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# TEACHING LABORATORY PRACTICE IN ELECTRICAL DRIVES

Discipline AXX9012 emprovement

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# TABLE OF CONTENTS

<b>INTRODUCTION AND SAFETY WARNINGS.....</b>	<b>3</b>
<b>1. CONTROL OF SERVO DRIVE.....</b>	<b>4</b>
1.1. LABORATORY SETUP.....	4
1.2. COMMISSIONING THE SERVO DRIVE .....	5
1.3. REFERENCE MOVE .....	5
1.4. SPEED CONTROL.....	6
1.5. POSITIONING.....	7
1.6. TORQUE CONTROL.....	8
1.7. PROBLEMS.....	10
1.8. REPORT CONTENTS.....	10
<b>2. CONTROL OF STEP DRIVE.....</b>	<b>11</b>
2.1. LABORATORY SETUP.....	11
2.2. RUNNING THE PROJECT .....	12
2.3. COMMISSIONING THE STEP DRIVE .....	12
2.4. REFERENCE MOVE .....	13
2.5. SPEED CONTROL.....	13
2.6. POSITIONING.....	16
2.7. SETTING RAMPS .....	17
2.8. PROBLEMS.....	19
2.9. REPORT CONTENTS.....	19

*This is a tutorial aid for laboratory practice in AXX9012 **Teaching Practice** intended for doctoral students and staff whose professional activity concerns education in the field of electrical drives. The goal of this work is to study the methodology of labs preparation, execution and reporting, to assess the instructor's and learner's roles, and to prepare recommendations relatively further teaching improvements.*

## **SAFETY WARNINGS**

Prior to start working on the laboratory setups, a learner is expected to have acquired knowledge of basics of electrical engineering, electronic components, standard electrical wiring, and electrical schematic symbols. As works are conducted on real industrial potentially dangerous equipment, the following safety warnings are to be fulfilled without fail.

1. Always remember the laboratory setups are dangerous device. Never apply power and never run the motors if it may cause danger or an injury.
2. Before powering the laboratory setup, make sure all equipment and measuring instruments are suitable for operation throughout the permissible speed, voltage, and current ranges.
3. Never power on equipment without instructor's permission.
4. In the case of overheating, smelling, the sparkles or electric arc, switch off the power source immediately by the STOP button, emergency push-button, the main switch on the cabinet console, or the red safety push-button on the laboratory switchboard.
5. To avoid electric shock, never open the covers and do not touch the cables or the motors while the mains power is applied or the shafts rotate.
6. Do not run the motors over the nominal speed continuously and do not allow their long-term overloading.
7. Do not control the motors by direct device connecting/disconnecting; instead, use the control keys and buttons.
8. Do not exceed 5 power-ups in 10 minutes to exclude the installation damage.
9. If the work is done remotely, follow the instructions concerning the net connection.

Before the lessons,

- download this manual or update it and read carefully the required work contents
- prepare the protocol of the future work with tables of observations for all the tasks related to your variant.

During the lessons,

- implement the work step by step
- fill your observations in the report tables
- solve the problems

After every lesson, present your report with the work protocol to the instructor, correct, and defend it if required. Clearly, deficiencies may be encountered in these regulations. Thus your commentaries, remarks, and criticism are appreciated.

## 1. CONTROL OF SERVO DRIVE

As an outcome of this work, a learner must

- to understand the work methodology
- to find the benefits and drawbacks of the proposed approach
- to evaluate the work connection with the basic course outcomes
- to suggest the work rearranging
- to prepare recommendations about the learning process enhancement

### 1.1. Laboratory setup

The TP 801 servo drive equipment set includes an axis slide with two limit switches, servo motor MTR-AC-55, servo controller SEC-AC-305 with a textbox, the set of power and encoder cables, and the toolkit **Wmemoc** with preliminary assigned options and Festo parameters. Electrical and mechanical data of the MTR-AC-55 servo motor are as follows:

Parameter	Unit	Value
Rated voltage	[V]	325
Rated current	[A]	2,15
Maximal current	[A]	6,4
Rated torque	[Nm]	0,66
Maximal torque	[Nm]	0,98
Rated speed	[rpm]	6800

To begin, establish communication between the personal computer (PC) and the SEC-AC controller. Before operation, the textbox and PC are to be connected to the controller and the mains power supply switch is in the OFF position. In the textbox all the toggles are OFF and potentiometers in 0 positions.

- Move the axis slide to the mid position of the axis.
- Switch ON the mains power supply (230 VAC) mounted on the controller.
- Switch ON the 24 VDC power supply.

After an internal self test, the **READY** LED on the front of the SEC-AC lights up. Powering OFF the system is to be conducted in reverse sequence.

- To establish communication between PC and SEC-AC, start **Wmemoc** on PC (if you start before this, an error message will occur). At normal communication, **Wmemoc** appears with three windows – **Commands**, **Status** and **Actual Values**.

To assign the **Wmemoc** options,

- Select **Actual Values** from menu and tick all values – this activates the **Actual values** dialog box.
- Select **Options > User Mode > Expert**. This ensures that you have access to all functions of **Wmemoc**.

To load the parameter set,

- Select **File > Parameter set > Read from file and store into servo**.
- Use the browser dialog box to find the correct parameter set. You should be in the

**Wmemoc** folder called **wpa** (.wpa is the file extension for parameter sets).

- The laboratory setup is provided with completely predefined parameter sets for all Festo axes–servo motor combinations (horizontal and vertical). These predefined parameter sets arrange an initial controller configuration for commissioning. Select the parameter set DGE 18ZR-AC55-3S-Ax\_h for the motor and controller used in the setup, ensuring the horizontal position is selected.
- Click **OK** to load the parameter set. A bar appears showing the downloading progress. On completion, the message "Data transferred" appears.
- Store data from SEC-AC RAM into SEC-AC EEPROM: **Parameters > Save parameters**. From now on, your data are saved even in the case of 24 VDC power failures.

## 1.2. Commissioning the servo drive

The commissioning procedure is intended for manual equipment validation, assigning **Command** and **Reference Position** settings, and enabling the system.

To commission the equipment by hand,

- Move the slide in both directions. Ensure that the counter for the **Position** value in the **Actual values** dialog box is counting up and down.
- Check the functioning of the limit switches: the counter should count up until reaching the limit switch. Then, **Limit switch 1** lights up in the **Status** dialog box.
- Check in the other direction – the counter counts down until **Limit switch 0** lights up in the **Status** dialog box.

Task 1		
Variant	Experiment	Observation
1	Measure the slide <b>Position</b> at <b>Limit switch 0</b>	Limit switch 0 =
2	Measure the slide <b>Position</b> at <b>Limit switch 1</b>	Limit switch 1 =
3	Calculate the slide maximal distance between the limit switches	Max =
4	Set the slide to the mid <b>Position</b> .	0

## 1.3. Reference move

To work accurately, servo drives need a reference point from which all positions are calculated. Two reference points are available: left and right.

To execute the reference move,

- Switch ON the power stage **Endst** toggle (LED lights up).
- Switch ON the controller **Regler** toggle (LED lights up).
- Read the drive state in the **Status** dialog box.
- In the **Commands** dialog box, tick the following settings: **Drive enable**, **Motor speed control**, **Position control**, and **Positioning**. Be careful: the system will start automatically when enabled/powering.
- The 7-segment display on the SEC-AC lights up showing "P" ("Positioning"). Ensure manually that the slide is locked into position and cannot be moved. You can now hear a slight noise from the servo controller.
- Click **Reference move** icon  to open the **Reference position** dialog box.

- Set **Destination** parameter **max. turns permitted** to **6,5**.
- Select **Method 1** in the **Mode** box.
- Select **Turn right** in the **Direction** box.

The next step will cause movement of the slide – make sure there is nothing obstructing the path of drive and everyone around you knows you are going to start.

- In the **Reference position** dialog box click **GO!** The slide moves to the reference point and stops. In the **Actual values** dialog box ensure that **Position** is 0. In the **Status** dialog box ensure that **In position** lights up.

If the system is noisy or moves erratically, power off the controller and tell the instructor.

- Change **Direction** and repeat the reference move.
- Click **OK** to close the dialog box.
- Return controller **Regler** to OFF (toggle down) - LED becomes dim.
- Return power **Endst** to OFF (toggle down) - LED becomes dim.
- All other toggles are to be OFF and potentiometers at 0.

## 1.4. Speed control

Tune the textbox as follows:

- Set **Analog-IN 0,1** toggle to **Ground**.
- Turn **Analog-IN 0** potentiometer to 0.

Change the **Wmemoc** settings as follows:

- In the **Commands** dialog box, select **Motor speed control** and clear all other checkboxes.
- Select menu **Set points > Set point selection**.
- In **Selector A** tab, select **Analog input 0** and click **OK**. This ensures that the controller is checking analog input 0.

For safety reasons and for setting the permissible speed of a drive in applications, restrict the speed of the axis. To this aim,

- Select menu **Parameters > Device parameters > Set point scaling**.
- Choose the tab **Channel 0** and change the scale of upper limit to **200**. This means that at 10 V the system operates at 200 rpm. This value is activated immediately.
- Click the **Auto offset calibration** button. If you have drift on ground – the motor turns without any input signal – this compensates for it. This is the default value and must be adapted during commissioning to suit an application!
- Click **OK** to close the dialog box.

Now, the system can be enabled via the textbox:

- Check again that the analogue potentiometer is at 0 and the switch **Analog-IN** is set to **Ground**.
- Enable power stage (**Endst**) and controller (**Regler**).
- Switch ON **Analog-IN 0,1** toggle.

Turn potentiometer **Analog-IN 0,1** to adjust the speed and direction of the slide, observe the slide reaction, and log your observations in the table below:

Task 2		
Variant	Experiment	Observation
1	Turn potentiometer slowly clockwise.	
	Return potentiometer to 0.	
2	Turn potentiometer slowly counter-clockwise.	
	Return potentiometer to 0.	
3	Turn potentiometer quickly clockwise.	
	Return potentiometer to 0.	
4	Turn potentiometer slowly clockwise and switch analogue toggle from ON to <b>Ground</b> .	
	Return analogue switch from <b>Ground</b> to ON.	

- Disable the power stage and controller.

## 1.5. Positioning

The positions, speeds and ramps have to be defined before they can be called in a program. Therefore it is important to know how these parameters are defined and stored in the system.

To check positions,

- Allocate the slide in the mid position of the axis.
- Click **Position**  icon. The **Destination 0** dialog box appears.

In the boxes **Acceleration** and **Deceleration** you can parameterize the ramps for accelerating and decelerating the drive. If the time in the field **Smoothing** is 0, this will result in linear ramps; otherwise the ramp shape will be parabolic. Switching along the **Select** box, define the following positions from 0 to 12:

Pos.	Position [R]	Running speed [rpm]	Positioning run	Acceleration [msec]	Deceleration [msec]
0	20 % of Max	100	absolute	400	400
1	80 % of Max	200	absolute	100	100
2	40 % of Max	300	absolute	100	100
3	50 % of Max	400	absolute	100	100
4	Max	500	absolute	100	100
5	50 % of Max	200	absolute	400	400
6	5 % of Max	250	absolute	400	400
7	10 % of Max	300	absolute	400	400
8	80 % of Max	400	absolute	400	400
9	90 % of Max	500	absolute	400	400
10	Max	500	absolute	100	100
11	-10 % of Max	300	relative	400	400
12	10 % of Max	300	relative	400	400

Here **Position [R]** is given according to the positioning mode, which may be **relative** (calculated from the last position), or **absolute** (calculated from the reference point).

After that, move to the selected positions:

- Enable power stage (**Endst**) and controller (**Regler**).
- Execute the reference move.
- Click **Go to destination** button  in the toolbar.

Now you can click buttons in the dialog box to move to a selected position.

## 1. CONTROL OF SERVO DRIVE

- Select the positions in the sequence shown in the table below starting from the reference move to the proper direction (left or right). As you go, make notes in the table about the motion of the slide.

Task 3			
Variant	Step	Move to position	Observation
1	1	Reference move	
	2	1	
	3	0	
	4	2	
	5	0	
	6	3	
	7	0	
	8	4	
2	9	0	
	10	5	
	11	0	
	12	6	
	13	0	
	14	7	
	15	0	
	16	8	
3	17	0	
	18	9	
	19	0	
	20	10	
	21	0	
	22	7	
	23	7	
	24	11	
4	25	11	
	26	12	
	27	12	
	28	12	
	29	7	
	30	7	
	31	0	

- Upon completion, disable the power stage and controller.

### 1.6. Torque control

Torque control is an important feature and benefit that offers safety to man, machine and products. Unlike the steppers that do not allow any torque control, servo motors are able to control torque easily by increasing its current to ensure that the torque remains.

Before experimentation,

- Move the slide to the mid position of the axis.
- Set **Analog-IN 0,1** toggle to **Ground**.
- Turn **Analog-IN 0** potentiometer to **0**.

Assign the software settings as follows:

## 1. CONTROL OF SERVO DRIVE

- In the **Commands** dialog box, select **Torque control** and clear all other options.
- Select menu **Set points > Set point selection > Selector A**.
- Select tab **Analog input 0** and click **OK**. The drive torque is now regulated by the analogue input 0.
- Select **Parameters > Device parameters > Set point scaling**.
- In tab **Channel 0** set the scale maximum peak to **0,2 Nm**. Note that all values are immediately effective! Do not set more than 0,2 Nm because of danger of injury!
- Click the button **Auto offset calibration**.
- Click **OK** to close the dialog box. Make sure that the slide is positioned in the middle of the axis and there are no obstacles in the way.

Accurately enable the system because it may cause movement of the slide:

- Enable power stage and controller.
- Switch ON **Analog-IN 0,1** toggle.
- Follow the instructions in the table below. By observing the **Actual values** dialog box, establish at what torque the slide starts to move.

<b>Task 4</b>		
<b>Variant</b>	<b>Experiment</b>	<b>Observation</b>
1	Slowly turn the potentiometer fully clockwise. What <b>Torque</b> the slide starts to move at?	
	Slowly return to 0.	
2	Slowly turn the potentiometer fully counter-clockwise. What <b>Torque</b> the slide starts to move at?	
	Slowly return to 0.	
3	Turn OFF the <b>Analog-IN 0,1</b> toggle ( <b>Ground</b> ).	
	Set the potentiometer to any position.	
4	Turn ON the <b>Analog-IN 0,1</b> switch. What <b>Torque</b> the slide starts to move at?	
1	Move the slide to one of the end positions	
2	While holding the slide in the end position, slightly turn the potentiometer to move the slide to the other end. What <b>Torque</b> the slide starts to move at?	
3	While holding the slide in the end position, gradually turn the potentiometer to increase the force. Do not increase the maximal <b>Torque</b> . What <b>Torque</b> the slide starts to move at?	
4	What would you consider about the safe setting that would avoid injury to people?	

- Upon completion, set all the toggles of the textbox to OFF positions and turn the potentiometers to 0.
- Switch OFF the laboratory setup.

## 1.7. Problems

Variant	Problems
1	2.1. Call the main commissioning functions of <b>Wmemoc</b> .
	2.2. Is the SPC 200 always essential?
	2.3. What dictates the maximal speed of the servo drive?
	2.4. What should be done to decrease slippage?
	2.5. Why the ramps are required?
2	2.1. What signals SEC-AC and testbox exchange?
	2.2. Explain the needs in the speed control and its problems.
	2.3. How can you change the speed?
	2.4. What factors affect the resolution of a position the slide is moving to?
	2.5. How long can a ramp be?
3	2.1. How to establish communication between PC and SEC-AC?
	2.2. Explain the needs in the position control and its problems.
	2.3. How flexible (precise) are the speeds executed by the servo motors?
	2.4. What the distance the slide moves per the motor revolution depends?
	2.5. Why the torque control is an important feature?
4	2.1. When a reference move is required?
	2.2. How the positions, speeds and ramps are defined and stored in the system?
	2.3. What must be done if slippage is suspected?
	2.4. How do you start <b>Wmemoc</b> programs or projects?
	2.5. What conclusion can you draw regarding the laboratory setup safety?

## 1.8. Report contents

- **functional diagram** of the laboratory setup and the nominal data
- **tables** of observations for the tasks related to your variant
- a **table** with your **program**
- **solutions of the problems** related to your variant

## 2. CONTROL OF STEP DRIVE

As an outcome of this work, a learner must

- to understand the work methodology
- to find the benefits and drawbacks of the proposed approach
- to evaluate the work connection with the basic course outcomes
- to suggest the work rearranging
- to prepare recommendations about the learning process enhancement

### 2.1. Laboratory setup

To work with the step drive, a stepper MTR-ST, a pulse/direction controller SPC 200, and a stepper card SEC-ST connected to the power supply and PC are used.

The axis is fixed to the H-rail support brackets. The stepper MTR-ST is attached to the axis via the special adapter flange on the coupling housing and tightens the knurled screws. The control assembly is fitted on the profile plate. Electrical connections are made for two limit switches and the reference switch. The signal cable is connected between SPC 200 and SEC-ST. The motor cable links MTR-ST to the SEC-ST. The power supply provides equipment with 24 VDC. SPC 200 converts programs into pulse direction signals. The SEC-ST converts these into the appropriate electrical power signals for the stepper. In this way, SPC 200 activates the slide motion from the stepper via SEC-ST. SPC 200 can be replaced by a PLC with integrated pulse direction card or by any other pulse direction source.

Electrical and mechanical data of the MTR-ST-42-48S-AA series stepper are as follows:

Parameter	Unit	Value
Rated voltage	[V]	48
Rated current	[A]	<b>3.1</b>
Holding torque	[N·m]	1.27
Full step angle	[°]	<b>1.8 ± 5 %</b>
Winding resistance	[Ω]	1 ± 10 %
Winding inductance	[mH]	3.8 ± 20 %
Moment of inertia	[kg·cm <sup>2</sup> ]	0.48
Product weight	[kg]	1.2
Feed constant	[mm/rev]	52

On the front panel of SEC-ST, 8 DIP switches are placed:

Name	Switch	ON/OFF	Name	Switch	ON/OFF
Step Mode	1	OFF	Current	5	OFF
Step Mode	2	ON	Current	6	OFF
Step Mode	3	OFF	I-Red.	7	ON
Current	4	OFF	Enable	8	ON

Changes on the DIP switches become valid only after power OFF/ON sequence.

The DIP switches 1, 2 and 3 assign the step mode as follows:

Steps/rev DIP	200 Full	400 Half	800 Quarter	1000 Fifth	1600 Eight	2000 Tenth
1	ON	OFF	ON	OFF	ON	OFF
2	OFF	ON	ON	OFF	OFF	ON
3	OFF	OFF	OFF	ON	ON	ON

The distance the slide moves per mm positioning path (drive resolution) is equal to the ratio between the number of steps per revolution and the feed constant given in electrical and mechanical data sheet.

The DIP switches 4, 5, and 6 assign the current value if the **Current reduction** DIP switch 7 (**I-Reg**) is ON. Current reduction provides energy saving and reducing motor heating.

DIP	DIP 7	Current
4	ON	1,25 A
5	ON	1,50 A
6	ON	1,80 A
	OFF	Max

It can be used as a safety function for torque reduction in holding positions.

## 2.2. Running the project

To run the laboratory setup,

- Ensure that the power supply is switched OFF.
- Check that all electrical connections are secure.
- Ensure that the DIP switches of SEC-ST are set as shown in table above.
- Ensure that the path of the slide is clear of obstructions
- Move the slide to the mid position.
- Switch ON the power supply and wait while both SPC 200 Power LED and the stepper card SEC-ST Power LED light up.

To start the project,

- Run **WinPISA**.
- Select **Open project** and open the sample project **festoxx.prj**.
- Click **Connect** icon in the program toolbar (always connect before your PC communicates with the SPC 200). The plug joins to show that the connection is made.
- Download the project to SPC 200 using menu **Online > Download > Project**. As a warning dialog box is displayed, click **Continue**.

## 2.3. Commissioning the step drive

- Select menu **Online > Commissioning > Reference travel** (Fig. 3.7). As a warning dialog box is displayed, click **Continue**.

The **Reference travel** window allows checking the status inputs, activation reference move or emergency travel, and running movements with **negative** and **positive** buttons.

The next step will cause movement of the slide – make sure there is nothing obstructing the path of the drive and everyone around you knows you are going to start.

Task 1		
Variant	Operation	Observation
1	Click <b>Start</b> button and read the <b>actual position</b> of the reference point	Start =
2	Click <b>positive</b> button and read the change of the <b>actual position</b> upon the single button click	Step =
3	By clicking <b>positive</b> button, read the maximal permissible distance of the slide movement accurate with a millimetre.	Max =
4	Click <b>negative</b> button. How then can you return to the reference poin?	

- Once you have completed commissioning, click **Exit**.

## 2.4. Reference move

To work accurately, step drives need a reference point from which all positions are calculated. The reference point is reset in the reference move, which must be conducted after powering up a step drive and whenever slippage (loss of steps) has occurred. Always move to the reference point before engaging to any new position. Before the reference move execution, **WinPISA** must be started, power supply switched ON, and the project downloaded.

- Select **Online > Control axes**. After a short time a dialog box **Program selection** appears.
- Select **Program 1** for the reference move and click **Ok**. Following the warning message click **Continue**.
- After a short loading time, **Program 1** is open (Fig. 3.1).

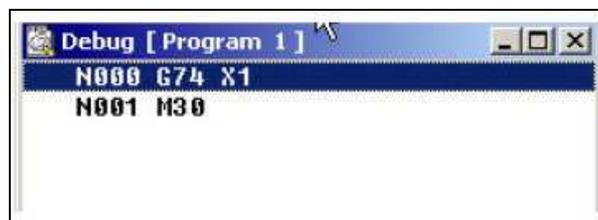


Fig. 3.1. Debug window

Next step may cause movement of the slide. Ensure that the path of the slide is clear of obstructions and the slide is in mid position.

- Click the **Execute step** icon. The reference move will now be done. The motor turns until the slide reaches the reference switch. The slide is now set to the reference position.
- Close **Program 1**.

## 2.5. Speed control

In practice, to vary the velocity of the slide, the frequency of supply pulses is changed. Before the experiment execution with different velocity profiles, the step drive must be running, **WinPISA** starting, and the sample project **festoxx.prj** open. Your goal is to create a simple **WinPISA** program for the speed diagram.

You must develop the new program, which includes 9 records:

## 2. CONTROL OF STEP DRIVE

Record	Move to Position	Speed
0	80 % of Max*	20 %
1	20 % of Max	20 %
2	80 % of Max	50 %
3	20 % of Max	50 %
4	80 % of Max	70 %
5	20 % of Max	70 %
6	80 % of Max	100 %
7	20 % of Max	100 %
8	End of Subroutine	

\*Calculate each position in mm using Max from Task 1.

To prepare the required program, do the following:

- Save the current project as your new project: **File > Save as** and give it your name. In this new project, the “Reference Move” program already exists as **Program 1**.
- Select **Software** icon in the project window (Fig. 3.2).

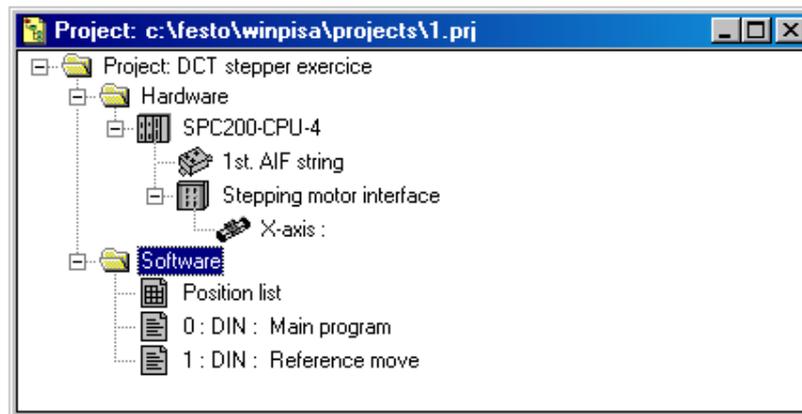


Fig. 3.2. Project window

- Select **Insert object** from **Edit** menu or press **Insert** key. A **New program** dialogue window appears.
- In the **New program** dialogue window, print a program title “Velocity Profiles” in the **Title** field, author’s names in the **Description** field, and the program number **2** in the **Program no.** field.
- Click **Ok** to confirm your entries. The new program appears in the project window as **Program 2** with the program window opened.
- Type your own records in the **Program** window similarly to those shown in Fig. 3.3.

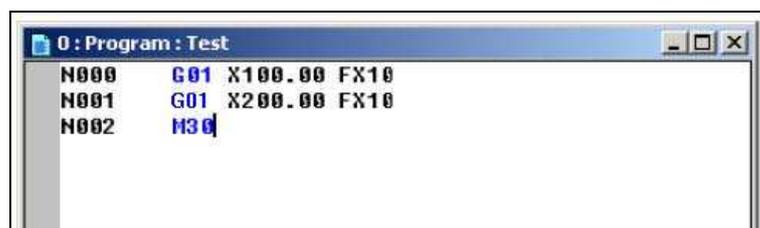


Fig. 3.3. Program example

Your program should comply with the syntax specified in DIN 66025. Every record starts with the record number following a command with the appropriate parameters.

## 2. CONTROL OF STEP DRIVE

For example, the first record in Fig. 3.3 calls the motion at 10 % of the maximal speed to the position  $X = 100$  mm. The second record calls the motion at the same speed to the position  $X = 200$  mm. The last record calls the program end with repeat. Here,

Code	Description
N0000	Record number
G01	NC command
G90	Type of positioning (optional)
X220.00	X axis position
FX10	X axis speed parameter (FX0 in the case of 100 %)
Y100.00	Y axis position (optional)
FY80	Y axis speed parameter (optional)

A record number begins with the letter N. The records are numbered strictly ascending (N000, N001, N002...). Other identifiers are listed in the table below:

Identifier	Description
N	Identifier for record number
G	Preparatory command function
M	Auxiliary command function
X, Y, Z, U	Axis identifiers: X-axis, Y-axis, etc
F	Move speed
E	Jump function
L	Subroutine call

The command functions are as follows:

Command	Function
G00	Move to position at the highest permissible speed
G01	Move to position at specified speed
G02	Move to position at start/stop frequency
G04	Dwell time
G08	Acceleration for approach ramp
G09	Deceleration for brake ramp
G74	Start reference travel
G90	Absolute measurement
G91	Relative measurement
M00	Program stop
M02	End of subroutine
M30	End program with repeat

After completing, check your program for correct syntax. To this aim,

- Make sure that the window of the program to be checked is active.
- Save the program.
- Select **Syntax check** from **Compile** menu or click the **Syntax check** icon. The progress of the syntax check will be displayed in **Compile** window. Wait until the checking procedure is complete.
- Click **Ok** in the **Compile** window to confirm the completed check. If there is an error, a new window appears showing you where the error occurs. Clicking on the error line will bring you to the place where the error occurs in the program box. Eliminate any errors displayed, save the program, and repeat the syntax check. Finally, close

**Message window**

- Ensure that the icon plug shows that the connection is made.
- Download the compiled project (**Online > Download > Project**).

To test your “Velocity Profiles” program,

- Select **Online > Control axes**.
- Choose **Program 2** and click **Ok**.
- While **Debug** window is active, you can execute it step by step (**Execute step** icon) or continuously (**Start** icon).
- Click **Execute step** icon.
- Go through the lines of the program step by step (Fig. 3.4), observing the different velocities (20, 50, 70 and 100% of the maximal speed).

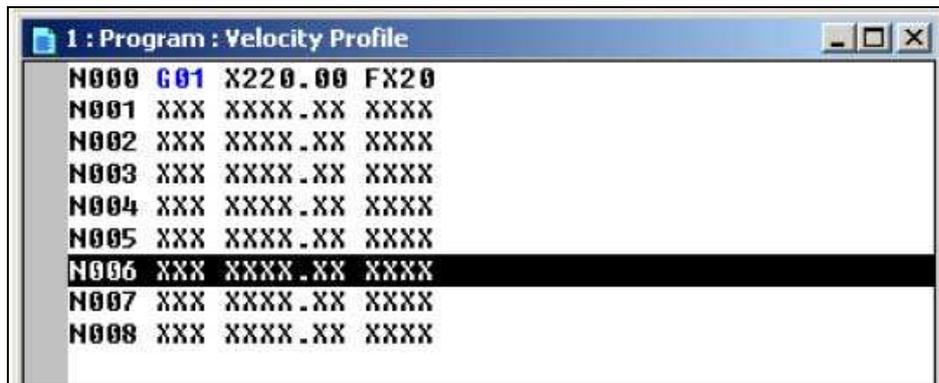


Fig. 3.4. Program execution steps

- Fill in your observations in the **Observation** column of the table below.

Task 2		
Variant	Record	Observation
1	0	
	1	
2	2	
	3	
3	4	
	5	
4	6	
	7	

- Close the **Program 2** window keeping the project open.

**2.6. Positioning**

The positions have to be defined before they can be called in a program. To execute the position move, the step drive must be running, **WinPISA** starting, and your project downloaded. Your new program must have 9 records colling the slide to move *at half of the maximum speed*:

Record	Move to Position
0	10 % of Max
1	25 % of Max
2	50 % of Max
3	75 % of Max

## 2. CONTROL OF STEP DRIVE

4	90 % of Max
5	10 % of Max
6	90 % of Max
7	50 % of Max
8	End of subroutine

- Create a new program in accordance with the table above.
- Once completed, do a syntax check and save the program as “Position Profiles”. It should be the **Program 3**.
- Download the project (**Online > Download > Project**).

To test the “Position Profiles” program,

- Select **Online > Control axes**.
- Choose **Program 3** (“Position Profiles”).
- While the program is active, click **Execute step** icon.
- Go through the lines of the program step by step, observing the different positions.
- Fill in your observations in the **Observation** column of the table below.

Task 3		
Variant	Record	Observation
1	0	
	1	
2	2	
	3	
3	4	
	5	
4	6	
	7	

- Close the **Program 3** window keeping the project open.

### 2.7. Setting ramps

With too hard acceleration or deceleration you can lose steps. Therefore, the speed ramping up and down is an important feature for providing smooth but fast motion. You have to find the profile for the individual movement dependently on the system performance, the length of the axes, the maximal velocity, the slippage, and the load. In practice, you should not start with more than 200 Hz as it will accelerate too fast.

To execute ramping, the step drive must be running, **WinPISA** starting, and your project downloaded. If you have undefined starting conditions, activate first the *reference move* and only afterwards test your program.

Your new program must provide the motion between the two positions with the required acceleration and deceleration *at the maximal speed*:

Record	Move to Position	Acceleration	Deceleration
0	90 % of Max	10 %	10 %
1	10 % of Max	10 %	10 %
2	90 % of Max	100 %	100 %
3	10 % of Max	100 %	100 %

## 2. CONTROL OF STEP DRIVE

4	90 % of Max	10 %	10 %
5	10 % of Max	10 %	10 %
6	90 % of Max	100 %	100 %
7	10 % of Max	100 %	100 %
8	90 % of Max	50 %	50 %
9	10 % of Max	50 %	50 %
10	90 % of Max	100 %	100 %
11	10 % of Max	100 %	100 %
12	End of subroutine		

- Using the table above, create the new program similarly to those shown in Fig. 3.5.

```

3 : Program : Kiirenduskõverad
N000 G08 X0
N001 G09 X20
N002 G01 X20.00 FX0
N003 G01 X180.00 FX0
N004 M02
    
```

Fig. 3.5. Program example

The description of the program is as follows:

NC Record	Description
N000 G08 X0	Accelerate 100 %
N001 G09 X20	Decelerate 20 %
N002 G01 X20.00 FX0	Move at 100 % of the maximal speed to position X = 20 mm
N003 G01 X180.00 FX0	Move at 100 % of the maximal speed to position X = 180 mm
N004 M02	End of subroutine

In the records “N000” and “N001” the acceleration and deceleration are assigned. Next, the motion is described in “N002” and “N003”. The acceleration and deceleration would be retained until they are changed further down the program. Any time as you need to change acceleration or deceleration rate, set the new G08 and G09 commands.

- Once completed, do a syntax check and save the program as “Ramp Profiles”.
- Download the project (**Online > Download > Project**).
- Select **Online > Control axes**.
- Select **Program 4** (“Ramp Profiles”) and click **Ok**.
- Go through the lines of the program step by step clicking **Execute step** icon and observing the different ramps. You can stop at any time by clicking the **Stop** button.

## 2. CONTROL OF STEP DRIVE

- Write down your **Observation** in the table below.

<b>Task 4</b>			
<b>Variant</b>	<b>Record</b>	<b>Accel./Decel.</b>	<b>Observation</b>
1	0		
	1		
	2		
2	3		
	4		
	5		
3	6		
	7		
	8		
4	9		
	10		
	11		

### 2.8. Problems

<b>Variant</b>	<b>Problems</b>
1	3.1. Without current reduction, does the slide move easily or difficult?
	3.2. What conclusion can you draw regarding the laboratory setup safety?
	3.3. Is the SPC 200 always essential?
	3.4. What must be done if slippage is suspected?
	3.5. Calculate the drive resolution in the half-step mode
2	3.1. When is it required to apply the current reduction?
	3.2. When a reference move is required?
	3.3. What dictates the maximal speed of the step drive?
	3.4. What should be done to decrease slippage?
	3.5. Calculate the drive resolution in the full-step mode
3	3.1. How the current reduction is activated and deactivated?
	3.2. How SPC 200 and SEC-ST are linked and what data do they exchange?
	3.3. How can you change the speed of motion?
	3.4. What factors define the resolution of the slide motion?
	3.5. Calculate the drive resolution in the quarter-step mode
4	3.1. Explain a relation between the motor torque and current values.
	3.2. Why do we need a pulse generator?
	3.3. How accurate are the speeds that can be set for the stepper?
	3.4. How the distance is defined the slide moves per the motor shaft revolution?
	3.5. Calculate the drive resolution in the fifth-step mode

### 2.9. Report contents

- **functional diagram** of the laboratory setup and the nominal data
- texts of your **programs**
- **tables** of observations for the tasks related to your variant
- solutions of the problems related to your variant