Mechatronics

PLC Applications

Electromechanical Systems Using Stepper Motors

Job Sheets - Courseware Sample

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Safety and Common Symbols

The following safety and common symbols may be used in this manual and on the equipment:

Symbol	Description
⚠ DANGER	**DANGER** indicates a hazard with a high level of risk which, if not avoided, will result in death or serious injury.
⚠ WARNING	**WARNING** indicates a hazard with a medium level of risk which, if not avoided, could result in death or serious injury.
⚠ CAUTION	**CAUTION** indicates a hazard with a low level of risk which, if not avoided, could result in minor or moderate injury.
CAUTION	**CAUTION** used without the *Caution, risk of danger* sign ⚠, indicates a hazard with a potentially hazardous situation which, if not avoided, may result in property damage.
	Caution, risk of electric shock
	Caution, hot surface
	Caution, risk of danger
	Caution, lifting hazard
	Caution, hand entanglement hazard
	Notice, non-ionizing radiation
⎓	Direct current
∼	Alternating current
$\overline{\sim}$	Both direct and alternating current
3∼	Three-phase alternating current

Safety and Common Symbols

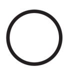
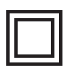
Symbol	Description
	Earth (ground) terminal
	Protective conductor terminal
	Frame or chassis terminal
	Equipotentiality
	On (supply)
	Off (supply)
	Equipment protected throughout by double insulation or reinforced insulation
	In position of a bi-stable push control
	Out position of a bi-stable push control

Table of Contents

Preface

The *Programmable Logic Controller, Basic Programming* student manual allowed the reader to become familiar with PLCs and ladder programming. This was accomplished with the help of the Programmable Logic Controller Training System (Model 3240).

The aim of the present series of PLC applications is to integrate the basic principles previously acquired by designing small-scale systems that can be found in the real world. Through practical examples, students will gain a strong knowledge of the PLC field of study.

Each manual of the PLC applications series concentrates on a specific example of PLC application that evolves along a path of increasing complexity. With each manual, new components are added to the PLC module to create different opportunities to learn.

We hope that your learning experience with the PLC Training System will be the first step of a successful career.

We invite readers of this manual to send us their tips, feedback, and suggestions for improving the book.

Please send these to did@de.festo.com.

The authors and Festo Didactic look forward to your comments.

About This Manual

Programmable Logic Controllers (PLC's) represent state-of-the-art microprocessor-based electronics that make up technologically advanced control systems with applications in virtually every segment of industry where automation is required.

The present manual includes five Job Sheets that introduce students to PLC control of the Electro-Mechanical Training System with Stepper Motor, Model 8075-4. Throughout the manual, students will learn how to program, connect, operate, and troubleshoot different configurations.

Prerequisite

Before performing the Job Sheets in this manual, it is recommended to review the *Programmable Logic Controller, Basic Programming* student manual, which explains how to use the programming software and the most common PLC instructions. If any difficulty is encountered while performing the exercises, the programming software's user guide and help menu can assist students in problem solving.

Safety considerations

Safety symbols that may be used in this manual and on the equipment are listed in the Safety Symbols table at the beginning of the manual.

Safety procedures related to the tasks that you will be asked to perform are indicated in each exercise.

Electromechanical systems can be harmful when not used properly. Before performing any of the exercises in this manual, make sure that you respect the following general guidelines:

- Put your safety glasses on.
- Avoid wearing any loose clothing (e.g., tie, long sleeves, jewelry).
- Have your hair tied out of the way if it is long.
- Clean your work area if necessary.

Remember that you should never perform an exercise if you have any reason to think that a manipulation could be dangerous to you or your teammates.

Systems of units

Units are expressed using the International System of Units (SI) followed by the units expressed in the U.S. customary system of units (between parentheses).

Appendices

Appendix A: *List of Equipment Required*, gives the list of equipment needed to perform the exercises.

Appendix B: *Ladder Program Design*, presents two different methods that can be employed to program a PLC ladder program.

Appendix C: *Boolean Algebra and Digital Logic*, shows the logical relationships that can be employed with normally-open (NO) and normally-closed (NC) contacts.

Appendix D: *Troubleshooting Procedures*, is a set of guidelines permitting students to locate and correct PLC system failures.

Appendix E: *Glossary of Terms*, defines technical words and expressions contained in this manual.

Appendix F: *Ladder Diagram Graphic Symbols*, depicts the main symbols used in ladder diagrams.

To the Instructor

You will find in this Instructor Guide all the elements included in the Student Manual together with the answers to all questions, results of measurements, graphs, explanations, suggestions, and, in some cases, instructions to help you guide the students through their learning process. All the information that applies to you is placed between markers and appears in red.

Accuracy of measurements

The numerical results of the hands-on exercises may differ from one student to another. For this reason, the results and answers given in this manual should be considered as a guide. Students who correctly performed the exercises should expect to demonstrate the principles involved and make observations and measurements similar to those given as answers.

The instructor should be familiar with PLCs to recognize erroneous results. It is advised that a complete run-through of each job sheet be included in the instructor's preparation for class. Each Job Sheet has several performance objectives. The instructor should ensure that each student understands them.

Sample
Extracted from
the Job Sheets Student
and the Job Sheets Instructor

Familiarization with the Electromechanical System

Motion control

The sub-field of automation pertaining to position and/or speed regulation is called motion control. Motion control is widely used in the packaging, printing, textile and assembly industries. It also plays an important role in robotics and CNC (computer numerical control) machine tools.

- A typical motion control system contains:
- A motion controller (e.g. a PLC).
- A drive or amplifier to transform the control signal (often desired velocity or torque signal) into a higher power output.
- An actuator such as a hydraulic pump, air cylinder, linear actuator, or electric motor for output motion.
- A feedback sensor such as an optical encoder, or proximity switch to return the position of the actuator to the motion controller.
- Mechanical components (gears, bearings, lead screw, etc.) to transform the motion of the actuator into the desired motion.

Stepper motor

Stepper motors are electric motors for which a single rotation is divided into many intermediate positions or steps. Knowing the number of steps accomplished by the motor and the angle pertaining to one step allows the control of the motor position without any feedback mechanism. Figure 1 shows a basic stepper motor in each of its four steps.

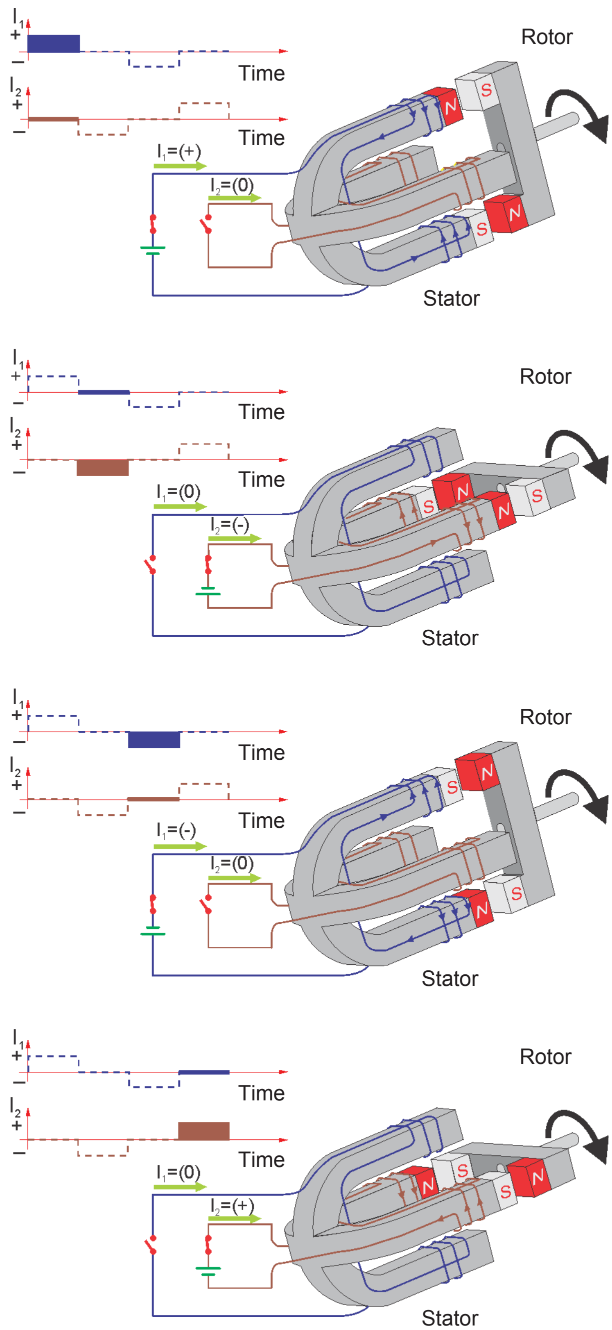


Figure 1. Stepper Motor.

To understand how a stepper motor is forced to move, consider the rotor (moving part of the motor) of the stepper motor as a magnet with a north and a south pole. The windings in the stator (fixed part of the motor) are electromagnets that can change polarity to modify the orientation of the resulting magnetic field. Upon a change in the magnetic field orientation, the rotor is forced to realign, causing the motor shaft to rotate. The stepper motor from the Electromechanical system contains more magnets than in this example, providing 200 different steps. Note that even more precise control can be accomplished through the stepper motor drive software by subdividing each step.

Electromechanical systems

The Electromechanical System – Stepper Motor is a PLC application designed to practice linear motion control. Figure 2 shows the Power Supply, the PLC, and the Stepper Motor drive used to control the position and the velocity of a sliding block moving on a lead screw driven by a stepper motor.

Figure 2. The Electromechanical System – Stepper Motor.

Figure 3 shows the control diagram of a stepper motor. This system performs open-loop control because no feedback is sent to the controller. For this reason, if the motor misses a step (e.g. the motor torque is too low), there is no means for the controller to sense that an error has occurred.

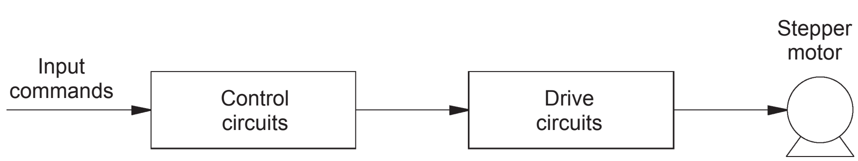


Figure 3. Open-loop control of a stepper motor system.

The Electro-Electromechanical – Stepper Motor System

The Electro-Electromechanical – Stepper Motor System includes three modules:

- DC Power Supply Drive – Stepper Motor (P/N 3206)
- Stepper Motor Drive (P/N 3207)
- Electromechanical – Stepper Motor Module (P/N 3294)

Figure 4 shows the DC Power Supply – Stepper Motor. Either one of the two power connectors can be used to provide electrical power to the Stepper Motor Drive.

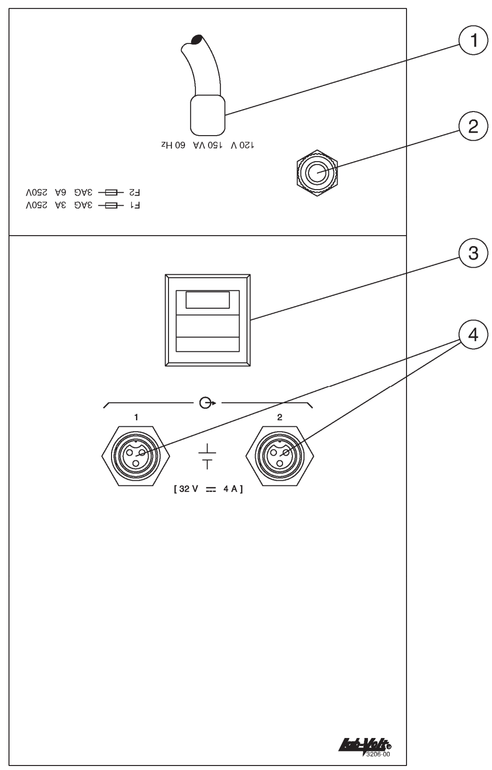


Figure 4. DC Power Supply – Stepper Motor, Model 3206.

1. Power Cord
2. Reset Button
3. ON/OFF Switch
4. Stepper Motor Drive Power Connectors

Figure 5 shows the Stepper Motor Drive. The Stepper Motor Drive is used to control motor displacements. It presents eight inputs, including two jog inputs and two limit switch inputs. Three different outputs can be used for feedback. The drive is supplied with a communication cable and software allowing the program and control of the drive from a PC.

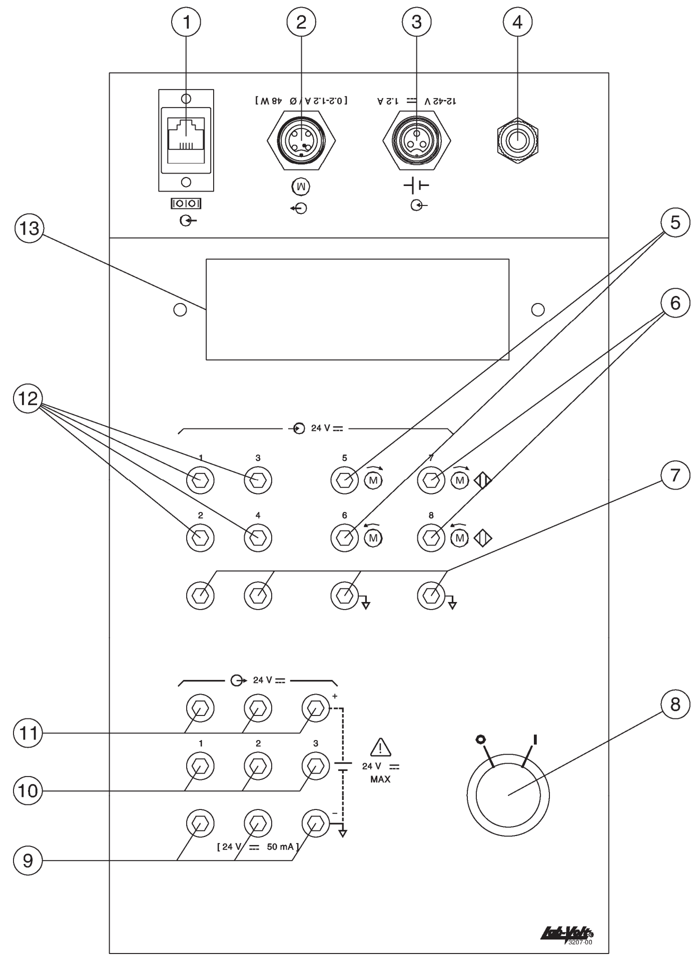


Figure 5. Stepper Motor Drive, Model 3207.

1. Communication Port
2. Motor Power Connector
3. Drive Power Input Terminal
4. Reset Button
5. Clockwise and Counterclockwise Jog Terminals
6. Clockwise and Counterclockwise Limit Switch Input Terminals
7. Input Common Terminals
8. ON/OFF Rotary Switch
9. Output Common Terminals
10. Output 1 to 3 Terminals
11. Output Power (+24 V) Terminals
12. Input 1 to 4 Terminals
13. Fault Panel

Figure 6 shows the Electromechanical – Stepper Motor module. It consists of a stepper motor coupled to a lead screw on which a sliding block is installed. Two magnetic limit switches detect when the sliding block approaches the start or end position.

The Electromechanical – Stepper Motor is designed with a gap on both sides of the lead screw that lets the sliding block rest safely in case of overtravel.

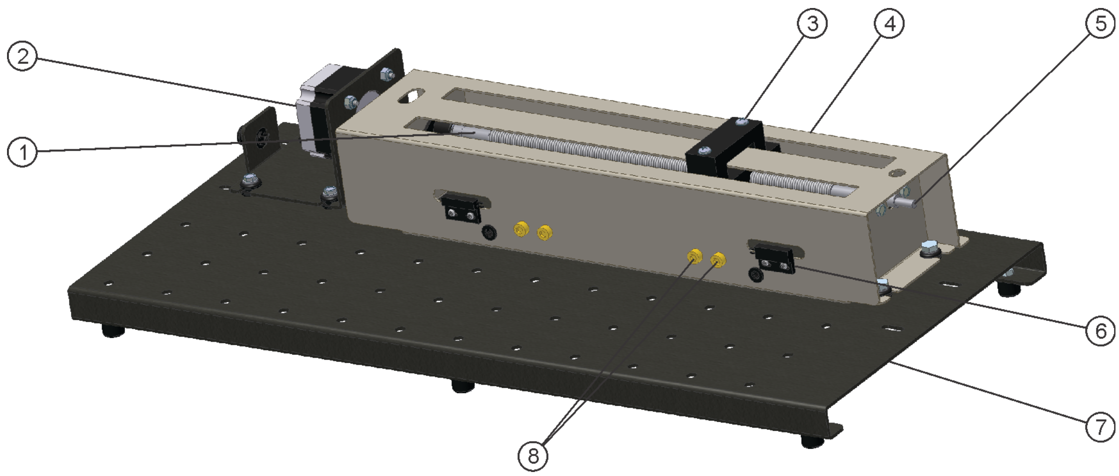


Figure 6. Electromechanical – Stepper Motor module.

1. Leadscrew
2. Stepper Motor
3. Sliding Block
4. Cover
5. Rod End
6. Magnetic Contact
7. Application Base
8. Magnetic Limit Switch Terminals

The system control section operates with low voltage signals (24 V dc). The PLC is programmed and monitored using a computer running ladder programming software.

Distance calculation in lead screw drive systems

In a lead screw drive system, the pitch of the lead screw threads determines the number of rotations needed to move the sliding block over a certain distance. The screw thread pitch of the Electromechanical System is 0.195 cm (1/13 in), meaning that 13 screw rotations result in a linear displacement of 2.54 cm (one inch).

The distance traveled by the sliding block during a given period of time can be determined by multiplying the number of steps that have occurred during this period by the lead screw pitch (distance between two threads) and dividing the result by the number of steps produced by the stepper motor drive for each turn (or thread), as shown below:

$$Distance = \frac{Number\ of\ steps\ \times Screw\ pitch}{Number\ of\ steps\ per\ thread}$$

To find the number of steps required to move the sliding block over a given distance, the formula is simply rearranged as:

$$Number\ of\ steps = \frac{Distance\ \times Number\ of\ steps\ per\ thread}{Screw\ pitch}$$

Stepper Motor Drive software

The *Si™ Programmer* Software accompanying the Stepper Motor Drive provides means to take full advantage of the system's stepper motor. Figure 7 shows the software's Program Window.

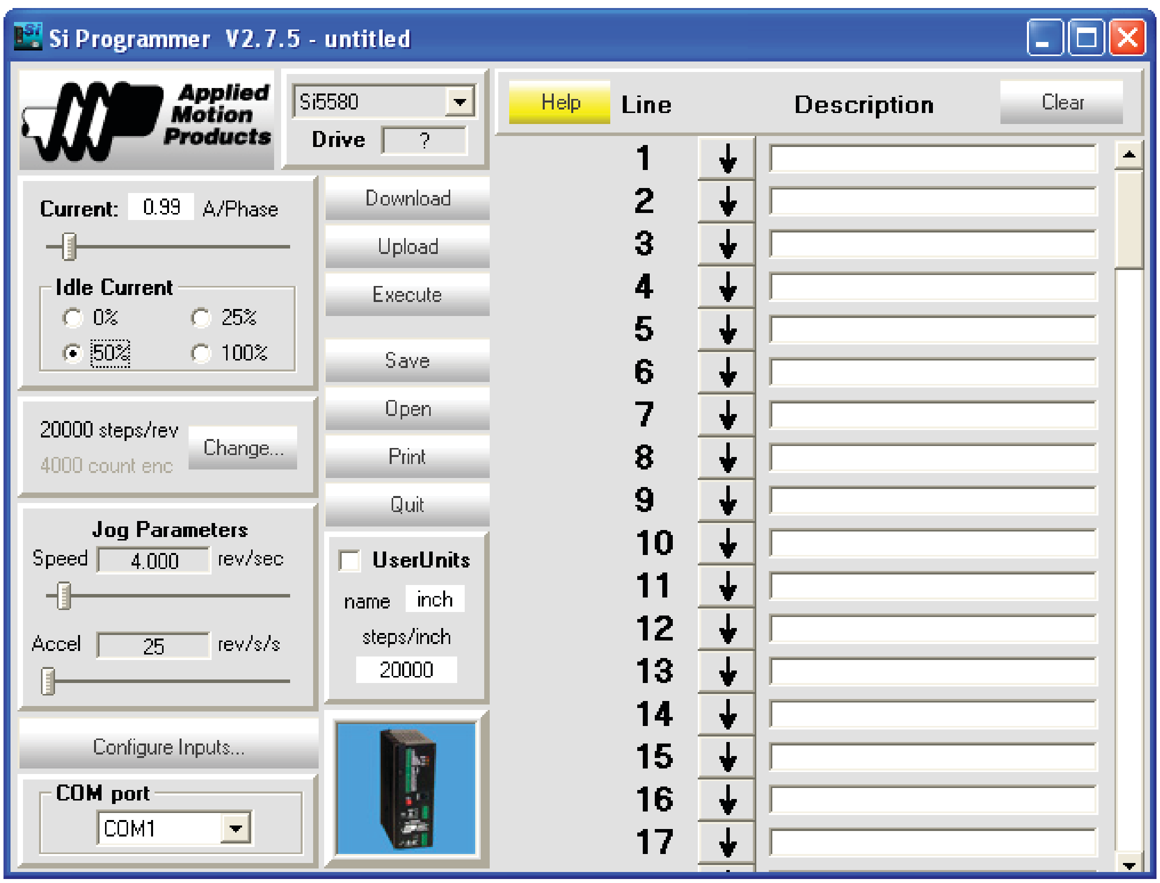
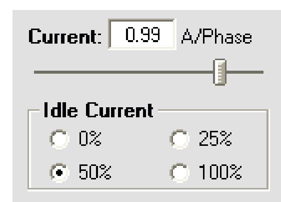


Figure 7. Stepper Motor Drive software program window.

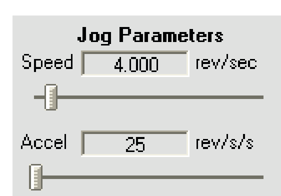
- The Drive box displays the model and firmware version of your drive. Make sure the drive model is 1240i.

- The Current box displays the current at which each phase is operated. The idle current is the current applied when the motor is not moving. High values provide high holding torque, but create higher drive and motor heating.



- The Microstep Resolution box sets the number of steps pertaining to one revolution.

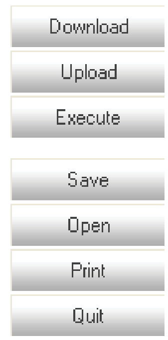
- The Jog Parameters box allows the setting of speed and acceleration when a Jog input is energized.



- The Configure Inputs button allows more options involving the inputs.

- The COM port box lets the user choose the communication port to which the communication cable is connected.

- The File Management buttons enable the user to open, execute, transfer, save, print, or exit the current program.



- The User Units box enables the scaling of data in other units than steps and revolutions per second.

- The Program box is where the lines of instructions are entered.

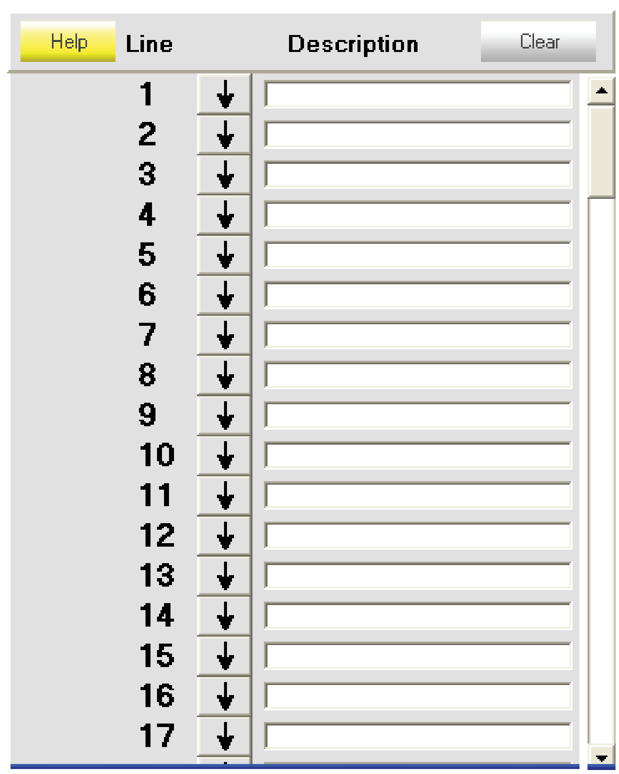


Figure 8 shows the Instruction Selection Menu that is displayed every time a downward pointing arrow or another instruction icon is clicked.

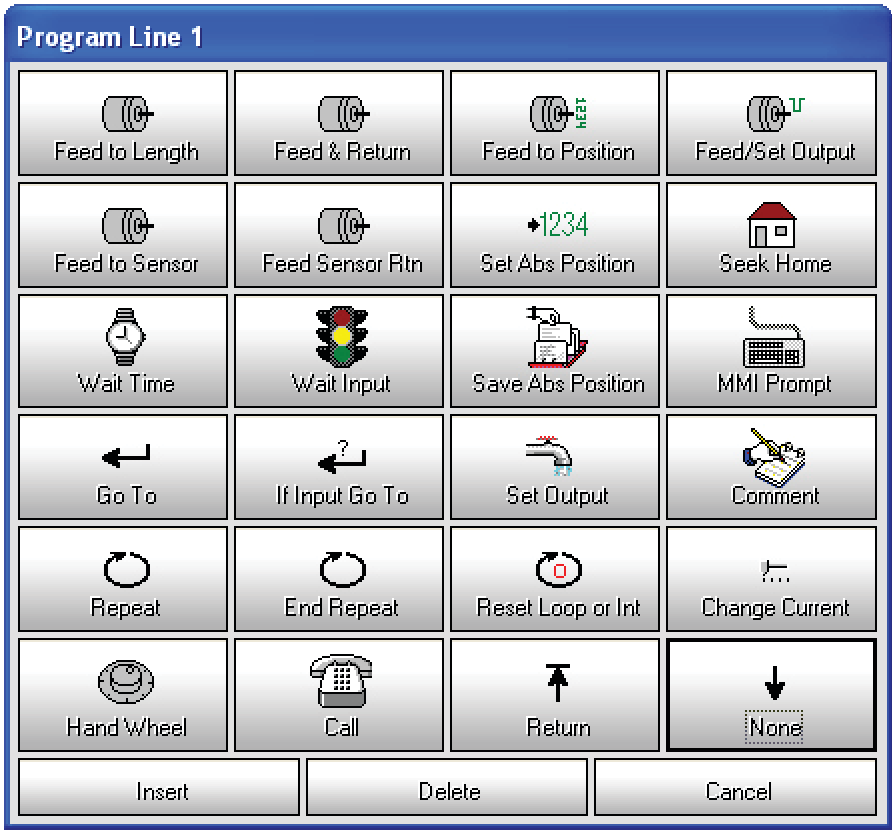


Figure 8. Instruction Selection Menu.

Familiarization with the Electromechanical System

OBJECTIVE

- Test the operation of some basic system components.

PROCEDURE

CAUTION

Make sure you are wearing appropriate protective equipment when performing the jobs. You should never perform a job if you have any reason to think that a manipulation could be dangerous for you or your teammates.

Familiarization with the Stepper Motor Drive

1. Connect the Electromechanical – Stepper Motor System according to Figure 9. All toggle switches must be turned off (down position). The sliding block must stand at an intermediate position.

PLC models may vary.

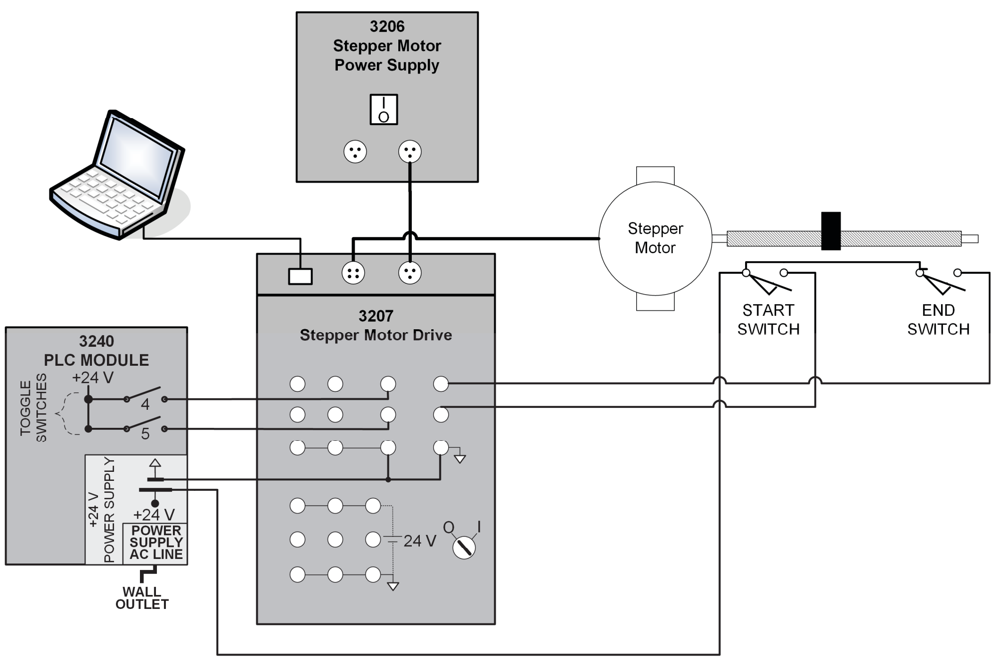


Figure 9. Stepper Motor Drive test circuit.

Table 1. Job Sheet 1 PLC connections.

PLC module port	Connected to
Switch 4 (Toggle)	Clockwise Jog
Switch 5 (Toggle)	Counterclockwise Jog

2. Open the Si Programmer software. Select the appropriate COM port and download the empty program into the drive.

3. Turn on toggle switch 4 to energize the drive clockwise jog terminal. Does the motor turn?

   ❑ Yes ❑ No

   Yes

4. What happens when the sliding block arrives at the end of the lead screw?

   The stepper motor stops working because of the signal sent to the drive limit switch input.

5. Turn off toggle switch 4 to deenergize the drive clockwise jog terminal. Turn on toggle switch 5 to energize the drive counterclockwise jog terminal. Does the motor turn?

   ❑ Yes ❑ No

   Yes

6. What happens when the sliding block arrives at the beginning of the lead screw?

   The stepper motor stops working because of the signal sent to the drive limit switch input.

Stepper Motor Drive software programming

7. Connect a cable between the PLC first pushbutton and the Stepper Motor Drive input 1.

8. Verify that the microstep resolution in Si Programmer is of 20 000 steps per revolution. Calculate the number of steps required to move the sliding block over 14 cm (5.5 in), knowing that the Electromechanical System screw thread pitch is 0.195 cm (1/13 in).

SI units:

$$Number\ of\ steps = \frac{Distance\ \times Number\ of\ steps\ per\ thread}{Screw\ pitch} = \frac{14\ \times 20\ 000}{0.195}$$
$$= 1\ 430\ 000\ steps$$

U.S. customary units:

$$Number\ of\ steps = \frac{Distance\ \times Number\ of\ steps\ per\ thread}{Screw\ pitch} = \frac{5.5\ \times 20\ 000}{1/13}$$
$$= 1\ 430\ 000\ steps$$

9. In the Si Programmer Program Window, enter a two-line program (Figure 10) that will:

- Wait until input 1 is actuated and
- Use the "Feed to Length" instruction to move the sliding block 14 cm (5.5 in) forward. Set the instruction speed to 10 Rev/sec.

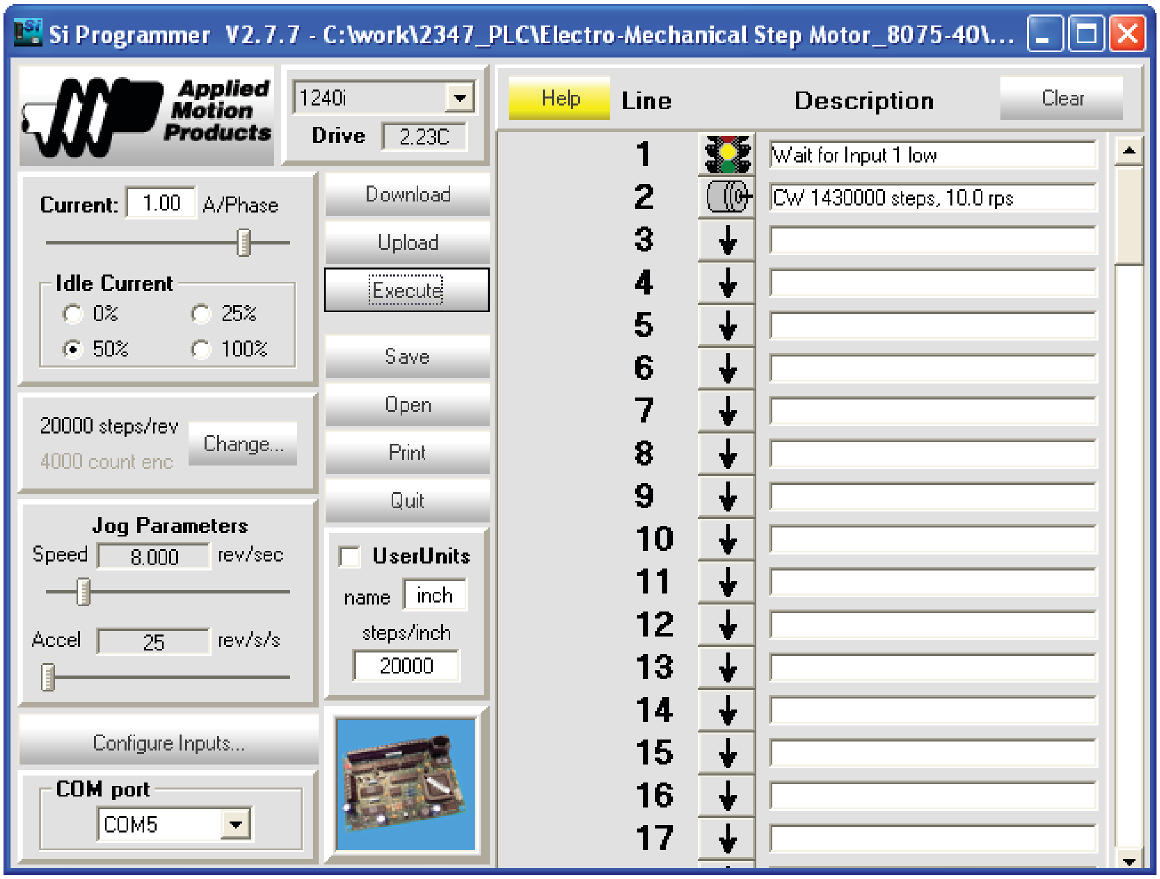


Figure 10. Job Sheet 1 Stepper Motor Drive program.

10. Download the program into the drive.

    If you have problem downloading the program, set Windows Regional and Language Options to English (United States).

11. Demonstrate the operation of the Electromechanical – Stepper Motor system to your instructor.

12. Disconnect and store all leads and components.

Name: ______________________________ Date: ___________________

Instructor's approval: ____

