

AUTOMATICS SIEMENS

Pneumatics control PLUS using Siemens PLC



CP2193

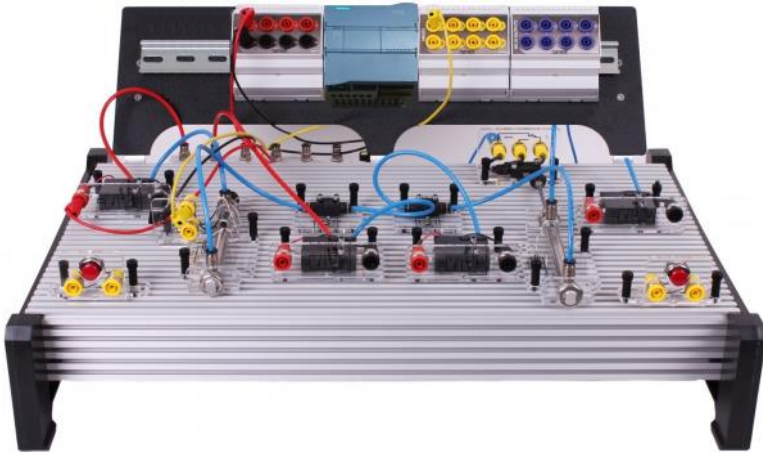
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	Page
Setup	3
Worksheet 1 - Electronic control	6
Worksheet 2 - Magazine feed	10
Worksheet 3 - Bank vault door controller	14
Worksheet 4 - In sequence	18
Worksheet 5 - Feedback	24
Revision questions	29
Design scenarios	31
Answers to revision questions	32
Tutor's notes	33

Setup

Components overview



In industry, complex pneumatic systems are often controlled by a microprocessor in systems called a 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 and requires the use of Siemens Step 7 software (TIA Portal V15)

PLC and adapter modules:



Power module
V+ 0V
sockets

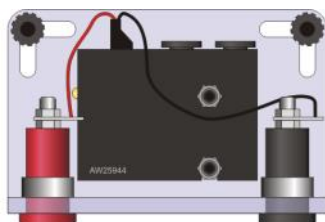
PLC

Inputs module
I0-I7
sockets

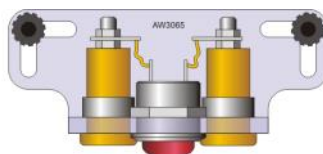
Relay module
Q0-Q3
sockets

Note that the number of usable inputs and outputs will depend upon the PLC model used

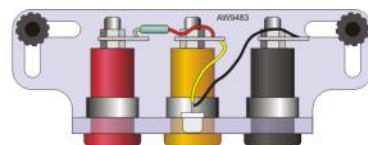
Automatics components:



3/2 solenoid valve



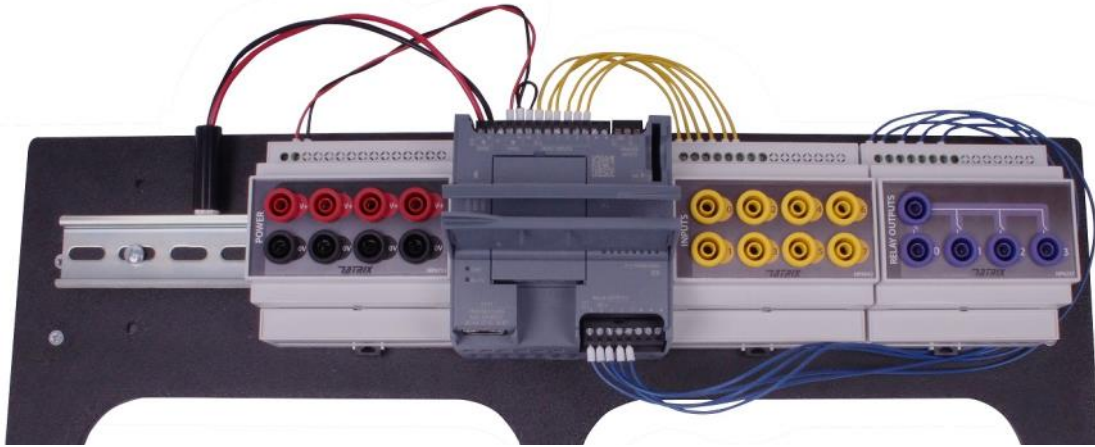
switch



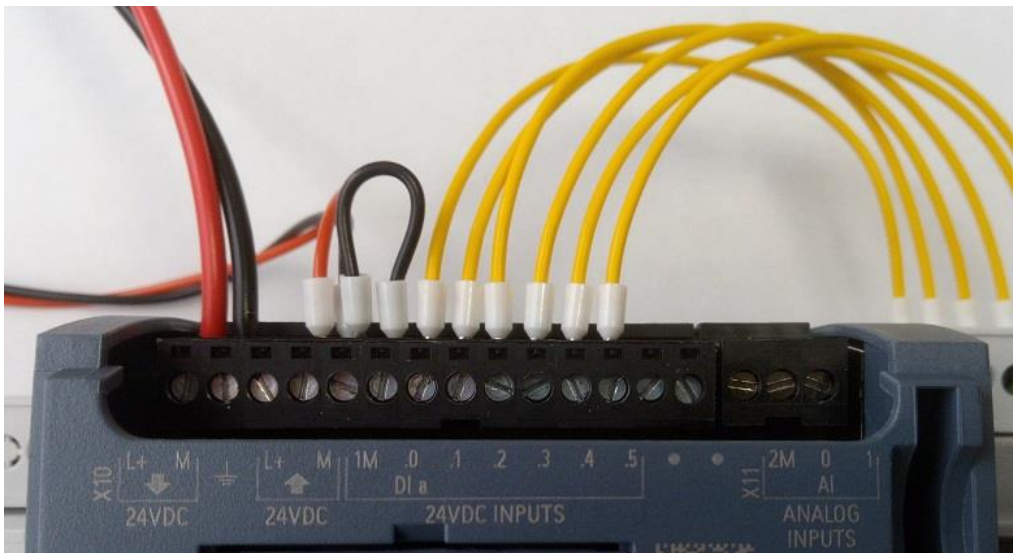
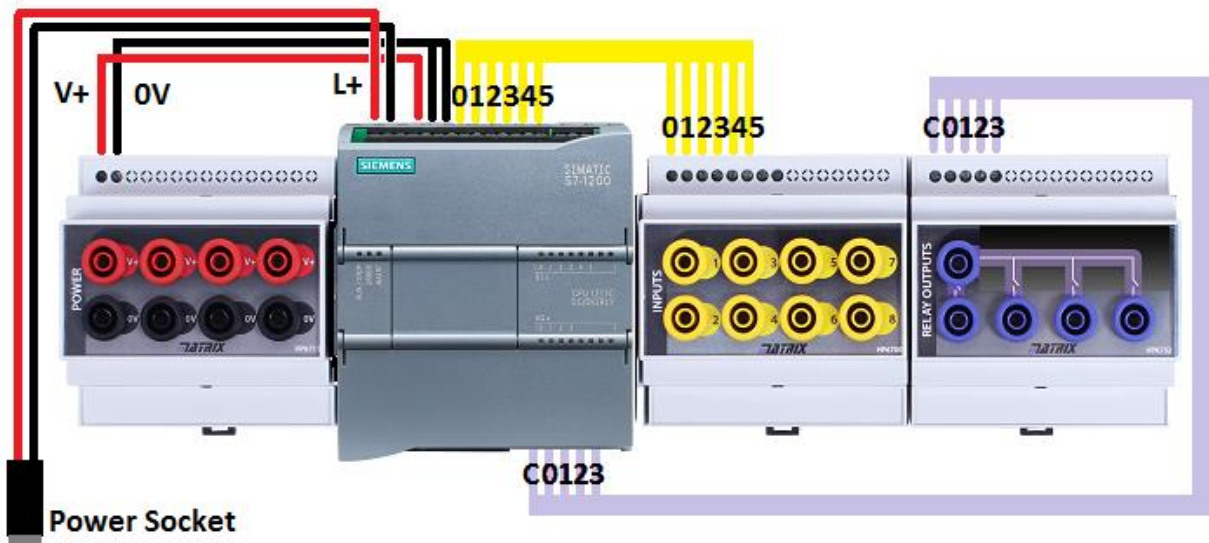
light sensor

Setup

System wiring



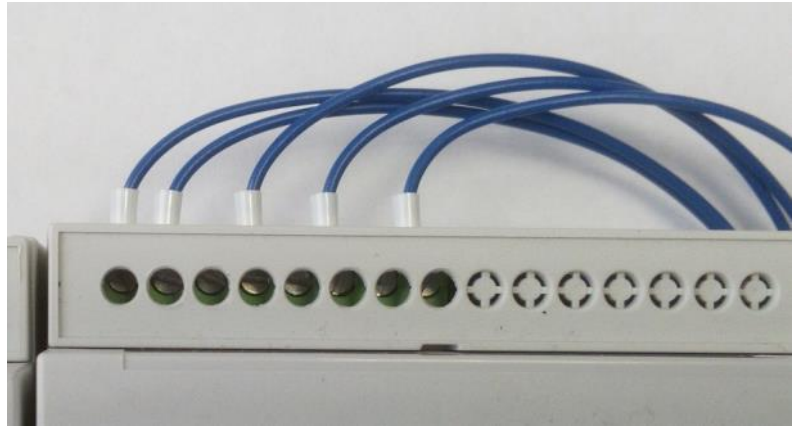
PLC and adapter modules panel wiring:



Setup

System wiring

Relay output wiring detail:



Relay output common power supply via banana plug lead:



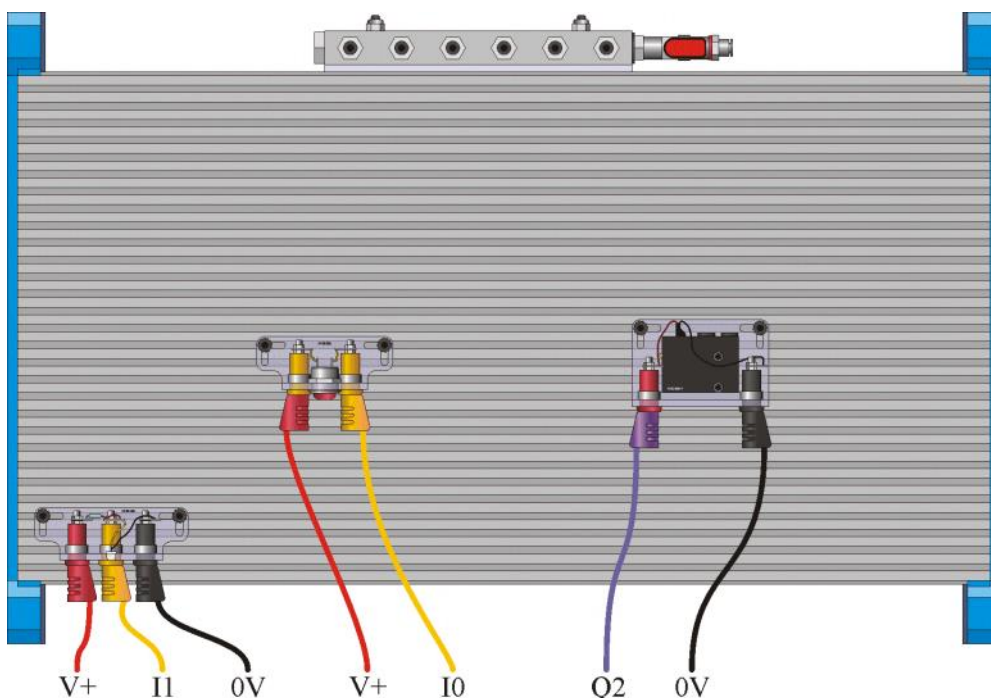
Worksheet 1

Electronic control

Over to you:

- Build the arrangement shown on 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:
 - power panel - red to V+ and black to 0V;
 - switch - red socket to power link panel red and black socket to PLC input 0;
 - light sensor - red socket to power link panel red, black socket to power panel black and yellow socket to PLC input 1;
 - solenoid valve - positive to PLC output **Q2** and negative to power panel black.
- Select Program 1A
- Plug in the power supply and switch on.
- 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:



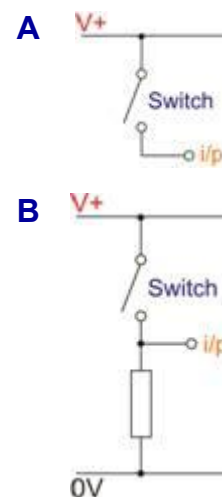
Worksheet 1

Electronic control

- The Siemens S7-1200 is a fully specified industrial controller which is wired to adaptor modules on the rail that are fitted with 4mm shrouded sockets for easy connection to the automatics parts on the platform via banana plug leads.
- The system is designed to operate at 24V DC.
- Of the 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 15V @ 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 Automatics light sensor will need to be connected to +V and 0V, with the sensor output connected to the PLC input terminal.



- The PLC has six relay outputs marked as Q0 to Q5.
- The output LEDs light when the corresponding output switches 'on'.

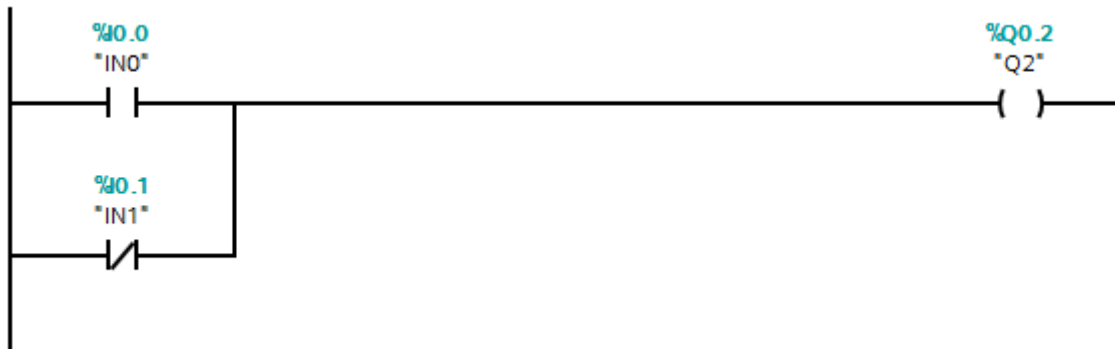
Worksheet 1

Electronic control

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	

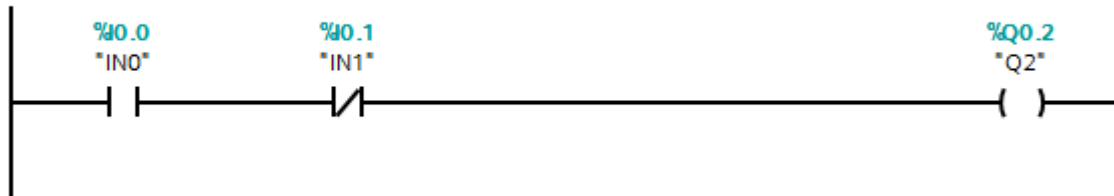
Worksheet 1

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:

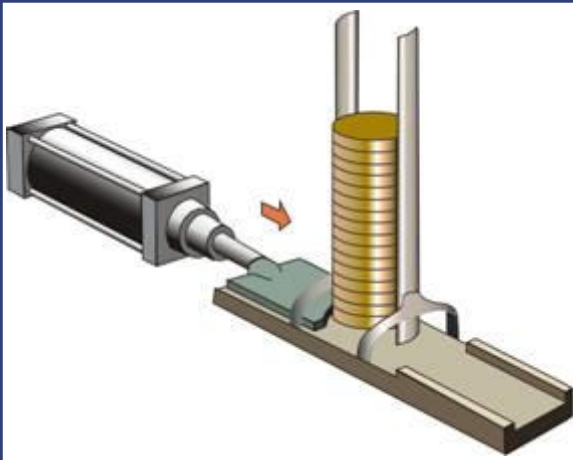
Use a multimeter to measure the quantities listed below.

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	

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:

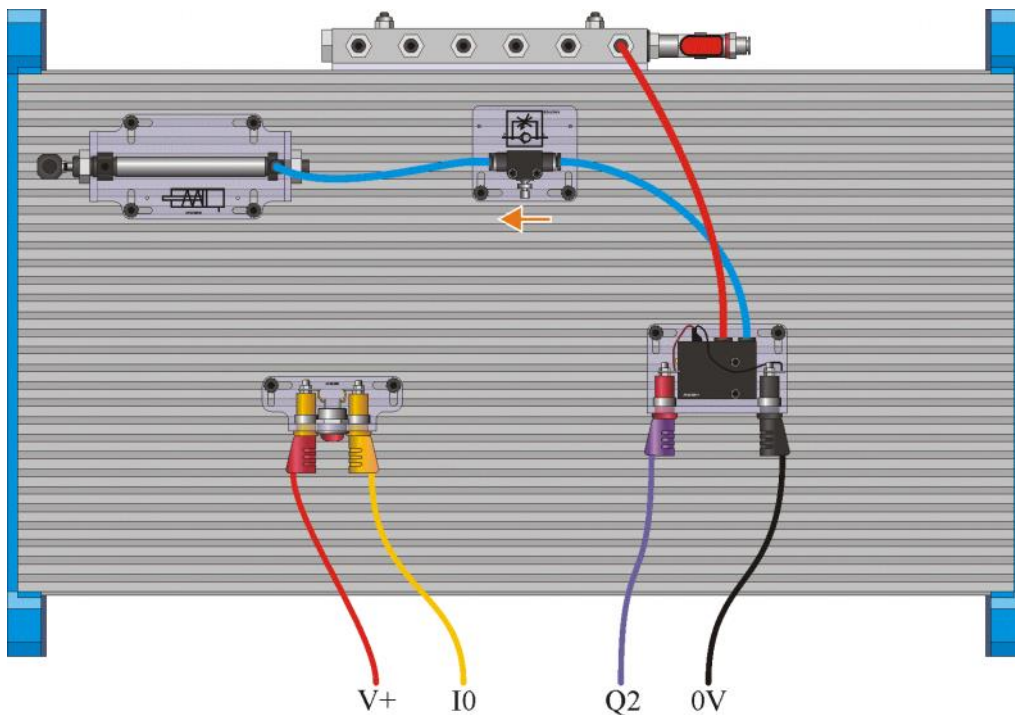
- **Read the safety rules given on the next page before you start.**
- **The red lever on the manifold must be turned off at this stage.**
- Build the arrangement shown on the next page. Compare the physical and pneumatic circuit diagrams, as you do so.
 - Clamp a switch and a 3/2 solenoid valve to the platform.
 - Add a flow-control valve, to restrict flow in the direction shown by the arrow.
 - Make the following electrical connections:
 - power panel - red to V+ and black to 0V;
 - switch - red socket to power link panel red and black socket to PLC input 0;
 - solenoid valve - positive to PLC output **Q2** and negative to power panel black.
- Select program 2A
- Plug in the power supply and switch on.
- 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.

Safety Rules for Pneumatic Systems

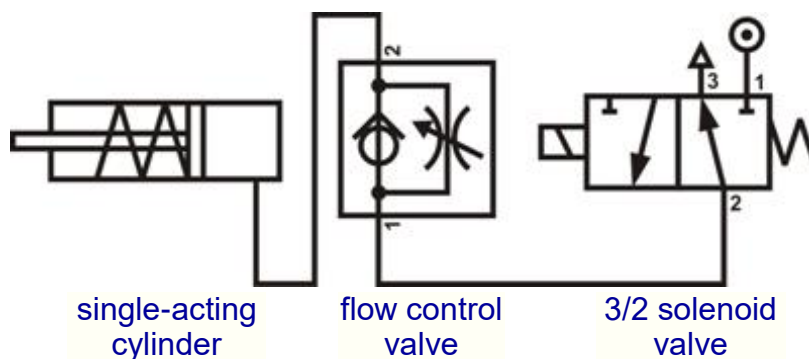
Remember that compressed air and its components are capable of exerting large forces.

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:



Worksheet 2

Magazine feed

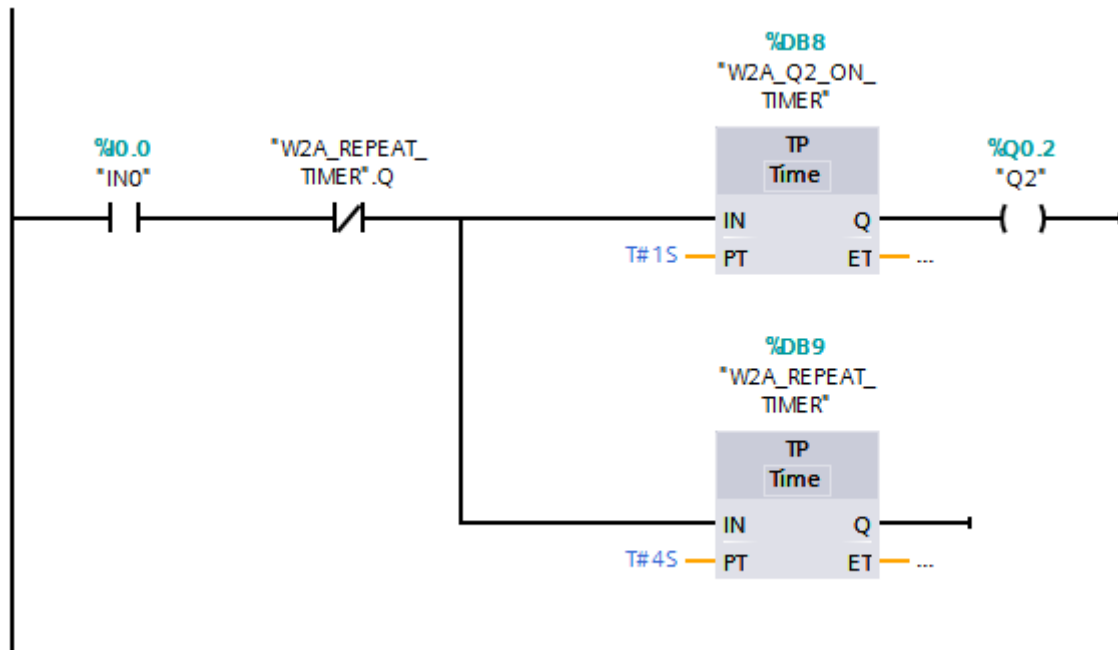
Overview of Program 2A:

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.

The sequence is:

- 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.

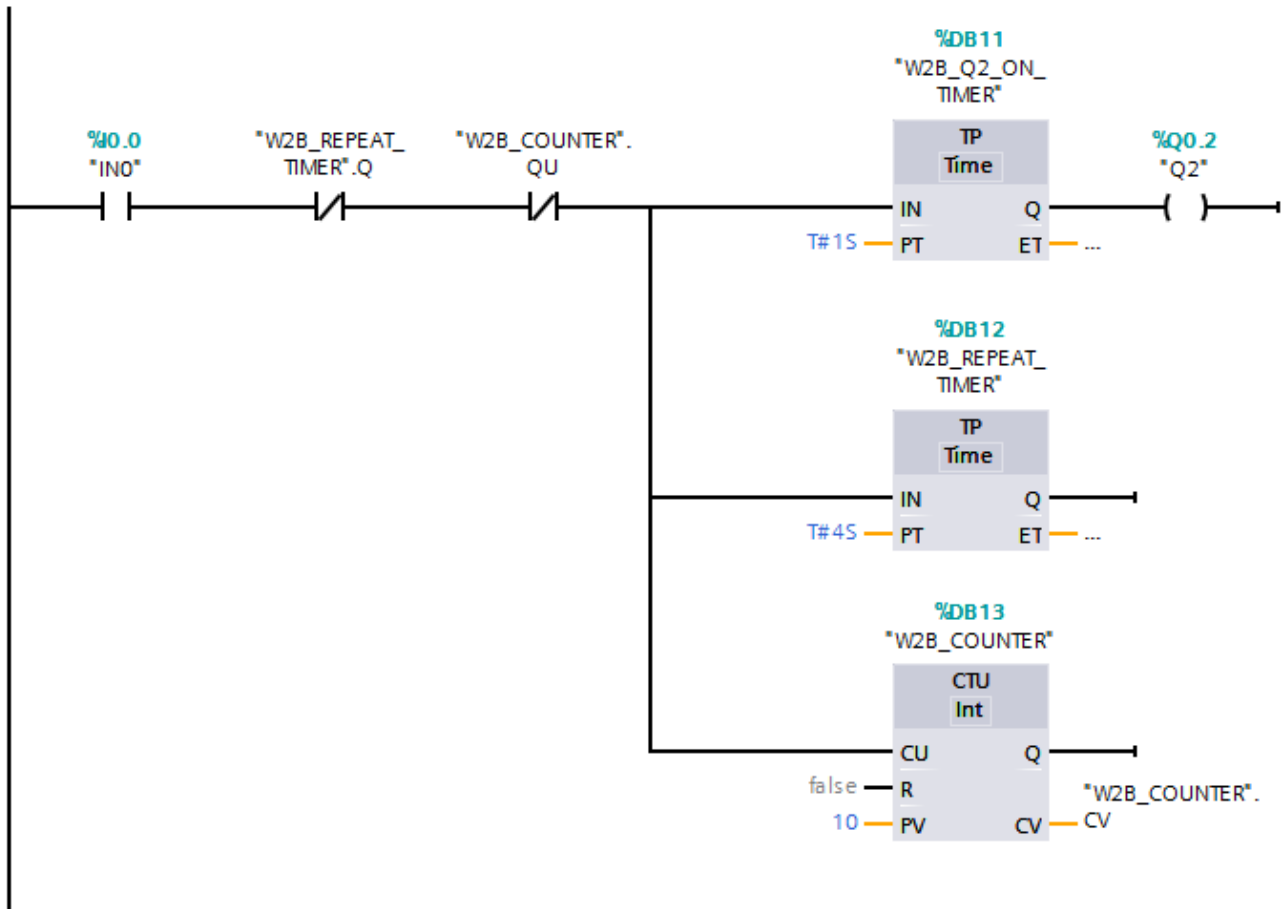
- Press and hold down the switch. The cylinder extends and retracts but only ten times. Instead of repeating indefinitely, the PLC keeps a count and inhibits the operation after 10 operations.

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?

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.

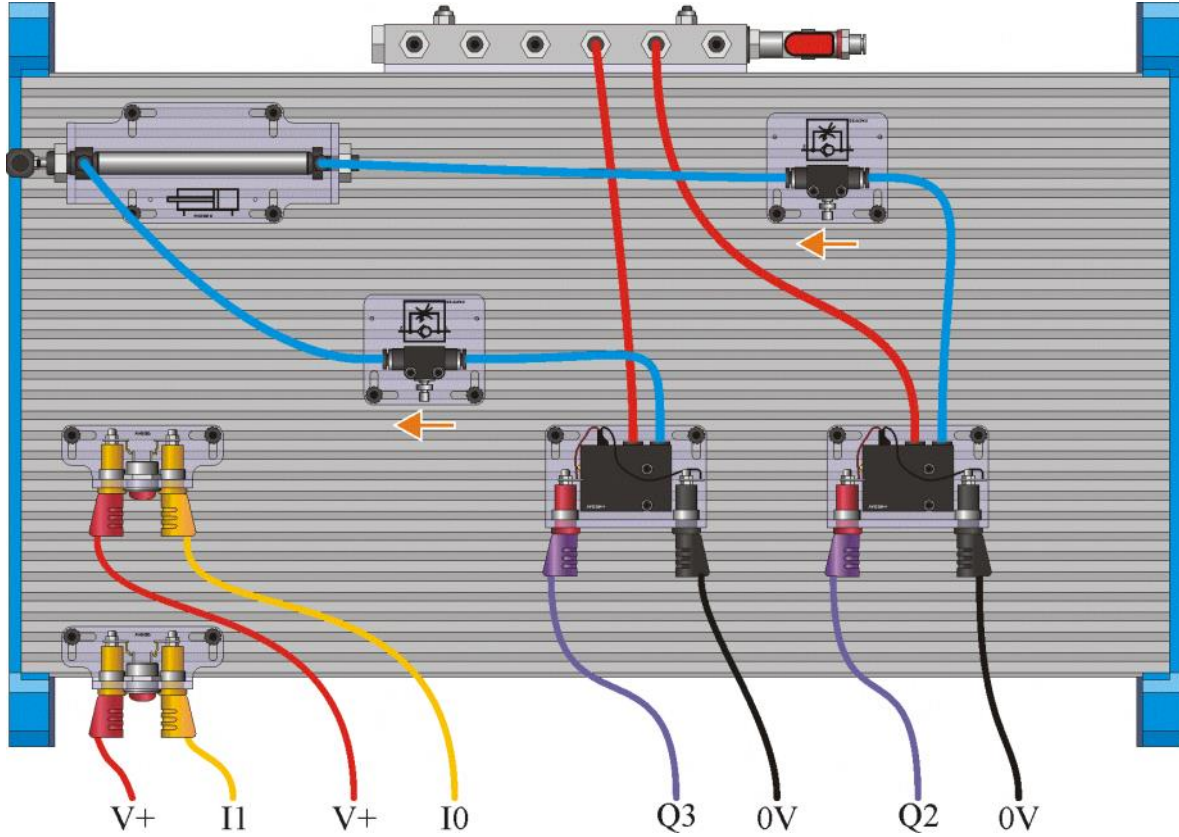
Over to you:

- **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:
 - power panel - red to V+ and black to 0V;
 - switch 1 - red socket to power panel red and black socket to PLC input 0;
 - switch 2 - red socket to power panel red and black socket to PLC input 1;
 - solenoid valve 1 - positive to PLC output **Q2** and negative to power panel black;
 - solenoid valve 2 - positive to PLC output **Q3** and negative to power panel black.
- Plug in the power supply and switch on.
- Create the logic program as detailed on page 16 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.

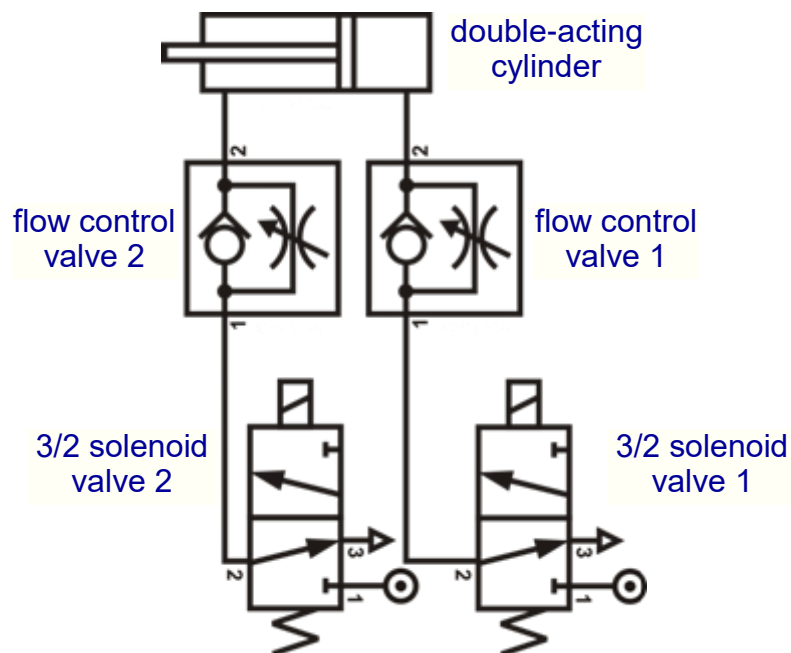
Worksheet 3

Bank vault door controller

Layout for worksheet 3:



Pneumatic circuit for worksheet 3:



Worksheet 3

Bank vault door controller

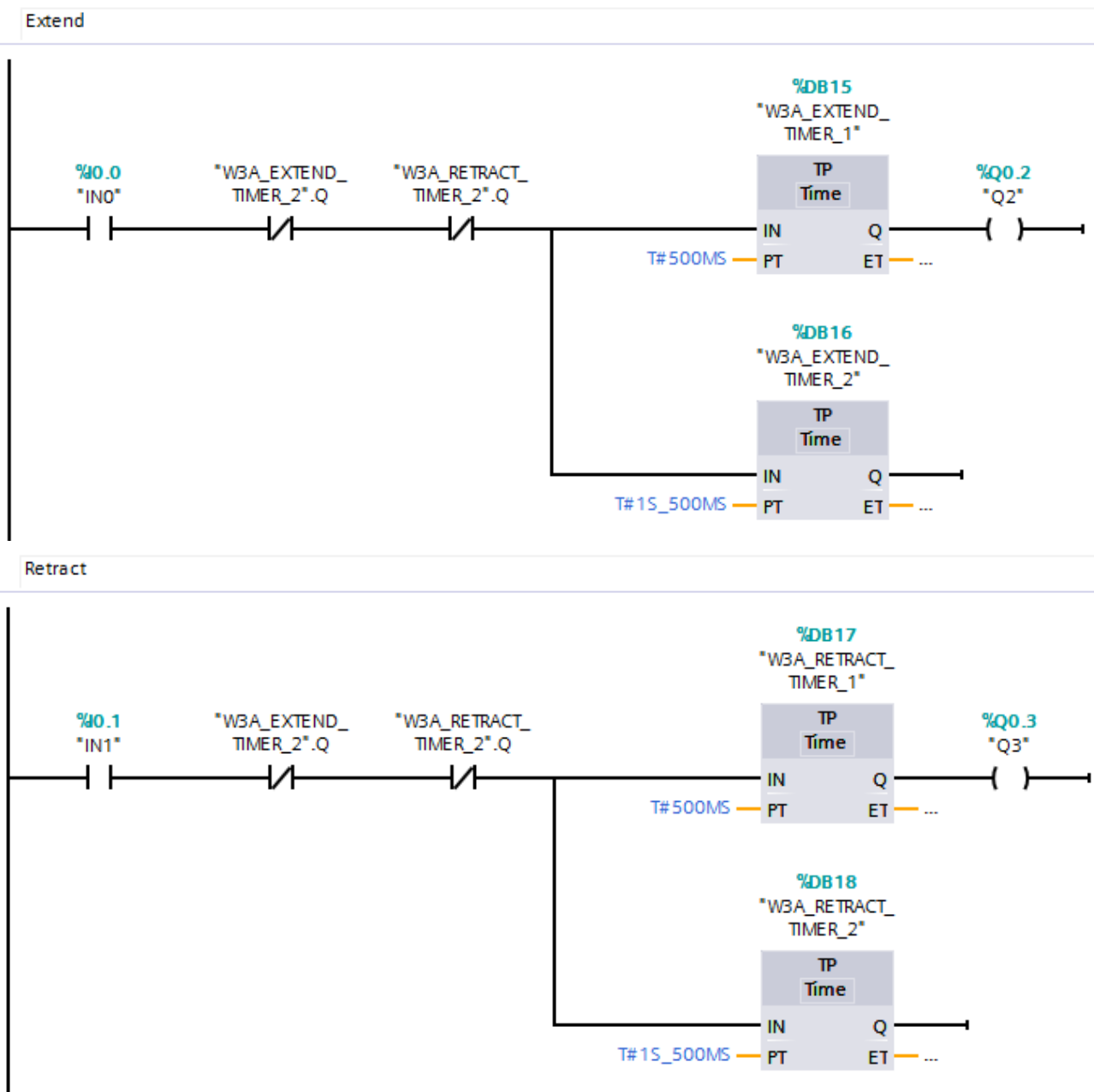
Overview of Program 3A:

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;

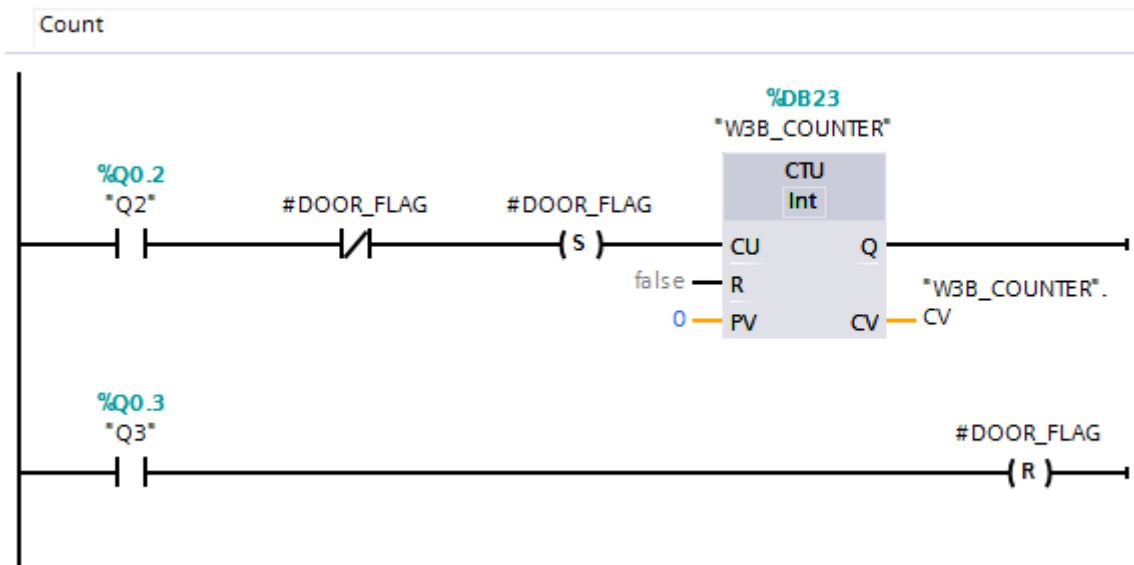


Worksheet 3

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



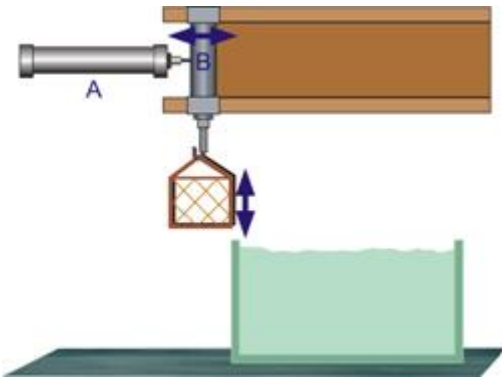
We do not want to add one to the count every time a switch is operated. We want it to increment only when the door is opened, and then closed.
 This requires the use of a flag, this has been named DOOR_FLAG

Worksheet3B							
	Name	Data type	Default value	Retain	Accessible ..	Writable..	Visible ...
8	DOOR_FLAG	Bool	false	Non-retain	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

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.

Worksheet 4

In sequence



Many applications of pneumatics require two, or more, cylinders to operate together in a sequence.

In the 'Automatics 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.

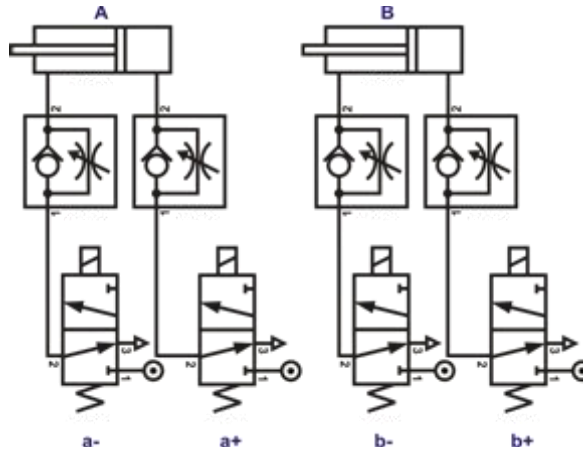
Over to you:

- **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:
 - power panel - red to V+ and black to 0V;
 - switch 1 - red socket to power panel red and black socket to PLC input 0;
 - switch 2 - red socket to power panel red and black socket to PLC input 1;
 - solenoid valve **a+** - positive to PLC output **Q0** and negative to power panel black;
 - solenoid valve **a-** - positive to PLC output **Q1** and negative to power panel black.
 - solenoid valve **b+** - positive to PLC output **Q2** and negative to power panel black;
 - solenoid valve **b-** - positive to PLC output **Q3** and negative to power panel black.
- 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.

Worksheet 4

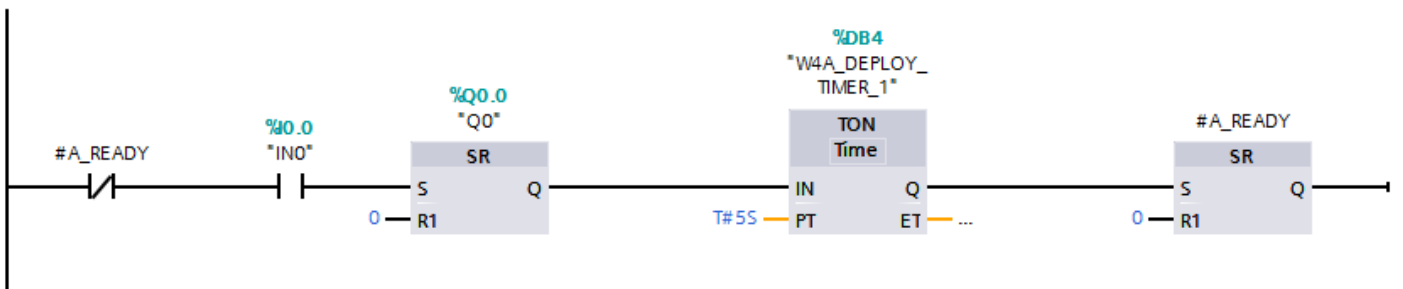
In sequence

Pneumatic circuit for worksheet 4:

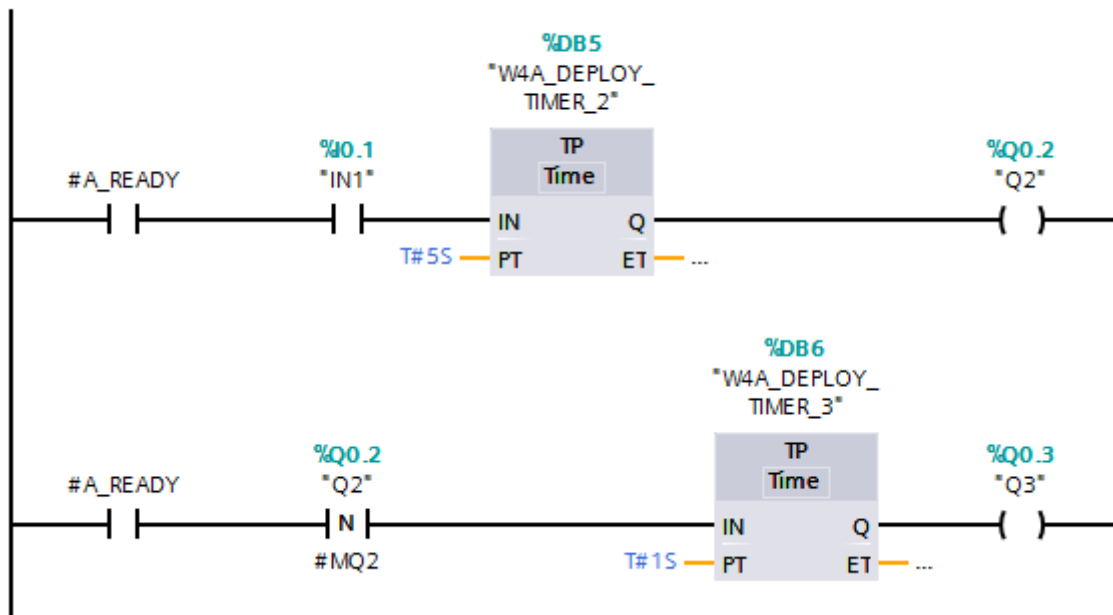


Program 4A:

Deploy Piston A

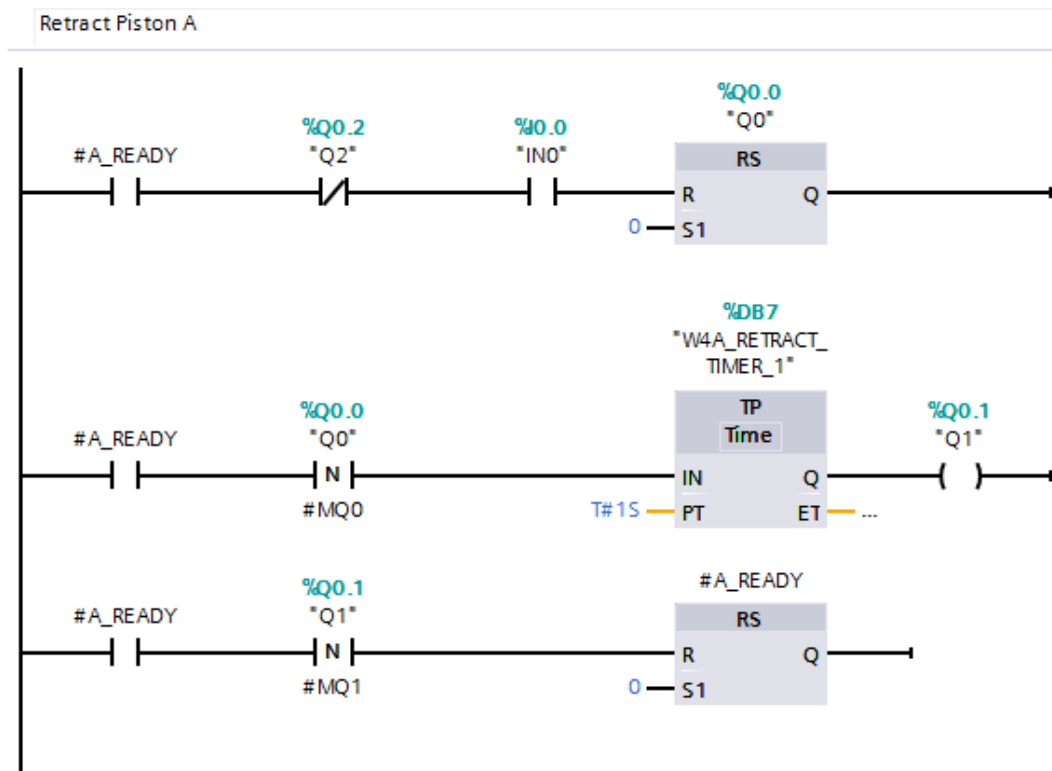


Deploy Piston B



Worksheet 4

In sequence



Worksheet4A							
	Name	Data type	Default value	Retain	Accessible ...	Writable ..	Visible...
10	A_READY	Bool	false	Retain	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

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 0 is activated, then the Q0 output is set and cylinder **A** extends, moving the basket over the tank.
 - After a 5 second delay the A_READY flag is set to give the piston time to deploy, .
- The second section is “Deploy Piston B”
 - When the A_READY flag is set and the switch on input 1 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 0. 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.

Worksheet 4

In sequence

Over to you:

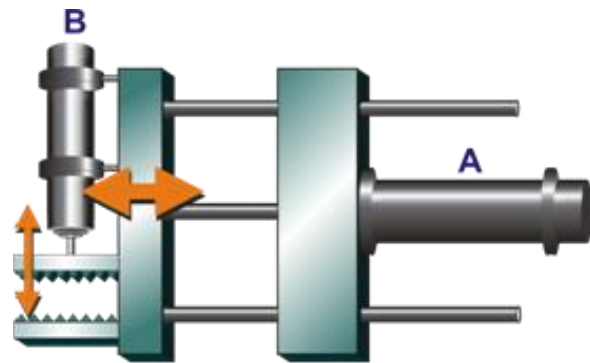
A modification:

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:

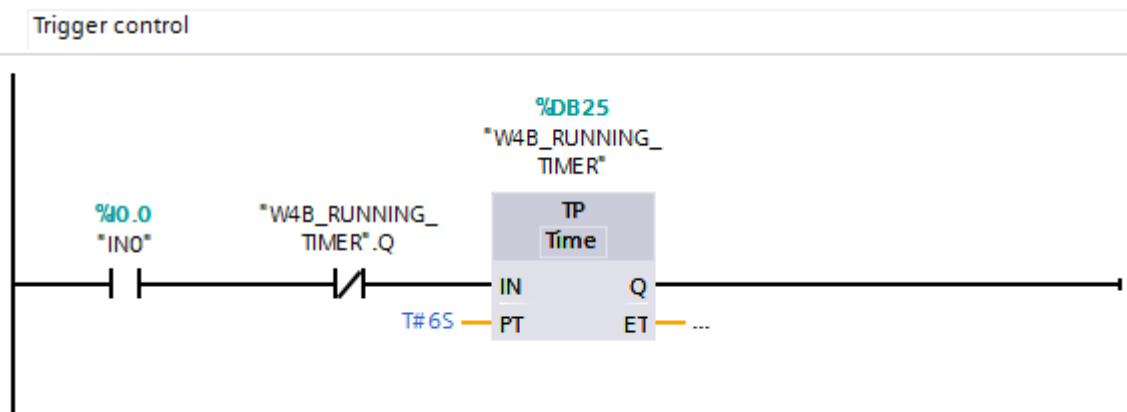
- reach out (**A+**);
- grip (**B+**);
- bring back (**A-**);
- release (**B-**).



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:

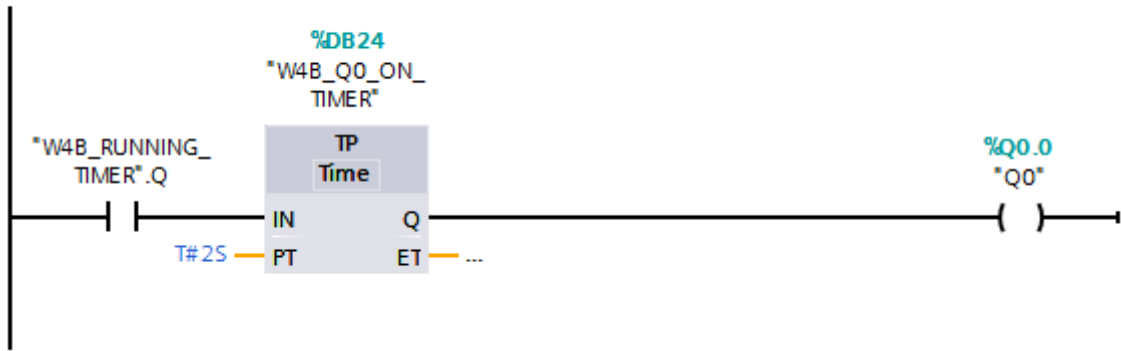


- The switch on input 0 triggers a “Running” timer that inhibits further triggers of operation for 6 seconds.

Worksheet 4

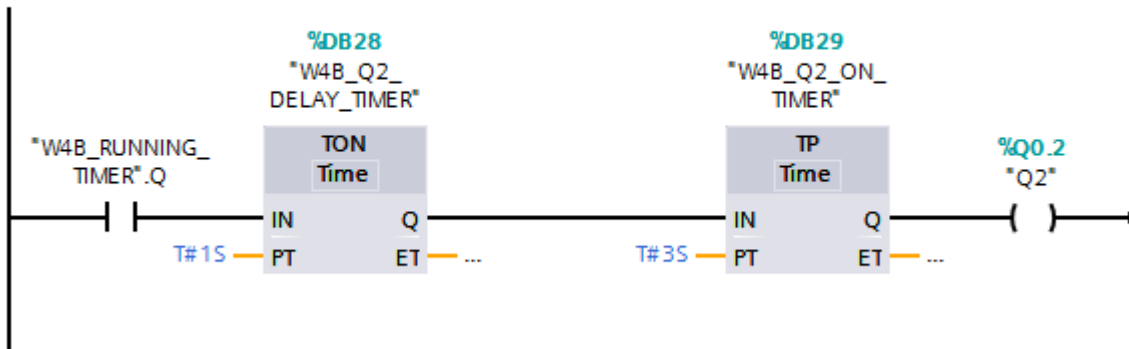
In sequence

Q0 control



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

Q2 control

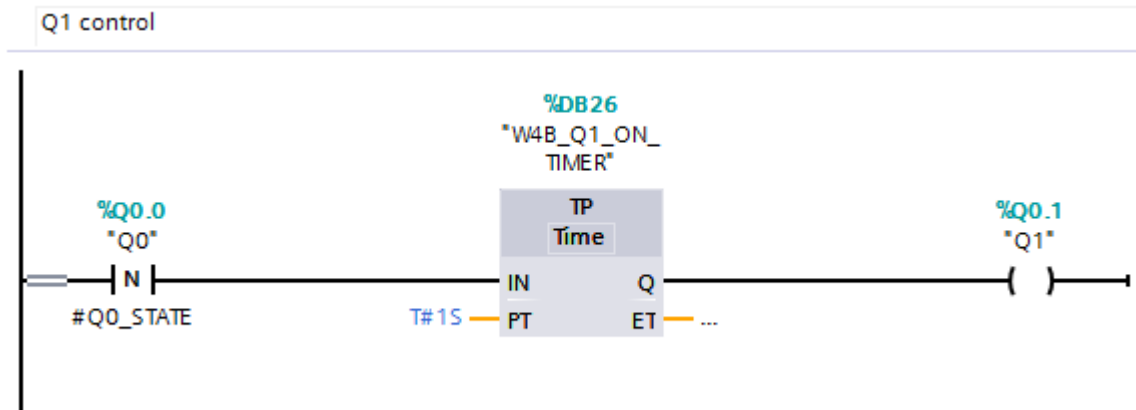


The starting of the “Running” timer also triggers a delay of 1 second, followed by operation of Q2 for 3 seconds. This extends cylinder **B** to operate the grip mechanism.

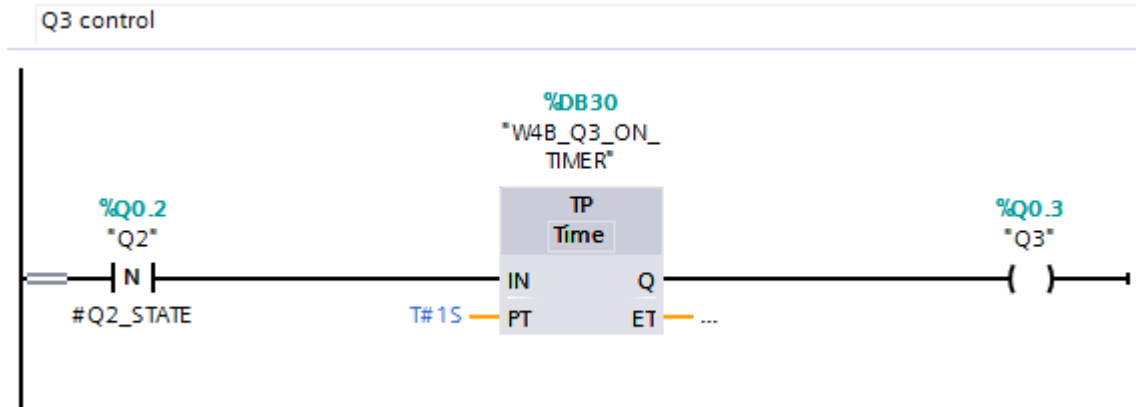
Worksheet 4

In sequence

Worksheet4B							
	Name	Data type	Default value	Retain	Accessible ...	Writable ...	Visible ..
8	Q0_STATE	Bool	false	Non-retain	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
9	Q2_STATE	Bool	false	Non-retain	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>



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.

Worksheet 5

Feedback

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'.

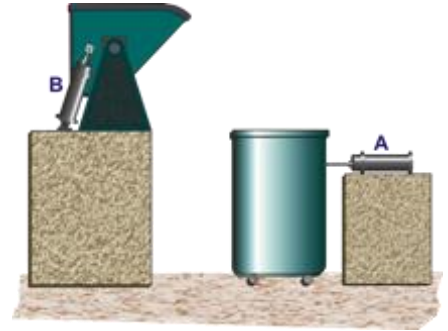
This worksheet illustrates why this is important.

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.

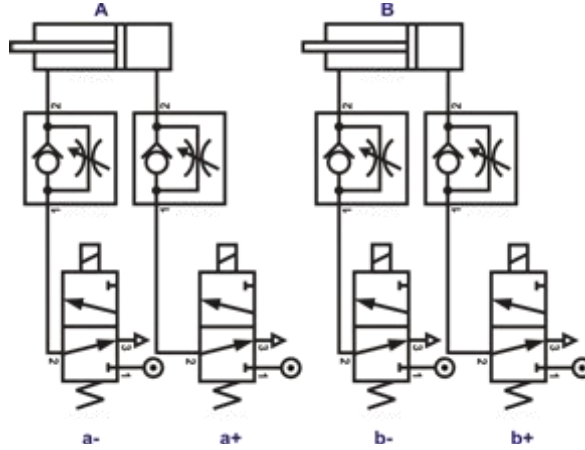
We incorporate a slight modification, so that cylinders **A** and **B** retract at the same time.

- **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:
 - power panel - red to V+ and black to 0V;
 - switch 1 - red socket to power panel red and black socket to PLC input 0;
 - solenoid valve **a+** - positive to PLC output **Q0** and negative to power panel black;
 - solenoid valve **a-** - positive to PLC output **Q1** and negative to power panel black.
 - solenoid valve **b+** - positive to PLC output **Q2** and negative to power panel black;
 - solenoid valve **b-** - positive to PLC output **Q3** and negative to power panel black.
- 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.

Worksheet 5

Feedback

Pneumatic circuit for worksheet 5:

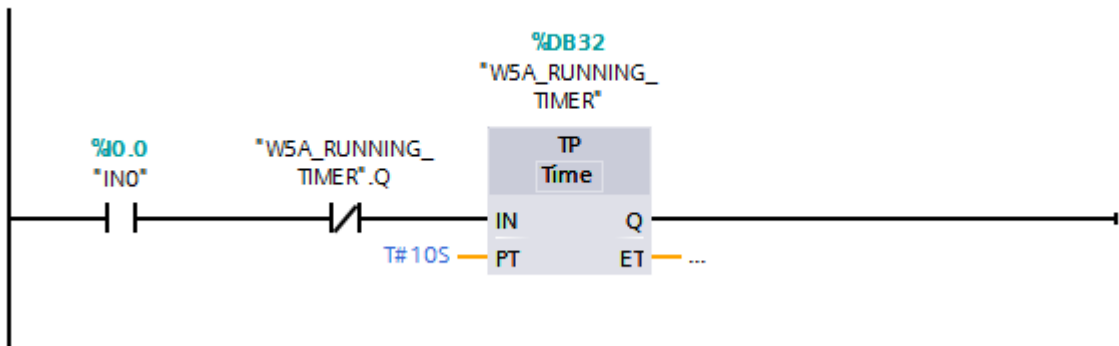


Program 5A:

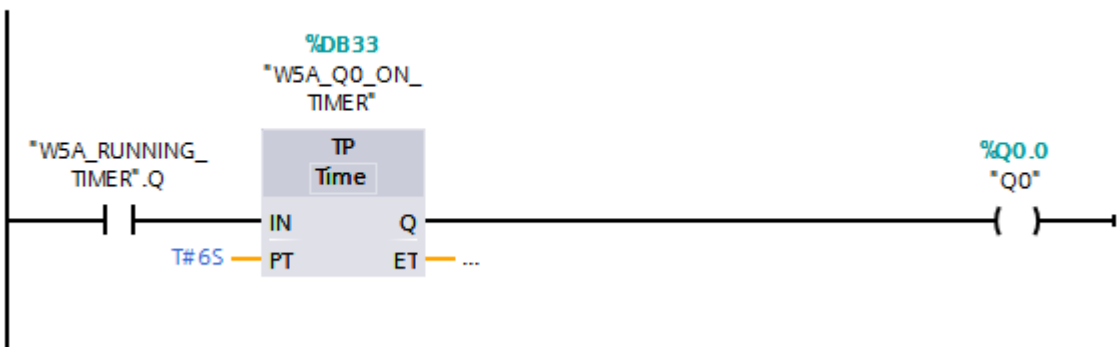
The program is shown in sections.

Examine it carefully and match the instructions to the actions of the cylinders.

Trigger control



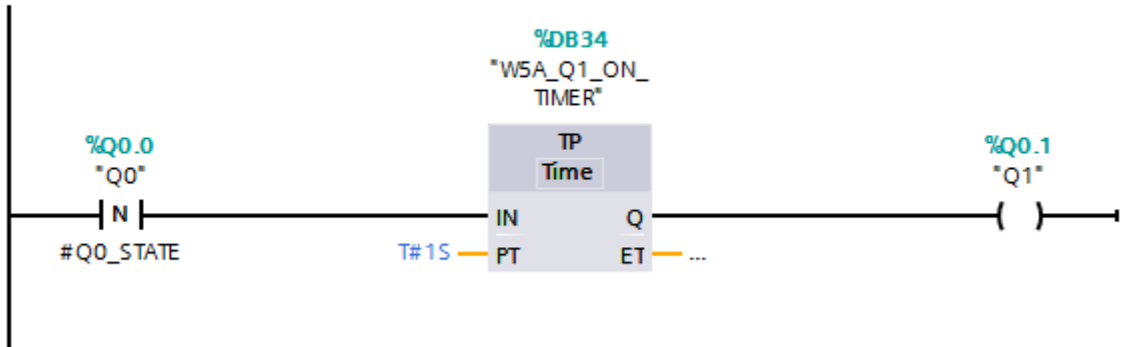
Q0 control



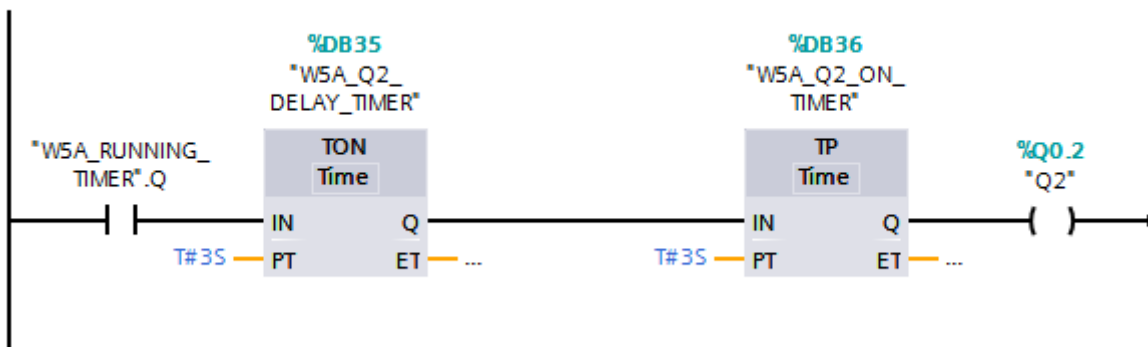
Worksheet 5

Feedback

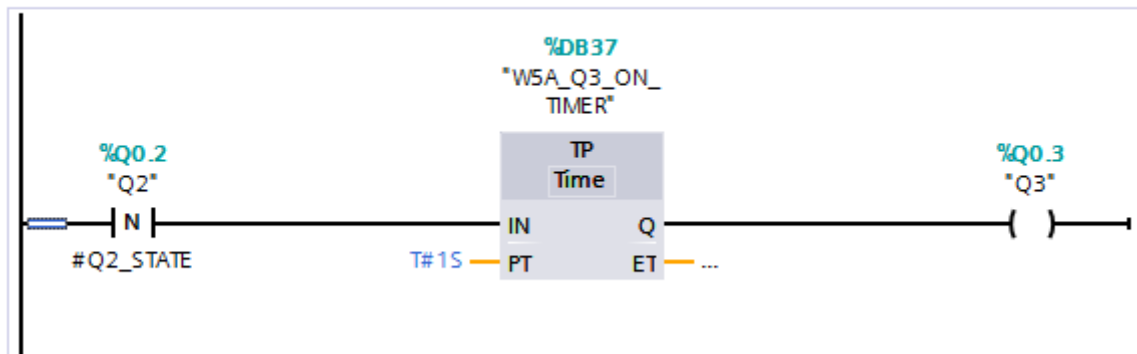
Q1 control



Q2 control



Q3 control



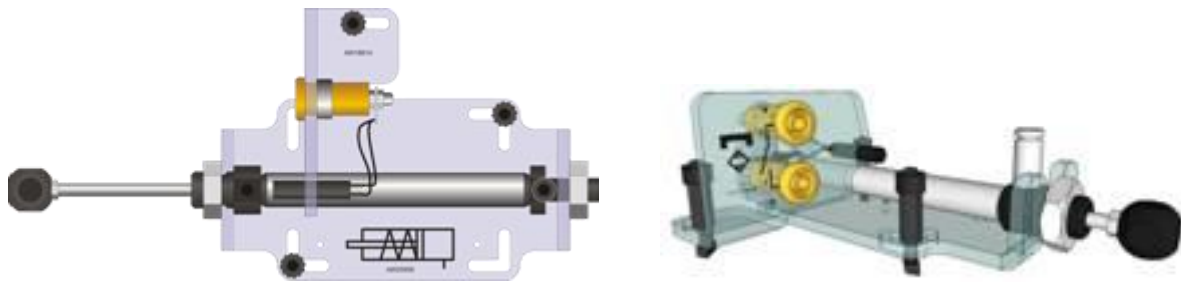
Worksheet 5

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:



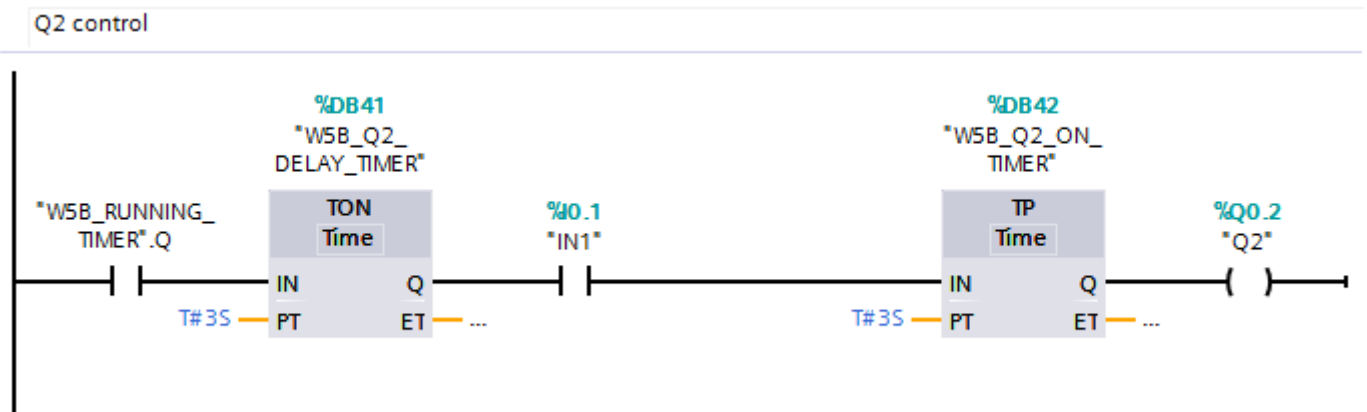
- The piston inside the cylinder is magnetised, and when it approaches the reed relay, the magnetic field causes the contacts in the reed relay to close.
- Connect one socket on the reed relay to V+, and the other to PLC input 1.
- Make the changes to the logic as described in the next pages and transfer 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!

Worksheet 5

Feedback

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.

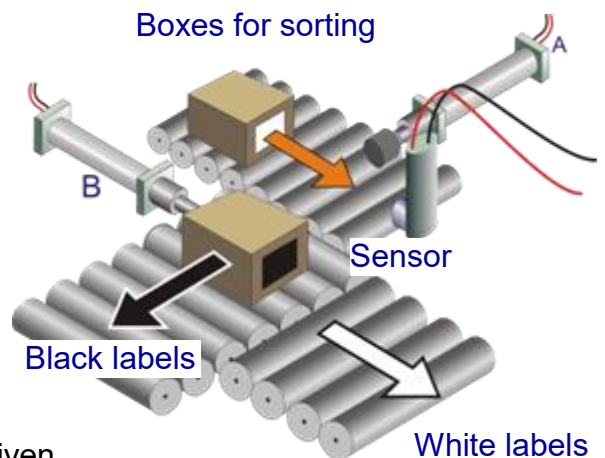


For your records:

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.



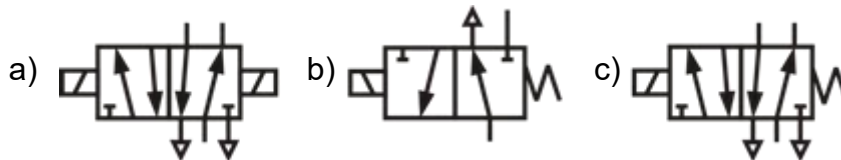
About these questions

These questions are designed to be a useful aid to revision.

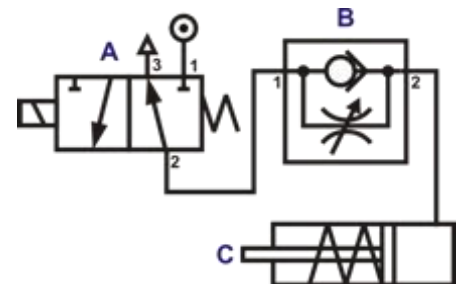
Allow 25 minutes to answer them and then check your answers with those given on page 30.

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

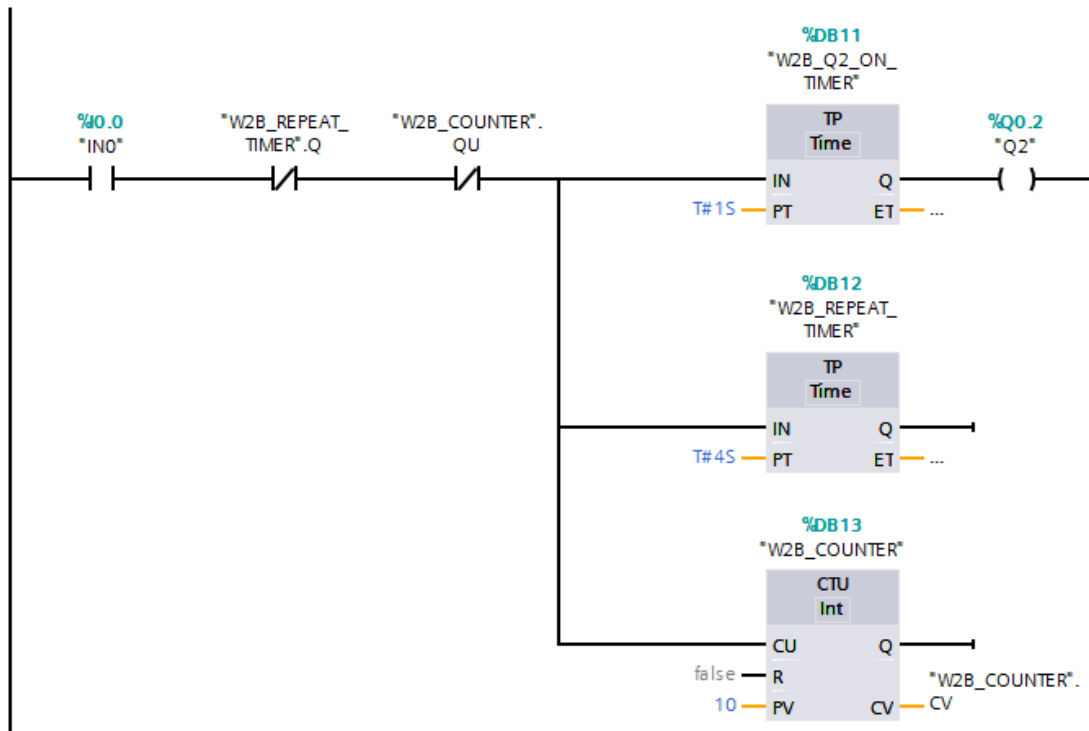
- Electrically operated pneumatic valves are operated by a:
 - solenoid
 - lever
 - permanent magnet
- Which is the correct description of a 'normally-open' push switch, connected in a circuit?
 - It has no cover on it.
 - It has a very low resistance when pressed.
 - it has a high voltage across it when pressed, and a low voltage when not pressed.
- What kind of switch is actuated by the magnetic piston ring of a cylinder?
 - reed switch
 - push switch
 - toggle switch
- Which is the correct symbol for a solenoid operated, spring return 5/2 control valve?
 q5



- Which statement is true for the pneumatic circuit opposite?
 - Port 3 on valve **A** is an exhaust port.
 - Flow control valve **B** is connected the wrong way round to control the flow of air into cylinder **C**.
 - When valve **A** is actuated, cylinder **C** will retract.

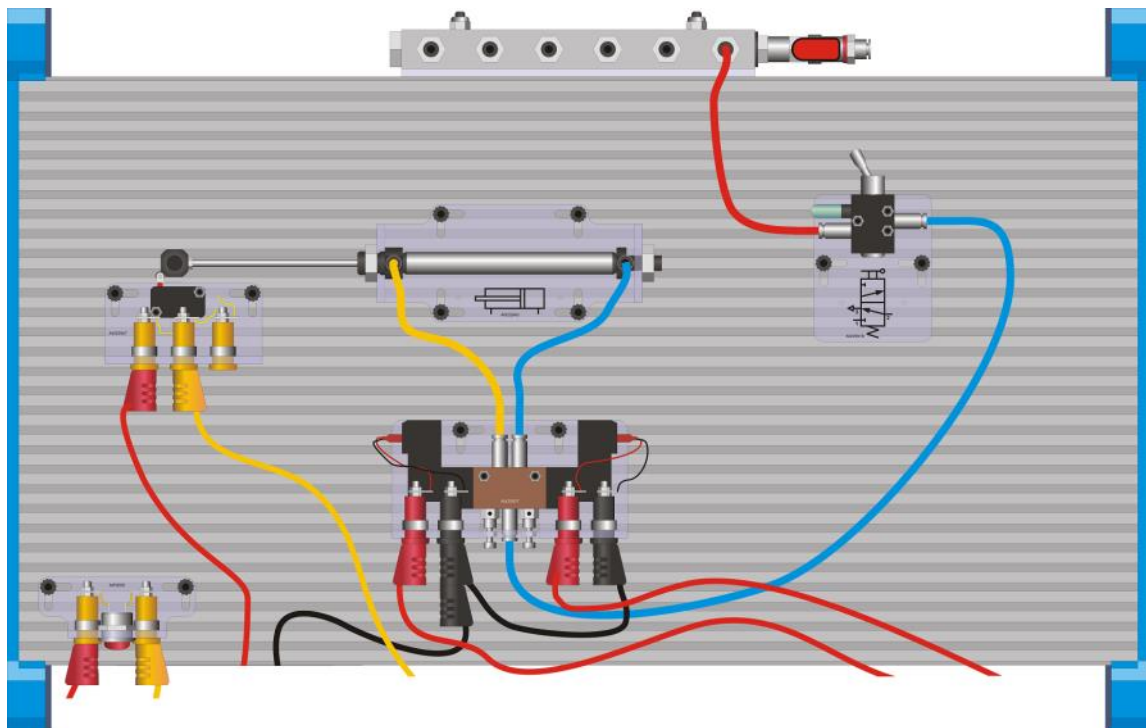


Revision questions



q7

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 .



q10

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.

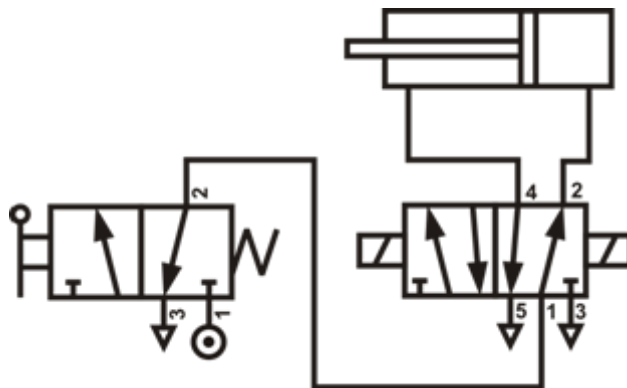
Unfortunately, it can provide misleading information because it continues to count even when the air supply is switched off by mistake.

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

Answers to revision questions (see page 27)

1. a)
2. b)
3. a)
4. c)
5. a)
6. W2B_COUNTER, PV parameter
7. 1s
8. 4s
- 9.



About this course

Introduction

This workbook reinforces the learning that takes place in the lecture room and is suitable for:

- Unit 12 of the BTEC National: Pneumatic and hydraulic systems.
- Unit 36 of the BTEC National: Programmable logic controllers.
- Unit 29 of the BTEC Higher National: Electro, pneumatic and hydraulic systems.

It provides practical activities and investigations to complement such courses.

It requires that the student has access to Siemens Simatic Step 7 automation software.

The learning aims are to:

- identify industrial electro pneumatic components, and use them correctly and safely;
- design, build and test control systems for pneumatic circuits to meet a given specification;
- read and draw pneumatic circuit diagrams using CETOP standard symbols;
- know how pneumatic systems are used in industry, transport and leisure contexts.

Automatics equipment makes it quick and easy to construct and investigate basic pneumatic circuits due to the pneumatic circuit symbols printed on each component carrier.

Prior Knowledge

Students should have followed the 'Automatics essentials' course, or have equivalent knowledge, and have the study skills and mathematical competence required to use these worksheets effectively.

Additionally, students should have basic knowledge of the use of the Siemens Simatic Step 7 automation software for the development of PLC controller programs.

Learning Objectives

On successful completion of this course the student will have learned to:

- apply six safety rules when building and using pneumatic circuits;
- turn on a solenoid operated pneumatic control valve using an input device such as a switch;
- analyse a simple ladder logic program controlling a pneumatic system;
- modify the number of times a program loops through its operating cycle;
- modify a delay within a program;
- use a flow-control valve to modify the speed of a cylinder while either extending or retracting;
- set up and control a reciprocating pneumatic cylinder;
- use a variable within a program to count events;
- describe two security features that could be built into an electronic door control system;
- analyse a program designed to operate two pneumatic cylinders sequentially;
- describe the advantages of incorporating feedback into a control system;
- use a reed relay to provide feedback in a 'proof of position' situation;
- use a light sensor as part of a sorting system to distinguish between two kinds of object.

What students will need:

The Automatics control add-on kit AU9077 contains the equipment shown in the table.

Qty	Code	Description
2	AU8030	Switch, push-to-make
1	AU8025	Reed Switch and Holder
2	AU3022	Valve, flow control
1	AU8010-2	Light Sensor (24V)
4	AU6024	Valve, 3/2, solenoid-spring (24V)
1	HP1650	24V Plug Top Power supply
10	LK5603	Lead, 4mm to 4mm, red
6	LK5604	Lead, 4mm to 4mm, black
2	LK5607	Lead, 4mm to 4mm, yellow
4	LK5609	Lead, 4mm to 4mm, blue
1	HP6785	PLC adaptor mounting bracket
1	HP4237	PLC adaptor Relay module
1	HP8042	PLC adaptor Input module
1	HP6711	PLC adaptor Power module
1	HP1300	PLC adaptor wiring pack
1	HP1699	Siemens S7-1211C PLC

This kit is intended as a supplement to the Automatics essentials solution, so you may also require the following additional items:

Qty	Code	Description
1	AU9020	Automatics essentials solution
1	AU1050	Compressor
1	LK1110	Multimeter

Using this course:

It is expected that the worksheets are printed / photocopied, preferably in colour, for the students' use. Students should retain their own copy of the entire workbook.

Worksheets usually contain:

- an introduction to the topic under investigation and its practical application;
- step-by-step instructions for the investigation that follows;
- each section aims both to challenge learners by questioning their understanding of a topic and also provides a useful summary of what has been learned.
It can be used to develop ideas and as a trigger for class discussion.
- a section headed 'For Your Records' which provides important summary information that students should retain for future reference, and extension exercises.

This format encourages self-study, with students working at a rate that suits their ability. It is for the tutor to monitor that students' understanding is keeping pace with their progress through the worksheets and to provide additional work that will challenge brighter learners. One way to do this is to 'sign off' each worksheet, as a student completes it, and in the process have a brief chat with the learner to assess their grasp of the ideas involved in the exercises that it contains.

A set of revision questions has been provided to conclude the work in this unit. These are of mixed difficulty and are designed to help students identify topics which might need more work. It is recommended that students should attempt these questions under examination conditions and without the use of notes.

Finally, three scenarios are included for students to use as realistic design problems (without solutions, as there are a number of valid approaches to each). These can be used as homework tasks if the instructor so wishes.

Time:

It will take most students between five and eight hours to complete the practical work and exercises in the worksheets. It is expected that a further, similar length of time will be needed to support the learning in a class, tutorial or in a self-study environment.

Worksheet	Notes for the Tutor	Timing
1	<p>This worksheet introduces the student to the Siemens PLC, and its role in switching on control valves in response to signals from input devices.</p> <p>It also revisits the fixing method used to attach components to the Automatics platform. In carrying out the assembly, students should consult the diagram, and the component layout on page 6.</p> <p>The following page lists some of the features of the device. In particular, they should be aware of the LEDs that monitor the inputs and outputs, as these are a reliable indicator of the progress of the 'program running on the PLC.</p> <p>Page 8 provides an overview of this program, which students should study carefully to understand the effect of each icon on the hardware.</p>	20 - 30 minutes
2	<p>This worksheet starts with a reminder of the safety rules that apply to pneumatic circuits. Instructors should emphasise the importance of these and enforce them strictly.</p> <p>The task involves setting up a reciprocating cylinder. The action is initiated by pressing a switch, though it is pointed out that, in practice, this may be an emergency stop button, attached to a safety guard, for example.</p> <p>On page 11, there are two diagrams - the physical component layout and the pneumatic circuit diagram. The students should take time to relate one to the other. Soon, worksheets will offer only the pneumatic circuit diagrams, and so the student must be adept at converting these into actual component layouts. The instructor should stress that the circuit diagram is an abstract representation, that does not attempt to suggest the actual position of the components on the platform, but does show connections between ports. The student should be encouraged to use coloured pipes to make the layout clear. In particular, it is a useful convention to use red pipes in all connections to the manifold.</p> <p>The next page gives an overview of program 2A. This checks the state of the switch which activates two timers, one to actuate the control valve that extends the cylinder, and the other that cause the controller to make no changes until the delays have expired.</p> <p>Program 2B modifies this behaviour by adding a counter that inhibits this cycle to 10 operations. This is shown on page 13.</p>	30 - 50 minutes

Worksheet	Notes for the Tutor	Timing
3	<p>Now, attention moves to the double-acting cylinder, as the return spring in the single-acting cylinder is unlikely to be strong enough to operate the door mechanism.</p> <p>Incorporating two flow-control valves allows control of the piston while extending and while retracting. Again, both the physical layout and the pneumatic circuit diagram are provided for the student to relate.</p> <p>Page 16 provides an overview of program 3A, which is structurally similar to program 2A, except that it monitors two switches. One switch when pressed causes the extend control valve to operate, the second switch causes the retract control valve to operate. Both operate for a controlled period, and with an inhibiting lockout period.</p> <p>The control system is next modified to display the number of times the door is opened, stored in a variable within the program. The modified program, program 3B, is illustrated on page 17.</p>	40 - 60 minutes
4	<p>This worksheet shows that the behaviour of a standard set of pneumatic components can be changed radically by changing the control program.</p> <p>In the earlier module, a sequence of cylinder operations was created entirely pneumatically. However, to change that sequence required changes to the physical layout of the components. Here, the only change is to the program that controls the system.</p> <p>The first program, 4A, produces the sequence, A+, B+, B-, A-, used earlier to control a de-greasing tank in a car factory. The separate parts of the sequence are still controlled manually, using two switches, but could be automated instead, using time delays to initiate lowering, raising and returning the basket. This program is outlined starting on page 19.</p> <p>Next, the program is changed to generate a different sequence, A+, B+, A-, B-, with the same hardware. This controls the gripper, shown on page 21, which could be part of a robot arm assembly. The elements of the new program, 4B, are the same as in program 4A, again delays are used to automate the process.</p> <p>Continued on next page...</p>	40 - 60 minutes

Worksheet	Notes for the Tutor	Timing
4	<p>continued...</p> <p>Although the de-greasing system appears to work as planned on the platform, in reality, the weight of the basket and contents would probably pull the basket back into the cleaning solution when the valve controlling the retraction of cylinder B is switched off. The students are asked how the program could be modified to prevent this. The obvious solution is to keep valve b- actuated as long as the basket is in the raised position. They are also asked to identify the sequence needed to control an air lock of two doors. In this case, the sequence is probably A+, A-, B+, B-.</p>	
5	<p>The introduction makes the point that often some kind of feedback is needed to ensure that a particular part of the process has taken place. This involves the use of a sensor, here a reed relay.</p> <p>This is mounted onto cylinder A, and detects whether or not it has extended. (The piston inside the cylinder is magnetised, and closes the reed relay contacts when in close proximity.) The output of the reed relay is used in the program to confirm that cylinder A has extended before the program proceeds.</p> <p>First of all, the program, 5A, runs without any feedback, to illustrate the problem. It is described on page 24. Then the reed relay is used as a 'proof of position' sensor, in program 5B. When a fault is introduced into the system by disconnecting the air supply from the control valve, the program pauses instead of tipping the contents of the hopper onto the floor!</p> <p>The modification, quite minor but very powerful, is described on page 28. In a practical situation, some warning device would sound to alert the operator.</p> <p>A similar application of sensors is in sorting components. The students are asked to design a program to sort out a mixture of black-labelled boxes from white-labelled boxes, using a light sensor, to model this kind of system. Although no solution is provided here, as there are a number of ways to do this, the students could be asked to deliver a presentation of their solution to the group, or document it as an item of coursework for the instructor.</p>	40 - 60 minutes

Worksheet	Notes for the Tutor	Timing
	<p>A number of design scenarios is presented on page 31. These are a challenging test of the student's understanding of this module. Again, there is no single solution to each, but students can be asked to deliver their solution to the group in a presentation, or to document it for the instructor. The tasks could be set as classwork or as homework as the instructor sees fit.</p>	

About this document:

Code: CP2193-01

Developed for product AU9077 - Pneumatics control with S7-1200 Siemens PLC add-on

Date	Release notes	Release version
January 2013	First version released	AW4956-80-01
January 2015	Part numbers changed	AW4956-80-02
May 2019	Adapted from AW4957 MIAC-based document	CP2193-01

10 08 23 Reformatted to new style