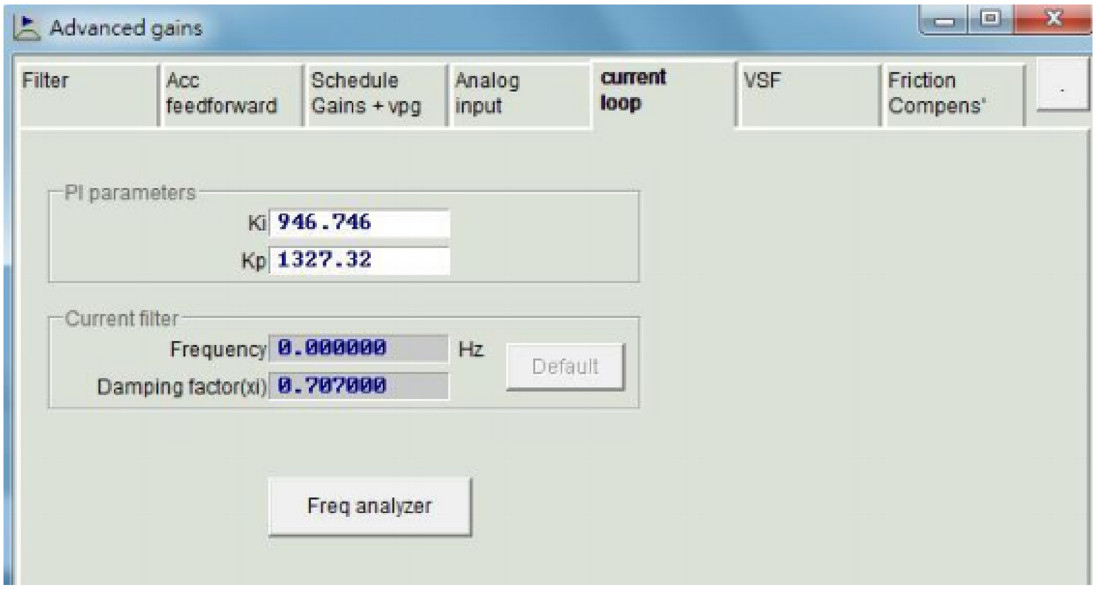
The velocity loop gain (vpg) is an internal control parameter of the D2 drive. The default value is computed by using the parameters user defined in the Configuration Center. Modification of vpg is not needed in general condition, but User can use the Freq analyzer to adjust its value. The steps are as below.

Step	Graphical (HM) description	Operation
1		Click the Freq analyzer button on the page as shown in Fig. 6-30. Then following screen appears.
2		Click the Enable button.
3		Click the Run button to activate the frequency analyzer. Motor vibrates from LF to HF, you may head the HF sound at the end. Then a frequency response diagram appears on the screen.

<table>
<tr><td>4</td><td rowspan="2">
</td><td>Left click on the frequency response diagram and a line of -20dB appears on the screen. Press and hold left key to drag the line to the position close to the bode diagram as shown in the figure below. The Gain is re-computed during the movement of line, and vpg value is displayed on the screen.
The Gain is increased when the cursor line is dragged downward, and decreased when the cursor line is dragged upward.</td></tr>
<tr><td>5</td><td>Click the Send button to save vpg value to the RAM of the drive.</td></tr>
</table>

6.6.5. Current loop

The gain values (Ki and Kp) of current loop are basically calculated by using the parameters of motor which is selected in the Configuration center and No adjustment is needed normally. But they can be adjusted by using this function if the parameters of motor were not set correctly. Noise might be generated if the gain of current loop is set too high.

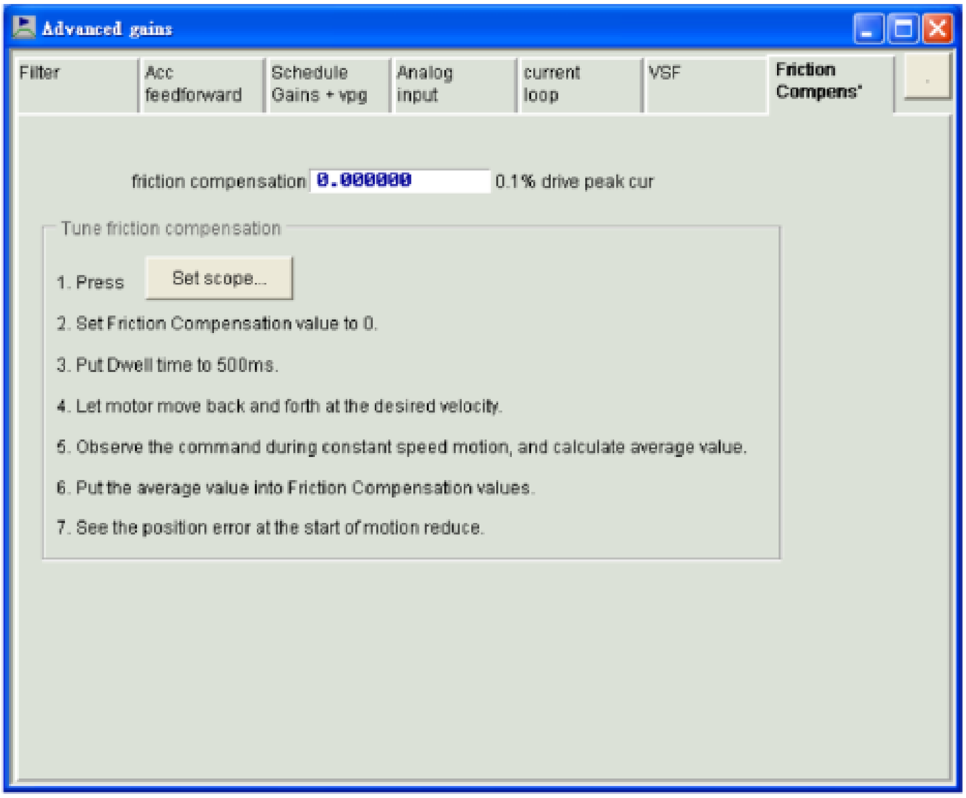


6.6.6. Vibration suppression function (VSF)

The VSF is used to suppress the vibration generated by the motor in motion. The vibration is significant when a cantilever beam is used as the loading mechanism. User can use a scope to measure the vibration frequency at the location where vibration is obvious and enter the measured value in the Frequency column. The "enable VSF" must be checked to enable the VSF. User then needs to move the motor for verification of the effectiveness. When the motor is moving, user can use the VSF factor value (1.0 by default) to adjust the effect of the suppression. The allowable range is 0.7~1.5.

6.6.7. Friction compensation

The position error is usually more significant in the period of acceleration and constant speed motion, especially for the use in a higher moving mass or moment of inertia. Setting the friction compensation parameter can effectively reduce the position error in the acceleration period. Fig. 6-34 shows the setting page of the friction compensation.



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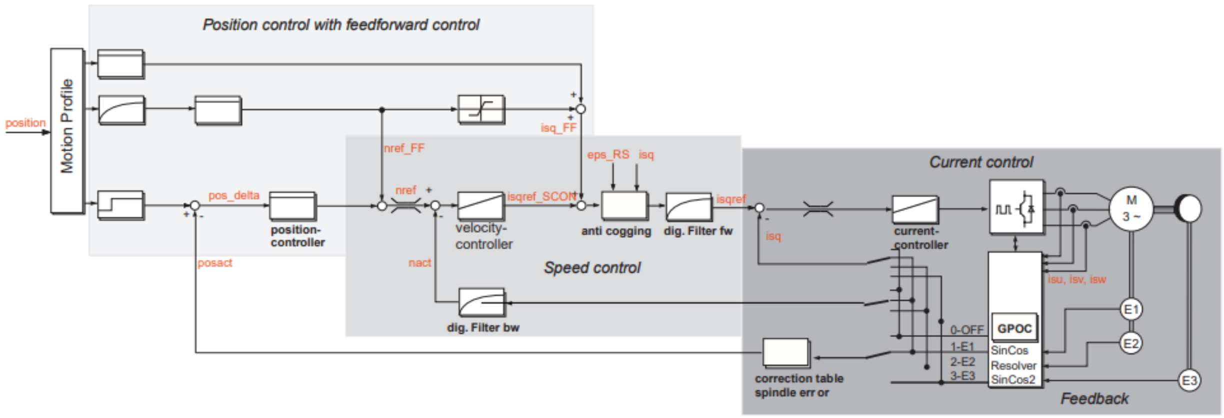
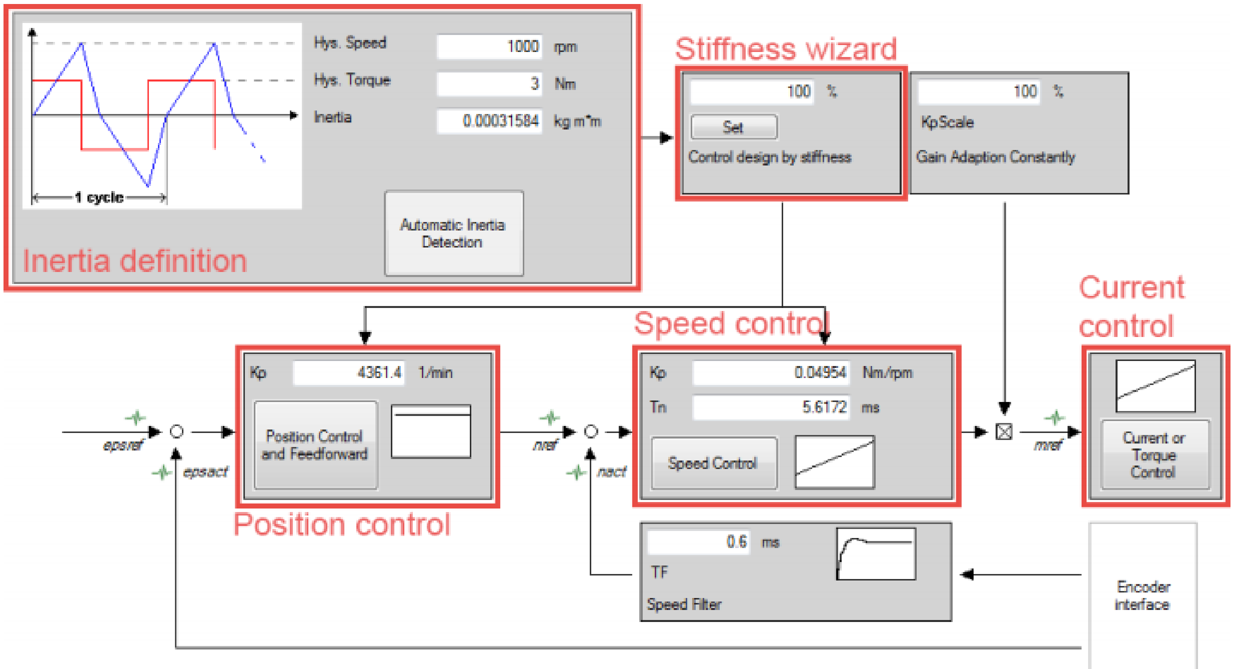


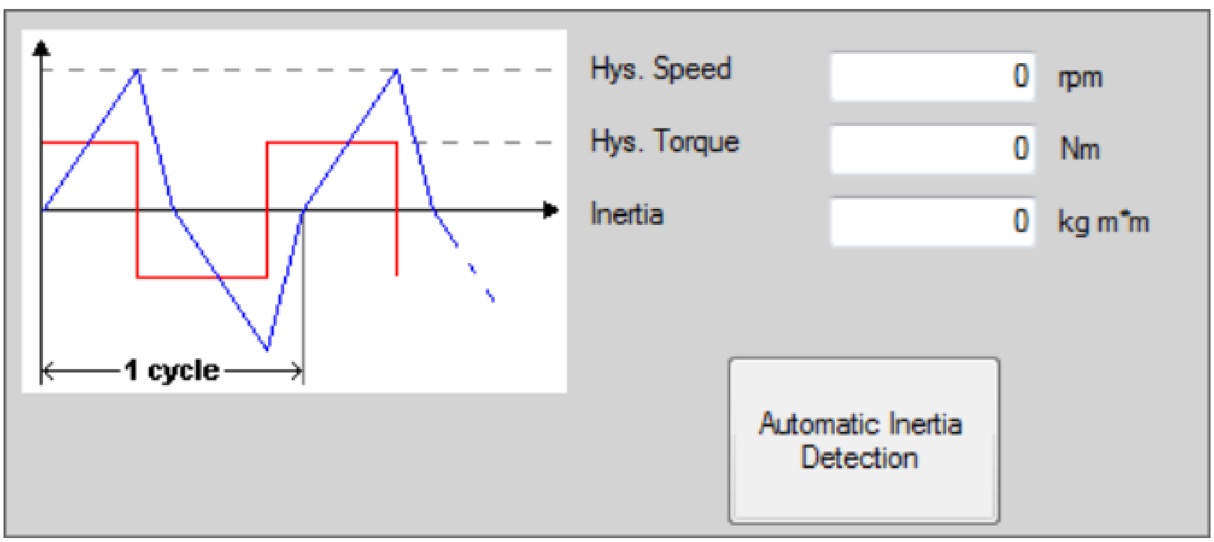
Figure 6.1: Control structure

The scanning times are dependent on the switching frequency:

- Current controller = 62.5 µs
- Speed controller = 125 µs
- Position controller = 125 µs



8.2.2 Automatic mass inertia definition



8.2.3 Stiffness wizard

Figure 6.5: Stiffness wizard dialog box

Click the "Activate" button for the wizard to automatically calculate the speed/position controller. This is done dependent on

- mass inertia (see chapter "Automatic mass inertia definition" on page 82)
- filtering of the actual speed value
- the configured current control.

A setting of **P 3059[1] - Stiffness** less than 100 % corresponds to a "soft" controller setting (e.g. for a toothed belt drive). A setting greater than 100 % corresponds to a "hard" controller setting (little slack and low elasticity of the mechanism).

P No.	Index	Name	Unit	Description
3059 / 5107 / 7155	1	Stiffness	%	Stiffness of distance <=> performance of speed control

8.2.4 Speed filter

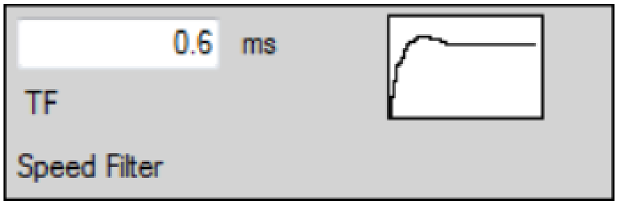


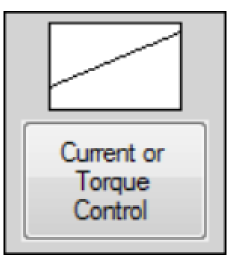
Figure 6.6: Speed filter dialog box

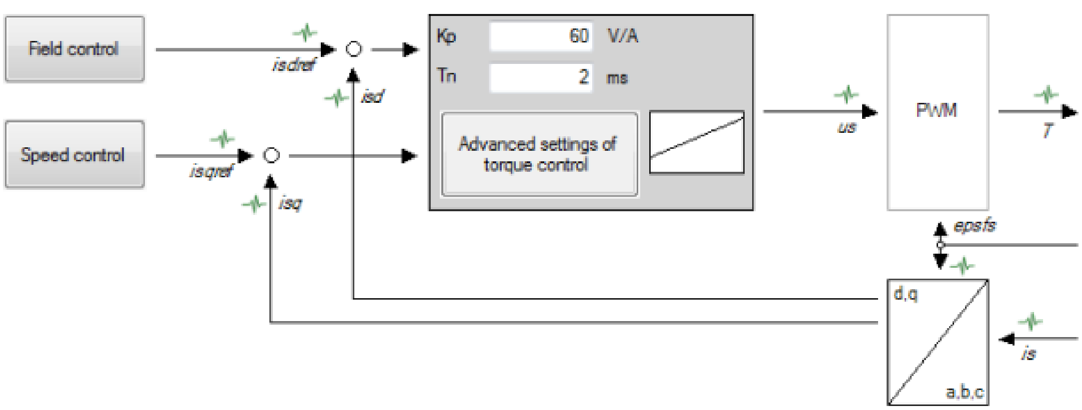
The time constant (**P 2949[0] - CON_SCALC_Tf**) filters the encoder signal of the actual speed value. The following settings are recommended:

- Resolver: 1 ms
- SinCos: 0.3–0.6 ms

P No.	Index	Name	Unit	Description
2949 / 4997 / 7045	0	CON_SCALC_Tf	ms	Filter time constant actual speed value

8.3 Current Controller

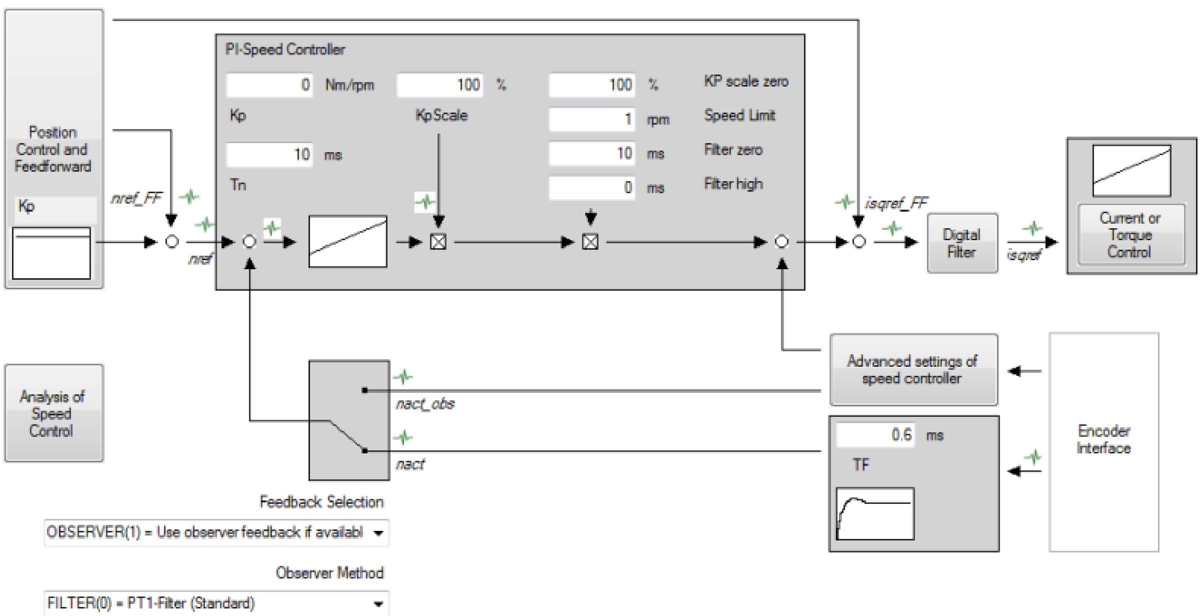




8.4 Speed controller

The motor model must be fine-tuned to the motor. The task of the speed controller is to keep the drive at a preset speed. Proportional gain must be adjusted to suit the moment of inertia of the system. The task of the integral component is to compensate the unknown load torque. A mechanical tendency of the system to oscillate limits the possible gain of the speed controller. Also, a tendency to oscillate can also be attenuated by means of the digital filter (chapter "Digital filter" on page 91) or speed determination.

In the default motor data set, the speed controller is pre-set for a moderately rigid mechanism and twice the moment of inertia of the motor.

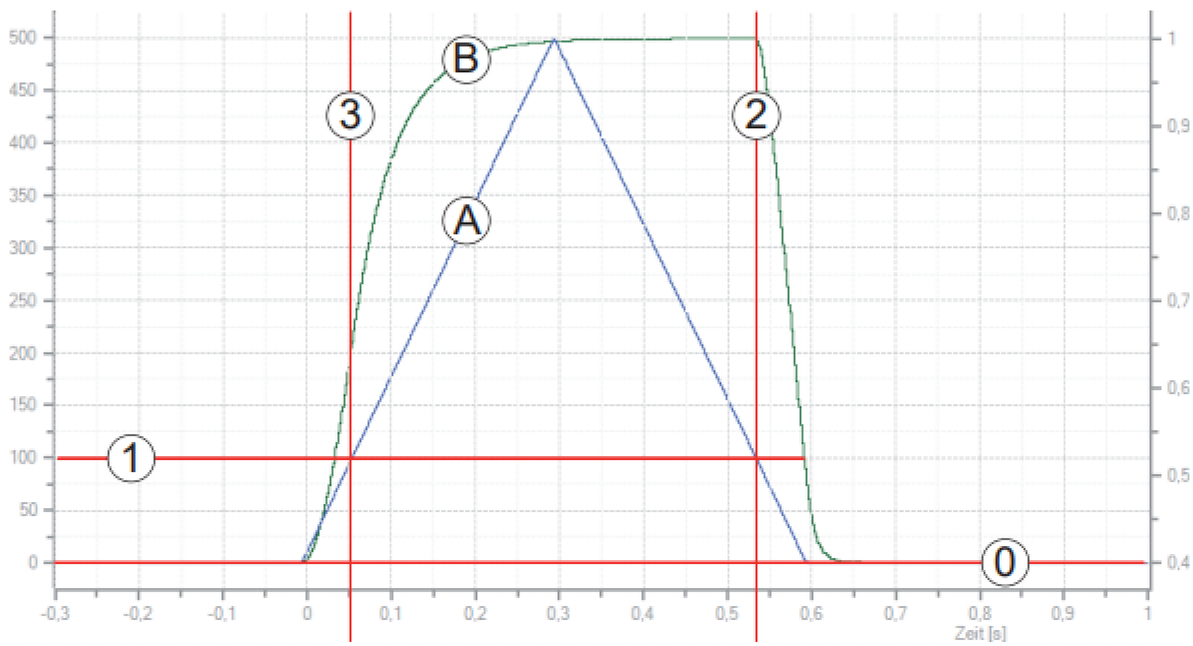


8.4.1 PI speed controller

This dialog box provides advanced configuration options for the speed controller. Gain is set via **P 2951[0] - Kp**, integral-action time via **P 2951[1] - Tn**. **P 2951[2] - Scale** is redundant to **P 2951[0] - Kp** and can also be used to modify the system.

8.4.2 Reduction at low speeds

When a speed controller is set dynamically, undesirable oscillation of the speed controller occurs at low speeds or at zero speed. An appropriate setting of parameter **P 2983 CON_SCON_KpScale** can reduce control gain at low speeds and the tendency to oscillate. In optimised positioning applications, it is then necessary to reduce position controller gain too (see chapter "Position Controller/Feed Forward Control" on page 99).



P No.	Index	Name	Unit	Description	Value in diagram	Name in diagram
2983 / 5031 / 7079	0	KpScaleScon	%	Scaling of speed control gain	40	⓪
2983 / 5031 / 7079	1	SpeedLimit	rpm	Speed threshold for scaling	100	①
2983 / 5031 / 7079	2	FilterZero	ms	Filter time for change from high to low speed	10	②
2983 / 5031 / 7079	3	FilterHigh	ms	Filter time for change from low to high speed	50	③
2983 / 5031 / 7079	4	KpScalePcon	%	Position controller gain scaling	40	
2983 / 5031 / 7079	5	KpScaleSconConst	%	Scaling of general speed control gain (adjustment to J)	100	
		Nref_FF		Setpoint speed, feed forward control scaled		Ⓐ
				Speed Control Scaling		Ⓑ

8.4.3 Speed control analysis

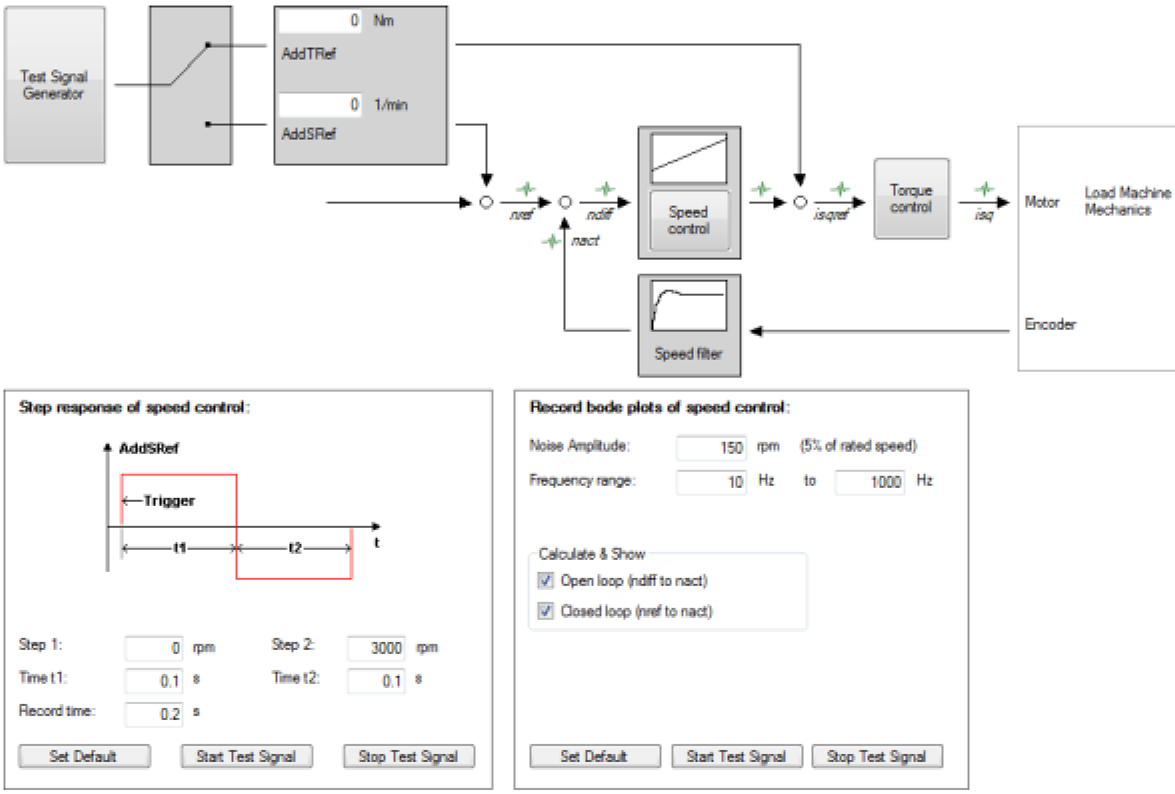


Figure 6.13: Speed control analysis dialog box

This dialog box provides a test signal generator for analysing speed control. **P 3052 [0] - AddTRef** and **P 2950[0] - AddSRef** can be used to specify a constant speed as setpoint for the controller.

To optimise the speed controller, the test signal generator can output a step response to the controller. It is automatically recorded by the digital oscilloscope.

The transfer function can be used to send a noise signal to the speed control. The result is recorded by the digital oscilloscope and output as a Bode diagram.

8.4.4 Digital filter

A digital filter of the fourth order can be inserted in the output of the speed controller. It filters the setpoint current from both control and feed forward control. The digital filter is usually used when the axis displays resonant frequencies above the bandwidth of speed control. These frequencies are filtered out of the setpoint current spectrum in order to prevent excitation.

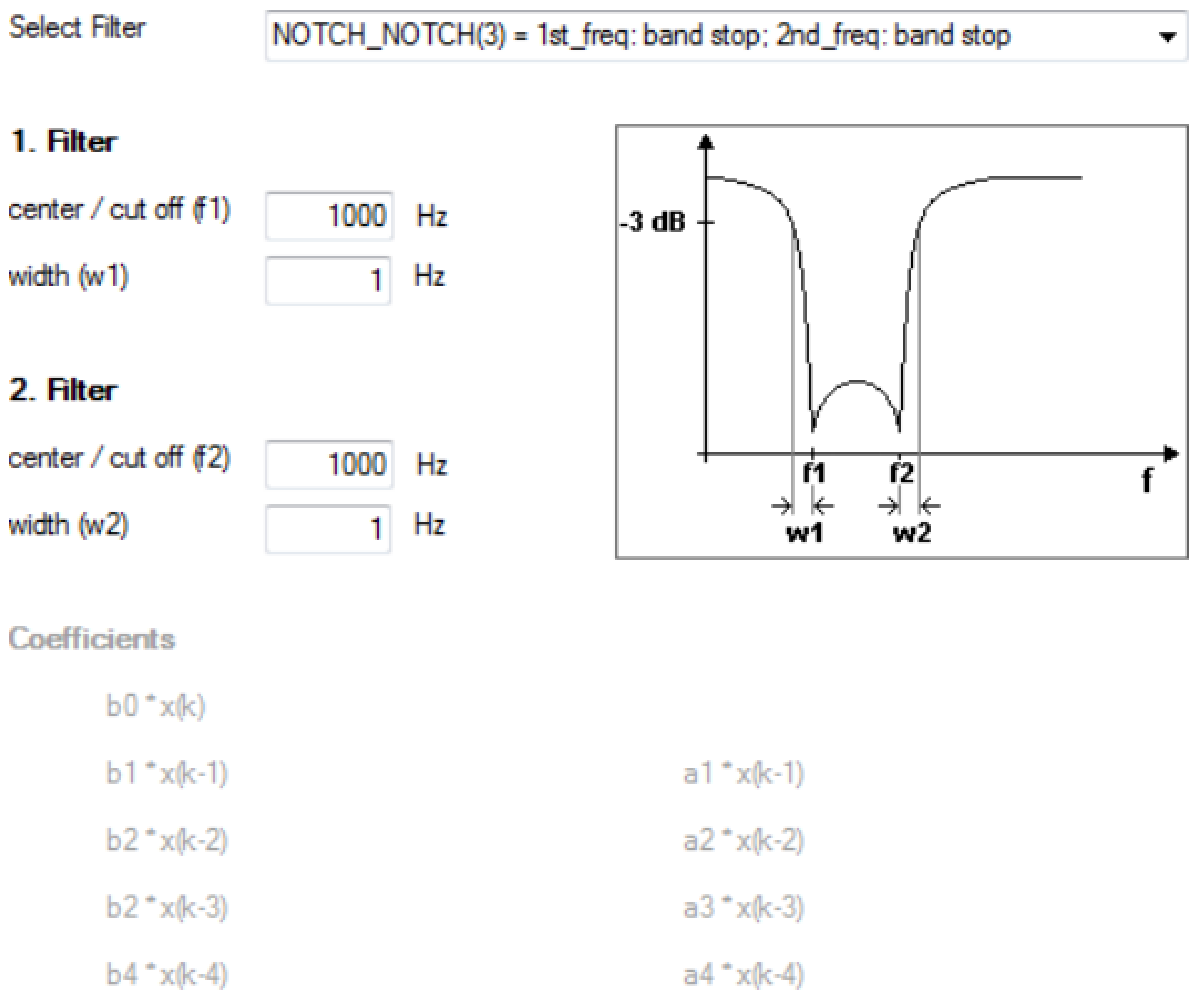


Figure 6.14: Digital filter dialog box

Configure the appropriate filter method using the “Filter selection” dropdown menu.

The filter can be configured by ServoOne CM as band-stop filter (NOTCH), deep pass filter (PTn) or a combination of both. A deep pass filter requires setting the cut-off frequency. A band lock filter requires setting the middle frequency and width. Width is the total width of the band lock between the two frequencies at which damping is 3 dB.

A large bandwidth will result in inadequate attenuation of the cut-off frequency. It is usually necessary to optimise the middle frequency and bandwidth iteratively as the band lock filter changes the phase response of the control circuit in the middle frequency range.

The filter can also be set as a BiQuad filter (inverse transfer function of a two-mass system). The resonant and antiresonant frequency of the two-mass system must be known for this purpose. The easiest way to determine them is by means of a Bode diagram of the system's transfer function (see chapter "Speed control analysis" on page 91). Enter the system's antiresonant frequency in fc_1, it is used as the filter's resonant frequency. Enter the system's resonant frequency in fc_2, this is the filter's antiresonant frequency. Then define the damping of the resonant and antiresonant point in the parameters **P 2981[2] - val_f1** and **P 2981[4] - val_f2**. The guide value is 0.1.

Finally, the filter can also be configured by the user. This is an expert option, as incorrect settings can cause the controller to behave unpredictably. Calculate a digital filter of the fourth order with a sampling rate of 125 µs in separate software. Set the **P 2981[0] - Type** parameter to USER(1) and copy the coefficients to **P 2982 - CON_SCON_DigFilPara**. Switch to list view if necessary. If possible, copy the data automatically and do not round the coefficients!

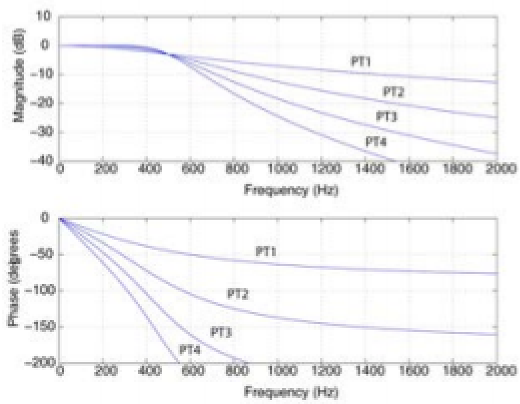
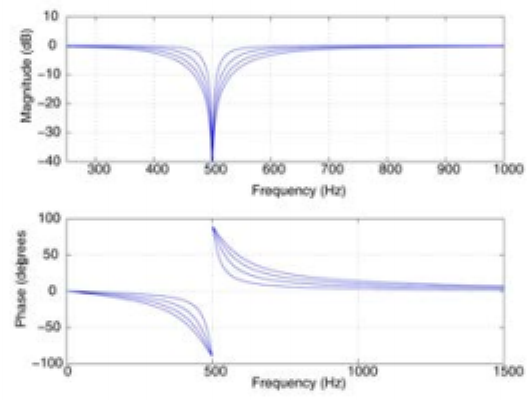
Bode diagrams PT1 to PT4	Bode diagrams for band lock filter (Notch)
	

Table 6.8: Bode diagrams of filters

P No.	Index	Name	Unit	Description
2981 / 5029 / 7077		CON_SCON_ DigFilSettings		Axis 1 / 2 / 3: Digital filter settings
2981 / 5029 / 7077	0	Type		Filter type selection
2981 / 5029 / 7077	1	fc_1	Hz	1st filter: Centre frequency / cut-off frequency
2981 / 5029 / 7077	2	val_f1		1st filter: Bandwidth / damping
2981 / 5029 / 7077	3	fc_2	Hz	2nd filter Centre frequency / cut-off frequency
2981 / 5029 / 7077	4	val_f2	Hz	value for 2nd frequency: band width [Hz] or damping[1]
2982 / 5030 / 7078		CON_SCON_DigFilPara		Axis 1 / 2 / 3: Digital filter parameters
2982 / 5030 / 7078	0	b0		b0 * x(k)
2982 / 5030 / 7078	1	b1		b1 * x(k-1)
2982 / 5030 / 7078	2	b2		b2 * x(k-2)
2982 / 5030 / 7078	3	b3		b3 * x(k-3)
2982 / 5030 / 7078	4	b4		b4 * x(k-4)
2982 / 5030 / 7078	5	a1		a1 * y(k-1)
2982 / 5030 / 7078	6	a2		a2 * x(k-2)
2982 / 5030 / 7078	7	a3		a3 * x(k-3)
2982 / 5030 / 7078	8	a4		a4 * x(k-4)

8.4.5 Advanced speed control

Advanced speed control is only available as a list view. It can be used to configure the

- Observer
- Quick stop without sensor
- Speed/position controller gain scaling

functions.

P No.	Index	Name	Unit	Description
2974 / 5022 / 7070		CON_SCALC_SLStop		Axis 1 / 2 / 3: Quick stop without sensor settings
2974 / 5022 / 7070	0	LowSpeedLimit	%	Speed limit for I/F control (in % of Nnom)
2974 / 5022 / 7070	1	LowSpeedCurrent	%	D-current for I/F control (in % of Inom)
2974 / 5022 / 7070	2	KpScale	%	Speed controller gain scaling
2974 / 5022 / 7070	3	KppScale	%	Position control gain scaling
2977 / 5025 / 7073		CON_SCALC_ObsSel		Axis 1 / 2 / 3: Observer / feedback method selection
2977 / 5025 / 7073	0	MethodSel		Selection of the observer method
2977 / 5025 / 7073	1	OnlineSel		
2978 / 5026 / 7074		CON_SCALC_ ObsDesign		Axis 1 / 2 / 3: Observer design parameter
2978 / 5026 / 7074	0	DesignAssist		Observer configuration wizard
2978 / 5026 / 7074	1	Tf	ms	Observer time constant
2978 / 5026 / 7074	2	Alpha		Damping coefficient
2978 / 5026 / 7074	3	Tf1	ms	Speed filter time constant
2978 / 5026 / 7074	4	Tf2	ms	Acceleration time constant
2978 / 5026 / 7074	5	J	kgm2	Moment of inertia of observed mass (0 = same as total moment of inertia of axis)
2983 / 5031 / 7079		CON_SCON_KpScale		Axis 1 / 2 / 3: Speed / position controller gain scaling
2983 / 5031 / 7079	0	KpScaleScon	%	Scaling of speed control gain

P No.	Index	Name	Unit	Description
2983 / 5031 / 7079	1	SpeedLimit	rpm	Speed threshold for scaling
2983 / 5031 / 7079	2	FilterZero	ms	Filter time for change from high to low speed
2983 / 5031 / 7079	3	FilterHigh	ms	Filter time for change from low to high speed
2983 / 5031 / 7079	4	KpScalePcon	%	Position controller gain scaling
2983 / 5031 / 7079	5	KpScaleSconConst	%	Scaling of general speed control gain (adjustment to J)

Table 6.10: Parameter list – Control axis – Advanced speed control (continued)

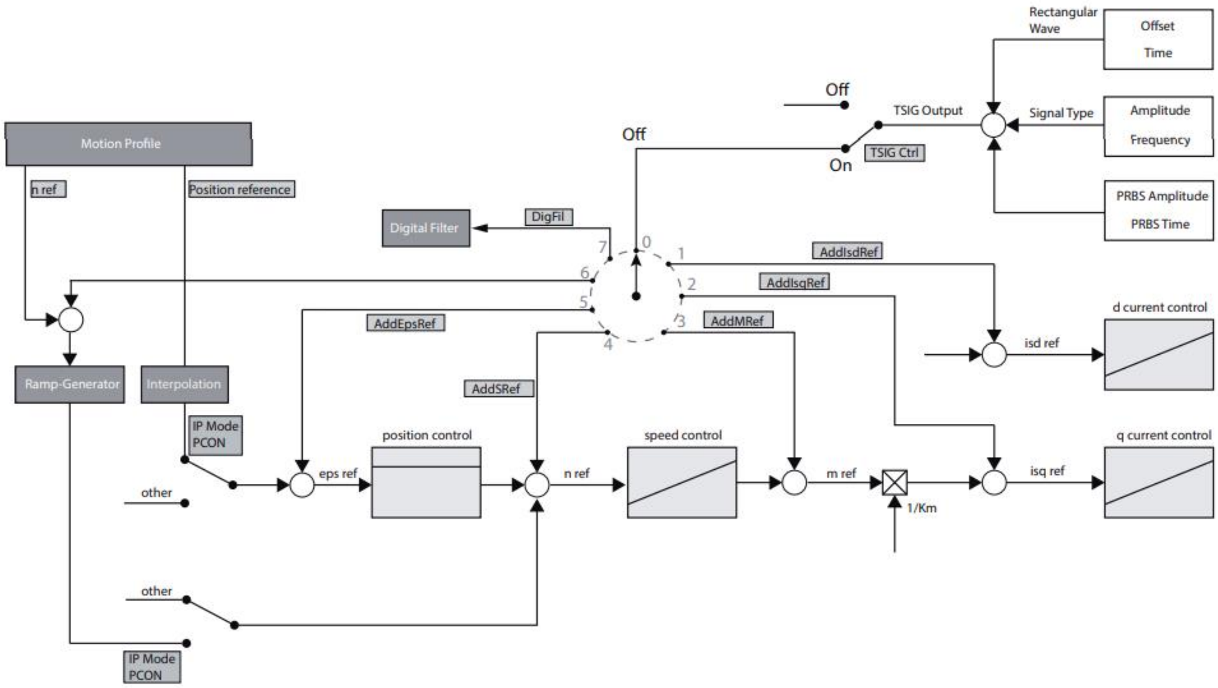
8.4.5.1 Observer

The speed observer is a simple model of the path with motor current as input, as estimation of load torque and feedback of the estimated error from encoder position for speed control. The observer generates an estimation of motor speed that is used as an alternative to the measured, filtered speed of the axis.

Procedure for using the observer

- Make sure that the mass inertia of the system (**P 2992[0] - SCD_JSum**) is known. To do so, determine the inertia of the system (see chapter "Automatic mass inertia definition" on page 82), if you haven't already done so.
- Another criterion for a reliable knowledge of mass inertia is functioning torque feed forward control (see chapter "Position Controller/Feed Forward Control" on page 99). Multiply the currently configured value of **P 2992[0] - SCD_JSum** by **P 2971[1] - Torque** and reset **P 2971[1] - Torque** to 100 %.
- Set **P 2977[0] - MethodSel** = OBS1(1) and **P 2978[0] - DesignAssist** = DR (1)
- Start the controller

The setting parameter for the observer is the time constant **P 2978[1] - Tf**. Use twice the time constant of the previously used speed filter **P 2949[0] - CON_SCALC_Tf** as an initial value. Configuration is also a compromise between input signal smoothing and phase shift in the control circuit. However, the observer does not have such a great effect on phase shift in the speed control circuit as a filter.



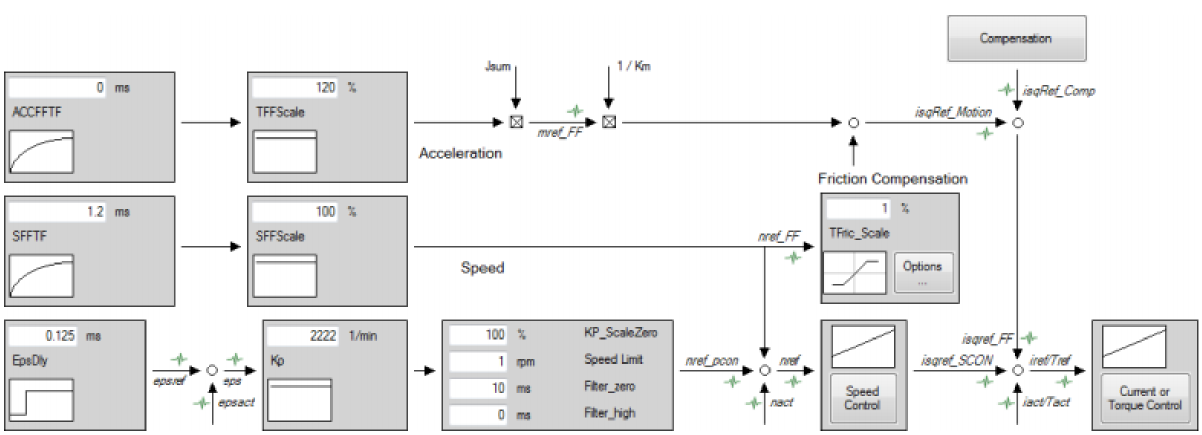
Rectangular Wave
Offset
Time
Off
TSIG Output
Signal Type
Amplitude
Frequency
Motion Profile
Off
TSIG Ctrl
On
PRBS Amplitude
PRBS Time
n ref
Position reference
Digital Filter
DigFil
AddIsdRef
AddIsqRef
d current control
AddEpsRef
AddMRef
isd ref
Ramp-Generator
Interpolation
AddSRef
IP Mode PCON
position control
speed control
q current control
eps ref
n ref
m ref
isq ref
other
1/Km
other
IP Mode PCON

P No.	Index	Name	Unit	Description
2950 / 4998 / 7046	0	AddSRef	1/min	Axis 1 / 2 / 3: Additive speed setpoint (without ramp)
2954 / 5002 / 7050		AddIsRef		Axis 1 / 2 / 3: Additive current setpoint
2954 / 5002 / 7050	0	AddIsdRef	A	Additive d-current setpoint
2954 / 5002 / 7050	1	AddIsqRef	A	Additive q-current setpoint
2954 / 5002 / 7050	2	SetPhase	deg	Set phase (V/Hz and current mode)
3052 / 5100 / 7148	0	AddTRef	Nm	Axis 1 / 2 / 3: Additive torque setpoint (without ramp)
3053 / 5101 / 7149	0	CON_TSIG_Ctrl		Axis 1 / 2 / 3: Control word test signal generator
3054 / 5102 / 7150		CON_TSIG_Settings		Axis 1 / 2 / 3: Test signal generator settings
3054 / 5102 / 7150	0	OutSel		Output signal selector
3054 / 5102 / 7150	1	Offset_0	var	Rectangle: Offset 0
3054 / 5102 / 7150	2	Offset_1	var	Rectangle: Offsets
3054 / 5102 / 7150	3	Time_0	s	Rectangle: Times
3054 / 5102 / 7150	4	Time_1	s	Rectangle: Times
3054 / 5102 / 7150	5	Cycles		Number of cycles
3054 / 5102 / 7150	6	SignalType		Sine / triangle: Selector
3054 / 5102 / 7150	7	Amplitude	var	Sine / triangle: Amplitude
3054 / 5102 / 7150	8	Frequency	Hz	Sine / triangle: Frequency
3054 / 5102 / 7150	9	SymVal	var	Sine / triangle: Symmetry
3054 / 5102 / 7150	10	PRBS_Amplitude	var	PBRS: Amplitude
3054 / 5102 / 7150	11	PRBS_Time	ms	PBRS: min. sampling time
3054 / 5102 / 7150	12	BreakTime0	ms	Pause time after a signal period (1/freq)
3054 / 5102 / 7150	13	BreakTime1	ms	Pause time after a half signal period (1/freq)
3056 / 5104 / 7152		CON_TSIG_Correlation		Axis 1 / 2 / 3: Test signal generator correlation
3056 / 5104 / 7152	0	CorrIp1Cos		Result correlation: Input 1 + cos
3056 / 5104 / 7152	1	CorrIp1Sin		Result correlation: Input 1 + sin
3056 / 5104 / 7152	2	CorrIp2Cos		Result correlation: Input 2 + cos
3056 / 5104 / 7152	3	CorrIp2Sin		Correlation of input signal 2 and sine
3056 / 5104 / 7152	4	Rs	Ohm	Result correlation: Stator resistance
3056 / 5104 / 7152	5	Ls	mH	Result correlation: Stator inductance
3058 / 5106 / 7154		SCD_SetCCON		Axis 1 / 2 / 3: Current controller control configuration
3058 / 5106 / 7154	0	Mode		Calculate current control

P No.	Index	Name	Unit	Description
3058 / 5106 / 7154	1	Bandwidth	Hz	Current control bandwidth
3059 / 5107 / 7155		SCD_SetSCON		Axis 1 / 2 / 3: Control configuration for speed / position / feed forward control
3059 / 5107 / 7155	0	Mode		Control configuration mode
3059 / 5107 / 7155	1	Stiffness	%	Stiffness of distance <=> performance of speed control
3020 / 5068 / 7116		SCD_AT_JSum_Settings		Axis 1 / 2 / 3: Total moment of inertia autotuning
3020 / 5068 / 7116	0	SConHysSpeed	rpm	Moment of inertia autotuning, speed limit
3020 / 5068 / 7116	1	SConHysTorq	Nm	Moment of inertia autotuning, torque limit
3020 / 5068 / 7116	2	TFric	Nm	Friction torque, calculated by autotuning
3020 / 5068 / 7116	3	TConst	Nm	Constant torque (weight), calculated by autotuning
3068 / 5116 / 7164		SCD_MotorIdent		Axis 1 / 2 / 3: Motor identification
3068 / 5116 / 7164	0	command		Motor identification
3068 / 5116 / 7164	1	settings		Identification settings
3070 / 5118 / 7166		SCD_State		Axis 1 / 2 / 3: Identification state
3070 / 5118 / 7166	0	State		Identification state
3070 / 5118 / 7166	1	ActCmdSrv		Current command server task

8.5 Position Controller/Feed Forward Control

The subject area position control and feed forward control serves to optimise the performance of positioning applications. The aim is usually to minimise tracking error during movement.

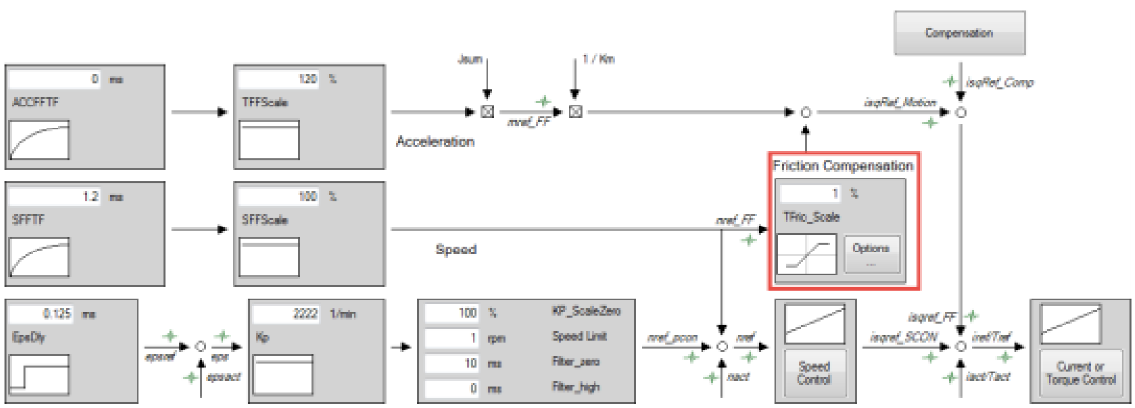


8.5.6 Friction torque compensation

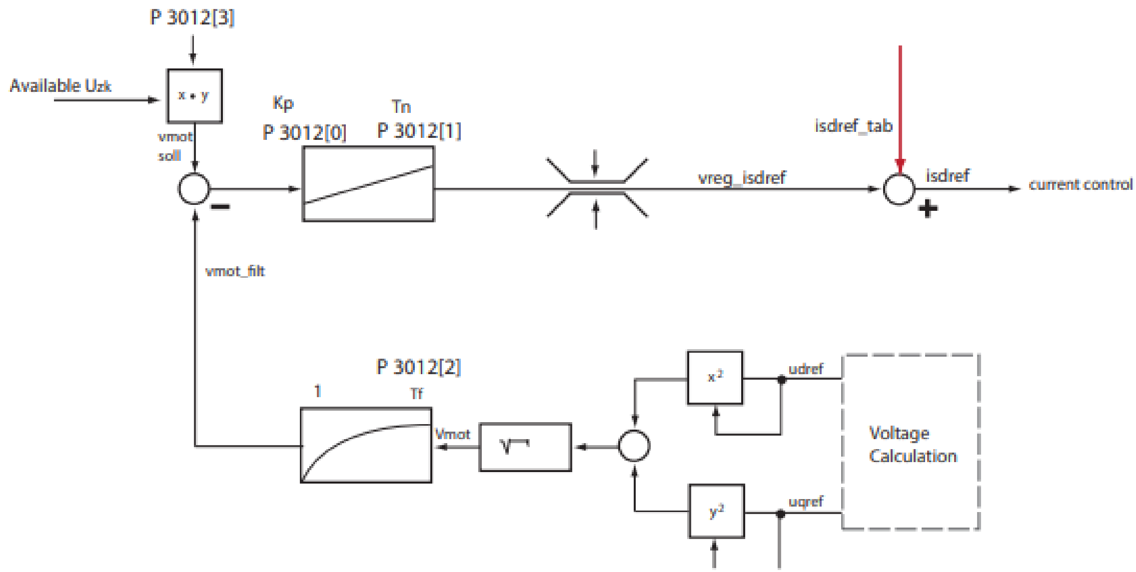
Two types of friction influence the variables of the position tracking error:

- Dry friction whose effect is dependent on the direction of movement but independent of speed.
- Viscous friction whose effect is proportional to speed.

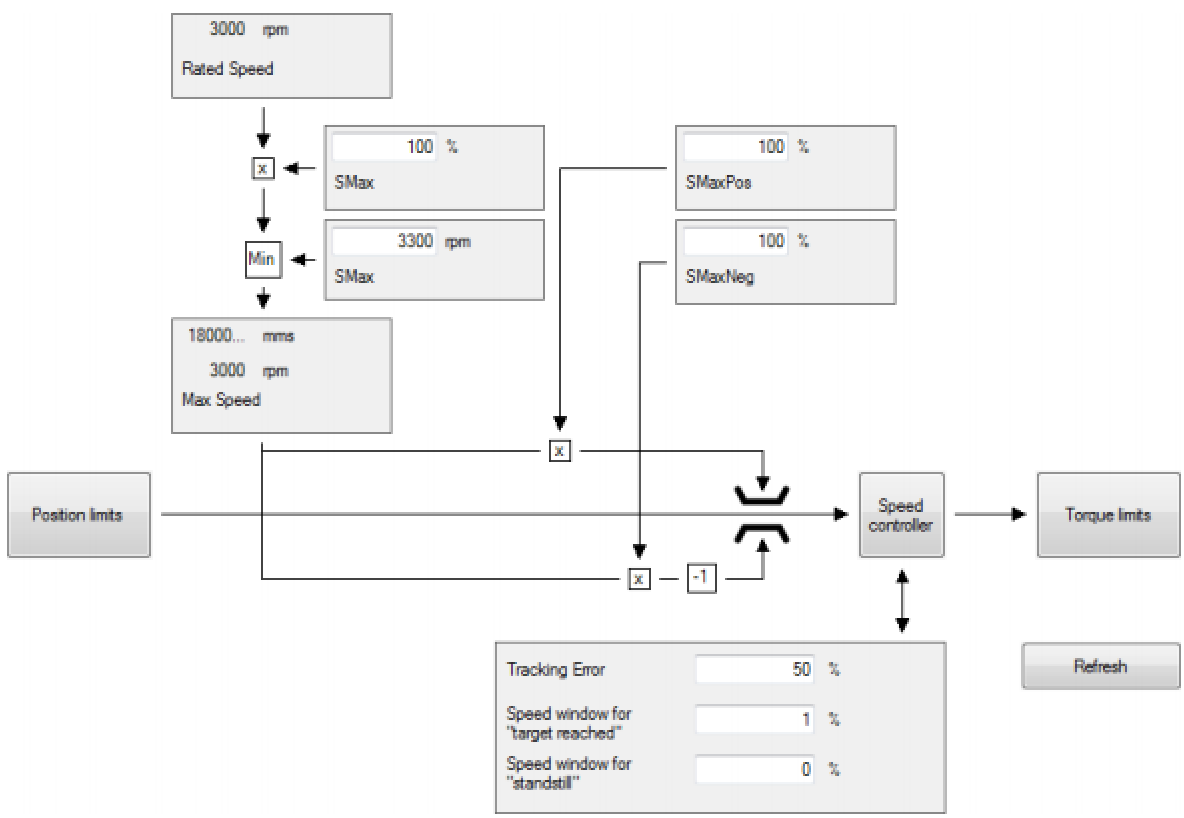
Friction torque compensation can be used for both types of friction. Both types of friction are described in the compensation table by a function starting from speed = 0 or force = 0 up to a defined speed or force. Above the specified limit, the speed or force remains constant. Compensation is performed as a percentage of rated motor torque and power.



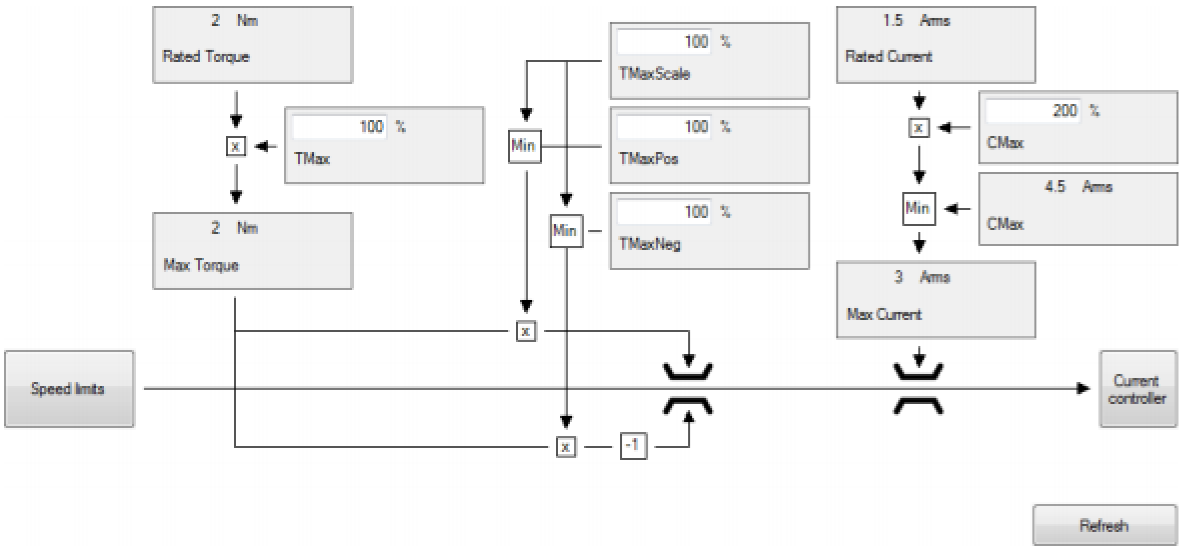
8.6.2 Voltage controller



11.1.2 Speed limitation



11.1.3 Torque limitation



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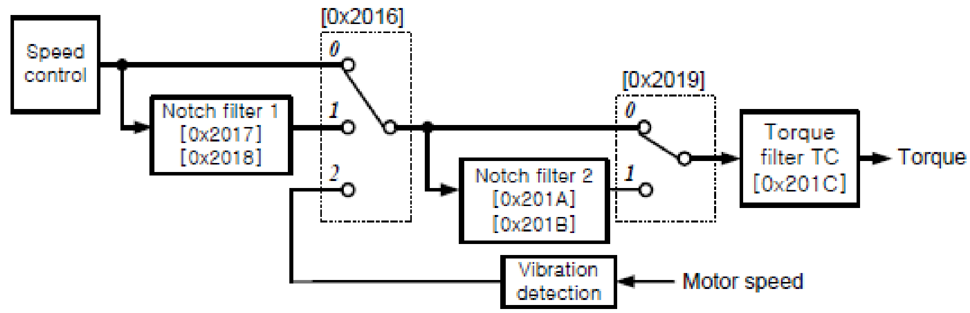
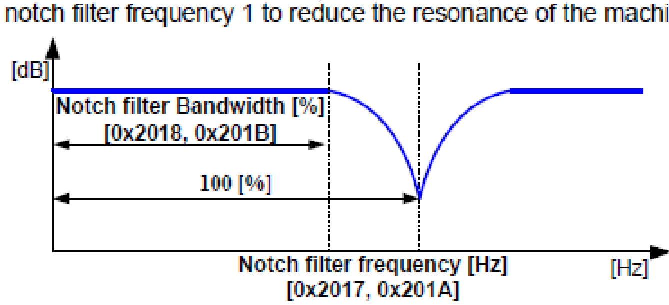
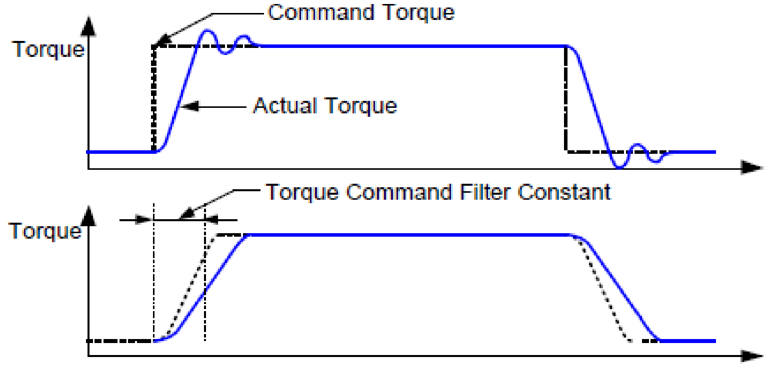
Index	0x2016	Notch Filter 1 Mode	Data Type	Property		Variable
				Access	PDO	Initial value
Sub-Index	Description		UINT8	RW	No	0x00
			Data range	0x00 ~ 0x02		
0x00	The operation of the notch filter is set to operate the notch filter to reduce the resonance of the machinery.					

Value	Operation explanation
0x00	Do not use the notch filter 1.
0x01	Operate the notch filter 1 in the set resonance frequency and resonance bandwidth.
0x02	This is the method of reducing the resonance after automatically detecting the resonance frequency, it automatically detects the frequency of which the vibration is generated and reduces the resonance. (Automatically value from 2 -> 1)

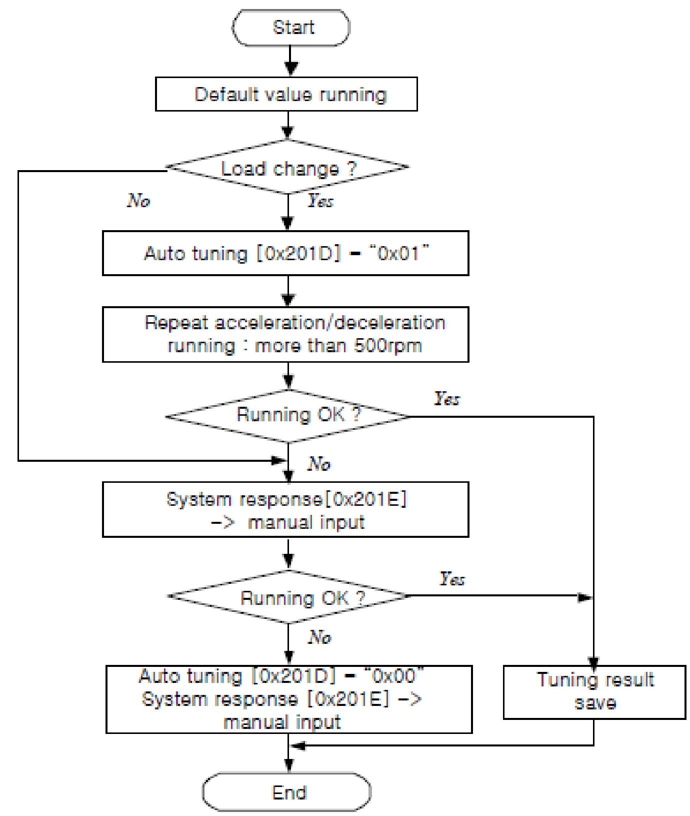


Index	0x2017	Notch Filter 1 Frequency	Data Type	Property		Variable
				Access	PDO	Initial value
Sub-Index	Description		UINT32	RW	No	0x00000BB8
			Data range	0x000001F4 ~ 0x00004E20		
			Unit	0.1 Hz		
0x00	This sets the notch filter frequency 1 to reduce the resonance of the machinery.					



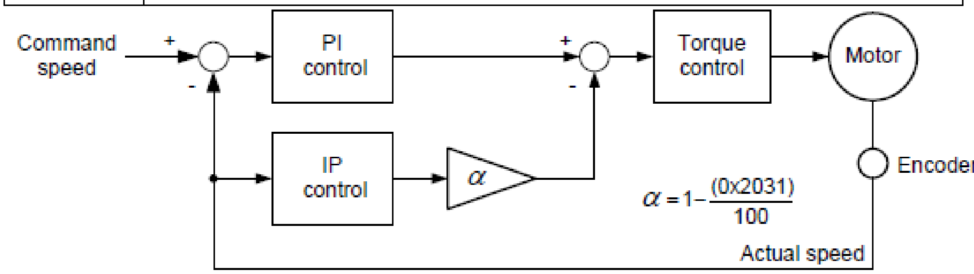
Index	0x201C	Torque Filter Time Constant	Data Type	Property		Variable
				Access	PDO	Initial value
Sub-Index	Description		UINT32	RW	No	by drive type
			Data range	0x00000000 ~ 0x00002710		
			Unit	0.1 ms		
0x00	Filter time constant for torque command in the servo drive. 					

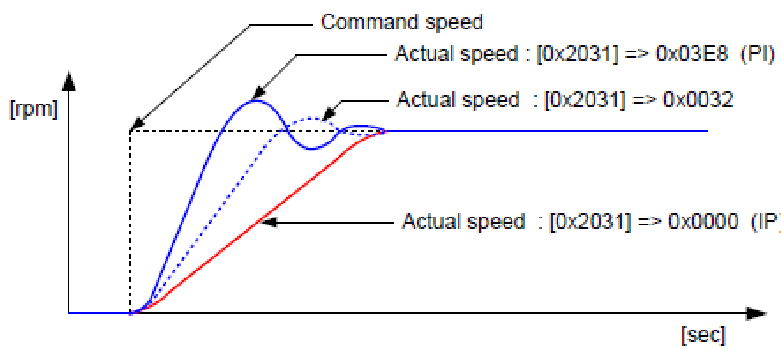
Index	0x201D	Auto Tuning	Data Type	Property		Variable
				Access	PDO	Initial value
Sub-Index	Description		UINT8	RW	No	0x00
			Data range	0x00 ~ 0x01		
0x00	In Auto Tuning, Position proportional Gain, Speed control loop Gain, Speed integral time constant and Torque command filter time constant shall be set by setting System response[0x201E], and the System inertia ratio[0x201F] shall be set by Auto Tuning Mode which is an automatic control part.					



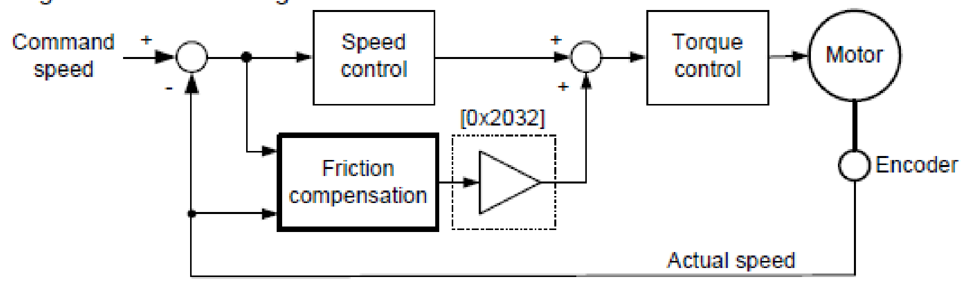
Index	0x2031	PI-IP Control Ratio	Data Type	Property		Variable
				Access	PDO	Initial value
Sub-Index	Description		UINT32	RW	No	0x000003E8
			Data range	0x00000000 ~ 0x000003E8		
			Unit	0.1 %		
0x00	The type of speed controller to set the mixing ratio.					

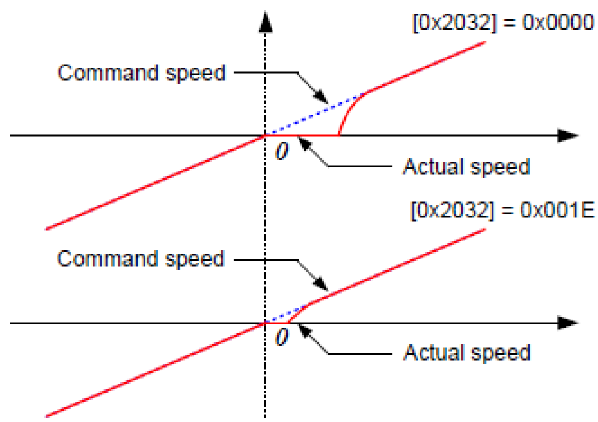
Value	Operation explanation
0x03E8	**PI** applied to the speed controller.
0x0000	**IP** applied to the speed controller.



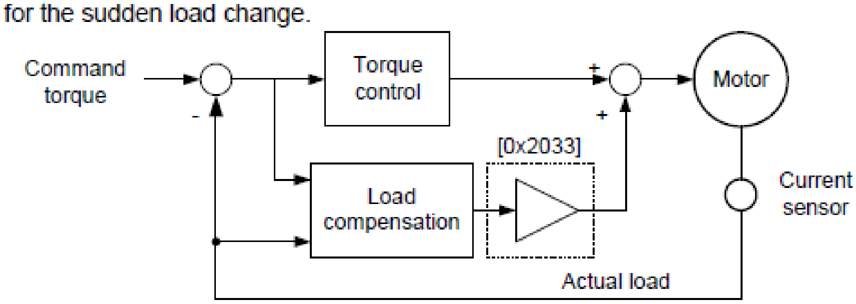


Index	0x2032	Friction Compensation Torque Ratio	Data Type	Property		Variable
				Access	PDO	Initial value
Sub-Index	Description		UINT32	RW	No	0x00000000
			Data range	0x00000000 ~ 0x000003E8		
			Unit	0.1 %		
0x00	When the servo motor is attached on the machinery with severe friction with ball screw etc., this sets the friction compensation coefficient to reduce the dead zone that occurs during conversion of turning direction.					





Index	0x2033	Load Compensation Torque Ratio	Data Type	Property		Variable
				Access	PDO	Initial value
Sub-Index	Description		UINT32	RW	No	0x00000000
			Data range	0x00000000 ~ 0x000003E8		
			Unit	0.1 %		
0x00	This sets the external load compensation coefficient to improve the response of the servo motor for the sudden load change.					

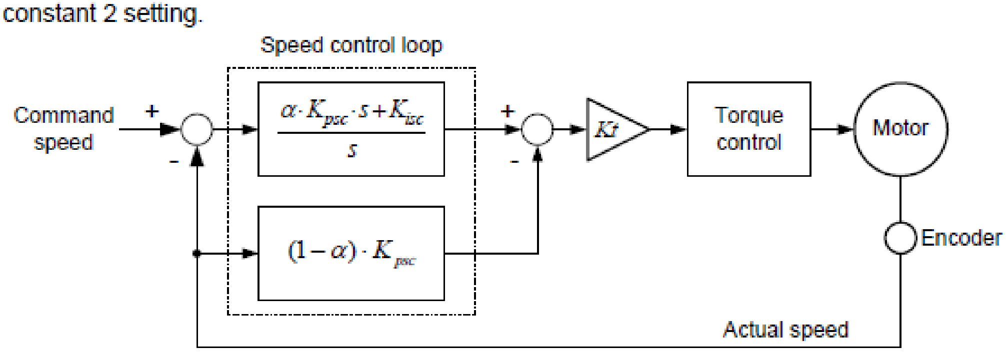


Index	0x2034	Speed Control Loop Gain 1	Data Type	Property		Variable
				Access	PDO	Initial value
Sub-Index	Description		UINT32	RW	No	by drive type
			Data range	0x00000000 ~ 0x00002710		
			Unit	0.1 Hz		
0x00	This parameter sets the acceleration needed to respond to the frequency 1 response.					

Index	0x2035	Speed Control Time Constant 1	Data Type	Property		Variable
				Access	PDO	Initial value
Sub-Index	Description		UINT32	RW	No	by drive type
			Data range	0x00000000 ~ 0x000186A0		
			Unit	0.1 ms		
0x00	This parameter is required for the response of the deceleration of the servo motor constant 1 setting.					

Index	0x2036	Speed Control Loop Gain 2	Data Type	Property		Variable
				Access	PDO	Initial value
Sub-Index	Description		UINT32	RW	No	by drive type
			Data range	0x00000000 ~ 0x00002710		
			Unit	0.1 Hz		
0x00	This parameter sets the acceleration needed to respond to the frequency 2 response.					

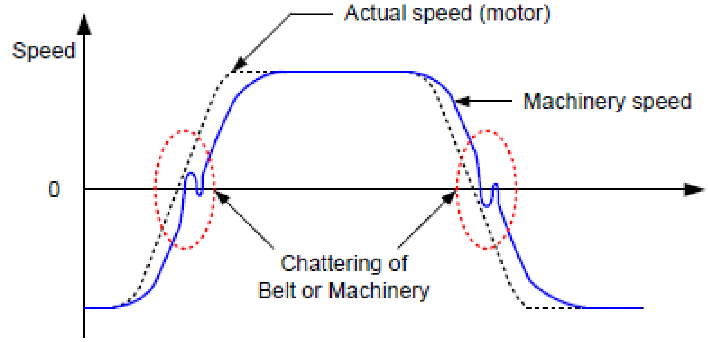
Index	0x2037	Speed Control Time Constant 2	Data Type	Property		Variable
				Access	PDO	Initial value
Sub-Index	Description		UINT32	RW	No	by drive type
			Data range	0x00000000 ~ 0x000186A0		
			Unit	0.1 ms		
0x00	This parameter is required for the response of the deceleration of the servo motor constant 2 setting.					

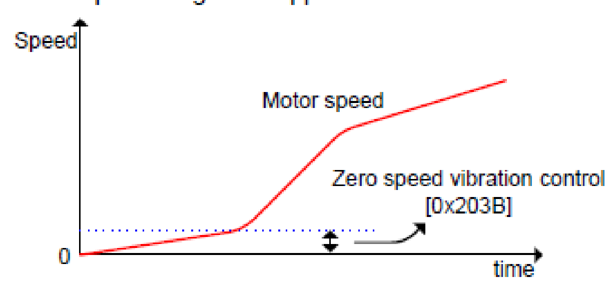


K_{psc} = System Inertia ×2π ×SC Loop Gain 1[0x2034], SC Loop Gain 2[0x2036]

$$K_{isc} = K_{psc} \times \frac{1000}{\text{SC TC 1[0X2035], SC TC 2[0X2037]}}$$

$$\alpha = \frac{\text{PI – IP control \%[0x2031]}}{100}$$

Index	0x203A*	Speed Feedback Time constant	Data Type	Property		Variable
				Access	PDO	Initial value
Sub-Index	Description		UINT32	RW	No	0x00000000
			Data range	0x00000000 ~ 0x00004E20		
			Unit	0.1 ms		
0x00	 * This object cannot be set in servo-on state.					

Index	0x203B	Zero Velocity Vibration Control	Data Type	Property		Variable
				Access	PDO	Initial value
Sub-Index	Description		UINT32	RW	No	0x00000001
			Data range	0x00000000 ~ 0x00002710		
			Unit	0.1 mm-1		
0x00	This parameter sets the speed range for suppress vibration at slow or stop state. 					

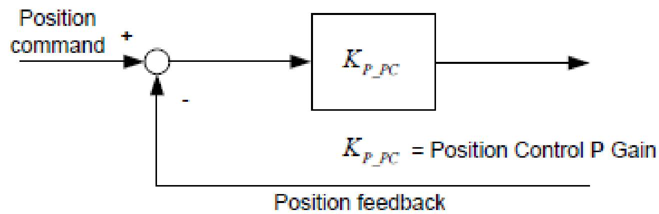
Index	0x2040	Position Gain Mode	Data Type	Property		Variable
				Access	PDO	Initial value
Sub-Index	Description		UINT8	RW	No	0x01
			Data range	0x00 ~ 0x04		
0x00	When the servo drive is set to position control mode, this parameter sets the position control gain type.					

Set value	Operation explanation
1	Use the position loop gain 1. [0x2042]
2	Use the position loop gain 2. [0x2043]
3	Apply variable gain using gain 1 [0x2042] and gain 2 [0x2043] according to set speed [0x2020, 0x2021] for the position controller gain.
4	Apply variable gain using gain 1 [0x2042] and gain 2 [0x2043] according to set speed [0x2020, 0x2021] for the position controller gain.

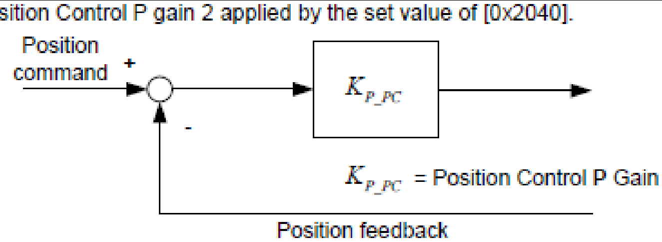
Index	0x2041	Position Feedforward Ratio	Data Type	Property		Variable
				Access	PDO	Initial value
Sub-Index	Description		UINT32	RW	No	0x00000000
			Data range	0x00000000 ~ 0x000003E8		
			Unit	0.1 %		
0x00	This parameter sets the Feedforward ratio[%] unit for the position command speed.					

R = [Speed loop gain]/ [Position loop gain]	Max_Value [Feedforward]
5	70 or below
7	80 or below
10	85 or below
20	90 or below

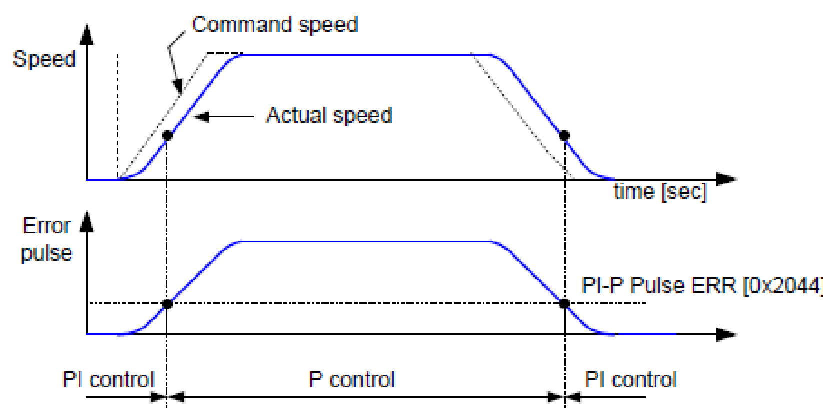
Index	0x2042	Position Control P Gain 1	Data Type	Property		Variable
				Access	PDO	Initial value
Sub-Index	Description		UINT32	RW	No	by drive type
			Data range	0x00000000 ~ 0x00001388		
			Unit	0.1 Hz		
0x00	This sets the Position Control P gain 1 applied by the set value of [0x2040].					

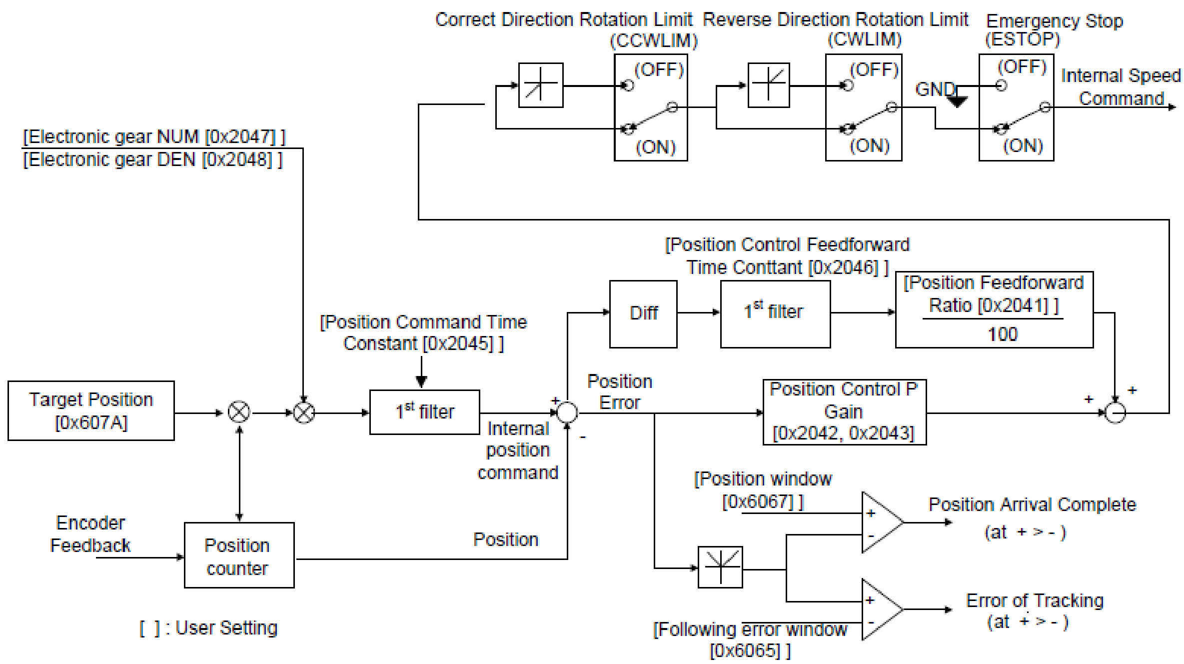


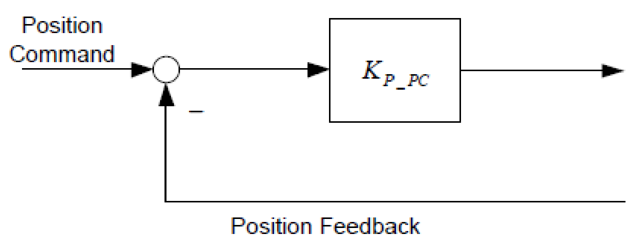
Index	0x2043	Position Control P Gain 2	Data Type	Property		Variable
				Access	PDO	Initial value
Sub-Index	Description		UINT32	RW	No	by drive type
			Data range	0x00000000 ~ 0x00001388		
			Unit	0.1 Hz		
0x00	This sets the Position Control P gain 2 applied by the set value of [0x2040].					



Index	0x2044	Position PI-P Pulse Error	Data Type	Property		Variable
				Access	PDO	Initial value
Sub-Index	Description		UINT32	RW	No	0x00000000
			Data range	0x00000000 ~ 0x000186A0		
			Unit	pulse		
0x00	In position control mode, when the error between command pulse and actual movement pulse exceeds the set value of [0x2044], it converts to P control mode to reduce the overshoot.					



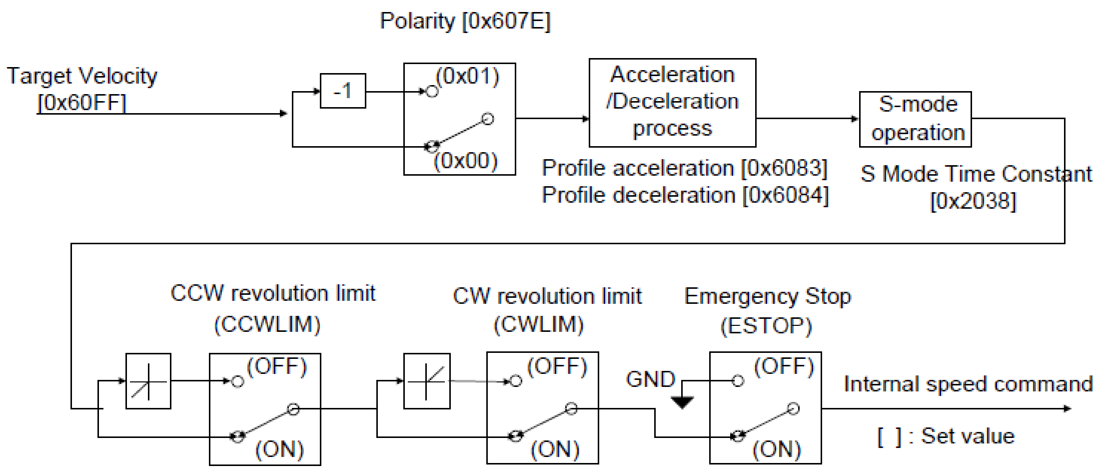


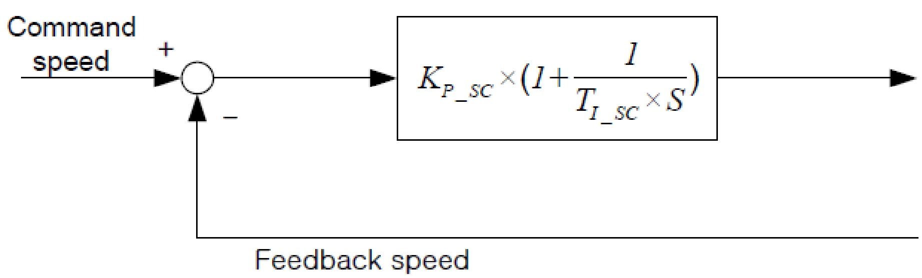


$$K_{P\_PC} = \text{PositionProportional Gain}$$

5.2 How to adjust Gain at Velocity Mode

This explains the gain adjustment method when using speed servo. The following diagram shows the generation sequence of the speed command in speed control.



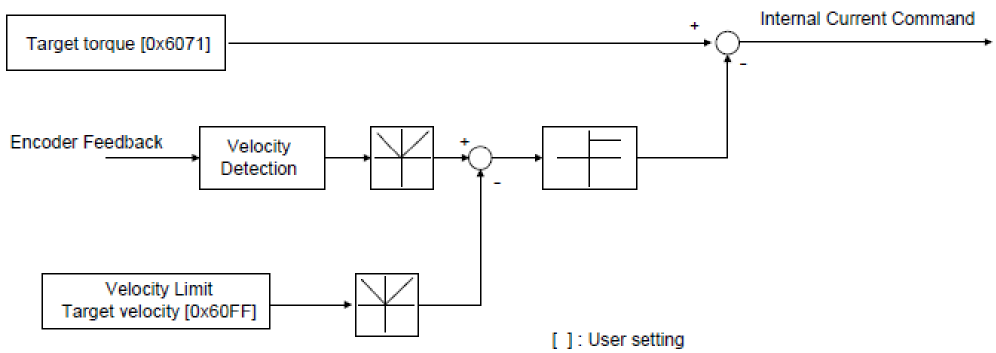


$K_{P\_SC} = \text{SCLoopGain}$

$T_{I\_SC} = \text{SCTC}$

5.3 How to adjust Gain at Torque Mode.

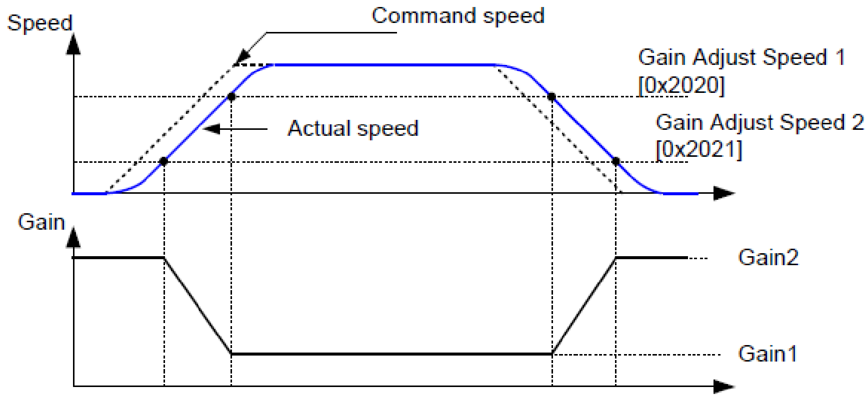
Explains how to use and adjust Gain at Torque Mode. Following figure shows the sequence of Current Command at Torque Mode.



When the master controller send a torque command to the Servo Drive by network, it sets the time constant of a filter which passes the low range of analog torque. When setting a time constant of analog torque command filter, you can limit the noise which is set more than a time constant of a filter. Analog torque command filter may more or less cause a reduction of response when its value is too big because it moderates the fast torque command.

0x2020	Gain ADJ Speed1	Unit 0.1rpm	Setting range 1000.0 ~ 50000.0	Value set from Factory 8000.0	Speed/Torque/Position Control
0x2021	Gain ADJ Speed2	Unit 0.1rpm	Setting range 100.0 ~ 5000.0	Value set from Factory 1000.0	Speed/Torque/Position Control

[Transition motions]



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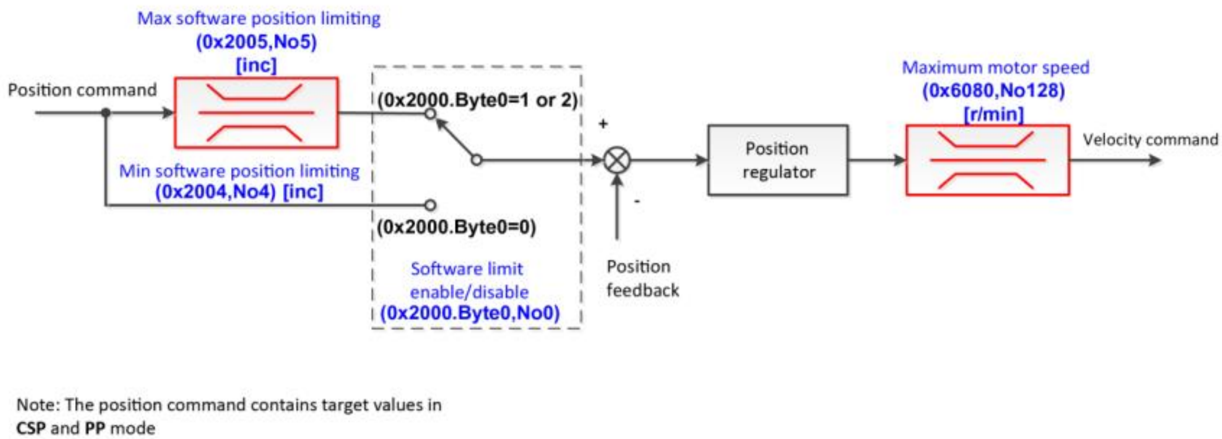
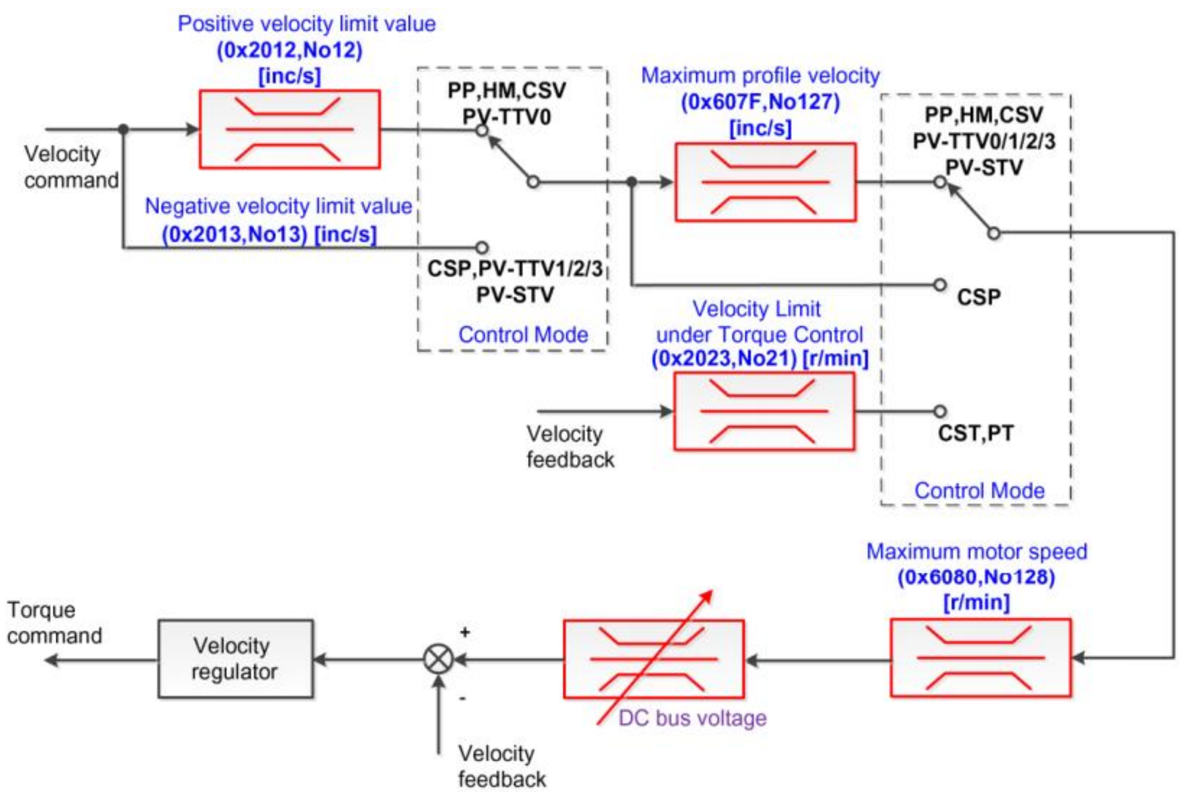
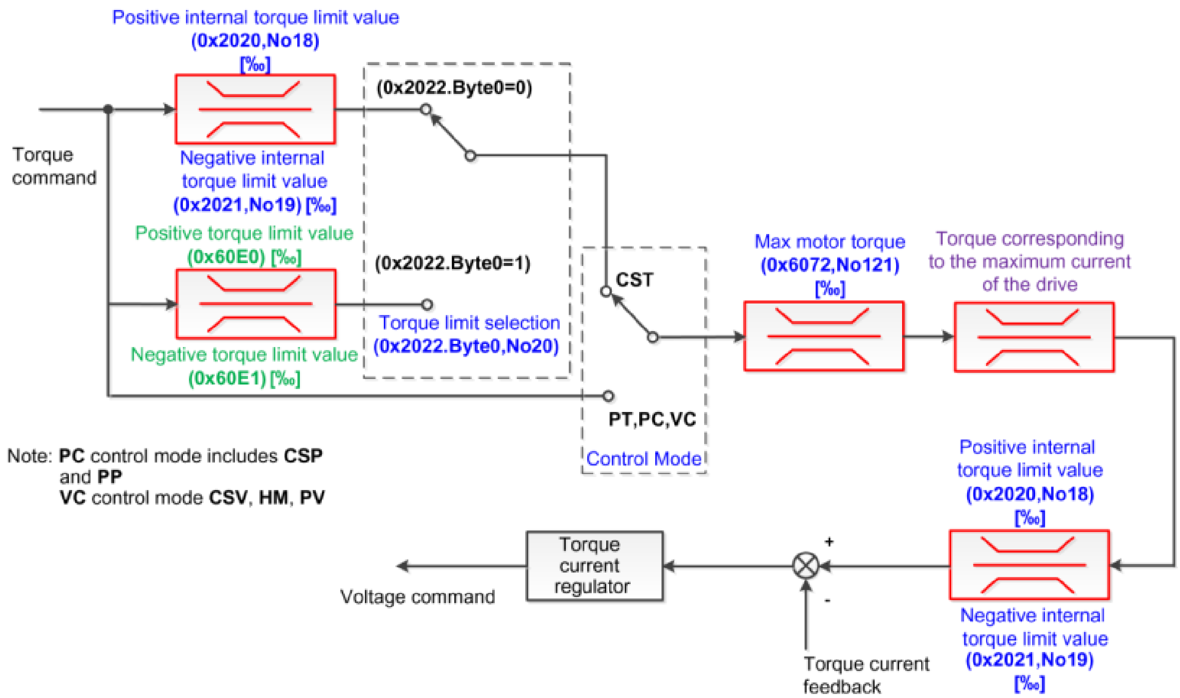
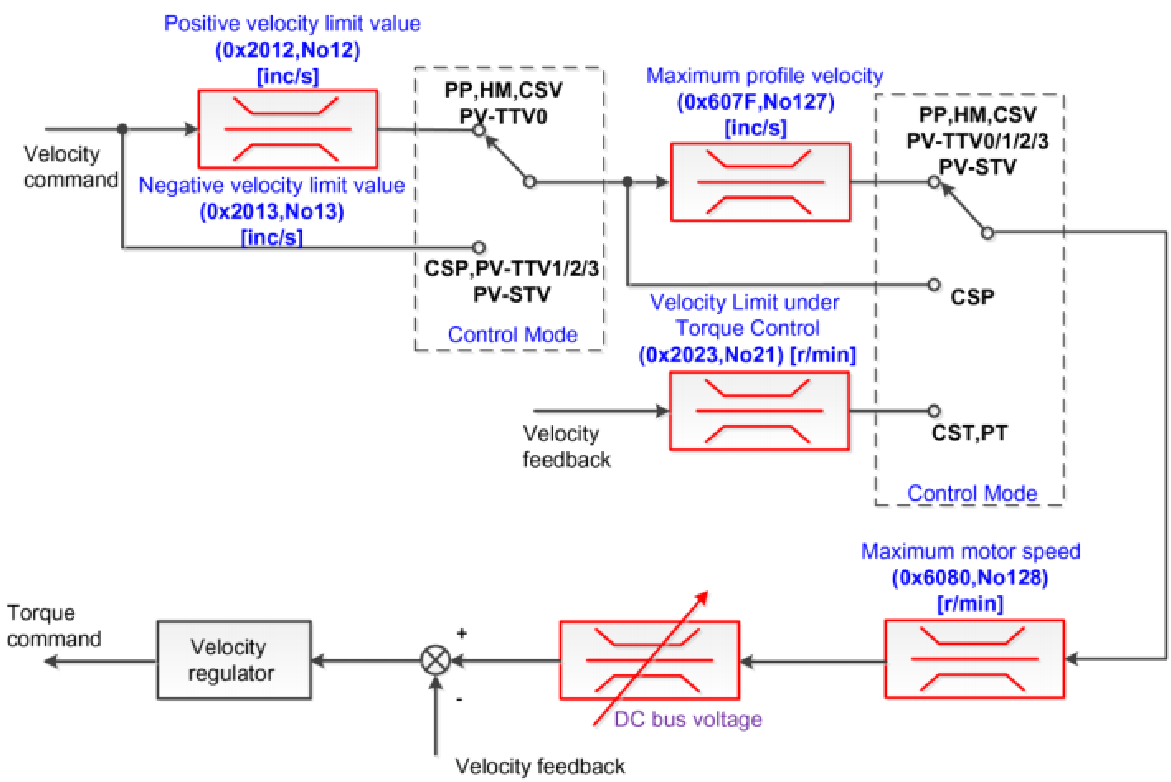
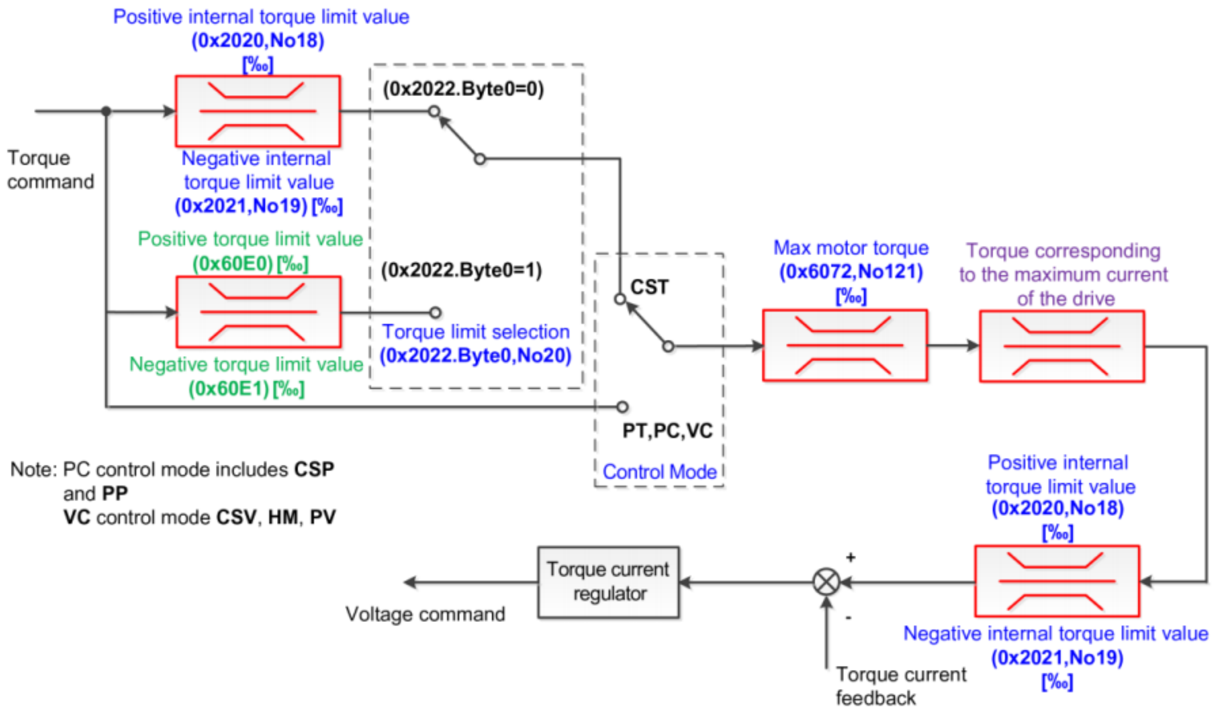





Positive internal torque limit value
(0x2020,No18)
[‰]
Torque command
Negative internal torque limit value
(0x2021,No19) [‰]
Positive torque limit value
(0x60E0) [‰]
Negative torque limit value
(0x60E1) [‰]
(0x2022.Byte0=0)
(0x2022.Byte0=1)
Torque limit selection
(0x2022.Byte0,No20)
CST
PT,PC,VC
Control Mode
Max motor torque
(0x6072,No121)
[‰]
Torque corresponding to the maximum current of the drive
Note: PC control mode includes CSP and PP
VC control mode CSV, HM, PV
Positive internal torque limit value
(0x2020,No18)
[‰]
Negative internal torque limit value
(0x2021,No19)
[‰]
Torque current regulator
Voltage command
+
-
Torque current feedback


Positive velocity limit value
(0x2012,No12)
[inc/s]
Velocity command
Negative velocity limit value
(0x2013,No13)
[inc/s]
PP,HM,CSV
PV-TTV0
CSP,PV-TTV1/2/3
PV-STV
Control Mode
Maximum profile velocity
(0x607F,No127)
[inc/s]
PP,HM,CSV
PV-TTV0/1/2/3
PV-STV
CSP
Velocity Limit under Torque Control
(0x2023,No21) [r/min]
Velocity feedback
CST,PT
Control Mode
Maximum motor speed
(0x6080,No128)
[r/min]
Torque command
Velocity regulator
+
-
DC bus voltage
Velocity feedback



7.9.13 Notch Filter

Notch filters are mainly used for driving mechanical equipment with high-velocity and high-precision. In such cases, servo gains are usually set to be relatively high, which may cause mechanical vibration. Vibration frequencies can be filtered through notch filters, resulting in higher gains and faster servo response. At present, R6 supports two notch filter functions.

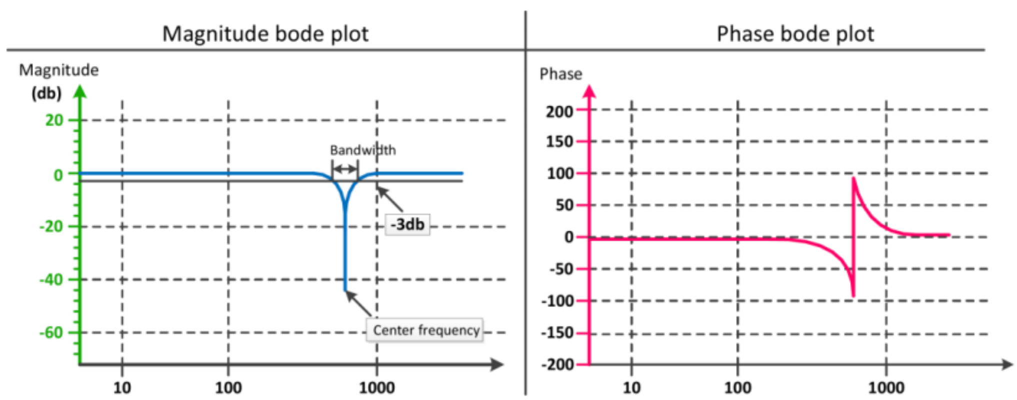


Figure 8.9-2. Diagram of notch filter functions

Number	Index	Name	Unit	Setting Range	Default Value	Effective Time
62	0x2060	Torque Command Notch Filter Control Switch	——	0x00000000~0x01010101	0	Immediately

7.10.8 Notch Filter Function

Notch filters are mainly used for driving mechanical equipment with high-velocity and high-precision. In such cases, servo gains are usually set to be relatively high, which may cause mechanical vibration. Vibration frequencies can be filtered through notch filters, resulting in higher gains and faster servo response. At present, R6 supports two notch filter functions.

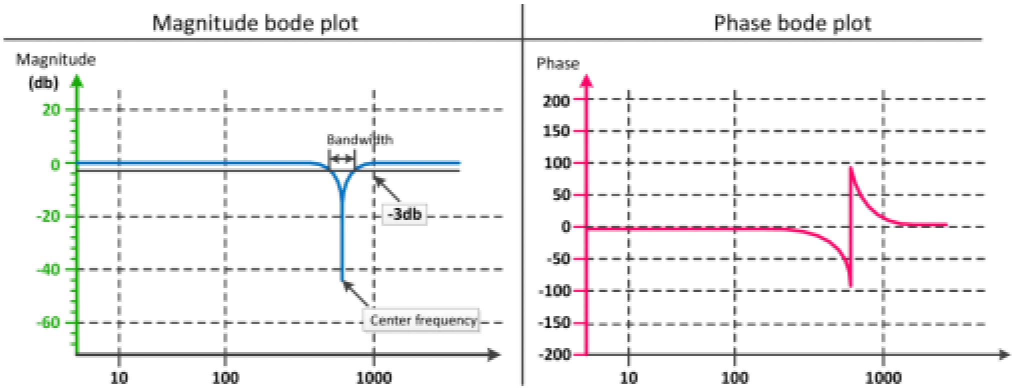


Figure 8.10-2. Diagram of notch filter functions

Number	Index	Name	Unit	Setting Range	Default Value	Effective Time
62	0x2060	Command Notch Filter Control Switch	——	0x00000000~0x01010101	0	Immediately

Byte0: Torque demand notch filter 1 enable switch

0x00 - Torque demand notch filter 1 is disabled;

0x01 - Torque demand notch filter 1 is enabled.

Byte1: Velocity demand value notch filter 1 enable switch

0x00 - Velocity demand value notch filter 1 is disabled;

0x01 - Velocity demand value notch filter 1 is enabled.

Byte2: Torque demand value resonant filter enable switch

0x00 - Torque demand value resonator filter is disabled;

0x01 - Torque command resonant filter is enabled.

Byte3: Velocity demand value notch filter 2 enable switch

0x00 - Disable the velocity demand value notch filter 2;

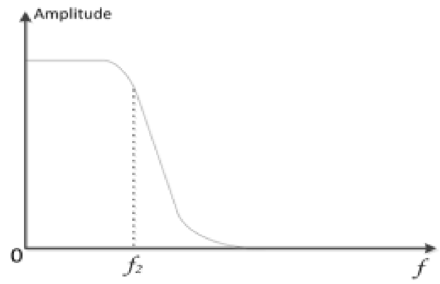
0x01 - Enable the velocity demand value notch filter 2.

User permission: User/Engineer

Parameter permission: Read and Write

8.3 Filter Adjustment

The filter is mainly used to suppress vibration. According to the frequency, filters can be classified into low-pass filters, high-pass filters, band-pass filters and band-stop filters. Here, we mainly introduce low-pass filters. As shown in Figure 9.3 (1), with frequency from 0 to f2, low-pass filters have linear amplitude-frequency characteristics, which means components of signals with frequency less than f 2 can pass without attenuation, while those with frequency higher than f 2 will be attenuated greatly.



Cutoff frequency of low-pass filters refers to the frequency when the magnitude-frequency characteristic of a signal is attenuated to -3dB and the phase characteristic is deviated by 90°. See Figure 9.3-2.

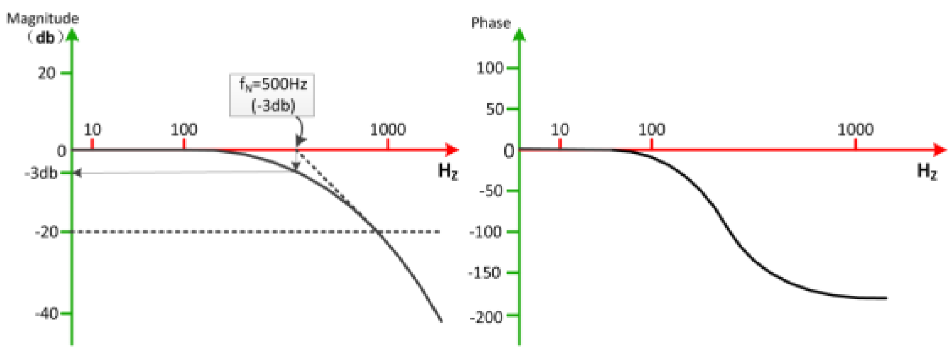


Figure 9.3-2. Cutoff frequency of low-pass filters

The lower the cutoff frequency of low-pass filters, the more stably the system runs and the smaller the high-frequency noise. However, the system will respond more slowly.

8.3.1 Position Filters

Number	Index	Name	Unit	Setting Range	Default Value	Effective Time
23	0x2026	Velocity Feedforward Low-pass Filter Cutoff Frequency	Hz	1~1000	1000	Immediately

Parameter Description:

User permission: User/Engineer.

Parameter permission: Read and Write

8.3.2 Velocity Filters

Number	Index	Name	Unit	Setting Range	Default Value	Effective Time
151	0x2066	Low-pass Filter Type Select	-	0x00000000~0x03030103	0x01020102	Power Cycle

Byte0: Velocity feedback low-pass filter type

0x00-Low-pass filter disabled;

0x01-First order low-pass filter;

0x02-Second order low-pass filter.

Byte1: Torque current feedback low-pass filter type

8.3.4 Notch Filter Function

Notch filters are mainly used for driving mechanical equipment with high-velocity and high-precision. In such cases, servo control rigidity is normally higher, which may cause mechanical vibration. Vibration frequencies can be suppressed through notch filters, resulting in higher gains and faster servo response.

Diagram of notch filter functions:

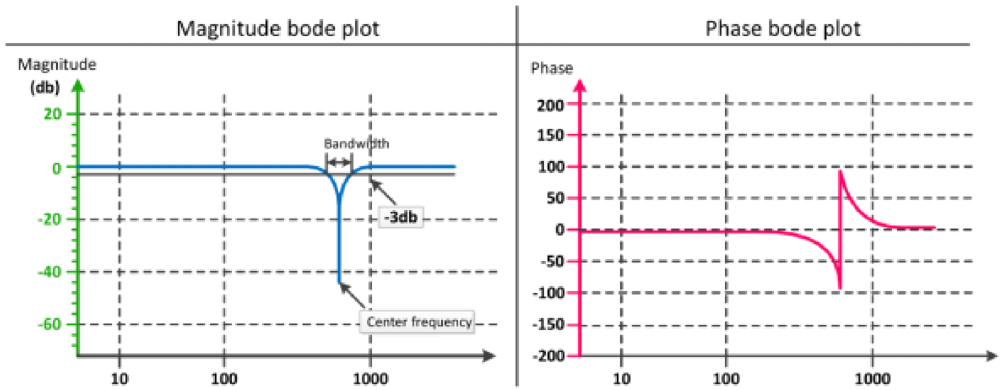


Figure 9.3-3. Diagram of notch filter functions

Number	Index	Name	Unit	Setting Range	Default Value	Effective Time
62	0x2060	Command Notch Filter Control Switch	——	0x00000000~0x0000010 1	0	Immediately

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8.4 Friction Torque Compensation Function (not open for use temporarily)

Number	Index	Name	Unit	Setting Range	Default Value	Effective Time
20	0x2022	Torque Control Switch	——	0x000000~0x01010101	0x00010000	Immediately

Byte0: Pulsating torque compensation control switch

0x00 - Suppression of ripple torque compensation control;

0x01 - Enable pulsating torque compensation control.

Byte1: Torque compensation control switch

0x00 - Torque compensation control is disabled;

0x01 - Torque compensation control is enabled.

Byte2: Static balance torque control switch

0x00 - Disable the static balance torque control;

0x01 - Enable the static balance torque control.

Byte3: Friction compensation control switch

0x00 - Disable the friction compensation control;

0x01 - Enable the friction compensation control

User permission: User/Engineer

Parameter permission: Read and Write

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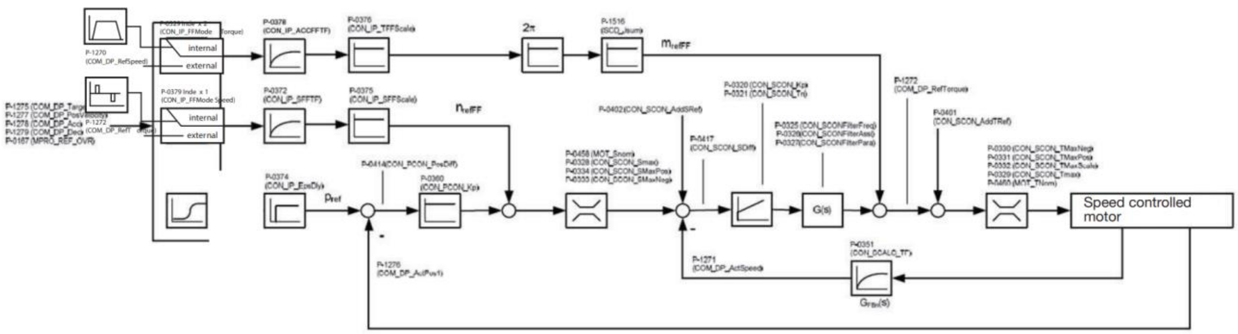
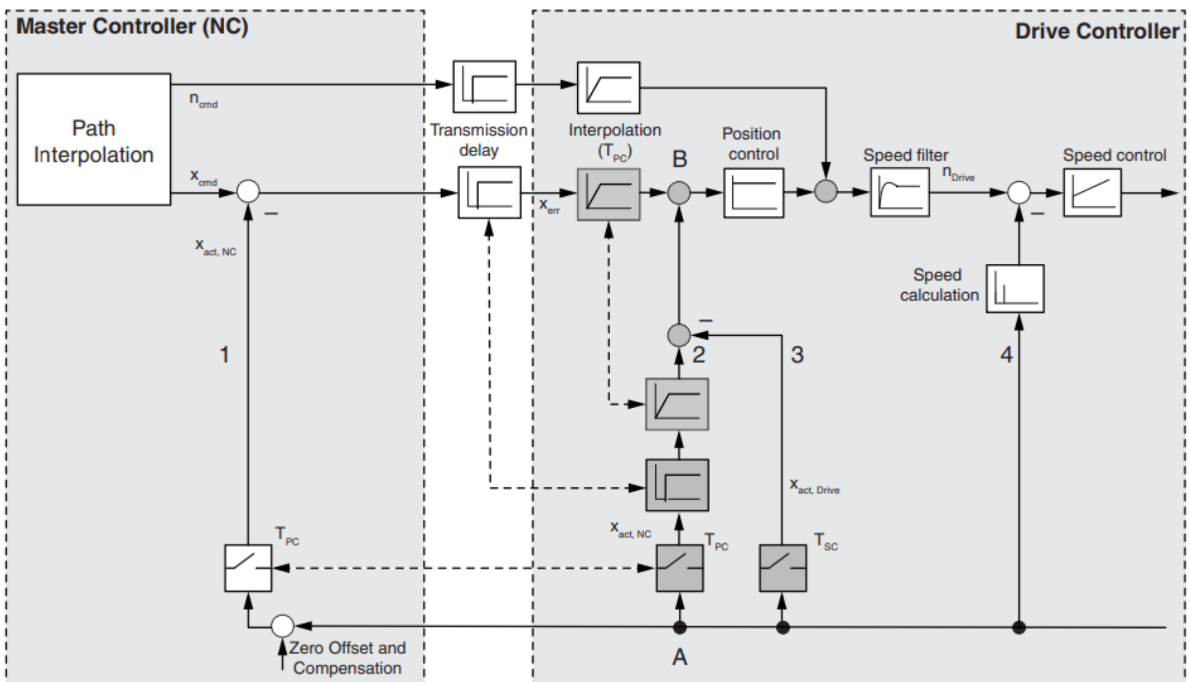
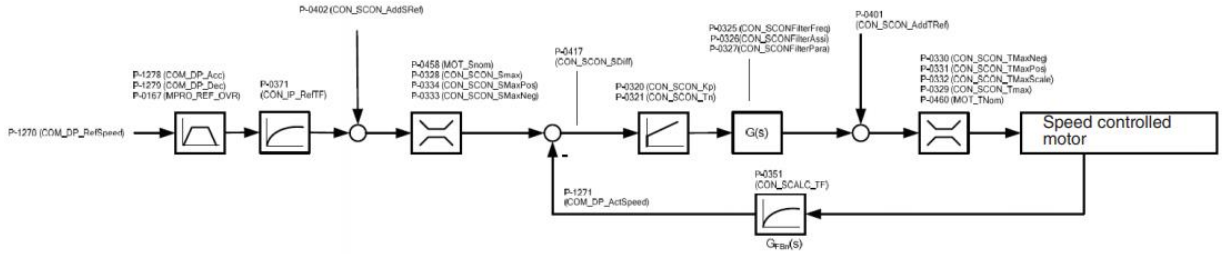
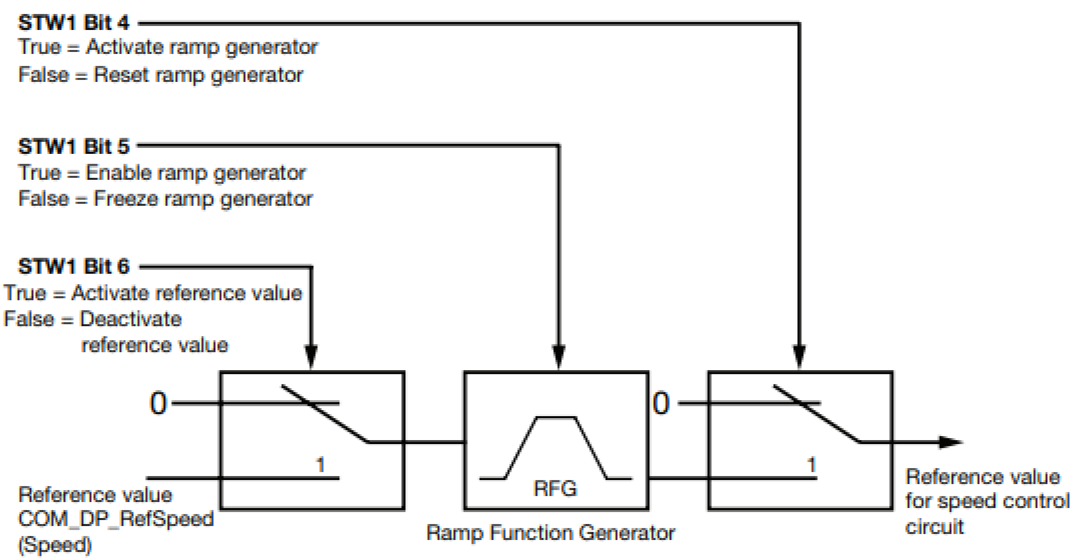


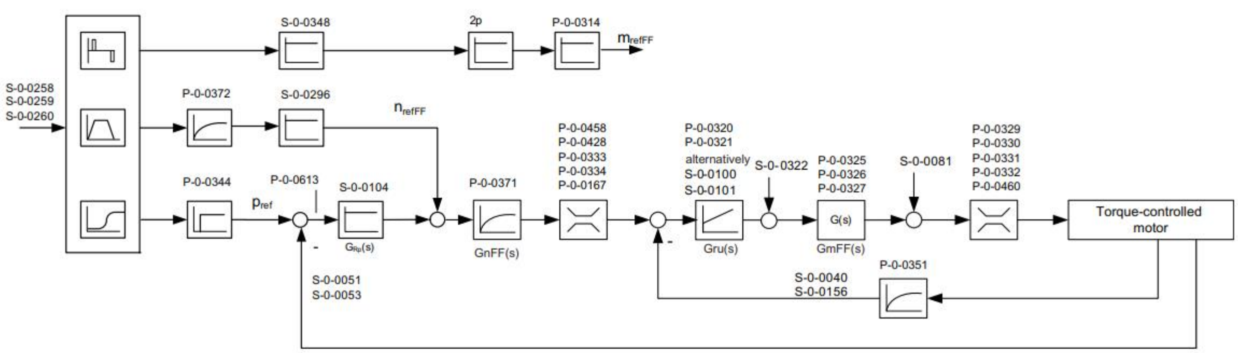


Legende: n_{cmd}: speed command
x_{cmd}: position command
x_{err}: position error command
x_{act}: actual position
T_{sc}: speed controller sampling time
T_{PC}: position controller sampling time ($=T_{CAC}$)
k_{PC}: position controller gain

10.4.1 Speed control loop and control parameters







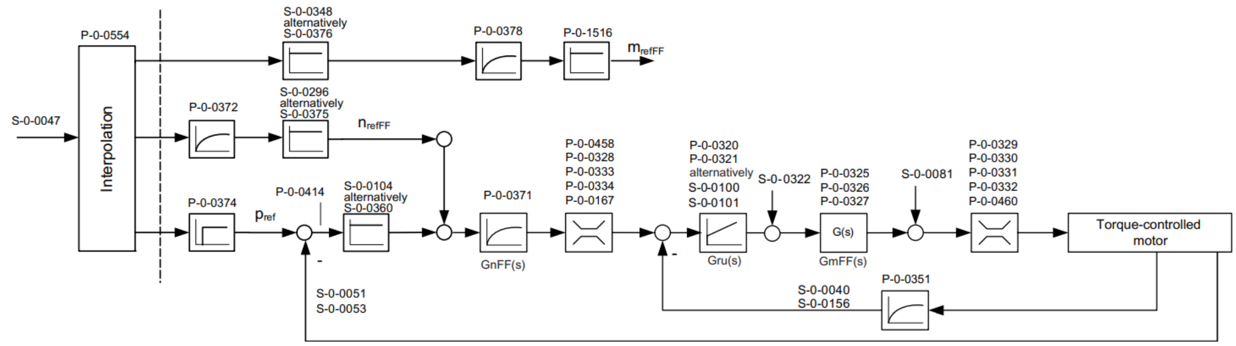


Figure 6.4 Schematic diagram of position control without tracking error with internal pre-control signals

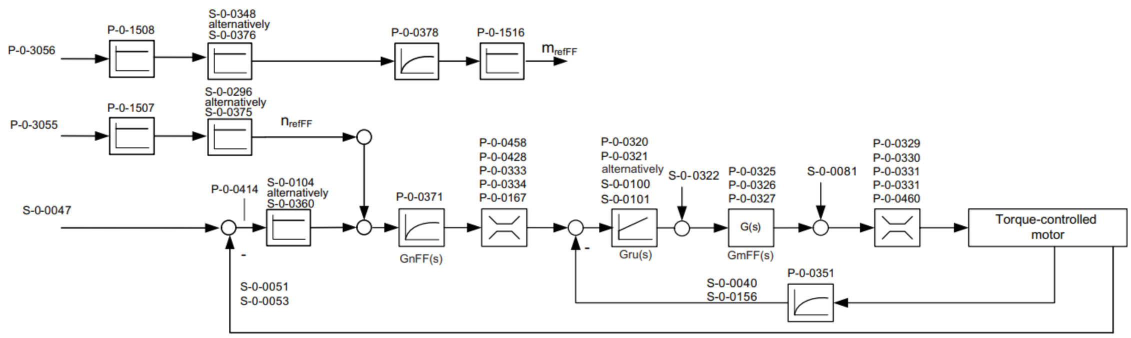


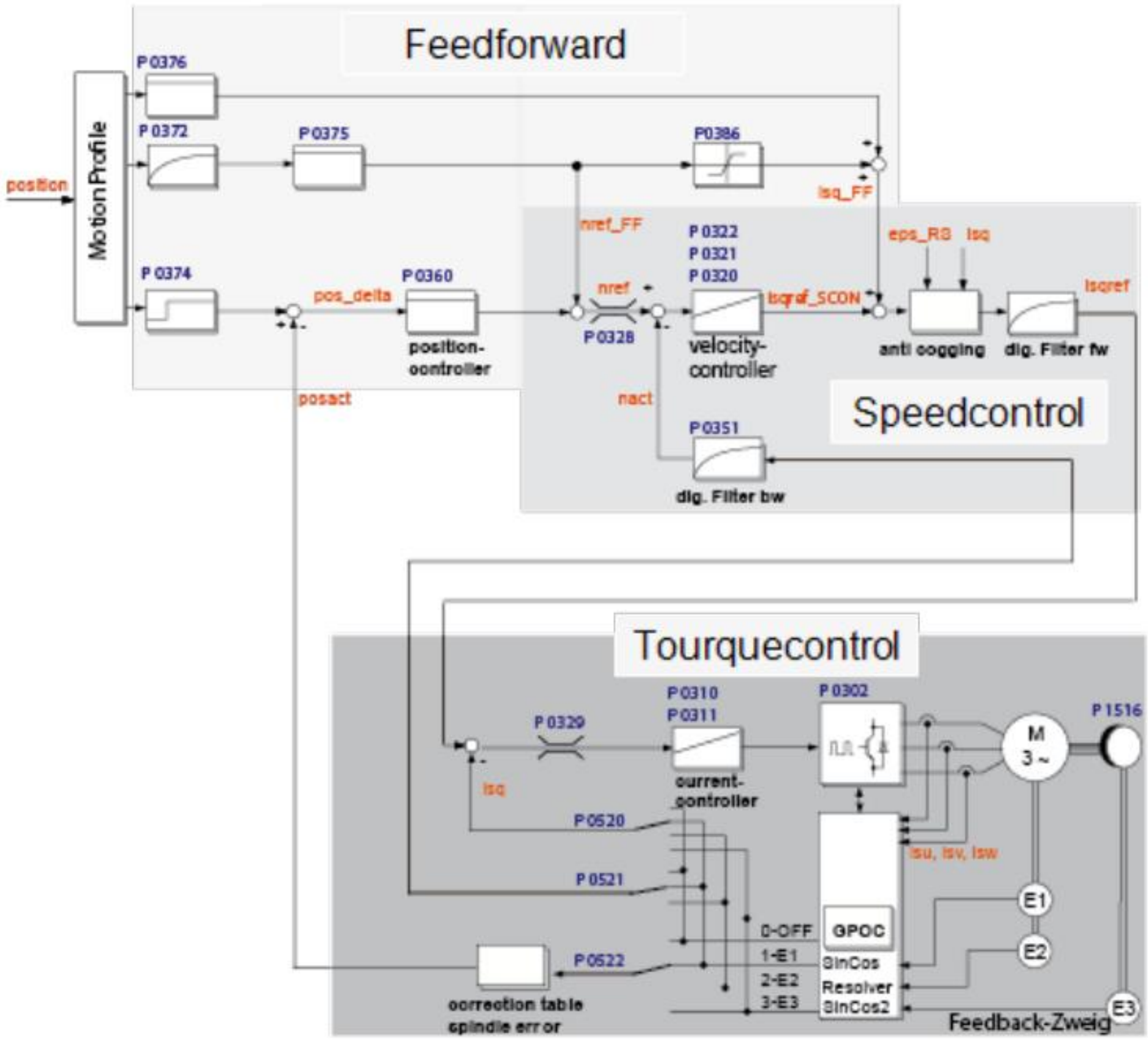
Figure 6.5 Schematic diagram of position control without tracking error with external pre-control signals

4.37 Encoder signal oversampling

Encoder signal oversampling optimizes the accuracy of resolver and Sin/Cos signals. Not applying asynchronous intermediate measurements leads to lesser rounding errors and a generally better quality of encoder signals.

Parameters

P. no.	Designation	Function
P 1956	CON_ACT_ Ovrs	Encoder signal oversampling. This function applies only to resolver and Sin/Cos signals
(0)	0	Oversampling disabled

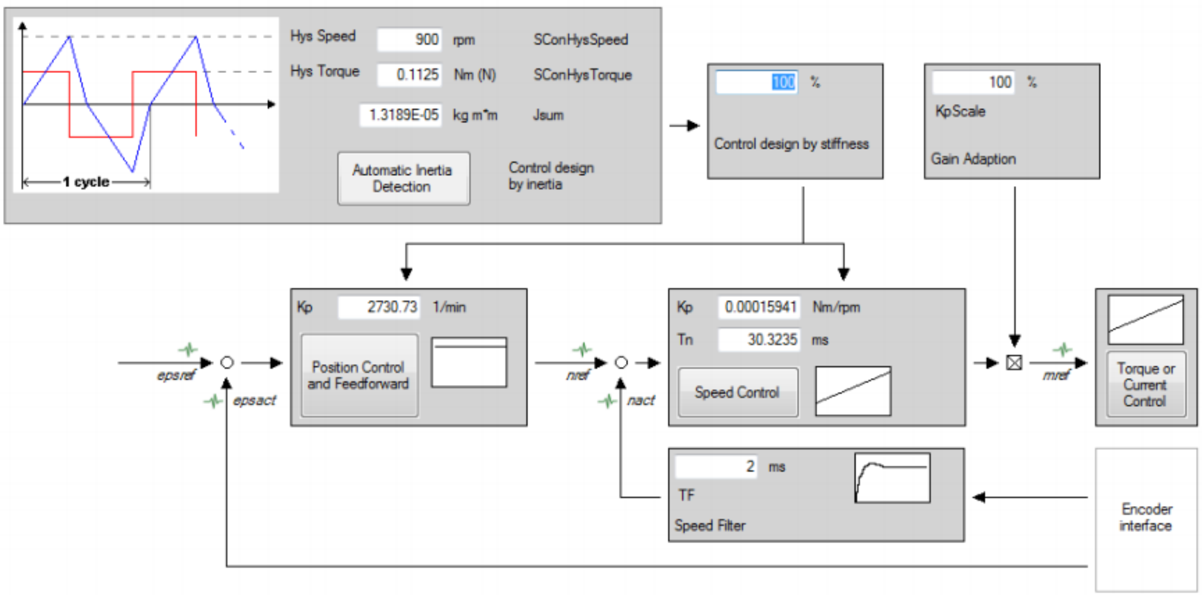


Sampling times of the individual control loops (switching frequency 8 kHz)

- Current/torque controller = 62.5 μs
- Speed controller = 125 μs
- Position controller = 125 μs

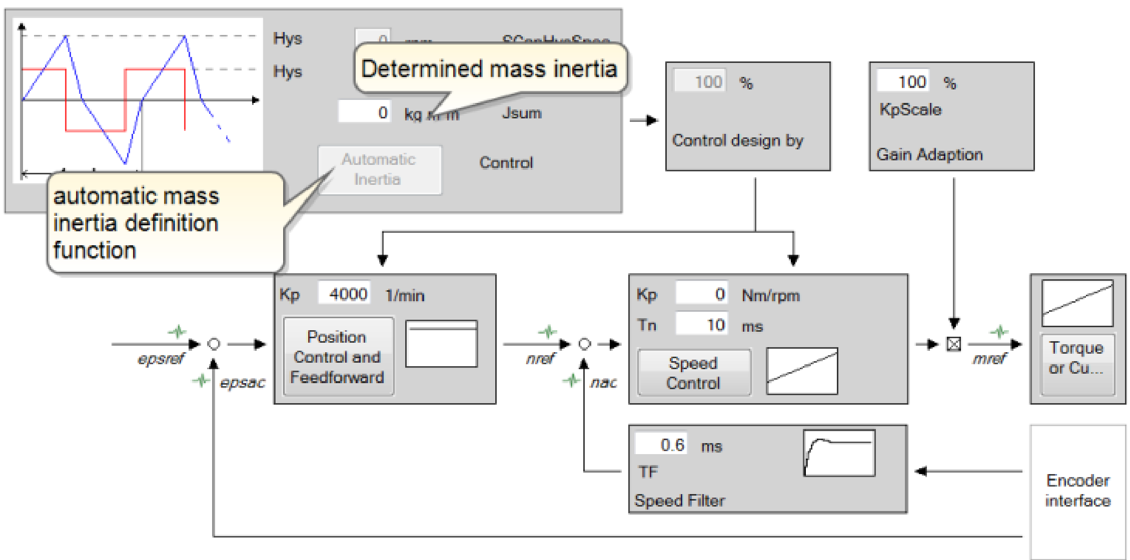
5.2.1 Motor control basic setting

Click on the "Basic settings" button opens the wizard to determine the mass inertia, the rigidity wizard, as well as the speed and position controllers.



5.3 Determining mass inertia

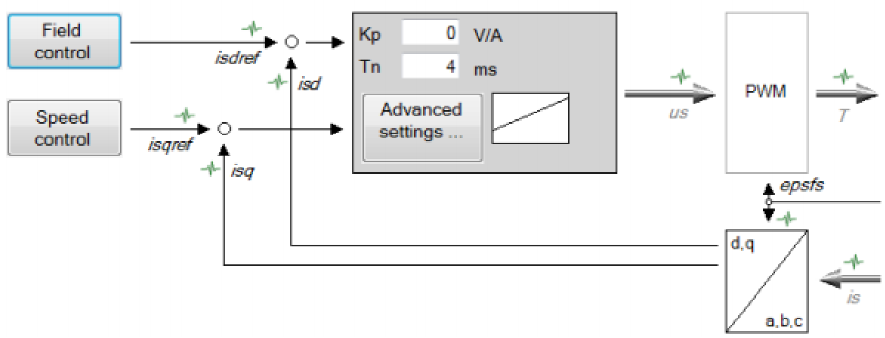
To define the mass inertia of a motor easily, the "automatic mass inertia definition" function is available. In the standard motor data set the speed controller is preset for a moderately stiff mechanism.
The automatic mass inertia definition function is started when the hardware has been enabled. Clicking the "Automatic Inertia Definition" button enters the latest value obtained in SCD_Jsum.

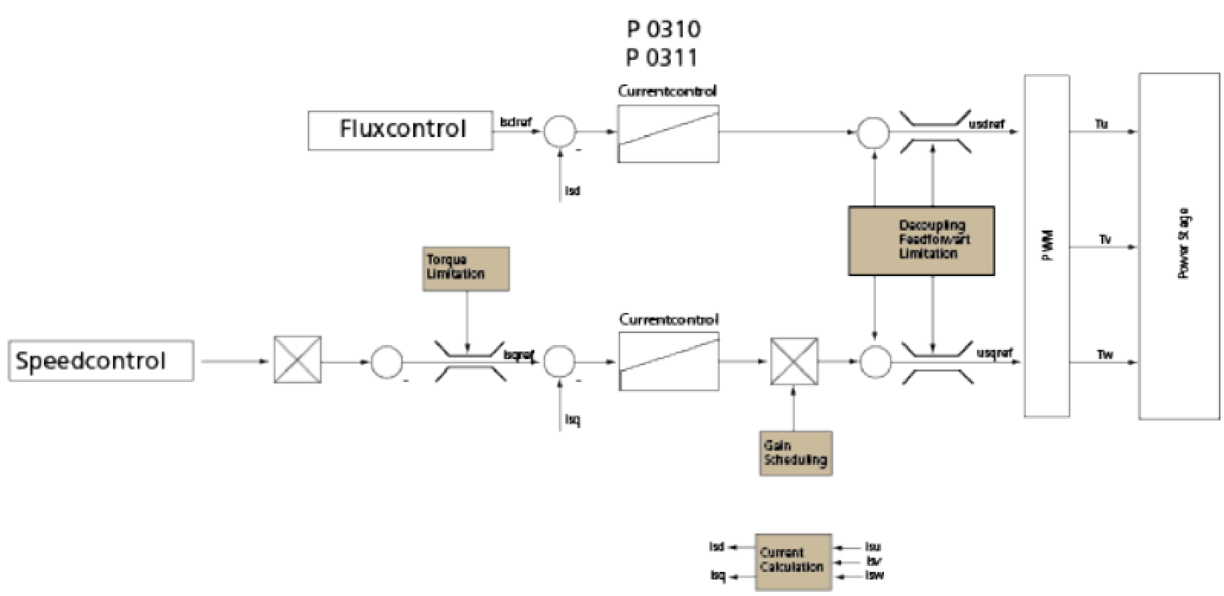


5.4.1 Current controller optimization

The torque controller is executed as a PI controller. The gain (P-component) and the integral-action time (I-component) of the individual controllers are programmable.
In order to optimize the current control loop, two rectangular reference steps are preset. The object of the optimization is a current controller with moderate dynamism and the following values:

- Current control time: = 1 ms
- Overshoot: < 5%



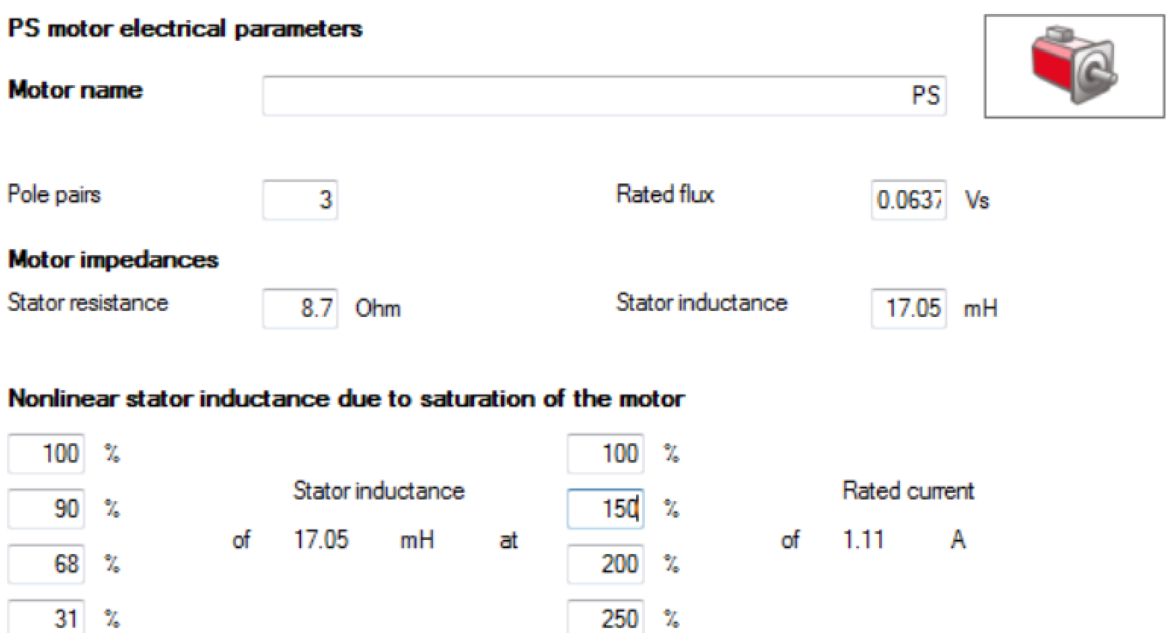


5.6 Adaptation of torque control

5.6.1 Saturation characteristic

In the overload range, saturation effects reduce the inductance of many motors. As a result, the current controller optimized to the rated current may oscillate or

become unstable. In this case the gain of the current controller should be adapted to the load case by way of four interpolation points. The values for the interpolation points are entered in the dialog box as a percentage of the rated current.
On the left are the inductance values, and on the right the values for the overload (> 100% of rated current).



5.12 Optimizing the speed controller

Speed controller setup dialog box

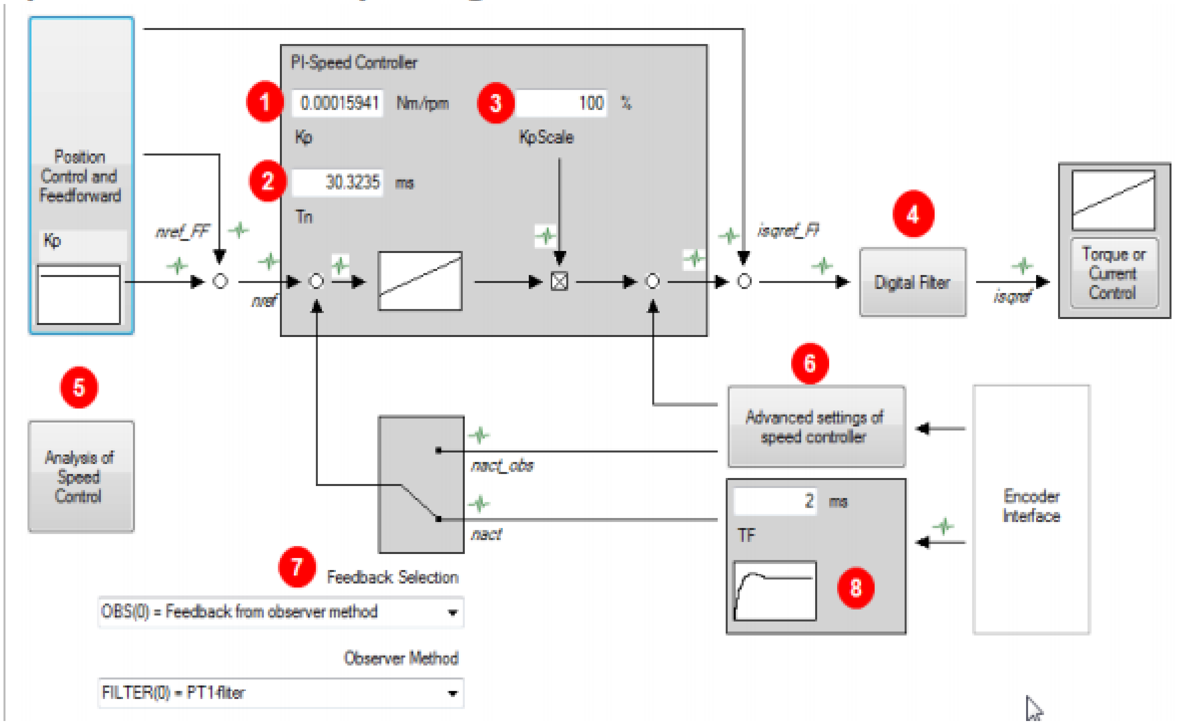


Bild 5.12.0.1 Speed controller setup dialog box

1	Gain (KP)
2	Integral-action time (I)
3	Scaling factor for gain
4	With these filters it is possible to filter noise in the actual speed value and increase the attenuation of resonance frequencies.

5.18 Position controller setup

The higher the dynamism of the speed controller, the more dynamically the position controller can be set and the tracking error minimized. The variables for the pre-control of the speed and position controller are additionally determined either from the change in reference values or alternatively are already calculated and outputted by the motion control. The time-related values for the position, speed and torque are transmitted to the drive control.
If the dynamic change in these values is within the limits which the drive is able to follow dynamically, the load on the controllers is significantly reduced. In order to improve the dynamism of the position controller, the following dialog box is provided to optimize the speed and acceleration pre-control.

Filters and scaling

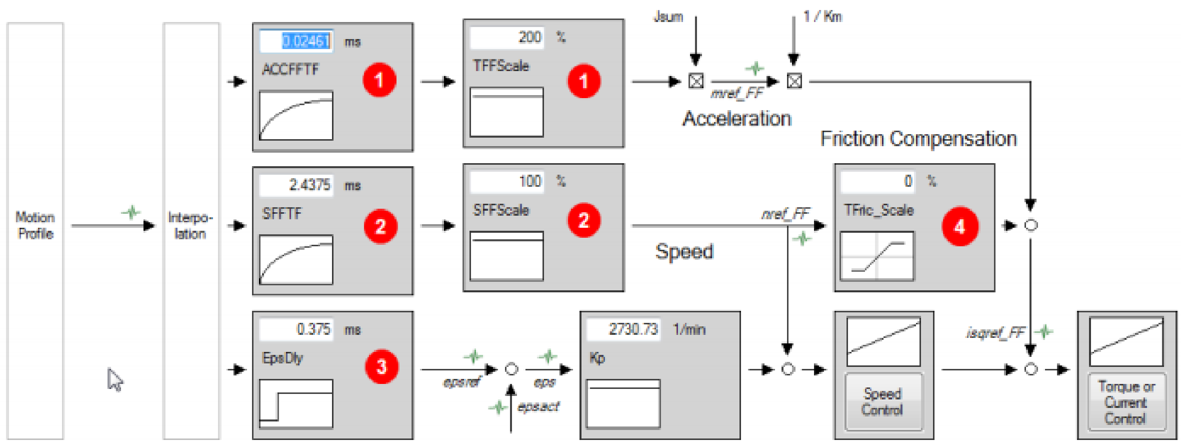


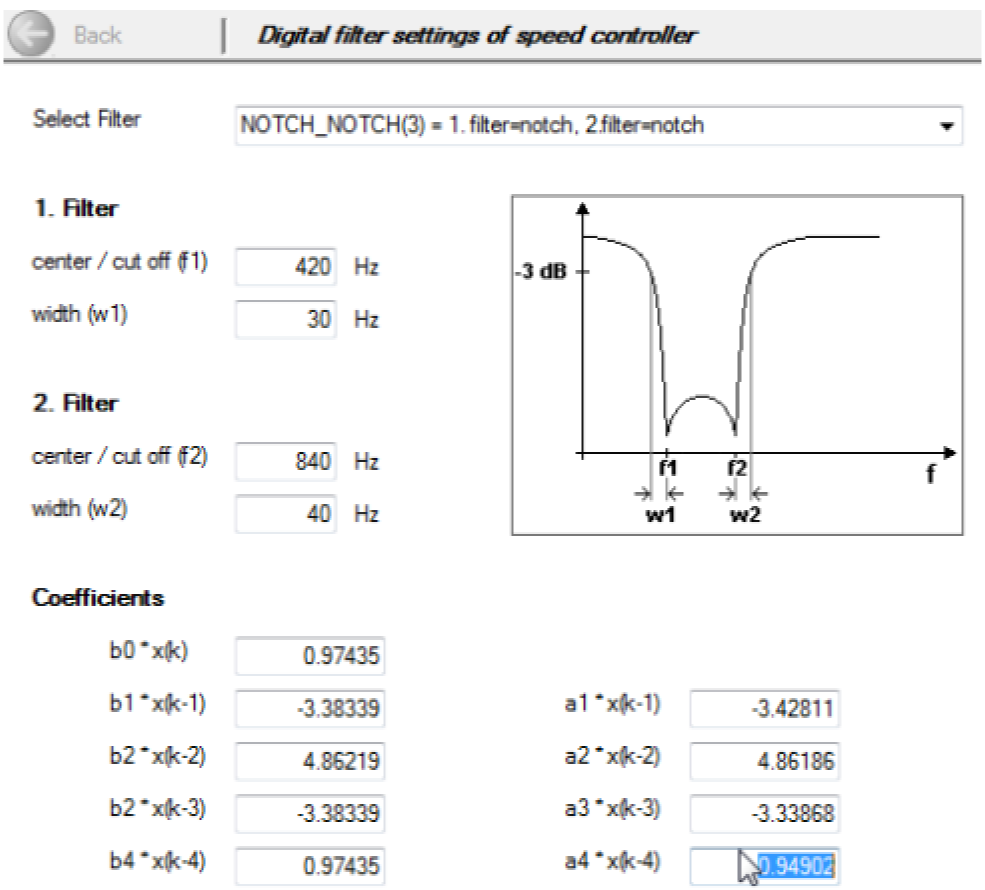
Bild 5.18.0.1 Pre-control dialog box

No.	Function
1	Delay time and scaling for torque pre-control
2	Delay time and scaling for speed pre-control
3	Delay time for position pre-control
4	Scaling of friction torque

5.14 Digital filters

5.14.1 Setting of filter combinations

To filter any noise on the actual speed value, or to damp resonance frequencies, various filter combinations can be used. A range of filter variants are available. The coefficients of the transfer function are automatically determined as soon as the values for the middle and limit frequency and the width have been entered.



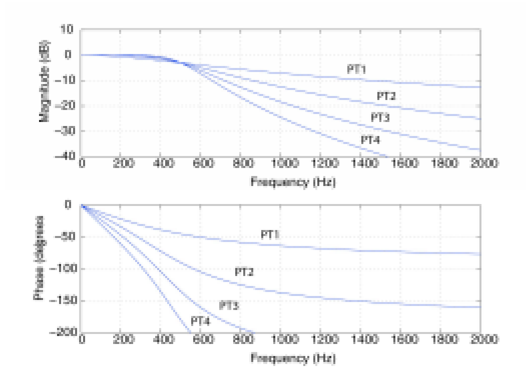
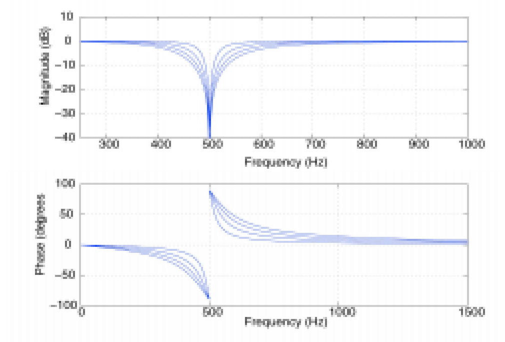
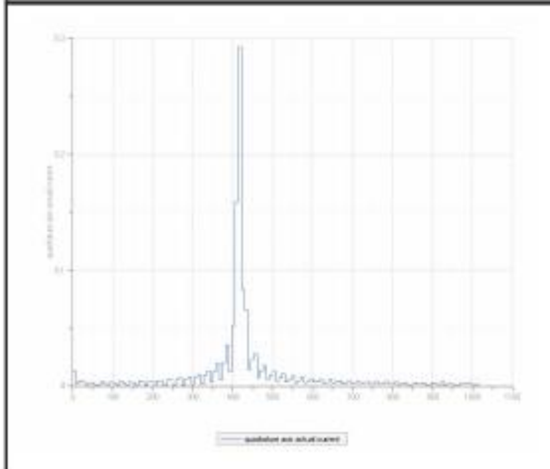
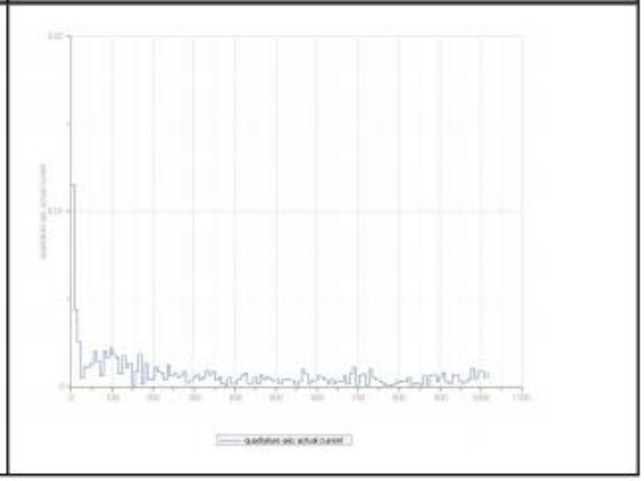
Bode diagrams PT1 to PT4	Phase response
	

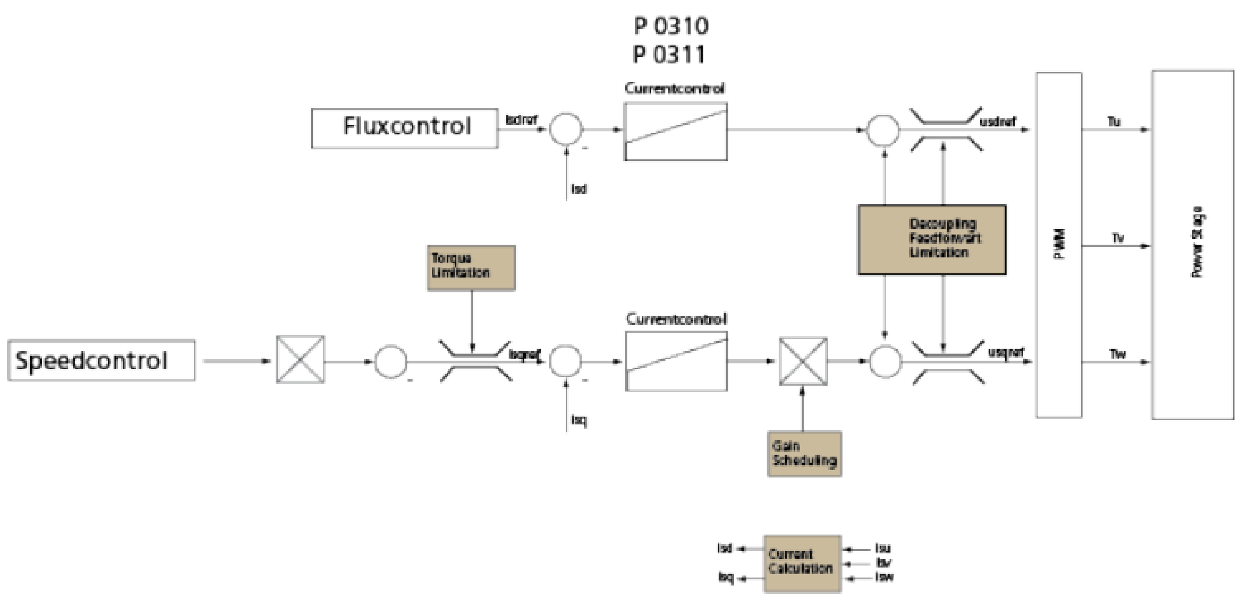
Bild 5.14.1.2 Bode diagrams PT1 to PT4

Parameters

P. no.	Parameter name	Function
P 0325	CON_ SCON_ FilterFreq	Limit frequencies
(0)	1 - 8000 Hz	Middle, limit frequency
(1)	1 - 8000 Hz	Width
(2)	1 - 8000 Hz	Middle, limit frequency
(3)	1 - 8000 Hz	Width
P 0326	CON_ SCON_ FilterAssi	Filter selector
(0)	Off	No filter active

P. no.	Parameter name	Function
(1)	USER	Manual writing of filter coefficients
(2)	Notch	Selection of a notch filter with the limit frequency from **P 0325(0) CON_SCON_FilterFreq** and the bandwidth from **P 0325(1)**.
(3)	Notch_ Notch	Selection of a notch filter with the limit frequency from **P 0325(0)** and bandwidth from **P 0325(1)** in series with a notch filter with the limit frequency from**P 0325(2)** and bandwidth from**P 0325(3)**
(4)	Notch_PT1	NOTCH_PT1(4) and NOTCH_PT2(5): A notch filter with the blocking frequency in **P 0325(0)** and bandwidth in **P 0325(1)** in series with a low-pass filter with limit frequency in **P 0325(2)**.
(5)	Notch_PT2	
(6)	PT1	PT1(6), PT2(7), PT3(8), PT4(9): A low-pass filter with the limit frequency in **P 0325(2)**At lower frequencies higher-order filters (PT3, PT4) should not be used.
(7)	PT2	
(8)	PT3	
(9)	PT4	
P 0327	CON_ SCON_ FilterPara	Coefficients of the digital filter

FFT without filtering	FFT with filtering
	



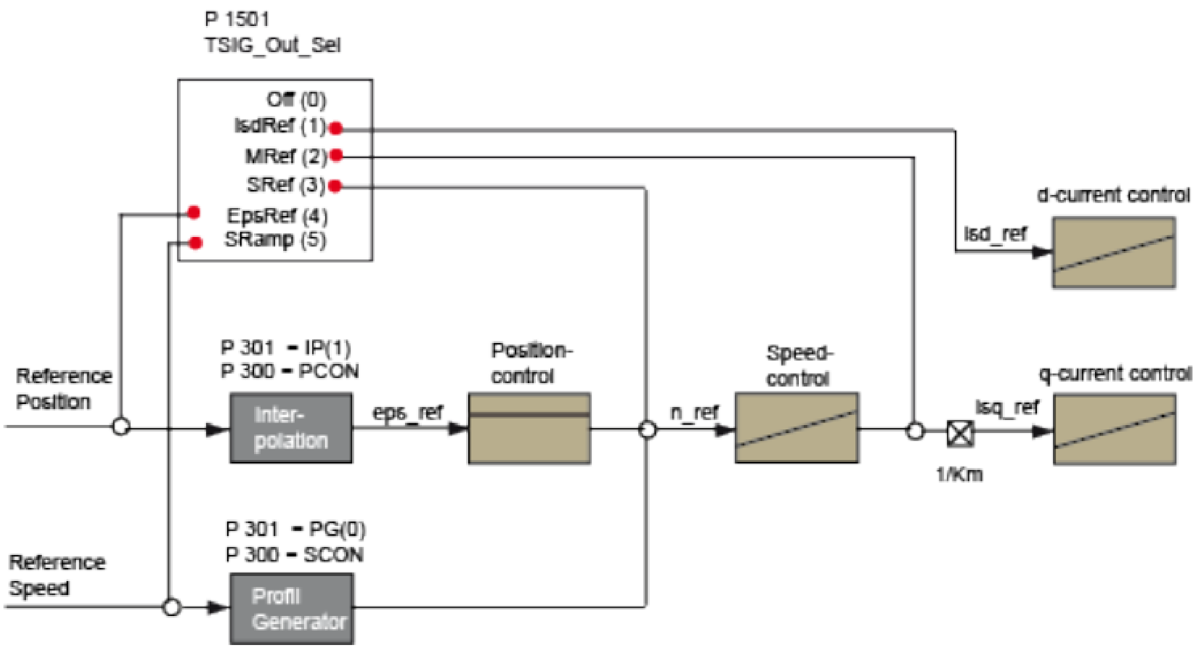


Bild 5.11.2.2 TSIG output: Signal curve of TG

5.19 Friction torque compensation

Compensation of friction components dependent on reference speed
It is advisable to compensate for higher friction torques, in order to minimize tracking error when reversing the speed of the axle. The servo drive enables compensation of friction components dependent on the reference speed "nref_ FF". The speed controller can compensate for viscous friction components because of their lower change dynamism. The compensation can be effected step-by-step as a percentage of the rated motor torque by means of **P 0386 CON_SCON_TFric**. Below **P 0387 CON_SCON_TFricZeroSpeed** the compensation is reduced by way of an internal ramp.

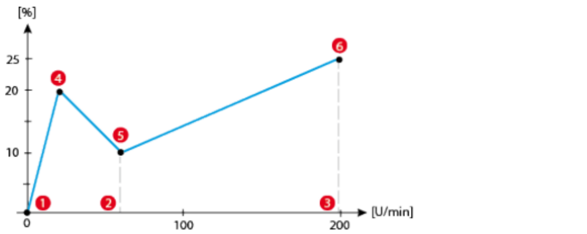


Bild 5.19.0.1 Friction curve with high static friction

Method: Friction torque compensation

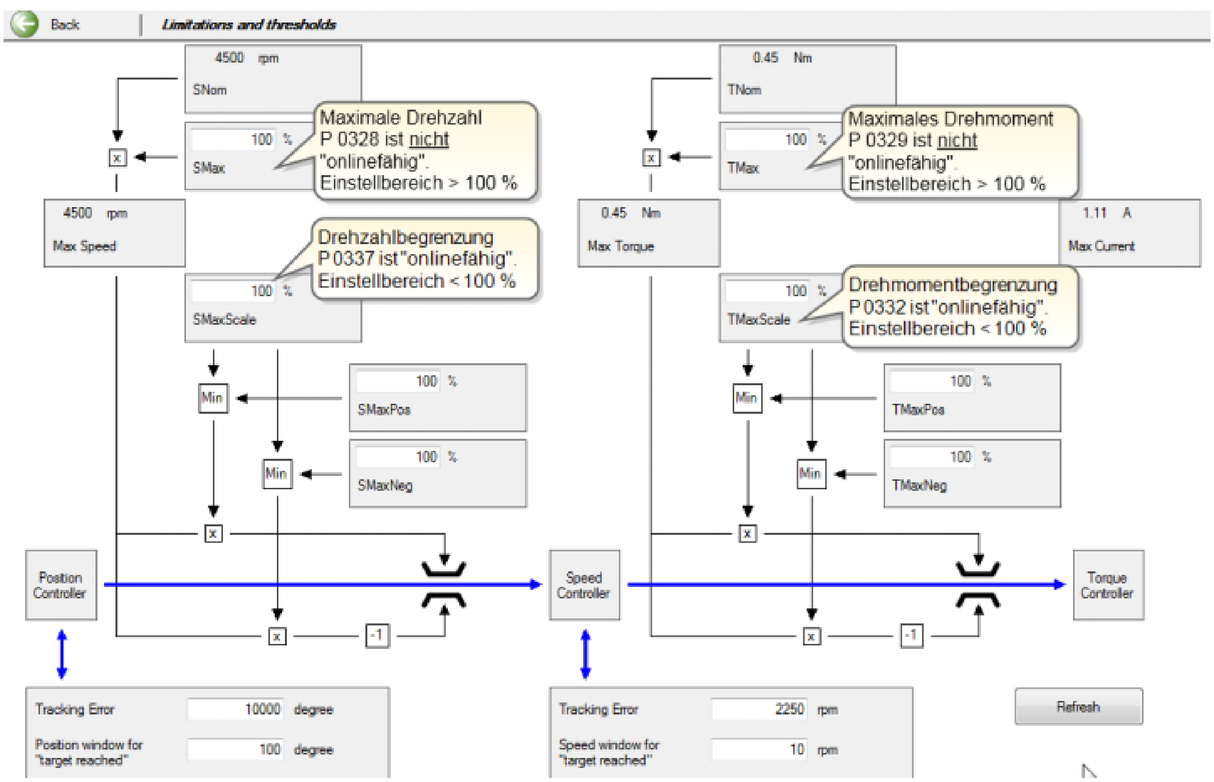
- Execute a fast movement
- Friction torque compensation via **P 0386(0), (1), (2)** "Friction torque compensation, scaled to the motor rated torque"
- Standstill window via **P 0387(0), (1), (2)** "Friction torque compensation, speed limitation"
- Observe tracking error

Scope setting:

- Pre-control:
  Reference torque with pre-control mref_FF
  Actual torque mact or
  Reference current isqref_FF
  Actual current isq
- Tracking error
  MPRO_FG_UsrPosDiff

Parameters for representation of the curve:

No.	P. no.	rpm
1	P 0387 CON_SCON_TFricSpeed (0)	5 rpm
2	P 0387 CON_SCON_TFricSpeed (1)	35 rpm
3	P 0387 CON_SCON_TFricSpeed (2)	200 rpm
4	P 0386 CON_SCON_TFric (0)	20%
5	P 0386 CON_SCON_TFric (1)	-10%
6	P 0386 CON_SCON_TFric (2)	15%



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7.2.1 Adjustment of the gain of the position loop

The position control block diagram of the SV-DA200 series servo drive is shown in the figure below.

The gain parameters that can be adjusted in the position mode are marked out on the block diagram.

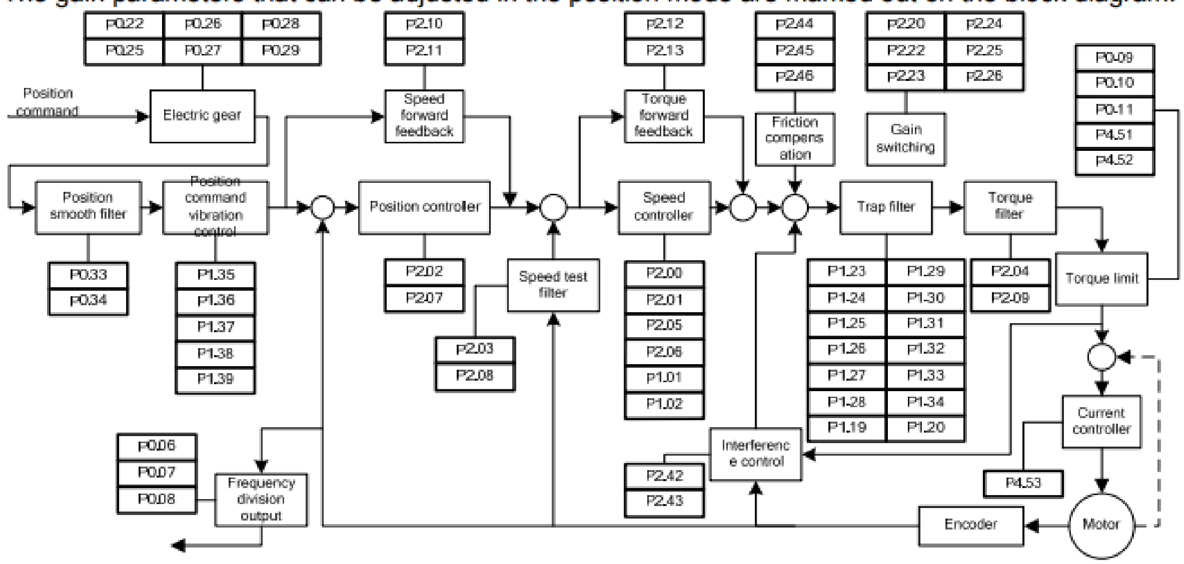

Fig. 7-1 Block diagram of position control

The general procedures for parameter adjustment in the position mode are:

1) Initial setting of the parameters

The defaults of the parameters can be recovered by the default parameter recovering operation (see chapter 5.2.4 for details).

2) Adjustment of the gain of the position loop

When the servo motor is running with default parameters, if the system oscillation occurs with buzz, the position gain(P2.02, P2.07) should be adjusted smaller. If the system rigidity is relatively small, the position gain should be adjusted larger.

3) Adjustment of the position smoothing filter

During position control, if the position pulse commands input frequency varies largely, it may be caused by a larger impulse. At this time the position smoothing filters time constant(P0.33) or position command FIR filter (P0.34) should be adjusted to moderate the impulse.

4) Adjustment of the electronic gear

If the pulse transmission frequency of the pulse generator is restricted, or the transmission frequency does not meet the mechanical requirements, we can change the pulse input frequency by adjusting the value of the electronic gear parameters (P0.25, P0.26, P0.27, P0.28 and P0.29) to meet the requirements for position control.

5) Adjustment of position feed-forward

In the case the retention pulse is large or fault-free follow-up is required, we can improve the position follow-up performance by adjusting the speed feed-forward gain parameter (P2.10) and speed feed-forward gain filter parameter (P2.11).However, it should be noted that if the speed feed-forward gain is too large, it may cause system oscillation.

6) Frequency division of the feedback pulse output

If the feedback pulse needs to be outputted, the frequency division coefficient of pulse output (P0.06, P0.07) can be used to change the frequency of the output pulse.

7.2.2 Adjustment of the gain of the speed loop

The speed control block diagram of the SV-DA200 series servo drive is shown in the figure below.

The gain parameters that can be adjusted in the speed mode are marked on the block diagram.

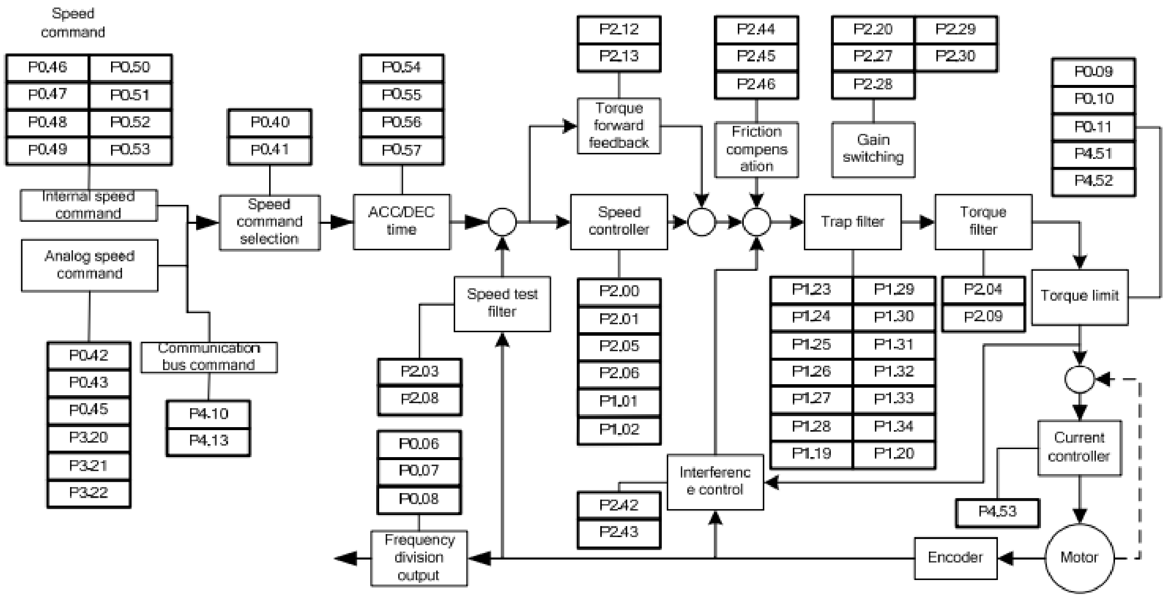

Fig. 7-2 Block diagram of speed control

The general procedures for parameter adjustment in the speed mode are:

1) Initial setting of the parameters

The defaults of the parameters can be recovered by the default parameter recovering operation (see chapter 5.2.4 for details).

2) Adjustment of the gain of the speed loop

When the servo motor is running with default parameters, if the system oscillation occurs with buzz, the speed gain (P2.00, P2.05) should be adjusted smaller. If the system rigidity is relatively small or the speed fluctuates largely, the speed gain should be adjusted larger.

3) Adjustment of the speed integration time constant

When the gain of the speed loop is increased, the speed integration time constant (P2.01, P2.06) should be increased at the same time. Similarly, when the gain of the speed loop is decreased, the speed integration time constant should be decreased at the same time.

4) Adjustment of the ACC/DEC time

If the speed varies violently during starting, it may cause large impulse or even overcurrent. At this time we adjust the ACC time (P0.54) to smoothen the speed rise. Similarly, we can adjust the DEC time (P0.55) to smoothen the speed fall during stopping.

5) S curve ACC/DEC adjustment

If the requirement for smooth variation of speed cannot be met by adjusting the ACC/DEC time, we can adjust the S curve ACC/DEC time (P0.56, P0.57) to make it change more smoothly.

6) Adjustment of the speed smoothing filter

In the case where the analog speed command is inputted, we can adjust the analog speed command filter (P3.21) to make the speed change smoothly.

7) Adjustment of torque feed-forward

If the speed follow-up performance is still poor after above parameter adjustment, we can adjust the torque feed-forward gain (P2.12) and torque forward feedback filter time (P2.13) to improve the speed follow-up performance. It should be noted however that too large torque feed-forward gain may affect the stability of the system.

8) Adjustment of speed filter

The performance of the speed loop can be improved by adjusting P2.04/P2.09 and P2.03/P2.08.

9) Adjustment of notch filtering

Refer to chapter 7.2.

10) Frequency division of the feedback pulse output

If the feedback pulse of the encoder needs to be outputted, the frequency division output coefficient (P0.06, P0.07) can be used to change the frequency of the output pulse.

11) Interference control adjustment

If the gain is small, the load changes or there is sudden external interference torque, it can adjust P2.42 and P2.43 to reduce the interference and improve the performance.

12) Friction compensation adjustment

If the following performance of the motor is bad during the direction changing of forward and reverse rotation, it can adjust P2.45 and P2.46 to improve the performance.

7.2.3 Adjustment of the gain of the torque loop

The torque control block diagram of the SV-DA200 series servo drive is shown in the figure below. The gain parameters that can be adjusted in the torque mode are marked out on the block diagram.

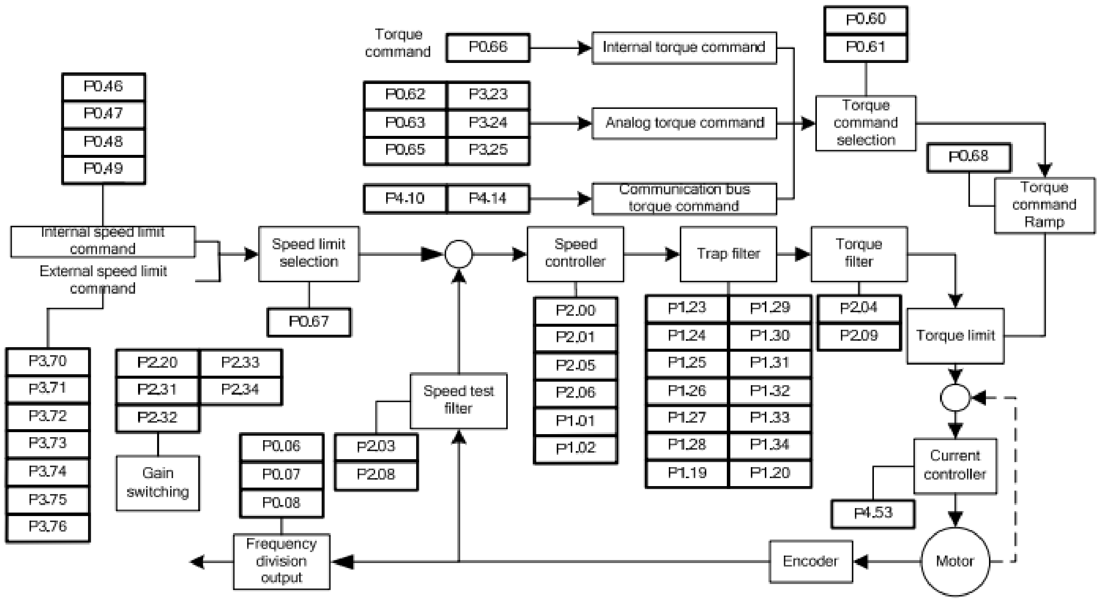

Fig. 7-3 Block diagram of torque control

The general procedures for parameter adjustment in the torque mode are:

1) Initial setting of the parameters

The defaults of the parameters can be recovered by the default parameter recovering operation (see chapter 5.2.4 for details).

2) Adjustment of the torque smoothing filter

In the case the analog torque command is inputted, we can adjust the torque smoothing filter time constant to make the torque change smoothly.

3) Frequency division of the feedback pulse output

If the feedback pulse of the encoder needs to be outputted, the frequency division coefficient of pulse output can be used to change the frequency of the output pulse.

7.2.4 Full closed loop gain adjustment

The gain parameters which can be adjusted are listed as the figure below:

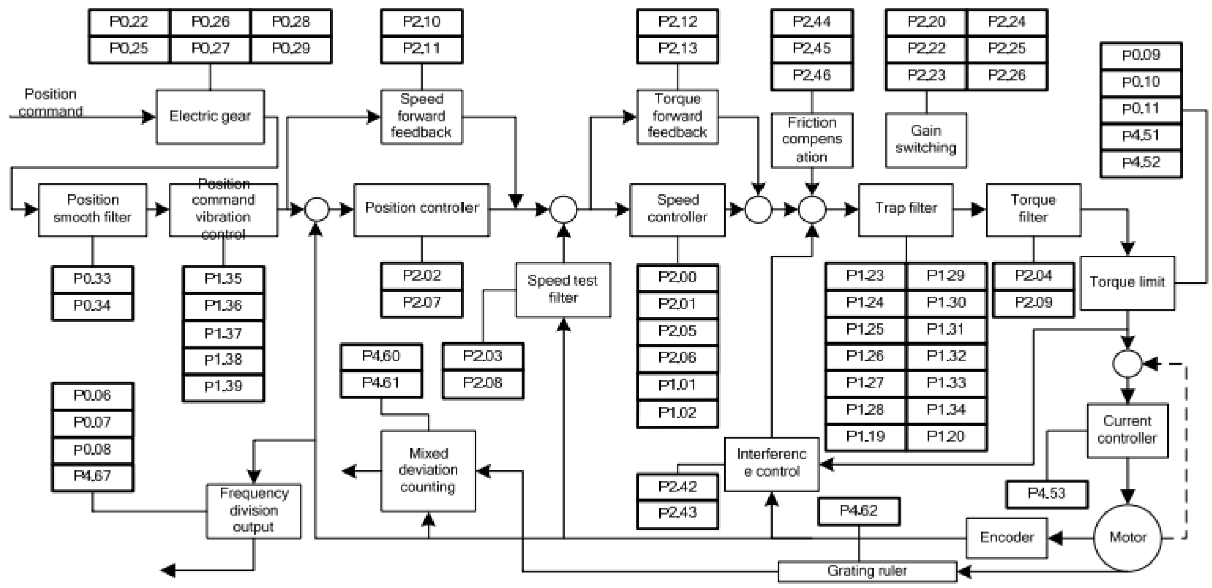

Figure 7-4 Block diagram of Full closed loop

Refer to the adjustment steps of position mode in section 7.2.1.

7.3 Suppression of mechanical resonance

The mechanical system has a certain resonant frequency. If the response speed of the servo is improved, the system may resonate (oscillation and abnormal noise) near the mechanical resonant frequency. The resonance of the mechanical system can be effectively suppressed by setting the parameters of the notch filters.

The notch filters achieve the goal of suppressing mechanical resonance by decreasing the gain of certain frequency. We can set the frequency to be suppressed as well as the suppression extent with relevant parameters.

This servo drive is equipped with four notch filters which can be set by the 1st notch filter parameter (P1.23, P1.24, P1.25), 2nd notch filter parameter (P1.26, P1.27, P1.28),,3rd notch filter parameter (P1.29, P1.30, P1.31) and 4th notch filter parameter (P1.32, P1.33, P1.34). The 1st and 2nd notch filter parameters need to be set manually; the 3rd and 4th notch filter parameters can be set by online self-adaption. The position of notch filter in speed loop is shown in fig. 7-2.

Note:

The notch filter is the lag factor for the servo system, so, if the center frequency of control width is large, the vibration may be strengthened. It is recommended to increase the width unit it meets the requirements.

The relationship between the Q value, width and depth:

Q value of the notch wave =center frequency of the notch wave /width of the notch wave

If the width of the notch is 0, the width of the filter is the deviation between two frequencies when the power of the center frequency drops to -3dB.

The width of the filter means the ratio of input and output, and the intensity attenuation 20log (P1.25%, P1.28%, P1.31%, P1.34%) dB.

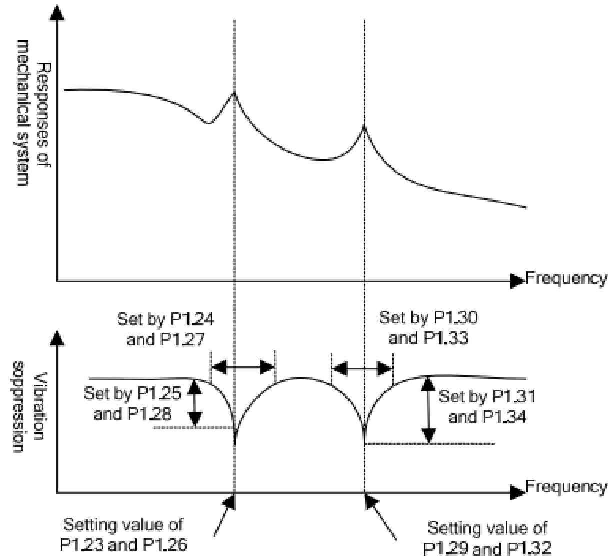

Figure 7-5 Schematic diagram of setting of the trap wave filters

7.4 Gain switching function

Gain switching operation is performed through internal data or external signal:

1) Can switch to lower gain to suppress vibration in the state when the motor is stopped;

2) Can switch to higher gain to shorten the positioning time in the state the motor is stop;

3) Can switch to high gain to obtain better command follow-up performance in the state when the motor is running.

4) Can switch between different gain settings through external signal according to the conditions of load, equipment and so on.

●Position control and full closed loop control (●: valid, —: invalid)

Condition setting of gain switching			Parameters setting of position control and full close loop control mode		
P2.22	Switch to the 2nd gain	Figure	Delay time*1	Level	Lag*2
			P2.23	P2.24	P2.25
0	Fixed on the 1st gain		-	-	-
1	Fixed on the 2nd gain		-	-	-
2	Gain switch input		-	-	-
3	Torque command	1	●	●(0.1%)	●(0.1%)
4	Speed command	3	●	●(r/min)	●(r/min)
5	Position deviation	4	●	●*3(pulse)	●*3(pulse)

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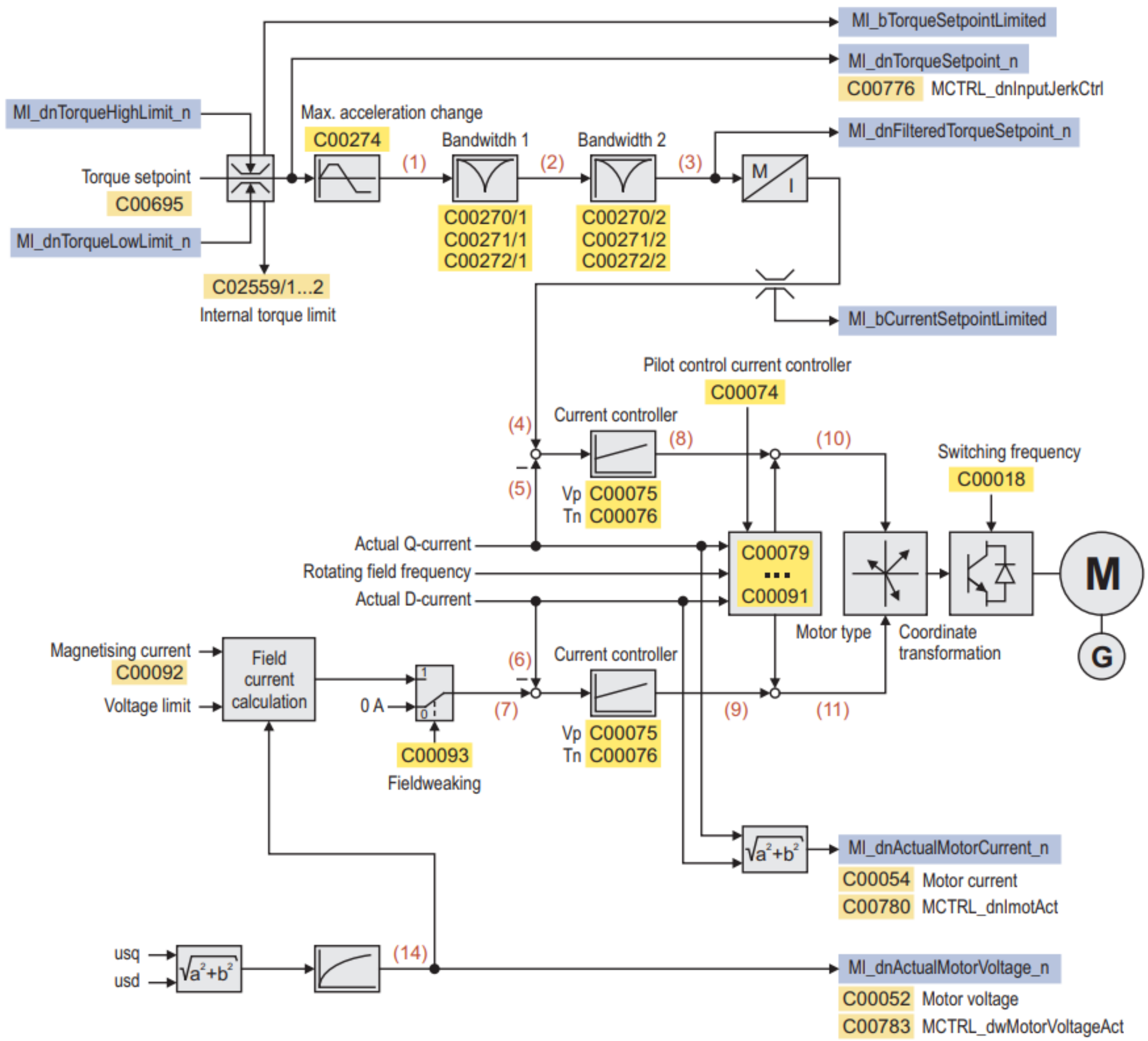
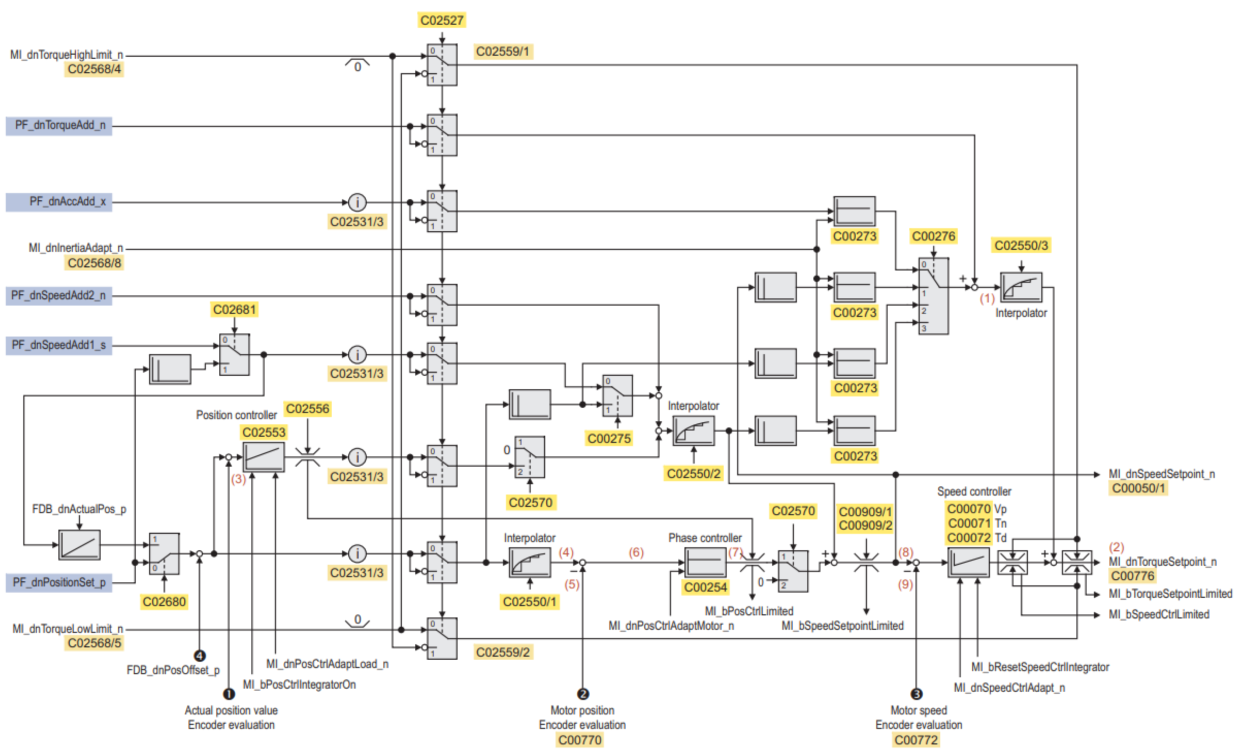

MI_bTorqueSetpointLimited
MI_dnTorqueSetpoint_n
C00776 MCTRL_dnInputJerkCtrl
MI_dnTorqueHighLimit_n
Max. acceleration change
C00274
Bandwitdh 1
Bandwidth 2
MI_dnFilteredTorqueSetpoint_n
Torque setpoint
C00695
(1)
(2)
(3)
M / I
MI_dnTorqueLowLimit_n
C00270/1
C00271/1
C00272/1
C00270/2
C00271/2
C00272/2
C02559/1...2
Internal torque limit
MI_bCurrentSetpointLimited
Pilot control current controller
C00074
Current controller
(4)
(8)
(10)
Switching frequency
C00018
(5)
Vp C00075
Tn C00076
Actual Q-current
Rotating field frequency
Actual D-current
C00079
...
C00091
M
Motor type
Coordinate transformation
G
Magnetising current
C00092
Field current calculation
Voltage limit
0 A
(6)
Current controller
(7)
(9)
(11)
Vp C00075
Tn C00076
C00093
Fieldweaking
MI_dnActualMotorCurrent_n
C00054 Motor current
C00780 MCTRL_dnImotAct
usq
usd
(14)
MI_dnActualMotorVoltage_n
C00052 Motor voltage
C00783 MCTRL_dwMotorVoltageAct

No.	Variable of the motor control	Meaning
(1)	Torque.dnInputNotchFilter1	Torque setpoint at the band-stop filter input 1
(2)	Torque.dnInputNotchFilter2	Torque setpoint at the band-stop filter 2 input
(3)	Torque.dnFilteredTorqueSetpoint	Filtered torque setpoint
(4)	Current.dnQuadratureCurrentSet	Q current setpoint
(5)	Current.dnActualQuadratureCurrent	Actual Q current
(6)	Current.dnActualDirectCurrent	Actual D current
(7)	Current.dnDirectCurrentSet	D current setpoint
(8)	Voltage.dnOutputQuadratureCurrentCtrl	Q-output voltage of the current controller
(9)	Voltage.dnOutputDirectCurrentCtrl	D-output voltage of the current controller
(10)	Voltage.dnQuadratureVoltage	Q voltage
(11)	Voltage.dnDirectVoltage	D voltage
(12)	-	
(13)	-	
(14)	Voltage.dnActualMotorVoltage	Current motor voltage



No.	Variable of the motor control	Meaning
(1)	Torque.dnTotalTorqueAdd	Additive torque feedforward control value
(2)	Torque.dnTorqueSetpoint	Torque setpoint
(3)	Position.dnActualLoadPos	Actual position
(4)	Position.dnPositionSetpoint	Position setpoint
(5)	Position.dnActualMotorPos	Current motor position
(6)	Position.dnContouringError	Following error
(7)	Speed.dnOutputPosCtrl	Output signal - phase controller
(8)	Speed.dnSpeedSetpoint	Speed setpoint
(9)	Speed.dnActualMotorSpeed	Current motor speed

Operating principle

Unlike the motor control known from the 9300 and ECS, the motor control of the 9400 HighLine servo controllers allows you to use two current setpoint filters (notch filters). In the signal flow, you can find the notch filters between speed and current controller:

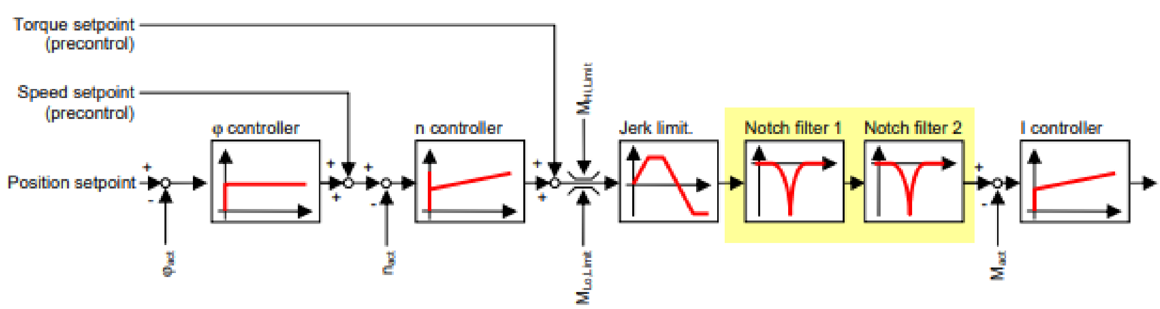


Fig. 1: **Notch filter position in the signal flow of the motor control**

Example:

The natural frequency of a drive system consisting of motor and feedback system is approx. 142[Hz][1].

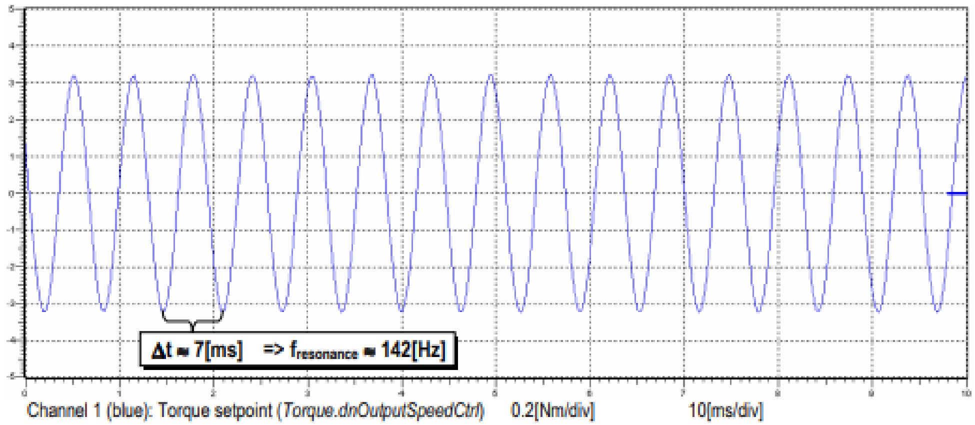


Fig. 2: Natural frequency in the motor torque characteristic without notch filter

Measurements have shown that an attenuation at ±20.0[Hz] by the resonant frequency will already at least lead to a 50% reduction of the torque setpoint (-3[dB]).
What settings must be selected for the notch filter to prevent excitations in the resonant frequency range?

Based on the above requirements, the following code values have to be selected:

=> Centre frequency of notch filter: C0270/1 = 142.0[Hz]
=> Notch filter width: C0271/1 = 40.0[Hz]
=> Notch filter attenuation: C0272/1 = 3.0[dB]

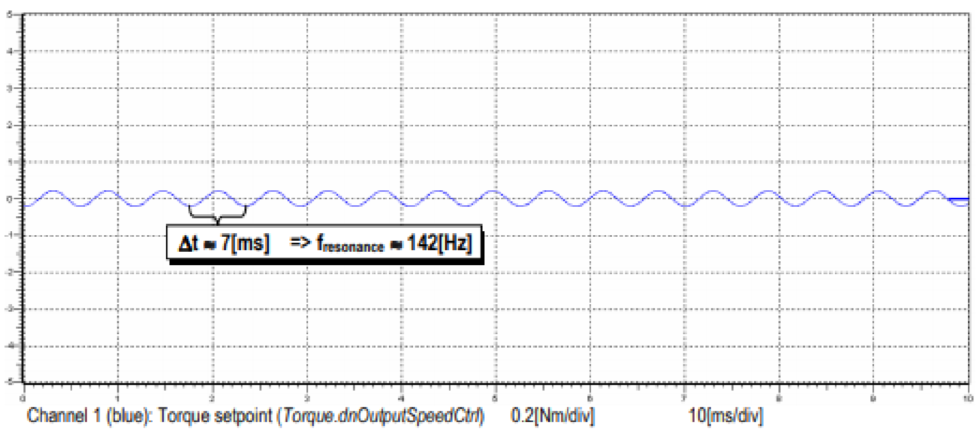


Fig. 3: Natural frequency in the motor torque characteristic with notch filter

From the measurement with activated notch filter you can clearly see the effectiveness of the notch filter. In many cases, the behaviour of speed and position controller can even be improved much further with optimum notch filter settings.

In the Bode plot, the amplitude and frequency response of the notch filter are as follows:

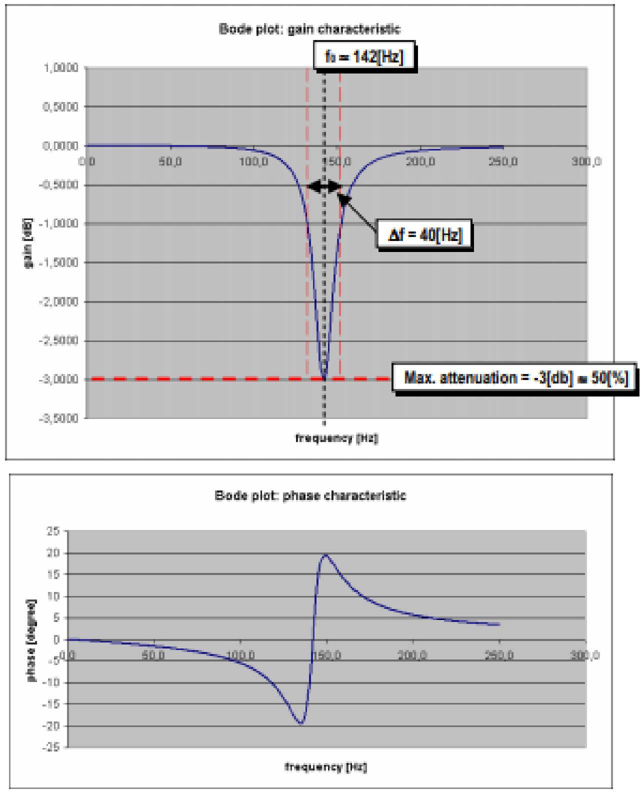


Fig. 4: **Amplitude and frequency response of notch filter (2nd-order filter)**

Note: The general transfer function of the notch filter is:

$$K_S(s) = \frac{\omega_0^2 + P \cdot \omega_b \cdot s + s^2}{\omega_0^2 + \omega_b \cdot s + s^2}$$

with:

Centre frequency	$\omega_0 = 2 \cdot \pi \cdot f_0$	$= 2 \cdot \pi \cdot$C0270/x
Bandwidth	$\omega_b = 2 \cdot \pi \cdot f_b$	$= 2 \cdot \pi \cdot$C0271/x
Maximum attenuation	P	= C0272/x

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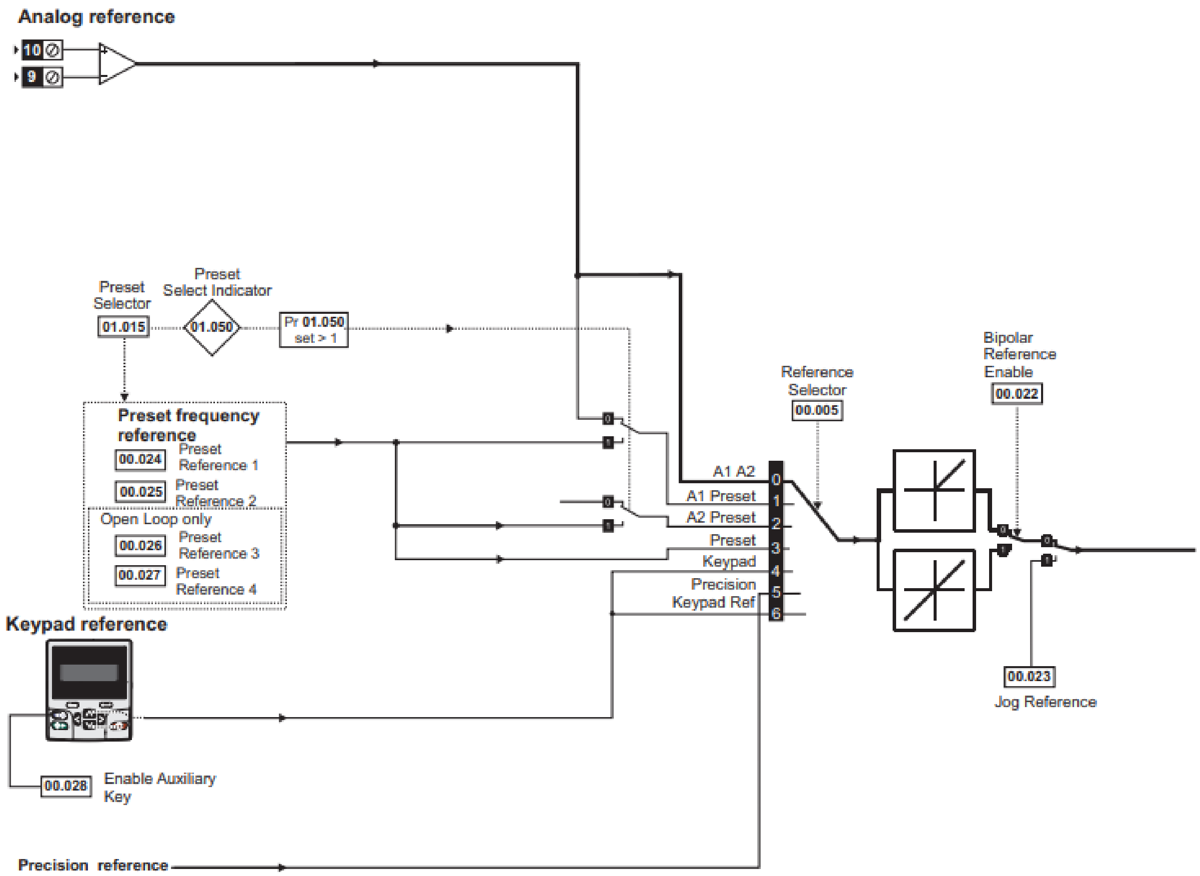
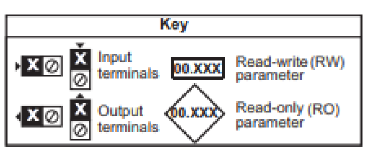
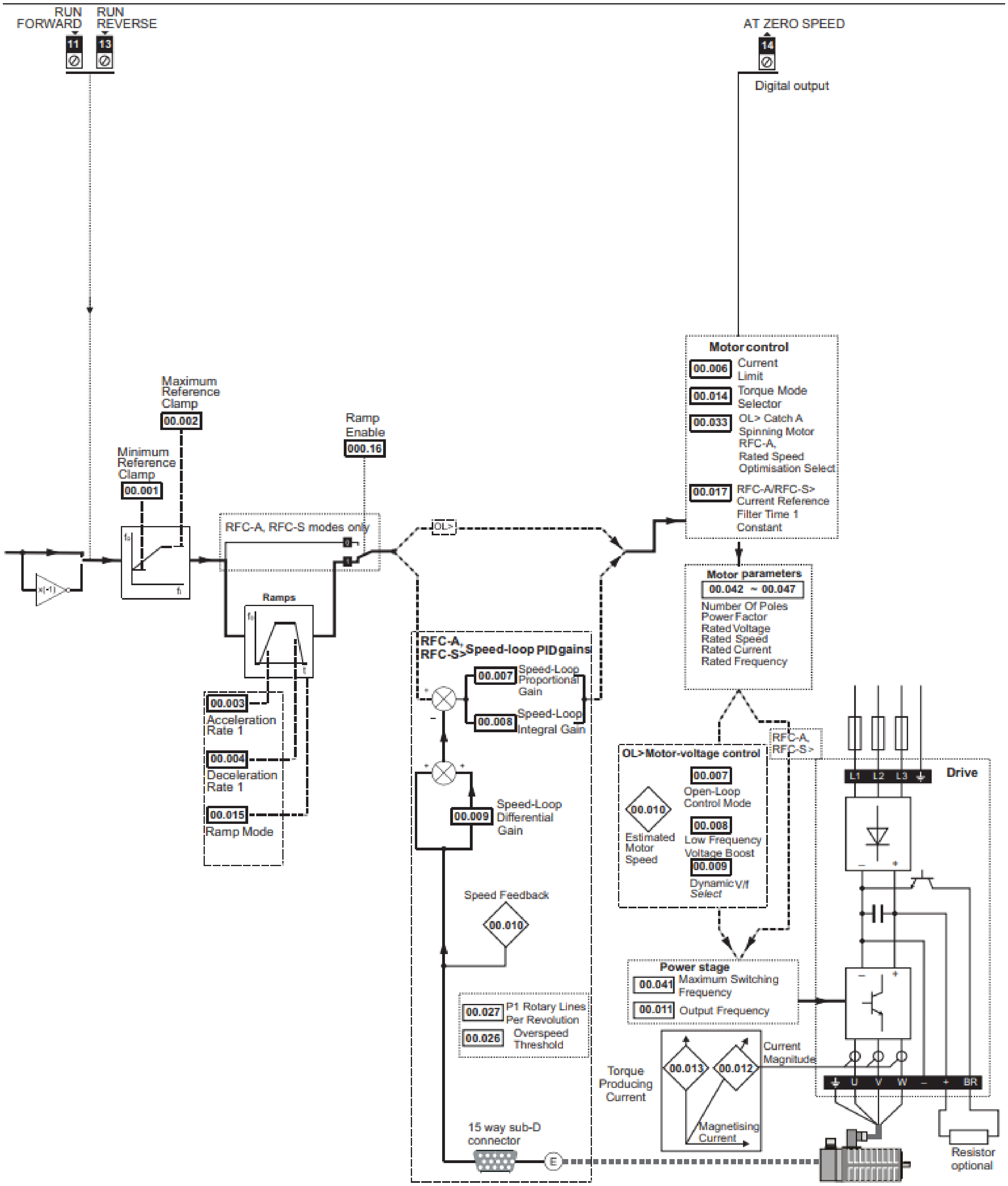
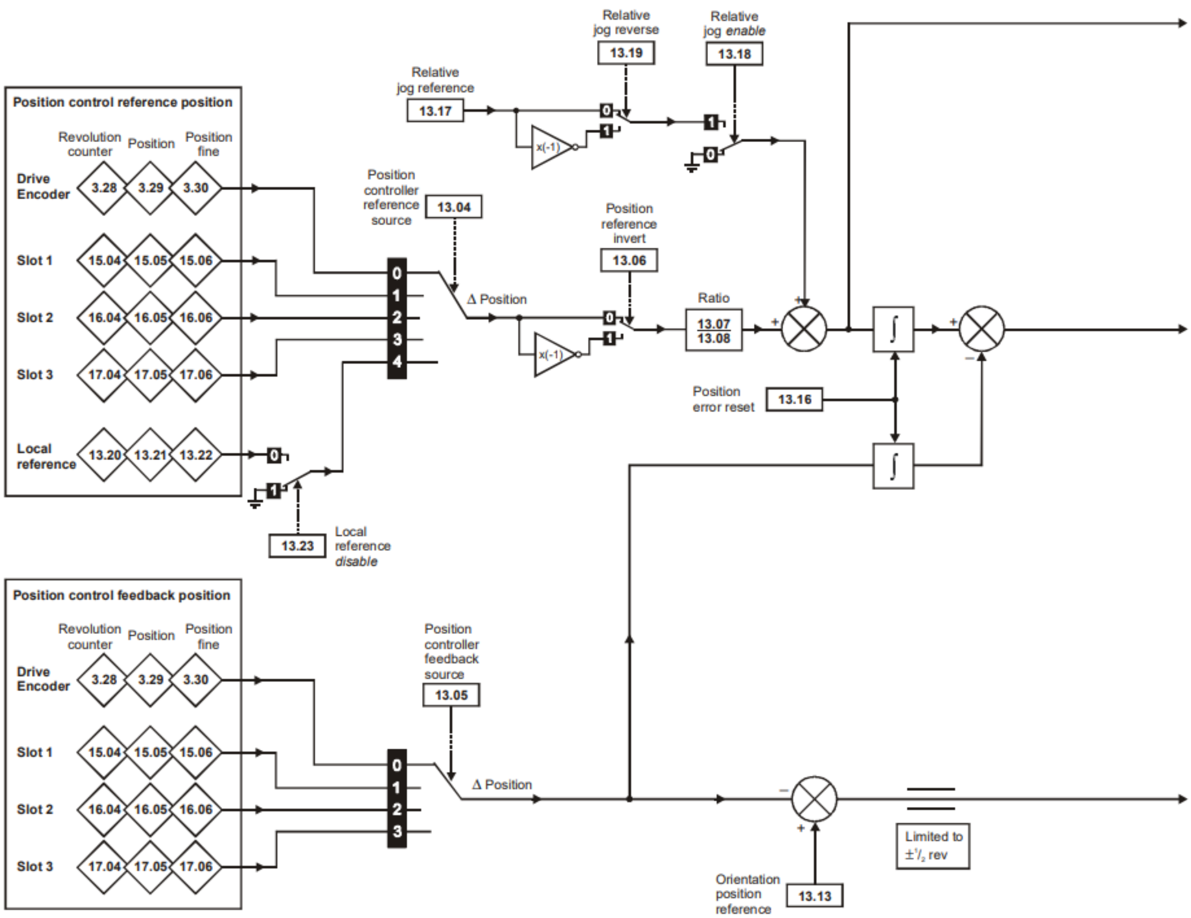


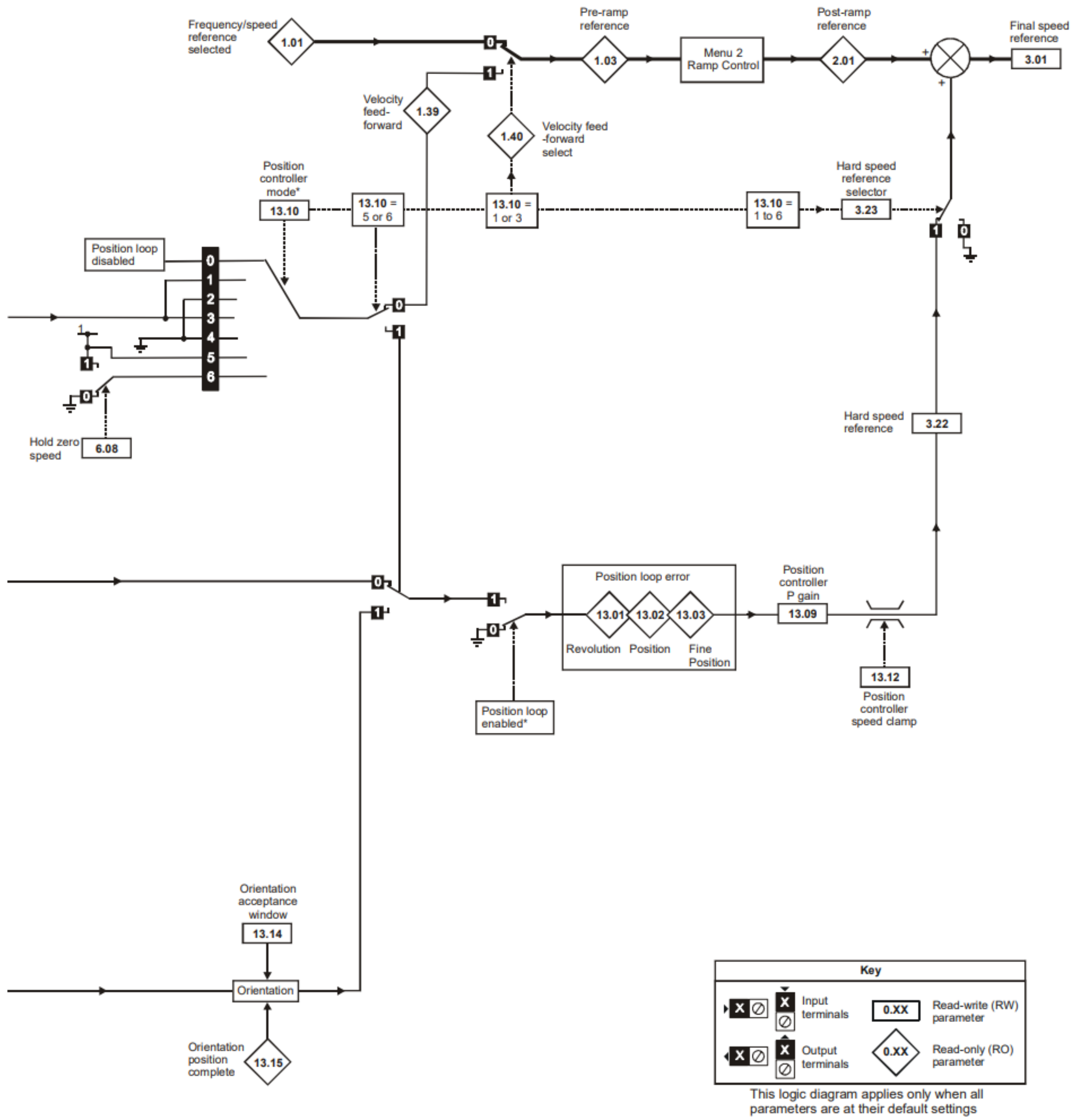


The parameters are all shown in their default settings

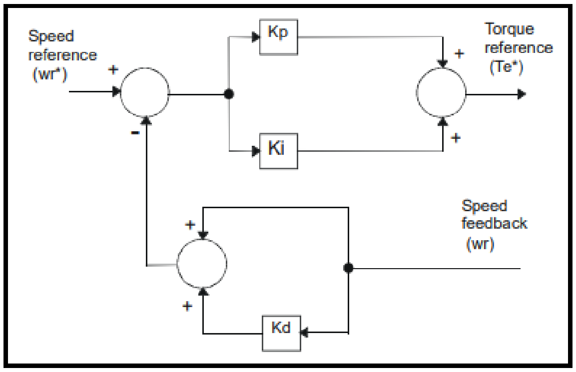


Position control


Position control reference position
Revolution counter
Position
Position fine
Drive Encoder
3.28
3.29
3.30
Slot 1
15.04
15.05
15.06
Slot 2
16.04
16.05
16.06
Slot 3
17.04
17.05
17.06
Local reference
13.20
13.21
13.22
13.23
Local reference disable
Relative jog reference
13.17
Relative jog reverse
13.19
Relative jog enable
13.18
x(-1)
Position controller reference source
13.04
Δ Position
Position reference invert
13.06
Ratio
13.07
13.08
Position error reset
13.16
Position control feedback position
Position controller feedback source
13.05
Limited to ±½ rev
Orientation position reference
13.13



Speed controller



Proportional gain (Kp)

If Kp has a value and Ki is set to zero the controller will only have a proportional term, and there must be a speed error to produce a torque reference. Therefore as the motor load increases there will be a difference between the reference and actual speeds. This effect, called regulation, depends on the level of the proportional gain, the higher the gain the smaller the speed error for a given load. If the proportional gain is too high either the acoustic noise produced by speed feedback quantisation (using digital encoders, resolvers, etc.) becomes unacceptable, or the closed-loop stability limit is reached (using SINCOS encoders).

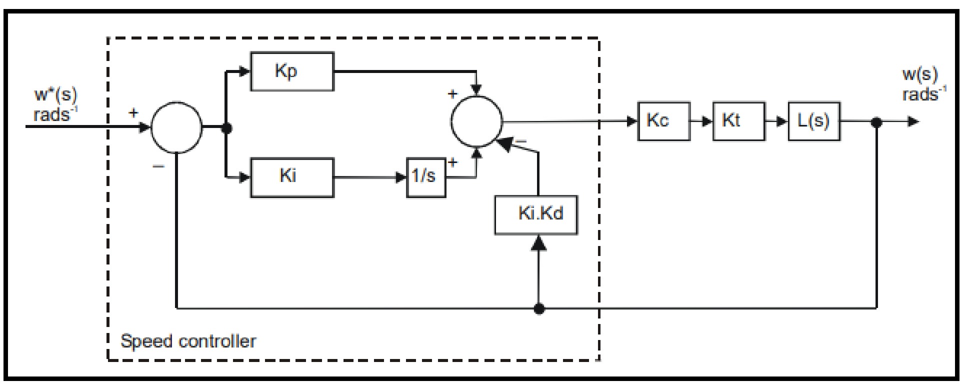
Integral gain (Ki)

The integral gain is provided to prevent speed regulation. The error is accumulated over a period of time and used to produce the necessary torque demand without any speed error. Increasing the integral gain reduces the time taken for the speed to reach the correct level and increases the stiffness of the system, i.e. it reduces the positional displacement produced by applying a load torque to the motor. Unfortunately increasing the integral gain also reduces the system damping giving overshoot after a transient. For a given integral gain the damping can be improved by increasing the proportional gain. A compromise must be reached where the system response, stiffness and damping are all adequate for the application. The integral term is implemented in the form of ∑(Ki x error), and so the integral gain can be changed when the controller is active without causing large torque demand transients.

Differential gain (Kd)

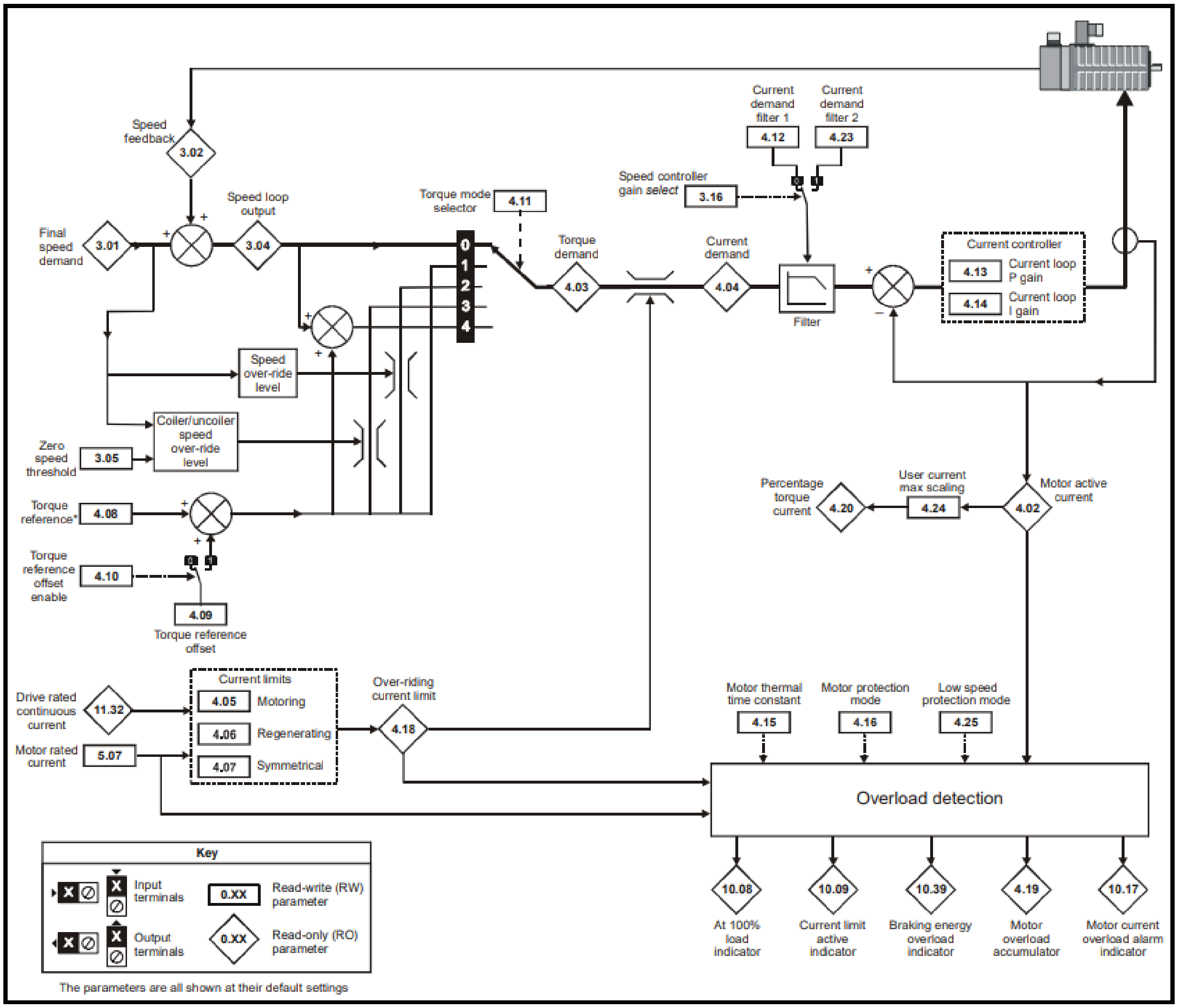
The differential gain is provided in the feedback of the speed controller to give additional damping. The differential term is implemented in a way that does not introduce excessive noise normally associated with this type of function. Increasing the differential term reduces the overshoot produced by under-damping, however, for most applications the proportional and integral gains alone are sufficient.

To analyse the performance of the speed controller it may be represented as an s-domain model as shown below.



Parameter descriptions: Servo

Figure 5-7 Menu 4 Servo logic diagram



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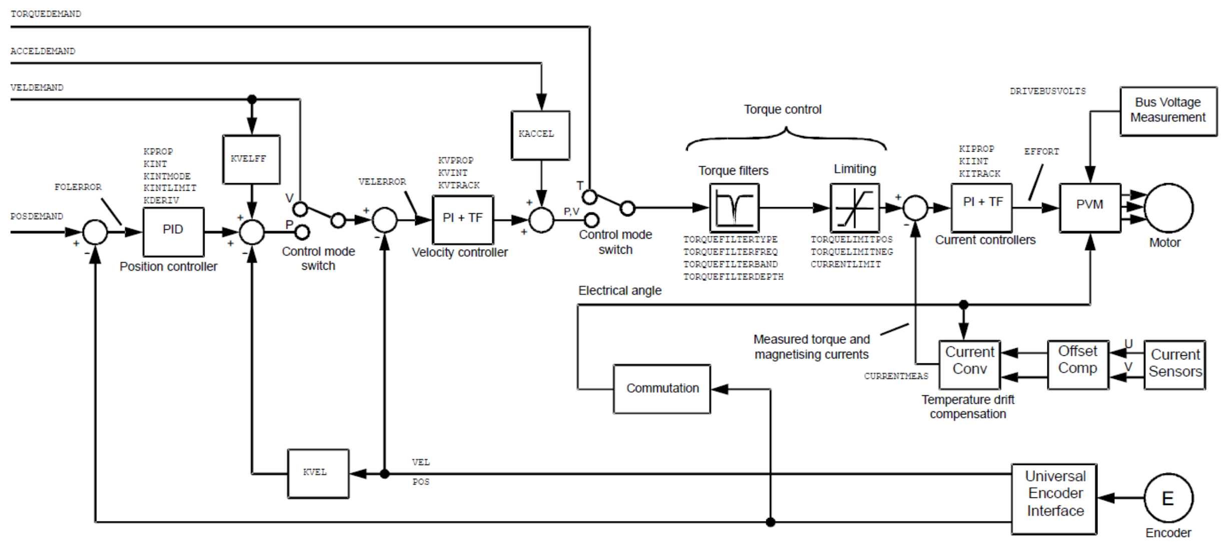

Figure 59: Servo configuration control structure

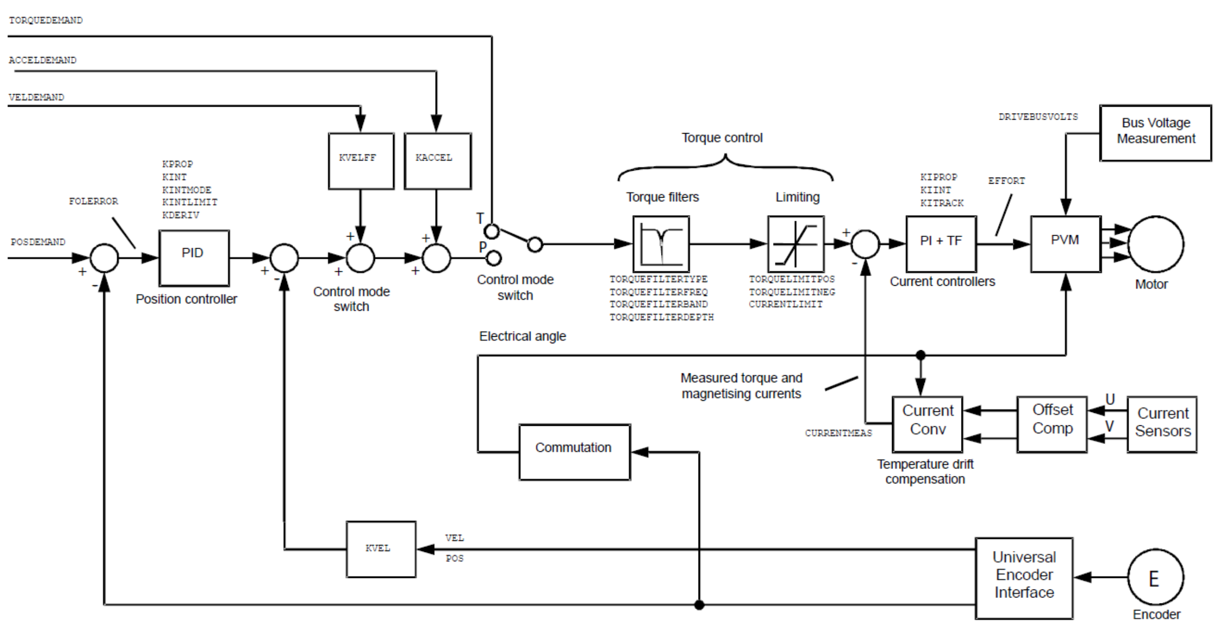

Figure 60: Torque Servo configuration control structure

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The block diagram is shown below.

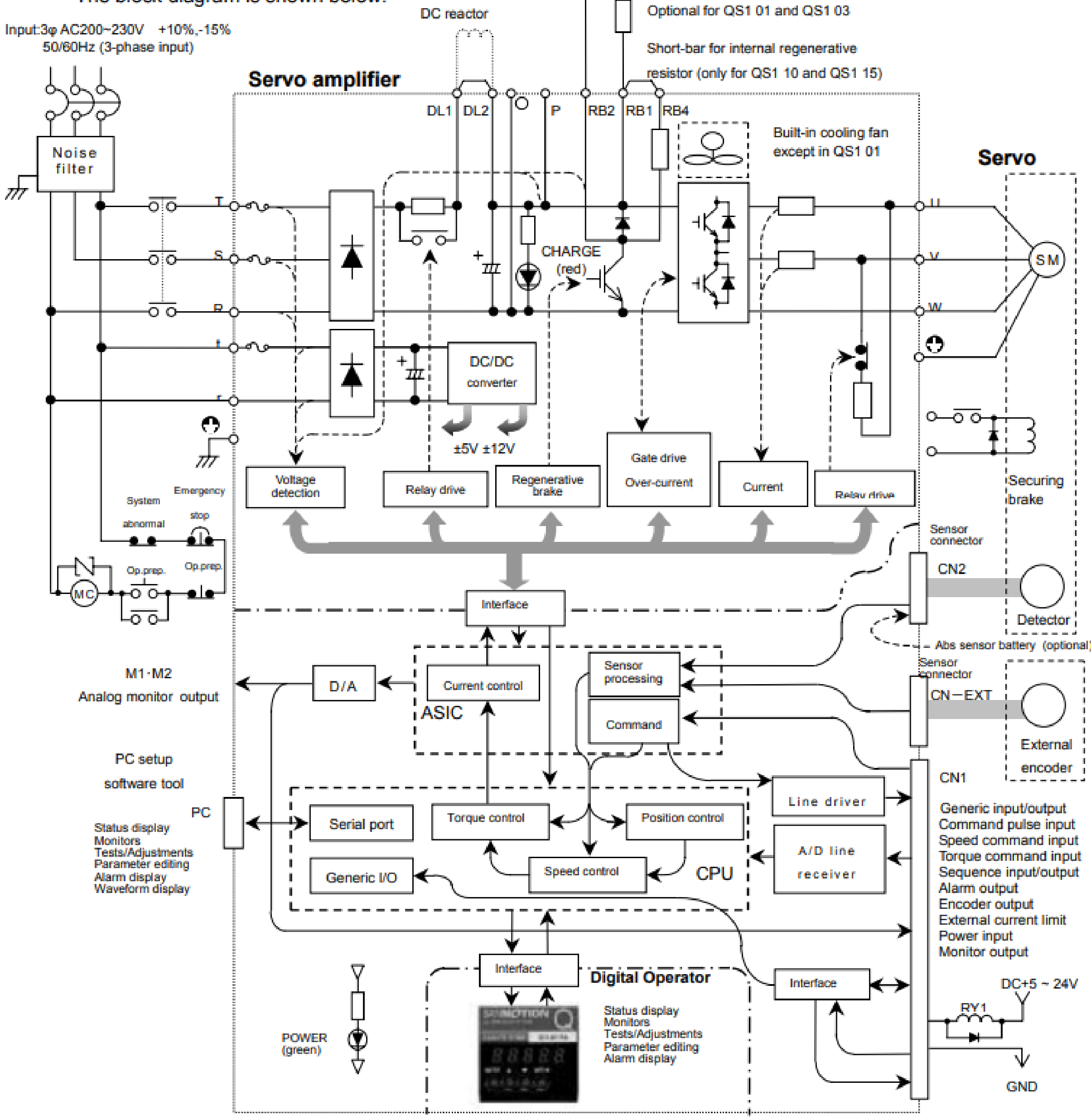
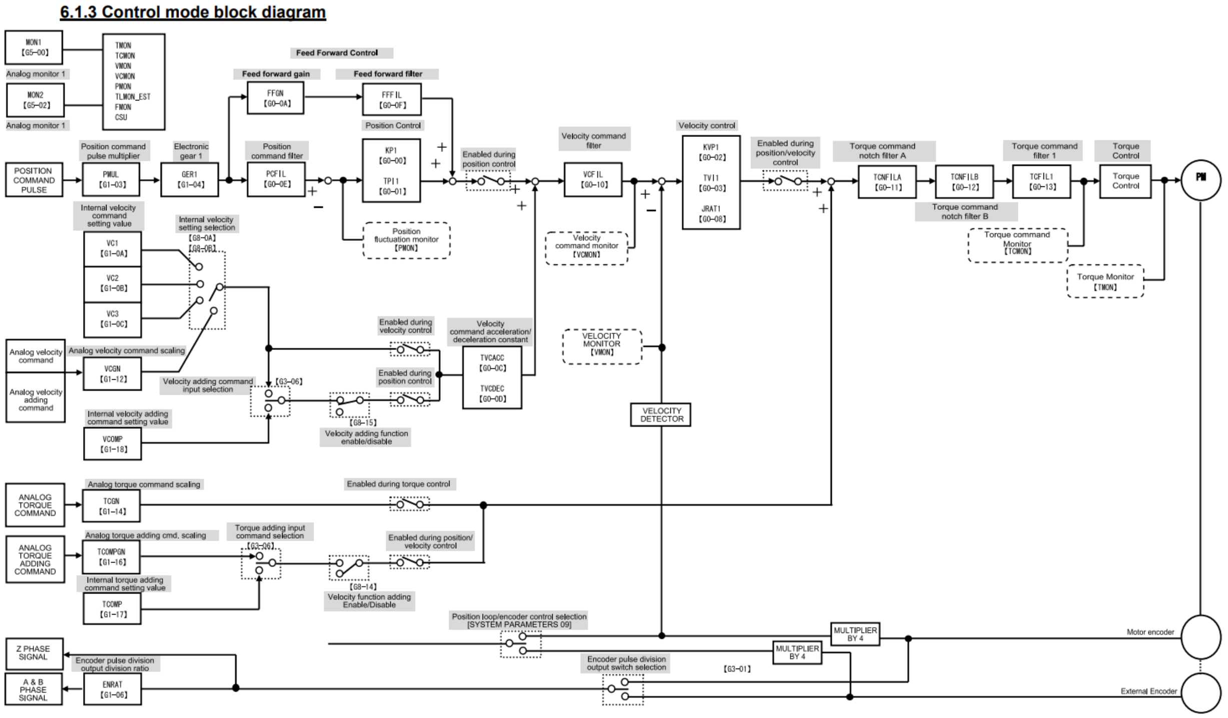
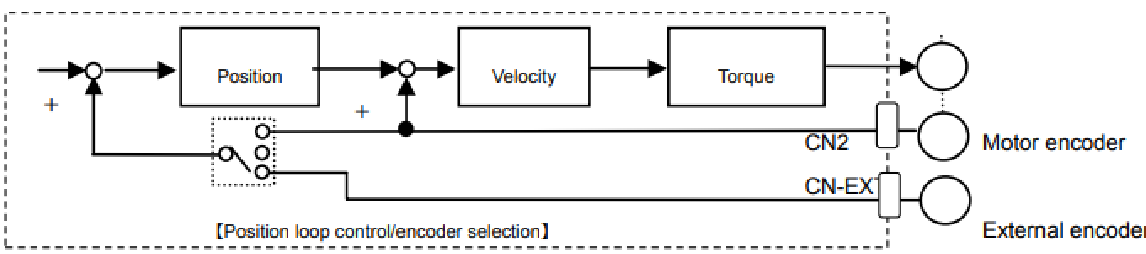


Fig. 3-1 Block diagram

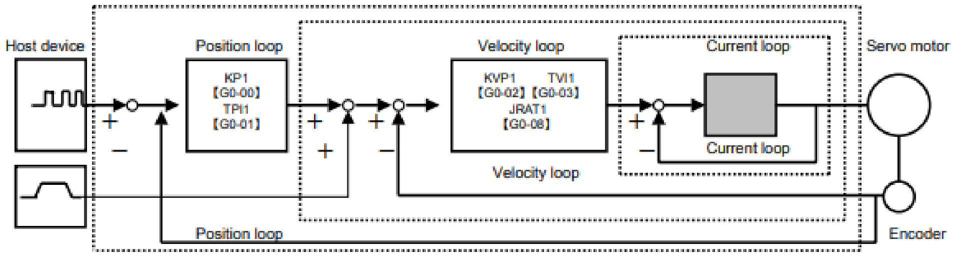

6.1.3 Control mode block diagram
Feed Forward Control
Feed forward gain
Feed forward filter
Position Control
Velocity command filter
Velocity control
Torque command notch filter A
Torque command filter 1
Torque Control
POSITION COMMAND PULSE
VELOCITY DETECTOR
ANALOG TORQUE COMMAND
ANALOG TORQUE ADDING COMMAND
Z PHASE SIGNAL
A & B PHASE SIGNAL
Motor encoder
External Encoder


Position
Velocity
Torque
CN2
CN-EX
Motor encoder
External encoder
【Position loop control/encoder selection】

6.4.1 Servo system

This section explains the servo motor gain setting parameters. A detailed Control Block Diagram can be found in section 6.1.

- The servo system consists of three sub-systems: the position loop, the velocity loop and the current loop. High responsiveness is required for the internal loops. The relationship of these three systems is shown below. If this structure is compromised, it could result in instability, low responsiveness, vibration and oscillation.



The responsiveness of the current loop is ensured internally in the servo amplifier; there is no need for the user to make additional adjustments.

6.4.2 Servo adjustment parameters used for velocity control

Group	Page	Symbol	Name	
0	02	KVP1 [Hz]	Velocity loop proportional gain 1	GAIN1
	03	TVI1 [ms]	Velocity loop integration time constant 1	
	08	JRAT1 [%]	Load inertia moment ratio 1	
	13	TCFIL1 [Hz]	Torque command filter 1	
	06	KVP2 [Hz]	Velocity loop proportional gain 2	GAIN2
	07	TVI2 [ms]	Velocity loop integration time constant 2	
	09	JRAT2 [%]	Load inertia moment ratio 2	
	14	TCFIL2 [Hz]	Torque command filter 2	
	10	VCFIL [Hz]	Velocity command filter	---
	11	TCNFILA [Hz]	Torque command notch filter A	
	12	TCNFILB [Hz]	Torque command notch filter B	

* 2 types of servo parameters can be set. GAIN1← →GAIN2 can be switched using the CONT* input. Refer to "8.5.8 Group7 Parameters" for more information.

6.4.3 GAIN adjustment parameters used for position control

Group	Page	Symbol	Name	
0	00	KP1 [1/S]	Position loop proportional gain 1	GAIN1
	01	TPI1 [ms]	Position loop integration time constant 1	
	02	KVP1 [Hz]	Velocity loop proportional gain 1	
	03	TVI1 [ms]	Velocity loop integration time constant 1	
	08	JRAT1 [%]	Load inertia moment ratio 1	
	13	TCFIL1 [Hz]	Torque command filter 1	
	04	KP2 [1/S]	Position loop proportional gain 2	GAIN2
	05	TPI2 [ms]	Position loop integration time constant 2	
	06	KVP2 [Hz]	Velocity loop proportional gain 2	
	07	TVI2 [ms]	Velocity loop integration time constant 2	
	09	JRAT2 [%]	Load inertia moment ratio 2	
	14	TCFIL2 [Hz]	Torque command filter 2	
	0A	FFGN [%]	Feed forward gain	---
	0E	PCFIL [ms]	Position command filter	
	10	VCFIL [Hz]	Velocity command filter	
	11	TCNFILA [Hz]	Torque command notch filter A	
	12	TCNFILB [Hz]	Torque command notch filter B	
	0F	FFFIL [Hz]	Feed forward filter	

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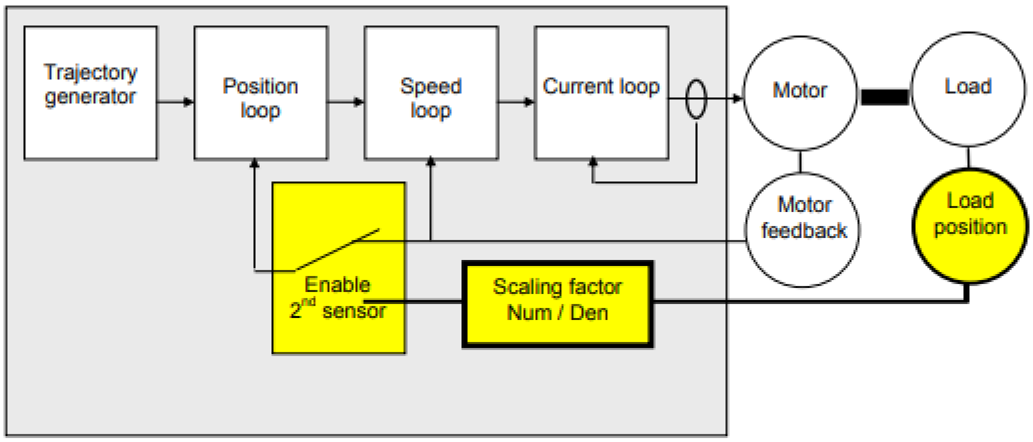
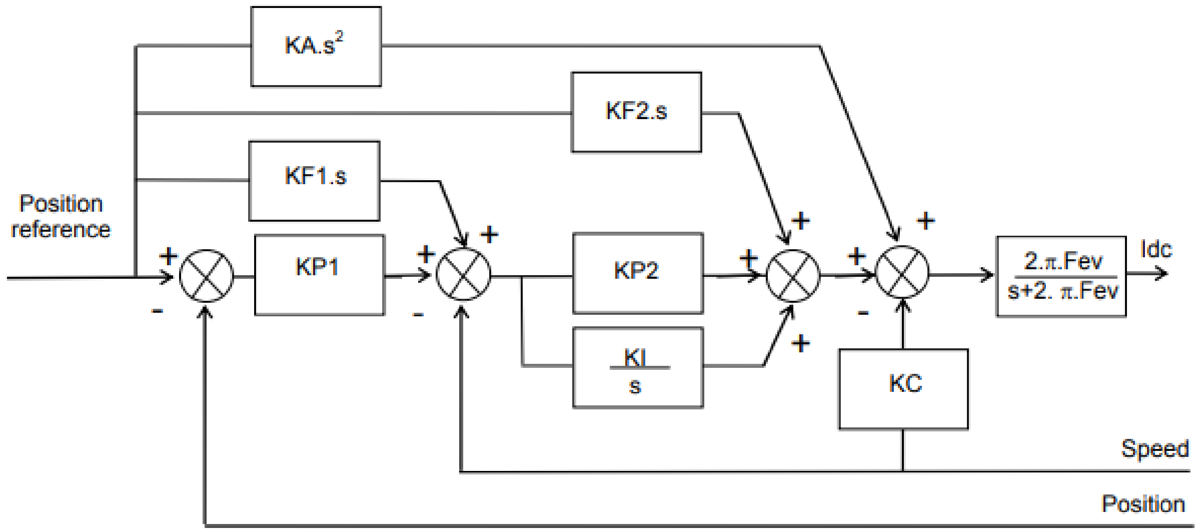
14.1 – SECOND POSITION SENSOR FEEDBACK



1 - SERVO CONTROLLER STRUCTURE



Speed error low-pass filter (Fev): defines the cut-off frequency at -3dB of the first order filter which acts on the current command (Idc). This value is calculated by the amplifier during the auto-tuning procedure and depends on the selected bandwidth and the selected filter type.

Proportional speed gain (KP2): defines the proportional gain of the controller which acts on the speed error. Its value is calculated by the amplifier during the auto-tuning procedure. It can then be modified by the user if required.

Integral speed gain (KI): defines the integral gain of the controller which acts on the speed error. Its value is calculated by the amplifier during the auto-tuning procedure. It can then be modified by the user if required.

Damping gain (KC): defines the proportional gain of the controller which acts only on the speed feedback. Its value is calculated by the amplifier during the auto-tuning procedure. It can then be modified by the user if required.

Proportional position gain(KP1): defines the proportional gain of the controller which acts on the position error. Its value is calculated by the amplifier during the auto-tuning procedure. It can then be modified by the user if required.

Feedforward speed 1 gain(KF1): defines the feedforward speed amplitude corresponding to the speed input command. This term allows to reduce the following error during the motor acceleration and deceleration phases. Its value is set at 1 after the auto-tuning procedure if a following error as small as possible is required. It can then be modified by the user if required.

Feedforward speed 2 gain(KF2): defines the feedforward speed amplitude corresponding to the viscous frictions. This term allows to reduce the viscous friction effect during the motor acceleration and deceleration phases. The gain value is equal to the damping gain value + the viscous friction compensation a term. After the auto-tuning procedure, the feedforward speed 2 gain is set equal to the damping gain value if a following error as small as possible is required. The viscous friction compensation term can be calculated by measuring the current/speed ratio at various motor speed values.

Feedforward acceleration gain(KA): defines the feedforward acceleration amplitude corresponding to the acceleration input command. This term allows to reduce the following error during the motor acceleration and deceleration phases. Its value is calculated by the amplifier during the auto-tuning procedure if a following error as small as possible is required. It can then be modified by the user if required.

The auto-tuning procedure identifies the characteristics of motor and load and calculates the controller gains. During the procedure, various choices are available to the user.

The choice of the time interval for speed measurement (speed measurement filter) allows to select the speed measurement resolution value according to the position sensor resolution value:

speed resolution (rpm) = 60000 / position sensor resolution (ppr) / time interval (ms).

The higher the time interval value, the better the resolution, but also the lower the servo loop gains because of the increased speed measurement delay.

The choice of the anti-resonance filter is necessary in case of loud noise in the motor due to the motor/load coupling elasticity.

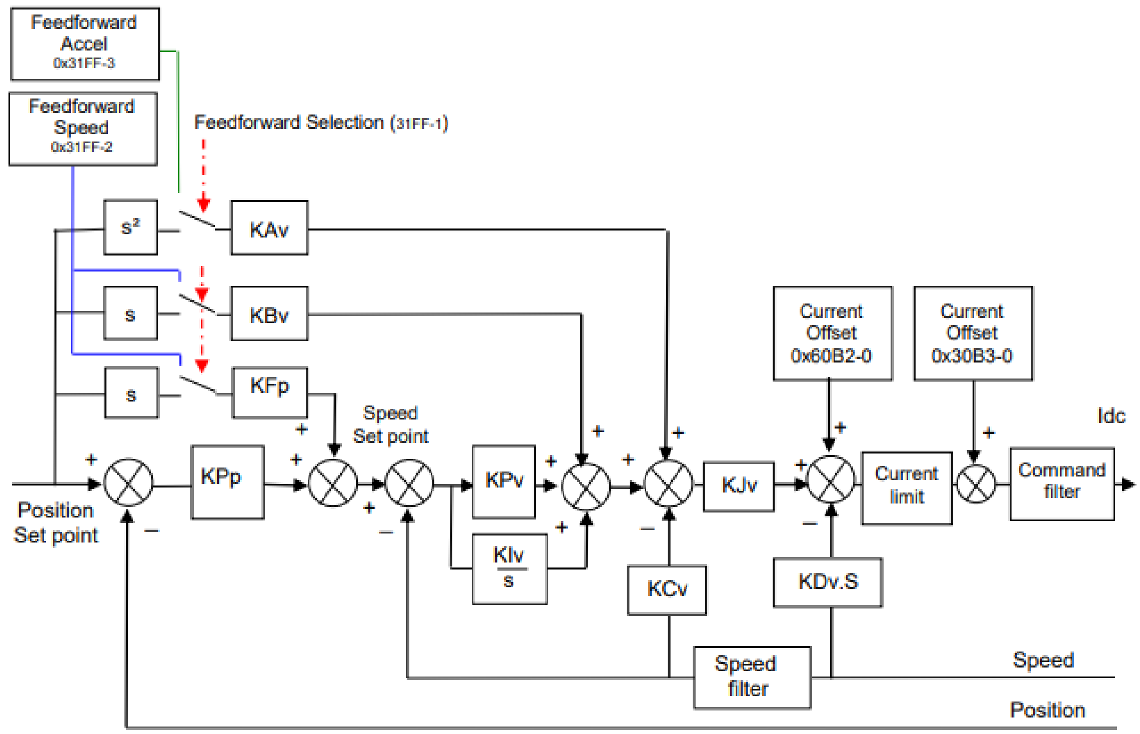
The choice of the maximum stiffness filter allows to get the maximum stiffness on the motor shaft with regard to the torque disturbances. However, this choice is only possible without any resonance due to the motor/load coupling elasticity.

The choice of the speed loop bandwidth defines the cut-off frequency value of the closed loop frequency response (Low = 50 Hz, Medium = 75 Hz, High = 100 Hz).

The choice "**minimum following error**" allows to get an accurate following of the position reference value during the entire motor displacement. In this case, all feedforward gain values are calculated.

The choice "**minimum position overshoot**" allows to get a motor positioning without any overshoot of the target position. In this case, all the feedforward gain values are set at 0, and the motor position is lagging with regard to the position reference value during the whole motor displacement.

SERVO CONTROLLER STRUCTURE



Speed loop gains are the most critical to adjust because they greatly depend on the mechanical load characteristics (inertias, frictions, coupling stiffness, resonances,...).

- **Proportional speed gain (KPv)**: defines the proportional gain of the controller which acts on the speed error. The higher this parameter value, the faster the speed loop response.

- **Integral speed gain (KIv)**: defines the integral gain of the controller which acts on the speed error. The higher this parameter value, the better the axis stiffness.

- **Integrator low frequency limit (KIvf in Hz)**: defines the low frequency value from where the controller integrator term is saturated. This parameter is used for reducing the motor heating in applications with large dry frictions due to the mechanical load.

- **Damping gain (KCv)**: defines the proportional gain of the controller which acts only on the speed feedback. This parameter allows reducing the speed loop overshoot in response to a step like set point change.

- **Derivative speed gain (KDv)**: defines the derivative gain of the controller which acts only on the speed feedback.

- **Derivator high frequency limit (KDvf in Hz)**: defines the high frequency value from which the controller derivative term is saturated.

- **Gain scaling factor (KJv)**: defines a multiplying factor for all speed regulator gains except the derivative gain KDv. This parameter is scaling the speed regulator gains in order to avoid any saturation when large values are required. This parameter also allows adjusting the servo loop stability in case of load inertia variations.

The **Current command filter** is a 3rd order, low-pass type filter, with 3 adjustable cut-off frequencies. Each cut-off frequency value can be freely adjusted according to the application, for the filtering of high frequency noise or of mechanical resonances.

The **Speed measurement filter** is a 1st order, low-pass type filter, with 3 selectable time constant values. The higher the time constant value, the lower the speed measurement noise, but also the lower the speed loop gains because of the increased speed measurement delay. The **Speed measurement filter** time constant is selected according to the motor position sensor resolution and the acceptable noise level in the speed measurement.

Position loop gains mainly influence the servo motor behaviour during the displacements (following error, position overshoot, audible noise, ...).

- Proportional position gain KPp): defines the proportional gain of the controller which acts on the position error. The higher this parameter value, the better the axis stiffness and the lower the following error.

- Feedforward speed 1 gain (KFp): defines the feedforward speed amplitude corresponding to the speed input command. This term allows reducing the following error during the motor displacement. Its value is set at the maximum (65536) after the auto-tuning procedure, if a following error as small as possible is required.

- Feedforward speed 2 gain (KBv): defines the feedforward speed amplitude corresponding to the viscous frictions. This term allows reducing the viscous friction effect during the motor displacement. The gain value is equal to the damping gain value + the viscous friction compensation term. After the auto-tuning procedure, the feedforward speed 2 gain is set equal to the damping gain value, if a following error as small as possible is required. The viscous friction compensation term can be calculated by measuring the current/speed ratio at various motor speed values.

- Feedforward acceleration gain (KAv): defines the feedforward acceleration amplitude corresponding to the acceleration input command. This term allows reducing the following error during the motor acceleration and deceleration phases. Its value is calculated by the amplifier during the auto-tuning procedure, if a following error as small as possible is required.

When the **auto-tuning** procedure is executed, the motor + mechanical load specifications are identified and the appropriate gain values are calculated according to the user selected requirements (controller type, filter type, bandwidth value, ...). All gain values can then be manually modified by the user, if required.

The choice of the time interval for speed measurement (speed measurement filter) allows selecting the speed measurement resolution value according to the position sensor resolution value:

speed resolution (rpm) = 60000 / position sensor resolution (ppr) / time interval (ms).

The higher the time interval value, the better the resolution, but also the lower the servo loop gains because of the increased speed measurement delay.

The choice of the anti-resonance filter is necessary in case of loud noise in the motor due to the motor/load coupling elasticity.

The choice of the maximum stiffness filter allows getting the maximum stiffness on the motor shaft with regard to the torque disturbances. However, this choice is only possible without any resonance due to the motor/load coupling elasticity.

The choice of the speed loop bandwidth defines the cut-off frequency value of the closed loop frequency response (Low = 50 Hz, Medium = 75 Hz, High = 100 Hz).

The choice "**minimum following error**" allows getting an accurate following of the position reference value during the whole motor displacement. In this case, all feedforward gain values are calculated.

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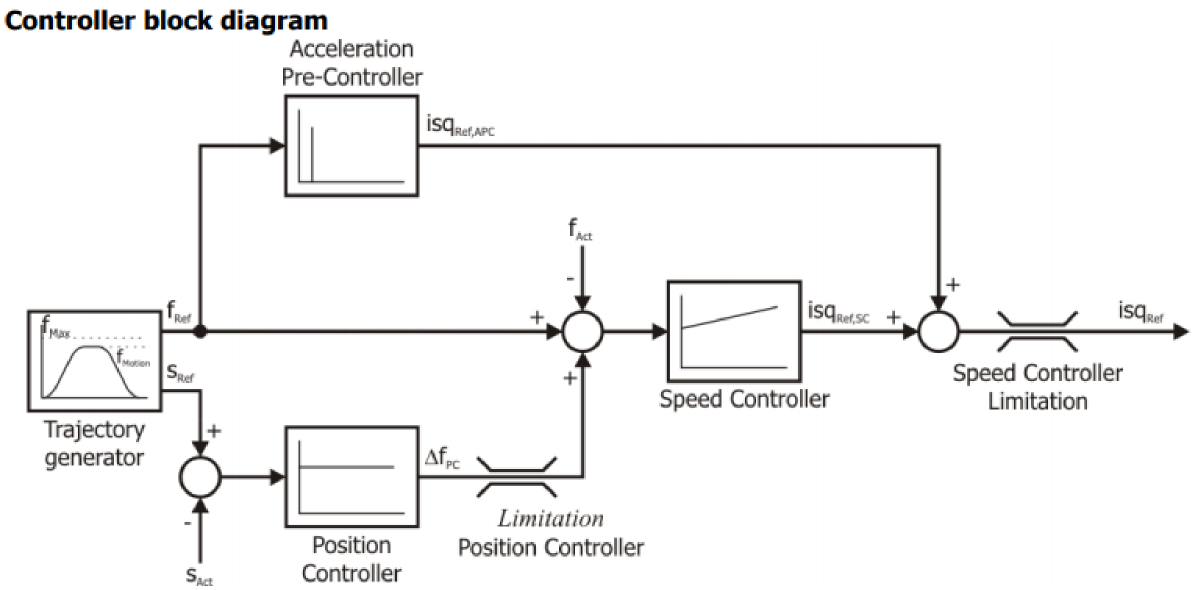

25 Applied Motion

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10 SV200 Tuning Guide

Like most modern servo drives, the SV200 series employs sophisticated algorithms and electronics for controlling the torque, velocity and position of the motor and load.

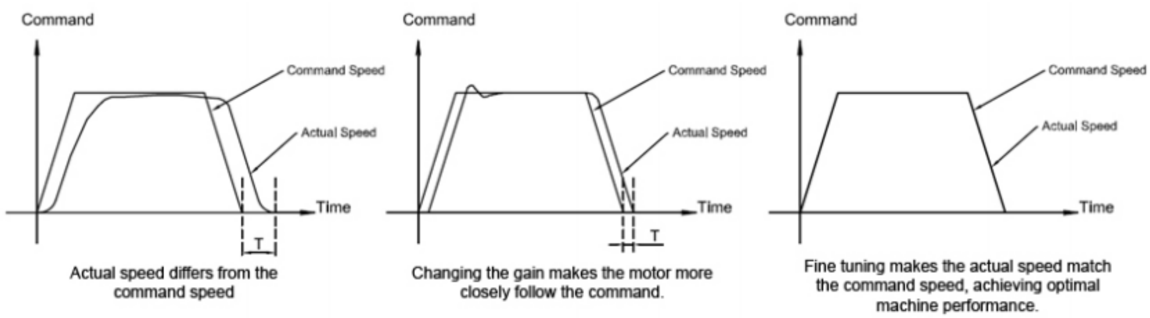
Feedback sensors are used to tell the drive what the motor is doing at all times. That way the drive can continuously alter the voltage and current applied to the motor until the motor meets the commanded torque, velocity or position, depending on the control mode selected. This form of control is called "closed loop control."

One of the loops controls the amount of current in the motor. This circuit requires no adjustment other than specifying the maximum current the motor can handle without overheating.

The PID loop compares the intended motor position to the actual motor position as reported by the encoder. The difference is called error, and the PID loop acts on this error with three gain terms: the Proportional term, the Integral term and the Derivative term. The Acceleration Feedforward term is also added to achieve greater system control.

10.1 Servo Tuning – Adjustment of Gain Parameters

Servo tuning is used to optimize the servo system's overall performance and reduce system response time. Servo tuning allows the servo motor to execute host control commands more precisely in order to maximize its system potential. Therefore, it is highly recommended that the gain parameters be optimized before actual system operation.



The PID loop compares the intended motor position to the actual motor position as reported by the encoder. The difference is called error. The PID loop acts on this error with these three gain terms: Global gain (KP), Integrator Gain (KI), Derivative gain (KD).
In addition to the PID loop control, the SV200 series drives add a number of extra terms to enable greater system control. These additional terms include: position loop gain (KF), Damping gain (KV), Inertia feed forward gain (KK), Follow Factor (KL), Derivative filter gain (KE), and PID filter (KC).

In general, for systems having stiff mechanical transmissions, increasing the servo gain parameters will improve response time. On the other hand, for systems having more compliant mechanical transmissions, increasing servo gain parameters will potentially cause system vibrations and reduce system response time.

10.1.1 Gain Parameter Introduction

Global gain (KP):

This parameter is the primary gain term for minimizing the position error. It defines the system stiffness. Larger KP values means higher stiffness and faster response times. However, if gain values are too high, vibration can result. Values ranging from 6000 to 16000 are commonly used. In general, use default parameter values when possible.

Position loop gain (KF):

This parameter is also used for minimizing the position error. Increasing KF will increase stiffness and reduce settling time. However, increasing this gain term too much may cause system vibration.

Derivative gain (KD):

This parameter is used to damp low speed oscillations and increase system smoothness.

Integrator gain (KI):

This parameter minimizes (or may even eliminate) position errors especially when motor is holding position.

Damping gain (KV):

KV minimizes the velocity error and reduces vibration in position control mode.

Inertia Feedforward Constant (KK):

KK improves acceleration control by compensating for the load inertia.

Follow Factor (KL):

Higher values will reduce system noise and eliminate overshoot, but will reduce the system's dynamic following performance. Lower values will raise system stiffness, but may cause system noise.

Derivative Filter Gain (KE):

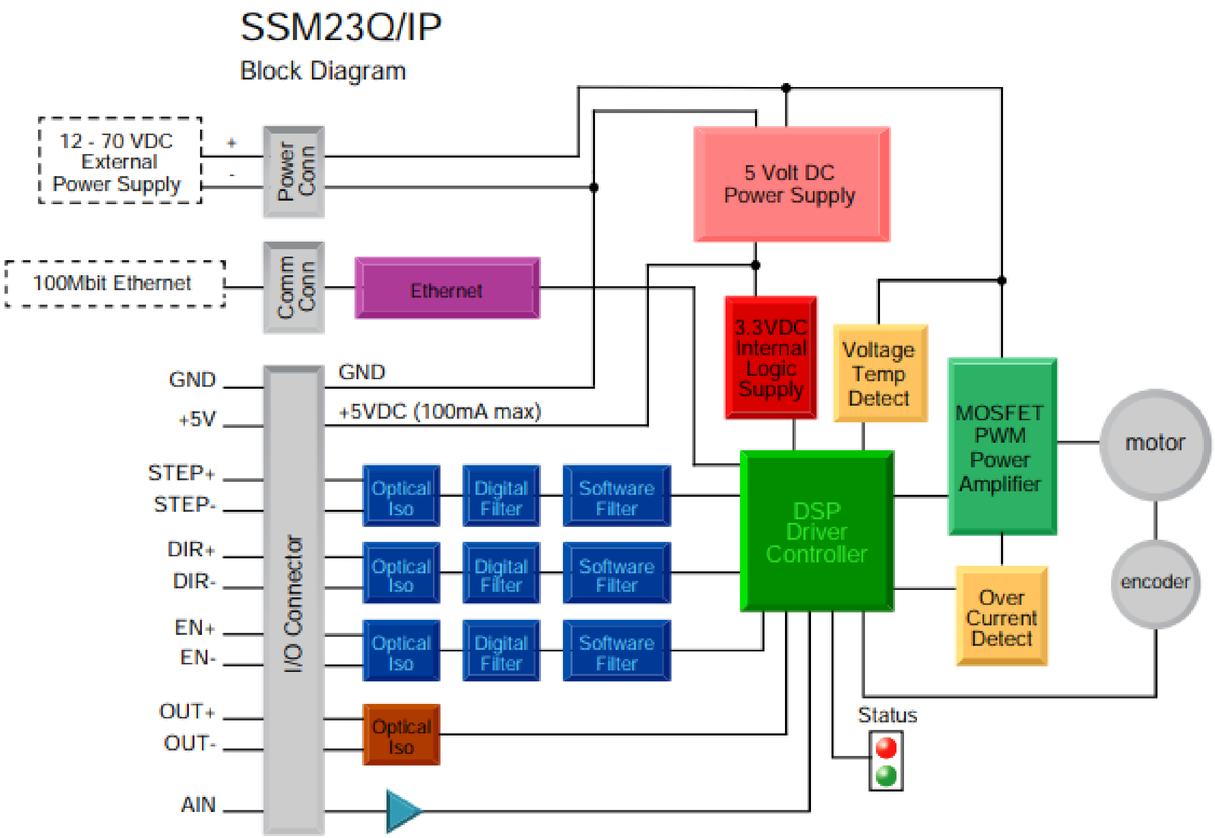
The differential control parameters filter frequency. This filter is a simple one-pole, low-pass filter intended for attenuating high frequency oscillations. This value is a constant that must be calculated from the desired roll off frequency.

PID Filter gain (KC):

The servo control overall filter frequency. This filter is a simple one-pole, low-pass filter intended for attenuating high frequency oscillations. The value is a constant that must be calculated from the desired roll off frequency.

Among all the parameters, changes for KP, KE, and KC are NOT recommended after system configuration. Therefore, parameter tuning is based more on KF, KD, KV, KI, KL and KK.

Motora entegre sürücü örneği blok şeması

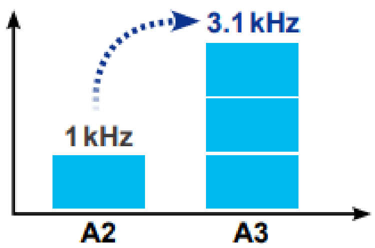

SSM23Q/IP
Block Diagram
12 - 70 VDC External Power Supply
+
-
Power Conn
100Mbit Ethernet
Comm Conn
Ethernet
5 Volt DC Power Supply
3.3VDC Internal Logic Supply
Voltage Temp Detect
MOSFET PWM Power Amplifier
motor
encoder
GND
+5V
GND
+5VDC (100mA max)
STEP+
STEP-
DIR+
DIR-
EN+
EN-
OUT+
OUT-
AIN
I/O Connector
Optical Iso
Digital Filter
Software Filter
Optical Iso
Digital Filter
Software Filter
Optical Iso
Digital Filter
Software Filter
Optical Iso
DSP Driver Controller
Over Current Detect
Status

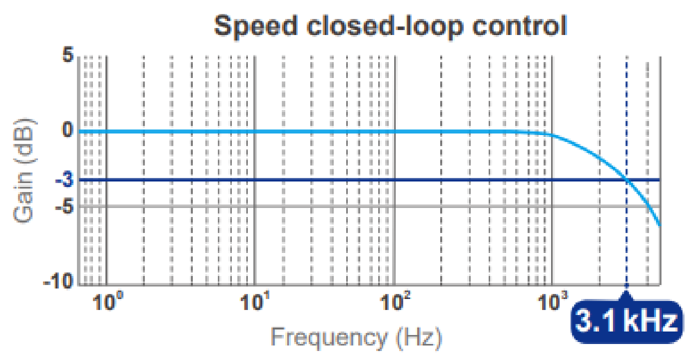
26 Delta

M

3.1 kHz Bandwidth

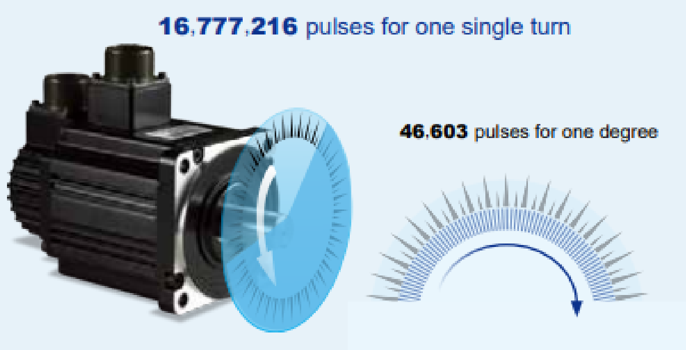
- Higher responsiveness and shorter settling time could increase productivity





24-bit Absolute Type Encoder

- The positioning precision is enhanced by the 16,777,216 pulses/turn encoder
- The speed variance in low speed is reduced
- Absolute type encoder keeps motor's position when power is off

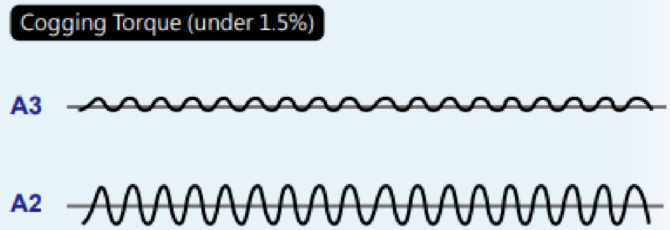


High speed motor with 6,000 r/min and 350 % peak torque

- A3 motor can accelerate and decelerate faster with its design
- This specification is available for motor frame size 40 mm, 60 mm and 80mm

Low Cogging Torque Motor

- Cogging torque of the ECM-A3 motor is only 1.5% of the rated torque, which brings smoother operating speed and increases the stability when machining at low speed



System Diagnosis Function

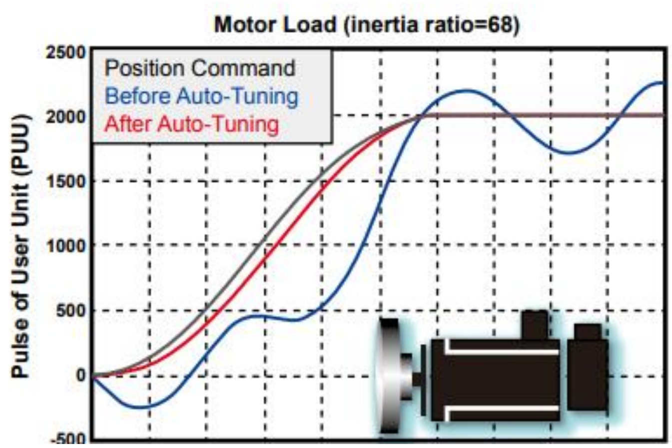
- The rigidity of a machine is known through a mathematical model
- The consistency of the machine's batch installation can be checked
- By comparing the data from different time span, the wear condition of a machine can be acquired

Low Frequency Vibration Suppression Function

- Vibration elimination algorithm is different from command filter and used as a creative algorithm on ASDA-A3
- The vibration can be eliminated without slowing down its response
- In addition to vibration elimination algorithm, the two command filters for low frequency vibration are included

Auto-Tuning Function

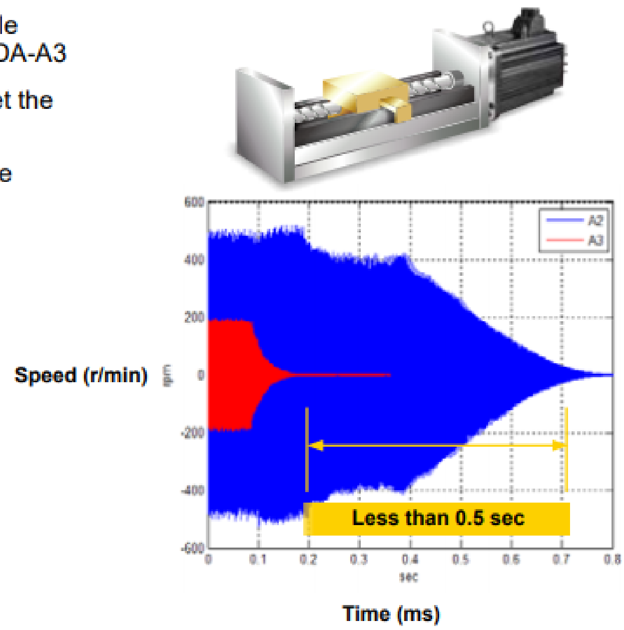
- Lower the barrier for users to use servo systems
- This function will optimize the machine performance with less tuning effort
- It can be done via panel keypad or software



Advanced Notch Filter

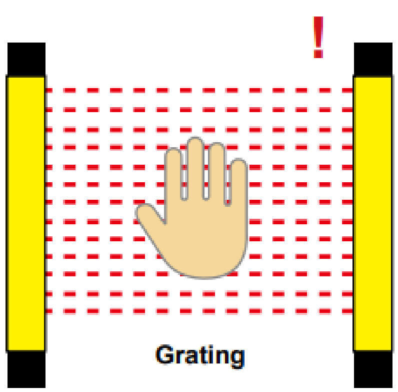
- There are 5 sets of notch filters with tunable bandwidth and up to 5000 Hz band for ASDA-A3
- Those filters can search resonance and set the attenuation level automatically
- With shorter search time for resonance, the machine is less likely to be damaged

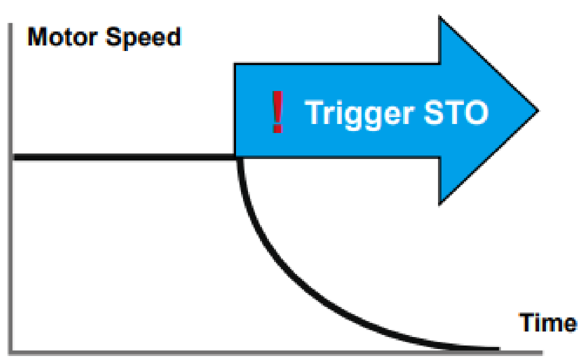
Test Machine Layout

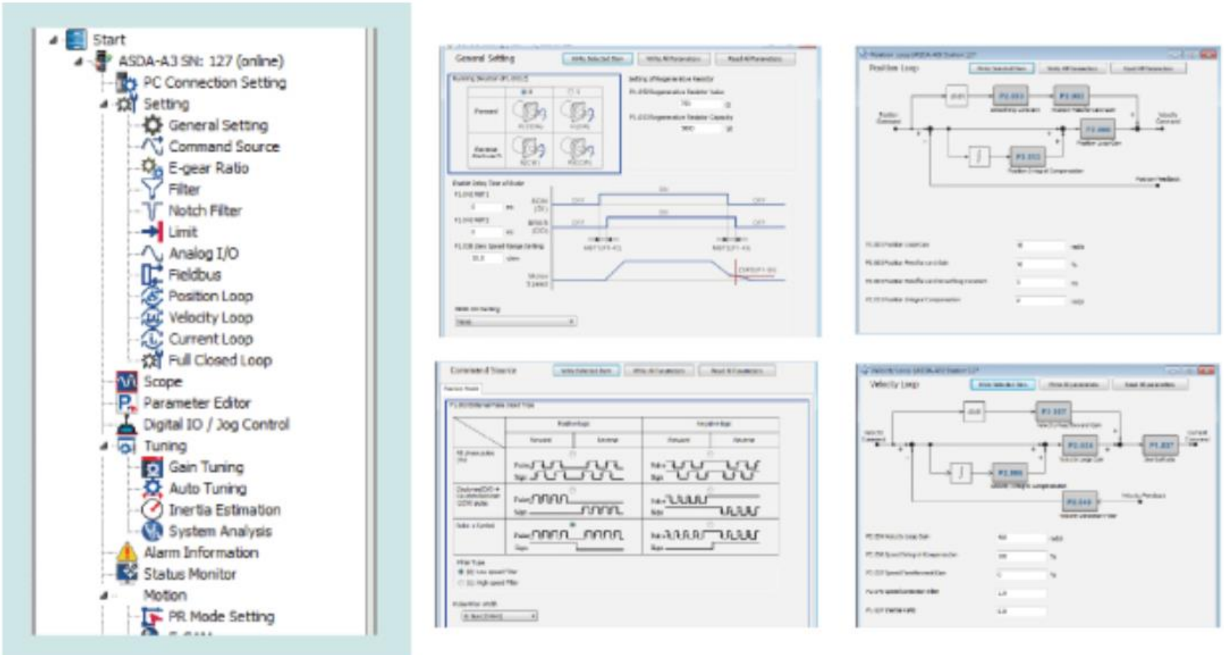


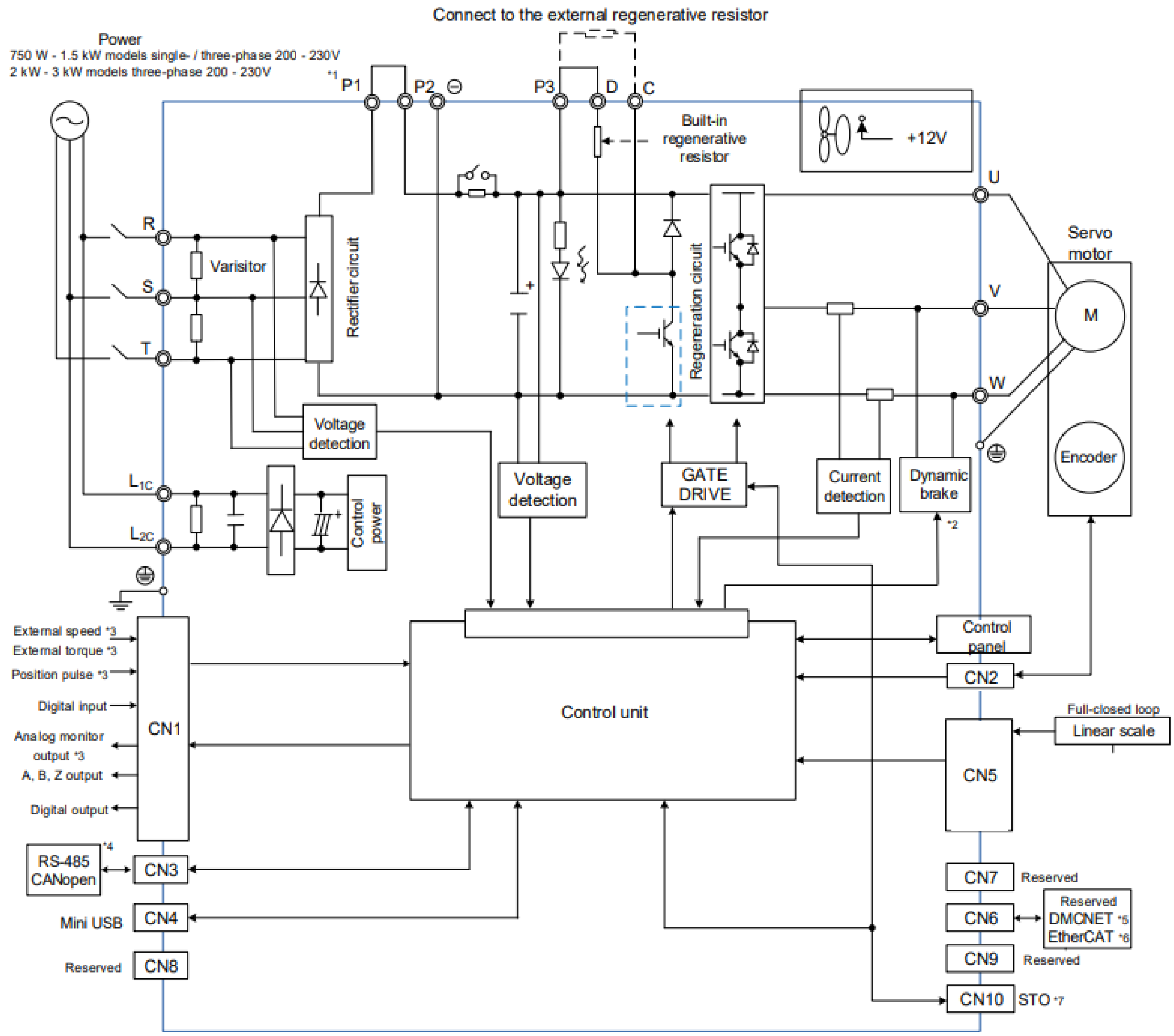
Safe Torque Off (STO) Function *note : to be certified

- Built-in STO (Safe Torque Off) function
- The motor power will be cut-off when STO is activated






Start
ASDA-A3 SN: 127 (online)
PC Connection Setting
Setting
General Setting
Command Source
E-gear Ratio
Filter
Notch Filter
Limit
Analog I/O
Fieldbus
Position Loop
Velocity Loop
Current Loop
Full Closed Loop
Scope
Parameter Editor
Digital IO / Jog Control
Tuning
Gain Tuning
Auto Tuning
Inertia Estimation
System Analysis
Alarm Information
Status Monitor
Motion
PR Mode Setting
General Setting
Command Source
Position Loop
Velocity Loop


Connect to the external regenerative resistor
Power
750 W - 1.5 kW models single- / three-phase 200 - 230V
2 kW - 3 kW models three-phase 200 - 230V
*1 P1
P2 ⊖
P3
D
C
Built-in regenerative resistor
+12V
U
V
W
R
S
T
Varisitor
Rectifier circuit
Regeneration circuit
Servo motor
M
Encoder
Voltage detection
Voltage detection
GATE DRIVE
Current detection
Dynamic brake
*2
L1C
L2C
Control power
External speed *3
External torque *3
Position pulse *3
Digital input
Analog monitor output *3
A, B, Z output
Digital output
CN1
Control unit
Control panel
CN2
Full-closed loop
Linear scale
CN5
RS-485 CANopen
*4
CN3
Mini USB
CN4
Reserved
CN8
CN7
Reserved
Reserved
CN6
DMCNET *5
EtherCAT *6
CN9
Reserved
CN10
STO *7

5.2 Auto tuning

The Auto Tuning function provided by the ASDA-A3 enables the system to perform real-time machine inertia estimation and upload the corresponding tuning parameters to the servo drive. You can start auto tuning with ASDA-Soft (software) or with the drive panel. The following table lists the parameters that change according to the results of auto tuning.

Gain related parameters	
Parameter No.	Function
P1.037	Load inertia ratio and load weight ratio of servo motor
P2.000	Position control gain
P2.004	Speed control gain
P2.006	Speed integral compensation
P2.031	Bandwidth response level
P2.032	Gain adjustment mode
P2.089	Command response gain (enabling the two dimensional control function (P2.094 [Bit12] = 1) is required)
-	-
-	-
-	-
-	-
-	-
-	-
-	-
-	-
-	-

Filter and resonance suppression parameters	
Parameter No.	Function
P1.025	Low-frequency vibration suppression frequency (1)
P1.026	Low-frequency vibration suppression gain (1)
P1.027	Low-frequency vibration suppression frequency (2)
P1.028	Low-frequency vibration suppression gain (2)
P2.023	Notch filter frequency (1)
P2.024	Notch filter attenuation level (1)
P2.025	Resonance suppression low-pass filter
P2.043	Notch filter frequency (2)
P2.044	Notch filter attenuation level (2)
P2.045	Notch filter frequency (3)
P2.046	Notch filter attenuation level (3)
P2.049	Speed detection filter and jitter suppression
P2.098	Notch filter frequency (4)
P2.099	Notch filter attenuation level (4)
P2.101	Notch filter frequency (5)
P2.102	Notch filter attenuation level (5)

5.3.5 Setting the bandwidth response level (stiffness)

You can use parameter P2.031 to tune the servo system in an easier and user-friendly way. With the fixed inertia ratio, when you increase the bandwidth level (P2.031), the servo's bandwidth increases as well. If resonance occurs, lower the parameter value by one or two bandwidth levels (you should adjust the bandwidth level according to the actual situation). For instance, if the value of P2.031 is 30, you can reduce the bandwidth level to 28. When you adjust the value of this parameter, the servo system automatically adjusts the corresponding parameters, such as P2.000 and P2.004.

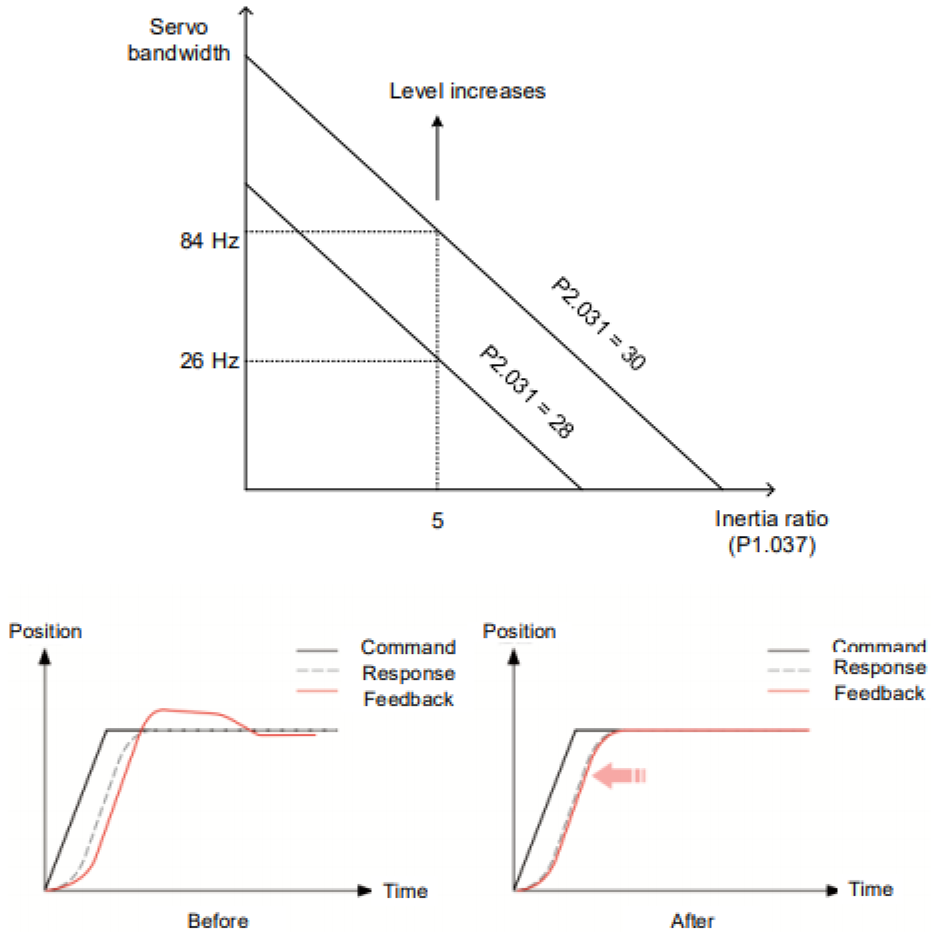
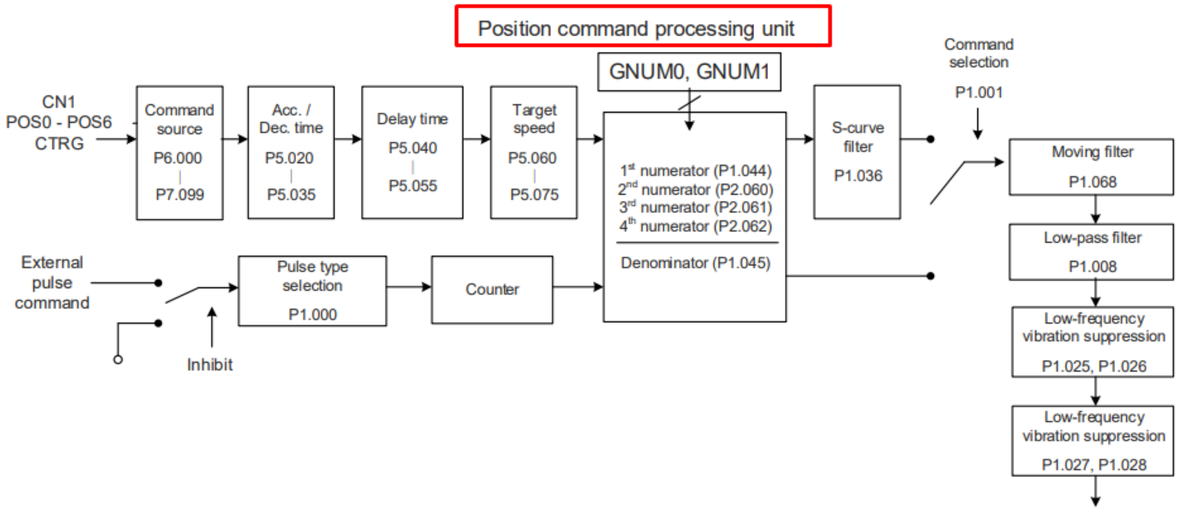
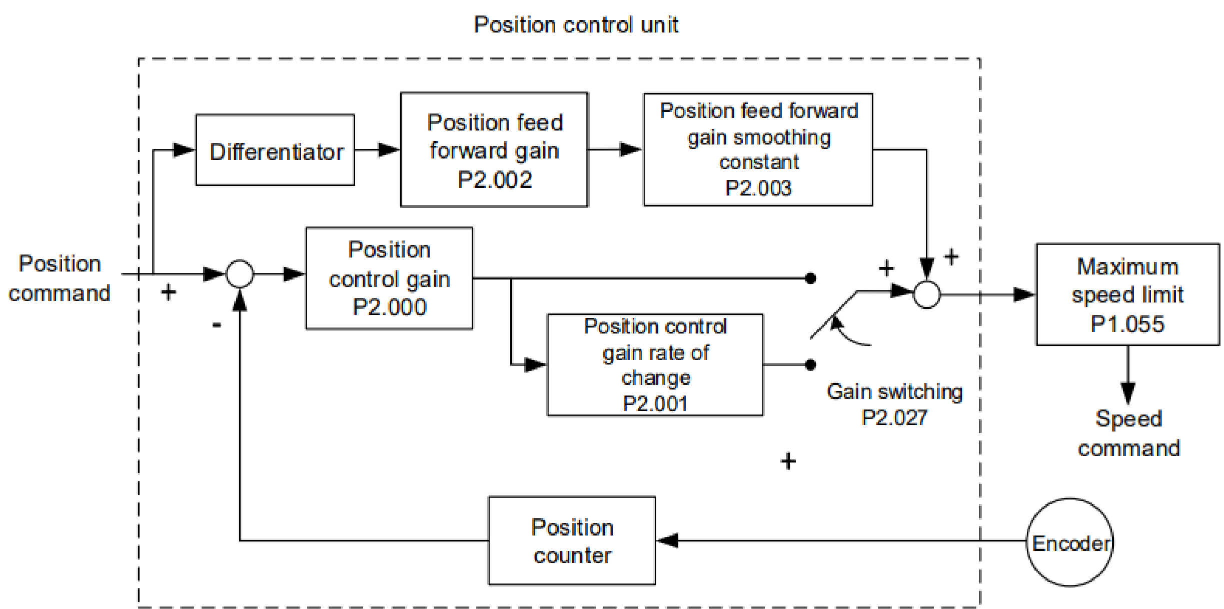


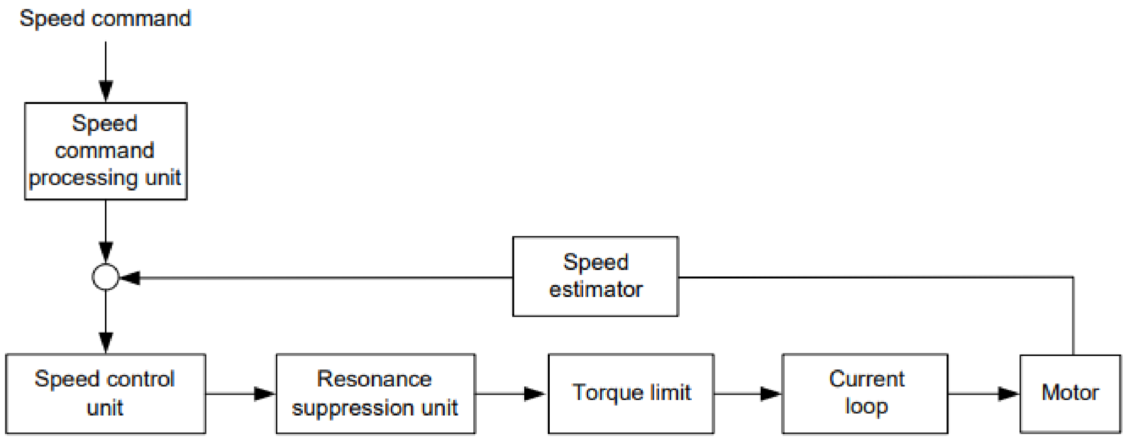
Figure 5.3.5.1 Adjust the bandwidth level


Position command processing unit
CN1
POS0 - POS6
CTRG
Command source
P6.000
P7.099
Acc. / Dec. time
P5.020
P5.035
Delay time
P5.040
P5.055
Target speed
P5.060
P5.075
GNUM0, GNUM1
1st numerator (P1.044)
2nd numerator (P2.060)
3rd numerator (P2.061)
4th numerator (P2.062)
Denominator (P1.045)
S-curve filter
P1.036
Command selection
P1.001
Moving filter
P1.068
Low-pass filter
P1.008
Low-frequency vibration suppression
P1.025, P1.026
Low-frequency vibration suppression
P1.027, P1.028
External pulse command
Pulse type selection
P1.000
Counter
Inhibit


Position control unit
Differentiator
Position feed forward gain
P2.002
Position feed forward gain smoothing constant
P2.003
Position command
+
-
Position control gain
P2.000
Position control gain rate of change
P2.001
+
+
Gain switching
P2.027
+
Maximum speed limit
P1.055
Speed command
Position counter
Encoder

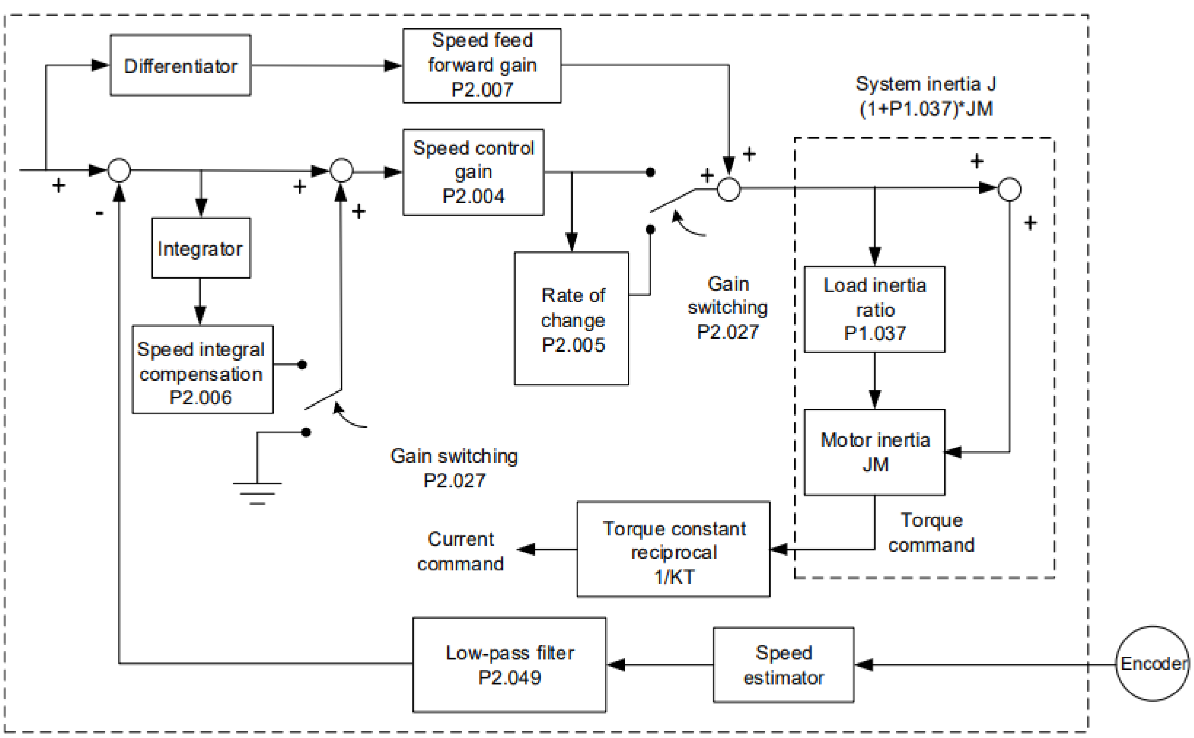
6.3.2 Control structure of Speed mode

The basic control structure is shown in the following flowchart:



6.3.6 Gain adjustment of the speed loop

The structure of the speed control unit is shown in the following diagram:



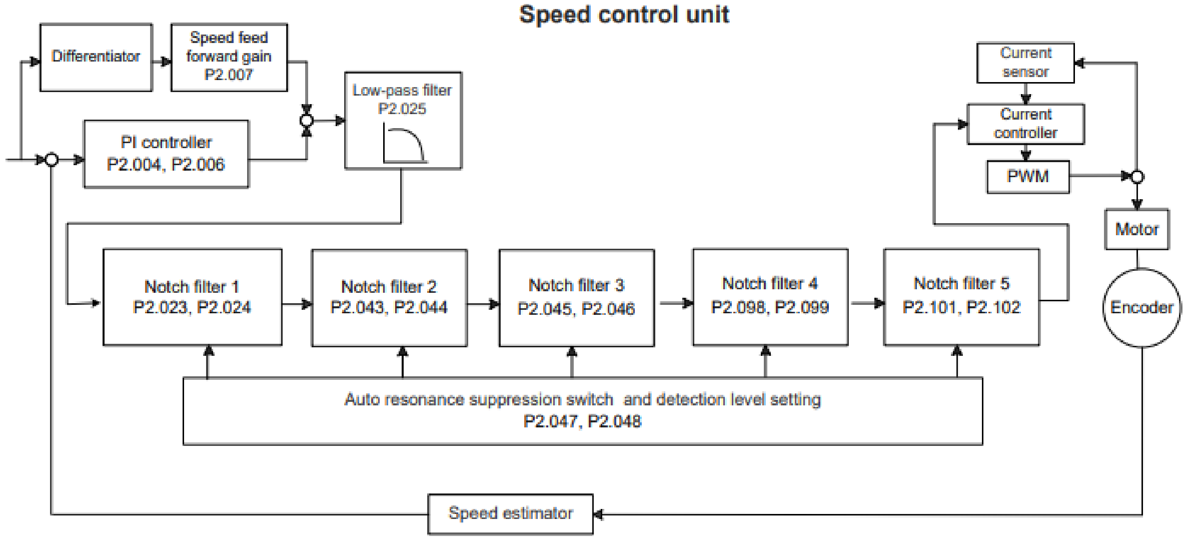
6.3.7 Resonance suppression unit

When resonance occurs, it is probably because the stiffness of the control system is too high or the response bandwidth is too great. Eliminating these two factors can improve the situation. In addition, you can use the low-pass filter (parameter P2.025) and Notch filter (parameters P2.023, P2.024, P2.043 – P2.046, and P2.095 – P2.103) to suppress the resonance if you want the control parameters to remain unchanged.

Refer to Chapter 8 for detailed descriptions of the relevant parameters.

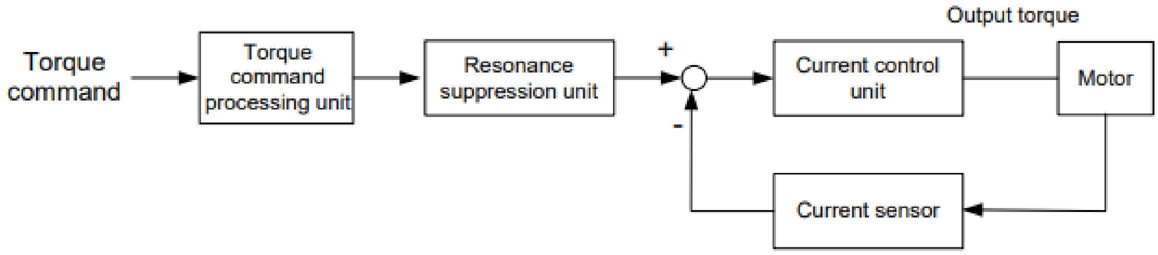
Parameter	Function
P2.023	Notch filter frequency (1)
P2.024	Notch filter attenuation level (1)
P2.043	Notch filter frequency (2)
P2.044	Notch filter attenuation level (2)
P2.045	Notch filter frequency (3)
P2.046	Notch filter attenuation level (3)
P2.095	Notch filter bandwidth (1)
P2.096	Notch filter bandwidth (2)
P2.097	Notch filter bandwidth (3)
P2.098	Notch filter frequency (4)
P2.099	Notch filter attenuation level (4)
P2.100	Notch filter bandwidth (4)
P2.101	Notch filter frequency (5)
P2.102	Notch filter attenuation level (5)
P2.103	Notch filter bandwidth (5)
P2.025	Resonance suppression low-pass filter

Speed control unit



6.4.2 Control structure of Torque mode

The basic control structure is shown in the following flowchart:



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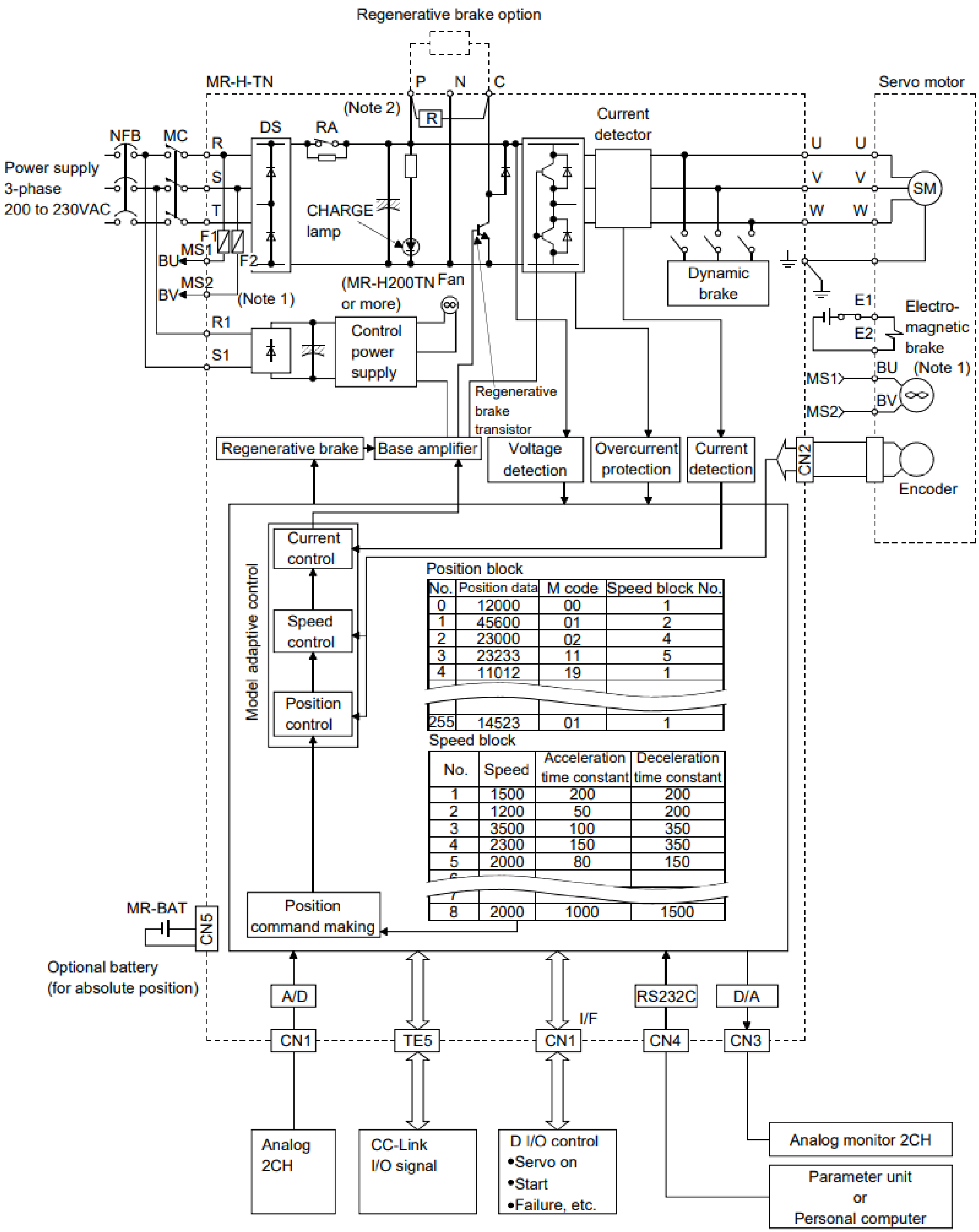


6.3 Auto tuning

6.3.1 Auto tuning mode

The servo amplifier has a real-time auto tuning function which estimates the machine characteristic (load to motor inertia ratio) in real time and automatically sets the optimum gains according to that value. This function permits ease of gain adjustment of the servo amplifier.

(1) Auto tuning mode 1

The servo amplifier is factory-set to the auto tuning mode 1.

In this mode, the load to motor inertia ratio of a machine is always estimated to set the optimum gains automatically.

The following parameters are automatically adjusted in the auto tuning mode 1.

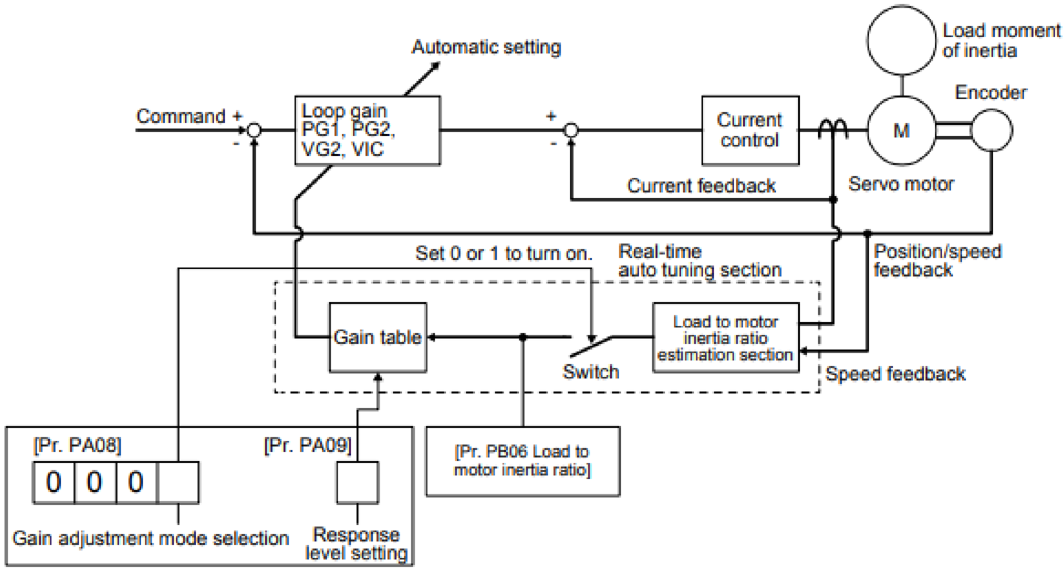
Parameter	Symbol	Name
PB06	GD2	Load to motor inertia ratio
PB07	PG1	Model loop gain
PB08	PG2	Position loop gain
PB09	VG2	Speed loop gain
PB10	VIC	Speed integral compensation

POINT

- The auto tuning mode 1 may not be performed properly if all of the following conditions are not satisfied.
  - The acceleration/deceleration time constant to reach 2000 r/min is 5 s or shorter.
  - The speed is 150 r/min or faster.
  - The load to motor inertia ratio is 100 times or smaller.
  - The acceleration/deceleration torque is 10% or higher of the rated torque.
- Under operating conditions which will impose sudden disturbance torque during acceleration or deceleration or on a machine which is extremely loose, auto tuning may not function properly, either. In such cases, use the auto tuning mode 2 or manual mode to make gain adjustment.

6.3.2 Auto tuning mode basis

The block diagram of real-time auto tuning is shown below.

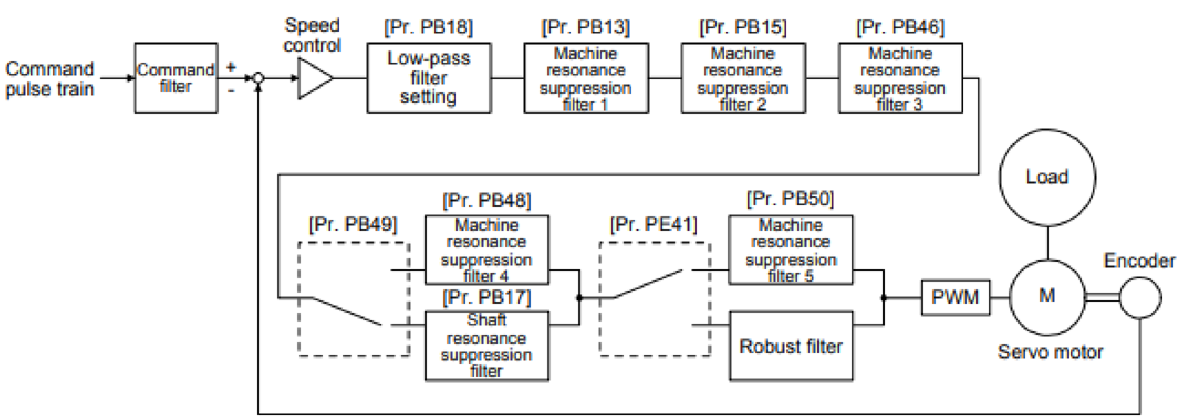


7. SPECIAL ADJUSTMENT FUNCTIONS

POINT
●The functions given in this chapter need not be used normally. Use them if you are not satisfied with the machine status after making adjustment in the methods in chapter 6.

7.1 Filter setting

The following filters are available with MR-JE servo amplifiers.



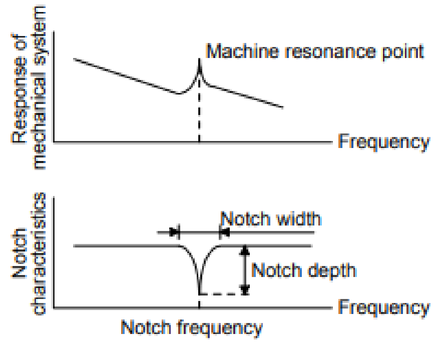
7.1.1 Machine resonance suppression filter

POINT
● The machine resonance suppression filter is a delay factor for the servo system. Therefore, vibration may increase if you set an incorrect resonance frequency or set notch characteristics too deep or too wide. ● If the frequency of machine resonance is unknown, decrease the notch frequency from higher to lower ones in order. The optimum notch frequency is set at the point where vibration is minimal. ● A deeper notch has a higher effect on machine resonance suppression but increases a phase delay and may increase vibration. ● A wider notch has a higher effect on machine resonance suppression but increases a phase delay and may increase vibration. ● The machine characteristic can be grasped beforehand by the machine analyzer on MR Configurator2. This allows the required notch frequency and notch characteristics to be determined.

If a mechanical system has a unique resonance point, increasing the servo system response level may cause resonance (vibration or unusual noise) in the mechanical system at that resonance frequency. Using the machine resonance suppression filter and adaptive tuning can suppress the resonance of the mechanical system. The setting range is 10 Hz to 4500 Hz.

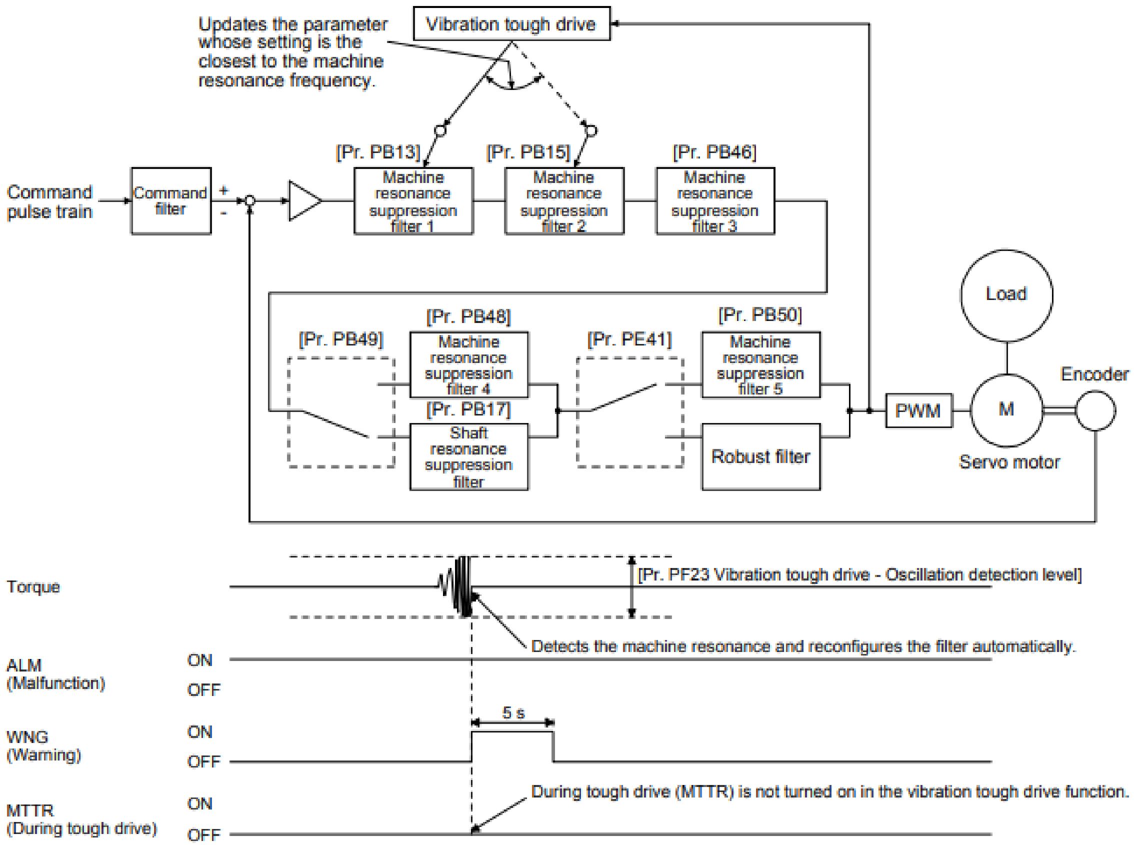
(1) Function

The machine resonance suppression filter is a filter function (notch filter) which decreases the gain of the specific frequency to suppress the resonance of the mechanical system. You can set the frequency (notch frequency) at which the gain is decreased, and the notch depth and width.



You can set five machine resonance suppression filters at most.

Filter	Setting parameter	Precaution	Parameter that is reset with vibration tough drive function	Parameter automatically adjusted with one-touch tuning
Machine resonance suppression filter 1	PB01/PB13/PB14	The filter can be set automatically with "Filter tuning mode selection" in [Pr. PB01].	PB13	PB01/PB13/PB14
Machine resonance suppression filter 2	PB15/PB16		PB15	PB15/PB16
Machine resonance suppression filter 3	PB46/PB47			PB46/PB47
Machine resonance suppression filter 4	PB48/PB49	Enabling the machine resonance suppression filter 4 disables the shaft resonance suppression filter. Using the shaft resonance suppression filter is recommended because it is adjusted properly depending on the usage situation. The shaft resonance suppression filter is enabled for the initial setting.		PB48/PB49
Machine resonance suppression filter 5	PB50/PB51	Enabling the robust filter disables the machine resonance suppression filter 5. The robust filter is disabled for the initial setting.		PB51



Updates the parameter whose setting is the closest to the machine resonance frequency.
Vibration tough drive
[Pr. PB13]
[Pr. PB15]
[Pr. PB46]
Command pulse train
Command filter
+
-
Machine resonance suppression filter 1
Machine resonance suppression filter 2
Machine resonance suppression filter 3
Load
[Pr. PB48]
[Pr. PB50]
[Pr. PB49]
[Pr. PE41]
Machine resonance suppression filter 4
Machine resonance suppression filter 5
Encoder
[Pr. PB17]
PWM
M
Shaft resonance suppression filter
Robust filter
Servo motor
Torque
[Pr. PF23 Vibration tough drive - Oscillation detection level]
Detects the machine resonance and reconfigures the filter automatically.
ALM (Malfunction)
ON
OFF
5 s
WNG (Warning)
ON
OFF
During tough drive (MTTR) is not turned on in the vibration tough drive function.
MTTR (During tough drive)
ON
OFF

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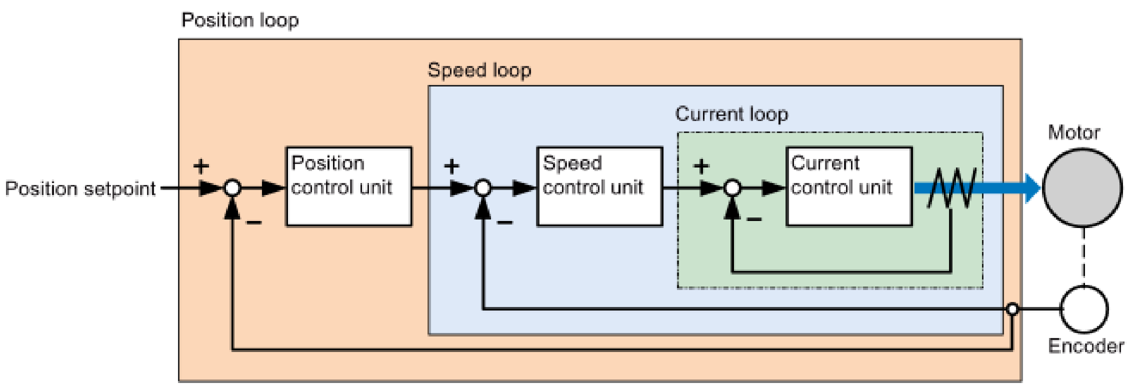
9.1 Controller overview

The SINAMICS V90 servo drive consists of three control loops:

- Current control
- Speed control
- Position control

The following block diagram shows the relationship between these three control loops:



In theory, frequency width of the inside control loop **must** be wider than that of the outer control loop; otherwise, the whole control system can vibrate or have a low response level. The relationship between the frequency widths of these three control loops is as follows:

Current loop > speed loop > position loop

Since the current loop of SINAMICS V90 servo drive already has a perfect frequency width, it is only necessary for you to adjust the speed loop gain and the position loop gain.

Servo gains

- Position loop gain

  Position loop gain directly influences the response level of the position loop. If the mechanical system does not vibrate or produce noises, you can increase the value of position loop gain so that the response level can be increased and positioning time can be shortened.

Parameter	Range	Default	Unit	Description
p29110[0]	0.00 to 300.00	Motor dependent	1000/min	Position loop gain 1
p29110[1]	0.00 to 300.00	1.00	1000/min	Position loop gain 2

- Speed loop gain

Speed loop gain directly influences the response level of the speed loop. If the mechanical system does not vibrate or produce noises, you can increase the value of speed loop gain so that the response level can be increased.

Parameter	Range	Default	Unit	Description
p29120[0]	0 to 999999	Motor de-pendent	Nms/rad	Speed loop gain 1
p29120[1]	0 to 999999	0.3	Nms/rad	Speed loop gain 2

- Speed loop integral gain

With adding integral component into speed loop, the servo drive can efficiently eliminate the steady-state error of speed and give response to a small change to speed.

Generally speaking, if the mechanical system does not vibrate or produce noises, you can decrease speed loop integral gain so that the system rigidity can be increased.

If the load inertia ratio is very high or the mechanical system has a resonance factor, it must be guaranteed that the speed loop integral time constant is big enough; otherwise, the mechanical system may have a resonance.

Parameter	Range	Default	Unit	Description
p29121[0]	0 to 100000	15	ms	Speed loop integral time 1
p29121[1]	0 to 100000	20	ms	Speed loop integral time 2
p29022	1 to 10000	1	-	Load moment of inertia ratio

- Position loop feed forward gain

With position loop feed forward gain, the responsiveness level can be increased. If the position loop feed forward gain is too big, motor speed can have overshoots and the digital output signal INP can have a repeated on/off. You, therefore, must monitor the changes to speed waveform and the action of the digital output signal INP during adjustment. You can slowly adjust the position loop feed forward gain. The effect of feed forward function is not obvious if the position loop gain is too big.

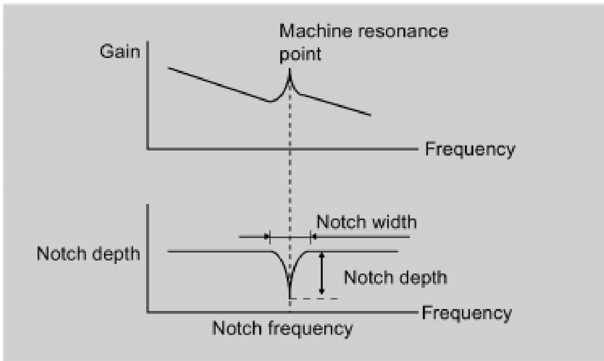
Parameter	Range	Default	Unit	Description
p29111	0.00 to 200.00	0	%	Position loop feed forward gain

9.6 Resonance suppression

The resonance suppression function is filter (notch filter) function. It detects mechanical resonance at a frequency between 250 Hz and 1500 Hz, and decreases the gain of specific frequency (by automatically setting notch filter) to suppress the mechanical resonance.

Now four current setpoint filters are available for the V90 servo drive. Filter 1 is lowpass filter. Filter 2, filter 3 and filter 4 are band damp filters.

The gain decreasing frequency, width as well as depth can be set by setting the notch filter:



9.7 Low frequency vibration suppression

The low frequency vibration suppression function is a position setpoint filter function. It can suppress the vibration from 0.5 Hz to 62.5 Hz. The function is available in IPos control mode.

Related parameters

When you use the vibration suppression function, you need to configure the following parameters accordingly:

Parameter	Range	Default	Unit	Description
p29035	0 to 1	0	-	Vibration suppression activation. • 0: disable • 1: enable
p31581	0 to 1	0	-	Vibration suppression filter type. • 0: filter type rugged • 1: filter type sensitive
p31585	0.5 to 62.5	1	Hz	Vibration suppression filter frequency.
p31586	0 to 0.99	0.03	-	Vibration suppression filter damp.

9.8 Gain switching

Note

The Gain Switching function is **not** available in **T** mode (torque control mode).

The function of auto-tuning must be disabled so that the function of gain switching can be available.

With this function, you can implement the following operations:

- Increase the gains during servo lock and decrease gains to reduce noise during rotation.
- Increase the gains during settling to shorten the stop settling time.
- Switch between two groups of gains using an external signal (G-CHANGE) to ensure stability of the servo system because the load inertia moment ratio varies greatly during a stop (for example, a large load is mounted on a carrier).

9.9 PI/P switching

Note

PI/P switching

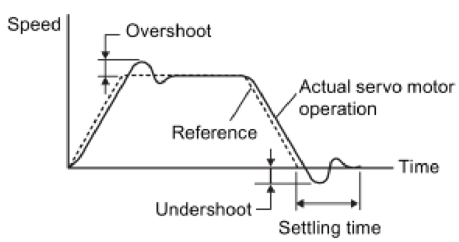
Function of PI/P switching is **not** available for the **T** mode (torque control mode).

The functions of auto-tuning and gain switching must be disabled so that the function of PI/P switching can be available.

The PI/P switching will respond with a delay time of several milliseconds.

The function of PI/P switching is used to switch from **PI** (Proportional/Integral) control of speed controller to **P** (Proportional) control. With this function, you can:

- shorten the position setting time (for the position control mode).
- avoid overshooting of actual speed value during acceleration or deceleration (for the speed control mode).
- avoid unnecessary torque when the target position is at a mechanical limitation (for the position control mode).



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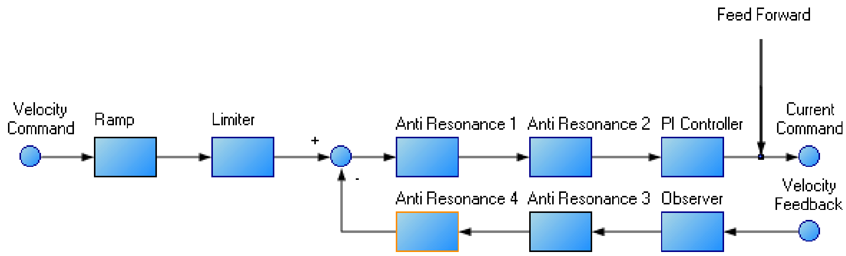
Closed Loop Tuning Methods

The closed loop control loop is responsible for the desired position and / or velocity (trajectory) of the motor and commanding the appropriate current to the motor to achieve that trajectory. The challenge in closed loop control loops is to make a system that not only follows the desired trajectory, but also is stable in all conditions and resist external forces, and do all of this at the same time.

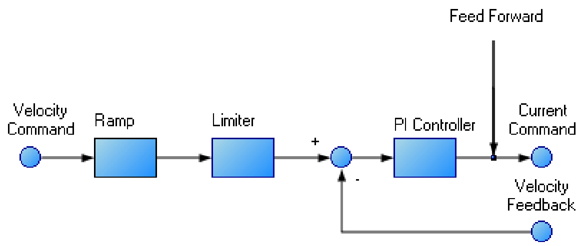
When in velocity operation mode, only the velocity loop is tuned. When in position operation mode, both the velocity and position loops must be tuned.

Tuning the Velocity Loop

The velocity loop on the AKD consists of a PI (proportional, integral) in series with two anti-resonance filters (ARF) in the forward path and two-anti resonance filters in series in the feedback path.

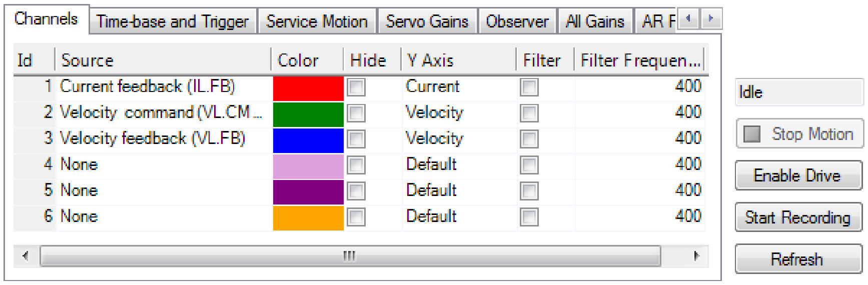


To perform basic tuning of the velocity loop, you can use just the PI block and set ARF1 and ARF2 to unity (no effect) and set the observer to 0 (no effect). Using just the PI block simplifies the process of tuning the velocity loop. To start tuning you can adjust the PI Controller block first. A simplified velocity loop without anti-resonant filters and observer is shown below. This is how you can think of the loop before the anti resonant filters and observer is used.



Procedure for simple velocity loop tuning:

1. Set DRV.OPMODE to velocity or position, as appropriate for your application. If DRV.OPMODE is set to position, set VL.KVFF to 1.0.
2. Set VL.KP to 0.
3. Set VL.KI to 0.
4. Set service motion to make a motion that is similar to the move speeds that will be used in the real application. Do not set the service motion to a speed higher than ½ of the maximum motor speed, to allow for safe overshoot during tuning. Set acceleration to an appropriate value for your application. Set service motion to reversing. Set time1 and time2 equal to 3 times the expected settling time for the system. 1.0 second is a reasonable value for time1 and time2, if you don't know the expected settling time.
5. Enable the drive and start the service motion. You should see no motion, as there are no velocity loop tuning gains at this point.
6. When adjusting VL.KP and VL.KI, below record VL.FB and VL.CMD. These are the traces that are used to determine the performance of the velocit loop.

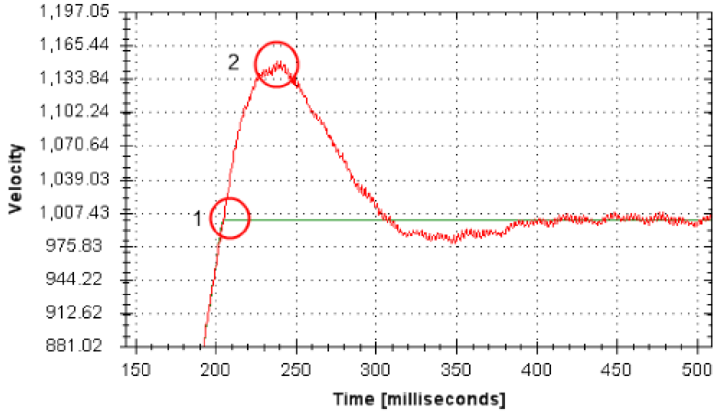


7. Adjust VL.KP. Keep increasing VL.KP by a factor of 2 until you either:

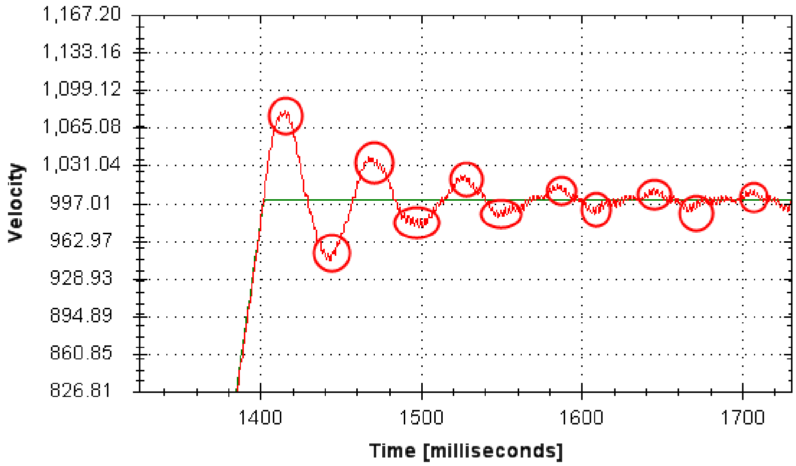
- Hear an objectionable noise from the system (buzzing, humming, etc) or
- See velocity overshoot. No velocity overshoot should be present when using only VL.KP.
- When you reach one of the limits above, decrease VL.KP to the value where there were no objectionable noises or overshoot.

8. Adjust VL.KI. Increase VL.KI by a factor of 1.5 until you either:

- Hear or see objectionable noise or shuddering from the system
- See > 15% overshoot
- Here is an example of 15% overshoot. This is zoomed in view of a service motion commanded to 1000 RPM (location 1), where the overshoot peaks at 1150 RPM (location 2).



- Here is an example of 11 overshoots. Each overshoot is shown by a red circle.

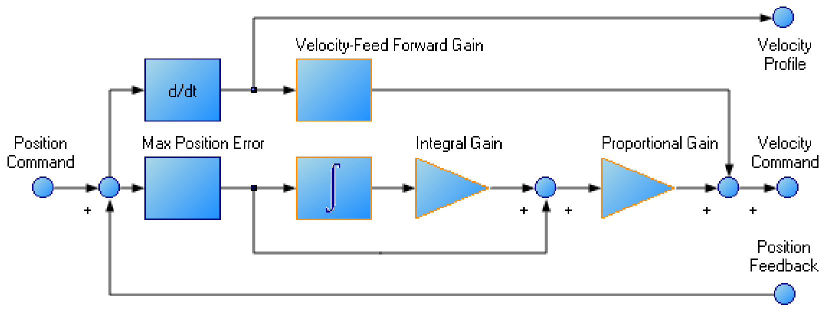


- When you reach one of the limits above, decrease VL.KI to the value where there were no objectionable noises or overshoot.

Tuning the Position Loop

The position loop is a second loop that builds upon a correctly tuned velocity loop to provide accurate control over position. The position loop is a simple element that consists of a PI loop. It is simplest to tune the P and I terms in the velocity loop and use only the P term in the position loop.

At most, use only three non-zero P and I terms from both the velocity loop and the position loop. One combination would be VL.KP, VL.KI, and PL.KP. Another valid combination would be VL.KP, PL.KP, and PL.KI. The VL.KP, VL.KI, and PL.KP combination is shown here.



Procedure for tuning position loop:

1. Set VL.KVFF to 1
2. Increase PL.KP until either:

- You see 25% overshoot, or
- You see > 3 overshoots, or
- You hear objectionable noises from the system.
- When you reach one of the limits above, decrease PL.KP to the value where there were no objectionable noises or overshoot.

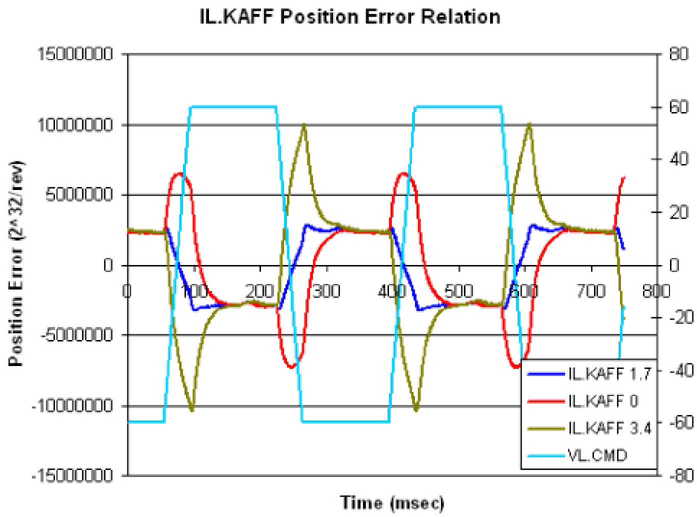
Torque Feedforward Tuning Methods

The torque based feedforward terms on the AKD effectively model the physics of your motor and allow the drive to command the appropriate current, even before the encoder has time to send data back to the drive. Torque based feedforward terms allow you to lower following error with virtually no stability penalty.

Shape Based Feedforward Tuning

To adjust IL .KAFF:

- Tune the VL.KP and VL.KI as shown above in the velocity loop tuning section. Set DRV.OPMODE to velocity (or set PL.KP and PL.KI to 0 and vl.kvff to 1).
- Set up a short, repeating service motion with accelerations that are representative of the moves you will use in your application (exact values for acceleration are not critical).
- Turn up IL.KAFF until the position error (PL.ERR) is proportional to the inverted velocity command. The adjustment of IL.KAFF will focus on removing bumps on acceleration and deceleration. The picture below has an ideal value of IL.KAFF of 1.7.



Using Anti-Resonance Filters

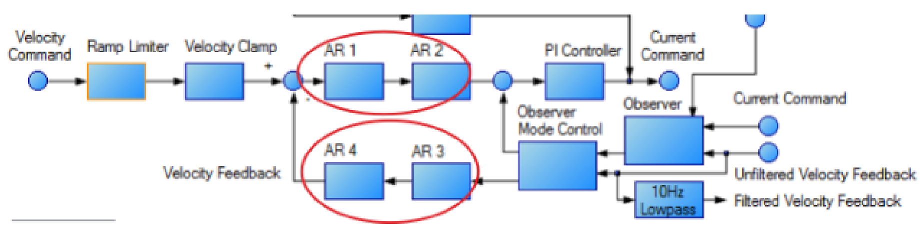
The AKD has four anti-resonance filters. Two filters are in the forward path and two are in the feedback path.

Similarities

- Both types are typically used to enhance stability and performance of the system.

Differences

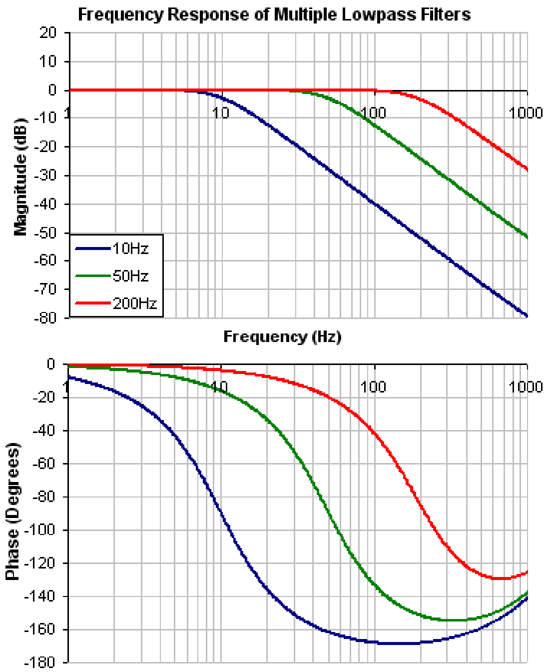
- Forward path filters result in higher phase lag in closed loop system response.
- Forward path filters limit spectrum from reaching the motor / feedback path filters only filter the feedback after it has been to the motor.



Types of Anti-Resonance Filters

Low Pass

A low pass filter allows signals through below a corner frequency and attenuates the signals above the same corner frequency. The behavior at the corner frequency can be specified with the low-spass Q.



To specify a lowpass filter, you must specify the frequency and Q for both the zero and pole on anti-resonance filter 1. To do this, see the following example using the terminal commands that sets:

- Filter Type = Biquad
- Zero frequency = 700 Hz (This is the Lowpass cutoff frequency)
- Zero Q = 0.707
- Pole frequency = 5000 Hz
- Pole Q = 0.707

VL.ARTYPE1 0

VL.ARZF1 700

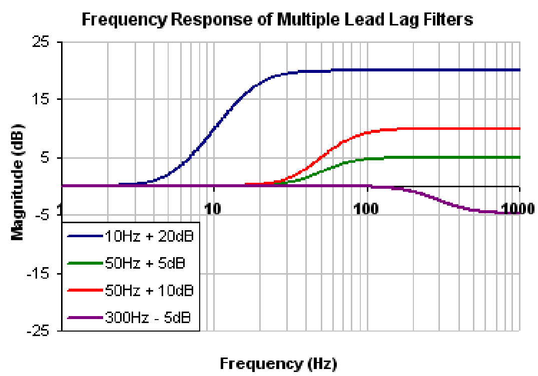
VL.ARZQ1 0.707

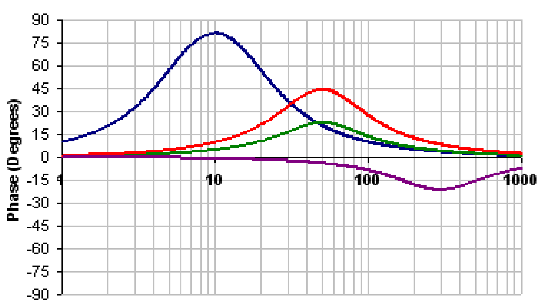
VL.ARPF1 5000

VL.ARPQ1 0.707

Lead Lag

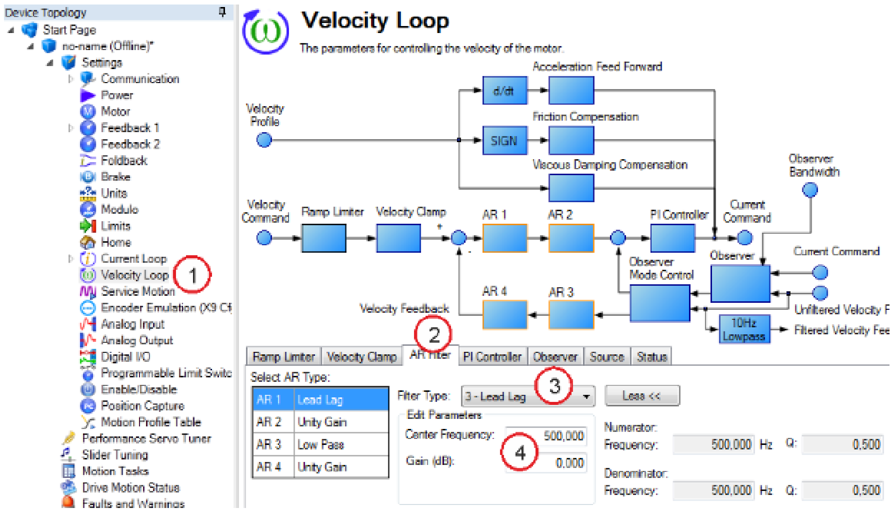
A lead lag filter is a filter that has 0 dB gain at low frequencies and a gain that you specify at high frequencies. You also specify the frequency that the gain at which the transition occurs.





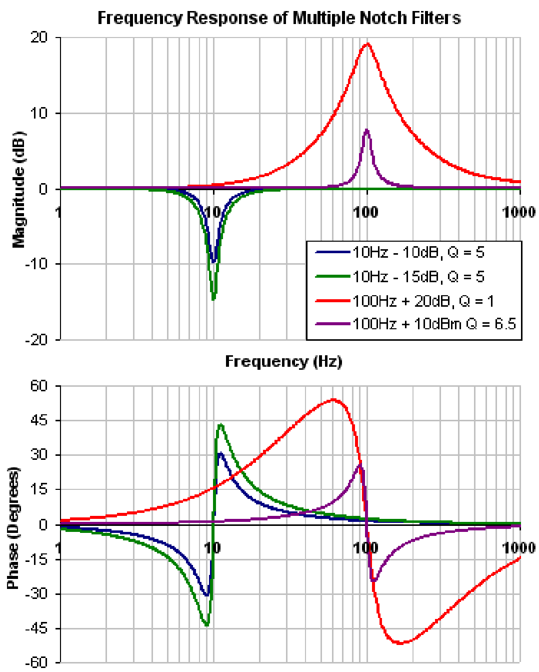
To specify a Lead Lag filter, you must specify the Center Frequency and high frequency Gain (dB). To do this, see the following example by clicking on the Velocity Loop:

Click on Velocity Loop tab (1), then select the AR1 Tab (2), using the Filter Type drop-down, select Lead Lag (3), lastly, enter the desired Center Frequency and Gain of the Lead Lag filter (4).



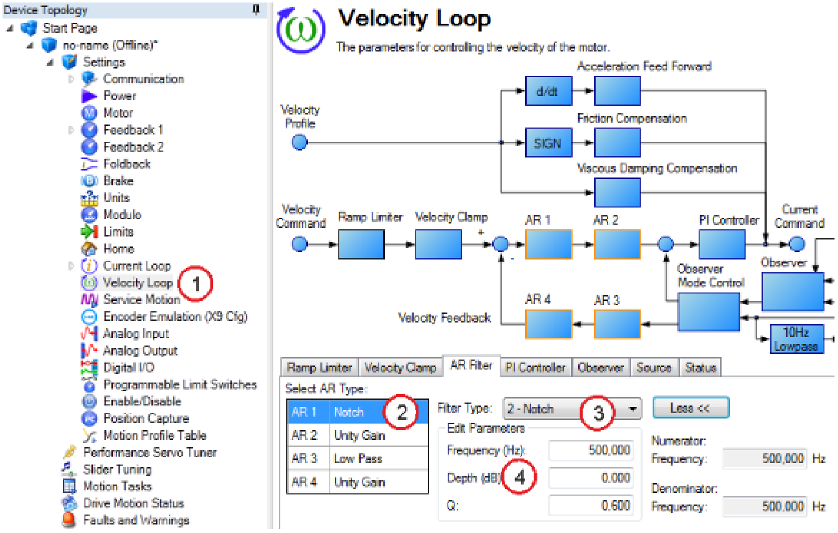
Notch

A notch filter changes gain at a specific frequency. You specify the frequency at which the gain change occurs (Frequency (Hz)), how wide of a frequency range the cut occurs (Q), and how much the gain changes (Notch Depth (dB)).



To specify a notch filter, you must specify the Frequency (Hz), Depth (dB) and Width (Q) of the notch. To do this, see the following example by clicking on the Velocity Loop:

Click on Velocity Loop (1), then select the AR1 Tab (2), using the Filter Type drop-down, select Notch (3), lastly, enter the desired Frequency, Depth and Q of the Notch filter (4).



Biquad

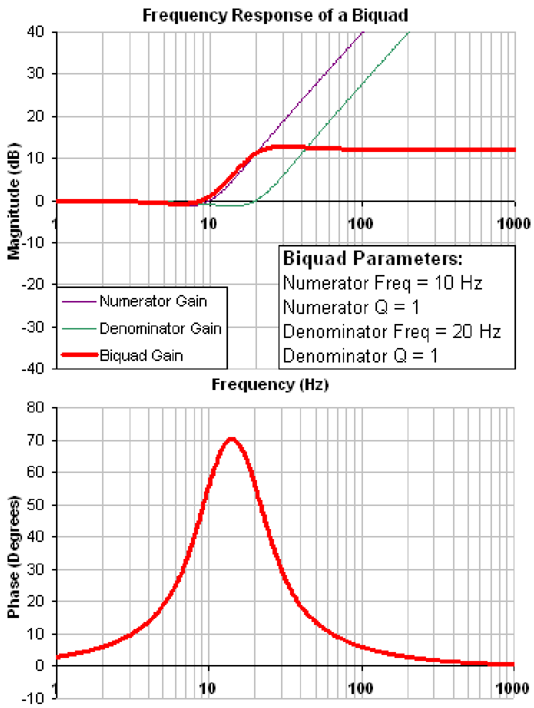
A biquad is a flexible filter that can be thought up as being made up of two simpler filters; a zero (numerator) and a pole (denominator). In fact, the pre-defined filters mentioned above are really just special cases of the biquad.

Both the zero (numerator) and the pole (denominator) have a flat frequency response at low frequencies and a rising frequency response at high frequencies. The transition frequency and damping must be specified for both the numerator and denominator.

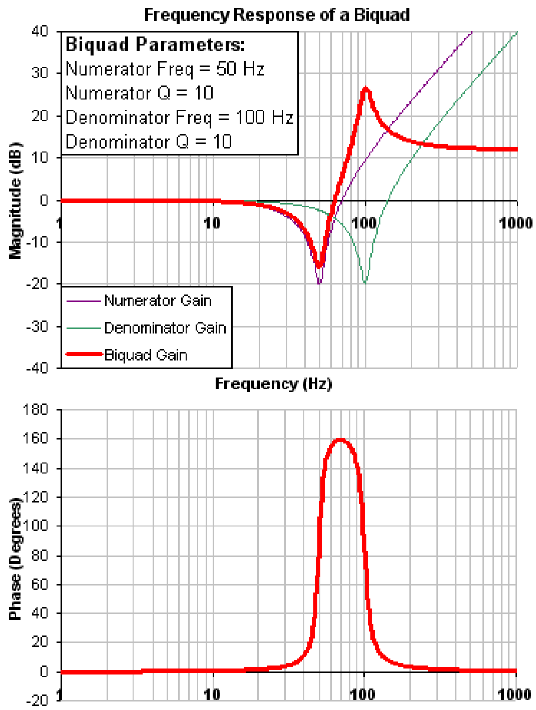
Analyzing the numerator and denominator, the frequency response calculation is simple:

If the numerator and denominator are plotted in dB, the biquad response is numerator – denominator. Understanding how the numerator and denominator work is crucial in understanding how a biquad frequency response is created.

Below is an example of a biquad filter similar to a Lead Lag filter type. To help understand how to determine the frequency response of the biquad, the numerator and denominator response have been plotted. If the denominator is subtracted from the numerator, the biquad response is the result.

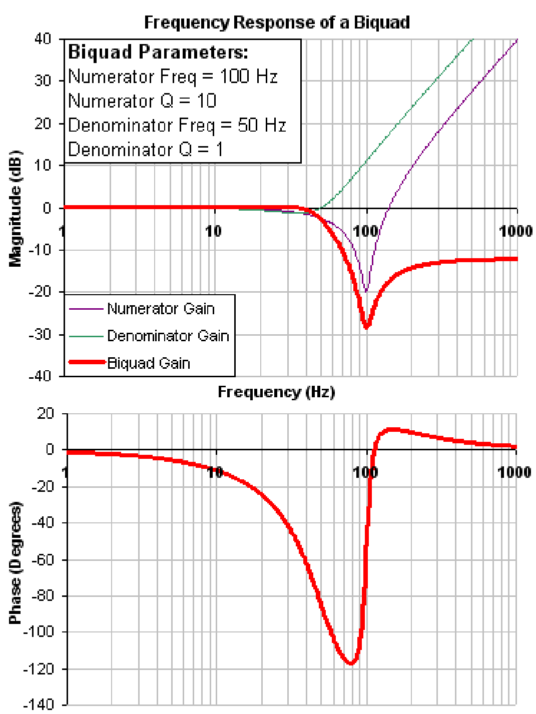

Frequency Response of a Biquad
Magnitude (dB)
Frequency (Hz)
Numerator Gain
Denominator Gain
Biquad Gain
Biquad Parameters:
Numerator Freq = 10 Hz
Numerator Q = 1
Denominator Freq = 20 Hz
Denominator Q = 1
Phase (Degrees)

The biquad filter is very flexible, which allows custom filters to be designed. Below is an example of a resonance filter using a biquad. Notice how the high Q values affect the numerator and denominator. This gives a biquad frequency response similar to a mechanical resonance.



The previous two examples used a numerator frequency lower than the denominator frequency, yielding a positive gain in high frequencies. If the denominator frequency is lower than the numerator frequency, then high frequencies will have a negative gain.

Below is an example where the numerator frequency is higher than the denominator. Notice the high frequencies have a negative gain.



To specify a biquad filter, you must specify the frequency and Q for both the zero and the pole on anti-resonance filter 3. To do this, see the following example using the terminal commands that sets:

- Filter Type = Biquad
- Zero frequency = 100 Hz
- Zero Q = 0.7
- Pole frequency = 1000 Hz
- Pole Q = 0.8

VL.ARTYPE3 0

VL.ARZF3 100

VL.ARZQ3 0.7

VL.ARPF3 1000

VL.ARPQ3 0.8

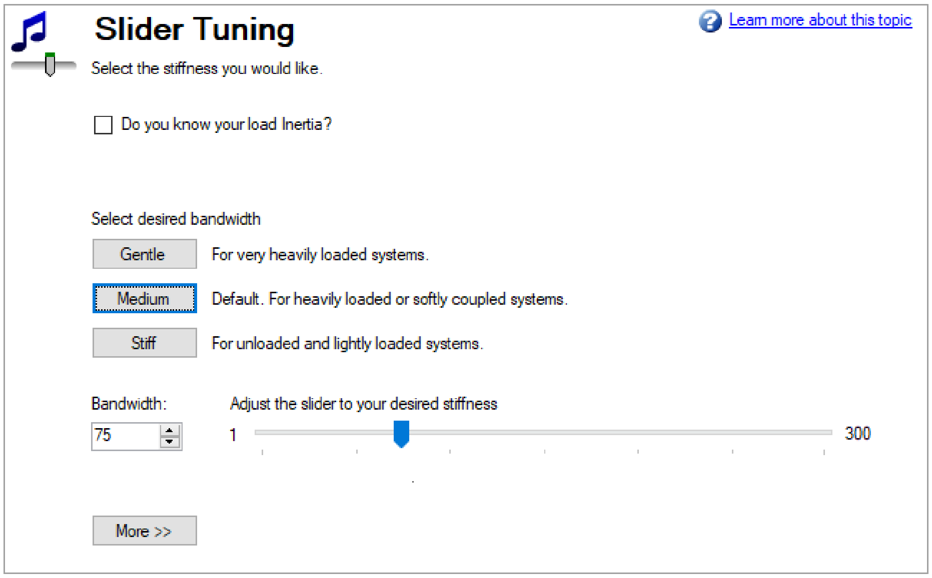
Biquad Calculations

In the s-domain, the linear biquad response is calculated:

$$\text{Biquad Frequency Response} = \frac{s^2 + \frac{\omega_N}{Q_N}s + \omega_N^2}{s^2 + \frac{\omega_D}{Q_D}s + \omega_D^2}$$

Slider Tuning

This view allows you to vary the tuning of your drive using the slider.



Load Inertia

If you know your load inertia (AXIS#.LOAD.INERTIA)(LOAD.INERTIA), enter it in kcgm^2 for rotary motors. If no load inertia is entered, WorkBench will assume a 1:1 ratio between your load inertia and motor inertia.

Gentle, Medium, and Stiff

These buttons select three of the most common bandwidths:

- Gentle works in all but the most challenging situations.
- Medium is the default and works in most situations.
- Stiff works for unloaded motors.

Gentle, Medium, and Stiff

These buttons select three of the most common bandwidths:

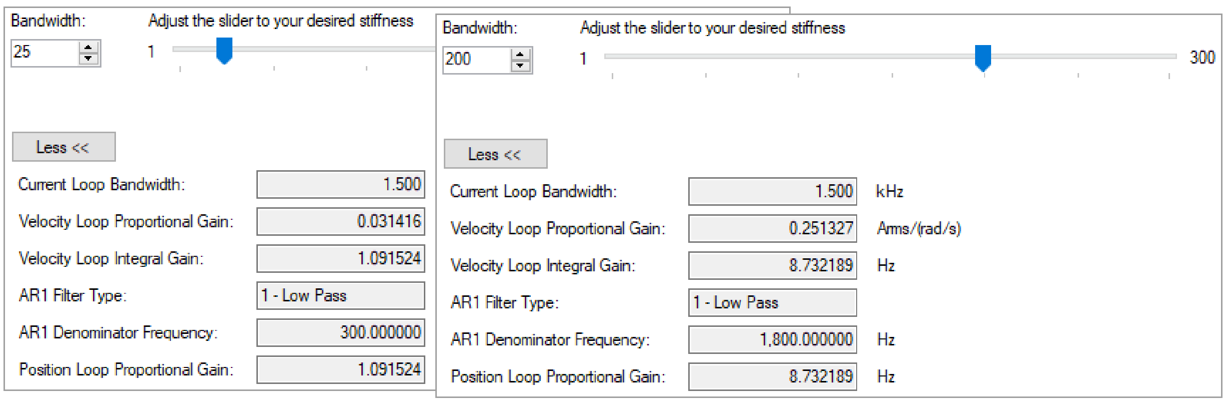
- Gentle works in all but the most challenging situations.
- Medium is the default and works in most situations.
- Stiff works for unloaded motors.

Bandwidth Slider

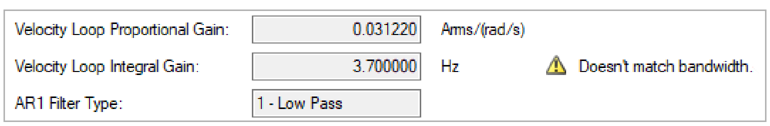
As you drag the slider to the right, the stiffness increases. In many situations, you cannot drag the slider fully to the right side because the system will become unstable. The Bandwidth field value updates to match the slider. You may also manually enter a value in the Bandwidth field.

More / Less Button

Clicking the More / Less button shows or hides some read-only values that are affected by the slider tuning. The following image provides an example of how the values change with different Bandwidth settings.

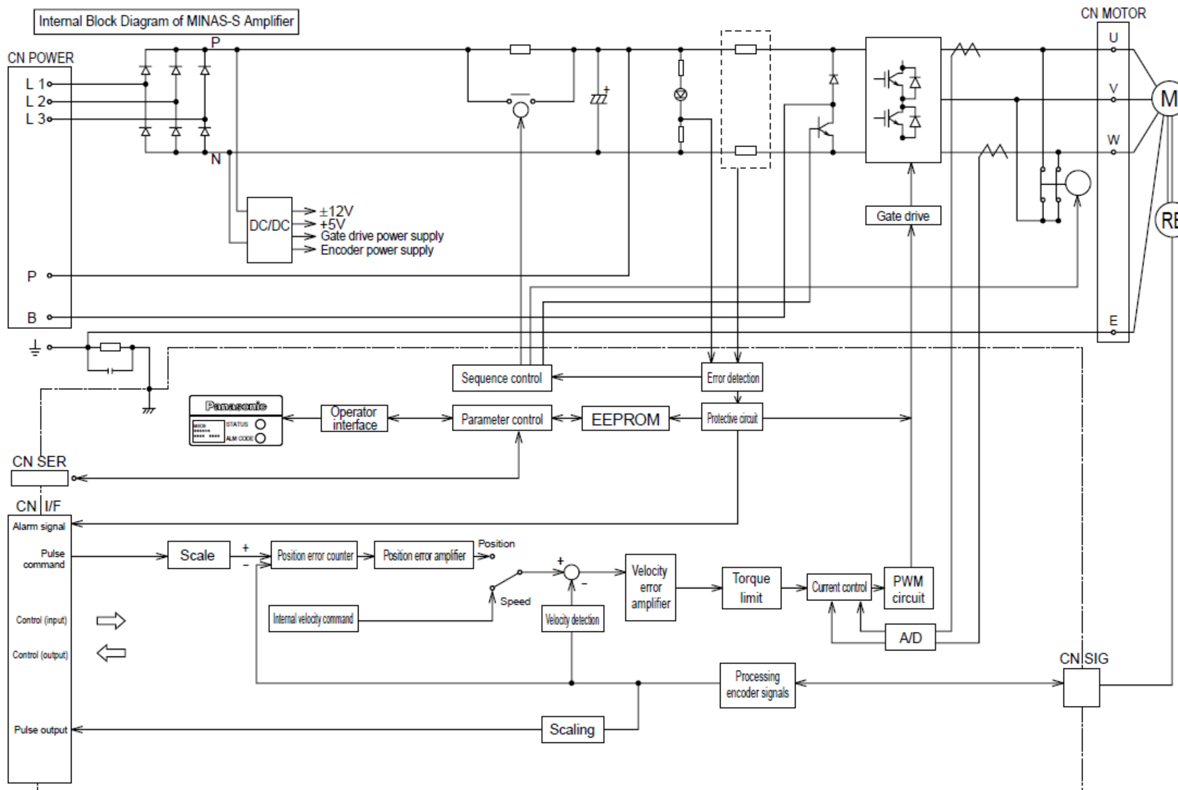


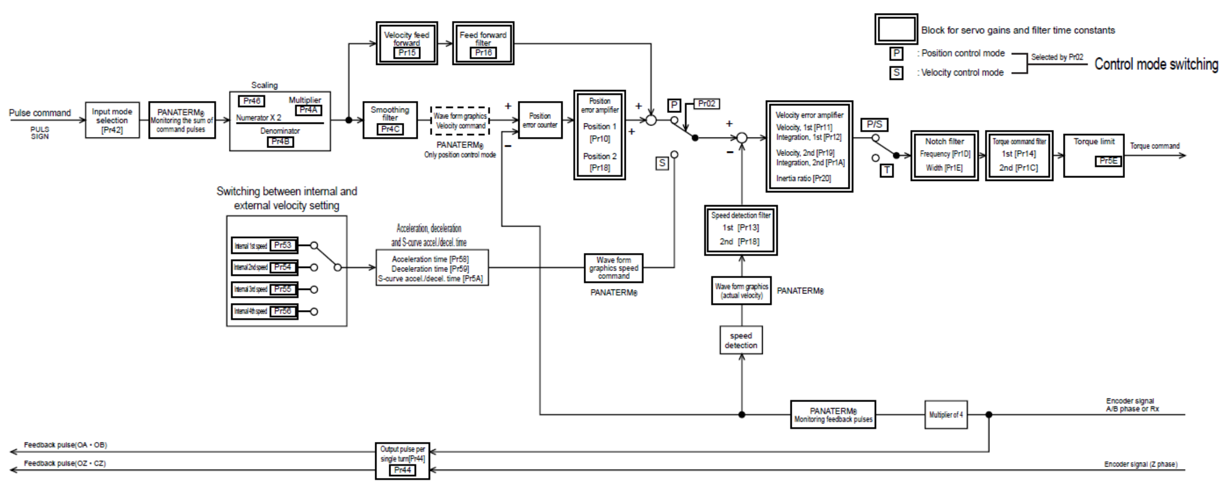
These fields will display a warning if the values are out of synch with the slider tuning. For example, a warning is shown if a value is changed in the Terminal. Moving the slider will clear the warning, putting the value back in synch with the slider tuning.



30 Panasonic

M





31 Festo

M

Once the auto-tuning is complete, use the button "Apply values" to transfer the results to the plug-in.
The following new values are then displayed on the page "Closed loop" and the page "Auto tuning":

– Result amplification gain of position controller
– Result amplification gain of velocity controller
– Result integration constant of velocity controller

2.3.9.9 Vibration compensation

Notch filters are provided to suppress interfering frequencies.

"1. Notch filter", "2. Notch filter" and "3. Notch filter"

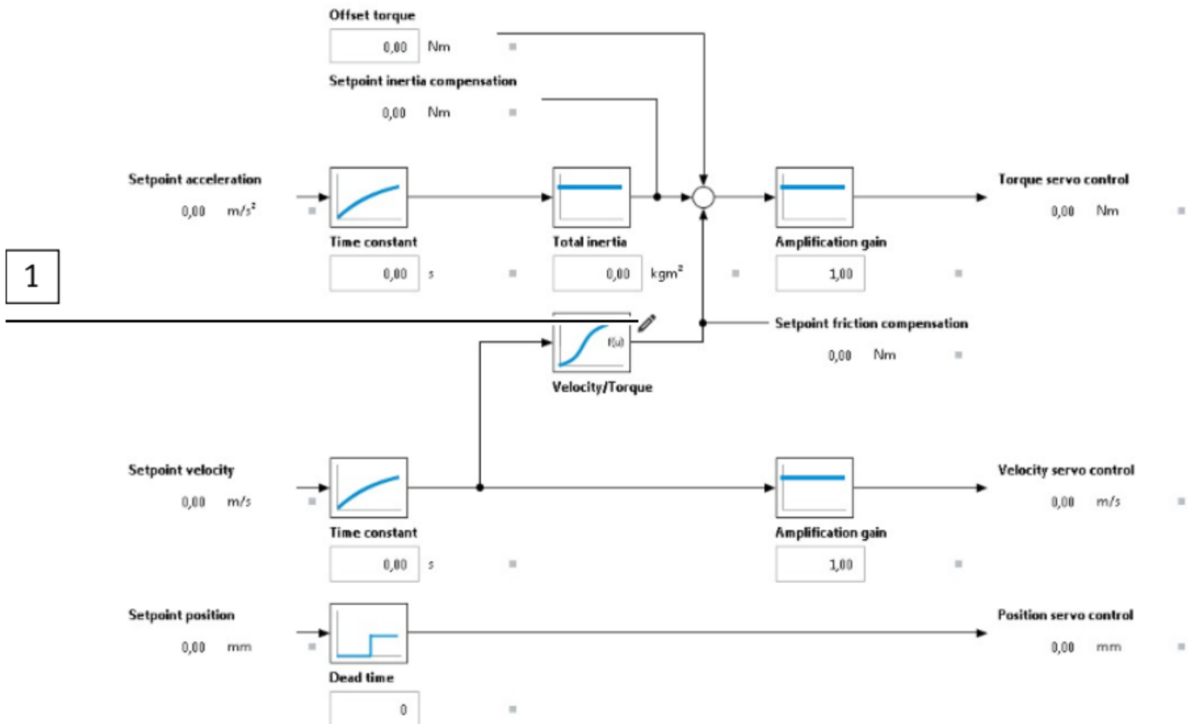
The properties of the notch filters are specified in these parameter groups.
Additional information on the notch filter → 6.4 Notch Filter.

"Vibration frequency 1" and "Vibration frequency 2"

By specifying a natural frequency, the specified frequency is suppressed in the positioning operating mode.

2.3.9.10 Feed forward control

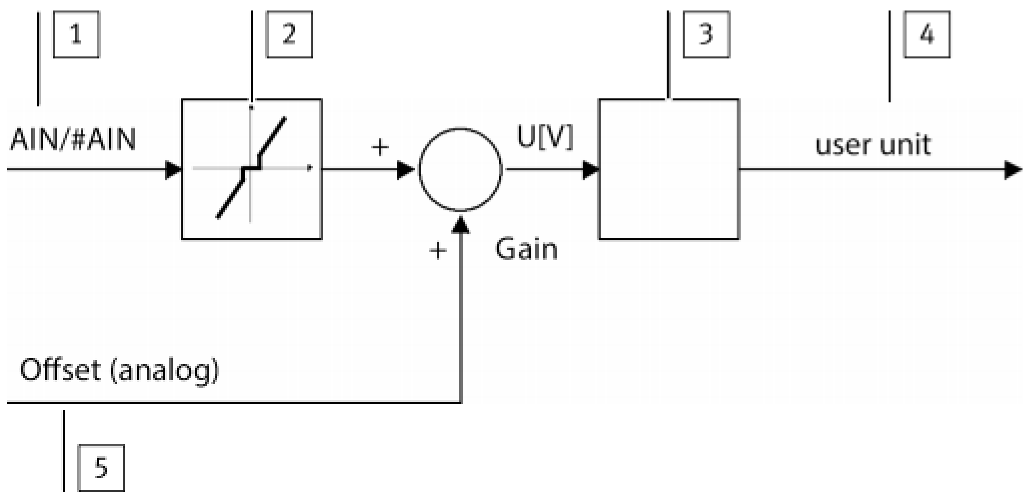
The pilot control prepares the deactivation variables for the closed-loop controller. This ensures that the positioning behaviour of the drive and run-in behaviour can be improved in accordance with the target position and that the contouring error can be reduced.
The input variables for the pilot control are directly connected to the output variable or are adjusted using a mathematical operation.
Additional information on pilot control → 6.3 Pilot control (Setpoint value control).
The working area contains a graphic to set the parameters for the pilot control calculation.



1 "Edit friction"

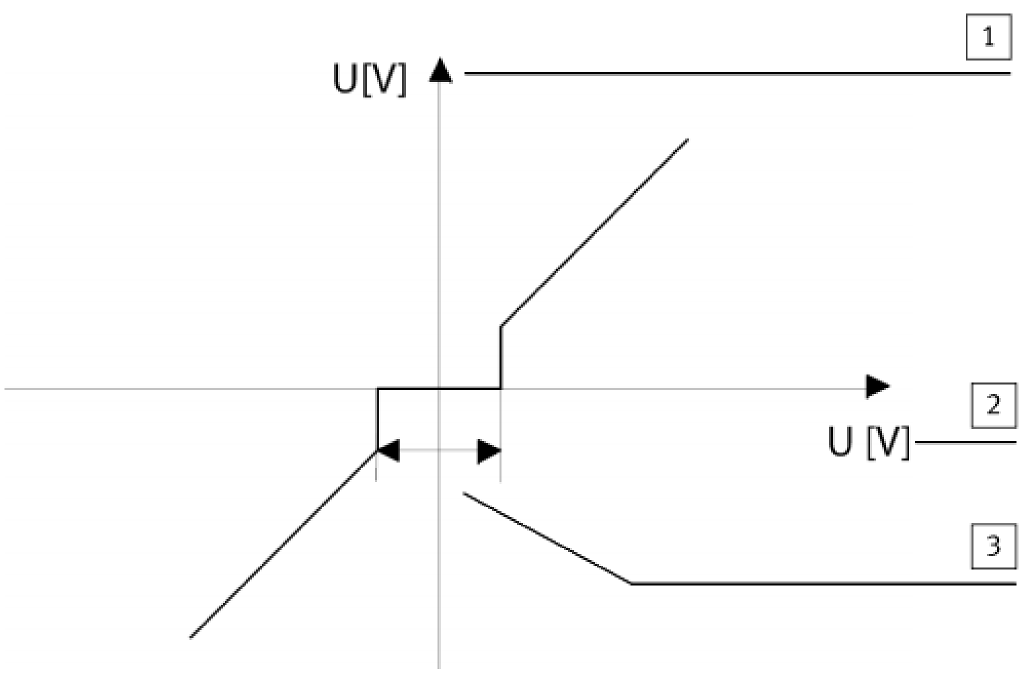
Fig. 20 "Feed forward control"parameter panel

Internal signal process, safe zero



1 Analogue input signal
2 Safe zero
3 Scaling factor
4 Set value in user units
5 Offset

Fig. 39 Internal signal process, safe zero



1 Safe zero function output
2 Voltage at analogue input AIN/#AIN
3 Safe zero window (width = 2 x parameters)

Fig. 40 Function of safe zero

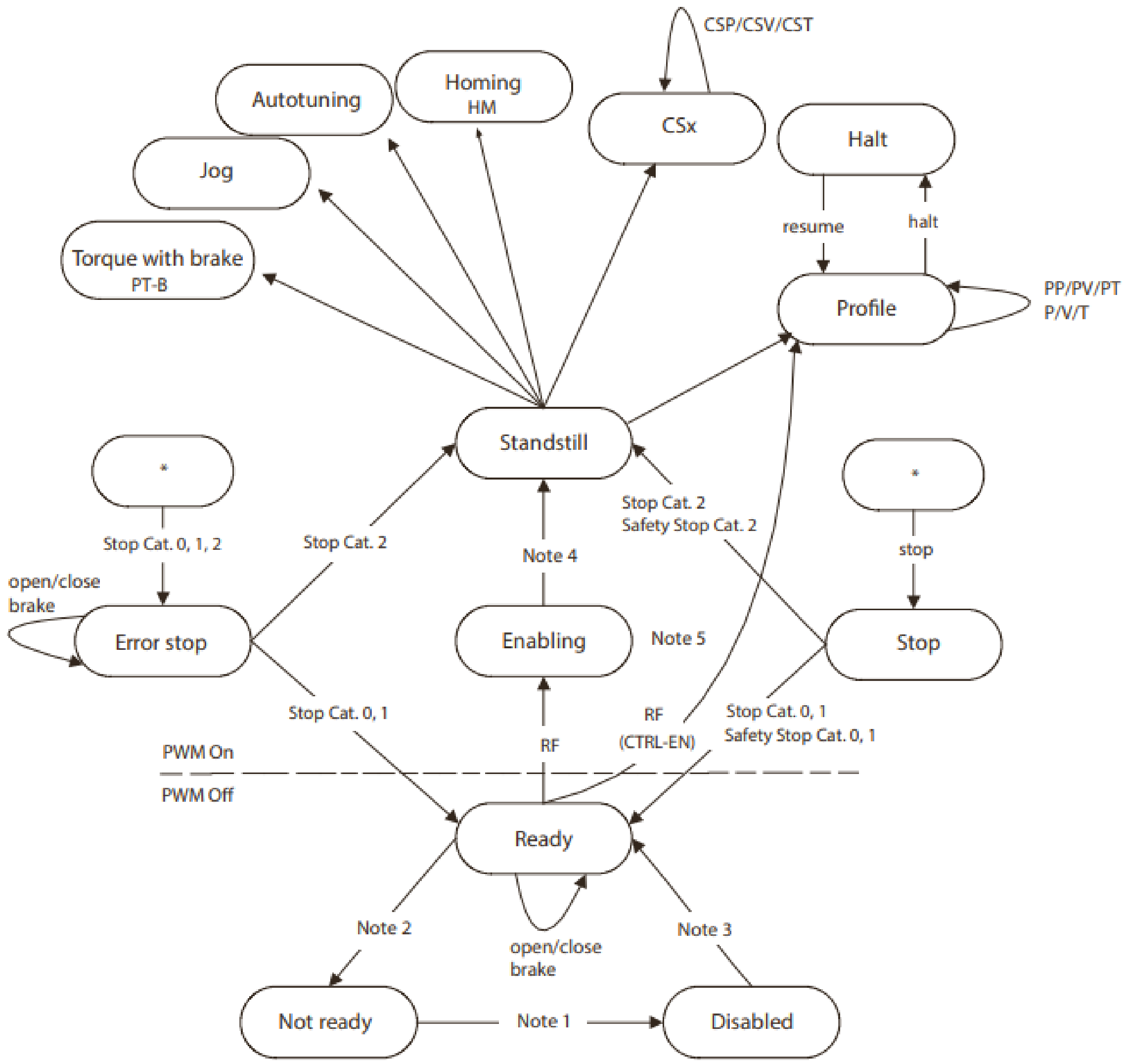


Fig. 42 Statuses and status transitions of the internal finite state machine

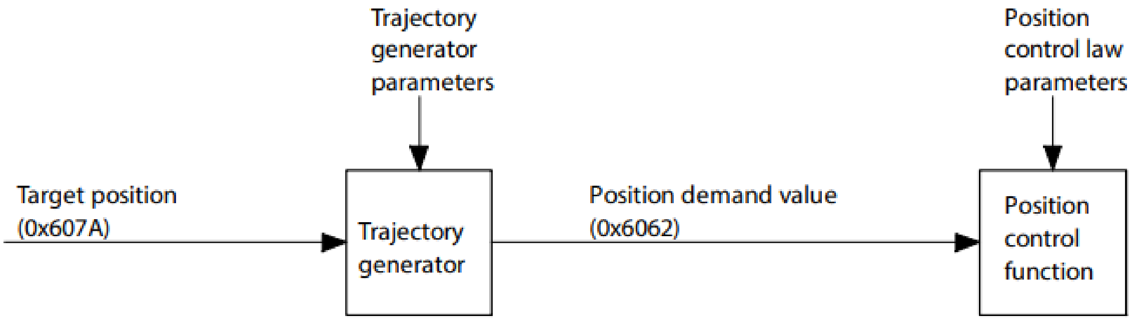


Fig. 46 Overview of the trajectory generator - position control operating mode (PP)

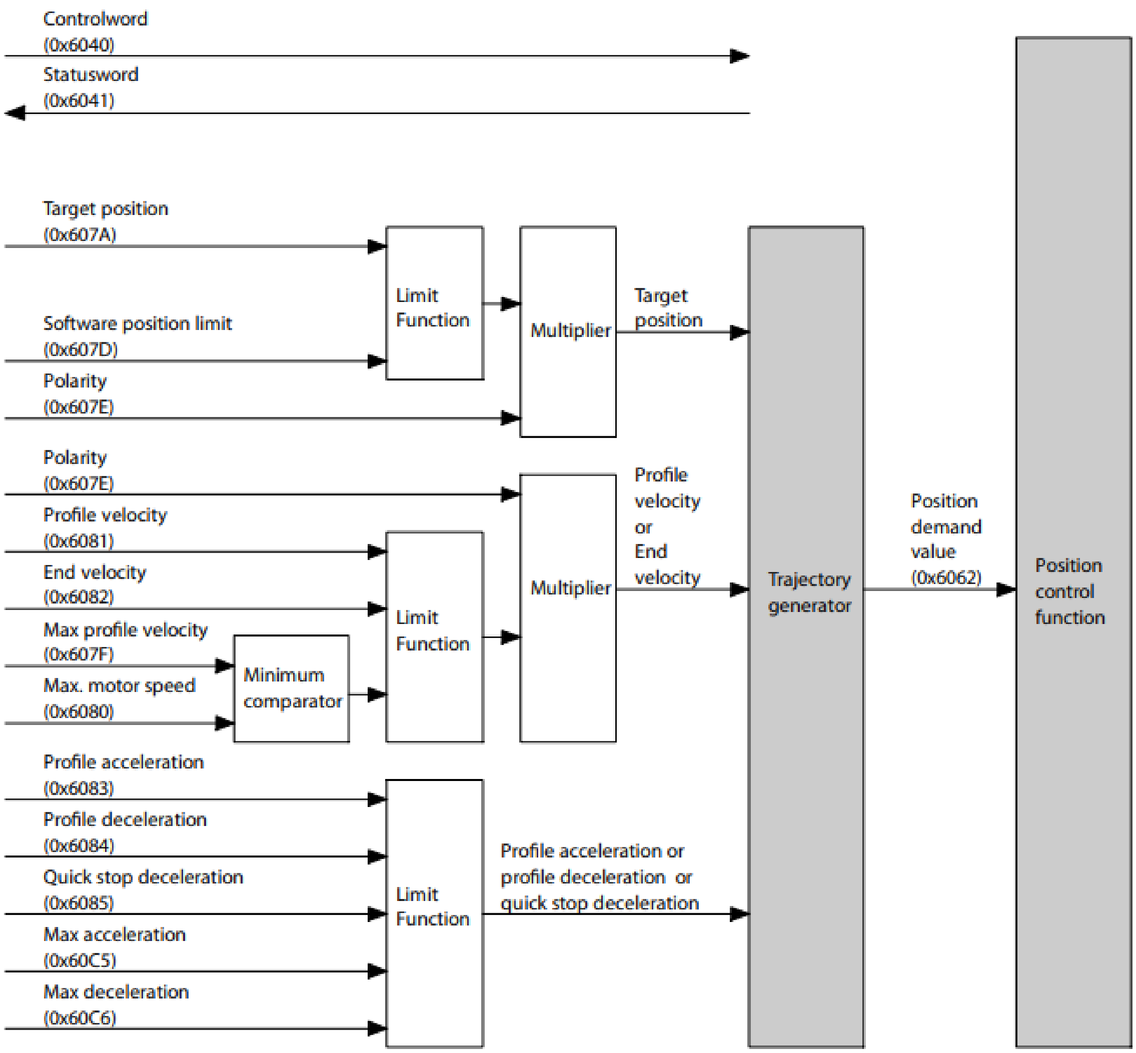


Fig. 47 Trajectory generator in positioning mode (PP)

Objects for positioning mode

Parameters	Index.Subindex	Name	Data type
Px.	CiA402: The factor group is effective.		
730	0x6040.0	Control word CiA402	UINT16
731	0x6041.0	Status word CiA402	UINT16
90	0x6062.0	Pilot control position output	SINT32
128	0x6064.0	Actual position value	SINT32
1210	0x606C.0	Actual velocity value	SINT32
151	0x6077.0	Actual torque value gear shaft	SINT16
8130	0x607A.0	Target position CiA402	SINT32
4629	0x607D.1	Negative software limit position	SINT32
4630	0x607D.2	Positive software limit position	SINT32
1170	0x607E.0	Reversing the direction of rotation	UINT8
1304	0x607F.0	Limit value velocity limiting	UINT32
7123	0x6080.0	Maximum rpm (user-defined)	UINT32
8131	0x6081.0	Profile velocity CiA402	UINT32
8132	0x6082.0	End velocity CiA402	UINT32
8133	0x6083.0	Profile acceleration CiA402	UINT32
8134	0x6084.0	Profile deceleration CiA402	UINT32
8135	0x6085.0	Quick stop deceleration CiA402	UINT32
8136	0x60A4.0	Profile jerk CiA402	UINT32
1305	0x60C5.0	Limit value acceleration limiting	UINT32
1306	0x60C6.0	Limit value deceleration limiting	UINT32
88817	0x60F2.0	Positioning option code CiA402	UINT16

Tab. 298 Objects

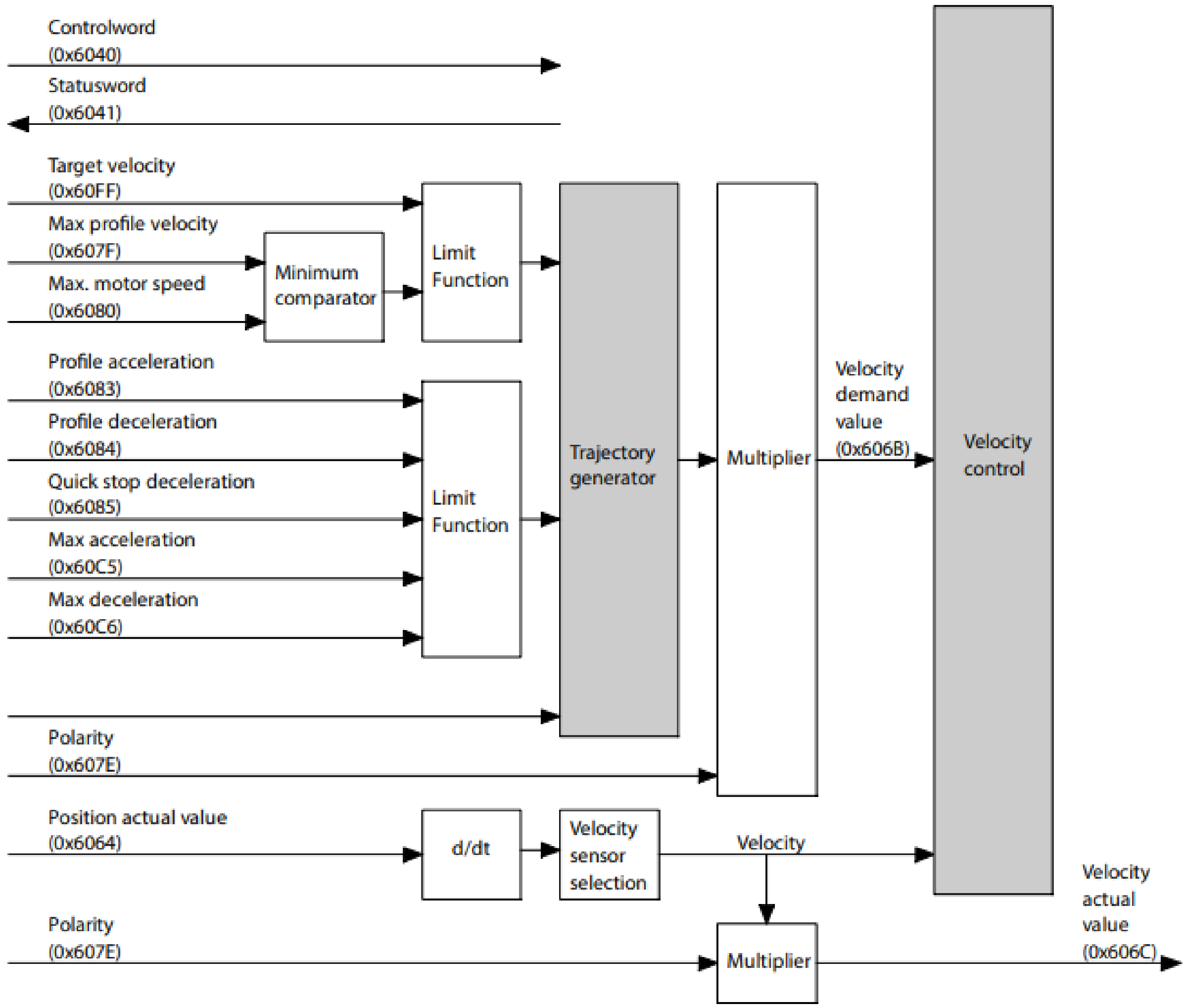


Fig. 52 Trajectory generator in velocity mode (PV)

Objects

Parameter	Index.Subindex	Name	Data type
Px.	CiA402: The factor group is effective.		
730	0x6040.00	Control word CiA402	UINT16
731	0x6041.00	Status word CiA402	UINT16
128	0x6064.00	Actual position value	SINT32
1210	0x606C.00	Actual velocity value	SINT32
4610	0x606D.00	Monitoring window target speed	UINT16
468	0x6068.00	Damping time target reached	UINT16
466	0x606F.00	Monitoring window speed standstill monitor-ing	UINT16
465	0x6070.00	Standstill damping time	UINT16
1170	0x607E.00	Reversing the direction of rotation	UINT8
1304	0x607F.00	Limit value velocity limiting	UINT32
7123	0x6080.00	Maximum rpm (user defined)	UINT32
8133	0x6083.00	Profile acceleration CiA402	UINT32
8134	0x6084.00	Profile deceleration CiA402	UINT32
8135	0x6085.00	Quick stop deceleration CiA402	UINT32
1305	0x60C5.00	Limit value acceleration limiting	UINT32
1306	0x60C6.00	Limit value deceleration limiting	UINT32
464	0x60F8.00	Monitoring window speed: following error	SINT32
8137	0x60FF.00	Target velocity CiA402	SINT32
Px.	Manufacturer-specific objects: The user or basic unit defined for the parameter is effective.		
730	0x216D.01	Control word CiA402	UINT16
731	0x216D.02	Status word CiA402	UINT16
128	0x2155.09	Actual position value	SINT64
1210	0x2155.0B	Actual velocity value	FLOAT32
4610	0x2166.0B	Monitoring window target speed	FLOAT32
468	0x2166.09	Damping time target reached	FLOAT32
466	0x2166.07	Monitoring window speed standstill monitor-ing	FLOAT32
465	0x2166.06	Standstill damping time	FLOAT32

Parameter	Index.Subindex	Name	Data type
1170	0x217D.01	Reversing the direction of rotation	BOOL
1304	0x2183.04	Limit value velocity limiting	FLOAT32
7123	0x216C.06	Maximum rpm (user defined)	FLOAT32
8133	0x216F.06	Profile acceleration CiA402	FLOAT32
8134	0x216F.07	Profile deceleration CiA402	FLOAT32
8135	0x216F.08	Quick stop deceleration CiA402	FLOAT32
1305	0x2183.05	Limit value acceleration limiting	FLOAT32
1306	0x2183.06	Limit value deceleration limiting	FLOAT32
464	0x2166.05	Monitoring window speed: following error	FLOAT32
8137	0x216F.0A	Target velocity CiA402	FLOAT32

Tab. 313 Objects

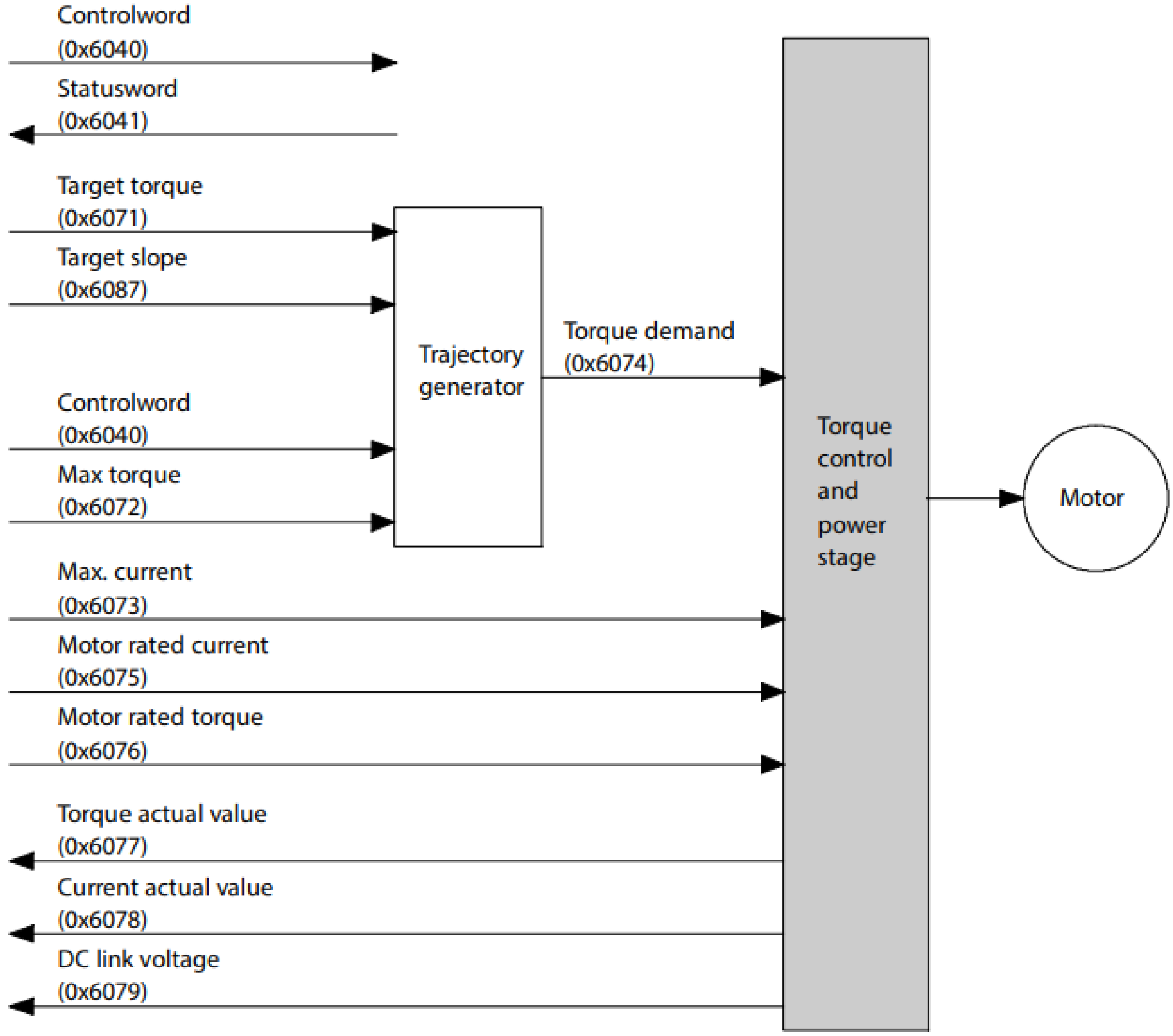


Fig. 54 Trajectory generator in force/torque (PT)

Objects

Parameter	Index.Subindex	Name	Data type
Px.	CiA402: The factor group is effective.		
730	0x6040.00	Control word CiA402	UINT16
731	0x6041.00	Status word CiA402	UINT16
526795	0x6071.00	Target torque CiA402	SINT16
526796	0x6072.00	Maximum torque symmetrical	UINT16
856	0x6073.00	Limit value total current (closed loop control-ler)	UINT16
3014	0x6074.00	Setpoint generator output torque	SINT16

Parameter	Index.Subindex	Name	Data type
7118	0x6075.00	Current nominal current	UINT32
7139	0x6076.00	Resulting nominal torque	UINT32
151	0x6077.00	Actual torque value gear shaft	SINT16
814	0x6078.00	Actual active current value	SINT16
480	0x6079.00	Actual value DC link voltage	UINT32
526799	0x6087.00	Torque slope CiA402	UINT32
853	0x60E0.00	Upper limit value torque (closed loop controller)	UINT16
852	0x60E1.00	Lower limit value torque (closed loop controller)	UINT16
Px.	Manufacturer-specific objects: The user or basic unit defined for the parameter is effective.		
730	0x216D.01	Control word CiA402	UINT16
731	0x216D.02	Status word CiA402	UINT16
526795	0x216F.0D	Target torque CiA402	FLOAT32
526796	0x2168.17	Maximum torque symmetrical	FLOAT32
856	0x2168.07	Limit value total current (closed loop controller)	FLOAT32
3014	0x2188.07	Setpoint generator output torque	FLOAT32
7118	0x2162.05	Current nominal current	FLOAT32
7139	0x2162.0C	Resulting nominal torque	FLOAT32
151	0x2157.02	Actual torque value gear shaft	FLOAT32
814	0x2153.0F	Actual active current value	FLOAT32
480	0x2114.01	Actual value DC link voltage	FLOAT32
526799	0x216F.0E	Torque slope CiA402	FLOAT32
853	0x2168.04	Upper limit value torque (closed loop controller)	FLOAT32
852	0x2168.03	Lower limit value torque (closed loop controller)	FLOAT32

Tab. 321 Objects

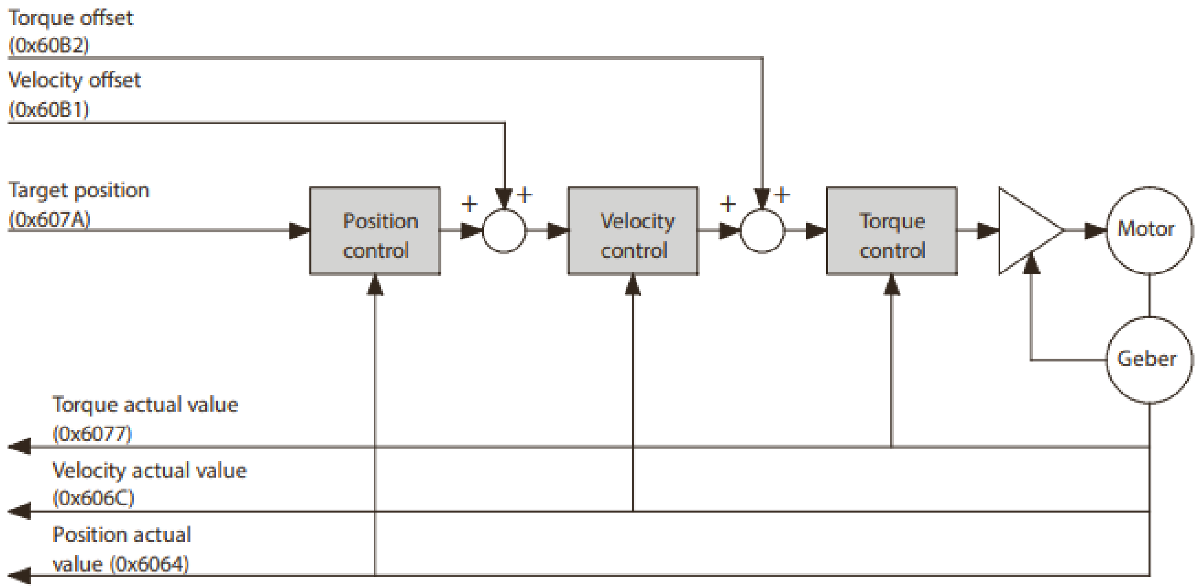


Fig. 57 Overview of the cyclic synchronised positioning operation (CSP)

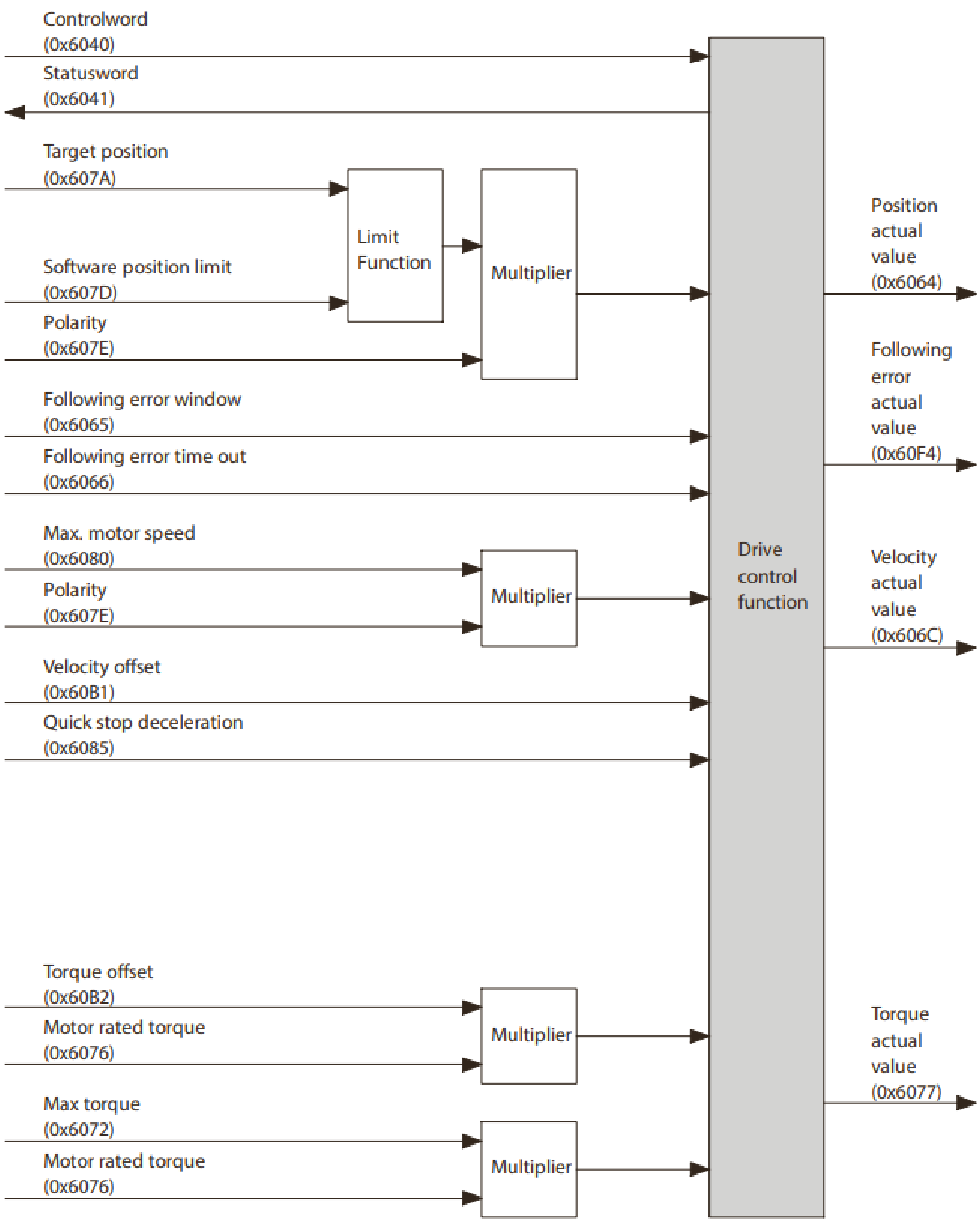


Fig. 58 Object overview of the cyclic synchronised positioning operation (CSP)

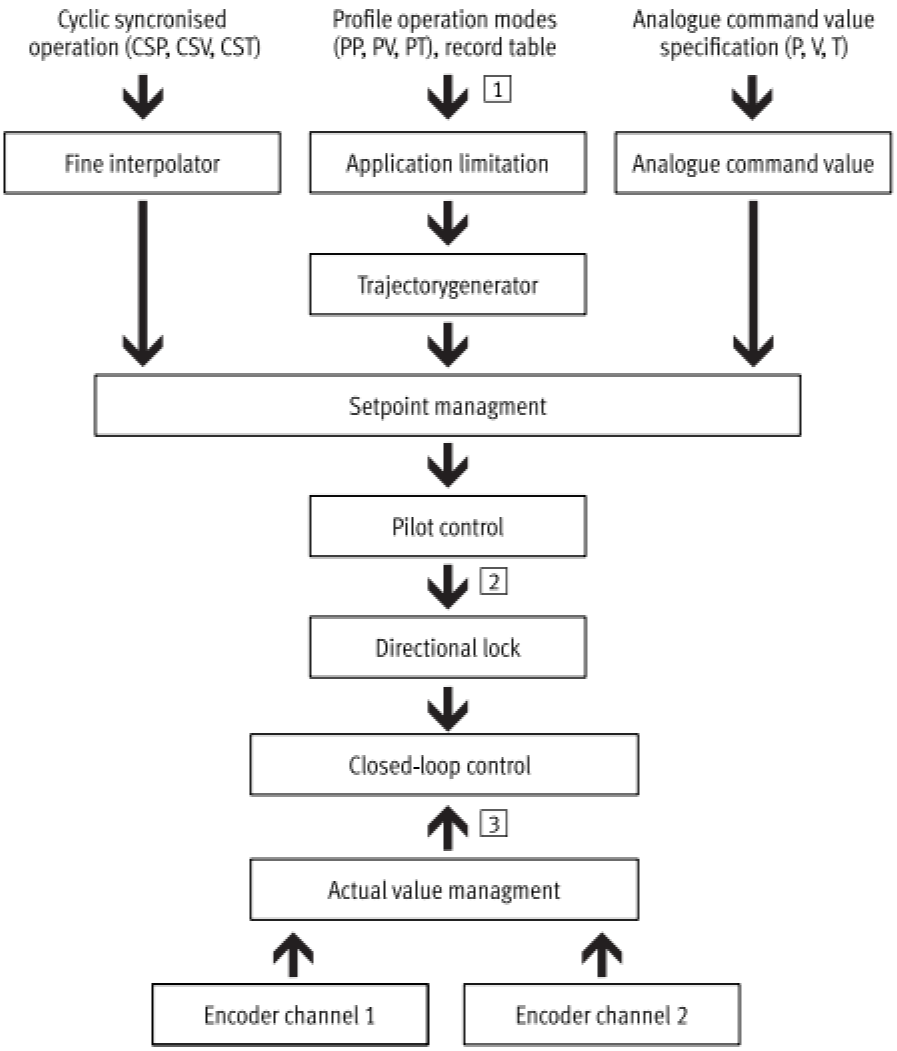


Fig. 76 Determining the target, setpoint and actual values

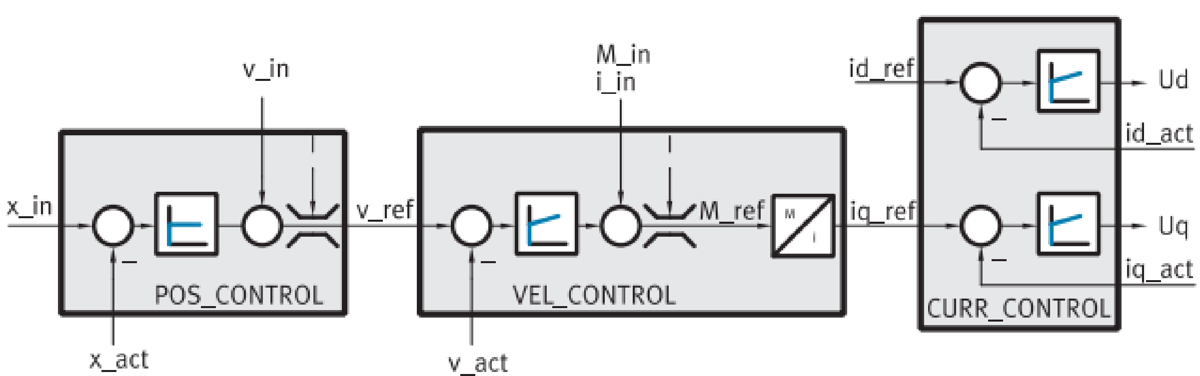


Fig. 83 Block diagram of cascade controller

Name	Parameter	ID Px.
i_in	Feed forward control current output The current value is used as a pilot control value for the current regulator. The resulting setpoint value is dependent on the parameterised upstream variables of the pilot control ➔ 6.3 Pilot control (Setpoint value control). Between i_in and M_in, there is the relationship i_in = M_in/(torque constant x gear unit factor).	95
id_act	Actual reactive current value	813
id_ref	Setpoint value reactive current	87
iq_act	Actual active current value	814
iq_ref	Setpoint value active current	86
M_in	Setpoint value torque The setpoint value torque is used as a pilot control value for the current regulator and refers to the output side (motor + gear unit). The resulting setpoint value is dependent on the parameterised upstream variables of the pilot control ➔ 6.3 Pilot control (Setpoint value control).	94
M_refM_r-ef	Setpoint value torque	2220
v_act	Actual velocity value	1210
v_in	Setpoint value velocity The setpoint value velocity is used as a pilot control value for the velocity regulator ➔ 6.3 Pilot control (Setpoint value control).	91

Name	Parameter	ID Px.
v_ref	Setpoint value velocity controller	2216
x_act	Actual position value	128
x_in	Setpoint value position	90

Tab. 501 Legend for the Block Diagram of the Cascade Controller

6.1.2 Position Controller

The position controller is designed as P-controller which calculates the velocity specification for the secondary velocity control circuit from the control difference (setpoint position - actual position). A dead zone member suppresses all control differences with the value "0" if it lies within the parametерised symmetrical dead zone. The P-member generates the setpoint velocity from the control difference and position controller amplification factor. This can be asymmetrically limited via the minimum and maximum correction velocity. At active velocity pilot control (default setting), values "Setpoint velocity" and "Velocity pilot control" are added and issued as velocity specification to the secondary velocity controller. The velocity controller setpoint value can be asymmetrically limited via the resulting lower and upper limit value velocity. If the setpoint value reaches the limit, this can be requested via a status.

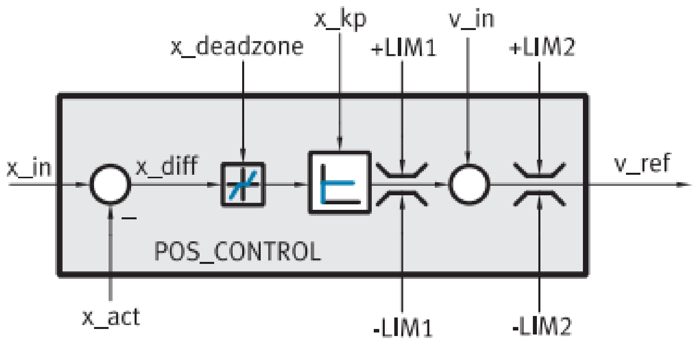
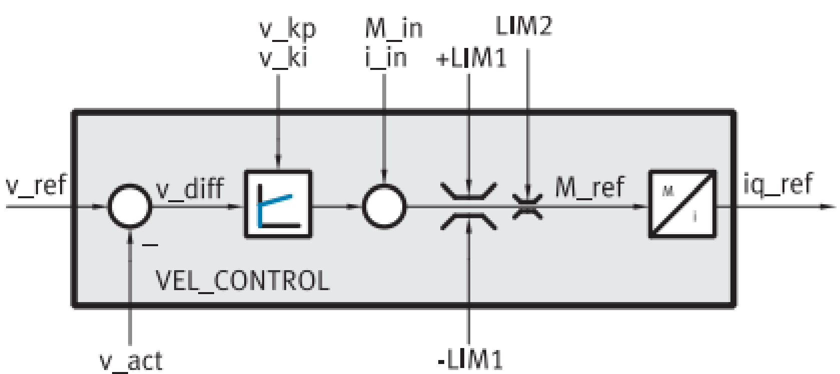


Fig. 84 Block diagram of position controller

Name	Parameter	ID Px.
x_act	Actual position value	128
x_deadzone	Dead zone position controller	221
x_diff	Position control error	2217
x_in	Setpoint value position	90
x_kp	Position controller amplification gain	220

Name	Parameter	ID Px.
v_in	Setpoint value velocity The setpoint value velocity is used as a pilot control value for the velocity regulator ➔ 6.3 Pilot control (Setpoint value control).	91
v_ref	Setpoint value velocity controller	2216
–LIM1	Minimum correction velocity	222
+LIM1	Maximum correction velocity	223
–LIM2	Resulting lower limit value velocity (closed loop controller)	6100
+LIM2	Resulting upper limit value velocity (closed loop controller)	6101

Tab. 502 Legend for the Block Diagram of the Position Controller



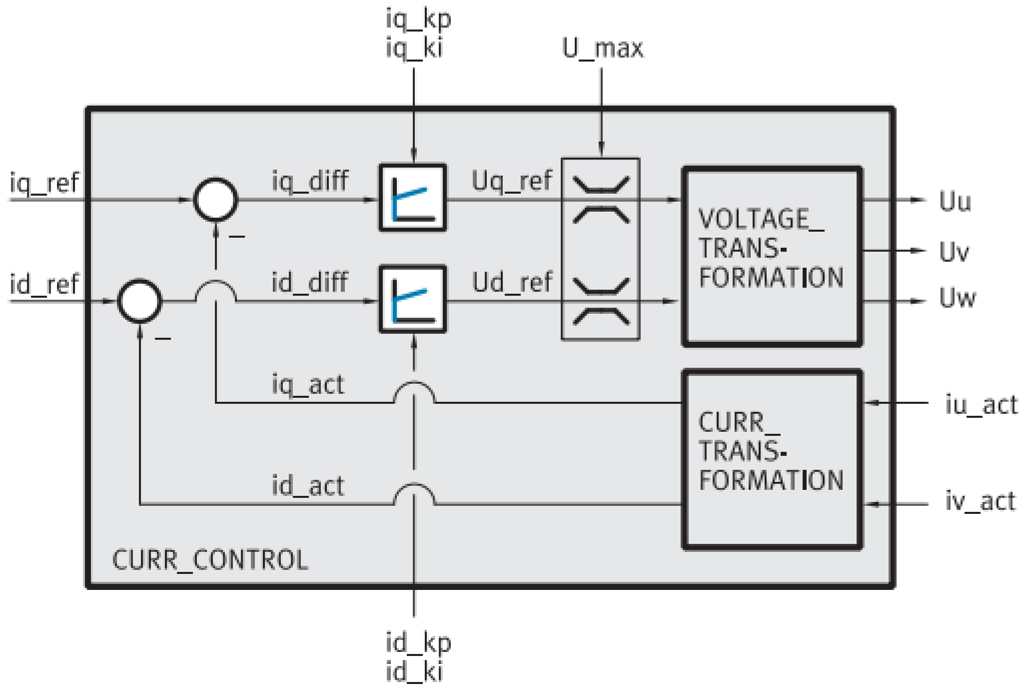
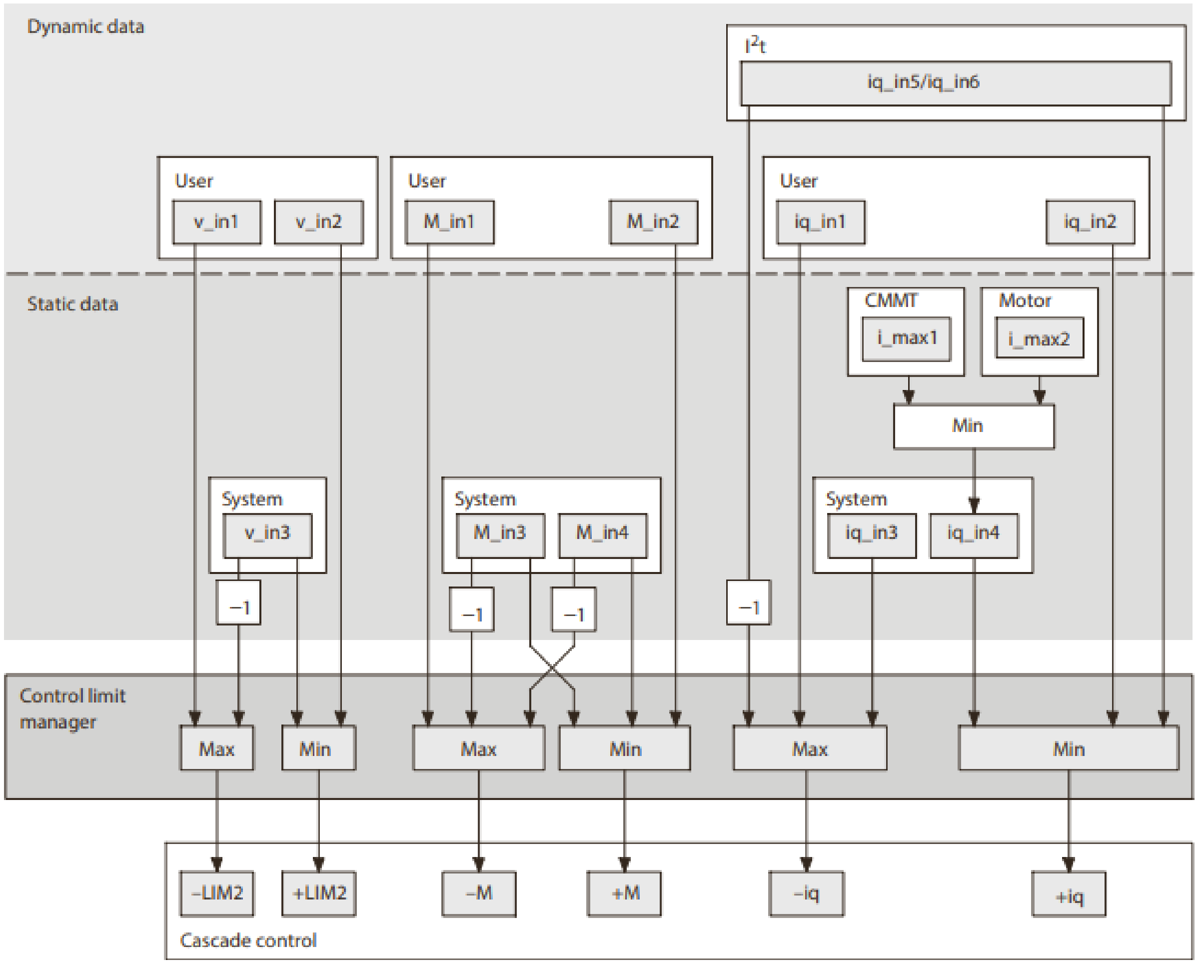


Fig. 86 Block diagram of current regulator



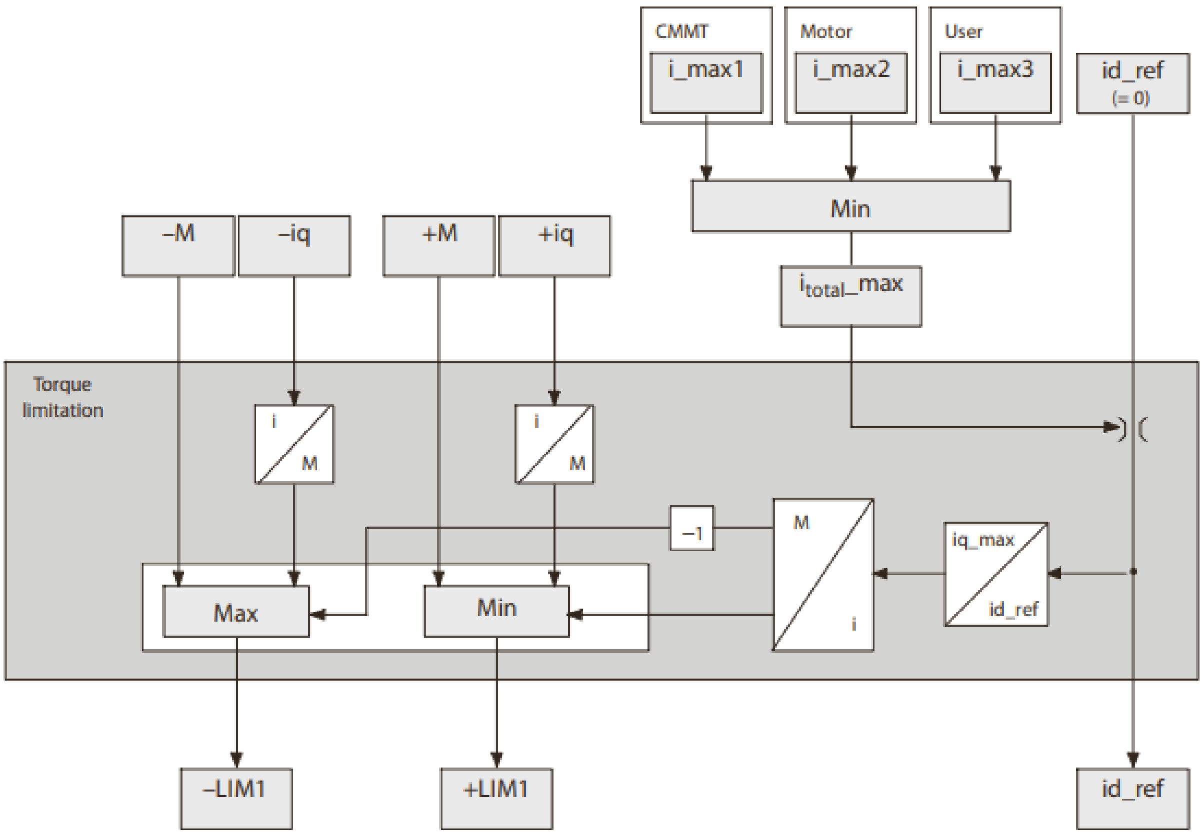
Name	Parameter	ID Px.
i_max1	Maximum current servo drive	622
i_max2	Maximum current motor	620
iq_in1	Lower limit value active current (closed loop controller)	854
iq_in2	Upper limit value active current (closed loop controller)	855
iq_in3	Resulting minimum current	625
iq_in4	Resulting maximum current	624
iq_in5	When the limit value is reached, the current of the motor is limited to the resulting rated current (ID Px.621).	–
iq_in6	When the limit value is reached, the current of the power output stage is limited to the resulting rated current (ID Px.623).	–
–iq	Resulting lower limit value active current (closed loop controller)	6108

Name	Parameter	ID Px.
+iq	Resulting upper limit value active current (closed loop controller)	6109
M_in1	Lower limit value torque (closed loop controller)	852
M_in2	Upper limit value torque (closed loop controller)	853
M_in3	Maximum motor or servo drive torque	381
M_in4	Maximum driving torque axis	1199
–M	Resulting lower limit value torque (closed loop controller)	6104
+M	Resulting upper limit value torque (closed loop controller)	6105
v_in1	Lower limit value velocity (closed loop controller)	850
v_in2	Upper limit value velocity (closed loop controller)	851
v_in3	Maximum motor or servo drive velocity	382
–LIM2	Resulting lower limit value velocity (closed loop controller)	6100
+LIM2	Resulting upper limit value velocity (closed loop controller)	6101

Tab. 527 Legend for the block diagram of the control limitation

6.2.3 Torque limitation

The torque limitation limits the torque related to the drive output shaft end directly at the output of the velocity controller. For drive systems with gear unit the shaft end of the gear unit output is on the drive output side. Current critical limits from the configuration of the servo drive, the motor and the specifications of the user are converted internally to a resulting torque related to the shaft end on the drive output side. The resulting limit values form the lower and upper limit value for the limitation.



Name	Parameter	ID Px.
i_max1	Maximum current servo drive	622
i_max2	Maximum current motor	620
i_max3	Limit value total current (closed loop controller)	856
id_ref	Setpoint value reactive current	87
i_{total}_max	Resulting upper limit value total current (closed loop controller)	6112
–iq	Resulting lower limit value active current (closed loop controller)	6108
+iq	Resulting upper limit value active current (closed loop controller)	6109
–M	Resulting lower limit value torque (closed loop controller)	6104
+M	Resulting upper limit value torque (closed loop controller)	6105
–LIM1	Minimum torque	2218
+LIM1	Maximum torque	2219

Tab. 532 Legend for the block diagram of the current limiter

6.3 Pilot control (Setpoint value control)

6.3.1 Setpoint value connection

The pilot control (FFC feed forward control) creates the setpoint values for the cascade controller, e. g. from

– the timely diversions of the set values
– a constant value (offset)

This ensures that the positioning behaviour of the drive is greatly improved, e. g. a reduction of the contouring error or improved run-in behaviour to the target position.

The input variables for the pilot control are directly connected to the output variable or are adjusted using a mathematical operation:

– Output variables with the same physical meaning are added within the pilot control component. The respective added value can additionally be influenced by a weighting factor (gain).
– Each mathematical operation with the input variables v (velocity) and a (acceleration) has a deceleration member of the first order connected in series. An inactive time member is connected in series for the position.

A constant value can be stipulated for the weight force compensation.

The following pilot control values are valid for the individual operating modes of the cascade controller. The pilot control also acts in the interpolating operating modes via a field bus and in the operating modes with analog voltage specification.

Input variable	Output variable	Pilot control	Operating mode[1]		
			P	V	T
v	v	Velocity (default)	•	–	–
a	M	Torque (inertia)	•	•	–
v	M	Torque (friction)	•	•	–
–	M	Torque (constant value)	•	•	•

1) P = positioning mode, V = velocity mode, T = torque mode

Tab. 536 Pilot control

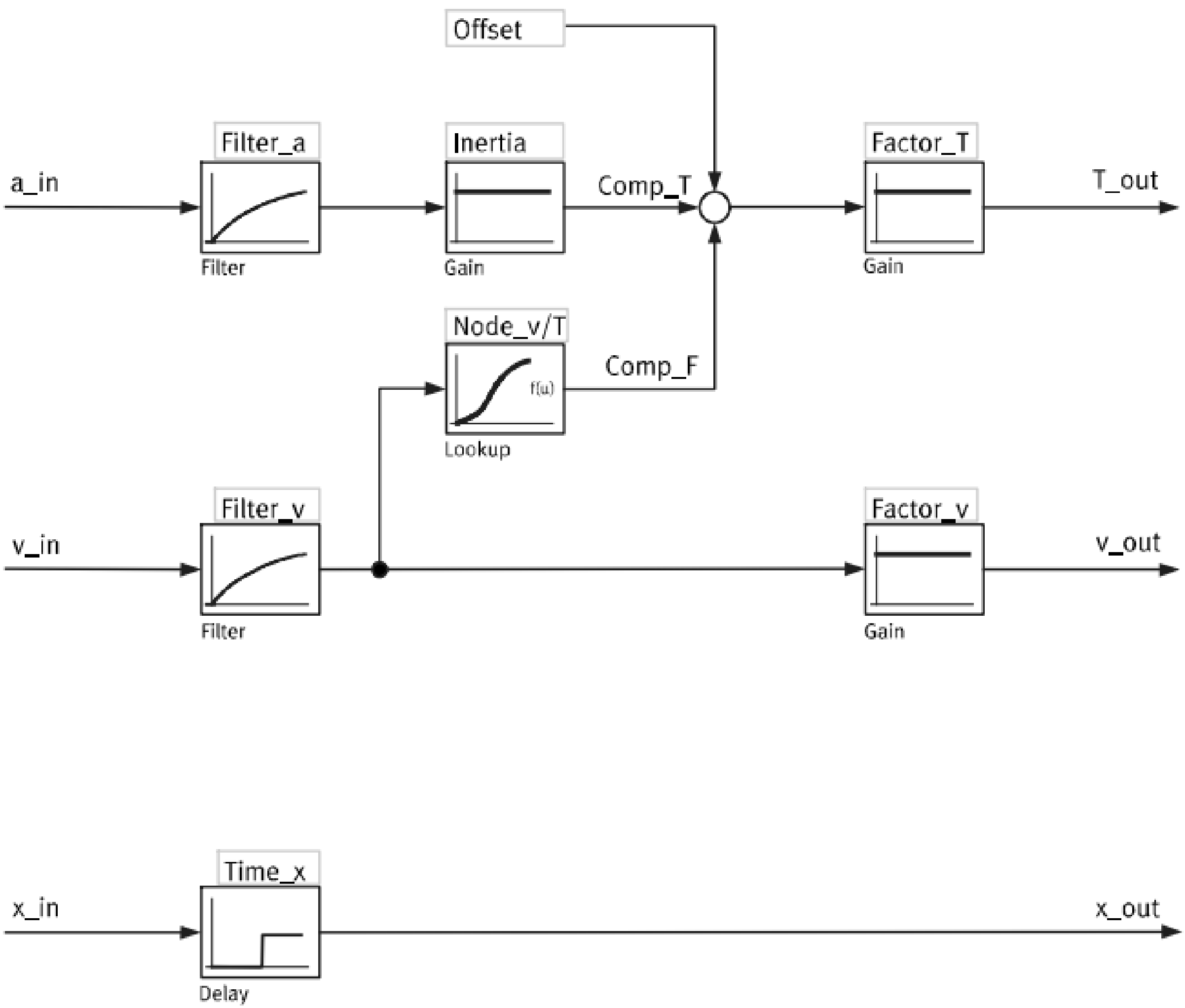


Fig. 91 Pilot control

Name	Description	ID Px.
x_in, v_in, a_in	Set values position, velocity and acceleration as input variables of the pilot control	
	Setpoint management output position	290
	Setpoint management output velocity	291
	Setpoint management output acceleration	292
x_out, v_out, T_out	Setpoint values for the cascade controller	
	Setpoint value position	90
	Setpoint value velocity	91
	Setpoint value torque	94
t_x <- Time_x	Inactive time position setpoint value (integer multiple of the device-specific scanning time of the closed-loop controller)	957
t_v <- Filter_v	Time constant velocity setpoint value filter	958
t_a <- Filter_a	Time constant acceleration setpoint value filter	959
Factor_v	Amplification gain velocity feed forward control	967
Factor_T	Amplification gain torque feed forward control	968
Offset	Offset torque	969
Inertia	Total inertia	973
Comp_F	Setpoint value friction compensation The parameter can be used, for example, to assess the component of the feed forward control from the friction compensation by means of measured data recording (trace).	974
Comp_T	Setpoint value inertia compensation The parameter can be used, for example, to assess the component of the feed forward control from the inertia compensation by means of measured data recording (trace).	975
Node_v	Support point velocity [rad/s]	976
Node_T	Support point torque [Nm]	977

Tab. 537 Legend for the block diagram of pilot control

6.3.2 Inertia and friction compensation

For the inertia compensation it is multiplied with the setpoint acceleration. The value for the inertia is the total inertia of the drive system. If the switchover is carried out on a different control parameter set, also the respective inertia is superimposed from the control parameter set.

The friction is compensated via a look-up table. In the table torque is plotted via support points via angular velocity. Linear interpolation is performed between the support points. The input variable is always the angular velocity independent of the selected user unit. The output variable is the torque. If the input variable is larger or smaller than the last value of the support point of the angular velocity, the last value of the torque support point is used as output variable.
The use of an offset can, for example, be practical for a vertical mounting position of an axis.
The ouput variables for the velocity and torque control can be weighted via separate factors.

6.4 Notch Filter

6.4.1 Function

Internal notch filters are provided to suppress oscillations. Notch filters can be used to filter out interfering frequencies from the active current calculated from the control loop. The notch filters are wired in series. The number of implemented notch filters is device-specific. The notch filters are arranged before the input of the current regulator and filter the complete setpoint signal including the pilot control values. The characteristics of the filter can be parameterised and are determined by the filter frequency and filter band width.

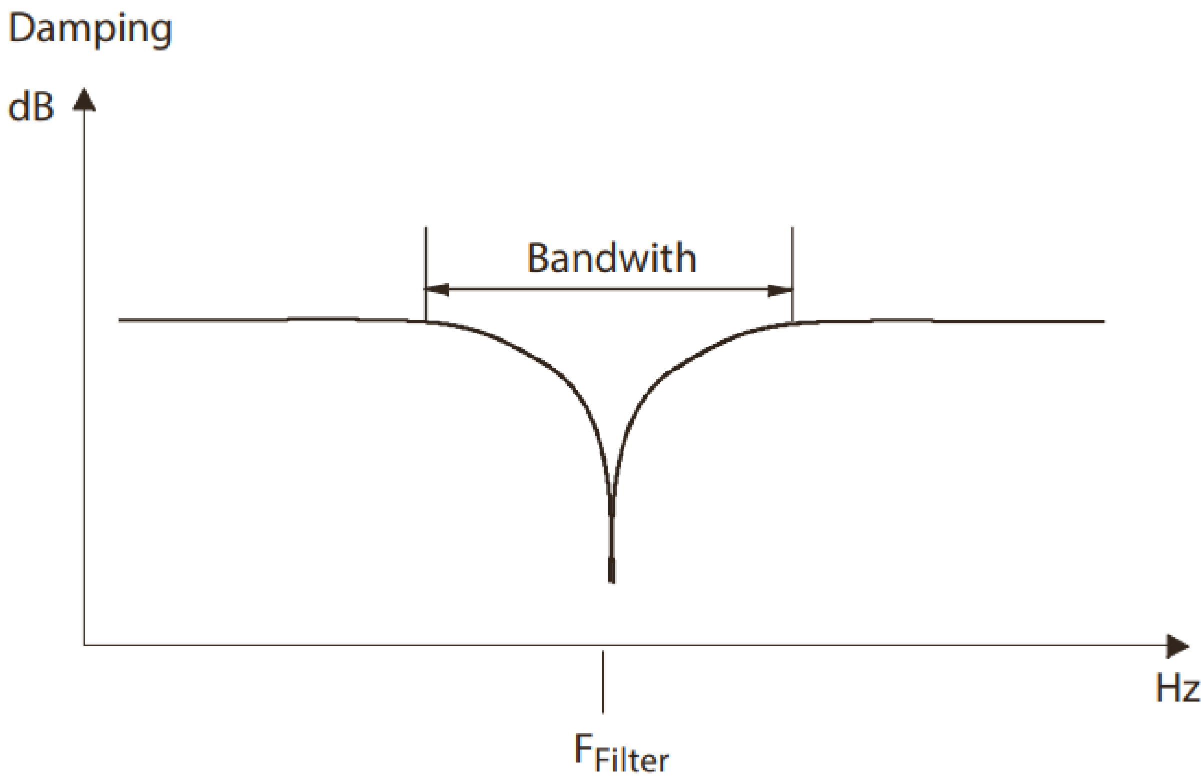


Fig. 93 Filter band width and filter frequency

Name	Description	ID Px.
Band with	Band width of notch filter	49
Damping	Cushioning	–
F_{Filter}	Filter frequency notch filter	40

Tab. 545 Legend for the Filter Band Width and Filter Frequency Diagram

Parameters and Diagnostic Messages

Parameter allocation:

- Index 0: notch filter 1
- Index 1: notch filter 2
- Index 2: notch filter 3

6.5 Auto-tuning

6.5.1 Function

Auto tuning can be used to determine the control parameters for position and velocity controllers. The basis for this is a current regulator that has already been designed and suitable start parameters for position controllers and velocity controllers, as well as the amplitude of the excitation signal. The start parameters are determined automatically on the basis of the drive configuration. Measurements are necessary as basis for the layout. The number of measurements can be adjusted. The measurements can be carried out during the standstill or during a movement command.

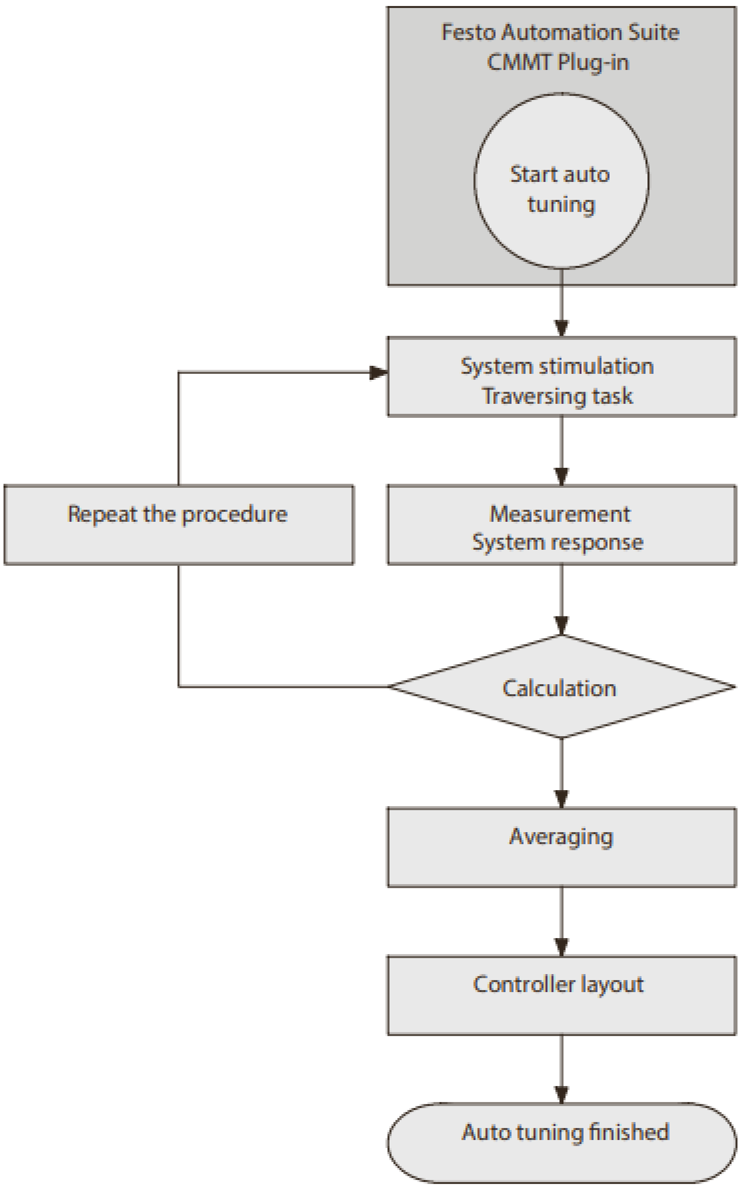


Fig. 94

ID Px.	Parameter	Description	
860	Status auto tuning	Specifies the status of auto tuning. – 0: Inactive – 1: Test run – 2: Start measurement – 3: Measurement active – 4: FFT calculation active – 5: FFT calculation finished – 6: Controller calculation active – 7: Controller calculation finished – 8: Error, stroke too short – 9: Auto tuning aborted – 10: Error, invalid controller parameters	
		Access	read/–
		Update	effective immediately
		Unit	–
8601	Result amplification gain of position controller	Specifies the results of auto tuning for the amplification gain in the position controller.	
		Access	read/write
		Update	effective immediately
		Unit	–
8602	Result integration constant of velocity controller	Specifies the result of auto tuning for the integration constant of the velocity controller.	
		Access	read/write
		Update	effective immediately
		Unit	–
8603	Result amplification gain of velocity controller	Specifies the result of auto tuning for the amplification gain of the velocity controller.	
		Access	read/write
		Update	effective immediately
		Unit	–
8611	Start value position controller amplification gain	Specifies the start value of auto tuning for the amplification gain of the position controller.	
		Access	read/write
		Update	effective immediately

12.4.2.2 Application Class 1 – Standard Drive (Velocity Mode)

In application class 1 the drive is controlled by a main setpoint, e.g. velocity setpoint. The velocity is controlled completely in the drive. The bus is simply the transmission medium between the automation system and the servo drive. The higher-level controller (PLC) contains all technological functions for the automation task. Process data (setpoint and actual values) are exchanged cyclically. Cyclical synchronous data transfer can be used, but is typically not necessary for this application class.

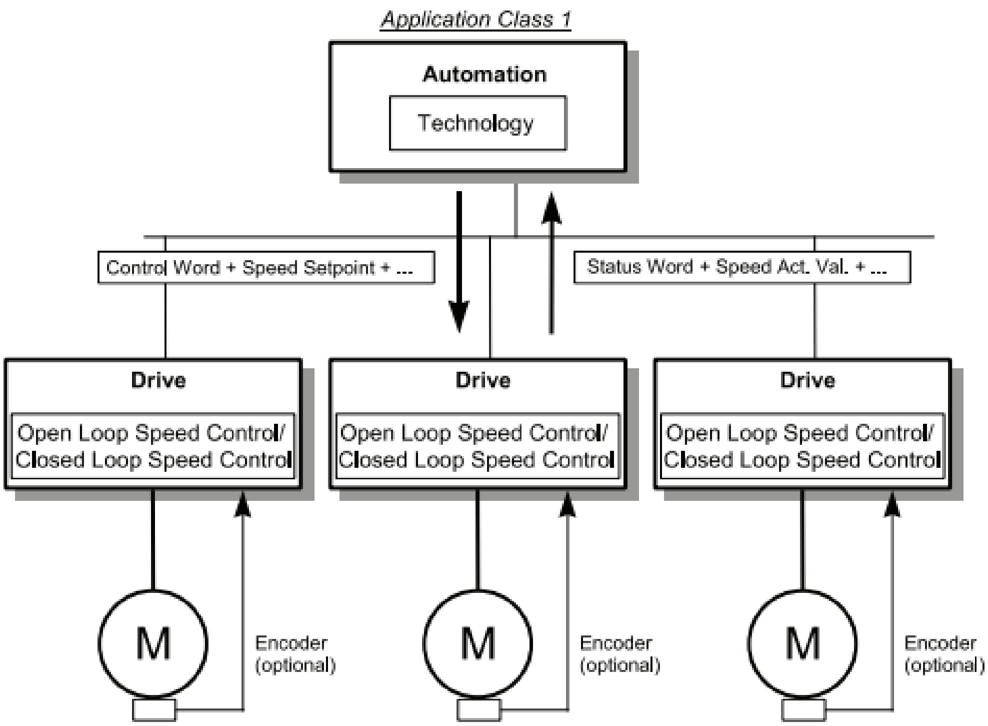


Fig. 145 Application class 1

12.4.2.3 Application Class 3 – Positioning Mode (PtP)

In application class 3 the positioning commands are sent to the drive by the higher-level controller (PLC). The higher-level controller (PLC) only contains the technological functions required for the automation task. The drive itself directly controls the interpolation, positioning and velocity and all time-critical control algorithms. Cyclical synchronous operation is only required for complex tracking tasks with multiple axes.

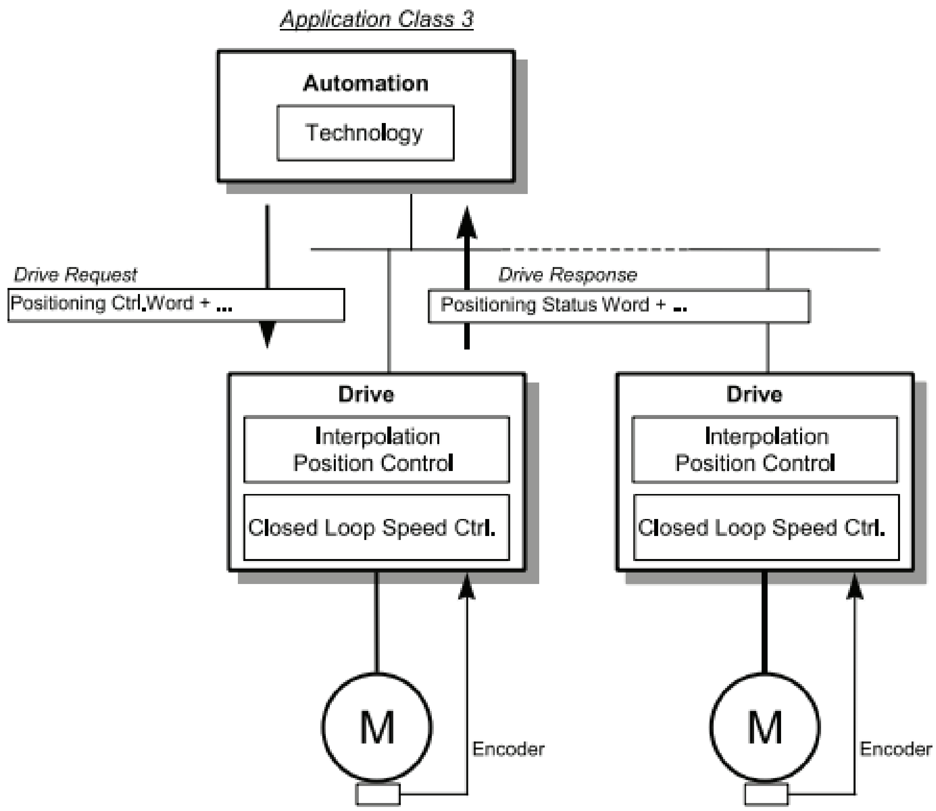


Fig. 146 Application class 3

12.4.2.4 Application Class 4 - Central Motion Control (Motion)

Application class 4 enables coordinated motion sequences of several drives, as required in robotics applications, for example.

Coordination and movement control are carried out centrally via a higher-level control system. In addition to the technology functions required to control the automation process, the controller also requires functions for interpolation and position control of the drives. The servo drives take over the velocity control of the drives.

Velocity setpoint values and actual position values are transmitted cyclically via the device profile.

If necessary, the stability and dynamic behaviour of the control can be increased by using the "Dynamic Servo Control" (DSC) functionality. Then the control deviation and the position controller amplification factor KPC are also transmitted in the telegram with the setpoint values. The position controller in

the drive can be used with this data. The position-setpoint value interpolation continues to take place in the controller.
Since coordination takes place via the device profile, synchronous operation is required to synchronise the position control in the open-loop controller and the velocity control in the servo drives.

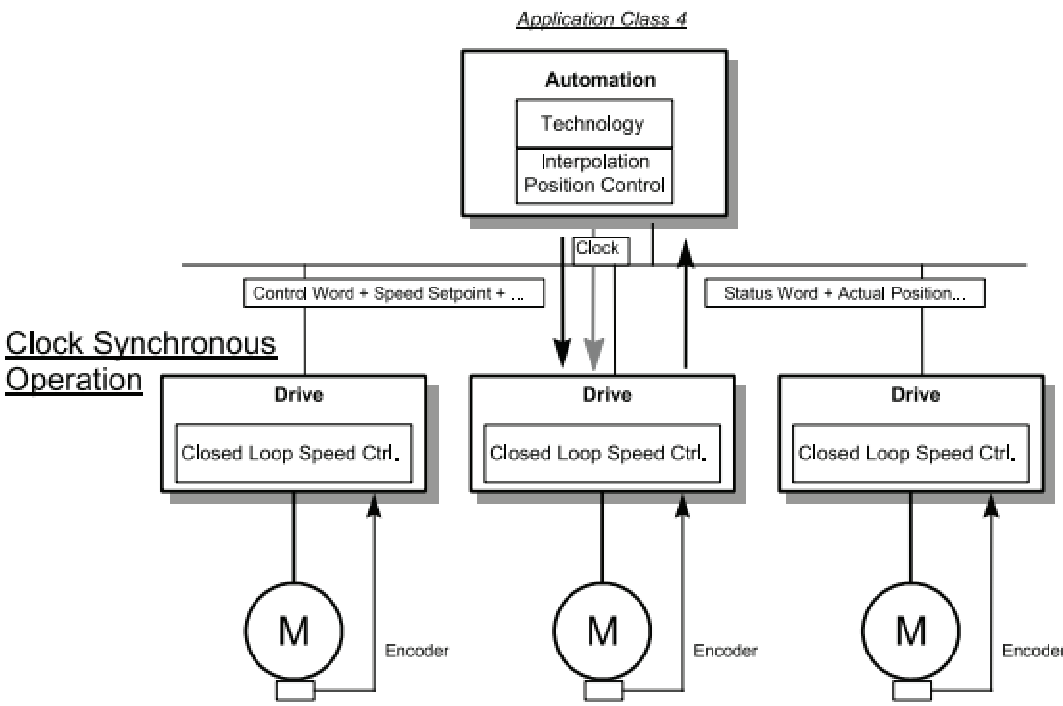


Fig. 149 Application class 4

Basic Controller Structure with DSC

Operation with "Dynamic Servo Control" (DSC) significantly increases the dynamic rigidity of the position control loop. In addition to the velocity setpoint value and the actual position value, the position controller amplification factor KPC and the position tracking error XERR are also transmitted. Position control takes place in the servo drive. The calculation of the position setpoint value path generator is still carried out in the controller.

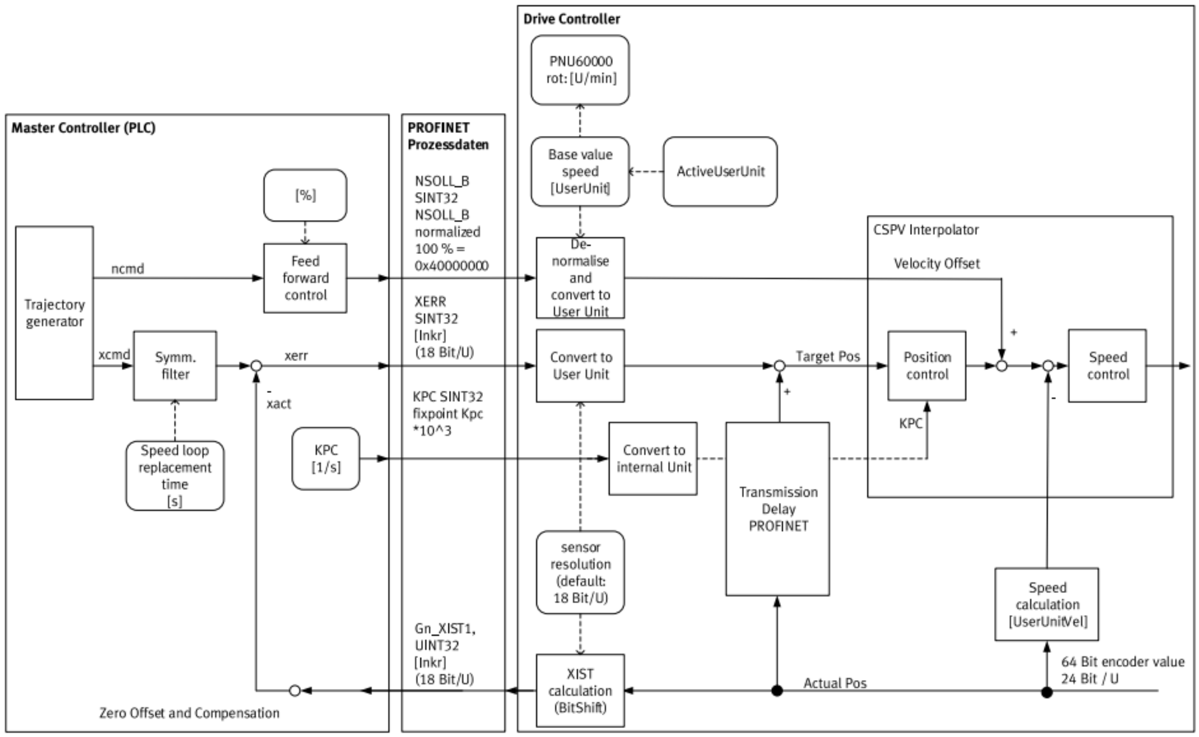


Fig. 151 Basic Controller Structure with DSC

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