DIGITIZING PRODUCTS:
CREATING DEMONSTRATORS
FOR FUTURE EDUCATION

Lift Demonstrator

Demonstrator classification and documentation

Dornbirn, March 2023

Co-funded by the Erasmus+ Programme of the European Union

Project consortium

Dissemination level

Code	Access granted to	
PU	Public	PU
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.

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Revision history

Version	Date	Author(s)	Description
1.0	2022-01-31	Raphael Schönberger	Initial draft
1.1	2023-03-08	Horatiu O. Pilsan	Added sustainability educational information and did some minor corrections

Document status

Status description
Final Version

Abbreviations

ESTA	ESTA Belfort (France)
FHV	Fachhochschule Vorarlberg (Austria)
FiV	Fagskolen i Viken (Norway)
UCN	University College Nordjylland (Denmark)
UBB	Universitatea "Babes-Bolyai" din Resita (Romania)
PLC	Programmable Logic Control
DC	Direct Current
LED	Light Emitting Diode

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1 Introduction

This demonstrator is mainly intended to let the students practice programmable logic control (PLC) programming in the automation of mechatronic systems.

It can be used with various tasks depending on the expected learning outcomes. The following educational information gives an exemplary use.

2 Overview

The key properties of the lift project are:

Table 1: Specification of key properties of the lift project

Key Property	Value
EQF level	6 (Bachelor)
Year of study	2
Domain	Mechatronics
Objective	Hands-on
Workload	4-8 hours
Keywords	PLC programming, sequential control, fieldbus systems, motor control, measurement technology

The lift demonstrator is part of a course in the 4th semester of the mechatronics undergraduate program at FHV. Students are split into groups of 2 people. The demonstrator, which can be seen in **Error! Reference source not found.** is given. All digital and analog signals are connected to a Beckhoff PLC via EtherCAT fieldbus, and the DC motor is controlled via the servo-controller.

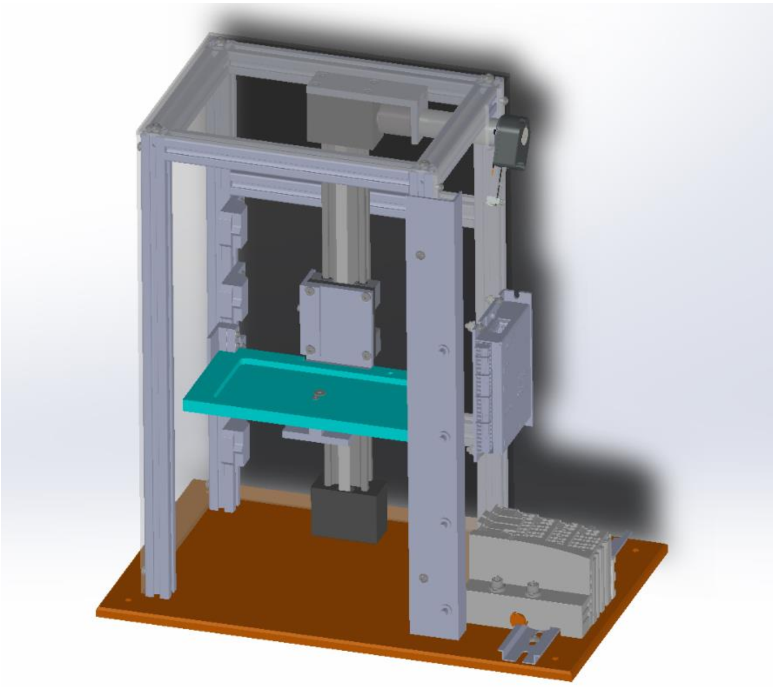

Figure 1: 3D-Assembly

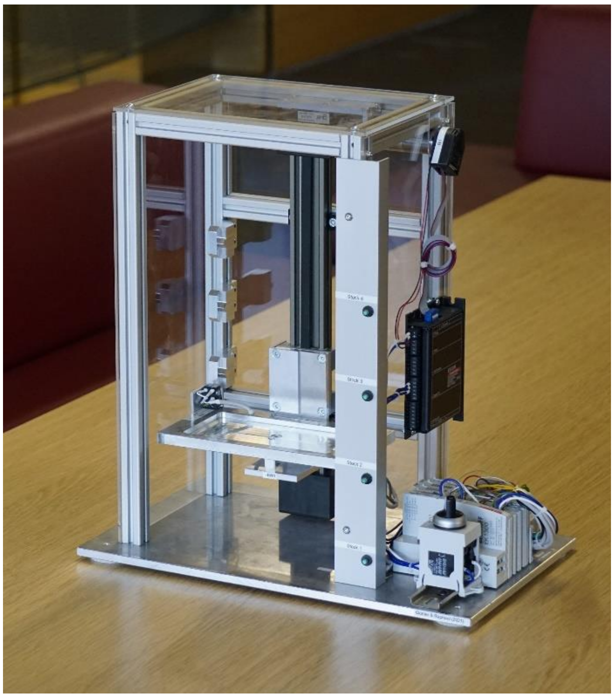

Figure 2: The lift setup

Task Description

The students' task is to implement and test the control of an elevator with 4 levels, which includes:

- the configuration of the EtherCAT fieldbus
- the configuration of the DC motor controller
- the programming of the sequential control and
- the overload protection for safe operation.

The Schematics of the Conveyor is given in Figure 3: Schematic of the lift project.

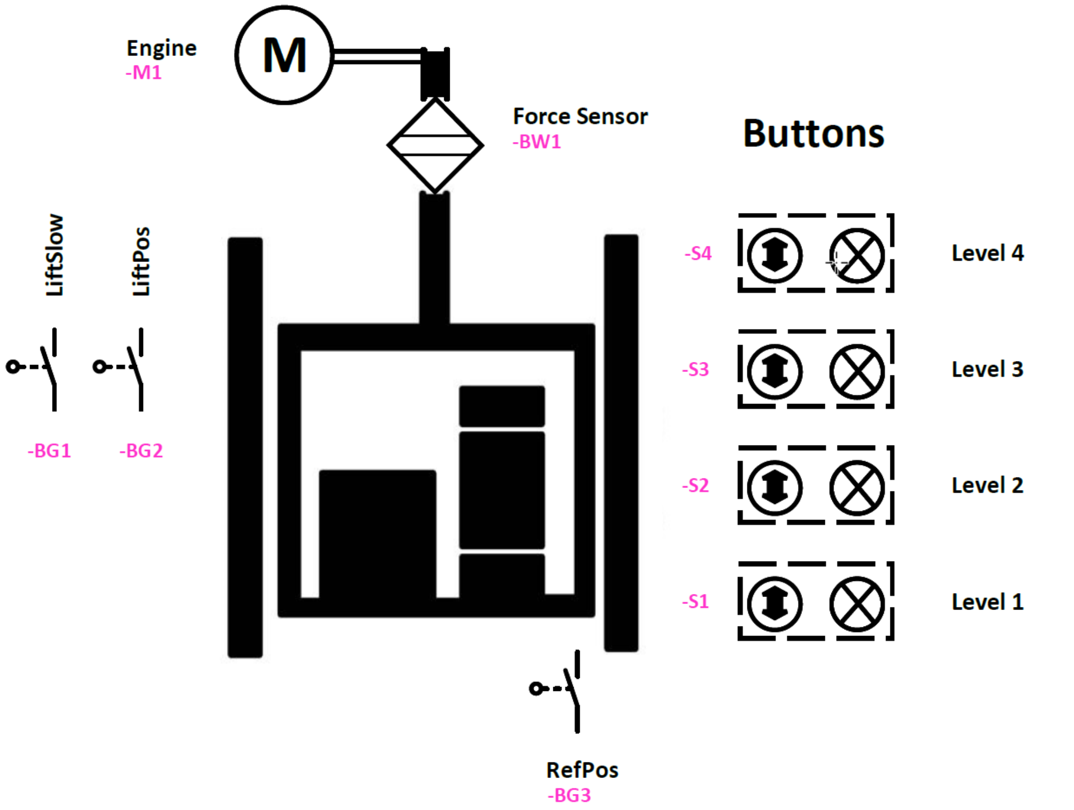

Figure 3: Schematic of the lift project

Equipment

-BG3	On startup, the lift shall move to the reference position
-S1, -S2, -S3, -S4	The operator can press a button. Each button has a corresponding LED for signaling a pending call.
-BG1, -BG2	Two limit switches are used for signaling the current position of the lift
-BW1	A force sensor is used for overload protection

3 Description of fulfilment of characteristics

The demonstrator fulfils the characteristics required as follows:

Table 2: Description of fulfilment of demonstrator characteristics for the lift project

Characteristic	Description
Teaching improvement	The lift demonstrator allows the students to understand the concepts of fieldbus technology, servo motor control, sequential control, and force measurement.
Sustainability awareness	Preventive monitoring for safe operation to avoid damage (force sensor). Modular build, using off the shelf components for easy replacement of broken parts.
Replicability	The demonstrator is implemented using off the shelf components, which are easy to replicate.
Industry needs	Industrial machines typically need the concepts and technologies which can be trained with the lift demonstrator: sequential controls, fieldbus technology, servo motor systems, sensor systems
Interdisciplinarity	The lift demonstrator includes different disciplines: - Software engineering (programming) - Electronics (DC motor, force sensor) Automation technology (fieldbus system)

4 Classification according to the dimensions

The demonstrator can be classified according to the dimension as follows:

Table 3: Classification of the lift 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	☑
	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	3000
Costs (operation)	EUR	0
Workload (implementation)*	Hours	100

Dimension	Property	Value
Workload (operation)*	Hours	4-8
Size	m	0.4 x 0.3 x 0.6
Weight	kg	3
Special requests	no/yes, if yes: which	no

* The workload refers to the effort needed by the teacher for implementation and operation of the demonstrator. As for the workload of the students please refer to chapter 5.

5 Educational information

5.1 Learning Goals

Communication: fieldbus technology: configuration of a EtherCAT communication system:

- Students understand the concepts of process image and fieldbus communication.
- Students are able to setup fieldbus communication with field devices.

Actuators: servo motor control: configuration of servo motor controller

- Students know how to configure a DC motor controller so that the motor can move in both directions with different speeds and trapezoidal velocity trajectory.

Programming: sequential controls: programming of sequential control

- Students know how to design and program a sequential control.

Sensors: force measurement: analog-digital conversion of signals

- Students understand force measurement using a full-bridge strain gauge configuration
- Students can configure PLC modules for analog signal conversion

5.2 Typical Task Description

A typical task description could be:

Implement and test a PLC program which observes following specification:

- After a download or reset, the lift moves to the reference position.
- Then the lift moves to the second floor.
- When a call button is pressed, a call is activated.
- When a call is activated, the corresponding call button lights up.
- The lift only moves when a call is active.
- When the lift stops in a station due to a call, the corresponding LED flashes for 2 seconds (at 10Hz), which is to simulate the opening and closing of a door.

5.3 Literature

Tiegelkamp M, John KH. IEC 61131-3: Programming Industrial Automation Systems. Berlin, Heidelberg: Springer Berlin Heidelberg; 2010.

IEC 61131-3:2013 Programmable controllers - Part 3: Programming languages. International Electrotechnical Commission (IEC). 2013.

5.4 Sustainability – questions for reflection

The questions below are meant as inspiration for the teacher using the demonstrator. The aim is to strengthen the student's awareness regarding sustainability through reflecting upon questions related to the demonstrator. The questions can be used during the lecture or as the starting point for individual or group work, connected to the lecture. It is suggested that the students in groups answer the questions and then present the result of the discussion on class.

The questions below are divided into three main categories, general considerations, recycling, and product integrity, where the last two categories are addressing this specific demonstrator.

General considerations

- Does the making or use of the product create pollution?
- How can the energy consumption of the demonstrator be reduced?
- How can the material consumption needed for the demonstrator be reduced?

Recycling

- Can the demonstrator, or parts of it be recycled?
- Can all the materials be recycled – are they "pure" or do they need special treatment?
- How can the recycling of the demonstrator or its parts be improved?

Product integrity

- Which parts of the demonstrator need maintenance?
- Can parts which should be maintained be easily disassembled from the demonstrator?
- Can an update of components (which?) be foreseen to enlengthen its lifespan?
- Is the software of the demonstrator easy to update?

6 Organizational information

For the organization of the project the following apply:

- Project duration: 4-8 hours
- Team size: The project teams are mixed and the optimal size is 2 students.
- Preparatory and follow-up activities. No special activities are needed.

7 Description of the technology and the setup

7.1 Demonstrator Documentation

The overview of the files supplied together with this description of the demonstrator is given below. It includes all files (e.g. CAD files, electrical drawings) needed to replicate the demonstrator.

File Structure:	**Lift_Beckhoff**		
	Filename/Folder	Comment	Software
00_Notes			
	FileStructure.xlsx	Description of the Files	
	Price_Calculation.xlsx	Price Calculation	
01_Pictures			
	3D_Assembly.PNG	Picture of the 3D Model	
	GUI_Simulation.PNG	Picture of the GUI of the Simulation	
	Schematics_Conveyor.pdf	Picture of the Schematics	
	Schematic_Conveyor.PNG	Picture of the Schematics	
10_Documents			
	Datasheets	Folder with the Datasheets of the used Components	
	BOM.xlsx	Bill of Materials	
	Framework_Conveyor.docx	Framework of the Demonstrator	
	Framework_Conveyor.pdf	Framework of the Demonstrator	
	Instructions_Connect2PLC.docx	Instruction how to connect to the PLC	
	Instructions_Connect2PLC.pdf	Instruction how to connect to the PLC	
	Instructions_Simulation.docx	Instruction how to use the Simulation	
	Instructions_Simulation.pdf	Instruction how to use the Simulation	
	Lab_Exercise_FHV	Lab Exercise at FHV 2022	
	Lift_Demonstrator	Description of the Demonstrator	
	Schematics_Conveyor.vsdx	Schematics of the Demonstrator	Microsoft Visio
20_ExportImport			
30_AdditionalEquipment			
	AdditionalEquipment.txt	Info for the required additional Equipment	
40_Simulation			
	Lift.exe	Simulation Programm	
50_CAD			
	extern	Folder with all CAD Data of the bought material	
	normParts	Folder with all CAD Data of the used norm Parts	
	Conveyor_CompleteBuild.SLDASM	Total Assembly of the Demonstrator	SolidWorks
60_ElectricalLayouts			
	Lift.elk	Electrical Layout of the Demonstrator	Eplan
	Lift_ElectricalLayout.pdf	Electrical Layout of the Demonstrator	
70_Programming			
	PLC\Lift.sln	Base Project of the PLC	TwinCAT XAE Shell [Beckhoff]
	Simulation\Lift.sln	Project of the Simulation	Visual Studio 2019 [C#]

Figure 4: File overview of the lift project documentation

7.2 Price Calculation

Details of the price calculation can be found in the table below:

Table 4: Price calculation of the lift demonstrator

Quantity (Unit)		Description	Price (per Unit)		Price (total)
3	m	Item Aluminium Profile 8 (40 x 40mm)	7	€/m	21
6	pc	Aluminium Parts (CNC Milled)	40	€/pc	240
6	pc	Aluminum Parts (Manually Manufactured)	20	€/pc	120
1	m²	Perspex 3mm	45	€/m²	45
1	pc	Force sensor KD24s (±20N)	195	€/pc	195
1	pc	Clawcoupling (Igus COU-AR-K-050-000-25-26-B-AAAB)	35	€/pc	35
1	pc	Linearmodule (Igus ZLW-0630-02-B-60-R 240mm)	210	€/pc	210
1	pc	Servo Controller Escon 50/5 (409510)	215	€/pc	215
1	pc	Motor Config (Maxon B745F15FBAEB)	350	€/pc	350
1	pc	PLC Buscoupler (EK1300)	135	€/pc	135
1	pc	PLC Card (EL1808)	38,7	€/pc	38,7
1	pc	PLC Card (EL2808)	43,75	€/pc	43,75
1	pc	PLC Card (EL3351)	148	€/pc	148
1	pc	small Material (Screws, Wire, Clamps, Buttons,...)	250	€/pc	250
					2046,45

Additionally, a PLC with an EtherCAT-P junction is necessary for controlling the lift, e.g. a Beckhoff CX2040-CPU with an EtherCAT-P junction EK1322.

References