

SERVOSTAR[®] S- and CD-series Velocity Control

The SERVOSTAR[®] S and SERVOSTAR[®] CD product lines offer two dedicated modes of operation for velocity control applications and give the user three possible approaches to commanding velocity. One mode of operation, OPMODE 0, allows you to command the drive serially through the C1 (D9) connector via a host terminal. The other, OPMODE 1, offers the flexibility of commanding the drive via an analog voltage or through pre-configured serial commands stored in the drive's memory. The analog signal are scaled and filtered before being passed through the velocity control algorithm. Motion results are then communicated back through either the Configurable Outputs (ANOUT, O1MODE) or through the serial port to the host.

There are four different control loop algorithms. Each has its own advantages depending on the type of application and the desired performance. Tuning is made easy for most applications with the drive's AutoTuning feature. Here, drive tuning is introduced. Refer to *SERVOSTAR[®] S/CD-Series Velocity Tuning Algorithms* for a more detailed and comprehensive analysis of this topic.

The SERVOSTAR product line comes with a software tool called **MOTIONLINK[®]**. This package gives you a friendly and intuitive interface by which to operate, tune, and monitor system performance. Velocity control features referencing the variable and command set of the drive are discussed. You are strongly encouraged to use **MOTIONLINK** to set the parameter values of this variable and command set. For the user desiring to interact with the drive's variables and commands through a "dumb" terminal or host, this software interface offers a terminal mode of operation.



Refer to the SERVOSTAR[®] S and SERVOSTAR[®] CD VarCom Reference or the SERVOSTAR[®] S and SERVOSTAR[®] CD Setup and Reference manual for the syntax and complete description of the variables and commands. This guide can also be downloaded from the website (www.DanaherMotion.com).

We begin by discussing the various command options, proceed to tuning and profile performance that apply to each of the command options, and then conclude with discussing optional features that enhance overall system control.

Serial Velocity Control

The SERVOSTAR is controlled serially through the C1 (D9) connector on the front of the drive by selecting the appropriate mode of operation (OPMODE 0). Communication rates of 9600 and 19200 BAUD are available. The following figure illustrates the various options of communication and is referred to through the remainder of this document. Two types of serial commands are offered:

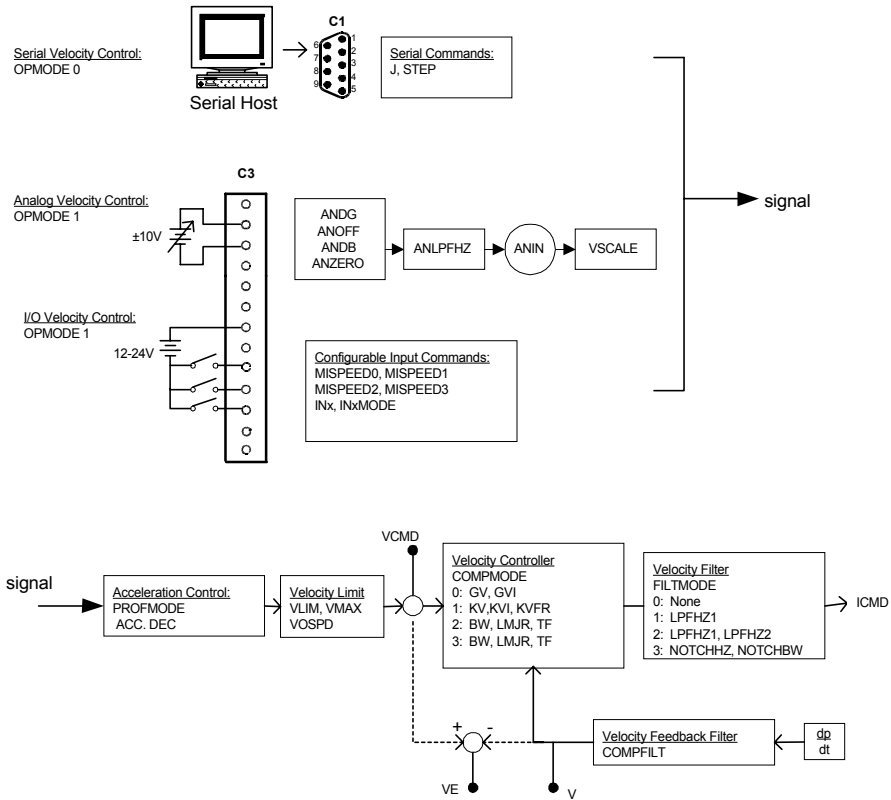


Figure 1 Variable/Command Flow Structure

Jog Command

From a host terminal or using **MOTIONLINK**'s terminal mode, a jog (J) command initiates a set speed for a pre-determined amount of time. If no time is set, the motor runs continuously at the specified speed. Upon system enable, the drive sets the J command to zero.

Step Command

A STEP command given through the host generates a step or square-wave response. This command is intended for use with the RECORD feature found in **MOTIONLINK** and can be set to give two profile cycles for easy stop-start-stop-start motion.



Both of these commands are prohibited while the drive is in the HOLD mode of operation.

Analog Velocity Control

The analog input to the SERVOSTAR is applied through the C3 connector (see Figure 1) and is a differential input. This means that the signals received at the two inputs are subtracted from each other to create a “difference”, that is then used to command the rest of the system. This type of input has a high degree of noise immunity and, in many cases, allows for ground isolation between systems. This analog input also has a digital low pass filter (ANLPHZ) to prevent high frequency noise from entering the system.

The input voltage from the differential receiver is applied to a precise 14-bit Analog-to-Digital (A/D) conversion system. The A/D conversion system is read by the microprocessor every 500 μ S for the position loop. Encoder-based units come with the additional benefit of a Dual Gain (ANDG) input. When enabled, the system uses two 14-bit A/D inputs to read the user-supplied analog signal. One input is a direct reading of the ± 10 V signal, while the other incorporates a 2x-gain term. When the input voltage is less than 4V, the 2x channel is used to determine the user’s input voltage, extending the resolution to a 15-bit equivalent. Above 4V, the system uses the straight 14-bit conversion. Special software algorithms are used to minimize crossover distortion and add 0.25V of hysteresis.

Analog systems often require scaling and offset bias. As shown in Figure 1, the SERVOSTAR adds an analog offset (ANOFF) variable to this reading, performs an analog deadband (ANDB) adjustment, and scales it internally from volts (± 10 V) to counts (16384). The analog input (ANIN) variable represents the analog reading in counts with a range of ± 22500 mV (counts equating to mV).

Command Scaling

In the analog velocity mode, the SERVOSTAR gives you various approaches to manipulating the analog input command to actual motor shaft movement. Overviewed in the previous section, the following discusses these features in detail (see the QRG for definition of variable syntax).

ANALOG SIGNAL DEAD BAND (ANDB)

This scaling feature allows you to set a dead band range for which no analog command is generated. This is particularly useful when the analog input signal is noisy or exhibits drift that results in undesired motor shaft movement. An example of this is a system set at idle with an applied signal to the analog input of 0 V, where an ambient room temperature change occurs of 15° creating a –500 mV drift. You could set ANDB = 600 in the form of a position command and experience no shaft movement because this 500 mV drift does not get passed to the next block (See Figure 3) until the analog input signal reaches –600 mV. The actual deadband range where ANDB = 600 is –600 mV to +600 mV.

ANALOG SIGNAL OFFSET (ANOFF)

The SERVOSTAR can only receive an analog input signal range of ± 10 V. The drive uses the value stored in the ANIN variable to command the position loop. As a default, the input relationship between the actual signal and the value of ANIN is ± 10 V = ± 10000 mV. However, there are applications that either provide a different analog input signal range or demand a different command range.

The SERVOSTAR provides an offset feature (ANOFF) that changes the range relationship between the analog input signal and the velocity loop command (ANIN). For example, if ANOFF = 5000, an analog input signal range of ± 10 V equates to a position loop command range of -5000 to +15000 mV. Motor movement reacts to a -5 to 15 V range on the input.

ZEROING THE ANALOG INPUT (ANZERO)

The SERVOSTAR offers an automatic analog input zeroing function. Executing this command samples the analog input 64 times, calculates an average, and adjusts ANOFF accordingly to cancel out any input offset that may be present from such factors as drift and noise.

INPUT FILTERING (ANLPFHZ)

The SERVOSTAR provides a first-order filter on the front end of the analog input. It is always present and adjusts automatically as the analog input sampling rate changes for different operational modes.

Pre-Configured Profiles with Configurable I/O

You can pre-configure up to four velocity commands in the drive's memory by entering your desired command values into the speed variables MISPEED_x (where $x = 0, 1, 2, 3$) via a host computer through the serial port, C1. The stored commands are selected by configuring the three Configurable Inputs with respect to the IN_xMODE variables (where $x = 0, 1, 2, 3$). One of the inputs must be set to toggle the feature on/off while the other two are used to select the desired command with a binary equivalent address sequence that corresponds to the "x" value of MISPEED_x.



Even though these serial commands are stored in memory, this feature only operates in the analog mode of operation (OPMODE 1). However, the Status Display indicates a "0" as if it is in the serial mode of operation.

Before we share examples of this operation, it is necessary to discuss the Configurable I/O in general, as it relates to velocity control.

Configurable I/O

The SERVOSTAR features three inputs, one analog output, and one digital output on the C3 connector that interact with the SERVOSTAR's variable/command set to enhance the communication capabilities of the drive. Particular to velocity control, these I/O provide triggering action that initiates velocity commands pre-configured in the drive's memory.

The following diagram highlights these I/O, as it pertains to velocity control, using the IN_x, IN_xMODE, ANOUT, O1MODE, and O1 variables. This diagram is referred to through the remaining discussions of this section. IN_x variables indicate the state (on/off) of the hardware switches tied to the three configurable input pins: 9, 10, and 11 respectively. IN_xMODE variables determine what the three Configurable Inputs are used to indicate. The Configurable Analog Output (ANOUT) is set up to give an analog representation of either the velocity feedback (V) or the velocity following error (VE). The Configurable Digital Output (O1), is a state indicator (on/off) and is used to communicate that a particular action, determined by O1MODE, has been performed.

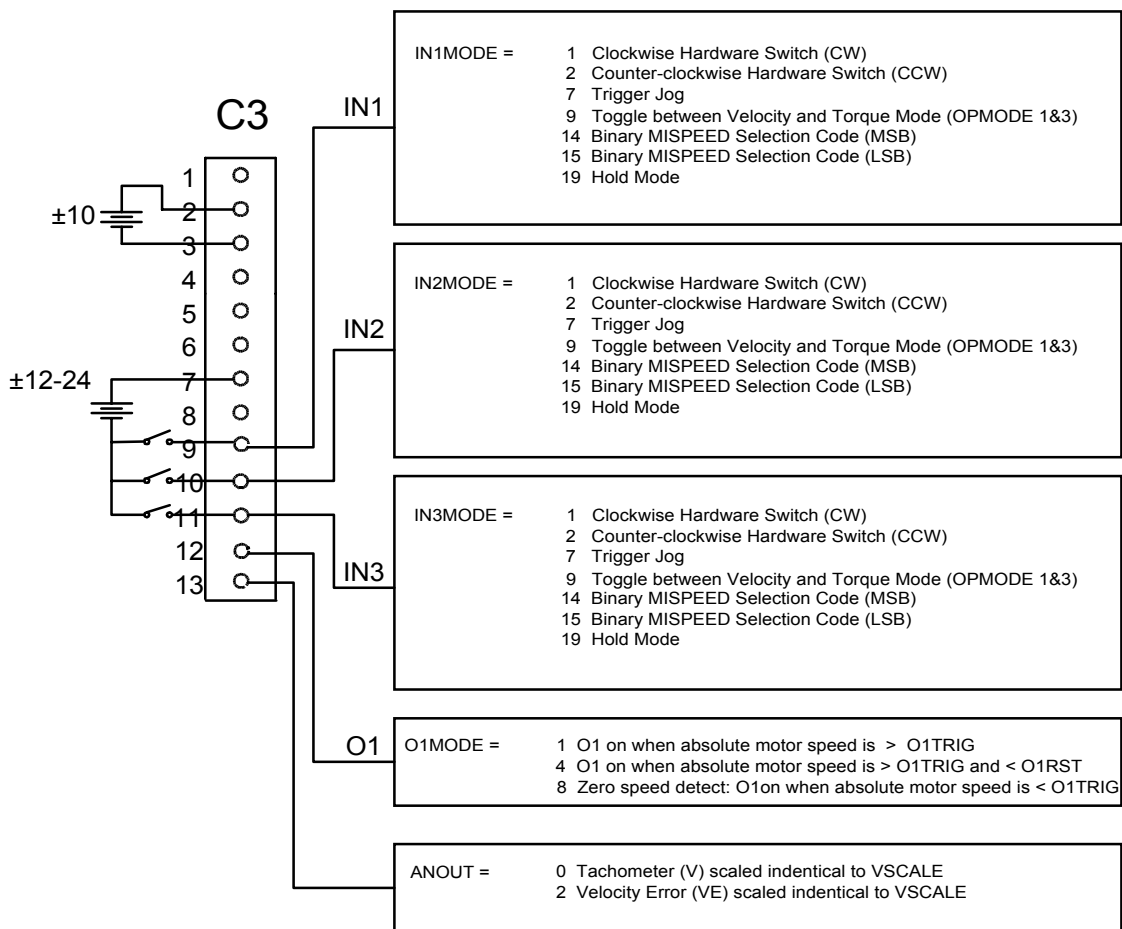


Figure 2: Configurable I/O for Velocity Control

I/O Example

Velocity values must first be entered in the drive's memory through the serial port. Figure 2 shows general C3 connection information to assist your understanding of the switches discussed in the table below. The following table demonstrates the Configurable I/O interaction with this velocity mode of operation:

Given:

MISPEED0 = 200
 MISPEED1 = 401
 MISPEED2 = 34
 MISPEED3 = 500

Binary Count		Switch		Velocity Command Executed (rpm)	OPMODE	Status Display
C3, pin 9 (IN1) (IN3MODE = 7)	C3, pin 10 (IN2) (IN1MODE = 14)	C3, pin 11 (IN3) (IN2MODE = 15)				
OFF	x	x		Reads analog input	1	1
ON	OFF	OFF		2000	1	0
ON	OFF	ON		4010	1	0
ON	ON	OFF		340	1	0
ON	ON	ON		5000	1	0

OFF = Open switch, ON = Closed switch, x = don't care

Any combination of the switches can be used to perform the above example as long as the corresponding INxMODE is set accordingly. Notice that INxMODE = 7 (can be any of the three inputs) turns this feature on and off. In the off position, the drive looks to the analog input for the command as explained in the previous section.

Hybrid Analog Command

There is one exception to the previous example that needs mentioning. If you set MISPEED0 = 0, the drive reads the analog input (not command a zero RPM speed). The following table demonstrates this exception:

Given:

MISPEED0 = 0
 MISPEED1 = 401
 MISPEED2 = 34
 MISPEED3 = 500

Binary Count		Switch		Velocity Command Executed (rpm)	OPMODE	Status Display
C3, pin 9 (IN1) (IN3MODE = 7)	C3, pin 10 (IN2) (IN1MODE = 14)	C3, pin 11 (IN3) (IN2MODE = 15)				
OFF	x	x		Reads analog input	1	1
ON	OFF	OFF		Reads analog input	1	0
ON	OFF	ON		4010	1	0
ON	ON	OFF		340	1	0
ON	ON	ON		5000	1	0

OFF = Open switch, ON = Closed switch, x = don't care

System Tuning

To tune a SERVOSTAR system for operation in either of the velocity loop modes discussed above (OPMODE 0 or 1), you must select the proper velocity compensator algorithm that best suits your application. There are two methods of tuning the drive in velocity control:

- 1) Automatically tune the drive using the TUNE feature.
- 2) Manually adjust the gain parameters for the selected algorithm selected.



This System Tuning section is thoroughly discussed in SERVOSTAR® S/CD-Series Velocity Tuning Algorithms. We will only highlight the drive's tuning features in this document.

Control Algorithms

The following briefly explains the four types of compensators available in the SERVOSTAR (see Figure 1 for variable process flow). Each has a slightly different effect on the performance of the system and is selectable through the COMPMODE variable. The variables associated with each compensator are detailed in the *SERVOSTAR® S and SERVOSTAR® CD VarCom Reference* or the *SERVOSTAR® S and SERVOSTAR® Setup and Reference* manuals.

PROPORTIONAL-INTEGRAL (PI), COMPMODE = 0

The PI compensator is best suited for applications requiring high, steady-state command-following accuracy. It gives a quick response to a command input (high acceleration), such as a master-slave application, but it may cause overshoot and settling difficulties when reaching the commanded velocity.

The parameters associated with the PI compensator are:

- GV - effects the drive's ability to match the command velocity
- GVI - effects the response time and tendency to overshoot.

PSEUDO-DERIVATIVE-FEEDBACK WITH FEED-FORWARD (PDFF), COMPMODE = 1

This compensator exhibits the best performance in applications requiring good speed regulation and command following accuracy in response to changing load conditions. The PDFF compensator generally matches the commanded acceleration very well, but its steady-state error may be greater than that of a PI compensator.

The parameters associated with the PDFF compensator are:

- KV - effects the command-matching ability of the drive.
- KVI - effects the response time to a changing command.
- KVFR - effects the response time to a changing command. It has a tendency to cause overshoot and oscillation of the response.
- COMPFLT - enables/disables the 400 Hz low pass filter.

STANDARD POLE-PLACEMENT, COMPMODE = 2

This compensator is the easiest to tune and exhibits the best overall performance. It offers good response time and command-following capability. However, it does not offer the flexible tuning options for response shaping.

The parameters associated with the Standard Pole-Placement compensator are:

MJ - sets the motor inertia

LMJR - sets the ratio between the load inertia and the motor inertia (MJ). Setting LMJR too high causes the drive response to overshoot and oscillate. Setting LMJR too low causes the drive response to be sluggish. Either situation may cause instability.

BW - sets the bandwidth of the velocity loop. The higher the bandwidth BW, the sharper the response time and the more accurately it follows a command. Higher bandwidths are also more likely to make the system become unstable. A bandwidth that makes the proper tradeoff between performance and stability must be carefully selected.

TF - sets the damping factor of the response.

STANDARD POLE PLACEMENT (EXTENDED PERFORMANCE), COMPMODE = 4

This pole placement compensator gives extended performance to that in COMPMODE 2. The algorithm allows bandwidths as high as 400 Hz (as compared to 200 Hz in COMPMODE 2).

This mode allows for faster response, but faster responses tend to be more susceptible to noise.

The parameters associated with this compensator are the same as that of COMPMODE 2.

AUTOMATIC TUNING (TUNE COMMAND)

The TUNE command is issued to the drive via the serial port and tunes the drive by performing closed-loop velocity steps, capturing the system dynamics, and setting the gain constants accordingly. This command performs the velocity steps in COMPMODE 2 and sets gain parameters for all COMPMODE options based on the system dynamics.

If the tuning process fails using the TUNE command, lower the speed and bandwidth parameters until a successful tune is achieved. The calculated values should give you a good starting point to manually tune for maximum performance.

MANUAL TUNING

You can tune the drive manually by setting the gain parameters for the selected COMPMODE and examining system response as those parameters are set to different values

The easiest way to tune the drive manually is to tune it in COMPMODE 2 using **MOTIONLINK**'s Tune Screen with its recording functions. The pole-placement design uses, in addition to the motor parameters (particularly MJ), the desired bandwidth (BW) and the inertia of the load (LMJR).

The inertia of the load is actually entered as a load-to-motor inertia ratio. The characteristics of the drive response can be examined to help set the value of LMJR. One of the pole-placement controller qualities is that it responds with an overshoot to a velocity step command if the load inertia value LMJR is less than the actual load inertia. If the load inertia value is greater than the actual load inertia, there might be undershoot in the step response (and possibly oscillations) and the controller could become unstable. Therefore, the way to tune LMJR is to set its value, examine the drive step response for overshoot or undershoot, adjust the value of LMJR, and examine the response again. To complete the tuning of the drive, continue to adjust LMJR until the desired response is achieved for the desired bandwidth BW. A well-tuned controller is one that the response to step command has overshoots, undershoots, or oscillations.



Remember to issue a SAVE command to store all new values into EEPROM.

FILTERING

The SERVOSTAR incorporates an array of filtering techniques just right for your application (see Figure 1 for variable process flow). First and second-order low pass filters (LPFHZ1, LPFHZ2) are available to help reduce high frequency resonance. A notch filter (NOTCHBW, NOTCHHZ) is used to reject a band of frequencies. These filters are selectable through the FILTMODE variable and effect the current command signal.

The drive also uses a 400 Hz filter (COMPFLT) in the velocity feedback signal. However, this filter automatically turns off when COMPMODE = 4.

PROFILE RAMPING CONTROL

As a default, the drive is set with no acceleration or deceleration limits (PROFMODE = 0). If a step command is given (in either OPMODE), the drive attempts to follow the command precisely. However, there are applications where the need for linear ramp control is vital for minimizing system overshoot or tracking (following) error. The profile mode (PROFMODE) of operation determines the state of linear ramp control.

ACCELERATION/DECELERATION CONTROL (PROFMODE = 1)

When this linear mode of ramp control is implemented, the value set in each variable becomes the upper limit and not a commanded acceleration. This drive provides two variables (ACC, DEC) for linear ramping with units in rpm/sec.

FAULT RAMP CONTROL

The SERVOSTAR provides a special deceleration ramp (DECSTOP) that over rides normal deceleration control in cases where a system fault occurs and a faster ramp is needed. The procedure is implemented through the ACTFAULT variable and, if enabled, uses a preset speed (DISSPEED) and time (DISTIME) to ramp to a stop. Other non-fault usage of this special ramp control are during a holding state (HOLD), a serial command to stop (S), or a trigger from a Configurable Input (INxMODE = 17).



S-curve ramp control (PROFMODE = 2) is only available in the position mode of operation.

Recording Performance

Using the PC scope feature in **MOTIONLINK**, you can monitor and plot the system's profile performance during the tuning process. This real-time monitoring gives you the ability to watch the effects of even the smallest change in the drive's tuning parameters on the profile performance.

Additional Features

These features apply to the overall velocity control, no matter which OPMODE is selected. These features complete the platform from which a thorough understanding of the velocity loop's functionality is possible.

Homing

The Homing feature of the **SERVOSTAR** is available in the analog velocity mode of operation. A command (or search) to home is initiated through either the Configurable inputs (INxMODE) or via a serial command (MH) - even while velocity travel is taking place. Once the inputs are correctly configured and the drive receives a trigger to home, motion stops and the homing process begins. An "8" appears in the Status Display (although operation is still in the analog velocity mode), as an indicator that homing is in process. It returns to "1" upon completion. Refer to *SERVOSTAR® S/CD-Series Position Control* for a detailed explanation of the **SERVOSTAR**'s homing capabilities and setup.

Tach Monitor

The drive's Configurable Output (ANOUT) provides a 10V analog signal on connector C3 that is set in relation to a desired speed. It can be scaled (VSCALE) such that any voltage range communicates a predetermined speed range. This speed range is limited by the application velocity limit (VLIM). For instance, the default setting of VSCALE is 125% of VLIM. Therefore, in the analog mode of operation (OPMODE = 1), a 0 V to 8 V command (not a 0 V to 10 V command) on the input gives you a velocity range of 0-VLIM. If you desire the full 10V input to command your full speed range, set VSCALE equal to VLIM.

Following Error Monitor

The Configurable Output (ANOUT) can also be used to monitor velocity following error (VE). Because this value is normally very small with respect to the commanded speed, you may need to scale (VSCALE) the output in such a way that a small change in speed causes a readable change in the analog output signal.

Speed Limits

There are several speed limits associated with the drive's operation. The application speed (VLIM) limit is usually the lowest value and is adjusted by the user. Other limits, such as the system speed limit (VMAX), are set internally by the drive and motor performance parameters. The drive contains an OverSpeed fault (VOSPD) that can be set up to a maximum fault trip value of 120% of the system's speed limit (VMAX). It can also be set to a value up to 180% of the application speed limit (VLIM). Because this OverSpeed limit feature creates a fault, a controlled deceleration (depending on the value of ACKFAULT) can be implemented.

Configurable Direction

The motor's direction of rotation (DIR) can be configured with respect to the sign value of a command parameter. If a clockwise direction is desired with applying either a positive analog input voltage or a positive serial command parameter, the value stored in the direction variable must be one (DIR = 1).

Control Loop Toggling

Although limited to the analog velocity (OPMODE 1) and the analog torque (OPMODE 3) modes of operation, the drive can be configured through the Configurable Inputs (INxMODE, where x=1, 2, 3) to toggle between these different control loops without being disabled.