APPLICATION NOTE YASKAWA

Title: How to set Linear Deceleration when using torque or speed mode	
Product(s): MP3200iec, MP2300iec, MP2600iec, MP3300iec	**Doc. No.** AN.MPIEC.30

How to set Linear Deceleration when using torque or speed mode

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1. Purpose

Users migrating from Sigma-5 to Sigma-7 servos have reported prolonged deceleration times during home to a hard stop or other torque-control moves when converting previously-working projects.

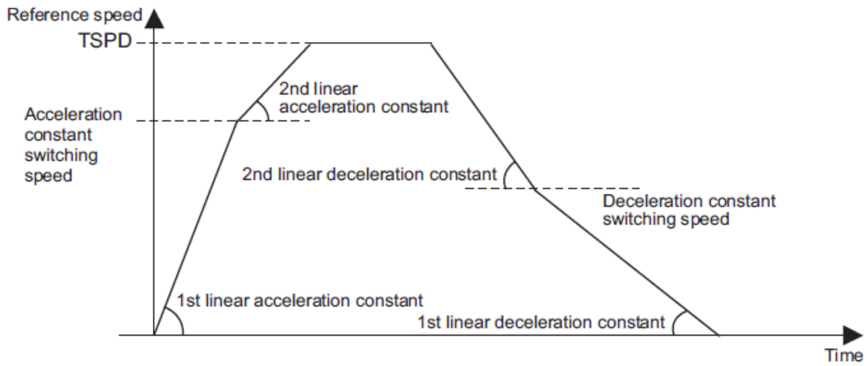
The prolonged deceleration time is due to the increased motor encoder resolution of Sigma-7 motors, which use 24-bit encoders, compared to the Sigma-5 motors which use 20-bit encoders.

The deceleration rate used during torque or speed mode operation is defined using a set of servopack parameters called ***linear acceleration/deceleration constants*** which are referenced in terms of motor encoder pulses. The default values of these parameters are the same for both Sigma-7 and Sigma-5 servopacks and so the default deceleration time on Sigma-7 systems is actually increased about 16 times that of Sigma-5 systems.

This application note explains how to calculate the linear deceleration constants to achieve the desired deceleration rate, and will also address different ways of setting and enabling the linear deceleration constants in order to prevent prolonged deceleration time when a Stop or Hold event is triggered during torque/speed mode. Finally, an example case study of a user migrating from Sigma-5 to Sigma-7 along with the list of parameters to be changed will be discussed.

2. Linear Deceleration Constants

Linear Acceleration/Deceleration Constants (LDC) is set of servopack parameters which defines the acceleration and deceleration rate (reference units/s^2) across different target speed ranges under torque/speed control mode. As shown in Figure 1, the two parameter values related to deceleration are named 1st and 2nd linear deceleration constant.



Note: Make settings so that the distance required for deceleration and the deceleration satisfy the following conditions.
Deceleration [reference unit/s^2] ≥ Maximum reference speed [reference unit/s]^2 / (Maximum deceleration distance [reference unit]*2)

Figure 1: Linear Acceleration/Deceleration Constants

2.1. Acceleration/Deceleration Constant Switch Setting (Pn833)

The LDC constants are further classified into two types based on their data sizes (2 or 4 bytes) as shown in Tables 1, 2 and 3. This feature exists to support both Sigma-5 & Sigma-7 motors with 20 and 24 bit encoder resolutions respectively. Pn833 can be used as a switch setting to enable which parameter setting should be used for the acceleration/deceleration with the 1st digit of parameter Pn833.

■ Acceleration/Deceleration Constant Switching Setting

Parameter		Meaning	Data Size (Byte)	Setting Range	Unit
Pn833	n.□□□0 (Factory setting)	Use parameters Pn80A to Pn80F and Pn827. (Parameters Pn834 to Pn840 are invalid.)	2	0000H to 0001H	–
	n.□□□1	Use parameters Pn834 to Pn840. (Parameters Pn80A to Pn80F and Pn827 are invalid.)			

Note: The setting will be validated by turning the power supply OFF and then ON again, or by executing the CONFIG command.

Table 1: Acceleration/Deceleration constant switch settings

■ Acceleration/Deceleration Parameters when Pn833=n.□□□0

Parameter	Name	Data Size (Byte)	Setting Range	Unit	Factory Setting
Pn80A	1st Linear Acceleration Constant	2	1 to 65535	10000 reference units/s^2	100
Pn80B	2nd Linear Acceleration Constant	2	1 to 65535	10000 reference units/s^2	100
Pn80C	Acceleration Constant Switching Speed	2	0 to 65535	100 reference units/s	0
Pn80D	1st Linear Deceleration Constant	2	1 to 65535	10000 reference units/s^2	100
Pn80E	2nd Linear Deceleration Constant	2	1 to 65535	10000 reference units/s^2	100
Pn80F	Deceleration Constant Switching Speed	2	0 to 65535	100 reference units/s	0
Pn827	Linear Deceleration Constant for Stopping	2	1 to 65535	10000 reference units/s^2	100

Table 2: Linear Acceleration/Deceleration Constants for 20 Bit Encoder

■ Acceleration/Deceleration Parameters when Pn833=n.□□□1

Parameter	Name	Data Size (Byte)	Setting Range	Unit	Factory Setting
Pn834	1st Linear Acceleration Constant 2	4	1 to 20971520	10000 reference units/s^2	100
Pn836	2nd Linear Acceleration Constant 2	4	1 to 20971520	10000 reference units/s^2	100
Pn838	Acceleration Constant Switching Speed 2	4	0 to 20971520	100 reference units/s	0
Pn83A	1st Linear Deceleration Constant 2	4	1 to 20971520	10000 reference units/s^2	100
Pn83C	2nd Linear Deceleration Constant 2	4	1 to 20971520	10000 reference units/s^2	100
Pn83E	Deceleration Constant Switching Speed 2	4	0 to 20971520	100 reference units/s	0
Pn840	Linear Deceleration Constant 2 for Stopping	4	1 to 20971520	10000 reference units/s^2	100

Table 3: Linear Acceleration/Deceleration Constants for 24 Bit Encoder

2.2. Units and Properties

Per Tables 2 and 3, acceleration/deceleration parameters are defined using *encoder reference units*. For a 20-bit encoder the number of reference units/rev is 1048576 and for a 24-bit encoder the number of reference units/rev is 16777216. The range for acceleration/deceleration parameter is limited based on their data size. For parameters Pn80A - Pn827 with size 2 bytes, the maximum value which can be assigned is 65535. For parameters Pn834-Pn836 with data size of 4 bytes, the range is extended up to 20971520.

1st and 2nd linear deceleration constants are always set to a **factory default value equating to 1,000,000 reference units/sec^2**. It is up to the user to configure these constants based on the application. In the case of a Sigma-7 motor with a 24-bit encoder the user might have to enter a value that equates to greater than 655,350,000 reference units/sec^2. Under such case, use parameter Pn83A-Pn83C (Ranging 1 to 2,097,152,000,000 reference unit/sec^2) and set Pn833 to 1 (Needs power recycle to take effect) to enable the new set of parameters.

3. Calculating and Writing Linear Deceleration Constants

For the required deceleration rate in user units (units/sec^2) the LDC values can be calculated by multiplying the deceleration rate in user unit (units/sec^2) with the number of encoder reference pulses per user unit.

Example:

For a Sigma-5 Motor with a 20-bit Encoder attached directly to a 5mm/rev ballscrew, the following calculation derives the required LDC for the deceleration rate of 1,000mm/sec^2 :

LDC = (1000[mm/s^2] * 1/5 [rev/mm] * 1048576 [ru/rev]) = **52,428,800** reference units/sec^2
Pn80D = Pn80E = 52428800 / 10000 = **5243** [10000ru/sec^2]

Important Note: The unit of LDCs is [10000 ref.unit/sec$^{2]}$, hence it must always be defined as integer multiples of 10,000.

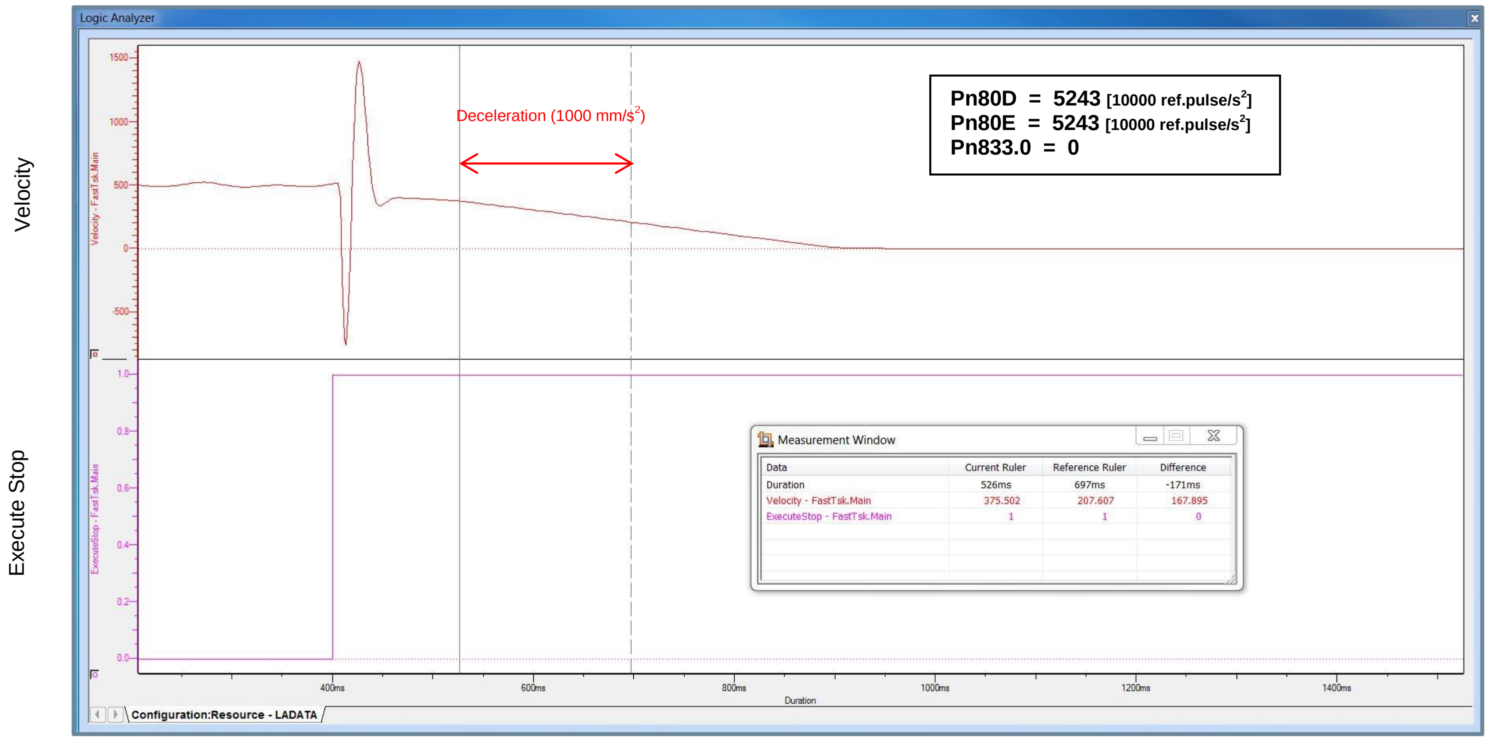


Figure 2: Calculating Linear Deceleration constants in terms of user units

There are several ways to write the parameters to the ServoPack. The following sub section will describe each method in detail. In either case, the servopack will require a Logic Power cycle (reboot) before the new settings will take effect.

3.1. Y_WriteDriveParameter

When using Y_WriteDriveParameter to set the LDC, remember that the input values will be multiplied by 10000 reference units/sec^2 (Unit of LDC).The following example illustrates the use of Y_DriveWriteParameter to set the 1st and 2nd Linear Deceleration constants (Pn80D and Pn80E). Parameter Pn833 is set to 0 to enable the constants (Pn80D and Pn80E) with data size of 2 bytes.

In the following example when Y_WriteDriveParameter is executed, Pn80D and Pn80E will be enabled and set to a value of 655,350,000 reference units/sec^2

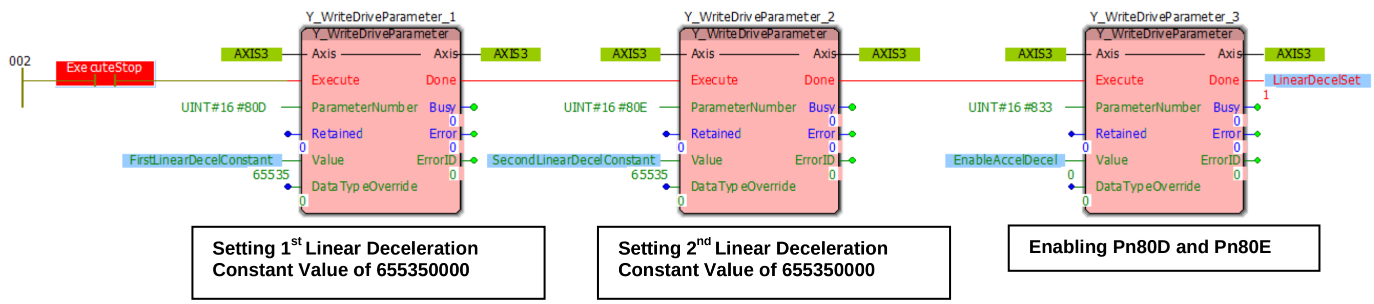


Figure 3: Using Y_WriteDriveParameters to write LDC values to the Servopack.

3.2. MotionWorks Hardware Configuration

The parameter could also be set using the Hardware configuration as shown in Figure 4 and 5. <u>When using Hardware Configuration, the units are in **RefUnits** NOT **10000RefUnits**. Therefore, the full number must be entered</u>.

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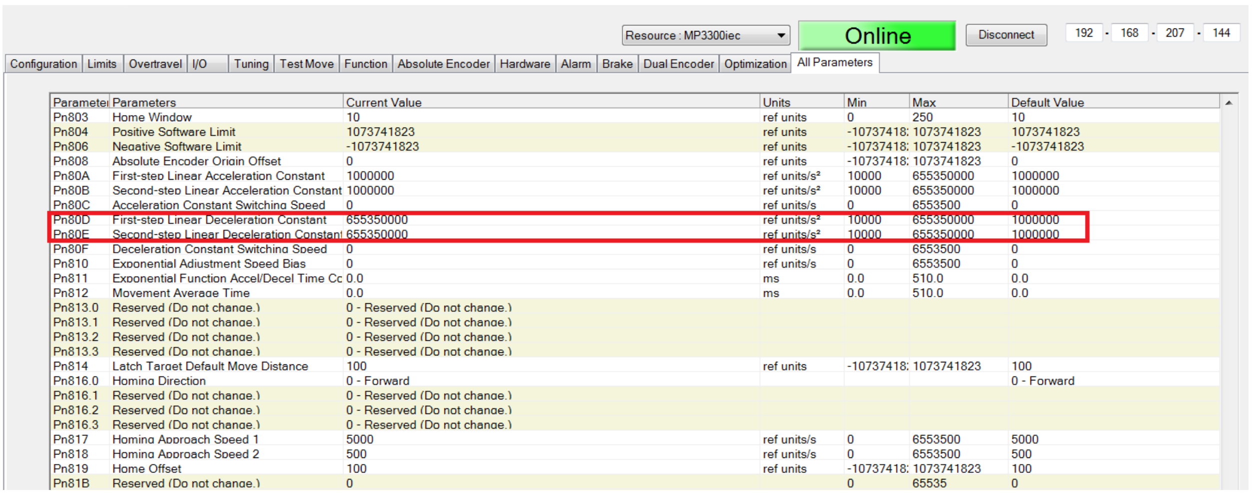
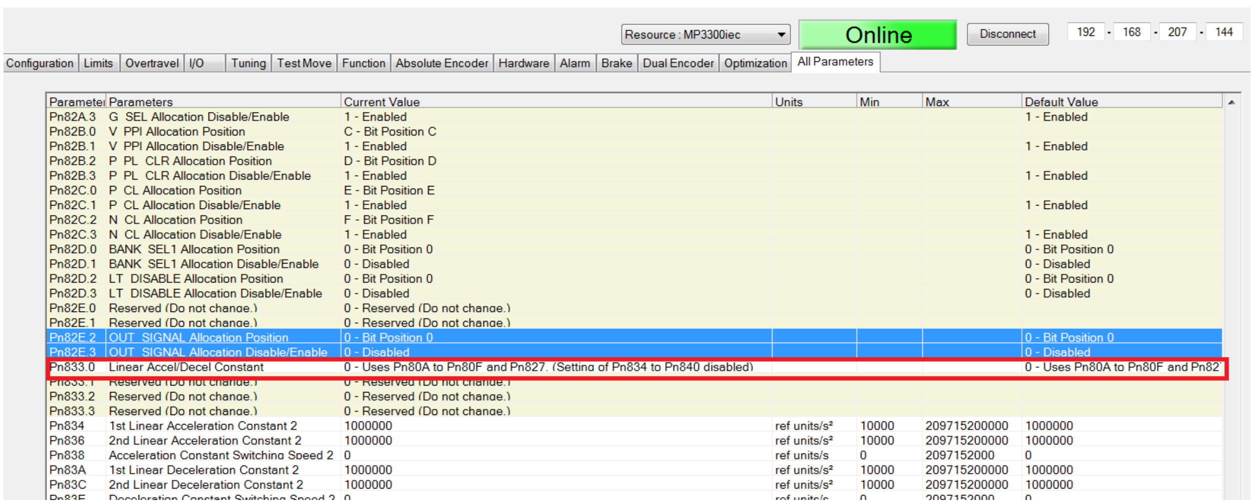


Paramete	Parameters	Current Value	Units	Min	Max	Default Value
Pn803	Home Window	10	ref units	0	250	10
Pn804	Positive Software Limit	1073741823	ref units	-10737418:	1073741823	1073741823
Pn806	Negative Software Limit	-1073741823	ref units	-10737418:	1073741823	-1073741823
Pn808	Absolute Encoder Origin Offset	0	ref units	-10737418:	1073741823	0
Pn80A	First-step Linear Acceleration Constant	1000000	ref units/s²	10000	655350000	1000000
Pn80B	Second-step Linear Acceleration Constant	1000000	ref units/s²	10000	655350000	1000000
Pn80C	Acceleration Constant Switching Speed	0	ref units/s	0	6553500	0
Pn80D	First-step Linear Deceleration Constant	655350000	ref units/s²	10000	655350000	1000000
Pn80E	Second-step Linear Deceleration Constant	655350000	ref units/s²	10000	655350000	1000000
Pn80F	Deceleration Constant Switching Speed	0	ref units/s	0	6553500	0
Pn810	Exponential Adjustment Speed Bias	0	ref units/s	0	6553500	0
Pn811	Exponential Function Accel/Decel Time Cc	0.0	ms	0.0	510.0	0.0
Pn812	Movement Average Time	0.0	ms	0.0	510.0	0.0
Pn813.0	Reserved (Do not change.)	0 - Reserved (Do not change.)				
Pn813.1	Reserved (Do not change.)	0 - Reserved (Do not change.)				
Pn813.2	Reserved (Do not change.)	0 - Reserved (Do not change.)				
Pn813.3	Reserved (Do not change.)	0 - Reserved (Do not change.)				
Pn814	Latch Target Default Move Distance	100	ref units	-10737418:	1073741823	100
Pn816.0	Homing Direction	0 - Forward				0 - Forward
Pn816.1	Reserved (Do not change.)	0 - Reserved (Do not change.)				
Pn816.2	Reserved (Do not change.)	0 - Reserved (Do not change.)				
Pn816.3	Reserved (Do not change.)	0 - Reserved (Do not change.)				
Pn817	Homing Approach Speed 1	5000	ref units/s	0	6553500	5000
Pn818	Homing Approach Speed 2	500	ref units/s	0	6553500	500
Pn819	Home Offset	100	ref units	-10737418:	1073741823	100
Pn81B	Reserved (Do not change.)	0		0	65535	0

Figure 4: Using Hardware configuration to write LDC values to the servopack



Paramete	Parameters	Current Value	Units	Min	Max	Default Value
Pn82A.3	G SEL Allocation Disable/Enable	1 - Enabled				1 - Enabled
Pn82B.0	V PPI Allocation Position	C - Bit Position C				
Pn82B.1	V PPI Allocation Disable/Enable	1 - Enabled				1 - Enabled
Pn82B.2	P PL CLR Allocation Position	D - Bit Position D				
Pn82B.3	P PL CLR Allocation Disable/Enable	1 - Enabled				1 - Enabled
Pn82C.0	P CL Allocation Position	E - Bit Position E				
Pn82C.1	P CL Allocation Disable/Enable	1 - Enabled				1 - Enabled
Pn82C.2	N CL Allocation Position	F - Bit Position F				
Pn82C.3	N CL Allocation Disable/Enable	1 - Enabled				1 - Enabled
Pn82D.0	BANK SEL1 Allocation Position	0 - Bit Position 0				0 - Bit Position 0
Pn82D.1	BANK SEL1 Allocation Disable/Enable	0 - Disabled				0 - Disabled
Pn82D.2	LT DISABLE Allocation Position	0 - Bit Position 0				0 - Bit Position 0
Pn82D.3	LT DISABLE Allocation Disable/Enable	0 - Disabled				0 - Disabled
Pn82E.0	Reserved (Do not change.)	0 - Reserved (Do not change.)				
Pn82E.1	Reserved (Do not change.)	0 - Reserved (Do not change.)				
Pn82E.2	OUT SIGNAL Allocation Position	0 - Bit Position 0				0 - Bit Position 0
Pn82E.3	OUT SIGNAL Allocation Disable/Enable	0 - Disabled				0 - Disabled
Pn833.0	Linear Accel/Decel Constant	0 - Uses Pn80A to Pn80F and Pn827. (Setting of Pn834 to Pn840 disabled)				0 - Uses Pn80A to Pn80F and Pn82
Pn833.1	Reserved (Do not change.)	0 - Reserved (Do not change.)				
Pn833.2	Reserved (Do not change.)	0 - Reserved (Do not change.)				
Pn833.3	Reserved (Do not change.)	0 - Reserved (Do not change.)				
Pn834	1st Linear Acceleration Constant 2	1000000	ref units/s²	10000	209715200000	1000000
Pn836	2nd Linear Acceleration Constant 2	1000000	ref units/s²	10000	209715200000	1000000
Pn838	Acceleration Constant Switching Speed 2	0	ref units/s	0	2097152000	0
Pn83A	1st Linear Deceleration Constant 2	1000000	ref units/s²	10000	209715200000	1000000
Pn83C	2nd Linear Deceleration Constant 2	1000000	ref units/s²	10000	209715200000	1000000
Pn83E	Deceleration Constant Switching Speed 2	0	ref units/s	0	2097152000	0

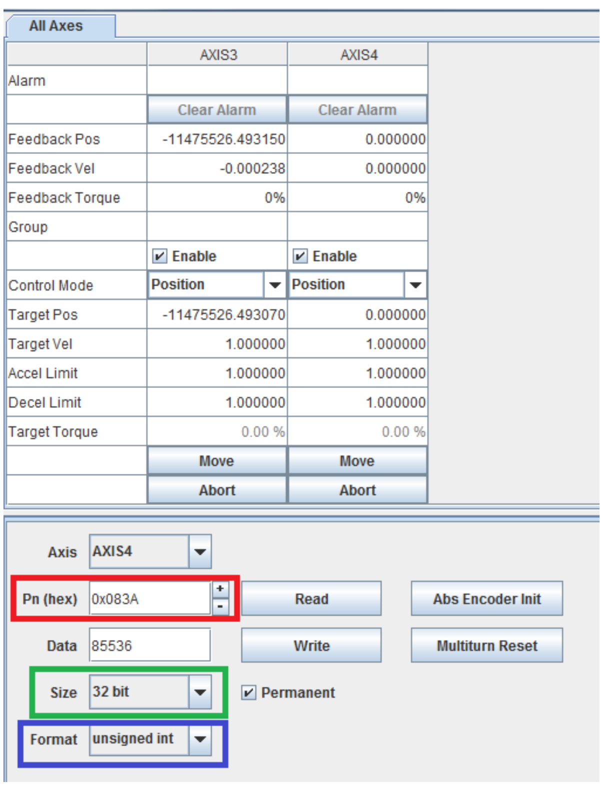
Figure 5: Using Hardware configuration to write constant switch settings to the servopack

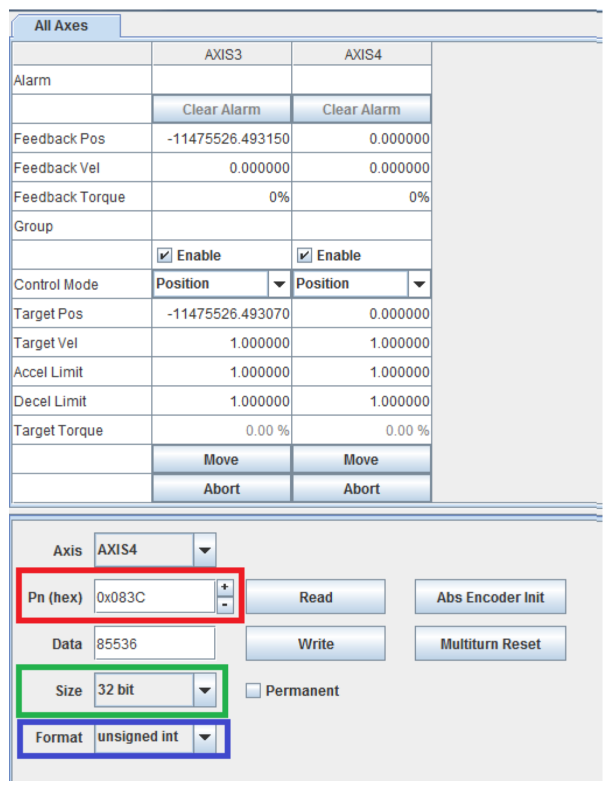
3.3. Controller Web Interface

The controller web interface can also be used to read and write the parameters. Select the Axis to be configured and enter the drive parameter as hexadecimal and set the data size and format before reading / writing the parameter. It is important to note that the unit of LDC is 10000 Ref. Pulse/s^2

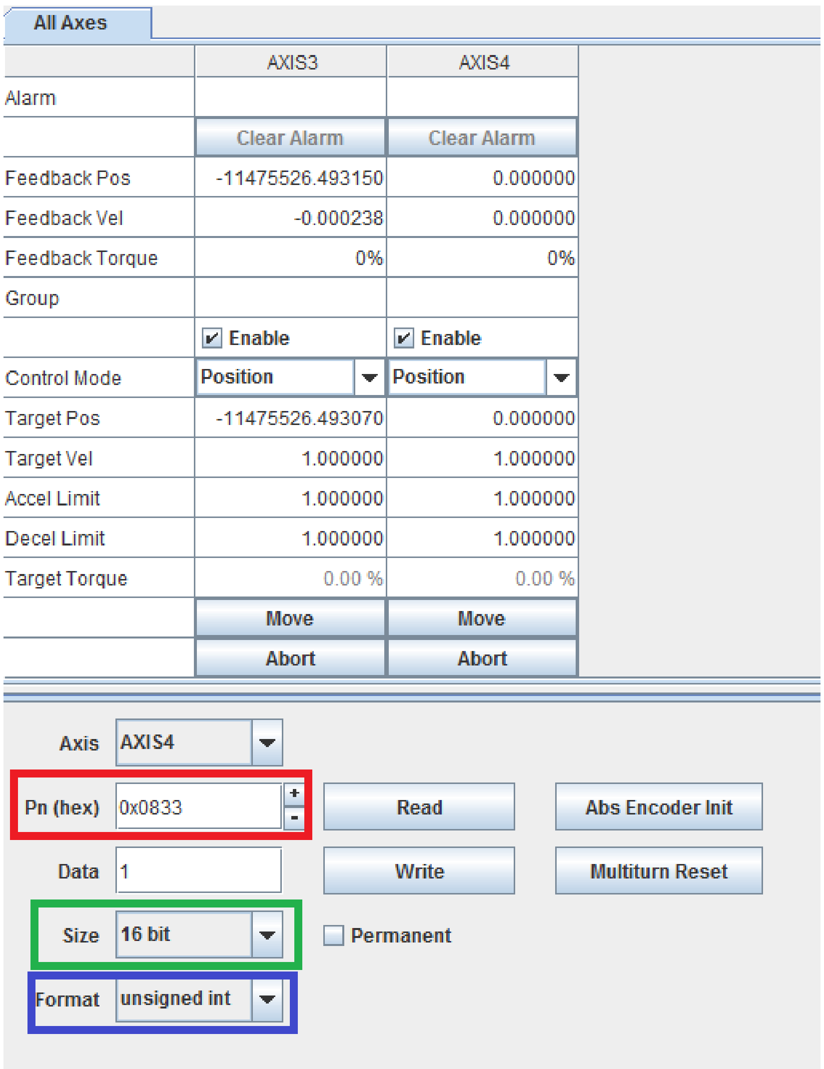
The following example illustrates setting the LDC parameters of size 4 bytes (Pn 83A and Pn 83C) by setting Pn833.0 to 1.

Step 1: In the example below Pn 83A and Pn 83C will be set to a value of 855,360,000 Ref.pulse/s^2





Step 2 : Enable Pn 83A and Pn 83C by setting the Parameter Pn 833.0 to 1.



4. Effects of Linear Acceleration/Deceleration constant on Axis Modes

Whenever an axis switches from position mode to either speed or torque control mode, the axis will follow the acceleration or deceleration rate dictated by the LDC parameters as described in the previous section. There are several ways the axis could switch to either of these modes. This section describes some of the Use Cases and function blocks that will cause the axis to switch modes. When using these function blocks, the user should take care to set the LDC parameters properly or improper stopping motion may occur.

4.1. Switching Axis between Position and Torque Mode

An axis by default is always under position mode and it can switch to torque mode using **MC_TorqueControl** or **Y_DirectControl** function blocks. These function blocks exert a torque or force of the specified magnitude on the axis. The axis ceases to be in torque control mode when another motion control block like **MC_Stop** or **Y_HoldPosition** is executed. The axis mode switch happens at different time instance for MC_Stop and Y_HoldPosition and hence the user must understand which deceleration rate is applicable when using these blocks.

4.1.1 MC_TorqueControl with MC_Stop

When MC_Stop is used to abort an MC_TorqueControl move, the axis switches to position mode instantly and begins to decelerate at the rate defined by the MC_Stop deceleration input as shown in Figures 6 & 7.

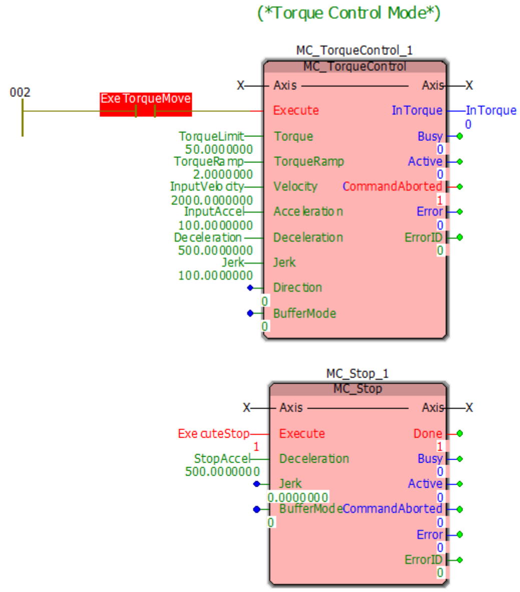


Figure 6: **Example Code to illustrate the use of MC_Stop with MC_TorqueControl**

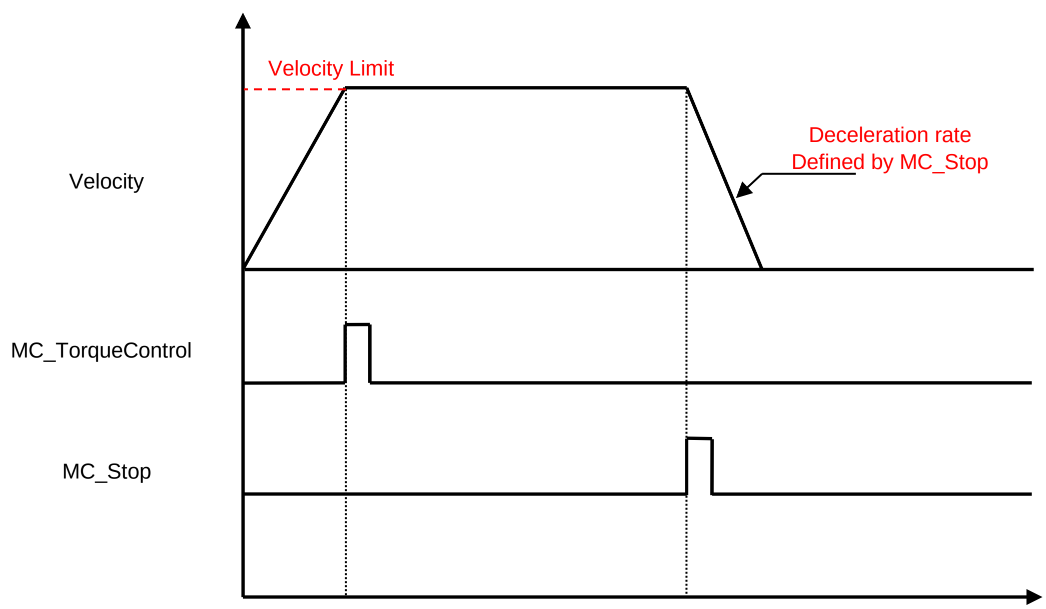


Figure 7: Timing diagram to illustrate that when under MC_TorqueControl Move, executing MC_Stop will cause the axis to immediately switch to position mode and then use the Deceleration rates defined using MC_Stop block

4.1.2 MC_TorqueControl with Y_HoldPosition

When Y_HoldPosition is used to abort an MC_TorqueControl move, the axis first decelerates at the rate defined by the linear deceleration constant as shown in Figures 8 & 9, and then switches to position mode.

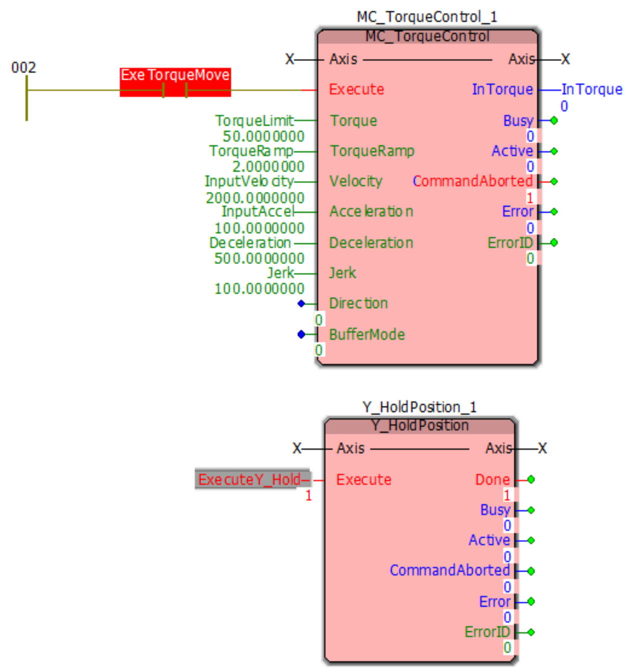


Figure 8: Example Code to illustrate the use of Y_HoldPosition with MC_TorqueControl

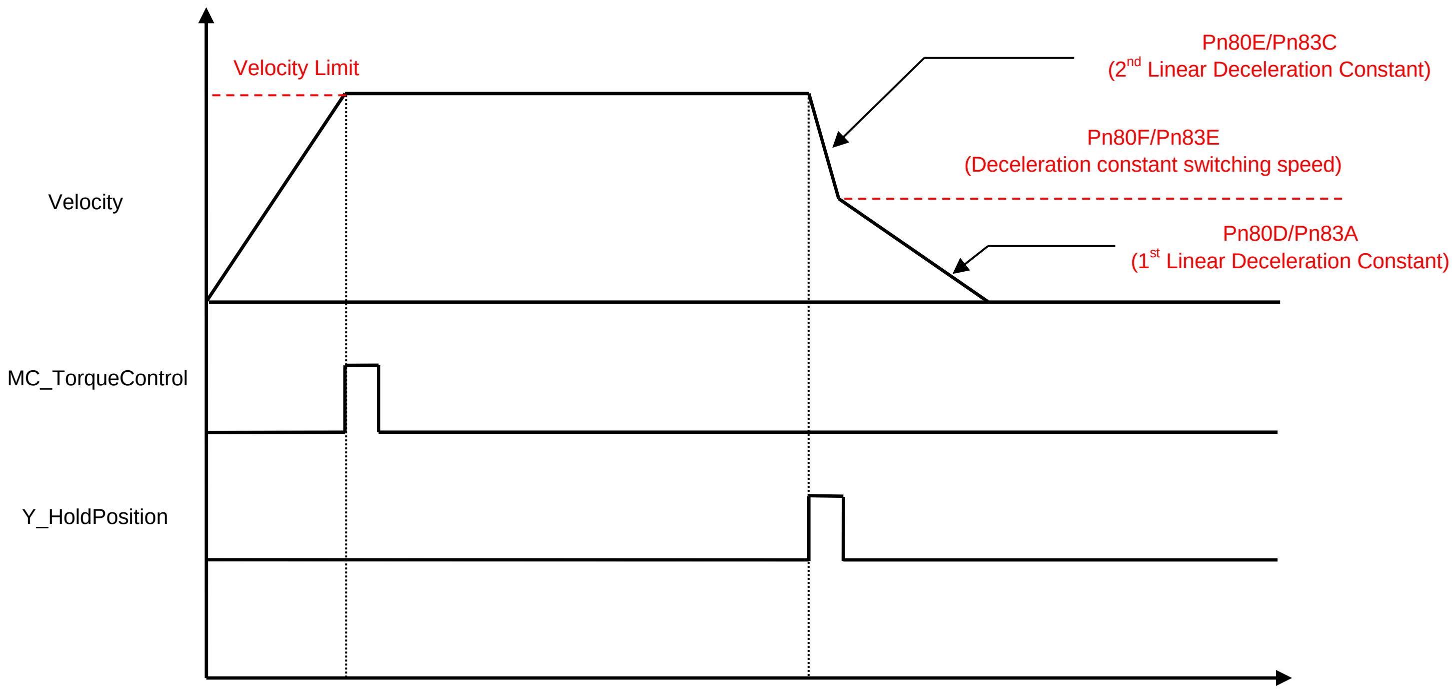


Figure 9: Timing diagram to illustrate that when under MC_TorqueControl Move, executing Y_HoldPosition will cause the axis to decelerate at the rate defined by the LDC and then switch to position mode.

4.1.3 Y_DirectControl (Torque/Speed Mode) with MC_Stop

Y_DirectControl can directly command torque or speed based on the given mode at every application task scan. To abort the move, MC_Stop block can be used and the axis will decelerate to a stop at the rate defined by the LDC values set on the servopack before switching to position mode as shown in Figures 10 thru 12.

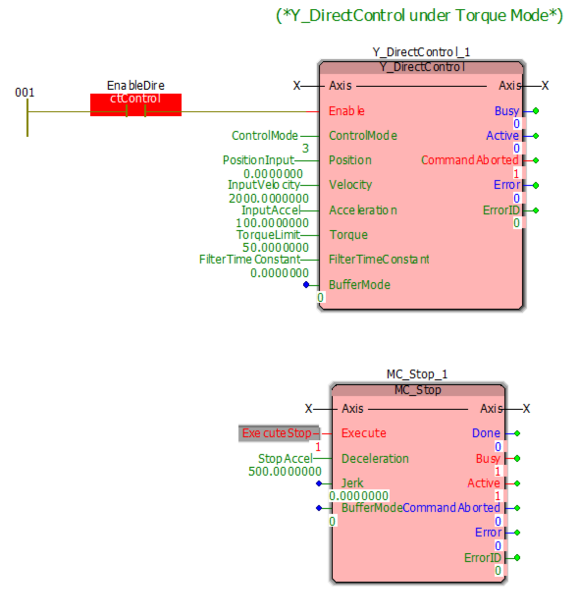


Figure 10: Example Code to illustrate the use of MC_Stop with Y_DirectControl (TorqueMode)

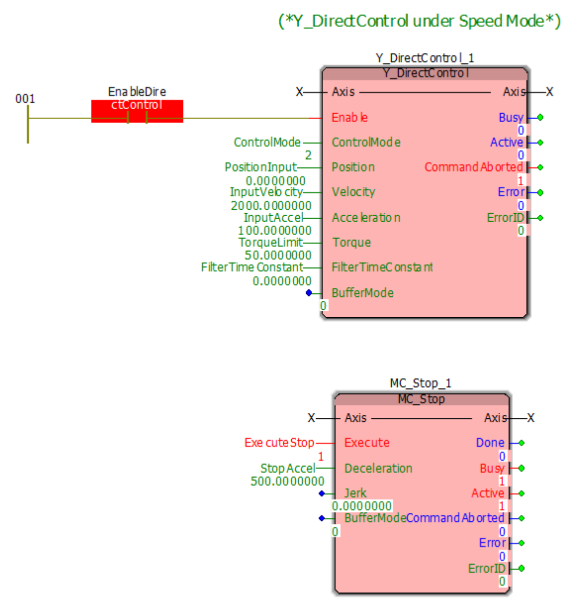


Figure 11: Example Code to illustrate the use of MC_Stop with Y_DirectControl (SpeedMode)

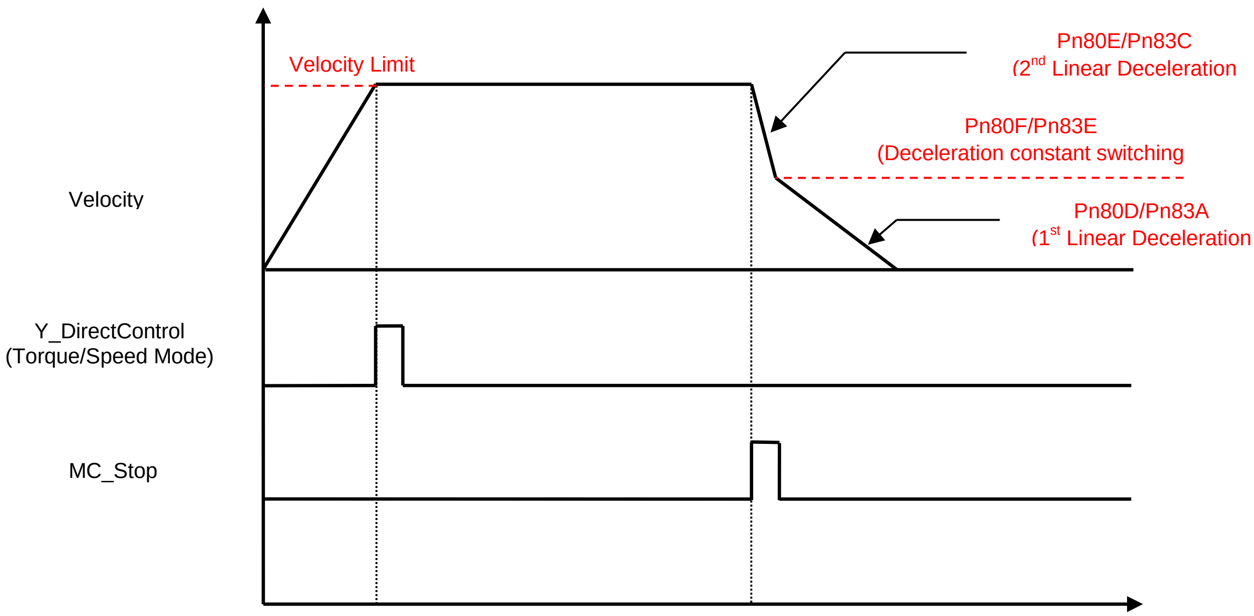


Figure 12: Timing diagram to illustrate that when an axis is under Y_DirectControl (TorqueMode), executing MC_Stop will cause the axis to decelerate at the rate defined by the LDC and then switch to position mode.

4.1.4 Y_DirectControl (Torque/Speed Mode) with Y_HoldPosition

When the axis is under Y_DirectControl (Torque/Speed Mode), Executing Y_HoldPosition commands an immediate position hold with the deceleration defined by LDC parameters and then switches the axis to position mode as shown in Figures 13 thru 15.

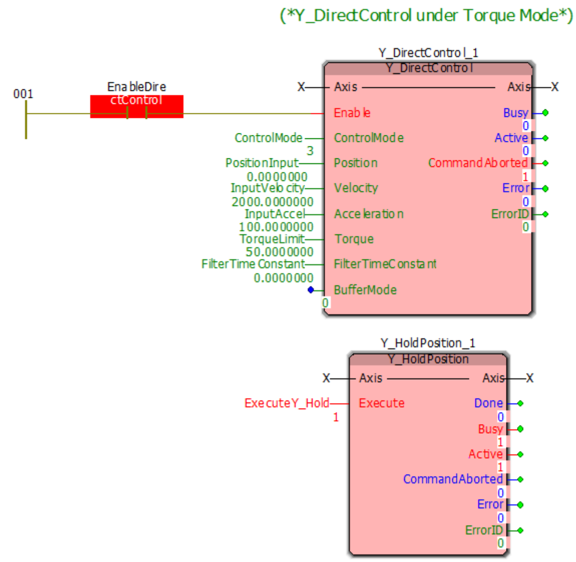


Figure 13: Example Code to illustrate the use of Y_HoldPosition with Y_DirectControl (TorqueMode)

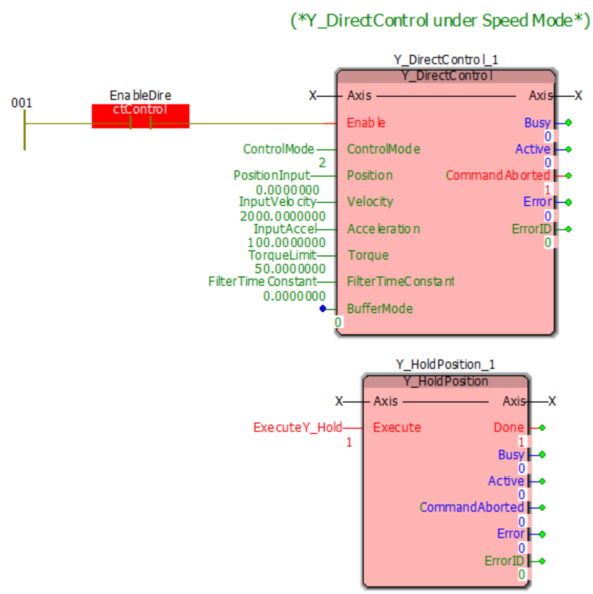


Figure 14: Example Code to illustrate the use of Y_HoldPosition with Y_DirectControl (SpeedMode)

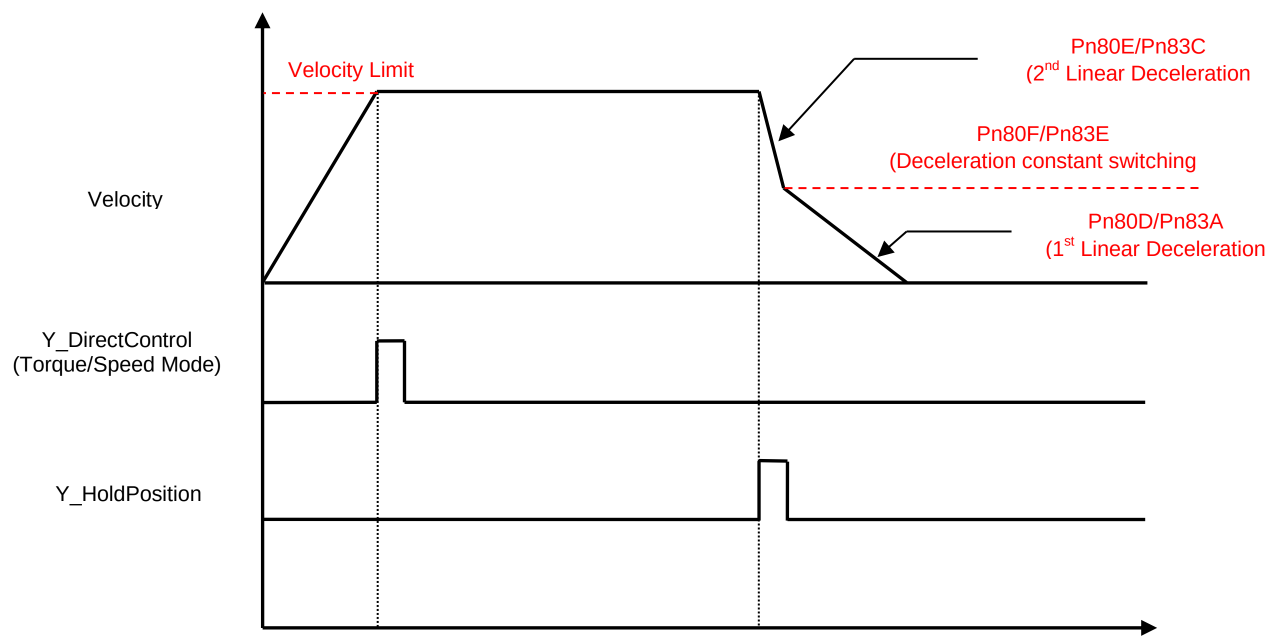


Figure 15: Timing diagram to illustrate that when an axis is under Y_DirectControl (TorqueMode/SpeedMode), executing Y_HoldPosition will cause the axis to decelerate at the rate defined by the LDC and then switch to position mode.

5. Initial Servopack Settings

Table 4 provides a list of recommended initial parameter settings for Sigma-5 and Sigma-7 servopacks so that good deceleration performance is achieved after MC_Stop while the axis is under torque control mode.

Parameter Number	Default Value (Sigma-5)	Default Value (Sigma-7)	Desired Value (Sigma-5)	Desired Value (Sigma-7)
1311	0	0	2	2
Pn812	0	40*	40*	40*

1310	False	False	True	True
Pn80A	1000000 ref unit	1000000 ref unit	655350000 ref unit	655350000 ref unit
Pn80B	1000000 ref unit	1000000 ref unit	655350000 ref unit	655350000 ref unit
Pn80D	1000000 ref unit	1000000 ref unit	655350000 ref unit	655350000 ref unit
Pn80E	1000000 ref unit	1000000 ref unit	655350000 ref unit	655350000 ref unit
Pn827	1000000 ref unit	1000000 ref unit	655350000 ref unit	655350000 ref unit
Pn833.1	0	0	0	1
Pn838	0	0	0	0
Pn83E	0	0	0	0
Pn836	1000000 ref unit	1000000 ref unit	1000000 ref unit	655350000 ref unit ^
Pn83C	1000000 ref unit	1000000 ref unit	1000000 ref unit	655350000 ref unit ^
Pn840	1000000 ref unit	1000000 ref unit	1000000 ref unit	655350000 ref unit ^

Table 4: Recommended initial settings for servopack parameters

***** Equal to Mechatrolink rate (Example: 4ms)

^ Required acceleration or deceleration rate based on reference units