

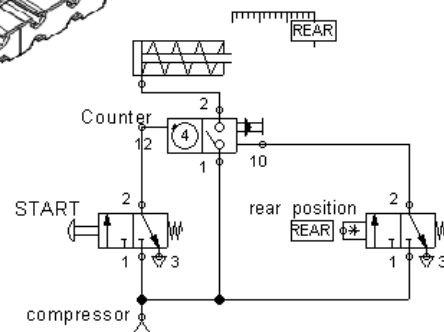
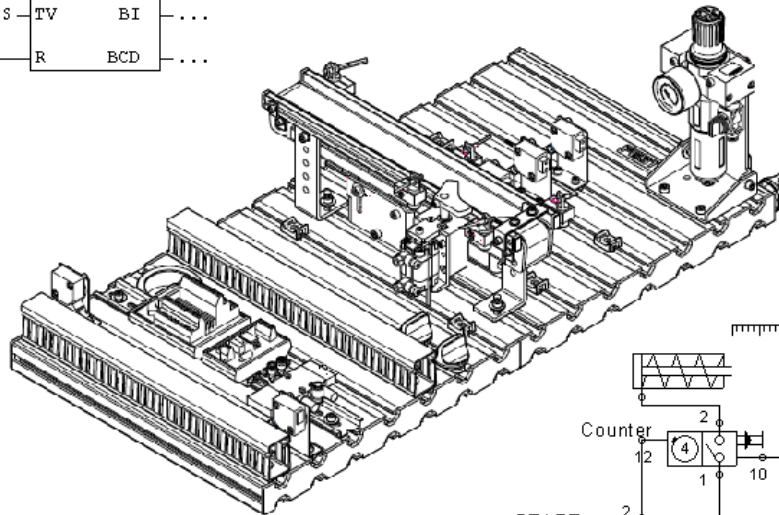
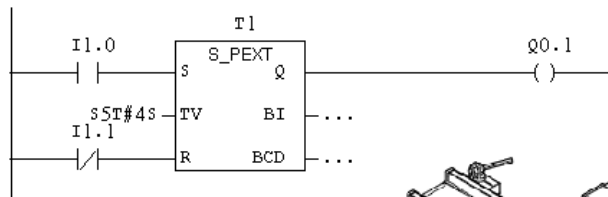


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Experiment 1 Introduction to PLC Stations

Objectives:

- To understand the main components of the PLC.
- To familiarize the students with common industrial inputs devices.
- To familiarize the students with common industrial output devices.
- To investigate a process station and conclude the address of the input/output devices address.

Apparatus:

1. Input/ Output simulator
2. Production Line Stations

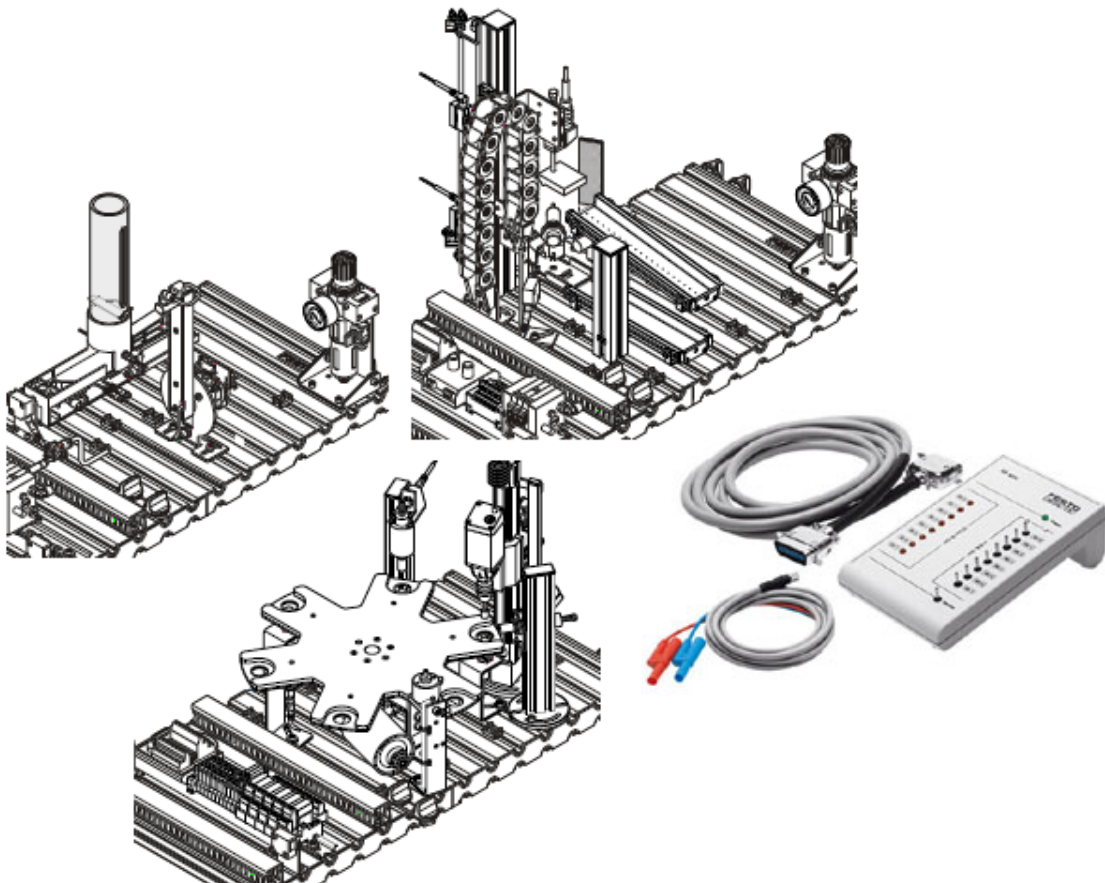


Figure 1.1: System Apparatus

Theoretical Background:

Programmable Logic Controller (PLC) is commonly used in industrial automated lines in many applications such as: packing, extruding, sorting, handling ... etc.

PLCs are available from many manufacturers such as: Siemens, Allen Bradley, Mitsubishi, Schneider and Omron. And each of these companies has many modules for the PLC.

During the rest of the semester, you will be studying industrial station models assembled by Festo Company. These station can work together to perform a complete industrial process. All the stations are provided by Siemens SIMATIC S7-300 PLC which is programmed using SIMATIC Step 7 software.

1. Siemens SIMATIC S7-300 PLC

Every PLC has four main components:

3. Power supply.
4. Processor.
5. Input cards.
6. Output cards.

Figure 1.2, shows the Siemens SIMATIC S7-300 PLC. This PLC has the main four components as any other PLC. It needs a dc power supply of 24 V. It has a processor (CPU 313C-2DP). And it can handle 16 inputs and 16 outputs distributed between 2 I/O cards (card 0 and card 1).



Figure 1.2: Siemens SIMATIC S7-300 PLC

Table 1.1 shows some technical data concerning Siemens SIMATIC S7-300 PLC with CPU 313C-2DP processor.

Table 1.1: Technical data for Siemens SIMATIC S7-300 PLC with CPU 313C-2DP processor

CPU S7-313C-2DP			
Supply voltage	24 V DC (20.4 – 28.8 V DC)		
Current consumption	typ. 0.1 A		
Main memory	32 kByte		
Buffering (min. 64kByte)	Micro memory card required (MMC)		
Flags / Counters / Timers	2048 / 256 / 256		
Remanence	adjustable		
Integrated interfaces:	MPI, Profibus-DP (Master/Slave)		
Integrated digital inputs	16		
	Input voltage	Nominal value	24 V DC
		for signal „1“	15 – 30 V
		for signal „0“	-3 – +5 V
	Input current	for signal „1“	9 mA
	Input delay	0.1/0.3/3/15 ms adjustable	
	Electrical isolation	Yes	
Integrated digital outputs	16		
	Nom. load voltage L+/L1	24 V DC	
	Permissible range	20.4 – 28.8 V DC	
	Output voltage	for signal "1", max.	L+/- 0.8 V
	Output current	for signal „1“	0.5 A
	Minimum current	5 mA	
		for signal „0“, max.	0.5 mA
	Short circuit protection	electronic, pulsed	
	Electrical isolation	Yes	
Integrated functions	3 Counters	30 kHz	
	3 Pulse outputs	2.5 kHz	
	Frequency measurement	Yes	
	Integrated function modules "Control"	PID	
	Controlled positioning	no	

As mentioned above, the inputs and outputs of the PLC are divided between two I/O cards: card 0 and card 1. Card 0 is connected to the inputs and outputs of the station, while card 1 is connected to the control console (the panel with Start, Stop and Reset push buttons). The connection between the cards and the PLC is done using the I/O terminal.

The input and the output signals are transmitted through wires to the I/O socket as in Figure 1.3 (the wires are fixed with screws to the I/O socket). The socket is connected to a 24 pins I/O cable. These pins are distributed between 8 input pins, 8 output pins and pins provided for 0 V and 24 V for the supply of sensors and actuators. The other side of the I/O cable is connected to the I/O cards of the PLC.

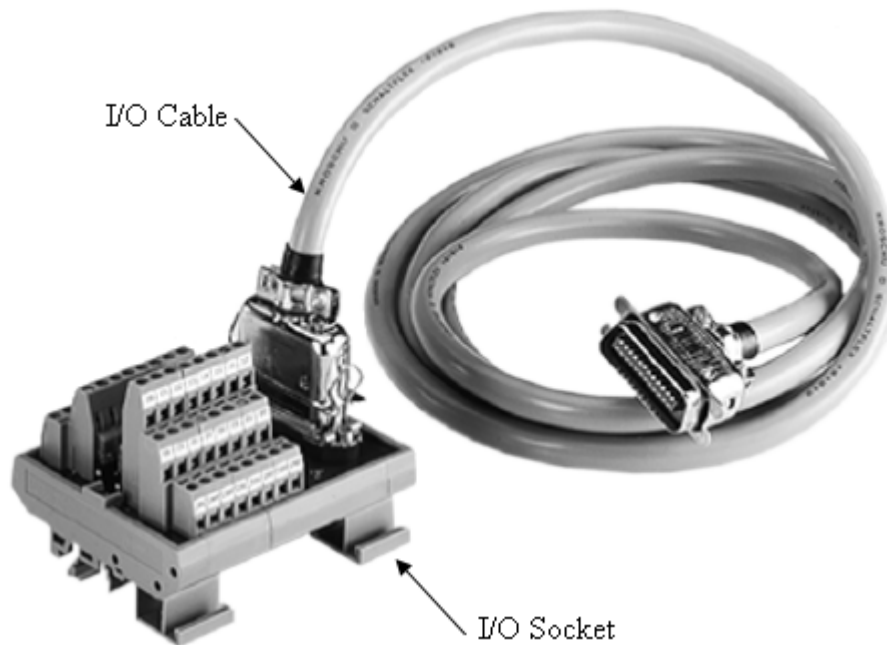


Figure 1.3: I/O terminal.

The PLC is programmed on a computer using SIMATIC Step 7 software. The PLC is linked to the computer using a A cable that is provided by an adapter and a USP port. Figure 1.4 shows a programming cable.

The stations are provided with many types of inputs and outputs. The next two sections of this session contain a brief description of the inputs and the outputs of the stations.



Figure 1.4: Programming cable.

2. Inputs

Since the human operator role is very small in automated systems, sensors play a major role in them. You will encounter the following sensors in many forms during your study of the PLC station where it will provide the feed back of the automated process.

a. Limit Switches

Limit switches are sensors that provide feedback to keep some physical value (for example, pressure, temperature, or distance) within a preset range. Mechanical limit switches are they sense the position of machine parts. These electromechanical devices are triggered by physical contact, translating mechanical position into electrical responses.

Mechanical limit switches do have moving parts that eventually wear out. Also, they must actually touch targets for output, which is inappropriate for some applications. However, limit switches are cost effective and extremely rugged.

Mechanical limit switches are contact sensors widely used for detecting the presence or position of objects in industrial environments. These products offer high precision in terms of accuracy and repeatability, due to the fact that physical contact is made with the target.

b. Proximity Sensors

A Proximity sensor can detect objects without physical contact. A proximity sensor often emits an electromagnetic field or beam and look for changes in the field. The object being sensed is often referred to as the proximity sensor's target. Different proximity sensor targets demand different sensors. There is four main types of proximity sensors which are:

1. Magnetic proximity switch
2. Capacitive proximity switch
3. Inductive proximity switch
4. Optical proximity switch

1. Magnetic Proximity Sensors

Magnetic proximity sensors are characterized by the possibility of large switching distances, available from sensors with small dimensions. They detect magnetic objects (usually permanent magnets) which are used to trigger the switching process. As the magnetic fields are able to pass through many non-magnetic materials, the switching process can also be triggered without the need for direct exposure to the target object. By using magnetic conductors (e.g. iron), the magnetic field can be transmitted over greater distances so that, for example, the signal can be carried away from high temperature areas. Magnetic sensors have a broad range of applications such as:

- Object detection through plastic containers/pipes.
- Object detection in aggressive media through protective Teflon walls.
- Object detection in high-temperature areas.
- Recognition of coding using magnets.

2. Capacitive Proximity Sensors

In capacitive proximity sensors, the sensed object changes the dielectric constant between two plates. A proximity sensor has a range, which is usually quoted relative to water. Because changes in capacitance take a relatively long time to detect, the upper switching range of a proximity sensor is about 50 Hz. The proximity sensor is often found in bulk-handling machines, level detectors, and package detection. One advantage of capacitive proximity sensors is that they are unaffected by dust or opaque containers, allowing them to replace optical devices.

The main disadvantage to this sensor is that its usefulness is dependent on properties of the obstacles it is sensing (namely, their dielectric constant). The higher the dielectric constant (say, water), the more sensitive a capacitive sensor is to that target. The sensing distance depends on the dielectric constant of the target and the surface areas of the probe and the target.

3. Inductive Proximity Sensors

An inductive proximity sensor has four components; the coil, oscillator, detection circuit and output circuit. The oscillator generates a fluctuating magnetic field. When a metal object moves into the inductive proximity sensor's field of detection, Eddy currents build up in the metallic object, magnetically push back, and finally reduce the Inductive sensor's own oscillation field. The sensor's detection circuit monitors the oscillator's strength and triggers an output from the output circuitry when the oscillator becomes reduced to a sufficient level.

Common applications of inductive sensors include metal detectors, traffic lights, car washes, and a host of automated industrial processes. Because the sensor does not require physical contact it is particularly useful for applications where access presents challenges or where dirt is prevalent. The sensing range is rarely greater than 6 cm, however, and it has no directionality.

4. Optical Proximity Sensors

Optical sensors come in many forms, but all of them share the property that each of these sensors consists of transmitter and a receiver. The optical sensors can be divided into three main categories:

4.1 Through beam optical sensors:

The transmitter and receiver in a through beam application are in separate housings mounted opposite each other. The transmitter emits pulsed light in the infrared or visible red wavelength range. The receiver detects the light beam. In this type of sensors, an object is detected when the light beam from the transmitter is blocked from getting to the receiver.



Figure 1.5: Through beam sensor.

These types of sensors offer the following advantages:

- The largest sensing ranges.
- The switching point is independent of the surface nature of the object.
- Excellent repeatability.

Through beam sensors can be used in many applications like monitoring doors and gates, counting and monitoring of objects over large distances or checking the level of liquid in a bottle.

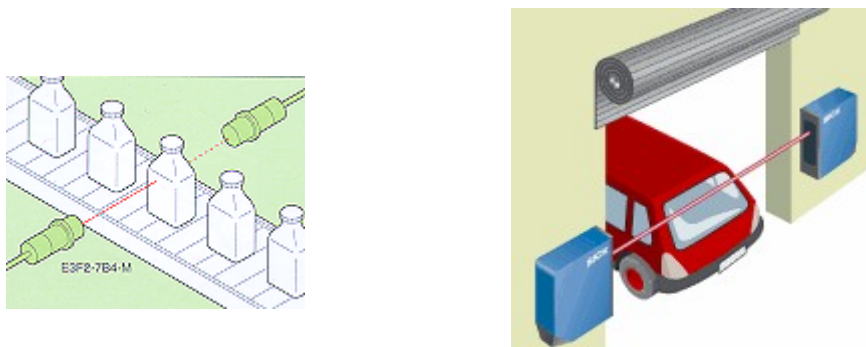


Figure 1.6: Through beam sensor applications.

4.2 Retro reflective optical sensors:

A retro reflective arrangement places the transmitter and receiver at the same location and uses a reflector to bounce the light beam back from the transmitter to the receiver. An object is sensed when the beam is interrupted and fails to reach the receiver. If the target is highly reflective, it can actually reflect enough light back to the receiver to make it appear as if the target was not present and the reflected light was coming from the reflector. To avoid this, the sensor and reflector can be mounted in line with each other, but at an angle with respect to the target.

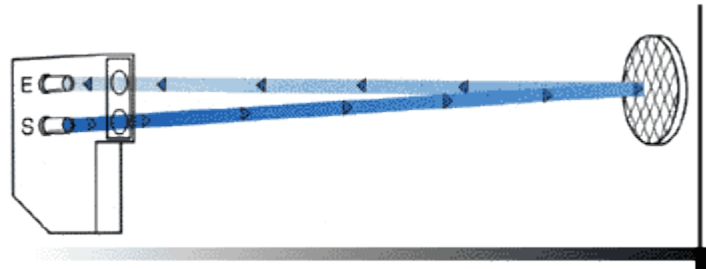


Figure 1.7: Retro reflective sensor.

These types of sensors offer the following advantages:

- Medium sensing ranges.
- Matte finished objects are recognized independent of their colors.

Retro reflective sensors can be used in many applications like height detection of stacked objects, control of randomly positioned objects on a conveyor or as a sensor looks across the doorway of a lift to detect the presence of passengers before closing.

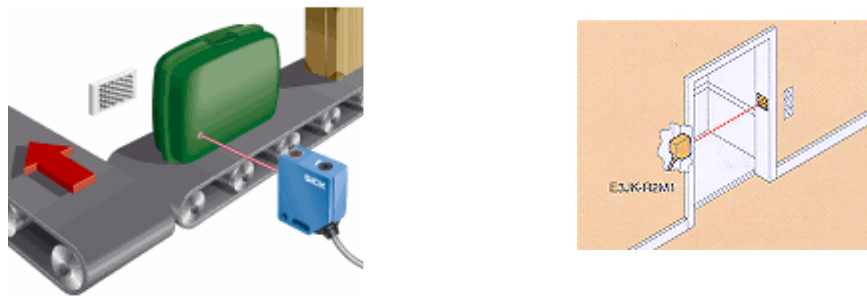


Figure 1.8: Retro reflective sensor applications.

4.3 Diffuse optical sensors:

A diffused arrangement has the transmitter and receiver in one package, like the retro reflective sensors, but unlike them diffuse sensors detect reflected radiation off its target. In this mode, an object is detected when the receiver sees the transmitted source rather than when it fails to see it.

Since the sensor evaluates the direct reflection of light by the target, detection depends on the reflective qualities of the target, i.e., size, texture, shape, and color. The more reflective the target, the easier it is to detect with a diffuse sensor.

Diffuse sensors have the advantage of high sensitivity where it needs only 2% of the light to be reflected from the object to be able to detect it and they are easy to mount since they come in one package. On the other hand, these sensors have the disadvantage of small sensing range.

These sensors come in two forms that determine their applications:

a. Standard diffuse sensors

The emitter (S) and receiver (E) shown by Figure 1.8 are in the same housing. The emitter sends out a beam of pulsed infrared or red light, which is reflected directly by the target. When the beam of light hits the target, (at any angle), it is diffused in all directions and some light is reflected back. The receiver sees only a small portion of the original light, switching the sensor when a target is detected within the reflective distance.

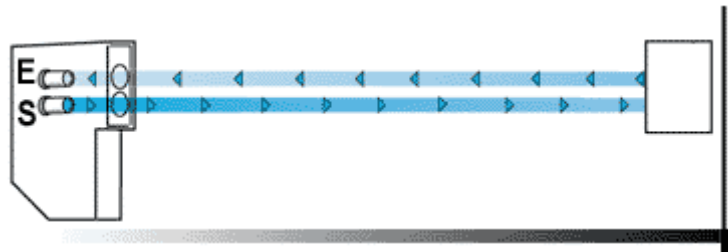


Figure 1.9: Standard diffuse sensor.

Standard diffuse sensors offer the following advantages:

- Using the targets own reflective properties.
- Suitable to distinguish between black and other colors.

The second advantage is one of most importance to us because it means that diffuse sensors can be used for color detection (distinguishing between black and other colors).

b. Diffuse sensors with background suppression

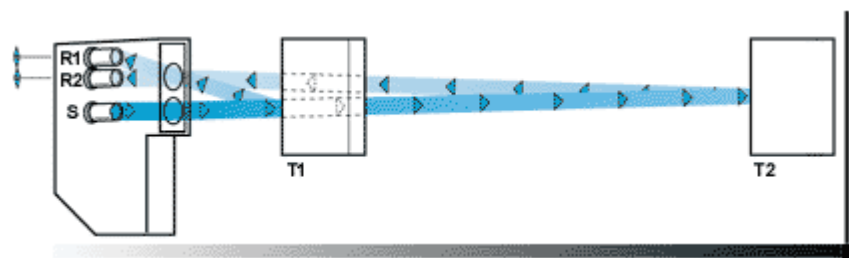


Figure 1.10: Diffuse sensor with background suppression.

Diffuse sensors with background or foreground suppression which work with triangulation do not only sense the light reflected from the target, but also sense the distance of the object to the

sensor. Figure 1.9 shows the receiver R1 receives the light from the object T1 and R2 from the background. Within the fully adjustable distance, objects which are at least as big as the diameter of the light beam are recognized independently of color and surface properties. The background distance should be at least 10% larger than the sensing distance.

Background suppression diffuse sensors offer the following advantages:

- Targets are recognized largely independent of color and surface properties even in front of changing background conditions.
- The background is largely suppressed, independent of color and surface properties.

Figure 1.10 shows some applications for diffuse sensors.



Figure 1.11: Diffuse sensor application.

3. Outputs

The lab stations have three main types of actuators: dc motors, linear cylinders and rotary cylinders.

a. Permanent Magnet DC Motor

The direct current (DC) motor is one of the first machines devised to convert electrical power into mechanical power. Permanent magnet (PM) direct current converts electrical energy into mechanical energy through the interaction of two magnetic fields. One field is produced by a permanent magnet assembly; the other field is produced by an electrical current flowing in the motor windings. These two fields result in a torque which tends to rotate the rotor. As the rotor turns, the current in the windings is commutated to produce a continuous torque output.

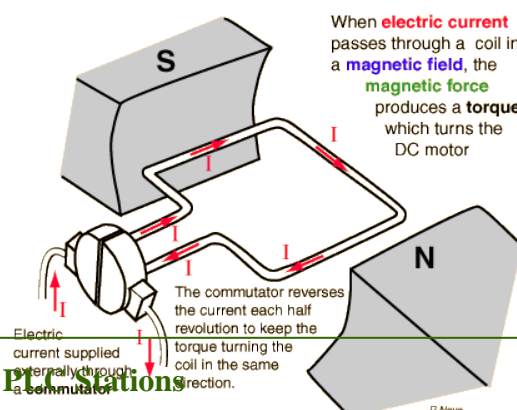


Figure 1.12: Permanent magnet dc motor.

b. Cylinders

Pneumatic cylinders (sometimes known as air cylinders) are mechanical devices which produce force, often in combination with movement, and are powered by compressed gas. To perform their function, pneumatic cylinders impart a force by converting the potential energy of compressed gas into kinetic energy. This is achieved by the compressed gas being able to expand, without external energy input.

Although pneumatic cylinders vary in appearance, size and function, they generally fall into one of the specific categories illustrated below. However there are also numerous other types of pneumatic cylinder available, many of which are designed to fulfill specific and specialized functions.

b.1. Linear Cylinders

- Single acting cylinders

Single acting cylinders (SAC) use the pressure imparted by compressed air to create a driving force in one direction (usually out), and a spring to return to the "home" position.

- Double acting cylinders

Double Acting Cylinders (DAC) use the force of air to move in both extend and retract strokes. They have two ports to allow air in, one for outstroke and one for instroke.

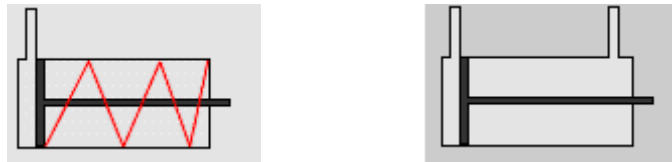


Figure 1.13: Single and double acting cylinders.

b.2. Rotary Cylinders

Rotary cylinders are pneumatic actuators that utilize pressure differentials, converting compressed air energy into mechanical energy which is manipulated to facilitate rotational movement. While a typical air cylinder allows lateral movement, these devices are designed to expand machining capabilities offering rotation angles ranging from below 45 degrees to beyond 360 degrees. While some rotary cylinders offer adjustable degrees of rotation, others have a fixed range of motion. It rotates a protruding shaft to which the arm and necessary load or tooling are attached.

Procedure:

1. Turn off the power and pressure supplies
2. Connect the Input/output simulator to the Input/output terminal (disconnect the PLC).
3. Turn on the power and pressure supplies
4. Turn on each output from the simulator and write down its address.
5. While running the output notice the status of the sensors , and write down their addresses.

Discussion and Analysis:

1. What is the process done by your station?
2. What type of sensors in your station? What is their normal state?
3. How many outputs available in your station? What are their types?

Experiment 2

Siemens PLC Programming Basics

Objectives:

- To control a process using PLC.
- To monitor a process using PLC.
- To understand the basic component of a PLC program.
- To Program a PLC using ladder diagram.

Apparatus:

1. SIMATIC S7-300 Production Line Stations.
2. Festo Didactic Stations.
3. Programming device (personal computer).

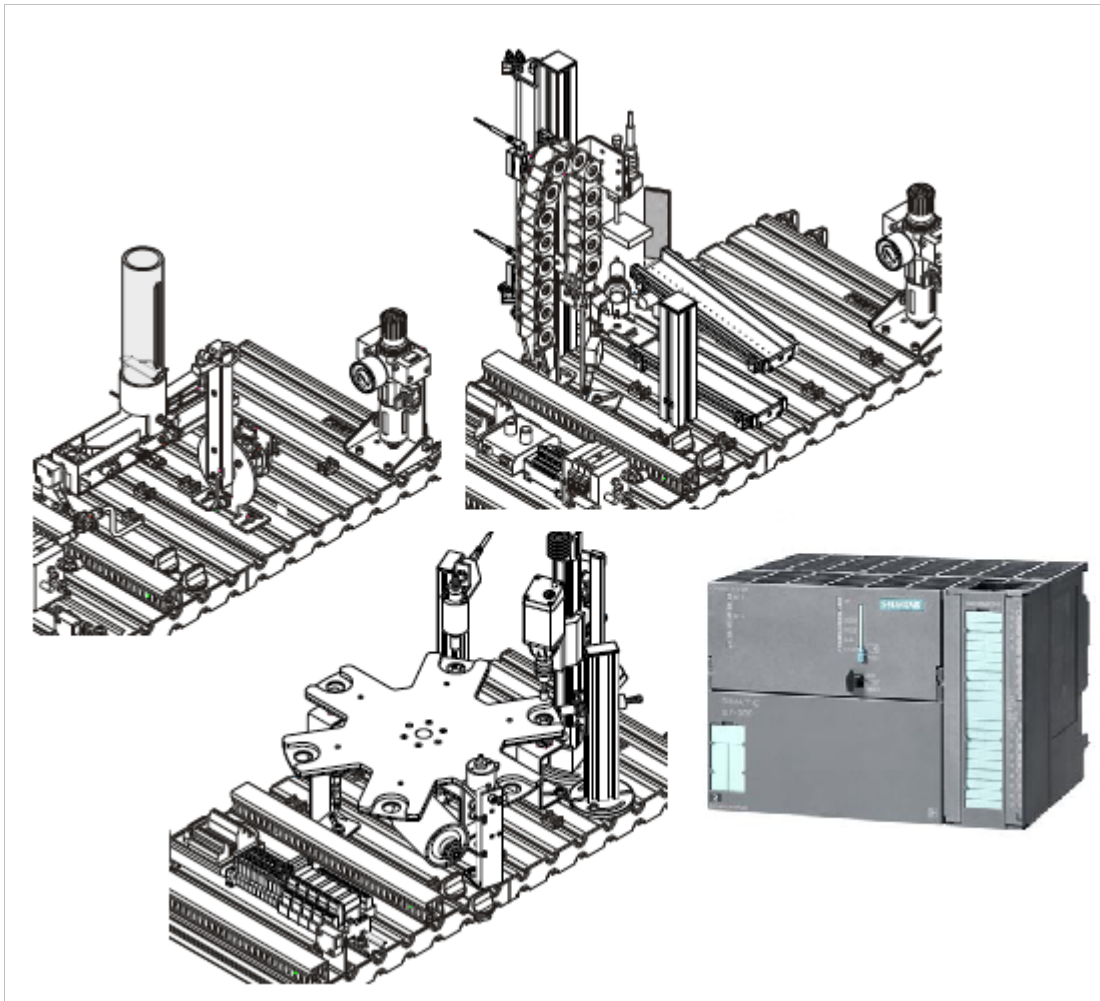


Figure 2.1: System Apparatus

Theoretical Background:

The automation lab is supplied with 11 PLC stations: Sorting, Separating, Processing, Handling, Buffering, Pick and Place, Fluidic Muscle Press, Testing, Distributing, Punching and the Assembly station. A Robotic Arm station works with these eleven stations to form a complete mini-production line.

As mentioned at the previous session, all of these stations are assembled by the Festo company and are provided with SIMATIC S7-300 PLCs from Siemens company. However, the Robotic arm is a Mitsubishi product.

This semester you will deal with only seven of the eleven stations which are: Sorting, Separating, Handling, Pick and Place, Fluidic Muscle Press, Testing and Distributing stations. The correct addresses and a brief description for the stations are provided in Appendix B.

1. SIMATIC S7-300 PLC Programming

All the stations are driven with SIMATIC S7-300 PLC. Then all the stations share the same principle of programming, but differ in the I/O addresses. At the previous session, you have learned how to connect the hardware to and from the PLC. Now assuming all the correct hardware wiring has been done correctly, it is time to open SIMATIC S7 software and start programming the PLC.

2. Getting started with SIMATIC S7 Software

This software is developed by Siemens Company, and this version specifically is designed to program the SIMATIC S7-300 PLC. The first step through programming is to open a project where the user can build the necessary *ladder diagram* for a certain operation of the station.

1. Double click on the software icon shown in Figure 2.2.



Figure 2.2: SIMATIC S7 icon

2. Create new project using the software wizard. This is done by checking the box beside "Display Wizard on starting SIMATIC Manager" as shown by Figure 2.3. Then click "Next".
3. Choose the CPU of the SIMATIC S7-300 PLC available in the lab which is CPU313C-2DP as shown by Figure 2.4. Then click "Next".

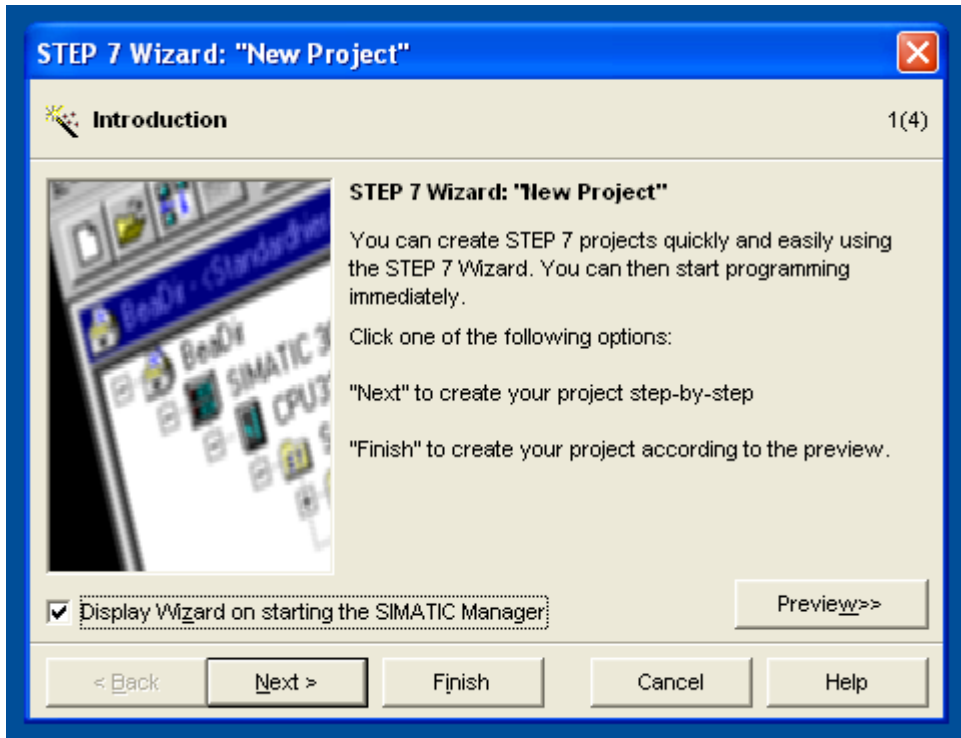


Figure 2.3: Step 1 in starting SIMATIC S7 manager

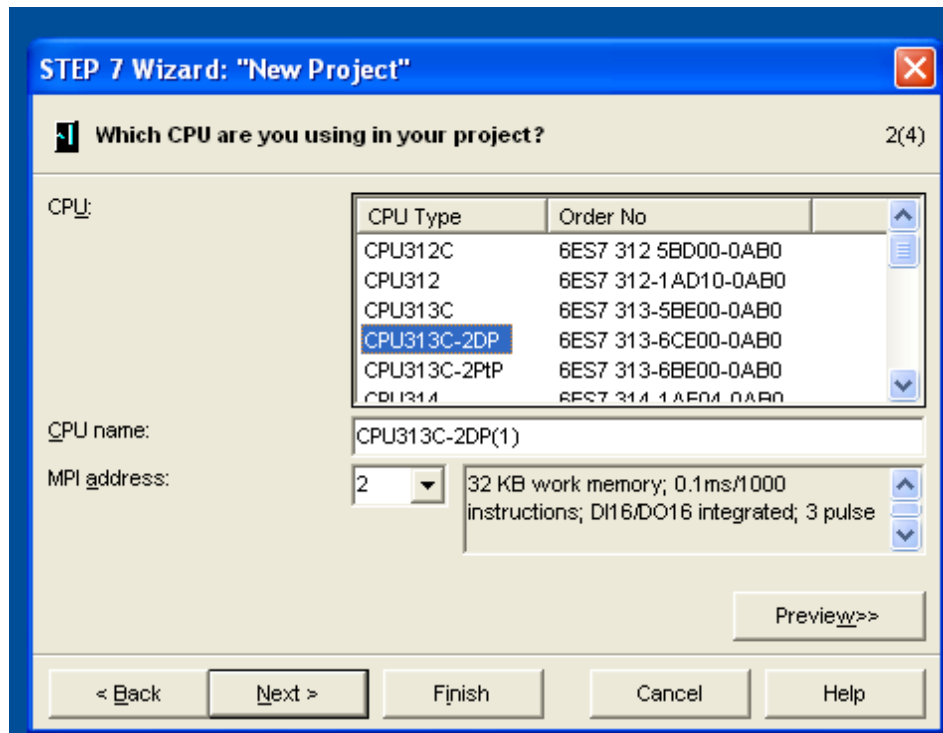


Figure 2.4: Step 2 in starting SIMATIC S7 manager

4. Since we program using Ladder diagram, choose LAD from "Language for Selected Blocks" as shown by Figure 2.5. Then Click "Next".



Figure 2.5: Step 3 in starting SIMATIC S7 manager

5. Name your program at "Project name" as shown in Figure 2.6 then click "Finish".

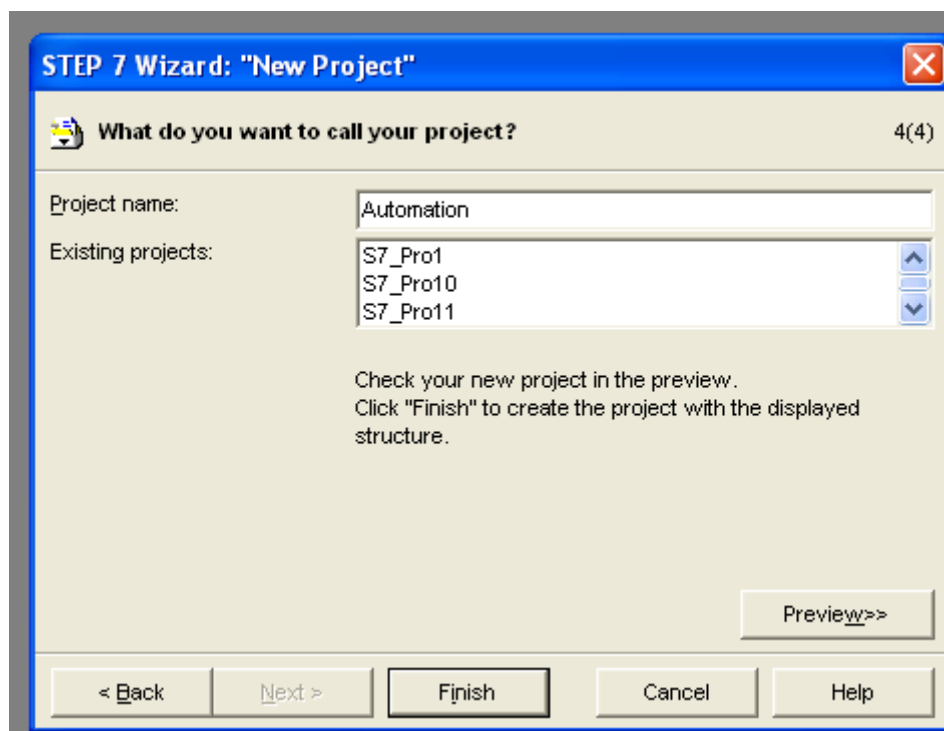


Figure 2.6: Step 4 in starting SIMATIC S7 manager

- The following window will appear. Double click on "OB1" (object 1) shown in Figure 2.7 to start programming.

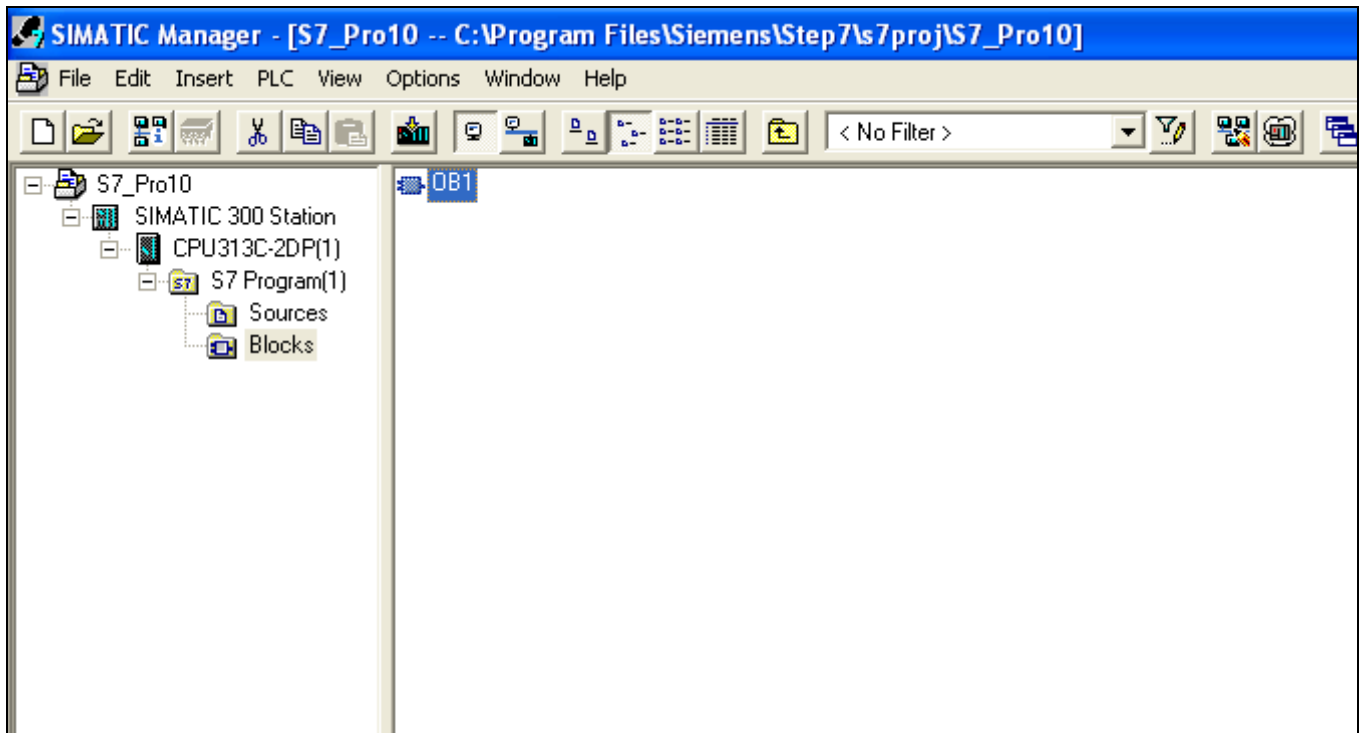


Figure 2.7: SIMATIC S7 first window

- The programming window shown in Figure 2.8 will appear. In this window you will find the rungs you will be building your ladder diagram at and the logic bits (inputs, outputs), timers, counters, comparators and any other component provided by the PLC that you can program with.

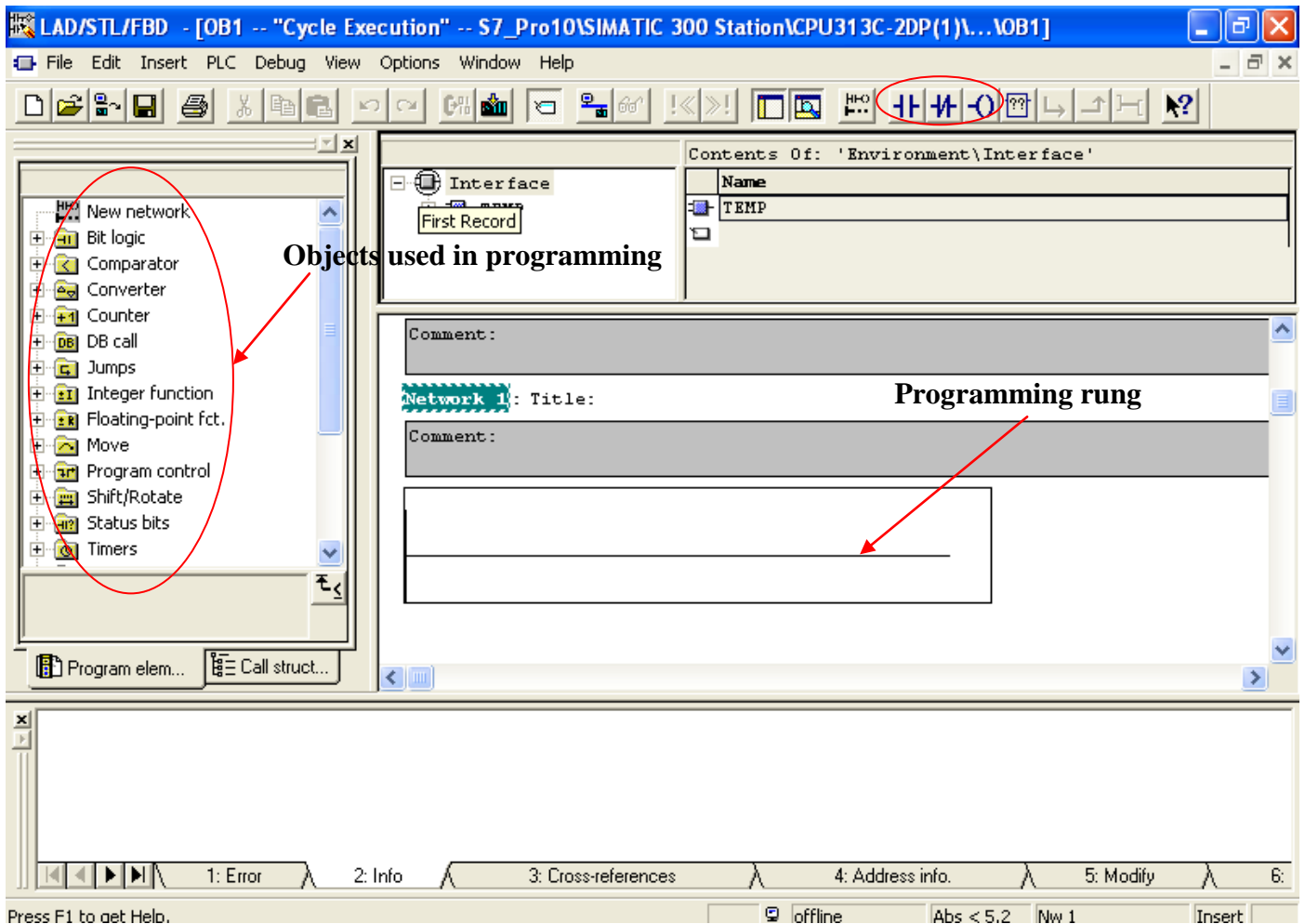


Figure 2.8: SIMATIC S7 programming window

3. Terminology

The important thing now is to familiarize yourself with the terminology for the inputs and outputs used in SIMATIC S7 software.

Normally open contacts in SIMATIC S7 are represented as follows:



On the other hand, normally closed contacts are represented as follows:



While the output coils are represented as follows:



Each input or output must be defined with an address corresponding to an input or output on the station or the control console board.

The program allows you to use as many NO or NC contacts of the same input as you want. But you can use the output **ONLY** once, because if you use it more than once, there will be conflict in the results.

A basic concept that should be understood here is: How do the inputs work on the PLC?

As mentioned above, you can use as many contacts as you wish from the same input. And as you learned during the electro-pneumatic sessions before, contacts can be obtained from relays. Then if each input to the PLC activates an imaginary relays' coil, contacts from this coil can be used then in the program.

As you have surely noticed, the stations in the lab are provided with two types of sensors and buttons: the NO and the NC ones.

a. Principle of operation of NO Inputs

Let's take the "Start" push button from the control console as an example. If you go to the I/O addresses' tables, you will find that "Start" corresponds to the input address "I1.0". Then Figure 5.8 will explain the NO Start push button operation.

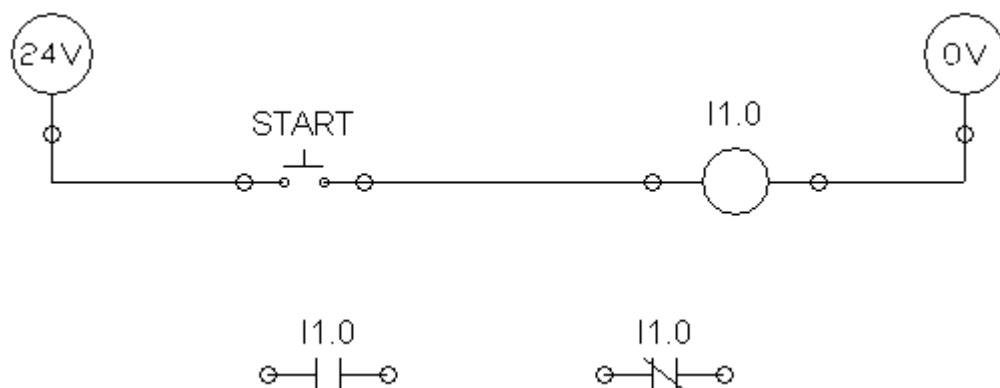


Figure 2.9: "Start" push button principle of operation

The ladder diagram shows the operation of "Start" push button. If we run the circuit (using FluidSIM) we will obtain the configuration shown by Figure 2.10. It is clear from the figure that since "Start" is not activated yet, the contacts have not changed state. When start push button is pressed (activated) as shown in Figure 2.11, the output coil "I1.0" which is the corresponding address of "Start" will be activated, then any NO contact with the address "I1.0" used on your ladder diagram will change state to CLOSED. On the other hand, any NC contact with the address "I1.0" used on your ladder diagram will change state to OPENED.

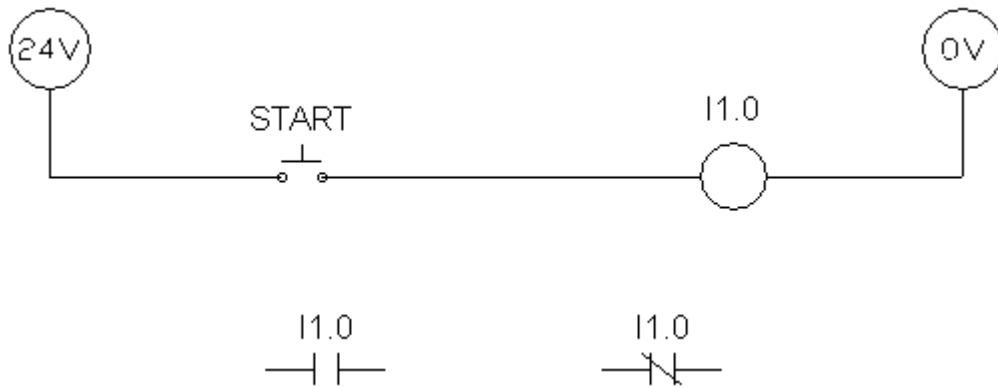


Figure 2.10: In the run mode while the button is not activated

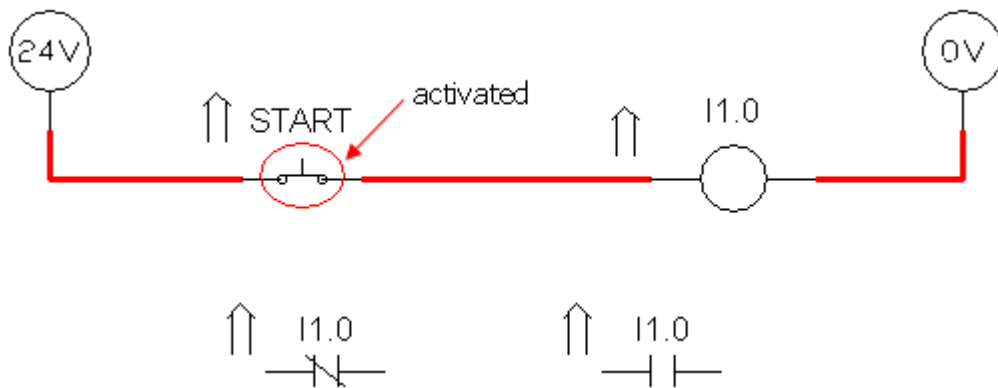


Figure 2.11: In the run mode while the button is activated

b. Principle of operation of NC Inputs

Let's take the "Stop" push button from the control console as an example. If you go to the I/O addresses' tables, you will find that "Stop" corresponds to the input address "I1.1" and besides it is written (normally closed). Then Figure 2.12 will explain the NC Stop push button operation.

The ladder diagram shows the operation of "Stop" push button. If we run the circuit (using FluidSIM) we will obtain the configuration shown by Figure 2.13. It is clear from the figure that since "Stop" is not activated yet, **current is flowing** through the output coil "I1.1" which is the corresponding address of "Stop", then any NO contact with the address "I1.1" used on your ladder diagram will change state to CLOSED. On the other hand, any NC contact with the address "I1.1" used on your ladder diagram will change state to OPENED.

Now, when "Stop" push button is activated as shown in Figure 2.14, the current will stop flowing through the coil "I1.1" and the contacts will go back to their original state shown by Figure 2.12.

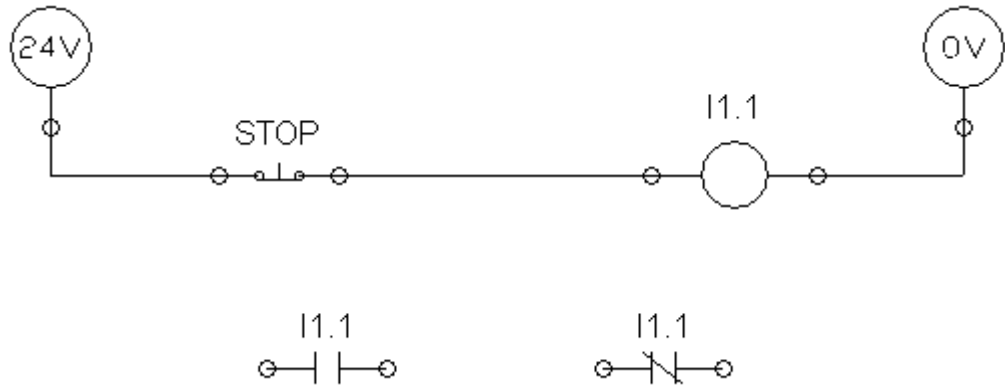


Figure 2.12: "Start" push button principle of operation

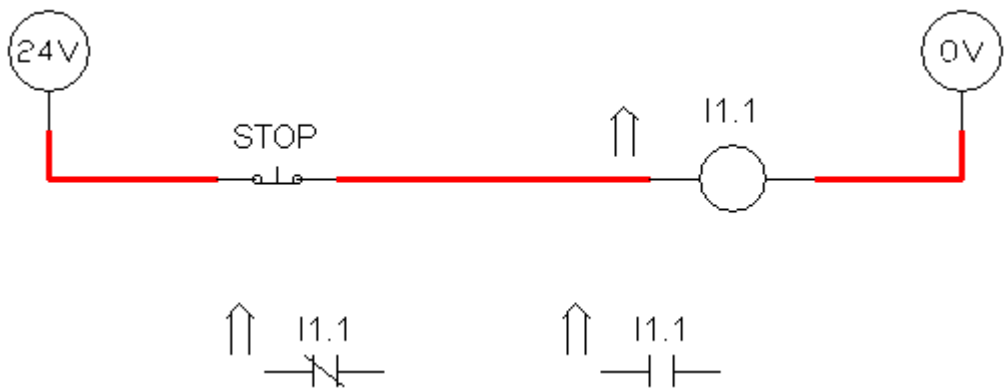


Figure 2.13: In the run mode while the button is not activated

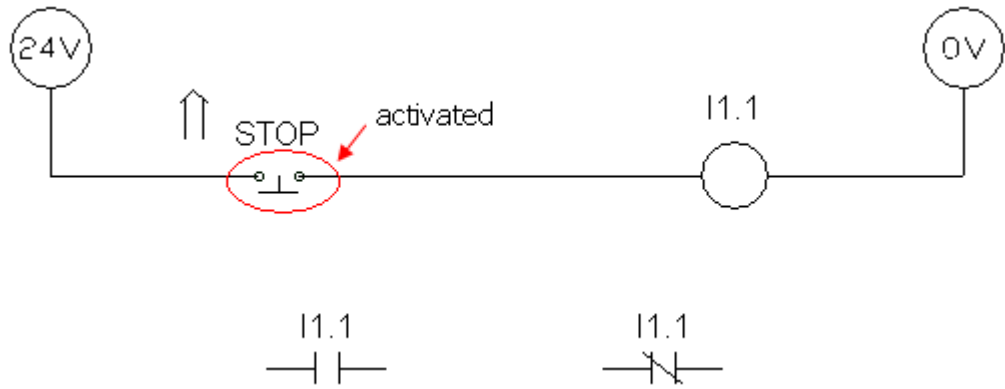


Figure 2.14: In the run mode while the button is activated

4. Programming

To learn how to program the PLC, let's take practical examples on the Buffering station Figure 2.15. The addresses for the Buffering station are provided in Table 2.1.

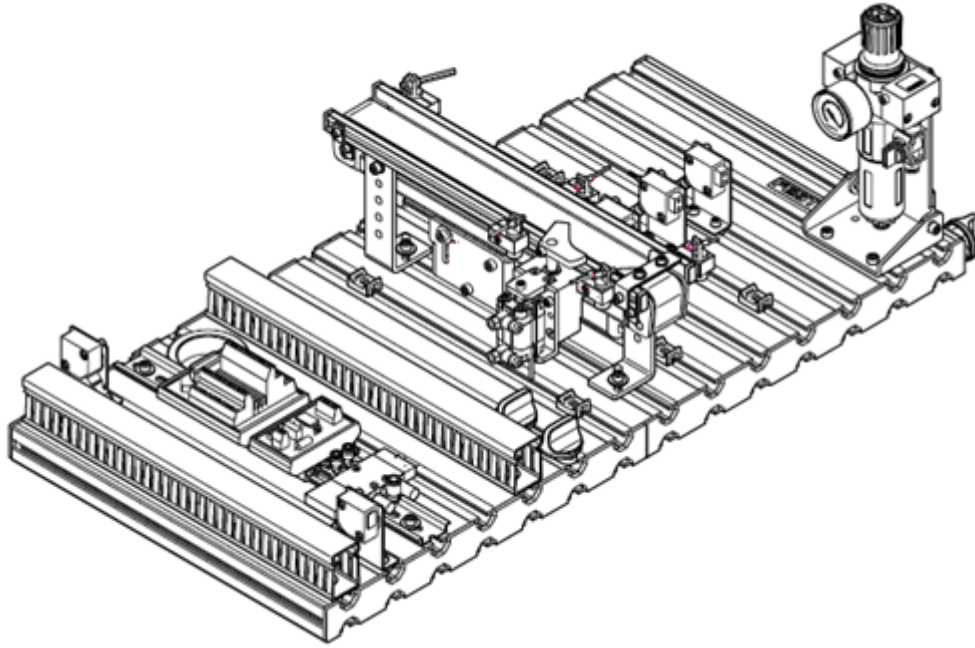


Figure 2.15: Buffering Station

Table 2.1: Buffering Station Addresses

Address	Description	Identity
I0.0	Work piece is available at the start of the conveyor belt	Diffuse sensor
I0.1	Work piece is at the buffering (separation) position (NC)	Through beam sensor
I0.2	Work piece is at the end of the conveyor belt (NC)	Through beam sensor
I0.3	Separator is fully retracted	Magnetic proximity sensor
I0.4	Separator is fully extended	Magnetic proximity sensor
Q0.0	Separator (Buffer) extends to hold the work piece	Permanent magnet DC motor
Q0.1	Conveyor belt	Linear short stroke cylinder
I1.0	START	Push button
I1.1	STOP (normally closed)	Push button
I1.3	RESET	Push button

Example 2.1:

If "Start" push button is pressed and a work piece is available at the beginning of the conveyor belt, then the conveyor belt will be actuated until "Reset" push button is pressed.

Solution:

The conveyor belt will be operated as long as current is flowing through the output "Q0.1". Since "Start" should be pressed in order for the current to flow through it to the output and since "Start"

is a normally open push button, a normally open contact of it was used in the ladder diagram. The same applies for the work piece available sensor "I0.0".

Both the signals from "Start" push button and "I0.0" are momentary signals (i.e. once "Start" push button is released or the piece leaves the beginning position, the signals from them will stop). For this reason, a latch will be needed to maintain "Q0.1" operated until "Reset" is pressed.

According to the question in hand, "Reset" or "I1.3" should conduct current until it is pressed and since "Reset" is a normally open push button, a normally closed contact should be used.

The ladder diagram needed to perform the operation described above is shown in Figure 2.16.

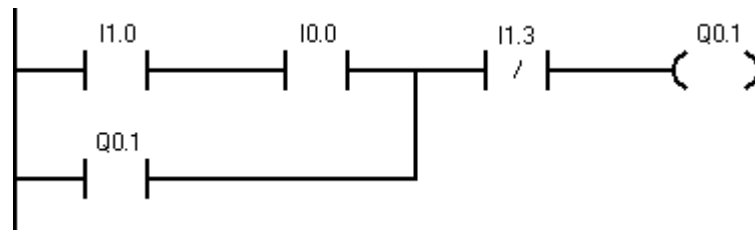


Figure 2.16: Ladder diagram for Example 2.1

Example 2.2:

If "Start" push button is pressed and a work piece is available at the beginning of the conveyor belt, then the conveyor belt will be actuated until the piece reaches the end of the belt.

Solution:

The conditions for operating the conveyor belt (activating it) are the same as the previous example. On the other hand, the normally open push button "Reset" was replaced with the normally closed sensor "I0.1". And as explained above, since the sensor is normally closed we will use a normally open contact from it that will maintain the current flowing through it until it is activated.

The ladder diagram needed to perform the operation described above is shown in Figure 2.17.

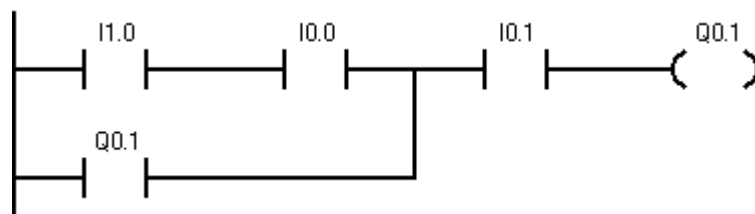


Figure 2.17: Ladder diagram for Example 2.2

Example 2.3:

If "Start" push button is pressed and a work piece is available at the separating (buffering) position, then the separator will extend until it reaches its full extent then will retract again.

Solution:

Here, the conveyor belt will be operated once "Start" or "I1.0" is pressed and a work piece is at the buffering position. The buffering sensor "I0.1" is a normally closed sensor, then if we want the sensor to conduct current once it is activated, we will use a normally closed contact from it.

The sensor that informs the system that the separator is fully extended is "I0.4" which is a normally open sensor, so if we want it to conduct current until it is activated, we will use a normally closed contact from it.

The ladder diagram needed to perform the operation described above is shown in Figure 2.18.

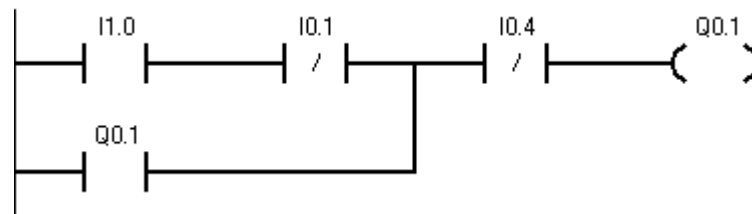




Figure 2.18: Ladder diagram for Example 2.3

Procedure:

1. Turn off the power and pressure supplies.
2. Write a ladder diagram based on the process you are required to control (use the address you acquired in the last experiment).
3. Turn on the power supply
4. Download the ladder diagram to the PLC by clicking this icon .
5. Turn on the pressure supply
6. Start your process according to your station.
7. Turn on the online monitoring by clicking this icon .
8. If the process is not running as required, turn off the pressure supply.
9. Repeat from 1 to 8 until, you are satisfied with your process.
10. Save your ladder diagram.
11. Turn off the power and pressure supplies and your computer.

Discussion and Analysis:

1. Use the monitor option to discuss the difference between N.O and N.C input devices?
2. Assume you have a N.O push button in your station, and you want to use it as a condition to start an output device, what is the state of its contact you will use in the ladder diagram?

3. Assume you have a N.C push button in your station, and you want to use it as a condition to stop an output device, what is the state of its contact you will use in the ladder diagram?
4. How the process is affected if you update the ladder diagram without downloading the new edition to the PLC?
5. Can you add to outputs in series in the rungs of your ladder diagram? Explain?
6. What happens if to the output device if –by accident- you programmed it in two different rungs and the status of one of them was active and the other is inactive?
7. Use the buffering station in Figure 2.15 to write a ladder diagram for the following process:
If "Stop" push button is pressed and a work piece is available at the beginning of the conveyor belt, then the conveyor belt will be actuated until "Start" push button is pressed or the piece reaches the end of the belt.

Experiment 3 Siemens PLC Programming 2

Objectives:

- To control a process using PLC.
- To monitor a process using PLC.
- To understand the benefits of the internal relay and use it in ladder diagrams.
- To understand the analogy between latch and set/reset coils.
- To understand the concept of set/reset coils and use them in ladder diagram.

Apparatus:

1. SIMATIC S7-300 Production Line Stations.
2. Festo Didactic Stations.
3. Programming device (personal computer).

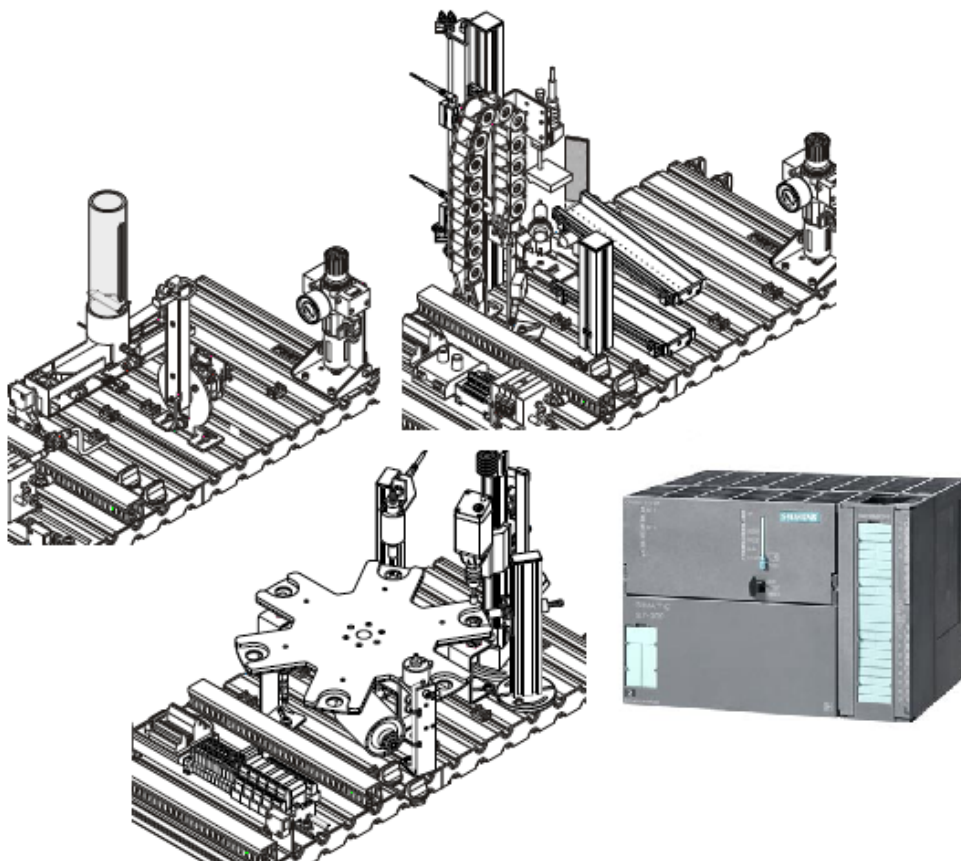


Figure 3.1: System Apparatus

Theoretical Background:

During the previous session, you have learned how to deal with SIMATIC S7 software. Then you used it to program your PLC using basic latch concept. During this session, you will learn about internal relays and set/reset coils.

Examples on Processing station -whose I/O addresses are given by Table 3.1- are illustrated through examples 3.1 to 3.5 for both internal relays and set/reset coils.

Table 3.1: I/O addresses of the processing station.

Address	Description	Identity
I0.0	Work piece available	Inductive sensor
I0.1	Work piece at rubbing machine	Inductive sensor
I0.2	Work piece at testing position	Inductive sensor
I0.3	Rubbing machine is up	Limit switch
I0.4	Rubbing machine is down	Limit switch
I0.5	Rotary table is in position	Mechanical operated switch
I0.6	Work piece hole is correct	
Q0.0	Rubbing Machine	
Q0.1	Rotary table	Motor, to rotate the table 60°
Q0.2	Rubbing machine move down	
Q0.3	Rubbing machine move up	
Q0.4	Work piece clamping for rubbing	Clamper
Q0.5	Testing the hole	
Q0.6	Reject the work piece to the following station	Flipper
I1.0	START	Push button
I1.1	STOP (normally closed)	Push button
I1.3	RESET	Push button

1. Internal Relays (Flags)

Internal relays are imaginary programmed relays that are not connected to any real output but have coils and contacts. Since they are not addresses for real outputs, internal relays cannot have addresses that start with "Q". Instead they have addresses of the user selection that starts with "M" like "M0.0" or "M1.3". Of course there is a certain number of coils allowed to be programmed in SIMATIC S7 software which is 2048 internal relay.

Internal relays have many uses. One of their common uses is the case when a certain condition must be used in the operation of more than one rung (network). An example for this case is illustrated in Example 3.1

Example 3.1:

The rubbing machine is to work in a reciprocating motion (i.e. it has to keep moving down each time it is up and has to move down each time it is down). **This motion begins with pressing "Start" push button and ends with pressing "Stop" push button.**

Solution:

If we are to solve the example without the condition in "Bold" it will be as follows:

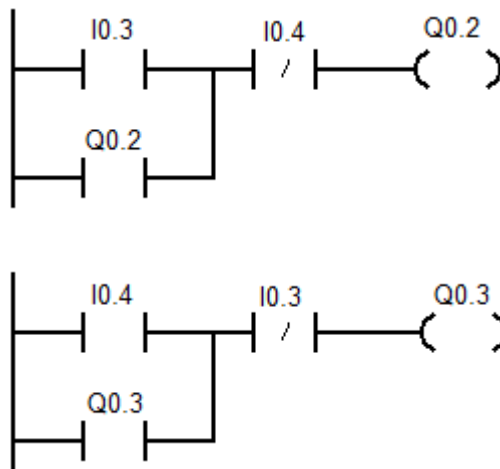


Figure 3.2: Ladder Diagram For Example 3.1 Without Internal Relay

But this way we cannot control the beginning and end of the motion. This is why the condition in "Bold" was added. This condition is needed to be in both rungs to control their motion, hence the need for the internal relay.

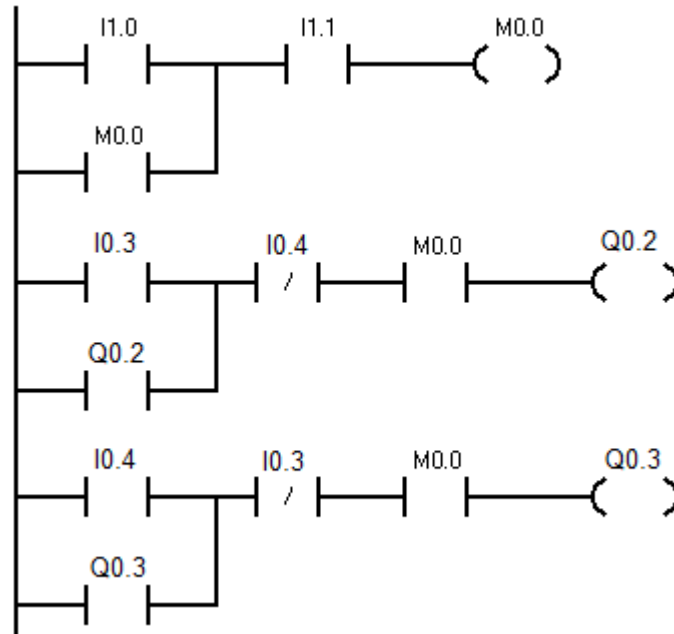


Figure 3.3: Ladder Diagram For Example 3.1 With Internal Relay

Another example that proves the necessity of internal relays is given by Example 3.2.

Example 3.2:

The conveyor belt of the Buffering station- address in Table 2.1 in the previous experiment- will start only if "Start" push button is pressed twice and will stop when "Stop" push button is pressed. **(You are not to use any counters).**

The ladder diagram to perform this operation is shown in Figure 3.4. Note that when "Start" or "I1.0" is pressed for the first time and since "Stop" or "I1.1" is a normally closed push button, current will flow through the internal relay "M0.0" activating it. On the other hand, as long as "Start" is pressed "M0.1" cannot be activated. Once "Start" is released for the first time, and since "M0.0" is activated now, the internal relay "M0.1" will be activated. Now, if "Start" is pressed again, the conveyor belt or "Q0.1" will get activated and will stays on this state until "Stop" is pressed which will deactivate "M0.0" deactivating "M0.1" deactivating the output "Q0.1".

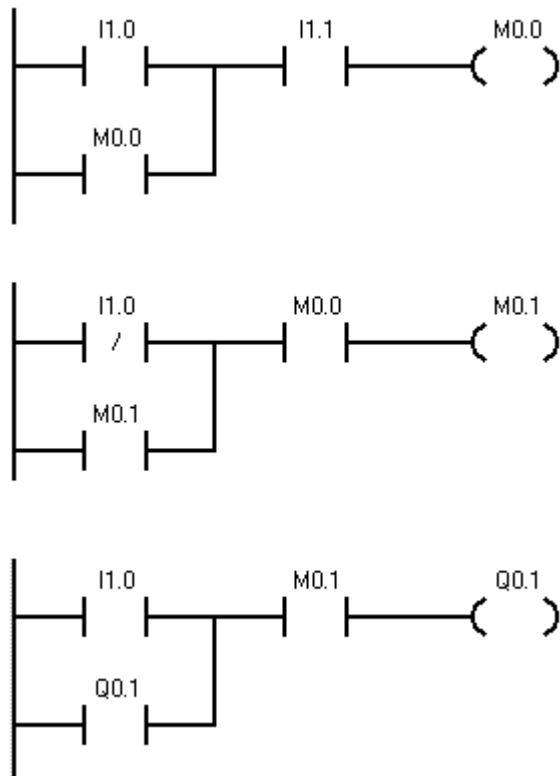


Figure 3.4: Ladder diagram for Example 3.2

2. Set/Reset Coils

Last session you have learned how to latch an output using normally open contacts related to the outputs. But this is not the only method for latching outputs. Another method used for latching the outputs is the Set/Reset coils method.

Set coil ladder symbol is shown in Figure 3.5.a. This coil is activated when a **positive edge trigger it**. (i.e. when a change of state from HIGH to LOW occurs in the rung of the set coil, it gets activated causing the output associated with it to be **set to 1**. Being activated by an edge means that: even if the HIGH signal is cut off the coil after it has been activated, it will still conduct current to the output associated with it.



Figure 3.5: (a) Ladder Symbol for Set Coil (b) Ladder Symbol for Reset Coil

Reset coil ladder symbol is shown in Figure 3.5.b. This coil is activated when a positive edge trigger it. (i.e. when a change of state from HIGH to LOW occurs in the rung of the reset coil, it gets activated causing the output associated with it to be **set to 0**. Being activated by an edge means that: even if the HIGH signal is cut off the coil after it has been activated, it will still conduct current to the output associated with it.

The best method to understand how these coils works is to take an example. Actually we will solve the same examples solved last session but this time Set/Reset coils method will be used.

Example 3.3:

If "Start" push button is pressed and a work piece is available at the beginning of the conveyor belt, then the conveyor belt will be actuated until "Reset" push button is pressed.

Solution:

The ladder diagram needed to perform the operation described above is shown in Figure 3.6. Note from the figure that when "Start" or "I1.0" is pressed and a work piece is available ("I0.0" is activated), current will flow (changing the state from LOW to High) through the **set** coil addressed "Q0.1" which is the address of the conveyor belt. This assigning of the address to the set coil means: set the output coil addressed "Q0.1" to 1 (or HIGH). Now even if "Start" is released or the piece is no longer available, the set coil addressed "Q0.1" will make sure that the output "Q0.1" is still activated (at least until a reset signal occurs).

On the other hand, when "Reset" button is pressed, current will flow (changing the state from LOW to High) through the **reset** coil addressed "Q0.1" which is the address of the conveyor belt. This assigning of the address to the reset coil means: set the output coil addressed "Q0.1" to 0 (or LOW) which will deactivate the output "Q0.1".

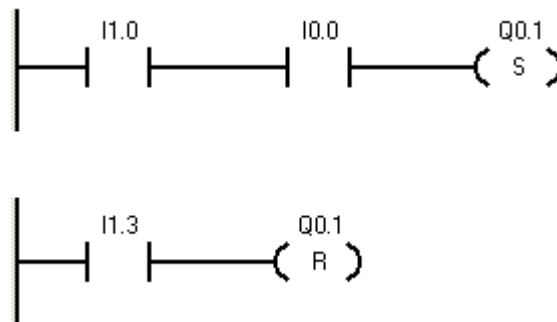


Figure 3.6: Ladder Diagram for Example 3.3

Example 3.4:

If "Start" push button is pressed and a work piece is available at the beginning of the conveyor belt, then the conveyor belt will be actuated until the piece reaches the separating position.

Solution:

The conditions for operating the conveyor belt (activating it) are the same as the previous example. On the other hand, the normally open push button "Reset" is replaced with the normally closed sensor "I0.1". Since the sensor is normally closed we will use a normally closed contact from it that will prevent the current from flowing through the reset coil addressed "Q0.1" until the sensor get activated (i.e. returning to its normal closed state, and allowing the current to

flow changing the state from LOW to High and triggering the reset coil, setting the output "Q0.1" to 0).

The ladder diagram needed to perform the operation described above is shown in Figure 3.7.

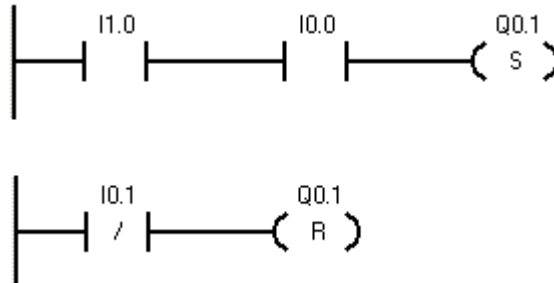


Figure 3.7: Ladder Diagram for Example 3.4

Example 3.5:

If "Start" push button is pressed and a work piece is available at the separating (buffering) position, then the separator will extend until it reaches its full extent then will retract again.

Solution:

Once "Start" or "I1.0" is pressed and a work piece is at the buffering position, the set coil "Q0.0" should be triggered. The buffering sensor "I0.1" is a normally closed sensor, then if we want the sensor to conduct current once it is activated we will use a normally closed contact from it.

The sensor that informs the system that the separator is fully extended is "I0.4" which is a normally open sensor, so if we want it to conduct current once it is activated, we will use a normally open contact from it. This way when "I0.4" is activated, it will change state from open to close allowing current to flow through the reset rung and changing state from LOW to HIGH triggering the reset coil assigned to the output "Q0.0".

The ladder diagram needed to perform the operation described above is shown in Figure 3.8.

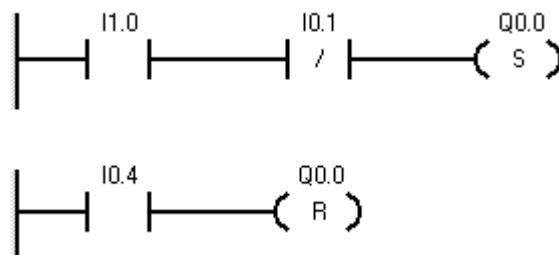




Figure 3.8: Ladder Diagram for Example 3.5

Procedure:

1. Turn off the power and pressure supplies.

2. Write a ladder diagram based on the process you are required to control (use the address you acquired in the last experiment).
3. Turn on the power supply
4. Download the ladder diagram to the PLC by clicking this icon .
5. Turn on the pressure supply
6. Start your process according to your station.
7. Turn on the online monitoring by clicking this icon .
8. If the process is not running as required, turn off the pressure supply.
9. Repeat from 1 to 8 until, you are satisfied with your process.
10. Save your ladder diagram.
11. Turn off the power and pressure supplies and your computer.

Discussion and Analysis:

Use the buffering station in Figure 2.15 in the previous experiment to answer the following:

1. The conveyor will start only if a work piece is available, and stops when the work piece reaches the end of the belt. After two work pieces the separator will be actuated until "Stop" push button is pressed. **(You are not to use any counters).**
2. Use the set/reset coils to solve example 2.2 and 2.3 in the last experiment?
3. Write a ladder diagram using set/reset coils for the following process:
If "Stop" push button is pressed and a work piece is available at the beginning of the conveyor belt, then the conveyor belt will be actuated until "Start" push button is pressed or the piece reaches the end of the belt.

Experiment 4 Siemens PLC Programming with Timers

Objectives:

- To control a process using PLC.
- To monitor a process using PLC.
- To understand the benefits of timing a process.
- To investigate the five different timers provided by SIMATIC S7.
- To differentiate between the SIMATIC S7 timers and their uses.
- To control a process using SIMATIC S7 timers.

Apparatus:

1. SIMATIC S7-300 Production Line Stations.
2. Festo Didactic Stations.
3. Programming device (personal computer).

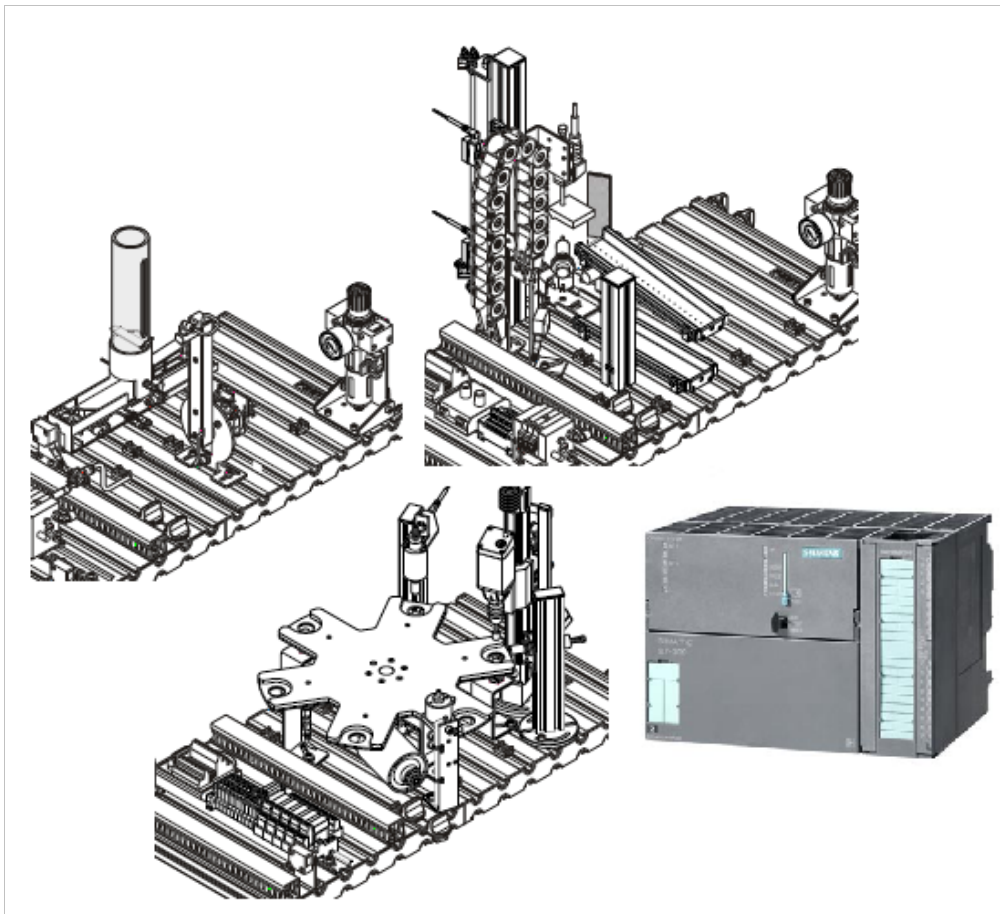


Figure 4.1: System Apparatus

Theoretical Background:

Timers are used to operate an output for a certain time or wait a certain time before operating an output. In Siemens S7-300 PLC timers have an area reserved for them in the memory of your CPU. This memory area reserves one 16-bit word for each timer address. The ladder logic instruction set supports 256 timers.

Siemens S7-300 PLC can be programmed with five types of timers: S_PULSE, S_PEXT, S_ODT, S_ODTS and S_OFFDT timer. These times differ in function but all of them have the block shown in Figure 4.2 in common.

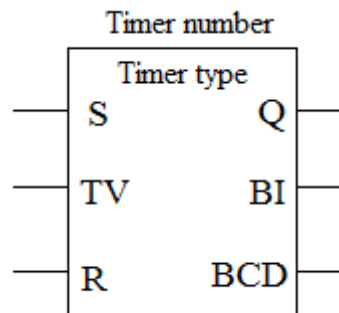


Figure 4.2: Timer Block

Where;

- S: is the Set (Trigger) signal of the timer.
- TV: is the time value stored in the timer which must be in the form (S5T#tv). The maximum time value for tv that you can enter is 9,990 seconds, or 2H_46M_30S.
- R: is the Reset signal of the timer.
- Q: is the output of the timer.
- BI: is the current time* in binary code.
- BCD: is the current time* in binary coded decimal code.
- Timer number: this can be in the form (T#), where # can be any number in the range (0-255), since Siemens S7-300 PLC allows the use of 256 timers at max.
- Timer type: is one of the 5 timer types mentioned above.

* The current time value is the initial TV value minus the time elapsed since the timer was started.

The following are examples on how to write the time tv in its correct form:

S5TIME#4S = 4 seconds

S5T#2h_15m = 2 hours and 15 minutes

S5T#1H_12M_18S = 1 hour, 12 minutes, and 18 seconds

The following five sections will discuss each timer type individually.

1. The Pulse Timer (S_PULSE)

S_PULSE (Pulse S5 Timer) starts the specified timer if there is a positive edge at the start (S) input. A signal change is always necessary in order to enable a timer. The timer runs as long as the signal state at input S is "1", the longest period, however, is the time value specified by input TV. The signal state at output Q is "1" as long as the timer is running. If there is a change from "1" to "0" at the S input before the time interval has elapsed the timer will be stopped. In this case the signal state at output Q is "0".

The timer is reset when the timer reset (R) input changes from "0" to "1" while the timer is running. The current time and the time base are also set to zero. Logic "1" at the timer's R input has no effect if the timer is not running.

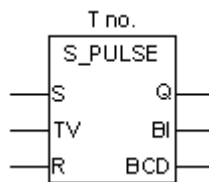


Figure 4.3: S_PULSE Timer Block

2. The Pulse Extended Timer (S_PEXT)

S_PEXT (Extended Pulse S5 Timer) starts the specified timer if there is a positive edge at the start (S) input. A signal change is always necessary in order to enable a timer. The timer runs for the preset time interval specified at input TV even if the signal state at the S input changes to "0" before the time interval has elapsed. The signal state at output Q is "1" as long as the timer is running. The timer will be restarted ("re-triggered") with the preset time value if the signal state at input S changes from "0" to "1" while the timer is running.

The timer is reset if the reset (R) input changes from "0" to "1" while the timer is running. The current time and the time base are set to zero.

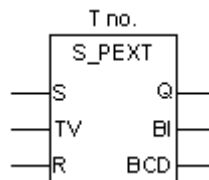


Figure 4.4: S_PEXT Ttimer Block

3. The On Delay Timer (S_ODT)

S_ODT (On-Delay S5 Timer) starts the specified timer if there is a positive edge at the start (S) input. A signal change is always necessary in order to enable a timer. The timer runs for the time interval specified at input TV as long as the signal state at input S is positive. The signal state at output Q is "1" when the timer has elapsed without error and the signal state at the S input is still

"1". When the signal state at input S changes from "1" to "0" while the timer is running, the timer is stopped. In this case the signal state of output Q is "0".

The timer is reset if the reset (R) input changes from "0" to "1" while the timer is running. The current time and the time base are set to zero. The signal state at output Q is then "0". The timer is also reset if there is a logic "1" at the R input while the timer is not running and the RLO at input S is "1".

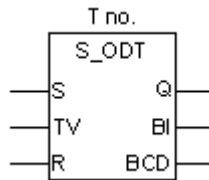


Figure 4.5: S_ODT Timer Block.

4. The ON Delay Retentive Timer (S_ODTS)

S_ODTS (Retentive On-Delay S5 Timer) starts the specified timer if there is a positive edge at the start (S) input. A signal change is always necessary in order to enable a timer. The timer runs for the time interval specified at input TV even if the signal state at input S changes to "0" before the time interval has elapsed. The signal state at output Q is "1" when the timer has elapsed without regard to the signal state at input S. The timer will be restarted (re-triggered) with the specified time if the signal state at input S changes from "0" to "1" while the timer is running.

The timer is reset if the reset (R) input changes from "0" to "1" without regard to the RLO at the S input. The signal state at output Q is then "0".

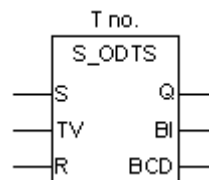


Figure 4.6: S_ODTS Timer Block

5. The Off Delay Timer (S_OFFDT)

S_OFFDT (Off-Delay S5 Timer) starts the specified timer if there is a negative edge at the start (S) input. A signal change is always necessary in order to enable a timer. The signal state at output Q is "1" if the signal state at the S input is "1" or while the timer is running. The timer is reset when the signal state at input S goes from "0" to "1" while the timer is running. The timer is not restarted until the signal state at input S changes again from "1" to "0".

The timer is reset when the reset (R) input changes from "0" to "1" while the timer is running.

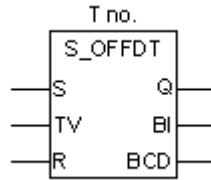


Figure 4.7: S_OFFDT Timer Block

Figure 4.7 summarizes the principle of operation of each SIMATIC S7 timer.

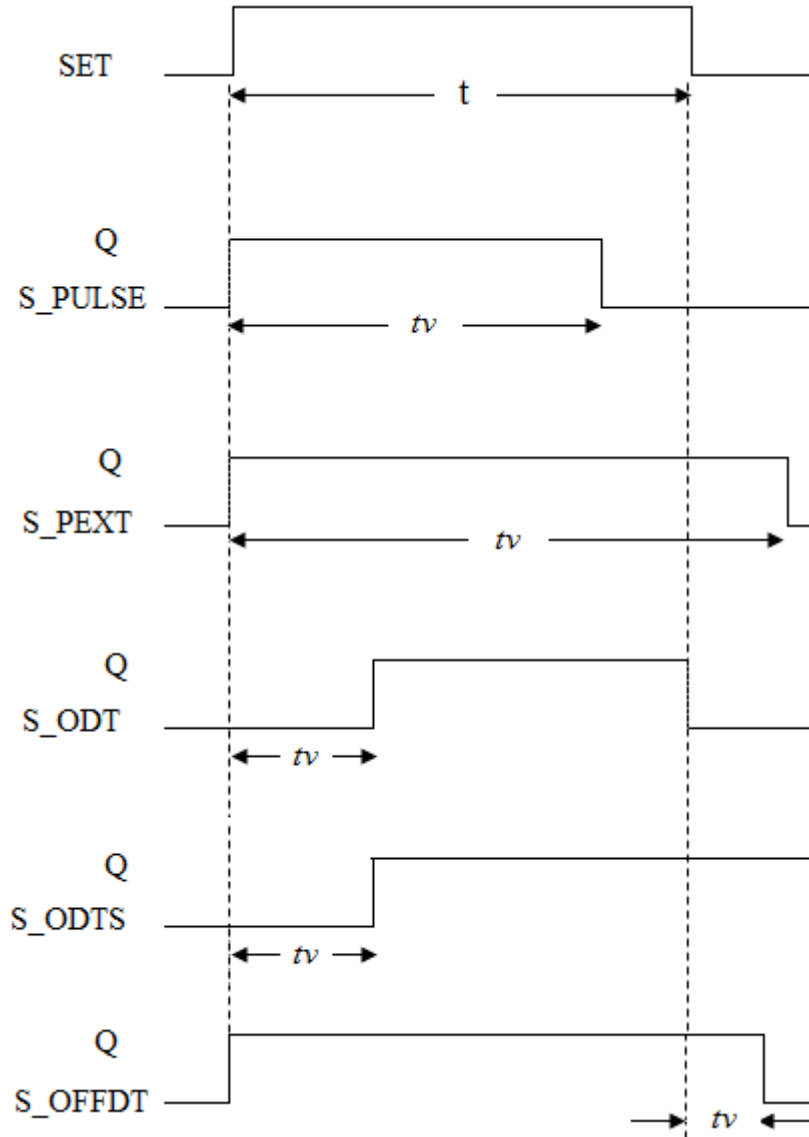


Figure 4.8: Timing Diagram.

Example 4.1:

If "Start" push button is pressed, the conveyor belt will be activated for 4 sec or till "Stop" push button is pressed.

It is obvious from the question that the conveyor belt will start immediately once "Start" is pressed, which mean that there is no delay. Then the proper timer for this type of question is S_PULSE or S_PEXT timers.

Using S_PULSE timer:

According to the timing diagram shown in Figure 4.8, S_PULSE timer needs the set signal to be maintained for at least $t \geq t_v$ if the time t_v is to elapse completely, hence the need for the latch. Once "Stop" is pressed or the 4 sec are over the timer will turn off so will the conveyor belt.

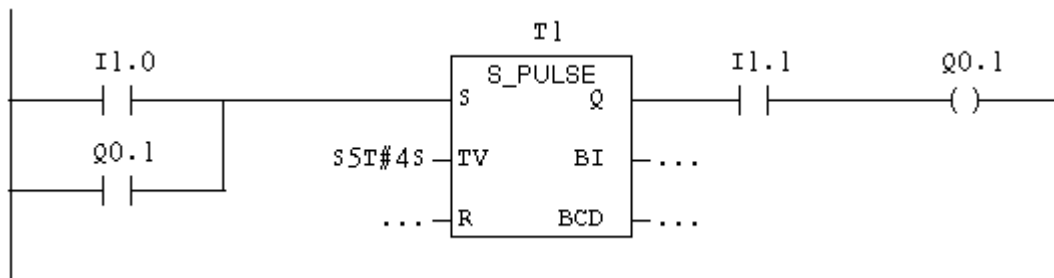


Figure 4.9: Example 4.1 Ladder Diagram Using S_PULSE Timer.

Using S_PEXT timer:

This type does not require a latch, then even if "Stop" is placed in series with "Start", it will has no effect. The solution then is to use "stop" as a reset signal but since "Stop" is a normally closed push button a normally close contact is used from it to ensure that no current exist at the reset terminal until "Stop" is pressed.

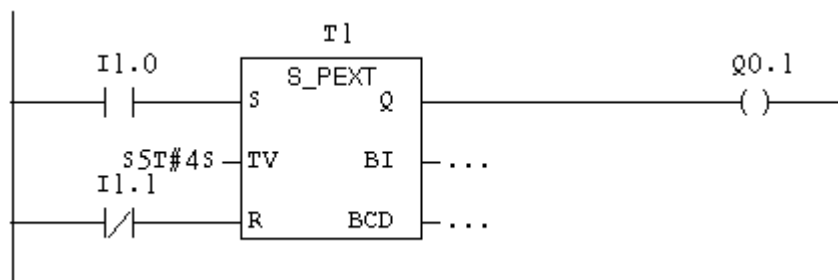


Figure 4.10: example 7.1 Ladder Diagram Using S_PEXT Timer

Example 4.2:

If "Start" push button is pressed, the conveyor belt will wait 4sec then get activated till "Stop" push button is pressed.

The obvious from the question is that there is a delay time between the press of "Start" and the operation of the conveyor belt. So obviously, an ON delay timer is needed. But there are two types of ON delay timers: S_ODT and S_ODTS.

Using S_ODT timer:

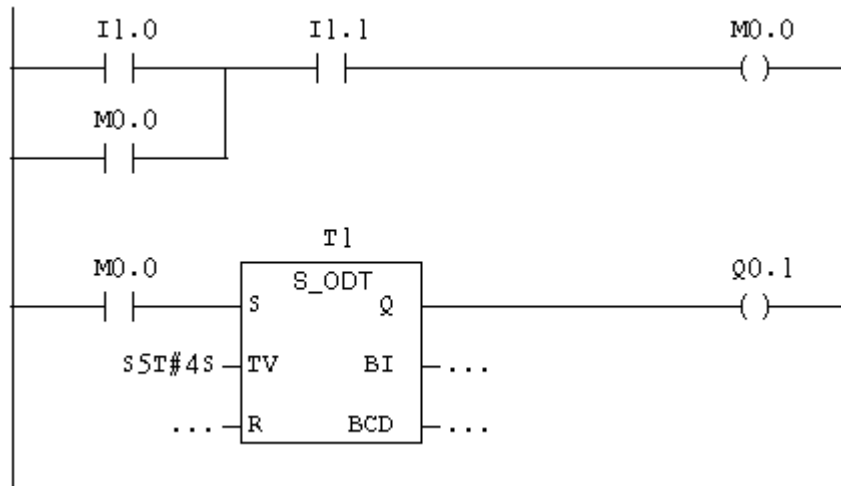


Figure 4.11: Example 4.2 Ladder Diagram Using S_ODT Timer

Using S_ODTS timer:

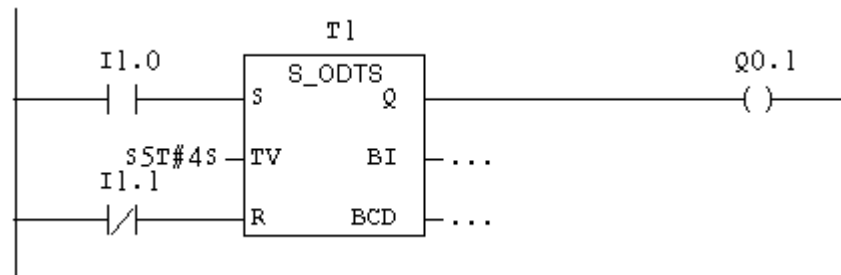


Figure 4.12: Example 4.2 Ladder Diagram Using S_ODTS Timer

The above two methods are obvious solution for this type of question. But we can manipulate the S_PULSE and S_PEXT timers to obtain the same result as follows:

Using S_PULSE timer:

The ladder diagram to solve this example using S_PULSE timer is shown in Figure 4.12. As shown in the diagram, once "Start" is pressed and since "Stop" is a normally closed push button, the internal coil "M0.0" will get activated. Consequently, the timer T1 will start timing. Once the 4 sec are over, the normally closed contact in the last rung will get back to its normally closed state and since the contact "M0.0" is closed now, current will flow through "Q0.0" activating the conveyor belt.

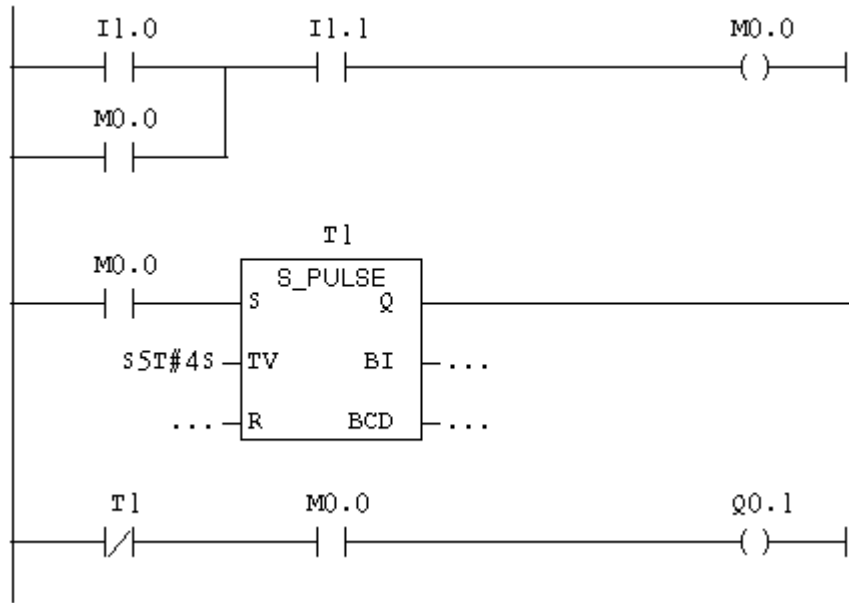


Figure 4.13: Example 4.2 Ladder Diagram Using S_PULSE Timer

Using S_PEXT timer:

The ladder diagram to solve this example using S_PEXT timer is shown in Figure 4.14. Here we "Start" directly at the set signal of the timer, since S_PEXT timer does not need latch. But even the use of "M0.0" here will be valid.

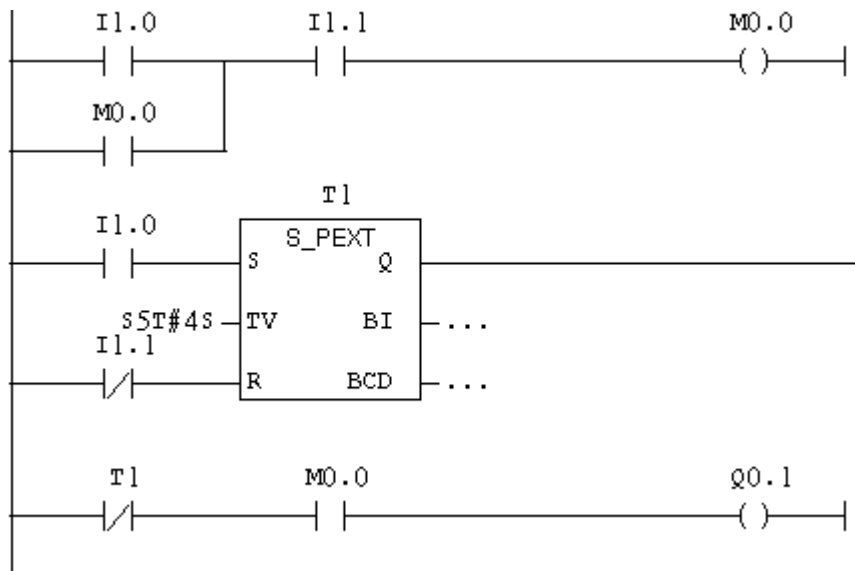


Figure 4.14: Example 4.2 Ladder Diagram Using S_PEXT Timer

Example 4.3:

If "Start" push button is pressed, the conveyor belt will be activated. If "Stop" push button is pressed, the conveyor belt will wait 4 seconds then stop.

In this question the conveyor belt will start immediately when "Start" push button is pressed but will start timing once "Stop" is pressed. This leads to an off delay timer or S_OFFDT.

The ladder diagram required to solve this question is shown in Figure 4.14.

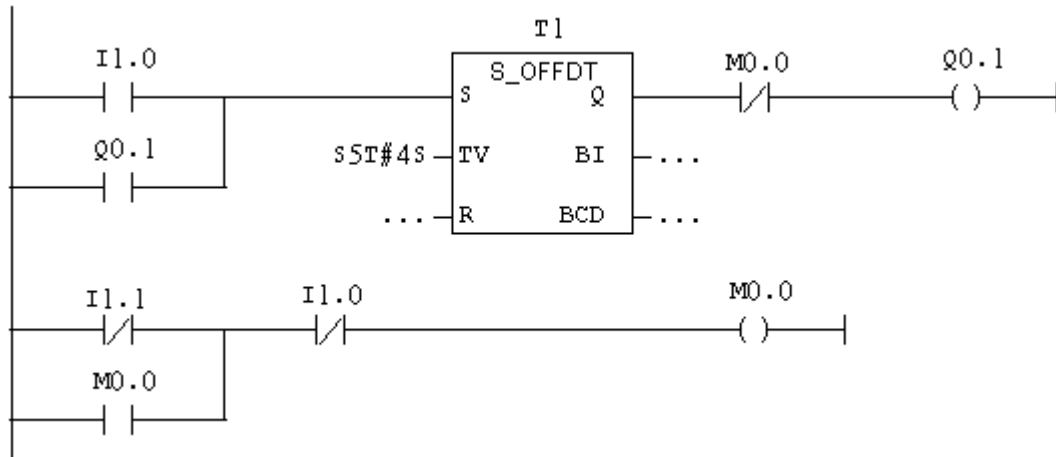




Figure 4.15: Example 4.3 Ladder Diagram Using S_OFFDT Timer

Procedure:

1. Turn off the power and pressure supplies.
2. Write a ladder diagram based on the process you are required to control (use the address you acquired in the last experiment).
3. Turn on the power supply
4. Download the ladder diagram to the PLC by clicking this icon .
5. Turn on the pressure supply
6. Start your process according to your station.
7. Turn on the online monitoring by clicking this icon .
8. If the process is not running as required, turn off the pressure supply.
9. Repeat from 1 to 8 until, you are satisfied with your process.
10. Save your ladder diagram.
11. Turn off the power and pressure supplies and your computer.

Discussion and Analysis:

Use the buffering station in Figure 2.15 in experiment 2 to answer the following:

1. When "Start" is pressed the separator will be activated for 2 seconds.
2. If a work piece is available the conveyor belt will be activated for 1 second or until the piece reaches the buffering position.
3. The conveyor will start 2 seconds after a work piece is available and "Reset" is pressed, and stops 5 seconds after the work piece reaches the end of the belt.

Experiment 5 Siemens PLC Programming with Counters

Objectives:

- To control a process using PLC.
- To monitor a process using PLC.
- To understand the benefits of counters in a process.
- To investigate the three different counters provided by SIMATIC S7.
- To use SIMATIC S7 comparators.
- To control a process using SIMATIC S7 counters.

Apparatus:

1. SIMATIC S7-300 Production Line Stations.
2. Festo Didactic Stations.
3. Programming device (personal computer).

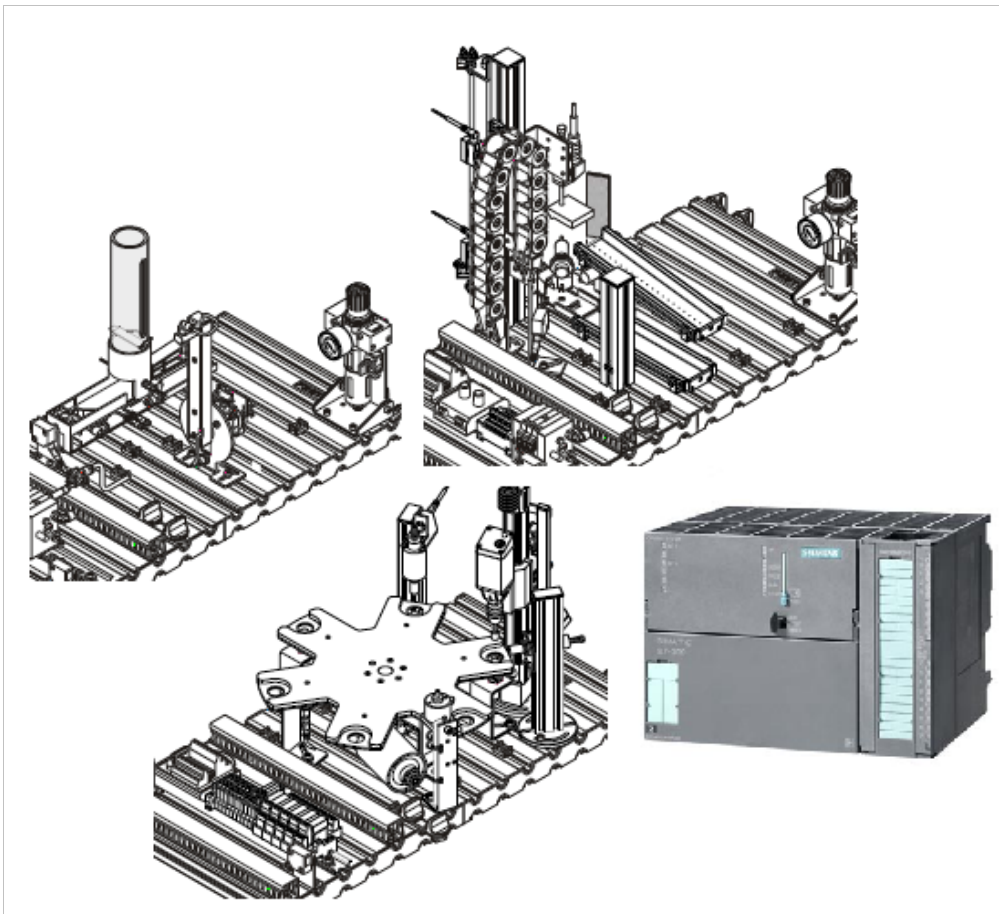


Figure 5.1: System Apparatus

Theoretical Background:

Counters are instructions used to count for an event. They are incremented or decremented by a certain factor each time that event happens. In Siemens S7-300 PLC, counters have an area reserved for them in the memory of the CPU. This memory area reserves one 16-bit word for each counter address. The ladder logic instruction set supports 256 counters.

Siemens S7-300 PLC can be programmed with three different types of counters: count up (S_CU), count down (S_CD) and count up/down counters (S_CUD). These counters differ in function but all of them have the block shown in Figure 5.2 in common.

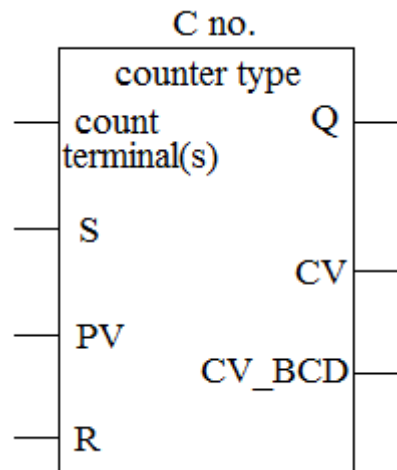


Figure 5.2: Counter Block

Where;

- Count terminal(s): it is one of the following:
- Count up (CU) in up counters. Each time a positive edge is given to this terminal it is incremented by one.
- Count down (CD) in down counters. Each time a positive edge is given to this terminal it is decremented by one.
- Count up and count down terminals in up/down counters (CUD).
- S: is the Set signal of the counter. By providing the counter with a positive edge on this terminal, the counter will be charged with the value stored in PV terminal.
- PV: is the count value to be stored in the counter when a positive edge is given to the set terminal. This value can be in the range of 0 to 999.
- R: is the Reset signal of the counter. A positive edge or a high level to this terminal will set the count value to 0 consequently setting the counter output to 0.
- Q: is the output of the counter. Q is 1 as long as the current count value of the counter is not 0. Once the count value drops to zero, the output Q is 0.
- CV: is the current count value in binary code.
- CV_BCD: is the current count value in binary coded decimal code.

- C no.: this is the counter number. This number can be any number in the range of 0 to 255 as mentioned above.
- Counter type: is one of the 3 counter types mentioned above.

You may provide a counter with a preset value by entering a number from 0 to 999, for example 127, in the following format: C#127.

The following three sections will discuss each counter type individually.

1. The Down Counter (S_CD)

S_CD (Down Counter) is shown in Figure 5.3. S-CD is set with the value at input PV if there is a positive edge at input S. The counter is reset if there is a 1 at input R and the count value is then set to zero.

The counter is decremented by one if the signal state at input CD changes from "0" to "1" and the value of the counter is *greater than zero*.

If the counter is set and if there is 1 at the input CD, the counter will count accordingly in the next scan cycle, *even if there was no change from a positive to a negative edge or vice versa*.

The signal state at output Q is "1" if the count value is greater than zero and "0" if the count value is equal to zero.

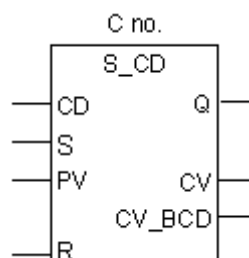


Figure 5.3: S_CD Counter Block

2. The Up Counter (S_UD)

S_CU (Up Counter) is shown in Figure 5.4. S_CU is preset with the value at input PV if there is a positive edge at input S. The counter is reset if there is a "1" at input R and the count value is then set to zero.

The counter is incremented by one if the signal state at input CU changes from "0" to "1" and the value of the counter is *less than "999"*.

If the counter is set and if there is 1 at the input CU, the counter will count accordingly in the next scan cycle, *even if there was no change from a positive to a negative edge or vice versa*.

The signal state at output Q is "1" if the count value is greater than zero and "0" if the count value is equal to zero.

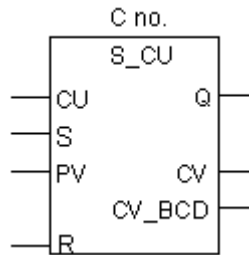


Figure 5.4: S_CU Counter Block

3. The UP/Down Counter (S_CUD)

S_CUD (Up-Down Counter) is shown in Figure 5.5. S_CUD is preset with the value at input PV if there is a positive edge at input S. If there is a 1 at input R, the counter is reset and the count value is set to zero.

The counter is incremented by one if the signal state at input CU changes from "0" to "1" and the value of the counter *is less than "999"*. The counter is decremented by one if there is a positive edge at input CD and the value of the counter *is greater than "0"*.

If there is a positive edge at both count inputs, both instructions are executed and the count value remains unchanged.

If the counter is set and if there is 1 at the inputs CU/CD, the counter will count accordingly in the next scan cycle, *even if there was no change from a positive to a negative edge or vice versa*.

The signal state at output Q is "1" if the count value is greater than zero and "0" if the count value is equal to zero.

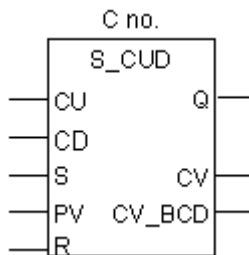


Figure 5.5: S_CUD counter block.

Example 5.1:

If "Start" push button is pressed, the conveyor belt will be activated until four work pieces have passed the end of the belt sensor or till "Stop" push button is pressed.

We can solve this question using one of two counter types: the up counter or the down counter.

Using S_CD counter:

Using this type of counter, means that we should start from a preset count value and start decrementing it till it reaches zero. At that point the counter will be reset and its output will go to zero. A simple suggested ladder diagram to solve this example using S_CD is shown in Figure 5.6.

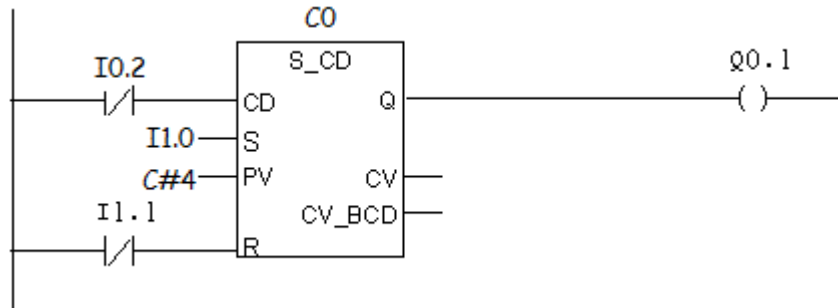


Figure 5.6: Example 5.1 Ladder Diagram Using S_CD Counter.

As shown in Figure 5.6, once "Start" push button is pressed, the counter is charged with the value stored in PV terminal which is the number of pieces required to pass (4 pieces) and the counter output will be set to 1 activating the conveyor belt.

Because the end of the conveyor belt sensor is a normally closed switch, each time a work piece passes the sensor, a transition from low to high occurs (positive edge) decrementing the count value by one. Hence, when the fourth piece passes the sensor, the count value will drop to setting the output to zero and stopping the motor.

If "Stop" push button is pressed and since it is a normally closed push button, the counter output will be set to 0 and the conveyor belt will stop.

Using S_CU counter:

Using this type of counter, means that if we start the counter from zero (its output is also 0), when the count value reaches 4, the counter should give a signal such that the conveyor belt will stop. But this is impossible if the counter is working on its own, thus the need for a comparator arises. A simple suggested ladder diagram to solve this example using S_CU is shown in Figure 5.6.

As shown in Figure 5.7, once "Start" push button is pressed, the counter is charged with the value stored in PV terminal which is 0. Also the conveyor belt will get started.

Because the end of the conveyor belt sensor is a normally closed switch, each time a work piece passes the sensor, a transition from low to high occurs (positive edge) incrementing the count value by one. Hence, when the fourth piece passes the sensor, the count value will reach 4.

As shown in the figure, the count value (CV) of the counter is stored in a MW0 which is memory word 0 (i.e. a 16 bit space is reserved in the memory for the counter 0 (C0) count value).

The equality comparator will give 1 once the value in MW0 equals 4 (2#100) where (2#) is used to indicate the binary system. When the comparator is 1, the internal relay M1.2 will get activated and the contact M1.2 will change state from closed to open removing the latch from "Start".

If "Stop" push button is pressed and since it is a normally closed push button, the counter output will be set to 0 and the conveyor belt will stop.

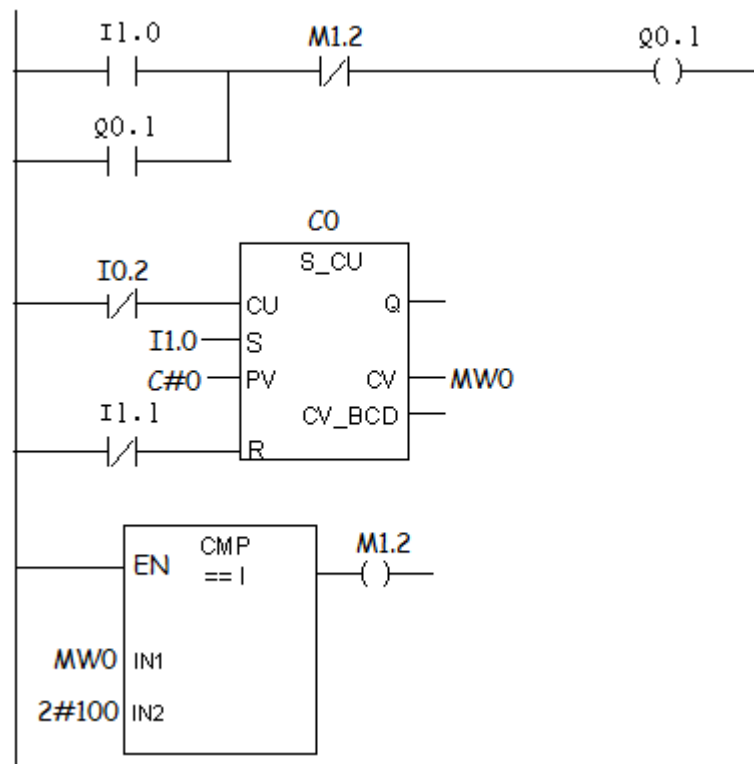




Figure 5.7: Example 5.1 Ladder Diagram Using S_CU Counter..

Procedure:

1. Turn off the power and pressure supplies.
2. Write a ladder diagram based on the process you are required to control (use the address you acquired in the last experiment).
3. Turn on the power supply
4. Download the ladder diagram to the PLC by clicking this icon .
5. Turn on the pressure supply
6. Start your process according to your station.
7. Turn on the online monitoring by clicking this icon .
8. If the process is not running as required, turn off the pressure supply.
9. Repeat from 1 to 8 until, you are satisfied with your process.
10. Save your ladder diagram.
11. Turn off the power and pressure supplies and your computer.

Discussion and Analysis:

Use the buffering station in Figure 2.15 in experiment 2 to answer the following:

1. When "Start" is pressed and a work piece is available the conveyor belt will be activated until 2 work pieces reach the buffering position.
2. The separator will be activated whenever "Reset" is pressed 3 times more than "Stop" is pressed.
3. The conveyor belt will be activated as long as there is 2 or more pieces on it.

Experiment 6 Introduction to Pneumatic Systems

Objectives:

- To introduce the students to pneumatic system.
- To study pneumatic system component.
- To investigate different types of supply elements.
- To differentiate between type of pneumatic valve and their actuation methods.
- To understand pneumatic cylinders.
- To design a pneumatic system.

Apparatus:

1. FESTO Pneumatic Basic Kit.



Figure 6.1: System Apparatus

Theoretical Background:

An incredible range of manufacturing systems use the force and power of fluids such as water, oil and air. Powered clamps open and close with the force of pressurized air or oil, large presses shape and form metal with hydraulic pressure, and assembly torque tools fasten components with

pressurized air. In each example, fluid power provides the energy necessary to exert significant mechanical forces. Systems that use air are called pneumatic systems while systems that use liquids like oil or water are called hydraulic system. The pneumatic systems will be the subject of the first three sessions in the course starting from this session.

Pneumatics is all about using compressed air to make a process happens. Compressed air is simply the air we breathe squeezed into a small space under pressure. You might remember that air under pressure possesses potential energy which can be released to do useful work.

Each system has its advantages and disadvantages. Tables 6.1 and 6.2 show the advantages and the disadvantages for pneumatic systems:

Table 6.1: Advantages of Pneumatic Systems

Advantages of Pneumatic Systems	
Availability	Air is available practically everywhere in unlimited quantities.
Transport	Air can be easily transported in pipelines, even over large distances.
Storage	Compressed air can be stored in reservoirs and removed as required. In addition, the reservoir is transportable.
Temperature	Compressed air is relatively insensitive temperature fluctuations. This ensures reliable operation, even under extreme conditions.
Explosion Proof	Compressed air offers no risk of explosion or fire.
Cleanliness	Un-lubricated exhaust air is clean. Any un-lubricated air that escapes through leaking pipes or components does not cause contamination.
Components	The operating components are of simple construction and therefore relatively inexpensive.
Speed	Compressed air is a very fast working medium. This enables high working speeds to be attained.
Overloads Safe	Pneumatic tools and operating components can be loaded to the point of stopping and are therefore overload safe.

Table 6.2: Disadvantages of Pneumatic Systems

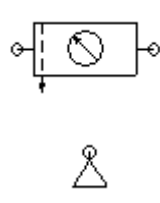
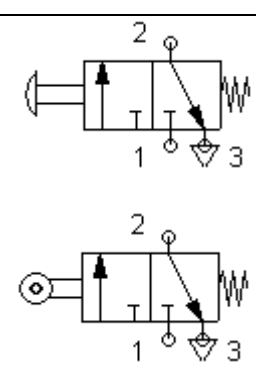
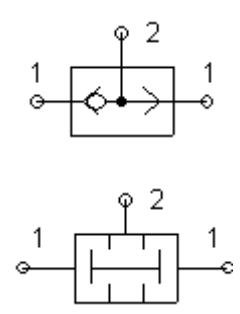
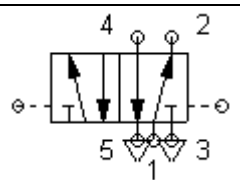
Disadvantages of Pneumatic Systems	
Preparation	Compressed air requires good preparation and constant piston speeds.
Compression	It is not always possible to achieve uniform and constant piston speeds with compressed air.
Force Requirement	Compressed air is economical only up to a certain force requirement. Under normal working pressure of 600 to 700 KPa (6 to 7 bar) and dependent on the travel and speed, the output is limited between 40 000 to 50 000 Newton.
Noise Level	The exhaust air is loud. This problem can be solved by the use of sound absorption material and silencers.

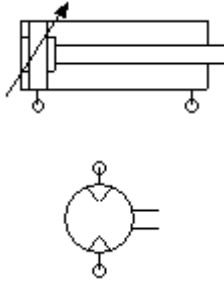
It is a knowledge that any system must consist of a group of components which work together to perform a task. A pneumatic system consists of a group of pneumatic components connected together so that a signal (compressed air) is passed through the system to make something happen at the output. This group of components can be divided into five categories according to their function in the pneumatic circuit as follows:

- 1. Supply elements:** these elements are the sources of power that drives the system which are the compressors.
- 2. Input elements:** these elements are used to send signals to the final control elements and come in two forms; either as components that is actuated by the operator like push buttons or sensors that determine the status of the power elements such as limit switches and proximity sensors.
- 3. Processing elements:** these elements may perform operations on the input signals before sending the signal to the final control elements such as nonreturn valves, directional control valves and presser control valves.
- 4. Final control elements:** to control the motion of actuators such as directional control valves.
- 5. Power elements (actuators):** these are the outputs of the pneumatic system which use the stored potential energy to perform a certain task such as pneumatic cylinders and motors.

Table 6.3 shows the main five categories for elements of pneumatic systems.

Table 6.3: Pneumatic System Components

Pneumatic System Elements	
<p>Supply elements</p> <p>Compressor</p> <p>Reservoir</p> <p>Pressure regulating valve</p> <p>Air service unit</p>	
<p>Input elements</p> <p>Push button valves</p> <p>Limit switches</p> <p>Proximity switches</p>	
<p>Processing elements</p> <p>Directional control valves</p> <p>Nonreturn valves</p> <p>Pressure control valves</p> <p>Timers, counters</p>	
<p>Final control elements</p> <p>Directional control valves</p>	

<p>Power elements (actuators)</p> <p>Pneumatic cylinders</p> <p>Pneumatic motors</p>	 <p>The image contains two schematic diagrams. The top diagram is a pneumatic cylinder, shown as a horizontal cylinder with a piston rod extending from the left side. A diagonal line with an arrowhead at the top indicates the piston's position. Two ports are shown at the bottom of the cylinder. The bottom diagram is a pneumatic motor, represented as a circle with two ports on the right side and two ports on the top and bottom. A curved arrow inside the circle indicates the direction of rotation.</p>
---	--

1. Supply Elements

The supply elements are the heart of the pneumatic systems so let's discuss them in more details:

- **Air Compressor:** It is a mechanical device that increases the pressure of air by reducing its volume. Compression of a gas naturally increases its temperature.
- **Reservoir:** It is used to stabilize compressed air. A reservoir compensates the pressure fluctuations when the compressed air is taken from the system. If the pressure in the reservoir drops below a certain value, the compressor will compensate until the set higher value is reached again. This has the advantage that the compressor does not need to operate continuously.

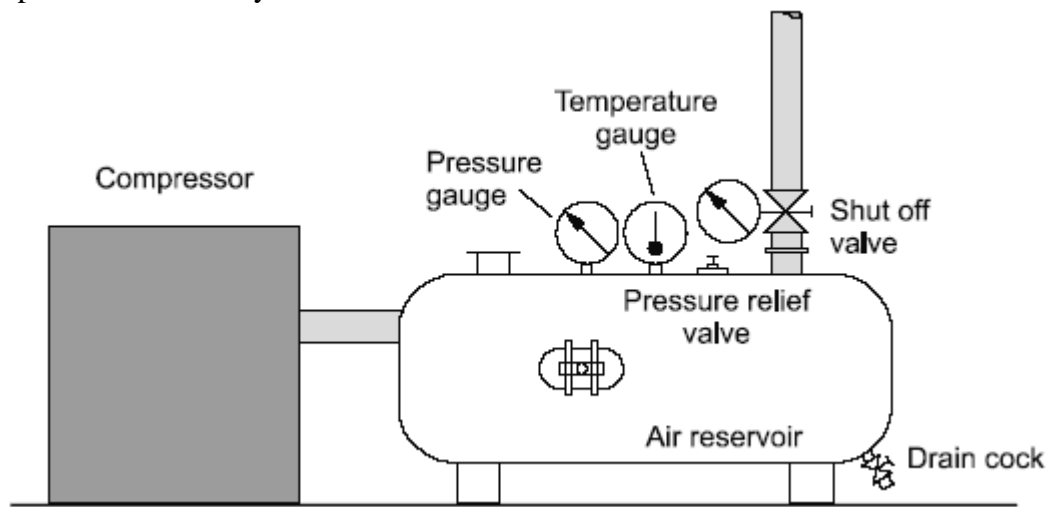


Figure 6.2: Air Reservoir

- **Air Service Unit:** It is a combination of a compressed air filter (with water separator) that removes all contaminants from the compressed air, a compressed air regulator that keeps the operating pressure of the systems virtually constant, regardless of fluctuations in the line pressure and the air consumption and a compressed air lubricator that delivers metered quantity of oil mist into a leg of the air distribution system when necessary.

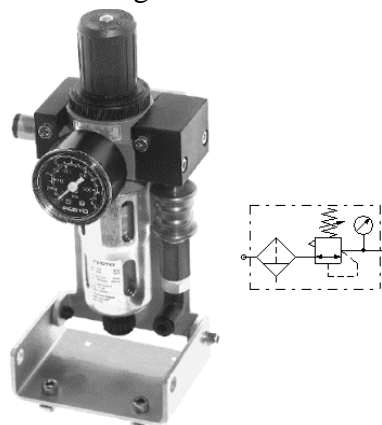


Figure 6.3: Air Service Unit

2. Valves

Valves are such an important part of a pneumatic system for they are used to control the pressure or flow rate of pressure media. Depending on their design, valves can be divided into the following categories:

2.1. Directional control valves

This type of valves controls the passage of air signals by generating, cancelling or redirecting signals. Each valve is described by two parameters:

Number of ports / Number of positions

- Number of ports: number of inlets and outlets of the valve.
- Number of positions: number of chambers (squares).

The following examples illustrate the describing method:

Example 1:

For Figure 6.4, there is one inlet (1) and one outlet (2) in each square which means there are two ports for this valve.

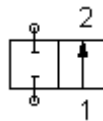
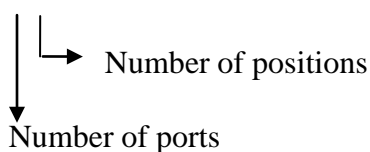


Figure 6.4: 2/2 Directional Valve

On the other hand there are two chambers (squares) which mean that this valve has two positions. Then we can describe the valve as follows:

2/2 directional valve.



Example 2:

For Figure 6.5, there is one inlet (1) and four outlets (2,3,4,5) in each square which means there are five ports for this valve.

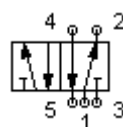
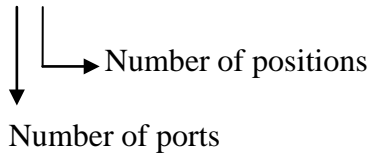


Figure 6.5: 5/2 Directional Valve

On the other hand there are two chambers (squares) which means that this valve has two positions. Then we can describe the valve as follows:

5/2 directional valve.



Example 3:

For Figure 6.6, there is one inlet (1) and three outlets (2,3,4) in each square which means there are four ports for this valve. On the other hand there are three chambers (squares) which means that this valve has three positions. Then we can describe the valve as follows:

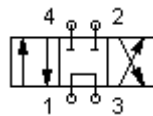
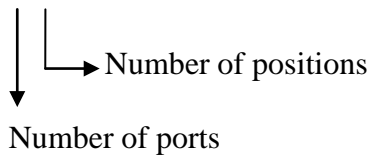


Figure 6.6: 4/3 Directional Valve



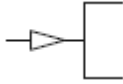

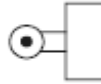


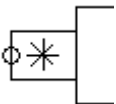


4/3 directional valve.



Now we have learned how to describe a directional valve based on its number of ports and position but this is not enough, because there is also the method of activation for the valves. Table 6.4 shows some of the activation methods.

Table 6.4: Activation Methods for Directional Valves

Manual Actuation	
General	
Push Buttons	
Lever Operated	

Dented Lever Operated	
Foot Pedal	
Pneumatic Actuation	
Direct Pneumatic Actuation	
Mechanical Actuation	
Plunger	
Roller Operated	
Idle Return, Roller	
Spring Return	
Proximity	
Electrical Actuation	
Single solenoid operation	
Double solenoid actuation	

How directional valves work?

The answer to this question is illustrated by Figure 6.7.



Figure 6.7: Principle of Directional Valves Operation

Figure 6.8 shows real photos for two types of direction valves



Figure 6.8: Real Photos for Directional Valves

2.2. Non-return valves:

This type of valves is the basis for the development of many combined components. Examples on these type of valve are shown in Table 6.5.

Table 6.5: Non-Return Valves

Check valve	
Spring loaded check valve	
Shuttle valve	
Dual pressure valve	
Quick exhaust valve	

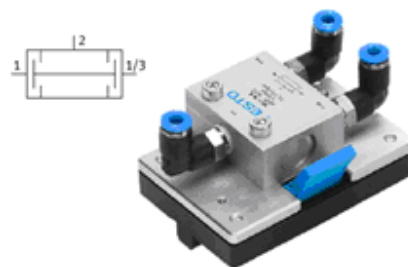

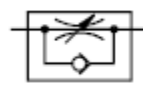


Figure 6.9: Real Photo For A Non-Return Valve

2.3. Flow control valves:

These valves can be adjustable and permit flow control in one or both directions. The arrow shows that the component is adjustable but does not refer to the direction of flow; it is diagrammatic only. Table 6.6 shows flow control valves.

Table 6.6: Flow Control Valves

Flow control valve (bidirectional)	
One-way flow control valve	

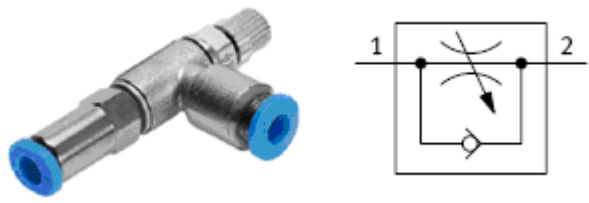
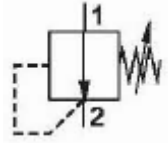
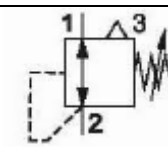
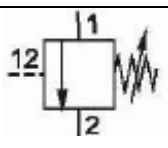


Figure 6.10: Real Photo for A Flow Control Valve

2.4. Pressure control valves:

These valves influence the pressure in an overall pneumatic system or in a part of the system. Pressure regulating valves are generally adjustable against spring compression. Table 6.7 shows types of pressure control valves.

Table 6.7: Pressure Control Valves

Adjustable pressure regulating valve, non-relieving type	
Adjustable pressure regulating valve, relieving type	
Sequence valve, external source	

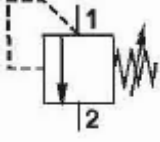
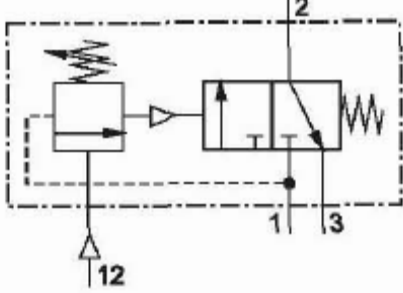
Sequence valve, in line	
Sequence valve combination	

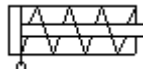


Figure 6.11: Real Photo For A Pressure Control Valve

3. Cylinders

Pneumatic cylinders are mechanical devices which produce force, often in combination with motion, and are powered by compressed gas. To perform their function, pneumatic cylinders impart a force by conversion the potential of the compressed gas into kinetic energy. There is two main types of pneumatic cylinders; single acting and double acting cylinders. Single acting cylinders (SAC) use the pressure imparted by compressed air to create a driving force in one direction (usually out), and a spring to return to the "home" position. Double Acting Cylinders (DAC) use the force of air to move in both extends and retract strokes. They have two ports to allow air in, one for outstroke and one for instroke. Figure 6.11 shows real photos for both a single acting and a double acting cylinders while Table 6.8 show the symbols for them.

Table 6.8: Pneumatic Cylinders

Single acting cylinder	
------------------------	---

Double acting cylinder

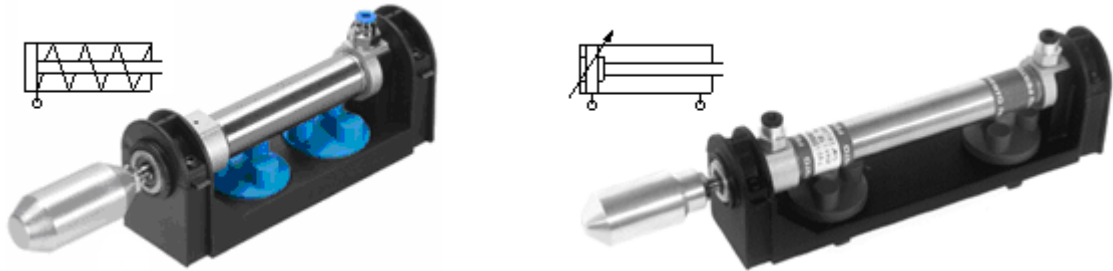
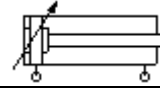


Figure 6.12: Real Photos for Cylinders

Procedure:

Note: In case of emergency turn off the pressure supply and consult your laboratory supervisor.

1. Draw a schematic circuit based on the pneumatic process you are required to control.
2. Turn off the pressure supply.
3. Implement the system.
4. Make sure to adjust the position of the limit switches you use.
5. Turn on the pressure supply.
6. Observe your process to check its functionality.
7. Repeat the steps if necessary.
8. Turn off the pressure supply.

Discussion and Analysis:

Use the buffering station in Figure 2.15 in experiment 2 to answer the following:

1. What is the main difference between directional control valves and flow control valve?
2. What are the components of the Air Service Unit, and what is the function of each stage?
3. What is the smallest valve needed to control a single acting cylinder?
4. What is the smallest valve needed to control a double acting cylinder?

Experiment 7 Electro-Pneumatic Circuits Design

Objectives:

- To introduce the students to electro-pneumatic system.
- To study electro-pneumatic system component.
- To understand the necessity of using relays in electro-pneumatic system.
- To draw a process state diagram.
- To design and build electro-pneumatic process using FESTO FluidSIM software based on a given state diagram.
- To implement an electro-pneumatic system.
- To implement a ladder diagram to control the electro-pneumatic system.

Apparatus:

1. FESTO Electro-Pneumatic Basic Kit.



Figure 7.1: System Apparatus

Theoretical Background:

A pneumatic system can be controlled either manually or automatically. In manual control systems, operation is sequenced by operator who decides which action to take. In automatic control systems, operation is sequenced by controller that automatically decides each action to be taken. Automatic control can be accomplished by means of:

- Electrical signals
- Pneumatic signals

In experiment 6 you have controlled pneumatic systems via pneumatic signals using pneumatically actuated valves. During this experiment you will learn how to control a pneumatic system using electrical signals.

In pneumatically controlled systems, signals are transmitted as compressed air. Whereas in electrically actuated systems, signals are transmitted as electrical current, but still the cylinders are driven by compressed air to perform their duties. So we expect to find two sources of power in electro-pneumatic systems: compressors and electrical power supplies. The electrical power supplies can be either dc or ac supplies but we will use dc power supplies of 24V in this lab session.

Electro-pneumatic system is still pneumatic system in essence, which means that it has the main five components of a pneumatic system.

1. Supply elements
2. Input elements
3. Processing elements
4. Final control elements
5. Power elements (actuators)

An important concept in electro-pneumatic systems is the ladder diagram. This diagram is a graphical representation of the electrical part of the electro-pneumatic system. It reflects your way of thinking. So in order to build an electro-pneumatic system, you have to start with putting the ladder diagram, testing it using FluidSIM then building the actual hardware.

1. Ladder Diagram

Ladder diagram is an important concept not only at electro-pneumatic systems, but also at PLC. Each ladder diagram is constructed from input switches and out relays that lies between the positive and negative power lines. The order of elements in a ladder diagram is shown by Figure 7.2.

As shown by the figure, the positive power line of the supply is on the extreme left of the ladder. While the negative line of the supply (ground here) is on the extreme right. Between the power lines come the inputs and outputs. Each line the ladder is called a "rung". Each rung may contain only one output unless the outputs are in parallel.

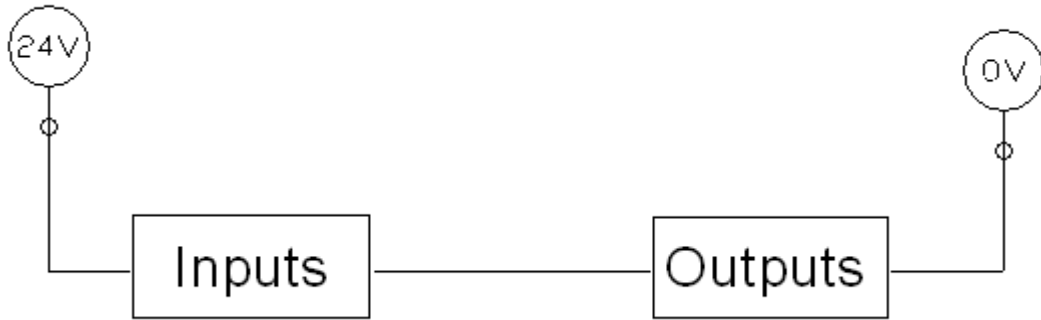


Figure 7.2: Ladder Diagram Main Components

Outputs in a ladder diagram are always at the right just before the negative line of the power supply. Mainly we want the current to flow from the positive line to the negative line through the output in order for it to be actuated. Outputs in ladder diagrams are mainly relays in operation. So let's discuss the principle of operation of relays.

2. Relays

Figure 7.3 shows the interior of a relay. The relay consists of a coil with a core (1) and winding (3) with inputs terminals (7), an armature (4), a return spring (2) and a contact assembly with a changeover contact (5) and output terminals (6). When power is applied to the coil connections, current flows through the winding, creating a magnetic field. The armature is pulled onto the coil core and the changeover contact is actuated changing its position. When the electrical current is removed, the magnetic field collapses and the armature and changeover contact are returned to their original position by a return spring.

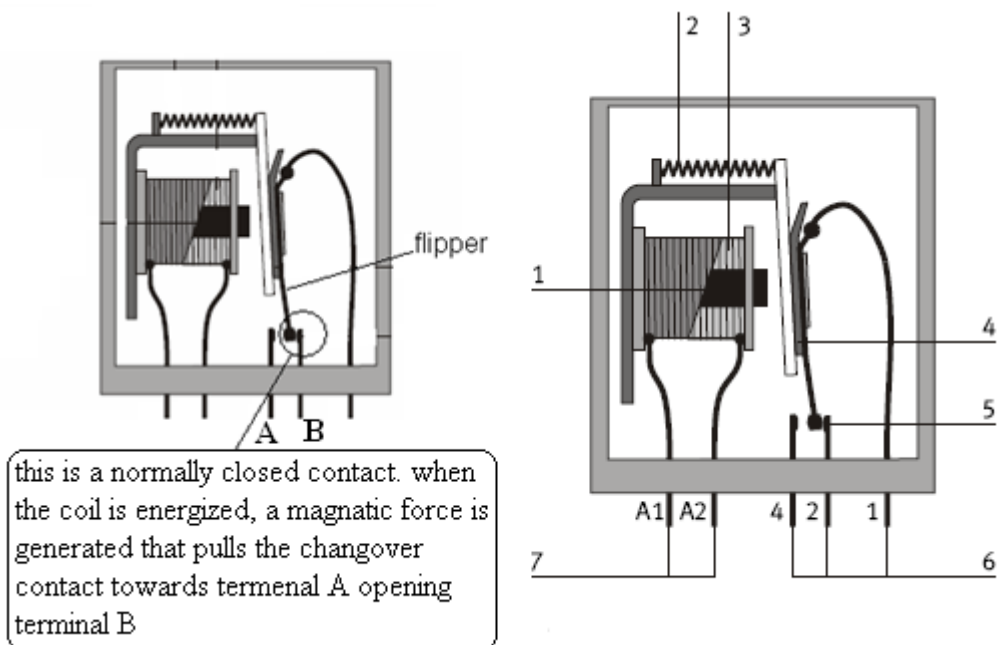


Figure 7.3: Relay

An associated concept with relays is the normally open and normally closed contacts. At Figure 7.3 you can see the two types of contacts. Terminal A with the flipper forms the normally open contact (NO) while terminal B with the flipper forms the normally closed contact (NC) of the relay. The name of the contact comes of its natural (normal) physical state when the relay's coil is not actuated. As you can see, as long as the coil of the relay is not activated (no current is flowing through it), then the spring force will keep the contacts in their positions. Once the coil is activated (energized) the contacts will change their physical state. Thus the normally open contact will become closed and the normally closed contact will become open.

As we said above, the inputs can be electrical push buttons or electrical limit and proximity switches. Proximity switches comes into four types: inductive, capacitive, magnet and optical proximity switches.

Principle of operation of the inputs is the same, but they differ at the method of actuation. Their principle is simple, if a normally open input is actuated; it changes its state to closed allowing current to flow from its positive terminal to its negative one. On the other hand for a normally closed input, when it is actuated it will change its state to open stopping the current flow through it.

The following examples illustrate the constructing and use of ladder diagram to drive an electro-pneumatic circuit.

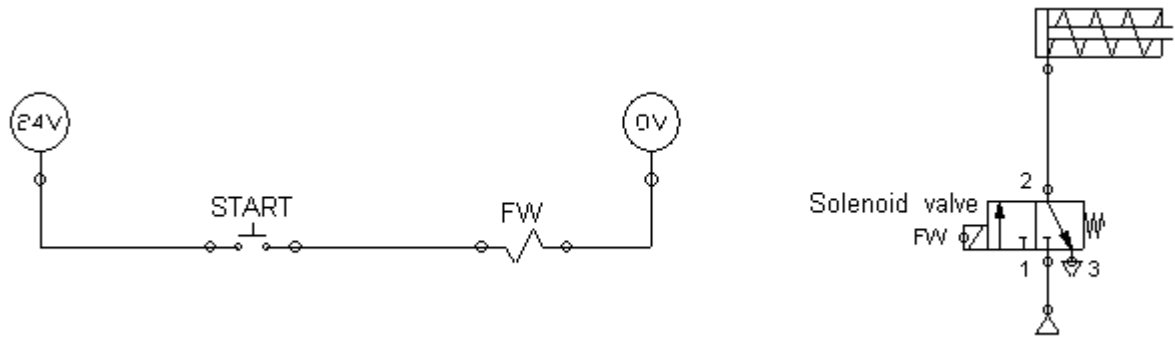
Example 7.1:

Design an electro-pneumatic circuit such that a single acting cylinder will advance upon pressing an electrical push button "START" and will retract upon releasing it.

(Use a 3/2 solenoid actuated spring returned control valve)

The pneumatic circuit, ladder diagram and parts' list needed to perform this operation are shown by Figure 7.4.

The circuit shown by Figure 7.4 is a simple single input single output circuit. As long as the electrical "START" push button is pressed, the rung will be closed and current will flow through the solenoid "FW" activating it. This solenoid is attached to "FW" on the valve. So as long as "FW" is energized the cylinder will advance. Once "START" is released, the current flow through the rung will stop and the spring will return the valve to its initial position causing the cylinder to retract. Figure 7.5 shows the circuit's state diagram.



Designation	Component Description
Solenoid valve	3/2 solenoid activated spring returned valve
	Single acting cylinder
	Compressed air supply
	Electrical connection 0V
	Electrical connection 24V
START	Pushbutton (make, Ladder)
FW	Valve solenoid

Figure 7.4: Pneumatic Circuit, Ladder Diagram and Parts' List for Example 7.1.

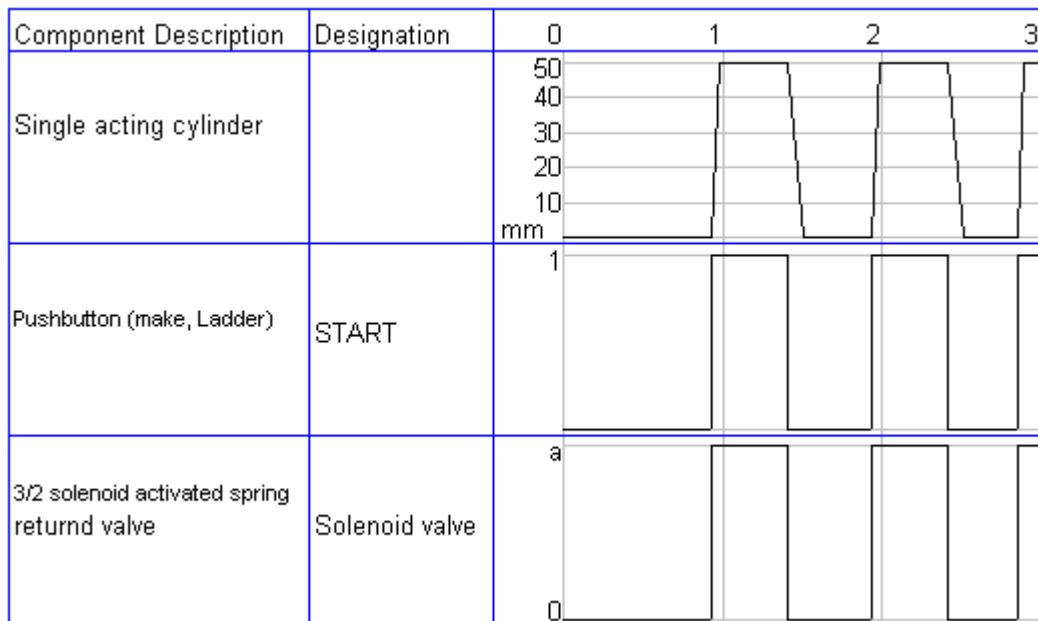


Figure 7.5: State diagram for Example 7.1.

If you go back to the beginning of the session you will find out that we said that the processing elements can be non-physical. The concept of non-physical AND and OR gates will be illustrated by Example 7.2.

Example 7.2:

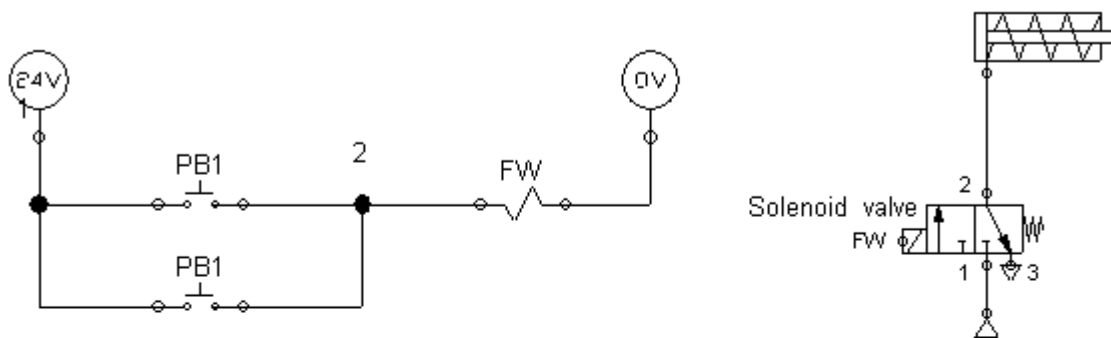
Design an electro-pneumatic circuit such that a single acting cylinder will advance upon pressing an electrical push buttons "PB1" or "PB2" and will retract upon releasing both of them.

(Use a 3/2 solenoid actuated spring returned control valve)

The pneumatic circuit, ladder diagram and parts' list needed to perform this operation are shown by Figure 7.6.

As shown by Figure 7.6, connecting the push buttons in a parallel combination have achieved the purpose of "OR" gate. Because at this configuration, as long as one of the push buttons or both of them are pressed current will flow through the solenoid valve activating it and causing the cylinder to advance. Once both of the push buttons are released the current flow will stop and the cylinder will retract.

Based on this principle, to "AND" two inputs, all you have to do is to put them in series. This way as long as both of them are actuated together, current will flow through the solenoid activating it. Once one or both of them are released, the solenoid will become de-energized.



Designation	Component Description
Solenoid valve	3/2 solenoid activated spring returned valve
	Single acting cylinder
	Compressed air supply
	Electrical connection 0V
	Electrical connection 24V
PB1	Pushbutton (make, Ladder)
FW	Valve solenoid
PB1	Pushbutton (make, Ladder)

Figure 7.6: Pneumatic Circuit, Ladder Diagram and Parts' List for Example 7.2

Figure 7.7 shows the circuit's state diagram:

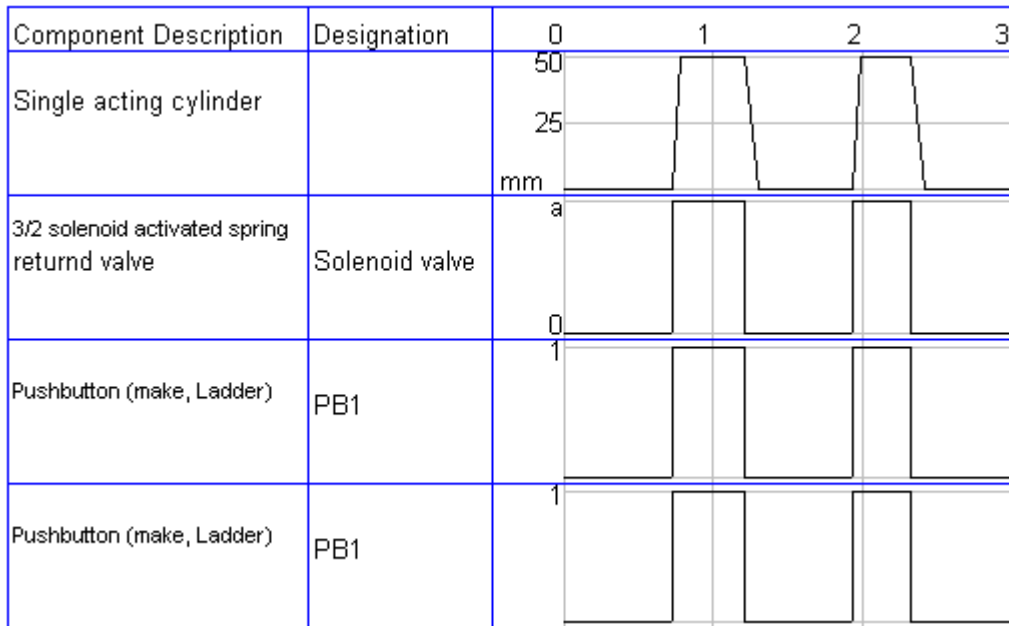


Figure 7.7: State Diagram for Example 7.2

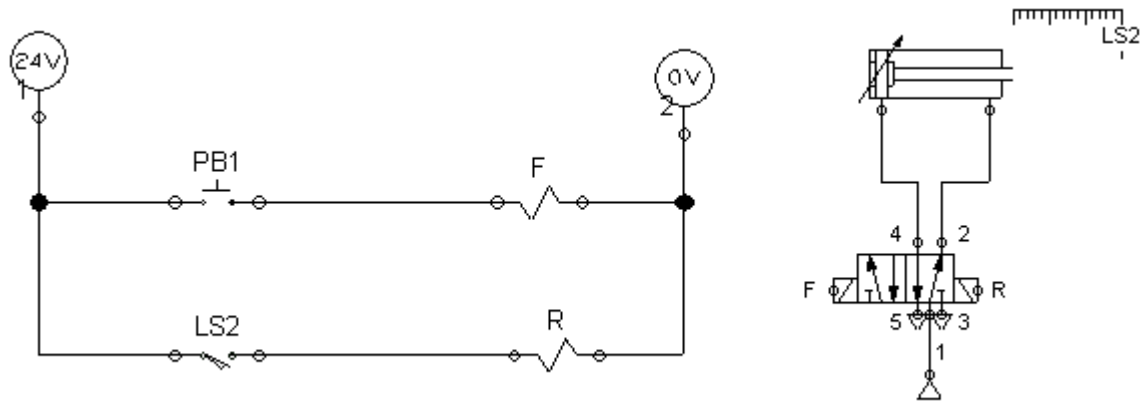
Example 7.3:

Design an electro-pneumatic circuit such that a double acting cylinder will advance upon pressing an electrical push button "PB1" and will retract upon reaching its full extent.

(Use a 5/2 solenoid actuated control valve and use electrical limit switches to determine the position of the cylinder)

The pneumatic circuit, ladder diagram and parts' list needed to perform this operation are shown by Figure 7.8.

Using a double solenoid actuated control valve as the one shown at Figure 7.8 is very useful. Using this type of valve means that it is actuated on both sides via electrical signals, which means that if a signal occurred at the left solenoid "F" by pressing "START" (even if it is a momentarily signal, the button is released) the valve will change state by switching positions allowing the compressed air to flow from port 1 to 4 causing the cylinder to advance. As long as there is no signal at the right solenoid "R", the valve will stay on its position and the cylinder will continue to advance. Once the cylinder reaches its full extent the limit switch will be activated causing current to flow through solenoid "R" momentarily (as long as the cylinder is at its full extent), and reversing the position of the valve causing the cylinder to retract.



Designation	Component Description
F	Valve solenoid
R	Valve solenoid
LS2	Make switch (Ladder)
	Electrical connection 0V
	Electrical connection 24V
PB1	Pushbutton (make, Ladder)
	5/2 solenoid actuated valve
	Compressed air supply
	Double acting cylinder

Figure 7.8: Pneumatic Circuit, Ladder Diagram and Parts' List for Example 7.3

Figure 7.9 shows the circuit's state diagram:

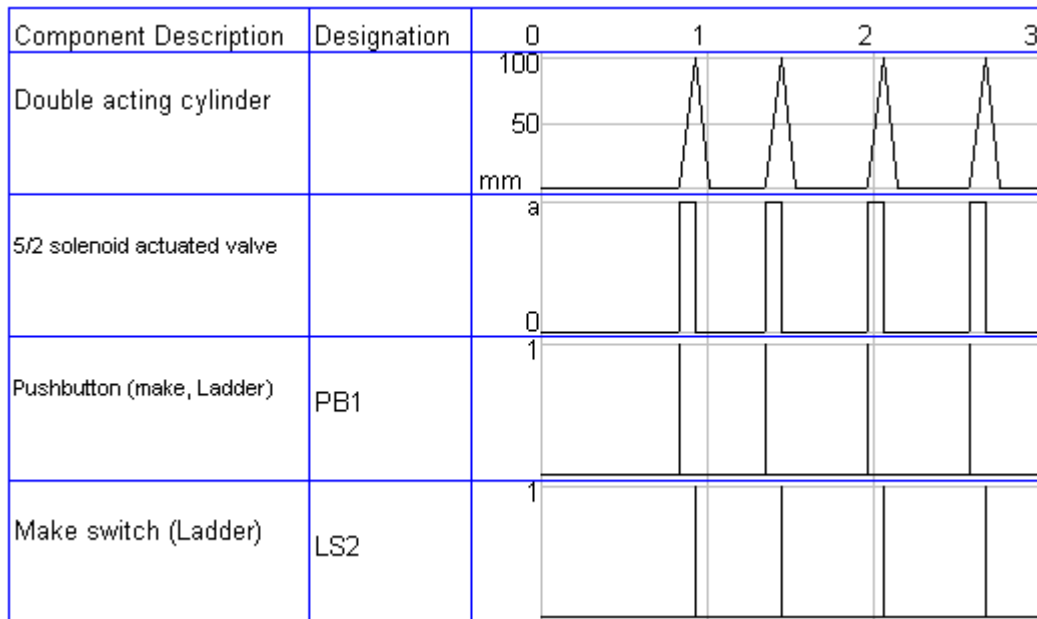


Figure 7.9: State Diagram for Example 7.3


Example 7.4:


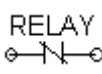
Design an electro-pneumatic circuit such that a double acting cylinder will advance upon pressing an electrical push button "PB1" and will retract upon reaching its full extent.

(Use a 5/2 solenoid actuated spring returned control valve and use electrical limit switches to determine the position of the cylinder)

The pneumatic circuit, ladder diagram and parts' list needed to perform this operation are shown by Figure 7.10.

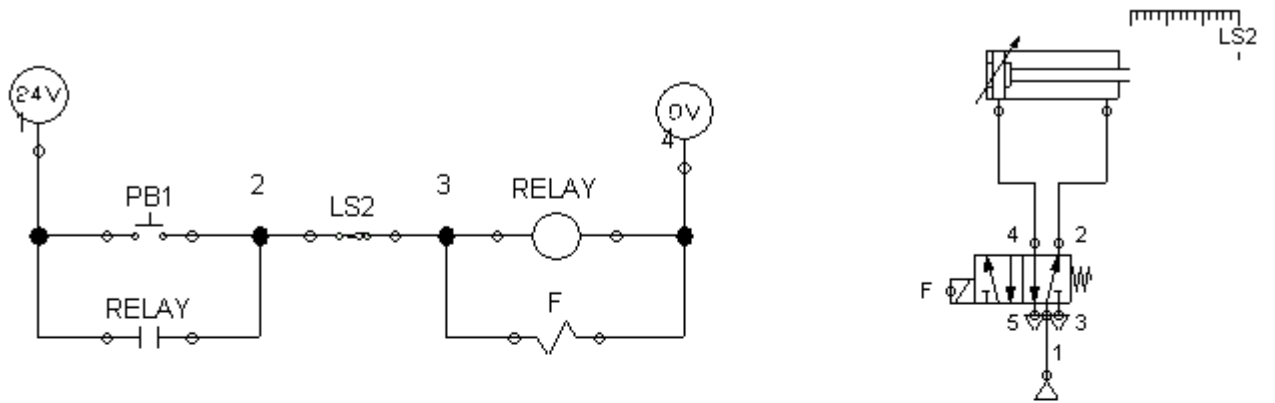
If you go carefully through the question, you will note that it is the same as Example 7.3 expect that the valve used is a solenoid actuated spring returned valve. If you recall what we said above about a doubly solenoid actuated valve, you will find that it no longer applies here. Because in the case of spring returned valves if the electrical signal from the solenoid stops flowing, the spring will return the valve to its original position. But we want the cylinder to continue its full stroke which means that we have to maintain the signal at the solenoid until the cylinder have reached its full extent. To achieve this, a new concept is to be introduced. It is called the **latch**. You can think of the latch as an alternative path for the current to flow through when the main path is opened. This latch is actually a contact from a relay. As we illustrated above, each relay has two main components, the coil and the contacts.

The relay's coil is represented in the  ladder as

While the contacts are represented as  for normally open contacts or  for normally closed contacts. The important thing that both the contacts and the coil have the same name and it doesn't have to be "RELAY" but any name you pick.

How do latches work?

Let's explain this by returning to Figure 7.10. As shown by the figure we have latched the element that will open the path if released. Here, it is PB1. Once PB1 is pressed it allows current to flow through RELAY coil. Now any contact related to that coil will change state. Thus the normally open contact RELAY will become closed and will allow current to flow through it to the coil (forming an alternative coil). Now even if the PB1 is released the coil will still be active as long as LS2 is closed. You note here the use of the normally closed limit switch, because we want the circuit to break once the limit switch is reached. How will this work? As long as the cylinder hasn't reached its full extent, LS2 will be closed and current will flow to the coil. Once the cylinder reaches LS2 the limit switch will be activated changing state from closed to open. This will cause the current flow to stop passing the RELAY coil causing the RELAY contacts to go back to its normal state which is open. Now even when the spring switches the position of valve and causes the cylinder to retract and LS2 to get closed again, the RELAY contact is opened and PB1 is opened then no current will flow through the RELAY coil.



Designation	Component Description
	Electrical connection 0V
	Electrical connection 24V
PB1	Pushbutton (make, Ladder)
	5/2 solenoid actuated valve
	Compressed air supply
	Double acting cylinder
LS2	Brake switch (Ladder)
RELAY	Make switch (Ladder)
RELAY	Relay (Ladder)
F	Valve solenoid

Figure 7.10: Pneumatic Circuit, Ladder Diagram and Parts' List for Example 7.4

Figure 7.11 shows the circuit's state diagram:

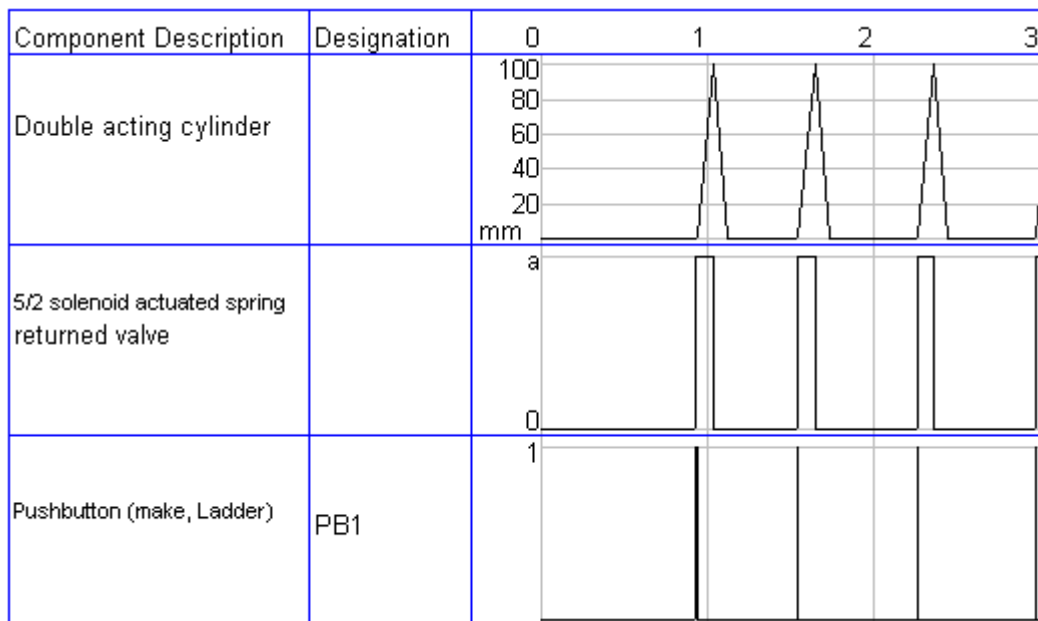


Figure 7.11: State Diagram for Example 7.4

Procedure:

Note: In case of emergency turn off the pressure supply and consult your laboratory supervisor.

1. Turn off the power and pressure supplies.
2. Draw a schematic circuit based on the pneumatic process you are required to control.
3. Implement the system.
4. Make sure to adjust the position of the limit switches and sensors you use.
5. Turn on the power and pressure supplies.
6. Observe your process to check its functionality.
7. Repeat the steps if necessary.
8. Turn off the power and pressure supplies.

Discussion and Analysis:

For the following two exercises, design the pneumatic circuit, ladder diagram, add the parts' list and the state diagram and label all your components.

1. A single acting cylinder is to advance slowly upon pressing "PB1" or "PB2" instantaneously, and it will retract upon reaching its full extent.

(Use a 3/2 solenoid actuated spring returned control valve and use limit switches to detect the position of the cylinder)

2. A double acting cylinder is to advance upon pressing "PB1" push button if the cylinder is fully retracted. And will retract upon pressing "PB2" push button or upon reaching its rear position.

(Use a 5/2 solenoid actuated control valve and use limit switches to detect the position of the cylinder)

Experiment 8 Computerized Electro-Pneumatic Systems

Objectives:

- To introduce the students to computerized electro-pneumatic system.
- To use EasyPort to connect input and output device to a computer.
- To use FESTO FluidSIM software electro-pneumatic system.

Apparatus:

1. FESTO Electro-Pneumatic Basic Kit.
2. EasyPort.
3. Universal Connection Unit.



Figure 8.1: System Apparatus

Theoretical Background:

At the previous experiment, you have learned about electro-pneumatic systems where you designed your ladder diagrams, simulated them using FluidSIM software, then implemented the

corresponding hardware. As surely you have noticed, implementing the hardware was not that easy job with all the wires, relays and contacts.

During this experiment, you will learn how to connect the electro-pneumatic systems with computers sparing yourself the trouble of most of the wiring and relays.

1. Computerized Electro-pneumatic Systems

As explained in the previous session, the electro-pneumatic system has inputs such as electrical push buttons, limit switches and proximity sensors which require to be connected to 24V. It also has outputs such as solenoid valves and relays which require to be connected to the ground. And to perform an operation such as latching, ANDing or ORing, extra wires, connections and contacts are needed to be used. All of this makes the system complicated and hard to troubleshoot.

The solution to this is to get rid of as much wiring as possible and this can be achieved using controllers. PC serves as a controller but still an interface circuit is needed between it and the electro-pneumatic hardware. Festo company has developed an interfacing tool between the electro-pneumatic system and the PC called *Easy port*.

2. EasyPort

EasyPort is a kind of interface that facilitates connection between electro-pneumatic systems (processes) and PCs (controllers). EasyPort implements bi-directional transmission of signals between a real control process using low voltage technology (24VDC) and a PC.

Figure 8.2 shows one type of EasyPorts which is EasyPort D8A (this is the EasyPort that will be used in the lab). EasyPort D8A has 8 digital and 4 analog inputs as well as 8 digital and 2 analog outputs. Transfer data to and from it is by means of single addressed read and write commands. EasyPort will report all changes of its inputs to the PC.

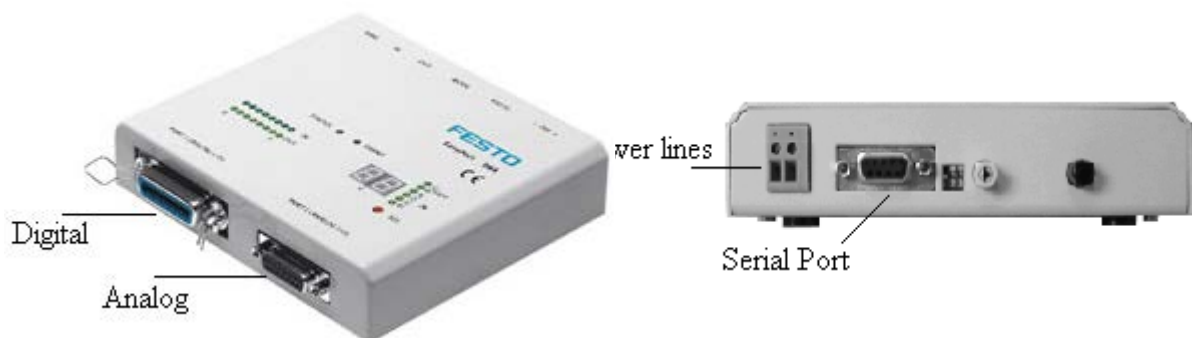


Figure 8.2: EasyPort D8A

In order to understand how EasyPort works, the following components must be studied:

2.1 Serial RS232 Cable

This is a 9-pins serial cable that is used to connect the EasyPort with the serial port of the PC (COM1, COM2, ...).



Figure 8.3: Serial RS232 Cable

2.2 Universal Connection Unit

Figure 8.4 and 8.5 represent the universal connection unit which has the following parts:

- 8 inputs connected to the process actuators (inputs to the process are outputs from the EasyPort). All these pins are internally connected to 24V when the input is actuated. Figure 8.6.
- 8 outputs connected to the process sensors and switches (outputs from the process are inputs to the EasyPort). All these pins are internally connected to 0V to complete the circuit. Figure 8.6.
- 24V and 0V buses.
- 24-pin socket.

The connection of the process inputs and outputs to the universal connection unit will be illustrated during the examples later this session.



Figure 8.4: Universal Connection Unit

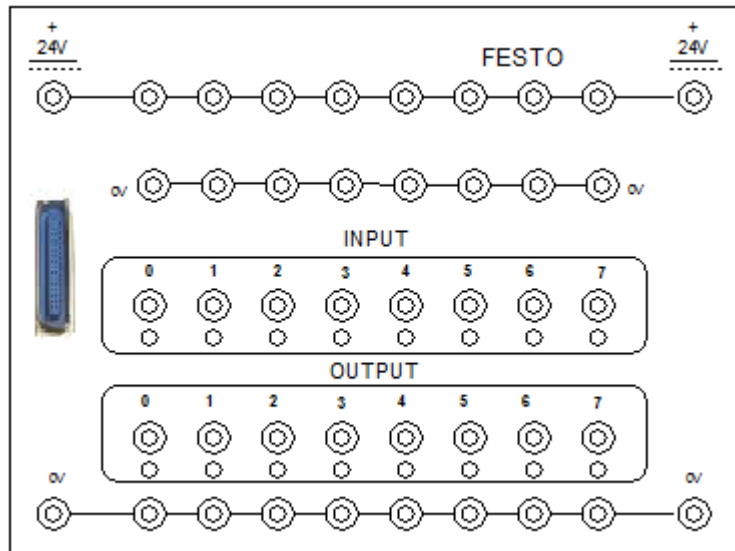


Figure 8.5: Sketch for a Universal Connection Unit

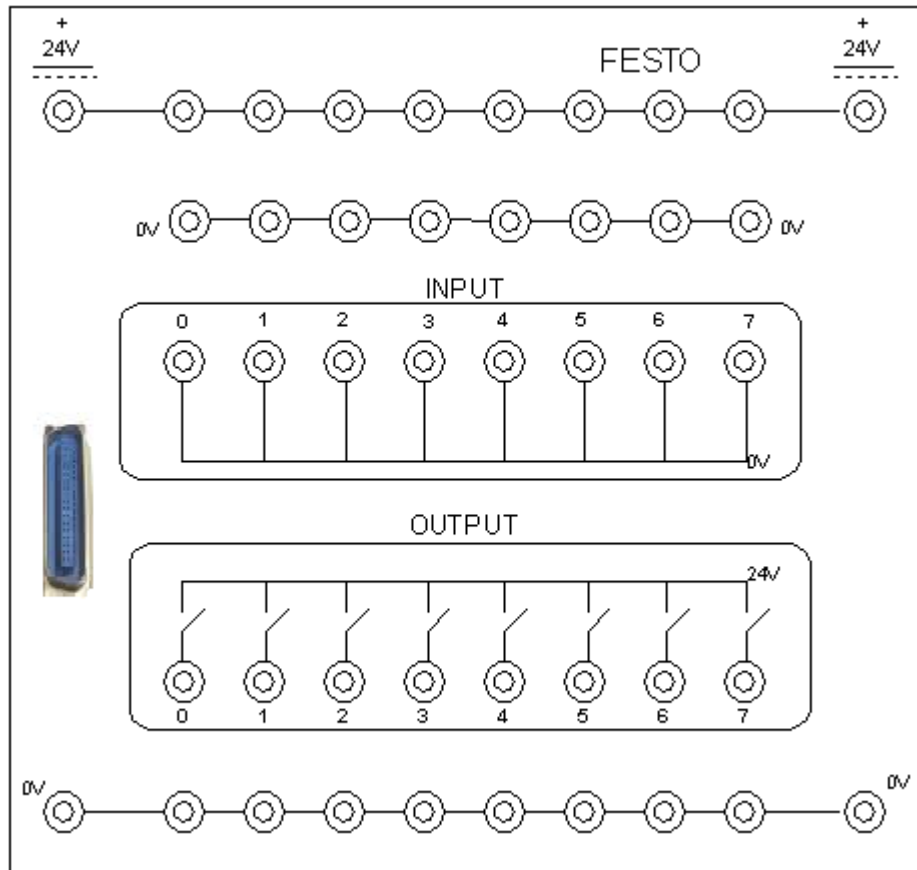


Figure 8.6: Internal Construction Of A Universal Connection Unit

2.3 Input /Output (I/O) Data Cable

It is a 24 pins I/O cable. These pins are distributed between 8 input pins, 8 output pins and pins provided for 0 V and 24 V for the power.



Figure 8.7: Input/output Data Cable

Now that accessories used with an EasyPort have been known, it is time to explain how these items connect to it.

1. The EasyPort is connected to the PC using the serial RS232 data cable. This cable has 9 pins and when used with EasyPort D8A, these pins are assigned for tasks as shown in Table 8.1.

Table 8.1: RS232 Data Cable Pin Assignment

Pin Task	Task abbreviation	PIN #
Unused		1
Receive data	RxD	2
Transmit data	TxD	3
Unused		4
Signal Ground	SGnd	5
Unused		6
Unused		7
Unused		8
Unused		9

2. The I/O data cable is used to transmit digital signals and is connected to EasyPort from one side and to the universal connection unit from the other.

The hardware connections are easy enough to be done. Now, even if the EasyPort is transmitting data to and from the PC, the PC still needs software to deal with the data. Therefore, Festo

company have developed CIROS Mechatronics, EasyVeep and the program you know well by now, FluidSIM. Of course we will use FluidSIM in the lab since it is available and familiar.

It should be understood that EasyPort is not a stand-alone device, i.e. you cannot make a program on FluidSIM then download it on EasyPort because EasyPort is only an interface and it is not a processor with memory. So as long as we wish to operate the system, FluidSIM ought to be in run mode.

3. FluidSIM with EasyPort

The following steps will explain how to use FluidSIM to communicate with EasyPort:

1. File >> New.
2. Options >> EasyPort/OPC/DDE connections. The following box will appear.
3. Select the same options selected on Figure 8.8, then press OK.

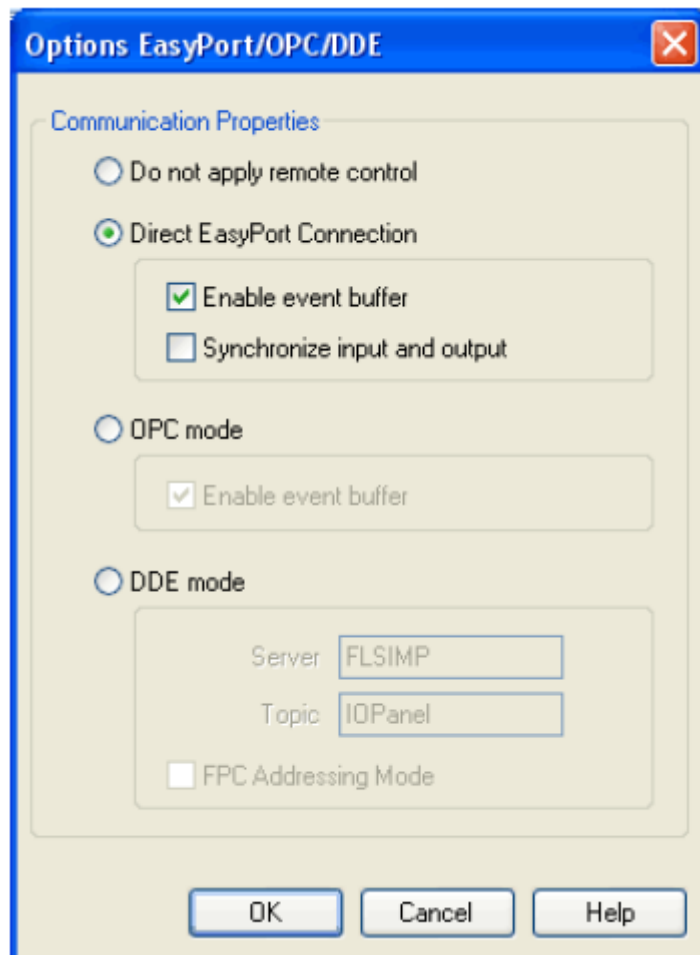


Figure 8.8: Options EasyPort/CPC/DDE

4. From the components library, drag the following: Logic module, FluidSIM Input module, FluidSIM Output module.

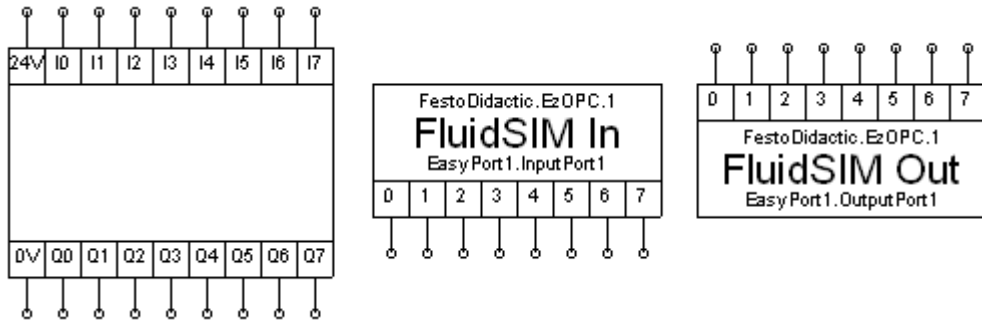


Figure 8.9: (from left to right): Logic Module, Fluidsim Input Module, Fluidsim Output Module

5. Double click on FluidSIM Input module, the following box appears:

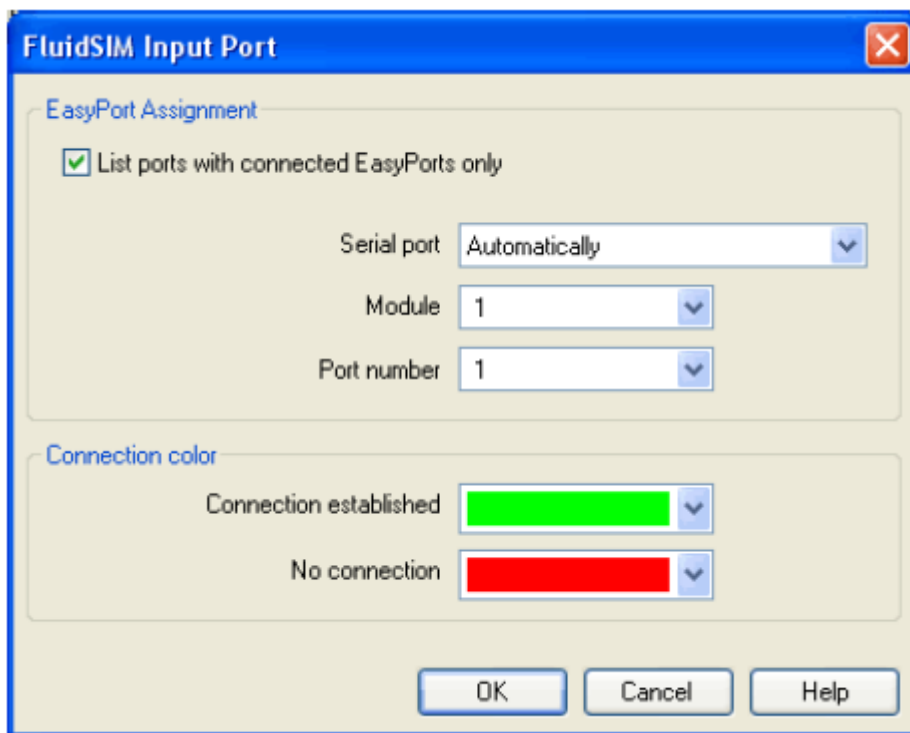


Figure 8.10: FluidSIM Input Port

6. If you are not sure what serial port you are using or what module, just select "Automatically" using the down arrow then press OK.
7. Repeat steps 5 and 6 for FluidSIM Output module.
8. Connect the FluidSIM input module and FluidSIM output module to the logic module as shown in Figure 8.11.

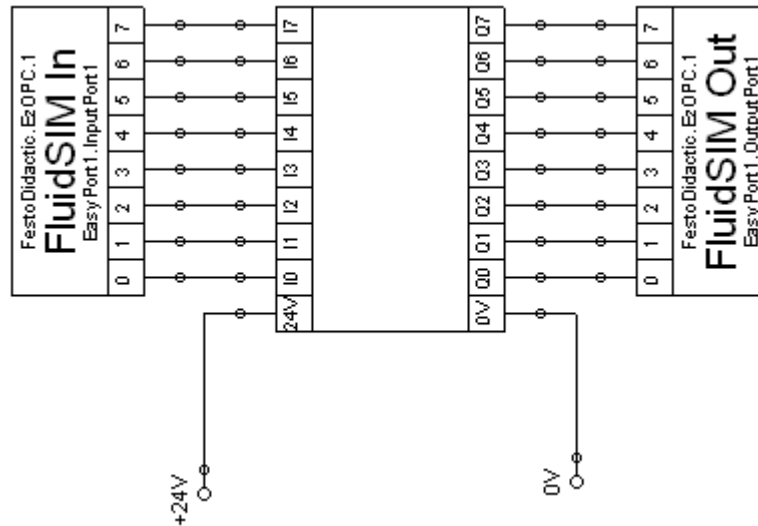


Figure 8.11: Connection to the Logic Module

9. As shown in Figure 8.11, make sure to connect the 24V and the 0V to the logic module, otherwise it will not work.
10. To write the rungs of the program, double click on the logic module, the following screen will appear.

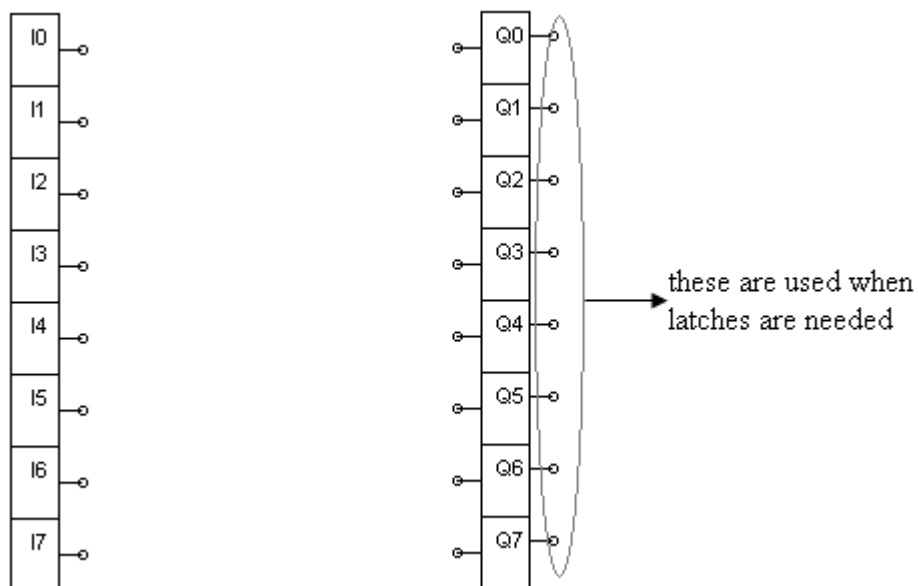


Figure 8.12: Logic Module

11. As shown in Figure 8.12, the column to the left is the inputs column corresponding to the system inputs (buttons, switches and sensors) , the column to the right is the outputs column corresponding to the system outputs (solenoid valves and relays).
12. Drag some logic operations, like AND, OR, HI, LOW like the ones shown in the figure below, to form the ladder.

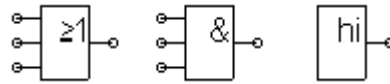


Figure 8.13: Logic Module Operations

13. If you press "start" on this screen, you will be able to simulate your ladder diagram (i.e. if you press I1 now it is like the input corresponding to it has been actuated and you can see its effect on the output).
14. If you want to test the whole circuit (hardware plus software), close the previous window, then press "start" in the original window. If "start" is not pressed, even if you are feeding inputs to the system, no output will be generated. "start" here is like "RUN".

The following examples illustrate the constructing of logic ladder diagrams and the connection to the universal connection unit needed to drive an electro-pneumatic circuit.

Example 8.1:

Design a logic ladder diagram such that a single acting cylinder will advance upon pressing an electrical push button "START" and will retract upon releasing it.

(Use a 3/2 solenoid actuated spring returned control valve)

The first step in solving the example will be to assign addresses that must be a match between the hardware shown in Figure 8.13 and the ladder shown in Figure 8.14.

Figure 8.15 shows the correct way to connect the hardware. The 24 and 0 buses are supplied with voltages from the dc power supply. These buses are then used to power the EasyPort, sensors, push buttons and solenoids. As previously explained and shown in Figure 8.5, all the universal connection card outputs (EasyPort inputs) are internally grounded, thus all you have to do is to connect them to 24V. the same principle holds for all the universal connection card inputs (EasyPort outputs) which are internally connected to 24V when energized. From Figure 8.13, the input/output addresses to the EasyPort for example 8.1 are as shown in Table 8.2.

Table 8.2: Input/output Addresses for Example 8.1.

Address	Corresponding Hardware
I0	START push button
Q0	Solenoid valve

Now the logic ladder connection is straight forward. I0 is directly connected to Q0 as shown in Figure 8.14.

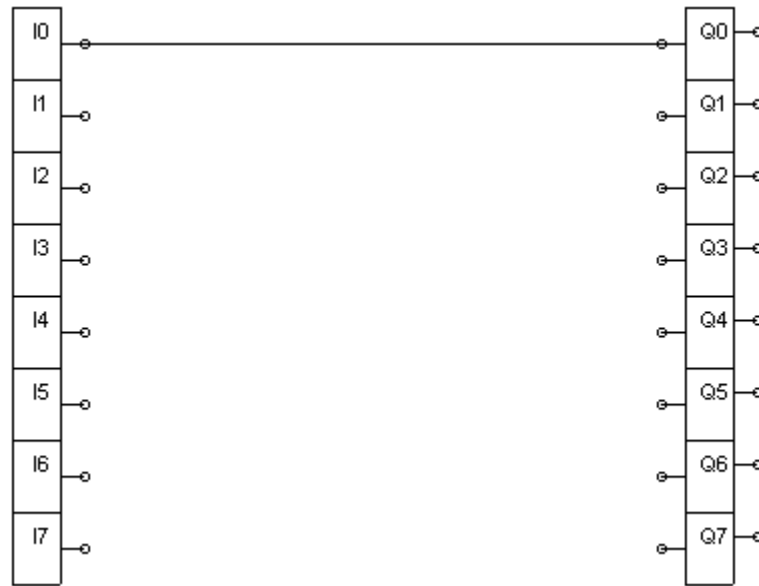


Figure 8.14: Logic Ladder Diagram for Example 8.1

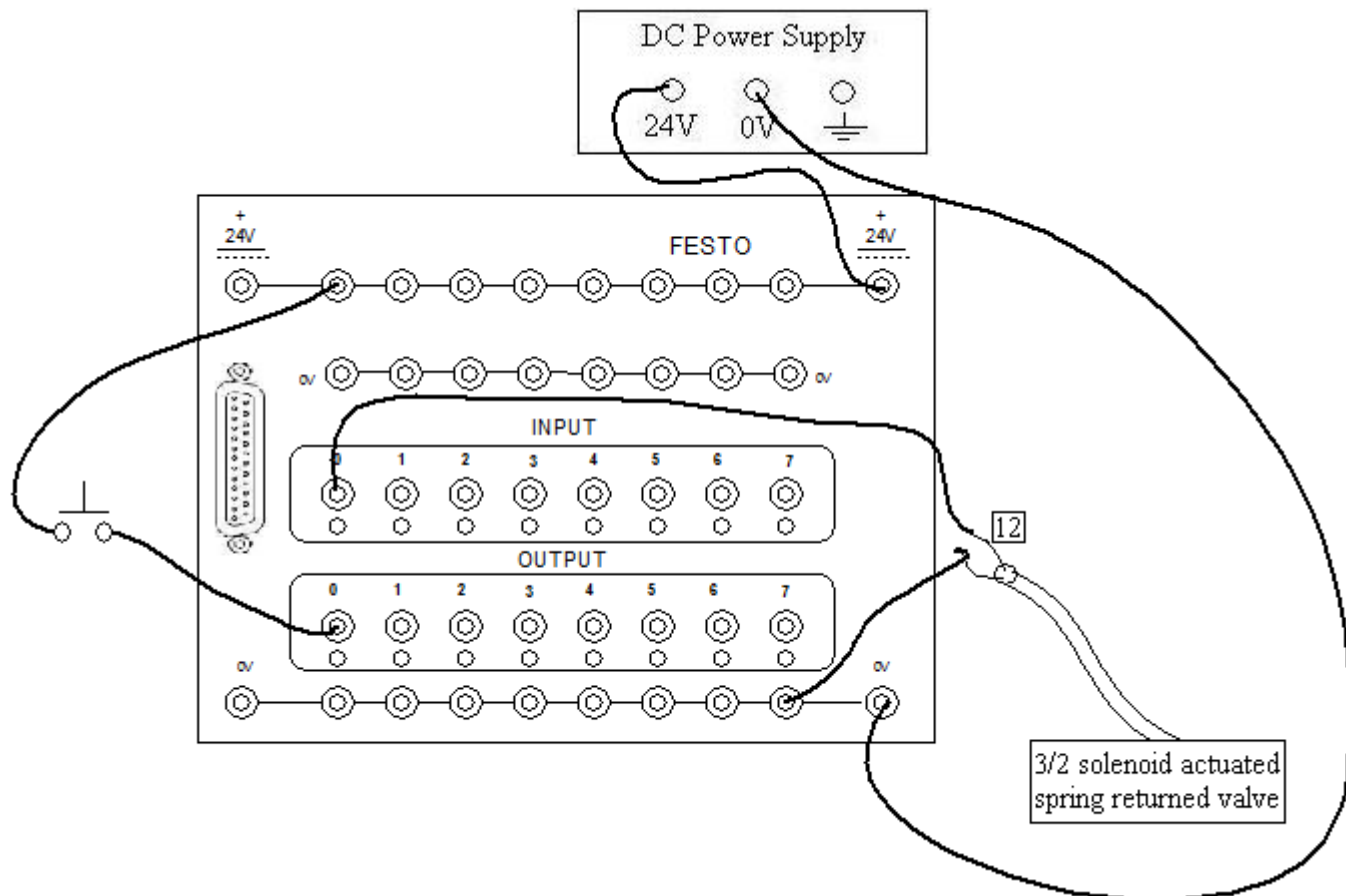


Figure 8.15: Hardware Connection for Example 8.1

Example 8.2:

Design a logic ladder diagram such that a single acting cylinder will advance upon pressing an electrical push buttons "PB1" or "PB2" and will retract upon releasing both of them.

(Use a 3/2 solenoid actuated spring returned control valve)

There is no need to show the hardware connection to the universal connection unit again here since no new elements are introduced in this example but the input/output addresses are given by Table 8.3. However, new elements were introduced to the logic ladder diagram which is the OR gate as shown in Figure 8.16. The OR gate is necessary since one of two conditions must happens in order for the output to get energized. It is well known from linear algebra that $X \text{ or } 0 \text{ equals } X$. Thus a "low" element was added to OR gate because it needs 3 inputs and the system provides only 2 of them.

Table 8.3: Input/output Addresses for Example 8.2

Address	Corresponding Hardware
I0	PB1 push button
I1	PB2 push button
Q0	Solenoid valve

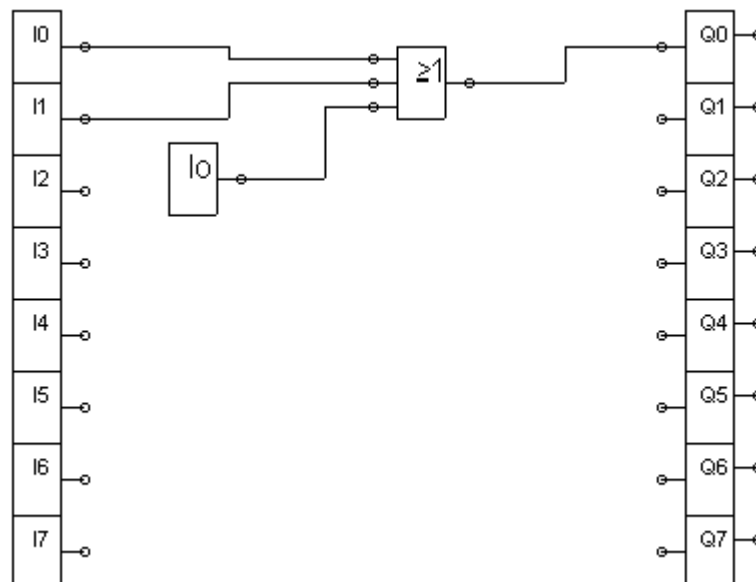


Figure 8.16: Logic Ladder Diagram for Example 8.2

Example 8.3:

Design a logic ladder diagram such that a double acting cylinder will advance upon pressing an electrical push button "PB1" and will retract upon reaching its full extent.

(Use a 5/2 solenoid actuated control valve and use electrical limit switches to determine the position of the cylinder)

The hardware connections needed to solve this example are shown in Figure 8.17 and consequently the input/output addresses are given by Table 8.4.

Table 8.4: Input/output Addresses for Example 8.3.

Address	Corresponding Hardware
I0	PB1 push button
I1	Full extent limit switch
Q0	Solenoid 14 (advance motion)
Q1	Solenoid 12 (retract motion)

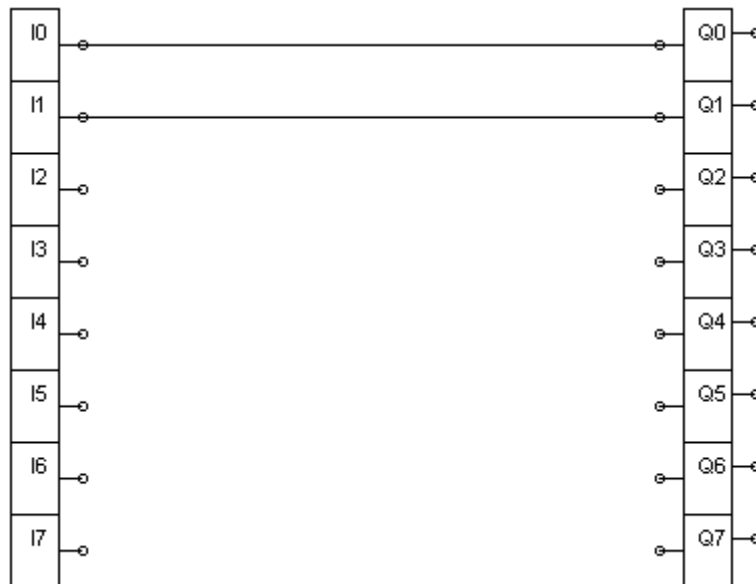


Figure 8.18: Logic ladder Diagram for Example 8.3

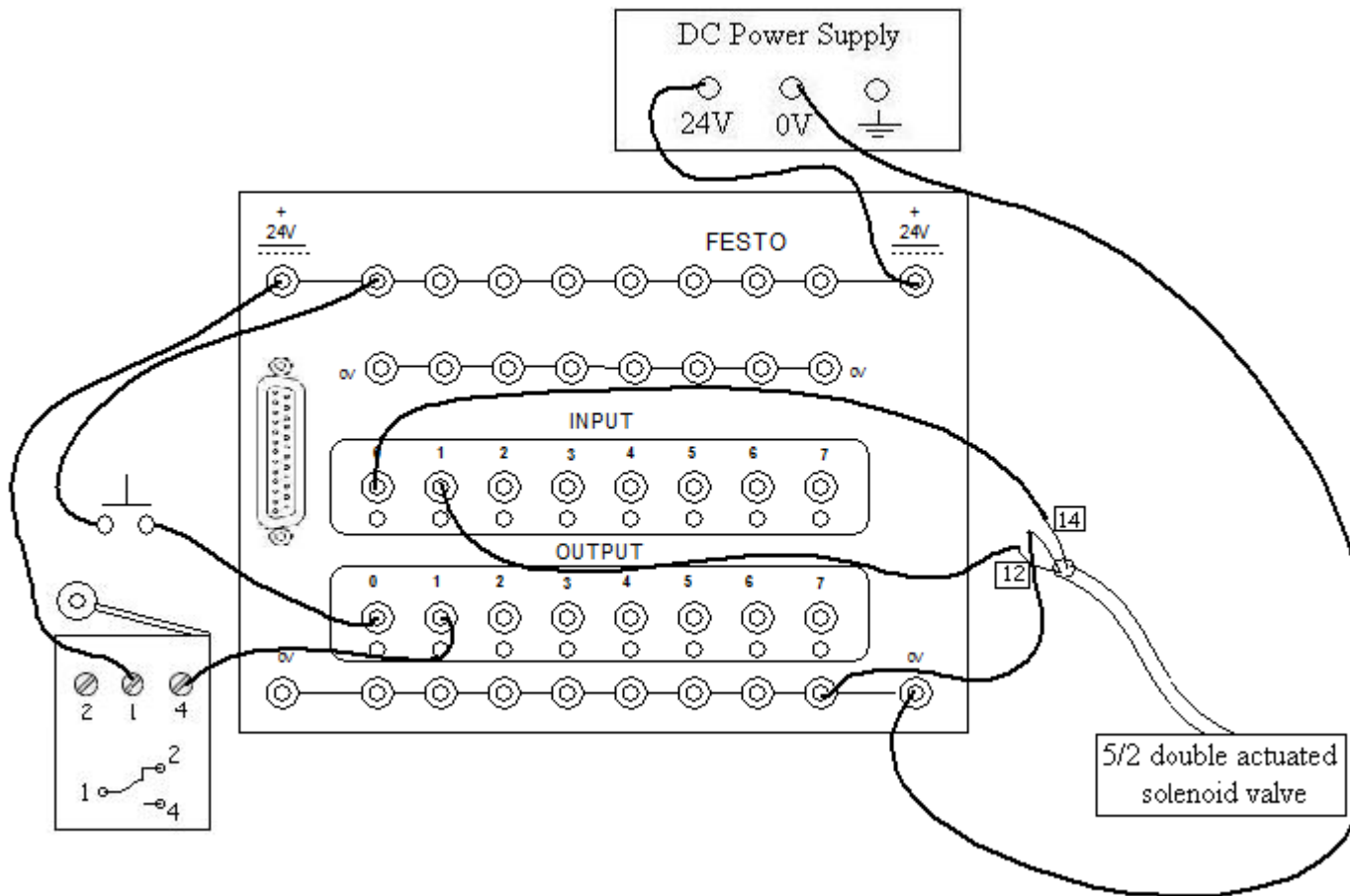


Figure 8.17: Hardware Connection for Example 8.3

Example 8.4:

Design a logic ladder diagram such that a double acting cylinder will advance upon pressing an electrical push button "PB1" and will retract upon reaching its full extent.

(Use a 5/2 solenoid actuated spring returned control valve and use electrical limit switches to determine the position of the cylinder)

Table 8.5 shows the assumed input/output addresses of the system.

Table 8.5: Input/output Addresses for Example 8.4.

Address	Corresponding Hardware
I0	PB1 push button
I2	Full extent limit switch
Q0	Solenoid valve

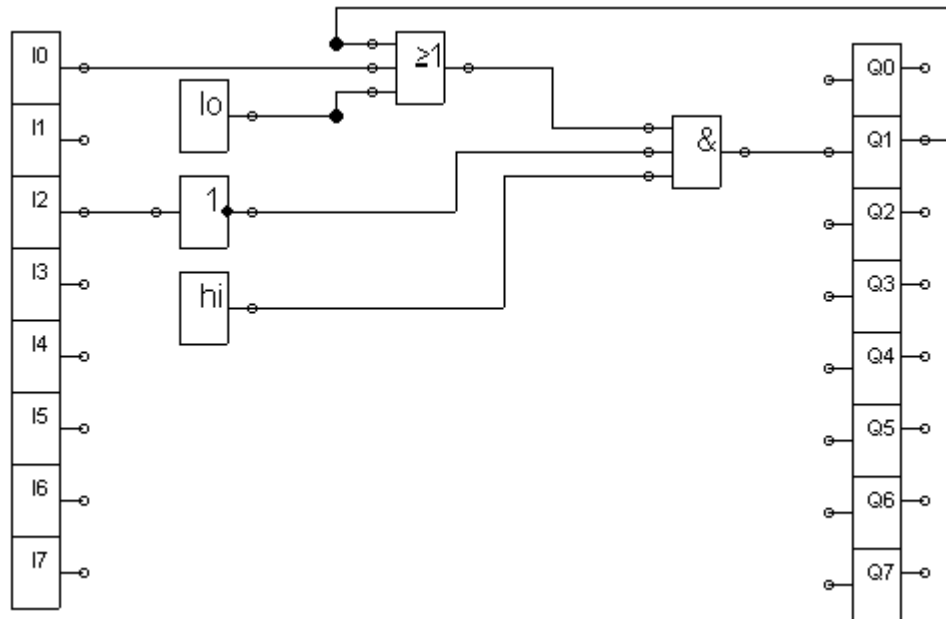


Figure 8.19: Logic Ladder Diagram for Example 8.4

Procedure:

Note: In case of emergency turn off the pressure supply and consult your laboratory supervisor.

1. Turn off the power and pressure supplies.
2. Draw a schematic circuit based on the pneumatic process you are required to control.
3. Implement the system.
4. Use EasyPort to connect all input and output devices based on the address provided by your supervisor.
5. Connect the EasyPort to a computer.
6. Use FESTO FluidSIM to control the process as required.
7. Make sure to adjust the position of the limit switches and sensors you use.
8. Turn on the power and pressure supplies.
9. Observe your process to check its functionality.
10. Repeat the steps if necessary.
11. Turn off the power and pressure supplies.

Discussion and Analysis:

For the following two exercises, design the logic ladder diagram and make the proper hardware connections that suit the addresses given with each exercise.

Exercise 1:

A single acting cylinder is to advance upon pressing "PB1" or "PB2" instantaneously, and it will retract upon reaching its full extent.

(Use a 3/2 solenoid actuated spring returned control valve and use limit switches to detect the position of the cylinder)

Address	Corresponding Hardware
I0	PB1 push button
I1	PB2 push button
I2	Limit switch fully extended
Q0	Solenoid valve

Make the proper hardware connections on the attached Figure 1 and submit it with your report.

Exercise 2:

A double acting cylinder is to advance upon pressing "PB1" push button if the cylinder is fully retracted. And will retract upon pressing "PB2" push button or upon reaching its rear position.

(Use a 5/2 double solenoid actuated control valve and use limit switches to detect the position of the cylinder)

Address	Corresponding Hardware
I0	PB1 push button
I1	PB2 push button
I2	Limit switch fully retracted
I3	Limit switch fully extended
Q0	Solenoid valve (extend)
Q1	Solenoid valve (retract)

Make the proper hardware connections on the attached Figure 2 and submit it with your report.

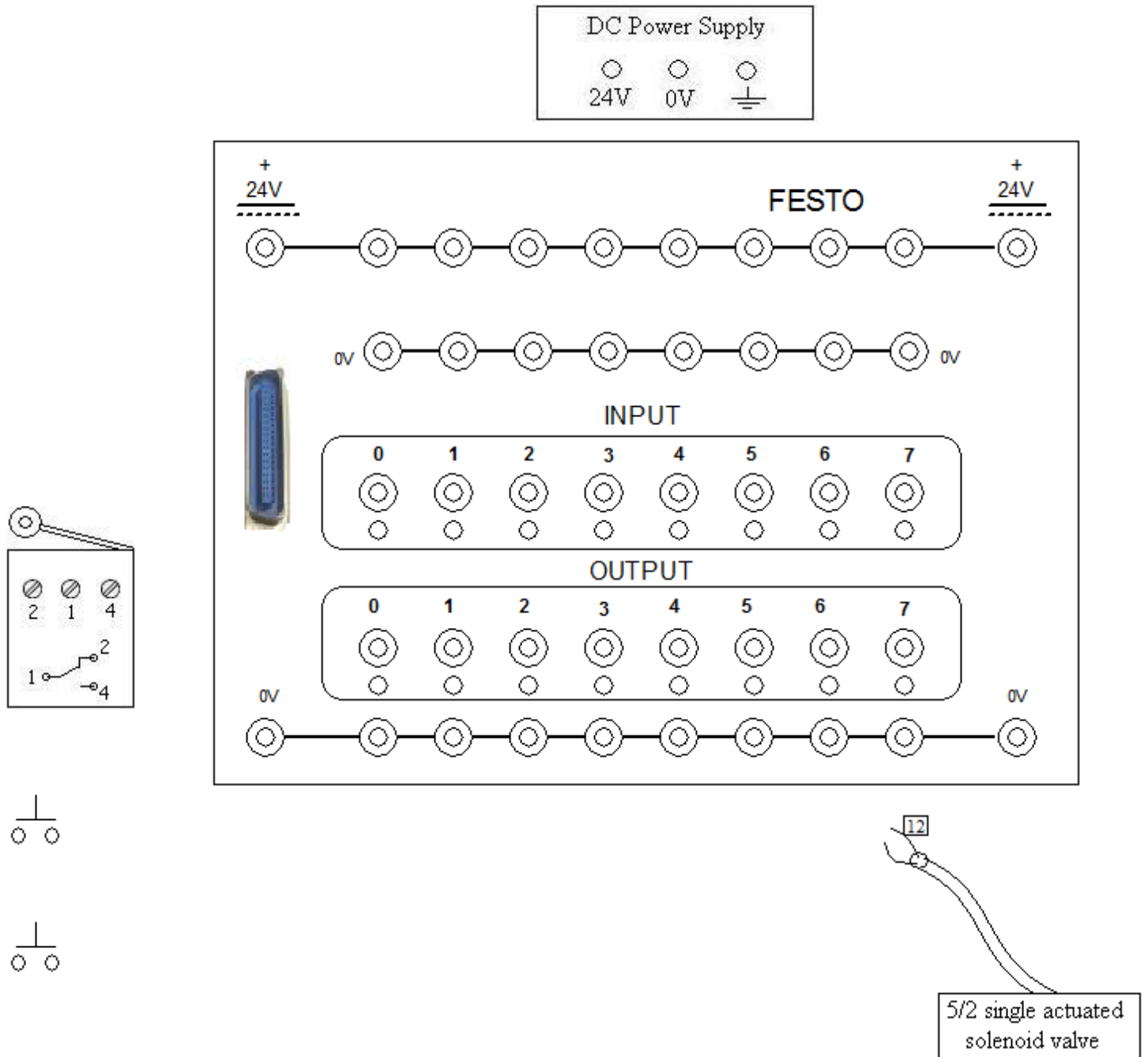


Figure 1: Exercise 1

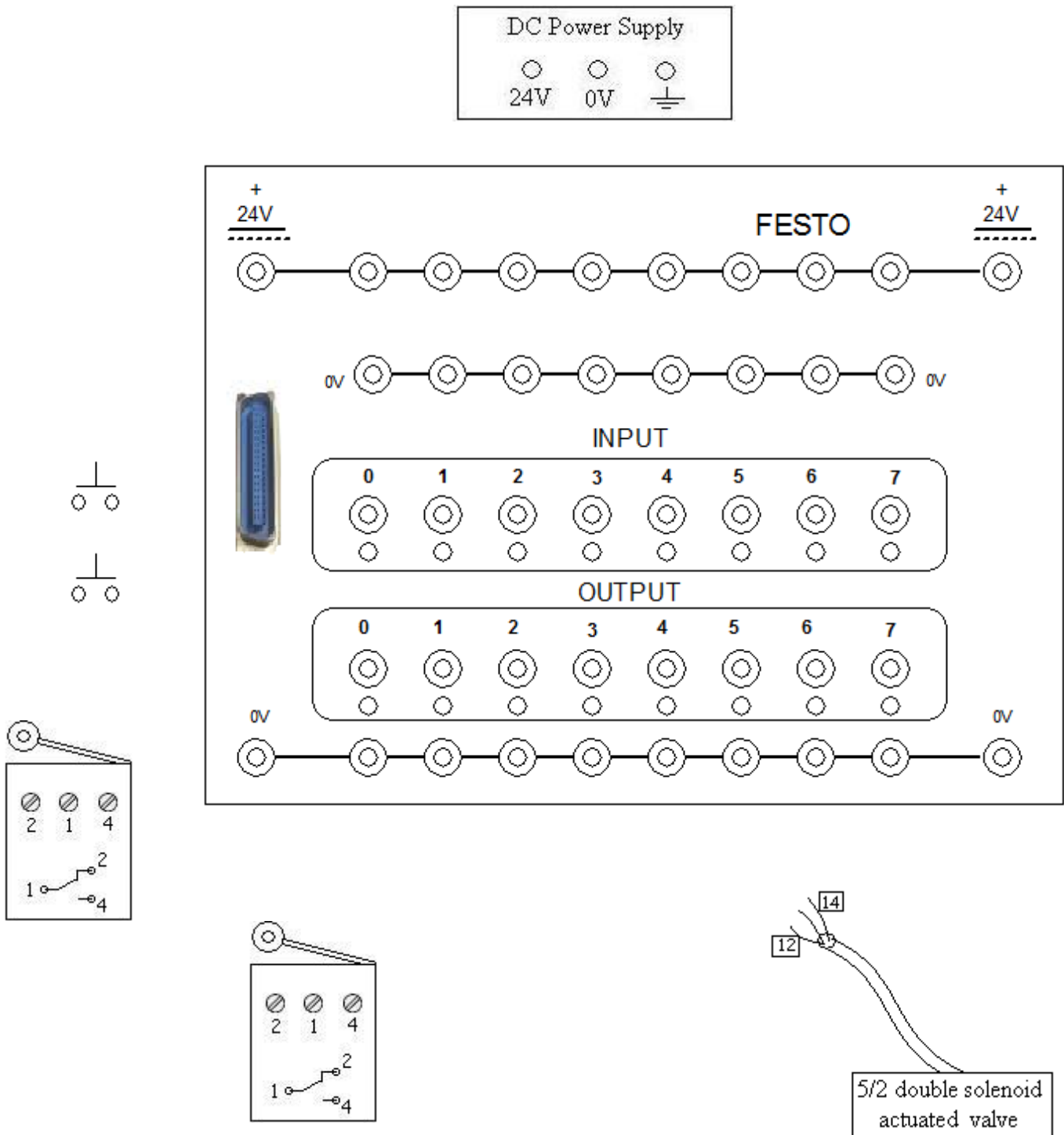

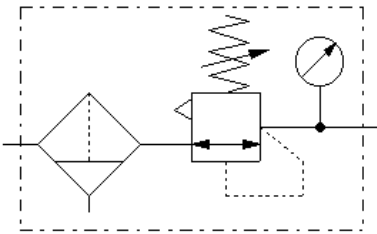
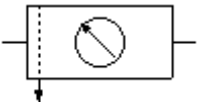





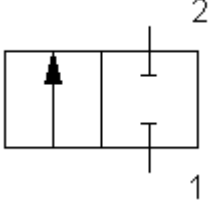
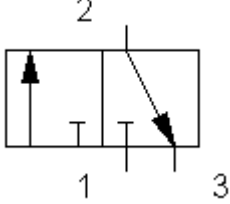
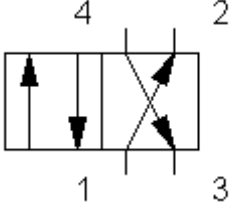
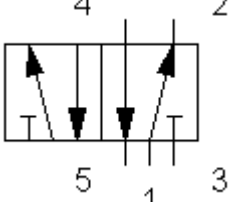
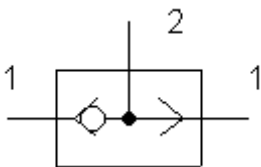
Figure 2: Exercise 2

Appendix A

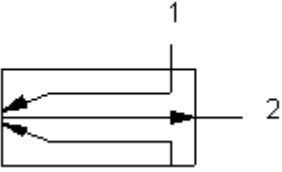

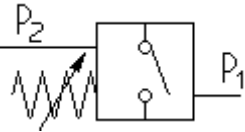
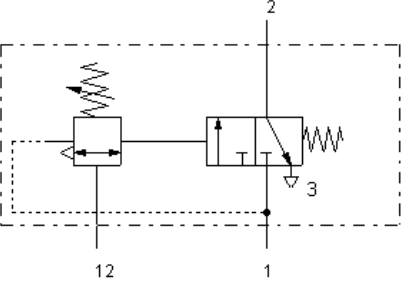
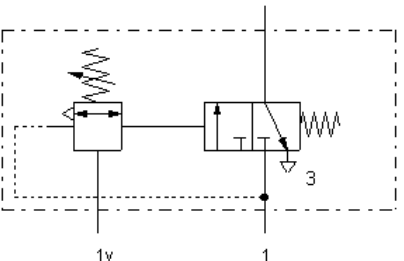
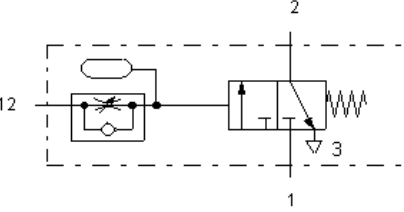
FluidSIM library

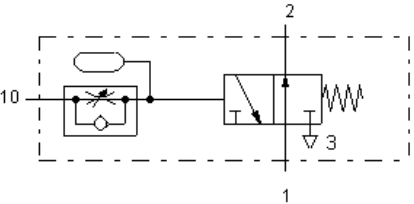
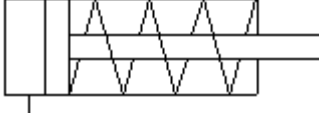

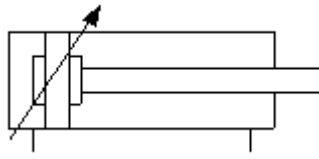
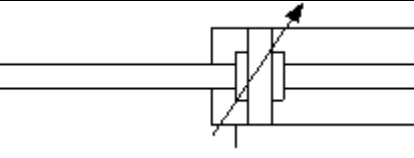
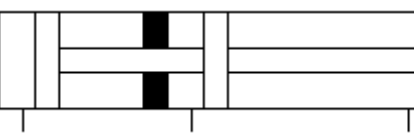
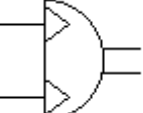
Table A.1 shows elements found in FluidSIM library with a brief description for each of them.

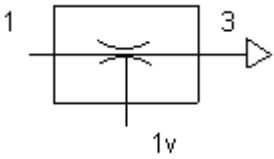

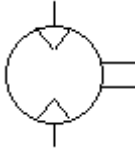







	<p>Compressed air supply</p> <p>The compressed air supply provides the needed compressed air. It contains a pressure control valve that can be adjusted to output the desired operating pressure.</p>
 <p>Simplified representation</p> 	<p>Air service unit</p> <p>The service unit is made up of a compressed air filter with water separator and a pressure control valve.</p>
	<p>Connection (pneumatic)</p> <p>A pneumatic connection is a place where a pneumatic line can be attached to. To simplify the line drawing process, a connection appears as a small circle in Edit Mode.</p> <p>Pneumatic connections can be shut by means of a blind plug. An open pneumatic connection may result in leaking air; FluidSIM-P thus pops up a warning message, if some pneumatic connection was left open. Note that at each pneumatic connection values for the flow and pressure can be displayed.</p>
	<p>Line (pneumatic)</p> <p>A pneumatic line links two pneumatic connections. Note that a pneumatic connection may be a simple pneumatic connection or a T-junction. A pneumatic line causes no pressure drop, i. e., it has no fluidic resistance.</p> <p>From a drawing point of view, FluidSIM distinguishes between control lines and main lines. The former is represented by a dashed line, the latter is represented by a solid line and establishes the default case.</p>



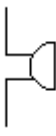


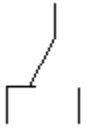

	<p>T-junction (pneumatic)</p> <p>A T-junction joins up to three pneumatic lines, thus having a single pressure potential. Note that T-junctions are introduced automatically by FluidSIM when dropping the line drawing cursor onto another line in Edit Mode.</p>
	<p>Configurable 2/n way valve</p> <p>The configurable 2/n way valve is a way valve with two connections, where both its body elements and its operation modes are user-definable.</p> <p>Additionally, the pneumatic connections can be closed with either blind plugs or exhausts.</p>
	<p>Configurable 3/n way valve</p> <p>The configurable 3/n way valve is a way valve with three connections, where both its body elements and its operation modes are user-definable.</p> <p>Additionally, the pneumatic connections can be closed with either blind plugs or exhausts.</p>
	<p>Configurable 4/n way valve</p> <p>The configurable 4/n way valve is a way valve with four connections, where both its body elements and its operation modes are user-definable.</p> <p>Additionally, the pneumatic connections can be closed with either blind plugs or exhausts.</p>
	<p>Configurable 5/n way valve</p> <p>The configurable 5/n way valve is a way valve with five connections, where both its body elements and its operation modes are user-definable.</p> <p>Additionally, the pneumatic connections can be closed with either blind plugs or exhausts.</p>
	<p>Shuttle valve</p> <p>The shuttle valve is switched based on the compressed air entering into either input connection 1 and leaving via an output connection 2. Should both input connections begin receiving compressed air, the connection with the higher pressure takes precedence and is put out (OR function).</p>




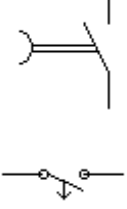
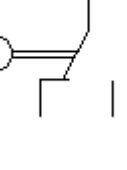


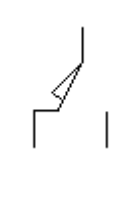
	<p>Quick exhaust valve</p> <p>The compressed air passes from connection 1 to connection 2. If the pressure should decrease at connection 1, then the compressed air from connection 1 will escape to the outside via the installed silencer.</p>
	<p>Two pressure valve</p> <p>The two pressure valve is switched based on the compressed air entering into both input connections 1 and leaving via an output connection 2. Should both input connections begin receiving compressed air, the connection with the lower pressure takes precedence and is put out (AND function).</p>
	<p>Piloted operated check valve</p> <p>If the entering pressure at connection 1 is higher than the outgoing pressure at 2, the check valve allows the flow to pass freely. Otherwise, the valve stops the flow. Additionally, the check valve can be opened via the control line 12. This action allows the flow to pass freely in both directions.</p>
	<p>Throttle valve</p> <p>The setting of the throttle valve is set by means of a rotary knob. Please note that by the rotary knob no absolute resistance value can be set. This means that, in reality, different throttle valves can generate different resistance values despite identical settings.</p>
	<p>One-way flow control valve</p> <p>The one-way flow control valve is made up of a throttle valve and a check valve. The check valve stops the flow from passing in a certain direction. The flow then passes through the throttle valve. The cross-section of the throttle is adjustable via a regular screw. In the opposite direction the flow can pass through the check valve.</p>
	<p>Pressure control valve with manometer</p> <p>The pressure control valve regulates the supplied pressure based on the adjustable operating pressure and the variations in the pressure. The manometer displays the pressure at connection 2.</p>
	<p>Pneumatic counter</p> <p>The counter registers pneumatic signals starting at a predetermined number and counting backwards. If zero is reached, then the counter releases an output signal. This output signal continues until the counter is reset either by hand or from a signal at connection 10.</p>



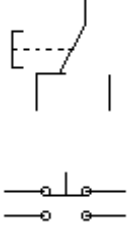
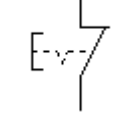
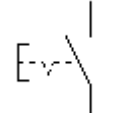
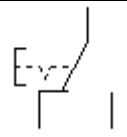
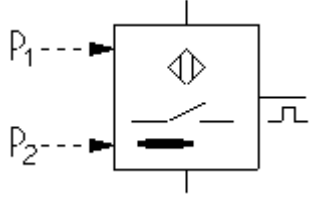
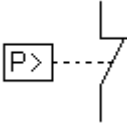
	<p>Ring sensor</p> <p>The ring sensor is a non-contact pneumatic signal output module. It is supplied with low pressure at connection 1. If, due to an object, the entering air flow is disturbed, a low pressure signal will be put out by connection 2.</p> <p>To simulate an object in the air flow, as presented above, simply click on the component during FluidSIM Simulation Mode.</p>
	<p>Analog pressure sensor</p> <p>The pressure sensor measures the pressure and operates the pressure switch when the adjustable switching pressure has been exceeded.</p>
	<p>Differential pressure switch</p> <p>The differential pressure switch can be employed as a pressure switch (connection P1), a vacuum switch (connection P2) or as a differential pressure switch (P1-P2). The respective pneumatic to electric converter is operated when the difference in pressure between P1-P2 exceeds the adjustable switching pressure.</p>
	<p>Pressure sequence valve</p> <p>The sequence valve is operated when the control pressure at connection 12 has been reached. The flow passes freely from 1 to 2. Removing the signal allows the valve to return to its starting position through the use of a return spring. Connection 1 is shut. The pressure of the control signal is infinitely adjustable via a pressure setting screw.</p>
	<p>Adjustable vacuum actuator valve</p> <p>The vacuum actuator valve is employed through the conversion of a vacuum signal. As soon as the vacuum reaches the adjustable value at connection 1v, the attached valve body is switched.</p>
	<p>Time delay valve, normally closed</p> <p>The time delay valve is made up of a pneumatically operated 3/2-way valve, a one-way flow control valve, and small air accumulator. When the necessary pressure is reached at the control connection 12 of the unit, the 3/2-way valve switches and the flow passes freely from 1 to 2.</p>

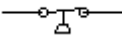
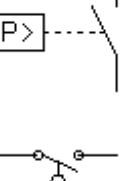
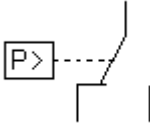
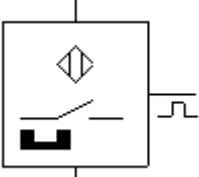
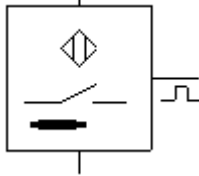
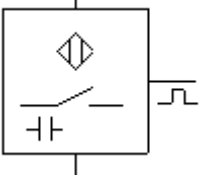
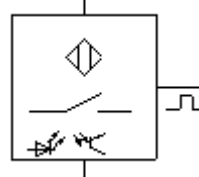
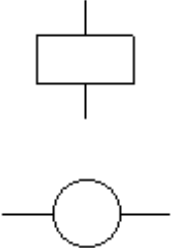
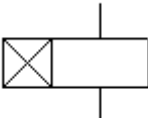
	<p>Time delay valve, normally open</p> <p>The time delay valve is made up of a pneumatically operated 3/2-way valve, a one-way flow control valve, and small air accumulator. When the necessary pressure is reached at the control connection 10 of the unit, the 3/2-way valve switches and stops the flow from passing between 1 and 2.</p>
	<p>Single acting cylinder</p> <p>The piston rod of a single acting cylinder is operated by the input of compressed air at the front end position. When the compressed air is shut off, the piston returns to its starting position via a return spring. The piston of the cylinder contains a permanent solenoid which can be used to operate a proximity switch.</p>
	<p>Single acting cylinder with return spring</p> <p>The piston of the single acting cylinder is extended to its back position by the input of compressed air. When the compressed air is switched off, a return spring moves the piston back to its front position.</p>
	<p>Double acting cylinder</p> <p>The piston rod of a double acting cylinder is operated by the reciprocal input of compressed air at the front and back of the cylinder. The end position damping is adjustable via two regular screws. The piston of the cylinder contains a permanent solenoid which can be used to operate a proximity switch.</p>
	<p>Double acting cylinder with in and out piston rod</p> <p>The in and out piston rod of the double acting cylinder is controlled by alternating the compressed air input. The cushioning can be adapted with two adjustment screws.</p>
	<p>Multiple position cylinder</p> <p>By connecting two cylinders of same piston diameter but different maximum stroke three piston stop positions can be realized. From the first stop position the third stop can be reached either directly or via the intermediate stop. Note that the maximum stroke of the second piston must be larger than the preceding one. When moving back, an intermediate stop requires a particular control. The shorter maximum stroke is half of the other maximum stroke.</p>
	<p>Semi-Rotary actuator</p> <p>The semi-rotary actuator is controlled by a reciprocal input of compressed air.</p>


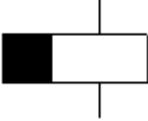



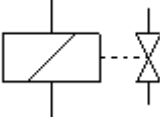

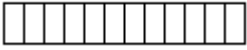

	<p>Vacuum suction nozzle</p> <p>The vacuum suction nozzle creates its vacuum based on the ejector principle. In this case, compressed air flows from connection 1 to 3, creating a vacuum at connection 1v. A sucker can be connected to the vacuum connection 1v. Stopping the input of compressed air at connection 1 stops any suction also.</p>
	<p>Sucker</p> <p>The sucker can be used in connection with the vacuum suction nozzle to suck in objects.</p> <p>The sucking in of objects can be simulated in FluidSIM-P by clicking on the component when in the Simulation Mode.</p>
	<p>Air motor</p> <p>The air motor transforms pneumatic energy into mechanical energy.</p>
	<p>Manometer</p> <p>The manometer displays the pressure at its connection.</p>
<p>(ladder)</p>  	<p>Electrical connection 0V</p> <p>0V connection of the power supply.</p>
<p>(ladder)</p>  	<p>Electrical connection 24V</p> <p>24V connection of the power supply.</p>
	<p>Connection (electrical)</p> <p>An electric connection is a place where an electric line can be attached to. To simplify the line drawing process, a connection appears as a small circle in Edit Mode.</p> <p>Note that at each electric connection values for the voltage and current can be displayed.</p>
	<p>Line (electrical)</p> <p>A electrical line links two electrical connections. Note that a electrical connection may be a simple electrical connection or a T-junction. A electrical line causes no voltage drop, i. e., it has no electrical</p>

	resistance.
	<p>T-junction (electrical)</p> <p>A T-junction joins up to three electrical lines, thus having a single voltage potential. Note that T-junctions are introduced automatically by FluidSIM when dropping the line drawing cursor onto another line in Edit Mode.</p>
	<p>Indicator light</p> <p>If current flows, the indicator light is displayed in the user-defined color.</p>
	<p>Buzzer</p> <p>If current flows, a flashing ring around the buzzer is shown. Moreover, if "buzzer" is activated in the menu under Options- Sound..., the buzzer is activated if a sound hardware is installed.</p>
<p>(ladder)</p> 	<p>Break switch</p> <p>General break switch that is tailored depending on the type of component that actuates it. For example, if the break switch is linked via a label to a switch-off delay relay, the break switch changes to a switch-off delay break switch in the circuit diagram.</p>
<p>(ladder)</p> 	<p>Make switch</p> <p>General make switch that is tailored according to the component that actuates it.</p> <p>For example, if the make switch is linked via a label to a switch-on delayed relay, the make switch changes to a switch-on delayed make switch in the circuit diagram.</p>
	<p>Changeover switch</p> <p>General changeover switch that is tailored according to the component that actuates it.</p> <p>For example, if the changeover switch is linked via a label to a switch-on delayed relay, the changeover switch changes to a switch-on delayed changeover switch in the circuit diagram.</p>
<p>(ladder)</p> 	<p>Break switch (switch-on delayed)</p> <p>Switch with delayed opening after pickup. Switch-on delayed break switches are created by using a general break switch and setting a label.</p>

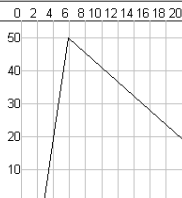
<p>(ladder)</p> 	<p>Make switch (switch-on delayed)</p> <p>Switch with delayed closing after pickup. Switch-on delayed make switches are created by using a general make switch and setting a label.</p>
	<p>Changeover switch (switch-on delayed)</p> <p>Changeover switch with delayed changeover after pickup. Switch-on delayed changeover switches are created by using a general changeover switch and setting a label.</p>
<p>(ladder)</p> 	<p>Break switch (switch-off delayed)</p> <p>Switch with delayed closing after dropout. Switch-off delayed break switches are created by using a general break switch and setting a label.</p>
<p>(ladder)</p> 	<p>Make switch (switch-off delayed)</p> <p>Switch with delayed opening after dropout. Switch-off delayed make switches are created by using a general make switch and setting a label.</p>
	<p>Changeover switch (switch-off delayed)</p> <p>Changeover switch with delayed changeover after dropout. Switch-off delayed changeover switches are created by using a general changeover switch and setting a label.</p>
<p>(ladder)</p> 	<p>Limit switch (break)</p> <p>Switch that is opened by a cam attached to the cylinder rod. The switch closes immediately when the cam has passed the switch. Limit switches are created by using a general break switch and setting a label.</p>
<p>(ladder)</p> 	<p>Limit switch (make)</p> <p>Switch that is closed by a cam attached to the cylinder rod. The switch opens immediately when the cam has passed the switch. Limit switches are created by using a general make switch and setting a label.</p>
	<p>Limit switch (changeover)</p> <p>Switch that is changed over by a cam attached to the cylinder rod. The switch changes back immediately when the cam has passed the switch. Limit switches are created by using a general changeover switch and setting a label.</p>

<p>(ladder)</p> 	<p>Pushbutton (break)</p> <p>Switch that opens when actuated and closes immediately when released.</p> <p>In FluidSIM switches can be actuated permanently (locked) when continuing to hold down the mouse button and pushing the Shift key. This permanent actuation is released by a simple click on the component.</p>
<p>(ladder)</p> 	<p>Pushbutton (make)</p> <p>Switch that closes when actuated and opens immediately when released.</p> <p>In FluidSIM switches can be actuated permanently (locked) when continuing to hold down the mouse button and pushing the Shift key. This permanent actuation is released by a simple click on the component.</p>
<p>(ladder)</p> 	<p>Pushbutton (changeover)</p> <p>Switch that changes over when actuated and changes back immediately when released.</p> <p>In FluidSIM switches can be actuated permanently (locked) when continuing to hold down the mouse button and pushing the Shift key. This permanent actuation is released by a simple click on the component.</p>
	<p>Detent switch (break)</p> <p>Switch that opens and locks when actuated.</p>
	<p>Detent switch (make)</p> <p>Switch that closes and locks when actuated.</p>
	<p>Detent switch (changeover)</p> <p>Switch that changes over and locks when actuated.</p>
	<p>Pneumatic to electric converter</p> <p>The converter produces an electrical signal, if the preset differential pressure of the differential pressure switch is exceeded.</p>
<p>(ladder)</p> 	<p>Pressure switch (break)</p> <p>Switch that opens when the preset switching pressure of the analog pressure sensor is exceeded. Pressure switches are created by using a general break switch and setting a label.</p>

	
<p>(ladder)</p> 	<p>Pressure switch (make) The switch closes when the preset switching pressure of the analog pressure sensor is exceeded. Pressure switches are created by using a general make switch and setting a label.</p>
	<p>Pressure switch (changeover) The switch changes over when the preset switching pressure of the analog pressure sensor is exceeded. Pressure switches are created by using a general changeover switch and setting a label.</p>
	<p>Magnetic proximity switch Switch that closes when a solenoid is brought near by. In the Simulation Mode the proximity switch can also be actuated by clicking on it.</p>
	<p>Inductive proximity switch Switch that closes when the induced electro-magnetic field is changed. In the Simulation Mode the proximity switch can also be actuated by clicking on it.</p>
	<p>Capacitive proximity switch Switch that closes when its electrostatic field is changed. In the Simulation Mode the proximity switch can also be actuated by clicking on it.</p>
	<p>Optical proximity switch Switch that closes when the light barrier is interrupted. In the Simulation Mode the proximity switch can also be actuated by clicking on it.</p>
<p>(ladder)</p> 	<p>Relay The relay picks up immediately when current is supplied and drops out immediately when current is removed.</p>
<p>(ladder)</p> 	<p>Relay with switch-on delay The relay picks up after a preset time when current is supplied and drops out immediately when current is removed.</p>

	
<p>(ladder)</p>  	<p>Relay with switch-off delay</p> <p>The relay picks up immediately when current is supplied and drops out after a preset time when current is removed.</p>
	<p>Status indicator</p> <p>In Edit Mode, the status indicator is automatically displayed at those components that are actuated in the circuit's initial position.</p>
	<p>Relay counter</p> <p>The relay picks up after a predefined number of current pulses has been counted between the connections A1 and A2. If a potential is supplied between the connections R1 and R2, the counter is reset to its predefined value.</p> <p>In the Simulation Mode the relay counter can also be reset by clicking on it.</p>
<p>(ladder)</p>  	<p>Valve solenoid</p> <p>The valve solenoid switches the valve.</p> <p>By means of a label the valve solenoid can be linked to a valve that is solenoid operated.</p>
	<p>Distance rule</p> <p>The distance rule is a device for attaching switches at the cylinder. The labels at the distance rule define links to the actual proximity switches or limit switches in the electrical circuit.</p>
	<p>Cam switch</p> <p>In Edit Mode, the cam switch is automatically displayed at those mechanically operated way valves that are actuated in the circuit's initial position.</p>
<p>Text</p>	<p>Text</p> <p>The concept of text components in FluidSIM gives the user a way in which to describe components in diagrams, assign identification texts, or to provide commentary on the diagram. The text and the appearance of text components can be customized to the user's liking.</p>

Process Control Lab.

<table border="1"> <tr> <th>Component Description</th> <th>Designation</th> </tr> <tr> <td>Single acting cylinder</td> <td></td> </tr> </table>	Component Description	Designation	Single acting cylinder			<p>State diagram</p> <p>The state diagram records the state quantities of important components and depicts them graphically.</p>			
Component Description	Designation								
Single acting cylinder									
<table border="1"> <thead> <tr> <th>Designation</th> <th>Component Description</th> </tr> </thead> <tbody> <tr> <td>1A</td> <td>Single acting cylinder</td> </tr> <tr> <td>1V</td> <td>Throttle check valve</td> </tr> <tr> <td>1S</td> <td>3/n Way Valve</td> </tr> </tbody> </table>	Designation	Component Description	1A	Single acting cylinder	1V	Throttle check valve	1S	3/n Way Valve	<p>Parts list</p> <p>The parts list component creates from the components of a circuit diagram a table, which contains for each component its designation and its description.</p>
Designation	Component Description								
1A	Single acting cylinder								
1V	Throttle check valve								
1S	3/n Way Valve								

Appendix B

Stations' Addresses

B.1 Distributing Station

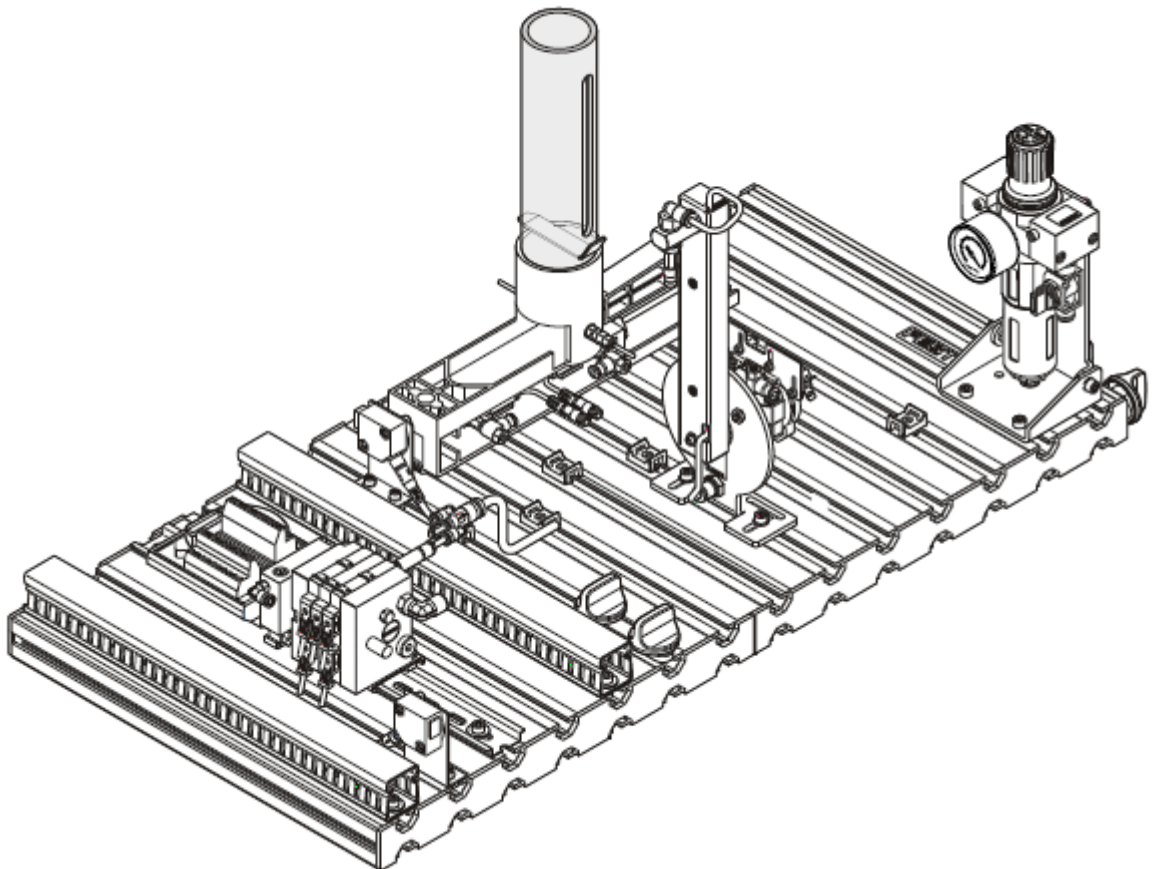


Figure B.1: Distributing station.

Station's Function

The distribution station separates work pieces from the stack magazine module. The magazine barrel of the stack magazine holds up to eight work pieces. The filling level of the stack magazine is monitored by means of a through beam sensor. A double acting cylinder pushes out the work pieces individually.

The changer module grips the separated out work pieces using a suction cup. A vacuum switch checks whether a work piece has been picked up. The arm of the transfer unit, which is driven by a rotary drive, conveys the work piece to the transfer point of the downstream station.

Input and Output Addresses

Address	Description	Identity
I0.1	Magazine is at back position	Magnetic Proximity Sensor
I0.2	Magazine is at front position	Magnetic Proximity Sensor
I0.3	A work piece is securely sucked	Pressure switch
I0.4	Swivel drive is at magazine position	Limit switch
I0.5	Swivel drive is in position to the next station	Limit switch
I0.6	Work piece is available (NC)	Through beam sensor
Q0.0	The magazine cylinder extends	Linear cylinder
Q0.1	The vacuum switches ON	-
Q0.2	The vacuum switches OFF	-
Q0.3	The swivel drive moves to the magazine	Rotary cylinder
Q0.4	The swivel drive moves to the next station	Rotary cylinder
I1.0	START	Push button
I1.1	STOP (normally closed)	Push button
I1.3	RESET	Push button

B.2 Fluidic Muscle Press Station

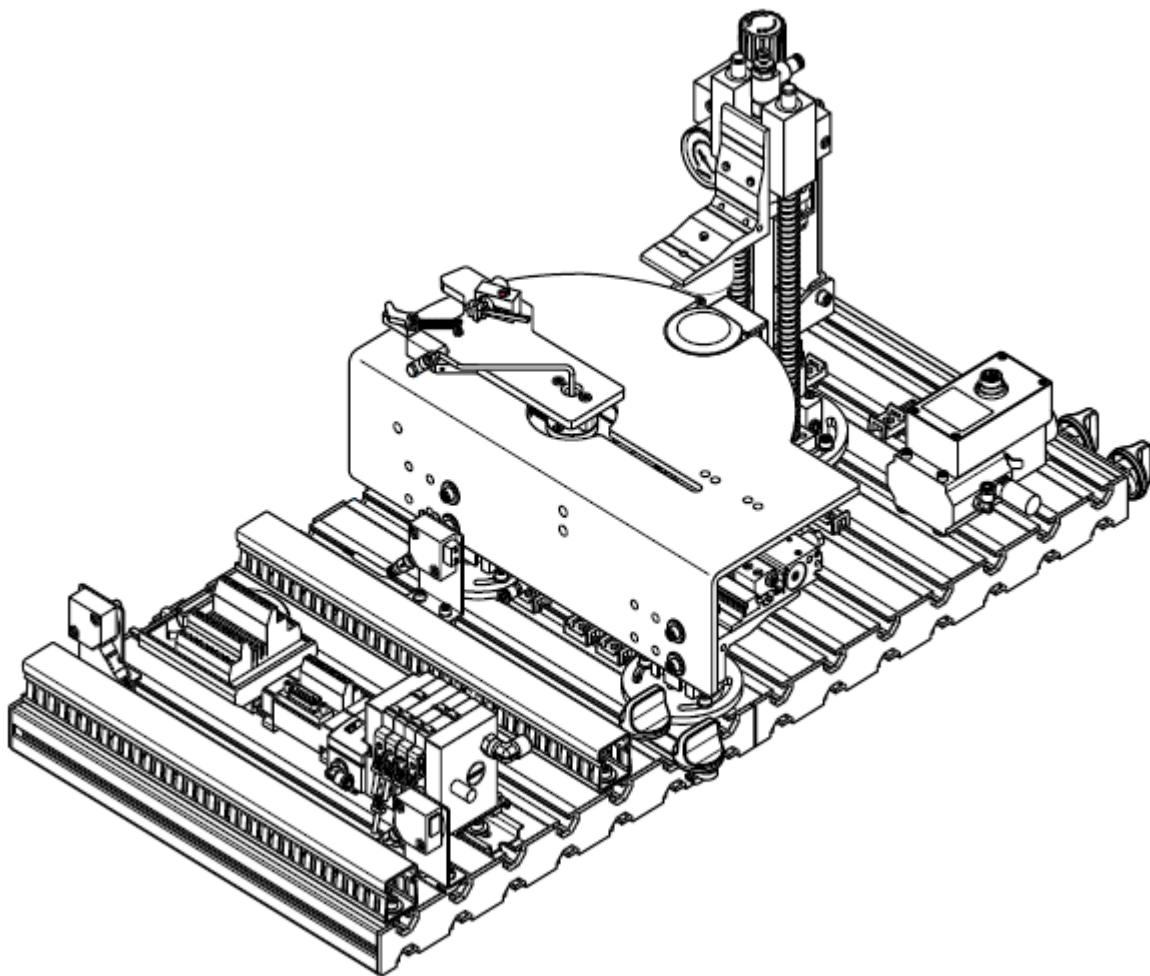


Figure B.2: Fluidic Muscle Press station.

Station's Function

Process Control Lab.

The fluidic muscle press station presses work piece covers into housings (body), the rotary-linear changer module positions the covered work pieces beneath the press. The fluidic muscle press carries out the pressing process. The rotary-linear changer then transports the finished work piece to the transfer position.

A diffuse sensor mounted on the changer arm for work piece interrogation.

The pressing force is monitored and displayed by an analog sensor. The pressing speed and depth can be set both manually via a flow control valve and pressure regulator and electronically with the proportional pressure regulator.

Input and Output Addresses

Muscle press

Address	Description	Identity
I0.0	Work piece is available	Diffuse Sensor
I0.1	Linear drive is at pick position (fully retracted)	Magnetic Proximity Sensor
I0.2	Linear drive is at deliver position (fully extended)	Magnetic Proximity Sensor
I0.3	Rotary drive is at 0	Magnetic Proximity Sensor
I0.4	Rotary drive is at 90	Magnetic Proximity Sensor
I0.5	Rotary drive is at 180	Magnetic Proximity Sensor
I0.6	Pressure has exceeded the set point=HIGH	Pressure switch
Q0.0	Gripper (active=hold the work piece)	Rotary cylinder
Q0.1	Linear drive retracts to pick position	Linear cylinder
Q0.2	Linear drive extends to deliver position	Linear cylinder
Q0.3	Rotary drive rotates to 0°	Rotary cylinder
Q0.4	Rotary drive rotates to 90°	Rotary cylinder
Q0.5	Rotary drive rotates to 180°	Rotary cylinder
Q0.6	Muscle press	Linear cylinder
I1.0	START	Push button
I1.1	STOP (normally closed)	Push button
I1.3	RESET	Push button

B.3 Handling Station

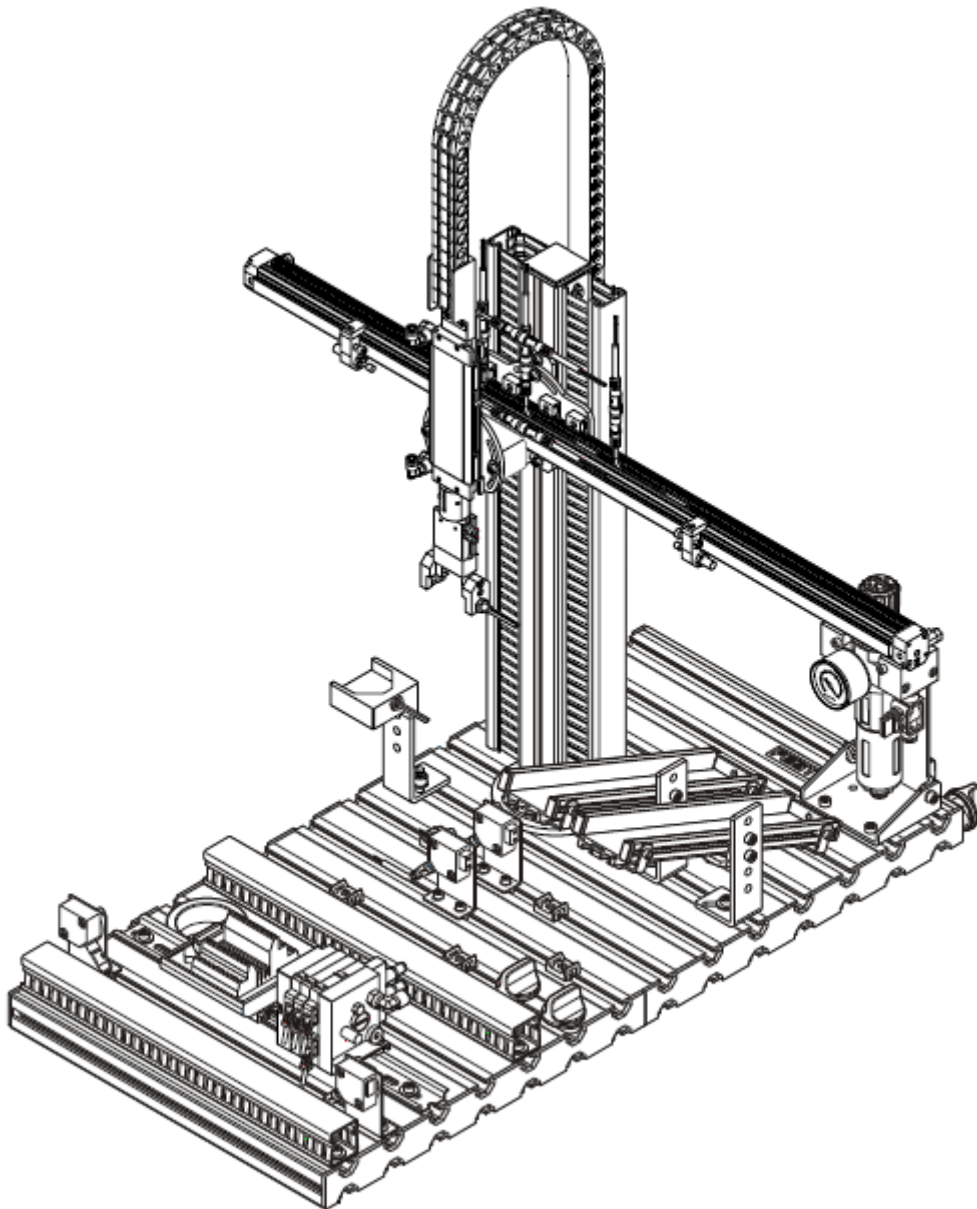


Figure B.3: Handling station.

Station's Function

The handling station is equipped with a flexible two axis handling device. Inserted work pieces are detected in the retaining device by an optical reflex light sensor.

The handling device fetches the work pieces from the retaining device with the help of a pneumatic gripper, which is fitted with an optical sensor. The sensor differentiates between black and non black pieces. The work pieces can be deposited on different slides on the bases of these criteria.

Input and Output Addresses

Handling

Address	Description	Identity
I0.0	Work piece is available	Diffuse sensor
I0.1	Handling device is at previous station	Magnetic sensor
I0.2	Handling device is at next station	Magnetic sensor
I0.3	Handling device is at sorting position	Magnetic sensor
I0.4	Lifting cylinder with gripper is down	Magnetic sensor
I0.5	Lifting cylinder with gripper is up	Magnetic sensor
I0.6	Black work pieces does not activate the sensor (Black=0)	Diffuse color sensor
Q0.0	Handling device goes to the previous station	Linear cylinder
Q0.1	Handling device goes to the next station	Linear cylinder
Q0.2	Lifting cylinder goes down	Linear cylinder
Q0.3	Gripper opens	Pneumatic cylinder
I1.0	START	Push button
I1.1	STOP (normally closed)	Push button
I1.3	RESET	Push button

B.4 Pick and Place Station

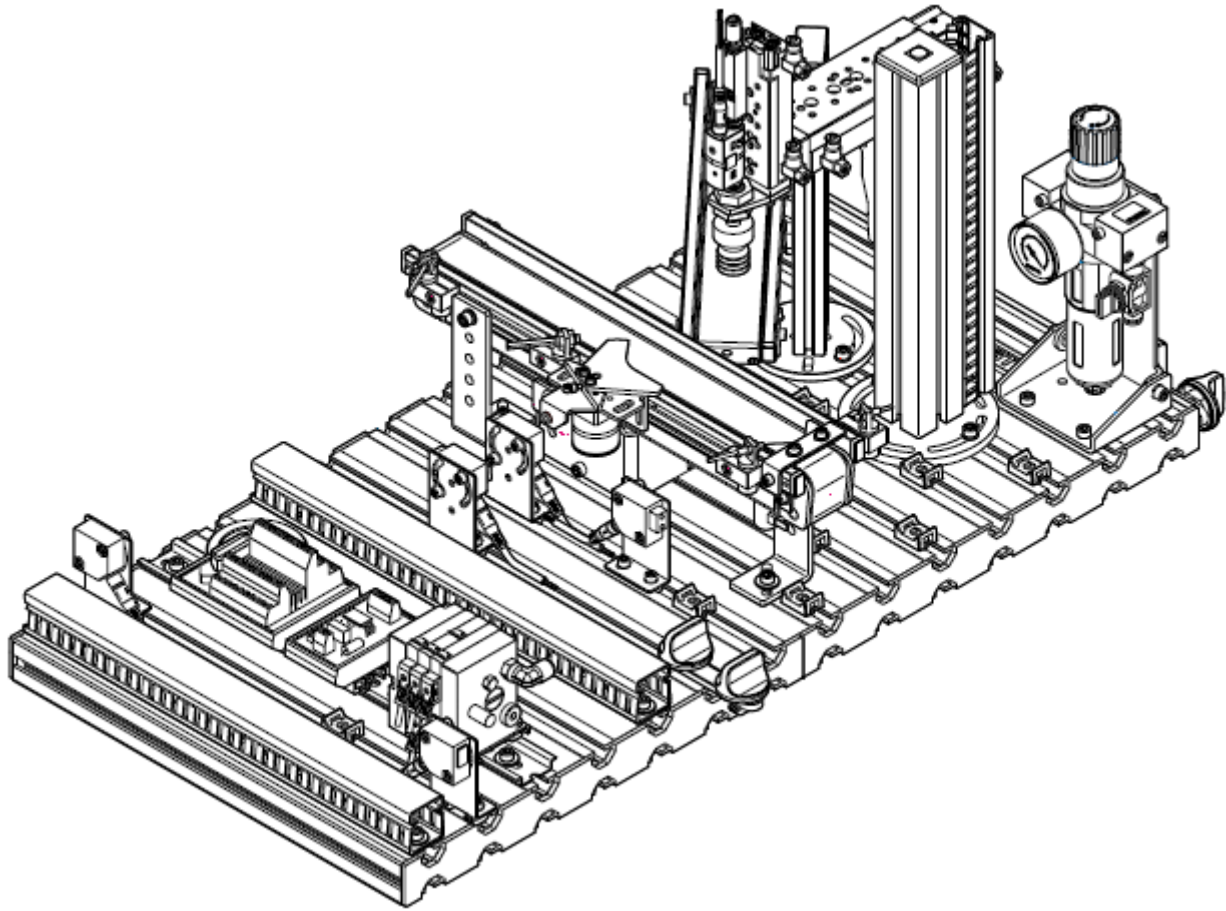


Figure B.4: Pick and Place station.

Station's Function

The Pick and Place station is equipped with two-axis Pick and Place module. Work piece housings placed on the conveyor belt are detected by the diffuse sensor. The work piece is transported to the pneumatic separator on the conveyor belt and detected by a second diffuse sensor.

The Pick and Place module picks up a work piece cover from the slide and places it on the work piece housing (body). The complete work piece (housing and cover) is released by the separator and transported to the end of the conveyor belt. A light barrier detects the work piece at the end of the conveyor belt.

Input and Output Addresses

Address	Description	Identity
I0.0	Work piece at the start of conveyor belt	Diffuse Sensor
I0.1	Horizontal cylinder is fully retracted (above the slide)	Magnetic Proximity Sensor
I0.2	Horizontal cylinder is fully extended (above the conveyor)	Magnetic Proximity Sensor
I0.3	Vertical cylinder is fully retracted (is up)	Magnetic Proximity Sensor
I0.4	Cover is securely sucked	Pressure switch
I0.5	Work piece is at separating position	Diffuse sensor
I0.6	Work piece is at the end of the conveyor belt (NC)	Through beam sensor
Q0.0	Conveyor belt	Permanent magnetic DC M
Q0.1	Horizontal cylinder retracts (go back)	Linear cylinder
Q0.2	Horizontal cylinder extends (go forward)	Linear cylinder
Q0.3	Vertical cylinder extends (go down)	Linear cylinder
Q0.4	Bellow suction cup	-
Q0.5	Separator (active= holding the work piece)	Rotary cylinder
I1.0	START	Push button
I1.1	STOP (normally closed)	Push button
I1.3	RESET	Push button

B.5 Separating Station

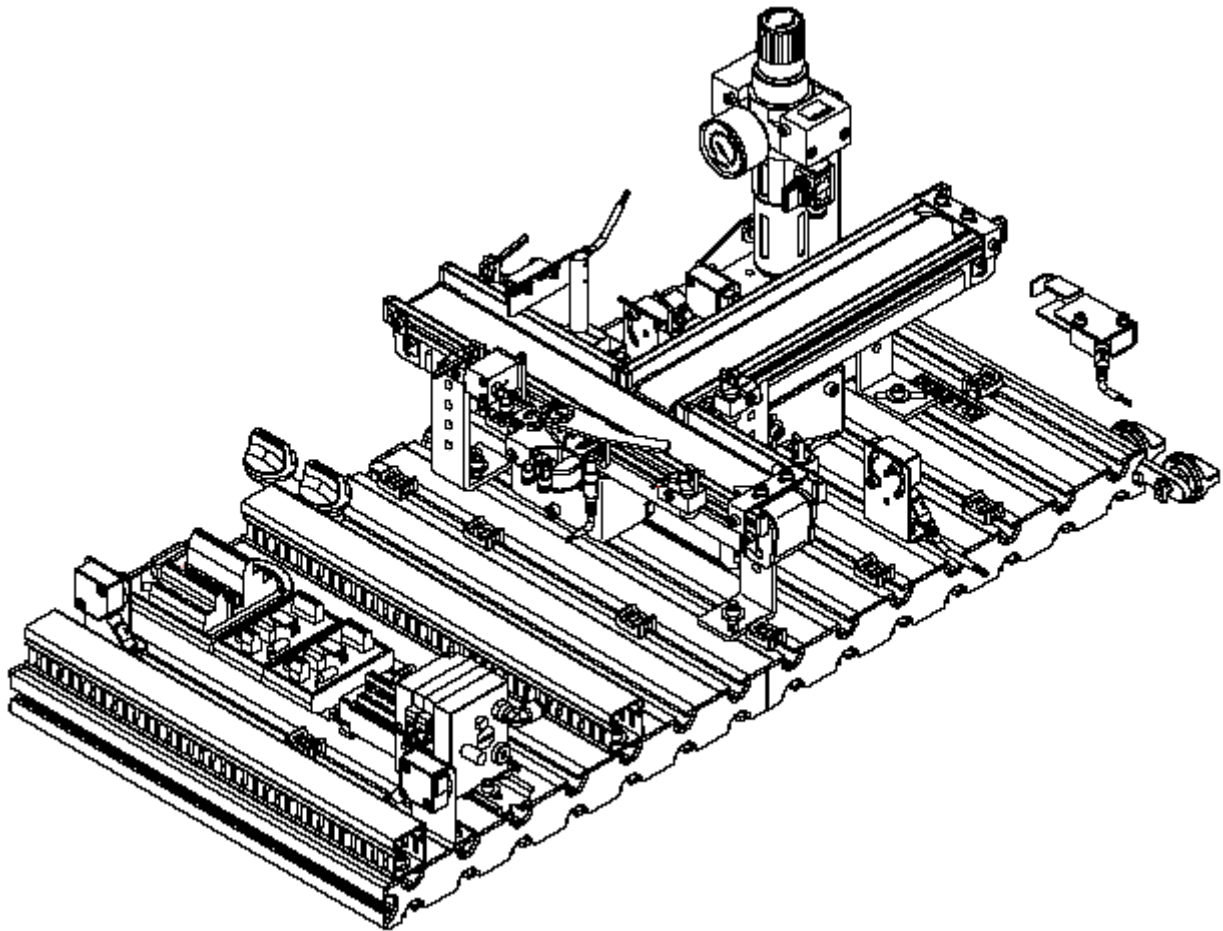


Figure B.5: Separating station.

Station's Function

The separating station detects if the coming pieces are covered or not and allocate them.

A diffuse sensor at the start of the conveyor detects work pieces. A diffuse sensor above the stopper detects the height of the work piece (covered or not) and determines the coming material flow. Depending on the program, a sorting branch is switched. If the pick-up point and the conveyor section are not occupied, the stopper is retracted and the work piece is transported to one of the two conveyor belts.

Input and Output Addresses

Sparating

Address	Description	Identity
I0.0	Work piece at start position	Diffuse sensor
I0.1	Work piece at test position	Through beam sensor
I0.2	Testing sensor (uncovered pieces activate the sensor)	Diffuse sensor
I0.3	Flipper is fully advanced	Inductive proximity sensor
I0.4	Work piece at the second belt (NC)	Diffuse sensor
I0.5	Work piece at the end of the first belt (NC)	Diffuse sensor
Q0.0	First belt	Permanent magnet DC motor
Q0.1	Second belt	Permanent magnet DC motor
Q0.2	Clamper retracts	Linear cylinder
Q0.3	Flipper	Rotary cylinder
I1.0	START	Push button
I1.1	STOP (normally closed)	Push button
I1.3	RESET	Push button

B.6 Sorting Station

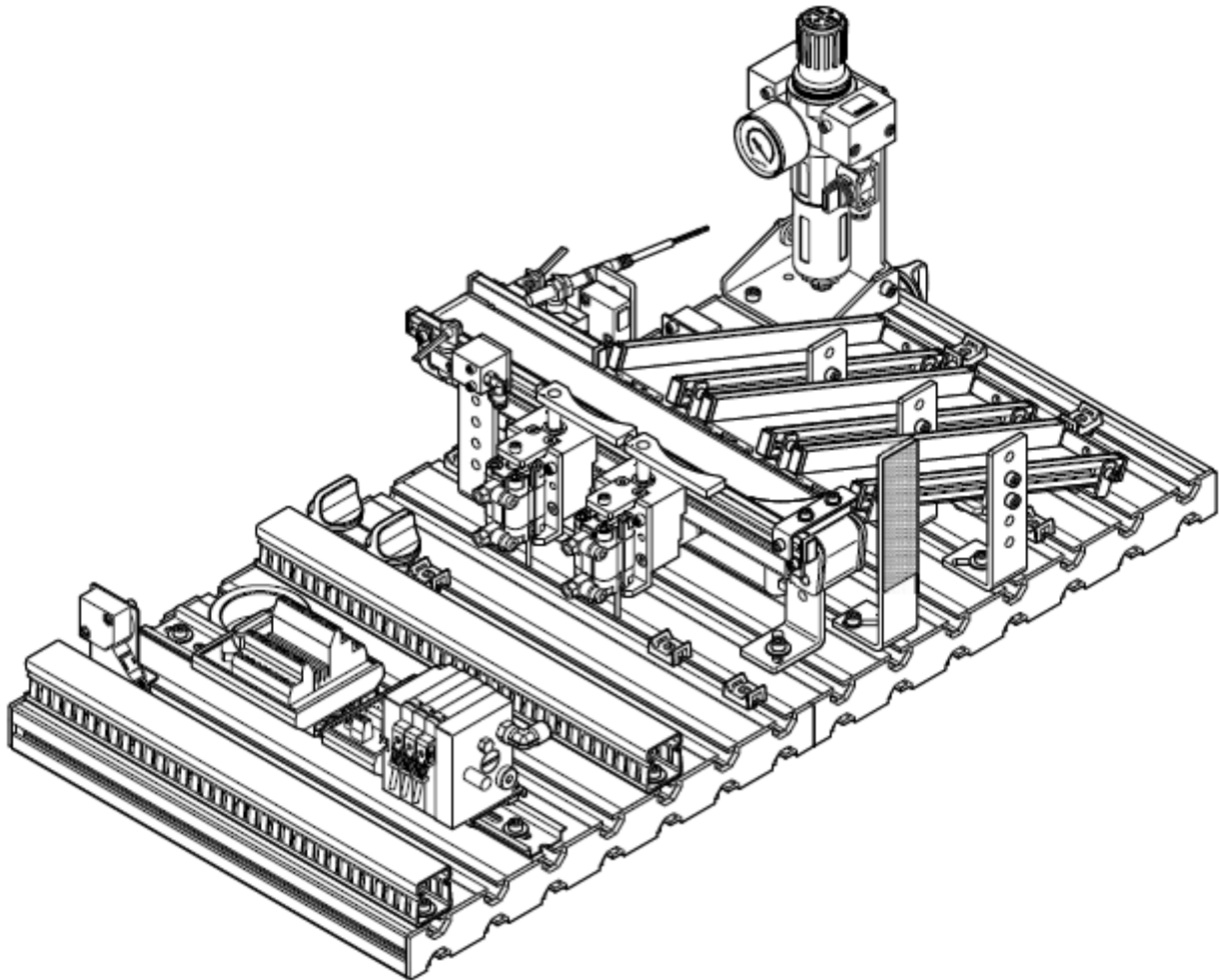


Figure B.6: Sorting station.

Station's Function

The sorting station detects the color of the incoming work pieces and deposit them on one of three sliders depending on the color (black, red or silver). Each slider can store up to 6 work pieces. To select which slider the work pieces should be on, two pneumatic cylinders in the form of flippers are used.

Input and Output Addresses

Sorting

Address	Description	Identity
I0.0	Work piece is available at the start of the conveyor belt	Diffuse sensor
I0.1	Work piece is metal (silver)	Inductive proximity sensor
I0.2	Work piece is black=0 , Work piece is red or metal=1	Diffuse color sensor
I0.3	Work piece is falling at one of any of the 3 sliders	Retro reflective sensor
I0.4	First flipper is retracted	Inductive proximity sensor
I0.5	First flipper is advanced	Inductive proximity sensor
I0.6	Second flipper is retracted	Inductive proximity sensor
I0.7	Second flipper is advanced	Inductive proximity sensor
Q0.0	Conveyor belt	Permanent magnetic DC motor
Q0.1	First flipper advances	Rotary cylinder
Q0.2	Second flipper advances	Rotary cylinder
Q0.3	Clamper retracts	Linear cylinder
I1.0	START	Push button
I1.1	STOP (normally closed)	Push button
I1.3	RESET	Push button

B.7 Testing Station

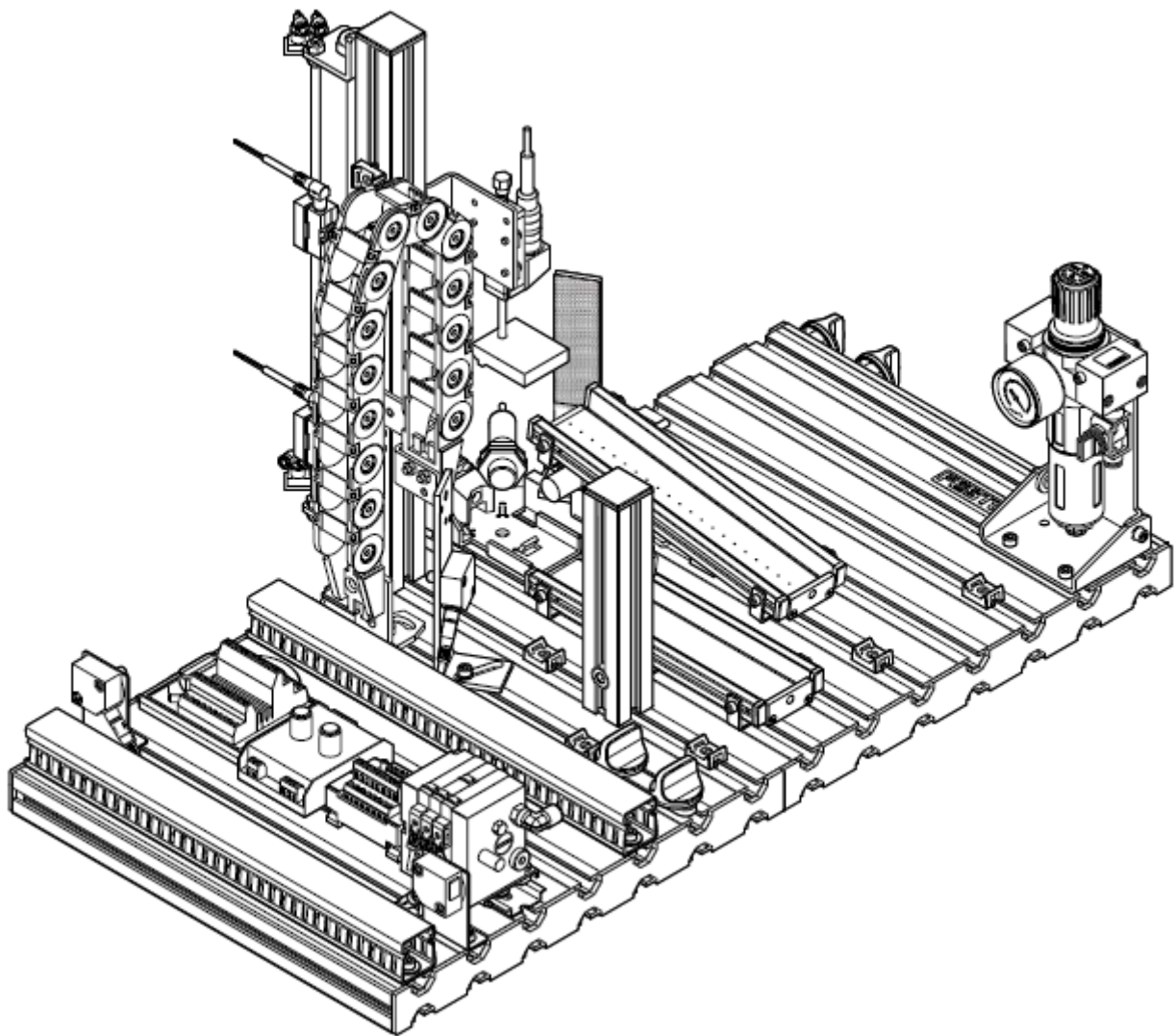


Figure B.7: Testing station.

Station's Function

The testing station determines the characteristics of inserted work pieces. The sensing module identifies the color of a work piece and a capacitive sensor detects each work piece irrespective of the color. A diffuse sensor identifies metallic and red work pieces. Black work pieces are not detected by the diffuse sensor. A retro reflective sensor monitors within the working area above the work piece retainer is free before the work piece is lifted by the lifting module.

The analogue sensor of the measuring module determines the height of the work piece. A linear cylinder guides the accepted work piece to the downstream station via the upper air cushioned slide. Rejected work pieces are sorted on the lower slide.

A linear cylinder guides the correct work pieces to the downstream station via the upper air cushioned slide. Other work pieces are sorted on the lower slide.

Input and Output Addresses

Address	Description	Identity
I0.0	Work piece is available	Capacitive proximity sensor
I0.1	Black work pieces does not activate the sensor (Black=0)	Diffuse color sensor
I0.2	Safety light barrier	Retro reflective sensor
I0.3	Check the height of the work piece if it Ok = 1	Comparator Height sensor
I0.4	Lifting cylinder is up	Magnetic proximity sensor
I0.5	Lifting cylinder is down	Magnetic proximity sensor
I0.6	Pushing cylinder is at back position	Magnetic proximity sensor
Q0.0	Lifting cylinder goes down	Linear cylinder
Q0.1	Lifting cylinder goes up	Linear cylinder
Q0.2	Pushing cylinder extends	Linear cylinder
Q0.3	Air slide	-
I1.0	START	Push button
I1.1	STOP (normally closed)	Push button
I1.3	RESET	Push button

B.8 Buffering station

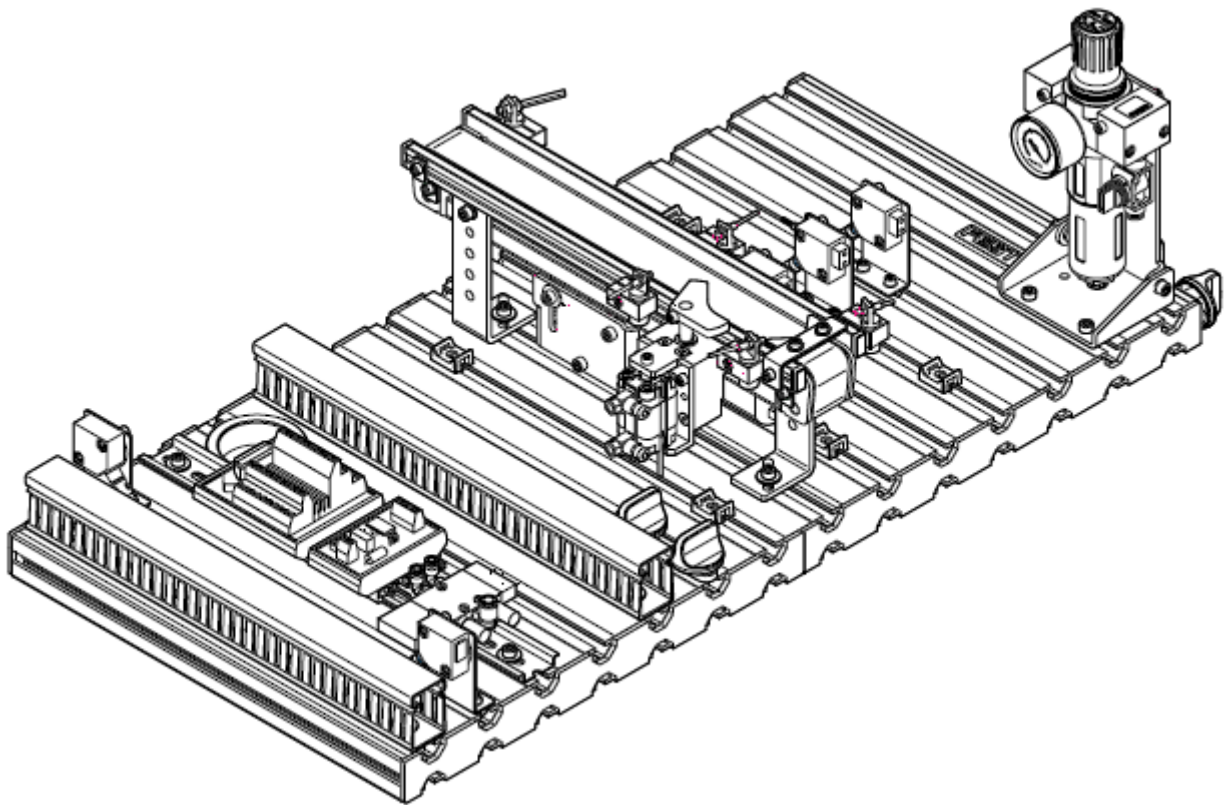


Figure B.8: Buffering station.

Station's Function

The Buffering station is a first-input-first output (FIFO). Though the work pieces order does not change, the work pieces are separated out at the output of the buffer zone prior to being passed on to the next (subsequent) station.

Input and Output Addresses

Address	Description	Identity
I0.0	Work piece is available at the start of the conveyor belt	Diffuse sensor
I0.1	Work piece is at the buffering (separation) position (NC)	Through beam sensor
I0.2	Work piece is at the end of the conveyor belt (NC)	Through beam sensor
I0.3	Separator is fully retracted	Magnetic proximity sensor
I0.4	Separator is fully extended	Magnetic proximity sensor
Q0.0	Separator (Buffer) extends to hold the work piece	Permanent magnet DC motor
Q0.1	Conveyor belt	Linear short stroke cylinder
I1.0	START	Push button
I1.1	STOP (normally closed)	Push button
I1.3	RESET	Push button

Appendix C

Pneumatic Circuits

Introduction

In session 1 you have learned about pneumatic systems and their main components. In addition to that your lab instructor has introduced to you how to use FluidSIM software. During this appendix you will use the basis you have learned at the session 1 to simulate pneumatic circuits.

As you have learned at the session 1, cylinders are the output elements of a pneumatic system. There are two ways of controlling the cylinder motion (system output):

Direct Control

The simplest level of control for the single or double-acting cylinder involves direct control signals. Using this type of control, the cylinder is actuated directly via a manually or mechanically actuated valve, without any intermediate switching of additional directional control valves. If the port sizes of the valve are too large, the operating forces required may be too great for direct manual operation. Example C.1 illustrates the idea of direct actuation.

Example C.1:

Design a pneumatic circuit such that a single acting cylinder will advance upon pressing "START" push button and will retract upon releasing it.

(Use a 3/2 manually actuated spring returned control valve)

The pneumatic circuit and parts' list needed to perform this operation are shown by Figure C.1.

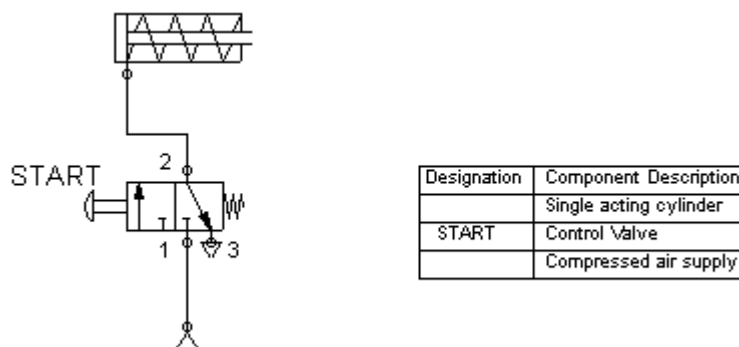


Figure C.1: Pneumatic circuit and parts' list for Example C.1.

Process Control Lab.

As you see in Figure C.1 a 3/2 manually actuated control valve is used to directly drive the cylinder. As long as the valve is actuated ("START" push button is pressed), the single acting cylinder will advance. Once the valve is de-activated ("START" push button is released), the cylinder will retract.

Figure C.2 shows the circuit's state diagram:

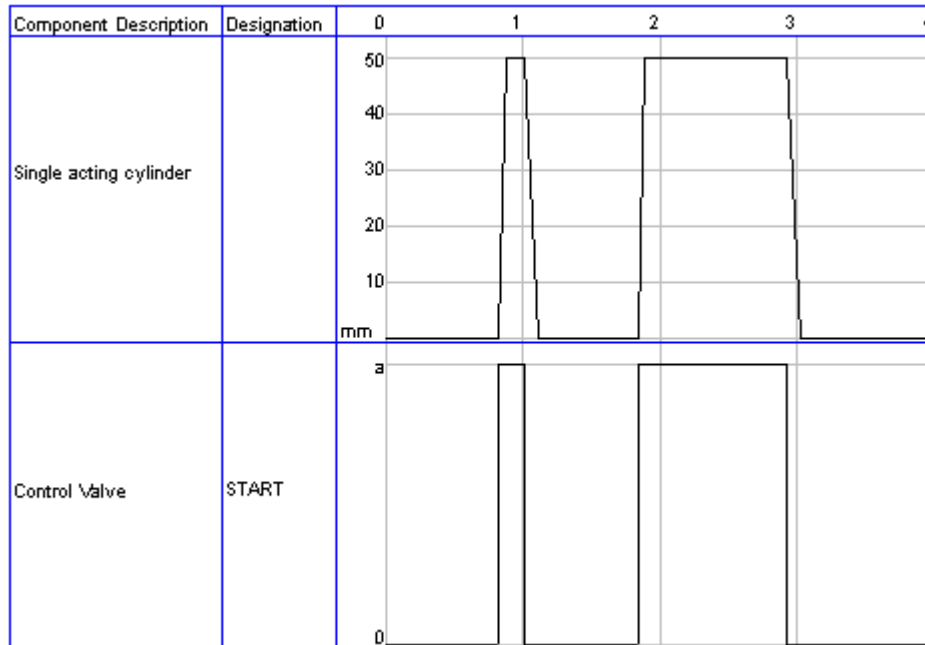


Figure C.2: State diagram for Example C.1.

Indirect Control

Cylinders with large piston diameter have a high air requirement. A control element with high nominal flow rate must be used to actuate them. If the force proves to be too large for a manual actuation of the valve, then an indirect actuation should be constructed where a signal is generated via a second smaller valve, which will provide the force necessary to switch the final control element.

For indirect control of a cylinder, you have to learn what type of valves is used to deliver the signals that actuate the final control element.

- *Input elements:* these are the directional control valves. You have learned about their naming method and methods of actuation during session 1.
- *Processing elements:* these elements form a wide category which includes flow control valves, pressure control valves, non-return valves in addition to pneumatic timers and counters. The principle of operation of each valve in these categories is illustrated at FluidSIM components library in Appendix A.

Example C.2 shows a method for controlling the forward speed of a single acting cylinder.

Example C.2:

Design a pneumatic circuit such that a single acting cylinder will advance **slowly** upon pressing "START" push button and will retract upon releasing it.

(Use a 3/2 manually actuated spring returned control valve)

The pneumatic circuit and parts' list needed to perform this operation are shown by Figure C.3.

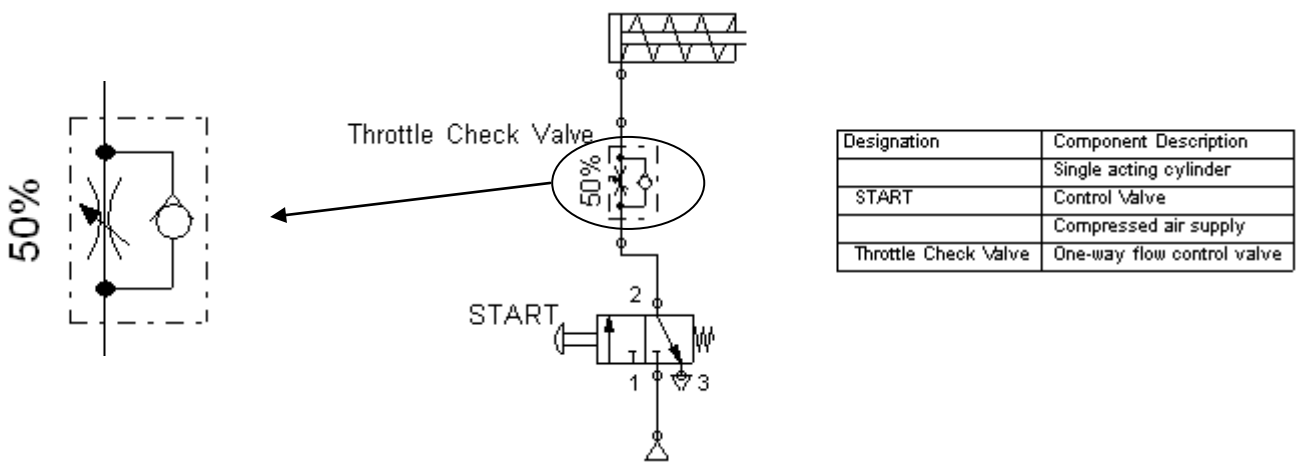


Figure C.3: Pneumatic circuit and parts' list for Example C.2.

Figure C.4 shows the circuit's state diagram:

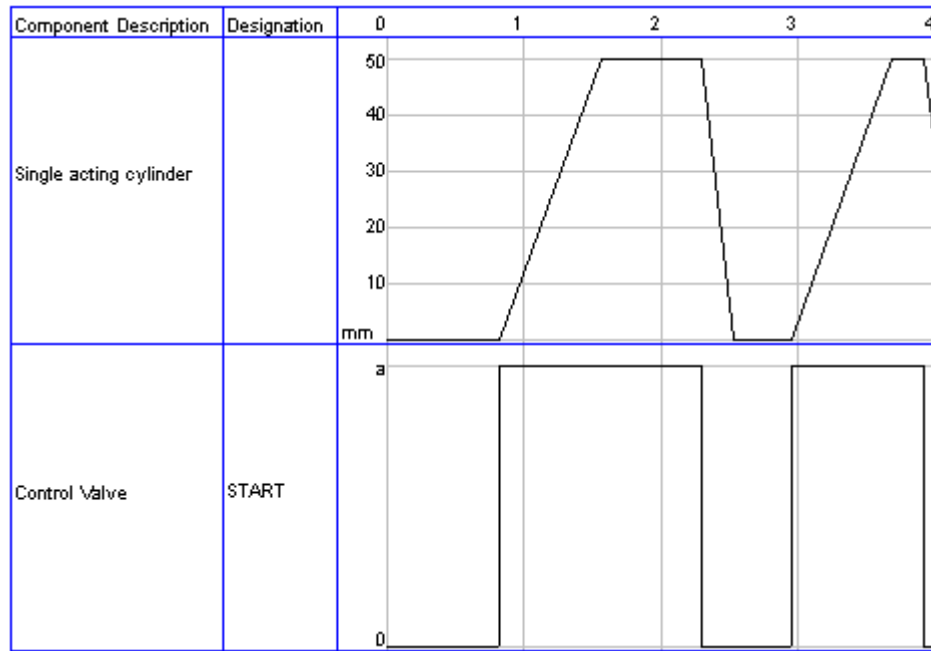


Figure C.4: State diagram for Example C.2.

Note that adding the throttle check valve slowed the speed of the advance motion. This can be noted by studying the slope of the advancing section and the retracting section and it clear that the retracting slope is steeper. Also note the configuration of the throttle check valve.

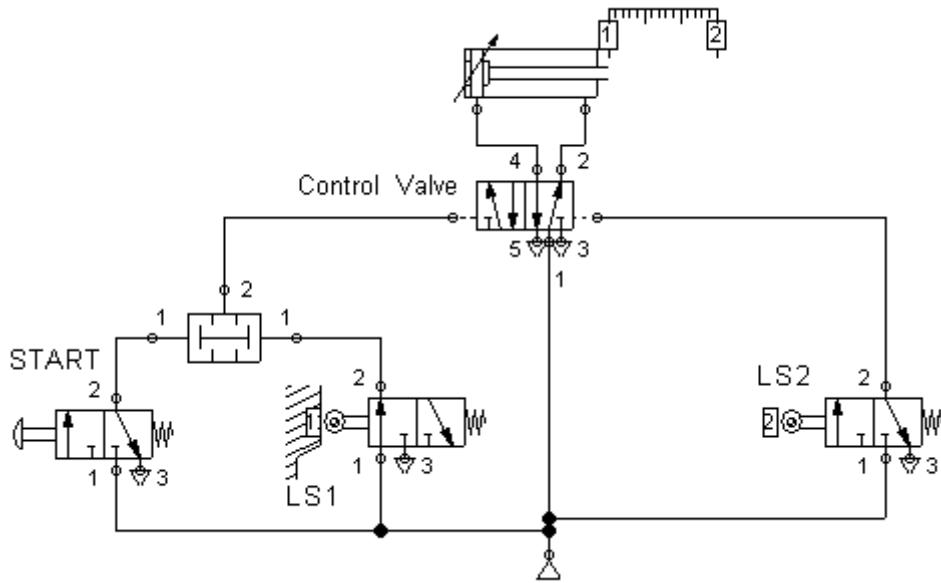
Single acting cylinders are not the only type of cylinders. Example C.3 is an example for indirect control of a double acting cylinder.

Example C.3:

Design a pneumatic circuit such that a double acting cylinder advances upon pressing "START" push button if it is fully retracted and will retract upon reaching its full extent.

(Use a 5/2 pneumatically actuated control valve and use limit switches to detect the position of the cylinder)

The pneumatic circuit and parts' list needed to perform this operation are shown by Figure C.5.



Designation	Component Description
	Two pressure valve
Control Valve	Control Valve
START	START PB
LS1	Limit switch 1
LS2	Limit switch 2
	Compressed air supply
	Double acting cylinder

Figure C.5: Pneumatic circuit and parts' list for Example C.3.

Note that because two conditions is needed in order for the forward motion to happen (the cylinder is fully retracted and "START" push button is pressed), AND gate is used.

Figure C.6 shows the circuit's state diagram:

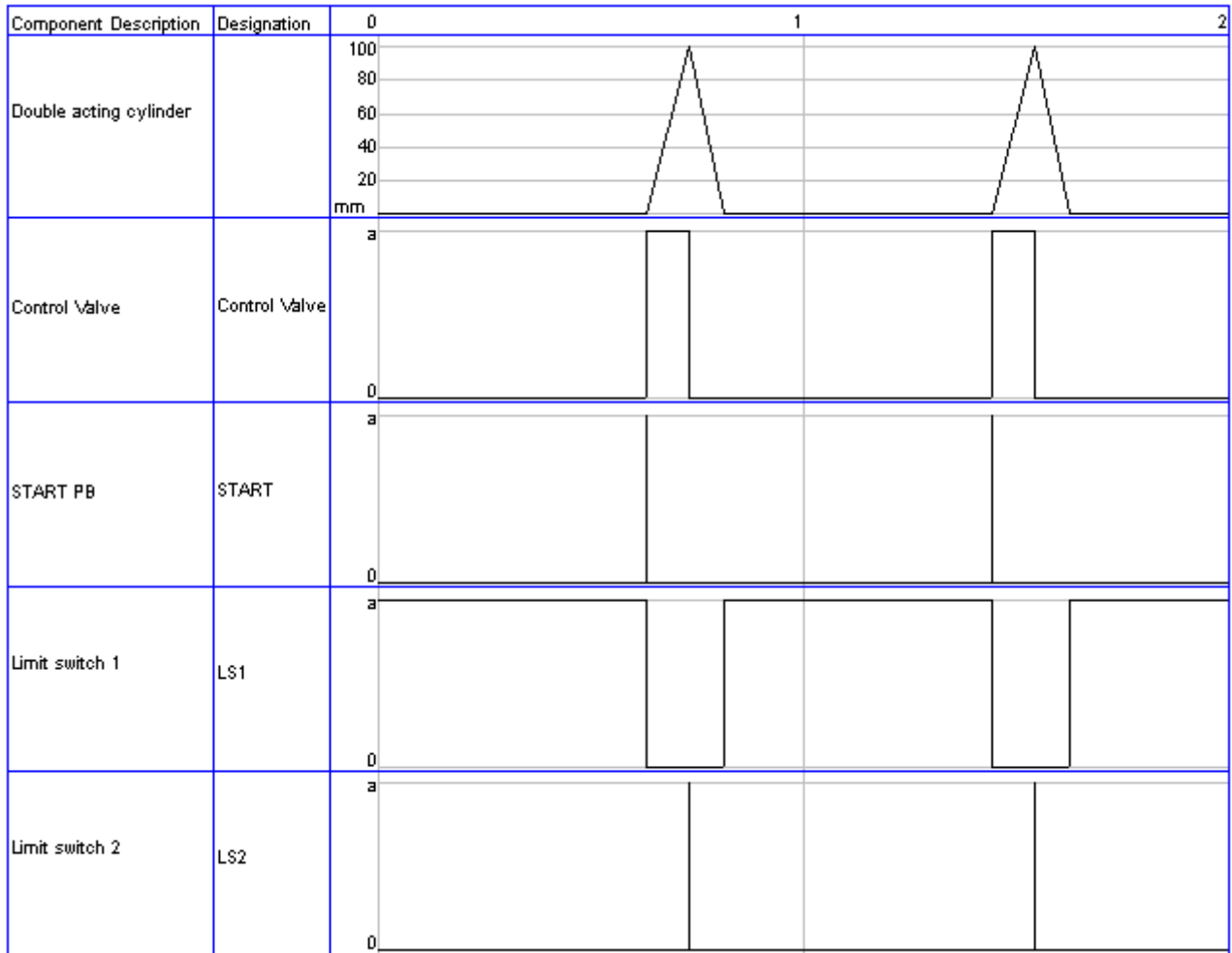


Figure C.6: State diagram for Example C.3.

As we have said above, pneumatic timers and counters are essential parts of indirectly controlled pneumatic systems. Examples C.4 and C.5 illustrates the use of pneumatic timers and counter consequently.

Example C.4:

Process Control Lab.

Continuing on example C.3, the cylinder waits 2 sec upon reaching it full extent before retracting.

The pneumatic circuit and parts' list needed to perform this operation are shown by Figure C.7.

Designation	Component Description
	Two pressure valve
Control Valve	Control Valve
START	START PB
LS1	Limit switch 1
LS2	Limit switch 2
	Compressed air supply
	Double acting cylinder
	Time delay valve, normally closed

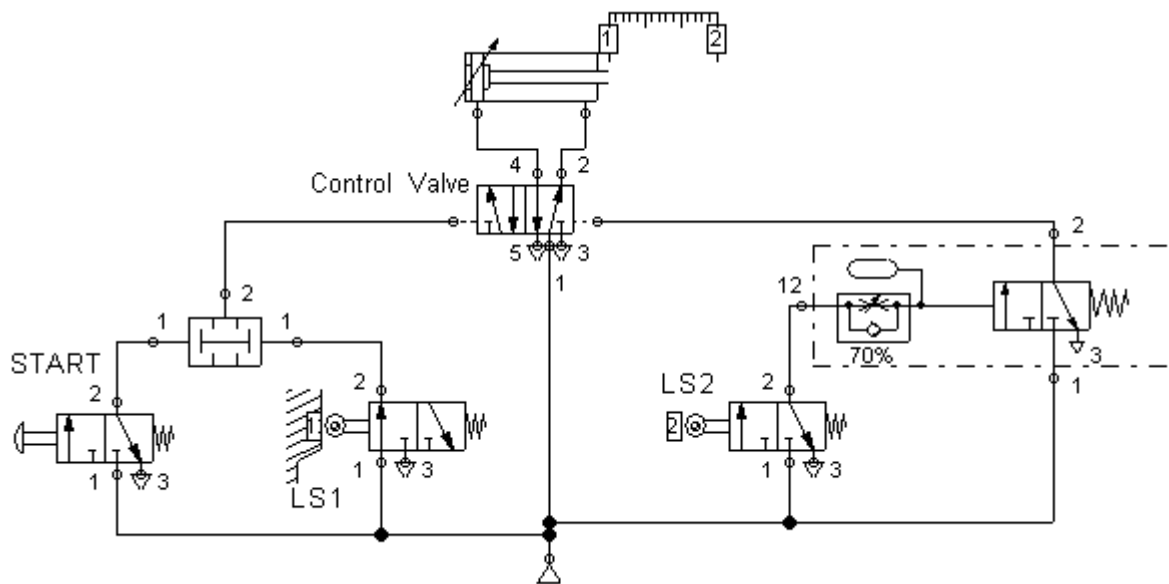


Figure C.7: Pneumatic circuit and parts' list for Example C.4.

Note that when the cylinder is fully extended a signal will arrive at port 12 of the timer. Starting from that moment the timer waits 2 seconds then allows air to flow from port 1 to port 2 causing the cylinder to retract. You should know here that the timer is timing as long as there is signal at port 12 and this is achieved in this circuit because as long as the cylinder have not retracted yet, there is still a signal at port 12. You should also note the use of the normally closed timer. Figure C.8 shows the circuit's state diagram.

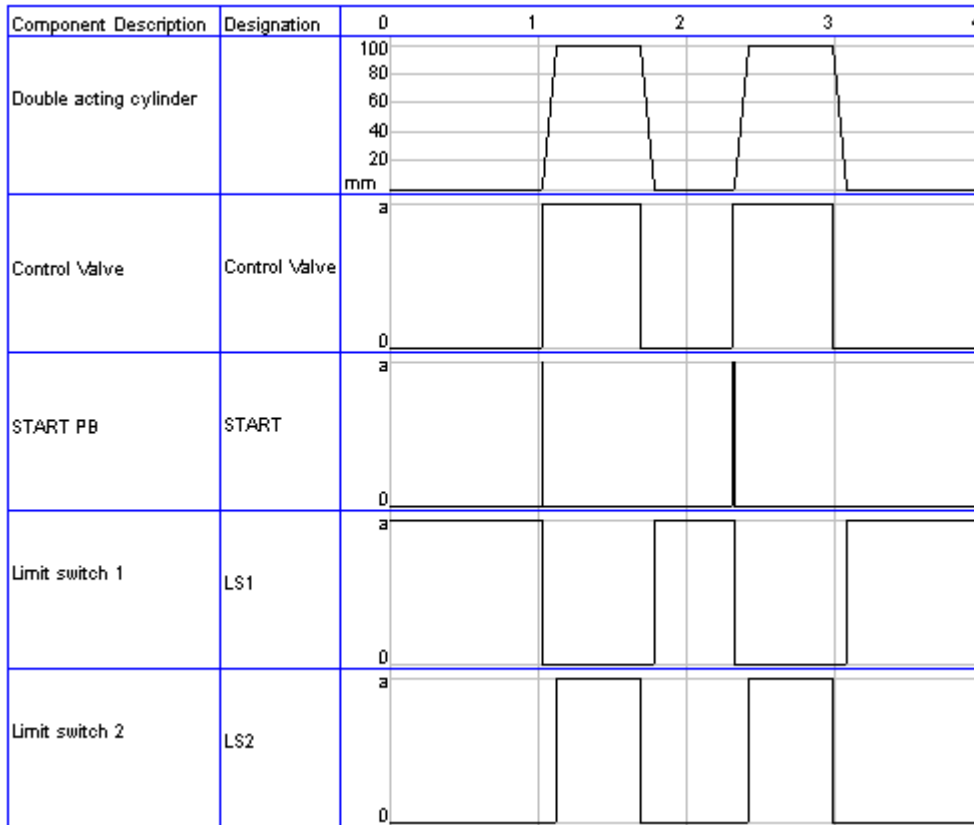


Figure C.8: State diagram for Example C.4.

Example 2.5:

Design a circuit such that a single acting cylinder will advance only if "START" push button is pressed four times and will retract upon reaching its full extent.

(Use a 3/2 manually actuated spring returned valve and a proximity sensor to detect the rear position of the cylinder)

The pneumatic circuit and parts' list needed to perform this operation are shown by Figure 2.9.

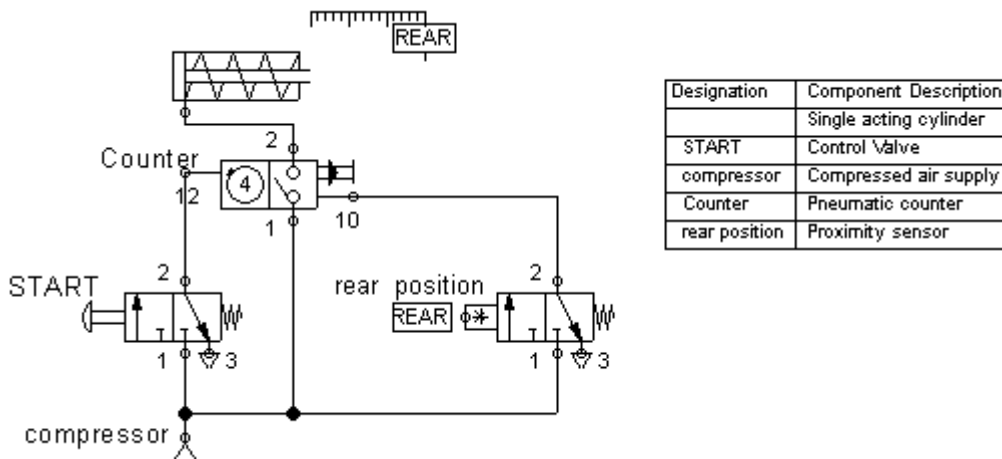


Figure C.9: Pneumatic circuit and parts' list for Example C.5.

Process Control Lab.

Note that after "START" push button have been pressed four times (i.e. four control signals have reached port 12) the counter allows the air to flow from port 1 to port 2 causing the cylinder to extend. When the cylinder reaches its full extent, a control signal will reach port 10 stopping the flow of air from port 1 to port 2 causing the cylinder to retract. Figure C.10 shows the circuit's state diagram.

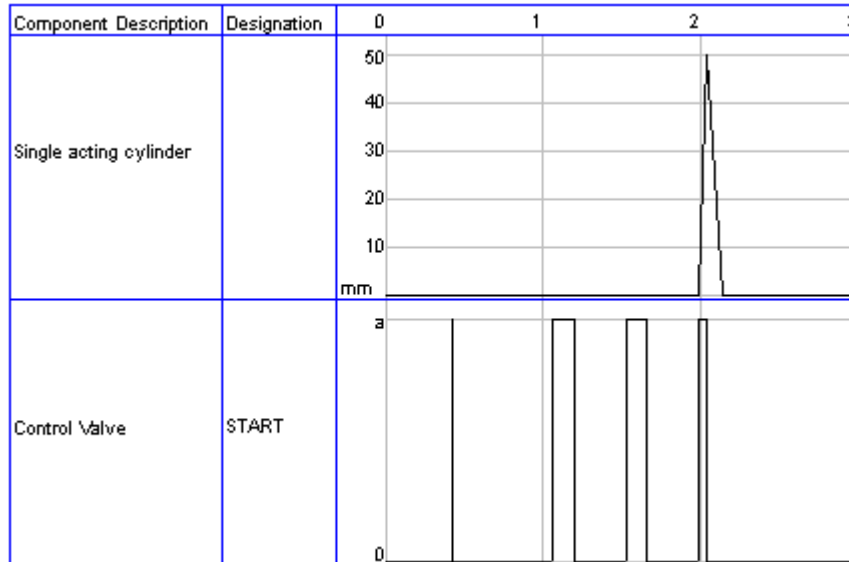


Figure C.10: State diagram for Example C.5.

Example C.6:

Continuing on Example C.3 design a circuit such that the cylinder will advance only if the system's pressure at least 4 bars.

The pneumatic circuit and parts' list needed to perform this operation are shown by Figure C.11.

Designation	Component Description
	Two pressure valve
Control Valve	Control Valve
START	START PB
LS1	Limit switch 1
LS2	Limit switch 2
	Compressed air supply
	Double acting cylinder
Pressure Sequence Valve	Pressure sequence valve

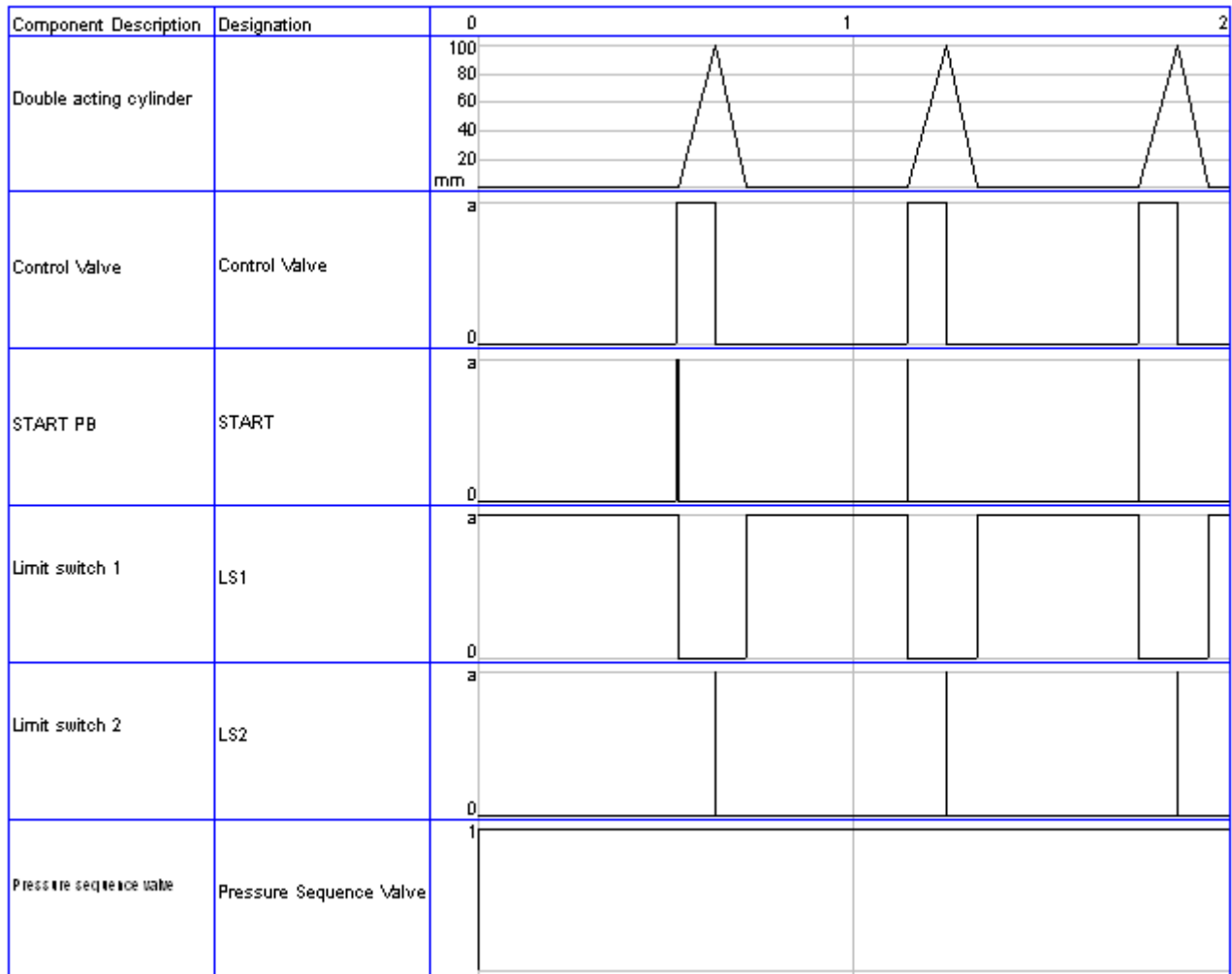


Figure C.12: State diagram for Example C.6.

Example C.7:

Design a circuit such that a single acting cylinder will advance slowly upon pressing a "Start" push button and retract upon releasing it.

(Use a 3/2 manually actuated spring returned valve and a throttle valve for the speed control)

The pneumatic circuit and parts' list needed to perform this operation are shown by Figure C.13.

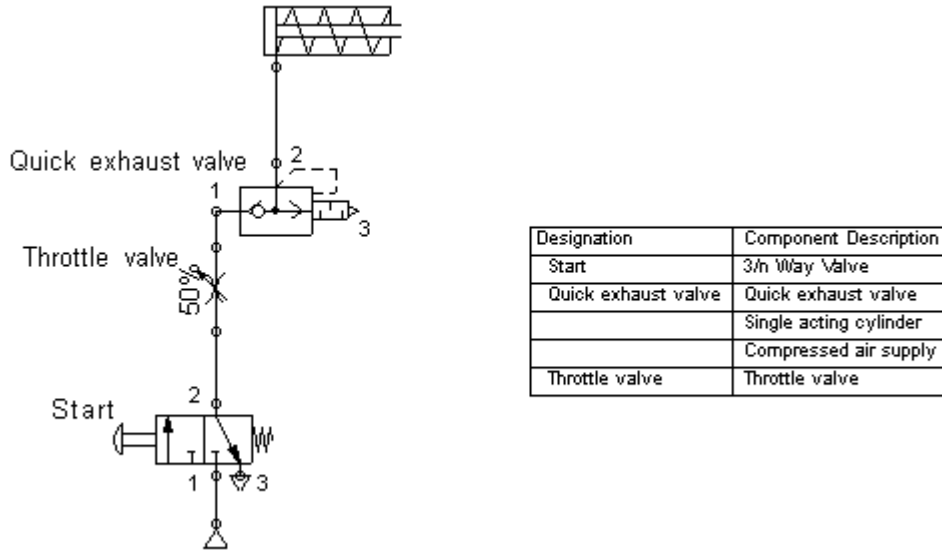


Figure C.13: Pneumatic circuit and parts' list for Example C.7.

Figure C.14 shows the circuit's state diagram.

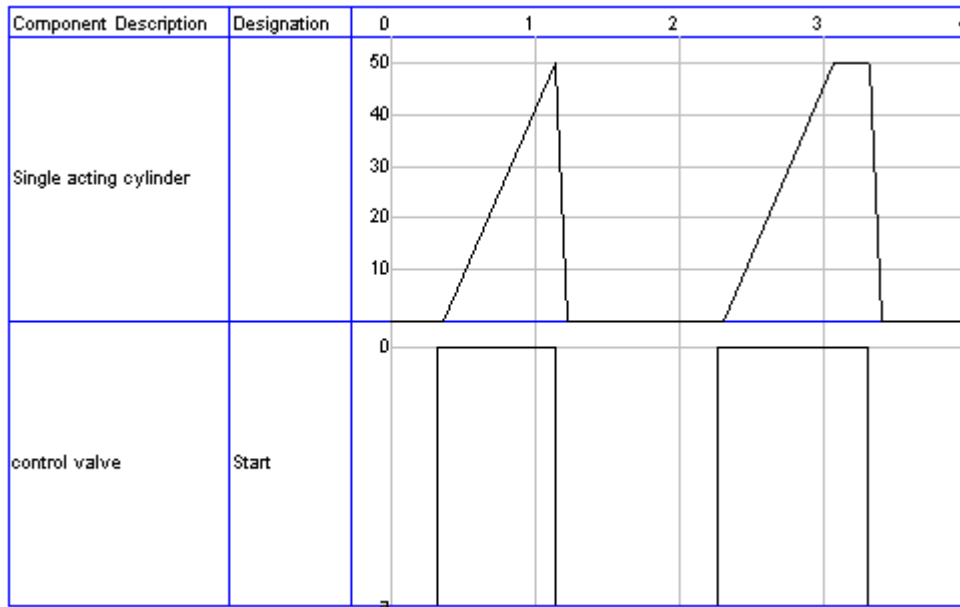


Figure C.14: State diagram for Example C.7.

Using the throttle valve as shown by Figure C.13 should have reduced the speed of the cylinder in both direction. But it is obvious from Figure C.14 that the speed of the cylinder has been slowed down only on the forward stroke. The reason for that is the use of the quick exhaust valve. As long as the pressure is supplied at port 1 of the quick exhaust valve, the flow will be from port 1 to 2. However, once "Start" is released the pressure will be at port 2, in this case the pressure will flow from port 2 to 3 (directly to the surroundings) without passing the throttle or the control valve.

Exercises

For the following two exercises, design the pneumatic circuit, add the parts' list and the state diagram and label all your components.

Exercise 1:

A double acting cylinder is to advance *slowly* upon pressing "PB1" push button *if* the cylinder is fully retracted. And will retract after *waiting 2 sec* upon pressing "PB2" push button *or* upon reaching its full extent.

(Use a 5/2 pneumatically actuated control valve and use proximity switches to detect the position of the cylinder)

Exercise 2:

A double acting cylinder is to advance upon pressing "PB1" push button 5 times *if* the cylinder is fully retracted. And will retract upon pressing "PB2" push button after it has reached its rear position.

(Use a 5/2 pneumatically actuated control valve and use limit switches to detect the position of the cylinder)