ELECTRICAL CIRCUITS AND ELECTRONIC CIRCUITS LABORATORY

The Mechatronics Engineering Electrical Circuits Laboratory is a working environment where the fundamental principles of electrical and electronic circuits are taught through practical experiments. In this laboratory, students can examine the experimental counterparts of the theoretical topics covered in the lectures and observe the basic electrical behaviour of sensor–actuator systems.

The laboratory infrastructure consists of power supplies, measuring instruments, signal generators, load elements and basic test equipment, and is used both in compulsory experiments and in design projects, robotic applications and R&D studies carried out within the scope of mechatronics engineering.

In this environment, basic electrical circuit applications such as resistance measurements and Ohm's law experiments, DC and AC current–voltage measurements, construction of series–parallel circuits, impedance and resonance analysis, verification of Kirchhoff's current and voltage laws, and Thevenin and Norton equivalent circuit experiments can be performed. At the same time, fundamental electronics experiments such as characteristic measurements of diodes, transistors and other semiconductor devices, analysis of rectifier and filter circuits, investigation of sensor input circuits and testing of simple actuator drive circuits are also among the main activities of this laboratory. In this way, students have the opportunity to learn both the basic principles of electrical circuits and the introductory electronic building blocks experimentally.

DEVICES

Experiment Set

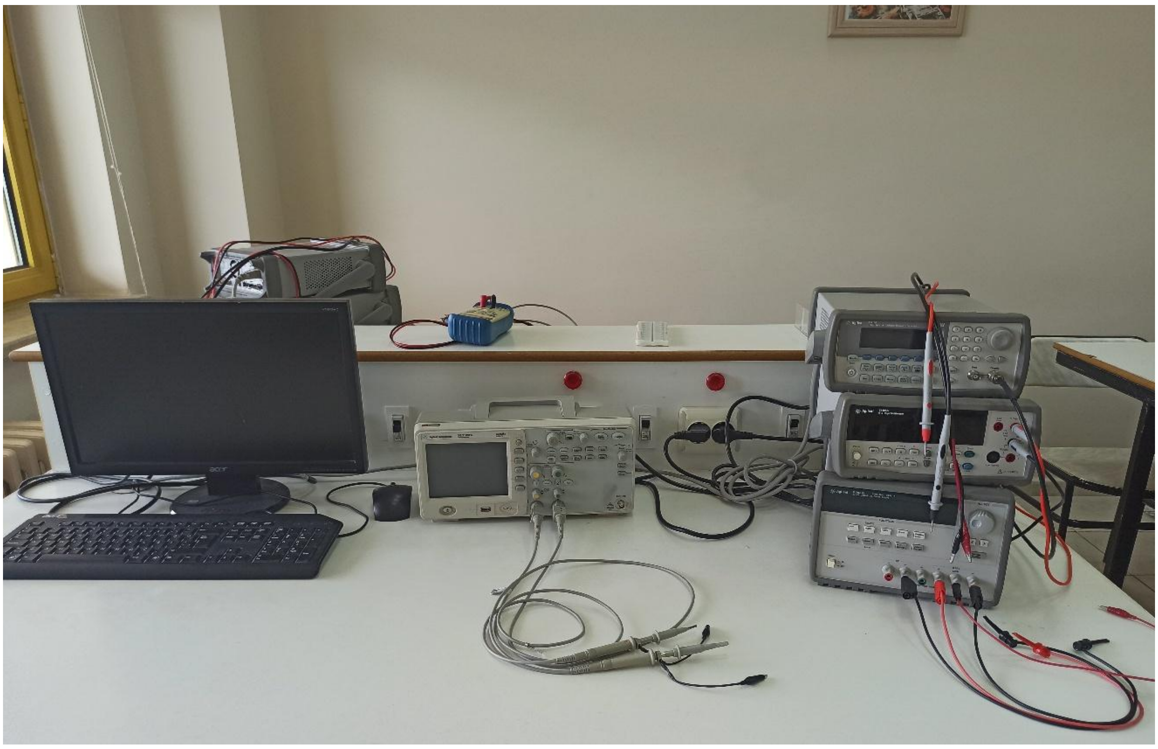

Figure 1. *Electrical Circuits Experiment Set*

Power Supplies

The technical specifications of the Agilent E3631A power supply are as follows:

- Adjustable current/voltage limits: independent limit setting for each output
- Multiple outputs: 6 V, +25 V and −25 V DC outputs; Track mode for symmetric operation
- Fine adjustment: precise voltage/current setting via control knob and resolution keys
- Output control: turning outputs on and off with a single key
- Memory function: saving settings with Store and recalling them with Recall
- External control: I/O Config options for connection to external devices
- Fault diagnosis: displaying error types via the Error function

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Multimeter

Technical specifications of the Agilent 34405A general-purpose multimeter:

- Measurement functions: can measure DC/AC voltage, DC/AC current, resistance, capacitance, frequency, temperature, and perform continuity and diode tests
- Input terminals:

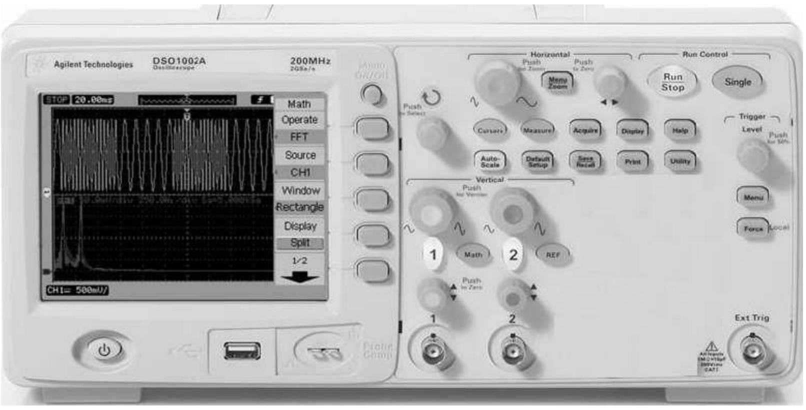
- Separate input for currents below 1.2 Arms
    - High-current input up to 12 A
    - Standard input for voltage/resistance/capacitance/diode measurements
- Range selection: automatic (auto-scale) and manual range selection
- Mathematical functions: additional analysis functions such as Min/Max, dB, dBm, Limit and Hold
- Memory feature: can store measurement setups and recall them later (Store/Recall)
- Safety: incorrect range selection may damage the instrument; choosing the correct range is important

Function Generator

The Agilent 33210A function generator is used to apply standard waveforms such as sine, square and triangle (ramp), or user-defined arbitrary waveforms to electronic circuits. In the laboratory, it serves as the main signal source in experiments on sensor circuits, filter testing, frequency response analysis and general signal processing.

- Frequency range: 1 μHz – 10 MHz
- Output amplitude: adjustable between 10 mVpp and 10 Vpp (on a 50 Ω load)
- Signal types: sine, square, ramp/triangle, pulse, noise, DC and arbitrary waveform
- Modulation features: AM, FM, PWM
- Sweep mode: linear or logarithmic frequency sweep
- Burst mode: generation of a specified number of pulses and phase/polarity adjustment
- Output impedance: 50 Ω
- Resolution: frequency resolution down to 1 μHz
- Amplitude accuracy approximately ±2%
- Can be controlled remotely via USB, GPIB and LAN interfaces
- Has a Store/Recall feature for saving and reloading settings

Oscilloscope



The Agilent DSO1002A is used in the laboratory to observe, in real time, voltage, frequency, period, waveform and phase relationships of signals in electrical and electronic circuits. Thanks to its dual-channel structure, two different signals can be monitored simultaneously, allowing students to experimentally verify their theoretical circuit analyses.

On the oscilloscope, the following basic quantities can be measured directly:

- Voltage values (Vp, Vpp)
- Period and frequency
- Phase difference
- Rise and fall times

In addition, detailed signal analysis can be performed using functions such as triggering, zoom, sampling and cursors.

Main technical specifications:

- Bandwidth: 60 MHz
- Channels: 2 independent analog channels
- Sampling rate: 1 GSa/s
- Memory depth: 20 kpts
- Vertical resolution: 8-bit ADC
- Time base range: 2 ns/div – 50 s/div
- Vertical range: 2 mV/div – 5 V/div
- Input impedance: 1 MΩ ±2% // approx. 16 pF
- Triggering features: edge, pulse, video, single/normal/auto trigger
- Measurement functions: voltage (Vp, Vpp, Vrms), frequency, period, phase, rise/fall time, duty cycle

- Cursor measurements: manual/automatic measurements on horizontal and vertical axes
- Zoom and display: zoom, Y–T / X–Y modes, close-up viewing
- Storage: saving waveforms and settings via USB memory stick
- Display: 5.7" LCD

ELECTRICAL MACHINES LABORATORY

The Electrical Machines Laboratory is a fundamental educational environment where the operating principles of electrical machines, starting techniques and speed control methods are taught in a hands-on manner. In this laboratory, students reinforce their theoretical knowledge by examining the behaviour of direct-current and alternating-current motors under real operating conditions, while at the same time developing practical engineering skills such as motor drive, measurement and circuit connection.

Within the scope of the laboratory, experiments on starting and speed control are first carried out on DC shunt motors, so that the magnetic field structure of DC motors and the relationship between armature voltage, field current and speed are observed experimentally. Subsequently, experiments on starting and speed control of three-phase induction motors are performed; the starting characteristics of the motor, slip, torque–speed relationship and speed control methods using variable-frequency drives are investigated. In addition, step motor control studies are conducted in the laboratory, and the principles of step angle, drive signals, micro-step control and positioning are learned through practical applications.

Through these experiments, students gain the opportunity to understand the dynamic behaviour of electrical machines, the differences between drive techniques, the effects of motor parameters on system performance and the fundamentals of control strategies used in industry. In this way, they acquire comprehensive practical experience in both power electronics and machine control.

EXPERIMENT SETS

1. STARTING AND SPEED CONTROL OF A DC SHUNT MOTOR

The aim of this experiment is to investigate the starting behaviour and speed control principles of a DC shunt motor in a practical manner. Within the scope of the experiment, students learn the structure of the shunt motor, the relationship between armature voltage, field current and motor speed, the control of starting current and how the speed can be adjusted both by armature voltage control and by field-weakening. In this way, they become familiar with the basic operating characteristics of DC motors.

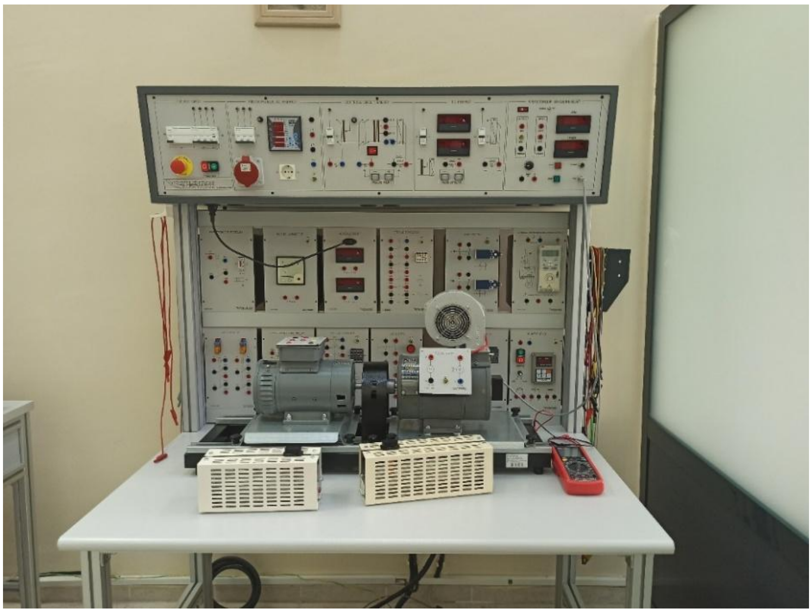


Figure 1. Experiment Set for Starting and Speed Control of a DC Shunt Motor

Devices:
In these experiments, modules designed by Yıldırım Elektronik are used.

- Experiment bench with power unit
- DC shunt machine
- Foucault (eddy current) brake
- DC measurement unit
- DC/AC ammeter (deflection-type)
- 50 Ω 100 W adjustable resistor (Ry)
- 100 Ω 500 W adjustable resistor (Ru)
- Measurement modüle

2. STARTING AND SPEED CONTROL OF A THREE-PHASE INDUCTION MOTOR

The aim of this experiment is to investigate the starting and speed control principles of three-phase induction motors in a practical way. Within the scope of the experiment, in addition to basic starting methods such as direct-on-line starting and star–delta starting, students will observe how the motor speed can be adjusted using various control strategies. In this context, speed control by using an autotransformer, speed control by changing the stator voltage, speed adjustment by changing the frequency (V/f method), speed steps obtained by changing the number of poles and speed reduction methods by inserting resistances into the stator will be examined.

In this way, students experimentally learn the slip–speed relationship of induction motors, their torque behaviour and the effect of different control techniques on motor performance.

Figure 2. Experiment Set for Starting and Speed Control of a Three-Phase Induction Motor

Devices:

- Experiment bench with power unit
- Three-phase induction machine
- Foucault (eddy current) brake
- AC measurement unit
- DC/AC ammeter (deflection-type)
- Three-phase variac
- Measurement module

3. STEP MOTOR CONTROL

The aim of this experiment is to investigate the basic operating principles and control methods of step motors in a practical manner. Within the scope of the experiment, students examine the step angle and phase structure of the motor and perform position and speed control via the driver circuit. The effect of the applied pulse frequency on motor speed is observed, and the behaviour of the motor under load is compared with its no-load operation. In this way, the role of step motors in precise positioning and motion control in industrial applications is understood.

Figure 3. Step Motor Control Experiment Set

Devices:

- Step motor driver module
- Tachometer
- Switch

POWER ELECTRONICS LABORATORY

The Power Electronics Laboratory is a fundamental working environment where circuits that perform the conversion of electrical energy to different levels, waveforms and controlled forms are studied experimentally. In this laboratory, students observe the behaviour of semiconductor switching devices, which are the building blocks of power electronics, thereby reinforcing their theoretical knowledge and improving their practical skills in circuit assembly and measurement.

Within the scope of the laboratory, experiments are carried out on DC–DC converters (choppers), uncontrolled rectifiers and controlled rectifiers. In the DC–DC chopper experiments, it is investigated how direct current is converted to different voltage levels by means of switching techniques; in the uncontrolled rectifier experiments, the basic AC–DC energy conversion performed with diodes is analysed. In the controlled rectifier experiments, it is demonstrated how the output voltage is controlled depending on the firing angle of thyristors (SCRs) and similar semiconductor devices.

Through these experiments, students are introduced to converter topologies used in real engineering applications by observing the operating principles of power electronics circuits, their waveforms, switching behaviour, efficiency and harmonic effects. The laboratory also aims to teach measurement techniques, triggering methods and safety rules related to power electronics circuits.

EXPERIMENT SETS

1. DC–DC CHOPPER CIRCUITS

The aim of this experiment is to investigate the operating principle of DC–DC chopper circuits, the effect of the PWM signal on the output voltage and the basic behaviour of switched-mode power conversion in a practical way. By observing the conduction and cutoff states of the chopper, the IGBT drive signals, the voltage–current waveforms on the load and the effect of the switching frequency on system performance, students learn the fundamentals of DC power control.

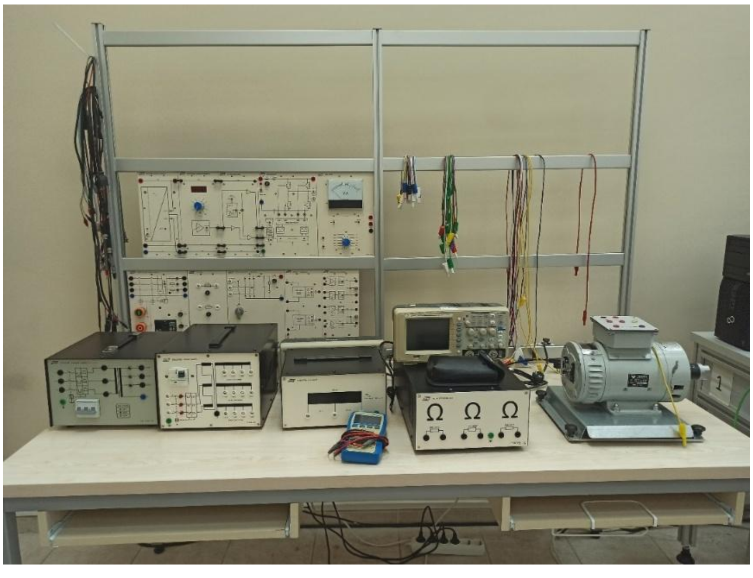


Figure 1. DC–DC Chopper Experiment Set

Devices:
The devices designed by Yıldırım Elektronik and used in this experiment set are as follows:

- PE-5310-1A DC Power Supply
- PE-5310-2A Reference Variable Generator
- PE-5310-2B Differential Amplifier
- PE-5310-2C Current Transducer
- PE-5310-3A RMS Meter
- PE-5310-3C Resistive Load Unit
- PE-5310-3E Inductive Load Unit
- PE-5310-4F IGBT Driver Set
- PE-5310-4G DC PWM Generator
- PE-5310-4J Three-Phase Rectifier and Filter
- PE-5310-5B Fuse Set
- PE-5340-3A Isolation Transformer
- Digital Storage Oscilloscope (DSO)
- Connection Cables
- Bridging Clips

2. SINGLE-PHASE AND THREE-PHASE FULL-WAVE UNCONTROLLED RECTIFIERS

The aim of this experiment is to examine how AC voltage is converted to DC voltage in single-phase and three-phase full-wave uncontrolled rectifier circuits using diodes. By observing the input–output waveforms, students learn, in a comparative manner, the conduction states of the diodes, the effect of the number of phases on the output voltage, the differences in average value and ripple, and the behaviour depending on the type of load.

Devices:

- PE-5340-3A Isolation Transformer
- PE-5310-5B Fuse Set
- PE-5310-5A Power Diode Set (3 pieces)
- PE-5310-3A RMS Meter
- PE-5310-3B Wattmeter (power meter)
- PE-5310-2B Differential Amplifier

- PE-5310-3C Resistive Load Unit
- PE-5310-3E Inductive Load Unit
- PE-5310-2C Current Transducer
- Digital Storage Oscilloscope (DSO)
- Connection Cables and Bridging Clips

Figure 2. Single-Phase and Three-Phase Full-Wave Uncontrolled Rectifier Experiment Set

3. SINGLE-PHASE AND THREE-PHASE FULL-WAVE CONTROLLED RECTIFIERS

The aim of this experiment is to examine the conversion of AC voltage to DC voltage in single-phase and three-phase full-wave controlled rectifier circuits using controlled semiconductor devices such as thyristors (SCRs). By analysing the effect of the firing angle on the output voltage, the conduction and cutoff conditions of SCRs, the contribution of the number of phases to rectification performance and the waveforms appearing on the load, students learn the basic principles of controlled rectification in a practical way.

Devices:

- PE-5340-3A Isolation Transformer
- PE-5310-5B Fuse Set
- PE-5310-5C Thyristor Set (3 pieces)
- PE-5310-3B Wattmeter (power meter)

- PE-5310-1A DC Power Supply
- PE-5310-2B Differential Amplifier
- PE-5310-3C Resistive Load Unit
- PE-5310-3E Inductive Load Unit
- PE-5310-2C Current Transducer
- PE-5310-2A Reference Variable Generator Module
- PE-5310-2D 3-Phase Phase Angle Controller Module
- Digital Storage Oscilloscope (DSO)
- Connection Cables and Bridging Clips

Figure 3. Single-Phase and Three-Phase Full-Wave Controlled Rectifier Experiment Set

PLC LABORATORY

In the PLC Laboratory, experimental studies are carried out on programmable logic controllers (PLCs), which form the basis of industrial automation systems, as well as input–output modules and the associated field devices. In this laboratory environment, students learn, through hands-on practice, topics such as digital input–output, analog input (ADC applications), timer and counter applications, motor and sensor integration, and basic communication applications.

In addition to experiments related to the laboratory curriculum, the testing and commissioning of automation applications developed by students within the scope of graduation projects and research projects are also performed in the PLC Laboratory. In this way, it is aimed to provide both fundamental PLC programming skills and competencies in system design and troubleshooting at an industrial scale.

DEVICES

1. SIMATIC S7-1200 PLC System and Training Set

Model: SIMATIC S7-1200 CPU

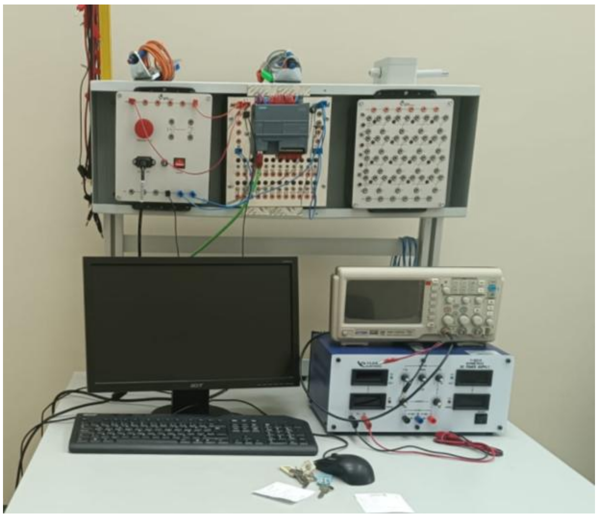


Figure 1. SIMATIC S7-1200 Training Set

Technical Specifications

- Compact and modular programmable logic controller (PLC) family.
- Digital inputs/outputs and analog inputs are integrated on the CPU module.
- The system can be expanded with additional digital/analog I/O modules, communication modules and technology modules as required. CPU 1214C supports one signal/communication board slot, up to 8 signal (I/O) modules and 3 communication modules (CM).
- Using TIA Portal (STEP 7 Basic) software, PLC, HMI and communication settings can be configured within the same project.

- For a CPU 1214C module:

– 14 digital inputs (24 V DC)

– 10 digital relay outputs
– 2 analog inputs (0–10 V / 0–20 mA, depending on model)
– 6 high-speed counters (3 × 100 kHz, 3 × 30 kHz)
– 4 pulse (PWM) outputs
– Integrated PROFINET (Ethernet) port for communication with other PLCs, HMIs and PCs

• Memory and addressing:
– User memory: 50 kByte (work memory)
– Load memory: 4 MByte
– Retentive memory: 2 kByte
– Input image memory: 1024 Byte
– Output image memory: 1024 Byte
– Bit memory (M area): 8192 Byte

• CPU and timing performance:
– 32-bit processor architecture
– Binary instruction execution time: approx. 0.08 μs per instruction
– Arithmetic instruction execution time: approx. 2.3 μs per instruction
– Timer resolution: 1 ms
– Integrated real-time clock (RTC) inside the PLC

• Thanks to its processor architecture and memory resources, it is suitable for small and medium-scale automation applications.
• A wide operating temperature range and industrial-grade protection class make it suitable for use in harsh field conditions.

Experimental / Educational Application Areas

The S7-1200 PLC system forms the main control and automation infrastructure of the PLC Laboratory. Its main experimental/educational application areas are:

- **Basic PLC Programming Applications:**
    - Input–output control using Ladder, FBD and similar languages
    - Start–stop circuits, interlocked circuits, bistable circuit examples
- **Timer and Counter Experiments:**
    - Delayed ON/OFF and periodic timer applications
    - Part counting, conveyor/cycle counters, production quantity tracking
- **Digital Input–Output Experiments:**
    - Reading pushbuttons, limit switches and various digital sensors from the inputs
    - Driving loads such as relays, contactors and indicator lamps via PLC outputs

- **Analog Signal Processing Applications:**
    - Reading 0–10 V / 0–20 mA signals from potentiometers and pressure/speed/temperature transducers
    - Scaling of analog signals and setting threshold and alarm values in software
- **Communication and HMI Applications:**
    - Data exchange between PLC and HMI panel via PROFINET
    - Monitoring process variables on the HMI screen and changing setpoints via HMI

In this way, students gain the ability to design, program and commission realistic automation scenarios using a PLC platform that is widely employed in industry.

2. DC Symmetrical Power Supply

Model: Y-0013 DC Symmetrical Power Supply

Technical Specifications

- Input supply: 220 V AC / 50 Hz (mains supply)
- Output voltage: 2 × 0–30 V DC adjustable outputs
- Output current: adjustable in the range 0–3 A for each channel
- Fixed auxiliary output: 5 V DC (TTL-level auxiliary supply output)
- Separate digital voltmeter and ammeter for each channel to monitor instantaneous voltage and current values
- Warning LEDs indicating constant voltage (CV) and constant current (CC) operating modes
- Impact-resistant metal housing and bench-top design suitable for the laboratory environment

Experimental / Educational Application Areas

The DC Symmetrical Power Supply is used to provide stable and adjustable DC power to the experimental setups in the PLC Laboratory. Its main uses are:

- Supplying elements such as pushbuttons, switches and sensors connected to PLC inputs
- Safely supplying loads such as relay and contactor coils, small DC motors and indicator lamps driven by PLC outputs
- Providing +V / –V supplies for potentiometers and converter circuits used in analog input experiments

- Demonstrating, through observation of CV/CC operating modes, the relationship between voltage and current and the effects of load changes on the power supply

This power supply serves as a central DC energy source for PLC training sets and auxiliary circuits, ensuring that laboratory experiments are conducted in a safe and controlled manner.

MECHANICAL LABORATORY

The Mechanical Laboratory provides a working environment where students can practically learn machining and joining methods and manufacture the parts required within the scope of course projects and senior graduation projects. With the lathe, column drill, gas metal arc welding machine, laser welding machine and bench grinder available in the laboratory, both educational experiments are carried out and manufacturing processes for project components are performed.

In this laboratory, students develop fundamental engineering skills such as planning manufacturing processes, selecting appropriate tools and cutting parameters, working in accordance with occupational safety rules, and gaining awareness of measurement, inspection and quality.

Lathe

The lathe is a basic machining tool used for processing cylindrical and conical parts by chip removal. On the lathe, students learn in practice how to clamp the workpiece, select appropriate spindle speed and feed rate, and perform basic operations such as external turning, internal turning, grooving, threading and chamfering.

Within the scope of graduation and project studies, shafts, spacers, fasteners and prototype mechanical components are produced on the lathe, thus enabling the realization of physical prototypes of the designed systems.

Figure 1. Lathe

Column Drill

The column drill (pillar drill) is a drilling and machining machine used for drilling holes of different diameters, countersinking and reaming operations. In the laboratory, students gain experience in essential workshop practices such as clamping the workpiece in a vice, selecting the drill bit, adjusting spindle speed and feed, centering the hole and drilling series of holes.

The necessary mounting holes on chassis, connection plates and machine elements used in projects are drilled with the column drill, thereby ensuring both proper tolerances and repeatability.

Figure 2. Column Drill

Gas Metal Arc Welding Machine

The gas metal arc welding machine is a wire-fed welding unit used especially for joining steel and similar metals by the MIG/MAG process. In the Mechanical Laboratory, students receive practical training on topics such as setting up the welding machine, selecting the shielding gas, weld bead formation techniques and visual inspection after welding.

Load-bearing constructions, tables, frames and metal skeleton structures of project systems are joined using the gas metal arc welding machine, allowing students to become familiar with real manufacturing conditions.

Figure 3. Gas Metal Arc Welding Machine

Laser Welding Machine

The laser welding machine is an advanced welding system that enables precise joining of materials with low heat input by using a high energy-density laser beam. With this machine, high quality and repeatability are achieved especially in thin sheets, in the joining of small parts and in applications requiring precise weld seams.

In the laboratory, students gain knowledge and skills related to modern manufacturing technologies by observing the safe use of the laser welding system, the effect of parameter settings (power, speed, focal distance, etc.) on weld quality and the differences compared with conventional gas metal arc welding. It is frequently used for joining precision mechanical parts within graduation projects.

Figure 4. Laser Welding Machine

Bench Grinder

The bench grinder is a two-wheel machine used for sharpening cutting tools, deburring, surface finishing and making final minor adjustments on small parts. On this machine, students receive practical training on appropriate wheel selection, wheel balancing, grinding of the workpiece and correct use of safety equipment (goggles, face shield, etc.).

The removal of sharp edges from manufactured parts, minor corrections of out-of-tolerance dimensions and maintenance of cutting tools are carried out using the bench grinder, thereby improving both occupational safety and manufacturing quality.

Figure 5. Bench Grinder

Thanks to the machines available in the Mechanical Laboratory, students reinforce their theoretical knowledge of manufacturing and materials through practical applications and, at the same time, gain a holistic engineering experience by personally producing and testing prototypes belonging to their project and graduation works.

HYDRAULIC-PNEUMATIC AND SENSOR TRAINING LABORATORY

In the Hydraulic-Pneumatic and Sensor Training Laboratory, practical training is provided on pneumatic and electro-pneumatic circuits, basic hydraulic principles, sensor technologies and the integration of these systems with industrial automation. The training sets used in the laboratory consist of components that are widely encountered in industry, enabling students to gain experience by working with real field equipment.

The pneumatic/electro-pneumatic training sets in the laboratory allow circuits of varying complexity—from basic to advanced level—to be built, fault scenarios to be examined and sensor-based automation applications to be implemented. All sets are used together with a common training bench and a silent-type compressor; thanks to double-sided working panels, more than one student group can carry out experiments simultaneously.

PNEUMATIC AND ELECTRO-PNEUMATIC TRAINING SETS

1 – Basic Level Pneumatic Training Set (PTS 2001)

Model: Basic Level Pneumatic Training Set – PTS 2001

General Description

The Basic Level Pneumatic Training Set is designed as an introductory set for pneumatic technology. It does not contain electrical (coil-driven) components; it focuses entirely on pneumatic logic and cylinder control. The set is used together with a pneumatic training bench and a laboratory compressor.

Technical Specifications (Summary)

- Operating pressure: 0–8 bar
- Connections via 4 mm pneumatic hose
- All fittings are of quick-connect type
- Mounting brackets are available for fixing the components onto the panel
- The set includes:
  - Air preparation units (conditioning unit, manometer, regulator)
  - Mechanically actuated directional control valves
  - Single-acting and double-acting cylinders
  - AND/OR logic valves
  - Flow control and quick exhaust valves

Experimental / Educational Application Areas

With this set, students can carry out the following basic experiments:

- Building basic pneumatic circuits and making decisions using logic operations (AND, OR)

- Control circuits for single-acting and double-acting cylinders
- Applications using mechanical directional control valves such as pushbutton, roller lever and toggle types
- Investigation of the effects of pressure and flow rate on cylinder behaviour
- Speed adjustment of cylinders and comparison of different speed control methods

This set enables the practical learning of pneumatic symbols, circuit diagrams and basic motion control concepts.

2 – Advanced Level Pneumatic Training Set (PTS 2002)

Model: Advanced Level Pneumatic Training Set – PTS 2002

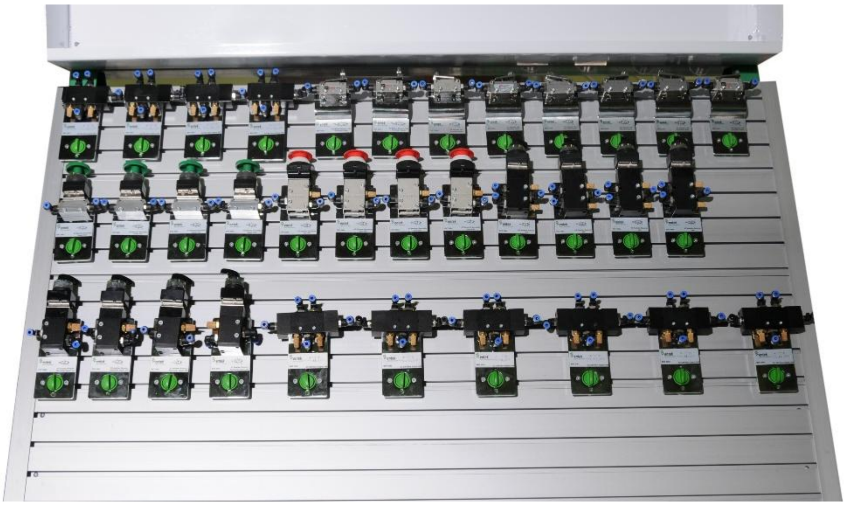


Figure 1. Advanced Level Pneumatic Training Set – PTS 2002

General Description
The Advanced Level Pneumatic Training Set allows the construction of advanced pneumatic circuits in addition to basic pneumatic applications. It does not contain electrical control components; however, it offers additional elements suitable for complex pneumatic logic circuits, multi-stage cylinder motions and counting/positioning applications. It includes all the functions of the basic set and extends them.

Technical Specifications (Summary)

- Operating pressure: 0–8 bar
- 4 mm pneumatic hose
- Quick-connect fittings and components with panel-mounting brackets
- In addition to the components in the basic pneumatic set:
    - 5/3 centre-closed valve
    - Vacuum generator and suction cup

    - Pneumatic counter
    - Pilot-operated valves and advanced flow control elements
    - A larger number of double-acting cylinders and directional control valves

Experimental / Educational Application Areas
Compared to the basic level, the experiments that can be performed with this set are more comprehensive:

- Basic and advanced pneumatic circuit applications
- Multi-stage, sequential cylinder motions and pneumatic step control
- Complex decision structures using advanced logic circuits
- Vacuum applications (pick-and-place with suction cups)
- Speed, position, time and counting applications in pneumatic systems
- Investigation of pressure and flow variations in different circuit configurations

The Advanced Level Pneumatic Training Set aims to enable students to read and design more complex pneumatic circuits and to understand the logic of industrial pneumatic systems.

3 – Basic Level Electro-Pneumatic Training Set (PTS 2003)

Model: Basic Level Electro-Pneumatic Training Set – PTS 2003

General Description
The Basic Level Electro-Pneumatic Training Set is designed to teach electro-pneumatic principles by combining pneumatic circuits with electrical control. It is a continuation of the basic pneumatic set and enables the electrical control of pneumatic cylinders through pushbuttons, relays, lamps and solenoid valves.

Technical Specifications (Summary)

- Operating pressure: 0–8 bar
- 4 mm pneumatic hose and quick-connect fittings
- Mounting brackets for fixing components onto the panel
- Electrical components are supplied with 24 V DC
- 4 mm terminal posts are used for electrical connections
- The set includes:
    - Single- and double-solenoid 3/2 and 5/2 directional control valves
    - Single-acting and double-acting pneumatic cylinders
    - 24 V DC power supply module

- Pushbutton, relay and lamp modules

Experimental / Educational Application Areas
With this set, students learn the fundamentals of electrically controlled pneumatic systems:

- Basic electrical circuits and relay logic
- Driving solenoid valves using pushbuttons, contacts and relays
- Electro-pneumatic control of single-acting and double-acting cylinders
- Comparison of pressure, flow and speed control applications with purely pneumatic circuits
- Simple start–stop, interlocked and automatic return electro-pneumatic circuits

This set provides an intermediate step for teaching classical electro-pneumatic systems operated with relay logic, before moving on to PLC-controlled systems.

4 – Advanced Level Electro-Pneumatic Training Set (PTS 2004)

Model: Advanced Level Electro-Pneumatic Training Set – PTS 2004

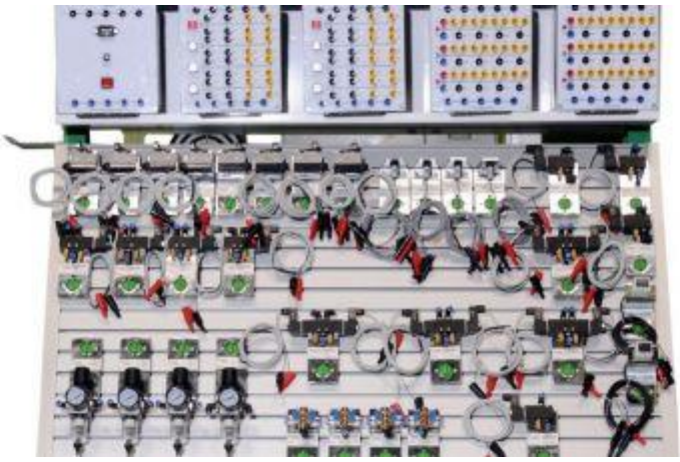


Figure 2. Advanced Level Electro-Pneumatic Training Set – PTS 2004

General Description
The Advanced Level Electro-Pneumatic Training Set enables the construction of sensor-based and time-controlled automation circuits in addition to basic electro-pneumatic functions. It offers a wide range of components for advanced applications in both electrical and pneumatic domains and aims to transfer industrial automation logic into laboratory-scale practice.

Technical Specifications (Summary)

- Operating pressure: 0–8 bar
- 4 mm pneumatic hose and quick-connect fittings
- Pneumatic and electrical components with panel-mounting brackets
- Electrical devices operate with 24 V DC supply

- Electrical connections are made via 4 mm terminal posts
- In addition to the components of the basic electro-pneumatic set:
    - Soft-start valve
    - Electrical counter and time relay
    - Inductive, capacitive and optical proximity sensors
    - Magnetic sensors and electrical limit switches
    - Pressure switch and additional solenoid valves/relays

Experimental / Educational Application Areas
With the Advanced Level Electro-Pneumatic Training Set:

- Basic and advanced electro-pneumatic circuits can be built
- Time, speed, position and counting applications can be implemented using time relays and counters
- Detection-based circuits can be designed with different types of sensors (inductive, capacitive, optical, magnetic, pressure switch, etc.)
- Automation scenarios such as conveyors, sequential cylinder motions, part detection and presence/absence control can be realised
- Complex control schematics can be interpreted, designed and subjected to fault analysis

This set is one of the main platforms in the Hydraulic-Pneumatic and Sensor Training Laboratory for experimentally demonstrating industrial-scale automation applications where sensor technologies and pneumatic actuation are used together.

PROJECT DEVELOPMENT AND APPLICATION LABORATORY

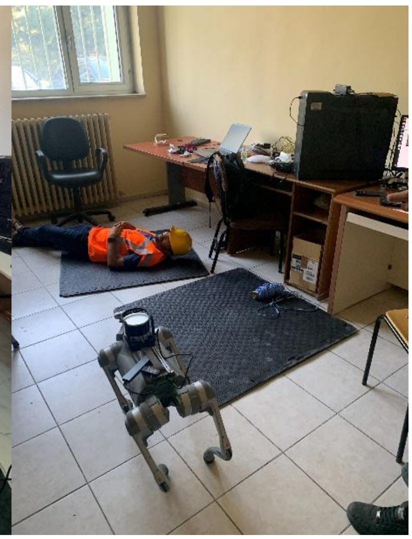
The Project Development and Application Laboratory provides a working environment in which undergraduate students can plan, prototype and test the designs they develop within the scope of in-semester course projects and senior graduation projects.

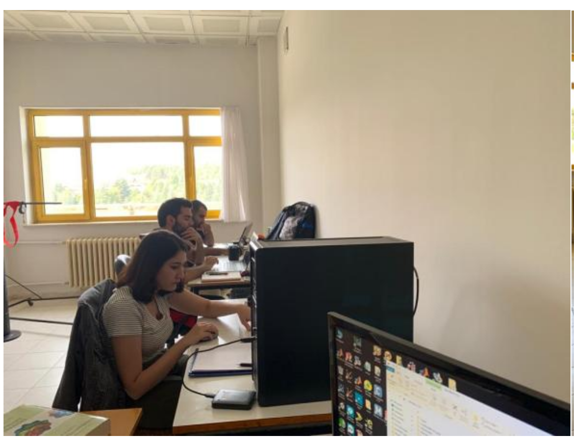
In the laboratory, there are computers, measuring instruments, training sets and basic hand tools for the realisation of projects that include electrical-electronics, mechanical, mechatronics and software components. In this environment, students transform their project ideas into technical drawings and circuit schematics, carry out hardware–software integration, and measure and evaluate the performance of the resulting systems.

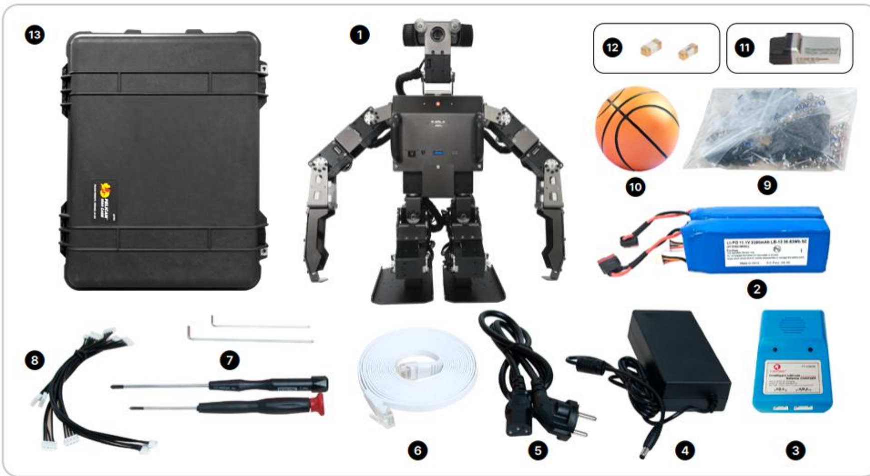
Thus, the Project Development and Application Laboratory functions as an applied workspace that not only enables students to reinforce their theoretical knowledge, but also aims to help them acquire fundamental engineering competencies such as teamwork, problem solving, experimental validation and reporting, which are essential for the engineering profession.

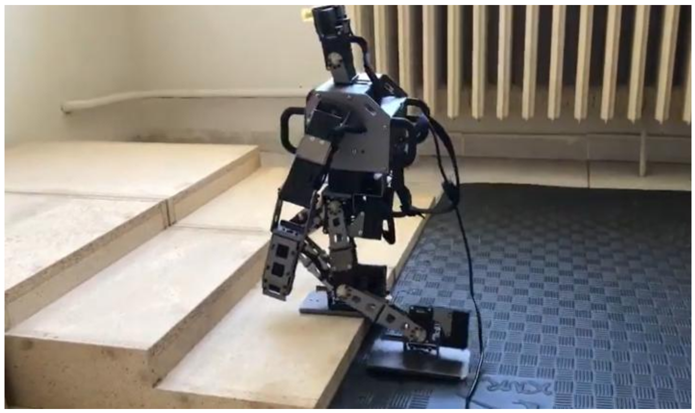
Figure 1. Project Development and Application Laboratory

Robotics and Artificial Intelligence Laboratory (RAI)







1- ROBOTIS OP3 Humanoid Robot – Technical Specifications

General Information:

ROBOTIS OP3 is an advanced miniature humanoid robot with a height of 510 mm, a weight of 3.5 kg, and 20 degrees of freedom (DOF). Its next-generation XM430-W350-R actuators provide higher torque and more precise control. The robot's main processor is Intel NUC i3–based; with 8 GB DDR4 RAM and a 250 GB M.2 SSD, it offers a significant performance increase compared to the previous generation.

Sensors and Hardware:

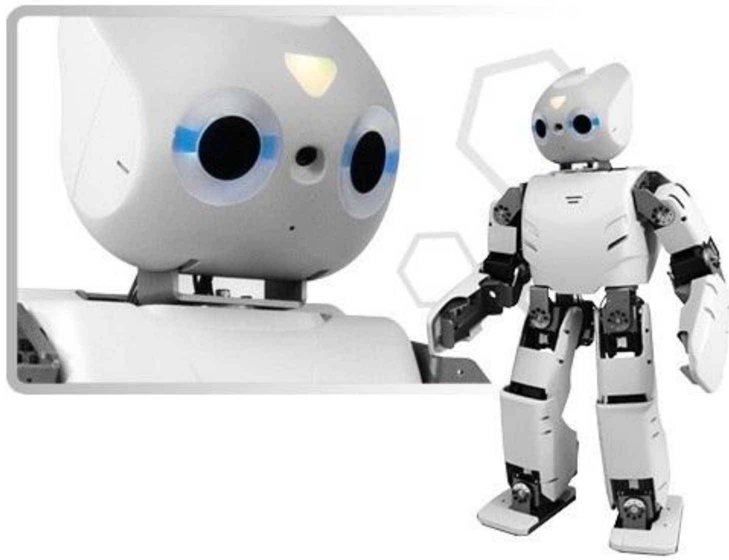
OP3 is equipped with a Logitech C920 HD camera and an IMU unit consisting of a 3-axis gyroscope, accelerometer, and magnetometer. It includes 1 RGB LED, 3 status LEDs, 4 buttons, and a speaker. A modern, open-source OpenCR board is used as the sub-controller.

Connectivity and Power:

It supports Ethernet, Wi-Fi 802.11ax, Bluetooth 5, USB 3.0, HDMI, and DisplayPort. Power is supplied by an 11.1 V 3300 mAh Li-Po battery.

Software and Development:

It operates most efficiently on 64-bit Linux. It supports C++, ROS2, and the DYNAMIXEL SDK. Thanks to its advanced computing power, high-resolution camera, and ROS2 compatibility, it is a strong platform for research, education, artificial intelligence, and RoboCup projects.




2- ROBOTIS OP2 Humanoid Robot – Technical Specifications

General Information:

ROBOTIS OP2 is a previous-generation humanoid robot with a height of 450 mm, a weight of approximately 3 kg, and 20 degrees of freedom (DOF). It uses MX-28 servo motors as actuators and features an older servo architecture compared to OP3.

Sensors and Hardware:

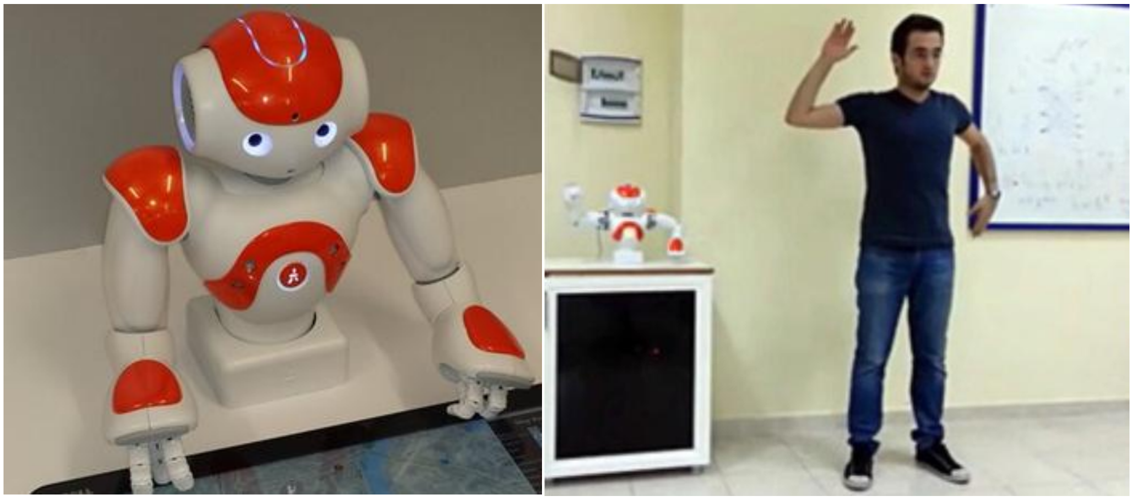
Its main processor is an Intel Atom N2600 dual-core CPU, paired with 2 GB DDR3 RAM and a 32 GB mSATA SSD. The vision system uses a Logitech C905 camera. The IMU includes a 3-axis accelerometer and a gyroscope. The CM-730 board serves as the sub-controller.

Connectivity and Power:

It supports Ethernet, 2.4 GHz Wi-Fi (802.11n), USB 2.0, and mini HDMI connections. It uses an 11.1 V 1800 mAh Li-Po battery. Compared to OP3, its communication options, processing power, and camera quality are more limited.

Software and Development:

It is compatible with 32-bit Linux and 32-bit Windows. Development can be done using C++, ROS (ROS1), and OpenCV. It has been used in education, computer vision, and RoboCup research, but its hardware capabilities are behind OP3's current standards.



3- Aldebaran / SoftBank NAO Torso Humanoid Robot – Technical Specifications

General Information:

NAO is a professional humanoid robot with a height of 58 cm, a weight of approximately 5–5.5 kg, and a total of 25 degrees of freedom (DOF). It is a compact humanoid platform widely used in education, research, artificial intelligence, social robotics, and laboratory studies. Thanks to its soft outer shell and safe servo design, it enables safe operation in both educational and research environments.

Sensors and Hardware:

NAO features an Intel Atom–based central processor (Z530 or E3845 depending on the model). It includes 2–4 GB RAM and 16–32 GB internal eMMC storage. The robot is equipped with dual cameras (an HD top camera and a VGA bottom camera), 4 microphones, stereo speakers, and a comprehensive IMU sensor package consisting of a 3-axis accelerometer, gyroscope, and magnetometer. It also includes balance sensors and tactile sensors located in the soles of the feet.

Connectivity and Power:

It provides Wi-Fi (802.11 a/b/g/n), Ethernet, USB, and mini HDMI ports on some models. Power is supplied by a 21.6 V Li-Ion battery, providing an average operating time of 1.5–2.5 hours.

Actuation and Motion:

NAO is equipped with custom-designed Aldebaran Smart Actuator servo motors. With 25 DOF distributed across the head, arms, legs, and hands, it can perform complex movements such as walking, sitting/standing, balancing, dancing, and expressive gestures.

Software and Development:

NAO runs on the Linux-based NAOqi OS. Programming can be done using multiple platforms including Python, C++, Java, ROS, and Choregraphe. OpenCV is supported for computer vision tasks. It offers rich API support for human–robot interaction, speech recognition, behavior programming, and educational research.

4- Unitree Go2 – Technical Specifications

General Information:
Unitree Go2 is an advanced quadruped robot dog platform distinguished by its high mobility and durability. It is designed for autonomous navigation, research, industrial applications, and education. It can carry an approximate payload of 40–45 kg and is frequently preferred in modern robotics research thanks to its high speed, advanced sensors, and AI-assisted locomotion capabilities.

Sensors and Hardware:
Go2 is equipped with a comprehensive sensor suite for environmental perception, including 3D LiDAR (LiDAR L1 / optional 4D LiDAR), depth sensors, an IMU, and ultrasonic sensors. It features high-torque leg actuators optimized for torque control and dynamic balance. An AI processor and an onboard computing unit enable real-time motion planning and autonomous navigation.

Connectivity and Power:
Go2 supports Wi-Fi, Bluetooth, and 4G/5G communication (depending on the model). With a high-capacity Li-ion battery, typical operating time is approximately 1.5–2.5 hours. The robot is also compatible with a wireless charging adapter and a standalone charging station.

Mobility and Performance:
Unitree Go2 provides advanced locomotion capabilities such as stable walking on rough terrain, jumping, running, obstacle traversal, and rapid direction changes. Its maximum speed is approximately 5 m/s. It delivers high performance through a next-generation BMS (Battery Management System), advanced balance algorithms, and a torque-based control system.

Software and Development:
Go2 can be programmed using ROS/ROS2, Python, C++, and Unitree's own SDK. It offers extensive API support for mapping, autonomous navigation, SLAM, computer vision, and deep learning applications. With mobile apps and dedicated controllers, users can quickly switch between manual and autonomous modes.

5- DJI Matrice 350 RTK – Technical Specifications

General Information:
DJI Matrice 350 RTK is an advanced industrial drone platform designed for industrial operations, mapping, search and rescue, infrastructure inspection, and professional aerial missions. It is widely regarded as a standard in professional field applications thanks to its enhanced flight safety, long-range transmission, high payload capacity, and RTK-based precision positioning.

Sensors and Hardware:
The M350 RTK is equipped with a triple-channel RTK GNSS module, vision sensors, infrared obstacle detection, an altimeter, an IMU, and omnidirectional sensing systems. This configuration provides high stability in complex terrain and centimeter-level positioning accuracy. Its payload capacity is approximately 2.7 kg and it is compatible with professional camera and LiDAR payloads such as the Zenmuse H20, H20T, P1, and L1.

Connectivity and Power:
With DJI O3 Enterprise, it offers a transmission range of up to 20 km. Thanks to the dual TB65 battery system, the maximum flight time can reach up to 55 minutes. Batteries are hot-swappable and include intelligent heating and cooling features. USB-C, CAN port, and modular connectivity options are supported.

Flight Performance:
The M350 RTK delivers high endurance for professional missions with a 7,000 m service ceiling, 15 m/s wind resistance, and multiple flight modes. It includes a sensor system that supports low-light flight for night operations. Its triple GNSS antenna design and dual IMU system further enhance flight safety.

Software and Development:
Advanced mission workflows (mapping, 3D modeling, route planning) can be managed via the DJI Pilot 2 application. For software development, DJI provides support through the DJI SDK, Payload SDK, and Cloud API. It is effectively used in industrial data acquisition, autonomous missions, RTK-based mapping, and inspection projects.

6- TurtleBot2 – Technical Specifications

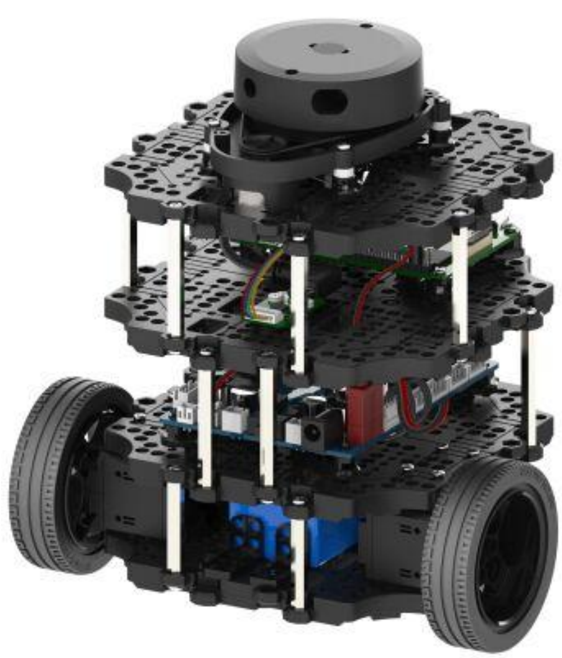
General Information:
TurtleBot2 is an open-source mobile robot platform designed for education, research, mobile robotics, SLAM, and autonomous navigation studies. It is fully compatible with ROS (Robot Operating System) and is widely used as a standard educational robot in university laboratories worldwide. Its chassis is lightweight, modular, and designed for easy expansion.

Sensors and Hardware:
The primary perception sensor of TurtleBot2 is the Kinect v1 / Asus Xtion Pro depth sensor (depending on the model). This sensor provides strong performance for 3D mapping, object detection, and SLAM applications. The robot is equipped with a gyroscope, wheel encoders, bumper/collision sensors, and battery monitoring sensors. Its two-wheel differential drive structure enables agile and stable motion.

Connectivity and Power:
The main control computer is typically configured as a laptop or an Intel NUC mini PC. Connectivity options depend on the chosen computer and are provided via USB, Wi-Fi, and Ethernet. TurtleBot2 uses a high-capacity 12 V 22 Ah LiFePO4 battery and offers approximately 2–3 hours of operation on a single charge.

Mobility and Performance:
Built on the Yujin iClebo Kobuki base, TurtleBot2 delivers reliable and stable mobile driving. The differential drive system provides high accuracy for forward/backward motion, turning, maneuvering in narrow spaces, autonomous mapping, and navigation tasks. Wheel encoders improve motion control precision.

Software and Development:
The robot fully supports ROS (ROS1) and benefits from a broad open-source package ecosystem. It is an ideal platform for SLAM (e.g., gmapping, Cartographer), autonomous navigation, mapping, computer vision, and robotics applications. It can be easily programmed with Python and C++, and sensor/accessory integrations can be implemented quickly.



7- TurtleBot3 Burger (Raspberry Pi 4 – 2GB) – Technical Specifications

General Information:
TurtleBot3 Burger is an ultra-compact mobile robot platform designed for education, research, ROS/ROS2 applications, SLAM, and autonomous navigation. With its open-source, lightweight, cost-effective, and modular design, it is widely used in laboratories as a standard entry-level research robot. Thanks to its small 138 mm footprint and lightweight chassis, it offers excellent maneuverability in tight spaces.

Sensors and Hardware:
The robot's primary perception sensor is a 360° 2D LiDAR (HLS-LFCD-LDS), providing high accuracy for distance measurements. It also includes an IMU (3-axis accelerometer + 3-axis gyroscope), wheel encoders, and collision sensors. A Raspberry Pi 4 (2GB RAM) is used as the main computer, enabling smooth operation of ROS1 and ROS2 packages.

Connectivity and Power:
Remote control is possible via Wi-Fi through the Raspberry Pi. USB ports allow integration of a camera or additional sensors. TurtleBot3 Burger uses an 11.1 V Li-Po battery and provides approximately 1.5–2.5 hours of operation depending on the application. The rechargeable, easily replaceable battery module supports fast field deployment.

Mobility and Performance:
Its differential drive system delivers high accuracy for forward/backward motion, turning, and precise autonomous navigation. Wheel encoders improve odometry accuracy. Due to its low weight, collision, slope, and speed control are safer and easier to manage. The open-source motor controller (OpenCR) ensures stable motor control.

Software and Development:
TurtleBot3 is fully compatible with both ROS1 and ROS2. It works with mapping packages such as Gmapping, Hector SLAM, and Cartographer, as well as autonomous navigation software such as the Navigation Stack or Nav2. It can be easily programmed in Python and C++. Thanks to open-source mechanical designs, electronic schematics, and 3D printing files, it can be customized, expanded, and modified by users.

8- OpenZeka Mini Autonomous Vehicle Kit – Technical Specifications

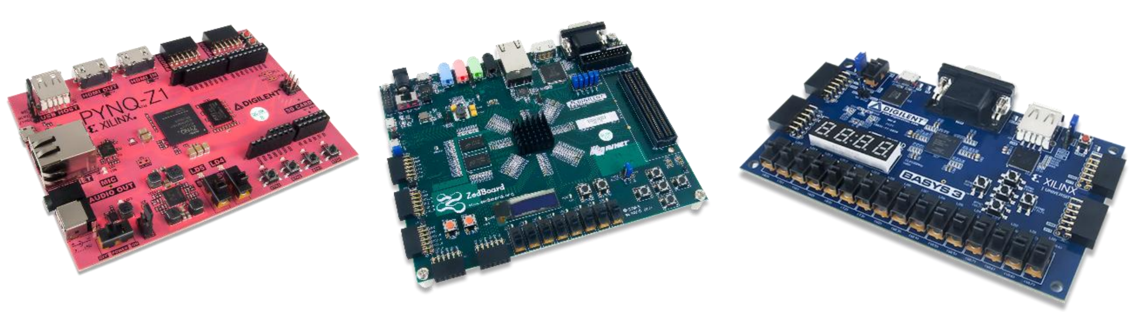
General Information:
The OpenZeka Mini Autonomous Vehicle Kit is a 1/10-scale mobile robotic vehicle platform designed for autonomous driving, deep learning, computer vision, mapping, and navigation research. It provides a standard solution for autonomous vehicle development training in universities and R&D laboratories. With its durable chassis, powerful AI computing unit, and multi-sensor perception architecture, it is ideal for modeling real vehicle behavior at a smaller scale.

Sensors and Hardware:
The vehicle supports 3D vision and depth perception using a ZED stereo camera, and enables environmental scanning, obstacle detection, and SLAM through a 360° LiDAR. In addition, an IMU (accelerometer, gyroscope, magnetometer) and wheel encoders allow precise measurement of position, stability, and motion. NVIDIA Jetson series platforms (available in the lab: TX1, TX2, and AGX Orion) are used as the computing unit, providing high performance for running real-time AI, computer vision, and autonomous driving algorithms.

Connectivity and Power:
The vehicle can be remotely managed via Wi-Fi. A 7-port USB 3.0 hub enables connection of the camera, LiDAR, and other peripherals. The power system includes a robust battery infrastructure capable of supplying the Jetson unit, sensors, and drive motors simultaneously. A high-capacity battery provides long operating time and is designed to be quickly replaceable.

Mobility and Performance:
The mini vehicle platform supports forward/reverse driving, precise steering, realistic acceleration/deceleration, and stable motion across different surfaces. Its control model, similar to differential-drive logic, is suitable for testing autonomous driving algorithms. High-accuracy mapping, obstacle detection, lane following, and route planning can be achieved using fused LiDAR and camera data.

Software and Development:
It comes with a ready-to-use autonomous vehicle software stack: joystick-controlled driving, data logging, lane tracking, traffic sign recognition, SLAM, and autonomous navigation functions are provided as baseline features. Thanks to its ROS-based architecture, users can implement new algorithms using Python or C++. Deep learning models can be deployed on the Jetson platform, and the open-source design allows the system to be easily extended and customized.



9- FPGA Boards – Technical Specifications

Our laboratory is equipped with PYNQ-Z1/Z2, ZedBoard, and Basys FPGA development boards, as well as high-cost, specialized FPGA platforms offering high computational performance and advanced image processing capabilities.

10- DJI Tello – Technical Specifications

General Information:
DJI Tello is a compact educational drone widely used in training and research activities such as computer vision, flight control, autonomous flight algorithms, and drone programming. Thanks to its lightweight structure, safety protections, and ease of programming, it is an ideal platform for laboratories, schools, and robotics training centers. Tello provides a reliable entry-level experience for both manual flight and basic autonomous missions.

Sensors and Hardware:
Tello maintains stable indoor flight using a downward-facing optical flow sensor and an ultrasonic altitude sensor. Its 5 MP camera provides a 720p HD video stream, serving as a suitable data source for applications such as image processing and target tracking. The IMU unit (accelerometer + gyroscope) improves stability and flight control. Its lightweight yet durable frame is suitable for intensive educational use.

Connectivity and Power:
The drone connects via Wi-Fi to a smartphone, computer, or control applications using the Tello SDK. Real-time video transmission is provided over Wi-Fi. Tello uses a 3.8 V 1100 mAh Li-Po battery and typically offers 12–13 minutes of flight time. Since the battery is easily replaceable, continuous use can be maintained in educational environments.

Mobility and Performance:
Tello supports automatic takeoff/landing, hovering, agile maneuvers, and safe flight modes. While providing high stability indoors, it also enables entry-level obstacle avoidance behavior and simple autonomous routines through programming. Due to its light weight, it has high tolerance to minor collisions, and its low-power propellers contribute to a safe learning experience.

Software and Development:
Tello can be easily programmed in Python using the Tello SDK. It is also used with Scratch, ROS via TelloBridge, OpenCV-based computer vision applications, and AI-driven control projects. In educational settings, it is commonly applied in studies such as autonomous flight, object recognition, drone choreography, and AI-assisted motion control.

11- ROBOTIS OpenMANIPULATOR-X (RM-X52-TNM) – Technical Specifications

General Information:
OpenMANIPULATOR-X is a modular robotic arm/manipulator platform developed with open-source hardware and software. It is suitable for education, research, mobile manipulation, pick-and-place tasks, kinematic/dynamic control, ROS-based robotics projects, and automation applications. Thanks to its lightweight and compact design, it can be used on desktop systems or integrated onto mobile robot platforms (e.g., TurtleBot3).

Sensors & Hardware / Actuation:

- **Actuators:** DYNAMIXEL XM430-W350-T servo motors
- **Degrees of Freedom (DOF):** 5 (4-DOF arm + 1-DOF gripper)
- **Maximum Payload:** 500 g
- **Joint Speed:** ~46 RPM (per joint)

Dimensions & Mechanics:

- **Assembled Weight:** ~0.70 kg
- **Reach:** ~380 mm
- **Gripper Opening Range:** ~20–75 mm

Electrical & Communication:

- **Input Voltage:** 12 V DC
- **Communication Interface:** TTL-level multidrop bus (DYNAMIXEL bus)

Control / Software / Development:

- **Controller:** Can be operated via a PC or an embedded controller such as OpenCR.
- **Software Compatibility:** Supports ROS (ROS and ROS-compatible), DYNAMIXEL SDK, Arduino, Processing, etc.
- **Key Features:** Open-source hardware and software, modular architecture, easy assembly/maintenance/expansion, and suitability for integration with mobile platforms.

Applications & Use Cases:

- Desktop manipulation and pick-and-place tasks
- Research and development of robotic control algorithms
- Building a mobile manipulator (e.g., robotic arm + wheeled base)
- ROS-based education and laboratory experiments
- Prototyping, end-user automation, and grasping tasks

12- DJI Mavic Pro 2 – Technical Specifications

General Information:
DJI Mavic Pro 2 is a compact and portable quadcopter designed for professional and hobbyist drone applications such as aerial photography, video recording, mapping, and surveillance. With its foldable structure, low weight, and powerful camera and sensor system, it is suitable for travel, field operations, and educational/research use.

Sensors and Camera:

- **Camera Sensor:** 1-inch CMOS, 20 MP effective pixels
- **Lens:** 28 mm equivalent (wide-angle), f/2.8–f/11 aperture range
- **Photo Resolution:** 5472 × 3648 px
- **ISO Range:** Photo (100–3200 auto / 100–12800 manual), Video (100–6400)
- **Shutter Speed:** 8 – 1/8000 s electronic shutter
- **Video:** 4K video recording with HDR and high-quality formats (H.265 / 10-bit), supported by DJI's advanced gimbal stabilization
- **Additional Sensors / Safety:** Equipped with an omnidirectional obstacle sensing and safety sensor suite

Connectivity and Control / Communication:

- Remote controller with GPS/GLONASS satellite positioning and sensor-assisted stabilization
- **Video Transmission System:** DJI OcuSync (current series) for HD video and control link transmission
- Real-time flight data monitoring, auto return-to-home, and safety functions

Power and Flight Performance:

- **Intelligent Flight Battery:** 3850 mAh (LiPo 4S) / 59.29 Wh
- **Maximum Flight Time:** ≈ 31 minutes (under ideal conditions)
- **Maximum Flight Speed:** 72 km/h (≈ 44.7 mph)

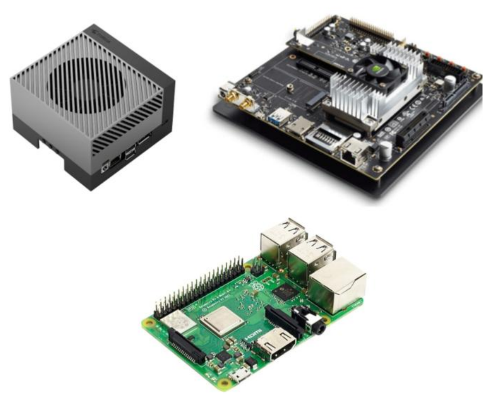
- Stable hover with GPS-assisted position hold, safe takeoff/landing, and autonomous mission modes

Applications and Use Cases:

- Aerial photography and 4K video production (high-resolution imaging)
- Mapping, terrain inspection, agriculture, infrastructure control, and field surveillance
- Image processing, orthophoto generation, and UAV map production
- Drone programming, automation, and sensor integration for education and research

13- LiDAR and Camera Sensors – Technical Specifications

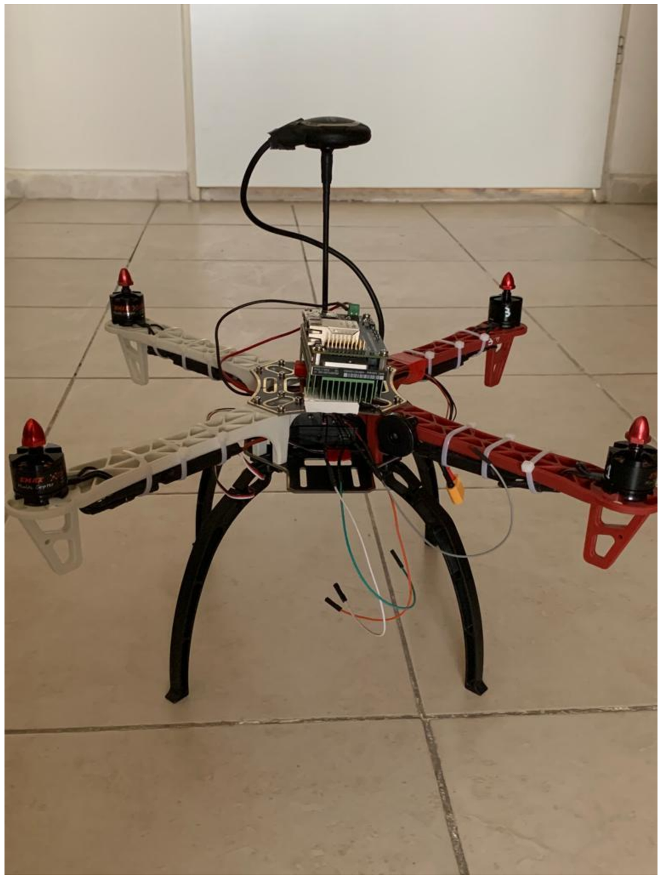
Our laboratory is equipped with 2D LiDAR, 3D LiDAR, and ToF LiDAR sensors, as well as ZED 1 and ZED 2 cameras and Kinect v1 and v2 cameras. In addition, a Raspberry Pi Camera and a FLIR Dev Kit thermal camera are available.



14- Embedded Computing Boards – Technical Specifications

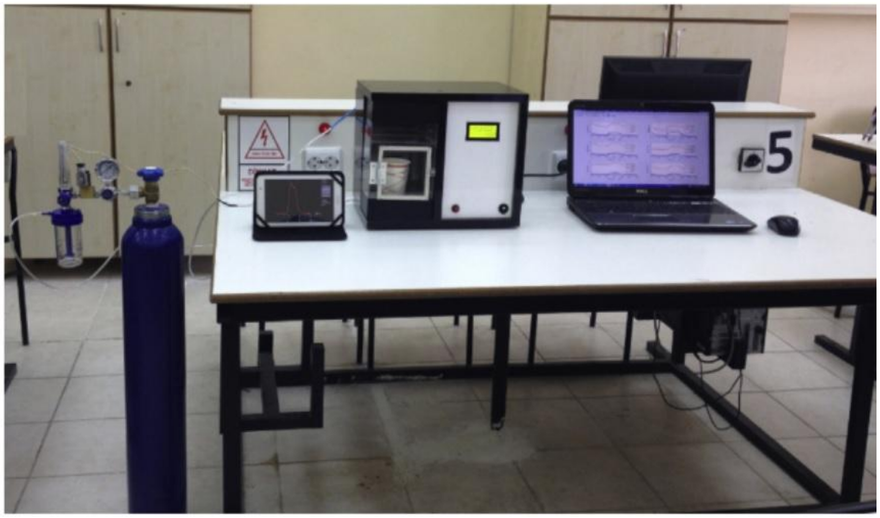
Our laboratory is equipped with Jetson TX1, Jetson TX2, Jetson AGX Orin, Raspberry Pi boards, and various Arduino models.

15- Hand-Built Humanoid Aerial Vehicle Powered by Jetson TX2



16- Hand-Built Flying Bird

17- AI-Powered Electronic Nose



18. Autonomous Powered Wheelchair

19- Computers

Our laboratory has two laptops and three desktop computers equipped with NVIDIA graphics cards, procured between 2014 and 2024.

20- Sensors

Our laboratory is equipped with a long-range communication kit, as well as various IMU sensors and Pixhawk sensors and autopilot units.