Electricity and New Energy

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
3∼	Three-phase alternating current
⏚	Earth (ground) terminal

Safety and Common Symbols

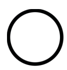
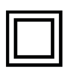
Symbol	Description
	Protective conductor terminal
	Frame or chassis terminal
	Equipotentiality
	On (supply)
	Off (supply)
	Equipment protected throughout by double insulation or reinforced insulation
	In position of a bi-stable push control
	Out position of a bi-stable push control

Table of Contents

Table of Contents

Table of Contents

Table of Contents

Preface

The Motor Drives Training System, model 8036-A, introduces the use of the AC and DC drives to control electric motors.

We hope that your learning experience will be the first step of a successful career.

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.

About This Manual

Manual objectives

The exercises in this manual, Motor Drives, provide the knowledge necessary to perform motor controls with the help of motor drives.

The present manual is divided into two units:

- Unit 1 introduces the AC Drive and its main functions;
- Unit 2 introduces the DC Drive and its main functions.

Each unit contains exercises which provide a systematic and realistic means of learning the subject matter. Each exercise is divided into the following sections:

- A clearly defined Exercise Objective;
- A Discussion of the theory involved in the exercise;
- A Procedure Summary which provides a bridge between the theoretical Discussion and the laboratory Procedure;
- A step-by-step laboratory Procedure in which the students observe and quantify important principles covered in the Discussion;
- A Conclusion to summarize the material presented in the exercise;
- Review Questions to verify that the material has been well assimilated.

A ten-question test at the end of each unit allows the student's knowledge of the unit material to be assessed.

Safety considerations

Safety symbols that may be used in this manual and on the equipment are listed in the Safety Symbols table at the beginning of the manual.

Safety procedures related to the tasks that you will be asked to perform are indicated in each exercise.

Make sure that you are wearing appropriate protective equipment when performing the tasks. You should never perform a task if you have any reason to think that a manipulation could be dangerous for you or your teammates.

Prerequisite

This practical hands-on course is presented in a way that it is readily understandable by anyone who has knowledge of electromechanical systems. However it should be preferable to have completed the manual Basic Controls, part number 39163.

Before performing an exercise, you should read the pages of the AC Drive or DC Drive user manuals that deal with the covered topics. Ask your instructor for a copy, or download the file from the manufacturer's website.

About This Manual

Systems of units

Units are expressed using the International System of Units (SI) followed by units expressed in the U.S. customary system of units (between parentheses).

To the Instructor

You will find in this Instructor Guide all the elements included in the Student Manual together with the answers to all questions, results of measurements, graphs, explanations, suggestions, and, in some cases, instructions to help you guide the students through their learning process. All the information that applies to you is placed between markers and appears in red.

Accuracy of measurements

The numerical results of the hands-on exercises may differ from one student to another. For this reason, the results and answers given in this manual should be considered as a guide. Students who correctly performed the exercises should expect to demonstrate the principles involved and make observations and measurements similar to those given as answers.

Notes 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 may differ from the current default settings of the AC Drive.
- If the AC Drive OMRON is displaying error E12 even if nothing is connected to the Multi-function inputs, one of the Multi-function inputs is configured for a low-level signal (like the normally closed contact of the Emergency Button). To clear error E12, you must apply 24 V dc on this input and press the STOP/RESET button. If you do not know which input is configured that way, apply 24 V dc (from terminal P24) to input S1 and try to clear the error. If it does not work, try again with input S2, S3, S4, S5, S6 and S7. Once the error is cleared, initialize the AC Drive by performing the Initialization procedure shown in the student manual.

Sample Exercise

Extracted from

the Student Manual

and the Instructor Guide

Ramp and Torque Boost

EXERCISE OBJECTIVE

The exercise objectives are listed below:

- Understand the acceleration and deceleration time settings.
- Introduce the linear and S-shape acceleration and deceleration patterns.
- Introduce the Torque boost function.

DISCUSSION OUTLINE

The Discussion of this exercise covers the following points:

- Acceleration and deceleration times
- Acceleration and deceleration patterns
- Torque boost

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. See Figure 1-10.

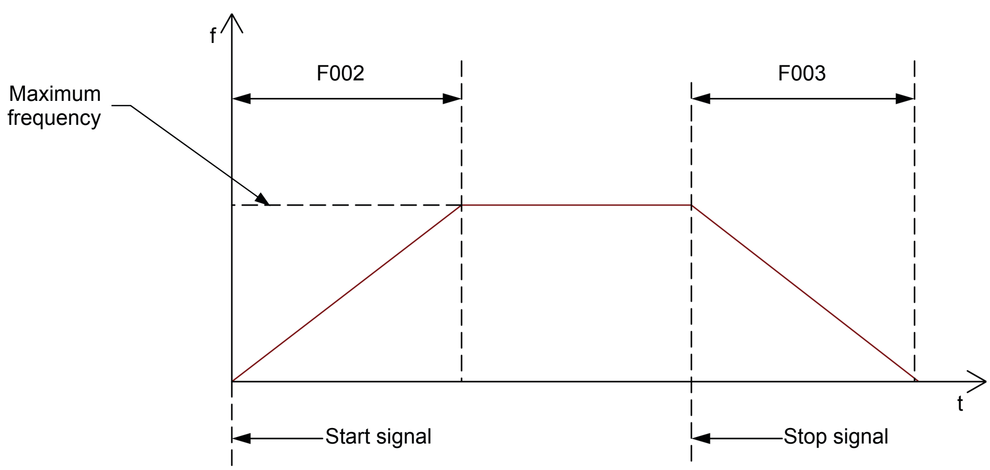


Figure 1-10. Acceleration/deceleration ramps.

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 time setting* and *Deceleration time setting* functions are set using parameters F002 and F003. The characteristics of these parameters are shown in Table 1-10.

Table 1-10. Characteristics of parameters F002, F003, A097, A098, and b082.

Parameter	Function	Value	DS
F002	*Acceleration time setting*	0.01 to 3600 s	10.00
F003	*Deceleration time setting*	0.01 to 3600 s	10.00
A097	*Acceleration pattern selection*	00: Linear 01: S-shape curve 02: U shape 03: Reverse-U shape 04: EL-S shape	01
A098	*Deceleration pattern selection*	00: Linear 01: S-shape curve 02: U shape 03: Reverse-U shape 04: EL-S shape	01
b082*	*Starting frequency*	0.01 to 9.99	1.5

* Parameter b082 directly affects real acceleration/deceleration times. In order to actually obtain the time values set to F002 and F003, the starting frequency must be set to its lowest value.

Acceleration and deceleration patterns

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

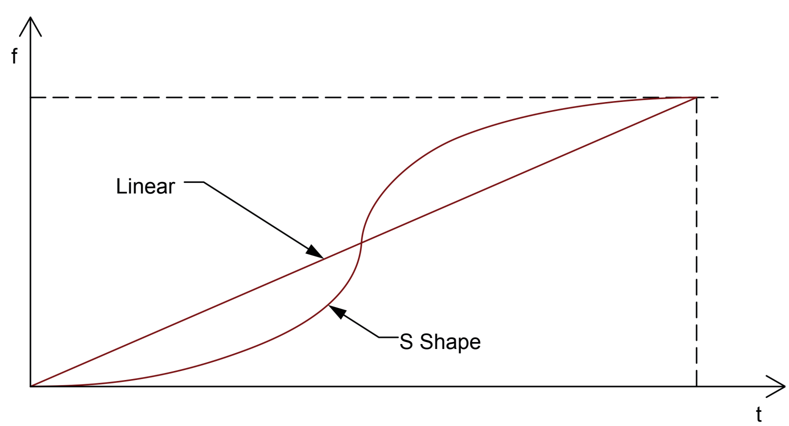


Figure 1-11. Linear and S-shape patterns during acceleration.

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

The *Acceleration pattern selection* and *Deceleration pattern selection* functions are set using parameters A097 and A098. The characteristics of these parameters are shown in Table 1-10.

Torque 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 V/f characteristics at low output frequencies. This compensates for the voltage drop in the motor windings and can be up to half the motor's nominal voltage.

The torque boost (voltage increase) is defined as a percentage value. As Figure 1-12 shows, the Manual torque boost voltage function (parameter A042) is a percentage of the output voltage and the Manual torque boost frequency function (A043) is a percentage of the frequency.

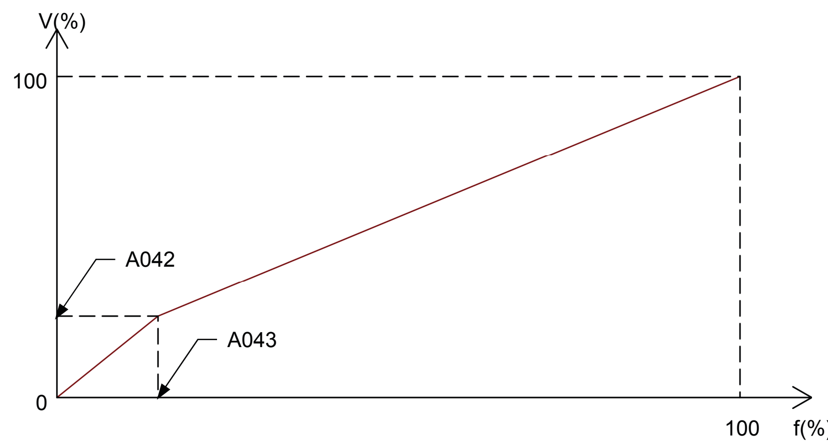


Figure 1-12. Torque boost.

The Torque boost selection function (parameter A041) lets you select between manual and automatic torque boost. Automatic torque boost is added to the V/f characteristics depending on the current load.

The torque boost functions are set using parameters A041, A042 and A043. The characteristics of these parameters are shown in Table 1-11.

Table 1-11. Characteristics of parameters A041, A042, and A043.

Parameter	Function	Value	DS
A041	*Torque boost selection*	00: Manual 01: Automatic	01
A042	*Manual torque boost voltage*	0 to 20 % of output voltage	1.0
A043	*Manual torque boost frequency*	0 to 50 % of base frequency	5.0

PROCEDURE OUTLINE

The Procedure is divided into the following sections:

- Set up and connections
- Acceleration and deceleration ramps
- Acceleration characteristic

PROCEDURE

Set up and connections

In this section, you will setup the AC Drive.

⚠ WARNING

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

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

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

2. Manually disengage the friction brake.

   Connect a voltmeter between terminals FV and SC on the AC Drive.

Acceleration and deceleration ramps

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

Perform the Energizing procedure.

Turn on the AC Power Supply.

3. Set the parameters of the AC Drive as follows:

   - Restore the default setting of the parameters and configure the AC Drive according to the ratings of the Brake Motor by performing the Initialization procedure;
   - Select *Control circuit terminal block* as *Frequency reference selection* function by setting parameter A001 to 01;
   - Set the *Starting frequency* to 0.01 Hz by setting parameter b082 to 0.01;
   - Set the AC Drive to display the output voltage by selecting parameter d013.

4. On the DC Drive, set the remote potentiometer to obtain 10.0 V dc on the voltmeter display.

Determine the acceleration time by starting a chronometer as you set the AC Drive to the run mode, and stopping it when the data display indicates the maximum output voltage for your network (200 V or 380 V depending on your local network). Repeat the measurement to validate your result.

Acceleration time = _______

10 s

5. Does this correspond to the default setting of the *Acceleration time setting* function (parameter F002)?

❑ Yes ❑ No

Yes

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

Determine the deceleration time by starting a chronometer as you set the AC Drive to the stop mode, and stopping it when the data display indicates 0 V. Repeat the measurement to validate your result.

Deceleration time = _______

10 s

7. Does this correspond to the default setting of the *Deceleration time setting* (F003)?

❑ Yes ❑ No

Yes

8. Familiarize yourself with the setting of acceleration and deceleration times by setting a 20.00 s acceleration time and a 15.00 s deceleration time.

Test the operation of your circuit.

9. Turn off the AC Power Supply.

Acceleration characteristic

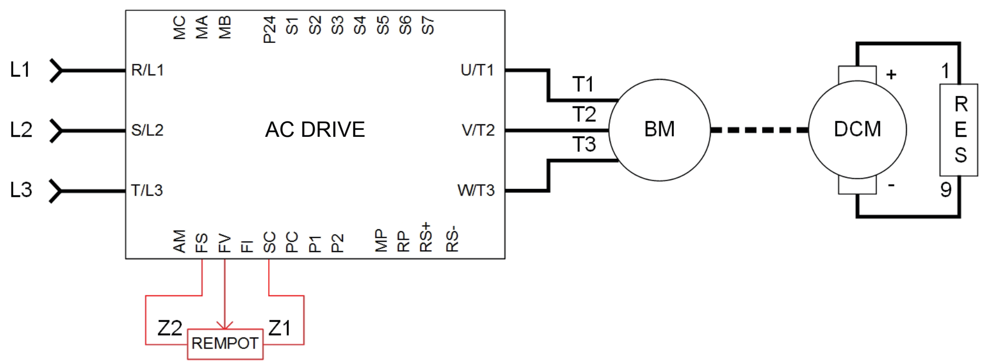
In this section, you will plot the linear and S-shape acceleration patterns.

10. Remove the Safety Guard, and Inertia Wheel.

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

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

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
REMPOT	= Remote potentiometer (dc drive potentiometer)
RES	= Load resistor
BM	= Brake motor

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

12. Turn on the AC Power Supply.

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

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

Set the *Acceleration pattern selection* function to Linear by setting parameter A097 to 00.

Select parameter d001 to display the output frequency.

13. 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 the measurement to validate your result.

Enter your result in the appropriate cell in the Linear column in Table 1-12.

Set the AC Drive to the stop mode.

Table 1-12. Linear and S-shape acceleration patterns.

Frequency range	Time (s)	
	Acceleration pattern	
	Linear	S-shape
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)		

Linear and S-shape acceleration patterns (120 V – 60 Hz network).

Frequency range	Time (s)	
	Acceleration pattern	
	Linear	S-shape
0 to 10 Hz	5.0	7.2
0 to 20 Hz	10.0	11.5
0 to 30 Hz	15.0	15.0
0 to 40 Hz	20.0	18.7
0 to 50 Hz	25.0	23.0
0 to 60 Hz	30.0	30.0

Linear and S-shape acceleration patterns (220/240 V – 50 Hz network).

Frequency range	Time (s)	
	Acceleration pattern	
	Linear	S-shape
0 to 10 Hz	6.0	8.2
0 to 20 Hz	12.0	13.0
0 to 30 Hz	18.0	17.2
0 to 40 Hz	24.0	22.0
0 to 50 Hz	30.0	30.0

Linear and S-shape acceleration patterns (220 V – 60 Hz network).

Frequency range	Time (s)	
	Acceleration pattern	
	Linear	S-shape
0 to 10 Hz	5.0	7.2
0 to 20 Hz	10.0	11.5
0 to 30 Hz	15.0	15.0
0 to 40 Hz	20.0	18.6
0 to 50 Hz	25.0	22.8
0 to 60 Hz	30.0	30.0

14. Repeat the previous measurement for all frequency ranges shown in Table 1-12.

Enter your results in the appropriate cells in the Linear column in Table 1-12.

15. Set the AC Drive to the stop mode.

Set the *Acceleration pattern selection* function (A097) to 01 to select the S-shape acceleration pattern.

Select parameter d001 to display the output frequency.

16. Repeat the measurements to fill out the empty cells of Table 1-12 with the S-shape acceleration pattern.

17. Set the AC Drive to the stop mode.

18. Plot the curves showing the linear and S-shape acceleration patterns in Figure 1-14. Place the Time values along the X-axis, and the Frequency values along the Y-axis.

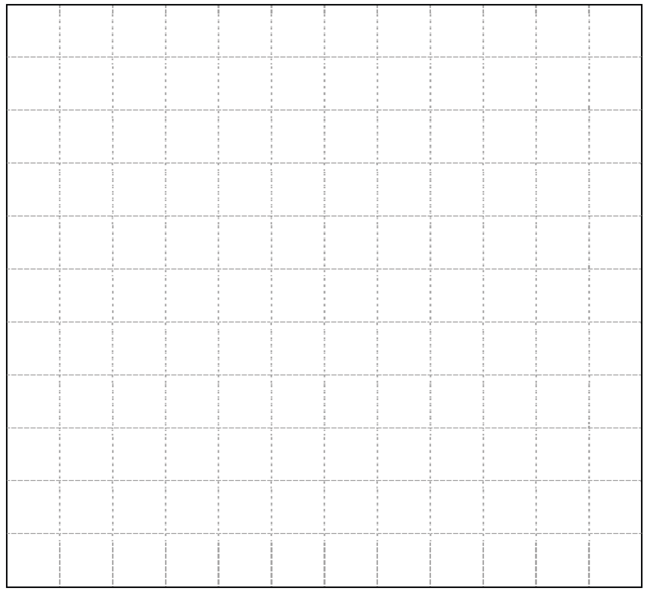


Figure 1-14. Linear and S-shape acceleration patterns.

19. Do your observations confirm that the S-shape acceleration pattern allows a motor to be started slowly?

❑ Yes ❑ No

Yes

20. Do your observations confirm the theory presented in the Discussion of this exercise?

❑ Yes ❑ No

Yes

21. Set the *Acceleration pattern selection* function to Linear by setting parameter A097 to 00.

Torque boost

In this section, you will observe the torque boost characteristics. You will plot the output voltage versus output frequency curve with and without torque boost.

22. Set the *Torque boost selection* function to *Manual torque boost* by setting parameter A041 to 00.

Set the *Manual torque boost voltage* function to 0% by setting parameter A042 to 0.

Set the *Manual torque boost frequency* function to 33% by setting parameter A043 to 33.

Select parameter d001 to display the output frequency.

On the DC Drive, set the potentiometer to obtain 0.0 V dc on the voltmeter display.

Set the AC Drive to the run mode.

23. For all voltage setpoint values shown in Table 1-13, determine the corresponding output frequency displayed on the data display of the AC Drive. Enter your results in the appropriate cells in Table 1-13.

Table 1-13. Torque boost characteristics.

Setpoint		Output voltage (V)	
Voltage (V)	f (Hz)	Without torque boost	With torque boost
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Torque boost characteristics (120 V – 60 Hz network).

Setpoint		Output voltage (V)	
Voltage (V)	f (Hz)	Without torque boost	With torque boost
1	6	20.0	32.1
2	12	40.0	64.2
3	18	60.0	96.3
4	24	80.0	115.9
5	30	100.0	129.9
6	36	120.0	143.9
7	42	140.0	158.0
8	48	160.0	172.0
9	54	180.0	186.0
10	60	200.0	200.0

Torque boost characteristics (220/240 V – 50 Hz network).

Setpoint		Output voltage (V)	
Voltage (V)	f (Hz)	Without torque boost	With torque boost
1	5	38.1	61.1
2	10	76.1	122.2
3	15	113.9	182.8
4	20	152.1	220.1
5	25	190.2	246.7
6	30	227.9	273.6
7	35	266.0	300.0
8	40	304.0	326.7
9	45	341.9	353.4
10	50	380.0*	380.0*

* The maximum voltage output by the AC Drive may be slightly below 380 V.

Torque boost characteristics (220 V – 60 Hz network).

Setpoint		Output voltage (V)	
Voltage (V)	f (Hz)	Without torque boost	With torque boost
1	6.0	38.1	61.1
2	12.0	76.1	122.2
3	18.0	113.9	182.8
4	24.0	152.1	220.1
5	30.0	190.0	246.9
6	36.0	227.9	273.3
7	42.0	266.0	300.0
8	48.0	304.0	326.8
9	54.0	341.9	353.4
10	60.0	380.0*	380.0*

* The maximum voltage output by the AC Drive may be slightly below 380 V.

24. Set the AC Drive to the stop mode.

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

Set the remote 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 1-13, determine the corresponding output voltage displayed on the data display of the AC Drive. Enter your results in the *Without torque boost* column in Table 1-13.

26. Set the AC Drive to the stop mode.

Set the *Manual torque boost voltage* function to 20% by setting parameter A042 to 20.

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

Set the remote 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 1-13, determine the corresponding output voltage displayed by the data display on the AC Drive. Enter your results in the *With torque boost* column in Table 1-13.

CAUTION

Do not let the motor operate for a long time when the torque boost is set for low voltage setpoint values. Since the output current is higher when the torque boost is active, an overload trip could occur.

28. Set the AC Drive to the stop mode.

29. Plot the curves with and without torque boost in Figure 1-15. Place the Frequency values along the X-axis, and the Output voltage values along the Y-axis.

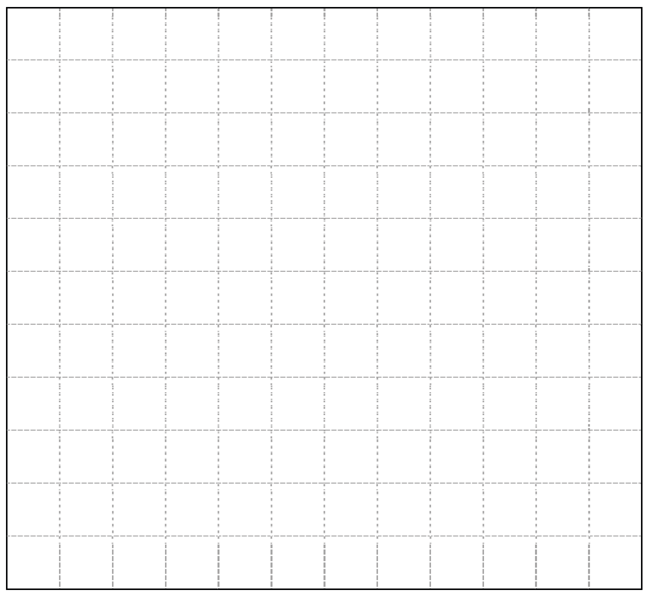


Figure 1-15. With and without torque boost characteristics.

30. At what frequency is the torque boost maximum?

Frequency where the torque boost is maximum = _______

33% of the base frequency.

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

❑ Yes ❑ No

Yes

32. Turn off the AC Power Supply, 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-shape acceleration patterns.

You also experimented with the Torque 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.

b

2. The purpose of an S-shape acceleration pattern 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.

a

3. Torque boost is applied at

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

b

4. Torque 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 V/f characteristic.
   d. All of the answers above are correct.

d

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