POWER ELECTRONICS LABORATORY WITH HARDWARE IN THE LOOP ASSISTED BY *MATLAB AND SIMULINK*

DL PEL-HIL

MATLAB & SIMULINK for model-based control algorithm design, simulation, and real-time testing

INTRODUCTION

This training system empowers users to design and develop advanced control algorithms within **MATLAB and Simulink** environments, while also enabling them to test and validate these algorithms using a fully equipped hardware setup. It serves as a comprehensive solution for in-depth studies and the validation of academic research findings**.**

It focuses on power converter topics such as DC choppers and inverters, along with electric drives for DC motor, permanent-magnet servo motor, and asynchronous motor. The integration of a complete measurement system with the powerful **MATLAB and Simulink** development environment allows users to design and implement sophisticated control algorithms effectively.

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With the integration of **H**ardware-**I**n-the-**L**oop (HIL) technology, the users will utilize **MATLAB and Simulink** for model-based control algorithm design, simulation, and real-time testing as **R**apid **C**ontrol **P**rototyping (RCP), focusing on power converters control and motor drives.

Its modular structure makes it easy to reconfigure the system to perform several experiments in various subjects and, in order to simulate various loading conditions for both DC and AC motors, we have introduced a brushless motor servo drive system that operates in both speed and torque control modes, supporting bidirectional rotation of brushless motor to facilitate four-quadrant operation for DC and AC motors.

MATLAB and Simulink

Note: Licenses are not included with the trainer and must be managed independently by the users

TRAINING OBJECTIVES

The system enables users to study and develop control strategies for power converters and electric drives.

They will be able to:

- Conduct hardware-in-the-loop testing in real-time,
- Model the complete system in offline simulation,
- Study Park and Clarke transformations in control design,
- Study space vector modulation to optimize control of IGBT-based inverters,
- Perform model-based design for control of DC choppers, inverters, DC motors, servo motors, and asynchronous motors in open-loop, single closed-loop, and cascade closed-loop configurations using a speed sensor,
- Convert control models in Simulink into discrete compiled code for real-time execution in the control system,
- Study and develop automatic current and speed controllers,
- Compare actual test results with offline simulations.

EXPERIMENTAL TOPICS

The users can cover the following topics:

- DC chopper,
- Inverter,
- DC Drives with Cascade Control,
- Variable-Speed Permanent-Magnet Servo Drives,
- Field-Oriented Control of Asynchronous Motors.

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LABORATORY'S COMPOSITION

The laboratory is composed of different modules, components, and motors as in the following list:

CODE	DESCRIPTION	QTY
DL RCPCORE	Rapid Control Prototyping Core module	1
DL 2106SPS-EXCT	AC and DC Power supply module	1
DL 2106T06	Frequency converter module	1
DL 2106LPF	Low-pass filter module	1
DL 2106T21-ADP	Fuses protection module	1
DL 2106RLC	RLC load module	1
DL 10400	Base for machines coupling	1
DL 10200A1	Shunt excitation DC motor	1
DL 10115A1	Three-phase squirrel cage motor	1
MOTBRA1.3NM	1.3Nm brushless motor	1
DL 2108T26-LP	Brushless motor controller module	1
DL 2108T26BR	Braking resistance module	1
DL 9026N	Three-phase waveform acquisition module	1
DL PCGRID	All-in-One Computer	1
DL T12090_SK	120x90 workbench	1
DL T06090	60x90 workbench	1
DL A120-3M	Frame with 3 levels, basic version	1
DL SP-A120-LED	Upper base with LED strip, for DL A120-3M	1
TLRCP	Kit of connecting leads	1
DL 1196	Holder for leads	1

ENVIRONMENT	DESCRIPTION
MATLAB and Simulink	This environment allows users to first perform offline simulations of the complete system. Subsequently, they can extract the control component and execute the compiled code on the **DL RCPCORE** for real-time control validation and performance evaluation.

MATLAB and Simulink

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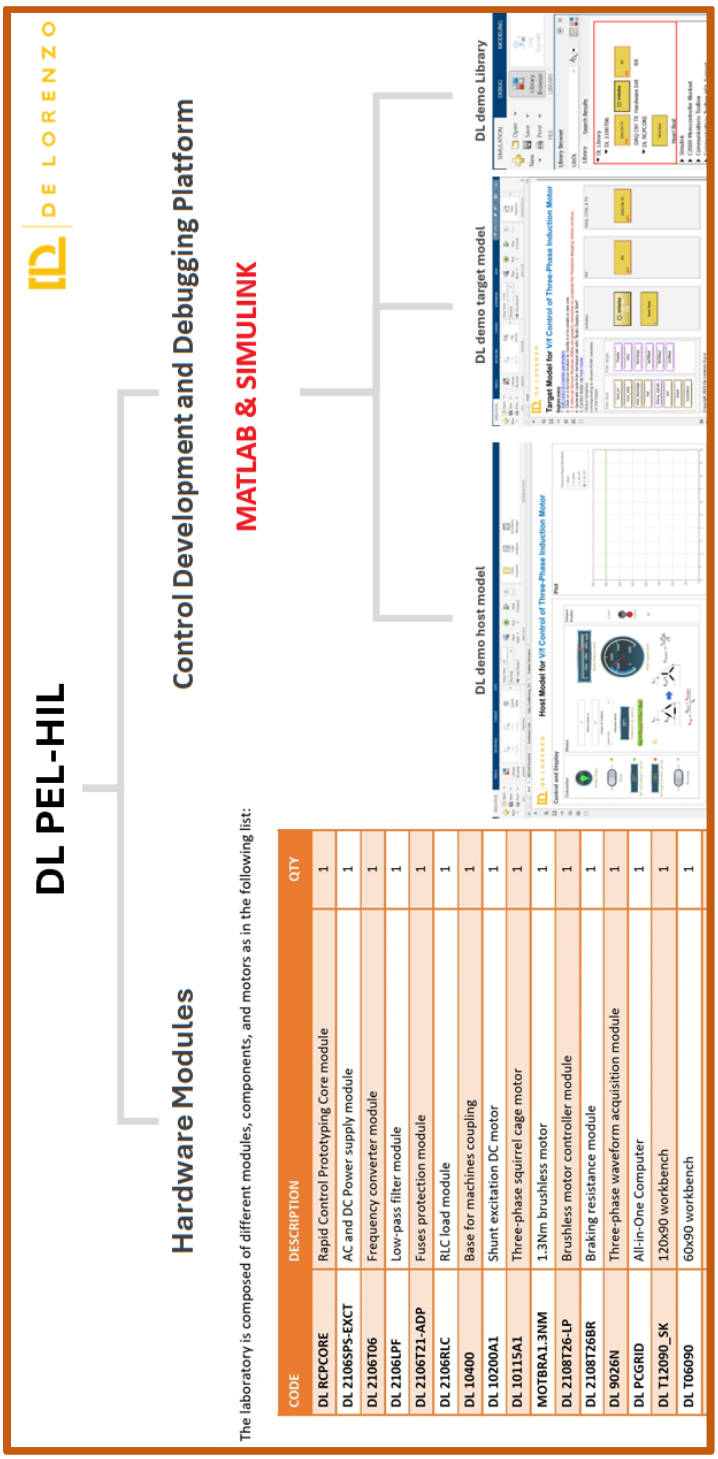
DEMO MODELS AND LIBARARY

Although we do not directly provide the development platform (**MathWorks**), we do offer for each experiment (see image below):

- a **target demo model** (control algorithm),
- a **host demo model** (interface for real-time debugging),
- and a **library** developed by DL, to be installed in Simulink, designed to facilitate further development by the user.



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LABORATORY'S MODULES

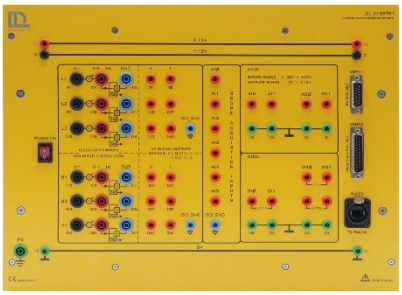
DL RCPCORE

This is the rapid control prototyping core, a real-time controller designed to execute code generated from **MATLAB and Simulink**. It seamlessly connects **Simulink** users to real hardware implementations, minimizing effort and eliminating the need for C programming skills typically required for embedded systems.

It is equipped with six channels for high-voltage and high-current measurements, functioning like six volt-ammeters.

These channels support measurements of up to ±1000 V and ±25 A, featuring protective bushings and built-in galvanic isolation for enhanced safety and reliability. This simplifies closed-loop control, enabling users to seamlessly integrate it into their control algorithms without worrying about missing hardware setups for distributed measurements.

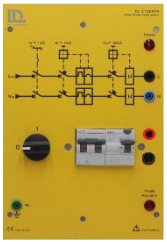
It also features digital and analog inputs and outputs, allowing users to customize the hardware setup to suit their needs.



DL 2106SPS-EXCT

This is a single-phase AC power supply for power converters and electric drives, featuring an integrated MCB (Miniature Circuit Breaker) and RCCB (Residual Current Circuit Breaker) for local protection.

It also provides excitation voltage to the DC shunt motor **DL 10200A1**.

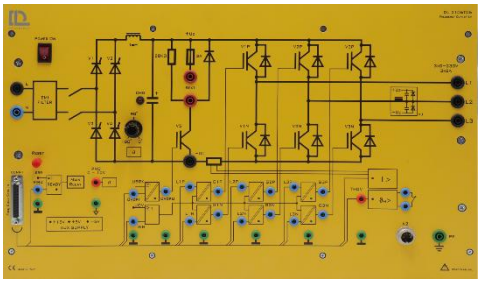


DL 2106T06

Intrinsically, this is a frequency converter consisting of a single-phase controlled rectifier, a DC link with regenerative braking, and a three-phase inverter.

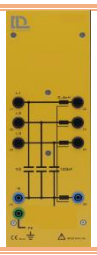
Thanks to the independent drive of the inverter IGBTs, it can also be configured to create various converters, such as DC choppers and single-phase inverter.

It will be controlled by the **DL RCPCORE**, acting as the actuator for the control algorithm to supply a passive load **DL 2106RLC** or motor loads like DC shunt motor **DL 10200A1**, three-phase asynchronous motor **DL 10115A1**, and permanent-magnet motor **MOTBRA1.3NM**.



DL 2106LPF

This low-pass filter is applied to the output of the **DL 2106T06** to filter AC or DC output voltage and current.



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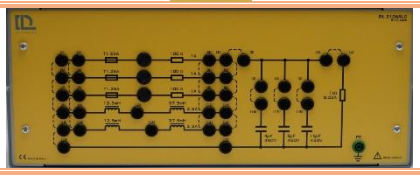
DL 2106T21-ADP Fuse box for hardware protection, suitable to various needs with different sets of fuses for varying protective currents.	
DL 2106RLC This module consists of a set of resistors, inductors, and capacitors, which can be used as passive loads or power filters.	
DL 10400 This is a metallic base designed for mounting DL motors. It includes an optical transducer for detecting rotational speed and features anti-vibration rubber feet, making it suitable for cases where two machines are coupled together.	
DL 10200A1 This is a shunt excitation DC motor with open excitation and armature windings, with thermal protection. *Technical features:* • Power: 200 W, • Voltage: 220 V, • Current: 1.2 A, • Excitation: 150 V/0.06 A, • Speed: 3000 rpm.	
DL 10115A1 This is a squirrel cage three-phase asynchronous motor, with armature windings suitable for delta or star connection, with thermal protection. *Technical features:* • Power: 370 W, • Voltage: 230/400 V - Δ/Y, • Current: 1.9/1.1 A - Δ/Y, • Frequency: 50 Hz, • CosØ: 0.7, • Speed: 2870 rpm.	
MOTBRA1.3NM This is a permanent-magnet servo brushless motor with an embedded encoder, used with the controller **DL 2108T26-LP** or with the frequency converter **DL 2106T06**. *Technical features:* • Nominal power: 400 W, • Nominal torque: 1.3 Nm, • Nominal speed: 3000 rpm.	

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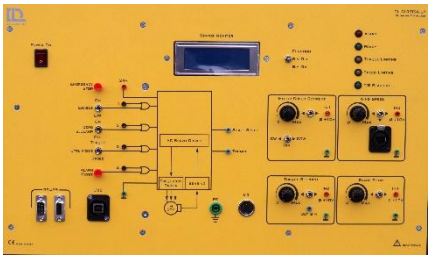
DL 2108T26-LP

This is the application-level controller module for the brushless motor **MOTBRA1.3NM**, enabling the operation of a servo motor in a generator application or in the braking of the motor.

Technical features:

- Motor speed setpoint,
- Torque setpoint with torque limiting Led,
- Torque analog output: 0…10V,
- T/S (Torque/Speed) reaching Led,
- Rated power: 300 W,
- Rated speed: 3000 rpm,
- Ports: 1 USB and 2 RS485,
- 5 pins connector: for speed reading.



DL 2108T26BR

This is the external brake resistor for the **DL 2108T26-LP**, used during regeneration to protect its internal DC link.

DL 9026N

Advanced module used in three-phase systems laboratories to visualize and measure waveforms.

Technical features:

- Selectable AC single-phase to measure V, I, P, Q, and S,
- An embedded data acquisition board, with a full-speed USB interface, to observe the voltage and current waveforms of the three-phases simultaneously with isolated input, and with RS485 communnication port,
- Complete with data acquisition SW developed in Labview for waveforms visualization. It shows the most importand electrical parameters (RMS for voltage and current for all phases, single and total, P, Q, S, and power factor) and performs the FFT transformation to show the voltage and current spectrum.

DL PCGRID

PC All-in-One.

Technical features:

- Display: 21.5", Full HD,
- Resolution: 1920 x 1080 Pixel,
- Processor: Intel® Core™ i3, 1,2 GHz ,
- RAM: 8 GB,
- SSD: 256 GB,
- OS: Windows 11.

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DL T12090_SK Workbench with melamine flatbed. Two holes are present on the flatbed to allow the assembly of a three level frame **DL A120-3M**. *Technical features:* • Dimensions (HxLxW): 80x120x90 cm, • With locking wheels, • Supplied with 15 sockets protected by a thermal magnetic circuit breaker.	
DL T06090 Multifunctional bench used in laboratories as support for modules and electrical machines. *Technical features:* • Dimensions (HxLxW): 80x60x90 cm, • With locking wheels.	
DL A120-3M Frame with 3 levels, basic version, for assembling the modules of the laboratory. To be fixed on the workbench **DL T12090_SK**.	
DL SP-A120-LED Base with LED strip, to be fixed on the upper side of the frame **DL A120-3M**.	
TLRCP Set of wiring cables of different diameters and lengths.	
DL 1196 A sturdy structure used to store and organize the various connection cables in the laboratory, with wheels.	

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