Home Energy Production Training System
579301 (8010-70)

LabVolt Series

Datasheet

Festo Didactic
en 120 V - 60 Hz
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General Description

The Home Energy Production Training System combines a modular design approach with computer-based data acquisition and control to provide unrivaled training in home energy production systems. The system features the Four-Quadrant Dynamometer/Power Supply, Model 8960-2, 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 Circuits
- Lead-Acid Batteries
- Solar Power
- Introduction to Wind Power

These courses introduce students to the fundamentals of dc power circuits, to the storage of electrical energy in lead-acid batteries, and to the generation of electrical energy from wind and sunlight, the two renewable resources most commonly used for home energy production. Training continues with the following two courses dealing with ac power:

- Single-Phase AC Power Circuits
- Single-Phase Power Transformers

These courses teach students the fundamentals of ac power circuits and power transformers, and are necessary to understand the principles of grid-tied home energy production. Students then continue with the following three courses:

- DC Power Electronics
- Single-Phase AC Power Electronics
- High-Frequency Power Transformers

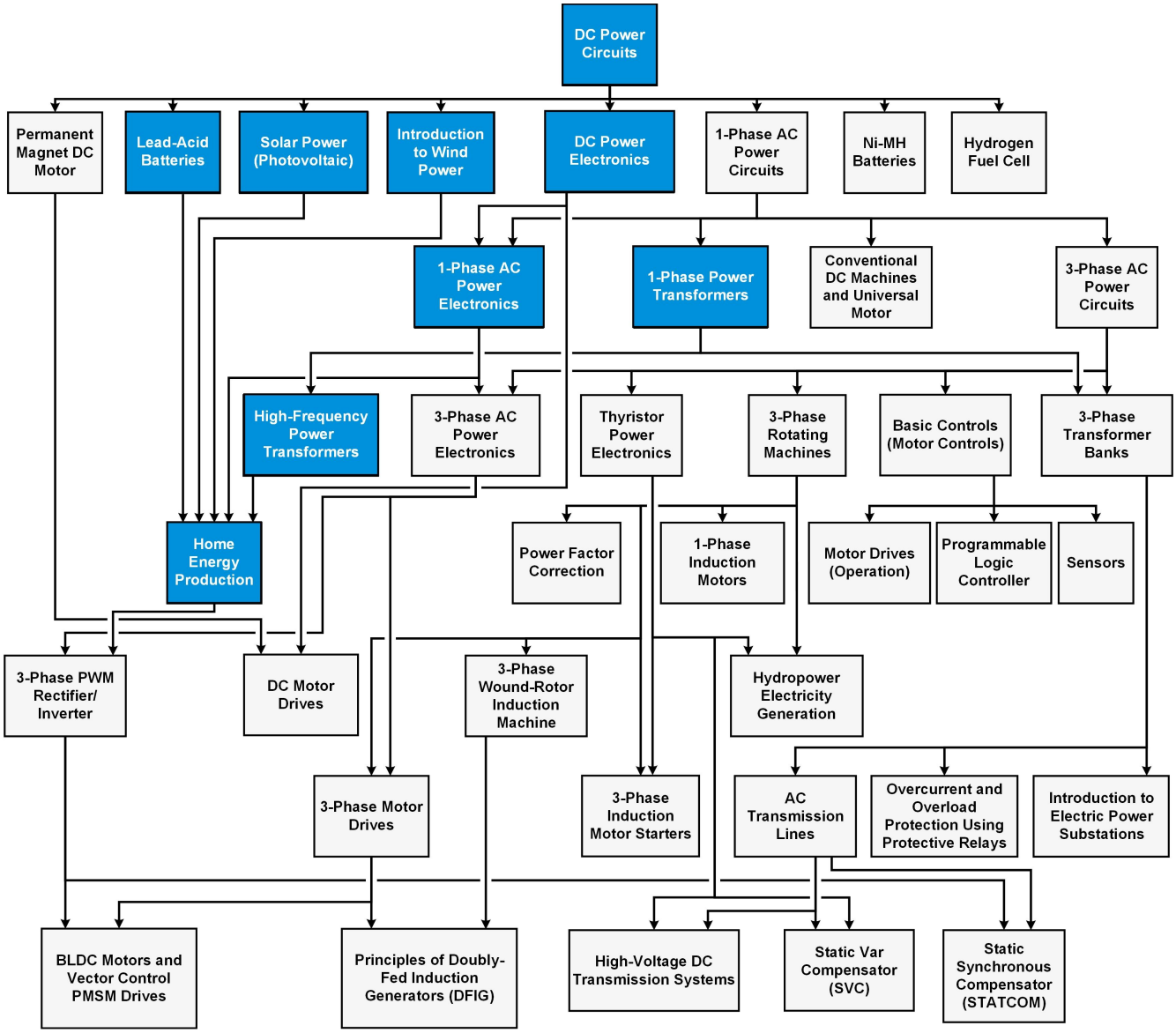
These courses familiarize students with the different power electronics devices used for home energy production, such as choppers, inverters, dc-to-dc converters, and high-frequency power transformers. After completion of the above courses, students finally possess all knowledge required to proceed with the main course of the training system:

- Home Energy Production

This course familiarizes students with the fundamentals of home energy production. It integrates all the different notions which students have acquired in the previous courses to cover both stand-alone home energy production and grid-tied home energy production. The course also explains and demonstrates how home energy production is an important contributor to the implementation of a smart grid, a concept of ever growing importance in today's electric power networks.

The Home Energy Production 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.



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.

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.

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.

Features & Benefits

- The training system teaches the principles of home energy production directly in the laboratory. To this end, students follow a complete curriculum that includes these topics:
  - An introduction to the fundamentals of electricity, beginning with dc power circuits.
  - Courses that cover the principles of electricity generation from renewable energy sources (solar power and wind power), as well as its subsequent storage in lead-acid batteries.
  - More advanced courses that cover different electrical concepts and necessary to home energy production, such as dc power electronics, single-phase ac power circuits, and high-frequency power transformers.
  - A comprehensive course covering in detail the production of energy at home from renewable resources.
- 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 very sturdy 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 and ac power source. It can also be used as a battery charger/discharger, a solar panel emulator, and a wind emulator, all with a large variety of configurable parameters.
  - 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 necessary to home energy production. 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:
  Insulated DC-to-DC Converter, Model 8835. This module is used to implement a solar/wind power inverter with HF transformer topology.
  IGBT Chopper/Inverter, Model 8837-B. This module is used to implement various types of choppers and inverters.
  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	Wind Turbine Generator/Controller	579487 (8216-00)
1	Resistive Load	763359 (8311-00)
1	Inductive Load	763362 (8321-00)
1	Filtering Inductors/Capacitors	579523 (8325-A0)
1	Capacitive Load	763366 (8331-00)
1	Transformer	763371 (8353-00)
1	AC Power Network Interface	579581 (8622-00)
1	Lead-Acid Batteries	763374 (8801-00)
1	Lead-Acid Battery Pack	579591 (8802-10)
1	Solar Panel Test Bench	579594 (8805-00)
1	Monocrystalline Silicon Solar Panel	579600 (8806-00)
1	Insulated DC-to-DC Converter	579618 (8835-00)
1	IGBT Chopper/Inverter	579623 (8837-B0)
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	579669 (8960-F0)
1	Data Acquisition and Control Interface	579689 (9063-E0)
1	24 V AC Power Supply	579696 (30004-20)

List of Manuals

Description	Manual number
Electric Power Technology Training Equipment (User Guide)	584778 (38486-E0)
DC Power Circuits (Student Manual)	579339 (86350-00)
DC Power Circuits (Instructor Guide)	579341 (86350-10)
Lead-Acid Batteries (Student Manual)	579343 (86351-00)
Lead-Acid Batteries (Instructor Guide)	579345 (86351-10)
Solar Power (Student Manual)	579347 (86352-00)
Solar Power (Instructor Guide)	579349 (86352-10)
Introduction to Wind Power (Student Manual)	579351 (86353-00)
Introduction to Wind Power (Instructor Guide)	579353 (86353-10)
DC Power Electronics (Student Manual)	579358 (86356-00)
DC Power Electronics (Instructor Guide)	579360 (86356-10)
Single-Phase AC Power Circuits (Student Manual)	579366 (86358-00)
Single-Phase AC Power Circuits (Instructor Guide)	579368 (86358-10)
Single-Phase AC Power Electronics (Student Manual)	579370 (86359-00)
Single-Phase AC Power Electronics (Instructor Guide)	579372 (86359-10)
Home Energy Production (Student Manual)	579385 (86361-00)
Home Energy Production (Instructor Guide)	579387 (86361-10)
Single-Phase Power Transformers (Student Manual)	579437 (86377-00)
Single-Phase Power Transformers (Instructor Guide)	579439 (86377-10)
High-Frequency Power Transformers (Student Manual)	579441 (86378-00)
High-Frequency Power Transformers (Instructor Guide)	579443 (86378-10)
Computer-Based Instruments for EMS (User Guide)	585219 (86718-E0)

Table of Contents of the Manual(s)

- 4 Battery Charging Methods

Solar Power (Student Manual) (579347 (86352-00))
- 1 The Diode
- 2 The Solar Panel (Photovoltaic Panel)
- 3 Effect of Temperature on Solar Panel Performance
- 4 Storing Energy from Solar Panels into Batteries
- 5 Effect of Shading on Solar Panel Operation
- 6 Solar Panel Orientation
- 7 Solar Panel Performance Versus Insolation

Introduction to Wind Power (Student Manual) (579351 (86353-00))
- 1 Voltage-Versus-Speed Characteristic of a Wind Turbine
- 2 Torque-Versus-Current Characteristic of a Wind Turbine
- 3 Power Versus Wind Speed
- 4 Storing the Energy Produced by Wind Turbines in Batteries

DC Power Electronics (Student Manual) (579358 (86356-00))
- 1 The Diode and Switching Transistor
- 2 The Buck Chopper
- 3 Introduction to High-Speed Power Switching
- 4 Ripple in Choppers
- 5 The Lead-Acid Battery Charger
- 6 The Boost Chopper
- 7 The Buck/Boost Chopper
- 8 The Four-Quadrant Chopper

Single-Phase AC Power Circuits (Student Manual) (579366 (86358-00))
- 1-1 The Sine Wave
- 1-2 Phase Angle and Phase Shift
- 1-3 Instantaneous Power and Average Power
- 2-1 Inductive Reactance
- 2-2 Capacitive reactance
- 2-3 Impedance
- 3-1 Active and Reactive Power
- 3-2 Apparent Power and the Power Triangle
- 4-1 Solving Simple AC Circuits Using Circuit Impedance Calculation
- 4-2 Solving AC Circuits Using the Power Triangle Method

Single-Phase AC Power Electronics (Student Manual) (579370 (86359-00))
- 1 Power Diode Single-Phase Rectifiers
- 2 The Single-Phase PWM Inverter

Home Energy Production (Student Manual) (579385 (86361-00))
- 1 Stand-Alone Home Energy Production
- 2 Single-Phase Grid-Tied Inverter (PWM Rectifier/Inverter)
- 3 Grid-Tied Home Energy Production Using a Solar or Wind Power Inverter without DC-to-DC Converter
- 4 Grid-Tied Home Energy Production Using a Solar or Wind Power Inverter with DC-to-DC Converter
- 5 Large-Scale Energy Storage: A Step in the Implementation of the Smart Grid

Single-Phase Power Transformers (Student Manual) (579437 (86377-00))

- 1 Voltage and Current Ratios
- 2 Transformer Winding Polarity and Interconnection
- 3 Transformer Losses, Efficiency, and Regulation
- 4 Transformer Rating
- 5 Effect of Frequency on Transformer Rating
- 6 The Autotransformer

High-Frequency Power Transformers (Student Manual) (579441 (86378-00))

- 1 High-Frequency Power Transformer Operation

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
2	Digital Multimeter	579782 (8946-20)
1	Personal Computer	579785 (8990-00) [1]
1	Heavy-Duty Tripod	583216 (40208-10)

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	Half-Size Blank EMS Module	579758 (8161-00)
1	Wind Turbine Demonstrator	579766 (8216-D0)
1	Resistive Load	763359 (8311-00)
1	Multimeters Module	586888 (8946-A0) [3]
1	Pyranometer	579784 (8989-00)
1	Home Energy Production Training System (Manuals on CD-ROM)	579747 (86378-A0)
1	Magnetic Field Strength Indicator	579793 (86618-00)
1	Wind Turbine Rotor	579794 (86630-00)

System Specifications

Parameter	Value
Power Requirements	
Service Installation	A standard single-phase ac outlet
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.

[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.

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

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)	900 x 930 x 530 mm (35.4 x 36.6 x 20.9 in)
Net Weight	TBE
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.

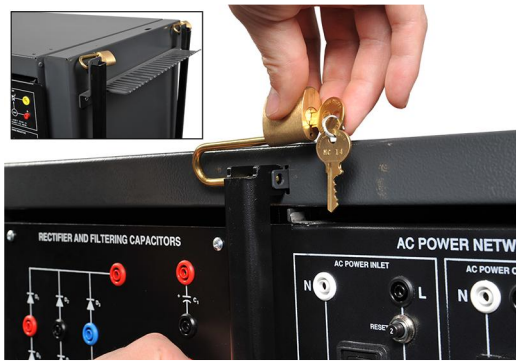
The Workstation consists of three rows of compartments designed to house EMS modules. Two of these rows have full-height compartments while the other row has half-height compartments. Each row of full-height compartments can accommodate up to three full-size EMS modules or six half-size EMS modules whereas 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) [4]
1	Industrial Controls Double-Rail Workstation	585964 (3105-B0) [5]
1	Dust Cover for Workstations	587004 (8991-00)
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)

Wind Turbine Generator/Controller 579487 (8216-00)

The Wind Turbine Generator/ Controller mainly consists of the generator and controller of an actual small-scale wind turbine, mounted in a full-size EMS module. The module also includes auxiliary components (a three-phase diode rectifier and a set of three power resistors) that can be used to apply a variable electric load to the generator. Color-coded, 4 mm safety banana jacks mounted on the front panel of the module provide access to the generator windings, controller input and output, diode rectifier, and power resistors.

The generator in the Wind Turbine Generator/Controller is a three-phase permanent-magnet synchronous generator. The controller is a power electronics device that converts the three-phase power produced by the generator into dc power and ensures that the generator produces the maximum amount of power possible at any wind speed within the operating range.

The controller also performs voltage regulation to maintain a constant dc voltage output and prevents overcharging of the battery pack used to store the electrical energy produced by the wind turbine generator. A control knob on the module front panel allows the maximum charge voltage to be adjusted. A

[4] 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.

[5] 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.

LED on the module front panel indicates the status (normal battery charging, voltage regulation, etc.) of the controller. Battery charging can be stopped anytime through a switch on the front panel.

Specifications

Parameter	Value
Wind Turbine Type	Direct-drive, fixed-pitch three blade rotor
Controller Output	
Power	200 W at a wind speed of 12.5 m/s (28 mph)
Charge Voltage Setpoint Range	54.4-68.0 V
Recommended Battery Pack Voltage	48 V
Diode Rectifier	600 V – 6 A
Power Resistors	
Ratings	15 – 100 W (each resistor)
Quantity	3
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	12.0 kg (26.4 lb)

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
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

Inductive Load
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
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)

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)

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 F
Reactance Values (Each Bank)	300/600/1200
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)

Transformer
763371 (8353-00)

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

Specifications

Parameter	Value
Nominal Power	240 VA
Primary Rating (2 windings)	24 V AC – 5 A for each winding
Secondary Rating (2 windings)	120 V ac – 1 A for each winding
Protection	10 k thermistor, type 2
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 440 mm (6.1 x 11.3 x 16.1 in)
Net Weight	TBE

AC Power Network Interface
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

Lead-Acid Batteries 763374 (8801-00)

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

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

Specifications

Parameter	Value
Batteries	
Quantity	2
Type	Valve-regulated lead-acid
Voltage	12 V
Capacity	2.3 Ah
Maximum Charge Current	0.69 A
Maximum Discharge Current	5 A
Auto-Reset Protective Fuse	
Battery	5 A (hold current), 10 A (trip current)

Parameter	Value
Test Point	0.1 A (hold current), 0.2 A (trip current)
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	4.6 kg (10.2 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 k
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
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 – 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)

Monocrystalline Silicon Solar Panel 579600 (8806-00)

The Monocrystalline Silicon Solar Panel consists of two independent photovoltaic (PV) modules mounted on a common metal chassis that can be installed in the Solar Panel Test Bench, Model 8805, when performing exercises indoors, or on a tripod when performing exercises outdoors. Both PV modules are made of high-quality monocrystalline silicon cells and protected by a coat of clear glass epoxy. Independent access to the output of each PV module is provided via a pair of miniature (2 mm) banana jacks mounted on the solar panel chassis to allow either series or parallel connection of the PV modules. A multi-pin connector on the solar panel chassis allows connection of the PV module outputs to four miniature banana jacks on the front panel of the Solar Panel Test Bench to allow PV module connection from the outside of the workstation.

Indoor Operation in the Solar Panel Test Bench

A digital thermometer attached to the solar panel chassis allows the temperature of the PV modules to be monitored. A transparent window in the front panel of the Solar Panel Test Bench allows temperature monitoring even when the solar panel is installed in the test bench.

Monocrystalline Silicon Solar Panel installed in the Solar Panel Test Bench (setup for indoor exercises).

Outdoor Operation On a Tripod

Monocrystalline Silicon Solar Panel installed on a tripod (setup for outdoor exercises).

The surface of the metal chassis on which the PV modules lie is provided with a perpendicularly mounted metal pin and silk-screened angular markers. When performing exercises outdoors, the metal pin allows the orientation to be adjusted so that the solar panel is perfectly aimed at the Sun. The angular markers allow the solar panel orientation to be offset a certain angle with respect to the Sun direction when experimenting with solar panel orientation.

The Monocrystalline Silicon Solar Panel includes a potentiometer and a set of diodes. The potentiometer is used to apply a variable electrical load to the output of the solar panel. The diodes can be connected to the solar panel to serve as either bypass diodes or blocking diodes. These components are used when performing solar panel exercises outdoors (i.e., without the Solar Panel Test Bench). Access to the potentiometer and diodes is through miniature (2 mm) banana jacks mounted on the solar panel chassis.

Specifications

Parameter	Value
PV Module	
Quantity	2
Type	Monocrystalline Silicon
Number of Cells	18
Open-Circuit Voltage (VOC)	9 V @ STC
Short-Circuit Current (ISC)	100 mA @ STC
Potentiometer	Single Turn - 500 - 2 W
Diodes	
Quantity	3
Peak Inverse Voltage	1000 V
Maximum Current	1 A
Thermometer	
Range	-50°C to +70°C (-58°F to +158°F)
Resolution	±0.1° from -19.9° to +199.9°, otherwise 1°
Accuracy	±1°C from -30°C to +70°C (±1.8°F from -22°F to +158°F)
Battery Voltage	1.5 V
Battery Type	A76 (LR44, G13) size or equivalent, 1 required
Angular Markers	
Range	65°
Interval	5°
Physical Characteristics	
Dimensions (H x W x D)	240 x 237 x 58 mm (9.4 x 9.3 x 2.3 in)
Net Weight	2.0 kg (4.4 lb)

Insulated DC-to-DC Converter 579618 (8835-00)

The Insulated DC-to-DC Converter is used to convert a low-voltage dc source, such as the Battery Pack, Model 8802, into a high-voltage dc output suitable for ac conversion. This type of converter (push-pull) can be found in most switched-mode power supplies and commercial inverters. The Insulated DC-to-DC Converter mainly consists of two power MOSFETs and their respective drivers, an high-frequency power transformer and a full-wave diode bridge on the output side. The MOSFETs can be controlled using an external controller or the digital outputs of the Data Acquisition and Control Interface, Model 9063. Internal electrical components are identified on the module front panel by silkscreened symbols and terminated by 4 mm safety banana jacks.

Specifications

Parameter	Value
Input	
Rating	285 W - 40-55 V dc
Circuit Breaker	7 A
Output Rating	250 W - 150-220 V dc
Switching Control Inputs	
Quantity	2
Signal Level	0-5 V (TTL compatible)
Nominal Frequency	36 kHz
Maximum Duty Cycle per signal	45 %
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

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 , 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)

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

Parameter	Value
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)

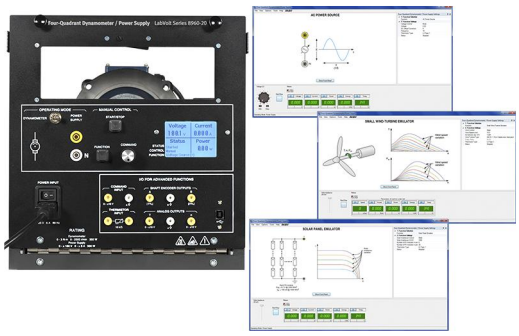
Connection Lead Set
579638 (8951-L0)

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 579669 (8960-F0)



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-F 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
- Turbine Emulator, Model 8968-3
- Lead-Acid Battery Charger, Model 8968-4
- Solar Panel Emulator, Model 8968-6

Additional Equipment Required to Perform the Exercises

Qty	Description	Model number
1	Personal Computer	579785 (8990-00) [6]

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
	Turbine Emulator, Model 8968-3
	Lead-Acid Battery Charger, Model 8968-4
	Solar Panel Emulator, Model 8968-6
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 k, 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
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

[6] 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.

- 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

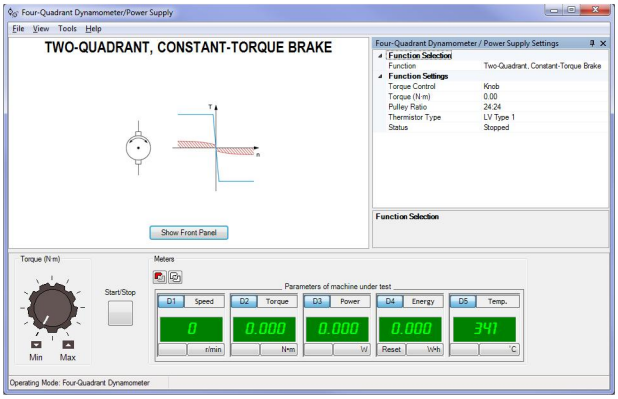
Power Supply operating mode

- 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
	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

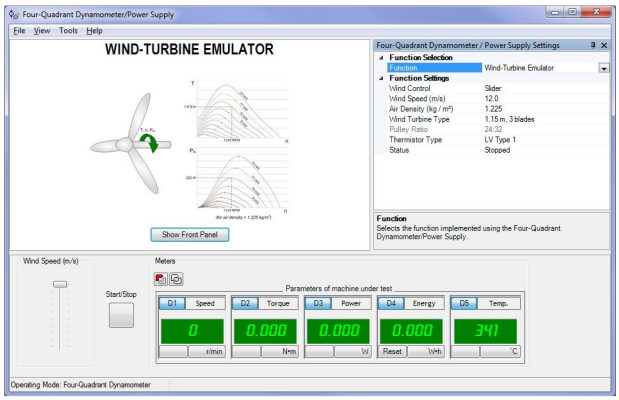
Specifications

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

Parameter	Value
	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	
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

Parameter	Value
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

Turbine Emulator Function Set 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.

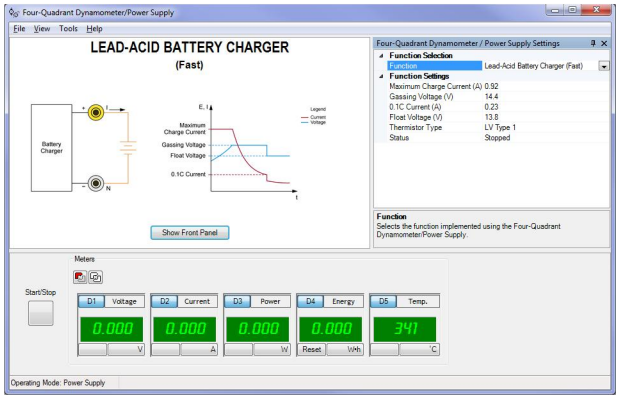
- Hydraulic Turbine Emulator: this function uses the permanent-magnet dc motor of the Four-Quadrant Dynamometer/Power Supply to recreate the behavior of an hydraulic turbine with a synchronous generator. The torque-speed characteristics at the shaft of the machine coupled to the Four-Quadrant Dynamometer/ 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

Parameter	Value
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

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.

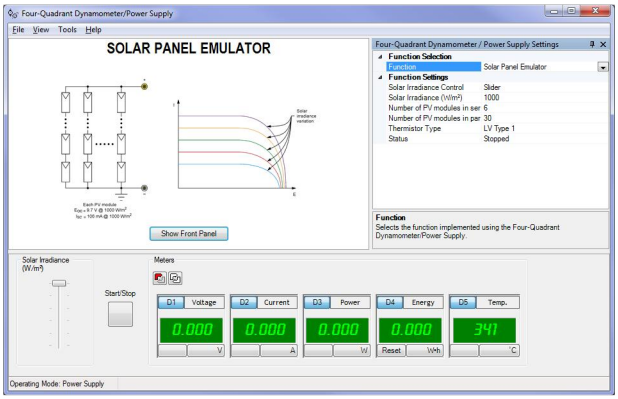
- Battery Discharger (Constant-Current Timed Discharge with Voltage Cutoff):

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

Solar Panel Emulator Function Set 581440 (8968-60)



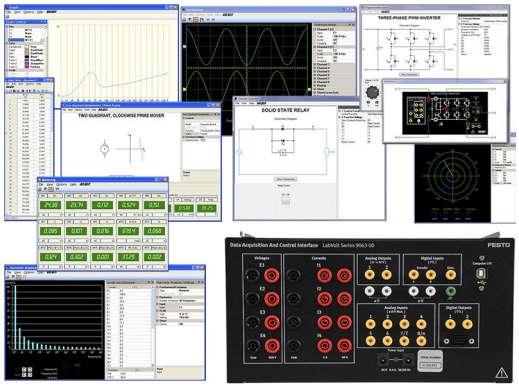
The Solar Panel Emulator Function Set is a function that can be activated in the Four-Quadrant Dynamometer/Power Supply, Model 8960-2, enabling the module to emulate a solar panel.

The Solar Panel Emulator 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 function emulates a solar panel consisting of an array of photovoltaic (PV) modules. The current-voltage characteristic of each PV module emulated is the same as that of the PV module used in the Monocrystalline Silicon Solar Panel, Model 8806. The function allows the user to determine the size of the PV module array emulated, by selecting the number of PV modules connected in series and in parallel. A sliding control in the Solar Panel Emulator interface provides the user full control of solar irradiance.

Specifications

Parameter	Value
Control Functions	Solar Panel Emulator
Solar Panel Emulator	
Solar Irradiance Control	Software slider or 8960 command input
Solar Irradiance	1-1000 W/m²
Number of PV Modules in Series	1-7 modules
Number of PV Modules in Parallel	5-45 modules

Data Acquisition and Control Interface 579689 (9063-E0)



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-E 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
- Home Energy Production Control Function Set, Model 9069-4

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))

- 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) [7]
1	24 V AC Power Supply	579696 (30004-20) [8]

Specifications

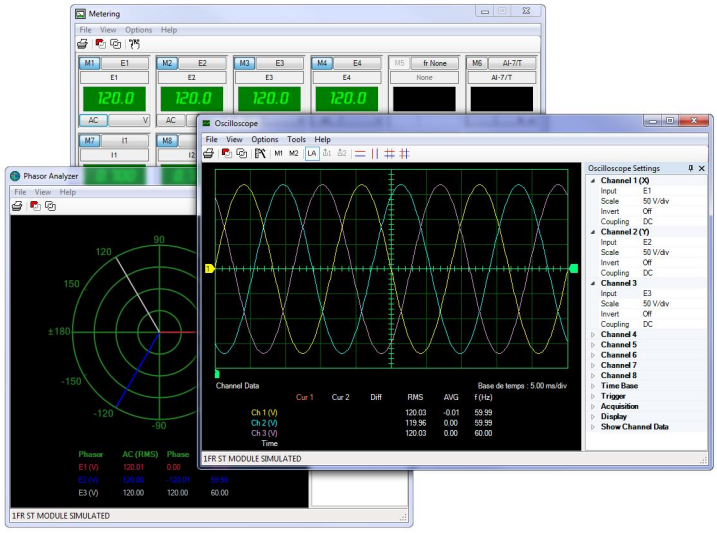
Parameter	Value
Insulated Voltage Inputs (4)	
Range (Low / High Scales)	-80 to +80 V / -800 to + 800 V (user-selectable through software)
Impedance (Low / High Scales)	326.6 k / 3.25 M
Bandwidth	DC to 65 kHz (-3 dB)
Accuracy	1% (dc to 10 kHz)
Insulation	800 V
Measurement Category	CAT II (283 V ac/400 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 m / 50 m
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 M
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
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 k
Digital Outputs (9)	
Types	Control (6 on a DB9 connector and 2 on 2 mm banana jacks), synchronization (1 on a DB9 connector)

[7] 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.

[8] 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
Signal Level	0-5 V (TTL compatible)
Maximum Output Frequency	20 kHz (software-limited)
Impedance	200
Control Functions	
Activated Sets	Computer-Based Instrumentation Function, Model 9069-1
	Chopper/Inverter Control Function Set, Model 9069-2
	Home Energy Production Control Function Set, Model 9069-4
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:

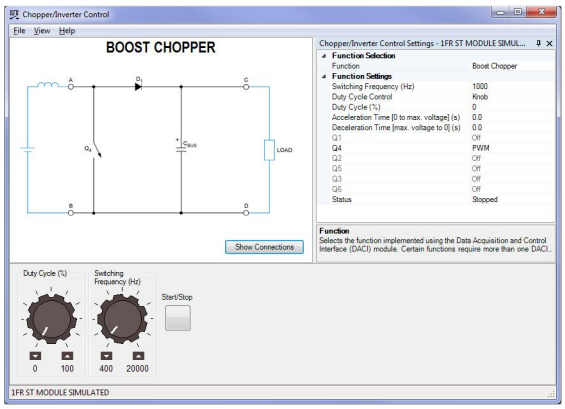
- Metering
- Data Table and Graph
- Oscilloscope
- Phasor Analyzer
- Harmonic Analyzer

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	

Parameter	Value
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
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

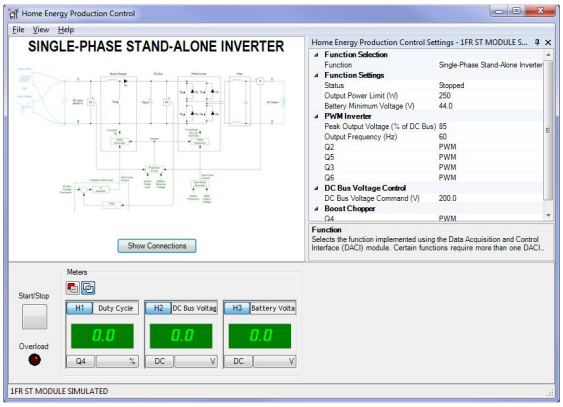
Specifications

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

Parameter	Value
	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
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

Parameter	Value
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)

Home Energy Production Control Function Set 581455 (9069-40)



The Home Energy Production Control Function Set enables the following devices required for home energy production 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:

- Single-Phase Stand-Alone Inverter
- Single-Phase Grid-Tied Inverter
- Solar Power Inverter (LF Transformer)
- Solar/Wind Power Inverter (HF Transformer)

Specifications

Parameter	Value
Control Functions	
Control Functions	Single-Phase Stand-Alone Inverter
	Single-Phase Grid-Tied Inverter
	Single-Phase Grid-Tied Inverter (LF Transformer)
	Solar/Wind Power Inverter (HF Transformer)
Single-Phase Stand-Alone Inverter Function	
Output Power Limit	50-250 W
Battery Minimum Voltage	35-55 V
PWM Inverter Peak Output Voltage	50-95% of dc bus voltage
PWM Inverter Output Frequency	50 or 60 Hz
DC Bus Voltage Command	100-400 V
Single-Phase Grid-Tied Inverter Function	
Active Current Command	-2 to 2 A
Reactive Current Command	-2 to 2 A
DC Bus Voltage Command	100-400 V
Solar Power Inverter (LF Transformer)	
MPP Tracker	On or off
Active Current Command	-10 A to 10 A (only available when the MPP Tracker parameter is switched to Off)
Reactive Current Command	-10 A to 10 A
Solar/Wind Power Inverter (HF Transformer)	
MPP Tracker Type	Solar panel or wind turbine

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

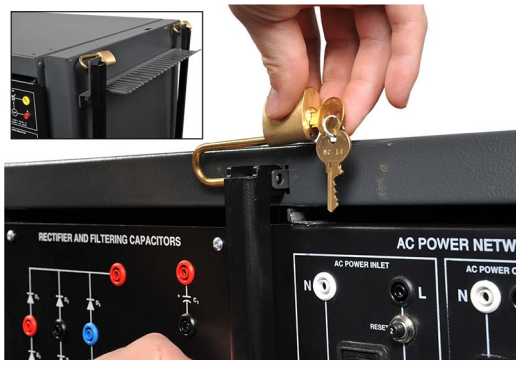
modules or six half-size EMS modules, whereas the row of half-height compartments can accommodate up to three half-size EMS modules.

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) [9]
1	Industrial Controls Double-Rail Workstation	585964 (3105-B0) [10]

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)

[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.

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

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

Wind Turbine Demonstrator (Optional) 579766 (8216-D0)

The Wind Turbine Demonstrator is an actual small-scale wind turbine modified to display the main internal components. The wind turbine has a fixed-pitch, three blade rotor that is directly coupled to the generator. The wind turbine is mounted atop a sturdy metal pole at a height that facilitates observation of the internal components. Casters at the base of the metal pole makes the whole unit easy to move. The casters have a built-in brake system to stabilize the unit when in place.

Openings made in the wind turbine nacelle allow observation of the main internal components, i.e., the generator and controller. The bladed rotor of the wind turbine is locked in place to reduce the risk of injuries.

Specifications

Parameter	Value
Wind Turbine Type	Direct drive, fixed-pitch three blade rotor
Blade Radius	62.2 cm (24.5 in)

Parameter	Value
Nacelle Length	67.6 cm (26.6 in)
Physical Characteristics	
Dimensions (H x W x D)	1800 x 991 x 991 mm (71.0 x 39.0 x 39.0 in)
Net Weight	21.8 kg (48 lb)

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 M
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

Parameter	Value
Current Range	0-10 A dc
Resistance Range	0-20 M
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

Pyranometer (Optional) 579784 (8989-00)

The Pyranometer is a high-quality instrument for measuring solar irradiance. The thermopile sensor construction measures the solar energy that is received from the total solar spectrum and the whole hemisphere (180° field of view). The output signal of the Pyranometer is a voltage proportional to the measured solar irradiance, expressed in Watts/m². The Pyranometer is a useful instrument when measuring the performance of solar panels versus insolation.

Specifications

Parameter	Value
Spectral Range	310 to 2800 nm
Sensitivity	5 to 20 uV/W/m²
Response Time	<18 s
Maximum Solar Irradiance	2000 W/m²
Field of View	180°
Operating Temperature Range	-40°C to +80°C (-40°F to +176°F)
Physical Characteristics	
Dimensions (H x W x D)	85 x 130 x 100 mm (3.4 x 5.1 x 3.9 in)
Net Weight	1.1 kg (2.4 lb)

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

Heavy-Duty Tripod (Optional) 583216 (40208-10)

The Heavy-Duty Tripod is a compact, heavy-duty unit that is perfectly suited to hold the Solar Panel, Model 8806, when performing outdoor exercises.

Specifications

Parameter	Value
Load Capacity	5 kg (11 lb)
Physical Characteristics	
Closed Length	53.5 cm (21.1 in)
Minimum Height	8.0 cm (3.1 in)
Maximum Height	146 cm (57.5 in)
Net Weight	1.8 kg (4 lb)

Magnetic Field Strength Indicator (Optional) 579793 (86618-00)

The Magnetic Field Strength Indicator displays the strength of the residual magnetism in a metallic object. It is enclosed in a rugged, pocket-sized enclosure and requires no power to operate.

Specifications

Parameter	Value
Scale Range	-10 – 0 – +10
Physical Characteristics	
Dimensions (H x W x D)	50.8 x 50.8 x 25.4 mm (2.0 x 2.0 x 1.0 in)
Net Weight	0.05 kg (0.1 lbs)

Wind Turbine Rotor (Optional) 579794 (86630-00)

The Wind Turbine Rotor is the same rotor as that used in the generator of the Wind Turbine Generator/ Controller, Model 8216-0, and the Wind Turbine Demonstrator, Model 8216-D. It enables observation of the rotor construction. It also allows observation of the arrangement of the permanent magnets on the rotor using the Magnetic Field Strength Indicator, Model 86618.

Specifications

Parameter	Value
Physical Characteristics	
Dimensions (H x W x D)	76.2 x 88.9 x 88.9 mm (3.0 x 3.5 x 3.5 in)
Net Weight	0.77 kg (1.7 lbs)

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.

AΣT Labs

For more information or a demo in New England contact your AET Labs technology consultant: 888.768.4550 or email info@aetlabs.com.

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