DIGITIZING PRODUCTS:
CREATING DEMONSTRATORS
FOR FUTURE EDUCATION

digi demo

ROBOTIC DEMONSTRATOR

FI UBB

Resita, September 2022

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

Project consortium

Dissemination level

Code	Access granted to
PU	Public

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.

Content

Document authors

	First name Last name	Institution
Key author	Zoltan Korka	FI UBB
Further authors	Gilbert-Rainer Gillich	FI UBB
	Cristian Paul Chioncel	FI UBB

Revision history

Version	Date	Author(s)	Description
1.0	01.09.2022	Zoltan Korka	Initial draft
1.1	30.01.2023	Zoltan Korka	Improvements

Document status

Status description	
For Information	
Draft Version	
Final Version (Internal document)	
Final Version (Public document)	x

Abbreviations

ESTA	ESTA Belfort (France)
FHV	Fachhochschule Vorarlberg (Austria)
FIV	Fagskolen I Viken (Norway)
UCN	University College Nordjylland (Denmark)
UBB	Babes-Bolyai University (Romania)

List of figures

List of tables

1 Introduction

The project is proposed for the *Industrial Robots* course, which can be found in the 8th semester from the study plans of the study programs of *Mechanical Engineering, Electro-mechanics, Industrial Informatics* and *Computer Science Applied in Electrical Engineering* at the Engineering Faculty of UBB. The typical class size is 15 – 20 students, who are split into five teams of 3-4 people. The teams are mixed in several manners.

Students from these four specialization can also form together a team. A typical laboratory and the teaching stand can be seen in Figure 1. The task of the students is to design and realize a system for attaching a linear displacement transducer to the mechanical structure of an existing industrial robot, respectively to program a microcontroller to receive the transducer signal in order to read the displacements on a liquid crystal display. We mention that this upgrade of an existing industrial robot can also be extended to a classical lathe for reading linear movements along an axis.

The new mechatronic system may be used by students in a new laboratory work, in which they study experimentally the positioning precision of the translation module of the existent robot or the carriage of a lathe.

Figure 1: Typical lab environment and teaching stands

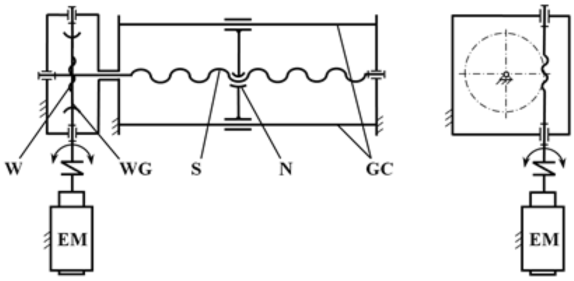
The key properties of the demonstrator are:

Table 1: Specification of key properties of the focus project

Key Property	Value
EQF level	6 (Bachelor)
Year of study	4
Domain	Mechatronics
Workload	5 ECTS
Keywords	Industrial robot, displacement transducer, microcontroller

2 Stand description

As before mentioned, we propose to upgrade an existent industrial robot in order to be able to measure with high precision its base translational motion. A brief overview of the kinematical scheme of the robot's base translational motion is given in Figure 2.



a) b)

Figure 2: Kinematical scheme of the robot's base translational motion
(a - top view; b - side view)

The components shown in the upper figure have following notations:

- EM - electric motor;
- W - worm shaft;
- WG - worm gear;
- S - screw;
- N - nut;
- GC - guiding columns.

As it can be noticed, the rotational motion, coming from the electric motor, goes through the worm transmission to the screw, which supports the worm gear. As the nut is bound to the robot's body, the screw rotation generates the linear motion of the robot along the guiding columns.

2.1 Displacement transducer

For measuring the displacement of the robot's base translational motion is intended to use an ELCIS transducer, which consists of an ruler and a counter, the two components of the transducer being shown in Figure 3.

a) b)

Figure 3: Ruler (a) and counter (b) of the ELCIS displacement transducer

The L/CR 80-1000 type linear transducer is an incremental one, where linear displacements are measured using a "pre-assembled" rack-and-pinion type system. The pinion is attached to the counter shaft and the rack is fixed on the ruler. The device allows to measure displacements of up to 1,000 mm, with a resolution between 1 µm and 1 mm.

The transducer is extremely robust and precise, with high reliability in heavy working conditions (vibrations, environment with oils, steam, chips, etc.), which is usually used in numerically controlled machine tools.

The main technical data of the translator are:

- supply voltage: 5 ÷ 30 V;
- maximum frequency 60 kHz;
- output signal: square or sinusoidal wave;
- measurement resolution: 1 µm- 1 mm;
- working temperature 0 ÷ 71 °C;
- maximum reading speed 20 m/min;
- maximum allowed acceleration: 15 m/s^2;
- starting force: 6N;
- impact resistance: 50Gx 11 ms.

2.2 System for reading and displaying the linear displacement

The ELCIS L/CR 80-1000 transducer is an incremental type, with four differential outputs, which give 2.000 pulses per rotation cycle. To read and display the measurement results, the students are requested to use following parts:

- a 5 volt stabilized direct voltage source, with adjustable current intensity protection (5 VDC Source);
- a PIC16F877 type microcontroller, on 8 bits and the possibility of expanding the values up to 16 bits (µC);
- a liquid crystal display on 2 lines, each with 20 characters (LCD Display);
- an incremental encoder (IE).

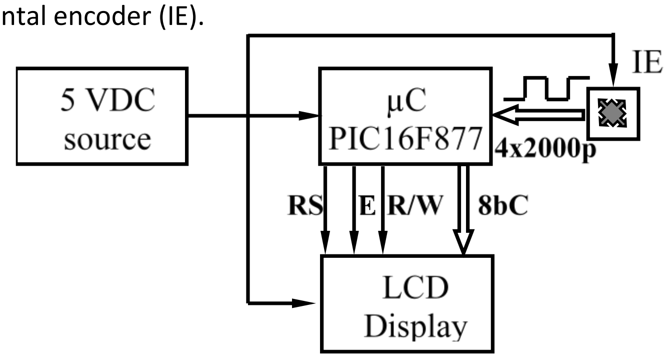


Figure 4: Flow information

The flow of information transmitted from the microcontroller to the display is represented in Figure 4, were the symbols have following meanings:

8bC - the displayed characters are encoded using 8 bits;
R/W - read/write display setting;
E - activation of reception of a transmitted character;
RS - display reset.

All components of the measurement system are powered by 5 VDC. The microcontroller has the task of receiving the pulses transmitted by the incremental displacement sensor. The pulses are counted and the resulting value is configured in order to be displayed. The displayed characters are coded on 8 bits and transmitted to the display. The display takes each character only at the moment of activation. The value corresponding to millimeters and the characters "mm" are displayed on the first line. On the second line, the value of micrometers and the characters "µm" are displayed.

The programming algorithm of the microcontroller has consider following requirements:

- definition of the conditions for connecting to the LCD;
- definition of the variables and their type.

The main routine has to follow the following logical steps:

- setting port C as digital input;
- initialization of LCD communication without flashing cursor;
- taking the value from port C;
- entering an infinite loop, in which:
  - # the value from port C is analyzed;
  - # port D.7 deletes the contents of variables a and b, and the LCD display;
  - # comparison of the current value with the previous one from port C;
  - # entering an infinite conditional loop, depending on the state of port C, as follows:
    - ► the value of a is set, incremented and displayed;
    - ► for each a > 999, b is incremented and displayed;

2.3 Programming of the microcontroller

Considering the conditions specified in the previous paragraph, the following program is written for the microcontroller, in order to display on the LCD the results of the linear displacement measurement:

```
Define LCD_BITS = 8                ' 8-bit coded characters
Define LCD_DREG = PORTB            'port B communicates the character code
Define LCD_RSREG = PORTD           'LCD reset is done by pot D pin 1
Define LCD_RSBIT = 1
Define LCD_EREG = PORTD            'Activation of the transmission of each displayed
character is done at port D pin 3
Define LCD_EBIT = 3
Define LCD_RWREG = PORTD           'LCD setting for read=1/write=0, at port D pin 2
Define LCD_RWBIT = 2  '
Define LCD_COMMANDUS = 500         'delay necessary for the execution of an LCDCMD OUT
command by LCD

Dim x As Byte                      'declaration of variables and their type (byte=8 bits,
word=16 bits)
Dim y As Byte
Dim a As Word
Dim b As Word

'start of the main routine

TRISC = 0xff                       'setting port C for digital inputs
```

```
  Lcdinit 1                          'LCD initialization wit flashing cursor
  Lcdcmdout LcdCurOff                ' elimination of the flashing cursor, for reasons
  of speed in the execution of the program
  Lcdcmdout LcdClear                 'delete LCD

  x = PORTC                          'variable x takes over the value of port C

  loop:                              'label of the main infinite loop

  If PORTD.7 Then                    'If pin 7 of Port D is at logic 1 = 5 Vdc, the
  contents of variables a and b, and the LCD display are deleted
        a = 0
        b = 0
        Lcdcmdout LcdClear
Endif                                ‘end of the conditional loop

y = x Xor PORTC                      'If the current value of port C differs from the
previous value (stored in variable x), y=1 logic

While y > 0                          'infinite loop conditioned by the state of the
variable y
        a = a + 10                   'measurement resolution is set to 10 µm
        Lcdcmdout LcdLine2Home       'cursor moves to the beginning of line 2
        Lcdout #a, " um"             ' content of the variable a and the characters
um are displayed
        If a > 999 Then           ' If a >= 1000 um, increment b, delete line 2 from the
display, reset the value of a, move the cursor to line 1 and display the value of b followed by
mm characters
                b = b + 1
                Lcdcmdout LcdLine2Clear
                a = 0
                Lcdcmdout LcdLine1Home
                Lcdout #b, " mm"
        Endif
        x = PORTC                    'new state of Port A is taken by variable x
        y = x Xor PORTC              'compare the previous state with the current
state of port C
Wend                                 'exiting the infinite conditional loop

Goto loop                            'jumps to the loop tag, resulting in infinite
iterations
```

2.4 Mechanical design of the system

The mechanical of the system design refers to the conception of a system for attaching the ruler on the table supporting the robot (fixed part), respectively the counter on the mobile part of the robot. For this purpose, standardized elements are used, such as clamps and corners existing in DIY (do it yourself) stores and shown in Figure 5.

a) b) c)

Figure 5: Fixing elements for the transducer

Thereby, the ruler is attached to two corners of the type shown in Figure 5 a, using 2 hexagonal head screws M5x 15 and two M5 hexagonal nuts. The assembly thus created is fixed to the robot support table with the help of. two screws with hexagonal head M10x50 and two hexagonal nuts M10, respectively.

To fix the counter to the robot body, two collars of the type shown in Figure 5.b and a perforated plate of the type shown in Figure 5.c were used, the connection of the three elements being made with 4 M5x15 hex head screws and 4 M5 hex nuts respectively. The counter was attached to this assembly using the same type of screws and nuts as described above.

In order to fix the assembly thus created to the robot body, the existing screws holding the sealing covers of the guides of the horizontal translation module of the robot were used. In order to avoid friction with the guides, a V-shaped recess has been cut in the corner brackets between the two fixing holes on the robot body. The construction details of the counter mounting system on the robot body are shown in Figure 6.

Figure 6: Location of measuring system on robot

3 Description of fulfilment of demonstrator characteristics for the focus project

The description is included in the table shown below:

Table 2: 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	The demonstrator can be used for teaching different issues related to the use of industrial robots.
Interdisciplinarity	The demonstrator requires electrical, mechanical an programming engineers to cooperate in implementing the mechatronic system. Software components are also part of the project, such as, for example, programming the microcontroller.

4 Classification of the focus project according to the dimensions

Table 3: 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	☑
	electronic circuits	☑
	edge device	☐
	data transmission	☑
	cloud	☐
Sustainability	energy reduction	☐
	material reduction	☑
	better materials	☐
	better production	☑
	repairability	☐
	recycling	☑
Physicality	physical setup	☑
	simulation	☐
Degree of student freedom	guided	☐
	coached	☑
	autonomous	☐
Transportability	fixed	☐
	transportable	☑
	portable	☐
Costs (implementation)	EUR	2.000
Costs (operation)	EUR	50
Workload (implementation)	Hours	100h
Workload (operation)	Hours	6h

Dimension	Property	Value
Size	m	1 x 1 x 0.2
Weight	kg	20
Special requests	no/yes, if yes: which	no

5 Technology and prices

Following materials (see table 4) were used in the fulfilment of the project. Description of the assembling may be taken from chapter 2.

Table 4: Equipment description and prices

Current No	Name	Quantite	Cost
1	ELCIS L/CR 80-1000 transducer	1	1500,00 €
2	Corners	2	2,00 €
3	Colars	2	2,00 €
4	Perforated plate	1	1,00 €
5	Hex. head screw M10x50mm	2	1,00 €
6	Hexagonal nut M10	2	1,00 €
7	Hex. head screw M5x15mm	6	2,00 €
8	Hexagonal nut M5	4	1,00 €
9	PIC16F877 type microcontroller	1	70 €
10	LCD display	1	10 €
		Total	**1.590,00 €**

6 Sustainability aspects

6.1 Mechanical design of the system6.1.1 Does the making or use of the product create pollution?

The making of the product is done by involving components with insignificant pollution during their production.

6.1.2 Can the material and energy used to make or use this product be reduced?

No

6.1.3 Can nature regenerate the resources used to make or use this product?

No

6.1.4 Does the making or use of the product permit to reduce energy consumption?

No

6.2 Recycling6.2.1 What are the main materials used for the product?

The system is mainly produced from steel.

6.2.2 Can all the materials be recycled – are they "pure"?

All the materials are able to be recycled. Electronic elements an can be reused in other contexts if the demonstrator is disassembled.

6.2.3 How should the parts be connected in order to be reused?

The different elements of the assembly are screwed together and thus can be disassembled easily to reuse or recycle components.

6.3 Product integrity6.3.1 What are the key aspects to obtain a durable product, in terms of construction and material?

- Use recyclable materials with screwing instead of gluing or welding;
- Optimised material use;
- Minimising source code of programming part (green programming)

6.3.2 What are the most important components to be maintained?

Normally, the assembly should work eternally, no maintenance is needed.

6.3.3 Do you foreseen the need to update any components in order to maintain the integrity of the product (e.g., the sensors)?

Normally, the assembly should work eternally, no updates are needed.

6.3.4 Can the demonstrator be repaired?

The demonstrator can be disassembled, and each component can individually be replaced (electronic and mechanical components) to repair the demonstrator.

6.3.5 Is it possible to design the sensors so they could relocate onto another context?

The sensors used in the demonstrator can be disassembled, and relocated for an other application which requests measurement of translation displacement.