6.3 Speed Mode

Speed control mode (S or Sz) is applicable in precision speed control, such as CNC machine tools. This servo drive includes two types of command input, analog and register. Analog command input can use external voltage to control the motor speed. There are two methods in register input. One is used before operation. Users set different value of speed command in three registers, and then use SP0, SP1 of CN1 DI signal for switching. Another method is to change the value of register by communication. In order to deal with the problem of non-continuous speed command when switching register, a complete S-curve program is provided. In close-loop system, this servo drive adopts gain adjustment and integrated PI controller and two modes (manual and auto) for selection.

Users can set all parameters and all auto or auxiliary function will be disabled in manual mode. While in auto mode, it provides the function of load inertia estimation and parameter adjustment. In auto mode, parameters which set by users will be regarded as the default value.

6.3.1 Selection of Speed Mode

There are two types of speed command source, analog voltage and internal parameters. The selection is determined by CN1 DI signal. See as the followings.

Speed Command	CN1 DI Signal		Command Source			Content	Range
	SPD1	SPD0					
S1	0	0	Mode	S	External analog signal	Voltage between V-REF-GND	+/-10V
				Sz	N/A	Speed command is 0	0
S2	0	1	Register parameter			P1-09	-50000 ~ 50000
S3	1	0				P1-10	-50000 ~ 50000
S4	1	1				P1-11	-50000 ~ 50000

■ Status of SPD0 ~ SPD1: 0 means DI OFF, 1 means DI ON.

■ When both SPD0 and SPD1 are 0, if it is in Sz mode, the command will be 0. Thus, if there is no need to use analog voltage as the speed command, Sz mode can be applied to tackle the problem of zero-drift. If it is in S mode, the command will be the voltage deviation between V-REF and GND. The range of

input voltage is between -10V and +10V and its corresponding speed is adjustable (P1-40).

■   When one of SPD0 and SPD1 is not 0, the speed command is from the internal parameter. The command is activated after changing the status of SPD0 ~ SPD1. There is no need to use CTRG for triggering.

■   The setting range of internal parameters is between -50000 and 50000. Setting value = setting range x unit (0.1 r/min).

For example: P1-09 = +30000, setting value = +30000 x 0.1 r/min = +3000 r/min

The speed command not only can be issued in speed mode (S or Sz), but also in torque mode (T or Tz) as the speed limit.

6.3.2 Control Structure of Speed Mode

The basic control structure is shown as the following diagram:
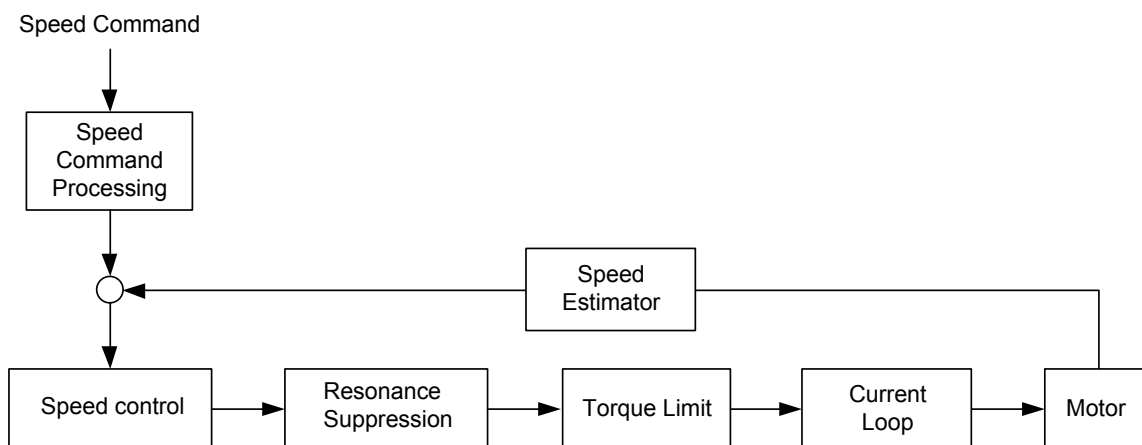
The speed command unit is to select speed command source according to Section 6.3.1, including the scaling (P1-40) setting and S-curve setting. The speed control unit manages the gain parameters of the servo drive and calculates the current command for servo motor in time. The resonance suppression unit is to suppress the resonance of mechanism. Detailed descriptions are shown as the following:

Here firstly introduces the function of speed command unit. Its structure is as the following diagram.
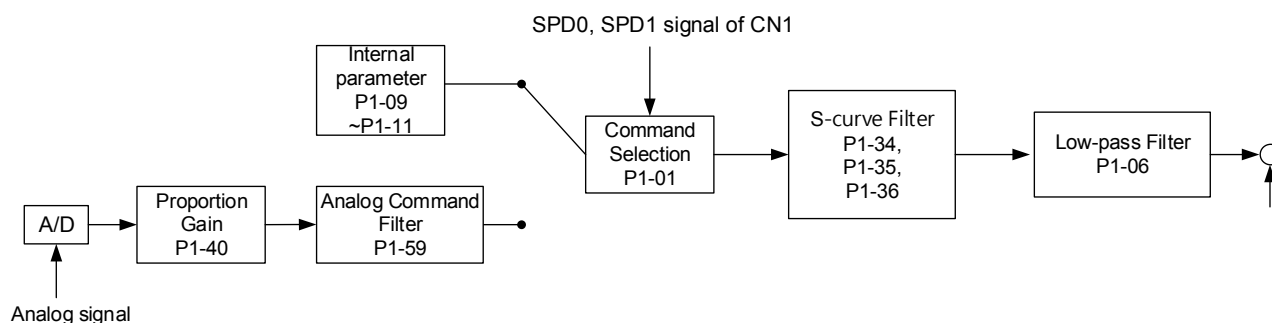
The upper path is the command from register while the lower one is external analog command. The command is selected according to the status of SPD0, SPD1 and P1-01 (S or Sz). Usually, S-curve and low-pass filter are applied for having a smooth resonance of command.

6.3.3 Smoothing Speed Command

S-curve Filter

During the process of acceleration or deceleration, S-curve filter applies the program of three-stage acceleration curve for smoothing the motion command, which generates the continuous acceleration. It is for avoiding the jerk (the differentiation of acceleration) came from the sudden command change and indirectly causes the resonance and noise. Users can use acceleration constant of S-curve (TACC) to adjust the slope changed by acceleration, deceleration constant of S-curve (TDEC) to adjust the slope changed by deceleration and acceleration / deceleration constant of S-curve (TSL) to improve the status of motor activation and stop. The calculation of the time to complete the command is provided.
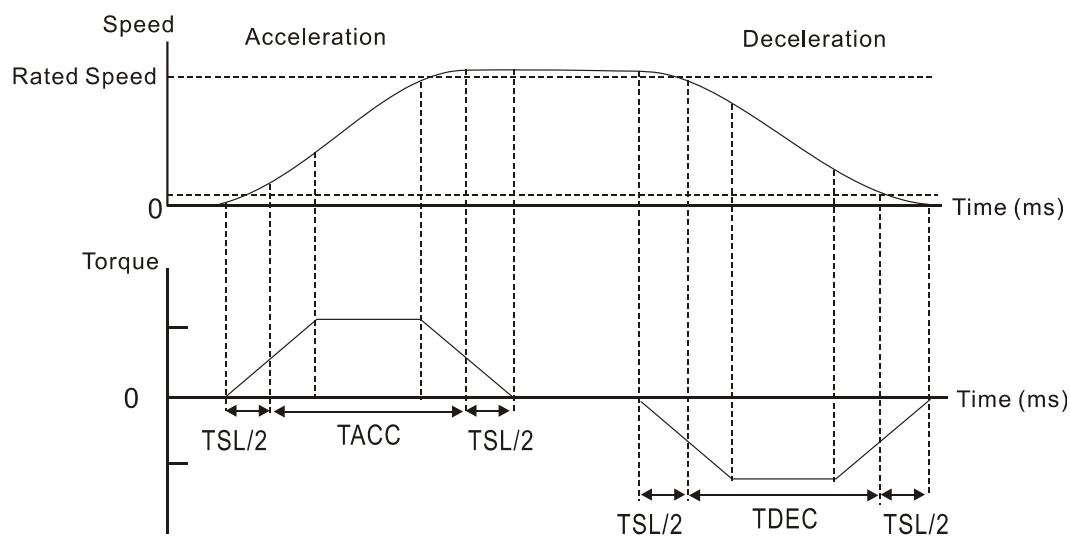
S-curve characteristics and Time relationship

Related parameters:

P1-34	TACC	Acceleration Constant of S-Curve	Address: 0144H 0145H
	Operation Interface:	Panel/Software	Communication	Related Section: Section 6.3.3
	Default:	200	
	Control Mode:	S	
	Unit:	ms	
	Range:	1 ~ 20000	
	Data Size:	16-bit	
	Display Format:	Decimal	

Settings: The time that speed command accelerates from 0 to 3000 r/min.

P1-34, P1-35, and P1-36, the acceleration time of speed command from zero to the rated speed, all can be set individually.

NOTE When the source of speed command is analog, and P1-36 is set to 0, it will disable S-curve function.

| P1-35	TDEC	Deceleration Constant of S-Curve	Address: 0146H 0147H
	Operation Interface:	Panel/Software	Communication	Related Section: Section 6.3.3
	Default:	200	
	Control Mode:	S	
	Unit:	ms	
	Range:	1 ~ 20000	
	Data Size:	16-bit	
	Display Format:	Decimal	

Settings: The time that speed command decelerates from 3000 r/min to 0.

P1-34, P1-35, and P1-36, the deceleration time of speed command from the rated speed to zero, all can be set individually.

NOTE When the source of speed command is analog, and P1-36 is set to 0, it will disable S-curve function.

P1-36	TSL	Acceleration / Deceleration Constant of S-curve	Address: 0148H 0149H

Operation Interface:	Panel/Software	Communication	Related Section: Section 6.3.3
Default:	0		
Control Mode:	S		
Unit:	ms		
Range:	0 ~ 10000 (0: Disabled)		
Data Size:	16-bit		
Display Format:	Decimal		

Settings: Acceleration / Deceleration Constant of S-Curve:
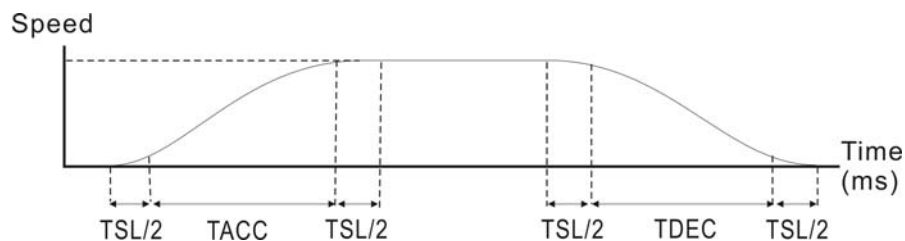
P1-34: Set the acceleration time of acceleration / deceleration of trapezoid-curve

P1-35: Set the deceleration time of acceleration / deceleration of trapezoid-curve

P1-36: Set the smoothing time of S-curve acceleration and deceleration
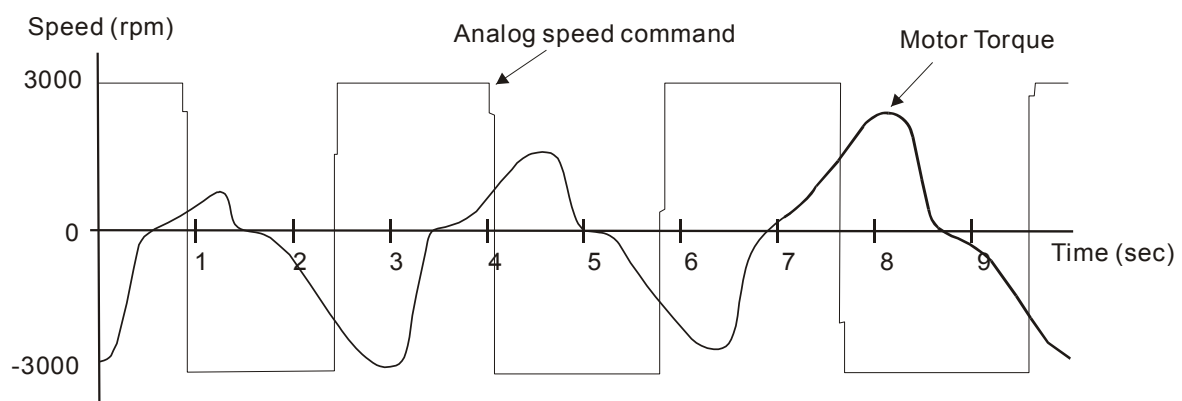
P1-34, P1-35, and P1-36 can be set individually.

NOTE When the source of speed command is analog, and P1-36 is set to 0, it will disable S-curve function.

Analog Speed Command Filter

Analog speed command filter is provided especially for ASDA-B2 series users.

It mainly helps with buffer when the analog input signal changes too fast.

Analog speed command filter smooth the analog input command. Its time program is the same as S-curve filter in normal speed. Also, the speed curve and the acceleration curve are both continuous. The above is the diagram of analog speed command filter. The slope of speed command in acceleration and deceleration is different. Users could adjust the time setting (P1-34, P1-35, and P1-36) according to the actual situation to improve the performance.

Command End Low-pass Filter

It is usually used to eliminate the unwanted high-frequency response or noise. It also can smooth the command.

Related parameters:

P1-06	SFLT	Analog Speed Command (Low-pass Filter)	Address: 010CH 010DH
	Operation Interface:	Panel/Software	Communication	Related Section: Section 6.3.3
	Default:	0		
	Control Mode:	S		
	Unit:	ms		
	Range:	0 ~ 1000 (0: Disabled)		
	Data Size:	16-bit		
	Display Format:	Decimal		

Settings: 0: Disabled
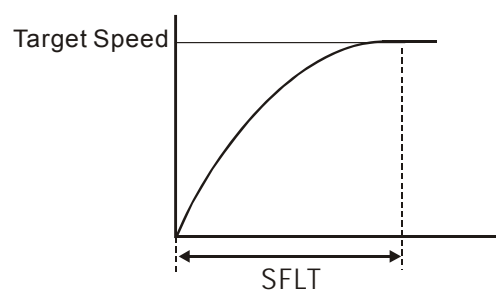
6.3.4 The Scaling of Analog Command

The motor speed command is controlled by the analog voltage deviation between V_REF and VGND. Use parameter P1-40 to adjust the speed-control slope and its range.
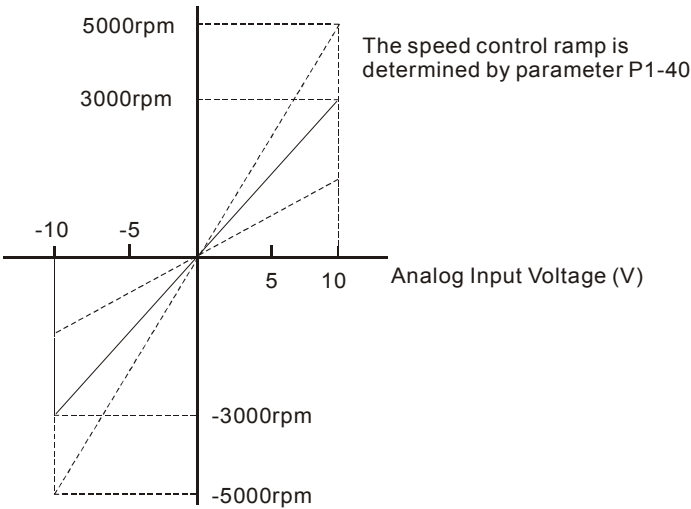
Related parameters:

P1-40▲	VCM	Max. Speed of Analog Speed Command	Address: 0150H 0151H
Operation Interface:	Panel/Software	Communication	Related Section: Section 6.3.4
Default:	rated speed		
Control Mode:	S, T		
Unit:	r/min		
Range:	0 ~ 50000		
Data Size:	32-bit		
Display Format:	Decimal		

Settings: Maximum Speed of Analog Speed Command:

> In speed mode, the analog speed command inputs the swing speed setting of the max. voltage (10V).

> For example, if the setting is 3000, when the external voltage input is 10V, it means the speed control command is 3000 r/min. If the external voltage input is 5V, then the speed control command is 1500 r/min.

6.3.5 Timing Diagram in Speed Mode
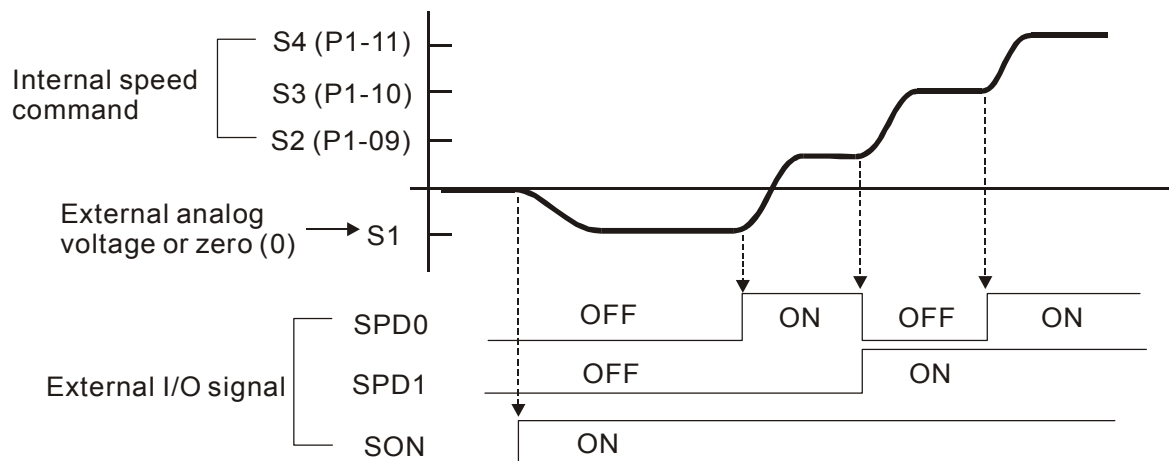
> **NOTE**   (1) OFF means the contact point is open while ON means the contact point is close.
>
> (2) When it is in Sz mode, the speed command S1 = 0; When it is in S mode, the speed command S1 is the external analog voltage input.
>
> (3) When the servo drive is On, please select the command according to SPD0 ~ SPD1 status.

6.3.6 Gain Adjustment of Speed Loop

Here introduces the function of speed control unit. The following shows its structure.
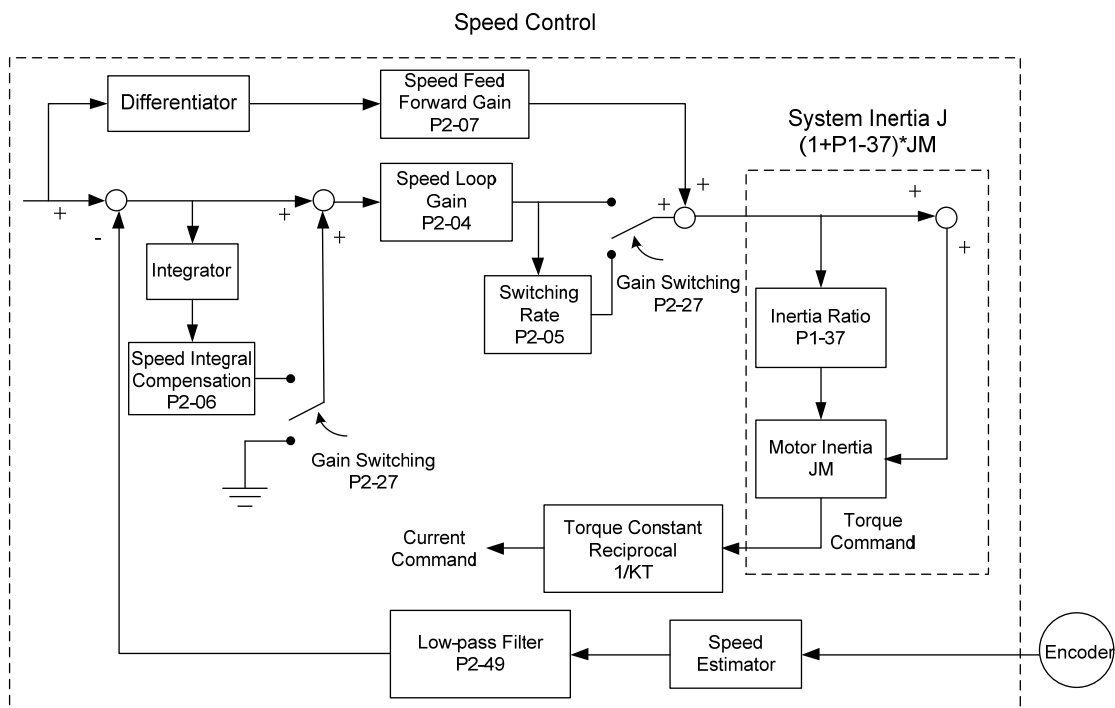
Many kinds of gain in speed control unit are adjustable. Two ways, manual and auto, are provided for selection.

Manual: All parameters are set by users and the auto or auxiliary function will be disabled in this mode.

Auto: General load inertia estimation is provided. It adjusts the parameter automatically. Its framework is divided into PI auto gain adjustment and PDFF auto gain adjustment.

Parameter P2-32 can be used to adjust the gain.

P2-32▲	AUT2	Tuning Mode Selection	Address: 0240H 0241H
	Operation Interface:	Panel/Software	Communication	Related Section: Section 5.6, Section 6.3.6
	Default:	0		
	Control Mode:	ALL		
	Unit:	N/A		
	Range:	0 ~ 2		
	Data Size:	16-bit		
	Display Format:	Hexadecimal		

Settings: 0: Manual Mode

1: Auto Mode (continuous adjustment)

2: Semi-auto Mode (non- continuous adjustment)

Relevant description of manual mode setting:

When P2-32 is set to 0, parameters related to gain control, such as P2-00, P2-02, P2-04, P2-06, P2-07, P2-25, and P2-26, all can be set by the user.

When switching mode from auto or semi-auto to manual, parameters about gain will be updated automatically.

Relevant description of auto mode setting:

Continue to estimate the system inertia, save the inertia ratio to P1-37 every 30 minutes automatically and refer to the stiffness and bandwidth setting of P2-31.

1. Set the system to manual mode 0 from auto 1 or semi-auto 2, the system will save the estimated inertia value to P1-37 automatically and set the corresponding parameters.

2. Set the system to auto mode 1 or semi-auto mode 2 from manual mode 0, please set P1-37 to the appropriate value.

3. Set the system to manual mode 0 from auto mode 1, P2-00, P2-04, and P2-06 will be modified to the corresponding

parameters of auto mode.

4. Set the system to manual mode 0 from semi-auto mode 2, P2-00, P2-04, P2-06, P2-25, and P2-26 will be modified to the corresponding parameters of semi-auto mode.

Relevant description of semi-auto mode setting:

1. When the system inertia is stable, the value of P2-33 will be 1 and the system stops estimating. The inertia value will be saved to P1-37 automatically. When switching mode to semi-auto mode (from manual or auto mode), the system starts to estimate again.

2. When the system inertia is over the range, the value of P2-33 will be 0 and the system starts to estimate and adjust again.

Manual Mode

When P2-32 is set to 0, users can define Speed Loop Gain (P2-04), Speed Integral Compensation (P2-06) and Speed Feed Forward Gain (P2-07). Influence of each parameter is as the followings.

Proportional gain: To increase proportional gain can enhance the response frequency of speed loop.

Integral gain: To increase the integral gain could increase the low-frequency stiffness of speed loop, reduce the steady-state error and sacrifice the phase margin. The over high integral gain will cause the instability of the system.

Feed forward gain: Diminish the deviation of phase delay.

Related parameters:

P2-04	KVP	Speed Loop Gain		Address: 0208H 0209H
	Operation Interface:	Panel/Software	Communication	Related Section: Section 6.3.6
	Default:	500		
	Control Mode:	ALL		
	Unit:	rad/s		
	Range:	0 ~ 8191		
	Data Size:	16-bit		
	Display Format:	Decimal		

Settings: Increase the value of speed loop gain can enhance the speed response. However, if the value is set too big, it would easily cause resonance and noise.

P2-06	KVI	Speed Integral Compensation	Address: 020CH 020DH
Operation Interface:	Keypad/Software	Communication	Related Section: Section 6.3.6
Default:	100		
Control Mode:	ALL		
Unit:	rad/s		
Range:	0 ~ 1023		
Data Size:	16-bit		
Display Format:	Decimal		

Settings: Increasing the value of speed integral compensation can enhance speed response and diminish the deviation of speed control. However, if the value is set too big, it would easily cause resonance and noise.

P2-07	KVF	Speed Feed Forward Gain	Address: 020EH 020FH
Operation Interface:	Panel/Software	Communication	Related Section: Section 6.3.6
Default:	0		
Control Mode:	ALL		
Unit:	%		
Range:	0 ~ 100		
Data Size:	16-bit		
Display Format:	Decimal		

Settings: When the speed control command runs smoothly, increasing the gain value can reduce the speed command error. If the command does not run smoothly, decreasing the gain value can reduce the mechanical vibration during operation.

Theoretically, stepping response can be used to explain proportional gain (KVP), integral gain (KVI) and feed forward gain (KVF). Here, the frequency domain and time domain are used to illustrate the basic principle.

Frequency Domain

STEP 1: Set the value of KVI=0, the value of KVF=0 and adjust the value of KVP.
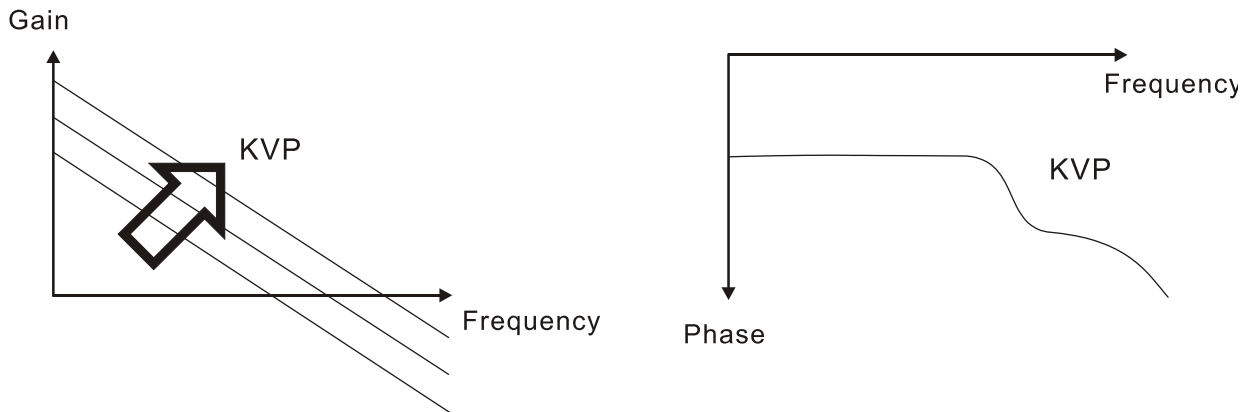
STEP 2：Fix the value of KVP and adjust the value of KVI.
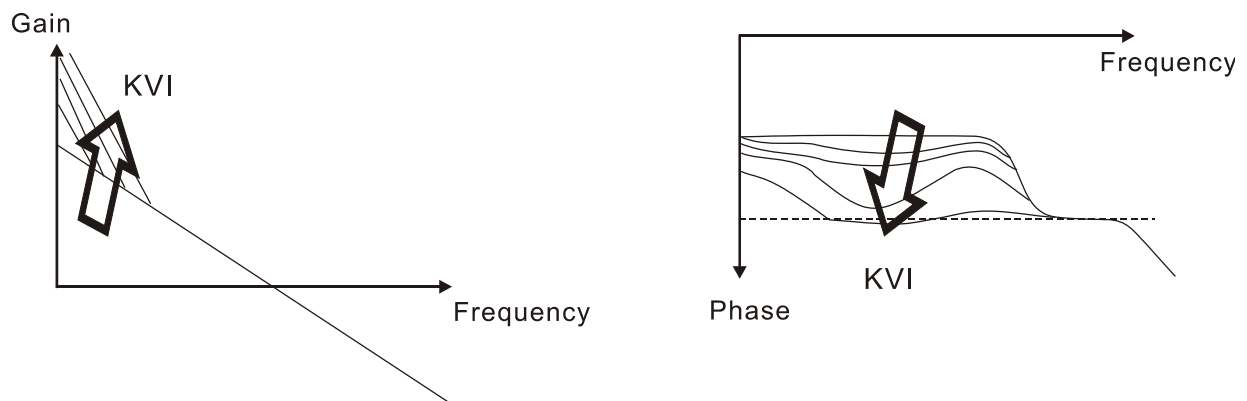
STEP 3：Select the value of KVI, if the value of phase margin is too small, re-adjust the value of KVP again to obtain the value, 45deg of phase margin.

Time Domain

Speed

KVP
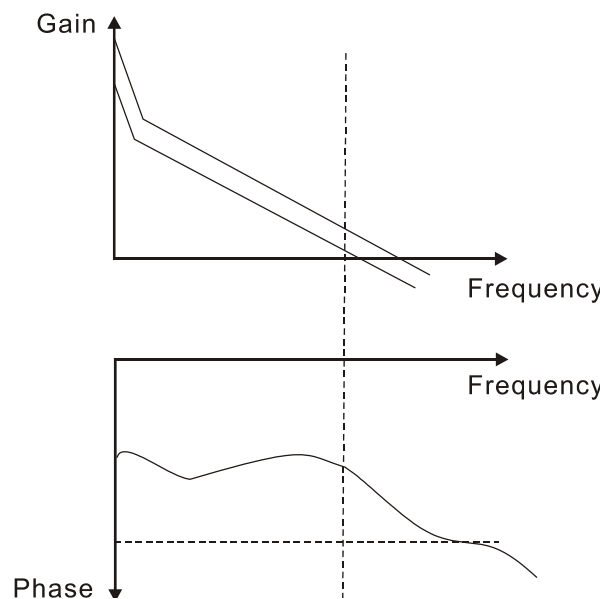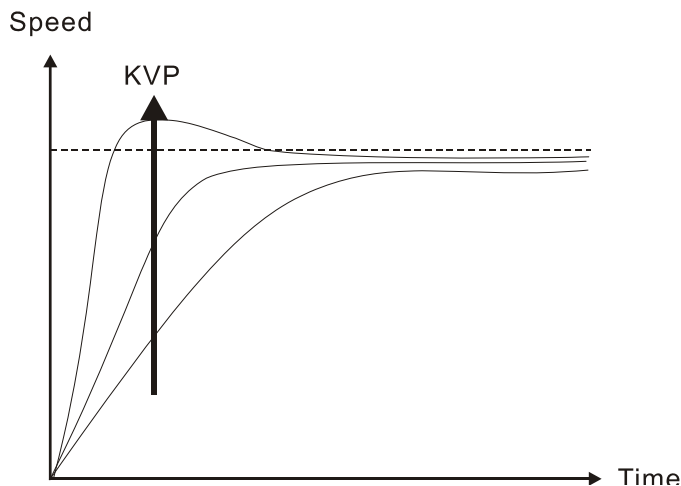
The bigger KVP value cause higher bandwidth and shorten the rising time. However, if the value is set too big, the phase margin will be too small.

To steady-state error, the result is not as good as KVI. But it helps to reduce the dynamic following error.

Speed

KVI
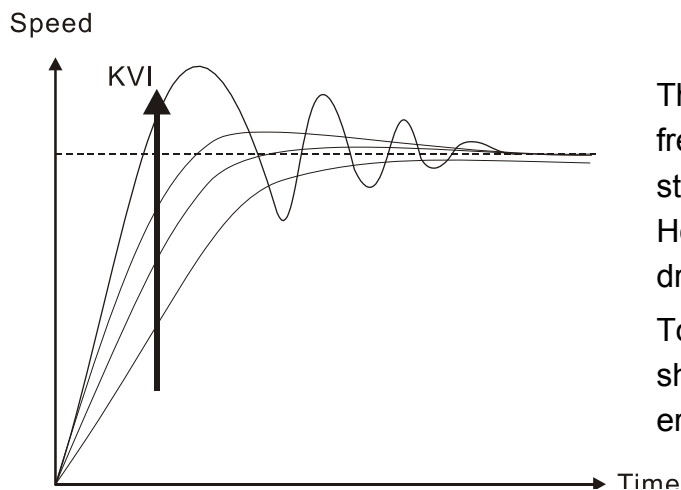
The bigger KVI value cause greater low-frequency gain and shorten the time the steady-state error returns to zero. However, the phase margin will dramatically decrease as well.

To steady-state error, it is very helpful but shows no benefit to dynamic following error.

Speed

KVF
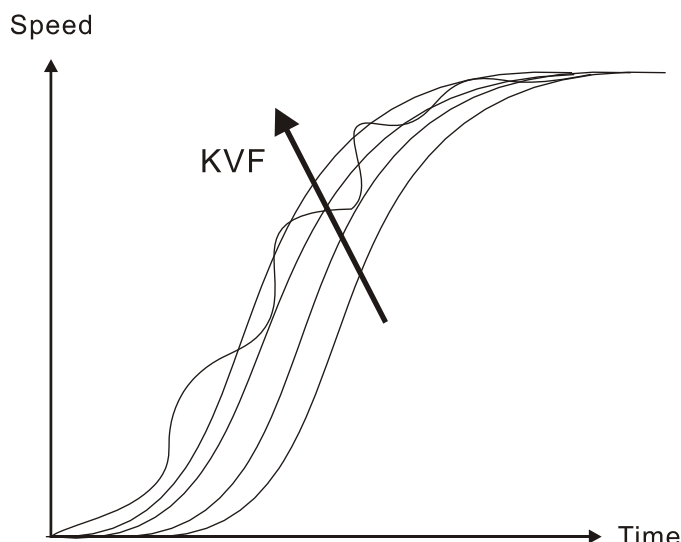
If the KVF value closes to 1, the feed forward compensation will be more complete and the dynamic following error will become smaller. However, if the KVF value is set too big, it would cause vibration.

Generally, instrument is needed when applying frequency domain for measurement. Users are required to adopt the measurement techniques; while time domain only needs a scope and goes with the analog input / output terminal provided by the servo drive. Thus, time domain is frequently used to adjust PI controller. The abilities of PI controller to deal with the resistance of torque load and the following command are the same. That is to say, the following command and resistance of torque load have the same performance in frequency domain and time domain. Users can reduce the bandwidth by setting the low-pass filter in command end.

Auto Mode

Auto mode adopts adaptive principle. The servo drive automatically adjusts the parameters according to the external load. Since the adaptive principle takes longer time, it will be unsuitable if the load changes too fast. It would be better to wait until the load inertia is steady or changes slowly. Depending on the speed of signal input, the adaptive time will be different from one another.
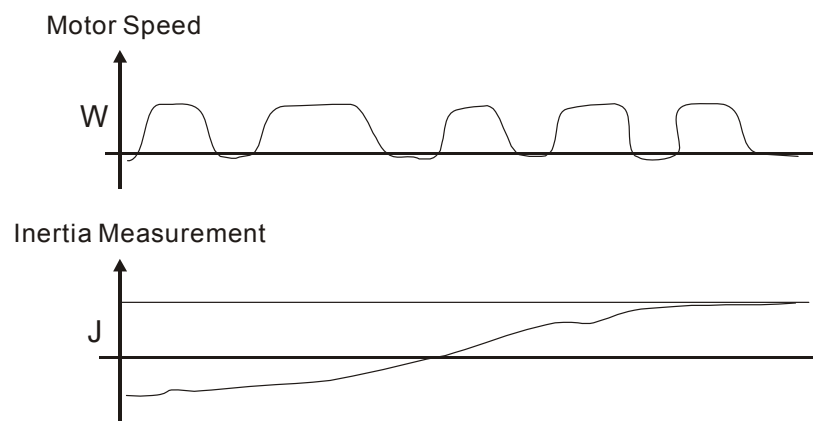
6.3.7 Resonance Suppression

When resonance occurs, it is probably because the stiffness of the control system is too strong or the response is too fast. Eliminating these two factors might improve the situation. In addition, low-pass filter (parameter P2-25) and notch filter (parameter P2-23 and P2-24) are provided to suppress the resonance if not changing the control parameters.

Related parameters:

P2-23	NCF1	Resonance Suppression (Notch Filter) 1	Address: 022EH 022FH
	Operation Interface:	Panel/Software	Communication	Related Section: Section 6.2.5
	Default:	1000		
	Control Mode:	ALL		
	Unit:	Hz		
	Range:	50 ~ 2000		
	Data Size:	16-bit		
	Display Format:	Decimal		

Settings: The first setting value of resonance frequency. If P2-24 is set to 0, this function is disabled. P2-43 and P2-44 are the second Notch filter.

P2-24	DPH1	Resonance Suppression (Notch Filter) Attenuation Rate (1)	Address: 0230H 0231H
	Operation Interface:	Panel/Software	Communication	Related Section: Section 6.3.7
	Default:	0		
	Control Mode:	ALL		
	Unit:	dB		
	Range:	0 ~ 32 (0: Disabled)		
	Data Size:	16-bit		
	Display Format:	Decimal		

Settings: The first resonance suppression (notch filter) attenuation rate. When this parameter is set to 0, the function of Notch filter is disabled.

P2-43	NCF2	Resonance Suppression (Notch Filter) 2	Address: 0256H 0257H

Operation Interface:	Panel/Software	Communication	Related Section: Section 6.3.7
Default:	1000		
Control Mode:	ALL		
Unit:	Hz		
Range:	50 ~ 2000		
Data Size:	16-bit		
Display Format:	Decimal		

Settings: The second setting value of resonance frequency. If P2-44 is set to 0, this function is disabled. P2-23 and P2-24 are the first Notch filter.

P2-44	DPH2	Resonance Suppression (Notch Filter) Attenuation Rate (2)	Address: 0258H 0259H

Operation Interface:	Panel/Software	Communication	Related Section: Section 6.3.7
Default:	0		
Control Mode:	ALL		
Unit:	dB (0: Disable the function of notch filter)		
Range:	0 ~ 32		
Data Size:	16-bit		
Display Format:	Decimal		

Settings: The second resonance suppression (notch filter) attenuation rate. When this parameter is set to 0, the function of Notch filter is disabled.

P2-45	NCF3	Resonance Suppression (Notch Filter) 3	Address: 025AH 025BH

Operation Interface:	Panel/Software	Communication	Related Section: Section 6.3.7
Default:	1000		
Control Mode:	ALL		
Unit:	Hz		
Range:	50 ~ 2000		
Data Size:	16-bit		
Display Format:	Decimal		

Settings: The third group of mechanism resonance frequency setting value.
If P2-46 is set to 0, this function will be disabled. P2-23 and
P2-24 are the first group of resonance suppression (Notch filter).

P2-46	DPH3	Resonance Suppression (Notch Filter) Attenuation Rate (3)	Address: 025CH 025DH

Operation Interface:	Panel/Software	Communication	Related Section: Section 6.3.7
Default:	0		
Control Mode:	ALL		
Unit:	dB		
Range:	0 ~ 32		
Data Size:	16-bit		
Display Format:	Decimal		

Settings: The third group of resonance suppression (Notch filter)
attenuation rate. Set the value to 0 to disable the function of
Notch filter.

P2-25	NLP	Low-pass Filter of Resonance Suppression	Address: 0232H 0233H
Operation Interface:	Keypad/Software	Communication	Related Section: Section 6.3.7
Default:	0.2 (1kW and below models) or 0.5 (other models)	2 (1kW and below models) or 5 (other models)	
Control Mode:	ALL		
Unit:	1ms	0.1ms	
Range:	0.0 ~ 100.0	0 ~ 1000	
Data Size:	16-bit		
Display Format:	One-digit	Decimal	
Input Value Example:	1.5 = 1.5 ms	15 = 1.5 ms	

Settings: Set the low-pass filter of resonance suppression. When the value is set to 0, the function of low-pass filter is disabled.
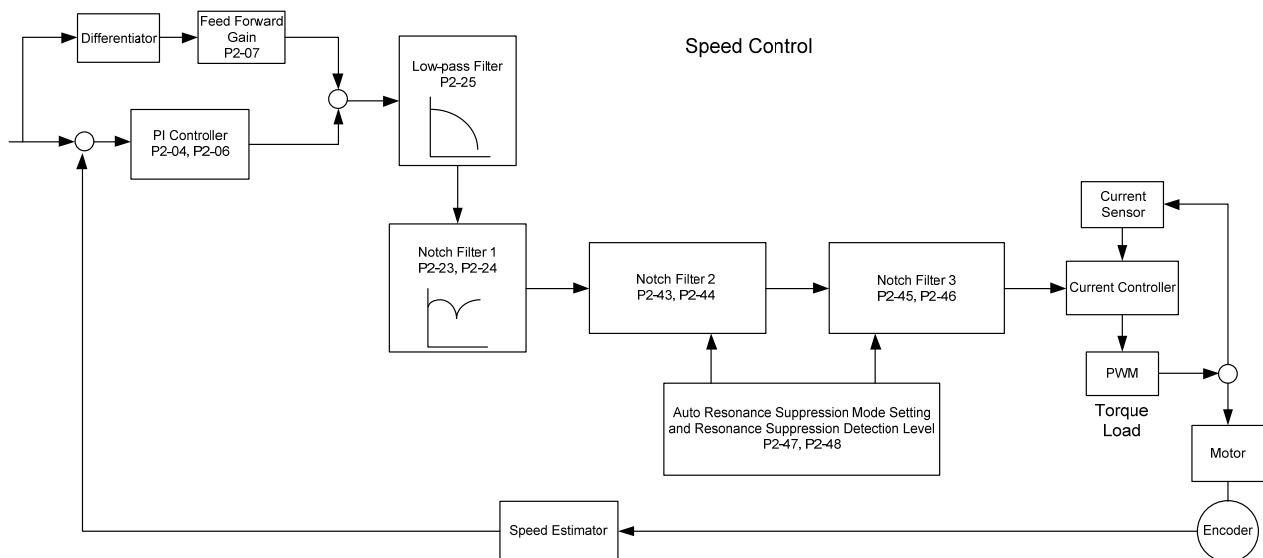
There are two sets of auto resonance suppression, one is P2-43 and P2-44 and another one is P2-45 and P2-46. When the resonance occurs, set P2-47 to 1 or 2 (enable the function of resonance suppression), the servo drive searches the point of resonance frequency and suppresses the resonance automatically. Write the point of frequency into P2-43 and P2-45 and write the attenuation rate into P2-44 and P2-46. When P2-47 is set to 1, the system will set P2-47 to 0 (disable the function of auto suppression) automatically after completing resonance suppression and the system is stable for 20 minutes. When P2-47 is set to 2, the system will keep searching the point of resonance.

When P2-47 is set to 1 or 2, but resonance still exists, please confirm the value of parameter P2-44 and P2-46. If one of them is 32, it is suggested to reduce the speed bandwidth first and then start to estimate again. If the value of both is smaller than 32 and resonance still exists, please set P2-47 to 0 first and then manually increase the value of P2-44 and P2-46. It is suggested to reduce the bandwidth if the resonance has not been improved. Then use the function of auto resonance suppression.

When manually increase the value of P2-44 and P2-46, please check if the value of both is bigger than 0. If yes, it means the frequency point of P2-43 and P2-45 is the one searched by auto resonance suppression. If the value of both is 0, it means the default, 1000 of P2-43 and P2-45 is not the one searched by auto resonance suppression. Deepen the resonance suppression attenuation rate might worsen the situation.

Settings of P2-47		
Current Value	Desired Value	Function
0	1	Clear the setting value of P2-43 ~ P2-46 and enable auto resonance suppression function.
0	2	Clear the setting value of P2-43 ~ P2-46 and enable auto resonance suppression function.
1	0	Save the setting value of P2-43 ~ P2-46 and disable auto resonance suppression function.
1	1	Clear the setting value of P2-43 ~ P2-46 and enable auto resonance suppression function.
1	2	Do not clear the setting value of P2-43 ~ P2-46 and enable auto resonance suppression function continuously.
2	0	Save the setting value of P2-43 ~ P2-46 and disable auto resonance suppression function.
2	1	Clear the setting value of P2-43 ~ P2-46 and enable auto resonance suppression function.
2	2	Do not clear the setting value of P2-43 ~ P2-46 and enable auto resonance suppression function continuously.

Flowchart of auto resonance suppression:

```
                    ┌──────────────────────┐
                    │   Drive the machine   │
                    │   by servo system     │
                    └──────────┬───────────┘
                               │
          ┌────────────────────▼──────────────┐   No
          │       Check if vibration          │──────────────────────┐
          │           occurs                  │                      │
          └────────────────┬──────────────────┘                      │
                         Yes │                                        │
        ┌───────────────────▼──────────┐                             │
        │         Set P2-47 = 1         │                             │
        └──────────────┬───────────────┘                             │
                       │                                              │
          ┌────────────▼──────────────┐   No                         │
          │    Check if vibration      │──────────────────┐          │
          │        occurs              │                  │          │
          └────────────┬──────────────┘                  │          │
                     Yes │                                │          │
    No  ┌────────────────▼──────────┐                    │          │
  ┌─────│     Set P2-47 = 1 for      │                    │          │
  │     │        three time          │                    │          │
  │     └────────────┬──────────────┘                    │          │
  │                Yes │                                   │          │
  │     ┌──────────────▼───────────┐   Yes  ┌──────────────────────┐ │
  │     │       P2-44 = 32          │───────▶│ Decrease frequency    │ │
  │     │     or P2-46 = 32         │        │ response              │ │
  │     └────────────┬──────────────┘        └──────────────────────┘ │
  │                No │                                                │
  │     ┌──────────────▼───────────┐                                  │
  │     │       Set P2-47 = 0       │                                  │
  │     └────────────┬──────────────┘                                 │
  │                  │                                                 │
  │   ┌──────────────▼─────────────────────────────┐                  │
  │   │ If P2-44 >0, value of P2-44 should + 1      │◀────┐            │
  │   │ If P2-46 >0, value of P2-46 should + 1      │     │            │
  │   └──────────────┬─────────────────────────────┘     │            │
  │          No      │                                    │            │
  │   ┌──────────────▼──────────────┐                     │            │
  └───│   Check if vibration         │                    │            │
      │   condition has improved     │                    │            │
      └──────────────┬───────────────┘                    │            │
                  Yes │                                    │            │
      ┌───────────────▼──────────────┐   Yes              │            │
      │   Check if vibration          │───────────────────┘            │
      │        occurs                 │                                 │
      └───────────────┬──────────────┘                                 │
                   No │◀────────────────────────────────────────────────┘
      ┌────────────────▼─────────────┐
      │        Set P2-47 = 0          │◀──────────────────────────────┐
      └────────────────┬─────────────┘                               │
                       │◀──────────────────────────────────────────────┘
              ┌────────▼────────┐
              │    Complete      │
              └─────────────────┘
```
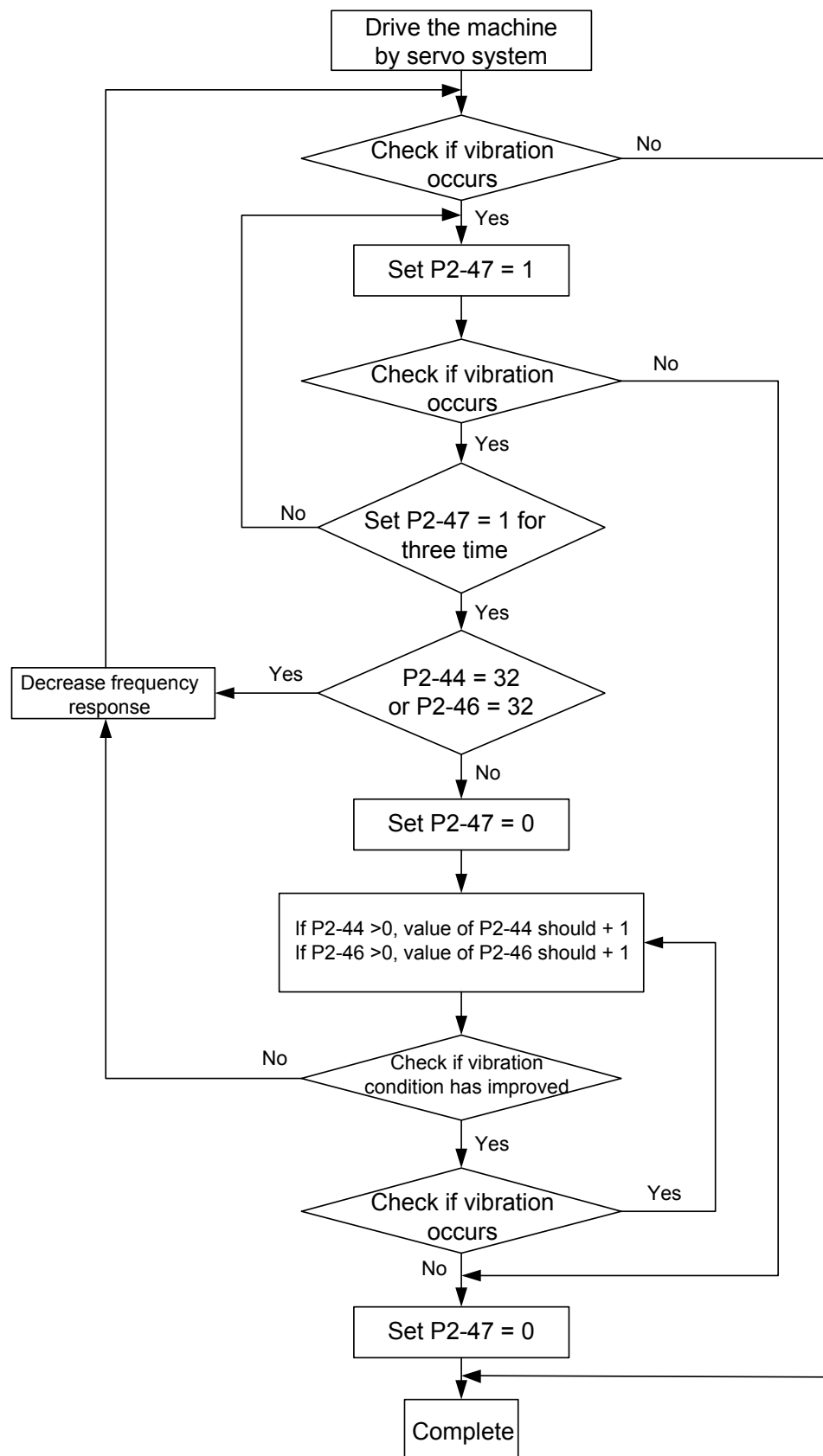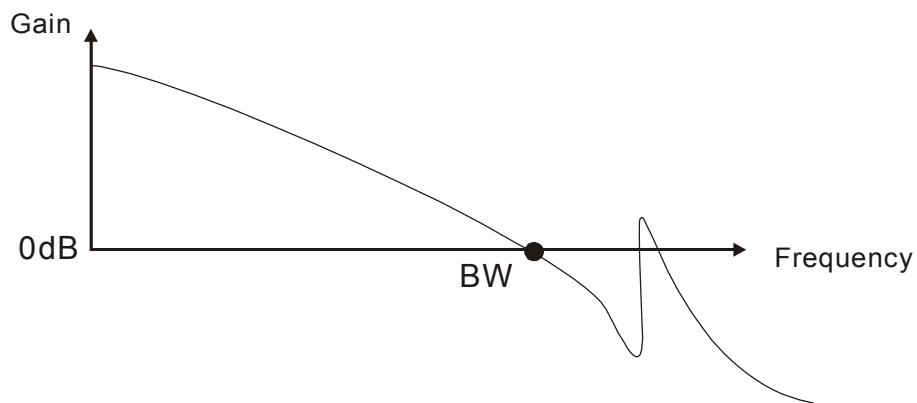
Here illustrates the effect via low-pass filter (parameter P2-25). The following diagram is the system open-loop gain with resonance.
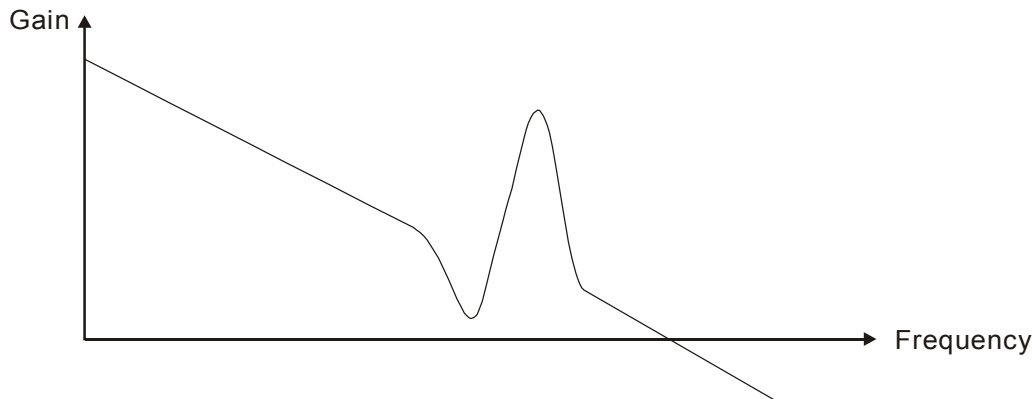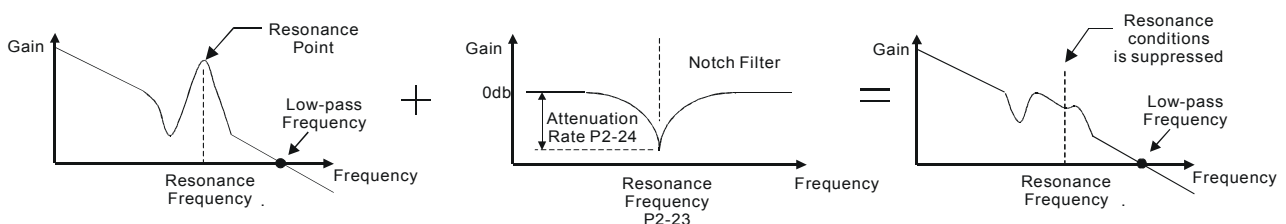

When the value of P2-25 is increased from 0, BW becomes smaller (See as the following diagram). Although it solves the problem of resonance frequency, the response bandwidth and phase margin is reduced.
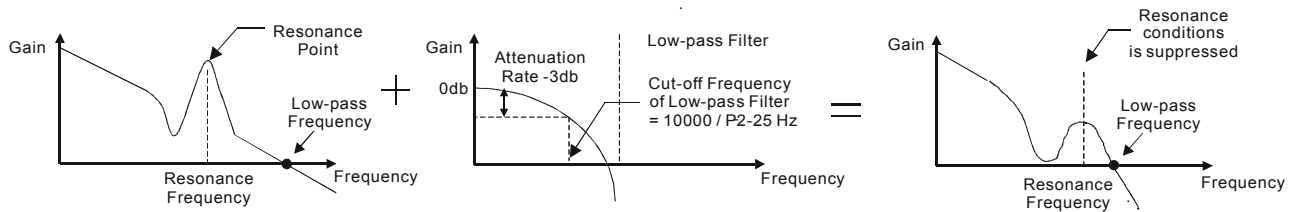

If users know the resonance frequency, notch filter (parameter P2-23 and P2-24) can directly eliminate the resonance. The frequency setting range of notch filter is merely from 50 to 1000 Hz. The suppression strength is from 0 to 32 dB. If the resonance frequency is not within the range, it is suggested to use low-pass filter (parameter P2-25).

Here firstly illustrates the influence brought by notch filter (P2-23 and P2-24) and low-pass filter (P2-25). The following diagrams are the system of open-loop gain with resonance.

Resonance suppression with notch filter

Resonance suppression with low-pass filter

When the value of P2-25 is increased from 0, BW becomes smaller. Although it solves the problem of resonance frequency, the response bandwidth and phase margin is reduced. Also, the system becomes unstable.

If users know the resonance frequency, notch filter (parameter P2-23 and P2-24) can directly eliminate the resonance. In this case, notch filter will be more helpful than low-pass filter. However, if the resonance frequency drifts because of time or other factors, notch filter will not do.