Electric Power Technology Training Equipment

Original Operating Instructions

Electric Power Technology

User Guide

Festo Didactic

en

584778

Electric Power Technology

Electric Power Technology Training Equipment

Original Operating Instructions

User Guide

584778

Order no.: 584778 (Printed version) 591259 (Electronic version)
First Edition 2015/05
Revision level: 2026/05

By the staff of Festo Didactic

Internet: www.festo.com
e-mail: services.didactic@festo.com

Printed in Canada

ISBN 978-2-89747-254-2 (Printed version)
ISBN 978-2-89747-255-9 (Electronic version)
Legal Deposit - Bibliothèque et Archives nationales du Québec, 2008
Legal Deposit - Library and Archives Canada, 2008

Table of Contents

Document Preliminaries

About this document

This user guide provides the information needed to install, operate, handle, and maintain the Electric Power Technology Training Equipment safely.

The first units present the general operating requirements, intended use, guarantee and liability information, and essential safety instructions. The guide then covers the system power requirements, quick-start installation and shutdown procedures, LVDAC-EMS software installation and use, workstation installation guidelines, and safe handling, installation, and removal of EMS modules.

The equipment description unit provides an overview of the EMS modules covered in this guide, including their main functions, controls, connectors, indicators, technical specifications, and maintenance instructions when applicable.

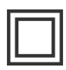
The final unit covers general maintenance, electrical continuity checks, equipment disposal, battery maintenance and disposal, and cleaning. Appendix A lists the checks required to confirm that the ac power network and classroom wall outlets are correctly wired before the equipment is used.

Safety Symbols and Procedures

The following table lists the safety and common symbols that may be used in this document and on the equipment. Before performing procedures with the equipment, you should read all sections regarding safety in the User Guide accompanying the equipment. Additional safety procedures are given before any task requiring specific safety precautions.

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.
NOTICE	**NOTICE** indicates a hazard with a potentially hazardous situation, which, if not avoided, may result in property damage.
	Caution, risk of danger. Consult the relevant user documentation.
	Caution, risk of electric shock.

Symbol	Description
	Caution, lifting hazard.
	Caution, hot surface.
	Caution, risk of fire.
	Caution, risk of explosion.
	Caution, belt drive entanglement hazard.
	Caution, chain drive entanglement hazard.
	Caution, gear entanglement hazard.
	Caution, hand crushing hazard.
	Static sensitive contents. Observe precautions for handling electrostatic discharge sensitive devices.
	Notice, non-ionizing radiation.
	Consult the relevant user documentation.
	Radio Equipment Directive (RED) geographical restrictions – consult the relevant user documentation.

Symbol	Description
	Direct current.
	Alternating current.
	Both direct and alternating current.
	Three-phase alternating current.
	Earth (ground) terminal.
	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.

General Requirements for Operating the Equipment

To safely operate electrical equipment in commercial or training environments, the following requirements apply:

- **Follow national regulations** that govern electrical systems and equipment in commercial or industrial facilities.
- **Ensure supervision.** A qualified supervisor (electrician or trained electrical engineer with documented training) must oversee the laboratory or classroom.
- **Perform correct setup.** Install and commission the equipment strictly according to the accompanying documentation before use.
- **Remove damaged equipment.** Immediately block off and remove damaged or defective devices, cables, leads, pneumatic tubing, or hydraulic hoses from the lab or classroom.
- **Ensure the room is equipped with all required safety devices.** Where local regulations apply, the room must include:
  - DC-sensitive residual current devices (RCDs), type B, ≤ 30 mA.
  - Overcurrent protection (circuit breakers or fuses).
  - One or more emergency-off devices to cut power either for the entire room or individual workstations.
  - Security features (e.g., lockable power-on switches or on-off valves) to prevent unauthorized activation of voltage or compressed air.

Use for Intended Purpose

The equipment may only be used:

- For its intended purpose in teaching and training applications.
- When its safety functions are in flawless condition.

The components of the equipment are designed in accordance with the latest technology and recognized safety rules. However, life and limb of the user and third parties may be endangered and the equipment may be impaired if it is used improperly.

The learning program from Festo Didactic has been developed and produced exclusively for training purposes. To ensure the safety of the trainees during their training, the training company and/or supervisors must make sure that all trainees use the equipment as directed in the accompanying Festo Didactic courses, and observe the safety instructions and precautions in the present document.

WARNING

Risk of danger from using the equipment in a way other than prescribed by Festo Didactic!

- Using the equipment in a way other than directed in the accompanying Festo Didactic courses, or using the equipment with equipment from other manufacturers, may increase the risk of danger for the users of the equipment.
- To minimize the risk of danger related to the situation described above, always respect the specifications marked on the equipment as well as the specifications in the Festo Didactic data sheet of the equipment.
- If the equipment includes a third-party component, always respect the specifications and directives provided in the user document on this component to minimize the risk of danger related to the situation described above.

Guarantee and Liability

Our "general terms and conditions of sale and delivery" are always applicable. These are made available to the operating company no later than on conclusion of the sales contract. Guarantee and liability claims resulting from personal injury and/or property damage are excluded if they can be traced back to one or more of the following causes:

- Use of the equipment for anything other than its intended purpose.
- Improper commissioning and/or operation of the equipment.
- Use of the equipment with defective safety equipment, or with improperly attached or non-functional safety and protective equipment.
- Non-compliance with instructions included in the core documentation about commissioning and operation.
- Unauthorized modifications to the equipment.
- Improperly executed repairs.
- Disasters resulting from the influence of foreign bodies and acts of nature.

Festo Didactic hereby excludes any and all liability for damages suffered by trainees, the training company, and/or any third parties, which occur during use of the equipment in situations which serve any purpose other than training and/or vocational education, unless such damages have been caused by Festo Didactic due to malicious intent or gross negligence.

For Your Safety

Important information

Follow the safety instructions for the safe use and trouble-free operation of the equipment.

In particular, the safety precautions must be adhered to by all persons who work with the equipment. In addition, all pertinent accident prevention rules and regulations, which are applicable at the respective place of use, must be adhered to.

Obligations of the operating company

The operating company only permits those who meet the following qualification to work with the equipment:

- Persons that are familiar with the basic regulations regarding work safety and accident prevention, and have been trained in the use of the equipment.
- Persons that have read and understood the chapter concerning safety and the warnings in this manual.

Personnel should be tested at regular intervals for safety-conscious work habits.

Obligations of the trainees

All persons who have been entrusted to work with the equipment must complete the following steps before beginning work.

- Read the chapter concerning safety and the warnings in this manual.
- Familiarize themselves with the basic regulation regarding work safety and accident prevention.

System Power Requirements

The equipment is available in different versions to accommodate the various ac power voltage and frequency combinations used worldwide. The system requirements for each version are listed below.

Table 1: 120 V, 60 Hz version.

System requirements	
Maximum Current	15 A when using the Power Supply, Model 8821-2 10 A when using the Power Supply, Model 8823
Typical Current	1.5 A per student group
AC Power Network Installation	3 phases (120/208 V – 60 Hz), star (wye) configuration including neutral and ground wires, protected by a 20 A circuit breaker
AC Power Network Connector	NEMA L21-20

Table 2: 220 V, 50 Hz version.

System requirements	
Maximum Current	10 A when using the Power Supply, Model 8821-2 5 A when using the Power Supply, Model 8823
Typical Current	1 A per student group
AC Power Network Installation	3 phases (220/380 V – 50 Hz), star (wye) configuration including neutral and ground wires, protected by a 20 A circuit breaker
AC Power Network Connector	NEMA L22-20

Table 3: 220 V, 60 Hz version.

System requirements	
Maximum Current	10 A when using the Power Supply, Model 8821-2 5 A when using the Power Supply, Model 8823
Typical Current	1 A per student group
AC Power Network Installation	3 phases (220/380 V – 60 Hz), star (wye) configuration including neutral and ground wires, protected by a 20 A circuit breaker
AC Power Network Connector	NEMA L22-20

Table 4: 240 V, 50 Hz version.

System requirements	
Maximum Current	10 A when using the Power Supply, Model 8821-2 5 A when using the Power Supply, Model 8823
Typical Current	1 A per student group
AC Power Network Installation	3 phases (240/415 V – 50 Hz), star (wye) configuration including neutral and ground wires, protected by a 20 A circuit breaker
AC Power Network Connector	AS/NZS3123

Some ac power networks may not have a neutral wire. Because line-to-neutral voltages are unpredictable without a neutral wire, it is impossible in this situation to perform single-phase exercises with the equipment. However, a neutral wire can be added to such ac power networks by installing a transformer specifically designed for this purpose. The transformer capacity depends on the number and rating of the training equipment to be powered. To determine the required transformer ratings, contact our customer service department.

Refer to Learning Unit 9 for the technical specifications of the various EMS modules and descriptions of their input and output terminals.

Learning Unit 6

Quick-Start Installation Guide

This unit provides a quick-start procedure for installing and powering up the equipment at the beginning of a laboratory session, a general procedure for powering off, disconnecting, and removing the equipment at the end of a session, and the information required to install and run the LVDAC-EMS software.

NOTICE
The verifications listed in Appendix A of this User Guide must be performed to ensure that the equipment is properly powered by the selected power supply model. Failure to do so may result in equipment damage.

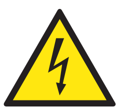
Installing and powering up the equipment

1. Make sure your workstation is properly installed (see the subsection "Workstation installation and use" in Learning Unit 7).

2. Install all EMS modules required for your laboratory exercise in the workstation (see the subsection "Installing EMS modules in a workstation" in Learning Unit 8).

3. Make sure all workstation compartments are filled with an EMS module.

⚠ WARNING
Never leave a workstation compartment empty; this prevents access to rotating machine parts. Failure to comply can result in serious hand or arm injury.



⚠ WARNING
Never leave a workstation compartment empty; this prevents access to electrical components or connections. Electric shocks can cause serious injuries.

4. Once the equipment is installed, install and padlock the two safety bars on the workstation front panel to prevent students from removing EMS modules during the session.

5. On the power supply, make sure the main power switch is in the off (O) position and its safety padlock is locked.

	⚠ WARNING
	Before making or modifying any connections on the EMS modules, always make sure the power supply is turned off to avoid electric shocks.

6. Connect the equipment as required for your laboratory exercise using the safety-plug connection leads supplied with the equipment.

	⚠ WARNING
	Do not use connection leads from other manufacturers. Always use the leads supplied with the equipment. Their live parts are concealed and insulated to prevent accidental contact and ensure safe connections without electric shock risk.

7. Make sure the front panels of all rotating machines are closed and firmly secured (see the following figure).

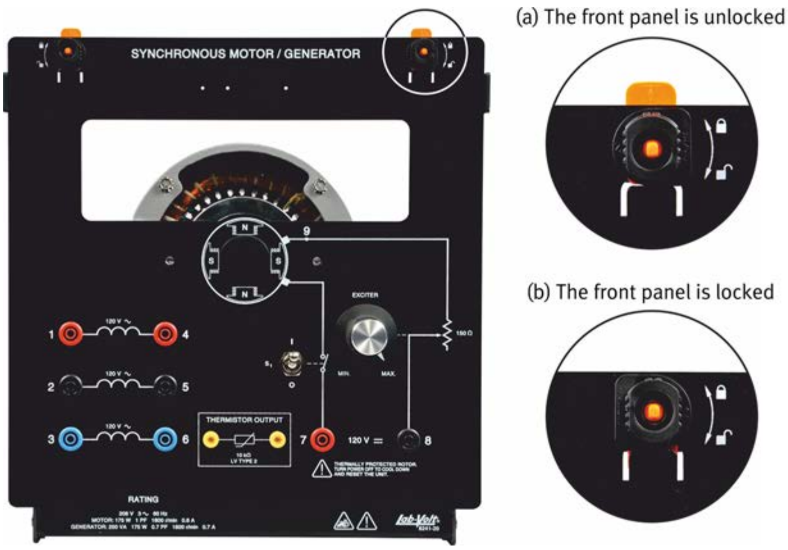


Figure 1: To secure the front panel of a rotating machine, set its rotating lock buttons to the locked position, as shown in (b).

⚠ WARNING

The front panel of rotating machines must remain closed and firmly locked whenever the machines are powered and until all rotating parts have completely stopped, to avoid injuries from electric shock or contact with rotating parts.

8. Have your equipment connections verified by a qualified, authorized person.

9. On the power supply, unlock and remove the safety padlock, then set the main power switch to I (on).

⚠ WARNING

When the equipment is powered on, follow these directives to avoid injuries from electric shock or rotating parts:

- Never leave the equipment unattended.
- Unless specifically stated otherwise, never modify equipment connections while power is on.
- Never remove an EMS module while power is on.
- Do not allow rotating parts of a machine to become accessible while power is on.

Powering off, disconnecting, and removing the equipment

1. Turn the power supply off by setting the main power switch to O (off).

2. On the power supply, install and lock the safety padlock on the main power switch.

3. Modify the equipment connections as required. If you have finished your laboratory session, remove all connection leads and return them to their storage location.

If you will perform another laboratory exercise that requires changing EMS modules and/or connections, unlock and remove the two safety bars from the workstation front panel, change the EMS modules and connections as required, then return to this step of the previous procedure, "Installing and powering up the equipment".

4. Unlock and remove the two safety bars from the workstation front panel, then remove the EMS modules (see the subsection "Removing EMS modules from a workstation" in Learning Unit 8).

⚠ WARNING

When removing EMS modules, do not touch components that may remain electrically charged (such as capacitors) to avoid electric shocks.

⚠ CAUTION

When removing EMS modules, do not touch components that may be hot (such as resistors). Contact with hot components can cause serious burns.

Installing and running the LVDAC-EMS software

Installation

5. Open a Windows session as an administrator.

6. Uninstall any LVDAC-EMS version installed on your computer.

   If an older LVDAC-EMS version is installed, launching the installer removes the old version. You must then launch the installer again to install the new version.

7. Download the LVDAC-EMS software as a "LVDacEms*****.zip" file here:

   LVDAC-EMS

   https://bit.ly/9063-00_data_acquisition_and_control_interface

   When the "LVDacEms*****.zip" download is complete, extract all files to the desired folder on your computer. In the extracted files, run "Setup.exe" and follow the LVDAC-EMS Installation Wizard instructions to complete the installation.

8. The installation is now complete.

Running the software

LVDAC-EMS can run in hardware-connected mode or demo (simulation) mode. In hardware-connected mode, the parameter values displayed come from samples of the signals sent to and received from the Data Acquisition and Control Interface (DACI), Model 9063, and/or the Four-Quadrant Dynamometer/Power Supply, Model 8960. In demo mode, the parameter values come from computer-simulated signals, so the DACI and Four-Quadrant Dynamometer/Power Supply are not required.

In this procedure, both the DACI and the Four-Quadrant Dynamometer/Power Supply are used, and LVDAC-EMS runs in hardware-connected mode.

For detailed information on the Data Acquisition and Control Interface (DACI) and the Four-Quadrant Dynamometer/Power Supply, refer to Learning Unit 9.

1. Connect the DACI and Four-Quadrant Dynamometer/Power Supply USB ports to the host computer, then power on both units.

   If the DACI, the Four-Quadrant Dynamometer/Power Supply, or both are connected to the host computer for the first time, Windows configures the new USB peripheral(s) with the pre-installed device driver(s).

2. Start the LVDAC-EMS software. A dialog box appears prompting you to select a language and notation system (see the following figure). Select the desired language and notation system, then click OK.

   The notation system determines how certain parameters are displayed in LVDAC-EMS. For example, voltage inputs are designated by "E" in American notation and "U" in European notation. The notation system selection does not affect the measurement system (SI or imperial) used in LVDAC-EMS.

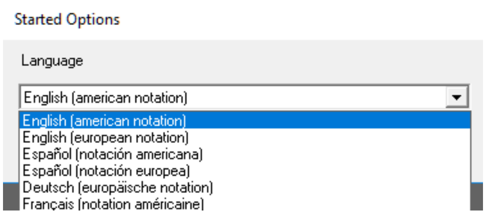


Figure 2: Selecting a language and notation system.

3. The LVDAC-EMS Launcher window appears, prompting you to select Connected mode or Demo mode (see the following figure). Select the desired mode, then click OK.

   If Connected mode is selected while the DACI and Four-Quadrant Dynamometer/Power Supply are not connected to the computer, LVDAC-EMS starts in Connected mode but without computer-based instruments or control functions. The DACI and Four-Quadrant Dynamometer/Power Supply can be connected later; LVDAC-EMS will detect them automatically.

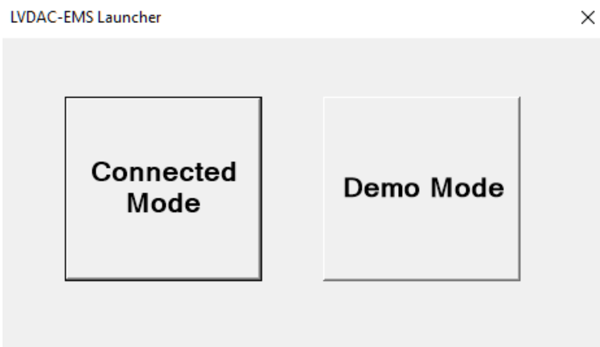


Figure 3: Selecting the Connected or Demo mode.

4. If Connected mode is selected and LVDAC-EMS establishes connections with the DACI and the Four-Quadrant Dynamometer/Power Supply, the LVDAC-EMS Start-Up window appears. It confirms that these modules have been found by displaying their names, serial numbers, and the function sets available for each (see the following figure). The available function sets are those activated on the DACI, so the Start-Up window on your computer may show fewer function sets than in the figure.

If LVDAC-EMS cannot establish a connection with the DACI, the "Data Acquisition and Control Interface" section does not appear in the Start-Up window. Similarly, if LVDAC-EMS cannot establish a connection with the Four-Quadrant Dynamometer/Power Supply, the "Four-Quadrant Dynamometer/Power Supply" section does not appear. If this occurs, perform the following:

Try again to establish connections between LVDAC-EMS and the modules by clicking the Refresh button in the LVDAC-EMS Start-Up window. If LVDAC-EMS still cannot establish a connection with one or both modules, make sure the modules are properly powered and check the USB connection between the modules and the host computer.

When an extension (second) DACI is used to implement advanced control functions, the LVDAC-EMS Start-Up window for this DACI indicates that no function set is detected (available) for this extension DACI.

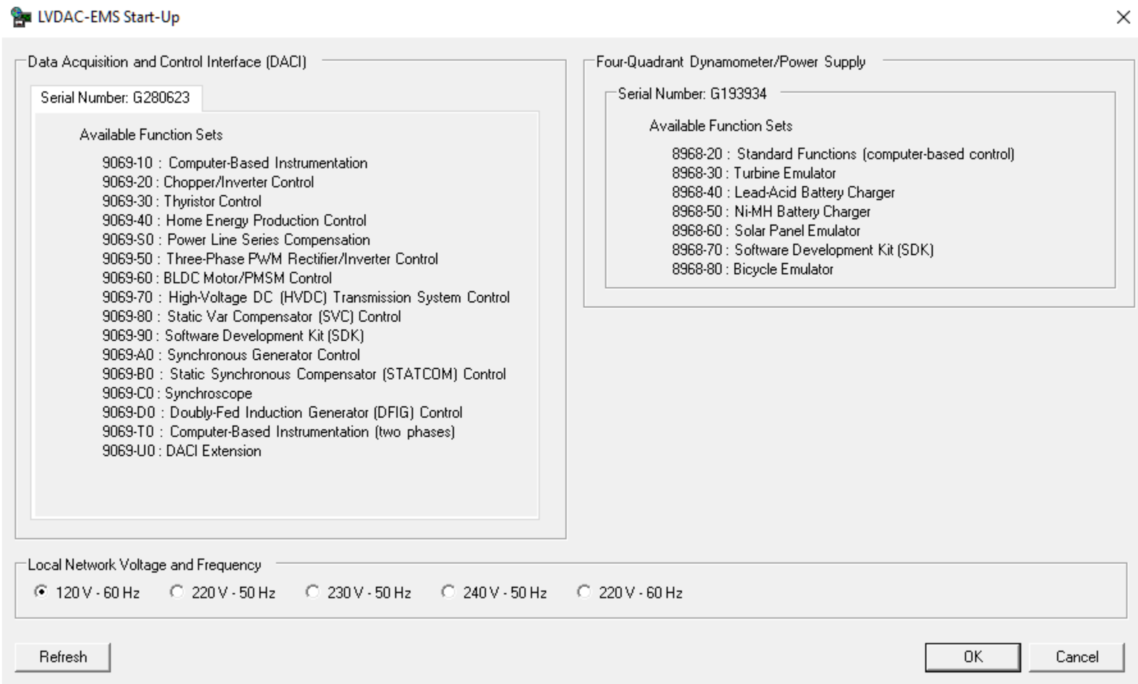


Figure 4: LVDAC-EMS Start-Up window (example).

5. In the LVDAC-EMS Start-Up window, select the Network voltage and frequency that match your local ac power network, then click OK. This closes the Start-Up window and opens the LVDAC-EMS Main window (see the following figure).

   After closing the LVDAC-EMS Start-Up window, a dialog box may appear prompting you to update the firmware in the DACI or the Four-Quadrant Dynamometer/Power Supply. In that case, click OK in the Firmware Update Required dialog box, then follow the on-screen instructions to update the firmware.

6. In the LVDAC-EMS Main window, the indication "Hardware-Connected Mode" in the lower right corner confirms that LVDAC-EMS is properly connected to the DACI and the Four-Quadrant Dynamometer/Power Supply. The Toolbar allows quick selection of an instrument or control function implemented with the DACI, or a function implemented with the Four-Quadrant Dynamometer/Power Supply.

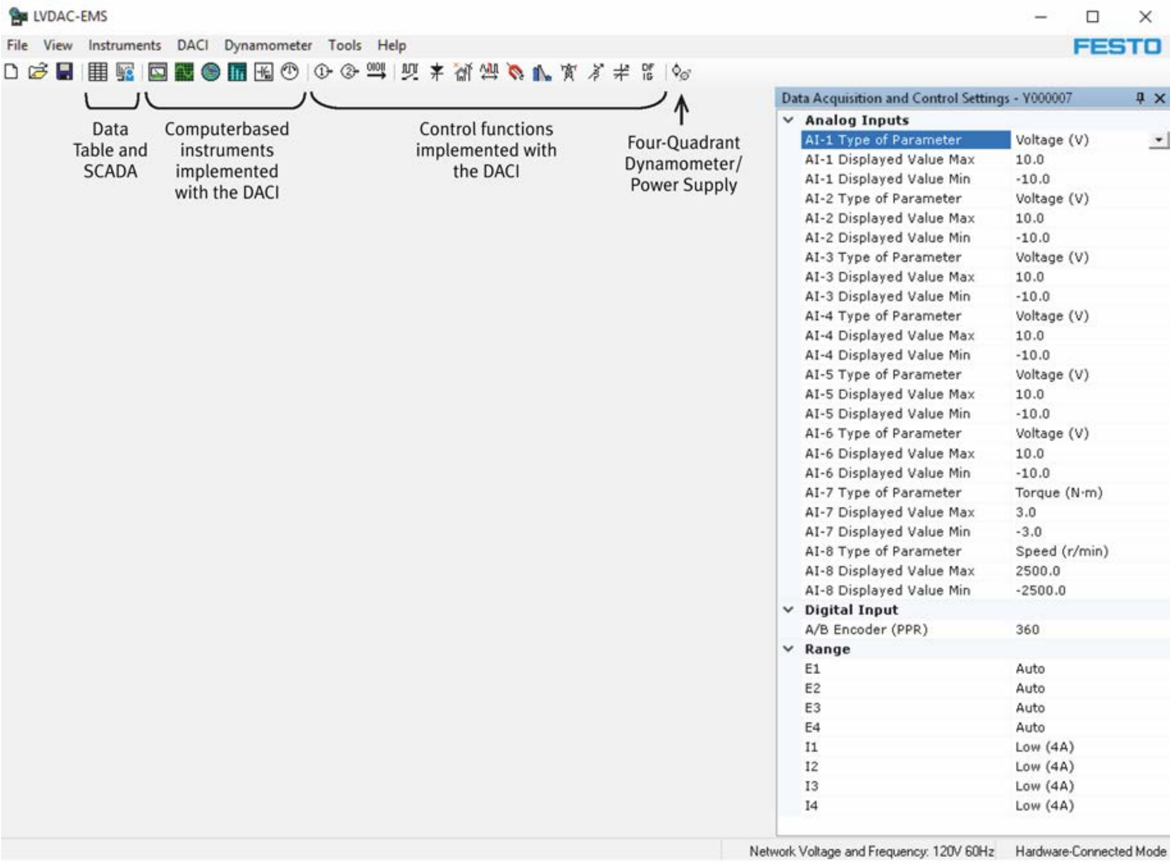


Figure 5: Main window of the LVDAC-EMS software.

The Toolbar in the LVDAC-EMS main window shows the buttons available when all DACI function sets (that is, all computer-based instruments and control functions) are activated. The Toolbar on your computer may show fewer buttons, depending on which function sets are activated in your DACI.

7. To select the system of units used in LVDAC-EMS, choose Options from the Tools menu to open the Options dialog box (see the following figure). In this box, select the desired system of units, then click OK to apply the changes and close the dialog box.

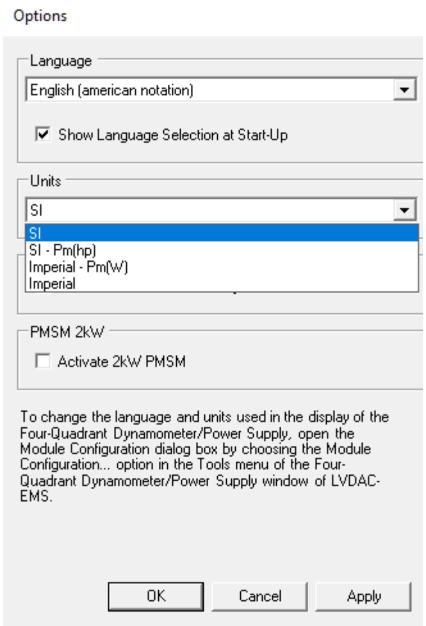


Figure 6: To change the system of units used in LVDAC-EMS, access the Options dialog box by selecting Options from the Tools menu.

8. To start a computer-based instrument implemented with the DACI, select it from the Instruments menu of LVDAC-EMS (see Figure 7), or click the corresponding Toolbar button. The selected instrument then appears on the screen. For example, Figure 8 shows the window that appears when the Metering instrument is started.

   Whenever a computer-based instrument is started, the Data Acquisition and Control Settings panel appears in the right-hand section of the LVDAC-EMS main window, as shown in Figure 5. This panel allows you to modify the DACI analog input and digital input settings, as well as the DACI voltage and current input ranges.

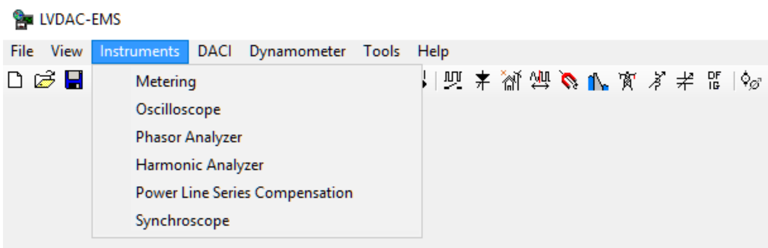


Figure 7: To start a computer-based instrument, select it from the Instruments menu of LVDAC EMS or click the corresponding Toolbar button.

Figure 8: When the Metering instrument is started, the Metering window appears.

9. To start a control function implemented with the DACI, select it from the DACI menu of LVDAC-EMS (see the following figure) or click the corresponding Toolbar button. The selected control function window appears.

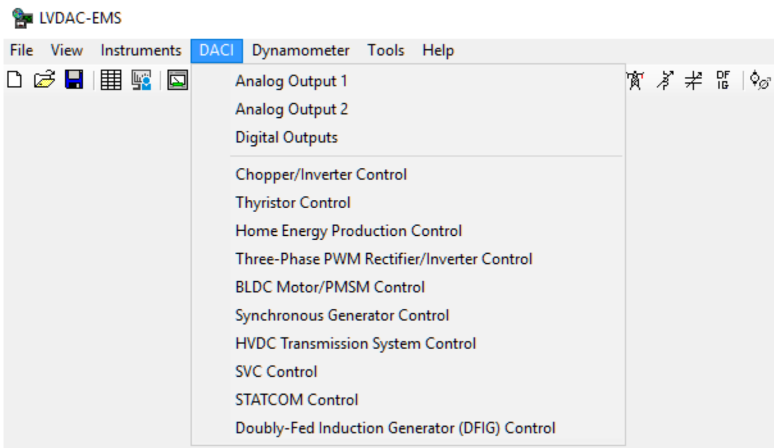


Figure 9: To start a control function implemented with the DACI, select it from the DACI menu or click the corresponding Toolbar button.

10. When a control function is started, a control window appears that lets you select the function to implement and adjust its parameters. For example, the following figure shows the control window that appears when the Home Energy Production Control function is selected.

The Control Settings panel in the control window lets you select the function to implement and set its parameter values. In the following figure, for example, the selected function is the Single-Phase Stand-Alone Inverter. Each parameter value can be set by clicking the parameter name and entering or selecting the desired value in the adjacent field. The bottom section of the Control Settings panel displays information about the currently selected function or parameter.

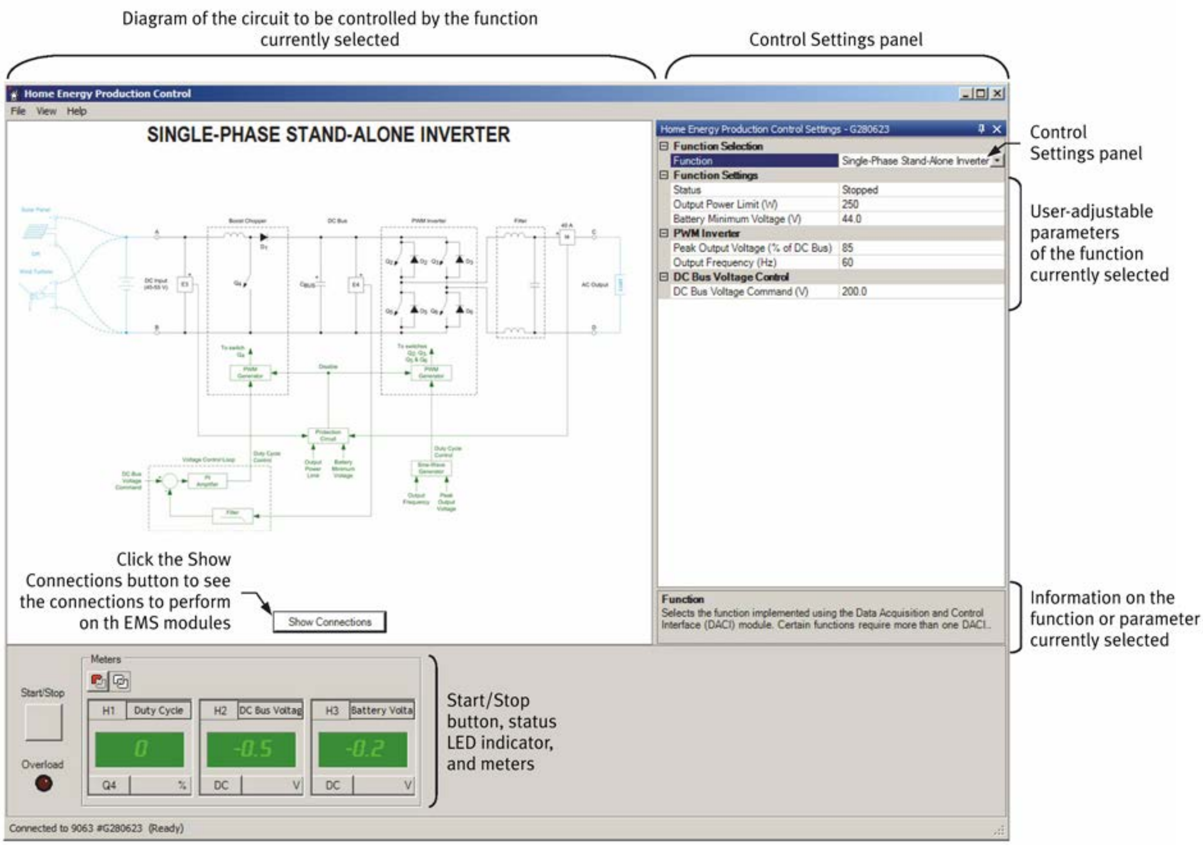


Figure 10: The Home Energy Production Control window.

11. The bottom section of the control window contains a start/stop button used to turn the selected function on and off. It can also contain additional devices, such as meters for real-time monitoring of parameter values, status LEDs, and control knobs for manual parameter adjustment, depending on the selected function.

12. The control window also shows a diagram of the electrical circuit controlled by the function selected in the Control Settings panel. Clicking the Show Connections button below this diagram opens a Connections window showing the connections to make on the EMS modules when setting up the equipment to implement the selected function (see the following figure). The connections shown in the Show Connections window correspond only to the black lines in the circuit diagram.

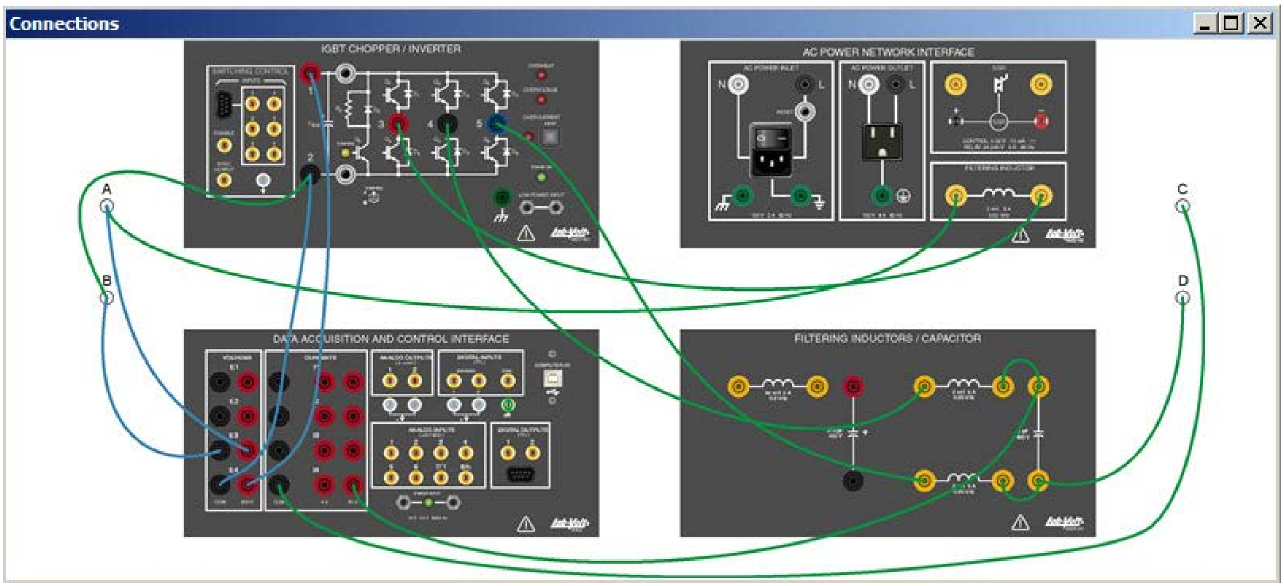


Figure 11: Connections window showing the connections to make on the EMS modules to implement the Single-Phase Stand-Alone Inverter function.

13. For functions that use a controller, a Controller Diagram button may appear below the circuit diagram in the control window. Clicking this button opens a Controller window showing the controller section of the function, as in the following example.

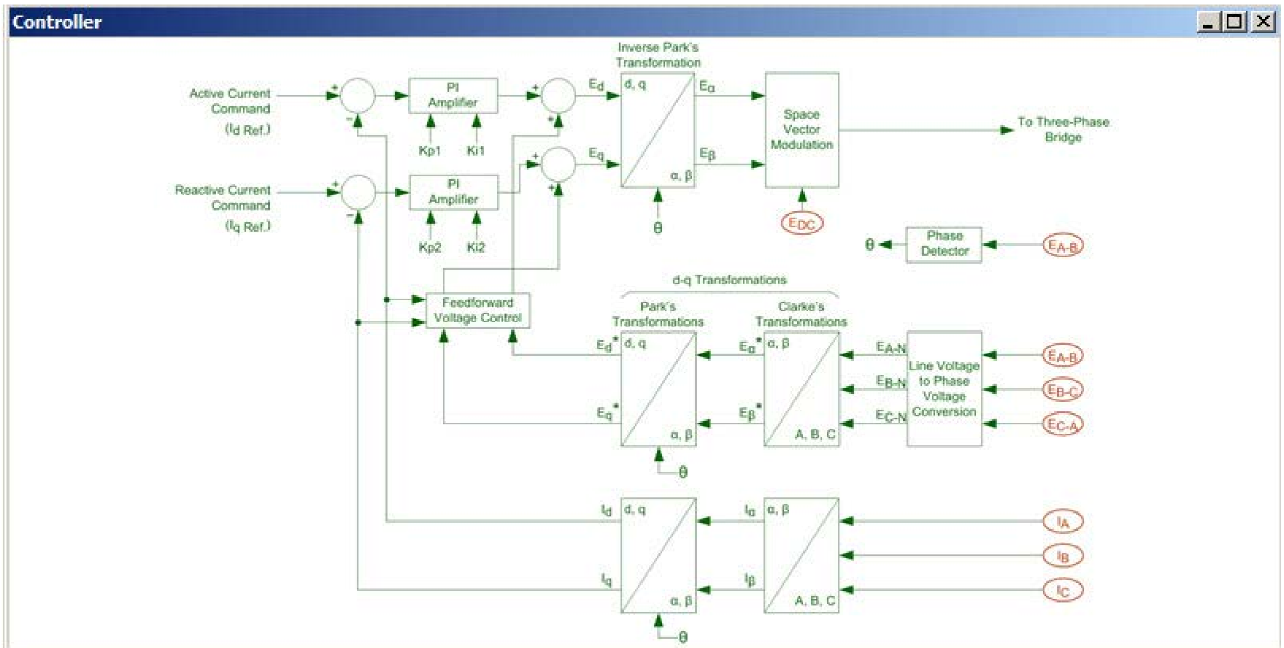


Figure 12: Controller window showing the controller section of the Three-Phase PWM Rectifier/Inverter section.

14. With advanced functions, such as the Hydropower Generator (Dead Bus – Balanced Load) function in the Synchronous Generator Control window, several buttons may appear below the circuit diagram, as shown in Figure 13.

- Clicking Show AVR opens a window showing the generator Automatic Voltage Regulation section.
- Clicking Show Speed Governor opens a window showing the generator Speed Governor section.
- Clicking Show SCADA View opens a SCADA view of the generator (Figure 14) with additional buttons used, among other things, to start and stop the generator emulator and controller.

For more information on the DACI and Four-Quadrant Dynamometer/Power Supply instruments and functions with LVDAC-EMS, refer to the sections "Four-Quadrant Dynamometer/Power Supply, Model 8960" and "Data Acquisition and Control Interface, Model 9063" in Learning Unit 9.

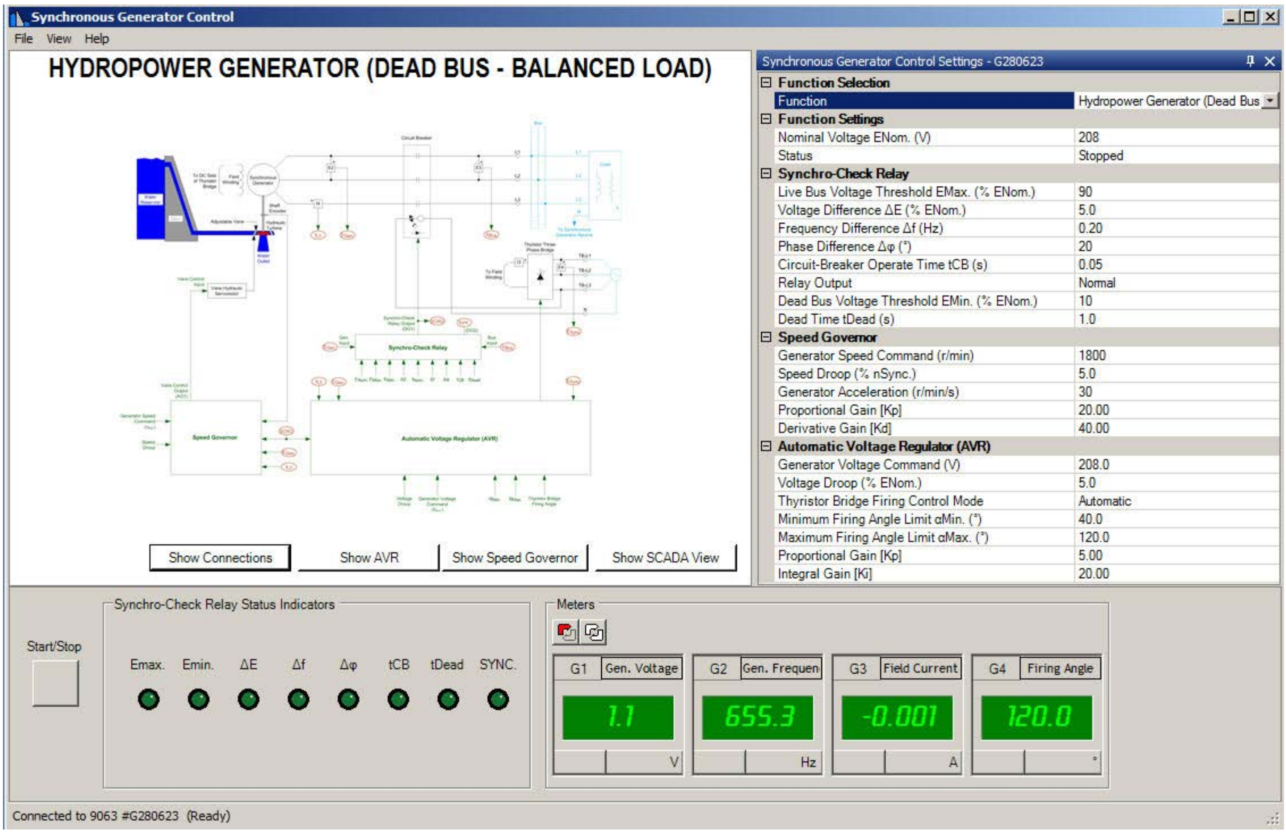


Figure 13: Synchronous Generator Control window, when the function Hydropower Generator (Dead Bus – Balanced Load) is selected.

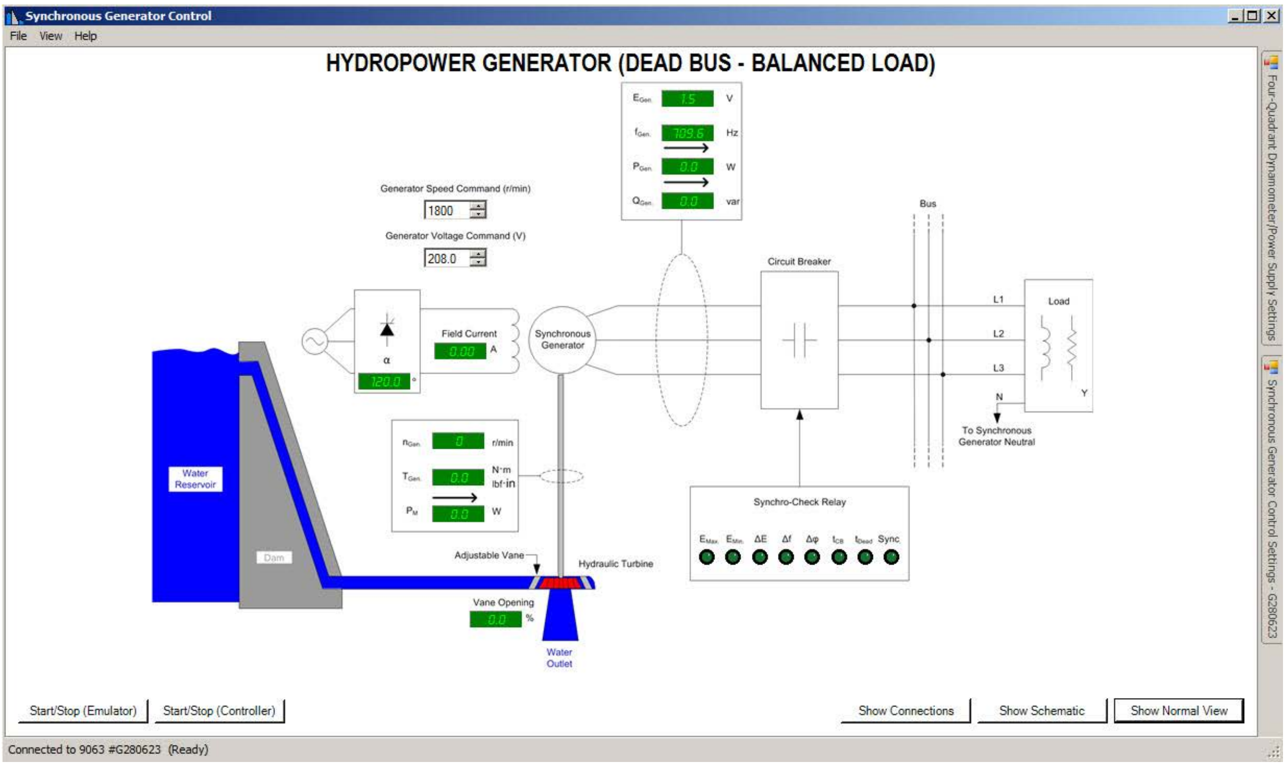


Figure 14: SCADA view of the Hydropower Generator (Dead Bus – Balanced Load) function.

Equipment Installation

Environmental requirements

The equipment is designed to be installed and stored indoors and must be operated in the following environmental conditions to ensure user safety:

- an altitude up to 2000 m (6560 ft)
- a temperature between 5°C and 40°C (41°F and 104°F)
- a maximum relative humidity of 80% for temperatures up to 31°C (88°F), decreasing linearly to 50% relative humidity at 40°C (104°F)
- mains supply voltage fluctuations which do not exceed ±10% of the nominal voltage
- transient overvoltages up to the levels of overvoltage category II
- temporary overvoltage occurring on the mains supply: 1500 V for 120 V mains and 2500 V for 230 V mains
- a pollution degree of 2 in accordance with IEC 60664-1

The word pollution used above refers to any addition of foreign matter, solid, liquid, or gaseous (ionized gases), that may produce a reduction of dielectric strength or surface resistivity.

Workstation installation and use

This section covers the installation and use of a workstation. It applies to the following models:

- Workstation, Model 8134
- Three-Module Workstation, Model 8131
- Mobile Workstation, Model 8110
- Module Enclosure, Model 8133

- Unless specifically stated otherwise, do not use the Electric Power Technology Training Equipment with equipment from other manufacturers.

⚠ WARNING

Using the Electric Power Technology Training Equipment with training equipment from other manufacturers can damage the equipment and present a risk of injury.

- Install all EMS modules of the Electric Power Technology Training Equipment in one of the workstations listed above.
- When one workstation must be connected to another, use 12-gauge wire to interconnect their protective conductor terminals.

  Then use an ohmmeter to verify electrical continuity between the protective conductor terminals of both workstations. The following figure shows a workstation protective conductor terminal.

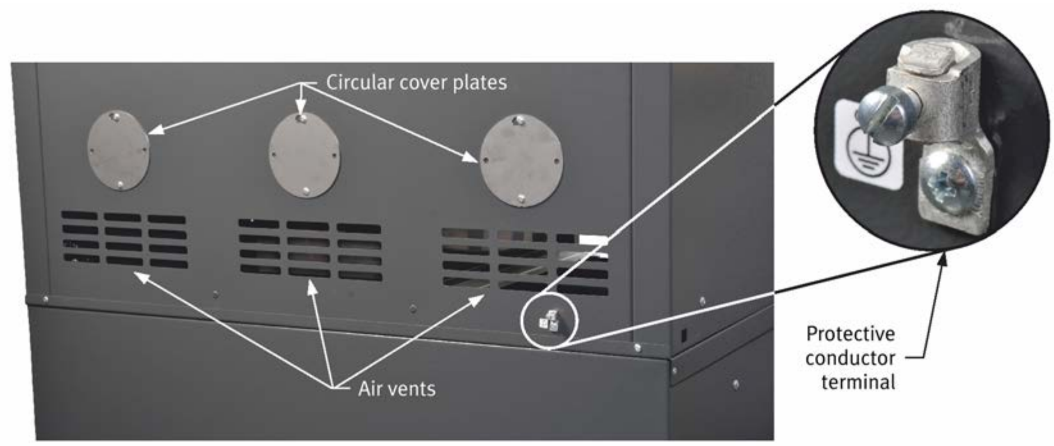


Figure 15: Rear view of a workstation.

- If you are using a mobile workstation, lock all four swivel casters whenever the workstation is not being moved. To lock a caster, press its foot brake, as shown in the following two figures.

⚠ CAUTION

Before installing EMS modules or operating equipment in a mobile workstation, make sure all four casters are locked. When moving the workstation, be careful not to pinch your hands between the workstation and a wall.

Figure 16: Press on the foot brake to lock the caster.

Figure 17: Caster in the locked condition.

- If you are using a tabletop workstation, place it on a bench that can support the weight of the workstation plus all installed equipment. Refer to the following table for the required bench load capacity for each workstation model. Each full-size EMS module is assumed to weigh about 20 kg (44 lb).

⚠ CAUTION

The bench must be stable enough to prevent the workstation from swaying when an EMS module is inserted.

Table 5: Required bench load capacity by workstation model.

Workstation model	Weight
8131	90 kg (200 lb)
8133	30 kg (67 lb)
8134	180 kg (400 lb)

- Make sure the workstation air vents are not blocked to ensure proper heat dissipation.
- Make sure the workstation top panel is completely clear of EMS modules, equipment, or objects to ensure proper heat dissipation.
- The workstation has six rear circular holes, each protected by a metal cover, providing access to rear connectors of various modules. The covers of the lower three holes can be unscrewed; the covers of the upper three holes can only be permanently removed by cutting the rivets.

When installing EMS modules with a rear connector, it is strongly recommended to use the lower three holes. Remove the metal covers of the upper three holes only if your setup requires more than three rear-connector modules.

> ⚠ **WARNING**
>
> Before powering up the system, make sure all unused rear circular holes are firmly covered. Leaving a rear circular hole open could cause serious injury and electric shock.

- For installing and removing EMS modules, see the subsections "Installing EMS modules in a workstation" and "Removing EMS modules from a workstation" in Learning Unit 8.

  Install EMS modules that dissipate significant heat (such as the Resistive Load, Model 8311 or 8509) as close as possible to the top of the workstation for optimal heat dissipation.

> ***NOTICE***
>
> Ensure that the total heat dissipated by all EMS modules in a workstation does not exceed the workstation nominal power to avoid equipment damage. The following table gives the nominal power of each workstation model.

Table 6: Nominal power of various Workstation models.

Workstation model	Nominal power
8131	500 W
8333	300 W
8134	500 W
8110	500 W

- Install heavy full-size EMS modules (such as motors and power supplies) in a full-height compartment in the bottom section of the workstation.
- Ideally, install heavy half-size EMS modules in half-height compartments. If this is not possible, stack a light half-size module on top of a heavy half-size module and install the stack in a full-height compartment.

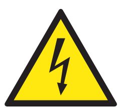
Heavy EMS modules are identified on their front panel by the symbol shown in the following figure, which complies with ISO 3864 safety symbol standards.

Figure 18: Symbol used to identify heavy modules of the Electric Power Technology Training Equipment.

- If you install the Data Acquisition and Control Interface, Model 9063, and the IGBT Chopper/Inverter, Model 8837, in the workstation, do not place them one above the other. Place them side by side to minimize electronic noise interference between them.
- All workstation compartments must contain an EMS module.

Use Full-Size Blank EMS modules, Model 8160, Half-Size Blank EMS modules, Model 8161, or unused EMS modules to fill empty compartments.

	**WARNING** Do not leave any workstation compartment empty; this prevents access to rotating machine parts and avoids serious hand or arm injury.

	**WARNING** Do not leave any workstation compartment empty; this prevents access to electrical components and avoids electric shocks.

- Before turning on the power supply (Workstation Models 8134, 8131, or 8110), make sure the two safety bars are padlocked to the workstation front panel (see the following figure) to prevent students from removing EMS modules. When the safety lock is not required, remove the safety bars and padlock them to the side of the workstation.
- This directive does not apply to Workstation Model 8133, which has no safety bars. For Model 8133, before turning on the power supply, make sure the EMS module is fully inserted and secured by the locking mechanism at the rear bottom of the enclosure.

- The pull-out work surface on Workstation Model 8110 is only for examining equipment and holding books and manuals. The total load on this surface must not exceed 20 kg (44 lb).
- Never push on the front or back of the Mobile Workstation, Model 8110, as this could cause it to tip over.

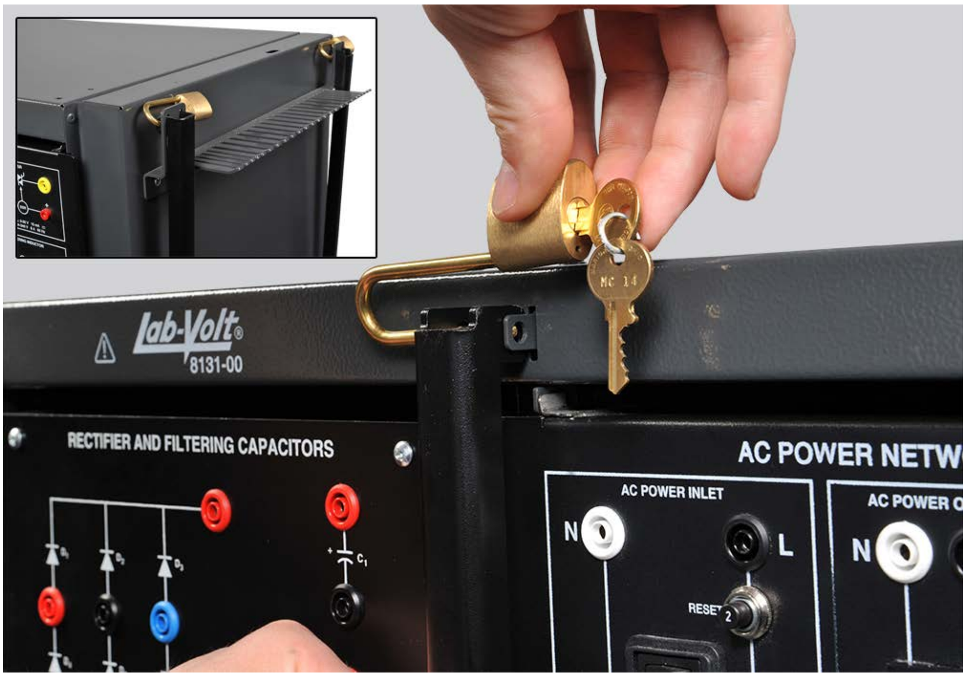


Figure 19: Padlock the two safety bars to the workstation front to prevent students from removing EMS modules during laboratory exercises. When the safety lock is not required, remove the bars and padlock them to the side of the workstation.

Cyber security

Festo Didactic provides products with security functions that support the safe operation of plants, systems, machines, and networks. Protecting these assets from cyber threats, however, requires a comprehensive and regularly updated security concept. Festo's products and services form only part of such a strategy.

The customer is responsible for preventing unauthorized access to equipment and networks. Connections to company networks or the Internet should be made only when necessary and only with appropriate security measures, such as firewalls, network segmentation, defense-in-depth strategies, etc.

Without these measures, connecting products to a network can expose vulnerabilities that allow unauthorized remote access, potentially affecting the entire system. This access can be exploited for data theft, manipulation, or sabotage. Common threats include Denial-of-Service attacks, remote code execution, privilege escalation, ransomware, and other malicious activities. In industrial environments, such attacks can create unsafe conditions, endangering both people and equipment.

Customers should follow Festo's security guidelines and keep their products up to date. Festo continuously improves its products for greater security and strongly recommends installing updates promptly. Using outdated or unsupported versions increases exposure to cyber threats.

Report security issues to the Festo Product Security Incident Response Team (PSIRT) in German or English by email at psirt@festo.com or through the online form at https://www.festo.com/psirt.

⚠ WARNING

Unsecure operating conditions due to software tampering

- Software tampering (e.g., viruses, Trojans, malware, worms) can cause unsafe system conditions, potentially leading to serious injury or property damage.
- Keep all software up to date.
- Integrate all automation and actuator components into a comprehensive industrial security concept aligned with current technological standards.
- Ensure all installed products are included in your security concept.
- Use protective tools, such as antivirus software, to scan files on removable storage media for malware.

⚠ WARNING

Firmware Update Security

This warning applies only to products with updatable firmware. To protect the security and integrity of your system, follow these guidelines during the firmware update process:

- **Download source.** Obtain firmware updates only from the official manufacturer's website.
- **Do not tamper.** Do not modify or interfere with the firmware update process.
- **Update process.** Strictly follow the firmware update instructions provided in the user guide.

Modules Handling, Installation, and Removal

This unit provides guidelines for safely handling, installing, and removing EMS modules. Improper handling, especially of heavy modules, can cause back, hand, or foot injuries. Heavy EMS modules are identified by the following symbol on their front panel, in accordance with ISO 3864:

Figure 20: Symbol used to identify heavy EMS modules.

EMS module handling

To handle the EMS modules safely, follow the guidelines below whenever you install, remove, lift, transport, support, or put down an EMS module.

- Before carrying an EMS module, assess its weight and make sure you can lift and carry it to the desired location. Know exactly where the module will be placed. Make sure your path is clear and that the floor is not bumpy, obstructed, or slippery.

- While carrying or supporting an EMS module, keep a firm grip and hold it as close as possible to your waist. Move slowly while keeping your body and feet stable. Keep your shoulders level, and turn by moving your feet, NOT your back. Never hold an EMS module at arm's length or away from your body.

Installing EMS modules in a workstation

Installing a half-size EMS module in a half-height compartment of a workstation

Half-height compartments of a workstation can be used to install light or heavy half-size EMS modules, as directed below (see the following figure). Ideally, use half-height compartments primarily for heavy half-size modules (such as the Lead-Acid Battery Pack, Model 8802).

1. While holding the half-size module by the bottom, with one hand at the front and the other at the rear, place the rear of the module at the bottom of the compartment entrance, as in (a).

2. Make sure that the side panels of the half-size module are aligned with the two guide rails at the bottom of the compartment, as in (b).

3. Insert the half-size module into the compartment, then press the push-lever on the right-hand side of the compartment row to fully insert the module, as in (c) and (d).

4. Make sure that the half-size module is firmly locked in place by pulling on its front panel. The module should not move.

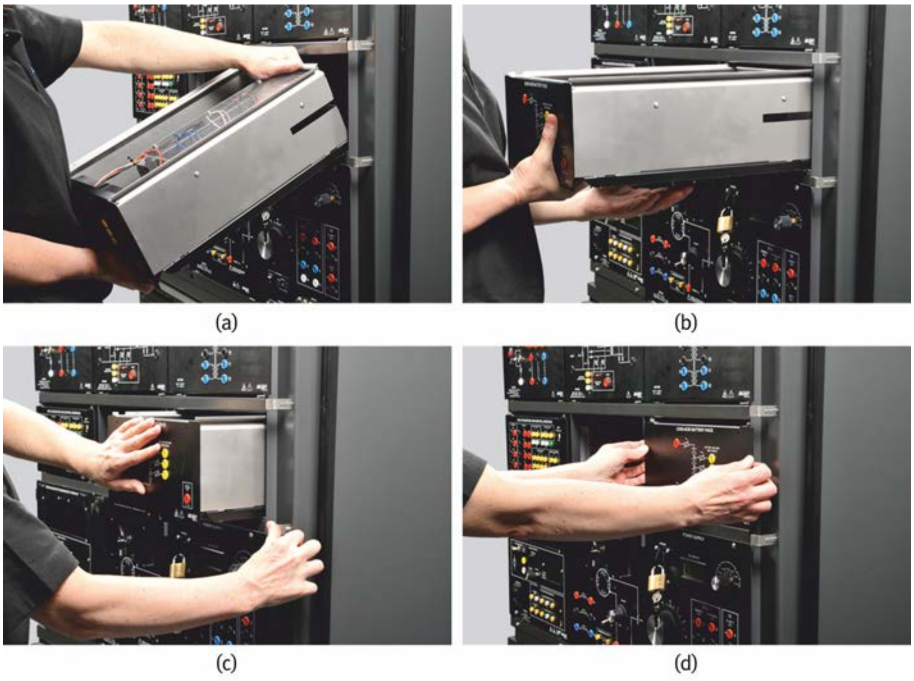


Figure 21: Installing a half-size EMS module in a half-height compartment of a workstation.

Installing two half-size EMS modules in a full-height compartment of a workstation

Full-height compartments of a workstation can be used to install pairs of stacked half-size EMS modules, as directed below (see the following figure). In this case, install the heavier module in the bottom section of the compartment (such as a Lead-Acid Battery Pack, Model 8802, or a half-size Power Supply, Model 8821) and the lighter module in the upper section.

1. First, install the heavier of the two half-size modules at the bottom of the full-height compartment, as in (a) and (b).

2. Then install the lighter of the two half-size modules on top of the heavier module by sliding it all the way into the full-height compartment, as in (c) and (d).

3. Make sure that both half-size modules are firmly locked in place by pulling on their front panels. The modules should not move.

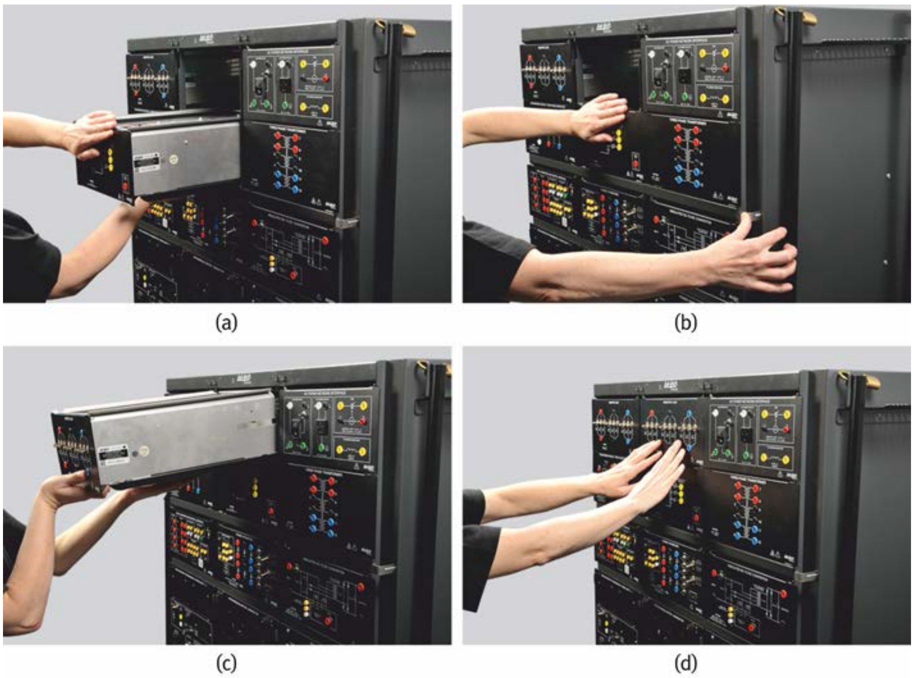


Figure 22: Installing a stack of two half-size EMS modules in a full-height compartment of a workstation.

Installing a full-size EMS module in a full-height compartment of a workstation

1. Full-height compartments of a workstation are also used to install full-size EMS modules, as directed below (see the following figure).

When using Workstation Model 8134 or Model 8110, the full-height compartments at the bottom of the workstation are normally reserved for the following EMS modules: the Four-Quadrant Dynamometer/Power Supply, Model 8960, rotating machines, and power supplies. Therefore, install these modules (when used) at the bottom of the workstation using the general procedure below, then refer to the next sub-sections for specific information on how to complete their installation.

When the EMS module to install is a rotating machine that must be mechanically coupled to a Four-Quadrant Dynamometer/Power Supply, Model 8960, install the rotating machine on the right-hand side of the Four-Quadrant Dynamometer/Power Supply to permit coupling of these machines.

2. If the front panel of the module can be opened and closed, make sure that it is closed and firmly secured by its lock buttons.

	⚠ WARNING
⚠	To avoid electric shocks and injuries caused by touching electrical components or rotating machine parts, the front panel of any rotating machine must remain closed and firmly secured by its lock buttons whenever the machine is powered on and its rotating parts have not completely stopped.

3. Before installing a full-size module in the workstation, assess its weight to make sure you are strong enough to move it to the full-height compartment where you want to install it. Ask for help if necessary.

4. Firmly grasp the module with both hands and place its base at the bottom of the compartment entrance. Make sure that the base is aligned with the two guide rails at the bottom of the compartment, as in (a).

5. Insert the module into the full-height compartment, as in (b) and (c). Press the push-lever on the right-hand side of the compartment row to fully insert the module, as in (d).

On Workstation Model 8133, there are no push-levers. A special locking mechanism at the rear bottom of the workstation enclosure (see the following figure) automatically secures the EMS module when it is fully inserted. When using Workstation Model 8133, insert the EMS module as shown in the figure, then go to the next step of this procedure.

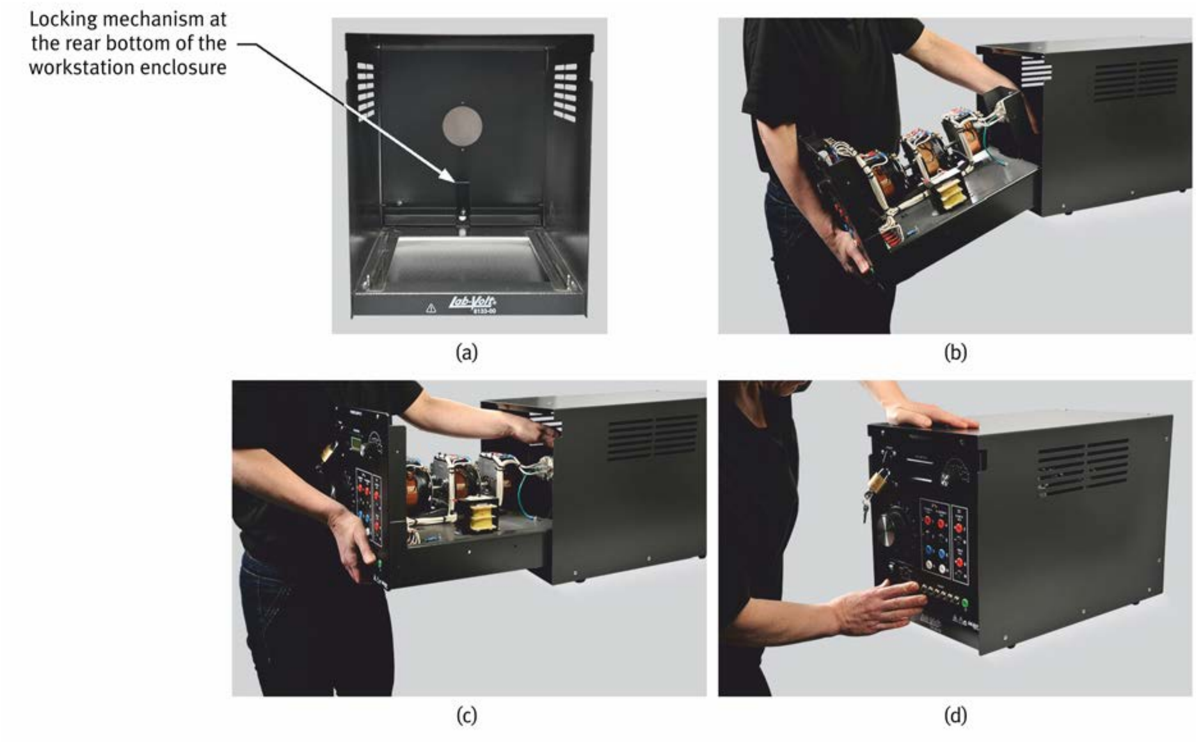


Figure 23: On Workstation Model 8133, a locking mechanism at the rear bottom of the enclosure automatically secures the EMS module when it is fully inserted.

6. Make sure that the module is firmly locked in place by pulling on its front panel. The module should not move.

7. Lock the circular plate at the rear of the compartment in which the module is installed to cover the opening, as in (e) and (f). Ignore this directive if the module (such as a Power Supply) has an ac power inlet that must be connected to the ac power network from the rear panel of the workstation.

⚠ WARNING

To avoid electric shocks, do not remove or rotate the circular plates covering the rear openings of the compartments unless a connection to a module through the rear panel of the workstation is required (for example, when connecting a power supply module to the ac power network).

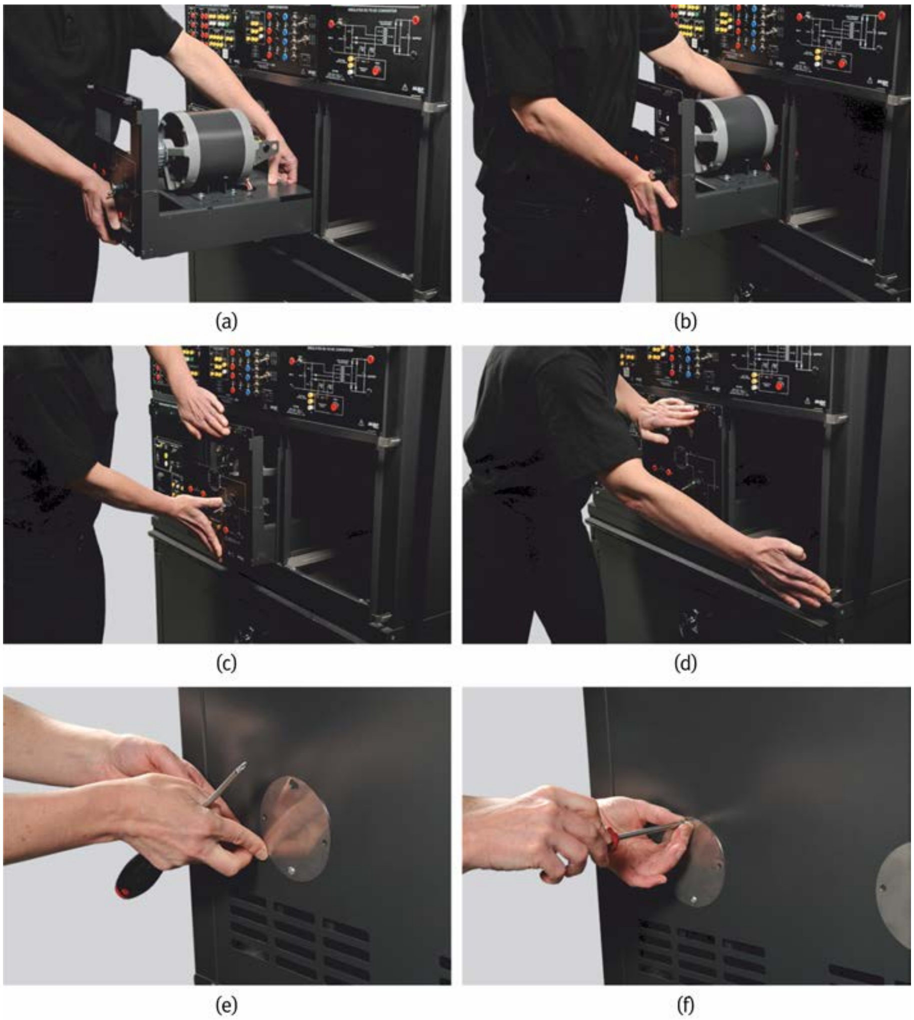


Figure 24: Installing a full-size EMS module in a full-height compartment of a workstation.

Installing a Four-Quadrant Dynamometer/Power Supply, Model 8960, in a workstation

Install the Four-Quadrant Dynamometer/Power Supply, Model 8960, in a full-height compartment at the bottom of the workstation as described in the previous sub-section, "Installing a full-size EMS module in a full-height compartment of a workstation".

Once the Four-Quadrant Dynamometer/Power Supply is installed, verify its earth (ground) terminal connection with an ohmmeter as described below (see the following figure).

If a rotating machine is to be mechanically coupled to the Four-Quadrant Dynamometer/Power Supply, install the Four-Quadrant Dynamometer/Power Supply on the left-hand side of the rotating machine to allow coupling. The sub-section entitled "Mechanically coupling a Four-Quadrant Dynamometer/Power Supply, Model 8960, to an EMS rotating machine" explains how to couple a rotating machine to the Four-Quadrant Dynamometer/Power Supply once these modules are properly installed.

1. Connect one ohmmeter probe to the earth (ground) terminal of the Power Input connector on the Four-Quadrant Dynamometer/Power Supply, as in (a).

2. Place the other ohmmeter probe on a metallic rail of the workstation, as in (b). The ohmmeter reading should indicate a null resistance (about 0 Ω), as in (c).

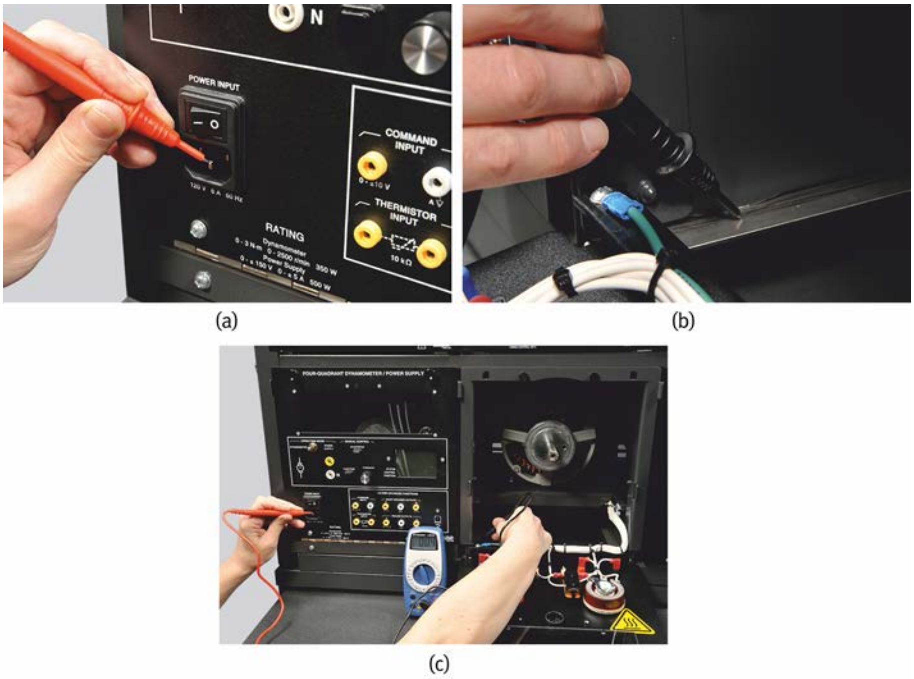


Figure 25: Verifying the earth (ground) terminal connection of the Four-Quadrant Dynamometer/Power Supply, Model 8960.

Installing an EMS rotating machine in a workstation

Install any EMS rotating machine in a full-height compartment at the bottom of the workstation, as directed in the sub-section entitled "Installing a full-size EMS module in a full-height compartment of a workstation". Then, perform the procedure below to complete the installation (refer to the following figure).

When an EMS rotating machine is to be mechanically coupled to a Four-Quadrant Dynamometer/Power Supply, Model 8960, it must be installed on the right-hand side of the Four-Quadrant Dynamometer/Power Supply to permit machine coupling.

1. To couple the EMS rotating machine to a Four-Quadrant Dynamometer/Power Supply, Model 8960, refer to the next sub-section, entitled "Mechanically coupling a Four-Quadrant Dynamometer/Power Supply, Model 8960, to an EMS rotating machine".

2. To install an inertia wheel on the shaft of the EMS rotating machine, perform the following steps.

- Loosen the cross-shape knob of the inertia wheel until its setscrew is out of the hub, as in (a) and (b).

- Position the flywheel near the shaft of rotating machine. Align the pin of the flywheel with the hole in the geared pulley of the rotating machine, as in (c).

- Make the flywheel hub slide onto the shaft of the rotating machine until the pin of the flywheel is fully entered into the hole of the geared pulley. The inertia wheel must rest against the geared pulley, as in (d), (e), and (f).

- Tighten the cross-shape knob of the inertia wheel firmly, as in (f).

⚠ CAUTION

Make sure that the inertia wheel is properly installed to avoid potential damage to the equipment, should the flywheel ever get loose.

3. If the EMS rotating machine has a hole on its front panel providing access to the machine shaft, install the plastic cap used to cover the end of the shaft (see Figure 27). Ignore this directive if the laboratory exercise to be performed requires you to couple an accessory to the machine shaft (like the Speed Sensor/Tachometer, Model 8931).

Figure 26: Installing a flywheel on the shaft of an EMS rotating machine.

Figure 27: Installing the plastic cap covering the end of the machine shaft.

Mechanically coupling a Four-Quadrant Dynamometer/Power Supply, Model 8960, to an EMS rotating machine

Perform the procedure below to mechanically couple a Four-Quadrant Dynamometer/Power Supply, Model 8960, to an EMS rotating machine, with a Timing Belt, Model 8942 (refer to Figure 28 and Figure 29). Figure 30 shows the geared pulleys of these two machines when they are properly coupled with the belt.

1. Make sure that there is no power applied to the Four Quadrant Dynamometer/Power Supply:

   - Make sure that the main power switch on the Four Quadrant Dynamometer/Power Supply is set to the O (off) position, as in (a).

   - Disconnect the ac power cord of the Four Quadrant Dynamometer/Power Supply from the Power Input connector of this module, as in (b).

⚠ WARNING

Before coupling rotating machines, make absolutely sure that power is turned off to prevent any machine from starting inadvertently. This situation, if not avoided, can result in serious hand or arm injury.

2. Unlock the front panels of the Four-Quadrant Dynamometer/Power Supply and the rotating machine by setting their rotating lock buttons to the unlocked position. Open the front panels of both modules, as in (c) and (d).

3. Install one end of the Timing Belt, Model 8942, around the geared pulley of the rotating machine, as in (e) and (f).

4. Make the timing belt pass on one of the two ball bearings of the Four-Quadrant Dynamometer/Power Supply, as in (g). Install the other end of the timing belt around the geared pulley of the Four-Quadrant Dynamometer/Power Supply, as in (h). Then, slightly press on the belt and make it pass through both ball bearings, as in (i) and (j).

5. Make sure that the timing belt is properly installed. The center width of the belt must be aligned with the grooves of the ball bearings, as in (k). The belt must not sit on the left or right edges of the ball bearings.

6. Manually rotate the geared pulleys of the Four-Quadrant Dynamometer/Power Supply and the rotating machine, as in (l), and make sure that the timing belt runs smoothly and that it stays tight. The center width of the belt must remain aligned with the grooves of the ball bearings.

7. Close the front panels of the Four-Quadrant Dynamometer/Power Supply and the rotating machine. Firmly secure the front panels of both modules by setting their rotating lock buttons to the locked position, as in (m). The front panels of the

Four-Quadrant Dynamometer/Power Supply and of the rotating machine must stay closed at all times whenever these machines are powered on to avoid the risk of severe injuries caused by electric shocks and by touching rotating machine parts.

8. Reconnect the ac power cord of the Four Quadrant Dynamometer/Power Supply to the Power Input connector of this module, as in (n).

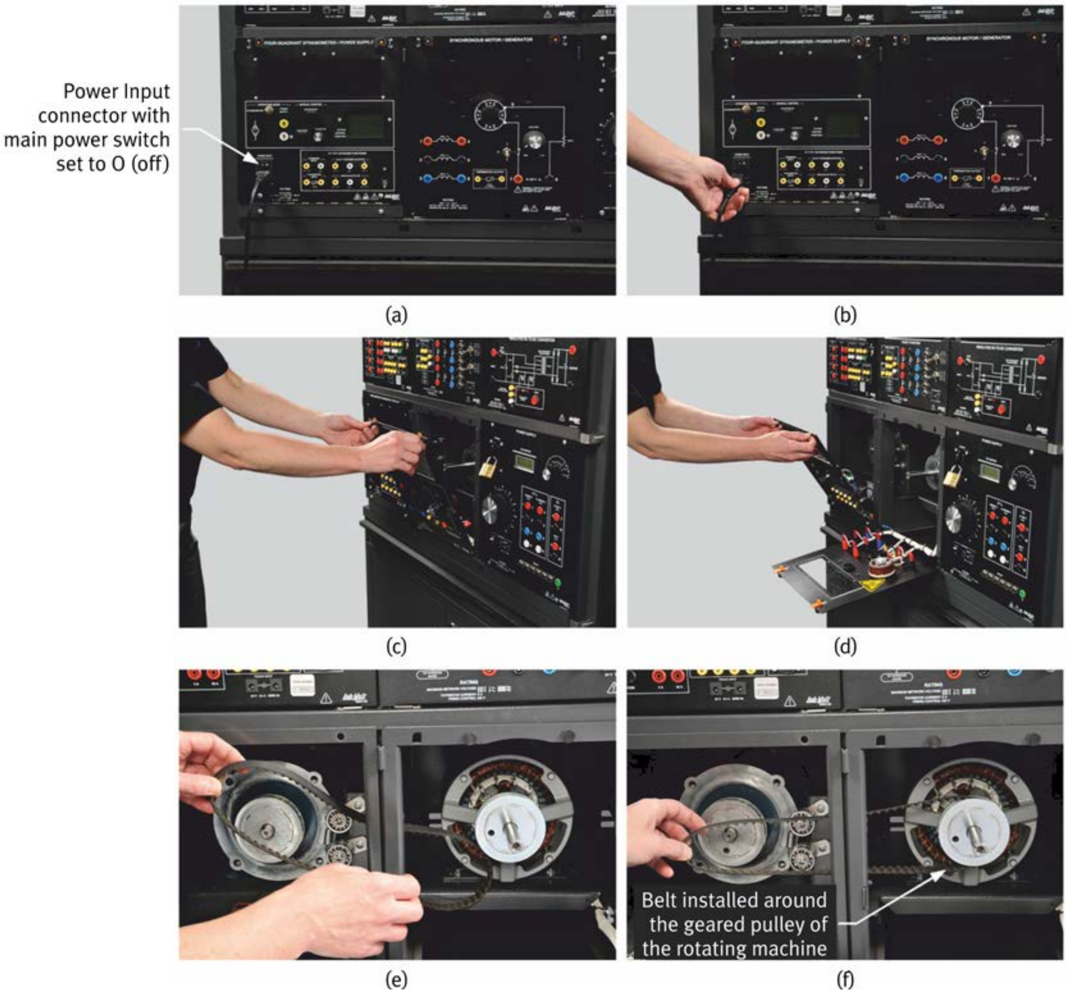


Figure 28: Mechanically coupling a Four-Quadrant Dynamometer/Power Supply, Model 8960, to an EMS rotating machine (part 1).

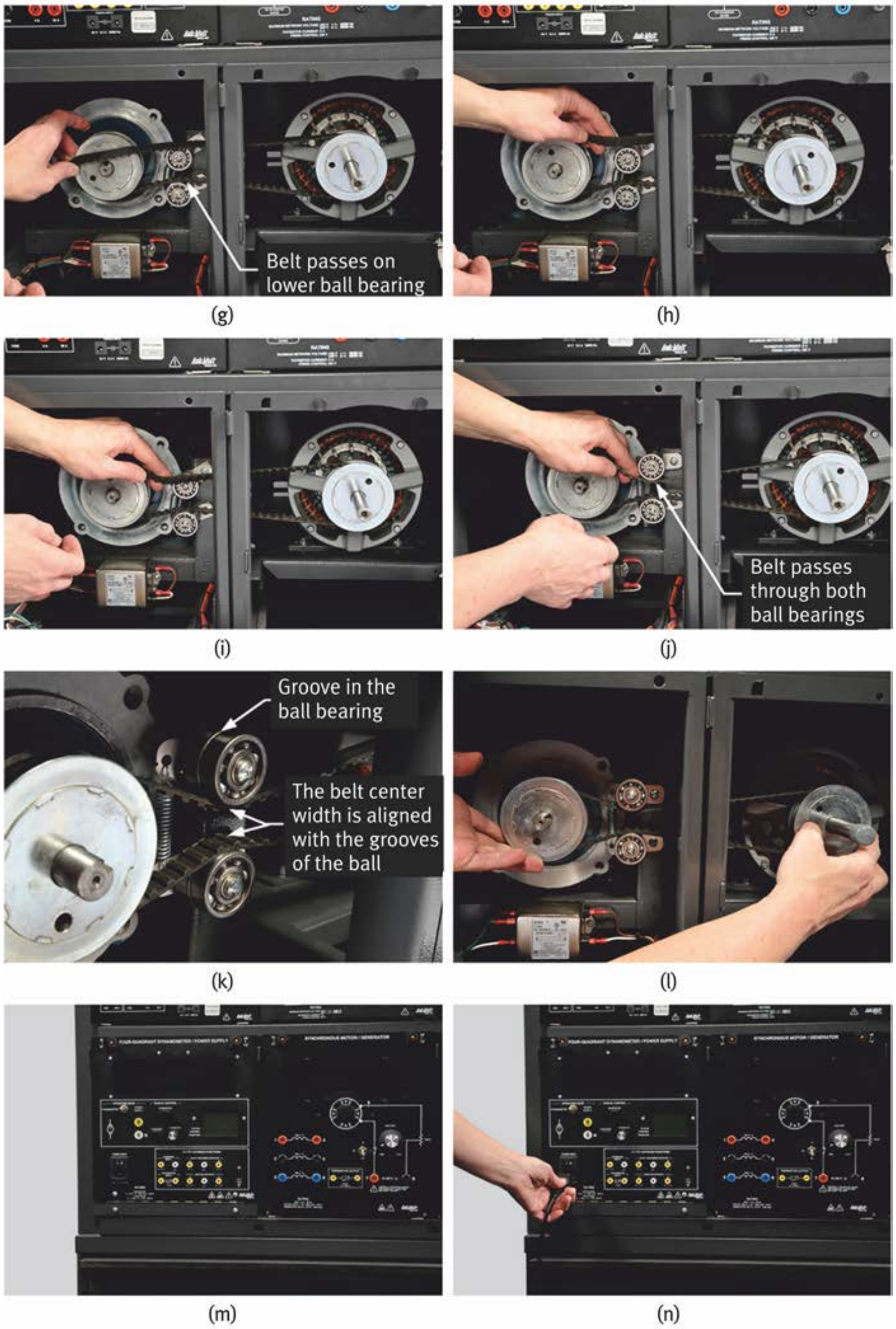


Figure 29: Mechanically coupling a Four-Quadrant Dynamometer/Power Supply, Model 8960, to an EMS rotating machine (part 2).

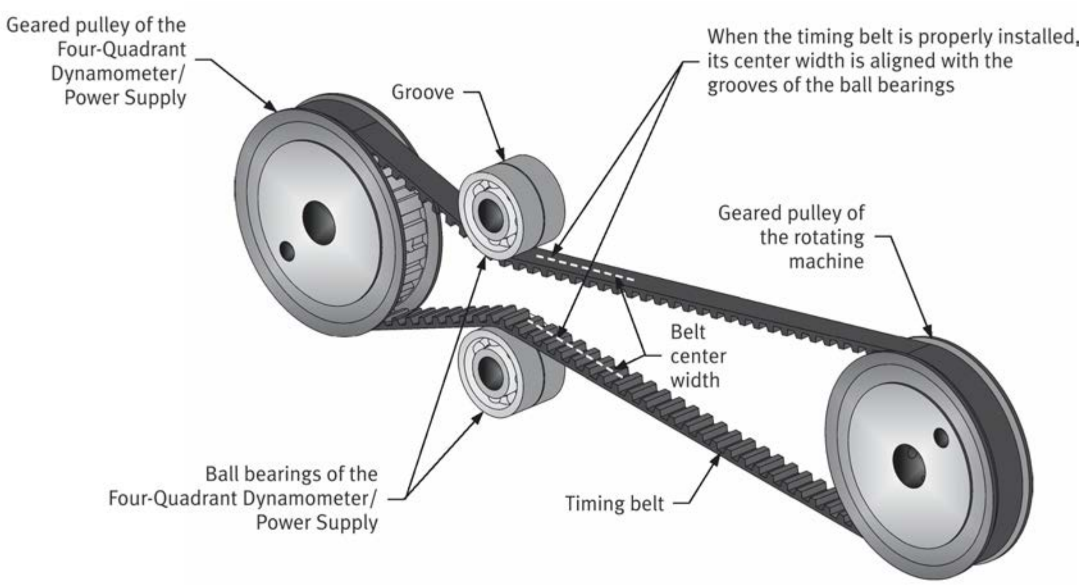


Figure 30: Four-Quadrant Dynamometer/Power Supply, Model 8960, mechanically coupled to an EMS rotating machine with a Timing Belt, Model 8942.

Installing a Power Supply in a workstation

To install a Power Supply, use a full-height compartment at the bottom of the workstation as directed in the sub-section entitled "Installing a full-size EMS module in a full-height compartment of a workstation". Then perform the procedure below to complete the installation.

If you are using the Power Supply, Model 8823, which is a half-size EMS module, install it at the bottom of a full-height compartment of the workstation, as directed in the subsection entitled "Installing two half-size EMS modules in a full-height compartment of a workstation". Then, perform the procedure below to complete the installation.

1. On the Power Supply, make sure that the main power switch is set to the off (O) position. Make sure that the safety padlock of the main power switch is installed and locked (see the following figure). Before making any electrical connection, always make sure that the power supply is turned off to avoid the risk of electric shocks.

⚠ WARNING

Before making any electrical connection, always make sure that the power supply is turned off to avoid the risk of electric shocks.

Figure 31: On the Power Supply, make sure that the main power switch is set to the O (off) position. Also, make sure that the safety padlock of the main power switch is installed and locked.

2. Verify the earth (ground) terminal connection of the Power Supply with an ohmmeter (see the following figure). To do so, connect one of the ohmmeter probes to the earth (ground) terminal of the Power Supply. Connect the other ohmmeter probe to a metallic rail of the workstation. The ohmmeter reading should indicate a null resistance (about 0 Ω).

⚠ WARNING
Make sure there is electrical continuity between the earth (ground) terminal of the Power Supply module and the metallic structure of the workstation before connecting the Power Supply to the ac power network. This prevents the risk of electric shocks caused by touching equipment that is not properly grounded.

Figure 32: Verifying the earth (ground) terminal connection of the Power Supply with an ohmmeter.

3. On the rear panel of the workstation, rotate the circular cover plate of the compartment giving access to the ac power inlet of the Power Supply, as in (a) and (b) of the following figure.

4. Connect the ac power cord provided with the Power Supply to the ac power inlet of the Power Supply, as in (c) and (d) of the following figure. Then, connect the other end of the ac power cord to a three-phase ac power wall outlet fed by an ac power network that meets the requirements stated in Learning Unit 6.

NOTICE
To connect the Power Supply to the ac power network, always use the ac power cord provided with the Power Supply. Failure to do so could result in damage to the Power Supply.

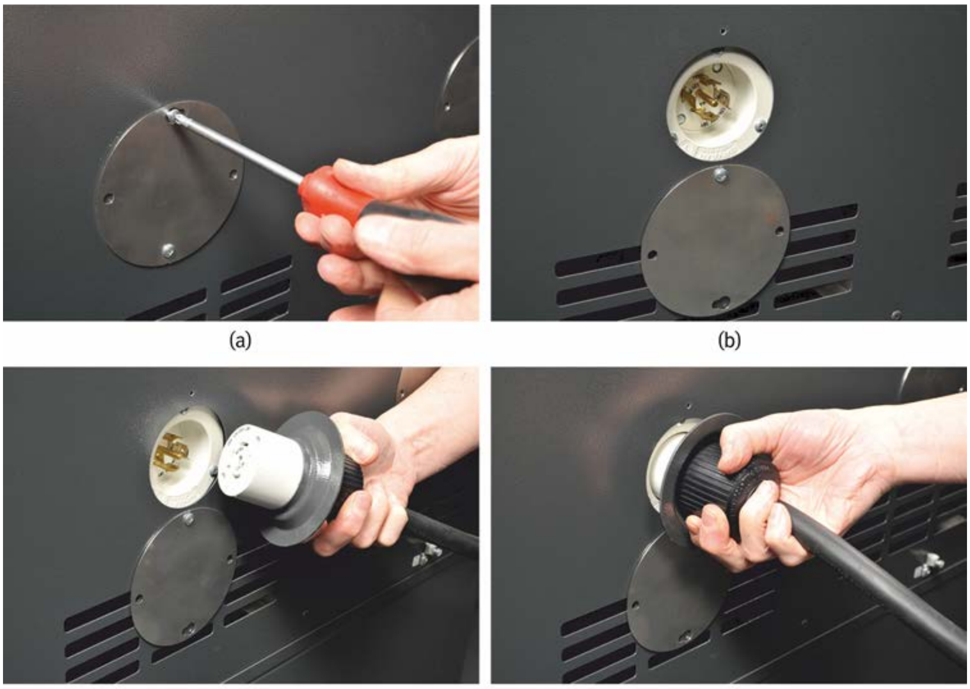

(a) (b) (c) (d)

Figure 33: Connecting the ac power cord provided with the Power Supply to the ac power inlet of the Power Supply.

5. Perform the verifications in Appendix A of this user guide in order to make sure that the ac power network is properly wired in your building.

NOTICE
The verifications listed in Appendix A must be performed to ensure that the Electric Power Technology Training Equipment is properly powered by the power supply. Failure to do so could result in damage to the equipment.

Removing a half-size EMS module from a half-height compartment of a workstation

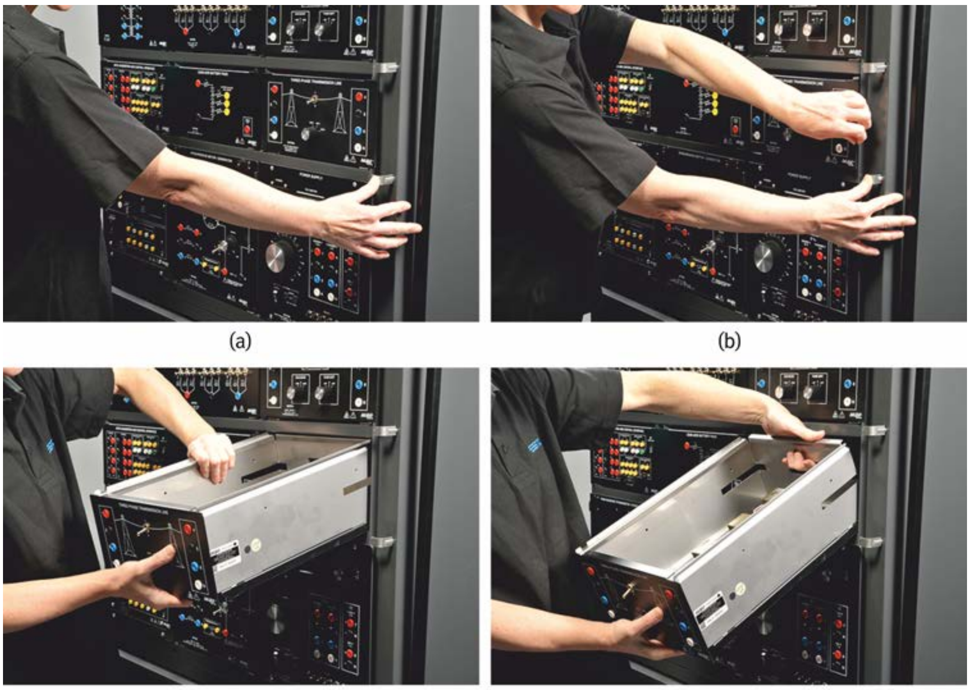
When the EMS module to remove is in a compartment on the right- or left-hand side of a half-height row, perform the steps below to remove it (refer to the following figure).

1. While pressing the push-lever on the right-hand side of the compartment row, pull on the front panel of the module, as in (a) and (b), to disengage the module from the compartment.

2. Remove the half-size module from the workstation while holding the module by the bottom, with one hand at the front and the other at the rear, as in (c) and (d).

3. Return the module to its storage location, being careful not to drop the module.

When the module to remove is in the center compartment of a half-height row, first remove the module on its right- or left-hand side, as directed above. Then, remove the module from the center compartment as directed above.



(a) (b) (c) (d)

Figure 34: Removing a half-size EMS module from a half-height compartment of a workstation.

Removing a stack of two half-size EMS modules from a full-height compartment of a workstation

When the stack of EMS modules to remove is in a compartment on the right- or left-hand side of a full-height row, perform the steps below to remove them (refer to the following figure).

⚠ WARNING

When removing a stack of EMS modules, first remove the upper (lighter) module, and then remove the lower (heavier) module. Never remove both modules at the same time. This situation, if not avoided, can result in serious injury.

1. While pressing the push-lever on the right-hand side of the compartment row, pull on the front panels of both stacked modules to disengage them from the workstation, and remove the modules only partially, as in (a) and (b).

2. Place your hands on both sides of the front panel of the upper module, as in (c), and slightly tilt this module upward to disengage it from the bottom module. Remove the upper module from the workstation, as in (d) and (e).

3. Remove the lower (heavier) module from the workstation while holding the module by the bottom, with one hand at the front and the other at the rear, as in (f).

   When the stack of EMS modules to remove is in the center compartment of a full-height row, first remove the modules on their right- or left-hand side, as directed above. Then, remove the stack of modules from the center compartment as directed above.

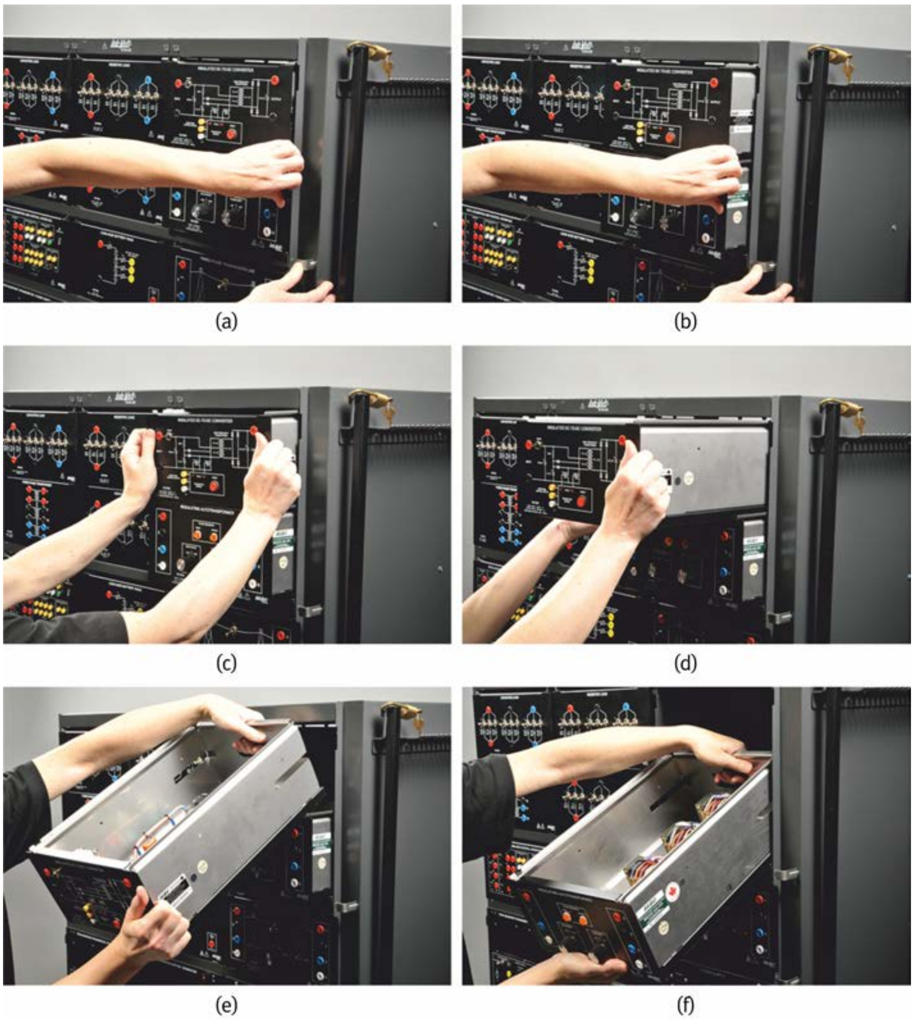


Figure 35: Removing a stack of two half-size EMS modules from a full-height compartment of a workstation.

Removing an EMS rotating machine from a full-height compartment of a workstation

Perform the steps below to remove an EMS rotating machine from the workstation (refer to the following two figures). It is assumed that the rotating machine to be removed (in this case, the Four-Quadrant Dynamometer/Power Supply, Model 8960) is coupled to another rotating machine, with a Timing Belt, Model 8942.

1. Make sure that there is no power applied to the Four Quadrant Dynamometer/ Power Supply:

   - Make sure that the main power switch of the Four Quadrant Dynamometer/Power Supply is set to the O (off) position, as in (a).

   - Disconnect the ac power cord of the Four Quadrant Dynamometer/Power Supply from the Power Input connector of this module, as in (b).

⚠ WARNING

Before removing the Timing Belt, make absolutely sure that power is turned off to prevent any machine from starting inadvertently. This situation, if not avoided, can result in serious hand or arm injury.

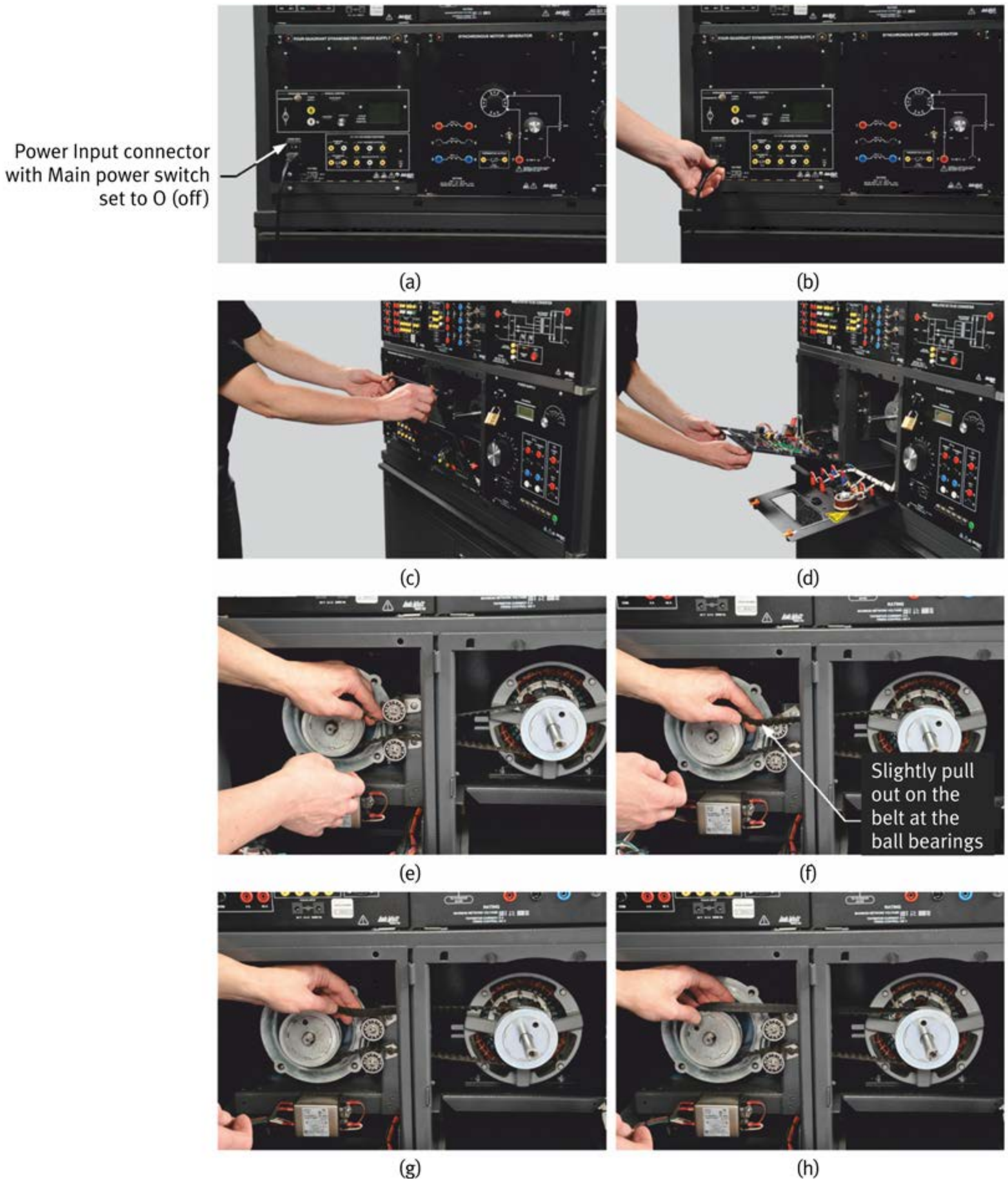


Figure 36: Removing an EMS rotating machine coupled to the Four-Quadrant Dynamometer/Power Supply, Model 8960, from a full-height compartment of a workstation (part 1).

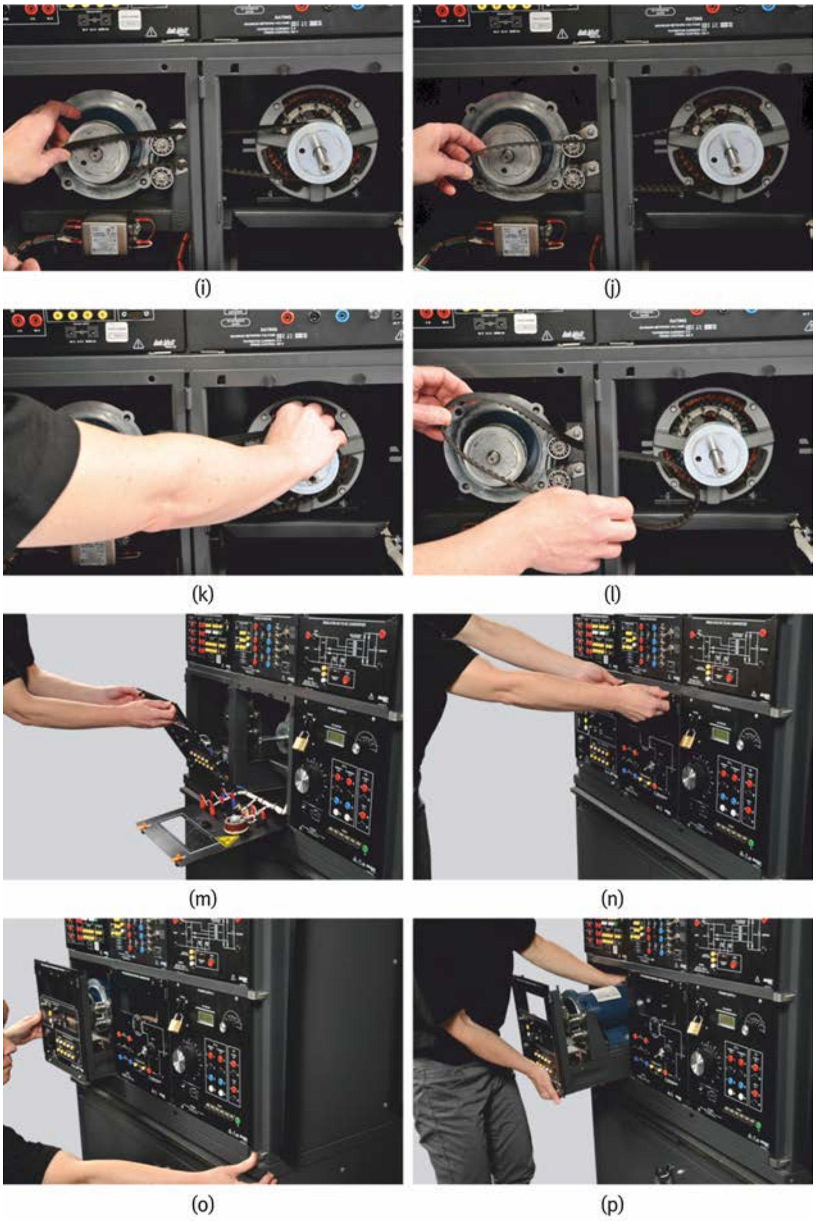


Figure 37: Removing an EMS rotating machine coupled to the Four-Quadrant Dynamometer/Power Supply, Model 8960, from a full-height compartment of a workstation (part 2).

2. Unlock the front panels of the rotating machine and the Four-Quadrant Dynamometer/Power Supply by setting their rotating lock buttons to the unlocked position. Open the front panels of both modules, as in (c) and (d).

3. Pull the belt slightly outward at the ball bearings and remove it from the geared pulley of the Four-Quadrant Dynamometer/Power Supply, as in (e), (f), (g), (h), (i), and (j).

4. Remove the other end of the belt from the geared pulley of the rotating machine, as in (k) and (l).

5. Close the front panels of the Four-Quadrant Dynamometer/Power Supply and the rotating machine, as in (m) and (n). Firmly secure the front panels of both modules by setting their rotating lock buttons to the locked position.

6. While pressing the push-lever on the right-hand side of the row containing the machine, pull on the front panel of the machine to disengage it from the compartment. Remove the machine from the workstation, as in (o) and (p).

Removing a Power Supply from a workstation

Remove a Power Supply from the workstation as directed below.

1. Make sure that the main power switch of the Power Supply is set to the O (off) position, and that the safety padlock of the main power switch is installed and locked in place, as in (a).

2. Disconnect the ac power cord of the Power Supply from its ac power inlet at the rear of the workstation, as in (b) and (c).

3. While pressing the push-lever on the right-hand side of the row containing the Power Supply, pull on the front panel of the Power Supply to disengage it from the compartment. Remove the Power Supply from the workstation, as in (d), (e), and (f).

4. Lock the circular cover plate at the rear of the compartment, as in (g) and (h).

If the power supply to remove is the Power Supply, Model 8823 (a half-size module), use the steps in the sub-section entitled "Removing a stack of two half-size EMS modules from a full-height compartment of a workstation" to remove half-size modules that are stacked and complete the removal procedure.

If the power supply to remove is in the Workstation, Model 8133, refer to Figure 39. First insert a flat-head screwdriver into the hole at the rear bottom of this workstation, as in (a). Gently pry up the Power Supply with the screwdriver while pulling on the front panel of the Power Supply to disengage it from the workstation, as in (b) to (d). Remove the Power Supply from the workstation, as in (e). Lock the circular cover plate at the rear of the workstation, as in (f).

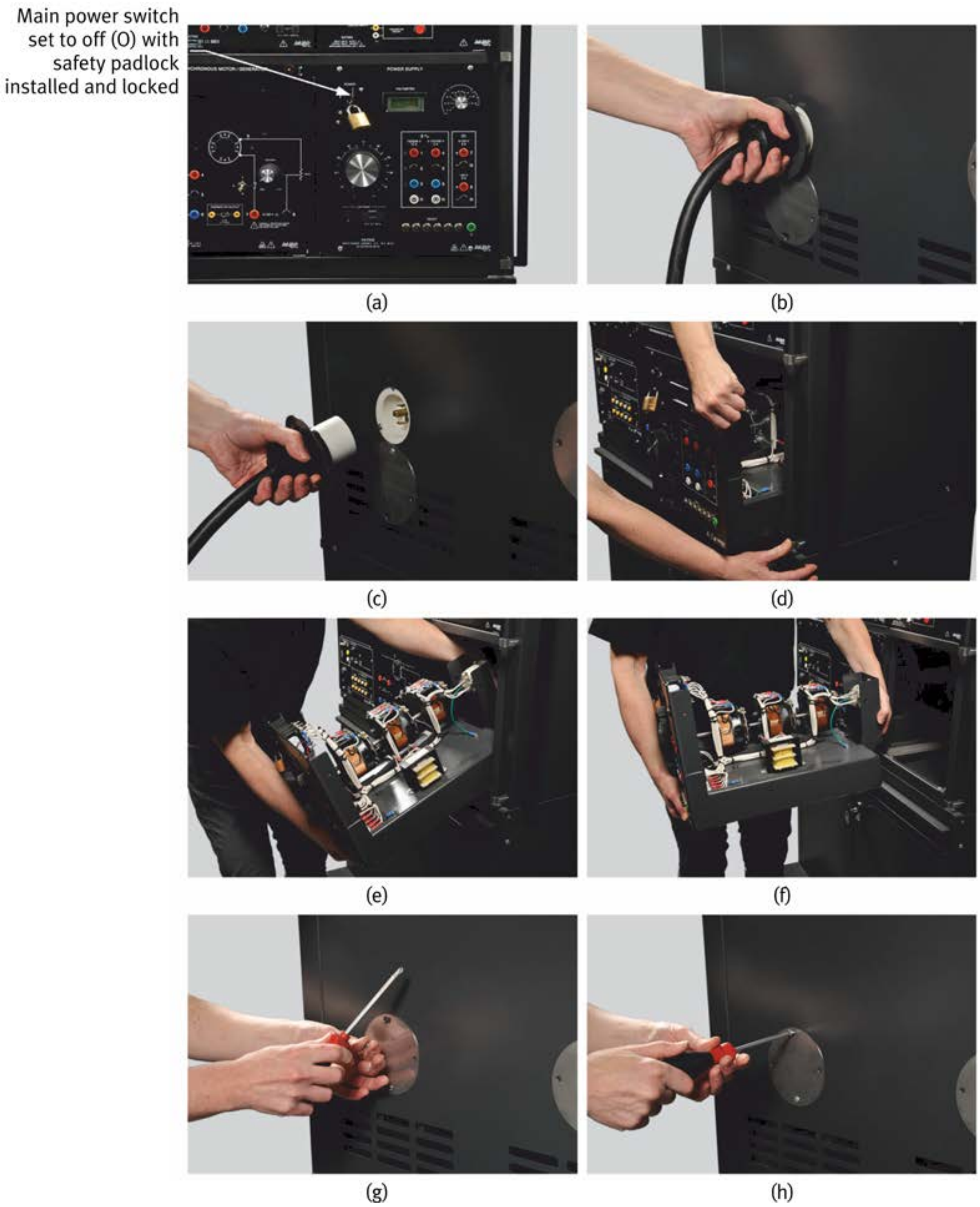


Figure 38: Removing a Power Supply from a workstation.

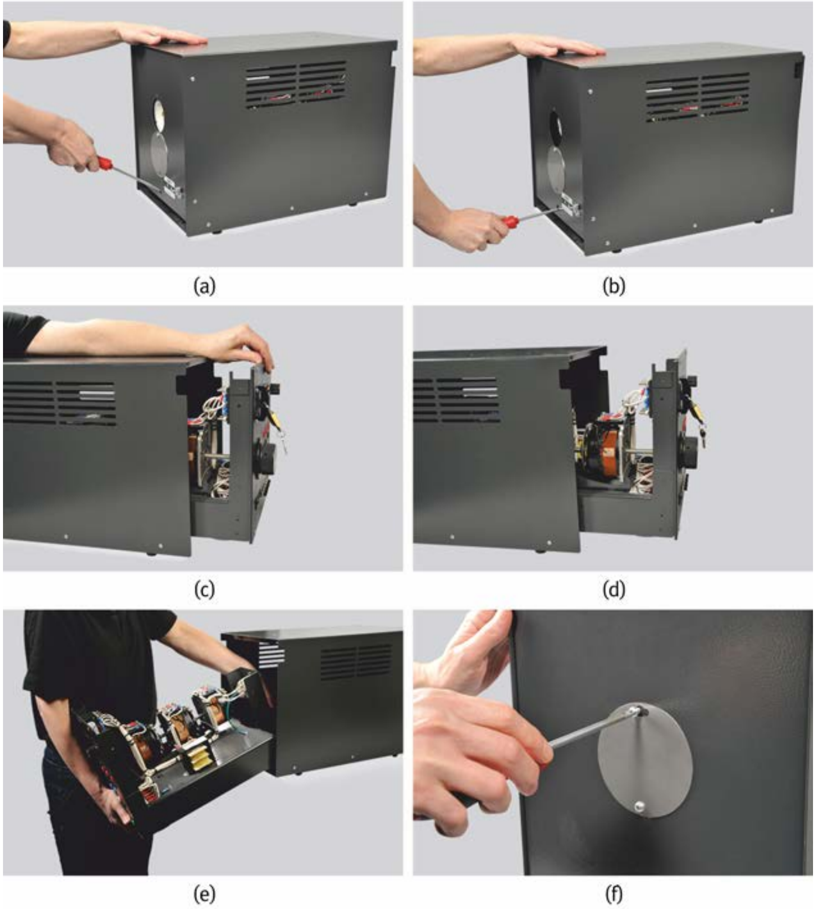


Figure 39: Removing a Power Supply from the Workstation, Model 8133.

Equipment Description

The present unit describes EMS modules of the Electric Power Technology Training Equipment. It provides the following information for each module: a general description, technical specifications, and instructions for operation and maintenance (if applicable). The following table lists the modules covered in this unit.

Table 7: Modules covered in the present unit.

EMS module	Model number
Permanent Magnet DC Motor	8213-2
Four-Pole Squirrel Cage Induction Motor	8221-2
Synchronous Motor/Generator	8241-2
Resistive Load	8311-0
Resistive Load	8311-A
Resistive Load	8509
Inductive Load	8321
Capacitive Load	8331
Three-Phase Transformer Bank	8348-4
Transformer	8353
Synchronizing Module	8621
Synchronizing Module/Three-Phase Contactor	8621-A
Lead-Acid Batteries	8801
Lead-Acid Battery Pack	8802-1

EMS module	Model number
Lithium-Ion Battery Pack	8802-B
Lithium-Ion Battery Pack	8802-C
Power Supply	8821-2
Power Supply	8823
IGBT Chopper/Inverter	8837-B
Power Thyristors	8841-2
Three-Phase Filter	8326
Four-Quadrant Dynamometer/Power Supply	8960-2 and -3
Data Acquisition and Control Interface	9063

Permanent Magnet DC Motor, Model 8213-1 and -2

The Permanent Magnet DC Motor is a high-speed brushed dc motor mounted in a full-size EMS module. Its magnetic field is produced by permanent magnets mounted on the stator. Connections to the motor are made through color-coded safety banana jacks on the front panel of the module. The motor must be powered by an external dc source. A toggle switch on the front panel switches dc power to the motor on and off when it is connected to a battery pack. When driven by a prime mover, the Permanent Magnet DC Motor operates as a dc generator.

The front panel of the Permanent Magnet DC Motor module can be opened to install a Timing Belt, Model 8942, on the motor shaft pulley. This allows mechanical coupling of this motor to the Four-Quadrant Dynamometer/Power Supply, Model 8960. The Permanent Magnet DC Motor pulley has 12 teeth, while the Four-Quadrant Dynamometer/Power Supply pulleys have 24 teeth. This pulley ratio (12 to 24) adapts the speed (0-4000 r/min) of the Permanent Magnet DC Motor to the speed (0-2000 r/min) of the Four-Quadrant Dynamometer/Power Supply.

Control, connectors, and indicators

1. Switch S_1 : this toggle switch is used to switch dc power to the Permanent Magnet DC Motor on and off, via the S_1 switch contact terminals when the motor is connected to a battery pack.

2. S_1 switch contact terminals: these banana jacks provide access to the terminals of switch S_1.

3. Permanent Magnet DC Motor terminals: these banana jacks allow connection of the motor.

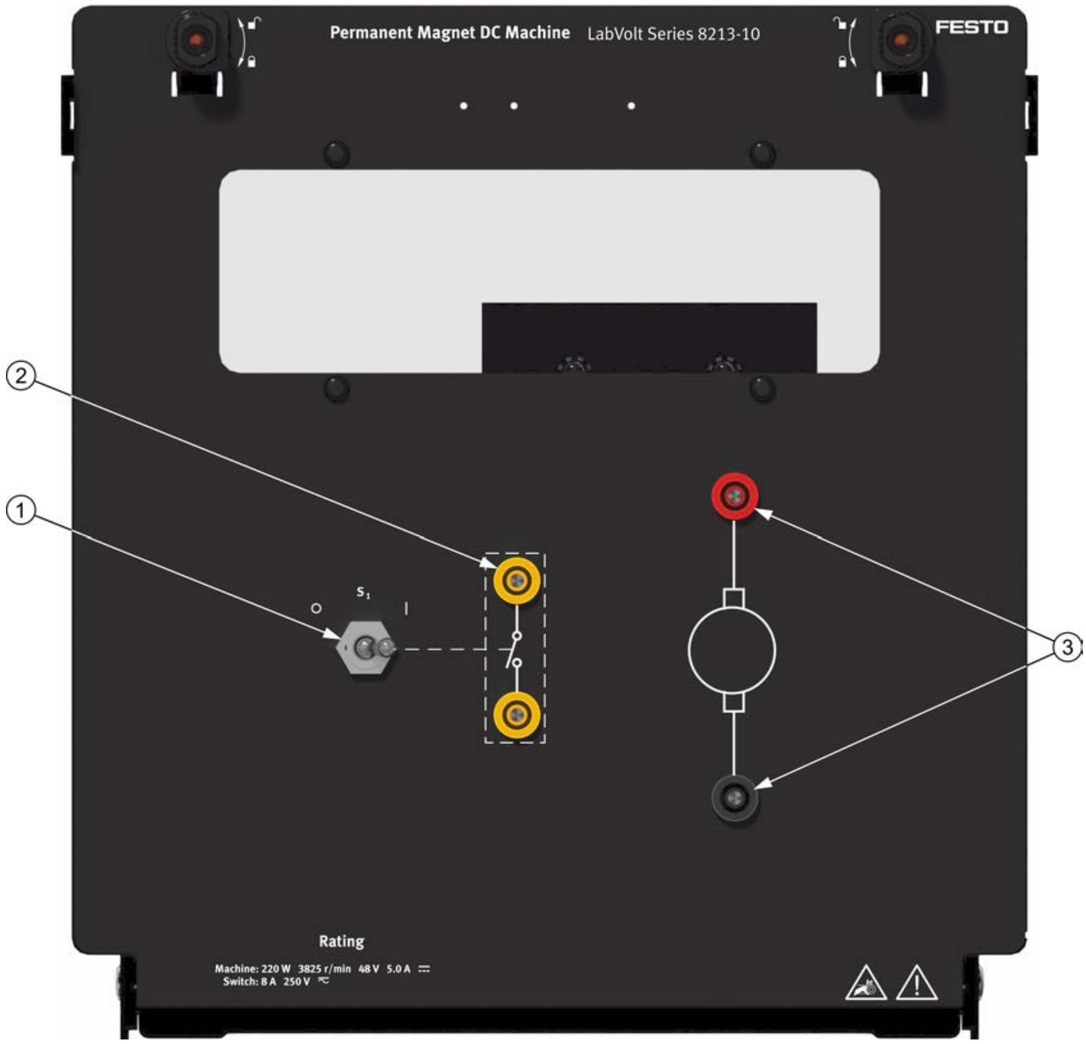


Figure 40: Front panel of the Permanent Magnet DC Motor, Model 8213-1.

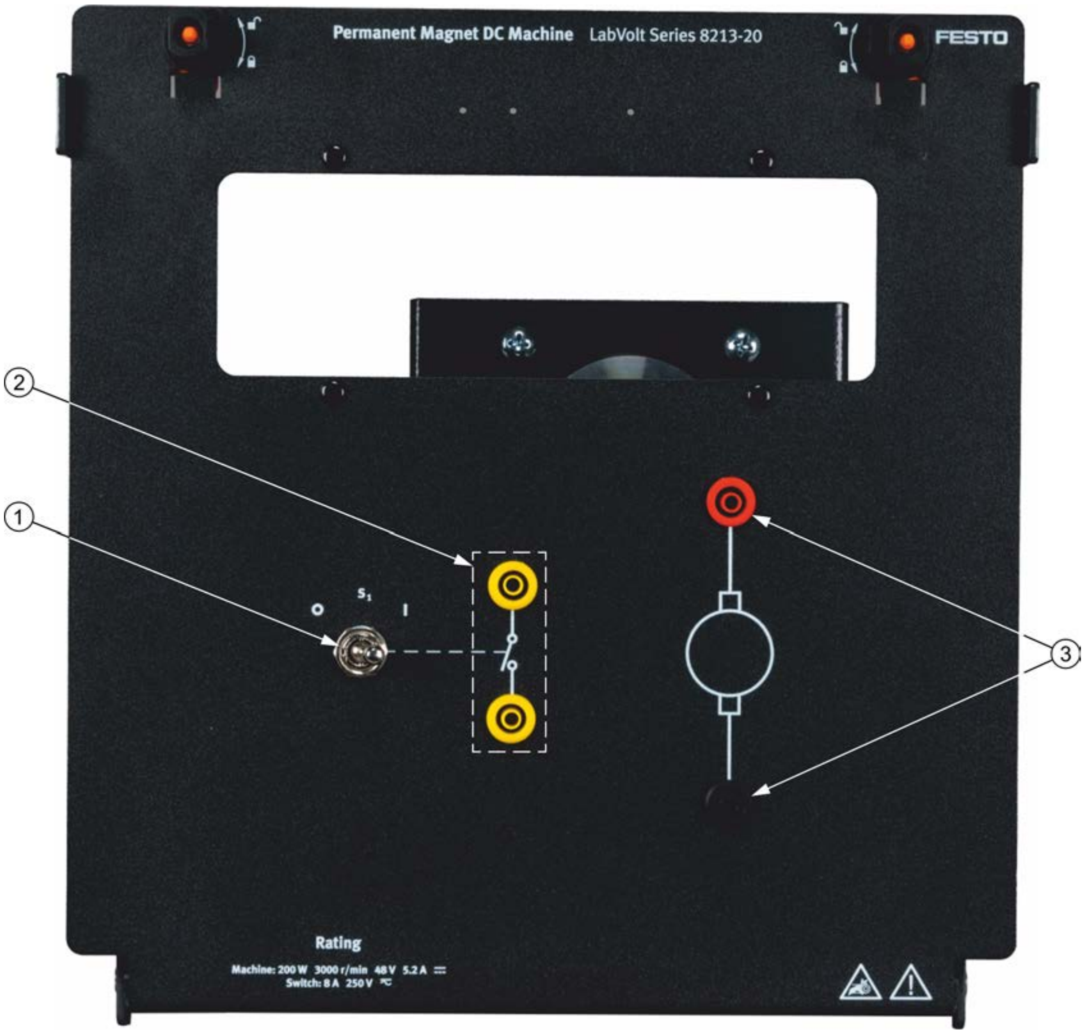


Figure 41: Front panel of the Permanent Magnet DC Motor, Model 8213-2.

Table 8: Specifications of the Permanent Magnet DC Motor.

Permanent Magnet DC Motor		8213-1	8213-2
Nominal characteristics	Power	220 W	200 W
	Voltage	48 V	48 V
	Current	5.0 A	5.2 A
	Speed	3825 r/min	3000 r/min
	Torque	0.5 N·m (4.4 lbf·in)	0.64 N·m (5,7 lbf·in)
Pulley	Number of teeth	12	12
Dimensions (H × W × D)		308 × 291 × 440 mm (2.1 × 11.5 × 17.3")	308 × 291 × 440 mm (2.1 × 11.5 × 17.3")
Weight		7.6 kg (16.8 lb)	9.9 kg (21.8 lb)

Four-Pole Squirrel Cage Induction Motor, Models 8221-0 and -2

The Four-Pole Squirrel-Cage Induction Motor, Model 8221, is a 0.2 kW squirrel-cage induction machine mounted in a full-size EMS module. The machine stator windings are independently connected (six jacks), allowing connection in either wye or delta configuration. Connections to the machine are made through color-coded safety banana jacks located on the front panel of the module. Model 8221-2 has a thermistor output that allows monitoring of the internal temperature of the machine to prevent overheating. Model 8221-2 does not have a tensioner bearing.

The tensioner is available as optional equipment.

The front panel of the Four-Pole Squirrel-Cage Induction Motor module can be opened to install a Timing Belt, Model 8942, on the pulley of the machine shaft. This permits mechanical coupling of this machine to the Four-Quadrant Dynamometer/Power Supply, Model 8960. When driven by a prime mover, the Four-Pole Squirrel-Cage Induction Motor operates as a three-phase asynchronous generator.

Control, connectors, and indicators

1. Stator winding terminals (six): these banana jacks provide access to the three stator windings.

NOTICE

The stator windings are not protected against short-circuits and overcurrents. Therefore, be sure not to exceed the rated current of these windings to avoid damage to the machine. The rated current of the windings is indicated on the front panel of the machine.

2. Thermistor Output (on Model 8221-2 only): provides a signal used to measure the temperature of the stator windings and prevent them from overheating. The thermistor is a type-2 thermistor. The Thermistor Output is intended to be connected to the Thermistor Input of Four-Quadrant Dynamometer/Power Supply, Model 8960. This allows control and monitoring of the stator temperature with the LVDAC-EMS software.

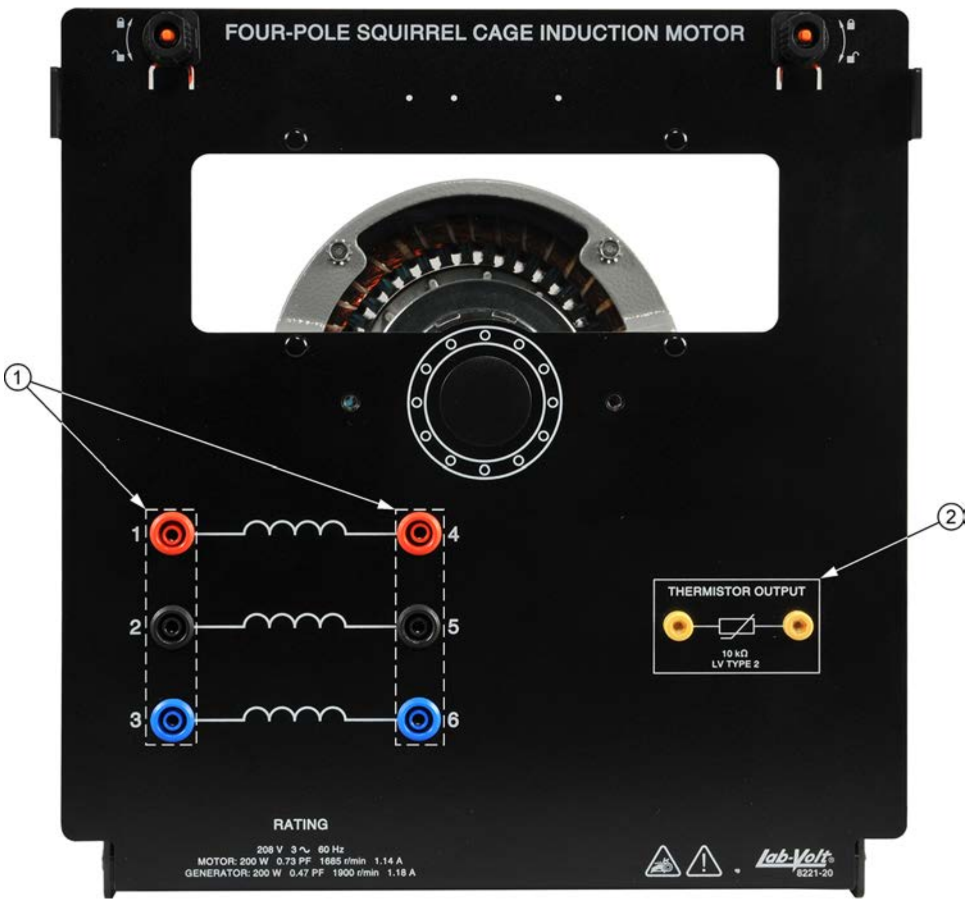


Figure 42: Front panel of the Four-Pole Squirrel-Cage Induction Machine, Model 8221-2.

Table 9: Specifications of the Four-Pole Squirrel-Cage Induction Machine, Model 8221.

<table>
<tr><th colspan="2">Four-Pole Squirrel-Cage Induction Machine</th><th>Models: 8221-20, -21, -22</th><th>Models: 8221-25, -26, -27</th><th>Models: 8221-2E, -2F</th><th>Models: 8221-2A</th></tr>
<tr><td colspan="2">Power requirement</td><td>120/208 V</td><td colspan="2">220/380 V</td><td>240/415 V</td></tr>
<tr><td rowspan="5">Motor</td><td>Stator voltage</td><td>120/208 V, 3-phase</td><td colspan="2">220/380 V, 3-phase</td><td>240/415 V, 3-phase</td></tr>
<tr><td>Mechanical power</td><td colspan="4">200 W</td></tr>
<tr><td>Nominal speed</td><td>1685 r/min</td><td>1364 r/min</td><td>1633 r/min</td><td>1364 r/min</td></tr>
<tr><td>Nominal current</td><td>1.14 A</td><td colspan="2">0.55 A</td><td>0.49 A</td></tr>
<tr><td>Power factor</td><td>0.73</td><td>0.78</td><td>0.81</td><td>0.70</td></tr>
<tr><td rowspan="5">Generator</td><td>Stator voltage</td><td>120/208 V, 3-phase</td><td colspan="2">220/380 V, 3-phase</td><td>240/415 V, 3-phase</td></tr>
<tr><td>Mechanical power</td><td colspan="4">200 W</td></tr>
<tr><td>Nominal speed</td><td>1900 r/min</td><td>1598 r/min</td><td>1912 r/min</td><td>1618 r/min</td></tr>
<tr><td>Nominal current</td><td>1.18 A</td><td>0.52 A</td><td>0.47 A</td><td>0.55 A</td></tr>
<tr><td>Power factor</td><td>0.47</td><td>0.58</td><td>0.65</td><td>0.51</td></tr>
<tr><td colspan="2">Protection (for Model 8221-2 only)</td><td colspan="4">10 kΩ thermistor, type 2, in the stator windings</td></tr>
</table>

Synchronous Motor/Generator, Models 8241-0 and -2

The Synchronous Motor/Generator, Model 8241, is a 0.2 kW three-phase synchronous machine mounted in a full-size EMS module. This machine can be operated either as a three-phase motor or a three-phase generator. Each phase of the machine stator windings is independently terminated and identified on the front panel to allow operation in either wye or delta configuration. The machine rotor is equipped with a squirrel-cage damper. Variable dc excitation to the rotor field windings is fed through externally mounted slip rings and brushes that are wired to a rheostat and control switch located on the front panel.

Connections to the machine are made through color-coded safety banana jacks located on the front panel of the module. The module front panel can be opened to install a Timing Belt, Model 8942, on the pulley of the machine shaft. This permits mechanical coupling of the machine to the Four-Quadrant Dynamometer/Power Supply, Model 8960. Note that Model 8241-2 has a thermistor output that allows monitoring of the internal temperature of the machine to prevent overheating. Model 8241-2 does not have a tensioner bearing.

Control, connectors, and indicators

1. Stator winding terminals (six): these banana jacks provide access to the three phases of the machine stator windings.

   NOTICE

   The stator windings are not protected against short-circuits and overcurrents. Therefore, be sure not to exceed the rated current of these windings to avoid damage to the machine. The rated current of the windings is indicated on the front panel of the machine.

2. Thermistor Output (on Model 8241-2): provides a signal used to measure the temperature of the stator windings and prevent them from overheating. The thermistor is a type-2 thermistor. The Thermistor Output is intended to be connected to the Thermistor Input of Four-Quadrant Dynamometer/Power Supply, Model 8960. This allows control and monitoring of the stator temperature with the LVDAC-EMS software.

3. Exciter input terminals: these banana jacks are used to apply dc voltage from an external dc power source to the exciter circuit in order to produce a field current I_f. The field current I_f produces a magnetic field in the rotor windings required for synchronous operation of the machine.

   Model 8241-2 has a bimetal thermal protection in series with a rotor field.

4. Exciter switch S_1 : this switch is used to turn the exciter circuit on and off.

5. Exciter knob: this knob permits varying the resistance of the exciter circuit, in order to vary the magnitude of the field current I_f.

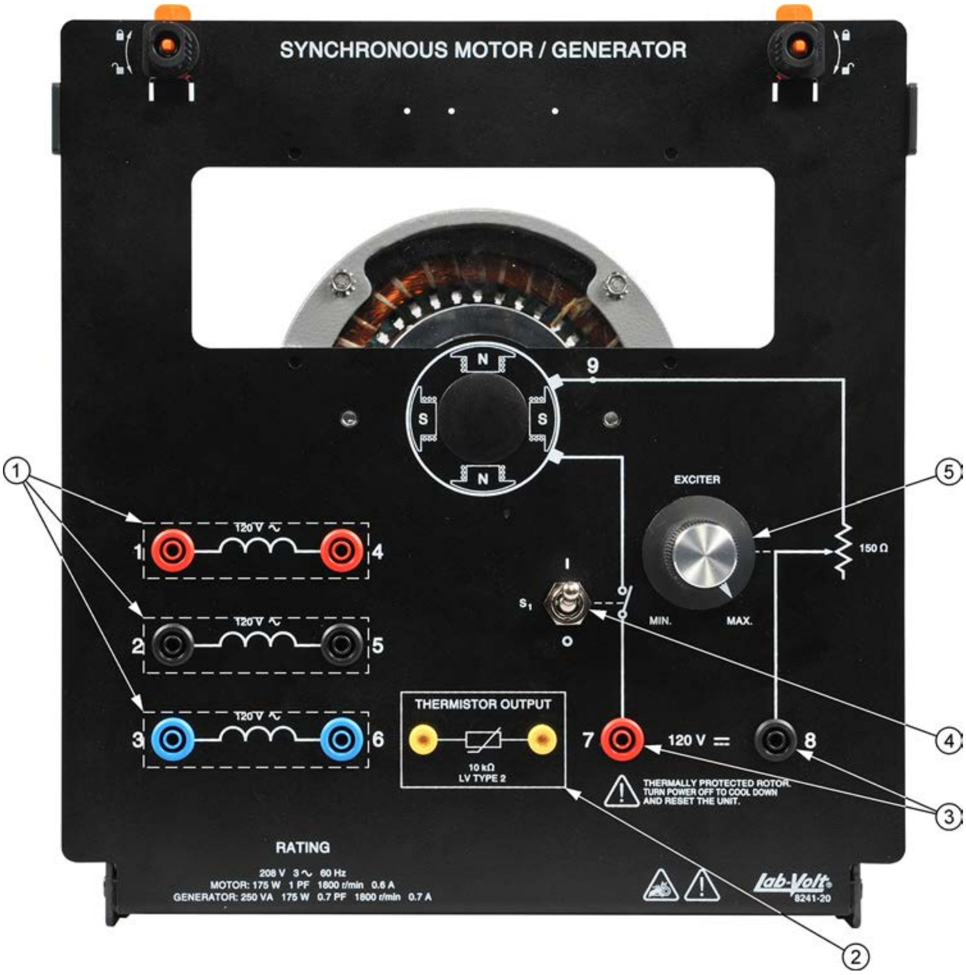


Figure 43: Front panel of the Synchronous Motor/Generator, Model 8241-2.

Table 10: Specifications of the Synchronous Motor/Generator, Model 8241-0.

Synchronous Motor/Generator		Models: 8241-00, -01, -02	Models: 8241-05, -06, -07	Models: 8241-0E, -0F	Models: 8241-0A
Power requirement		120/208 V	220/380 V		240/415 V
Motor	Stator voltage	120/208 V, 3-phase	220/380 V, 3-phase		240/415 V, 3-phase
	Rotor voltage	0-150 V dc	0-240 V dc		0-260 V dc
	Output power	200 W			
	Synchronous speed	1800 r/min	1500 r/min	1800 r/min	1500 r/min

<table>
<tr><th colspan="2">Synchronous Motor/Generator</th><th>Models:
8241-00, -01, -02</th><th>Models:
8241-05, -06, -07</th><th>Models:
8241-0E, -0F</th><th>Models:
8241-0A</th></tr>
<tr><td rowspan="2"></td><td>Full-load current</td><td>0.55 A</td><td colspan="2">0.30 A</td><td>0.28 A</td></tr>
<tr><td>Power factor</td><td colspan="4">1</td></tr>
<tr><td rowspan="5">Generator</td><td>Stator voltage</td><td>120/208 V, 3-phase</td><td colspan="2">220/380 V, 3-phase</td><td>240/415 V, 3-phase</td></tr>
<tr><td>Rotor voltage</td><td>0-150 V dc</td><td colspan="2">0-240 V dc</td><td>0-260 V dc</td></tr>
<tr><td>Output power</td><td colspan="4">200 VA</td></tr>
<tr><td>Synchronous speed</td><td>1800 r/min</td><td>1500 r/min</td><td>1800 r/min</td><td>1500 r/min</td></tr>
<tr><td>Power factor</td><td colspan="4">0.80</td></tr>
</table>

Table 11: Specifications of the Synchronous Motor/Generator, Model 8241-2.

<table>
<tr><th>Synchronous Motor/Generator</th><th>Models:
8241-20, -21, -22</th><th>Models:
8241-25, -26, -27</th><th>Models:
8241-2E, -2F</th><th>Models:
8241-2A</th></tr>
<tr><td>Power requirement</td><td>120/208 V</td><td colspan="2">220/380 V</td><td>240/415 V</td></tr>
<tr><td>Motor</td><td colspan="4">Same as Model 8241-0</td></tr>
<tr><td>Generator</td><td colspan="4">Same as Model 8241-0</td></tr>
<tr><td rowspan="2">Protection</td><td colspan="4">10 kΩ thermistor, type 2, in the stator winding</td></tr>
<tr><td colspan="4">Rotor field bimetal thermal protection</td></tr>
</table>

Resistive Load, Model 8311-0 and -A

The Resistive Load, Model 8311, is a half-size EMS module containing nine wire-wound power resistors arranged in three identical groups. Each group consists of three parallel resistors that can be switched on or off with toggle switches to obtain various resistance values, allowing stepwise increase or decrease of the group's total (equivalent) resistance. Six safety banana jacks on the front panel provide access to each group. The three groups can be used separately in three-phase circuits or connected together for single-phase circuits.

Control, connectors, and indicators

1. Resistive Load terminals: six banana jacks (one pair per resistor group) for connecting the groups to circuits.

2. Toggle switches: each switch is in series with one resistor in a group and inserts or removes that resistor from the group. When a switch is set to I (on), the resistor is inserted, adding its resistance in parallel to the group and changing the total resistance. When a switch is set to O (off), the resistor is removed, subtracting its parallel contribution from the group's total resistance.

   The current values printed next to the toggle switches are valid only when the voltage across the resistor group is at its nominal value. These values can be used to determine the group's equivalent admittance.

⚠ CAUTION

The resistors in the Resistive Load, Model 8311, can become very hot during prolonged use. To prevent burns, let the resistors cool before removing the module from the workstation. Install the Resistive Load in the highest row of the workstation to optimize heat dissipation.

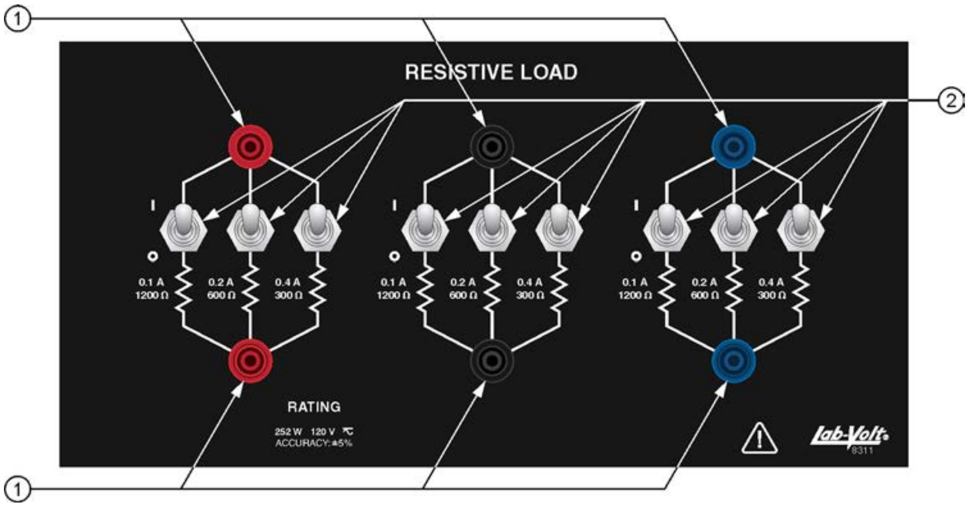


Figure 44: Front panel of the Resistive Load, Model 8311-00, 8311-01, 8311-02, 8311-05, 8311-06, 8311-07, 8311-0E, 8311-0F.

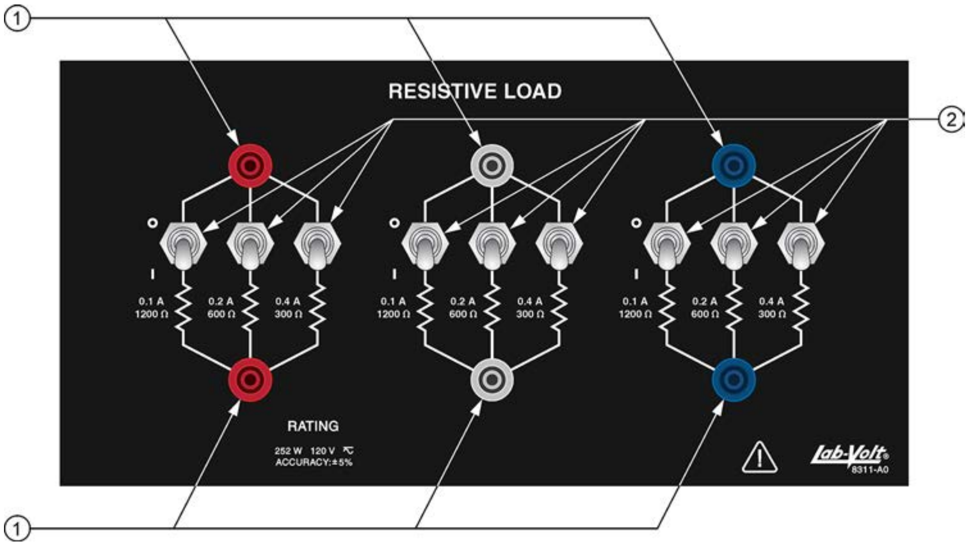


Figure 45: Front panel of the Resistive Load, Model 8311-A0 and 8311-0A.

Table 12: Specifications of the Resistive Load, Model 8311-0.

<table>
<tr><th colspan="2">Resistive Load
8311-00</th><th>Models:
8311-00, -01, -02</th><th>Models:
8311-05, -06, -07</th><th>Models:
8311-0E, -0F</th><th>Models:
8311-0A</th></tr>
<tr><td rowspan="4">Resistors</td><td>Quantity</td><td colspan="4">Three identical groups of three resistors</td></tr>
<tr><td>Resistance values (each group)</td><td>300/600/1200 Ω</td><td colspan="2">1100/2200/4400 Ω</td><td>1200/2400/4800 Ω</td></tr>
<tr><td>Nominal voltage</td><td>120 V ac/dc</td><td colspan="2">220 V ac/dc</td><td>240 V ac/dc</td></tr>
<tr><td>Resistance accuracy</td><td colspan="4">± 5%</td></tr>
<tr><td rowspan="4">Load at nominal voltage (group)</td><td>Power</td><td>12-84 W</td><td colspan="2">11-77 W</td><td>12-84 W</td></tr>
<tr><td>Current</td><td>0.1-0.7 A</td><td colspan="3">0.05-0.35 A</td></tr>
<tr><td>Steps</td><td colspan="4">Seven, of equal increment</td></tr>
<tr><td>Current increment</td><td>0.1 A</td><td colspan="3">0.05 A</td></tr>
</table>

Table 13: Specifications of the Resistive Load, Model 8311-A0.

8311-A0 Resistive Load		
Resistors	Quantity	Three identical groups of three resistors
	Resistance values (each group)	300/600/1200 Ω
	Nominal voltage	120 V ac/dc
	Resistance accuracy	± 5%
Load at nominal voltage (group)	Power	12-84 W
	Current	0.1-0.7 A
	Steps	Seven, of equal increment
	Current increment	0.1 A

Resistive Load, Model 8509

The Resistive Load, Model 8509, is a half-size EMS module containing five parallel power resistors that can be switched on or off with toggle switches to obtain various resistance values, allowing stepwise increase or decrease of the group's total (equivalent) resistance. Two safety banana jacks on the front panel allow connection of the resistor group to circuits.

Control, connectors, and indicators

1. Resistor terminals: two banana jacks that connect the resistor group to circuits.

2. Toggle switches: each switch inserts or removes its associated resistor from the resistor group. When a switch is set to the I (on) position, the associated resistor is inserted into the group, so its resistance is added in parallel to the total resistance of the group. When a switch is set to the O (off) position, the associated resistor is removed from the group, so its resistance is subtracted in parallel from the total resistance of the group.

   The current values indicated next to the toggle switches on the front panel of the Resistive Load are valid only when the voltage across the resistor group is at the nominal value. These current values can be used to determine the equivalent admittance of the resistor group.

⚠ CAUTION

The resistors in the Resistive Load, Model 8509, can become very hot when used for a long period. To prevent burn injuries, let the resistors cool down before removing the Resistive Load from the workstation. Install the Resistive Load in the highest row of the workstation to optimize heat dissipation.

NOTICE

Do not use the Resistive Load, Model 8509, at the nominal power rating for more than 5 minutes. Then let the Resistive Load module cool down for at least 20 minutes.

The Resistive Load can be used at the nominal power rating without damage to the unit, provided that the following conditions are met:

- Maximum on-time (t_{ON}): 5 min
- Maximum cyclic duration factor [$t_{ON}/(t_{ON} + t_{OFF})$]: 0.2 (5 min/25 min)

The on-time (t_{ON}) above is the maximum period during which the Resistive Load can be used at the nominal power rating. The off-time (t_{OFF}) above is the period during which the Resistive Load must be allowed to cool down (no voltage applied to the module) at 25°C.

Consequently, when the module operates at the nominal power for 5 minutes, voltage must be removed from the Resistive Load for at least the next 20 minutes to respect the maximum cyclic duration factor (0.2).

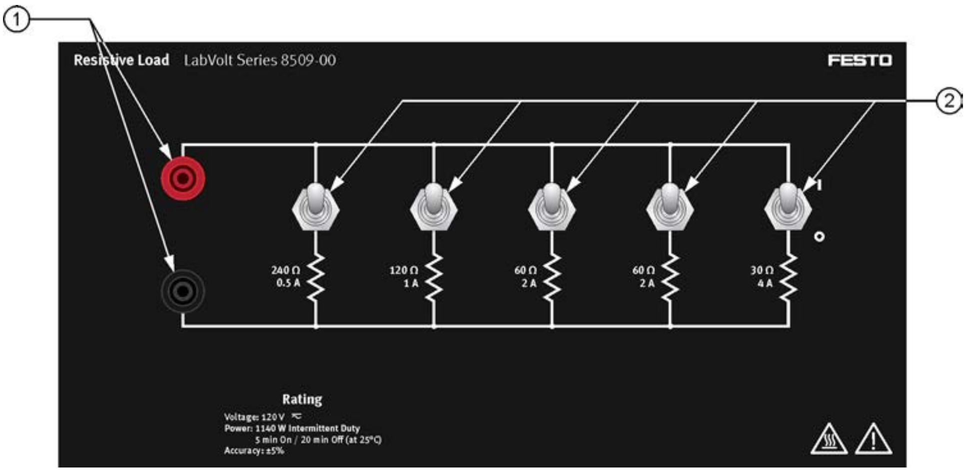


Figure 46: Front panel of the Resistive Load, Model 8509-00, 8509-01, 8509-02, 8509-05, 8509-06, 8509-07, and 8509-0A.

Table 14: Specifications of the Resistive Load, Model 8509.

Resistive Load 8509-00		Models: 8509-00, -01, -02	Models: 8509-05, -06, -07	Models: 8509-0E, -0F
Resistors	Quantity	Five resistors		
	Resistance values (each group)	30/60/120/240 Ω	110/220/440/880 Ω	120/240/480/960 Ω
	Nominal voltage	120 V ac/dc	220 V ac/dc	240 V ac/dc
	Resistance value accuracy	± 5%		
Load at nominal voltage (group)	Power	60-1140 W	55-1045 W	60-1140 W
	Current	0.5-9.5 A	0.25-4.75 A	
	Steps	19, of equal increment		
	Current increment	0.5 A	0.25 A	

Inductive Load, Model 8321

The Inductive Load, Model 8321, is a half-size EMS module that houses nine iron-core power inductors arranged in three identical groups. Each group consists of three inductors connected in parallel that can be switched on or off with toggle switches to obtain various inductance values. This allows the equivalent inductance of each group to be increased or decreased in steps. Six safety banana jacks on the front panel provide access to each inductor group. The three inductor groups can be connected separately for operation in three-phase circuits, or connected together for operation in single-phase circuits.

Control, connectors, and indicators

1. Inductive Load terminals: six banana jacks (one pair of jacks for each inductor group) that connect the inductor groups to circuits.

2. Toggle switches: each switch is connected in series with one inductor in an inductor group and inserts or removes its associated inductor from the group. When a switch is set to the I (on) position, the associated inductor is inserted into the group, so its inductance is added in parallel to the total inductance of the

group. When a switch is set to the O (off) position, the associated inductor is removed from the group, so its inductance is subtracted in parallel from the total inductance of the group.

The current values indicated next to the toggle switches on the front panel of the Inductive Load are valid only when the magnitude and frequency of the voltage across the inductor group are at their nominal values. These current values can be used to determine the equivalent admittance.

⚠ CAUTION

The Inductive Load, Model 8321, is a heavy module. Install this module in a half-height compartment of the workstation, or in the bottom section of a full-height compartment of the workstation, as directed in Learning Unit 8 of this document.

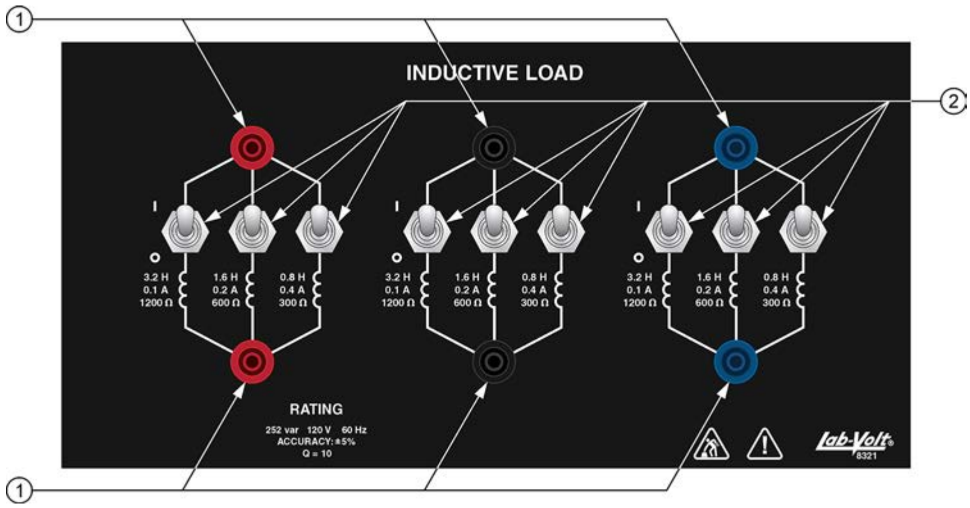


Figure 47: Front panel of the Inductive Load, Model 8321. (See note below.)

On Model 8321-0A, the color of the safety banana jacks differs from that shown in the preceding figure, and actuation of the toggle switches is in the reverse direction (that is, the toggle switches are set to I (on) when their operator is in the downward position).

Table 15: Specifications of the Inductive Load, Model 8321.

Inductive Load 8321-00		**Models: 8321-00, -01, -02**	**Models: 8321-05, -06, -07**	**Models: 8321-0E, -0F**	**Models: 8321-0A**
Inductors	Quantity	Three identical groups of three inductors			
	Inductance values (each group)	0.8/1.6/3.2 H	3.5/7/14 H	2.92/5.84/11.67 H	3.8/7.6/15.3 H
	Reactance values (each group)	300/600/1200 Ω	1100/2200/4400 Ω		1200/2400/4800 Ω
	Nominal voltage	120 V-60 Hz	220 V-50 Hz	220 V-60 Hz	240 V-50 Hz
	Inductance value accuracy	± 5%			
Load at nominal voltage (group)	Reactive power	12-84 var	11-77 var		12-84 var
	Current	0.1-0.7 A	0.05-0.35 A		
	Steps	Seven, of equal increment			
	Current increment	0.1 A	0.05 A		

Capacitive Load, Model 8331

The Capacitive Load, Model 8331, is a half-size EMS module that houses nine capacitors arranged in three identical groups. Each group consists of three capacitors connected in parallel that can be switched on or off with toggle switches to obtain various capacitance values. This allows the equivalent capacitance of each group to be increased or decreased in steps. Six safety banana jacks on the front panel provide access to each capacitor group. The three capacitor groups can be connected separately for operation in three-phase circuits, or connected together for operation in single-phase circuits.

A permanently connected discharge resistor reduces the voltage across the terminals of each capacitor group to 5% of the applied voltage within 15 seconds after the load is disconnected from the supply. The Capacitive Load may be used with both dc and ac power.

Control, connectors, and indicators

1. Capacitive Load terminals: six banana jacks (one pair of jacks for each capacitor group) that connect the capacitor groups to circuits.

2. Toggle switches: each switch is connected in series with one capacitor in a capacitor group and inserts or removes its associated capacitor from the group. When a switch is set to the I (on) position, the associated capacitor is inserted into the group, so its capacitance is added in parallel to the total capacitance of the group. When a switch is set to the O (off) position, the associated capacitor is removed from the group, so its capacitance is subtracted in parallel from the total capacitance of the group.

   The current values indicated next to the toggle switches on the front panel of the Capacitive Load are valid only when the magnitude and frequency of the voltage across the capacitor group are at their nominal values. These current values can be used to determine the equivalent admittance.

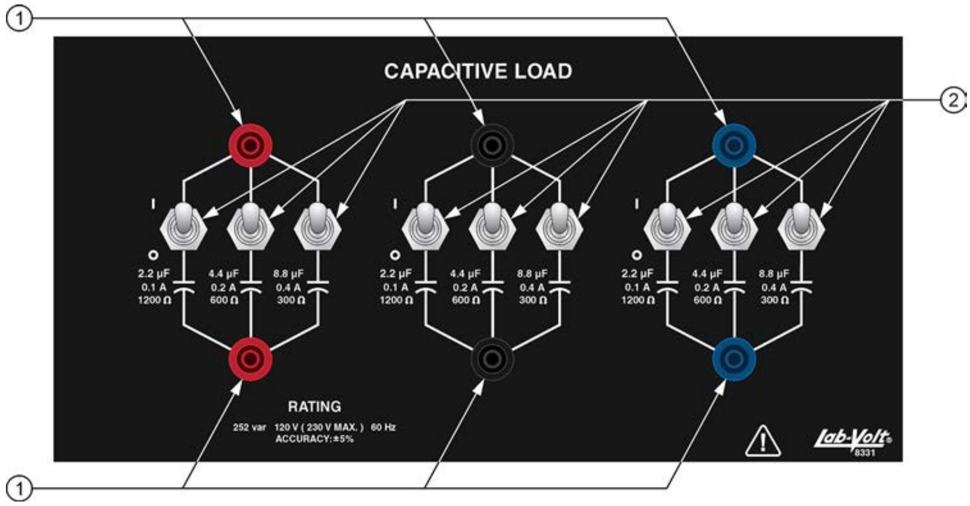


Figure 48: Front panel of the Capacitive Load, Model 8331. (See note below.)

On Model 8331-0A, the color of the safety banana jacks differs from that shown in the preceding figure, and actuation of the toggle switches is in the reverse direction (that is, the toggle switches are set to I (on) when their operator is in the downward position).

Table 16: Specifications of the Capacitive Load, Model 8331.

<table>
<tr><th colspan="2">Capacitive Load
8331-00</th><th>Models:
8331-00, -01, -02</th><th>Models:
8331-05, -06, -07</th><th>Models:
8331-0E, -0F</th><th>Models:
8331-0A</th></tr>
<tr><td rowspan="6">Capacitors</td><td>Quantity</td><td colspan="4">Three identical groups of three capacitors</td></tr>
<tr><td>Capacitance values (each group)</td><td>2.2/4.4/8.8 μF</td><td>0.72/1.45/2.89 μF</td><td>0.60/1.21/2.41 μF</td><td>0.66/1.33/2.65 μF</td></tr>
<tr><td>Reactance values (each group)</td><td>300/600/1200 Ω</td><td colspan="2">1100/2200/4400 Ω</td><td>1200/2400/4800 Ω</td></tr>
<tr><td>Nominal voltage</td><td>120 V-60 Hz</td><td>220 V-50 Hz</td><td>220 V-60 Hz</td><td>240 V-50 Hz</td></tr>
<tr><td>Maximum voltage</td><td>230 V</td><td colspan="3">440 V</td></tr>
<tr><td>Capacitance value accuracy</td><td colspan="4">± 5%</td></tr>
<tr><td rowspan="4">Load at nominal voltage (group)</td><td>Reactive power</td><td>12-84 var</td><td colspan="2">11-77 var</td><td>12-84 var</td></tr>
<tr><td>Current</td><td>0.1-0.7 A</td><td colspan="3">0.05-0.35 A</td></tr>
<tr><td>Steps</td><td colspan="4">Seven, of equal increment</td></tr>
<tr><td>Current increment</td><td>0.1 A</td><td colspan="3">0.05 A</td></tr>
</table>

Three-Phase Transformer Bank, Model 8348-4

The Three-Phase Transformer Bank, Model 8348-4, consists of three independent power transformers enclosed in a half-size EMS module. Safety banana jacks on the front panel provide individual access to the windings of each power transformer, allowing connection in either wye or delta configuration. The transformer windings are polarized, and the polarity of each winding is indicated by a small dot on the front panel. Electronic fuses protect the primary and secondary windings of each transformer against overcurrents. Fuse status lamps on the front panel turn on when the electronic fuses detect an overcurrent condition. When the overcurrent condition is eliminated, the electronic fuses reset automatically and the fuse status lamps turn off.

Control, connectors, and indicators

1. Terminals of power transformer 1 (terminals 1, 2, 3, 4, and 5): these banana jacks provide access to the primary and secondary windings of the first transformer. The polarity of the transformer windings is indicated by dot marks in the schematic symbols of the windings on the front panel. The primary and secondary windings of this transformer are protected against overcurrents by electronic fuses that reset automatically.

2. Terminals of power transformer 2 (terminals 6, 7, 8, 9, and 10): these banana jacks provide access to the primary and secondary windings of the second transformer. The polarity of the transformer windings is indicated by dot marks in the schematic symbols of the windings on the front panel. The primary and secondary windings of this transformer are protected against overcurrents by electronic fuses that reset automatically.

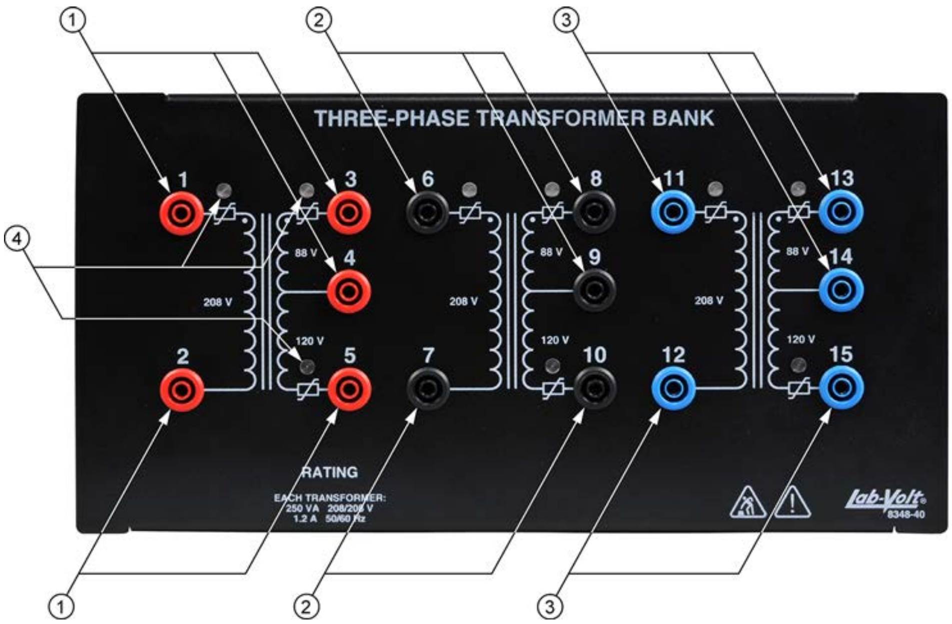


Figure 49: Front panel of the Three-Phase Transformer Bank, Model 8348-4. (See note below.)

On Model 8348-4A, the color of the safety banana jacks differs from that shown in the preceding figure.

3. Terminals of power transformer 3 (terminals 11, 12, 13, 14, and 15): these banana jacks provide access to the primary and secondary windings of the third transformer. The polarity of the transformer windings is indicated by dot marks in the schematic symbols of the windings on the front panel. The primary and secondary windings of this transformer are protected against overcurrents by electronic fuses that reset automatically.

4. Fuse status lamps: these lamps indicate the status of the electronic fuses that protect the primary and secondary windings of power transformer 1 against overcurrents. (The two other power transformers have identical fuse status lamps that protect their primary and secondary windings against overcurrents.) When an electronic fuse interrupts excessive current through a transformer, the corresponding status lamps turn on. When the overcurrent condition is eliminated, this electronic fuse resets automatically and the corresponding status lamps turn off.

⚠ CAUTION

The Three-Phase Transformer Bank, Model 8348-4, is a heavy module. Install it in a half-height compartment of the workstation, or in the bottom section of a full-height compartment of the workstation, as directed in Learning Unit 8 of this document.

Table 17: Specifications of the Three-Phase Transformer Bank, Model 8348-4.

Three-Phase Transformer Bank 8348-40		**Models: 8348-40, -41, -42**	**Models: 8348-45, -46, -47**	**Models: 8348-4E, -4F**	**Models: 8348-4A**
Rating (each transformer)	Primary voltage	208 V	380 V		415 V
	Secondary voltage	208/120 V	380/220 V		415/240 V
	Line current	1.20 A	0.66 A		0.60 A
	Power	250 VA			
Dimensions (H × W × D)		154 × 287 × 410 mm (6.1 × 11.3 × 16.1 in)			
Weight		13.9 kg (30.6 lb)			

Transformer, Model 8353

The Transformer, Model 8353, consists of a power transformer enclosed in a half-size EMS module. Both the primary and secondary sides of the Transformer are made of two identical separate windings. Banana jacks on the module front panel provide access to each winding, allowing connection in a variety of configurations. The Transformer has a turns ratio of 1:5, when considering the totality of its primary and secondary windings. The Transformer windings are polarized and the polarity of each winding is indicated by a small dot on the module front panel. A thermistor output allows monitoring of transformer temperature to prevent overheating. A typical application of the Transformer is to convert the energy stored in batteries to a suitable voltage level (for example, to the level of the ac power network voltage).

Control, connectors, and indicators

⚠ WARNING

The Transformer is not designed to provide a Safety Extra-Low Voltage (SELV) from the mains. Consider each winding as hazardous live.

1. Primary winding terminals: these banana jacks provide access to each primary winding of the Transformer. The polarity of the primary windings is indicated by dot marks in their schematic symbol on the module front panel.

2. Secondary winding terminals: these banana jacks provide access to each secondary winding of the Transformer. The polarity of the secondary windings is indicated by dot marks in their schematic symbol on the module front panel.

3. Thermistor Output: provides a signal used to measure the temperature of the transformer and prevent it from overheating. The thermistor is a type 2 thermistor. The Thermistor Output is intended to be connected to the Thermistor Input of Four-Quadrant Dynamometer/Power Supply, Model 8960. This allows control and monitoring of the Transformer temperature with the LVDAC-EMS software.

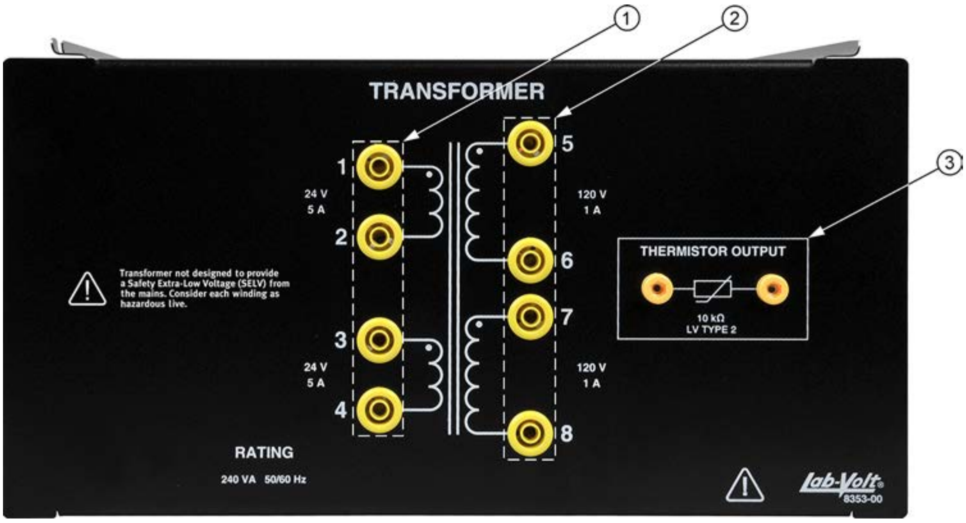


Figure 50: Transformer, Model 8353.

Table 18: Specifications of the Transformer, Model 8353.

Transformer **8353**	**Models:** **8353-00, -01, -02**
Nominal power	240 VA
Primary rating (two windings)	24 V ac 5 A for each winding
Secondary rating (two windings)	120 V ac 1 A for each winding
Thermistor output	10 kΩ type 2
Dimensions (H × W × D)	154 x 287 x 440 mm (6.1 x 11.3 x 16.1 in)
Weight	TBE

Synchronizing Module, Model 8621

The Synchronizing Module, Model 8621, is a power control device enclosed in a half-size EMS module. The Synchronizing Module is mainly used to synchronize two ac generators. It can also be used to determine the phase sequence in three-phase circuits. The synchronizing Module has three indicator lamps indicating the relative voltage difference between two circuits. The brightness of the indicator lamps increases with the voltage difference between the two circuits. The Synchronizing Module has a three-phase switch mounted on the module front panel. This three-phase switch is a triple-pole, single-throw switch. Each phase leg of the three-phase switch is protected against overcurrents and short-circuits by a thermal-magnetic circuit breaker.

Control, connectors, and indicators

1. S_1 three-phase switch: this switch is a triple-pole, single-throw switch. It has three normally-open contacts permitting connection of two circuits across the three-phase terminals of the module. When switch S_1 is set to the O (off) position, its three contacts are open, so that the voltages across the three-phase terminals are applied to the corresponding indicator lamps. Conversely, when switch S_1 is set to the I (on) position, its three contacts are closed, so that the voltages across the three-phase terminals are null and the lamps are turned off.

2. Three-phase terminals: these three pairs of banana jacks (one pair per phase) provide access to each phase of the Synchronizing Module.

3. Indicator lamps: these three lamps indicate the relative level of the voltage across their corresponding phase terminals when the three-phase switch S_1 is set to the O (off) position. The brightness of these indicator lamps increases when the voltage difference across their phase terminals increases. Conversely, the brightness of these indicator lamps decreases when the voltage difference across their phase terminals decreases.

4. Reset buttons: these three push-buttons are used to manually reset the magnetic circuit breakers on each phase leg.

   On Model 8621-0A, the color of the safety banana jacks differs from that shown in the following figure.

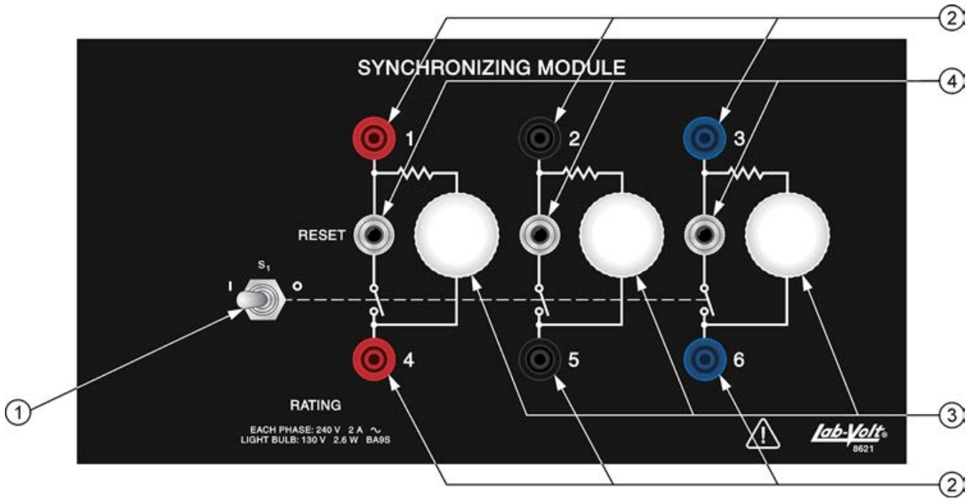


Figure 51: Front panel of the Synchronizing Module, Model 8621-0.

To replace a light bulb, use Festo's part 70-23965 or an equivalent S-6, Candelabra-screw, 6 W, 125 V bulb.

Table 19: Synchronizing Module, Model 8621.

<table>
<tr><th>Parameter</th><th>Subparameter</th><th>8621-00, -01, -02</th><th>8621-05, -06, -07</th><th>8621-0E, -0F</th><th>8621-0A</th></tr>
<tr><td rowspan="3">Rating</td><td>Each phase</td><td>240 V – 2 A ac</td><td colspan="2">440 V – 1 A ac</td><td>480 V – 1 A ac</td></tr>
<tr><td>Light bulbs</td><td colspan="4">130 V - 2.6 W - BA9S</td></tr>
<tr><td>Circuit breakers</td><td>2 A</td><td colspan="3">1 A</td></tr>
<tr><td colspan="2">Dimensions (H × W × D)</td><td colspan="4">154 × 287 × 410 mm (6.1 × 11.3 × 16.1 in)</td></tr>
<tr><td colspan="2">Weight</td><td colspan="4">3.6 kg (7.9 lb)</td></tr>
</table>

Synchronizing Module/Three-Phase Contactor, Model 8621-A/-B

The Synchronizing Module/Three-Phase Contactor, Model 8621-A/-B, is a half-size EMS module used to control various electric devices, or synchronize two ac power sources like a synchronous generator with an ac power network. The Synchronizing Module/Three-Phase Contactor consists of a three-phase contactor whose coil can be energized either:

- manually with a toggle switch.
- automatically with a thyristor fired by applying to the Remote Control input of the module a low-level (TTL) signal or, for Model 8621-B only, a 0-24 V.

Six safety banana jacks (one pair per phase) allow connection of electric devices or ac power sources across the contacts of the three-phase contactor. Three indicator lamps indicate the relative level of the voltage across their corresponding contact terminals.

Control, connectors, and indicators

1. Power Input terminals (L and N): these two banana jacks are used to apply the line voltage to the coil (coil A) of the three-phase contactor via the Sync. switch contact or via a thyristor controlled by a remote control signal. Also, the line voltage must be applied to the Power Input terminals for the indicator (synchronizing) lamps to be operational.

2. Sync. switch: when the line voltage is applied across the Power Input terminals, this switch can be used to energize or de-energize coil A of the three-phase contactor. When the Sync. switch is set to the I (on) position, the line voltage is applied to coil A, which energizes this coil and causes the three contacts (contacts A) of the contactor to close. Conversely, when the Sync. switch is set to the O (off) position, the line voltage is removed from coil A, which leaves it de-energized and available for remote control.

3. Remote Control terminals: when the line voltage is applied to the Power Input terminals, these two miniature jacks permit using a logic control signal of an appropriate level to energize or de-energize coil A of the three-phase contactor.

4. Contact terminals: these three pairs of banana jacks (one pair per phase) allow connection of electric devices to the contactor, or connection of two ac power sources on both sides of the contactor.

5. Lamps switch: this toggle switch must be set to I (on) for the indicator lamps to be operational. Also, the line voltage must be applied to the Power Input terminals for the lamps to be operational.

6. Indicator (synchronizing) lamps: these three lamps indicate the relative level of the voltage across the three corresponding contact terminals. Thus, the brightness of these lamps increases when the voltage difference across their contact terminals increase. Conversely, the brightness of these lamps decreases when the voltage difference across their contact terminals decreases.

To replace a light bulb of Model 8621-A, use Festo's part 70414 or an equivalent bulb. The LEDs in Model 8621-B should not require any replacement.

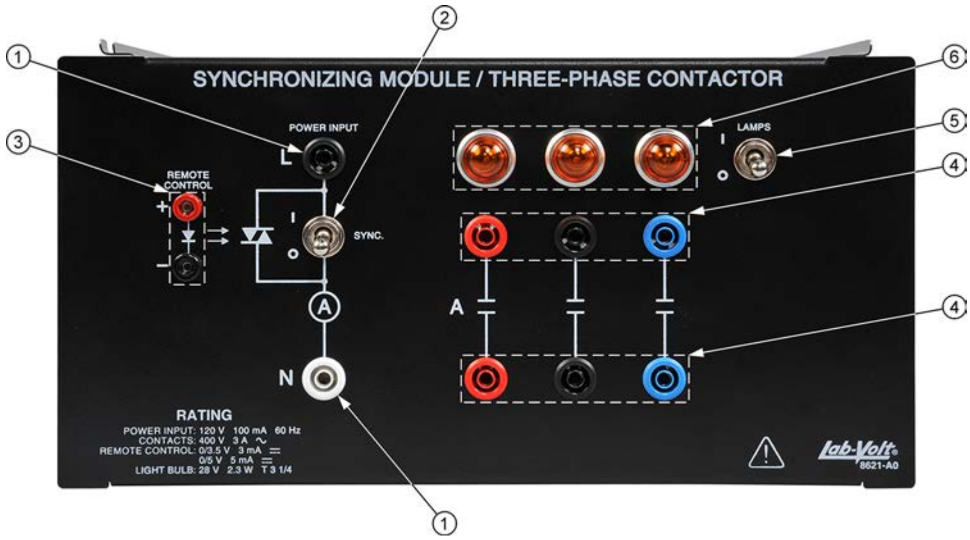


Figure 52: Front panel of the Synchronizing Module/Three-Phase Contactor, Model 8621-A.

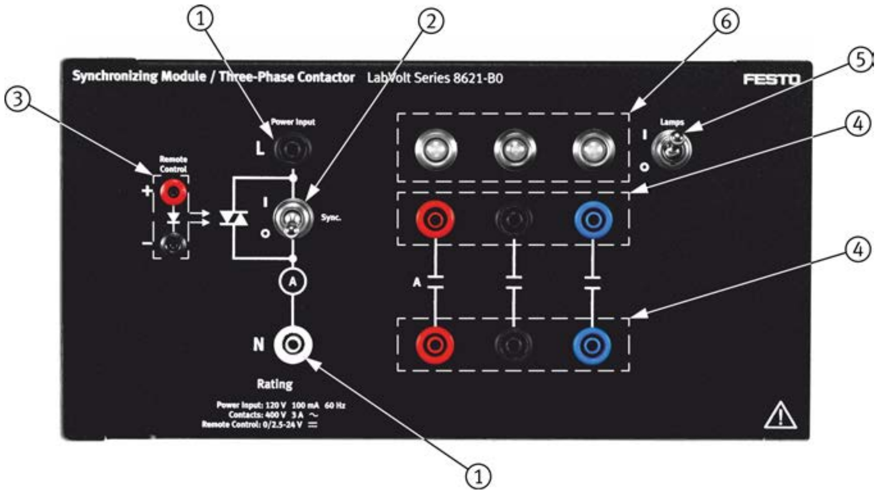


Figure 53: Front panel of the Synchronizing Module/Three-Phase Contactor, Model 8621-B.

Table 20: Synchronizing Module/Three-Phase Contactor, Model 8621-A.

Parameter	**Subparameter**	**8621-A0, -A1, -A2**	**8621-A5, -A6, -A7**	**8621-AE, -AF**	**8621-AA**
Contactor	Power input	120 V – 100 mA – 60 Hz	220 V – 50 mA – 50 Hz		240 V – 50 mA – 50 Hz
	Contacts	400 V – 3 A ac	600 V – 1.5 A ac		
Remote Control input		0/3.5-5 V dc			
Light bulbs		28 V – 2.3 W – T 3 1/4			
Dimensions (H × W × D)		154 × 287 × 410 mm (6.1 × 11.3 × 16.1 in)			
Net Weight		3.6 kg (7.9 lb)			
Shipping Weight		5.2 kg (11.4 lb)			

Table 21: Synchronizing Module/Three-Phase Contactor, Model 8621-B.

Parameter	Subparameter	8621-B0, -B1, -B2	8621-B5, -B6, -B7	8621-BA
Contactor	Power input	120 V – 50 mA – 60 Hz	220 V – 25 mA – 50/60 Hz	240 V – 25 mA – 50 Hz
	Contacts	400 V – 3 A ac	600 V – 1.5 A ac	
Remote Control input		0/2.5-24 V dc		
Dimensions (H × W × D)		154 × 287 × 410 mm (6.1 × 11.3 × 16.1 in)		
Net Weight		3.2 kg (7.1 lb)		
Shipping Weight		4.8 kg (10.6 lb)		

Lead-Acid Batteries, Model 8801

The Lead-Acid Batteries module consists of two 12 V valve-regulated, lead-acid (VRLA) batteries enclosed in a half-size EMS module. These batteries are part of the Electric Power Technology Training Program and are used to study lead-acid battery characteristics as well as the storage of electrical energy in various applications, such as solar power and wind power electricity generation. They can easily be charged using the Four-Quadrant Dynamometer/Power Supply, Model 8960-2.

The batteries can be connected in series or parallel. Connection to the batteries is through 4 mm safety banana jacks mounted on the front panel of the module. These jacks are used when large amounts of power are supplied to the batteries or drawn from the batteries. A pair of miniature (2 mm) banana jacks mounted on the front panel of the module provides access to one of the two batteries via a low-capacity auto-reset fuse. These miniature jacks are used to connect the battery to either the Solar Panel Test Bench, Model 8805, or the Solar Panel, Model 8806, when performing lab exercises dealing with the storage of electrical energy produced from solar power.

Control, connectors, and indicators

1. Terminals of the first lead-acid battery: these two color-coded safety jacks allow connection of the first lead-acid battery to circuits.

2. Terminals of the second lead-acid battery: these two color-coded safety jacks allow connection of the second lead-acid battery to circuits. This battery can be accessed via the low-capacity auto-reset fuse terminals.

3. Auto-reset fuse terminals: these two miniature jacks provide access to one of the two batteries via a low-capacity auto-reset fuse. They are used to connect the battery to either the Solar Panel Test Bench, Model 8805, or the Solar Panel, Model 8806, when performing lab exercises dealing with the storage of electrical energy produced from solar power.

4. Parallel Charging Input terminal: this terminal is used to charge several Lead-Acid Batteries (connected in parallel) at the same time, using the Four-Quadrant Dynamometer/Power Supply, Model 8960.

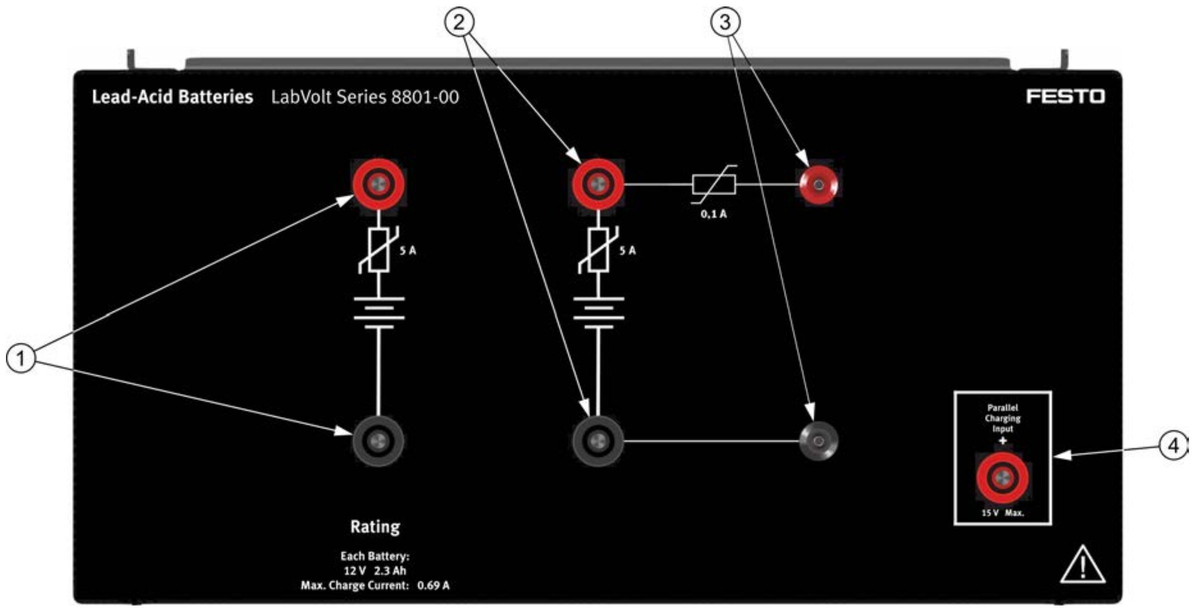


Figure 54: Front panel of the Lead-Acid Batteries module.

Maintenance

In order to optimize the cycle life of the batteries in the Lead-Acid Batteries and to prevent sulfation, the battery should be charged as soon as possible after a discharge cycle (e.g., after completion of a laboratory exercise). The Lead-Acid Batteries should never be stored discharged for an extended period of time.

Also, it is recommended to perform an equalization charge every six months. To do so, perform the following two-step procedure recommended by the battery manufacturer:

1. Fully discharge the Lead-Acid Batteries, i.e., down to a voltage of 10.5 V.

2. Charge the Lead-Acid Batteries during 24 hours using a constant-voltage of 14.7 V while limiting the charge current to a maximum value of 0.69 A.

Sulfation test

After the equalization charge, it is recommended to check each battery for sulfation. To do so, wait for about 12 hours after performing an equalization charge, then measure the open-circuit voltage across each battery with a multimeter. Refer to the following table to know if the battery is sulfated and needs desulfation or replacement.

Table 22: Measured open-circuit voltage and battery sulfation.

Open-circuit voltage	Battery sulfation
Below 12.6 V	The battery is sulfated and must be replaced.
Between 12.6 V and 12.8 V	The battery is sulfated, but can be desulfated. To do so, use a commercial charger with a desulfating function.
Above 12.8 V	The battery is in good condition.

Table 23: Lead-Acid Batteries, Model 8801.

Lead-Acid Batteries 8801		Models: 8801-00, -01, -02
Batteries	Quantity	2
	Type	Valve-regulated lead-acid
	Voltage	12 V
	Capacity	2.3 Ah
	Maximum charge current	0.69 A
	Maximum discharge current	5 A
Auto-reset protective fuse	Battery	5 A (hold current), 10 A (trip current)
	Test point	0.1 A (hold current), 0.2 A (trip current)

Lead-Acid Batteries 8801	Models: 8801-00, -01, -02
Dimensions (H × W × D)	154 × 287 × 410 mm (6.1 × 11.3 × 16.1 in)
Weight	4.6 kg (10.2 lb)

Lead-Acid Battery Pack, Model 8802-1

The Lead-Acid Battery Pack, Model 8802-1, is a half-size EMS module housing four 12 V lead-acid batteries connected in series. The Lead-Acid Battery Pack thus provides a fixed dc voltage of 48 V, available at two color-coded safety banana jacks on the module front panel. Three battery voltage test points allow measurement of the voltage provided by each of the four 12 V batteries. A parallel charging input terminal permits the charging of several Lead-Acid Battery Packs connected in parallel at the same time. A voltmeter measures the voltage across the battery pack.

The Lead-Acid Battery Pack is protected against overcurrents and short-circuits by electronic fuses that reset automatically. The Lead-Acid Battery Pack can be used as a 48 V dc power source, and in energy production and storage applications implemented with the Electric Power Technology Training Equipment.

Control, connectors, and indicators

1. Lead-Acid Battery Pack terminals: these two color-coded safety jacks allow connection of the Lead-Acid Battery Pack to circuits.

2. Battery Voltage Test Points terminals: these three safety jacks are used to measure the voltage provided by each of the four 12 V batteries in the Lead-Acid Battery Pack. These terminals are used to perform voltage measurements only.

NOTICE
Never use any of the three Battery Voltage Test Points terminals to supply power to circuits. This situation, if not avoided, can result in damage to the batteries.

3. Voltmeter: this voltmeter measures and displays the voltage across the lead-acid battery pack. The measured voltage can be used to approximate the state of charge of the battery pack. The lower the measured voltage, the lower the state of charge of the battery pack.

4. Parallel Charging Input terminal: this terminal is used to charge several Lead-Acid Battery Packs (connected in parallel) at the same time, using the Four-Quadrant Dynamometer/Power Supply, Model 8960.

⚠ CAUTION

The Lead-Acid Battery Pack, Model 8802-1, is a heavy module. Therefore, install it in a half-height compartment of the workstation, or in the bottom section of a full-height compartment of the workstation, as directed in Learning Unit 8 of this document.

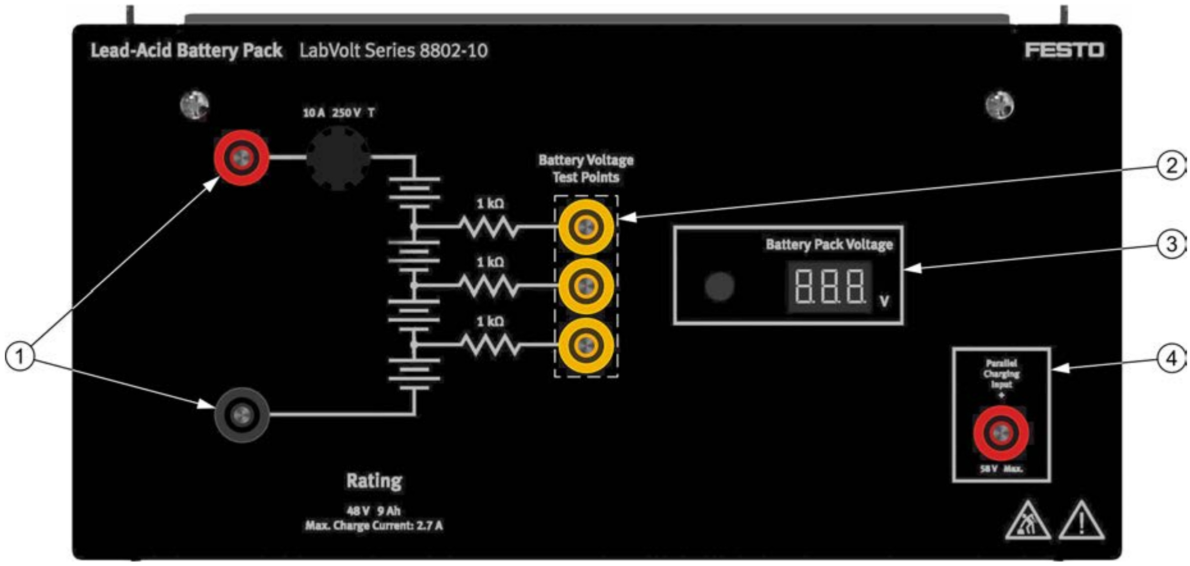


Figure 55: Front panel of the Lead-Acid Battery Pack, Model 8802-1.

Maintenance

To optimize the cycle life of the batteries in the Lead-Acid Battery Pack and to prevent sulfation, the battery pack should be charged as soon as possible after a discharge cycle (e.g., after completion of a laboratory exercise). The Lead-Acid Battery Pack should never be stored with the batteries discharged for an extended period of time.

Also, it is recommended to perform an equalization charge every six months. To do so, perform the following two-step procedure recommended by the battery manufacturer:

- Fully discharge the Lead-Acid Battery Pack down to a voltage of 42 V.
- Charge the Lead-Acid Battery Pack during 24 hours using a constant-voltage of 58.8 V while limiting the charge current to a maximum value of 2.7 A.

Sulfation test

After the equalization charge, it is recommended to check each battery for sulfation. To do so, wait for about 12 hours after performing an equalization charge, then measure the open-circuit voltage across each battery with a multimeter. Refer to the following table to know if the battery is sulfated and needs desulfation or replacement.

Table 24: Measured open-circuit voltage and battery sulfation.

Open-circuit voltage	Battery sulfation
Below 12.6 V	The battery is sulfated and must be replaced.
Between 12.6 V and 12.8 V	The battery is sulfated, but can be desulfated. To do so, use a commercial charger with a desulfating function.
Above 12.8 V	The battery is in good condition.

Table 25: Lead-Acid Battery Pack, Model 8802-1.

Lead-Acid Battery Pack 8802-1		Models: 8802-10, -11, -12
Battery pack	Type	4 valve-regulated lead-acid batteries
	Voltage	48 V (12 V for each battery)
	Capacity	9 Ah
	Maximum charge current	2.7 A
	Maximum discharge current	7 A
	Parallel charging input	58 V max.
Auto-reset protective fuses	Battery pack	7 A (hold current), 14 A (trip current)
	Test points (3)	0.2 A (hold current), 0.4 A (trip current)
Dimensions (H × W × D)		154 × 287 × 410 mm (6.1 × 11.3 × 16.1 in)
Weight		13.8 kg (30.4 lb)

Lithium-Ion Battery Pack, Model 8802-B

The Lithium-Ion Battery Pack, Model 8802-B, is an EMS half-module housing 39 rechargeable lithium-ion cells in standard 18650 format with a nominal voltage of 3.6 V. These cells are connected in parallel in packs of three, and these packs (13×) are connected in series (13S3P). All these cells create a 48 V, 10.2 Ah battery pack, accessed via two red and black terminals on the left-hand side of the front panel.

A specialized circuit called the Battery Management System (BMS) measures several battery parameters and controls a protective relay and cell-balancing circuits. This system must be connected to the internal processor (CPU) by an RJ11 phone cable (terminals IMA/IPA to IM/IP) in the center of the front panel. The CPU ensures that all cells operate in safe conditions, activates (by sending a command to the BMS) the protection relay if necessary, and activates the cell voltage balancing circuits. The CPU and BMS use an external 24 V ac power supply (Low Power Input), and therefore do not consume battery power.

The front panel features 4 green LEDs providing a rough indication of the battery's state of charge (SOC). In addition, 12 battery status LEDs provide information on battery operation. The red LEDs indicate faults which have caused the battery pack to be disconnected by the protection relay in series with the red terminal.

The Lithium-Ion Battery Pack can be used as a 48 V dc power source, and in energy production and storage applications implemented with the Electric Power Technology Training Equipment as a replacement for the Lead-Acid Battery Pack, Model 8802-1. Two or three modules can be connected in series to produce a 96 V, 10.2 Ah or 144 V, 10.2 Ah battery pack respectively. However, before connecting modules in series, each module must have an SOC of 100%.

To charge the battery pack module, we recommend using the Four-Quadrant Dynamometer/Power Supply, Model 8960-3 (in power supply mode).

- For overnight charging, without taking measurements, only the Four-Quadrant Dynamometer/Power Supply and Lead-Acid Battery Pack modules can be used. In addition to the positive and negative wire connections, the USB cable must be connected between the two modules.
- If you want to take measurements in the laboratory, use the Four-Quadrant Dynamometer/Power Supply (in power supply mode), but connect its USB connector to the computer running the LVDAC-EMS software, with the Lithium-Ion Charger window open. You also need to connect the battery pack module's RJ45 cable to this same computer.

In both cases, charging will start with a constant current (CC) equal to the maximum charging current, and continue with a constant voltage (CV) equal to the maximum charging voltage. During the constant voltage phase, the charger will progressively reduce the charging current so as not to exceed the charging voltage limit. When the current drops below the cutoff current, charging ends.

The battery pack module can discharge or charge during laboratory exercises. It is recommended to perform exercises with an SOC of less than 75%. This ensures that the full charging current is obtained without tripping any protections.

Control, connectors, and indicators

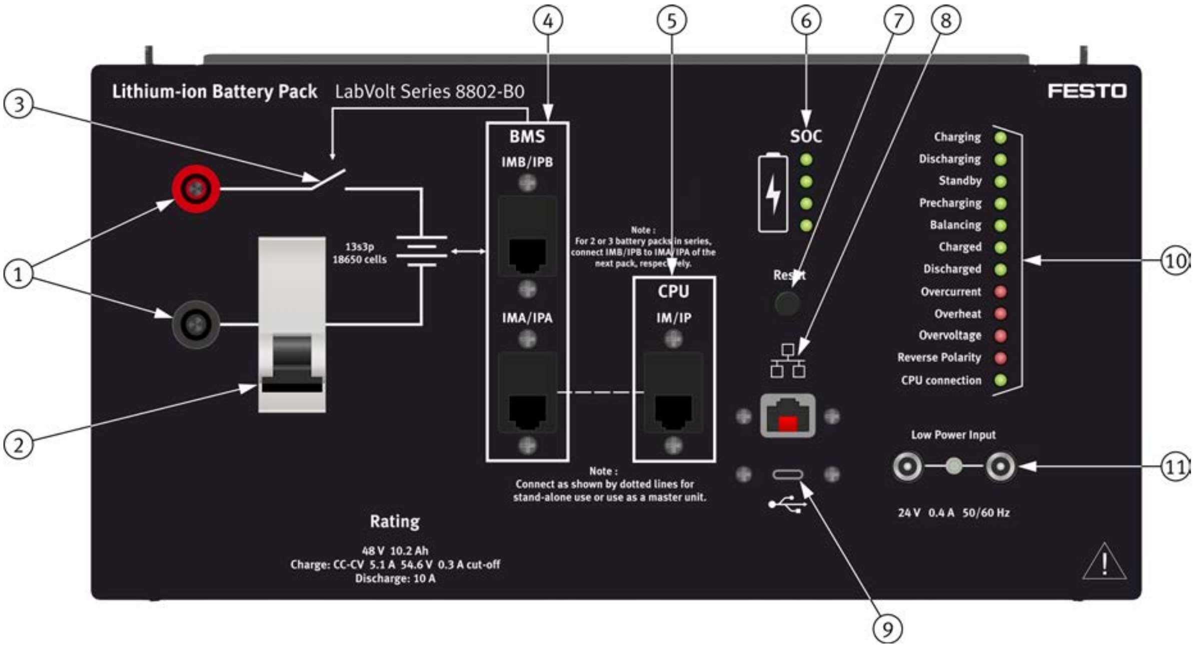


Figure 56: Front panel of the Lithium-ion Battery Pack, Model 8802-B.

1. Lithium-ion Battery Pack terminals: these two color-coded safety jacks allow connection of the module to external circuits.

2. Circuit breaker: disconnects the battery from short-circuit or overload currents in case the BMS has not yet opened the protection relay.

3. Protection relay: controlled by the BMS. Disconnects the battery pack from the external circuit in the event that the BMS detects a condition outside the battery's safe operating range.

4. BMS terminals: these two RJ11 phone terminals connect the Battery Management System (BMS) to the processor (CPU) or to other batteries when several modules are used in series to increase the battery pack voltage.

   - For operation with a single battery pack, connect terminal IMA/IPA to IM/IP as indicated by the dotted lines. This enables the CPU to communicate with the BMS via the ISOlated Serial Peripheral Interface (ISO-SPI).
   - For operation with two series-connected battery packs, connect IMB/IPB of the first pack to IMA/IPA of the second pack. That way, only the CPU of the first module communicates with both BMSs.
   - For operation with three series-connected battery packs, the same principle applies as for two battery packs. Only the CPU of the first battery pack communicates with all three BMSs.

The function of the BMS is to measure the voltage and temperature of each pack of three parallel-connected cells, and to measure the total battery current. It sends this information to the CPU via ISO-SPI communication for analysis. The BMS can also activate the protection relay and cell voltage balancing circuits after a command from the CPU.

5. CPU: the CPU is a computer running under the Linux operating system. It controls the BMS, connects to the user's computer via the LVDAC-EMS software, or connects to an 8960-3 module for recharging. The CPU uses information from the BMS to control the protection relay or to activate balancing circuits to balance the voltages of the 13 cell packs. The CPU also calculates the SOC.

   The RJ11 phone terminal (IM/IP) must be connected to the IMA/IPA terminal, as previously explained.

6. SOC LEDs: provide a rough indication of the battery's SOC. A more precise value can be obtained using the LVDAC-EMS software.

7. RESET button: restarts battery operation when a fault is detected, forcing the protection relay to open. The condition which caused the fault must be removed before resetting the module by pressing the RESET button.

8. RJ45 connector: used to connect to the user's computer to communicate with the LVDAC-EMS software. This Ethernet connection is not required to operate the battery pack module.

   To communicate with the battery pack through the RJ45 connector, the network adapter of the user's computer must be configured to obtain an IP address automatically (DHCP). If communication cannot be established, check the computer's Ethernet adapter settings.

9. USB port: allows for direct connection to the Four-Quadrant Dynamometer/Power Supply (8960-3), enabling recharging with parameters tailored to battery configurations (8802-B or 8802-C) and type while satisfying technical specifications.

10. Battery pack status LEDs: these LEDs are divided into two packs. Green LEDs indicate normal operating states and red LEDs indicate fault states. A more detailed description of each LED follows:

    - **Charging** indicates that the battery pack is charging normally.
    - **Discharging** indicates that the battery pack is discharging normally.
    - **Standby** indicates that the battery pack is on standby without charging or discharging.
    - **Precharging** indicates that the battery pack detects that it is connected to capacitors and is recharging them through a resistor in order to limit the current.
    - **Balancing** indicates that the BMS has activated balancing circuits to balance the voltages across the 13 cell packs.

- **Charged** indicates that the battery pack is fully charged. If charging is carried out by the Four-Quadrant Dynamometer/Power Supply (8960-3), the CPU also sends a signal via the USB cable to stop charging.

- **Discharged** indicates that the battery pack's SOC is low enough that it needs to be charged. The CPU sends a command to open the protection relay to avoid further discharging the battery pack. To reset this fault, disconnect the battery pack and connect it to a voltage source higher than the battery pack voltage.

- **Overcurrent** indicates that the charging or discharging current has exceeded the limits. The CPU sends a command to open the protection relay. To reset this fault, remove the condition that created the overcurrent, then press the RESET button.

- **Overheat** indicates that the temperature of one cell or more has exceeded the limit. The CPU sends a command to open the protection relay. This fault resets automatically when the temperature decreases to a safe level.

- **Overvoltage** indicates that one pack of cells or more has reached a too high voltage. The CPU sends a command to open the protection relay. To reset this fault, remove the condition that created the overvoltage, then press the RESET button.

- **Reverse Polarity** indicates that a negative voltage is detected at the battery pack terminals. The CPU sends a command to open the protection relay. To reset this fault, reverse the connection to the battery pack terminals, then press the RESET button.

- **CPU Connection** indicates when the CPU is connected to the BMS. This LED should always be lit for normal battery operation. If it does not light up, check that you have connected terminal IMA/IPA to IM/IP. When connecting multiple modules in series, only one module will have its CPU connected, and therefore, only its LED will be lit.

11. Low Power Input terminals: a 24 V ac power supply is required to power the CPU and the BMS through either of these terminals. Since both terminals are connected, when one of the terminals is powered, the other terminal can be used to power another module.

Maintenance

For an optimal cycle life, store the Lithium-ion Battery Pack at or near the following conditions:

- SOC of 40%
- Temperature of 15°C (59°F)

Storage at an SOC below 80% and at a temperature below 27°C (80.6°F) is acceptable.

Considering this, at the end of an exercise, it is **not** recommended to recharge the battery if the SOC is above 40%. However, if you know that the next short-term use of the battery pack will be for discharging only, a full charge can be carried out.

All cells in a module originate from the same production batch. Once installed, cells should not be removed to maintain a balanced state of health. Every cell is protected by a miniature fuse located on the printed circuit board to prevent fire hazard from improper insertion into the cell holder. If any of these fuses are damaged (open circuit), the module must be returned for repair at the factory.

⚠ WARNING

Use only with certified battery kit. This module is designed exclusively for operation with battery kit P/N 8200281. Do not use with any other power sources. Batteries are sold separately and must be purchased with the appropriate kit.

Table 26: Lithium-ion Battery Pack, Model 8802-B.

Lithium-ion Battery Pack **8802-B**	**Models:** **8802-B0, -B1, -B2**
Cell Type	Lithium-ion
Cell Cathode	Nickel Manganese Cobalt Oxide (NMC)
Cell Dimensions (diameter, length)	18650 (18.6 mm, 65.2 mm)
Voltage (nominal)	48 V (≈ 13 × 3.6 V)
Minimum Discharge Voltage	32.5 V
Maximum Charge Voltage	54.6 V
Charging Cutoff Current	0.3 A
Capacity	10.2 Ah (3 × 3.4 Ah)
Maximum Charge Current	5.1 A
Maximum Discharge Current	10 A
Charging Mode	Constant Current / Constant Voltage (CC-CV)
Charging Time	2.5 h

Lithium-ion Battery Pack **8802-B**	**Models:** **8802-B0, -B1, -B2**
Series Stacking	2× (96 V, 10.2 Ah) or 3× (144 V, 10.2 Ah)
Cell PCB Fuses (39)	20 A
Breaker Trip Current	10 A
BMS	LTC6813
CPU	Raspberry Pi CM4
Power Requirements	24 V, 0.4 A, 50/60 Hz
Included accessories	24 V low power cable (1) RJ11 phone cable (1) RJ45 cable (1) USB-C to USB-B cable (1) 18650 cells (39)
Dimensions (H × W × D)	154 × 287 × 410 mm (6.1 × 11.3 × 16.1 in)
Weight	6.6 kg (14.55 lb)

Lithium-Ion Battery Pack, Model 8802-C

The Lithium-Ion Battery Pack, Model 8802-C, is an EMS half-module housing 13 rechargeable lithium-ion cells in standard 18650 format with a nominal voltage of 3.6 V. These 13 cells are connected in series (13S1P). All these cells create a 48 V, 3.4 Ah battery pack, accessed via two red and black terminals on the left-hand side of the front panel.

A specialized circuit called the Battery Management System (BMS) measures several battery parameters and controls a protective relay and cell-balancing circuits. This system must be connected to the internal processor (CPU). The CPU ensures that all cells operate in safe conditions, activates (by sending a command to the BMS) the protection relay if necessary, and activates the cell voltage balancing circuits. The CPU and BMS use an external 24 V ac power supply (Low Power Input), and therefore do not consume battery power.

The front panel features 4 green LEDs providing a rough indication of the battery's state of charge (SOC). In addition, 12 battery status LEDs provide information on battery operation. The red LEDs indicate faults which have caused the battery pack to be disconnected by the protection relay in series with the red terminal.

This battery pack is designed to study the behavior of lithium-ion batteries in a reasonable amount of laboratory time using the course Lithium-Ion Batteries. With the LVDAC-EMS software, it is possible to measure the voltages and temperatures of individual cells and to manually control the balancing circuits.

To charge the battery pack module, we recommend using the Four-Quadrant Dynamometer/Power Supply, Model 8960-3 (in power supply mode).

- For overnight charging, without taking measurements, only the Four-Quadrant Dynamometer/Power Supply and Lead-Acid Battery Pack modules can be used. In addition to the positive and negative wire connections, the USB cable must be connected between the two modules.

- If you want to take measurements in the laboratory, use the Four-Quadrant Dynamometer/Power Supply (in power supply mode), but connect its USB connector to the computer running the LVDAC-EMS software, with the Lithium-Ion Charger window open. You also need to connect the battery pack module's RJ45 cable to this same computer.

In both cases, charging will start with a constant current (CC) equal to the maximum charging current, and continue with a constant voltage (CV) equal to the maximum charging voltage. During the constant voltage phase, the charger will progressively reduce the charging current so as not to exceed the charging voltage limit. When the current drops below the cutoff current, charging ends.

Control, connectors, and indicators

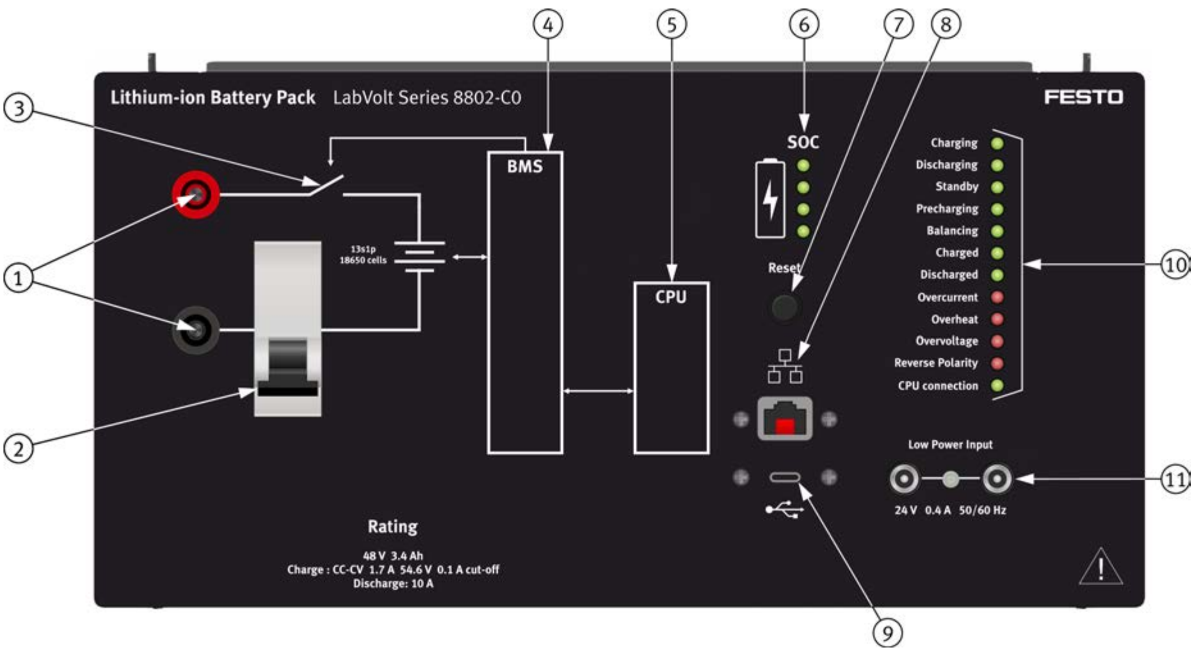


Figure 57: Front panel of the Lithium-ion Battery Pack, Model 8802-C.

1. Lithium-ion Battery Pack terminals: these two color-coded safety jacks allow connection of the module to external circuits.

2. Circuit breaker: disconnects the battery from short-circuit or overload currents in case the BMS has not yet opened the protection relay.

3. Protection relay: controlled by the BMS. Disconnects the battery pack from the external circuit in the event that the BMS detects a condition outside the battery's safe operating range.

4. Battery Management System (BMS): measures the voltage and temperature of each cell, as well as the total battery current. The BMS then sends this information to the CPU via ISO-SPI communication for analysis. The BMS can also activate the protection relay and cell voltage balancing circuits after a command from the CPU.

5. CPU: the CPU is a computer running under the Linux operating system. It controls the BMS, connects to the user's computer via the LVDAC-EMS software, or connects to an 8960-3 module for recharging. The CPU uses information from the BMS to control the protection relay or to activate balancing circuits to balance the voltages of the 13 cells. The CPU also calculates the SOC.

6. SOC LEDs: provide a rough indication of the battery's SOC. A more precise value can be obtained using the LVDAC-EMS software.

7. RESET button: restarts battery operation when a fault is detected, forcing the protection relay to open. The condition which caused the fault must be removed before resetting the module by pressing the RESET button.

8. RJ45 connector: used to connect to the user's computer to communicate with the LVDAC-EMS software. This Ethernet connection is not required to operate the battery pack module.

   To communicate with the battery pack through the RJ45 connector, the network adapter of the user's computer must be configured to obtain an IP address automatically (DHCP). If communication cannot be established, check the computer's Ethernet adapter settings.

9. USB port: allows for direct connection to the Four-Quadrant Dynamometer/Power Supply (8960-3), enabling recharging with parameters tailored to battery configurations (8802-B or 8802-C) and type while satisfying technical specifications.

10. Battery pack status LEDs: these LEDs are divided into two packs. Green LEDs indicate normal operating states and red LEDs indicate fault states. A more detailed description of each LED follows:

    - **Charging** indicates that the battery pack is charging normally.
    - **Discharging** indicates that the battery pack is discharging normally.
    - **Standby** indicates that the battery pack is on standby without charging or discharging.
    - **Precharging** indicates that the battery pack detects that it is connected to capacitors and is recharging them through a resistor in order to limit the current.
    - **Balancing** indicates that the BMS has activated balancing circuits to balance the voltages across the 13 cells.

- **Charged** indicates that the battery pack is fully charged. If charging is carried out by the Four-Quadrant Dynamometer/Power Supply (8960-3), the CPU also sends a signal via the USB cable to stop charging.

- **Discharged** indicates that the battery pack's SOC is low enough that it needs to be charged. The CPU sends a command to open the protection relay to avoid further discharging the battery pack. To reset this fault, disconnect the battery pack and connect it to a voltage source higher than the battery pack voltage.

- **Overcurrent** indicates that the charging or discharging current has exceeded the limits. The CPU sends a command to open the protection relay. To reset this fault, remove the condition that created the overcurrent, then press the RESET button.

- **Overheat** indicates that the temperature of one cell or more has exceeded the limit. The CPU sends a command to open the protection relay. This fault resets automatically when the temperature decreases to a safe level.

- **Overvoltage** indicates that one pack of cells or more has reached a too high voltage. The CPU sends a command to open the protection relay. To reset this fault, remove the condition that created the overvoltage, then press the RESET button.

- **Reverse Polarity** indicates that a negative voltage is detected at the battery pack terminals. The CPU sends a command to open the protection relay. To reset this fault, reverse the connection to the battery pack terminals, then press the RESET button.

- **CPU Connection** indicates when the CPU is connected to the BMS. This LED should always be lit for normal battery operation.

11. Low Power Input terminals: a 24 V ac power supply is required to power the CPU and the BMS through either of these terminals. Since both terminals are connected, when one of the terminals is powered, the other terminal can be used to power another module.

Maintenance

For an optimal cycle life, store the Lithium-ion Battery Pack at or near the following conditions:

- SOC of 40%
- Temperature of 15°C (59°F)

Storage at an SOC below 80% and at a temperature below 27°C (80.6°F) is acceptable.

Considering this, at the end of an exercise, it is **not** recommended to recharge the battery if the SOC is above 40%. However, if you know that the next short-term use of the battery pack will be for discharging only, a full charge can be carried out.

All cells in a module originate from the same production batch. Once installed, cells should not be removed to maintain a balanced state of health.

⚠ **WARNING**

Use only with certified battery kit. This module is designed exclusively for operation with battery kit P/N 8200282. Do not use with any other power sources. Batteries are sold separately and must be purchased with the appropriate kit.

Table 27: Lithium-ion Battery Pack, Model 8802-C.

Lithium-ion Battery Pack **8802-C**	**Models:** **8802-C0, -C1, -C2**
Cell Type	Lithium-ion
Cell Cathode	Nickel Manganese Cobalt Oxide (NMC)
Cell Dimensions (diameter, length)	18650 (18.6 mm, 65.2 mm)
Voltage (nominal)	48 V (≈ 13 × 3.6 V)
Minimum Discharge Voltage	32.5 V
Maximum Charge Voltage	54.6 V
Charging Cutoff Current	0.1 A
Capacity	3.4 Ah
Maximum Charge Current	1.7 A
Maximum Discharge Current	10 A
Charging Mode	Constant Current / Constant Voltage (CC-CV)
Charging Time	2.5 h
Series Stacking	Not possible
Breaker Trip Current	10 A
BMS	LTC6813

Lithium-ion Battery Pack **8802-C**	**Models:** **8802-C0, -C1, -C2**
CPU	Raspberry Pi CM4
Power Requirements	24 V, 0.4 A, 50/60 Hz
Included accessories	24 V low power cable (1) RJ45 cable (1) USB-C to USB-B cable (1) 18650 cells (13)
Dimensions (H × W × D)	154 × 287 × 410 mm (6.1 × 11.3 × 16.1 in)
Weight	5.4 kg (12.0 lb)

Power Supply, Model 8821-2

The Power Supply is enclosed in a full-size EMS module. It can be used to power most of the EMS modules of the Electric Power Technology Training Equipment. This Power Supply provides dc power and ac power, both fixed and variable, single-phase and three-phase. Color-coded safety banana jacks provide access to all the power sources in the Power Supply. All these power sources can be used simultaneously, provided that the total current drawn does not exceed the maximum current rating. A built-in voltmeter with selector switch and liquid crystal display (LCD) indicates the voltage provided by any of the power sources. The inputs and outputs of the Power Supply are protected by independent circuit breakers.

The Power Supply has a main power switch/supplementary protector used to turn the main power on and off. The main power switch/supplementary protector protects all power lines of the Power Supply against overcurrents. Three LED indicators on the front panel of the Power Supply light up when the main power is turned on. There is one LED per phase. A 24 V ac output provides a low voltage required to power certain EMS modules like the Data Acquisition and Control Interface, Model 9063.

A five-wire flexible ac power cord, terminated with a five-prong twist-lock plug and line cap, is used to feed the Power Supply. For safety purpose, a mechanical interlock on the line cap prevents students from removing the Power Supply from the EMS workstation while it is energized by keeping it locked to the workstation.

The Power Supply requires a three-phase, wye-connected, five-wire service installation. An appropriate plug or wall outlet is provided with the Power Supply so that the ac power network connection point in your classroom can be properly terminated to match the ac power cord of the Power Supply. In addition to the three-phase and neutral legs, a separate copper ground allows proper grounding of the Power Supply chassis and workstation compartments, thus providing added safety for students using the Power Supply.

Control, connectors, and indicators

1. Main Power switch/Supplementary protector: this on/off (I/O) switch is used to turn the main power on and off. When the Main Power switch/Supplementary protector is set to on (I), power is applied to all output terminals, except for the 24 V Low Power Output section. The Main Power switch/Supplementary protector protects all power input lines of the Power Supply against overcurrents.

2. Voltage control knob: this knob allows you to vary the percentage of the nominal voltage applied to the ac and dc variable output terminals.

3. Voltmeter: ac/dc voltmeter with a liquid crystal display (LCD) indicating the voltage present between the terminals currently selected.

4. Voltmeter selection knob: this knob permits selection of the output terminals for which the Voltmeter indicates the measured voltage.

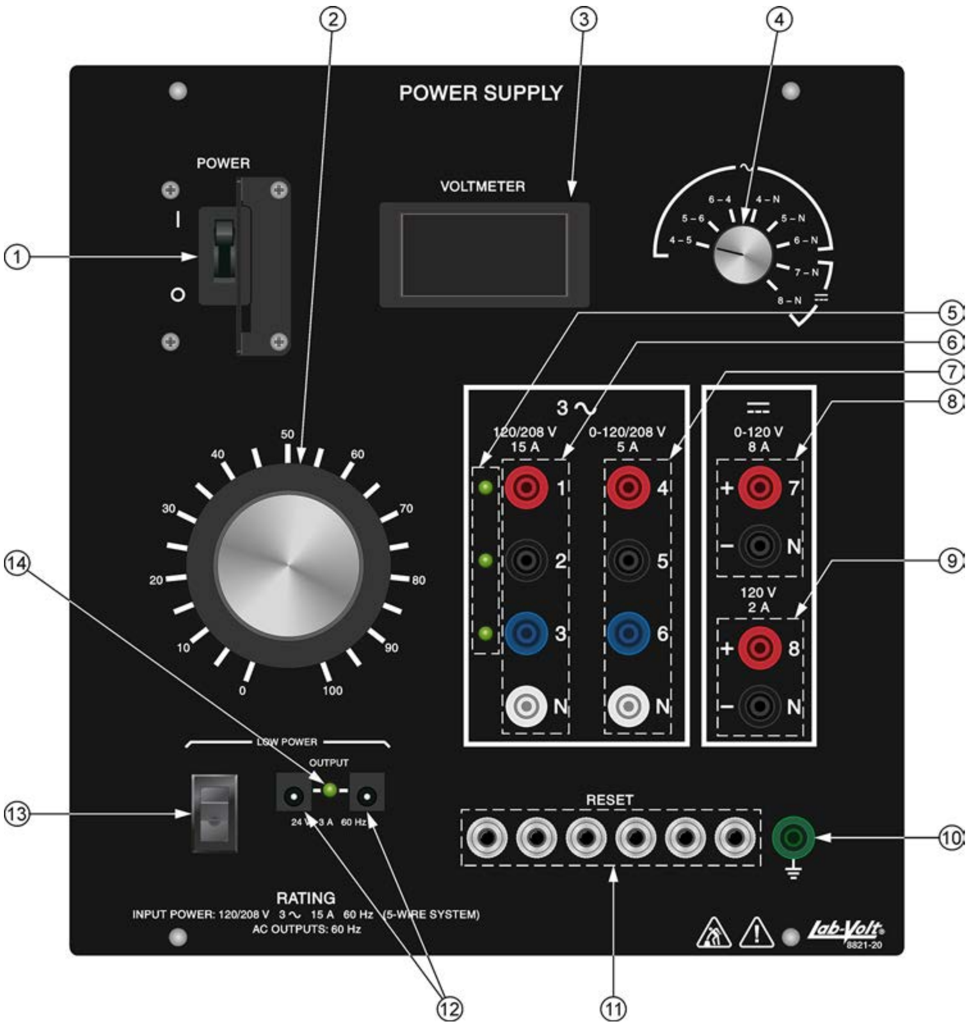


Figure 58: Front panel of the Power Supply, Model 8821-2.

5. Main power indicators: these LEDs light up when the main power is turned on. There is one lamp per phase.

NOTICE
The Power Supply, Model 8821, is a very heavy module. It must be installed in a full-height compartment at the bottom of the workstation, as directed in Learning Unit 8 of this document.

6. Fixed-voltage, three-phase, four-wire output (terminals 1, 2, 3, and N on the front panel): these banana jacks provide a fixed, three-phase ac voltage.

7. Variable-voltage, three-phase, four-wire output (terminals 4, 5, 6, and N on the front panel): these banana jacks provide an ac voltage whose level can be varied manually, using the voltage control knob.

8. Variable-voltage dc output (terminals 7 and N on the front panel): these banana jacks provide a dc voltage whose level can be varied manually, using the voltage control knob.

9. Fixed-voltage dc output (terminals 8 and N on the front panel): these banana jacks provide a fixed dc voltage.

10. Earth (ground) terminal: this banana jack is connected to the earthing (grounding) prong of the main power cord of the Power Supply.

11. Reset buttons: these buttons are used to reset the output circuit breakers that protect output terminals 4 through 8. The three left-hand buttons are used to reset the breakers of output terminals 4 through 7. The three right-hand buttons are used to reset the breakers of output terminal 8.

12. Low Power Output terminals: these jacks provide 24 V ac power when the Low Power Output section is turned on.

13. Low Power Output switch/reset: this switch/reset is used to turn the Low Power Output section on and off. This switch/reset is also used to turn on the voltmeter. This switch/reset will automatically reset if the current exceeds the rating of the Low Power Output.

14. Low Power Output indicator: this LED lights up when the Low Power Output section is turned on.

Table 28: Specifications of the Power Supply, Model 8821-2.

<table>
<tr><th colspan="2">Power Supply
8821-2</th><th>Models:
8821-20, -21, -22</th><th>Models:
8821-25, -26, -27</th><th>Models:
8821-2E, -2F</th><th>Models:
8821-2A</th></tr>
<tr><td rowspan="4">Module Requirements</td><td>AC power network voltage and frequency</td><td>120/208 V – 60 Hz</td><td>220/380 V – 50 Hz</td><td>220/380 V – 60 Hz</td><td>240/415 V – 50 Hz</td></tr>
<tr><td>AC power network installation</td><td colspan="4">3 phases, star (wye) configuration including neutral and ground wires, protected by a 20 A circuit breaker</td></tr>
<tr><td>AC power network connector</td><td>NEMA L21-20</td><td>NEMA L22-20</td><td>NEMA L22-20</td><td>AS/ NZS3123</td></tr>
<tr><td>Maximum current</td><td>15 A</td><td colspan="3">10 A</td></tr>
<tr><td rowspan="5">Outputs*</td><td>Fixed ac 3-phase</td><td>120/208 V – 15 A</td><td colspan="2">220/380 V – 10 A</td><td>240/415 V – 10 A</td></tr>
<tr><td>Variable ac 3-phase</td><td>0-120/208 – 5 A</td><td colspan="2">0-220/380 – 3 A</td><td>0-240/415 – 3 A</td></tr>
<tr><td>Variable dc</td><td>0-120 V – 8 A</td><td colspan="2">0-220 V – 5 A</td><td>0-240 V – 5 A</td></tr>
<tr><td>Fixed dc</td><td>120 – 2 A</td><td colspan="2">220 V – 1 A</td><td>240 V – 1 A</td></tr>
<tr><td>Low power ac</td><td colspan="4">24 V – 3 A</td></tr>
<tr><td colspan="2" rowspan="5">Included accessories</td><td colspan="4">3 m (10 ft) ac power cord (1)</td></tr>
<tr><td colspan="4">Padlock (1)</td></tr>
<tr><td rowspan="3">NEMA L21-20 wall connector with wall plate (1)</td><td colspan="2">NEMA L22-20 wall connector with wall plate (1)</td><td rowspan="3">AS/ NZS3123 wall connector with wall plate (1)</td></tr>
<tr><td colspan="2">Square metal outlet box (1)</td></tr>
<tr><td colspan="2">Outlet box cover (1)</td></tr>
</table>

Power Supply 8821-2	Models: 8821-20, -21, -22	Models: 8821-25, -26, -27	Models: 8821-2E, -2F	Models: 8821-2A
		Outlet box connector (1)		
AC/DC voltmeter	0-250 V	0-500 V		
Dimensions (H × W × D)	308 × 287 × 495 mm (12.1 × 11.3 × 19.5 in)			
Weight	18.4 kg (40.5 lb)			

* The Power Supply cannot supply all the amounts of current indicated by the current ratings on the front panel of the module at the same time. The current indicated for the fixed ac three-phase output section can only be obtained if no current is drawn from any other section, because this section is protected by the main circuit breaker common to every section. If currents flow in other sections, the available current for the fixed ac three-phase output section decreases. The variable ac output section and the variable dc output section are protected by a common set of circuit breakers placed after the fixed ac three-phase output section, which means that the current capacity has to be shared between the two sections. For instance, if current of the variable dc output section is at 70% of its nominal value, current drawn from the variable ac output section should not exceed 30% of its nominal value. The fixed dc output section is also protected by circuit breakers placed after the fixed ac three-phase output section.

Power Supply, Model 8823

The Power Supply, Model 8823, consists of a fixed-voltage three-phase ac power source and a fixed-voltage dc power source enclosed in a half-size EMS module. It can be used to power most of the EMS modules of the Electric Power Technology Training Equipment. Color-coded safety banana jacks provide access to both power sources. Independent circuit breakers, with a reset button on the front panel of the module, protect the inputs and outputs from overcurrent conditions. Indicator lamps allow monitoring the presence of input voltage on each phase.

The Power Supply requires connection to a three-phase, wye-connected, five-wire service installation. This is achieved by using the five-wire flexible ac power cord provided with the Power Supply. This ac power cord is terminated with a five-prong twist-lock plug and line cap. For safety purpose, a mechanical interlock on the line cap prevents students from removing the Power Supply from the EMS workstation while it is energized by keeping it locked to the workstation.

The Power Supply also includes a three-phase ac wall outlet appropriate for connection of the ac power cord. In addition to the three-phase and neutral legs, a separate copper ground allows proper grounding of the Power Supply chassis and workstation compartments, thus providing added safety for students using the Power Supply.

Control, connectors, and indicators

1. AC power switch: this switch is used to turn the fixed-voltage three-phase ac power source on (switch set to I) and off (switch set O).

2. Three-phase ac power source output (terminals 1, 2, 3, and N on the front panel): when the AC power switch is set to on (I), these banana jacks provide a fixed, three-phase ac voltage.

3. Power On indicator lamps: when the fixed-voltage three-phase ac power source is turned on, each of these three lamps (one lamp per phase) turns on to indicate the presence of normal input voltage on each phase leg. When the voltage on a phase leg of the ac power network goes off, the corresponding lamp turns off to reflect this condition.

4. Earth (ground) terminal: this banana jack is connected to the earthing (grounding) prong of the ac power cord of the Power Supply.

5. DC power switch: this switch is used to turn the fixed-voltage dc power source on (switch set to I) and off (switch set to O).

Figure 59: Front panel of the Power Supply, Model 8823.

6. DC power source output (terminals + and - on the front panel): when the DC power switch is set to on (I), these terminals provide a fixed dc voltage.

NOTICE
The dc power source is not insulated. Therefore, do not connect the output terminals (terminals + and -) of this source to the ground to avoid damage to the equipment.

7. Power On indicator lamp: when the dc power source is turned on, this lamp turns on to indicate the presence of normal input voltage to this source. If the input voltage goes off, the lamp also turns off to reflect this condition.

8. Reset pushbutton: this pushbutton is used to reset the circuit breakers protecting the inputs and outputs of the Power Supply from overcurrent conditions.

⚠ CAUTION

The Power Supply, Model 8823, is a heavy module. Therefore, install it in a half-height compartment of the workstation, or in the bottom section of a full-height compartment of the workstation, as directed in Learning Unit 8 of the present document.

Table 29: Specifications of the Power Supply, Model 8823.

Power Supply 8823		**Models: 8823-00, -01, -02**	**Models: 8823-05, -06, -07**	**Models: 8823-0E, -0F**	**Models: 8823-0A**
Module Requirements	Maximum current	10 A	5 A		
	AC power network voltage and frequency	120/208 V – 60 Hz	220/380 V – 50 Hz	220/380 V – 60 Hz	240/415 V – 50 Hz
	AC power network installation	3 phases, star (wye) configuration including neutral and ground wires, protected by a 20 A circuit breaker			
	AC power network connector	NEMA L21-20	NEMA L22-20	NEMA L22-20	AS/ NZS3123
Outputs	Fixed ac 3-phase	120/208 V – 5 A	220/380 V – 2.5 A		240/415 V – 2.5 A
	Fixed dc	120 V – 4 A	220 V – 2 A		240 V – 2 A
AC power cord		3 meters (10 feet)			
Dimensions (H × W × D)		212 × 287 × 496 mm (8.3 × 11.3 × 19.5 in)			
Weight		5.7 kg (12.5 lb)			

IGBT Chopper/Inverter, Model 8837-B

Control, connectors, and indicators

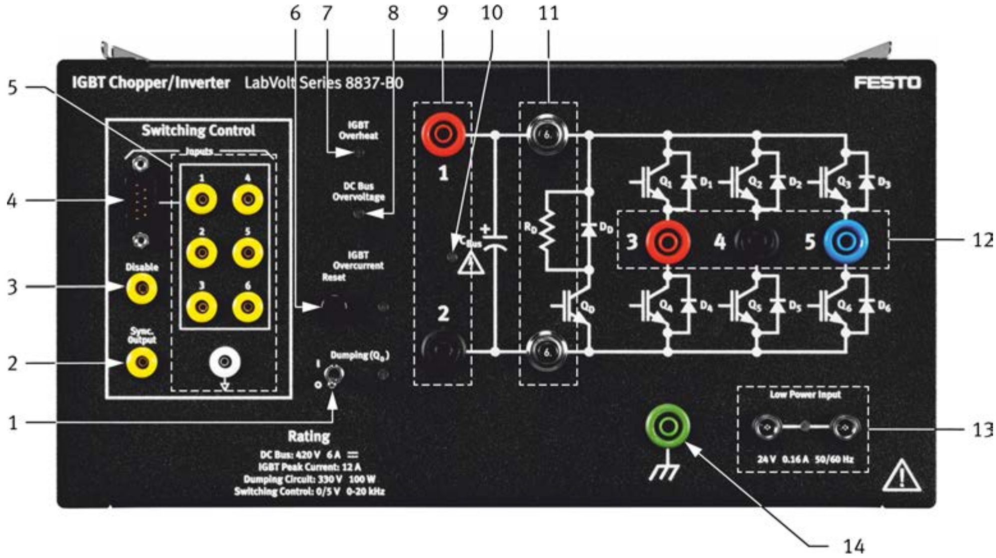


Figure 60: Front panel of the IGBT Chopper/Inverter.

> ***NOTICE***
>
> The IGBT Chopper/Inverter needs a good air flow to prevent its overheating protection from triggering. For this reason, it is preferable to install the module in the center row of the workstation and to make sure that no heat-generating module (e.g., the Resistive Load) is underneath it.

1. Dumping (Q_D) switch and LED. The dumping circuit is used to prevent overvoltage on the dc bus of the module. This circuit is enabled by setting the Dumping switch to the I position. The LED turns on when energy is dumped into the dumping resistor (R_D).

2. Synchronization output (terminal Sync. Output). This terminal provides access to the synchronization signal from the Data Acquisition and Control Interface or the Chopper/Inverter Control Unit. This signal can be used to synchronize an oscilloscope when observing the switching control signals.

3. Disable terminal. This terminal allows to switch off the IGBTs when 5 V is applied to it. When this happens, the gate voltage of the IGBTs is forced to 0 V so that the IGBTs remain open. The IGBTs can only be controlled when no voltage is applied to the Disable terminal.

4. Switching Control input 9-pin connector. This connector allows a controller to control Q_1 to Q_6 of the IGBT Chopper/Inverter (typically, using the Digital Outputs of the Data Acquisition and Control Interface or the Control Outputs of the Chopper/Inverter Control Unit).

5. Switching Control inputs (input terminals 1 to 6 and common). These terminals are directly connected to the Switching Control input 9-pin connector. Typically, they allow the observation of the switching control signals applied to the gates of Q_1 to Q_6. Furthermore, when no controller is connected to the 9-pin connector, these Switching Control inputs can be used to control Q_1 to Q_6. Finally, the Switching Control inputs allow the introduction of faults in the module (e.g., connecting terminal 2 to the common terminal deactivates Q_2).

6. IGBT Overcurrent reset button and LED. The LED turns on when an instantaneous overcurrent condition is detected by the circuit. When such a condition is detected on either IGBT, the 6 IGBTs (Q_1 to Q_6) are switched off and the button must be depressed to reset this protection circuit.

7. IGBT Overheat LED. This LED turns on when an overheat condition is detected. When this happens, the 6 IGBTs (Q_1 to Q_6) are switched off to prevent damage. This protection circuit resets automatically once the temperature of the IGBTs is back to a safe level.

8. DC Bus Overvoltage LED. This LED turns on when an overvoltage condition is detected on the dc bus. When this happens, the 6 IGBTs (Q_1 to Q_6) are switched off to prevent damage. This protection circuit resets automatically once the voltage on the dc bus is back to a safe level.

9. DC bus terminals (1 and 2). These te^{2}rminals are used to apply dc voltage to the IGBT converter.

10. Hazardous voltage LED. When this LED turns on, the capacitors of the dc bus are charged at a voltage that may be hazardous.

⚠ CAUTION

As long as this LED is on, the module must remain properly grounded to prevent any shock hazard.

11. Circuit Breaker reset buttons. These circuit breakers protect the positive and negative branches of the dc bus against overload conditions.

12. Chopper/inverter branch terminals (3, 4, and 5). These terminals provide access to the middle of the three branches of the chopper/inverter.

NOTICE

If you are connecting the branch terminals to the grid, make sure that the dc bus has first been precharged at an appropriate voltage, which corresponds to the line voltage of your local ac power network times $\sqrt{2}$ (e.g., 294 V for a 120/208 V ac power network).

13. Low Power Input terminals. A 24 V ac power supply is required to power the module through either of these terminals. Since both terminals are connected, when one of the terminals is powered, the other terminal can be used to power another module.

NOTICE

Make sure to connect one of the Low Power Input terminals to a 24 V ac power supply **before** using the IGBT Chopper/Inverter in any way. Doing otherwise could damage the module.

14. Chassis terminal. This terminal is used to prevent harmful electromagnetic emissions from interfering with other components. For this purpose, the shield of a special connection cable must be connected to this terminal.

Table 30: Specifications of the IGBT Chopper/Inverter, Model 8837-B.

<table>
<tr><th colspan="2">IGBT Chopper/Inverter
8837-B</th><th>Models:
8837-B0, -B1, -B2</th><th>Models:
8837-B5, -B6, -B7</th><th>Models:
8837-BA</th></tr>
<tr><td rowspan="3">DC bus</td><td>Maximum voltage</td><td>420 V</td><td>770 V</td><td>840 V</td></tr>
<tr><td>Maximum current</td><td colspan="3">6 A</td></tr>
<tr><td>Filtering capacitor</td><td>1360 µF</td><td>680 µF</td><td>680 µF</td></tr>
<tr><td rowspan="2">Protections</td><td>DC bus overvoltage</td><td>440 V</td><td>810 V</td><td>880 V</td></tr>
<tr><td>DC bus circuit breaker</td><td colspan="3">6 A</td></tr>
</table>

IGBT Chopper/Inverter 8837-B		Models: 8837-B0, -B1, -B2	Models: 8837-B5, -B6, -B7	Models: 8837-BA
	IGBT electronic overcurrent	12 A	12 A	12 A
	IGBT overheat	About 60°C (140°F)		
Dumping circuit	Voltage threshold	330 V	660 V	
	Resistor	100 Ω, 100 W	250 Ω, 100 W	
Switching control signals	Level	0/5 V		
	High-level current	≈600 µA		
	Frequency range	0-20 kHz		
	Minimum dead time	1.2 µs		
Power requirements		24 V, 0.16 A, 50/60 Hz		
Accessories		• 24 V power cable (1) • 2 mm banana plug test leads (2) • DB9 connector control cable (1)		
Dimensions (H × W × D)		154 × 287 × 410 mm (6.1 × 11.3 × 16.1 in)		
Weight		6.8 kg (15 lb)		

Power Thyristors, Model 8841-2

Control, connectors, and indicators

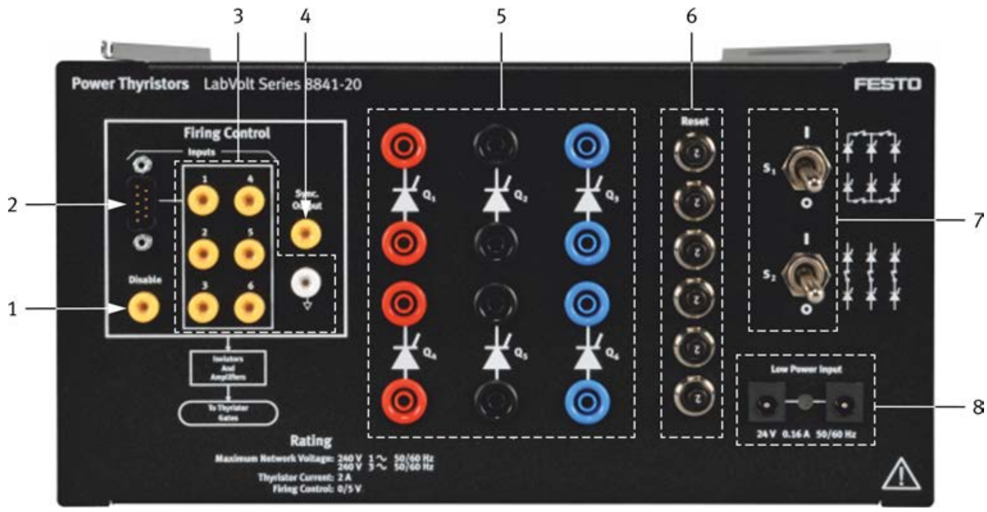


Figure 61: Front panel of the Power Thyristors.

1. Disable terminal. This terminal allows to switch off the thyristors when 5 V is applied to it. When this happens, the thyristors are forced to remain open. The thyristors can only be controlled when no voltage is applied to the Disable terminal.

2. Firing Control input 9-pin connector. This connector allows a controller to control Q_1 to Q_6 of the Power Thyristors (typically, using the Digital Outputs of the Data Acquisition and Control Interface).

3. Firing Control inputs (input terminals 1 to 6 and common). These terminals are directly connected to the Firing Control input 9-pin connector. Typically, they allow the observation of the firing control signals applied to the gates of Q_1 to Q_6. Furthermore, when no controller is connected to the 9-pin connector, these Firing Control inputs can be used to control Q_1 to Q_6. Finally, the Firing Control inputs allow the introduction of faults in the module (e.g., connecting terminal 2 to the common terminal deactivates Q_2).

4. Synchronization output (terminal Sync. Output). This terminal provides access to the synchronization signal from the Data Acquisition and Control Interface. This signal can be used to synchronize an oscilloscope when observing the switching control signals.

5. Thyristor anode and cathode terminals. These terminals allow access to the power thyristors for connection to a circuit.

6. Circuit Breaker reset buttons. These circuit breakers protect the thyristors against overload conditions.

7. Thyristor interconnection switches (S_1 and S_2). These switches allow the interconnection of the power thyristors in two different arrangements. Setting either of these switches to the I position connects the power thyristors as indicated beside the switch on the front panel.

8. Low Power Input terminals. A 24 V ac power supply is required to power the module through either of these terminals. Since both terminals are connected, when one of the terminals is powered, the other terminal can be used to power another module.

Table 31: Specifications of the Power Thyristors, Model 8841-2.

Power Thyristors 8841-2		**Models: 8841-20, -21, -22**	**Models: 8841-25, -26, -27**	**Models: 8841-2A**
Ratings	Peak inverse voltage	600 V	1200 V	
	Maximum network voltage	240 V, three-phase, 50/60Hz	415 V, three-phase, 50/60Hz	
	Maximum current	2 A	1 A	
	Gate control signals	0-5 V Pulses (TTL compatible)		
	Auxiliary power input	24 V ac – 0.16 A – 50/60 Hz		
Dimensions (H x W x D)		154 x 287 x 440 mm (6.1 x 11.3 x 17.3 in)		
Weight		5.6 kg (12.35 lb)		

Three-Phase Filter, Model 8326

Control, connectors, and indicators

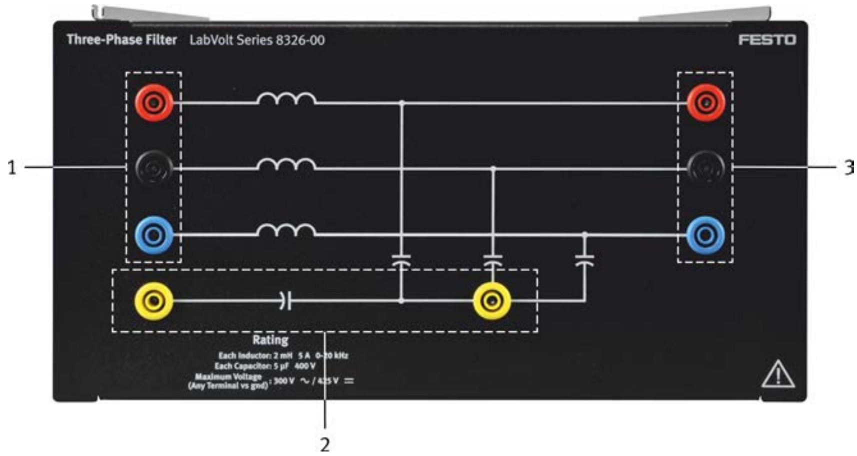


Figure 62: Front panel of the Three-Phase Filter.

1. Three-phase filter, inductor side
2. Filtering capacitor common terminals
3. Three-phase filter, capacitor side

Table 32: Main specifications of the Three-Phase Filter.

Parameter	Subparameter	Main specifications
Maximum network voltage		415 V, three-phase, 50/60 Hz
Inductors	Number	3
	Ratings	2 mH – 5 A – 0-20 kHz
Capacitors	Number	4
	Type	Metallized polypropylene
	Ratings	5 µF – 400 V
Dimensions (H x W x D)		154 x 287 x 440 mm (6.1 x 11.3 x 17.3 in)
Weight		TBE kg (TBE lb)

Four-Quadrant Dynamometer/Power Supply, Models 8960-2 and -3

The Four-Quadrant Dynamometer/Power Supply is enclosed in a full-size EMS module. It mainly consists of a permanent magnet dc motor, a four quadrant power supply, and an onboard microcontroller. The front panel of the Four-Quadrant Dynamometer/Power Supply can be opened to install a Timing Belt, Model 8942, on the pulley of its permanent magnet dc motor. This permits mechanical coupling of this motor to another rotating machine of the Electric Power Technology Training Equipment. The Four-Quadrant Dynamometer/Power Supply can operate in either Dynamometer mode or Power Supply mode. A toggle switch on the module front panel allows selection of the operating mode (Dynamometer or Power Supply). In each operating mode, a wide variety of user-selectable functions is available.

- When the Four-Quadrant Dynamometer/Power Supply is in the Dynamometer mode, user-selectable functions allow operating the machine as various electric devices, such as a prime mover, a brake, a mechanical load, and other optional devices like a small wind-turbine emulator or a hydraulic-turbine emulator.

- When the Four-Quadrant Dynamometer/Power Supply is in the Power Supply mode, user-selectable functions allow operating the machine as various types of electrical sources, such as a variable dc voltage source, a variable dc current source, or a variable-voltage and variable-frequency ac power source. Two safety banana jacks on the module front panel provide access to the power supply terminals. Optional devices like a battery charger/discharger, a solar panel emulator, and an SDK (software development kit) are also available.

In both operating modes (Dynamometer or Power Supply), the values of key parameters related to the selected function are shown on a LCD display mounted on the module front panel. Thus, when the Four-Quadrant Dynamometer/Power Supply is in the Dynamometer mode, the values of speed, torque, mechanical power, and energy are shown on the LCD display. Similarly, when the Four-Quadrant Dynamometer/Power Supply in the Power Supply mode, the values of voltage, current, electric power, and energy are shown on the LCD display.

The functions performed by the Four-Quadrant Dynamometer/Power Supply can be controlled in Manual- or Computer-Based mode. The Manual control mode allows control of basic functions, while the Computer-based control mode allows control of all basic functions plus additional advanced functions.

- In the Manual control mode, the Four-Quadrant Dynamometer/Power Supply operates as a stand-alone unit. The function performed by this module is selected, set, and monitored using the controls and LCD display mounted on the module front panel.

- In the Computer-Based control mode, the function performed by the Four-Quadrant Dynamometer/Power Supply is selected, set, and monitored using the Data Acquisition and Control for Electromechanical Systems (LVDAC-EMS) software. In the Computer-Based mode, communication between the Four-Quadrant Dynamometer/Power Supply and the host computer running the LVDAC-EMS software is achieved through a USB connection.

Refer to the sub-section "Learning Unit 6" to learn how to install the LVDAC-EMS software for use with the Four-Quadrant Dynamometer/Power Supply.

Control, connectors, and indicators

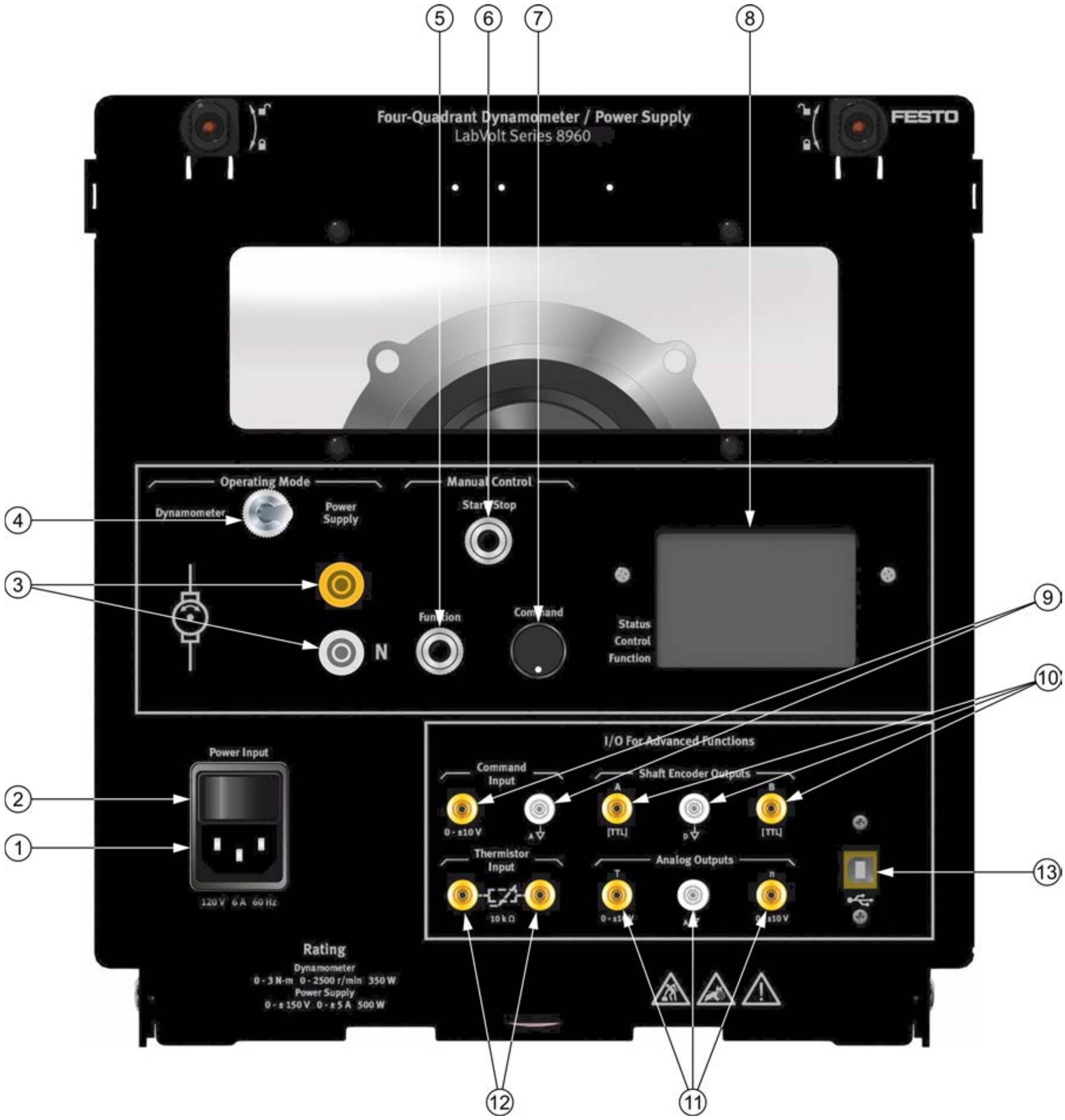


Figure 63: Front panel of the Four-Quadrant Dynamometer/Power Supply.

1. Power Input: this ac power input is used to power the Four-Quadrant Dynamometer/Power Supply from a standard ac power outlet via an ac line cord.

2. Main power switch: this on/off (I/O) switch is used to turn the Four-Quadrant Dynamometer/Power Supply on and off.

3. Power Supply terminals: these two safety banana jacks provide access to the four-quadrant power supply terminals.

4. Operating Mode switch: this toggle switch allows selection of the operating mode (Dynamometer or Power Supply).

5. Function push-button: when the Four-Quadrant Dynamometer/Power Supply is in the Manual mode, this push-button allows selection of the function to be performed by the Four-Quadrant Dynamometer/Power Supply.

6. Start/Stop push-button: when the Four-Quadrant Dynamometer/Power Supply is in the Manual mode, this push-button is used to start and stop the function performed by the Four-Quadrant Dynamometer/Power Supply.

7. Command knob: when the Four-Quadrant Dynamometer/Power Supply is in the Manual mode, this knob is used to set the value of the parameter related to the function performed by the Four-Quadrant Dynamometer/Power Supply (see the following table).

Table 33: Parameters manually adjustable using the Command knob in the Dynamometer mode.

Selected function	Parameter adjustable using the Command knob
Two-quadrant constant-torque brake (2QCT)	Torque
Clockwise constant-speed (CW CS) prime mover/brake	Speed
Counterclockwise constant-speed (CCW CS) prime mover/brake	Speed
Positive constant-torque (CT) prime mover/brake	Torque
Negative constant-torque (CT) prime mover/brake	Torque
Clockwise (CW) prime mover/brake	Speed
Counterclockwise (CCW) prime mover/brake	Speed

Table 34: Parameters manually adjustable using the Command knob in the Power Supply mode.

Selected function	Parameter adjustable using the Command knob
Voltage source (+)	Voltage
Voltage source (-)	Voltage
Current source (+)	Current
Current source (-)	Current
50 Hz power source	Voltage
60 Hz power source	Voltage
200 V DC bus	None
Lead-acid battery float charger	Voltage
Lithium-ion battery charger	None

8. Liquid crystal display (LCD): this display shows the current status, control mode, and selected function of the Four-Quadrant Dynamometer/Power Supply, as well as values of important parameters related to the selected function. The LCD display also shows important information related to the Four-Quadrant Dynamometer/Power Supply, such as faults and error messages.

9. Command Input: this input is used to inject an analog signal into the Four-Quadrant Dynamometer/Power Supply. The voltage of the analog signal determines the command (for example, the current command of a dc current source) of the function performed by the Four-Quadrant Dynamometer/Power Supply, when the Command Input is selected as the source of command (option available in the Computer-Based control mode).

10. Shaft Encoder Outputs: these outputs provide the digital (TTL-level) signals (A-B output type) produced by the shaft encoder mounted on the permanent magnet dc motor of the Four-Quadrant Dynamometer/Power Supply.

11. Analog Outputs T and n: these outputs provide analog signals proportional to the torque and speed measured at the shaft of the permanent magnet dc motor of the Four-Quadrant Dynamometer/Power Supply. These outputs are intended to be connected to the corresponding inputs of the Data Acquisition and Control Interface, Model 9063, of the Electric Power Technology Training Equipment for torque and speed measurements.

12. Thermistor Input: this input allows connection of an external temperature sensor (thermistor) for temperature measurement using the Four-Quadrant Dynamometer/Power Supply. Temperature measurement is required for some advanced functions such as the Ni-MH battery chargers.

13. USB port connector: this connector allows connection of the Four-Quadrant Dynamometer/Power Supply to a USB port of the computer running the LVDAC-EMS software (for this purpose, a USB cable is included with the module).

Setup procedure for Manual control operation

Perform the procedure below to install, connect, and power up the Four Quadrant Dynamometer/Power Supply for Manual control operation.

1. Install the Four-Quadrant Dynamometer/Power Supply in the workstation.

2. Mechanically couple the Four-Quadrant Dynamometer/Power Supply to another rotating machine, if necessary.

⚠ WARNING

Before coupling rotating machines, make absolutely sure that power is turned off to prevent any machine from starting inadvertently.

3. Make sure that the main power switch on the Four-Quadrant Dynamometer/Power Supply is set to the O (off) position, and then connect its Power Input to an ac power outlet.

4. Turn the Four-Quadrant Dynamometer/Power Supply on.

5. Set the Operating Mode switch to either Dynamometer or Power Supply, depending on the required mode of operation. You are now ready to perform manipulations with the Four-Quadrant Dynamometer/Power Supply operating in the Manual control mode.

Setup procedure for Computer-Based control operation

Before performing the procedure below, make sure that the latest version of LVDAC-EMS, available on the Festo Didactic website, is installed on the host computer. When LVDAC-EMS is open, you can select Check for Update from the Help menu of this software to verify if you have the latest software version.

Perform the procedure below to install, connect, and power up the Four-Quadrant Dynamometer/Power Supply for operation in the Computer-Based control mode.

1. Install the Four-Quadrant Dynamometer/Power Supply in the workstation.

2. Mechanically couple the Four-Quadrant Dynamometer/Power Supply to another rotating machine, if necessary.

⚠ WARNING

Before coupling rotating machines, make absolutely sure that power is turned off to prevent any machine from starting inadvertently.

3. Make sure the main power switch on the Four-Quadrant Dynamometer/ Power Supply is set to the O (off) position, and then connect its Power Input to an ac power outlet.

4. Connect the USB port of the Four-Quadrant Dynamometer/Power Supply to a USB port of the host computer.

5. Turn the Four-Quadrant Dynamometer/Power Supply on.

   If the Four-Quadrant Dynamometer/Power Supply is connected to the host computer for the first time, wait for a message indicating that the new USB peripheral has been recognized to appear on the screen. This message should also appear when the Four-Quadrant Dynamometer/Power Supply is connected to the host computer for the first time in DFU mode. The LVDAC-EMS software will indicate when to switch the module to DFU mode.

   If a message appears indicating that the installation of the peripheral has failed, simply restart the Four-Quadrant Dynamometer/Power Supply by setting its main power switch to the O (off) position, then setting it back to the I (on) position.

6. Turn the host computer on, and then start the LVDAC-EMS software.

   In the LVDAC-EMS Start-Up window, make sure the Four-Quadrant Dynamometer/ Power Supply is detected. Make sure that all functions in the Four-Quadrant Dynamometer/Power Supply are available. Select the network voltage and frequency that correspond to the voltage and frequency of your local ac power network, and then click the OK button to close the LVDAC-EMS Start-Up window.

   At this point, a message may appear on the screen indicating that the firmware in the Four-Quadrant Dynamometer/Power Supply needs to be updated before proceeding. Make sure to follow the instructions indicated on the screen before proceeding with the rest of the manipulations below.

7. On the Four-Quadrant Dynamometer/Power Supply, set the Operating Mode switch to either Dynamometer or Power Supply, depending on the required mode of operation.

   You are now ready to perform manipulations with the Four-Quadrant Dynamometer/Power Supply operating in the Computer-Based control mode.

Function set activation procedure

When you buy a new function set for the Four-Quadrant Dynamometer/Power Supply, you must activate this new function set by performing the procedure below.

1. Perform the previously described "Setup procedure for Computer-Based control operation".

2. In the Tools menu of the LVDAC-EMS window, select Activate Function Set. This brings up the Select File dialog box.

3. In the Select File dialog box, find the DFU file (file_name.dfu) you received with the new function set(s) to be activated. This DFU file is required for activating the new function set(s). Select this file, which will bring up the Prepare to Upgrade dialog box.

   Each DFU file required for activating new function set(s) has a specific serial number. This means that a DFU file can only activate new function set(s) on the Four-Quadrant Dynamometer/Power Supply whose serial number corresponds to the serial number in the name of the DFU file. The serial number is indicated at the back of the Four-Quadrant Dynamometer/Power Supply.

4. Follow the on-screen instructions to activate the new function set(s) in the Four-Quadrant Dynamometer/Power Supply.

   You will have to restart both the Four-Quadrant Dynamometer/Power Supply and the LVDAC-EMS software for the new function set(s) to become available.

Module configuration (language settings)

The Four-Quadrant Dynamometer/Power Supply can display text, parameters, and messages on its LCD display in any of the following languages: English, French, German, or Spanish.

Perform the following procedure to configure the language setting of the Four-Quadrant Dynamometer/Power Supply. The four-Quadrant Dynamometer/Power Supply must be in the Computer-Based control mode to perform this procedure.

1. Perform the previous procedure Set up procedure for Computer-Based control operation.

2. In LVDAC-EMS, open the Four-Quadrant Dynamometer/Power Supply window.

3. In the Tools menu of the Four-Quadrant Dynamometer/Power Supply window, select Module Configuration. This brings up the Module Configuration dialog box.

4. In the Module Configuration dialog box, scroll through the Language drop-down list to select the language setting you want to apply to the Four-Quadrant Dynamometer/Power Supply. Click on the OK button to apply the language selected.

Module configuration (unit settings)

The parameter values shown on the LCD display of the Four-Quadrant Dynamometer/Power Supply can be expressed in any of the four following systems of units:

- SI (International System of Units)
- SI (International System of Units) with mechanical power expressed in horsepower (hp)
- Imperial system
- Imperial system with mechanical power expressed in watts (W)

Perform the following procedure to select a system of units on the Four-Quadrant Dynamometer/Power Supply. This module must be in the Computer-Based control mode to perform the procedure.

1. Perform the previously described "Setup procedure for Computer-Based control operation".

2. In LVDAC-EMS, open the Four-Quadrant Dynamometer/Power Supply window.

3. In the Tools menu of the Four-Quadrant Dynamometer/Power Supply window, select Module Configuration. This brings up the Module Configuration dialog box.

4. In the Module Configuration dialog box, scroll through the Units drop-down list to select the system of units you want to use on the Four-Quadrant Dynamometer/Power Supply. Click on the OK button to apply the system of units selected.

   Complete instructions on how to use the functions of the Four-Quadrant Dynamometer/Power Supply are available in the related courseware.

Dynamometer auto-calibration procedure (Model 8960-3 only)

The dynamometer auto-calibration function allows the calibration of the torque measured by the Four-Quadrant Dynamometer/Power Supply. Only qualified personnel may perform this function. For this reason, it is protected using a password: 1959. Do not perform a dynamometer auto-calibration unless authorized by your instructor.

The procedure required to perform a dynamometer auto-calibration is as follows:

1. Perform the previously described "Setup procedure for Computer-Based control operation".

2. On the Four-Quadrant Dynamometer/Power Supply window, set the Operating Mode switch to Dynamometer.

3. In LVDAC-EMS, open the Four-Quadrant Dynamometer/Power Supply window.

4. In the Tools menu of the Four-Quadrant Dynamometer/Power Supply window, select Dynamometer Auto-Calibration. This brings up the Dynamometer Auto-Calibration dialog box.

5. Follow the instructions as they appear on screen.

6. Wait for the Four-Quadrant Dynamometer/Power Supply to stop rotating. The torque measured by the module is now calibrated.

Friction compensation calibration procedure

When the Four-Quadrant Dynamometer/Power Supply is in the Dynamometer mode of operation, it compensates for the torque produced by its own friction, the belt friction, and the friction of the belt tensioner. For example, if the Four-Quadrant Dynamometer/Power Supply operates as a constant-torque prime mover, the torque applied by the prime mover is slightly higher than its torque command. The magnitude of the friction compensation primarily depends on the rotation speed.

The following manipulations describe the procedure for calibrating the friction compensation of the Four-Quadrant Dynamometer/Power Supply. This module must be in the Computer-Based control mode to perform the procedure.

If you intend to overwrite the default friction compensation table (see the note at the end of the present procedure), it is recommended to perform the previously described "Dynamometer auto-calibration procedure" before performing the friction compensation calibration procedure.

The Four-Quadrant Dynamometer/Power Supply should be mechanically coupled to the Zero Friction Machine, Model 8969, or the machine specified in the course you are doing.

1. Perform the previously described "Setup procedure for Computer-Based control operation".

2. On the Four-Quadrant Dynamometer/Power Supply window, set the Operating Mode switch to Dynamometer.

3. In LVDAC-EMS, open the Four-Quadrant Dynamometer/Power Supply window.

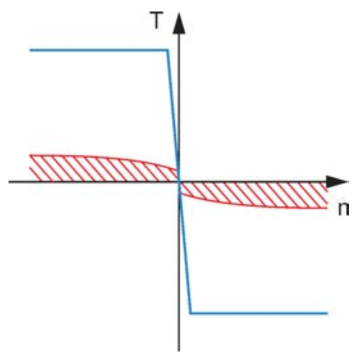
4. In the Tools menu of the Four-Quadrant Dynamometer/Power Supply window, select Friction Compensation Calibration. This brings up the Friction Compensation Calibration dialog box.

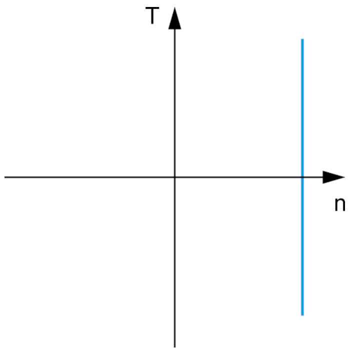
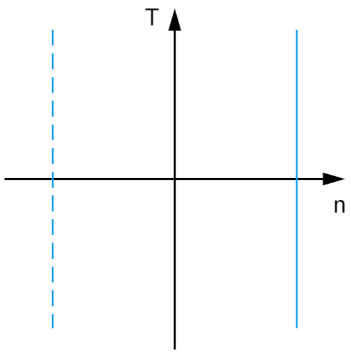
5. In the Friction Compensation Calibration dialog box, click OK to start the calibration process.

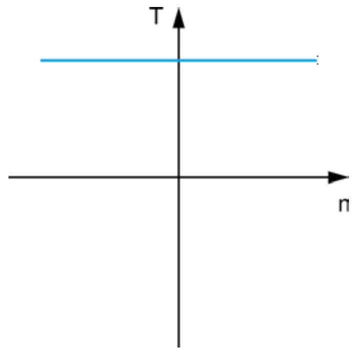
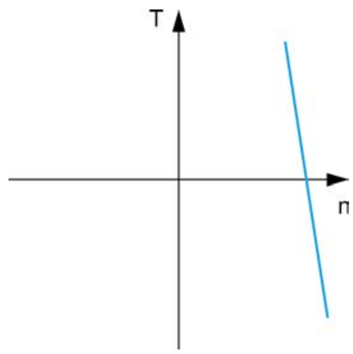
6. Wait for the Four-Quadrant Dynamometer/Power Supply to stop rotating. If you are using Model 8960-2, restart the module by turning it off then on again. The friction compensation curve of the module is now calibrated.

If you perform this procedure using the Zero Friction Machine, you can use the newly measured friction compensation table as the default friction compensation table. To do so, select the function Overwrite Default Friction Compensation Table. Only qualified personnel may perform this function. For this reason, it is protected using a password: 1959. Do not overwrite the default friction compensation table unless authorized by your instructor.

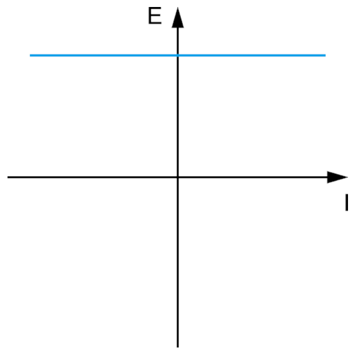
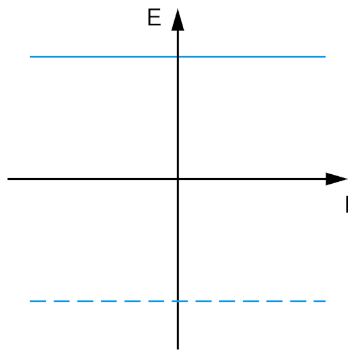
Function description (Dynamometer operating mode)

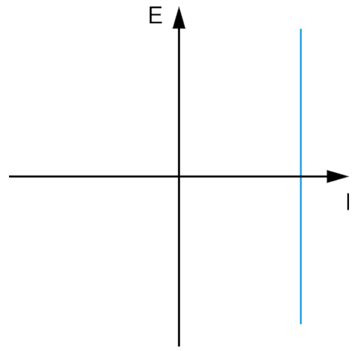
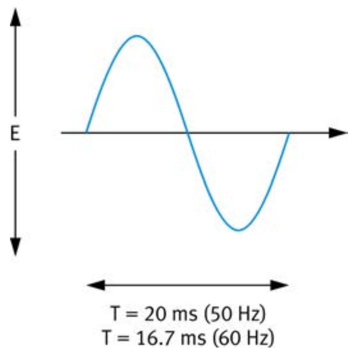
Two-Quadrant, Constant-Torque Brake This function makes the PM-DC motor operate as a generator to apply a constant opposing torque to the machine coupled to the Four-Quadrant Dynamometer/Power Supply (the machine under test). Closed-loop control keeps this opposing torque constant as speed changes. A user-entered torque command sets the magnitude of the torque opposing the machine under test. The function displays the shaft speed, torque, mechanical power, and energy of the machine under test, and can also display its temperature when the machine's temperature sensor (if present) is connected to the Thermistor Input of the Four-Quadrant Dynamometer/Power Supply.	

Clockwise Constant-Speed Prime Mover/Brake This function uses the PM-DC motor to drive the machine coupled to the Four-Quadrant Dynamometer/Power Supply (the machine under test) clockwise at a fixed speed. Closed-loop control keeps the speed constant under varying load conditions. A user-entered speed command sets the rotation speed of the machine under test. The function displays the shaft speed, torque, mechanical power, and energy of the machine under test, and can also display its temperature when the machine's temperature sensor (if present) is connected to the Thermistor Input of the Four-Quadrant Dynamometer/Power Supply. **Counterclockwise Constant-Speed Prime Mover/ Brake** Same as the Clockwise Constant-Speed Prime Mover/Brake except for the direction of rotation.	
Four-Quadrant, Constant-Speed Prime Mover/ Brake This function uses the PM-DC motor to drive the machine coupled to the Four-Quadrant Dynamometer/Power Supply (the machine under test) at a fixed speed. Closed-loop control keeps the speed constant under varying load conditions. A user-entered speed command sets the speed value (direction and magnitude) of the machine under test. The function displays the shaft speed, torque, mechanical power, and energy of the machine under test, and can also display its temperature when the machine's temperature sensor (if present) is connected to the Thermistor Input of the Four-Quadrant Dynamometer/Power Supply.	

Positive Constant-Torque Prime Mover/Brake This function uses the PM-DC motor to apply a positive (clockwise) constant torque to the machine coupled to the Four-Quadrant Dynamometer/Power Supply (the machine under test). Closed-loop control keeps the torque constant as speed changes, whether the machine under test operates as a motor or a brake (generator). A user-entered torque command sets the torque applied to the machine under test. The function displays the shaft speed, torque, mechanical power, and energy of the machine under test, and can also display its temperature when the machine's temperature sensor (if present) is connected to the Thermistor Input of the Four-Quadrant Dynamometer/Power Supply. **Negative Constant-Torque Prime Mover/Brake** Same as the Positive Constant-Torque Prime Mover/Brake except that the torque is negative (i.e., applied in counterclockwise direction).	
Clockwise Prime Mover/Brake This function uses the permanent magnet dc motor to drive the machine coupled to the Four-Quadrant Dynamometer/Power Supply (the machine under test) clockwise at an adjustable speed, set with the Command knob on the module front panel. The function displays the shaft speed, torque, and mechanical power of the machine under test. It is well suited for studying ac generator synchronization. **Counterclockwise Prime Mover/Brake** Same as the Clockwise Prime Mover/Brake function except for the direction of rotation.	

Function description (Power Supply operating mode)

Positive Voltage Source This function uses the four-quadrant power supply as a DC voltage source with positive polarity that can source or sink current (two-quadrant operation). A user-entered voltage command sets the source voltage. The function displays the output voltage, current, electrical power, and energy, and can also display circuit temperature (e.g., battery temperature) when a temperature sensor is connected to the Thermistor Input of the Four-Quadrant Dynamometer/Power Supply. **Negative Voltage Source** Same as the Positive Voltage Source function except for the polarity.	
DC Voltage Source This function uses the four-quadrant power supply as a dc voltage source with positive or negative polarity. It can source or sink current for either polarity (four-quadrant operation). A user-entered voltage command sets the source voltage polarity and value. The function displays output voltage, current, electrical power, and energy, and can also display circuit temperature (e.g., battery temperature) when a temperature sensor is connected to the Thermistor Input of the Four-Quadrant Dynamometer/Power Supply.	

Positive Current Source This function uses the four-quadrant power supply as a dc current source that sources current at its output. The voltage across the source can be positive or negative (two-quadrant operation). A user-entered current command sets the source current. The function displays output voltage, current, electrical power, and energy, and can also display circuit temperature (e.g., battery temperature) when a temperature sensor is connected to the Thermistor Input of the Four-Quadrant Dynamometer/Power Supply. **Negative Current Source** Same as the Positive Current Source function except for the direction of current flow.	
50 Hz Power Source This function uses the four-quadrant power supply as a non-regulated variable-voltage 50 Hz source. A user-entered voltage command sets the rms "no-load" source voltage. The source can source or sink current for positive or negative instantaneous voltage (four-quadrant operation). The function displays circuit temperature (e.g., transformer core temperature) when a temperature sensor is connected to the Thermistor Input of the Four-Quadrant Dynamometer/Power Supply. **60 Hz Power Source** Same as the 50 Hz Power Source function except for the frequency.	

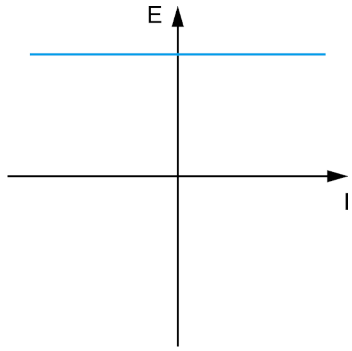
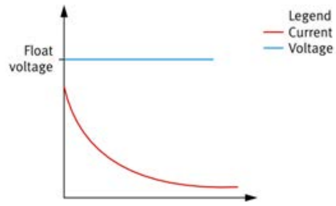
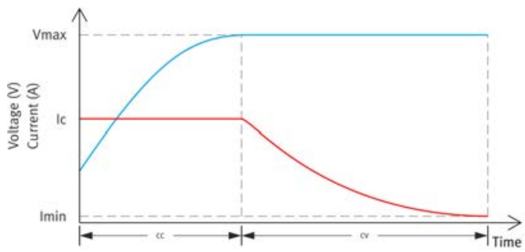
200 V DC Bus This function uses the four-quadrant power supply to provide a fixed 200 V dc bus that can source or sink current (two-quadrant operation). It displays the output voltage, current, and power.	
Lead-Acid Battery Float Charger This function uses the four-quadrant power supply as a lead-acid battery float charger that applies a constant voltage to the battery. The user sets the battery float charging voltage. The function displays the charger output voltage, current, and electrical power. It is well suited for charging several parallel-connected lead-acid batteries overnight so they are ready for next-day lab sessions.	
Lithium-Ion Battery Charger This function uses the four-quadrant power supply as a lithium-ion battery charger, mainly for the Lithium-Ion Battery, Model 8802-A. Charging starts with constant current and then switches to constant voltage (CC/CV method). When charging is complete, the module disconnects automatically. If the module fails to disconnect, the function automatically stops the charge to prevent overcharging.	

Table 35: Specifications of the Four-Quadrant Dynamometer/Power Supply, Models 8960-2 and -3.

Four-Quadrant Dynamometer/Power Supply 8960-2 and 8960-3		Models: 8960-20, -21, -22 8960-30, -31, -32	Models: 8960-25, -26, -27 8960-35, -36, -37	Models: 8960-2A 8960-3A
Dynamometer	Magnetic torque	0 to 3 N·m (0 to 27 lbf·in)		

Four-Quadrant Dynamometer/Power Supply 8960-2 and 8960-3		Models: 8960-20, -21, -22 8960-30, -31, -32	Models: 8960-25, -26, -27 8960-35, -36, -37	Models: 8960-2A 8960-3A
	Direction of rotation	CW/CCW		
	Speed	0 to 2500 r/min		
	Nominal power	350 W		
Power supply mode	DC voltage	0 to ± 150 V		
	AC voltage (rms)	0 to 105 V ("no-load")		
	DC current	0 to ± 5 A		
	AC current (rms)	0 to 3.5 A		
	Maximum output power	500 W		
	AC frequency	10 to 120 Hz		
Liquid Crystal Display (LCD)		76 mm (3 in), monochrome, background illuminated, 240 x 160		
Control inputs	Command input	0 to ± 10 V		
	Thermistor input	10 kΩ, type 1		
Control outputs	Shaft encoder	Quadrature encoder (A-B) – 360 pulses/revolution – TTL compatible		
	Torque output sensitivity	0.3 N·m/V (2.655 lbf·in/V)		
	Speed output sensitivity	250 r/min/V		
Communication port		USB 2.0		
Power requirements (must include live neutral, and ground conductors)		120 V – 6 A – 60 Hz	220 V – 3 A – 50/60 Hz	240 V – 3 A – 50 Hz

Data Acquisition and Control Interface, Model 9063

Introduction to data acquisition and control systems

A data acquisition and control system is a computer-based system that can gather and analyze information from several external sources, and perform different calculations on the acquired data. A single computer can thus replace a variety of meters and instruments, display several waveforms simultaneously, analyze waveforms and data to extract important information, record data, and plot graphs.

Generally, data acquisition and control systems gather information represented by electrical signals. Some information, such as the input or output voltage of an electrical device is already in electrical form. Other information can be converted to electrical form by a transducer. For example, the speed of a motor can be converted into an electrical signal by a speed sensor.

The electrical signal from a speed sensor is called an analog signal because it is analogous to the speed; if the speed increases, the voltage increases, and vice versa. The voltage of an analog signal can vary continuously and take on any value within a certain range.

Computers are digital devices that use discrete numbers to store and process data. A data acquisition and control system therefore requires a circuit that converts continuous analog signals to discrete digital values. The type of circuit used for this purpose is called an analog-to-digital converter, or A/D converter. The sampling and conversion process is illustrated in the following figure.

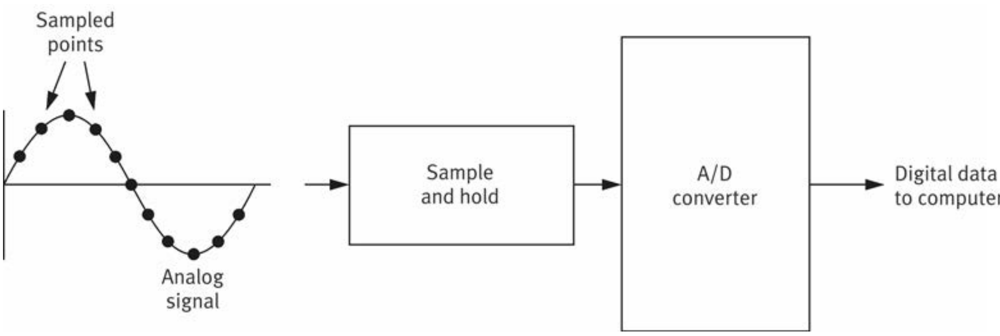


Figure 64: Sampling and analog-to-digital (A/D) conversion of an analog signal.

The analog signal is first sampled at regular intervals by a sample-and-hold circuit, which holds each sampled level until the analog-to-digital (A/D) converter has converted it to a digital number. The rate at which the signal is sampled is called the sampling rate. The higher the sampling rate, the more faithfully the digital numbers produced will follow the original signal. High sampling rates, however, generate lots of numbers and these may fill the computer memory very quickly, so the sampling rate should not be too high.

When a data acquisition and control system must acquire data from several different sources, a single A/D converter can be used along with a multiplexer, as shown in the following figure. The multiplexer is a switch that selects each analog input, or channel, in turn. Each time the multiplexer selects a new analog input, the signal present at the input is sampled and converted to a digital number.

The number of channels sampled by the multiplexer affects the sampling rate per channel. If the A/D converter can convert 100 000 samples per second, a single channel could be sampled at that rate. However, if two channels were used, each channel would be sampled at 50 000 samples per second, and four channels would be sampled at 25 000 samples per second.

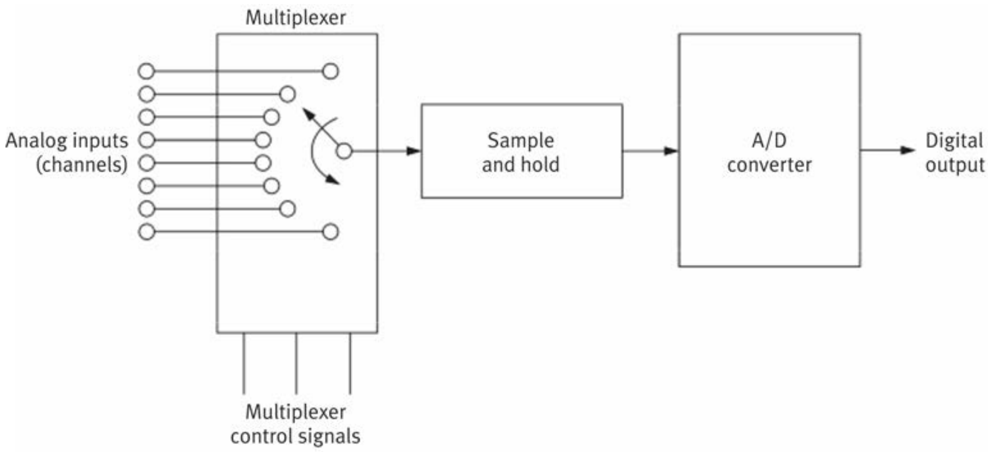


Figure 65: Input configuration of a typical multi-channel A/D converter.

Depending on the application, a data acquisition and control system may sample signals continuously, or it may take a certain number of samples and then stop sampling until commanded to take another batch of samples. In either case, the digital numbers representing the samples can be processed and analyzed by the computer to extract useful information. Usually, this information can be presented on the computer screen in different ways, which are selected by the user of the system.

Description of the Data Acquisition and Control Interface (DACI), Model 9063

The Data Acquisition and Control Interface (DACI), Model 9063, is a versatile USB peripheral enclosed in a half-size EMS module. The DACI is intended to be used with the LVDAC-EMS software. Together, the DACI and LVDAC-EMS provide a complete set of modern computer-based instruments to measure, observe, analyze, and control electrical and mechanical parameters. The provided instruments include voltmeters, ammeters, power meters, frequency meters, efficiency meters, impedance meters, power factor meters, energy meters, torque and speed meters, an oscilloscope, a phasor analyzer, a harmonic analyzer, and a spectrum analyzer. The DACI and LVDAC-EMS also allow manual and timed data recording. The recorded data can be saved to files in any specified location, graphically represented with the provided graph plotting tool, and exported into a spreadsheet application.

The DACI and LVDAC-EMS can also be used with the Four-Quadrant Dynamometer/ Power Supply, Model 8960, to implement a variety of control functions for advanced training in various fields of electricity and new energy, including electric power technology, ac/dc rotating machines, renewable energy, transmission lines, and power electronics.

The DACI has two main functions: it performs data acquisition to feed raw signal data to the LVDAC-EMS computer based instruments, and it performs various types of control functions, mainly to control the electronic switches of the IGBT Chopper/ Inverter module, Model 8837, or those of the Power Thyristors module, Model 8841. The DACI can perform these two functions at the same time. However, when a complex control function is implemented, certain voltage inputs (E) or current inputs (I) of the DACI are not available for the computer-based instrumentation.

To activate data acquisition for a specific computer-based instrumentation function, a license for this function must be ordered for each DACI on which the function is to be used. Similarly, to activate a specific control function, a license for this function must be ordered for each DACI on which the function is to be used.

The firmware (program used to run the microcontroller) of the DACI can be upgraded anytime by using the device firmware upgrade (DFU) included with the latest version of LVDAC-EMS available on the Festo Didactic website.

Refer to the sub-section "Learning Unit 6" to learn how to install the LVDAC-EMS software for use with the DACI.

Please refer to the User Guide Computer-Based Instruments for EMS provided with the DACI to become familiar with the following computer-based instruments: Metering window, Oscilloscope, Phasor Analyzer, and Harmonic Analyzer.

Control, connectors, and indicators

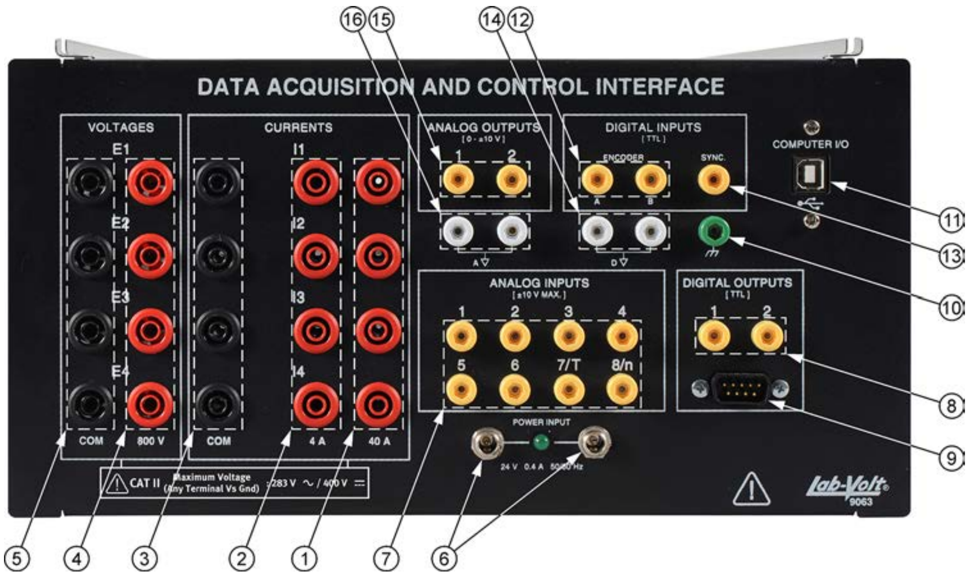


Figure 66: Front panel of the Data Acquisition and Control Interface, Model 9063.

NOTICE

The DACI is part of measurement category II (CAT II), which means that the module is intended to perform measurements on circuits connected to a low-voltage installation such as plug-connected equipment powered from the building wiring.

1. Current inputs, high-range (40 A terminals I1, I2, I3, and I4): these four safety banana jacks are used to measure current levels up to 40 A. These inputs are electrically insulated from the circuitry in the DACI module through optoisolators. When you are using the high-range Current inputs, you must set the Range of these inputs to High (40 A) in the Data Acquisition and Control Settings panel of the LVDAC-EMS software.

2. Current inputs, low-range (4 A terminals I1, I2, I3, and I4): these four safety banana jacks are used to measure current levels up to 4 A. These inputs are electrically insulated from the circuitry in the DACI module through optoisolators. When you are using the low-range Current inputs, you must set the Range of these inputs to Low (4 A) in the Data Acquisition and Control Settings panel of the LVDAC-EMS software.

   Each of the low- and high-range Current inputs is protected against overcurrents by fuses. Whenever a fuse blows out, make sure to replace it with an identical fuse.

3. Current COM terminals: these four safety banana jacks are used as neutral (common) connection points for the Current inputs.

4. Voltage inputs (terminals E1, E2, E3, and E4): these four safety banana jacks are used to measure voltage levels up to ± 800 V. These inputs are electrically insulated from the circuitry in the DACI module through optoisolators. All voltage inputs are fully protected against over-voltage conditions. The voltage range of each input can be set to high (800 V) or low (80 V) with the LVDAC-EMS software.

5. Voltage COM terminals: these four safety banana jacks are used as neutral (common) connection points for the voltage inputs.

6. Power Input jacks: one (either) of these two jacks is used to power the DACI with an ac voltage of 24 V provided by the 24 V ac source of the Power Supply, Model 8821-2, or by the Power Supply, Model 30004-2. The other Power Input jack can be connected to one of the 24 V ac Power Input jacks on another module of the Electric Power Technology Training Equipment in order to power this module.

7. Analog Inputs: these eight miniature jacks are low-voltage (± 10 V) inputs used to measure circuit parameters. The gain, range, and unit of each input are programmable with the LVDAC-EMS software. Analog Inputs "7/T" and "8/n" can also be used to measure torque and speed, respectively, with the meters dedicated for this purpose (that is, meters AI-7/T and AI-8/n) in the Metering window of the LVDAC-EMS software. In that case, the gain is pre-adjusted for outputs T and n of the Four-Quadrant Dynamometer/Power Supply, Model 8960.

8. Digital Output jacks: these two miniature jacks provide TTL level signals used for different purposes.

9. Digital Output connector: this 9-pin, D-type connector provides TTL level signals used to control different electronic power switches like those in the IGBT Chopper/Inverter module, Model 8837, or the Power Thyristors module, Model 8841.

10. Earth (ground) terminal: this banana jack can be used to remove noise when performing measurements under certain conditions.

11. Computer I/O port: this connector is used to connect the DACI to a USB port of the computer running the LVDAC-EMS software (a USB cable is included with the DACI).

    Make sure to use the cable provided with the DACI to connect the DACI to a USB port of the computer. Do not use a different cable, as this could result in communication problems.

12. Digital Inputs Encoder terminals (A and B): these two miniature jacks are used as an incremental encoder input (A-B) for measuring the rotation speed of a machine of the Electric Power Technology Training Equipment.

13. Digital Inputs Sync. terminal: this input is used to facilitate synchronization of the Oscilloscope in LVDAC-EMS when the Oscilloscope is used to observe PWM signals. To do so, the Digital Inputs Sync. must be connected to the Sync. Output of the IGBT Chopper/Inverter module, Model 8837, and the Trigger Source of the Oscilloscope must be set to External (Ext.).

14. Digital Inputs (D) common terminals: these two miniature jacks provide common (neutral) connection points for the Digital Inputs.

15. Analog Outputs terminals (1 and 2): these two miniature jacks provide a voltage whose level can be set between +10 V and -10 V using the LVDAC-EMS software. Each voltage can be used to control a device in an electrical power circuit.

16. Analog Outputs (A) common terminals: these two miniature jacks provide common (neutral) connection points for the Analog Outputs.

DACI operation

The DACI consists of an insulation unit and a data acquisition and control unit.

- The insulation unit isolates and converts the high-level voltages and currents applied to the DACI voltage and current inputs into low-voltage signals. Each low-voltage signal is proportional to, and electrically isolated from, the corresponding high-level input signal. These low-voltage signals, along with other low-voltage input signals, are internally routed to the data acquisition and control unit.

- The data acquisition and control unit contains the circuitry for analog signal sampling and A/D conversion. It converts the low-voltage signals into digital data, which the LVDAC-EMS software reads and analyzes. Results are displayed on the computer according to the selected representation, such as meter panels showing measured values or an oscilloscope showing waveforms.

A USB cable connects the DACI module to the personal computer. The following figure gives an overview of the data acquisition and control process.

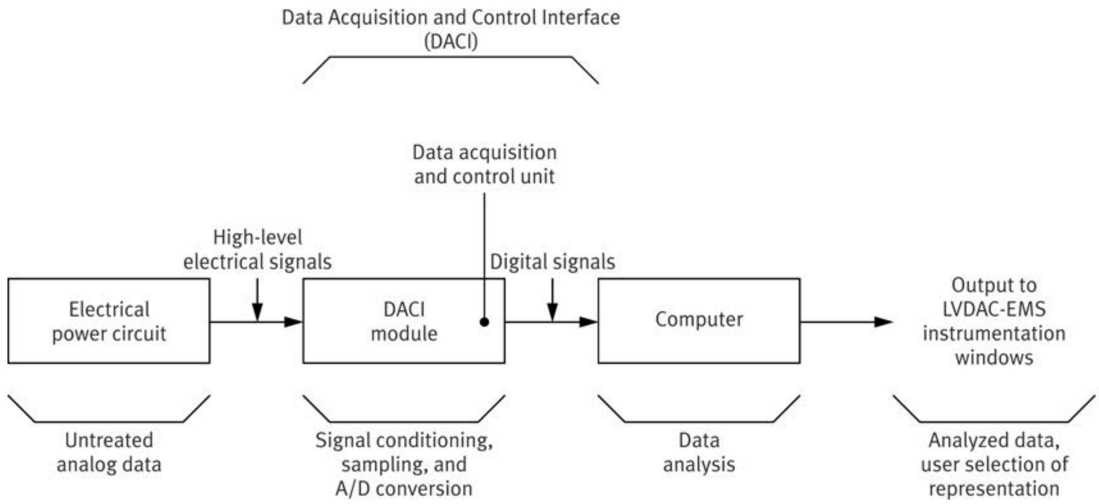


Figure 67: Data acquisition and control process.

DACI model variants

The DACI is available in several model variants, each with a unique set of factory-activated functions. Additional functions can be activated at any time by purchasing a license for the desired function and performing the DACI upgrade procedure. The available functions are:

- Computer-Based Instrumentation Function
- Chopper/Inverter Control Function Set
- Thyristor Control Function Set
- Home Energy Production Function set
- Three-Phase PWM Rectifier/Inverter Control Function Set
- BLDC Motor/PMSM Control Function Set
- High-Voltage DC (HVDC) Transmission System Control Function Set
- Static Var Compensator (SVC) Control Function Set
- 9063 SDK (Software Development Kit)
- Synchronous Generator Control Function Set
- Static Synchronous Compensator (STATCOM) Control Function Set
- Synchroscope Function

Setup procedure for DACI operation with the LVDAC-EMS software

Before performing the steps below, make sure the latest version of LVDAC-EMS, available on the Festo Didactic website, is installed on the host computer. When LVDAC-EMS is open, you can check this by selecting Check for Update in the Help menu.

1. Install the DACI in the workstation.

2. Connect the DACI Power Input to a 24 V ac power supply (Power Supply, Model 8821-2 or 30004-2), then turn the power supply on.

3. Connect the DACI USB port to a USB port on the host computer.

4. Turn the host computer on and start the LVDAC-EMS software.

   In the LVDAC-EMS Start-Up window, verify that the DACI is detected and that the Computer-Based Instrumentation function is available. Select the network voltage and frequency corresponding to your local ac power network, then click OK to close the window.

   A message may appear indicating that the DACI firmware must be updated before proceeding. If so, follow the on-screen instructions to update the firmware.

Complete instructions for using DACI control applications are provided in the related courseware.

Function set activation procedure

When you buy a new function set for the DACI, you must activate this new function set by performing the procedure below.

First, perform the previous procedure "Setup procedure for DACI operation with the LVDAC-EMS software."

1. In the Tools menu of the LVDAC-EMS window, select Activate Function Set. This will bring up the Select File dialog box.

2. In the Select File dialog box, find the DFU file (file_name.dfu) you received with the new function set(s) to be activated. This DFU file is required for activating the new function set(s). Select this file, which will bring up the Prepare to Upgrade dialog box.

   Each DFU file required for activating new function set(s) has a specific serial number. This means that a DFU file can only activate new function set(s) on the DACI whose serial number corresponds to the serial number in the name of the DFU file. The serial number is indicated on the right side of the DACI.

3. Follow the on-screen instructions to activate the new function set(s) in the DACI.

You will have to restart the LVDAC-EMS software for the new function set(s) to become available.

Table 36: Specifications of the Data Acquisition and Control Interface, Model 9063-0.

Insulated voltage inputs (4)	
Range (low/high scales)	-80 V to +80 V/-800 to +800 V (user selectable through software)
Impedance (low/high scales)	326.6 kΩ/3.25 MΩ
Bandwidth	DC to 65 kHz (-3dB)
Accuracy	1% (DC to 10 kHz)
Insulation	800 V
Note	Designed for use within MEASUREMENT CATEGORY I. Network voltage ≤ 240 V
Insulated current inputs (4)	
Range (low/high scales)	-4 A to +4 A/ -40 to +40 A (25 A RMS)
Impedance (low/high scales)	50 mΩ/5 mΩ
Bandwidth	DC to 65 kHz (-3 dB)
Accuracy	1% (dc to 10 kHz)
Insulation	800 V
Note	Designed for use within MEASUREMENT CATEGORY I. Network voltage ≤ 240 V
Analog inputs (8)	
Voltage range	-10 V to +10 V
Impedance	> 10 MΩ

Bandwidth	DC to 125 kHz
Measured parameters	User-selectable through software
Parameter-to-voltage ratio	User-determined through software
A/D converter for insulated and analog inputs (16)	
Type	Successive approximation
Resolution	12 bits
Integral non-linearity	≤ ± 1.5 LSB
Differential non-linearity	≤ ± 1 LSB
Maximum sampling rate	600 ksamples/s (one channel)
FIFO buffer size	16 ksamples
Analog outputs (2)	
Voltage range	-10 to +10 V
Operational load impedance	> 600 Ω
D/A converter for analog outputs (2)	
Type	Resistor string
Resolution	12 bits
Integral non-linearity	≤ ± 8 LSB
Differential non-linearity	-0.5 to +0.7 LSB
Digital inputs (3)	
Types	Encoder (2), synchronization (1)
Signal level	0-5 V (TTL compatible)
Maximum input frequency	50 kHz
Impedance	5 kΩ

Digital outputs (9)	
Type	Control (six on a DB9 connector and two on 2-mm banana jacks) Synchronization (one on a DB9 connector)
Signal level	0-5 V (TTL compatible)
Maximum output frequency	20 kHz (software limited)
Impedance	200 Ω
Computer I/O interface	USB 2.0 full speed via type-B receptacle
Power requirement	24 V - 0.4 A 50/60 Hz
Accessories	
	2 m USB interconnection cable (1)
	24 V power cable (1)
	2 mm banana plug test leads (3)
	DB9-connector control cable (1)
Personal computer requirements	
	A personal computer with a USB port, running under one of the following Microsoft® operating systems, Windows®7, Windows®8, or Windows®10, is required.

Computer-based-instrumentation of the DACI

Table 37: Specifications of the computer-based instrumentation functions of the Data Acquisition and Control Interface, Model 9069-1.

Metering	
Number of meters	18
Sampling window	250 ms or user adjusted through software (11.4 to 819 ms)
Sampling frequency (each meter)	7.68 kHz (at 120/208 V 60 Hz), 6.4 kHz (at 220/380 V, 50 Hz or 240/415 V, 50 Hz), or user adjustable with software (1.25 kHz to 22.4 kHz)
Display type	Digital or analog, user selectable with software
Oscilloscope	
Number of channels	8
Vertical sensitivity	2 V/div. to 200 V/div.
Time base	0.1 ms/div. to 10 s/div.
Sampling window	20 x selected time base
Sampling frequency	512 samples per measured parameter per horizontal sweep, up to a maximum of 512 kHz
Phasor analyzer	
Sensitivity	2 V/div. to 200 V/div., 0.05 A/div. to 5 A/div.
Sampling window	Software adjusted (2 ms to 614 ms)
Sampling frequency (each phasor)	Software adjusted (10 kHz to 512 kHz)
Harmonic analyzer	
Fundamental-frequency range	1 Hz to 1400 Hz

Number of harmonic components	5 to 40, user-selectable with software
Vertical scale (relative scale)	0.1%/div. to 10%/div.
Vertical scale (absolute scale)	0.5 V/div. to 50 V/div., 0.01 A/div. to 1 A/div.
Sampling window	Software adjusted (10 ms to 15 s)
Sampling frequency	Software adjusted (120 Hz to 180 kHz)
Synchroscope (Provided with Model 9069-C)	
Values monitored (on one phase)	Network voltage, generator voltage, voltage difference, network frequency, generator frequency

Equipment Maintenance

The equipment is designed for user safety, reliability, and effective learning. To maintain safety and performance, it must be kept in good condition.

The learning system requires regular maintenance. Students perform some tasks as part of their training, while qualified personnel handle periodic maintenance.

Because trainees may not yet detect issues, a technician or instructor should inspect the system before and after each use.

Replace defective or missing components immediately. Contact our service department for replacement parts and instructions.

⚠ DANGER

Always turn off, disconnect, and secure the power supply before performing maintenance.

⚠ CAUTION

- Instructors and laboratory personnel must communicate these directions and guidelines to students, as they are essential for maintaining equipment safety and functionality.
- Do not operate the equipment with missing or damaged parts.

General maintenance

The equipment requires no special maintenance, but a visual inspection must be performed before each laboratory exercise. If any component appears damaged or worn, replace it to ensure user safety and prevent further damage.

There are no user-serviceable parts inside the equipment, other than items such as fuses, button cells, and batteries. Opening or removing the housing to replace parts may expose you to dangerous voltages. Do not open the housing; have a qualified technician replace internal parts.

Maintenance and electrical continuity of EMS modules

If EMS modules have been unused for a long time, check their electrical continuity to ensure safe grounding.

The bottom edge of Electric Power Technology Training Equipment modules is bare metal to maintain a connection between the EMS module and the workstation protective conductor terminal. If a module is stored under certain environmental conditions, this connection may be compromised. Therefore, in addition to regular visual checks, any EMS module not used for a long time must be tested to confirm electrical continuity (resistance of about 0 Ω) with the workstation metallic structure, as explained in the next section.

Before using a module:

- Make sure the bottom edge and metallic rails are clean and free of substances that could block electrical contact.
- For half-size modules, clean soiled rails with isopropyl alcohol.
- If needed, gently sand small bumps on the Power Supply module bottom edge (do not sand the entire surface).

To test the electrical continuity of a module:

- Insert the EMS module into the workstation.

  Use an ohmmeter to confirm continuity between the module housing and the workstation metallic structure (target resistance ≈ 0 Ω).

Maintenance of EMS rotating machines

In addition to the general maintenance requirements stated above, the idler tensioning ball bearings (see the following figure) of rotating machines require periodic lubrication. If, after some time, these bearings become noisier, they need lubrication. Apply a small amount (a few drops on each bearing) of lubricating oil such as Multi-Purpose Oil from 3-IN-ONE®. This prevents premature bearing wear and module damage.

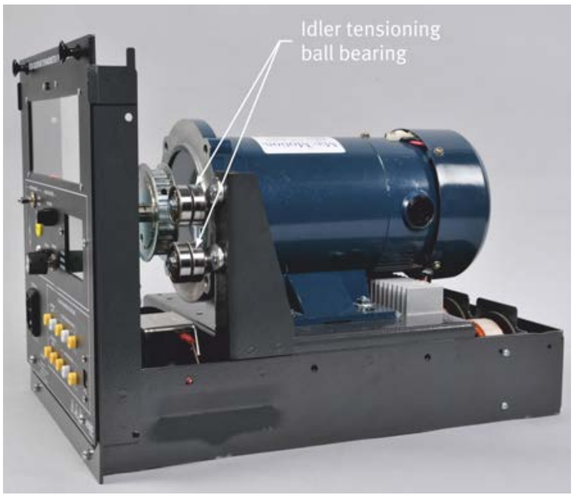


Figure 68: The idler tensioning ball bearings of EMS rotating machines require periodic lubrication.

Equipment disposal

Do not discard the equipment with normal waste: it contains electrical and electronic components. A specialist must dismantle the product. Each component must be recycled or disposed of according to your local legislation.

It is the owner's responsibility to make provisions for the equipment recycling and safe disposal.

Waste from Electrical and Electronic Equipment (WEEE) directive:

- In accordance with European regulations, used electrical and electronics devices cannot be disposed of in unsorted municipal waste. The symbol of the waste bin on wheels indicates the necessity for separate collection. For environmental protection, make sure the equipment is disposed of in the waste sorting processes designed for this purpose. DIRECTIVE 2012/19/EU of the EUROPEAN PARLIAMENT AND OF the COUNCIL of 4 July 2012 on waste electrical and electronic equipment (WEEE).

The presence of this symbol on the equipment indicates the necessity of separate collection.

Battery maintenance and disposal

Do not leave rechargeable batteries in the equipment discharged or unused for extended periods of time. Make sure to recharge these batteries every six months if they are unused.

Do not leave batteries in excessively heated spaces. Never use a battery that shows any sign of damage like a cracked or swollen case, corroded or damaged terminals.

NOTICE
Batteries and accumulators are not to be disposed of in the normal house waste bin. Every user is legally obliged, to hand over all batteries and accumulators, irrespective of whether or not they contain harmful substances to a communal collection point in the local town area or to a trade dealer so that they can be disposed of in an orderly environmentally friendly manner. Batteries and accumulators should only be handed over when they are completely discharged.

Cleaning

To clean the equipment front panel(s) and housing(s), use a soft cloth with a mild detergent-and-water solution. Do not apply the solution directly to the equipment; apply it to the cloth.

NOTICE
Unless specifically stated otherwise, do not use abrasive cleaners or solvents on any part of the equipment.

Appendix A

Connection of the Power Supply to the AC Power Network

This appendix lists the checks required to ensure that your building ac power network is properly wired and that the Power Supply of your Electric Power Technology Training Equipment provides adequate power to the equipment.

Checking the wiring of the ac power wall outlet in your classroom

Single-phase ac power wall outlet

Connect the Four-Quadrant Dynamometer/Power Supply, Model 8960, to the single-phase ac power wall outlet, then check the module LCD for any error message. If no error message appears, the connection to the ac power network complies with the module requirements.

Three-phase ac power wall outlet

Perform the following steps to confirm that the Power Supply is connected to a proper three-phase, five-wire ac power network.

A Resistive Load module (such as Model 8311 or 8509), an ac ammeter with a range of at least 2 A, and an ac voltmeter are required.

1. Make sure that the ac power network to which the Power Supply is connected complies with the requirements stated in Learning Unit 5.

   NOTICE

   Pay particular attention to the network configuration (wye or delta). The Power Supply is designed for a wye ac power network; connecting it to a delta network can cause severe damage to the Power Supply.

2. On the Power Supply, set the main power switch to the O (off) position.

3. Connect the Resistive Load module and an ac ammeter between terminals 1 and N of the Power Supply.

4. Set the main power switch of the Power Supply to the I (on) position and make sure that the three pilot lamps (L1, L2, and L3) light up.

5. Adjust the Resistive Load so that a current of 2 A flows between terminals 1 and N for a 120 V ac network, or 1 A for a 220 V or 240 V ac network.

6. Using an ac voltmeter, make sure that the voltages between terminals 2 and N and between terminals 3 and N both meet the requirements for your local ac power network stated in Learning Unit 5.

   If the measured voltages do not meet these requirements, the ac power wall outlet to which the Power Supply is connected is faulty. Have this outlet repaired by qualified authorized personnel before using it for any experiment.

WARNING

Only qualified authorized personnel may repair a wall outlet, as this operation presents a high risk of electric shock.

7. On the Power Supply, set the main power switch to the O (off) position.

8. Repeat Step 3 to Step 7, using the earth (ground) terminal as the reference instead of the neutral (N) terminal.

9. Disconnect the Resistive Load module, the ac ammeter, and the ac voltmeter from the Power Supply terminals.

   Perform the above verification for all three-phase ac power wall outlets in your classroom laboratory.

Checking the phase sequence of a three-phase ac power wall outlet

An oscilloscope with probes rated for the appropriate voltage is required for the following steps.

1. On the Power Supply, set the main power switch to the O (off) position.

2. Using probes with a suitable voltage range, connect oscilloscope channels 1 and 2 to terminals L1 and L2 of the Power Supply.

   Connect each probe ground clip to the earth (ground) terminal of the Power Supply.

3. Set the main power switch of the Power Supply to the I (on) position.

4. If the Power Supply has a voltage control knob, gradually increase its output voltage using this knob.

5. On the oscilloscope, observe the phase relationship between the sine-wave voltages at outputs L1 and L2. The voltage at L1 should lead the voltage at L2 by about 120°.

   If the voltage at L2 leads the voltage at L1, the phase sequence is incorrect. Correct this by reversing any two of the three lines supplying power to the wall outlet.

NOTICE
Only qualified personnel may reverse the lines supplying power to a wall outlet, as this operation presents a high risk of electric shock.

6. On the Power Supply, set the main power switch to the O (off) position.

7. Disconnect the probes from the Power Supply terminals.

   Perform this verification on all three-phase ac power wall outlets in your classroom laboratory.

Checking that several wall outlets of a classroom have the same phase sequence and are wired in exactly the same way

When more than one Electric Power Technology Training Equipment workstation is installed in a classroom, all wall outlets must have the same phase sequence and identical wiring. Perform the following steps to verify that the wall outlets are properly wired.

Refer to the following figure, which shows the required setup. An ac voltmeter is required.

1. Select one wall outlet as the reference. This outlet must already have been verified using the procedures in Checking the wiring of the ac power wall outlet in your classroom and Checking the phase sequence of a three-phase ac power wall outlet.

   From now on, this outlet is called the reference wall outlet ($WO_{Ref.}$).

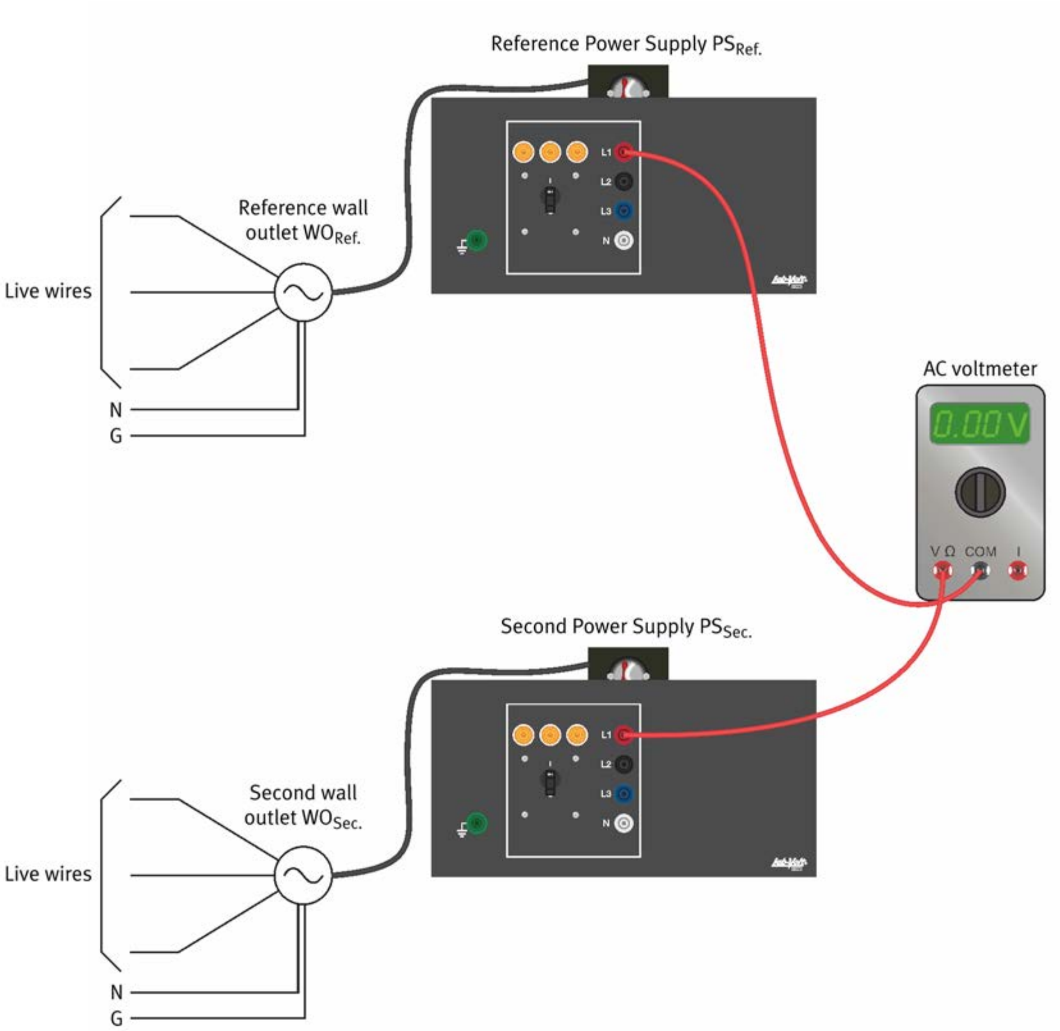


Figure 69: Setup for checking that several classroom wall outlets have the same phase sequence and identical wiring.

2. Connect a Power Supply to the reference wall outlet ($WO_{Ref.}$).

   From now on, this Power Supply is called the reference Power Supply ($PS_{Ref.}$).

3. Connect a second Power Supply to a second wall outlet. This outlet must already have been verified using the procedures in Checking the wiring of the ac power wall outlet in your classroom and Checking the phase sequence of a three-phase ac power wall outlet.

   From now on, this second Power Supply is called $PS_{Sec.}$, and the second wall outlet is called $WO_{Sec.}$.

4. Set the main power switch of each Power Supply to the I (on) position and make sure that the three pilot lamps (L1, L2, and L3) on each unit light up.

5. Using an ac voltmeter, measure the voltage between terminal L1 of the reference Power Supply $PS_{Ref.}$ and terminal L1 of the second Power Supply $PS_{Sec.}$. The measured voltage should be approximately 0 V. If not, go to Step 8.

6. Measure the voltage between terminal L2 of $PS_{Ref.}$ and terminal L2 of $PS_{Sec.}$. The measured voltage should be approximately 0 V. If not, go to Step 8.

7. Measure the voltage between terminal L3 of $PS_{Ref.}$ and terminal L3 of $PS_{Sec.}$. The measured voltage should be approximately 0 V. If not, go to Step 8.

8. If any measured voltage is not 0 V, $WO_{Sec.}$ is incorrectly wired. Correct this by interchanging at least two of the three lines supplying power to $WO_{Sec.}$. Then repeat Step 5 to Step 7 and make sure that all three measured voltages are approximately 0 V.

⚠ WARNING

Only qualified personnel may interchange the lines supplying power to a wall outlet, as this operation presents a high risk of electric shock.

9. Repeat Step 3 to Step 8 for each three-phase ac power wall outlet in the classroom laboratory.

CE Importer:
Festo Didactic SE
Rechbergstr. 3
73770 Denkendorf
Germany
Tel.: +49 711 3467-0
did@festo.com

US Importer:
Festo Didactic Inc.
607 Industrial Way West
Eatontown, NJ 07724
United States
Tel.: +1 732 938-2000
Toll Free: +1-800-522-8658
services.didactic@festo.com

CA Manufacturer:
Festo Didactic Ltée/Ltd
675, rue du Carbone
Québec (Québec) G2N 2K7
Canada
Tel.: +1 418 849-1000
Toll Free: +1-800-522-8658
services.didactic@festo.com

UK Importer:
Festo Ltd
Applied Automation Centre
Brackmills
Northampton, NN4 7PY
United Kingdom
T +44 800 626 422
info_gb@festo.com

www.festo.com

Electric Power Technology Training Equipment

User Guide

000058477800000000100