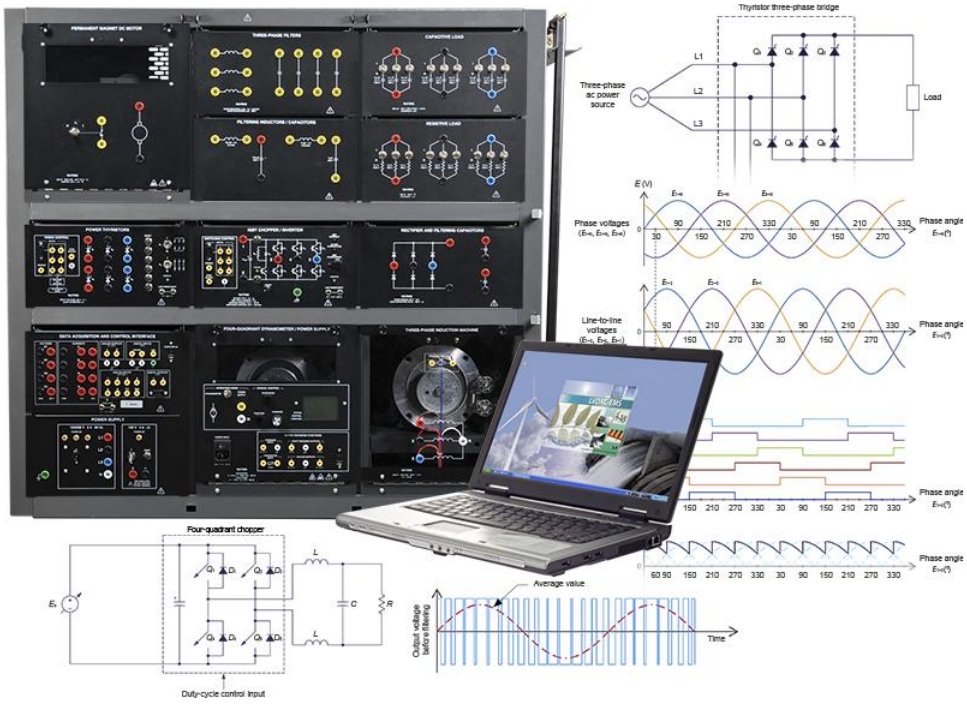
Power Electronics Training System
579314 (8010-A0)

LabVolt Series

Datasheet



Festo Didactic
en 120 V - 60 Hz
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General Description

The Power Electronics Training System combines a modular design approach with computer-based data acquisition and control to provide unrivaled training in power electronics to students already having a sound knowledge of basic electric power technology. The system features the Four-Quadrant Dynamometer/Power Supply, Model 8960, and the Data Acquisition and Control Interface, Model 9063, two state-of-the-art USB peripherals that greatly enhance the learning experience of students.

Training begins with the following four courses:

- DC Power Electronics
- Single-Phase AC Power Electronics
- Three-Phase AC Power Electronics
- Thyristor Power Electronics

These courses introduce the student to the most common power electronic components (power diode, thyristor, and power transistor) as well as to many power electronic devices used in numerous applications today (power diode single-phase and three-phase rectifiers, choppers, single-phase and three-phase inverters, thyristor single-phase and three-phase bridges, solid-state relays or SSRs, and thyristor ac power controllers). Training continues with the following three courses which deal with common industrial applications using power electronics:

- DC Motor Drives
- Three-Phase Motor Drives
- Three-Phase Induction Motor Starters

The following two courses from the Electric Power Technology Training Program, can be optionally added to the Power Electronics Training System to enhance student training in power electronic applications:

- Hydropower Electricity Generation
- High-Voltage DC Transmission Systems

These two courses familiarize the student with the use of hydropower to produce electrical power using synchronous generators, as well as with the transmission of large amounts of electrical power using high-voltage, direct-current (HVDC) lines, two advanced applications using thyristor power electronics.

The Power Electronics Training System is part of the Electric Power Technology Training Systems, Series 8010. Each training system in Series 8010 is based on the Electric Power Technology Training Program and provides a turn-key solution dealing with some aspects of the wide field of electrical energy. The exhaustive courseware provided with each training system covers all the theory required to perform the laboratory exercises, while review questions and unit tests allow students to test the knowledge they have gained.

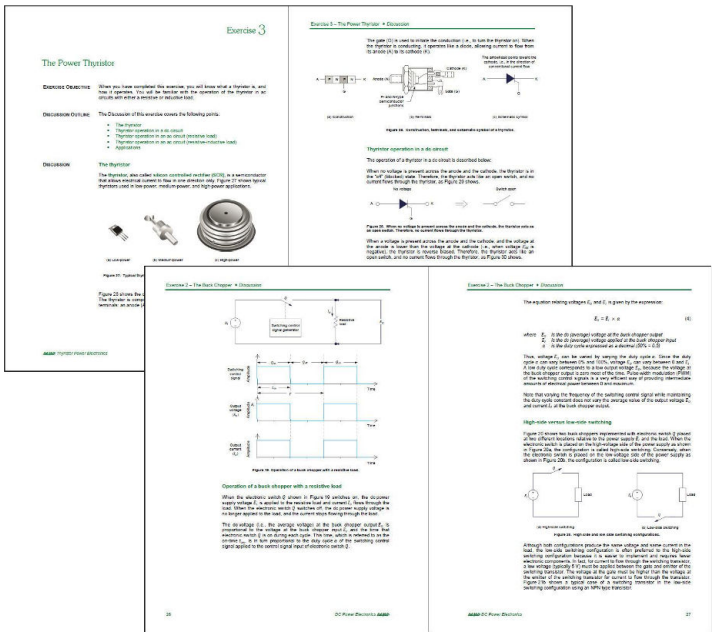
The Electric Power Technology Training Program is highly modular in both courseware and hardware. Because of this, courses and equipment from the program are available as required, either individually or in the context of a specific training system. The program covers several different subjects in the field of electrical energy, such as rotating machines, electrical power transmission, power electronics, home energy production from renewable resources (wind and sunlight), large-scale electricity production from hydropower and wind power, smart-grid technologies (SVC, STATCOM, HVDC transmission, etc.), storage of electrical energy in batteries, and drive systems for small electric vehicles and cars.

Modular Design Approach

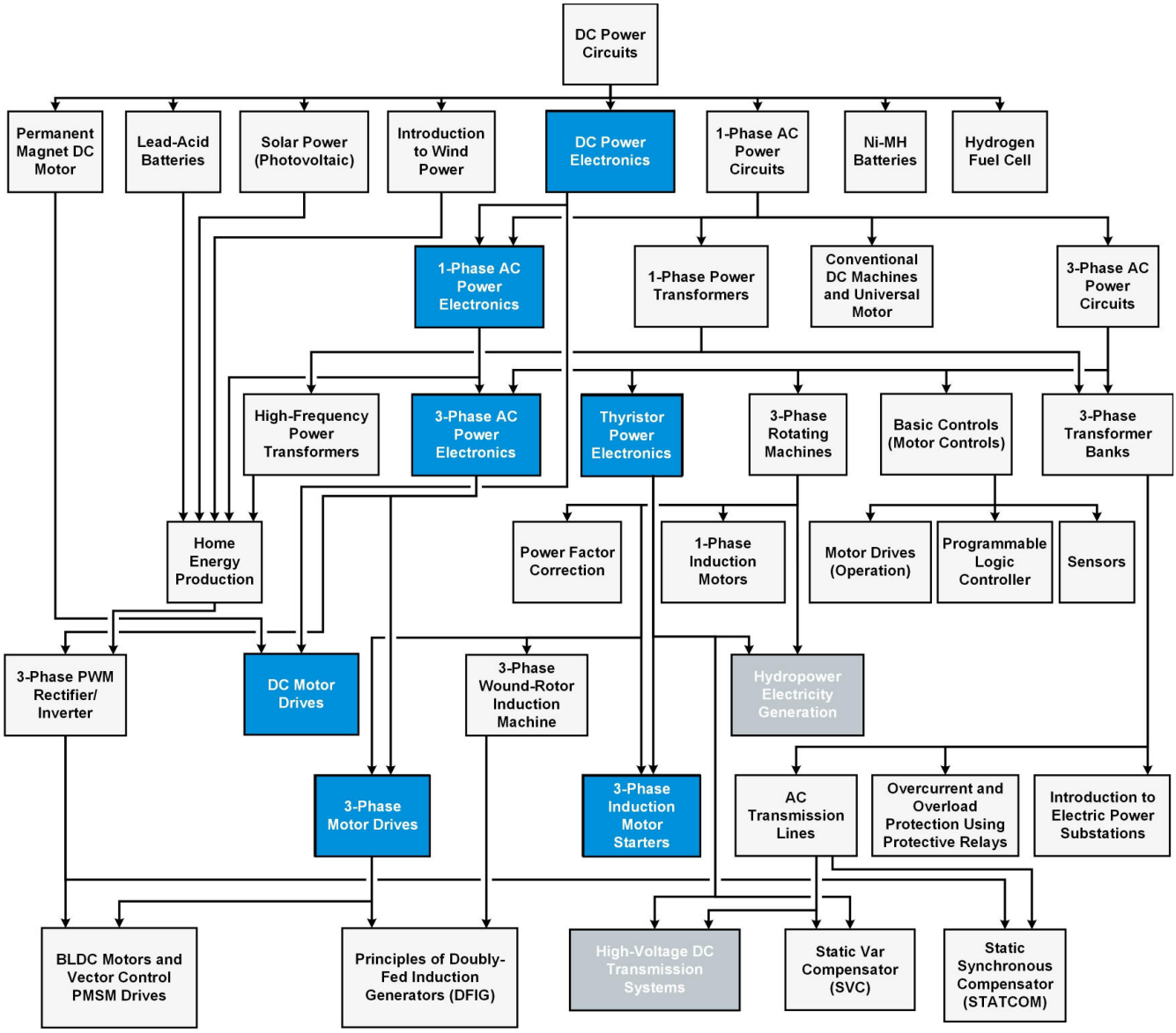
The modular approach for designing the training program and lab equipment enables instructors to start building their electrical-energy laboratory with a basic package of courses and equipment and add new courses and equipment over time without needless duplication of equipment.

All lab equipment consists of modules that can be inserted into a workstation. Module dimensions vary between two standard EMS sizes: full-size and half-size. Symbols and diagrams representing the electrical components in each module are clearly silk-screened on the front panel. Standard, color-coded safety banana jacks are used to provide access to the various components in each module.

Courseware



Each course in the training system includes a full-color student manual providing all the theoretical matter required, guided lab-exercise procedures to be performed with the training equipment, and review questions that test the knowledge gained by the student. Whenever possible, each course is built to bring the student to actual applications as soon as possible. A full-color instructor guide providing all lab results and answers to questions is also included with each course.



The above chart shows all courses in the Electric Power Technology Training Program. Blue boxes highlight courses included in the training system covered in this datasheet, while dark grey boxes, if any, highlight courses that can be optionally added to this training system.

Features & Benefits

- The training system teaches the principles of dc and ac power electronics. To this end, students follow a complete curriculum that includes these topics:
  - Courses that cover the operation of various power electronics devices, both dc and ac, as well as single-phase and three-phase.
  - Courses that cover a variety of common power electronics applications, such as dc motor drives, three-phase motor drives, and three-phase induction motor starters.
  - Optional courses that cover advanced applications of power electronics, such as hydropower electricity generation, and HVDC transmission systems.
- All control of power electronics devices is computerized via the LVDAC-EMS software, allowing for user-friendly operation, high configurability, and ease of monitoring.

- Video presentations of several power electronics control functions used in the training system are available on Youtube.
- The course curriculum of the Electric Power Technology Training Program is highly flexible and allows a multitude of different customized training solutions.
- The courseware includes student manuals and instructor guides with all the theory required to perform the hands-on experiments.
- All workstations, modules, and components are sturdy and protected against electrical damage to ensure a prolonged service life in a demanding environment such as a training laboratory.
- The modular design approach of the training equipment allows a large variety of courses to be performed using a small number of modules, without unnecessary duplication of equipment.
- All electrical components can be interconnected without electric shock hazard since all live parts of the connection leads are concealed and insulated.
- All electrical symbols representing the components used in a laboratory exercise are clearly silk-screened on the front panel of the modules.
- The training system includes two highly versatile USB peripherals:
  - Four-Quadrant Dynamometer/Power Supply, Model 8960-2. This module is used as a dc power source and a battery charger/discharger with a large variety of configurable parameters. It can also be used as an overnight battery float charger.
  - Data Acquisition and Control Interface, Model 9063. This module gives access to a large variety of computer-based measuring instruments and is used to control the various dc power electronics devices. All functions are implemented via the LVDAC-EMS software.
- The training system also includes three highly versatile power electronics modules controlled using the Data Acquisition and Control Interface:
  - IGBT Chopper/Inverter, Model 8837-B. This module is used to implement various types of choppers and inverters.
  - Power Thyristors, Model 8841. This module is used to implement various thyristor-based devices (e.g., bridges, ac power controllres, solid-state relays)
  - Rectifier and Filtering Capacitors, Model 8842-A. This module is used to implement various types of power diode rectifiers.
- Software upgrades for LVDAC-EMS and firmware upgrades for the Four-Quadrant Dynamometer/Power Supply and Data Acquisition and Control Interface are available for download free of charge on the Festo Didactic website.

List of Equipment

Qty	Description	Model number
1	Workstation	579484 (8134-20)
1	Permanent Magnet DC Motor	8114247 (8213-10)
1	Four-Pole Squirrel-Cage Induction Motor	586267 (8221-20)
1	Resistive Load	763359 (8311-00)
1	Filtering Inductors/Capacitors	579523 (8325-A0)
1	Three-Phase Filter	579529 (8326-00)
1	Capacitive Load	763366 (8331-00)
1	Three-Phase Transformer Bank	579559 (8348-40)
1	Synchronizing Module / Three-Phase Contactor	579576 (8621-A0)
1	Lead-Acid Battery Pack	579591 (8802-10)
1	Power Supply	579612 (8823-00)
1	IGBT Chopper/Inverter	579623 (8837-B0)
1	Power Thyristors	763376 (8841-20)

Qty	Description	Model number
1	Rectifier and Filtering Capacitors	579630 (8842-A0)
1	Timing Belt	579637 (8942-00)
1	Connection Lead Set	579638 (8951-L0)
1	Four-Quadrant Dynamometer/Power Supply	579662 (8960-E0)
1	Data Acquisition and Control Interface	579686 (9063-D0)
1	24 V AC Power Supply	579696 (30004-20)

List of Manuals

Description	Manual number
DC Power Electronics (Student Manual)	579358 (86356-00)
DC Power Electronics (Instructor Guide)	579360 (86356-10)
Single-Phase AC Power Electronics (Student Manual)	579370 (86359-00)
Single-Phase AC Power Electronics (Instructor Guide)	579372 (86359-10)
Three-Phase AC Power Electronics (Student Manual)	579393 (86362-00)
Three-Phase AC Power Electronics (Instructor Guide)	579395 (86362-10)
Thyristor Power Electronics (Student Manual)	579402 (86363-00)
Thyristor Power Electronics (Instructor Guide)	579403 (86363-10)
Three-Phase Motor Drives (Student Manual)	579426 (86368-00)
Three-Phase Motor Drives (Instructor Guide)	579427 (86368-10)
Three-Phase Induction Motor Starters (Student Manual)	579462 (88197-00)
Three-Phase Induction Motor Starters (Instructor Guide)	579463 (88197-10)
Electric Power Technology Training Equipment (User Guide)	584778 (38486-E0)
Computer-Based Instruments for EMS (User Guide)	585219 (86718-E0)
DC Motor Drives (Instructor Guide)	8113740
DC Motor Drives (Student Manual)	8113742

Table of Contents of the Manual(s)

DC Power Electronics (Student Manual) (579358 (86356-00))

Single-Phase AC Power Electronics (Student Manual) (579370 (86359-00))

Three-Phase AC Power Electronics (Student Manual) (579393 (86362-00))

Thyristor Power Electronics (Student Manual) (579402 (86363-00))

- 1 Power Diode Single-Phase Rectifiers
- 2 Power Diode Three-Phase Rectifiers
- 3 The Power Thyristor
- 4 The Solid State Relay
- 5 Single-Phase AC Power Control
- 6 Three-Phase AC Power Control
- 7 Thyristor Three-Phase Rectifier/Inverter

Three-Phase Motor Drives (Student Manual) (579426 (86368-00))

- 1 Three-Phase, Variable-Frequency Induction-Motor Drive
- 2 Three-Phase, Variable-Frequency Induction-Motor Drive with Constant V/f ratio

Three-Phase Induction Motor Starters (Student Manual) (579462 (88197-00))

- 1 DOL Starters and Soft Starters
- 2 Advanced Features of Soft Starters

Electric Power Technology Training Equipment (User Guide) (584778 (38486-E0))

- 1 General Safety Recommendations
- 2 System Power Requirements
- 3 Quick Start Installation Guide
- 4 Equipment Installation
- 5 Modules Handling, Installation, and Removal
- 6 Equipment Maintenance
- A Connection of the Power Supply to the AC Power Network
- B Description, Specifications, and Operation of the EMS Modules

Computer-Based Instruments for EMS (User Guide) (585219 (86718-E0))

- 1 Familiarization with the Metering Window and the Data Table
- 2 Familiarization with the Oscilloscope
- 3 Familiarization with the Phasor Analyzer
- 4 Familiarization with the Harmonic Analyzer
- 5 Measuring Three-Phase Power Using the Metering Window

Additional Equipment Required to Perform the Exercises

Qty	Description	Model number
1	Digital Multimeter	579782 (8946-20)
1	Personal Computer	579785 (8990-00) [1]

Optional Equipment

Qty	Description	Model number
1	Mobile Workstation	579755 (8110-20) [2]
1	Storage Shelves	579756 (8150-10)
1	Full-Size Blank EMS Module	579757 (8160-00)

[1] Refer to the Computer Requirements in the System Specifications section of this datasheet if the computer is to be provided by the end-user. Note that only one computer is required per station.

[2] Can replace the Workstation, Model 8134.

Qty	Description	Model number
1	Half-Size Blank EMS Module	579758 (8161-00)
1	Synchronous Motor/Generator	579502 (8241-20)
1	Inductive Load	763362 (8321-00)
1	Three-Phase Transmission Line	579535 (8329-00)
1	Three-Phase Transformer Bank	579559 (8348-40)
2	Three-Phase Regulating Autotransformer	763369 (8349-00)
1	AC Power Network Interface	579581 (8622-00) [3]
1	Solar Panel Test Bench	579594 (8805-00) [4]
1	Power Supply	579603 (8821-20) [5]
1	Power Thyristors	763376 (8841-20)
1	Multimeters Module	586888 (8946-A0) [6]
1	Connection Lead Set	579639 (8951-N0)
1	Turbine Emulator Function Set	579783 (8968-30)
1	Data Acquisition and Control Interface	579677 (9063-00)
1	High-Voltage DC (HVDC) Transmission System Control Function Set	579790 (9069-70)
1	Synchronous Generator Control Function Set	579788 (9069-A0)
1	Power Electronics Training System (Manuals on CD-ROM)	579717 (86359-A0)

Optional Manual(s)

Qty	Description	Model number
1	Hydropower Electricity Generation (Student Manual)	579742 (86369-00) [7]
1	Hydropower Electricity Generation (Instructor Guide)	579743 (86369-10)
1	HVDC Transmission Systems (Student Manual)	579460 (86380-00) [8]
1	HVDC Transmission Systems (Instructor Guide)	579461 (86380-10)

System Specifications

Parameter	Value
Sytem Requirements	
Maximum Current	10 A
Typical Current	1.5 A per student group
AC Power Network Installation	3 phases (120/208 V – 60 Hz), star (wye) configuration including neutral and ground wires, protected by a 20 A circuit breaker
AC Power Network Connector	NEMA L21-20
Computer Requirements	A currently available personal computer with USB 2.0 ports, running under one of the following operating systems: Windows® 7 or Windows® 8.
Physical Characteristics	
Intended Location	On a table able to support the weight of the workstation and installed equipment

[3] Required solely to perform an optional section in an exercise of the course Thyristor Power Electronics, Model 86363.

[4] Required solely to perform an optional section in an exercise of the course Thyristor Power Electronics, Model 86363.

[5] Remove the Power Supply, Model 8823, and the 24 V AC Power Supply, Model 30004-2, included in this training system when ordering the Power Supply, Model 8821-2.

[6] Can replace the Digital Multimeter, Model 8946-2.

[7] To perform the exercises in this optional course, the following equipment is required: Synchronous Motor/Generator, Model 8241-2, Inductive Load, Model 8321, Synchronizing Module / Three-Phase Contactor, Model 8621-A, Turbine Emulator, Model 8968-3, and Synchronous Generator Control, Model 9069-A.

[8] To perform the exercises in this optional course, the following equipment is required: Three-Phase Transmission Line, Model 8329, Three-Phase Transformer Bank, Model 8348-4, Three-Phase Regulating Autotransformer, Model 8349, Power Supply, Model 8821-2, Power Thyristors, Model 8841-2, and Connection Leads, Model 8951-N.

Parameter	Value
Dimensions (H x W x D)	900 x 930 x 530 mm (35.4 x 36.6 x 20.9 in)
Net Weight	191 kg (420 lb)
EMS Modules	
Full-Size Dimensions (H x W x D)	308 x 287 x 440 mm (12.1 x 11.3 x 17.3 in)
Half-Size Dimensions (H x W x D)	154 x 287 x 440 mm (6.1 x 11.3 x 17.3 in)

Equipment Description

Workstation
579484 (8134-20)

The Workstation is a fully assembled workstation that serves the same purpose as the Mobile Workstation, Model 8110-2, but has no storage cabinet or pull-out work surface. This workstation is intended for use on a bench (not supplied) and is fitted with rubber feet to protect the bench top. Alternatively, this workstation can be mounted on either a Mobile Storage Cabinet, Model 89117-1, to make a Mobile Workstation, Model 8110-2, or on a Mobile Base, Model 88863, to make a mobile workstation without storage cabinet. In that case, it is possible to mount and lock a second Workstation, Model 8134-2, on top of the first Workstation to double the space available for EMS modules.

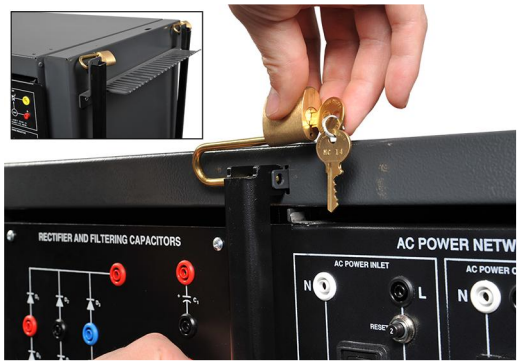
The Workstation consists of three rows of compartments designed to house EMS modules. Two of these rows have full-height compartments while the other row has half-height compartments. Each row of full-height compartments can accommodate up to three full-size EMS modules or six half-size EMS modules whereas the row of half-height compartments can accommodate up to three half-size EMS modules.

Module Installation

The EMS modules are guided into position along stainless steel guide rails. Separators between each bay of the workstation ensure perfect alignment of the EMS modules and allow their easy insertion in the workstation. A holding mechanism ensures that each EMS module stays in place once it is installed in a compartment of the workstation. Front-mounted push levers allow all EMS modules on a single row to be released for easy removal.

Safety Padlock Bars

Two safety padlock bars on the front of the workstation prevent students from removing EMS modules during laboratory exercises. The bars can be removed and locked to the side of the workstation when the safety lock is not necessary.



Additional Information

Six holes in the rear panel of the workstation allow connection to a power supply, as well as the connection of 2 kW machines to their interconnection modules. Assembly of the workstation before painting ensures that each EMS module in the workstation is correctly grounded.

Manual

Description	Manual number
Electric Power Technology Training Equipment (User Guide)	584778 (38486-E0)

Table of Contents of the Manual(s)

Electric Power Technology Training Equipment (User Guide) (584778 (38486-E0))

- 6 Equipment Maintenance
- A Connection of the Power Supply to the AC Power Network
- B Description, Specifications, and Operation of the EMS Modules

Optional Equipment

Qty	Description	Model number
1	Industrial Controls Single-Rail Workstation	581243 (3105-A0) [9]
1	Industrial Controls Double-Rail Workstation	585964 (3105-B0) [10]
1	All-in-One Touch Screen Computer (including Monitor Stand with Articulating Arm)	8108708 (8990-A0)
1	Dust Cover for Workstations	587004 (8991-00)
1	Mounting Stand with Articulating Arm	8108710 (36653-A0)
1	Mobile Base	587518 (88863-00)
1	Mobile Storage Cabinet	587519 (89117-10)

Specifications

Parameter	Value
Physical Characteristics	
Intended Location	On a table able to support the weight of the workstation and installed equipment
Dimensions (H x W x D)	890 x 935 x 465 mm (35.0 x 36.8 x 18.3 in)
Net Weight	31.8 kg (70 lb)

Permanent Magnet DC Motor 8114247 (8213-10)

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

The front panel of the Permanent Magnet DC Motor module can be opened to install a Timing Belt, Model 8942, on the pulley of the motor shaft. This permits mechanical coupling of this motor to the Four-Quadrant Dynamometer/Power Supply, Model 8960. The diameter of the Permanent Magnet DC Motor pulley is smaller (12 teeth) than that of the pulleys of the Four-Quadrant Dynamometer/Power Supply (24 teeth). This difference

[9] This add-on workstation allows modules from the Industrial Controls Training Systems, Models 8036, to be installed in the EMS workstation. Refer to the 8036 datasheet for more information.

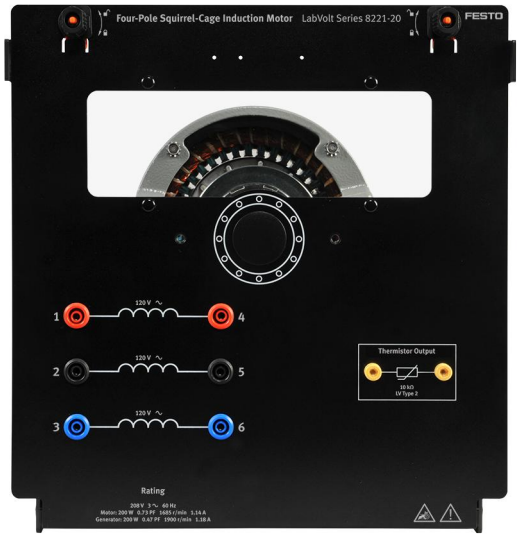
[10] This add-on workstation allows modules from the Industrial Controls Training Systems, Models 8036, to be installed in the EMS workstation. Refer to the 8036 datasheet for more information.

of pulley ratio (12 to 24) permits adapting the speed (0 4000 r/min) of the Permanent Magnet DC Motor to the speed of the Four-Quadrant Dynamometer/Power Supply (between 0 2000 r/min).

Specifications

Parameter	Value
Nominal Characteristics	
Power	220 W
Voltage	48 V
Current	5.0 A
Speed	3825 rpm
Duty Cycle	15 min ON / 60 min OFF
Pulley	
Number of teeth	12
Physical Characteristics	
Dimensions (H x W x D)	308 x 291 x 440 mm (2.1 x 11.5 x 17.3 in)
Net Weight	7.6 kg (16.8 lb)

Four-Pole Squirrel-Cage Induction Motor 586267 (8221-20)



The Four-Pole Squirrel-Cage Induction Motor is a 0.2 kW squirrel-cage induction machine mounted in a full-size EMS module. The machine stator windings are independently connected (six jacks), allowing connection in either wye or delta configuration. Connections to the machine are made through color-coded safety banana jacks located on the front panel on the module. The machine has a thermistor output that allows monitoring of the machine internal temperature to prevent overheating. A tensioner bearing can be ordered as an option.

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

Specifications

Parameter	Value
Motor	
Stator Voltage	120/208 V, 3-phase
Mechanical Power	200 W
Nominal Speed	1685 r/min
Nominal Current	1.14 A
Power factor	0.73
Generator	
Stator Voltage	120/208 V, 3-phase
Output Power	200 W
Nominal Speed	1900 r/min
Nominal Current	1.18 A
Power factor	0.47

Parameter	Value
Protection	
Type	10 kΩ thermistor, type 2, in the stator windings
Physical Characteristics	
Dimensions (H x W x D)	308 x 287 x 440 mm (12.1 x 11.3 x 17.3 in)
Net Weight	TBE

Resistive Load
763359 (8311-00)

The Resistive Load consists of a module housing nine wire-wound power resistors arranged in three identical banks. Each bank consists of three resistors connected in parallel that can be switched on or off with toggle switches to obtain various resistance values. This allows the total (equivalent) resistance of each bank to be increased or decreased by steps. Six safety banana jacks on the module front panel provide access to each resistor bank. The three resistor banks can be connected separately for operation in three-phase circuits. Also, the three resistor banks can be connected together for operation in single-phase circuits.

The Resistive Load is commonly used in conjunction with other basic load modules, like the Inductive Load and the Capacitive Load to experiment with the effects of different types of load on a circuit.

Specifications

Parameter	Value
Resistors	
Quantity	Three identical banks of three resistors
Resistance Values (Each Group)	300/600/1200 Ω
Nominal Voltage	120 V ac/dc
Resistance Value Accuracy	± 5%
Load at Nominal Voltage (Each Bank)	
Power	12-84 W
Current	0.1-0.7 A
Steps	Seven, of equal increment
Current Increment	0.1 A
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 410 mm (6.1 x 11.3 x 16.1 in)
Net Weight	4.5 kg (9.9 lb)
Color	
Front panel color	Black

Filtering Inductors/Capacitors 579523 (8325-A0)

This Filtering Inductors/Capacitors module consists of two separate filters enclosed in a half-size EMS module: a low-frequency filter and a high-frequency filter. The low-frequency filter consists of an inductor and a polarized capacitor, while the high-frequency filter consists of two inductors and a non-polarized capacitor. Internal electrical components are identified on the module front panel. 4 mm banana jacks provide access to the different components in the module.

Specifications

Parameter	Value
Low Frequency Filter	
Inductance	50 mH - 5 A - 0-2 kHz
Capacitor (Aluminium Electrolytic)	210 µF - 450 V
High Frequency Filter	
Inductance (2)	2 mH - 5 A - 0-20 kHz
Capacitor (Metallized Polypropylene)	5 µF - 400 V
Supplementary Capacitor (Met. Prop.)	N/A
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 440 mm (6.1 x 11.3 x 17.3 in)
Net Weight	12.3 kg (27.12 lb)

Three-Phase Filter 579529 (8326-00)

The Three-Phase Filters consists of three inductors and four capacitors enclosed in a half-size EMS module. Eight safety banana jacks on the module front panel provide access to the three-phase filter. The module is used to filter three-phase signals in power electronics applications.

Specifications

Parameter	Value
Inductors	
Number	3
Ratings	2 mH – 5 A – 0-20 kHz
Capacitors	
Number	4
Type	Metallized polypropylene
Ratings	5 µF – 400 V
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 440 mm (6.1 x 11.3 x 17.3 in)

Parameter	Value
Net Weight	TBE

Capacitive Load 763366 (8331-00)

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

A permanently connected discharge resistor reduces the voltage across the terminals of each bank of capacitors to 5% of the applied voltage within 25 seconds after the load is disconnected from the supply. The Capacitive Load may be used with both dc and ac power.

The Capacitive Load is commonly used in conjunction with the other basic load modules, the Resistive Load and the Inductive Load to experiment with the effects of different types of load on a circuit.

Specifications

Parameter	Value
Capacitors	
Quantity	Three identical banks of three capacitors
Capacitance Values (Each Bank)	2.2/4.4/8.8 µF
Reactance Values (Each Bank)	300/600/1200 Ω
Nominal Voltage	120 V – 60 Hz
Maximum Voltage	230 V
Capacitance Value Accuracy	± 5%
Load at Nominal Voltage (Each Bank)	
Reactive Power	12-84 var
Current	0.1-0.7 A
Steps	Seven, of equal increment
Current Increment	0.1 A
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 410 mm (6.1 x 11.3 x 16.1 in)
Net Weight	5.7 kg (12.6 lb)

Three-Phase Transformer Bank 579559 (8348-40)

The Three-Phase Transformer Bank consists of three independent power transformers enclosed in a module. Safety banana jacks on the module front panel provide individual access to the windings of each power transformer, allowing connection in either wye or delta configuration. The transformer windings are polarized and the polarity of each winding is indicated by a small dot on the module front panel. Resettable fuses protect the primary and secondary windings of each transformer against overcurrents. Fuse status lamps on the module front panel turn on when the resettable fuses open.

Specifications

Parameter	Value
Rating (Each Transformer)	
Primary Voltage	208 V
Secondary Voltage	208/120 V
Power	250 VA
Full-Load Current	1.2 A
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 410 mm (6.1 x 11.3 x 16.1 in)
Net Weight	13.9 kg (30.6 lb)

Synchronizing Module / Three-Phase Contactor 579576 (8621-A0)

The Synchronizing Module / Three-Phase Contactor is a half-size EMS module used to control various electric devices, or synchronize two ac power sources like a synchronous generator with an ac power network. The Synchronizing Module / Three-Phase Contactor consists of a three-phase contactor whose coil can be energized either manually with a toggle switch, or automatically with a thyristor fired by applying to the Remote Control input of the module, a low-level (TTL) signal from the Data Acquisition and Control Interface, Model 9063. Six safety banana jacks (one pair per phase) allow connection of electric devices or ac power sources across the contacts of the three-phase contactor. Three indicator lamps indicate the relative level of the voltage across their corresponding contact terminals.

Specifications

Parameter	Value
Contactor	
Power Input	120 V – 100 mA – 60 Hz
Contacts	400 V – 3 A ac

Parameter	Value
Light Bulbs (3)	
Rating	28 V – 2.3 W – T 3 1/4
Remote Control Input	
Voltage	0/3.5-5 V dc
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 440 mm (6.1 x 11.3 x 17.3 in)
Net Weight	3.6 kg (7.9 lb)
Shipping Weight	5.2 kg (11.4 lb)

Lead-Acid Battery Pack 579591 (8802-10)

The Lead-Acid Battery Pack is a half-size EMS module housing four 12 V lead-acid batteries connected in series. The Lead-Acid Battery Pack thus provides a fixed dc voltage of 48 V, available at two color-coded safety banana jacks on the module front panel. Three battery voltage test points allow measurement of the voltage provided by each of the four 12 V batteries. A parallel charging input terminal permits the charging of several Lead Acid Battery Packs connected in parallel at the same time. The Lead-Acid Battery Pack is protected against overcurrents and short-circuits. The Lead-Acid Battery Pack can be used as a 48 V dc power source, and in energy production and storage applications implemented with the Electricity and New Energy Training Equipment.

Specifications

Parameter	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
Test Point Limiting Resistors (3)	1 kΩ
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 440 mm (6.1 x 11.3 x 17.3 in)
Net Weight	TBE

Power Supply
579612 (8823-00)

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

Specifications

Parameter	Value
Power Requirements	
Maximum Current	10 A
AC Power Network Installation	3 phases (120/208 V – 60 Hz), star (wye) configuration including neutral and ground wires, protected by a 20 A circuit breaker
AC Power Network Connector	NEMA L21-20
Outputs	
Fixed AC 3-Phase	120/208 V – 5 A
Fixed DC	120 V – 4 A
Included Power Cord	3 m (10 ft)
Physical Characteristics	
Dimensions (H x W x D)	212 x 287 x 496 mm (8.3 x 11.3 x 19.5 in)
Net Weight	5.7 kg (12.5 lb)

IGBT Chopper/Inverter
579623 (8837-B0)

The IGBT Chopper/Inverter module consists of seven insulated-gate bipolar transistors (IGBT) mounted in a half-size EMS module. Six IGBTs are used to implement choppers and inverters. These IGBTs are protected against a variety of abnormal operating conditions, such as short-circuits, overvoltage, overcurrent, and overheat. The seventh IGBT and a dumping resistor allow smooth dissipation of excess energy at the dc bus. The dumping circuit can be activated through the use of a toggle switch on the front panel.

The module switching control section allows 0/5 V pulse signals from either the Data Acquisition and Control Interface, Model 9063, the Chopper/Inverter Control Unit, Model 9029, or any compatible 0/5 V control unit, to be applied to the gating circuits of the IGBTs. The signals are input in the IGBT Chopper/Inverter module through a nine-pin connector.

Six miniature banana jacks can be used as test points to monitor the pulse signals using an oscilloscope. These jacks can also be used to inject 0/5 V pulse signals from an alternate control unit, as well as to inhibit each gating circuit. The IGBT Chopper/Inverter module also includes a synchronization output to trigger an oscilloscope when observing the switching control signals, as well as a switching control disable input that allows all six IGBTs in the chopper/inverter section to be switched off.

Specifications

Parameter	Value
DC Bus	
Maximum Voltage	420 V
Maximum Current	6 A
Filtering Capacitor	1360 µF
Protections	
DC Bus Overvoltage	440 V
DC Bus Circuit Breaker	6 A
IGBT Electronic Overcurrent	12 A
IGBT Overheat	About 70°C
Dumping Circuit	
Voltage Threshold	330 V
Resistor	100 Ω, 100 W
Switching Control Signals	
Level	0/5 V
Frequency Range	0-20 kHz
Minimum Dead Time	700 ns
Power Requirements	24 V, 0.16 A, 50/60 Hz
Accessories	
Accessories	24 V power cable (1)
	2 mm banana plug test leads (2)
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 410 mm (6.1 x 11.3 x 16.1 in)
Net Weight	5.67 kg (12.5 lb)

Power Thyristors 763376 (8841-20)

The Power Thyristors module consists of six power thyristors (SCRs) mounted in a half-size EMS enclosure. Each individual thyristor is protected against overcurrents and short-circuits. All the anodes and cathodes of the thyristors are terminated on the front panel by color-coded, 4 mm safety banana jacks. To reduce the number of external connections, the most typical thyristor configurations can be achieved through the use of two toggle switches on the front panel.

A firing control section allows six 0-5 V pulse signals from either the Data Acquisition and Control Interface, Model 9063, the Thyristor Firing Unit, Model 9030, or any compatible 0-5 V control unit, to be applied to the gating circuits of the thyristors. The signals are input in the Power Thyristors module through a nine-pin connector.

Six miniature banana jacks in this section are used as test points to monitor the firing control signals using an oscilloscope. They can also be used to inject 0-5 V pulse signals from an alternate firing unit, as well as to inhibit each gating circuit. The Power Thyristors module also includes a synchronization output to trigger an

oscilloscope when observing the firing control signals as well as a firing control disable input that prevents all six power thyristors from being fired.

Specifications

Parameter	Value
Rating	
Peak Inverse Voltage	600 V
Maximum Current	2 A
Gate Control Signals	0-5 V Pulses (TTL compatible)
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 440 mm (6.1 x 11.3 x 17.3 in)
Net Weight	5.6 kg (12.35 lb)

Rectifier and Filtering Capacitors 579630 (8842-A0)

This Rectifier and Filtering Capacitors module consists of a three-phase bridge rectifier and two separate capacitors enclosed in a half-size EMS module. The bridge allows the conversion of a three-phase voltage input into an unfiltered dc voltage. This dc voltage can then be filtered using the polarized capacitors (each one protected by a diode). Internal electrical components are identified on the module front panel by silkscreened symbols and terminated by 4 mm safety banana jacks.

Specifications

Parameter	Value
Electrical Characteristics	
Maximum Network Voltage	230 V - 3~ - 50/60 Hz
Maximum Diode Current	8 A
Each Capacitor	210 µF - 450 V dc
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 440 mm (6.1 x 11.3 x 17.3 in)
Net Weight	2.9 kg (6.4 lb)

Timing Belt 579637 (8942-00)

The Timing Belt is a high-quality industrial synchro-cog timing belt made of rubber whose teeth exactly mesh with the geared pulley fitted on the shaft of all 0.2 kW EMS machines. The Timing Belt is supplied in a fixed length appropriate for coupling two adjacent EMS machines together without slippage between them.

Specifications

Parameter	Value
Physical Characteristics	
Pitch	9.5 mm (0.375 in)
Pitch Length	819 mm (32.25 in)
Number of Teeth	86
Dimensions (Width)	12.7 mm (0.5 in)
Net Weight	0.1 kg (0.2 lb)

Connection Lead Set 579638 (8951-L0)

This Connection Lead Set consists of extra-flexible leads terminated with stacking 4 mm safety banana plugs. In addition, the set includes stacking 2 mm banana plug leads of the same length and color.

Specifications

Parameter	Value
4 mm Safety Banana Plug Leads Characteristics	
Cross Section	1 mm² (1974 cmil)
Rated Current	19 A
Rated Voltage	600 V, CAT II
4 mm Safety Banana Plug Leads Quantities	
Yellow, 30 cm (12 in)	20
Red, 60 cm (24 in)	10
Blue, 90 cm (36 in)	4
2 mm Safety Banana Plug Leads Characteristics	
Cross Section	0.5 mm² (987 cmils)
Rated Current	10 A
Rated Voltage	30 V ac / 60 V dc
2 mm Safety Banana Plug Leads Quantities	
Red, 60 cm (24 in)	4

Four-Quadrant Dynamometer/Power Supply 579662 (8960-E0)

The Four-Quadrant Dynamometer/ Power Supply is a highly versatile USB peripheral designed to be used in the Electric Power Technology Training Systems. Two operating modes are available: Dynamometer and Power Supply. A wide variety of user-selectable functions is available in each operating mode.

In the Dynamometer mode, the unit becomes a four-quadrant dynamometer that can act as either a fully configurable brake (i.e., a mechanical load) or a fully configurable prime mover (i.e., a motor drive). In the Power Supply mode, the unit becomes a four-quadrant power supply that can act as a dc voltage source, dc current source, ac power source, etc.

In each operating mode, key parameters related to the selected function are displayed. Speed, torque, mechanical power, and energy are displayed in the Dynamometer mode while voltage, current, electrical power, and energy are displayed in the Power Supply mode. Optional functions, such as a small wind-turbine emulator, a hydraulic turbine emulator, a solar panel emulator, battery chargers, an SDK (Software Development Kit) etc.,

can be added to the standard functions to further enhance the training possibilities of the Four-Quadrant Dynamometer/Power Supply.

Two modes are available to control the function which the Four-Quadrant Dynamometer/Power Supply performs: Manual and Computer-Based.

In the Manual control mode, the module operates as a stand-alone unit, and the function performed is selected, set, and monitored using front-panel mounted controls and display. This mode provides access to all basic functions. In the Computer-Based control mode, the function performed by the module is selected, set, and monitored using the LVDAC-EMS software. In this mode, communication between the Four-Quadrant Dynamometer/Power Supply and the host computer running the LVDAC-EMS software is achieved through a USB connection. This mode provides access to all basic functions, as well as to additional advanced functions.

Model 8960-E includes the Four-Quadrant Dynamometer/Power Supply, Model 8960-2, with the following function sets activated:

- Standard Functions (Manual Control), Model 8968-1
- Standard Functions (Computer-Based Control), Model 8968-2
- Lead-Acid Battery Charger, Model 8968-4

Additional Equipment Required to Perform the Exercises

Qty	Description	Model number
1	Personal Computer	579785 (8990-00) [11]

Specifications

Parameter	Value
Dynamometer Mode	
Magnetic Torque	0 to 3 N·m (0 to 27 lbf·in)
Direction of Rotation	CW / CCW
Speed	0 to 2500 r/min
Nominal Power	350 W
Power Supply Mode	
DC Voltage	0 to ± 150 V
AC Voltage (RMS)	0 to 105 V (no-load)
DC Current	0 to ± 5 A
AC Current (RMS)	0 to 3.5 A
Maximum Output Power	500 W
AC Frequency	10 to 120 Hz
Control Functions	
Activated Sets	Standard Functions (Manual Control), Model 8968-1
	Standard Functions (Computer-Based Control), Model 8968-2
	Lead-Acid Battery Charger, Model 8968-4
Liquid-Crystal Display (LCD)	76 mm (3 in), monochrome, background-illuminated, 240 x 160 dots
Control Inputs	
Command Input	0 to ± 10 V
Thermistor Input	10 kΩ, type 1
Control Outputs	
Shaft Encoder	Quadrature encoder (A-B) - 360 pulses/revolution - TTL compatible
Torque Output Sensitivity	0.3 N·m/V (2.655 lbf·in/V)
Speed Output Sensitivity	500 r/min/V
Communication Port	USB 2.0
Power Requirements	120 V - 6 A - 60 Hz, must include live, neutral, and ground wires

[11] Refer to the Computer Requirements in the System Specifications section of this datasheet if the computer is to be provided by the end-user. Note that only one computer is required per station.

Parameter	Value
Computer Requirements	A currently available personal computer with USB 2.0 ports, running under one of the following operating systems: Windows® 7 or Windows® 8.
Physical Characteristics	
Dimensions (H x W x D)	308 x 287 x 490 mm (12.1 x 11.3 x 19.3 in)
Net Weight	19.5 kg (43.0 lb)

Standard Functions (manual control) Set 581436 (8968-10)

The Standard Functions (manual control) Set is a package of control functions that can be activated in the Four-Quadrant Dynamometer/Power Supply, Model 8960-2, enabling the module to perform a wide variety of functions in each of its two operating modes (Dynamometer and Power Supply).

The set allows only manual control of the functions. This means that the Four-Quadrant Dynamometer/Power Supply operates as a stand-alone unit, and the function performed is selected, set, and monitored using front-panel mounted controls and display. The following control functions are available in the set:

Dynamometer operating mode

- Two-Quadrant, Constant-Torque Brake
- Clockwise Prime Mover/Brake
- Counterclockwise Prime Mover/Brake
- Clockwise Constant-Speed Prime Mover/Brake
- Counterclockwise Constant-Speed Prime Mover/Brake
- Positive Constant-Torque Prime Mover/Brake
- Negative Constant-Torque Prime Mover/Brake

Power Supply operating mode

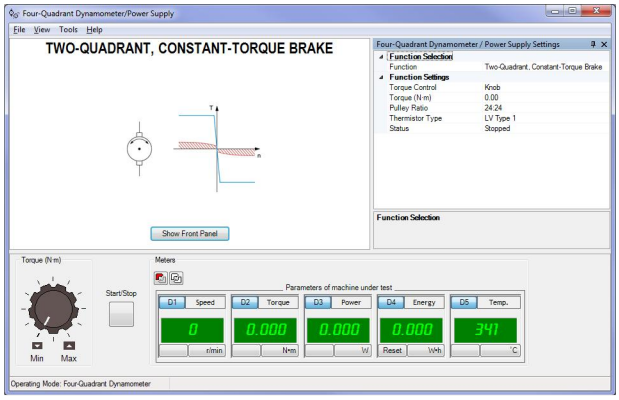
- Positive Voltage Source
- Negative Voltage Source
- 200 V DC Bus
- Positive Current Source
- Negative Current Source
- 50 Hz Power Source
- 60 Hz Power Source
- Lead-Acid Battery Float Charger

Specifications

Parameter	Value
Control Functions	
Control Functions	Two-Quadrant, Constant-Torque Brake
	Clockwise Prime Mover/Brake
	Counterclockwise Prime Mover/Brake
	Clockwise Constant-Speed Prime Mover/Brake
	Counterclockwise Constant-Speed Prime Mover/Brake
	Positive Constant-Torque Prime Mover/Brake
	Negative Constant-Torque Prime Mover/Brake
	Positive Voltage Source
	Negative Voltage Source
	Positive Current Source
	Negative Current Source
	50 Hz Power Source
	60 Hz Power Source

Parameter	Value
	200 V DC Bus
	Lead-Acid Battery Float Charger
Two-Quadrant, Constant-Torque Brake	
Torque	0-3 N·m (26.55 lbf·in)
Clockwise/Counterclockwise Prime Mover/Brake	
Speed	0-2500 r/min
Clockwise/Counterclockwise Constant-Speed Prime Mover/Brake	
Speed	0-2500 r/min
Positive/Negative Constant-Torque Prime Mover/Brake	
Torque	0-3 N·m (26.55 lbf·in)
Positive/Negative Voltage Source	
Voltage	0 to ±150 V
Positive/Negative Current Source	
Current	0 to ±5 A
50 Hz/60 Hz Power Source	
No-Load Voltage	0-140 V
200 V DC Bus	
Status	On or off
Lead-Acid Battery Float Charger	
Float Voltage	0-150 V

Standard Functions (computer-based control) Set 581437 (8968-20)



The Standard Functions (computer-based control) Set is a package of control functions that can be activated in the Four-Quadrant Dynamometer/ Power Supply, Model 8960-2, enabling the module to perform a wide variety of functions in each of its two operating modes (Dynamometer and Power Supply).

The set allows only computer-based control of the functions. This means that the function performed by the Four-Quadrant Dynamometer/Power Supply is selected, set, and monitored using the LVDAC-EMS software. The following control functions are available in the set:

Dynamometer operating mode

- Two-Quadrant, Constant-Torque Brake
- Clockwise Prime Mover/Brake
- Counterclockwise Prime Mover/Brake
- Clockwise Constant-Speed Prime Mover/Brake
- Counterclockwise Constant-Speed Prime Mover/Brake
- Positive Constant-Torque Prime Mover/Brake
- Negative Constant-Torque Prime Mover/Brake
- Four-Quadrant Constant-Speed Prime Mover/Brake
- Speed Sweep

Power Supply operating mode

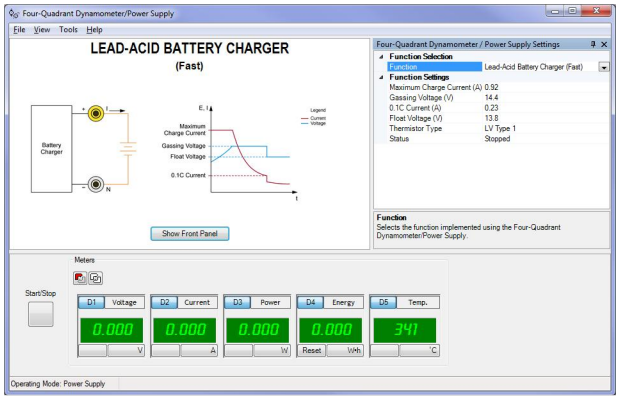
- Positive Voltage Source
- Negative Voltage Source
- DC Voltage Source
- Positive Current Source
- Negative Current Source
- DC Current Source
- 50 Hz Power Source
- 60 Hz Power Source
- AC Power Source
- Lead-Acid Battery Float Charger

Specifications

Parameter	Value
Control Functions	
Control Functions	Two-Quadrant, Constant-Torque Brake
	Clockwise Prime Mover/Brake
	Counterclockwise Prime Mover/Brake
	Clockwise Constant-Speed Prime Mover/Brake
	Counterclockwise Constant-Speed Prime Mover/Brake
	Positive Constant-Torque Prime Mover/Brake
	Negative Constant-Torque Prime Mover/Brake
	Four-Quadrant, Constant-Speed Prime Mover/Brake
	Speed Sweep
	Mechanical Load
	Positive Voltage Source
	Negative Voltage Source
	DC Voltage Source
	Positive Current Source
	Negative Current Source
	DC Current Source
	50 Hz Power Source
	60 Hz Power Source
	AC Power Source
	Lead-Acid Battery Float Charger
Two-Quadrant, Constant-Torque Brake	
Torque Control	Software knob, 8960 module knob, or 8960 command input
Torque	0-3 N·m (26.55 lbf·in)
Pulley Ratio	24:24, 24:12, or 24:32
Clockwise/Counterclockwise Prime Mover/Brake	
Speed Control	Software knob, 8960 module knob, or 8960 command input
Speed	0-2500 r/min
Pulley Ratio	24:24, 24:12, or 24:32
Clockwise/Counterclockwise Constant-Speed Prime Mover/Brake	
Speed Control	Software knob, 8960 module knob, or 8960 command input
Speed	0-2500 r/min
Pulley Ratio	24:24, 24:12, or 24:32
Positive/Negative Constant-Torque Prime Mover/Brake	
Torque Control	Software knob, 8960 module knob, or 8960 command input
Torque	0-3 N·m (26.55 lbf·in)
Pulley Ratio	24:24, 24:12, or 24:32
Four-Quadrant, Constant-Speed Prime Mover/Brake	
Speed Control	Software knob, 8960 module knob, or 8960 command input
Speed	0-2500 r/min
Pulley Ratio	24:24, 24:12, or 24:32
Speed Sweep	

Parameter	Value
Start Speed	-3000 r/min to 3000 r/min
Finish Speed	-3000 r/min to 3000 r/min
Number of Steps	0-50 steps
Step Duration	2-10 s
Record Data to Table	Yes or no
Pulley Ratio	24:24, 24:12, or 24:32
Mechanical Load	
Load Type	Flywheel, fan, grinder, conveyor, calender, crane, user defined
Inertia	0.005-1 kg·m² (0.119-23.73 lb·ft²)
Friction Torque	0.05-3 N·m (0.44-26.55 lbf·in)
Pulley Ratio	24:24, 24:12, or 24:32
Positive/Negative Voltage Source	
Voltage Control	Software knob, 8960 module knob, or 8960 command input
Voltage	0 V to 147 V / -147 V to 0 V
DC Voltage Source	
Voltage Control	Software knob, 8960 module knob, or 8960 command input
Voltage	-147 V to 147 V
Positive/Negative Current Source	
Current Control	Software knob, 8960 module knob, or 8960 command input
Current	0 A to 5 A / -5 A to 0 A
DC Current Source	
Current Control	Software knob, 8960 module knob, or 8960 command input
Current	-5 A to 5 A
50 Hz/60 Hz Power Source	
Voltage Control	Software knob, 8960 module knob, or 8960 command input
No-Load Voltage	0-140 V
AC Power Source	
No-Load Voltage	0-140 V
DC Offset Correction	-1000 to 1000
Frequency	10-100 Hz
Lead-Acid Battery Float Charger	
Float Voltage	0-150 V

Lead-Acid Battery Charger Function Set 581438 (8968-40)



The Lead-Acid Battery Charger Function Set is a package of control functions that can be activated in the Four-Quadrant Dynamometer/Power Supply, Model 8960-2, enabling the module to implement a lead-acid battery charger, as well as a battery discharger.

The Lead-Acid Battery Charger control function is only available in computer-based mode. This means that the function performed by the Four-Quadrant Dynamometer/Power Supply is selected, set, and monitored using the LVDAC-EMS software. The following control functions are available in the set:

Power Supply operating mode

- Lead-Acid Battery Charger (Fast):

This function uses the four-quadrant power supply to implement a battery charger that is able to rapidly charge lead-acid batteries of various capacities (typically in less than two hours). A three-step charge algorithm is used. Battery charging starts with a constant current corresponding to the battery maximum charge current until the battery gassing voltage is reached. At this point, battery charging continues with a constant voltage (close to gassing voltage) until the charge current decreases to 0.1 C. Then, constant-voltage charging continues but at a lower voltage (float charging voltage). The user has to specify the following four battery characteristics for the charger to achieve proper charge control: maximum charge current, gassing voltage, 0.1C current (10% of battery capacity), and float charging voltage. The function indicates the voltage, current, electrical power, and energy at the charger output. The function can also indicate battery temperature when the temperature sensor of the battery (if so equipped) is connected to the Thermistor Input of the Four-Quadrant Dynamometer/Power Supply. The function can also indicate battery temperature when the temperature sensor of the battery (if so equipped) is connected to the Thermistor Input of the Four-Quadrant Dynamometer/Power Supply. The license for the Lead-Acid Battery Charger, Model 8968-4, is required to activate the Lead-Acid Battery Charger (Fast) function in the Four-Quadrant Dynamometer/Power Supply.

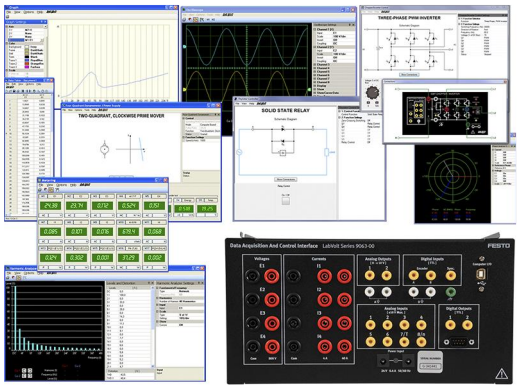
- Battery Discharger (Constant-Current Timed Discharge with Voltage Cutoff):

This function uses the four-quadrant power supply to sink a constant current from a battery, thereby discharging the battery at a specific rate, during a specific period. The discharger also monitors the battery voltage during discharge. Battery discharging terminates immediately when the battery voltage decreases to a specific cutoff voltage. The user has to specify the discharge current, discharge duration, and cutoff voltage for the discharger to achieve proper discharge control. The function indicates the voltage, current, electrical power, and energy at the discharger output. The function can also indicate battery temperature when the temperature sensor of the battery (if so equipped) is connected to the Thermistor Input of the Four-Quadrant Dynamometer/ Power Supply. The Battery Discharger function is perfectly suited to measure discharge characteristics of batteries at various rates as well as to bring a battery to a specific depth of discharge before a battery charging experiment. The license for the Lead-Acid Battery Charger, Model 8968-4, or the license for the Ni-MH Battery Chargers, Model 8968-5, is required to activate the Battery Discharger (Contant-Current Timed Discharge with Voltage Cutoff) function in the Four-Quadrant Dynamometer/Power Supply.

Specifications

Parameter	Value
Control Functions	
Control Functions	Lead-Acid Battery Charger (Fast)
	Battery Discharger (Constant-Current Timed Discharge with Voltage Cutoff)
Lead-Acid Battery Charger (Fast)	
Maximum Charge Current	0-5 A
Gassing Voltage	0-150 V
0.1C Current	0-5 A
Float Voltage	0-150 V
Battery Discharger (Constant-Current Timed Discharge with Voltage Cutoff)	
Discharge Current	0-5 A
Discharge Duration	0-2000 min
Cutoff Voltage	0-150 V

Data Acquisition and Control Interface 579686 (9063-D0)



The Data Acquisition and Control Interface (DACI) is a versatile USB peripheral used for measuring, observing, analyzing, and controlling electrical and mechanical parameters in electric power systems and power electronics circuits. For these purposes, a set of computer-based instruments as well as a variety of control functions are available for the DACI. These instruments and control functions are accessed through the LVDAC-EMS software. The LVDAC-EMS software, as well as all available upgrades, is free and can be downloaded anytime on the Festo Didactic website.

Together, the DACI and the LVDAC-EMS software allow training in various areas such as electric power technology, ac/dc machines, renewable energy, transmission lines, and power electronics using modern and versatile measuring instruments and control functions. LVDAC-EMS also offers the possibility to use pre-built SCADA interfaces for several applications to ease the view and understanding of the process taking place. The user guide provided allows students to quickly become familiar with the instruments and control functions available.

Model 9063-D includes the DACI, Model 9063, with the following function sets activated:

- Computer-Based Instrumentation Function, Model 9069-1
- Chopper/Inverter Control Function Set, Model 9069-2
- Thyristor Control Function Set, Model 9069-3

Manual

Description	Manual number
Computer-Based Instruments for EMS (User Guide)	585219 (86718-E0)

Table of Contents of the Manual(s)

Computer-Based Instruments for EMS (User Guide) (585219 (86718-E0))

- 1 Familiarization with the Metering Window and the Data Table
- 2 Familiarization with the Oscilloscope
- 3 Familiarization with the Phasor Analyzer
- 4 Familiarization with the Harmonic Analyzer
- 5 Measuring Three-Phase Power Using the Metering Window

Additional Equipment Required to Perform the Exercises

Qty	Description	Model number
1	Personal Computer	579785 (8990-00) [12]
1	24 V AC Power Supply	579696 (30004-20) [13]

Specifications

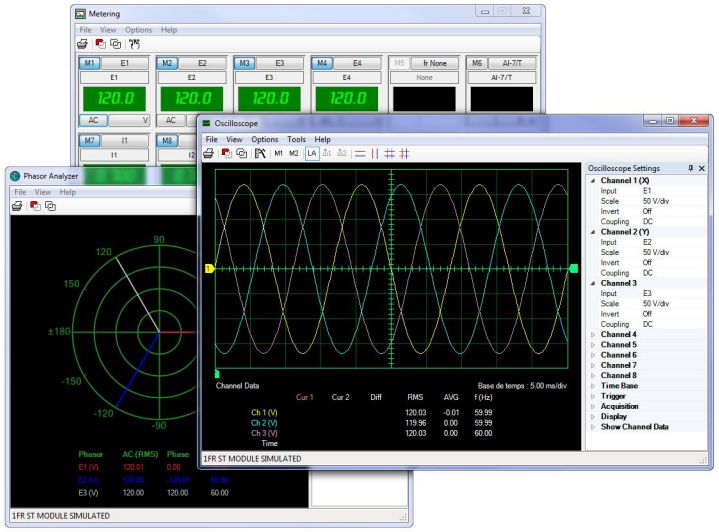
Parameter	Value
Insulated Voltage Inputs (4)	
Range (Low / High Scales)	-80 to +80 V / -800 to + 800 V (user-selectable through software)
Impedance (Low / High Scales)	326.6 kΩ / 3.25 MΩ
Bandwidth	DC to 65 kHz (-3 dB)
Accuracy	1% (dc to 10 kHz)
Insulation	800 V
Measurement Category	CAT II (283 V ac/400 V dc versus ground)
Insulated Current Inputs (4)	
Range (Low / High Scales)	-4 to +4 A / -40 to + 40 A (25 A rms)
Impedance (Low / High Scales)	5 mΩ / 50 mΩ
Bandwidth	DC to 65 kHz (-3 dB)
Accuracy	1% (dc to 10 kHz)
Insulation	800 V
Measurement Category	CAT II (283 V ac/400 V dc versus ground)
Analog Inputs (8)	
Voltage Range	-10 to +10 V
Impedance	› 10 MΩ
Bandwidth	DC to 125 kHz
Measured Parameters	User-selectable through software
Parameter-to-Voltage Ratio	User-determined through software
A/D Converter for Insulated and Analog Inputs (16)	
Type	Successive approximation
Resolution	12 bits
Integral Non-Linearity	≤ ±1.5 LSB
Differential Non-Linearity	≤ ±1 LSB
Maximum Sampling Rate	600 ksamples/s (one channel)
FIFO Buffer Size	16 ksamples
Analog Outputs (2)	
Voltage Range (2)	-10 to +10 V
Operational Load Impedance	› 600 Ω
D/A Converter for Analog Outputs (2)	
Type	Resistor string
Resolution	12 bits
Integral Non-Linearity	≤ ±8 LSB
Differential Non-Linearity	-0.5 to +0.7 LSB
Digital Inputs (3)	
Types	Encoder (2), synchronization (1)
Signal Level	0-5 V (TTL compatible)
Maximum Input Frequency	50 kHz
Impedance	5 kΩ
Digital Outputs (9)	
Types	Control (6 on a DB9 connector and 2 on 2 mm banana jacks), synchronization (1 on a DB9 connector)
Signal Level	0-5 V (TTL compatible)
Maximum Output Frequency	20 kHz (software-limited)
Impedance	200 Ω
Control Functions	
Activated Sets	Computer-Based Instrumentation Function, Model 9069-1

[12] Refer to the Computer Requirements in the System Specifications section of this datasheet if the computer is to be provided by the end-user. Only one computer is required per station. This model is available in multiple voltage- and frequency dependent variants. Contact a Festo representative to obtain the correct part number.

[13] Required if power is not supplied by the Power Supply, Model 8821-2. This model is available in multiple voltage- and frequency dependent variants. Contact a Festo representative to obtain the correct part number.

Parameter	Value
	Chopper/Inverter Control Function Set, Model 9069-2
	Thyristor Control Function Set, Model 9069-3
Computer I/O Interface	USB 2.0 full speed via type-B receptacle
Power Requirements	24 V - 0.4 A - 50/60 Hz
Accessories	
Included Accessories	2 m USB interconnection cable (1)
	24 V power cable (1)
	2 mm banana plug test leads (3)
	DB9 connector control cable (1)
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 410 mm (6.1 x 11.3 x 16.1 in)
Net Weight	3.9 kg (8.6 lb)

Computer-Based Instrumentation Function Set 581452 (9069-10)



The Computer-Based Instrumentation Function Set, Model 9069-1, includes the following computer-based instruments:

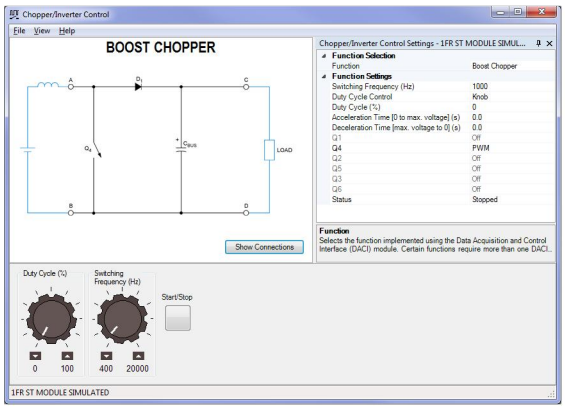
- Metering
- Data Table and Graph
- Oscilloscope
- Phasor Analyzer
- Harmonic Analyzer

Specifications

Parameter	Value
Metering	
Number of Meters	18
Sampling Window	266.7 ms or user adjusted through software (11.4-819 ms)
Sampling Frequency (each meter)	7.68 kHz or user adjusted through software (2.5-179.2 kHz)
Display Type	Digital or analog, user selectable through software
Oscilloscope	
Number of Channels	8
Vertical Sensitivity	2-500 V/div.
Time Base	0.0001-10 s/div.
Sampling Window	20 x selected time base (software triggering) / 10 x selected time base (hardware triggering)
Sampling Frequency	512 samples per measured parameter per horizontal sweep, up to a maximum of 512 kHz
Phasor Analyzer	
Voltage Sensitivity	2-200 V/div.
Current Sensitivity	0.1-5 A/div.
Sampling Window	2-409 ms
Sampling Frequency (Each Phasor)	5-102.4 kHz
Harmonic Analyzer	
Fundamental-Frequency Range	1-1400 Hz
Number of Harmonic Components	5 to 40, user selectable through software
Vertical Scale (Relative Scale)	0.1-10%/div.
Vertical Scale (Absolute Scale)	0.1-50 V/div., 0.01-10 A/div.
Sampling Window	10 ms to 1 s

Parameter	Value
Sampling Frequency	16-102 kHz

Chopper/Inverter Control Function Set 581453 (9069-20)



The Chopper/Inverter Control Function Set enables the following choppers and inverters to be implemented using the Data Acquisition and Control Interface, Model 9063, the IGBT Chopper/Inverter, Model 8837-B, and the Insulated DC-to-DC Converter, Model 8835:

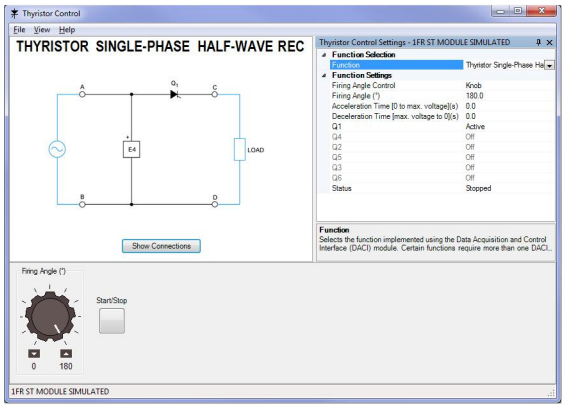
- Buck Chopper (high-side switching)
- Buck Chopper (low-side switching)
- Buck/Boost Chopper
- Boost Chopper
- Four-Quadrant Chopper
- Buck Chopper with Feedback
- Boost Chopper with Feedback
- Single-Phase, 180° Modulation Inverter
- Single-Phase PWM Inverter
- Three-Phase, 180° Modulation Inverter
- Three-Phase PWM Inverter
- Three-Phase Inverter (constant V/f ratio)
- Insulated DC-to-DC Converter
- Four-Quadrant DC Motor Drive without Current Control
- Four-Quadrant DC Motor Drive

Specifications

Parameter	Value
Control Functions	
Control Functions	Buck Chopper (high-side switching)
	Buck Chopper (low-side switching)
	Buck/Boost Chopper
	Boost Chopper
	Four-Quadrant Chopper
	Buck Chopper with Feedback
	Boost Chopper with Feedback
	Single-Phase, 180° Modulation Inverter
	Single-Phase PWM Inverter
	Three-Phase, 180° Modulation Inverter
	Three-Phase PWM Inverter
	Three-Phase PWM Inverter (constant V/f ratio)
	Insulated DC-to-DC Converter
	Four-Quadrant DC Motor Drive without Current Control
	Four-Quadrant DC Motor Drive
Buck Chopper (high-side switching), Buck Chopper (low-side switching), Buck/Boost Chopper, Boost Chopper, Four-Quadrant Chopper	
Switching Frequency	400 Hz to 20 kHz
Duty Cycle Control	Knob or analog input on the DACI

Parameter	Value
Duty Cycle	0-100%
Acceleration Time (0 to Max. Voltage)	0-100 s
Deceleration Time (Max. Voltage to 0)	0-100 s
IGBTs Q1 to Q6	PWM, on, off (certain IGBTs are unavailable depending on the selected chopper control function)
Buck Chopper with Feedback, Boost Chopper with Feedback	
Switching Frequency	2-20 kHz
Command Input	Knob or analog input on the DACI
Command	0-100%
Feedback Input	Voltage, current, speed, power, or low-power analog signal
Feedback Filter Cutoff Frequency	100-4900 Hz
Feedback Range (100% Value =)	10-400 V
Acceleration Time (0 to 100%)	0-100 s
Deceleration Time (100% to 0)	0-100 s
Single-Phase, 180° Modulation Inverter	
DC Bus	Unipolar or bipolar
Frequency	0-120 Hz
IGBTs Q1 to Q6	180° Modulation, on, or off (certain IGBTs are unavailable)
Single-Phase PWM Inverter	
DC Bus	Unipolar or bipolar
Switching Frequency	400 Hz to 20 kHz
Frequency	0-120 Hz
Peak Voltage	0-100% of dc bus
IGBTs Q1 to Q6	PWM, on, or off (certain IGBTs are unavailable)
Three-Phase, 180° Modulation Inverter	
Phase Sequence	Forward (1-2-3), reverse (1-3-2), or forward/reverse
Frequency	0-120 Hz
IGBTs Q1 to Q6	180° Modulation, on, or off
Three-Phase PWM Inverter	
Switching Frequency	400 Hz to 20 kHz
Phase Sequence	Forward (1-2-3), reverse (1-3-2), or forward/reverse
Frequency	0-120 Hz
Peak Voltage	0-117% of dc bus/2
Modulation Type	Sinusoidal pulse-width modulation or space vector
IGBTs Q1 to Q6	PWM, on, or off
Three-Phase PWM Inverter (Constant V/f Ratio)	
Switching Frequency	400 Hz to 20 kHz
Phase Sequence	Forward (1-2-3), reverse (1-3-2), or forward/reverse
Frequency	0-120°
Knee Peak Voltage	0-117% of dc bus voltage/2
Knee Frequency	1-120 Hz
Modulation Type	Sinusoidal pulse-width modulation or space vector
Acceleration Time (0 to Knee)	0-100 s
Deceleration Time (Knee to 0)	0-100 s
Insulated DC-to-DC Converter	
Duty Cycle	0-45%
Four-Quadrant DC Motor Drive with and without Current Control	
Switching Frequency	2-20 kHz
Speed Command Input	Knob or analog input on the DACI
Speed Command	-5000 r/min to 5000 r/min
Pulley Ratio	24:12 or 24:24
Acceleration Time (0 to Max. Speed)	0-100 s
Deceleration Time (Max. Speed to 0)	0-100 s
Current Feedback Range	4 A or 40 A (only available in current control)
Current Feedback Filter Cutoff Frequency	100-4900 Hz (only available in current control)
Current Command Limit	0-40 A (only available in current control)

Thyristor Control Function Set 581454 (9069-30)



The Thyristor Control Function Set enables the following thyristor-based devices to be implemented using the Data Acquisition and Control Interface, Model 9063, and the Power Thyristors, Model 8841:

- Thyristor Single-Phase Half-Wave Rectifier
- Thyristor Single-Phase Bridge
- Thyristor Three-Phase Bridge
- Thyristor Three-Phase Bridge with Feedback
- Solid-State Relay
- Thyristor Single-Phase AC Power Control
- Thyristor Three-Phase AC Power Control
- Direct-On-Line Starter
- Soft Starter

Specifications

Parameter	Value
Control Functions	
Control Functions	Thyristor Single-Phase Half-Wave Rectifier
	Thyristor Single-Phase Bridge
	Thyristor Three-Phase Bridge
	Thyristor Three-Phase Bridge with Feedback
	Solid-State Relay
	Thyristor Single-Phase AC Power Control
	Thyristor Three-Phase AC Power Control
	Direct-On-Line Starter
	Soft Starter
Thyristor Single-Phase Half-Wave Rectifier, Thyristor Single-Phase Bridge, Thyristor Three-Phase Bridge	
Firing Angle Control	Knob or analog input on the DACI
Firing Angle	0-180°
Acceleration Time (0 to Max. Voltage)	0-100 s
Deceleration Time (Max. Voltage to 0)	0-100 s
Thyristors Q1 to Q6	Active, on, or off (certain thyristors are unavailable depending on the selected thyristor control function)
Thyristor Three-Phase Bridge with Feedback	
Command Input	On or off
Command	Knob or analog input on the DACI
Inverter Limit	100-180°
Arc-Cosine	On or off
Feedback Input	Voltage, rms voltage, current, speed, power, or low-power analog signal
Feedback Range (Voltage Input Only)	80-800 V
Current Feedback Range (Current Input Only)	0.4-4 A
Speed Feedback Range (Speed Input Only)	250-2500 r/min
Analog Feedback Range (Analog Input Only)	1-10 V
Power Feedback Range (Power Input Only)	32-3200 W
Feedback Filter Cutoff Frequency	10-180 Hz
Acceleration Time (0 to 100%)	0-100 s
Deceleration Time (100% to 0)	0-100 s
Thyristors Q1 to Q6	Active, on, or off
Solid-State Relay	
Zero-Voltage Switching	On or off
Relay Control	Open or close

Parameter	Value
Thyristors Q1 to Q6	Active, on, or off (certain thyristors are unavailable)
Thyristor Single-Phase AC Power Control	
Control Mode	Phase control, synchronous burst fire control, or asynchronous burst fire control
Firing Angle Control	Knob or analog input on the DACI
Firing Angle	0-180°
Thyristors Q1 to Q6	Active, on, or off (certain thyristors are unavailable)
Thyristor Three-Phase AC Power Control	
Load Configuration	3 wires star (3S), 3 wires delta (3D), 4 wires star (4S), or 6 wires delta (6D)
Control Mode	Phase control or synchronous burst fire control (certain control modes are unavailable depending on the selected thyristor control function)
Firing Angle Control	Knob or analog input on the DACI
Acceleration Time (0 to Max. Voltage)	0-100 s
Deceleration Time (Max. Voltage to 0)	0-100 s
Thyristors Q1 to Q6	Active, on, or off
Direct-On-Line Starter	
Motor Full-Load Current	0.4-2 A
Overload	On or off
Overload Class	5, 10, 15, 20, 25, 30, 35, or 40
Soft Starter	
Mode	Soft Start or current-limit start
Motor Full-Load Current	0.4-2 A
Initial Torque	15%, 25%, 35%, or 65% of LRT
Start Time	2-200 s
Kick-Start Time	0 s, 0.5 s, 1 s, or 1.5 s
Soft Stop	0, 1, 2, or 3 times the start time
Overload	On or off
Overload Class	5, 10, 15, 20, 25, 30, 35, or 40

24 V AC Power Supply 579696 (30004-20)

The 24 V AC Power Supply is used to power specific modules of the Electric Power Technology Training Systems, such as the Data Acquisition and Control Interface, the IGBT Chopper/ Inverter, and the Power Thyristors.

Specifications

Parameter	Value
Power Requirements	
Maximum Current	0.75 A
AC Power Network Installation	120 V – 50/60 Hz, must include live, neutral, and ground wires
Power Outputs	
Fixed, Single-Phase AC	24 V – 2,5 A

Optional Equipment Description

Mobile Workstation (Optional)
579755 (8110-20)

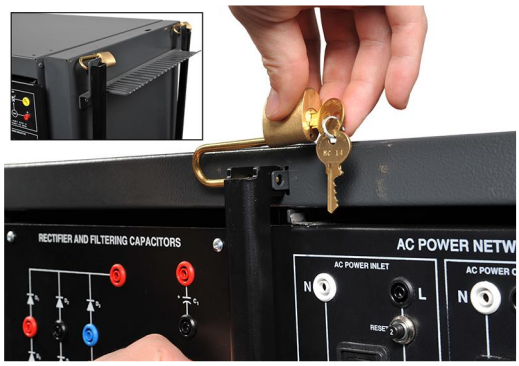
The Mobile Workstation is a ready-for-use workstation that consists of two fully assembled modules: a Workstation, Model 8134-2, mounted on a Mobile Storage Cabinet, Model 89117-1. Four rubber-tire swivel casters allow easy movement of the workstation in the laboratory classroom. The lower portion of the workstation serves as a storage cabinet with two hinged panels and a lock handle. Immediately above the storage cabinet is a pullout work surface with a scuff- and burn-resistant laminate finish. The upper portion of the workstation consists of three rows of compartments designed to house EMS modules. Two of these rows have full-height compartments while the other row has half-height compartments. Each row of full-height compartments can accommodate up to three full-size EMS modules or six half-size EMS modules, whereas the row of half-height compartments can accommodate up to three half-size EMS modules.

Module Installation

The EMS modules are guided into position along stainless steel guide rails. Separators between each bay of the workstation ensure perfect alignment of the EMS modules and allow their easy insertion in the workstation. A holding mechanism ensures that each EMS module stays in place once it is installed in a compartment of the workstation. Front-mounted push levers allow all EMS modules on a single row to be released for easy removal.

Safety Padlock Bars

Two safety padlock bars on the front of the workstation prevent students from removing EMS modules during laboratory exercises. The bars can be removed and locked to the side of the workstation when the safety lock is not necessary.



Additional Information

Six holes in the rear panel of the workstation allow connection to a power supply, as well as the connection of 2 kW machines to their interconnection modules. Assembly of the workstation before painting ensures that each EMS module in the workstation is correctly grounded.

Manual

Description	Manual number
Electric Power Technology Training Equipment (User Guide)	584778 (38486-E0)

Table of Contents of the Manual(s)

Electric Power Technology Training Equipment (User Guide) (584778 (38486-E0))

Optional Equipment

Qty	Description	Model number
1	Industrial Controls Single-Rail Workstation	581243 (3105-A0) [14]
1	Industrial Controls Double-Rail Workstation	585964 (3105-B0) [15]

[14] This add-on workstation allows modules from the Industrial Controls Training Systems, Models 8036, to be installed in the EMS workstation. Refer to the 8036 datasheet for more information.

[15] This add-on workstation allows modules from the Industrial Controls Training Systems, Models 8036, to be installed in the EMS workstation. Refer to the 8036 datasheet for more information.

Qty	Description	Model number
1	All-in-One Touch Screen Computer (including Monitor Stand with Articulating Arm)	8108708 (8990-A0)
1	External Shelf for the Mobile Workstation	581465 (36653-00) [16]
1	Mounting Stand with Articulating Arm	8108710 (36653-A0)

Specifications

Parameter	Value
Physical Characteristics	
Intended Location	On the floor (stands on casters)
Dimensions (H x W x D)	1660 x 935 x 665 mm (65.4 x 36.8 x 26.2 in)
Net Weight	77.1 kg (170 lb)

Storage Shelves (Optional) 579756 (8150-10)

The Storage Shelves module contains five shelves, each of which can accommodate four full-size EMS modules or eight half-size EMS modules. Stainless steel rails guide the modules on the storage shelves and protect them against wear. The Storage Shelves module requires assembly. A diagram is provided to facilitate assembly. Note that this model cannot stand by itself and must be attached to a wall.

Optional Equipment

Qty	Description	Model number
1	Dust Cover for Model 8150	587006 (8992-00)

Specifications

Parameter	Value
Physical Characteristics	
Intended Location	On the floor and attached to a wall
Dimensions (H x W x D)	1980 x 1225 x 480 mm (78 x 48.2 x 18.9 in)
Net Weight	TBE

[16] Extra shelf to be mounted on side of the Mobile Workstation.

Full-Size Blank EMS Module (Optional)
579757 (8160-00)

The Full-Size Blank EMS Module is used to fill unused locations in a workstation, preventing students from accessing electrical or moving parts inside the other modules. Combined with the use of safety bars to prevent students from removing modules, blank EMS modules ensure student safety during lab exercises.

Specifications

Parameter	Value
Physical Characteristics	
Dimensions (H x W x D)	308 x 287 x 415 mm (12.1 x 11.3 x 16.3 in)
Net Weight	TBE

Half-Size Blank EMS Module (Optional)
579758 (8161-00)

The Half-Size Blank EMS Module is used to fill unused locations in a workstation, preventing students from accessing electrical or moving parts inside the other modules. Combined with the use of safety bars to prevent students from removing modules, blank EMS modules ensure student safety during lab exercises.

Specifications

Parameter	Value
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 410 mm (6.1 x 11.3 x 16.1 in)
Net Weight	TBE

Synchronous Motor/Generator (Optional) 579502 (8241-20)

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

Connections to the machine are made through color-coded safety banana jacks located on the front panel of the module. This front panel of the module can be opened to install a Timing Belt, Model 8942, on the pulley of the machine shaft. This permits mechanical coupling of the machine to the Four-Quadrant Dynamometer/Power Supply, Model 8960. The machine has a thermistor output that allows monitoring of the machine internal temperature to prevent overheating.

Specifications

Parameter	Value
Power Requirement	120/208 V
Motor	
Stator Voltage	120/208 V, three-phase
Rotor Voltage	0-150 V dc
Output Power	200 W
Synchronous Speed	1800 r/min
Full-Load Current	0.55 A
Power Factor	1
Generator	
Stator Voltage	120/208 V, three-phase
Rotor Voltage	0-150 V dc
Output Power	200 VA
Synchronous Speed	1800 r/min
Power Factor	0.8
Protection	
Type	10 kΩ thermistor, type 2, in the stator winding, and rotor field bimetal thermal protection
Physical Characteristics	
Dimensions (H x W x D)	308 x 291 x 440 mm (12.1 x 11.5 x 17.3 in)
Net Weight	TBE

Inductive Load (Optional)
763362 (8321-00)

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

The Inductive Load is commonly used in conjunction with other basic load modules, like the Resistive Load and the Capacitive Load to experiment with the effects of different types of load on a circuit.

Specifications

Parameter	Value
Inductors	
Quantity	Three identical banks of three inductors
Inductance Values (Each Bank)	0.8/1.6/3.2 H
Reactance Values (Each Bank)	300/600/1200 Ω
Nominal Voltage	120 V – 60 Hz
Inductance Value Accuracy	± 5%
Load at Nominal Voltage (Each Bank)	
Reactive Power	12-84 var
Current	0.1-0.7 A
Steps	Seven, of equal increment
Current Increment	0.1 A
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 410 mm (6.1 x 11.3 x 16.1 in)
Net Weight	10.1 kg (22.3 lb)

Three-Phase Transmission Line (Optional)
579535 (8329-00)

The Three-Phase Transmission Line consists of three iron-core inductors enclosed in a half-size EMS module. The inductors are specifically designed to simulate a high-voltage ac transmission line (typically 315 kV lines). The line impedance can be adjusted to four different values using a selector switch mounted on the front panel. A three-pole switch is used to induce transients by momentarily interrupting the power flow. Both sides (sender and receiver) of the Three-Phase Transmission Line are terminated on the front panel by 4 mm color-coded safety banana jacks.

Specifications

Parameter	Value
Ratings	
Line Reactance Settings	0, 60, 120, and 180 Ω
Nominal Line Current	1 A
Line Simulated Lengths	175, 350 and 525 km (109, 217 and 326 miles)
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 440 mm (6.1 x 11.3 x 17.3 in)
Net Weight	8.2 kg (18 lb)
Shipping Weight	9.8 kg (21.6 lb)

Three-Phase Regulating Autotransformer (Optional) 763369 (8349-00)

The Three-Phase Regulating Autotransformer consists of a three-phase autotransformer enclosed in a half-size EMS module. Eight safety banana jacks on the module front panel provide access to both sides of the regulating autotransformer. A buck-boost selector switch can be used to increase or decrease the autotransformer output voltage by 15%. A phase-shift selector switch can be used to set the phase shift produced by the autotransformer output voltage to ±15°. A phase sequence indicator on the module front panel indicates the phase sequence of the voltages across the autotransformer.

Specifications

Parameter	Value
Rating	
Line Voltage	120/208 V
Power	360 VA
Line Current	1 A
Buck-Boost Voltage	-15, 0, -15%
Phase Shift	-15, 0, -15°
Phase Sequence	1-2-3
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 440 mm; (6.1 x 11.3 x 17.3 in)
Net Weight	7.6 kg (16.7 lb)
Shipping Weight	9.2 kg (20.2 lb)

AC Power Network Interface (Optional) 579581 (8622-00)

The AC Power Network Interface is used to interface the ac power network with EMS modules. It consists of an AC Power Inlet section comprising a C14 power cord inlet with 4 mm color-coded safety sockets for each terminal (line, neutral, and ground). The line is fuse-protected between the inlet and the safety jacks. The module also consists of an AC

Power Outlet section comprising a standard ac outlet (country dependent) with direct connections to safety sockets. A solid-state relay used for network disconnection and a filtering inductor are also included in the model to complete the interface with the ac network.

All components of the AC Power Network Interface are industrial components and are mounted in the module to allow visual inspection. Where necessary, these components are protected against overload or short-circuit conditions by thermal-magnetic circuit breakers. The components are terminated on the module faceplate by 4 mm color-coded safety sockets and are identified by schematic symbols, numbered terminal codes, and electrical ratings.

Specifications

Parameter	Value
AC Power Inlet	
Rating	120 V - 2 A - 60 Hz
Type	C14 connector
Circuit Breaker	2 A
AC Power Outlet	
Rating	120 V - 8 A - 60 Hz
Type	NEMA 5-15 (type B)
Solid-State Relay	
Coil Rating	3 to 32 V dc - 15 mA
Contact Rating	24 to 240 V - 8 A - 60 Hz
Filtering Inductor	2 mH - 5 A - 0 to 20 kHz
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 440 mm (6.1 x 11.3 x 17.3 in)
Net Weight	TBE

Solar Panel Test Bench (Optional) 579594 (8805-00)

The Solar Panel Test Bench is a full-size EMS module in which a Solar Panel, Model 8806 can be installed to perform a wide variety of tests and experiments. A powerful halogen lamp is used to illuminate the solar panel under test. The distance between the halogen lamp and solar panel can be changed to adjust the irradiance. A ventilation system is provided in the Solar Panel Test Bench to keep the solar panel at near room temperature and study the effects of temperature. The halogen lamp and ventilation system can be turned on and off through switches mounted on the front panel of the test bench. Pilot lamps on the front panel indicate the status (on or off) of the halogen lamp and ventilation system. The complete Solar Panel Test Bench is powered by a standard wall outlet.

A potentiometer and a set of diodes are included in the Solar Panel Test Bench. The potentiometer is used to apply a variable electrical load to the output of the solar panel under test. The diodes can be connected to the solar panel to serve as either bypass diodes or blocking diodes. Access to the potentiometer and diodes is through miniature (2 mm) banana jacks mounted on the front panel of the test bench. Four other miniature banana jacks on the front panel of the test bench provide direct access to the output terminals of the solar

panel to make connections easy. A set of connection leads terminated with miniature banana plugs is provided with the Solar Panel Test Bench.

Specifications

Parameter	Value
Power Requirements	
Current	3 A
Service Installation	Standard single-phase outlet
Halogen Lamp	
Power	300 W
Ventilation System	
Flow Rate	115 CFM
Potentiometer	Single Turn – 500 Ω – 2 W
Diodes	
Quantity	3
Peak Inverse Voltage	1000 V
Maximum Current	1 A
Physical Characteristics	
Dimensions (H x W x D)	308 x 291 x 440 mm (2.1 x 11.5 x 17.3 in)
Net Weight	6.9 kg (15.2 lb)

Power Supply (Optional) 579603 (8821-20)

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

Specifications

Parameter	Value
Module Requirements	
AC Power Network Installation	3 phases (120/208 V – 60 Hz), star (wye) configuration including neutral and ground wires, protected by a 20 A circuit breaker
AC Power Network Connector	NEMA L21-20
Maximum Current	15 A
Outputs (*see note)	
Three-Phase Fixed AC	120/208 V – 15 A - 60 Hz
Three-Phase Variable AC	0-120/208 V – 5 A - 60 Hz
Variable DC	0-120 V – 8 A
Fixed DC	120 V – 2 A
Low Power AC	24 V – 3 A - 60 Hz
Included Accessories	

Parameter	Value
	3 m (10 ft) ac power cord (1)
	NEMA L21-20 wall connector with wall plate (1)
	Padlock (1)
Physical Characteristics	
Dimensions (H x W x D)	308 x 287 x 495 mm (12.1 x 11.3 x 19.5 in)
Net Weight	18.4 kg (40.5 lb)
***Note**	The Power Supply cannot supply all the amounts of current indicated by the current ratings on its front panel at the same time. The current indicated for the fixed ac three-phase output section can only be obtained if no current is drawn from any other section, because this section is protected by the main circuit breaker common to every section. If currents flow in other sections, the available current for the fixed ac three-phase output section decreases. The variable ac output section and the variable dc output section are protected by a common set of circuit breakers placed after the fixed ac three-phase output section, which means that the current capacity has to be shared between the two sections. For instance, if current of the variable dc output section is at 70% of its nominal value, current drawn from the variable ac output section should not exceed 30% of its nominal value. The fixed dc output section is also protected by circuit breakers placed after the fixed ac three-phase output section.

Digital Multimeter (Optional)
579782 (8946-20)

The Digital Multimeter consists of an Amprobe AM-510 Tool Kit Digital Multimeter with Battery Test. It is ideal to perform voltage, current, and resistance measurements in exercises.

Specifications

Parameter	Value
Voltage	
Ranges	0-600 V ac/dc
Current	
Range	0-10 A ac/dc
Resistance	
Range	0-40 MΩ
Physical Characteristics	
Dimensions (H x W x D)	182 x 90 x 45 mm (7.17 x 3.54 x 1.77 in)
Net Weight	354 g (0.78 lb)

Multimeters Module (Optional)
586888 (8946-A0)

The Multimeters Module, Model 8946-A, consists of three Digital Multimeters, Model 8946-2, installed on the front panel of a half-size module. This allows the Multimeters Module to be inserted in a Workstation, just like any other module.

Specifications

Parameter	Value
Multimeters	
Quantity	3
Voltage Range	0-600 V dc and ac
Current Range	0-10 A dc
Resistance Range	0-20 MΩ
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 440 mm (6.1 x 11.3 x 17.3 in)
Net Weight	TBE

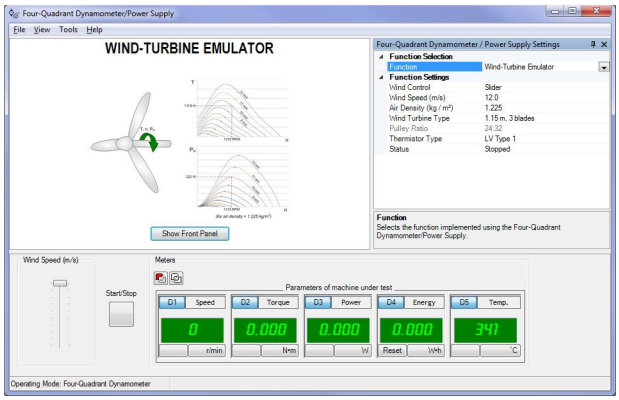
Connection Lead Set (Optional)
579639 (8951-N0)

This Connection Lead Set consists of extra-flexible leads terminated with stacking 4 mm safety banana plugs. The leads are supplied in different lengths and are color-coded according to length. The set also includes three-phase leads, which are made of three color-coded leads bundled together along their length to simplify the connection of three-phase circuits.

Specifications

Parameter	Value
4 mm Safety Banana Plug Leads Characteristics	
Cross Section	1 mm² (1974 cmil)
Rated Current	19 A
Rated Voltage	600 V, CAT II
4 mm Safety Banana Plug Leads Quantities	
Yellow, 30 cm (12 in)	14
Red, 60 cm (24 in)	8
Blue, 90 cm (36 in)	4
Three-Phase 4 mm Safety Banana Plug Leads Characteristics	
Cross Section	1 mm² (1974 cmil)
Rated Current	19 A
Rated Voltage	600 V, CAT II
Three-Phase 4 mm Safety Banana Plug Leads Quantities	
Red/Black/Blue, 60 cm (24 in)	4

Turbine Emulator Function Set (Optional) 579783 (8968-30)



The Turbine Emulator Function Set is a package of control functions that can be activated in the Four-Quadrant Dynamometer/Power Supply, Model 8960-2, enabling the module to emulate the operation of various types of turbines.

The control functions in the set are only available in computer-based mode. This means that the function performed by the Four-Quadrant Dynamometer/Power Supply is selected, set, and monitored using the LVDAC-EMS software. The following control functions are available in the set:

Dynamometer operating mode

- Small Wind-Turbine Emulator: this function makes the permanent-magnet dc motor of the Four-Quadrant Dynamometer/Power Supply faithfully reproduce the effect of wind on the bladed rotor of a small-scale wind turbine. The torque-speed characteristic at the shaft of the machine coupled to the Four-Quadrant Dynamometer/Power Supply is the same as the one that is obtained when wind blows at a certain speed on the rotor of the actual wind turbine. The user has control over the wind speed and air density.

- Hydraulic Turbine Emulator: this function uses the permanent-magnet dc motor of the Four-Quadrant Dynamometer/Power Supply to recreate the behavior of an hydraulic turbine with a synchronous generator. The torque-speed characteristics at the shaft of the machine coupled to the Four-Quadrant Dynamometer/Power Supply is the same as that of a Francis-type hydraulic turbine. The user has control over the vane angle (manually or through the module analog input), the vane variation speed, and the inertia.

Specifications

Parameter	Value
Control Functions	
Control Functions	Wind-Turbine Emulator
	Hydraulic-Turbine Emulator
Wind-Turbine Emulator	
Wind Control	Software slider or 8960 command input
Wind Speed	3-12 m/s (6.7-26.8 mph)
Air Density	1.12-1.44 kg/m³ (0.07-0.09 lb/ft³)
Wind Turbine Type	1.15 m with 3 blades, 1.15 m with 3 blades and gearbox, 0.72 m with 3 blades and passive stall
Pulley Ratio	24:24, 24:12, 24:32 (different pulley ratios are available depending on the wind turbine type)
Inertia J	0.02-0.4 kg·m² (0.475-9.492 lb·ft²) (only available for certain wind turbine types)
Gear Ratio R	0.5-2 (only available for certain wind turbine types)
Hydraulic-Turbine Emulator	
Vane Control	Software slider or 8960 command input
Turbine Type	300 W Francis
Vane Maximal Speed	0-100%/s
Runner Inertia	0.005-1 kg·m² (7.119 lb·ft²)
Pulley Ratio	24:24

Personal Computer (Optional)
579785 (8990-00)

The Personal Computer consists of a desktop computer running under Windows® 10. A monitor, keyboard, and mouse are included.

Specifications

Parameter	Value
Power Requirements	
Current	2 A
Service Installation	Standard single-phase ac outlet

Data Acquisition and Control Interface (Optional)
579677 (9063-00)

The Data Acquisition and Control Interface (DACI) is a versatile USB peripheral used for measuring, observing, analyzing, and controlling electrical and mechanical parameters in electric power systems and power electronics circuits. For these purposes, a set of computer-based instruments as well as a variety of control functions are available for the DACI. These instruments and control functions are accessed through the LVDAC-EMS software. The LVDAC-EMS software, as well as all available upgrades, is free and can be downloaded anytime on the Festo Didactic website.

Together, the DACI and the LVDAC-EMS software allow training in various areas such as electric power technology, ac/dc machines, renewable energy, transmission lines, and power electronics using modern and versatile measuring instruments and control functions. LVDAC-EMS also offers the possibility to use pre-built SCADA interfaces for several applications to ease the view and understanding of the process taking place. The user guide provided allows students to quickly become familiar with the instruments and control functions available.

Model 9063-0 includes only the DACI, Model 9063, with no control function set activated. This enables the user to customize the DACI by individually picking the computer-based instruments and control function sets that he wants to activate in the DACI.

Alternately, variant 9063-0 is also used in several courses as an extension module. This means that it is used in conjunction to another DACI in which particular control function sets are activated. Both DACIs are connected to

a single computer running LVDAC-EMS. When used in such a way, variant 9063-0 shares all control function sets activated in the other DACI. For example, if the Computer-Based Instrumentation Function, Model 9069-1, and the Three-Phase PWM Rectifier/Inverter Control Function Set, Model 9069-5, are activated in the other DACI, these function sets will also be available in variant 9063-0. This enables the user to perform courses requiring the use of more than one DACI without having to activate the same control function sets in all DACIs.

Manual

Description	Manual number
Computer-Based Instruments for EMS (User Guide)	585219 (86718-E0)

Table of Contents of the Manual(s)

Computer-Based Instruments for EMS (User Guide) (585219 (86718-E0))

- 1 Familiarization with the Metering Window and the Data Table
- 2 Familiarization with the Oscilloscope
- 3 Familiarization with the Phasor Analyzer
- 4 Familiarization with the Harmonic Analyzer
- 5 Measuring Three-Phase Power Using the Metering Window

Additional Equipment Required to Perform the Exercises

Qty	Description	Model number
1	Personal Computer	579785 (8990-00) [17]

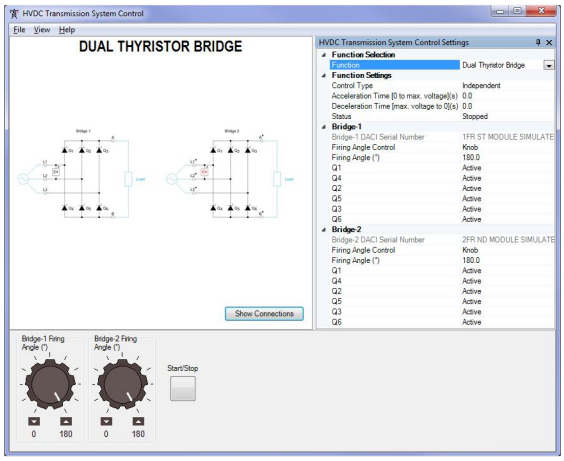
Optional Equipment

Qty	Description	Model number
1	24 V AC Power Supply	579696 (30004-20) [18]

[17] Refer to the Computer Requirements in the System Specifications section of this datasheet if the computer is to be provided by the end-user. Only one computer is required per station. This model is available in multiple voltage- and frequency dependent variants. Contact a Festo representative to obtain the correct part number.

[18] Required if power is not supplied by the Power Supply, Model 8821-2. This model is available in multiple voltage- and frequency dependent variants. Contact a Festo representative to obtain the correct part number.

High-Voltage DC (HVDC) Transmission System Control Function Set (Optional) 579790 (9069-70)



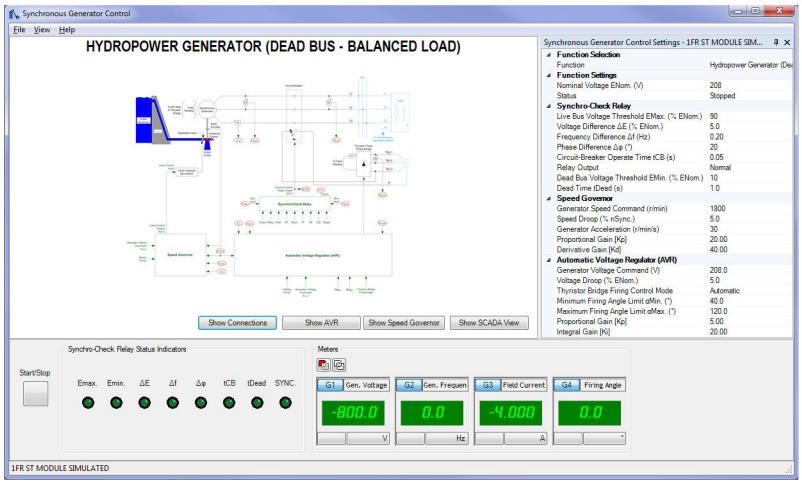
The High-Voltage DC (HVDC) Transmission System Control Function Set enables the following devices required for the study of HVDCs to be implemented using two Data Acquisition and Control Interface, Model 9063, and two Power Thyristors, Model 8841:

- Dual Thyristor Bridge
- Monopolar HVDC Transmission System
- 12-Pulse Converter

Specifications

Parameter	Value
Control Functions	
Control Functions	Dual Thyristor Bridge
	Monopolar HVDC Transmission System
	12-Pulse Converter
Dual Thyristor Bridge	
Control Type	Independent, common (α,α), or common (α,ß)
Acceleration Time (0 to Max. Voltage)	0-100 s
Deceleration Time (Max. Voltage to 0)	0-100 s
Firing Angle Control (for Each Bridge)	Knob or analog input on the DACI
Firing Angle (for Each Bridge)	0-180°
Monopolar HVDC Transmission System	
Control Type	Independent, linked (rectifier = bridge 1), or linked (rectifier = bridge 2)
Command Input (for Each Bridge)	Knob or analog input on the DACI
Current Command (for Each Bridge)	0-2 A
Inverter Limit (for Each Bridge)	90-180°
Arc-Cosine (for Each Bridge)	On of off
Feedback Filter Cutoff Frequency (for Each Bridge)	10-180 Hz
12-Pulse Converter	
Firing Angle	0-180°
Acceleration Time (0 to Max. Voltage)	0-100 s
Deceleration Time (Max. Voltage to 0)	0-100 s

Synchronous Generator Control Function Set (Optional)
579788 (9069-A0)



The Synchronous Generator Control Function Set enables the control of synchronous generators using different prime movers (emulated using the Four-Quadrant Dynamometer/Power Supply, Model 8960-2) and different control types for each prime mover. The function set allows the following prime movers and control types to be implemented using the Data Acquisition and Control Interface, Model 9063, and the Power Thyristors, Model 8841:

- Hydropower Generator (Dead Bus - Balanced Load)
- Hydropower Generator (Infinite Bus)
- Hydropower Generator (Balanced Infinite Bus)
- Hydropower Generator (Generator Paralleling - Balanced Bus)

Specifications

Parameter	Value
Control Functions	
Control Functions	Hydropower generator (dead bus - balanced load)
	Hydropower generator (infinite bus)
	Hydropower generator (balanced infinite bus)
	Hydropower generator (gen. paralleling - balanced bus)
Controller Features	Each function of the Synchronous Generator Control Function Set comprises a synchro-check relay, a speed governor, and an automatic voltage regulator.
Synchro-Check Relay	
Live Bus Voltage Threshold	50-100 V
Voltage Difference	2-40 V
Frequency Difference	0.02-2 Hz
Phase Difference	5-50°
Circuit-Breaker Operate Time	0.05-0.25 s
Relay Output	Normal, high, or low
Dead Bus Voltage Threshold	10-80% of nominal voltage
Dead Time	0.1-20 s
Speed Governor	
Speed Command	0-2000 r/min
Speed Droop	0-10%
Generator Acceleration	10-100 r/min/s
Automatic Voltage Regulator (AVR)	
Generator Voltage Command	0-240 V
Voltage Droop	0-10%
Thyristor Bridge Firing Control Mode	Automatic or manual
Minimum Firing Angle Limit	40-120°
Maximum Firing Angle Limit	120°

Power Electronics Training System (Manuals on CD-ROM) (Optional)
579717 (86359-A0)

List of Manuals

Description	Manual number
Electric Power Technology Training Equipment (User Guide)	591259 (38486-E0)
DC Power Electronics (Student Manual)	591836 (86356-00)
DC Power Electronics (Instructor Guide)	591839 (86356-10)
Single-Phase AC Power Electronics (Student Manual)	591852 (86359-00)
Single-Phase AC Power Electronics (Instructor Guide)	591855 (86359-10)
Three-Phase AC Power Electronics (Student Manual)	591883 (86362-00)
Three-Phase AC Power Electronics (Instructor Guide)	591886 (86362-10)
Thyristor Power Electronics (Student Manual)	591895 (86363-00)
Thyristor Power Electronics (Instructor Guide)	591897 (86363-10)
Three-Phase Motor Drives (Student Manual)	591928 (86368-00)
Three-Phase Motor Drives (Instructor Guide)	591930 (86368-10)
Hydropower Electricity Generation (Student Manual)	591936 (86369-00)
Hydropower Electricity Generation (Instructor Guide)	591937 (86369-10)
HVDC Transmission Systems (Student Manual)	591979 (86380-00)
HVDC Transmission Systems (Instructor Guide)	591980 (86380-10)
Computer-Based Instruments for EMS (User Guide)	592016 (86718-E0)
Three-Phase Induction Motor Starters (Student Manual)	592118 (88197-00)
Three-Phase Induction Motor Starters (Instructor Guide)	592121 (88197-10)
DC Motor Drives (Student Manual)	592153 (88553-00)
DC Motor Drives (Instructor Guide)	592156 (88553-10)
DC Motor Drives (Instructor Guide)	8113741
DC Motor Drives (Student Manual)	8113743

Reflecting the commitment of Festo Didactic to high quality standards in product, design, development, production, installation, and service, our manufacturing and distribution facility has received the ISO 9001 certification.

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