CZECH TECHNICAL UNIVERSITY IN PRAGUE

FACULTY OF MECHANICAL ENGINEERING

DEPARTMENT OF INSTRUMENTATION AND CONTROL ENGINEERING

MASTER’S THESIS IN INSTRUMENTATION AND CONTROL ENGINEERING

Control and Visualization of the Pneumatic Drives Applications

AYDIN ELBIRLIK

PRAGUE 2021

SUPERVISOR: ING. MARIE MARTINÁSKOVÁ, Ph.D.

STATEMENT

I declare that I have worked out this thesis independently, assuming that the results of the thesis can also be used at the discretion of the supervisor of the thesis as its co-author. I also agree with the possible publication of the results of the thesis or its substantial part provided I will be listed as the co-author.

Prague, 2021

Signature: ______________________

ANNOTATION

Title: Control and Visualization of the Pneumatic Drives Application

Aim: Converting the circuits to GRAFCET language, simulating it, and visualizing them

Methods: To simulate the circuits Festo FluidSIM® software used. To convert the sequences into GRAFCET language the built-in module in Festo FluidSIM® was used. Reliance SCADA software is used for visualization for the sequences.

Results: Same results were achieved with GRAFCET language and electro pneumatics simulations

Keywords: Pneumatics, PLC ,Vacuum Technology, FluidSIM®, RELIANCE SCADA, GRAFCET, electropneumatics, Visualization.

LIST OF ABBREVIATIONS

A: MOTOR_A

B: MOTOR_B

A+, B+, C+ ……… Pneumatic motor A, B, C forward movement

A-, B-, C- ………… Pneumatic motor A, B, C backward movement

TAU x ……………………Time delay of x seconds

PLC: Programmable Logic Controller

SCADA: Supervisory Control And Data Acquisition

SFC : Sequential Function Chart

Contents

1.INTRODUCTION

In this project 8 circuits with different sequences were given. For the control and simulation of the circuits, GRAFCET language in fluidsim were used. With this tool fine control and easy modifications were possible. In the second part SCADA program Reliance 4 was used for visualizing one of the sequences. More detailed descriptions of the tasks will be given with the schematics.

1.1 Thesis Guidelines

Title:

Didactic tasks in the GRAFCET language for the virtual PLC (Programmable Logic Controller) in the FluidSIM® software.

Description of the tasks:

1. Study thoroughly the syntax and the sémantics of the GRAFCET language.
2. Study all the tasks for the advanced electropneumatics in the FluidSIM®.
3. Study all the tasks for the vacuum technology in the FluidSIM®.
4. Prepare the set of the didactic tasks (at least 8 tasks) programmed in the GRAFCET language for the virtual PLC in the FluidSIM® with the respect to the particular modes of the virtual machine.
5. Prepare also visualization project for at least one of the tasks chosen.

Literature and sources recommended:

Martinásková, MOODLE: course B191-E371524 - Instrumentation for Automatic Control, Ladder Diagram in the FluidSIM®

Martinásková, MOODLE, course B191-E371524 - Instrumentation for Automatic Control, FluidSIM_AJ_v2

Martinásková, MOODLE, course B191-E371524 - Instrumentation for Automatic Control, Application Examples in Electropneumatics

Martinásková, MOODLE, course B182-E371135 - Programmable Logic Controllers and Visualization

Martinásková, MOODLE, course B182-2371509 - Prostředky automatického řízení II_MM, GRAFCET

Martinásková, MOODLE, course B182-E371509 - Instrumentation for automatic control lI_MM, Vacuum_technology-slides

Martinásková, MOODLE, course B182-E371509 - Instrumentation for automatic control lI_MM, Basics_of_vacuum_technology_V1_slides

Software FluidSIM® Pneumatic, sublibrary: GRAFCET

Software FluidSIM® Pneumatic, sublibrary: Advanced Electropneumatics, TP202

Software FluidSIM® Pneumatic, sublibrary: Vacuum Technique TP230

Fundamentals of vacuum technology. Festo Didactic, 567258 EN, Workbook TP230.

Festo Didactic: Easy Port, User Manual

2. GRAFCET LANGUAGE

GRAFCET is a language that was developed in France. Its purpose of development is to have a uniform description tool for automation and its related systems. European standard DIN EN 60848 was created from this development.

The chart consists of elements called steps, transitions and actions. This chart may represent control system or a part of it.[1] A number of actions can be assigned to a particular step. These actions can will be activated when the step is active. The part of the chart where we can insert conditions is called transition nodes. If the conditions are met, in a transition node program will move to next step. With this way the actions of a control system can be shown in a standardized way.

2.1 Elements of GRAFCET language

2.1.1 Steps

The structure of a GRAFCET consists of at least one step and the step enabling condition, or what is known as the transition. There is always at least one initial step, which is also referred to as starting step. İnitial step is activated as soon as the GRAFCET is started. This makes the step part of what is referred to as the initial situation.[2] After activating and performing and action a step deactivates and stay deactivated until the next loop or they are called again. Another property of steps is called the labels. The step label in the step symbol is also the name of the step variable. In fluidsim there are seven different step types: simple step, initial step, macro-step, macro input, macro output, enclosing step and initial enclosing step

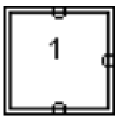

Figure 1 Initial step[2]

2.1.2 Transitions

Transitions connect the first step to the next one. They have Boolean conditions for activating. The result of the transition condition for a transition determines the transition as soon as the transition is released. If a transition is released and the transition condition returns the value *True*, then the transition to the subsequent step takes place, otherwise not.[2]Following operations can be used.

*	AND operation	S1*S2: Condition is true if S1 = 1 and S2 = 1
+	OR operation	S1+S2: Condition is true if S1 = 1 or S2 = 1
!	Negation	S1*!S2: Condition is true if S1 = 1 and S2 = 0
↑	Rising edge	S1*↑S2: Condition is true if S1 = 1 and there is a rising edge for S2.
↓	Falling edge	S1*↓S2: Condition is true if S1 = 1 and there is a falling edge for S2.

In addition to Boolean operations time conditions can be entered into a transition. On and off delays can also be entered in a transition.

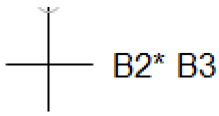

Figure 2 AND condition in a transition[2]

2.1.3 Actions

Actions represent the output of the system. One or more actions may be assigned to each step. There are three types of action: assignations, allocations and compulsory commands.

For a "conditional action" or an "*Action on event*", a condition should be entered that has to be fulfilled before the action is executed. (AND, OR, NOT, falling edge, rising edge, delay) Boolean operators can be chosen.

For an allocation a Boolean term must be entered whose value is to be allocated to the action variable.

For a "compulsory command", the name of the partial GRAFCET should be directly entered.[3]

2.2 Sequence Types

There three main sequence types that is used in GRAFCET: Linear, Parallel and Alternative.

2.2.1 Linear Sequence

In linear sequence steps and transitions moves in a subsequent way. Steps are followed by transitions without any branching out.

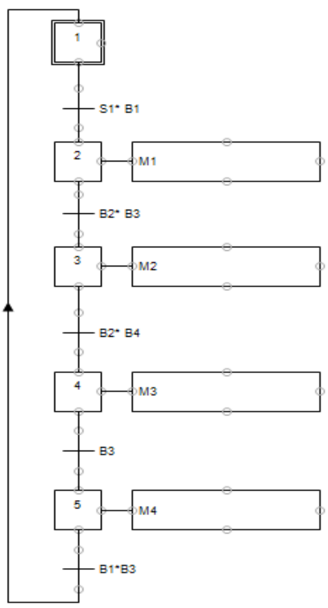

Figure 3 A linear sequence

2.2.2 Parallel Sequence

A parallel sequence is used when several sequences need to be started simultaneously after a transition. The first steps in the partial sequences are activated simultaneously by a transition here. The partial sequences then remain independent. At the end, the partial sequences connects to a synchronisation symbol and a subsequent transition. The partial sequences are also synchronised at the end.[3]

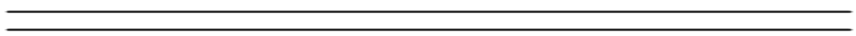

Figure 4 Synchronization symbol

2.2.3 Alternative Sequence

If only one process is to be done alternative sequence is used. For this reason starting transitions of the branches need to be mutually exclusive. Failing this the behaviour of the program stays inconclusive. Alternative Branching starts and ends with a transition.

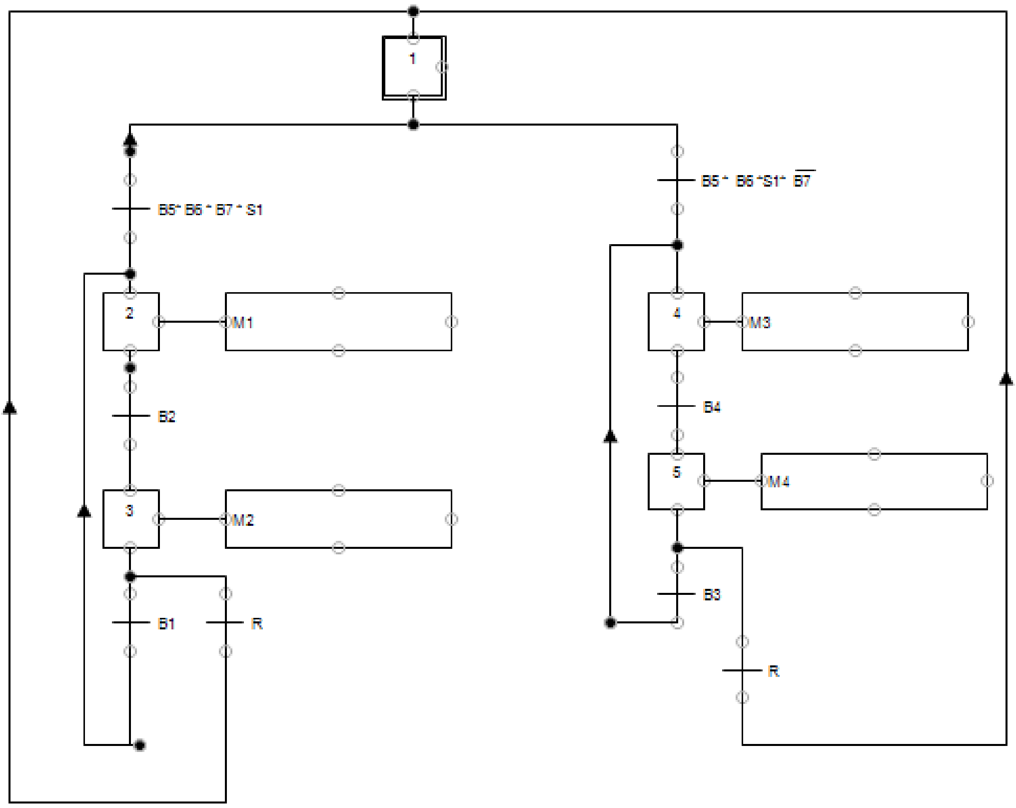

Figure 5 An Alternative Sequence

2.3 Macro Steps

Macro steps are used to keep the charts compact and easy to view. A macro step has a starting step and an ending step. Once the process inside the macro is finished sequence proceeds normally.Input is symbolised by a E and output by a S

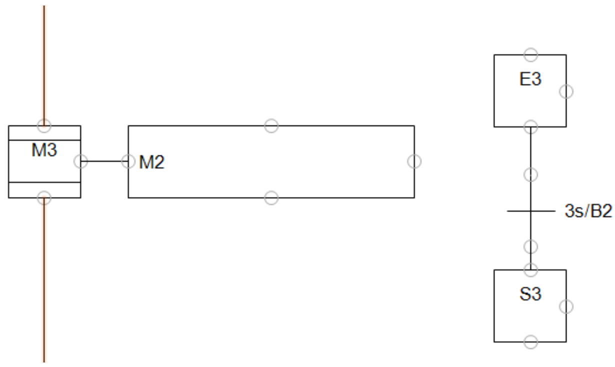

Figure 6 A Macro Step

2.4 Enclosing Steps

Enclosing steps are similar in function to macro steps. The difference is enclosing steps activates a group of partial GRAFCET charts. The charts run in parallel until the enclosing step is deactivated.

2.5 Forced Commands

Forced commands are used when the normal sequence needs to be overridden (eg. Alarms resets etc.)

There are 4 kinds of forced commands in GRAFCET language these are:

1 Forcing to the current situation:
This variant of the command is defined in the curly brackets. The character "*" is indicated in the view. This means that the forced command is keeping the sequence in its presen situation.[2]

2 Jumping to a certain step:

This command forces the chart to move to a certain step indicated between the brackets.eg G5{10}

3 Forcing to empty state:

If the brackets are left empty the sequence moves to a empty state.eg G{}. As long as the command is active all the steps stay deactivated.

4 Forcing to Initial Condition:

G{INIT} command forces all the sequence to the initial steps in the chart.

3.ELECTROPNEUMATICS

3.1 Valves

3.1.1 3/2 Way Pneumatic valves

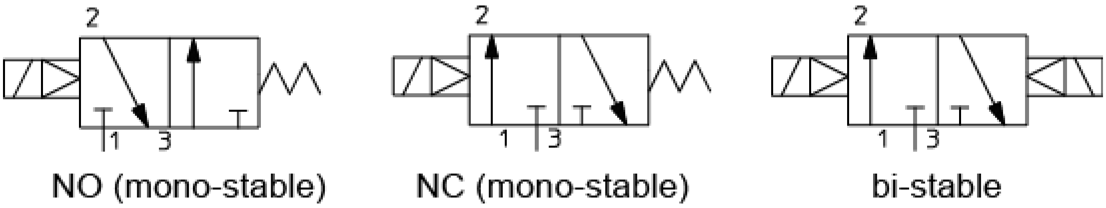

Figure 7 Symbols of 3/2 valves [4]

The 3/2-way pneumatic valve has three connection ports and two states. The three ports are:

inlet (P, 1),

outlet (A, 2)

exhaust (R, 3)

The two states of the valve are open and closed. Air flows from the inlet (P, 1) to theoutlet when the valve is open (A, 2). Air flows from the outlet (A, 2) to the exhaust when the valve is closed (R, 3). A valve that is closed in non-actuated state is normally closed (N.C.), the opposite is called normally open (N.O.).

The two states of the valve are open and closed. The air flows from the inlet (P, 1) to the outlet when the valve is open (A, 2). Air flows from the outlet (A,2) to the exhaust when the valve is closed (R, 3). A valve that is closed in non-actuated state is normally closed (N.C.), the opposite is called normally open (N.O.). 3/2-Way valves are suitable for driving pneumatic actuators, blow-off, pressure release and vacuum applications.[4]

Figure 8 Festo 3/2 single solenoid valve[9]

3.1.2 5/2 Way Pneumatic Valve

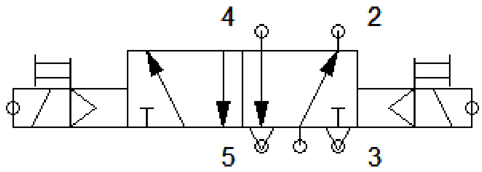

Figure 9 5/2 bistable piloted valve[4]

There are five ports of connection and two states in the 5/2-way pneumatic valve. It has one pressure port (P,1), two ports (A,2) that connect to the device that needs to be controlled, and two exhaust ports (EA,3) and (EB,5). Mono-stable 5/2h-way valves, when they are not actuated, return to their rest position. Using a spring, the valve returns to its resting place. Bi-stable 5/2-way valves keep their position if pressure is lost, and require a separate action to switch the valve to a safe position. 5/2-way valves are used to actuate double acting pneumatic actuators and rotary actuators.[5]

3.2 Relays

3.2.1 Relay

The relay picks up immediately when current is supplied and drops out immediately when current is removed.

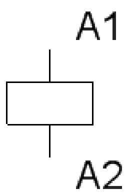

Figure 10 Relay[3]

3.2.2 switch-on delay relay

The relay picks up after a preset time when current is supplied and drops out immediately when current is removed.[6]

3.2.3 switch off delay relay

The relay picks up immediately with the current and drops after a preset time after the current is stopped.

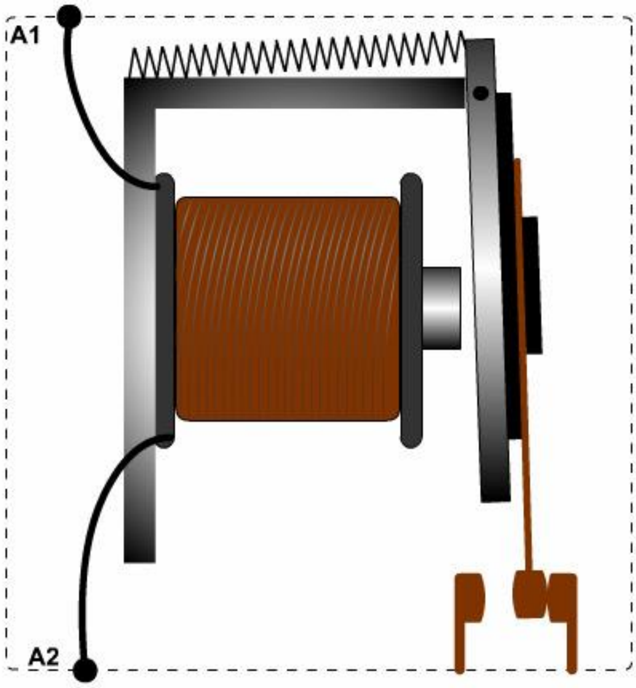

Figure 11 Schematics of a relay[10]

3.3 Actuators

3.3.1 Double acting cylinder

Pressurised air can flow through both sides of the cylinder in a double-acting cylinder and drive the piston forward and backward. Two cylinder ports are connected via a valve to the air supply and the piston can extract and retract when the air flow is reversed. A solenoid for proximity switch[6] may be present in the piston of the cylinder.

Figure 12 Festo Double acting cylinder[9]

3.3.1 Single acting cylinder

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 with a return spring. Single acting cylinders have a single connection to the air supply.

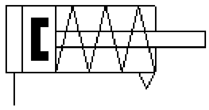

Figure 13 Single acting cylinder symbol [6]

Figure 14 Festo single acting cylinder[9]

3.4 One way flow control valve

In one way flow control valves flow can only go in one direction. This direction can be controlled by the way the valve is connected. The amount of air going through can be controlled by a rotary knob. With this method the air flow can be controlled without any additional user input.

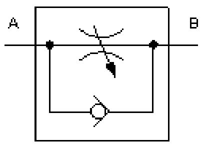

Figure 15 One way flow valve[3]

3.5 Pressure switch

Pressure switch detects the pressure and activates the switch if the certain threshold value is exceeded.[6]

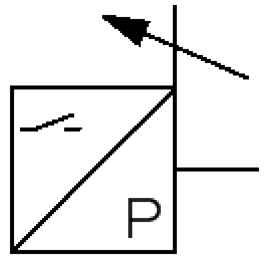

Figure 16 Pressure switch[3]

3.6 Vacuum Gauge

Depending on the application there are different types of vacuum gauges that can be chosen. Generally if the application does not require high vacuum mechanical types can be chosen. Some of the types are following:

3.6.1 Bourdon Vacuum Gauge

A circular shaped tube is inside gauge. Due to atmospheric pressures the tube is bent and a pointer connected to the tube can show the pressure with the help of this bending

3.6.2 Diaphragm Vacuum Gauge

In this type of gauge there is a sealed diaphragm between vacuum chamber and outside. The displacement on this diaphragm can be measured by means of strain gauges, pointers or a lever.

3.6.3 Capacitance Vacuum Gauge

Similar to the diaphragm vacuum gauge a diaphragm is used in this kind of gauge. With the help of a plate a capacitor is created. The changes in capacitance gives the pressure differential.

3.6.4 Thermal conductivity Gauge

The working principle of this kind of gauge is as following: A filament heat source radiates heat and the temperature change is measured. Since heat transfer depends on the pressure of the gas, the pressure can be calculated. A disadvantage of this method is all the thermal properties of the gas must be known.

3.6.5 Cathode Ionization Vacuum Gauge

This method is used for precise measurements. The gas that is to be measured is ionized and resulting positive ion current is measured. With this method pressures as low as 10^{-10}mbar/Torr can be measured.[7]

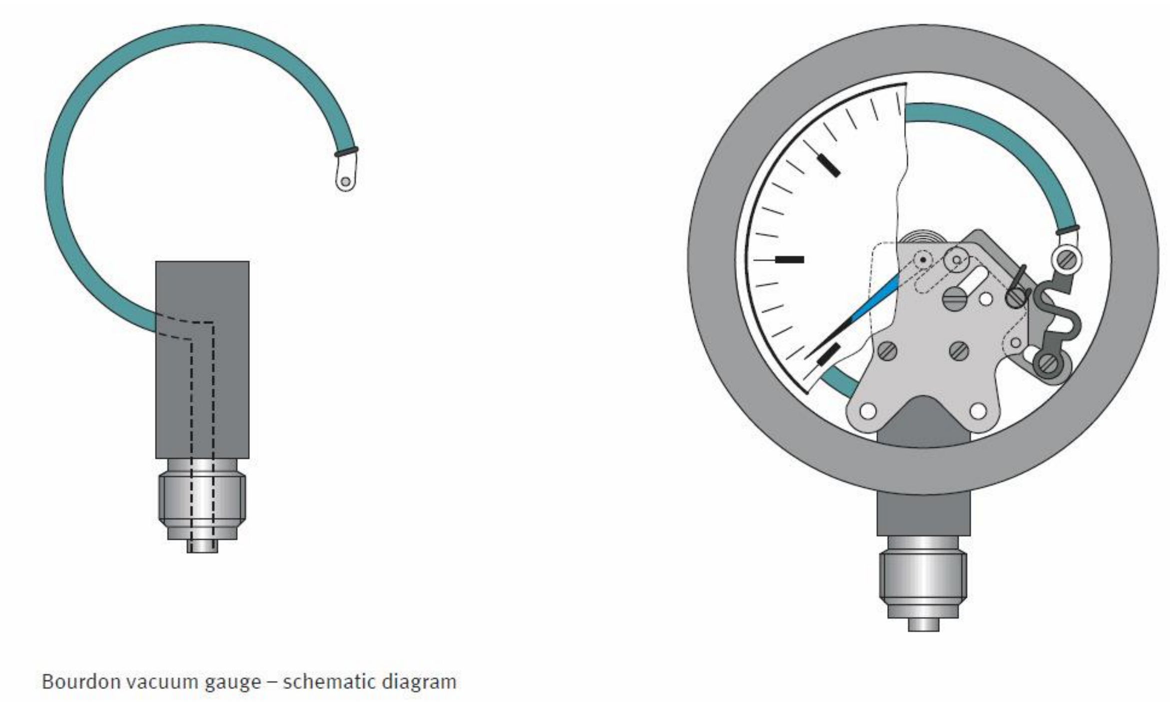

Figure 17 Bourdon vacuum gauge [7]

3.7 Vacuum generator

For applications that does not need high vacuum a vacuum generator may be used. This kind of generators work with venturi principle. Air entering from inlet 1 increase its speed because of the choke point. This speed difference causes a pressure differential on 2 creating a vacuum. These kind of simple generators are able to reach around 85% efficiency.[8]

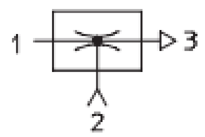

Figure 18 Vacuum generator[3]

3.8 Vacuum suction cups

There are different kinds of suction cups depending on surface finish and function. Standard suction cups are good for flat surfaces while deep suction cups are used for more round surfaces. Bellows suction cups are used for more elaborate shapes. Oval suction cups are good for slim oblong pieces.

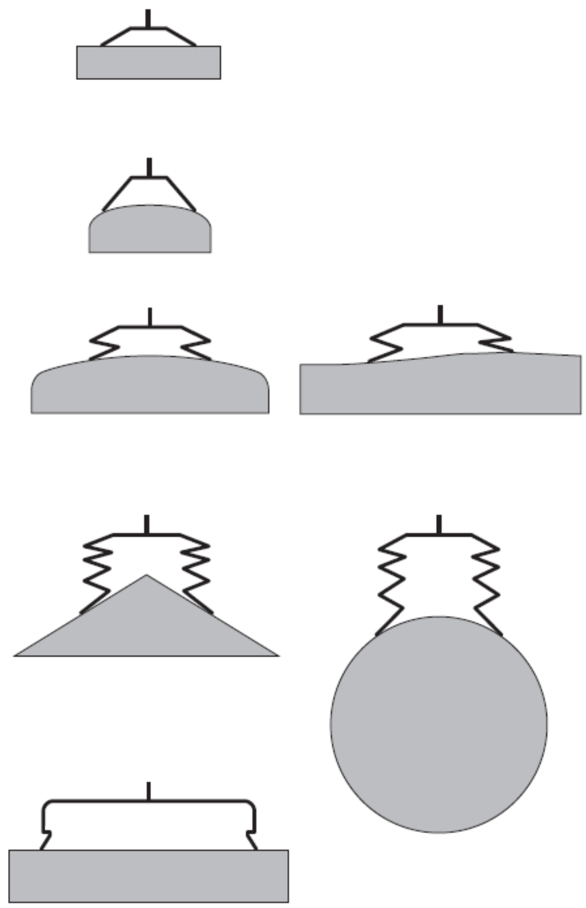

Figure 19 Various types of suction cup[8]

3.9 Vacuum security valves

When suctions cups are used in series, failure to grip for one suction cup causes vacuum to collapse in all of the system. To prevent this security valves are installed between vacuum generator and suction cup. During the operation if a suction cup fails to grip the material , security valve stops the air for that particular suction cup.

3.10 Sensors

3.10.1 Roll switch

Switch that is opened by a cam attached to the cylinder rod. The switch closes immediately when the cam has passed the switch.

3.10.2 Magnetic proximity sensor

This switch is activated by a magnetic field.

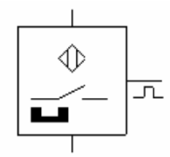

Figure 20 Magnetic switch[3]

3.10.3 Capacitive proximity switch

It detects the changes in the electro static field, allowing it to detect any object with a density greater than air.

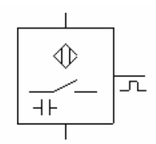

Figure 21 Capacitive proximity switch[3]

3.10.4 Inductive proximity switch

It detects the induced electromagnetic field allowing it to detect metallic objects.

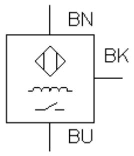

Figure 22 Inductive proximity switch[3]

3.10.5 Optical switch

If the light barrier is interrupted this switch closes.[6]

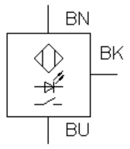

Figure 23 Optical switch[3]

4.GRAFCET APPLICATIONS

FluidSim 5

FluidSim is a broad software simulation tool to help engineers design and simulate various systems including pneumatics, hydraulics and electronic circuits. With FluidSim's extensive and configurable components, it is very efficient to debug and improve systems before realizing them. While allowing configuration on the sub components, FluidSim also offers detailed overview on the whole system with descriptive animations and text on the components. As FluidSim offers realistic behaving components to accurately simulate the circuits, diagnostic tools such as virtual measuring tools make it possible to show the internal states of the circuit without interfering it electrically as it would have been in the real world measurements. Ladder Diagram languages and GRAFCET also can be used to model subsequent actions along with FluidSim.

4.1 TASK 1(A+ A-)

In this task the purpose is to create a manually operated double acting cylinder with two push buttons. The speed of the piston is adjustable by two throttle check valves. To achieve this two conditional actions were connected to initial step.

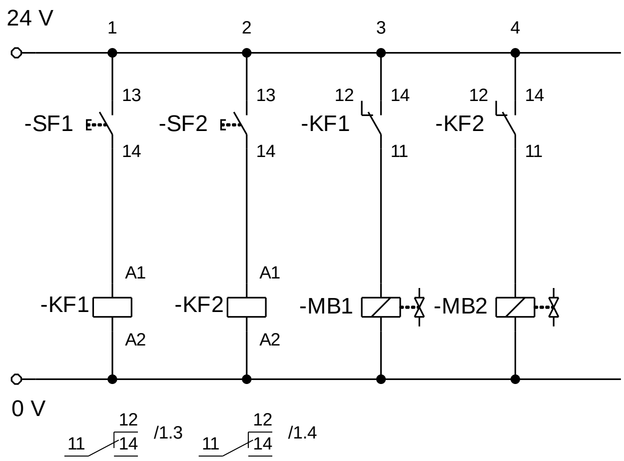

Figure 24 Task 1 electrical schematic

Pos. No.	Identification	Location	Connector Labels	Target ID from	Target ID to	Description
1	?604	/1.1				Electrical connection 24V
2	?602	/1.1				Electrical connection 0V
3	-MB1	/1.3				Valve solenoid
4	-SF1	/1.1				Pushbutton (make)
5	-KF1	/1.1				Relays
6	-SF2	/1.2				Pushbutton (make)
7	?2	/1.1				Compressed air supply
8	-RZ1	/1.1				Throttle check valve
9	-MM1	/1.1				Double acting cylinder
10	-RZ2	/1.1				Throttle check valve
11	-QM1	/1.1	-MB1, -MB2			5/2-way solenoid impulse valve
12	-KF2	/1.2				Relays
13	-MB2	/1.4				Valve solenoid

Figure 25 Task 1 Part list for electrical version

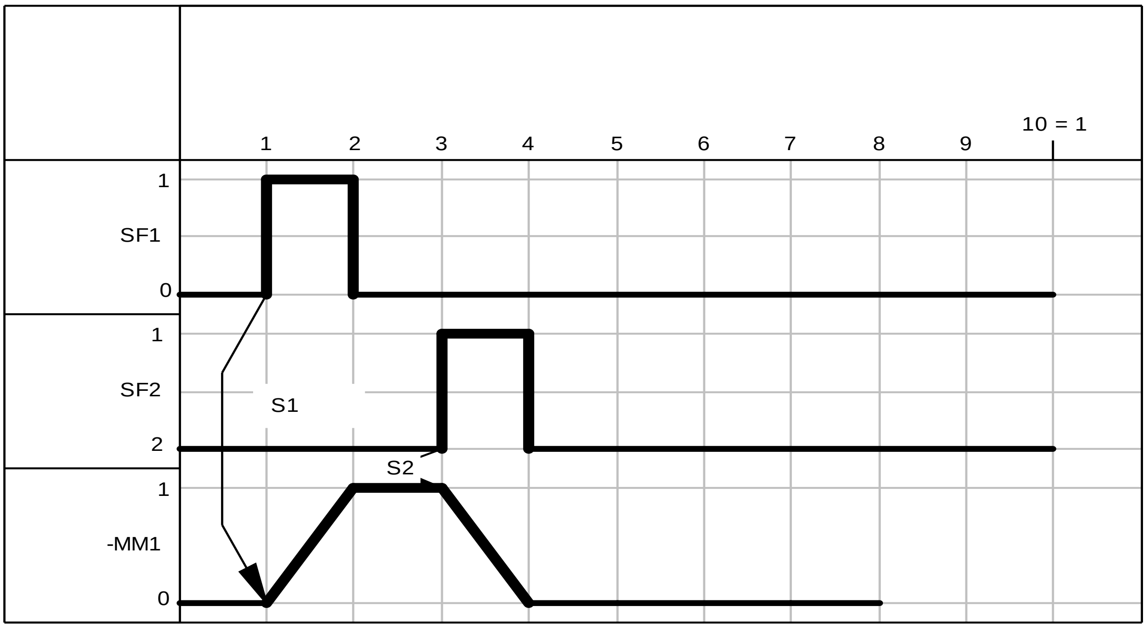

Figure 26 Functional diagram of circuit

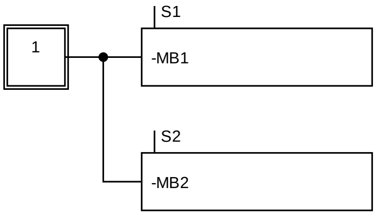

Figure 27 GRAFCET chart of task 1

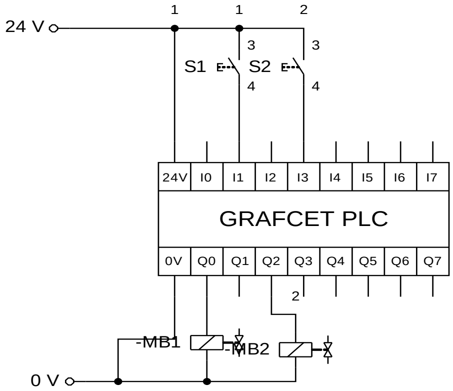

Figure 28 PLC schematics of TASK 1

Pos. No.	Identification	Location	Connector Labels	Target ID from	Target ID to	Description
1	?2	/1.1				Compressed air supply
2	-RZ1	/1.1				Throttle check valve
3	-MM1	/1.1				Double acting cylinder
4	-RZ2	/1.1				Throttle check valve
5	-QM1	/1.1	-MB1, -MB2			5/2-way solenoid impulse valve
6	S1	/1.2				Pushbutton (make)
7	S2	/1.2				Pushbutton (make)
8	?6524	/1.2				GRAFCET PLC
9	?3313	/1.1				Electrical connection 24V
10	-MB1	/1.1				Valve solenoid
11	-MB2	/1.2				Valve solenoid
12	?3318	/1.1				Electrical connection 0V
13	S1	/1.1				Pushbutton (make)
14	S2	/1.2				Pushbutton (make)

Figure 29 Part List for Grafcet version

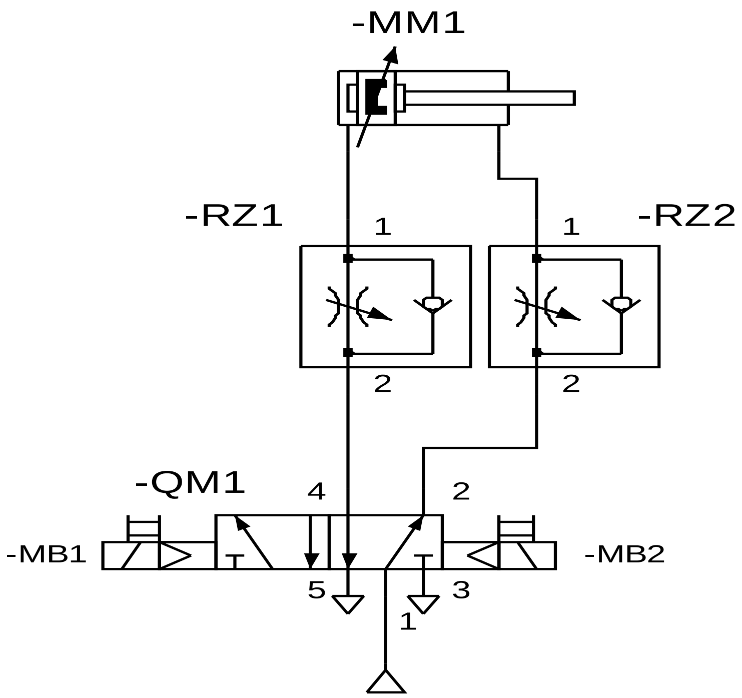

Figure 30 Physical schematics of task 1

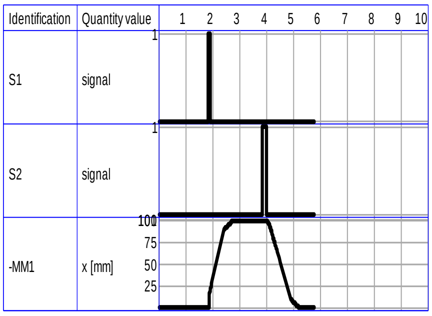

Figure 31 Grafcet state diagram

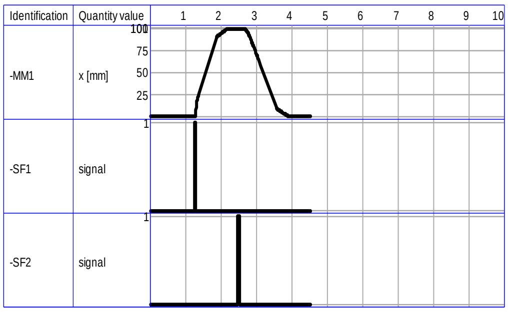

Figure 32 Electrical state diagram

From the figure we can observe both Grafcet and electro-pneumatic cases are same in regards to their response times.

4.2 Task 2 (A+ B+ A- B-)

In this task sequence is started by a push button and a sensor. Sequence is controlled by the sensors on the cylinders. After finishing the loop the sequence can be started again. Since valves are bi-stable moving chain method is used.

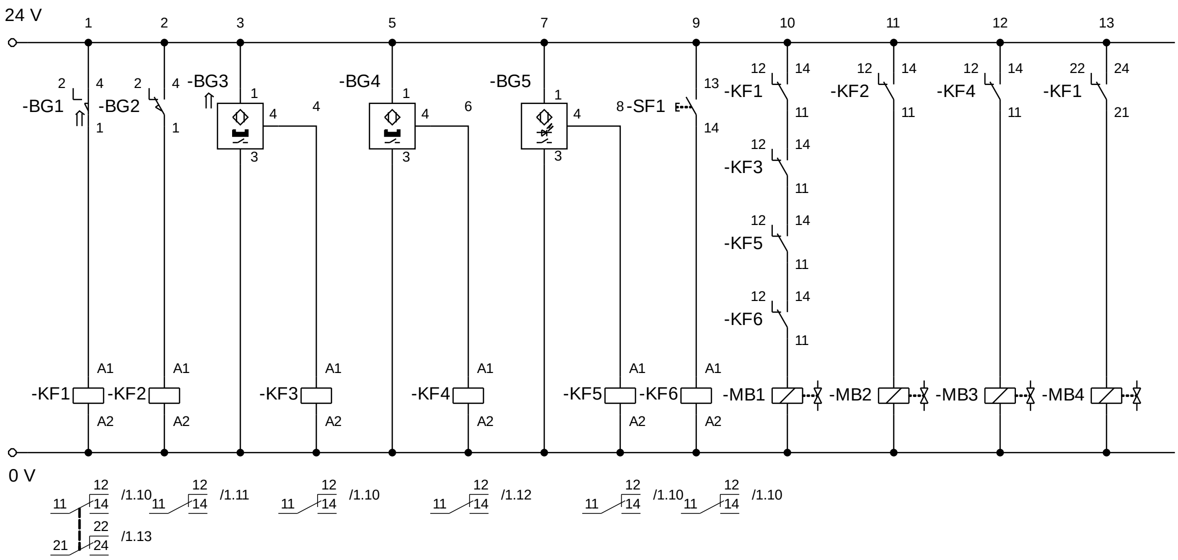

Figure 33 Electrical connections Task 2

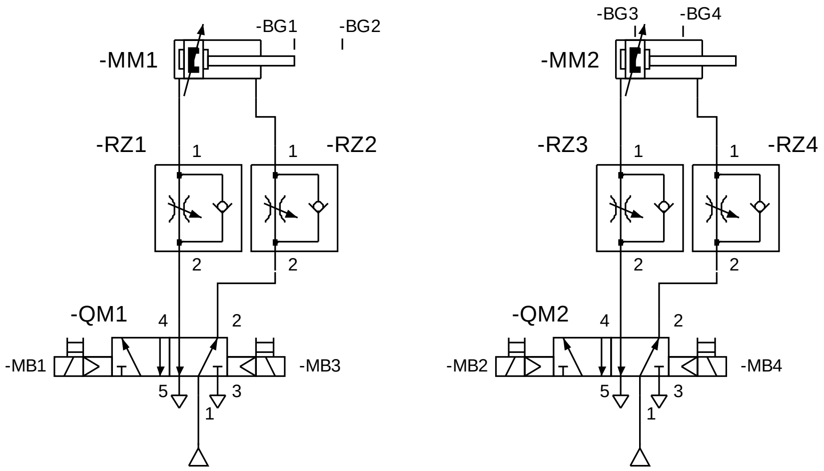

Figure 34 Pneumatic diagram for Task 2

Pos. No.	Identification	Location	Connector Labels	Target ID from	Target ID to	Description
1	?604	/1.1				Electrical connection 24V
2	?602	/1.1				Electrical connection 0V
3	-MB1	/1.10				Valve solenoid
4	-SF1	/1.9				Pushbutton (make)
5	-KF1	/1.1				Relays
6	?2	/1.2				Compressed air supply
7	-RZ1	/1.2				Throttle check valve
8	-MM1	/1.2				Double acting cylinder
9	-RZ2	/1.3				Throttle check valve
10	-QM1	/1.2	-MB1, -MB3			5/2-way solenoid impulse valve
11	-KF2	/1.2				Relays
12	-MB3	/1.12				Valve solenoid
13	-KF3	/1.4				Relays
14	-BG3	/1.3				Magnetic proximity switch
15	-BG4	/1.5				Magnetic proximity switch
16	?28	/1.6				Compressed air supply
17	-RZ3	/1.6				Throttle check valve
18	-MM2	/1.7				Double acting cylinder
19	-RZ4	/1.7				Throttle check valve
20	-QM2	/1.6	-MB2, -MB4			5/2-way solenoid impulse valve
21	-MB2	/1.11				Valve solenoid
22	-MB4	/1.13				Valve solenoid
23	-KF4	/1.6				Relays
24	-KF5	/1.8				Relays
25	-KF6	/1.9				Relays
26	-BG5	/1.7				Optical proximity switch

Figure 35 Task 2 Parts list

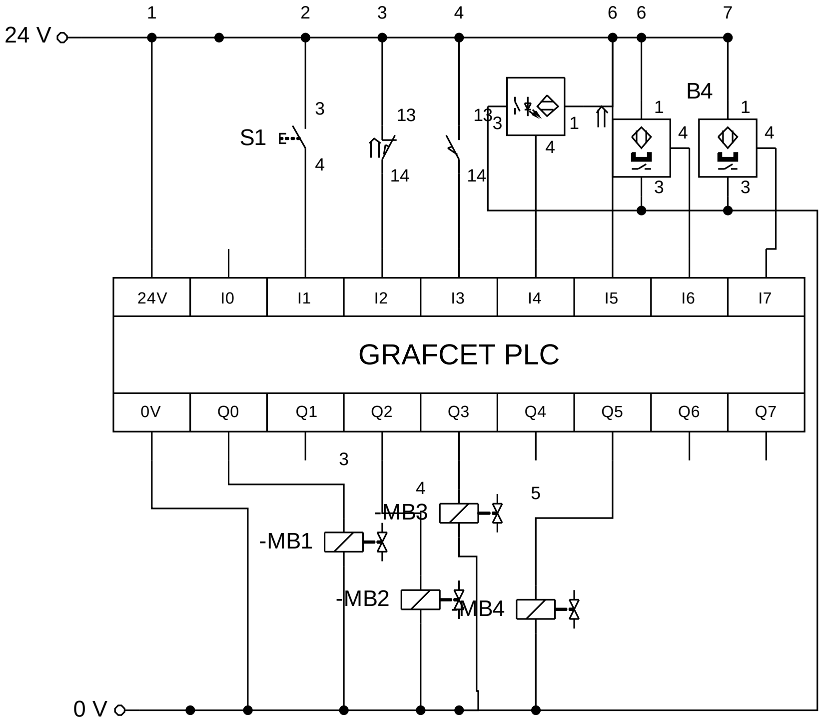

Figure 36 PLC Connection Schematics for the circuit

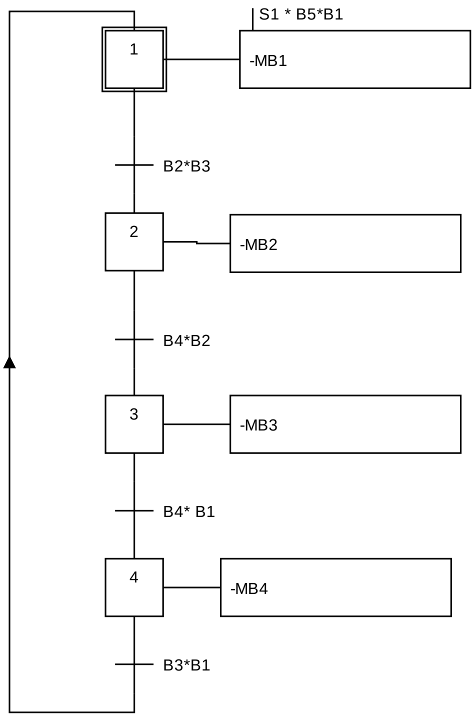

Figure 37 Grafcet Structure for task 2

Since the task is a recurring loop activated by an optical sensor and a pushbutton a linear structure is used. Once the loop returns to initial position and if B5 is active it can be restarted again.

Pos. No.	Identification	Location	Connector Labels	Target ID from	Target ID to	Description
1	?2	/1.1				Compressed air supply
2	?-RZ1	/1.1				Throttle check valve
3	?-MM1	/1.1				Double acting cylinder
4	?-RZ2	/1.1				Throttle check valve
5	?-QM1	/1.1	-MB1, -MB3			5/2-way solenoid impulse valve
6	?28	/1.1				Compressed air supply
7	?-RZ3	/1.1				Throttle check valve
8	?-MM2	/1.1				Double acting cylinder
9	?-RZ4	/1.1				Throttle check valve
10	?-QM2	/1.1	-MB2, -MB4			5/2-way solenoid impulse valve
11	?6524	/1.4				GRAFCET PLC
12	?3313	/1.1				Electrical connection 24V
13	-MB1	/1.3				Valve solenoid
14	-MB2	/1.4				Valve solenoid
15	?3318	/1.1				Electrical connection 0V
16	S1	/1.2				Pushbutton (make)
17	-MB3	/1.4				Valve solenoid
18	-MB4	/1.5				Valve solenoid
19	B5	/1.5				Optical proximity switch
20	B3	/1.7				Optical proximity switch
21	B4	/1.7				Optical proximity switch

Figure 38 Part list for Gracet circuit

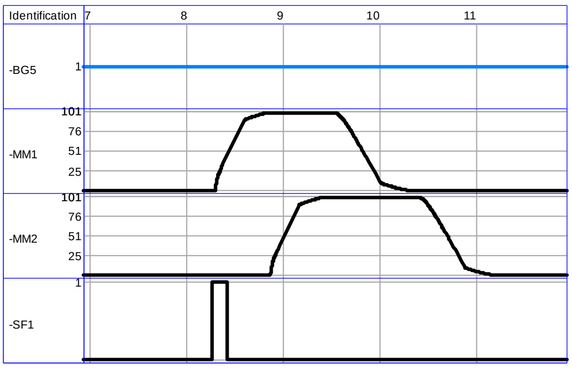

Figure 39 State Diagram(electrical)

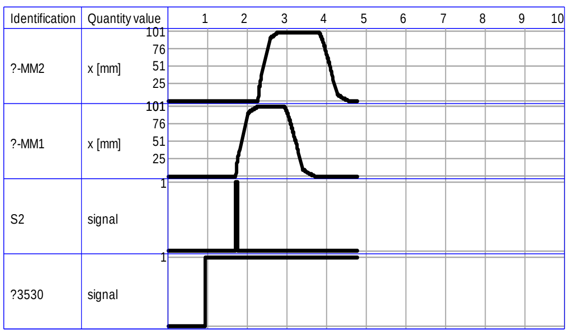

Figure 40 State diagram -(GRAFCET)

4.3 Task 3 (A+ B+ B- A-)

Sequence and is similar to Task 2. Two magnetic and two limit switch is used as sensors. Moving Chain Method was used since the bi-stable valves are used.

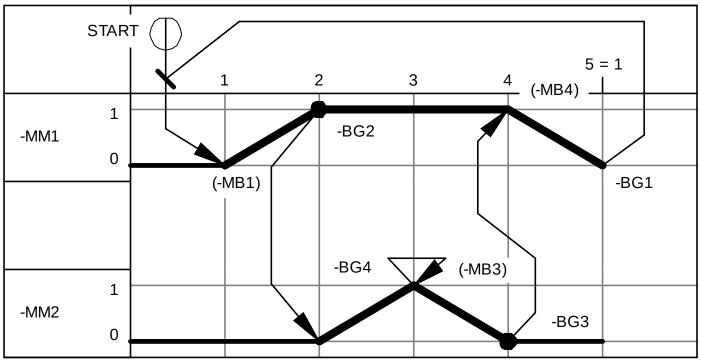

Figure 41 Functional Diagram of Task 3

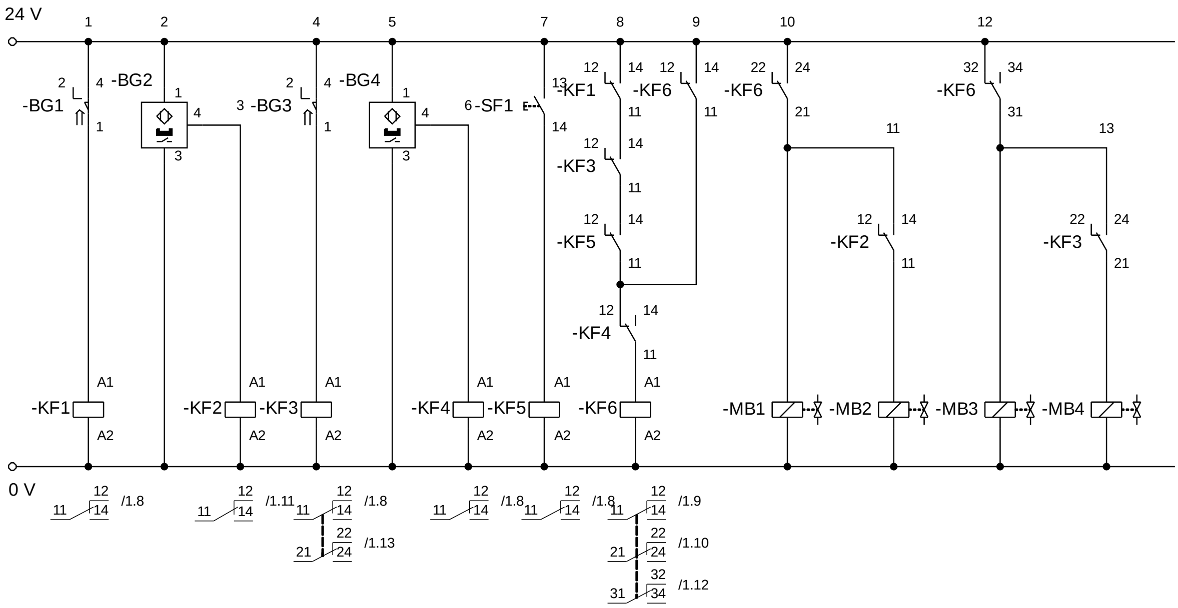

Figure 42 Electrical Schematics of task 3

Pos. No.	Identification	Location	Connector Labels	Target ID from	Target ID to	Description
1	?604	/1.1				Electrical connection 24V
2	?602	/1.1				Electrical connection 0V
3	-MB1	/1.10				Valve solenoid
4	-SF1	/1.7				Pushbutton (make)
5	-KF1	/1.1				Relays
6	?2	/1.2				Compressed air supply
7	-RZ1	/1.2				Throttle check valve
8	-MM1	/1.2				Double acting cylinder
9	-RZ2	/1.3				Throttle check valve
10	-QM1	/1.1	-MB1, -MB4			5/2-way solenoid impulse valve
11	-KF2	/1.3				Relays
12	-MB3	/1.12				Valve solenoid
13	-KF3	/1.4				Relays
14	-BG2	/1.2				Magnetic proximity switch
15	-BG4	/1.5				Magnetic proximity switch
16	?28	/1.6				Compressed air supply
17	-RZ3	/1.6				Throttle check valve
18	-MM2	/1.7				Double acting cylinder
19	-RZ4	/1.7				Throttle check valve
20	-QM2	/1.6	-MB2, -MB3			5/2-way solenoid impulse valve
21	-MB2	/1.11				Valve solenoid
22	-MB4	/1.13				Valve solenoid
23	-KF4	/1.6				Relays
24	-KF5	/1.7				Relays
25	-KF6	/1.8				Relays

Figure 43 Parts List of Electrical Circuit

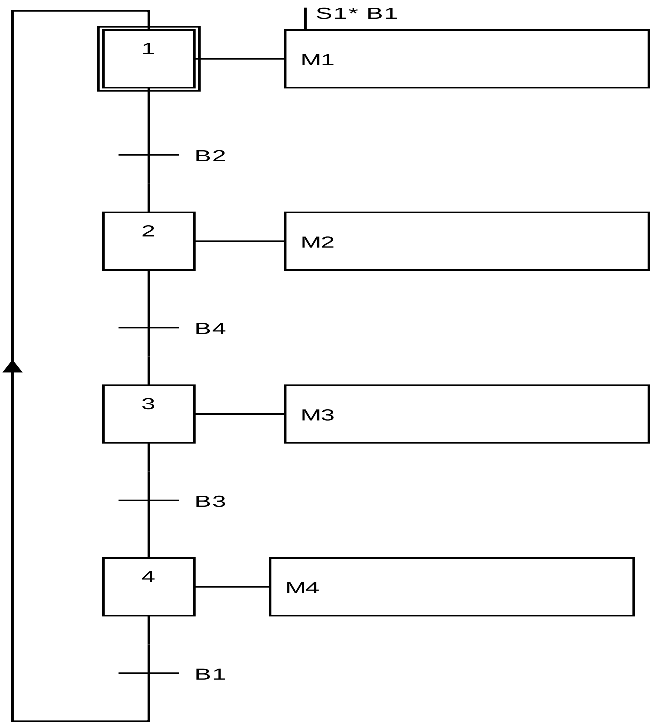

Figure 44 GRAFCET chart of task 3

A linear chart is used to create the sequence in GRAFCET.

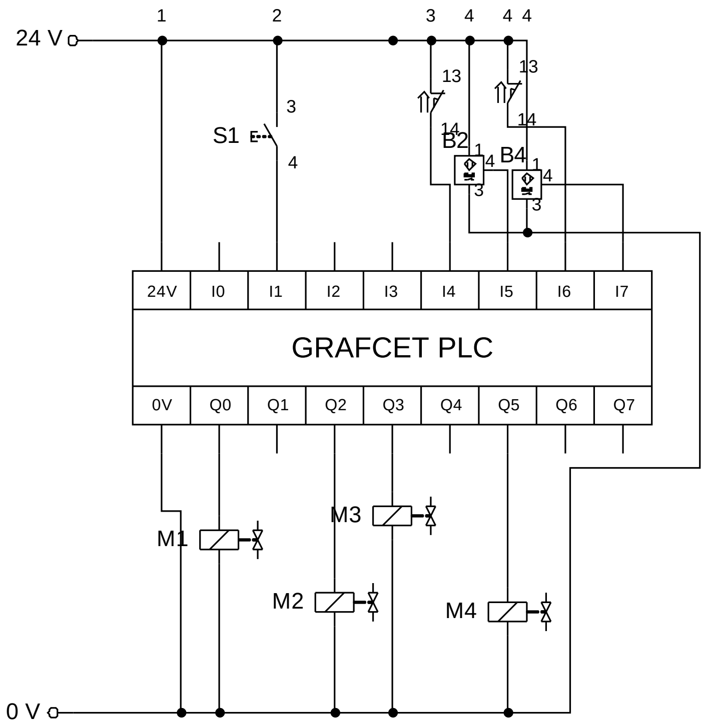

Figure 45 PLC circuit

Pos. No.	Identification	Location	Connector Labels	Target ID from	Target ID to	Description
1	?2	/1.1				Compressed air supply
2	?-RZ1	/1.1				Throttle check valve
3	?-MM1	/1.1				Double acting cylinder
4	?-RZ2	/1.1				Throttle check valve
5	?-QM1	/1.1	M1, M4			5/2-way solenoid impulse valve
6	?28	/1.1				Compressed air supply
7	?-RZ3	/1.1				Throttle check valve
8	?-MM2	/1.1				Double acting cylinder
9	?-RZ4	/1.1				Throttle check valve
10	?-QM2	/1.1	M2, M3			5/2-way solenoid impulse valve
11	S1	/1.2				Pushbutton (make)
12	?6524	/1.3				GRAFCET PLC
13	?3313	/1.1				Electrical connection 24V
14	M1	/1.2				Valve solenoid
15	M2	/1.3				Valve solenoid
16	?3318	/1.1				Electrical connection 0V
17	S1	/1.2				Pushbutton (make)
18	M3	/1.3				Valve solenoid
19	M4	/1.4				Valve solenoid
20	B4	/1.4				Magnetic proximity switch
21	B2	/1.4				Magnetic proximity switch

Figure 46 Parts List(PLC circuit)

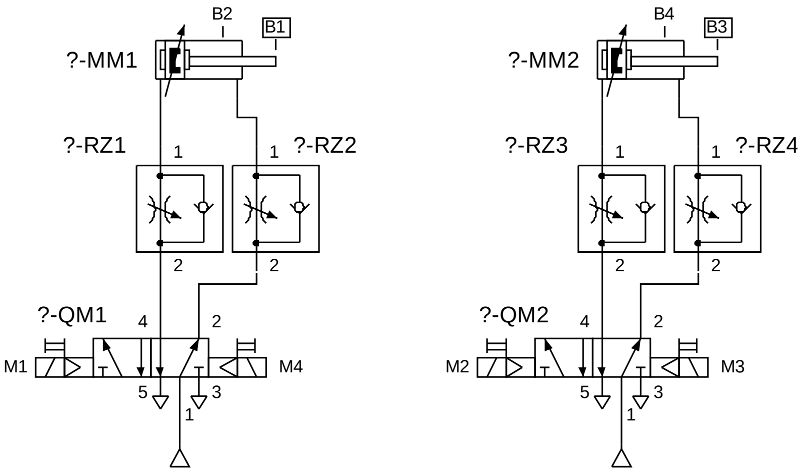

Figure 47 Pneumatic Diagram (Task 3)

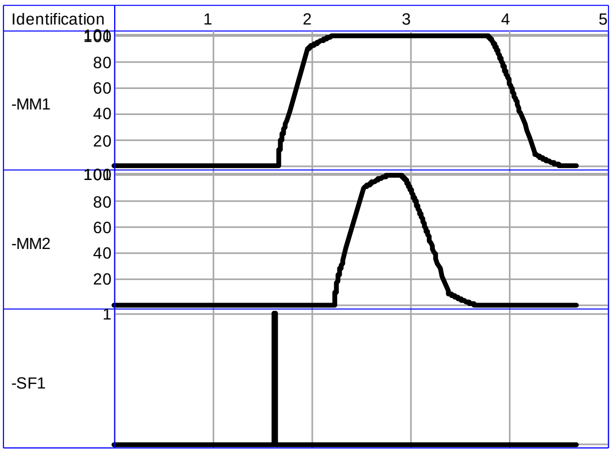

Figure 48 State Diagram (GRAFCET)

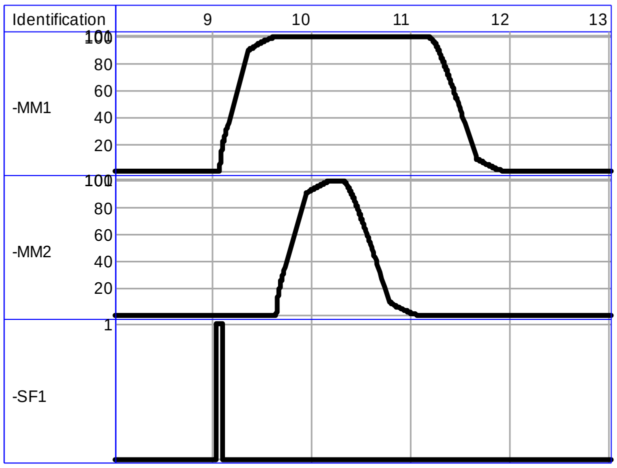

Figure 49 State Diagram (Electrical)

As it can be seen from state diagrams sequence and timing is 2.9s

4.4 Task 4(A+ B+ B- A-)

This task is done with monostable valves. In electrical circuit it is achieved with standing chain method which involves keeping the relays on for a time. In Grafcet to keep monostable valve m1 on position action had to be repeated. Only after releasing the second valve first valve could be released.

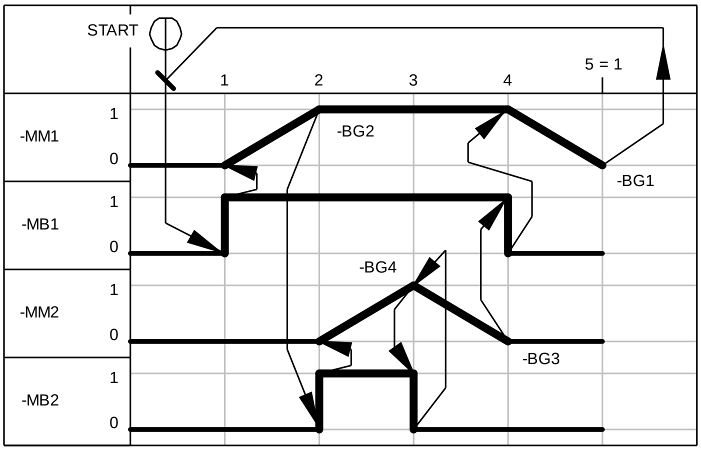

Figure 50 Functional Diagram Task 4

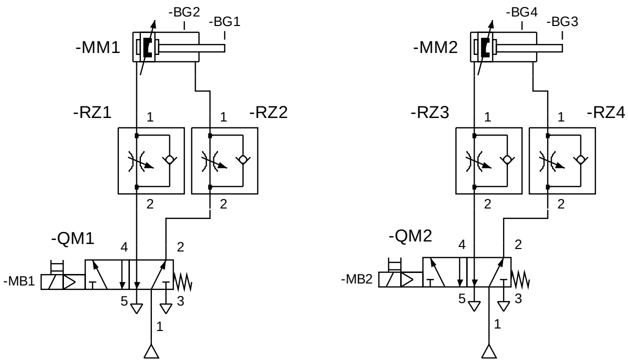

Figure 51 Pneumatic equipment

Pos. No.	Identification	Location	Connector Labels	Target ID from	Target ID to	Description
1	?604	/1.1				Electrical connection 24V
2	?602	/1.1				Electrical connection 0V
3	-MB1	/1.16				Valve solenoid
4	-SF1	/1.7				Pushbutton (make)
5	-KF1	/1.1				Relays
6	?2	/1.2				Compressed air supply
7	-RZ1	/1.2				Throttle check valve
8	-MM1	/1.2				Double acting cylinder
9	-RZ2	/1.3				Throttle check valve
10	-KF2	/1.3				Relays
11	-KF3	/1.4				Relays
12	-BG2	/1.2				Magnetic proximity switch
13	-BG4	/1.5				Magnetic proximity switch
14	?28	/1.6				Compressed air supply
15	-RZ3	/1.6				Throttle check valve
16	-MM2	/1.7				Double acting cylinder
17	-RZ4	/1.7				Throttle check valve
18	-MB2	/1.17				Valve solenoid
19	-KF4	/1.6				Relays
20	-KF5	/1.7				Relays
21	-KF6	/1.8				Relays
22	-QM1	/1.1	-MB1			5/2-way solenoid valve
23	-QM2	/1.6	-MB2			5/2-way solenoid valve
24	-KF7	/1.10				Relays
25	-KF8	/1.12				Relays
26	-KF9	/1.14				Relays

Figure 52 Part list for electropneumatic circuit

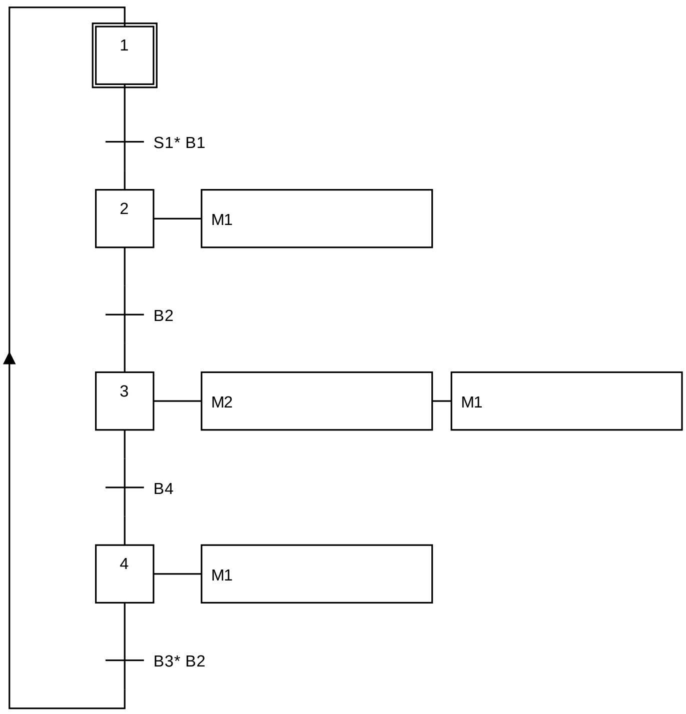

Figure 53 Grafcet program for Task 4

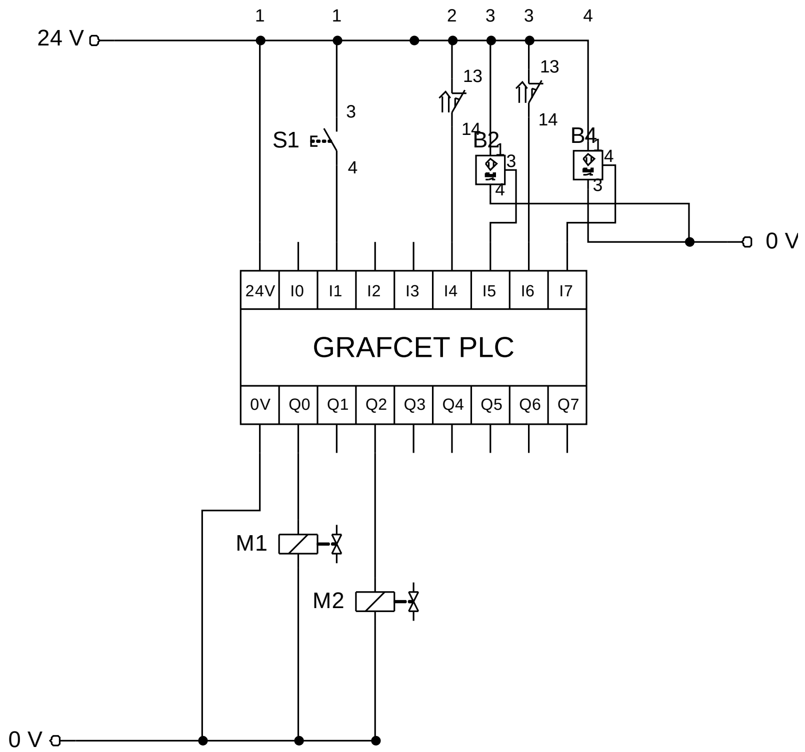

Figure 54 PLC circuit for Task 4

Pos. No.	Identification	Location	Connector Labels	Target ID from	Target ID to	Description
1	?2	/1.1				Compressed air supply
2	?-RZ1	/1.1				Throttle check valve
3	?-MM1	/1.1				Double acting cylinder
4	?-RZ2	/1.1				Throttle check valve
5	?28	/1.1				Compressed air supply
6	?-RZ3	/1.1				Throttle check valve
7	?-MM2	/1.1				Double acting cylinder
8	?-RZ4	/1.1				Throttle check valve
9	?-QM1	/1.1	M1			5/2-way solenoid valve
10	?-QM2	/1.1	M2			5/2-way solenoid valve
11	S1	/1.1				Pushbutton (make)
12	?6524	/1.2				GRAFCET PLC
13	?3313	/1.1				Electrical connection 24V
14	M1	/1.1				Valve solenoid
15	M2	/1.2				Valve solenoid
16	?3318	/1.1				Electrical connection 0V
17	S1	/1.1				Pushbutton (make)
18	B2	/1.3				Magnetic proximity switch
19	B4	/1.4				Magnetic proximity switch
20	?27	/1.4				Electrical connection 0V

Figure 55 Part List (PLC)

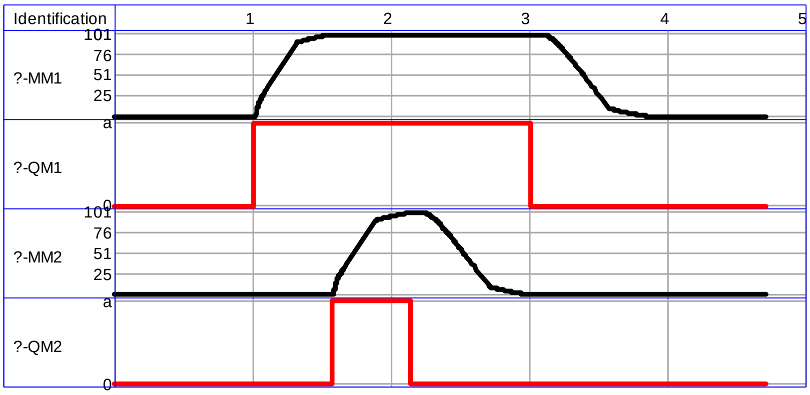

Figure 56 State diagram (GRAFCET)

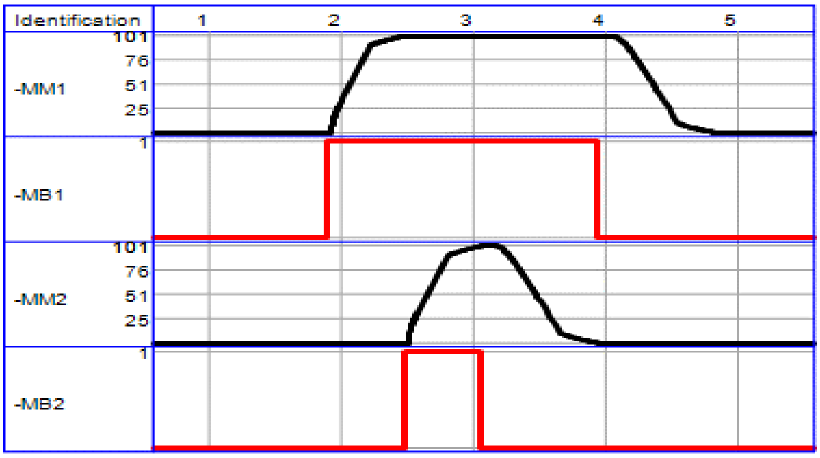

Figure 57 State Diagram (Electrical)

The sequence last 2.9s and identical for both of the cases. And signals and the response of the cylinders are also identical.

4.5 Task 5 (A+ B+ B- A+)

Task 5 is the variant of Task 4 with bi-stable valves. Instead standing chain method moving chain method is used.

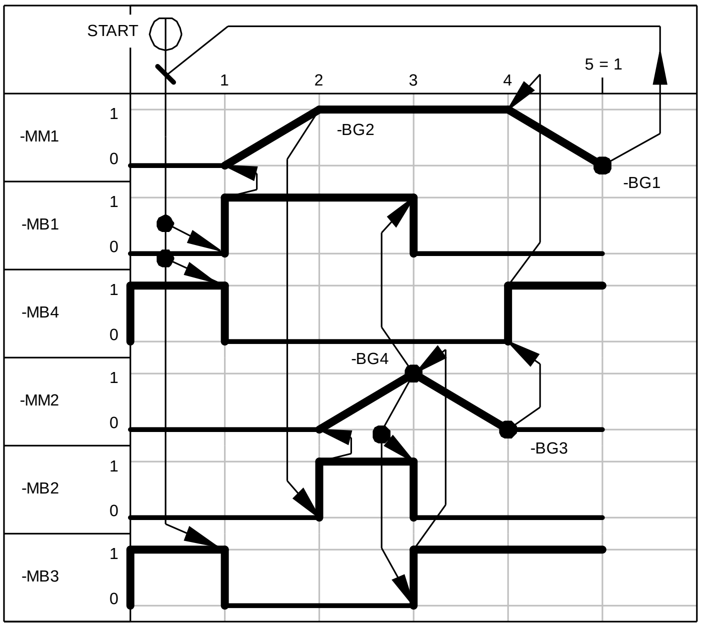

Figure 58 Task 5 functional diagram

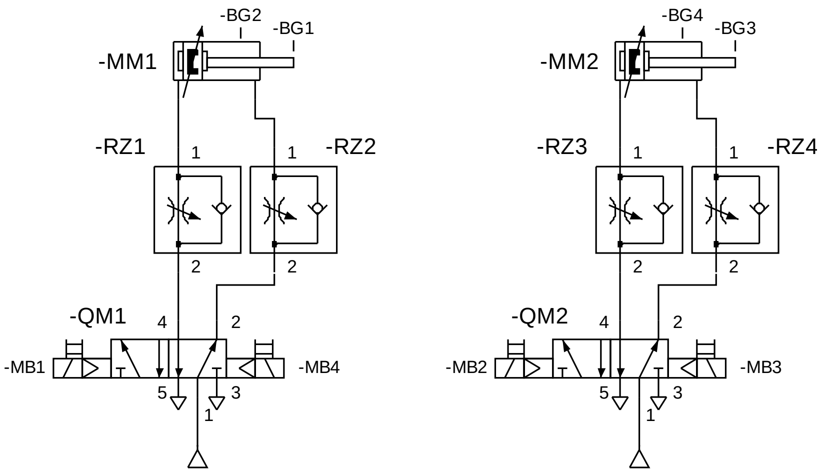

Figure 59 Task 5 Pneumatic circuit

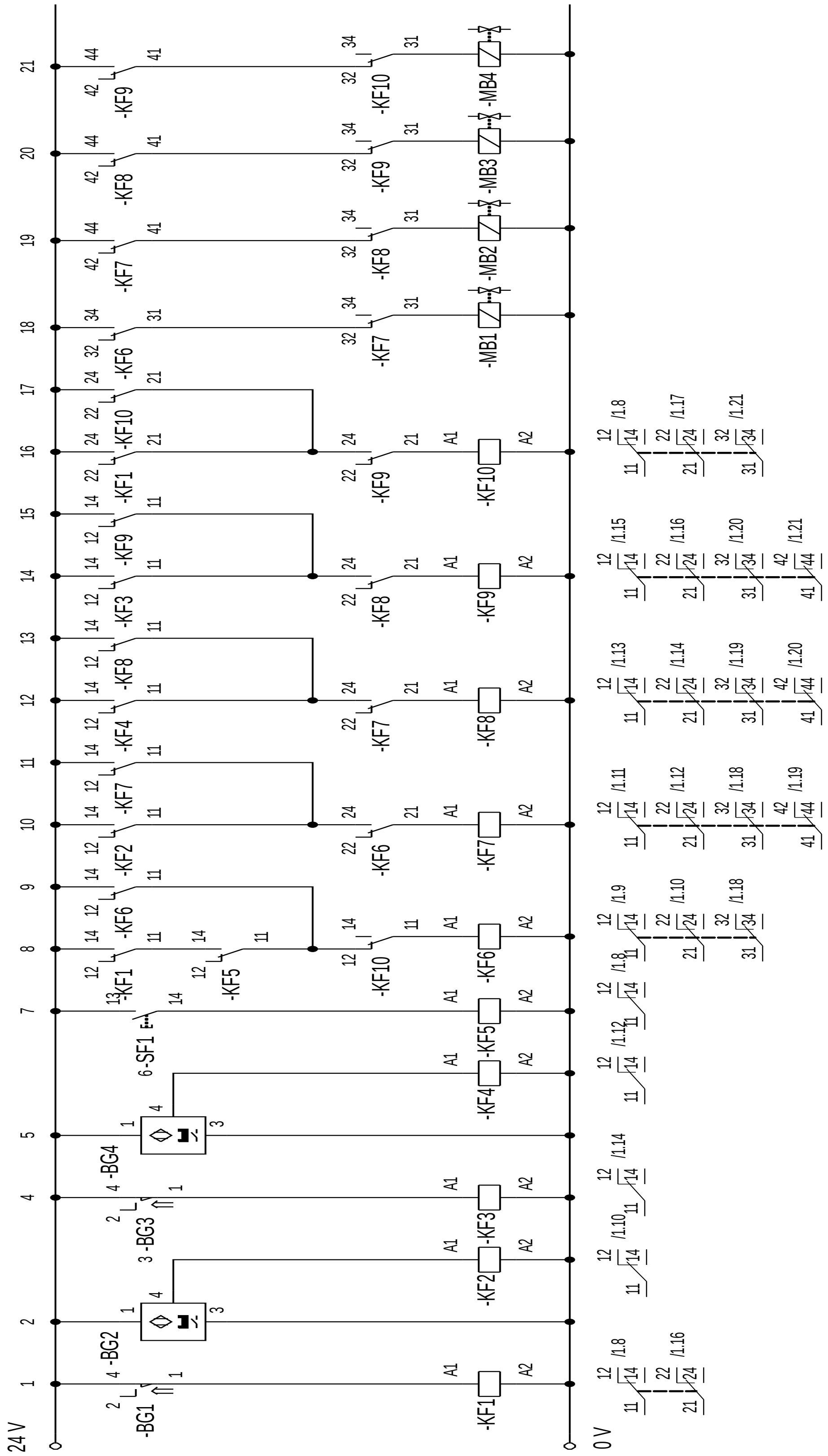

Figure 60 Electrical Schematic task 5

Pos. No.	Identification	Location	Connector Labels	Target ID from	Target ID to	Description
1	?604	/1.1				Electrical connection 24V
2	?602	/1.1				Electrical connection 0V
3	-MB1	/1.18				Valve solenoid
4	-SF1	/1.7				Pushbutton (make)
5	-KF1	/1.1				Relays
6	?2	/1.2				Compressed air supply
7	-RZ1	/1.2				Throttle check valve
8	-MM1	/1.2				Double acting cylinder
9	-RZ2	/1.3				Throttle check valve
10	-QM1	/1.1	-MB1, -MB4			5/2-way solenoid impulse valve
11	-KF2	/1.3				Relays
12	-MB3	/1.20				Valve solenoid
13	-KF3	/1.4				Relays
14	-BG2	/1.2				Magnetic proximity switch
15	-BG4	/1.5				Magnetic proximity switch
16	?28	/1.6				Compressed air supply
17	-RZ3	/1.6				Throttle check valve
18	-MM2	/1.7				Double acting cylinder
19	-RZ4	/1.7				Throttle check valve
20	-QM2	/1.6	-MB2, -MB3			5/2-way solenoid impulse valve
21	-MB2	/1.19				Valve solenoid
22	-MB4	/1.21				Valve solenoid
23	-KF4	/1.6				Relays
24	-KF5	/1.7				Relays
25	-KF6	/1.8				Relays
26	-KF7	/1.10				Relays
27	-KF8	/1.12				Relays
28	-KF9	/1.14				Relays
29	-KF10	/1.16				Relays

Figure 61 Part List (electrical)

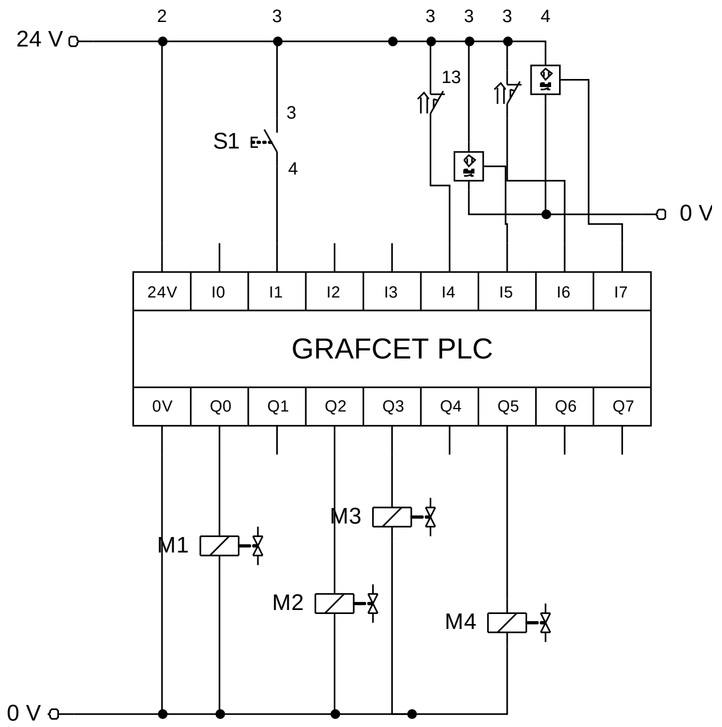

Figure 62 PLC Diagram Task 5

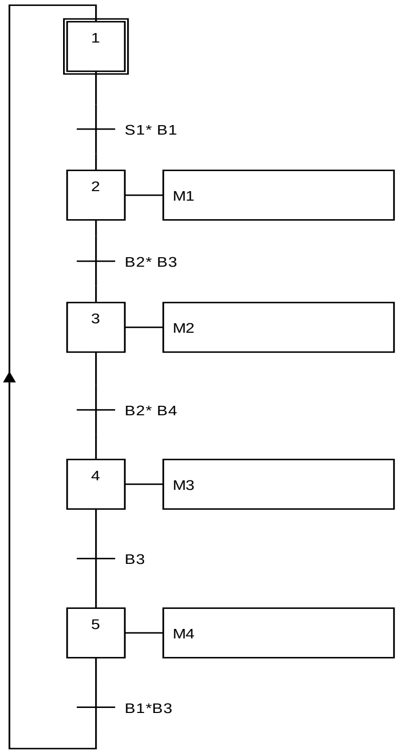

Figure 63 Grafcet Sequence Task 5

Pos. No.	Identification	Location	Connector Labels	Target ID from	Target ID to	Description
1	?2	/1.1				Compressed air supply
2	?-RZ1	/1.1				Throttle check valve
3	?-MM1	/1.1				Double acting cylinder
4	?-RZ2	/1.1				Throttle check valve
5	?-QM1	/1.1	M1, M4			5/2-way solenoid impulse valve
6	?28	/1.2				Compressed air supply
7	?-RZ3	/1.2				Throttle check valve
8	?-MM2	/1.2				Double acting cylinder
9	?-RZ4	/1.3				Throttle check valve
10	?-QM2	/1.2	M2, M3			5/2-way solenoid impulse valve
11	S1	/1.4				Pushbutton (make)
12	?6524	/1.3				GRAFCET PLC
13	?3313	/1.1				Electrical connection 24V
14	M1	/1.2				Valve solenoid
15	M2	/1.3				Valve solenoid
16	?3318	/1.1				Electrical connection 0V
17	S1	/1.2				Pushbutton (make)
18	M3	/1.3				Valve solenoid
19	M4	/1.4				Valve solenoid
20	B2	/1.4				Magnetic proximity switch
21	B4	/1.4				Magnetic proximity switch
22	?26	/1.4				Electrical connection 0V

Figure 64 Parts list (PLC)

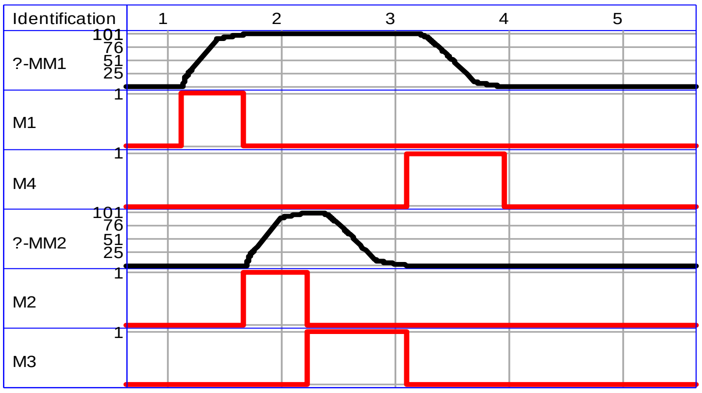

Figure 65 State Diagram (GRAFCET)

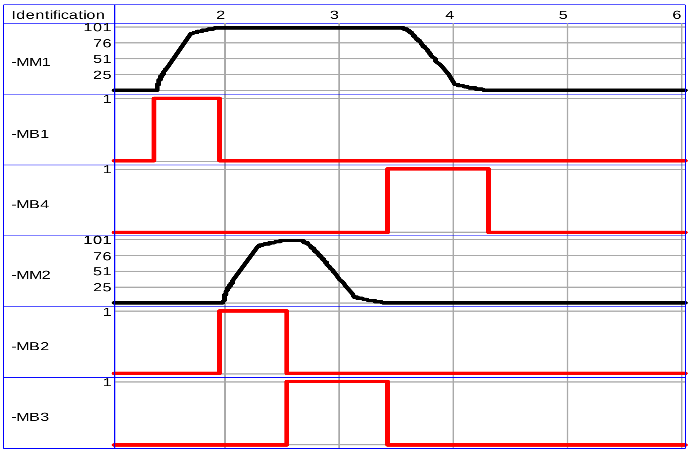

Figure 66 State Diagram (Electrical)

4.6 Task 6

In task 6 there is two alternative sequences. Depending on the signals from sensors two cylinders extracts and retracts in automatic mode. To activate cylinder 1 all three sensors (B5, B6, B7) must be activated. To activate cylinder 2 B5 and B6 but not B7 activated. There is also a reset button to reset the system. Forced command in the initial step resets all of the circuit.

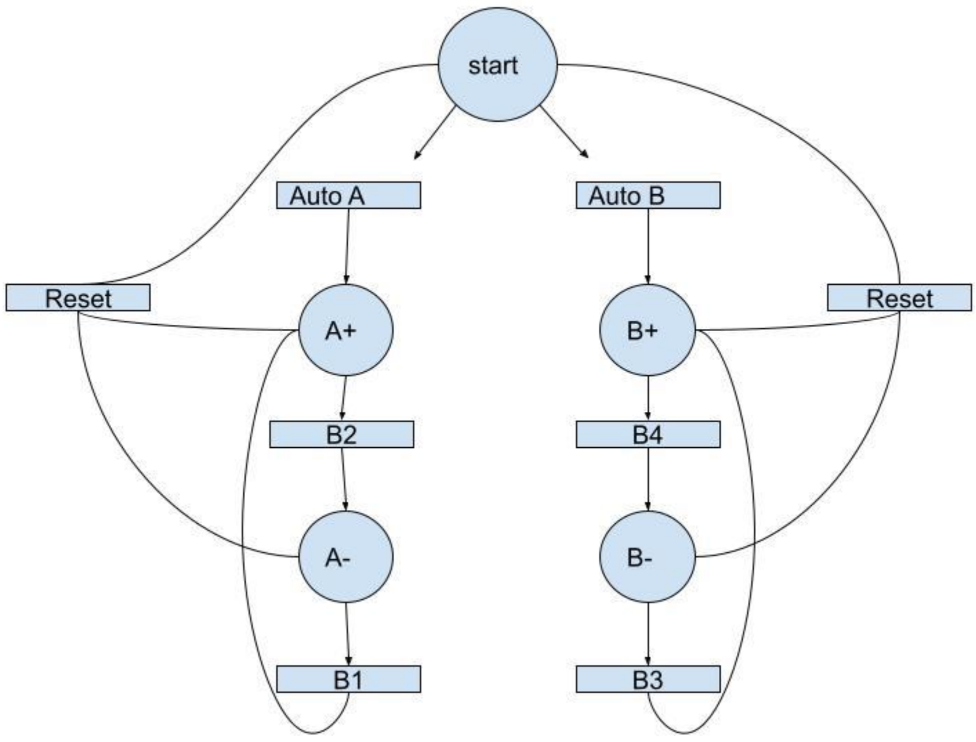

Figure 67 Petri net diagram of Task 6

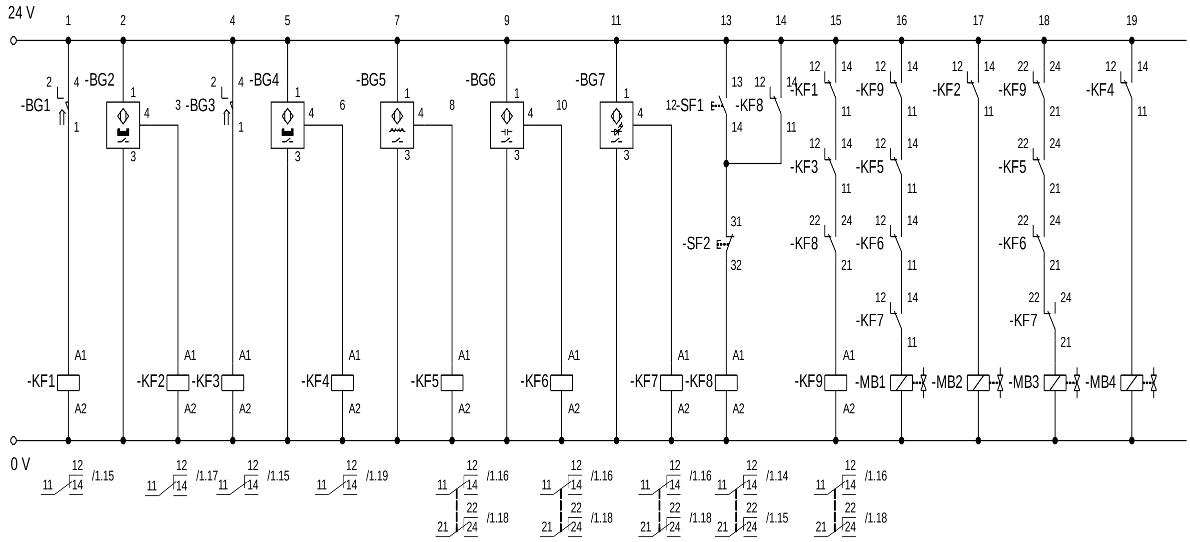

Figure 68 Electrical diagram of task 6

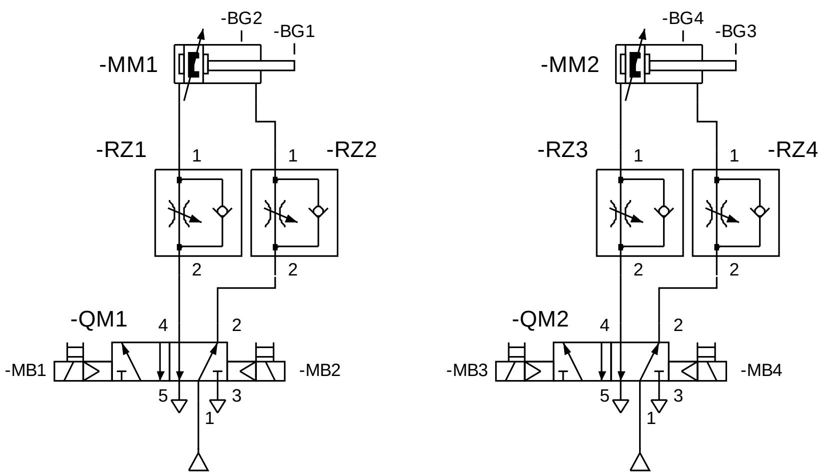

Figure 69 Pneumatic diagram of task 6

Pos. No.	Identification	Location	Connector Labels	Target ID from	Target ID to	Description
1	?604	/1.1				Electrical connection 24V
2	?602	/1.1				Electrical connection 0V
3	-MB1	/1.16				Valve solenoid
4	-SF1	/1.13				Pushbutton (make)
5	-KF1	/1.1				Relays
6	?2	/1.2				Compressed air supply
7	-RZ1	/1.2				Throttle check valve
8	-MM1	/1.2				Double acting cylinder
9	-RZ2	/1.3				Throttle check valve
10	-QM1	/1.1	-MB1, -MB2			5/2-way solenoid impulse valve
11	-KF2	/1.3				Relays
12	-MB3	/1.18				Valve solenoid
13	-KF3	/1.4				Relays
14	-BG2	/1.2				Magnetic proximity switch
15	-BG4	/1.5				Magnetic proximity switch
16	?28	/1.6				Compressed air supply
17	-RZ3	/1.6				Throttle check valve
18	-MM2	/1.7				Double acting cylinder
19	-RZ4	/1.7				Throttle check valve
20	-QM2	/1.6	-MB3, -MB4			5/2-way solenoid impulse valve
21	-MB2	/1.17				Valve solenoid
22	-MB4	/1.19				Valve solenoid
23	-KF4	/1.6				Relays
24	-KF5	/1.8				Relays
25	-KF6	/1.10				Relays
26	-KF7	/1.12				Relays
27	-KF8	/1.13				Relays
28	-BG6	/1.9				Capacitive proximity switch
29	-BG7	/1.11				Optical proximity switch
30	-BG5	/1.7				Inductive proximity switch
31	-SF2	/1.13				Pushbutton (break)
32	-KF9	/1.15				Relays

Figure 70 Part List for electrical schematic

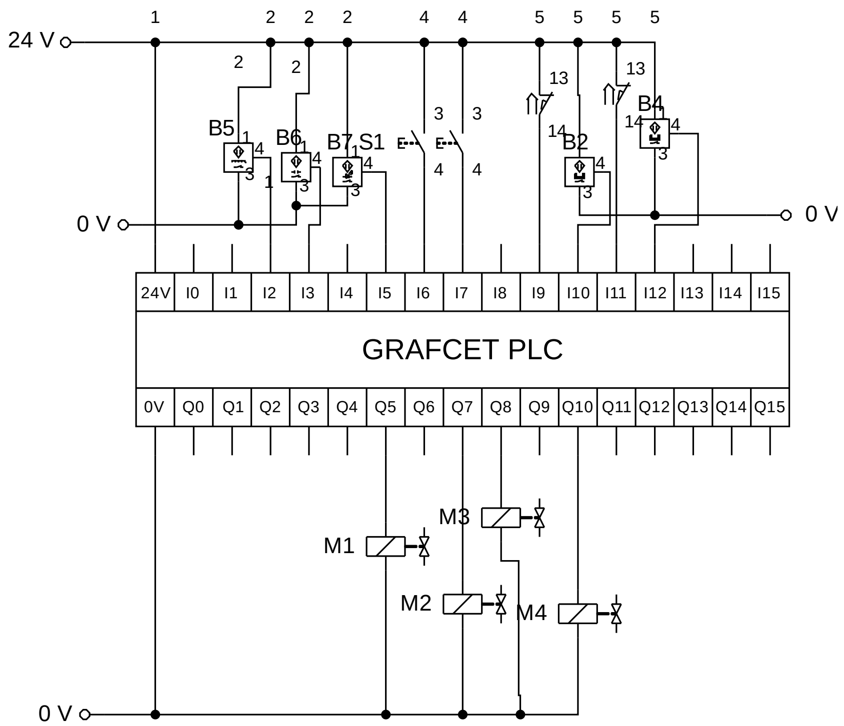

Figure 71 PLC schematic for task 6

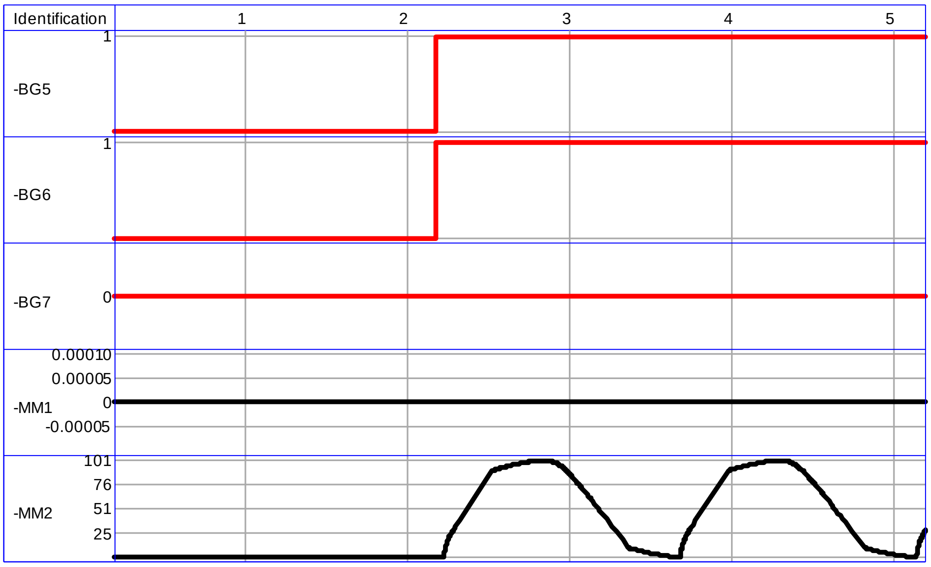

Figure 72 cylinder 2 electrical state diagram

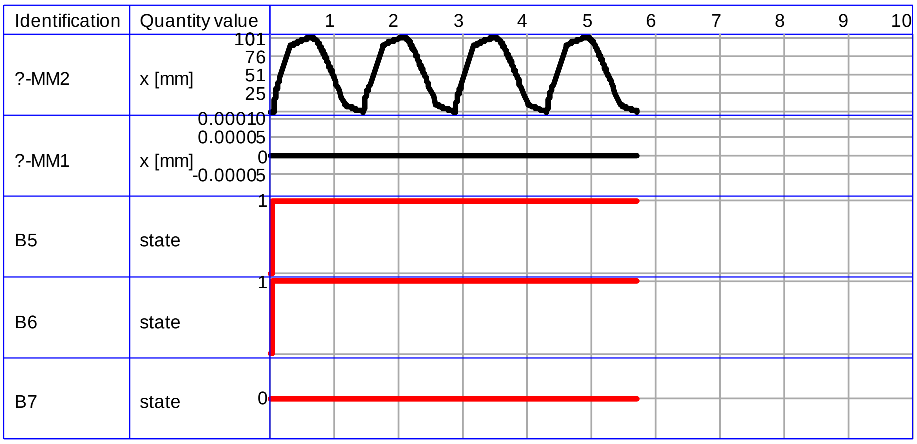

Figure 73 cylinder 2 GRAFCET state diagram

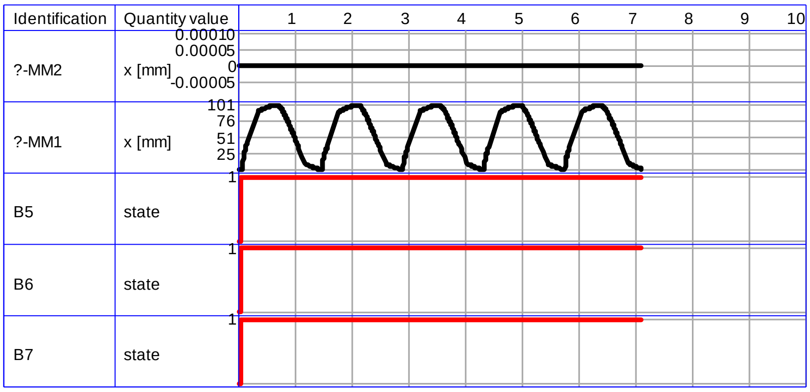

Figure 74 Cylinder 1 Grafcet state diagram

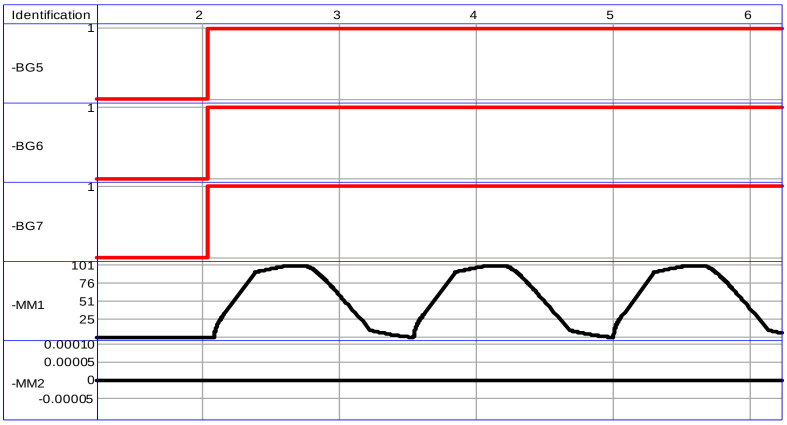

Figure 75 Cylinder 1 Electrical state diagram

In both modes of the cylinders are same.

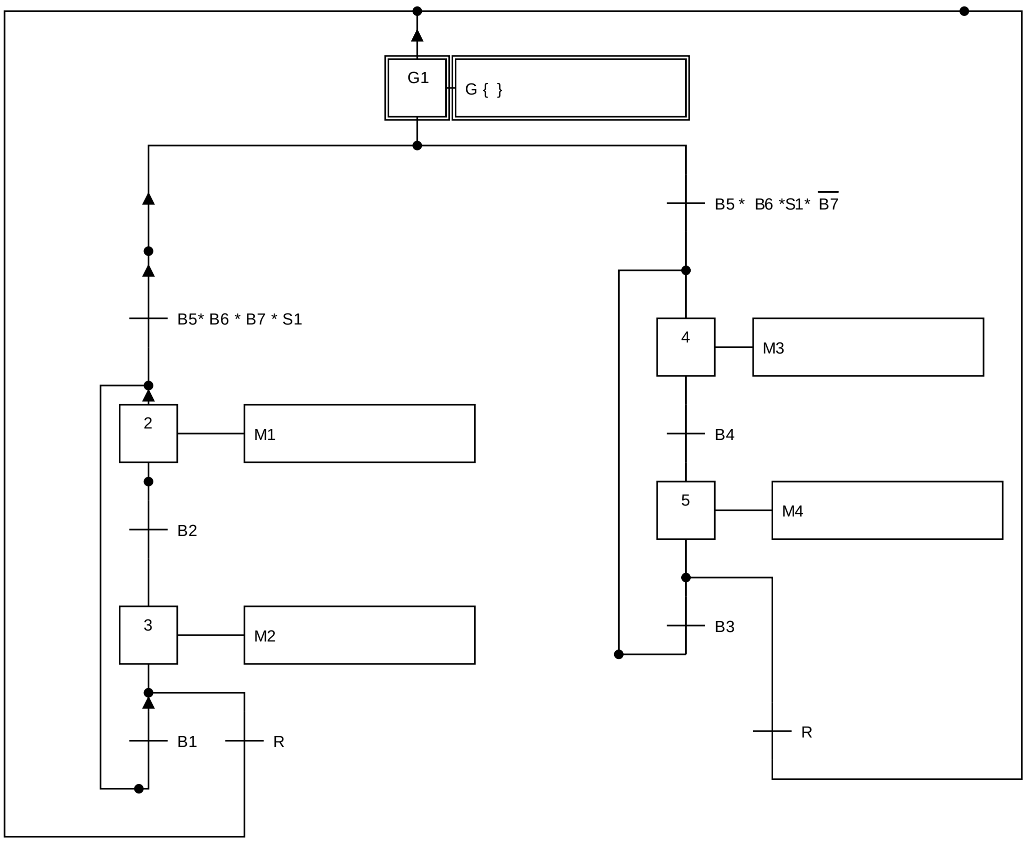

Figure 76 Task 6 Grafcet Schematic

4.7 Task 7 (A+ TAU3 A-)

The pneumatical system have a pressure sensor and with activation of this sensor and a push button system activates. After the activation of B2 a 3 second delay relay gets activated. After 3 seconds MB2 activates and system returns to initial position.

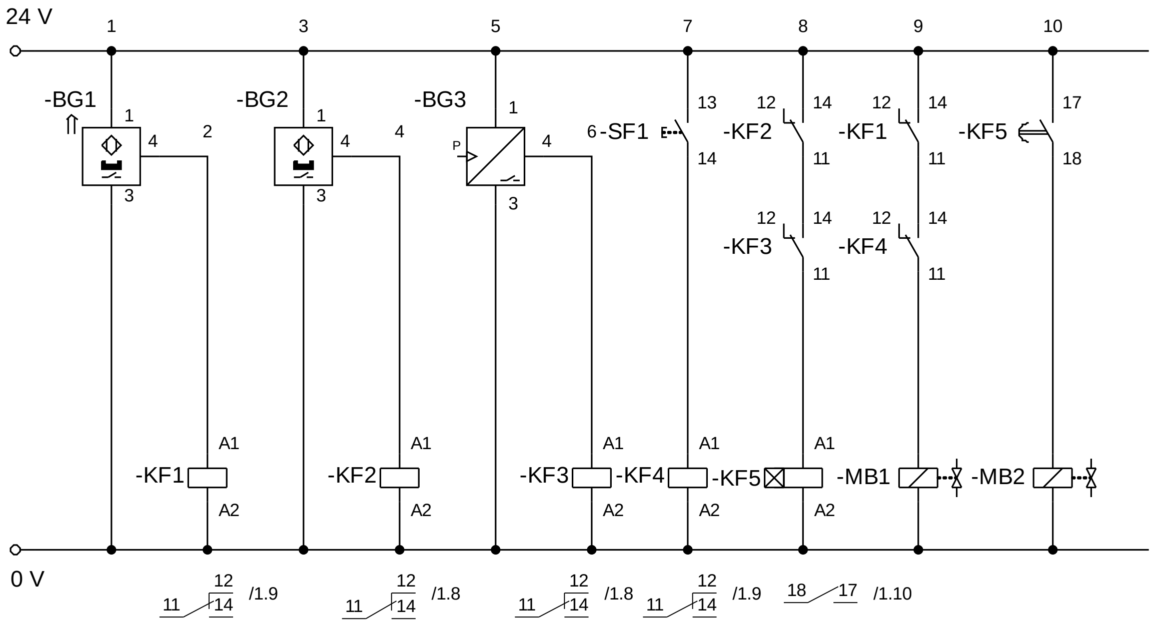

Figure 77 Electrical Schematic of task 7

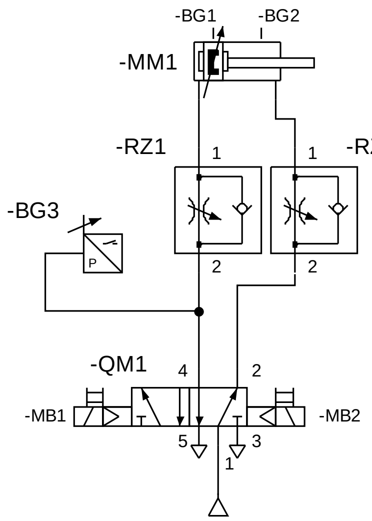

Figure 78 Pneumatic diagram of task 7

Pos. No.	Identification	Location	Connector Labels	Target ID from	Target ID to	Description
1	?604	/1.1				Electrical connection 24V
2	?602	/1.1				Electrical connection 0V
3	-MB1	/1.9				Valve solenoid
4	-SF1	/1.7				Pushbutton (make)
5	-KF1	/1.2				Relays
6	?2	/1.2				Compressed air supply
7	-RZ1	/1.2				Throttle check valve
8	-MM1	/1.3				Double acting cylinder
9	-RZ2	/1.3				Throttle check valve
10	-QM1	/1.2	-MB1, -MB2			5/2-way solenoid impulse valve
11	-KF2	/1.4				Relays
12	-KF3	/1.6				Relays
13	-BG1	/1.1				Magnetic proximity switch
14	-BG2	/1.3				Magnetic proximity switch
15	-MB2	/1.10				Valve solenoid
16	-KF5	/1.8				Relay with switch-on delay
17	-BG3	/1.1				Pressure switch
18	-KF4	/1.7				Relays

Figure 79 Part list task 7 (electrical)

Pos. No.	Identification	Location	Connector Labels	Target ID from	Target ID to	Description
1	?2	/1.1				Compressed air supply
2	?-RZ1	/1.1				Throttle check valve
3	?-MM1	/1.1				Double acting cylinder
4	?-RZ2	/1.1				Throttle check valve
5	?-QM1	/1.1	M1, M2			5/2-way solenoid impulse valve
6	?-BG3	/1.1				Pressure switch
7	S1	/1.1				Pushbutton (make)
8	?6524	/1.2				GRAFCET PLC
9	M1	/1.1				Valve solenoid
10	M2	/1.2				Valve solenoid
11	?3313	/1.1				Electrical connection 24V
12	?3318	/1.1				Electrical connection 0V
13	B2	/1.3				Magnetic proximity switch
14	?17	/1.3				
15	B1	/1.2				Magnetic proximity switch
16	?22	/1.2				
17	?23	/1.3				Electrical connection 0V

Figure 80 Part list task 7 (Grafcet)

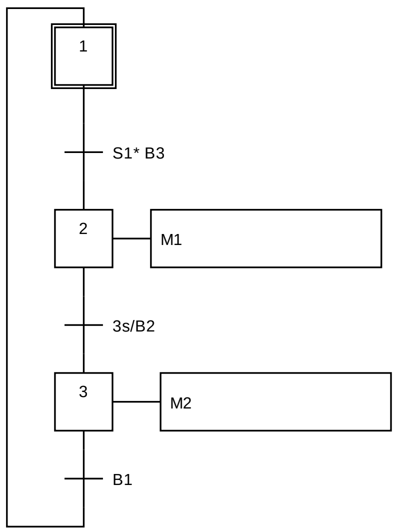

Figure 81 Grafcet solution

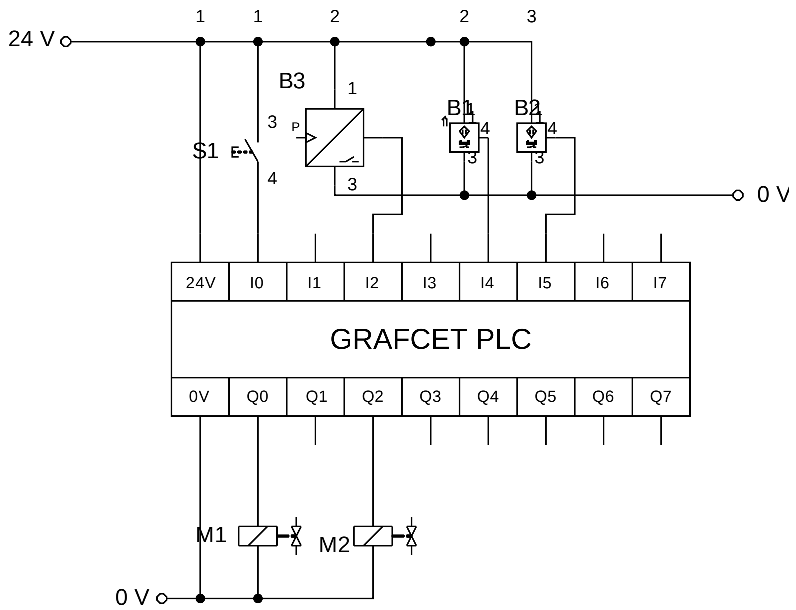

Figure 82 PLC schematics

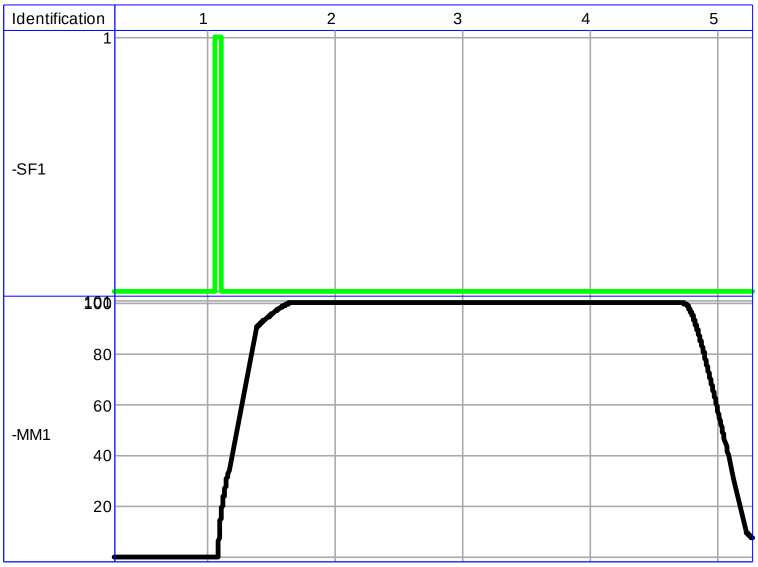

Figure 83 State Diagram 7 (electrical)

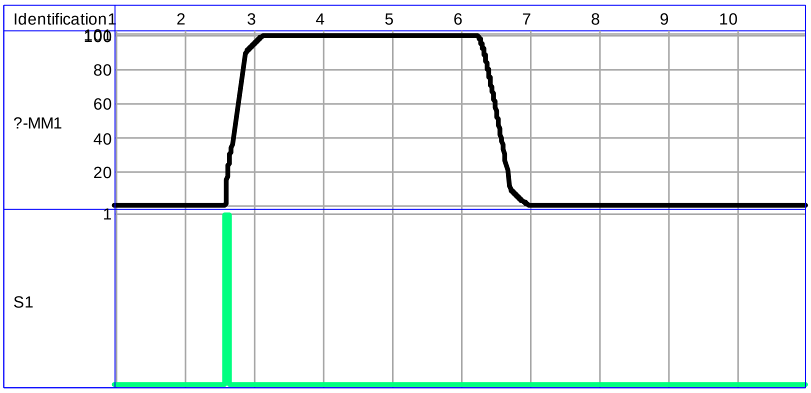

Figure 84 State Diagram (Grafcet)

4.8 Task 8 (A+ A-)

In Task 8 there are two modes of action. One is a manual mode activated by pressing of the pushbutton the other one is the automatic mode. There are 3 sensors connected to schematic. 2 of them on the cylinder are magnetic proximity sensors. Third one is a pressure sensor that sends a signal after the necessary pressure is reached. Also for the counting task a counter relay is put into system. This relay sends a signal after the counter reaches 10 and breaks the contact.

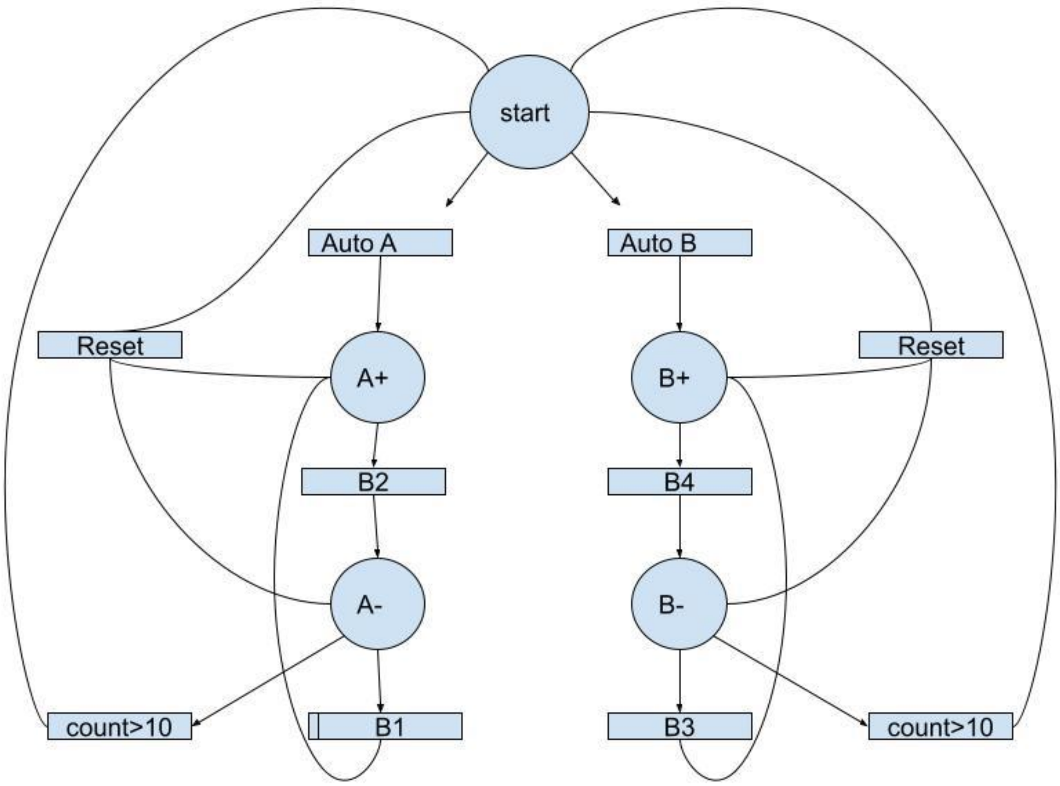

Figure 85 Task 8 Petri Net

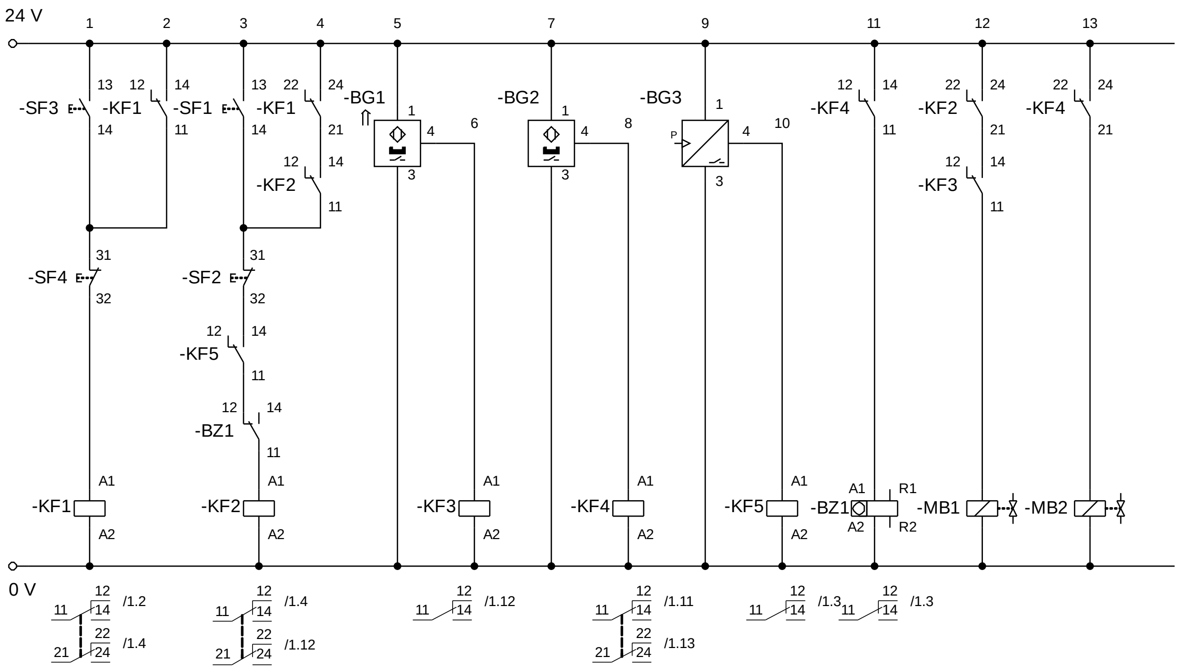

Figure 86 Task 8 electrical schematic

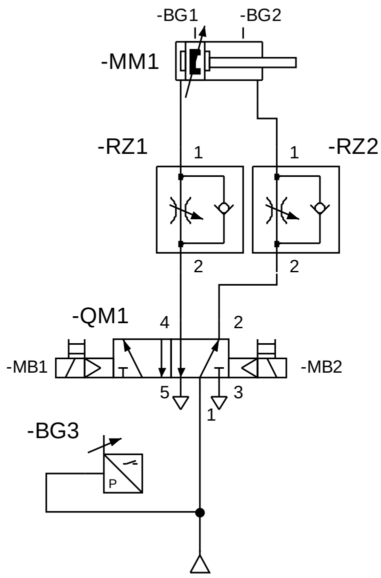

Figure 87 Task 8 pneumatical schematic

Pos. No.	Identification	Location	Connector Labels	Target ID from	Target ID to	Description
1	?604	/1.1				Electrical connection 24V
2	?602	/1.1				Electrical connection 0V
3	-MB1	/1.12				Valve solenoid
4	-SF3	/1.1				Pushbutton (make)
5	-KF1	/1.1				Relays
6	?2	/1.2				Compressed air supply
7	-RZ1	/1.2				Throttle check valve
8	-MM1	/1.3				Double acting cylinder
9	-RZ2	/1.3				Throttle check valve
10	-QM1	/1.2	-MB1, -MB2			5/2-way solenoid impulse valve
11	-KF2	/1.3				Relays
12	-KF3	/1.6				Relays
13	-BG1	/1.5				Magnetic proximity switch
14	-BG2	/1.7				Magnetic proximity switch
15	-MB2	/1.13				Valve solenoid
16	-BG3	/1.2				Pressure switch
17	-KF4	/1.8				Relays
18	-SF2	/1.3				Pushbutton (break)
19	-SF1	/1.3				Pushbutton (make)
20	-KF5	/1.10				Relays
21	-SF4	/1.1				Pushbutton (break)

Figure 88 Part List task 8 (electrical)

In the Grafcet solution two branches are created for auto and manual modes respectively. A variable that activates and stores the value was assigned to act as a counter. After 10 cycles system automatically stops and returns to initial position. Also a small separate branch was created for resetting the counter.

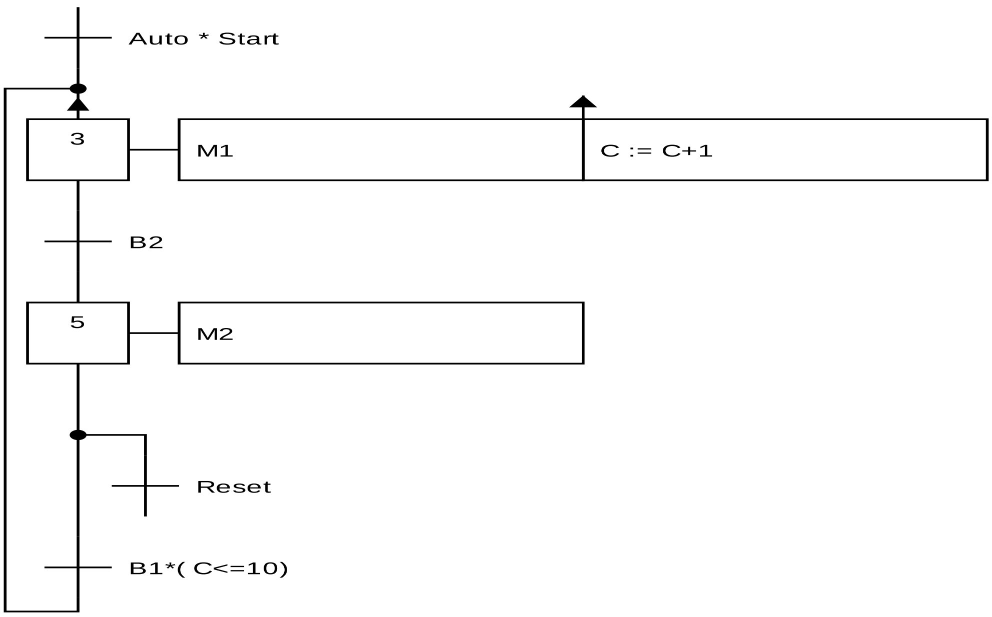

Figure 89 Task 8 automatic mode

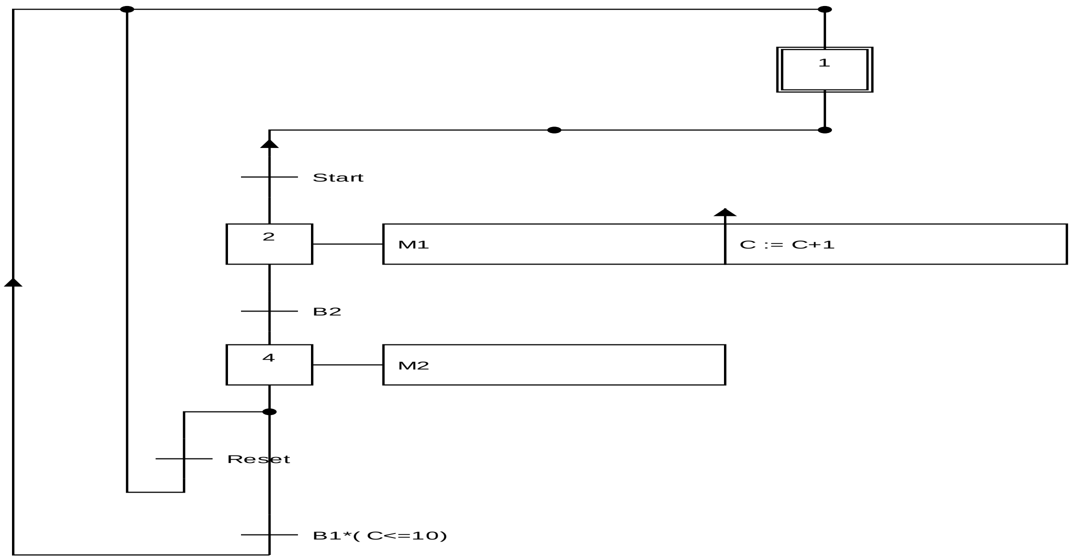

Figure 90 Task 8 manual mode

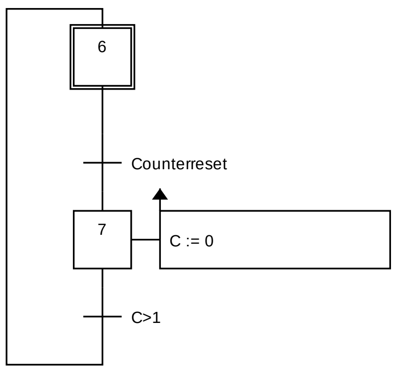

Figure 91 Counter reset

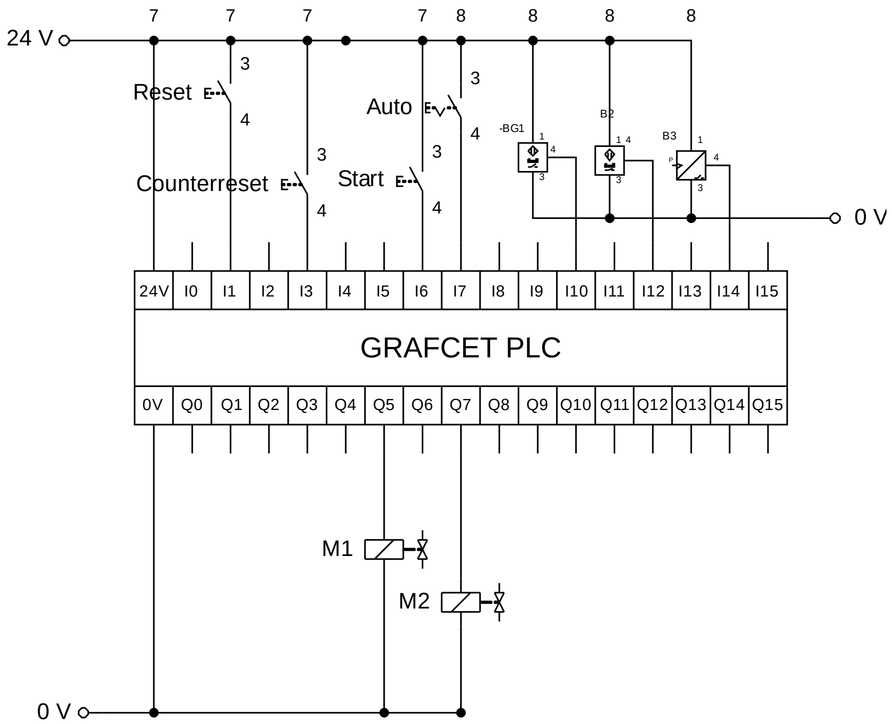

Figure 92 Task 8 PLC connections

Pos. No.	Identification	Location	Connector Labels	Target ID from	Target ID to	Description
1	?2	/1.2				Compressed air supply
2	?-RZ1	/1.2				Throttle check valve
3	?-MM1	/1.2				Double acting cylinder
4	?-RZ2	/1.2				Throttle check valve
5	?-QM1	/1.2	M1, M2			5/2-way solenoid impulse valve
6	?-BG3	/1.2				Pressure switch
7	Start	/1.3				Pushbutton (make)
8	Auto	/1.4				Pushbutton (make)
9	Reset	/1.4				Pushbutton (make)
10	Counterreset	/1.5				Pushbutton (make)
11	?3313	/1.6				Electrical connection 24V
12	M1	/1.7				Valve solenoid
13	M2	/1.8				Valve solenoid
14	?3318	/1.6				Electrical connection 0V
15	Start	/1.7				Pushbutton (make)
16	?6560	/1.8				GRAFCET PLC
17	Reset	/1.7				Pushbutton (make)
18	Counterreset	/1.7				Pushbutton (make)
19	Auto	/1.7				Detent switch (make)
20	-BG1	/1.8				Magnetic proximity switch
21	B2	/1.8				Magnetic proximity switch
22	?48	/1.9				Electrical connection 0V

Figure 93 Part list task 8 (PLC)

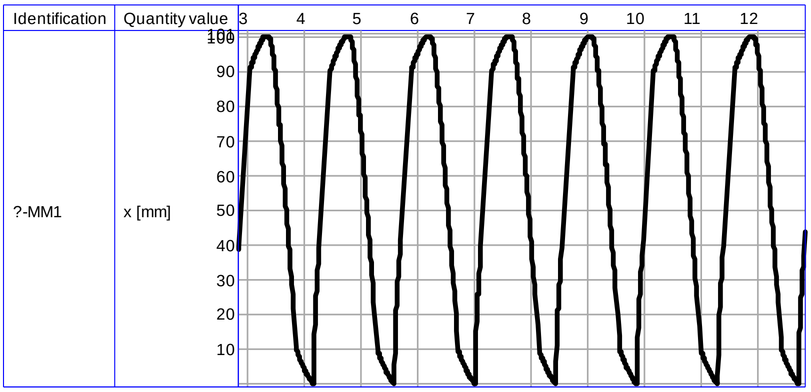

Figure 94 Task 8 Auto mode(GRAFCET)

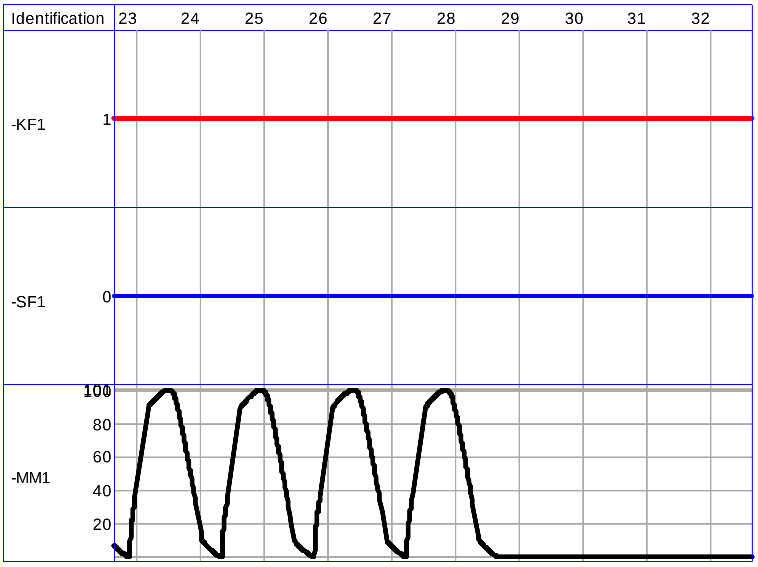

Figure 95 Task 8 Auto mode (Electrical)

As we can see from the both graphs time for each cycle is 1.4s and their behaviour regarding their position is same.

4.9 Task 9 (A+ B+ B- A-)

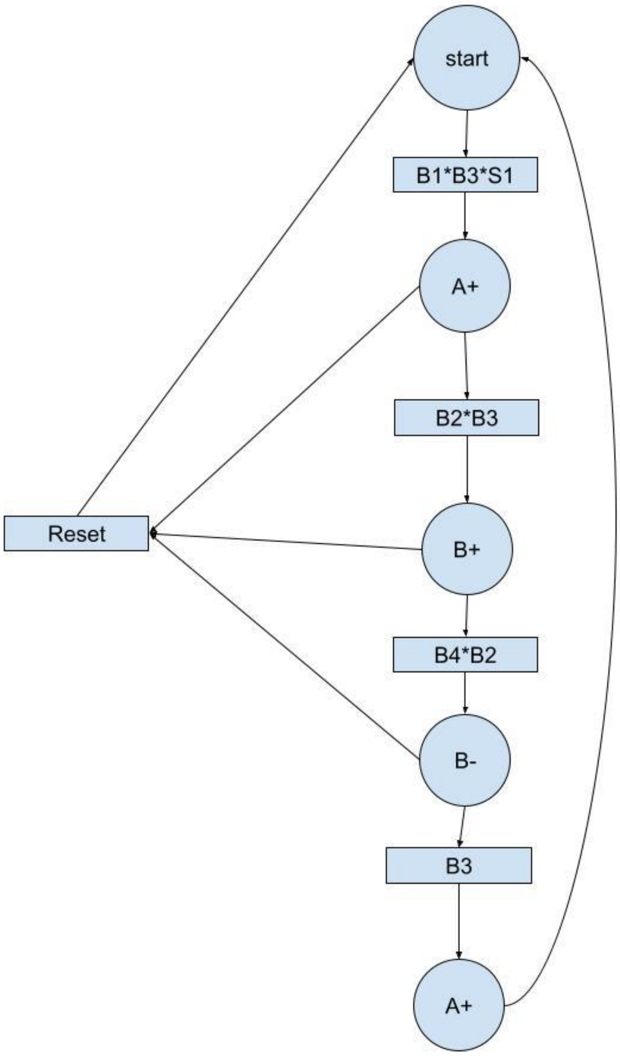

Figure 96 Petri net task 9

In task 9 4 sensors are used magnetic proximity switches are used for interior of cylinder and limit switches are used for the extracting action. Two monostable 5/2 valves are used for control. To control the valves standing chain method was used. And a reset button was placed to stop the cycle and return to initial position.

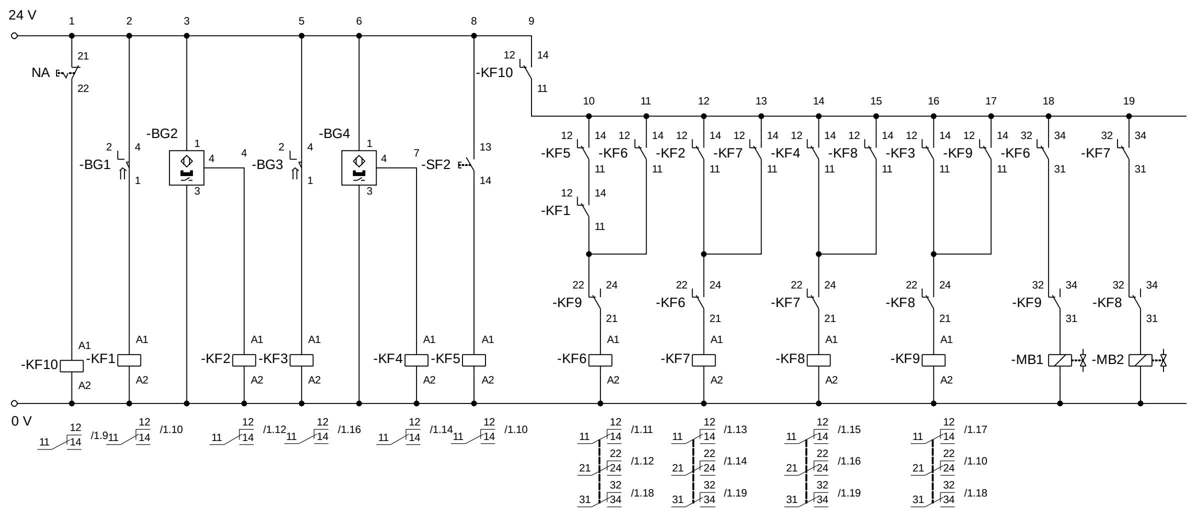

Figure 97 Electrical Connections of task 9

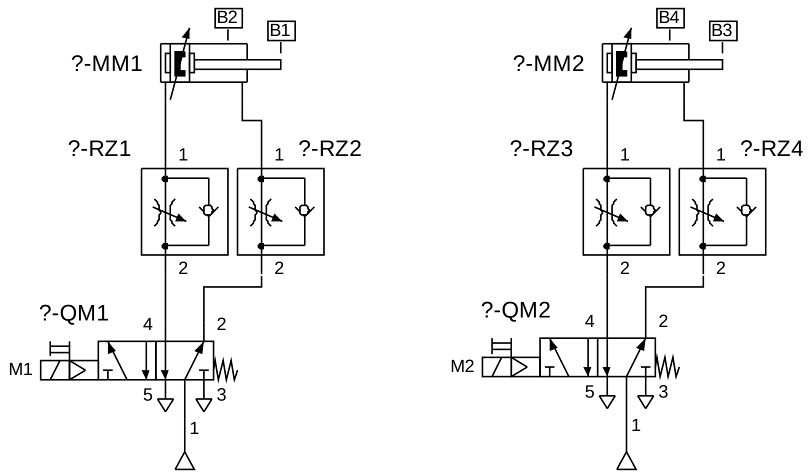

Figure 98 Schematic of Cylinders

Pos. No.	Identification	Location	Connector Labels	Target ID from	Target ID to	Description
1	?604	/1.1				Electrical connection 24V
2	?602	/1.1				Electrical connection 0V
3	-MB1	/1.18				Valve solenoid
4	-SF2	/1.8				Pushbutton (make)
5	-KF1	/1.2				Relays
6	?2	/1.2				Compressed air supply
7	-RZ1	/1.2				Throttle check valve
8	-MM1	/1.2				Double acting cylinder
9	-RZ2	/1.3				Throttle check valve
10	-KF2	/1.4				Relays
11	-KF3	/1.5				Relays
12	-BG2	/1.3				Magnetic proximity switch
13	-BG4	/1.6				Magnetic proximity switch
14	?28	/1.6				Compressed air supply
15	-RZ3	/1.6				Throttle check valve
16	-MM2	/1.7				Double acting cylinder
17	-RZ4	/1.7				Throttle check valve
18	-MB2	/1.19				Valve solenoid
19	-KF4	/1.7				Relays
20	-KF5	/1.8				Relays
21	-KF6	/1.10				Relays
22	-QM1	/1.1	-MB1			5/2-way solenoid valve
23	-QM2	/1.6	-MB2			5/2-way solenoid valve
24	-KF7	/1.12				Relays
25	-KF8	/1.14				Relays
26	-KF9	/1.16				Relays
27	-KF10	/1.1				Relays
28	NA	/1.1				Detent switch (break)

Figure 99 Part List task 9(electrical)

In grafcet to add the reset function, branches added after each step. For initializing a forced command was used in the initial step.

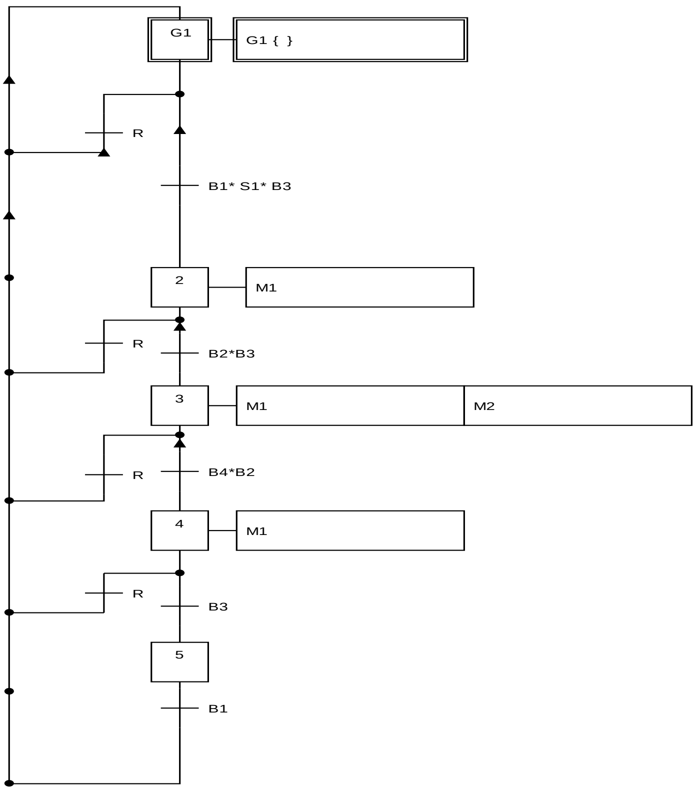

Figure 100 Task 9 Grafcet Chart

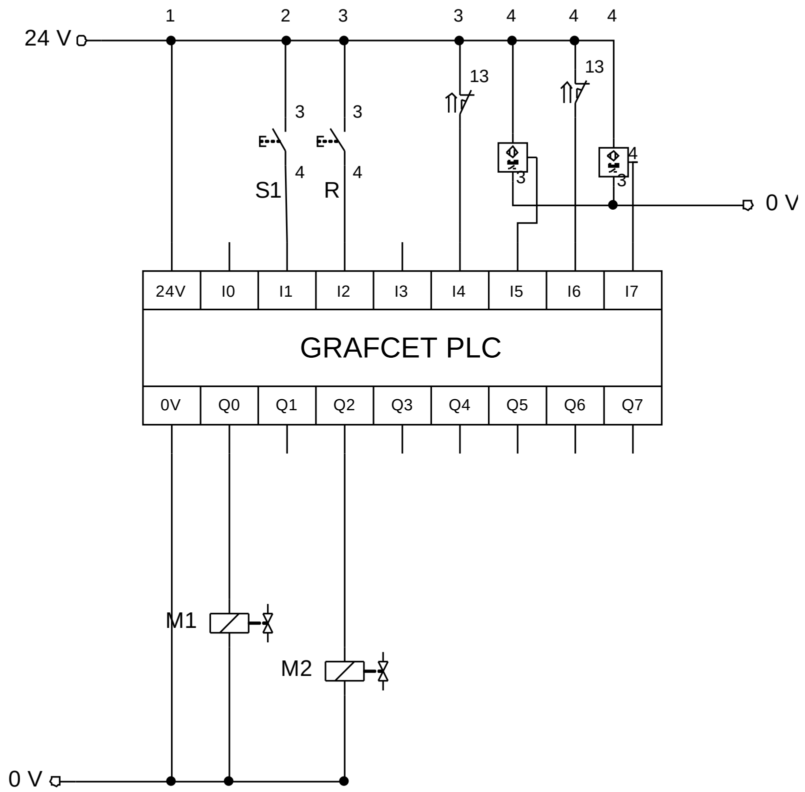

Figure 101 PLC schematic of task 9

Pos. No.	Identification	Location	Connector Labels	Target ID from	Target ID to	Description
1	?2	/1.1				Compressed air supply
2	?-RZ1	/1.1				Throttle check valve
3	?-MM1	/1.1				Double acting cylinder
4	?-RZ2	/1.1				Throttle check valve
5	?28	/1.1				Compressed air supply
6	?-RZ3	/1.1				Throttle check valve
7	?-MM2	/1.1				Double acting cylinder
8	?-RZ4	/1.1				Throttle check valve
9	?-QM1	/1.1	M1			5/2-way solenoid valve
10	?-QM2	/1.1	M2			5/2-way solenoid valve
11	S1	/1.1				Pushbutton (make)
12	?6524	/1.3				GRAFCET PLC
13	?3313	/1.1				Electrical connection 24V
14	M1	/1.2				Valve solenoid
15	M2	/1.3				Valve solenoid
16	?3318	/1.1				Electrical connection 0V
17	S1	/1.2				Pushbutton (make)
18	R	/1.1				Pushbutton (make)
19	R	/1.2				Pushbutton (make)
20	B2	/1.4				Magnetic proximity switch
21	B4	/1.4				Magnetic proximity switch
22	?27	/1.4				Electrical connection 0V

Figure 102 Part list task 9 (PLC)

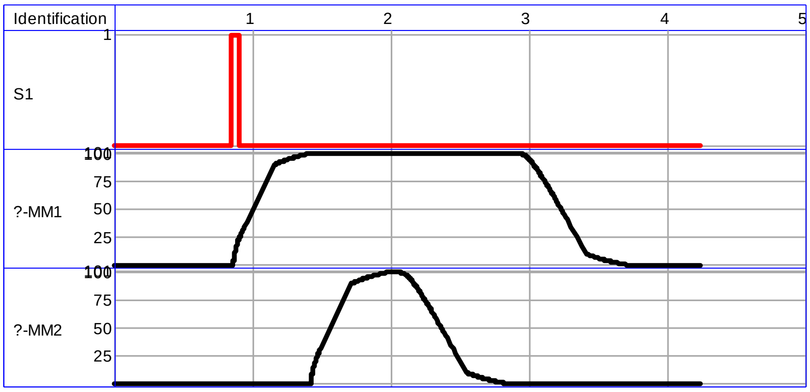

Figure 103 State Diagram (PLC)

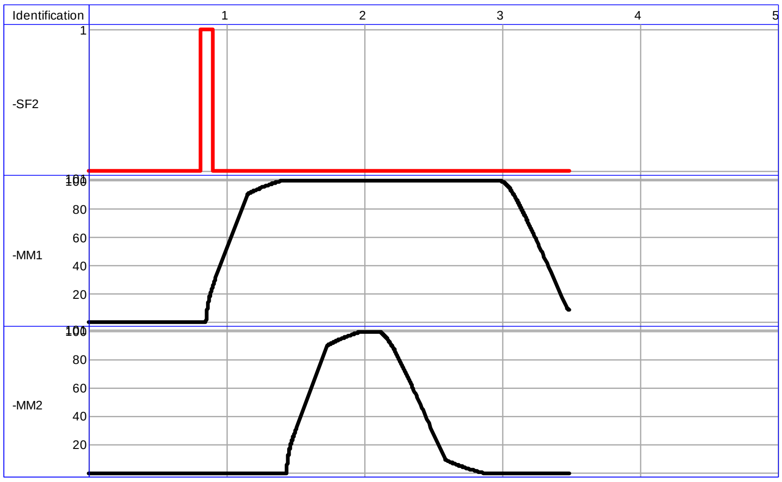

Figure 104 State Diagram (electrical)

As it can be seen from the figures both sequences are identical.

5. VISUALIZATION

5.1 SCADA

Scada, acronym for “Supervisory control and data acquisition”, is an extensive monitoring and control system architecture for collecting, monitoring and controlling industrial processes. It consists of subsystems reporting back to the main station, allowing the whole system to be supervised or specific commands to be issued to some parts.

5.2 SCADA Reliance 4

Scada Reliance is a human machine interface (HMI) for Scada systems. It allows quick visualization of the system, enabling the user to monitor and control the parts of the system. A Reliance project typically consists of messages from sub-systems and scripts for automation.

Reliance 4 SCADA software has been used to visualize and control a sequence in this thesis. Reliance’s structructure is divided in to submodules and managers. Final product is a runtime software that is produced to run on the end-user's computer by given privileges in User Manager.

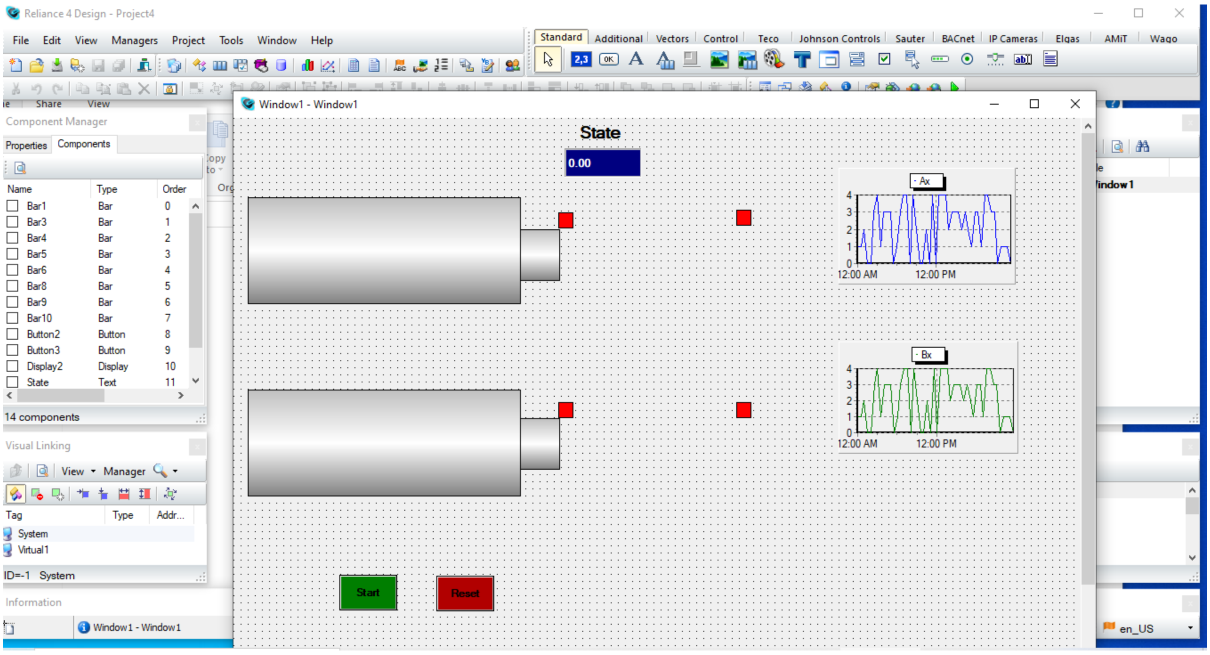

Figure 105 Overview of the project[11]

5.2.1 User Manager

User manager is a privilege management system that can create new users and privilege hierarchies for these end users. These users then can modify, visualize and control the system based on their assigned privilege. Typical end-user logs into the system with username and password combination.

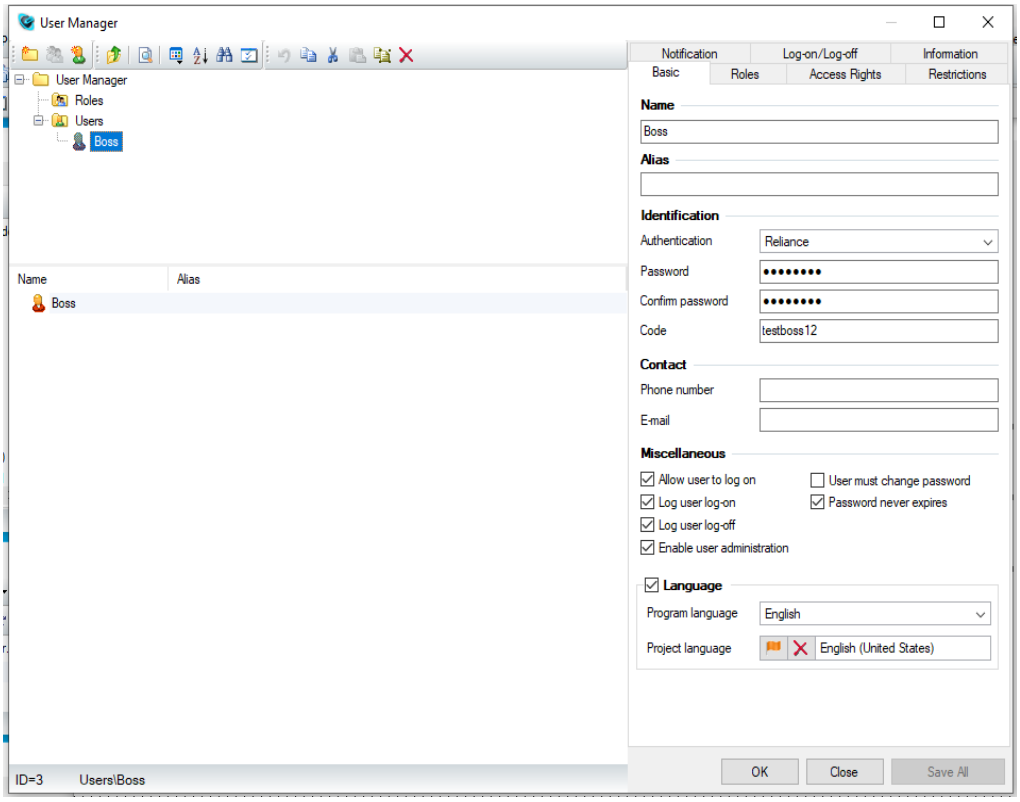

Figure 106 User Manager Interface[11]

5.2.2 Device Manager

Device Manager is an environment which lists physical devices that are connected and virtual devices which are set for visualization. Through this, new types of physical or virtual devices can be added to the project. New tags can be assigned to these devices in this manager with different types such as Bool, Int indicating whether values are of data type boolean and integer. In this project Sensors and pushbuttons were assigned Boolean values to obtain the control in the script. Coordinates for piston A and piston B were assigned integer values to simulate their movement.

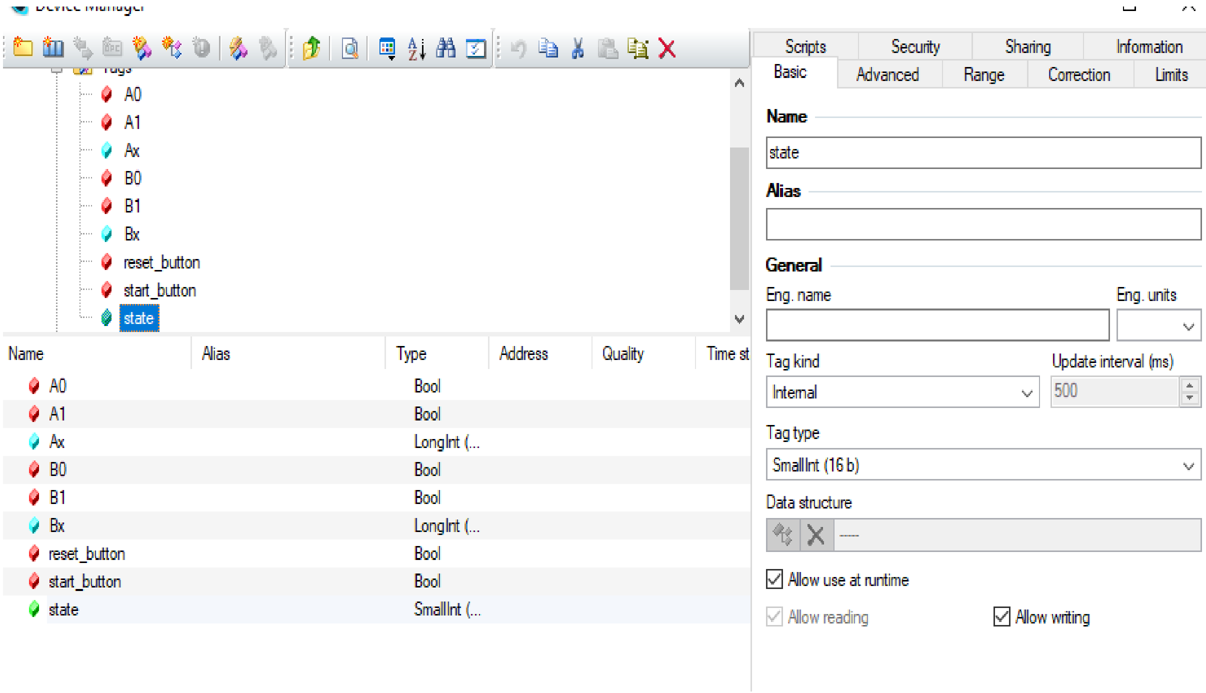

Figure 107 Device Manager[11]

5.2.3 Script Manager

Script Manager is an environment for creating scripts for run-time visualizations. Variables defined in the script can be loaded with the tag values, calculate new values based on the script and load back the calculated value to the previous tags, changing the value and state of these tags. Through these scripts, automation and visual animations can be displayed on the run-time program. VB language is used to program the script.

5.2.4 Trend Manager

This Manager is used for getting real time and historical data from the visualization. With this method it is possible to display data received from the simulation in various types of charts and graphs.

5.2.5 Description of Task

In this visualization task 2 (A+ B+ A- B-) with an added reset button was created. The piston stroke was chosen as 200 mm. The projects has two modes: manual mode that activates the sequence once the start button is pressed and the automatic mode which works in a loop indefinitely until the reset button is pressed. Two real time trend graphs were added monitor the position of the cylinders. A display called state was added to show which phase of the sequence is active.

The start button activates the cylinder A and it moves forward. When A1 is activated cylinder B moves forward. A1 and B1 activates A- movement.A0 and B1 activates B-.

The function of the script is following: first tag values were read from Reliance 4 as they correspond to latest system states. Then reset flag is checked to see if it can stop the system. If not active, the sensor outputs are set according to piston positions. In the next step if the start button is active, we determine the next state of the system. Each state corresponds to extracting or retracting of the cylinder. After completing consecutive states system reverts to its initial state,0.

In auto mode start flag is checked in each step, so if it is active making a loop effectively until it is resetted.

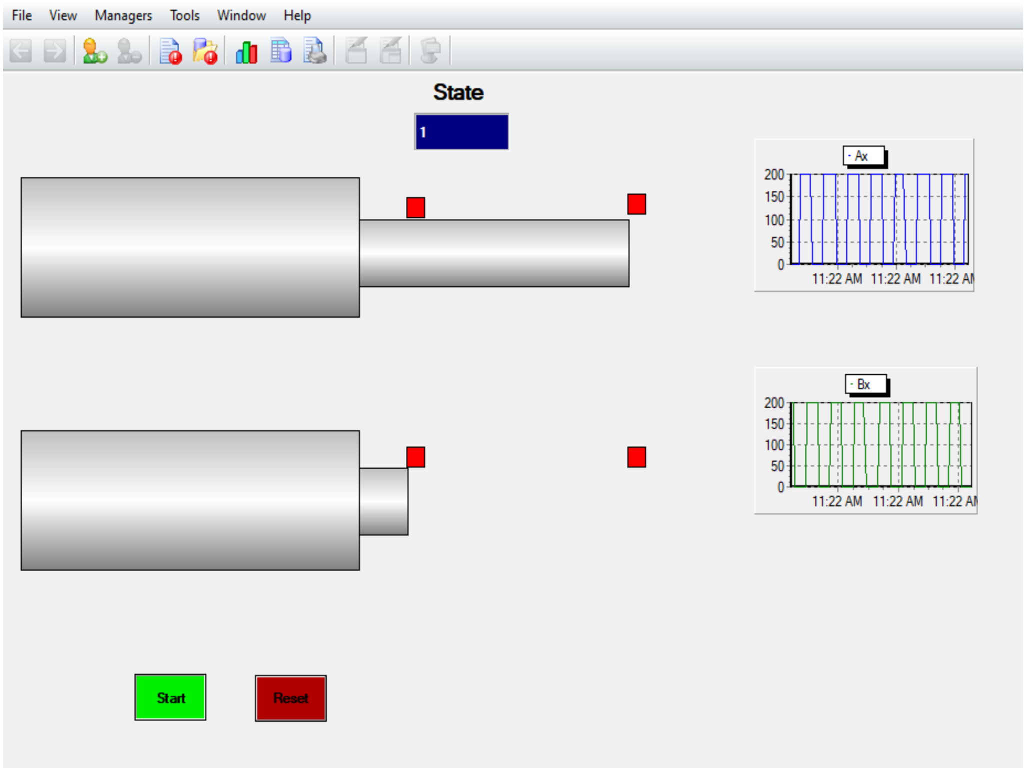

Figure 108 Visual of the system in runtime model [11]

6.Vacuum Applications

6.1 Vacuum Security Valves

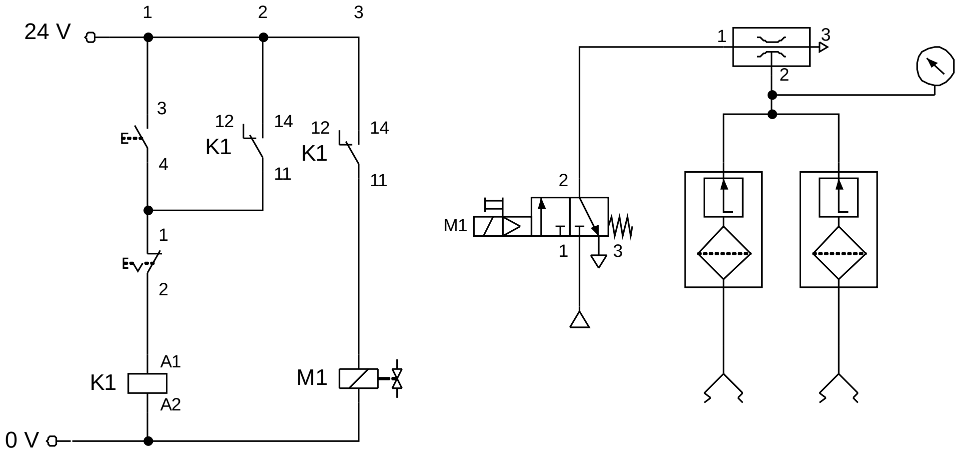

Figure 109 Maintaining Vacuum with double suction cups

In this example with the help of vacuum efficiency valves ,vacuum is maintained even though one of the suction cups does not form a grip. If the during the operation a suction cup is uncovered valve automatically stops the influx of air which Prevents pressure loss.

6.2 Controlled Release of Part

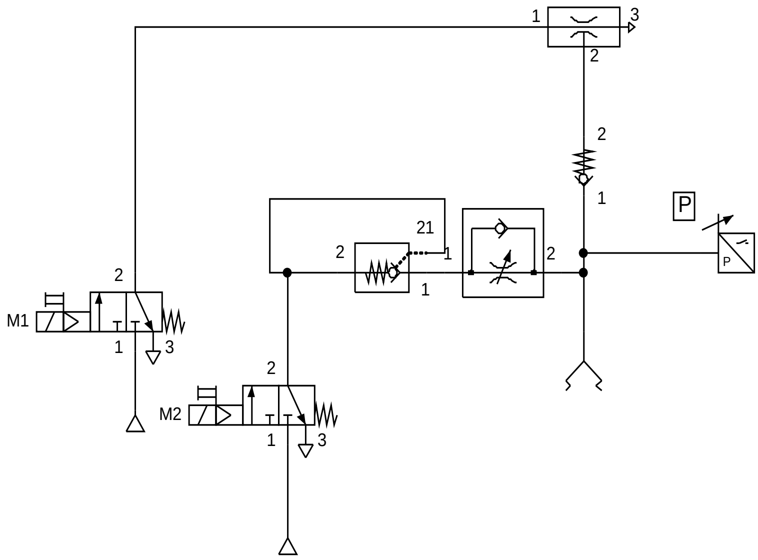

Figure 110 Pneumatic Schematic of system

After S1 is pressed work piece is caught by activated vacuum. To release the piece in a controlled manner second valve is activated. S2 is connected with a push button and cancels first valve. At the same time second valve is activated and sends a pulse of air. The amount of air can be adjusted with the check valve connected. Piloted one way valve only opens during pulse generation. Also a pressure sensor is connected into circuit.If the pressure levels change into an unacceptable level this cuts the flow of first valve.

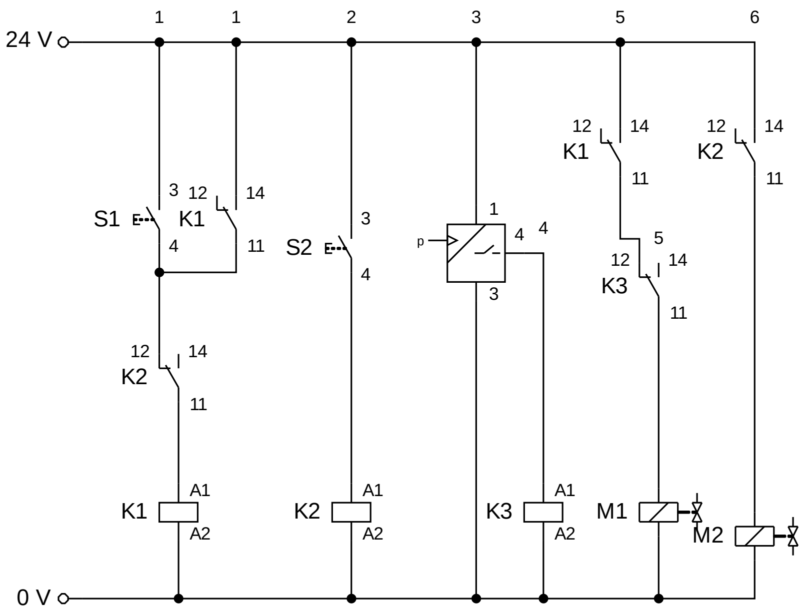

Figure 111 Electrical Schematics

7.Conclusion

My first task was to study Grafcet language semantics and syntax. I studied and practiced it in Fluidsim. In the second chapter of this thesis grammar and syntax is reviewed more in detail.

Second task was literature review in electro-pneumatics technology respectively which is in 3rd chapter.

Third task was about vacuum applications which is in 6^{th} chapter.

My fourth task was to study and create alternative Grafcet solutions for 9 electro-pneumatic circuits. The circuits have been simulated in FluidSIM® V5.0 using classical electro-pneumatic and using virtual PLC in GRAFCET language.

During the simulations I observed that if the sequences were correct the results were identical. Both virtual PLC and electro-pneumatic circuits used the identical pneumatic elements so any difference could be attributed to simulating differences between the methods. The results of these two methods are in 4th chapter.

The fifth task was to design visualization of application in the SCADA system of Task 2 with further modifications such as changing the working mode to automatic or adding a reset button. Despite the shortcomings of not being able to compare visualization results with real life applications, writing a script in Visual Basic and making it match the simulation was an important subject to me. Further work in reliance software help to achieve the best result.

REFERENCES

1-Baker A D, Johnson T L, Kerpelman D I, et al. GRAFCET and SFC as Factory Automation Standards Advantages and Limitations[C]// American Control Conference. IEEE, 1987:1725-1730.

2 https://www.mhj-wiki.de/en/grafcet-workbook

3 Fluidsim user manual

4 https://tameson.com/32-way-pneumatic-valve.html

5 https://tameson.com/52-way-and-42-way-pneumatic-valve.html

6 Festo Didactic: Easy Port, User Manual

7 https://instrumentationtools.com/vacuum-gauges-working-principle/

8https://www.festo.com/net/SupportPortal/Files/17541/Poster_VacuummTechnology_en.pdf

9 www.festo-didactic.com

10 Martinásková, MOODLE, course B191-E371524 - Instrumentation for Automatic Control, Application Examples in Electropneumatics

11 Reliance 4

APPENDIX

Script for Manual Mode

```
Option Explicit

'Declare variables to be used.
Dim start, reset, A_xpos,B_xpos
Dim sens_A0, sens_A1, sens_B0, sens_B1, state
```

```
'Reading Values from Reliance Tags

start = RTag.GetTagValue("Virtual1", "start_button")
reset = RTag.GetTagValue("Virtual1", "reset_button")
A_xpos = RTag.GetTagValue("Virtual1", "Ax")
B_xpos = RTag.GetTagValue("Virtual1", "Bx")
sens_A0 = RTag.GetTagValue("Virtual1", "A0")
sens_B0 = RTag.GetTagValue("Virtual1", "B0")
sens_A1 = RTag.GetTagValue("Virtual1", "A1")
sens_B1 = RTag.GetTagValue("Virtual1", "B1")
state = RTag.GetTagValue("Virtual1", "state")



'if reset flag is up, reset positions.

If reset=true Then

  A_xpos = 0
  B_xpos = 0
  start = false
  state = 0
  reset = false
```

```
End If

'Put sensor states according to read values from the tags.
if A_xpos = 0 Then
  sens_A0 = 1
else
  sens_A0 = 0
end if

if A_xpos = 200 Then
  sens_A1 = 1
else
  sens_A1 = 0
end if

if B_xpos = 0 Then
  sens_B0 = 1
else
  sens_B0 = 0
End if

if B_xpos = 200 Then
  sens_B1 = 1
else
  sens_B1 = 0
End if
```

'If start flag is up and system at rest, set state to 1. State 1 : extract piston A

```
if (start and state = 0) and (sens_A0=1 and sens_B0=1)  Then
  state = 1
  start= false
end if
```

'If at state1 and sensor A1 reads position, proceed to state 2. State 2 : extract piston B

```
if (sens_A1=1 and state = 1) Then
  state = 2
end if
```

'If at state 2 and sensor B1 reads position, proceed to state 3. State 3: retract piston A

```
if (sens_B1=1 and state = 2) Then
  state = 3
end if
```

'If at state 3, and piston A is retracted, proceed to state 4. State 4: retract piston B

```
if (sens_A0=1 and state = 3) Then
  state = 4
```

```
end if

' If B is retracted, system at rest. Revert back to state 0.
if (sens_B0=1 and state = 4) Then
  state = 0
end if




'State 1 = extract piston A
if state = 1 Then

  while A_xpos<200
    A_xpos= A_xpos + 50
  wend

End if

'State 2= extract piston B
if state = 2 Then

  while B_xpos<200
    B_xpos = B_xpos + 50
  wend
```

```
end if

'State 3 = retract piston A
if state = 3 Then

  while A_xpos>0
    A_xpos = A_xpos - 50
  wend

end if


'State 4 = retract piston B
if state = 4 Then

  while B_xpos <0
    B_xpos = B_xpos -50
  wend
end if

'İf state is 0, stay at rest.
if state = 0 Then

  A_xpos = 0
  B_xpos = 0
end if
```

```
' Set reliance tags to calculated values.

RTag.SetTagValue "Virtual1", "start_button",start
RTag.SetTagValue "Virtual1", "Ax",A_xpos
Rtag.SetTagValue "Virtual1", "Bx",B_xpos
RTag.SetTagValue "Virtual1", "A0",sens_A0
RTag.SetTagValue "Virtual1", "A1",sens_A1
RTag.SetTagValue "Virtual1", "B0",sens_B0
RTag.SetTagValue "Virtual1", "B1",sens_B1
RTag.SetTagValue "Virtual1", "reset_button",reset
RTag.SetTagValue "Virtual1", "state",state
```

Script for Auto Mode

```
Option Explicit

'Declare variables to be used.
Dim start, reset, A_xpos,B_xpos
Dim sens_A0, sens_A1, sens_B0, sens_B1, state
```

```
'Reading Values from Reliance Tags

start = RTag.GetTagValue("Virtual1", "start_button")
reset = RTag.GetTagValue("Virtual1", "reset_button")
A_xpos = RTag.GetTagValue("Virtual1", "Ax")
B_xpos = RTag.GetTagValue("Virtual1", "Bx")
sens_A0 = RTag.GetTagValue("Virtual1", "A0")
sens_B0 = RTag.GetTagValue("Virtual1", "B0")
sens_A1 = RTag.GetTagValue("Virtual1", "A1")
sens_B1 = RTag.GetTagValue("Virtual1", "B1")
state = RTag.GetTagValue("Virtual1", "state")



'if reset flag is up, reset positions.

If reset=true Then

  A_xpos = 0
  B_xpos = 0
  start = false
  state = 0
  reset = false
```

```
End If

'Put sensor states according to read values from the tags.
if A_xpos = 0 Then
  sens_A0 = 1
else
  sens_A0 = 0
end if

if A_xpos = 200 Then
  sens_A1 = 1
else
  sens_A1 = 0
end if

if B_xpos = 0 Then
  sens_B0 = 1
else
  sens_B0 = 0
End if

if B_xpos = 200 Then
  sens_B1 = 1
else
  sens_B1 = 0
End if
```

```
'If start flag is up and system at rest, set state to 1. State 1 : extract piston A

if (start and state = 0) and (sens_A0=1 and sens_B0=1)  Then
  state = 1
  start= false
end if

'If at state1 and sensor A1 reads position, proceed to state 2. State 2 : extract piston B

if (sens_A1=1 and state = 1) Then
  state = 2
end if


'If at state 2 and sensor B1 reads position, proceed to state 3. State 3: retract piston A
if (sens_B1=1 and state = 2) Then
  state = 3
end if

'If at state 3, and piston A is retracted, proceed to state 4. State 4: retract piston B
if (sens_A0=1 and state = 3) Then
  state = 4
```

```
end if

' If B is retracted, system at rest. Revert back to state 0.
if (sens_B0=1 and state = 4) Then
 state = 0
end if




'State 1 = extract piston A
if state = 1 Then

 while A_xpos<200
   A_xpos= A_xpos + 50
 wend

End if

'State 2= extract piston B
if state = 2 Then

 while B_xpos<200
   B_xpos = B_xpos + 50
 wend
```

```
end if

'State 3 = retract piston A
if state = 3 Then

  while A_xpos>0
    A_xpos = A_xpos - 50
  wend

end if


'State 4 = retract piston B
if state = 4 Then

  while B_xpos <0
    B_xpos = B_xpos -50
  wend
end if

' if start flag is up, proceed back to state 1.  Auto loop.
if state = 0 Then

  A_xpos = 0
  B_xpos = 0
  if (start = true)  Then
```

```
   state = 1
  end if

end if

' Set Reliance tags to calculated values.

RTag.SetTagValue "Virtual1", "start_button",start
RTag.SetTagValue "Virtual1", "Ax",A_xpos
Rtag.SetTagValue "Virtual1", "Bx",B_xpos
RTag.SetTagValue "Virtual1", "A0",sens_A0
RTag.SetTagValue "Virtual1", "A1",sens_A1
RTag.SetTagValue "Virtual1", "B0",sens_B0
RTag.SetTagValue "Virtual1", "B1",sens_B1
RTag.SetTagValue "Virtual1", "reset_button",reset
RTag.SetTagValue "Virtual1", "state",state
```