MATRIX | PNEUMATICS

PNEUMATICS CONTROL PLUS USING SIEMENS PLC

CP2193

Inspiring The Next Generation Of Engineers

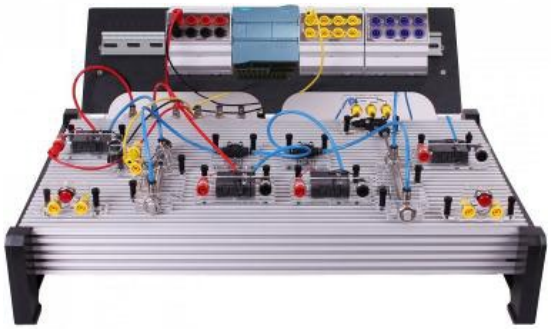
www.matrixtsl.com

Introduction

SETUP

Components Overview

In industry, complex pneumatic systems are often controlled by a microprocessor in systems called programmable logic controllers (PLCs).

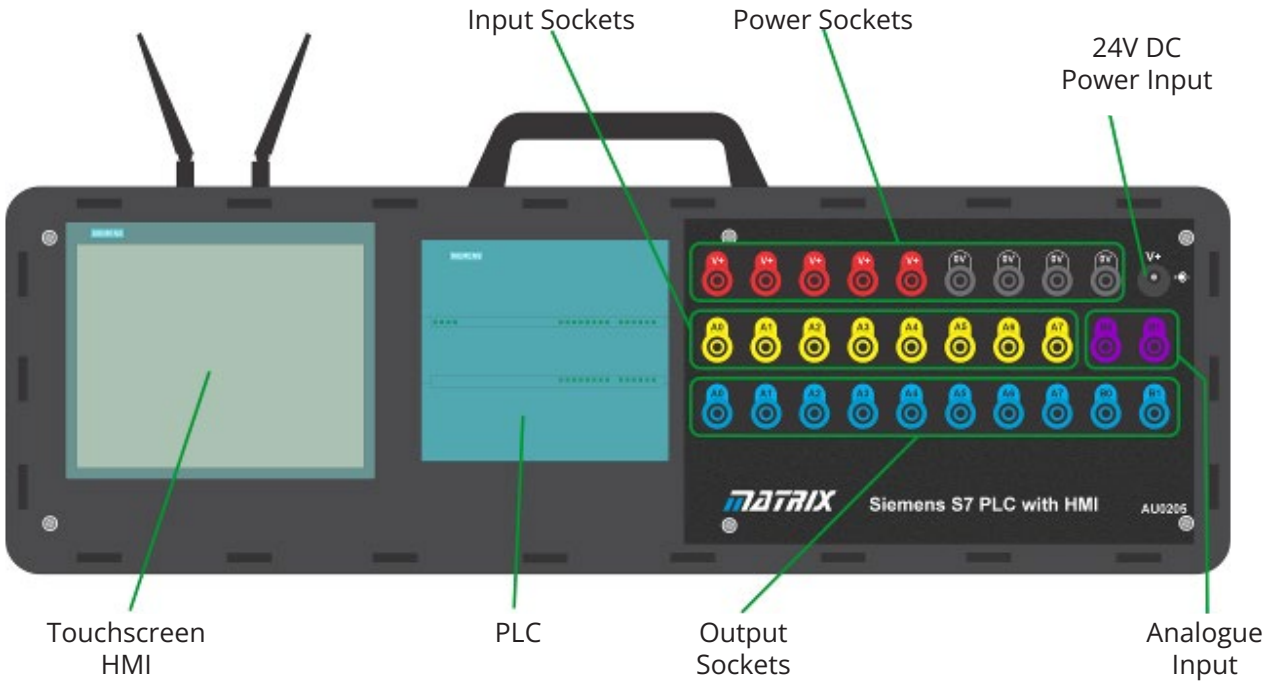


These make it relatively easy to:

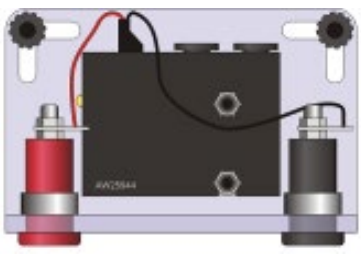
- extend and retract cylinders in any sequence;
- include timing and counting;
- make the system respond to sensors.

This module uses a Siemens S7-1200 series PLC to control pneumatic circuits.

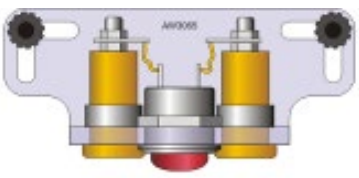
PLC with HMI



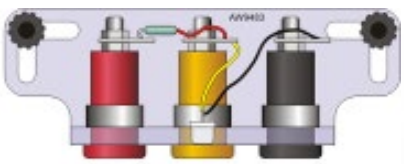
Pneumatics Components:



3/2 Solenoid Valve

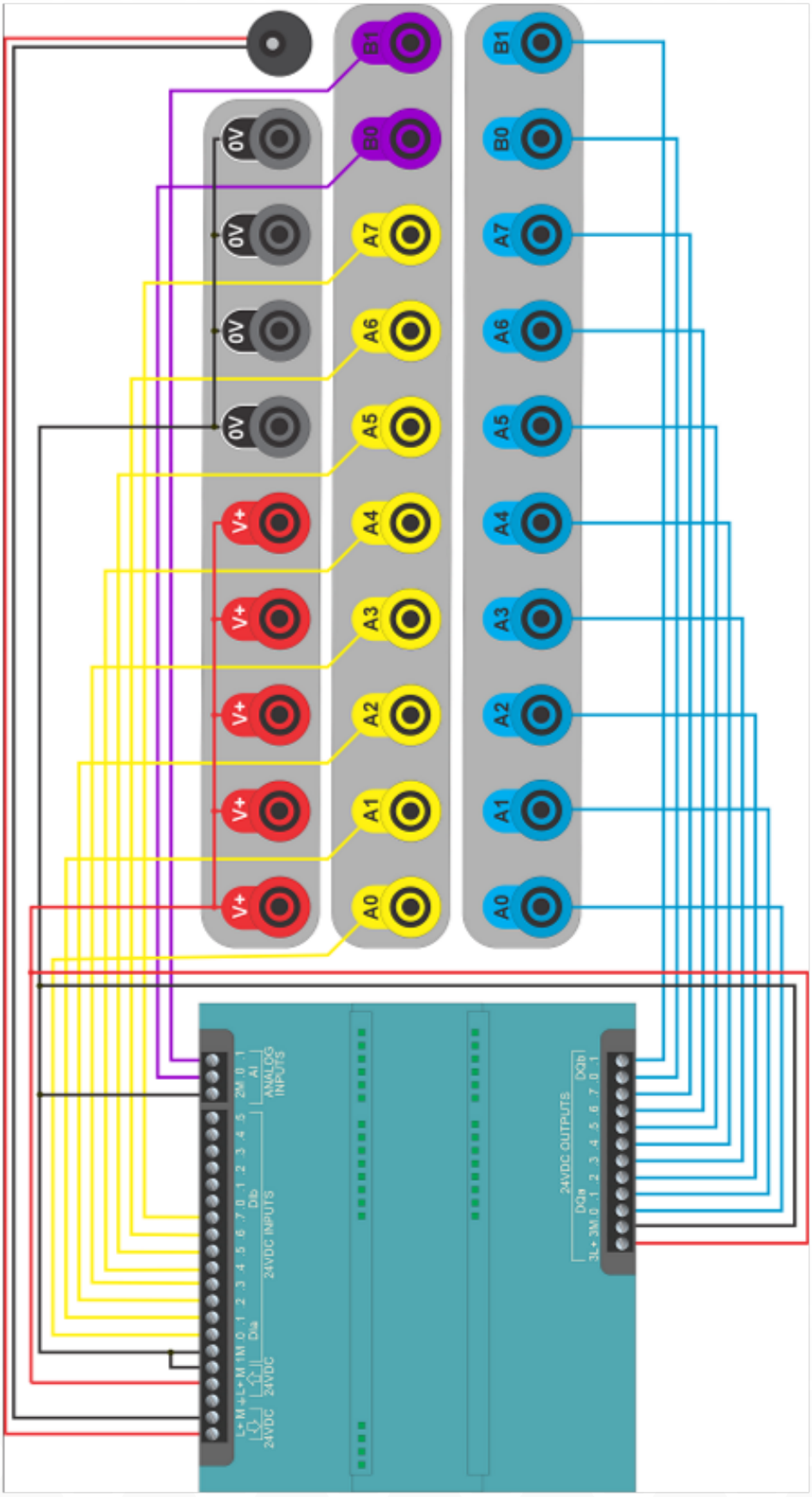


Switch



Light Sensor

PLC Input and Output Wiring:

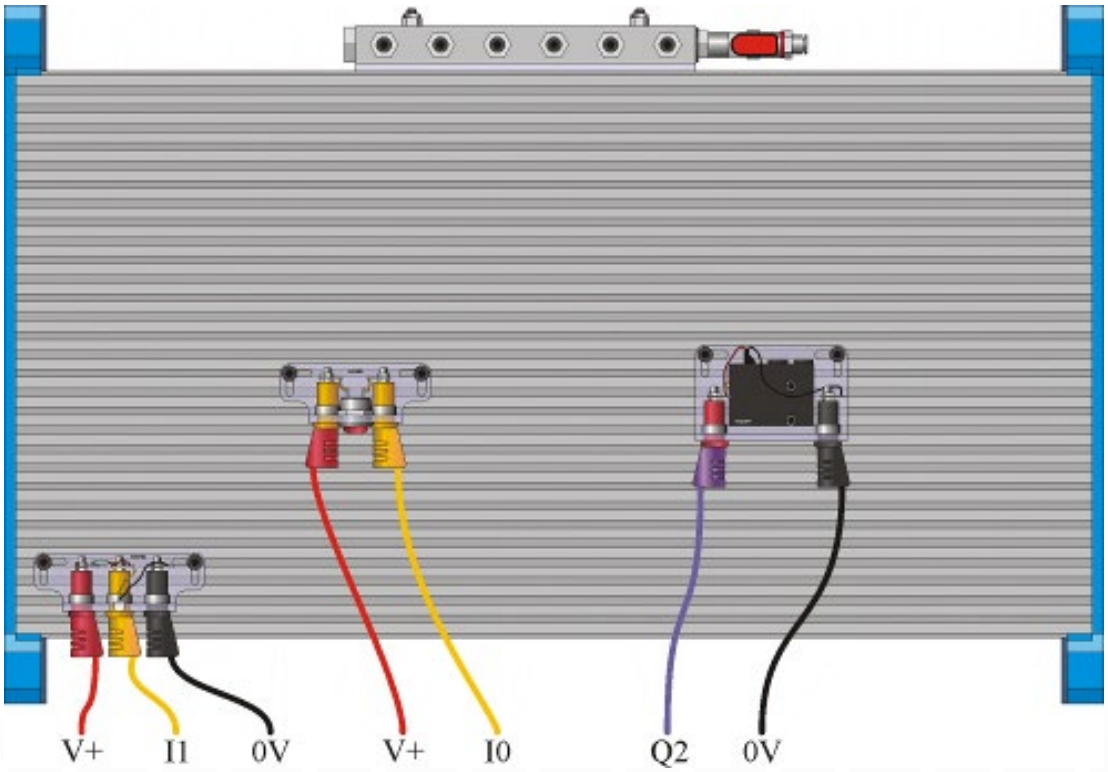


WORKSHEETS

Over to You

- Build the arrangement shown below, used to demonstrate how the PLC can control pneumatic valves. There are no pneumatic connections, only electrical ones!
- Clamp a switch and a light sensor to the platform.
  - Fasten a 3/2 solenoid valve to the platform.
  - Make the following connections:
    - switch - red socket to a red V+ socket and black socket to PLC input A0;
    - light sensor - red socket to a red V+ socket, black socket to a black 0V socket and yellow socket to PLC input A1;
    - solenoid valve - red positive to blue PLC output A2 and negative to a black 0V socket.
- Plug in the power supply and switch on.
- Create the logic program as detailed on page 7 and transfer to the PLC
- Press the switch, and notice that the PLC LED on Input 0 lights. You should also hear the solenoid operate inside the control valve.
- Now shade the light sensor with your hand. Look at PLC LED on Input 1 as you do so. You should hear the solenoid valve operate again.

Layout for worksheet 1:



WORKSHEETS

Worksheet 1 – Electronic Control

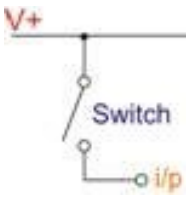
The Tour Continues:

- The Siemens S7-1200 is a fully specified industrial controller which is wired to 4mm shrouded sockets on the AU0205 front panel for easy connection to the Pneumatics parts on the platform via banana plug leads.
- The system is designed to operate at 24V DC.
- The yellow sockets are digital inputs, two are used for these worksheet exercises and four as program selectors. The input LEDs show the state of each input.
- Each input has a resistance to the 0V rail and requires an input voltage of at least 15V at 2.5mA to register as a logic high.

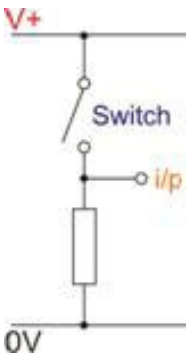
As a result:

- The PLC inputs sit at 0V when no external input signal is present;
- Passive sensing components like a switch or thermistor can be attached directly, as in circuit A, rather than requiring the full voltage divider sub-system, shown in circuit B.
- Active sensing components like the Pneumatics light sensor will need to be connected to +V and 0V, with the sensor output connected to the PLC input terminal.

A



B

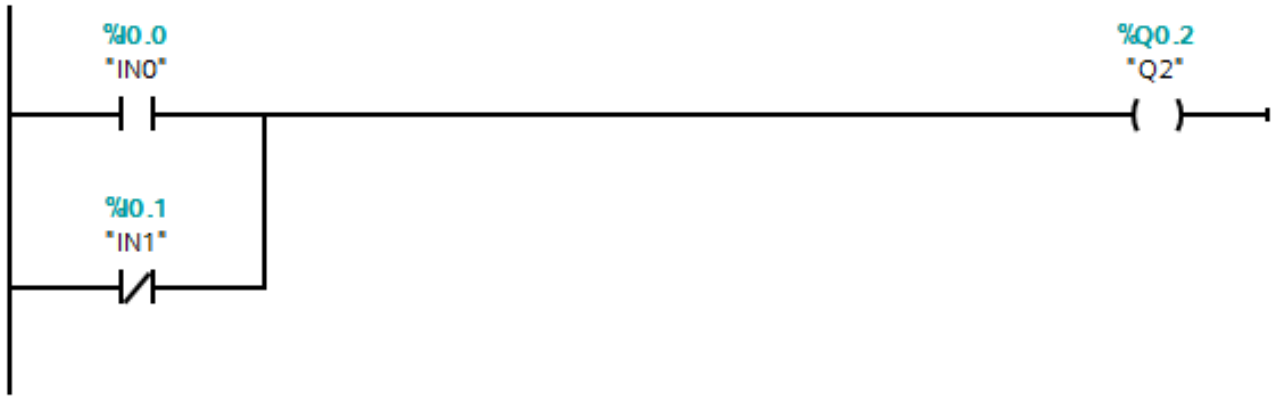


- The blue sockets are digital outputs. The PLC has ten solid state outputs marked as A0 to A7, B0 and B1. These outputs supply 24V to external components. They are represented in the PLC program as Q0.0 to Q0.7, Q1.0 and Q1.1.
- The output LEDs light when the corresponding output switches ‘on’.

Overview of Program 1A:

The sequence is:

- check whether the switch is pressed (input high and LED on)
- if it is, switch on the control valve;
- check whether the light sensor is in darkness (input low and LED off)
- if it is, switch on the control valve;



The switch and light sensor are in a logic OR configuration.
The control valve switches on if the switch is pressed OR if the light sensor is in darkness.

For your records:

Use a multimeter to measure the quantities listed below.
Then copy and complete the table with your results.

Quantity	Measurement
PLC input I0 – switch not pressed	
PLC input I0 – switch pressed	
PLC input I1 – light sensor in daylight	
PLC input I1 – light sensor in darkness	
PLC output Q2 – solenoid not activated	
PLC output Q2 – solenoid activated	

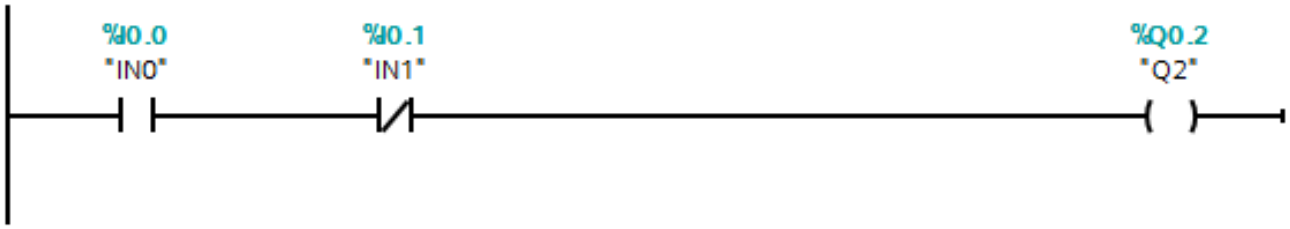
WORKSHEETS

Worksheet 1 – Electronic Control

Overview of Program 1B:

The sequence is:

- check whether the switch is pressed and the light sensor is in darkness;
- if it is, switch on the control valve;



The switch and light sensor are in a logic AND configuration.
The control valve switches on if the switch is pressed AND if the light sensor is in darkness.

For your records:

Use a multimeter to measure the quantities listed below.
Then copy and complete the table with your results.

Quantity	Measurement
PLC input I0 – switch not pressed	
PLC input I0 – switch pressed	
PLC input I1 – light sensor in daylight	
PLC input I1 – light sensor in darkness	
PLC output Q2 – solenoid not activated	
PLC output Q2 – solenoid activated	

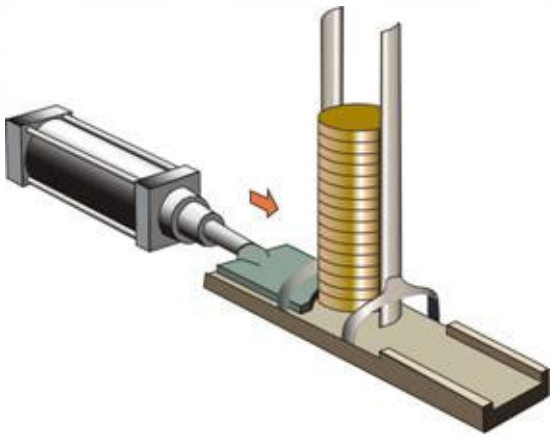
WORKSHEETS

Worksheet 2 – Magazine Feed

In automated production, it is often necessary to feed blanks into the process from a store, known as a magazine.

Pneumatics offers a reliable and speedy way to do this, as the diagram illustrates. A single-acting cylinder pushes a new blank onto the conveyor belt, and then retracts.

This worksheet examines how an electronic control system can automate this part of the process



Over to You

- Read the safety rules given on the next page before you start.
- The red lever on the manifold must be turned off at this stage.
- Build the arrangement shown on the next page. Compare the physical and pneumatic circuit diagrams, as you do so.
  - Clamp a switch and a 3/2 solenoid valve to the platform.
  - Add a flow-control valve, to restrict flow in the direction shown by the arrow.
  - Make the following electrical connections:
    - switch - red socket to a red V+ socket and black socket to PLC input A0;
    - solenoid valve - red positive to PLC output A2 and black negative to a black 0V socket.
- Plug in the power supply and switch on.
- Create the logic program as detailed on page 11 and transfer to the PLC
- Turn on the air supply.
- The switch represents a safety device:
  - It could ensure that a cover is in place over the machinery.
  - It could be a 'dead-man's handle' (emergency stop button) which stops the process unless the operator keeps the switch pressed.
- Press and hold down the switch. The cylinder extends and retracts repeatedly, governed by the time delays built into the program. This is described later.
- Adjust the flow rate with the flow control valve so that the cylinder extends fully, within the time allowed, but does so at a moderate speed.

WORKSHEETS

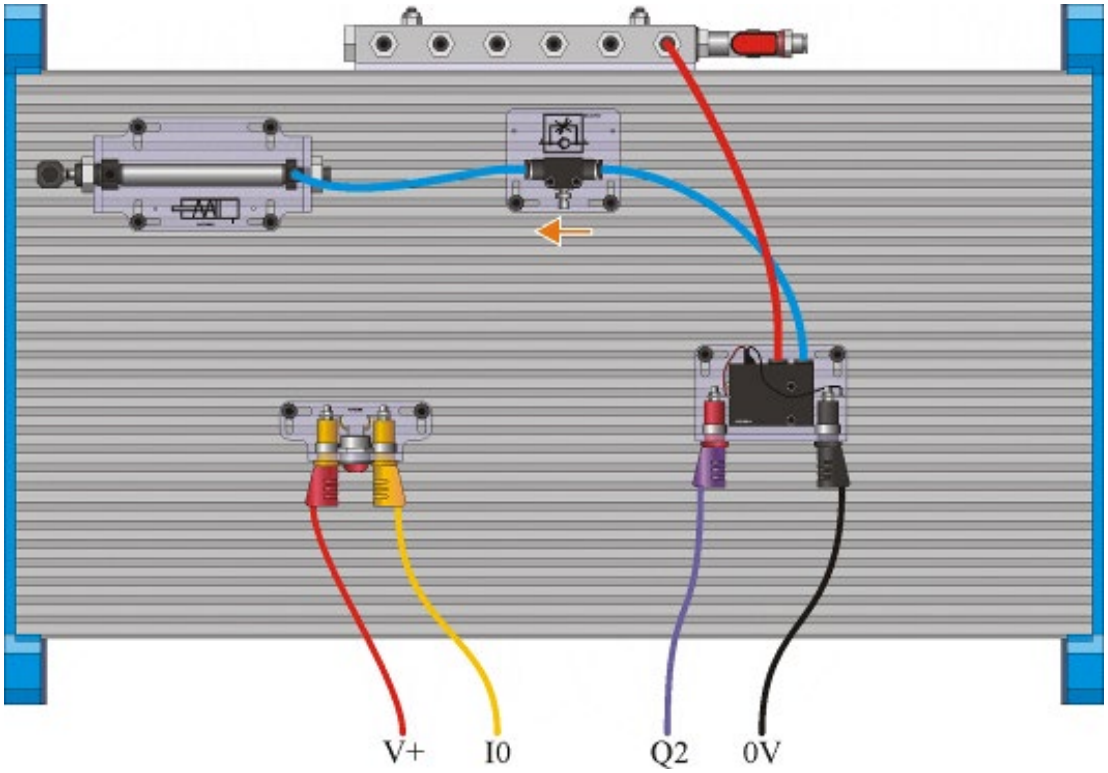
Worksheet 2 – Magazine Feed

Safety Rules for Pneumatic Systems

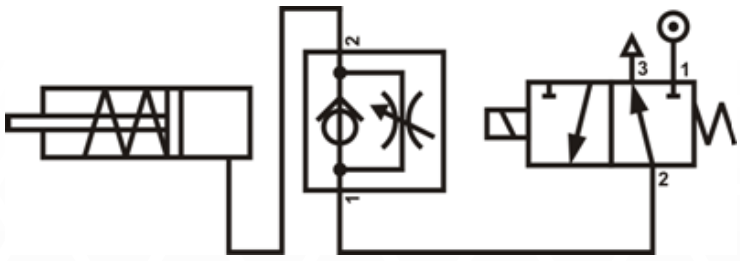
Remember: compressed air and its components are capable of exerting large forces.

1. Never blow compressed air at anyone.
2. Don't turn on the air supply until the circuit is complete.
3. If you find an air leak, turn off the air supply at once.
4. Always turn off the air supply before you alter a circuit.
5. Keep fingers clear of moving parts such as piston rods.
6. Wear safety spectacles when building and operating pneumatic circuits.

Layout for worksheet 2:



Pneumatic circuit for worksheet 2:

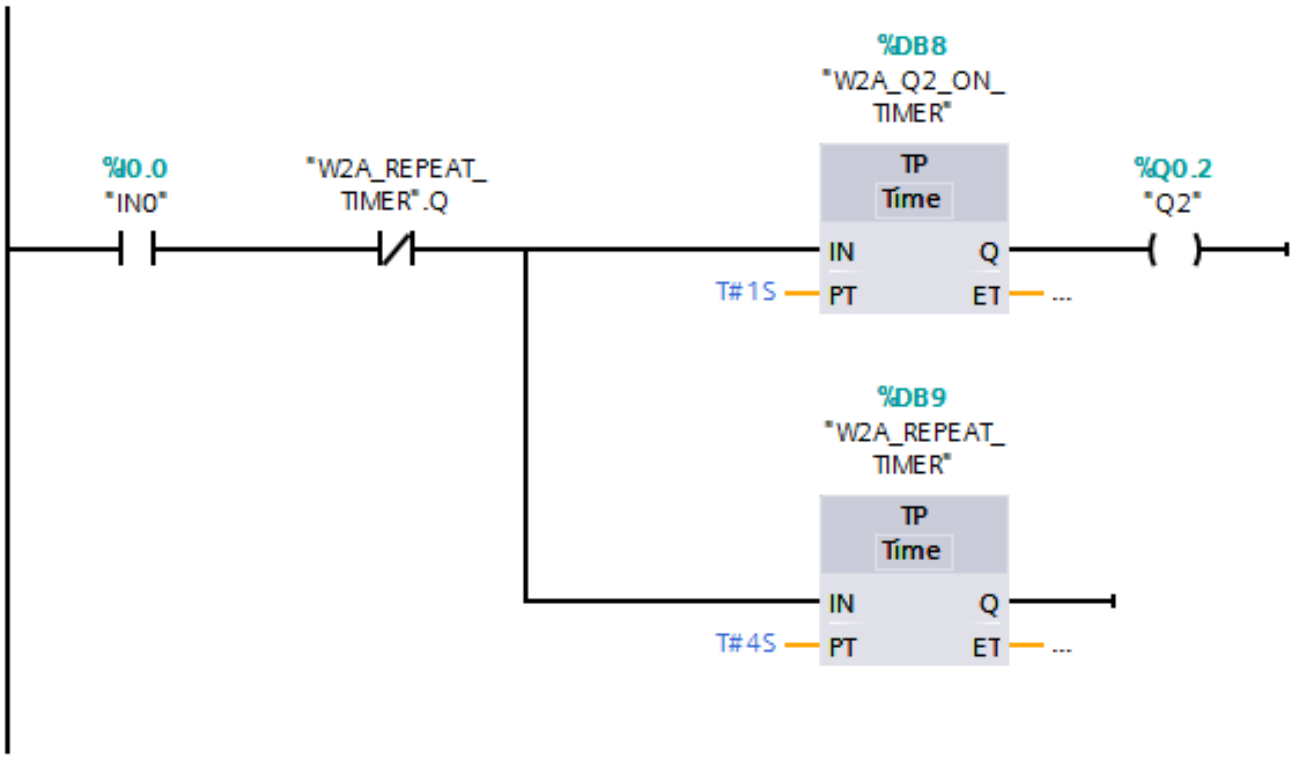


Single-acting Cylinder | Flow Control Valve | 3/2 Solenoid Valve

Overview of Program 2A:

The program is similar to that used in worksheet 1, except that the light sensor is not needed.
This introduces the use of two timer delays, one to allow the cylinder to extend fully, and one to delay the next blank until the production process is ready for it.

- check whether the switch is pressed;
- if it is, switch on the extend control valve for 1 second;
- Start a timer to disable re-operation for 4 seconds;



A Modification

The processing company may want a limited run on a particular commodity. Program 2A keeps running as long as the switch is pressed. Program 2B is a modification that loops back only ten times, so that only ten blanks are processed.

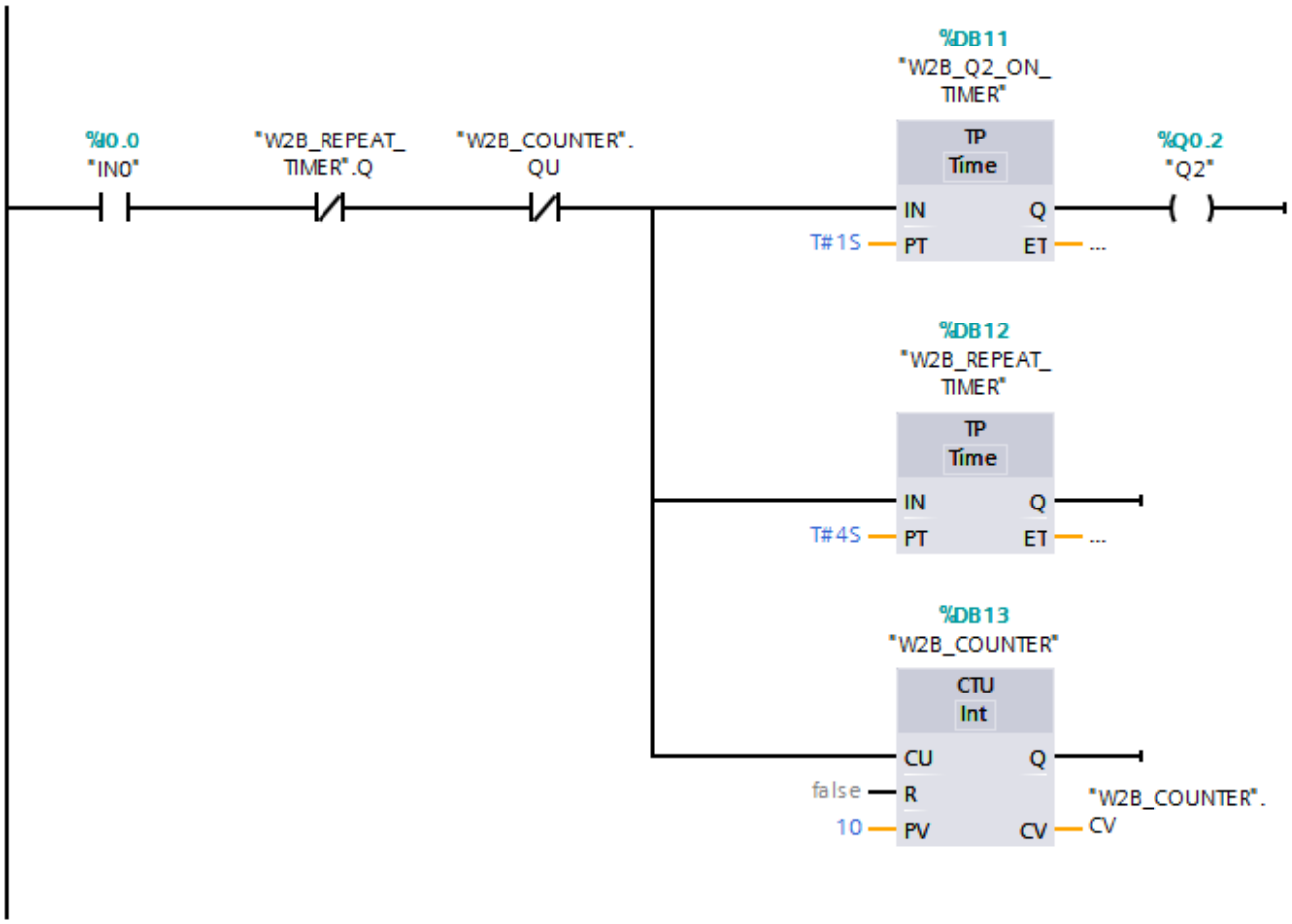
- Press and hold down the switch. The cylinder extends and retracts but only ten times. Instead of repeating indefinitely, the PLC keeps a count and inhibits the operation after 10 operations.

WORKSHEETS

Worksheet 2 – Magazine Feed

The Modified Program (2B):

The only change to the previous program is that the program is now configured to act only ten times. Previously, it acted continuously. This is done by the addition of a counter to the logic.



For your records:

- Copy the ladder logic for program 2B, given above.
- Explain the function of each symbol in the program.
- Which symbol would be modified to:
  - make the process repeat 20 times;
  - increase the time for the cylinder extend;
  - increase the time between process cycles.
- How would you make the cylinder extend more quickly?

WORKSHEETS

Worksheet 3 – Bank Vault Door Controller

Bank vaults often have heavy steel doors for enhanced security. Their weight makes them difficult to move manually.

They can be opened and closed pneumatically, using a double-acting cylinder. This can be linked to an electronic security system, requiring a correct PIN number, finger-print or retina scan.

This worksheet looks at the control system for the pneumatic circuit.

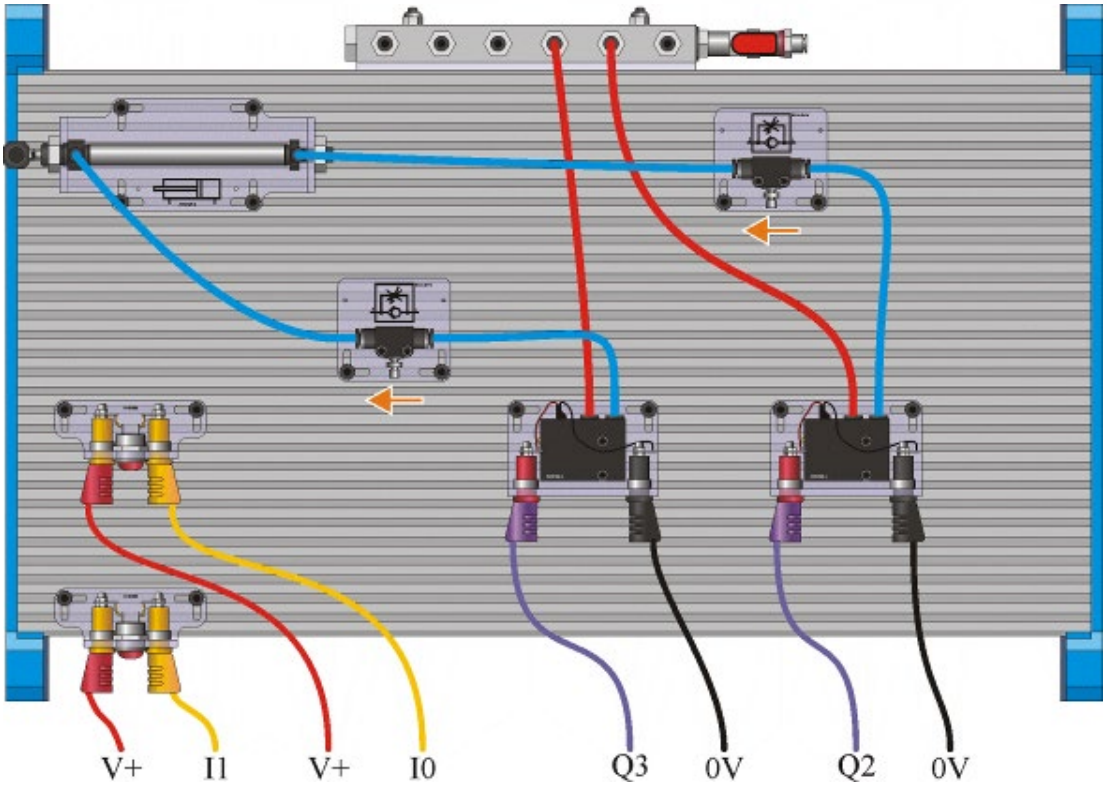
Over to You

- Make sure that you apply the safety rules given in the previous worksheet!
- The red lever on the manifold must be turned off at this stage.
- Build the arrangement shown on the next page. Again, compare the physical and pneumatic circuit diagrams.
- Make the following electrical connections:
  - switch 1 - red socket to a red V+ socket and black socket to PLC input A0;
  - switch 2 - red socket to a red V+ socket and black socket to PLC input A1;
  - solenoid valve 1 - positive to PLC output A2 and negative to a black 0V socket;
  - solenoid valve 2 - positive to PLC output A3 and negative to a black 0V socket.
- Plug in the power supply and switch on.
- Create the logic program as detailed on page 15 and transfer to the PLC
- Turn on the air supply.
- Press and hold down switch 1. The cylinder extends. Adjust the flow rate with flow control valve 1 so that it extends fully at a moderate speed.
- Press and hold down switch 2. The cylinder now retracts. Again, adjust the flow rate, now with flow control valve 2 so that it also retracts at a moderate speed.

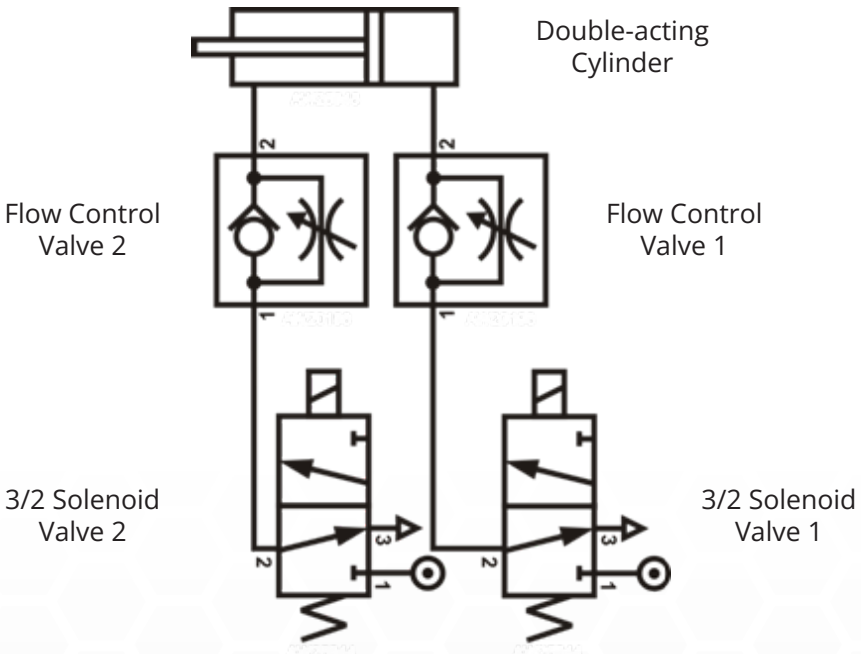
WORKSHEETS

Worksheet 3 – Bank Vault Door Controller

Layout for worksheet 3:



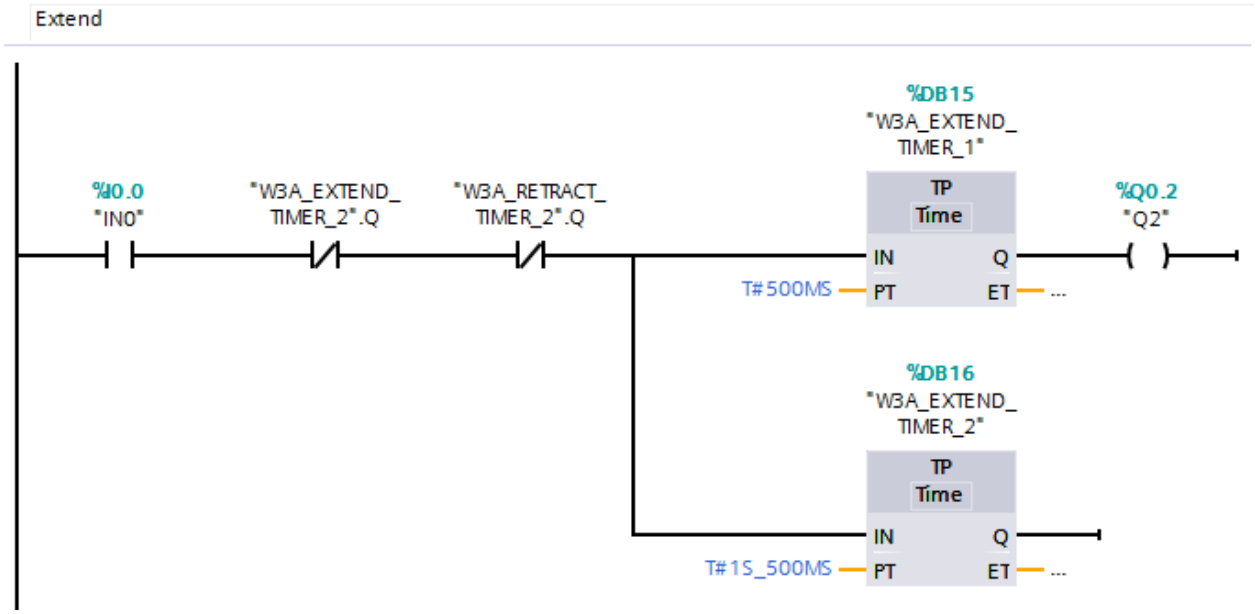
Pneumatic circuit for worksheet 3:

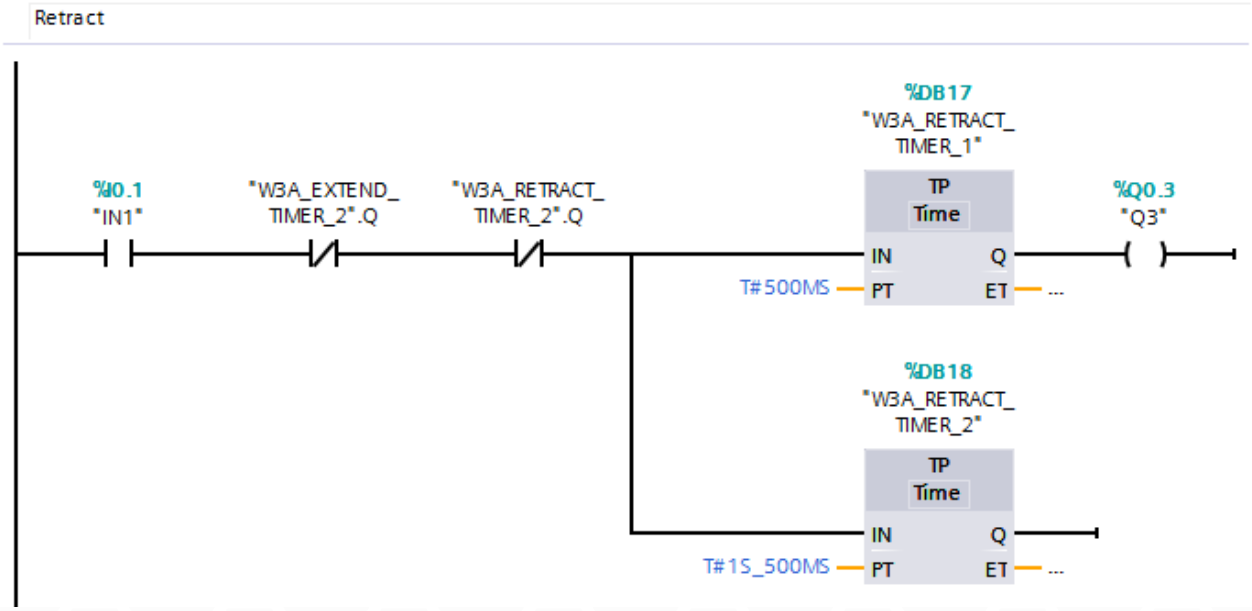


Overview of Program 3A:

There are two sections in the program.
One responds to closing the 'extend' switch, and the other to closing the 'retract' switch
The sequence is:

- check whether the 'extend' switch is closed;
- if it is, switch on the 'extend' control valve for 0.5 seconds;
- check whether the 'retract' switch is closed;
- if it is, switch on the 'retract' control valve for 0.5 seconds;
- In both cases inhibit re-operation for 1.5 seconds;



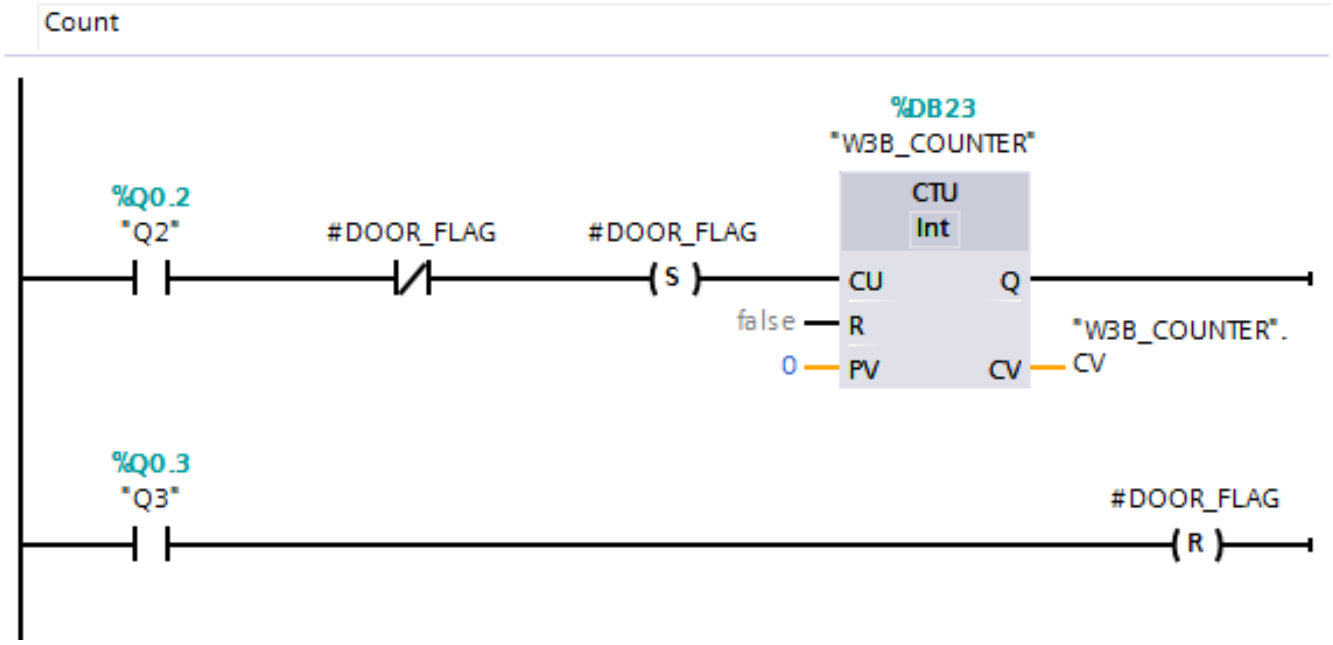


WORKSHEETS

Worksheet 3 – Bank Vault Door Controller

Overview of Program 3B:

The bank wants to monitor how many times the bank vault is opened.
The program is modified to do this by incrementing a counter.
This is achieved by adding another two ladder rungs to program 3A



We do not want to add one to the count every time a switch is operated. We want it to increment only when the door is opened, and then closed.
This requires the use of a flag, this has been named DOOR_FLAG

Worksheet3B

		Name	Data type	Default value	Retain	Accessible ..	Writable..	Visible ...
8		DOOR_FLAG	Bool	false	Non-retain	☑	☑	☑

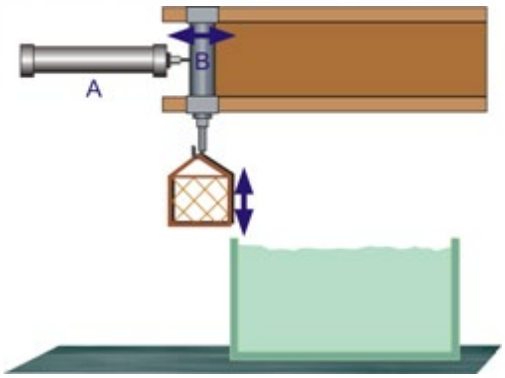
When the door is opened, by pressing the 'extend' switch, the flag is not set (DOOR_FLAG = 0) and so the count is incremented. In addition, the flag is set (DOOR_FLAG = 1).

No further increments can take place as the flag is still set. When the 'retract' switch is pressed, one effect is to reset the flag, (DOOR_FLAG = 0) again. The next time the door is opened, the count is incremented, and the process described above repeats.

WORKSHEETS

Worksheet 4 – In Sequence

Many applications of pneumatics require two, or more, cylinders to operate together in a sequence.
In the 'Pneumatics Pneumatics' module, it was shown how a purely pneumatic circuit could control a system used to move a basket of car components into and out of a tank of cleaning fluid. The sequence needed was **A+, B+, B-, A-.**
That system used three 5/2 control valves, and five 3/2 control valves, and had to be rebuilt to accommodate any modification of the sequence.
In this worksheet, we show how a standard pneumatic circuit can be made to perform different sequences simply by choosing the appropriate program.



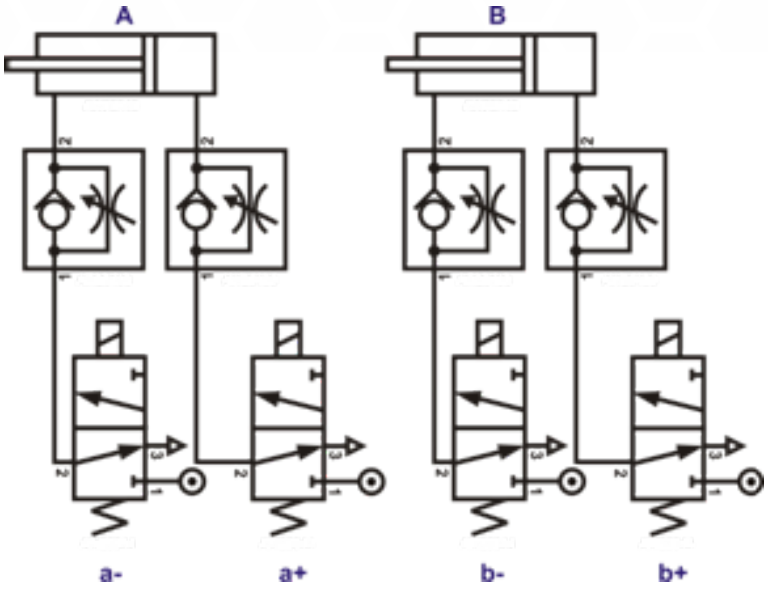
Over to You

- Make sure that the red lever on the manifold is turned off.
- Build the arrangement shown on the next page. Only the pneumatic circuit diagram is given. However, the connections for each cylinder are the same as in the last worksheet.
- Make the following electrical connections:
  - switch 1 - red socket to a red V+ socket and black socket to PLC input A0;
  - switch 2 - red socket to a red V+ socket and black socket to PLC input A1;
  - solenoid valve **a+** - positive to PLC output **A0** and negative to a black 0V socket;
  - solenoid valve **a-** - positive to PLC output **A1** and negative to a black 0V socket.
  - solenoid valve **b+** - positive to PLC output **A2** and negative to a black 0V socket;
  - solenoid valve **b-** - positive to PLC output **A3** and negative to a black 0V socket.
- Plug in the power supply and switch on.
- Create the logic program as described on the next page and transfer to the PLC
- Then turn on the air supply.
- Press and hold down switch 1. The sequence should begin by extending cylinder A, to move the basket of components over the tank. Adjust the flow control valve to give a sensible speed of movement.
- Press switch 2 to extend cylinder **B** to lower the basket into the tank.
- After a delay of ten seconds, cylinder **B** should retract, raising the tank.
- Now press switch 1 again. This time it retracts cylinder **A**, returning the basket to its initial
- position.

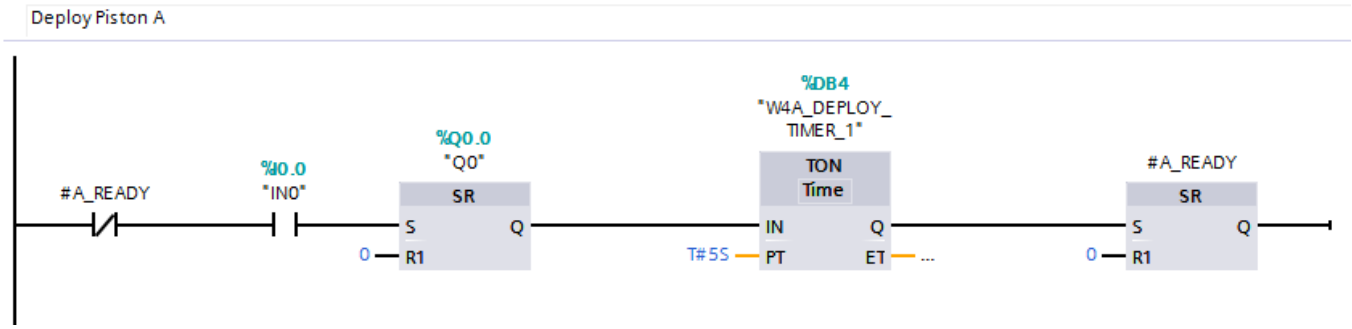
WORKSHEETS

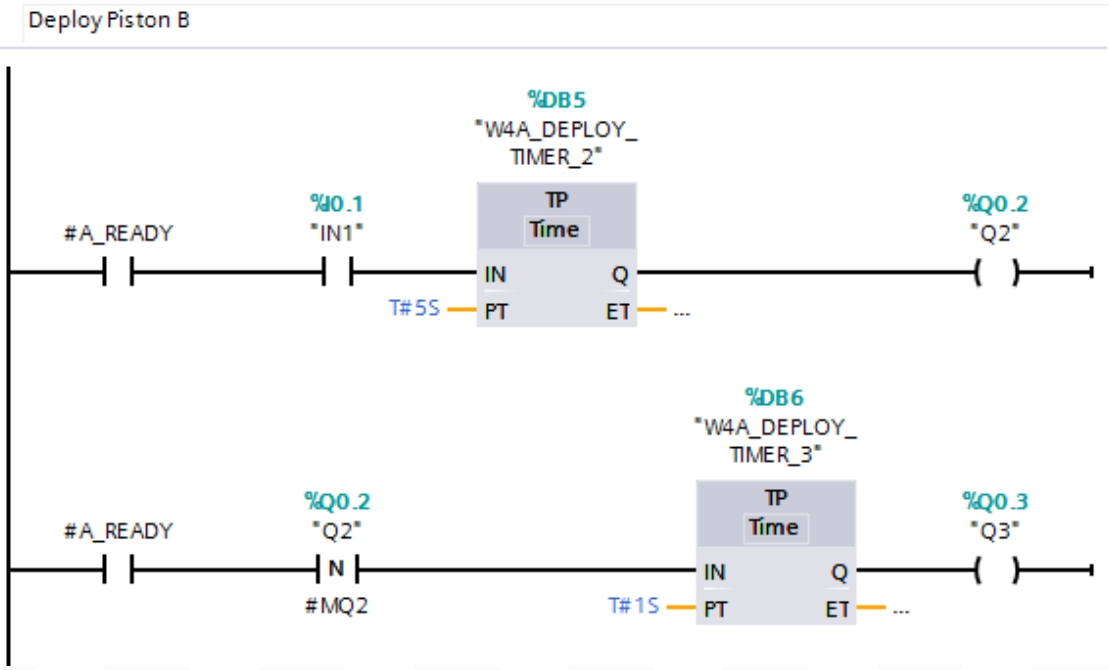
Worksheet 4 – In Sequence

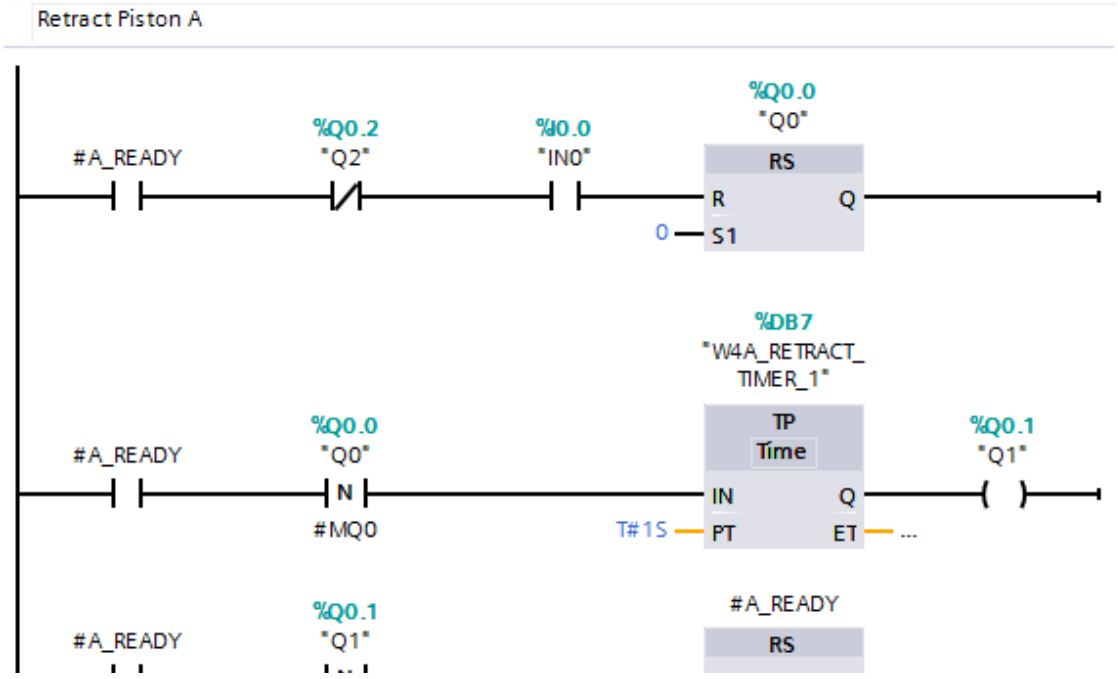
Pneumatic circuit for worksheet 4:



Program 4A:







Worksheet4A

		Name	Data type	Default value	Retain	Accessible ...	Writable ...	Visible...
10		A_READY	Bool	false	Retain	☑	☑	☑

Overview of Program 4A:

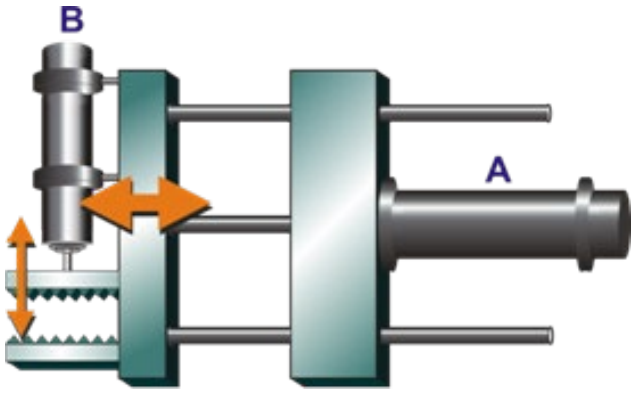
- The first program section is the “Deploy Piston A”
  - The program has a flag that indicates if piston A is deployed, named A_READY
  - If the flag is not set and input A0 is activated, then the Q0 output is set and cylinder **A** extends, moving the basket over the tank.
  - After a 5 second delay, to ensure the piston has had time to deploy, then the A_READY flag is set.
- The second section is “Deploy Piston B”
  - When the A_READY flag is set and the switch on input A1 is activated, Q2 output is turned on for 5 seconds, cylinder **B** extends, lowering the basket into the tank.
  - At the end of this period when Q2 is turned off, the negative edge triggers timer 3 to active output Q3 for 1 second. Hence valve **b-** is actuated to raise the basket.
- The third section is “Retract Piston A”
  - This monitors the switch on input A0. When pressed, valve **a+** is switched off by resetting Q0. This triggers activation of Q1 for 1 second. Cylinder **A** retracts, returning the basket to its starting position. This triggers the resetting of the A_READY flag back to 0.

WORKSHEETS

Worksheet 4 – In Sequence

Over to You

A modification:
The next pneumatic control system operates a gripper.



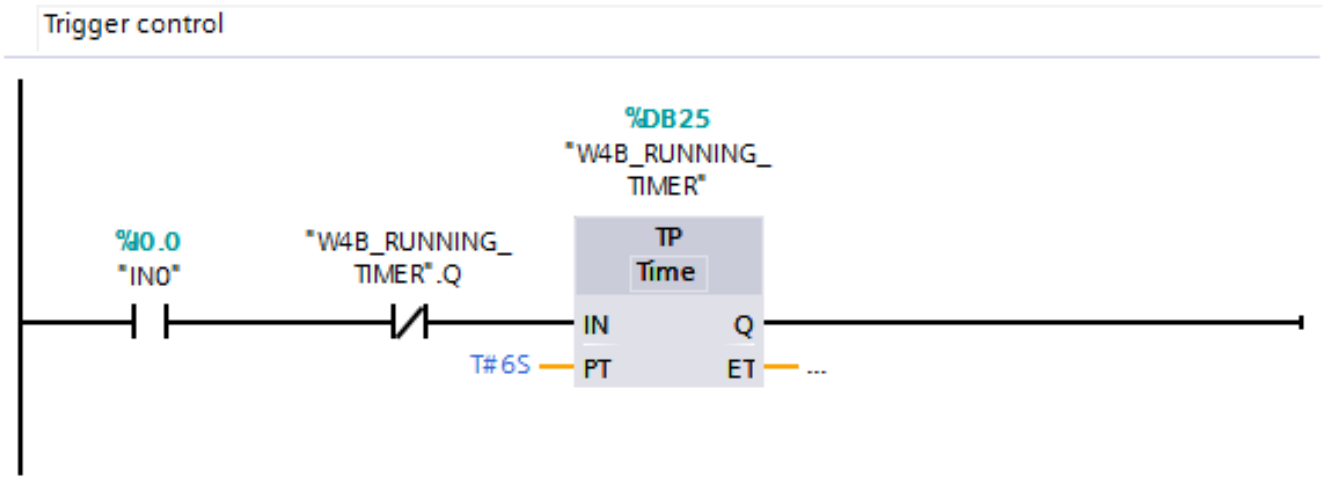
The aim is that the gripper reaches out and brings back an object, such as a cup, when a switch is pressed.

The sequence required is:

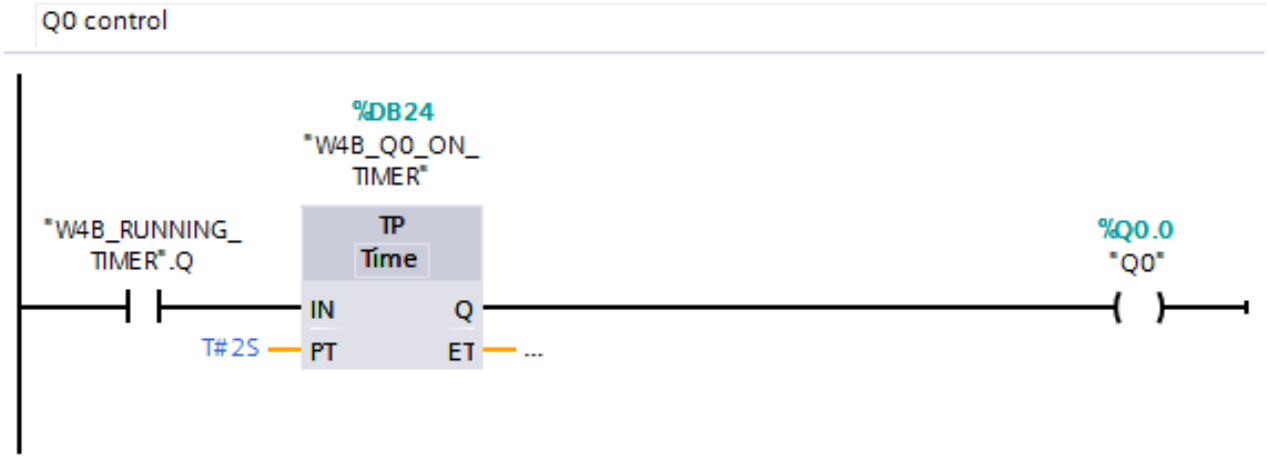
- reach out (**A**+);
- grip (**B**+);
- bring back (**A**-);
- release (**B**-).

The pneumatic circuit is the same as before. The program controlling it changes to generate the required sequence, which is **A+, B+, A-, B-.**

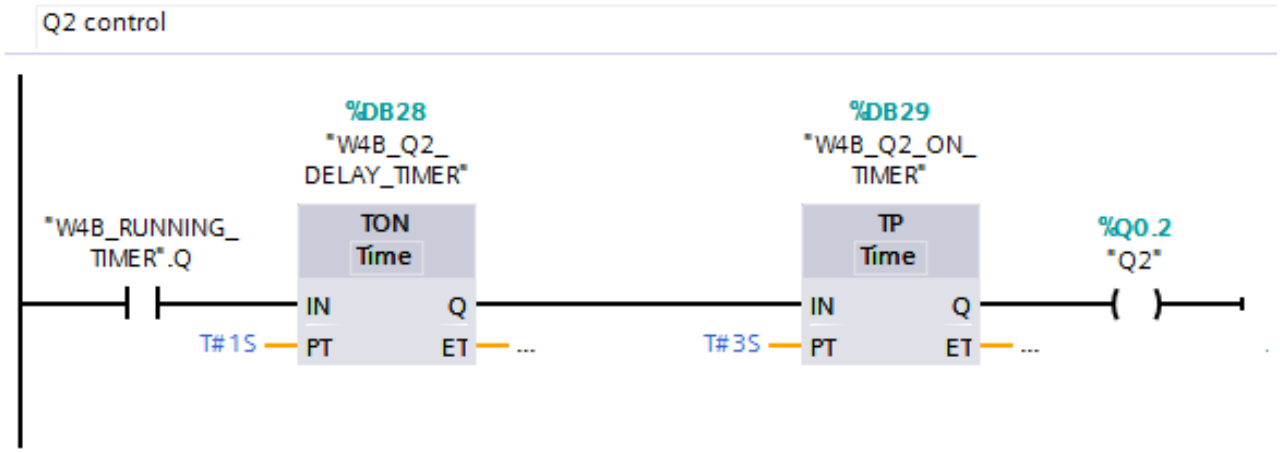
- Add the changes as described below and transfer to the PLC
- Press switch 1, and then release it.
- The sequence begins by extending cylinder **A**, and then **B**, and then retracting **A** and then **B. Program 4B** is as follows:



- The switch on input 0 triggers a “Running” timer that inhibits further triggers of operation for 6 seconds.



The starting of the "Running" timer triggers output Q0 to turn on for 2 seconds, cylinder **A** extends, moving the gripper forwards.



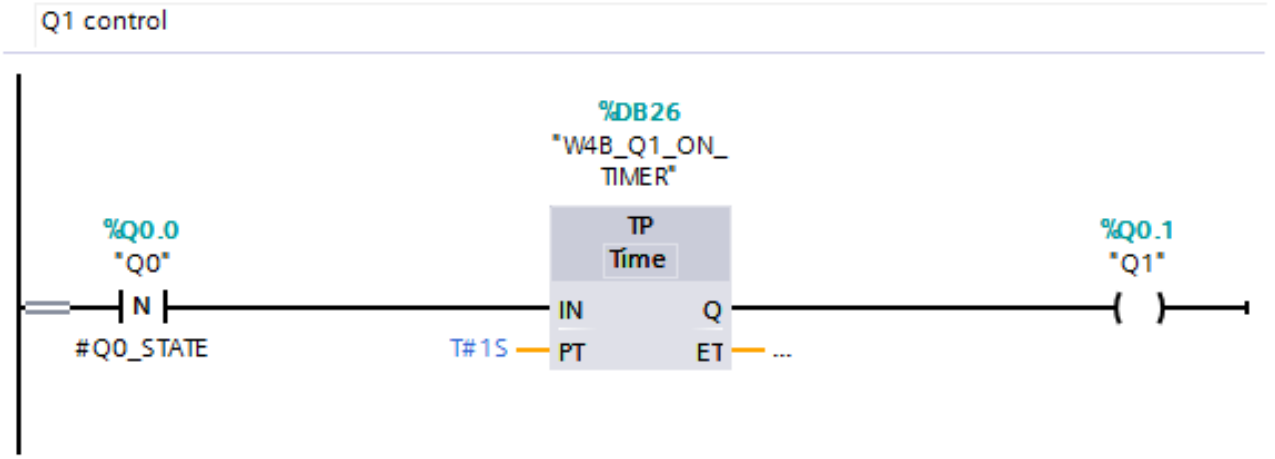
The starting of the "Running" timer also triggers a delay of 1 second, followed by operation of Q2 for 3 seconds. This extends cylinder **B** to operate the grip mechanism.

WORKSHEETS

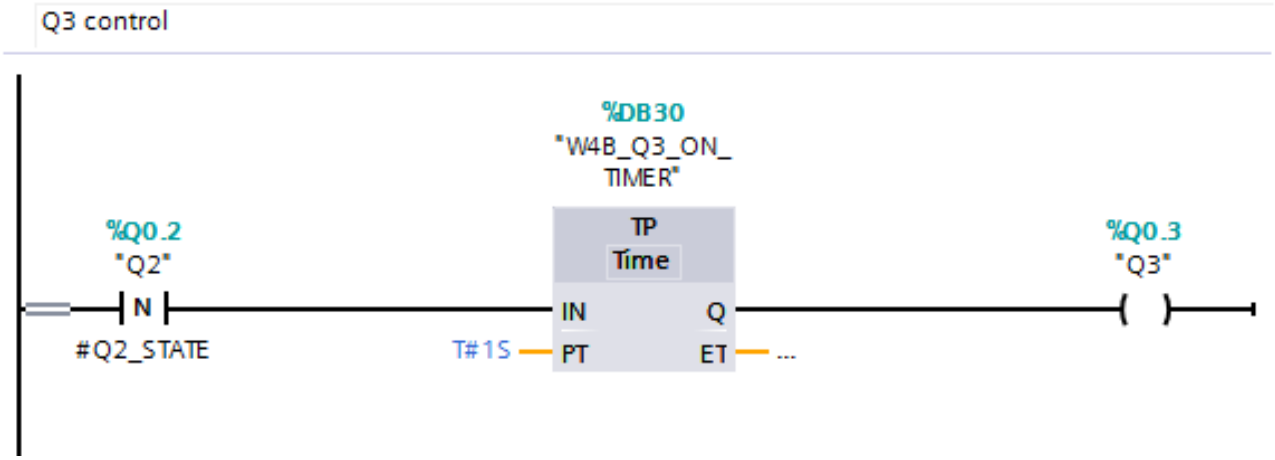
Worksheet 4 – In Sequence

Worksheet4B

		Name	Data type	Default value	Retain	Accessible ...	Writable ...	Visible ...
8		Q0_STATE	Bool	false	Non-retain	☑	☑	☑
9		Q2_STATE	Bool	false	Non-retain	☑	☑	☑



The turning off of Q0 triggers the activation of Q1 for 1 second to retract cylinder A.



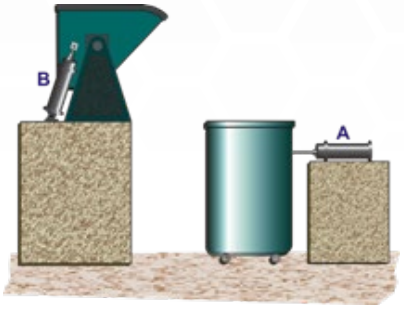
The turning off of Q2 triggers the activation of Q3 for 1 second to retract cylinder B.

For your records:

- A problem with the basket controller - the basket will lower itself again when **b-** switches off, because of the weight of the basket and contents. How do you overcome this?
- What sequence would be required to control an air lock, where cylinder A operates the outer door, and cylinder **B** the inner door? Explain each stage of the sequence as part of your answer.

The programs created so far operate blindly. The PLC continues to send out signals without knowing whether the cylinders respond or not. The reed switch provides feedback to the control system, to let it know that a cylinder has extended or retracted, called 'proof of position'.

This worksheet illustrates why this is important.
The scenario - a container is pushed under a hopper by cylinder **A**. Cylinder **B** then tips the hopper to pour its contents into the container.
The control system needs to know when cylinder **A** fails to function, as otherwise cylinder **B** will tip the contents of the hopper onto the floor!



Over to You

Version 1 - No feedback

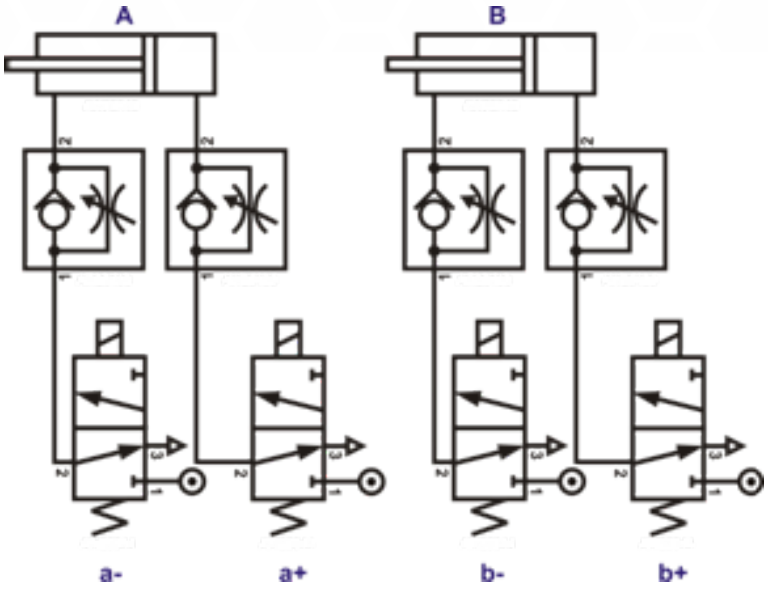
The sequence could be the same used at the beginning of worksheet 4.
We incorporate a slight modification, so that cylinders **A** and **B** retract at the same time.

- Make sure that the red lever on the manifold is turned off.
- Build the arrangement shown in the pneumatic circuit diagram on the next page. It is the same as in the last worksheet.
- Make the same electrical connections as in the last worksheet:
  - switch 1 - red socket to a red V+ socket and black socket to PLC input A0;
  - solenoid valve **a+** - positive to PLC output **A0** and negative to a black 0V socket;
  - solenoid valve **a-** - positive to PLC output **A1** and negative to a black 0V socket.
  - solenoid valve **b+** - positive to PLC output **A2** and negative to a black 0V socket;
  - solenoid valve **b-** - positive to PLC output **A3** and negative to a black 0V socket.
- Change the logic program as detailed on the next pages and transfer to the PLC
- Then turn on the air supply.
- Press switch 1 to initiate the sequence. It begins by extending cylinder **A**, to push the container into position. Adjust the flow control valve to give a sensible speed of movement.
- Then cylinder **B** extends to tip the hopper. Again, adjust the flow-rate to a sensible value. After a short delay, both cylinders retract, returning the hopper and container to their initial positions.

WORKSHEETS

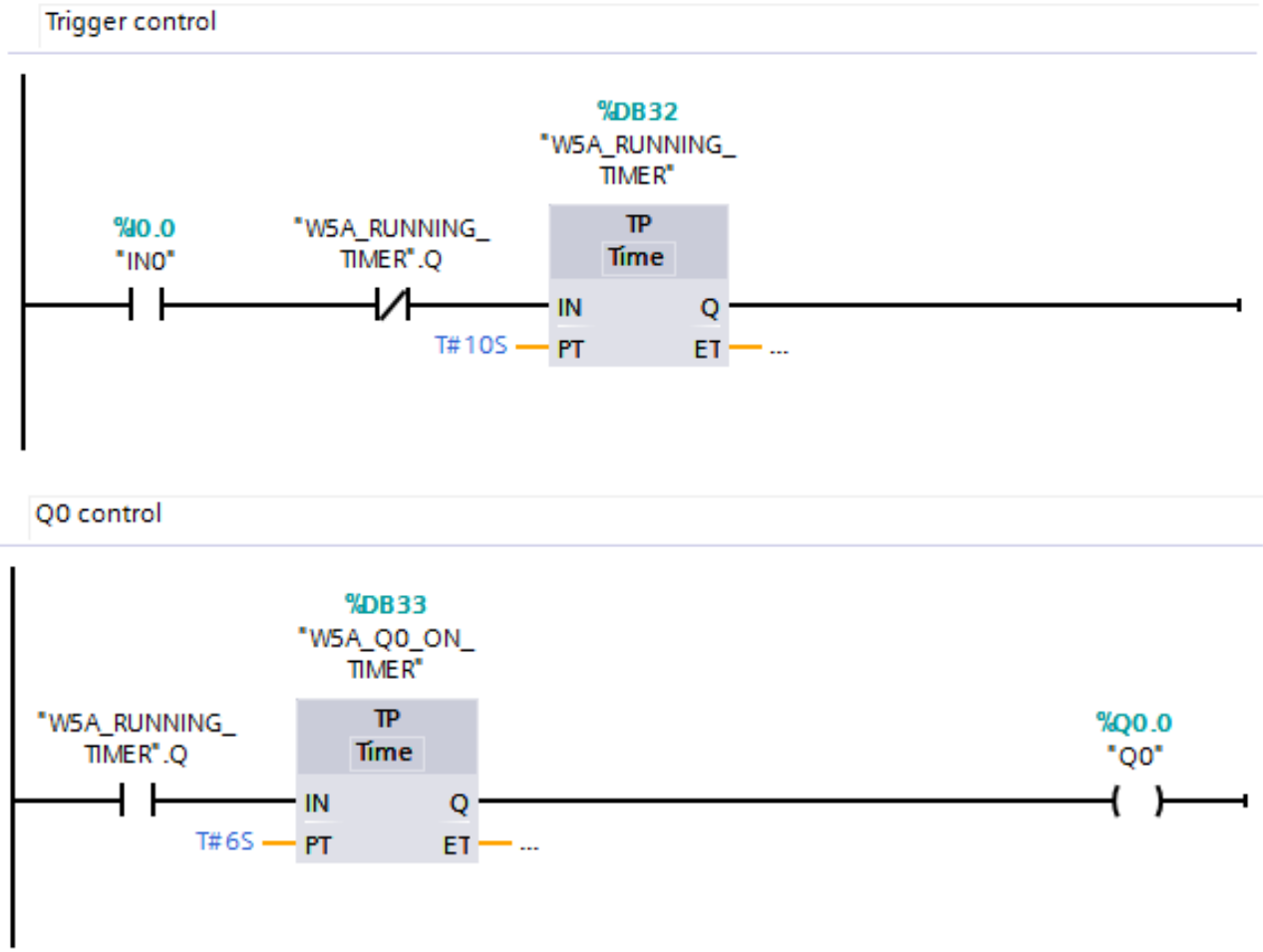
Worksheet 5 – Feedback

Pneumatic circuit for worksheet 5:

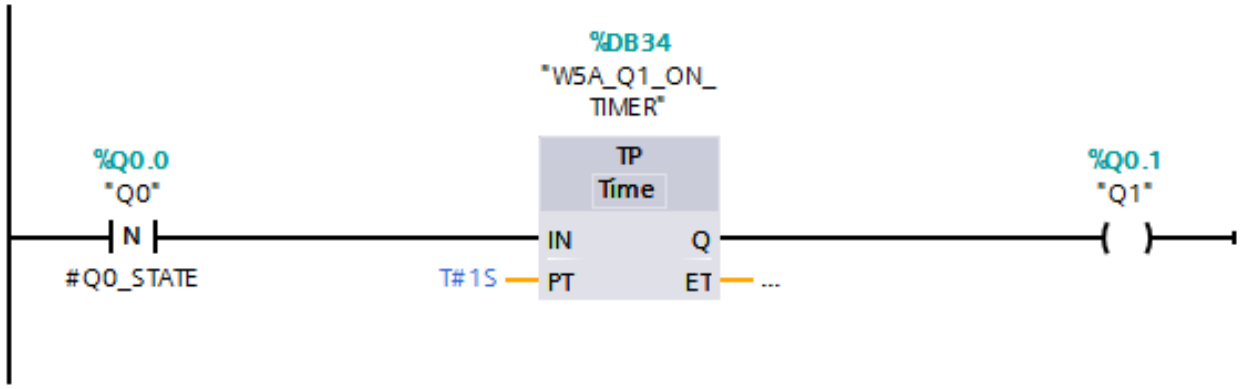


Program 5A:

The program is shown in sections.
Examine it carefully and match the instructions to the actions of the cylinder.

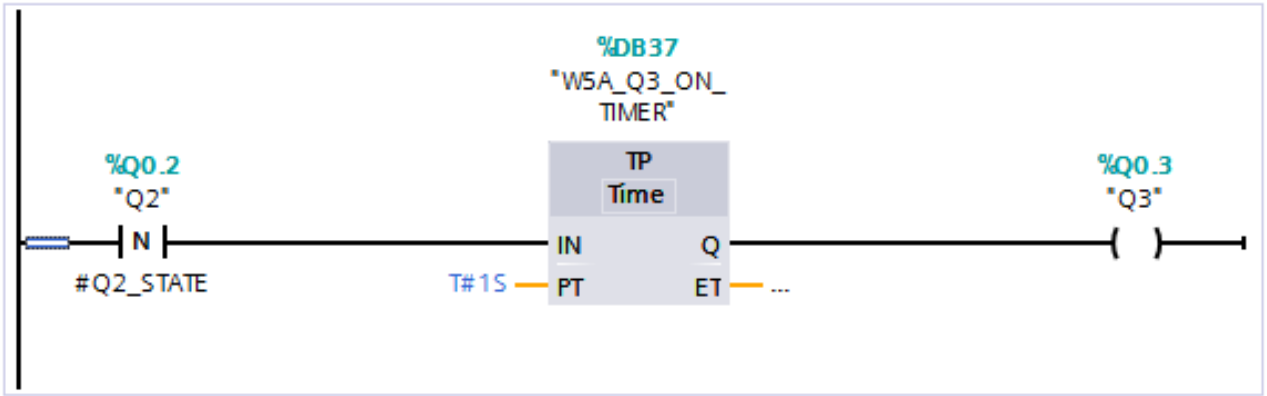


Q1 control



Q2 control

Q3 control



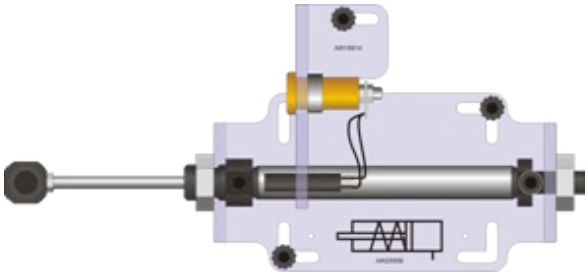
WORKSHEETS

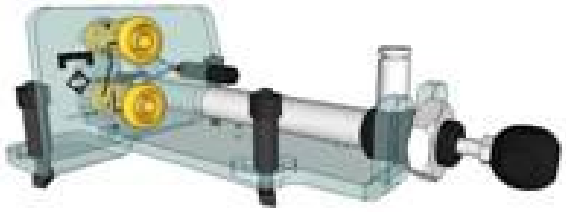
Worksheet 5 – Feedback

Over to You

Version 2 - with feedback:

- Switch off, and then disconnect the power supply.
- Using the same pneumatic circuit as before, add a reed relay to cylinder **A**, as shown in the following diagrams:

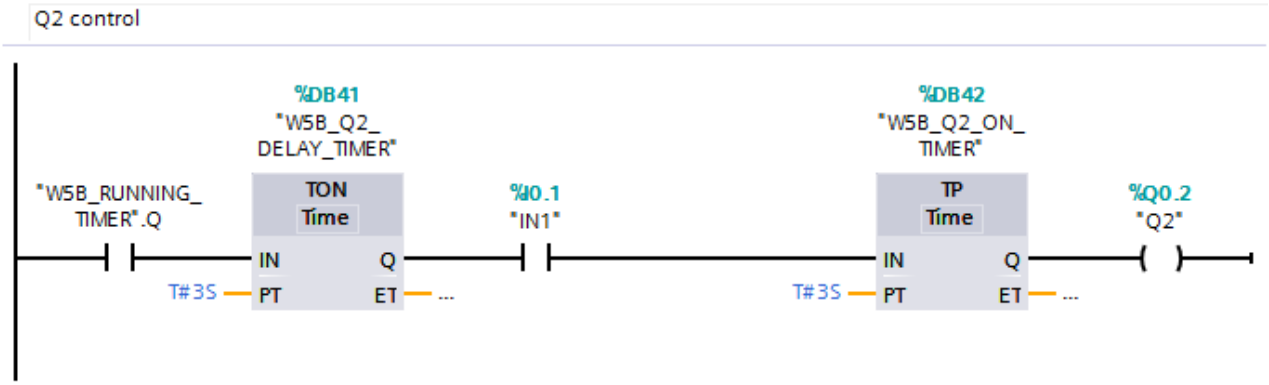




- The piston inside the cylinder is magnetised, and when it approaches the reed relay, the magnetic field causes the contacts in the reed relay to close.
- Connect one socket on the reed relay to V+, and the other to PLC input A1.
- Make the changes to the logic as described in the next pages and transfer to the PLC
- Press switch 1 to initiate the sequence. As before, it begins by extending cylinder **A**, to push the container into position, and then extends cylinder **B** to tip the hopper, before both cylinders retract.
- Turn the red lever to switch off the air supply.
- Identify the pipe that supplies cylinder **A** from the manifold, and disconnect it from the manifold. (Remember that the manifold outlets are self-sealing. Air will not come out unless a pipe is pushed in.)
- Turn on the air supply, and press switch 1 again. Notice the difference!

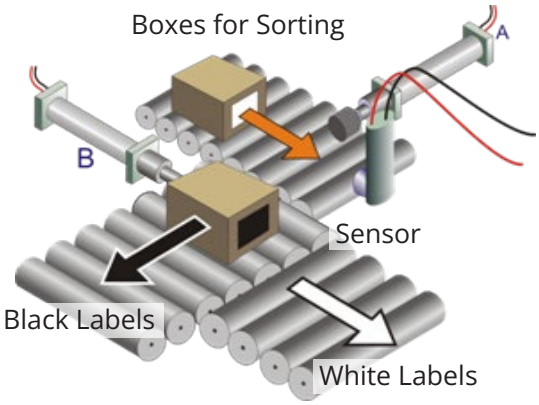
Overview of Program 5B:

The program is the same as program 5A, except that we have introduced an extra check in the Q2 control rung. After the initial trigger delay timer has expired, input 1, the reed switch, has to be in an activated position to allow Q2 to operate and deploy piston B.



For your records:

Many modern production facilities use pneumatic systems to sort their products. In one version,
a sensor 'reads' a barcode stuck on the side of the product.
You are asked to design a system that models this behaviour. Instead of a bar code, the products carry
either a black label or a white one. They have to be sorted and sent down the appropriate conveyor belt to be packed.
Draw the ladder logic for this system, using the ones given
in the worksheets so far as a guide.



REVISION
Revision Questions

About These Questions

These questions are designed to be a useful aid to revision.
Allow 25 minutes to answer them and then check your answers with those given on page 30.

Choose the correct answer (a, b or c).

1. Electrically operated pneumatic valves are operated by a:

a) solenoid b) lever c) permanent magnet

2. Which is the correct description of a 'normally-open' push switch, connected in a circuit?

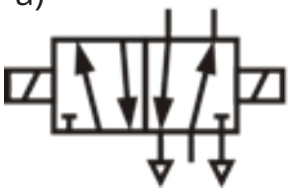
a) It has no cover on it.
b) It has a very low resistance when pressed.
c) it has a high voltage across it when pressed, and a low voltage when not pressed.

3. What kind of switch is actuated by the magnetic piston ring of a cylinder?

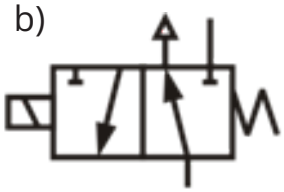
a) reed switch b) push switch c) toggle switch

4. Which is the correct symbol for a solenoid operated, spring return 5/2 control valve?

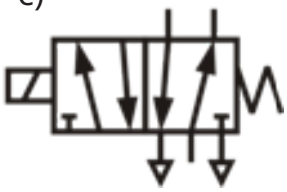
a)



b)

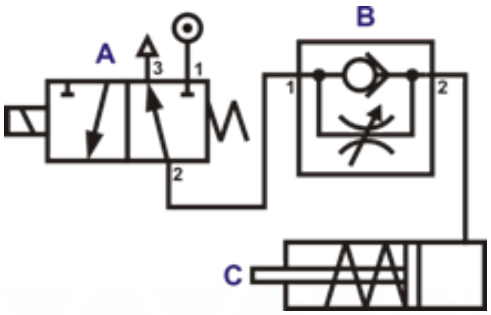


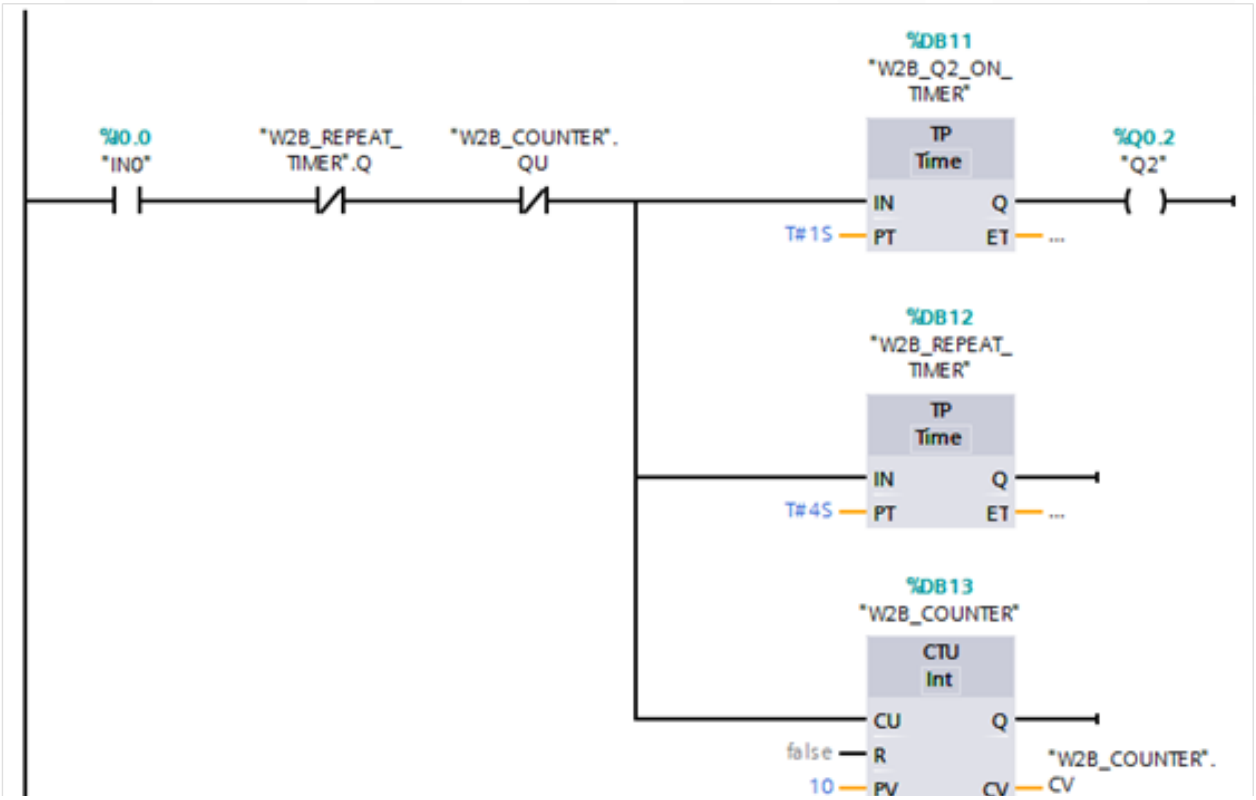
c)



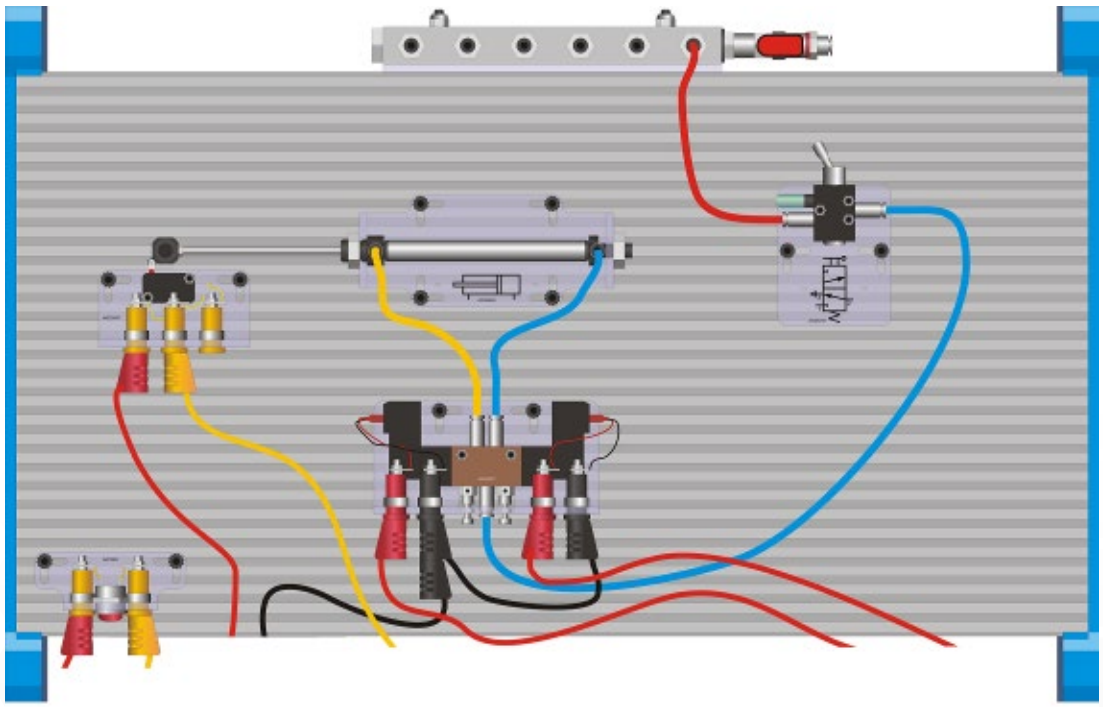
Which statement is true for the pneumatic circuit opposite?

a) Port 3 on valve **A** is an exhaust port.
b) Flow control valve **B** is connected the wrong way round to control the flow of air into cylinder **C**.
c) When valve **A** is actuated, cylinder **C** will retract.





6. Which parameter would be modified to make the process repeat twenty times?
7. For how many seconds is the cylinder extended?
8. How long does it take to complete one cycle of the program after the switch is pressed?
9. Draw the pneumatic circuit diagram for the following system .



DESIGN SCENARIOS

Design Scenarios

Design a program to satisfy the requirements set out in the following letters.
For each, provide ladder logic diagrams, like those in the worksheets, together with a description of what each section of the program does.

PLAYFUN TOYS LTD

Dear Designer,

Could you please design a control system for our new wooden toy gluing system?

Components move along a conveyor belt to the machine. As each arrives, it activates a sensor. When five components have arrived, a pneumatic cylinder pushes them into position in the machine.

A second cylinder then carries out five process cycles. In each, the cylinder waits for five seconds in the extended position to hold the components in place while the glue sets.

Yours faithfully

Coldham Borough Council
Department of Health and Safety

Dear KnivesRUs,
Our inspector noted on her last visit that your knife-sharpening machine makes use of two pneumatic cylinders operating in the sequence A+, A-, B+, B-.

A machine guard must be fitted immediately to protect the operator from possible injury.

The guard must be designed so that it presses a switch when closed. The guard switch and On/Off switch must both be pressed to start the machine.

While the machine is running, it must stop automatically if the guard is opened, or if the On/Off switch is pressed again.

Yours sincerely,

Ken~Ju
Martial Arts Clothing

Dear Designer

We use a pneumatically-operated test rig, with a continuously reciprocating cylinder to test fabric samples for wear and tear. The system counts the number of cycles completed by the cylinder.

Unfortunately, it can provide misleading information because it continues to count even when the air supply is switched off by mistake.

Please design a new counting system that stops counting when the cylinder stops moving, no matter whether extended or retracted, and then displays the number of test cycles completed.

Yours faithfully

Notes

Notes

PNEUMATICS CONTROL PLUS USING SIEMENS PLC

CP2193

www.matrixtsl.com

Matrix Technology Solutions
The Factory, 33 Gibbet Street, Halifax, HX1 5BA, United Kingdom
t: +44 (0) 1422 252380 e: sales@matrixtsl.com