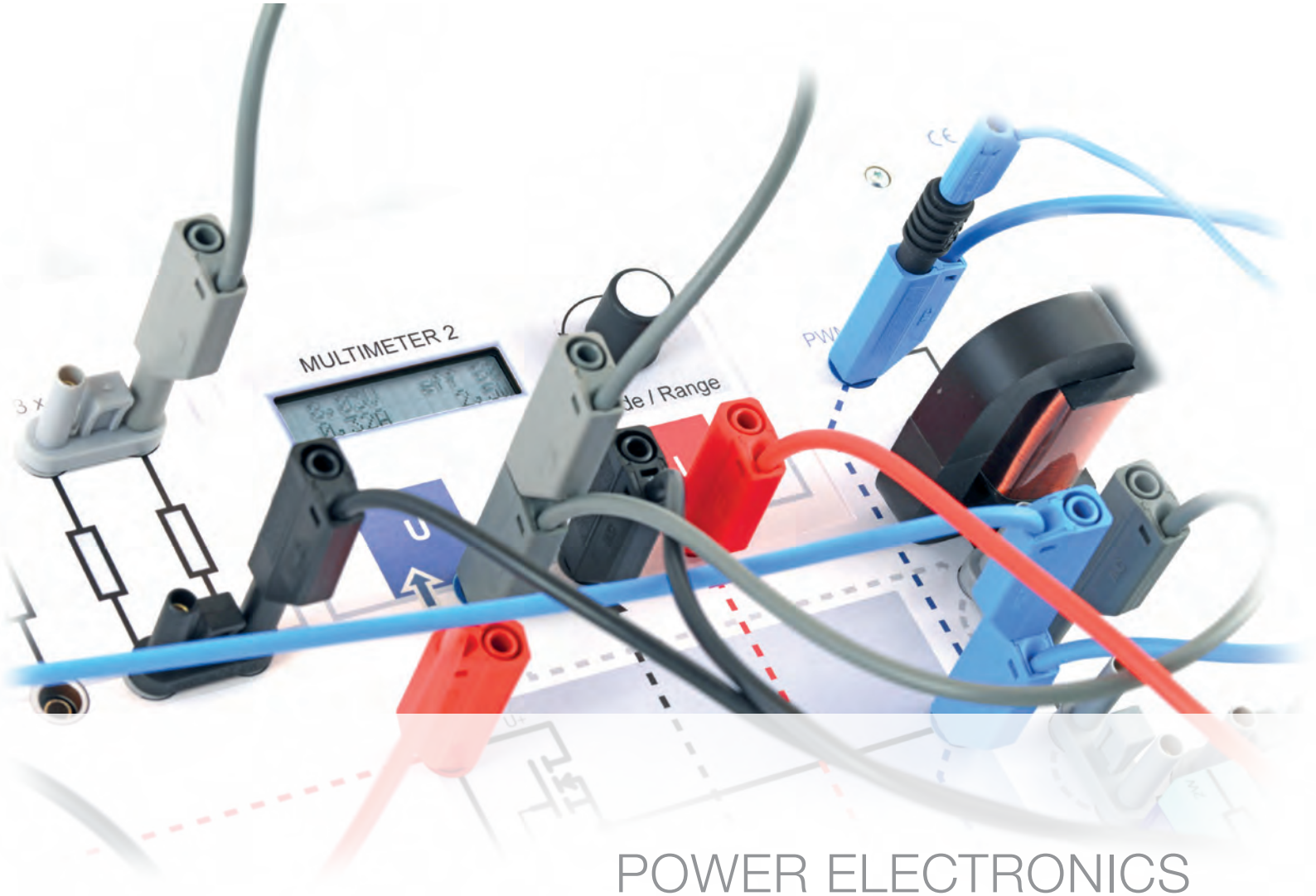
DIDACTIC GMBH

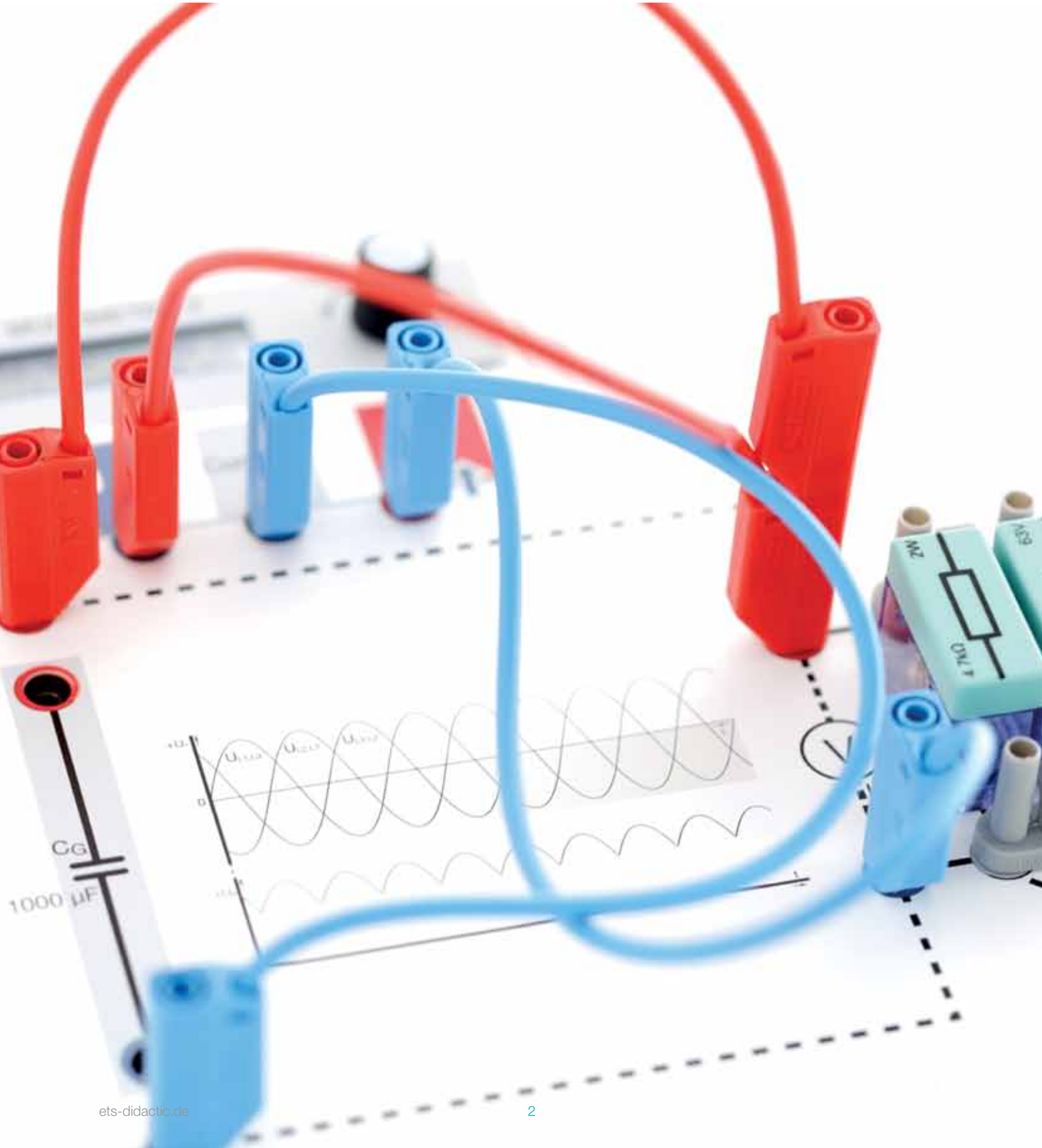


POWER ELECTRONICS

From the Fundamentals up to Real Industrial Applications

POWER ELECTRONICS

Compact – safe – close to practice



CONTENTS

Didactic Solutions

Made in Germany

PEOPLE AND TECHNOLOGY – A PERFECT MATCH

Technology to inspire you: understanding – comprehending – applying

ETS DIDACTIC is your partner for in-house and institutional education and training in the professional fields of electrical engineering and metal technology.

Subjects like pneumatics, electropneumatics, drive technology, power electronics, automation engineering, sensor systems, bus systems, instrumentation, gear technology and the complete scope of building systems engineering including renewable energies can all be counted among the strengths of the company.

The spectrum of services offered by ETS DIDACTIC ranges from the planning and outfitting of complete training facilities to the provision of learning and teaching materials. Apart from the after-sales service, the offering of services is rounded off by practical workshops specially tailored for trainers and instructors.

Vocational schools, training centres of the ICC, Chamber of Crafts or the industry, polytechnics and universities are among the long-standing customers of ETS DIDACTIC.

Welcome to ETS DIDACTIC

Udo Urban
Managing Director (CEO)
ETS DIDACTIC GMBH

ETS DIDACTIC is the pioneer and market leader in the development, manufacture and sales of electrical, automation and mechatronic workstations for training and instruction.

ETS DIDACTIC counts among the leading international manufacturers in the market environment. Located in Kinding, in the beautiful natural reserve of Altmühltal – high-quality products and solutions are developed and manufactured for you.

In the training centre in Kinding, the focus is on the practical application of the systems and fast learning of new technologies by the customers.

The knowledge, experience and the above-average personal involvement of the motivated employees of **ETS DIDACTIC** are vital factors for the company's efficiency.

MADE IN GERMANY

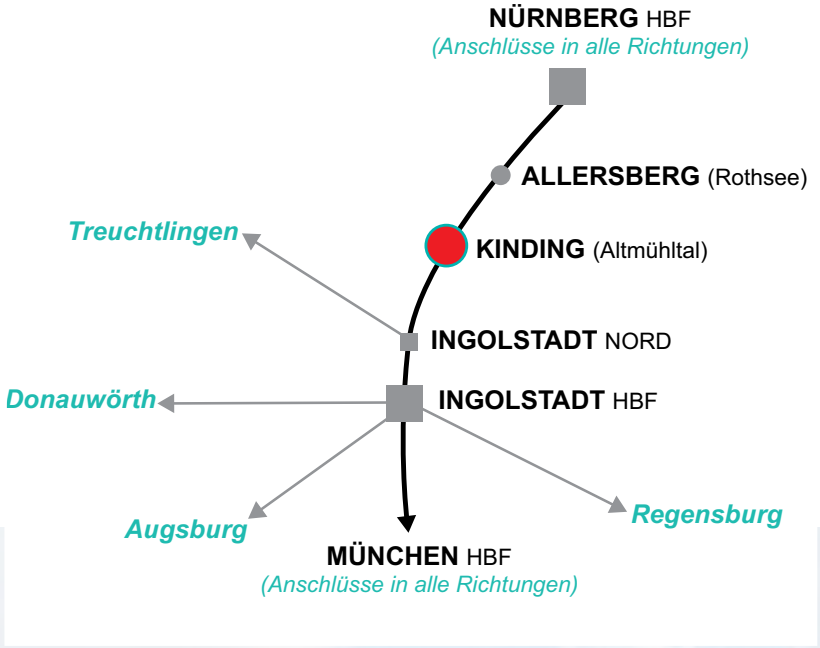
Visit ETS in the Valley of River Altmühl

Welcome in Germany - Bavaria

With the start-up of the new ICE-route between Munich and Nuremberg, the Altmühl region, with its regional railway station at Kinding has got a new connection to the national and international railway network. You now have the option to travel comfortably by train when you visit us for seminars taking place in Kinding-Haunstetten. There are local taxi companies in service for the drive to Haunstetten. We would be happy to provide help in organising the trip.

Monastery Weltenburg

Nature park "Altmühltal"



APPROACH AND ROOM CONCEPT

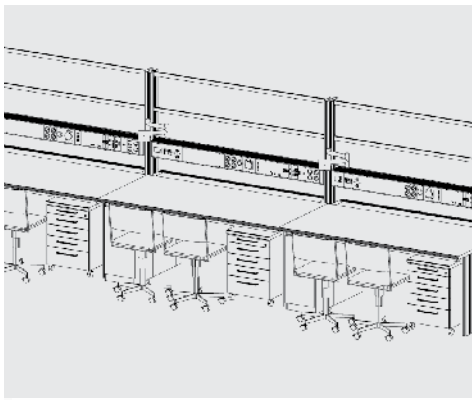
To plan a custom-made room concept with you, we proceed in the following steps:

⟩ A good room concept is based on professional advice. The technical consultants of ETS DIDACTIC are pleased to support you in the local planning phase. Benefit from their technical expertise and experience.

⟩ Planning a room concept is more than selecting the furniture. Each room concept is adapted to and developed for the local requirements of the customer.

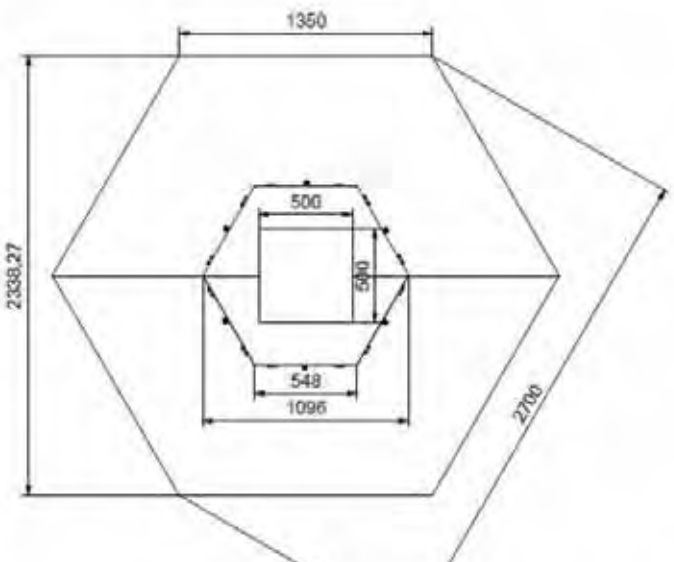
⟩ Taking into account the learning contents an equipment list can be set up. As soon as the extent is defined, the storage equipment is optimised and designed.

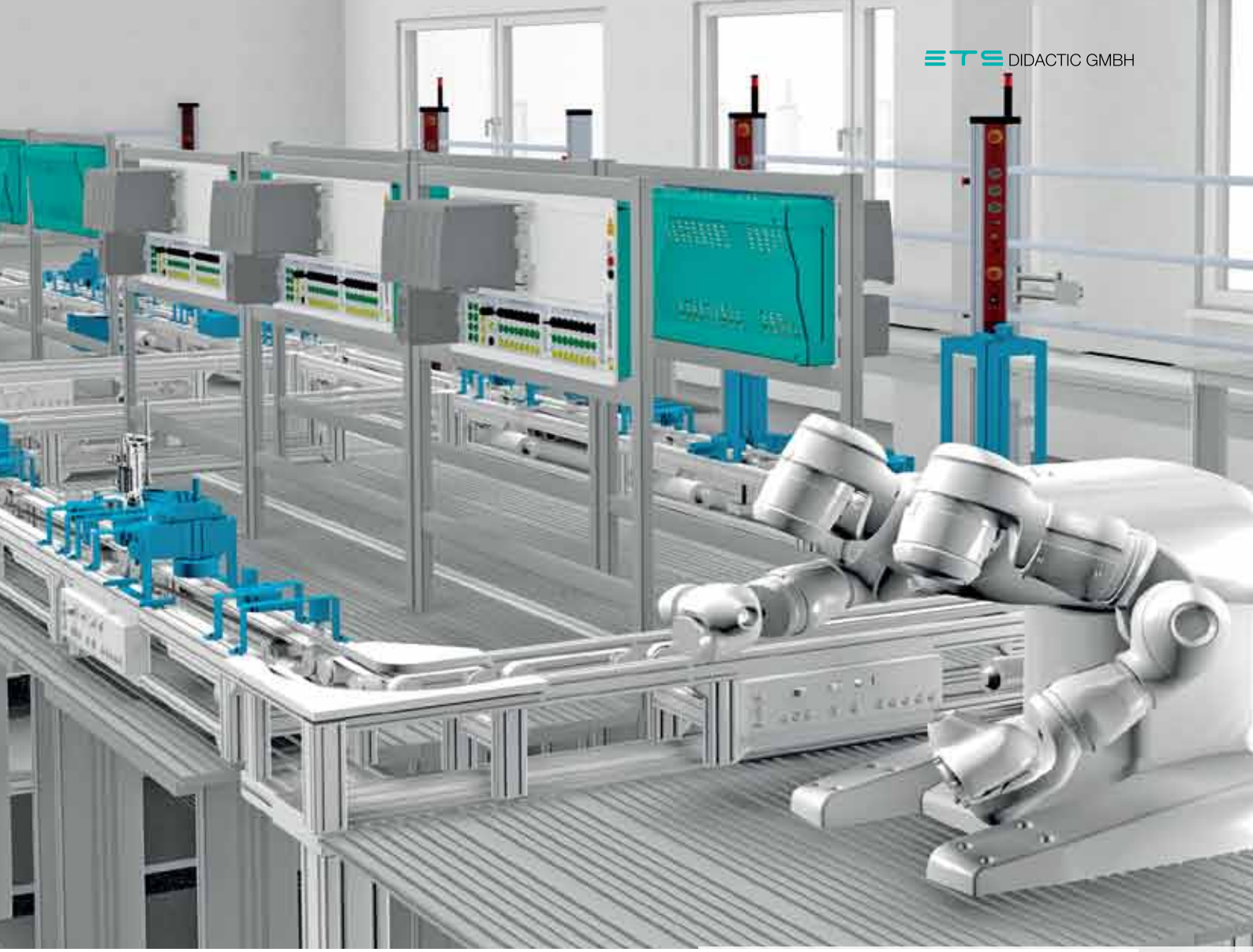
Analysis



Conception

Consultation / Planning





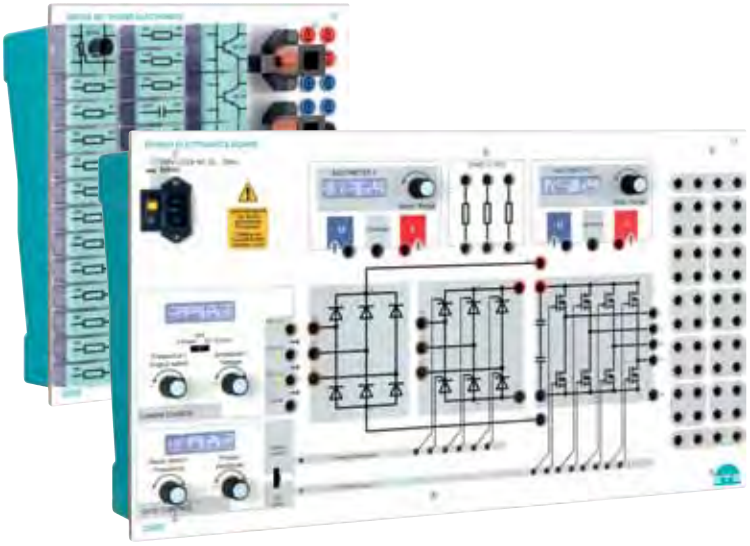
Design / Construction

Workshops

Application

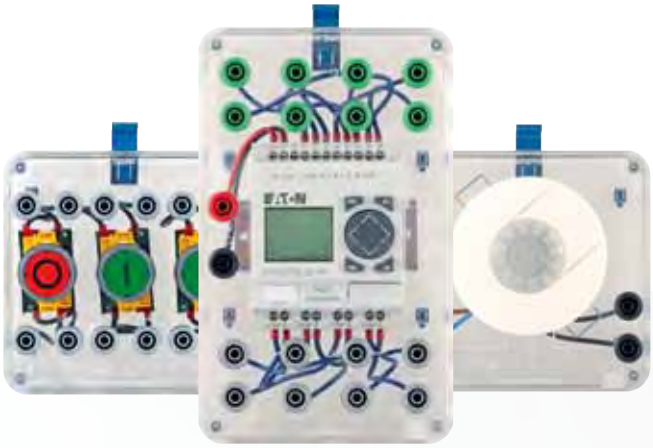
PEOPLE AND TECHNOLOGY – A PERFECT MATCH

Didactic and Technology Result in the ETS-Concept



Compact Boards

- Their didactical concept makes our training systems in A4 format outstanding.
- The photorealistic design of their front panels with graphics, pictures, connection details or warning messages assist and guide the experiments - cognitive didactics. Due to the graphics, users comprehend and remember the technologies more easily.
- The systems can be mounted in an A4 frame or placed directly on a table.



Experimental Boxes

- Construct your own experiments. Beside the wiring, the arrangement of the components is focused. The components basic circuits and extend them to complex installations - always close to practice, fast and safe!
- Wide range of industrial components.

BST®-BuildingSystemsTrainer

- The BuildingSystemsTrainer® is a mobile training system that can be taken from one classroom to another and then is ready for use within some minutes.

- Beside our laboratory equiment with the experimental boards, these flexible training systems represent an independent product line covering many topics as e.g. the VDE protective measures according to VDE 0100 or the KNX building communication sector, communications technology and renewable engergies, SmartBuilding and internet-of-things.

- Boards can also be integrated in the BuildingSystemsTrainer® using an H-shaped frame.

WORKSHOPS WITH ETS

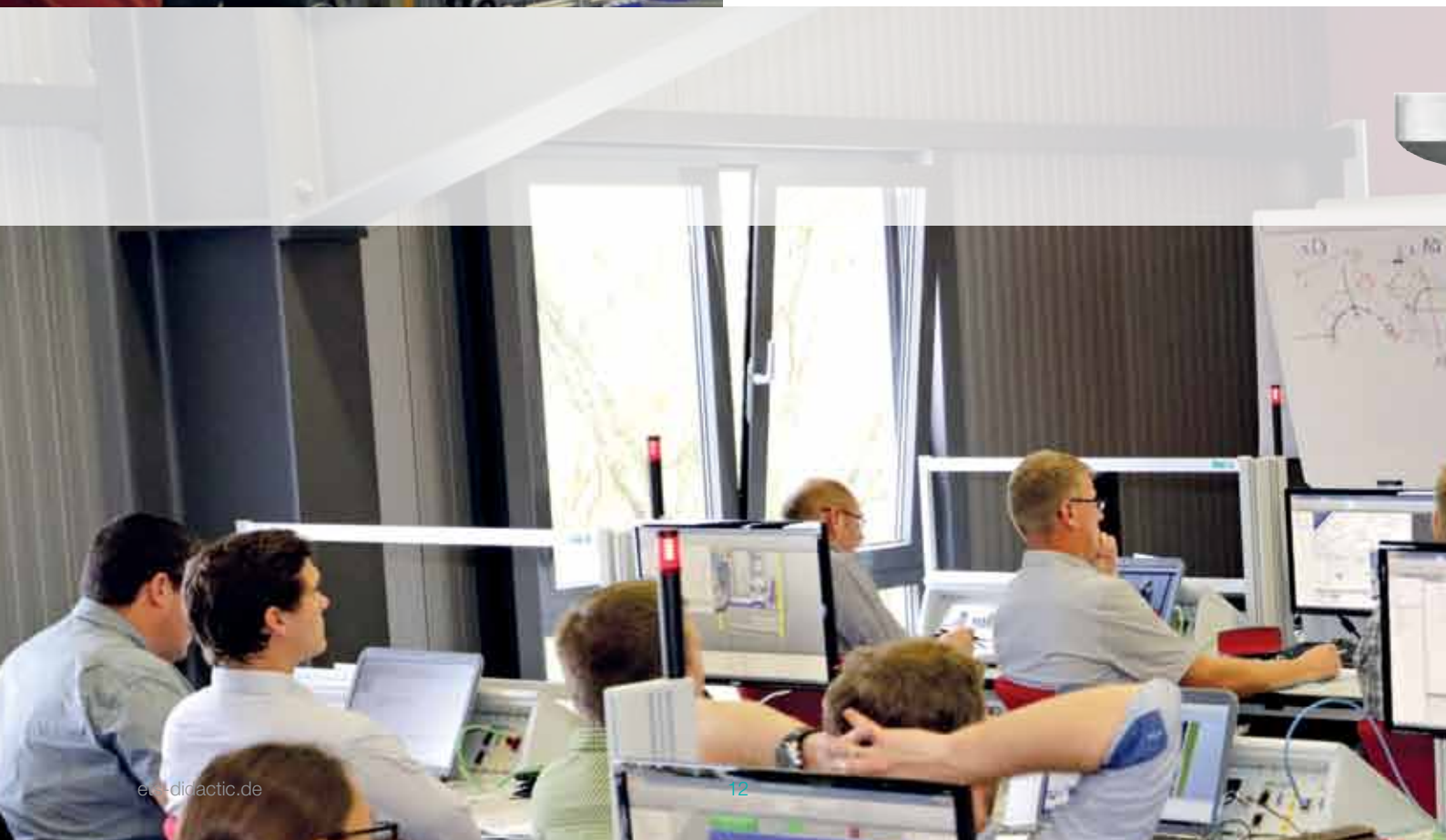
Always up to Date – Training at the Highest Level!

⟩ Train the Trainer – workshops for teachers, trainers and lecturers in the field of electrical engineering, mechatronics and metal technology.

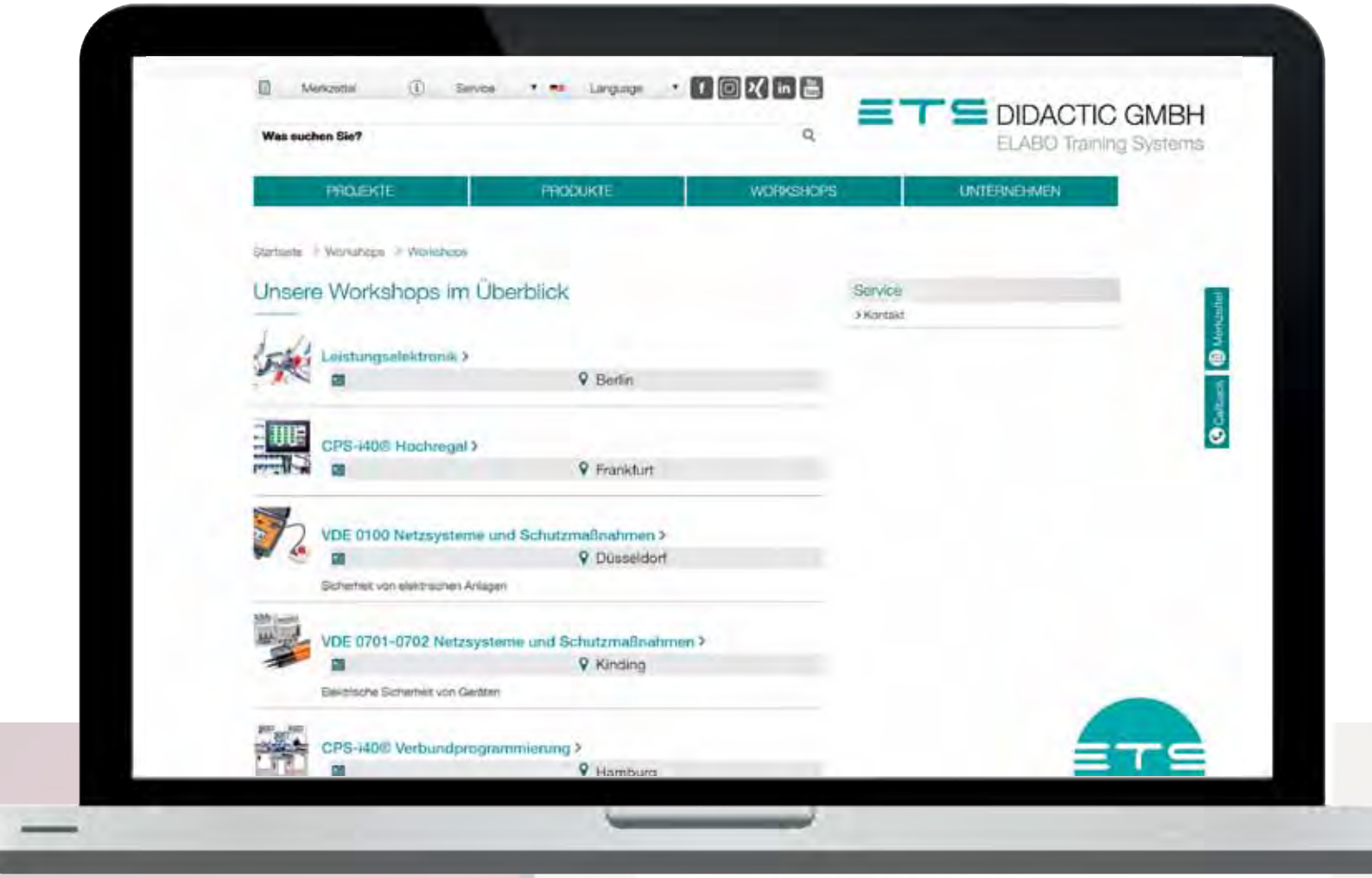
⟩ Learn more about the management and the application of various technologies with the support of the ETS trainers. Find out more about the didactic concept and learn to teach the material quickly and safe.

⟩ ETS offers a perfect seminar for all groups of products and topics of technical education. Scan the QR code to subscribe in a workshop:

https://ets-didactic.de/hp584/Workshops.htm



Fast and Safe into New Technologies



THE ETS TRAINING CONCEPT

Innovative Hardware / Perfect Courseware

compact

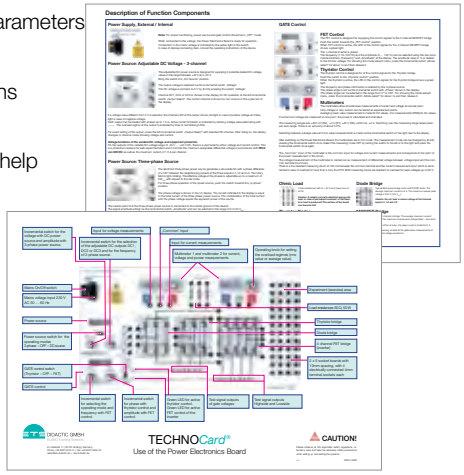
Structure of the Manuals

- Ringbinder principle
- Dividers
- Incorporation of personal documents

close to practice

TECHNO*Cards*®

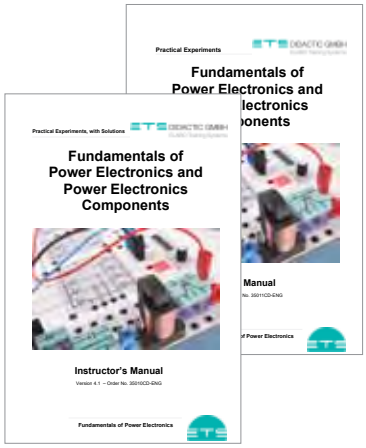
- Depiction of the parameters in function groups
- Start-up instructions
- Safety functions
- Individual learning help



motivating

Instructor's Edition / Student Edition

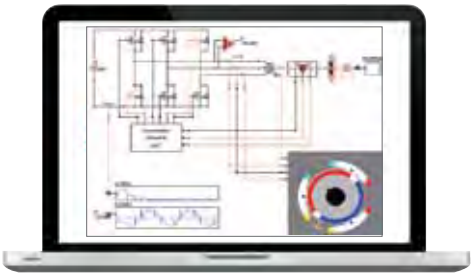
- 100 % function guarantee
- High print quality
- Digital and on paper
- Original photographs with practical references
- Detailed work instructions



multimedia

Simulations Software

- Accompanying the courseware
- Function simulation
- Combination of theory and practice



efficient

Front panel overlays

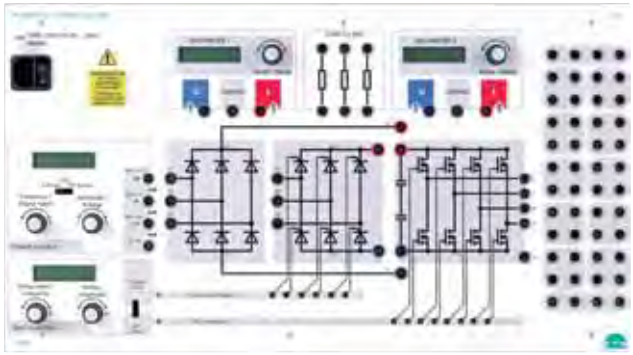
- Contents reduced to main focus of the experiment
- Clear layout
- Basic function
- Various languages

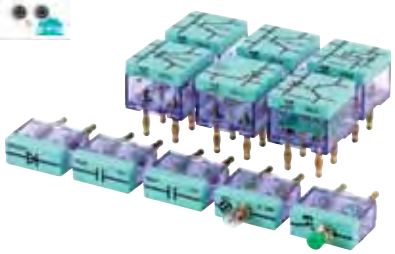
ergonomics

Furniture

- Technically matched conception
- Excellent functionality
- Ergonomics at the workplace
- Outstanding design

... the System for Power Electronics





- State-of-the-art technology
- Easy to operate
- Didactically prepared courseware
- Safety for people and machine
- Perfect ergonomic workplaces

POWER ELECTRONICS

Key Technology for Today's and Tomorrow's Requirements

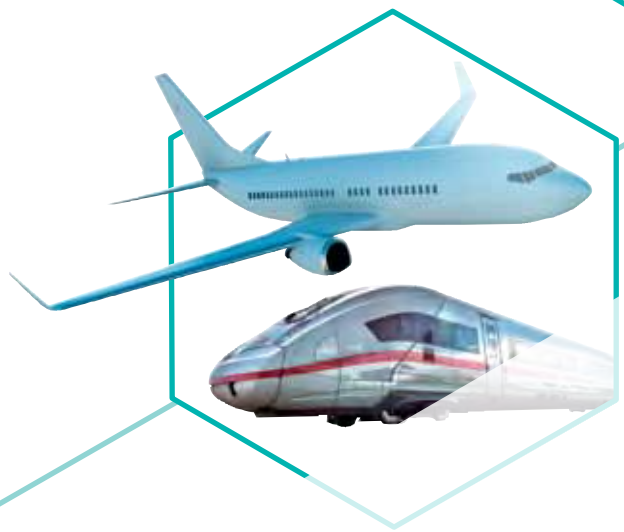
Power electronics as a part of electrical engineering and electronics is focused on the transformation of electrical energy by using switching electronic components (mainly semiconductor components).

Power electronics applications are inverters, power inverters or frequency converters in the field of electrical drive systems, solar interters and converters in wind power stations for grid-feeding of regenerative energy, or e.g. switching power supplies.

Using power electronics equipment, it is possible to make targeted and highly efficient use of electrical energy. So, it is opening the way to improve significantly the functionality of equipment and systems along with reduced energy consumption.
The demand for greater energy efficiency is realized in mobile transport, traffic systems, industrial facilities, power distribution systems as well as in power supplies and lighting materials and that is why power electronics is one of the most important future technologies.

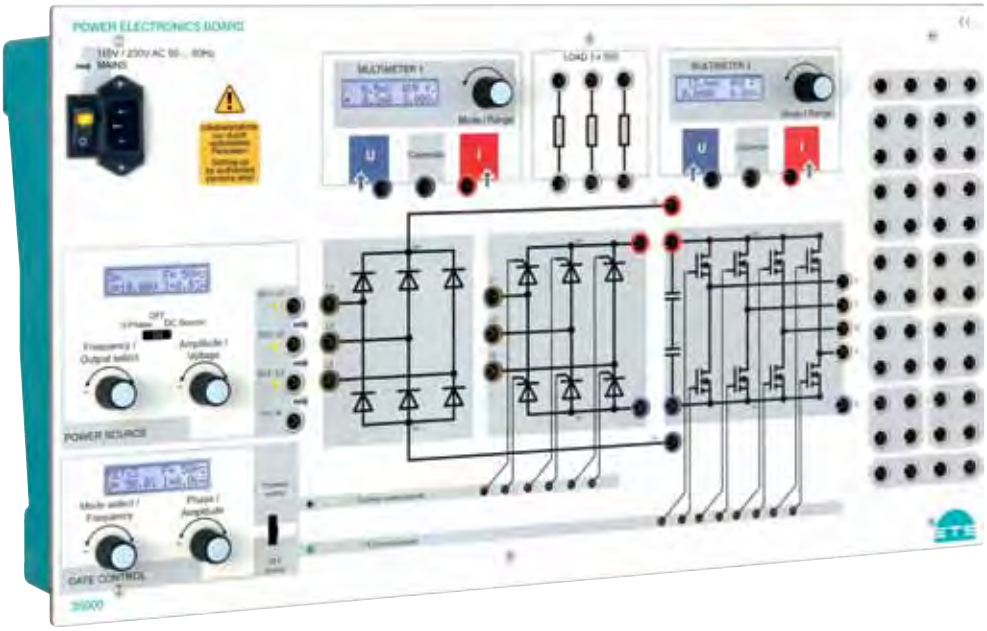
Modern power electronics applied in the ETS motor test bench.

Power Electronics



TRAINING AND PRACTICAL EXPERIMENTS

Power Electronics Board



1

Learning Objectives

Familiarizing, comprehending and applying power electronics components and their functions in rectifiers and inverters:

- Resistor, diode, coil (characteristics, losses, power)
- Transistor, IGBT and MOSFET as switch (characteristics, losses, power)
- Thyristor (characteristics, trigger current, holding current)

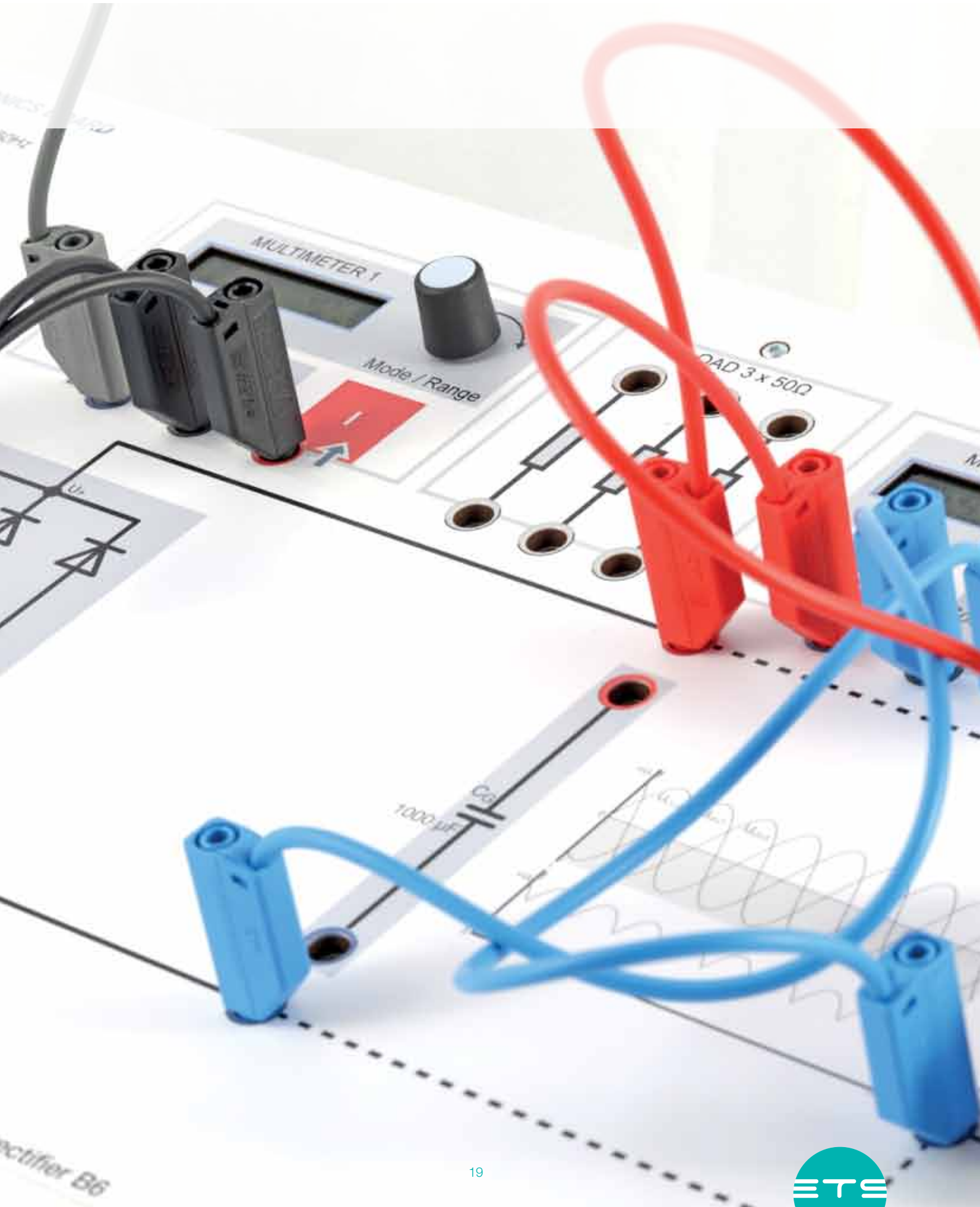
Familiarizing, setting up and applying the functions of power electronics components:

- Rectifier one-phase, rectifier 3-phase, full-wave rectifier, bridge circuit
- Controlled rectifier with thyristors (phase-synchrone switching, trigger delay angle, operating angle/phase angle)
- PWM to MOSFET half bridge
- DC/DC converter step-down converter
- Inverter 1-phase, 2-phase
- Inverter 3-phase; PWM as f (U, f)
- Control of motors (phase current, phase, power factor, no-load, load)
- Inverter 4-phase in microstepping mode

Technical Data

- Total power consumption 230 W
- PELV system acc. to IEC 61140
- Short-circuit proof, safe against reverse polarity DC 60V, AC 40V, 60W
- 3 channel DC source adjustable for outputs -40 V …+40V, maximum current per output 1.5A, common mass 0 V
- Three-phase current source: phase voltage 0 … 23 V_{eff}, maximum current per phase 2 A_{eff}, common star point 0 V (neutral conductor N), frequency adjustable in 1 Hz increments 1 Hz ... 100 Hz
- With digital current and voltage display
- Two integrated multimeters for average and true r.m.s. 3-phase, full-wave rectifier, bridge circuit

No.	Description	Order No.
1	Power Eletronics Board	35000


MULTIMETER 1
Mode / Range
OAD 3 x 50Ω
1000 µF
ectifier B6

THE POWER ELECTRONICS BOARD IN DETAIL

Power Supply, Control and Multimeter

The system combines the latest technology with simple, easy-to-use handling. Except from the Principles of power electronics components and modules, modern drive system solutions with inverter and motor can be examined safely in the low voltage range.

The Power Electronics Board is the basic module of the training systems for power electronics allowing the design and operation of basic power electronics circuits as a function module or by means of plug-in components in 19 mm grids.

The individual connection of components and modules is realized either by means of a jumper plug with 4 mm pins in a 19 mm grid or 4 mm connecting leads. The 4-mm connecting leads should be safety measuring leads.

Multimeter

Two separate, isolated multimeters allow simultaneous measuring of current and voltage at one point of measurement. It is possible to carry out voltage as well as current measurements. At separate points of measurement, either measurement of the voltage or the current can be taken.

Voltage and current are measured differentially. The measuring of identical magnitudes is realized by averaging, whereas measuring of alternating values is made as true r.m.s. value measurement. The power is determined and displayed from both measured quantities. The switchover between average and r.m.s. measurements is performed by the incremental switch positioned on the right beside the display.

The measuring range values are ±400 mV (B2), ±4 V (B1), ±40 V (B0), ±200 mA, ±2 A. The measuring range switchover is made by auto range. The accuracy is about 0.5 %.

Power Supply

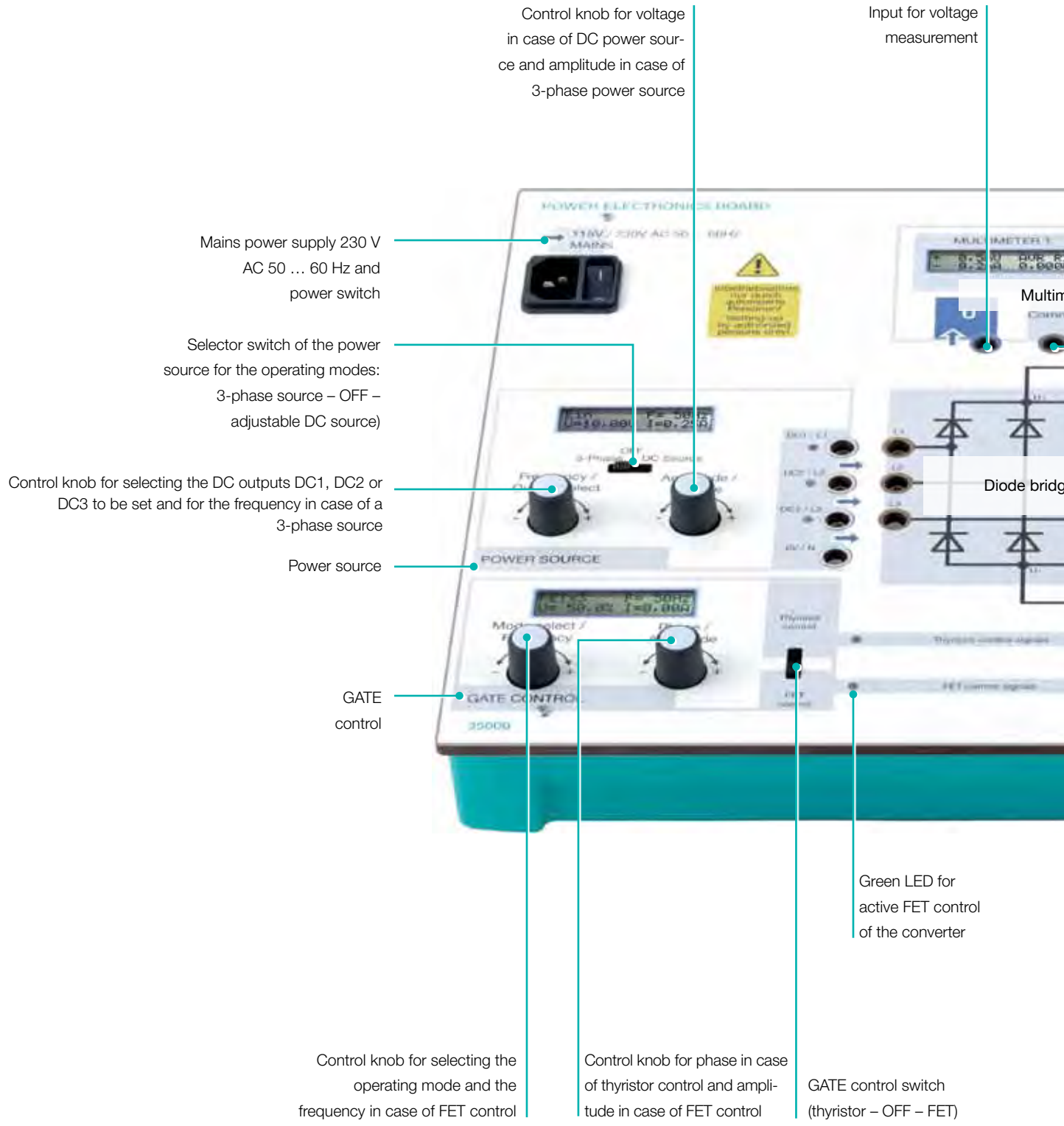
The power supply of the experimental circuits is provided by means of protective extra low voltages from the integrated power supply with adjustable DC voltages ±40 V or an electronic 3-phase current source with a variable phase voltage of 0 … 23 V_{eff}. The maximum adjustable DC voltage difference of the outputs is electronically limited to 60 V.

The Control

of the components „thyristor bridge“ and „FET bridge“ is realized by the „Gate Control““.

POWERFUL AND SAFE

Functions and Operation Elements



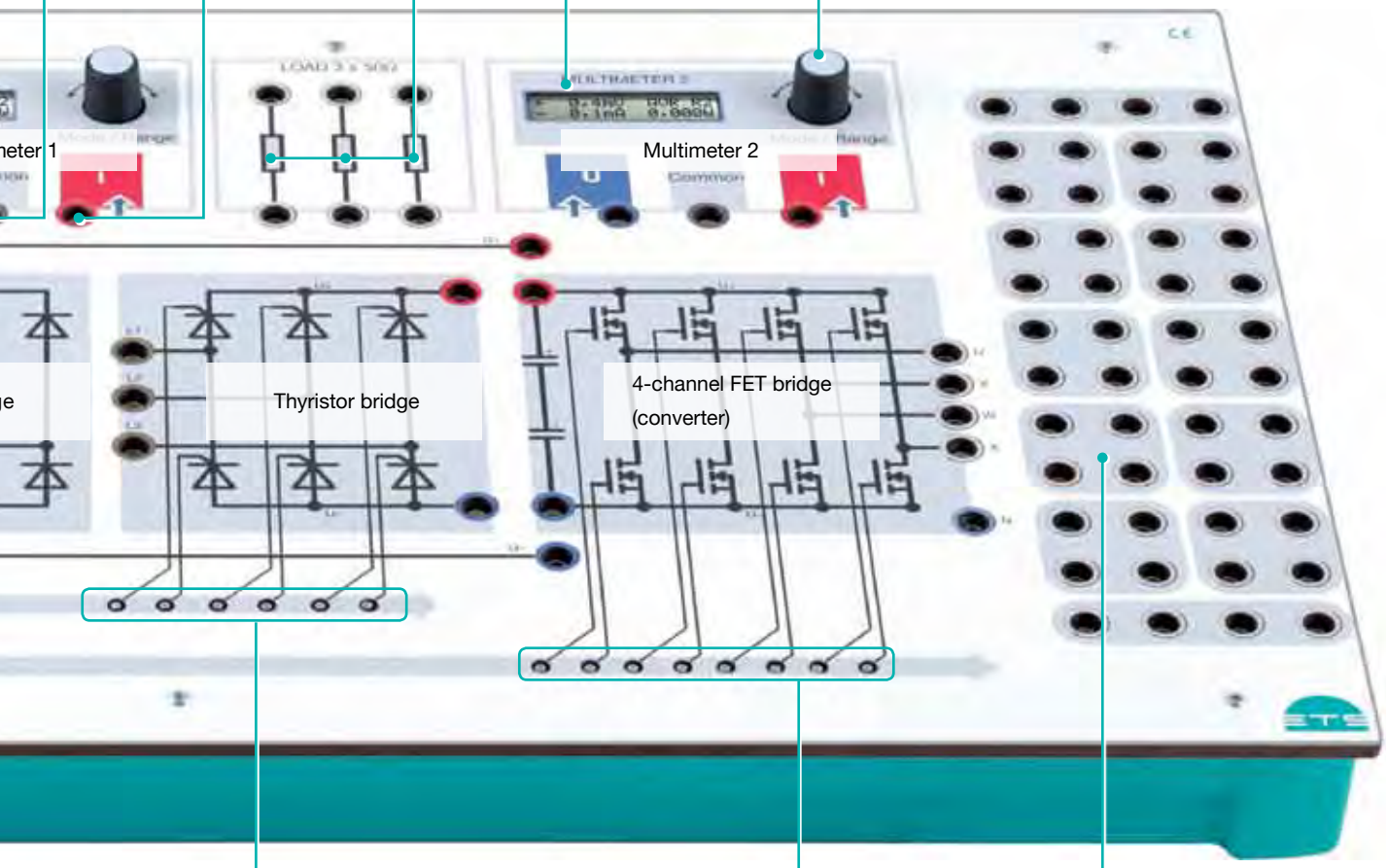
„Common“ input

Input for current measurement

Load resistances 3x 50 Ω, 50 W

Multimeter 1 and **Multimeter 2** for current, voltage and power measurements

Control knob for setting the measuring routine (r.m.s. or average values)



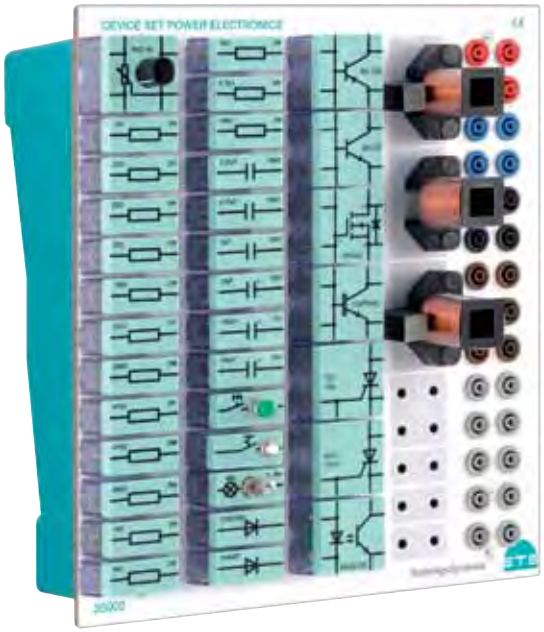
Measuring signal outputs of gate voltages of the controller

Measuring signal outputs "highside" and "lowside" of the controller

Experimenting field for designing individual circuit modifications

SETS OF PLUG-IN COMPONENTS

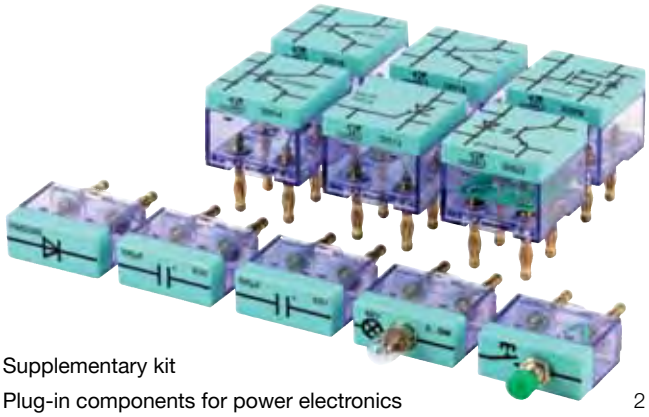
Easily Adaptable Experiments



1

Set of plug-in components for power electronics

- For experiments covering the principles of power electronics
- Incl. storage plate for plug-in modules and safety bridge plugs
- Printed with the component symbols.



2

... for the sake of good order

The storage plates for plug-in components are printed with the corresponding symbols.

Gold-plated connectors

at all components and plug-in connections ensure corrosion resistance and low contact resistance.

Supplementary kit

Plug-in components for power electronics

The optional "Supplementary kit for power electronics" designed for experiments dealing with the principles of power electronics supplements the known "Set of compontents for electronics", Order No. 32203.

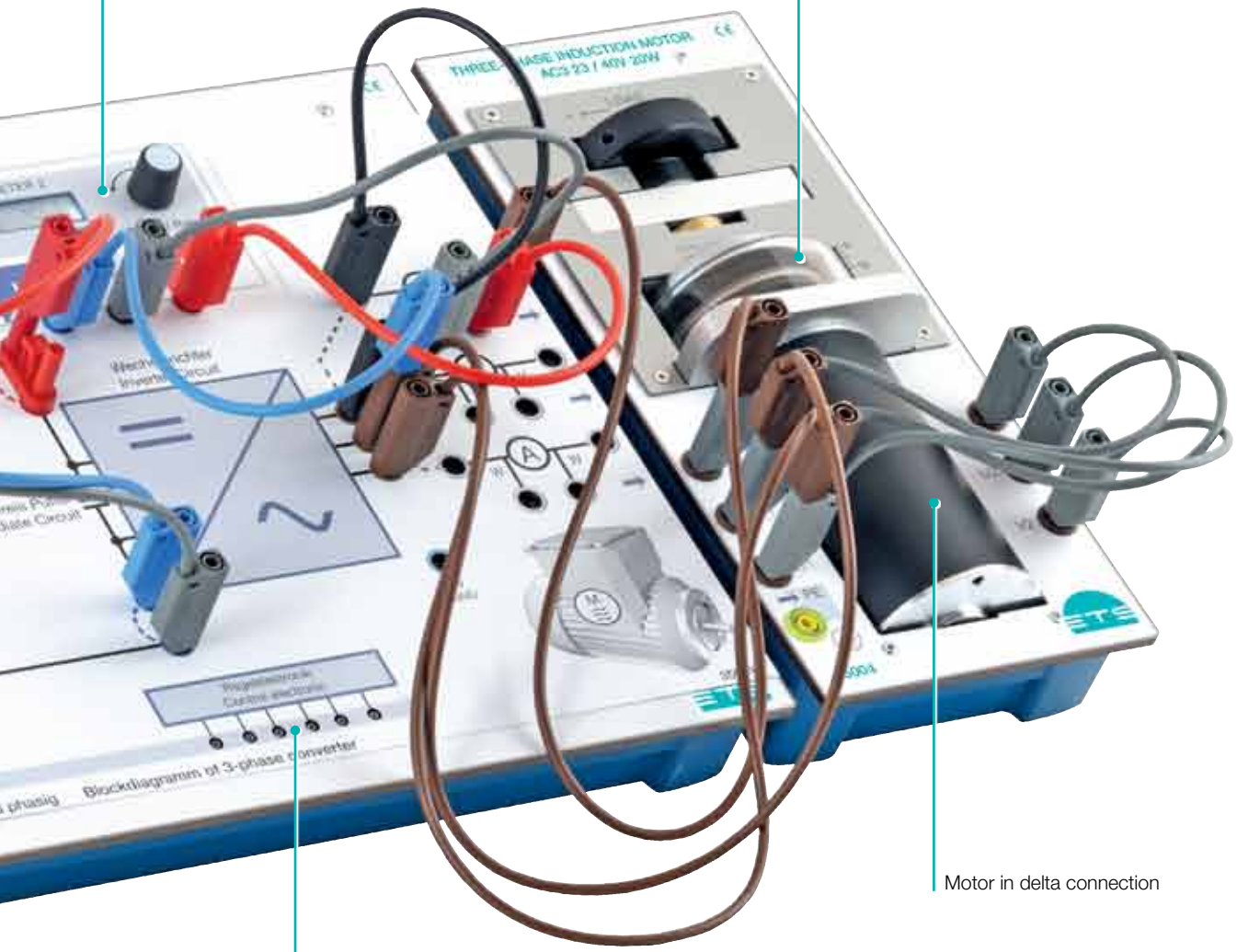
No.	Description	Order No.
1	Set of plug-in components for power electronics	35002
2	Supplementary kit: Plug-in components for power electronics (optional)	35007

POWER ELECTRONICS

Functioning of a Frequency Converter

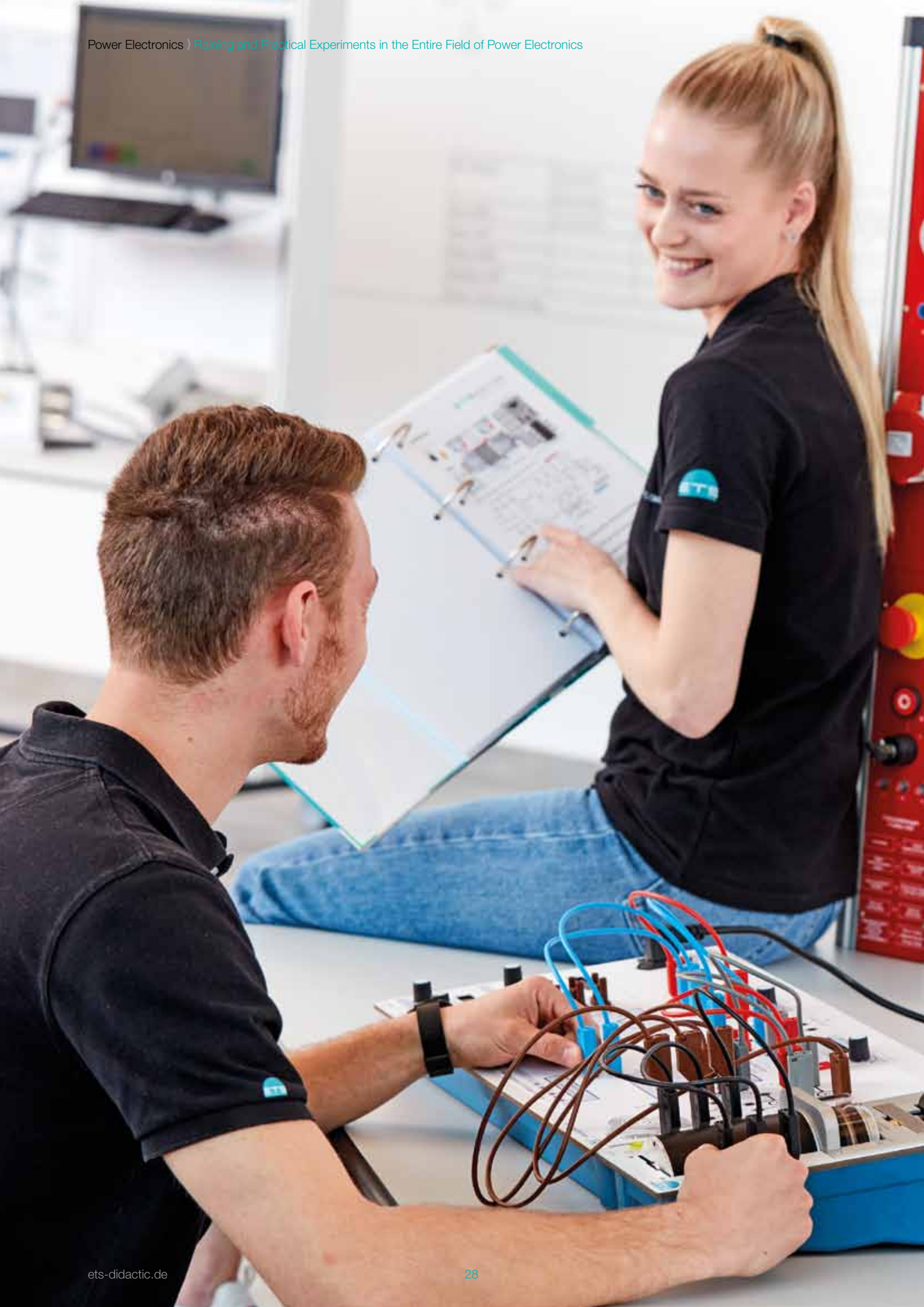
Measuring the r.m.s. of phase voltage and phase current.
The displayed power multiplied with the chaining factor results in the apparent power.

Adjustable applying load to motor



Motor in delta connection

Facility for measuring the gate control impulses of the controller



DISCOVER POWER ELECTRONICS SAFE AND CLOSE TO PRACTICE

DIRECT CURRENT AND THREE-PHASE MOTORS

Real Inductive Loads Determine Standards towards Practical Orientation

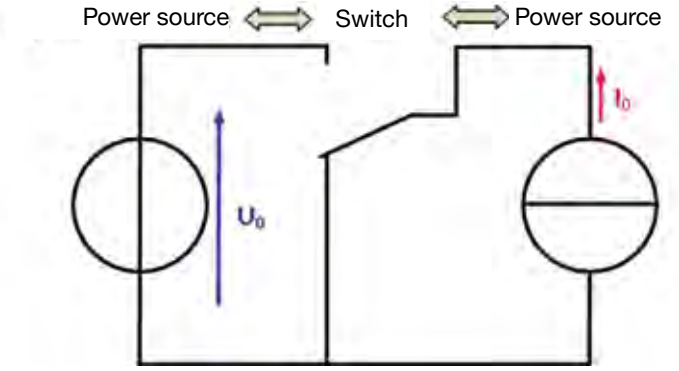
1

2

3

Direct current motor
DC 24 V, 34 W
permanent-magnet (1)

- Nominal voltage 24 V DC
- Rated speed 3000 rpm
- Eddy current brake for applying load to motor
- Input /outputs on 4-mm safety sockets



Three-phase induction motor
AC3 23/40 V, 20 W (2)

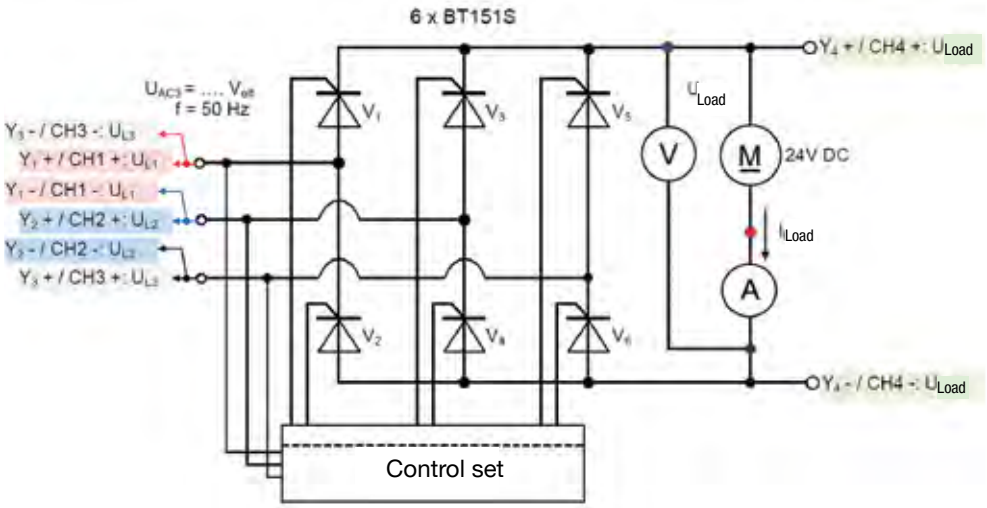
- Star/delta AC3 40/23 V 50 Hz
- Rated speed 1250 rpm at 50Hz
- Eddy current brake for applying load to motor
- Inputs/outpus on 4-mm safety sockets

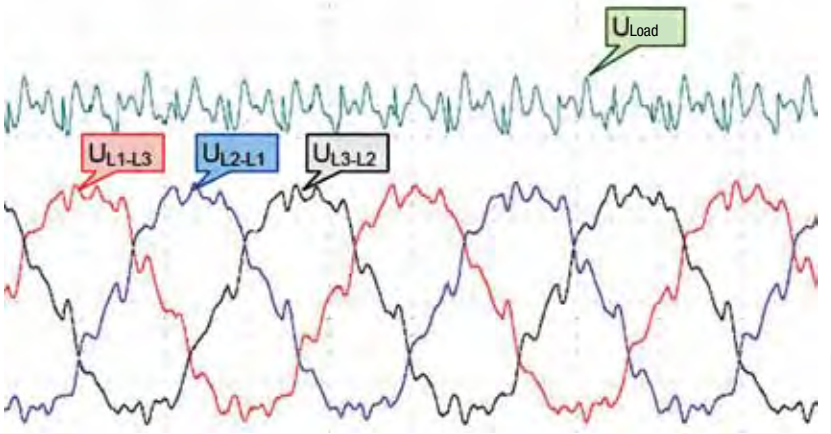
Three-phase synchon motor
AC3 23/40 V, 10 W (3)

- Star/delta AC3 40/23 V 50 Hz
- Rated speed 1500 rpm at 50 Hz
- Eddy current brake for applying load to motor
- Inputs/outpus on 4-mm safety sockets

No.	Description	Order No.
1	Direct current motor DC 24 V, 34 W	35003
2	Three-phase induction motor AC3 23/40 V, 20 W	35004
3	Three-phase synchon motor AC3 / 40 V, 10 W	35005

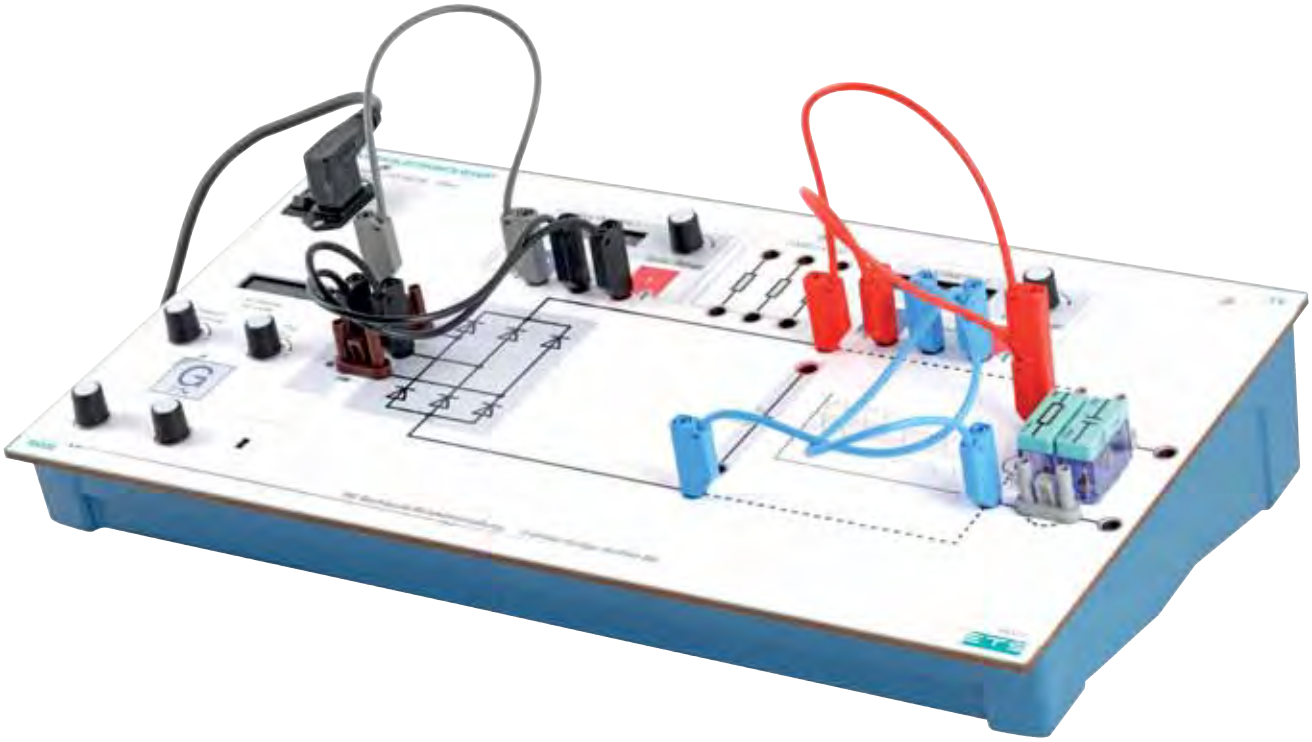
Controlled converter studs
with thyristors need an inductive load for realizing the basic pricip-les of power electronics.
A permanent-magnet direct current motor is used for complementing the experiment in practice.





RECTIFIER CIRCUITS

Circuit Set-up

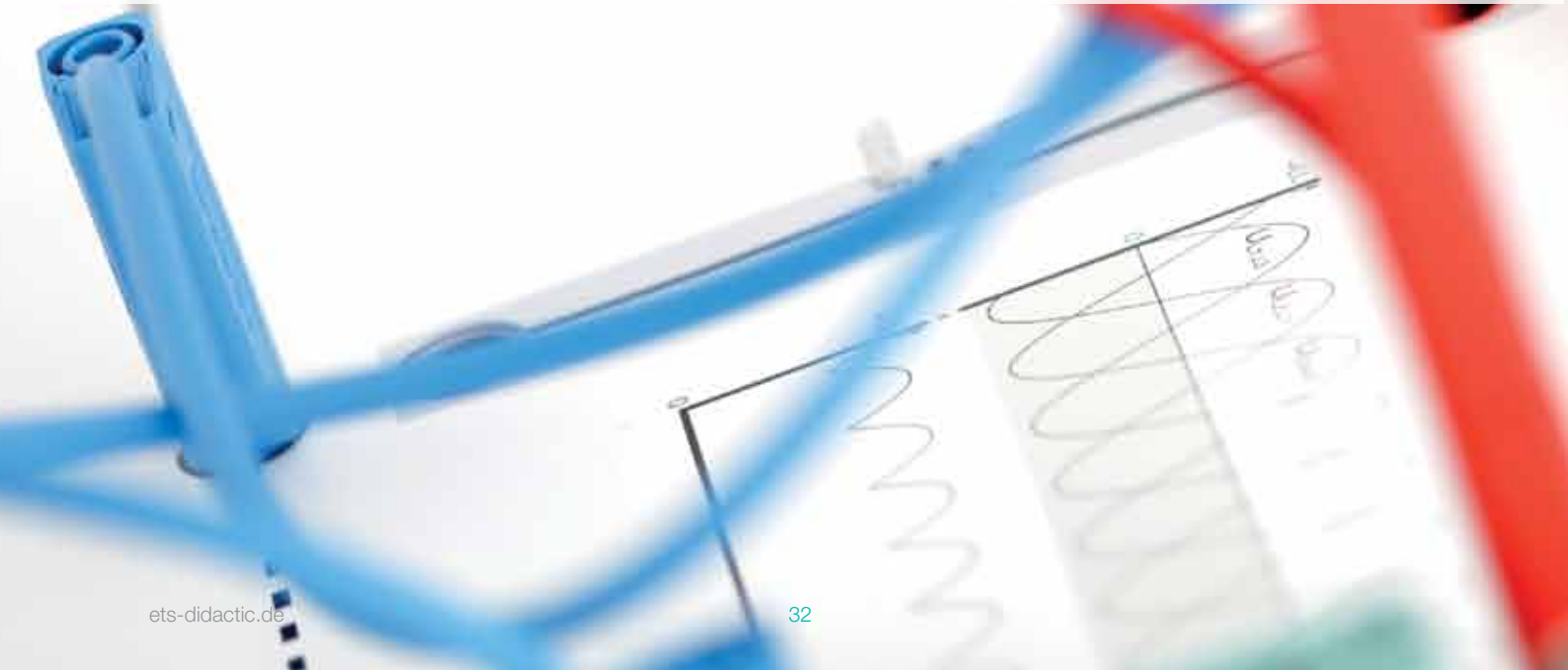


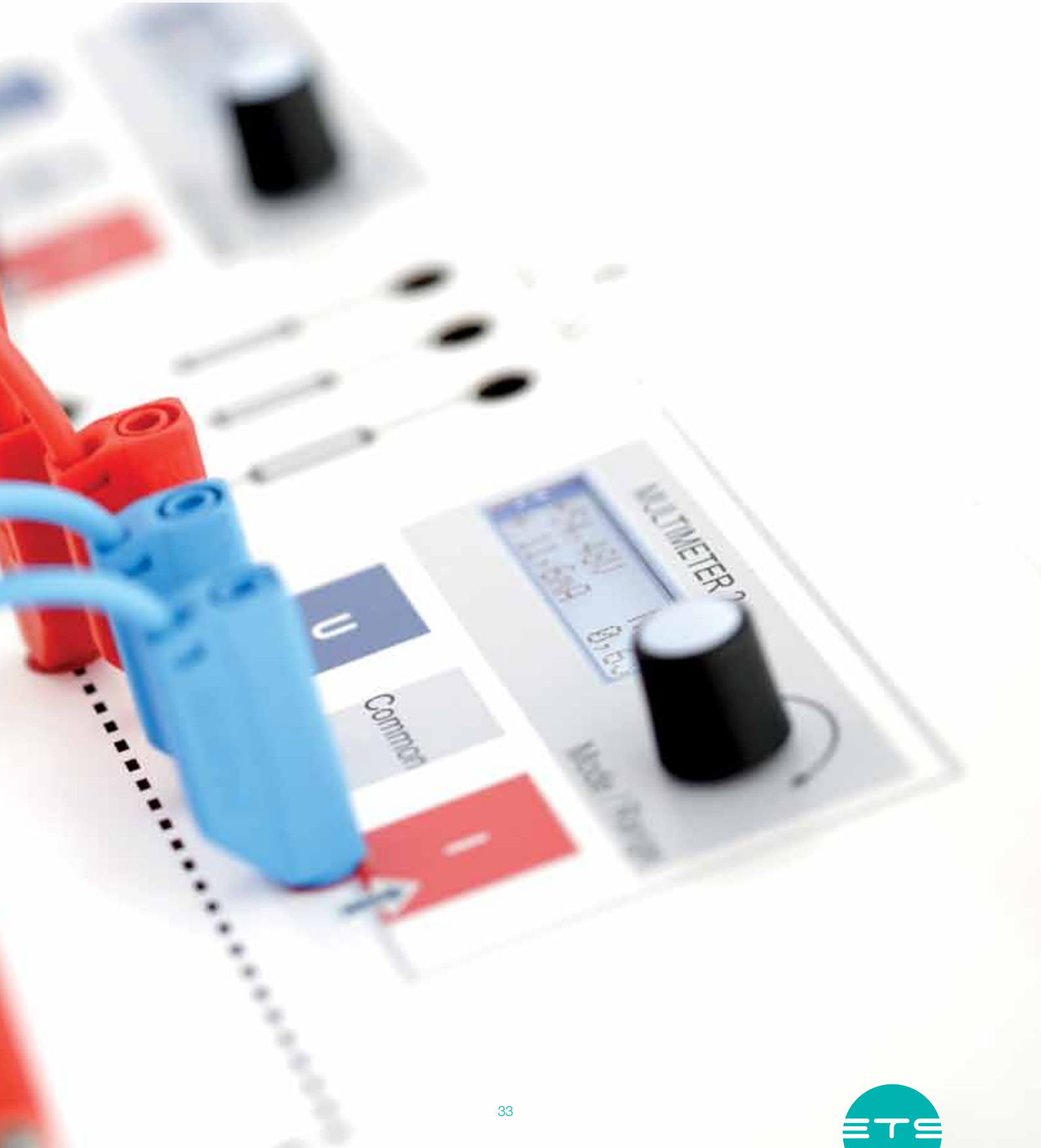
Learning Objectives for Rectifier Circuits

⟩ One-pulse M1 center point circuit

⟩ Two-pulse bridge circuit B2

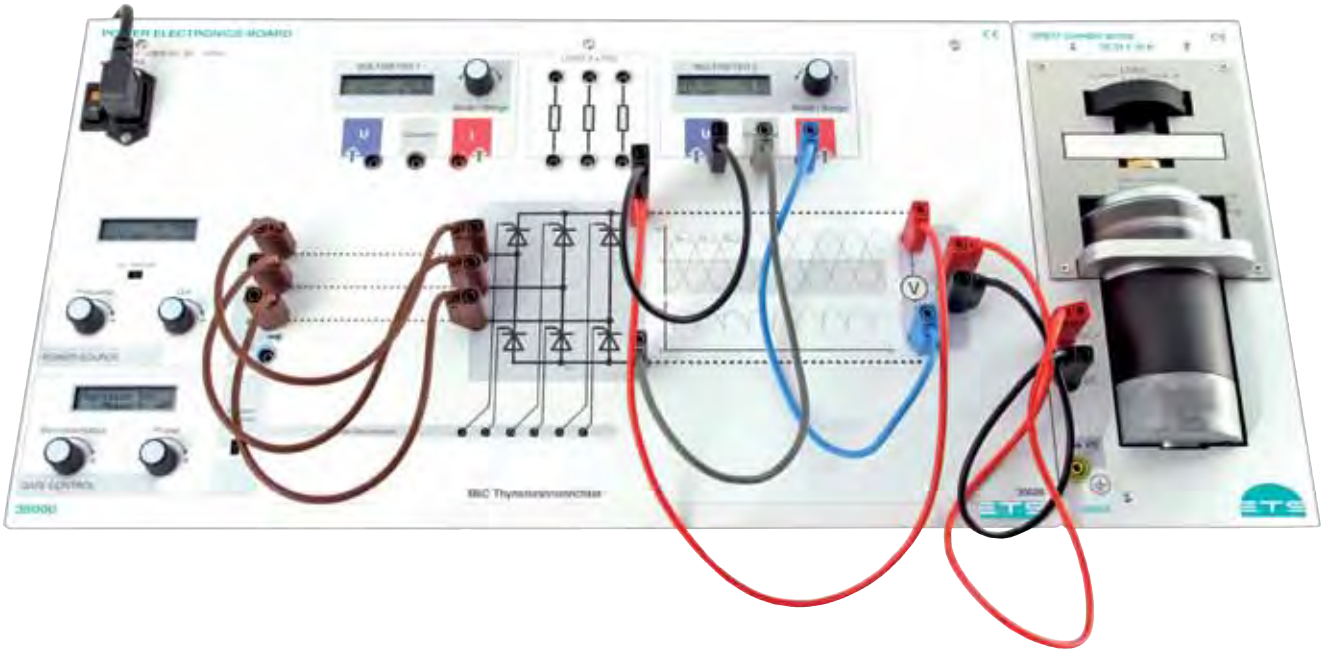
⟩ Six-pulse bridge circuit B6




MULTIMETER
U
Common
I

THYRISTOR CONVERTER

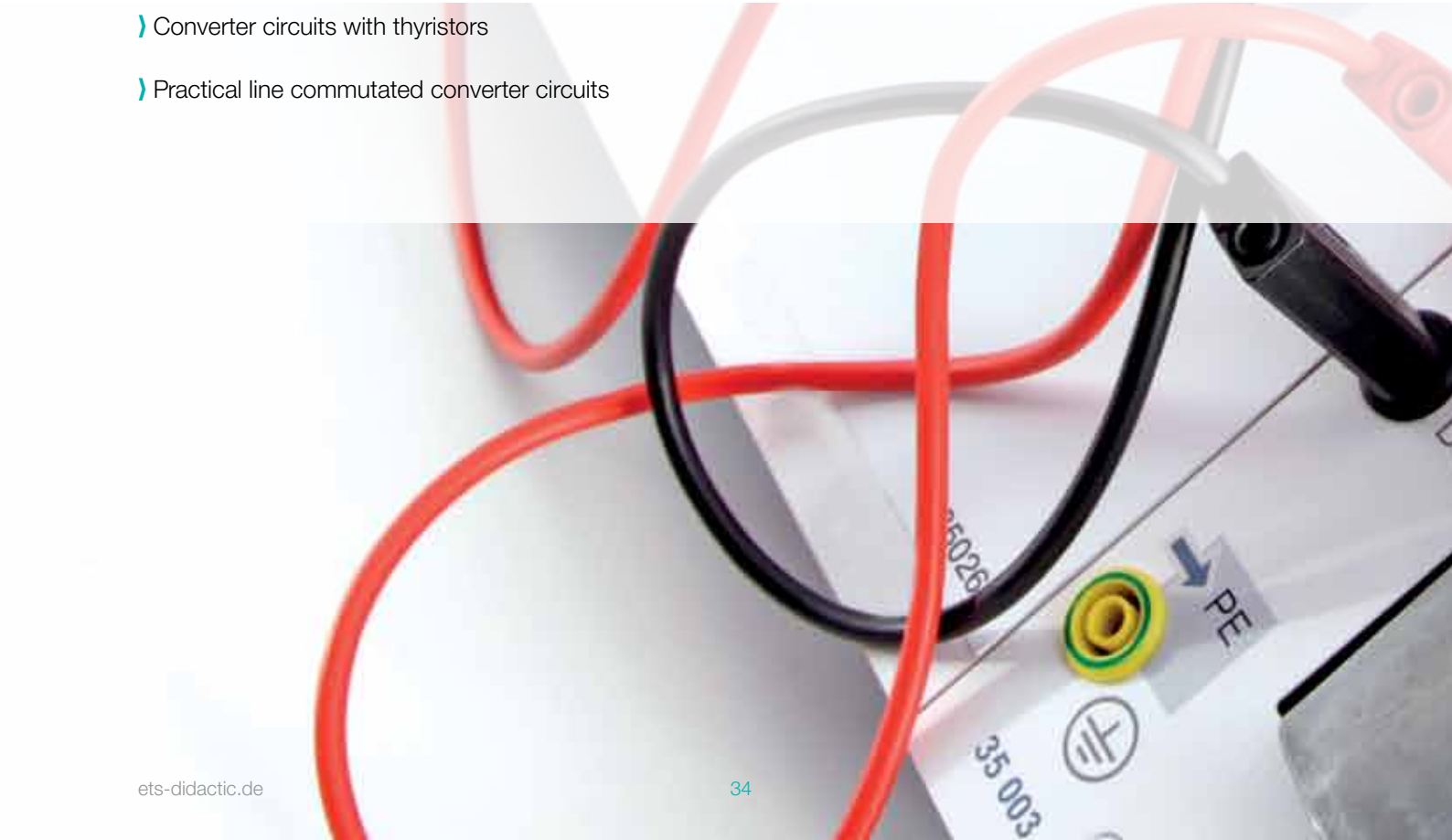
Understanding Correlations



Learning Objectives of Thyristor Converters

⟩ Converter circuits with thyristors

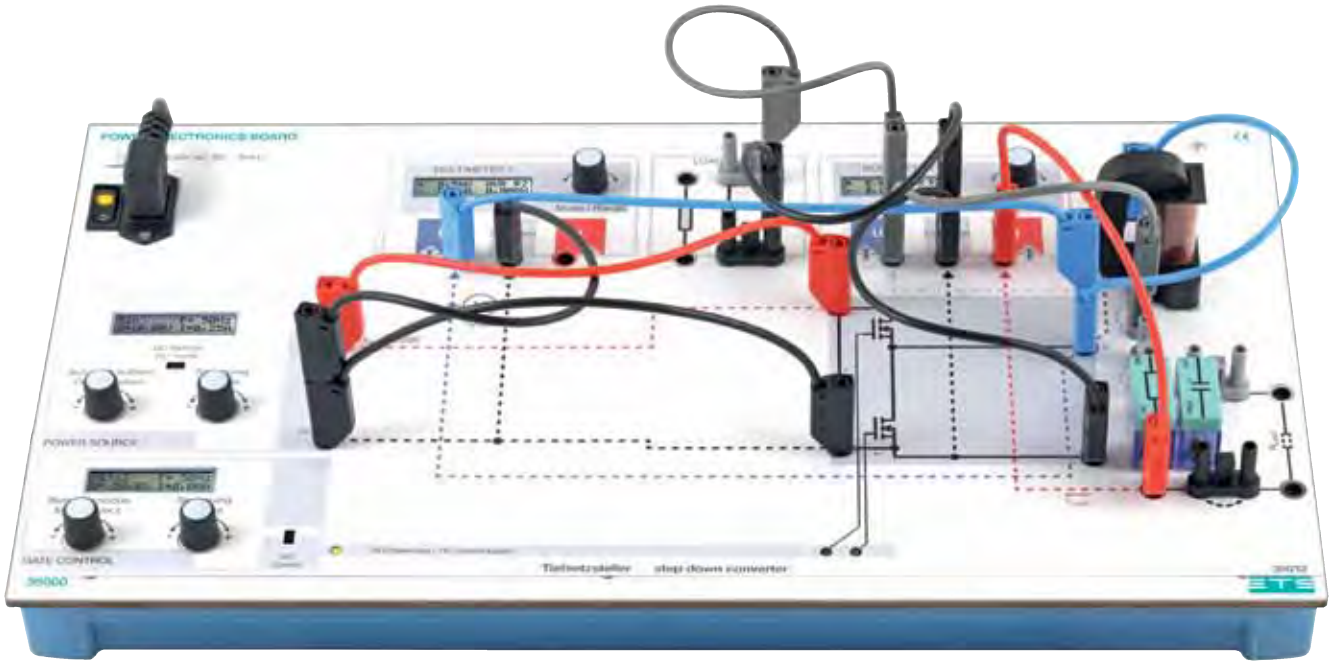
⟩ Practical line commutated converter circuits




DIRECT CU
Eddy-current Brake
Wirbelstrombremse
0
10
DC+
DC-

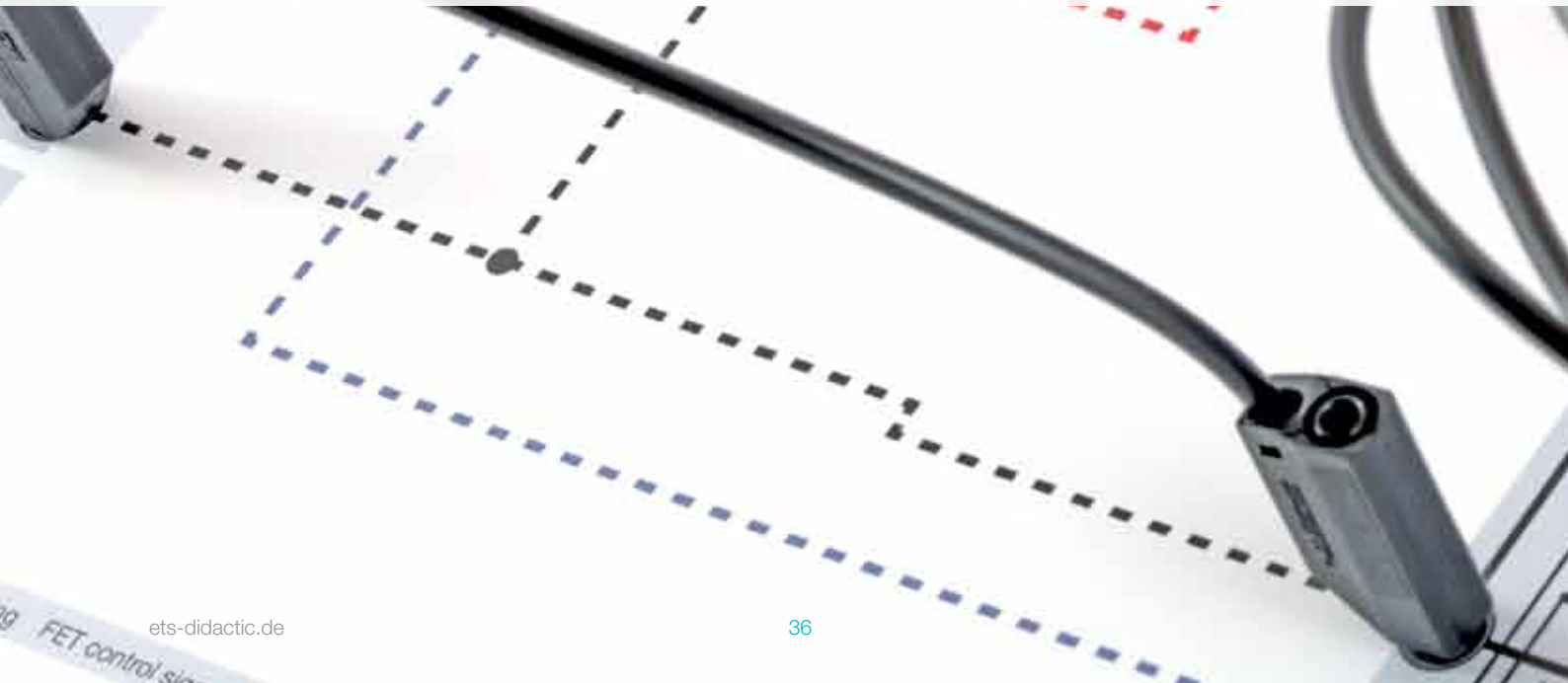
PULSE WIDTH MODULATION

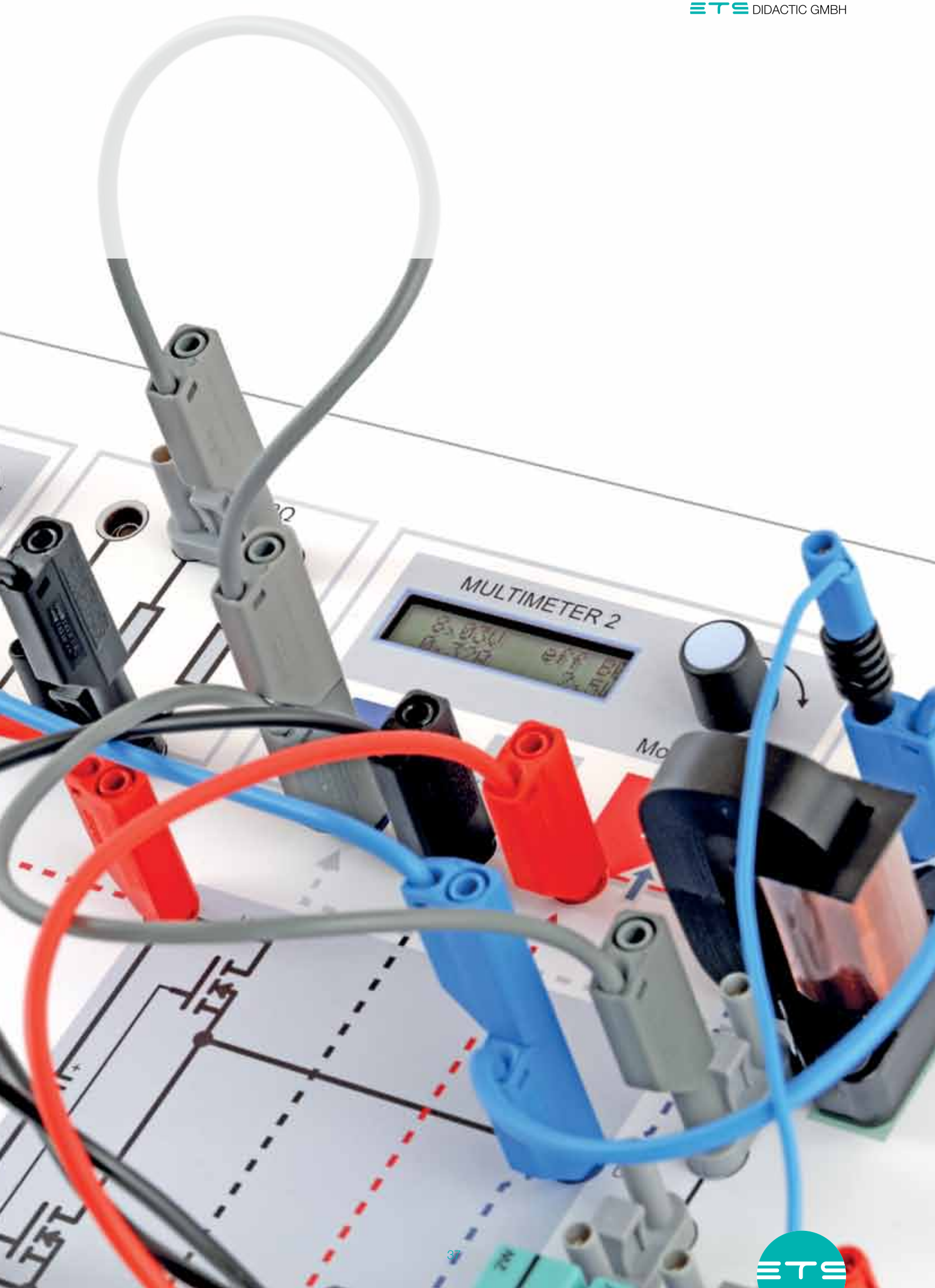
Performing Experiments



Learning Objectives for Pulse Width Modulation

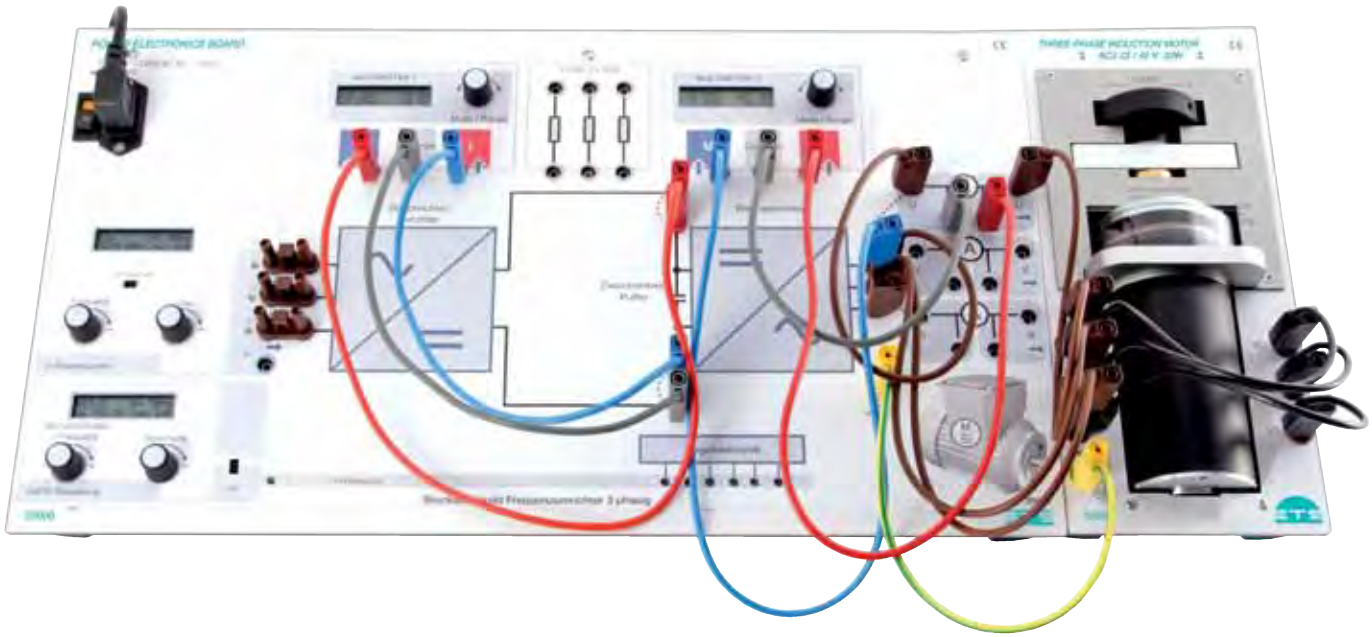
- Basic principle of pulse width modulation
- Duty cycle
- Generation of a variable DC voltage
- Generation of a sinus-shaped AC voltage
- MOSFET half bridge in the experiment




MULTIMETER 2

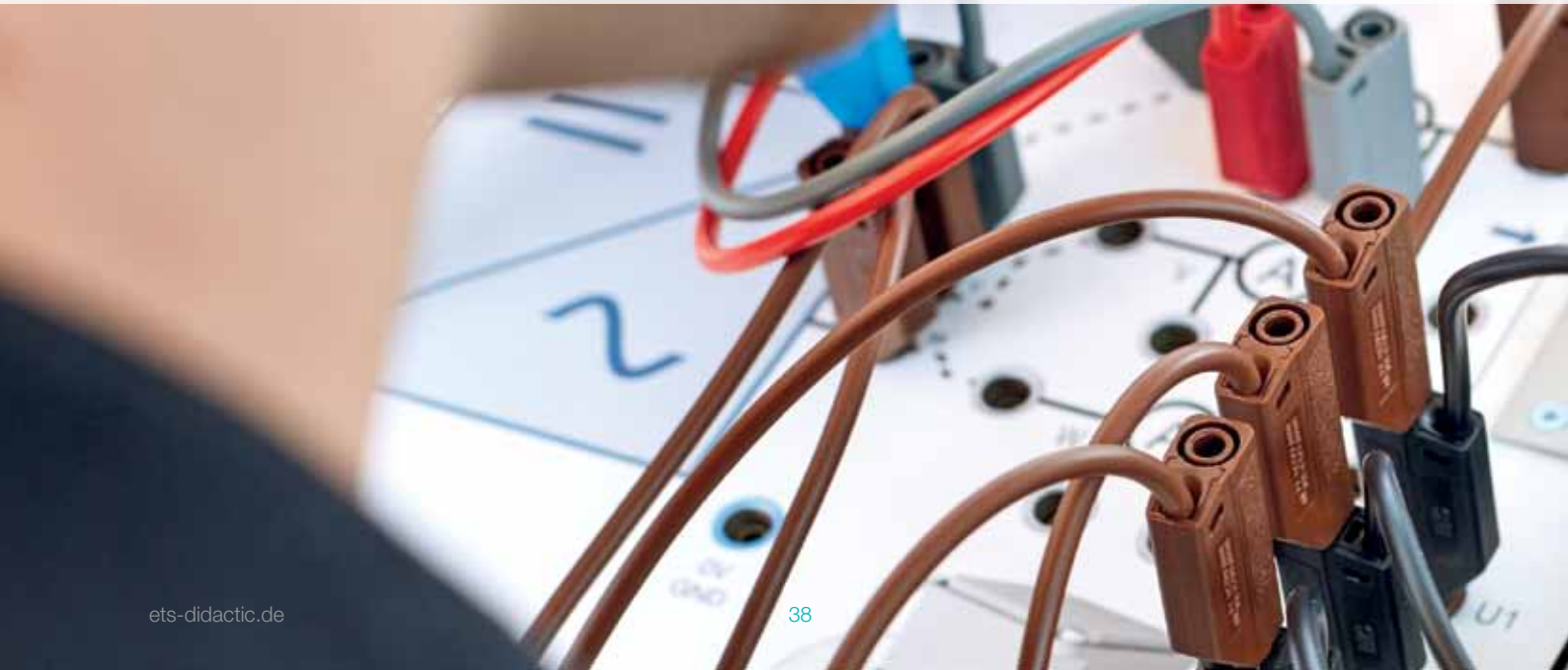
CONVERTER AND POWER INVERTER

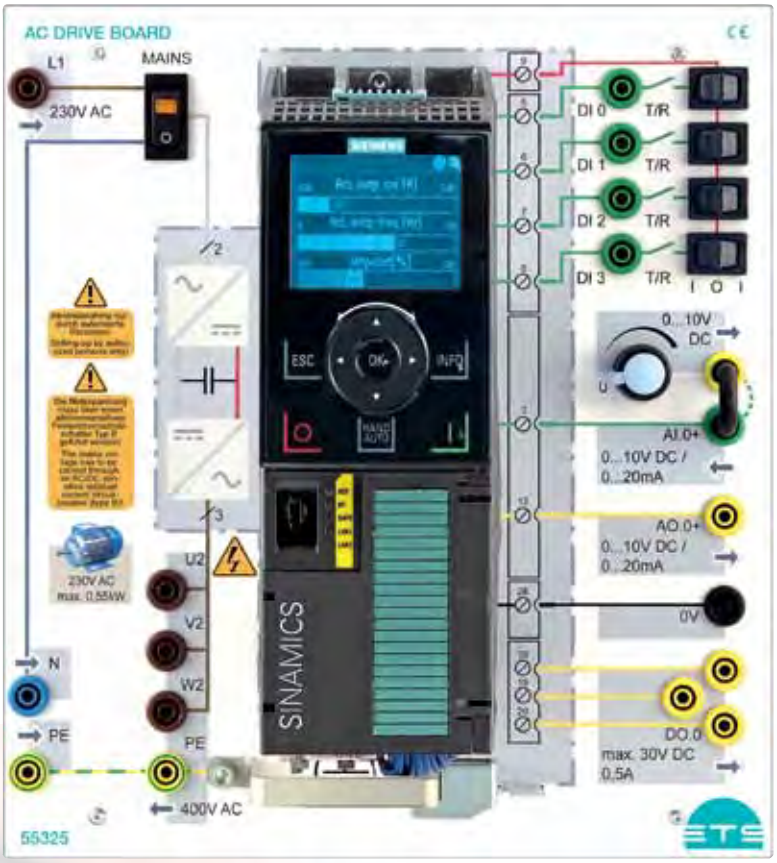
Comprehending Industrial Applications



Learning Objectives - Converter / Power Inverter

- ⟩ One-Channel Power Inverter
- ⟩ Two-Channel Power Inverter
- ⟩ 3-phase Converter
- ⟩ PWM as Function of Voltage and Frequency
- ⟩ Four-channel Converter with Step Motor





Frequency converter and drive technology

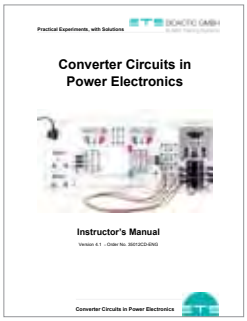
Further information on the topic

"Frequency Converter"
can be found on our website.

COURSEWARE

Rectifier Circuits in Power Electronics

1



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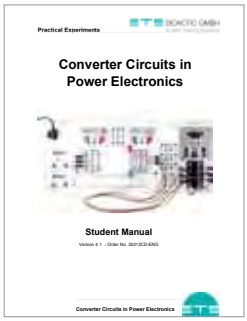

3

On paper and digital

Contents of the Manual

- ⟩ Rectifier circuits
  - One-pulse center point circuit M1
  - Two-pulse bridge circuit B2
  - Six-pulse bridge circuit B6
- ⟩ Thyristor power converter
  - Power converter circuit with thyristors
  - Practical grid-connected rectifier circuits
- ⟩ Pulse width modulation
  - Basic principle of pulse width modulation
  - Duty cycle
  - Generation of a variable DC voltage
  - Generation of a sinusoidal alternating voltage
  - MOSFET half bridge in a practical experiment
- ⟩ Converter and inverter
  - One-channel inverter
  - Two-channel inverter
  - 3-phase converter
  - PWM as function of voltage and frequency
  - Four-channel converter with step motor

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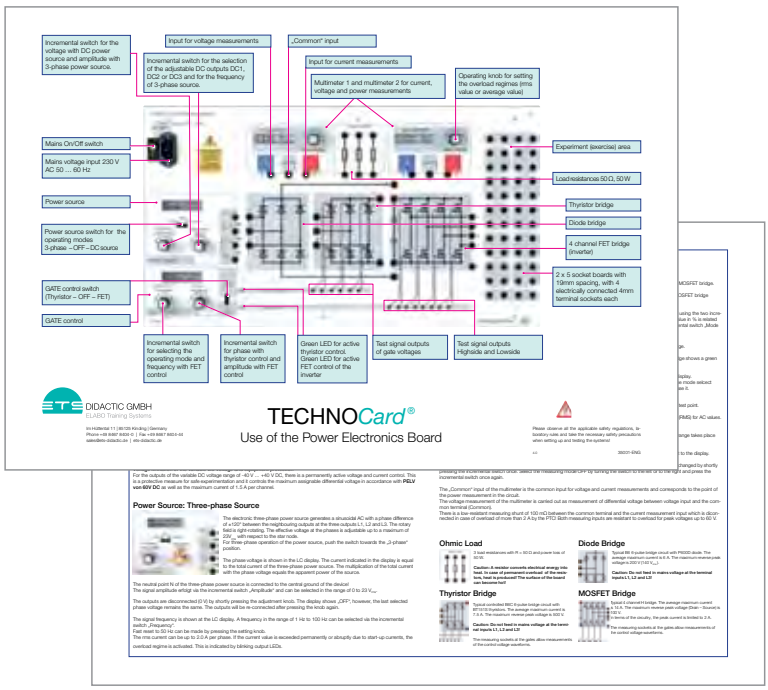
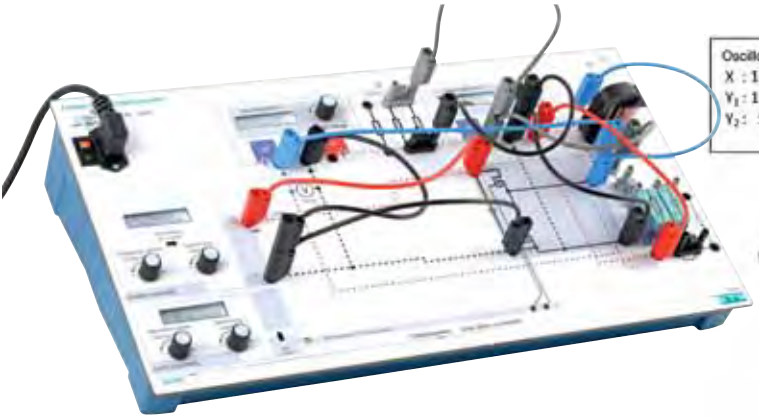
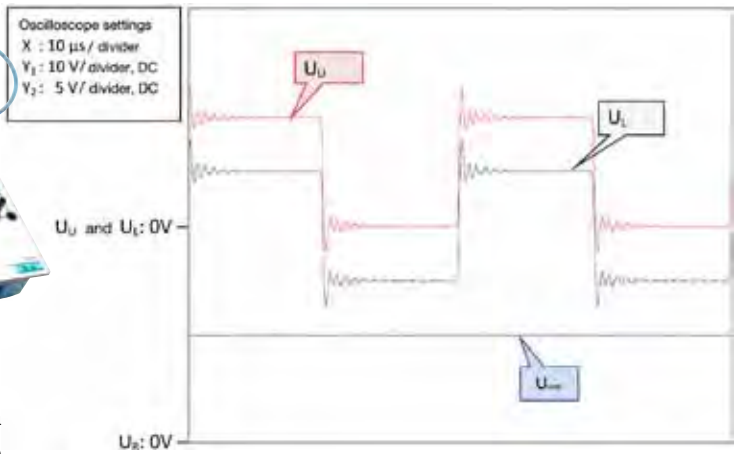


4

No.	Description	Order No.
1	Ringbinder incl. dividers	91903
2	Rectifier circuits in power electronics - Instructor's Edition	35012CD-ENG
3	Rectifier circuits in power electronics - Student Edition	35013CD-ENG
4	TECHNOCard® Use of the Power Electronics Board	35001-ENG

Example of a Step-down Converter

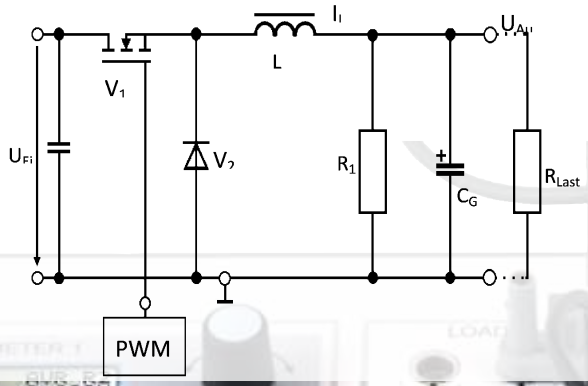


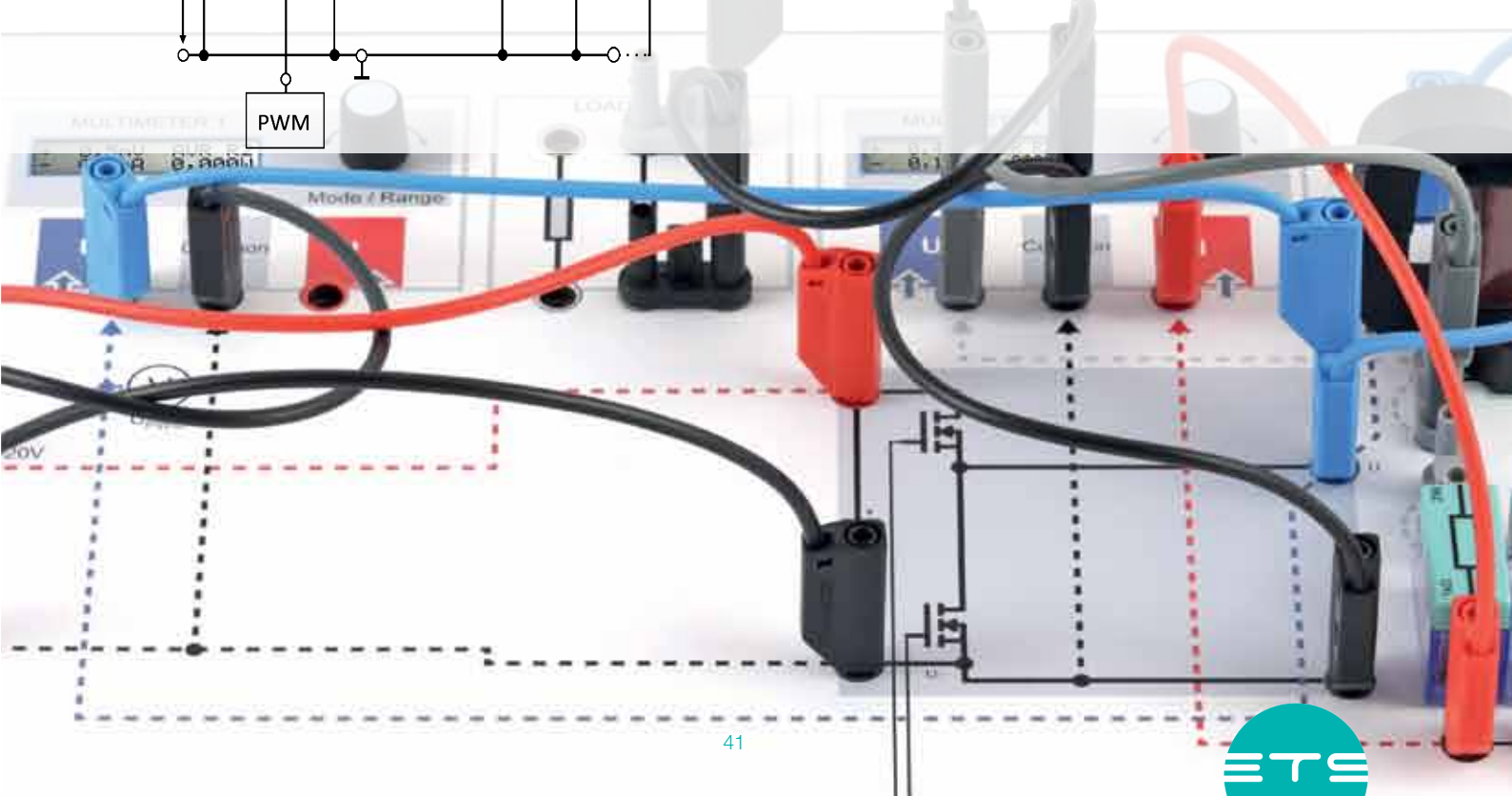


In the pulse width modulation test, the low-loss generation of a pure, adjustable DC current which is not pulse-shaped and the DC voltage are to be examined. We get to know the function of a switching power supply on the basis of a step-down converter.
As long as we are realizing the PWM directly with a pure ohmic consumer, the current follows the voltage directly through the consumer. The average of the current flowing through the consumer can be adjusted more or less continuously by changing the duty cycle.

These pulse-shaped voltages and the resulting pulse current are not suited as operating voltage for electronic circuits. A switching power supply is expected to supply a „plain“ DC voltage.

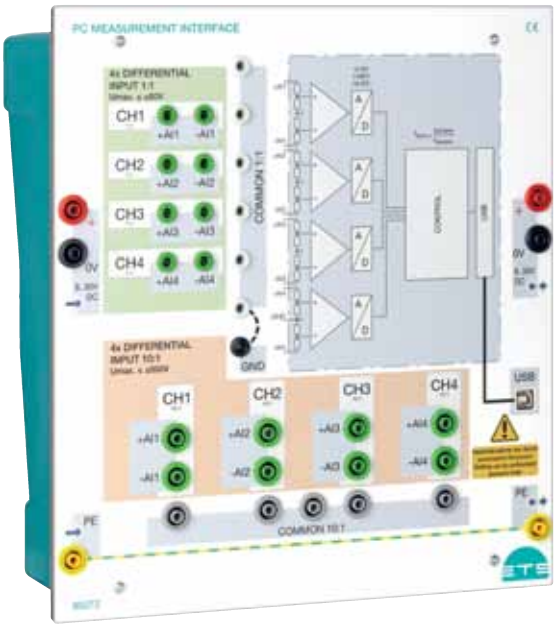
If we fit the load circle with a coil with such high inductance that the energy stored in the magnetic field is sufficient for pushing the current continuously through the entire impulse pause, a DC current is generated in the coil.





MEASURING TECHNOLOGY

For optional signals data logging, measuring devices w ith differential inputs are required in power electronics.



1

PC Measurement Interface

The „PC Measurement Interface“ is a four-channel measuring instrument with differential inputs. This allows safe measuring of voltages up to 600V AC and of variables derived therefrom. The representation and evaluation of the measuring results is made by the software via a connected personal computer.

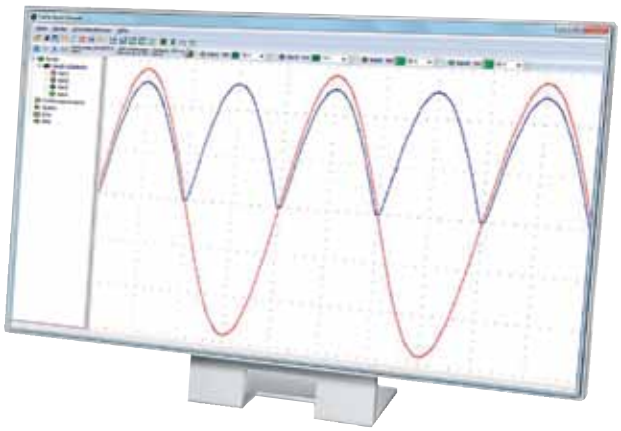
Performance parameters:

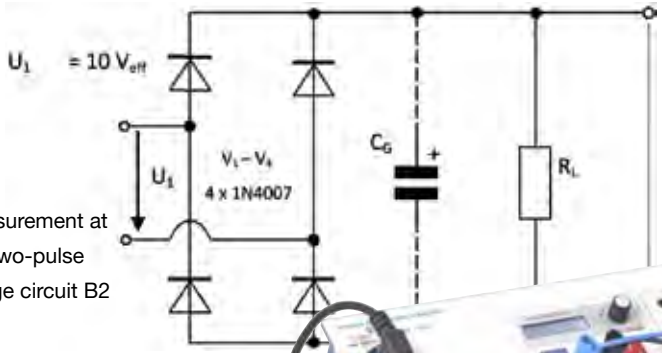
- 4 analog input channels with differential input
- 5 MHz bandwidth (5.000.000 samples/s)
- Sampling rate of to 5MHz per channel
- Input 1:1:
  - Voltage-proof up to 200V_{eff} AC
  - 2mm safety sockets
  - Measuring range from ±200mV up to ±80V (peak value)
- Input 10:1:
  - Voltage-proof up to 600V_{eff} AC
  - 4mm safety sockets
  - Measuring range from ±2V up to ±800V (peak value)
- All inputs are insulated from touching up to 600V, CATIII
- All inputs can clearly be configured using 19mm jumper plugs
- 4 measuring instruments integrated in one device
  - 4-channel oscilloscope
  - Spectrum analyzer
  - Transient recorder
  - Voltmeter (mean value, r.m.s. value)
- USB 2.0 high speed (480MBit/s)
- Optional rated voltage: 8 … 30V DC
- Including: USB cable, software, operating instructions
- Operating system requirements: Windows7 / Windows8 Windows10 (32 or 64 bit)

No.	Description	Order No.
1	PC Measurement Interface Board	90272

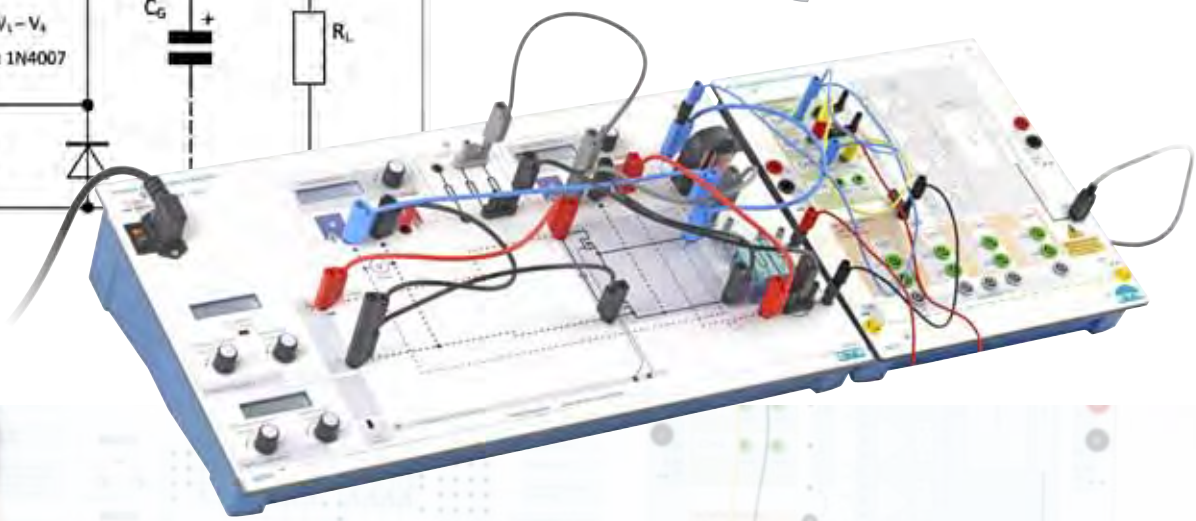
Simultaneous measuring of signals at the B2 bridge circuit input and at the output across the load resistance is only possible with the help of either an oscilloscope with differential input or an isolation amplifier. The measuring interface offers 4 differential inputs thus making it easy to perform such measuring tasks.

Additionally, the test descriptions contain preformed measuring profiles for loading the measuring software to the measuring interface.





Measurement at the two-pulse bridge circuit B2



FRONT PANEL OVERLAYS

Didactic Reduction to Essential Elements

1

Front panel overlays

Front panel overlays simplify experimental set-ups and draw the trainee's attention to relevant assemblies and connections.

The multi-color, graphically designed front panel overlays for didactcn reduction are tailored to the experiments described in the manual.

Principles of power electronics

- Resistance characteristics, electrical power and work
- Power, voltge and current adjustments
- Efficiency
- Active, reactive and apparent power
- Reaction of the coil to square wave voltage
- Inductance at sinus-shaped AC voltage
- Transformer

Converter circuits in power electronics

- Half-wave rectifier
- B2 two-pulse bridge circuit
- B6 six-pulse bridge circuit
- Half-wave thyristor converter
- B2C thyristor converter
- B6C thyristor converter
- One-channel converter
- Buck converter
- Two-channel converter/full bridge
- Frequency converter, 3-phase
- Four-channel conv./step motor
- Block diagram frequency converter 3-phase

Semiconductors in power electronics

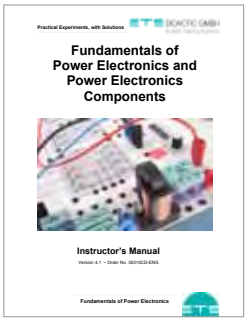
- Diode characteristics
- Ignition and deletion of a thyristor
- Phase angle control
- Conductivity of bipolar transistors
- Bipolar transistors and effects of the base current on the collector current
- Bipolar transistor and IGBT as switch
- N-channel-enrichment-FET and charactristic recording
- N-channel-enrichment-FET as switch

No.	Description	Order No.
1	Set of front panel overlays „Rectifier circuits in power electronics“	35020
n. ill.	Set of front panel overlays „Principles of power electronics“	35050
n. ill.	Set of front panel overlays „Semiconductors of power electronics“	35040

COURSEWARE

Principles and Components of Power Electronics

1



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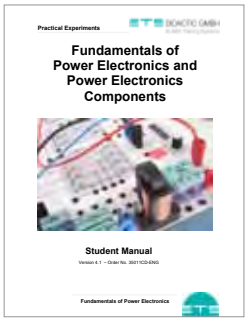

3

On paper and digital

Contained in the Manual

- Electrical power and work
- Efficiency of electrical power
- Power, voltage and current adaptation
- Electrical resistors
- Current types and their characteristics
- Power in case of AC voltages
- Three-phase AC current
- Electromagnetism and coils
- Transformers
- Diodes and rectifier circuits
- Thyristors
- Bipolar transistors
- Unipolar transistors

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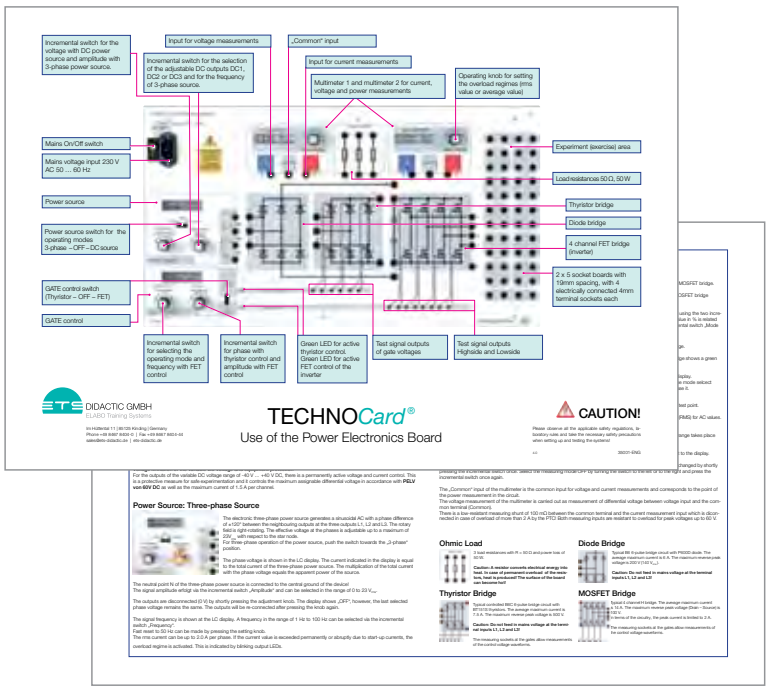
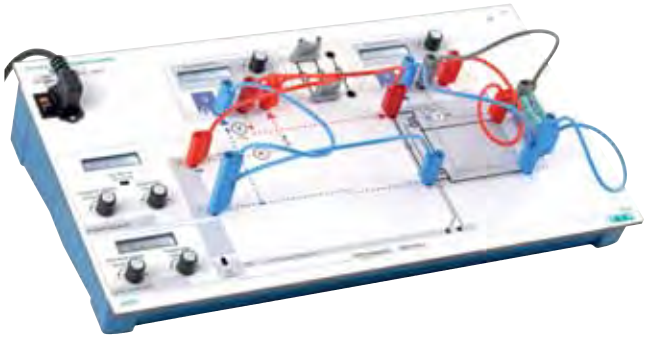


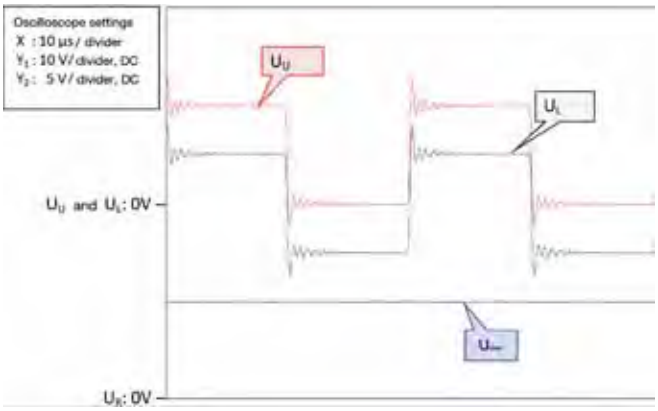
4

No.	Description	Order No.
1	Ringbinder incl. dividers	91903
2	Principles and components of power electronics - Instructor's Edition	35010CD-ENG
3	Principles and components of power electronics - Student Edition	35011CD-ENG
4	TECHNOCard® Use of the Power Electronics Board	35001-ENG

Specific Example for the Efficiency

In modern converters, FET half bridges are used as switching stages. The control gates are driven by a microcontroller in such a way that a converter is in an active state in case of an active FET and the other FET is in a high-impedance state exactly at this point.

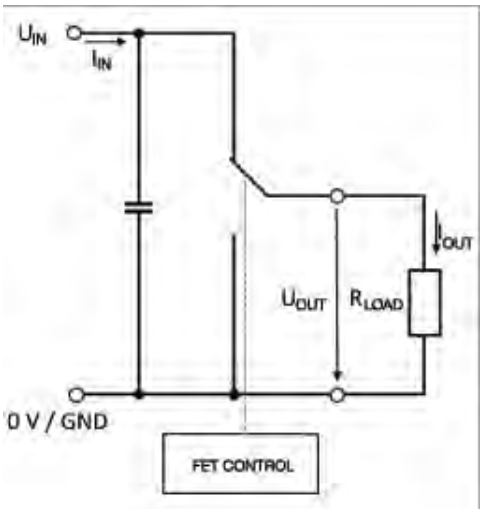




If a FET half bridge is loaded with a pure resistance, there is only a current flowing through the resistor if the semiconductor switch is closed at the supply voltage side. If the semiconductor switch is closed at the ground side, there is no current flow.

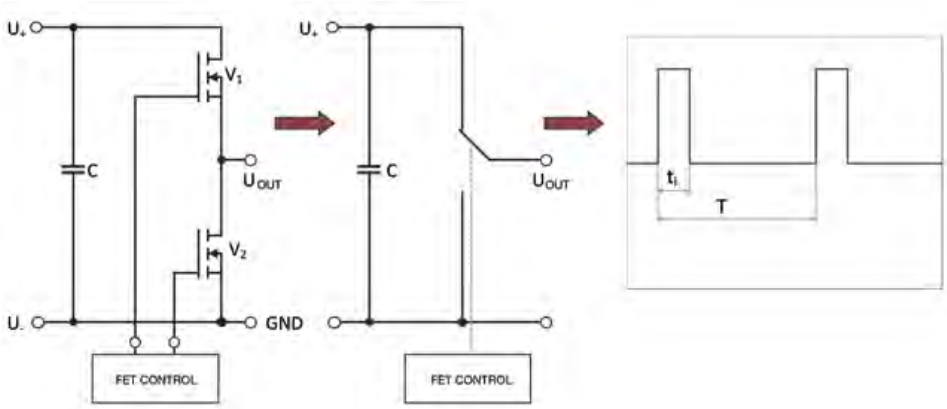
The average value of the load current caused by the load resistance is nearly equal to the input current of the operating voltage. The small difference lies in the portion of current required for operating the switching stage.

The operating voltage is permanently present while the voltage at the output is only present if the switch is closed at operating voltage side. Accordingly, this results in an average voltage value at the output $U_{out} = g \bullet U_{in}$. Also in this case, there is a slight divergence in practical experiments. The output voltage is slightly smaller than the theoretically calculated voltage. This is due to the switching losses across the semiconductor switch rising with an increase of the current.



The efficiency is defined as the ratio of electric work at the ouput to electric work at the input. If an ideal switch is assumed, we can ideally expect that there will not be any switching losses. Consequently, the efficiency of the PWM connected FET half bridge is nearly 100 %.

This is the biggest advantage when compared to voltage dividers or analog voltage regulators. Additionally, it is possible to set the output voltage in the range of 0 to 100%.

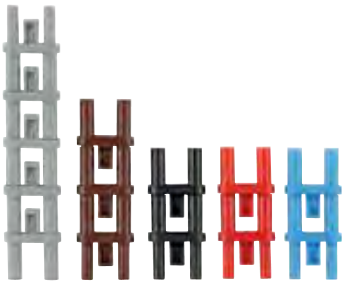


ACCESSORIES

Additional Components for Your Experiments

1

5



2

6

3

7

4

No.	Description	Order No.
1	Set of 4mm safety measuring leads for power electronics	90032
2	Set of 4mm safety bridge plugs for power electronics (19 mm grid)	90033
3	2mm safety measuring lead, 60 cm, black	91160
4	2mm safety measuring lead, 60 cm, green	91161
5	Reduction adapter 4mm to 2mm	90034
6	Set of safety bridge plugs for PC measurement interface	90024
7	Revolution counter – laser	90213


MULTIMETER 1
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L1
L2
L3
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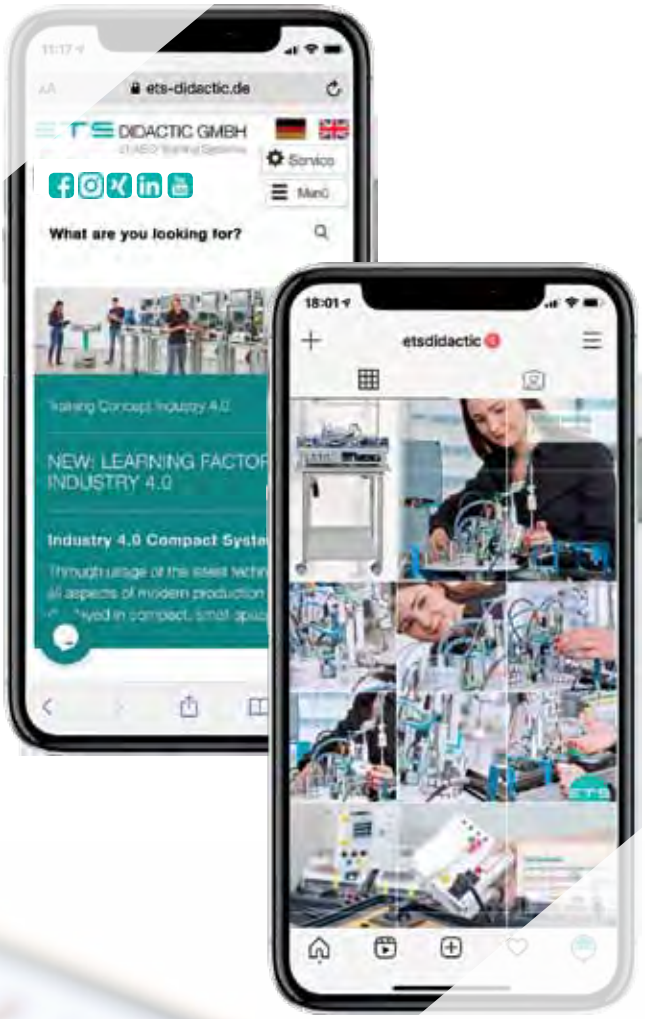
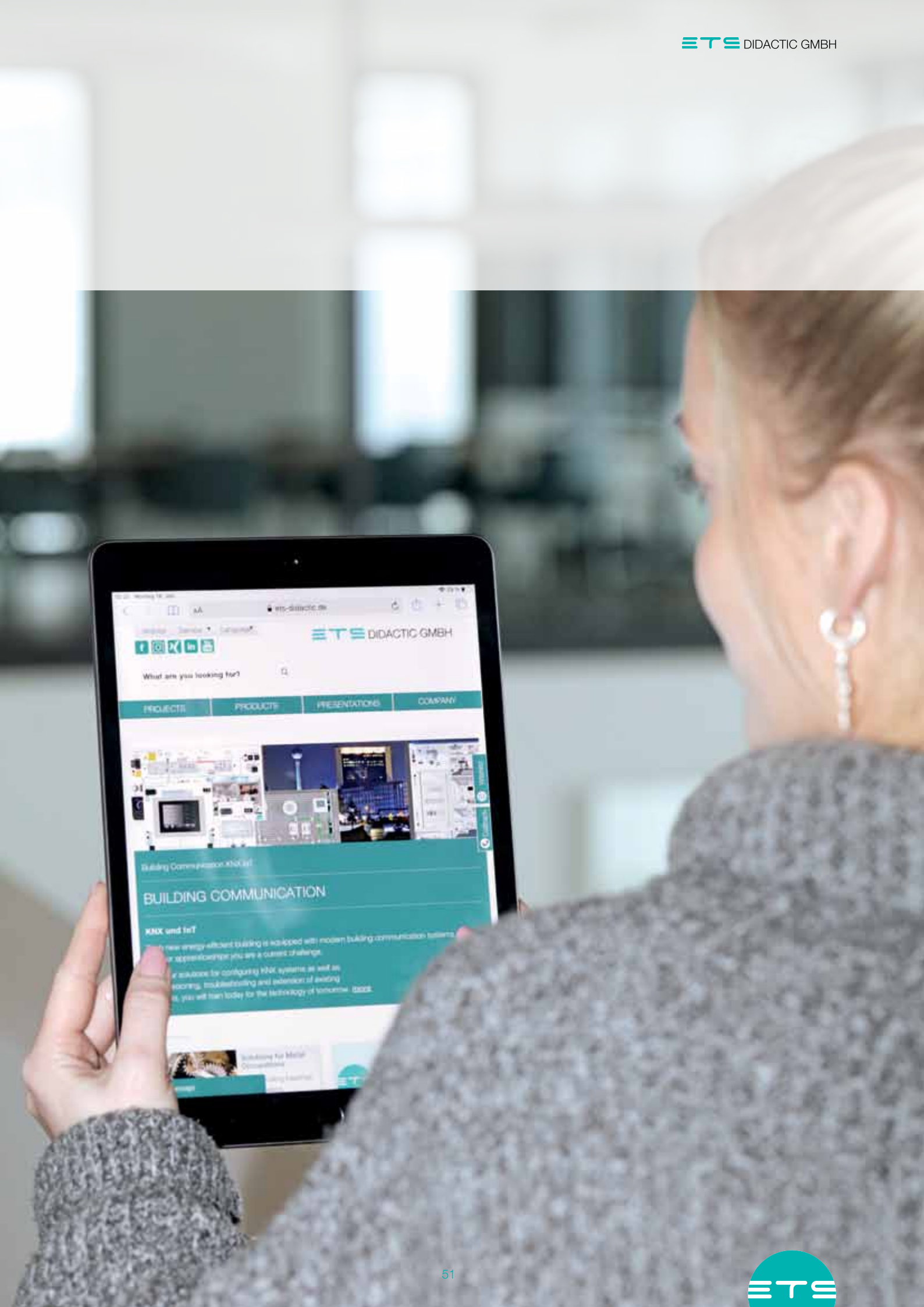


Your plus for Information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Catalog „Electrical Engineering/Electronics/Digital Technology“

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The basics in detail

Catalog „Motor test bench“

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Zip code, City

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○ to be contacted by telephone ○ to have an on-site consultation ○ to receive an offer for ....

Anzahl	Description	Order No.
	Power Eletronics Board	35000
	Set of plug-in components for power electronics	35002
	Supplementary kit of plug-in components – Power electronics (optional)	35007
	Direct current motor DC 24 V, 34 W	35003
	AC induction motor AC3 23/40 V, 20 W	35004
	AC synchon motor AC3 / 40 V, 20 W	35005
	PC Measurement Interface Board	90272
	Set of front panel overlays „Rectifier circuits in power electronics“	35020
	Set of front panel overlays „Principles of power electronics“	35050
	Set of front panel overlays „Semiconductors in power electronics“	35040
	Courseware	
	Ringbinder incl. dividers	91903
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	Manual – Rectifier Circuits in power electronics- Instructor's Edition	35012CD-ENG
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	Reduction adapter 4mm / 2mm	90034
	Set of safety bridge plugs for PC measurement interfaces	90024
	Revolution counter – laser	90213

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