

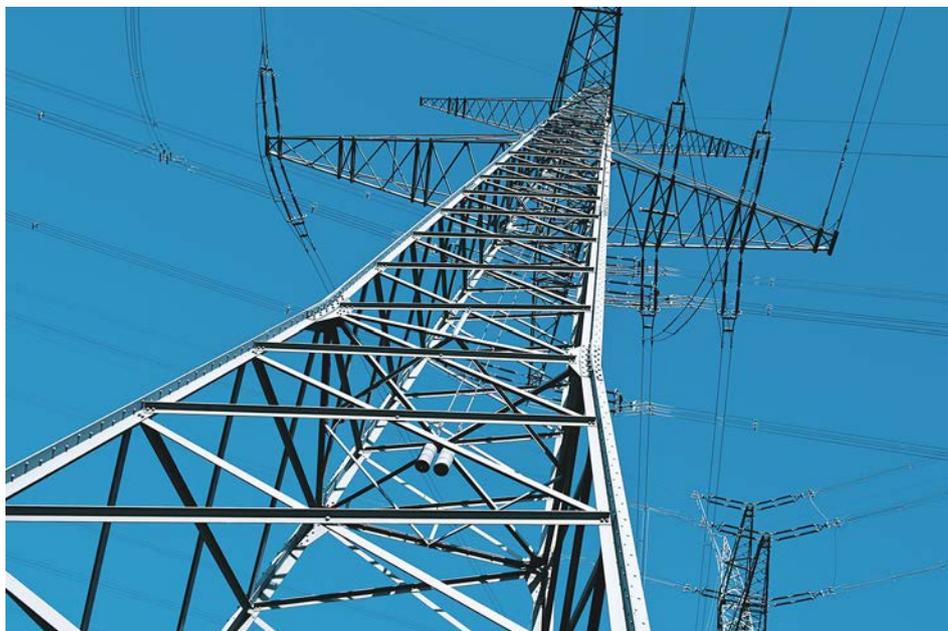
# Electric Power Technology Training Equipment – A4 Format

Original Operating Instructions

**FESTO**

Electric Power Technology

User Guide



**Electric Power Technology**

**Electric Power Technology  
Training Equipment – A4 Format**

**Original Operating Instructions**

**User Guide**

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# Document Preliminaries

## About this document

The operator should familiarize himself/herself with the contents of this document before installing and operating the equipment.

The Safety Symbols table at the beginning of this document lists safety symbols that may be present in this document or on the equipment.

This document is freely available for download from the Festo Didactic website.

Upon request, printed copies of this document are freely available. Contact your Festo Didactic sales representative.



**Important.** In this document, "the equipment" and/or "the training system" specifically refers to the Electric Power Technology Training Equipment.

## Electric Power Technology Training Program

Electrical energy has been part of daily life for more than a century, and the number of applications using electric power continues to increase.

This trend is reflected in the steady worldwide growth in electric power demand. In response, electrical energy production from renewable natural resources such as wind, sunlight, rain, tides, and geothermal heat has gained importance in recent years, as it helps meet rising demand and reduces greenhouse gas (GHG) emissions.

To address the growing training needs in the field of electrical energy, Festo Didactic developed a series of modular courses. These courses are shown below as a flow chart, where each box represents a course.

Teaching includes courses that provide in-depth coverage of fundamental topics such as dc power circuits, ac power circuits, and power transformers.

Additional courses focus on solar and wind power. Two courses are dedicated to photovoltaic systems and wind power systems, with emphasis on their practical aspects.

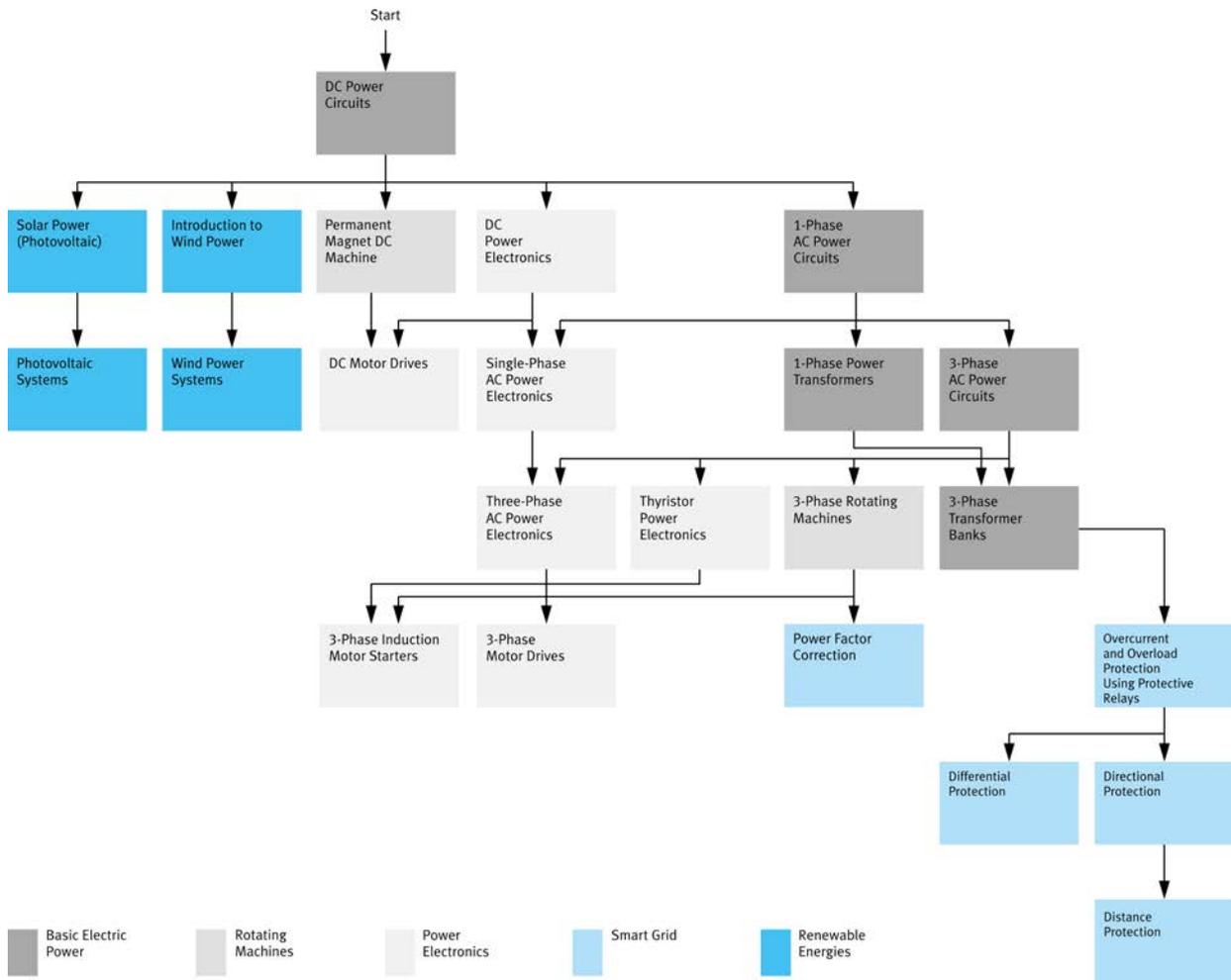


Figure 1: Festo Didactic courses in electrical energy.

## 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
	<b>DANGER</b> indicates a hazard with a high level of risk, which, if not avoided, will result in death or serious injury.
	<b>WARNING</b> indicates a hazard with a medium level of risk, which, if not avoided, could result in death or serious injury.
	<b>CAUTION</b> indicates a hazard with a low level of risk, which, if not avoided, could result in minor or moderate injury.

Symbol	Description
	<p><b>NOTICE</b> indicates a hazard with a potentially hazardous situation, which, if not avoided, may result in property damage.</p>
	<p>Caution, risk of danger. Consult the relevant user documentation.</p>
	<p>Caution, risk of electric shock.</p>
	<p>Caution, lifting hazard.</p>
	<p>Caution, hot surface.</p>
	<p>Caution, risk of fire.</p>
	<p>Caution, risk of explosion.</p>
	<p>Caution, belt drive entanglement hazard.</p>
	<p>Caution, chain drive entanglement hazard.</p>
	<p>Caution, gear entanglement hazard.</p>
	<p>Caution, hand crushing hazard.</p>
	<p>Static sensitive contents. Observe precautions for handling electrostatic discharge sensitive devices.</p>

Symbol	Description
	Notice, non-ionizing radiation.
	Consult the relevant user documentation.
	Radio Equipment Directive (RED) geographical restrictions – consult the relevant user documentation.
	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).

Symbol	Description
	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,  $\leq 30$  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 equipment components are designed with the latest technology and adhere to recognized safety standards. However, improper use can endanger the user and others, and may damage the equipment.

The Festo Didactic learning program is designed solely for training. To keep trainees safe, the training company or supervisors must ensure that all trainees use the equipment as instructed in the Festo Didactic courses and follow the safety guidelines in this document.

	 <b>WARNING</b>
	<p><b>Risk of danger from using the equipment in a way other than prescribed by Festo Didactic!</b></p> <ul style="list-style-type: none"> <li>• 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 injuries or property damage.</li> <li>• To minimize the risk of danger, always respect the specifications marked on the equipment as well as the specifications in the Festo Didactic data sheet of the equipment.</li> <li>• If the equipment includes a third-party component, consult the manufacturer's official documentation for that component—available from the manufacturer or online—to ensure safe use and compliance with all specifications and directives.</li> </ul>



## 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.



## Work and Safety Instructions

### Safety responsibilities

Responsibilities are divided by role as shown in the following table.

**Table 1: Responsibilities by role.**

Role	Responsibilities
Operating company	<ul style="list-style-type: none"> <li>● Allow only qualified personnel to work with the equipment.</li> <li>● Ensure personnel are trained in safety regulations and have read the safety information in this document.</li> <li>● Periodically evaluate personnel for safe working practices.</li> </ul>
Instructor	<ul style="list-style-type: none"> <li>● Supervise trainees at all times.</li> <li>● Permit only harmless mistakes and prevent actions that could cause injury or damage.</li> </ul>
Trainees	<ul style="list-style-type: none"> <li>● Read the safety chapter and warnings before use.</li> <li>● Follow all applicable work-safety and accident-prevention rules.</li> <li>● Work only under the supervision of a qualified person.</li> </ul>

## General operational safety

	 <b>CAUTION</b>
	<p><b>Ignoring basic operational safety rules may lead to accidents, injuries, or equipment damage.</b></p> <ul style="list-style-type: none"> <li>• Trainees must be supervised by an instructor at all times when working with the equipment.</li> <li>• Use the equipment only as instructed in Festo Didactic documentation.</li> <li>• Keep switches, buttons, and disconnectors unobstructed and easy to reach.</li> <li>• Repair or secure faulty equipment immediately.</li> <li>• Wear suitable personal protective equipment (PPE), such as safety glasses and safety shoes.</li> <li>• Avoid wearing loose clothing or accessories that could become entangled in equipment.</li> <li>• Secure long hair to prevent it from interfering with moving parts or obstructing vision.</li> <li>• Keep the work area clean, dry, and free of substances that could cause slips or interfere with equipment operation.</li> </ul>
	 <b>CAUTION</b>
	<p><b>Improper handling of heavy equipment may cause personal injury or equipment damage.</b></p> <ul style="list-style-type: none"> <li>• Use proper lifting techniques or assistance when moving heavy components marked with the lifting-hazard symbol.</li> </ul>

## Personal protective equipment (PPE)

Despite built-in safety features, residual risks remain due to misuse or faulty components. To reduce injury risk, always follow these PPE guidelines:

- Wear **safety shoes** when frequently moving equipment between storage and workstations.
- Wear **safety glasses** when working with polarized capacitors, which may explode unexpectedly.
- Wear **hearing protection** when using noisy equipment such as rotating machines.

- Wear **insulating gloves** when handling live electrical components.
- Wear **safety gloves** for mechanical handling (e.g., sharp edges, heavy parts, hot surfaces).

### Equipment handling and layout

#### *NOTICE*

##### **Cable handling**

- Lay out cables without bends, pinches, or contact with hot surfaces (clearly marked if applicable).
- Always unplug by pulling the plug itself—never pull on the cable.
- Prevent continuous tension on cables to avoid damage and disconnection.

#### *NOTICE*

##### **Ventilation and heat management**

- Keep all ventilation slots unobstructed. Place equipment only on hard, flame-resistant surfaces to allow proper airflow.
- Do not install heat-generating equipment near or underneath temperature-sensitive components.

#### *NOTICE*

##### **Workstation setup**

- Check the maximum load capacity of the workstation and ensure it is not exceeded.

## Electrical safety

	 <b>WARNING</b>
	<p><b>Risk of electric shock due to dangerous voltage</b></p> <p>The equipment contains hazardous voltage that can cause death, serious injury, or major property damage if safety instructions are ignored.</p> <p><b>Protective earth (PE)</b></p> <ul style="list-style-type: none"> <li>• Always earth equipment fitted with a PE terminal.</li> <li>• Connect the PE first and disconnect it last.</li> <li>• Do not break or damage yellow-green PE conductors.</li> <li>• Equipment with high leakage current needs a separate PE lead on its extra PE terminal.</li> </ul> <p><b>Prohibited practices</b></p> <ul style="list-style-type: none"> <li>• Never connect power sources in series.</li> <li>• Never connect multiple power supplies to a single ac power wall outlet, as this can cause higher leakage currents.</li> <li>• Do not exceed the input voltage or current rating of any device, as this can lead to heating, shocks, and fires.</li> </ul> <p><b>Safe voltage limits</b></p> <ul style="list-style-type: none"> <li>• Contact with &gt; 30 V ac rms or &gt; 60 V dc can be fatal.</li> <li>• Shield power source outputs and leads from touch; use shrouded safety leads rated CAT II or higher.</li> <li>• Switch off all power sources and de-energize circuits before wiring changes.</li> <li>• Only use detachable mains supply cords, cables, and connection leads with adequate ratings.</li> </ul> <p><b>Capacitors</b></p> <ul style="list-style-type: none"> <li>• Large capacitors may stay charged after power-off. Wait several minutes before opening housings.</li> </ul> <p><b>Low-voltage circuits</b></p> <ul style="list-style-type: none"> <li>• Power low-voltage circuits only with Class II SELV or double-insulated supplies (e.g., Festo Didactic power sources).</li> </ul>

### Mechanical safety with rotating machines

	<b>⚠ WARNING</b>
	<p><b>Risk of serious injury from rotating parts!</b></p> <ul style="list-style-type: none"><li>• Always turn off electric power before mechanically coupling rotating machines.</li><li>• Wait until all moving parts have completely stopped before touching or servicing the equipment.</li><li>• Inspect the protective guard before installation to ensure it is undamaged. Secure the guard by tightening its top screw into the corresponding hole on the prime mover frame using the provided hexagonal key. The rotating machines will not operate without a correctly installed guard. Immediately remove damaged guards from the laboratory or classroom.</li></ul>
	<b>⚠ CAUTION</b>
	<ul style="list-style-type: none"><li>• Rotating machines generate high noise levels, which may cause fatigue or headaches. Always wear appropriate hearing protection, such as protective earpieces, when operating the machines.</li></ul>
<b>NOTICE</b>	
<ul style="list-style-type: none"><li>• Before moving the system, always remove any inertia wheel from the motor shaft to avoid damaging it during transportation.</li></ul>	
<b>NOTICE</b>	
<ul style="list-style-type: none"><li>• Follow all installation and positioning instructions to ensure correct operation of rotating machines.</li></ul>	

## 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](mailto: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.



## Equipment Installation and Commissioning

### Environmental requirements

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

- 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  $\pm 10\%$  of the nominal voltage.
- Transient overvoltages up to the levels of overvoltage category II (1500 V for 120 V mains and 2500 V for 230 V mains).
- Temporary overvoltage occurring on the mains supply.
- A pollution degree of 2 (dry, non-conductive pollution).



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.

### Equipment handling

Before handling equipment, ensure the following:

- You know where to install or relocate the equipment.
- The path is clear—no obstacles, bumps, or slippery surfaces.
- You can safely lift and carry the equipment. Check its weight beforehand if needed.

While carrying equipment, make sure to:

- Maintain a firm grip.
- Hold the equipment close to your waist, with level shoulders. Do not extend your arms.
- Move slowly and maintain stable footing.
- Turn by moving your feet, not by twisting your back.

	 <b>CAUTION</b>
	<p><b>Physical stress likely to occur when handling heavy equipment.</b></p> <ul style="list-style-type: none"><li>• Take extra care when lifting or moving heavy equipment.</li><li>• Equipment heavier than 5 kg (10 lb) are marked with a lifting hazard symbol where not otherwise obvious.</li></ul>

### Equipment installation in an A4 workstation

The equipment is designed either for tabletop use or for installation in an A4 workstation. The following safety guidelines apply when equipment is installed in an A4 workstation.

To install equipment in an A4 workstation, first place the equipment between the lower and upper rails of a workstation row. Then, insert the top edge of the equipment in the upper rail of the workstation row. Finally, insert the bottom edge of the equipment in the lower rails so that the equipment is up straight. Once properly installed, the equipment can slide on the rails.

Always respect the following recommendations when installing equipment in an A4 workstation.

- If the A4 workstation comprises more than one row, equipment that dissipates heat should be installed in the top row. Heat-dissipating equipment are recognized by a hot surface caution sign cut in the top surface of the equipment.
- The manufacturer gives the maximum load limit of the rails of the A4 workstation. It is important to consult the document on the A4 workstation before installing the equipment in order to avoid overloading the rails.



Festo Didactic A4 workstations 8153360 and 8158409 are rated for 50 kg (110 lb) per row.

### Connection of three-phase equipment

Connect three-phase equipment to a three-phase power supply using four power leads and one protective earthing (PE) lead, as the following figure shows. The PE lead connects the PE terminal of the supply to that of the powered module.

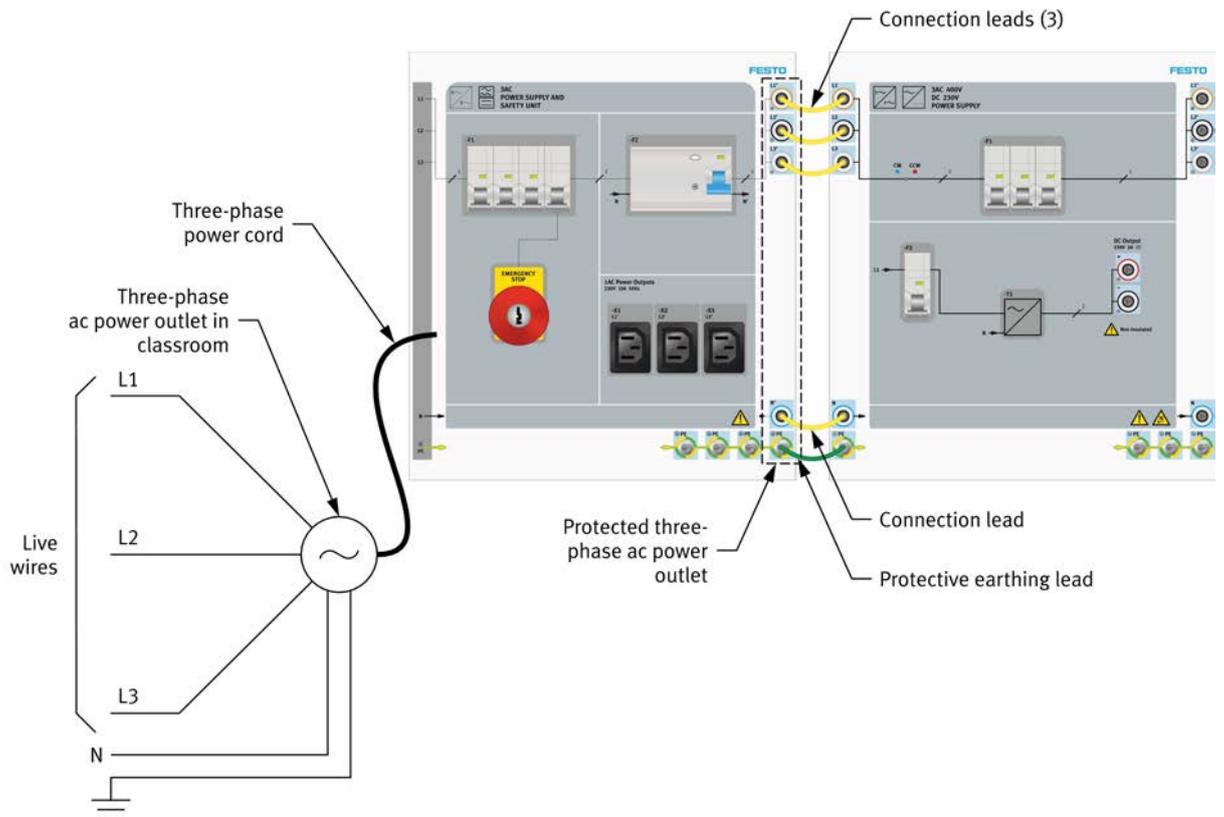


Figure 2: Three-phase equipment connected to an ac power outlet via a three-phase power supply.

### Connection of single-phase powered equipment

Connect single-phase equipment to a three-phase power supply using a polarized three-prong power cord, as the following figure shows. The cord prevents line and neutral inversion and provides protective earthing through its third prong, so no separate PE connection is needed.

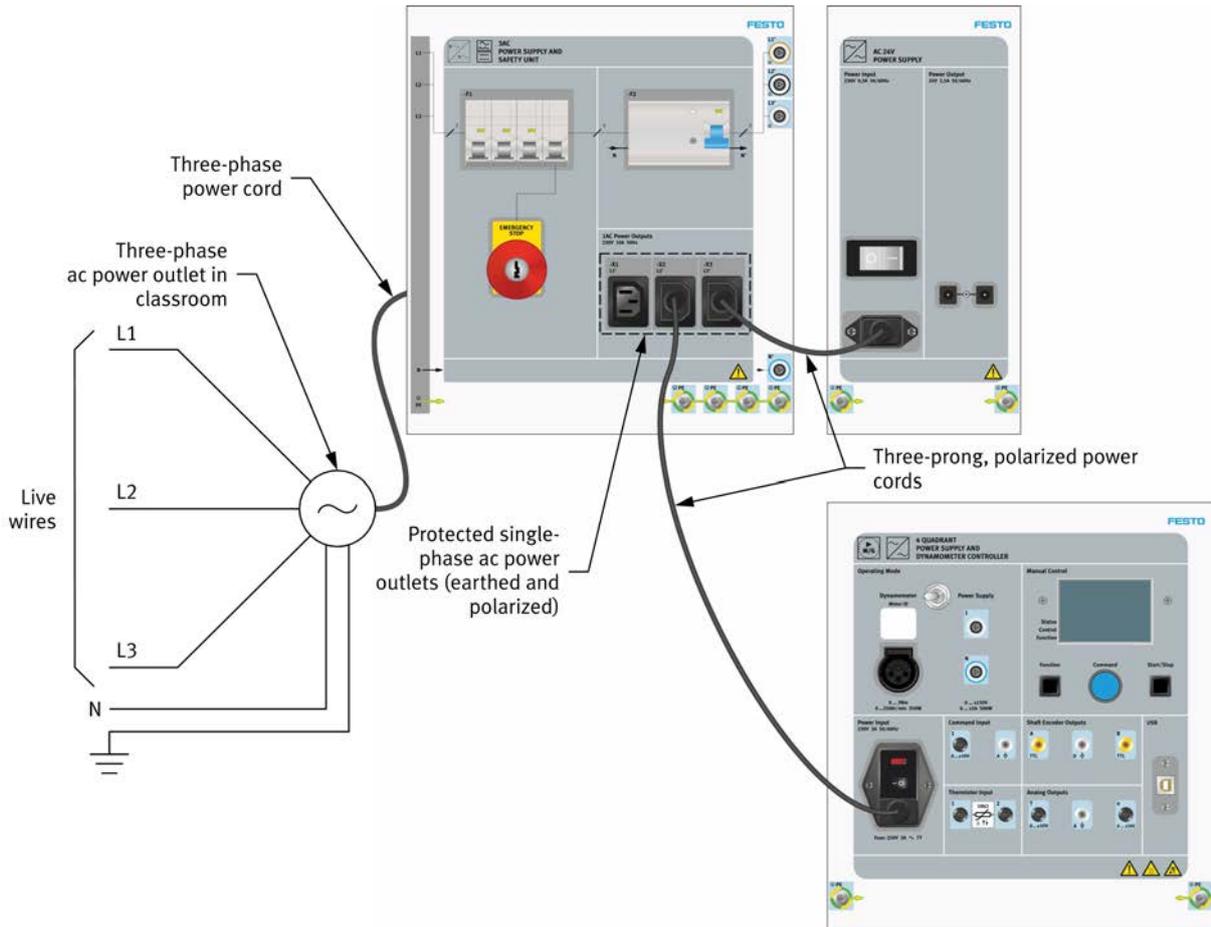


Figure 3: Single-phase equipment connected to an ac power outlet via a three-phase power supply.

## Protective earthing instructions

### For Festo Didactic equipment

Before using equipment provided solely by Festo Didactic, always perform the protective earthing procedure described in the present section.

Protective earthing of the equipment is achieved via the power supply modules, including:

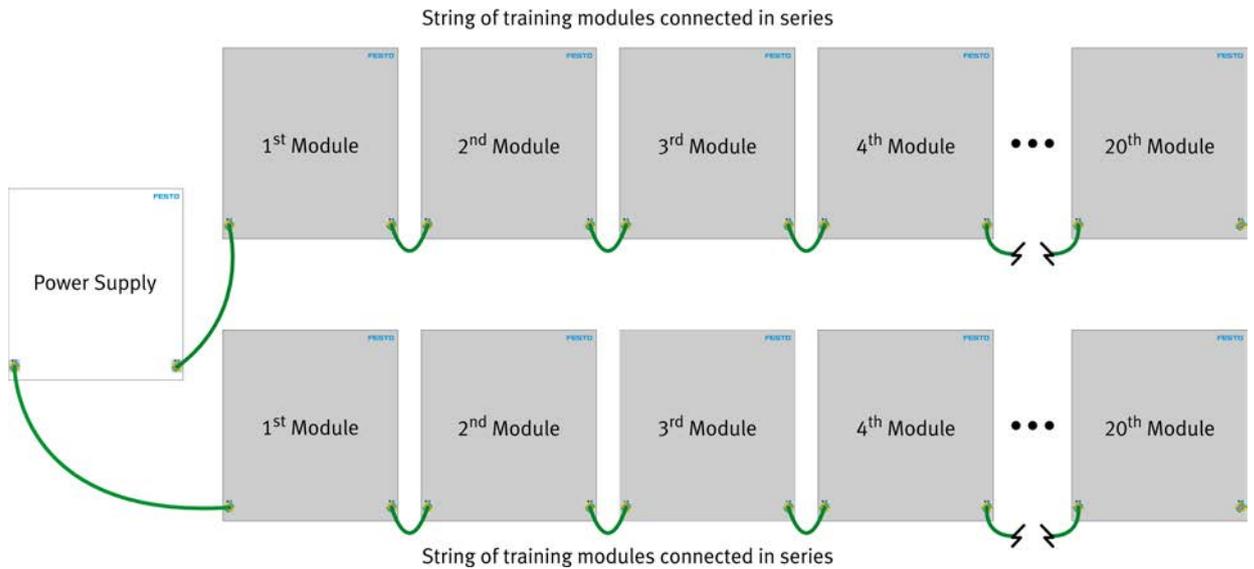
- 3AC 400V/DC 230V Power Supply
- AC 24V Power Supply
- 4 Quadrant Power Supply and Dynamometer Controller
- 3AC Power Supply and Safety Unit

Each power supply module includes two or more protective earthing (PE) terminals. These terminals are maintained at earth potential when the module is connected to an ac power outlet, as explained in the section “Connecting equipment to ac power outlets.”

Like the power supply modules, each other module in the equipment includes two PE terminals. These terminals must be interconnected using the provided protective earthing leads to form strings of modules. Strings of up to twenty series-connected modules are permitted. Each string must then be connected to the PE terminal of a power supply module.

<b>NOTICE</b>
<p>If you use protective earthing leads other than those provided with the equipment, they must have a cross-section of at least 1.5 mm<sup>2</sup>, in accordance with EN 60204-1.</p>

The interconnection of the PE terminals between the power supply module(s) and the training modules for effective protective earthing depends on the number of power supply modules used in the setup. When a single power supply module is used, connect the strings of training modules to the PE terminals on the power supply module, as shown in the following figure.



**Figure 4: Protective earthing in a setup containing a single power supply module.**

When two power supply modules are used, connect one PE terminal on the first power supply module to one PE terminal on the second. Then connect the strings of training modules to the remaining available PE terminals on the power supply modules, as shown in the following figure.

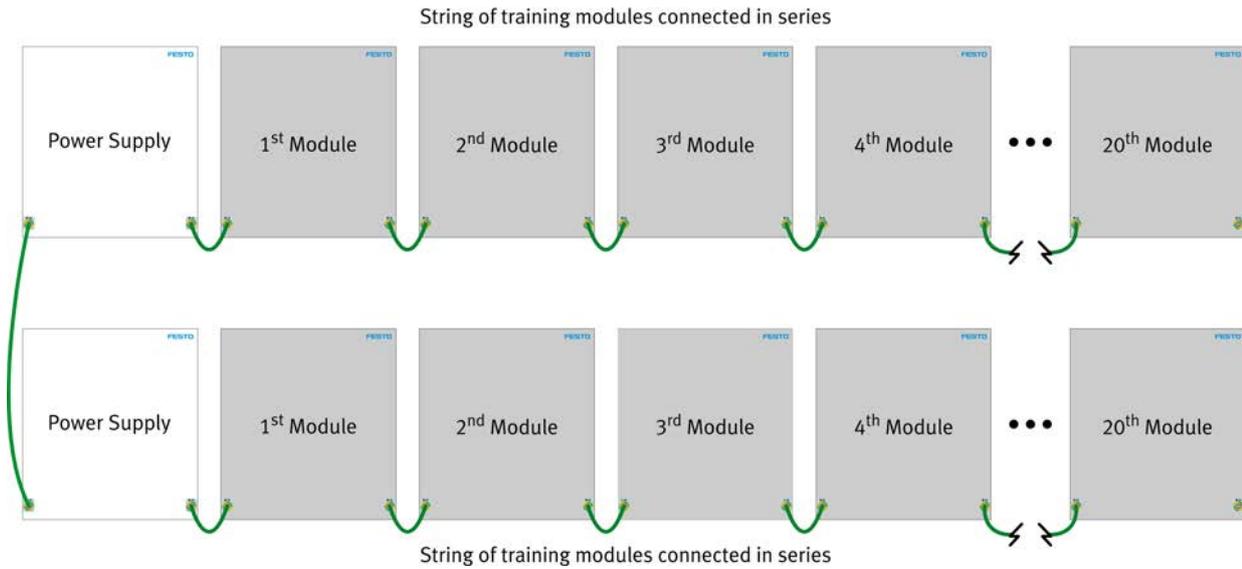


Figure 5: Protective earthing in a setup containing two power supply modules.

When three power supply modules are used, connect one PE terminal on the first power supply module to one PE terminal on the second. Then connect a second PE terminal on the second power supply module to one PE terminal on the third. Finally, connect the strings of training modules to the remaining available PE terminals on the power supply modules, as shown in the following figure.

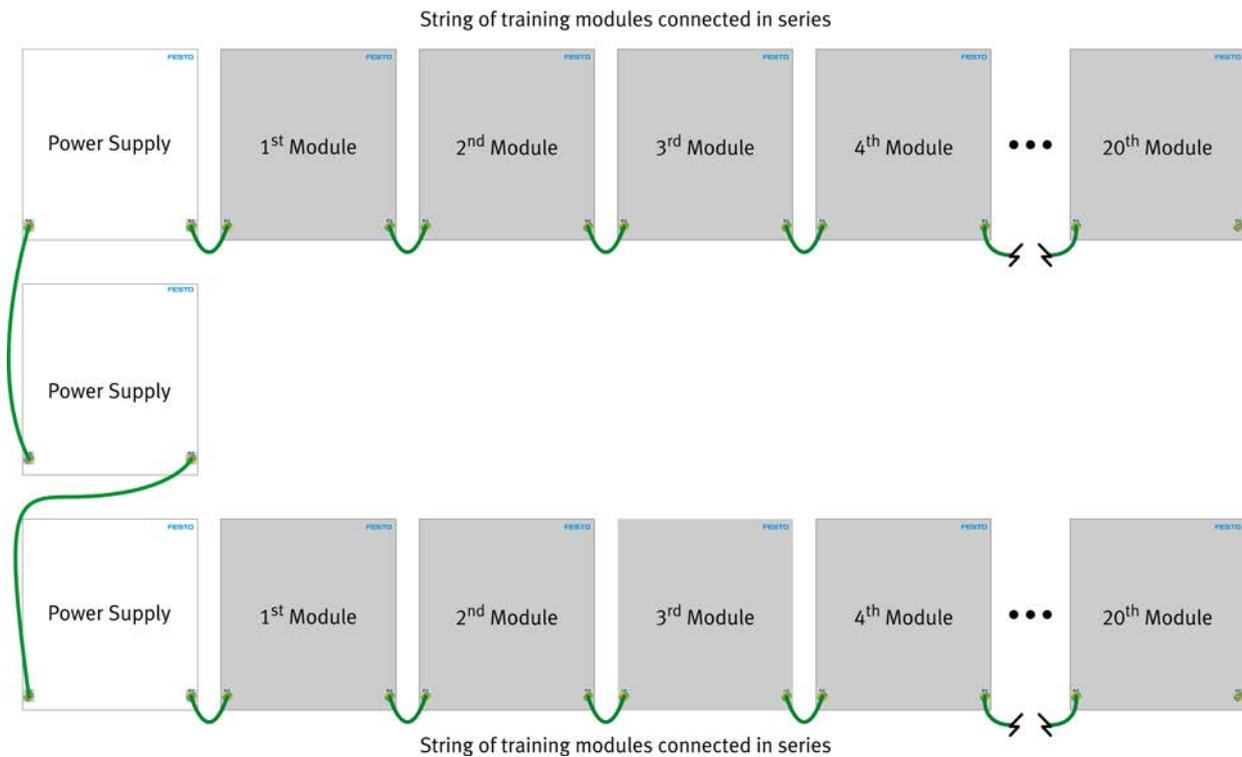


Figure 6: Protective earthing in a setup containing three power supply modules.

## For Festo Didactic equipment combined with equipment from other manufacturers

Before using equipment provided by Festo Didactic or other manufacturers, always perform the protective earthing procedure described in this section.

Each protective earthing terminal on the equipment consists of a 6 mm POAG stud insert mounted in a green safety banana jack. The POAG stud insert is a male-type terminal that prevents the connection of a protective earthing terminal to a safety banana jack using the provided leads. This design makes it impossible to connect a protective earthing terminal to a live terminal (e.g., one carrying 230 V), thereby eliminating the risk of applying voltage to the metal housings of the equipment and the associated risk of electric shock.

On equipment from other manufacturers, the protective earthing terminals often consist of safety banana jacks (typically green). This prevents the use of the provided leads to connect such equipment to the Festo Didactic protective earthing system. In this case, Festo Didactic recommends upgrading the equipment by installing a POAG stud insert in each protective earthing terminal. This allows easy earthing connections between Festo Didactic equipment and other manufacturers' devices and eliminates the risk of electric shock due to inadvertent connection of a protective earthing terminal to a live terminal. POAG stud insert kits for such upgrades can be ordered from Festo Didactic under item no. 8067500 (set of POAG stud inserts with Allen wrench and installation instructions).

Alternatively, the POAG stud inserts can be removed from the protective earthing terminals of the equipment (using a standard Allen wrench) to enable earthing connections to equipment from other manufacturers with the provided leads. However, Festo Didactic discourages this practice because it allows the possibility of connecting a protective earthing terminal to a live terminal, reintroducing the risk of applying voltage to the metal housings and the associated risk of electric shock.

	 <b>WARNING</b>
	<p><b>Risk of electric shock when operating the equipment without POAG stud inserts in the protective earthing terminals!</b></p> <ul style="list-style-type: none"> <li>• Removing the POAG stud inserts from the protective earthing terminals increases the risk of electric shock due to possible inadvertent connection of a protective earthing terminal to a live terminal.</li> <li>• Only remove POAG stud inserts when absolutely necessary to allow protective earthing connections to equipment from other manufacturers.</li> <li>• To minimize the risk of electric shock in such cases, always have a qualified person (e.g., an instructor or lab supervisor) verify the protective earthing connections before applying electric power to the equipment.</li> </ul>

## Setting up rotating machines

The equipment includes several rotating machines that can be set up in three ways:

1. **Side by side.** Machines are set up next to each other and coupled using a timing belt.
2. **In line.** Machines are aligned and directly coupled. This setup is often used with a four-quadrant prime mover/dynamometer and is used in the Basic Motor Control Technology course.
3. **Stand-alone.** Most machines can also operate independently.

The following subsections explain how to set up each configuration.

### Setting up rotating machines side by side

Some rotating machines are designed for side-by-side setup. Each has a geared pulley on its shaft for mechanical coupling to a prime mover—such as the 4 Quadrant Dynamometer Motor—using a timing belt.

The following procedure explains how to set up a side-by-side configuration, couple the rotating machine to the prime mover using a timing belt, and install the protective guard to prevent contact with moving parts.

	 <b>WARNING</b>
<p>Always disconnect power before coupling rotating machines. Failure to do so may cause the machines to start unexpectedly, leading to serious hand or arm injury.</p>	

1. Place the prime mover on a horizontal surface near the A4 workstation that houses the rest of the equipment. This positioning facilitates its interconnection with the equipment.



If the prime mover is already positioned near the A4 workstation, ensure it is disconnected from any power supply.

Orient the prime mover so that its pulley faces you.

2. Identify the rotating machine required for the lab exercise and ensure it has a geared pulley attached to its shaft.

Place the rotating machine on the work surface to the right of the prime mover.



If the rotating machine is already positioned to the right of the prime mover, ensure it is disconnected from any equipment installed in the A4 workstation.

Orient the rotating machine so that its pulley faces you.

- Note that two guiding pins are mounted on the right-hand side of the prime mover's base plate, and two guiding slots are located on the left-hand side of the rotating machine's base plate.

Slide the rotating machine toward the prime mover until the guiding pins fully engage the guiding slots (see the following figure). The machines are correctly installed when their base plates make full contact along their entire length.

	 <b>CAUTION</b>
	Never attempt to lift two rotating machines together, as this may cause personal injury or equipment damage.

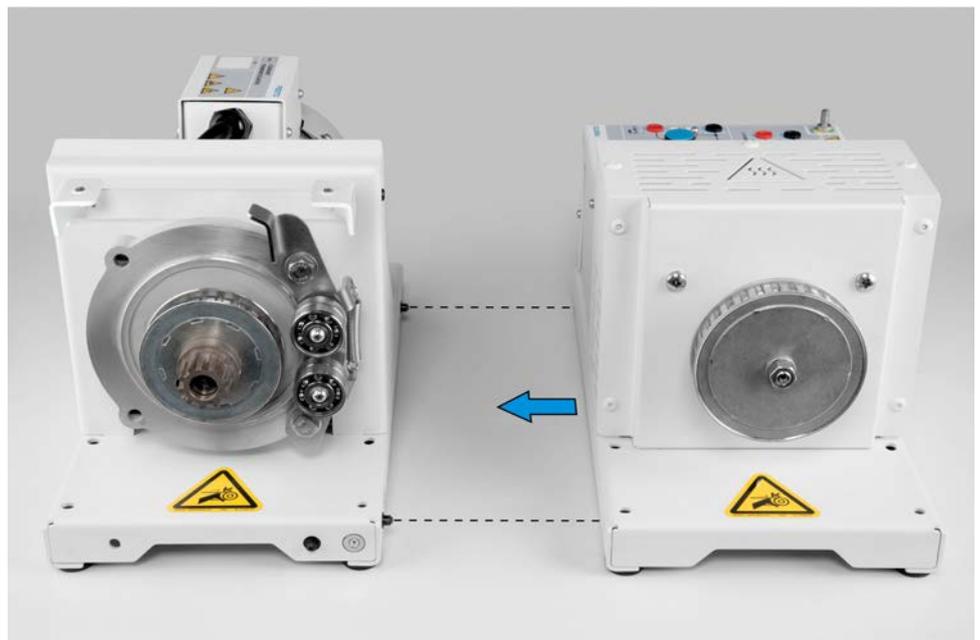


Figure 7: Setting up the prime mover and a rotating machine side by side.

- Place one end of a timing belt of the correct length around the geared pulley of the prime mover (see (a) in the following figure). Then place the other end of the belt around the geared pulley of the rotating machine (see (b) in the following figure).
- Pull the timing belt toward you with a slight twisting motion at the location shown in (c) of the following figure. With your other hand, press down the lower bearing of the belt tensioner on the prime mover as shown in (d). Then push the belt toward the machines so it rests over the lower bearing (see (e) in the following figure).

6. Pull the timing belt toward you with a slight twisting motion at the location shown in (f) of the following figure. With a finger of your other hand, lift the upper bearing of the belt tensioner on the prime mover by pushing the metal lever as shown in (g). Then push the belt toward the machines so it slides underneath the upper bearing (see (h) in the following figure).

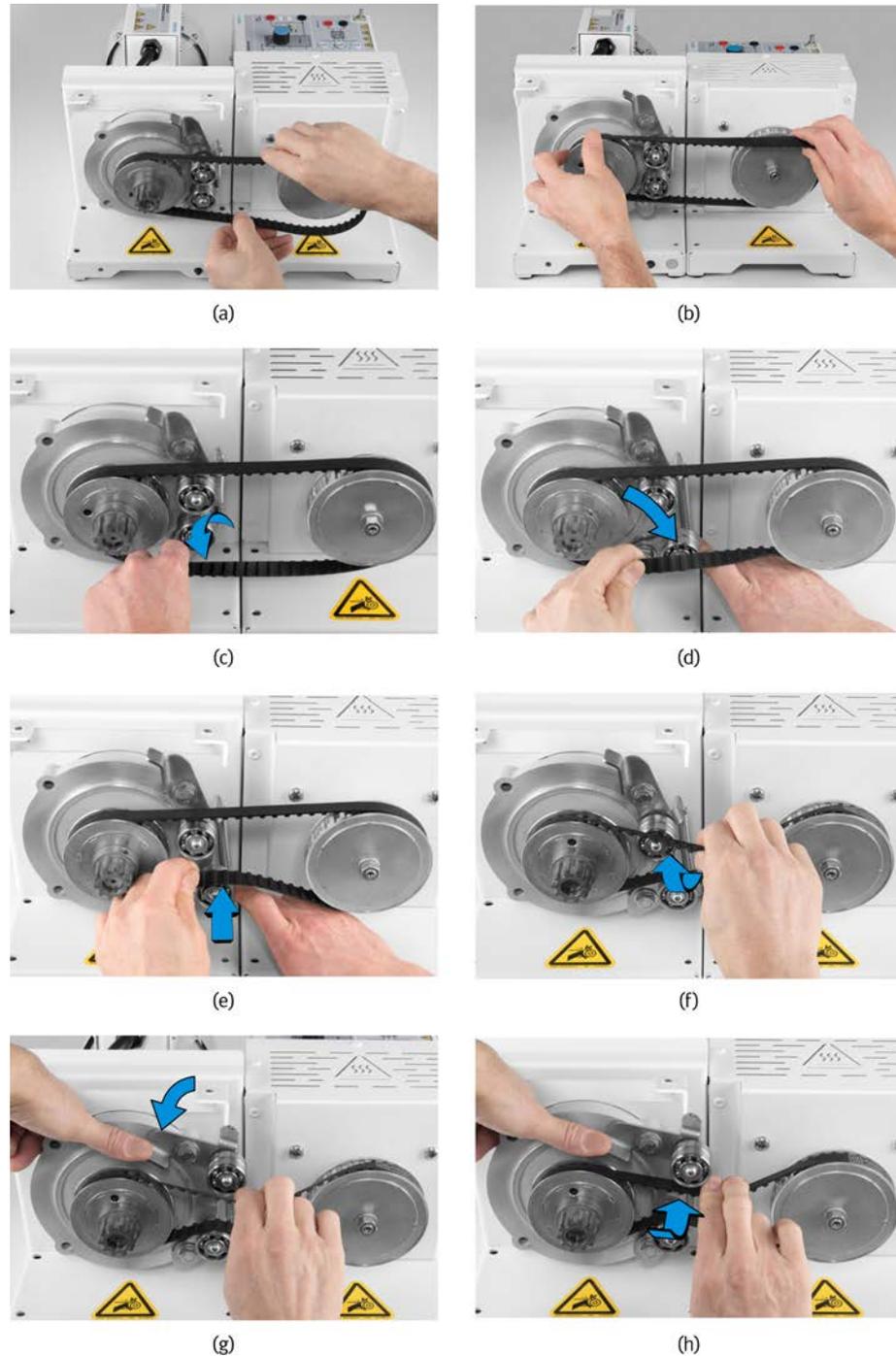


Figure 8: Mechanically coupling a rotating machine to the prime mover using a timing belt.

7. To confirm that the timing belt is the correct length and properly installed, rotate the shaft of either the prime mover or the rotating machine by hand. The belt is correctly installed when both machines rotate and both belt tensioner bearings apply tension to it. The timing belt must also contact both bearings across its full width. See the following figure.



Figure 9: To verify correct installation of the timing belt, rotate the shaft of either the prime mover or the rotating machine by hand. Both machines must rotate, and both tensioner bearings must apply tension to the belt.

8. A limit switch (see the following figure) located in the base plate of each rotating machine, including the prime mover, prevents operation unless a protective guard is installed. This guard helps prevent injuries from accidental contact with rotating parts.



Figure 10: A limit switch in the base plate of each rotating machine prevents machine operation as long as a protective guard is not properly installed.

9. Locate the protective guard for side-by-side rotating machines. Note the guiding pins on the underside of the guard (see the following figure).

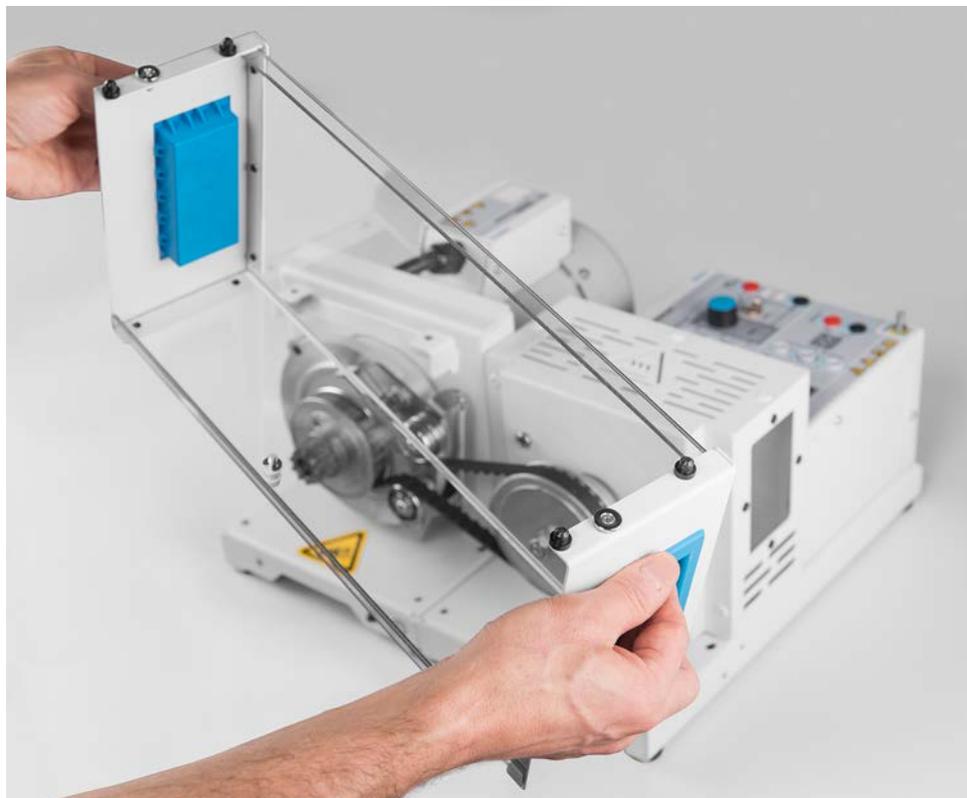


Figure 11: Guiding pins at the bottom of the protective guard for side-by-side rotating machines.

10. To install the protective guard on the prime mover and the rotating machine, align the guiding pins of the guard with the holes in the base plates of both machines. Insert the guard into the base plates (see the following figure). Ensure all guiding pins are fully engaged in the holes of the base plates.

Using the provided hex key, tighten the top screw on the protective guard into the corresponding hole on the prime mover frame to secure the guard in place.

Installing the protective guard on the prime mover and the rotating machine actuates the limit switch in each base plate, enabling both machines to operate.

 <b>WARNING</b>	
	Serious injury can occur from accidental contact with moving parts of rotating machines operated without a protective guard secured by the top screw. Never operate rotating machines without the guard or by inserting objects into the base plate holes to activate the limit switches.

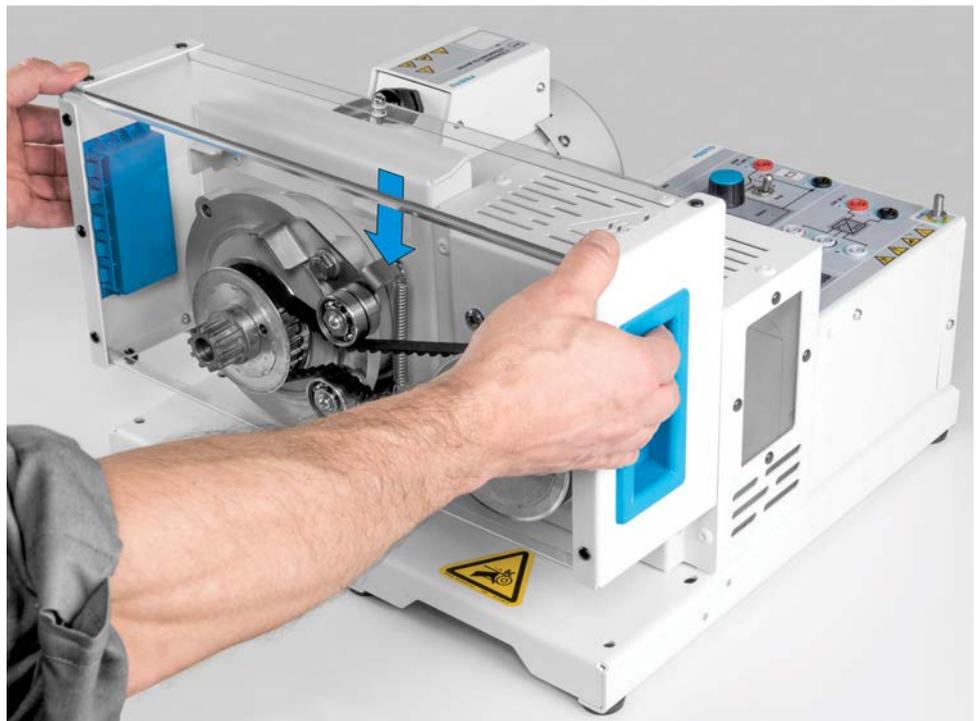


Figure 12: Installing the protective guard on side-by-side rotating machines.

### Setting up rotating machines in line with each other

Several rotating machines are designed for in-line setup. A gear coupling at the end of each machine's shaft allows direct mechanical connection to a prime mover, such as the 4 Quadrant Dynamometer Motor or the Squirrel-Cage Induction Machine.

The following step-by-step procedure describes how to properly set up a rotating machine in line with a prime mover, mechanically couple them, and install a protective guard to prevent accidental contact with rotating parts.

	<b>! WARNING</b>
	<p>Before coupling rotating machines, ensure they are completely disconnected from all electric power sources to prevent accidental startup, which could cause serious hand or arm injuries.</p>

1. Place the prime mover on a horizontal surface near the A4 workstation that houses the rest of the equipment. This positioning facilitates interconnection between the modules.



If the prime mover is already positioned near the A4 workstation, ensure it is disconnected from any power supply.

Orient the prime mover so that its shaft points toward the right-hand side of the work surface.

2. Identify the rotating machine required for the lab exercise and ensure it has a gear attached to the end of its shaft.

Place the rotating machine on the work surface to the right of the prime mover.



If the rotating machine is already positioned to the right of the prime mover, ensure it is disconnected from any equipment installed in the A4 workstation.

Orient the rotating machine so that its shaft faces the prime mover.

3. Note that the front side of the prime mover's base plate has a guiding pin and a guiding hole. The rotating machine's base plate also has a guiding pin and a guiding hole on its front side. Align the rotating machine with the prime mover so that the guiding pins match the guiding holes (see the following figure).

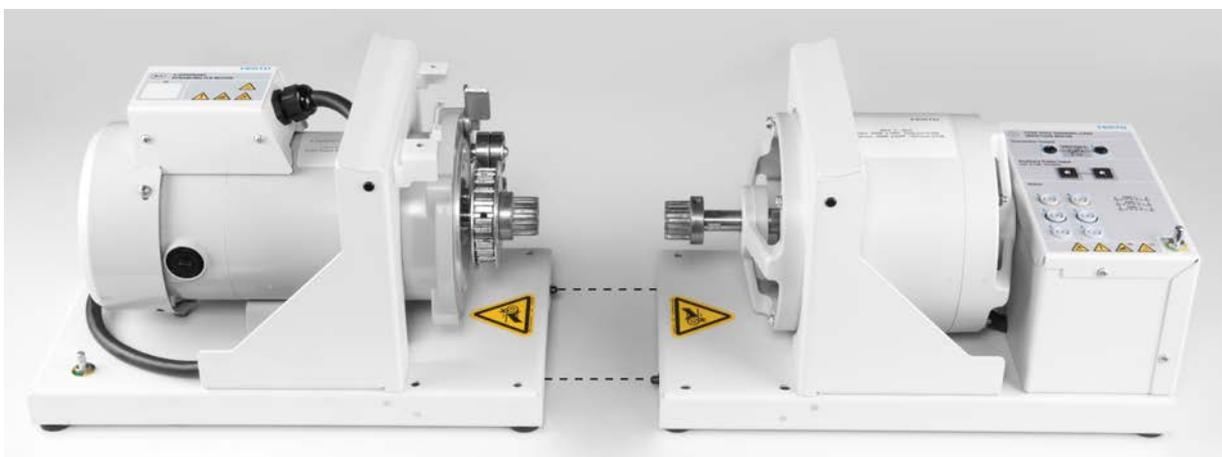


Figure 13: Aligning the rotating machine with the prime mover.

- Slide the direct coupling supplied with the equipment onto the gear attached to the prime mover's shaft.

Slide the rotating machine toward the prime mover so that the gear on its shaft fits into the direct coupling (you may need to rotate the coupling slightly) and the guiding pins fully engage the guiding holes (see the following figure). The machines are correctly installed when their base plates make full contact along their entire width.

	 <b>CAUTION</b>
	Never attempt to lift two rotating machines together, as this may cause personal injury or equipment damage.

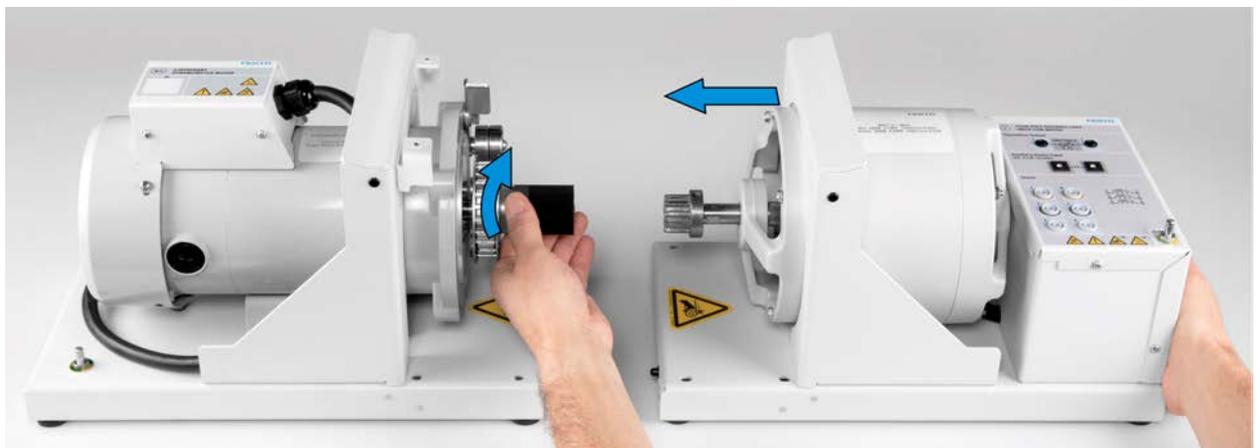


Figure 14: Mechanically coupling a rotating machine to the prime mover using direct coupling.

- A limit switch (see the following figure) located in the base plate of each rotating machine, including the prime mover, prevents operation unless a protective guard is installed. The guard helps prevent injuries caused by accidental contact with rotating parts.



Figure 15: A limit switch in the base plate of each rotating machine prevents operation unless a protective guard is properly installed.

6. Locate the protective guard for in-line rotating machines. Note the guiding pins on the underside of the guard (see the following figure).



Figure 16: Guiding pins at the bottom of the protective guard for in-line rotating machines.

7. To install the protective guard on the prime mover and rotating machine, align its guiding pins with the holes in the base plates of both machines. Insert the guard fully into the base plates (see the following figure) and ensure all guiding pins are completely engaged.

Using the provided hex key, tighten the top screw of the protective guard into the corresponding hole on the prime mover frame to secure the guard in place.

When the protective guard is installed, it actuates the limit switch in each machine's base plate, enabling both machines to operate.

	 <b>WARNING</b>
	Serious injuries can result from accidental contact with moving parts if rotating machines are operated without the protective guard secured by the top screw. Never operate rotating machines without the guard or by inserting objects into the base plate holes to activate the limit switches.

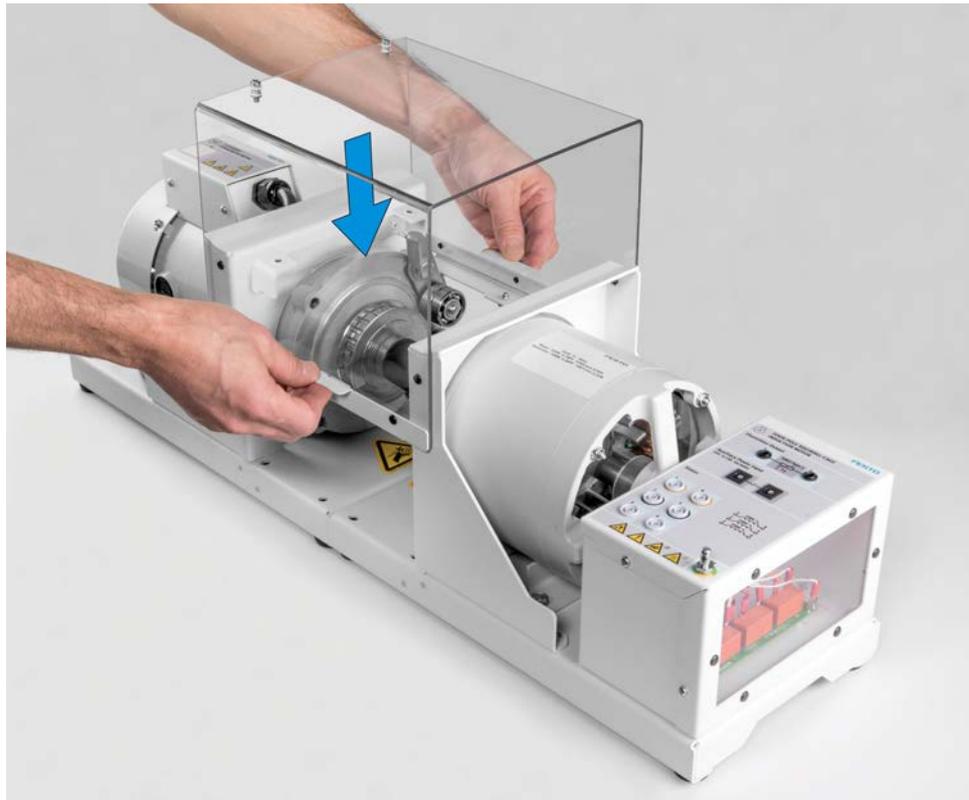


Figure 17: Installing the protective guard on in-line rotating machines.

### Setting up a rotating machine for stand-alone operation

Most rotating machines in the equipment can operate independently. The following step-by-step procedure explains how to correctly configure a rotating machine for stand-alone use. It also shows how to install a protective guard to prevent accidental contact with rotating parts.

1. Locate the rotating machine required for the lab exercise.
2. Place the rotating machine on a horizontal surface near the A4 workstation that houses the rest of the equipment. This positioning facilitates interconnection with the equipment.



If the rotating machine is already positioned near the A4 workstation, ensure it is disconnected from any equipment installed in the workstation.

Ensure the rotating machine is oriented so that its pulley faces you.

3. A limit switch (see the following figure) located in the base plate of each rotating machine, including the 4 Quadrant Dynamometer Motor, prevents operation unless a protective guard is installed. The guard helps prevent injuries caused by accidental contact with rotating parts.



Figure 18: A limit switch in the base plate of each rotating machine prevents operation unless a protective guard is properly installed.

4. Locate the protective guard for stand-alone rotating machines. Note the guiding pins on the underside of the guard (see the following figure).

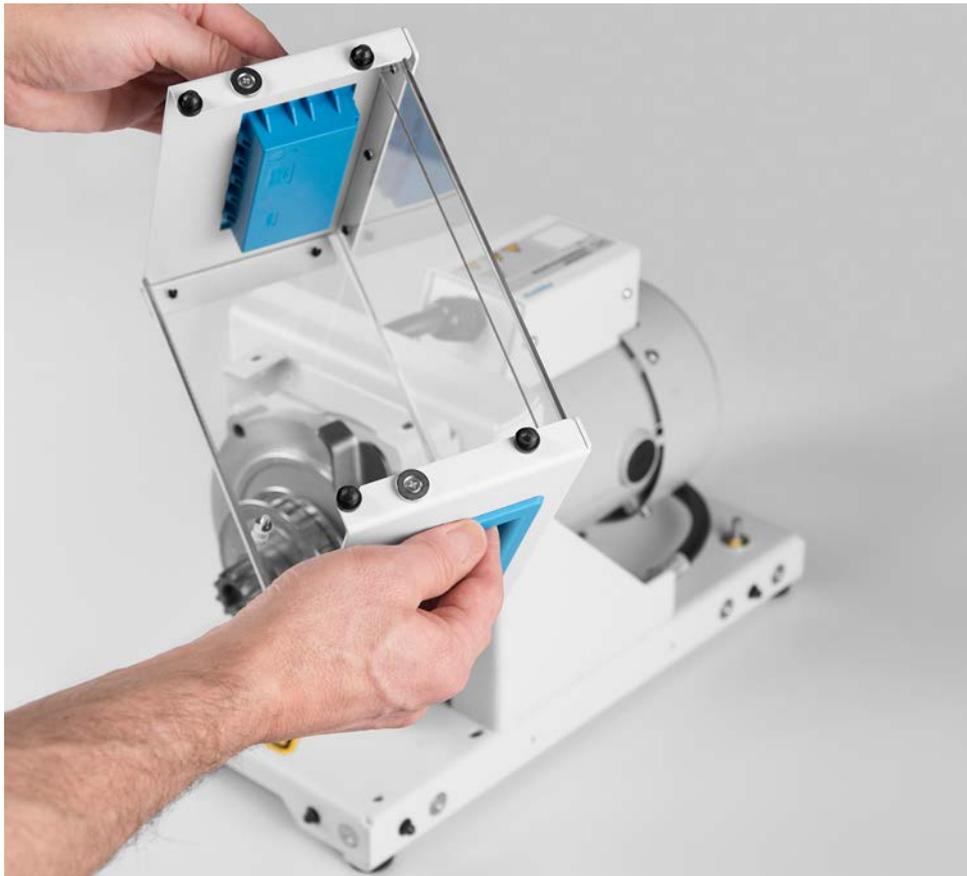


Figure 19: Guiding pins at the bottom of the protective guard for a stand-alone machine.

5. To install the protective guard on the rotating machine, align the guiding pins of the guard with the holes in the machine's base plate, then insert the guard into the base plate (see the following figure). The guard is properly installed when all guiding pins are fully engaged in the base plate holes. Installing the protective guard actuates the limit switch located in the base plate, allowing the machine to operate.

 <b>WARNING</b>	
	<p>Serious injuries can occur from accidental contact with moving parts if a rotating machine is operated without a protective guard. Never operate a rotating machine without the guard or by inserting an object into the base plate hole to activate the limit switch.</p>

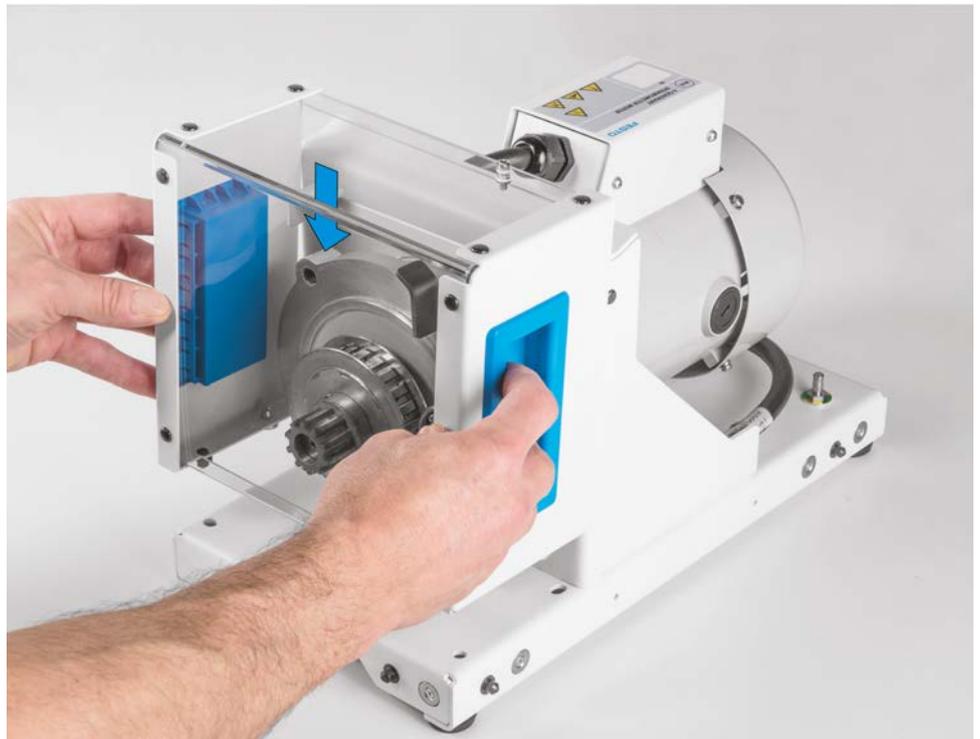


Figure 20: Installing the protective guard on a stand-alone rotating machine.

### Uncoupling rotating machines

The following step-by-step procedure explains how to safely uncouple rotating machines.

	<b>! WARNING</b>
	Before uncoupling rotating machines, ensure they are completely disconnected from all electric power sources to prevent accidental startup, which could cause serious hand or arm injuries.

1. Turn all electric power sources in the system off.
2. Remove all connections from the rotating machines.
3. Using the provided hex key, unscrew the top screw of the protective guard. Remove the guard from the rotating machines by lifting it upward, then return it to its storage location.

4. If the rotating machines are coupled with a timing belt, proceed to the next step. Otherwise, continue with this step.

Slide one of the rotating machines sideways until the gear on the end of its shaft disengages from the direct coupling (see the following figure). Remove the direct coupling from the machine's shaft and return it to its storage location.

Proceed to the final step of the procedure.

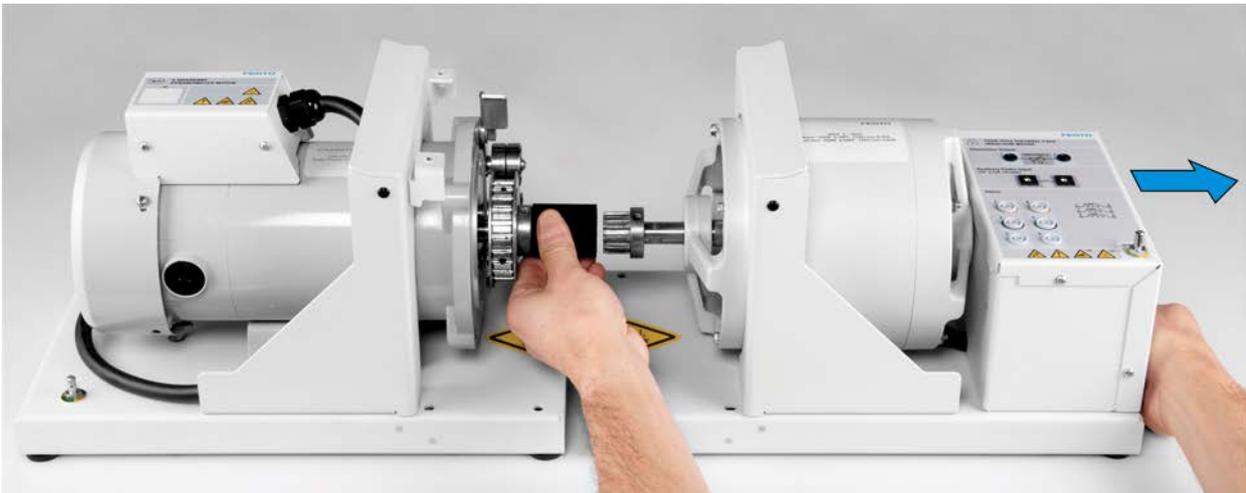


Figure 21: Uncoupling in-line rotating machines.

5. Lift the upper bearing of the belt tensioner on the prime mover by pushing the metal lever with one hand, as shown in (a) of the following figure. With your other hand, pull the timing belt toward you at the location shown in (a) until it slips off the tensioner bearings. Then remove the timing belt from the geared pulleys of both rotating machines (see (b) of the following figure) and return it to its storage location.



(a)



(b)

Figure 22: Uncoupling side-by-side rotating machines.

## Quick start

This section provides a quick-start procedure for installing and powering up the equipment at the beginning of a practice session. It also includes a general procedure for powering off, disconnecting, and removing the equipment at the end of the session.

### *NOTICE*

The check procedures described in the “Checking the electrical installation in the laboratory classroom” section must be completed to ensure that the equipment is properly powered by the power supply modules. Failure to do so may result in equipment damage.

## Installing and powering up the equipment

1. Ensure that you have read and understood the directives in the Safety precautions section of this document before using the equipment.
2. Install all modules required for your practice session in or near the A4 workstation, depending on the module. Refer to the Handling and installing modules section if needed.

Set up any rotating machine required for your practice session following the directives in the Setting up rotating machines section.

3. Make the required protective earthing connections according to the directives in the Protective earthing instructions section.

4. Ensure that all power supply modules are turned off.

Connect each power supply module to a properly protected ac power outlet. Refer to the Connecting equipment to ac power outlets section if needed.

5. Connect the equipment as required for your practice session using only the safety connection leads provided with the equipment.

	 <b>WARNING</b>
	Do not use connection leads from other manufacturers. Always use the provided leads, as their live parts are concealed and insulated to prevent accidental contact, ensuring safe equipment connection and protection against electric shock.

6. Verify your equipment connections.
7. Turn on (unlock) the electric power at your workstation, if applicable.



If needed, ask your instructor for assistance.

8. Turn all power supply modules on. If more than one is present, proceed in order of power rating, starting with the lowest.

	 <b>WARNING</b>
	<p>When the equipment is powered on, keep in mind the following directives to avoid the risk of injuries caused by electric shocks:</p> <ul style="list-style-type: none"><li>• Never leave the equipment unattended.</li><li>• Unless specifically stated otherwise, never modify the equipment connections while power is on.</li><li>• Never move a module while power is on.</li></ul>

### **Powering off, disconnecting, and removing the equipment**

1. Turn all power supply modules off. If more than one is present, proceed in order of power rating, starting with the highest.
2. Turn electric power off at your workstation (if applicable).
3. Disconnect all equipment connections, ending with the protective earthing connections. Remove the protective guard and uncouple the rotating machines, if applicable. Return all equipment and connection leads to their storage locations.



## Indications of conformity

The following EU directives are relevant for the CE marking of the equipment:

- Low-Voltage Directive
  - The Low-Voltage Directive requires that products do not cause electrical hazards.
- Electromagnetic Compatibility (EMC) Directive
  - The EMC Directive requires that electric devices must only influence one another to a limited extent.
- Restriction of the Use of Certain Hazardous Substances (RoHS) Directive
  - The RoHS Directive requires a limit to hazardous substances such as lead, mercury, cadmium, or chrome.
- Radio Equipment Directive (RED)
  - The Radio Equipment Directive establishes a regulatory framework to make radio equipment available on the market and its commission in the EU.

Declarations of conformity (CE or UKCA) for the equipment are available on request.

### **Electromagnetic compatibility (EMC)**

The following table outlines international electromagnetic compatibility (EMC) compliance requirements, specifying applicable standards, equipment classifications, and usage limitations.

**Table 2: Overview of electromagnetic compatibility (EMC) compliance.**

<p>International</p>	<p>EN IEC 61326-1: Basic Electromagnetic Environment            CISPR 11: The equipment in this user guide is Group 1 only, Class A</p> <ul style="list-style-type: none"> <li>● Group 1: Equipment covered by this standard that is not classified as Group 2.</li> </ul> <p>Group 2: Industrial, scientific, and medical radio-frequency (ISM RF) equipment that intentionally generates or uses radio-frequency energy (9 kHz to 400 GHz), locally applied via electromagnetic radiation, inductive or capacitive coupling, for purposes such as material treatment, inspection, analysis, or energy transfer.</p> <ul style="list-style-type: none"> <li>● Class A: Equipment is suitable for use in all establishments other than domestic and those directly connected to a low-voltage power supply network that supplies buildings used for domestic purposes. There may be potential difficulties in ensuring electromagnetic compatibility in other environments due to conducted and radiated disturbances.</li> <li>● Caution: This equipment is not intended for use in residential environments and may not provide adequate protection to radio reception in such environments.</li> </ul>
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## Safety Precautions

### Prerequisite for the safe use of the equipment

Even though the equipment has been carefully designed to ensure trainees' safety, there are residual risks that cannot be reduced via technical solutions without impairing the learning process. The first and foremost safety measure that must be enforced at all times is the proper supervision of the trainees.

Nothing can replace the supervision and guidance of a qualified instructor. Trainees have an incomplete mastery of the subject. They can make mistakes and most certainly will. That is an essential part of the learning process.

The instructor's task is to let trainees make harmless mistakes while preventing those that could have serious consequences.

	 <b>CAUTION</b>
	<p>Working with electrical and mechanical components may involve potential hazards.</p> <p>Ensure that all activities are supervised by a qualified professional.</p>

### General warnings

	<p style="text-align: center;"><b>⚠ WARNING</b></p> <ul style="list-style-type: none"> <li>• Before operating the equipment, make sure that the leads interconnecting the protective earthing terminals of the modules form an uninterrupted protective earthing conductor. Also, make sure that the insulation of each of these leads is not damaged or removed.</li> <li>• Before making or modifying connections on the equipment, make sure that the power supply is off.</li> <li>• Establish a protective earthing connection before connecting a power supply module. The protective earthing connection must have a cross-section of at least 1.5 mm<sup>2</sup>, according to EN60204-1. Refer to the Protective earthing instructions section.</li> <li>• Do not use connection leads from other manufacturers. Always use the connection leads provided with the equipment to make all connections. The live parts of these leads have their plugs concealed and insulated in such a way that they cannot be contacted accidentally, allowing safe connection of the equipment without danger of electric shock.</li> </ul>
	<p style="text-align: center;"><b>⚠ CAUTION</b></p> <ul style="list-style-type: none"> <li>• Set the modules up so that activation of switches and disconnectors is not made difficult.</li> <li>• Wear personal safety equipment when working on electrical circuits. Refer to the Personal protective equipment (PPE) section.</li> </ul>
	<p style="text-align: center;"><b>⚠ CAUTION</b></p> <p>Some modules can become very hot when used for a long time. To prevent burn injuries, let them cool down before handling them.</p>
	<p style="text-align: center;"><b>⚠ CAUTION</b></p> <p>There is a risk of personal injury, such as intervertebral disk injury, when transporting or mounting modules that are heavier than 15 kg. Ask for assistance or lay the modules on the table top.</p>

### NOTICE

- Always install heat-dissipating modules in the top row of the workstation to optimize heat dissipation. This prevents equipment that is not designed to resist heat from heating.
- Always verify the maximal weight which the A4 workstation can support and make sure not to exceed it.

### Degrees of ingress protection (IP)

### NOTICE

The equipment is rated IP20. The equipment is not protected against liquid infiltration or immersion. Keep it away from all types of liquids. Failure to do so could damage the equipment.

### Personal protective equipment (PPE)

Despite built-in safety features, residual risks remain due to misuse or faulty components. To reduce injury risk, always follow these PPE guidelines:

- Wear **safety shoes** when frequently moving equipment between storage and workstations.
- Wear **safety glasses** when working with polarized capacitors, which may explode unexpectedly.
- Wear **hearing protection** when using noisy equipment such as rotating machines.
- Wear **insulating gloves** when handling live electrical components.
- Wear **safety gloves** for mechanical handling (e.g., sharp edges, heavy parts, hot surfaces).

### Equipment modification

Do not modify the equipment without prior written permission of Festo Didactic. The equipment was designed in accordance with various regulations (safety, electromagnetic compatibility, etc.). Modifications could have undesired consequences on product integrity and safety.

The use or installation of spare parts by unqualified persons, as well as any repair or modifications not complying with the product's original specifications and manufacturing methods, can cause material damage, serious injury, or even death. It may also void any warranty or product approval.



## Equipment Description

This section identifies the main components (connectors, controls, displays, indicators, etc.) on the equipment. It may also provide safety directives and/or operating instructions specific to certain pieces of equipment as well as instructions for the replacement of parts in the equipment.

The following modules are covered:

- **Control modules**
  - Data Acquisition and Control Interface (594500)
  - 4 Quadrant Power Supply and Dynamometer Controller (594828)
  
- **Power supplies**
  - 3AC Power Supply and Safety Unit (594826)
  - 3AC 400V/DC 230V Power Supply (594825)
  - AC 230V Power Supply (595930)
  - AC 230V/DC 325V Variable Power Supply (8089266)
  - AC 24V Power Supply (772050)
  - DC Motor Power Supply (8111319)
  
- **Loads**
  - Resistive load (594820)
  - Wind Turbine Load Resistors (594819)
  - Inductive Load (594821)
  - Capacitive Load (594822)
  
- **Rotating machines**
  - 4 Quadrant Dynamometer Motor (595062)
  - Squirrel-Cage Induction Machine (595064)
  - Synchronous Machine (595802)
  - Permanent Magnet DC Machine (8100085)

- **Power electronics**
  - DC 48V PWM Charge Controller (595051)
  - DC 48V MPPT Charge Controller (595050)
  - 1AC 230V Stand-Alone Inverter (595052)
  - 1AC 230V Grid-Tied Inverter (595053)
  - Rectifier and Filtering Inductors/Capacitors (8136516)
  - IGBT Chopper/Inverter (8167609)
  - 3AC Filter (8166653)
  - Power Thyristors (8167245)
  
- **Renewable energies**
  - Wind Turbine Generator and Controller (595061)
  - Solar Panel Test Bench (595057)
  - Monocrystalline Silicon Solar Panel (595058)
  - 1AC 230V Energy Meter (594904)
  - Pyranometer (579784)
  
- **Transformers**
  - 3AC Transformer Bank (594823)
  - 1AC Transformer (594824)
  
- **Lamps**
  - DC 48V Lamps (595055)
  - AC 230V Lamps (595056 and 595149)
  - Synchronization Lamps and Contactor (8100086)
  - Synchronization Lamps and Contactor (8208627)
  
- **Batteries**
  - 12V Lead-Acid Batteries (595060)
  - 48V Lead-Acid Battery Pack (595059 and 8174051)
  
- **Various**
  - Communications Gateway (595054)
  - Soft Starter (8121090)

## Data Acquisition and Control Interface (594500)

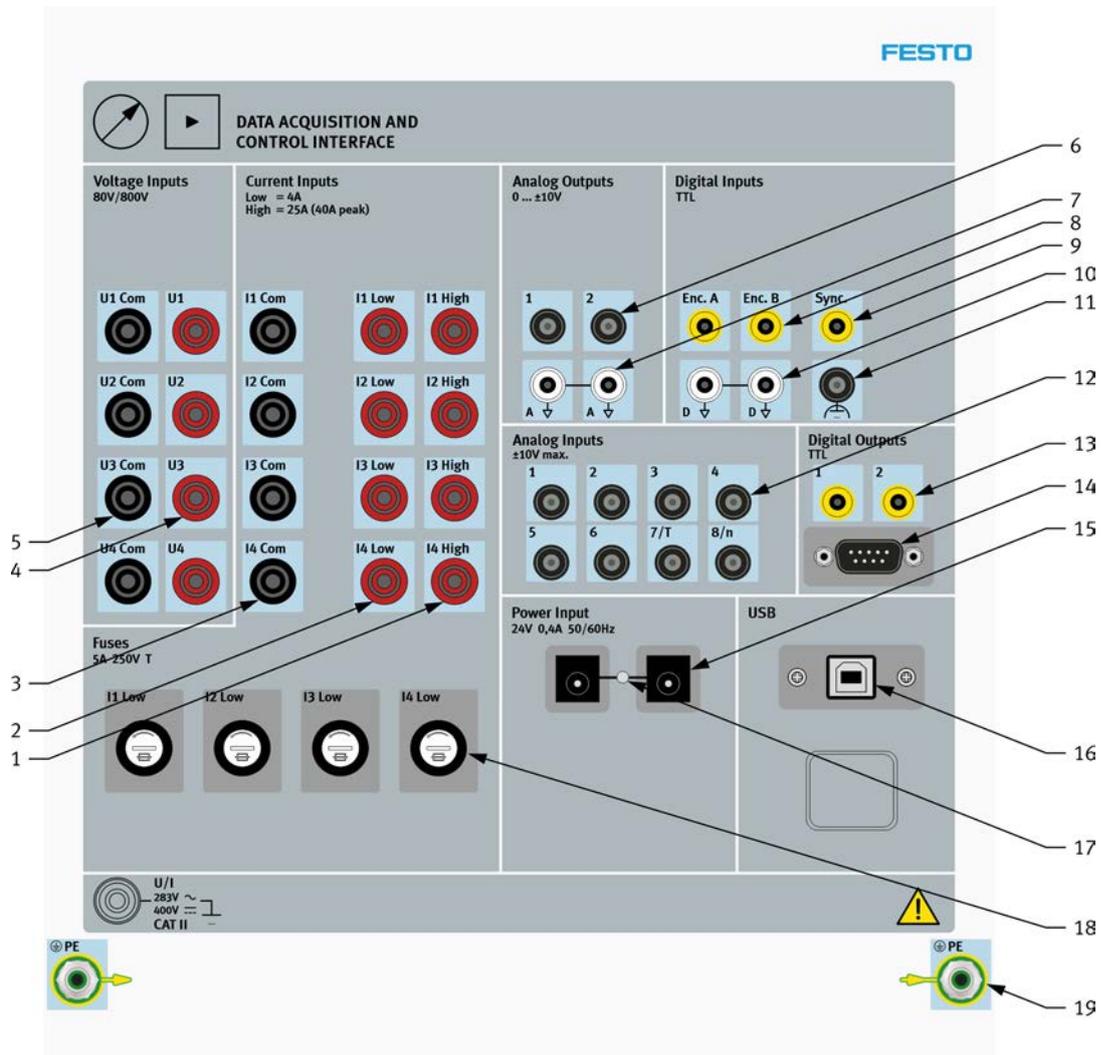


Figure 23: Front panel of the Data Acquisition and Control Interface module.

Table 3: Description of the Data Acquisition and Control Interface module.

Number	Component name
1	Current Inputs, high-range (25 A terminals I1, I2, I3, and I4)
2	Current Inputs, low-range (4 A terminals I1, I2, I3, and I4)
3	Common terminals (4) of the Current Inputs
4	Voltage Inputs (terminals U1, U2, U3, and U4)

Number	Component name
5	Common terminals (4) of the Voltage Inputs
6	Analog Outputs 1 and 2
7	Common terminals (2) of Analog Outputs 1 and 2
8	Encoder A and B Digital Inputs
9	Sync. Digital Input
10	Common terminals (2) of the Digital Inputs and Outputs
11	Functional earth terminal
12	Analog Inputs 1, 2, 3, 4, 5, 6, 7/T, and 8/n
13	Digital Outputs 1 and 2 terminals
14	Digital Outputs 1 and 2 connector
15	Power Input connectors (2)
16	USB port connector
17	Power-on LED indicator
18	Current Inputs (low range) fuses (4)
19	Protective earthing terminals (2)

	 <b>WARNING</b>
	<p><b>Risk of electric shock when auxiliary power comes from a 24 V ac power source not certified for operation with CAT II circuits!</b></p> <p>Always use a doubly-insulated 24 V ac power source, such as the Festo Didactic AC 24V Power Supply, to feed the equipment with auxiliary power.</p>

### NOTICE

The Data Acquisition and Control Interface 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.

#### Fuse replacement

Use specified fuses only with the correct current rating and tripping characteristic.

#### Installing the LVDAC-EMS software



This equipment can be used in conjunction with the LVDAC-EMS software for additional measurement options and control functions. The following procedure describes how to install the LVDAC-EMS software.

1. Open a Windows session as an administrator.
2. Uninstall any version of LVDAC-EMS software that might be present on your computer.



If an older version of the LVDAC-EMS software is present on your computer, launching software installation will cause the old version to be removed, and you will then have to launch the installation again for installation of the new version to actually take place.

3. Download the LVDAC-EMS software as a LVDacEms\*\*\*\*\*.zip file here:



LVDAC-EMS

[https://bit.ly/  
9063-00\\_data\\_acquisition\\_and\\_control\\_interface](https://bit.ly/9063-00_data_acquisition_and_control_interface)

When the LVDacEms\*\*\*\*\*.zip file download has completed, extract all compressed (zipped) files to the desired folder on your computer. In the extracted files, find and run the Setup.exe file and follow the indications provided by the LVDAC-EMS Installation Wizard to complete software installation.

4. The installation is now complete.

## 4 Quadrant Power Supply and Dynamometer Controller (594828)

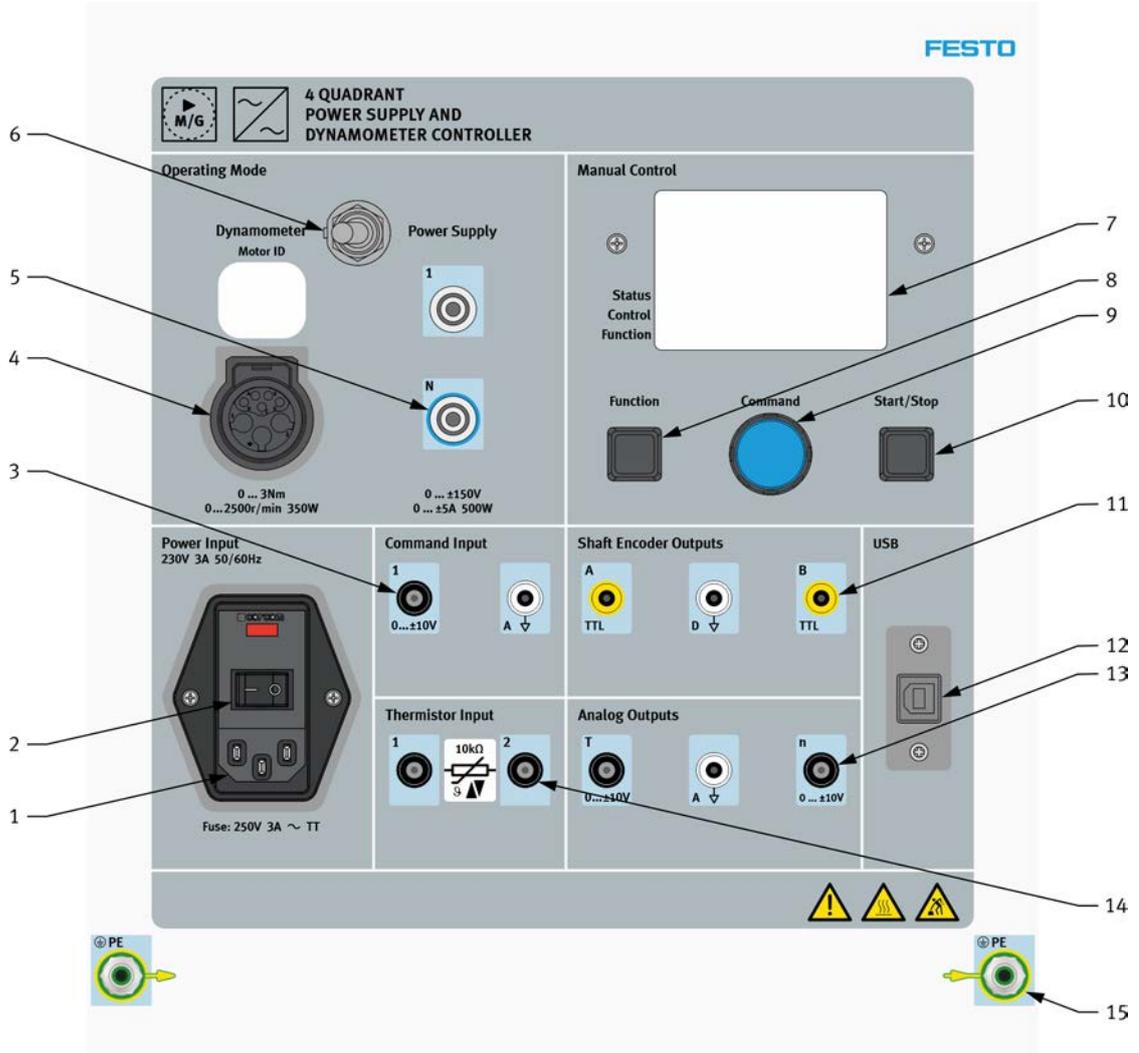


Figure 24: Front panel of the 4 Quadrant Power Supply and Dynamometer Controller module.

Table 4: Description of the 4 Quadrant Power Supply and Dynamometer Controller module.

Number	Component name
1	Power Input connector with fuse holder
2	Main power switch
3	Command input

Number	Component name
4	4 Quadrant Dynamometer Motor connector
5	Power Supply terminals (terminals 1 and N)
6	Operating Mode switch
7	Liquid crystal display (LCD)
8	Function push-button
9	Command knob
10	Start/Stop push-button
11	Shaft Encoder Outputs A and B
12	USB port connector
13	Analog Outputs T and n
14	Thermistor Input
15	Protective earthing terminals (2)

### Fuse replacement

Remove the detachable line cord from the unit to allow opening of the fuse holder. Use the specified fuses only with the correct current rating and tripping characteristic.

	 <b>WARNING</b>
	<p><b>Risk of fire and/or explosion when trying to charge non-rechargeable batteries!</b></p> <ul style="list-style-type: none"> <li>• Charging non-rechargeable batteries may cause dangerous chemicals to escape from the batteries which represents a risk of fire and/or explosion.</li> <li>• Never attempt to charge non-rechargeable batteries using the 4 Quadrant Power Supply and Dynamometer Controller.</li> </ul>

**Table 5: Main specifications of the 4 Quadrant Power Supply and Dynamometer Controller.**

Parameter	Rating
Input	3.0 A, 230 V – 50/60 Hz, 1 phase, including line, neutral, and earth wires, protected by a circuit breaker in accordance with local regulations.
Mounting	Designed for DIN A4 mounting frames
Ingress protection rating	IP20
Electromagnetic compatibility	Group 1, Class A (industrial environment, EN 55011)
Dimensions (H x W x D)	297 x 266 x 140 mm (11.69 x 10.47 x 5.51 in)
Weight	X kg (X lb)
CE and UKCA markings	<ul style="list-style-type: none"> <li>● Low-Voltage Directive</li> <li>● EMC Directive</li> <li>● RoHS Directive</li> </ul>

### Installing the LVDAC-EMS software



This equipment can be used in conjunction with the LVDAC-EMS software for additional measurement options and control functions. The following procedure describes how to install the LVDAC-EMS software.

1. Open a Windows session as an administrator.
2. Uninstall any version of LVDAC-EMS software that might be present on your computer.



If an older version of the LVDAC-EMS software is present on your computer, launching software installation will cause the old version to be removed, and you will then have to launch the installation again for installation of the new version to actually take place.

3. Download the LVDAC-EMS software as a LVDacEms\*\*\*\*\*.zip file here:



LVDAC-EMS

[https://bit.ly/  
9063-00\\_data\\_acquisition\\_and\\_control\\_interface](https://bit.ly/9063-00_data_acquisition_and_control_interface)

When the LVDacEms\*\*\*\*\*.zip file download has completed, extract all compressed (zipped) files to the desired folder on your computer. In the extracted files, find and run the Setup.exe file and follow the indications provided by the LVDAC-EMS Installation Wizard to complete software installation.

4. The installation is now complete.

### **3AC Power Supply and Safety Unit (594826)**

The 3AC Power Supply and Safety Unit provides power to circuits. It can operate as any of the following:

- Three-phase ac power source
- Single-phase ac power source

The 3AC Power Supply and Safety Unit provides power to and removes power from the circuits in the practical exercises. It must be connected to a three-phase power outlet. The module is equipped with two types of circuit breakers and an emergency switch push button.

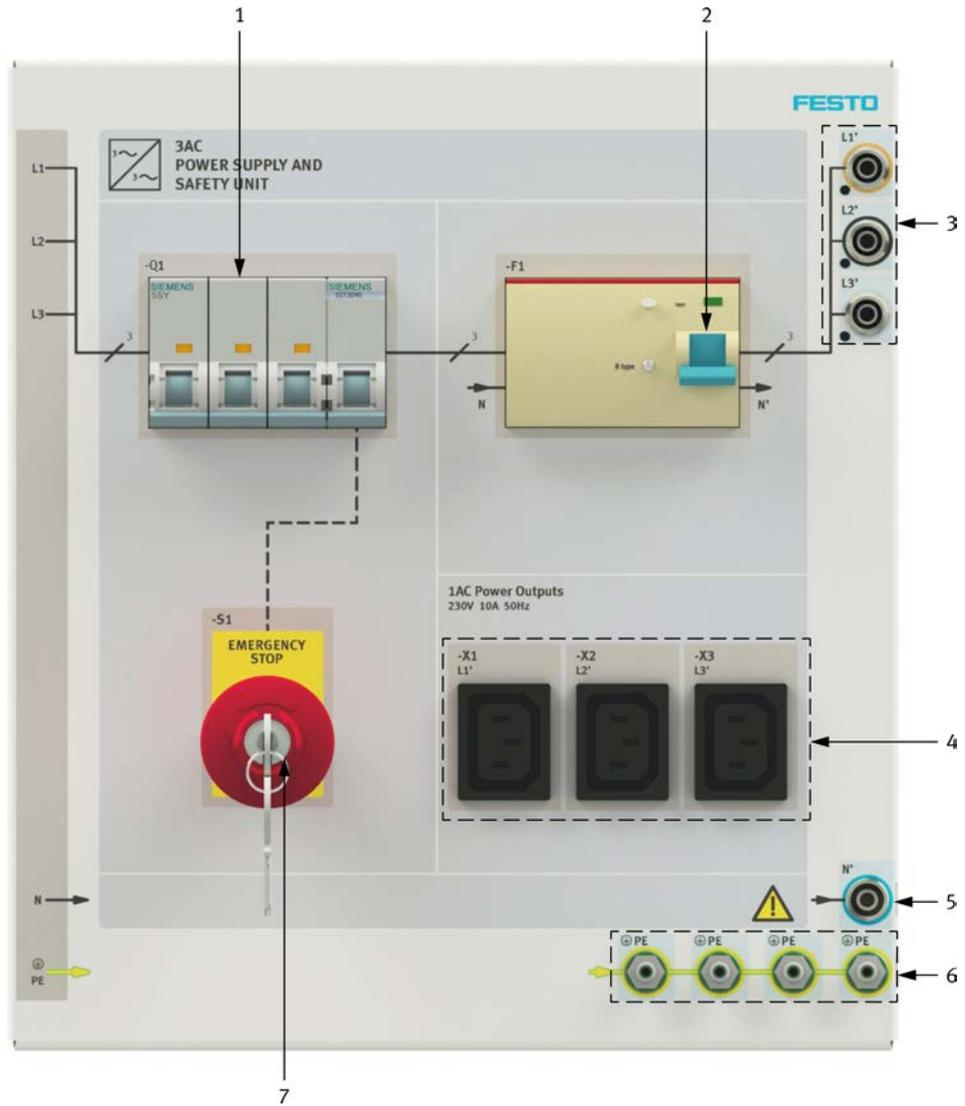


Figure 25: 3AC Power Supply and Safety Unit (594826).

**Table 6: Components of the 3AC Power Supply and Safety Unit (594826).**

Number	Component	Description
1	Three-pole circuit breaker with undervoltage release	Protection against short circuits.
2	Residual current circuit breaker	Protection that disconnects the circuit in case of current leakage.
3	Three-phase ac power output	Output terminals for each of the three lines (L1', L2', L3'). Near each terminal is an LED that lights up when that terminal is powered.
4	Single-phase ac power outlets	Standard power outlets.
5	Neutral output	Output terminal for the neutral line.
6	Protective earthing terminals	Terminals that provide protective earthing to the module and any connected module.
7	Lockable power-on switch and emergency stop button	Protection that removes power from the circuit when depressed. A key is required to reset the push button.

	 <b>WARNING</b>
	<p>Always connect a ground terminal of each module in your setup to a ground terminal of a 3AC Power Supply and Safety Unit.</p>

	 <b>CAUTION</b>
	<p>Do not leave the key in the power-on switch after locking or unlocking it. If you need to rapidly press on the emergency stop button, the presence of a key in the switch could cause a hand injury.</p>

**Table 7: Main specifications of the 3AC Power Supply and Safety Unit (594826).**

Parameter	Rating
Input power	<ul style="list-style-type: none"> <li>• Maximum current: 10 A</li> <li>• AC power network voltage and frequency: 230/400 V – 50 Hz</li> <li>• Electrical installation: 3 phases, star (wye) configuration including neutral and earth wires, protected by a 20 A circuit breaker.</li> </ul>
Output	3 AC 400 V, 50 Hz, 10 A (max)
Protections	Short circuit and overload
RCD protection	Type B, 30 mA
Outputs	<ul style="list-style-type: none"> <li>• Three-phase output via 4 mm safety sockets with pilot lights indicating voltage presence</li> <li>• Three single-phase IEC C13 outlets</li> </ul>
Mounting	Designed for DIN A4 mounting frames
Ingress protection rating	IP20
Electromagnetic compatibility	Group 1, Class A (industrial environment, EN 55011)
Dimensions (H x W x D)	297 x 266 x 140 mm (11.69 x 10.47 x 5.51 in)
Weight	4.6 kg (10.14 lb)
CE and UKCA markings	<ul style="list-style-type: none"> <li>• Low-Voltage Directive</li> <li>• EMC Directive</li> <li>• RoHS Directive</li> </ul>

### 3AC 400V/DC 230V Power Supply (594825)

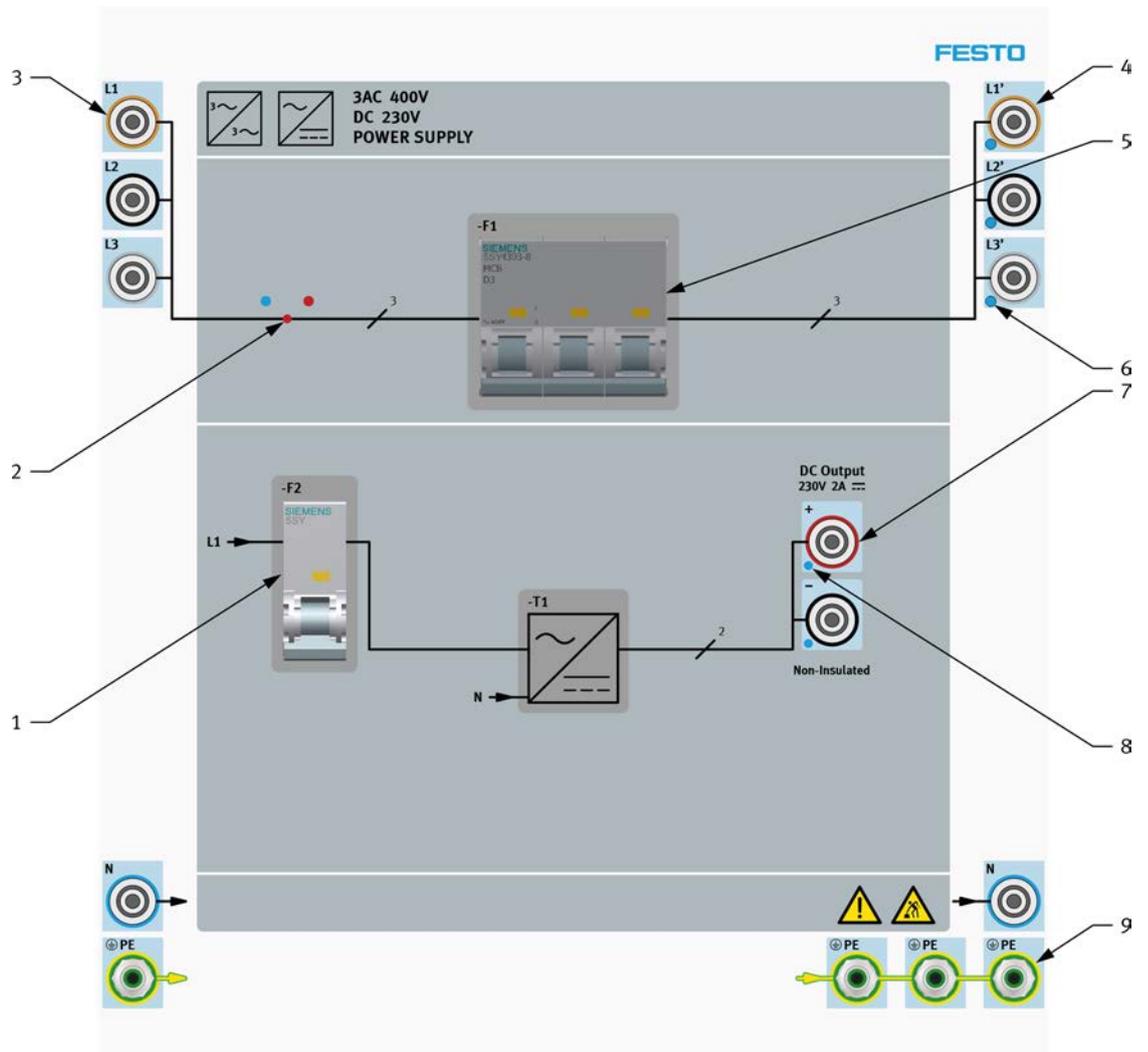


Figure 26: Front panel of the 3AC 400V/DC 230V Power Supply.

**Table 8: Description of the 3AC 400V/DC 230V Power Supply.**

Number	Component name
1	Single-pole circuit breaker, class C, 3 A
2	Phase sequence LED indicator
3	Three-phase ac power input (terminals L1, L2, L3, and N)
4	Three-phase ac power output (terminals L1', L2', L3', and N)
5	Three-pole circuit breaker, class C, 3 A
6	AC output power-on LED indicators (L1', L2', and L3')
7	DC Output (terminals + and -)
8	DC Output power-on LED indicators (2)
9	Protective earthing terminals (4)

**Table 9: Main specifications of the 3AC 400V/DC 230V Power Supply.**

Components and parameters	Main specifications
Input	3 A, 230/400 V – 50 Hz, 3 phases, star (wye) configuration, including neutral and earth wires, protected by a circuit breaker in accordance with local regulations.
Output	<ul style="list-style-type: none"> <li>• 3 AC, 400 V, 3 A (max.), protected against short circuits and overloads</li> <li>• DC, 230 V, 2 A (max.), protected against short circuits and overloads</li> </ul>
Features	<ul style="list-style-type: none"> <li>• Phase sequence indicator</li> <li>• Indicator for presence of output voltage per phase</li> <li>• Lockable emergency stop</li> </ul>
Mounting	Designed for DIN A4 mounting frames
Ingress protection rating	IP20

Components and parameters	Main specifications
Electromagnetic compatibility	Group 1, Class A (industrial environment, EN 55011)
Dimensions (H x W x D)	297 x 266 x 140 mm (11.69 x 10.47 x 5.51 in)
Weight	5.9 kg (13 lb)
CE and UKCA markings	<ul style="list-style-type: none"> <li>• Low-Voltage Directive</li> <li>• EMC Directive</li> <li>• RoHS Directive</li> </ul>

### AC 230V Power Supply (595930)

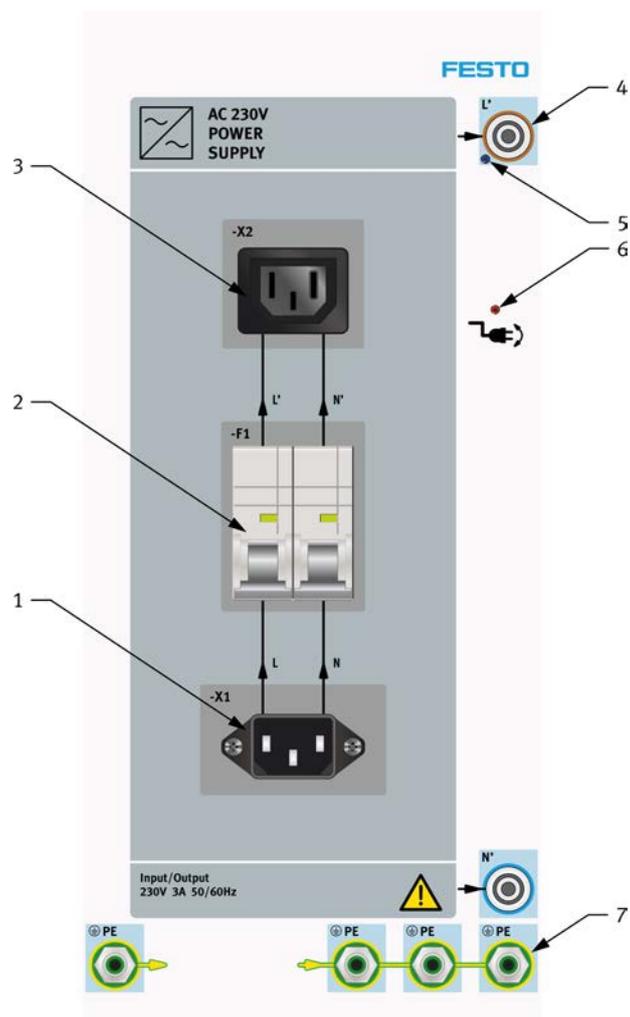


Figure 27: Front panel of the AC 230V Power Supply module.

**Table 10: Description of the AC 230V Power Supply module.**

Number	Component name
1	Power input connector
2	Two-pole circuit breaker, class C, 3 A
3	Single-phase ac power outlet
4	Single-phase ac power output (terminals L' and N')
5	Power-on LED indicator
6	Line-neutral reversed LED indicator. Do not operate the module when this LED is on.
7	Protective earthing terminals (4)

**Table 11: Main specifications of the AC 230V Power Supply module.**

Components and parameters	Main specifications
Input	3 A, 230 V – 50/60 Hz, 1 phase, including line, neutral, and earth wires,, protected by a circuit breaker in accordance with local regulations.
Output	3 AC 230 V, 50 Hz
Mounting	Designed for DIN A4 mounting frames
Ingress protection rating	IP20
Electromagnetic compatibility	Group 1, Class A (industrial environment, EN 55011)
Dimensions (H x W x D)	297 x 266 x 140 mm (11.69 x 10.47 x 5.51 in)
Weight	X kg (X lb)
CE and UKCA markings	<ul style="list-style-type: none"> <li>● Low-Voltage Directive</li> <li>● EMC Directive</li> <li>● RoHS Directive</li> </ul>

### AC 230V/DC 325V Variable Power Supply (8089266)

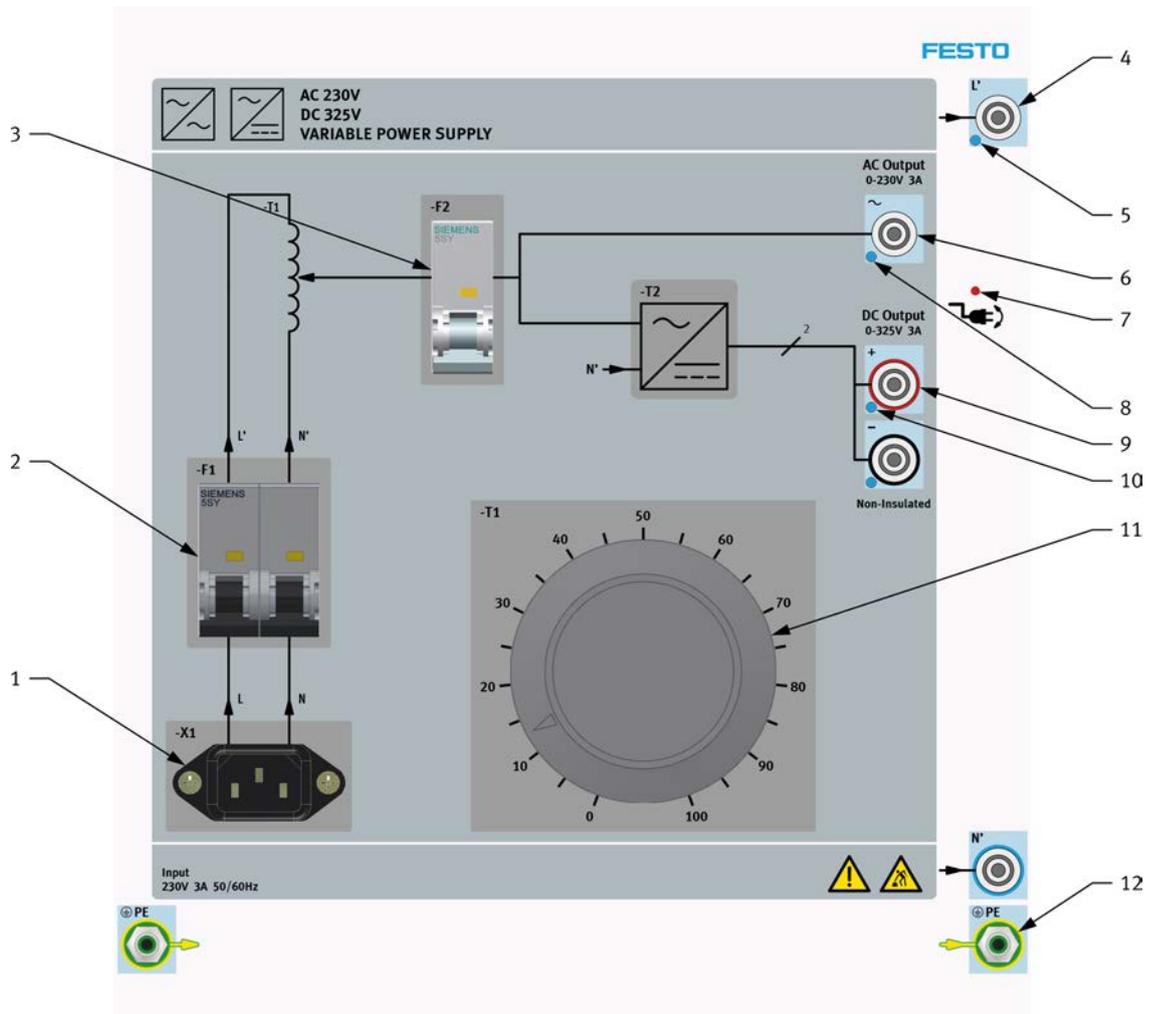


Figure 28: Front panel of the AC 230V/DC 325V Variable Power Supply module.

**Table 12: Description of the AC 230V/DC 325V Variable Power Supply module.**

Number	Component name
1	Power input connector
2	Two-pole circuit breaker, class C, 3 A
3	Single-pole circuit breaker, class C, 3 A
4	Fixed-voltage ac power output (terminals L' and N')
5	Fixed-voltage ac output power on LED indicator
6	Variable-voltage AC Output (terminals ~ and N')
7	Line-neutral reversed LED indicator. Do not operate the module when this LED is on.
8	Variable-voltage AC Output power on LED indicator
9	Variable-voltage DC Output (terminals + and -)
10	Variable-voltage DC Output power on LED indicators (2)
11	Voltage control knob
12	Protective earthing terminals (2)

**Table 13: Main specifications of the AC 230V/DC 325V Variable Power Supply module.**

Parameter	Rating
Input	3 A, 230 V – 50/60 Hz, 1 phase, including neutral and earth wires, protected by a circuit breaker in accordance with local regulations.
Output	3 AC 230 V, 50 Hz
Mounting	Designed for DIN A4 mounting frames
Ingress protection rating	IP20
Electromagnetic compatibility	Group 1, Class A (industrial environment, EN 55011)
Dimensions (H x W x D)	297 x 266 x 140 mm (11.69 x 10.47 x 5.51 in)
Weight	X kg (X lb)
CE and UKCA markings	<ul style="list-style-type: none"> <li>● Low-Voltage Directive</li> <li>● EMC Directive</li> <li>● RoHS Directive</li> </ul>

## AC 24V Power Supply (772050)

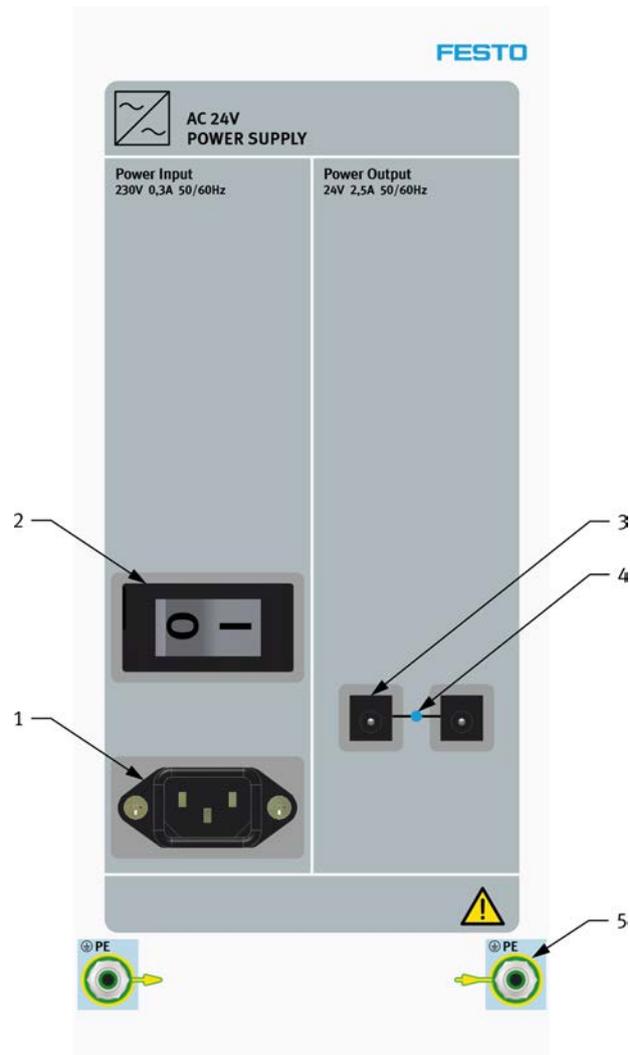


Figure 29: Front panel of the AC 24V Power Supply module.

**Table 14: Description of the AC 24V Power Supply module.**

Number	Component name
1	Power Input connector
2	Main power switch with thermal circuit breaker
3	Power Output connectors (2)
4	Power-on LED indicator
5	Protective earthing terminals (2)

**Table 15: Main specifications of the AC 24V Power Supply module.**

Components and parameters	Main specifications
Input	0.3 A A, 230 V – 50/60 Hz, 1 phase, including neutral and earth wires, protected by a circuit breaker in accordance with local regulations.
Mounting	Designed for DIN A4 mounting frames
Ingress protection rating	IP20
Electromagnetic compatibility	Group 1, Class A (industrial environment, EN 55011)
Dimensions (H x W x D)	297 x 266 x 140 mm (11.69 x 10.47 x 5.51 in)
Weight	X kg (X lb)
CE and UKCA markings	<ul style="list-style-type: none"> <li>● Low-Voltage Directive</li> <li>● EMC Directive</li> <li>● RoHS Directive</li> </ul>

## DC Motor Power Supply (8111319)

The DC Motor Power Supply is an A4 module that provides electrical supplies for electrical machines where dc power is required. It is dedicated only to motor applications and is not meant as a standard dc power supply for other applications. It provides the following:

- A fixed 210 V dc power supply.
- A variable dc power supply from 0 V to 240 V. This supply is adjustable using the front panel knob and digital display.

A second front-panel knob allows the current to be limited during startup in motor applications. It is not designed to limit overcurrents over a long period of time (about three seconds or more). If this happens (e.g., if the rotor is jammed or an unexpected motor overcurrent occurs), the limiter will trigger a fault and the power supply will turn off.

The current limit should be set just over the motor's nominal rating or the desired load rating. This way, the limiter will only activate briefly during motor startup and short overcurrents, without triggering a fault.

**Table 16: Description of the DC Motor Power Supply module.**

Number	Component name
1	Voltage control knob (Vset)
2	Reset push-button. This button resets the overload protection when it is tripped.
3	Overload (OL) LED indicator
4	Current limit control knob (Imax)
5	Fuse holder of variable dc power supply
6	Three-phase ac power bus (terminals L1, L2, L3, and N)
7	Fixed dc power supply output (terminals + and -)
8	Fixed dc power supply output LED indicators (2)
9	Variable dc power supply output (terminals + and -)
10	Variable dc power supply output on LED indicators (2)
11	Voltmeter display
12	Variable dc power supply on (I)/off (O) switch
13	Protective earthing terminals (2)
14	Variable dc power supply on LED indicator

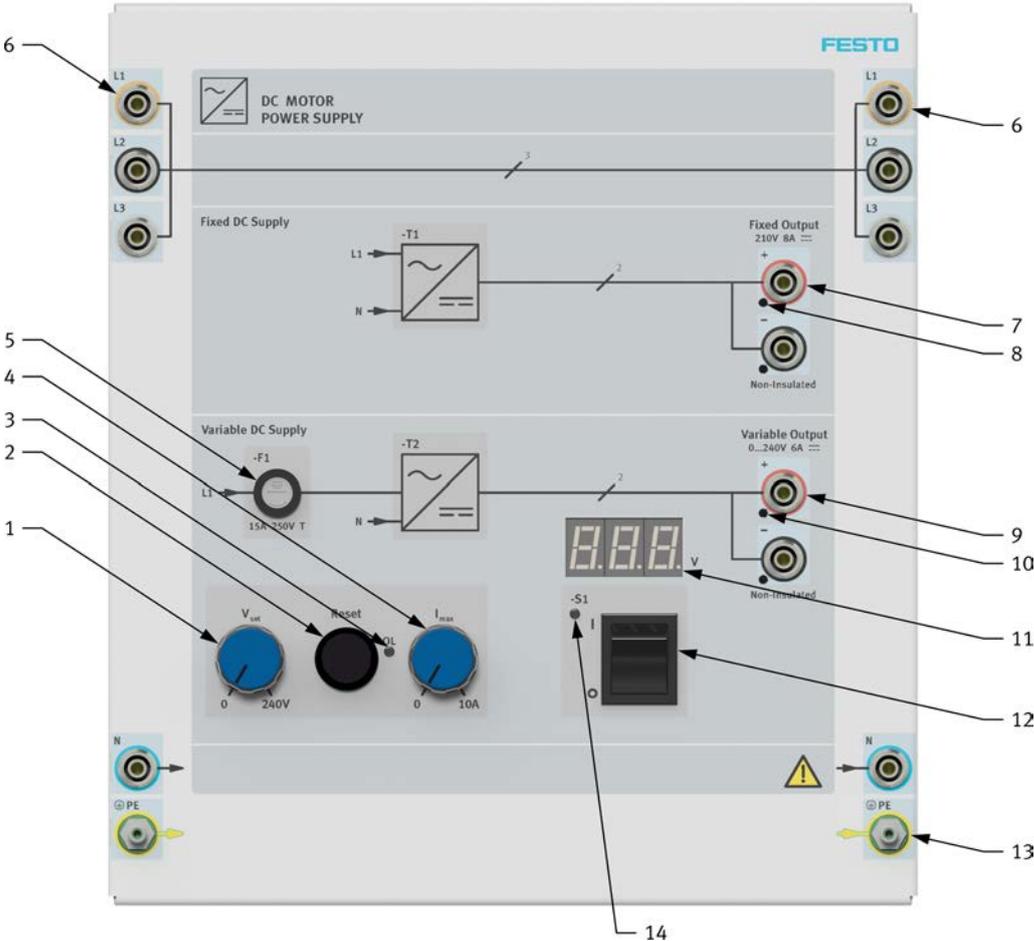


Figure 30: Front panel of the DC Motor Power Supply module.

**Table 17: Main specifications of the DC Motor Power Supply module.**

Parameter	Rating
Input	16 A, 230/400 V – 50 Hz, 3 phases, star (wye) configuration, including neutral and earth wires, protected by a circuit breaker in accordance with local regulations.
Mounting	Designed for DIN A4 mounting frames
Ingress protection rating	IP20
Electromagnetic compatibility	Group 1, Class A (industrial environment, EN 55011)
Dimensions (H x W x D)	297 x 266 x 140 mm (11.69 x 10.47 x 5.51 in)
Weight	X kg (X lb)
CE and UKCA markings	<ul style="list-style-type: none"> <li>● Low-Voltage Directive</li> <li>● EMC Directive</li> <li>● RoHS Directive</li> </ul>

### Resistive Load (594820)

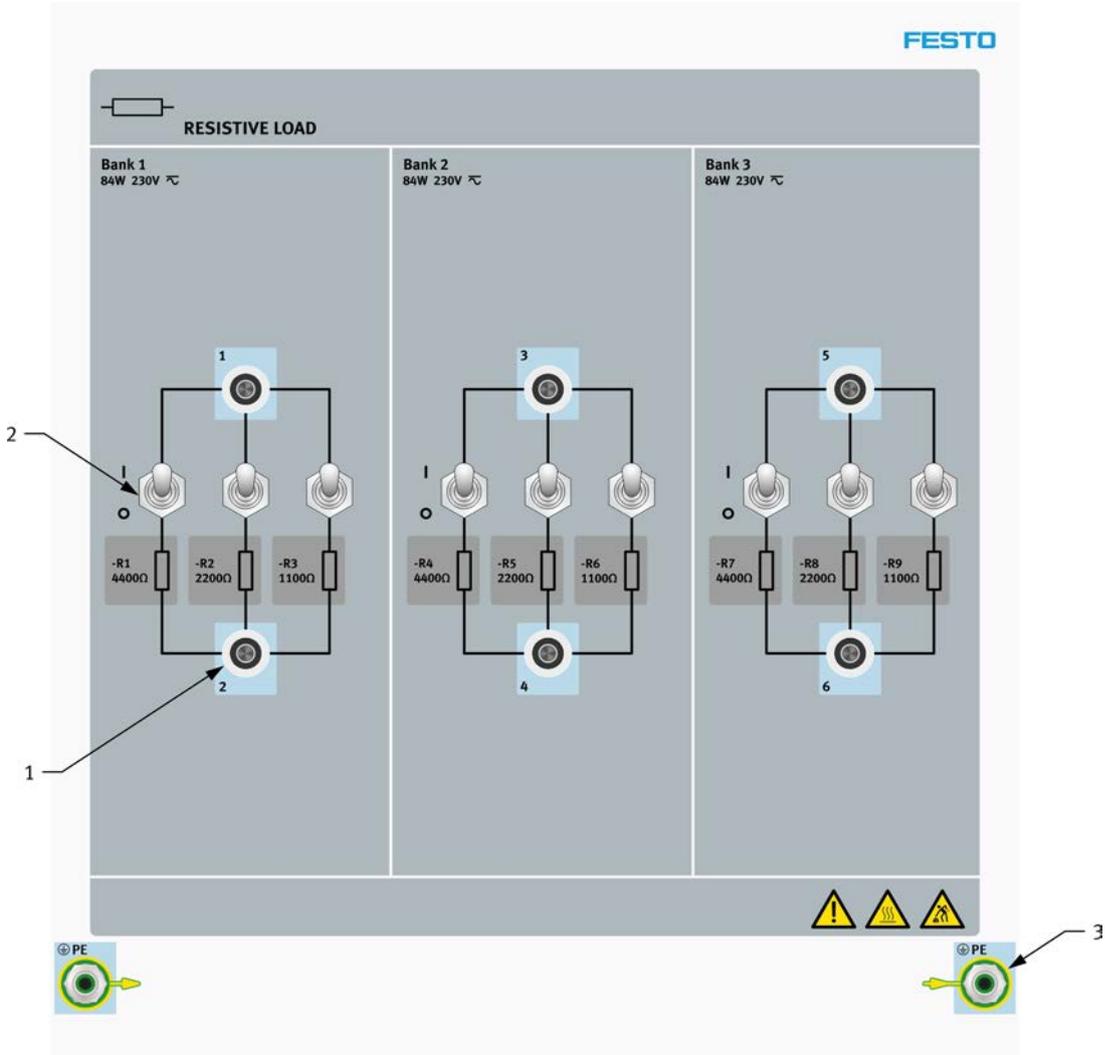


Figure 31: Front panel of the Resistive Load module.

**Table 18: Description of the Resistive Load module.**

Number	Component name
1	Resistive load terminals (6)
2	Toggle switches (9)
3	Protective earthing terminals (2)

### Intermittent use at voltages exceeding the nominal value

The Resistive Load can be used intermittently at voltages exceeding the nominal value, without damage to the unit, provided that the following conditions are respected:

- Maximum voltage: 400 V
- Maximum on-time ( $t_{ON}$ ): 2 min
- Maximum cyclic duration factor [ $t_{ON}/(t_{ON} + t_{OFF})$ ]: 0.091 (1/11)

The on-time ( $t_{ON}$ ) above is the period during which voltage is applied to the Resistive Load. The off-time ( $t_{OFF}$ ) above is the period during which no voltage is applied to the Resistive Load to allow it to cool down.

Consequently, when voltage exceeding the nominal value (without exceeding the maximum value of 400 V) is applied to the Resistive Load during 2 minutes, voltage must be removed from the Resistive Load for at least the next 20 minutes to respect the maximum cyclic duration factor (0.091).

	 <b>CAUTION</b>
	<p><b>Risk of burn when the maximum on-time is exceeded!</b></p> <ul style="list-style-type: none"> <li>• Applying voltage exceeding the nominal value to the Resistive Load for more than the maximum on time (2 min) results in equipment overheating and a risk of burn (by contacting the module housing).</li> <li>• To minimize the above risk of burn, never apply voltage exceeding the nominal value to the Resistive Load for more than the maximum on-time (2 min) permitted.</li> </ul>

<b>NOTICE</b>
<p>Never apply voltage exceeding the nominal value to the Resistive Load for more than the maximum on time (2 min). Failure to respect this condition could result in damage to the Resistive Load due to overheating.</p>

## Wind Turbine Load Resistors (594819)

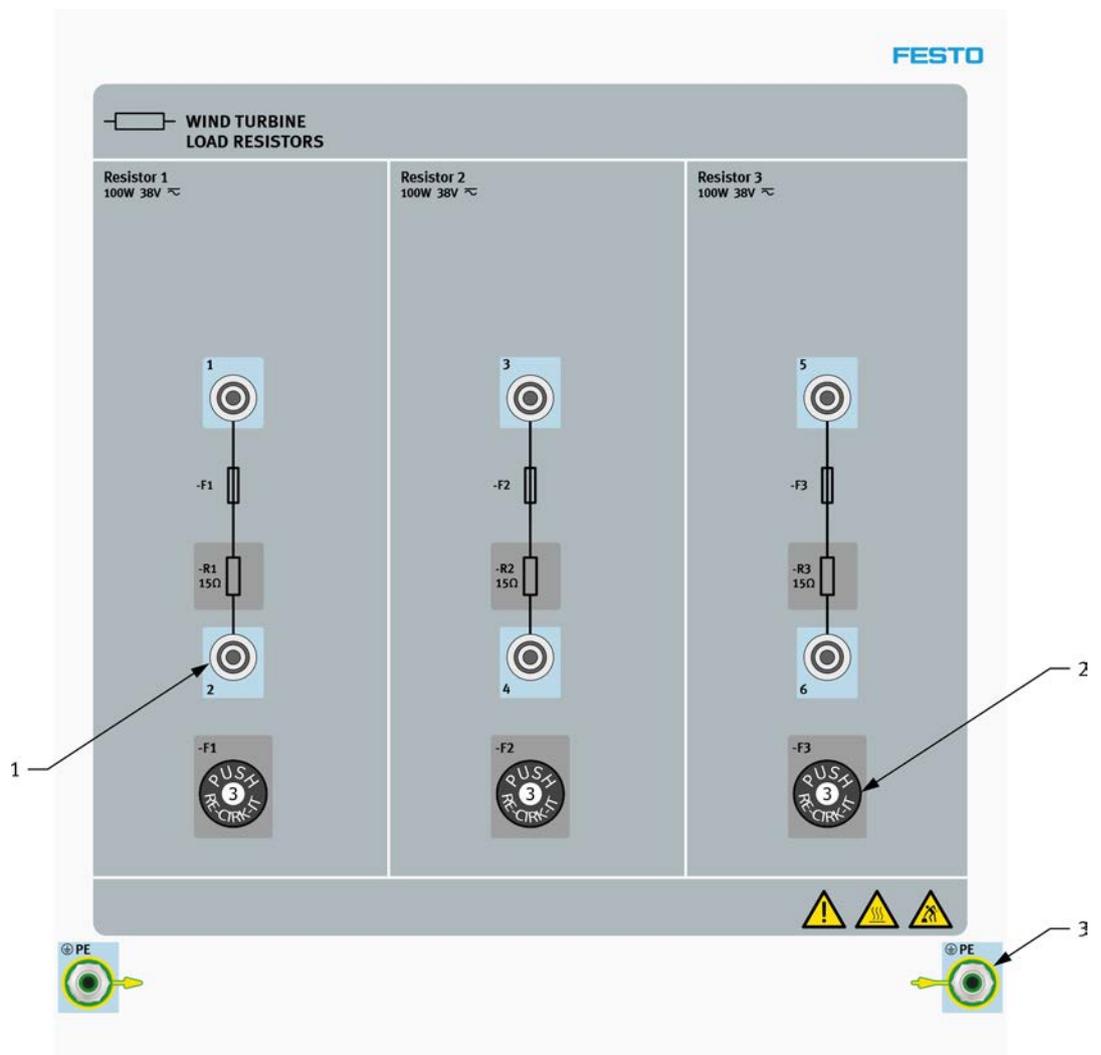


Figure 32: Front panel of the Wind Turbine Load Resistors module.

Table 19: Description of the Wind Turbine Load Resistors module.

Number	Component name
1	Resistive load terminals (6)
2	Circuit-breaker reset buttons (3)
3	Protective earthing terminals (2)

## Inductive Load (594821)

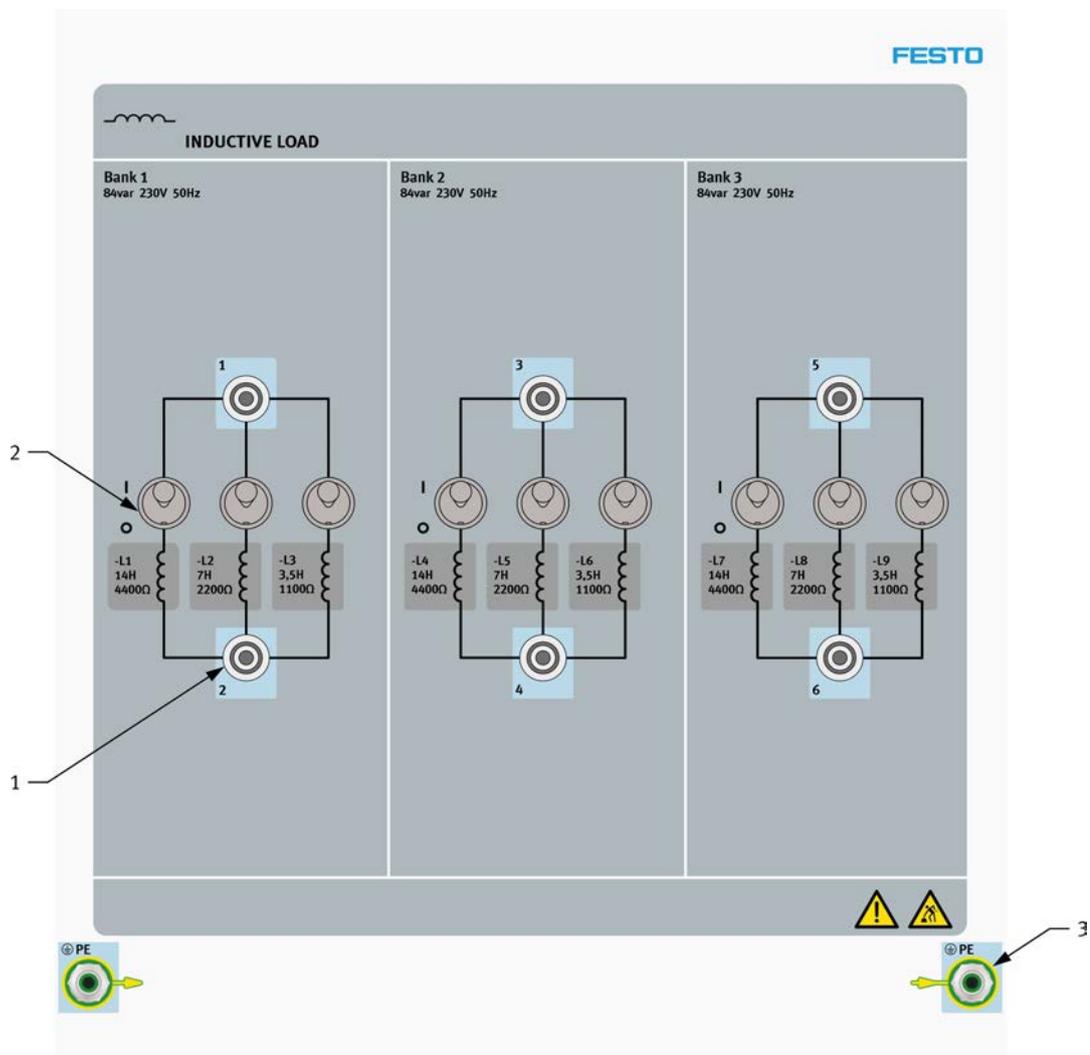


Figure 33: Front panel of the Inductive Load module.

Table 20: Description of the Inductive Load module.

Number	Component name
1	Inductive load terminals (6)
2	Toggle switches (9)
3	Protective earthing terminals (2)

## Capacitive Load (594822)

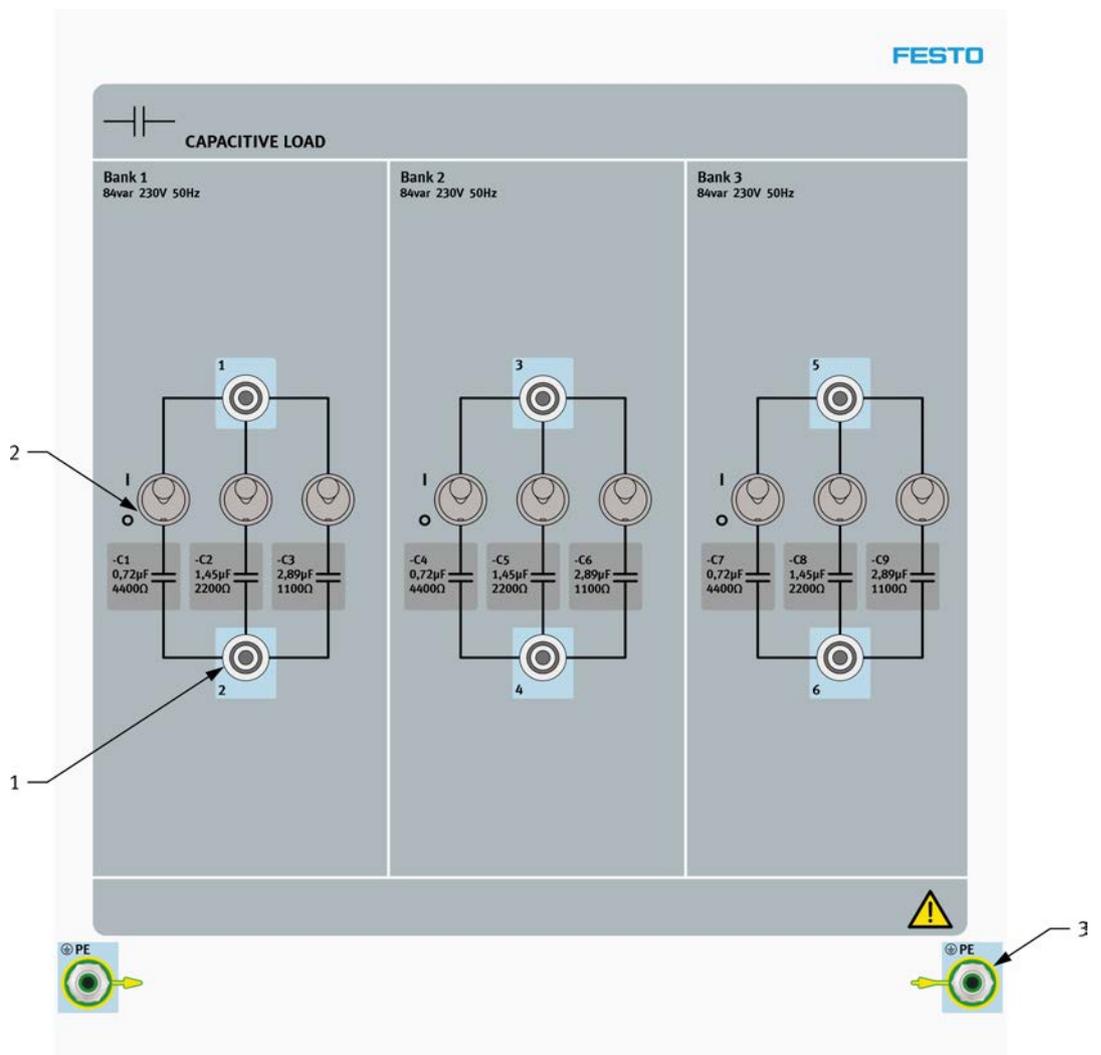


Figure 34: Front panel of the Capacitive Load module.

Table 21: Description of the Capacitive Load module.

Number	Component name
1	Capacitive load terminals (6)
2	Toggle switches (9)
3	Protective earthing terminals (2)

## 4 Quadrant Dynamometer Motor (595062)

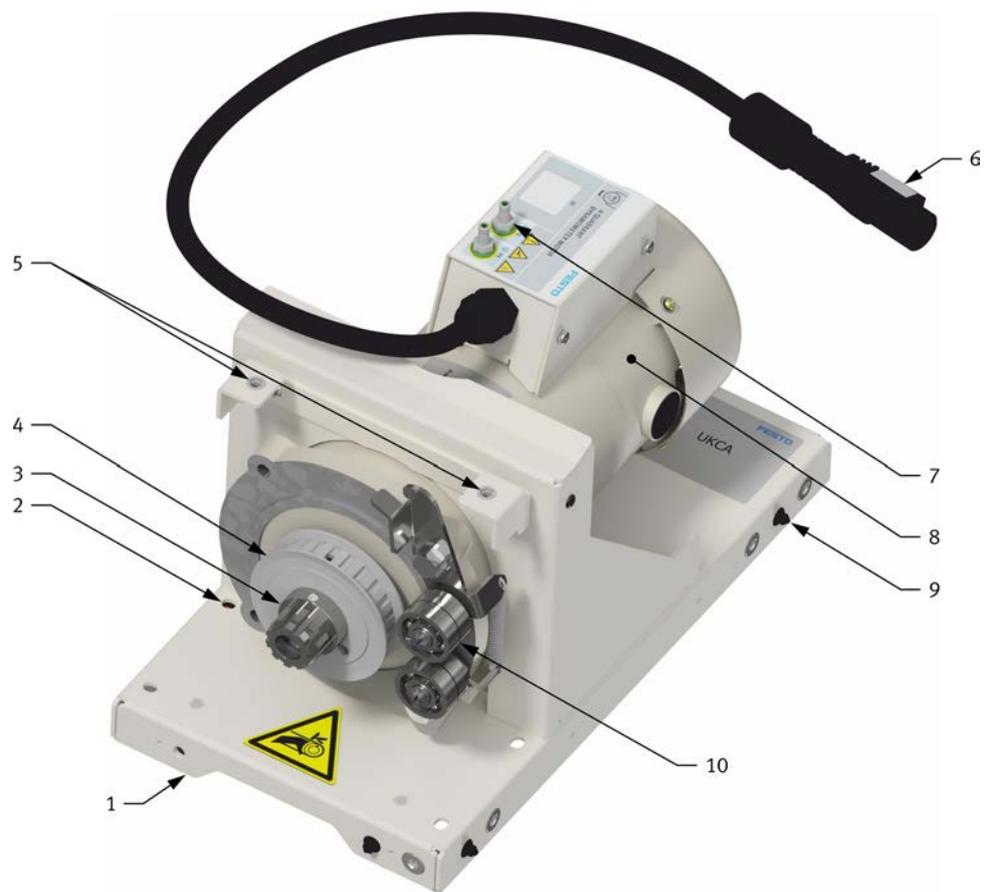


Figure 35: Front panel of the 4 Quadrant Dynamometer Motor.

**Table 22: Description of the 4 Quadrant Dynamometer Motor.**

Number	Component name
1	Base plate guiding hole
2	Limit switch
3	10 teeth gear
4	24 teeth belt pulley
5	Screw holes for securing a protective guard
6	Connection cable
7	Protective earthing terminals (2)
8	Permanent magnet dc motor
9	Base plate guiding pins (3)
10	Belt tensioner

**Table 23: Main specifications of the 4 Quadrant Dynamometer Motor.**

Parameters	Main specifications
Voltage (dc)	90 V
Current (dc)	5.2 A
Power	373 W
Speed	1750 r/min

## Squirrel-Cage Induction Machine (595064)

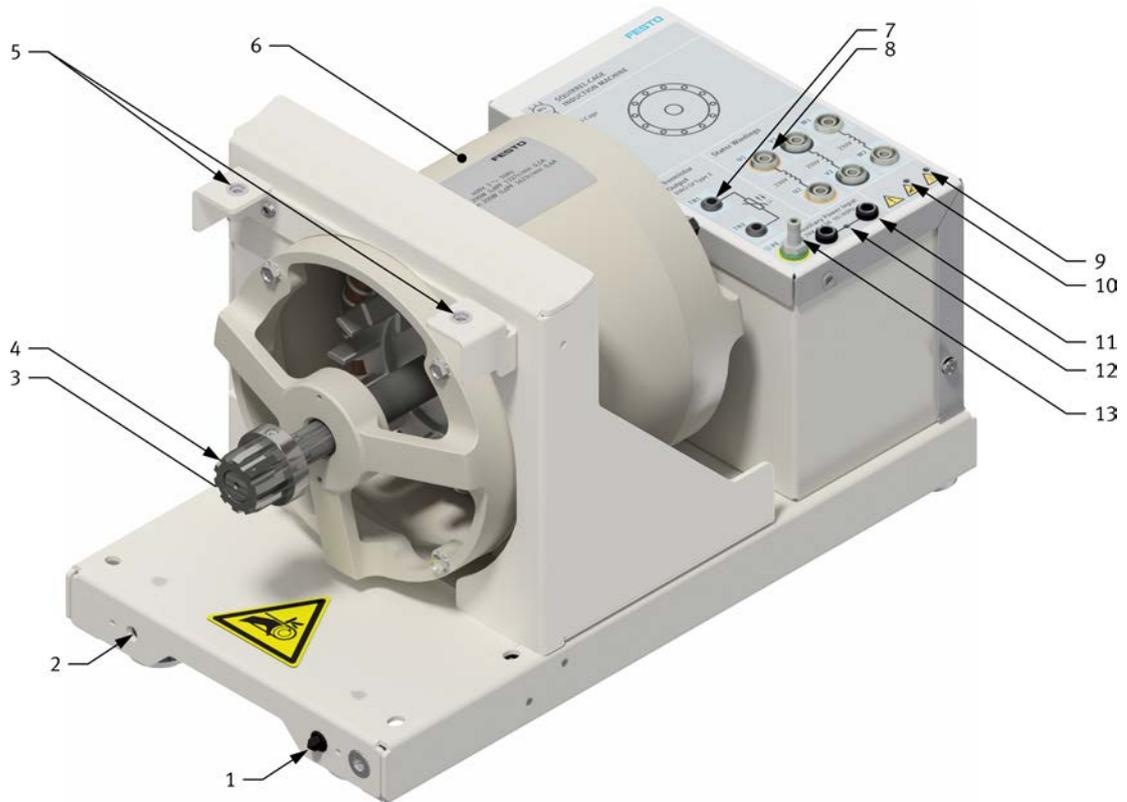


Figure 36: Front panel of the Squirrel-Cage Induction Machine module.

Table 24: Description of the Squirrel-Cage Induction Machine module.

Number	Component name
1	Base-plate guiding pin
2	Base plate guiding hole
3	Limit switch (accessible through hole in baseplate)
4	10 teeth gear
5	Screw holes for securing a protective guard
6	Squirrel-cage induction machine
7	Thermistor Output (terminals TN1 and TN2)

Number	Component name
8	Stator Windings (terminals U1, U2, V1, V2, W1, and W2)
9	Machine overheating LED indicator
10	Protective guard missing LED indicator
11	Auxiliary Power Input connectors (2)
12	Auxiliary power on LED indicator
13	Protective earthing terminal

**Table 25: Main specifications of the Squirrel-Cage Induction Machine.**

Components and parameters	Main specifications
Main power requirements	Delta/wye, 230/400 V, three-phase, 50 Hz
Motor	200 W, 0.8 PF, 1327 r/min, 0.87/0.50 A
Generator	200 W, 0.6 PF, 1623 r/min, 0.69/0.40 A
Auxiliary power input	24 V, 0.13 A, 50/60 Hz

## Synchronous Machine (595802)

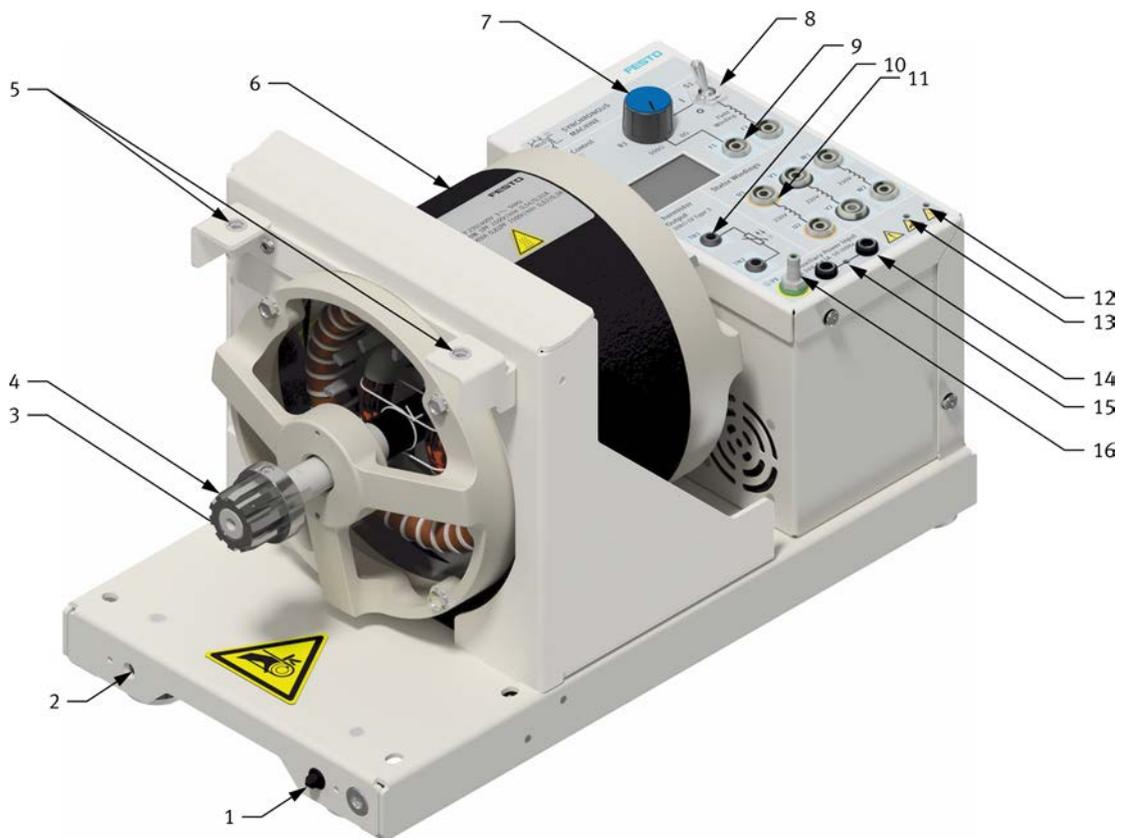


Figure 37: Front panel of the Synchronous Machine module.

Table 26: Description of the Synchronous Machine module.

Number	Component name
1	Base-plate guiding pin
2	Base plate guiding hole
3	Limit switch (accessible through hole in baseplate)
4	10 teeth gear
5	Screw holes for securing a protective guard
6	Synchronous machine
7	Field Control knob (R1)

Number	Component name
8	Field Control switch (S1)
9	Field Winding (terminals F1 and F2)
10	Thermistor Output (terminals TN1 and TN2)
11	Stator Windings (terminals U1, U2, V1, V2, W1, and W2)
12	Machine overheating LED indicator
13	Protective guard missing LED indicator
14	Auxiliary Power Input connectors (2)
15	Auxiliary power on LED indicator
16	Protective earthing terminal

**Table 27: Main specifications of the Synchronous Machine.**

Components and parameters	Main specifications
Main power requirements	Delta/wye, 230/400 V, three-phase, 50 Hz
Motor	200 W, 1.0 PF, 1500 r/min, 0.54/0.31 A
Generator	200 W, 0.81 PF, 1500 r/min, 0.52/0.30 A
Field control (dc)	230 V, 0.60 A
Auxiliary power input	24 V, 0.13 A, 50/60 Hz

## Permanent Magnet DC Machine (8100085)

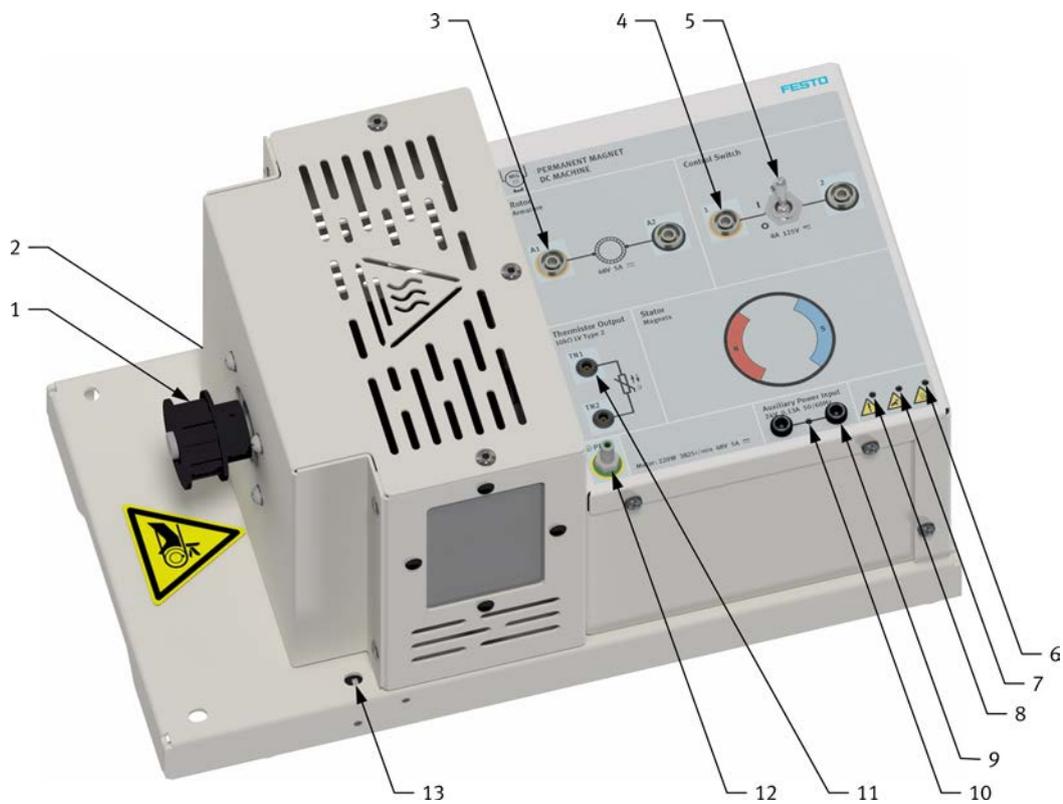


Figure 38: Front panel of the Permanent Magnet DC Machine module.

Table 28: Description of the Permanent Magnet DC Machine module.

Number	Component name
1	12 teeth belt pulley
2	Guiding pin and guiding hole
3	Rotor Armature (terminals A1 and A2)
4	Control Switch terminals (terminals 1 and 2)
5	Control Switch (S1)
6	Machine overheating LED indicator
7	Protective guard missing LED indicator

Number	Component name
8	Rotor overvoltage/overcurrent LED indicator
9	Auxiliary Power Input connectors (2)
10	Auxiliary power on LED indicator
11	Thermistor Output (terminals TN1 and TN2)
12	Protective earthing terminal
13	Limit switch

**Table 29: Main specifications of the Permanent Magnet DC Machine module.**

Components and parameters	Main specifications
Motor	220 W, 3825 r/min, 48 V, 5 A, dc
Rotor armature	48 V, 5 A, dc
Control switch	8 A, 125 V, ac
Thermistor output	10 k $\Omega$ , LV type 2
Auxiliary power input	24 V, 0.13 A, 50/60 Hz

## Capacitor-Start Motor (8100743)

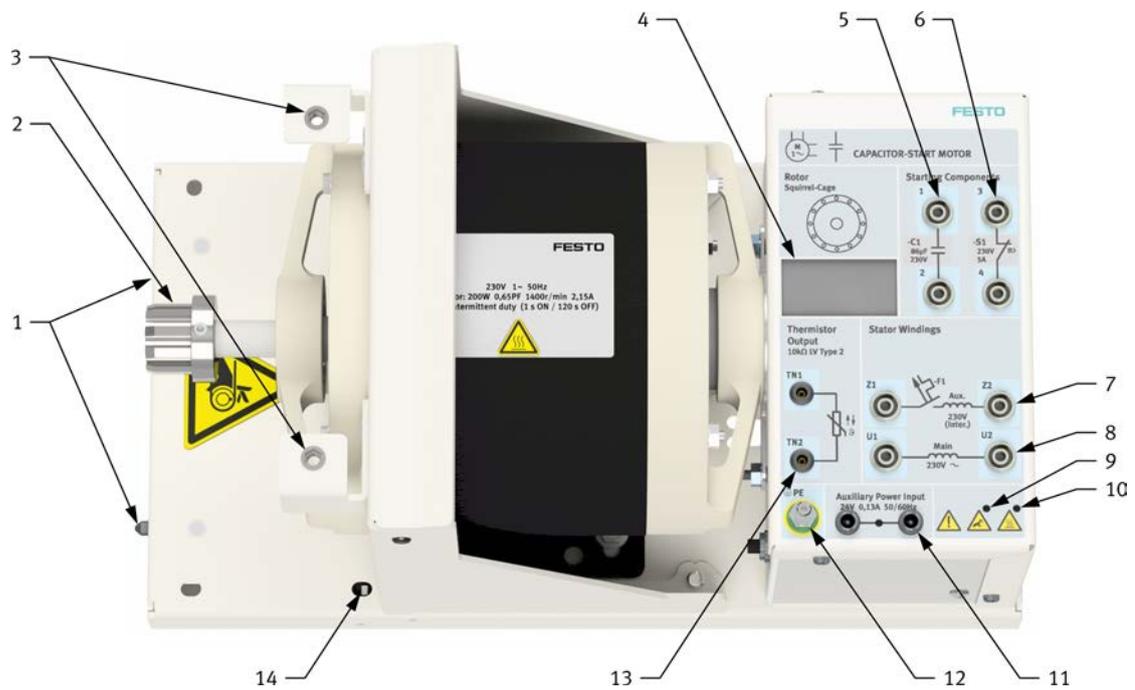


Figure 39: Front panel of the Capacitor-Start Motor module.

Table 30: Description of the Capacitor-Start Motor module.

Number	Component
1	Base-plate guiding pin and hole
2	10 teeth gear
3	Screw holes for securing a protective guard
4	Display
5	Starting capacitor connectors (2)
6	Starting switch connectors (2)
7	Auxiliary stator winding connectors (2)
8	Main stator winding connectors (2)
9	Machine overheating LED indicator

Number	Component
10	Protective guard missing LED indicator
11	Auxiliary Power Input connectors (2)
12	Protective earthing terminal
13	Thermistor Output connectors (2)
14	Limit switch

**Table 31: Main specifications of the Capacitor-Start Motor.**

Components and parameters	Main specifications
Main power requirements	230 V, single-phase, 50 Hz
Mechanical power	200 W
Power factor	0.62
Full-Load Speed	1426 r/min
Full-Load Current	2.15 A
Capacitor C1 operation	Intermittent duty (1 s ON / 120 s OFF)
Dimensions (H × W × D)	TDB
Net weight	TBD

## DC 48V PWM Charge Controller (8241563)

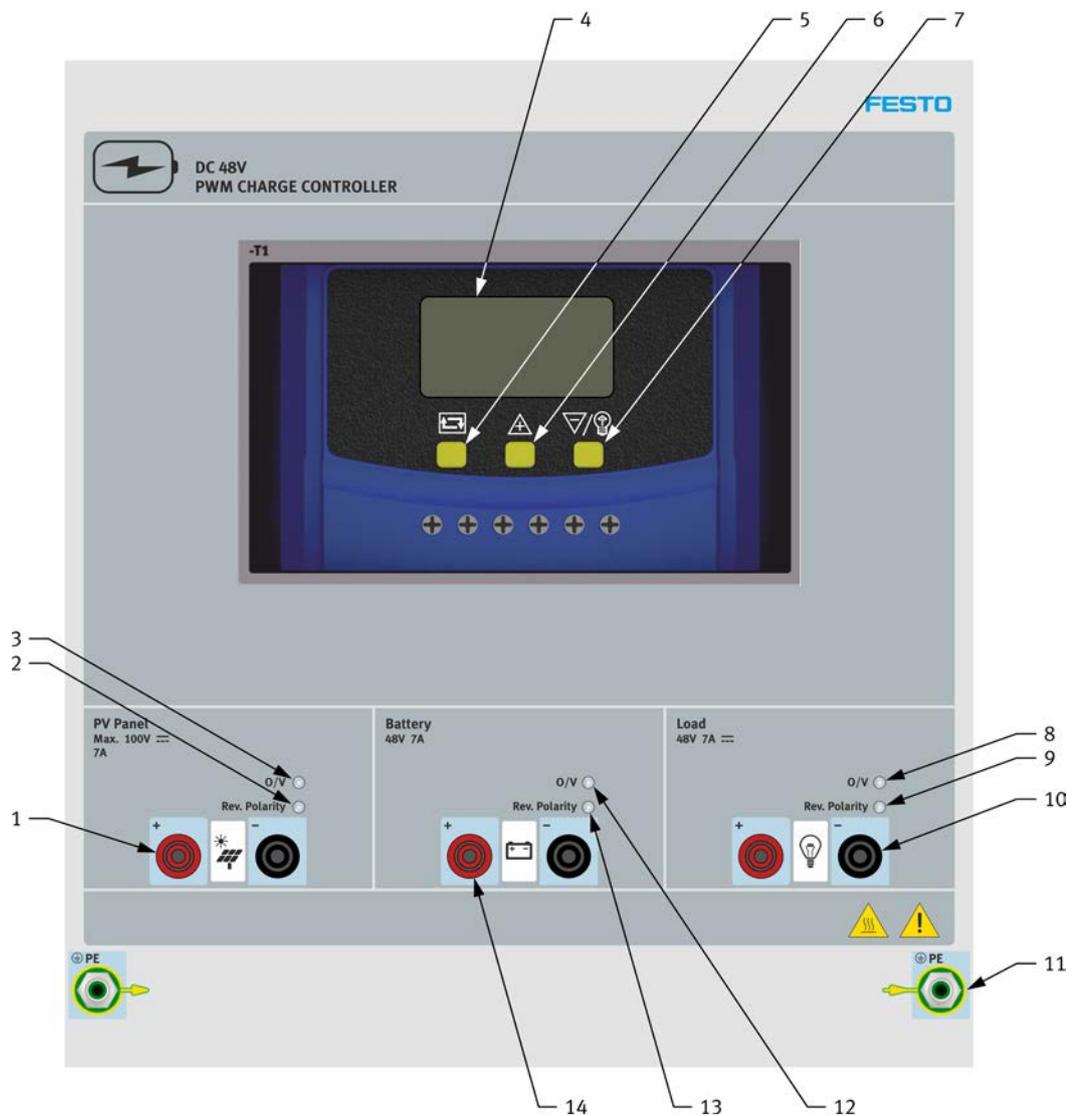


Figure 40: Front panel of the DC 48V PWM Charge Controller module.

Table 32: Description of the DC 48V PWM Charge Controller module.

Number	Component name
1	PV Panel input (terminals + and -)
2	PV Panel input reverse-polarity LED indicator
3	PV Panel input overvoltage (O/V) LED indicator

Number	Component name
4	Charge controller display
5	Menu key <ul style="list-style-type: none"> <li>• Short press: switches to the parameter display interface.</li> <li>• Long press: enters or exits parameter mode.</li> </ul>
6	Up key: press to increase value.
7	Down key: press to decrease value.
8	Load output overvoltage (O/V) LED indicator
9	Load output reverse-polarity LED indicator
10	Load output (terminals + and -)
11	Protective earthing terminals (2)
12	Battery overvoltage (O/V) LED indicator
13	Battery reverse-polarity LED indicator
14	Battery terminals (terminals + and -)

	 <b>WARNING</b>
	<p><b>Risk of fire and/or explosion when trying to charge non-rechargeable batteries!</b></p> <ul style="list-style-type: none"> <li>• Charging non-rechargeable batteries may cause dangerous chemicals to escape from the batteries which represents a risk of fire and/or explosion.</li> <li>• Never attempt to charge non-rechargeable batteries using the DC 48V PWM Charge Controller.</li> </ul>

## DC 48V MPPT Charge Controller (595050)

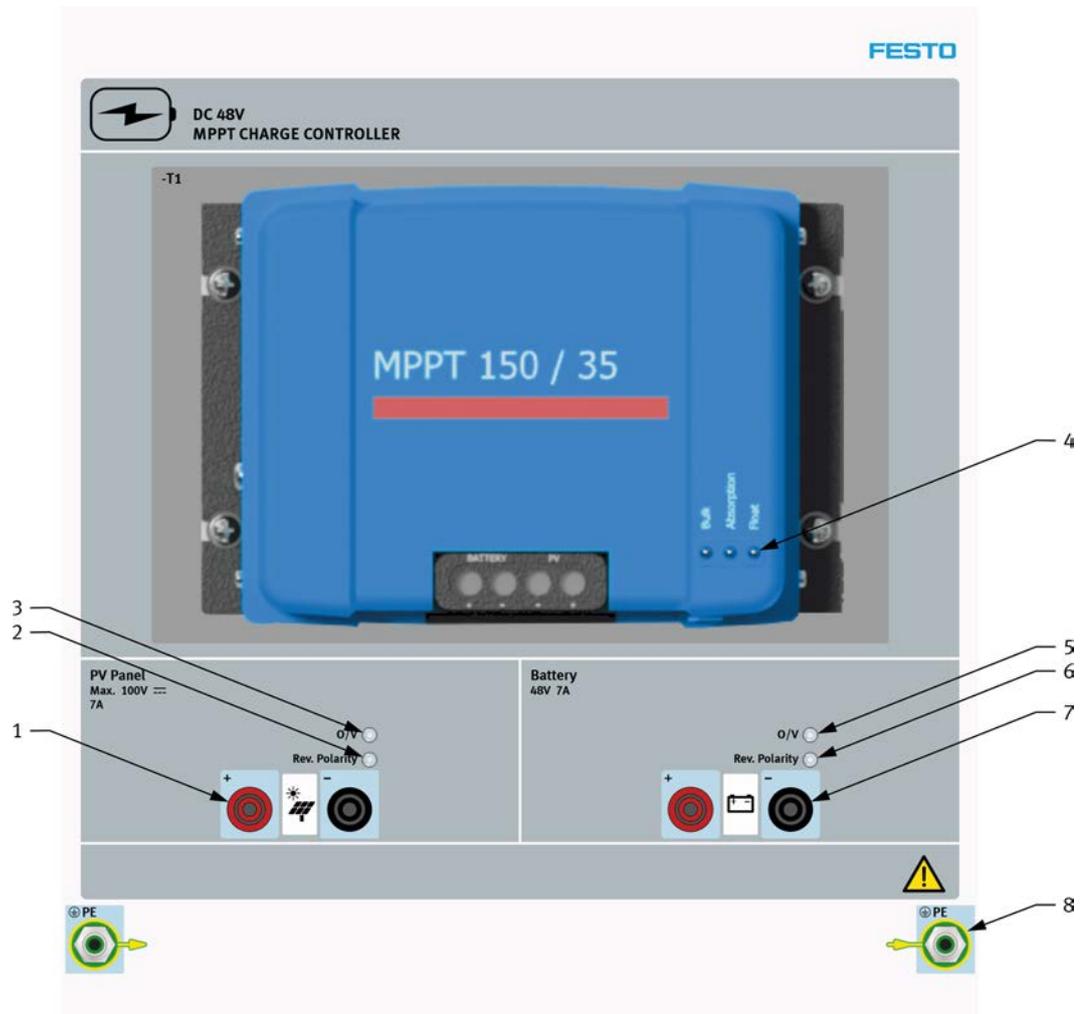


Figure 41: Front panel of the DC 48V MPPT Charge Controller module.

**Table 33: Description of the DC 48V MPPT Charge Controller module.**

Number	Component name
1	PV Panel input (terminals + and -)
2	PV Panel input reverse-polarity LED indicator
3	PV Panel input overvoltage (O/V) LED indicator
4	Battery charging stage LED indicators (Bulk, Absorption, and Float stages)
5	Battery overvoltage (O/V) LED indicator
6	Battery reverse-polarity LED indicator
7	Battery terminals (terminals + and -)
8	Protective earthing terminals (2)

	 <b>WARNING</b>
	<p><b>Risk of fire and/or explosion when trying to charge non-rechargeable batteries!</b></p> <ul style="list-style-type: none"> <li>• Charging non-rechargeable batteries may cause dangerous chemicals to escape from the batteries which represents a risk of fire and/or explosion.</li> <li>• Never attempt to charge non-rechargeable batteries using the DC 48V MPPT Charge Controller.</li> </ul>

## 1AC 230V Stand-Alone Inverter (595052)

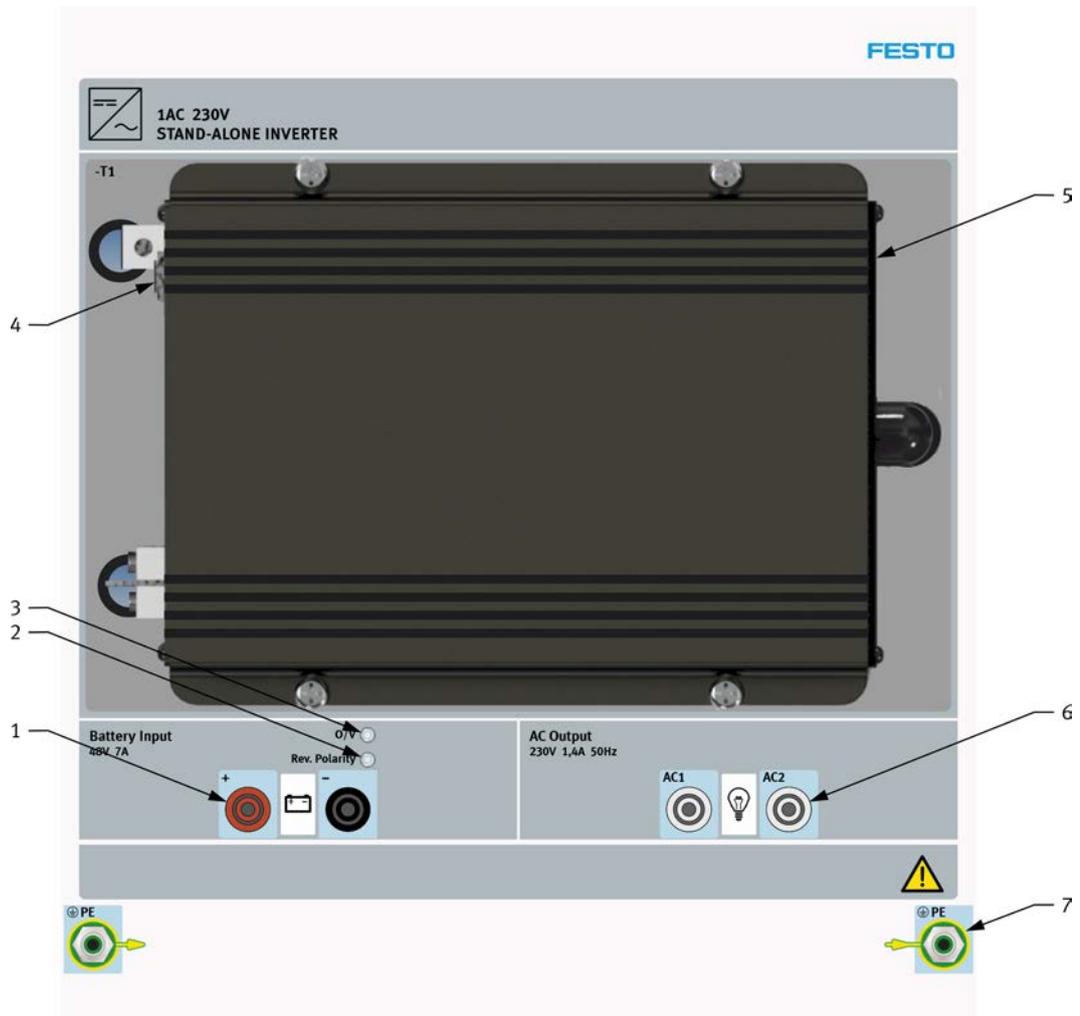


Figure 42: Front panel of the 1AC 230V Stand-Alone Inverter module.

**Table 34: Description of the 1AC 230V Stand-Alone Inverter module.**

Number	Component name
1	Battery Input (terminals + and -)
2	Battery Input reverse-polarity LED indicator
3	Battery Input overvoltage (O/V) LED indicator
4	Power on-off switch
5	Inverter operating status LED indicator (on right-hand side of unit)
6	AC Output (terminals AC1 and AC2)
7	Protective earthing terminals (2)

	 <b>WARNING</b>
	<p>To prevent fire, do not obstruct the ventilation openings at both sides of the inverter housing. Allow at least 15 cm of space at both sides of the inverter housing.</p>

## 1AC 230V Grid-Tied Inverter (595053)

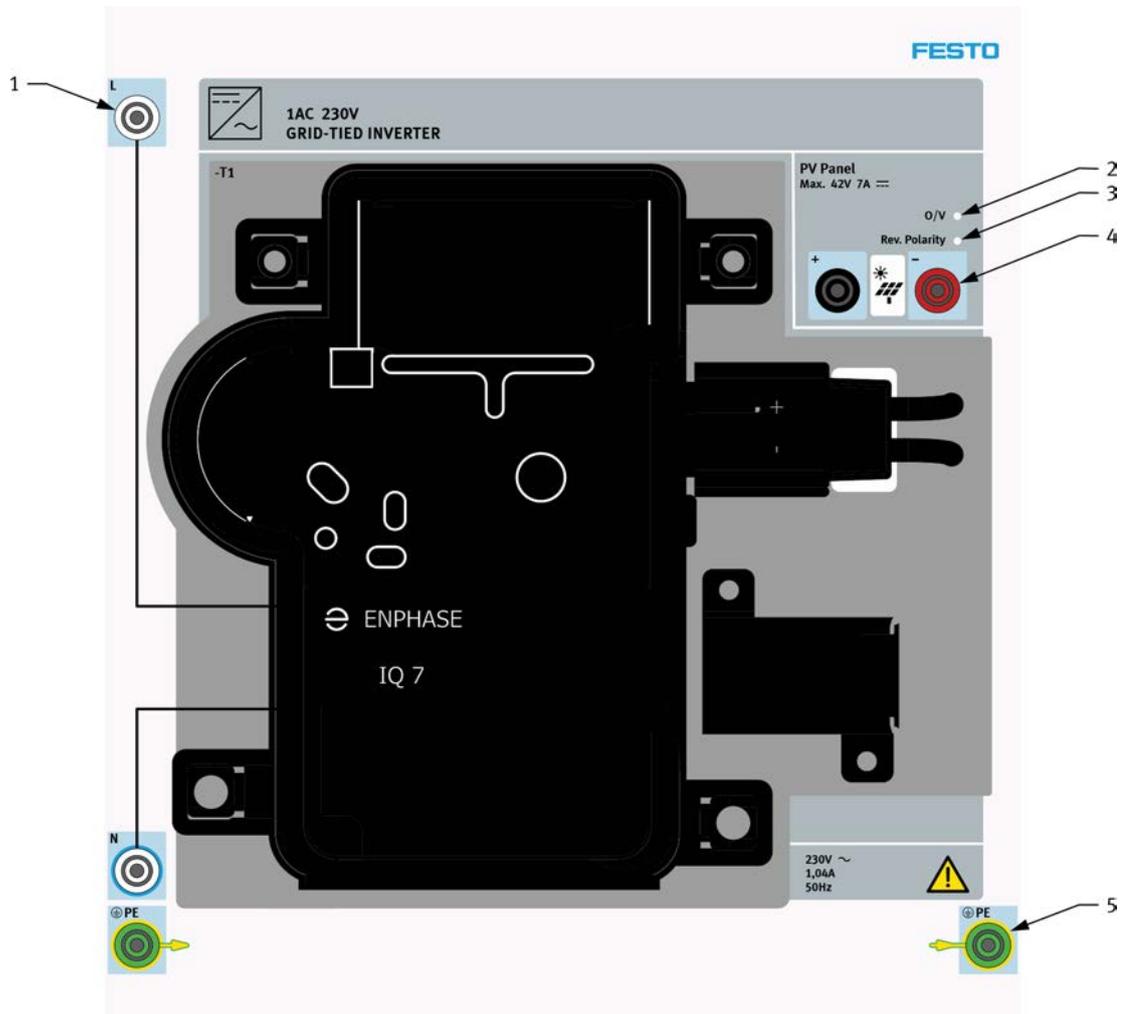


Figure 43: Front panel of the 1AC 230V Grid-Tied Inverter module.

**Table 35: Description of the 1AC 230V Grid-Tied Inverter module.**

<b>Number</b>	<b>Component name</b>
1	AC power output (terminals L and N)
2	PV Panel input overvoltage (O/V) LED indicator
3	PV Panel input reverse-polarity LED indicator
4	PV Panel input (terminals + and -)
5	Protective earthing terminals (2)

## Rectifier and Filtering Inductors/Capacitors (8243905)

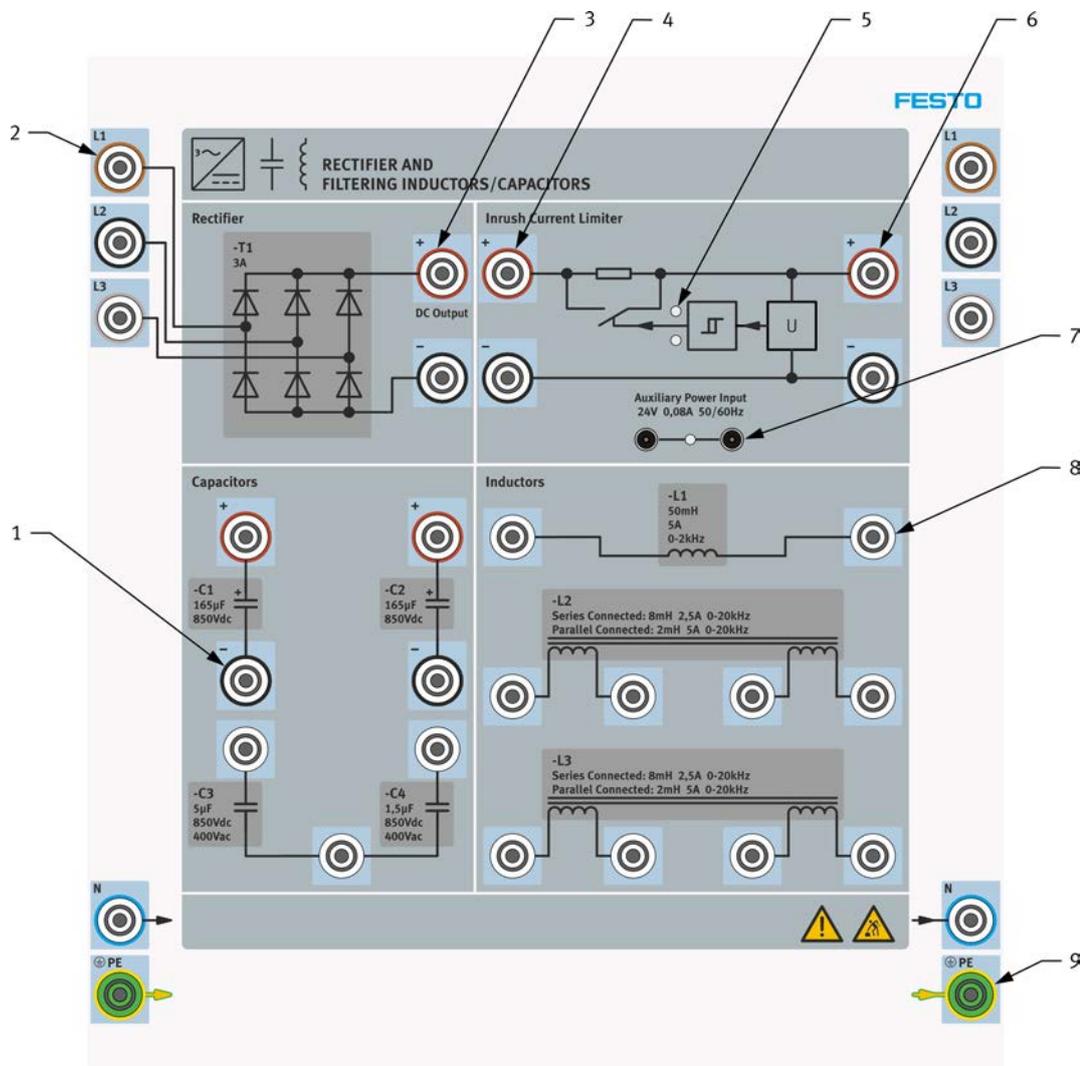


Figure 44: Front panel of the Rectifier and Filtering Inductors/Capacitors module.

**Table 36: Description of the Rectifier and Filtering Inductors/Capacitors module.**

Number	Component
1	Inputs and outputs of the filtering capacitors (terminals + and – of sections -C1, -C2, -C3, and -C4)
2	Rectifier three-phase input (terminals L1, L2, and L3)
3	DC output (terminals + and – of section -T1)
4	Input of the inrush current limiter (terminals + and –). The inrush current limiter is required when the rectifier output supplies the dc bus of the IGBT chopper/inverter. The large dc-bus capacitors draw a high inrush current at power-up; the limiter reduces this current and prevents the main circuit breaker from opening.
5	Green and red LED indicators of the inrush current limiter
6	Output of the inrush current limiter (terminals + and –)
7	Auxiliary power input
8	Inputs and outputs of the filtering inductors (all terminals of sections -L1, -L2, and -L3)
9	Protective earthing terminals (2)

**Table 37: Main specifications of the Rectifier and Filtering Inductors/Capacitors module.**

Parameter	Value
Maximum network voltage	230/400 V ac, three-phase
Network Frequency	50 Hz
Maximum Rectifier output current	3 A
Auxiliary power	24 V ac, 0.13 A, 50/60 Hz
Dimensions (H × W × D)	299 × 266 × 143 mm (11.69 × 10.47 × 5.51")
Weight	9.50 kg (20.9 lb)

## IGBT Chopper/Inverter (8167609)

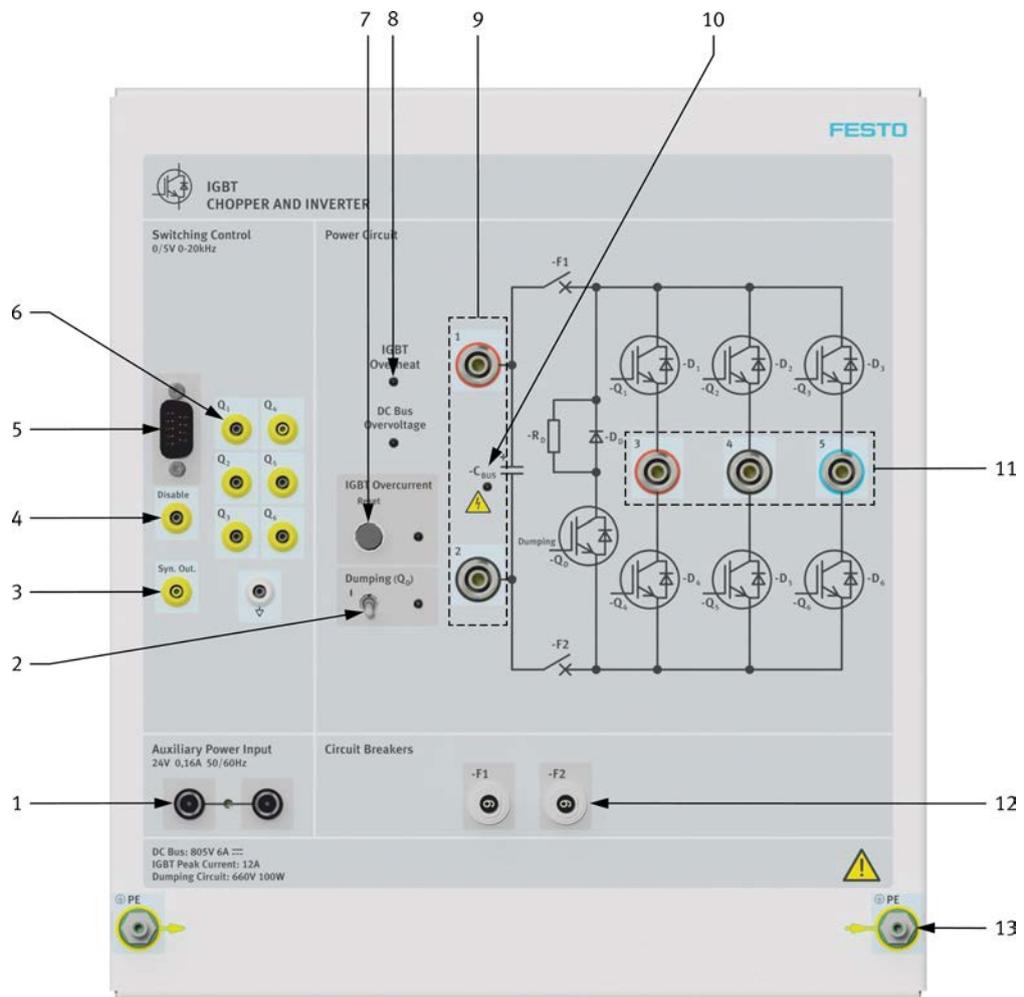


Figure 45: Front panel of the IGBT Chopper/Inverter.



In setups where the dc bus is directly connected to the three-phase ac power network, compliance of the IGBT Chopper/Inverter (8167609) to the requirements for electromagnetic emissions of EN 61326-1:2021 requires the use of both the 3AC Filter (8166653) and 3AC 400V/DC 230V Power Supply (594825). When using the IGBT Chopper/Inverter, always include the 3AC Filter and 3AC 400V/DC 230V Power Supply in the circuit if instructed as such in the course setups.

1. Auxiliary 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 Auxiliary Power Input terminals to a 24 V ac power supply **before** using the IGBT Chopper/Inverter. Doing otherwise could damage the module.

2. 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 ( $R_D$ ).
3. Synchronization output (terminal Syn. Out.). 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.
4. 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.
5. 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).
6. Switching Control inputs (terminals  $Q_1$  to  $Q_6$  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  $Q_2$ ).
7. 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.
8. IGBT Overheat and DC Bus Overvoltage LEDs. These LEDs turn on when the corresponding condition is detected. When either condition is detected by the circuits, the 6 IGBTs ( $Q_1$  to  $Q_6$ ) are switched off to prevent damage. These protection circuits will be reset automatically once the temperature of the IGBTs and/or the voltage on the dc bus are back to a safe level.
9. DC bus terminals (1 and 2). These terminals 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.

	 <b>CAUTION</b>
	As long as this LED is on, the module must remain connected to a protective earth to prevent any shock hazard.

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

<b>NOTICE</b>
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., 566 V for a 230/400 V ac power network).

12. Circuit Breaker reset buttons (-F1 and -F2). These circuit breakers protect the positive and negative branches of the dc bus against overload conditions.
13. Protective earthing terminals (2).

Table 38: Main specifications of the IGBT Chopper/Inverter.

Parameter	Subparameter	Value
DC bus	Maximum voltage	805 V
	Maximum current	6 A
	Filtering capacitor	680 $\mu$ F
Protections	DC bus overvoltage	847 V $\pm$ 10%
	DC bus circuit breaker	6 A
	IGBT electronic overcurrent	15 A
	IGBT overheat	60°C
Dumping circuit	Voltage threshold	660 V $\pm$ 10%
	Resistor	250 $\Omega$ , 100 W
Switching control signals	Level	0/5 V
	High-level current	600 nA
	Frequency range	0-20 kHz
	Minimum dead time	1.2 $\mu$ s
Power requirements		24 V, 0.2 A, 50/60 Hz
Accessories		<ul style="list-style-type: none"> <li>● 24 V power cable (1)</li> <li>● 2 mm banana plug test leads (2)</li> <li>● DB9 Cable (1)</li> </ul>
Dimensions (H x W x D)		297 x 266 x 140 mm (11.69 x 10.47 x 5.51 in)
Weight		5.85 kg (12.9 lb)

## 3AC Filter (8166653)

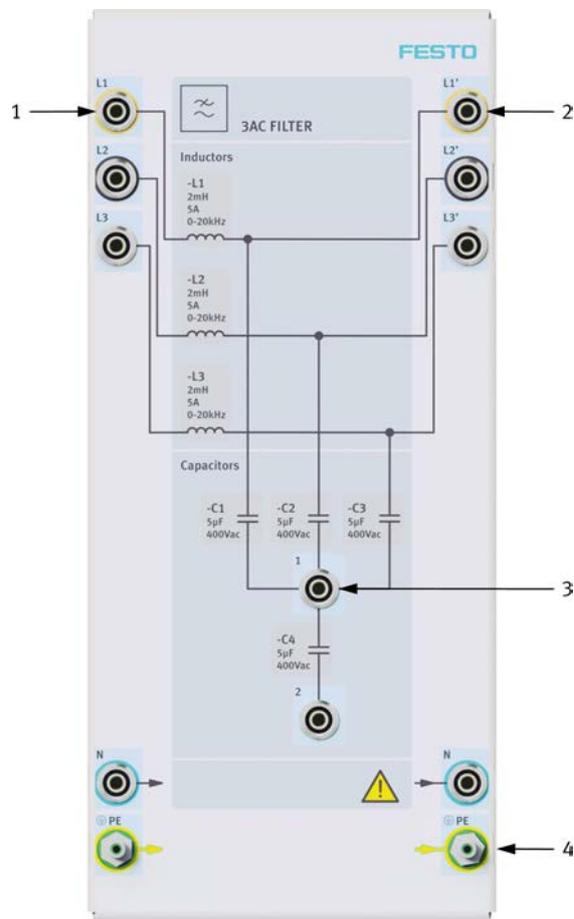


Figure 46: Front panel of the 3AC Filter.

1. Three-phase filter, inductor side (terminals L1, L2, L3, and N)
2. Three-phase filter, capacitor side (terminals L1', L2', L3', and N)
3. Filtering capacitor common (terminals 1 and 2)
4. Protective earthing terminals (2)

**Table 39: Main specifications of the 3AC Filter.**

Parameter	Subparameter	Main specifications
Maximum network voltage		400 V ac, three-phase
Inductors	Number	3
	Ratings	2 mH – 5 A – 0-20 kHz
Capacitors	Number	4
	Type	Metallized polypropylene
	Ratings	5 $\mu$ F – 400 V
Dimensions (H x W x D)		297 x 133 x 140 mm (11.69 x 5.24 x 5.51 in)
Weight		3.15 kg (6.94 lb)

## Power Thyristors (8167245)

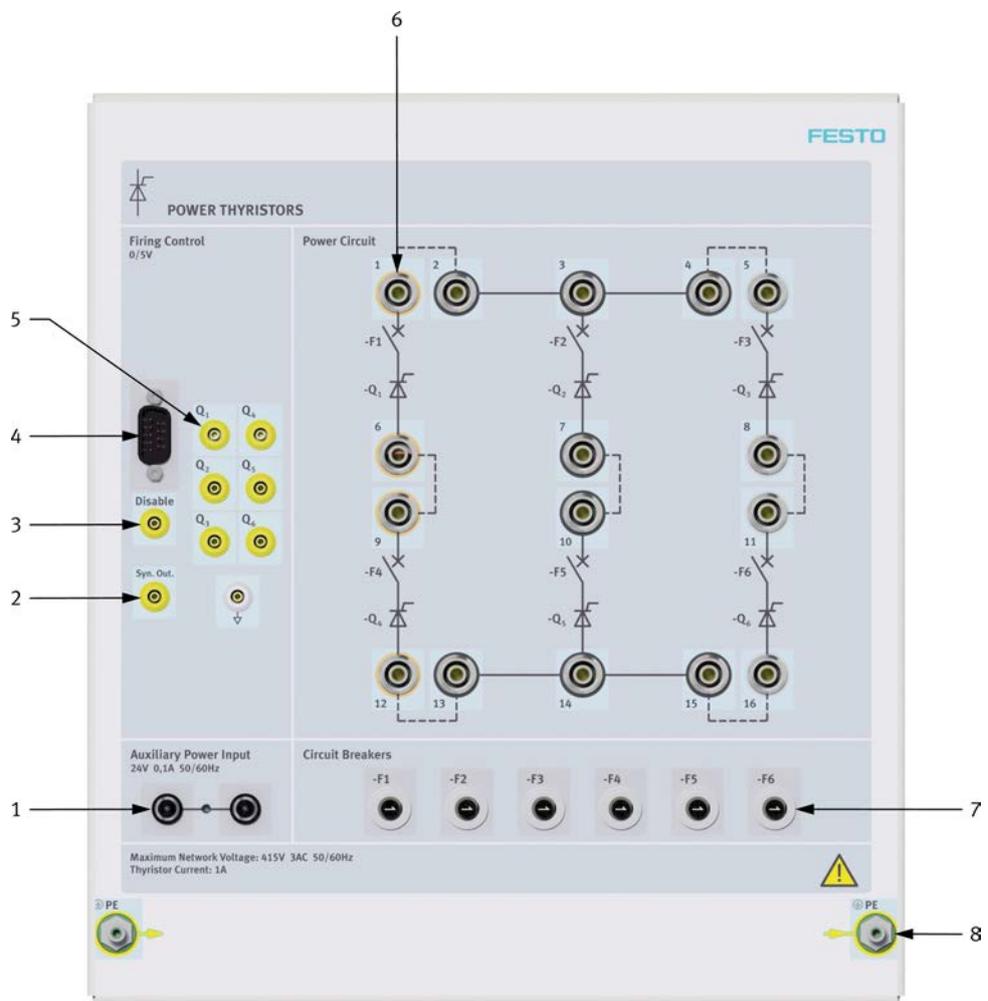


Figure 47: Front panel of the Power Thyristors.

### NOTICE

Compliance of the Power Thyristors (8167245) to the conducted emissions requirements of EN 61326-1:2021 requires the use of the 3AC Filter (8166653). When using the Power Thyristors, always include the 3AC Filter in the circuit as instructed in the course setups.

1. Auxiliary 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 Auxiliary Power Input terminals to a 24 V ac power supply **before** using the Power Thyristors. Doing otherwise could damage the module.

2. Synchronization output (terminal Syn. Out.). 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.
3. 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.
4. 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).
5. Firing Control inputs (terminals  $Q_1$  to  $Q_6$  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  $Q_2$ ).
6. Thyristor anode and cathode terminals (terminals 1 to 16). These terminals allow access to the power thyristors for connection to a circuit.
7. Circuit Breaker reset buttons (-F1, -F2, -F3, -F4, -F5 and -F6). These circuit breakers protect the thyristors against overload conditions.
8. Protective earthing terminals (2)

**Table 40: Main specifications of the Power Thyristors.**

Parameter	Value
Maximum network voltage	415 V – 3AC – 50/60Hz
Thyristor current	1 A
Auxiliary power input	24 V ac – 0.1 A – 50/60 Hz
Firing controls	0-5 V
Dimensions (H x W x D)	297 x 266 x 140 mm (11.69 x 10.47 x 5.51 in)
Weight	3.20 kg (7.05 lb)

## Wind Turbine Generator and Controller (595061)

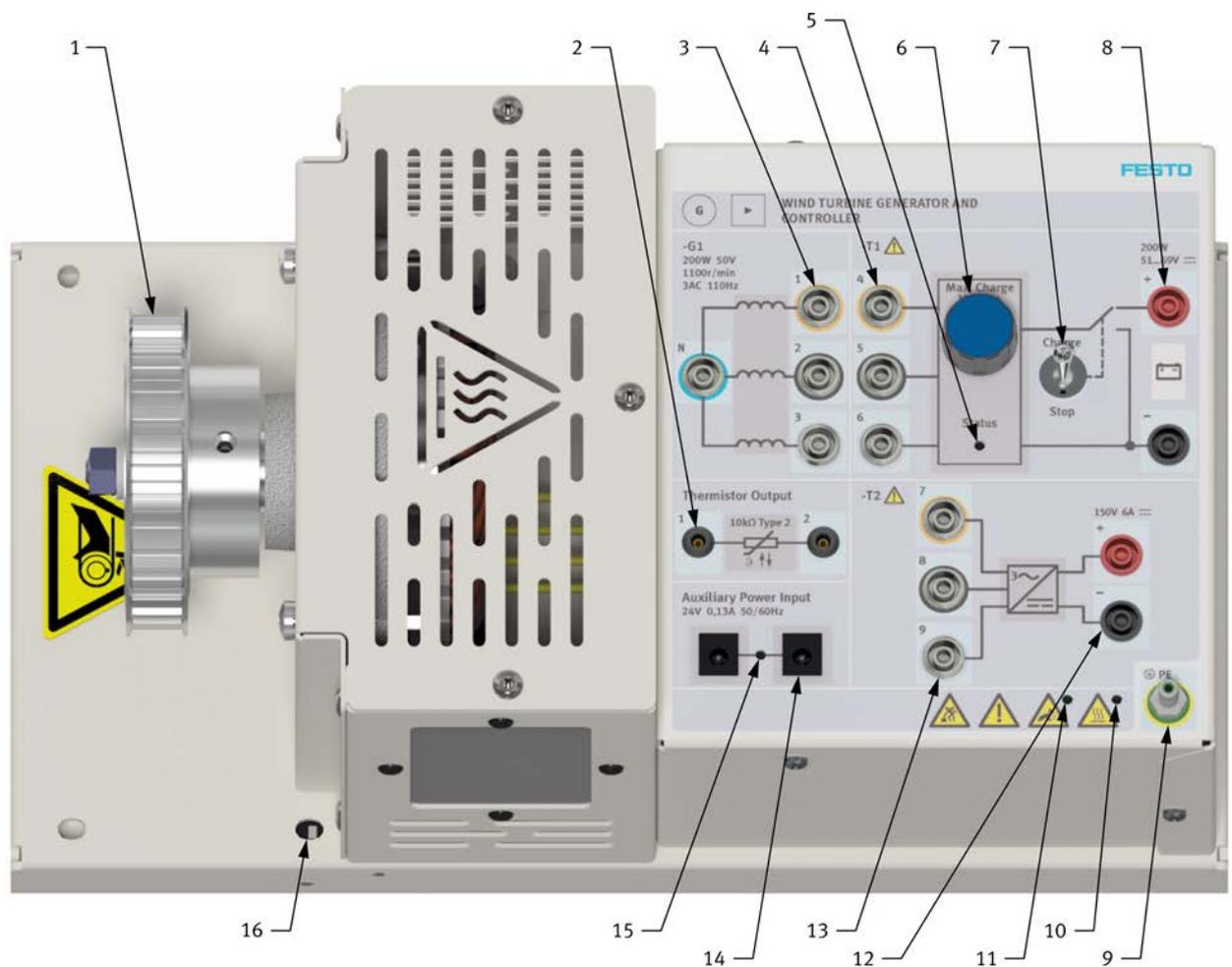


Figure 48: Front panel of the Wind Turbine Generator and Controller module.

Table 41: Description of the Wind Turbine Generator and Controller module.

Number	Component name
1	32 teeth belt pulley
2	Generator Thermistor Output (terminals 1 and 2)
3	Generator windings (terminals 1, 2, 3, and N)
4	Controller three-phase ac power input (terminals 4, 5, and 6)
5	Controller operating status LED indicator

Number	Component name
6	Controller Max. Charge Voltage control knob
7	Controller Charge/Stop switch
8	Controller dc power output (terminals + and -)
9	Protective earthing terminal
10	Generator overheating LED indicator
11	Protective guard missing LED indicator
12	Three-phase bridge rectifier output (terminals + and -)
13	Three-phase bridge rectifier input (terminals 7, 8, and 9)
14	Auxiliary Power input connectors (2)
15	Auxiliary power on LED indicator
16	Limit switch

	<b>WARNING</b>
	<p><b>Risk of fire when using a battery pack without an overcurrent protection device!</b></p> <ul style="list-style-type: none"> <li>• Short-circuiting a battery pack with no overcurrent protection causes excessive current which may result in overheating and a risk of fire.</li> <li>• When using the Wind Turbine Generator Controller with a battery pack other than the Festo Didactic 48V Lead-Acid Battery Pack, always connect a suitable overcurrent protection device (e.g., a circuit breaker) in series with the battery pack to minimize the risk of fire.</li> </ul>

	 <b>WARNING</b>
	<p><b>Risk of electric shock when auxiliary power comes from a 24 V ac power source not certified for operation with CAT II circuits!</b></p> <p>Always use a doubly-insulated 24 V ac power source, such as the Festo Didactic AC 24V Power Supply, to feed the equipment with auxiliary power.</p>

<b><i>NOTICE</i></b>	
<ul style="list-style-type: none"><li>• Terminals 4, 5, and 6 (-T1, Controller three-phase ac power input) can be connected to terminals 1, 2, and 3 (-G1, Generator windings) only.</li><li>• Terminals 7, 8, and 9 (-T2, Three-phase bridge rectifier input) can be connected to terminals 1, 2, and 3 (-G1, Generator windings) only.</li></ul>	

## Solar Panel Test Bench (595057)

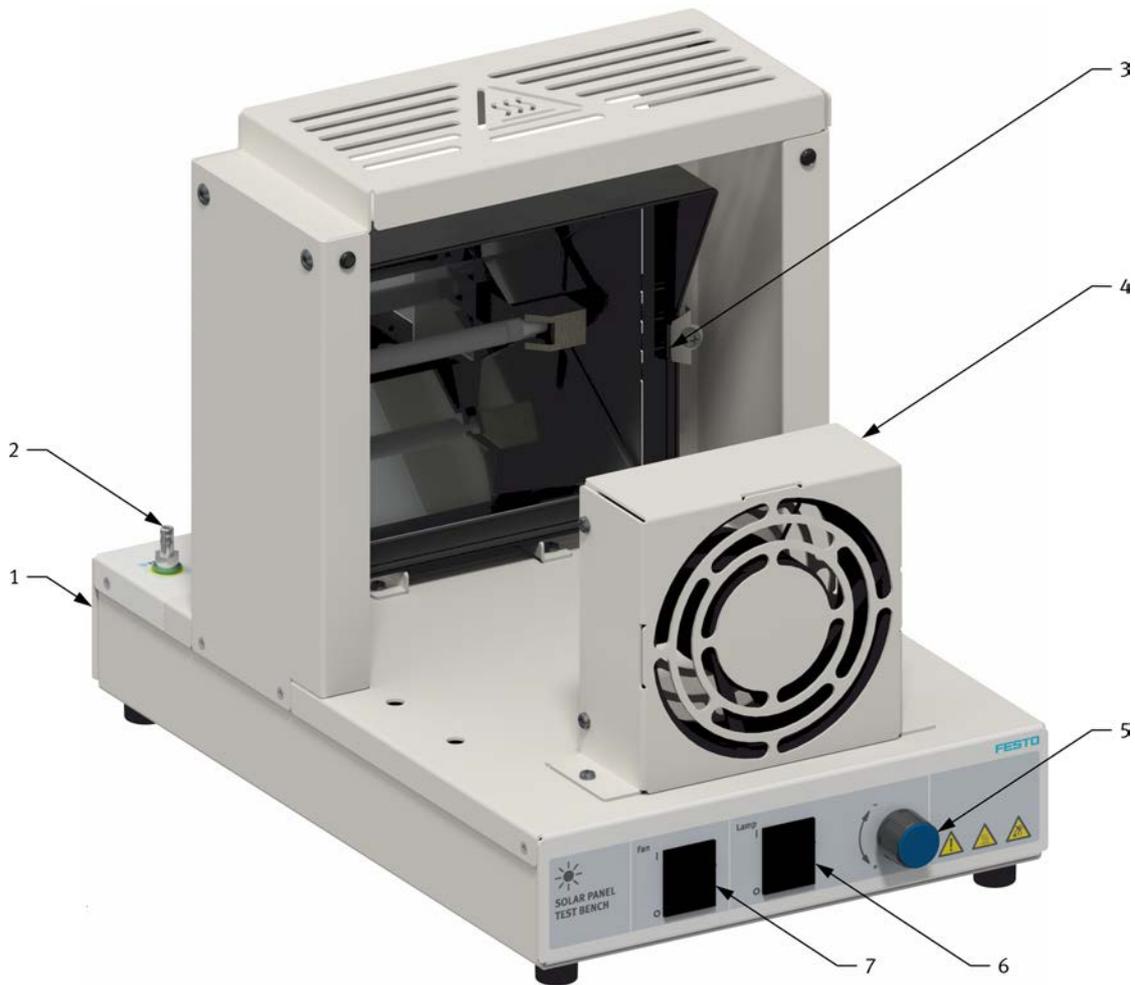


Figure 49: Front panel of the Solar Panel Test Bench module.

**Table 42: Description of the Solar Panel Test Bench module.**

Number	Component name
1	Power Input connector with fuse holder (back side of unit)
2	Protective earthing terminals (2)
3	Halogen lamp
4	Fan
5	Dimmer (lamp brightness) control knob
6	Halogen lamp on (I)/off (O) switch
7	Fan on (I)/off (O) switch

**Table 43: Main specifications of the Solar Panel Test Bench module.**

Parameter	Rating
Input	1.5 A, 230 V – 50/60 Hz, 1 phase, including line, neutral, and earth wires, protected by a circuit breaker in accordance with local regulations.
Mounting	Designed for DIN A4 mounting frames
Ingress protection rating	IP20
Electromagnetic compatibility	Group 1, Class A (industrial environment, EN 55011)
Dimensions (H × W × D)	297 × 266 × 140 mm (11.69 × 10.47 × 5.51")
Weight	X kg (X lb)
CE and UKCA markings	<ul style="list-style-type: none"> <li>● Low-Voltage Directive</li> <li>● EMC Directive</li> <li>● RoHS Directive</li> </ul>

### Light bulb replacement

Disconnect the unit from any source of electric power before replacing one of the light bulbs. Always use a light bulb of the same type and having the same rating as the original one.

	 <b>CAUTION</b>
	<p>Light bulbs become very hot when used for a long period of time. To prevent burn injuries, let them cool down before any replacement.</p>

### Monocrystalline Silicon Solar Panel (595058)

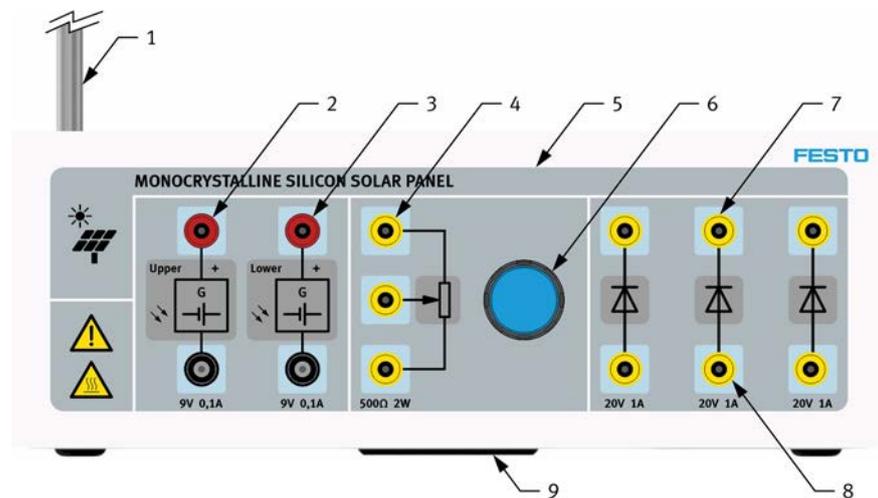


Figure 50: Front panel of the Monocrystalline Silicon Solar Panel module.

**Table 44: Description of the Monocrystalline Silicon Solar Panel module.**

Number	Component name
1	Panel orientation guiding stem
2	Upper PV module terminals (2)
3	Lower PV module terminals (2)
4	Potentiometer terminals (3)
5	Upper and lower PV modules (front side of PV panel)
6	Potentiometer control knob
7	Diode cathode terminals (3)
8	Diode anode terminals (3)
9	Digital thermometer (back side of PV panel)

**Thermometer cell replacement**

Always use a cell of the same type and having the same rating as the original one.

## 1AC 230V Energy Meter (594904)

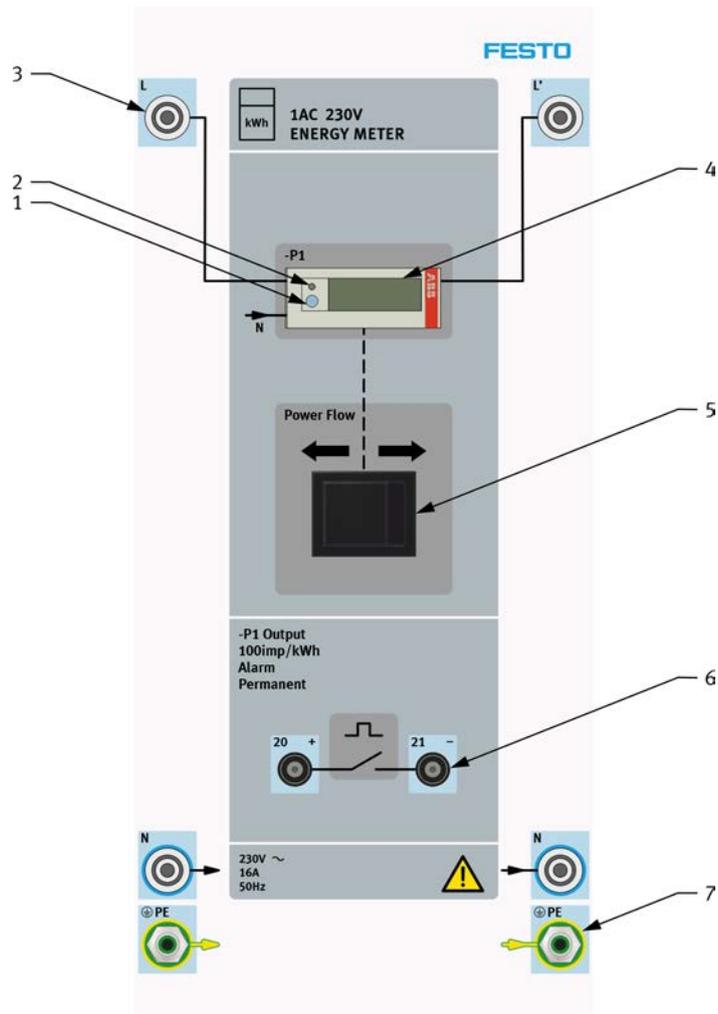


Figure 51: Front panel of the 1AC 230V Energy Meter module.

Table 45: Description of the 1AC 230V Energy Meter module.

Number	Component name
1	Meter setting/display push-button
2	Metered energy LED indicator
3	Voltage and current measuring terminals (L, L', and N)
4	Meter display
5	Direction of power flow selector switch
6	Pulse Output (terminals 20 and 21)
7	Protective earthing terminals (2)

### Pyranometer (579784)

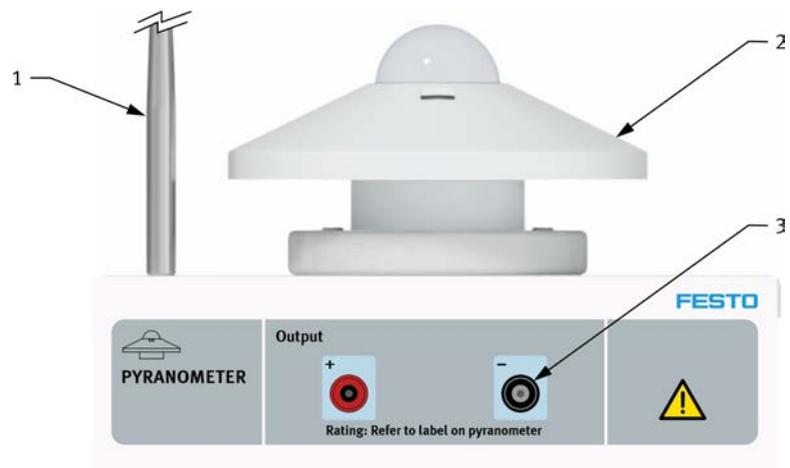


Figure 52: Front panel of the Pyranometer module.

Table 46: Description of the Pyranometer module.

Number	Component name
1	Pyranometer orientation guiding stem
2	Pyranometer
3	Pyranometer Output (terminals + and -)

### 3AC Transformer Bank (594823)

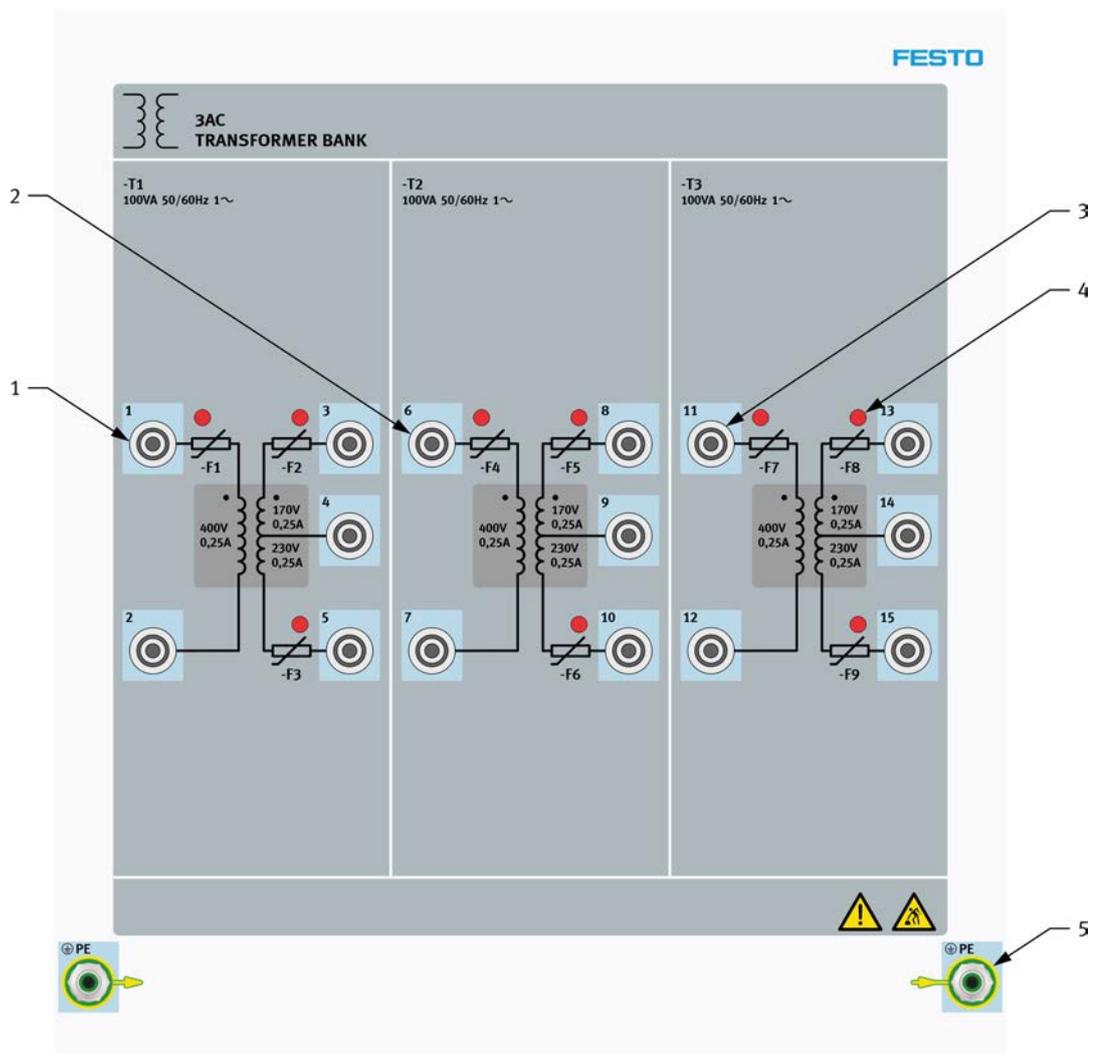


Figure 53: Front panel of the 3AC Transformer Bank module.

**Table 47: Description of the 3AC Transformer Bank module.**

Number	Component name
1	Terminals of power transformer T1 (terminals 1, 2, 3, 4, and 5)
2	Terminals of power transformer T2 (terminals 6, 7, 8, 9, and 0)
3	Terminals of power transformer T3 (terminals 11, 12, 13, 14, and 15)
4	Fuse status LED indicators (9)
5	Protective earthing terminals (2)

	 <b>WARNING</b>
	<p><b>Risk of electric shock when using the 3AC Transformer Bank with an ac power source from another equipment manufacturer!</b></p> <ul style="list-style-type: none"> <li>• The 3AC Transformer Bank is classed as an overvoltage category II (CAT II) equipment.</li> <li>• To minimize the above risk of electric shock, never use the 3AC Transformer Bank with an ac power source whose line-to-neutral voltage exceeds 230 V, as stated in the Power requirements section of this document.</li> </ul>

## 1AC Transformer (594824)

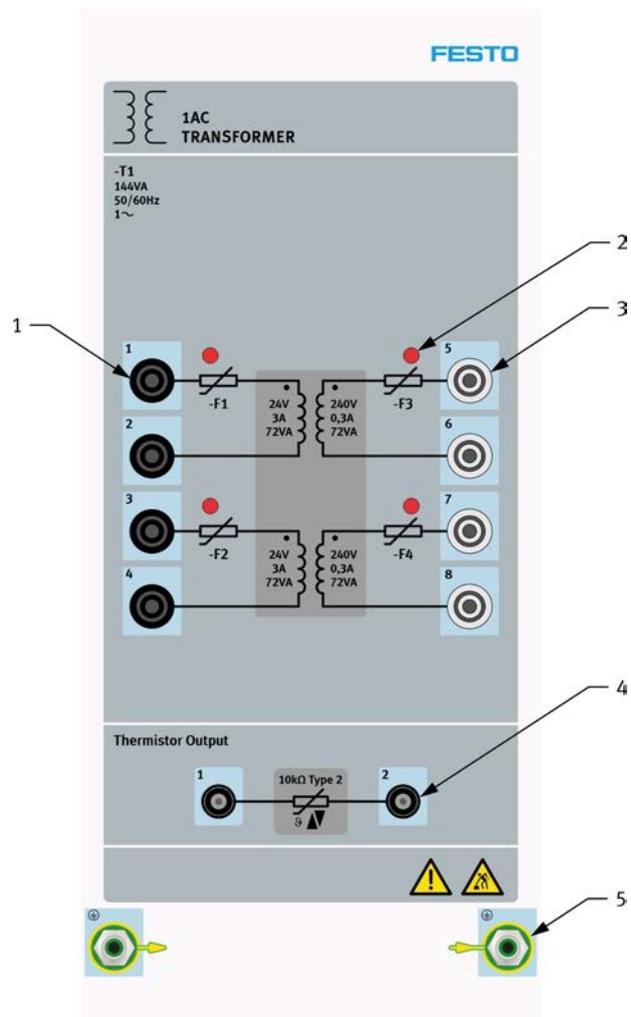


Figure 54: Front panel of the 1AC Transformer module.

Table 48: Description of the 1AC Transformer module.

Number	Component name
1	Primary winding terminals (terminals 1, 2, 3, 4)
2	Fuse status LED indicators (4)
3	Secondary winding terminals (terminals 5, 6, 7, 8)
4	Thermistor Output (terminals 1 and 2)
5	Protective earthing terminals (2)

## DC 48V Lamps (595055)

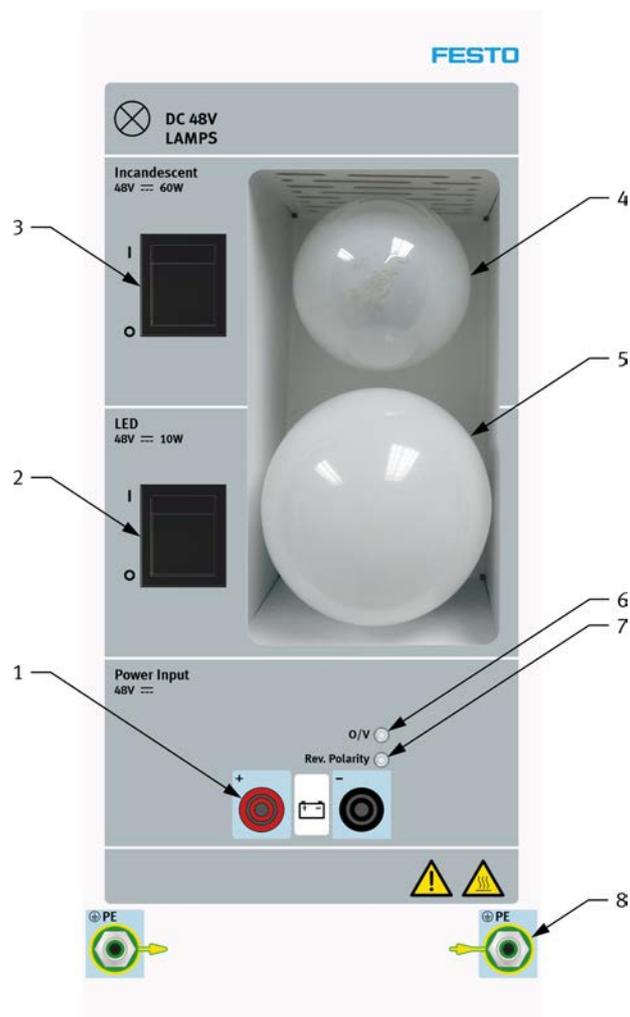


Figure 55: Front panel of the DC 48V Lamps module.

**Table 49: Description of the DC 48V Lamps module.**

Number	Component name
1	Power Input (terminals + and -)
2	LED lamp on (I)/off (O) switch
3	Incandescent lamp on (I)/off (O) switch
4	Incandescent lamp
5	LED lamp
6	Overvoltage (O/V) LED indicator
7	Reverse polarity LED indicator
8	Protective earthing terminals (2)

### Light bulb replacement

Disconnect the unit from any source of electric power before replacing one of the light bulbs. Always use a light bulb of the same type and having the same rating as the original one.

	 <b>CAUTION</b>
	<p>Light bulbs become very hot when used for a long period of time. To prevent burn injuries, let them cool down before any replacement.</p>

### AC 230V Lamps (595056 and 595149)

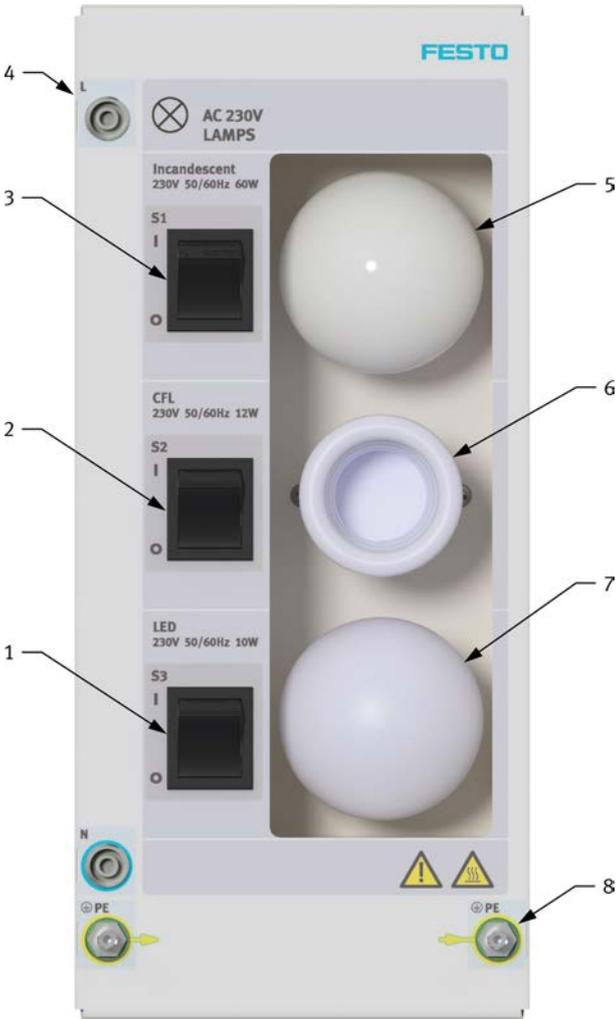


Figure 56: Front panel of the AC 230V Lamps module (595056, three-lamp version).

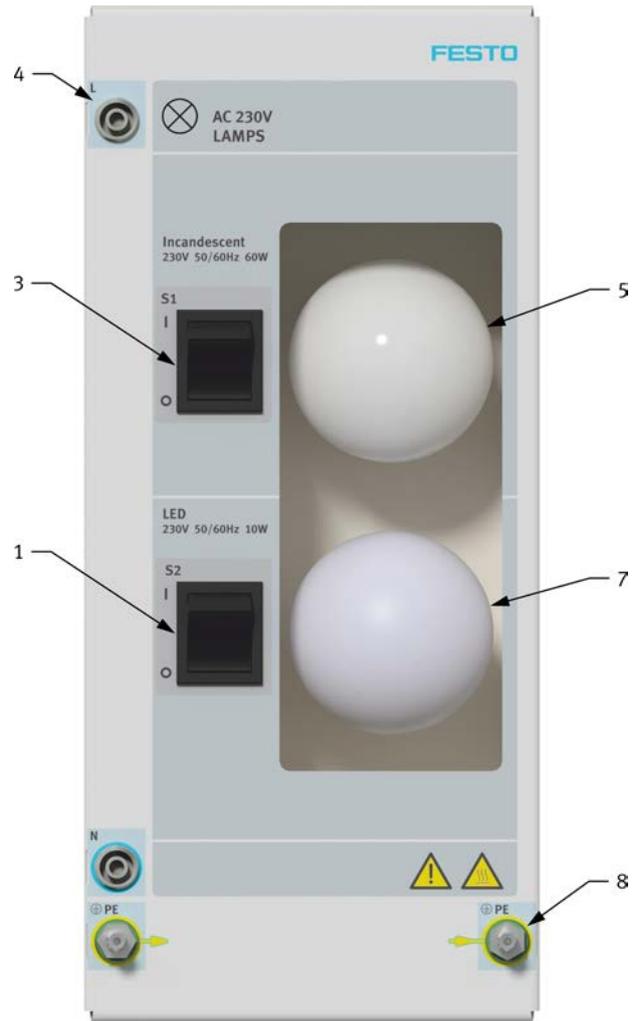


Figure 57: Front panel of the AC 230V Lamps module (595149, two-lamp version).

**Table 50: Description of the AC 230V Lamps module.**

Number	Component name
1	LED lamp on (I)/off (O) switch
2	Compact fluorescent lamp (CFL) on (I)/off (O) switch (three-lamp version only)
3	Incandescent lamp on (I)/off (O) switch
4	AC power input (terminals L and N)
5	Incandescent lamp
6	Compact fluorescent lamp (CFL) (three-lamp version only)
7	LED lamp
8	Protective earthing terminals (2)

### Light bulb replacement

Disconnect the unit from any source of electric power before replacing one of the light bulbs. Always use a light bulb of the same type and having the same rating as the original one.

	 <b>CAUTION</b>
	<p>Light bulbs become very hot when used for a long period of time. To prevent burn injuries, let them cool down before any replacement.</p>

Table 51: Main specifications of the AC 230V Lamps module.

Components and parameters	Main specifications
Incandescent lamp	230 V, 50/60 Hz, 60 W
Compact fluorescent lamp (595056 only)	230 V, 50/60 Hz, 12 W
LED lamp	230 V, 50/60 Hz, 10 W
Dimensions (H x W x D)	297 x 133 x 140 mm (11.69 x 5.24 x 5.51 in)
Weight	2.10 kg (4.63 lb)

### Synchronization Lamps and Contactor (8100086)

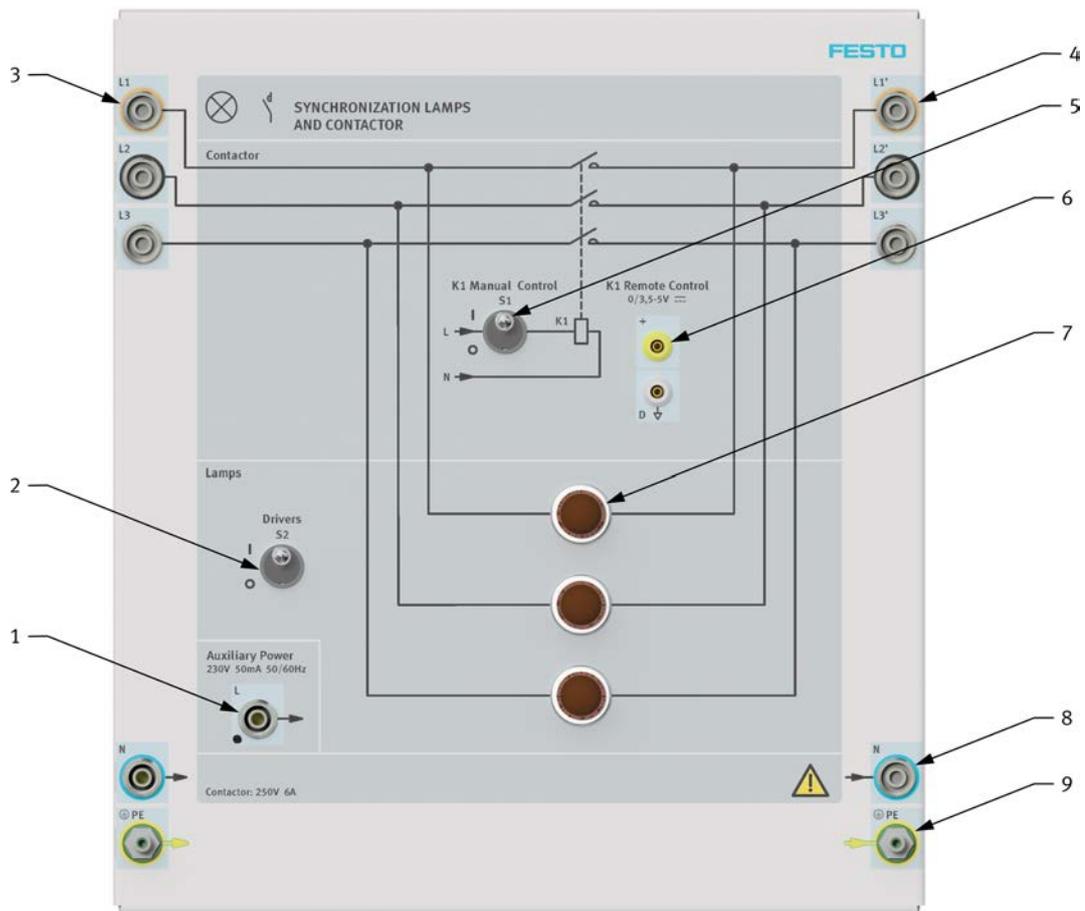


Figure 58: Front panel of the Synchronization Lamps and Contactor module.

**Table 52: Description of the Synchronization Lamps and Contactor module.**

Number	Component name
1	Auxiliary Power input (terminal L)
2	Lamp Drivers switch (S2)
3	Main contacts of contactor K1 (terminals L1, L2, and L3)
4	Main contacts of contactor K1 (terminals L1', L2', and L3')
5	K1 Manual Control switch (S1)
6	K1 Remote Control input (terminals + and D)
7	Synchronization lamps (3)
8	Neutral (N) terminals (2)
9	Protective earthing terminals (2)

	 <b>WARNING</b>
	<p><b>Risk of electric shock due to live parts within the lamp sockets becoming accessible when the lamps are removed!</b></p> <p>Before powering the Synchronization Lamps and Contactor, always make sure that a lamp is inserted into each socket of the module. Furthermore, never remove a lamp from its socket during operation.</p>

## Synchronization Lamps and Contactor (8208627)

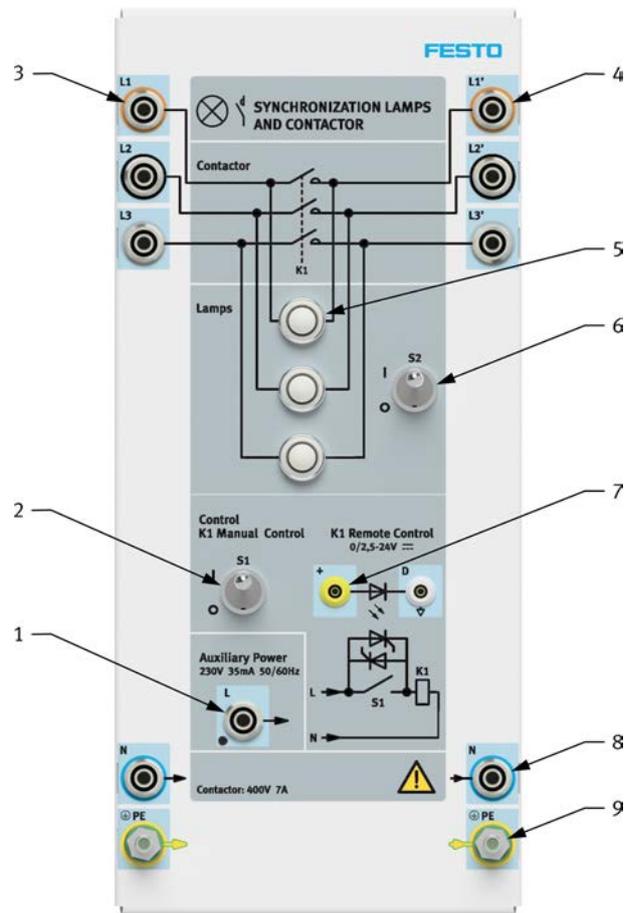


Figure 59: Front panel of the Synchronization Lamps and Contactor module.

**Table 53: Description of the Synchronization Lamps and Contactor module.**

Number	Component name
1	Auxiliary Power input (terminal L)
2	K1 Manual Control switch (S1)
3	Main contacts of contactor K1 (terminals L1, L2, and L3)
4	Main contacts of contactor K1 (terminals L1', L2', and L3')
5	Synchronization lamps (3)
6	Lamps switch (S2)
7	K1 Remote Control input (terminals + and D)
8	Neutral (N) terminals (2)
9	Protective earthing terminals (2)

**Table 54: Main specifications of the Synchronization Lamps and Contactor.**

Parameter	Value
Contactor (contacts)	3AC 400 V, 7.0 A, 50/60 Hz
Auxiliary power	1AC 230 V, 35 mA, 50/60 Hz
Remote control	DC 0/2.5...24 V
Dimensions (H × W × D)	299 × 133 × 140 mm (11.69 × 5.24 × 5.51")
Weight	2.00 kg (4.41 lb)

## 12V Lead-Acid Batteries (595060)

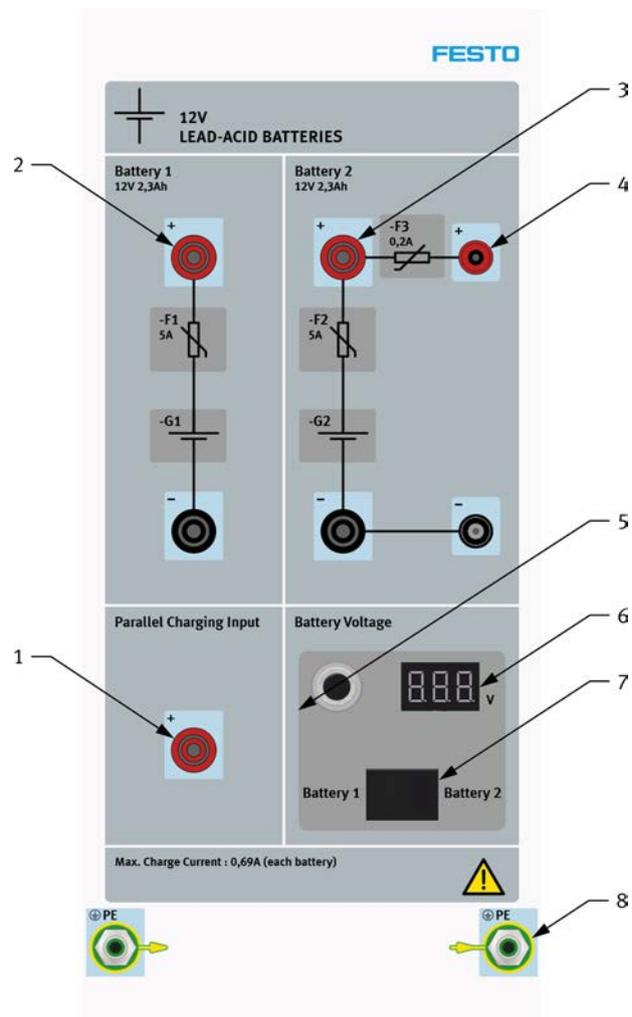


Figure 60: Front panel of the 12V Lead-Acid Batteries module.

**Table 55: Description of the 12V Lead-Acid Batteries module.**

Number	Component name
1	Parallel Charging Input
2	Terminals of Battery 1 (terminals + and -)
3	Terminals of Battery 2 (terminals + and -)
4	Low-power terminals of Battery 2 (terminals + and -)
5	Battery-voltage test push-button
6	Battery voltage display
7	Battery selector switch
8	Protective earthing terminals (2)

	 <b>WARNING</b>
	<p><b>Risk of explosion when charging a lead-acid battery in a non-ventilated area!</b></p> <ul style="list-style-type: none"> <li>• Explosive gases may be produced when a lead-acid battery is being charged. This may result in a risk of explosion when the battery is in a non-ventilated area.</li> <li>• To minimize the risk of explosion, make sure that the battery is placed in a well-ventilated area before attempting to charge it.</li> <li>• Never operate a lead-acid battery charger when ventilation around the battery is restricted in any way.</li> <li>• Do not smoke and avoid creating sparks or flames in the vicinity of the battery when it is charging.</li> </ul>

 <b>WARNING</b>	
	<p><b>Risk of explosion and/or fire when overcharging a lead-acid battery!</b></p> <ul style="list-style-type: none"><li>• Overcharging a lead-acid battery causes excessive gassing and overheating which, if sustained, may result in battery failure and a risk of explosion and/or fire.</li><li>• To avoid battery overcharging, always use a battery charger that suits the lead-acid battery to be charged.</li></ul>

### Parallel Charging Input

The Parallel Charging Input allows the 12V Lead-Acid Batteries module to be connected in parallel with other modules of the same type while preventing the batteries in these modules to discharge in each other. This allows the batteries in several 12V Lead-Acid Batteries modules to be charged at the same time using a single lead-acid battery charger.

To do so, connect the negative terminals of the batteries in each 12V Lead-Acid Batteries module to the negative terminal of the battery charger. Then, connect the Parallel Charging Input of each 12V Lead-Acid Batteries module to the positive terminal of the battery charger. Finally, follow the instructions provided with the lead-acid battery charger to perform battery charging.

### Maintenance

In order to optimize the cycle life of the batteries in the 12V 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 12V 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 12V Lead-Acid Batteries, i.e., down to a voltage of 10.5 V.
2. Charge the 12V 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 56: 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.

### Battery replacement

Always use batteries of the same type and having the same rating as the original ones.

#### *NOTICE*

Access to the batteries requires the equipment housing to be opened. Battery replacement must be performed by a qualified technician.

## 48V Lead-Acid Battery Pack (595059 and 8174051)

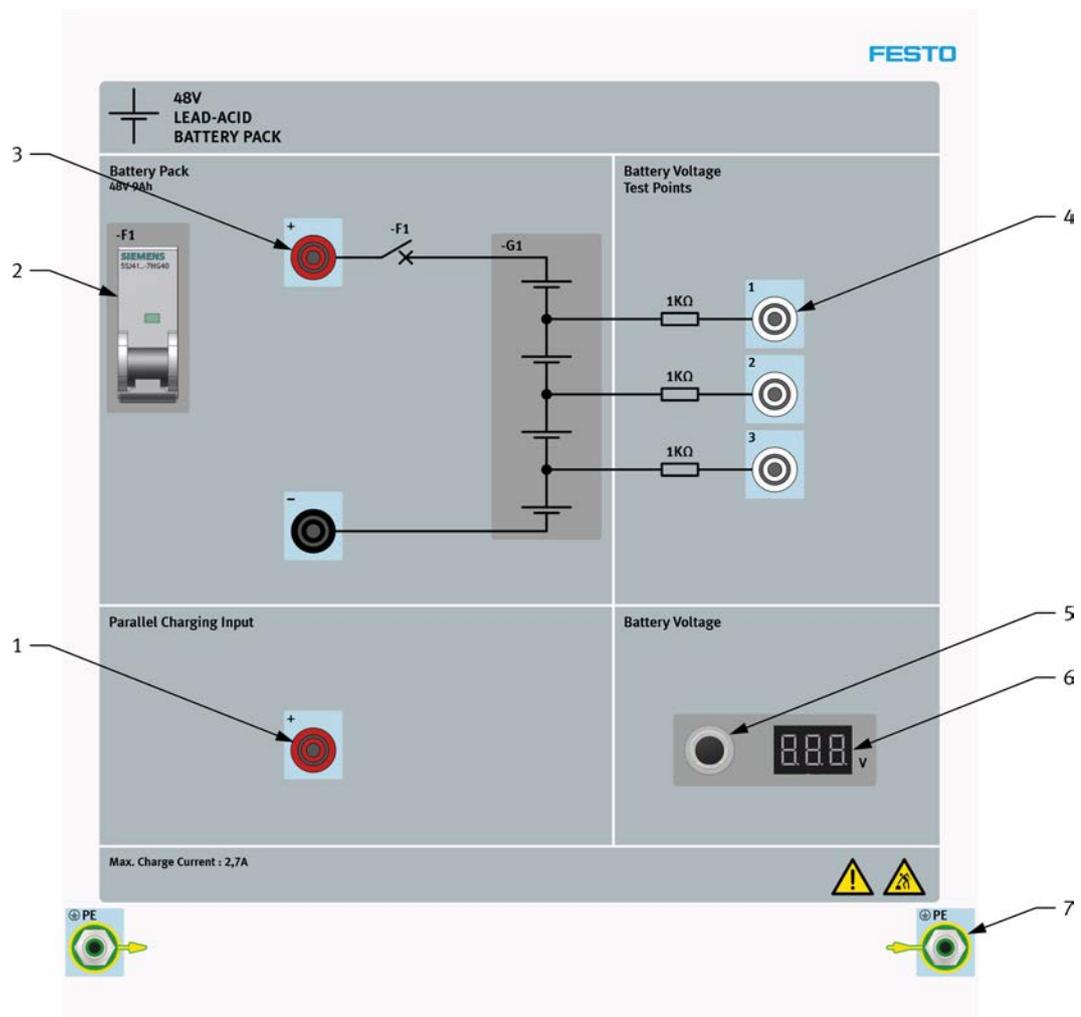


Figure 61: Front panel of the 48V Lead-Acid Battery Pack.

Table 57: Description of the 48V Lead-Acid Battery Pack.

Number	Component name
1	Parallel Charging Input
2	Single-pole circuit breaker, class B, 10 A
3	Battery pack terminals (terminals + and -)
4	Battery voltage test points (terminals 1, 2, and 3)
5	Battery-voltage test push-button
6	Battery voltage display
7	Protective earthing terminals (2)

	 <b>WARNING</b>
	<p><b>Risk of explosion when charging a lead-acid battery pack in a non-ventilated area!</b></p> <ul style="list-style-type: none"> <li>• Explosive gases may be produced when a lead-acid battery pack is being charged. This may result in a risk of explosion when the battery pack is in a non-ventilated area.</li> <li>• To minimize the risk of explosion, make sure that the battery pack is placed in a well-ventilated area before attempting to charge it.</li> <li>• Never operate a lead-acid battery charger when ventilation around the battery pack is restricted in any way.</li> <li>• Do not smoke and avoid creating sparks or flames in the vicinity of the battery pack when it is charging.</li> </ul>

	 <b>WARNING</b>
	<ul style="list-style-type: none"> <li>• <b>Risk of explosion and/or fire when charging an unbalanced lead-acid battery pack!</b> <ul style="list-style-type: none"> <li>• Charging a lead-acid battery pack with unbalanced batteries causes excessive gassing and overheating which, if sustained, may result in failure of one or several of the batteries in the pack and a risk of explosion and/or fire.</li> <li>• To minimize the risk above, start charging the battery pack then verify that the voltage across each battery in the pack is about the same.</li> </ul> </li>   <li>• <b>Risk of explosion and/or fire when overcharging a lead-acid battery pack!</b> <ul style="list-style-type: none"> <li>• Overcharging a lead-acid battery pack causes excessive gassing and overheating which, if sustained, may result in failure of one or several of the batteries in the pack and a risk of explosion and/or fire.</li> </ul> <p>To avoid battery overcharging, always use a battery charger that suits the lead-acid battery pack to be charged.</p> </li> </ul>

### Parallel Charging Input

The Parallel Charging Input allows the 48V Lead-Acid Battery Pack to be connected in parallel with other modules of the same type while preventing the battery packs in these modules to discharge in each other. This allows several 48V Lead-Acid Battery Pack modules to be charged at the same time using a single lead-acid battery charger. To do so, connect the negative terminal of each 48V Lead-Acid Battery Pack to the negative terminal of the battery charger. Then, connect the Parallel Charging Input of each 48V Lead-Acid Battery Pack to the positive terminal of the battery charger. Finally, follow the instructions provided with the lead-acid battery charger to perform battery charging.

### Maintenance

To optimize the cycle life of the batteries in the 48V 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 48V 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 48V Lead-Acid Battery Pack down to a voltage of 42 V.
- Charge the 48V 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 58: 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.

### Battery replacement

Always use batteries of the same type and having the same rating as the original ones. The batteries in a battery pack are balanced, i.e., they have the same state of charge (SOC). Also, these batteries are subjected to the same charge and discharge cycles since they are connected in series. Consequently, the batteries in a battery pack should remain balanced even after many charge and discharge cycles. It is recommended to replace all batteries in the battery pack at the same time to avoid having unbalanced batteries in the pack.

#### **NOTICE**

Access to the batteries requires the equipment housing to be opened. Battery replacement must be performed by a qualified technician.

**Table 59: Main specifications of the 48V Lead-Acid Battery Pack.**

Parameter	Subparameter	Value
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 maximum
Overcurrent protection	Battery pack fuse	10 A (595059 only)
	Battery pack circuit breaker	10 A – 250 V (8174051 only)
	Test point limiting resistors (3)	1 k $\Omega$
Dimensions (H x W x D)		297 x 266 x 140 mm (11.69 x 10.47 x 5.51 in)
Weight		13.7 kg (30.2 lb)

### Communications Gateway (595054)

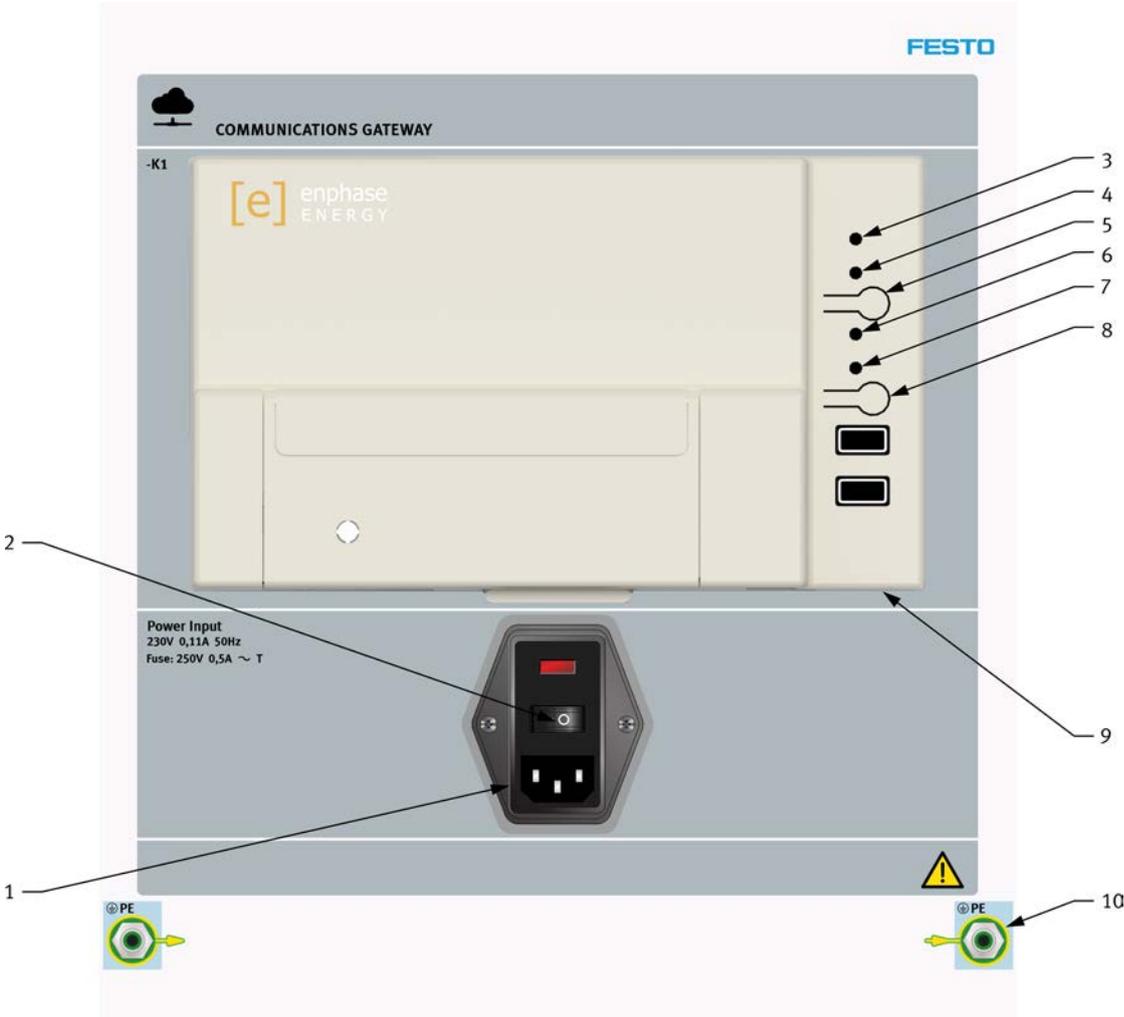


Figure 62: Front panel of the Communications Gateway module.

**Table 60: Description of the Communications Gateway module.**

Number	Component name
1	Power Input connector with fuse holder
2	Main power switch
3	Network Communications LED indicator
4	Access Point (AP) Mode LED indicator
5	Access Point (AP) Mode push-button
6	Power Production LED indicator
7	Device Communications LED indicator
8	Device Scan button
9	Ethernet port connector (accessed via bottom side of unit)
10	Protective earthing terminals (2)

### **Fuse replacement**

Remove the detachable line cord from the unit to allow opening of the fuse holder. Use the specified fuses only with the correct current rating and tripping characteristic.

**Table 61: Main specifications of the Communications Gateway module.**

Parameter	Rating
Input	0.11 A, 230 V – 50 Hz, 1 phase, including line, neutral, and earth wires, protected by a circuit breaker in accordance with local regulations.
Mounting	Designed for DIN A4 mounting frames
Ingress protection rating	IP20
Electromagnetic compatibility	Group 1, Class A (industrial environment, EN 55011)
Dimensions (H x W x D)	297 x 266 x 140 mm (11.69 x 10.47 x 5.51 in)
Weight	X kg (X lb)
CE and UKCA markings	<ul style="list-style-type: none"> <li>● Low-Voltage Directive</li> <li>● EMC Directive</li> <li>● RoHS Directive</li> </ul>

## Soft Starter (8121090)

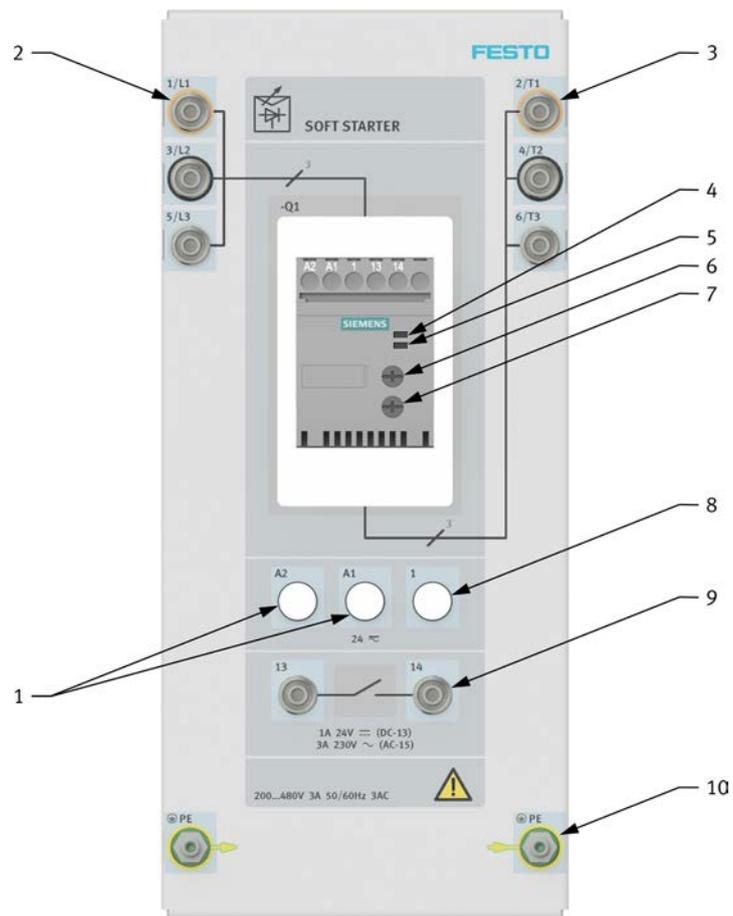


Figure 63: Front panel of the Soft Starter module.

**Table 62: Description of the Soft Starter module.**

Number	Component name
1	Control supply voltage input (terminals A1 and A2)
2	Mains three-phase ac power input (terminals 1/L1, 3/L2, and 5/L3)
3	Motor output (terminals 2/T1, 4/T2, and 6/T3)
4	DEVICE power-on LED indicator
5	STATE/BYPASSED/FAILURE LED indicator
6	Ramp-up time adjustment screw
7	Starting voltage adjustment screw
8	Motor start/stop control input (terminal 1)
9	Auxiliary contact (terminals 13 and 14)
10	Protective earthing terminals (2)



## Equipment Maintenance

The equipment is designed to ensure user safety, reliability, and effective learning outcomes. To maintain safety and performance, it is important to keep the equipment in good condition.

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

Since 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.

	 <b>CAUTION</b>
	<ul style="list-style-type: none"> <li>• Instructors and laboratory personnel must communicate these directions and guidelines to students, as they are essential for maintaining the equipment's safety and functionality.</li> <li>• Do not operate the equipment with missing or damaged parts.</li> </ul>

### General maintenance

The equipment does not require any particular maintenance. However, it is very important to perform a visual inspection of the equipment before each laboratory exercise. If a piece of equipment appears damaged or shows wear, it must be replaced to ensure user safety and prevent further damage to the equipment.

There are no user serviceable parts inside the equipment, other than certain parts that may need to be replaced, such as fuses, button cells, batteries, etc. Opening or removing the equipment housing to replace parts may expose you to dangerous voltages. Do not try to open the equipment housing to replace parts. Have a qualified technician replace parts in the equipment.

### Maintenance of rotating machines

In addition to the general maintenance requirements stated above, the idler tensioning ball bearings (see the following figure) of rotating machines require periodical lubrication. You may notice that a while after the last lubrication, the idler tensioning ball bearings of a rotating machine become noisier. This indicates that the ball bearings require lubrication. When it is needed, lubricate the idler tensioning ball bearings using a small amount (a few drops on each ball bearing) of lubricating oil like the Multi-Purpose Oil from 3-IN-ONE®. Doing so prevents premature wear of the ball bearings and damage to the module.

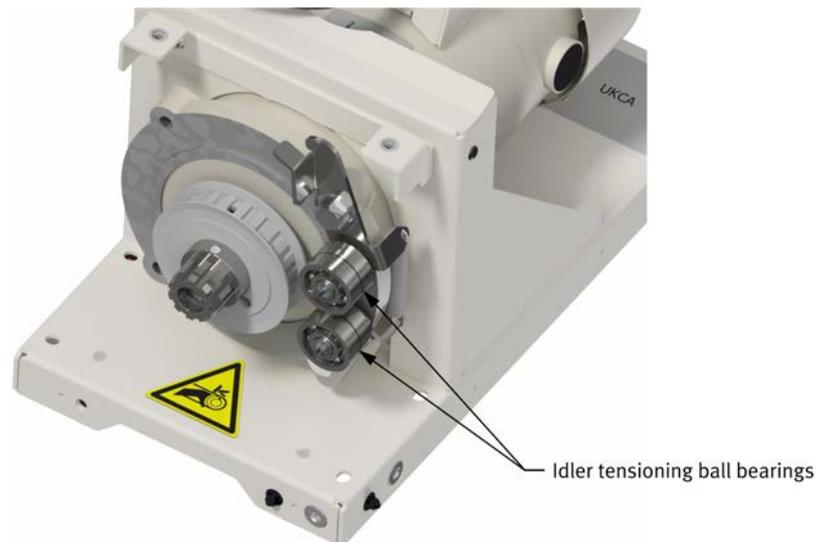


Figure 64: The idler tensioning ball bearings of rotating machines require periodical lubrication.

### Consumables and replacement parts

It is possible to replace certain pieces of equipment that are consumable or that have been damaged. Use only Festo Didactic parts and accessories to ensure compatibility and sustainability of the equipment. Available replacements parts and accessories are listed below.

Table 63: Connections leads.

Part	Type	Rating	Order no.
Connection lead	4 mm safety connection lead	50 mm, 1000 V CAT II, 16 A	572103
		300 mm, 1000 V CAT II, 16 A	572105
		500 mm, 1000 V CAT II, 16 A	572109

Part	Type	Rating	Order no.
		1000 mm, 1000 V CAT II, 16 A	572113
		1500 mm, 1000 V CAT II, 16 A	572117
	2 mm connection lead	100 mm, 500 V CAT II, 5 A	574200
		200 mm, 500 V CAT II, 5 A	574203
		300 mm, 500 V CAT II, 5 A	574204
		500 mm, 500 V CAT II, 5 A	574205

Table 64: Protective earthing leads.

Part	Type	Rating	Order no.
Protective earthing lead	6 mm protective earthing lead (POAG)	100 mm, 4 mm <sup>2</sup> cross section wire	8067504
		400 mm, 4 mm <sup>2</sup> cross section wire	8067505
		1500 mm, 4 mm <sup>2</sup> cross section wire	8067506

**Table 65: Machine accessories and parts.**

Part	Type	Rating	Order no.
Direct coupling	Rubber, sleeve	38 mm diameter, 44 mm length	792271
Timing belt	Rubber, cranted	12.5 mm x 638 mm, 67 teeth	793140
Timing belt	Rubber, cranted	12.5 mm x 676 mm, 72 teeth	793141
Protective guard	Stand-alone machine	N/A	794193
Protective guard	In-line machines	N/A	794194
Protective guard	Side-by-side machines	N/A	794195
Guiding pin	Round, beveled end	N/A	793142

**Table 66: Other module accessories and parts.**

Part	Type	Rating	Order no.
<b>DC 48V Lamps</b>			
Light bulb	Incandescent	48 V, DC, 60 W	791966
Light bulb	LED	48 V, DC, 10 W	793127
<b>AC 230V Lamps</b>			
Light bulb	Incandescent	230 V, 50/60 Hz, 60 W	793126
Light bulb	Compact fluorescent	230 V, 50/60 Hz, 12 W	791954
Light bulb	LED	230 V, 50/60 Hz, 10 W	791955
<b>Wind Turbine Generator and Controller</b>			
AC power cable	Male-to-male	24 V, 3 A	772037
<b>3AC Power Supply and Safety Unit</b>			

Part	Type	Rating	Order no.
Key for Siemens Ronis key-operated switch	Lock no. SB30	N/A	791795
<b>AC 230V Power Supply</b>			
Detachable line cord	C13 connector, C14 plug	250 V, 10 A	792617
<b>AC 24V Power Supply</b>			
Detachable line cord	C13 connector, C14 plug	250 V, 10 A	792617
AC power cable	Male to male	24 V, 3 A	772037
<b>Solar Panel Test Bench</b>			
Light bulb	Halogen, T3 shape	240 V, 300 W	783697
Detachable line cord	C13 connector, C14 plug	250 V, 10 A	792617
<b>Monocrystalline Silicon Solar Panel</b>			
Thermometer cell	Button, no. 357	1.55 V, 175 mAh	790260
<b>12V Lead-Acid Batteries</b>			
Battery	Valve regulated lead-acid (VLRA)	12 V, 2.3 Ah	782998
<b>48V Lead-Acid Battery Pack</b>			
Battery	Valve regulated lead-acid (VLRA)	12 V, 9.0 Ah	786316
<b>Synchronization Lamps and Contactor</b>			
Lamp	T-3 ¼, miniature bayonet base	28 V, 2.3 W	780674
<b>Communications Gateway</b>			
Detachable line cord	C13 connector, C14 plug	250 V, 10 A	792617

Part	Type	Rating	Order no.
Fuse	3AG, fast acting	250 V, 0.5 A	789245
Ethernet cable	Category 5e, RJ-45 connectors	3 m	776778
<b>4 Quadrant Power Supply and Dynamometer Controller</b>			
Detachable line cord	C13 connector, C14 plug	250 V, 10 A	792617
Fuse	Lead-free 3AG, slow blow	250 V, 3 A	765139
USB cable	USB 2.0, AB	1.82 m	782988
<b>Data Acquisition and Control Interface</b>			
Fuse	Lead-free 3AG, slow blow	250 V, 5 A	780770
AC power cable	Male to male	24 V, 3 A	772037
USB cable	USB 2.0, AB	1.82 m	782988

### *NOTICE*

- Before replacing a blown fuse, identify and correct the problem that caused the overcurrent.
- Replace a blown fuse with a fuse of the exact same type. Using the wrong type of fuse may cause damage to the equipment or cause injury.

### 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 front panel(s) and housing(s) of the equipment, use a soft cloth and a mild solution of detergent and water. It is important not to apply the solution directly onto the surface of the equipment. Instead, apply the solution onto the soft cloth.

#### *NOTICE*

Unless specifically stated otherwise, do not use abrasive substances or solvents to clean any part of the equipment.

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