DIGITIZING PRODUCTS:
CREATING DEMONSTRATORS
FOR FUTURE EDUCATION

digi demo

Framework for Demonstrators

A Guideline to Develop, Classify and Document Demonstrators

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Project consortium

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Dissemination level

Code	Access granted to	
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Legal Disclaimer

About the DigiDemo project

Environmental challenges and digital transformation are two of the main drivers changing the world and the way business will be is done in the future. Therefore, it is essential to enable future employees to address these drivers. The skills and competences needed to develop digitalized products and awareness of the environmental challenges are therefore crucial for the European workforce and industry to continue being competitive in a future green economy and to maintain jobs across Europe.

The DigiDemo project addresses these challenges by developing demonstrators especially for higher education allowing to improve mainly mechanical engineering studies by integrating skills and competences allowing them to understand, develop and commercialise connected products. The results will be publicly available and can be used by every institution interested in integrating this type of training in their cursus.

www.digidemo-project.eu

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Abbreviations

ESTA	ESTA Belfort (France)
FHV	Fachhochschule Vorarlberg (Austria)
FSV	Fagskolen I Viken (Norway)
IoT	Internet of Things
SME	Small and Medium Enterprises
UBB	Centrul Universitar UBB din Resita (Romania)
UCN	University College Nordjylland (Denmark)

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1 Introduction

This document describes demonstrators. In brief these are educational setups to be used in academic education of mechanical and electrical engineers to improve the students' skills in digitalizing products.

The target audience of the document are teachers using demonstrators in their educational environment or developing new ones.

Demonstrators are to be used in courses either to demonstrate (show) something, but more likely to have students do practical work using the demonstrators. This allows reaching higher levels of learning according to Bloom's taxonomy (Anderson & Krathwohl, 2000).

The term of digitalization used in this document consists of mainly two other terms: mechatronics and Internet of Things (IoT). Mechatronics is the connection of mechanical and electrical components with software allowing the implementation of intelligent products. IoT connects these intelligent products to a cloud allowing additional services to be supplied (e.g. predictive maintenance). An illustration of this connection is given in Figure 1. A digitalized product ideally spans the entire range.

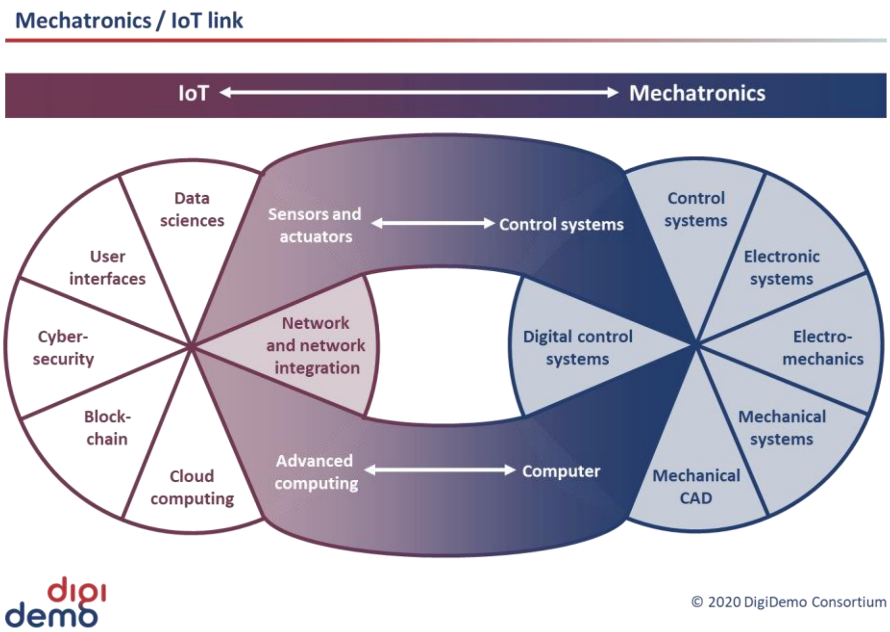

Figure 1: Digitalization as connection of mechatronics and IoT (DigiDemo Consortium (2021) based on Vaccaro et al. (2016))

This framework shall be seen as a guideline – not a step-by-step guideline, but rather a checklist – to develop, classify and document demonstrators.

The structure of the document is as follows. Chapter 2 specifies the characteristics of a demonstrator, chapter 3 lists the key properties a demonstrator needs, whilst chapter 4 enumerates dimensions along which demonstrators have to be classified. An overview of both mandatory and optional elements of demonstrators is given in chapter 5. Finally, chapter 6 includes an example description of a demonstrator.

2 Characteristics of a Demonstrator

This chapter lists the characteristics of a demonstrator.

Every person or team developing a demonstrator shall reflect on the way it conforms to these characteristics.

2.1 It shall improve teaching

The rationale of a demonstrator is to strengthen the cross disciplinary capabilities of students. By using the demonstrator in a course, the learning outcomes with respect to digitalization shall be improved.

2.2 It shall improve sustainability awareness

By using the demonstrators, students shall be aware of sustainability issues and get used to include this aspect into the design of every system from the very beginning. Sustainability is mainly meant as sparing use of resources, both raw materials and energy and good recycling properties (as detailed in chapter 0).

2.3 It shall be replicable

Any academic institution shall be able to implement its own demonstrator by using the data supplied by the creator of the demonstrator. This shall be feasible with as low as possible effort, both workload and materials. Hence the demonstrator materials will be open source. A copyright license can be added (e.g. CC BY-SA).

2.4 It shall follow industry needs

One of the main goals for using a demonstrator is to ensure that industry gets highly skilled engineers, able to promote digitalization of products. In order to ensure this purpose a demonstrator shall be based on an explicit use-case from industry, preferable of a SME (Small and Medium sized Enterprise), since these companies have higher challenges in incorporating digital elements into their products. In the description of this characteristic the concrete industrial example shall be given.

2.5 It shall be interdisciplinary

Interdisciplinarity is a must in today's product design; hence a demonstrator shall improve students' interdisciplinary skills. In order to address this issue, several elements of the chain of technology dimension (as listed in chapter 4.2) shall be covered.

3 Key Properties of a Demonstrator

This chapter lists the key properties of a demonstrator in its original use. They allow a teacher to briefly evaluate if the demonstrator is suited for their course. These Properties need to be specified in the first chapter of a demonstrator description, the Overview.

3.1 EQF level

According to the European Quality Framework this can be: 5 (Technician), 6 (Bachelor), 7 (Master) or 8 (PhD).

3.2 Year of study

The year of study within the program in which the demonstrator is used shall be specified. In general, more a demonstrator is used towards the end of studies, more it will be complex and challenging for students.

3.3 Objective

A demonstrator can be either be used to **demonstrate** a functioning, or, more likely, will need an active participation – **hands-on** – of the students.

3.4 Domain

This can be either **Mechatronics** or **IoT** (Internet of Things) or **both**.

3.5 Workload

The student's workload shall be defined in ECTS credits.

3.6 Keywords

Relevant keywords shall be specified, allowing a quick first evaluation and a search in a larger database.

4 Dimensions for the Classification of Demonstrators

This chapter defines the dimensions among which demonstrators shall be classified. It also offers a guideline how to do this classification and states minimal requirements.

4.1 Value chain

Digitalization can be valuable in several stages of the product life cycle. For this reason, the position of the demonstrator in the value chain must be considered. Usual stages are listed below.

In product **development** specific features can be built in (e.g. data acquisition, cloud communication) enabling later use.

In the **production** stage data on the manufacturing process can be used for quality assurance or traceability.

In the case of **sales**, data can be used for product configurators, used either by the customer or the sales personnel.

In **after-sales-support** digital information can be used for instance to improve product usability or for predictive maintenance.

In the **end-of-life** stage data can be used for appropriate recycling of the product.

It might not be possible to cover all stages of the value chain, but at least **two** stages shall be strived for.

4.2 Chain of technology

In technical products designed by mechanical and electrical engineers, different technological elements shall be considered to achieve digitalized products including the benefits digitalization can offer.

An understanding of the **mechanical structure** of the system is mandatory in order to know where to place appropriate sensors to get meaningful data. The information provided by the **sensors** must be transformed using **electronic circuits**, which need to be designed or adapted, in order to be preprocessed on **edge devices** (embedded systems), where filtering and data reduction will take place. For **data transmission** appropriate networks shall be chosen and protocols must be used. Finally, the **cloud** must be considered, where data storage and data processing will occur.

A demonstrator shall cover at least **four** of these elements in the chain of technology.

4.3 Sustainability

Educating engineers with a mindset for sustainability becomes a must in the future. Demonstrators shall address sustainability issues engineers can include in their daily doing. The following list gives easy applicable sustainability elements:

- Reduce energy consumption of the product
- Reduce material consumption of the product
- Use materials with better environmental characteristics in the product
- Use manufacturing processes with better environmental characteristics
- Develop a product that can be easily repaired, components changed or upgraded
- Consider recycling (end-of-life) of the product

A demonstrator shall cover at least **three** of these sustainability elements.

4.4 Physicality

A demonstrator can be either a physical setup or a simulation.

4.5 Degree of student freedom

It is necessary to know in which manner students need to be guided by the tutor if the demonstrator is intended for hands-on activity. The following can apply:

- **Demonstrated**: The setup is used to demonstrate; no active interaction of the students is needed.
- **Guided**: It is necessary that the tutor is present all the time students work with the demonstrator.
- **Coached**: The students need to be coached by the tutor on a regular basis in order to check if the goals are reached and the direction of work is appropriate.
- **Autonomous**: The students work largely autonomous. They only ask for support, if needed. It is up to them, when to do it and what to ask.

4.6 Transportability

In some educational settings it can be important to move the demonstrator from one room to another or even from one campus to another. A demonstrator shall be classified as follows.

- **Fixed**: This can be due to weight, size or special infrastructure required (e.g. compressed air, water supply), or if it is too delicate to be transported.
- **Transportable**: This is the case if the setup can be moved e.g. by using a trolley.
- **Portable**: If its size and weight are moderate and it can be carried in a bag.

4.7 Costs

The **costs** (excluding the workload) needed to implement the demonstrator must be specified in **EUR**. These shall include the **materials** but also **licenses** or **external services** if applicable. If applicable also the costs needed to operate the demonstrator shall be specified.

4.8 Workload

The **workload** needed to implement the demonstrator must be specified in **work hours**. This workload includes only the effort needed to make the demonstrator run and not the effort needed to integrate the demonstrator into the course. Additionally, if applicable, the workload for preparatory and follow-up activities shall be specified.

4.9 Size

The size of the demonstrator must be specified (length, width, height).

4.10 Weight

The weight of the demonstrator must be specified.

4.11 Special requests

Does the demonstrator have special requirements (e.g. infrastructure) (yes/no)? If yes, then this needs to be specified: three-phase voltage, compressed air, water supply, etc. Also, the quality level needs to be specified (e.g. pressure of compressed air).

5 Elements of a Demonstrator

This chapter lists elements a demonstrator must contain. All of them are mandatory, except for some sub-elements at 4 e) and f), since not all the items listed there are relevant to all demonstrators.

5.1 Overview

A brief overview of the demonstrator is the first mandatory element.

The first part of the overview is the specification of the key properties:

Table 1: Specification of key properties

Key Property	Value
EQF level	
Year of study	
Domain	
Objective	
Workload	
Keywords	

The next shall be a brief description of the demonstrator.

The justification for the overview is to allow a teacher to decide swiftly if the demonstrator could be of interest for their teaching context.

As this text is also intended to be used by the teacher in their courses, it shall contain a broader contextual description of the case, allowing the students to understand the context.

Photos of the demonstrator shall be included, and a block schematic if meaningful.

5.2 Description of fulfilment of demonstrator characteristics

This description shall be included as a table as shown below:

Table 2: Description of fulfilment of demonstrator characteristics

Characteristic	Description
Teaching improvement	
Sustainability awareness	
Replicability	

Characteristic	Description
Industry needs	
Interdisciplinarity	

5.3 Classification according to the dimensions

A demonstrator must be classified along the dimensions specified in chapter 4 by filling in the table below.

Table 3: Classification according to the dimensions

Dimension	Property	Value
Value chain	development	☐
	production	☐
	sales	☐
	after-sales-support	☐
	end-of-life	☐
Chain of technology	mechanical structure	☐
	sensors	☐
	electronic circuits	☐
	edge device	☐
	data transmission	☐
	cloud	☐
Sustainability	energy reduction	☐
	material reduction	☐
	better materials	☐
	better production	☐
	reparability	☐
	recycling	☐
Physicality	physical setup	☐
	simulation	☐
Degree of student freedom	demonstrated	☐
	guided	☐
	coached	☐
	autonomous	☐
Transportability	fixed	☐

Dimension	Property	Value
	transportable	☐
	portable	☐
Costs (implementation)	EUR	
Costs (operation)	EUR	
Workload (implementation)	Hours	
Workload (operation)	Hours	
Size	m	
Weight	kg	
Special requests	no/yes, if yes: which	

5.4 Educational information

As the demonstrator is to be included into an educational setting, an exemplary use in a course is valuable information for the prospective user.

The description of the course in which the demonstrator is used at the university of origin shall include typical elements of course descriptions: credits, prerequisites, learning outcomes (both hard and soft), course contents, teaching methods, assessment method and criteria, recommended reading.

Also, a description of the way in which the demonstrator is integrated into the course shall be provided, including at least the following elements of the demonstrator itself: number of credits, prerequisites and learning outcomes.

It is also important to know in which study programs the students using the demonstrators are enrolled in the original setup.

5.5 Organizational information

Some information is important to be supplied, on the way the project shall be organized, in which the demonstrator is integrated:

- Project duration. The optimal time frame (for instance in weeks) for the project shall be estimated.
- Team size. The number of student team members is useful.
- Preparatory and follow-up activities. If this type of activities is needed prior to the use of the demonstrator, or after the project has been finished, these shall be listed.

5.6 Description of the technology and the setup

This description is very important to allow the teacher to replicate the demonstrator. Therefore, the following is needed:

- For the mechanical parts the CAD drawings, part lists and assembly information must be provided.
- As for the electrical part of the system the schematics and the part lists are mandatory. If relevant also test programs and/or layout data shall be provided.
- Regarding the software firstly the relevant diagrams must be included (e.g. class diagram, state diagram, flow chart, interaction, sequence diagram), allowing the user to understand the software. Secondly the commented source code must be added, as well as information about the tools used (and licenses needed, if applicable) and test programs, if relevant.
- If applicable a manual on how to use the demonstrator shall be supplied.
- Since the data of the previous four points is usually available in separate documents (files), a commented list of documents provided with the description shall be added.
- Finally, background information on the rationale must be supplied in text form, allowing the user to make modifications to the demonstrator, if needed.

6 Example Description

This is a first example description of the existing FHV "Focus Project" setup using the above elements. Some elements of a demonstrator are missing since it has been set up long before the start of the DigiDemo project.

6.1 Overview

The key properties of the focus project are:

Table 4: Specification of key properties of the focus project

Key Property	Value
EQF level	6 (Bachelor)
Year of study	3
Domain	Mechatronics
Objective	Hands-on
Workload	10 ECTS
Keywords	Gantry robot, manipulator, stepper motor, pick-and-place, PLC

The focus project is part of a course in the 5th semester of the mechatronics undergraduate program at FHV. This semester is the exchange semester in which many of the students working in the project are from partner institutions. The typical class size is 20 – 25. Students are split into five teams of 4-5 people. The teams are mixed in several manners. Both exchange students (from different countries) and local students work in a team. Students are allowed to choose between two courses "focus mechanical engineering" and "focus electronic engineering", depending on their interests. Students from both the mechanical and the electronic course work in a team. A gantry robot as can be seen in Figure 2 is given. X and Y axes are controlled by a Beckhoff PLC which is given too. The task of the students is to add a Z axis moved by a stepper motor controlled by an embedded system, build a gripper and a spinning top (to be picked and then placed) and some other parts needed. The details of the task are given below.

The students' task is not only to design, implement and test the missing components, but also to set up a requirements specification document and to put all things together and make the mechatronic system running.

Figure 2: Two focus project setups in a typical lab environment

Task Desciption The students' task is to build a manipulator that will package 4 spinning tops in a box with a lid. The lid will have a slot for a card, and the manipulator will put a stamp on the card. A brief overview of the task is given in Figure 3.

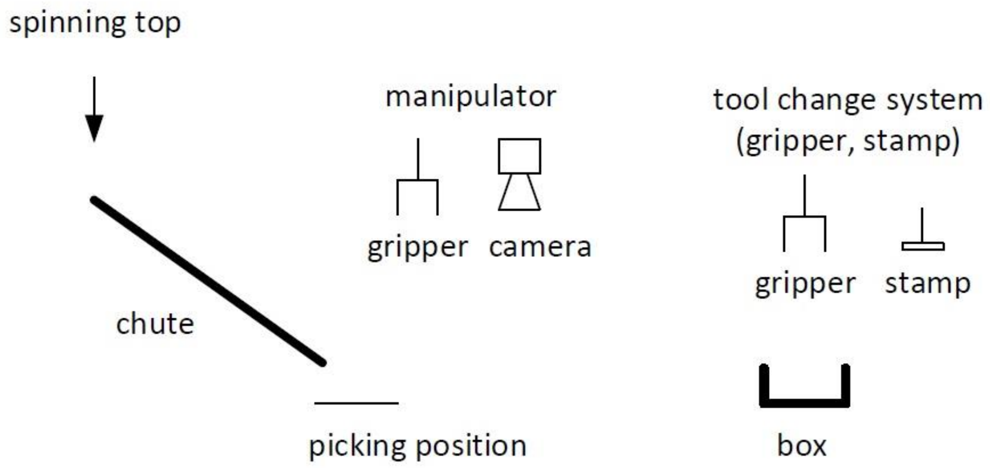

Figure 3: Brief overview of the task

Process Flow

- The operator must drop the first spinning top into a defined position on a feeding chute.
- The operator can drop the spinning top in any orientation, the top doesn't have to be upright when the operator drops it.
- The spinning top slides down the feeding chute towards the picking position and it realigns to become upright when it lands in the picking position.
- When the top cannot be realigned, it shall drop off the chute.
- The manipulator grips the spinning top at the picking position and places it in compartment 1 of the box.
- The operator drops the next spinning top.
- The process repeats, beginning with step 1, until the box is full.
- The manipulator closes the lid, changes the tool and stamps the card on the lid.
- A smart camera is used for checking the success of different process steps.

Packaging

- The picking position and casing (box) must be in diagonally opposite positions on different heights.
- Minimum distance between picking position and box in X, Y and Z-direction: 300mm, 150mm, 50mm
- The manipulator realizes all movements with high speed.

Stamping

- The students design and manufacture a stamp which is used by the manipulator for stamping a card which is manually inserted in a slot of the lid.

Force Measurement

- The force in direction of the Z-axis must be measured and displayed during the whole process.

Graphical user interface

- A graphical user interface (GUI) is used to: start and stop the process; show status of the machine; display force signal

Mechanical parts

Spinning top

The students construct a spinning top. The maximum diameter is 30mm and maximum height is 40mm.

Casing (box) with lid

- The students build a casing with a lid for packaging 4 spinning tops.
- The casing shall be able to hold 4 spinning tops in 4 separated compartments.
- The casing has a lid with a hinge.
- The lid has a slot for a business card.
- The casing shall be suited for assembly automation.

Feeding chute

- The students build a mechanical construction (without actuators) for delivering a spinning top.
- The spinning top is manually put down at a predefined position. The orientation of the spinning top is undefined.
- The feeding chute shall reorient the spinning wheel in a defined orientation and moves the part to the picking position.

Z-axis

- The students construct a Z-axis which is actuated by a stepper motor.
- The Z-axis uses a force sensor for measuring the forces in Z-direction during the hole process.
- The students use a dummy for the force sensor, which can be used for testing the system without force sensor.

Protector

- The students build a protector that can detect a crash before or during a collision of the tools.
- The protector is compliant in X and Y-axis.
- The protector sends a signal to the PLC which stops the movement.
- The protector can be mounted (or removed) within 1 minute.
- It shall be possible to replace the protector with a dummy in order to test the functionality beforehand or whenever it is removed.
- The dummy can also be mounted (or removed) within 1 minute.

Tools

- The students construct a tool 1 (gripper) for gripping spinning wheels.
- The gripper for grabbing the spinning wheels must not use an additional motor; using an electromagnet is allowed.
- The students construct a tool 2 (stamp) for stamping cards.

Tool change system

- The students construct a tool change system for changing tool 1 and tool 2 which uses snap connections. It is not mandatory that the students use a tool change system.

Mechanical Engineering

- Mechanical construction and manufacturing of all parts
- Most of the parts shall be manufactured with 3D printing (at FHV).

PLC Programming

- Sequence control
- Motor movements
- Monitoring of force
- GUI

Electronic Engineering

The movement of the Z-axis and the force measurement shall be realized with an embedded system:

- ❖ Design and manufacturing of a carrier board which connects the strain gauge signal amplifier and the motor driver and the RS232 level shifter.
- ❖ Design and manufacturing of voltage supply for the carrier board, because the carrier board is supplied from 24V DC and the supply voltages needed by the other boards must be generated.
- ❖ The maximum size of the carrier board is 100mm x 100mm.
- ❖ It is highly recommended (but not mandatory) that the students design and manufacture their own strain gauge signal amplifier and/or motor driver and/or RS232 level shifter.
- ❖ Microcontroller programming must include Z-axis-movement (SPI communication) and force measurement (AD-conversion) and communication (RS232) with the PLC.

Mechatronics

- ❖ Requirements analysis
- ❖ Writing requirements documents
- ❖ The result will be checked against the requirements documents
- ❖ Design, development, testing of the complete system

Image Processing

- ❖ A smart camera is used for checking the success of different process steps.
- ❖ The smart camera is triggered by the PLC (digital IO).
- ❖ A digital output of the smart camera is connected to the PLC for signaling the result of the visual check.
- ❖ Option: the smart camera sends further information (e.g. color of spinning top) to the PLC for visualization.

Figure 4 shows a block schematic of the focus project.

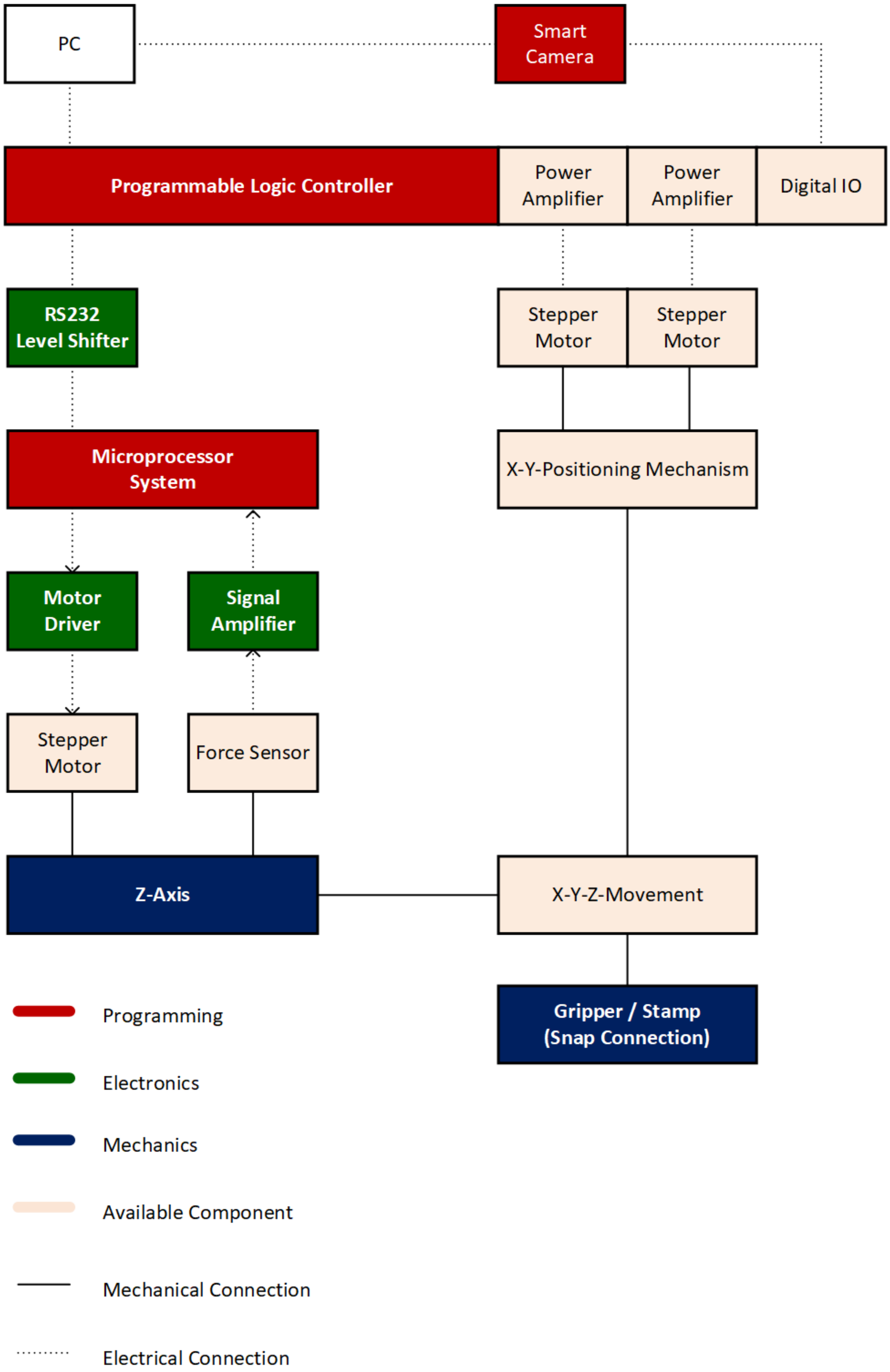

Figure 4: Block schematic of the focus project

6.2 Description of fulfilment of demonstrator characteristics for the focus project

The manner how the focus project conforms to the characteristics defined in chapter 2 is shown below:

Table 5: Description of fulfilment of demonstrator characteristics for the focus project

Characteristic	Description
Teaching improvement	The focus project allows the students to go through the entire process of development of a mechatronic product starting with requirements, through design, implementation, test, and integration of both mechanical and electronic components with software. They work in interdisciplinary teams.
Sustainability awareness	This issue is **not** addressed by the existing setup.
Replicability	The demonstrator is implemented using off the shelf components, which are easy to replicate.
Industry needs	As the demonstrator is a gantry robot, lots of pick and place application in industry exist.
Interdisciplinarity	The demonstrator requires both electrical and mechanical engineers to cooperate in implementing a mechatronic system. Software components are also part of the project, both PLC and microcontroller programming.

6.3 Classification of the focus project according to the dimensions

This is given in the table below.

Table 6: Classification of the focus project according to the dimensions

Dimension	Property	Value
Value chain	development	☑
	production	☑
	sales	☐
	after-sales-support	☐
	end-of-life	☐
Chain of technology	mechanical structure	☑
	sensors	☑

Dimension	Property	Value
	electronic circuits	☑
	edge device	☑
	data transmission	☐
	cloud	☐
Sustainability	energy reduction	☐
	material reduction	☐
	better materials	☐
	better production	☐
	reparability	☐
	recycling	☐
Physicality	physical setup	☑
	simulation	☐
Degree of student freedom	demonstrated	☐
	guided	☐
	coached	☑
	autonomous	☐
Transportability	fixed	☐
	transportable	☑
	portable	☐
Costs (implementation)	EUR	7500
Costs (operation)	EUR	100
Workload (implementation)	Hours	150h
Workload (operation)	Hours	8h
Size	m	0.9 x 0.65 x 0.7
Weight	kg	50
Special requests	no/yes, if yes: which	no

6.4 Educational information

The focus project is the core of two courses. The students enrolled in the Mechatronics undergraduate program can choose among “Focus Electronic Engineering” and “Focus Mechanical Engineering”. Both courses have a workload of 18 ECTS credits and a total of 120 contact hours, both for teaching and coaching.

Mixed teams are set up to work together on the focus project. The workload for the project itself is 10 ECTS credits. The courses prepare the students for the project work and take place in advance, respectively while the students set up the requirements specification document.

The ECTS descriptions of the two courses are given below based on FH Vorarlberg (2020a) and FH Vorarlberg (2020b).

6.4.1 Focus Electronic Engineering

Prerequisites and co-requisites

To be specified

Course content

Requirement analysis: determining requirements, documenting requirements, checking and reconciling requirements, requirements management, systems development life cycle, SysML

Programmable Logic Controllers: automation pyramid, PLC versus microcontrollers, PLC versus soft PLC, function of a controller, introduction to IEC61131-3, applications, security

Practical aspects: industrial volume products, standards, risk analysis (FMEA), thermal management, protection circuits, EMC - design guidelines, reliability

E-CAD and E-manufacturing: electronic systems and components, methods for describing electronic systems and components, packaging, tools (overview), types of circuit, information coding, measurement circuits, communication, digital interfaces, signal interfaces, circuit design and PCB layout, manufacturing and assembly of electronic components.

Learning outcomes

The students can determine and document requirements.

The students can program a sequence control in the PLC programming language Structured Text.

The students can describe the process of risk analysis.

The students can apply selected best practices and design guidelines for thermal management, protection circuits, EMC and further selected topics.

The students can read and apply data sheets and application notes for electronic circuits.

The students are able to design simple circuits for power electronics (H-bridge) and measurement technology (instrument amplifier).

The students are able to design PCB prototypes considering the most important layout design rules.

The students can program a microcontroller (digital IO, ADC, SPI communication, UART communication).

Planned learning activities and teaching methods

Lectures, project work, coaching sessions

Assessment methods and criteria

Written examination, technical documentation, project result.

Recommended or required reading

To be specified

Mode of delivery (face-to-face, distance learning)

Face-to-face

6.4.2 Focus Mechanical Engineering

Prerequisites and co-requisites

To be specified

Course content

Requirement analysis: determining requirements, documenting requirements, checking and reconciling requirements, requirements management, systems development life cycle, SysML

Programmable Logic Controllers: automation pyramid, PLC versus microcontrollers, PLC versus soft PLC, function of a controller, introduction to IEC61131-3, applications, security

CAD: snap connections, manipulators, CAD

FEM: computer aided engineering, principle of the finite element method, types of structural analyses, function of structural analyses, finite element analyses, procedure, adjusting the geometry, boundary conditions, element types, material, mesh, common mistakes in modeling.

Learning outcomes

The students can determine and document requirements.

The students can program a sequence control in the PLC programming language Structured Text.

The students can describe the process of risk analysis.

The students can design and manufacture snap connections.

The students can design and manufacture a simple manipulator.

The students can apply the FEM (finite element method) to a mechanical structure.

Planned learning activities and teaching methods

Lectures, project work, coaching sessions

Assessment methods and criteria

Written examination, technical documentation, project result.

Recommended or required reading

To be specified

Mode of delivery (face-to-face, distance learning)

Face-to-face

6.5 Organizational information

For the organization of the project the following apply:

- Project duration: the project spans an entire semester, starting in the first days of September and ending mid-December with the final presentations.
- Team size: The project teams are mixed (both electronically and mechanically interested students) and the optimal size is of 4 – 6.
- Preparatory and follow-up activities. No special activities are needed. Prior to the start of the project the demonstrators must be set up and checked by a lab technician. After project completion the mechanical parts added by the project groups will be removed.

6.6 Description of the technology and the setup

We do not have a manual or background information on the rationale.

For the moment the document list is still incomplete:

	Filename/Folder	Comment	Software
00_Notes			
	FileStructure.xlsx	Description of the Files	
	Price_Calculation.xlsx	Calculation of the Material costs of the Build	
01_Pictures			
10_Documents			
20_ExportImport			
30_AdditionalEquipment			
	3ChannelEncoder	Datasheets of the Encoders used for the X- & Y-Axis	
	LinearModule	Datasheets of the Linear module of the Z-Axis	
	Microcontroller	Datasheets of the Microcontroler	
	RS232LevelShifter	Datasheets of the additional RS232LevelShifter	
	SmartCamera	Datasheets & Guids of the SmartCamera Omron MicorHAWK	
	StepperDrivers	Datasheets of all Drivers X-, Y- & Z-Axis	
	StepperMotorBoosterPack	Datasheet of the Stepper Motor BoosterPack	
40_Simulation			
50_CAD			
	Portal_Manipulator_new.prt	Total Assembly of the Project	Siemens NX
60_ElectricalLayouts			
	FOCUS_XY-Mechanik.elk	EPLAN Electrical layout ProjectFile	Eplan
	FOCUS_XY-Mechanik.pdf	Electrical layout of the Project	
70_Programming			
	PLC\BasePrj	Base Project of the PLC	
	PLC\Documents	Additional Documents for the PLC programming	
	PLC\Libs	Libaries and exteranl FB´s for the PLC programming	

Details of the price calculation can be found here:

Quantity (Unit)		Description	Price (per Unit)		Price (total)
7	m	Item Aluminium Profile 8 (40 x 40mm)	€ 21,00	€/m	€ 147,00
1	pc	Steelplate 600 x 800 x 12mm	€ 400,00	€/pc	€ 400,00
15	pc	Aluminium Parts (CNC Milled)	€ 40,00	€/pc	€ 600,00
2,5	m	Linear Axle	€ 10,00	€/m	€ 25,00
4	pc	Linear Bearing	€ 60,00	€/pc	€ 240,00
3	pc	Perspex (600x400)	€ 10,00	€/pc	€ 30,00
3	pc	Toothed Belt drive	€ 60,00	€/pc	€ 180,00
1	m	Energy Chain	€ 50,00	€/m	€ 50,00
1	pc	Linear Module Z-Axis	€ 50,00	€/pc	€ 50,00
1	pc	Force Sensor	€ 200,00	€/pc	€ 200,00
1	pc	Smart Camera	€ 2 700,00	€/pc	€ 2 700,00
3	pc	Steppermotor	€ 50,00	€/pc	€ 150,00
2	pc	3 Channel Encoder	€ 90,00	€/pc	€ 180,00
1	pc	Microcontroller Board Atmel	€ 60,00	€/pc	€ 60,00
1	pc	BOOSTER PACK DRIVER	€ 25,00	€/pc	€ 25,00
1	pc	RS232 SHIFTER	€ 15,00	€/pc	€ 15,00
1	pc	PLC CPU (CX5130-0175)	€ 900,00	€/pc	€ 900,00
1	pc	PLC C-Flash Card (CX2900-0026)	€ 70,00	€/pc	€ 70,00
1	pc	PLC Card (EL1859)	€ 60,00	€/pc	€ 60,00
1	pc	PLC Card (EL6001)	€ 175,00	€/pc	€ 175,00
3	pc	PLC Card (EL7041	€ 245,00	€/pc	€ 735,00
1	pc	PLC Card (EL3351)	€ 150,00	€/pc	€ 150,00
1	pc	small Material (Screws, Wire, Clamps)	€ 500,00	€/pc	€ 500,00
					€ 7 642,00 Total

Annex A: References

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