Industrial Maintenance

Motor Drives

Courseware Sample

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Safety and Common Symbols

The following safety and common symbols may be used in this manual and on the equipment:

Symbol	Description
DANGER	**DANGER** indicates a hazard with a high level of risk which, if not avoided, will result in death or serious injury.
WARNING	**WARNING** indicates a hazard with a medium level of risk which, if not avoided, could result in death or serious injury.
CAUTION	**CAUTION** indicates a hazard with a low level of risk which, if not avoided, could result in minor or moderate injury.
CAUTION	**CAUTION** used without the *Caution, risk of danger* sign ⚠, indicates a hazard with a potentially hazardous situation which, if not avoided, may result in property damage.
	Caution, risk of electric shock
	Caution, hot surface
	Caution, risk of danger
	Caution, lifting hazard
	Caution, hand entanglement hazard
	Notice, non-ionizing radiation
	Direct current
	Alternating current
	Both direct and alternating current
	Three-phase alternating current
	Earth (ground) terminal

Safety and Common Symbols

Symbol	Description
	Protective conductor terminal
	Frame or chassis terminal
	Equipotentiality
	On (supply)
	Off (supply)
	Equipment protected throughout by double insulation or reinforced insulation
	In position of a bi-stable push control
	Out position of a bi-stable push control

We invite readers of this manual to send us their tips, feedback, and suggestions for improving the book.

Please send these to did@de.festo.com.

The authors and Festo Didactic look forward to your comments.

Table of Contents

To the Instructor

- Before a student begins an exercise, ensure that the equipment is in good condition and does not represent any risk when used.
- This guide provides you with the answers to questions.
- Make sure that the students understand the objectives of the work to do.
- The default setting of some parameters depends on the Country parameter of the AC Drive. For this reason, the default setting values shown in the user guide and the quick start guide supplied with your training system (on a CD) may differ from the current default settings of the AC Drive.
- In order to keep the circuits as simple as possible, the use of the Emergency Button has not been integrated to all circuits in this manual. If you choose to use it, refer to Exercise 1-5 to learn how to stop the Brake Motor with a fault signal initiated from the Emergency Button. You may also use Relay K1 and a contactor to disconnect the AC Drive when the Emergency Button is pressed.

Sample Exercise

Extracted from

Motor Drives

Ramp and Voltage Boost

EXERCISE OBJECTIVE

- Understand the acceleration and deceleration time settings.
- Introduce the linear and S-curve acceleration and deceleration characteristics.
- Introduce the Voltage boost function.

DISCUSSION

Acceleration and deceleration times

The Acceleration time defines the time duration in which the AC Drive reaches its maximum frequency after a start signal is issued. Short acceleration times are usually for light loads, and long acceleration times for heavy loads, or in applications requiring soft start such as a bottle conveyor. The Acceleration time function is also known as ramping or soft start. See Figure 1-10.

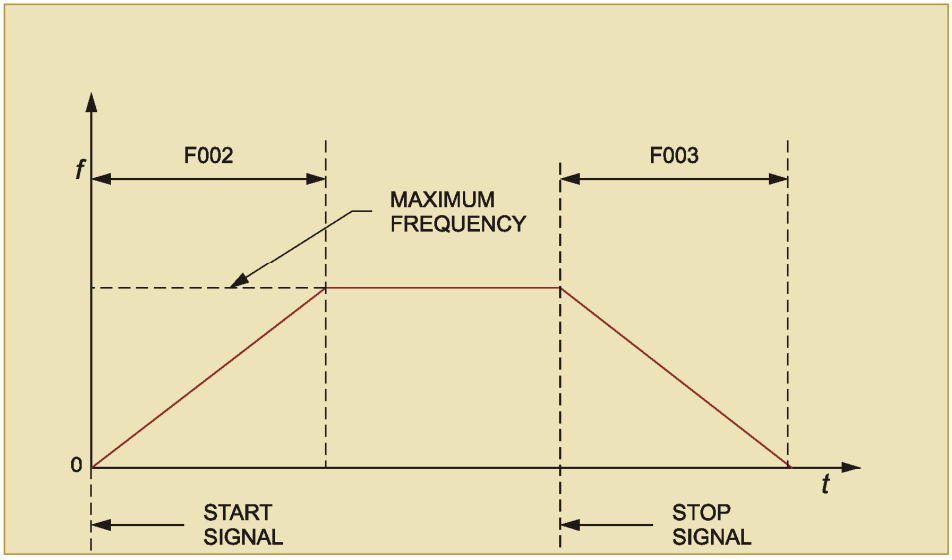


Figure 1-10. Acceleration/deceleration ramps.

Conversely, the Deceleration time defines the time duration in which the AC Drive reduces the output frequency from the maximum frequency to 0 Hz after a stop signal. If the equipment connected to a motor has low friction and a lot of inertia, it could coast for a long time. The Deceleration time function allows the load to be stopped more quickly.

The acceleration and deceleration times are set using PNUs F002 and F003. The characteristics of these parameters are shown in Table 1-8.

PNU	FUNCTION	VALUE	DS
F002	Acceleration time	0.01 to 3000 s	10.00
F003	Deceleration time	0.01 to 3600 s	10.00
A097	Acceleration characteristic	00 = Linear 01 = S-curve	00
A098	Deceleration characteristic	00 = Linear 01 = S-curve	00

Table 1-8. Characteristics of PNUs F002, F003, A097, and A098.

Acceleration and deceleration characteristics

The acceleration and deceleration characteristics can be linear or S-curve. When a motor is started or stopped using the linear acceleration or deceleration characteristic, its rate of change until it reaches full speed, or comes to a complete stop, is linear. See Figure 1-11.

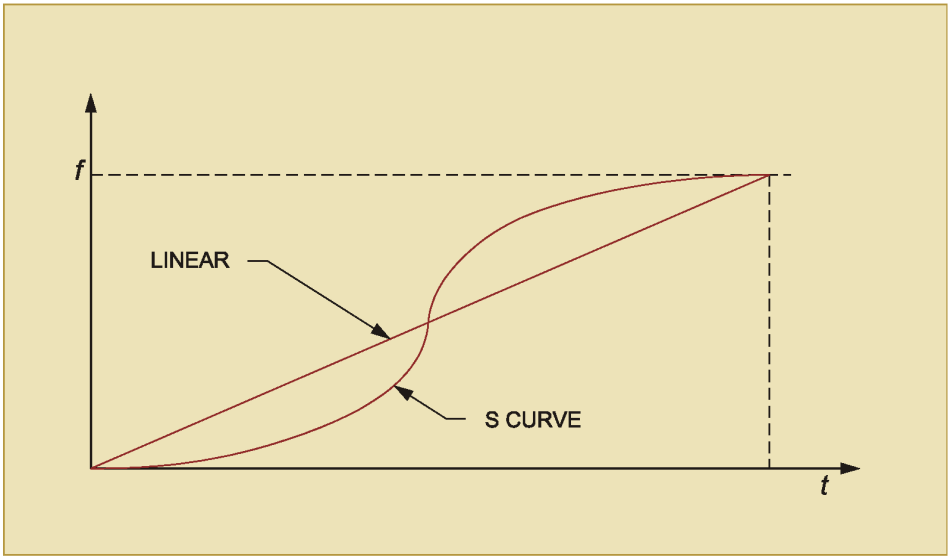


Figure 1-11. Linear and S-curve characteristics.

When the motor is started, or stopped, using the S-curve acceleration or deceleration characteristic, its rate of change gradually increases or decreases until it reaches full speed, or comes to a complete stop. The purpose of the S-curve characteristic is to combine soft starts and soft stops with high speeds between them. The movement of an elevator is an example of the S-curve acceleration/deceleration characteristic.

The *Acceleration* and *Deceleration characteristics* are set using PNUs A097 and A098. The characteristics of these parameters are shown in Table 1-8.

Voltage boost

If the mass inertia moment or static friction of the connected load is high, it may be necessary to increase (boost) the output voltage beyond the normal U/f characteristic at low output frequencies. This compensates for the voltage drop in the motor windings and can be up to half of the motor's nominal voltage.

The voltage boost is defined as a percentage value. As Figure 1-12 shows, PNU A042 is a percentage of the output voltage and PNU A043 is a percentage of the frequency.

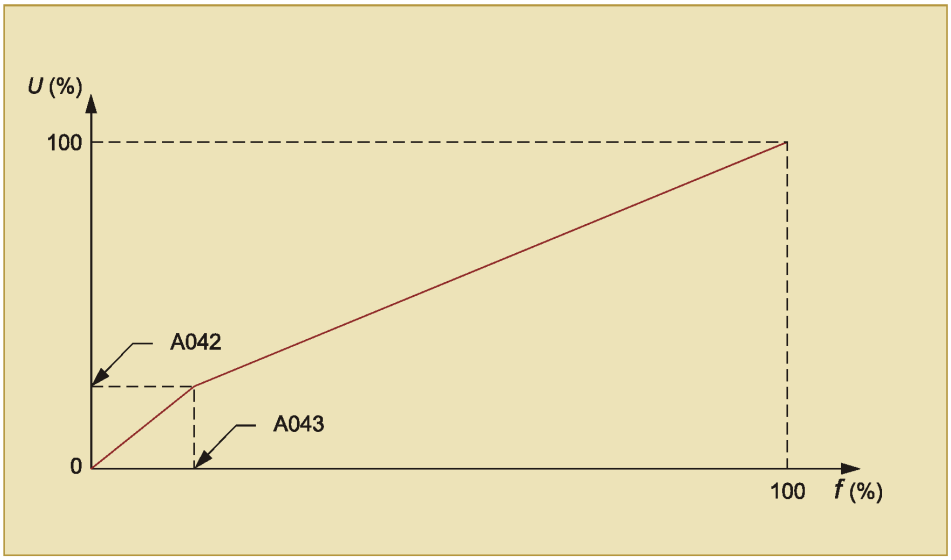


Figure 1-12. Voltage boost.

The *Voltage boost characteristic*, PNU A041, lets you select between a manual boost characteristic and automatic voltage boost. Automatic voltage boost is added to the U/f characteristic value depending on the current load.

The voltage boost functions are set using PNUs A041, A042 and A043. The characteristics of these parameters are shown in Table 1-9.

PNU	FUNCTION	VALUE	DS
A041	Voltage boost characteristic	00 = Manual 01 = Automatic	00
A042	% of output voltage increase with manual boost	0 to 20 % of output voltage	(1)
A043	% of base frequency where maximum boost is applied	0 to 50 % of base frequency	10.0

(1) The default setting of this parameter depends on the *Country* parameter of the AC Drive. For this reason, the default setting values shown in the user guides supplied with your training system may differ from the actual values.

Table 1-9. Characteristics of PNUs A041, A042, and A043.

Procedure Summary

In the first part of this exercise, you will familiarize yourself with the setting of the acceleration and deceleration times.

In the second part, you will plot the linear and S-curve acceleration characteristics.

In the third part, you will observe the voltage boost characteristics. You will plot the output voltage versus output frequency curve with and without boost.

EQUIPMENT REQUIRED

Refer to the Equipment Utilization Chart in Appendix A to obtain the list of equipment required for this exercise.

PROCEDURE

WARNING

The AC Power Supply provides high voltages. Do not change any AC connection with the power on.

Basic setup

☐ 1. Perform the Basic Setup and Lockout/Tagout procedures.

Acceleration and deceleration ramps

☐ 2. Install the Brake Motor, Inertia Wheel, and Safety Guard.

☐ 3. Set up the circuit shown in Figure 1-8.

☐ 4. Manually disengage the friction brake.

Connect a voltmeter between terminals O and L on the AC Drive.

Perform the Energizing procedure.

☐ 5. Set the parameters of the AC Drive as follows:

- Load the default settings;
- Select *Analog input* as *Frequency setpoint input* by setting PNU A001 to 01;
- Set the AC Drive to display the output voltage by selecting PNU d013.

☐ 6. Set the remote potentiometer (on the DC Drive) to obtain 10.0 V dc on the voltmeter display.

Start the chronometer as you set the AC Drive to the run mode, and stop it when the display indicates the maximum output voltage for your network. Repeat for best results.

Acceleration time: _____

☐ 7. Does this correspond to the default setting of PNU F002?

☐ Yes ☐ No

☐ 8. Set the AC Drive to the run mode and wait for the motor to attain maximum speed.

Start the chronometer as you set the AC Drive to the stop mode, and stop it when the display indicates 0 V. Repeat for best results.

Deceleration time: _____

☐ 9. Does this correspond to the default setting of PNU F003?

☐ Yes ☐ No

☐ 10. Familiarize yourself with the setting of acceleration and deceleration times by setting a 20-s acceleration time and a 15-s deceleration time.

Test the operation of your circuit.

☐ 11. Turn off the Lockout Module.

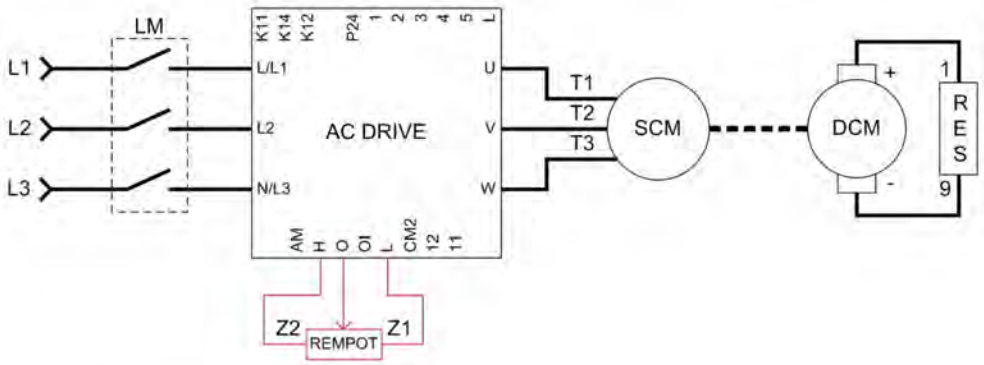
Acceleration characteristic

☐ 12. Remove the Safety Guard, and Inertia Wheel.

Couple the DC Motor with the Brake Motor as described in Appendix D.

☐ 13. Connect the Starting Resistors module to the DC Motor as shown in Figure 1-13.

Note: *The DC Motor with the Starting Resistors module acts as a load for the Brake Motor. Connect the resistors in series for maximum resistance.*



LEGEND

AC DRIVE	=	THREE-PHASE AC DRIVE
DCM	=	DC MOTOR
LM	=	LOCKOUT MODULE
REMPOT	=	REMOTE POTENTIOMETER (DC DRIVE POTENTIOMETER)
RES	=	LOAD RESISTOR
SCM	=	SQUIRREL CAGE MOTOR

Figure 1-13. Connect the Starting Resistors module to the DC Motor.

☐ 14. Turn on the Lockout Module.

Set the potentiometer to obtain 10.0 V dc on the voltmeter display.

Set the *Acceleration time* to 30 s by setting PNU F002 to 30.00.

Make sure that the *Acceleration characteristic* is set to linear.

Set the AC Drive to display the output frequency by selecting PNU d001.

☐ 15. Measure the time taken by the AC Drive to attain 10 Hz by starting the chronometer as you set the AC Drive to the run mode, and stopping it when the AC Drive indicates 10 Hz. Repeat for best results.

Enter your result in the appropriate cell in the Linear column in Table 1-10.

Set the AC Drive to the stop mode.

FREQUENCY RANGE	TIME (s)	
	ACCELERATION CHARACTERISTIC	
	Linear	S-curve
0 to 10 Hz		
0 to 20 Hz		
0 to 30 Hz		
0 to 40 Hz		
0 to 50 Hz		
0 to 60 Hz (if applicable)		

Table 1-10. Linear and S-curve acceleration characteristics.

☐ 16. Repeat the previous measurement for all frequency ranges shown in Table 1-10.

Enter your results in the appropriate cells in the Linear column in Table 1-10.

☐ 17. Set the AC Drive to the stop mode.

Set the *Acceleration characteristic* to S-curve by setting PNU A097 to 01.

Set the AC Drive to display the output frequency by selecting PNU d001.

☐ 18. Repeat the measurements to fill out the empty cells of Table 1-10 with the S-curve acceleration characteristic.

☐ 19. Set the AC Drive to the stop mode.

☐ 20. Plot the curves showing the linear and S-curve acceleration characteristics in Figure 1-14. Place the Time in the X-axis, and the Frequency in the Y-axis.

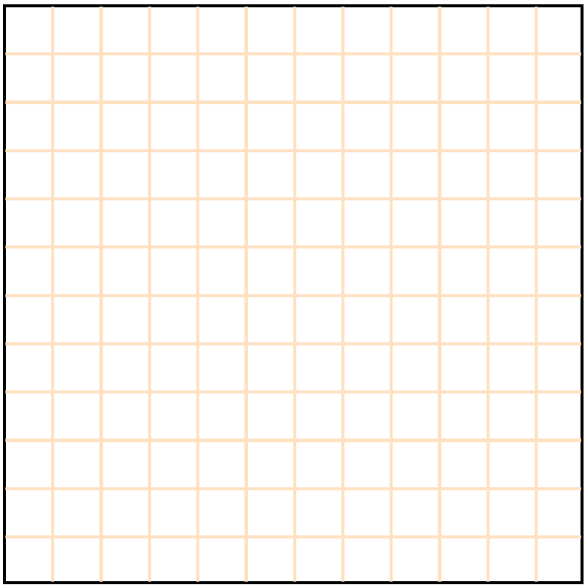


Figure 1-14. Linear and S-curve acceleration characteristics.

☐ 21. Do your observations confirm that the S-curve characteristic allows a motor to be started slowly?

☐ Yes ☐ No

☐ 22. Do your observations confirm the theory presented in the Discussion?

☐ Yes ☐ No

☐ 23. Reset the *Acceleration characteristic* to linear by setting PNU A097 to 00.

Voltage boost

☐ 24. Make sure that the *Voltage boost characteristic* of the AC Drive is set to manual (PNU A041 = 00).

Set the *% of output voltage increase with manual boost* to 0% by setting PNU A042 to 0.

Set the *% of base frequency where maximum boost is applied* to 33% by setting PNU A043 to 33.

Set the AC Drive to display the output frequency by selecting PNU d001.

Set the potentiometer to obtain 0.0 V dc on the voltmeter display.

Set the AC Drive to the run mode.

☐ 25. For all voltage setpoint values shown in Table 1-11, determine the corresponding output frequency displayed by the AC Drive. Enter your results in the appropriate cells in Table 1-11.

SETPOINT		OUTPUT VOLTAGE U (V)	
Voltage (V)	**f (Hz)**	**Without voltage boost**	**With voltage boost**
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Table 1-11. Voltage boost characteristic.

☐ 26. Set the AC Drive to the stop mode.

Set the AC Drive to display the voltage output by selecting PNU d013.

Set the potentiometer to obtain 0.0 V dc on the voltmeter display.

Set the AC Drive to the run mode.

☐ 27. For all voltage setpoint values shown in Table 1-11, determine the corresponding voltage output (U) displayed by the AC Drive. Enter your results in the Without voltage boost column in Table 1-11.

☐ 28. Set the AC Drive to the stop mode.

Set the *% of output voltage increase with manual boost* to 20% by setting PNU A042 to 20.

Set the AC Drive to display the voltage output by selecting PNU d013.

Set the potentiometer to obtain 0.0 V dc on the voltmeter display.

Set the AC Drive to the run mode.

☐ 29. For all voltage setpoint values shown in Table 1-11, determine the corresponding voltage output (U) displayed by the AC Drive. Enter your results in the With voltage boost column in Table 1-11.

☐ 30. Set the AC Drive to the stop mode.

☐ 31. Plot the curves With and Without voltage boost characteristics in Figure 1-15. Place the Frequency in the X-axis, and the Output voltage (U) in the Y-axis.

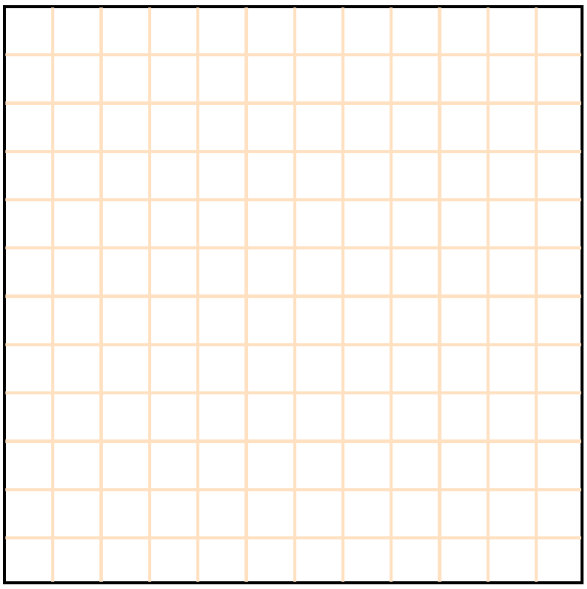


Figure 1-15. With and without voltage boost characteristics.

☐ 32. At what frequency is the voltage boost maximum?

Frequency where the voltage boost is maximum: _____

☐ 33. Does the voltage boost correspond to approximately 20% the voltage output (U) at that frequency (33% of the base frequency)?

☐ Yes ☐ No

☐ 34. Turn the individual power switch of the AC Power Supply off, disconnect the circuit, and return the equipment to the storage location.

CONCLUSION

In this exercise, you familiarized yourself with the acceleration and deceleration time settings. You plotted the curves showing the linear and S-curve acceleration characteristics.

You also experimented with the Voltage boost function. You saw that it is possible to increase the voltage at a particular frequency to compensate for the voltage drop in the motor windings.

REVIEW QUESTIONS

1. Applications requiring slow start usually have

   a. short acceleration time.
   b. long acceleration time.
   c. short deceleration time.
   d. long deceleration time.

2. The purpose of an S-curve acceleration curve is

   a. to combine soft starts and stops with high speeds when moving from a point to another.
   b. to combine rapid starts and stops with high speeds when moving from a point to another.
   c. to combine rapid starts and stops with low speeds when moving from a point to another.
   d. to combine soft starts and stops with low speeds when moving from a point to another.

3. Voltage boost is applied at

   a. high frequencies.
   b. low frequencies.
   c. frequencies required by the load.
   d. None of the answers above is correct.

4. Voltage boost is applied

   a. when the mass inertia moment of the connected load is high.
   b. to compensate for the voltage drop in the motor windings.
   c. beyond the normal U/f characteristic.
   d. All of the answers above are correct.

Instructor Guide Sample

Extracted from

Motor Drives

Volts per Hertz Characteristics

ANSWERS TO PROCEDURE STEP QUESTIONS

☐ 6. Clockwise.

☐ 8. No. The potentiometer is disabled through PNU A001.

☐ 10. Yes.

☐ 13. Yes.

☐ 15. Constant torque curve.

☐ 17.

U/f CHARACTERISTIC				
SETPOINT		n (r/min)	OUTPUT VOLTAGE U (V)	
VOLTAGE (V)	f (Hz)		CONSTANT TORQUE	REDUCED TORQUE
1	6	172	28	27
2	12	352	51	32
3	18	532	74	44
4	24	712	97	60
5	30	892	121	81
6	36	1072	144	106
7	42	1252	168	134
8	48	1432	191	168
9	54	1612	209	205
10	60	1792	210	210

Table 1-7. U/f characteristics (60 Hz network).

U/f CHARACTERISTIC				
SETPOINT		n (r/min)	OUTPUT VOLTAGE U (V)	
Voltage (V)	f (Hz)		CONSTANT TORQUE	REDUCED TORQUE
1	5	148.5	48	14
2	10	318.6	88	32
3	15	478.8	128	58
4	20	635.2	168	92
5	25	792	210	132
6	30	951	250	180
7	35	1105	290	230
8	40	1259	332	290
9	45	1394	366	352
10	50	1492	366	366

Table 1-7. U/f characteristics (50 Hz network).

☐ 22. Yes.

☐ 23. Yes.

☐ 24. The speed varies proportionally with frequency.

ANSWERS TO REVIEW QUESTIONS

1. c; 2. b; 3. b; 4. a; 5. c.