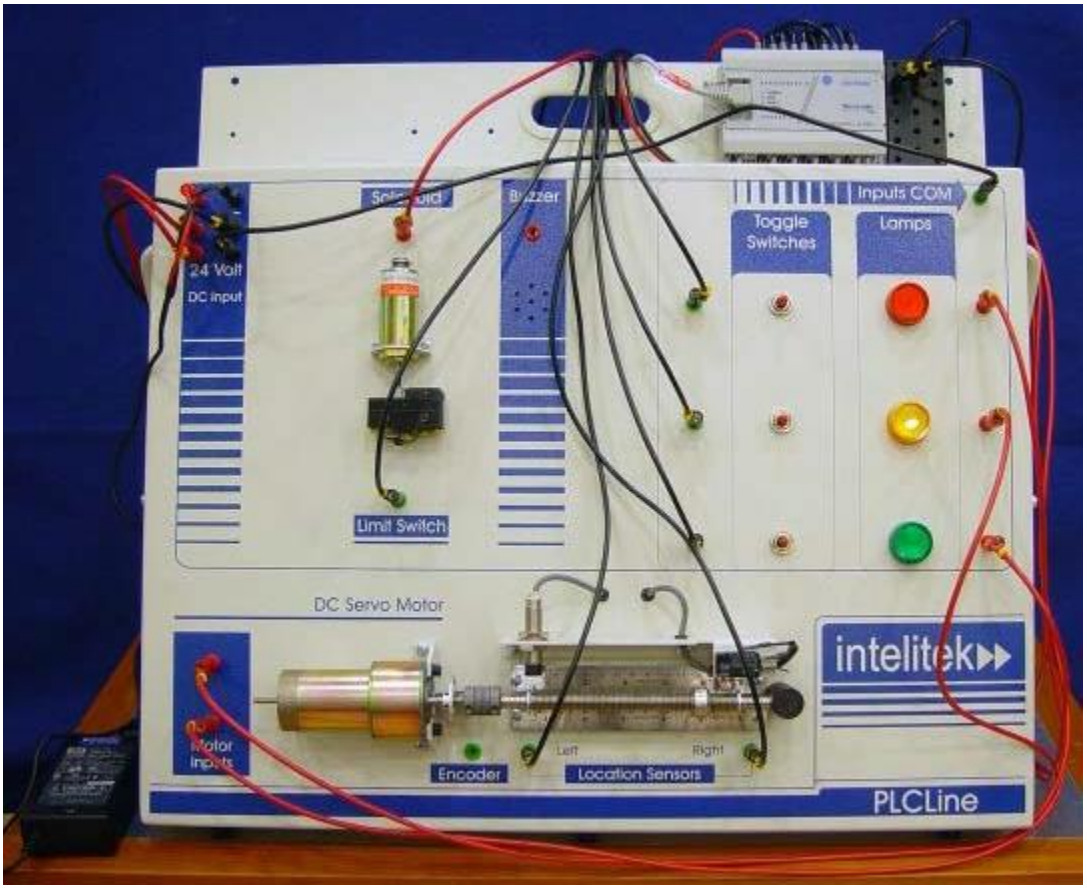
PLC Line



USER'S MANUAL

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PLC Line User's Manual

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Table of Contents

1. Introduction

1.1. ABOUT PLC LINE

PLC Line is a training unit which demonstrates the principles of programmable controllers and sequence control systems.

The unit has a number of devices which can be activated and controlled in numerous configurations.

Each device on the panel has either a red or a green banana socket.

- Red sockets are inputs which require 24VDC for activation.
- Green sockets are outputs.

The black (–) and red (+) sockets are the voltage inputs of the PLC Line panel.

The Inputs COM socket is the common contact for all the outputs.

1.2. WARNINGS

Avoid damaging the PLC Line:

- Do not touch or tamper with the DC motor unit, especially when it is in motion.
- Do not tamper with the solenoid or limit switch units.

To immediately halt all system operation, switch OFF the power supply.

Make sure you do not short the 24VDC socket to ground when connecting the wires. It is strongly recommended that you prepare a circuit diagram before making an actual connection.

1.3. COMPONENTS

1.3.1. Prerequisites

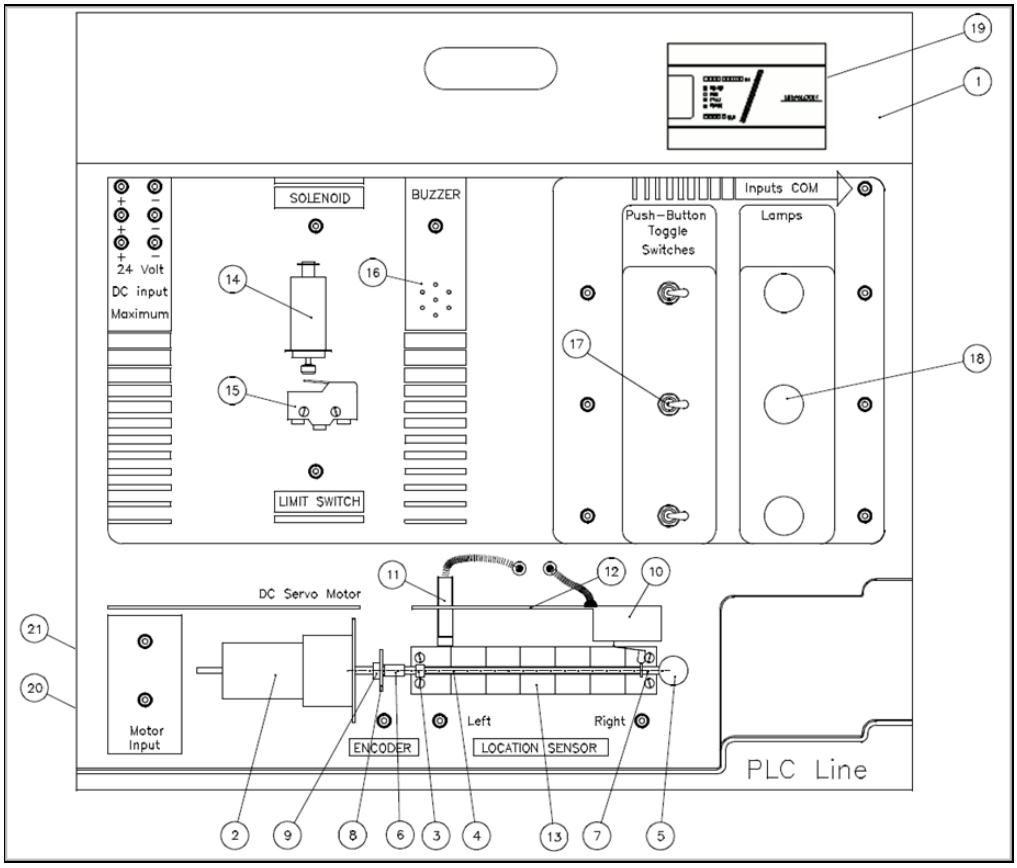
The PLC Line requires the following two items:

- 24 VDC power supply unit, 2A minimum
- Allen-Bradley MicroLogix 1000 PLC; Allen-Bradley 1747 SLC™ 500 PLC; Siemens S7-1200; or any commercial PLC and wires with banana plugs.

For more details, see the list of optional items in Section 1.3.3.

1.3.2. PLC Line

The following diagram shows the PLC Line. Numbers in the diagram refer to the component list.



1. PLC Line Panel
2. DC Servo Motor, Pittman GM9213
3. Nut with Pointer
4. Lead Screw
5. Bearing
6. Coupling
7. 2 Springs with Washer
8. Optical Encoder
9. Encoder Disk, 1-Slot
10. Small Limit Switch
11. Inductive Sensor, M12–NPN
12. Bracket for Sensor and Limit Switch
13. 2 Rulers, 15cm/6"
14. Solenoid, Shindengen's M250 31H
15. Large Limit Switch
16. Buzzer
17. 3 Pushbutton/Toggle Switches
18. 3 Lamps
19. Allen-Bradley MicroLogix 1000 PLC controller, includes communication cable RS232 (option of Allen-Bradley SLC 500 controller or Siemens S7-1200)
20. Power Socket
21. 2A Fuse
22. PLC Line User's Manual
23. 1 Banana Plug Cables - black - 60cm
24. Power Supply unit 110-240VAC to 24VDC 2A

1.3.3. Optional Items for PLC Line

The following items can be ordered from Intelitek for use with the PLC Line training unit.

- PLCMotion Software
- Allen-Bradley SLC 500 controller
- Allen-Bradley MicroLogix 1000 controller
- Siemens S7-1200 controller

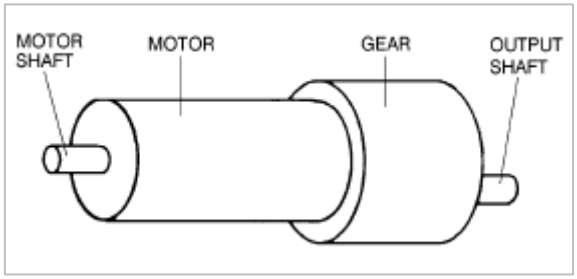
2. Components

The diagrams in this chapter are for illustration purposes and do not necessarily represent the actual PLC Line components.

2.1. MOTOR UNIT

2.1.1. DC Servo Motor

The PLC Line contains a DC servo motor which drives a lead screw.



2.1.1.1. Activation

The direction of motor revolution is determined by the polarity of the operating voltage: positive DC voltage turns the motor in one direction, while negative DC voltage turns it in the opposite direction.

- When the upper Motor Input socket is connected to 24VDC, the motor rotates counter-clockwise.
- When the lower Motor Input socket is connected to 24VDC, an internal relay in the panel reverses the polarity, causing the motor to rotate clockwise.

Specifications: Pittman GM9213 DC Servo Motor

Motor Size Data (25°C)			
Parameter	**Symbol**	**Units**	**Specifications**
Motor Constant	K_M	oz • in$\sqrt{W}$	3.01
Peak Torque (Stall)	T_P	oz • in	41.3
No Load Speed	S_0	rpm	6151
Motor Friction Torque	T_F	oz • in	0.60
Viscous Damping Factor	D	oz • in/krpm	0.0387
Damping Constant	K_D	oz • in/krpm	6.68
Electrical Time Constant	τ_E	ms	0.85
Mechanical Time Constant	τ_M	ms	9.25
Thermal Time Constant	τ_{TH}	min	12.0
Thermal Impedance	R_{TH}	deg C/W	17.1
Maximum Winding Temperature	θ_{MX}	deg C max	5.9×10^{-4}

Motor Size Data (25°C)			
Motor Inertia	J_M	oz • in • s^2	10.1
Motor Weight	W_M	oz	2.403
Motor Length	L_1	in max	2.354

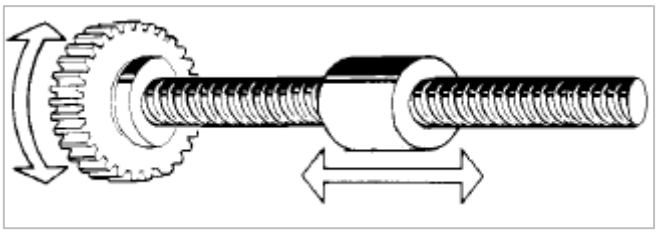
Motor Winding Data (25°C)			
Parameter	**Symbol**	**Units**	**Specifications**
Voltage	E	V	30.3
Torque Constant	KT	oz • in/A	6.50
Back EMF Constant	KE	V/krpm	4.81
Terminal Resistance	RT	ohms	4.62
Inductance	L	mH	3.97
No Load Current	I0	A	0.13
Peak Current (Stall)	IP	A	6.55

Spur Gearmotor Data (25°C) Gear Ratio 127.78			
Parameter	**Symbol**	**Units**	**Output Shaft**
N.L. Speed	S_0	rpm	48.1

2.1.2. Lead Screw and Nut

A lead screw with a nut is connected to the motor output shaft by means of a coupling. The lead screw converts the rotary motion of the DC motor into linear motion of the nut.

2.1.2.1. Activation

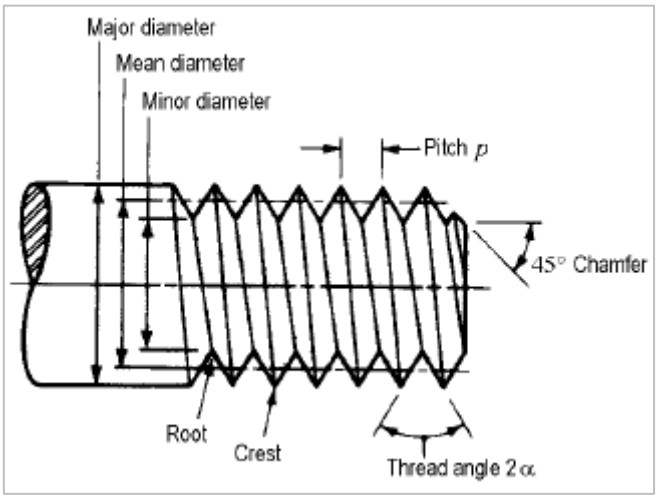


As the motor rotates, a nut travels along the length of the lead screw.

- When the upper Motor Input socket is connected to 24VDC, the nut moves right.
- When the lower Motor Input socket is connected to 24VDC, the nut moves left.

In addition, the motor can be moved by simply twisting the motor shaft manually.

As the nut moves, the distance traveled is measured on the rulers by the pointer attached to the nut.



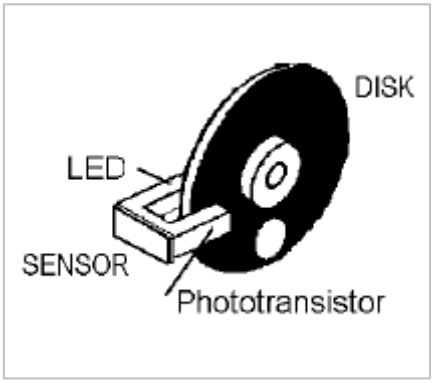
In addition, the nut can be detected by two types of sensors: a mechanical limit switch and an inductive proximity sensor.

2.1.2.2. Specifications

	Coarse-Pitch Series		
Nominal Major Diameter d	**Pitch p**	**Tensile-Stress Area At**	**Minor-Diameter Area Ar**
12	1.75	84.3	76.3

2.1.3. Optical Encoder

The encoder used in the PLC Line has a photoelectric sensor and a one-slot rotating disk.



2.1.3.1. Activation

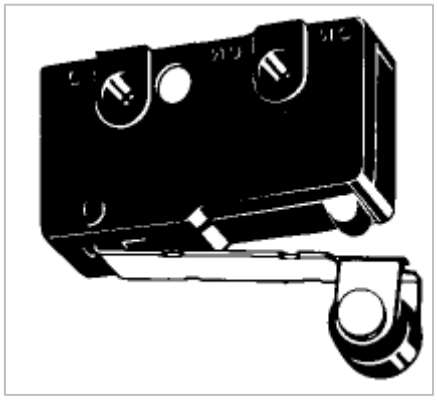
While the disk blocks the light beam from the LED to the phototransistor, an output on (1) signal is sent to the PLC.

When the slot allows the light beam to pass from the LED to the phototransistor, an output off (0) signal is sent to the PLC.

2.1.3.2. Specifications

Supply voltage	5 to 24 VDC ±10%
Current	100mA
Configuration	NPN, Normally Open (sink)

2.1.4. Small Limit Switch



2.1.4.1. Activation

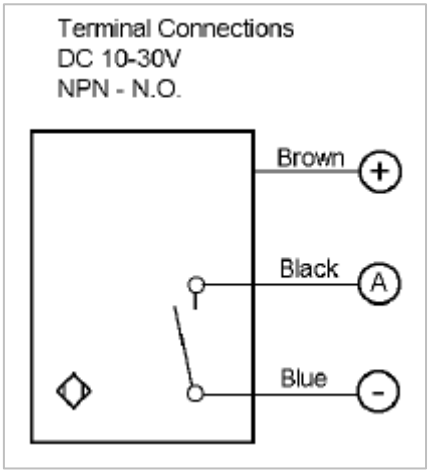
When the nut on the lead screw applies force to the limit switch's actuator (the roller lever), the switch is activated.

When the switch is activated, an output on (1) signal is sent to the PLC through the Location Sensor Right socket.

2.1.4.2. Specifications

Configuration:	Normally open

2.1.5. Inductive Proximity Sensor



This sensor can be moved horizontally within the bracket slot. It can also be adjusted vertically.

2.1.5.1. Activation

The switch is activated when the sensor detects an electrically conductive material (such as the ferrous nut on the lead screw).

When the switch is activated, an output on (1) signal is sent to the PLC through the Location Sensor Left socket. Also, a red LED within the switch lights up.

When the electrically conductive material (the nut) is removed from the sensor's field, the switch reverts to its initial state. The red LED shuts off.

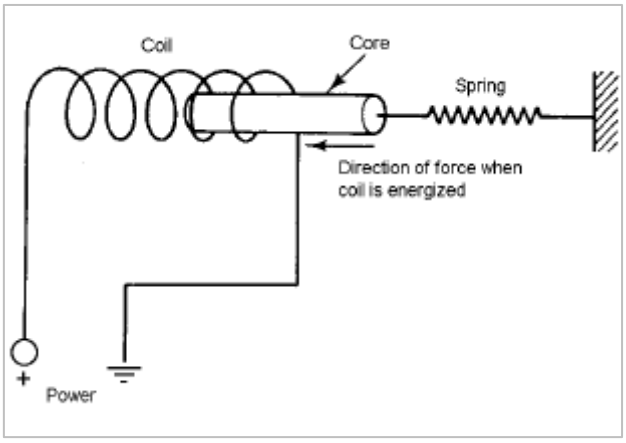
2.1.5.2. Specifications

Supply Voltage	10–30 VDC
Maximum Consumption	200mA
Configuration	NPN, Normally Open (sink)
Thread	M12 thread
Length	50mm
Normal Operating distance	6mm

2.2. SOLENOID UNIT

The PLC Line uses a tubular solenoid housed in a mild steel case.

2.2.1. Solenoid



2.2.1.1. Activation

When the Solenoid input socket is connected to 24VDC, the solenoid coil is energized; the magnetic field pulls the core into the coil, and the plunger is pushed into the actuator of the large limit switch.

When de-energized, the spring pulls the core out of the coil.

Specifications: Shindengen's M25031H

Duty Cycle (on time / "on time"+"off time") x 100			**100% Continuous**	**50% or less**	**25% or less**	**10% or less**
Avg. No.	**Resistance (20°C)**	**No. Turns**	**Volts DC**	**Volts DC**	**Volts DC**	**Volts DC**
31	71.6	2990	26	37	53	84

2.2.2. Large Limit Switch

2.2.2.1. Activation

This switch is activated when the stroke of the solenoid plunger applies force to the actuator (hinge lever).

When the switch is activated, an output on (1) signal is sent to the PLC through the Limit Switch socket.

2.2.2.2. Specifications

Configuration	Normally open

2.3. BUZZER

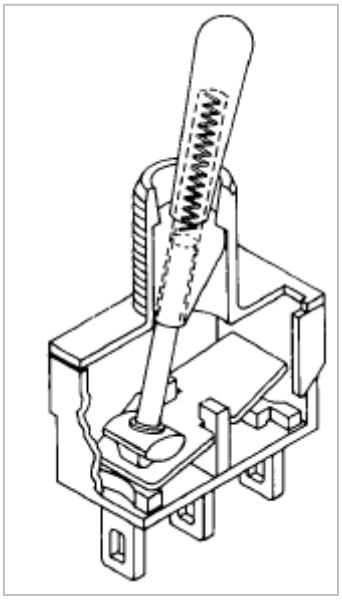
2.3.1. Activation

The buzzer sounds when 24VDC is connected to the Buzzer inputs socket.

2.3.2. Specifications

Supply voltage	24 VDC
Current	10mA

2.4. PUSHBUTTON/TOGGLE SWITCHES



2.4.1. Activation

When pushed to the left, these three switches are activated momentarily; then they return to the middle position (pushbutton function).

When pushed to the right, these switches remain activated (toggle function). They must be manually toggled back to the middle position.

When any of these switches is activated, an output on (1) signal is sent to the PLC through the corresponding output sockets.

2.4.2. Specifications

Supply voltage	250V
Current	10A

2.5. LED INDICATOR LIGHTS

2.5.1. Activation

Each of these lights light up whenever 24VDC is connected to the input socket.

2.5.2. Specifications

Supply voltage	24V
Power	0.5 W
Current	20 mA

2.6. BANANA PLUG CABLES

The PLC Line requires stacking banana plug cables. Stacking simplifies circuit connections and changes, and keeps the circuitry neater.

2.6.1. Specifications

Short Black	60 cm
Supply voltage	24 VDC
Current	10A

2.7. POWER SUPPLY

The PLC Line requires a 24 VDC, 2A minimum, power supply unit.

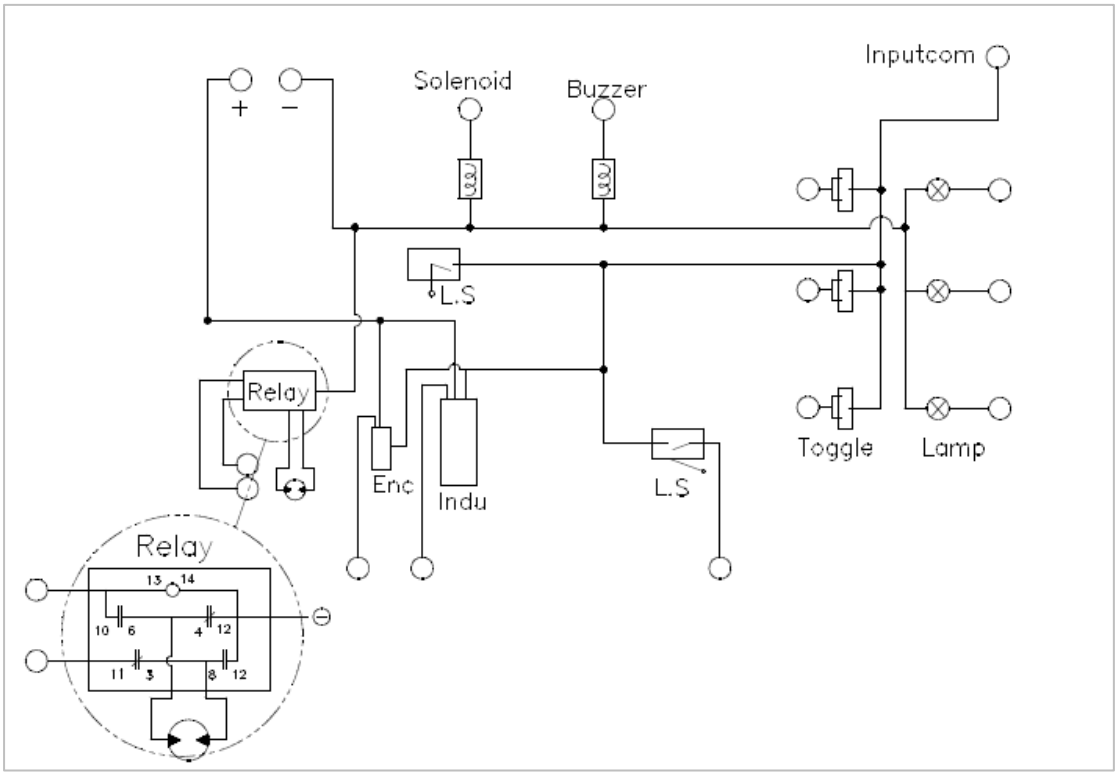
The power supply can be replaced only with a UL approved power supply.

2.7.1. Specifications

Input	100 ~ 230 VAC 50 ~ 60 Hz
Output	24VDC 2A minimum

3. Wiring

The following is the PLC Line electric circuit diagram.



4. PLC Applications

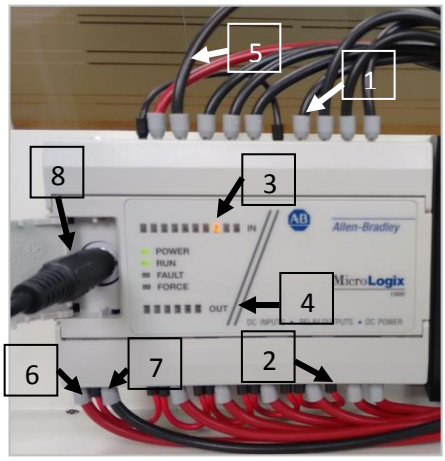
In this section you will learn about the interface of the MicroLogix 1000, SLC 500 and Siemens S7-1200 controllers, how to connect the PLC Line, controller and power supply together. In addition, you will program and simulate some ladder diagrams.

4.1. THE MICROLOGIX 1000 INTERFACE

The MicroLogix 1000 switches the electrical power supply to the PLC Line outputs according to ladder diagram schemes (which you will create) and the condition of various electrical switching devices.

The MicroLogix 1000, which is connected to the computer, contains the following channels.

- **Eight Input Channels**, connected to the panel switches, which transfer the status of the switches to the computer via the interface. The input cables are numbered from #1 to #8, where cable #1 corresponds to LED **0 IN**, cable #2 corresponds to LED **1 IN** and so on. Two additional input channels are available, but are not used).
- **Six Output Channels**, connected to the panel outputs (such as solenoids or other electrical consumers). The switches' status will then activate, via the interface, the outputs. The output cables are numbered from #1 to #6, where cable #1 corresponds to LED **0 OUT**, cable #2 corresponds to LED **1 OUT** and so on.



1. Input Channels
2. Output Channels
3. Input LEDs
4. Output LEDs
5. COM cable
6. Power + cable
7. Power - cable
8. Communication cable

4.1.1. PLC Line - MicroLogix 1000 - Power Supply Connections

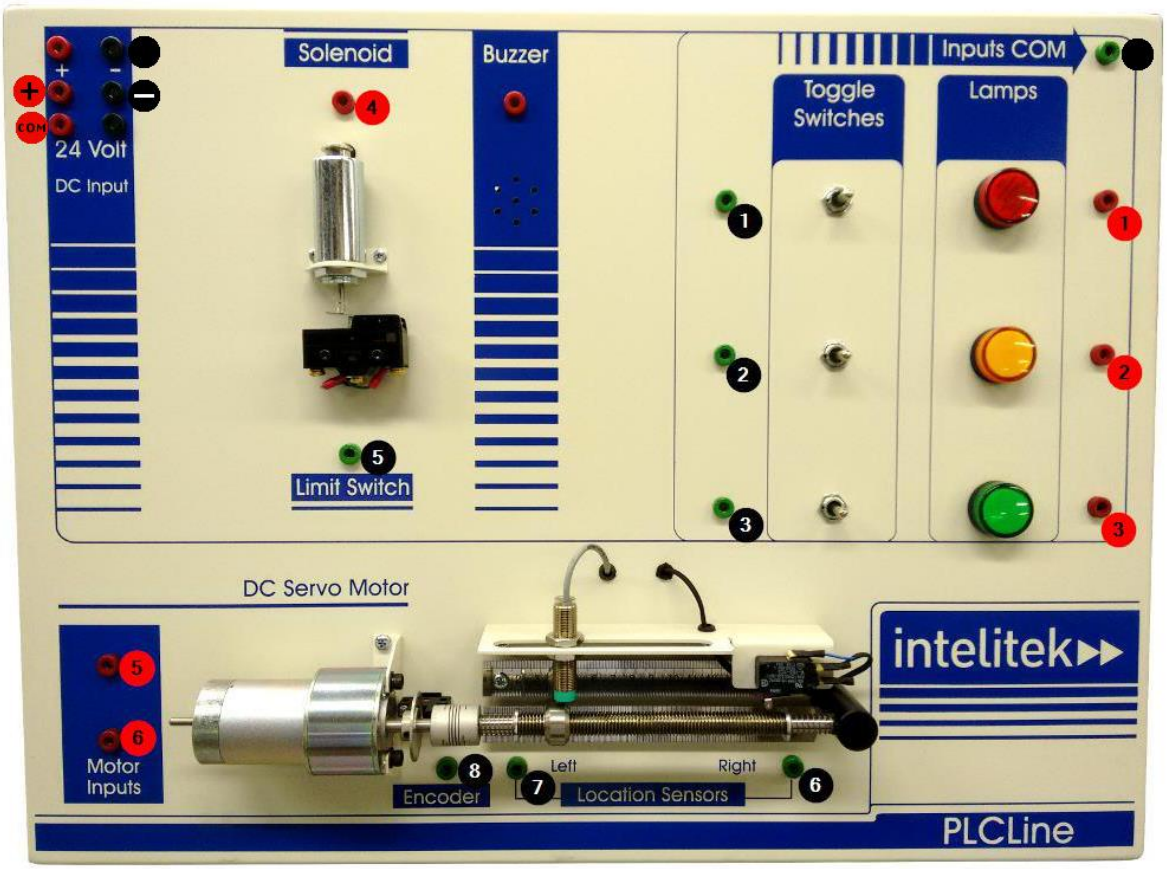
Once the PLC software is installed, you must connect the PLC panel to the MicroLogix 1000 and the power supply.

You need to make:

- Input connections
- Output connections
- Power connections

4.1.2. Panel Connections

Each Micrologix cable has a red or black plastic identifying label attached to it. The cable label for each socket is shown in the image below. Refer to this image when connecting the input and output cables to the panel.



4.1.3. Input Connections

The input cables exit the input ports of Micrologix 1000 (its top side) and are colored **black**. Each cable is labeled with an identifying yellow label. The input sockets on the PLC board are colored **green**.

Make the following input connections:

1. Connect input cable #1 to the top switch input socket.
2. Connect input cable #2 to the middle switch input socket.
3. Connect input cable #3 to the bottom switch input socket.

   Note: Input cable #4 is not used.
4. Connect input cable #5 to the solenoid's limit switch input socket, (marked **Limit Switch**).
5. Connect input cable #6 to the input socket at the right end of the screw, (marked **Location Sensors: Right**).

6. Connect input cable #7 to the proximity sensor input socket at the left end of the screw, (marked **Location Sensors: Left**).
7. Connect input cable #8 to the encoder input socket, (marked **Encoder**).

4.1.4. Output Connections

The output cables exit the output ports of Micrologix 1000 (its bottom side) and are colored **red**. Each cable is labeled with an identifying yellow label. The input sockets on the PLC board are colored **red**.

Make the following output connections:

1. Connect output cable #1 to the red lamp's output socket.
2. Connect output cable #2 to the yellow lamp's output socket.
3. Connect output cable #3 to the green lamp's output socket.
4. Connect output cable #4 to the solenoid's output socket, (marked **Solenoid**).
5. Connect output cable #5 to the motor's upper output socket, (this moves the motor to the right).
6. Connect output cable #6 to the motor's lower output socket, (this moves the motor to the left).

4.1.5. Power Connections

There are six power sockets on the PLC panel (marked **24 Volt DC Input**).

To connect the 24 Volt power supply:

1. Connect the power supply cable to the power socket on the left side of the panel.
2. Connect the + red cable from the MicroLogix 1000 to the middle left power socket.
3. Connect the - black cable from the MicroLogix 1000 to the middle right power socket.
4. Connect the COM red cable from the MicroLogix 1000 to the bottom left power socket.
5. Connect one end of the unmarked loose black cable to the top right black power socket and the other end to the Inputs COM green socket on the top right of the PLC board.
6. Connect the power supply to an electrical outlet using the power cable.

4.1.6. Connecting MicroLogix 1000 to the Computer

To connect MicroLogix 1000 to the computer:

1. Open the small door on the left side of MicroLogix 1000 to access the socket.
2. Connect one end of the communication (gray) cable to the communication cable socket.

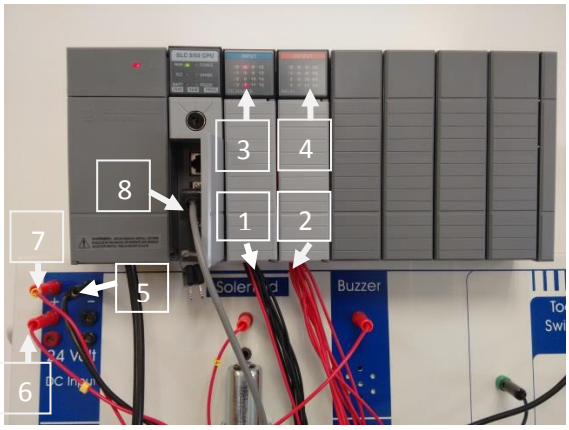
3. Connect the other end of the communication (gray) cable to the COM 1 or COM 2 port of the computer.

4.2. THE SLC 500 INTERFACE

The SLC 500 switches the electrical power supply to the PLC Line outputs according to ladder diagram schemes (which you will create) and the condition of various electrical switching devices.

The SLC 500, which is connected to the computer, contains the following channels.

- **Sixteen Input Channels**, connected to the panel switches, which transfer the status of the switches to the computer via the interface. The input cables are numbered and labeled from #0 to #16, and +.
- **Sixteen Output Channels**, connected to the panel outputs (such as solenoids or other electrical consumers). The switches' status will then activate, via the interface, the outputs. The output cables are numbered and labeled from #0 to #16, and +.



1. Input Channels
2. Output Channels
3. Input LEDs
4. Output LEDs
5. COM cable
6. Input Power + cable
7. Output Power + cable
8. Communication cable

4.2.1. PLC Line – SLC 500 - Power Supply Connections

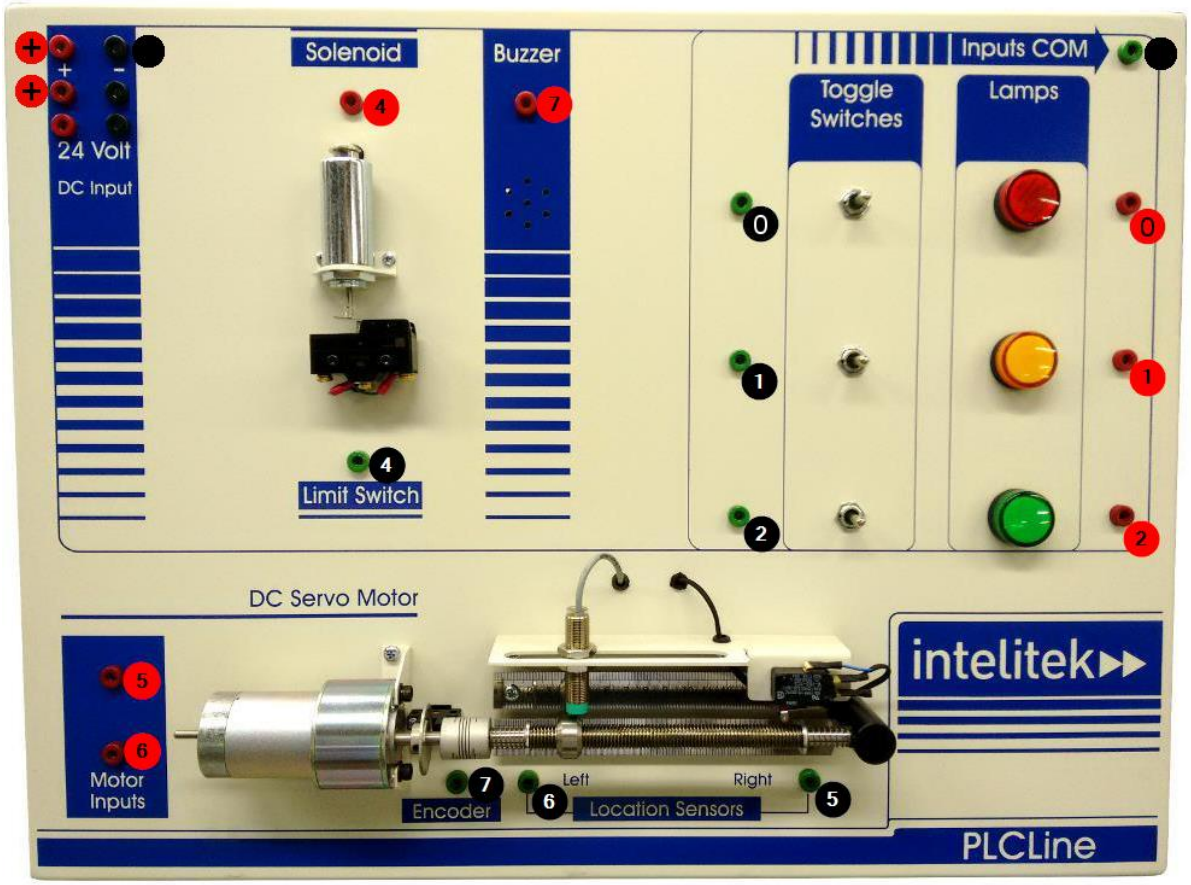
Once the PLC software is installed, you must connect the PLC panel to the SLC 500 and the power supply.

You need to make:

- Input connections
- Output connections
- Power connections

4.2.2. Panel Connections

Each SLC 500 cable has a red or black plastic identifying label attached to it. The cable label for each socket is shown in the image below. Refer to this image when connecting the input and output cables to the panel.



4.2.3. Input Connections

The input cables exit the input ports of the SLC 500 (its top side) and are colored **black**. Each cable is labeled with an identifying yellow label. The input sockets on the PLC board are colored **green**.

Make the following input connections:

1. Connect input cable #0 to the top switch input socket.
2. Connect input cable #1 to the middle switch input socket.
3. Connect input cable #2 to the bottom switch input socket.

   Note: Input cable #3 is not used.
4. Connect input cable #4 to the solenoid's limit switch input socket, (marked **Limit Switch**).
5. Connect input cable #5 to the input socket at the right end of the screw, (marked **Location Sensors: Right**).

6. Connect input cable #6 to the proximity sensor input socket at the left end of the screw, (marked **Location Sensors: Left**).
7. Connect input cable #7 to the encoder input socket, (marked **Encoder**).

4.2.4. Output Connections

The output cables exit the output ports of SLC 500 (its bottom side) and are colored **red**. Each cable is labeled with an identifying yellow label. The input sockets on the PLC board are colored **red**.

Make the following output connections:

1. Connect output cable #0 to the red lamp's output socket.
2. Connect output cable #1 to the yellow lamp's output socket.
3. Connect output cable #2 to the green lamp's output socket.
4. Connect output cable #4 to the solenoid's output socket, (marked **Solenoid**).
5. Connect output cable #5 to the motor's upper output socket, (this moves the motor to the right).
6. Connect output cable #6 to the motor's lower output socket, (this moves the motor to the left).
7. Connect output cable #7 to the buzzer's output socket, (marked **Buzzer**).

4.2.5. Power Connections

There are six power sockets on the PLC panel (marked **24 Volt DC Input**).

To connect the 24 Volt power supply:

1. Connect the power supply cable to the power socket on the left side of the panel.
2. Connect the output + red cable from the SLC 500 to the top left power socket.
3. Connect the input + red cable from the SLC 500 to the middle left power socket.
4. Connect one end of the unmarked loose black cable to the top right black power socket and the other end to the Inputs COM green socket on the top right of the PLC board.
5. Connect the power supply to an electrical outlet using the power cable.

4.2.6. Connecting SLC 500 to the Computer

To connect the SLC 500 to the computer:

1. Open the small door on the left side of the SLC 500 to access the port.
2. Either:
   - Connect an RS232 cable from the port on the controller to an open COM port on the computer, or

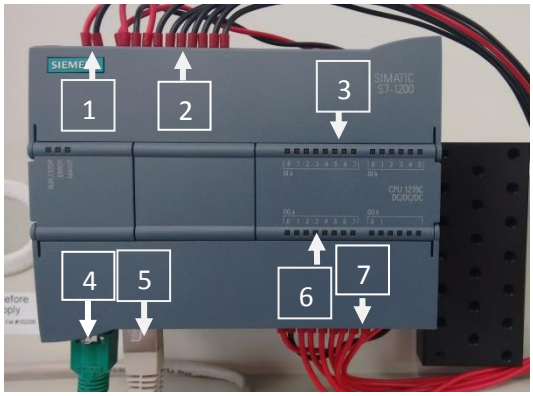
- Connect an RS232 cable from the port on the controller to an RS232 – USB adapter and connect the adapter to an open USB port on the computer.

4.3. THE SIEMENS SIMATIC S7-1200 INTERFACE

The S7-1200 switches the electrical power supply to the PLC Line outputs according to ladder diagram schemes (which you will create) and the condition of various electrical switching devices.

The S7-1200, which is connected to the computer, contains the following channels.

- **Fourteen Input Channels**, connected to the panel switches, which transfer the status of the switches to the computer via the interface. The input cables are numbered and labeled.
- **Ten Output Channels**, connected to the panel outputs (such as solenoids or other electrical consumers). The switches' status will then activate, via the interface, the outputs. The output cables are numbered and labeled.



1. Input Power + cable
2. Input Channels
3. Input LEDs
4. Ethernet cable to PC
5. Ethernet cable to HMI
6. Output LEDs
7. Output Channels

4.3.1. PLC Line – S7-1200 - Power Supply Connections

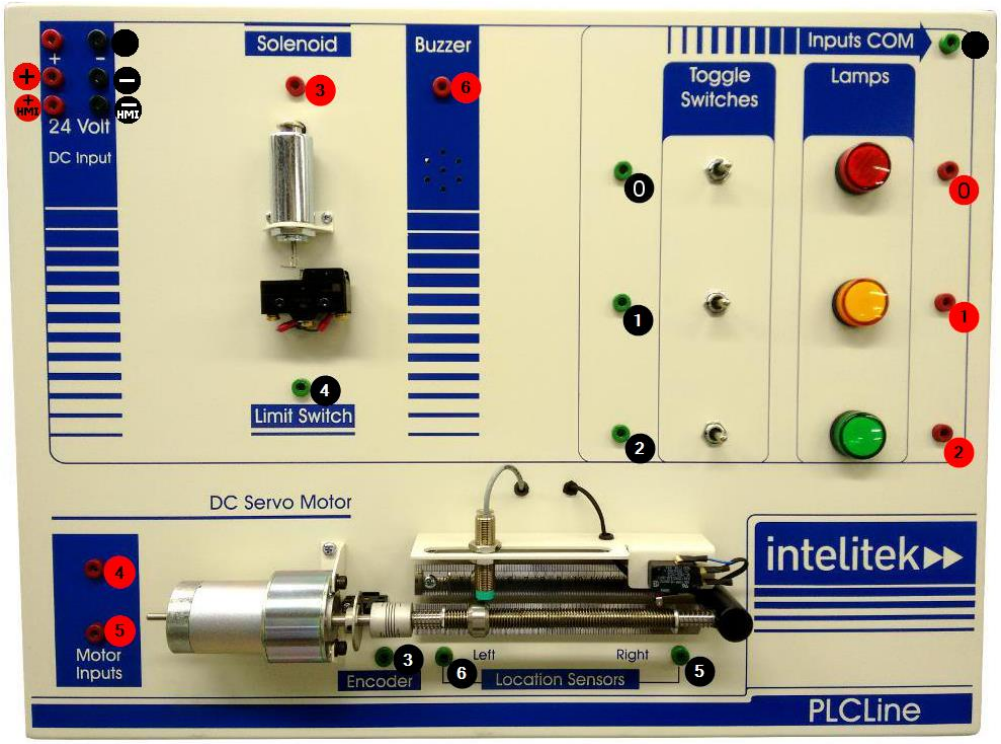
Once the PLC software is installed, you must connect the PLC panel to the S7-1200 and the power supply.

You need to make:

- Input connections
- Output connections
- Power connections

4.3.2. Panel Connections

Each S7-1200 cable has a Yellow plastic identifying label attached to it. The cable label for each socket is shown in the image below. Refer to this image when connecting the input and output cables to the panel.



4.3.3. Input Connections

The input cables exit the input ports of the S7-1200 (its top side) and are colored **black**. Each cable is labeled with an identifying yellow label. The input sockets on the PLC board are colored **green**.

Make the following input connections:

1. Connect input cable #0 to the top switch input socket.
2. Connect input cable #1 to the middle switch input socket.
3. Connect input cable #2 to the bottom switch input socket.
4. Connect input cable #3 to the encoder input socket, (marked **Encoder**).
5. Connect input cable #4 to the solenoid's limit switch input socket, (marked **Limit Switch**).
6. Connect input cable #5 to the input socket at the right end of the screw, (marked **Location Sensors: Right**).
7. Connect input cable #6 to the proximity sensor input socket at the left end of the screw, (marked **Location Sensors: Left**).

4.3.4. Output Connections

The output cables exit the output ports of S7-1200 (its bottom side) and are colored **red**. Each cable is labeled with an identifying yellow label. The input sockets on the PLC board are colored **red**.

Make the following output connections:

1. Connect output cable #0 to the red lamp's output socket.
2. Connect output cable #1 to the yellow lamp's output socket.
3. Connect output cable #2 to the green lamp's output socket.
4. Connect output cable #3 to the solenoid's output socket, (marked **Solenoid**).
5. Connect output cable #4 to the motor's upper output socket, (this moves the motor to the right).
6. Connect output cable #5 to the motor's lower output socket, (this moves the motor to the left).
7. Connect output cable #6 to the buzzer's output socket, (marked **Buzzer**).

4.3.5. Power Connections

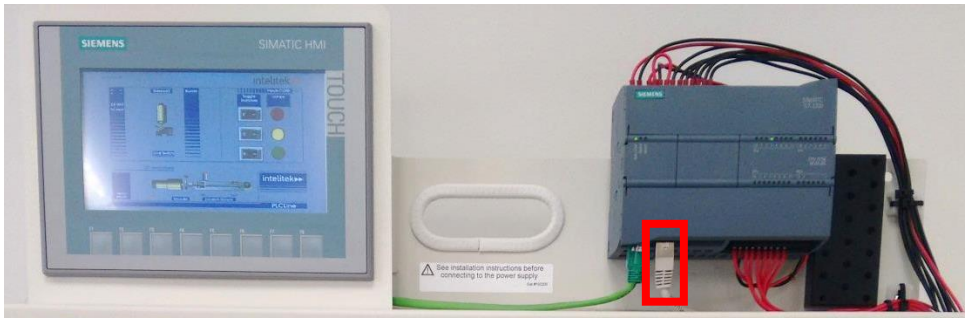
There are six power sockets on the PLC panel (marked **24 Volt DC Input**).

To connect the 24 Volt power supply:

1. Connect the power supply cable to the power socket on the left side of the panel.
2. Connect the input + red cable from the Siemens S7-1200 to the middle left power socket.
3. Connect the output - black cable from the Siemens S7-1200 to the middle right power socket.
4. Connect one end of the unmarked loose black cable to the top right black power socket and the other end to the Inputs COM green socket on the top right of the PLC board.
5. Connect the power supply to an electrical outlet using the power cable.

4.3.6. HMI Connections

To connect the S7-1200 to the SIMATIC HMI, connect an Ethernet cable from the right Ethernet port on the controller to the Ethernet port on the HMI.



To power the HMI, connect the red (+) cable from the HMI to the bottom left power socket on the PLC panel, and the black (-) cable from the HMI to the bottom right power socket.

4.3.7. Connecting the Siemens S7-1200 to the Computer

To connect the S7-1200 to the computer, connect an Ethernet cable from the left Ethernet port on the controller to an Ethernet port on the computer.

4.4. EXAMPLE 1

The following examples are for demonstration purposes only, and are not necessarily recommended for student use.

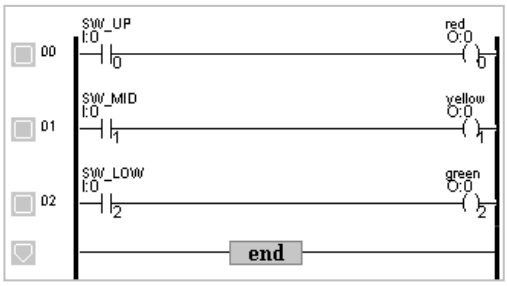
In this application, turning on the upper switch will light the red (top) light, turning on the middle switch will light the yellow (middle) light, and turning on the lower switch will light the green (lower) light.

4.4.1. Requirements

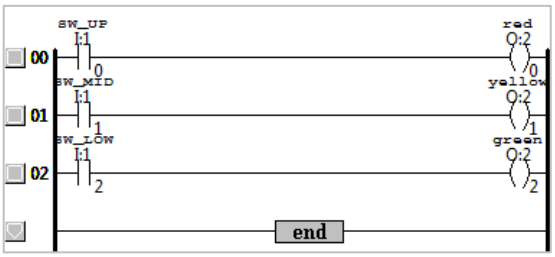
- PLC Line
- PLCMotion software
- PLCMotion software for the MicroLogix 1000 and SLC 500 controllers, or SIMATIC STEP 7 software for the S7-1200 controller
- Power Supply

4.4.1.1. Procedure

1. Using PLC Editor, build the ladder diagram for your controller as shown below, and save.
2. Prepare the PLC Line panel depending on which controller you are using as described in Section 4.1.1, PLC Line - MicroLogix 1000 - Power Supply Connections, Section 4.2.1, PLC Line – SLC 500 - Power Supply Connections or Section 4.3.1, PLC Line – S7-1200 - Power Supply Connections.
3. Using PLC Simulator, open the ladder diagram and run the ladder diagram simulation.
4. From the PLC Line panel, turn on and off the three switches.



MicroLogix 1000



SLC 500 and S7-1200

4.5. EXAMPLE 2

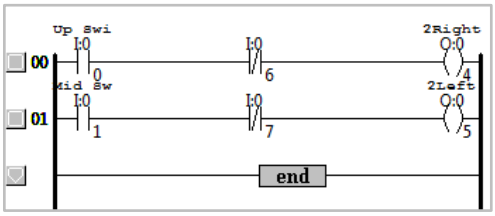
In this application, turning on the upper switch will start the motor, causing the nut on the lead screw to move to the right. When the nut reaches the right limit switch, it stops. Turning on the middle switch will start the motor, causing the nut to move to the left. When the nut reaches the left limit switch, it stops.

4.5.1. Requirements

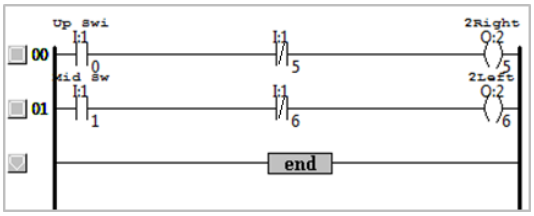
- PLC Line
- PLCMotion software for the MicroLogix 1000 and SLC 500 controllers, or SIMATIC STEP 7 software for the S7-1200 controller
- MicroLogix 1000, SLC 500 or S7-1200 controller
- Power Supply

4.5.2. Procedure

1. Using PLC Editor, build the ladder diagram for your controller as shown below, and save.
2. Prepare the PLC Line panel depending on which controller you are using as described in Section 4.1.1, PLC Line - MicroLogix 1000 - Power Supply Connections, Section 4.2.1, PLC Line – SLC 500 - Power Supply Connections or Section 4.3.1, PLC Line – S7-1200 - Power Supply Connections.
3. Using PLC Simulator, open the ladder diagram and run the ladder diagram simulation.
4. From the PLC Line panel, turn on and leave on the upper switch. The nut moves to the right and stops when it reaches the right limit switch.
5. Turn off the upper switch.
6. Turn on and leave on the middle switch. The nut moves to the left and stops when it reaches the left limit switch.
7. Turn off the middle switch.



MicroLogix 1000



SLC 500 and S7-1200