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FESTO

Motor Drives

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Industrial Maintenance

LabVolt Series

Student Manual

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Motor Drives

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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

Preface

The Lab-Volt Motor Drives Training System, model 8036-3, introduces the use of the AC and DC drives to control electric motors.

The Motor Drives Training System is part of the Industrial Controls Training Program, which includes the following systems:

- Basic Controls, model 8036-1;
- Programmable Logic controller, model 8036-2;
- Motor Drives, model 8036-3;
- Sensors, model 8036-4;
- Troubleshooting, 8036-5.

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

About This Manual

The exercises in this manual, Motor Drives, complement the exercises contained in the manual Basic Controls. They 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

Make sure that you are wearing appropriate protective equipment before performing any of the exercises in this manual. Remember that you should never perform an exercise if you have any reason to think that a manipulation could be dangerous to you or your teammates.

Reference Material

Refer to the user manuals of the drives for detailed information on how to use the devices. These manuals are included on the CD supplied with the training system.

Prerequisite

To perform the exercises in this manual, you should have completed the manual Basic Controls, Lab-Volt part number 39163.

Before performing an exercise, you should have 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.

AC Drives

UNIT OBJECTIVE

Upon completion of this unit, you will be able to use an AC Drive. You will know how to set the operating parameters. You will also learn how to protect the equipment from overcurrent, overvoltage, and overheating by setting the protection parameters.

DISCUSSION OF FUNDAMENTALS

AC induction motors are sized for maximum loads and are operated at a constant full speed because they are supplied with power from AC lines at a fixed-sinusoidal voltage and fixed frequency.

However, a high percentage of pumps, fans, and blowers that are driven by AC motors have output flow requirements that fluctuate. To vary the flow of liquids or gases, manufacturers often employ restrictive devices, such as valves, dampers, and orifices. Even though these mechanical restrictors provide effective control methods, up to 30 percent of the power consumed by motors is not used for the work they are meant to perform. The wasted energy is consumed by the restrictors as friction and heat diffusion. Figure 1-1 shows a typical cooling fan system as an example.

Figure 1-1. Cooling fan system.

By adjusting the motor speed using an AC drive, most restrictors can be eliminated.

Motor speed

AC drives control the speed of AC motors by controlling the frequency and voltage of the power supplied to the motor. An inverter provides the controlled power, and in most cases, the AC drive includes a rectifier so that DC power required by the inverter can be provided from the mains AC power. AC drives are also called variable-frequency drives, frequency inverters, or inverters.

The speed of an AC motor is determined by the frequency (f) of the alternating current it receives, i.e. the number of cycles of the current at each second. The speed is derived from the following equation:

$$N = \frac{f \times 60}{P}$$

where N is the speed in r/min
f is the frequency of the alternating current in Hz
P is the number of motor pole pairs
60 is a constant used to express the speed in r/min instead of r/s.

Since the number of poles of a motor remains constant, the speed is more easily controlled by varying the frequency.

AC Drive Overview

EXERCISE OBJECTIVE

- Familiarize yourself with the AC Drive.
- Read AC Drive parameter settings.
- Set the basic AC Drive parameters to control the Brake Motor.

DISCUSSION

Figure 1-2 shows the AC Drive module, model 3183, which includes the general-purpose Inverter 3G3JX from OMRON.

Figure 1-2. AC Drive, model 3183 (version 120/208 V, 60 Hz).

Keypad

The name and the description of the keypad items are shown in Table 1-1.

NUMBER	NAME	DESCRIPTION
8888	Data display	Displays relevant data, such as frequency reference, output current, and set values.
○	RUN LED indicator	Lit when the Inverter is running.
RUN	RUN key	Activates the Inverter. Available only when operation via the Digital Operator is selected.
STOP RESET	STOP/RESET key	Decelerates and stops the Inverter. Functions as a reset key if an Inverter error occurs.
	Mode key	Switches between: the monitor (display) mode (d□□□), the basic function mode (F□□□), and the extended function mode (A□□□, b□□□, C□□□, H□□□).
	Increment key	Changes the mode. Also, increases the set value of each function.
	Decrement key	Changes the mode. Also, decreases the set value of each function.
	Enter key	Enters the set value. (To change the set value, be sure to press the Enter key.)
○ Hz ○ A	Data display LED indicator	Lit according to the indication on the data display. Hz: Frequency - A: Current
○POWER	POWER LED indicator	Lit when the power is supplied to the control circuit.
○ALARM	ALARM LED indicator	Lit when an Inverter error occurs.
○RUN	RUN LED indicator	Lit when the Inverter is running.
○PRG	PROGRAM LED indicator	Lit when the set value of each function is indicated on the data display. Blinks during warning (when the set value is incorrect).
MIN MAX	Volume LED indicator	Lit when the RUN command is set to Digital Operator. (The RUN key on the Digital Operator is available for operation.)
	FREQ. adjuster	Activates the Inverter. Available only when the operation via the Digital Operator is selected.

Table 1-1. Keypad description.

Input and output terminals

The input and output terminals of the AC Drive are accessible through the terminals on the module faceplate. The function of the terminals is shown in Table 1-2.

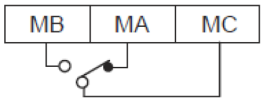
TERMINAL SYMBOL	TERMINAL TYPE AND FUNCTION
R/L1, S/L2, T/L3	Main power supply input terminals. Connects the input power supply.
U/T1, V/T2, W/T3	Inverter output terminals. Connects to the motor.
MC	Relay output signal. Contact MA-MC is normally closed, and contact MB-MC is normally is open. 
MB	
MA	
AM	Monitor signal. Analog frequency monitor/Analog output current monitor.
FS	Frequency reference input. Frequency reference power supply.
FV	Frequency reference input. Voltage frequency reference signal.
FI	Frequency reference input. Current frequency reference signal.
FC	Frequency reference input. Frequency reference common.
P1	Output signal. Multi-function output terminal. Select the status of the Inverter and allocate it to terminal P1.
PC	Output signal. Output signal common.
S1	Input signals. Multi-function input terminals S1 to S5. Select 5 functions among the 31 functions and allocate them to terminals S1 to S5. The terminal allocation is changed automatically when the emergency shutoff function is used.
S2	
S3	
S4	
S5	
P24	Internal 24 V DC. 24 V DC output.

Table 1-2. Function of the terminals on the AC Drive module faceplate.

Microswitches

As Figure 1-3 shows, there are two microswitches behind the terminal shroud. These microswitches allow configurating the AC Drive for special operating modes. The use of these microswitches will not be explained in this manual. However, it is important to know their default position when troubleshooting.

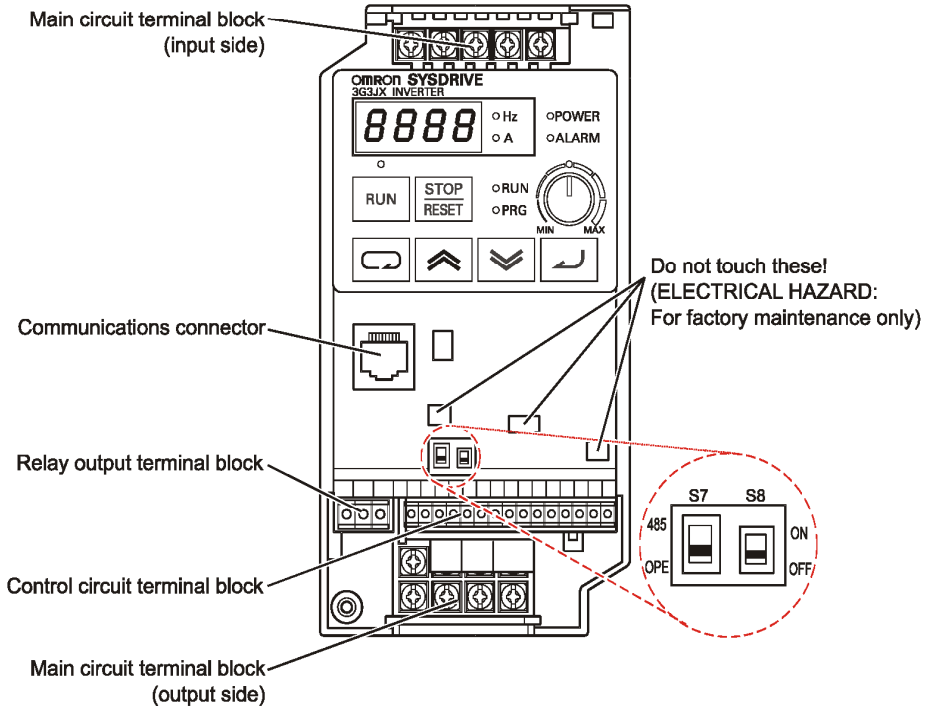


Figure 1-3. Location of the microswitches.

You do not have to change the position of these microswitches to perform the exercises in this manual.

The default position of the microswitches is shown in Table 1-3.

MICROSWITCH	DEFAULT POSITION
OPE/485 communication selector (S7)	OPEN
Emergency shutoff function selector (S8)	OFF

Table 1-3. Default position of the microswitches.

Parameters

The AC Drive of your training system can be adapted for specific applications. It is adapted by setting the value of various parameters. As an example, the direction of rotation, and the time taken by the motor to attain full speed, are parameters that can be set.

Appendix F shows the list of the parameters that can be set to fit an application. This Appendix shows the parameter number, the function, the value range, and the default setting.

The AC Drive model of your training system has been selected to fit the Brake Motor characteristics. For this reason, the default setting of the parameters of the AC Drive corresponds to the rated voltage, current, and number of poles of the Brake Motor.

In the following exercises you will be introduced to many parameters, and learn how to use them. Notice that you will not learn how to use all parameters in this manual.

Parameters are set by navigating into the menu shown in Figure 1-4.

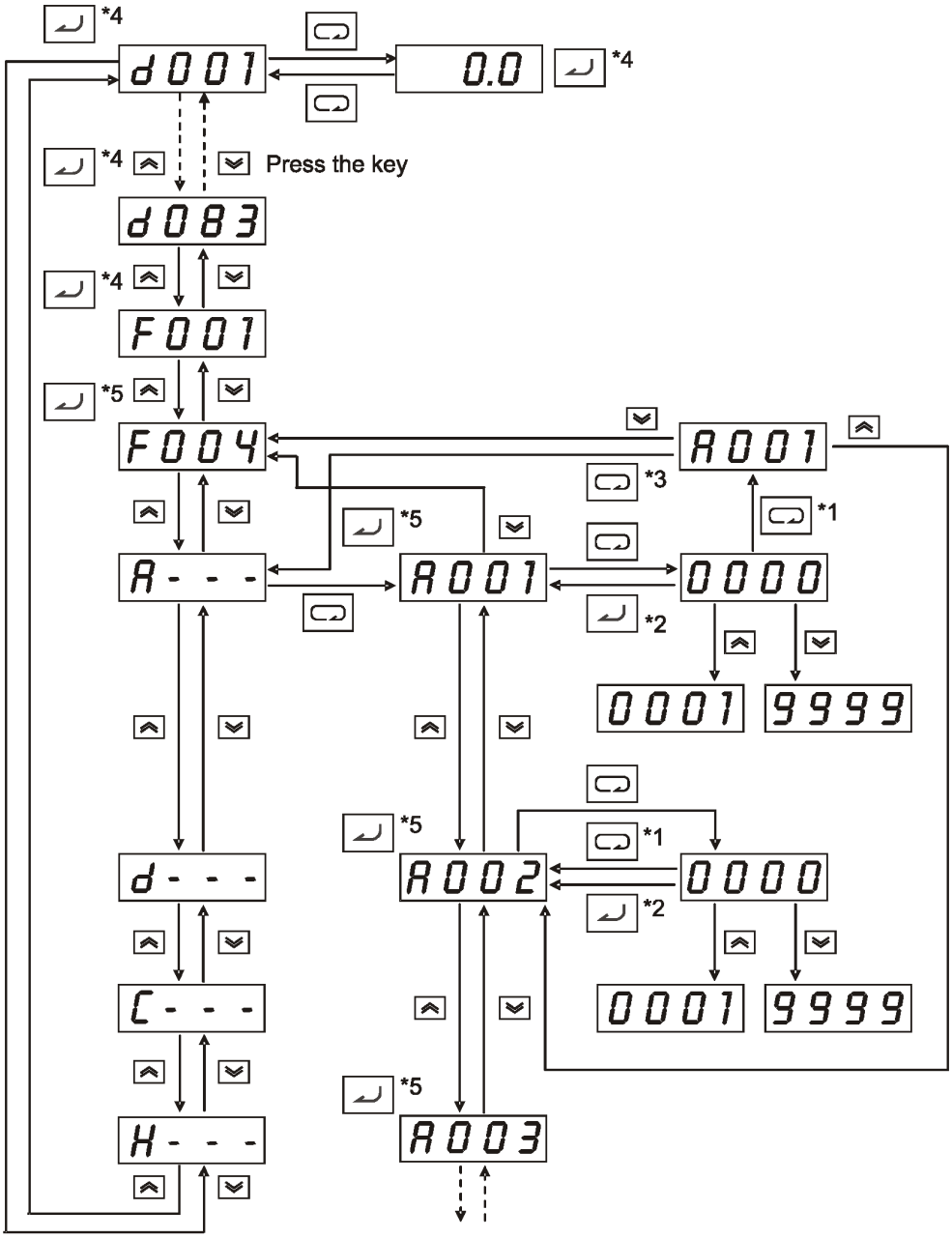


Figure 1-4. Parameter transition.

(1) Data is not stored by pressing the Mode key.
(2) Press the Enter key to store the data.
(3) When you press the Mode key after you return to the parameter number display without storing data in the extended function mode, the mode selection function is selected.
(4) When you press the Enter key with d*** or F001 displayed, the monitor value is stored as the initial display that appears when the power is turned on.
(5) When you press the Enter key, the first digit of each parameter setting is stored as the initial display that appears when the power is turned on.

Setting the value of a parameter

Perform the following steps to set the value of a parameter:

- Press the Mode key once or twice to display the selected mode.
- Press the Increment and Decrement keys to select a parameter number (d000 to d083 or F001 to F009), or a parameter type (H, C, b, or A).
- If you selected a parameter type H, C, b, or A (extended function mode):
  - press the Mode key once.
  - press the Increment and Decrement keys to select a parameter number.
  - press the Mode key to display the current value of the parameter.
  - press the Increment and Decrement keys to set a new parameter value.
  - press the Enter key to save the value and return to the parameter number.
- If you selected a parameter type d (monitor mode):
  - press the Increment and Decrement keys to select a parameter number.
  - press the Mode key to display the value of the parameter.
- If you selected a parameter type F (basic function mode):
  - press the Mode key to display the current value of the parameter.
  - press the Increment and Decrement keys to set a new parameter value.
  - press the Enter key to save the value and return to the parameter number.

Reading the current setting of a parameter

Perform the following steps to read the current setting of a parameter:

- Select the parameter number.
- Press the Mode key to display the current value.
- Press the Mode key to return to the parameter number.

Quick parameter selection

The quick parameter selection is a rapid method for changing from a parameter to another. It is activated by pressing the Increment and Decrement keys simultaneously.

The digit at the left of the data display then flashes. Use the Increment and Decrement keys to select a parameter type (A, b, C, d, F, H). Press the Enter key to fix the blinking digit.

The second digit from the left of the data display then flashes. Use the Increment and Decrement keys to select the required value (between 0 and 9). Press the Enter key to fix the blinking digit.

Repeat the previous step for the third and fourth digit from the left of the data display.

If the number you have entered does not exist, the data display returns to the parameter previously displayed.

Once the parameter is selected, press the Mode key to change the value of the parameter.

Initialization procedure (restoring default settings)

Because of a change in application, or to prevent the operation of the AC Drive with a parameter set to an unexpected value, it is sometimes required to restore the default setting of the parameters.

Perform the following steps to restore the default setting of all parameters:

- Select parameter b084.
- Set the value of parameter b084 to 02[(1)].
- Press the STOP/RESET key while holding down the Mode and Decrement keys simultaneously. When the display blinks, release the STOP/RESET key first, and then the Mode and Decrement keys.
- When initialization is completed, the data display shows d001.

(1) Setting parameter b084 to 02 clears the trip monitor and initializes data.

Procedure Summary

In the first part of this exercise, you will connect the AC Drive and read the current setting of some parameters. You will compare the current setting to the default setting of the parameters.

In the second part, you will perform the Initialization procedure to restore the default setting of the parameters.

In the third part, you will operate the Brake Motor using the AC Drive. You will also set the AC Drive to display parameters.

EQUIPMENT REQUIRED

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

PROCEDURE

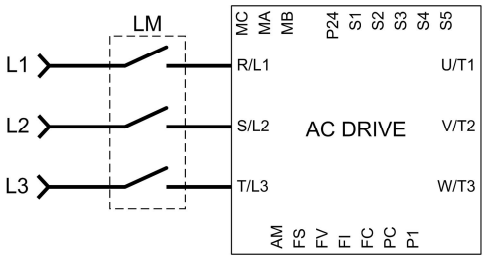
⚠ WARNING

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 described in Appendix C.

☐ 2. Set up the circuit shown in Figure 1-5.



LEGEND

AC DRIVE = THREE-PHASE AC DRIVE
LM = LOCKOUT MODULE

Figure 1-5. AC Drive connected to the Lockout Module.

☐ 3. Perform the Energizing procedure described in Appendix C.

Parameter settings

☐ 4. Read the current values of the following parameters:

A038: _____ A043: _____ b002: _____

b021: _____ C001: _____ C026: _____

☐ 5. Do these values correspond to the default setting of the parameters as indicated in Appendix F? If not, explain why.

_____

_____

Initialization procedure

☐ 6. Perform the Initialization procedure described in the Discussion of this exercise to restore the default setting of the parameters.

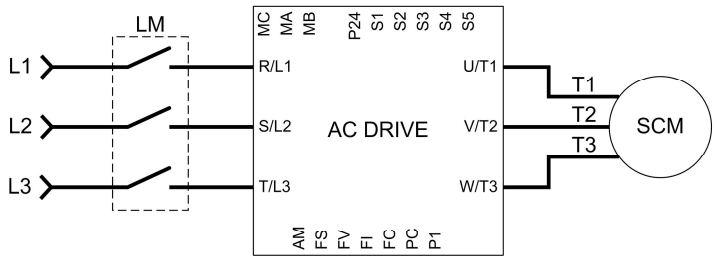
Note: *If the display does not show d001 at the end of the Initialization procedure, repeat the procedure.*

☐ 7. Turn off the Lockout Module.

Basic motor control functions

☐ 8. Install the Brake Motor and Safety Guard.

☐ 9. Set up the circuit shown in Figure 1-6.



LEGEND

AC DRIVE = THREE-PHASE AC DRIVE
LM = LOCKOUT MODULE
SCM = SQUIRREL CAGE MOTOR

Figure 1-6. AC Drive controlling the Brake Motor.

☐ 10. Manually disengage the friction brake.

On the AC drive, turn the FREQ. adjuster fully counterclockwise.

☐ 11. Turn on the Lockout Module.

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

Turn the FREQ. adjuster fully clockwise.

Does the Brake Motor start to rotate?

☐ Yes ☐ No

☐ 12. Press the RUN key to set the AC Drive to the run mode.

Does the Brake Motor start to rotate?

☐ Yes ☐ No

☐ 13. Wait until the motor stabilizes, then enter the output frequency shown on the data display of the AC Drive.

Output frequency: _____

☐ 14. Vary the position of the FREQ. adjuster while observing the frequency shown on the data display of the AC Drive and the speed of the motor.

Does the motor speed slow down as the output frequency is reduced?

☐ Yes ☐ No

☐ 15. Turn the FREQ. adjuster of the AC Drive fully clockwise.

Set the AC Drive to display the output current by selecting parameter d002.

> **Note:** *It is not necessary to stop the AC Drive to modify the display parameters. However, many parameters require the AC Drive to be in the stop mode to be modified.*

Wait until the motor stabilizes, then enter the output current shown on the data display of the AC Drive.

Output current: _____

☐ 16. Which LEDs are lit in this operating mode (run mode)?

_____

_____

_____

☐ 17. Press the STOP/RESET key to set the AC Drive to the stop mode.

Quick parameter selection

☐ 18. Familiarize yourself with the quick parameter selection method by selecting one after the other the following parameters:

A001, b023, C004, and F004

☐ 19. 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 basic operation of the AC Drive. You read the value of some parameters, and performed the Initialization procedure to restore the default setting of the parameters. You operated the Brake Motor, and varied the speed using the FREQ. adjuster. You saw that the quick parameter selection allows you to select the parameters easily and rapidly.

REVIEW QUESTIONS

1. Determine the speed of a two-pole AC motor when the frequency of the current is 60 Hz.

   a. 450 r/min
   b. 900 r/min
   c. 1800 r/min
   d. 3600 r/min

2. How can an AC Drive be adapted for specific applications?

   a. by changing the default setting of the parameters.
   b. by setting the value of various parameters.
   c. by changing the FREQ. adjuster position.
   d. by selecting another AC Drive model.

3. What is the quick parameter selection used for?

   a. Rapidly selecting a parameter number.
   b. Rapidly changing from a parameter number to a parameter function.
   c. Rapidly changing from a parameter function to another.
   d. Rapidly selecting a parameter value.

4. What is the Initialization procedure used for?

   a. Store a special application setting.
   b. Prevent the operation with a parameter set to an unexpected value.
   c. Start the system rapidly.
   d. Reset the security parameters.

5. What happens when the Initialization procedure is completed?

   a. The AC Drive display shows d001.
   b. The value of all parameters is set to default setting.
   c. The AC Drive is set to the stop mode.
   d. All of the answers above are correct.

Volts per Hertz Characteristics

EXERCISE OBJECTIVE

- Set the rotation direction of the motor.
- Understand the V/f (volts per hertz) characteristics.
- Learn how to use an analog voltage to assign the frequency setpoint.

DISCUSSION

Direction of rotation

The *Operator rotation direction selection* function defines the direction in which the motor turns after a start signal is issued.

The *Operator rotation direction selection* function is set using parameter F004. The characteristics of this parameter are shown in Table 1-4.

PARAMETER	FUNCTION	VALUE	DS
F004	*Operator rotation direction selection*	00: Forward 01: Reverse	00
A004	*Maximum frequency*	30 to 400	60
A003	*Base frequency*	30 to Max. Frequency [A004]	60
DS: default setting			
Set parameters A003 and A004 to 50 if the frequency of your local network is 50 Hz.			

Table 1-4. Characteristics of parameter F004.

V/f characteristics

The V/f (volts per hertz) characteristic is the ratio of output voltage to output frequency, which determines the motor's ability to develop torque. As seen previously, an increase in frequency causes a corresponding increase in speed. However, increasing the frequency without increasing the voltage reduces the motor's ability to develop torque.

The AC Drive of your training system offers three V/f characteristics: constant torque, reduced torque, and special reduced torque. See Figure 1-7.

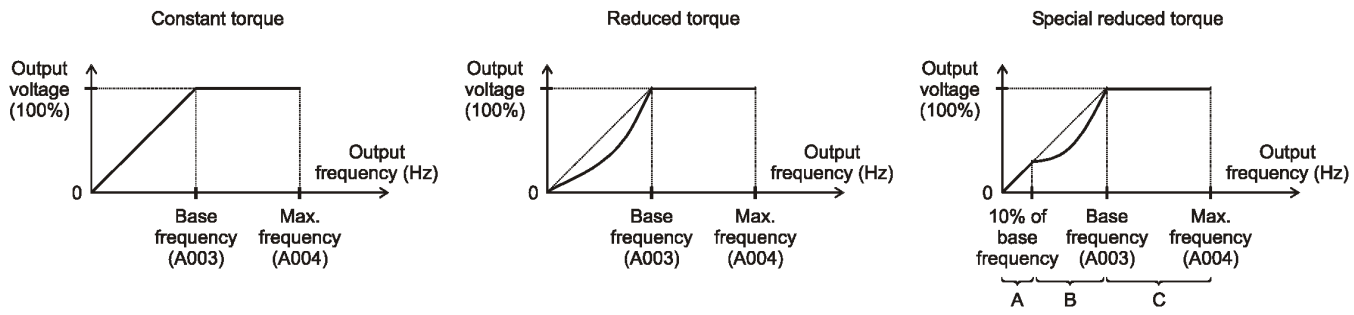


Figure 1-7. V/f characteristics.

With the *Constant torque characteristics*, the output voltage is proportional to the output frequency. While proportional from 0 Hz to base frequency, the output voltage is constant from base to maximum frequencies regardless of the frequency.

The *Reduced torque characteristics* are suitable for a fan or pump that does not require large torque in a low speed range. These characteristics provide high efficiency, reduced noise and vibration, due to reduced output voltage at a low speed range.

The *Special reduced torque characteristics* are suitable for a fan or pump that requires torque in a low speed range. They provide constant torque characteristics within a range from 0 Hz to 10% of the base frequency. Then, they provide reduced torque characteristics within a range from 10% to 100% of the base frequency. For frequencies higher than the base frequency, they provide constant voltage within a range from the base frequency to the maximum frequency.

The *V/f characteristics selection* function is set using parameter A044. The characteristics of this parameter are shown in Table 1-5.

PARAMETER	FUNCTION	VALUE	DS
A044	*V/f characteristics selection*	00: Constant torque 01: Reduced torque 06: Special reduced torque	00

Table 1-5. Characteristics of parameter A044.

Frequency reference selection

In Exercise 1-1, you used the FREQ. adjuster on the digital operator to vary the frequency reference (setpoint). There are other ways to assign the frequency reference:

- through terminal analog input voltage and analog input current;
- through digital operator;
- using ModBus communication;
- using frequency operation result.

The *Frequency reference selection* function is set using parameter A001. The characteristics of this parameter are shown in Table 1-6.

PARAMETER	FUNCTION	VALUE	DS
A001	*Frequency reference selection*	00: Digital operator (FREQ. adjuster) 01: Terminal 02: Digital operator (F001) 03: ModBus communication 10: Frequency operation result	00

Table 1-6. Characteristics of parameter A001.

Procedure Summary

In the first part of this exercise, you will use a remote potentiometer for controlling the rotation speed of the Brake Motor, and you will change the rotation direction by changing the setting of the *Operator rotation direction selection* function.

In the third part, you will plot the curves showing the constant torque and reduced torque V/f characteristics.

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

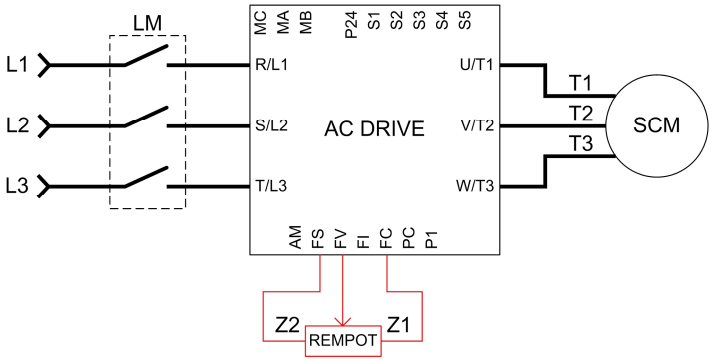
☐ 1. Perform the Basic Setup and Lockout/Tagout procedures.

Direction of rotation

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

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

Note: *In this circuit, the potentiometer of the DC Drive is used as remote potentiometer. You will apply the Frequency reference power supply (+10 V dc) supplied via terminal FS on the AC Drive to the remote potentiometer and you will apply the wiper voltage from the remote potentiometer (↑) to the Frequency reference input voltage (terminal FV) as shown in the following figure.*



LEGEND

AC DRIVE	=	THREE-PHASE AC DRIVE
LM	=	LOCKOUT MODULE
REMPOT	=	REMOTE POTENTIOMETER (DC DRIVE POTENTIOMETER)
SCM	=	SQUIRREL CAGE MOTOR (BRAKE MOTOR)

Figure 1-8. Circuit using a remote potentiometer.

☐ 4. Manually disengage the friction brake.

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

On the DC Drive, set the remote potentiometer to 0.

Perform the Energizing procedure.

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

- Restore the default setting of the parameters by performing the Initialization procedure;
- Select *Terminal* as *Frequency reference selection* function by setting parameter A001 to 01;
- Set the AC Drive to display the output frequency by selecting parameter d001.

☐ 6. Referring to the default setting of the *Operator rotation direction selection* function, parameter F004, in which direction will the motor rotate?

☐ Forward ☐ Reverse

☐ 7. Press the RUN key to set the AC Drive to the run mode.

☐ 8. Is the Volume LED indicator on the digital operator of the AC Drive lit? Explain why.

_____

_____

☐ 9. On the DC Drive, set the remote potentiometer to obtain 1.0 V dc on the voltmeter display.

☐ 10. Does the direction of rotation correspond to the default setting of the *Direction of rotation* parameter?

☐ Yes ☐ No

☐ 11. Enter the frequency displayed by the AC Drive in Table 1-7.

Repeat the voltage setting for all the values shown in the Voltage column of Table 1-7. For each setting, enter the corresponding frequency displayed by the AC Drive.

☐ 12. Press the STOP/RESET key to set the AC Drive to the stop mode.

☐ 13. Set the *Operator rotation direction selection* to reverse by setting parameter F004 to 01.

On the DC Drive, set the remote potentiometer to obtain 1.0 V dc on the voltmeter display.

Set the AC Drive to the run mode.

Does the motor rotate in the reverse direction?

☐ Yes ☐ No

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

V/f characteristics

☐ 15. What is the default setting of the *V/f characteristics selection* function?

☐ Constant torque
☐ Reduced torque
☐ Special reduced torque

☐ 16. Set the *Operator rotation direction selection* function to forward by setting parameter F004 to 00.

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

Set the AC Drive to the run mode.

☐ 17. On the DC Drive, set the potentiometer to obtain 1.0 V dc on the voltmeter display.

Enter the output voltage value displayed by the AC Drive display in the CONSTANT TORQUE column, and the speed of rotation, in the n column of Table 1-7. Fill out the table for all other setpoint values.

Note: *If a tachometer is not available, determine the speed from the equation shown in the DISCUSSION OF FUNDAMENTALS.*

V/f CHARACTERISTIC				
SETPOINT		n (r/min)	OUTPUT VOLTAGE (V)	
Voltage (V)	f (Hz)		CONSTANT TORQUE	REDUCED TORQUE
1				
2				
3				
4				
5				
6				
7				
8				
9				
10 (1)				
(1) The *AVR* function of the Inverter outputs voltage to the motor correctly even if the incoming voltage to the Inverter fluctuates. With this function, output voltage to the motor is limited to 200 V or 400 V depending on your local network.				

Table 1-7. V/f characteristics.

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

☐ 19. Select the *Reduced torque characteristics* by setting parameter A044 to 01 to reduce the torque at low speed.

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

Set the AC Drive to the run mode, and repeat the measurements for all setpoint values shown in Table 1-7. Enter the output voltage values displayed by the AC Drive display in the REDUCED TORQUE column.

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

☐ 21. Plot the curves showing the constant torque and reduced torque V/f characteristics in Figure 1-9.

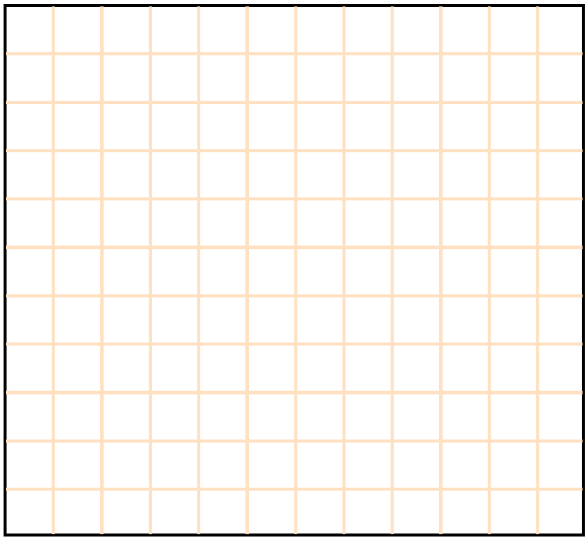


Figure 1-9. Constant torque and reduced torque V/f characteristics.

☐ 22. Are the curves plotted with the constant torque and reduced torque V/f characteristics similar to those shown in the Discussion of this exercise?

☐ Yes ☐ No

☐ 23. Does the reduced torque curve confirm that the AC Drive can be used as a soft starter when the *Reduced torque* function is selected?

☐ Yes ☐ No

☐ 24. 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 changed the rotation direction by changing the value of the *Operator rotation direction selection* function parameter. You learned how to apply the setpoint using a remote potentiometer connected to an analog input of the AC Drive.

You plotted the constant torque and reduced torque V/f characteristics of the AC Drive, and saw that the reduced torque V/f characteristics give a reduced starting torque.

REVIEW QUESTIONS

1. The V/f characteristics of the AC Drive of your training system are

   a. constant torque, reduced torque, and special reduced torque.
   b. constant torque and torque boost.
   c. reduced torque and torque boost.
   d. special reduced torque and torque boost.

2. The V/f characteristic is

   a. the ratio of output frequency to output voltage.
   b. the ratio of output voltage to output frequency.
   c. the ratio of output current to output voltage.
   d. None of the answers above is correct.

3. Increasing the frequency without increasing the voltage

   a. increases the motor's ability to develop torque.
   b. reduces the motor's ability to develop torque.
   c. does not affect the motor's ability to develop torque.
   d. None of the answers above is correct.

4. On the AC Drive, what is the terminal FC used for?

   a. Frequency reference common
   b. Frequency reference power supply output
   c. Frequency reference input (voltage directive)
   d. Frequency reference input (current directive)

5. Parameter A001 function determines the

   a. frequency reference output.
   b. country parameter.
   c. frequency reference input.
   d. V/f characteristic.

Ramp and Torque Boost

EXERCISE OBJECTIVE

- Understand the acceleration and deceleration time settings.
- Introduce the linear and S-shape acceleration and deceleration patterns.
- Introduce the Torque 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. See Figure 1-10.

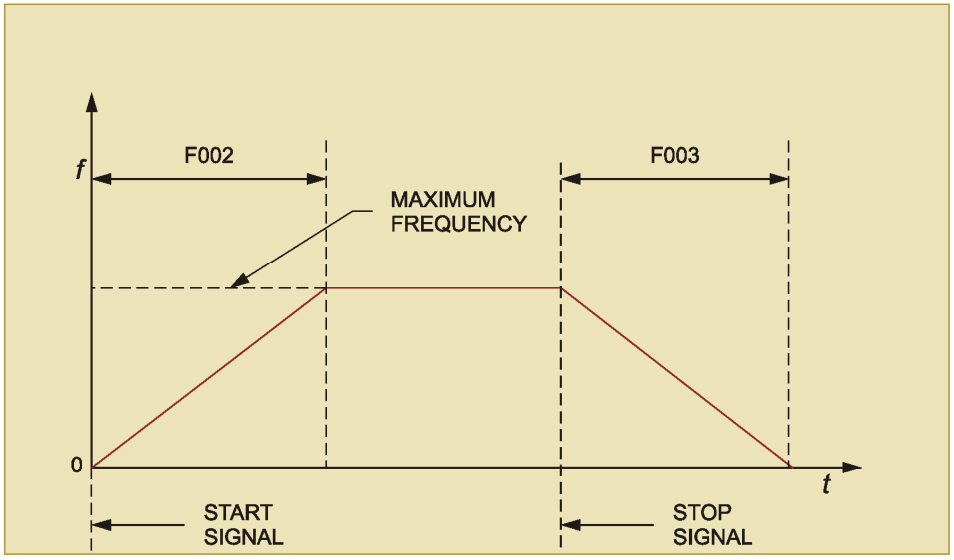


Figure 1-10. Acceleration/deceleration ramps.

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* and *Deceleration time* functions are set using parameters F002 and F003. The characteristics of these parameters are shown in Table 1-8.

PARAMETER	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 pattern selection*	00: Line 01: S-shape curve	00
A098	*Deceleration pattern selection*	00: Line 01: S-shape curve	00

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

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 pattern, its rate of change until it reaches full speed, or comes to a complete stop, is linear. See Figure 1-11.

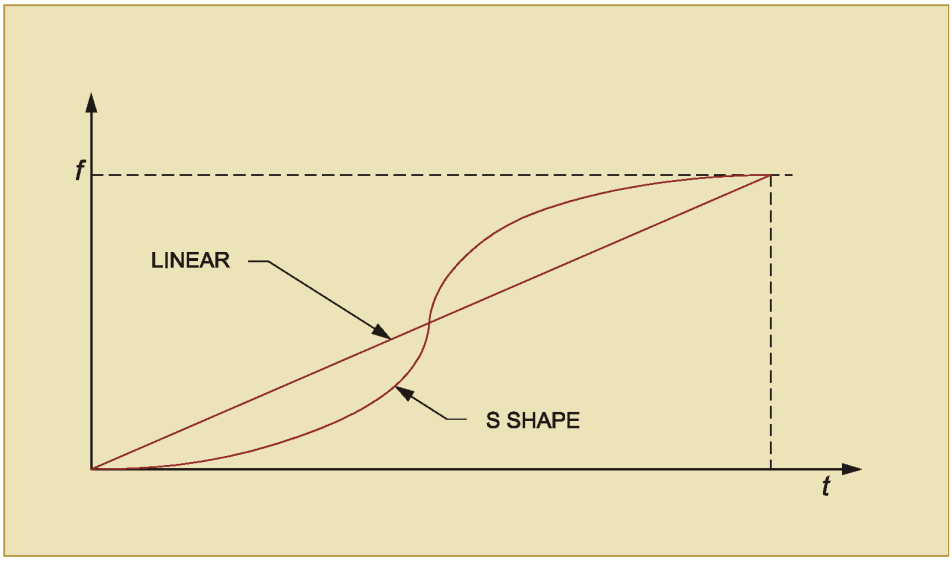


Figure 1-11. Linear and S-shape patterns during acceleration.

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

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 of 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.

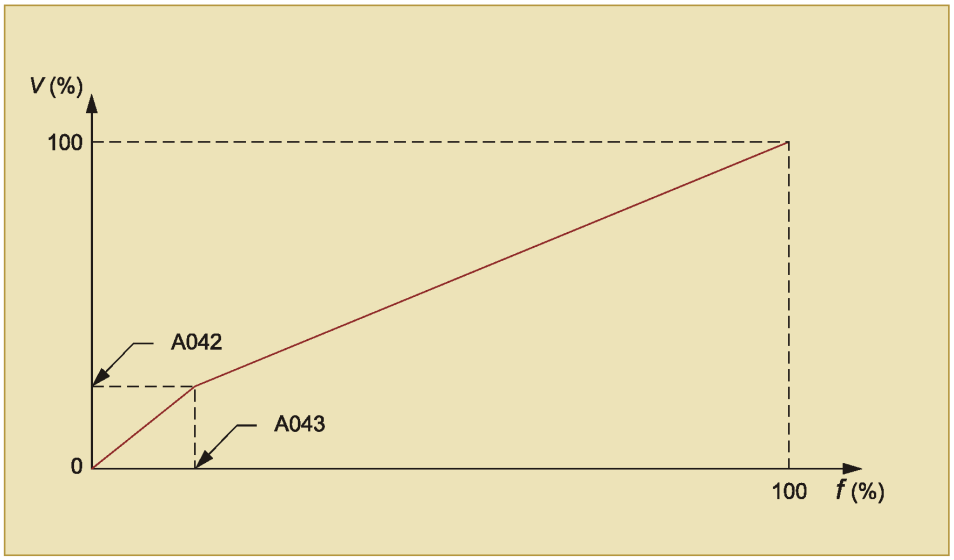


Figure 1-12. Torque boost.

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 1-9.

PARAMETER	FUNCTION	VALUE	DS
A041	*Torque boost selection*	00: Manual 01: Automatic	00
A042	*Manual torque boost voltage*	0 to 20 % of output voltage	5.0
A043	*Manual torque boost frequency*	0 to 50 % of base frequency	2.5

Table 1-9. Characteristics of parameters 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-shape acceleration patterns.

In the third part, you will observe the torque boost characteristics. You will plot the output voltage versus output frequency curve with and without torque 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 FV and FC on the AC Drive.

Perform the Energizing procedure.

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

- Restore the default setting of the parameters by performing the Initialization procedure;
- Select *Terminal* as *Frequency reference selection* function by setting parameter A001 to 01;
- Set the AC Drive to display the output voltage by selecting parameter d013.

☐ 6. 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 400 V depending on your local network). Repeat the measurement to validate your results.

Acceleration time: _____

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

☐ Yes ☐ No

☐ 8. 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 results.

Deceleration time: _____

☐ 9. Does this correspond to the default setting of the *Declaration time* (F003)?

☐ Yes ☐ No

☐ 10. 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.

☐ 11. Turn off the Lockout Module.

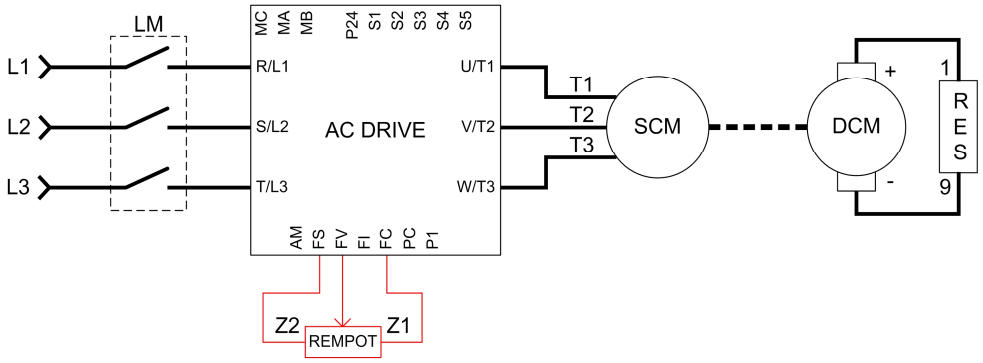
Acceleration characteristic

☐ 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 (BRAKE MOTOR)

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

☐ 14. Turn on the Lockout Module.

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

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

Make sure that the *Acceleration pattern selection* function (A097) is set to Line. Set the AC Drive to display the output frequency by selecting parameter 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 the measurements to validate your 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 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)		

Table 1-10. Linear and S-shape acceleration patterns.

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

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

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

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

☐ 20. 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.

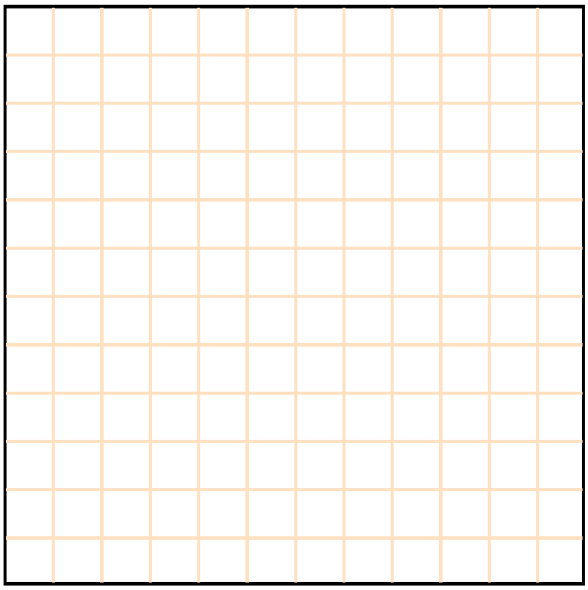


Figure 1-14. Linear and S-shape acceleration patterns.

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

☐ Yes ☐ No

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

☐ Yes ☐ No

☐ 23. Set the *Acceleration pattern selection* function to Line by setting parameter A097 to 00.

Torque boost

☐ 24. Make sure that the *Torque boost selection* function is set to Manual torque boost (parameter A041 : 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.

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

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.

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

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

Table 1-11. Torque boost characteristics.

☐ 26. 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.

☐ 27. For all voltage setpoint values shown in Table 1-11, 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 1-11.

☐ 28. 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.

☐ 29. For all voltage setpoint values shown in Table 1-11, 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 1-11.

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

☐ 31. 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.

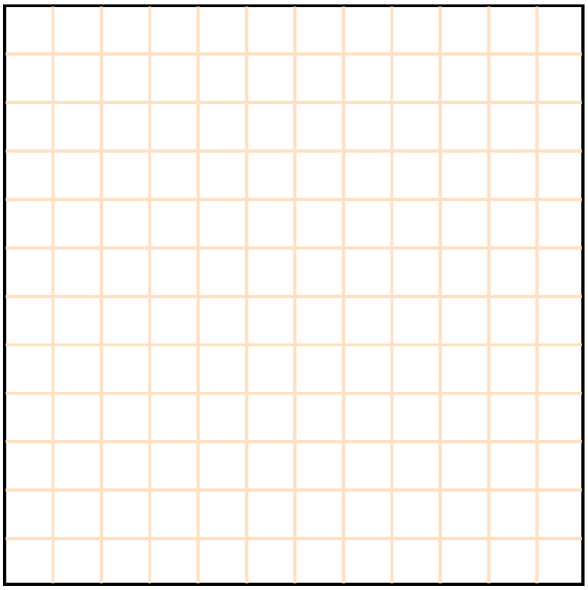


Figure 1-15. With and without torque boost characteristics.

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

Frequency where the torque boost is maximum: _____

☐ 33. Does the torque boost correspond to approximately 20% the output voltage 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 line 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.

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.

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.

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.

Protection

EXERCISE OBJECTIVE

- Learn how to limit motor current.
- Introduce the overload alarm signals.
- Introduce overvoltage during deceleration protection.
- Learn how to configure a multi-function output.

DISCUSSION

Most drives have the capability to detect a fault condition. There may be a defect in the drive circuitry, a problem with the motor, the power supply, an unexpected load condition, etc.

The AC Drive of your training system features several built-in monitoring functions. To protect against damage, the AC Drive is automatically inhibited when a fault signal is detected. The connected motor then coasts to a halt, the fault signal is indicated by the red ALARM LED indicator, and the data display shows an error code. An emergency mechanical friction brake is installed when necessary.

The AC Drive remains inhibited until the fault message is acknowledged.

Limiting motor current

The AC Drive can limit the motor current by reducing the output frequency. The output current limit is set using the *Overload limit level* function, parameter b022. The time taken by the AC Drive to reduce the frequency at a secure level is set by the *Overload limit parameter* function, parameter b023. See Figure 1-16.

The *Overload limit selection* function determines when the *Overload limit level* function is applied. The selection is done using parameter b021. The characteristics of parameters b021, b022 and b023 are shown in Table 1-12.

PARAMETER	FUNCTION	VALUE	DS
b021	*Overload limit selection*	00: Disabled 01: Enabled in acceleration/constant speed operation 02: Enabled in constant speed operation	01
b022	*Overload limit level*	0.1 × rated current to 1.5 × rated current	1.5 × rated current
b023	*Overload limit parameter*	0.1 to 3000 s	1.0
C041	*Overload warning level*	0.1 × rated current to 2.0 × rated current	Rated current

Table 1-12. Characteristics of parameters b022, b023, and C041.

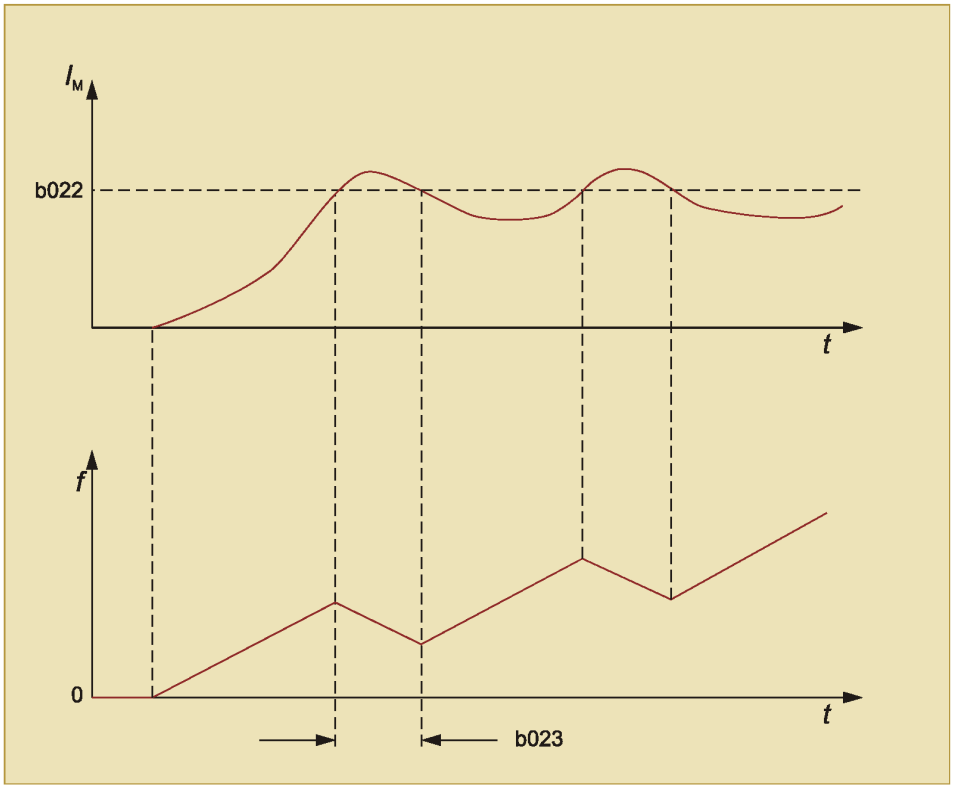


Figure 1-16. Limiting motor current.

Overload alarm signal

The AC Drive can output an overload alarm signal when the *Overload warning level* function, parameter C041, is exceeded. See Figure 1-17. The overload signal can be output through a multi-function output terminal (P11) or the relay M (MA, MB, MC). The characteristics of parameter C041 are shown in Table 1-12.

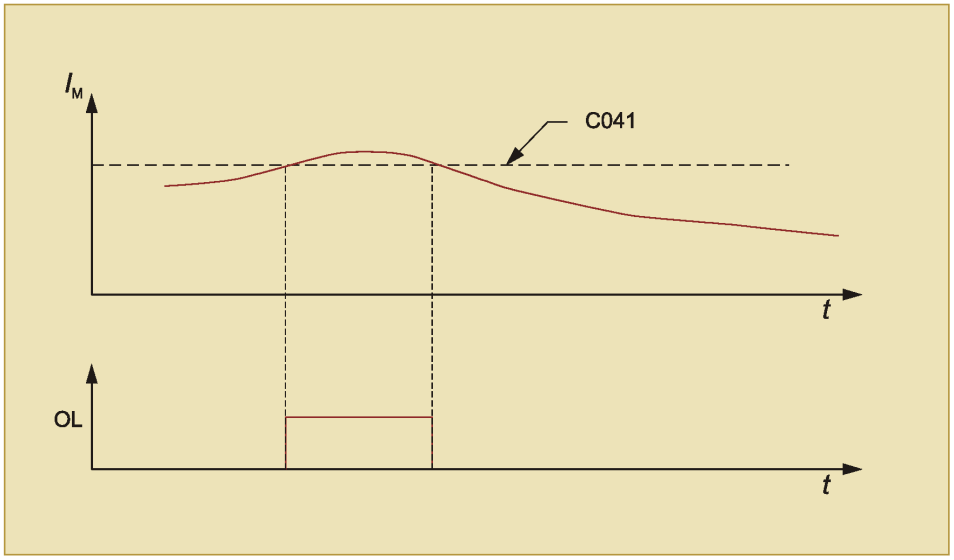


Figure 1-17. Overload function chart.

Overvoltage during deceleration

Excessively short deceleration ramps or high-inertia loads can cause unsynchronized operation during deceleration. The motor then works regeneratively and charges up the internal DC link. Excessive voltage during deceleration results in fault signal (Overvoltage trip, error code E07).

Multi-function output

Multi-function output P1 is configurable to signal various operating conditions. It can signal when a determined reference frequency is reached, or when a fault occurs, as examples. The operating conditions are selected by parameter C021. The characteristics of the parameters are shown in Table 1-13.

PARAMETER	FUNCTION	VALUE	DS
C021	*Multi-function output terminal P1 selection*	00: RUN (signal during RUN) 01: FA1 (constant speed arrival signal) 02: FA2 (over set frequency arrival signal) 03: OL (overload warning) 04: OD (excessive PID deviation) 05: AL (alarm output) 06: Dc (disconnection detection) 07: FBV (PID FB status output) 08: NDc (network error) 09: LOG (logic operation output) 10: ODc (Do not use.) 43: LOC (light load detection signal)	00

Table 1-13. Characteristics of parameter C021.

Procedure Summary

In the first part of this exercise, you will set the *Overload limit level* function, and observe that the AC Drive limits the output frequency when the current reaches the overload limit setting.

In the second part, you will observe that an overload signal can be produced to indicate an overload condition without stopping the motor.

In the last part, you will observe the effect of an overvoltage during deceleration.

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

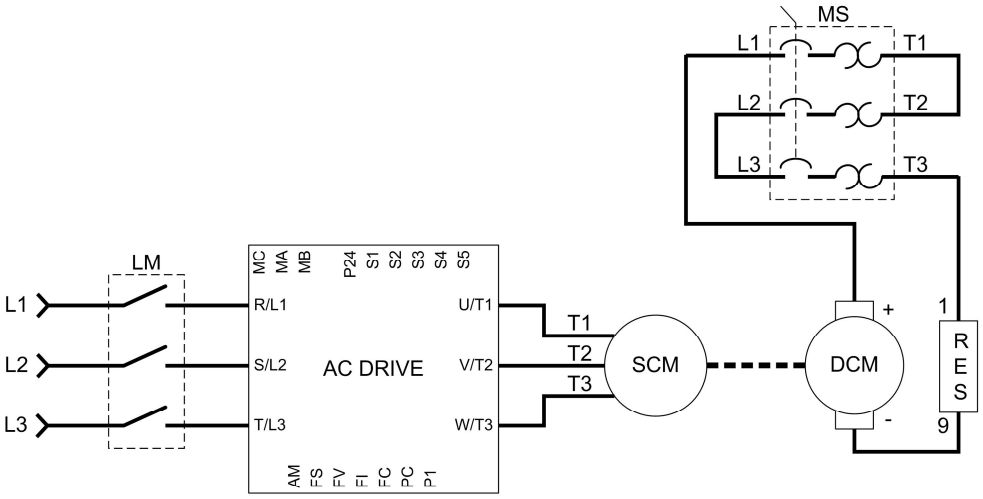
☐ 1. Perform the Basic Setup and Lockout/Tagout procedures.

Limiting motor current

☐ 2. Couple the DC Motor with the Brake Motor as described in Appendix F.

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

☐ 3. Set up the circuit shown in Figure 1-18.



LEGEND

AC DRIVE	=	THREE-PHASE AC DRIVE
DCM	=	DC MOTOR
LM	=	LOCKOUT MODULE
MS	=	MANUAL STARTER
RES	=	LOAD RESISTOR
SCM	=	SQUIRREL CAGE MOTOR

Figure 1-18. Circuit using the DC Motor with the Starting Resistors modules as load.

☐ 4. Manually disengage the friction brake.

Perform the Energizing procedure.

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

- Restore the default setting of the parameters by performing the Initialization procedure;
- Set the AC Drive to display the output current by selecting parameter d002;
- Turn the FREQ. adjuster fully clockwise.

☐ 6. Set the Manual Starter to the O position (without load).

Set the AC Drive to the run mode.

Enter the current value without load shown on the data display of the AC Drive after 10 seconds.

Current value without load: _____

☐ 7. Set the Manual Starter to the I position (with load).

Wait until the motor stabilizes, then enter the current value with load shown on the data display of the AC Drive.

Current value with load: _____

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

☐ 9. Read the default setting of the *Overload limit level*, parameter b022. Does this value correspond to 1.5 times the rated current (default setting of parameter C041)?

☐ Yes ☐ No

☐ 10. Referring to the current value with load you measured, how will the motor operation be affected by the *Overload limit level*, when this parameter (b022) is set to the default value? Explain.

_____

_____

☐ 11. Subtract 0.2 A from the current value with load you measured, and set the *Overload limit level* function, parameter b022, to the value obtained.

Set the *Overload limit parameter* function, parameter b023, to 5.0 s.

Set the *Overload limit selection* function, parameter b021, to 02 in order to disable the overload limit functions during the acceleration of the motor.

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

☐ 12. Set the Manual Starter to the O position (without load).

Set the AC Drive to the run mode.

Is the output frequency limited by the *Overload limit parameter*?

☐ Yes ☐ No

☐ 13. What will happen if the Manual Starter is set to the I position (with load) at this moment?

_____

_____

☐ 14. Set the Manual Starter to the I position (with load).

Does the frequency displayed by the data display on the AC Drive confirm your prediction?

☐ Yes ☐ No

☐ 15. Set the AC Drive to display the output current by selecting parameter d002.

Does the value correspond to the setting of the *Overload limit level* function (parameter b022)?

☐ Yes ☐ No

☐ 16. Set the AC Drive to display the output frequency by selecting parameter d001.

Set the Manual Starter to the O position (without load).

What happens to the frequency displayed by the AC Drive?

_____

_____

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

Set the *Overload limit level*, parameter b022, to the default setting.

Overload alarm signal

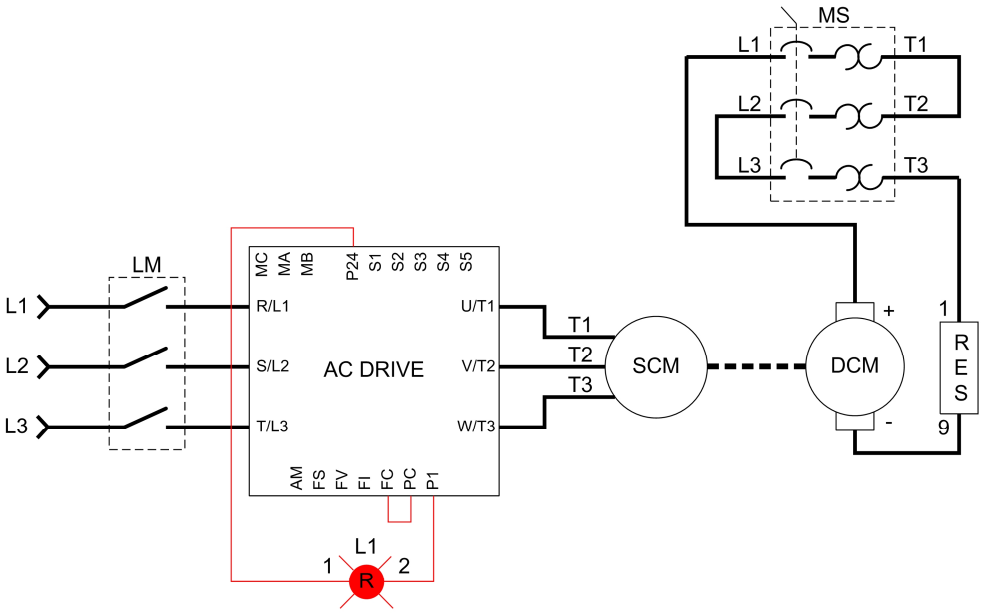
☐ 18. Modify your circuit to add a pilot light as shown in Figure 1-19.

☐ 19. Set the *Overload warning level* function, parameter C041, to the current value with load you measured earlier minus 0.2 A.

Set the *Multi-function output terminal P1 selection* function to OL (overload warning) by setting parameter C021 to 03.

Set the AC Drive to display the output current by selecting parameter d002.

☐ 20. Set the Manual Starter to the O position (without load).



LEGEND

AC DRIVE	=	THREE-PHASE AC DRIVE
DCM	=	DC MOTOR
L1	=	PILOT LIGHT #1 (RED)
LM	=	LOCKOUT MODULE
MS	=	MANUAL STARTER
RES	=	LOAD RESISTOR
SCM	=	SQUIRREL CAGE MOTOR

Figure 1-19. Circuit with a pilot light.

☐ 21. Set the AC Drive to the run mode, and wait for the motor to reach full speed before proceeding with the next step.

Does the pilot lamp turn on to indicate that the setting of the *Overload warning level* function has been reached?

☐ Yes ☐ No

☐ 22. Does the current value displayed by the AC Drive equal or exceed the setting of the *Overload warning level* function?

☐ Yes ☐ No

☐ 23. Set the Manual Starter to the I position (with load).

☐ 24. Does the pilot lamp turn on to indicate that the setting of the *Overload warning level* function has been exceeded?

☐ Yes ☐ No

☐ 25. Does the current value displayed by the AC Drive equal or exceed the *Overload warning level* setting?

☐ Yes ☐ No

☐ 26. Does the motor stop when the pilot lamp indicates that the setting of the *Overload warning level* function has been exceeded?

☐ Yes ☐ No

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

Set the *Overload warning level*, parameter C041, to the default setting.

Overvoltage during deceleration

☐ 28. Set the *Deceleration time* to 0.4 s by setting parameter F003 to 0.40.

☐ 29. Set the AC Drive to the run mode.

After a 10s delay, set the AC Drive to the stop mode. Describe what happens.

_____

_____

☐ 30. What is the meaning of the error code displayed by the AC Drive?

_____

_____

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

☐ 32. 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 observed that the AC Drive limits the output frequency to not exceed the *Overload limit level* setting. You saw that an overload signal can be produced to indicate an overload condition. You also observed the effect of an overvoltage during deceleration.

REVIEW QUESTIONS

1. How does the *Overload limit level* parameter limit the motor current?

   a. Stopping the motor
   b. Reducing the voltage
   c. Reducing the current
   d. Reducing the frequency

2. What parameter determines the level at which an overload alarm is output through a multi-function output?

   a. *Overload limit parameter*, parameter b023
   b. *Overload limit level*, parameter b022
   c. *Overload warning level*, parameter C041
   d. *Multi-function output terminal P1 selection*, parameter C021

3. Which error code is associated with an overvoltage during deceleration?

   a. E03
   b. E05
   c. E07
   d. E09

4. What can be done to prevent an overvoltage during deceleration?

   a. Increase the deceleration time
   c. Reduce the deceleration time
   c. Increase the acceleration time
   d. Reduce the acceleration time

Braking and Jogging

EXERCISE OBJECTIVE

- Familiarize yourself with mechanical and DC braking.
- Learn how to set up a jogging circuit.

DISCUSSION

One method of quickly stopping a motor and the load to which it is mechanically coupled is to use the deceleration function of the drive. However, if the inertia of the load is too large, it will overcome the magnetic field strength of the stator coil; the motor will rotate faster than the synchronous speed of the rotating stator field. When the synchronous speed drops below the actual speed of the coasting load, the motor becomes a three-phase generator and feeds voltage back into the drive.

To provide braking that cannot be achieved by the deceleration function, the AC Drive of your training system allows the following braking methods:

- Mechanically by actuating an external mechanical friction brake;
- Electrically by applying direct current to the three-phase motor, called DC braking.

Mechanical friction brake

The actuation of the Brake Motor friction brake can be controlled using relay M on the AC Drive. When a fault occurs, the relay coil is deactivated, causing normally-closed contact MA-MC to open. The opening of contact MA-MC deactivates the brake coil of the Brake Motor though control relay CR, causing the friction brake to be applied.

Refer to the manual Basic Controls, part number 39163, for more information about friction brakes.

DC braking

DC braking consists in applying a pulsed DC voltage to the motor stator. A braking torque, acting against the rotation of the motor, is then induced in the rotor. With DC braking, a high level of stopping and positioning accuracy can be achieved.

DC braking can apply a braking force to hold the motor after the motor is stopped, however it is not suitable for holding loads, or taking the place of a friction brake in applications requiring the motor shaft to be held for long periods. Once DC braking is activated, the output frequency of the AC Drive returns to zero and the motor

comes to a standstill. Note that DC braking causes increased heat dissipation in the motor.

The DC braking functions are set using parameters A051 to A056. The characteristics of parameters A051 and A054 are shown in Table 1-14.

PARAMETER	FUNCTION	VALUE	DS
A051	*DC injection braking*	00: disabled 01: enabled 02: frequency control (A052 set value)	00
A054	*DC injection braking power*	0 to 100%	50

Table 1-14. Characteristics of parameters A051 and A054.

Figure 1-20 shows a comparison of the time taken by a motor to stop, using different braking methods.

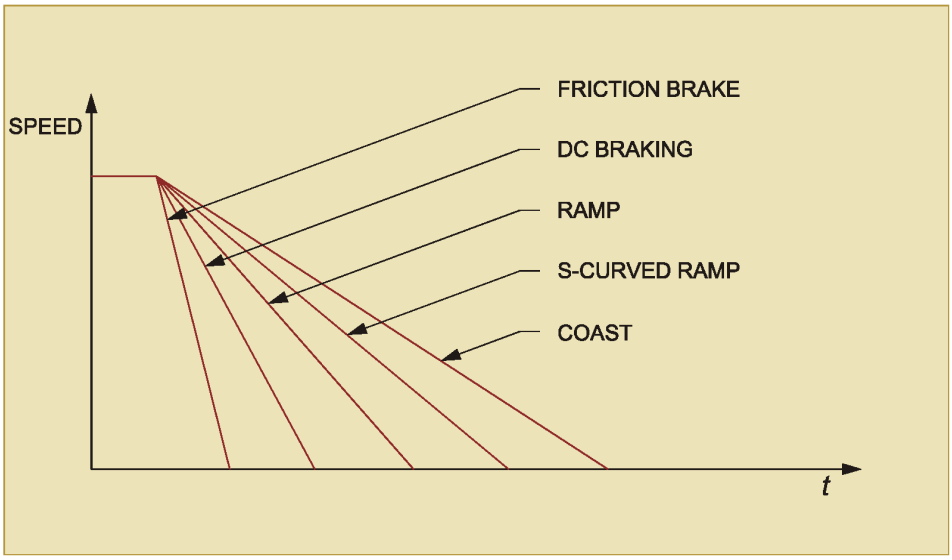


Figure 1-20. Braking time comparison.

Jog mode

To use the jog mode, select the jogging (JG) function for one of the multi-function inputs of the AC Drive. Then, if a start signal is applied to that input, a relatively low frequency without acceleration ramp is applied to the motor.

You can set the jog frequency under the *Jogging frequency*, parameter A038. Make sure that the frequency is not too high, as it is applied directly to the motor without acceleration ramp. See Figure 1-21.

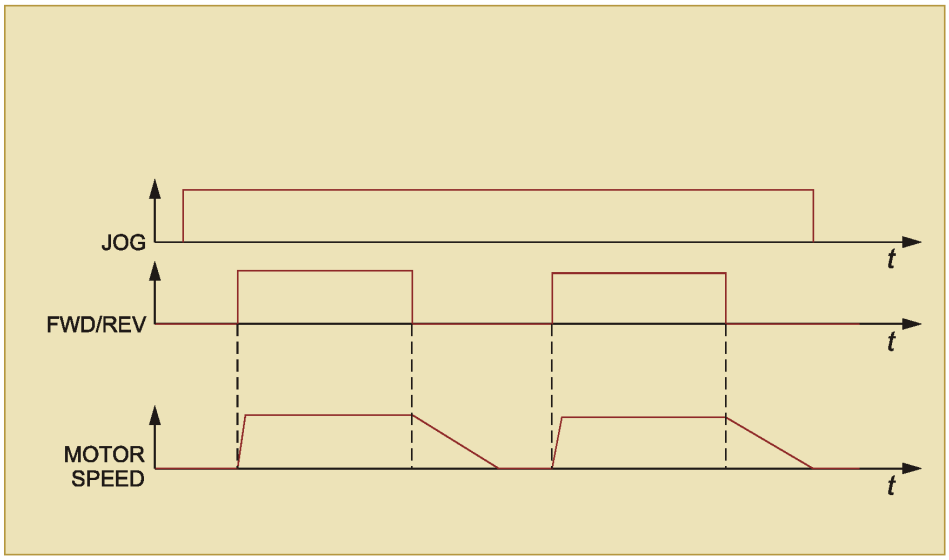


Figure 1-21. Function chart for the jogging mode.

Refer to the manual Basic Controls, part number 39163, for more information about jogging.

The jogging functions are set using parameters A038 and A039. The characteristics of these parameters are shown in Table 1-15.

PARAMETER	FUNCTION	VALUE	DS
A038	*Jogging frequency*	0.0/0.0 to 9.99 Hz	6.00
A039	*Jogging stop*	00: Free-run stop 01: Deceleration time 02: DC injection braking stop	00

Table 1-15. Characteristics of parameters A038 and A039.

Multi-function inputs

Multi-function inputs 1 to 5 are configurable for many functions. They can be configured to start and stop the motor, select the rotation direction, jogging, etc. They can be triggered by a low or high level signal depending on the setting of parameters C011-C015.

The multi-function inputs are set using parameters C001-C005 and C011-C015. The characteristics of these parameters are shown in Table 1-16.

PARAMETER	FUNCTION	VALUE	DS
C001	*Multi-function input 1*	00: FW (forward) 01: RV (reverse) 06: JG (jogging) 07: DB (external DC injection braking) 11: FRS (free-run stop 12: EXT (external trip) 18: RS (reset)	00
C002	*Multi-function input 2*		01
C003	*Multi-function input 3*		18
C004	*Multi-function input 4*		12
C005	*Multi-function input 5*		02
C011 to C015	*Multi-function input 1 to 5 - operation (logic)*	00: NO (high signal triggers switching) 01: NC (low signal triggers switching)	00

Table 1-16. Characteristics of parameters C001 to C005 and C011 to C015.

Procedure Summary

In the first part of this exercise, you will set up a circuit using an emergency button to control the application of a friction brake. You will configure a multi-function input to trigger on a low level signal.

In the second part, you will familiarize yourself with DC braking. You will observe that the braking is effective in both directions by rotating the Inertia Wheel manually. You will also apply DC braking while the motor is running at full speed.

In the last part, you will familiarize yourself with the jog mode parameters.

EQUIPMENT REQUIRED

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

⚠ 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.

Mechanical friction brake

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

☐ 3. Set up the circuit shown in Figure 1-22.

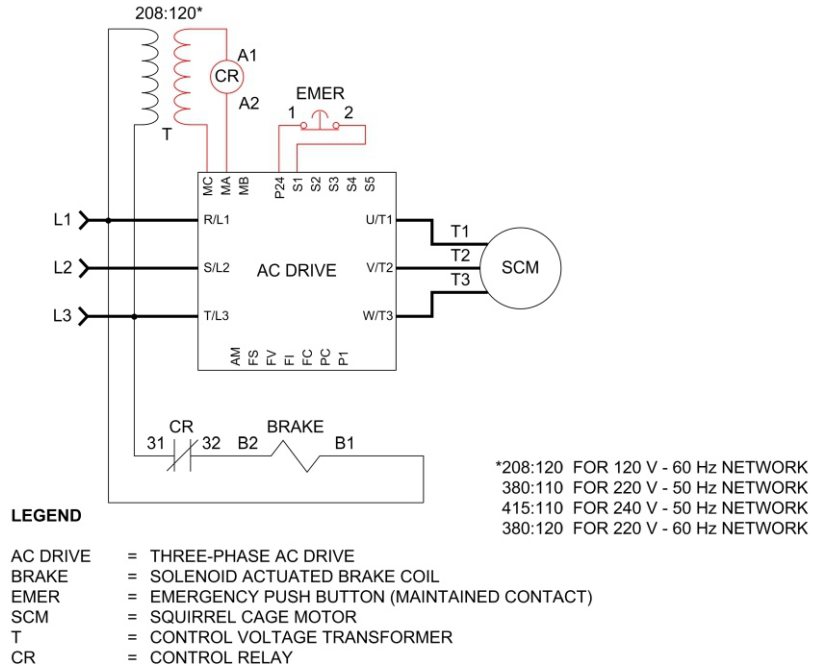


Figure 1-22. Circuit with emergency button and mechanical friction brake.

☐ 4. Press the Emergency Button.

Perform the Energizing procedure.

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

- Restore the default setting of the parameters by performing the Initialization procedure;
- Select *EXT (external trip)* for Multi-function input 1 by setting parameter C001 to 12;
- Select NC (normally closed) for Multi-function input 1 operation by setting parameter C011 to 01. This will cause Multi-function input 1 to trigger on low level signal. Since the Emergency Button is actuated, a fault signal should occur at this moment. This is because Multi-function input 1 detects a low level signal, indicating a fault condition. Release the Emergency Button to clear the fault condition;
- Press the STOP/RESET key to reset the fault signal;
- Turn the FREQ. adjuster fully clockwise;
- Set the AC Drive to the run mode.

☐ 6. Once the motor is rotating at full speed, press the Emergency Button.

Describe what happens, and explain why.

_____

_____

_____

☐ 7. Release the Emergency Button to clear the fault condition.

Set parameter PNU C001 to 00.

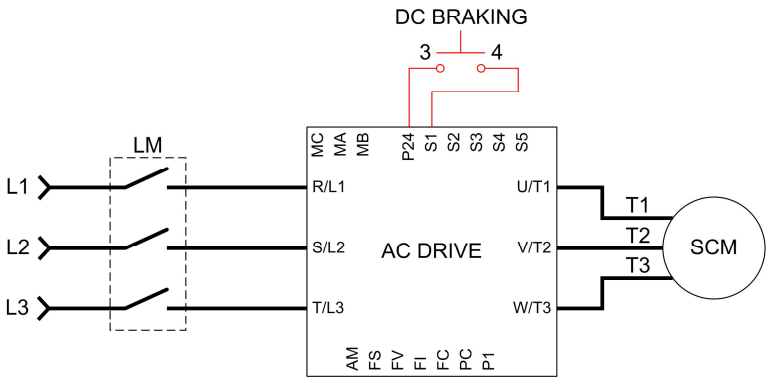
Restore the default setting of the parameters of the AC Drive by performing the Initialization procedure.

Turn off the Lockout Module.

Manually disengage the friction brake.

DC braking

☐ 8. Modify your circuit as shown in Figure 1-23.



LEGEND

AC DRIVE	=	THREE-PHASE AC DRIVE
DC BRAKING	=	DC BRAKING PUSH BUTTON (MOMENTARY CONTACT)
LM	=	LOCKOUT MODULE
SCM	=	SQUIRREL CAGE MOTOR

Figure 1-23. DC braking circuit.

☐ 9. Turn on the Lockout Module.

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

- Select *DB (external DC injection braking*) for Multi-function input 1 by setting parameter C001 to 07;
- Enable the *DC braking injection* by setting parameter A051 to 01;
- Set the *DC injection braking power* to 100% by setting parameter A054 to 100;
- Set the AC Drive to display the output frequency by selecting parameter d001.

☐ 11. Do not start the motor at this moment.

Remove the Safety Guard.

Do you feel the braking effect when you manually rotate the Inertia Wheel?

☐ Yes ☐ No

☐ 12. Press and hold the DC BRAKING push button to apply the DC braking.

Note: *If the ambient noise level in your laboratory is low, you might hear the high frequency noise generated by the DC braking.*

Do you feel the braking effect when you manually rotate the Inertia Wheel?

☐ Yes ☐ No

☐ 13. Is the DC braking effective in both directions of rotation?

☐ Yes ☐ No

☐ 14. Release the DC BRAKING push button.

Install the Safety Guard.

Set the AC Drive to the run mode. Turn the FREQ. adjuster of the AC Drive fully clockwise.

☐ 15. Wait for the motor to rotate at full speed.

Observe the AC Drive display as you press and hold the DC BRAKING push button.

How does the output frequency vary when the DC BRAKING push button is pressed?

_____

_____

☐ 16. Set the AC Drive to the run mode.

☐ 17. Wait for the motor to rotate at full speed.

Describe what happens when you press the DC BRAKING push button briefly and then release it.

_____

_____

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

☐ 19. Turn off the Lockout Module.

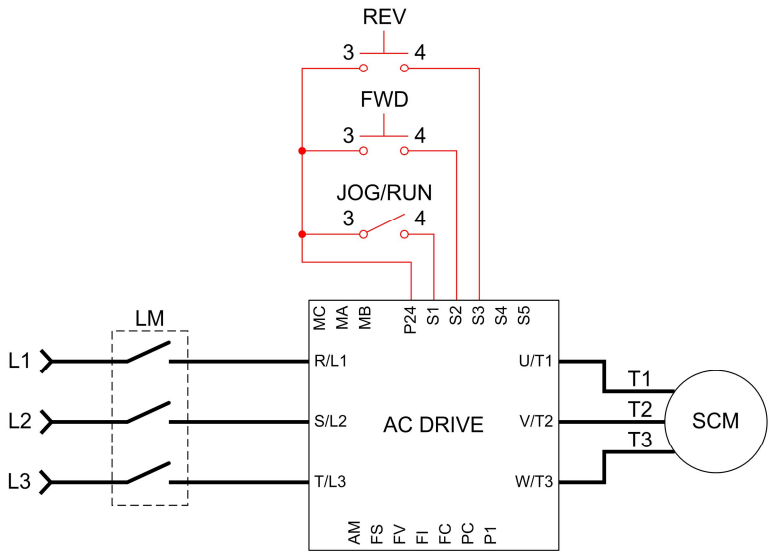
Jog mode

☐ 20. Set up the circuit shown in Figure 1-24.

☐ 21. Identify your circuit with magnetic labels, and turn on the Lockout Module.

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

- Restore the default setting of the parameters by performing the Initialization procedure;
- Select Terminal as *Run command selection* function by setting parameter A002 to 01;
- Select JG (jogging) as function for *Multi-function input 1* by setting parameter C001 to 06;
- Select FW (forward) as function for *Multi-function input 2* by setting parameter C002 to 00;
- Select RV (reverse) as function for *Multi-function input 3* by setting parameter C003 to 01;
- Set the *Jogging frequency* function to 8 Hz by setting parameter A038 to 8.00.



LEGEND

AC DRIVE	=	THREE-PHASE AC DRIVE
FWD	=	FORWARD PUSH BUTTON (MOMENTARY CONTACT)
JOG/RUN	=	JOG/RUN SELECTOR SWITCH (MAINTAINED CONTACT)
LM	=	LOCKOUT MODULE
REV	=	REVERSE PUSH BUTTON (MOMENTARY CONTACT)
SCM	=	SQUIRREL CAGE MOTOR

Figure 1-24. Jogging circuit.

☐ 23. Set the JOG/RUN selector of the Switches module to the RUN position (O).

Make sure that the FREQ. adjuster is turned fully clockwise.

Describe what happens when you press and hold the FWD push button of the Switches module.

_____

_____

☐ 24. Release the FWD push button.

Set the JOG/RUN selector to the JOG position (L).

Describe what happens when you press and hold the FWD push button.

_____

_____

☐ 25. Describe what happens when you release the FWD push button.

_____

_____

☐ 26. By which method does the motor stop?

☐ Free running (free coasting) ☐ Deceleration time ☐ DC Braking

☐ 27. Describe what happens when you press and hold the REV push button.

_____

_____

☐ 28. Does this correspond to the Jog mode of operation?

☐ Yes ☐ No

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

☐ 30. 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 set up a circuit using a friction brake controlled by an emergency button. You configured a multi-function input to trigger on a low level signal and you used a relay to control the motor-brake operation. You experienced DC braking, and observed that the braking is effective in both directions. In the last part you set the parameters of a jogging circuit.

REVIEW QUESTIONS

1. DC braking

   a. causes increased heat dissipation in the motor.
   b. consists in applying a pulsed DC voltage to the motor rotor.
   c. is suitable for holding loads.
   d. does not affect the output frequency.

2. In the circuit shown in Figure 1-24, what should be done to use a normally closed pushbutton instead of a normally open pushbutton as the REV push button?

   a. Multi-function input 2 must be configured to trigger on a high level signal.
   b. Multi-function input 2 must be configured to trigger on a low level signal.
   c. Multi-function input 3 must be configured to trigger on a high level signal.
   d. Multi-function input 3 must be configured to trigger on a low level signal.

3. What happens when the load rotates faster than the synchronous speed of the rotating stator field in deceleration mode?

   a. A fault signal will occur and the motor will continue to rotate.
   b. The motor becomes a three-phase generator and feeds voltage back into the drive.
   c. The load cannot rotate faster than the synchronous speed of the rotating stator field in deceleration mode.
   d. Nothing.

4. What is(are) the available braking method(s) in jog mode?

   a. free running (free coasting)
   b. deceleration time
   c. DC braking
   d. All of the answers above are correct.

5. Which parameter sets the rotation speed of the motor in jog mode?

   a. A038
   b. A039
   c. C001
   d. C011

Remote Controls

EXERCISE OBJECTIVE

- Implement a remote control circuit.

DISCUSSION

As seen, motor drives can be controlled locally or remotely. In the remote control mode, the frequency is controlled by an external potentiometer connected at the motor drive control terminals. External control switches can also be used to control the rotation direction, start and stop functions, and many other operating parameters.

Procedure Summary

In this exercise, you will design a remote control circuit.

Referring to a project description, you will select the equipment, draw the schematic diagram of the circuit, set up the circuit, configure the AC Drive, and test the circuit.

If you have some spare time, you will modify the remote control circuit to add an emergency button, and a push button to apply DC braking.

EQUIPMENT REQUIRED

The list of equipment required for this exercise is part of the work to be done.

PROCEDURE

⚠ WARNING

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

Project description

Your client wants to remotely control the operation of a motor (Brake Motor). The remote controls that he asked for are:

- A potentiometer to control the speed of the motor;
- A green push button to start the motor;
- A red push button to stop the motor;
- A selector switch to control the direction of rotation;
- A green pilot light to indicate when the motor is running.

Tips

- Select *Terminal* as *Frequency reference selection*. See parameter A001 in Appendix F;
- Select *Terminal* as *Run command selection*. See parameter A002 in Appendix F;
- Use the *STA (3-wire start)*, *STP (3-wire stop)*, and *F/R (3-wire forward/reverse)* functions for the multi-function inputs receiving the motor control signals. See parameter C001 in Appendix F;

> **Note:** *The "STP (3-wire stop)" function, requires an enabled signal for motor operation (wire breakage causes automatic motor stop).*

- Select *RUN (signal during RUN)* as *Multi-function output terminal P1 selection* to control the green pilot light. See parameter C021 in Appendix F.

Equipment selection

Select the equipment required in Table 1-17.

EQUIPMENT		
MODEL	**DESCRIPTION**	**SELECTION**
3103-3	Mobile Workstation	
3112	Switches	
3114	Emergency Button	
3115-A	Pilot Lights	
3125	Lockout Module	
3126	Manual Starter	
3140-3	Cam Switch	
3147-1	Inertia Wheel	
3150-1	Starting Resistors	
3165-1	Power Diodes	
3176-A	Brake Motor	
3179-2	DC Motor	
3183	AC Drive	
3184	DC Drive	
3196	AC Power Supply	
8951-8	Connection Leads	
8951-E	Connection Leads	
38503	Magnetic Labels	

Table 1-17. Equipment list.

Schematic diagram of the circuit

Draw the schematic diagram of the circuit in Figure 1-25.

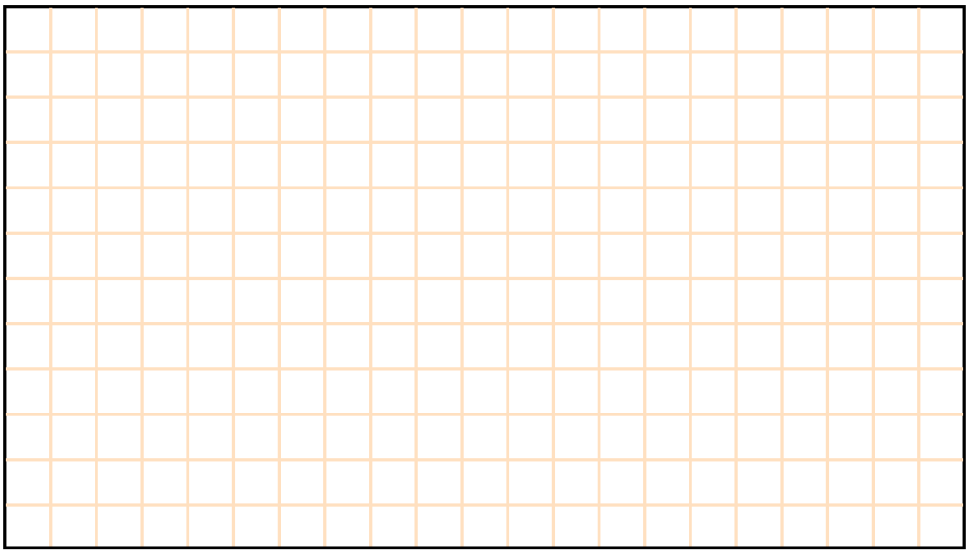


Figure 1-25. Schematic diagram of the circuit.

Circuit setup

Set up the circuit you designed. Identify the controls with magnetic labels.

AC Drive parameter values

Enter the AC Drive parameter values to configure in Table 1-18.

FUNCTION NAME AND PARAMETER NUMBER	VALUE

Table 1-18. Parameters to configure.

Configure the AC Drive parameters with the values shown in Table 1-18.

Circuit approval

Test your circuit to make sure that all controls operate as desired by your client.

Once your circuit is approved, turn the individual power switch of the AC Power Supply off, disconnect the circuit, and return the equipment to the storage location.

Additional experiment

If you have some spare time, perform the following changes to your remote control circuit.

Add the following remote controls to your circuit:

- Add a push button to apply DC braking;
- Add the Emergency Button;

Set the following parameter values:

- Acceleration time: 5 s;
- Deceleration time: 8 s;
- Torque applied when braking: 80%.

Select the equipment to add in Table 1-19, draw the schematic diagram of the circuit in Figure 1-25, and enter the AC Drive parameter values that need to be configured in Table 1-20.

Set up and test the circuit.

Tips

- Select *DB (external DC injection braking*) as *Multi-function input selection* for the input receiving the motor braking control signal. See parameter C001 in Appendix F;
- Select *EXT (external trip) as Multi-function input selection* for the input receiving the signal from the Emergency Button. See parameters C001 and C011 in Appendix F.

EQUIPMENT		
MODEL	DESCRIPTION	SELECTION
3103-3	Mobile Workstation	
3112	Switches	
3114	Emergency Button	
3115-A	Pilot Lights	
3125	Lockout Module	
3126	Manual Starter	
3140-3	Cam Switch	
3147-1	Inertia Wheel	
3150-1	Starting Resistors	
3165-1	Power Diodes	
3176-A	Brake Motor	
3179-2	DC Motor	
3183	AC Drive	
3184	DC Drive	
3196	AC Power Supply	
8951-8	Connection Leads	
8951-E	Connection Leads	
38503	Magnetic Labels	

Table 1-19. Equipment list, additional equipment.

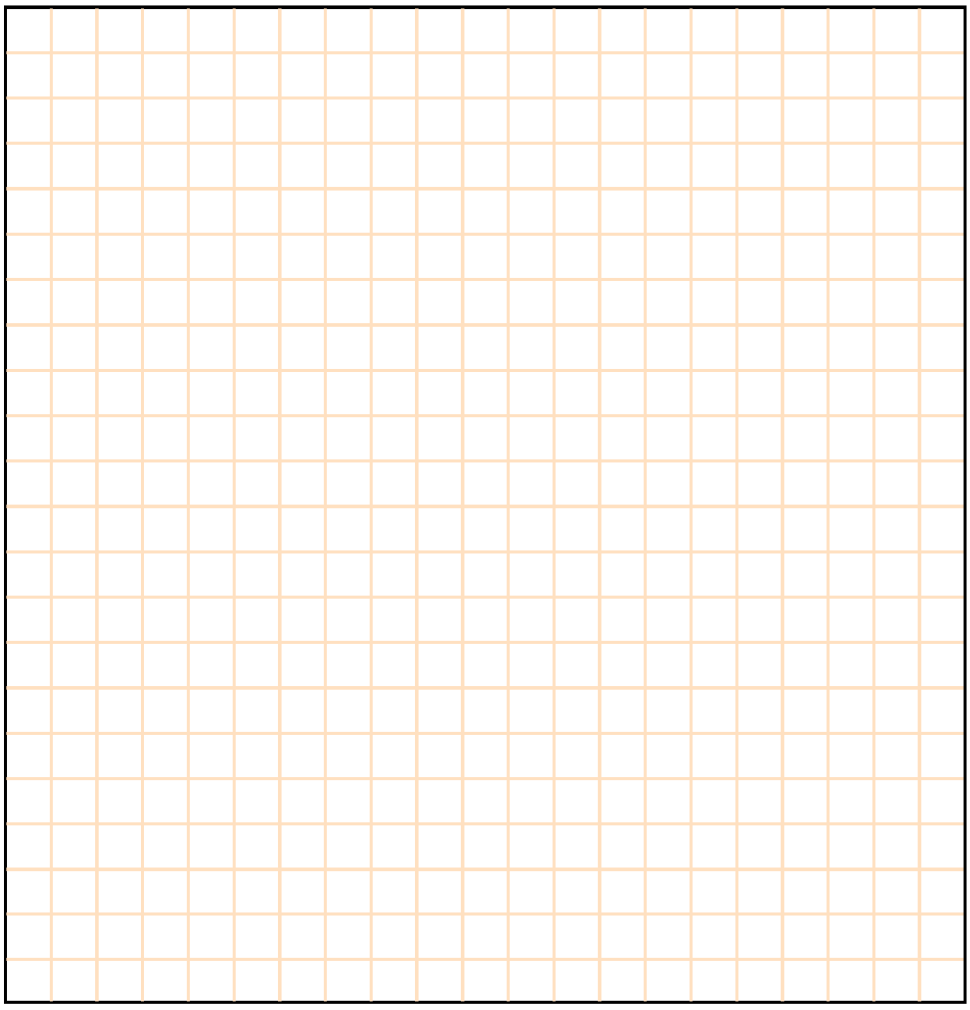


Figure 1-26. Schematic diagram of the circuit, additional experiment.

FUNCTION NAME AND PARAMETER NUMBER	VALUE

Table 1-20. Parameters to configure, additional experiment.

IMPORTANT

Before disconnecting the circuit, reset parameter PNU C001 to 00 and reset the AC Drive to its factory default. If this is not performed, the next user may have a "E12" error message "External fault message" because one of the inputs is configured to trip on an external low signal. This fault is difficult to clear if the user does not know which input is configured this way.

CONCLUSION

In this exercise, you designed a remote control circuit. Following a project description, you selected the equipment, drew the schematic diagram, set up the circuit, configured the AC Drive, and tested the circuit.

Unit Test

1. The quadratic V/f characteristic is used to energy-optimize the operation of pieces of equipment requiring

   a. slow speed.
   b. reduced starting torque.
   c. reduced starting frequency.
   d. reduced starting acceleration.

2. Which parameter controls the speed of an AC motor?

   a. Current
   b. Voltage
   c. Frequency
   d. All of the answers above are correct.

3. A decrease in frequency causes

   a. an increase in torque.
   b. a decrease in torque.
   c. an increase in speed.
   d. a decrease in speed.

4. Determine the number of pole pairs of an AC motor running at 500 r/min when 50 Hz is applied.

   a. 2
   b. 4
   c. 5
   d. 6

5. Which parameter controls the torque produced by an AC motor?

   a. Current
   b. Voltage
   c. Frequency
   d. All of the answers above are correct.

6. The linear V/f characteristic is mainly used for motors

   a. having a low rating.
   b. running at low speed.
   c. running at high speed.
   d. driving high inertia loads.

7. Short acceleration times are usually for

   a. heavy loads.
   b. light loads.
   c. heavy and light loads.
   d. All of the answers above are correct.

8. Name the two acceleration patterns

   a. Automatic and S-shape
   b. Linear and S-shape
   c. Manual and S-shape
   d. Linear and automatic

9. Why is it usually better not to use a high frequency in jogging mode?

   a. Because it is difficult to start the load at high speed.
   b. Because it is difficult to stop the load at high speed.
   c. Because the frequency is applied directly to the motor without deceleration ramp.
   d. Because the frequency is applied directly to the motor without acceleration ramp.

10. What happens when the AC Drive detects a fault signal?

    a. The ALARM LED turns on.
    b. An error code is displayed.
    c. The AC Drive is automatically inhibited.
    d. All of the answers above are correct.

DC Drives

UNIT OBJECTIVE

Upon completion of this unit, you will be able to use a DC Drive. You will know how to set the minimum and maximum speeds. You will learn how to limit the current supplied by the drive and how to compensate for the internal resistance of the motor.

DISCUSSION OF FUNDAMENTALS

DC motors are used in industrial applications that require variable speed control, high torque, or both. DC motors are used in many acceleration and deceleration applications because the speed of most DC motors can be controlled smoothly and easily from zero to full speed. In addition to having excellent speed control, DC motors are ideal in applications that call for momentarily high torque outputs.

A DC motor can deliver three to four times its rated torque for short periods of time. Most AC motors stall with a load that requires twice the rated torque.

Good speed control and high torque are the reasons why DC motors are used in running cranes, hoists, and large machine tools found in the mining industry. Figure 2-1 shows a DC Drive industrial application.

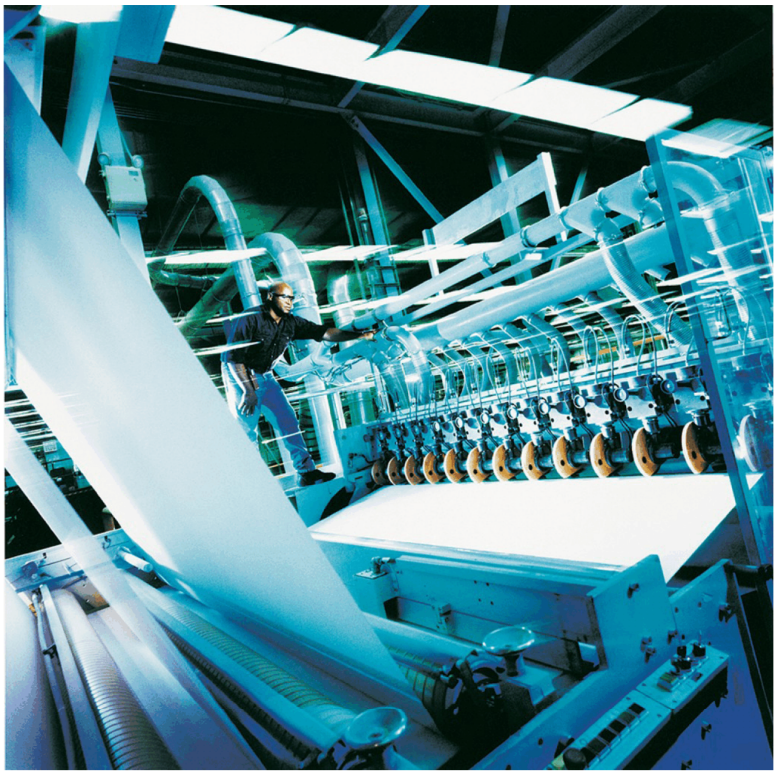


Figure 2-1. DC drives are used in paper mills for tension control (courtesy of Domtar).

The characteristics of the DC Motor supplied with your training system are shown on the motor nameplate, and in Appendix G.

DC Drive Overview

EXERCISE OBJECTIVE

- Familiarize yourself with the DC Drive.
- Set the DC Drive parameters to control the DC Motor.

DISCUSSION

The DC Drive of your training system is shown in Figure 2-2. It is a non-regenerative DC drive, the most conventional type in common use. It is capable of controlling motor speed and torque in one direction only.

Figure 2-2. DC Drive module, model 3184-5 (version 208/230 V, 50/60 Hz).

Input and output terminals

The input and output terminals of the DC Drive are accessible through the terminals on the module faceplate. The function of the terminals is shown in Table 2-1.

NUMBER	FUNCTION	DESCRIPTION
L1, L2	Supply voltage inputs	Power terminals
A+, A-	DC Drive outputs	Power terminals
Under L1 and N terminals	Line fuse	Fuse terminals
Under A+ and A- terminals	Armature fuse	Fuse terminals
Z1	Remote potentiometer (low side)	Remote potentiometer terminal
↑	Remote potentiometer (wiper)	Remote potentiometer terminal
Z2	Remote potentiometer (high side)	Remote potentiometer terminal
P1	Potentiometer input (low side)	Potentiometer input terminal
P2	Potentiometer input (wiper)	Potentiometer input terminal
P3	Potentiometer input (high side)	Potentiometer input terminal

Table 2-1. Function of the terminals on the DC Drive module faceplate.

Parameters

The DC Drive can be adapted to fit the motor and load characteristics. It is adapted by setting the value of some parameters using trim-pots. The operating parameters that can be set are:

- Minimum speed;
- Maximum speed;
- IR compensation;
- Current limit;
- Acceleration time (on the 220/240 V version only);
- Deceleration time (on the 220/240 V version only).

Minimum speed

The minimum speed sets the minimum speed of the motor by setting the minimum output voltage of the drive. It is set using the MIN trim-pot as follows:

- Rotate the potentiometer to the minimum speed position;
- Set the MIN trim-pot so that motor runs at the desired minimum speed.

Maximum speed

The maximum speed sets the maximum speed of the motor by setting the maximum output voltage of the drive. The maximum speed value is determined to fit the load requirements, or to prevent the motor from rotating at a speed exceeding the rated value. It is set using the MAX trim-pot as follows:

- Rotate the potentiometer to the maximum speed position;
- Set the MAX trim-pot so that motor runs at the desired maximum speed.

The IR compensation and Current limit parameters are explained in the next exercise.

Procedure Summary

In the first two parts of this exercise, you will set the MIN and MAX trim-pots to specific speed values.

In the third part, you will plot the speed versus voltage curve.

In the fourth part, you will demonstrate the effects of inverting the poles of a DC motor.

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.

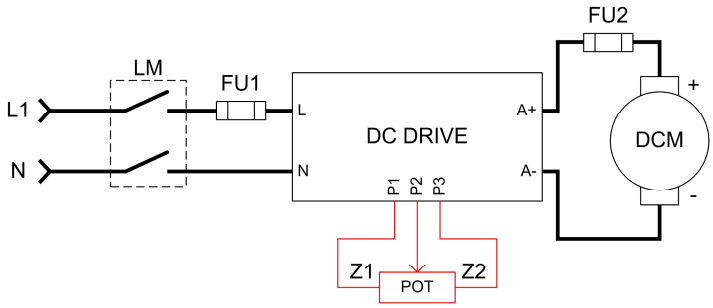
Basic setup

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

☐ 2. Install the DC Motor and Safety Guard as shown in Figure 2-3.

Figure 2-3. Place the DC Motor at your right.

☐ 3. Set up the circuit shown in Figure 2-4.



LEGEND

DC DRIVE	=	DC DRIVE
DCM	=	DC MOTOR
FU1	=	LINE FUSE
FU2	=	ARMATURE FUSE
LM	=	LOCKOUT MODULE
POT	=	POTENTIOMETER

Figure 2-4. Circuit using a DC Drive to control the operation of a DC Motor.

CAUTION

The DC Drive module requires single phase supply. Make sure to connect the DC Drive between a line terminal and the N terminal on the AC Power Supply.

☐ 4. Set the MIN, MAX, IR, and CL trim-pots to the 12 o'clock position.

Note: *Be careful when setting the trim-pots, they are fragile. Always use the plastic screwdriver supplied with your training system.*

☐ 5. Perform the Energizing procedure.

Note: *The DC Drive Module can be supplied with 240 V – 50 Hz even if the input rating on the module front panel reads 208/230 V - 50/60 Hz.*

Minimum speed

☐ 6. Turn the potentiometer POT fully counterclockwise (minimum speed).

☐ 7. Turn the MIN trim-pot slowly in the reverse direction until the motor stops.

Maximum speed

☐ 8. Turn the potentiometer POT fully clockwise (maximum speed).

☐ 9. Turn the MAX trim-pot slowly in the forward direction until the motor rotates at the rated speed (refer to the motor nameplate).

Note: *Use a tachometer to measure the motor speed.*

Speed versus voltage characteristic

☐ 10. Turn off the Lockout Module.

Connect a voltmeter at the DC Motor input terminals.

Turn on the Lockout Module.

☐ 11. Vary the potentiometer position to obtain the speed values shown in Table 2-2. For each speed value, measure the voltage at the motor input (armature voltage). Enter your results in the appropriate cells in Table 2-2.

SPEED (r/min)	VOLTAGE (V)
0	
195	
390	
585	
780	
975	
1170	
1365	
1560	
1750	

Table 2-2. Voltage versus speed characteristic.

☐ 12. Turn off the Lockout Module.

☐ 13. Plot the Speed versus Voltage curve in Figure 2-5. Place the Voltage values along the X-axis, and the Speed values along the Y-axis.

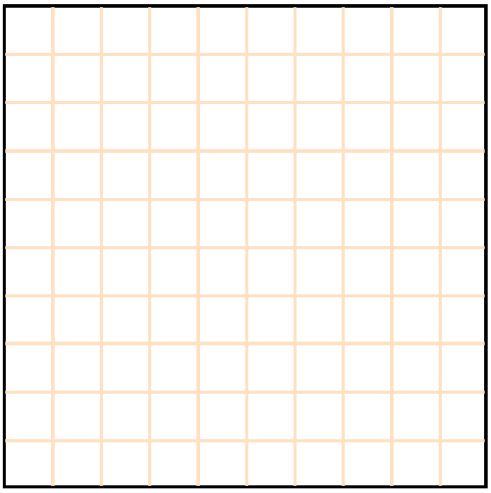


Figure 2-5. Voltage versus Speed curve.

☐ 14. Does your graph confirm that the speed of the motor is directly proportional to the armature voltage?

☐ Yes ☐ No

Additional speed settings

☐ 15. In the previous steps, you set the minimum speed to zero, and the maximum speed to the rated speed of the motor.

Familiarize yourself with these controls by setting the following speed range: 200 to 1500 r/min.

Note: *Speed settings interact. Once a setting is completed, check the other and readjust if necessary.*

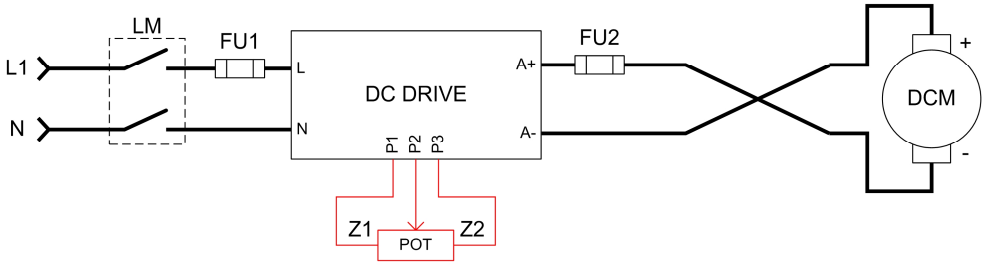
Direction of rotation

☐ 16. In which direction does the motor rotate?

☐ Forward ☐ Reverse

☐ 17. Turn off the Lockout Module.

Modify the circuit as shown in Figure 2-6.



LEGEND

DC DRIVE	=	DC DRIVE
DCM	=	DC MOTOR
FU1	=	LINE FUSE
FU2	=	ARMATURE FUSE
LM	=	LOCKOUT MODULE
POT	=	POTENTIOMETER

Figure 2-6. Changing the rotation direction by inverting the poles of a DC motor.

Do your observations confirm that switching the motor poles changes the rotation direction of the DC Motor?

☐ Yes ☐ No

☐ 19. 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 basic operation of the DC Drive. You set the minimum and maximum speeds of the motor. You plotted the speed versus voltage characteristic and observed that the speed is proportional to the armature voltage. In the last part, you demonstrated that the rotation direction of a DC motor changes when the poles of the motor are inverted.

REVIEW QUESTIONS

1. How can the rotation direction of a motor be changed with the DC Drive of your training system?

   a. Inverting the leads at the DC Drive terminal inputs.
   b. Inverting the leads at the DC Motor terminal inputs.
   c. Inverting the leads at the DC Motor terminal outputs.
   d. Not possible with this DC Drive model.

2. Name the parameters that can be set on the DC Drive of your training system.

   a. Minimum and maximum speeds, IR compensation, and current limit.
   b. Operating speed, minimum and maximum current, IR compensation.
   c. Operating current, minimum and maximum speeds, IR compensation.
   d. Minimum and maximum speeds, IR limit, and current compensation.

3. The DC Drive of your training system is capable of controlling

   a. the motor speed in both directions.
   b. the torque in both directions.
   c. the motor speed in one direction.
   d. the motor speed and the torque in both directions.

4. The speed of the motor is directly proportional to the armature current.

   ☐ True ☐ False

Current Limiting and IR Compensation

EXERCISE OBJECTIVE

- Understand current limiting and IR compensation.

DISCUSSION

Current limiting

If the motor stalls or slows down far below its rated speed, the current through the armature will become excessive. Excessive currents occur because the slow rotation of the motor reduces the electromotive force which tends to oppose the passage of current (CEMF) so that the net armature current becomes very high. To limit the current to a safe value, a current limiting circuit is added. Note that the motor torque is proportional to the DC current value.

The current limit is set using the CL trim-pot as follows:

- Turn the CL trim-pot to minimum (fully counterclockwise);
- Connect an ammeter in series with the armature lead;
- Lock the shaft of the motor;
- Set the potentiometer to mid span;
- Apply power;
- Slowly rotate the CL trim-pot until the desired current limit is reached.

IR compensation

The IR compensation circuit refers to the internal resistance of the motor. It is used to compensate for the inefficiency and power losses in the motor. It allows the speed to be maintained constant with and without load. Note that too much IR compensation will cause unstable operation.

The IR compensation is set using the IR trim-pot as follows:

- Run the motor at approximately 50% of the rated speed under no load and measure the actual speed;
- Load the motor;
- Rotate the IR trim-pot so that the loaded speed is the same as the unloaded speed.

Procedure Summary

In the first part of this exercise, you will limit the current supplied by the DC Drive by setting the CL trim-pot to the rated current value of the DC Motor.

In the second part, you will set the IR trim-pot to compensate for the inefficiency and power losses in the motor. To do so, you will set the IR trim-pot to maintain the speed constant with and without load.

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

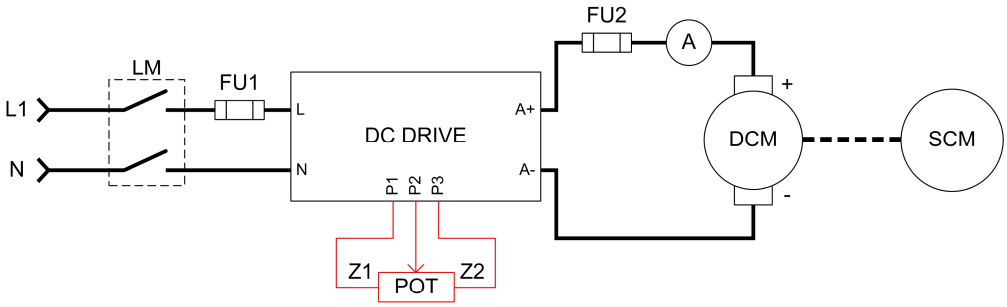
☐ 1. Perform the Basic Setup and Lockout/Tagout procedures.

> **Note:** *The DC Drive Module can be supplied with 240 V – 50 Hz even if the input rating on the module front panel reads 208/230 V - 50/60 Hz.*

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

> **Note:** *In this part of the exercise, the Brake Motor is used to prevent the DC Motor from rotating.*
>
> *The characteristics of the DC Motor are shown in Appendix G.*

☐ 3. Set up the circuit shown in Figure 2-7.



LEGEND

A	=	AMMETER
DC DRIVE	=	DC DRIVE
DCM	=	DC MOTOR
FU1	=	LINE FUSE
FU2	=	ARMATURE FUSE
LM	=	LOCKOUT MODULE
POT	=	POTENTIOMETER
SCM	=	SQUIRREL CAGE MOTOR

Figure 2-7. The Brake Motor is used to lock the DC Motor.

CAUTION

The DC Drive module requires single phase supply. Make sure to connect the DC Drive between a line terminal and the N terminal on the AC Power Supply.

Current limiting

☐ 4. Set the DC Drive as follows:

- Set the potentiometer to the 12 o'clock position;
- Set the CL trim-pot to minimum (fully counterclockwise).

☐ 5. Apply the friction brake of the Brake Motor.

Perform the Energizing procedure.

☐ 6. Slowly rotate the CL trim-pot until the rated current of the DC Motor is reached. Do not exceed the rated motor current.

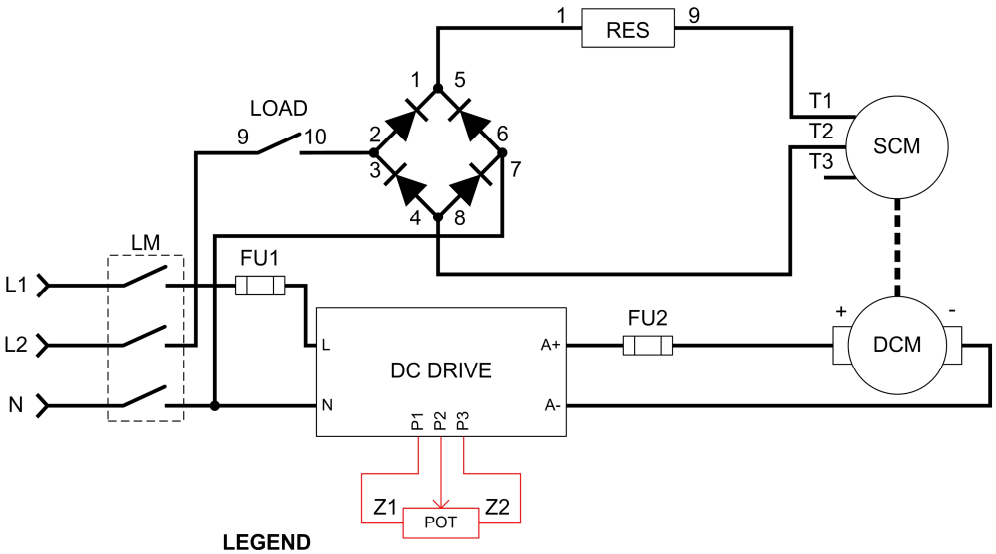
Note: *Do not leave the motor in a locked condition for more than a few seconds since armature damage may occur.*

☐ 7. Turn off the Lockout Module.

IR compensation

☐ 8. Modify the circuit as shown in Figure 2-8.

Note: *The Brake Motor, Starting Resistors, and Power Diodes modules act as load to the DC Motor. Load insertion is controlled by the Cam Switch module. Connect the resistors in series for maximum resistance.*



LEGEND

DC DRIVE	=	DC DRIVE
DCM	=	DC MOTOR
FU1	=	LINE FUSE
FU2	=	ARMATURE FUSE
LM	=	LOCKOUT MODULE
LOAD	=	LOAD CAM SWITCH
POT	=	POTENTIOMETER
RES	=	RESISTOR
SCM	=	SQUIRREL CAGE MOTOR

Figure 2-8. Circuit used to load the DC Motor.

☐ 9. Set the Cam Switch to the STOP position (no load).

Manually disengage the friction brake.

Turn on the Lockout Module.

☐ 10. Set the IR trim-pot to minimum (fully counterclockwise).

Set the MIN and MAX trim-pots to obtain a 200-1500 r/min speed range.

Set the potentiometer to obtain a 900-r/min DC Motor speed (without load).

☐ 11. Set the Cam Switch to the REV position to load the DC Motor.

Measure the motor speed.

Note: *You should observe that the speed lowered when the load was added.*

☐ 12. Set the IR trim-pot so that the loaded speed is the same as the unloaded speed. Repeat the speed setting with and without load until you obtain 900 r/min.

☐ 13. Do your observations confirm that the IR compensation can compensate for the inefficiency and power losses in the motor?

☐ Yes ☐ No

☐ 14. 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 current limit parameter. You locked the rotor of the DC Motor to set the CL trim-pot to the rated current. You have loaded the motor to set the IR trim-pot to maintain the speed constant with and without load.

REVIEW QUESTIONS

1. When a DC motor stalls, the current through the armature becomes excessive because the slow rotation of the motor increases the electromotive force which tends to oppose the passage of current.

☐ True ☐ False

2. The motor torque is proportional to the

a. speed.
b. armature voltage.
c. armature current.
d. None of the answers above is correct.

3. Too much IR compensation

   a. reduces the torque.
   b. reduces the speed.
   c. causes unstable operation.
   d. causes stable operation.

4. How can the speed of a DC motor be maintained constant with and without load?

   a. Setting the maximum speed
   b. Increasing the minimum speed
   c. Increasing the current limit
   d. Setting the IR compensation

Unit Test

1. Which parameter controls the speed of a DC motor?

   a. Current
   b. Voltage
   c. Both answers are correct

2. Which parameter controls the torque produced by a DC motor?

   a. Current
   b. Voltage
   c. Both answers are correct

3. Rotating the MIN trim-pot in the counterclockwise direction

   a. decreases the minimum speed.
   b. decreases the maximum speed.
   c. increases the minimum speed.
   d. increases the maximum speed.

4. The DC Drive is capable of controlling motor

   a. speed.
   b. rotation direction and torque.
   c. rotation direction and speed.
   d. rotation direction and current.

5. How does the speed vary with voltage?

   a. Inversely proportional
   b. Directly proportional
   c. In a square-law pattern
   d. None of the answers above is correct.

6. When the poles of a dc motor are inverted, the motor

   a. speed changes.
   b. can be damaged.
   c. rotation direction changes.
   d. rotates very slowly.

7. DC motors can deliver three to four times their rated torque for long periods of time.

   ☐ True ☐ False

8. How can the speed range of the DC Motor be set?

   a. setting the MIN trim-pot
   b. setting the MAX trim-pot
   c. setting the minimum and maximum speeds
   d. using the potentiometer

9. Which parameter is used to compensate for the power losses in the motor?

   a. IR compensation
   b. Current limiting
   c. Maximum speed
   d. Setpoint

10. When a DC motor stalls, the current through the armature

    a. increases.
    b. decreases.
    c. is not affected.
    d. None of the answers above are correct.

Equipment Utilization Chart

The following Lab-Volt equipment is required to perform the exercises in this manual.

EQUIPMENT		EXERCISE							
MODEL	DESCRIPTION	1-1	1-2	1-3	1-4	1-5	1-6	2-1	2-2
3103-3	Mobile Workstation	1	1	1	1	1	1	1	1
3112	Switches					2	2		
3114	Emergency Button					1	1		
3115-A	Pilot Lights				1		1		
3125-1	Lockout Module	1	1	1	1	1	1	1	1
3126	Manual Starter				1			1	
3130-2	Control Relay					1			
3138-3	Control Transformer					1			
3140-3	Cam Switch								1
3147-1	Inertia Wheel		1	1		1			
3150-1	Starting Resistors				1				1
3165-1	Power Diodes								1
3176-A	Brake Motor	1	1	1	1	1	1		1
3179-2	DC Motor			1	1			1	1
3183	AC Drive	1	1	1	1	1	1		
3184	DC Drive		1	1				1	1
3196	AC Power Supply	1	1	1	1	1	1	1	1
8951-8	Connection Leads	1	1	1	1	1	1	1	1
8951-E	Connection Leads		1	1	1	1	1	1	1
38503	Magnetic Labels		1	1	1	1	1	1	1
Option	Multimeter[1]		1	1				1	1
Option	Chronometer			1					
Option	Tachometer		1					1	1

[1] Voltmeter and DC ammeter

Diagram Symbols

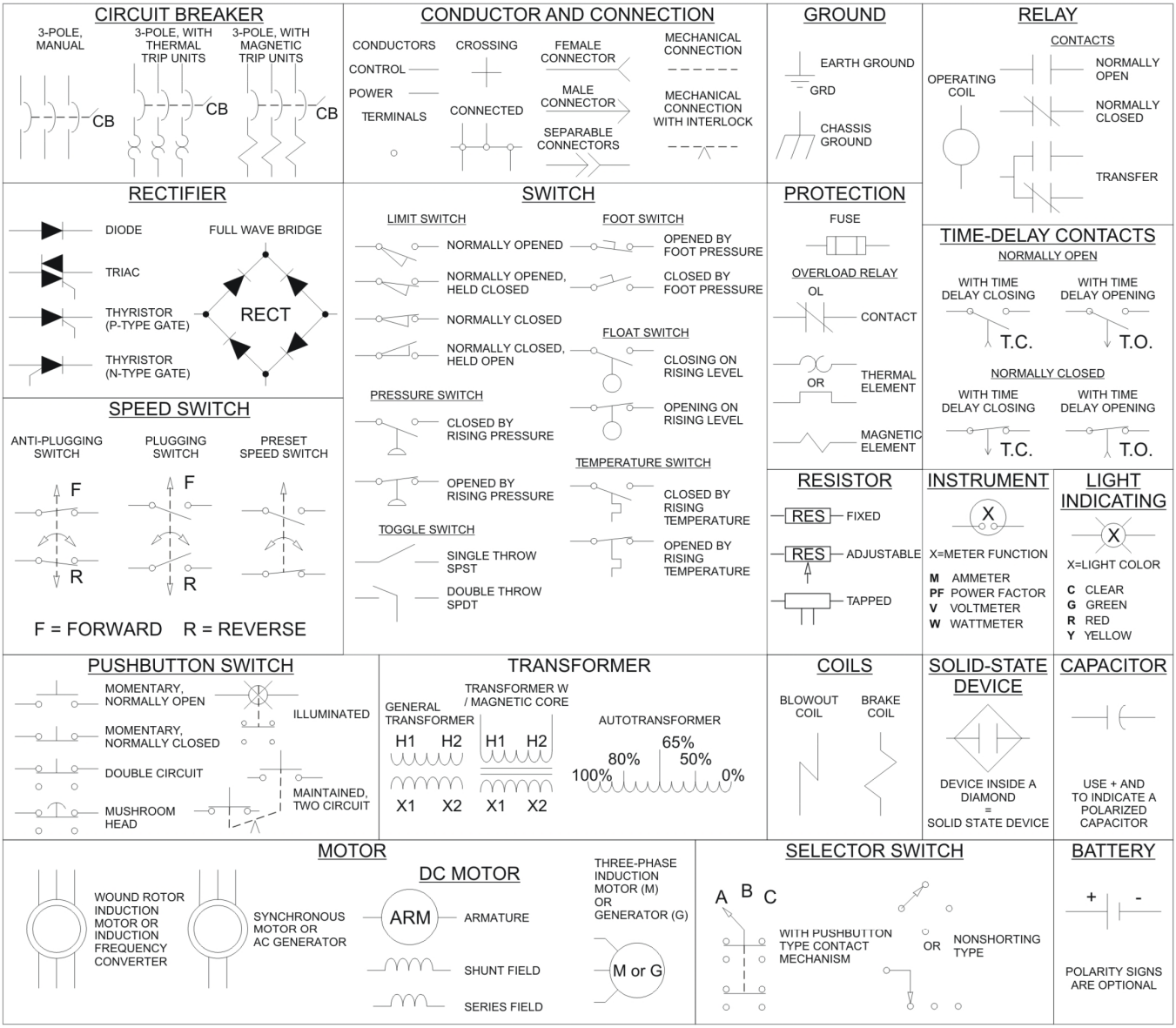


Figure B-1. NEMA symbols.

FUNCTION OR DEVICE	DESIGNATION	FUNCTION OR DEVICE	DESIGNATION
Accelerating	A	Overload	OL
Ammeter	AM	Overvoltage	OV
Braking	B	Plugging or Potentiometer	P
Capacitor, Capacitance	C or CAP	Power Factor Meter	PFM
Circuit Breaker	CB	Pressure Switch	PS
Closing Coil	CC	Push Button	PB
Control Relay	CR	Reactor, Reactance	X
Current Transformer	CT	Rectifier	REC
Demand Meter	DM	Resistor, Resistance	R or RES
Diode	D	Reverse	R or REV
Disconnect Switch	DS or DISC	Rheostat	RH
Dynamic Braking	DB	Selector Switch	SS
Field Accelerating	FA	Silicon Controlled Rectifier	SCR
Field Contactor	FC	Solenoid Valve	SV
Field Decelerating	FD	Squirrel Cage	SC
Field-Loss	FL	Starting Contactor	S
Forward	F or FWD	Suppressor	SU
Frequency Meter	FM	Tachometer Generator	TACH
Fuse	FU	Terminal Block or Board	TB
Ground Protective	GP	Time-Delay Closing Contact	TC or TDC
Holding Coil	HC	Time-Delay Opening Contact	TO or TDO
Hoist	H	Time Relay	TR
Jog	J	Transformer	T
Latch Coil	LC	Transistor	Q
Limit Switch	LS	Trip Coil	TC
Lower	L	Unlatch Coil	ULC
Main Contactor	M	Undervoltage	UV
Master Control Relay	MCR	Voltmeter	VM
Master Switch	MS	Watthour Meter	WHM
Overcurrent	OC	Wattmeter	WM

Figure B-2. Device designations.

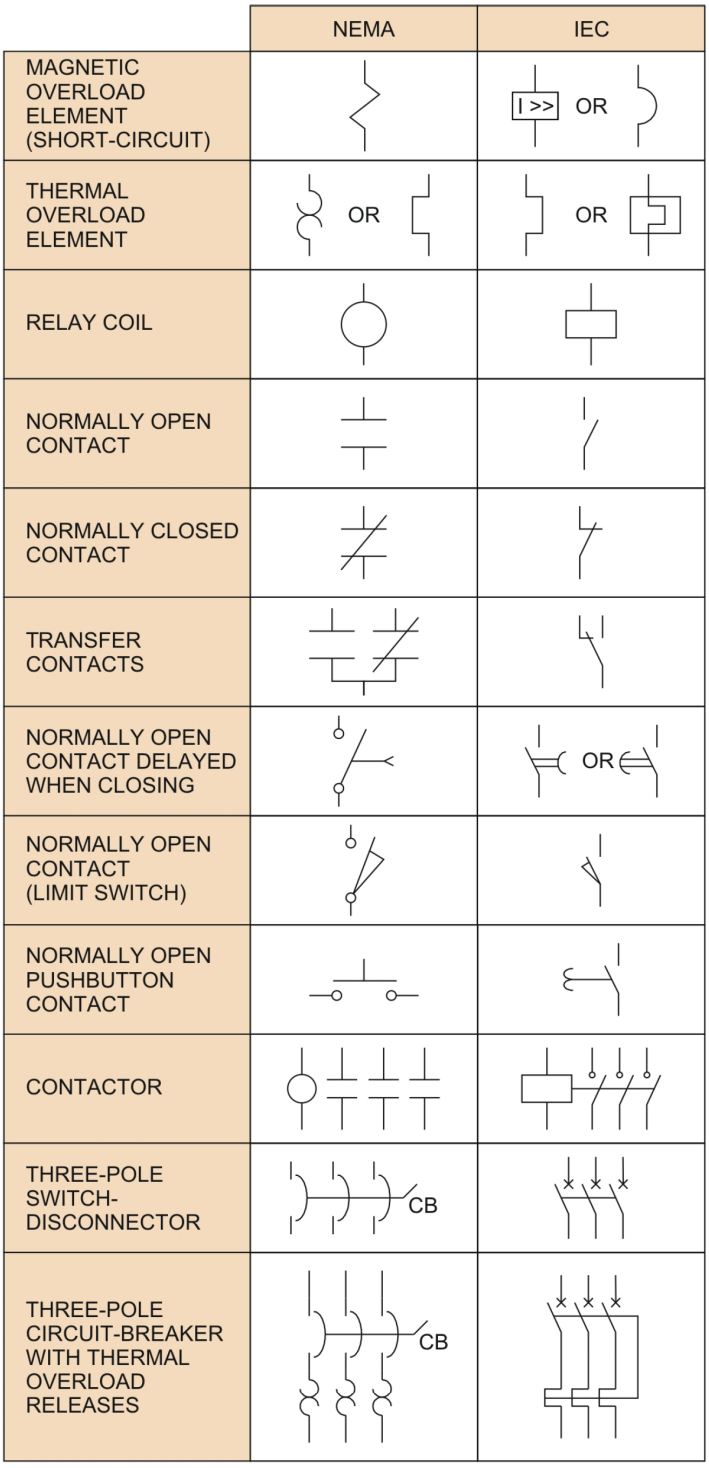


Figure B-3. Comparison of NEMA and IEC symbols.

Basic Setup and Lockout/Tagout Procedures

This appendix contains the Basic Setup and Lockout/Tagout procedures specific to the Industrial Controls Training System from Lab-Volt. It is divided into four sections:

- Basic Setup procedure, explains the basic operations that must be performed at the beginning of the exercise procedures.
- Lockout/Tagout procedure (de-energizing procedure), describes the lockout/tagout procedure used to de-energize the training system before setting up a circuit.
- Energizing procedure, gives details on how to end a lockout/tagout procedure and energize the training system.
- Module identification, gives instructions on how to use the magnetic labels to identify the modules.

Basic Setup procedure

This procedure is recommended at the beginning of every experiment involving the modules of the training system. It ensures that the system is safe prior to cabling specific circuits.

Figure C-1 shows the AC Power Supply, Model 3196. Individual power switches are located on both faces of the module, for separate control of the power source.

Figure C-1. AC Power Supply, Model 3196.

☐ 1. Make sure that the power switch located on your side of the AC Power Supply is set to the O position.

Note: *The AC Power Supply should already be installed in the Mobile Workstation.*

☐ 2. Install the Lockout module into the Mobile Workstation.

Note: *Each time you install a module in the Mobile Workstation, make sure that the fault switches located behind the module faceplate are set to the O position as shown in Figure C-2.*

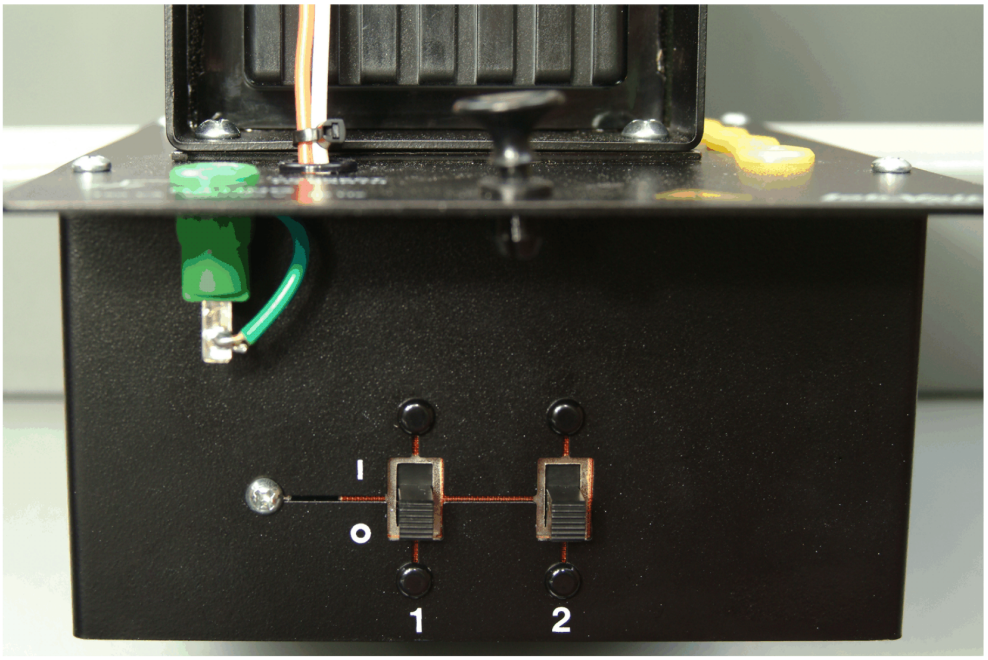


Figure C-2. Make sure that the fault switches are set to the O position.

☐ 3. Turn off the Lockout Module.

☐ 4. Connect the Lockout Module cables to the AC Power Supply module terminals, noting the phase sequence. See Figure C-3.

Figure C-3. Lockout Module connected to the AC Power Supply module.

Lockout/Tagout procedure (de-energizing procedure)

☐ 5. Turn off the Lockout Module.

☐ 6. Install the lockout hasp and the student padlocks and tags on the Lockout Module. Ask the instructor to install the lab padlock and tag as well. Refer to Figure C-4 for details.

Figure C-4. Installation of padlocks and hasps.

☐ 7. Check that the Lockout Module switch cannot be opened. With a voltmeter, verify that no voltage is present between the Lockout Module output terminals to confirm that the circuit is de-energized. You may now set up your circuit.

Energizing procedure

☐ 1. Interconnect the ground terminal (green) of all AC modules with the ground terminal of the Lockout Module.

Note: *DC modules do not incorporate ground terminals.*

☐ 2. Make sure the Security Guard is installed if you are using a motor.

☐ 3. Identify the modules with labels as described in the Module Identification section of this Appendix.

☐ 4. Once the connections have been made, ask for the instructor to check the circuit. When the circuit is correctly wired, notify all the people working around the Mobile Workstation that the system will be energized.

☐ 5. Remove the lockout hasp, padlocks and tags.

☐ 6. Turn on the AC Power Supply and Lockout Module, and return to your exercise.

Module identification

☐ 1. Once the setup is completed, identify all buttons, pilot lights, switches, etc, in accordance with the circuit schematic diagram. Place the magnetic labels on the module faceplates as shown in Figure C-5.

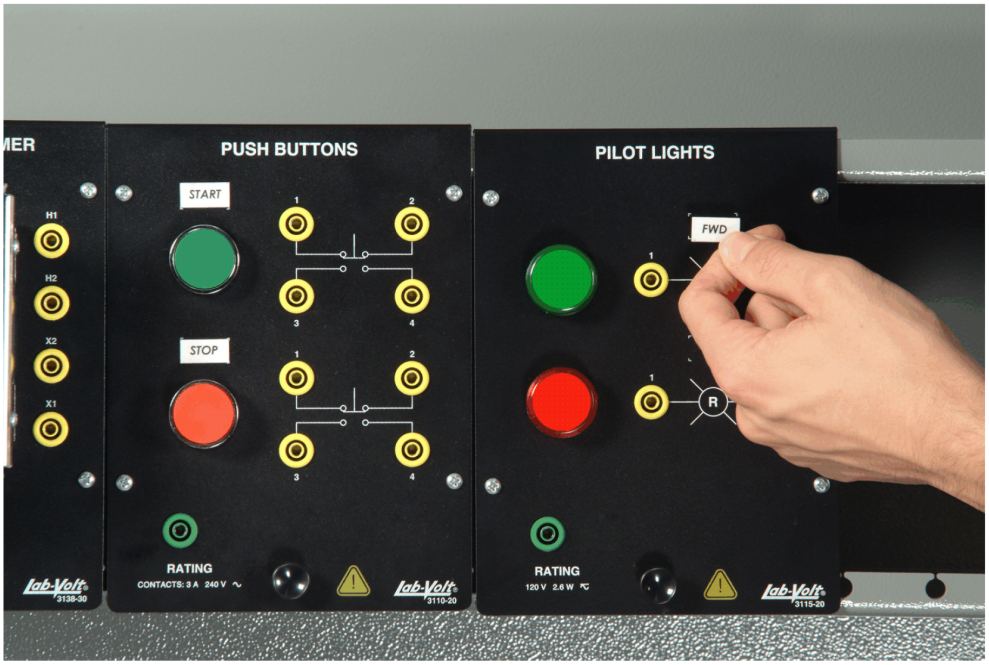


Figure C-5. Module identification.

Note: *For storing purposes, arrange the magnetic labels in alphabetic order on the vertical surface of the Mobile Workstation as shown in Figure C-6.*

Figure C-6. Store the magnetic labels on the vertical surface of the Mobile Workstation.

Coupling Motors

This procedure describes how to couple two motors on the Mobile Workstation.

Note: *To facilitate electrical connections, the Brake Motor should be installed at your left.*

- Fix the Brake Motor to the Mobile Workstation (See appendix E in the Basic Controls manual, part number 39163 if necessary).
- Remove the Inertia Wheel from the Brake Motor (when applicable).
- Slide a coupling half on the Brake Motor shaft taking care of aligning the coupling keyway with the key.
- Align the end of the coupling with the end of the shaft and tighten the set screw on the shaft key. See Figure D-1.

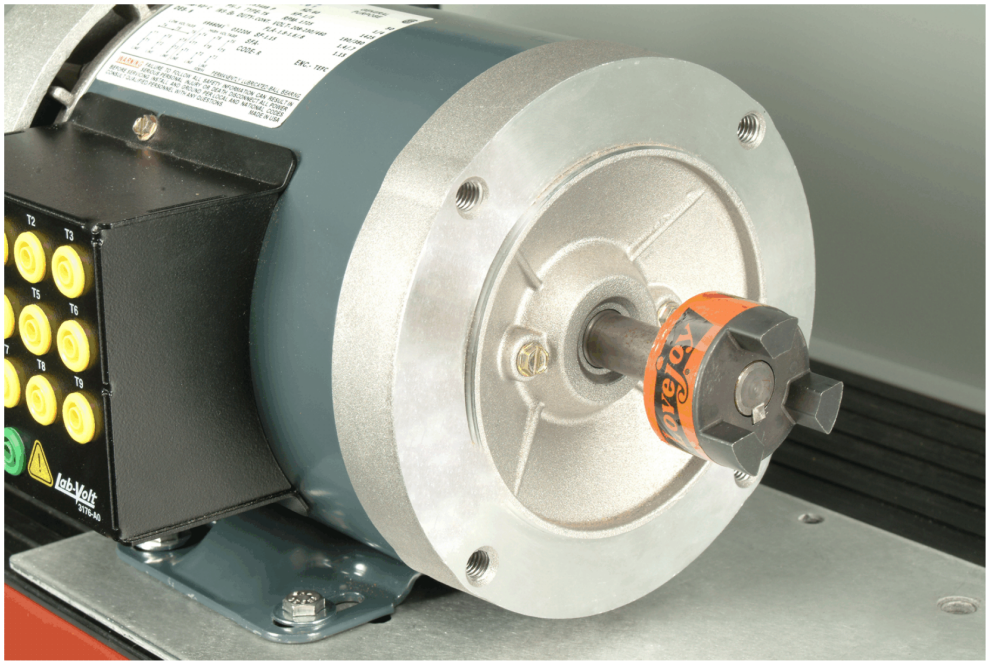


Figure D-1. Installation of a coupling half on a motor shaft.

- Install the insert in the coupling half.
- Slide a coupling half on the DC Motor taking care of aligning the coupling keyway with the key. Do not tighten the setscrew now.

- Position the DC Motor so the shafts of both motors are facing. Do not forget to insert the spacer plate between the motor base and the Mobile Workstation.
- Join the two coupling sections, allowing a 1.6 mm-gap (1/16 in) between the two halves sections, then tighten the setscrew.
- Align and fix the DC Motor to the Mobile Workstation surface using hexagonal head screws and knurled nuts.

> **Note:** *Misalignment will cause noise and vibration. Refer to Appendix E for basic information about alignment.*

- Install the Safety Guard.

> **Note:** *Ask your instructor to check your setup.*

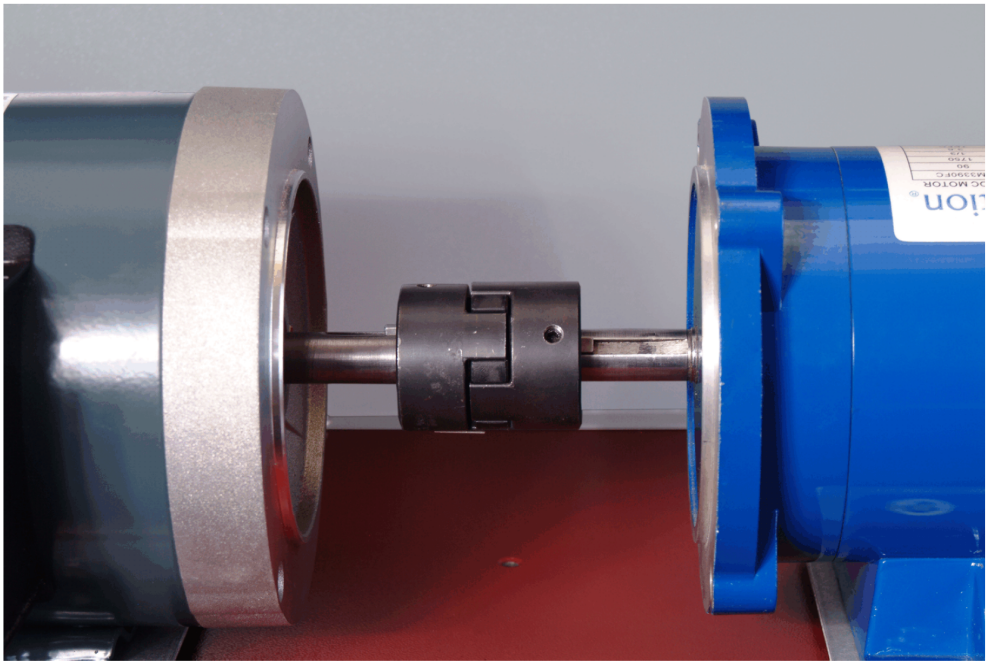


Figure D-2. DC Motor coupled with the Brake Motor without Safety Guard.

Alignment

Flexible couplings

Flexible shaft couplings are used for joining shafts of equal or different diameters. A flexible jaw coupling is shown in Figure E-1.

Figure E-1. Flexible coupling.

Flexible couplings can usually compensate for slight errors in shaft alignment. Improper shaft alignment can lead to premature failure of couplings and bearings, and may cause excessive vibration.

Alignment

The two basic types of shaft misalignment are parallel and angular.

Parallel misalignment results when two shafts are parallel but not on the same plane, as shown in Figure E-2.

Figure E-2. Parallel misalignment.

Angular misalignment, also called axial misalignment, results when the shafts are at a different angle with the horizontal or vertical planes as shown in Figure E-3.

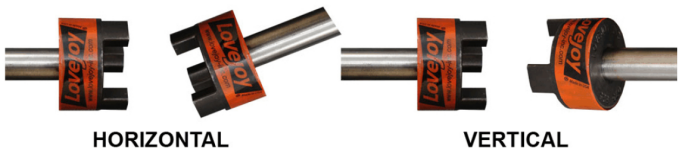


Figure E-3. Angular misalignment.

Both the vertical and horizontal planes must be checked to ensure a correct angular alignment.

Alignment methods

Depending on the required precision, many alignment methods may be used. One of the simplest methods (low precision method) is as follows:

- Lay a straightedge (supplied with the training system) as shown in Figure E-4 to check the alignment of the shafts in the horizontal plane.

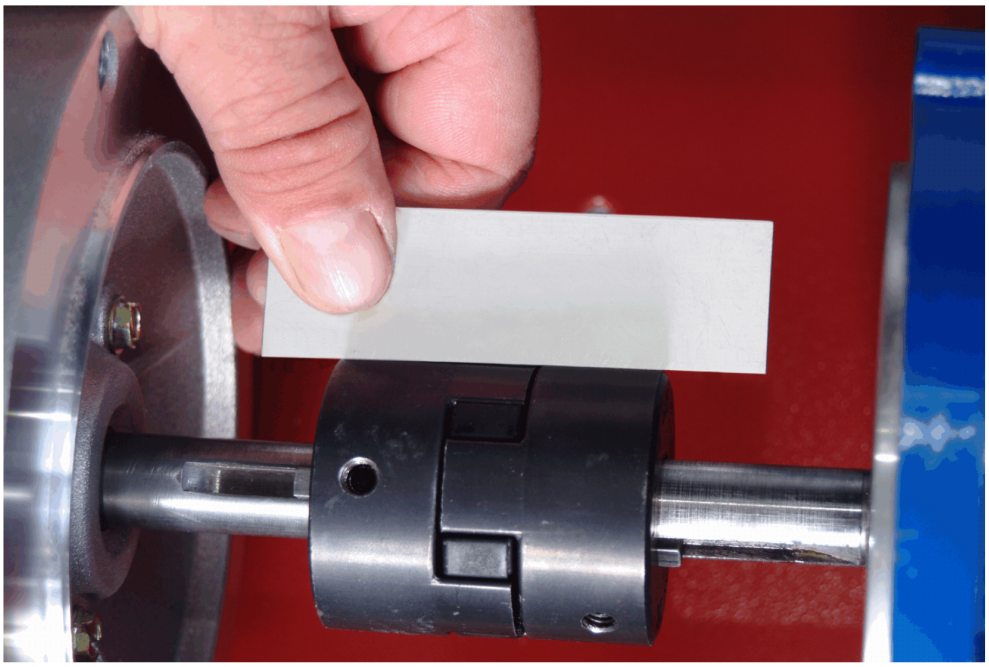


Figure E-4. Alignment in the horizontal plane.

- The horizontal alignment is correct when the straightedge is in contact with the two coupling halves at any point. Alignment is adjusted in the horizontal plane by moving one of the motors to the right or left.

Note: *Remove the labels on the coupling halves if necessary.*

- Once the alignment in the horizontal plane is completed, lay the straightedge as shown in Figure E-5 to align the shafts in the vertical plane.

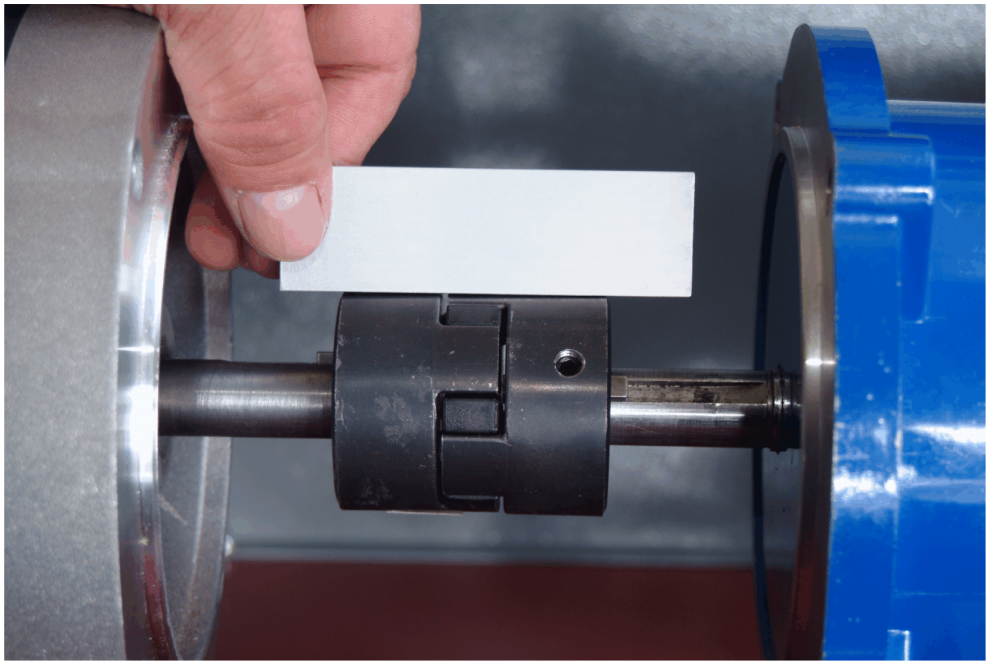


Figure E-5. Alignment in the vertical plane.

- Alignment is adjusted in the vertical plane by raising or lowering one of the motors with shims (supplied with the training system) as shown in Figure E-6.

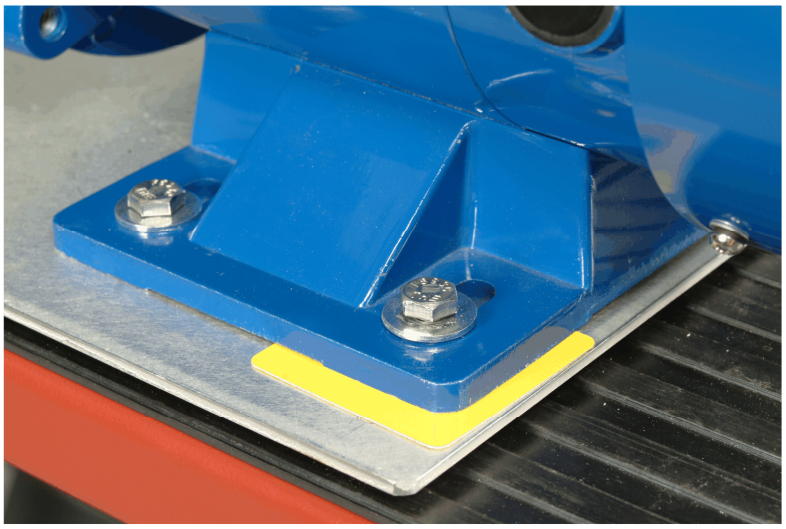
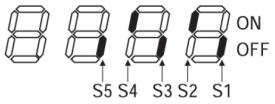
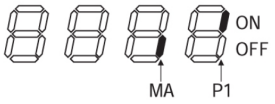


Figure E-6. Insert shims to align the shafts in the vertical plane.

AC Drive – Error Codes and Parameter Numbers

ERROR CODES	
DISPLAY	**CAUSE**
E01	Inverter overcurrent in static operation
E02	Inverter overcurrent during deceleration
E03	Inverter overcurrent during acceleration
E05	Overload
E07	Overvoltage
E08	EEPROM fault
E09	Undervoltage
E11	Processor malfunction
E12	External fault message
E14	Ground fault
E15	Mains overvoltage
E21	Overtemperature
E35	Thermistor fault signal
E60	Communication fault

Monitor Mode (d□□□) / Basic Function Mode (F□□□)

Parameter No.	Name	Monitor or data range (Digital Operator)	Default setting	Changes during operation	Unit	Set value
d001	Output frequency monitor	0.0 to 400.0	—	—	Hz	
d002	Output current monitor	0.0 to 999.9	—	—	A	
d003	Rotation direction monitor	F: Forward o: Stop r: Reverse	—	—	—	
d004	PID feedback value monitor	0.00 to 99.99 100.0 to 999.9 1000. to 9999. (Enabled when the PID function is selected)	—	—	—	
d005	Multi-function input monitor	 Example) Terminal S4, S2: ON Terminal S5, S3, S1: OFF	—	—	—	
d006	Multi-function output monitor	 Example) Terminal P1: ON Terminal MA: OFF	—	—	—	
d007	Output frequency monitor (after conversion)	0.00 to 99.99 100.0 to 999.9 1000. to 9999. 1000 to 3996 (10000 to 39960) (Output frequency × Conversion factor of b086)	—	—	—	
d013	Output voltage monitor	0. to 600.	—	—	V	
d016	Total RUN Time	0. to 9999. 1000 to 9999 ⌈100 to ⌈999[h]	—	—	h	
d017	Power ON time monitor	0. to 9999. 1000 to 9999 ⌈100 to ⌈999[h]	—	—	h	
d018	Fin temperature monitor	0.0 to 200.0			°C	
d080	Fault frequency monitor	0. to 9999.	—	—	—	
d081	Fault monitor 1 (Latest)	Error code (condition of occurrence) → Output frequency [Hz] → Output current [A] → Internal DC voltage [V] → RUN time [h] → ON time [h]	—	—		
d082	Fault monitor 2					
d083	Fault monitor 3					

Parameter No.	Name	Monitor or data range (Digital Operator)	Default setting	Changes during operation	Unit	Set value
d102	DC voltage monitor	0.0 to 999.9	—	—	V	
d104	Electronic thermal monitor	0.0 to 100.0	—	—	%	
F001	Output frequency setting/monitor	Starting frequency to 1st or 2nd max. frequency	—	Yes	Hz	
F002	Acceleration time 1	0.01 to 99.99 100.0 to 999.9 1000. to 3000.	10.0	Yes	s	
F202	*2nd acceleration time 1	0.01 to 99.99 100.0 to 999.9 1000. to 3000.	10.0	Yes	s	
F003	Deceleration time 1	0.01 to 99.99 100.0 to 999.9 1000. to 3000.	10.0	Yes	s	
F203	*2nd deceleration time 1	0.01 to 99.99 100.0 to 999.9 1000. to 3000.	10.0	Yes	s	
F004	Operator rotation direction selection	00: Forward 01: Reverse	00	No	—	

* 2nd function is displayed when SET(08) is allocated to one of from C001 to C005.

Extended function mode

Parameter No.		Function name	Monitor or data range (Digital Operator)	Default setting	Changes during operation	Unit	Set value
Basic setting	A001	Frequency reference selection	00: Digital Operator (FREQ adjuster) 01: Terminal 02: Digital Operator (F001) 03: ModBus communication 10: Frequency operation result	00	No	—	
	A201	*2nd frequency reference selection		00	No	—	
	A002	RUN command selection	01: Terminal 02: Digital Operator 03: ModBus communication	02	No	—	
	A202	*2nd RUN command selection		02	No	—	
	A003	Base frequency	30. to Max. frequency [A004]	60.	No	Hz	
	A203	*2nd base frequency	30. to Max. frequency [A204]	60.			
	A004	Maximum frequency	30. to 400.	60.	No	Hz	
	A204	*2nd maximum frequency		60.			

* 2nd control is displayed when SET (08) is allocated to one of from C001 to C005.

Parameter No.		Function name	Monitor or data range (Digital Operator)	Default setting	Changes during operation	Unit	Set value
Analog input	A005	FV/FI selection	02: Switches between FV/FREQ adjuster via terminal AT 03: Switches between FI/FREQ adjuster via terminal AT 04: FV input only 05: FI input only	02	No	—	
	A011	FV start frequency	0.0 to Max. frequency	0.0	No	Hz	
	A012	FV end frequency	0.0 to Max. frequency	0.0	No	Hz	
	A013	FV start ratio	0. to 100.	0.	No	%	
	A014	FV end ratio	0. to 100.	100.	No	%	
	A015	FV start selection	00: External start frequency (A011 set value) 01: 0 Hz	01	No	—	
	A016	FV, FI sampling	1. to 17.	8.	No	—	
Multi-step speed, Jogging	A020	Multi-step speed reference 0	0.0/Starting frequency to Max. frequency	6.0	Yes	Hz	
	A220	*2nd multi-step speed reference 0	0.0/Starting frequency to 2nd max. frequency	6.0	Yes	Hz	

* 2nd control is displayed when SET (08) is allocated to one of from C001 to C005.

Parameter No.		Function name	Monitor or data range (Digital Operator)	Default setting	Changes during operation	Unit	Set value
Multi-step speed, Jogging	A021	Multi-step speed reference 1	0.0/Starting frequency to Max. frequency	0.0	Yes	Hz	
	A022	Multi-step speed reference 2		0.0			
	A023	Multi-step speed reference 3		0.0			
	A024	Multi-step speed reference 4		0.0			
	A025	Multi-step speed reference 5		0.0			
	A026	Multi-step speed reference 6		0.0			
	A027	Multi-step speed reference 7		0.0			
	A028	Multi-step speed reference 8		0.0			
	A029	Multi-step speed reference 9		0.0			
	A030	Multi-step speed reference 10		0.0			
	A031	Multi-step speed reference 11		0.0			
	A032	Multi-step speed reference 12		0.0			
	A033	Multi-step speed reference 13		0.0			
	A034	Multi-step speed reference 14		0.0			
	A035	Multi-step speed reference 15		0.0			
	A038	Jogging frequency	0.00/Starting frequency to 9.99	6.00	Yes	Hz	
	A039	Jogging stop selection	00: Free-run stop 01: Deceleration stop 02: DC injection braking stop	00	No	—	

* 2nd control is displayed when SET (08) is allocated to one of from C001 to C005.

Parameter No.		Function name	Monitor or data range (Digital Operator)	Default setting	Changes during operation	Unit	Set value
Characteristics, Torque boost	A041	Torque boost selection	00: Manual torque boost only 01: Automatic (simple) torque boost	00	No	-	
	A241	*2nd torque boost selection		00			
	A042	Manual torque boost voltage	0.0 to 20.0	5.0	Yes	%	
	A242	*2nd manual torque boost voltage		0.0			
	A043	Manual torque boost frequency	0.0 to 50.0	2.5	Yes	%	
	A243	*2nd manual torque boost frequency		0.0			
	A044	V/f characteristics selection	00: Constant torque characteristics (VC) 01: Reduced torque characteristics (VP 1.7th power) 06: Special reduced torque characteristics (Special VP)	00	No	-	
	A244	*2nd V/f characteristics selection		00			
	A045	Output voltage gain	20. to 100.	100.	Yes	%	
	A245	*2nd output voltage gain		100.			
DC injection braking	A051	DC injection braking selection	00: Disabled 01: Enabled 02: Frequency control [A052 set value]	00	No	—	
	A052	DC injection braking frequency	0.0 to 60.0	0.5	No	Hz	
	A053	DC injection braking delay time	0.0 to 5.0	0.0	No	s	
	A054	DC injection braking power	0. to 100.	50	No	%	
	A055	DC injection braking time	0.0 to 60.0	0.5	No	s	
	A056	DC injection braking method selection	00: Edge operation 01: Level operation	01	No	—	

* 2nd control is displayed when SET (08) is allocated to one of from C001 to C005.

Parameter No.		Function name	Monitor or data range (Digital Operator)	Default setting	Changes during operation	Unit	Set value
Upper/Lower limit, Jump	A061	Frequency upper limit	0.0/Frequency lower limit to Max. frequency	0.0	No	Hz	
	A261	*2nd frequency upper limit	0.0/Frequency lower limit to 2nd Max. frequency	0.0			
	A062	Frequency lower limit	0.0/Starting frequency to Frequency upper limit	0.0	No	Hz	
	A262	*2nd frequency lower limit	0.0/Starting frequency to 2nd frequency upper limit	0.0			
	A063	Jump frequency 1	Jump frequency: 0.0 to 400.0 Jump frequency width: 0.0 to 10.0	0.0	No	Hz	
	A064	Jump frequency width 1		0.5			
	A065	Jump frequency 2		0.0			
	A066	Jump frequency width 2		0.5			
	A067	Jump frequency 3		0.0			
	A068	Jump frequency width 3		0.5			
PID control	A071	PID selection	00: Disabled 01: Enabled	00	No	—	
	A072	PID P gain	0.2 to 5.0	1.0	Yes	—	
	A073	PID I gain	0.0 to 150.0	1.0	Yes	s	
	A074	PID D gain	0.00 to 100.0	0.0	Yes	s	
	A075	PID scale	0.01 to 99.99	1.00	No	Time	
	A076	PID feedback selection	00: FI 01: FV 02: RS485 communication 10: Operation function output	00	No	—	
	A077	Reverse PID function	00: OFF (Deviation = Target value - Feedback value) 01: ON (Deviation = Feedback value - Target value)	00	No	—	
	A078	PID output limit function	0.00 to 100.0	0.0	No	%	
AVR	A081	AVR selection	00: Always ON 01: Always OFF 02: OFF during deceleration	02	No	—	
	A082	AVR voltage selection	200-V class: 200/215/220/230/240 400-V class: 380/400/415/440/460/480	200/ 400	No	V	

* 2nd control is displayed when SET (08) is allocated to one of from C001 to C005.

Parameter No.		Function name	Monitor or data range (Digital Operator)	Default setting	Changes during operation	Unit	Set value
RUN mode, Acceleration/Deceleration functions	A085	RUN mode selection	00: Normal operation 01: Energy-saving operation	00	No	-	
	A086	Energy-saving response/ accuracy adjustment	0 to 100	50	No	%	
	A092	Acceleration time 2	0.01 to 99.99 100.0 to 999.9 1000. to 3000.	15.00	Yes	s	
	A292	*2nd acceleration time 2		15.00			
	A093	Deceleration time 2	0.01 to 99.99 100.0 to 999.9 1000. to 3000.	15.00	Yes	s	
	A293	*2nd deceleration time 2		15.00			
	A094	2-step acceleration/ deceleration selection	00: Switched via multi-function input 09 (2CH) 01: Switched by setting	00	No	—	
	A294	*2nd 2-step acceleration/ deceleration selection		00			
	A095	2-step acceleration frequency	0.0 to 400.0	0.0	No	Hz	
	A295	*2nd 2-step acceleration frequency		0.0			
	A096	2-step deceleration frequency	0.0 to 400.0	0.0	No	Hz	
	A296	*2nd 2-step deceleration frequency		0.0			
	A097	Acceleration pattern selection	00: Line 01: S-shape curve	00	No	—	
	A098	Deceleration pattern selection	00: Line 01: S-shape curve	00	No	—	

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Parameter No.		Function name	Monitor or data range (Digital Operator)	Default setting	Changes during operation	Unit	Set value
External frequency adjustment	A101	FI start frequency	0.0 to 400.0	0.0	No	Hz	
	A102	FI end frequency	0.0 to 400.0	0.0	No	Hz	
	A103	FI start ratio	0. to 100.	0.	No	%	
	A104	FI end ratio	0. to 100.	100.	No	%	
	A105	FI start selection	00: Use FI start frequency [A101] 01: 0 Hz start	01	No	—	
Operation frequency	A141	Operation frequency input A setting	00: Digital Operator (F001) 01: Digital Operator (FREQ adjuster) 02: Input FV 03: Input FI 04: RS485 communication	01	No	—	
	A142	Operation frequency input B setting		02	No	—	
	A143	Operator selection	00: Addition (A + B) 01: Subtraction (A - B) 02: Multiplication (A × B)	00	No	—	
Frequency addition	A145	Frequency addition amount	0.0 to 400.0	0.0	Yes	Hz	
	A146	Frequency addition direction	00: Adds A145 value to output frequency 01: Subtract A145 value from output frequency	00	No	—	
VR adjustment	A151	VR start frequency	0.0 to 400.0	0.0	No	Hz	
	A152	VR end frequency	0.0 to 400.0	0.0	No	Hz	
	A153	VR start ratio	0. to 100.	0.	No	%	
	A154	VR end ratio	0. to 100.	100.	No	%	
	A155	VR start selection	00: Use VR start frequency [A151] 01: 0 Hz start	01	No	—	

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Parameter No.		Function name	Monitor or data range (Digital Operator)	Default setting	Changes during operation	Unit	Set value
Restart during momentary power interruption	b001	Retry selection	00: Alarm 01: 0 Hz start 02: Frequency matching start 03: Trip after frequency matching deceleration stop	00	No	—	
	b002	Allowable momentary power interruption time	0.3 to 25.0	1.0	No	s	
	b003	Retry wait time	0.3 to 100.0	1.0	No	s	
	b004	Momentary power interruption/ undervoltage trip during stop selection	00: Disabled 01: Enabled	00	No	—	
	b005	Momentary power interruption retry time selection	00: 16 times 01: No limit	00	No	—	
	b011	Starting frequency at frequency pull-in restart	00: Frequency at interruption 01: Max. frequency 02: Set frequency	00	No	—	
Electronic thermal	b012	Electronic thermal level	0.2 × Rated current to 1.0 × Rated current	Rated current	No	A	
	b212	*2nd electronic thermal level		Rated current			
	b013	Electronic thermal characteristics selection	00: Reduced torque characteristics 1 01: Constant torque characteristics 02: Reduced torque characteristics 2	00	No	—	
	b213	*2nd electronic thermal characteristics selection		00			

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Parameter No.		Function name	Monitor or data range (Digital Operator)	Default setting	Changes during operation	Unit	Set value
Overload limit	b021	Overload limit selection	00: Disabled 01: Enabled in acceleration/constant speed operation 02: Enabled in constant speed operation	01	No	—	
	b221	*2nd overload limit selection		01			
	b022	Overload limit level	0..1 × Rated current to 1.5 × Rated current	1.5 × Rated current	No	A	
	b222	*2nd overload limit level		1.5 × Rated current			
	b023	Overload limit parameter	0.1 to 3000.0	1.0	No	s	
	b223	*2nd overload limit parameter		1.0			
	b028	Overload limit source selection	00: b022, b222 set values 01: Input terminal FV	00	No	—	
	b228	*2nd overload limit source selection		00			
Frequency pull-in	b029	Deceleration rate constant at frequency pull-in restart	0.1 to 3000.0	0.5	No	s	
	b030	Frequency pull-in restart level	0.2 × Rated current to 2.0 × Rated current	Rated current	No	A	
Lock	b031	Soft lock selection	00: Data other than b031 cannot be changed when terminal SFT is ON. 01: Data other than b031 and the specified frequency parameter cannot be changed when terminal SFT is ON. 02: Data other than b031 cannot be changed. 03: Data other than b031 and the specified frequency parameter cannot be changed. 10: Data other than parameters changeable during operation cannot be changed.	01	No	—	

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Parameter No.		Function name	Monitor or data range (Digital Operator)	Default setting	Changes during operation	Unit	Set value
Non-stop function at momentary power interruption	b050	Selection of non-stop function at momentary power interruption	00: Disabled 01: Enabled (Stop) 02: Enabled (Restart)	00	No		
	b051	Starting voltage of non-stop function at momentary power interruption	0.0 to 1000.	0.0	No	V	
	b052	Stop deceleration level of non-stop function at momentary power interruption	0.0 to 1000.	0.0	No	V	
	b053	Deceleration time of non-stop function at momentary power interruption	0.01 to 99.99 100.0 to 999.9 1000 to 3000	1.0	No	s	
	b054	Deceleration starting width of non-stop function at momentary power interruption	0.0 to 10.0	0.0	No	Hz	
Others	b055	Overvoltage protection proportional gain during deceleration	0.2 to 5.0	0.2	Yes	—	
	b056	Overvoltage protection integral time during deceleration	0.0 to 150.0	0.2	Yes	s	
	b080	AM adjustment	0. to 255. (Shared with C086 for AM offset adjustment)	100.	Yes	—	
	b082	Starting frequency	0.5 to 9.9	1.5	No	Hz	
	b083	Carrier frequency	2.0 to 12.0	3.0	No	kHz	
Initialization	b084	Initialization selection	00: Clears the trip monitor 01: Initializes data 02: Clears the trip monitor and initializes data	00	No	—	
	b085	Initialization parameter selection	00 * Do not change.	00	No	—	

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Parameter No.		Function name	Monitor or data range (Digital Operator)	Default setting	Changes during operation	Unit	Set value
Others	b086	Frequency conversion coefficient	0.1 to 99.9	1.0	Yes	—	
	b087	STOP key selection	00: Enabled 01: Disabled	00	No	—	
	b088	Free-run stop selection	00: 0 Hz start 01: Frequency pull-in restart	00	No	—	
	b089	Monitor display selection	01: Output frequency monitor 02: Output current monitor 03: Rotation direction monitor 04: PID feedback value monitor 05: Multi-function input monitor 06: Multi-function output monitor 07: Frequency conversion monitor	01	Yes	—	
	b091	Stop selection	00: Deceleration → Stop 01: Free-run stop	00	No	—	
	b092	Cooling fan control	00: Always ON 01: ON during RUN 02: Depends on the fin temperature	01	No	—	
	b130	Overvoltage LAD stop function	00: Disabled 01: Enabled	00	No	—	
	b131	Overvoltage LAD stop function level setting	200-V class: 330. to 395. 400-V class: 660. to 790.	380/ 760	Yes	V	
	b133	Overvoltage protection function selection during deceleration	00: Disabled 01: Enabled	00	No	—	
	b134	Overvoltage protection level setting during deceleration	200-V class: 330. to 395. 400-V class: 660. to 790.	380/ 760	No	V	
	b140	Overcurrent suppression function	00: Disabled 01: Enabled	01	No	—	
	b150	Automatic carrier reduction	00: Disabled 01: Enabled	00	No	—	
	b151	Ready function selection	00: Disabled 01: Enabled	00	No	—	

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Parameter No.		Function name	Monitor or data range (Digital Operator)	Default setting	Changes during operation	Unit	Set value
Multi-function input terminals	C001	Multi-function input 1 selection	00: FW (forward) 01: RV (reverse) 02: CF1 (multi-step speed setting binary 1) 03: CF2 (multi-step speed setting binary 2) 04: CF3 (multi-step speed setting binary 3) 05: CF4 (multi-step speed setting binary 4) 06: JG (jogging) 07: DB (external DC injection braking) 08: SET (2nd control) 09: 2CH (2-step acceleration/deceleration) 11: FRS (free-run stop) 12: EXT (external trip) 13: USP (USP function) 15: SFT (soft lock) 16: AT (analog input switching) 18: RS (reset) 19: PTC (thermistor input) 20: STA (3-wire start) 21: STP (3-wire stop) 22: F/R (3-wire forward/reverse) 23: PID (PID enabled/disabled) 24: PIDC (PID integral reset) 27: UP (UP/DWN function accelerated) 28: DWN (UP/DWN function decelerated) 29: UDC (UP/DWN function data clear) 31: OPE (forced operator) 50: ADD (frequency addition) 51: F-TM (forced terminal block) 52: RDY (ready function) 53: SP-SET (special 2nd function) 64: EMR (emergency shutoff *1) 255: No function *1. The EMR is set forcibly with switch S8, not with parameters.	00	No	—	
	C201	*2nd multi-function input 1 selection		00			
	C002	Multi-function input 2 selection		01			
	C202	*2nd multi-function input 2 selection		01			
	C003	Multi-function input 3 selection		18			
	C203	*2nd multi-function input 3 selection		18			
	C004	Multi-function input 4 selection		12			
	C204	*2nd multi-function input 4 selection		12			
	C005	Multi-function input 5 selection		02			
	C205	*2nd multi-function input 5 selection		02			
	C011	Multi-function input 1 operation selection	00: NO 01: NC	00	No	—	
	C012	Multi-function input 2 operation selection		00			
	C013	Multi-function input 3 operation selection		00			
	C014	Multi-function input 4 operation selection		00			
	C015	Multi-function input 5 operation selection		00			

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Parameter No.		Function name	Monitor or data range (Digital Operator)	Default setting	Changes during operation	Unit	Set value
Multi-function output setting	C021	Multi-function output terminal P1 selection	00: RUN (signal during RUN) 01: FA1 (constant speed arrival signal) 02: FA2 (over set frequency arrival signal) 03: OL (overload warning) 04: OD (excessive PID deviation) 05: AL (alarm output) 06: Dc (disconnection detection) 07: FBV (PID FB status output) 08: NDc (network error) 09: LOG(logic operation output) 10: ODc (Do not use.) 43: LOC (light load detection signal)	00	No	—	
	C026	Relay output (MA, MB) function selection		05			
	C028	AM selection	00: Output frequency 01: Output current	00	No	—	
	C031	Multi-function output terminal P1 contact selection	00: NO contact at MA; NC contact at MB 01: NC contact at MA; NO contact at MB	00	No	—	
	C036	Relay output (MA, MB) contact selection		01			
	C038	Light load signal output mode	00: Enabled during acceleration/deceleration/ constant speed 01: Enabled only during constant speed	01	No	—	
	C039	Light load detection level	0.0 to 2.0 × Rated current (0.0 setting: Function disable)	Rated current	No	—	
Level output status setting	C041	Overload warning level	0.0: Does not operate 0.1 × Rated current to 2.0 × Rated current	Rated current	No	A	
	C241	*2nd overload warning level		Rated current			
	C042	Arrival frequency during acceleration	0.0 to 400.0	0.0	No	Hz	
	C043	Arrival frequency during deceleration	0.0 to 400.0	0.0	No	Hz	
	C044	PID deviation excessive level	0.0 to 100.0	3.0	No	%	
	C052	PID FB upper limit	0.0 to 100.0	100	No	%	
	C053	PID FB lower limit		0.0			

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Parameter No.		Function name	Monitor or data range (Digital Operator)	Default setting	Changes during operation	Unit	Set value
Communication function adjustment	C070	Operator/ModBus selection	02: Digital Operator 03: ModBus	02	No	—	
	C071	Communication speed selection (Baud rate selection)	04: 4800 bps 05: 9600 bps 06: 19200 bps	04	No	—	
	C072	Communication station No. selection	1. to 32.	1.	No	—	
	C074	Communication parity selection	00: No parity 01: Even 02: Odd	00	No	—	
	C075	Communication stop bit selection	1: 1-bit 2: 2-bit	1	No	—	
	C076	Communication error selection	00: Trip 01: Trip after deceleration stop 02: Ignore 03: Free run 04: Deceleration stop	02	No	—	
	C077	Communication error timeout	0.00 to 99.99	0.00	No	s	
	C078	Communication wait time	0. to 1000.	0.	No	ms	
Various adjustment	C081	FV adjustment	0.0 to 200.0	100.0	Yes	%	
	C082	FI adjustment	0.0 to 200.0	100.0	Yes	%	

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Parameter No.		Function name	Monitor or data range (Digital Operator)	Default setting	Changes during operation	Unit	Set value
Others	C086	AM offset adjustment	0.0 to 10.0	0.0	Yes	V	
	C091	Not used	Use "00". *Do not change.	00	—	—	
	C101	UP/DWN selection	00: Do not store the frequency data 01: Store the frequency data	00	No	—	
	C102	Reset selection	00: Trip reset at power-on 01: Trip reset when the power is OFF 02: Enabled only during trip (Reset when the power is ON.)	00	No	—	
	C141	Logic operation function A input	00: RUN (signal during RUN) 01: FA1 (constant speed arrival signal) 02: FA2 (over set frequency arrival signal) 03: OL (overload warning) 04: OD (excessive PID deviation) 05: AL (alarm output) 06: Dc (disconnection detected) 07: FBV (PID FB status output) 08: NDc (network error) 10: ODc (Do not use.) 43: LOC (light load detection signal)	00	No	—	
	C142	Logic operation function B input		01	No	—	
	C143	Logic operator selection	00: AND 01: OR 02: XOR	00	No	—	
	C144	Output terminal P1 ON delay	0.0 to 100.0	0.0	No	s	
	C145	Output terminal P1 OFF delay	0.0 to 100.0	0.0	No	s	
	C148	Relay output ON delay	0.0 to 100.0	0.0	No	s	
	C149	Relay output OFF delay	0.0 to 100.0	0.0	No	s	
Control parameter	H003	Motor capacity selection	200-V class 0.2/0.4/0.75/1.5/2.2/3.7/5.5/7.5 400-V class 0.4/0.75/1.5/2.2/3.7/5.5/7.5	Factory default	No	kW	
	H203	*2nd motor capacity selection		Factory default			
	H004	Motor pole number selection	2 4 6 8	4	No	Pole	
	H204	*2nd motor pole number selection		4			
	H006	Stabilization parameter	0. to 255.	100	Yes	%	
	H206	*2nd stabilization parameter		100	Yes	%	

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DC Motor Characteristics

The characteristics of the DC Motor are:

RATINGS	120 V	220 V	240 V
Power rating (hp)	1/3	1/3	
Full-load current (A)	3.6	1.8	
Armature DC volts	90	180	
Enclosure type	TEFC		
Duty rating	CONT.		
Maximum ambient temperature [°C (°F)]	40 (104)		
Rotation speed (r/min)	1750		
Torque	1.52 n•m (13.5 lb•in)		
Insulation class	F		

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