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Powerframes

60-070 Electrical Power & Machines system

- Universal Series Motor
- Synchronous Machine
- Single Phase Transformers
- Three Phase Transformers
- Electrical Circuits
- Electromagnetic Motor Control
- dc Motor Speed Control
- ac Motor Speed Control
- Measuring Instruments

Electrical Power and Machines is one of the most important areas of study for students in further and higher education. As we become more aware of the finite energy resources available to us it is imperative that we use them in the most efficient manner. Engineers and technicians need to know which machines and motors are best suited for particular applications, how to generate and distribute power with the minimum losses and how electrical circuits behave at higher voltages and currents. For example, would you use the same type of motor in a Fan as you would for a power tool or a Railway Locomotive for example? How can we distribute and utilise the maximum amount of power? Why do we use Three Phase electrical power generation?

Feedback Instruments Limited has been supplying teaching and training systems to educational establishments throughout the world for nearly fifty years. Using the experience we have gained we have configured a teaching system for Electrical Power and Machines which addresses the requirements of colleges and universities and enables students to get a “hands-on” understanding in these subjects.

This brochure describes the modular 60-070 system which provides curriculum coverage for Electrical Circuits, Transformers, and Motors and Generators. From our knowledge of the market we believe that the standard configurations described in this brochure will satisfy the needs of most courses at different academic levels. However, the system is modular and can be configured to suit individual requirements. Should one of the standard packages not satisfy your needs we would be pleased to help you put together a specific package.

The 60-070 and all the other products in the complete Electrical Power and Machines range are available for operation with three phase 230/400V 50Hz or 120/208V 60Hz supplies. Please specify clearly when ordering which supply you will be using.

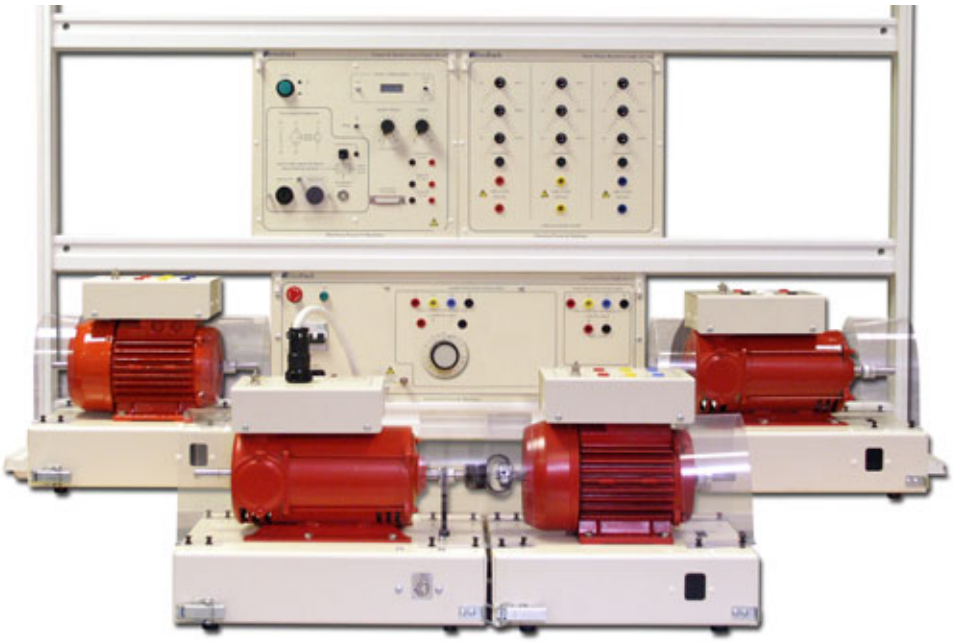
System Benefits

- Low cost start-up
- High level of electrical and mechanical safety built-in
- Comprehensive course curriculum
- Choice of conventional or virtual instruments
- Ideally suited for University and Technical College courses
- Covers most areas of Electrical Power and Machines
- All products provided with in-depth teaching manuals

Powerframes 60-070 core system

Features

- Low cost entry level
- Industrial style dc, single and three phase machines
- Choice of instrumentation available
- Supplied with comprehensive Torque/Speed measurement system
- High level of electrical and mechanical safety
- Quick and easy machine coupling
- Multi-output dc, single and three phase protected supply



Curriculum Coverage

dc Motors and Generators

- dc Shunt Motor
- dc Series Motor
- dc Compound Motor
- dc Separately Excited Motor
- dc Shunt Generator
- dc Compound Generator
- Separately Excited dc Generator

ac Motors

- Single Phase Induction Motor - Capacitor Start / Induction run
- Starting requirements
- Effect of start capacitor
- Effect of capacitor on output characteristics
- Torque/speed and efficiency characteristics

Three phase ac Motors

- Three phase Squirrel Cage Induction Motor
- Star connected motor
- Voltages and currents
- Delta connected motor Voltages and currents
- Torque/speed and efficiency characteristics

The 60-070 Core System provides a versatile but cost effective introduction to the study of Electrical Power and Machines which will be sufficient for many applications but can be enhanced at any time by adding any of the various modules described later in this brochure.

Safety has been paramount during the development of this system and every effort has been made to protect both the user and the equipment. Safety 4mm sockets are used throughout for interconnections and guards are provided to cover rotating components.

All machines and motors are nominally rated at 250W and are bench mounted. They are purpose designed to provide characteristics more typical of larger machines. All other modules; Power Supplies, Loads, Measuring Instruments etc are available separately and mount in a rigid insulating Frame into which they can be easily inserted or removed.

A detailed manual providing both theory and experimental procedure is provided in hard copy and electronic formats to help the student gain a working understanding of the subjects listed.

In order to make full use of the system some additional measuring instruments are required. Feedback can supply both conventional meters, or PC based ones as described on the following pages and referenced in the experimental manual. Alternatively any suitable instruments can be used although experimental procedures might be slightly more difficult to follow in certain instances.

The 60-070 Core System comprises:

63-120 dc Compound Wound Machine
64-110 Single Phase Induction Motor - Capacitor Start / Induction Run
64-501 Three Phase Induction Motor - Squirrel Cage, Dual Voltage
67-004 Manual Armature Current Dynamometer
60-105 Universal Power Supply
67-142 Switched Three Phase Resistance Load
91-200 System Frame
plus Motor Couplings, Leads, Safety Guards, Manual

as described on the following page.

Powerframes 60-070 core system

The following modules comprise the Core system

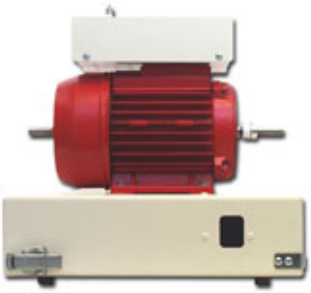
63-120 dc Compound Wound Machine

The Compound dc Machine can be used to compare the characteristics of dc machines with windings connected in Series, Shunt or Compound configurations as both a motor and a generator.

63-120

64-110 Single Phase Induction Motor - Capacitor Start / Induction Run

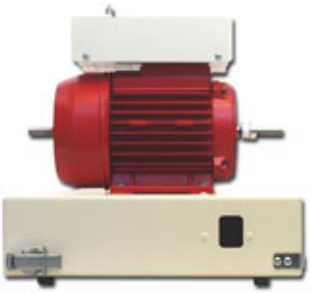
The Capacitor Start (Induction Run) single phase machine is very widely used. The main and auxiliary windings identified and their effect on the starting and running characteristics being studied.



64-110

64-501 Three Phase Induction Motor - Squirrel Cage, Dual Voltage

The Squirrel Cage Induction Motor is the most cost effective three phase machine used widely throughout industry. Among the many topics considered are Speed and Slip, reversal of rotation and torque/speed characteristics.

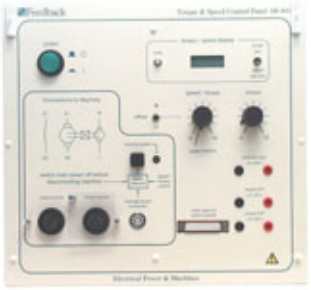


64-501

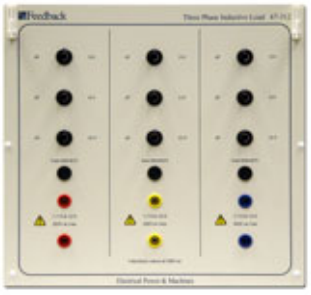
67-004 Manual Armature Current Dynamometer

This is a very versatile machines loading system comprising an electrical Dynamometer with integral Tachogenerator, and the 68-441 Torque/Speed controller and all connecting leads. Can be used to manually apply torque to a motor or control the speed of a generator.
In addition it can be used in constant torque, torque proportional to speed and constant speed modes. These modes can also be controlled with external analogue signals or via a PC.

67-530



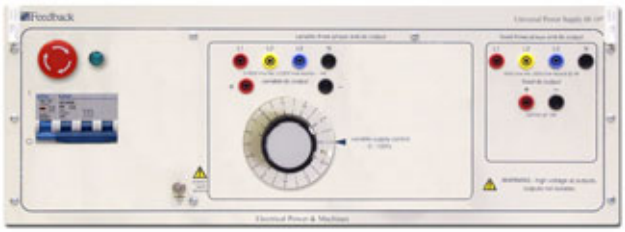
68-441



67-142

60-105 Universal Power Supply

This provides sufficient fixed and variable dc and Three Phase power supplies to conduct all the experiments offered by the 60-070 Core System and Options. It is fully protected. It requires a three phase five wire supply.

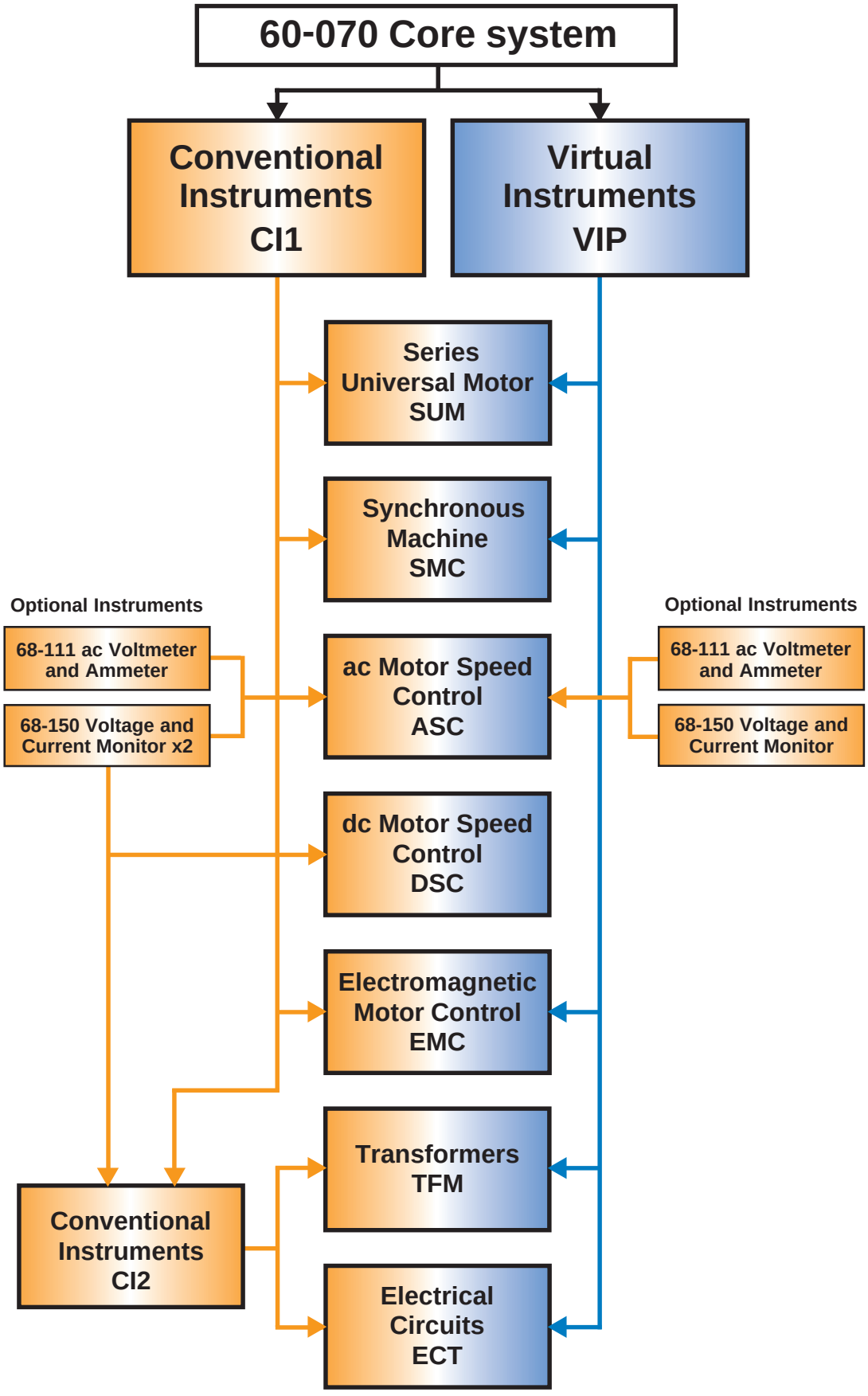


60-105

67-142 Switched Three Phase Resistance Load

The 67-142 provides three banks of switched resistors which are used for loading purposes and for teaching basic circuit theory.

Electrical Power & Machines 60-070 Structure



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Core System Additional Machines

Series Universal Motor 60-070-SUM

The Series Universal Motor is a simple, versatile and very widely used device which can operate using a dc supply or a single phase ac supply. Comparison is made between the operation using the different supplies and the need for a compensation winding is shown.

All electrical machines available in the 60-070 series are fitted with fully shrouded electrical connectors, shaft guards, alignment pins and quick fasten and release mechanical catches to retain coupled machines.

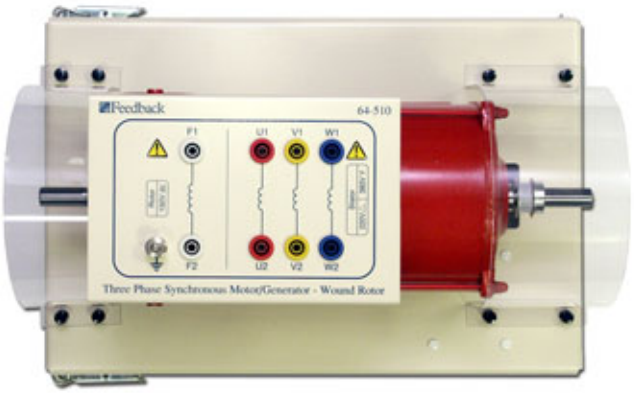
Features

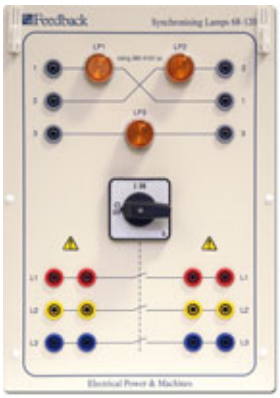
- Mimic diagram of motor windings
- Realistic industrial frame size
- Electrical and mechanical protection

Curriculum Coverage

- Motor characteristics with dc supply
  - Speed versus torque
  - Power versus torque
  - Efficiency versus torque
- Motor characteristics with ac supply
  - Speed versus torque
  - Power versus torque
  - Efficiency versus torque
- Control of shaft direction of rotation
- Compensation winding

Synchronous Machine 60-070-SMC





Three Phase Synchronous Machine & Synchronising Module 60-070 SMC

The Three Phase Synchronous Machine can be used as a Motor or a Generator. Starting requirements, synchronisation, load and no-load characteristics and its use as a synchronous capacitor are some of the topics covered.

In addition the Synchronising Module shows how the Three Phase generator can be synchronised to the existing power supply. The versatility of the 60-070 allows sophisticated experiments to be performed, such as, running the machine up to synchronous speed, synchronising as a generator, changing the synchronous mode to a motor and studying the characteristics and pull-out torque.

Features

- Lamps dark or lamps bright configuration possible
- Synchronising switch included
- Star or delta winding configuration possible
- High degree of mechanical and electrical protection

Curriculum Coverage

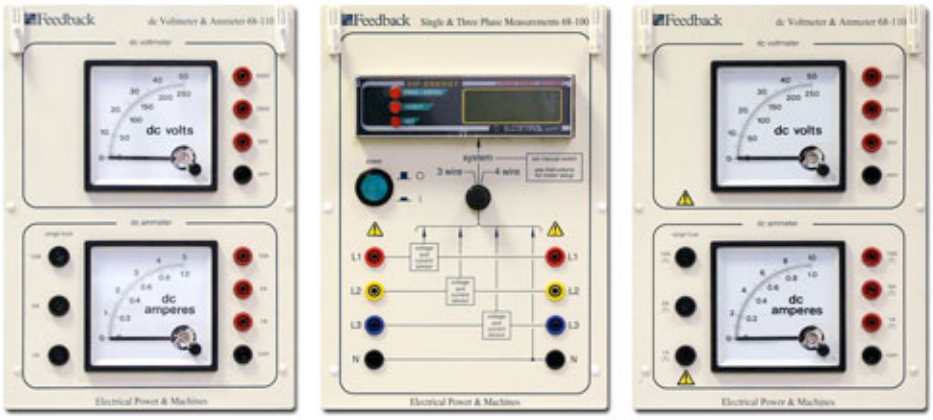
- Open circuit test
- Short circuit test
- Effect of speed variation on output voltage and frequency
- Synchronisation procedure
- Operation of a synchronous machine
- Voltage regulation of a synchronous machine
- Variable reactor V curves

Core System Conventional Instruments option

Conventional Instruments 60-070-CI1

Features

- Electronic single and three phase measurements
- Long scale style dc voltmeter and ammeter
- High accuracy industrial style analogue instruments
- Fuses protected current input ranges



Various Measuring Instruments are required in order to perform the full range of experiments described in the teaching manual. These can be conventional meters, virtual instruments or a combination of the two.

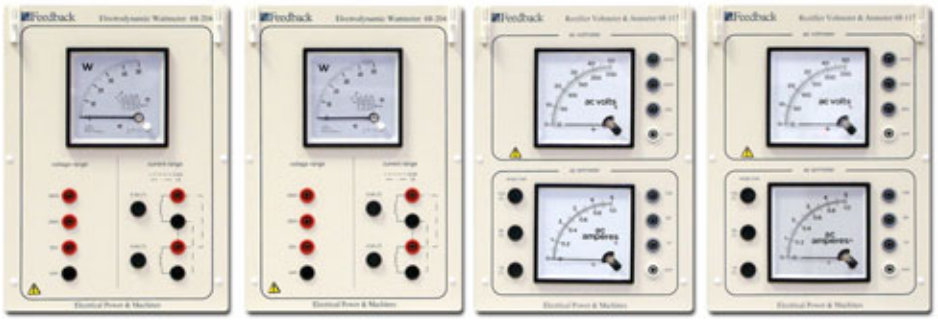
The use of conventional meters is highly relevant in the field of Electrical Power and is both industrially relevant and provides good practice.

The range of high quality conventional instruments available for use with the 60-070 includes pointer type meters and a multi-functional single and three phase digital measuring system. All instruments are mounted within the frame system. The accuracy class of the pointer instruments is typically 2% which allows for precision measurements and the ability to measure small variations on line voltages and currents.

Conventional Instruments 60-070-CI2

Features

- Two wattmeters for three phase power measurement
- Selectable voltage and current wattmeter ranges
- Multi-range voltmeters and ammeters
- Fuse protected current inputs



To perform the full range of experiments described in the teaching manual with options TFM Transformers and ECT Electrical Circuits additional conventional instruments are required. The additional instruments are two ac Voltmeter/Ammeters and two ac/dc Electrodynamic Wattmeters.

The combination of 60-070 CI1 and CI2 provides an instant measurement of all the values required to be measured in three phase circuits and three phase transformers where often many readings need to be recorded, several at any one time.

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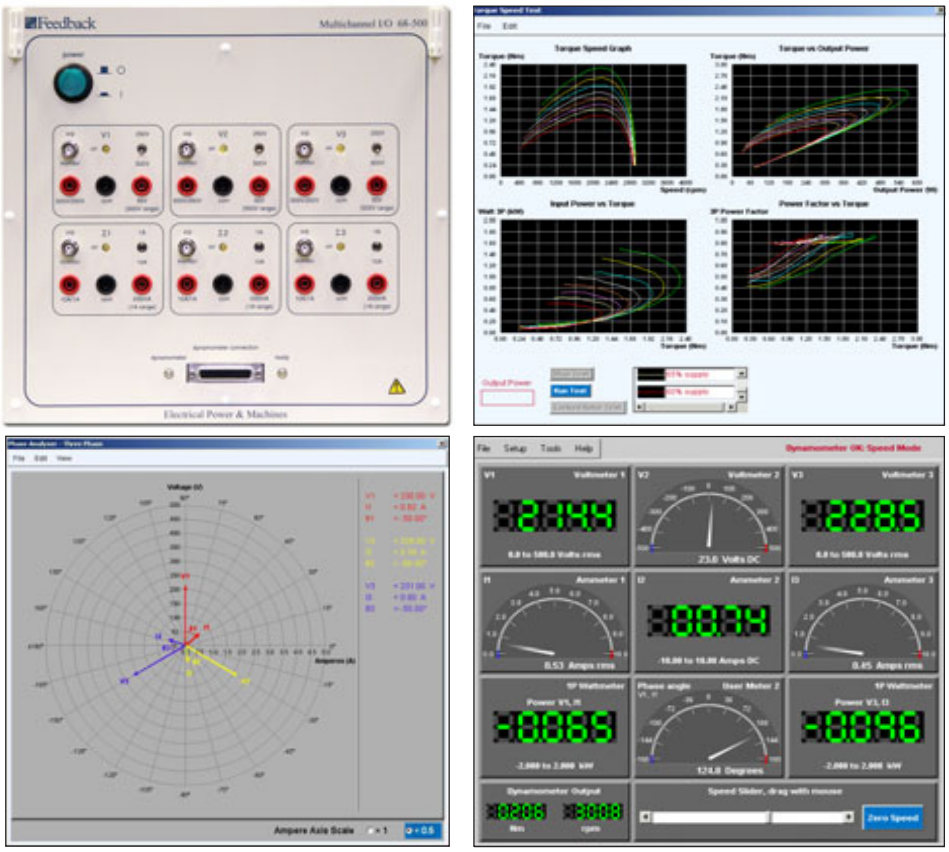
Core System Virtual Instruments option

Virtual Instrumentation 60-070-VIP



The Virtual Instrumentation Pack comprises the 68-500 Multichannel I/O Module which is connected to a PC via a USB Interface and a software package which provides a suite of virtual instruments.

The 68-500 accepts up to three ac or dc voltages and up to three ac or dc currents. These inputs are isolated from each other and each includes a single ended monitoring point so that waveforms can be studied using a conventional low cost oscilloscope. In addition a 25 pin socket is used to connect the 68-500 to the 68-441 Torque/Speed Controller described earlier. This connector is used to read Torque & Speed information and also allows Torque setting via the PC.

The standard virtual instrument screen provides nine analogue or digital meters (three voltmeters, three ammeters and three user defined meters) plus a display of Torque and Speed and a slider to allow loading of a machine via the PC. Instrument settings can be saved for later use.

In addition to the meters the software provides very powerful plotting features. Any measured or calculated parameters (eg. Torque and Speed or Power Factor and Current) can be plotted against each other. Multiple plots can be included on one set of axes to obtain a family of curves at perhaps different voltages and up to four graphs can be displayed simultaneously. Data can be saved or exported.

A Phasor Diagram graphically shows the real time relationship between the various three phase voltages and currents.

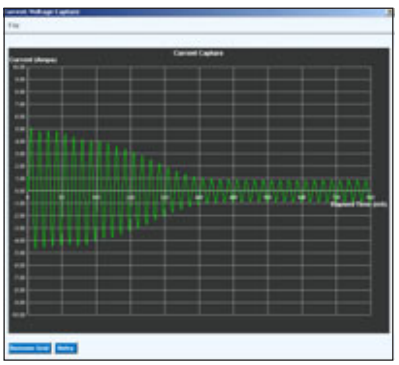
A Transient Recorder allows plotting of in-rush current and starting characteristics.

Software Features

- Computer based machines testing system
- Displays up to nine selectable meter windows
- Choice of meter functions
- Analogue or digital virtual meter
- User definable meters
- Real-time plotting
- Four separate graph plots simultaneously
- Graph plotting with multiple functions
- Data export facility
- Browser based software

Hardware Features

- Purpose built, multi-channel I/O unit
- Six isolated channels
- Three voltage and three current inputs
- ac and dc measurements
- 50V - 500V ranges
- 0.2A - 10A ranges
- Six isolated oscilloscope monitoring points
- PC interface included



Motor in-rush current display

Core System Additional Equipment

Single & Three Phase Transformers 60-070-TFM

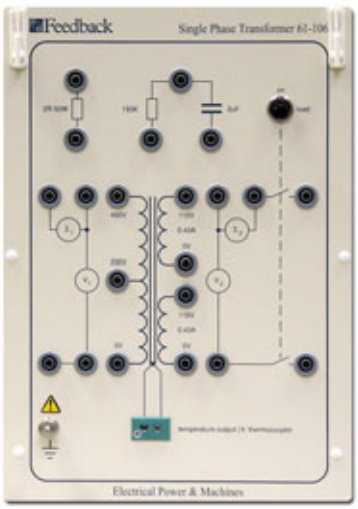
Curriculum Coverage

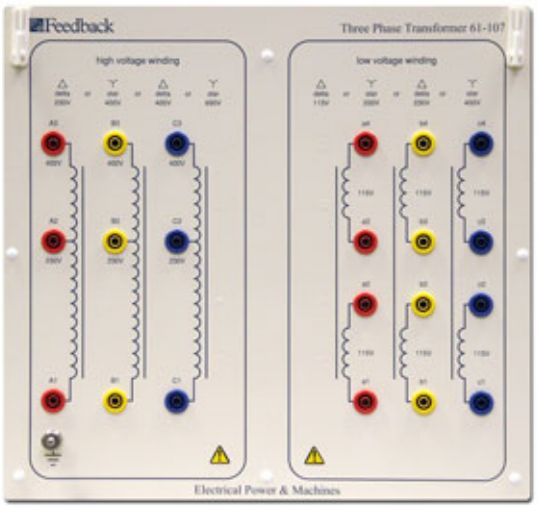
Single Phase Transformers

- Voltage and current ratios, turns ratio, step-up, step-down
- Voltage and current waveforms
- Winding polarity, series and parallel connection
- On-load characteristics, voltage regulation
- Auto-transformer, transformers in parallel, current transformer

Three Phase Transformers

- Winding polarity, connecting Star, Delta, Open Delta and Zig-Zag secondary windings
- Voltage & current relationships, establishing the root 3 factor
- On load characteristics
- Voltage and current phasor relationships for no-load and on-load transformer
- Phase shift between primary and secondary





The TFM Transformer option provides two additional modules; the 61-106 Single Phase Transformer and the 61-107 Three Phase Transformer. Each is fully enclosed for safety and electrically protected. Front panel mimic diagrams simplify experimental connections.

Curriculum is provided for a comprehensive Transformer course covering Voltage and Current ratios, turns ratios and step-up and step-down operation, no-load and on-load performance, auto-transformers, star, delta, open-delta and zig-zag windings primary-secondary phase relationships and efficiency.

Electrical Circuits 60-070-ECT

Curriculum Coverage

Electrical Fundamentals

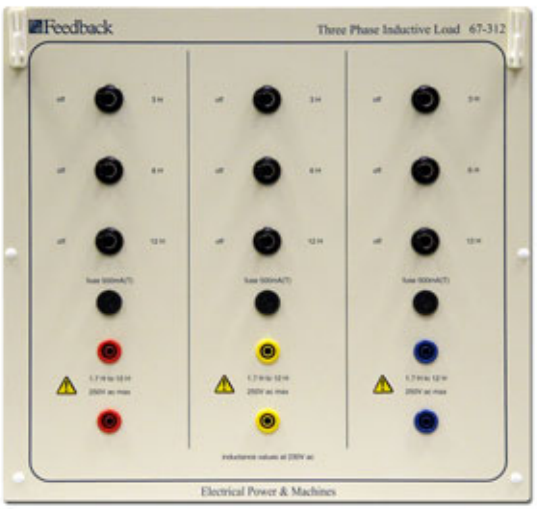
- Voltage, current, resistance and Ohms Law
- Resistors in series and parallel
- Power in dc circuits
- Solving resistive networks using Kirchoffs voltage & current laws

Alternating Current

- The sinewave, Phase angle, and power
- Capacitive reactance, Series & Parallel equivalent capacitance
- Phase shift & reactive current
- Inductive reactance, series and parallel equivalent inductance
- Phase shift and reactive power
- Power in ac circuits
- Vectors and phasors in RL, RC, RLC circuits
- Impedance

Three Phase Circuits

- Balanced 3-Phase resistive load in Star and Delta connections
- Root 3 relationships of voltage and current values
- 3-Phase power measurement
- 3-Phase sequence-determination



The ECT Electrical Circuits option introduces two additional modules; the Three-phase Switched Capacitor Load 67-212 and the Three-phase Switched Inductor Load 67-312. These are used in conjunction with the 67-142 Three-phase Resistor Load (supplied in the 60-070 Core System) to provide a comprehensive introduction to dc, single and three-phase circuits.

Curriculum coverage includes Ohm's law, series and parallel circuits, resistance, reactance and impedance, phase relationships, balance loads and dc and ac power.

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Core System Additional Equipment

Electromagnetic Motor Control 60-070-EMC

The use of power relays to provide a switched sequence of events for starting, stopping, foward and reversing of electrical machines has been traditionally carried out by Electromagnetic control gear. The application of these devices is widely used today and therefore the principles need to be understood.

The EMC Electromagnetic Motor Control 60-070 provides study methods and terminology associated with the implementation of control devices in some of the most commonly used circuits for control of ac and dc machines, to a level that can be understood by both maintenance engineers and technicians alike.

The equipment consists of a wide range of control gear that is provided on three panels. One has electromagnetic contactors, and the other two have pushbutton and rotary switch gear and indicator lights.

Contactor Panel 65-123

This is the main control panel. It consists of a ‘power’ control supplies switch, three phase isolating switch, contactor and overload relays, mechanically interlocked contactors, control and speed relays, and timer circuit. Additionally, power resistors are provided and magnetic pick-up connection terminals.
A low voltage, protected ac output is also provided to supply the control circuit configuration. All components are connected to a mimic diagram on the front of the unit.

Control Pushbuttons 65-132

To manually operate the contactors and relays available in the 65-123 panel and to provide an indication of the control sequence status a variety of pushbuttons and coloured indicators are available.

The pushbuttons and indicators provided are typical for their application, following industrial practices, both in function and connectivity.

Motor Switches 65-133

This panel is similar to the Control Pushbuttons panel in function but provides a selector switch control to implement dual circuit operation. Together the two panels, in conjunction with the Contactor Panel, are used to demonstrate a wide range of typical motor control applications.

Magnetic Pickup 68-431

The magnetic pickup is used to sense and measure the rotational shaft speed of a motor. The unit 68-431 consists of a steel gear, which is rotated by the shaft of a motor in front of a magnetic sensor that produces a pulse output.

Output from the 68-431 unit is supplied to the speed relay input circuit, which converts the pulses to a voltage proportional to speed.

Features

- Provides study of a wide range of motor control circuits
- Typical industrial control gear components
- Low voltage control circuit operation
- Safety using 2mm and 4mm shrouded connections

Curriculum Coverage

- DOL starter, electromagnetic, locally controlled
  - Two wire control
  - Three wire control
  - Local and Remote control
- DOL starter, starting/inching/jogging
- Star/Delta starter
  - Timer control of start to run
  - Shaft speed switching
- Primary impedance starter
- DOL starter: Foward/Reverse operation
- DOL starter with dc injection braking
  - Timer control
  - Speed relay control
- DOL starter with plug-braking
  - Timer control
  - Speed relay control
- dc motor starter
  - Operation with Timing relay
  - Operation with speed relay
- Dynamic braking of a dc Motor
  - Without added inertia
  - With added inertia
- Introduction to switchgear
  - Switching devices
  - Electromagnetic switches
  - Sensing relays
  - Overload protection of motors
  - ac contactor
  - ac switch utilisation
  - Switchgear symbols
- Motor configurations
  - Three-phase Induction Motor - Star Connection
  - Three-phase Induction Motor - Delta Connection
  - dc Compound-wound Motor - Shunt Connection

Core System Additional Equipment

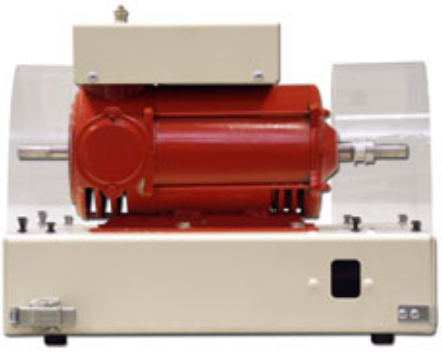
dc Motor Speed Control 60-070-DSC

Features

- Easily configurable
- Built-in safety features
- Comprehensive students manual includes theory and practicals
- Safe output waveform display using isolated probes
- Suitable for use with 63-120 dc motor
- Speed range 0-3000 rev/min, provides 300W output
- IR compensation control for improved speed regulation
- Electronic armature current limit
- Acceleration and deceleration control
- For use in testing of generators (in conjunction with the dc motor)

Curriculum Coverage

- Thyristor dc motor control principles
- Motor voltage and current waveforms
- Speed regulation with and without phase angle control
- Phase angle versus motor speed
- Effect of feedback voltage on speed regulation
- Current limit control
- Torque/speed performance



The dc Compound Machine 63-120 is supplied as part of the Core System

The DSC dc Motor Speed Control option extends the core curriculum to include a comprehensive introduction to Power Electronics and dc Motor Drives. It comprises one additional module, the 66-120 dc Motor Speed Controller. Experiments are performed using the 63-120 dc Compound Wound Machine which is included in the 60-070 Core System.

Separate Field and Armature connections are made via safety 4mm sockets. The controller output is protected by high speed fuses. Motor protection is by an internal current limiting circuit.

Front panel controls allow the variation of:

Set Speed
Minimum Speed
IR Compensation
Acceleration/deceleration Time

Optional Equipment

To perform the complete range of assignments the following equipment is recommended:

Voltage and Current Monitor 68-150

- For use where isolated voltage and current waveform measurements are required
- Precision four terminal shunt current monitor
- Shunt output isolated via voltage probe
- Probes output connects directly to a scope for safe monitoring
- Current monitor output 100mV/A
- Isolated voltage probe input 1000V dc or 700V ac rms
- Switched attenuation 1/200 and 1/20 dc to 15MHz bandwidth
- Battery powered or external 6V dc power adapter
- Fully shrouded 4mm connections with BNC to scope

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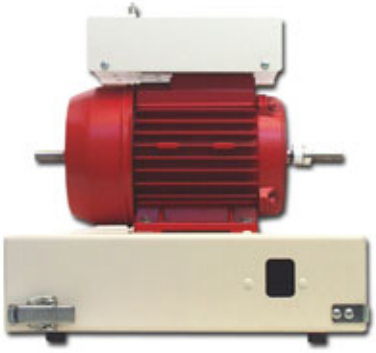
Core System Additional Equipment

ac Motor Speed Control 60-070-ASC

The Three phase Induction Motor 64-501 is supplied as part of the Core System



The ASC ac Motor Speed Control option introduces the concepts of speed control of ac motors using a variable frequency drive. It comprises one additional module, the 66-110 Variable Frequency Drive. Experiments are performed using the 64-501 Three Phase Squirrel Cage Induction Motor which is included in the 60-070 Core System.

Connections to the Motor are made using safety 4mm sockets and all outputs are fully overload protected.

Front panel controls allow the variation of:

Set Speed
Minimum Frequency
Voltage Boost
Acceleration/deceleration Time

Features

- Easily configurable
- Built-in safety features
- Comprehensive students manual includes theory and practicals
- Safe output waveform display using isolated probes
- Suitable for use with Induction Motor 64-501
- Basic control functions for:
  - Max and min speed settings
  - Acceleration & deceleration times
  - Torque boost
  - Variable frequency control
- Protection is provided for over-current and overvoltage

Curriculum Coverage

- Basic Theory
- Control Functions
- Inverter Voltage Waveforms
- Carrier Frequency
- Inverter Current Waveforms
- Frequency, Speed, Current and Motor Voltage
- Torque/Speed test at various frequency settings
- Voltage Boost
- Voltage/Frequency (V/F) characteristics

Optional Equipment

To perform the complete range of assignments the following equipment is recommended:

ac Voltmeter and Ammeter 68-111

- A rectifier voltmeter and moving iron ammeter
- Suited to the measurement of variable frequency drives and ac supplies
- Rectifier voltmeter range 0-250V and 0-500V ac
- Moving iron ammeter range 0-3A, fuse protected
- Meters are DIN standard 96 x 96mm
- Safety earth connection provided

Ordering Information

Core System

Electrical Power and Machines Core System	60-070

Additions to Core System

Series Universal Motor	60-070-SUM
Synchronous Machine	60-070-SMC
Conventional Instruments	60-070-CI1
Virtual Instrumentation	60-070-VIP
Transformers	60-070-TFM
Electrical Circuits	60-070-ECT
Electromagnetic Motor Control	60-070-EMC
dc Motor Speed Control	60-070-DSC
ac Motor Speed Control	60-070-ASC

Optional Equipment

Conventional Instruments	60-070-CI2
ac Voltmeter and Ammeter	68-111
Voltage and Current Monitor	68-150
Three Phase Earth Leakage Breaker	60-140-1

Optional Equipment

Three Phase Earth Leakage Breaker 60-140-1

- For use in systems where earth leakage breakers are not provided as part of the electrical installation
- Provides protection against the hazard of electric shock
- Suitable for connection to three-phase, 5 wire systems
- Four pole, 30mA trip, earth leakage breaker
- Three phase power ‘on’ indicators
- Single phase outlets on front and rear
- Safety earth terminals
- Three-phase output on rear panel for use with 60-105

Electrical Power & Machines - 0306-1

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